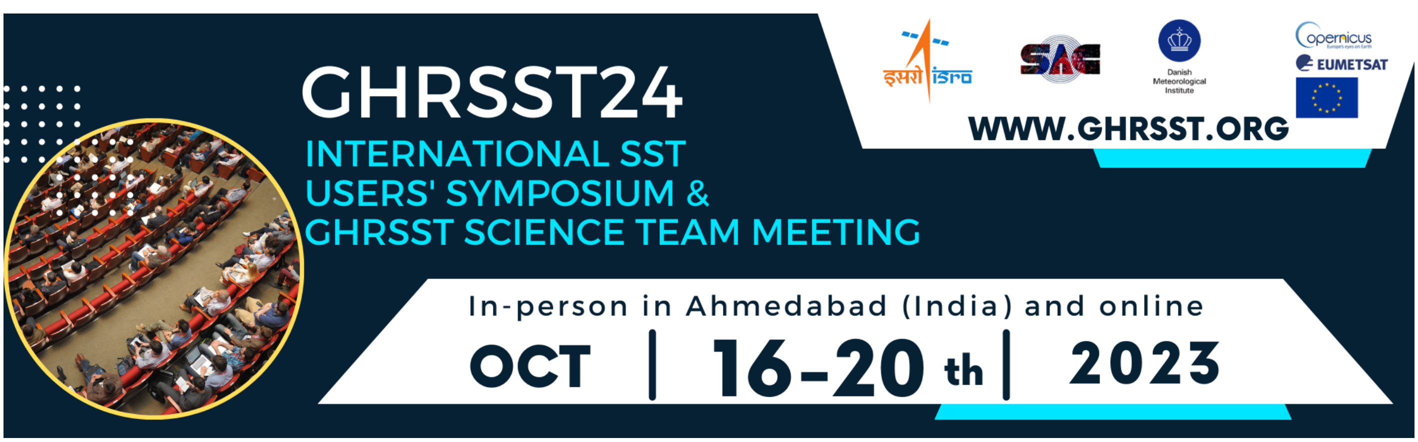
Proceedings of the GHRSST24 International SST Users' Symposium and GHRSST Science Team Meeting



About GHRSST

The Group for High Resolution Sea Surface Temperature (GHRSST) is an open international science group that promotes the application of satellites for monitoring Sea Surface Temperature (SST).

The 24th International SST Users' Symposium and GHRSST Science Team Meeting

The 24th International SST Users' Symposium and GHRSST Science Team Meeting (GHRSST24) took place in Ahmedabad, India and online on 16-20 October 2023. The event was hosted by the Indian Space Research Organisation (ISRO) and was organised in collaboration with the GHRSST Project Office, located at the Danish Meteorological Institute (DMI).

Aim of the Symposium

The primary objective of this symposium was to foster discussion and collaboration among experts in the field and promote the utilization of satellite sea-surface temperature (#SST) data products for oceanographic research and applications.

Target audience

Researchers, scientists, students, and practitioners working with satellite sea-surface temperature, SST users, SST producers.

Organisers

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SAC

Danish Meteorological Institute

Contact details

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The GHRSST Project Office is funded by the European Union Copernicus Programme and is hosted by the Danish Meteorological Institute, Sankt Kjelds Plads 11, 2100 Copenhagen (DK).
The animation of the GHRSST website is performed in the frame of the Sci4MaST project led by NOVELTIS and funded by the European Union Copernicus Programme.

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Science Session S1 - Science applications for Operational users of SST in India

Chair: T. Srinivas Kumar (1)
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Description of the session

Sea surface temperature displays variability over a wide range of space and time scales in the North Indian Ocean. The most pronounced oscillations in the SST are known to occur over the Bay of Bengal during the Indian summer monsoon season. Indian Ocean Dipole is another dominant mode of interannual variability in the tropical Indian Ocean that affects large-scale weather patterns. SST variability at mesoscale and sub-mesoscale plays a vital role in influencing air-sea interaction processes that modulate monsoons, tropical cyclone track and intensity, marine biodiversity, heat wave conditions, etc., and this, in turn, affects the population in the Indian subcontinent. The Indian Ocean rim countries, accounting for one-third of the Earth's human population, depend on the Indian Ocean (including the Bay of Bengal and the Arabian Sea) for food and resources and are significantly impacted by its variability. Hence, increasing our understanding of sea surface temperature variations at various spatiotemporal scales is extremely important.

In this session, the goal was to understand the requirements of SST for operational use in India. Speakers are invited to raise awareness in the GHRSST community of the various SST-based operational applications in India. The session mainly discussed the spatiotemporal requirements and error tolerance in SST for these applications. The presenters highlighted the challenges the existing GHRSST products pose while in use for applications like numerical weather prediction and data assimilation, fine-scale features and thermal front detection, coastal processes, marine heat waves, cyclone track forecasting, tropical cyclone heat potential, marine ecosystem studies and many more. Another beneficial point of discussion was whether the rapid sensing of SST by a constellation of satellites or by using a geostationary platform helps resolve fine-scale features, and whether the diurnal variations are crucial for any application. Sensor definition studies for SST observations, evaluation of different SST products for applications, and gap areas in existing observations are vital topics that were also addressed.

Keywords: thermal fronts, eddies, heat waves, air-sea interactions, potential fishing zones, Indian Ocean Dipole, Indian summer monsoon

Summary of the session

The report summarizes the contributions to the science session S1 that was conducted on the second day of the GHRSST24 meeting (17 October 2023).

The session began with a keynote address from Dr. V.S. Prasad of the National Centre for Medium Range weather forecast, titled "Impact of satellite-derived sea surface temperature data in the variational assimilation system."

Dr. V.S. Prasad discussed the importance of Sea Surface Temperature (SST) in air-sea interaction processes which is a critical boundary condition in numerical weather prediction. SST impacts the weather and climate through heat variation at regional and global scales. Therefore, accurate SST information is crucial for the ocean forecasting community, boundary conditions for the high-resolution numerical weather prediction models and the development of climate datasets. Dr. V.S. Prasad further mentioned that, due to the lack of in-situ SST observations, satellite data with high spatial and temporal resolution is crucial to improve the data coverage. He talked about the work that The National Centre for Medium Range Weather Forecasting (NCMRWF) carried out using the real-time satellite-derived SST observations from the Group for High Resolution SST (GHRSST) for operational basis in the Nucleus European Modelling of Ocean (NEMO) based variational assimilation system (NEMOVAR) with a first guess at an appropriate time (FGAT). However, the satellite-derived SST observations have biases due to the various approximations used in the retrieval algorithm. Before assimilation of the satellite-derived SST observations, the data are corrected against the in-situ observations at 0.25° x 0.25° degree resolution. The bias-corrected satellite-derived SST data are assimilated in the NEMOVAR system. The sensitivity experiments with and without satellite-derived SST data are also carried out to understand the impact of satellite observations in the variational data assimilation system, especially over the Tropical Indian Ocean region. Details on bias correction of SST observations, surface boundary fluxes, satellite-derived SST data assimilation, and the impact of satellite data were also presented during the keynote address.

The following presentation was made by Nandini Ray Chaudhary from SAC, ISRO, on Space based Coral Bleaching Monitoring over the Indian Reef Region: Need for High-resolution SST Data.

The monitoring and prediction of Mass Coral Bleaching (MCB) events in space require a combination of climate-quality, long-term Sea Surface Temperature (SST) data and high-resolution, real-time, daily SST observations. Zooxanthellate corals and other marine invertebrates in reef ecosystems typically adapt to the temperature ranges specific to their local and seasonal conditions, which define their tolerance limits. However, when the SSTs exceed the normal summer maximum for an extended period, these marine invertebrates experience thermal stress. This stress leads to the expulsion of their photosynthesizing endosymbiont, resulting in the loss of tissue colour and eventual mortality. The Coral Bleaching Monitoring System, developed at the Space Applications Centre (SAC), ISRO, for the Indian coral reef regions, utilizes NOAA's Optimum Interpolated Sea Surface Temperature (OISST) data to detect unusual warming in the Lakshadweep reef region and forecast the likelihood of mass coral bleaching in summer 2020. Ground observations from the Lakshadweep islands confirmed the occurrence of in situ coral bleaching. Out of the sixteen coral reefs in Lakshadweep, six showed a significant overlap in average summer SST anomalies when compared to the SST anomalies of the El Niño-impacted MCB year of 2016. The Degree Heating Week (DHW) index comparison revealed pronounced thermal stress for the northern and six central islands of Lakshadweep in 2020, compared to 2016. To enhance real-time coral bleaching monitoring, it would be beneficial to improve the current continuous series of accurate OISST. The availability of high-resolution SST products from various advanced multi-thermal sensor satellites has the potential to contribute to this effort.

Next talk was given by Neeraj Agarwal from SAC, ISRO on "Impact of different GHRSST data sets on simulation of Indian summer monsoon."

The presenter discussed the outcomes of an atmospheric model that was specifically configured for the Indian region and driven by various GHRSST products. The evaluation of the simulated monsoon rainfall was conducted by comparing it with observed data. This research aimed to assess the influence of different remotely sensed sea surface temperature (SST) datasets provided by GHRSST on the monthly prediction of the Indian summer monsoon. Multiple hindcast experiments were performed using an atmospheric general circulation model, and the impact of GHRSST products from Canadian Meteorological Centre (CMC v3.0), Danish Meteorological Institute (DMI v1.0), Jet Propulsion Laboratory Multi-scale Ultra high Resolution (JPL-MUR v4.1), Remote Sensing Systems (REMSS v5.0), and United Kingdom Met Office (UKMO v2.0) were examined. The experiments were carried out with a spatial resolution of 10 km over India and 60 km elsewhere, initializing on 25 June 2020, and integrating until 31July 2020. The only difference between these experiments was the SST boundary forcing derived from the aforementioned GHRSST products. The model's simulated rainfall for July was compared with observed rainfall data from the India Meteorological Department (IMD), while the simulated circulation patterns were compared with ERA5 analysed circulation patterns. Preliminary findings indicate that SST has a significant impact on both circulation patterns and rainfall simulation. Among the various SST products, the use of CMC SST appears to capture more accurately the circulation pattern as well as rainfall.

Simi Mathew from IIT-Madras presented (online) the results on "Sea surface temperature anomaly over the south-eastern Arabian Sea with the changing phase of the Indian Ocean Dipole."

The Arabian Sea is experiencing a significant increase in sea surface temperature (SST), with a warming rate of 0.18°C per decade. This rate is higher compared to the Pacific and Atlantic Ocean. The higher SST in the Arabian Sea contributes to active convection, intense cyclones, and heavy rainfall. The ratio of cyclones between the Arabian Sea and the Bay of Bengal has changed from 1:4 to 1:2, which is a cause for concern. This change in ratio indicates that the destructive impact on the west coast of India will be substantial. However, during negative Indian Ocean Dipole (nIOD) years, there is a noticeable decrease in SST over the South-Eastern Arabian Sea (SEAS) during the Fall transition months. This decrease in SST is primarily due to the intense cooling that occurs during the previous southwest monsoon (SWM) season. The strong easterly winds associated with nIOD years result in a significant loss of latent heat flux from the ocean surface. Additionally, convective mixing with the cooler deeper water further contributes to intense cooling. To study the variability during nIOD and pIOD (positive IOD) years, we analyse the SST data obtained from GHRSST averaged over the SEAS. In 2010 and 2016, both nIOD years, there was a significant cooling observed with a measured SST anomaly of -0.5°C recorded in August and September, respectively. This cooling has a direct impact on the SST during the subsequent fall transition months, with recorded SST lower than the climatology in October of both years. Interestingly, there were no cyclonic disturbances over the Arabian Sea during the fall transition months of these two nIOD years. By analysing the cooling rate observed during the SWM season, we can potentially improve predictions for cyclone occurrences during the fall transition months. In contrast, during pIOD years such as 2015 and 2019, the scenario is opposite, with warmer SSTs recorded during the fall transition months. The cooling rate during the SWM season is considerably lower during pIOD years. From July to October of 2015 and 2019, the SST is warmer than the climatology by 0.5°C. This warmer SST has favoured the development of cyclones.

Greeshma from NIT, Suratkal made a presentation on "Monitoring phytoplankton bloom occurrence and its associated parameters in the North Eastern Arabian Sea using GHRSST data."

The Arabian Sea is renowned for its high productivity in the world's oceans, primarily due to the circulation patterns influenced by the monsoon. In recent years, there has been a significant increase in the occurrence of phytoplankton bloom in the Arabian Sea, attributed to changing climatic conditions and seasonal patterns. This study focuses on monitoring the coastal water bloom along the North Eastern Arabian Sea (19-23°N & 62-67°E) over a span of five years (2018-2022). Additionally, the study examines the oceanic conditions that may trigger the algal bloom, including Sea Surface Temperature (SST), Chlorophyll-a Concentration, Sea Level Anomaly (SLA), and Wind speed. Globally, the monthly average Chl-a concentrations ranged from 0.01 to 20 mg/m^3. To conduct this study, the Group for High Resolution Sea Surface Temperature (GHRSST) Level-4 DMI product was utilized, incorporating data from various sensors such as Advanced Very High-Resolution Radiometer (AVHRR), Spinning Enhanced Visible and Infrared Imager (SEVIRI), Advanced Microwave Scanning Radiometer 2 (AMSR2), Visible Infrared Imager Radiometer Suite (VIIRS), and Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua. By integrating multiple variables and datasets, this approach provides a comprehensive understanding of algal blooms, enhancing the accuracy and reliability of bloom monitoring. The observed SST temperature range for the study area was approximately between 24 to 32 °C. The findings suggest that SST patterns directly influence the occurrence of phytoplankton bloom. Furthermore, this study has the potential to differentiate between different algal species and predict productive coastal zones for fishing activities

The last talk of the session was by Balaji Baduru from INCOIS on "Assimilation of in-situ and remote sensing data in Regional Ocean Modelling System for the Indian Ocean."

A high-resolution ocean circulation model for the Indian Ocean (IO) using Regional Ocean Modelling System (ROMS) is operational at the Indian National Centre for Ocean Information Services

(INCOIS) which provides ocean state forecasts for the Bay of Bengal and the Arabian Sea to the Indian Ocean rim countries. To provide an improved estimate of ocean state, an ensemble based regional ocean data assimilation system using Local Ensemble Transform Kalman Filter (LETKF) scheme has been developed and interfaced with basin-wide operational ROMS. This system assimilates remote sensing track data of sea surface temperature data from Group for High Resolution Sea Surface Temperature (GHRSST), in-situ temperature and salinity profiles. The assimilated system simulates the ocean state better than the operational ROMS. Improvements permeate to deeper ocean depths with better correlation and reduced root-mean-squared deviation (RMSD) with respect to observations. Analysis shows domain averaged RMSD reduction of about 0.2 - 0.4^{o}C in sea surface temperature. The most profound improvements concern the currents, with an error reduction of 15 cm/s in zonal currents of central Bay of Bengal. The data assimilation system also provides an improved initial condition to the ocean forecast model and regional analysis.

Conclusions

The session concluded with a closing remark by the Session chair and he praised all the speakers for presenting various applications of SST database. He also highlighted the significance of having such dataset for several other applications, like fisheries and marine heat waves.

Questions

Questions to Nandini Ray Chaudhary:

1. *What climatology did you use to compute the anomaly?*

Nandini Ray Chaudhary: Initially we used the HADISST data to compute the maximum and minima and later on we used OISST data from 1982-2018 to compute the climatologies, and the thermal thresholds were calculated for different regions. Pallavi Govekar (BoM) suggested that the overall analysis may be affected by the fact that no recent data has been used to compute the climatologies, to which Nandini replied that this is an ongoing study and they plan to include more data in their analysis.

2. *Did you use mooring data in your analysis?*

Nandini Ray Chaudhary: Since their main assumption is to limit themselves to the skin depth radiance, whereas the mooring data will provide SSTs that are more representative of sub-skin or bulk, in-situ measurements of SST should come within 10 microns of the depth.

3. *What kind of spatial resolution are you looking at for studying coral bleaching?*

Nandini Ray Chaudhary: For smaller corals, < 100m resolution SST is required. However for large corals, even 1km resolution SSTs should suffice.

4. *Have you looked at any model outputs for carrying out your study?*

Nandini Ray Chaudhary: No, we haven't looked at them, but we are open to this idea as long as simulations are available.

Overview of the talks

Nr.	Presenter	Institution	Title	Link
31-S1	Imranali M Momin, J. P. George and V. S. Prasad	National Centre for Medium Range Weather Forecasting (NCMRWF), Ministry of Earth Sciences (MoES)	Impact of satellite-derived sea surface temperature data in the variational assimilation system	**KEYNOTE PDF** Video: https://youtu.be/Ms9lLa1ZpY8
50-S1	Simi Kennedy Mathew	Indian Institute of Technology Madras	Sea surface temperature anomaly over the south-eastern Arabian Sea with the changing phase of the Indian Ocean Dipole	**Invited talk PDF** Video: https://youtu.be/FHPdJoR0-Nw
66-S1	Greeshma K. U.	National Institute of Technology, Karnataka, Surathkal	Monitoring phytoplankton bloom occurrence and its associated parameters in the North Eastern Arabian Sea using GHRSST data	**Invited talk PDF** Video: https://youtu.be/iiFWnQ_GUSo
68-S1	Nandini Ray Chaudhury	Space Applications Centre (SAC), ISRO	Space-based Coral Bleaching Monitoring over Indian Reef Region: Need for High-resolution SST Data	**Invited talk PDF** Video: https://youtu.be/SSyDw1Nqk84
61-S1	Neeraj Agarwal	Space Applications Centre (SAC), ISRO	Impact of different GHRSST data sets on simulation of Indian summer monsoon	**Invited talk PDF** Video: https://youtu.be/WxiLqHKV_8g
72-S1	Balaji Baduru	Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES),	Assimilation of in-situ and remote sensing data in the Regional Ocean Modelling System for the Indian Ocean	**Invited talk PDF** Video: https://youtu.be/4pksFB0KCug

	Government of India		

Overview of the posters

Nr.	Name	Institution	Title	Download the PDF	Watch the video
52-S1	Piyali Goswami	On the Variability of Yearly Maximum Sea Surface Temperature in the Bay of Bengal using GHRSST	School of Earth, Ocean, and Climate Sciences, Indian Institute of Technology Bhubaneswar	**PDF**	Video: https://youtu.be/AnloVJEnXis
58-S1	Jishad Mandayi	Assessing the Diversity and Utility of Satellite-Based Sea Surface Temperature Measurements in various applications.	Space Applications Centre (SAC), ISRO	**PDF**	Video: https://youtu.be/iMLcCLtoUcA
64-S1	Brenna Mei Concolis	Characteristics of Marine Heatwaves in the Philippines	University of the Philippines Cebu	**PDF**	Video: https://youtu.be/iq7Np_A9TBw
67-S1	Ranith Rajamohanan Pillai	Assessing Safe Operating Space and Response of Coral Reefs to Bleaching under Varying Thermal Stress	Nansen Environmental Research Centre, KUFOS Amenity centre	**PDF**	Video: https://youtu.be/joQQxg7Bo60

70-S1	Shouvik Dey	On the Nature of Pre-monsoon Coastal Upwelling on the North-Western Bay of Bengal using GHRSST	Indian Institute of Technology Bhubaneswar	**PDF**	Video: https://youtu.be/jiNZr4omraM
77-S1	Manik H. Kalubarme	Comparative Analysis of Sea Surface Temperature (SST) Data Covering Gujarat Coast (INDIA)	Space Applications Centre, Indian Space Research Organization (ISRO)	**PDF**	Video: https://youtu.be/vWG6IZSIGHI
86-S1	Rachel Spratt	Using SST to characterize 18 years of Yukon river discharge in the Norton Sound from 2003–2020	NASA Jet Propulsion Laboratory/California Institute of Technology	**PDF**	Video: https://youtu.be/-ohKFUdqRG4
103-S1	Neeru Jaiswal	Sea surface temperature in the East Central Pacific Ocean as a new potential predictor of post-monsoon cyclonic activity over the North Indian Ocean	Space Applications Centre (ISRO)	**PDF**	Video: https://youtu.be/OCt1LVIfVSw

Abstracts Science Session S1 - Science applications for Operational users of SST in India

KEYNOTE 31-S1: Impact of satellite-derived sea surface temperature data in the variational assimilation system

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Submission date: 04/07/2023

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Abstract

Sea surface temperature (SST) is an important oceanic parameter for air-sea interaction and is an interface between the ocean and the overlaying atmosphere. It also impacts the weather and climate through heat variation at regional and global scales. So, accurate SST information is crucial for the ocean forecasting community, boundary conditions for the high-resolution numerical weather prediction models and the development of climate datasets. However, due to the lack of in-situ SST observations, satellite data with a high spatial and temporal resolution plays a crucial role to improve the data coverage. The National Centre for Medium Range Weather Forecasting (NCMRWF) used the real-time satellite-derived SST observations from the Global High-Resolution SST (GHRSST) for operational basis in the Nucleus European Modelling of Ocean (NEMO) based variational assimilation system (NEMOVAR) with a first guess at an appropriate time (FGAT). However, the satellite-derived SST observations have biases due to the various approximations used in the retrieval algorithm. Before assimilation of the satellite-derived SST observations, the data are corrected against the in-situ observations at 0.25° x 0.25° degree resolution. The bias-corrected satellite-derived SST data are assimilated in the NEMOVAR system. The sensitivity experiments with and without satellite-derived SST data are also carried out to understand the impact of satellite observations in the variational data assimilation system especially over the Tropical Indian Ocean

region. More details on bias correction of SST observations, surface boundary fluxes, satellite-derived SST data assimilation, and the impact of satellite data are presented at this conference.

Talk 50-S1: Sea surface temperature anomaly over the south-eastern Arabian Sea with the changing phase of the Indian Ocean Dipole

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Abstract

Sea surface temperature (SST) over the Arabian Sea is warming at a rate of 0.18°C per decade, which is higher than the Pacific and Atlantic Ocean. Higher SST supports active convection, intense cyclones and heavy rainfall. The ratio of number of cyclones between Arabian Sea and Bay of Bengal was 1:4 and it has changed to 1:2. This is alarming and the destruction it causes to the west coast of India will be enormous. However, during negative Indian Ocean Dipole (nIOD) years it is observed that the SST over the South-Eastern Arabian Sea (SEAS) during the fall transition months is lower than the climatology. This low SST is caused largely by the intense cooling during the previous southwest monsoon (SWM) season. The strong easterly winds associated with the nIOD year favours large loss of latent heat flux from the ocean surface. The convective mixing with the deeper cool water too favours intense cooling. We investigate the SST obtained from GHRSST averaged over the SEAS to study the variability during the nIOD years of 2010 and 2016 and positive IOD (pIOD) years of 2015 and 2019. Both nIOD years showed an intense cooling with a measured SST anomaly of -0.5 °C recorded during August (2010) and September (2016), respectively. This has a direct impact on the SST during the following fall transition months, with SST lower than the climatology recorded during October of both the years. Coincidentally there were no cyclonic disturbances over the Arabian Sea during the fall transition months of these two nIOD years. A detailed analysis of the cooling rate observed during the SWM season can be used as a tool for a better prediction for the cyclone occurrences during the fall transition months. The scenario during the positive IOD year is the opposite, with warmer SST recorded during the fall transition months of 2015 and 2019. The cooling rate during the SWM season is considerably low during the pIOD years. The SST is warmer than the climatology by 0.5 °C from July to October of 2015 and 2019. The warmer SST has favoured the

formation of severe to extremely severe cyclones over the Arabian Sea during the fall transition months of pIOD years.

Talk 66-S1: Monitoring phytoplankton bloom occurrence and its associated parameters in the North Eastern Arabian Sea using GHRSST data

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Abstract

The Arabian Sea is considered to be one of the most productive regions of the world ocean due to the monsoon-forced circulation. Over the last decade, there is a tremendous increase in spatial distribution of phytoplankton bloom in Arabian Sea due to changing climatic conditions and seasonal patterns. In the present study, we monitor the occurrence of coastal water bloom along the North Eastern Arabian Sea (19-23°N & 62-67°E) for five years (2018-2022). The study also analyses the oceanic conditions that may trigger the algal bloom through parameters such as Sea Surface Temperature (SST), Chlorophyll-a Concentration, Sea Level Anomaly (SLA) and Wind speed. Globally, it was found that the monthly average Chl-a concentrations varied between 0.01 and 20 mg/m^3. The study utilizes Group for High Resolution Sea Surface Temperature (GHRSST) Level-4 DMI product which includes sensors such as Advanced Very High-Resolution Radiometer (AVHRR), Spinning Enhanced Visible and Infrared Imager (SEVIRI), Advanced Microwave Scanning Radiometer 2 (AMSR2), Visible Infrared Imager Radiometer Suite (VIIRS), and Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua. These integrations provide a comprehensive understanding of

algal blooms by combining multiple variables and datasets, enhancing the accuracy and reliability of bloom monitoring. The SST temperature range observed for the study area was found approximately between 24 to 32 ℃. The findings from the analysis indicate that SST pattern have direct implications on the occurrence of phytoplankton bloom. The study can also be extended to distinguish different algal species and to predict the productive coastal zones for fishing grounds.

Talk 68-S1: Space based Coral Bleaching Monitoring over Indian Reef Region: Need for High-resolution SST Data

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Abstract

Space based monitoring and forewarning of Mass Coral Bleaching (MCB) events require a synergy of climate quality, long-term Sea Surface Temperature (SST) data record and high-resolution, real-time, diurnal SST observations. Zooxanthellate corals and other marine invertebrates in reef ecosystem are generally adapted to their local, seasonal temperature ranges that define their tolerance limits. In case of above-normal SSTs beyond the local summer maxima for a prolonged period, these marine invertebrates are exposed to thermal stress. This stress leads to expulsion of their photosynthesizing endo-symbiont, loss of tissue colour and eventual mortality. Coral Bleaching Monitoring System developed at Space Applications Centre (SAC), ISRO, for Indian coral reef regions based on NOAA's Optimum Interpolated Sea Surface Temperature (OISST) data detected an unusual warming of the Lakshadweep reef region and forecasted likelihood of mass coral bleaching in summer of 2020. Co-incident ground observations from Lakshadweep islands confirmed in situ coral bleaching. Six out of the sixteen coral reefs of Lakshadweep showed close overlap of average summer SST anomalies when compared with the SST anomalies of summer 2016, an El Niño impacted

MCB year. Comparison of Degree Heating Week (DHW) index revealed pronounced thermal stress for a northern and six central islands of Lakshadweep in 2020 as compared to 2016. Improvisation on the current continuous series of accurate OISST will be a welcome step towards real-time coral bleaching monitoring. The availability of high-resolution SST products from a host of advanced multi-thermal sensor satellites has the potential to augment this effort.

Talk 61-S1: Impact of different GHRSST data sets on simulation of Indian summer monsoon

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Abstract

This study evaluates the impact of several remotely sensed sea surface temperature (SST) data sets provided by the Group of high resolution sea surface temperature (GHRSST) on the monthly prediction of the Indian summer monsoon using numerous sets of hindcast experiments employing the atmospheric general circulation model. Canadian Meteorological Centre CMC v3.0 (10 km), Danish Meteorological Institute DMI v1.0 (5 km), Jet Propulsion Laboratory Multi-scale Ultra high Resolution JPL-MUR v4.1 (1 km), Remote Sensing Systems REMSS v5.0 (9 km), and United Kingdom Met Office UKMO v2.0 (5 km) GHRSST products have been utilised in this study. To this end, five different experiments were carried out using an atmospheric general circulation model with a spatial resolution of 10 km over India and 60 km elsewhere. The model was initialized on June 25th, 2020, and integrated until July 31st, 2020. The SST boundary forcing, which is produced from the aforementioned products, is the only difference between these experiments.

Model simulated July average rain in different experiments was compared with the India Meteorological Department (IMD) observed rainfall, while model simulated circulation patterns were compared with ERA5 analysed circulation pattern. Preliminary findings show that SST has a considerable impact on both circulation and rainfall simulation. When compared to other SST products, the use of REMSS SST appears to more accurately capture the circulation pattern as well as rainfall. Detailed analysis of the results will be presented in the meeting.

Talk 72-S1: Assimilation of in-situ and remote sensing data in Regional Ocean Modelling System for the Indian Ocean

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Submission date: 07/07/2023

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Abstract

A high-resolution ocean circulation model for the Indian Ocean (IO) using Regional Ocean Modelling System (ROMS) is operational at Indian National Centre for Ocean Information Services (INCOIS) which provides ocean state forecasts for the Bay of Bengal and the Arabian Sea to the Indian Ocean rim countries. To provide an improved estimate of ocean state, an ensemble based regional ocean data assimilation system using Local Ensemble Transform Kalman Filter (LETKF) scheme has been developed and interfaced with basin-wide operational ROMS. This system assimilates remote sensing track data of sea surface temperature data from Group for High Resolution Sea Surface Temperature (GHRSST), in-situ temperature and salinity profiles. The assimilated system simulates the ocean state better than the operational ROMS. Improvements permeate to deeper ocean depths with better correlation and reduced root-mean-squared deviation (RMSD) with respect to observations. Analysis shows domain averaged RMSD reduction of about 0.2 - 0.4 ^{o}C in sea surface temperature. The most profound improvements are seen in currents, with an error reduction of 15 cm/s in zonal currents of central Bay of Bengal. The data assimilation system also provides an improved initial condition to the ocean forecast model and regional analysis.

Posters

52-S1: On the Variability of Yearly Maximum Sea Surface Temperature in the Bay of Bengal Using GHRSST

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Abstract

Understanding Sea Surface Temperature (SST) variability is crucial to monitor and prediction of marine ecosystem, ocean circulation, cyclonic, and monsoon activity. This study investigates the variability of SST in the Bay of Bengal (BoB) for the period of 2007–2022 by utilizing daily available Group for High-Resolution Sea Surface Temperature (GHRSST) dataset having spatial resolution of 0.05°. The daily mean SST time series showed a bimodal distribution with two maxima: higher peak around mid-May and secondary peak around mid-October. Area-averaged GHRSST revealed warming trends (per year) in the yearly mean SST, maximum SST, and climatology removed SST with a value of 0.022°C/year, 0.034°C/year, 0.022°C/year with more than 90% significant, respectively. The analysis also showed a delay in attaining the maximum temperature of the bay. Exceptionally high SST were observed in the recent year 2020–2021. Maximum temperature during 2012 was the earliest (12 April) and during 2018 was the delayed (24 May); the mean time of the maximum temperature is 7 May. The maximum (minimum) value of maximum temperature of the year is 31.06°C (29.8°C) during 2016 (2011). Further analysis by splitting the time series in two parts showed that higher (lower) mean (standard deviation) values in period 2015–2022 compared to period 2007–2014 during all the seasons. This study further investigates the linkage between the maximum temperatures of the basin with the monsoon onset.

58-S1: Assessing the Diversity and Utility of Satellite-Based Sea Surface Temperature Measurements in various applications

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Submission date: 07/07/2023

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Abstract

This study presents a comparative analysis of various Group for High-Resolution Sea Surface Temperature (GHRSST) products, highlighting their diversity and utility in capturing the spatiotemporal variability of SST. The study encompasses a comprehensive review of different GHRSST products provided by Canadian Meteorological Centre CMC v3.0 (10 km), Danish Meteorological Institute DMI v1.0 (5 km), Jet Propulsion Laboratory Multi-scale Ultra high Resolution JPL-MUR v4.1 (1 km), Remote Sensing Systems REMSS v5.0 (9 km), and United Kingdom Met Office UKMO v2.0 (5 km). This study primarily focused on utilizing GHRSST products for identifying potential fishing zones (PFZs) and determining the distribution of thermal fronts, which detected using the histogram method. The high-resolution JPL-MUR products proved valuable in detecting fine-scale frontal features including coastal waters. As thermal fronts play a crucial role in the PFZ detection algorithm, the JPL-MUR product provided accurate PFZ locations, albeit with noise. On the other hand, the coarser resolution data from REMSS and CMC had the advantage of detecting strong fronts with greater precision. The DMI and UKMO datasets offered a good balance between noise reduction and improved resolution for various applications. The comparison of frontal locations with iQuam drifters (in-situ Quality Monitor) shows that the strong fronts detected across all datasets matched, whereas the weaker fronts were only detected in the MUR-JPL dataset. The strong frontal locations are highly correlated with the high fish catch. Alignment of these fronts with Lagrangian Coherent Structures (LCS) derived from sea surface currents is also checked. Gradients from Finite Time Lyapunov Exponent (FTLE) fields

were compared with different SST products. Initial results show less alignment in CMC product and alignment in JPL product needs more processing due to presence of noise in gradients.

64-S1: Characteristics of Marine Heatwaves in the Philippines

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Abstract

Marine Heatwaves (MHWs) are prolonged, discrete, and anomalously warm events, which have recently gained global attention due to their far-reaching effects and reported impacts. Although intensive studies have been carried out at global and regional scales, these events remained understudied in the Philippines – a country with high marine biodiversity. The Philippines is highly vulnerable to the impacts of these extreme events as it lies in the western boundary of the Pacific that is considered as a hotspot for MHWs. The present study used multi-year climatic sea surface temperature (SST) record to detect MHWs in the Philippines. Linear trend analysis was conducted to determine the magnitude and direction of the change of the MHW metrics over time. Decadal trend revealed that MHWs in the Philippines significantly increased from seven MHWs in the 1980s to 37 MHWs in the last decade. Moreover, increased duration was remarkable in 2020 with 276 MHW days. MHW frequency and duration were increasing at a rate almost twice as its neighbouring waters.

Intensities did not significantly increase with time, but the highest SST anomaly is associated with El Niño Southern Oscillation. Furthermore, the eastern and western region of the Philippines is vulnerable to MHWs, but hotspots are mostly confined in the West Philippine Sea and western tropical Pacific. The findings have significant implications for coastal marine resource management, highlighting the need for adaptive management strategies and increased monitoring and research efforts to mitigate the impacts of MHWs on marine ecosystems and local economies in the Philippines.

67-S1: Assessing Safe Operating Space and Response of Coral Reefs to Bleaching Under Varying Thermal Stress

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Abstract

The threat from rising SST is increasing the stress on coral reefs, leading to coral bleaching and infectious diseases. For efficient conservation of this sensitive ecosystem, detailed information on the regional responses of coral reefs to varying temperatures and identification of safe operating spaces from thermal stress are necessary. Here we tried to understand the responses of coral reefs in the major coral reef regions of India - Andaman and Nicobar, Lakshadweep, Gulf of Mannar and Gulf of Kachchh. Level 4 GHRSST data were used to derive the indices like degree heating week (DHW), minimum SST, maximum SST, SST anomaly and bleaching hotspot for all the four coral reef regions. Coral bleaching data from reefbase.org and surveys were integrated to assess the coral bleaching responses to SST variability during the bleaching reported years. The coral bleaching response analysis using linear model showed significant coral bleaching susceptibility at Andaman and Nicobar Island. Considering the significant amount of field observations, the safe operating space assessment was done for Lakshadweep and Gulf of Mannar regions only. For Lakshadweep region, a thermal range under both the minimum (29.9°C) and maximum SST (31.1°C) was found as the safe zone without significant bleaching stress. For the Gulf of Mannar reefs, a thermal range below both 29.6°C (minimum SST) and 31.3°C (maximum SST) was identified as the safe zone. This study identified regional scale differences in the temperature tolerance of coral reefs and emphasise the need to develop regional management plans for the conservation of coral reefs.

70-S1: On the Nature of Pre-monsoon Coastal Upwelling on the North-Western Bay of Bengal using GHRSST

Submitting author/speaker (Name and Surname): Shouvik Dey

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Abstract

The Coastal Upwelling is an important oceanic process, mainly driven by alongshore wind, elevates the biological productivity of the coastal region. Being a high resolution (5 km) product, Sea Surface Temperature (SST) from GHRSST provide an opportunity to study the tempo-spatial variability in coastal upwelling in the north-western Bay of Bengal region. Though the prevailing wind during April to August is upwelling favourable, the Sea Surface Temperature (SST) showed an upwelling occurred only from mid-April to the first week of June with several peak and break periods. Analysis showed that down welling kelvin wave and low salinity stratified ocean supressed the upwelling after June. Within the upwelling (Mid-April to first week of June) period three active phases, each followed by break phases are identified. The active upwelling phases lasted for about 15, 6 and 9 days. The variability of upwelling signature followed wind with a lag of 2 – 4 days. The horizontal extent of the cold upwelled water varied between 75 – 140 km during peak phases and contracted as low as 45 km during break phases. The temperature during peak upwelling dropped to -3.5 ℃. The work is supported by the currents from the HF radar and satellite derived altimetry tracks. The cross-shore surface current also varied between 45 – 135 km during peak phases and were completely absent during break phases.

77-S1: Comparative Analysis of Sea Surface Temperature (SST) Data Covering Gujarat Coast (INDIA)

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Abstract

The Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) mission data product covering Gujarat Coast was downloaded using Application for Extracting and Exploring Analysis Ready Samples. The analysis of ECOSTRESS LST data of 10-May-2023 covering Gulf of Cambay showed a marginal variation of SST from 270 C to 280 C. The Land and Water Surface Temperature (L/WST) for 1988, 1998, 2008 and 2018 covering were retrieved using Landsat Thermal data and the results indicated that there is gradual increase in Summer WST from 280 C to 300 C during the period of 30-years.

The Sea Surface Temperature (SST) data from various sources covering Gujarat Coast was analysed to study the SST variations. The SST data collected from the KNMI Climate Explorer website from 1860 to 2020 and analysis indicated that there was gradual increase in SST and Saurashtra coast shows highest SST values as compared to other Gulf areas. The analysis of SST and CO2 data indicated a steeply rising trend during the period from 2010 to 2020 in both the parameters. The peak of SST follows the peak of Annual Sun Spot Activity (SSA) till-2000. During the decade of 2010, the annual mean SSA indicated declining trend, however, SST shows increasing trend even though the annual mean SSA shows declining trend till 2020. The intercomparison study of these SST products needs to be carried out using Group for High Resolution Sea Surface Temperature (GHRSST) data product to assess their accurate representation of the SST relevant to climate analysis.

86-S1: Using SST to characterize 18 years of Yukon River discharge in the Norton Sound from 2003–2020

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Abstract

River discharge in the high latitudes can be a sign for climate change because river flux can signal (among many things) changes in warming along coastlines, variations in local biogeochemistry, depleted food web fisheries, altered shipping lanes, degraded coastal structures, and more.

In this study, we compare the Group for High Resolution Sea Surface Temperature's 0.09 degree, level 4, globally gridded dataset (GHRSST-MWIR) with the Arctic Great Rivers Observatory (Ar-GRO) Yukon River volumetric discharge dataset in the Gulf of Alaska and the Bering Sea. We not only find a decadal scale pattern in the river discharge volume that is comparable to SST from 2003 –2020, but juxtaposition with a Yukon headwaters temperature dataset reveals a possible down-regulation of river temperature during modes of cooler SST in the Bering Strait. This study reveals a need for future modelling experiments on longer timescales and emphasizes the need for data continuity going forward.

103-S1 Sea surface temperature in the East Central Pacific Ocean as a new potential predictor of post-monsoon cyclonic activity over the North Indian Ocean

Submitting author/speaker (Name and Surname): Neeru Jaiswal

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Submission date: 16/08/2023

Authors: Neeru Jaiswal and Randhir Singh

Abstract

The Power Dissipation Index (PDI) of post-monsoon season tropical cyclones (TCs) over the north Indian Ocean (NIO) is examined in relation to interannual variability of sea surface temperature (SST) over global ocean during 1982–2021. TCs PDI over NIO and SST over the east central Pacific Ocean (ECPO) are strongly correlated; this relationship first appears in June and persists through December, with maximum correlation occurring in November-December, which also happens to be the time of peak TCs activity. The physical mechanism underlying this teleconnection is examined by numerical simulations employing Weather Research and Forecasting (WRF) model with SST anomalies prescribed over the ECPO. The Gill-Matsuno mechanism, which is activated by heating over the ECPO, triggered an upper tropospheric disturbance that propagated eastward and produced an abnormal upper anticyclonic circulation over North East India and lower level cyclonic circulation over the Bay of Bengal. This upper level anticyclonic and low level cyclonic circulation contributed to the favourable conditions (such as enhanced low level convergence and upper level divergence, enhanced low and mid-level relative vorticity, moist atmosphere, enhanced convective available potential energy, and reduced vertical wind shear) for TC genesis and intensification over the NIO.
Therefore, SST over the ECPO can be highly helpful in predicting post-monsoon TC activity over the NIO with a lead-time of around 4 months.

Science Session S2 - Processing and product generation

Chair: Claudia Fanelli (2)
Rapporteur and Co-Chair: Pallavi Govekar (1)
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Description of the session

SST products, following the GHRSST Data Specification (https://zenodo.org/record/6984989), rely on data from low-Earth orbit infrared and microwave satellite imagery, geostationary orbit infrared satellite imagery, and in-situ data from moored and drifting buoys, Argo floats, and Fiducial Reference Measurements (FRM) for product validation. The products comprise a suite of global high-resolution SST products to support operational forecast systems, climate science, and many diverse applications, and to facilitate a wide range of research in the broader scientific community.
Additional user-driven priorities in the coming year have been identified to be in relation to the Arctic, where Sea Ice Surface Temperature needs to be homogenised with SST as a uniform variable in order to define the boundaries between ocean/sea-ice and land and where the existing Arctic SST/IST analyses need to be connected with the global L4 SST counterparts.

In this session, the goal was to provide a review of state of art processing SST algorithms at different levels (L2, L3, L4) and improvements developed (e.g., cloud masking, noise reduction, application of different new-merged techniques like machine learning…) using satellite and in-situ data. We also welcomed discussion on generating ice and lake surface temperature products and downstream products to cater for biologists and ocean modelling communities such as reef-specific products, marine heat wave monitoring matrices, current and front detection and long-term time series of SST.

Gap-free SST L4 analysis using satellite, and possibly in situ data, are the most widely used SST products for both operational and research applications. Comparison and validation of the different analyses were covered in the session, in order to provide information to producers to enable them to improve their analysis systems and to provide users in their particular applications.

Keywords: SST algorithms, cloud masking, SST L4 intercomparison, SST Feature resolution, near-coastal applications, machine learning, user scientific applications.

Summary of the session

This report summarises the key points from the 2nd session of GHRSST24, which took place on Tuesday, 17 October 2023.

A Keynote Speech was given by Owen Embury from the University of Reading and National Centre for Earth Observation on "*A 42-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative*".

The third major version of the SST CCI Climate Data Record (CDR) will be released soon. It now spans over 42 years, using data from Advanced Very High Resolution Radiometer (AVHRR), Along Track Scanning Radiometer (ATSR), Sea and Land Surface Temperature Radiometer (SLSTR) instruments, Advanced Microwave Scanning Radiometer (AMSR)-E and AMSR2. The dataset includes both single-sensor products plus a Level-4 SST analysis generated using the Met Office Operational Sea Surface Temperature and Ice Analysis (OSTIA) system.

Version 3 of the SST CCI CDR is the first to make use of data from AVHRR/1 instruments carried on board NOAA-6, -8, and -10 platforms. This increases data coverage in the 1980s and extends the dataset back to 1980. The dataset also includes passive microwave AMSRE and AMSR2 data, FRAC MetOp AVHRR, and dual-view SLSTR data. Comparison of CMC, OSTIA 2.0, DOISSTv2.1 and ESA CCI v3.0 was discussed. DOISST is the only product to include Argo data.

An Interim-CDR will provide ongoing extension in time of the SST-CCI CDR at short notice (approximately 3 weeks behind present). Public data release scheduled in late 2023 via the CCI open data portal (https://climate.esa.int/en/odp/), while regional and re-gridded data product will be available from the webpage https://surftemp.net.

Questions:

1. *Why are MODIS, HRPT AVHRR and VIIRS not included in CCI?*

Answer: The inclusion may be considered in the future. We don't have time to include HRPT AVHRR SST into CCI, something to add to the wish list.

2. *Is the product in GHRSST format?*

Answer: Yes, they are GHRSST compliant.

Chong Jia from Rosenstiel School of Marine and Atmospheric Science, University of Miami, presented "*Significant Diurnal Warming Events and Ocean Warm Skin Signals Observed by Saildrone at High Latitudes*".

Data from two Saildrones, deployed in the Arctic in summer 2019, were used to investigate the diurnal variability of upper ocean thermal structure and the warm skin layers. Several local large diurnal warming events were observed; the amplitudes of warming in the skin layer was > 5 K. It was noted that the warming signals can persist beyond one day. Salinity plays an important role in the formation of upper ocean stratifications during diurnal warming at high latitudes. Some warm skin layers were identified from the combined effect of positive air-sea temperature difference, humid surface air and cloudy skies. Most warm skins were found during and shortly after rainfall. Model simulations indicate it is necessary to improve the diurnal warming models when applied at high latitudes and to incorporate the ability to simulate warm skin layers in present cool skin models. Haifeng commented that Faiall (2006) cool-skin model does not allow a warm skin.

Jacob L. Høyer from Danish Meteorological Institute made a presentation on "*A satellite-based surface temperature climate dataset of the Arctic ocean and sea ice, 1982–2021*".

Within the framework of the Copernicus Marine Monitoring Service Sea Ice Thematic Assembly Centre, the first gap-free (L4) of combined SST and IST climate dataset of the Arctic (>58°N) has been developed for the period 1982-2021. The CDR has been generated using optimal interpolation to combine multiple infrared satellite observations to daily, gap-free fields with a spatial resolution of 0.05 degrees. The combination of SST and IST provides a consistent climate indicator which can be used to monitor day-to-day variations as well as climate trends in the Arctic Ocean. Analysis of the CDR shows sea and sea-ice surface temperature of the Arctic has risen by about 4.5°C over the period 1982–2021, with a peak warming of around 10°C in the north-eastern Barents Sea. The combination of IR and Microwave shows superior spatial coverage and improves the SST estimates, without degrading the spatial resolution of the product.

Daniele Ciani from Consiglio Nazionale delle Ricerche, Istituto di Science Marine presented on "*Joint reconstruction of ocean surface currents and temperature through deep learning algorithms*".

Relying on CNN algorithms, two Observing System Simulation Experiments (OSSEs) were conducted based on numerical simulations. The neural networks were trained using OSSE data and then tested on Copernicus/GHRSST satellite-based products. The study was focused on the Mediterranean Sea, a challenging area dominated by small features (< 10 km). In the first experiment, synthetic, low-resolution L4 Ocean ADTs were combined with high-resolution "perfectly known" SSTs to derive high-resolution sea surface dynamical features. This approach integrated information from original and degraded resolution channels in a multi-channel image, leveraging the physical relationships learned from model physics and prior knowledge of observation geometry. In the second experiment, realistic SST L4 processing errors were introduced and the network was modified to simultaneously predict high-resolution SST and ADT from simulated L4 products. This allowed to assess the potential improvement in both variables while incorporating dynamical constraints through customized, physics-informed loss functions. These constraints ensure that the small-scale evolution of SSTs is driven by surface currents advection.

Pallavi Govekar from Bureau of Meteorology presented on "*Sea Surface temperature reprocessing of Himawari-8 archive*".

The Bureau of Meteorology produces numerous high-resolution satellite-derived SST data products as a contribution to the Integrated Marine Observing System (IMOS). Every 10 minutes, the Himawari-8 geostationary satellite, full disk is processed to retrieve SSTs by using the Radiative Transfer Model (RTTOV12.3) and the Bayesian cloud clearing method based on the ESA CCI SST code developed at the University of Reading. For ease of use, these native resolution SST data have been composited to hourly, 4-hourly and daily SST products and projected onto the rectangular Integrated Marine Observing System (IMOS) 2km grid. All the Himawari-8 data have been reprocessed back to

September 2015. In response to user requirements for gap-free, highest spatial resolution and highest accuracy SST data, the Bureau composites the geostationary Himawari-8 data with data from the Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Very High-Resolution Radiometer (AVHRR) satellite in polar-orbits to construct new "Geo-Polar Multi-sensor L3S" products on the IMOS grid.

The validation of different Himawari-8 SST products against in-situ SST data was presented. Downstream applications for L3S were demonstrated by showing preliminary results for development of marine heat wave monitoring and coral heat stress monitoring tools in the IMOS domain.

Questions

1. *Does BoM also validate sub-daily SST products? Is there a difference in validation of hourly H08 L3C and Daily H08 L3C?*

Pallavi Govekar: Yes, BoM validates hourly, 4-hourly and daily h08 products. Only monthly validation was shown in the presentation for reasons of time. You get better time match between satellite observations and in-situ observations for sub-daily product compared to daily/monthly product. We get similar results for our sub-daily and daily products, bearing in mind that the range will of course be different.

2. *How does the RTTOV model deal with the non-linear operator in the linear optimal interpolation?*

Owen Embury: In the SST retrieval the RTTOV assumes that the prior is sufficiently close and a linear adjustment from the prior is a valid approximation in the infrared.

3. *Have you considered feeding the neural network with information coming from Maximum Cross Correlation (MCC) techniques as well? It would help extract information on ocean currents from the evolution of SST patterns.*

Daniele Ciani: We have considered this, although MCC techniques mainly assume SST as a passive tracer, which may fail under strong ageostrophic processes.

4. *Why are there regions in the 1-hourly field you showed, which do not appear to have data in the 4-hourly composite?*

Pallavi Govekar: The 1-hourly and 4-hourly SSTs shown in the presentation are not from the same time step.

5. *How much data is lost going from QL3 to QL5?*

The CCI version 2 was used for Bayesian cloud clearing and for SST retrieval for H08. TheBayesian approach used was found stringent and only very high-level quality SST was retrieved. As a result, the product has a majority of valid SST pixels with QL=5.

6. *What is the resolution of the standard altimetry products used in your application? What is the resolution of such products after the correction by means of SST?*

Daniele Ciani: We start from an altimeter-derived product with nominal 1/8° resolution, although the effective resolution is around 50 – 60 km. SST can help improve the spatial resolution up to 30 km in clear-sky conditions, i.e. when the L4 SST products used in the application are not smoothed by interpolation procedures.

7. *Do you plan to process pre-2000 1km AVHRR data or only the GAC data from that period?*

Owen Embury: Currently we only process the GAC data from NOAA sensors but it is something that we will do in the future.

Discussion

Chris Merchant wondered if the GHRSST community should be putting out a public statement about the record SSTs we are observing and the effects of the global warming.

Anne O'Carroll added that this would require to organize a sub-team of GHRSST experts and can be discussed in Friday's W1 session.

Helen Beggs commented that CSIRO, Australia, is in process of rescuing level-0 and level-1 HRPT AVHRR data back to 1981. If interested, contact Edward King.

Conclusions

Science Session 2 of GHRSST24 revealed the importance of the production of several new high-resolution datasets and the development of new processing techniques for Sea Surface Temperature analysis. A new version of ESA-CCI Climate Data Record (provided in GHRSST compliant format) will extend the data coverage over the global ocean back to 1980s and will include several infrared and microwave-based sensors as well as in-situ data. Moreover, a new SST and IST climate dataset has been developed over the Arctic zone for the period 1982-2021. This time extension provides new insights on daily variation of SST in the Arctic Ocean and can also be exploited to derive climate indicators, with a particular focus on the raising trend of SSTs. Evidences of severe diurnal warming events in the Arctic were also depicted, exploiting data from Saildrones, which highlights the importance of incorporating the ability to simulate warm skin layers in present cool skin models. Moreover, the importance of producing high-resolution datasets such as the Himawari-8 SST products and of exploiting the impressive results derived from the application of machine learning techniques to reconstruct sea surface dynamical features was presented and demonstrated.

The conclusion of the session revealed that the GHRSST community feels the responsibility to communicate to the general public on several insights of climate trends and global warming that can be derived from the production and the analysis of high-resolution SST products over the global ocean and the regional seas.

Overview of the talks

Nr.	Name	Institution	Title	Link
62-S2	Owen Embury	University of Reading and National Centre for Earth Observation	A 40-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative	**KEYNOTE PDF** Video: https://youtu.be/p-PIX3cTxQk
7-S2	Chong Jia	Rosenstiel School of Marine and Atmospheric Science, University of Miami	Significant Diurnal Warming Events and Ocean Warm Skin Signals Observed by Saildrone at High Latitudes	**Invited talk PDF** Video: https://youtu.be/A2M_hEH1XJM
32-S2	Pia Nielsen-Englyst (Speaker: Jacob L. Høyer)	Danish Meteorological Institute	A satellite-based surface temperature climate dataset of the Arctic ocean and sea ice, 1982–2021.	**Invited talk PDF** Video: https://youtu.be/G1xgQ9_XmnQ
80-S2	Daniele Ciani	Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine, Via del Fosso del	Joint reconstruction of ocean surface currents and temperature through deep learning algorithms	**Invited talk PDF** Video: https://youtu.be/16GshGHIRQw
16-S2	Peter Minnett, Jorge Vazquez-Cuervo, & Edward Armstrong	NASA Jet Propulsion Laboratory/California Institute of Technology	Options for MODIS discontinuity with use case of MUR SST	**Invited talk in PDF** Video: https://youtu.be/2m0n9Iq2Szg
21-S2	Pallavi Govekar	Bureau of Meteorology	Sea Surface temperature reprocessing of Himawari-8 archive	**Invited talk PDF** Video: https://youtu.be/gkT_jf4b4-Y ;

Overview of the posters

Nr.	Name	Institution	Title	PDF	Watch the video
2-S2	Anne O'Carroll	EUMETSAT	Copernicus Sentinel-3 Sea (and sea-Ice) Surface Temperature: product status, evolutions and projects	**PDF**	Video: https://youtu.be/Ey7P5gj0I7s
18-S2	Danielle Carpenter	Naval Oceanographic Office	Naval Oceanographic Office Sea Surface Temperature Processing and Products	**PDF**	Video: https://youtu.be/IKMFR3MSswA
38-S2	Thibault Guinaldo	CNRM, Météo-France	Impact of France's 2022 meteorological summer heatwaves on sea surface temperature	**PDF**	
46-S2	Sujuan Wang	National Satellite Meteorological Center (National Center for Space Weather)	The FY-3/VIRR Reprocessing Sea Surface Temperature Dataset V1.1	**PDF**	Video: https://youtu.be/8Kma_UDhKXM
82-S2	Ioanna Karagali	Danish Meteorological Institute	North and Baltic Sea GHRSST-compliant SST products for the Copernicus Marine Service	**PDF**	Video: https://youtu.be/IHGn4UIhNsU
94-S2	Marouan Bouali	ORBTY Ltda.	Multidimensional Dynamic Data Fusion of satellite sea surface temperature: Application to Level 3C/3S products and impact on gradients	**PDF**	Video: https://youtu.be/2X7sbUqhcq0
97-S2	Lucile Gaultier	OceanDataLab	New ocean dynamics assessment strategy through SST frontal detection	**PDF**	Video: https://youtu.be/NqiL1fg9bvc
89-S2	Benoît Tournadre	Meteo France	OSISAF's reprocessing and extension of Meteosat/SEVIRI 0°sea	**PDF**	Video: https://youtu.be/h1kkHjd8qWg

	surface temperature data record

Abstracts Science Session S2 - Processing and product generation

KEYNOTE 62-S2: A 40-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative

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Abstract

ESA's Climate Change Initiative (CCI) will soon release the third major version of the SST CCI Climate Data Record (CDR) which now spans over 40 years, using data from Advanced Very High Resolution Radiometer (AVHRR), Along Track Scanning Radiometer (ATSR), Sea and Land Surface Temperature Radiometer (SLSTR) instruments, Advanced Microwave Scanning Radiometer (AMSR)-E and AMSR2. The dataset includes both single-sensor products plus a Level 4 SST analysis generated using the Met Office Operational Sea Surface Temperature and Ice Analysis (OSTIA) system.

Version 3 of the SST CCI CDR is the first to make use of data from AVHRR/1 instruments carried on board NOAA-6, -8, and -10 platforms. This increases data coverage in the 1980s and extends the dataset back to 1980. The quality of the AVHRR retrievals has been improved by using a new bias aware optimal estimation (BAOE) technique and updated radiative transfer modelling which significantly reduces the SST biases due to dust aerosols seen in previous CDRs. Additionally, the dataset also includes passive microwave AMSRE and AMSR2 data, MetOp AVHRR now at full resolution, and dual-view SLSTR data.

Complementary to the ESA CCI CDR we are producing an Interim CDR (ICDR) to proving an ongoing extension in time of the SST-CCI CDR at short delay (approx. 2 weeks behind present). The ICDR was funded by the Copernicus Climate Change Service (C3S) for 2022 and is now funded by the UK Earth Observation Climate Information Service (EOCIS) and Marine Climate Advisory Service (MCAS) for 2023 onwards.

TALK 7-S2: Significant Diurnal Warming Events and Ocean Warm Skin Signals Observed by Saildrone at High Latitudes

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Abstract

The existence of a cool sea surface skin layer in the global ocean during both day and night is generally recognized. However, a skin sea surface temperature (SST_{skin}) warmer than subsurface temperature (SST_{depth}) may result from diurnal warming under strong insolation and low wind speed, or if there is a warm skin when the total surface net heat flux (Q_{net}) is from the atmosphere into ocean. Here, data from two Saildrones, deployed in the Arctic in the summer of 2019, are used to investigate the diurnal variability of upper ocean thermal structure and the warm skin layers. Several local large diurnal warming events were observed, the amplitudes of warming in the skin layer > 5 K, rarely reported in previous studies. Furthermore, the warming signals can persist beyond one day. Salinity also plays an important role in the formation of upper ocean stratifications during diurnal warming at high latitudes. A less salty surface layer may be created by precipitation or melting sea ice, providing favourable conditions for the formation of upper ocean stratification. Some warm skin layers were identified due to the Q_{net} gain resulting from the combined effect of positive air-sea temperature difference, humid surface air and cloudy skies. Moreover, most warm skins were found during and shortly after rainfall. Model simulations indicate it is necessary to improve the diurnal

warming models when applied at high latitudes and to incorporate the ability to simulate warm skin layers in present cool skin models.

TALK 32-S2: A satellite-based surface temperature climate dataset of the Arctic Ocean and sea ice, 1982–2021.

Submitting author/speaker (Name and Surname): Jacob L. Høyer, Pia Nielsen-Englyst, Wiebke Kolbe, Ioanna Karagali and Gorm Dybkjær.

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Abstract

Accurate estimates of sea surface (SST) and sea-ice surface temperatures (IST) are crucial for understanding, monitoring and predicting climate change in the Arctic. Within the framework of the Copernicus Marine Monitoring Service Sea Ice Thematic Assembly Center, the first gap-free (L4) of combined SST and IST climate data set of the Arctic (>58°N) has been developed for the period 1982-2021. The CDR has been generated using optimal interpolation to combine multiple infrared satellite observations to daily, gap-free fields with a spatial resolution of 0.05 degrees. The combination of SST and IST provides a consistent climate indicator which can be used to monitor day-to-day variations as well as climate trends in the Arctic Ocean. Validation against in situ measurements from drifting buoys, moored buoys and Argo floats shows mean differences of 0.01 °C, 0.04 °C and 0.04 °C and standard deviations of 0.54 °C, 0.56 °C and 0.51 °C, respectively for the open ocean. Analysis of the CDR show sea and sea-ice surface temperature of the Arctic has risen with about 4.5 °C over the period 1982–2021, with a peak warming of around 10 °C in the north-eastern Barents Sea. Different methodologies have been tested to assess the optimal way of including passive microwave SST observations from the ESA CCI project in the L4 IR SST product. The combination of IR and Microwave show superior spatial coverage and improve the SST estimates, without degrading the spatial resolution of the product.

TALK 16-S2: Options for MODIS discontinuity with use case of MUR SST

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Abstract

With the anticipated end of the Terra and Aqua missions in the next few years, there is concern about how best to ensure continuing the time series of the Climate Data Record of SSTskin, and of widely used L3 and L4 fields.

Currently, operational VIIRS on S-NPP, NOAA-20, NOAA-21, and future satellites in this series are the best candidates to continue Aqua MODIS SSTskin time series. Major similarities are a 13:30 Equatorial Crossing Time as the maintained Aqua orbit; a wide swath that gives daily global coverage; and Infrared SSTskin channels that are a subset of MODIS. A further advantage for not disrupting the time series, is the continuity of algorithms for cloud screening and atmospheric corrections. Demonstrated accuracies for VIIRS SSTskin are comparable to those of MODIS.

The current best option for MODIS on Terra is SLSTRs on Sentinel-3s, with a better option in the future METimage on MetOp-SGs, the first planned for launch in early 2025. METimage is a wide-swath imager with infrared channels that closely match those of MODIS.

An example of the use of MODIS to create a more highly derived fields is the Multi-Scale Ultra-High Resolution (MUR) sea surface data set. MUR is widely used with over 2,500 unique users between March 2022 and February 2023 in both the research and operational communities, including the NOAA CoastWatch on both east and west coasts of the USA.

TALK 80-S2: Joint reconstruction of ocean surface currents and temperature through deep learning algorithms

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Abstract

Recently, advancements in technology have fostered the use of deep-learning techniques across various fields. Computer vision, a branch of artificial intelligence, has benefited from complex model architectures based on deep Convolutional Neural Networks (CNN), bringing significant improvements.

We focus on the optimization of Absolute Dynamic Topography (ADT) and Sea Surface Temperature (SST) Level 4 (L4) observations, specifically those provided by the Copernicus Marine Service. Retrieving these variables from space is limited by instrument/sampling constraints, as well as degradations caused by interpolation algorithms to reach the L4 analysis.

Relying on CNN algorithms, we conducted two Observing System Simulation Experiments (OSSEs) based on numerical simulations. In the first experiment, we combined synthetic, low-resolution L4 Ocean ADTs with high-resolution "perfectly known" SSTs to derive high-resolution sea surface dynamical features. This approach integrates information from original and degraded resolution channels in a multi-channel image, leveraging the physical relationships learned from model physics and prior knowledge of observation geometry.

In the second experiment, we introduced realistic SST L4 processing errors and modified the network to simultaneously predict high-resolution SST and ADT from simulated L4 products. This allowed us to assess the potential improvement in both variables while incorporating dynamical constraints through customized, physics-informed loss functions. These constraints ensure that the small-scale evolution of SST is driven by surface currents advection.

The neural networks were trained using OSSE data and then tested on Copernicus/GHRSST satellite-based products. Our study focuses on the Mediterranean Sea, a challenging area dominated by features with scales down to 10 km.

TALK 21-S2: Sea Surface temperature reprocessing of Himawari-8 archive

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Abstract

SST measurements benefit a wide spectrum of operational and research applications, including ocean, weather, climate and seasonal monitoring/forecasting, military operations, coral bleaching assessment, commercial fisheries and aquaculture, and environmental management. The Bureau of Meteorology produces numerous high-resolution satellite-derived SST data products as a contribution to the Integrated Marine Observing System (IMOS). Every 10 minutes, the Himawari-8 geostationary satellite, full disk is processed to retrieve SSTs by using the Radiative Transfer Model (RTTOV12.3) and the Bayesian cloud clearing method based on the ESA CCI SST code developed at the University of Reading. For ease of use, these native resolution SST data have been composited to hourly, 4-hourly and daily SST products and projected onto the rectangular Integrated Marine Observing System (IMOS) 2km grid. All the Himawari-8 data have been reprocessed back to September 2015. In response to user requirements for gap-free, highest spatial resolution and highest accuracy SST data, the Bureau composites the geostationary Himawari-8 data with data from the Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Very High-Resolution Radiometer (AVHRR) satellite in polar-orbits to construct new "Geo-Polar Multi-sensor L3S" products on the IMOS grid.

The new Himawari-8 and Geo-Polar Multi-sensor L3S SST products are expected to provide improved data for applications such as IMOS OceanCurrent, the Bureau's ReefTemp Coral Risk Monitoring

service, and studies of marine heatwaves and ocean upwelling in near-coastal regions. We will present retrieving process along with validation of different Himawari-8 SST products against in-situ SST data and demonstrate applications for the new products.

Posters

2-S2: Copernicus Sentinel-3 Sea (and sea-Ice) Surface Temperature: product status, evolutions and projects

Submitting author/speaker: Anne O'Carroll

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Abstract

The first Copernicus Sentinel-3 satellite was launched on 16th February 2016 and the second on 25th April 2018. The Sentinel-3A/B satellites observe high quality Sea Surface Temperature (SST) from the Sea and Land Surface Temperature Radiometer (SLSTR). These accurate SSTs provide a reference satellite SST dataset and time-series for other satellite SST missions and are important for climate monitoring.

Operational SLSTR SST products have been distributed from the EUMETSAT marine centre since 5th July 2017. EUMETSAT performs ongoing validation activities for SLSTR SST, together in coordination with the Sentinel-3 validation team, and real time monitoring is shown from the link to metis.eumetsat.int. Validation results show the products performing extremely well, and dual-view SSTs are recommended to be able to be used as a reference SST source.

EUMETSAT began activities in 2021 towards revised and improved algorithms for SLSTR SST and sea-ice Surface Temperature (ST) with the intention of the operational implementation of SLSTR day-2 SST and day-1 sea-ice ST by 2025. This includes improvements to the Bayesian cloud-screening, retrieval coefficient updates, inclusion of depth SST in addition to skin SST, inclusion of full nadir grid, and the first operational implementation of sea-ice ST for SLSTR. Improvements implemented in December 2022 included revised SST coefficients, theoretical uncertainties, quality level flagging and updates to the SSES scheme. A demonstrational sea-ice ST prototype processor continues routinely on the

Copernicus WEkEO platform. Recent results and information on further ongoing projects and evolutions relating to Sea Surface Temperature at EUMETSAT will be presented.

18-S2: Naval Oceanographic Office Sea Surface Temperature Processing and Products

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Abstract

The Naval Oceanographic Office (NAVOCEANO) Ocean Measurements Division is responsible for providing near-real-time sea surface temperature (SST) measurements to the US Navy and national/international partners. NAVOCEANO and other Navy partners provide the research and development of the SST processing for numerous satellite data sets that NAVOCEANO operationally produces. This SST data assimilates into the Navy's Global Ocean Forecast System (GOFS) and Global Environmental Model (NAVGEM) and soon in the Navy Global Earth System Prediction Capability (ESPC). NAVOCEANO is a member of the Group for High Resolution SST (GHRSST), operationally providing and acquiring GHRSST datasets. The intent of our poster is to go into further detail on the products we create, show the satellites we currently use as well as ones we will use in the future, and display our contributions to the GHRSST community.

38-S2: Impact of France's 2022 meteorological summer heatwaves on sea surface temperature

Submitting author/speaker (Name and Surname): Stéphane SAUX PICART

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Abstract

The summer of 2022 in France is ranked as the second hottest summer since 1900, with an average surface air temperature of 22.7 °C, primarily explained by numerous atmospheric heatwaves. In this study, we examined the sea surface temperature (SST) of French maritime basins using remote sensing data to understand how surface waters responded to the atmospheric heatwaves and to determine the magnitude of this feedback. In addition to exploring the direct relationship between SST and surface air temperature, we investigated the atmospheric parameters that primarily influence the upper-layer ocean heat budget. Despite some data gaps, the measured SSTs during the meteorological summer of 2022 broke records, with mean SSTs ranging from 1.3°C to 2.6 °C above the long-term average (1982–2011). The studied areas experienced 4 to 22 days where basin-averaged SSTs exceeded the maximum recorded from 1982 to 2011. We also observed a significant SST response during heatwave periods, with local maximum temperatures reaching 30.8 °C in the north-western Mediterranean Sea. Our analysis reveals that in August 2022 (31 July to 13 August), France encountered above-average surface solar radiation, below-average total cloud cover, and negative wind speed anomalies. Our attribution analysis, based on a simplified mixed-layer heat budget, highlights the critical role of ocean-atmosphere fluxes in initiating abnormally warm SSTs, while ocean mixing plays a crucial role in the cessation of such periods. This study emphasizes the necessity of an effective and sustainable operational system that combines polar-orbiting and geostationary satellites. Such a system is crucial for monitoring the changes that threaten the oceans in the context of climate change.

46-S2: The FY-2/VIRR Reprocessing Sea Surface Temperature Dataset V1.1

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Submission date: 06/07/2023

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Abstract

The FY-3/VIRR Reprocessing Sea Surface Temperature Dataset V1.1 (RV1.1) was created from L1 data of the VIRR instruments, flown onboard FY-3A/B/C satellites from January 2009 to September 2021. The dataset includes both single-sensor products at L2P and L3C (two global maps per 24hr, for day and night), which is "subskin" SST, highly sensitive to skin SST. The major features of the RV1.1 will be discussed during GHRSST24.

82-S2: North and Baltic Sea GHRSST-compliant SST products for the Copernicus Marine Service

Submitting author/speaker (Name and Surname): Ioanna Karagali

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Submission date: 7/7/2023

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Abstract

Satellite missions carrying Thermal Infrared (TIR) and Passive Microwave Sensors (PMW) allow for high-resolution SST retrievals under clear skies (TIR) and all weather retrievals (PMW) albeit with coarser resolution. This allows the continuous provision of SST to operational Numerical Weather Prediction systems, climate models and to the wider scientific community. DMI is a Production Unit (PU) for the SST Thematic Assembly Center (TAC) of the Copernicus Marine Monitoring Service (CMS) providing a suite of level 4 SST products for the Baltic and North Sea daily, hourly and as multi-year products.

The L4 Near-Real-Time (NRT) SST product SST-BAL-SST-L4-NRT-OBSERVATIONS-010-007-b is a daily, multi-sensor, gap-free, optimally interpolated product derived from night-time SST retrievals at high resolution (0.02°), available from 2016 onward. The L4 Multi-Year SST product SST-BAL-SST-L4-REP-OBSERVATIONS-010-016 is a daily, multi-sensor, level 4 optimally interpolated product using infra-red satellite observations from the ESA CCI and Copernicus C3S projects and high resolution sea ice information from SMHI and the Copernicus Marine Service Sea Ice (SI) TAC available from 1982 to 2022. The L4 Near-Real-Time Diurnal SST product SST-BAL-PHY-SUBSKIN-L4-NRT-010-034 is an hourly, gap-free satellite sub-skin SST analysis using L2P and L3 single-sensor SST data as input. Within the next C3S portfolio, DMI will provide the SST ECV, i.e. a global (up to 90° latitude), sub-skin product (20 cm) with a 0.05° spatial resolution. The aim of the present study is to provide an overview of the available products and their performance along with insights on future developments and products.

94-S2: Multidimensional Dynamic Data Fusion of satellite sea surface temperature: Application to Level 3C/3S products and impact on gradients

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Submission date: 7/7/2023

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Abstract

Time averaged (3 days, weekly, monthly) composite maps of satellite-based geophysical parameters may display artifacts that result from the temporal variability of the geophysical variable under consideration, sensor calibration errors or uncertainties in Level 2 retrieval algorithms. The presence of such spatial discontinuities can affect downstream applications including the spatio-temporal analysis of gradients. Using computer vision principles, ORBTY has recently developed the Metocean Multi-Dimensional Dynamic Data Fusion System (M3DFS), a new methodology that seamlessly ingests multitemporal Level 2 datasets from a single or multiple instruments to produce Level 3 maps of Metocean parameters with significantly improved spatio-temporal representation.

In this presentation, a technical description of the M3DFS is provided. Results from the application of the M3DFS for the generation of Level 3C (collated) and Level 3S (super-collated) Sea Surface Temperature (SST) from microwave and Infrared instruments are illustrated along with the impact on the spatial distribution and temporal variability of SST gradients.

97-S2: New ocean dynamics assessment strategy through SST frontal detection

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Abstract

New satellite sensors arose during the past decade, enabling to observe a wide range of oceanic physical variables at various scales. Regarding ocean temperature retrieval, we benefit from very high resolution sensors (S3-SLSTR, VIIRS, and MODIS), medium resolution geostationary InfraRed sensors (SEVIRI) and low resolution microwave sensors (AMSR2/GMI). All these observations are complementary and contain important information regarding the upper ocean dynamics at various scales. Thus there is a need to better exploit the wealth of satellite data by considering them as structured information rather than pointwise.

In this study, we have built an automatic front detection algorithm from the SST in the upper ocean. This processing relies on the detection of two separated populations and is less sensitive to noise or clouds than gradient. It has been applied successfully on a wide variety of observations (L2/L3/L4). A 10-year database is already available on the WOC website (https://www.worldoceancirculation.org/Products). These SST fronts can then be compared with Ocean surface current derived from observation and model as they reveal Lagrangian Coherent Structures.

In this talk, we will explain the fronts retrieval methodology, and we will then illustrate with examples from the 10 year database. Finally we will demonstrate the interest of using SST fronts to perform ocean surface current assessment. Indeed, they have been used to perform long term ocean surface current assessment within the WOC project and are also operationally used to help with ship routing and compute an optimised current.

89-S2: OSISAF's reprocessing and extension of Meteosat/SEVIRI 0° sea surface temperature data record

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Abstract

EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSI SAF) produces and distributes various satellite-based data sets describing the interface between ocean and atmosphere. The OSI SAF provides a data record of sea surface temperature (SST) based on the imagery from SEVIRI sensors onboard Meteosat Second Generation platforms at 0° longitude. The data product, projected on a 0.05° grid and with an hourly resolution, covers the entire MSG's field of view, currently for the period from 2004 to 2012. We present ongoing developments for extending OSI SAF's dataset onto the 2004-2023 period, ensuring its stability over time despite changes and ageing of satellite instruments, and improving the treatment of observations affected by Saharan dust episodes.

Science Session S3 - Calibration, Validation and Product Assessment

Chair: Mingkun Liu (1)
Rapporteur and Co-Chair: Prasanjit Dash (2)
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Description of the session

This session aimed to highlight recent advancements in sea-surface temperature (SST), with a particular focus on the calibration and validation of satellite-derived SST products and the assessment of their quality and applicability.

The session focused on the following:

- Calibration and inter-calibration of satellite instruments.
- Validation of satellite-derived SST products.
- Comparisons between satellite data products and in situ measurements.
- Inter-comparisons of satellite data products from various platforms and sensors.
- Quality control and quality assurance of satellite data products.
- Evaluation of uncertainties and error sources in SST products.

Keywords: calibration, intercalibration, validation, product assessment, inter-comparison, quality control, quality assurance, uncertainties, evaluation, error sources.

Summary of the session

This is a short summary of session 3 of GHRSST24 which featured five oral presentations and an open discussion.

A Keynote Speech was given by Haifeng Zhang (Bureau of Meteorology) on the "Validation of Himawari-8 Sea Surface Temperature Retrievals Using Infrared SST Autonomous Radiometer Measurements".

Conclusions:

This Bureau/IMOS physically retrieved fv02 H8 SST L2P product proves to have:

- High sensitivity to the skin temperature variation
- Overall good quality
- A cold bias during daytime (-0.12 ± 0.47 K) under almost all environmental conditions
- Consistently more stable night-time SSTs (-0.04 ± 0.37 K)
- Reprocessed ISAR skin SSTs - a reliable fiducial source of 'ground truth' for satellite R SST retrieval validations

Future Work:

- Dig deeper into the daytime cold bias
- Look into the many unusually cold outliers during night-time in year 2016
- Validate the Bureau's IMOS Himawari-9 L2P SST data (to be available in June 2024)

Questions

During a conversation with Gary Wick, he suggested using diurnal warming as a way to assess the quality of a geostationary satellite SST product. Building on the previous presentation, he found it intriguing to observe the spatial variations in diurnal amplitude for overall quality considerations. Haifeng's initial example demonstrating the diurnal cycle was promising and reassuring. Despite some minor night time temperature dips, deriving diurnal amplitude from a noisy record is a complex process. Gary is interested in examining spatial maps of diurnal warming to assess the stability of spatial patterns. Haifeng's initial results are encouraging, and further investigation could provide valuable insights.

Haifeng Zhang responded: I think that can be a very interesting thing to dig deeper in the future to have a spatial distribution product like that.

Jorge Vazquez, NASA Jet Propulsion Laboratory/California Institute of Technology, presented on the "Identification of Sea Surface Temperature and Sea Surface Salinity Fronts along the California Coast: Application Using Saildrone and Satellite Derived Products".

Conclusions and Future work:

- Comparison of satellite derived SST and SSS gradients with the Saildrone uncrewed Vehicle is encouraging for the application of remote sensing derived salinity and sea surface temperature in coastal regions.

- Challenges that remain include improvements in cloud-masking for infrared sensors in coastal regions and improvements in applications of land contamination in microwave sensors.
- The Saildrone Uncrewed Vehicle has proved it has a unique capability for validation of gradients.
- High resolution matters. Future SST datasets from ECOSTRESS and TRISHNA. Current work led by David Wethey on producing a sub-kilometre SST dataset from ECOSTRESS.

Surisetty V V Arun Kumar, Space Applications Centre (ISRO), presented on the "Inter-comparison of GHRSST Sea Surface Temperature Products from Different Resolutions and Datasets: A Case Study in the Indian Ocean Region".

Key Findings and Conclusion:

JPL SST data is capable of resolving small scale features well, as compared to other datasets, suggesting it could thus be used in PFZ identification. However, the comparative analysis with in-situ data shows JPL is having RMSE ~0.3°C with negative bias and R~0.951 at native resolution. When interpolated to 10km resolution, no major changes in metrics have been observed. The datasets from CMC and UKMO give better comparison with in-situ data for the year of study. The RMSE~0.25°C and R~0.982 have been observed. DMI is showing a lower performance compared to other GHRSST datasets (RMSE~0.45°C and R~0.94). More GHRSST data with independent SST observations have thus been required in order to assess the performance of all the datasets. All the datasets showed a significantly poor statistics during pre and post monsoon (transition phases), which should be further evaluated and taken proper measures to correct it.

Questions

1. *What is the collocation criteria with respect to time of measurements, are any collocation criteria kept?*

Surisetty V V Arun Kumar: We inter-compared the daily averaged data because these GRIS products were daily averaged. So we averaged the IQAM datasets on a daily temporal scale.

2. *You took all the data measurements within the 24 hours and you have averaged for every grid? Because normally when we do validation, we try to do it at L2 level.*

Surisetty V V Arun Kumar: The analysed datasets are foundation SSTs, which have minimal diagonal variation. Therefore, we averaged all available in-situ data for that day, resulting in these findings. Initially, we considered limiting our validation datasets to evenings when solar insulation effects are negligible. However, we discovered that this is a foundation dataset, making the inclusion or exclusion of these datasets less crucial. Nonetheless, further research is needed to assess the impact of daily and timely averages on this validation dataset.

Surisetty V V Arun Kumar: Day and night buoy data, drifting or mooring data are not used for validating L4. Drifting buoys experience diurnal warming under low wind and high insulation conditions. We rely on night-time observations with higher wind speeds for validation. Saildrone and independent skin SST from ships provide separate sources of validation. Argo SST should not be included in L4 products for independent validation. GIMPI's suitability is being questioned.

Independent in situ data is required for a perfect solution. Coastal moorings and specific in situ sources can be considered, but ensure they are not heavily weighted in the L4 product. Drifting buoy and tropical mooring data are extensively used in L4 products, making their use for validation redundant.

3. *You said that it's not right to use the drifting moored data during daytime for the validation studies? But by also considering wind speeds, over very high wind speeds, we can use it?*

Surisetty V V Arun Kumar: The quality control of in situ data depends on the producer. At the Bureau, I reject daytime in situ SSTs, including those from tropical moorings and drifting buoys, for wind speeds above six meters per second. For night-time, the threshold is above two meters per second. This sensitivity analysis showed negligible differences for wind speeds above six. The OI SST V2.1, being a blended product, gives equal weight to daytime and night-time data without considering wind speeds. This means wind speed is not used to quality control the in situ data incorporated in the OI SST. Understanding how the L4 product is produced is crucial for validation purposes.

Guisella Gacitúa, Danish Meteorological Institute, presented on the Ship-Borne Inter-Comparison of Thermal Infrared and Passive Microwave Instruments for Sea Surface Temperature Measurements.

Instrument design consideration: Sensitivity to noise, cables losses due to manipulation, improved robustness. Incorporate complementary instrumentation: PMW incidence angle, Local weather conditions. Ensure a larger matchup dataset.

Boyin Huang (Speaker: Huai-min Zhang), NOAA/NCEI, presented on the Importance of Uncertainties and Benchmark Metrics in the Diagnostics and Intercomparisons of Sea Surface Temperature Records.

"Discrepancies" of GHRSST L4 performance on different sites/studies are assessed: Results are different for aera-averaged metrics vs pointwise metrics, as well as the exact data QC used ("Orang and Apple Comparisons"). DOISST has a good performance in long term time series against in-situ data (lower SD and DIFF). OISST's performance suffers in localized areas, due to the bias-correction at large scale - needs to be improved. SDs decrease to the lowest in OSTIA and CMC, when they are interpolated from their native grids and compared to in-situ point observations, which may result from their high resolutions and bias correction by matchups in a small scale. SDs relative to Argo and drifting buoys are smaller, which may result from their longer observing interval; including high-resolution (6m - 1 h) moored buoy data increases the SDs. SDs in SQUAM (relative to iQuam QC flag-5) are smaller than those relative to ICOADS (FG or CLM OC) due to smaller numbers of observations near the ocean coasts. GMPE has its own biases and are not necessarily better than the input L4 products.

Questions

To clarify, the Met Office products from 2021 onwards do not use optimal interpolation. So, if the focus is on the impact of OI, data prior to February 2018 should be used. It would be helpful to mention which specific products were compared, as it seems that the Met Office products used are the newer mobile version, more recent than the OI and some other participating products in OSTIA.

SLSTR and AATSR are not the most up-to-date. The UK Met Office used the OSTIA product, while JPL used the L4 MUR product for comparison.
Huai-min Zhang: The results mentioned are from 2021, but if it's the near real-time Met Office OSTIA, it does not use OI since OI version was discontinued in February 2018. To assess OI impact, the period before February 2018 should be considered.

Conclusion

Science Session 2 of GHRSST24 revealed that:

- Validation of Himawari-8 SST retrievals showed high sensitivity to skin temperature variation and overall good quality. However, a cold bias was observed during daytime, while night-time SSTs were more stable. Reprocessed ISAR skin SSTs were considered a reliable source of validation.
- The identification of sea surface temperature and sea surface salinity fronts along the California coast using Saildrone and satellite-derived products showed encouraging results. Challenges include improving cloud-masking and addressing land contamination. The Saildrone Uncrewed Vehicle proved to have a unique capability for validating gradients. High-resolution data and future datasets from ECOSTRESS and TRISHNA were emphasized.
- The inter-comparison of GHRSST sea surface temperature products revealed that JPL data resolved small-scale features well but had a negative bias and higher RMSE compared to in-situ data. Datasets from CMC and UKMO showed better comparison with in-situ data. DMI dataset performed least among GHRSST datasets. More independent SST observations were recommended to assess dataset performance. Poor statistics were observed during pre and post monsoon periods.
- The ship-borne inter-comparison of thermal infrared and passive microwave instruments for sea surface temperature measurements highlighted the importance of instrument design considerations, sensitivity to noise, cable losses, and robustness. Incorporating complementary instrumentation for PMW incidence angle and local weather conditions was suggested. Ensuring a larger matchup dataset was also emphasized.

Overview of the talks

Nr.	Name	Institution	Title	Link
14-S3	Haifeng Zhang	Bureau of Meteorology	Validation of Himawari-8 Sea Surface Temperature Retrievals Using Infrared SST Autonomous Radiometer Measurements	**KEYNOTE PDF** Video: https://youtu.be/LdyqsOr-FOU
8-S3	Jorge Vazquez	NASA Jet Propulsion Laboratory/California Institute of Technology	Identification of Sea Surface Temperature and Sea Surface: Salinity Fronts along the California Coast: Application Using Saildrone and Satellite-Derived Products	**Invited talk PDF** Video: https://youtu.be/53MshHza3B8?feature=shared
30-S3	Surisetty V V Arun Kumar	Space Applications Centre (ISRO)	Inter-comparison of GHRSST Sea Surface Temperature Products from Different Resolutions and Datasets: A Case Study in the Indian Ocean Region	**Invited talk PDF** Video: https://youtu.be/RqZ2RYItx8o
43-S3	Guisella Gacitúa	Danish Meteorological Institute	Ship-Borne Inter-Comparison of Thermal Infrared and Passive Microwave Instruments for Sea Surface Temperature Measurements	**Invited talk PDF** Video: https://youtu.be/7RHEDG3IIDY
11-S3	Boyin Huang	NOAA/NCEI, Asheville, North Carolina, USA	Importance of Uncertainties and Benchmark Metrics in the Diagnostics and Intercomparisons of Sea Surface Temperature Records	**Invited talk PDF** Video: https://youtu.be/xRB-V-pgLac

Overview of the posters

Nr.	Name	Institution	Title	Download the PDF	Watch the video
1-S3	Albert Larson	University of Rhode Island	Holistic Water Cycle Analysis via the Confluence of Climate Model, Satellite, Ground Truth, and Machine Learning Signal Processing Technologies: Two North American Transboundary River Watersheds	**PDF**	Video: https://youtu.be/VNmzA_20Q84
6-S3	Chong Jia	Rosenstiel School of Marine and Atmospheric Science, University of Miami	Validation for MODIS SST Retrievals Using the Saildrone Uncrewed Surface Vehicle Data	**PDF**	Video: https://youtu.be/XQcuphACNME
9-S3	Boris Petrenko	NOAA STAR and GST, Inc.	Towards Improved Quality Control of in situ SSTs from drifting and moored buoys in the NOAA iQuam system	**PDF**	Video: https://youtu.be/B0ZrCKxJVDM
10-S3	Olafur Jonasson	STAR, NOAA Center For Weather and Climate Prediction (NCWCP)	NOAA 1st MODIS SST Reanalysis (RAN1) from Terra and Aqua	**PDF**	Video: https://youtu.be/1xadwQf7Osw
13-S3	Samadrita Basu	National Institute of	Intercomparison of Sea Surface Temperature	**PDF**	Video: https://youtu.be/cl8snxwdVeo

		Technology Rourkela	datasets and estimating Spatial and Temporal Variability of SST over the Arabian Sea and Bay of Bengal region.		
20-S3	Swapna Mulukutla	National Remote Sensing Centre (NRSC), ISRO	Diurnal variability of INSAT-3D SST in the Indian Ocean-intercomparison with in-situ and satellite observations	**PDF**	Video: https://youtu.be/nf5l_bSLyTs
37-S3	David S. Wethey	University of South Carolina	ECOSTRESS vs Saildrone SST: Noise Comparisons	**PDF**	Video: https://youtu.be/tOcqgu1vAw4
40-S3	Kohei Mizobata	Tokyo University of Marine Science and Technology	Verification of AMSR2 SST in the Arctic Ocean and Implications of Freshwater Distribution on Estimation Error	**PDF**	Video: https://youtu.be/elnwpxAE-Uk
44-S3	Sebastien Marq	Centre National d'Etudes Spatiales (CNES)	TRISHNA Vicarious calibration of TIR sensors over oceans	**PDF**	Video: https://youtu.be/WcVFjyHbzwg
51-S3	Hitesh Gupta	Indian Institute of Technology Bhubaneswar	Assessment of GHRSST on the detection of Marine-Heat Waves and Heat-Spikes in the Bay of Bengal	**PDF**	Video: https://youtu.be/zRskI9GOO_U
65-S3	Kirstin Petzer	University of Cape Town, Rondebosch	A hierarchical approach to defining marine heatwaves	**PDF**	Video: https://youtu.be/sV78TsSZLow?feature=shared

71-S3	Munn Vinayak Shukla	Space Applications Centre (ISRO)	Entropy based evaluation of INSAT-3D/3DR Sea Surface Temperature products	**PDF**	Video: https://youtu.be/YfAqLNk24GM
83-S3	Kyung-Ae Park, Hye-Jin Woo	Seoul National University, Dep. of Earth Science Education	Assessment of the Accuracy and Error Characteristics of GK2A/AMI Sea Surface Temperatures: A Recent Three-Year Validation Study		Video: https://youtu.be/xFxdE4nLMWE
88-S3	Rachel Stumpf	St. Olaf College	An Evaluation of NOAA's LS Super-Collated SST Datasets	**PDF**	Video: https://youtu.be/7MStftxhEGU
91-S3	Sandra L. Castro	Colorado Center for Astrodynamics Research, University of Colorado Boulder	Examining the Consistency of Sea Surface Temperature and Sea Ice Concentration in Arctic Satellite Products	**PDF**	Video: https://youtu.be/6GGW5-Q4n18
95-S3	Raheema Rahman	Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES), Government of India	Evaluation of Sea surface Temperature from ocean reanalysis products over north Indian Ocean	**PDF**	Video: https://youtu.be/PJsEFj1xeIo

98-S3	Ajith Joseph Kochuparampil	Nansen Environmental Research Centre (India), KUFOS Amenity Centre	A Comparison of in-situ SST and Chlorophyll data with GHRSST and MODIS data	**PDF**	Video: https://youtu.be/0dRar0Z9MY4
104-S3	Neerja Sharma	Space Applications Centre (SAC), ISRO	Performance Evaluation of different GHRSST Products under Heavy Rain Conditions over North Indian Ocean	**PDF**	Video: https://youtu.be/TvqSeUp862U

Abstracts Science Session S3 - Calibration, Validation and Product Assessment

KEYNOTE 14-S3: Validation of Himawari-8 Sea Surface Temperature Retrievals Using Infrared SST Autonomous Radiometer Measurements

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Abstract

This study has evaluated five years (2016–2020) of Himawari-8 (H8) Sea Surface Temperature (SST) Level 2 Pre-processed (L2P) data produced by the Australian Bureau of Meteorology (Bureau) against shipborne radiometer SST measurements obtained from the Infrared SST Autonomous Radiometer (ISAR) onboard research vessel RV Investigator. Before being used, all data sets employed in this study have gone through careful quality control, and only the most trustworthy measurements are retained. With a large matchup database (31,871 collocations in total, including 16,418 during daytime and 15,453 during night-time), it is found that the Bureau H8 SST product is of good quality, with a mean bias ± standard deviation (SD) of -0.12°C ± 0.47°C for the daytime and -0.04°C ± 0.37°C for the night-time. The performance of the H8 data under different environmental conditions, determined by the observations obtained concurrently from RV Investigator, is examined. Daytime and night-time satellite data behave slightly differently. During the daytime, a cold bias can

be seen under almost all environmental conditions, including for most values of wind speed, SST, and relative humidity. On the other hand, the performance of the night-time H8 SST product is consistently more stable under most meteorological conditions with the mean bias usually close to zero.

TALK 8-S3: Identification of Sea Surface Temperature and Sea Surface Salinity Fronts along the California Coast: Application Using Saildrone and Satellite-Derived Products

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Abstract

Coastal upwelling regions are one of the most dynamic areas of the world's oceans. The California and Baja California Coasts are impacted by both coastal upwelling and the California Current, leading to frontal activity that is captured by gradients in both Sea Surface Temperature (SST) and Sea Surface Salinity (SSS). Satellite data are a great source of spatial data to study fronts. However, biases near coastal areas and coarse resolutions can impair its usefulness in upwelling areas. In this work gradients in SST from NASA Multi-Scale Ultra-High Resolution (MUR) and in two SSS products derived from the Soil Moisture Active Passive (SMAP) NASA mission are compared directly with gradients derived from the Saildrone uncrewed vehicles to validate the gradients as well as to assess their ability to detect known frontal features. The three remotely sensed data sets (MURSST/JPL, SMAP SSS/RSS, and SMAP SSS) were co-located with the Saildrone data prior to the calculation of the gradients. Wavelet analysis is used to determine how well the satellite-derived SST and SSS products are reproducing the Saildrone-derived gradients. Overall results indicate the remote sensing products are reproducing features of known areas of coastal upwelling. Differences between the SST and SSS gradients are mainly associated with the limitations of the microwave-derived SSS coverage near land and its reduced spatial resolution. The results are promising for using remote

sensing data sets to monitor frontal structure along the California Coast and the application to long-term changes in coastal upwelling and dynamics.

TALK 30-S3: Inter-comparison of GHRSST Sea Surface Temperature Products from Different Resolutions and Datasets: A Case Study in the Indian Ocean Region

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Abstract

This paper presents an inter-comparison study of sea surface temperature (SST) products derived from different resolutions and datasets within the Indian Ocean region. The study focuses on assessing the performance and consistency of GHRSST (Group for High-Resolution Sea Surface Temperature) products provided by Canadian Meteorological Centre CMC v3.0 (10 km), Danish Meteorological Institute DMI v1.0 (5 km), Jet Propulsion Laboratory Multi-scale Ultra high Resolution JPL-MUR v4.1 (1 km), Remote Sensing Systems REMSS v5.0 (9 km), and United Kingdom Met Office UKMO v2.0 (5 km). In-situ datasets from the iQuam (in-situ Quality Monitor) database are used for validation purposes. These datasets offer reliable reference measurements of SST, enabling a thorough evaluation of the

accuracy and reliability of the GHRSST products. The inter-comparison analysis focuses on quantifying the differences and similarities among the various GHRSST products. Statistical metrics, including bias, root mean square error (RMSE), and correlation coefficients, are employed to assess the level of agreement between datasets. The study also examines the spatial and temporal variability of SST captured by the GHRSST products. Preliminary results reveal both similarities and differences among the GHRSST products. While there is overall agreement, disparities in SST values and spatial patterns are evident across resolutions. Higher-resolution products, like JPL-MUR v4.1, demonstrate improved spatial details and better representation of thermal fronts compared to lower-resolution datasets such as CMC v3.0 and UKMO v2.0. Validation against iQuam in-situ datasets reveals RMSE of the range 0.3 – 0.5°C in various GHRSST products with the product from CMC and REMSS having least and product from JPL having the maximum RMSE in the entire Indian Ocean. This inter-comparison study enhances our understanding of the performance and suitability of GHRSST products for the Indian Ocean region in various applications.

TALK 43-S3: Ship-Borne Inter-Comparison of Thermal Infrared and Passive Microwave Instruments for Sea Surface Temperature Measurements

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Submission date: 06/07/2023

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Abstract

A ship-borne inter-comparison of sea surface temperature (SST) measurements using Thermal Infrared (TIR) and Passive Microwave (PMW) radiometers was conducted in spring 2021. The Danish Meteorological Institute (DMI) and the Danish Technical University (DTU) jointly deployed two TIR and two PMW instruments onboard the Norröna ferry, traveling between Denmark and Iceland for a week. This pioneering experiment provides a unique opportunity to compare TIR and PMW measurements in close proximity to the sea surface, minimizing atmospheric influences. The data set obtained enables a better understanding of SST skin (TIR) and sub-skin (PMW) temperatures.

A linear regression algorithm was developed using TIR SST skin data as a reference to retrieve PMW SST sub-skin from brightness temperature. The analysis focuses on examining variability and discrepancies between TIR and PMW data, considering factors like instrument noise, incident angles, surface roughness and skin versus sub-skin temperature. The overall root mean square error (RMSE) of the SST difference was found to be 0.88 K while the ship was moving and 0.94 K under steady conditions when the ship was moored. The error budget of PMW versus TIR temperature differences was analysed using observed quantities and forward models.

The objective of this study is to enhance our understanding and application of integrated PMW and TIR instruments, in anticipation of the forthcoming Copernicus Imaging Microwave Radiometer (CIMR) and Sentinel 3 SLSTR for SST measurements. This research endeavour serves as a foundation for future comparisons, for advancing in the precision and consistency of combined SST data.

TALK 11-S3: Importance of Uncertainties and Benchmark Metrics in the Diagnostics and Intercomparisons of Sea Surface Temperature Records

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Abstract

The year 2023 features a rapid ocean surface warming after the end of the past prolonged triple-dip La Nina event (2020-2022), which has caused significant media coverage. Most media coverage focused on whether the ocean surface has a record warming or not, at a certain time point or time period, and major available international sea surface temperature (SST) products gave different answers. Among the unanswered questions: 1) Are the differences among the various SST products scientifically/statistically different? And 2) what benchmark metrics should be used in SST intercomparisons? These questions remain important for the GHRSST community both scientifically and in communications with the general public.

In a recent study, we demonstrated that the performance ranking among the major SST products depends on the exact benchmarks used, against Argo and Buoy SST observations. For example, (i) when the reference SSTs are averaged onto 0.25° × 0.25° grid boxes, and for the global area-averaged SST time series, the magnitude of biases is lower in DOISST and MGDSST (<0.03°C), and magnitude of root-mean-square differences (RMSDs) is lower in DOISST (0.38°C) and OSTIA (0.43°C);

(ii) when the same reference SSTs are evaluated at pointwise in situ locations of buoy/Argo observations, and for the global point-averaged (without weighting by the cosines of the latitudes) SST time series, the standard deviations (SDs) are smaller in DOISST (0.38°C) and OSTIA (0.39°C); (iii) but the SDs become smaller in OSTIA (0.34°C) and CMC (0.37°C) on products' original grids, showing the advantage of those high-resolution analyses for resolving finer-scale SSTs. This presentation is intended to stimulate discussions among the GHRSST community on ways to intercompare SST products and the interpretation of the results, thereof.

Poster

1-S3: Holistic Water Cycle Analysis via the Confluence of Climate Model, Satellite, Ground Truth, and Machine Learning Signal Processing Technologies: Two North American Transboundary River Watersheds

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Abstract

Water continuously cycles throughout the land, ocean, and atmosphere. Accordingly, it is important for hydrological analyses to consider water as it moves throughout the entire hydrosphere, and not just a single facet of the process. We use neural networks as a device to transform geospatial observations of water quantity and quality into forecasts of ground truth streamflow measurements. Two very large transboundary basins, the Columbia River and Yukon River, are subjects of this investigation. We first describe the basins. Then we create two datasets for each basin: one with coupled surface flow, subsurface flow, and sea surface temperature of the basin adjacent oceans; and another with simply the surface and subsurface flow land measurements constrained to the definitive boundaries of the delineated watershed. Finally, we load these datasets into Flux to Flow (F2F), our neural network test platform. Our results indicate that, even with the smallest neural network we try (four neurons only), use of sea surface temperature greatly improves forecasting of monthly streamflow from up to two years lag between the input images and the output gauged streamflow measurements. We see the future use of the F2F pattern having more output targets and likely requiring multiple compute nodes to scale the work. We discuss and identify drought monitoring as a suitable next step. We believe this work has only scratched the surface regarding the integration of land and ocean parameter datasets to fields devoid of non-numerical observations.

6-S3: Validation for MODIS SST Retrievals Using the Saildrone Uncrewed Surface Vehicle Data

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Abstract

Two Saildrone uncrewed surface vehicles (USVs) equipped with infrared radiation pyrometers in a "unicorn" structure on the deck for the determination of the ocean sea surface skin temperature (SST_{skin}) were deployed for 150-day cruises from 15th May to 11th October 2019, from the Dutch Harbour, Alaska. Each Saildrone also collected a suite of atmospheric and oceanographic measurements. We present an algorithm to derive SST_{skin} from the downward- and upward-looking radiometers and estimate the main contributions to the inaccuracy of SST_{skin}. After stringent quality control of data and eliminating measurements influenced by sea ice and precipitation, and restricting the acceptable tilt angles of the USV based on radiative transfer simulations, SST_{skin} can be derived to an accuracy of approximately 0.12 K [*Jia et al.*, 2023]. Thus, Saildrones equipped with these sensors could provide sufficiently accurate SST_{skin} retrievals for validating satellite-derived SST_{skin}

fields, such as MODIS, VIIRS, and SLSTR, at high latitudes where conditions are more challenging than elsewhere. *Jia and Minnett* [2020] focused on making more appropriate atmospheric corrections than the standard MODIS algorithm, but there is still great room for refinement. The SST_{skin} and SST_{depth} from the Saildrone Arctic Cruises provide a supplementary dataset for satellite validation at the northern Pacific side of the Arctic, where the in-situ measurements are much sparser than those at the Atlantic side. Therefore, using the SSTs measured by Saildrone is a good opportunity to quantify error sources in SST_{skin} retrievals and to further improve atmospheric correction algorithms.

References:

Jia, C., and P. J. Minnett (2020), High latitude sea surface temperatures derived from MODIS infrared measurements, *Remote Sensing of Environment*, *251*, 112094.

Jia, C., P. J. Minnett, M. Szczodrak, and M. Izaguirre (2023), High Latitude Sea Surface Skin Temperatures Derived From Saildrone Infrared Measurements, *IEEE Transactions on Geoscience and Remote Sensing*, *61*, 1-14.

9-S3: Towards Improved Quality Control of in situ SSTs from drifting and moored buoys in the NOAA iQuam system

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Abstract

The In situ Sea Surface Temperature (SST) Quality Monitor (iQuam) is the NOAA online system that collects in situ SST from various sources, performs quality control (QC) and provides data to users. Like other in situ QCs, the iQuam employs comparisons with L4 SST analyses. However, the current daily L4 analyses do not capture the diurnal cycle as well as the fine structure of spatial and temporal SST variations in dynamic areas. As a result, some high-quality in situ SSTs deviating from the L4 are rejected. This presentation discusses the QC procedure developed to address the overscreening for buoys, whose sampling frequency is sufficient for resolving the diurnal cycle. Records from individual buoys are subdivided into 24hr segments. For each segment, the median night-time SST (MNT) and the amplitude of the diurnal signal (ADS) are calculated. The segments with unrealistically large ADS's are rejected. The segments affected by large systematic errors are also rejected by comparison of the MNTs with L4 SST, using geographically dependent thresholds, set to be more liberal in the dynamic zones. The outliers are further screened out by comparison of the individual in situ SSTs with MNT, using an ADS-dependent threshold. All thresholds are determined using matchups with reprocessed ACSPO satellite products from VIIRS, AVHRR FRAC and GAC, and MODIS sensors. The satellite matchups are also used to validate the QC results. The new QC minimizes the overscreening, increases the numbers of high-quality in situ data by ~5%, and reduces the dependency on the L4 analyses compared with the current iQuam QC. In addition, a new retrospective satellite-based quality level is introduced to identify matchups most useful for Cal/Val of reprocessed satellite data.

10-S3: NOAA 1st MODIS SST Reanalysis (RAN1) from Terra and Aqua

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Abstract

NOAA provides satellite SST datasets from VIIRS, AVHRR FRAC/GAC and MODIS sensors onboard LEO and ABI, AHI and FCI sensors onboard GEO satellites, using its Advanced Clear-Sky Processor for Ocean (ACSPO) enterprise SST system. To extend, supplement and check for consistency with the previously developed long-term hi-resolution (~1km) SST records, JPSS VIIRS RAN3 and Metop-FG AVHRR FRAC RAN1, and facilitate their feed into the NOAA's global 0.02° gridded super-collated SST, L3S-LEO, full-mission reprocessing of two MODISs onboard Terra (launched Dec 18, 1999) and Aqua (launched May 4, 2002) was performed with the NOAA ACSPO v2.80 resulting in the 1st MODIS Reanalysis (MODIS RAN1) dataset.

During initial steps of the MODIS RAN1, systematic SST drifts wrt *in-situ* SSTs of ~0.05K (Aqua) and ~0.10K (Terra) were identified, over the course of the full missions, corresponding to gradual degradation of MODISs' brightness temperatures (BTs). Moreover, a step change occurred in Terra BTs/SSTs, due to its MODIS nominal blackbody temperature change in 2020. Special efforts were taken to stabilize the BTs in all SST bands (using comparisons with radiative transfer simulated BTs), before feeding them into ACSPO, which stabilized the derived SSTs. We also mitigated periodic systematic anomalies in Terra BTs concurrent with variations in its MODIS blackbody temperature, during quarterly warm-up/cool-down exercises. We present validation of the ACSPO MODIS RAN1 dataset against iQuam

drifting buoys, tropical moorings, and Argo floats, using functionalities developed for another NOAA SST system, SQUAM.

13-S3: Intercomparison between the decadal (2000-2020) trend of Phytoplankton growth and Chlorophyll-a concentration over Bay of Bengal and Arabian Sea

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Abstract

The impacts of global warming on marine ecosystems are among the most urgent environmental concerns of recent years. Phytoplankton, as primary producers in marine food webs, form the basis of many marine ecosystems. Chlorophyll-a concentration is a key indicator of phytoplankton biomass and is closely linked to the growth and health of phytoplankton communities. Among the many factors influencing marine environments, sea surface temperature (SST) and surface net solar radiation (SSR) stands out as a crucial driver to marine life such as phytoplankton. Sea surface temperature (SST) observations are extremely important in terms of estimating climate variability, monitoring and predicting weather patterns and phenomenon, air-sea interactions and acts as a key indicator in regulating the marine ecosystem. As SST rises, it can alter the physical and chemical properties of the water column, impacting phytoplankton physiology, distribution, and productivity. Results show an increasing trend of chlorophyll-a and phytoplankton over the Bay of Bengal and its strong correlation with the decadal changes in dissolved phosphate concentration (mmole/m^3). Contrasting to the Bay of Bengal region, the Arabian Sea region, however, shows a promising decreasing trend over the 20 years which can only be accounted for the rise in sea surface temperature (SST). Moreover, the pH scale shows an alarming decreasing trend indicating both the regions tending to be less alkaline with time.

20-S3: Diurnal variability of INSAT-3D SST in the Indian Ocean- intercomparison with in-situ and satellite observations

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Abstract

Sea Surface Temperature (SST) is an Essential Climate Variable used in oceanographic and meteorological application studies such as air-sea interaction, ocean mixing, boundary layer processes and ocean state forecast, which require high temporal resolution SST. Indian Geostationary Satellite INSAT-3D imager has been designed to provide 30 minute SST for the tropical Indian Ocean with frequent sampling. In order to ascertain about the quality and usability of INSAT-3D SST products for various oceanographic studies its evaluation is essential to best access the accuracy of the retrieved SST product. In this regard, latest version (V02) of INSAT-3D SST data from May 2021 to December 2022 has been considered along with in-situ buoys SST data obtained from Indian Moored Buoy network available at 1m depth for intercomparison. Contemporary MODIS SST is also used for the same period to understand the spatiotemporal variation in SST product accuracy in the Indian Ocean region. The intercomparison of INSAT-3D SST is performed against in-situ and MODIS SST observations using standard statistical parameters such as Mean, Bias, Standard Deviation, correlation coefficient (r), and Root Mean Square Error. We attempted to study the diurnal variability of SST over Indian Ocean region, as the Indian Ocean is noted as one of the hot-spot region and significantly contributes for the global ocean warming. Accordingly, we present results about the diurnal variability captured by INSAT-3D, its comparison with buoy measured diurnal variability, and the role of skin versus bulk SST differences in the observed diurnal variability will be discussed.

37-S3: ECOSTRESS vs Saildrone SST: Noise Comparisons

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Abstract

The 70 m pixel scale ECOSTRESS thermal radiometer on the International Space Station serves as a precursor for future 60-70 m resolution thermal missions including TRISHNA (ISRO/CNES), SBG (NASA), and LSTM (ESA). The ECOSTRESS spatial sampling scale matches 1 to 5 minute observations from autonomous Saildrone platforms. We compared Saildrone SST (IR and thermistor) to ECOSTRESS skin temperatures in upwelling regions off California. In clear sky conditions, bias-corrected ECOSTRESS skin temperature is highly correlated with in-situ observations from Saildrones (R^2>0.80, RMSE < 0.35 C). However, systematic and Gaussian noise levels in ECOSTRESS observations are on the order of 5× greater than noise levels in Saildrone observations made at similar spatial scales. ECOSTRESS NEdT is 0.1 to 0.3 K in the 3 active IR bands, and systematic noise levels range from 0 to 0.5 K depending upon IR band and pixel location in the focal plane. The highest noise levels are in the 12.49 µm band. The future TRISHNA, SBG and LSTM missions all are expected to have NEdT similar to ECOSTRESS, which may cause problems for high resolution coastal SST retrievals in the future. Current work is focused on improving SST results in the critical coastal regions.

40-S3: Verification of AMSR2 SST in the Arctic Ocean and Implications of Freshwater Distribution on Estimation Error

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Abstract

The accuracy of the latest AMSR2 SST estimates in the Arctic Ocean was investigated with iQuam ver2.1. For the standard product, 6.9 GHz SST, the RMSE (bias removal value) was 0.104K (Descending) and 0.132K (Ascending). For the research product, multiband SST, the RMSEs were almost the same, 0.102K (Descending) and 0.123K (Ascending). In the beta ocean (below 10°C), where salinity variability dominates with respect to density change, the RMSE worsens to 0.15 K (Descending) for the 6.9 GHz SST. The underestimation of SSTs for both products is particularly significant in the Beaufort Gyre region of the Arctic Ocean, which shows a warming trend of around 0.1K. In other words, while cloud-free microwave radiometer observations are extremely powerful in generating the Climate Data Record, long-term data including SST data from the AMSR series may lead to underestimation of the warming trend.

In this study, we focus on the salinity-dependent brightness temperature change in the low-temperature region as the cause of this non-negligible underestimation.

The AMSR2 standard SST is derived from the relationship between the 6.9G-V brightness temperature and SST given by Fresnel's equation and the complex dielectric constant of Klein and Swift (1977). Here, we focus on the dielectric constant that causes the change in brightness temperature: the emissivity based on Meissner and Wentz (2004) shows a change with respect to changes in salinity, while Klein and Swift (1997) shows no change. The change in emissivity contributes to the change in radiance water temperature, but this effect is not taken into account, which may be the reason for the underestimation.

44-S3: TRISHNA Vicarious calibration of TIR sensors over oceans

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Abstract

TRISHNA's TIR and VSWIR instruments will be extensively calibrated and characterized in on-ground facilities to ensure that their performance will meet the specifications throughout TRISHNA's lifetime. Yet, the operation in space after the launch and during several years can lead to different behaviours as the ones expected from ground calibration, justifying a validation and if necessary a calibration of some parameters of the ground processing.

The TRISHNA TIR instrument radiometric performances rely on an on-board calibration device (blackbody) and cold space viewing. Some so-called vicarious calibration methods are being developed in the TIR using natural targets in order to validate and monitor the calibration performed using the blackbody, and to potentially be used as a backup in case of hardware failure. These natural targets include the oceans, the Moon, snow deserts in Antarctica or Greenland and instrumented sites.

The presentation will mostly focus on a calibration method over the ocean. Meteorological data (ECMWF) are used to derive the sea surface temperature and the relevant atmospheric variables in order to simulate through radiative transfer the TOA radiance which should be observed by the sensor. The comparison between the simulated radiance and the one actually observed by the sensor provides an assessment of its radiometric calibration.

This method has been implemented and tested for Sentinel3/SLSTR. Calibration results will be presented along with the method uncertainty budget.

51-S3: Assessment of GHRSST on the detection of Marine-Heat Waves and Heat-Spikes in the Bay of Bengal

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Abstract

According to a latest WMO report, the average global temperature in 2022 was approximately 1.15°C higher compared to the pre-industrial period. Therefore, accurate observations of Sea-Surface Temperature (SST) are vital for understanding and predicting its impact on Earth's climate. In our study, we examined the strengths/weaknesses of Group for High Resolution SST (GHRSST), in comparison to various in-situ datasets like RAMA Buoy at 15N, 90E (RM15), Wave-Rider Buoys (WRB), OMNI buoys, and the widely used Optimally Interpolated SST (OISST). On comparing GHRSST and OISST with RM15 (for the period 2008 – 2020), strong correlations of ~0.97 and 0.96 (p-value<0.01) and low Root-Mean-Squared-Error (RMSE) values of 0.30°C and 0.35°C were observed, respectively. OMNI buoys, BD10 and BD11, exhibited high correlations with both GHRSST and OISST, but OISST slightly outperformed. However, near at WRBs locations, both OISST and GHRSST showed degraded performance, with RMSEs>1°C. Consequently, substantial upgrades are required for both datasets to improve their suitability for coastal-process studies. Wavelet analysis of RM15, GHRSST, and OISST time series showed accurate seasonal signals, but discrepancies arose in high-frequency signals (<4-months), introducing errors in the datasets. Our findings revealed that both GHRSST and OISST significantly overestimated the counts and Marine-Heat Wave (MHW) days compared to RM15. However, the number of heat-spikes was similar, indicating that RM15 crosses the threshold as frequently as GHRSST and OISST but do not persist for more than four-days to be categorized as an MHW. These disparities highlight the overestimation of MHWs in GHRSST and OISST due to the sustained higher temperatures present in these datasets compared to RM15.

65-S3: Marine heatwaves in the Cape peninsula upwelling cell, Southern Benguela

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Abstract

Marine Heatwaves (MHWs) are considered to be one of the emerging threats to marine ecosystems globally. Extreme warm Sea Surface Temperature (SST) anomalies can cause severe ecological impacts. MHWs were identified off Cape Point by in situ and reanalysis (CCI and REMSS) SST datasets, with a focus on MHW duration and maximum SST values as well as a focus on the influence of the wind on the formation and dissipation on MHWs and warm events (WEs). MHWs are defined events for which the SST exceeds the climatological 90th percentile for at least five days [1], while the WEs event ST values must exceed the climatological 90th percentile for at least three days. The observed average event duration is between 7 to 8 days but the longest events occurred during periods of decreased upwelling, while the highest maximum SSTs occurred during periods of upwelling dominance. The dominant wind during the formation of MHWs and WEs is a north-westerly wind, indicating the main driver of events at the Cape Point mooring is the movement of warm water masses to the mooring location. The dominant wind direction at the end of the MHWs and WEs is a south-easterly wind indicating that coastal upwelling limits the duration of warm water events at the Cape Point mooring. MHWs are expected to worsen with climate change by lasting longer with high temperature increases but the projected increase in south easterly winds could further limit the duration of MHWs in the Southern Benguela Upwelling System.

Key words: Marine heatwaves, Coastal Upwelling system, SST *in situ* vs satellite

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71-S3: Entropy based evaluation of INSAT-3D/3DR Sea Surface Temperature products

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Abstract

INSAT-3D/3DR provide large number of meteorological parameters that are important for weather and climate studies. Sea Surface Temperature (SST) is one of the most important parameters that is derived using INSAT-3D/3DR observations. The operational SST parameter from INSAT-3D/3DR provides two SST products. First SST product is derived using the regression based algorithm, the second SST product is retrieved using one dimensional variational (1-D Var) algorithm. SST taken as the first guess from the GFS model output is also provided along with these two SST products. The present work, aimed at inter-comparing two SST products from INSAT-3D/3DR and first guess SST using the Shannon's entropy concept. The present work computes the entropy of SST images and entropy of gradient of all three SST products. The entropy estimation is done by first computing the probability distribution functions (pdfs) of SST images and SST gradients using kernel density estimation and then these pdfs are eventually used to generate probabilities. These probabilities are finally used in computing entropies. The preliminary analysis of different entropies of SST products from INSAT-3D/3DR is carried out.

83-S3: Assessment of the Accuracy and Error Characteristics of GK2A/AMI Sea Surface Temperatures: A Recent Three-Year Validation Study

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Abstract

The Geostationary Korean Satellite GK2A was launched in December 2018 and has been operated by the Korea Meteorological Administration (KMA) since July 2019. Sea surface temperatures (SSTs) derived from GK2A/Advanced Meteorological Imager (AMI) have been obtained using four multi-band infrared datasets. In this study, we conducted a validation of GK2A/AMI SST accuracy over the full disk region for the past three years, from September 1, 2019, to August 31, 2022, and analysed the characteristics of SST errors. In-situ data were collected from the Global Telecommunication System (GTS) and KMA buoy stations. A matchup database was made by collocating satellite data and in-situ measurements, with a spatial resolution of 2 km and a temporal resolution of 10 minutes. The analysis presented the error characteristics influenced by diurnal SST variations, wind fields, coast-offshore processes, and oceanic fronts. Although the satellite zenith angle was taken into account in the SST retrieval algorithm, relatively large errors were observed at the edges of the full disk and in frontal regions. Satellite SST tended to be overestimated at very low sea surface temperatures, and errors were amplified near the coastline. The results indicated that the GK-2A-derived SSTs during the initial three years after launch exhibited errors within 0.4 K, meeting the target accuracy set prior to its launch and demonstrating successful operation. The satellite is expected to continue contributing to the production of daily composite products and various studies on oceanic phenomena in the future.

88-S3: An Evaluation of NOAA's LS Super-Collated SST Datasets

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Abstract

The Center for Satellite Applications and Research at NOAA/NESDIS has developed three Level-3 Super-collated (L3S) global sea surface temperature (SST) datasets from the AVHRR and VIIRS data streams covering daytime, nighttime, and daily periods from 2012 to present. The combination of data from varying sensors and times often introduces submesoscale artifacts, limiting the datasets' utility in studying physical processes at these scales. This study aims to identify and measure any such issues in these new NOAA data products. We evaluate 128 km x 128 km 'cutouts' extracted from the L3S fields for 2012-2020 using a probabilistic autoencoder, which condenses each cutout into a single log likelihood (LL) value representing the SST structure within the cutout. For each L3S cutout corresponding to a clear-sky VIIRS cutout, the LLs are compared. If an L3S cutout aligns only with a cloudy VIIRS cutout, we compare the median LL of all L3S and Level-2 extractions within approximately one-degree square regions, based on the study period's climatological month. The outcomes from both comparisons are presented as global 1°x1° maps, showing the level of concurrence or discrepancy in the submesoscale field structure between the two datasets. The goal is to determine whether and to what extent these issues are present in the new NOAA datasets.

91-S3: Examining the Consistency of Sea Surface Temperature and Sea Ice Concentration in Arctic Satellite Products

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Abstract

Available observations and a theoretical simulation are used to explore the consistency and relationship between sea surface temperature (SST) and sea ice concentration (SIC) within open-ocean-sea ice mixed satellite pixels as a function of grid resolution. The maximum limiting SST value for a specified SIC and spatial resolution is first examined within collocated satellite-derived products contained within existing Level 4 SST analyses distributed using the data specification from the Group for High Resolution Sea Surface Temperature. The shape of the interdependence is further validated with manually quality-controlled buoy SST and SIC collocations. A parametric equation for the limiting SST value is derived from simulations of a mixed ocean/ice pixel with specified ice fraction and a linear SST gradient extending away from the ice edge. The exponential curve matching the observed interdependence suggests a maximum 5 km pixel-averaged SST at SIC values approaching zero between 6 and 8 ◦C. This maximum value is significantly greater than the previously assumed limiting values of ~3 ◦C and the corresponding SST gradient is larger than those typically observed with

satellite SST products, but agrees well with recent Saildrone SST observations near ice. The curve provides a conservative limit with which inconsistent SST/SIC pairings can be identified, not only near the ice edge but at intermediate ice concentrations. Application of the filter improves the agreement between the SST/SIC relationship in satellite products and available Saildrone observations as well as the internal consistency of the different satellite products.

95-S3: Evaluation of Sea surface Temperature from ocean reanalysis products over north Indian Ocean

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Abstract

Ocean and sea-ice reanalyses (ORAs, or ocean syntheses) are reconstructions of the ocean and sea-ice states using an ocean model integration constrained by atmospheric surface forcing, and ocean observations via a data assimilation method. Ocean reanalyses are a valuable tool for monitoring and understanding long-term ocean variability at depth, mainly because this part of the ocean is still largely unobserved. Deep and abyssal circulations are crucial for several climate indexes that can affect predictability over long time scales. Ocean reanalyses have been used for the initialization of ocean and sea ice components of seasonal to decadal forecasting systems. Despite improvements in model and reanalysis schemes, Ocean reanalyses show errors when evaluated with independent observations. Sea surface temperature (SST) is one of the Essential Climate Variables (ECVs). The independent evaluation studies of sea surface temperature (SST) from ocean reanalysis over the Indian Ocean are limited. In this study, we evaluated the SST from two most widely used reanalysis products, ORAS5 and SODA3, for 2012-2017. We also included the upgraded GODAS with MOM4p1 (GODAS p1). In this evaluation study, we used twelve (12) in-situ buoy observations (OMNI) over the Arabian Sea and Bay of Bengal. These buoys are considered as independent observations since it is not been assimilated in any of these reanalysis products. GODASp1 shows the least bias, Root Mean Square Deviation (RMSD), and the highest correlation out of these three reanalysis products. The variability in all the reanalysis products is close to buoy observations, with GODASp1 being the closest.

98-S3: A Comparison of in-situ SST and Chlorophyll data with GHRSST and MODIS data

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Abstract

This study presents a comprehensive comparison between in situ measurements of sea surface temperature (SST) and chlorophyll-a concentration with satellite-derived data from the Group for High-Resolution Sea Surface Temperature (GHRSST) and the Moderate Resolution Imaging Spectroradiometer (MODIS) respectively. The aim of this analysis is to assess the accuracy and reliability of satellite-derived data in capturing the temporal and spatial variability of SST and chlorophyll-a levels in the tropical seas. To achieve this, a match-up dataset comprising in situ measurements and satellite-derived data is compiled for coastal waters of Kochi, India. The comparative analysis indicates that both GHRSST and MODIS datasets exhibit a reasonable agreement with in situ measurements. However, some differences were observed, primarily due to the inherent limitations of satellite remote sensing. GHRSST and MODIS datasets captured the large-scale spatial patterns and seasonal variations of SST reasonably well. Similarly, the comparison of chlorophyll-a data indicated a significant correlation between in situ measurements and satellite-derived data. The satellite data captured the overall trends and seasonal variability of chlorophyll-a concentrations with respect to varying temperature but missed certain fine-scale features related to localized blooms and patchiness. Overall, this study demonstrates the usefulness and limitations of satellite-derived GHRSST and MODIS data in representing SST and chlorophyll-a concentrations when compared to in situ measurements for the tropical waters during pre-monsoon conditions.

104-S3 Performance Evaluation of different GHRSST Products under Heavy Rain Conditions over North Indian Ocean

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Authors: Neerja Sharma, Neeraj Agarwal and P.K. Thapliyal

Abstract

Under rainy conditions, satellite based Sea surface temperature (SST) retrieval is carried out by making use of microwave radiometers, as Infra-red sensors fail to penetrate the clouds. However, rain still affects the accuracy of SST retrieval, which needs closer examination on regional scale. Thus, the present study evaluates the performance of Group for High-Resolution Sea Surface Temperature (GHRSST) products, which combine data from all available remote sensing platforms to generate gap free global SST fields. For this purpose study utilizes various GHRSST products provided by Canadian Meteorological Centre CMC v3.0 (10 km), Danish Meteorological Institute DMI v1.0 (5 km), Jet Propulsion Laboratory Multi-scale Ultra high Resolution JPL-MUR v4.1 (1 km), Remote Sensing Systems REMSS v5.0 (9 km), and United Kingdom Met Office UKMO v2.0 (5 km) under heavy rain events over North Indian Ocean during 2020. Study utilizes surface rain information from GPM-DPR measurements. Whereas, in-situ SST observations are used to evaluate the performance of GHRSST. The outcomes of the study are not only important to assess the performance of different GHRSST products but also to identify the product that possess least errors under heavy rain conditions over NIO.

Science Session S4 - Retrieval Algorithms

Chair: Rashmi Sharma (1)
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Description of the session

Sea surface temperature (SST) plays a key role in the monitoring and prediction of the ocean and weather processes, apart from being an excellent indicator for climate change. These weather and climate observations require accurate estimates of SST that are also consistent over a long period of time. Satellite-based infrared and microwave instruments have been providing valuable information for SST at a global scale, apart from conventional SST measurements from Buoys and other oceanic platforms. However, estimation of the SST from satellite based IR and MW instruments is indirect in nature and significantly affected due to the presence of water vapour, cloud and aerosols as well as uncertainties in spectral surface emissivity. This requires development of advanced techniques for retrieval and atmospheric correction through improved radiative transfer models and numerical techniques.

In this session, the goal was to discuss the recent developments in the retrieval algorithm including techniques for cloud mask, atmospheric correction due to water vapour as well as aerosol. Special emphasis was placed on recent advances in the field of AI/ML techniques for retrieval algorithm as well as cloud detection and atmospheric correction.

Contributions in the following broad areas have been anticipated:

- Development of physical and AI/ML based algorithms.
- Optimal Estimation and bias-aware optimal estimation.
- System definition studies for new instruments for SST estimation.
- Synergy of IR/MW observations towards improved merged SST products.
- Algorithms for generating climate quality SST products.
- Improved techniques for regional bias correction.
- Modelling differences of skin SST to SST depth.
- Demonstration of high resolution coastal SST products.
- Synergy of GEO/LEO for studying diurnal variability in SST.

Keywords: SST, Physical retrieval, AI/ML techniques, Cloud Mask, Climate quality, IR Radiometers, MW Radiometers, optimal estimation.

Session report and conclusions

This report summarises the key points from Session 4 (Retrieval Algorithms) of GHRSST24, which took place on Wednesday, 18 October 2023.

The Keynote Speech was delivered by Chong Jia from University of Miami on "*Effects of the Hunga Tonga-Hunga Ha'apai Eruption on MODIS-retrieved Sea Surface Temperatures*".

The eruption of Hunga Tonga-Hunga Ha'apai (HTHH) volcano on 15 January 2022 was the most explosive eruption since Mt. Pinatubo in 1991. It injected a large amount of water vapour (~146 Tg) along with a moderate amount of SO2 (~0.4 Tg) into the stratosphere. This produced a pronounced and persistent sulfate aerosol layer (1-3 Tg) in the mid-stratosphere. These aerosols affect the MODIS retrievals of SST causing a large negative bias (-0.3 K) when compared to the in-situ SST. The spatial and temporal evolution of sulphate aerosols in global stratosphere was presented, as well as its impact on the MODIS derived SST anomalies. The dependency of SST bias in relation to the aerosol loading the stratosphere was also studied by analysing the SST bias with respect to simultaneous MODIS AOD over different locations. The effect of aerosol was also shown using RTTOV simulations that cause a BT deficit at 11 µm and a reduction in BT differences. The study focuses on the importance of a suitable correction procedure for aerosol loading for improved SST estimation from satellite measurements.

Questions

1. *The water vapour (WV) in the stratosphere obviously influenced the aerosol evolution but it does decouple in its location and altitude over time, and the elevated stratospheric WV is still persisting to some degree even now. Do you have any plans to actually look at the WV impact in isolation rather than in conjunction with the aerosol, because WV in the stratosphere doesn't have the same brightness temperature impact as WV in the troposphere on average, and there will be some effect on NLSST. What are your plans for looking at that?*

Chong Jia: Basically WV effect and the aerosol effect are connected and interact together, so it's difficult to isolate the WV effect from the aerosol effect. The abundant WV injected into stratosphere is significant, but for the total column WV the increase is very small, because the amount of WV in stratosphere is much smaller than in the troposphere. We found that the total column WV in the matchup data shows a reduced tendency in 2022 after the volcanic eruption. Therefore it might be the aerosol effect on the precipitation, so it's not necessary to reprocess the algorithm coefficients for the MODIS SST retrieval but it's still necessary to study the water vapour effect and it is worth looking at this.

2. *Can you do radiative transfer modelling to explore this?*

Chong Jia: Yes, I did radiative transfer simulations using RTTOV but the SST error introduced by this is very insignificant. Therefore it may be necessary to use LBLRTM or other accurate RTM. This could be done in the future.

Jacob L. Høyer of Danish Meteorological Institute presented "*A sea surface temperature retrieval algorithm for the Copernicus Imaging Microwave Radiometer CIMR*".

This presentation focused on the future passive microwave radiometer, Copernicus Imaging Microwave Radiometer (CIMR), that will complement SST observations from traditional infrared (IR) instruments. It highlighted the gap areas of observations from current microwave imagers, such as coarser resolution which is not enough to capture subscale to mesoscale variability apart from limitations due to coastal and sea ice contamination. The CIMR is currently being prepared by the European Space Agency (ESA) with an expected launch in 2029. CIMR is designed to observe high-resolution and high-accuracy measurement of SST. A two-step regression retrieval algorithm for CIMR SST similar to ESA V3 AMSR algorithm with adaptation for CIMR frequencies is developed. All codes and documents will be available openly and freely in GIT. The CIMR L1b brightness temperatures will be re-mapped on common location and resolution before application of the SST algorithm. The performance is assessed using demonstration reference scenario scenes, consisting of typical brightness temperatures for different surface types arranged in artificial patterns corresponding to real world scenarios, such as ocean-land and ocean-sea ice transitions.

Emilie Delogu from CNES presented "*TRISHNA Sea Surface Temperature Retrievals: comparison of multiple algorithms*".

This presentation provided an overview of the SST retrieval algorithm for future CNES-ISRO joint mission, TRISHNA, that will be launched in 2026. TRISHNA mission has 4 thermal bands, so sea surface temperature retrieval algorithm, DirecTES, has been developed. DirecTES is based on the use of a comprehensive spectral database of emissivity to end up in a well-posed deterministic problem. Over water, as emissivity is known, the algorithm uses the potential of all the bands available combined to an actual atmospheric correction to retrieve sea surface temperature. The performances of the algorithms were first evaluated using theoretical simulation study, and then applied to ECOSTRESS level 1 data and compared to in-situ measurements. The study shows that the DirecTES algorithm performance is promising.

Alice Yepremyan from NASA Jet Propulsion Laboratory presented "*MAESSTRO: Masked AutoEncoders for Sea Surface Temperature Reconstruction under Occlusion*".

This presentation focused on the high-resolution, gap-free sea surface temperature (SST) data products. Existing gap-filled SST data, MUR SST, tends to smooth out the small-scale features under clouds. The present work investigates the effectiveness of masked autoencoders (MAE) to reconstruct small-scale features at high resolution (1 km) under clouds. The MAE model is trained on SST tiles (500 km x 500 km) from the LLC4320 forward simulation, whereby the model learns to predict the SST values under randomly masked out portions of the tiles. Preliminary results show that MAE can reconstruct global SST to within 0.3°C RMSE across all test-time masking ratios. An evaluation with the real SST tile from VIIRS shows that MAESSTRO maintains RMSE < 0.1 C for range of masking ratios 10% to 90%, and the RMSE is < 0.5 C globally with 80% pixels removed. This methodology has the potential to generate the next generation of high-resolution SST products which are useful for small-scale physical oceanography.

Rishi Gangwar from SAC/ISRO presented "*Inter-comparison of various AI/ML techniques for SST retrieval from INSAT-3D Imager*".

The presentation discussed the outcomes of the four different SST retrieval algorithms for INSAT-3D Imager that are based on machine learning (ML) techniques, such as Random Forest (RF), K-Neighbour Regressor (KNR), Multi-Layer Perceptron (MLP) and Deep Neural Network (DNN). A matchup data was prepared using INSAT-3D Imager observations and collocated SST measurements from in-situ quality monitor (iQuam) data for 2017-2020. Training was performed on 70% random matchups, whereas the remaining 30% were used for the testing. The assessment shows a similar bias (RMSE) of 0.11 K (0.48 K) in DNN, -0.01 K (0.59) in KNR, -0.04 K (0.54 K) in MLP and 0.0 K (0.08 K) in RF for both training and testing matchups. The retrieval errors (RMSE) for the independent matchups are found to be significantly larger (~1 K) in case of RF and KNR as compared to MLP (0.6 K) and DNN (0.55 K) based algorithms. This shows that DNN based algorithm outperforms the two others.

Questions

1. *You mentioned that the next step will be to use real cloud mask fields, and that is going to be very different because it's quite common to have a tile with a little bit of SST in one corner rather than information scattered across the tile in the test you have done so far. How this technique will cope in that sort of situation and what strategies will you implement to deal with the situation where frontal clouds or other forms of cloud are obscuring continuous part of the image.*

Alice Yepremyan: I completely agree that, with the previous technique applied with random masking, we are hoping that situation where we had 90% masking might quasi-mimic the real world, but I do agree that they are going to be different and that we might have to try different methodology in order to handle the real cloud cover.

2. *You are using certain size of the tile, and of course another issue in going global will be to face a problem too large to solve all at once. How will you address the issues of tiling up to a global scale?*

Alice Yepremyan: Yes, we are going to tile based on this one day.

3. *You used a high resolution numerical model for the training dataset for gap filling of the SST. This will be highly dependent on the accuracy of the model too. It should be able to simulate real world features like the gradients in SST, so unless that is achieved, using the synthetic data may not be effective. So it would be better to use large years of satellite observations to train as a part of the training dataset.*

Alice Yepremyan: In terms of immediate next step, the first step in moving this project forward into making it a more real product is to experiment with more VIIRS tiles as a test set, and then the next step would be to use real cloud mask, and that will get better results, but we need to do these experiments to be sure what the outcome is going to be.

4. *Maybe we can add different noises to the simulations before using them for training so that can also help account for instrument errors.*

Alice Yepremyan: Agreed with this suggestion.

5. *On training the dataset, when you are looking at L4 data, the subscale features are compromised, so if you start at that level to train there might be some issues. So taking it down perhaps to L3 as single sensor and then how does it deal with anomalies instead of just having the*

cloud already masked. If you refer anomalies like a spurious temperature difference, how do you resolve a continuous expected image like you would expect in a scene VIIRS image.

Alice Yepremyan: The simulation data we have, we're not seeing any noise or any anomalies. Definitely a concern when we're going to be training or testing on real satellite data that's something we are expecting. So we will have to be experimenting with and see how it will handle it. One of the issues we are anticipating might be that the data that was taken during the night or the day, if areas under the clouds are colder, things like that aren't currently captured and simulated data we do anticipate will have some hurdles, and we will have to come up with new methodologies to overcome.

6. *How do you take care of the seasonality and the diurnal behaviour of the SST, because when you take static images they don't change, but SST has a strong seasonal and diurnal variation? Is there anything you can do in the model to take care of this?*

Alice Yepremyan: More data will always be captured and will make models more generalised. We are also experimenting into multi-temporal models, where we will be adding in the time component. At present there is no relation between the tiles, so that's also something we are looking into.

7. *Can the gap filling technique be used to make the coarse resolution SST products to the high resolution SST products?*

Alice Yepremyan: I think it is conceptually possible.

8. *For comparison, what is the ground truth that is considered?*

Alice Yepremyan: The ground truth was from the simulation itself which is all clean data.

9. *You described CIMR targeted accuracy as 0.2 C, what is the instrument accuracy in terms of NEDT for different channels and how is it going to affect the retrieval of SST, and what is the expected uncertainty due to the WV and the cloud liquid water, and emissivity change due to wind speed?*

Jacob Høyer: ESA has made a Mission Requirement Document that contains all the specifications and all requirements on what should be the target requirement for different variables. So SST is one of the drivers in terms of design, and that for SST is 0.2 C globally but 0.3 C for the polar ocean due to smaller sensitivity to the colder surface temperatures. So the noise in the instrument should be very small.

Conclusions

Session 4 on "Retrieval Algorithms" had 5 talks including a keynote speech. There was an interesting study on the impact of the Hunga-Tonga-Humga volcanic eruption on the SST retrieval from MODIS. Large amount of water vapour and SO2 into the stratosphere caused the persistent sulphate aerosol layer causing a large bias of -0.3C in the MODIS SST. The development and progress of the Passive Microwave Radiometer CIMR, which will be ready by 2029, was discussed. This will provide accurate high resolution SST under all-sky conditions. The retrieval algorithm, DirecTES, for the future TRISHNA mission whose launch is scheduled in 2026 was also presented. As the emissivity is known over, the algorithm uses the potential of all the 4 bands available to an actual atmospheric correction to retrieve sea surface temperature. The ECOSTRESS data was used for assessment of the algorithm. There was a presentation that described the technique for creating a gap-free SST data product using masked autoencoders (MAE) to reconstruct small-scale features at high resolution (1 km) under clouds. This methodology has the potential to generate the next generation of high-resolution SST products useful for small-scale physical oceanography. A presentation focused on the comparison of different AL/ML techniques for SST retrieval. Overall, Session 4 discussed various aspects of retrievals related to the impact of volcanic eruption, generation of gap-free SST products, comparison of different AI/ML techniques and discussions on future high resolution IR and MW missions for SST measurements.

Overview of the talks

Nr.	Name	Institution	Title	Link
5-S4	Chong Jia	Rosenstiel School of Marine and Atmospheric Science, University of Miami	Effects of the Hunga Tonga-Hunga Ha'apai Eruption on MODIS-retrieved Sea Surface Temperatures	**KEYNOTE PDF** Video: https://youtu.be/uCQW5_vb88o
81-S4	Jacob L. Høyer	Danish Meteorological Institute	A sea surface temperature retrieval algorithm for CIMR	Invited talk PDF Video: https://youtu.be/y6Sdkf_h-zc
42-S4	Emilie Delogu	Centre National d'Etudes Spatiales (CNES)	TRISHNA Sea Surface Temperature Retrievals: comparison of multiple algorithms	**Invited talk PDF** Video: https://youtu.be/mcJsZPe7pj4
90-S4	Alice Yepremyan, Edwin Goh	NASA Jet Propulsion Laboratory/California Institute of Technology	MAESSTRO: Masked AutoEncoders for Sea Surface Temperature Reconstruction under Occlusion	**Invited talk PDF** Video: https://youtu.be/vADbL8GvEGU
29-S4	Rishi Kumar Gangwar	Space Applications Centre (ISRO)	Inter-comparison of various AI/ML techniques for SST retrieval from INSAT-3D Imager	**Invited talk PDF** Video: https://youtu.be/8-AiCPtvGUI

Overview of the posters

Nr.	Name	Institution	Title		Link
36-S4	Mingkun Liu	College of Marine Technology, Faculty of Information Science and Engineering, Ocean University of China	Sea surface temperature from HY-1D COCTS by optimal estimation	**PDF**	Video: https://youtu.be/eM1fLD6aTD0
60-S4	Swadhin Satapathy	National Institute of Science Education and Research	Retrieval of Sea Surface Temperature and Atmospheric Profiles from INSAT-3DR: Comparing Bayesian Inference, 1D-Var, and Machine Learning	**PDF**	Video: https://youtu.be/wDbAKcWCNKM
27-S4	Zhuomin Li	Sanya Oceanographic Institution/College of Marine Technology, Faculty of Information Science and Engineering, Ocean University of China	Sea Surface Temperature Retrieval from HY-1C and HY-1D COCTS in the South China Sea	**PDF**	Video: https://youtu.be/Opslw1kLzdA

Abstracts Science Session S4 - Retrieval Algorithms

KEYNOTE 5-S4: Effects of the Hunga Tonga-Hunga Ha'apai Eruption on MODIS-retrieved Sea Surface Temperatures

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Submission date: 07/06/2023

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Abstract

The eruption of Hunga Tonga-Hunga Ha'apai (HTHH) volcano on 15 January 2022 injected a great amount of H_2O and a moderate amount of SO_2 into the stratosphere, producing a pronounced and persistent sulphate aerosol layer centred around the mid-stratosphere, mostly confined to Southern Hemisphere (SH) tropics. These aerosols affect the Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals of sea surface temperature (SST) where negative biases reached -0.3 K and an annual mean of -0.1 K when compared to the in situ SST measured by drifting buoys north of 40ºS in the SH. The spatial and temporal evolution of MODIS SST anomalies are presented. Despite the remarkable hydration of the stratosphere, the negative biases are shown to be highly associated with the anomalies in stratospheric sulphate aerosol and these persisted at least until the end of 2022. Radiative transfer simulations demonstrate the aerosol effect on MODIS SST retrievals by causing an additional brightness temperature (BT) deficit at 11 µm and a reduction in BT differences since the characteristic of spectral attenuation between 11 µm and 12 µm is opposite to that of H_2O. A correction for HTHH aerosol effects in the retrieval algorithm is therefore desirable due to the high accuracy requirements for SST in scientific studies.

TALK 81-S4: A sea surface temperature retrieval algorithm for CIMR

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Submission date: *07/07/2023*

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Abstract

Observations of sea surface temperature (SST) from passive microwave (PMW) sensors are important complements to traditional infrared (IR) observations. However, the resolution of the current microwave imagers is not enough to capture subscale to mesoscale variability. Furthermore, they suffer from coastal and sea ice contamination. The Copernicus Imaging Microwave Radiometer (CIMR) is currently being prepared by the European Space Agency (ESA) as a part of the Copernicus Expansion program for the European Union, with an expected launch in 2029. CIMR is designed to observe high-resolution and high-accuracy PMW measurement of a select range of geophysical variables, such as SST. Currently, a prototype retrieval algorithm for CIMR Level-2 SST is being developed. The CIMR SST retrieval algorithm is a statistically-based model for retrieving both SST and associated uncertainty, using satellite brightness temperatures and ancillary data, such as e.g. wind speed. The CIMR Level-2 SST algorithm also involves re-sampling and re-mapping. The CIMR Level-1b brightness temperatures need to be re-mapped on common location and resolution before application of the SST algorithm. The prototype retrieval algorithm is developed and validated using simulated CIMR data. The performance is assessed using demonstration reference scenario scenes, consisting of typical brightness temperatures for different surface types arranged in artificial patterns corresponding to real world scenarios, such as ocean-land and ocean-sea ice transitions.

TALK 42-S4: TRISHNA Sea Surface Temperature Retrievals: comparison of multiple algorithms

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Abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural ressources Assessment) is a cooperation between the French (CNES) and Indian (ISRO) space agencies, for a satellite to be launched in 2026. During its 5 years lifetime, TRISHNA will measure every 2 to 3 days the visible, near infrared and thermal infrared signal of the surface-atmosphere system globally and at 60 m resolution for the continents and coastal ocean. Level 2 products –free and open data policy- include Sea Surface Temperature. TRISHNA scientific objectives are strongly linked to coastal and inland waters monitoring (water quality, fish resource, sea ice).
The retrieval of sea surface temperature is commonly achieved with an empirical Split-Window method that allows to derive surface temperatures from measurements in two adjacent TIR channels. In the context of the TRISHNA mission that offers 4 thermal bands, we compared SW sea surface temperatures to another algorithm retrievals: direcTES. DirecTES was developed for TRISHNA and is based on the use of a comprehensive spectral database of emissivities to end up in a well-posed deterministic problem while not assuming strong hypotheses. Over water, as emissivity is known, the algorithm uses the potential of all the bands available combined to an actual atmospheric correction to retrieve sea surface temperature.

The performances of the algorithms were evaluated first in a theoretical study. The algorithms were then applied to ECOSTRESS level 1 images and compared to in situ measurements in order to evaluate their potential to retrieve SST in a concrete and operational process.

TALK 90-S4: MAESSTRO: Masked AutoEncoders for Sea Surface Temperature Reconstruction under Occlusion

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Abstract

High-resolution, gap-free sea surface temperature (SST) data products are crucial for various analyses, from climatology to socioeconomics. While free of gaps, the 1km-scale blended MUR SST was unable to reconstruct high-resolution, small-scale features under clouds, instead relying on low-resolution measurements from microwave radiometers. In this study, we investigate the effectiveness of masked autoencoders (MAE) to reconstruct small scale features at high resolution (1 km) under clouds. The MAE model is trained on SST tiles from the ECCO LLC4320 forward simulation, whereby the model learns to predict the SST values under randomly masked out portions of the tiles. Preliminary results show that MAE can reconstruct global SST under a random 80% mask to within 0.3°C root mean squared error (RMSE). The results we obtained emphasize the capacity of deep learning models such as MAE to enhance the precision and resolution of SST data at kilometre scales. We present an example evaluation on a real SST tile from VIIRS, showing that MAE exhibits the potential to transfer from synthetic to real SST images. This computationally-efficient methodology can be used in a multi-step pipeline to generate the next generation of high-resolution SST products, opening new avenues for novel investigations in small-scale physical oceanography.

TALK 29-S4: Inter-comparison of various AI/ML techniques for SST retrieval from INSAT-3D Imager

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Abstract

Sea Surface Temperature (SST) is a key parameter to monitor the climate change, which necessitates the availability of the accurate and consistent SST. Satellites provide consistent and continuous observations over the global oceans from which SST can be retrieved. The present study highlights the outcomes of the four different SST retrieval algorithms for INSAT-3D Imager that are based on machine learning (ML) techniques. The proposed SST retrieval algorithms are developed using Random Forest (RF), K-Neighbour Regressor (KNR), Multi-Layer Perceptron (MLP) and Deep Neural Network (DNN) ML techniques. To develop the algorithms, a matchup is prepared using INSAT-3D Imager observations and collocated SST measurements from in-situ quality monitor (iQuam) data portal of National Oceanic and Atmospheric Administration (NOAA) for year 2017-2020. All four algorithms are trained on 70% randomly selected matchups, whereas rest 30% is used for the testing. The trained algorithms are further applied on limited independent matchups created using data of INSAT-3D Imager and iQuam SST for 01 January 2021. In the assessment, the similar bias (RMSE) of 0.11K (0.48K) in DNN, -0.01K (0.59) in KNR, -0.04K (0.54K) in MLP and 0.0K (0.08K) in RF are observed for both training and testing matchups except in RF where a larger RMSE (0.22) is obtained in the testing matchups. However, the retrieval errors (RMSE) for the independent matchups are found to be significantly larger (~1K) in case of RF and KNR as compared to MLP (0.6K) and DNN (0.55K) based algorithms. The comparison clearly shows that DNN based algorithm outperforms the others and is consistent in all three cases.

Posters

36-S4: Sea surface temperature from HY-1D COCTS by optimal estimation

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Abstract

This study focuses on the inter-calibration, cloud detection, and sea surface temperature (SST) retrieval of the Chinese Ocean Colour and Temperature Scanner (COCTS) on board HY-1D satellite. COCTS has two thermal infrared channels that enable the observation of sea surface temperature (SST). To obtain accurate sea surface skin temperature, the evaluation and correction of calibration of COCTS two thermal infrared channels was conducted using VIIRS as the reference instrument. The calibrated accuracy and stability of COCTS were improved, with calibration accuracies of 0.28K and 0.29K for the 11 μm and 12 μm channels, respectively. A physically constrained deep learning algorithm was adopted for cloud detection. The algorithm primarily employed the U-Net model, considering the physical characteristics of clouds and their manifestation in satellite data. The labels for the cloud detection dataset were generated by combining the Bayesian algorithm mask with manual labelling. The cloud detection results were validated based on cloud imagery and SST,

demonstrating good performance. The optimal estimation (OE) algorithm was used for SST retrieval, and atmospheric correction smoothing was applied to improve the sensitivity of SST. The uncertainty of the background field SST in the OE algorithm was dynamically set based on the spatial variation of SST. The average difference and standard deviation of COCTS SST compared to buoy measurements were -0.14°C and 0.37°C, respectively, with an average sensitivity of 0.74. The validation results indicated that the HY-1D COCTS SST, obtained through calibration correction, cloud detection, and OE retrieval, achieved a relatively ideal level of accuracy.

27-S4: Sea Surface Temperature Retrieval from HY-1C and HY-1D COCTS in the South China Sea

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Abstract

The Haiyang-1C (HY-1C) and Haiyang-1D (HY-1D) satellites are two operational ocean observation satellites. The HY-1C and HY-1D satellites form the morning and afternoon satellite networking, which improves the spatial and temporal coverage capacity. The Chinese Ocean Colour and Temperature Scanner (COCTS) on the HY-1C/D satellites provides observation of the sea surface temperature (SST) by two thermal channels centred on 10.8 μm and 12.0 μm. The South China Sea has the characteristics of high water vapour and high SST. In this study, regional algorithms were developed based on radiative transfer modelling. The atmospheric profiles suitable for the South China Sea were selected. The relationship between the skin SST and simulated brightness temperature (BT) of the selected profiles was established, and the algorithm was used to derive the HY-1C/D COCTS SST in the South China Sea. The HY-1C/COCTS SST was compared with the SST from the Sea and Land Surface Temperature Radiometer (SLSTR) onboard Sentinel-3. The bias was −0.07°C, and the standard

deviation was 0.50 °C. The HY-1D/COCTS SST was compared with the SST from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard NOAA-20. The bias was −0.04 °C, and the standard deviation was 0.53 °C. The average difference of the HY-1C and HY-1D COCTS SST was 0.38 °C in the daytime, and 0.03 °C in the nighttime, which was consistent with the characteristics of diurnal warming in the region.

60-S4: Retrieval of Sea Surface Temperature and Atmospheric Profiles from INSAT-3DR: Comparing Bayesian Inference, 1D-Var, and Machine Learning

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Abstract

Accurately measuring Sea Surface Temperature (SST) along with the temperature and water vapour profiles and monitoring their diurnal variations are paramount for weather and climate applications. However, the commonly used NLSST algorithm has limitations by regressing the buoy SST with the satellite-measured skin temperature. We have developed a novel approach for the remote measurement of SST and atmospheric profiles using INSAT-3DR data, combining Bayesian inference and the 1D-Var method. This work aims to solve the inverse problem by incorporating prior knowledge and uncertainties from diverse atmospheric profile datasets of over 5.1 million profiles we have generated, incorporating minor zenith angle variations. We have used the RTTOV model to solve the retrieval process iteratively. Our algorithm leverages the synergy between observed radiances from various channels to retrieve sea surface temperature (SST) and atmospheric profiles jointly. By utilizing all the imager and sounder channels, we can obtain valuable information on atmospheric properties, enabling a complete understanding of the atmospheric state and facilitating accurate SST estimates. To augment this approach, we have integrated machine learning techniques such as Artificial Neural Networks and Random Forests which can learn complex patterns and relationships from the data, thereby improving retrieval. By addressing the limitations of the existing methods and harnessing the power of Bayesian inference, the 1D-Var method, and machine learning, we aim to advance the accuracy and effectiveness of measuring SST and atmospheric profiles, contributing to better weather forecasting, climate analysis, and ecosystem impact mitigation.

Science Session S5 - Novel Computing and Products

Chair: Edward Armstrong (1)
Rapporteur and Co-Chair: Nitant Dube (2)
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Description of the session

In recent years, several satellite SST products have become available to users. The number of GHRSST-formatted datasets is more than 100 and the data volumes have increased significantly, calling for new ways of formatting and analysing the datasets. In this session, the goal was to present new SST products to the SST users and producers community. The products included both level 2, 3 and level 4 products. Improvements to existing products were also presented in this session, together with new ways of analysing the vast amount of satellite data that are available.

These new approaches included the usage of cloud computing resources or the formatting of existing satellite products, to facilitate the analysis.

In this session, contributions were provided on:

- New satellite SST products or improvements to existing datasets.
- Examples of the usage and assimilation of SST products.
- Innovative ways of analysing large amounts of data.
- Use of cloud computing for analysing the datasets.

Keywords: New satellite SST products, cloud computing, analysis ready data, innovative analysis methods.

Session report and conclusions

Science Session 5, Computing and Products consisted of one Keynote Speech and four paper presentation and Q&A session.

A Keynote Speech was given by Ed Armstrong (NASA Jet Propulsion Laboratory/California Institute of Technology) on "Optimizing Data and Services in the Cloud for User Exploration".
The GHRSST data provided by NASA PO.DAAC is now available on AWS Cloud for users. The availability of this data on cloud provides collocated computing and storage to the users and helps address the scalability requirements of processing large time series data. The availability of this data on cloud has seen transition from conventional analysis method, where users download the data and then carry out analysis, to online analysis. Different use cases demonstrated include calculation of Global mean of SST data. The cloud infrastructure used includes AWS Lamda and Elastic Compute (EC2 with Dask). The Terraform workflow tools were used for cross comparison of different SSTs. Utilization of EC2 with Dask has seen the performance improvement from 8 hours to 15 minutes. The results of HDF5 optimizations were presented and showed that utilization of page aggregation and read buffering helps improve the read access time of HDF products. ZARR is one of the upcoming cloud native formats which improves the performance, as the metadata contains address of all data locations allowing faster access to subset of data.

Prasanjit Dash (NOAA NESDIS STAR / CSU CIRA) presented on "Temporal and geospatial characterization of trends in sea surface temperature".
SST is an important parameter used for monitoring the trend and is an important climate indicator. Trend and Trend rates are important parameters for analysis of long time series data. SST trends from ESA's Climate Change Initiative v2.1 data were presented. Trends derived employing linear fit and various decomposition methods, including seasonal-trend decomposition using LOESS (STL) and multiple STL (MSTL), and for global oceans, the Bay of Bengal, and the Chesapeake Bay were presented.

Jean-François Piollé (Ifremer) presented on "Searching and selecting GHRSST data with OpenSearch".
The OpenSearch provides a mechanism for federation of different GHRSST data provided by different data providers. OpenSearch provides a mechanism for searching GHRSST granules based on time and geolocation. A jupyter notebook based search mechanism using OpenSearch was demonstrated.

Jean-Louis Raynaud (Centre National d'Etudes Spatiales, CNES) presented on "TRISHNA products format and content for water users".
A brief overview of the joint India and France satellite called TRISHNA planned for launch in 2025/2026 was provided. The data from TRISHNA will be disseminated from India and France, and this is a global mission with high resolution data near the coast. Different levels of products (Level1C and Level2A) will be available for water users. Products will be available in Cloud Optimized GeoTiff (COG) and

NetCDF with JSON. Compatibility of TRISHNA products with LSTM is being worked out. This satellite will be generating approximately 720 TB of data in one year. Products containing intermediate variables will also be provided for Expert users.

Katharina Gallmeier (Institute for Defense Analyses, IDA Headquarters, IDA Systems and Analyses Center) presented on "An evaluation of the LLC4320 global ocean simulation based on the submesoscale structure of modelled sea surface temperature fields".
The results of MIT general circulation model LLC4320 study for reproducing the structure of the upper ocean at the sub-mesoscale over global oceans by comparing the output with the Level-2 VIIRS SST dataset was presented. Mean Standard Deviation and power spectrum statistics along with trained PAE for comparison were used to assess the model's level of accuracy. LLC4320 simulation reproduces well both globally and regionally. Differences were observed (1) in the vicinity of the point at which western boundary currents separate from the continental margin, (2) in the Antarctic Circumpolar Current, especially in the eastern half of the Indian Ocean, and (3) in an equatorial band equatorward of 15°. The reasons for these differences need to be further investigated.

Conclusions
With increasing data volumes, collocation of data and computation have become an essential requirement. SST providers are now shifting to cloud to address this challenge. Migrating products to cloud requires both optimization of product formats (support for cloud native format such as COG and ZARR) and associated services such as use of Dask to achieve parallelism. These optimizations result in considerable performance improvement. The long time series data helps derive information about trend, and trend rates different decomposition methods can be used for deriving these parameters. OpenSearch provides capability for federation of metadata from multiple data providers. This results in each search based on spatial and temporal filters for user required SST data. Trishna is a joint Indo-French mission, which will be providing high resolution SST near the coast. GHRSST to ensure that the products generated by Trishna and LSTM are GHRSST compatible. Models such as LLC4320 can be used for reproducing the structure of the upper ocean at the sub-mesoscale over global oceans. However, the results of these models at regional level need further validation.

Overview of the talks

Nr.	Name	Institution	Title	Link
26-S5	Ed Armstrong	NASA Jet Propulsion Laboratory/California Institute of Technology	Optimizing Data and Services in the Cloud for User Exploitation	**KEYNOTE PDF** Video: https://youtu.be/klitJ9Oyo1w
92-S5	Prasanjit Dash	NOAA NESDIS STAR / CSU CIRA	Temporal and geospatial characterization of trends in sea surface temperature	**Invited talk PDF** Video: https://youtu.be/kxynqlp9IbM
99-S5	Jean-François Piolle	Ifremer	Searching and selecting GHRSST data with OpenSearch	**Invited talk PDF** Video: https://youtu.be/smgTQ-Qtzlo
96-S5	Jean-Louis Raynaud	Centre National d'Etudes Spatiales (CNES)	TRISHNA products format and content for water users	**Invited talk PDF** Video: https://youtu.be/JIDc9KFdBp0
56-S5	Katharina Gallmeier	Institute for Defense Analyses, IDA Headquarters, IDA Systems and Analyses Center	An evaluation of the LLC4320 global ocean simulation based on the submesoscale structure of modelled sea surface temperature fields	**Invited talk PDF** Video: https://youtu.be/HM6hpFZuTgc

Overview of the posters

Nr.	Name	Institution	Title	Download the PDF	Watch the video
23-S5	Wen-Hao Li	Raytheon	PO.DAAC Cloud Data Discovery, Distribution and Tools/Services	**PDF**	Video: https://youtu.be/ful_zuAK26s
24-S5	Charlie N. Barron	U.S. Naval Research Laboratory	Testing ocean data assimilation to use information on scales resolved by satellite SST	**PDF**	Video: https://youtu.be/YJDdjyFErXA
28-S5	Suresh Vannan	NASA Jet Propulsion Laboratory/ California Institute of Technology	PO.DAAC Cloud Access - Getting started	**PDF**	Video: https://youtu.be/VpJR1x_DCQc
35-S5	Benjamin Loveday	EUMETSAT	EUMETSAT Code-based Resources for Sea Surface Temperature Training	**PDF**	Video: https://youtu.be/VpJR1x_DCQc
93-S5	Prasanjit Dash	NOAA NESDIS STAR / CSU CIRA	A preliminary prototype of CEOS COAST Application Knowledge Hub (AKH) for monitoring events and the state of coastal areas	**PDF**	Video: https://youtu.be/TuUe9rxdYSo

Abstracts Science Session S5 - Novel Computing and Products

KEYNOTE 26-S5: Optimizing Data and Services in the Cloud for User Exploitation

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Submission date: 27/06/2023

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Abstract

GHRSST sea surface temperature data served from the NASA PO.DAAC have now found a new permanent home in the Amazon Web Services (AWS) Cloud. Maximizing the utilization of these data requires new approaches, a keen understanding of the cloud ecosystem and its related services. While at first this may appear a barrier, there are many inherent advantages to having data hosted in a cloud environment. These include leveraging computing services directly on the data, employing enterprise services for data pre-conditioning, and the proximate location of other cloud-based interdisciplinary earth science datasets. In this presentation, we will review the challenges and some of the solution space with regard to real world use cases, leveraging a spectrum of open/enterprise services. These include both AWS specific services like Lambda and python specific like Dask in performing science on the cloud. We also present an optimization study for the HDF5 data container whereby cloud access is enhanced by implementing best practice guidelines for internal metadata packaging, data chunking and read buffering. The cloud, despite a modest learning curve and ever evolving suite of services and processing capabilities, presents a tremendous opportunity for performing faster, and more open and reproducible science.

TALK 92-S5: Temporal and geospatial characterization of trends in sea surface temperature

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Abstract

Sea surface temperature (SST) provides an indicator of the ocean's physical state. Changes in SST during the past decades are significant, and monitoring its patterns and trends is critical to understanding various oceanographic and climatic processes. We will present SST trends from ESA's Climate Change Initiative v2.1 data available at https://cds.climate.copernicus.eu.

A trend is a time series in the same space as the original parameter after removing seasonalities and noise. We will discuss trends derived employing linear fit and various decomposition methods, including seasonal-trend decomposition using LOESS (*STL*) and multiple STL (MSTL), and for global oceans, the Bay of Bengal, and the Chesapeake Bay. In addition, implementation challenges will be discussed, *i.e.*, spectral analysis for specifying periodicities and handling an extensive array of data.

SST generally shows up-trends with rates in K×decade^{-1} of 0.07±6% (global), 0.16±8% (Bay of Bengal), and 0.22±50% (Chesapeake Bay). A continuous long-term (1982-2022) analysis helped overcome the shortcomings flagged by the global warming hiatus debate. The geospatial distribution of trend rates is pervasive. Parts of the Southern Ocean, areas around the Peruvian current, the eastern Pacific cold tongue, a North Atlantic patch (due to disruption of the Atlantic Meridional Overturning Circulation), and many smaller coastal segments show negative trends. Conversely, other oceanic parts show an increasing trend at different levels. Some are intense, exceeding 0.4 K×decade^{-1}, in the North Atlantic (Baffin Bay, Labrador Sea), Arctic (Barents Sea), and other areas. Increasing trends are ubiquitous and, combined with other parameters, can have far-reaching consequences on Earth's ecosystems.

TALK 99-S5: Searching and selecting GHRSST data with Opensearch

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Abstract

The GHRSST granule files are stored and accessed at different DACs. The GHRSST portal now provides a single OpenSearch end-point search service, which federates all GHRSST DAC inventories. It does not host itself any inventory database, it just acts as a broker. The GHRSST granule inventory service allows the users to discover, search and locate GHRSST granules (or files) for any collection from a single access point, based on time and geographical area. A request to this web service does not return any file, just the file names and metadata of each found granule matching the user request, including at least one URL for each of them (that can be used by a user for the actual download). This presentation will demonstrate how it can be used by GHRSST product's user community to select and collect files of interest from a script or a jupyter notebook, in a harmonized syntax, wherever they are located.

TALK 96-S5: TRISHNA products format and content for water users

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Abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment) is the result of a cooperation between the French and Indian space agencies: CNES and ISRO. Planned to be launched in 2026, TRISHNA will provide, during 5 years, surface-atmosphere system measurements from visible to near infrared and thermal infrared signals, at 60 m resolution and at a global scale for continents, but also for coastal ocean.

TRISHNA near-real time products will be distributed according to a free and open data policy. The proposed format is based on Cloud Optimised GeoTiff files for main variables, in association with Json

files for metadata. Work is still on-going to fit as much as possible with the GHRSST specifications in terms of format and content. In particular, analysis is carried out around the definition of uncertainties, linked to land and water variables.

In the frame of TRISHNA products, specific algorithms are used to compute variables related to water surface. Sea Surface Temperature, visible and near infrared water surface reflectances as well as water surface emissivities, for which the added value is still under investigation, will therefore be provided to water community. Currently, two hypotheses are considered for these variables to limit the products size: creation of specific water variables over a dilated water mask or inclusion in global variables containing land and water information depending on the location. In the latest case, priority would thus be given to land information over common areas such as intertidal zones.

TALK 56-S5: An evaluation of the LLC4320 global ocean simulation based on the submesoscale structure of modeled sea surface temperature fields

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Abstract

We have extracted all (approximately 2.8 million) >98% cloud free, 192x192 pixel^2 squares (144x144 km^2), which we refer to as cutouts, from the Level-2 VIIRS SST dataset for 2012-2020 to evaluate the degree with which the MIT general circulation model reproduces the structure of the upper ocean at the submesoscale. Specifically, we evaluate outputs from the LCC4320 1/48 global-ocean simulation for a one-year period starting on November 17, 2011 but otherwise matched in geography and day-of-year, to the VIIRS observations. In lieu of simple (e.g., mean, standard deviation) or more complex (e.g., power spectrum) statistics, we analyse the demeaned cutouts with an unsupervised Probabilistic AutoEncoder (PAE) trained to learn the geographic distribution of their structure on ~10-to-80-km scales. A principal finding is that the LLC4320 simulation reproduces well, over a large fraction of the ocean, the observed distribution of SST patterns, both globally and regionally, but there are also regions of significant difference: (1) in the vicinity of the point at which western boundary currents separate from the continental margin, (2) in the Antarctic Circumpolar Current, especially in the eastern half of the Indian Ocean, and (3) in an equatorial band equatorward of 15°. Although we do not yet know the exact causes for these model-data SSTa differences, we expect that this type of comparison will help guide future developments of high-resolution global-ocean simulations.

Posters

23-S5: PO.DAAC Cloud Data Discovery, Distribution and Tools/Services

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Abstract

On April 24th, 2023, PODAAC transitioned from on-premise to the NASA Earthdata Amazon Web Services Cloud, ushering in a new era for NASA's earth data archiving and distribution system. This shift not only migrated the entire archive of datasets but also introduced new tools and services within the Earthdata Cloud ecosystem. Legacy on-premise tools like PO.DAAC Drive, OPeNDAP, THREDDS, LAS, and web services were discontinued and (mostly) replaced with cloud-based equivalents. The Earthdata Cloud now offers data download via HTTPS and S3 bucket direct access, OPeNDAP for efficient data retrieval and subsetting, the Level 2 subsetting tool HiTIDE, the SOTO visualization tool and a powerful data-downloader/subscriber script. Furthermore, a collection of Harmony Application Programming Interface (APIs) has been introduced, enabling users to discover and access Earth observation data from 12 different NASA data centres. These APIs encompass services for subsetting, Zarr reformatting, regridding, and more. The transition to the Earthdata Cloud presents an array of advantages and opportunities for the user community, but also brings certain challenges. To help ease users into this transition, PO.DAAC has created a Cookbook of data recipes and tutorials for its datasets, tools and services. Overall, the transition to the Earthdata Cloud signifies a significant improvement in data accessibility. The PODAAC cloud platform expands the reach of earth data to a wider user community and empowers users to access diverse scientific datasets.

24-S5: Testing ocean data assimilation to use information on scales resolved by satellite SST

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Abstract

New data assimilation approaches in development at the U.S. Naval Research Laboratory (NRL) seek to make better use of the high-resolution Sea Surface Temperature (SST) information from satellites. The Naval Oceanographic Office (NAVOCEANO) is one of the SST production centres providing SST retrievals to the global community under the auspices of the international Group for High Resolution Sea Surface Temperature (GHRSST). Aggregate statistics based on matchups between individual SST retrievals and independent in situ samples do not convey the spatial information on fronts and eddies that are evident in cloud-cleared portions of the observed fields. Present SST assimilation on global scales makes limited use of this spatial detail; a multi-scale assimilation approach is being evaluated as an efficient method to utilize the higher resolution SST fidelity in basin or global ocean model applications. We show preliminary results in the western North Atlantic using a model on a 1-km grid. Future plans are to apply these approaches in a high resolution global coupled earth system prediction capability (ESPC).

35-S5: EUMETSAT Code-based Resources for Sea Surface Temperature Training

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Abstract

Through its mandatory-, optional- and third-party programmes, EUMETSAT operates missions carrying a broad range of infrared radiometry and interferometry sensors. Data from these sensors, alongside additional contributions, is processed to GHRSST format sea surface temperature products (SST) at various levels and is disseminated to users either directly (level-2), via the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) (level-2 to level-3C), and as part of the Copernicus programme through the downstream Marine Monitoring service (level-3 to level-4). This data landscape is difficult to navigate, and many users require assistance to help them find and work with the products that are most suitable for their research and application needs.

To support these users, EUMETSAT Copernicus and OSI SAF training teams have authored a catalogue of Python-based Jupyter Notebooks that provide practical examples of common SST workflows. This catalogue includes modules on product access, product structure, and product quality, as well as case study examples of data in use. The catalogue is open source, freely available via GitLab, and in the case of notebooks relevant to Copernicus products, available on the WEkEO DIAS cloud system. This poster will provide an overview of these resources, provide information on ongoing training programmes to support their use, and invite feedback from the community on suggestion improvements and directions for expansion.

28-S5: PO.DAAC Cloud Access - Getting started

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Abstract

The Physical Oceanography Distributed Active Archive Center (PO.DAAC https://podaac.jpl.nasa.gov/) is NASA's data center for the GHRSST datasets (https://podaac.jpl.nasa.gov/GHRSST).

PO.DAAC has been serving data from its on-premise data centre. However, high-data-volume missions have necessitated the need for new data management technologies and architectures that are more cost-effective, flexible, and scalable than traditional on-premise systems. To meet these needs, the Earth Science Data Systems (ESDS) Program, PO.DAAC's sponsor, has transformed a strategic vision into an operational capability to develop and operate multiple components of the Earth Observing System Data and Information System (EOSDIS) in a commercial cloud environment.

In alignment with the ESDS vision, PO.DAAC has moved its entire GHRSST data collection to the Earthdata Cloud hosted in Amazon Web Services (AWS), as well as all operational functions, such as data ingest, and archive distribution, and tools and services for end users. PO.DAAC's new capabilities will enable new frontiers in SST research and applications. Users now have the ability to explore SST data directly in the Earthdata Cloud and also interface with the data using web services.

In this talk, an overview of PO.DAAC cloud tools and services offering will be provided. Various training materials, tutorials covering cost, in-cloud access, and scalable compute will be shared. A

getting started tutorial using a cloud playground will be provided. While data is being delivered from the cloud all SST data from PO.DAAC will remain free and open to discover and access.

93-S5: A preliminary prototype of CEOS COAST Application Knowledge Hub (AKH) for monitoring events and the state of coastal areas

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Abstract

Assessing changes in coastal zones is crucial as most of the global population lives there, with significant goods and services produced and great social and ecological concerns. Coastal zones are challenging to observe as they are highly dynamic, marked by complex ecosystems (physics, biology, and biogeochemistry), coupled trans-boundary (*e.g.*, land-sea interface), and trans-disciplinary (environmental-social) interactions. Satellite data provide a valuable synoptic framework but need to be coupled with sub-orbital and field measurements and diverse socio-economic data.

Increases in spatial, temporal, and spectral coverage and resolution are required. Integrating a vast amount of satellite and non-satellite observations, coupled with advanced mathematical methods and informatics to derive information (*e.g.*, trends and shoreline changes) and modern visualization, provide an opportunity to better understand and communicate coastal changes.

Waters that are warming, rising, acidifying, and experiencing other changes require timely and accurate assessments. Therefore, the CEOS Coastal Observations, Applications, ServicesTools (COAST) Team, Co-led by NOAA and ISRO, are spearheading an effort to visualize and provide a knowledge base for characterizing events and the overall state of the coasts: the COAST Application Knowledge Hub (AKH).

We will discuss the initial AKH prototype that simultaneously shows [1] satellite-based ocean parameters (*e.g.*, SST, Chl-a), [2] trends in ocean parameters, [3] social indicators (*e.g.*, poverty, vulnerability), [4] land loss/gain, [5] station measurements (*e.g.*, standard ocean and meteorological parameters), [6] waterways, [7] elevation, [8] projection of episodic extreme events, [9] bathymetry, [10] land cover/use, and [11] a set of curated major coastal events resulting in significant damage (*e.g.*, hurricanes).

Science Session S6 - High-resolution future satellite missions

Chair: S S Sarkar (1)
Rapporteur and Co-Chair: Bimal Bhattacharaya (1)
(1) Space Applications Centre, ISRO

Description of the session

Over the next few years, several new satellites are planned to be launched, including infrared and microwave instruments in polar and geostationary orbits. The high spatial resolution of SST will continue to be maintained and improved, including those with very high-resolution SST observations less than 100 meters. New evolutions, including the introduction of very high spatial resolution missions, will provide new opportunities for applications but will also require developments within retrievals, validations and cloud masking. It is therefore important that the new developments within high resolution SST products are coordinated with the ongoing international SST activities.

Many global ocean SST users are requesting improved SST products near and at the coastal zones, products with improved feature resolution including at frontal zones, and improved consistency of products at high-latitudes and in the marginal ice zone. At the recent GHRSST science team meeting, it was therefore concluded that the coordination of high-resolution SST science would be a priority for the coming years.

In this session, the goal was to focus on the following:

- Overview of the future high-resolution thermal infrared missions for coastal and inland waters SST (TRISHNA, LSTM, SBG …).
- Towards new data products combining high-resolution water colour variables and SST.
- Improving continuous monitoring of SST with future high resolution thermal infrared missions: issues and challenges.
- How to enhance synergies between future missions for data processing, reprocessing, archival, dissemination, and utilization.
- On-orbit cross-calibration of thermal infrared instruments.
- Assess GHRSST contribution to the future missions (gathering user's needs, expertise on the SST retrieval algorithms, validation of the products).

Keywords: future missions, high-resolution thermal infrared missions, synergies between future missions, cross-calibration, future, coordination.

Session report and conclusions

The first keynote was delivered by Bimal K Bhattacharya (ISRO): TRISHNA – A joint Indo-French TIR-VSWIR science mission towards global water and food security. Continuous products from TRISHNA and similar global missions (LSTM, SBG) will help several downstream applications and quantifying various sustainable development indicators related to water- food security, land and coastal management.

The second keynote was delivered by Steffen Dransfeld on Land Surface Temperature Monitoring (LSTM) Mission. Steffen Dransfeld provided an overview of the proposed Copernicus Land Surface Temperature Monitoring (LSTM) Mission including user requirements, a technical system concept overview, Level-1/Level-2 core products description and a range of use cases addressing mission objectives. As the complementary objective also aims to support the coastal water and inland water temperature retrieval, feedback from the GHRSST community is sought for associated data requirements. Key questions are needs for data format, retrieval algorithms and associated auxiliary processing such as cloud masking to assess how these can complement the overall mission objectives.

Emmanuelle Autret (IFRMER) presented the Designing of new ultra high resolution Sea Surface Temperature products in coastal areas for the future TRISHNA mission: The primary objective of this study is to develop a state-of-the-art processing for ultra-high resolution SST retrieval in coastal areas from the future TRISHNA mission. To achieve this objective and to fill the gap, the study aims at designing new 100m ultra-high resolution satellite-derived Sea Surface Temperature (SST) products dedicated to coastal waters from the existing Landsat-9 and ECOSTRESS imagery. By designing those new products (called "CALISTA"), the main challenges of the SST retrieval in coastal environment were addressed.

Christopher Merchant (University of Reading and National Centre for Earth Observation), Coastal-zone sea surface temperature at ~100m resolution, presented the results for cloud detection and sea surface temperature and discussed in terms of lessons towards future missions that have smaller errors and enable more frequent observations, first of all TRISHNA.

Paolo Cipollini (presenter: Steffen Dransfeld) from ESA, Enhanced continuity of SST measurements from Sentinel-3 Next Generation Optical. Sentinel-3 Next-Generation Optical will be launched after 2032, and will provide continuity of SLSTR SST, with an improvement in resolution to 500 m. Steffen Dransfeld presented the status of the mission and the technical solutions that are being analysed to improve performance, and we will discuss both the synergies with the colour measurements, and the complementarities and interoperability with the high-resolution observations

Jonathan Mittaz (University of Reading), in his talk on Towards the next generation Sentinel instruments: The Advanced SLSTR, showed the results for a range of case studies including SST showing the likely impact of modifying or adding additional IR channels as well as the impact of different instrument architectures.

Questions

Could a fifth channel that we have in TRUSHNA improve the coastal SST performance for a similar algorithm to be applied to the LSTM?

Christopher Merchant: It certainly will do no harm if you have the right algorithm. It may help beat down the noise, but I have not yet explored whether which of the additional channels help with the cloud detection. Having an extra channel, if it's not noisier, will beat down the noise overall if you use all the channels within the retrieval and it possibly can disambiguate some of the water vapour correction better too, as long as it's well characterised.

Overview of the talks

Nr.	Name	Institution	Title	Link
101-S6	Bimal K Bhattacharya	Space Applications Centre, Indian Space Research Organization (ISRO)	TRISHNA – A joint Indo-French TIR-VSWIR science mission towards global water and food security	**KEYNOTE 1 PDF** Video: https://youtu.be/bQbNZ0Hnw8l
3-S6	Steffen Dransfeld	European Space Agency	Land Surface Temperature Monitoring (LSTM) Mission	**KEYNOTE 2 PDF** Video: https://youtu.be/cWBGE-Zx6EE
73-S6	Emmanuelle Autret	Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d' Oceanographie Physique et Spatiale (LOPS)	Designing new ultra high resolution Sea Surface Temperature products in coastal areas for the future TRISHNA mission	**Invited talk PDF** Video: https://youtu.be/3Bmj7YAZ-3U
69-S6	Christopher Merchant	University of Reading and National Centre for Earth Observation	Coastal-zone sea surface temperature at ~100 m resolution	**Invited talk** Video: https://youtu.be/rNsx7JKQmkY
102-S5	Paolo Cipollini (presenter: Steffen Dransfeld)	European Space Agency	Enhanced continuity of SST measurements from Sentinel-3 Next Generation Optical	**Invited talk PDF** Video: https://youtu.be/AUlsYa5phkA ;

34-S6	Jonathan Mittaz	University of Reading	Towards the next generation Sentinel instruments: The Advanced SLSTR	**Invited talk_PDF** Video: https://youtu.be/gfPH1uNmOOQ

Overview of the posters

Nr.	Name	Institution	Title	Download the PDF	Watch the video
74-S6	Elea Paul	Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d'Oceanographie Physique et Spatiale (LOPS)	The TRISHNA mission in coastal ocean: Building a reference validation and algorithm calibration dataset	**PDF**	Video
75-S6	Emmanuelle Autret	Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d'Oceanographie Physique et Spatiale (LOPS)	Introducing the ISRO-CNES TRISHNA mission for high resolution SST observations in coastal ocean and continental waters	**PDF**	Video
76-S6	Philippe Gamet	Centre National d'Etudes Spatiales (CNES)	TRISHNA mission: High resolution and high revisit surface temperature for land and coastal ocean	**PDF**	Video: https://youtu.be/Q81CPSWfv2 c
100-S6	Aida Alvera-Azcárate	University of Liège	Study of coastal Marine Heat Waves with high spatial resolution sea surface temperature data	**PDF**	Video https://youtu.be/opbFH2Q9Yhk

Abstracts Science Session S6 - High-resolution future satellite missions

KEYNOTE 1) 101-S6: TRISHNA – A joint Indo-French TIR-VSWIR science mission towards global water and food security

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Abstract

Strong signal of human-induced global warming for earth climate change is evident which is potentially triggered by high population growth, irrational resource consumption and land use land cover change. Increasing trends of water consumption, withdrawal, widening gap are highest in agriculture sector leading to severe water stress and deteriorating water quality. TRISHNA, a joint Indo-French TIR-VSWIR space-borne mission, will provide first of its kind systematic records of surface temperature and variety of biophysical, radiative and water variables at approximately 60 m spatial resolution with 8-day repetivity having 3-day sub-cycle. Observations from four-band thermal infrared and 7-band visible-shortwave infrared are aimed to meet two primary science objectives such as (i) Terrestrial ecosystem water stress and water use, (ii) Coastal and inland waters and will also provide scientific insights into urban micro-climate, cryosphere, solid earth and atmosphere. Three levels of science products (Level 2A, Level 2B and 3) have been identified to be derived from TRISHNA Level 1 Top-of-Atmosphere (TOA) radiances. Level 2A comprises of atmospherically corrected products such as surface temperature, emissivity, surface reflectance and atmospheric by-products on water vapour, aerosol optical depth. These primary variables will be used to derive higher order science

products (Level 2B, 3) and to drive different land-coastal-ocean process models to quantify daily evapotranspiration, water stress, primary productivity etc. Continuous products from TRISHNA and similar global missions (LSTM, SBG) would help in several downstream applications and quantifying various sustainable development indicators related to water- food security, land and coastal management.

KEYNOTE 2) 3-S6: Land surface temperature monitoring (LSTM) mission

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Abstract

The existing Copernicus space infrastructure, including particularly the Sentinel-1 and Sentinel-2 missions, already provides useful information for agricultural applications. Although Sentinel-3 routinely delivers global LST measurements, its 1 km spatial resolution does not capture the field-scale variability required for irrigation management, crop growth modelling and reporting on crop water productivity. Therefore, a dedicated LSTM mission is foreseen in the frame of the Copernicus expansion with the following mission objectives:

- Primary objective: to enable monitoring evapotranspiration rate at European field scale by capturing the variability of LST (and hence ET) allowing more robust estimates of field scale water productivity.
- Complementary objective: to support mapping and monitoring of a range of additional services benefitting from TIR observations – e.g. soil composition, urban heat islands, coastal zone management and high-temperature events.

ESA collaborates with partner space agencies to create synergy with relevant international missions such as TRISHNA (CNES, ISRO), Surface Biology Geology SBG (NASA/JPL, ASI) and the Landsat program (USGS/NASA) to achieve optimal temporal coverage of high-resolution thermal observations.

This paper provides an overview of the proposed Copernicus LSTM mission including user requirements, a technical system concept overview, Level-1/Level-2 core products description and a range of use cases addressing mission objectives. As the complementary objective also aims to support the coastal water and inland water temperature retrieval, feedback from the GHRSST community is sought for associated data requirements. Key questions are needs for data format, retrieval algorithms and associated auxiliary processing such as cloud masking to assess how these can complement the overall mission objectives.

TALK 73-S6: Designing new ultra high resolution Sea Surface Temperature products in coastal areas for the future TRISHNA mission

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Abstract

Thermal infrared imagery onboard land dedicated satellite missions - but also covering coastal areas - has been around since 1984 with Landsat series, offering today 100m resolution with a revisit time of the order of 10 days in mid-latitude. In coastal ocean, this wealth of data has been exploited only through limited and very localized demonstrations, mainly because of low revisiting time. Still they are invaluable for many applications ranging from forecasting system improvement to coastal process understanding and monitoring, and to the support to many economic activities such as aquaculture. Besides new missions (ECOSTRESS on ISS, TRISHNA in 2026, SBG in 2027, Copernicus LSTM in 2028) are now available or on their way, that will provide better radiometric performances, higher spatial resolution and temporal sampling and increase the value and operational capacity of this source of observation. Despite the wide range of coastal applications from such resolution satellite derived observations, there is no dedicated and validated coastal SST product from the existing missions distributed on regional or global scale.
The primary objective of this study is to develop a state-of-the-art processing for ultra-high resolution SST retrieval in coastal areas from the future TRISHNA mission. To achieve this objective and to fill the gap, the study aims at designing new 100m ultra-high resolution satellite-derived Sea Surface Temperature (SST) products dedicated to coastal waters from the existing Landsat-9 and ECOSTRESS imagery. By designing those new products (called "CALISTA"), the main challenges of the SST retrieval in coastal environment are addressed. The results using ECOSTRESS and Landsat-9 data and the well-known split-window non-linear algorithm over the French coasts will be presented.

TALK 69-S6: Coastal-zone sea surface temperature at ~100 m resolution

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Abstract

Sea surface temperature observation in highly dynamic and spatially variable coastal zones will be advanced by future high-resolution (<100 m) thermal remote sensing missions. Meanwhile, the Landsat missions offer opportunity to prepare for these later missions that will bring finer resolution, lower noise, more thermal channels and more frequent coverage. We adapt well-established sea surface temperature processing applied to global meteorological-type sensors to Landsat observations. Cloud detection and temperature retrieval are the two principal steps, along with quality-flag derivation and uncertainty estimation. Bayesian cloud detection based on thermal and reflectance channels is expected to be effective, as the approach is by design generic and adaptable given a suitable radiative transfer model. Use of a channel set as would be used for processing (for example) an AVHRR-like sensor confirms this. Points of difference when classifying high resolution imagery for sea surface temperature retrieval are the need for finer land-sea boundary auxiliary information and the greater importance of tides in changing the land-sea boundary. For Landsat specifically, the available (regridded) thermal data "bleed" across high temperature contrasts, making assessment of the cloud edges more ambiguous. Similarly to Bayesian cloud detection, optimal estimation used for the temperature retrieval is a highly transferrable technique, reliably and rapidly giving good results when applied to new instruments. Simulation studies are a useful means of assessing optimal estimation in comparison to other temperature retrieval options. In the application to Landsat, the calibration is a significant source of error in retrieved surface

temperature. Results for cloud detection and sea surface temperature will be presented, and discussed in terms of lessons towards future missions that will have smaller errors and enable more frequent observation, first of all TRISHNA.

TALK 102-S6: Enhanced continuity of SST measurements from Sentinel-3 Next Generation Optical

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Abstract
Sustained high-quality SST measurements are one of the pillars of the Copernicus Programme, delivering crucial input to Services like the Copernicus Marine Environment Monitoring Service. SST is currently measured at 1-km resolution and daily revisit (with two satellites) from the SLSTR radiometer on board Sentinel-3 A and B. This radiometer has inherited the qualifying features of the ATSR/AATSR family, first and foremost the dual-view that enables accurate atmospheric correction. The requirements of enhanced continuity for the Evolution of the Copernicus constellation call for an improvement in resolution, while preserving or improving the daily revisit time needed by many applications. Sentinel-3 Next-Generation Optical, to be launched after 2032, will provide continuity of SLSTR SST, with an improvement in resolution to 500 m. The mission is entering Phase A and a strong focus is on improving the synergy of the observations coming from the Advanced SLSTR with the observations from the Advanced Ocean and Land Colour Instrument, also on the same platform. This synergy should lead to improved data quality, beneficially affecting GHRSST data products, and support enhanced services and new services. It also enables R&D into new exploratory applications. We will present the status of the mission and the technical solutions that are being analysed to improve performance, and we will discuss both the synergies with the colour measurements, and the complementarities and interoperability with the high-resolution observations over the coastal zone (plus the full Mediterranean, Caspian and coral reef areas) that will be provided by Copernicus Expansion Land Surface Temperature Monitoring (LSTM) Mission, due for launch in 2028.

TALK 34-S6: Towards the next generation Sentinel instruments: The Advanced SLSTR

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Abstract

Given that the final Sentinel-3 satellite (Sentinel-3D) is due for launch in 2028, work has now begun on the next generation of Sentinel-3 sensors which will be called the Advanced Ocean and Land Colour Instrument (AOLCI) and the Advanced Sea and Land Surface Temperature Radiometer (ASLSTR) each of which has two dedicated science support teams to provide requirements to ESA, one for each sensor. Each instrument must both maintain continuity with the current generation of sensors as well as provide enhanced capabilities. Here, we will be reporting on the initial work done on defining requirements for the ASLSTR sensor. This has been done by looking at both possible calibration effects as well as using a range of different retrieval types including sea surface temperature, land surface temperature, aerosol optical depth, fire detection and measurement and possible synergies between ASLSTR and AOLCI to help optimise some of the requirements/channel selection. We will be looking at both instrument architecture questions (e.g. 1 blackbody and a

space view versus the current two blackbody setup) as well as the possibility of new, extra channels and will look at optimising the ASLSTR channel set (central wavelength and width) constrained by a detailed study of user based and Copernicus based requirements. Results will be shown for a range of case studies including SST showing the likely impact of modifying or adding additional IR channels as well as the impact of different instrument architectures.

Posters

74-S6: The TRISHNA mission in coastal ocean: Building a reference validation and algorithm calibration dataset

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Abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment) is a cooperation between the French (CNES) and Indian (ISRO) space agencies. It will measure the optical and thermal spectra emitted and reflected by the Earth from a low-altitude Sun synchronous orbit, over a swath with a width of 1026 km, approximately twice a week, at 57 m resolution for the continents and the coastal ocean. The targeted launch date for TRISHNA satellite is 2025, being then positioned as a precursor of the LSTM Copernicus mission from ESA. TRISHNA is designed for a lifetime of 5 years.

Providing high-quality imagery in coastal ocean and inland waters is one of the design drivers of the mission. Retrieving and improving Sea Surface Temperature with such resolution in coastal zones is challenging, including: high variability in atmospheric water vapour, temperature and aerosol; complex shoreline, numerous islands, tides, offshore constructions; possible emissivity modification due to contaminants or high turbid waters; and turbidity in interaction with cloud detection; availability of high-quality in-situ data for optimization of retrieval algorithms and validation. In order to calibrate the SST retrieval algorithms and to validate the satellite-derived SST, satellite and in-situ reference measurements over the French coasts have been collected and databased. The assessment of the validity of the different networks (COAST-HF, ECOSCOPA, TmedNET, ISAR network, etc.) for the qualification of the future TRISHNA SST coastal products will be presented.

75-S6: Introducing the ISRO-CNES TRISHNA mission for high resolution SST observations in coastal ocean and continental waters

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Abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment) is a cooperation between the French (CNES) and Indian (ISRO) space agencies. It will measure the optical and thermal spectra emitted and reflected by the Earth from a low-altitude Sun synchronous orbit, over a swath with a width of 1026 km, approximately twice a week, at 57 m resolution for the continents and the coastal ocean. The targeted launch date for TRISHNA satellite is 2026, being then positioned as a precursor of the LSTM Copernicus mission from ESA. TRISHNA is designed for a lifetime of 5 years. Providing high-quality imagery in coastal ocean and inland waters is one of the design drivers of the mission. Sea Surface Temperature (SST) and Lake Water Surface Temperature are Essential Climate Variables. At present, about 40% of the world's population live within 100 km of the coast. In many regions, populations are exposed to a variety of natural hazards, as well as to the effects of global climate change, and to the impacts of human activities. Coastal zones are subject to local and remote forcings implying a wide range of phenomena, including fronts, eddies, horizontal currents, vertical velocities, plumes, tides, waves, turbulence and mixing, stratification, ice formation. Coastal marine ecosystems, such as large upwelling ecosystems, are rich and diverse, supporting much of the commercial fisheries of the world. Regarding inland waters, thermal information at fine scale is of added-value to stress the turbidity and waterborne particles.

In the same regard, fine scale observations allow to assess water quality in its link with temperature, thereby bringing new insights for the productivity of biological communities, the estuary ecosystems, the halieutic resources, the detection of algal blooms and eutrophication conditions, the characterizations of marine habitats, the industrial discharge of pollutants from the rivers and estuaries into the coastal area. Improved understanding and monitoring of coastal or inland waters processes is therefore of high importance, and high resolution SST resolving fine scales of the order of 100m in coastal zones and inland waters, as expected with TRISHNA, should make an increasingly important contribution. Applications, user needs and SST retrieval challenges in coastal and inland waters will be presented.

76-S6: TRISHNA mission: High resolution and high revisit surface temperature for land and coastal ocean

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Abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment) is a cooperation between the French (CNES) and Indian (ISRO) space agencies, for a satellite to be launched in 2026. During its 5 year lifetime, TRISHNA will measure every 2 to 3 days the visible, near infrared and thermal infrared signal of the surface-atmosphere system globally and at 60 m resolution for the continents and coastal ocean. Level 2 products –free and open data policy- include Sea Surface Temperature, visible and near infrared surface reflectances as well as cloud mask, aerosol optical thickness and data quality flags.

TRISHNA aims at: (i) monitoring of ecosystem stress and water use, focusing on agriculture and water content of vegetation, through evapotranspiration; and (ii) coastal and inland waters: characterization of the dynamics of the shallow bathymetry; monitoring of exchanges in estuaries and intertidal zones; sea surface temperatures and winds; sub-mesoscale activity in coastal areas and in the high seas; oil spills, thermal pollutants, effluents and wastewater discharges.

The mission is being designed with the involvement of experts and future users: definition of monitored coastal areas and polar zones, algorithms for SST and optical surface variables computation, cloud mask, product content: variables, auxiliary and ancillary data.

Regular meetings and international events also involve other future operational high-resolution thermal infrared missions: Surface Biology and Geology (SBG, 2027) from NASA and ASI, Land Surface Temperature Monitoring (LSTM, 2029) from ESA).

100-S6: Study of coastal Marine Heat Waves with high spatial resolution sea surface temperature data

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Abstract

A changing climate is driving increasingly common and prolonged Marine Heat Waves (MHWs). These extreme events can cause severe impacts on marine ecosystems globally, with in turn huge ecological and socioeconomic consequences, especially in near-shore, shallow environments.

Studying the impact of MHWs on coastal marine ecosystems is currently hampered by the resolution mismatch between traditional satellite data (typically 1 km spatial resolution for sea surface temperature, SST) and species habitat/substrate. In the southern North Sea, a multitude of shallow sandbanks, sand, mud and coarser sediment substrates are present, offering a multitude of habitats to different species. Ocean dynamics, and hence water mass and temperature distribution, are impacted by the presence of these sandbanks, so fine spatial resolution data are required for accurate analysis of MHWs. The Thermal InfraRed Sensor (TIRS) onboard the Landsat constellation provides SST at a spatial resolution of 30 m, and allows for the study of small-scale dynamics in coastal regions, including the development of MHWs. However, Landsat data have a low revisit time (7-9 days), not optimal to study MHWs, which can evolve on a daily basis. In the frame of the North-Heat project (https://www.gher.uliege.be/North-Heat), we will use synergistically several satellite sensors at different spatial and temporal resolutions, to provide a frequent, high resolution SST dataset in the southern North Sea, with the aim of studying the spatio-temporal variability of SST during MHWs. This approach is based in DINEOF (Data Interpolating Empirical Orthogonal Functions) and has been successfully used with ocean colour data.

News Item: Marine Heatwaves

Marine Heatwaves are warm water events where the observed Sea Surface Temperature (SST) is above the climatological 90th percentile for at least 5 days (Hobday et al., 2016). Marine heatwave events have already caused serious impacts on the marine environment worldwide.
This is a "hot" topic in GHRSST24, this is why we have listed it as "News item" for this specific symposium. Three contributions were presented and a discussion followed the presentations.

Session report and considerations

The Mediterranean case study was presented by Andrea Pisano. There has been a record breaking persistence of the 2022-2023 MHW in the region. The SST trend due to climate warming is the main responsible for the intensification of MHW in the Mediterranean Sea. MHWs under warming oceans: a proper definition for a reference baseline is needed to separate the long-term changes from abrupt and short variability. The 2022 MHW was an exceptional event in terms of duration and extension when compared with the MHW in the last four decades. After a reduction in spring 2023, the Med MHW has re-intensified by three Celsius degrees in July-August 2023. In situ observations offshore the island of Lampedusa allowed us to directly observe the propagation of the MHW, highlighting the role of wind-induced mixing in transferring the surface heat to deeper layers.
Brenna Mei Concolis introduced the topic of Marine Heatwaves in the Philippines: Although intensive studies have been carried out at global and regional scales, these events remained understudied in the Philippines – a country with high marine biodiversity. The Philippines is highly vulnerable to the impacts of these extreme events as it lies in the western boundary of the Pacific that is considered as a hotspot for MHWs. Her present study used multi-year climatic sea surface temperature (SST) records to detect MHWs in the Philippines. The conclusion presented shows that: 1) out of the 96 detected events from 1981-2021, 75 occurred in the last two decades, implying an increasing number of MHWs over the years; 2) although the mean annual hotspots for imean, imax, and icum were mostly confined in the West Philippine Sea and western tropical Pacific, growth rates were higher in the east; 3) it is recommended to investigate the effects of ENSO on the development of MHWs in the country; and 4) the results of this study have implications for resource management, highlighting the need for monitoring, research, and adaptive strategies.
Kerstin Petzer presented the case of the MHW in the Cape peninsula upwelling cell, Southern Benguela. In this area, MHWs are expected to worsen with climate change by lasting longer with high temperature increases but the projected increase in south easterly winds could further limit the duration of MHWs in the Southern Benguela Upwelling System.

Questions

1. To Brenna Mei Concolis: You said that you were going to look at the use of higher resolution SST datasets in your next steps: which ones are you going to use?

Brenna Mei Concolis: The OSTIA and the MUR SST by NASA are more effective in detecting MHW in the coast and there are actually more Marine heat waves that we detected using those higher resolutions, but then there are still some requirements to meet, for example: the period of the SST or the historical data that we have to use has to be longer than 30 years.
Helen Beggs: The presentation by Owen Embury earlier this week on the CCI version 3 reprocessed product could be an interesting tool to use to see how it performs close to the coast.
2. To Brenna Mei Concolis: you mentioned that you have observed 75 events, so did you look into that, e.g., what is the time span of these events like what are the minimum and the maximum as well as the average over the time?

Discussion
Kerstin Petzer indicated we should be looking if we can correlate any of these events with Marine impacts. There's been a lot of work in Marine Biology looking at temperature and thermal fluctuations, and how that affects fish in tropical regions but I haven't seen any work done in cold water regions with kelp die off and change in kelp but that would definitely be something that we should look into.
Andrea Pisano remarked that it is surely important to extend the assessment of MHW by also considering the depth of temperatures other than the sea surface ones. As shown in his presentation, the warm anomalies that penetrate in the depth can persist because of the mixed layer in altered form until winter; so in practice, this warm water remains unchanged and does not propagate and could then enhance the evolution of successive Marine waves. It is also important to study biological impacts: in a current project on MWH funded by ESA my colleagues are studying data from bio Argo in order to analyse possible correspondences between what happens to chlorophyll during the MHW events. William Skirving remarked that we have to understand the thresholds that trigger stress in the flora and behavioural changes in the fauna. It is important to ask what phenomenon we're trying to understand in the biological world and then go and build a product as opposed to the other way round.

Overview of the talks

Nr.	Name	Institution	Title	Link
78-S2	Andrea Pisano	National Research Council of Italy, Institute of Marine Sciences (CNR-ISMAR)	Marine Heatwaves: Extreme warming in the Mediterranean 2023	Video: https://youtu.be/t8zXosYtvmM
64-S1	Brenna Mei Concolis	University of the Philippines Cebu	Characteristics of Marine Heatwaves in the Philippines	**Link to PDF:** Video: https://youtu.be/iq7Np_A9TBw

65-S3	Kirstin Petzer	University of Cape Town, Rondebosch	Marine heatwaves in the Cape peninsula upwelling cell, Southern Benguela	**Link to PDF** Video: https://youtu.be/sV78TsSZLow?feature=shared
Full recording of the discussion on YouTube: https://www.youtube.com/watch?v=CP__b_oWe4g				

Abstracts of the talks

78-S2: Updates on the Copernicus Marine SST products' evolutions and recent applications on Marine Heatwaves and Medicanes events

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Abstract

The aim of this work is (i) to present the most recent Sea Surface Temperature (SST) products' evolutions and R&D activities carried out within the Copernicus Marine Service SST Thematic Assembly Centre (TAC) and (ii) to show recent applications of these products on Marine Heatwaves (MHWs) characterization and the role of the SST in the genesis of Medicanes. The main evolutions performed in 2023 by the SST TAC include (but are not limited to) the release of a new global daily near-real-time gap-free (L4) SST product and a new daily multi-year (1982-present) merged multi-sensor (L3S) SST product. All Copernicus SST data will be also published in the new online GHRSST Catalogue.

The Mediterranean SST dataset has been used to investigate the impact of a warming trend in MHW detection. The work evidenced that the intensification in Mediterranean MHW occurrences, observed over 41 years, is mainly due to sustained SST trend, and that a careful choice of the baseline reference (e.g., fixed versus shifting) becomes essential, since it can lead to different interpretations of properties (intensity, frequency, duration) and tendencies of MHWs. To this purpose, a detrended approach is analysed and the results shown.

The role of the SST in the genesis of Mediterranean tropical-like cyclones, known as Medicanes, is presented. Exploiting the multi-year dataset over the Mediterranean Sea, SST fields and anomaly during several Medicanes events from 1982 to present are analysed to understand the relation between the variation of the sea surface temperature and the development of these hurricanes.

65-S3: Marine heatwaves in the Cape peninsula upwelling cell, Southern Benguela

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Abstract

Marine Heatwaves (MHWs) are considered to be one of the emerging threats to marine ecosystems globally. Extreme warm Sea Surface Temperature (SST) anomalies can cause severe ecological impacts. MHWs were identified off Cape Point by in situ and reanalysis (CCI and REMSS) SST datasets, with a focus on MHW duration and maximum SST values as well as a focus on the influence of the wind on the formation and dissipation on MHWs and warm events (WEs). MHWs are defined events for which the SST exceeds the climatological 90th percentile for at least five days [1], while the WEs event ST values must exceed the climatological 90th percentile for at least three days. The observed average event duration is between 7 to 8 days but the longest events occurred during periods of decreased upwelling, while the highest maximum SSTs occurred during periods of upwelling dominance. The dominant wind during the formation of MHWs and WEs is a north-westerly wind, indicating the main driver of events at the Cape Point mooring is the movement of warm water masses to the mooring location. The dominant wind direction at the end of the MHWs and WEs is a south-easterly wind indicating that coastal upwelling limits the duration of warm water events at the Cape Point mooring. MHWs are expected to worsen with climate change by lasting longer with high temperature increases but the projected increase in southeasterly winds could further limit the duration of MHWs in the Southern Benguela Upwelling System.

Key words: Marine heatwaves, Coastal Upwelling system, SST *in situ* vs satellite

[1] Hobday, A.J., Alexander, L.V., Perkins, S.E., Smale, D.A., Straub, S.C., Oliver, E.C., Benthuysen, J.A., Burrows, M.T., Donat, M.G., Feng, M. and Holbrook, N.J. 2016. A hierarchical approach to defining marine heatwaves. Progress in Oceanography. 141:227-238.

64-S1: Characteristics of Marine Heatwaves in the Philippines

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Abstract

Marine Heatwaves (MHWs) are prolonged, discrete, and anomalously warm events, which have recently gained global attention due to their far-reaching effects and reported impacts. Although intensive studies have been carried out at global and regional scales, these events remained understudied in the Philippines – a country with high marine biodiversity. The Philippines is highly vulnerable to the impacts of these extreme events as it lies in the western boundary of the Pacific that is considered as a hotspot for MHWs. The present study used multi-year climatic sea surface temperature (SST) record to detect MHWs in the Philippines. Linear trend analysis was conducted to determine the magnitude and direction of the change of the MHW metrics over time. Decadal trend revealed that MHWs in the Philippines significantly increased from seven MHWs in the 1980s to 37 MHWs in the last decade. Moreover, increased duration was remarkable in 2020 with 276 MHW days. MHW frequency and duration were increasing at a rate almost twice as its neighboring waters. Intensities did not significantly increase with time, but the highest SST anomaly is associated with El

Niño Southern Oscillation. Furthermore, the eastern and western region of the Philippines is vulnerable to MHWs, but hotspots are mostly confined in the West Philippine Sea and western tropical Pacific. The findings have significant implications for coastal marine resource management, highlighting the need for adaptive management strategies and increased monitoring and research efforts to mitigate the impacts of MHWs on marine ecosystems and local economies in the Philippines.

Workshop 1: What are the next GHRSST priorities?

Chair: Anne O'Carroll
Panelists: Emmanuelle Autret (IFREMER), Andrea Pisano (CNR), Christo Whittle (CSIR), Raj Kumar (ISRO), Ed Armstrong (NASA JPL), Helen Beggs and Pallavi Govekar (BOM), and Jacob Høyer (DMI).

Goal: This session consulted the GHRSST community on the definition of GHRSST progress and the assessment of the priorities in the upcoming years regarding Data access and usage, high-latitudes, feature resolution/coasts, L3/L4 applications and microwave SST. What still needs to be done?

Session considerations

A list of GHRSST Priorities and key considerations from 2023 was discussed during this session:

- GHRSST is to continue preparations for new SST missions and datasets including the further new generation geostationary and low-earth orbit SST, Copernicus reference SST, microwave SST and ultra-high resolution coastal SST.
- There is a very clear priority in 2023 on coastal SST and ultra-high resolution SST, including potentially developing new dedicated products, connections with space agencies on user requirements (e.g. algorithms, cloud-masking, uncertainties) and advising users on the most appropriate SST products for coastal applications. There is a recommendation for a new coastal SST Task Team including relevant experts, to prepare users for these new ultra-high-resolution SST observations.
- There is a need for revising information on Single Sensor Error Statistics (SSES) bias and standard deviation, for strengthening and developing observational (total standard) uncertainties, but mostly for creating a framework and best practices for defining SSES and uncertainties, rather than leaving it only to individual data producers.
- The GHRSST Data Specification (GDS) should be updated to focus on evolving new data models and formats (cloud too), preparations for ultra-high resolution SST, consistency of high latitude products, in addition to sea-ice surface temperature and observational uncertainties.
- There is also a strong need for communication on marine heat waves (MHW) and the development of climate indicators from GHRSST. This could include a dashboard for MHW visualisation.

Resources

- Miro board:
  https://miro.com/jointheteam/bjIad09hTWxacUlvb2RMQU5GUUxzVDhibGxUeEdGMUxmRkZEYldoOHZkSmRZT2F5UTVzR3BRTVJBVjR6WmNKWXwzMDc0NDU3MzU3MzY1MjQxMTU5/
- YouTube playlist of the contributions and discussion:
  https://youtube.com/playlist?list=PLzbTdJgL-5K1vvQUutl9Cr8V5DVLzRAYc&feature=shared

Workshop 2: What are the best practices for SST data producers?

SST data producers workshop, with presentations on GHRSST data specifications, showcasing the use of the GHRSST GDS.

Chair: Jacob Høyer (DMI)

Presenters and panelists:

- Jean-Francois Piolle (IFREMER), Possible future improvements and evolutions we can foresee for the GDS
- Helen Beggs and Pallavi Govekar (BOM), Producing and using GHRSST products – the Australian perspective
- Cristina Tronconi/Andrea Pisano (CNR), The Copernicus Marine SST products
- Nitant Dube (ISRO), ISRO report

Goal: Showcase your experience in SST data production using the GHRSST data specifications, and share your knowledge/experience with other SST producers, who perhaps have not adopted the GHRSST data specifications yet.

Session considerations

- Metadata compliance checker as an online interface tool is needed to check compliance against L2, L3 and L4. This tool will be brought back online by NASA JPL in the next months.
- The newer version of the GHRSST GDS format should also introduce an optional variable that can include data for validation: we have heard a lot of data has a validated dataset, but once it is up and running it is difficult to trace back what validation has been used; so if you include this with the dataset, the user can always trace it back for quality control about the SST data products.
- A discussion from previous GHRSST meetings on how to go from Level 2 to Level 3 is still ongoing: we have not reached consensus yet, but this should be sought even if producers are doing this in different ways.
- We need to go to Cloud format and it is really critical. But if we all move to the cloud, we all solve the interoperability between the different cloud providers, define the best SST algorithm for the specific sensor and a way on how to produce the level three from the level two. Does this mean that we aim to have single product per sensor? It is important that we have variability, but it is still important to show the users what the most accurate algorithm or product is for specific sensors. We are not close to this for the time being, but we need to think about this in the future, in the framework of cloud computing, and aim at sensor-specific products.

Resources

- Miro board: https://miro.com/welcomeonboard/SlJNZW14cEZZNzVIRmx0YnVBaHdzTmFPNHdJSXlRTmpKNzEzcE90UVhhWGs0QnpkSmR2UVNoUjB1Vm9DZzVmS3wzMDc0NDU3MzU3MzY1MjQxMTU5fDI=?share_link_id=203552691879
- YouTube playlist of the contributions and discussion: https://youtube.com/playlist?list=PLzbTdJgL-5K2QleZzH8QpanndH5eEvoRb&feature=shared

GHRSST Task Team Reports

Some of the task teams of GHRSST reported in plenary about the progress in their activities.
Their progress reports (in the form of a presentation) are available on Moodle:
https://training.eumetsat.int/mod/folder/view.php?id=16229
All the reports to the science team have been recorded and are available on YouTube:
https://www.youtube.com/playlist?list=PLzbTdJgL-5K1RFrtUbb8s8X91c262Qw15

Climatology and L4 Inter-Comparison (IC)

The task focusing on the validation of the L2, L3, and L4 SST gradients in highly variable regions using SailDrone has been finalised. Eight SailDrones deployments of the USA West Coast took place to validate Modis L2 and MUR L4 SST at 1KM resolution; the deployments have ensured better accuracies for the MUR products and have proven the ability of the SailDrone to accurately validate near-shore satellite SST products. A paper on this topic has been published in open access by the team (Koutantou, Brunner and Vazquez-Cuervo, 2023 https://doi.org/10.3390/rs15092277). A major result of the paper was that, when applying the right quality flags, Level 2 data would lead to better correlations with SailDrone. The task team also progressed on the task focusing on the development of science to calculate SST fronts and inter-comparison: the approach and results have been published in a paper in January 2023 (Ciani et al., 2023, https://doi.org/10.3390/rs15041163). Additionally, the lead author presented the results in the GHRSST Talk in August 2023. The research activity is devoted to the retrieval of SST gradients from the future ESA Earth Explorer 10 mission "Harmony", which (among other objectives covering land and sea-ice monitoring) will provide simultaneous observations of surface roughness and SST to support air-sea interaction studies. The work focusing on inter-comparison of feature resolution and spatial consistency of L4 products is ongoing, and is based on the use of L4 SST products for the computation of ocean surface currents. The task on the "Salinity as independent data to validate SST gradient" has also been finalized with the following results: The coastal upwelling and the California Current, leading to frontal activity, have been captured by gradients in both Sea Surface Temperature (SST) and Sea Surface Salinity (SSS). It was found that the differences between the SST and SSS gradients are mainly associated with the limitations of the microwave-derived SSS coverage near land and its reduced spatial resolution. A paper has been published on this topic (Vazquez-Cuervo et al., https://doi.org/10.3390/rs15020484). Several other tasks are still ongoing in this task team and there is potential interest to implement an additional activity on SST fronts and Ocean Colour Fronts. The work focusing on the validation of gradients in the Arctic region is also ongoing.

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/3IWRDkukk5I?si=UE9yx-qRZrXaE4g4

Evolution of the Regional/Global Task Sharing (R/G TS)

The current work is focusing on maintaining the GHRSST Data Specification Document (GDS), coordinating the implementation of GHRSST R/G TS framework and ensuring it operates correctly, but also on populating and maintaining the GHRSST Central Catalogue and providing serve data inventories through OpenSearch service, ensuring availability and access to data through HTTPS and FTP. What still needs to be done includes reviewing and publishing the datasets, removing duplicates and obsolete products, as well as adding the datasets that are still missing and completing those that are missing a dataset description in collaboration with the GDPs and DACs.

The GHRSST Central Catalogue and OpenSearch service implementation was funded by Copernicus through EUMETSAT. Several resources have been made available to the DAC and GDPs on the GHRSST website: https://www.ghrsst.org/ghrsst-data-services/for-sst-data-producers/guidelines-for-dataproducers/

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/bqhFDwb5DdM?si=IkO5n9dMG1elLtYj

Coral Heat Stress User SST Requirements (Coral)

Updates have been included in the SST User Requirements document. This includes the update to the section about the need for SST resolution, as the extreme marine heatwave in the Caribbean has highlighted the need for higher resolution satellite SST. An update to the section about diurnal resolution needs has also been implemented, including the need for mortality products that require information about day and night SST. A new section has been included to discuss the unique requirements of the marine biology science community who work in polar waters.

Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
YouTube: https://youtu.be/dtRlvRqRARw?feature=shared

Climate Data Assessment Framework (CDAF)

The CDAF is intended to be used to support users of sea surface temperature (SST) datasets to understand the suitability of GHRSST datasets for use as Climate Data Records (CDRs). The CDAF will provide authoritative, comparable information about GHRSST datasets that will allow users to make their own judgment about the use of the datasets as CDRs for their application. The task team has been in existence for several years but other pressures/projects have meant that progress has been slow to date. Progress has been made this year on the coding side. Together with MDB Task Team the CDAF team will get reference data and produce matchups in coordination with the Matchup TT (Felyx based). Initial data have been produced but not yet integrated. The next steps include the creation of statistics and an initial design for the web/form output.

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/LFf8MPye60s?feature=shared

Shipborne Radiometry (ISFRN)

The partners in this task team are involved in a UK-funded project, the ASTeRN, the Advanced Surface Temperature Radiometer Network, funded by the UK government Earth Observation Investment plan. The project is to design and manufacture radiometers with the capability to measure sea, land and ice surface temperatures with high accuracy and precision. The design is based on a recent study funded by ESA and performed by RAL and the University of Southampton. The radiometers will be calibrated to standards traceable to SI realised by NPL standards. The current UK in situ radiometer designs (ISAR, SISTeR) are now 20+ years old.

A new generation of radiometers is required to enhance and maintain the capability for the next decade, provide additional spectral channels for atmospheric characterisation, extend the capability for measuring Land Surface Temperatures, address obsolescence issues and improve manufacturability and maintainability. The new radiometer design will be an evolution of existing designs: the same basic measurement approach as existing instruments but drawing on lessons learned and incorporating modern components. Ships4SST study has already defined requirements for the next generation. More updates can be found:

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/OqTcpz-BF4c?si=B5IwF4BtCaAMnaw

Matchup Database Standards (MDB)

The goal of the MDB task team is to suggest the way forward towards common SST MDB production method and assessment metrics and protocols. The work has been focusing on the first three tasks of this task team: the screening of papers explaining MDB criteria, tools metrics in the SST analysis, and the MDB tools metrics and protocols. Little progress was achieved in 2023 due to busy schedule and procurement preparation. Work has been done on identifying matchup methods, metrics, protocols and datasets for SST MDB analysis and on the round robin validation, which has been systematically applied to different datasets (e.g. L2P/L3/L4; IR/MW; LEO/GEO vs. in situ types). The work on the round robin validation will be extended in 2024 and 2025. As for Felyx, there has been a new release of the distributed and cloud/HPC-ready multi-matchup dataset production framework. A draft version is available on https://felyx.readthedocs.io The next steps include the support for kubernetes, the testing on external cloud platforms w/ object storage hosting GHRSST datasets: WEkEO, PO.DAAC/AWS, the demonstration of the ability to produce in a consistent manner multiple GHRSST MMDBs close to data location for fair intercomparison.

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/Pb97AFGbVNs?feature=shared

Cloud Masking (CMT2)

In the past year, advancement has been achieved by Met Norway with the Sci4MaST project (funded by Copernicus), using cloud lidar and SynObs to test masks. In the Sci4MaST project the focus has been on the testing the NWC SAF PPSv2021 cloud products software and checking if the software can improve cloud marking over sea ice. The teams have also used Caliop cloud lidar data and synoptical cloud observations to validate the cloud mask products (data from 2019). The test performed were aimed at checking how classical cloud mask and cloud mask probability can be combined to improve cloud masking and quality level scheme. The results were also presented at the S3VT conference in December 2023 (link to the talk).
Additionally, the teams improved the use of thermal and reflectance imagery for SLSTR, reducing overflagging from thermal texture, with a publication of an article on "Improving the combined use of reflectance and thermal channels for ocean and coastal cloud detection for the Sea and Land Surface Temperature Radiometer (SLSTR)" (Bulgin et al., 2023, doi: https://doi.org/10.1016/j.rse.2023.113531). Reflectance imagery is used to aid daytime cloud detection in thermal remote sensing. The paper presents new approaches to utilization of reflectance for sea surface temperature (SST) remote sensing for the Sea and Land Surface Temperature Radiometer (SLSTR). The new chair of this task team, Mingkun Liu, has also applied physically based deep learning for cloud detection. Her study proposed an innovative Spectral-and-Textural-Information-Guided deep neural Network (STIGNet) on the cloud detection for the Chinese Ocean Color and Temperature Scanner (COCTS) onboard the Haiyang-1C (HY-1C) satellite. The STIGNet utilizes a combined spectral and textural information as the model input, containing a large amount of potential physical-informed features. Additionally, the STIGNet incorporates an edge learning module, designed to emphasize the identification of cloud edges, which can automatically encode the textural information into the modeling process, leading to performance improvement.

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229
- YouTube: https://youtu.be/miekNUjLPN4?si=ZmlBO_5ph7WnmDby

HRSST Drifters for Satellite SST Validation (HRSST)

The objective of the task team is to coordinate HRSST drifter activities with the drifting buoy community. The current focus is on HRSST-2 drifters (not FRM). In the past year, the work has been focused on the continued performance evaluation of HRSST2 drifters. A preliminary list of HRSST2 drifters has been defined in collaboration with the Global Drifter Programme (GDP). The task team will further work on refining the minimum metadata standard with the GDP. Two deliveries are currently available in open access: the High-resolution Sea-Surface Temperature (HRSST) drifting buoys for satellite SST Workshop Report https://www.cls-telemetry.com/trusted-hrsst-drifting-buoys-for-satellite-sst-workshop-report/ and the Report to DBCP 37 https://oceanexpert.org/document/29267

- Presentation: https://training.eumetsat.int/mod/folder/view.php?id=16229

Agencies' Reports

Representatives of the agencies participating in GHRSST have contributed by providing brief reports of their agency's activities over the last year:

In this session, special timeslots were allocated to the agencies to report to the plenary.

Report from the Australian DAC to GHRSST-XXIV

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Abstract

This is a report of progress during the period July 2022 to August 2023 in the Australian Data Assembly Centre (DAC) at the Bureau of Meteorology (Bureau), relating to the provision and validation of Group for High Resolution Sea Surface Temperature (GHRSST) products, and related SST research.

Introduction

With support from the Integrated Marine Observing System (IMOS: www.imos.org.au), the Australian Bureau of Meteorology, in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the University of Reading, produces several real-time and delayed mode (reprocessed), GHRSST GDS2.0 format products (GHRSST Science Team, 2012) for a range of operational and research applications, using locally received and overseas sea surface temperature (SST) datasets obtained from polar-orbiting and geostationary satellites (Beggs, 2021; Beggs and Govekar, 2022).

Products developed

The satellite sensors currently used to generate the Bureau's GHRSST-formatted products are AHI on Himawari-9, AVHRR on NOAA-18, MetOp-B and MetOp-C, VIIRS on Suomi-NPP and NOAA-20, and AMSR2 on GCOM-W. These are used to produce Level 2 (L2P), Level 3 Uncollated (L3U), Level 3 Collated (L3C), Level 3 Super-collated (L3S) and Level 4 (L4) products (Beggs, 2021; Beggs and Govekar, 2022). A complete list of the GHRSST-formatted satellite SST products produced by the

Bureau is at https://opus.nci.org.au/pages/viewpage.action?pageId=141492235, along with data access details. IMOS GHRSST-formatted products discoverable via the GHRSST Catalogue (https://www.ghrsst.org/ghrsst-data-services/ghrsst-catalogue) are AVHRR L2P/L3U/L3C/L3S, Multi-sensor (AVHRR + VIIRS) L3S, Himawari-8 1-hour/4-hour/1-day night L3C, Geo-Polar Multi-sensor 1-day night L3S, and daily regional and global Multi-Sensor L4 SST Analyses (RAMSSA and GAMSSA).The infra-red AVHRR radiometer level 3 SST records form a 31-year dataset, from 1992 to present, of quality-assured SST data from NOAA-9 to NOAA-19 satellites (Griffin et al., 2017). They are provided as single swath (L3U), single sensor (L3C), or multiple AVHRR sensors (L3S) SST composites over 1, 3, 6 days or 1 month on a 0.02° x 0.02° grid over two domains – Australia (70°E - 190°E, 70°S - 20°N) and the Southern Ocean (2.5°E - 202.5°E, 77.5°S - 27.5°S).

With NOAA-19 being the last of the NOAA Polar-Orbiter Series of satellites, in 2012 NASA and NOAA launched the Suomi-NPP satellite, equipped with the first VIIRS infra-red radiometer. The Bureau has used the operational NOAA ACSPO VIIRS L3U SST products to produce real-time Multi-sensor L3S products over the IMOS 0.02° x 0.02° Australian and Southern Ocean grids from 16 November 2018, and has reprocessed from 2012 to 2022, using AVHRR data from NOAA-18/19 and MetOp-A/B/C, and VIIRS data from Suomi-NPP and NOAA-20. Sensors and platforms used to produce each file are recorded in the file header. The novel method used by the Bureau to composite SST data from multiple sensors (AVHRR and VIIRS) into these widely used IMOS "Multi-sensor" L3S products is documented in Govekar et al. (2022). An example is shown in Figure 1(c). The IMOS Multi-sensor L3S SSTs exhibit significantly greater spatial coverage and improved accuracy compared with the pre-existing IMOS AVHRR-only L3S SSTs. When compared to the NOAA Geo Polar Blended level 4 analysis SST data over the Great Barrier Reef region for 2017 - 2018, 1-day night-time Multi-sensor L3S SST differs by less than 1°C on average, while exhibiting a wider range of SSTs over the region. It shows more variability and restores small-scale surface ocean features more effectively than the Geo Polar Blended level 4 analysis SST data (Govekar et al., 2022).

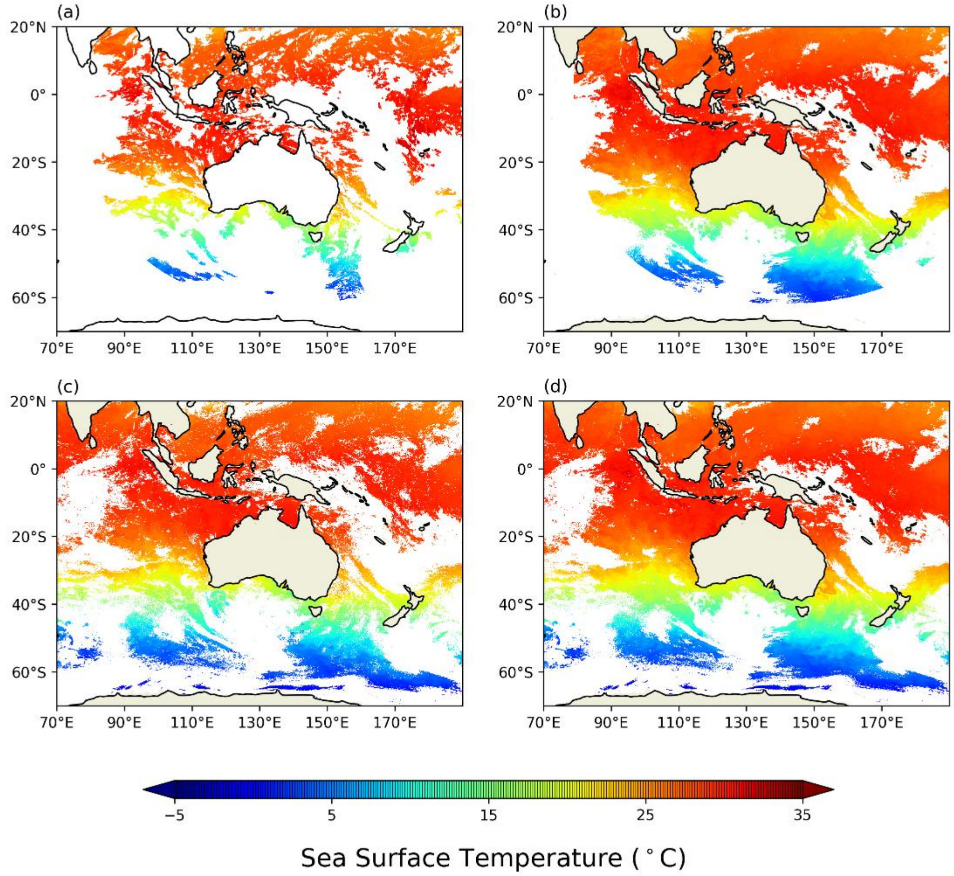

Figure 1: SST from (a) 1-hour Himawari-8 L3C, (b) 1-day night Himawari-8 L3C, (c) 1-day night Multi-sensor (AVHRR, VIIRS) L3S and (d) 1-day night Geo-Polar Multi-sensor (Himawari-8, AVHRR, VIIRS) L3S for 15th March 2020 over the Australian IMOS 0.02° x 0.02° grid (70°E - 190°E, 70°S - 20°N).

During 2022-2023, the full record of Himawari-8 AHI SST data (1st September 2015 to 12 December 2022) was reprocessed to L2P and 1-day night-time L3C (on the IMOS 0.02° x 0.02° grid), following the GHRSST GDS2 format. The L2P skin SST data were validated using IMOS Infra-red SST Autonomous Radiometer (ISAR) skin SST observations from RV Investigator cruises around the Australian coasts and Southern Ocean (Zhang et al., 2023). The product is found to be of good quality, with a mean bias ± standard deviation of -0.12 ± 0.47 K for the daytime and -0.04 ± 0.37 K for the night-time. While the night-time data is consistently more stable under most meteorological conditions and closer to in situ measurements, a cold bias can be seen for daytime retrievals under almost all environmental conditions. In 2022, to reduce data gaps due to cloud, but retain feature resolution, the Bureau composited Himawari-8 AHI 10-minute 2 km SST data with data from VIIRS (on Suomi-NPP and NOAA-20) and AVHRR (on MetOp-A/B/C) to construct new "Geo-Polar Multi-sensor L3S" products on the IMOS grid for 1st September 2015 to 12th December 2022 (Figure 1(d)). Hourly, 4-hourly, and daily Himawari-8 L3C SST products have also been produced (Figures 1(a) and (b)). All these reprocessed Himawari-8 Level 3 products are available via the Australian Ocean Data Network (AODN) at https://portal.aodn.org.au/ (search for "Himawari-8"), with the Himawari-8 L2P products available via the National Computational Infrastructure (NCI) on request from ghrsst@bom.gov.au.

Ship SST for satellite SST validation and ingestion into SST analyses

Since 2008, the IMOS Ship of Opportunity SST Sensors for Australian Vessels Sub-facility has provided near real-time, quality-controlled, SST observations at depths ranging from 0.5 - 10 m from hull temperature sensors and water intake thermistors installed on 24 vessels (currently 7 in operation). The IMOS ship SSTdepth data are used by NOAA and the Bureau for near real-time validation of satellite SST and are ingested into operational L4 SST analyses. They are valuable as they provide QC'd data in coastal regions not sampled by either drifting buoys or Argo floats. Data are available from the Global Telecommunications System (GTS) in either SHIP (FM 13) or TRACKOB (FM 62) TAC data formats, and in netCDF format from the AODN (https://portal.aodn.org.au/ - search for "ship SST"). All these data are also available via NOAA/NESDIS/STAR iQuam in netCDF "L2i" format from https://www.star.nesdis.noaa.gov/socd/sst/iquam/data.html (as platform type = 7).

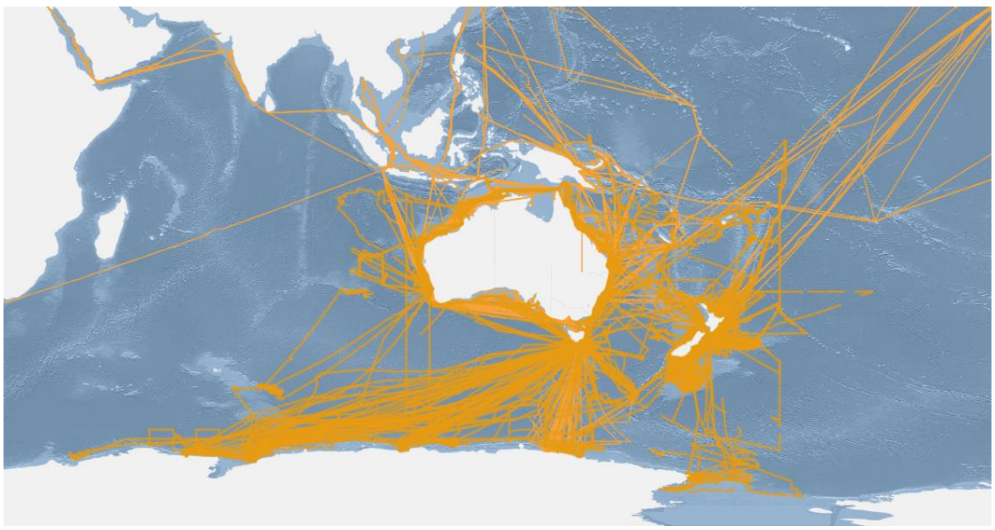

Figure 2: Locations of all IMOS ship SST data from 4th February 2008 to 5th September 2023.

Since October 2014, "skin" SST observations at ~10-micron depth have been measured by the Infrared Autonomous SST Radiometer (ISAR) on *RV Investigator*. This ISAR currently provides the only sustained in situ skin SST observations in the Australian region and measures ocean temperatures at the same depth as infrared radiometers on satellites. These ISAR skin SST observations are processed and QC'd in real-time by the SOOP SST Sensors Sub-facility and provided to the AODN Portal. The data are reprocessed by Ms Nicole Morgan (CSIRO) to the higher accuracy required for satellite SST validation, in collaboration with Dr Werenfrid Wimmer (NOCS). ISAR "L2R" netCDF format data from 2016 onwards are provided to www.ships4sst.org for satellite SST validation. Currently ISAR L2R data are available up to 28h July 2021. A new ISAR instrument (ISAR5E) was purchased from the National Oceanographic Centre Southampton in 2021, tested at the June 2022 FRM4SST Workshop by Nicole Morgan and has now been installed on *RV Investigator*. It operated intermittently on the IN2023_V03 cruise from Hobart to the Southern Ocean Flux Station (SOFS) site, from 10h to 25h May 2023.

GHRSST-formatted products used by the Agency

Table 1: GHRSST-formatted products used by the Bureau for operational and research applications.

Producer	Product	Applications
NOAA/NESDIS/OSPO	VIIRS L3U (Suomi-NPP, NOAA-20)	Generate IMOS VIIRS L3C and Multi-sensor L3S products, ingest into daily L4 SST analyses (RAMSSA, GAMSSA), and assimilate into global and regional ocean models.
NAVOCEANO	GAC AVHRR L2P (MetOp-B, MetOp-C)	Ingest into daily and weekly L4 SST analyses (RAMSSA, GAMSSA, Weekly OI, and Monthly OI), assimilate into global and regional ocean models. Weekly and Monthly OI SST analyses are used to calculate climate drivers (e.g., NINO/IOD indices).
JAXA	AMSR2 (GCOM-W1)	Ingest into daily L4 SST analyses (RAMSSA, GAMSSA), assimilate into global and regional ocean models.
Ifremer	FRAC AVHRR L2P (MetOp-B, MetOp-C)	Generate IMOS AVHRR L3U, L3C and Multi-sensor L3S products
UKMO	OSTIA L4	Sea ice fraction is used in reprocessed fv02 IMOS satellite SST products, and in test SST analyses and test ACCESS-G4/GE4 NWP models. Sea ice fraction will be used in all future Bureau operational products and systems.
Bureau	RAMSSA L4 and GAMSSA L4	Boundary condition for all Bureau operational NWP models and to initialise seasonal prediction model (ACCESS-S2), weather forecasting, MetEye, SST anomaly maps.
Bureau	IMOS fv01 Multi-sensor L3S	ReefTemp Next Generation coral bleaching risk tool for Great Barrier Reef, trial Marine Heatwave metrics
Bureau	IMOS HRPT AVHRR L3C (NOAA-18)	IMOS HRPT AVHRR L3S, IMOS Multi-sensor L3S products

Bureau	IMOS fv02 Himawari-8 1-hour L3C	Trials for assimilation into regional ocean model

Future plans

By June 2024, in collaboration with University of Reading, the Bureau aims to release real-time Himawari-9 L2P and 1-hour, 4-hour, 1-day night L3C Himawari-9 SST products, along with 1-day night Geo-Polar Multi-sensor L3S incorporating Himawari-9, VIIRS and AVHRR data.

We also aim to ingest Ifremer's FRAC AVHRR L2P from MetOp-C into our operational real-time IMOS Multi-sensor L3S and Geo-Polar Multi-sensor L3S products. NAVOCEANO's GAC AVHRR L2P from MetOp-C was ingested into the Bureau's Global Weekly and Monthly 1° L4 SST analyses from 9th August 2023, and is being tested for ingestion into the Bureau's daily global 1/4° L4 analysis (GAMSSA) and daily regional 1/12° L4 analysis (RAMSSA).

The NCEP daily 1/12° Sea Ice Analysis product is currently used for ice masking in the Bureau's GHRSST processing system. We are in the process of replacing the NCEP sea ice analyses with OSTIA sea ice analyses (Good et al., 2020) for all our operational IMOS SST products, including L4. OSTIA ice is being ingested into the Bureau's test global NWP models (ACCESS-G4/GE4) and test RAMSSA and GAMSSA L4 analyses. These are expected to become operational in the coming year.

Over the coming year the IMOS 1-day Multi-sensor L3S SST product will be used with the SSTAARS daily SST climatology (Wijffels et al., 2018) to produce experimental marine heatwave monitoring metrics in netCDF format over the Australian IMOS domain (70°E to 190°E, 70°S to 20°N), such as SST anomaly, Degree Heating Days, Daily Marine Heatwave Category and SST Percentiles. If the trial is successful, then these products will be routinely supplied to IMOS OceanCurrent (https://oceancurrent.aodn.org.au) for display and to AODN.

By the end of 2023, the Bureau will upload real-time SSTdepth and meteorological data from Australia's new icebreaker, *RSV Nuyina*, to the GTS, AODN and iQUAM. In early 2024, work will commence to transform all IMOS ship SSTdepth data streams to BUFR SHIP format (required by WMO) for upload to the GTS. In 2024 we also aim to provide real-time SSTdepth and meteorological data from a cargo vessel making repeat transects across Bass Strait from Melbourne, Victoria, to Burnie, Tasmania (*MV Tasmanian Achiever II*).

Conclusions

The Bureau of Meteorology will continue to support the production and validation of GHRSST-formatted L2P, L3U, L3C, L3S and L4 data products under a new IMOS agreement for the period from July 2023 to June 2027. GHRSST-formatted SST products are widely used at the Bureau of Meteorology for operational weather, ocean and seasonal prediction systems and coral bleaching nowcasting.

Acknowledgment

Data were sourced from Australia's Integrated Marine Observing System (IMOS) – IMOS is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent.

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Report from China Meteorological Administration

Agency: China Meteorological Administration

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Abstract

LEO FY-3E/MERSI L2P and L3C SST were released in June 2022. GEO FY-4B/AGRI SST L2P and L3C SST were released in July 2022. MWRI and MERSI SST of Rainfall Mission satellite FY-3G are in post-launch test phase. LEO FY-3F/MERSI and MWRI SST are undergoing in-orbit algorithm test phase. Reprocessing of FY-3/VIRR SST and FY-3B/C/D MWRI SST are underway. Experimental L4 FY_OISST is developed.

Introduction

LEO FY-3E, the first FengYun(FY) operational meteorological satellite in an early morning orbit, was launched on 5 July 2021. FY-3E/MERSI L2P and L3C SST were released in June 2022. Destriping of FY-3E/MERSI L1 split-window band has been employed since 8 March 2022. GEO FY-4B, the second satellite of FY-4 series, was designed to be the first operational satellite of FY-4 series and launched on 3 June 2021. L2P and L3C SST of FY-4B/AGRI were released in July 2022. FY-3G, the first FY precipitation measurement satellite was launched on April 16 2023. FY-3G MWRI and MERSI SST are in post-launch test phase. The midmorning FY-3F was launched on 3 August 2023, FY-3F/MERSI and MWRI SST are undergoing in-orbit algorithm test phase.

Products developed

FY-3E/MERSI L2P and L3C SST were released in June 2022.
FY-4B/AGRI SST L2P and L3C SST were released in July 2022.
FY-3G MWRI and MERSI SST are in post-launch test phase.

Reprocessing of FY-3B/C/D MWRI SST V1.0 is underway.
Reprocessing of FY-3A/B/C VIRR SST V1.0 is released and reprocessing of FY-3A/B/C VIRR SST V1.1 is underway.
Base on FY-3A/B/C VIRR Reprocessing SST and iQUAM V2.1, experimental L4 FY_OISST is developed.

GHRSST-formatted products used by the Agency

IQUAMV2.1 in situ data is used for Cal/Val of FY satellite SST and experimental L4 FY_OISST.
L4 OSTIA, OISST and CMC are often used for quality comparison of FY satellite SST. OSTIA is also used for first guess SST.
OSI SAF and AHI8/9 SST are occasionally used for quality comparison of FY satellite SST.

Future plans

After completing a successful on-orbit checkout and passing through the on-line review, FY-3G MWRI and MERSI SST, will be transitioned to operations.
After FY-3F satellite pass through in-orbit test, FY-3F/MERSI and MWRI SST will be transitioned to post-launch test phase. FY-3F MERSI and MWRI SST will be blended to produce FY-3F L3S SST.

Conclusions

Since last GHRSST meeting, the main activities include: FY-3E/MERSI and FY-4B/AGRI SST passed through the on-line review and transitioned to operations. Its products ware released. FY-3A/B/C VIRR Reprocessing SST and FY-3B/C/D MWRI Reprocessing SST are underway. Experimental L4 FY_OISST is developed. FY-3G MWRI and MERSI SST continue post-launch testing to prepare for operational.

The EUMETSAT Satellite Application Facility on Ocean and Sea Ice (OSI SAF)

Agency: EUMETSAT OSI-SAF

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Introduction

The EUMETSAT Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data. They form an integral part of the distributed EUMETSAT Application Ground Segment. The Ocean and Sea Ice SAF has the responsibility of developing, validating and distributing in near real time products of Sea Surface Temperature (SST), Ice Surface Temperature (IST), radiative fluxes, wind and Sea Ice parameters for a variety of platforms/sensors.
The OSI SAF consortium includes Meteo-France, as leading institute, and the following co-operating institutes: MET Norway (Norway), DMI (Denmark), Ifremer (France), KNMI (Netherlands).
The current SST and IST OSI SAF production is presented hereafter.

Products developed

OSI SAF provides users with a large panel of operational SST and IST products mostly derived from European and American meteorological satellites. All products distributed by the OSI SAF are compliant with the GHRSST Data Specifications (v2.0). The OSI SAF products are in the GHRSST catalogue, with the DOI provided by EUMETSAT for each product. Any redistribution of the products shall use these DOIs, without the mention of any other DOI.

Low Earth orbiting satellites production

Currently OSI SAF is processing data from the Advanced Very High Resolution Radiometer (AVHRR) on-board Metop-B and from the Visible Infrared Imaging Radiometer Suite (VIIRS) on-board Suomi-NPP. OSI SAF also distributes IASI SST products developed by EUMETSAT.
Sea and Sea Ice Surface Temperature products are listed in the table below.

Name	Id	Satellite	Level	Spatial coverage	Sampling
Global Metop Sea Surface Temperature	OSI-201-b	Metop-B/AVHRR	L3C	Global	0.05°
North Atlantic Regional Sea Surface Temperature	OSI-202-c	Metop-B/AVHRR and NOAA-20/VIIRS	L3C	North Atlantic	2km

Northern High Latitude L3 Sea and Sea Ice Surface Temperature	OSI-203-a	Metop-B/AVHRR	L3C	Poleward of 50N	5km
Northern High Latitude L3 Sea and Sea Ice Surface Temperature	OSI-203-b	NPP/VIIRS	L3C	Poleward of 50N	5km
Full resolution Metop Sea Surface Temperature metagranules	OSI-204-b	Metop-B/AVHRR	L2P	Global	1km
Full resolution Metop Sea Surface Temperature metagranules	OSI-204-c	Metop-C/AVHRR	L2P	Global	1km
High Latitude L2 Sea and Sea Ice Surface Temperature	OSI-205-a	Metop-B/AVHRR	L2	Poleward of 50N and 50S	1km
High Latitude L2 Sea and Sea Ice Surface Temperature	OSI-205-b	NPP/VIIRS	L2	Poleward of 50N and 50S	1km

Geostationary satellites production

OSI SAF is currently processing data from three geostationary satellites: GOES-16 which is in East position (75W), Meteosat-10 (MSG3) in 0E position and Meteosat-9 (MSG2) over Indian Ocean in 41.5E. Note that the Indian Ocean products is currently produced on best effort basis (this means that production may stop if the server is down – no backup).

Products are all Level-3 hourly composites mapped onto regular lat/lon 0.05° grids.

OSI SAF is also distributing a SST data record from the Meteosat-8 and 9 satellites which covers the time period between 2004 and 2012.

Meteosat Sea Surface Temperature	OSI-206-a	Meteosat-10/SEVIRI	L3C	East Atlantic, West Indian: 60N-60S 60W-60E	0.05°
GOES-East Sea Surface Temperature	OSI-207-b	GOES-16/ABI	L3C	West Atlantic East Pacific: 60N-60S 135W-15W	0.05°
Infrared Atmospheric Sounding Interferometer Sea Surface Temperature	OSI-208-b	METOP-B/IASI	L2P	Global	12 to 40 km
MSG/SEVIRI Sea Surface Temperature data record (2004-2012)	OSI-250	MSG / SEVIRI (Meteosat-8, Meteosat-9)	L3C	East Atlantic, West Indian: 60N-60S 60W-60E	0.05° Lat-Lon

Future plans

MTG-I1 satellite has been launched at the end of 2022 and will become operational in the next months. OSI SAF has been preparing in order to deliver day-1 SST products to users. The SST retrieval for FCI is identical to the one used for MSG and the characteristics (domain, resolutions...) of final products are identical as well. The products will be compliant with the GHRSST Data Specifications v2.1.

OSI SAF is currently preparing the creation of Climate Data Record of the complete archive of MSG (2004-2024). This CDR will be based on the Level 1.5 MSG archive and the Cloud Mask CDR CLASS 3 produced by the Climate Monitoring SAF. OSI SAF will use a classical non-linear SST algorithm and an algorithm correction based on radiative transfer simulation and ERA-5 atmospheric profiles.
As part of the joint effort between EUMETSAT SST team and OSI SAF, work is ongoing to harmonize all SST production distributed by OSI SAF and EUMETSAT. One of the actions that will be carried out is to implement a model to be able to provide skin SST as well as depth SST.
The OSISAF is preparing for the third edition of the combined SST and IST Climate Data Record, AASTI v3, following the procedures that are operational in OSI-205-a. The combined SST and IST CDR (AASTI v3) will cover the period 1979-2023.

Naval Oceanographic Office Sea Surface Temperature Processing and Products

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Abstract

The Naval Oceanographic Office (NAVOCEANO) Ocean Measurements Division is responsible for providing near-real-time sea surface temperature (SST) measurements to the US Navy and national/international partners. The US Naval Research Laboratory (NRL) provides the research and development of the SST processing for numerous satellite data sets that NAVOCEANO operationally produce. This SST data assimilates into the Navy's Global Ocean Forecast System (GOFS) and Global Environmental Model (NAVGEM) and soon in the Navy Global Earth System Prediction Capability (ESPC). NAVOCEANO is a member of the Group for High Resolution SST (GHRSST), operationally providing and acquiring GHRSST datasets.

Introduction

NAVOCEANO operationally processes satellite-derived SSTs, which are ingested into GOFS and NAVGEM to provide forecasts at both the global and regional scale. Our customers include Fleet Numerical Meteorology and Oceanography Center (FNMOC), Naval Research Lab (NRL), National Centers for Environmental Prediction (NCEP), National Centers for Environmental Information (NCEI), Jet Propulsion Lab (JPL) Physical Oceanography Distributed Active Archive Center (PO-DAAC), NOAA Earth System Research Laboratories (ESRL), Bureau of Meteorology AU (BOM), Global Ocean Data Assimilation Experiment (GODAE), Ocean Imaging, Associated Scientists at Woods Hole, and Environment Canada.

Products developed

The following satellites/sensors are used in NAVOCEANO processing: MetOp-B & MetOp-C GAC/FRAC AVHRR, Sentinel 3A & 3B SLSTR, EWS-G1/GOES-13 Imager, SNPP & NOAA-20 VIIRS, GCOM-W1 AMSR2 SST, Meteosat-9/MSG-2 & Meteosat-10/MSG-3 SEVIRI, Himawari-9 AHI, GOES-16 & GOES-18 ABI. Depending on the customer, products are delivered in text files and a variety of binary files such as, def, ocnqc, smdb, tmp, and netCDF.

GHRSST-formatted products used by the Agency

As a Regional Data Assembly Center (RDAC) for GHRSST, NAVOCEANO provides an L4 GDS2.0 global K10 product, as well as the following products: L2P GDS2.0 - MetOp-B/C AVHRR GAC global 4km, S-NPP VIIRS global 750m, EWS-G1/GOES-13 Imager IO 8km. We acquire the following GHRSST for processing: GCOM-W1 AMSR2_NRT L2P (via JAXA ftp), Sentinel-3A SLSTR L2P (via STAR), Sentinel-3B SLSTR L2P (via STAR), MSG2 SEVIRI L3C (OSISAF), MSG3 SEVIRI L3C (OSISAF)

Future plans

Future satellites/sensors that will be ingested are: NOAA-21 VIIRS, MetOp-SG-A1 & B1 FRAC, Sentinel 3C, 3D SLSTR, GOSAT-GW AMSR3 SST, WSF-M1 & WSF-M2 SST, EWS-P1 & EWS-P2 SST, MTG-I-1 & MTG-I-2 SST, GOES U SST, JPSS-3 SST, GeoXO SST, CIMR

Conclusions

NAVOCEANO looks forward to continuing the collaborative work with NRL and GHRSST, and all our data providers and partners, in the future.

Report from Japan Aerospace Exploration Agency RDAC & Agency Reports

Agency: Japan Aerospace Exploration Agency (JAXA)

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Abstract

Updates of RDAC in JAXA and highlights of SST-related missions since the last year's GHRSST meeting are introduced.

Introduction

JAXA produces both IR and microwave SST products in GDS 2.0 format. JAXA's GHRSST-formatted products are available from JAXA Himawari Monitor (https://www.eorc.jaxa.jp/ptree/) for Himawari-8/AHI SST, and JAXA GHRSST server (https://suzaku.eorc.jaxa.jp/GHRSST/) for other SSTs (AMSR2, GMI, SGLI, and old microwave imagers).

Products developed

Table 1 is a list of JAXA developed GHRSST-formatted products (GDS2.0 format).
Followings are updates and highlights of GHRSST-formatted products from the last year's meeting.

(1) GCOM-C/SGLI (IR): Nominal mission phase was completed in Dec. 2022 and GCOM-C continues its observation as extended-mission phase. SGLI SST Ver.3 is continued distribution.
(2) Himawari-8/AHI (IR): Switch-over from Himawari-8 to Himawari-9 was conducted on 13 Dec. 2022. Himawari-9 SST Ver.2.1 is available since end of Sep. 2022, with 3-month overlap with Himawari-8. Since calibration table used in current Ver.2.1 was produced only from autumn data, we will re-create it using data in all seasons. Recalibration of SST using whole period from Himawari-8 to Himawari-9 including correction of decreasing trends found in Himawari-8 SST is also planned.
(3) GCOM-W/AMSR2 (MW): AMSR2 SST (6G, 10G, multi-band) Ver.4.1 was released in Jul. 2022 to correct decreasing trends in the Northern Hemisphere. SSTs in windy/weak-rainy pixels are retrieved with low-accuracy flag.

Table 1: List of JAXA GHRSST datasets

Satellite/ Sensor	Processing Type	Product	Archive Period	Latency	Version	URL
Aqua/ AMSR-E	Standard	L2P	from June 2002 to Oc. 2011	N/A	Ver.8	JAXA GHRSST server https://suzaku.eorc.jaxa.jp/GHRSST/
		L3C				
GCOM-W/ AMSR2	Near RealTime	L2P	latest 7 days (10GHz SST is available from V3.0.)	4 hours	Ver.4.1 (updated in Jul. 2022)	
		L3C				
	Standard	L2P	from 3 July 2012 to present (10GHz SST is available from V3.0.)	1 day		
		L3C				
GPM /GMI	Near RealTime	L2P	latest 7 days	4 hours	Ver.5 (updated in May 2022)	
		L3C				
	Standard	L2P	from 4 Mar. 2014 to present	1 day		
		L3C				
Coriolis/ WindSat	Near RealTime	L2P	from 3 Aug. 2011 to 19 Oct. 2020	N/A	Ver.8	
		L3C				
GCOM-C/ SGLI	Near RealTime	L2P	1km: from 1 Jan. 2020 to present 250m: latest 7 days	1 day	Ver.3000 (updated in Nov. 2021)	
Himawari-8/ Himawari-9/ AHI	Near Realtime	L2P	latest 4 days	25 minutes	Ver.2.1 (updated in Dec. 2022)	JAXA Himawari Monitor https://www.eorc.jaxa.jp/ptree/
		L3C				
	Standard	L2P	from 7 Jul. 2015 to 13 Dec. 2022 (H08) from 3 Oct. 2022 to present (H09)	4 days		
		L3C				

GHRSST-formatted products used by the Agency

None.

Future plans

Response to R/G TS requirements is currently investigated within JAXA. Due to hardware replacement of web/ftp system scheduled in JFY2023, and actual implementation will be conducted in the next fiscal year.

JAXA is currently developing AMSR3 on board the GOSAT-GW satellite to be launched in JFY2024 (Apr. 2024 - Mar. 2025). GOSAT-GW satellite system Critical Design Review (CDR) was completed in Oct. 2023. Currently, spacecraft integration has been started and AMSR3 flight components are manufacturing and testing. Near-real-time data distribution of AMSR3 will be available (regional data at direct receiving stations & global data with latency of 2-3 hours). AMSR3 product will be released to the public about one year after the launch. Early data access will be available to the selected PIs by the research announcement (EORA) and partner agencies during CAL/VAL phase. JAXA's next research announcement (EORA4, JFY2025-2027) for JAXA's EO missions including AMSR3 & GCOM-W will be issued in the summer of 2024.

NPP/VIIRS SST over Japan area is produced by applying same algorithm to Himawari and SGLI and distributed through JASMES Climate Monitor (https://www.eorc.jaxa.jp/JASMES/JASMES_monitor/index.html?area=j) but not in GDS2.0 format. We plan to switch our processing system from NPP to JPSS-1 in near future.

Conclusions

JAXA continues to contribute to the GHRSST by developing and operating SST-related missions, providing the GHRSST-formatted SST products to the community in near-real-time basis, and improving accessibility to our datasets.

Recent developments in sea surface temperature analysis by the Japan Meteorological Agency

Agency:

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Abstract

JMA operates two high-resolution analysis, MGDSST and HIMSST, based on satellite remote sensing data and in-situ observation data to provide real-time information on sea surface temperature. MGDSST covers the global area with a horizontal resolution of 0.25°, and HIMSST covers the western North Pacific with a higher resolution of 0.1°. In the past year, we have improved the time response of MGDSST and switched satellites used for analysis from NOAA-19/AVHRR to NOAA-20/VIIRS and from HIMAWARI-8 to HIMAWARI-9. JMA plans to continue developing SST analysis.

Introduction

Japan Meteorological Agency (JMA) operates two high-resolution analyses to provide real-time information on sea surface temperature. One is MGDSST (Merged satellite and in-situ data Global Daily Sea Surface Temperature) and the other is HIMSST (High-resolution Merged satellite and in-situ data Sea Surface Temperature). The former covers the global area with a horizontal resolution of 0.25°, and the latter covers the western North Pacific with a higher resolution of 0.1°. There is also a difference in the use of satellite data, as the former does not use HIMAWARI, while the latter uses it. Partly due to this difference, it has been pointed out that there is a time lag in the MGDSST analysis when SST changes rapidly, such as when a typhoon passes. Therefore, in 2023, we newly introduced the 10-27 day period scale component of GCOM-W/AMSR2 data to the MGDSST analysis. In addition, some of satellites used for analysis were changed for both MGDSST and HIMSST. This report briefly introduces SST analysis provided by JMA, including these developments.

Products developed

1. MGDSST

For MGDSST, we use SST data obtained from satellite infrared sensors (Suomi-NPP/VIIRS, NOAA-20/VIIRS) and microwave sensors (GCOM-W/AMSR2) together with in-situ SST observations. For combining data, we have developed an operational method based on decomposition into several spatio-temporal components and optimum interpolation, as follows. First, SST anomalies (SSTA) from daily SST climatologies are calculated for each satellite. The SSTA data are decomposed into large/middle/small scales with cutoff wavelengths of 580, 143 and 55 km, respectively, and long/middle/short-time scales with cutoff periods of 53, 27 and 10 days, respectively. Here, only the AMSR2 data is used for the short-time scale. Thus, signals varying with a period shorter than 27 days and 10 days are cut off for VIIRS and AMSR2, respectively, due to the significant data noise they contain. The large and long-time scale component is calibrated with in-situ SST data for each satellite. Then, by using space-time optimum interpolation, we combine the satellite data to an interpolated component for each spatio-temporal scale. Finally, all the components and the climatology are summed to create the daily SST product.

We had not used the 10-27 days period band of AMSR2 data, but we started using it from late March in 2023 to improve the time response of the real-time MGDSST analysis. In a verification experiment, we confirmed that the new MGDSST could track the SST drop during the passage of Typhoon Bavi in 2020 better than before. (Details of the results are omitted.) Satellite data has also been switched from NOAA-19/AVHRR to NOAA-20/VIIRS, improving the data acquisition rate.

2. HIMSST

The HIMSST analysis framework is based on that of MGDSST. In addition to the satellite data used in MGDSST, JMA Himawari-9 L3 SSTs produced with a 0.02° horizontal resolution and 10-minute intervals are incorporated. HIMSST uses the Himawari-9 L3 SSTs instead of AMSR2 for the short-time scale component of 10-27 days. In addition, the cutoff wavelength of the small scale component is shortened from MGDSST's 55 km to 22 km. As a result, the HIMSST product contains finer scale structures than MGDSST.

In 2023, satellite data used for analysis has been switched from NOAA-19/AVHRR to NOAA-20/VIIRS and from HIMAWARI-8 to HIMAWARI-9.

GHRSST-formatted products used by the Agency

GHRSST Level 3U NOAA STAR SST v2.80 from VIIRS on S-NPP Satellite
GHRSST Level 3U NOAA STAR SST v2.80 from VIIRS on NOAA-20 Satellite

Future plans

Development of global SST analysis with resolution of 0.1°.

Conclusions

JMA operates two high-resolution MGDSST and HIMSST analysis based on satellite remote sensing data and in-situ observation data to provide real-time information on sea surface temperature. In the past year, we have improved the time response of MGDSST and switched satellites used for analysis from NOAA-19/AVHRR to NOAA-20/VIIRS and from HIMAWARI-8 to HIMAWARI-9. JMA plans to continue developing SST analysis. The analysis data are available from the NEAR-GOOS Regional Real Time Database (https://www.data.jma.go.jp/goos/data/database.html).

Met Office Updates and Development

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Abstract

This document presents information about GHRSST format products produced at the Met Office and the GHRSST format products used at the Met Office. GHRSST related development is introduced, as well as a brief introduction to the UK based data service, UK Marine Climate Advisory Service (UKMCAS), which is on track to be made available for users in late 2023 or early 2024.

Introduction

The Met Office produces a series of ocean analyses and reanalyses operationally, many of which follow the data standard and specification set by GHRSST. The Ocean Sea surface Temperature and Ice Analysis (OSTIA) system provides operational foundation and diurnal SST products and there are also monthly and seasonal products based on the same configuration. The GHRSST Multi-Products Ensemble (GMPE) product provides an ensemble of L4 SST products, please see the section below for a list of the participating L4 products. Monthly validation results against Argo floats are available for the ensemble median and L4 products. Main developments in the past year are the extension of the reprocessed SST products as well as the progress on the new UK based data dissemination portal for continuous availability of OSTIA and other UK based marine products outside the Copernicus Marine Service.

Products developed

- OSTIA near real time foundation SST products
  - Daily, global L4 operational product on 0.05 degree grid resolution. Daily bias and anomaly files available on 0.25 degree grid resolution
  - Monthly and seasonal, global L4 operational product on 0.25 degree grid resolution
- OSTIA near real time diurnal SST
  - Daily, global L4 operational product on 0.25 degree grid resolution.
- GMPE near real time product
  - Daily, L4 product on 0.25 degree grid resolution
- Reprocessed SST product (funded by CMEMS with an extension from UKMCAS)

    - Daily from 24 August 1981 to 31 December 2022
    - Foundation SST at 0.05 degree grid resolution
- Reprocessed SST product (ESA CCI / C3S)
    - Current version is 2.1 but version 3.0 has been produced and will eventually replace this
    - Daily, 20 cm depth daily average at 0.05 degree grid resolution

OSTIA foundation SST near real time and reprocessed data are available from the Copernicus Marine Service (https://marine.copernicus.eu) and PODAAC (https://podaac.jpl.nasa.gov/). Daily monitoring fields can be found on the OSTIA webpage (https://ghrsst-pp.metoffice.gov.uk/ostia-website/index.html). The current version of the ESA CCI data set is available from ESA (https://climate.esa.int/en/odp/#/dashboard) and with a temporal extension from C3S (https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-sea-surface-temperature?tab=overview).

GHRSST-formatted products used by the Agency

OSTIA systems assimilate L2 and L3 satellite SST products in GHRSST format. Table 1 lists the products used in the foundation and diurnal systems, including the filenames on the dissemination portal. Currently, SSTs from only one geostationary mission and one microwave satellite are included in OSTIA.

Table 1. L2 and L3 satellite SST products are assimilated into OSTIA foundation and diurnal SST products.

Sensor	Product	Dissemination Portal	Usage in OSTIA systems	Notes
MetOp-B	METOP-B MGR SST, OSI-204-b	EUMETCast	Foundation	
MetOp-C	METOP-C MGR SST, OSI-204-c	Ifremer FTP	Foundation	
SEVIRI_OSISAF	OSIHSSTN, OSI-206-a, MET SST	EUMETCast	Foundation and diurnal	Geostationary satellite
S-NPP VIIRS	VIIRSSST	EUMETCast	Foundation and diurnal	Produced by NOAA and are also available on PODAAC
NOAA-20 VIIRS	VIIRSSST	EUMETCast	Foundation and diurnal	
Sentinel-3A and -3B	SL_2_WST_NRT	EUMETCast	Foundation	
AMSR2_REMSS	AMSR2-REMSS-L2P_RT-v8.2	Earthdata (PODAAC)	Foundation	Microwave sensor

GMPE uses a series of L4 SST products in GHRSST format to produce the ensemble. Table 2 shows the current participating products in addition to the OSTIA foundation product, as well as the resolution and the agencies responsible for providing them.

Table 2. A list of the participating L4 products in GHRSST format in GMPE

L4 product	Agency	Spatial resolution
CMC0.1deg-CMC-L4-GLOB-v3.0	Environment Canada	0.1 degree
DMI_OI-DMI-L4-GLOB-v1.0	Danish Meteorological Institute	0.05 degree
seatmp_sfc_anafld	Fleet Numerical Meteorology and Oceanography Centre	9 km
GAMSSA_28km-ABOM-L4-GLOB-v01	Australian Bureau of Meteorology	0.25 degree
mgd_sst_glb	Japan Meteorological Agency	0.25 degree
MUR-JPL-L4-GLOB-v04.1	Jet Propulsion Laboratory	0.01 degree
K10_SST-NAVO-L4-GLOB-v01	Naval Oceanographic Office	0.1 degree
Geo_Polar_Blended_Night-OSPO-L4-GLOB-v1.0	Office of Satellite Products and Operations, NOAA	0.05 degree
mw.fusion	Remote Sensing System	25 km
mw_ir.fusion		9 km

Future plans

A UK based data dissemination portal, the UK Marine Climate Advisory Service (UKMCAS), is under development and making steady progress.
The service will be made available via ftp and internal testing is expected to start around early September, with the hope to make the service available to wider users by mid- to late October.
The OSTIA foundation SST operational product is amongst the first group of products to be made available via UKMCAS.
Please contact chongyuan.mao@metoffice.gov.uk for more information on UKMCAS.

Conclusions

GHRSST format products produced and used at the Met Office are listed in the documents. Main developments in the past year includes the extension of the reprocessed SST products and the UK based marine data service. A first point of contact is provided as the service is still under development and aims to start user testing in late 2023.

ACSPO SST Products at NOAA: Update for GHRSST24

NOAA STAR

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Abstract

The NOAA Advanced Clear Sky Processor for Ocean (ACSPO) efforts in 2022-23 focused on: Cal/Val of existing products; Release of interim ACSPO v2.90 (for improved geostationary, GEO, SST); Release of SST products from 3 new platforms, NOAA-21, GOES-18, and Himawari-9; Full-mission re-analyses of VIIRS, AVHRR GAC/FRAC, and MODIS SSTs; Adding new daily gridded super-collated product from low Earth Orbiting (LEO) satellites, L3S-LEO-DY, to the previously released L3S-LEO-AM/PM line, and adding MODIS and N21 to L3S-LEO.

Introduction

ACSPO is the NOAA enterprise SST system, which processes L1 data of various LEO and GEO satellites using maximally consistent clear-sky mask, SST retrieval and SSES algorithms (Petrenko et al, 2010; 2014; 2016).

A consistent line of L2P/L3U products (144 10-min granules per 24hr) is generated from individual LEO satellites/sensors, including N07/N09/N11/N12/N14/N15/N16/N17/N18/N19 AVHRR GAC, Metop-A/B/C AVHRR FRAC, Terra/Aqua MODIS, and NPP/N20/N21 VIIRS. The individual-satellite gridded uncollated L3Us are further aggregated into gridded collated L3C (2 files, day and night, per 24hr). L3U data from multiple LEO satellites flying in close orbits (mid-morning Metop, and afternoon JPSS) are also aggregated into two super-collated products, L3S-LEO-AM/PM, each reported twice daily, one for day and one for night.

A consistent line of L2P/L3C products (24 1hr Full Disk granules per 24hr) is also generated from geostationary (GEO) satellites and sensors, including G16/G17/G18 ABI and H08/H09 AHI. Work on aggregating regional FD L3C GEO data into gridded super-collated GEO products, L3S-GEO, is underway.

ACSPO products are available to users via NOAA Coast Watch, PDA, and NCEI, NASA PO.DAAC, and EUMETSAT EumetCast archival and data distribution venues. ACSPO SSTs are widely used at NOAA, nationally and internationally, for a wide range of oceanographic, meteorological, and climate applications. This abstract summarizes major recent advances with the ACSPO products.

Products Developed

In 2022, the current NOAA LEO (JPSS) and GEO (GOES-R) fleets have added two new satellites: G18 (launched 1 Mar 2022; operational 3 Jan 2023) and N21 (launched 10 Nov 2022; approved for public release 24 Aug 2023). On 14 Dec 2022, the JMA discontinued H08 (launched 7 Oct 2014; operational 4 Jul 2015) and transitioned to H09 (launched 2 Nov 2016; operational 14 Dec 2022). G18 and H09 data products are currently processed at NOAA with the ACSPO system and distributed to the public.

The new G18 and H09 are processed with the newly released ACSPO v2.90, which replaced the prior v2.70 used for processing G16/G17/H08. The v2.90 improves clear-sky mask, SST and SSES algorithms, and adds SST fronts. The v2.90 improvements are currently being documented.

LEO products (including the newly launched N21) continue being processed with v2.80. Upon extensive testing with GEO data, the v2.90 improvements will be propagated into the ACSPO v3.00 LEO processing.

In 2021-23, NOAA completed four full-mission reprocessings of individual LEO sensors: Metop AVHRR FRAC (Pryamitsyn et al., 2021), NOAA AVHRR GAC (Petrenko et al, 2022), JPSS VIIRS (Jonasson et al., 2022), and Terra/Aqua MODIS (Jonasson et al., 2023).

The previously developed and released L3S-LEO-AM/PM products have been also fully reprocessed for the duration of the Metop-FG and JPSS missions in 2022. Following multiple users' requests, the new daily L3S-LEO-DY product was developed. It aggregates 4 L3S-LEO-AM/PM Day/Night files into one daily file, which does not resolve the diurnal cycle at 4 data point (~9:30 am/pm, and 1:30 am/pm) but significantly improves ocean coverage. Terra and Aqua MODIS SSTs have been added to the L3S-LEO.

GHRSST-formatted products at NOAA CoastWatch (CW), PDA, NCEI and NASA PO.DAAC

ACSPO SST products are available through various distribution venues and mechanisms.

The JPSS VIIRS RAN3 (including newly launched N21) and AVHRR FRAC RAN1 data are fully archived at NASA PO.DAAC, and somewhat less complete holdings are also available at NOAA NCEI. Two-week rotated buffers, along with links to the NCEI and full PO.DAAC holdings, are available at CW

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-viirs.html

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-avhrr-frac.html

The AVHRR GAC RAN2 and MODIS RAN1 L3C data are currently available at CW:

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-avhrr-gac.html

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-modis.html

Archival of full L2P/L3U/L3C time series will also be discussed with PO.DAAC and NCEI.

The L3S-LEO-AM/PM RAN1 data have been archived at NASA PO.DAAC and NCEI. For data access, see:

https://coastwatch.noaa.gov/cwn/products/acspo-global-002o-gridded-super-collated-sst-and-thermal-fronts-low-earth-orbiting.html

The L3S-LEO RAN2 (produced with ACSPO v2.81, which includes MODIS RAN1 and N21 VIIRS, and adds the L3S-LEO-DY daily product) is now available at CW, and will be updated in PO.DAAC and NCEI holdings.

Including Terra L3U SST into L3S-LEO-AM was considered but not implemented, due to different Terra and Metop overpass times (10:30 am/pm vs 9:30 am/pm). We didn't find an easy way to reconcile those. Aqua SST is included in the L3S-LEO-PM, and both Terra and Aqua are included into the L3S-LEO-DY product.

SST products from the newly added GEO satellite (G18/West and H09) are archived in PO.DAAC and NCEI, along with G16/East and now discontinued G17/West. The access points are found in the CW:

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-abi.html

https://coastwatch.noaa.gov/cwn/products/acspo-global-sst-ahi.html

We closely work together with the GHRSST Data Management Team led by Jean-François Piollé, to ensure access to all ACSPO products via the community consensus GHRSST Catalogue.

Additionally, ACSPO near-real products are available via the NOAA OSPO Product Distribution and Access (PDA) and EUMETSAT EumetCast services.

Future Work

Development of ACSPO v3.00 is underway, to propagate the algorithm/product improvements across GEO and LEO platforms and sensors. We plan to generate SST from the new generation European LEO (Metop-SG) and GEO (MTG) platforms and sensors, when their L1b data will become available.

We will continue ACSPO data fusion efforts, including the improved and extend L3S-LEO-PM/AM/DY line of products. We will also continue development of a new quasi-global gridded L3S-GEO product, which will bring together data from multiple GEO platforms, reconcile them, and generate twenty-four hourly quasi-global GEO SST maps (in addition to the current multiple GEO FD files from individual GEO platforms).

We will continue to process, reprocess and perform Cal/Val of all full-mission ACSPO satellite SST products, and ensure their consistency, and accurate performance in a maximally wide ocean domain.

We will continue working with data services (CoastWatch), archives (PO.DAAC and NCEI), GHRSST Catalogue and NOAA, national and international users, to facilitate access to all ACSPO products.

Work is underway to improve quality control of the *iQuam in situ* data, to mitigate overscreening due to the excessive reliance on the external L4 analyses. In particular, during the daytime, in situ SSTs are subject to the diurnal warming, which is not captured by the current L4 analyses. Furthermore, the current L4s do not accurately resolve the fine spatial structure of the SST field, especially in dynamic areas. This over-reliance on L4 SST in iQuam QC is currently being mitigated (Petrenko et al., 2023).

Conclusions

NOAA continues to sustain and improve ACSPO SST products, while processing data from a wider range of satellite sensors. Our priorities are reprocessing full-mission data from multiple current and historical LEO and GEO satellites. Upon ensuring their accurate performance and consistency (using the NOAA Monitoring systems SQUAM, iQuam, MICROS, ARMS, 3S), the next step is to perform their fusion (in particular, aggregate LEO SSTs into L3S-LEO, and GEO SSTs into L3S-GEO products). Eventually, L3S-LEO and L3S-GEO products will be combined into one L3S product, with superior coverage of the world ocean, at highest spatial and temporal resolution. In response to multiple NOAA users' requests (in particular, Fisheries), every ACSPO product now reports thermal fronts (location and intensity in K/km).

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8. Pryamitsyn, V.; Petrenko, B.; Ignatov, A.; Kihai, Y. Metop First Generation AVHRR FRAC SST Reanalysis Version 1. *Remote Sens.* **2021**, *13*, 4046. https://doi.org/10.3390/rs13204046.

European Space Agency report to GHRSST XXIV

ESA has strongly supported and continues to support the establishment and continuation of an operational capability for SST for Copernicus
• Copernicus Sentinel-3A and -3B are providing the operational dual-view SST capability from the SLSTR instrument
• Sentinel-3C/D are in final stages of preparation: S-3C launch planned for 2025 in Copernicus Long-Term Scenario with -3D afterwards (2028)
• Sentinel-3 Next Generation Optical mission is now entering Phase A.
• The ITT for Phase A has just been issued (Oct 2023).
• The Mission Advisory Group has been established in mid-2023 and is holding regular meetings
• Two science support studies are running and supporting the consolidation of the Mission Requirements • Synergy of VIS/NIR and TIR from the two instruments on S3NGO (AOLCI and SLSTR) is strongly supported.

Synergy of missions

S3NGO highly complementary to two Copernicus Expansion Missions:
• Land Surface Temperature Monitoring (LSTM) will provide high-resolution (50m) SST in the coastal zone
• Copernicus Imaging Microwave Radiometer (CIMR) will complement with observations with polar and global SST, with sub-daily revisit time in the polar regions.
Both LSTM and CIMR missions are now in Phase C, with launches in the 2028/2029 timeframe Particularly worth of note is the EU-led design and development of the large (>7m) CIMR deployable reflector.

Sentinel-3 Next Generation Optical (NGO) – Objectives

Enhanced continuity of observations of the current Sentinel-3 mission and follow-on of Sentinel-3 OLCI and SLSTR (Advanced OLCI and Advanced SLSTR). SLSTR is very mature and ASLSTR will be similar (dual-view) but enhanced ASLSTR should provide sampling along- and across-track at the sub satellite point of 500 m at least, with additional channels and forward oblique view.

LSTM

High spatio-temporal resolution TIR observations over land and coastal regions
SSD 50 m • swath 687 km • 5 TIR, 4 VNIR, 2 SWIR • NedT <0.15 K ARA< 0.5 K

CIMR: Copernicus Imaging Microwave Radiometer

SST with res ≤15 km and total standard uncertainty ≤ 0.3K Sub -daily coverage of polar seas

Summary - Enhanced continuity for SST

The legacy of Sentinel-3 SLSTR for operational and climate-quality SST is being continued and enhanced:

- S3-NGO ASLSTR: 500 m resolution
- LSTM: high resolution, for coastal applications
- CIMR: all-weather SST from passive microwave.

EUMETSAT Sea Surface Temperature –highlights since last meeting

Copernicus Sentinel-3A/B SLSTR SST (skin SST):
•Updates to SLSTR processing 12thDecember 2022 improving product quality
Revised SST coefficients, uncertainties, quality level flagging and SSES
https://www.eumetsat.int/media/50469
•SLSTR A-B SST tandem reprocessing available (2018)
•Evolution of SLSTR day-2 SST / day-1 IST planned for 2024 (pre-op on WEkEO) & 2025 (operational)
To include depth SST and Bayesian cloud improvements at coasts
•Sentinel-3 C/D launches approx. 2025/2028
All information: http://slstr.eumetsat.int

EUMETSAT Sea Surface Temperature –current and future updates

•Ocean and Sea-ice SAF: https://osi-saf.eumetsat.int/ operational production of EUMETSAT (non-Copernicus) SST
•Meteosat-9replaced Meteosat-8 in support of Indian Ocean Data Coverage Mission (IODC) on 2ndJune 2022 https://www.eumetsat.int/indian-ocean-data-coverage-iodc
•MTG-I1 launch: 13thDecember 2022 (FCI)
More information: https://osi-saf.eumetsat.int/
MTG-S1 (IRS) launch planned for early 2025

•Metop-IASI SST (skin SST)
IASI-A and IASI-B SST continue in NRT; algorithm development underway towards reprocessing
•Validation results for SLSTR-A/B, Metop-IASI/AVHRR continue to be available from https://metis.eumetsat.int
•EPS-SG A1: expected 2025 (METimage, IASI-NG).
•CIMR L2 SST over global ocean
Study on synergistic global ocean & atmos. products begins 2024
CIMR-A/B launches expected 2029/2031
•S3NGO ASLSTR: Global ocean SST from EUMETSAT. Definition of mission requirements and Phase A/B1 begins. Launch approx. 2034. (See ESA presentation for more details).

EUMETSAT and Copernicus Sea-Surface Temperature Projects

Copernicus FRM drifters (TRUSTED) : >170 high resolution drifting buoys:
https://www.eumetsat.int/TRUSTED TRUSTED MDB available for sharing:
https://s3calval.eumetsat.int/ma/sst/trusted/
Next steps: 25 buoys / year; QC & Metrology
Uncertainty models; FRM standard for drifters
Design and prototype of sea-ice ST drifter
Copernicus Sci4MaST: https://www.eumetsat.int/Sci4MaST
Development of SLSTR day-2 SST and day-1 IST

Evolution of Cal/Val tools and MMDB
GHRSST Project Office: https://www.ghrsst.org/
Implementation of GHRSST data discovery & cataloguing

Report from the Copernicus Marine Service & The SST TAC for the provision of Sea Surface Temperature products

Mission -Global and Regional Ocean Monitoring and Forecasting

Copernicus Marine offers Observation and Model products

- Observation products
- Model products (data assimilation)
- Access to products: A cloud-based infrastructure (Marine Data Store)
- Description of each product
- Information on quality
- Service desk / expert advice

A pan-European network of Production Centres feeding our Marine Data Store. An integrated Copernicus Marine and WEkEO service platform.

The SST TAC

Currently (March 2023), the SST TAC portfolio includes 21 SST products (13 NRT/8 REP) + 18 OMIs (Ocean Monitoring Indicators). Overall, each SST product provides a daily mean map of foundation SST at a given spatial res. More recently, daily hourly mean maps of skin/subskin SST (MED/BS/BAL) were made available. Detailed information of each product is reported in the PUM and QUID. Regional products are particularly suited for the specific regional sea. Due to Brexit, since January 2023 Met Office is no more part of this consortium (impacting the OSTIA family) and ESA-CCI SST products.

Observation Product Achievements & Plans

Achievements 2022/2023:

- New Global L4 NRT Product (Odyssea)
- New Global and Regional L3S REP products (complementing the existing L4 REP)
- REP regularly updated to reach 1 month before RT

Plans 2024/post-2024:

- Super Resolution Convolutional Neural Networks
- Integration of MTG-I in all regional and global products
- Exploitation of future HR missions (e.g. TRISHNA) to develop coastal products

The Copernicus Marine Service is highly dependent on satellite (Sentinels) and in-situ observing capabilities. Our role: operational interfaces (ESA, Eumetsat, in-situ incl. links with EMOdnet), requirements and advocacy.

From integration of S1, 2, 3 A & B in Copernicus 1 to S6 A & B and S1, 2, 3 C & D in Copernicus 2. We are preparing for expansion missions (in particular Arctic Ocean). Support the EC for New Generation Sentinel mission design.
We are working with EEA, EuroGOOS, EOOS to strengthen in-situ coordination and development of in-situ observing system. Horizon Europe projects (e.g. EuroSea, Arctic passion). International cooperation (GOOS) and UN Decade of Ocean Science.

Conclusions

- Copernicus Marine Service and SST TAC is highly user driven55 800 REGISTERED USERS (+ 30% PER YEAR
- Provide continuous evolution of global and regional algorithms to guarantee state-of-the-art and up-to-date SST products in terms of quality and accuracy, and new products;
- A substantial effort will need to be put for coastal application and in the preparation for the use of future missions, such as CIMR, LSTM and TRISHNA.

ISRO Agency Report

Policy level developments

The "Indian Space Policy-2023": Unleashes the reforms in Space Sector by opening the doors for NGEs, Pvt Sector and Start-ups.
The "New Geospatial Data Policy ": Promotes Open Data and Open Science from Indian Earth Observation missions.

Programmatic Developments

Presently, 2 satellites INSAT-3D and INSAT-3DR are operational in GEO with Imager and Sounder.

- EOS-06/OS3 was successfully launched on 26 Nov 2022 with Ku-band scatterometer, Dual-Band Sea Surface Temperature Monitor (SSTM), and 13-band Ocean Color Monitor (OCM-3). Presently CALVAL phase is going on. Data from Scatterometer and OCM-3 released to the users. SSTM operations have been stopped due to in-orbit anomaly.
- INSAT-3DS is planned to be launched later this year, 2023, with many improvements to mitigate the issues related to the blackbody calibration and mid-night sun-intrusion.
- GISAT-1R is scheduled for launch in the first half of 2024.

INSAT-3D/3DR/3DS SST: Present Capability & New Algorithm

INSAT-3D/3DR SST is being generated and disseminated operationally at MMDRPS, IMD, New Delhi and MOSDAC, SAC/ISRO.

- Operational products are based on both NLSST and 1DVAR based algorithms.
- Real-time bias corrections are implemented using cumulative density function matching with GFS analysis/forecast simulated BTs as reference.
- 1DVAR produces better retrieval accuracy (Std.Dev. < 0.7K) than NLSST.
- Reprocessing of entire dataset is in progress.

EOS-06/Oceansat-3

Oceansat-3 Successfully launched on 26 Nov 2022

- Ku-band Scatterometer (SCAT-3) - High Resolution winds (12.5 km)
- 13-band Ocean Colour Monitor (OCM-3) - Narrow bandwidth
- 2-band Sea Surface Temperature Monitor (SSTM)
- ARGOS by CNES

FUTURE INDIAN GEO SATELLITES: (GISAT)

EOS-06/Oceansat- MX-VNIR: Multispectral - Visible Near Infrared, HySI-VNIR: Hyperspectral Imager - Visible Near Infrared, HySI-SWIR: Hyperspectral Imager - Short Wave Infrared, MX-LWIR: Multispectral - Long Wave Infrared. 3 GISAT Strengths: High spatial (1.2 km) and temporal resolution (10 minutes) from LWIR.

Thermal InfRared Imaging Satellite for High resolution Natural resource Assessment (TRISHNA)

Primary design drivers

- Ecosystem Stress and Water Use
- Coastal, Shore and Inland waters

Secondary design drives

- Urban Heat Island
- Minerals, Volcanoes and Coal fire
- Snow and Ice
- Water Vapour, Aerosol and Cloud

Other Satellites/instruments: In consideration

GEO: INSAT-4th Generation Satellite

a) Advanced Imager (legacy: GOES-ABI)

- 16 bands from 0.5 – 13.5 µm with spatial resolution 250-500m for VIS and 1-2 km for IR
- Faster scanning for nowcasting applications
- FD (Full Disk), India (3000 km x 3000 km) and Mesoscale (1000 km x 1000 km)
- Capability to provide FD image every 5 minutes, Indian landmass every 2 minutes and Mesoscale images every 30 seconds.

b) Lightning mapper

c) Hyperspectral Infrared Sounder

LEO:

a) MW Temperature & Humidity Sounder in low-inclination orbit

b) 6-89 GHz MW Radiometer in low-inclination orbit

c) Dual Frequency Scatterometer, C/Ku with 5 km (Regional)/25 km (global)

d) Hyperspectral Infrared Sounder

NASA PO.DAAC Report to the GHRSST Project

PO.DAAC now distributing 100% from the cloud.

AWS science enabling studies

Develop cloud workflows to inform user decisions on performance, access, services and cost

- AWS Lambda for science – high volume time series analysis
    - On-demand serverless compute workflow for global Level 4 MUR SST means and statistics
    - Exploring advantages and limitations
    - Presented at ESIP Summer Meeting
- Parallel computing using Dask on EC2
    - Data downscaling workflow for level 4MUR SST data from 1 km to 100 km
    - Benchmarking speed and cost
    - Other tutorials on data aggregation and chunking impacts, EOF analysis

SST specific progress in support of GHRSST

14 GHRSST datasets have been published since last meeting

- MW_IR_OI-REMSS-L4-GLOB-v5.1 (July 14, 2022)
- MW_OI-REMSS-L4-GLOB-v5.1 (July 14, 2022)
- AMSR2-REMSS-L2P-v8.2 (February 15, 2023)
- AMSR2-REMSS-L2P_RT-v8.2 (February 15, 2023)
- OSTIA-UKMO-L4-GLOB-REP-v2.0 (March 30, 2023)
- MSG01-OSPO-L2P-v1.0 (April 17, 2023)
- MSG02-OSPO-L2P-v1.0 (April 17, 2023)
- MSG04-OSPO-L2P-v1.0 (April 17, 2023)
- AMSR2-REMSS-L3U-v8.2 (May 31, 2023)
- AMSR2-REMSS-L3U_RT-v8.2 (May 31, 2023)
- G18-ABI-L2P-ACSPO-v2.90 (August 17, 2023)
- G18-ABI-L3C-ACSPO-v2.90 (August 17, 2023)
- H09-AHI-L2P-ACSPO-v2.90 (September 13, 2023)
- H09-AHI-L3C-ACSPO-v2.90 (September 13, 2023)

NOAA MSG metadata issues resolved for forward stream

See GHRSST-24 presentations by:

- Suresh Vannan (suresh.vannan@jpl.nasa.gov),
- Wen-Hao Li (wen-hao.li@jpl.nasa.gov),
- Jorge Vazquez (jorge.vazquez@jpl.nasa.gov),
- Ed Armstrong (edward.m.armstrong@jpl.nasa.gov)

For more detailed progress in PO.DAAC support of the GHRSST Project.

General inquiries and questions

- podaac@podaac.jpl.nasa.gov
- PO.DAAC Forum: https://forum.earthdata.nasa.gov/viewforum.php?f=7&tagMatch=all&DAAC=146&keywords=&

Final Remarks

The 25th International SST Users' Symposium will be held in Montreal in June 2024 and co-hosted by Dorina Surcel-Colan and colleagues from Environment Canada as well as the University of Quebec Montreal (UQAM).

The Advisory Council recommendations to the Science Team are available in the form of a report with a list of actions to be implemented by the Science Team members and the GHRSST Project Office.

Watch the Advisory Council report from GHRSS24 on YouTube here:
https://www.youtube.com/watch?v=guPM2ni93W0

Group Photo

The GHRSST24 Padlet is available at this link: https://padlet.com/chb7/ghrsst24-padlet-uekjah99hokypcv4

Annex 1 - Agenda of the Symposium

Monday 16-10-2023		
Agencies' Reports and Task Teams' Reporting		
T Srinivas Kumar (INCOIS)		
Neeraj Agarwal (ISRO)		
Welcome Session		
Highlights from the Agencies		
Agency 1: ISRO/SAC	Rashmi Sharma	ISRO/SAC
Agency 2: NOAA	Sheekela Baker-Yeboah	NOAA
Agency 3: ESA	Paolo Cipollini (Speaker: Steffen Dransfeld)	ESA
Agency 4: Australian Bureau of Meteorology	Helen Beggs and Pallavi Govekar	Australian Bureau of Meteorology
Agency 5: RDAC-NOAA-NCEI	John Huai-Min Zhang	NOAA
Agency 6: NASA PO.DACC	Ed Armstrong	NASA JPL
Agency 7: Copernicus Marine Services	Andrea Pisano	CNR, SST-TAC coordinator
Agency 8: Japan Meteorological Agency	Kei Sakamoto	JMA
Agency 9: NOAA STAR ACSPO Update	Alexander Ignatov, Olafur Jonasson	NOAA STAR ACSPO
Agency 10: JAXA	Misako Kachi	JAXA
Agency 11: CSIR	Christo Whittle	CSIR
Agency 12: EUMETSAT	Anne O' Carroll	EUMETSAT
Agency 13: NAVOCEANO	Danielle Carpenter	NAVOCEANO
Agency 14: STAR-2 RDAC	Andy Harris	NOAA
Q&A Discussion		
GHRSST task teams reporting		
Climatology and L4 Inter-Comparison	Chunxue Yang (CNR) and Jorge Vazquez (JPL/NASA)	
Climate Data Assessment Framework	Jonathan Mittaz (Univ. Reading), Prasanjit Dash (NOAA), Rishi Gangwar (ISRO)	
Coral Heat Stress User SST Requirements	William Skirving (NOAA), Jonathan Mittaz (Univ. Reading)	

Cloud Masking (CMT2)	Christopher Merchant (UK Met Office/Univ. Reading)	UK Met Office/Univ. Reading

Tuesday 17-10-2023		
Opening of the Symposium		
J V Thomas (ISRO)		
Raj Kumar (ISRO)		
Welcome by Director SAC	Director SAC	ISRO/SAC
Keynote ISRO/SAC	Mehul Pandya on behalf of the Director SAC	ISRO/SAC
International collaboration in EO missions	J V Thomas	ISRO/SAC
UN Ocean Decade Activity and India's Initiatives	Srinivasa Kumar Tummala	ESSO/INCOIS, IOC UNESCO
Capacity Building	R P Singh	ISRO
Introduction: Who are GHRSST and what does GHRSST do	Anne O'Carroll, Chair of the GHRSST Science Team	EUMETSAT
Science session 1: Science applications for operational users of SST in India		
T Srinivas Kumar (INCOIS)		
Neeraj Agarwal (ISRO)		
31- S1 Keynote Speech and Q&A: Impact of satellite-derived sea surface temperature data in the variational assimilation system	V S Prasad	National Centre for Medium Range Weather Forecasting (NCMRWF), Ministry of Earth Sciences (MoES)
50-S1 Sea surface temperature anomaly over the south-eastern Arabian Sea with the changing phase of the Indian Ocean Dipole	Simi Mathew	Indian Institute of Technology Madras
66-S1 Monitoring phytoplankton bloom occurrence and its associated parameters in the North Eastern Arabian Sea using GHRSST data	Greeshma K. U.	National Institute of Technology, Karnataka, Surathkal

68-S1 Space based Coral Bleaching Monitoring over Indian Reef Region: Need for High-resolution SST Data	Nandini Ray Chaudhury	Space Applications Centre (SAC), ISRO
61-S1 Impact of different GHRSST data sets on simulation of Indian summer monsoon	Neeraj Agarwal	Space Applications Centre (SAC), ISRO
72-S1 Assimilation of in-situ and remote sensing data in Regional Ocean Modeling System for the Indian Ocean	Balaji Baduru	Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES), Government of India
Joint Q&A session		
Session 2: Processing and product generation		
Claudia Fanelli (ISMA-CNR)		
Pallavi Govekar (BoM)		
62-S2 Keynote Speech and Q&A: A 40-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative	Owen Embury	University of Reading and National Centre for Earth Observation
7-S2 Significant Diurnal Warming Events and Ocean Warm Skin Signals Observed by Saildrone at High Latitudes	Chong Jia	Rosenstiel School of Marine and Atmospheric Science, University of Miami
32-S2 A satellite-based surface temperature climate dataset of the Arctic ocean and sea ice, 1982–2021	Pia Nielsen-Englyst (Speaker: Jacob L. Høyer)	Danish Meteorological Institute
80-S2 Joint reconstruction of ocean surface currents and temperature through deep learning algorithms	Daniele Ciani	Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine
21-S2 Sea Surface temperature reprocessing of Himawari-8 archive	Pallavi Govekar	Bureau of Meteorology
Joint Q&A session		
Session 3: Calibration, Validation and Product Assessment		
Mingkun Liu (OUC)		
Prasanjit Dash (NOAA)		

14-S3 Keynote Speech and Q&A: Validation of Himawari-8 Sea Surface Temperature Retrievals Using Infrared SST Autonomous Radiometer Measurements	Haifeng Zhang	Bureau of Meteorology
8-S3 Identification of Sea Surface Temperature and Sea Surface: Salinity Fronts along the California Coast: Application Using Saildrone and Satellite Derived Products	Jorge Vazquez	NASA Jet Propulsion Laboratory/California Institute of Technology
30-S3 Inter-comparison of GHRSST Sea Surface Temperature Products from Different Resolutions and Datasets: A Case Study in the Indian Ocean Region	Surisetty V V Arun Kumar	Space Applications Centre (ISRO)
43-S3 Ship-Borne Inter-Comparison of Thermal Infrared and Passive Microwave Instruments for Sea Surface Temperature Measurements	Guisella Gacitúa	Danish Meteorological Institute
11-S3 Importance of Uncertainties and Benchmark Metrics in the Diagnostics and Intercomparisons of Sea Surface Temperature Records	Boyin Huang (Speaker: Huai-min Zhang)	NOAA/NCEI, Asheville, North Carolina, USA
16-S2 Options for MODIS discontinuity with use case of MUR SST	Peter Minnett, Jorge Vazquez, Edward Armstrong	NASA Jet Propulsion Laboratory/California Institute of Technology
In-person poster session (icebreaker)		
D Sengupta (IISc)		
A K Varma (ISRO)		

Wednesday 18-10-2023		
Session 4: Retrieval Algorithms		
Rashmi Sharma (ISRO)		
Pradeep Thapliyal (ISRO)		
5-S4 Keynote Speech and Q&A: Effects of the Hunga Tonga-Hunga Ha'apai Eruption on MODIS-retrieved Sea Surface Temperatures	Chong Jia	Rosenstiel School of Marine and Atmospheric Science, University of Miami

81-S4 A sea surface temperature retrieval algorithm for CIMR	Jacob L. Høyer	Danish Meteorological Institute
42-S4 TRISHNA Sea Surface Temperature Retrievals: comparison of multiple algorithms	Emilie Delogu	Centre National d'Etudes Spatiales (CNES)
90-S4 MAESSTRO: Masked AutoEncoders for Sea Surface Temperature Reconstruction under Occlusion	Alice Yepremyan, Edwin Goh	NASA Jet Propulsion Laboratory/California Institute of Technology
29-S4 Inter-comparison of various AI/ML techniques for SST retrieval from INSAT-3D Imager	Rishi Kumar Gangwar	Space Applications Centre (ISRO)
Joint Q&A session		
Session 5: Computing and products		
Edward Armstrong (NASA JPL)		
Nitant Dube (ISRO)		
26-S5 Keynote Speech and Q&A: Optimizing Data and Services in the Cloud for User Exploitation	Ed Armstrong	NASA Jet Propulsion Laboratory/California Institute of Technology
92-S5 Temporal and geospatial characterization of trends in sea surface temperature	Prasanjit Dash	NOAA NESDIS STAR / CSU CIRA
99-S5 Searching and selecting GHRSST data with OpenSearch	Jean-François Piollé	Ifremer
96-S5 TRISHNA products format and content for water users	Jean-Louis Raynaud	Centre National d'Etudes Spatiales (CNES)
56-S5 An evaluation of the LLC4320 global ocean simulation based on the submesoscale structure of modeled sea surface temperature fields	Katharina Gallmeier	Institute for Defense Analyses, IDA Headquarters, IDA Systems and Analyses Center
Joint Q&A session		
In-person poster session		
D Sengupta (IISc)		

A K Varma (ISRO)		

Thursday 19-10-2023		
GHRSST News Item: Marine Heatwaves		
Mini Raman (ISRO)		
M M Ali (ISRO)		
Marine Heatwaves: Extreme warming in the Mediterranean 2023	Andrea Pisano	National Research Council of Italy, Institute of Marine Sciences (CNR-ISMAR)
64-S1 Characteristics of Marine Heatwaves in the Philippines	Brenna Mei Concolis	University of the Philippines Cebu
65-S3 Marine heatwaves in the Cape peninsula upwelling cell, Southern Benguela	Kirstin Petzer	University of Cape Town, Rondebosch
Discussion on MHW		
GHRSST task teams reporting		
Mini Raman (ISRO)		
M M Ali (ISRO)		
Shipborne Radiometry	Werenfrid Wimmer	University of Southampton
Evolution of the Regional/Global Task Sharing: Demonstration of Catalogue and OpenSearch	Jean-Francois Piolle	IFREMER
Matchup Database Standards	Jean-Francois Piolle	IFREMER

Session 6: High-resolution future satellite missions		
S S Sarkar (ISRO)		
Bimal Bhattacharaya (ISRO)		
101-S6 Keynote Speech Nr.1 and Q&A: TRISHNA – A joint Indo-French TIR-VSWIR science mission towards global water and food security	Bimal K Bhattacharya	Space Applications Centre, Indian Space Research Organization (ISRO)

3- S6 Keynote Speech Nr.2 and Q&A: Land Surface Temperature Monitoring (LSTM) Mission	Steffen Dransfeld	European Space Agency
73-S6 Designing new ultra high resolution Sea Surface Temperature products in coastal areas for the future TRISHNA mission	Emmanuelle Autret	Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d'Oceanographie Physique et Spatiale (LOPS)
69-S6 Coastal-zone sea surface temperature at ~100 m resolution	Christopher Merchant	University of Reading and National Centre for Earth Observation
102-S5 Enhanced continuity of SST measurements from Sentinel-3 Next Generation Optical	Paolo Cipollini (Speaker: Steffen Dransfeld)	European Space Agency
34-S3 Towards the next generation Sentinel instruments: The Advanced SLSTR	Jonathan Mittaz	University of Reading
Joint Q&A session		
In-person poster session		
D Sengupta (IISc)		
A K Varma (ISRO)		

Friday 20-10-2023	
Workshop W1: GHRSST Priorities, Panel discussion	Moderation: Anne O'Carroll (EUMETSAT). With contributions by: Emmanuelle Autret (IFREMER), Andrea Pisano (CNR), Christo Whittle (CSIR), Raj Kumar (ISRO), Ed Armstrong (NASA JPL), Helen Beggs and Pallavi Govekar (BOM), Jacob Høyer (DMI)
Break	
Workshop W2: SST producers workshop, with presentations on GHRSST data specifications, use of the GDS	Moderation: Jacob Høyer (DMI). Presenters and panelists: Jean-Francois Piolle (IFREMER), Possible future improvements and evolutions we can foresee for the GDS; Helen Beggs and Pallavi Govekar (BOM), The Bureau of Meteorology GHRSST products; Cristina Tronconi/Andrea Pisano (CNR), Copernicus Marine SST products; Nitant Dube (ISRO), ISRO report

Recommendations of the Advisory Council to the GHRSST Science Team	Jacob Høyer, Member of the Advisory Council (Danish Meteorological Institute)
Closing remarks	Anne O'Carroll, Chair of the GHRSST Science Team (EUMETSAT) Dorina Surcel-Colan (Environment Canada)