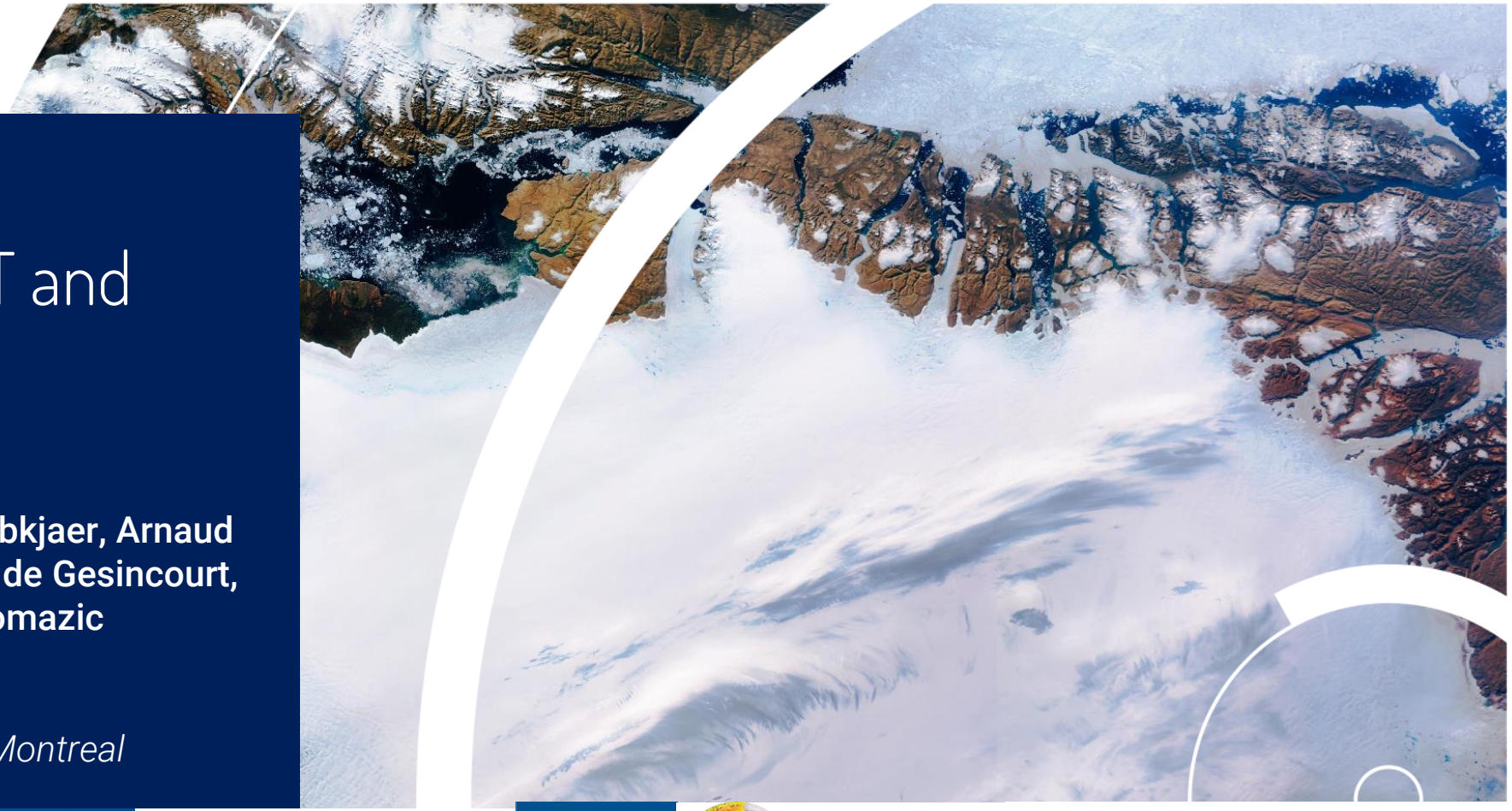
Fiducial Reference Measurements for SST and sea-ice



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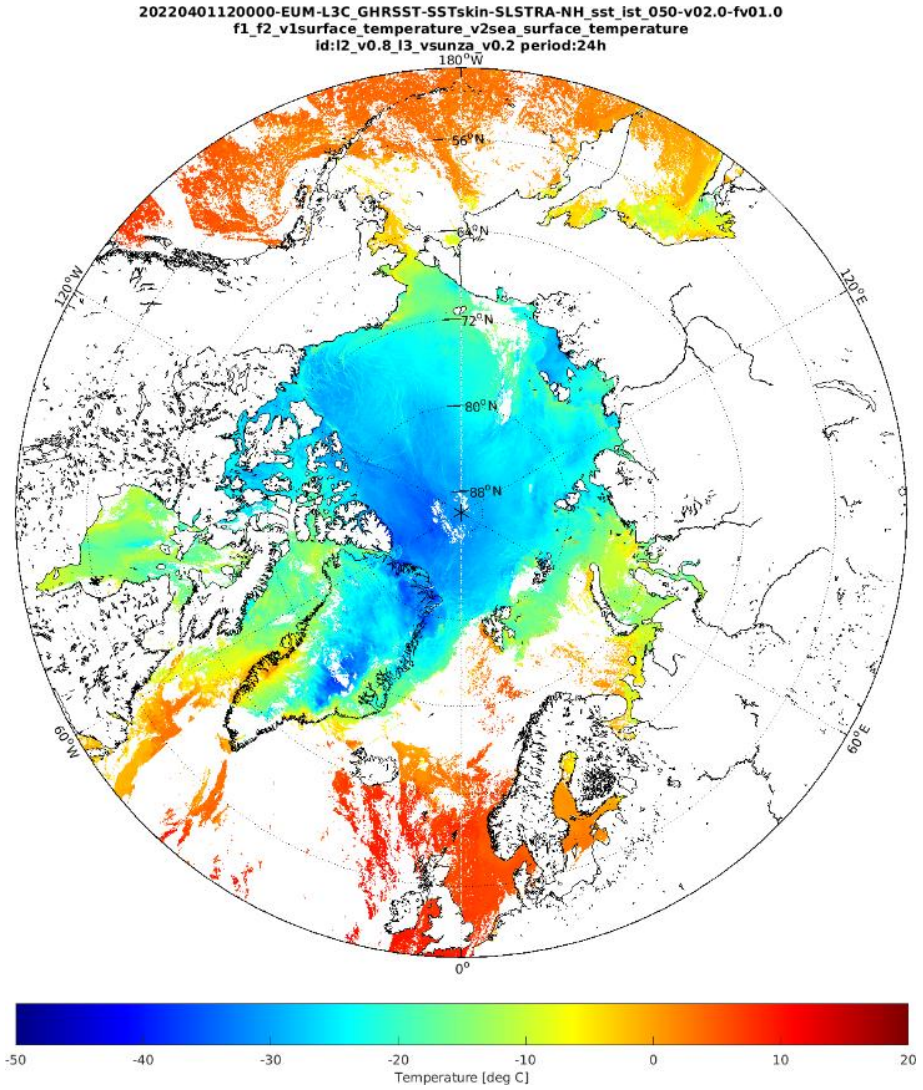
12th June 2024
25th GHRSST Science Team meeting, Montreal

Outline

- Reference SLSTR SST
- Fiducial Reference measurements – background and purpose
- TRUSTED SST drifting buoys
- Uncertainty diagrams and metadata, QC
- SLSTR SST validation with TRUSTED
- International coordination (DBCP, GHRSST, EMN)
- High quality satellite IST
- Sea-ice FRM buoy development
- Summary and recommendations



Global satellite Sea-Surface Temperature validation

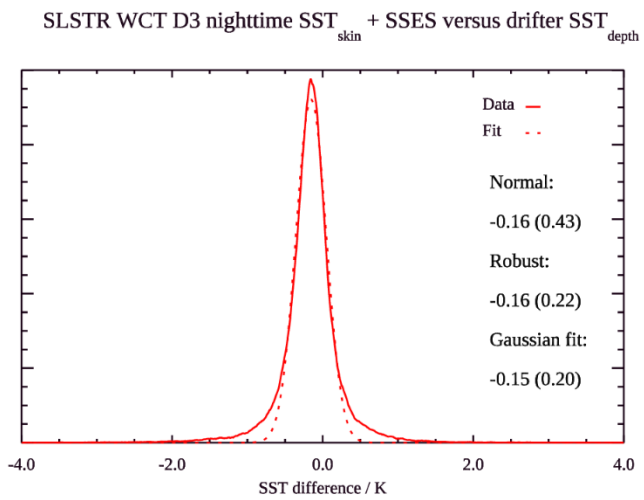
Reference data, such as from radiometers, drifting buoys, moored buoys and Argo, are essential for satellite SST validation

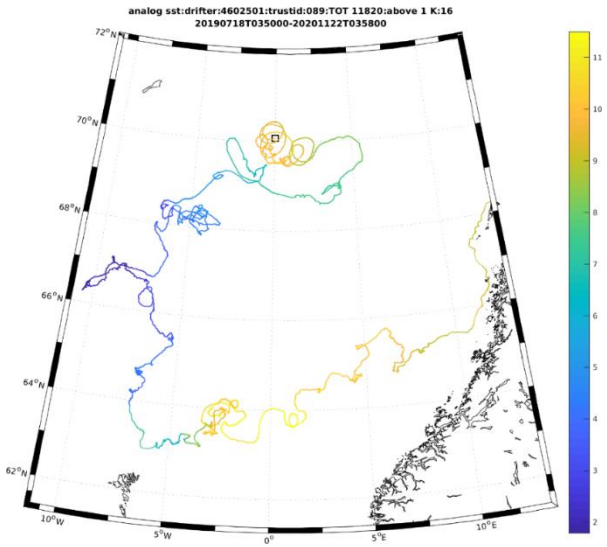
Validation activities crucial to assessing and maintaining satellite SST product quality

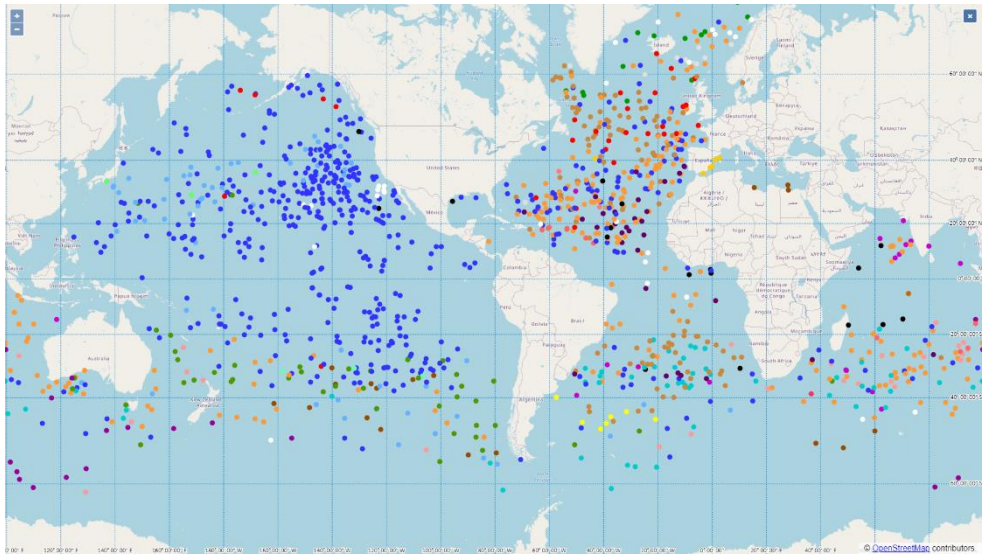
- Collocations with all drifting buoy SST, Argo, GTMBA
- Inter-comparisons with other satellite SST
- For climate quality and reference satellite SSTs: collocations with Fiducial Reference Measurements

This talk focuses on drifters as they are the largest set of *in situ* reference data available for validation.

Matchup database (MDB) with satellite Sea Surface Temperature and *in situ* SST produced at EUMETSAT







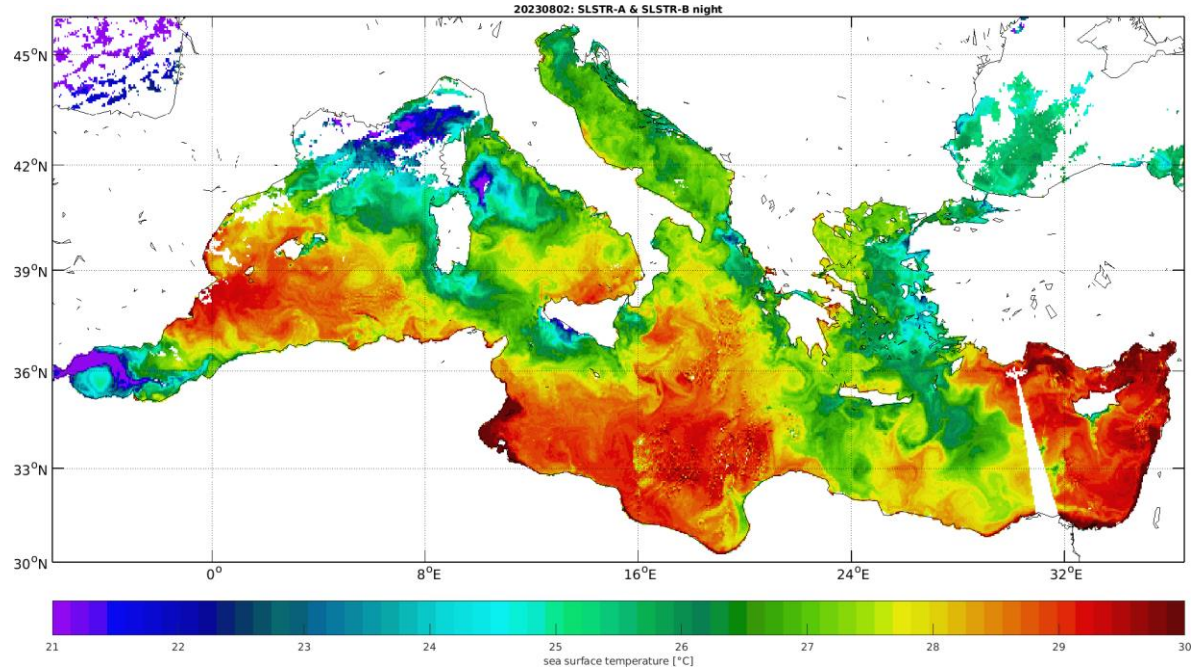
Global Drifter Programme array 4th May 2022 https://www.aoml.noaa.gov/phod/gdp/interactive/drifter_array.html

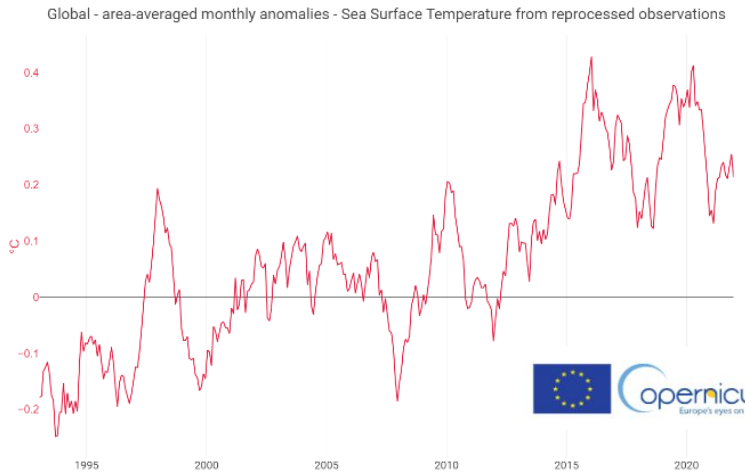
Reference SST from SLSTR

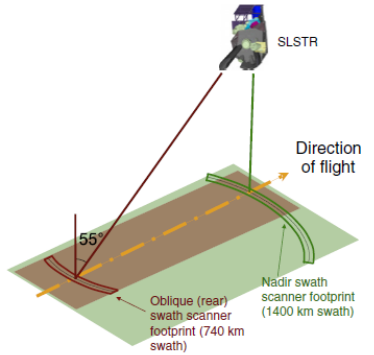
SLSTR provides Reference satellite Sea-Surface and Sea-ice Surface Temperature for the marine domain

- SLSTR provides critical **reference** SST data for operational weather and ocean forecasting and climate monitoring
- Significance of data increasing as the climate crisis amplifies
- Therefore, high quality reference FRM data for validation are also critical to ensure satellite SST data quality, uncertainties, stabilities

  -> Fiducial Reference Measurements



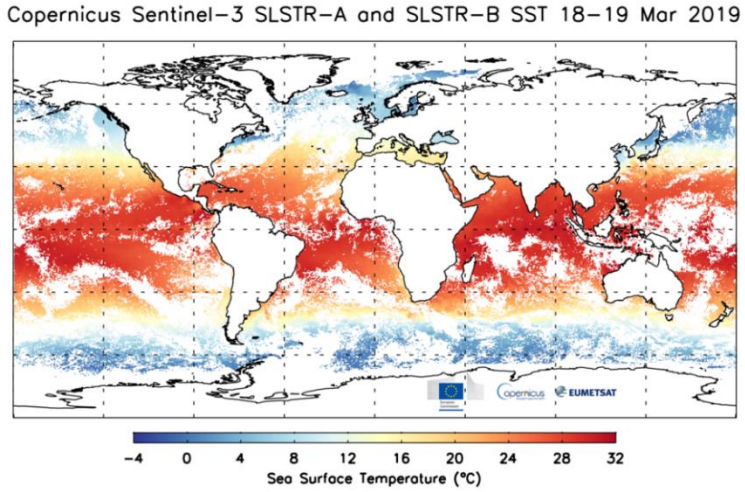


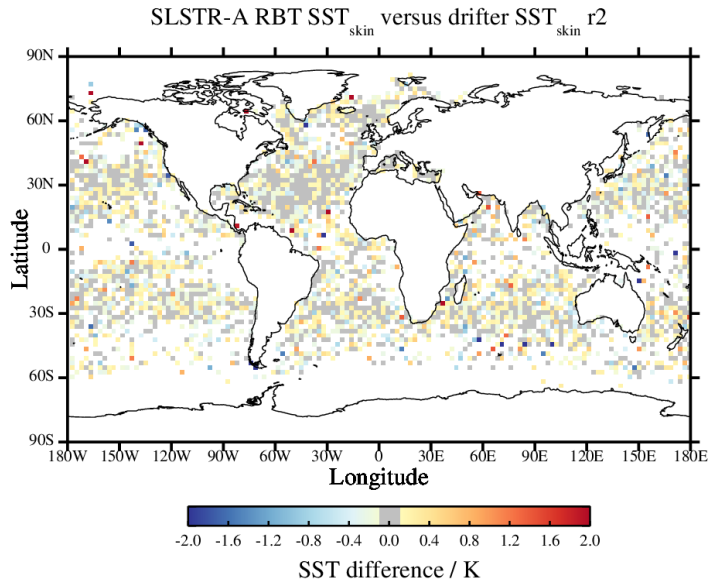


Copernicus Marine Service

Fiducial Reference Measurements (FRM)

- The validation of **Climate quality and operational reference satellite Sea Surface Temperature** requires a sub-set of extremely high quality Fiducial Reference Measurements
  - Traceability for climate data records -> understand how accurate products really are and to deliver the required confidence e.g. GEO/CEOS QA4EO
  - Long-term investment -> balanced to deliver a satellite mission with a known product quality that is fit for purpose
  - Global coordination increases quality in whole network -> beneficial for both satellite and ground based users

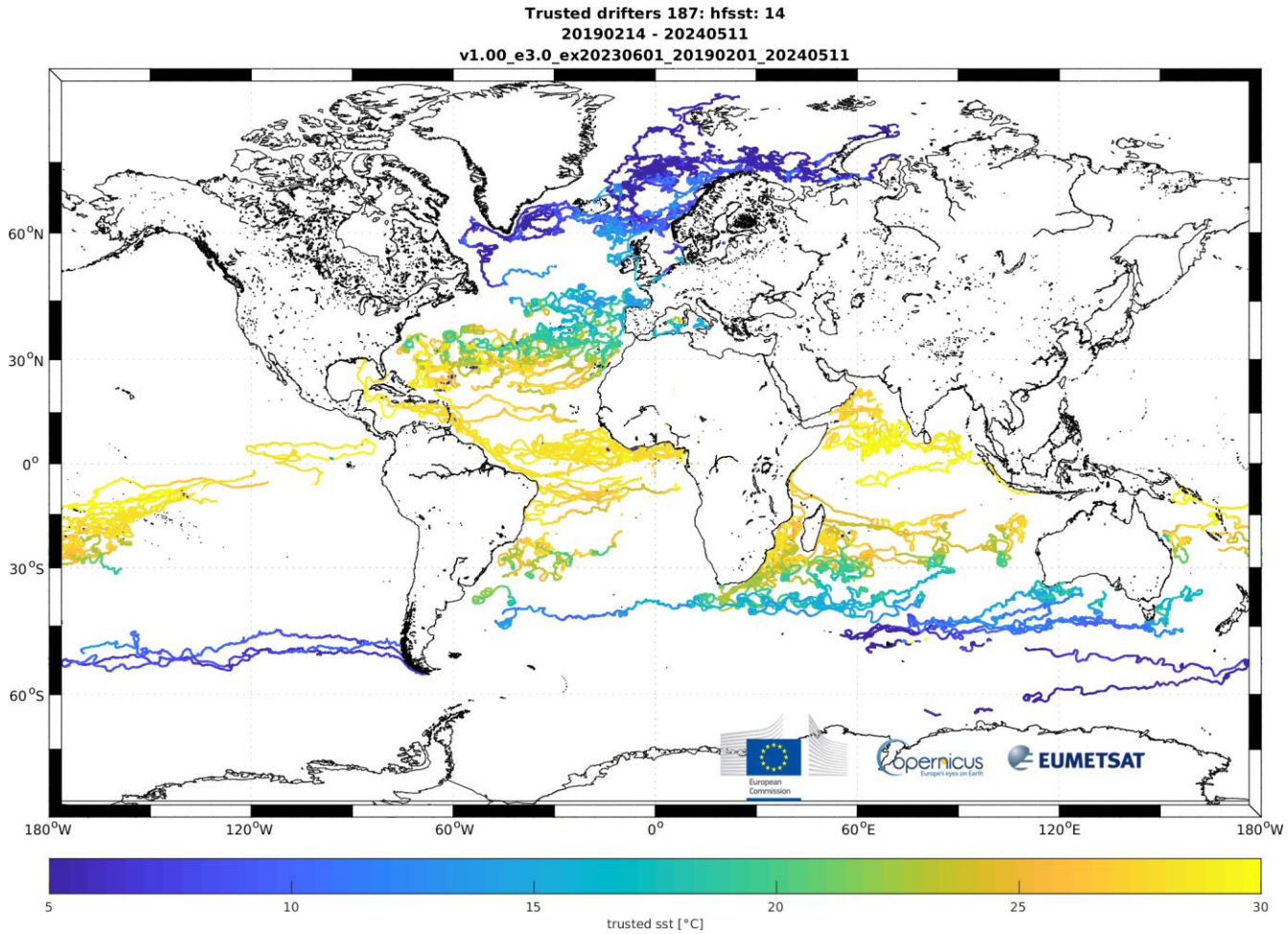




Copernicus FRM drifting buoys (TRUSTED project)

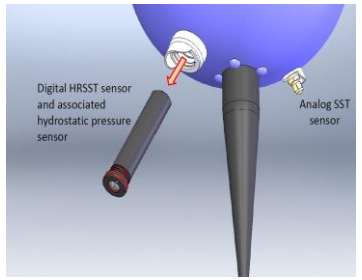
Establish sustainable Fiducial Reference Measurements (FRM) for satellite SST / IST

- FRM drifting buoys for Copernicus satellite validation (TRUSTED), began 2018
- Over 187 SVP-BRST high resolution drifters deployed so far with TRST and SST sensors
- Calibration per sensor, metadata access, storage and QC, stability analyses
- Traceability diagrams and metrology and coordination with European Metrology Network
- Recent focus on high-latitude deployments and Baltic / Mediterranean Seas as well as global
- IST buoy development (started in 2022)



Project info:

https://www.eumetsat.int/TRUSTED



TRUSTED diagnostics:
https://s3calval.eumetsat.int/ma/sst/trusted/

SVP-BRST design

Design based on the SVP-B:

- DBCP compliant
- 4 sensors: P, SST, TRST, HP
- GNSS positioning
- Iridium modem

Technical specs:

https://www.eumetsat.int/media/44077

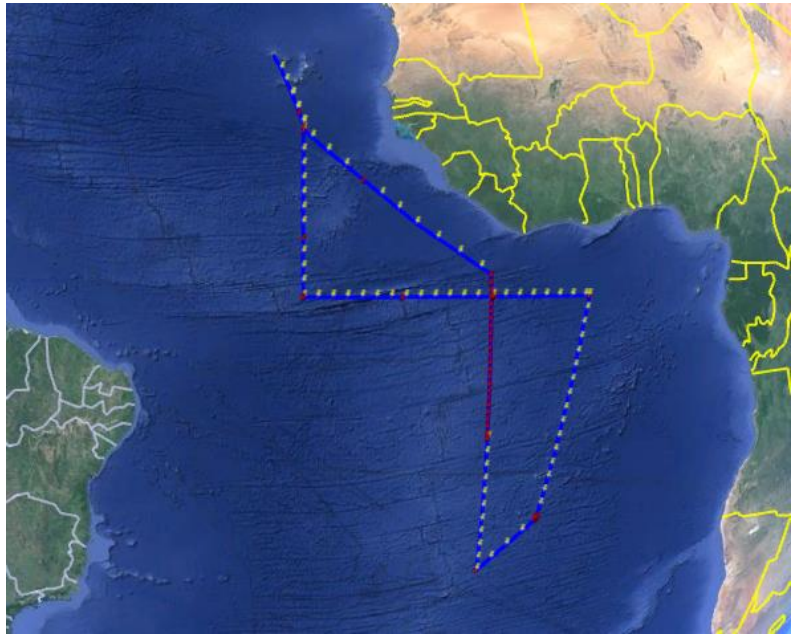
CLS
COLLECTE LOCALISATION SATELLITES

nke INSTRUMENTATION

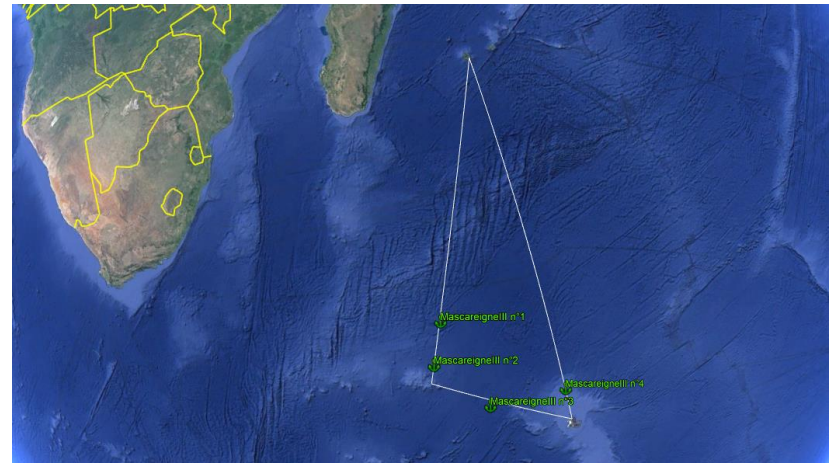
copernicus

Recent and planned deployments

- Recent deployments:
  - North Atlantic (1)
  - Indian Ocean (2)
  - North (4) and South (4) Pacific Ocean
  - North (2) and South (3) Atlantic



- Deployments in June 2024:
  - Indian Ocean (3)
  - Arctic (2)
  - South Atlantic (2)



Development of traceability trees and uncertainty diagrams

Fiducial Reference Measurements require full uncertainty modelling and traceability diagrams (e.g. Wimmer & Robinson, 2016; Le Menn et al., 2024, in preparation)

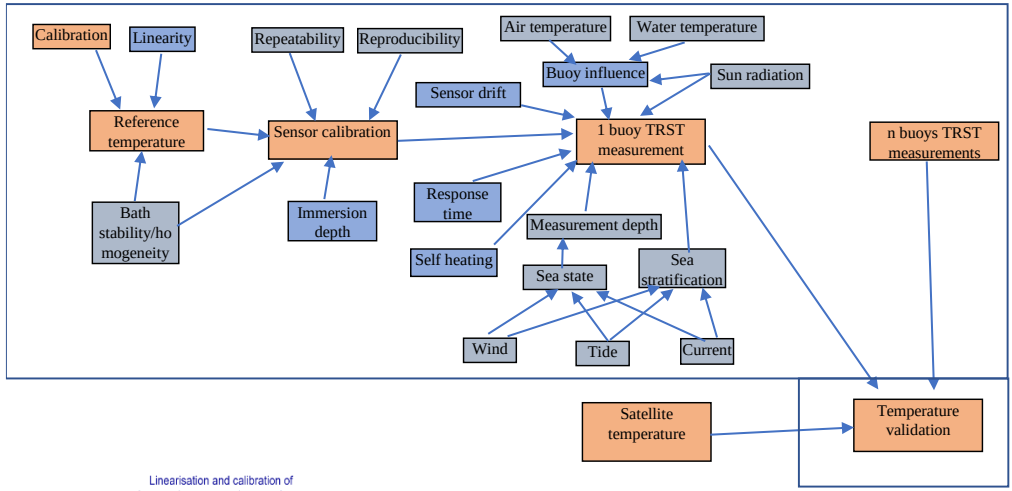
Uncertainty traceability diagrams for TRUSTED drifting buoys prepared by SHOM (M. Le Menn)

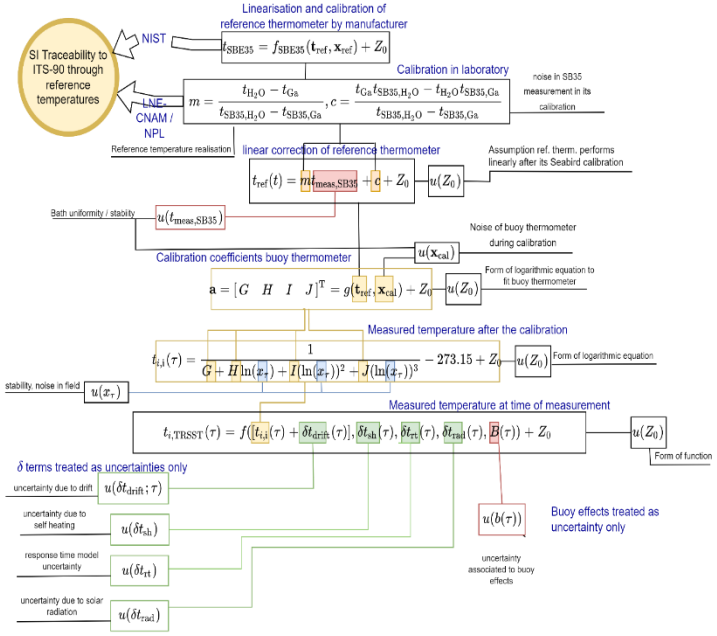
- Aim for an uncertainty model per buoy with specifically defined measurand
- Drifting buoy SST at depth of sensor and at measurement time

Coordination with European Metrology Network

- Independent review and contributions by expert metrologists
- Critical to ensure Fiducial Reference Measurement standard is met

Link from in situ to satellite measurement including uncertainty diagrams addressing validation methodologies such as skin to depth models are needed.

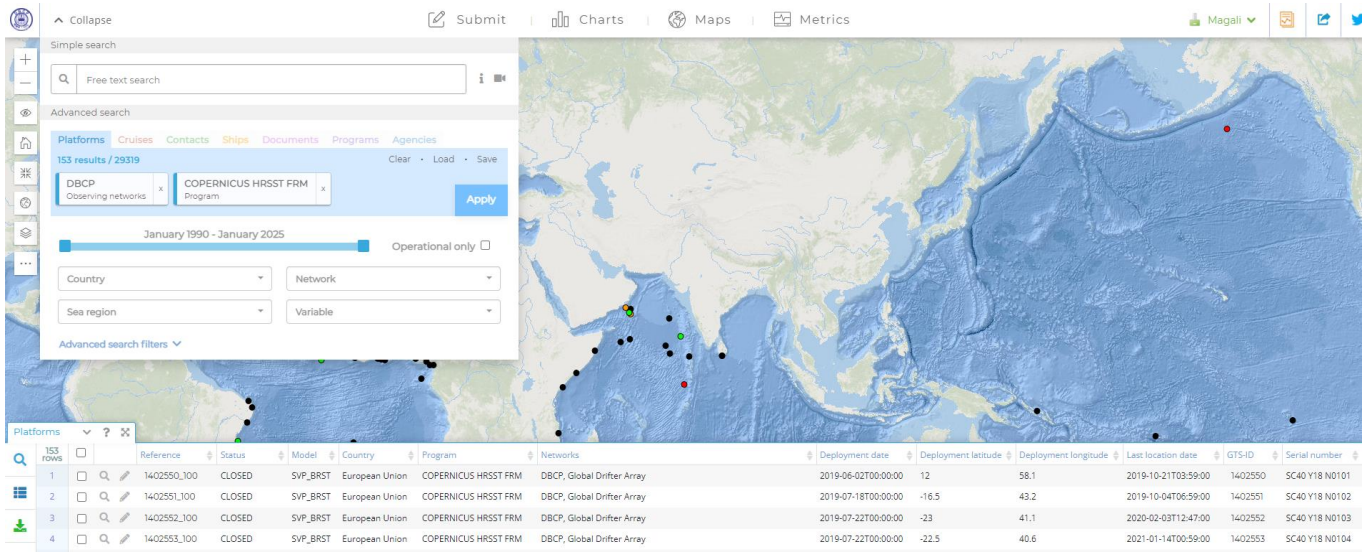


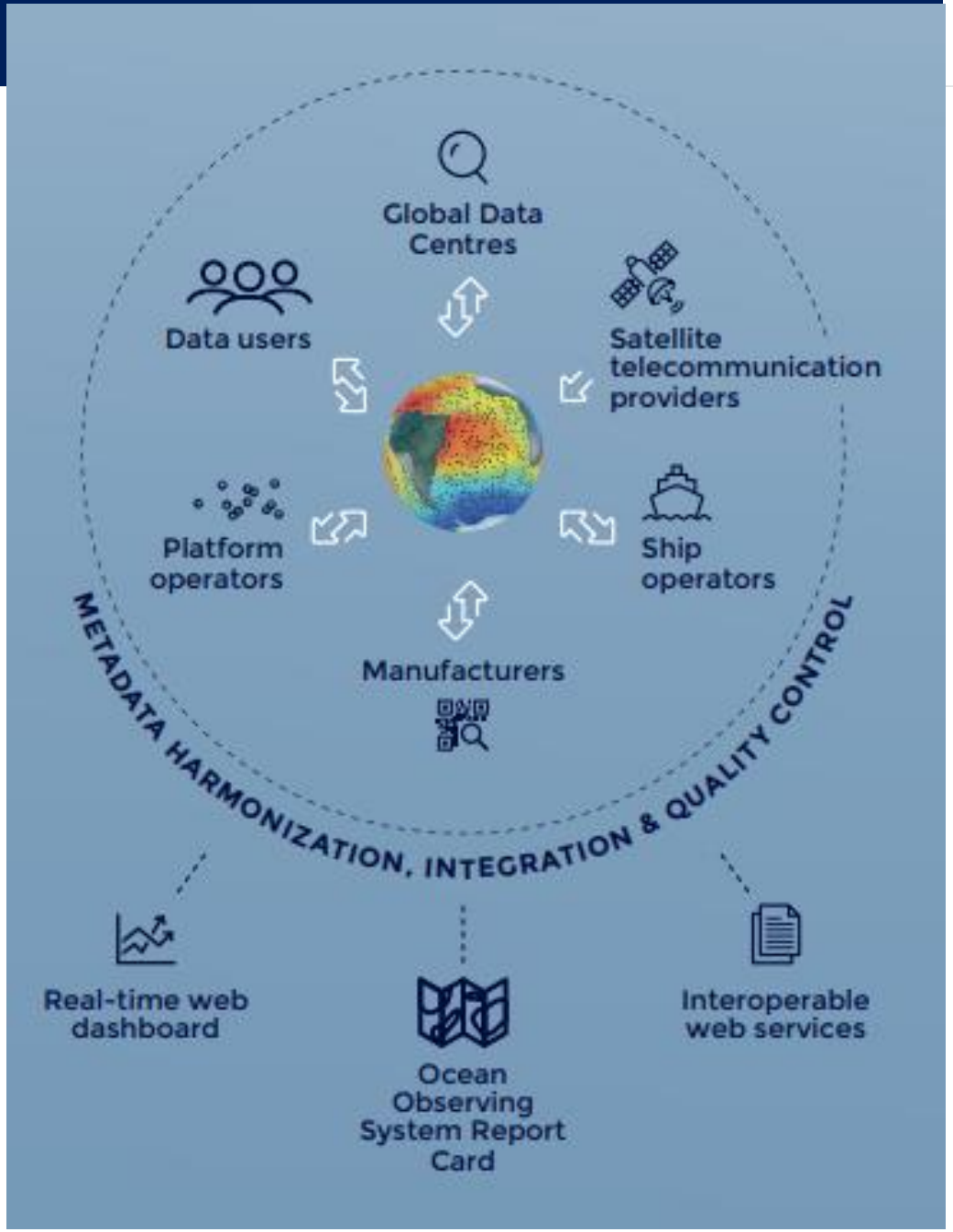


Figures in draft
Le Menn et al., 2024

Quality Control and metadata for FRM

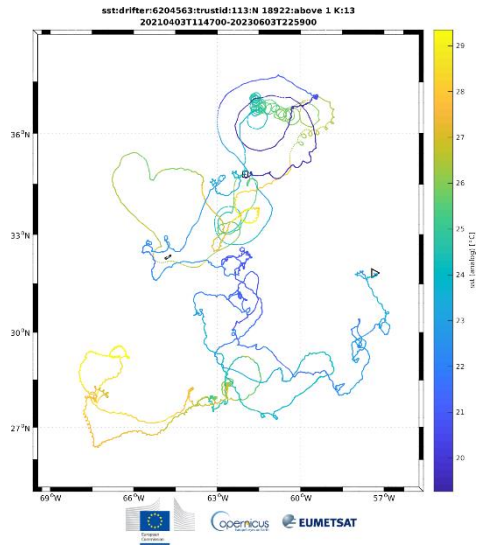
- Machine searchable and accessible global and measurement metadata
- Specification of full QC procedure and definition for route to FRM
- Quality Control data propagated through full data acquisition and processing steps
- Easily available to users
- Methods in progress to automatically include OceanOps metadata and Meteo-France / Coriolis QC data

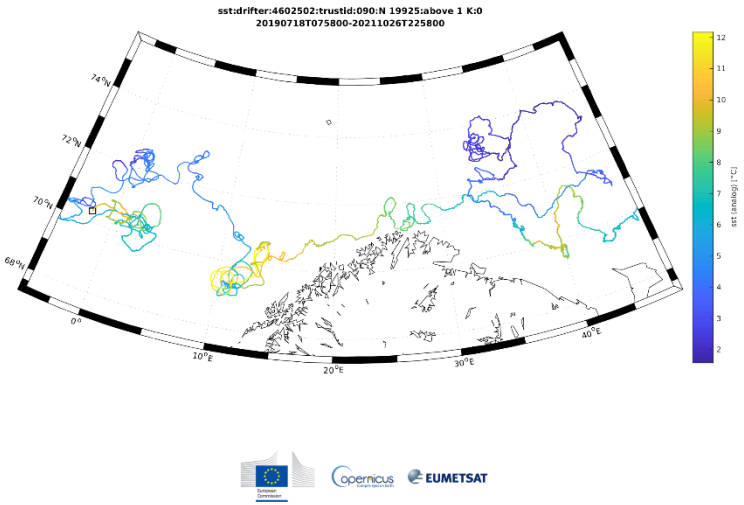


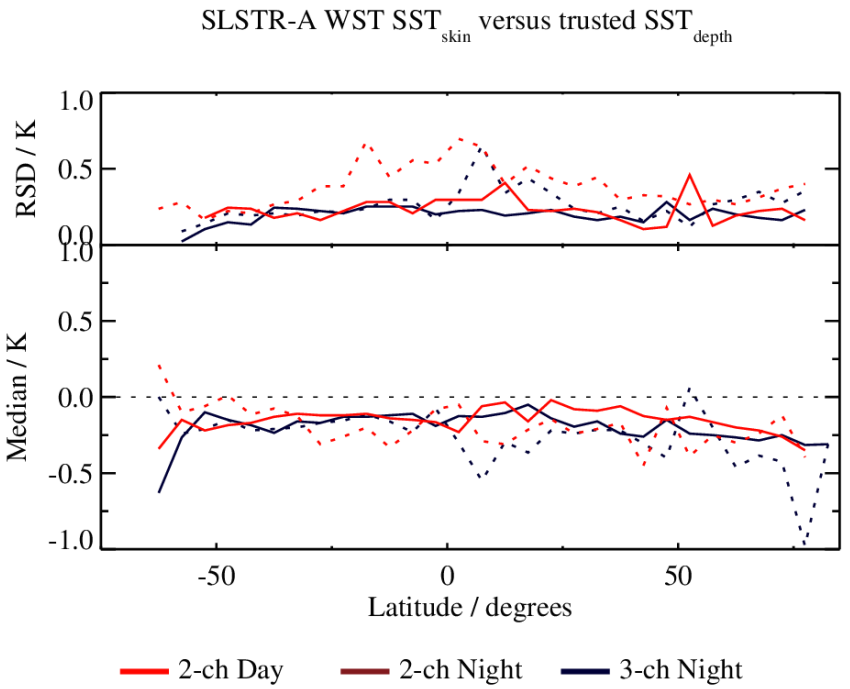


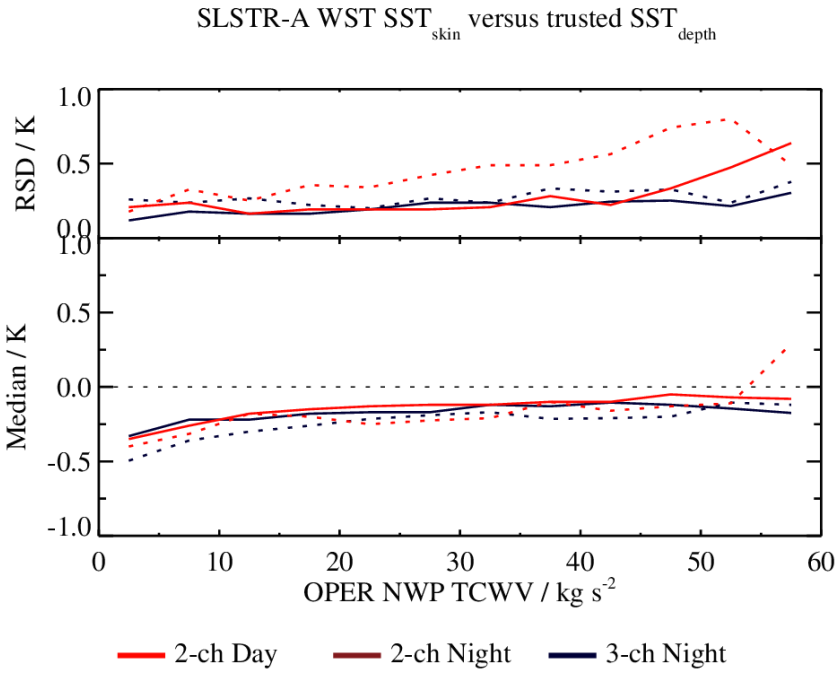
SLSTR SST validation using TRUSTED drifters

- TRUSTED SSTs included in SLSTR MMDB and available on request
- Validation and results ongoing
- Utilisation of full metadata and QC in progress
- Considerations of validation methodology in progress
  - Whether to use traditional drifting buoy validation methods or to treat TRUSTED in a similar way to GTMBA and ship-borne radiometers for long-term stability analyses
  - This would have impacts on deployment planning to ensure the longest lifetime possible for each buoy for the stability analyses









Definitions and coordination with WMO-Data Buoy Cooperation Panel

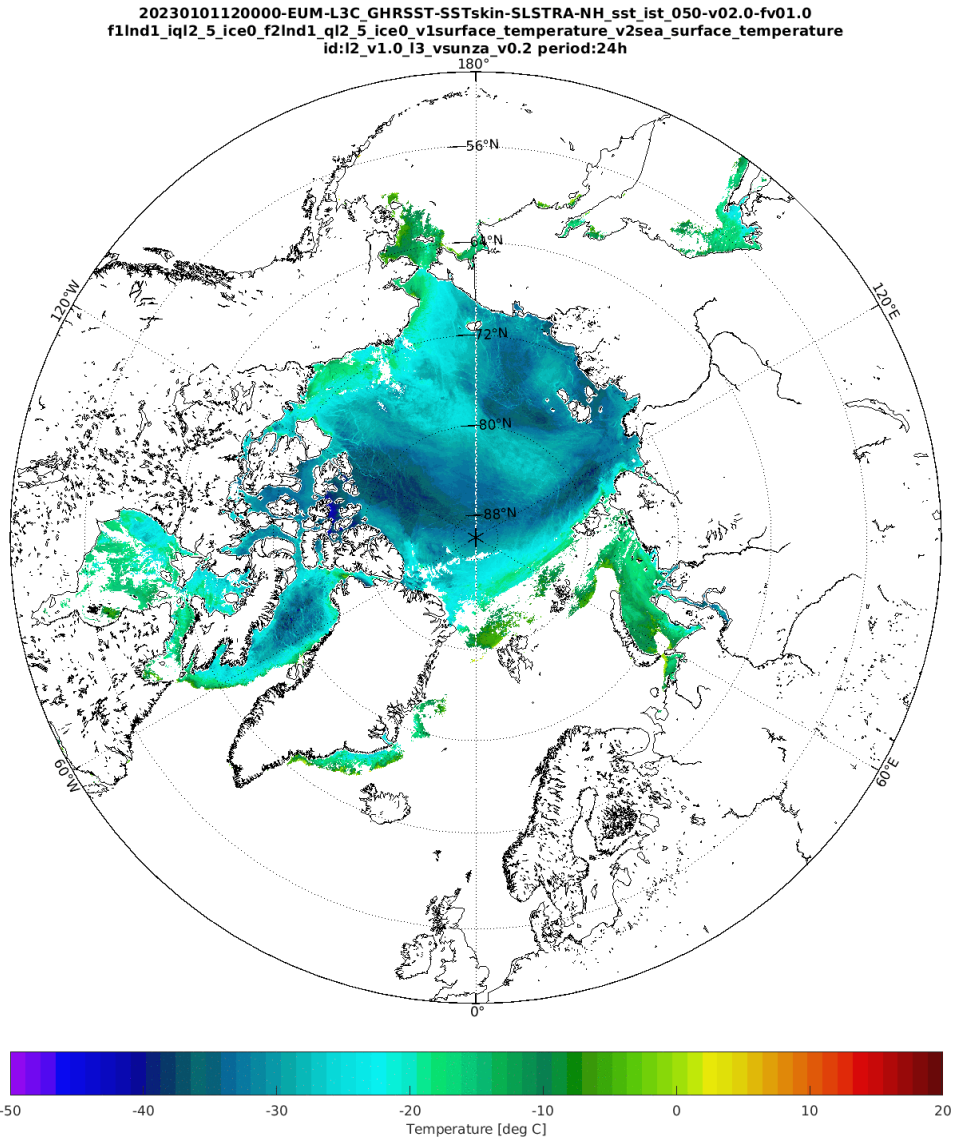
- WMO DBCP-GHRSST Pilot Project (2013)
  - Position accuracy and reporting to 0.01degrees (HRSST-1)
  - SST accuracy < 0.05K; reporting to 0.01K (HRSST-2)
  - Total standard uncertainty in measured SST to be < 0.05K

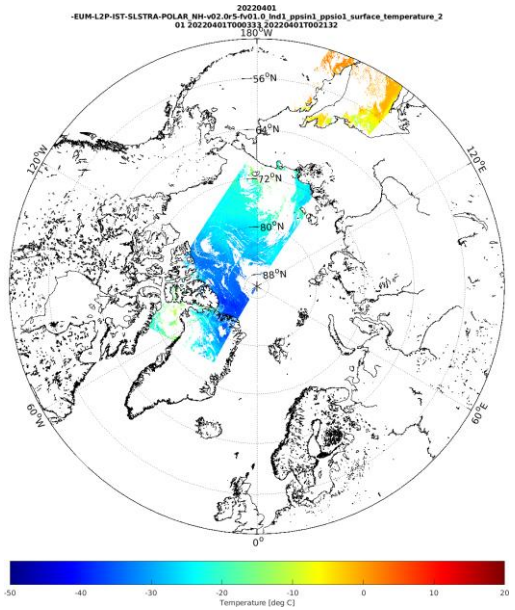
- Two definitions for HRSST-2 and FRM drifters presented to DBCP-37 (https://www.eumetsat.int/media/48924):
  - HRSST-2 Original DBCP/GHRSST specification plus machine searchable / accessible global metadata information (in progress with OceanOps)
    - Global reference dataset
  - FRM for drifters (e.g. TRUSTED)
    - TRUSTED follows HRSST-2 specification (sensor referred to as TRST)
    - **PLUS:** Calibration per sensor in laboratory independent of sensor manufacture
    - Definition of uncertainty budget / traceability diagram
    - Measurement metadata and improved Quality Control
    - Coordination with National Metrology Institutes and EMN
    - Post-deployment calibration and analysis where opportunity

Task Team 3 – HRSST drifters for satellite SST validation – Gary Corlett

High quality satellite sea-ice surface temperature (IST)

- IST classified as an ECV with requirements of 1K total uncertainty
- Poor coverage of IST in situ observations in the high-latitudes limits the satellite IST algorithm development and validation
- Developments towards reference dual-view SLSTR IST, now pre-operational, require IST FRM for validation



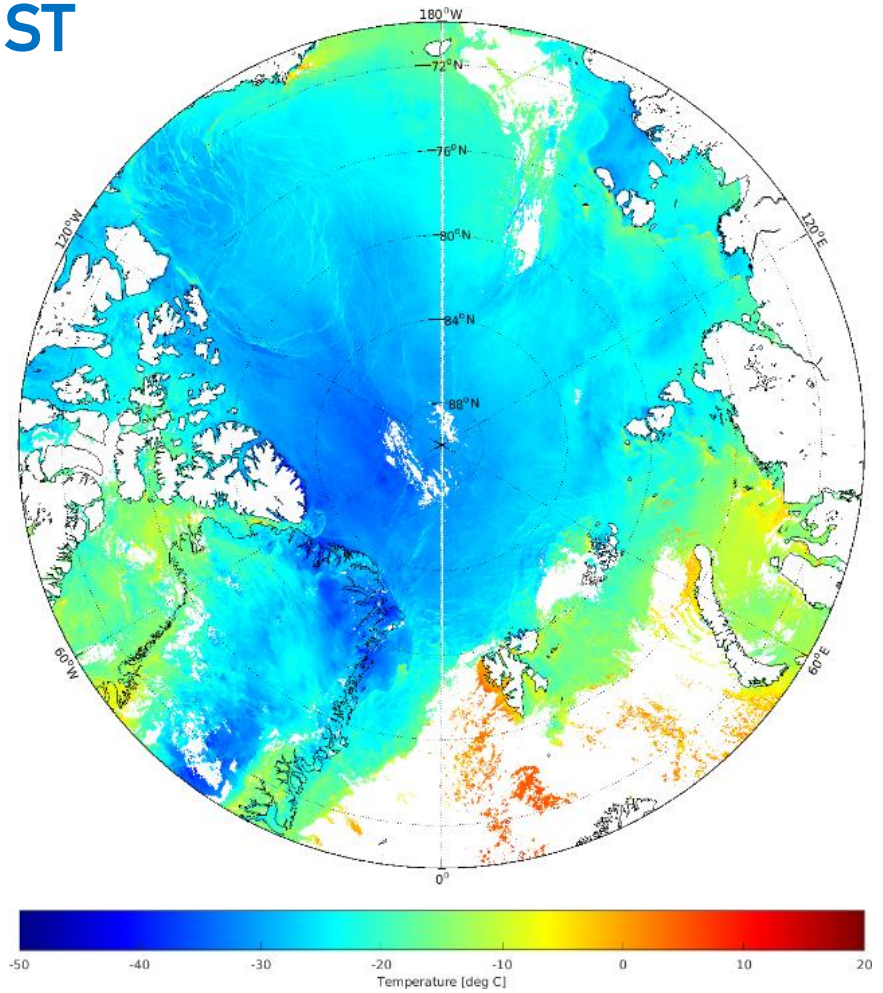


For details on SLSTR IST see presentation by Gary Corlett on Wed 12 June "**Evolution of Copernicus Marine Surface Temperature Products in Coastal Regions and High Latitudes**" in Science Session 3 – Challenging Regions: the coastal margin and the Arctic

Development of FRM for sea-ice surface temperature (IST)

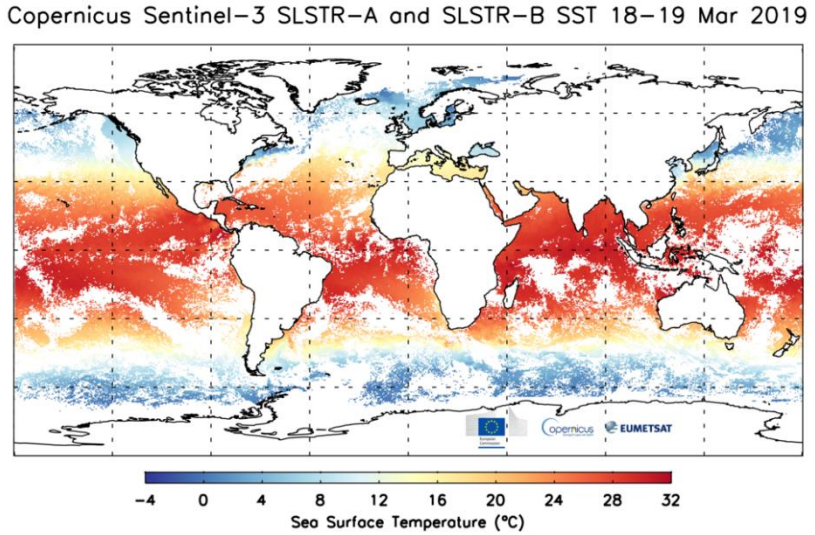
Critical need for Fiducial Reference Measurements for IST

- Design and prototype in progress to provide Copernicus FRM over sea-ice began in TRUSTED project in 2022
- Sea-ice buoy requirements (2022), DMI, NKE, SHOM et al.: https://www.eumetsat.int/media/50550
- Last year 2023 focused on the IST sensor design and prototype
- This year 2024 focuses on buoy prototype, testing and calibration activities;
- Testing, calibration, and operational deployments and service to follow in 2025-2027.



Summary and conclusions

- Continuation of FRM is crucial for underpinning climate and reference satellite SST data quality, validating uncertainties and assessing long term stabilities for Climate Data Records.
- Activities on developing FRM for sea-IST is critical to continue for validating the new era of highest quality, dual-view, satellite sea-IST products e.g. from Sentinel-3 SLSTR.
- TRUSTED project deployed over 187 SST FRM drifters since 2019, and IST prototype testing and calibration is underway
- Further work is needed on documenting the traceability trees and uncertainty diagrams for the validation methodology e.g. conversion of skin to depth SST
  - Consideration of skin to depth in validation methodology
- Considerations needed on validation methodology for TRUSTED e.g. traditional method of drifting buoys or using stability methods such as those used for GTMBA and ship-borne radiometers



Further acknowledgements

Jerome Sagot, Mathieu Belbeoch, Long Jiang, Kai Herklotz, Sebastien Pere

- ## Publications

- Le Menn M., et al, 2019, Development of Surface Drifting Buoys for Fiducial Reference Measurements of Sea-Surface Temperature, Frontiers in Marine Science,6, https://doi.org/10.3389/fmars.2019.00578

- Poli P., et al, 2019, The Copernicus Surface Velocity Platform drifter with Barometer and Reference Sensor for Temperature (SVP-BRST): genesis, design and initial results, Ocean, Sci., 15, 199 214, https://doi.org/10.5194/os-15-199-2019

Thank you!

Questions are welcome.

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