Relevance of passive microwave data for the activities in the Copernicus Marine Environment Monitoring Service (CMEMS) and Mercator

Marine Monitoring

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European Commission | Copernicus Europe's eyes on Earth

Implemented by MERCATOR OCEAN OCEAN FORECASTERS

OUTLINE

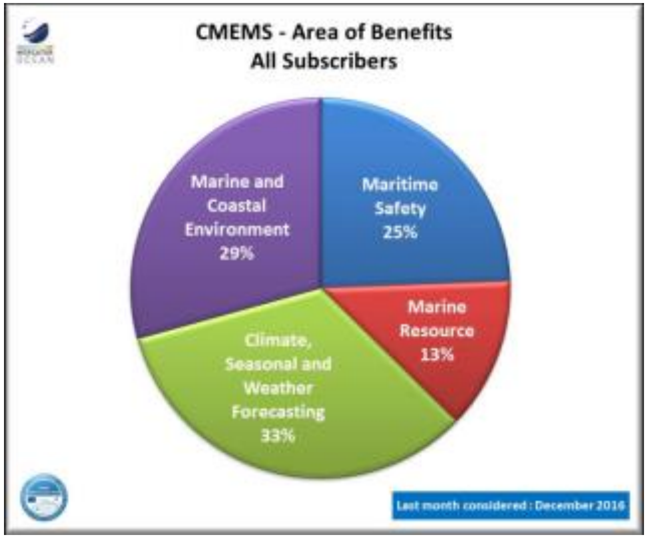
- Copernicus Marine Service overview
- Use of PMW in SST CMEMS products
- Use of PMW in Sea Ice CMEMS products
- Ice data assimilation in Mercator ocean and ice analysis system
- SSS data assimilation in Mercator global ocean analysis system
- Conclusion

The Copernicus Marine Environment Monitoring Service

Marine Monitoring

The Copernicus Marine Environment Monitoring Service (CMEMS) provides **regular and systematic reference information on the physical state, variability and dynamics of the ocean and marine ecosystems** for the global ocean and the European regional seas with **a free open access to the datasets.**

A **network** of European producers



The service is targeted around four main areas of benefits: Maritime Safety, Coastal and Marine Environment, Marine Resources, and Weather, Seasonal Forecasting and Climate activities.

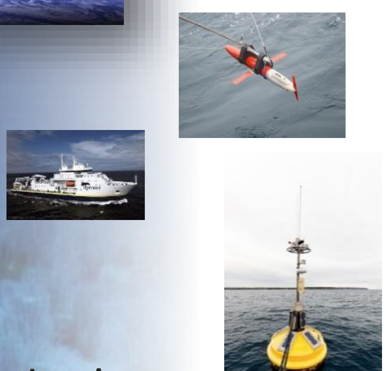
Generic to serve a **wide range of downstream applications**. More than 8500 registered users

Copernicus Marine Service

Marine Monitoring

ESA; EUMETSAT; Direct agreement with other space agencies

L1 / L2 Space data



In situ observations

CMEMS Thematic Assembly Centers

Sea Level (SL)

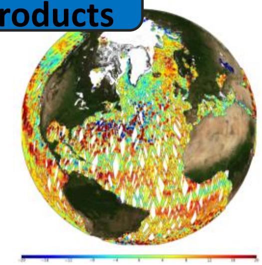
Ocean Color (OC)

SST, Sea Ice & Wind (OSI)*

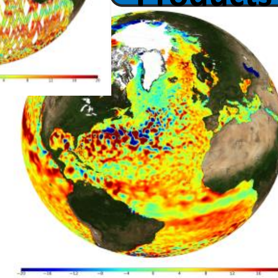
In Situ (INS)

CMEMS Monitoring and Forecast Centers

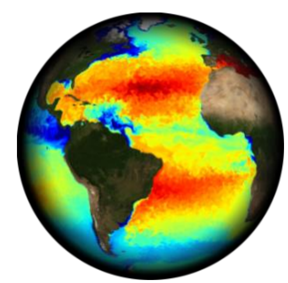
L3 Products



L4 Products



Analysis and forecasts



**After April 2018: SST TAC and Sea Ice TAC*

CMEMS products

Marine Monitoring

Observations and Models

REPROCESSING
REANALYSES
30 years

REAL-TIME
Daily, hourly

FORECAST
2 to 10 days

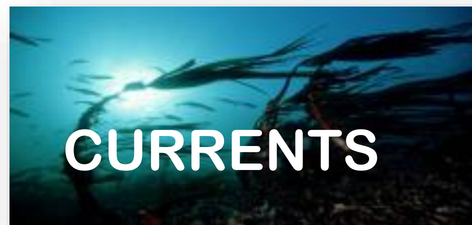
ESSENTIAL OCEAN VARIABLES

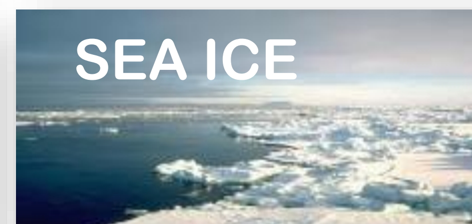
DISCOVER

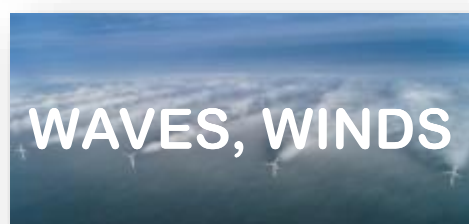
VIEW

DOWNLOAD

Open & Free







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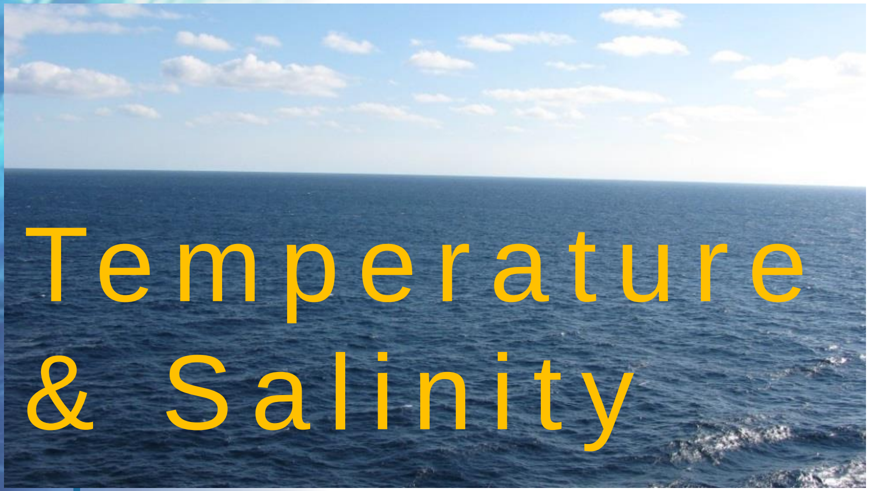
Satellite observations used today by CMEMS

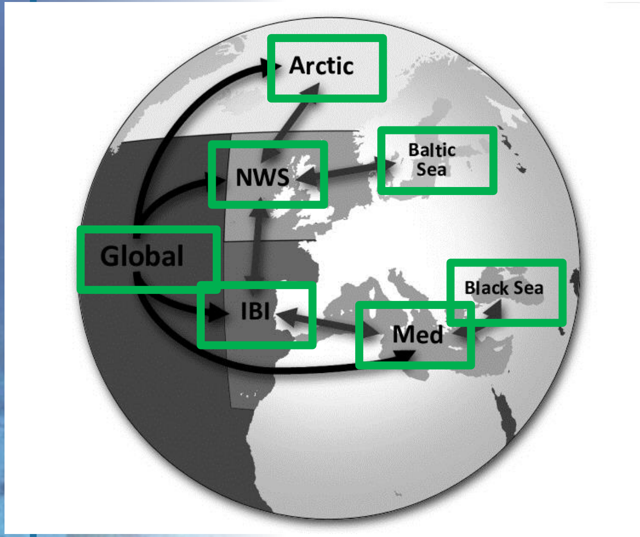
Multi-frequency Passive microwave Radiometry	Low-resolution (~25 km) sea ice concentration, area and extent, sea ice types, and sea ice drift. Sea surface temperature, near surface wind speed.
L-band passive microwaves*	Thin sea ice with thickness less than 0.5 m Sea surface salinity but with questionable sensitivity in cold water regions.
SAR	High-resolution for iceberg, sea ice deformation, drift, sea ice roughness, leads and ridges.
Scatterometry	Medium-resolution (~10 km) sea ice concentration, area and extent, sea ice types, and sea ice drift. Wind vector in ice free waters.
Altimetry*	Sea ice freeboard height and snow depth. Open ocean sea level and sea surface height and hence dynamic topography and surface geostrophic current.
IR radiometry	High-resolution sea and ice surface temperature
Spectrometry	Chlorophyll a concentration and distribution. Used for estimation of phytoplankton concentration.

* Note that the sea ice thickness presently derived from Cryosat 2 and SMOS is not yet in the list of CMEMS satellite high level products. However, the data are used for model validation and data assimilation tests are underway. It is likely that a near real time sea ice thickness product will be added in the OSI TAC portfolio for CMEMS Phase II (2018-2021).

Catalogue of product: SST



Temperature & Salinity



Model products

TEMPERATURE (T)
SALINITY (S)
From - 6000 m to surface
Forecast, NRT and Reanalysis
Source: MFC

In Situ Observation products

TEMPERATURE (T)
SALINITY (S)
From – 6000 m to surface
NRT and Reprocessing
Source: INSITU TAC

Satellite Observation products

SEA SURFACE TEMPERATURE (SST)
L3 and L4
NRT and Reprocessing
Source: OSI TAC

Marine Monitoring

SST products

SST	NRT L3	NRT L4	REP
GLO			
ARC			
BAL			
NWS			
IBI			
MED			
BS			

Arctic Ocean High resolution Sea Surface Temperature Analysis.
Baltic Sea- Sea Surface Temperature Analysis
Baltic Sea- Sea Surface Temperature Reprocessed (1982-2009)
Black Sea - High Resolution and Ultra High Resolution L3S Sea Surface Temperature
Black Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis
Black Sea - High Resolution L4 Sea Surface Temperature Reprocessed (1981-2012)
European Ocean- Sea Surface Temperature **Mono-Sensor** L3 Observations
European Ocean- Sea Surface Temperature **Multi-Sensor** L3 Observations
European Ocean- Sea Surface Temperature Multi Sensor L4 three-hourly Observations
Global Ocean Sea Surface Temperature L3 Observations
Global Ocean **OSTIA** Sea Surface Temperature and Sea Ice Analysis
Global Ocean Sea Surface Temperature **Multi Product Ensemble (GMPE)**
Global Ocean OSTIA **Diurnal Skin** Sea Surface Temperature
Global Ocean OSTIA Sea Surface Temperature and Sea Ice Reprocessed (1985-2007)
ESA SST CCI analyses (1991-2010)
Mediterranean Sea - High Resolution and Ultra High Resolution L3S Sea Surface Temperature
Mediterranean Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis
Mediterranean Sea - High Resolution L4 Sea Surface Temperature Reprocessed (1981-2012)
Atlantic European North West Shelf Ocean - ODYSSEA Sea Surface Temperature Analysis

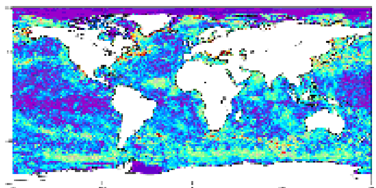
CMEMS SST products

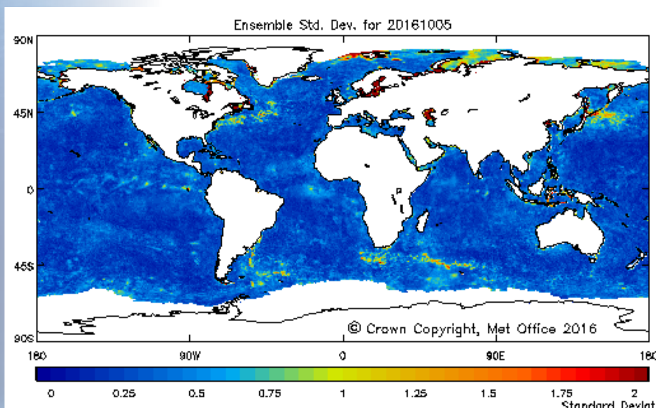
GLOBAL OCEAN SEA SURFACE TEMPERATURE MULTI PRODUCT ENSEMBLE (GMPE)

Satellite-observation, Temperature, Near-real-time, Global-ocean

SST_GLO_SST_L4_NRT_OBSERVATIONS_010_005

For The Global Ocean- The GHRSST Multi-Product Ensemble (GMPE) system has been implemented at the UK Met Office which takes inputs from various analysis production centres on a routine basis and produces ensemble products at 0.25deg.x0.25deg. horizontal resolution.





K

- 0.25 degree grid
- Daily
- Median
- Standard deviations

- Anomalies
- Gradients
- From 2009

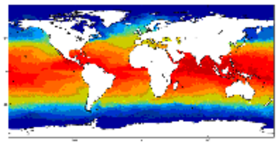
GLOBAL OCEAN OSTIA SEA SURFACE TEMPERATURE AND SEA ICE ANALYSIS

Satellite-observation, Sea-ice, Temperature, Near-real-time, Global-ocean

SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001

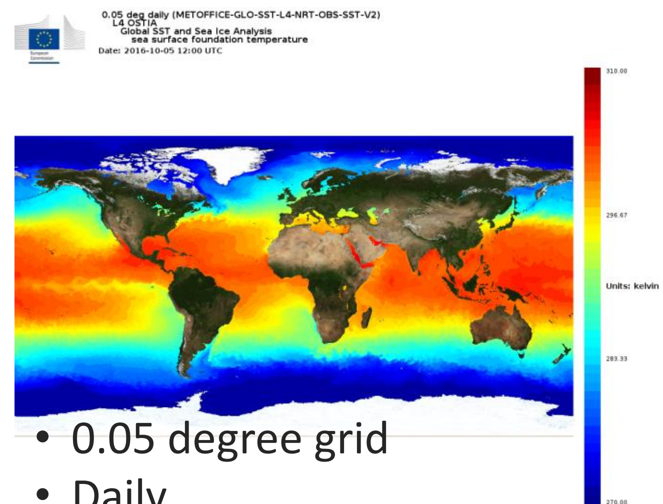
For the Global Ocean- the OSTIA global foundation Sea Surface Temperature product provides daily gap-free maps of:

- Foundation Sea Surface Temperature at 0.05° x 0.05° horizontal resolution, using in-situ and satellite data from both infra-red and micro-wave radiometers.
- Sea Surface Temperature anomaly from the Pathfinder climatology at 0.25° x 0.25° horizontal resolution.
- Estimates of SST bias in each of the satellites contributing to the OSTIA SST analysis at 0.25° x 0.25° horizontal resolution.Monthly and seasonal means of the daily Sea Surface Temperature product at 0.25° x 0.25° horizontal resolution are also available. This product provides the foundation Sea Surface Temperature which is the surface temperature free of diurnal variability.



MORE INFO

ADD TO CART



- 0.05 degree grid
- Daily
- Foundation SST
- From 2007
- Reprocessed available

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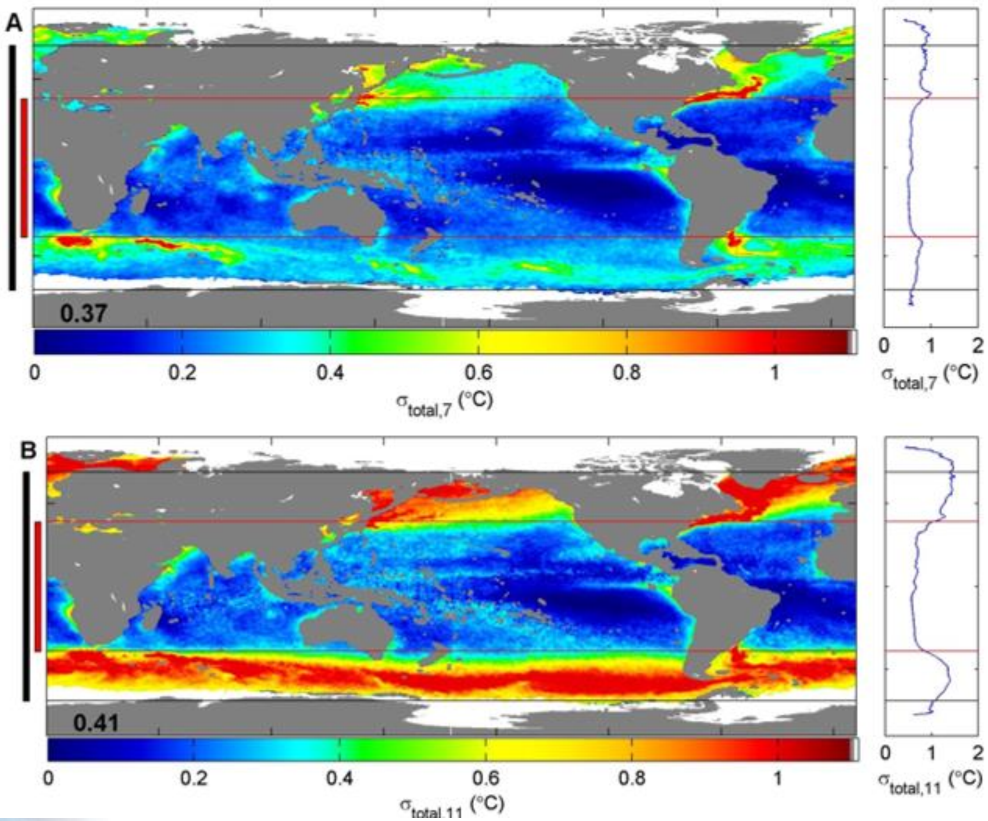
Marine Monitoring

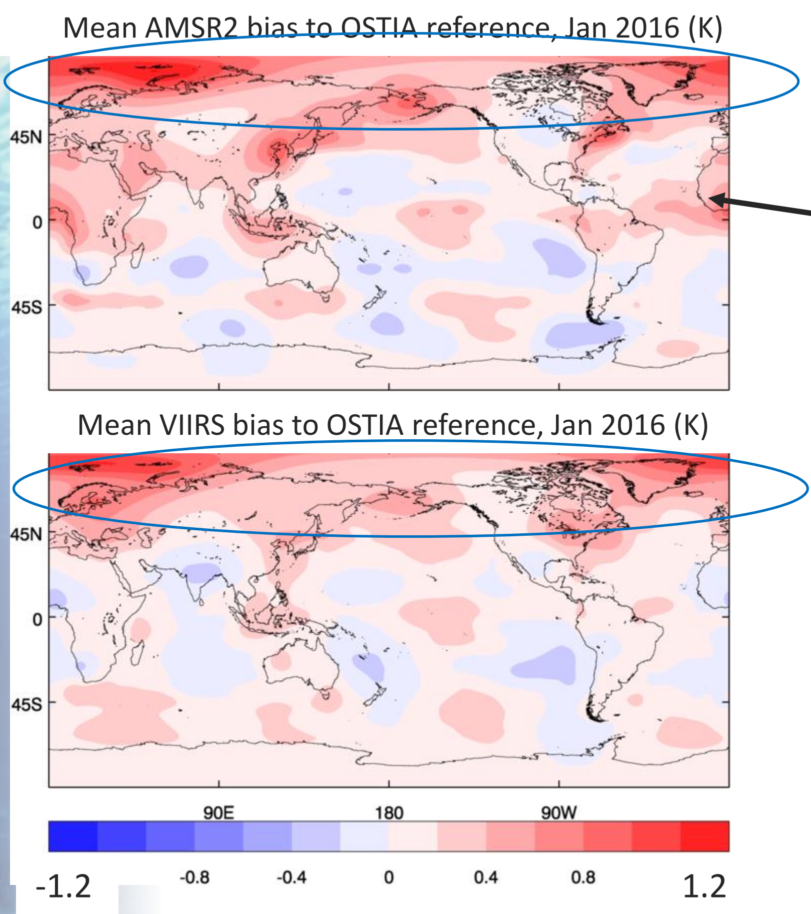
The benefit to SST retrievals using ~7GHz and ~11GHz channels



- Standard deviation of differences between AMSR-E and Reynolds SST for top (7GHz AMSR-E SST) and bottom (11GHz AMSR-E SST).
- Map using 11GHz demonstrates significant errors above 40 degree latitude for both hemispheres, due to decreased sensitivity to colder SST at 11 GHz.
- Importance of 6-7GHz channel at high-latitudes.
- From Gentemann et al. (2010).

Sensors wrt Reference Data

Marine Monitoring



AMSR2 and VIIRS bias vs OSTIA reference dataset which is in situ and high quality subset of MetOp AVHRR

- AVHRR sensitive to aerosols
- AMSR2 - large positive "bias" coast of Africa for AMSR2 - Saharan aerosols.
- AMSR2 is being "corrected" and losing good data.

Both **AMSR2 and VIIRS warmer than reference** dataset in the **Arctic**. NOAA AVHRR also warmer in the Arctic than MetOp AVHRR.

The agreement of independent datasets (IR and MW) suggests the MetOp AVHRR reference data is too cold in the Arctic.

-> Switching to use VIIRS as the reference in OSTIA improved the quality of the product as measured against Argo data.

Current status of the different "sensors"

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Low Earth Orbit IR

- Currently have several sensors in operation
- Status: **Satisfactory**

Geostationary IR

- Geostationary constellation well supported
- Status: **Satisfactory (TBC)**

Low Earth Orbit PMW

- Microwave satellites limited and without (presently usable) redundancy
- AMSR2 main workhorse: no confirmed continuity of plans for an AMSR-2
- Products available in GHRSST L2P format from JAXA and RSS
- Status: **Sub-critical – need redundant capability for global data**

(GHRSST analysis)

SST satellite requirements overview

Marine Monitoring

A **range** of **sensors** (IR and MW) and **platforms** (polar/geostationary) giving **wide coverage** of the globe **each day**.

Key features such as:

- Sensor(s) yielding very **high quality reference** SSTs.
  - SLSTR on the Sentinel 3 satellites is hoped to provide this.
- **Microwave** sensor(s) for a regular space/time coverage even in frequently **cloudy** locations.
  - AMSR2 currently provides this. What will replace it when it ceases to function?
- Sensors on **geostationary** satellites
  - for the the diurnal cycle in SST.

-> complementarity with the in situ surface temperature (mainly from Argo and surface drifters)

Passive Microwave Requirements

Passive Microwave Radiometers (PMW) for SST retrievals is an essential component of global constellation of SST sensors.

Provides temperature of ocean under **clouds**, not possible from infrared sensors, albeit **with poorer spatial** resolution.

- areas of extensive and persistent cloud cover
- in case of a large volcanic event
- Areas of high aerosol

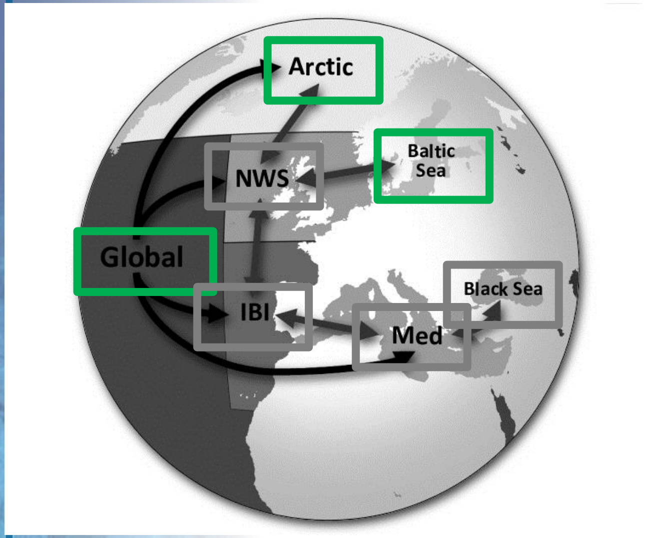
Impact studies of SST analyses / ocean forecasts show PMW importance:

- For **verification** of SST analyses (and inter-comparisons) at the poles.
- Improves feature definition (e.g. fronts) esp. where persistent cloud.
- Improvement in RMSD, particularly **at high latitudes**.

Sustainable passive microwave SST observations are also very important in the global ocean as well as in polar regions.

-> SST from PMW is a crucial contribution providing input to weather forecasting and CMEMS ocean and analysis and forecasting models. The future for PMW SSTs is very uncertain and as, of today, CMEMS cannot solely rely on USA or Japan contributing missions.

Catalogue of products



Model products

SEA ICE COVERAGE, THICKNESS, DRIFT, SURFACE TEMPERATURE

Surface

NRT, Forecast and analysis

Source: 3 MFCS (Arctic, Baltic and Global)

In Situ Observation products

Satellite Observation products

ICE ST, SEA ICE COVERAGE, THICKNESS, DRIFT, EDGE, TYPE, ICEBERG DENSITY

Surface

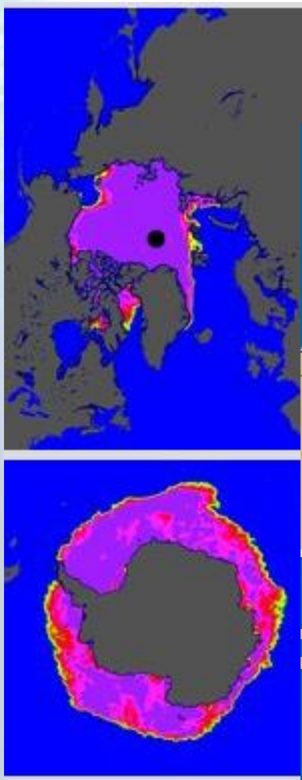
NRT and Reprocessing

Source: OSI TAC

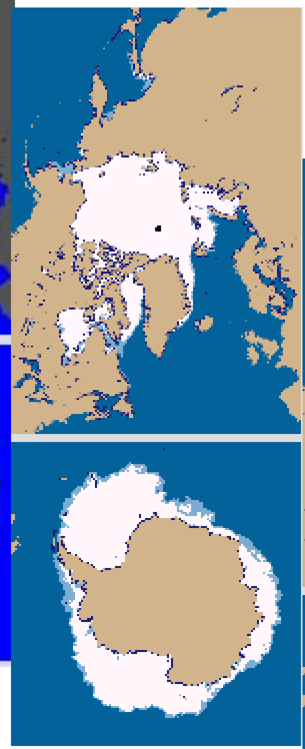
Marine Monitoring

Sea Ice products including PMW measurements

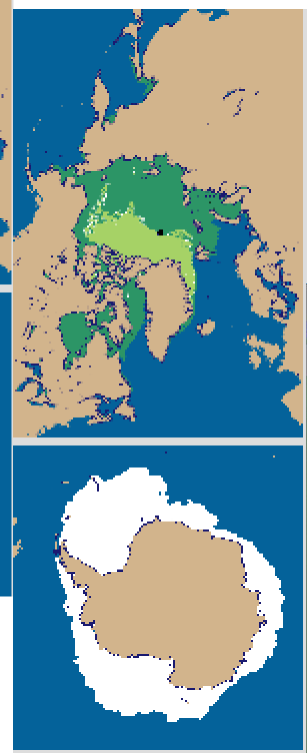
Concentration



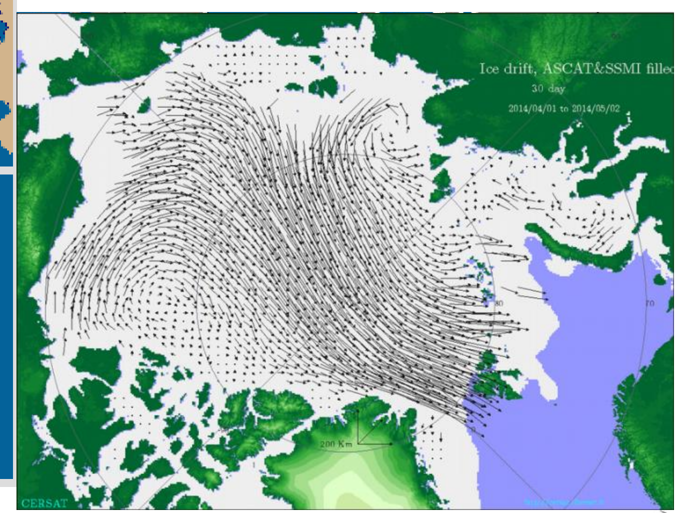
Edge



Type



Sea Ice Drift



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Satellite sea ice thickness

<u>CryoSat2:</u>

Pro:

- Thick ice
- High resolution along track 300m.

Contra:

- Low coverage
- Requires long processing windows
- High latency
- Imprecise in thin ice (small freeboard)
- Uncertainty with snow
- Not available in summer

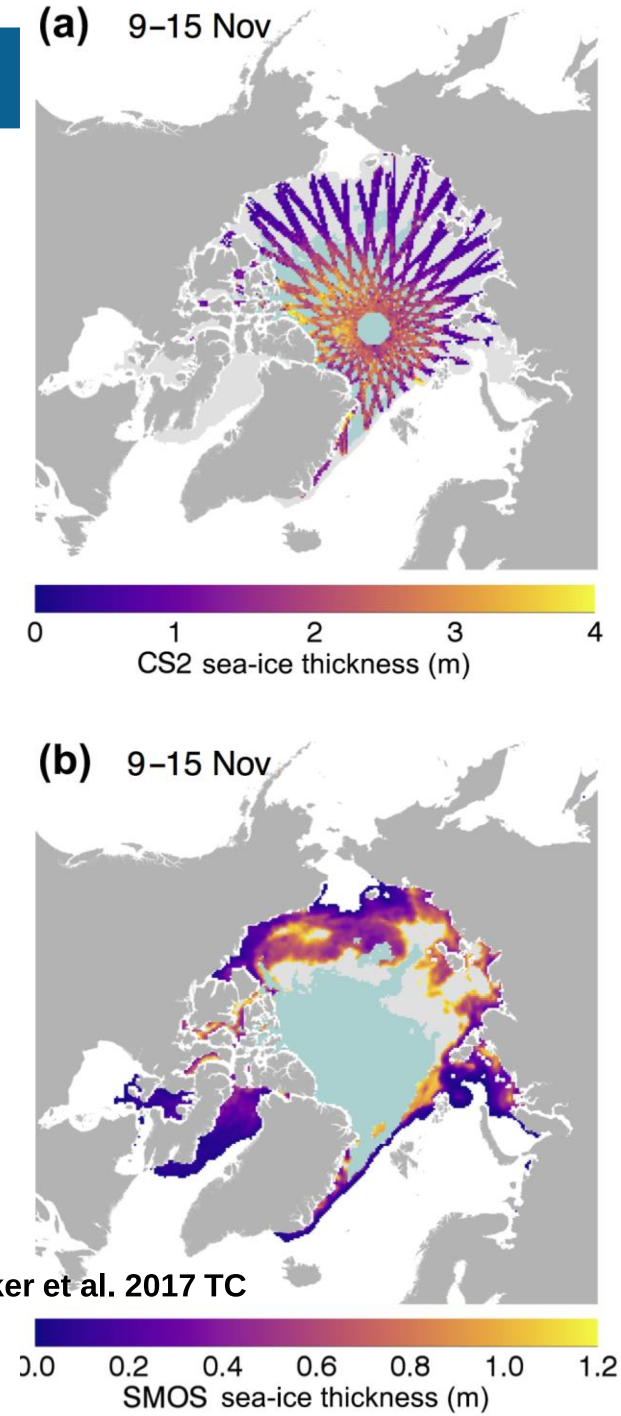
<u>SMOS:</u>

Pro:

- Daily full coverage, October – March
- Better for NRT operations

Contra:

- Coarse resolution ~35 km.
- Only 0 to 0.5m in level ice
- Until 1.5 m in deformed ice
- Not available in Summer



Ricker et al. 2017 TC

Satellite ice thickness: relative uncertainties

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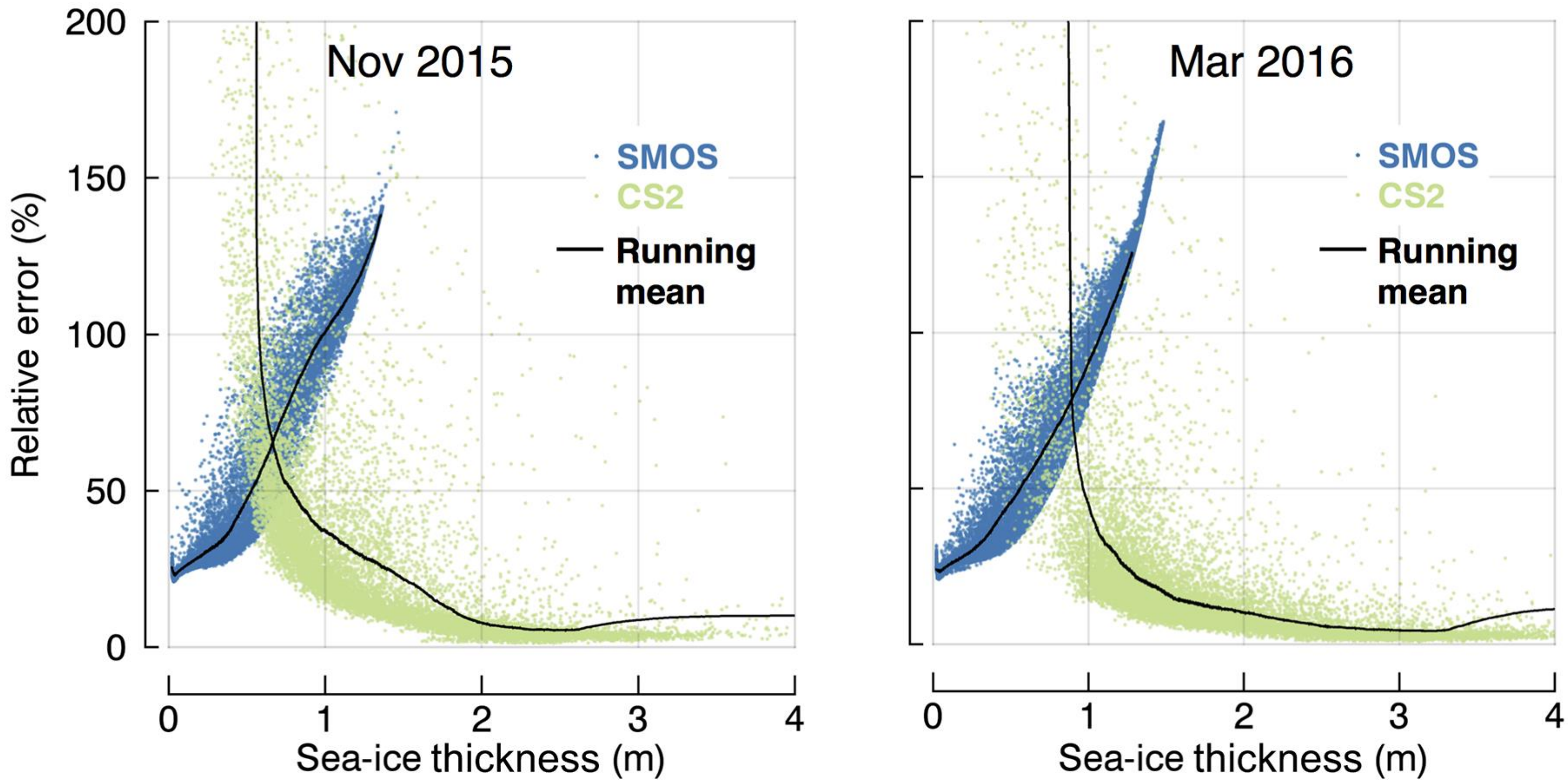

What about biases? …

Ricker et al. 2017 TC

Sea Ice data assimilation in Mercator

Marine Monitoring

Evolution of the ice DA component in the Mercator system

Assimilation

- SAM2 / 3D-FGAT innovation (First Guess at Appropriate Time) / IAU (Incremental Analysis Update)/ Local 2D Technic.
- **3D-VAR** Large Scale Biases Correction

Assimilated Observations

- **SST**
- **Altimetry** (Envisat, Jason, Cryosat2,…)
- **In situ** (T,S) (Argo) from CORA (CMEMS) data base
- Hybrid Mean Dynamical Topography (**MDT**)
- **Assimilation switched off in ice covered areas**

Core of the system

+

• Implementation of **OSI SAF** sea ice concentration assimilation into a multi category sea ice model context (**LIM3**).
• A 2007-2014 reanalysis has been performed with a pan-Arctic configuration.

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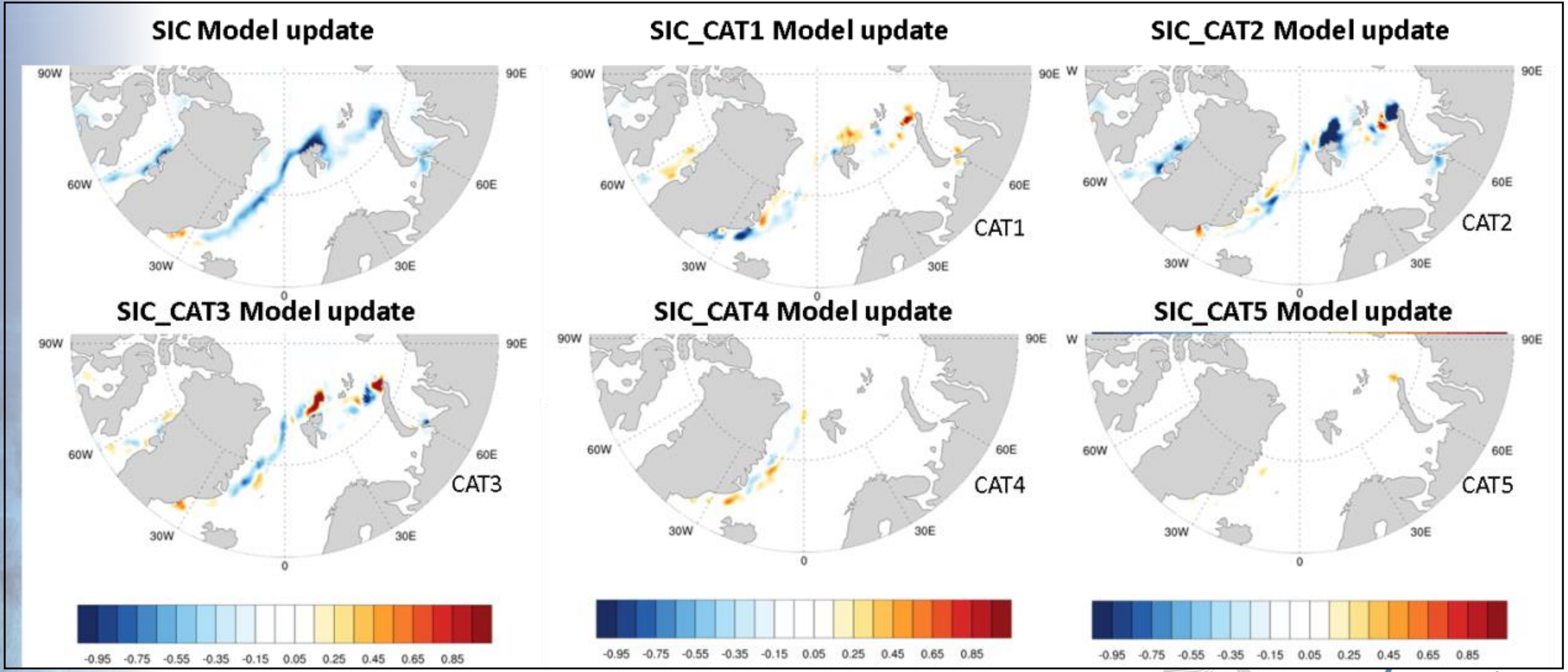
Sea Ice data assimilation in Mercator

Multivariate Sea Ice Model update

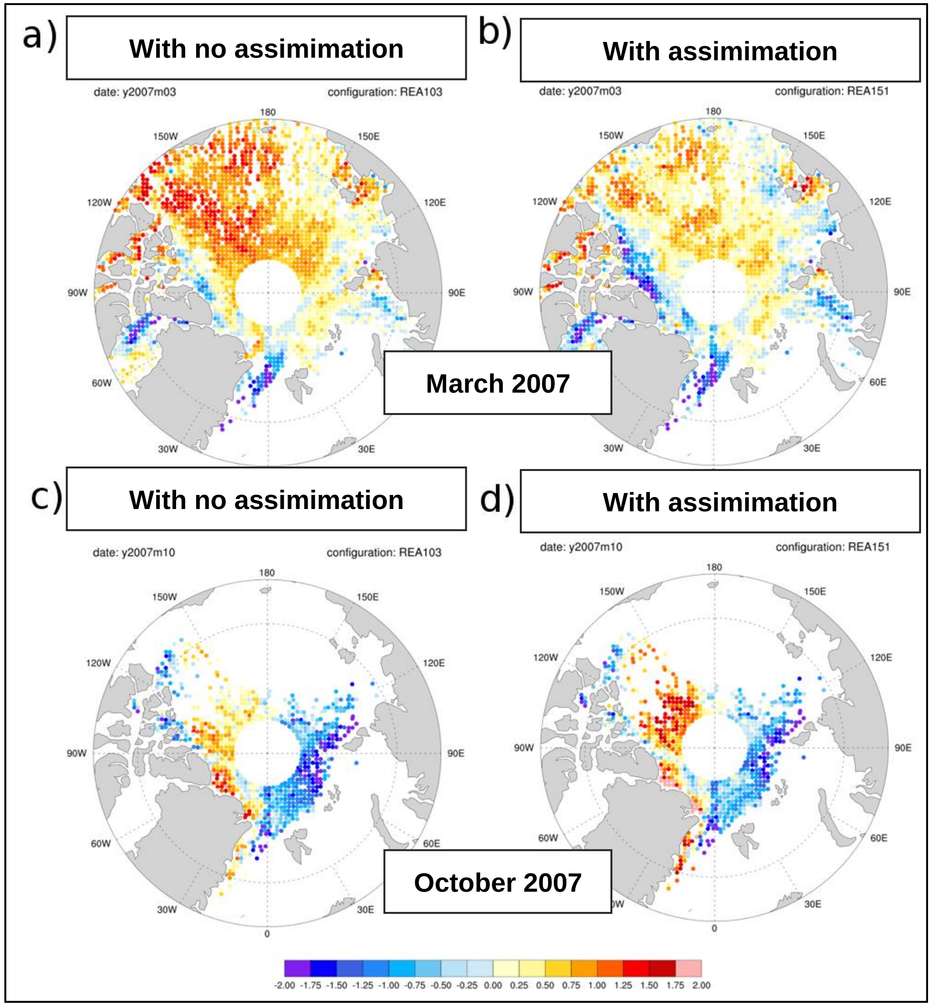
The SIC innovation is projected on total SIC variable of the state vector and each category of SIC is extrapolated statistically using covariance and through the sea ice analysis.

Total SIC increment analysis (top left), increment for each single category with LIM3 having 5 categories (28th December 2006)



Sea Ice data assimilation in Mercator

Differences with ICESat-GSFC ice thickness



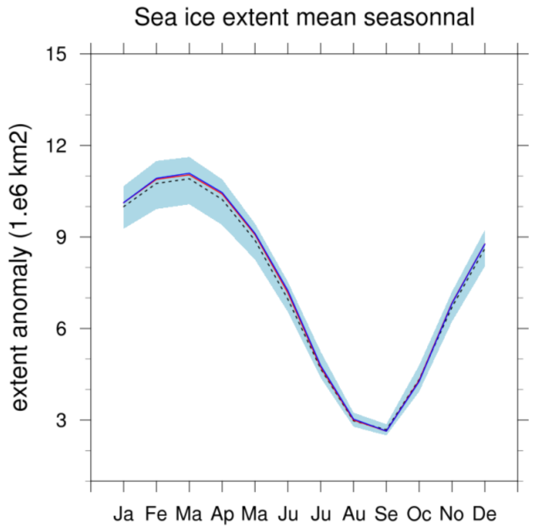
Impact of SIC (OSI SAF) data assimilation:

A 2007-2014 short reanalysis has been performed with the updated **pan-Arctic configuration at 1/4°** .

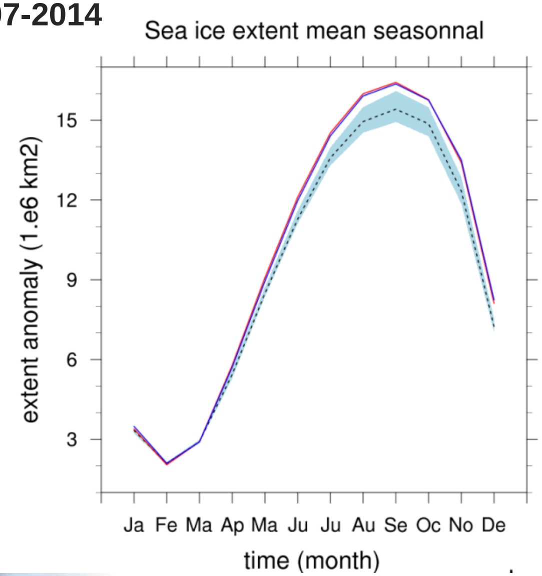
- Assimilation of sea ice concentration into a multi category sea ice model context has been successfully implemented.
- This reanalysis improves the sea ice thickness representation in winter.

Sea Ice data assimilation in Mercator

Marine Monitoring



2007-2014

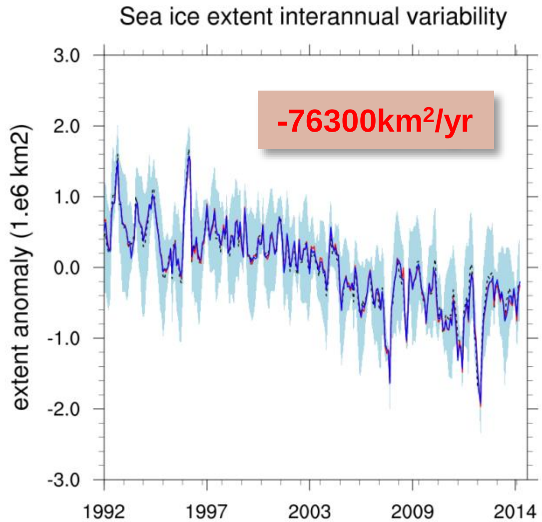


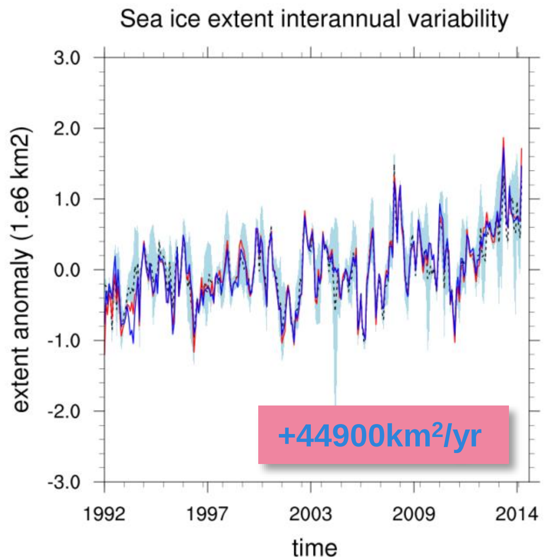
- Global ¼° Reanalysis
- Observations

Arctic Ocean

Use of different data using PMW: CERSAT, NSIDC, OSI SAF (CMEMS) to assess uncertainties.

Antarctica





Assimilated data: SIC from CERSAT (PMW / SSMI) -> soon OSI SAF

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Sea Ice data assimilation in Mercator

Perspectives:

- LIM3 sea ice model and NEMO3.6 for the next real time and reanalysis system in 2019, with a sea ice multi-category assimilation.

- Assimilation of Cryosat-2/SMOS SIT merged product in LIM3 sea ice model:

  first tests with the pan-Arctic configuration

  implementation in the global system.

Specific Requirements from CMEMS: Polar regions

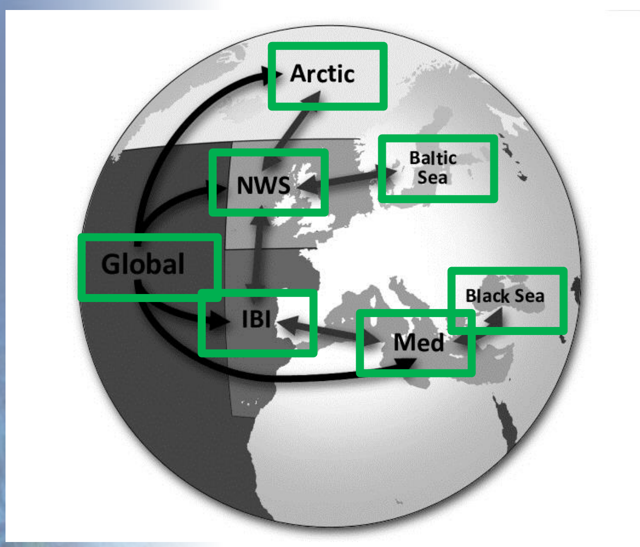
Marine Monitoring

Improvements of the satellite observations over these areas are of paramount importance to ensure that future user needs, in terms of resolution and data availability and of resolution will be satisfied.

- Sustainable **operation of medium-resolution** (5-10 km) multi-frequency and -polarization **passive microwave observations** of SST, sea ice lead fraction and sea ice concentration, area and extent.
- **Continuation** of the **Cryosat-2** mission to monitor sea ice thickness, continental ice shelves elevation changes and contribute to the observation of the **ocean surface topography** in ice free regions.
- Reliable retrieval of **sea level in the leads** to reach the retrieval accuracy required to monitor Climate Change.
- Continuation of **SMOS** like observations of **thin sea ice** below 0.5 m.
- Automated production of ice chart-like products from a combination of SAR data and other data (e.g. bi-static SAR, passive microwave, multi-frequency SAR).
- Reliable retrieval of **ocean colour in the marginal ice zone**.

CMEMS requirements for the evolution of the Copernicus Satellite Component (February 2017)

Catalogue of products



SMOS **SSS** is not a CMEMS product

Model products

TEMPERATURE (T)

SALINITY (S)

From - 6000 m to surface

Forecast, NRT and Reanalysis

Source: MFC

In Situ Observation products

TEMPERATURE (T)

SALINITY (S)

From – 6000 m to surface

NRT and Reprocessing

Source: INSITU TAC

Satellite Observation products

SEA SURFACE TEMPERATURE (SST)

L3 and L4

NRT and Reprocessing

Source: OSI TAC

Data assimilation of satellite SSS

Marine Monitoring

The salinity is an ocean variable playing a key role in the ocean variability.

➔Observing this Sea Surface Salinity (SSS) is crucial for monitoring, understanding and forecasting the ocean circulation, water cycle and climate changes.

The launch of ESA's SMOS mission (2009-Now) as well as NASA's Aquarius (2011-2015) and SMAP missions (2015-Now) provide for the first time satellite measurements of SSS.

Several studies already demonstrated the ability of SMOS and Aquarius missions to provide useful and new information on SSS.

BUT, these data are not widely used by the ocean modelling community and in particular by the ocean forecasting centers

➔ Land contamination, RFI, latitudinal bias, galactic noise and so on

➔Technical challenges of assimilating SSS data and assessing the impact of these data in the forecasting systems.

The SSS products are still in development and constantly evolving toward an increased quality.

SMOS-Nino2015 ESA project

Objectives

Design, implement and perform an **Observing System Experiment** of the **SSS** with different operational ocean forecasting systems.

- UK MetOffice: global ¼° ocean forecasting system with a 3DVar – FGAT DA and a bias correction
- Mercator Ocean: global ¼° ocean forecasting system with SAM2 and a 3DVar large scale bias correction

- Provide feedbacks to the **operational forecasting community (GODAE** Ocean View), **promote and enhance the use the SSS SMOS products**
- **Refine** the **requirements for SSS** (Sea Surface Salinity) after the analysis of the errors associated with these experiments

Context: the onset and evolution of the **2015/16 El Niño event**

https://www.godae-oceanview.org/projects/smos-nino15/

S M O S - N i n o 2 0 1 5   E S A   p r o j e c t

Marine Monitoring

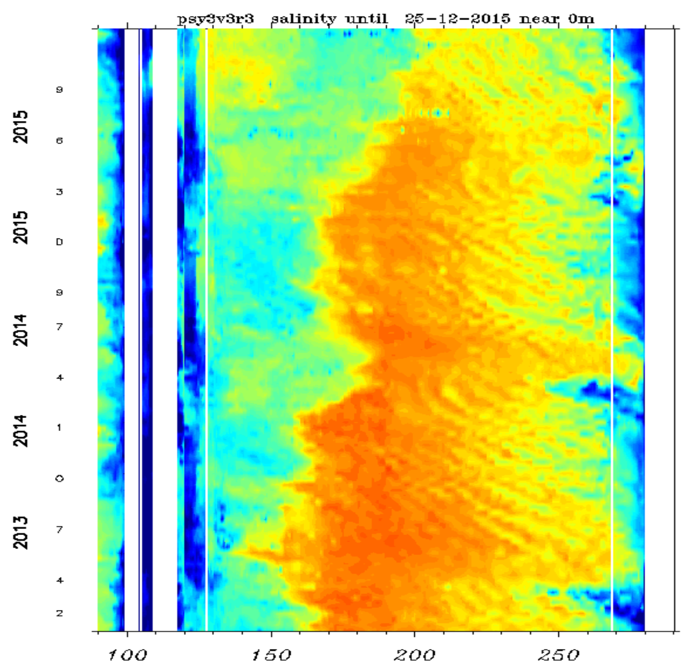
Data assimilation of different data sets: **daily/weekly products from:**

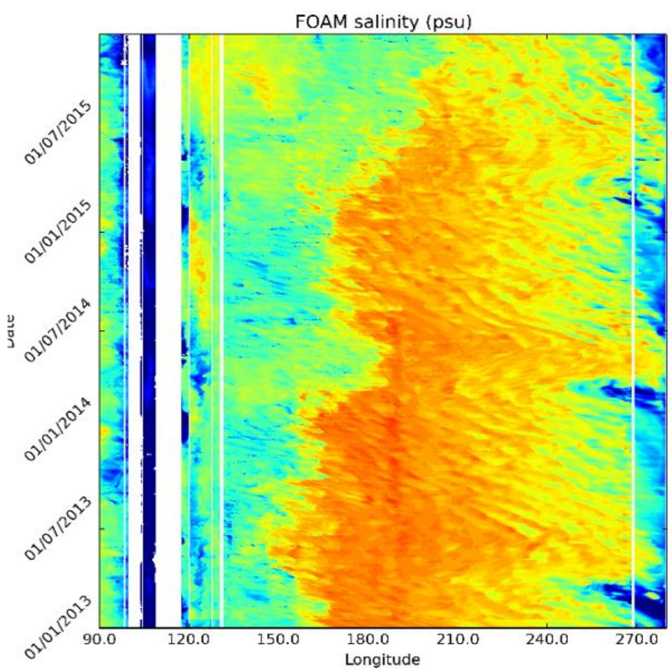
- ESA's SMOS
- Aquarius (V4.0)
- SMAP (V2.0)

SSS data assimilation between 40°S and 40°N. All other observations routinely assimilated are kept (SLA, SST and in-situ observations).

Hovmöller diagrams of salinity along the Equator in the Pacific

→The freshening increases in the West from 2013 to 2015.
The onset of the El-Niño 2015/16 event is evident in the SSS from both systems.





Marine Monitoring

Observing System Experiments with the Mercator global ocean ¼°

- **REFERENCE experiment** (January 2014 to March 2016) :
  Assimilation of the current network (SLA (along tracks), satellite SST (OSTIA), in situ profiles (no salinity TAO/TRITON moorings) and NO satellite SSS assimilation.
- **SMOS** (2015-March 2016):
  REFERENCE + **SMOS CEC-LOCEAN v2-18km,25km, 4 days (debiased)**
- **AQUARIUS/SMAP** (2015-March 2016):
  REFERENCE + **Aquarius V4.0 (1°x1°) from JPL**, 7-day running mean (until May 2015) + **SMAP V2.0 (0.25°x0.25°) from RSS**, 8-day running mean (from June 2015)

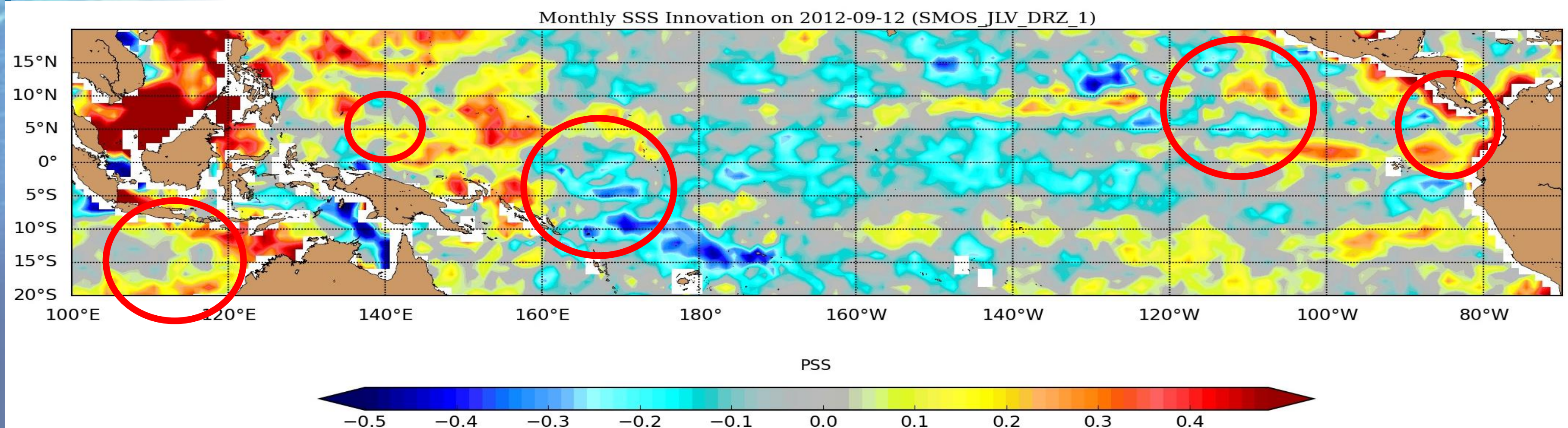
The observation operator H for the weekly mean SSS
- No spatial filtering for SMOS and SMAP (0.25°x0.25°)
- Spatial smoothing (shapiro filter) for Aquarius (1°x1°)

➔ **BIAS CORRECTION**: 3Dvar scheme for large scale bias correction of in-situ data and for SSS data ➔ observation errors of SSS estimated from an adaptive method

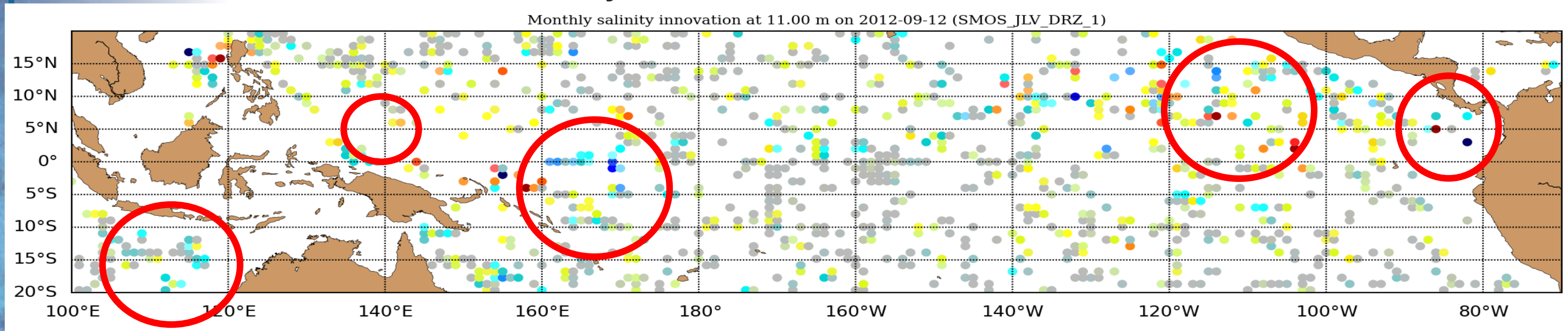
Data assimilation of SMOS SSS data

SSS innovation vs in-situ innovation before bias correction

Monthly **SMOS SSS** innovation



Monthly **in-situ SSS** innovation



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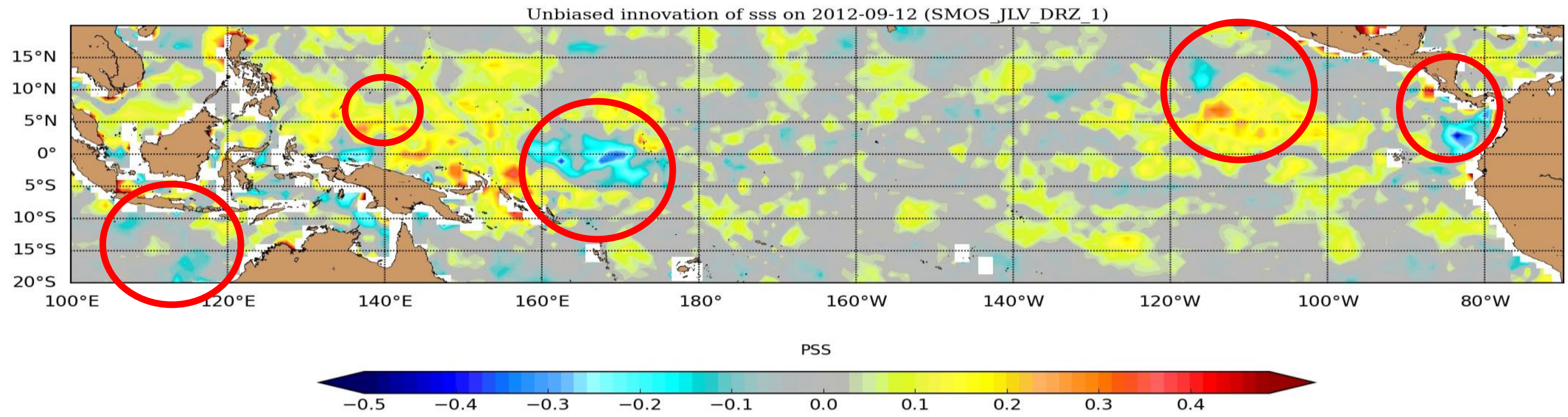
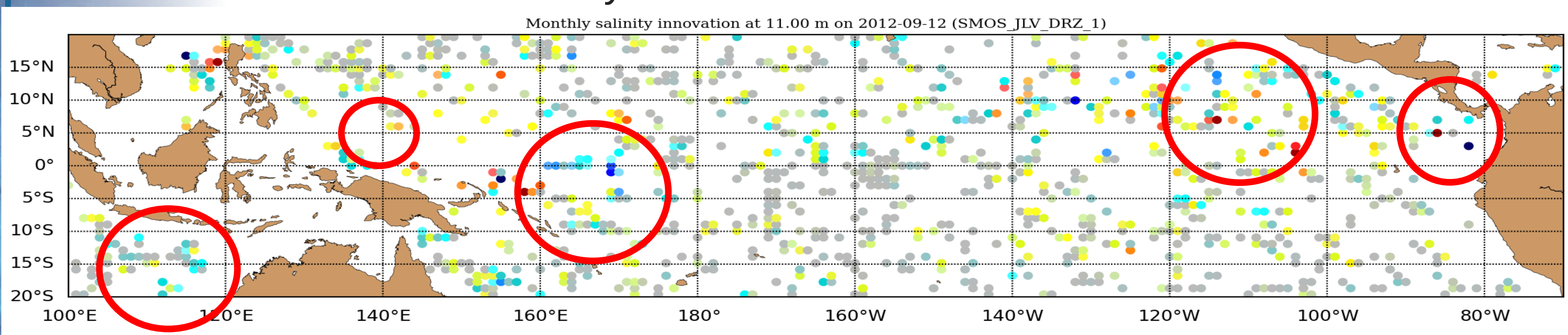
Data assimilation of SMOS SSS data

SSS innovation vs in-situ innovation **AFTER** bias correction

Monthly **SMOS SSS** innovation



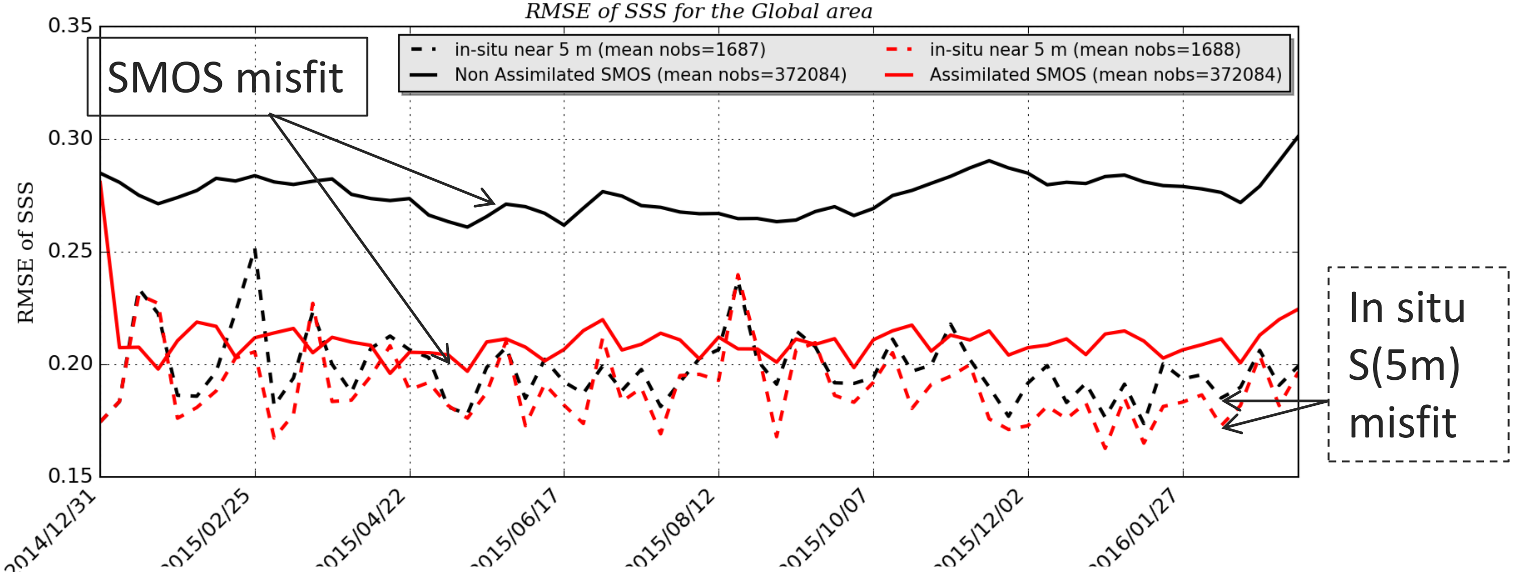
Monthly **in-situ SSS** innovation

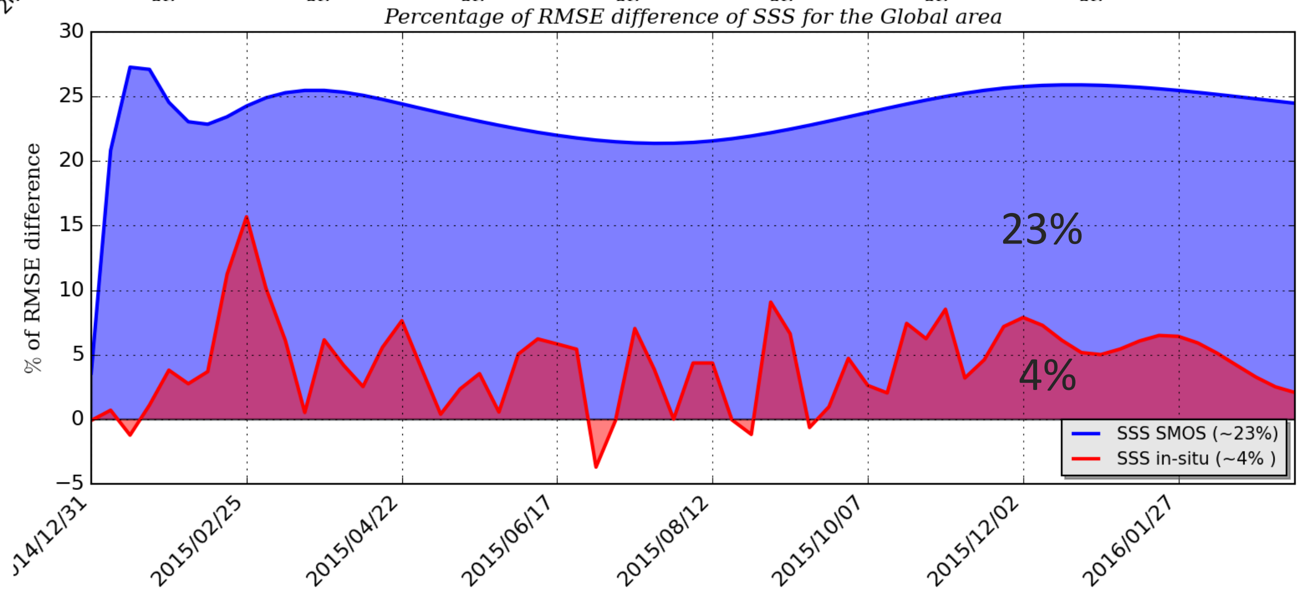


SSS data assimilation

Marine Monitoring

Global RMSE and % of difference of RMSE (SMOS)





RMSE and % of difference of RMSE (SMOS/global)

SSS data assimilation

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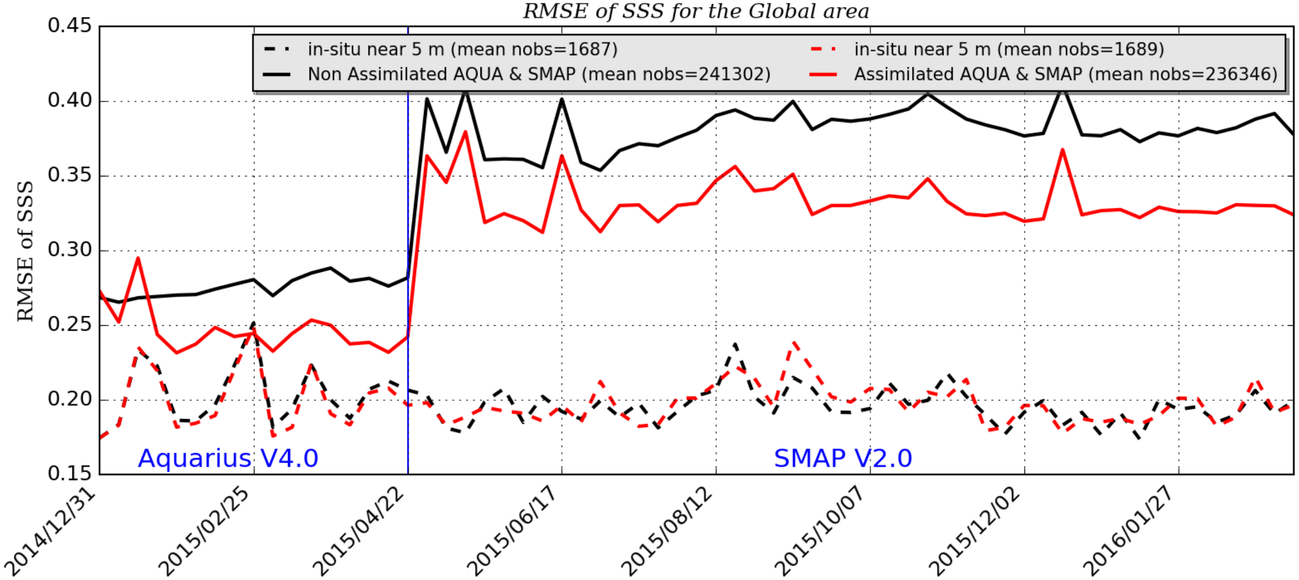
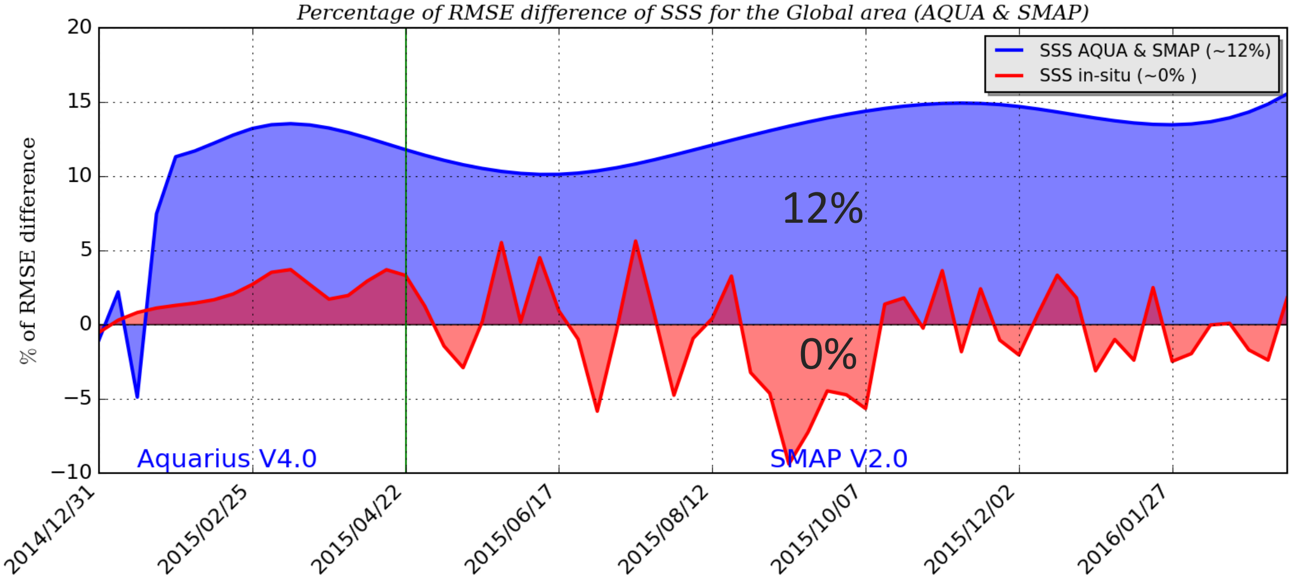
Global RMSE and % of difference of RMSE (Aquarius &SMAP/global)





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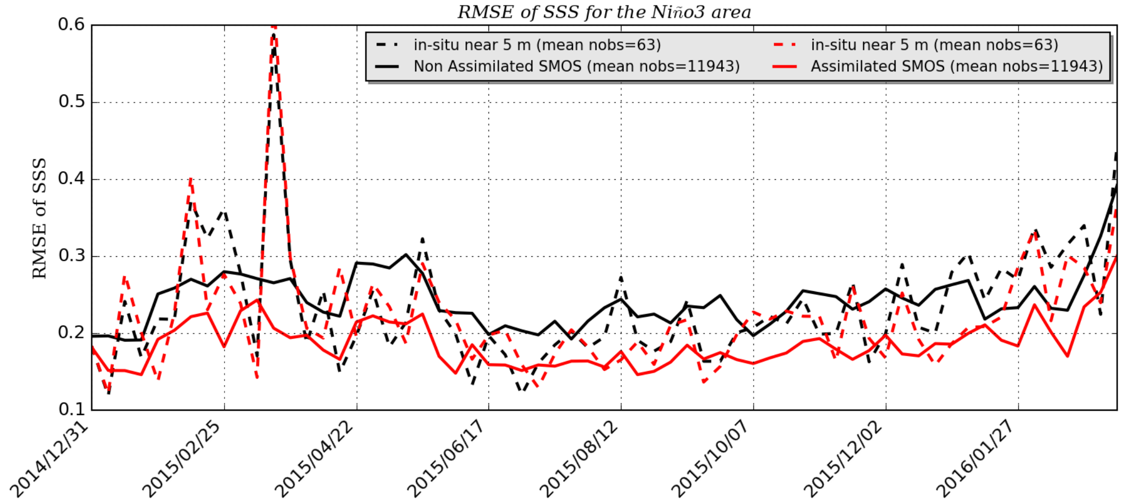
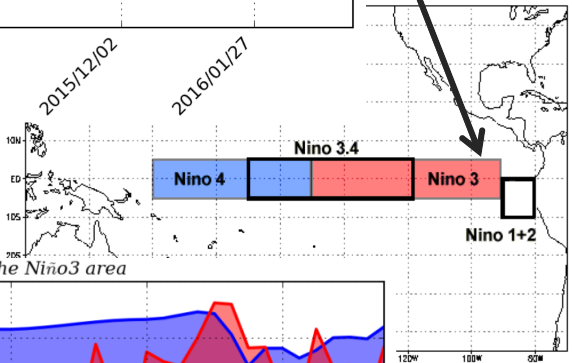
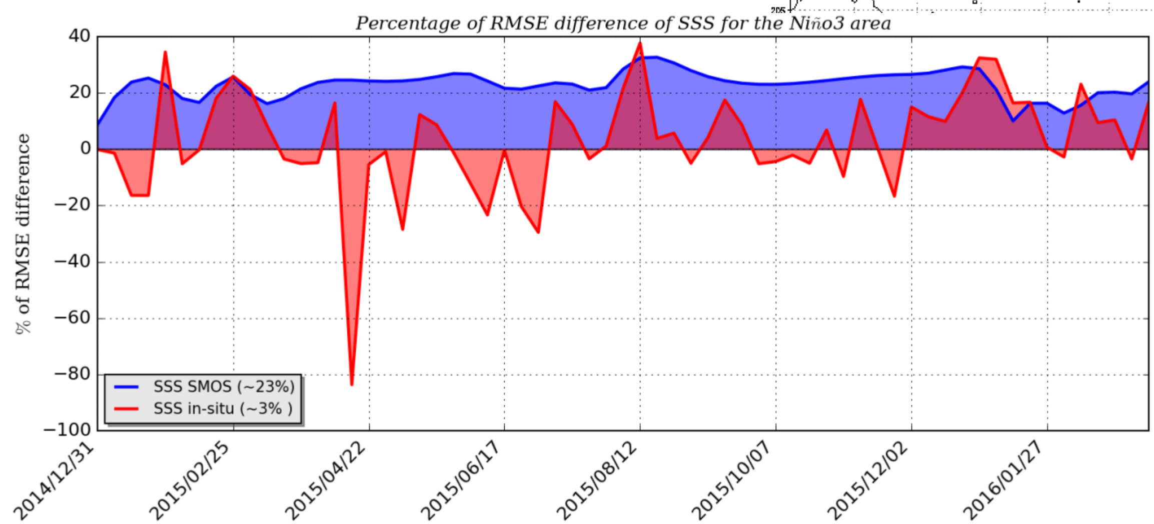
Marine Monitoring

S S S   d a t a   a s s i m i l a t i o n

RMSE and % of difference of RMSE (SMOS/Niño3)







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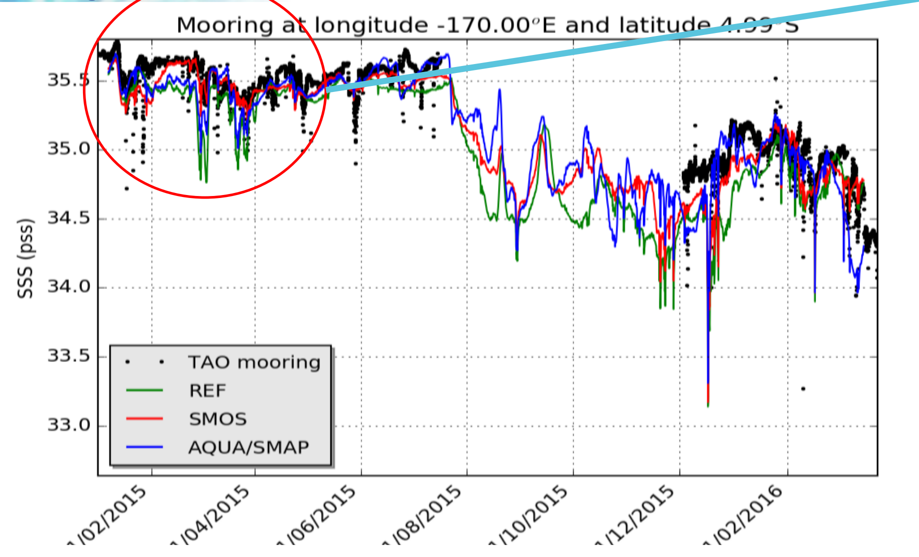
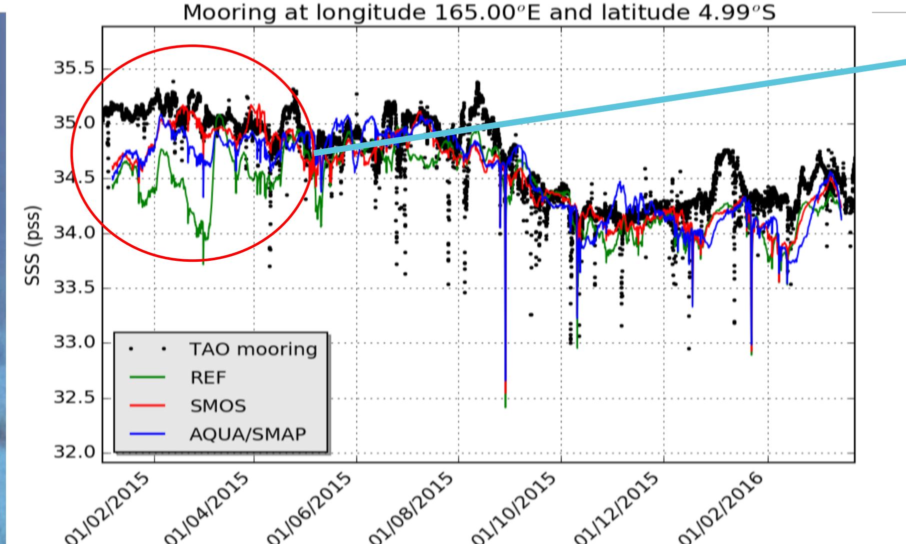
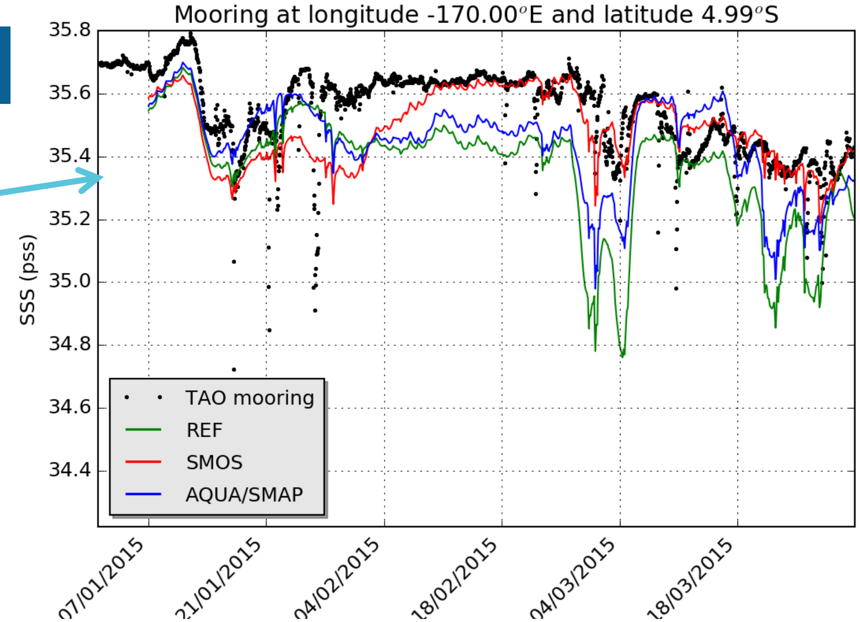
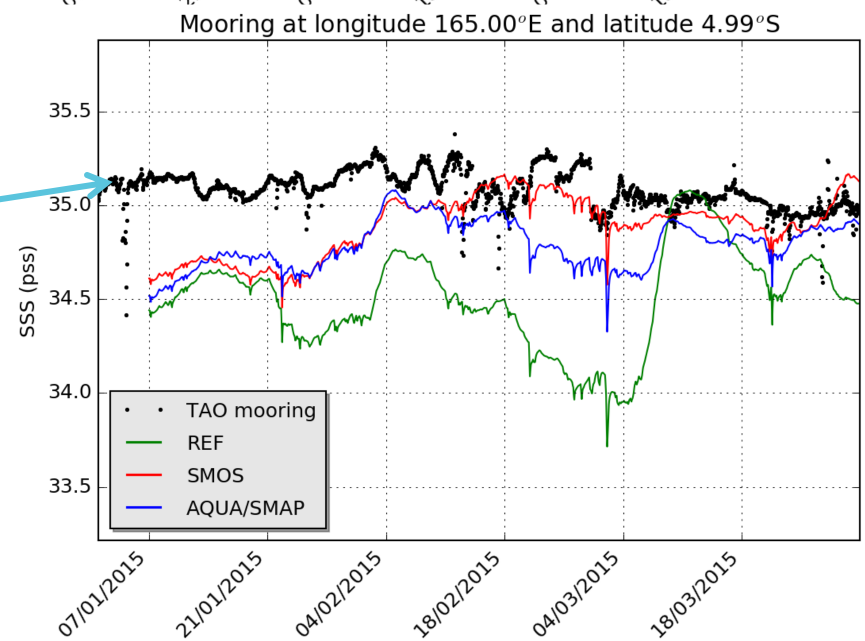
SMOS Data assimilation

TAO data Withheld from the analysis









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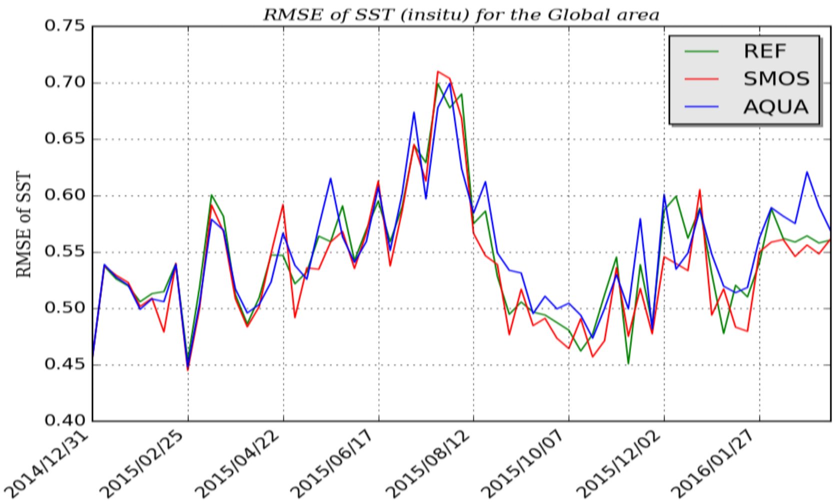
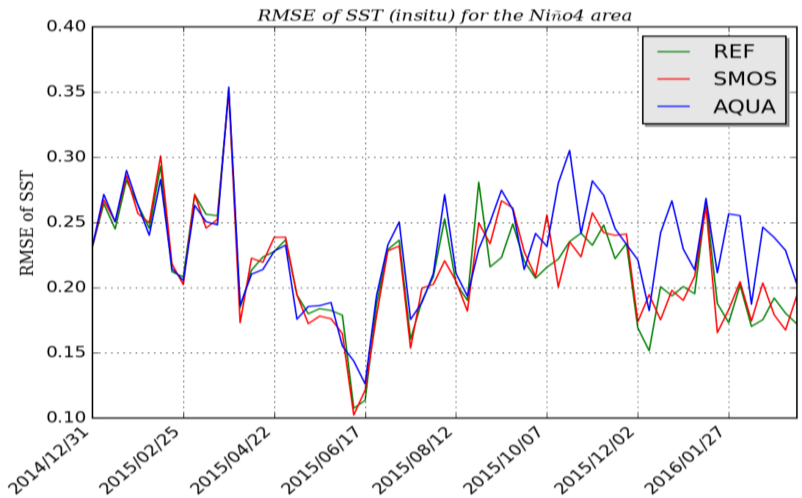
SSS data assimilation

RMSE to **in-situ temperature** (5 m) for all experiments

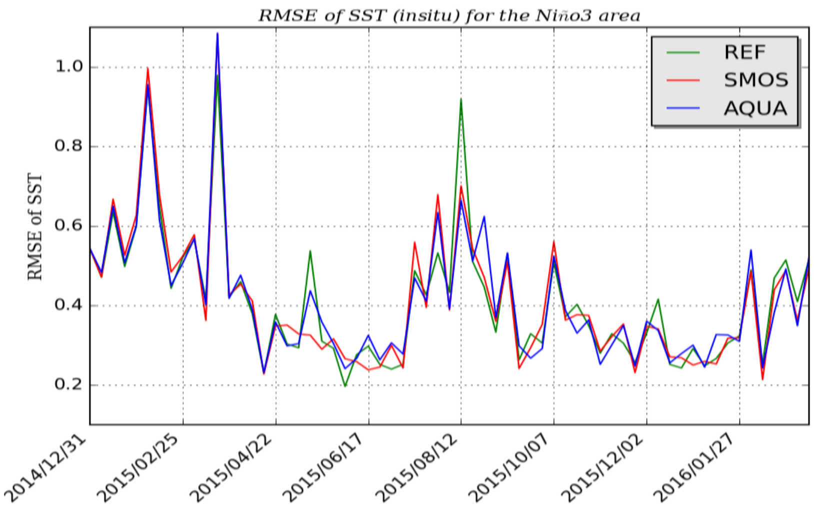
Global



Nino4



Nino3

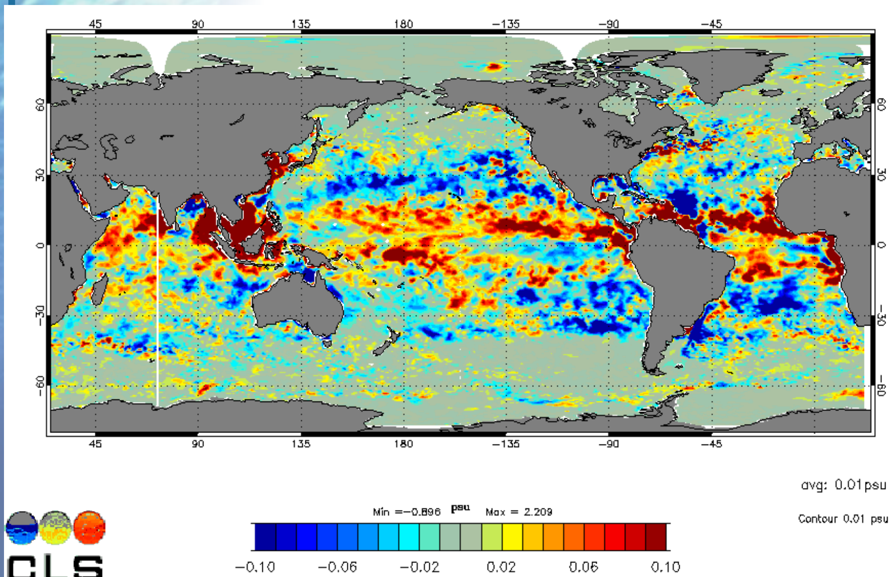


S S S d a t a a s s i m i l a t i o n

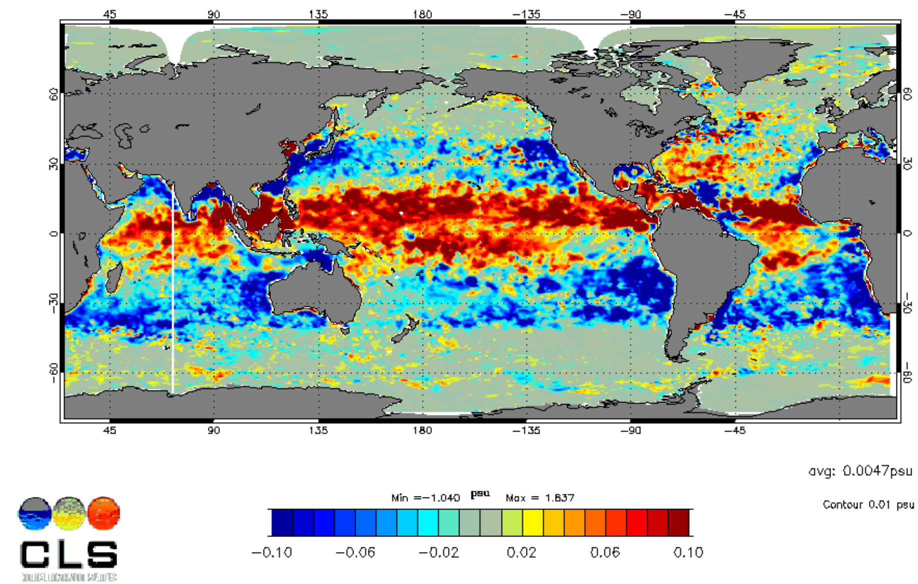
Marine Monitoring

Impact of SMOS data assimilation on SSS

SSS mean differences (SMOS - REF)



SSS mean differences (AQUA/SMAP - REF)



- Saltier in the tropic ➔ reduce the precipitation
- Fresher at mid-latitudes ➔ reduce the evaporation

The AQUA+SMAP impact is stronger. There are very similar patterns (Atlantic NECC) but the impact is opposed in the Pacific Warm Pool.

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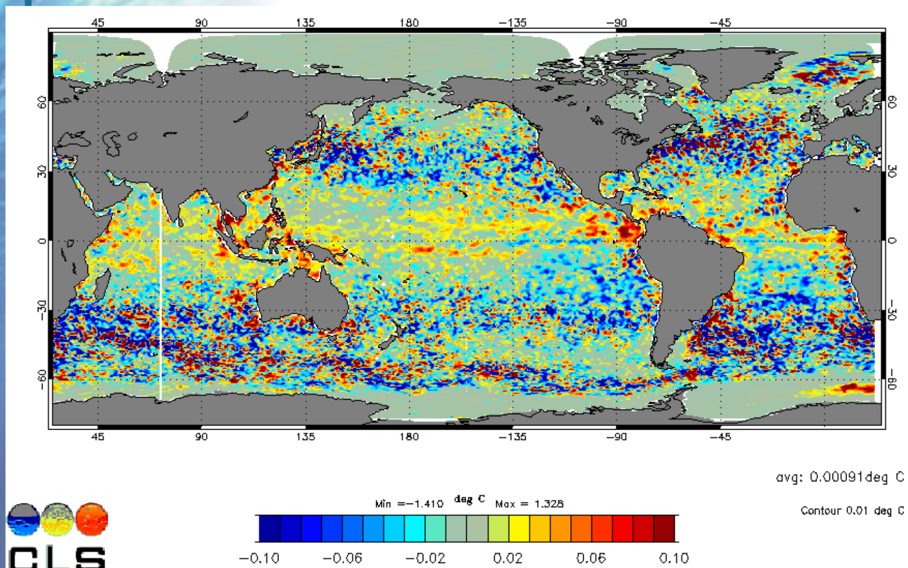
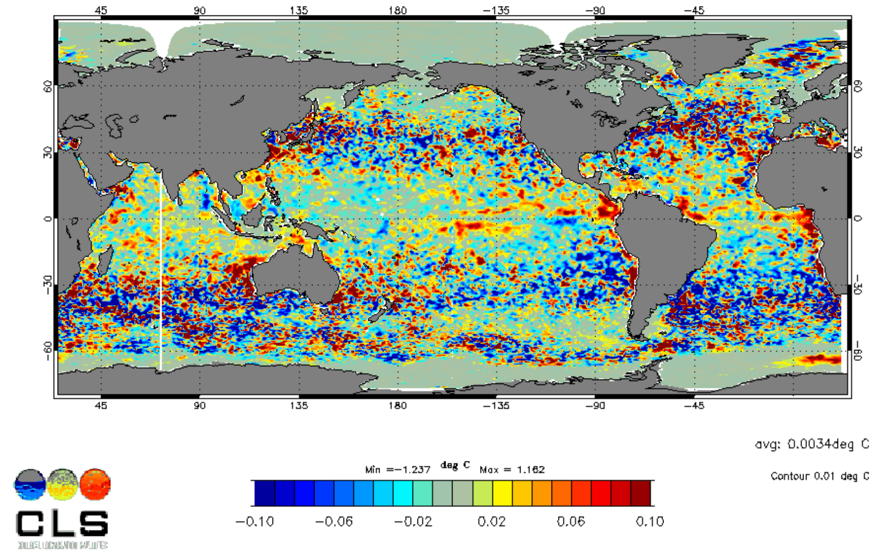
SSS data assimilation

Impact of SMOS data assimilation on SST

SST mean differences (SMOS - REF)



SST mean differences (AQUA/SMAP - REF)



- The **impact of the SSS on the SST is not negligible.**
- SSS DA generally “warms” the tropics, AQUA/SMAP cools down the Warm Pool.

-> impact on the mixed layer bias?

SSS data assimilation in Mercator system

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DA of SSS from SMOS seems to have **a positive impact on the ocean analysis and forecast**

- **A bias correction is necessary**
  - Reduction of the RMS of SSS innovation → closer to the in-situ
- RMS of SMAP (rss product at 0.25°x0.25°) innovation is higher than for SMOS ⇒ ongoing discussions
- The **SST is significantly impacted**
- Misfits to insitu T/S profiles
  - Not significantly changed

  The sub-surface T/S equilibrium has changed, may be we correct too much the sea surface (SST and SSS)?
- **SLA: slight improvement →** the mean SLA increment (2015) has been reduced in the tropical Pacific.

SSS data assimilation

Further analysis of the results are needed:

Impact of SSS DA at depth, especially **on the stratification:**

- Barrier Layer Thickness
- Increase of stratification at the base of MLD?

Focus on the Tropical Pacific Region, impact in other regions/processes:

-> in the **Amazon plume region**

-> in the Bay of Bengal.

Comparisons with the MetOffice experiments

Difficulty to assess the small scale changes in SSS due to the sparsity of in situ data.

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GENERAL REQUIREMENTS

In the post 2025 time period, **CMEMS model resolutions will be increased** by a factor of at least 3 (e.g. global 1/36°, regional 1/108°) compared to the present and more advanced data assimilation methods will be available. The objective will be to describe at fine scale the upper ocean dynamics to improve, in particular, our capabilities to describe and forecast the ocean currents and provide better boundary conditions for very high resolution coastal models (a few hundred of meters).

…

The three main areas of improvements are:

- **Improved space/time resolution of upper ocean dynamics** -> *currents and salinity surface observations are required*
- Better monitoring and forecasting of the coastal ocean.
- Better monitoring of biogeochemical state of ocean.

+ specific requirements for the monitoring of the ***rapidly changing polar regions.***

From “CMEMS requirements for the evolution of the Copernicus Satellite Component”, February 2017.

Specific Requirements: SST

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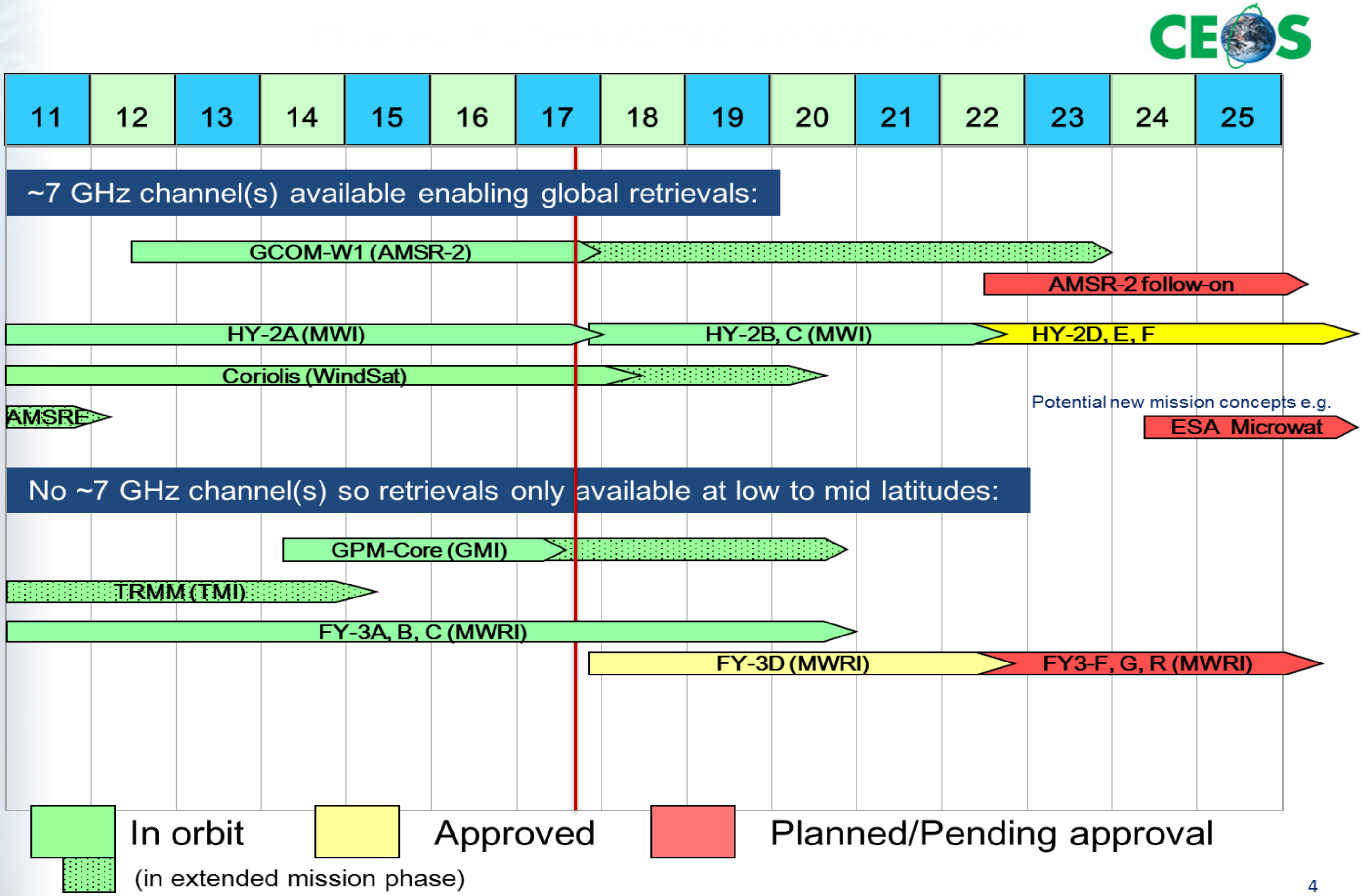
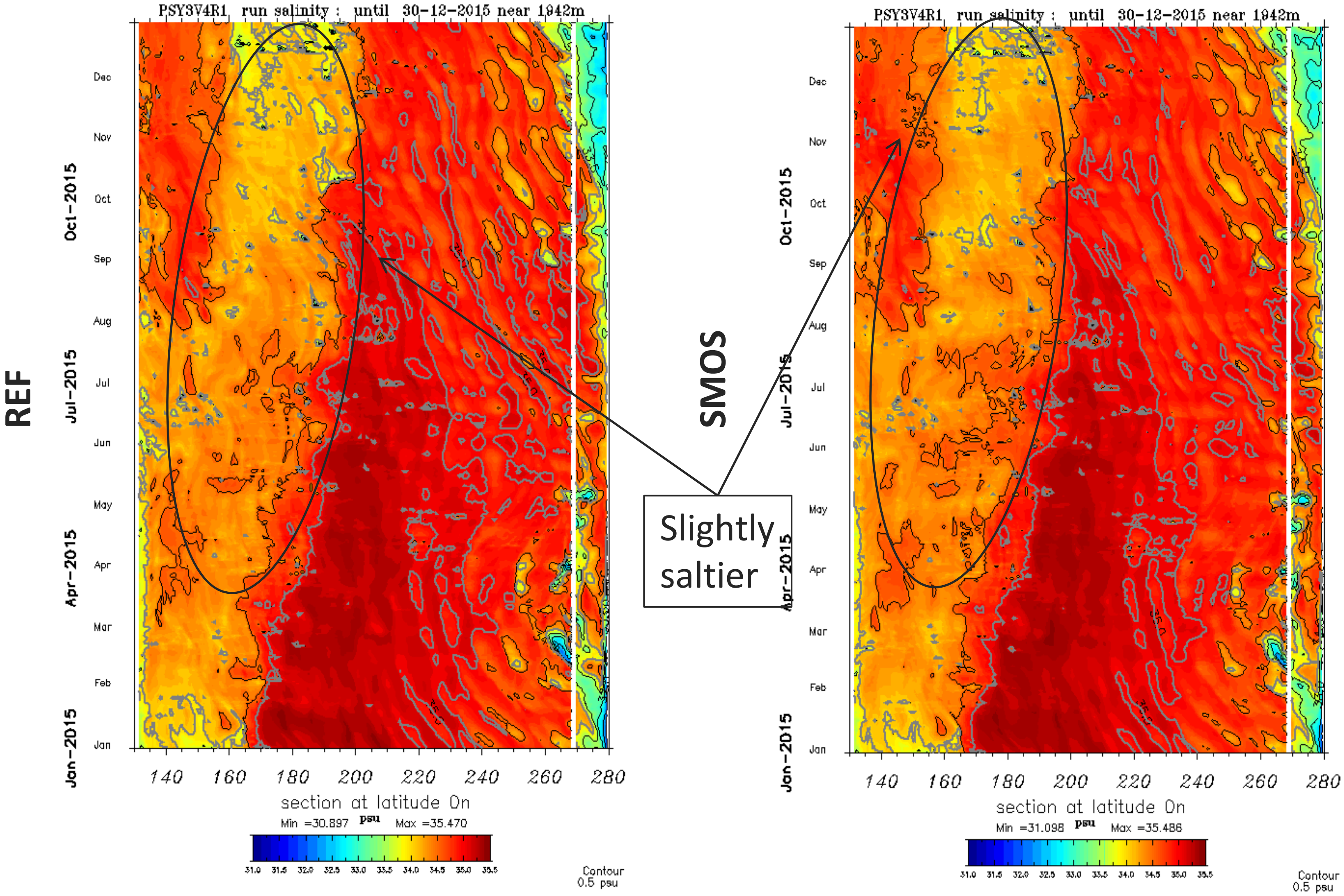
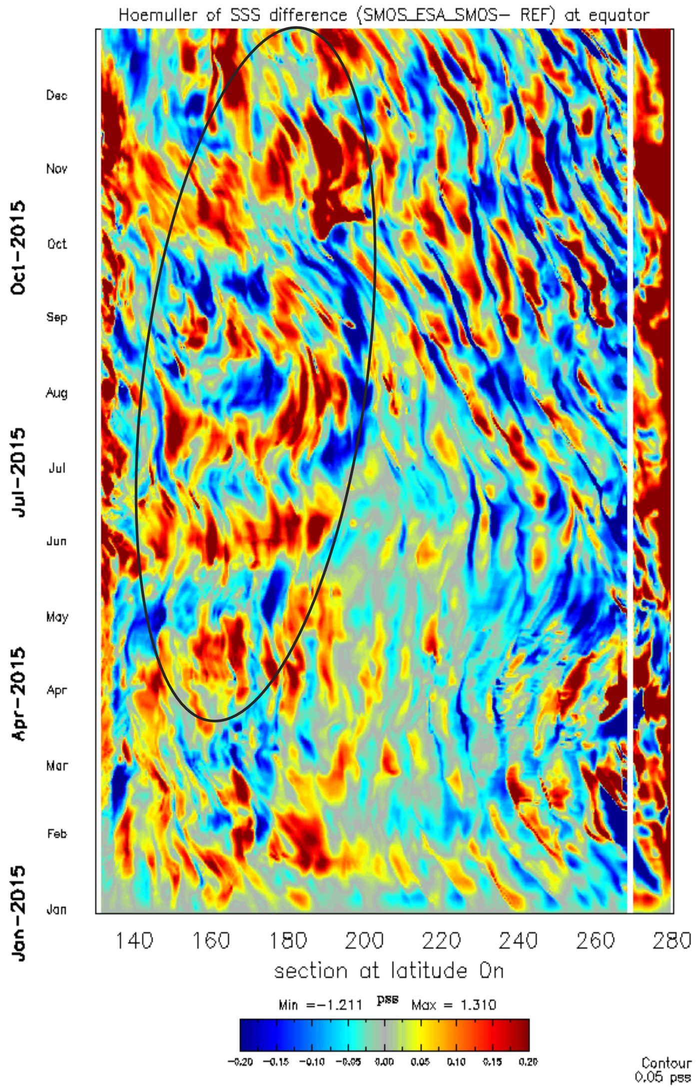


SSS: Hoevmuller at equator

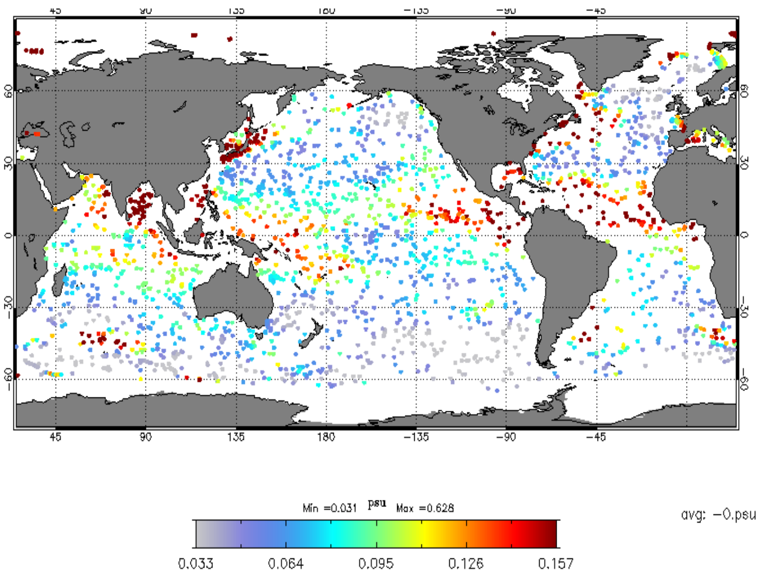


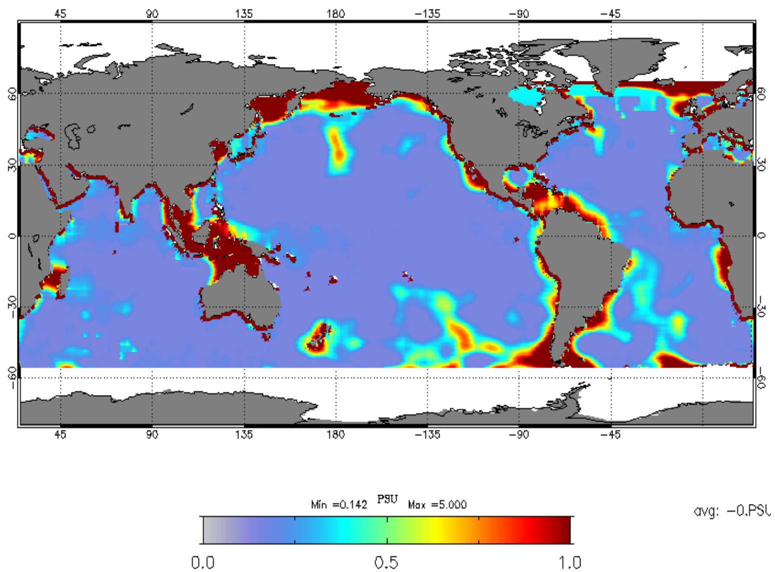
SSS difference (SMOS-REF): Hoevmuller at the equator

Slightly saltier



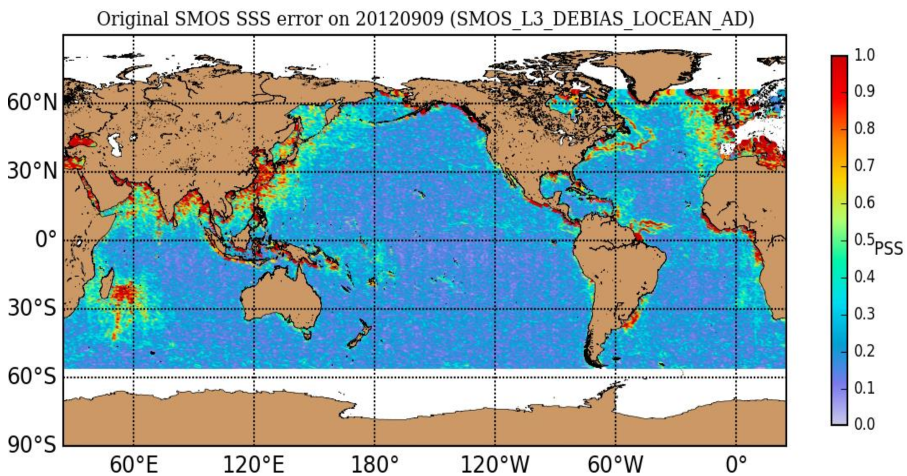
Data assimilation of debiased SSS: Observation errors for a DA cycle





SSS error for in-situ data

SSS error for SMOS data diagnosed by the bias and used in the DA scheme



SSS error specified by LOCEAN

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Ice products

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MFC/TAC

Sea Ice Drift

METno:ARC,ARC_RAN;MO : GLO,GLO_RAN ; UkMet : GLO_CPL,GLO_RAN; CMCC: GLO_RAN; LGGE :GLO_RAN; CERSAT : ARC ; FMI: BAL; METno : ARC & ANT ; DTU : ARC &ANT

Sea Ice Thickness

METno:ARC,ARC_RAN;SMHI:BAL,BAL_RAN;DMI: BAL_RAN ; MO: GLO, GLO_RAN ; UkMmet : GLO_CPL,GLO_RAN; CMCC : GLO_RAN ; LGGE: GLO_RAN; FMI : BAL+SAR; METno : GLO

Snow Thickness

METno : ARC, ARC_RAN
LGGE : GLO_RAN

Sea Ice Concentration

METno : ARC,ARC_RAN ; MO: GLO,GLO_RAN ; UKMet : GLO_CPL,GLO_RAN ; CMCC : GLO_RAN ; DMI : BAL,BAL_RAN ; LGGE : GLO_RAN ; Metno : ARC, GLO ; DMI : ARC ; FMI : ARC; DMI : SST_BAL; MEF : SST_EUR ;UKMet : SST_GLO

Sea Ice Edge

Metno : ANT,GLO

Sea ice albedo

METno : ARC

Sea Ice Type

METno :GLO

Density of icebergs

DMI : ARC

Ice surface temperature

DMI : ARC

http://marine.copernicus.eu/web/69-interactive-catalogue.php