Assessment of SLSTR L2P SST data as inputs in the CMEMS MED L3S/L4 multi-sensor operational system

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Introduction

- Integration of SLSTR-3A/-3B is one of the priorities of the evolution plans of the CMEMS SST operational systems

- The objective is to include the Sentinel-3A SLSTR data in the CMEMS CNR MED SST operational system that runs operationally to produce and deliver daily (nighttime) merged multi-sensor (L3S) and gap-free (L4) SST maps for the Mediterranean Sea

- L3S data are assimilated into the CMEMS MED MFCs

- L4 is assimilated to the national regional model component of MONGOOS and one of the most downloaded products of CMEMS

CMEMS Mediterranean SST Products

Product name	Parameters
SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012	Mediterranean Sea - High Resolution and Ultra High Resolution L3S Sea Surface Temperature
SST_MED_SST_L4_NRT_OBSERVATIONS_010_004	Mediterranean Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis
SST_MED_SST_L4_REP_OBSERVATIONS_010_021	Mediterranean Sea - High Resolution L4 Sea Surface Temperature Reprocessed (1981-2015)

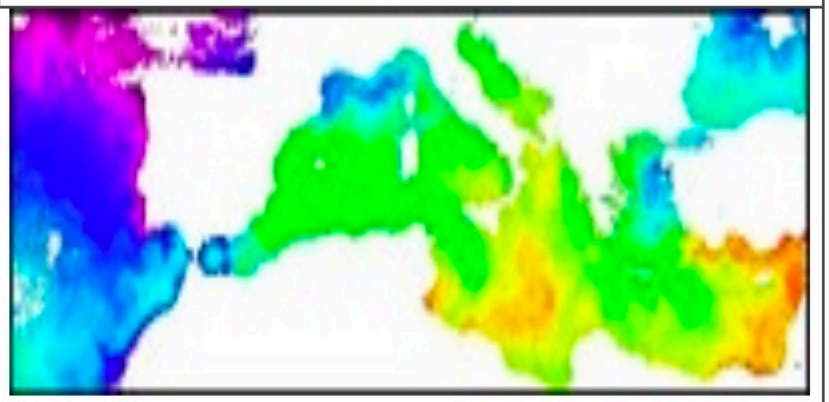
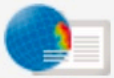
NRT: products within few hours, NRT **replaced by consolidated product** after few days
REP: consistent re-processed time series

L3S: daily (**merged-multisensor)** products; **L4** analysis (no data gaps)

L3S and L4 includes two datasets:

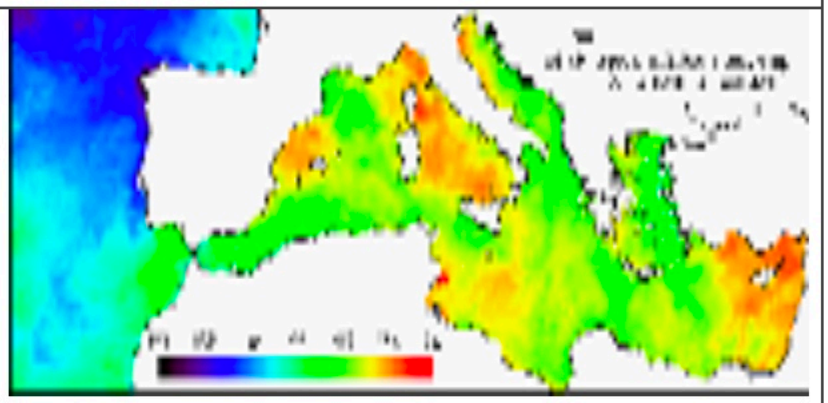
- High Resolution (HR): 1/16° (0.0625°) spatial resolution ;
- Ultra High Resolution (UHR): 0.01° spatial resolution

CMEMS Mediterranean SST Products

SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012		
MEDITERRANEAN SEA - HIGH RESOLUTION AND ULTRA HIGH RESOLUTION L3S SEA SURFACE TEMPERATURE		
OBSERVATION	L3	MED
SST ⓘ		
0.063 degree x 0.063 degree (Surface only)		
From 2008-01-01 to Present		
daily-mean		
MORE INFO  ADD TO CART  WMS Sub-setting		

The L3S data are produced selecting only the highest quality input data from input L2P/L3P images within a strict temporal window (local nightime), to avoid diurnal cycle and cloud contamination.
L3S processing is run daily, but L3S files are produced only if valid SST measurements are present on the area considered.

CMEMS Mediterranean SST Products

SST_MED_SST_L4_NRT_OBSERVATIONS_010_004		
MEDITERRANEAN SEA HIGH RESOLUTION AND ULTRA HIGH RESOLUTION SEA SURFACE TEMPERATURE ANALYSIS		
OBSERVATION	L4	MED
SST ⓘ		
0.01 degree x 0.01 degree (Surface only)		
From 2008-01-01 to Present		
daily-mean		
MORE INFO ADD TO CART WMS Sub-setting		

The CNR MED Sea Surface Temperature provides daily gap-free maps (L4) at high (HR 0.0625°) and ultra-high (UHR 0.01°) spatial resolution over the Mediterranean Sea. The data are obtained from infra-red measurements collected by satellite radiometers and statistical interpolation.

A two-step algorithm allows to interpolate SST data at high (HR 0.0625°) and ultra-high (UHR 0.01°) spatial resolution, applying statistical techniques.

CNR Processing Chain

CNR-ISAC-GOS SST processing chain is designed as a two-step process:

1) high resolution (HR) processing and interpolation
2) ultra-high resolution (UHR) is run in sequence

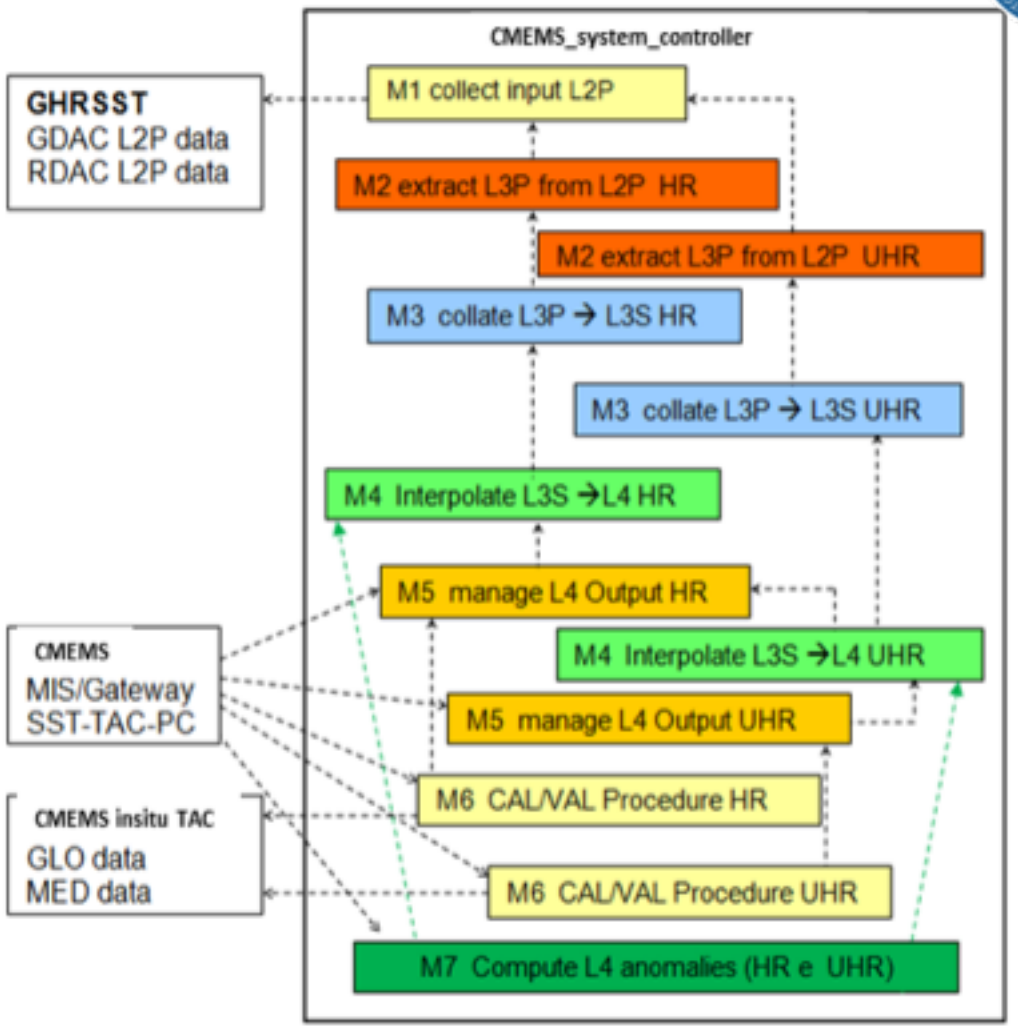


Figure III.1 Schematic diagram of the operational processing chain at GOS - ISAC - CNR.

Buongiorno Nardelli B., C.Tronconi, A. Pisano, R.Santoleri, 2013: High and Ultra-High resolution processing of satellite Sea Surface Temperature data over Southern European Seas in the framework of MyOcean project, Rem. Sens. Env., 129, 1-16, doi:10.1016/j.rse.2012.10.012.

CNR Processing Chain: Quality control of L2P

Quality control and CLOUD detection algorithms

Cloud detection is an essential step to provide "high quality" SST fields for data assimilation

Cloud detection requires a compromise between maximization of coverage and minimization of cloud contaminated pixels

Cloud detection at CNR is performed at various steps:

→ **On original images, before the composite is performed:**

Applying selection criteria on L2P confidence flag, rejection flag, proximity confidence (etc.)

→ **Before selecting SST data in the optimal interpolation algorithm:** comparison to the nearest analysis available (if interpolation error is lower than a fixed value)

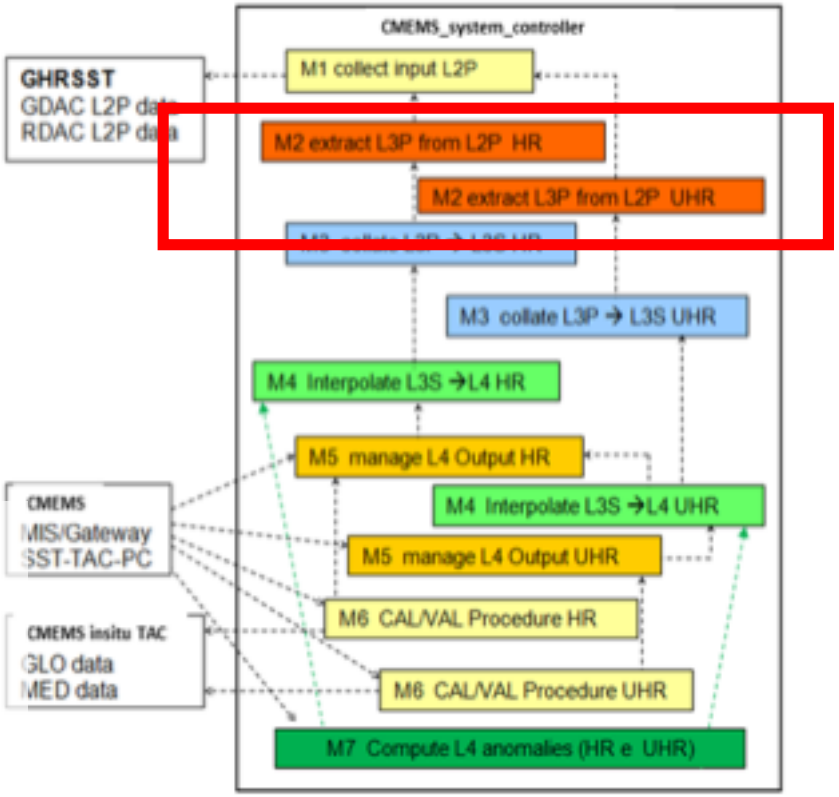


Figure III.1 Schematic diagram of the operational processing chain at GOS - ISAC - CNR.

CNR Processing Chain: Merging L2P -> L3C

”SUPERCOLLATED” files (L3S):

- External product
- Interpolation uses L3S in input (1 SST map per day)

Merging procedure selects valid pixels using a **predefined sensor hierarchy**

Before adding data to the merged map, the bias between each new image and the pixels that have already been merged is estimated and removed
(only if sufficient co-located pixels are found)

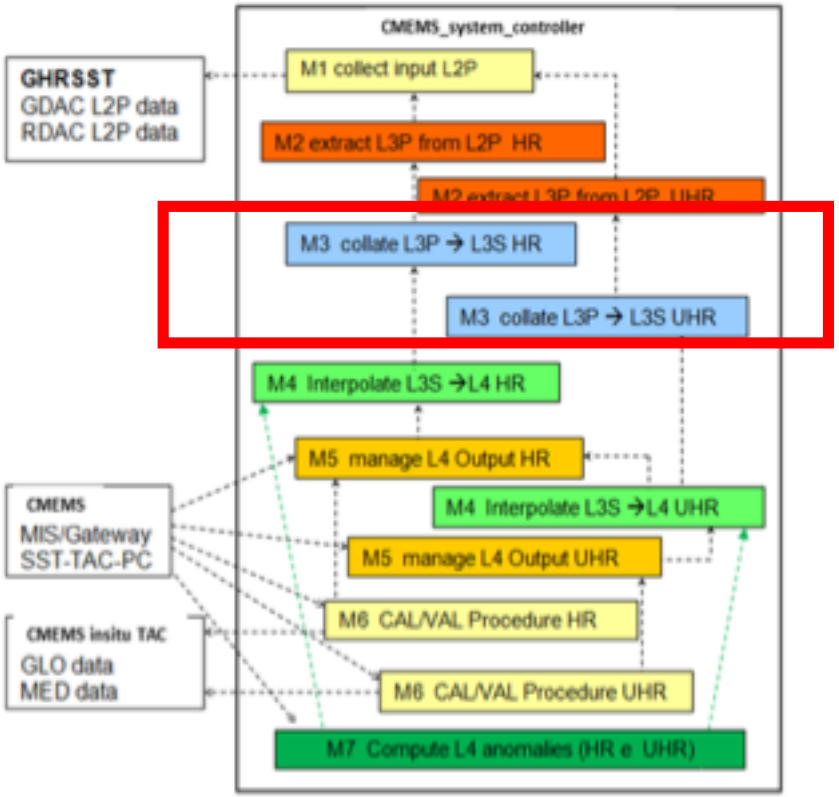


Figure III.1 Schematic diagram of the operational processing chain at GOS - ISAC - CNR.

CNR Processing Chain: interpolation

Estimates the anomaly field with respect to a ***first guess***, assuming statistical characteristics of the variability are known (***background error covariance*** and ***observation error covariance***).

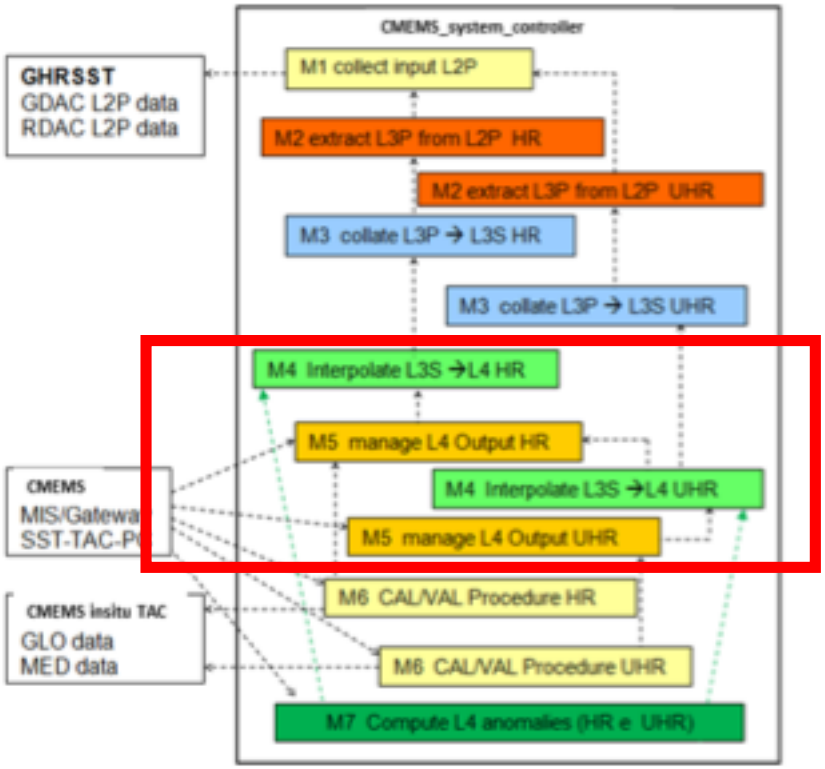


Figure III.1 Schematic diagram of the operational processing chain at GOS - ISAC - CNR.

1) **MED HR L4 near-real-time** processing algorithm based on:

- Spatially variable covariance function model
- Pentad climatological background field

2) **MED UHR L4 near-real-time** processing algorithm based on:

- the first guess is the HR SST field→ scale separation
- Covariance function and decorrelation time/space scales are defined a priori

CMEMS product update procedure

- CMEMS, being an operational system, requires that any update of algorithm/input data must be scientific evaluated before to transferred in the operational system.

- The qualification steps before the update of an existing products require:
  - Validation against in situ data via matchup data analysis
  - Comparison with operational version of the products
  - results of the evaluation should demonstrate not regression in accuracy of the product.

- Product assessed: SLSTR-3A L2P SST NRT with processing baseline 2.18
- Validation period: July 2017 – March 2018 (9 months)

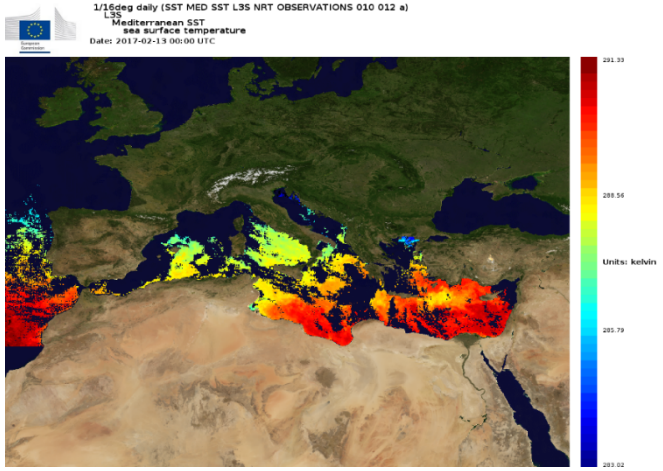
CMEMS MED SST Processing System: Overview

- CNR provides daily (nighttime) supercollated (merged multi-sensor) **L3S** and gap-free **L4** maps
  - The data are obtained from **L2P** infrared measurements collected by satellite radiometers from 18.00 UTC to 06.00 UTC
    - The MED product is representative of the foundation SST

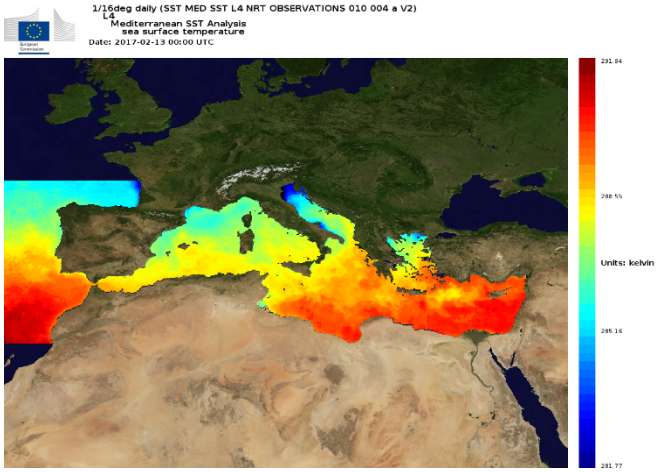
L2P

Hierarchy	L2P Code
1	VIIRS
2	METOP B
3	MODIS AQUA
4	MODIS TERRA
5	SEVIRI

L3S



L4



- VIIRS is the reference sensor with which the other sensors are bias adjusted

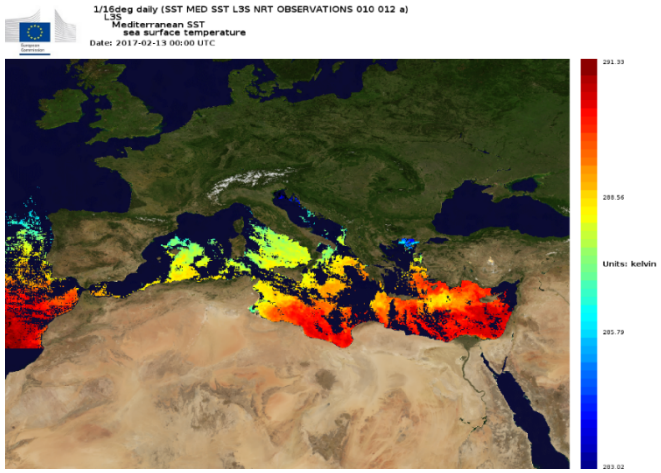
CMEMS MED SST Processing System: Overview

- For the Mediterranean Sea, CNR provides daily (nighttime) supercollated (merged multi-sensor) **L3S** and gap-free **L4** maps at 1/16°deg. horizontal resolution
  - The data are obtained from **L2P** infrared measurements collected by satellite radiometers from 18.00 UTC to 06.00 UTC
  - The MED product is representative of the foundation SST

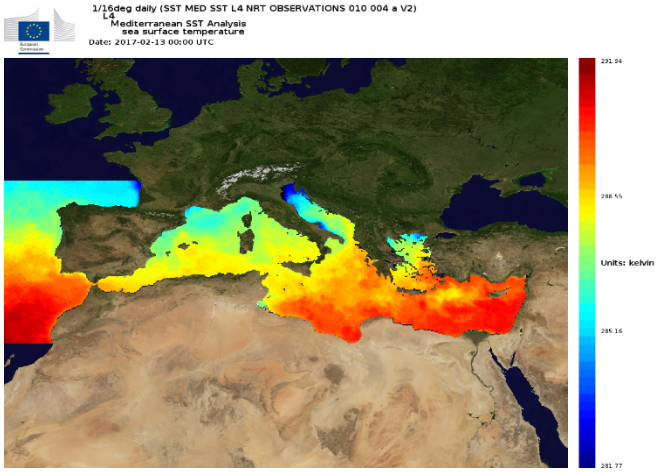
L2P

Hierarchy	L2P Code
1	VIIRS
2	METOP B
3	MODIS AQUA
4	MODIS TERRA
5	SEVIRI

L3S



L4

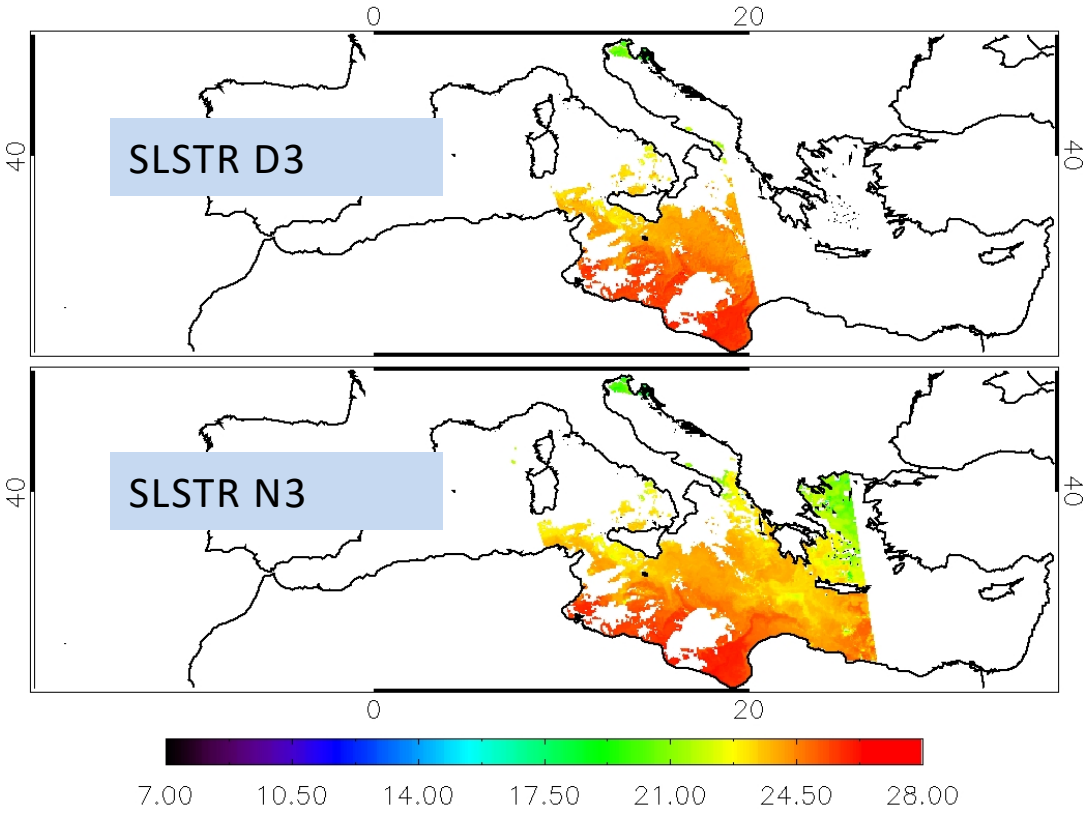


- **CMEMS System Evolution:** ingest, validate and possibly use SLSTR L2P as reference in the MED operational chain

SLSTR L2P SST: Dual and Nadir View Separation

- The offset at the edges of the oblique-view in the combined-view product is still present

- The *sea_surface_temperature* variable is split into two distinct variables, by using the *sst_algorithm_type* variable:
  1. SLSTR D3: Dual View (just extrapolated and left unchanged)
  2. SLSTR N3: Nadir view, obtained by subtracting to *sea_surface_temperature* the *dual_nadir_sst_difference* variable



- The offset has been removed in the nadir view
- Then, for each L2P file, we deal with two different SST maps each of which will be treated separately
- The basic idea is to choose D3 (the most accurate) as the reference SST while N3 will be adjusted by using the sensor hierarchy

SLSTR L2P SST: Dual and Nadir View Separation

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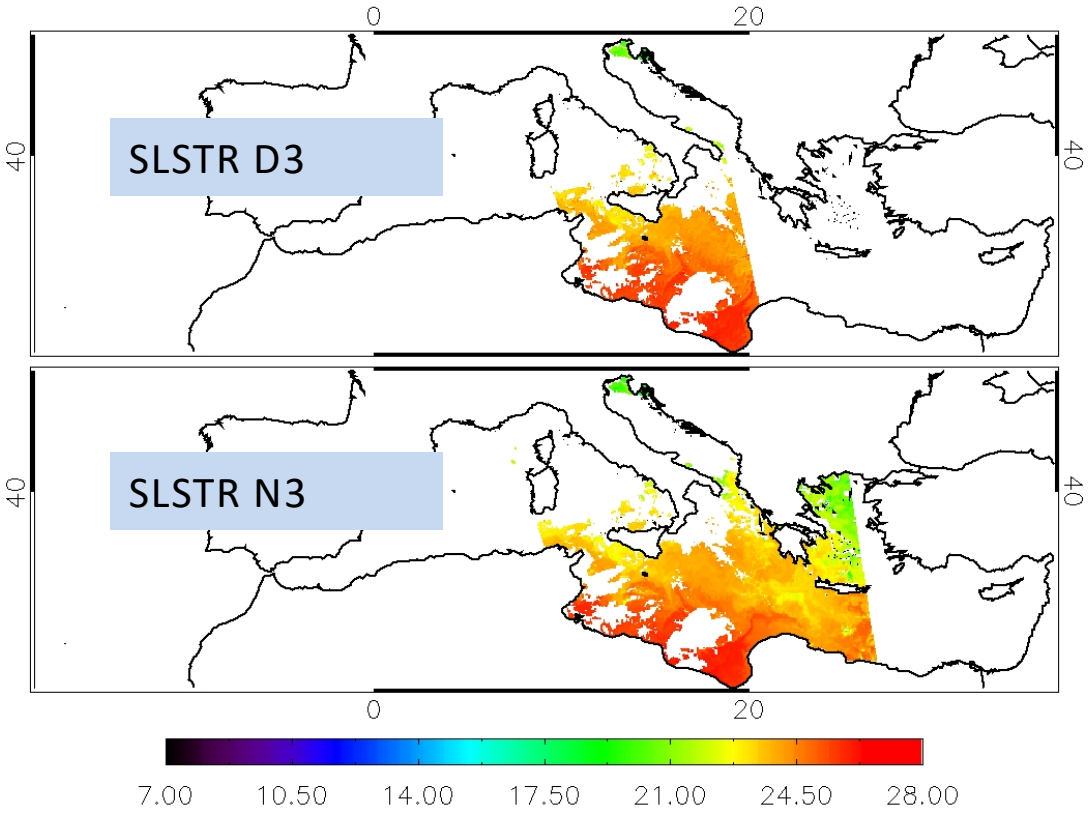


- This is the L2P hierarchy configuration we tested:

Hierarchy	L2P
1	SLSTR D3
2	VIIRS
3	METOP B
4	MODIS AQUA
5	MODIS TERRA
6	SLSTR N3
7	SEVIRI

SLSTR L2P SST: Skin to foundation adjustment

- A huge bias of about -0.35 °C between SLSTR D3 vs. surface drifter data was found
- This is likely due to the fact that:
  - SLSTR SST retrieval provides SKIN SST
  - CNR MED retrieval provides FOUNDATION SST
- On average, the difference between skin and bulk temperature is about −0.2 °C at night (Gentemann & Minnett, 2008)
  - **Skin + 0.2 °C** SLSTR L2P SST data are now corrected to foundation SST

Gentemann, C. L., & Minnett, P. J. (2008)
Radiometric measurements of ocean surface
thermal variability.
Journal of Geophysical Research, 113, C08017. http://dx.doi.org/10.1029/2007JC004540.

Ingestion of SLSTR: Matchup analysis

- First step: SLSTR/VIIRS/METOP B intercomparison as mono sensor L3C products angainst a common in situ dataset

- Final step: SLSTR impact on the L3S and L4 products

- Validation period

July 2017 – March 2018

- Matchup Dataset

co-located satellite - drifter obs. (in space and time) with the following criterion:

1. *Space Criterion* drifter obs. always falling within the L3S/L4 grid cell
2. *Time Criterion* drifter obs. restricted from 9 p.m. to 6 a.m. solar local time
3. *Quality Control* (applied only to the selected drifter obs.):
   - 3.1 |drifter – daily climatology| < 5 °C
   - 3.2 |drifter – prev. L4 day| < 1.5 °C

Mono Sensor vs. In Situ: SLSTR/VIIRS/METOP B Intercomparison

L3C vs. In Situ comparison [July 2017 – March 2018]

L3C SLSTR D3/VIIRS/METOP B vs. in situ on common matchups

MED L3C	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
SLSTR D3	-0.13 ± 0.04	0.37 ± 0.04	0.39 ± 0.04	297
VIIRS	-0.26 ± 0.04	0.39 ± 0.04	0.47 ± 0.04	297
METOP B	-0.12 ± 0.05	0.42 ± 0.04	0.44 ± 0.04	297

L3C SLSTR D3/VIIRS vs. in situ on common matchups

MED L3C	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
SLSTR D3	-0.09 ± 0.03	0.38 ± 0.02	0.39 ± 0.03	834
VIIRS	-0.28 ± 0.03	0.43 ± 0.03	0.51 ± 0.03	834

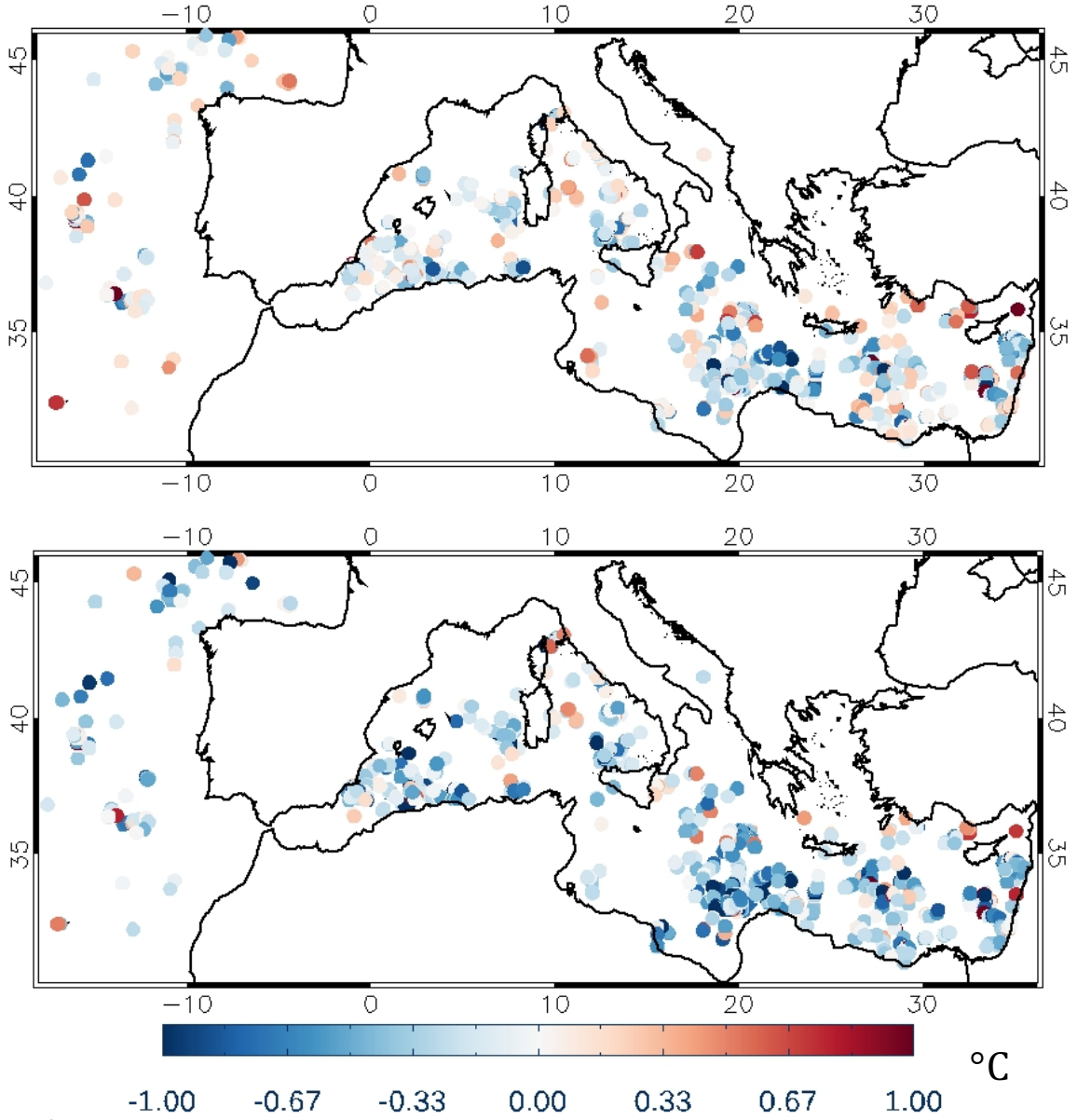
L3C SLSTR D3/METOP B vs. in situ on common in situ matchups

MED L3C	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
SLSTR D3	-0.10 ± 0.03	0.37 ± 0.03	0.38 ± 0.03	440
METOP B	-0.09 ± 0.04	0.42 ± 0.04	0.43 ± 0.04	440

Mono Sensor vs. In Situ: SLSTR and VIIRS on common matchups

SLSTR D3 - in situ (bias)

VIIRS - in situ (bias)



Ingestion of SLSTR: Assessment Results

- Validation period

05th July 2017 – 31th March 2018

- Matchup Dataset

co-located satellite - drifter obs. (in space and time) with the following criterion:

1. *Space Criterion* drifter obs. always falling within the L3S/L4 grid cell
2. *Time Criterion* drifter obs. restricted from 9 p.m. to 6 a.m. solar local time
3. *Quality Control* (applied only to the selected drifter obs.):
   - 3.1 |drifter – daily climatology| < 5 °C
   - 3.2 |drifter – prev. L4 day| < 1.5 °C

MED L4	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
Upgrade to SLSTR	-0.09 ± 0.01	0.41 ± 0.01	0.42 ± 0.01	10617
Ref. L4	-0.18 ± 0.01	0.41 ± 0.01	0.45 ± 0.01	10613

MED L3S	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
Upgrade to SLSTR	-0.15 ± 0.01	0.43 ± 0.01	0.46 ± 0.01	7694
Ref. L3S	-0.24 ± 0.01	0.43 ± 0.01	0.49 ± 0.01	7579

Ingestion of SLSTR: Comments

- A Bias reduction is evident with respect to the reference operational product
- No significant (at 95% conf. interval) difference in the Standard Deviation
- Significant (at 95% conf. Interval) difference in the RMSE for both L3S/L4 products

MED L4	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
Upgrade to SLSTR	-0.09 ± 0.01	0.41 ± 0.01	0.42 ± 0.01	10617
Ref. L4	-0.18 ± 0.01	0.41 ± 0.01	0.45 ± 0.01	10613

MED L3S	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
Upgrade to SLSTR	-0.15 ± 0.01	0.43 ± 0.01	0.46 ± 0.01	7694
Ref. L3S	-0.24 ± 0.01	0.43 ± 0.01	0.49 ± 0.01	7579

Conclusions

- Careful validation of SLSTR data has been carried out before its integration, in order to assess the impact and accuracy in the MED and BS products.
- The new L2P SST product from SLSTR sensor on board Sentinel-3A has been sucessfully integrated in the MED and BS processing chains.
- SLSTR-3A is operational used as reference sensor in CNR processing chain
- Since 23 March 2018, Sentinel-3A SLSTR data used to build daily (nighttime) merged multi-sensor (L3S) and gap-free (L4) SST maps for the Mediterranean Sea by using the CMEMS CNR MED SST operational system and the results validated by using drifter observations in NRT
- As soon as the reprocessed Sentinel-3A SLST will be available we plan to reprocessed the entire time series of L3S a L4 NRT in order to provide a consistent time series of SST produts to CMEMS the users
- Evaluation of SLSTR will continue in the future

1km daily (SST MED SST L4 NRT OBSERVATIONS 010 004 c V2)
L4
Mediterranean SST Analysis
sea surface temperature
Date: 2018-06-05 00:00 UTC

Thanks for your attention