Copernicus Sentinel-3 SST L1 to L4 processing chain and GHRSST perspectives

Anne O'Carroll

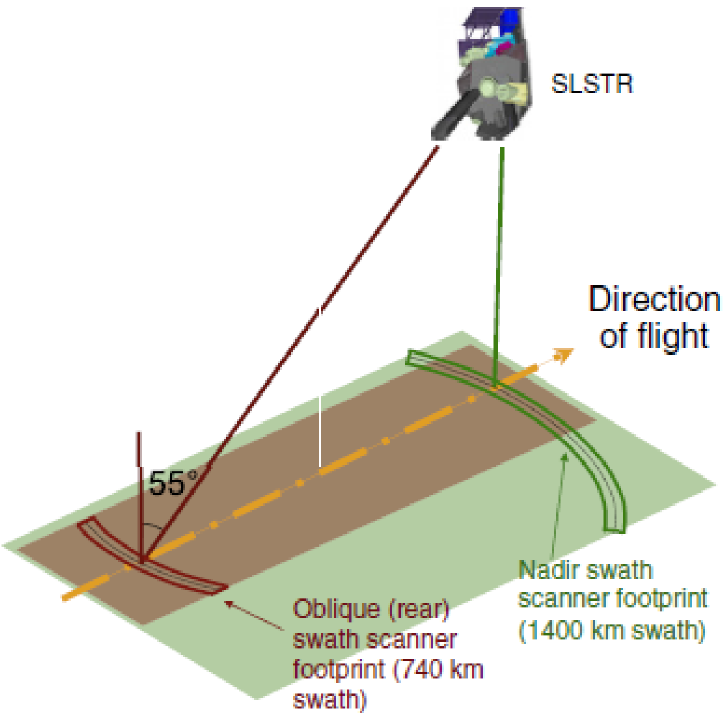
23/1/2018

ECMWF workshop on SST and sea-ice

Outline

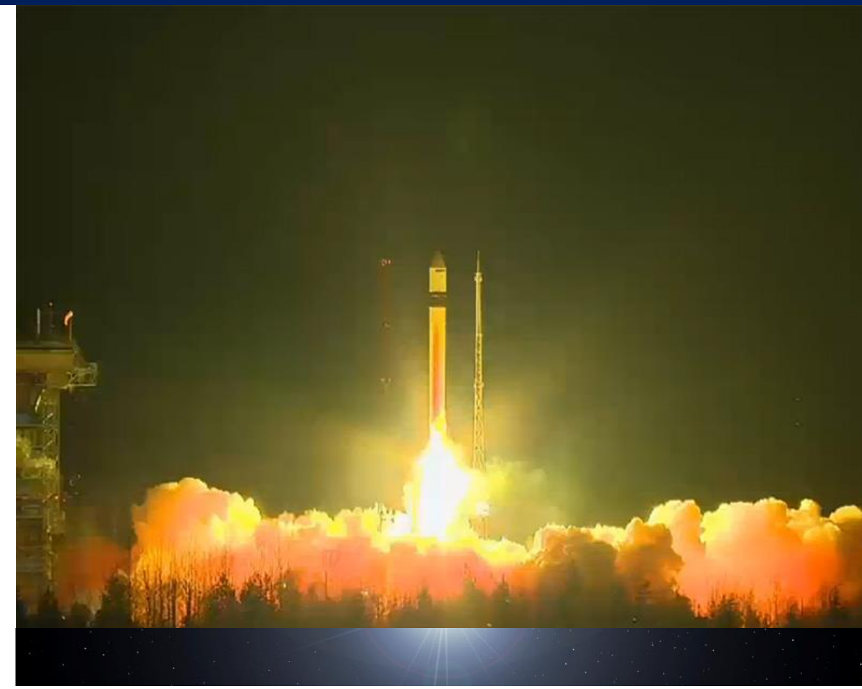
- Sentinel-3 Sea Surface temperature
  - Products and mission organisation
  - L1 to L2
- CMEMS examples (L3 to L4)
- GHRSST internationally agreed standards
- Improved drifting buoy SST
- Summary

Copernicus Sentinel-3 SLSTR



Sea and Land Surface Temperature Radiometer

-



Band characteristics of the Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR). F1 and F2 are dedicated active fire monitoring bands.

SLSTR band	L centre [μm]	ΔL [μm]	SNR [−]/ NeΔT [mK]	SSD [km]	Function
S1	0.555	0.02	20	0.5	Cloud screening, vegetation monitoring, aerosol
S2	0.659	0.02	20	0.5	NDVI, vegetation monitoring, aerosol
S-3	0.865	0.02	20	0.5	NDVI, cloud flagging, Pixel co-registration
S4	1.375	0.015	20	0.5	Cirrus detection over land
S5	1.61	0.06	20	0.5	Cloud clearing, ice and snow, vegetation monitoring,
S6	2.25	0.05	20	0.5	Vegetation state and cloud clearing
S7	3.74	0.38	80 mK	1.0	SST, LST, Active Fire
S8	10.95	0.9	50 mK	1.0	SST, LST, active fire
S9	12	1.0	50 mK	1.0	SST, LST
F1	3.74	0.38	<1 K	1.0	Active fire
F2	10.95	0.9	<0.5 K	1.0	Active fire

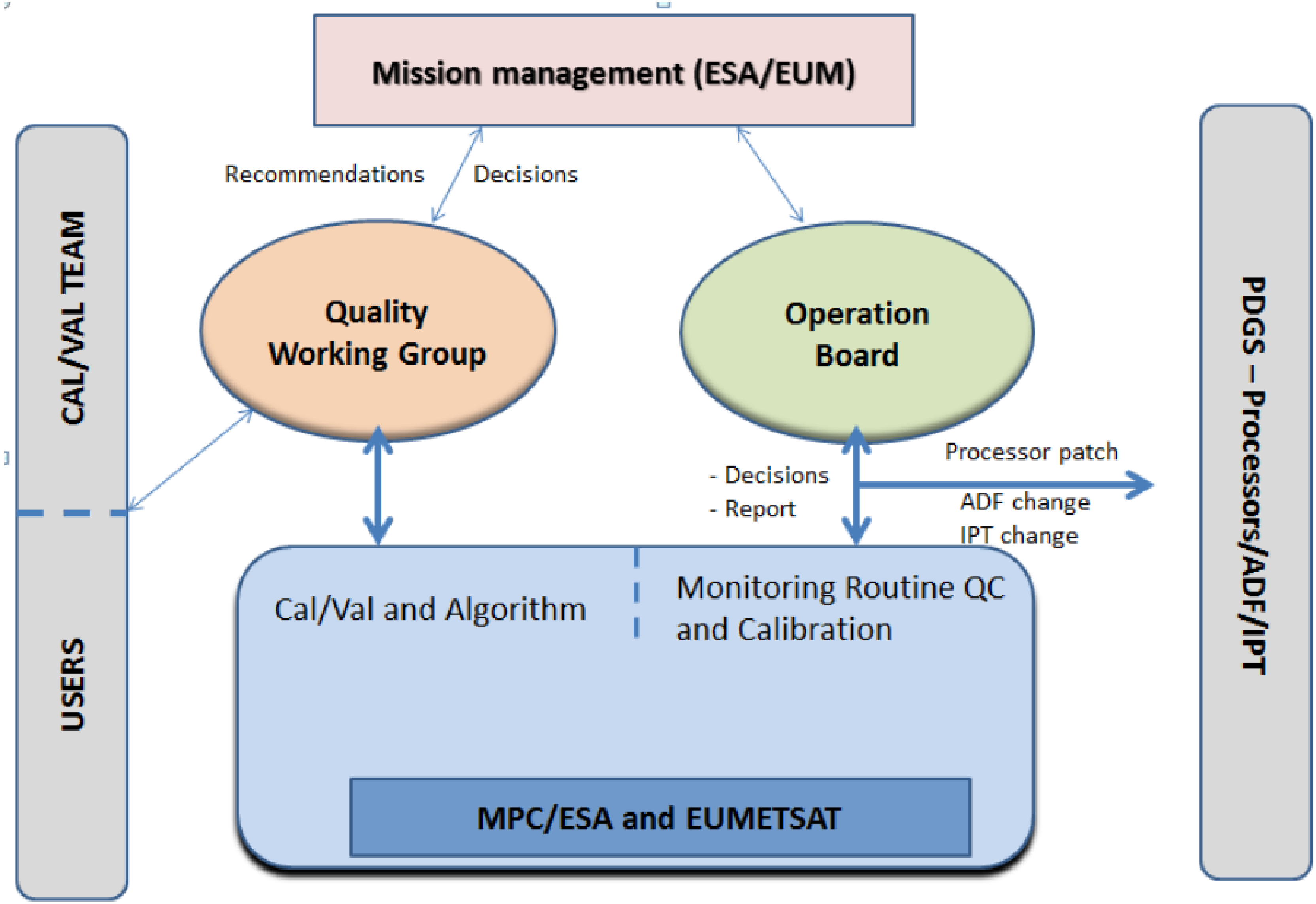
- S3A launched 16th February 2016.
- SLSTR L2 data to S3VT 21/6/16.
- Operational L2 SST 5/7/17.
- Bayesian cloud implementation 01/18.

SLSTR marine products from EUMETSAT

Product	EUMETCast	ODA	Data Centre (UMARF)	Timeliness
SLSTR L1B		✓	✓	NRT, NTC
SLSTR L2 WST (GHRSST L2P)	✓	✓	✓	NRT
		✓	✓	NTC
SLSTR L2 WCT	Internal products only available to "special users"		✓	NRT
			✓	NTC

- Internal products available to Sentinel-3 validation team

Mission Performance Framework



Level-1: SLSTR

Overview and constraints:

- Continuity with (A)ATSR
- Incorporation of new features: wider swath, new channels and high resolution in some channels

Main processes (level-1a and level-1b):

Source packet processing

IR and VIS/SWIR calibration (without applying)

Time calibration

Geolocation

Measurement calibration

Time domain averaging (SWIR)

Re-gridding and cosmetic filling

Surface classification and cloud identification

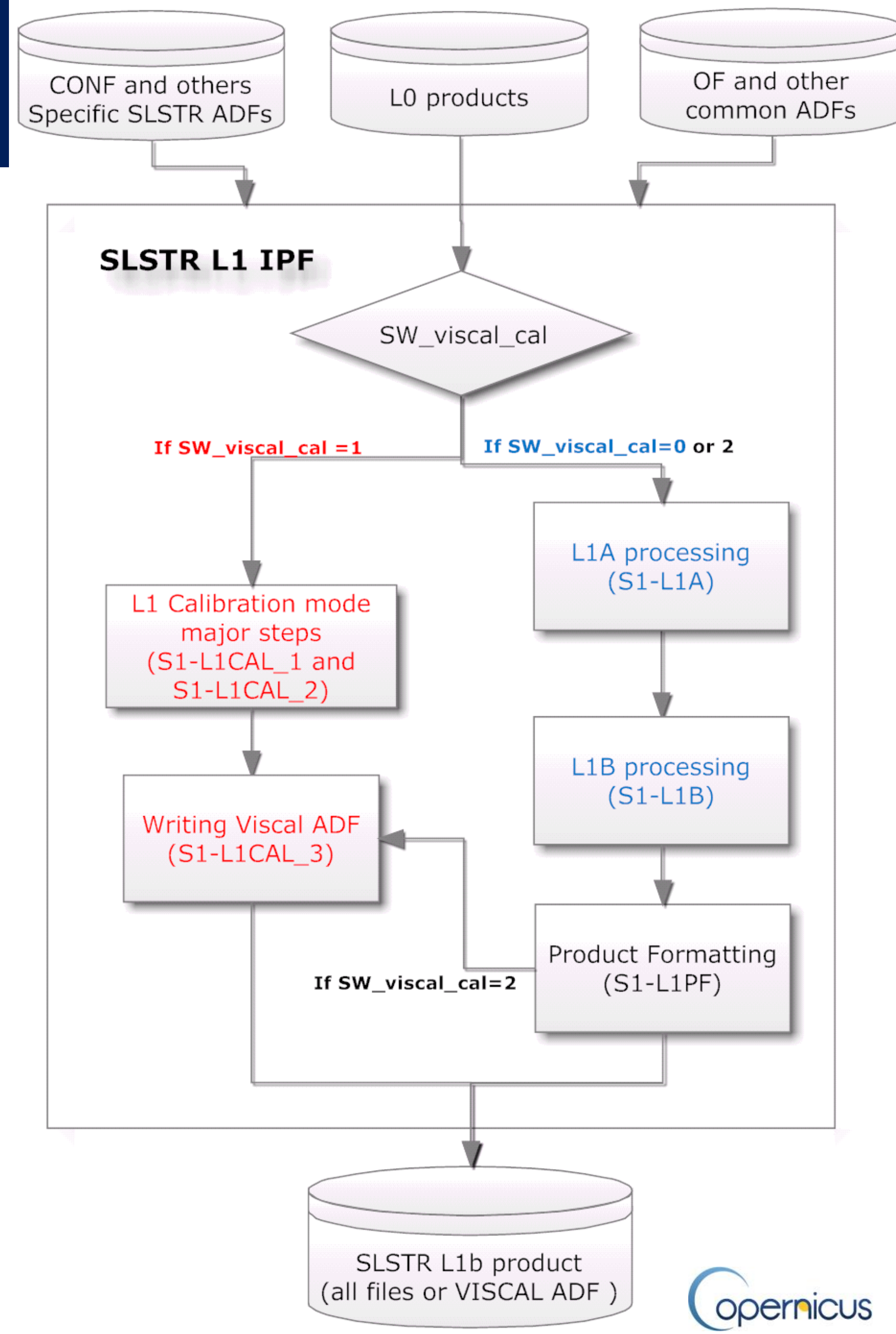
Provision of meteorological fields at tie points

Science & Technology Facilities Council
Rutherford Appleton Laboratory

SLSTR L1 processor

1) L1 calibration: computation of calibration parameters

2) Calculate radiances / BTs from counts



EUMETSAT

Science & Technology Facilities Council
Rutherford Appleton Laboratory

esa

Copernicus

Level-2: SLSTR

Overview and constraints:

- Derivation of single-algorithm SSTs (D3, D2, N3, N2, N3R)

Main processes:

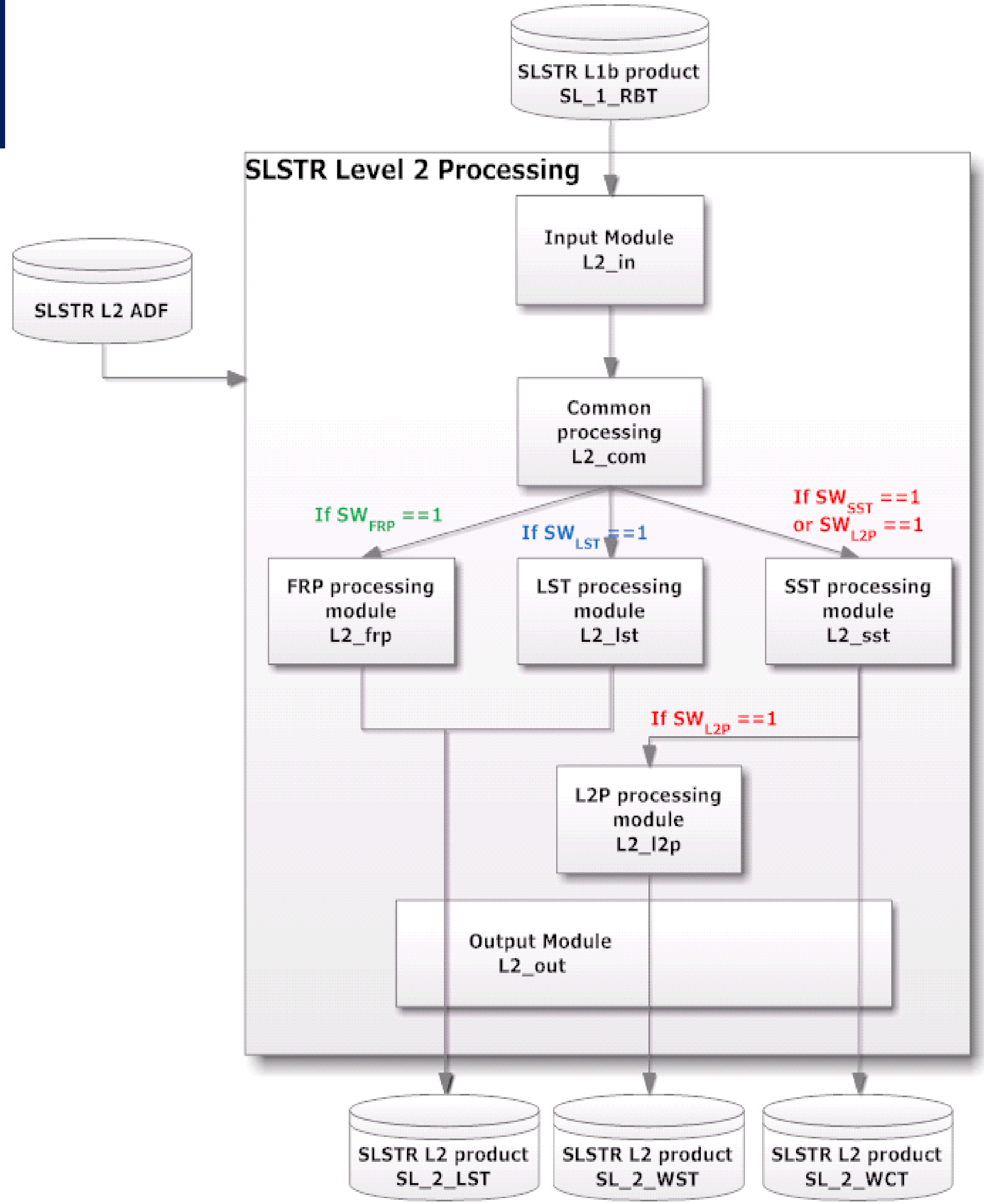
Common processing e.g. uncertainty estimation on all channels

SST step: single-algorithm SST and uncertainty calculations

L2P step: GHRSST quality levels, Sensor Specific Error Statistics, populate L2P with "best" choice SST and auxiliary data

SLSTR L2 processor

- Marine -> EUMETSAT
- Land -> ESA



Copernicus S3-SLSTR SST

Follows GHRSST L2P Specification (GDS2r5)

GHRSST
Group for High Resolution Sea Surface Temperature

https://www.ghrsst.org/documents/q/category/ghrsst-data-processing-specification-gds/operational/

- NetCDF4
- Level-2 swath product
- Skin Sea Surface Temperature (one of D3, N3, D2, N2, N3R)
- Auxiliary ECMWF wind-speed, sea-ice fraction, background SST
- Aerosol dynamic indicator – Saharan Dust Index
- Uncertainty estimates: SSES, pixel theoretical uncertainty
- Experimental fields: nedt, nadir BTs.

SLSTR SST: retrieval

- Five single SST algorithms (view/time of day/aerosol) derived from weighted combinations of BTs measured in both views (nadir and oblique) by the thermal channels.

- Weights are functions of viewing geometry and WV loading.

- Inter-algorithm adjustments

- Lake Surface Water Temperature in the L2P (initially using SST retrieval).

-> Sentinel-3 SLSTR products guides and ATBD's available from https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr

SLSTR SST:
L2 Uncertainties and Sensor Specific Error Statistics

SLSTR GHRSST L2P (WST), per pixel:

1) SSES bias and standard deviation (to drifting buoys)
   -> SLSTR L2 DPM
   -> Currently under revision to be in line with CCI methodology

2) Theoretical uncertainty (experimental field)
   -> SLSTR L2 ATBD

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/key-resources/technical-documents

SLSTR SST Level-2 SSES methodology

Formation follows GHRSST data specification:

Quality Level:

0 no data
1 cloud contaminated data
2 worst quality of usable data
3 low quality of usable data
4 acceptable quality of usable data
5 best quality usable data

UNIVERSITY OF LEICESTER

Quality Levels 3 to 5 based on thresholds of the Theoretical Uncertainty per pixel.
Quality Level 2 based on threshold or if Theoretical Uncertainty is a fill_value. (To be updated soon with CCI methodology).

SSES bias and standard deviation:

-> Bias and standard deviation for each Quality Level determined from drifting buoy comparisons in collaboration with ESA-MPC and continuing.

SLSTR SST Level-2 Theoretical Uncertainty

"Experimental field":

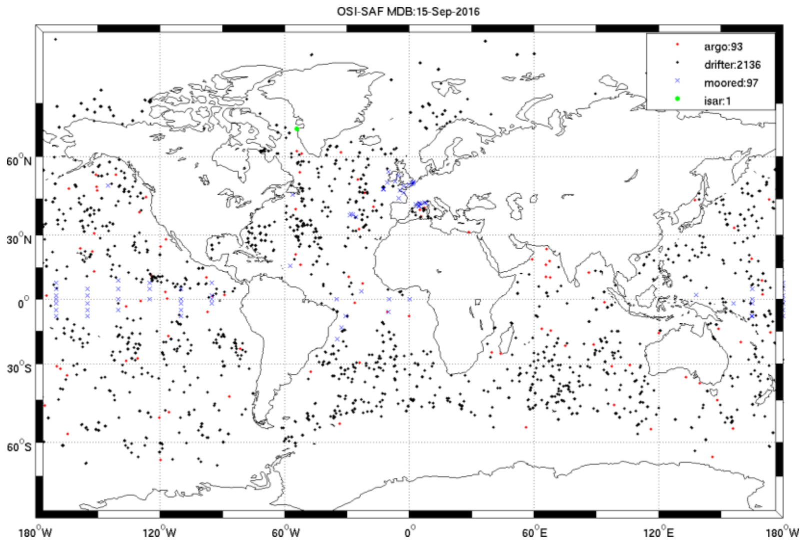
Combination of – measurement noise to retrieved SST; uncertainty from water vapour loading; uncertainty from proximity to land and cloud

Derived separately for each SLSTR SST retrieval (D3, D2, N3, N2, N3R).

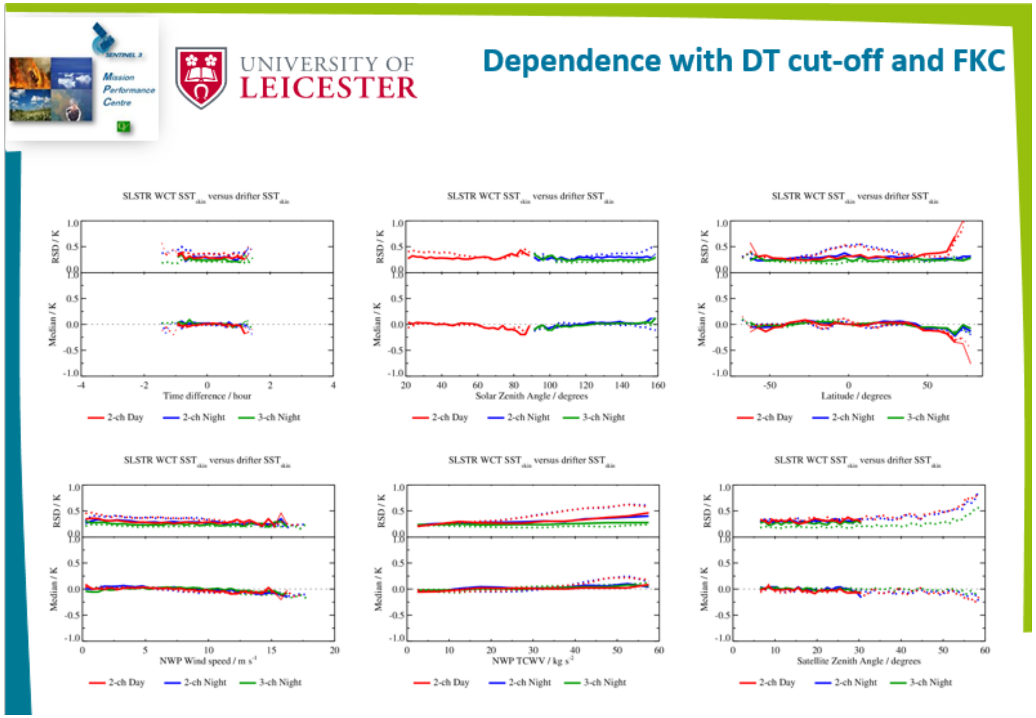
- Interpolation of scan nedt to pixel value.
- Interpolation of SST coefficients to tie point, WV and path length (symmetric uncertainties).
- Cloud and land contamination (asymmetric uncertainties).

Validation of SLSTR SST

- Sentinel-3 Validation Team (contact Anne / Craig)
- EUMETSAT / MPC collaborative validation activities (Igor Tomazic, J-F Piolle, Gary Corlett, Prasanjit Dash, Kevin Pearson)



http://metis.eumetsat.int



Preliminary SLSTR statistics with Bayesian cloud (G. Corlett)

Drifter (Current operational version):
Num Mean (SD) Median (RSD)

Night:

N2:	2217	-0.917 (2.588)	-0.137 (0.366)
N3:	3163	-0.755 (2.476)	-0.033 (0.259)
D2:	1257	-0.066 (1.208)	0.028 (0.299)
D3:	1257	-0.086 (1.247)	-0.001 (0.266)

Drifter (Bayesian cloud version)
Num Mean (SD) Median (RSD)

Night:

N2:	2001	-0.156 (0.685)	-0.089 (0.301)
N3:	2850	-0.090 (0.568)	0.009 (0.207)
D2:	1273	-0.065 (0.662)	-0.003 (0.309)
D3:	1273	-0.089 (0.684)	-0.028 (0.284)

- July 2016
- No QL split-> all results
- FKC model applied (so bias should be zero)
- Use of SLSTR MDB & CCI MDB
- Promising results so far

UNIVERSITY OF LEICESTER

CMEMS examples (Level 3 and Level 4)

Plans for SLSTR in OSTIA

- Chongyuan Mao
- Simon Good

- SLSTR is being ingested in a trial version of OSTIA and the outputs are monitored (some example results are shown in the following slides)
- Once the new cloud algorithm is introduced we will start the process of testing the data for inclusion in our operational product
- In the long term the hope is to use it as a reference sensor used to correct the other satellite data we use (currently VIIRS is used as the reference)

SLSTR in NEMOVAR OSTIA

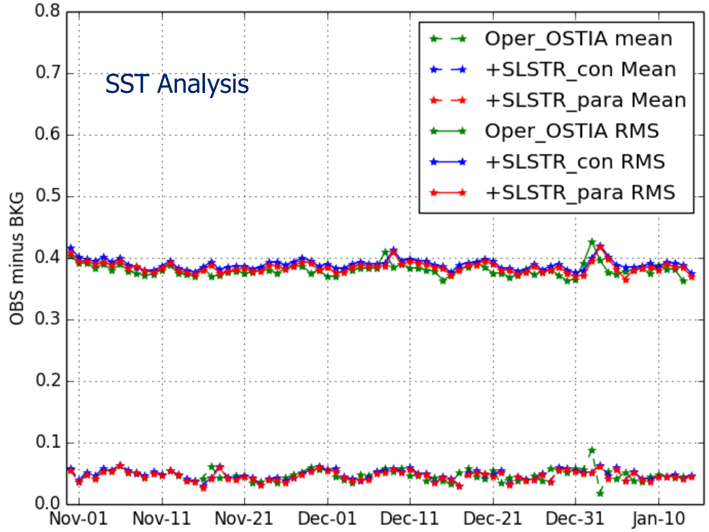
- Experiment runs:
- +SLSTR_con ⇔ NEMOVAR OSTIA configuration + all available SLSTR ⇔ Set up since September 2016
- +SLSTR_para ⇔ NEMOVAR OSTIA configuration + dual view SLSTR ⇔ Set up since August 2017
- Statistics comparison:
- Against operational NEMOVAR OSTIA for SST analysis using Observation-minus-Background (O-B) field for 1 Nov 2017 – 14 Jan 2018
- Against independent Argo observations at Argo locations for 15 Dec 2017 – 14 Jan 2018
- O-B statistics for SLSTR field between two +SLSTR runs for 1 Nov 2017 – 14 Jan 2018

Met Office

Argo minus OSTIA Statistics for 15 Dec 2017 – 14 Jan 2018

Region	Mean Diff (°C)			RMS		
	Oper	+SLSTR con	+SLSTR para	Oper	+SLSTR con	+SLSTR para
Global	0.02	0.03	0.02	0.37	0.36	0.37
North Atlantic	0.02	0.04	0.03	0.53	0.52	0.52
North Pacific	0.01	0.02	0.02	0.38	0.37	0.38
Indian Ocean	0.04	0.04	0.04	0.28	0.28	0.28
Southern Ocean	0.01	0.02	0.01	0.38	0.37	0.38

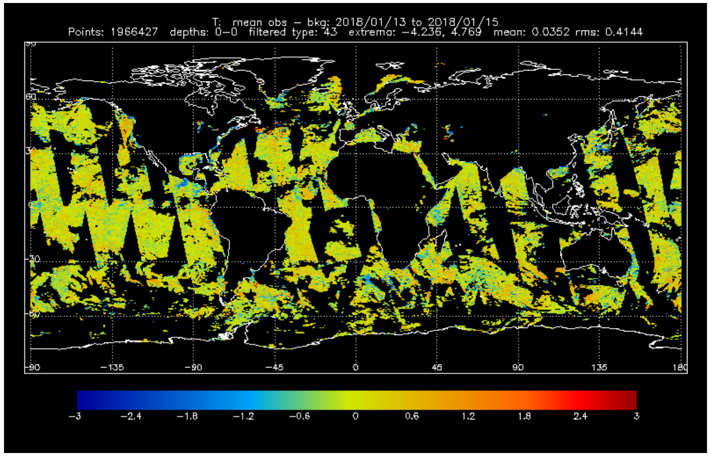
O-B **Statistics for SST analysis during 1 Nov 2017 – 14 Jan 2018**



- Argo statistics indicate neutral impact from assimilating SLSTR data and comparable results when assimilating all available SLSTR and dual view SLSTR
- Obs-Bkg statistics show that both +SLSTR runs show slightly larger RMS than the operational NEMOVAR OSTIA, but the difference is generally < 0.02

EUMETSAT

Met Office

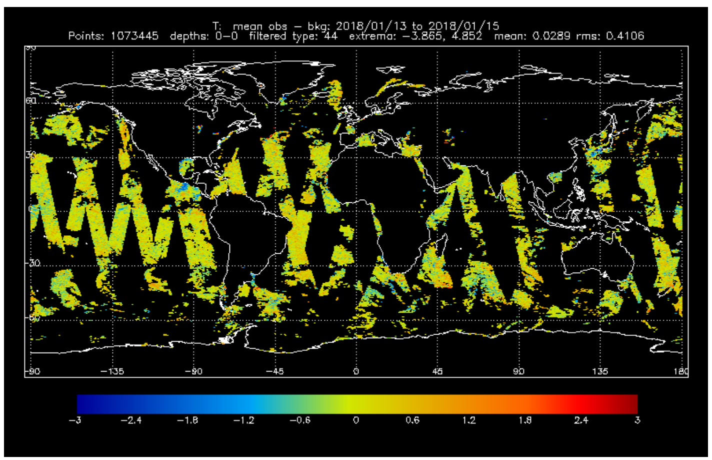


+SLSTR_con: assimilating all available SLSTR data

1966427 observations

Mean: 0.035

RMS: 0.41



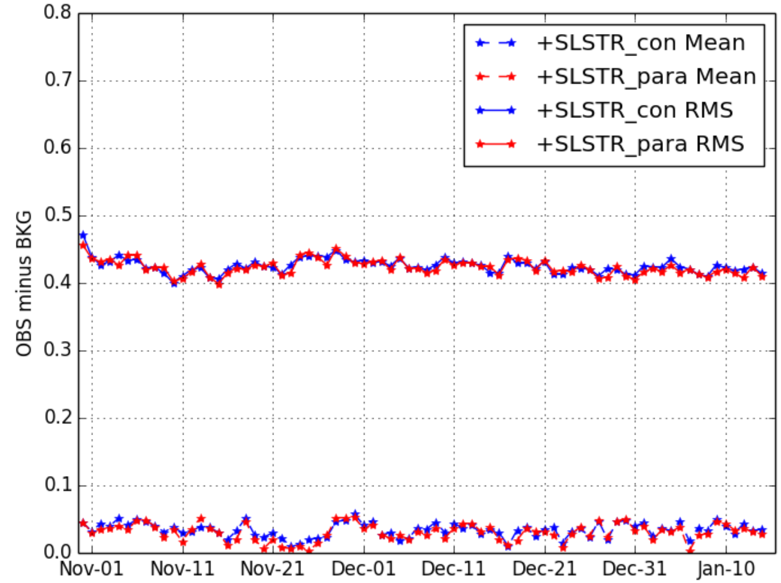
+SLSTR_para: assimilating dual view SLSTR data

1073445 observations

Mean: 0.029

RMS: 0.41

O-B Statistics for SLSTR during 1 Nov 2017 – 14 Jan 2018



O-B statistics for SLSTR field show that assimilating dual view SLSTR generates slightly better results, although the difference is small

EUMETSAT

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

Andrea Pisano, andrea.pisano@artov.isac.cnr.it

B. Buongiorno Nardelli, C. Tronconi, R. Santoleri

Synthesis

Main objective:

- **Following the approach presented last year at the S3VT (Feb. 2017), Sentinel-3A SST data have been 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**

- **Product assessed: SLSTR L2P SST NRT with processing baseline 2.18**

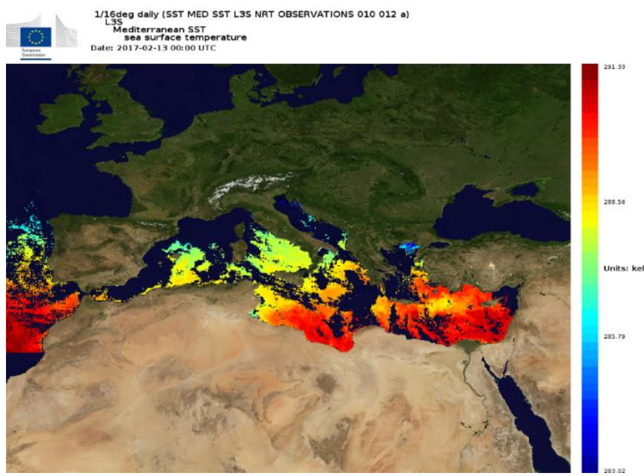
- **Validation period: July – August – September 2017 (92 days)**

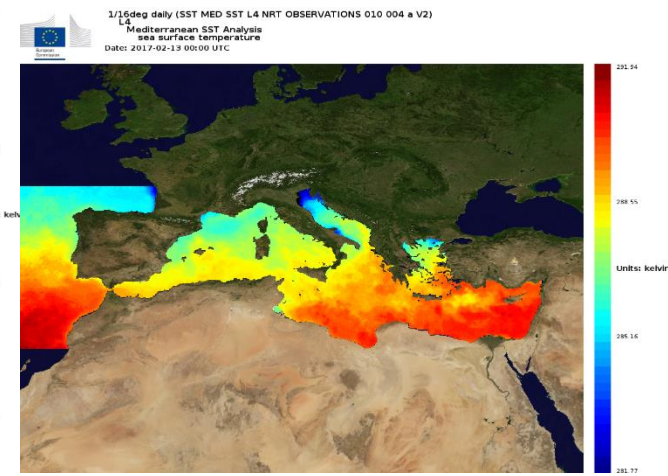
- **Integration of SLSTR is also required by CMEMS as evolution of the system by the end of March 2018**

CMEMS CNR 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 infrared measurements collected by satellite radiometers and statistical interpolation (OI)**

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



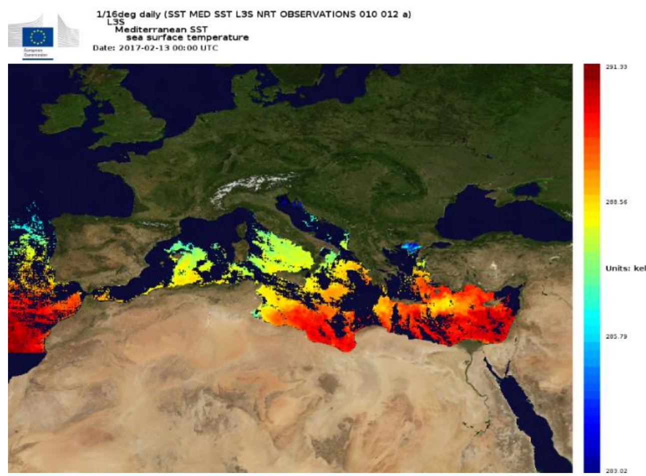


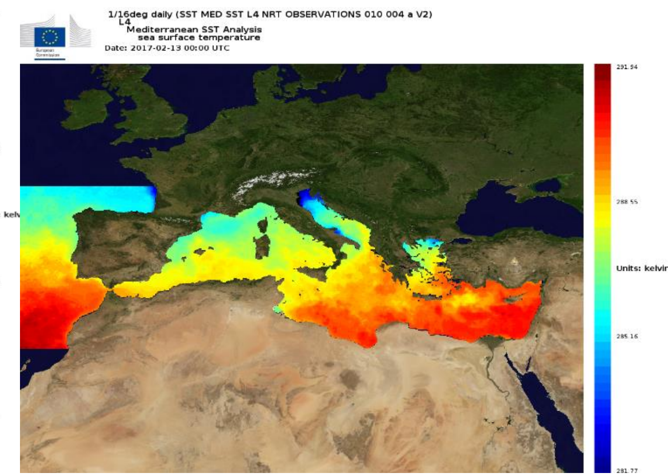
- **Currently, VIIRS is the reference sensor with which the other sensors are bias adjusted**

CMEMS CNR 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 infrared measurements collected by satellite radiometers and statistical interpolation (OI)**

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

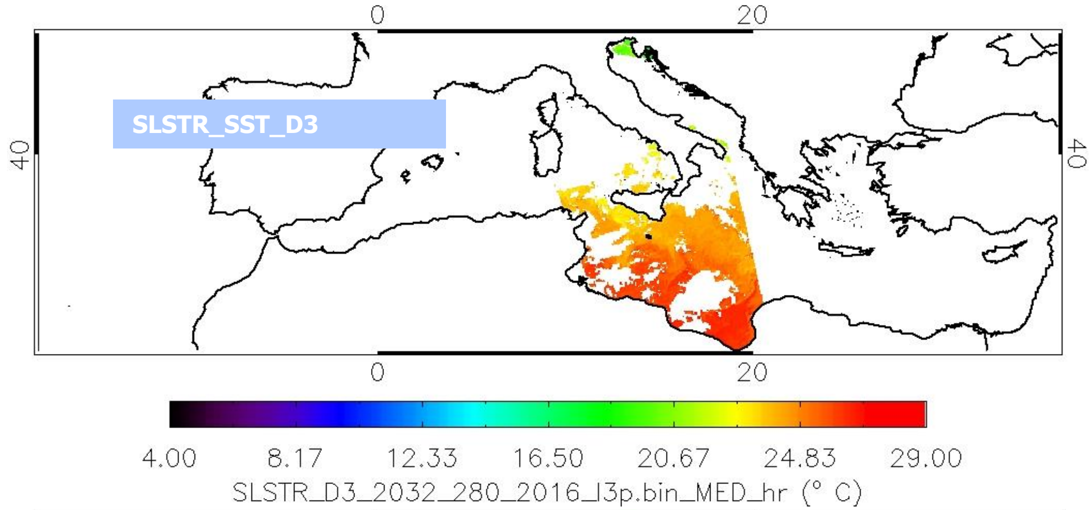


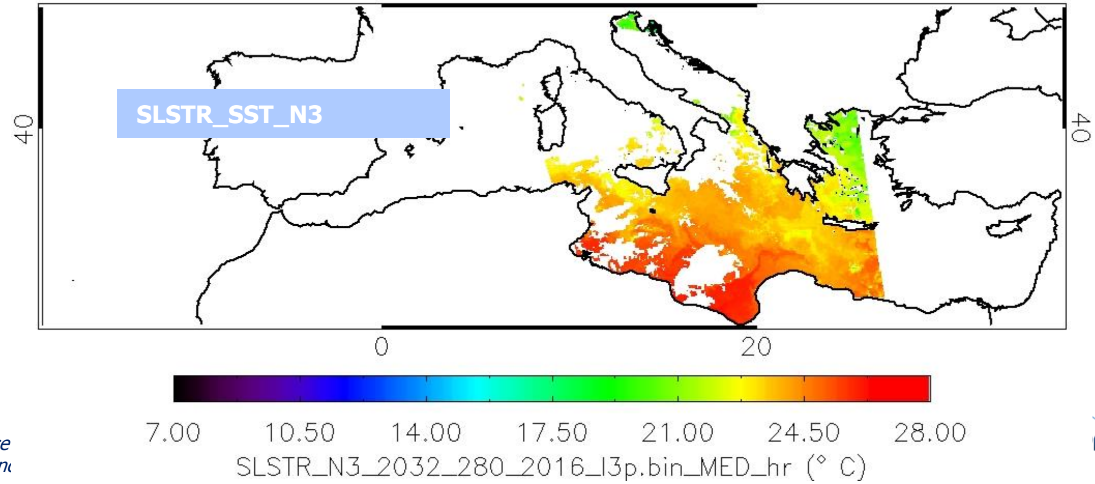


- **System evolution:**

SLSTR L2P SST: Dual and Nadir View Separation

- We splitted the *sea_surface_temperature* variable into two distinct variables, i.e. the dual and nadir view, by using the *sst_algorithm_type* variable:
  1) SLSTR_SST_D3: the dual view (just extrapolated and left unchanged)
  2) SLSTR_SST_N3: the nadir view, obtained by subtracting to *sea_surface_temperature* the *dual_nadir_sst_difference* variable





- The step 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 L3S/L4 SST Assessment **Results**

- **Using SLSTR_D3 as reference and SLSTR_N3 as the last of the high res. sensors, we obtained the following statistics**

July – November 2016

REP_004_SL2_W

	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
SLSTR L4	-0.08 +- 0.02	0.42 +- 0.01	0.43 +- 0.01	2959
OPER L4	-0.13 +- 0.02	0.44 +- 0.01	0.46 +- 0.01	2965
SLSTR L3S	-0.13 +- 0.02	0.41 +- 0.02	0.43 +- 0.02	2222
OPER L3S	-0.17 +- 0.02	0.44 +- 0.02	0.48 +- 0.02	2175

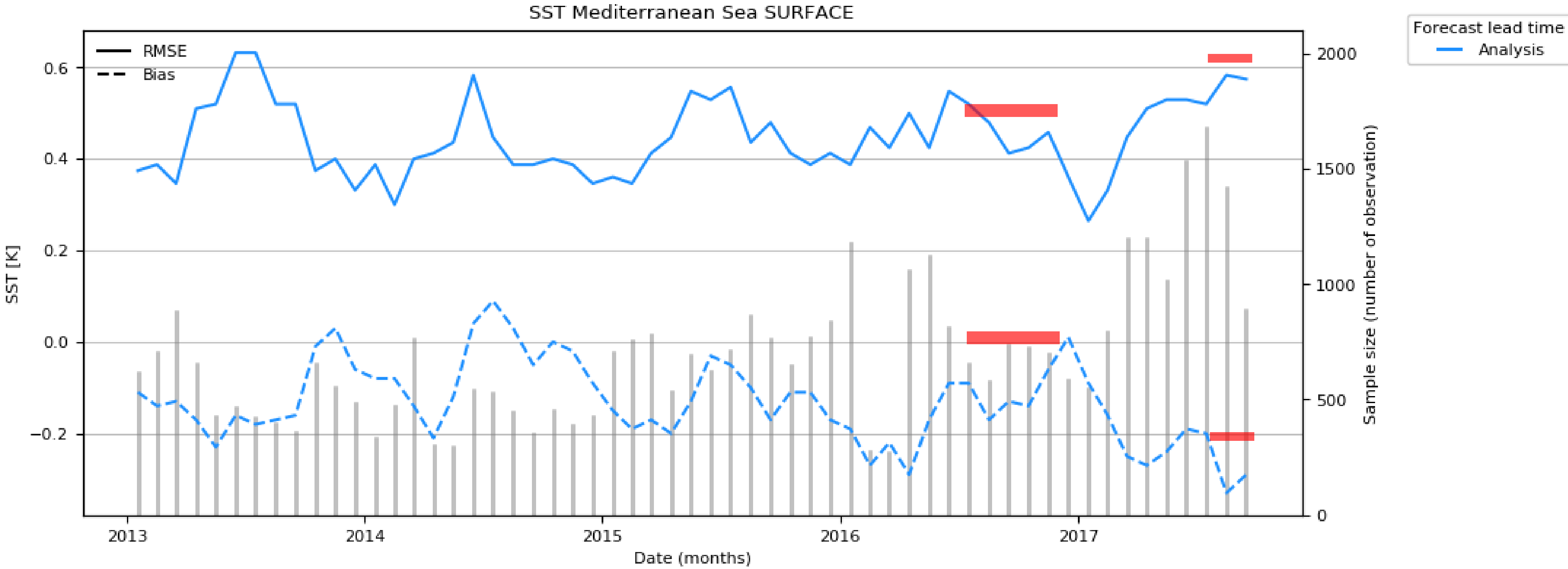
July – September 2017

SLSTR WST NRT

	MBE (°C)	STDDEV (°C)	RMSE (°C)	N_MUP
SLSTR L4	-0.27 +- 0.01	0.47 +- 0.01	0.54 +- 0.01	4286
OPER L4	-0.27 +- 0.01	0.46 +- 0.01	0.53 +- 0.01	4277
SLSTR L3S	-0.31 +- 0.01	0.46 +- 0.01	0.55 +- 0.01	3590
OPER L3S	-0.31 +- 0.01	0.46 +- 0.01	0.56 +- 0.02	3552

Comments

- **By using SLSTR, we obtained a statistics (bias and rmse) which is consistent with the near real time product quality monitoring (blue line of the figure below)**



- **These are preliminary results. Further analysis will be done in the next few months, by e.g. extending the validation period and trying different L2P hierarchy configurations, i.e. using SLSTR D3 not only as reference**

Francoise Orain, CMS, Meteo-France
CMEMS analysis

Validation SLSTR_A over European seas at CMS in OSITAC/CMEMS

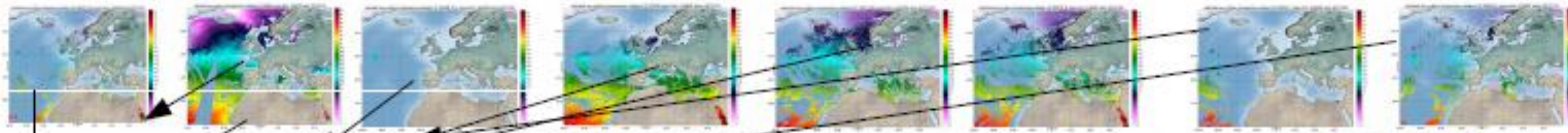
(Françoise Orain , Emma SauxpicartMeteo France Lannion)

1) Operational activity : daily night near real time SST products over European seas integrated in operational control system of CMS Meteo France

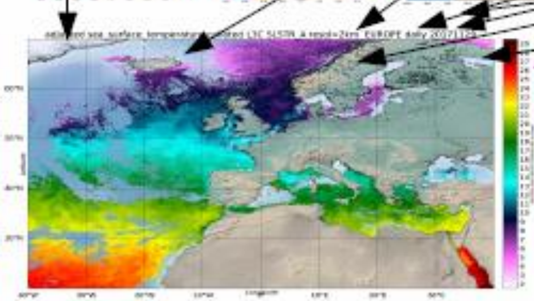
A) SST_EUR_SST_L3C_NRT_OBSERVATIONS_010_009_b (« Collated » currently corrected by Metop_B reference native resolution,subskin):

AVHRR_18_G AMSR2 AVHRR_19_L SEVIRI VIIRS_NPP METOP_B MODIS_T MODIS_A

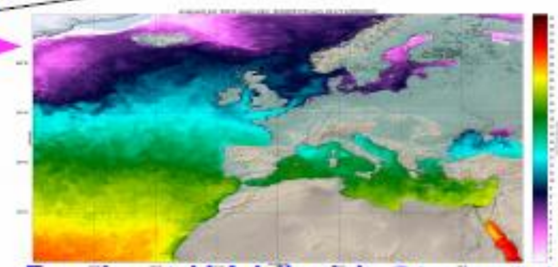
L3C



L3S

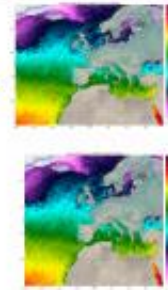


L4



Experimental L4 daily night (2 km resolution)

L4 trihourly



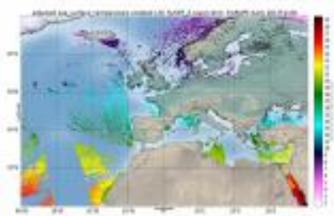
B) SST_EUR_SST_L3S_NRT_OBSERVATIONS_010_009_a
(“supercollated “ subskin daily night 2 km resolution)

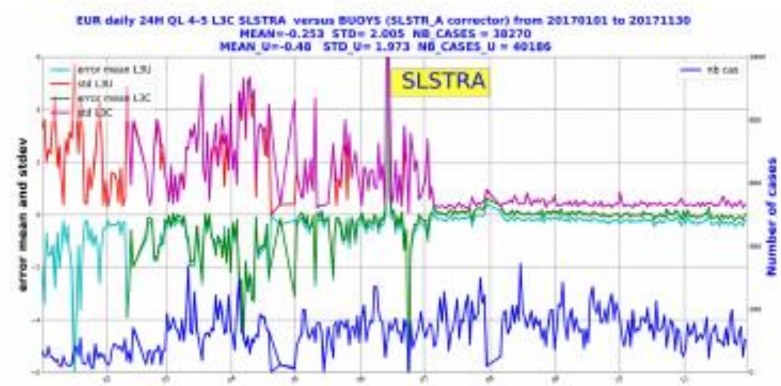
C) SST_EUR_SST_L4_NRT_OBSERVATIONS_010_018
(trihourly subskin L4 2km)

2) Research and validation activity

- Validation SLSTR A since January 2017 to November 2017 in a test chain where SLSTRA is the reference corrector

L3C SLSTR_A



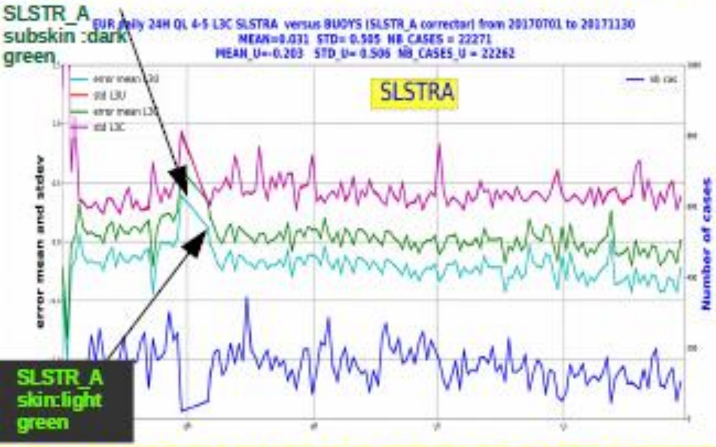


Bad statistics until July 201 . Mainly problem of clouds contamination until July 2017. From July Eumetsat applies a filter dt_analysis [-5,5] . To avoid more trouble in CMS-CMEMS chain application of dt_analysis[-2,2], l2p_flag controlled , quality level(4,5)....

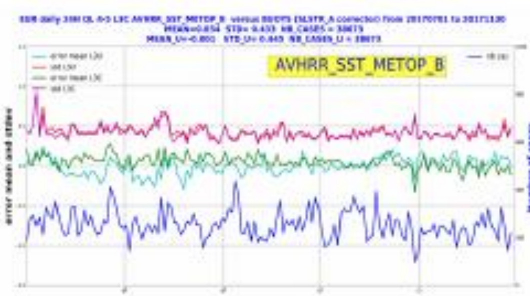
Goals:

- Collaboration of CMEMS with Eumetsat SLSTSR_A validation team
- Use of SLSTR_A as reference instead of Metop_B currently

a) Statistics against BUOYS over the improved period July to November 2017 test chain



Light green: uncorrected —dark green : corrected by SLSTR_A



SLSTR_A (the corrector) is a little warmer than buoys (error mean=0.031)
METOP_A corrected by SLSTR_A is warmer than buoy(error mean=0.054)
VIIRS_NPP corrected by SLSTR_A is warmer than buoy(error mean=0.05)

b) Statistics against corrector SLSTR_A over the improved period July to November 2017 in test chain b)

SLSTR_A is colder than METOP_B
SLSTR_A is colder than VIIRS_NPP

c) Comparison of corrected L3C VIIRS_NPP against buoy between operational chain(METOP_B corrector) and test chain (SLSTR_A corrector)

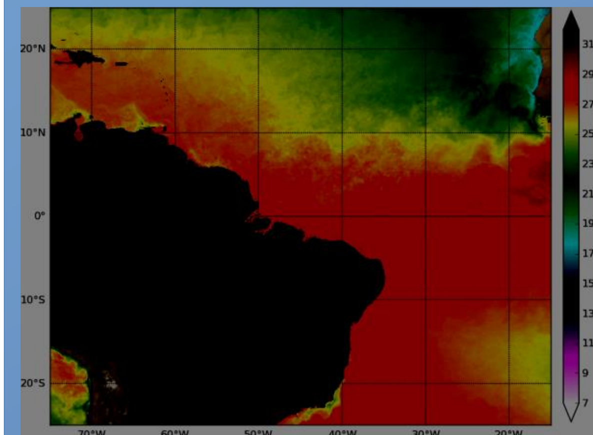
Conclusion

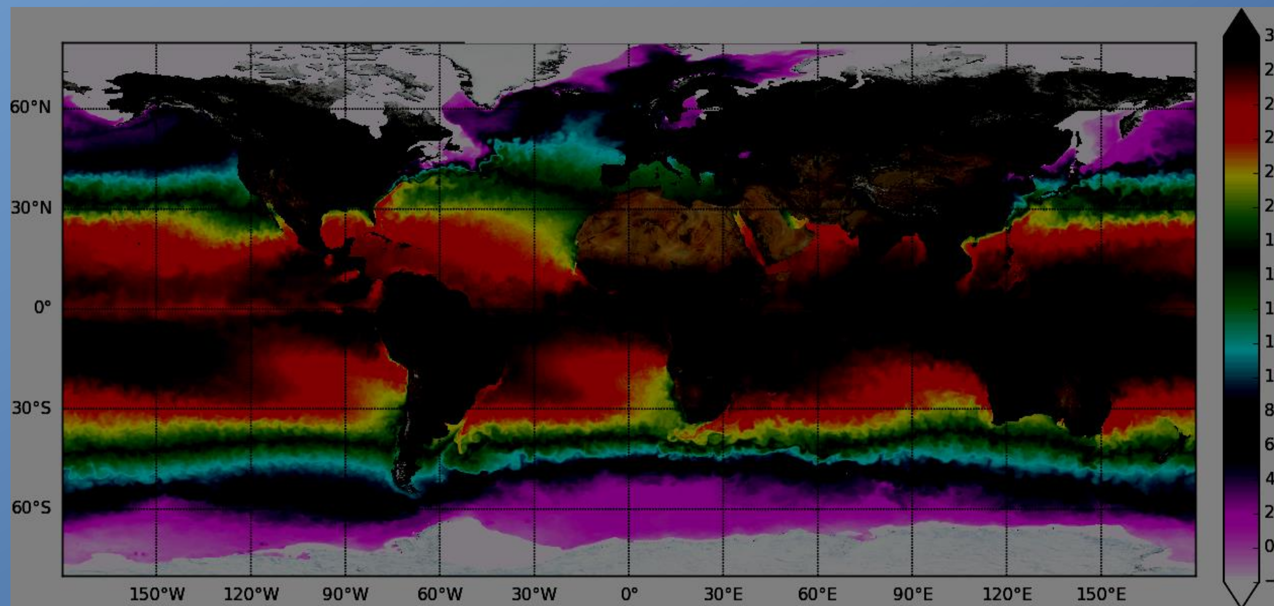
- Better results since July 2017
- Not enough data to use SLSTR_A as reference corrector due to our severe selection
- CMS/CMEMS will use SLSTR as a common sensor in 2018
- After validation of SLSTR_B,if good results and good correction of cloud contamination :use of SLSTR_A and B as reference corrector

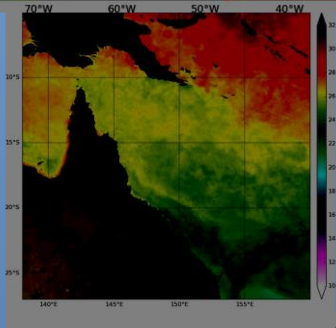
Ifremer ODYSSEA SST products

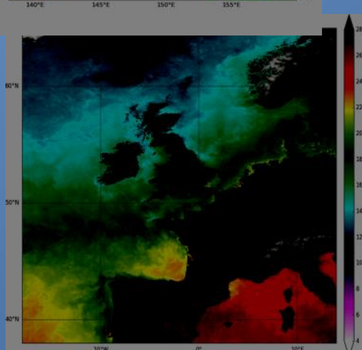
Emmanuelle Autret, Jean-François Piollé*, Cédric Prévost***

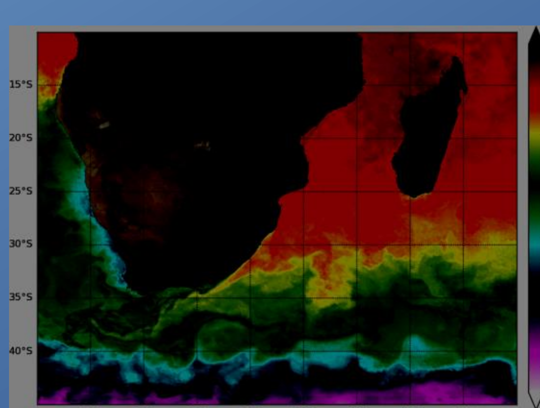
** IFREMER, Univ. Brest, CNRS, IRD, Laboratoire d'Océanographie Physique et Spatiale (LOPS), IUEM*
*** Cap Gemini*

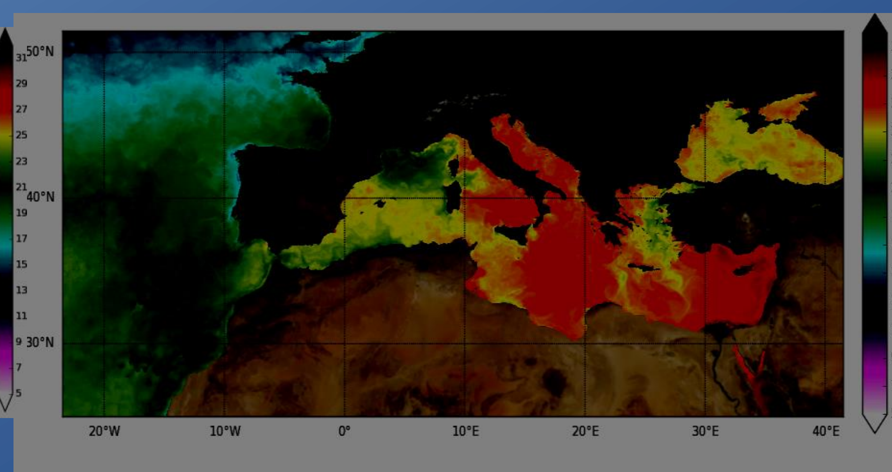






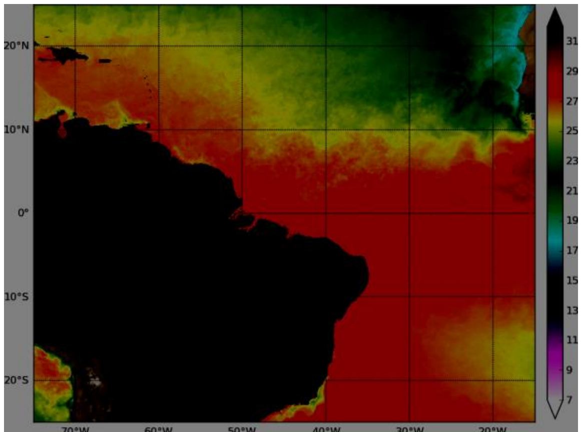


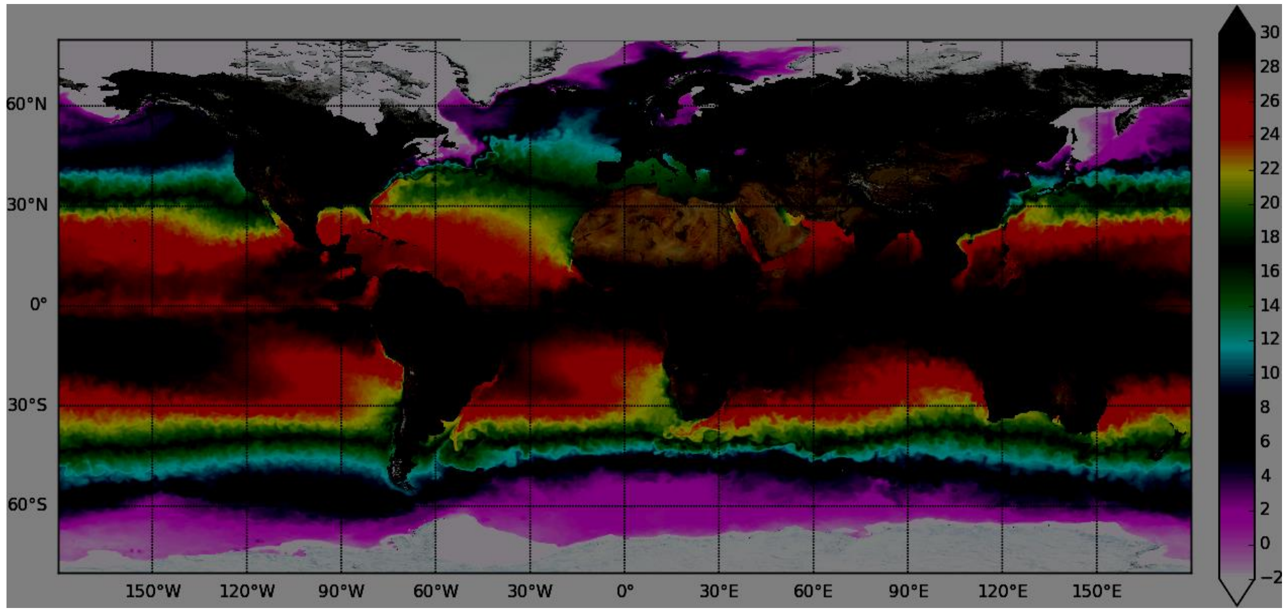


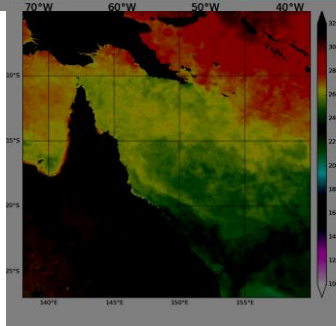


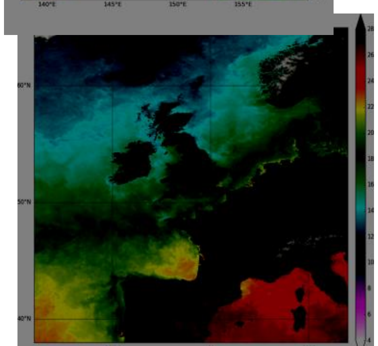
Ifremer ODYSSEA SST products

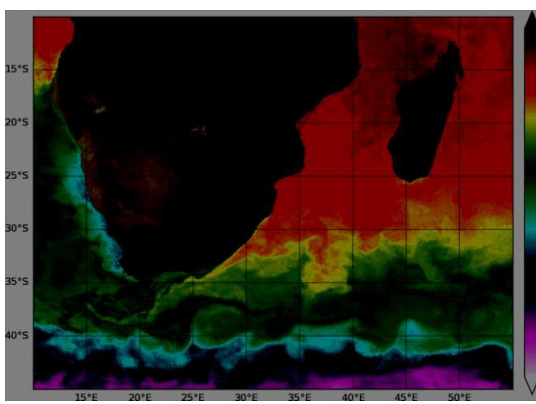
Daily sea surface temperature fields (SST) global (resolution ~10 km) and 5 regional areas (res. ~2 km) since 2007 (projects *Medspiration*, *MERSEA*, *GMES*, *CMEMS*) from available satellite observations. Long regional (Europe) time series (1982-2016).

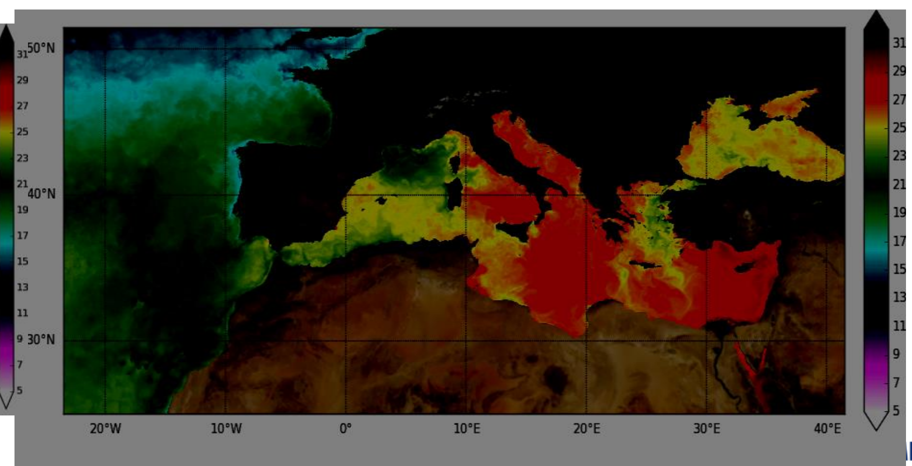








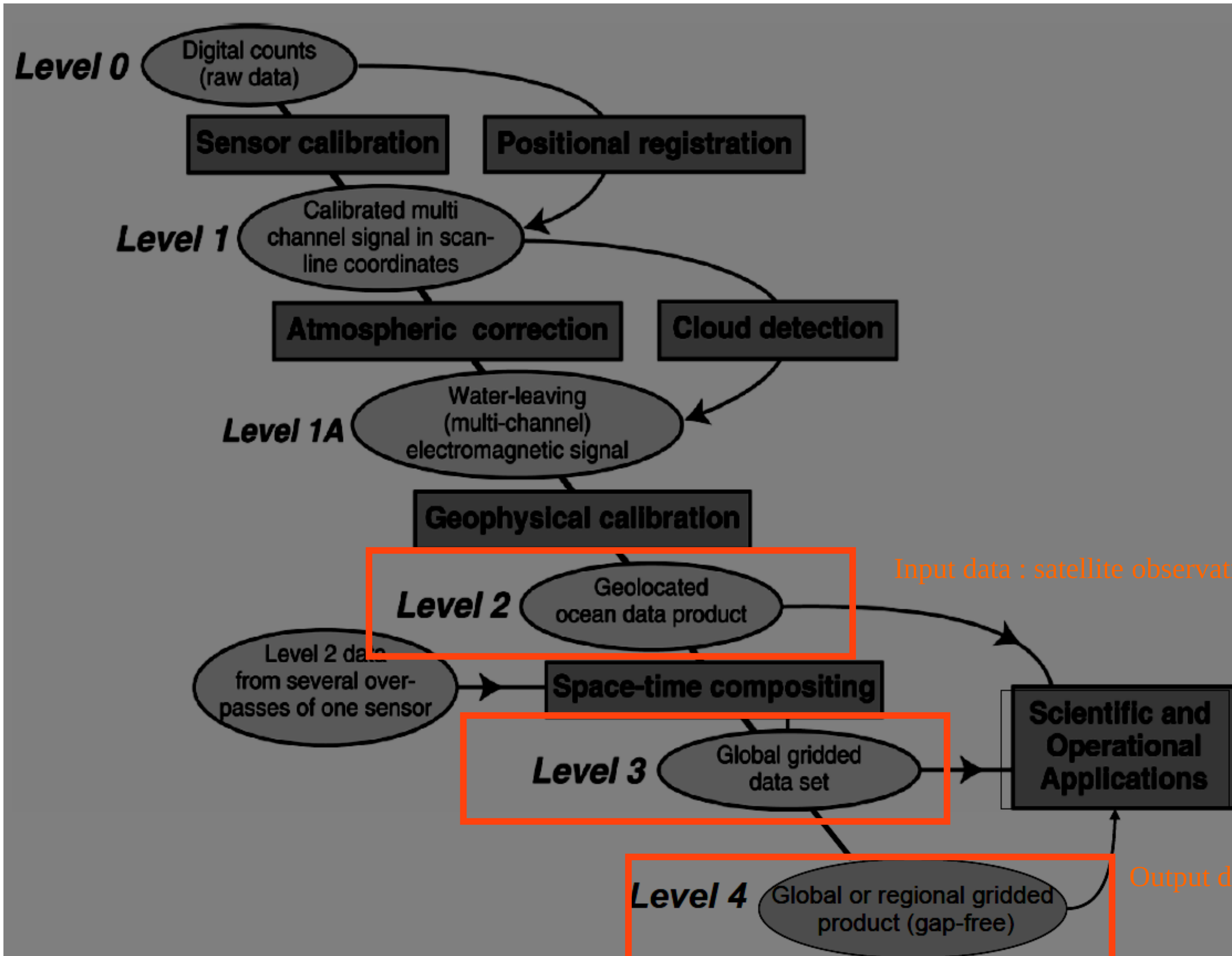




Ifremer ODYSSEA SST products

Processing chain

Product levels :

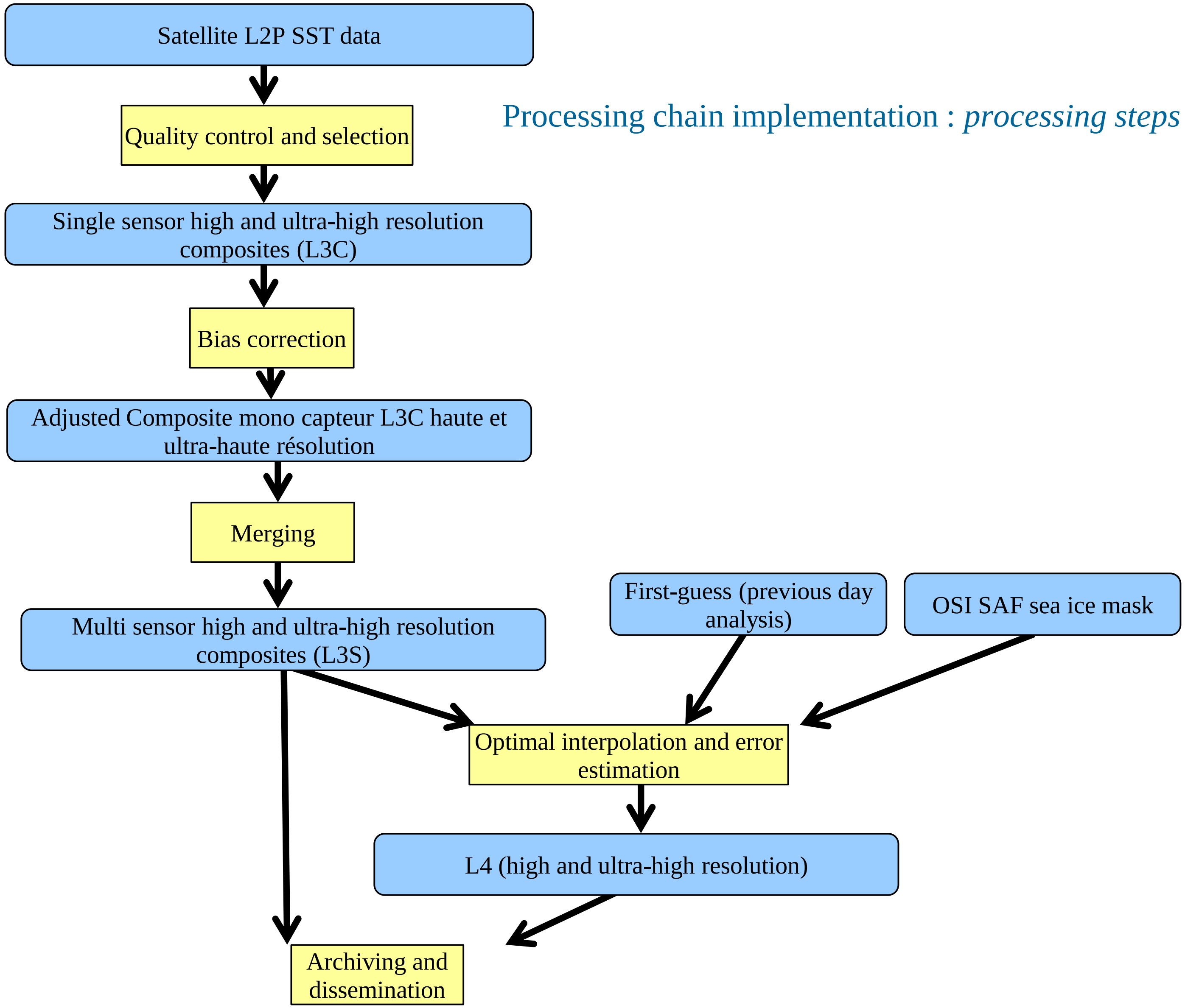


Input data : satellite observations from SST L2

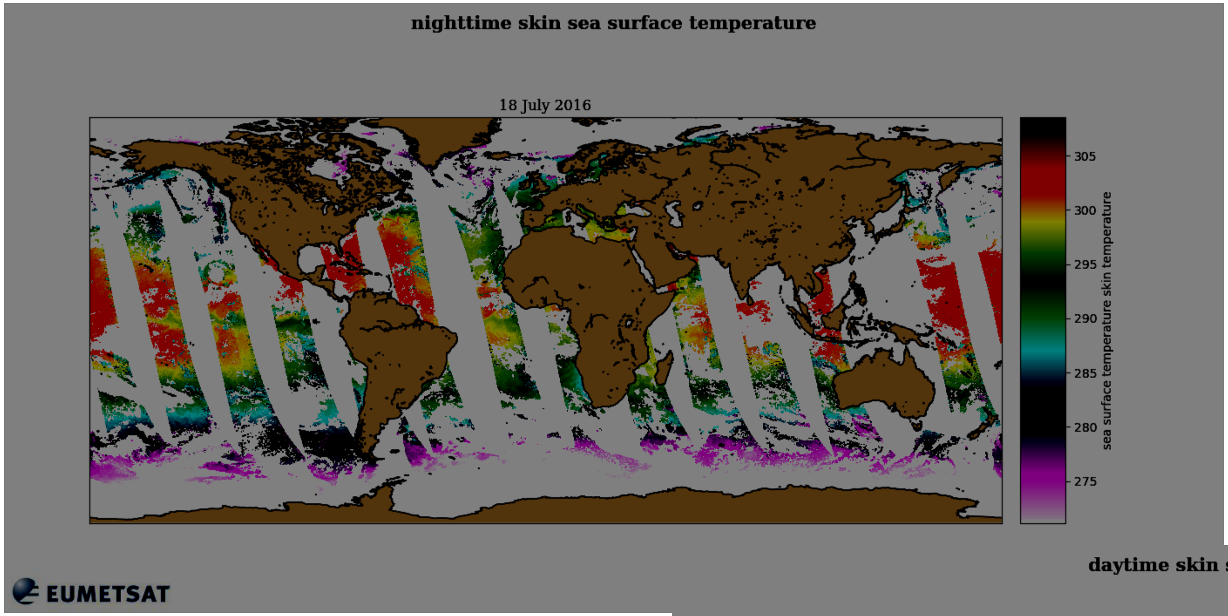
Output data: SST products L3

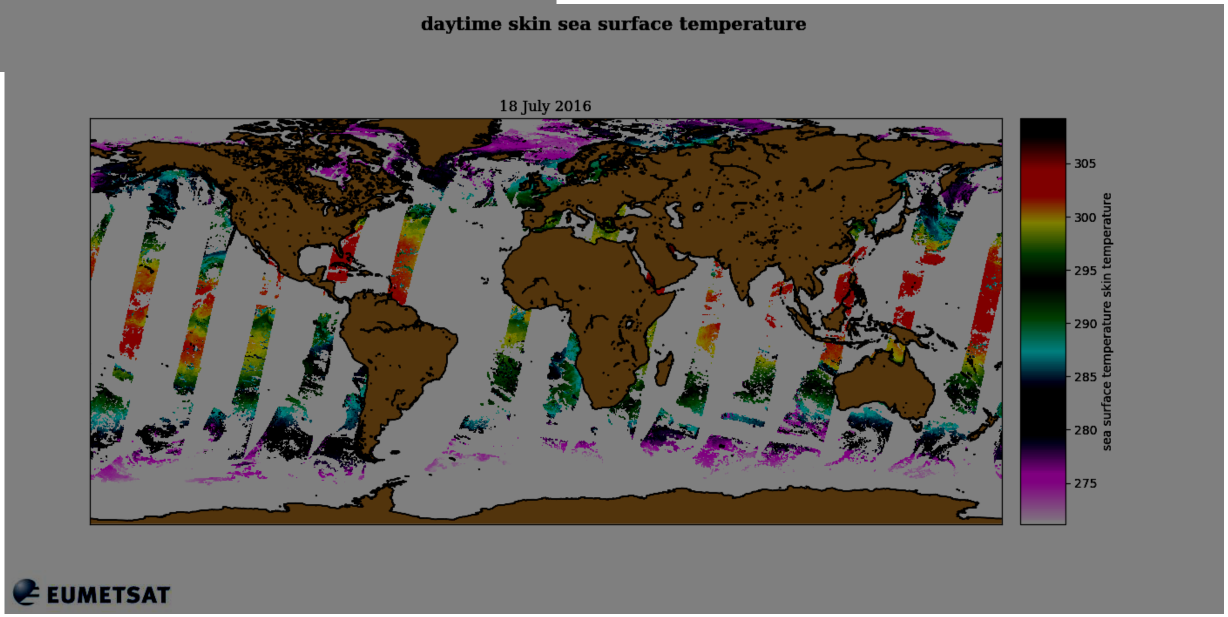
Ifremer ODYSSEA SST products

Processing chain implementation : *processing steps*

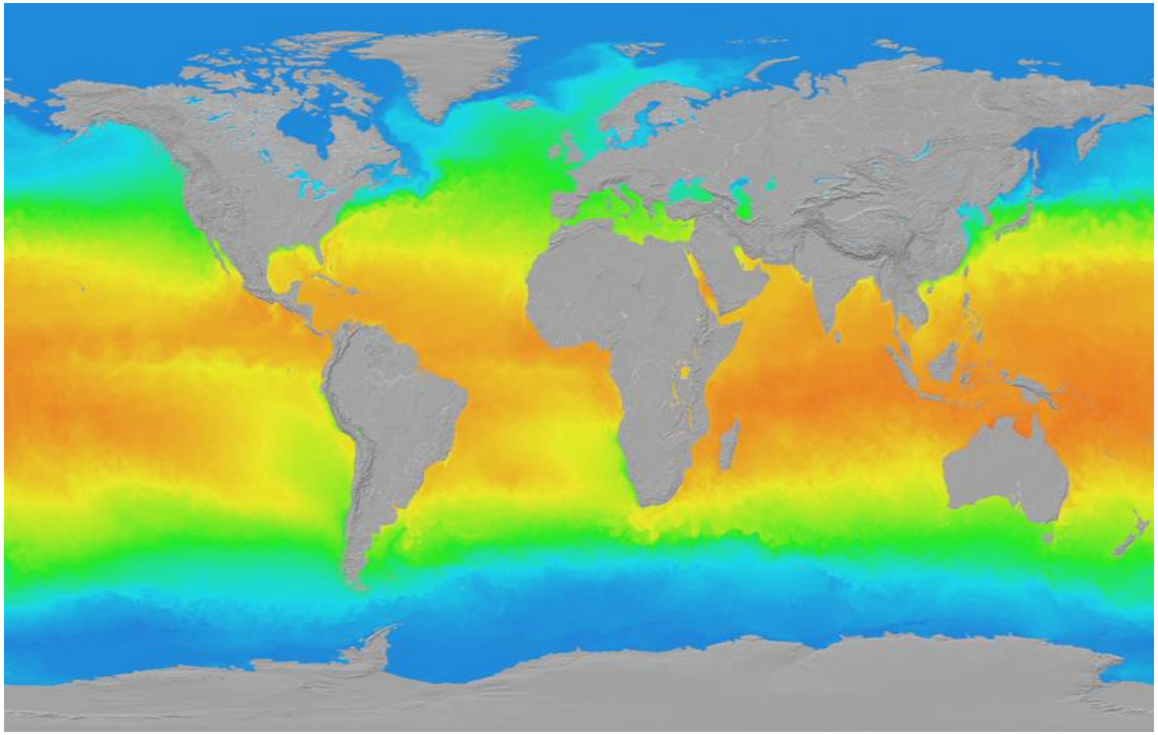


SLSTR nighttime / daytime WST SST





The Group for High Resolution Sea Surface Temperature (GHRSST)



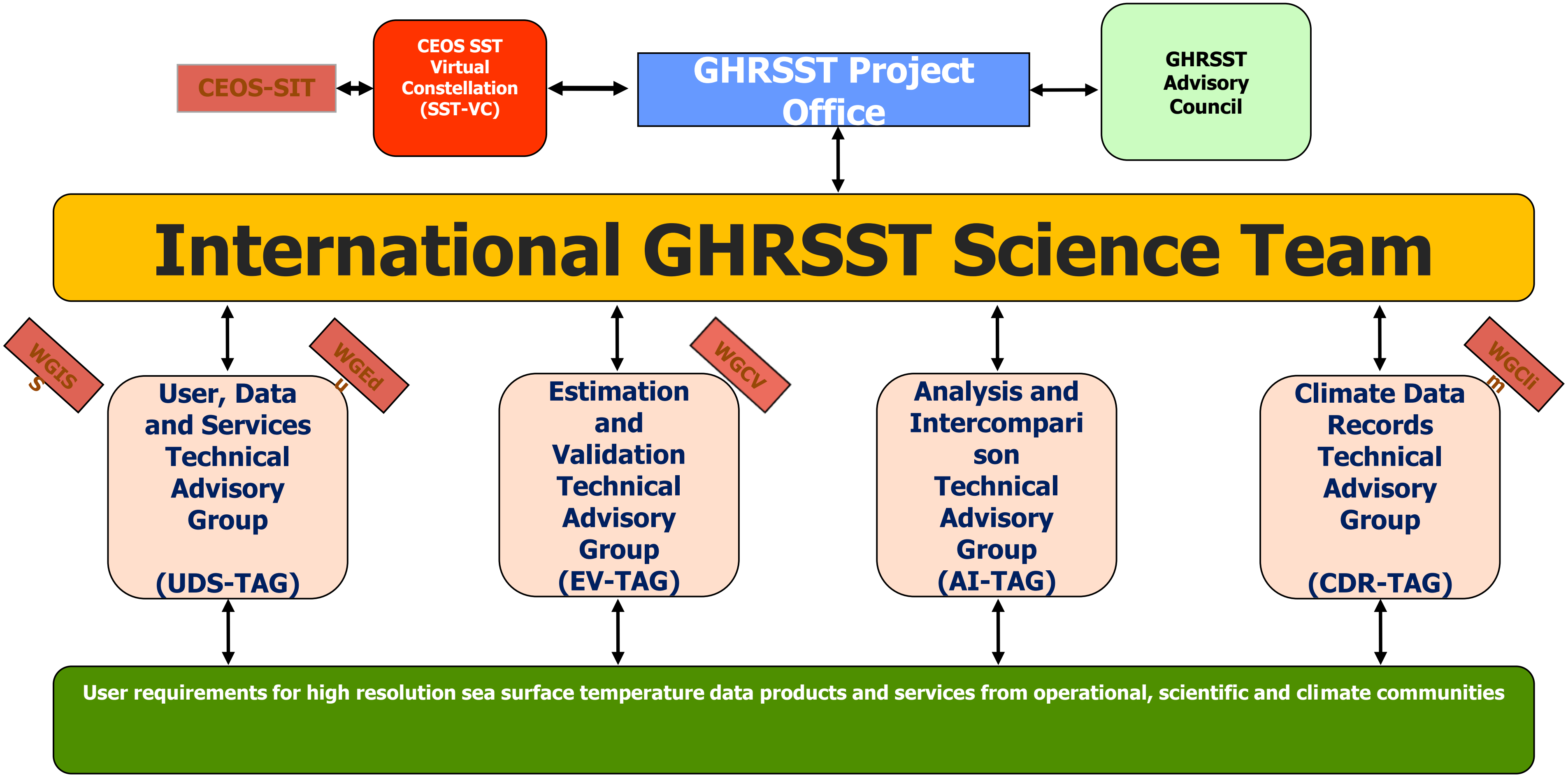
GHRSST mission: To provide operational users and the science community with the SST measured by the satellite constellation

GHRSST provides a framework for SST knowledge and data sharing, best practices for data processing, assessing uncertainties in the satellite SSTs, and a forum for scientific dialog including how best to provide SSTs for climate studies, bringing SST to the operational users and scientific researchers.

Patrons and Sponsors

Australian Government Bureau of Meteorology
CEOS
European Commission
DMI Danish Meteorological Institute
ECMWF
Environment Canada
esa
sst cci
EUMETSAT
OSI SAF
GODAE OceanView
Ifremer
IMOS
IOOS
JAXA Japan Aerospace Exploration Agency
気象庁 Japan Meteorological Agency
METEO FRANCE
Met Office
MRSU Marine Remote Sensing Unit
NASA
National Centre for Earth Observation, Natural Environment Research Council
National Oceanography Centre, Southampton, University of Southampton and Natural Environment Research Council
Department of the Navy, United States of America
NEODAAS
NOAA
Ocean University of China
Remote Sensing Systems
Science & Technology Facilities Council Rutherford Appleton Laboratory
University of Colorado Boulder
University of Leicester
University of Miami Rosenstiel School of Marine & Atmospheric Science
University of Reading
The University of Rhode Island

GHRSST CEOS SST-VC Interaction

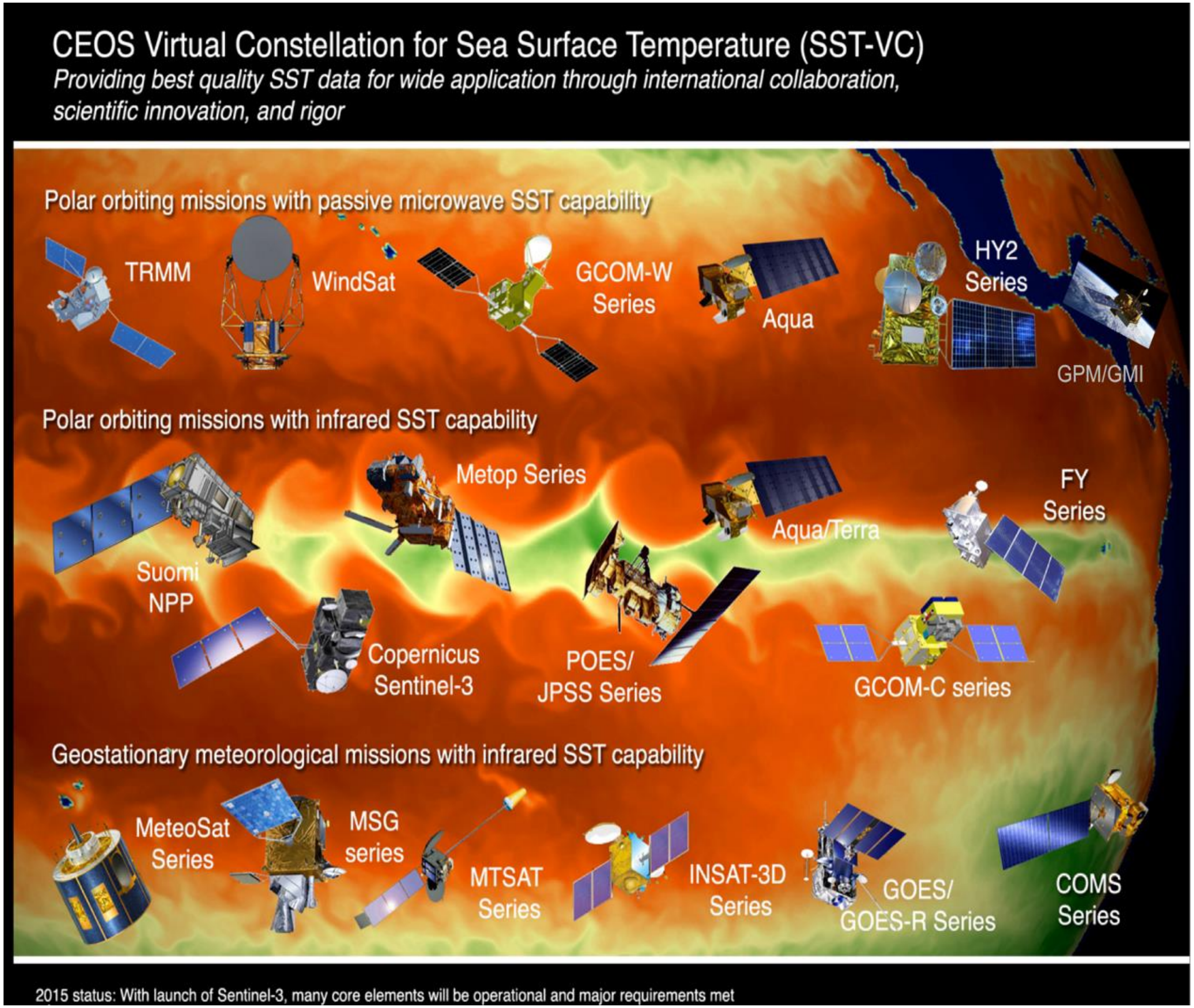


GHRSST is driven by user requirements

- GHRSST sources users requirements from many communities, including, for example:
  - The WMO Rolling Requirements Review
  - GODAE Ocean View and JCOMM ETOOFS
  - GCOS
  - OOPC
  - Internal GHRSST Science Team members

- GHRSST then synthesises these requirements into a common set of:
  - Measurement requirements for both space based and surface based instrumentation
    - Includes a gap analyses and list of priorities
  - Scientific and technical challenges for ongoing R&D elements
    - Drives the program of the working groups and technical advisory groups

CEOS SST-VC



kenneth.casey@noaa.gov

Anne.Ocarroll@eumetsat.int

Fiducial Reference Measurements - definition

"The suite of independent ground measurements that provide the maximum return on investment for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission"

(Sentinel-3 Validation Team)

- Based on specific requirements
- Linked to a mission's Cal/Val plan activities
- Building on existing capabilities
- Forward thinking and long-term vision
- Not necessary mission specific

Improved drifting buoys for Copernicus SLSTR SST

- Provide well-calibrated drifting buoy SST, towards SI-traceable standards, HRSST-FRM
- Assess and establish the benefit of improved incremental capability of drifting buoys for satellite SST validation
- Position accuracy and reporting to 0.01degrees (HRSST-1)
- Total standard uncertainty < 0.05K; reporting to 0.01K (HRSST-2)
- Understand d depth of drifter in water with near-surface water pressure sensor; more metadata; links with FRM4STS on traceability
- 100 (+50) drifting buoys; 4 year project; KO Jan 2018

copernicus

Summary

- Overview of SLSTR L1 through to L4:
  - Wide contributions throughout Europe.
  - Large distributed team.
  - SLSTR L2 operational since July 2017, Bayesian cloud implementation due February 2018 expected to give significant improvement.
  - Project on improved drifting buoys KO 29/30 January 2018.

- GHRSST:
  - International mechanism to agree standards plus CEOS context e.g. SST-VC.
  - Next GHRSST science team meeting, 4-8 June 2018, EUMETSAT.
  - Please see GHRSST poster / GHRSST PO Director (Gary Corlett).