Use of Sea Surface Temperature and Sea Ice observations for the Copernicus Marine Service and its applications

A. Reppucci; P.Y. Le Traon ;
Mercator Ocean

Marine Monitoring

Implemented by

ECMWF, 23/01/2018

Marine Monitoring

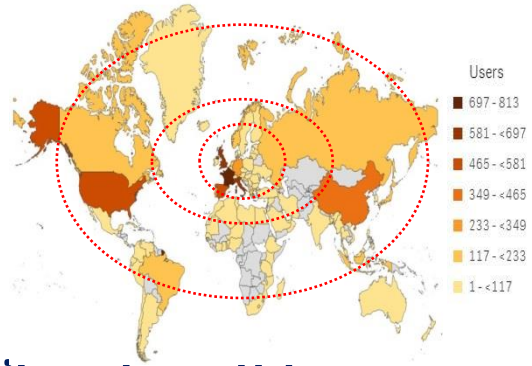
Outline

- The CMEMS
- Use SST and Sea Ice observations in CMEMS
- CMEMS Requirements
- Conclusions

Marine Monitoring

The Copernicus Marine Service

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.**



More than 10 000 subscribers (~ + 200 new subscribers/month)

Downloads (2017) : 290 000+
Downloaded Volume (2017) : 371 Tb,
User satisfaction (2017) : 4,7/5

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Drivers

- **Support a sustainable ocean and blue growth**

Coastal Environment, Marine policies and public information, Marine operation and Safety, Marine Pollution, Research, Climate, New Services.

- **Provide pioneering solutions**

Operational and scientifically assessed, Worldwide and European-wide coverage, long-term sustainability, thousands of users.

- **Provide Open and easy access to marine data**

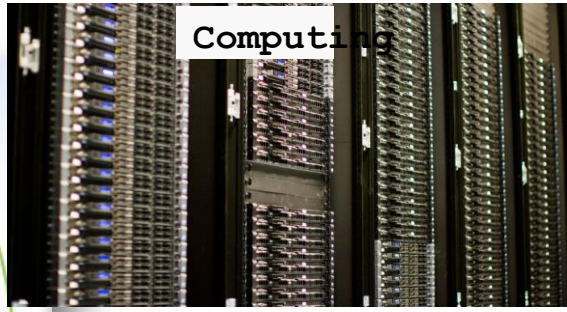
Open and free data policy, network of producers throughout Europe, Modular organization, Common standards, Single point of access.

Implementation

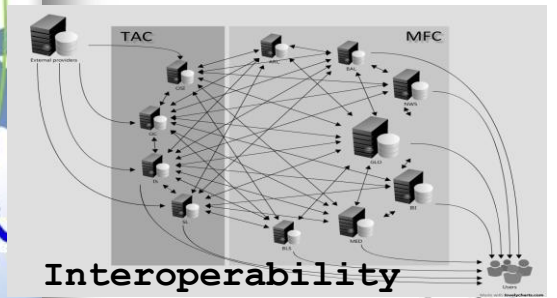
Mercator Ocean entrusted by the European Commission to implement the Copernicus Marine Service, with the support of an extended network

Space data

In-situ data



Computing



Interoperability Protocols

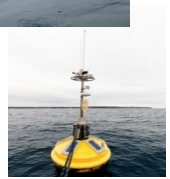
The Copernicus Marine Service

Marine Monitoring

Architecture

ESA; EUMETSAT; Direct agreement with other space agencies

L1 / L2 Space data



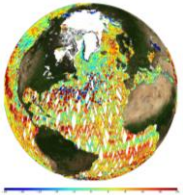
In situ observations

CMEMS Thematic Assembly Centers

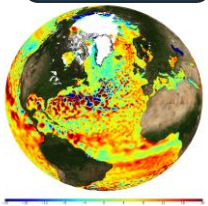
- SL
- OC
- SST
- SI
- WAVE
- WIND
- MOB
- In Situ (INS)

CMEMS Monitoring and Forecast Centers

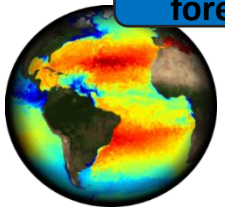
L3 Products



L4 Products



Analysis and forecasts



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The Copernicus Marine Service

Products:

Reanalysis
10 to 45 years

Real-Time
Daily Hourly

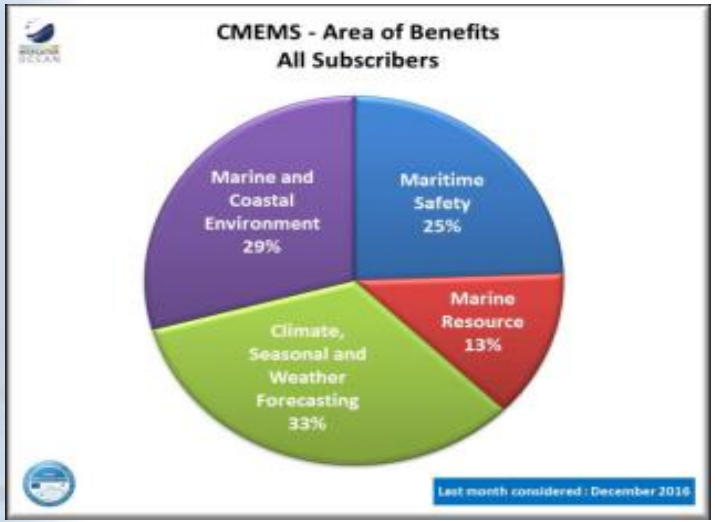
Forecast
2 to 10 days

~ 160 Products

The Copernicus Marine Environment Monitoring Service

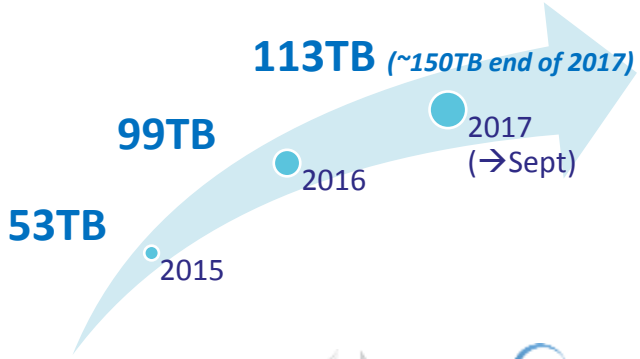
Products Uptake

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.



Commercial Application :

- ~4000 downloads/month, widely spread over Europe
- + 50TB each year since 2015
- In 2017, 28% of the total CMEMS downloaded volume



Marine Monitoring

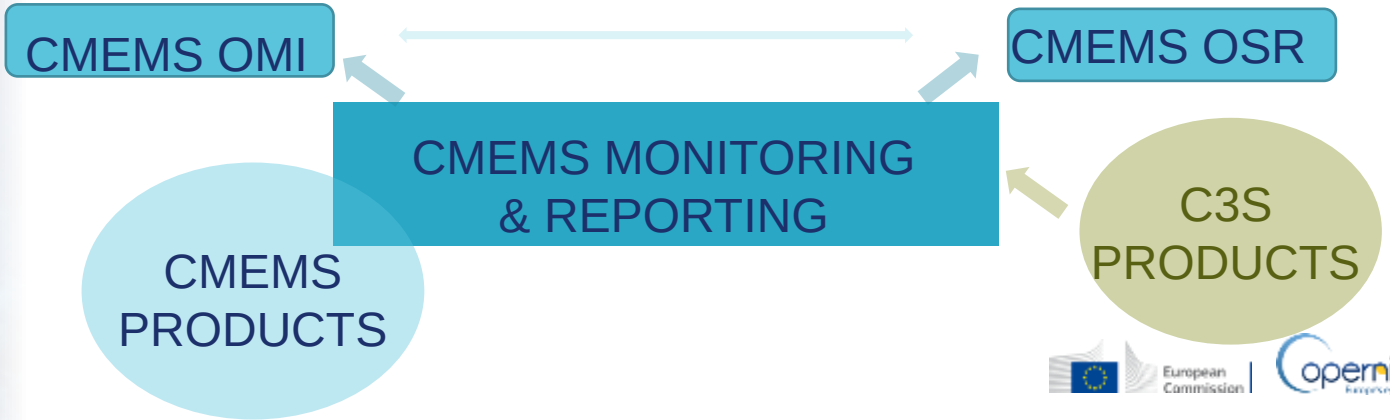
CMEMS OCEAN Monitoring activities:

MONITORING AND REPORTING OF …

- … the state and variability of the marine environment
- … climate change signal in the marine environment
- … near real-time changes affected by climate change

… THROUGH TWO PRINCIPAL TOOLS:

1. Annual release of the Ocean State Report
2. Distribution of Ocean Monitoring Indicators on the web portal



Outline

Marine Monitoring

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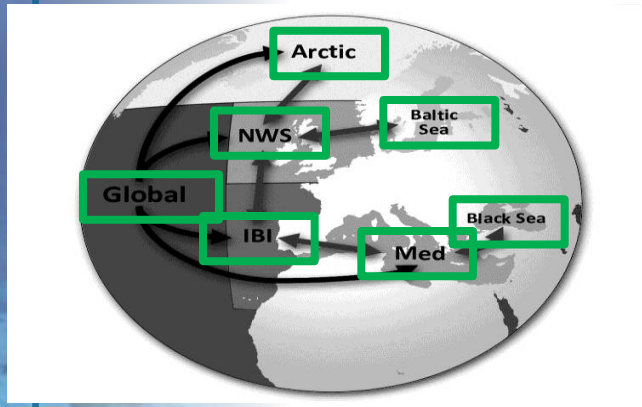
Marine Monitoring

Upstream 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.
L-band passive microwaves*	Thin sea ice with thickness less than 0.5 m .
SAR	High-resolution for iceberg, sea ice deformation, drift, sea ice roughness, leads and ridges, thickness
Scatterometry	Medium-resolution (~10 km) sea ice concentration, area and extent, sea ice types, and sea ice drift.
Altimetry*	Sea ice freeboard height and snow depth. .
IR radiometry	High-resolution sea and ice surface temperature
In-Situ	Argo, Ships, Drifting buoys, Moorings, Gliders

Catalogue of product: SST

Sea Surface Temperature



Satellite Observation products

SEA SURFACE TEMPERATURE (SST)

L3 and L4

NRT and Reprocessing

Source: SST -TAC

In Situ Observation products

TEMPERATURE (T)

From – 6000 m to surface

NRT and Reprocessing

Source: INSITU TAC

Model products

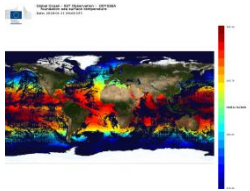
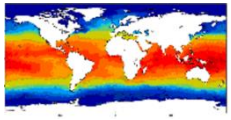
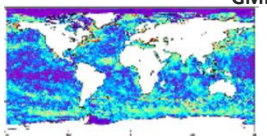
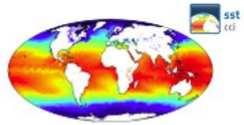
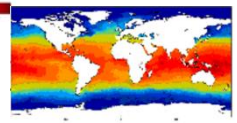
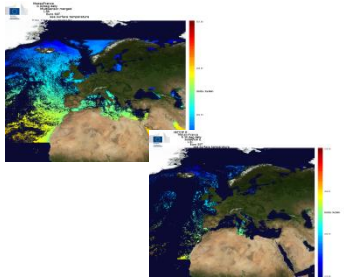
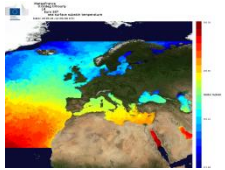
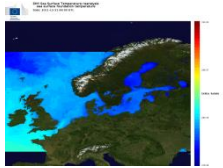
TEMPERATURE (T)

From - 6000 m to surface

Forecast, NRT and Reanalysis

Source: MFCs

CMEMS SST Satellite Observation products

Product Type	NRT L3	NRT L4	REP
Global		OSTIA  GMPE 	 OSTIA 
Regional			

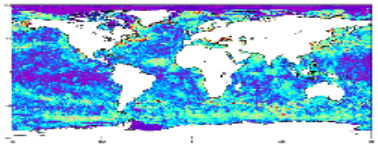
CMEMS SST products

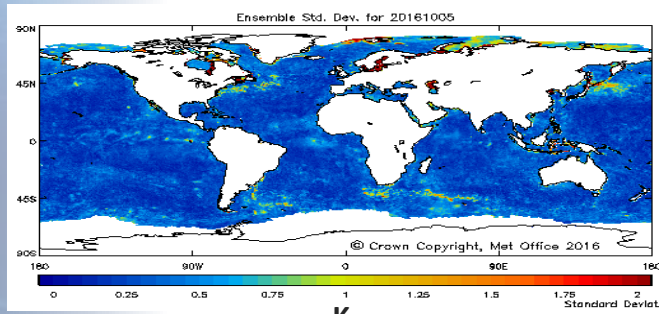
GLOBAL OCEAN SEA SURFACE TEMPERATURE MULTI PRODUCT ENSEMBLE (GMPE)

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.





- 0.25 degree grid
- Daily
- Median
- Standard deviations

- Anomalies
- Gradients
- From 2009

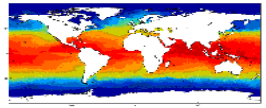
GLOBAL OCEAN OSTIA SEA SURFACE TEMPERATURE AND SEA ICE ANALYSIS

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

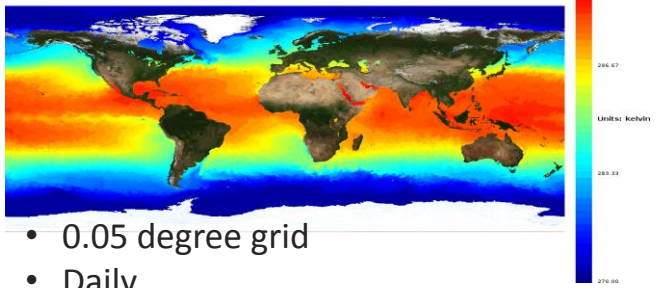
SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001

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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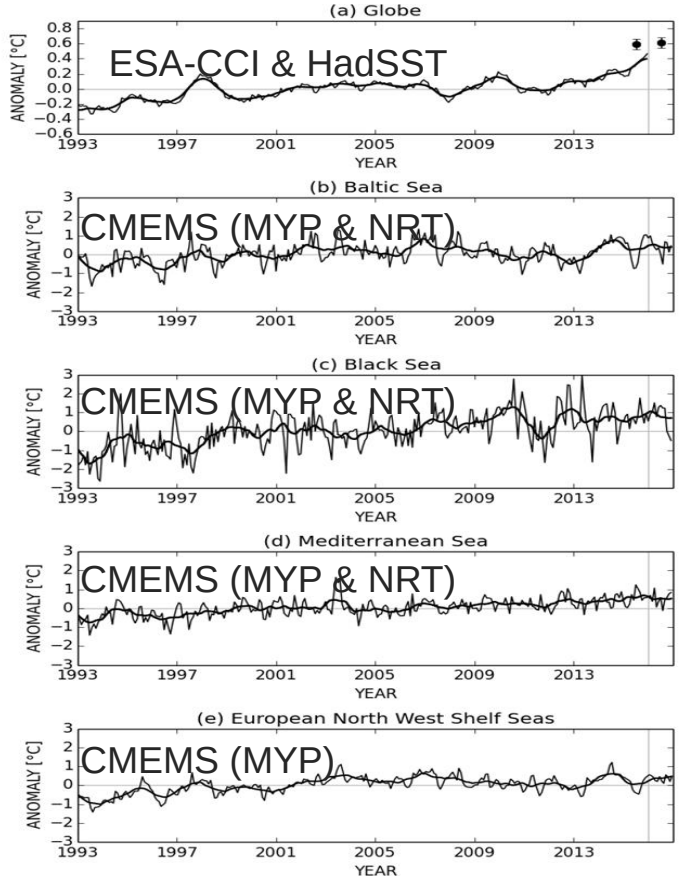
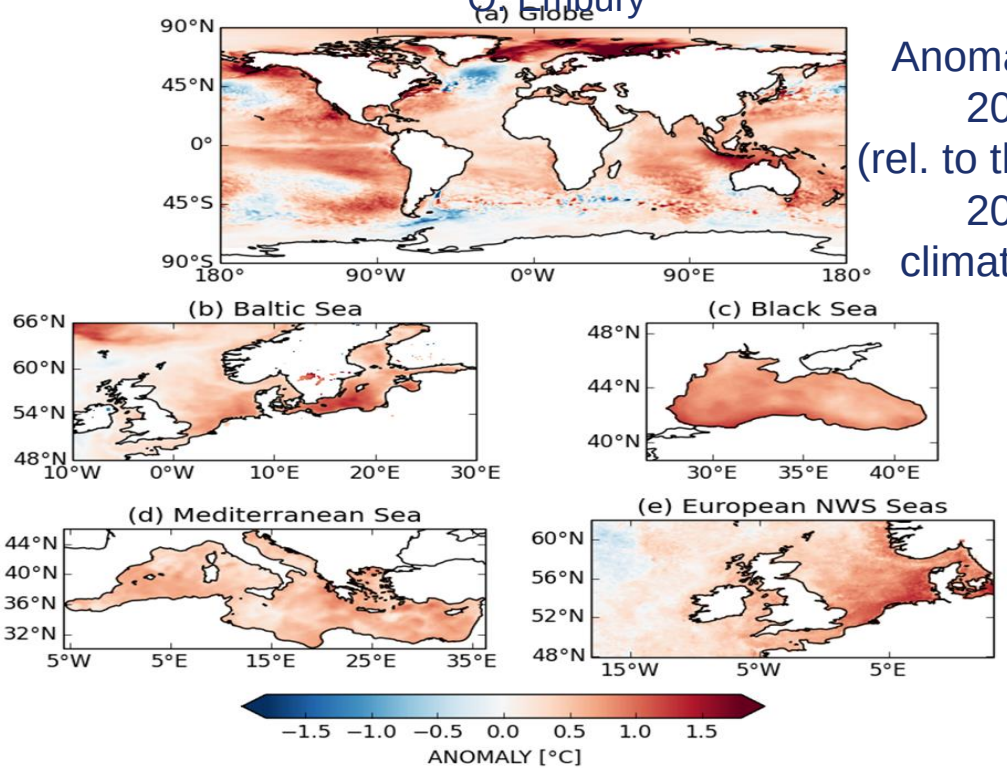
ESSENTIAL VARIABLE: Sea Surface Temperature

CMEMS Ocean State Report authors: S. Good, A. Pisano, E. Autret, J. Høyer, R. Reid, F. Boberg, B. Buongiorno Nardelli, J. Tinker, J. Kennedy, O. Embury





Anomalies in 2016 (rel. to the 1993-2007 climatology)

ESSENTIAL VARIABLE: Sea Surface Temperature

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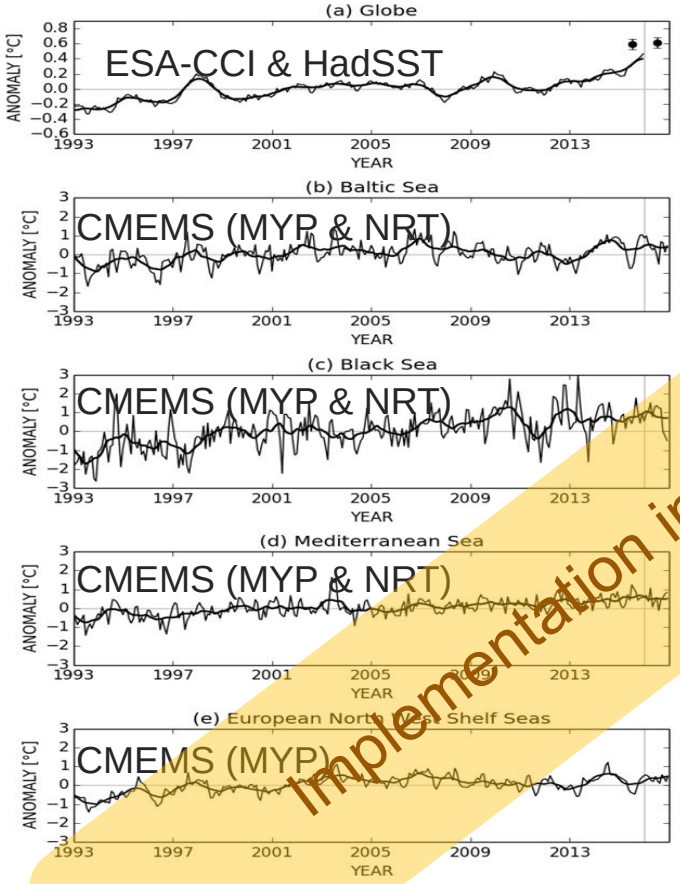
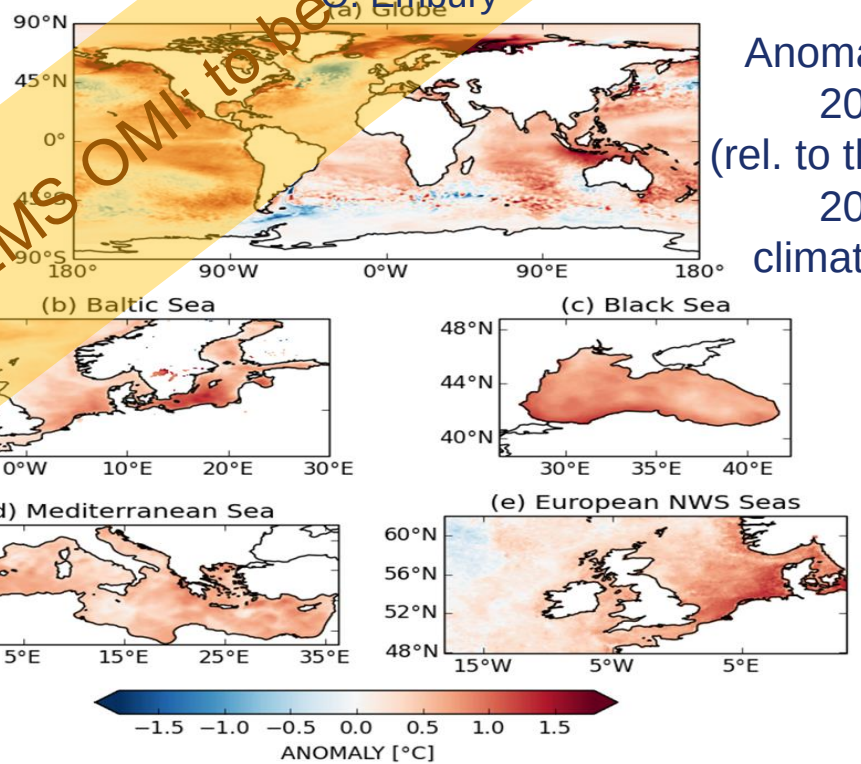




Anomalies in 2016 (rel. to the 1993-2007 climatology)

Implementation into CMEMS OMI: to be discussed

Marine Monitoring

Global high resolution reanalysis and real time systems

Real Time Forecasting System

Model

- NEMO OGCM coupled with LIM2_EVP sea-ice model
- Horizontal resolution 1/12° and 50 vertical levels (1m at the surface)
- 3h ECMWF atmospheric forcing

Data assimilated & Assimilation

- SEEK (Kalman filter)
- 3D-Var large scales bias correction
- SLA MDT CNES-CLS13 (SL TAC)
- In Situ T/S profile (INS TAC)
- SST OSTIA (SST TAC)
- Sea-ice concentration (SST TAC)
- **Adaptive tuning of SLA and SST observation errors**
- **WOA 2013 "weak assimilation" below 2000m**

Service

- Daily 10-day forecasts at 1/12°
- Available Period: 2007 → now

High Resolution Reanalysis

Model

ERAinterim atmospheric forcing

Data assimilated & Assimilation

Assimilation of reprocessed data (CORA insitu, SLA REP, Sea Ice from CERSAT, NOAA AVHRR SST)

Service

Daily 3D regular fields at 1/12°

Available Period: 1993 → 2016

Production

Finished beginning Nov started in Apr (7-month)

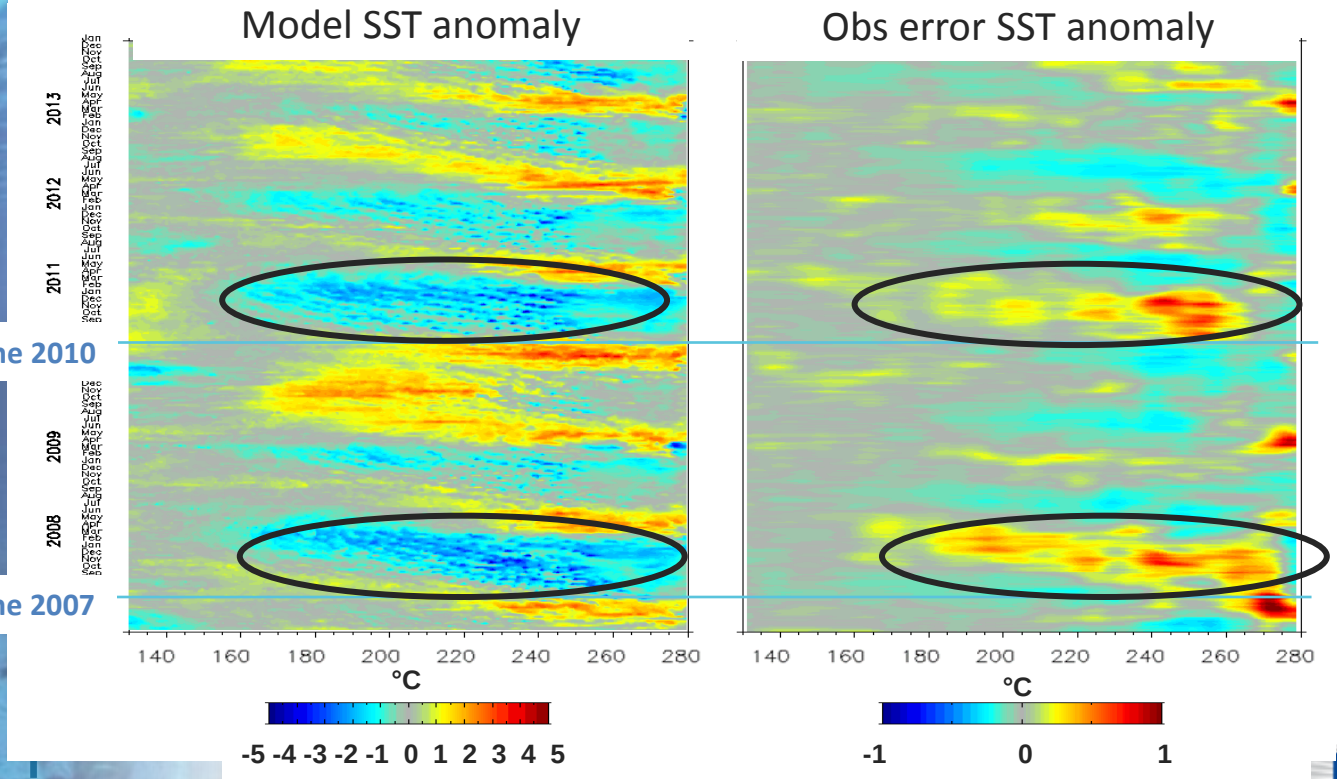
~1300 CPUs; >6M CPU hours

250To outputs

Adaptive tuning of observation errors (SST)

Marine Monitoring

Section at latitude 3°N (seasonal cycle removed)



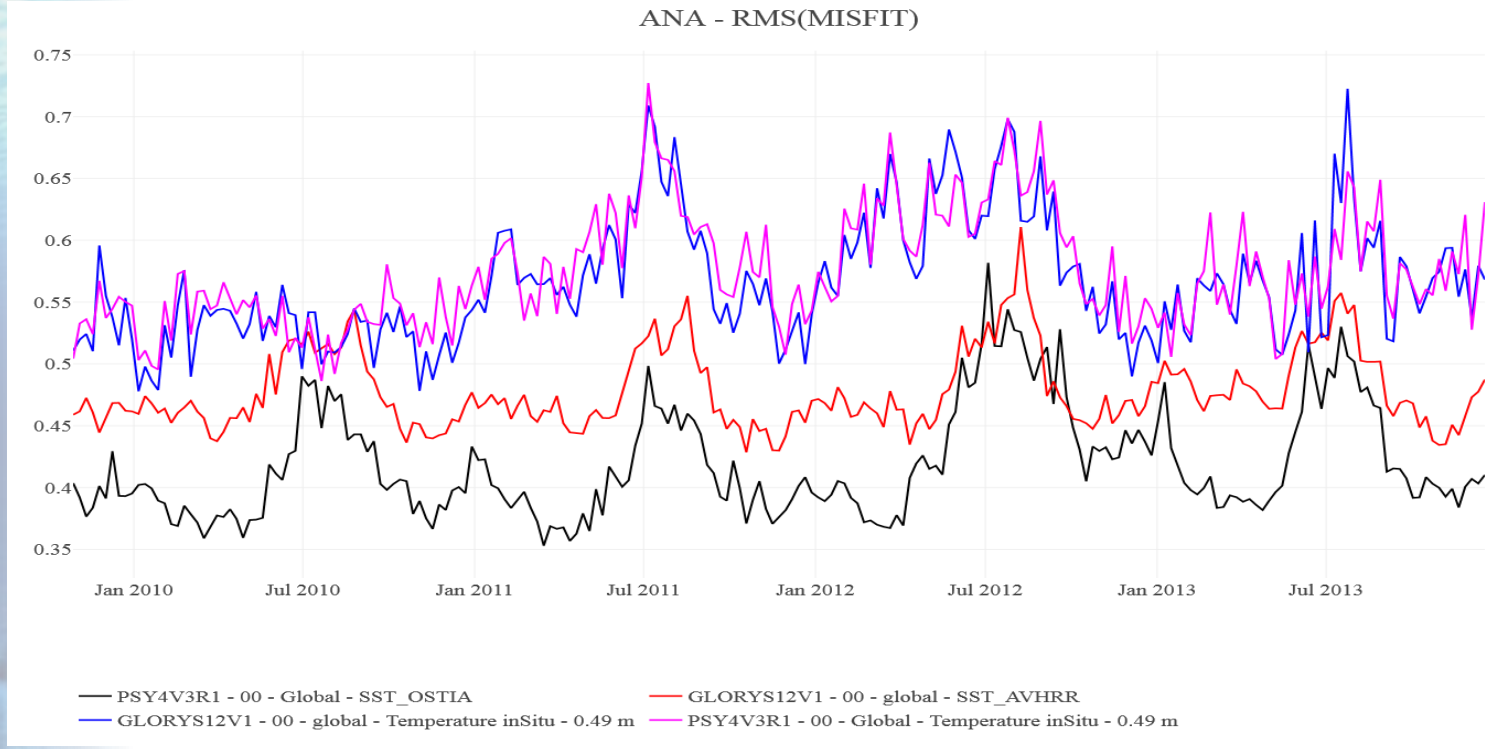
The SST anomalies in the equatorial Pacific clearly show the propagation westwards of TIW in the second half of the year. This is more pronounced during episodes of La Nina (mid- 2007 and mid-2010).

The error anomalies estimated by “Desroziers method” show that the error increases when these TIWs are more marked.

When model SST and OSTIA SST are smoother, the error decreases.

SST statistics at global scale

Marine Monitoring



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Marine Monitoring

SST observation needs / model and Assim

- **Current observations used in the system**
  - L4 « low » resolution satellite SST maps, only one map per assimilation cycle (1 week)
  - Some in situ SST observations
- **Short term perspectives**
  - L3 high resolution satellite SST observations
  - All the in situ surface drifter observations
- **Longer term needs**
  - Higher resolution and higher frequency satellite SST observations. Solve the diurnal cycle

SST observation needs / validation & verification

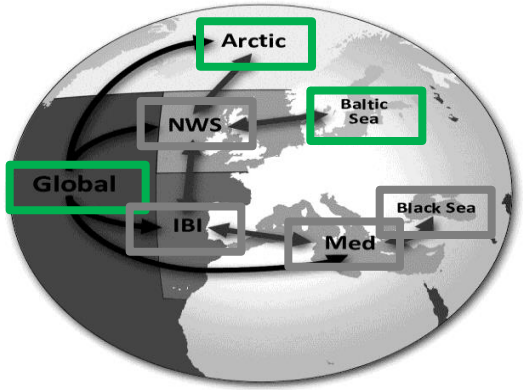
Marine Monitoring

- **Current observations used in the system**
  - L4 gridded SST maps
  - Drifter (GOV Class 4)
  - Argo surface data
  - Moored data (Class 2 assessment)

- **Short term perspectives**
  - L3 high resolution satellite SST observations + quality index
    - Verification of 1-3 km CMEMS regional models
  - Better definition of the time frame of the reference data
    - Need to verify quality of CMEMS hourly product with relevant observation !
    - Need to better characterize type of temperature value: skin, bulk, foundation

- **Longer term needs**
  - Provide reliable (observed) values of the diurnal cycle

Catalogue of products



Satellite Observation products

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

Surface

NRT and Reprocessing

Source: SI TAC (OSI-SAF)

Model products

SEA ICE COVERAGE, THICKNESS, DRIFT, SURFACE TEMPERATURE

Surface

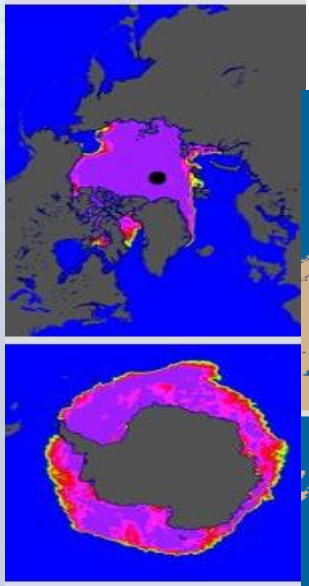
NRT, Forecast and analysis

Source: 3 MFCS (Arctic, Baltic and Global)

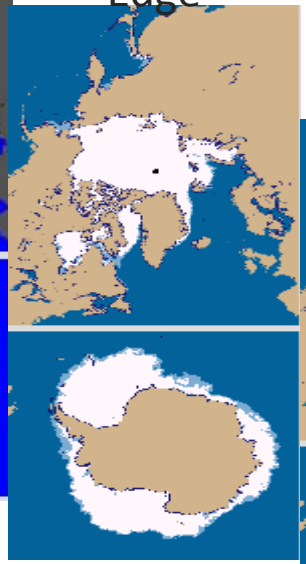
Sea Ice products

Marine Monitoring

Concentration



Edge



Type

Sea Ice Drift

European Commission

opernicus

MERCATOR OCEAN

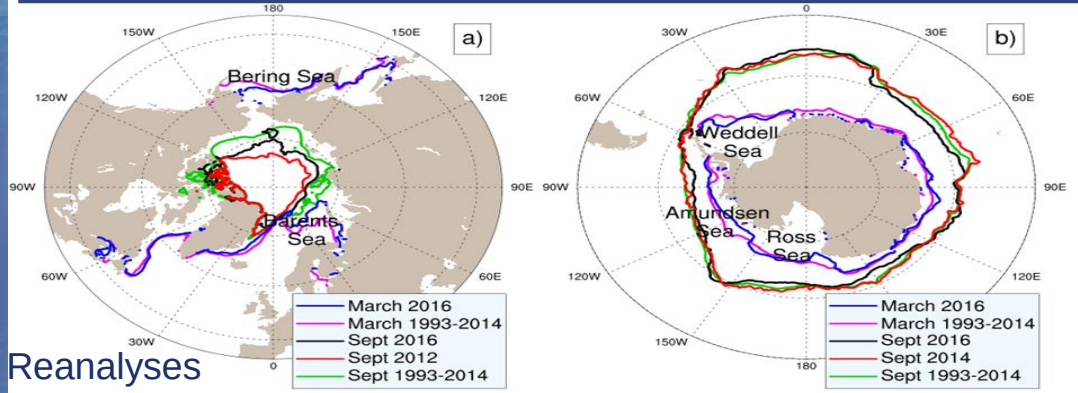
Marine Monitoring

ESSENTIAL VARIABLE: SEA ICE

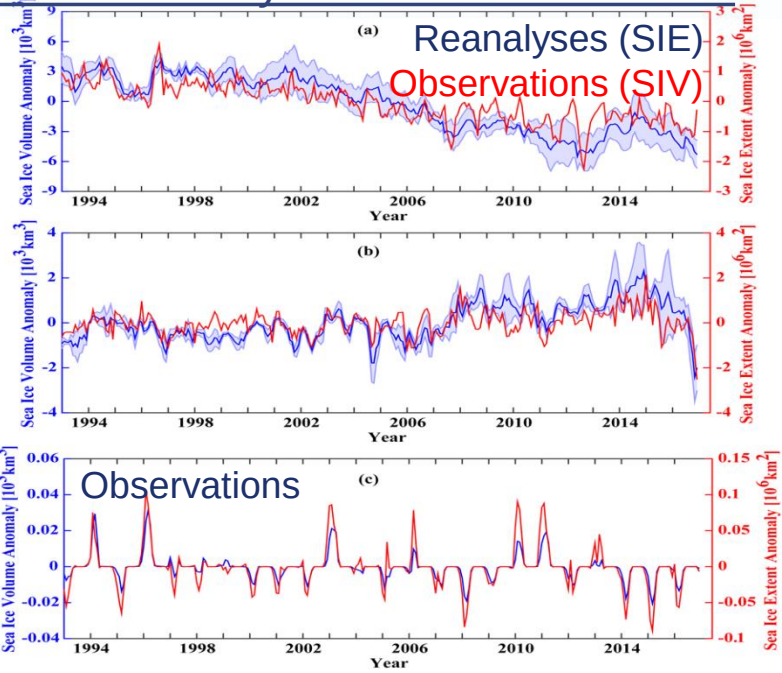
CMEMS Ocean State Report authors:

Annette Samuelsen, Gilles Garric, Roshin P. Raj, Lars Axell, Hao Zuo, K. Andrew Peterson, Signe Aaboe, Andrea Storto, Thomas Lavergne, Lars-Anders Breivik

Arctic, Antarctic and Baltic Sea sea ice extent & volume: reanalyses and observations



Reanalyses



	Arctic		Antarctic	
	Extent 10^6 km^2/decade	Volume 10^3 km^3/decade	Extent 10^6 km^2/decade	Volume 10^3 km^3/decade
Trend for product reference 1.7.4	-0.85		0.42	
Trend for product reference 1.7.1	-0.90	-3.84	0.47	0.89
Uncertainty for product reference 1.7.1	0.102	0.46	0.06	0.14

Marine Monitoring

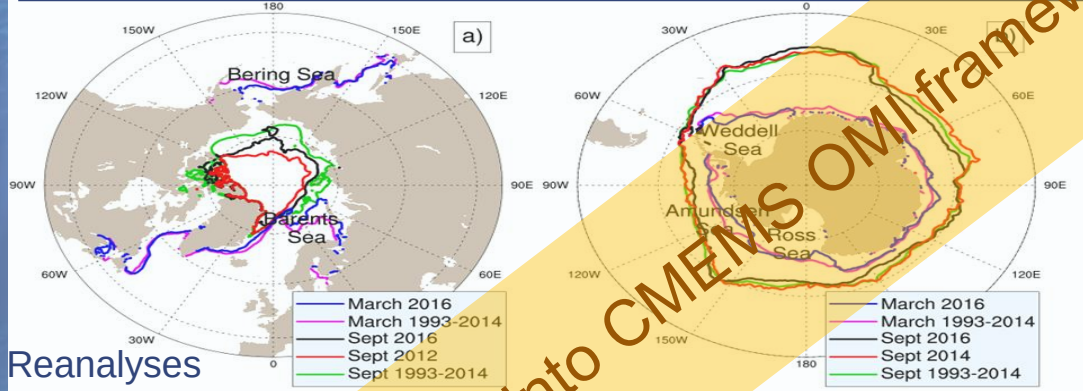
ESSENTIAL VARIABLE: SEA ICE

CMEMS Ocean State Report authors:

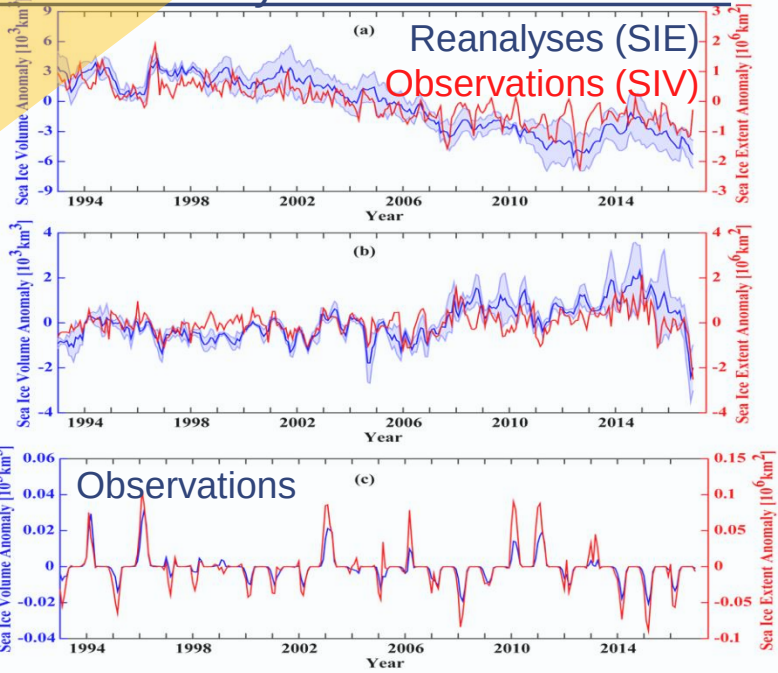
Annette Samuelsen, Gilles Garric, Roshin P. Raj, Lars Axell, Hao Zuo, K. Andrew Peterson, Signe Aaboe, Andrea Storto, Thomas Lavergne, Lars-Anders Breivik

Implementation into CMEMS OMI framework. February 2018

Arctic, Antarctic and Baltic Sea sea ice extent & volume: reanalyses and observations



Reanalyses



	Arctic Extent 10^6 km^2/decade	Arctic Volume 10^3 km^3/decade	Antarctic Extent 10^6 km^2/decade	Antarctic Volume 10^3 km^3/decade
Trend for product reference 1.7.4	-0.85		0.42	
Trend for product reference 1.7.1	-0.90	-3.84	0.47	0.89
Uncertainty for product reference 1.7.1	0.102	0.46	0.06	0.14

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.

Sea Ice data assimilation in Mercator

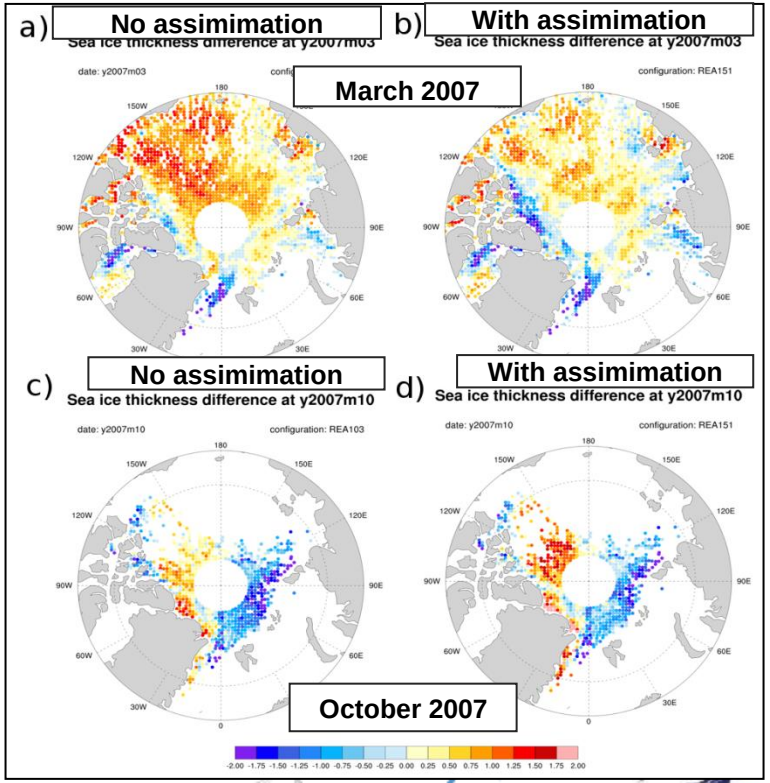
Marine Monitoring

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.

Differences with ICESat-GSFC ice thickness



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Sea Ice observation needs / model and Assim

- **Current observations used in the system**
  - L4 « low » resolution satellite sea ice concentration maps, only one map per assimilation cycle (1 week)
  - No in situ sea ice observations
- **Short term perspectives**
  - Sea ice thickness from satellite observations (Cryosat SMOS)
- **Longer term needs**
  - Higher resolution and higher frequency (sub-daily) satellite sea ice observations.
  - Less uncertainties in sea ice retrievals from satellite.

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Sea Ice observation needs /validation & verification

- **Current observations used in the system**
  - Sea Ice Concentration verification using satellite gridded products (AMSR2 etc…)
  - Regional verification using ice charts
  - Sea ice drift using SAR data
  - Sea ice thickness validation using Cryosat2, SMOS data
    - New approaches separating type of ice
  - Derived validated quantities: sea ice edge, sea ice extent

- **Short term perspectives**
  - Observed products for type of ice and for ice thickness

- **Longer term needs**
  - Observed description of ice-free areas (leads, polynyas…)

Outline

Marine Monitoring

- The CMEMS
- Use SST and Sea Ice observations in CMEMS
- **CMEMS Requirements**
- Conclusions

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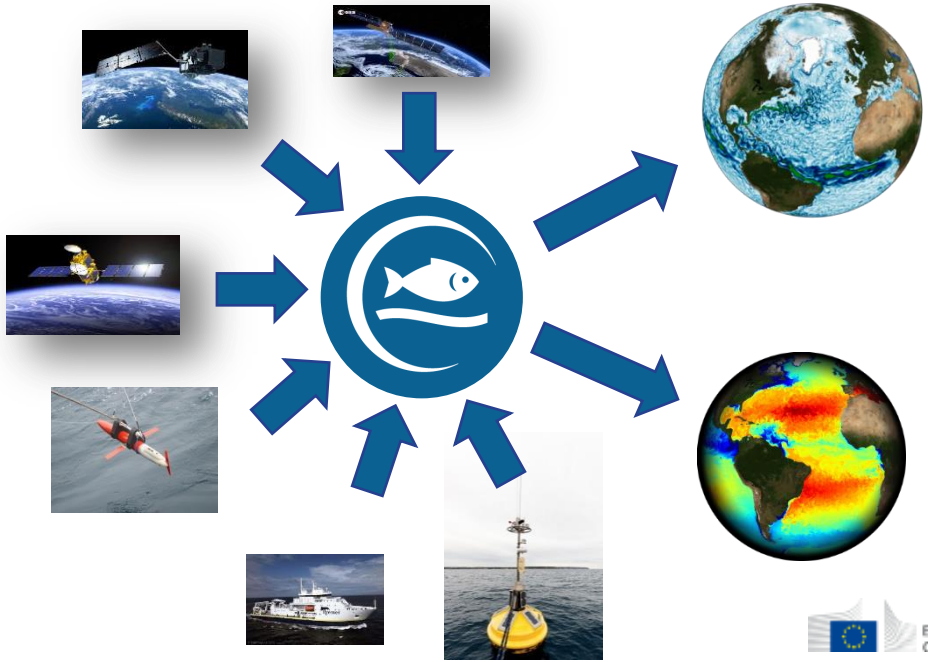
CMEMS Requirements Definition

CMEMS critically depends on the near real time availability of high quality satellite and in-situ data with a sufficiently dense space and time sampling, required to constrain ocean models through data assimilation and also to validate them.



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Satellite band In-Situ Data Coordination

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MO as a delegated body from the EU is in charge of the coordination of Upstream data required for CMEMS.

ESA – EUMETSAT - EEA

- Development of the space segment component.
- Operation of Sentinels Satellites .
- Provision of data from Contributing mission.
- In Situ Cross-cutting activities and political aspects/agreements at member state and EU levels

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- Report on user requirements
- Status of activities

CMEMS Requirements for Satellite Component

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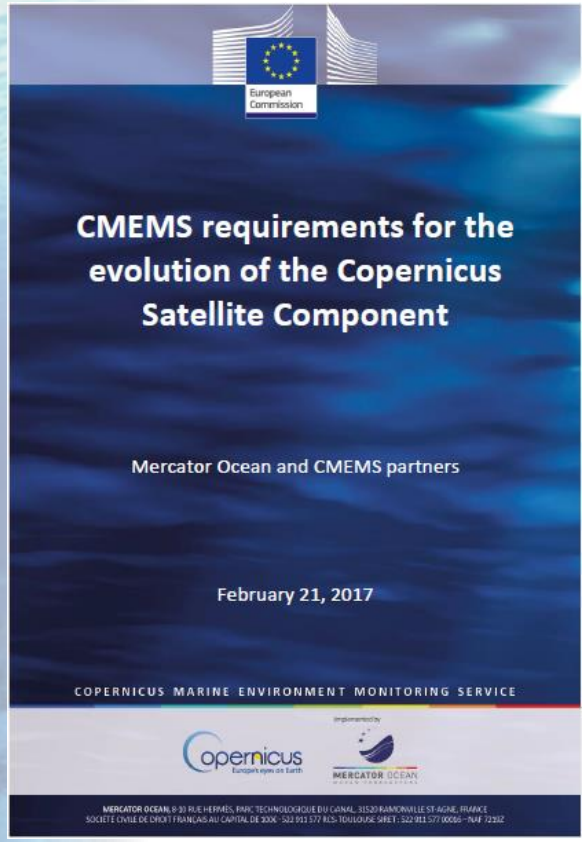

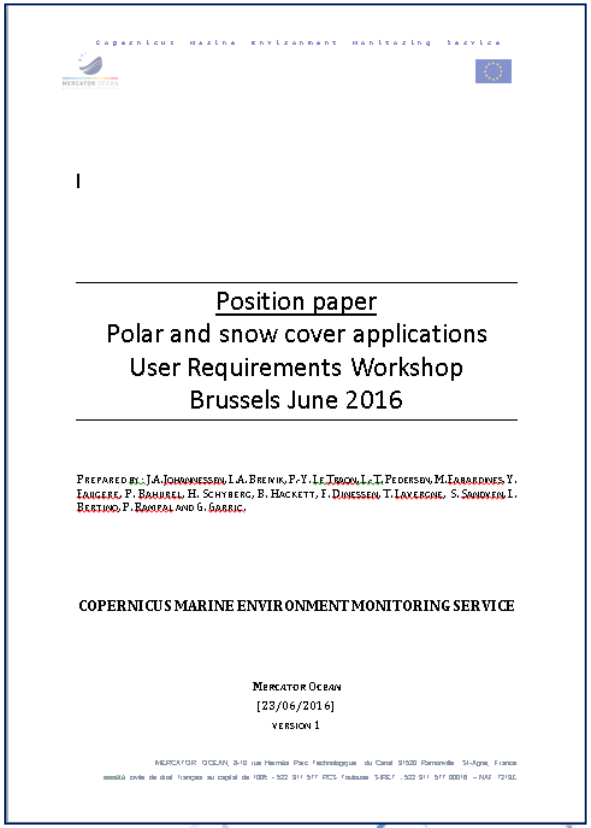

Position paper

Polar and snow cover applications

User Requirements Workshop

Brussels June 2016

Prepared by : J.A. Johannessen, I.A. Brevik, P.-Y. Le Traon, L. T. Pedersen, M. Tabarbines, Y. Faugere, P. Bahurel, H. Schyberg, B. Hackett, F. Dinessen, T. Lavergne, S. Sandven, I. Bertino, P. Rampal and G. Garric.

COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

Mercator Ocean

[23/06/2016]

version 1

MERCATOR OCEAN, 8-10 rue Hermès Parc Technologique du Canal 31520 Ramonville St-Agne, France

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CMEMS Requirements for Satellite Component

CMEMS evolution is driven by an **increasing need for ocean and marine ecosystem monitoring and forecasting**.

- Major evolutions are required to **monitor** and forecast **the ocean at fine scale** and to improve the monitoring of **the coastal zone**.
- CMEMS must also **improve** its capacities to **monitor and forecast the biogeochemical (BGC) state of the ocean** (e.g. ocean carbon uptake, acidification, de-oxygenation, eutrophication, water quality, biological productivity).
- There are also specific requirements for the **monitoring** of the **rapidly changing polar regions.**

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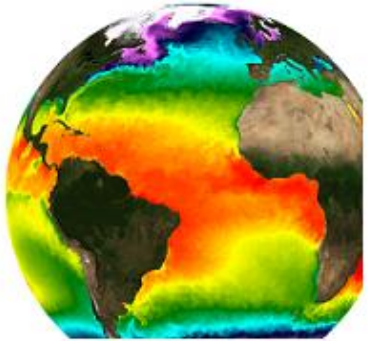
Specific Requirements: SST

GLOBAL OCEAN SEA SURFACE TEMPERATURE L3 OBSERVATIONS

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

SST_GLO_SST_L3S_NRT_OBSERVATIONS_010_010

For the Global Ocean- Sea Surface Temperature L3 Observations



- **SST from Passive Microwave sensors (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.

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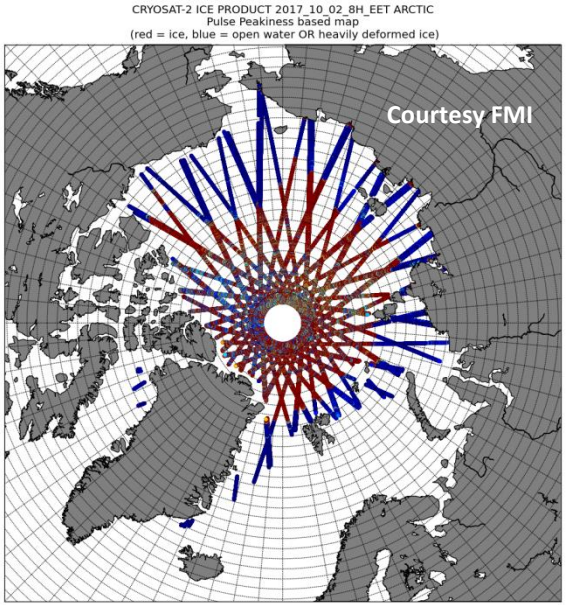
Specific Requirements: Polar regions



- One of the most important short term priorities is the **continuation** of the **Cryosat-2** mission to monitor sea ice thickness, continental ice shelves elevation changes and ocean surface topography in ice free regions.
- Sustainable **operation of** multi-frequency and -polarization **PMW observations** of SST, sea ice lead fraction and sea ice concentration, area and extent.
- 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**, PMW, **multi-frequency SAR**).

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Outline

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Conclusions

- CMEMS critically depends on the near real time availability of high quality satellite and in-situ SST and Sea Ice data with a sufficiently dense space and time sampling.
- These Observations are required to constrain ocean models through data assimilation and also to validate them.
- Higher resolution and higher frequency satellite SST observations are a priority for CMEMS (Solve the diurnal cycle).
- **SST from Passive Microwave sensors (PMW)** is a crucial contribution providing input to weather forecasting and CMEMS ocean and analysis and forecasting models.
- One of the most important short term priorities for Sea Ice monitoring is the **continuation** of the **Cryosat-2** mission.

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Thanks for Your attention

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