Present status and evolution perspectives from CMEMS: a state-of-the-art-contribution to operational oceanography.

Marine Monitoring

Presented by Antonio Reppucci
Mercator Ocean International

European Commission | Copernicus Europe's eyes on Earth
Implemented by MERCATOR OCEAN

OSOS, Washington DC, 17-20/06/2019

The world ocean plays a key role in the Earth system

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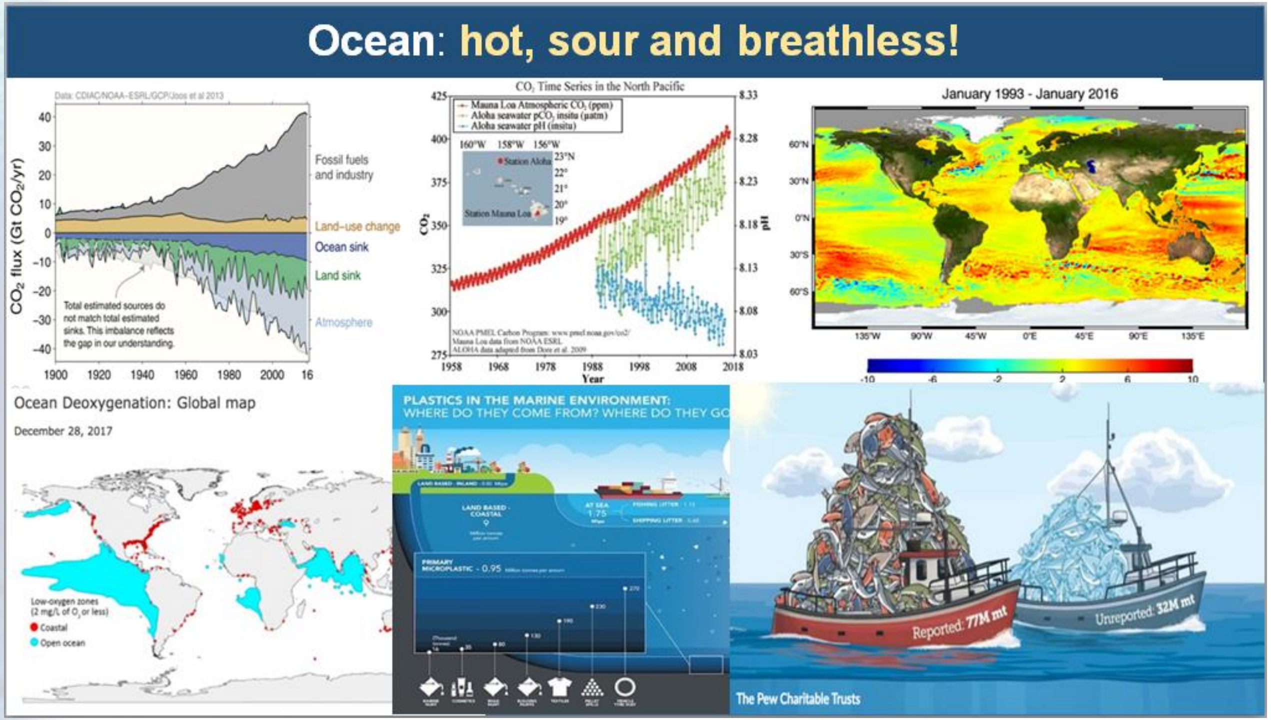
The oceans = a major source of food, energy and a strong contributor to the global economy

Face strong pressures due to climate change and other human activities



Cit. "Dr. Vladimir Ryabinin; Executive Secretary IOC of UNESCO"

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Needs for Ocean Monitoring

Increasing & pressing ocean monitoring needs:

- To understand and predict the evolution of our weather and climate.
- To develop sound mitigation and adaptation to climate change
- For a better and sustainable management of the oceans and its resources and the development of the blue economy.

SUSTAINABLE DEVELOPMENT GOALS

14 LIFE BELOW WATER

Recognized at the highest political levels (e.g. UN/Agenda 2030/SDG, UN Decade of Ocean Science), IPCC/Ocean&Cryosphere, OECD/the future of ocean economy, G7/future of the oceans and seas, G20.

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The European Contribution to Ocean Monitoring and Forecast

Oct. 2005 — MCS WORKSHOP

Apr. 2009 — myOcean

Apr. 2012 — myOcean 2

May. 2015 — CMEMS Copernicus Europe's eyes on Earth

•The formative Workshop held in Brussels on **October 2005** led to the acceptance of the Marine Core Service as a GMES Fast Track.

CMEMS Implementation

1st year of operations	2nd year of operations	3rd year of operations	4th year of operations	5th year of operations

CMEMS Operations

Phase 1 | Phase 2

The Copernicus Marine Service Today

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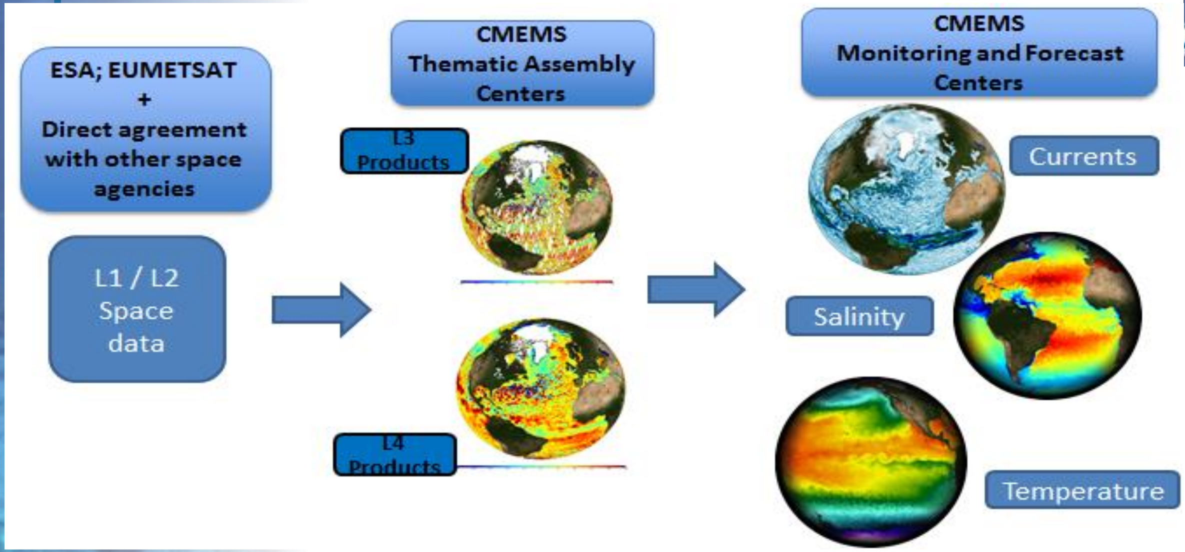
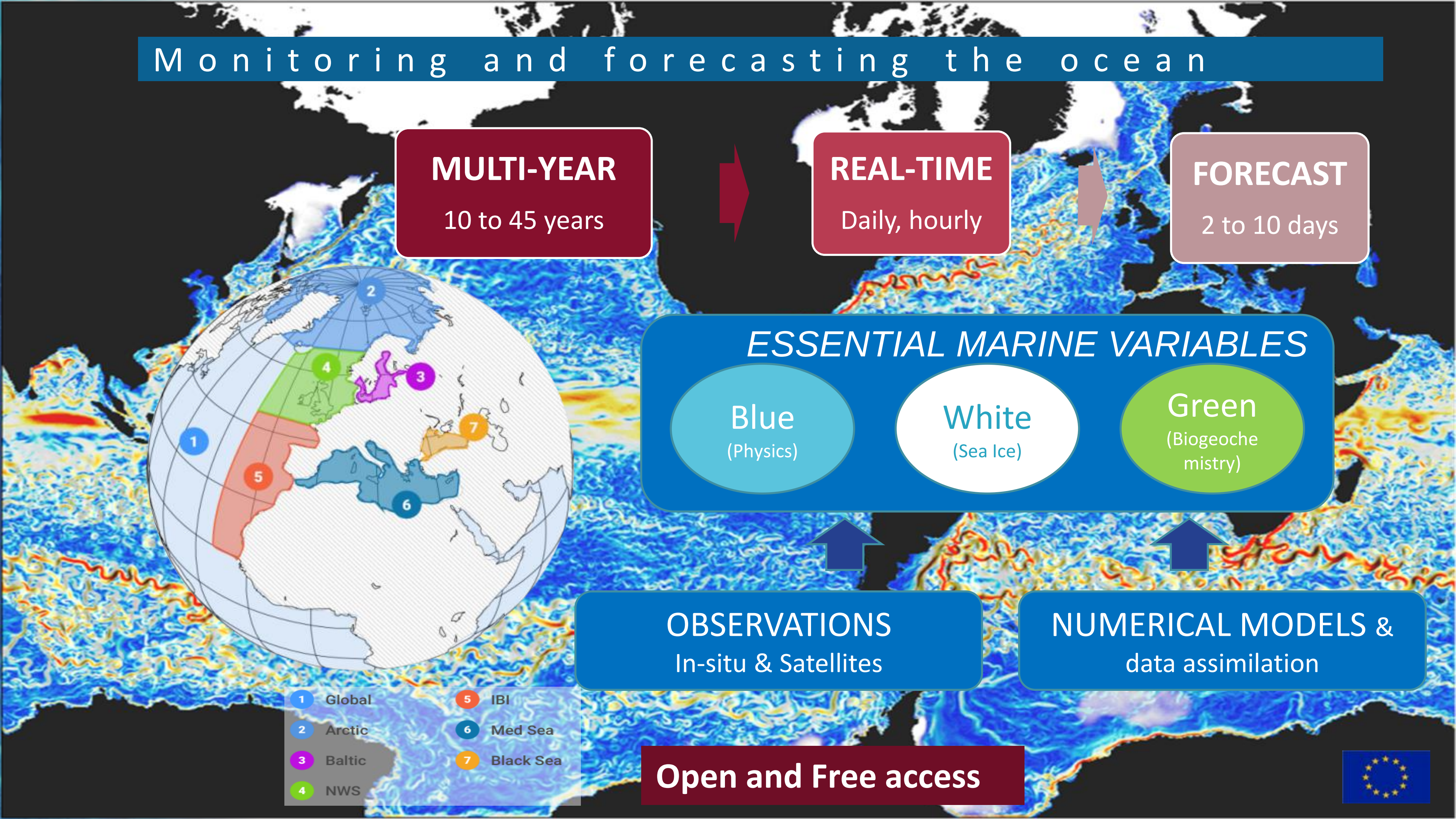
A state of the art and user driven Copernicus service

- **Physics** and **Biogeochemistry**
- **Operational** and **scientifically assessed**
- A **network** of European producers



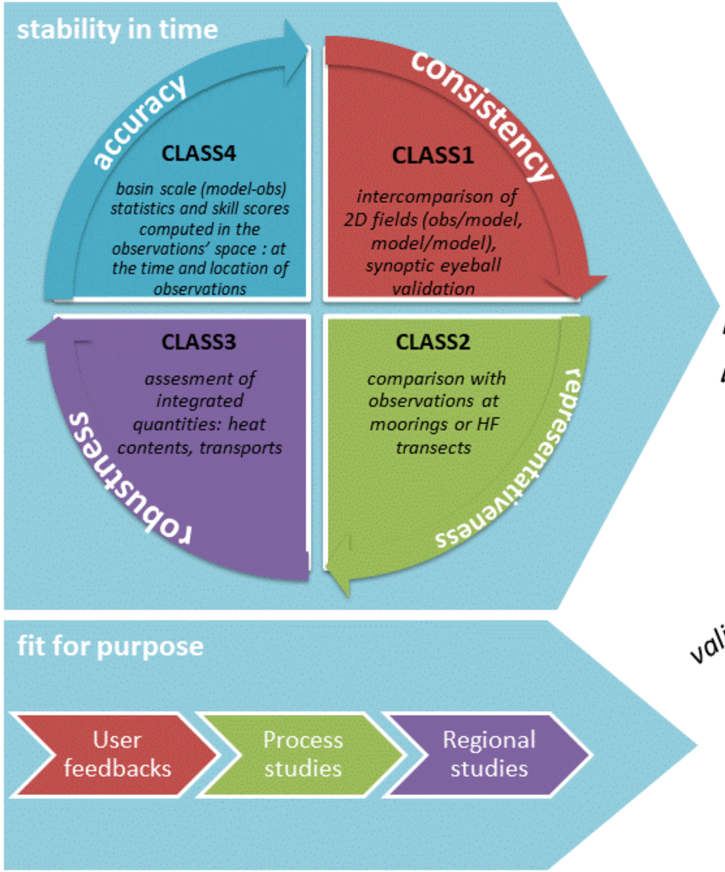
A **central information system** to search, view, download products and monitor the system

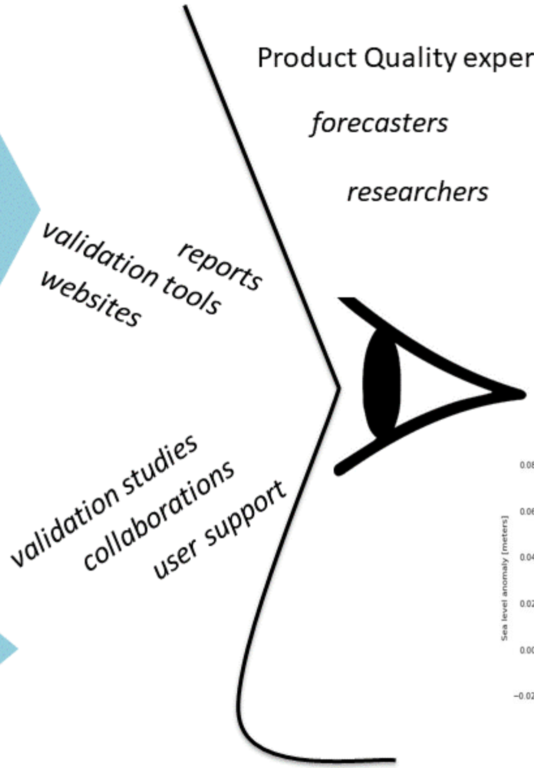
- A **service desk** to support users who relies on a network of technical & marine experts



Monitoring and forecasting the ocean
MULTI-YEAR
10 to 45 years
REAL-TIME
Daily, hourly
FORECAST
2 to 10 days
ESSENTIAL MARINE VARIABLES
Blue
(Physics)
White
(Sea Ice)
Green
(Biogeochemistry)
OBSERVATIONS
In-situ & Satellites
NUMERICAL MODELS &
data assimilation
1 Global
2 Arctic
3 Baltic
4 NWS
5 IBI
6 Med Sea
7 Black Sea
Open and Free access

with operational, state-of-the-art, and fully-verified data & information

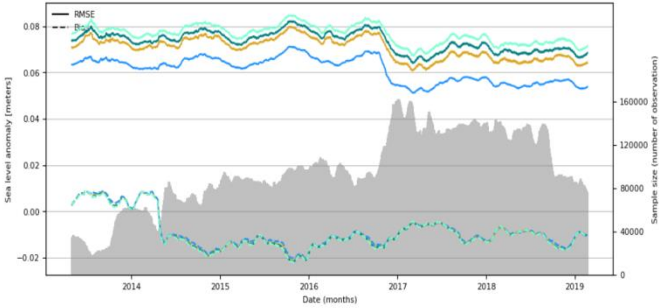




Product Quality experts

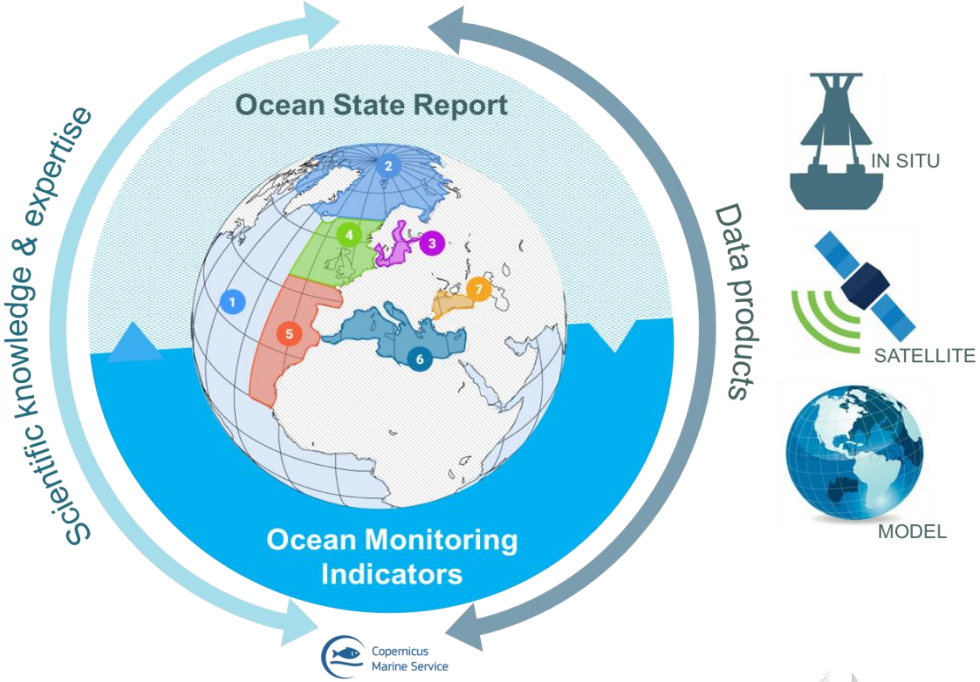
forecasters

researchers



Contribution to marine reporting

The Copernicus Marine Ocean State Report and Ocean Monitoring Indicator framework: Combining high-quality marine products and scientific expertise



Marine
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The Copernicus Marine Ocean State Report

Contribution of more than 150 scientific experts from more than 30 European Institutions

ISSUE #1

ISSUE #2

ISSUE #3: Accepted

ISSUE #4: Under development

- ❖ Published in the Journal of Operational Oceanography
- ❖ Independent peer review
- ❖ Open access

More info: http://marine.copernicus.eu/science-learning/ocean-state-report/

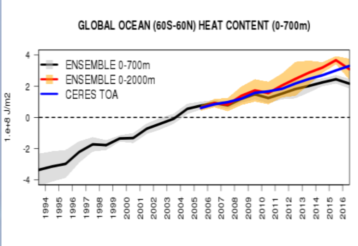
The Ocean Monitoring Indicators

Marine Monitoring

Each OMI includes :

1. The time series (1-D, or 2-D) in NetCdf format
2. A scientific context, including a high-quality figure for visualization
3. Product information (PUM document)
4. Quality information (QUID document, including visualization)

OCEAN HEAT CONTENT

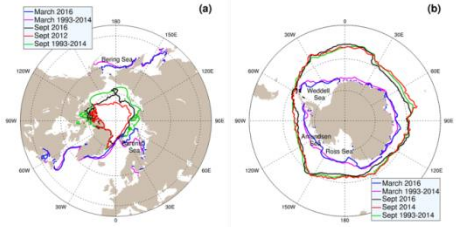


- IPCC
- GCOS in support of UN SDG framework
- Climate research
- Climate variability (e.g. ENSO, hurricanes)

SEA LEVEL

- Agencies
- IPCC & climate science
- Flooding
- Impact on land use
- Coastal erosion

SEA ICE



- Agencies
- IPCC & climate science
- Shipping routes

European Commission | Copernicus | Mercator Ocean

A single catalogue: Worldwide and European-wide coverage

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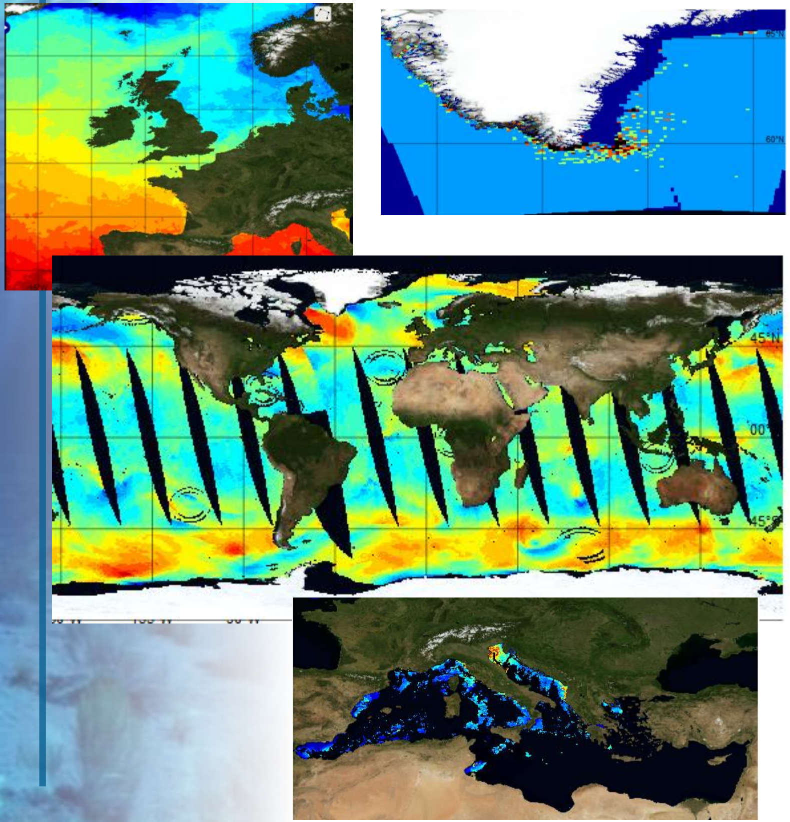
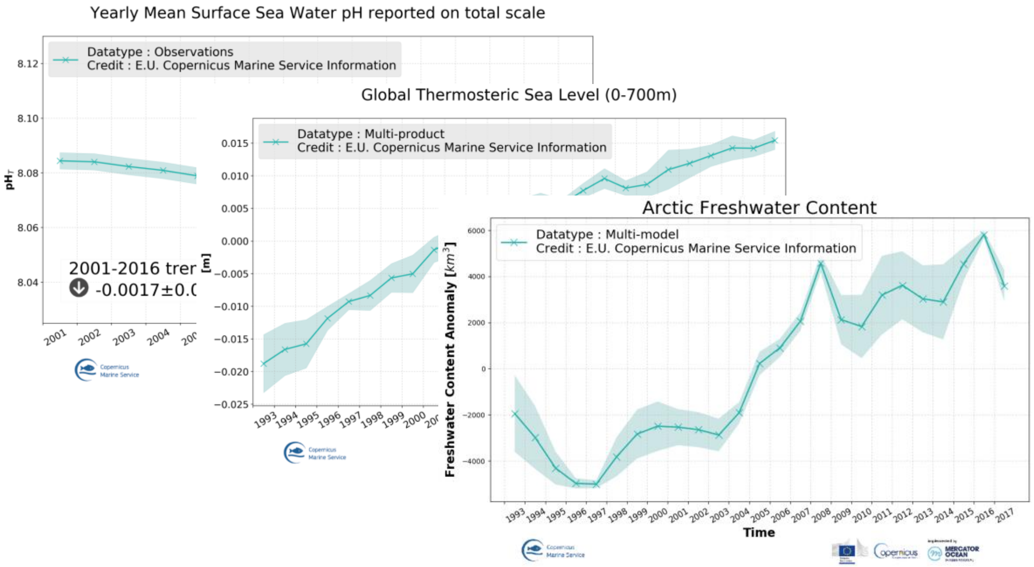
Catalogue of products



Catalogue of Ocean Monitoring Indicators made from products

Useful for European policies, Sustainable Development Goal & blue economy



Uptake of products

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- 17 000 Subscribers
- 5100 Different Entities among which 1330 Business Companies

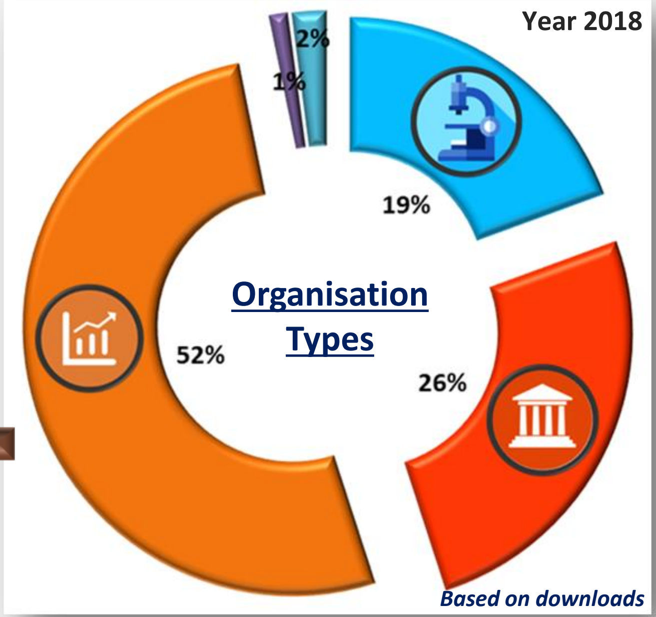
LAST 12 MONTHS

- Downloads/month: 55 000
  Download = Pair User/Dataset per Day
- Volume/month: 125 TB
- 97% products on time
- Satisfaction of Users: 4,7/5

Business

Public Sector

Research



80% of downloads by Business are for intermediate use

Final Users

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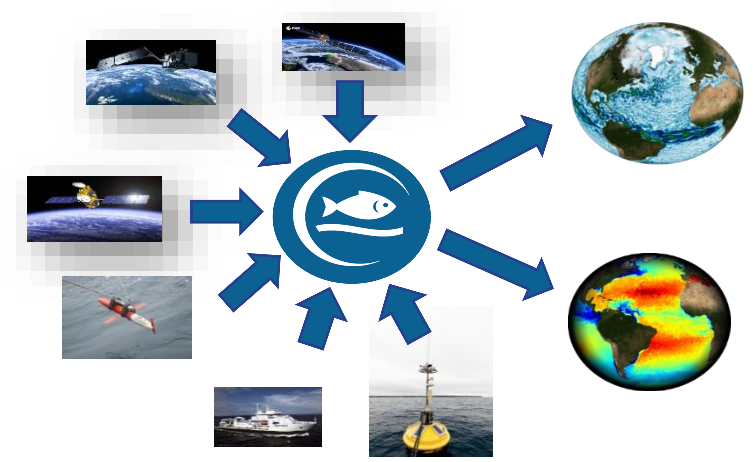
The essential role of observations

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



Impact of observations on CMEMS production systems is regularly Performed

Impact of Satellite Observations

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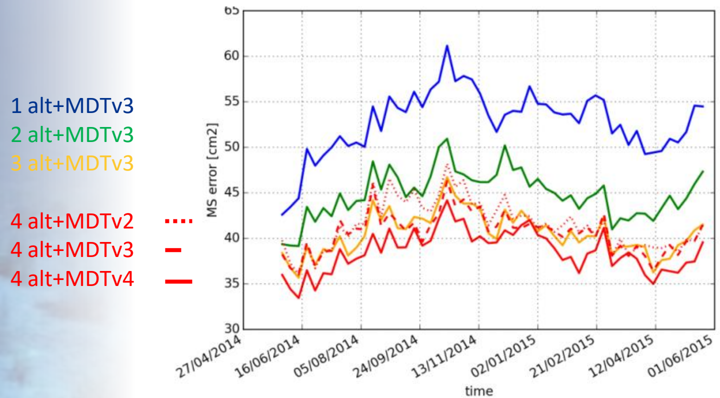
Comparison of simulations assimilating 1 to 4 altimeters and different MDT based on the CNES/CLS MDTs (1-year OSE) shows a global SSH MSE reduction of around 20% when going from 2 to 4 altimeters assimilated.

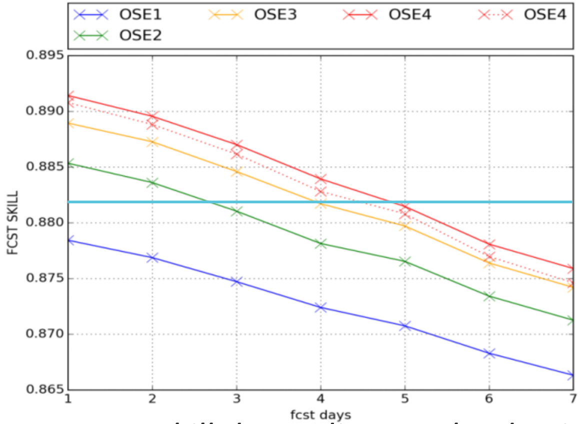
- The error reduction is still significant with 4th altimeter assimilated compared to 3, with a gain close to 1-day forecast.
- The SSH MSE is also sensitive to the Mean Dynamic Topography accuracy.

SLA obs. model comparison in DA scheme:

$(SLA_{altimeter} - (SSH_{model} - \mathbf{MDT}))^2 / R_{obs\ error}$



Global SSH MSE



Forecast skill depending on the day in the assimilation window for the different OSEs.

(M. Hamon, JAOT, 2019)

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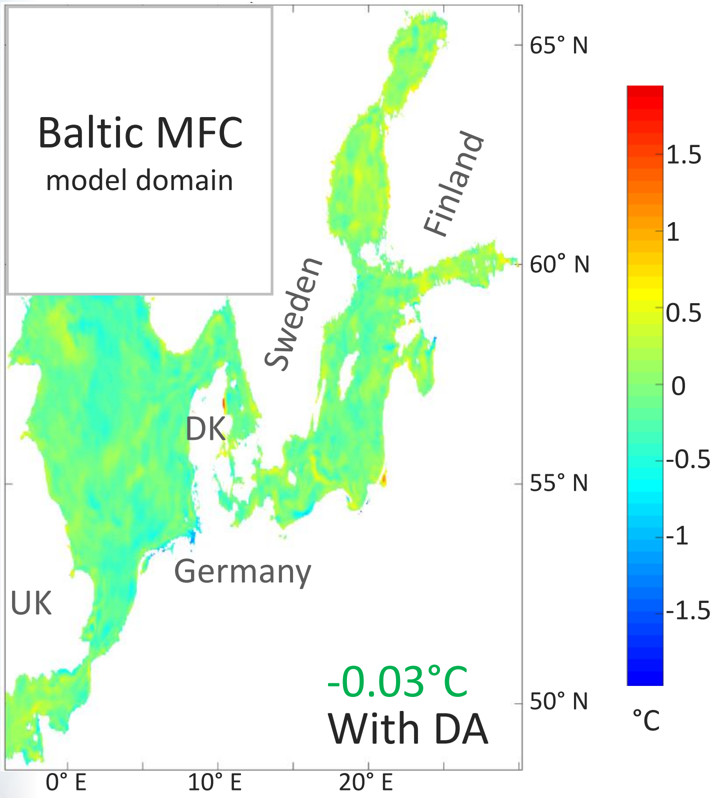
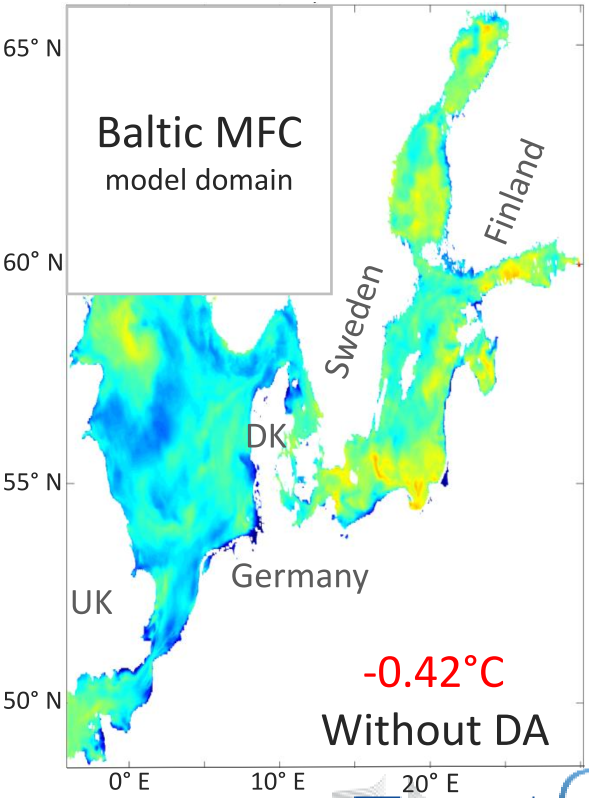
SST Data Assimilation BAL-MFC

SST bias December 2014





Better swell forecasting : thanks to assimilation of SAR wave spectra

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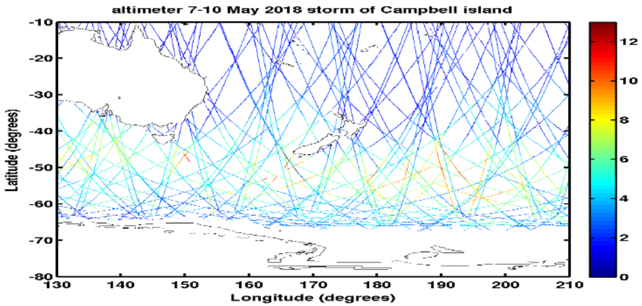
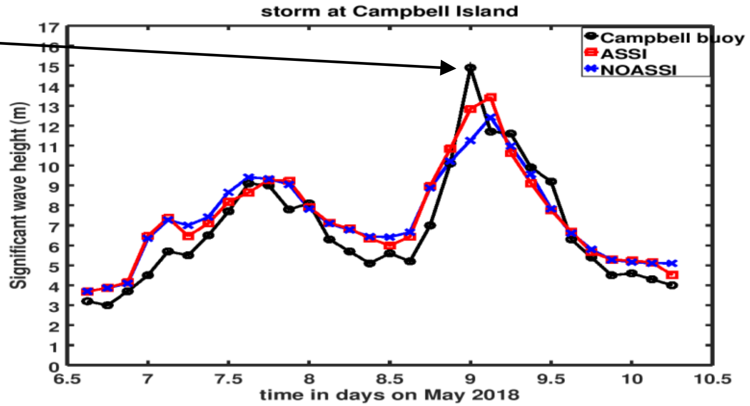
5 altimeters tracks (SWH) during the storm 7-10 May 2018



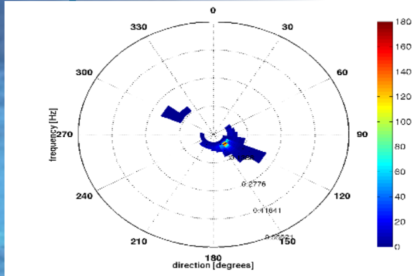
NOASSI EXP: 5 altimeters tracks

ASSI EXP: 5 altimeters tracks + SAR wave spectrum

Peak Better Captured



SAR wave Spectrum from Sentinel-1



News > World > Australasia

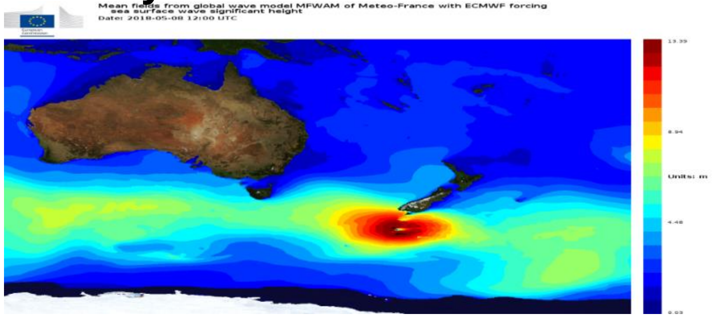
Massive wave in New Zealand biggest ever recorded in southern hemisphere

09.05.2018 00:00 UTC

Seven-storey high wave

The largest wave yet recorded in the Southern Ocean was detected around midnight last night. It reached over 23m high, about the height of a seven-storey building

SWH from CMEMS-MFC at 8 May 2018 at 12:00UTC



Impact of SENTINEL in NRT-BIO MFCs

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- **NWS case study: assimilation of ocean colour phytoplankton functional types (PFTs) surface chlorophyll vs total surface chlorophyll (ChlTot)**

NWS

Skákala et al. (2018)
Ciavatta et al. (2018)
J. Geoph. Res. Oceans

=> DA of PFTs improves the operational forecasting and the representation of the PFTs CHL

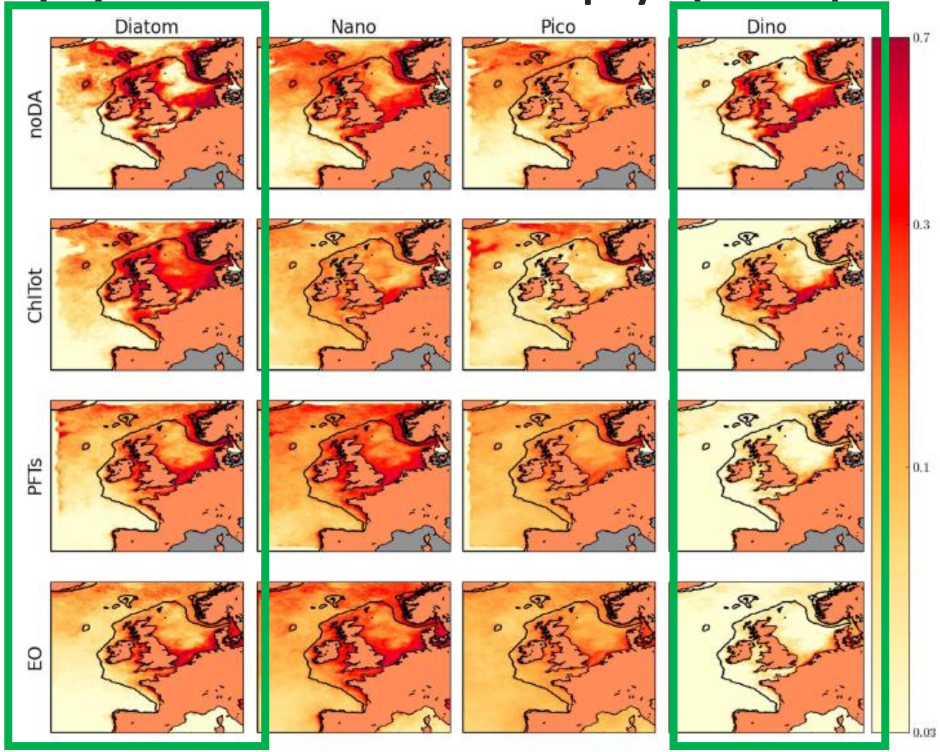


Figure 1. The figure shows the 2010 annual median spatial distributions for the four PFTs chlorophyll (in mg/m^3) for the free run (first row), total chlorophyll DA (second row), PFTs DA (third row), and satellite EO data (fourth row). The shelf boundary (bathymetry <200 m) is marked by the black line. The model data were masked whenever the EO data were missing. DA = data assimilation; PFT = phytoplankton functional type; EO = Earth Observation.

Assimilating combined CS2SMOS in reanalysis

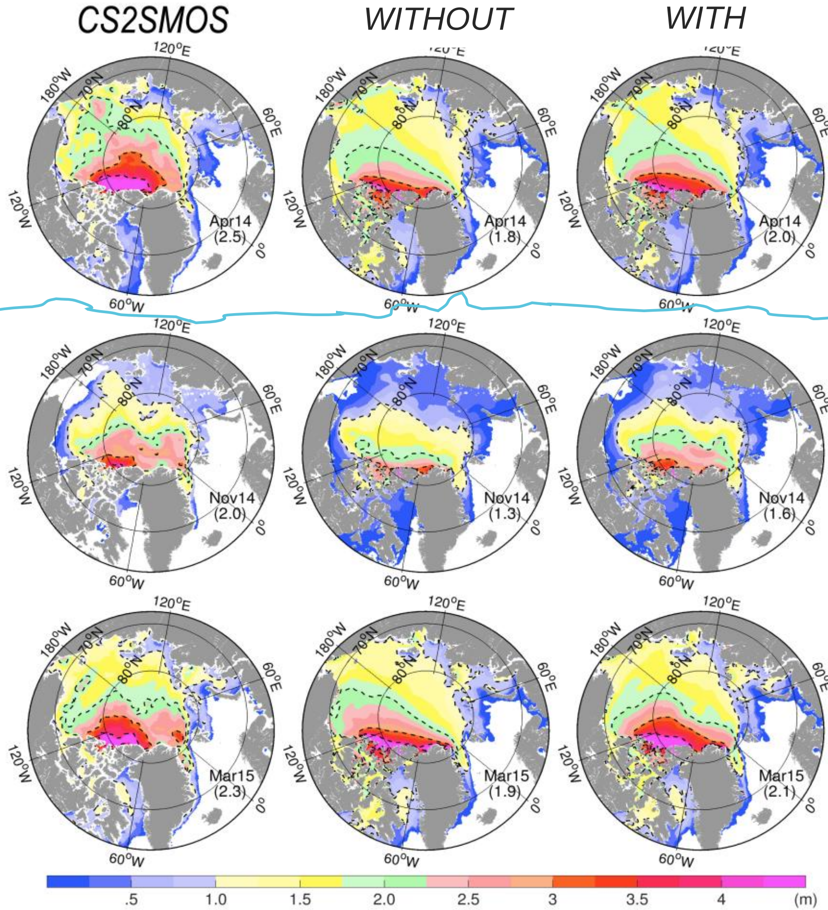
April 2014

May – Oct Summer Break

Nov 2014

Improvements by 12% to 24% in thick ice *[Xie et al. TC 2018]*

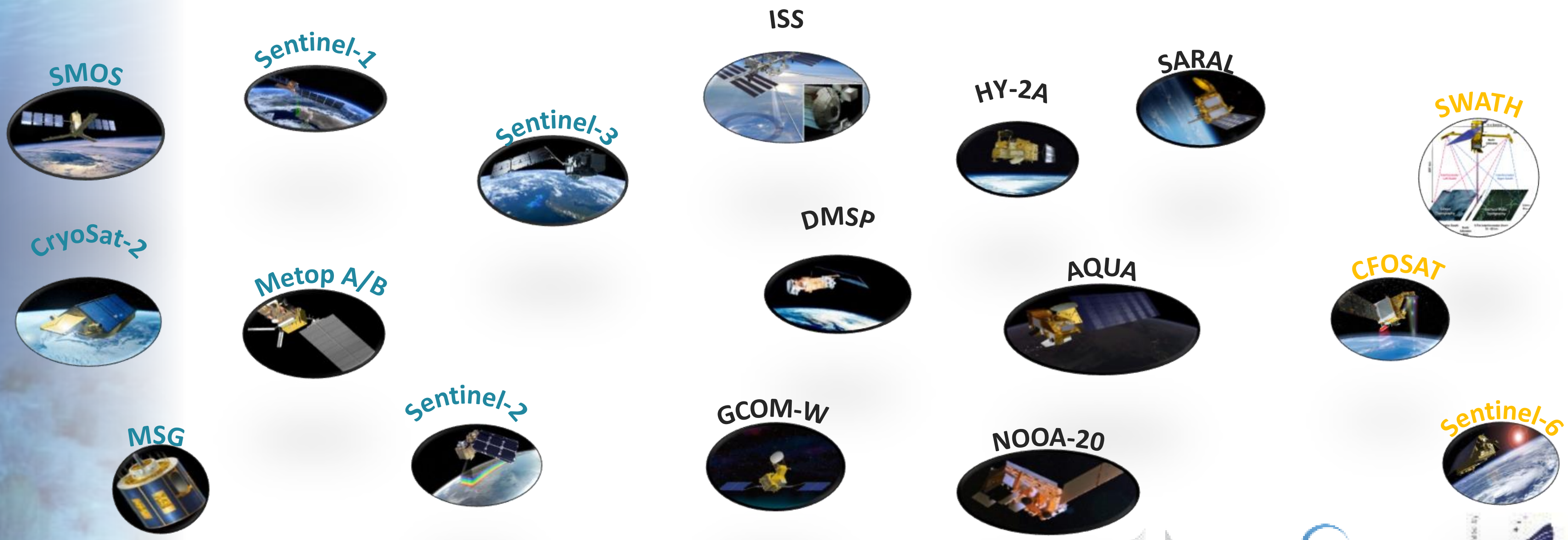
Mar 2015



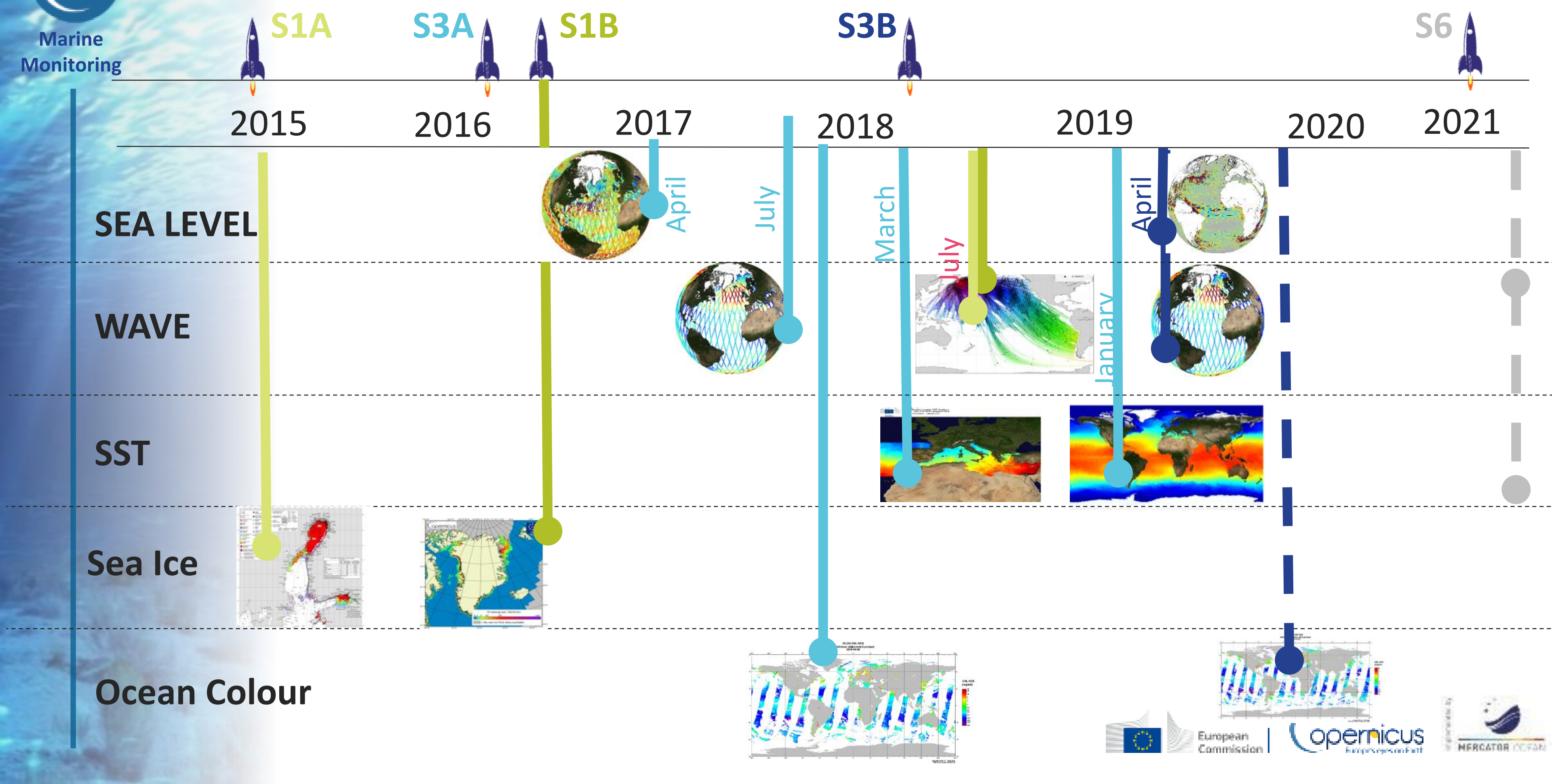
Satellite Missions

★**93% of products** in the catalogue depend on at least one satellite sensor.

★The service uses data from more than **60 different Satellites** (past and present missions).



Sentinels data integration in CMEMS



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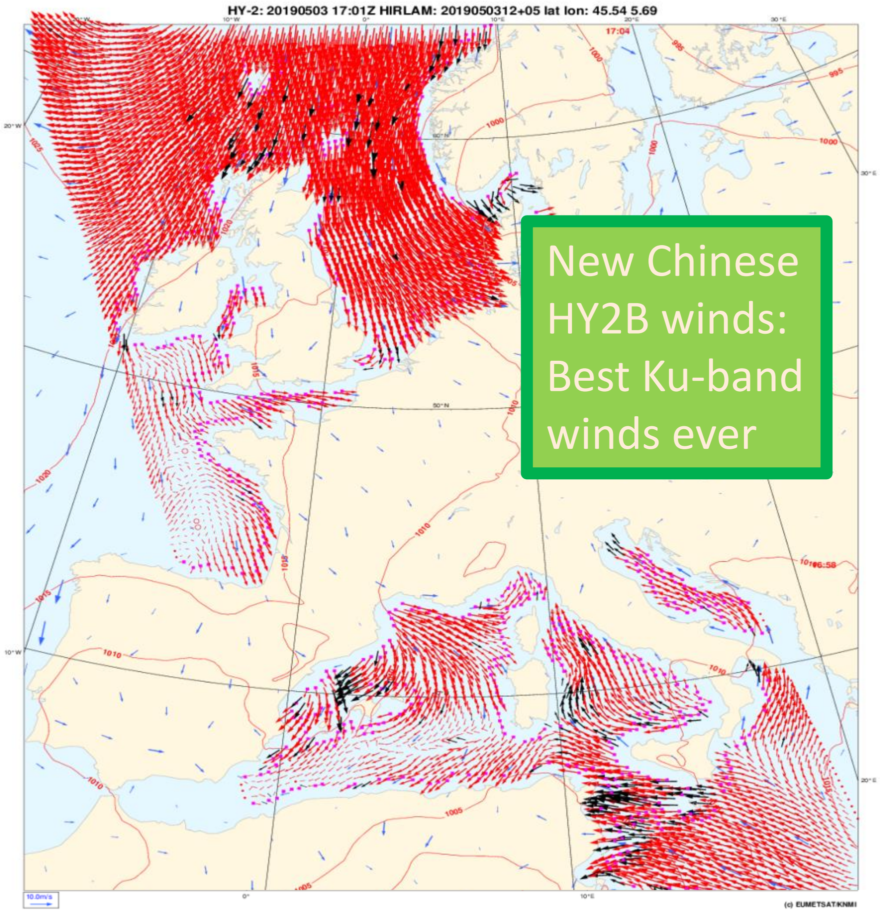
Upstream EO data integration

Additionally to the Sentinels, CMEMS integrates complementary and opportunity missions

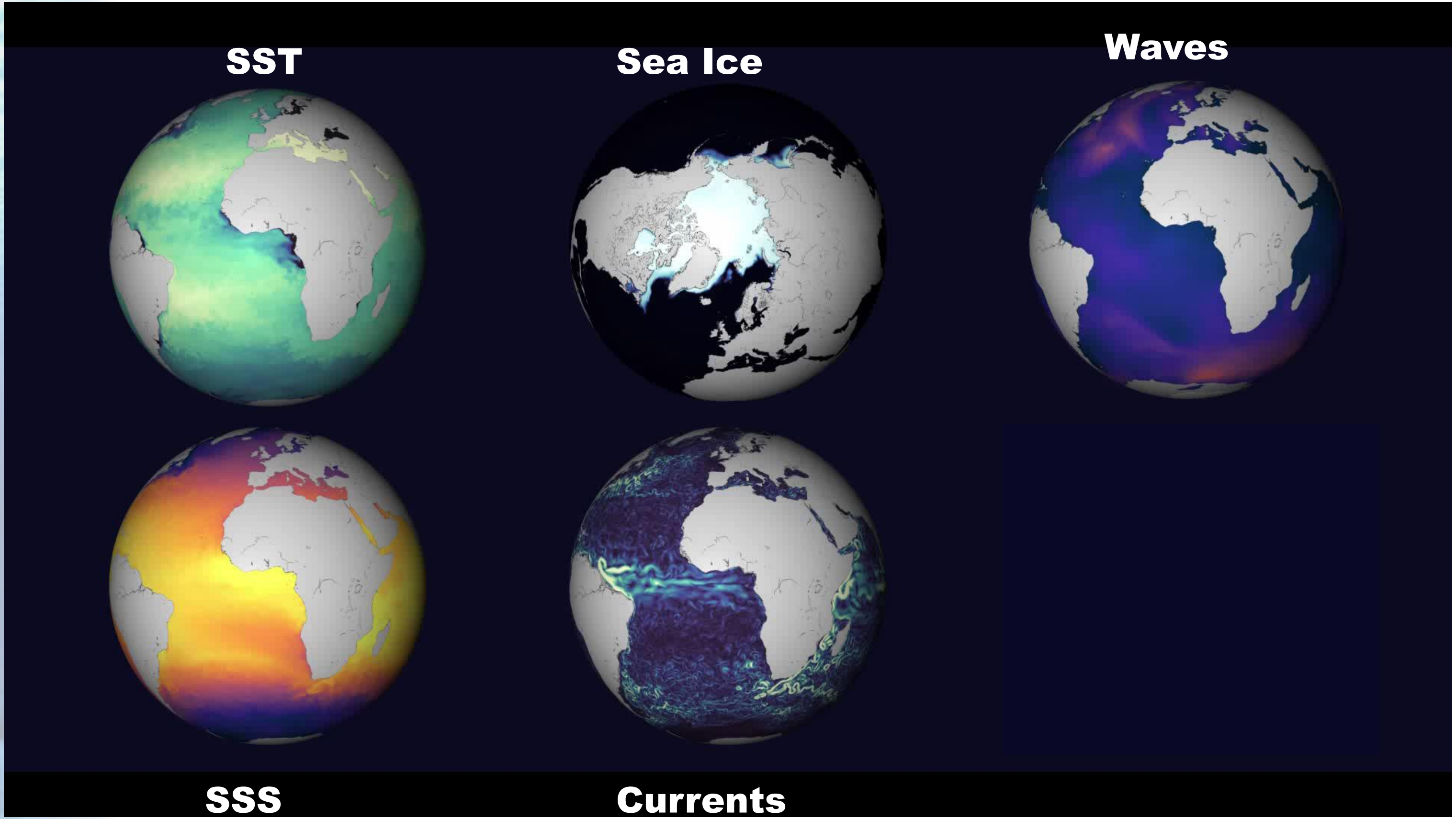
- European: Cryosat-2, Altika, Meteosat …
- US: NOAA, GOES, QuikScat, SSMI(S) …
- Chinese/Indian: HY2, OceanSat …

TAC	period	Nb sat DT	Nb sat NRT
WIND	1992-2019	23	7
WAVE	2018-2019	-	5
SST	1993-2019	>20	10
SL	1993-2019	13	4-6
MOB	1993-2019	*L4 products used*	



New Chinese HY2B winds: Best Ku-band winds ever

CMEMS GLOBAL HR MODEL



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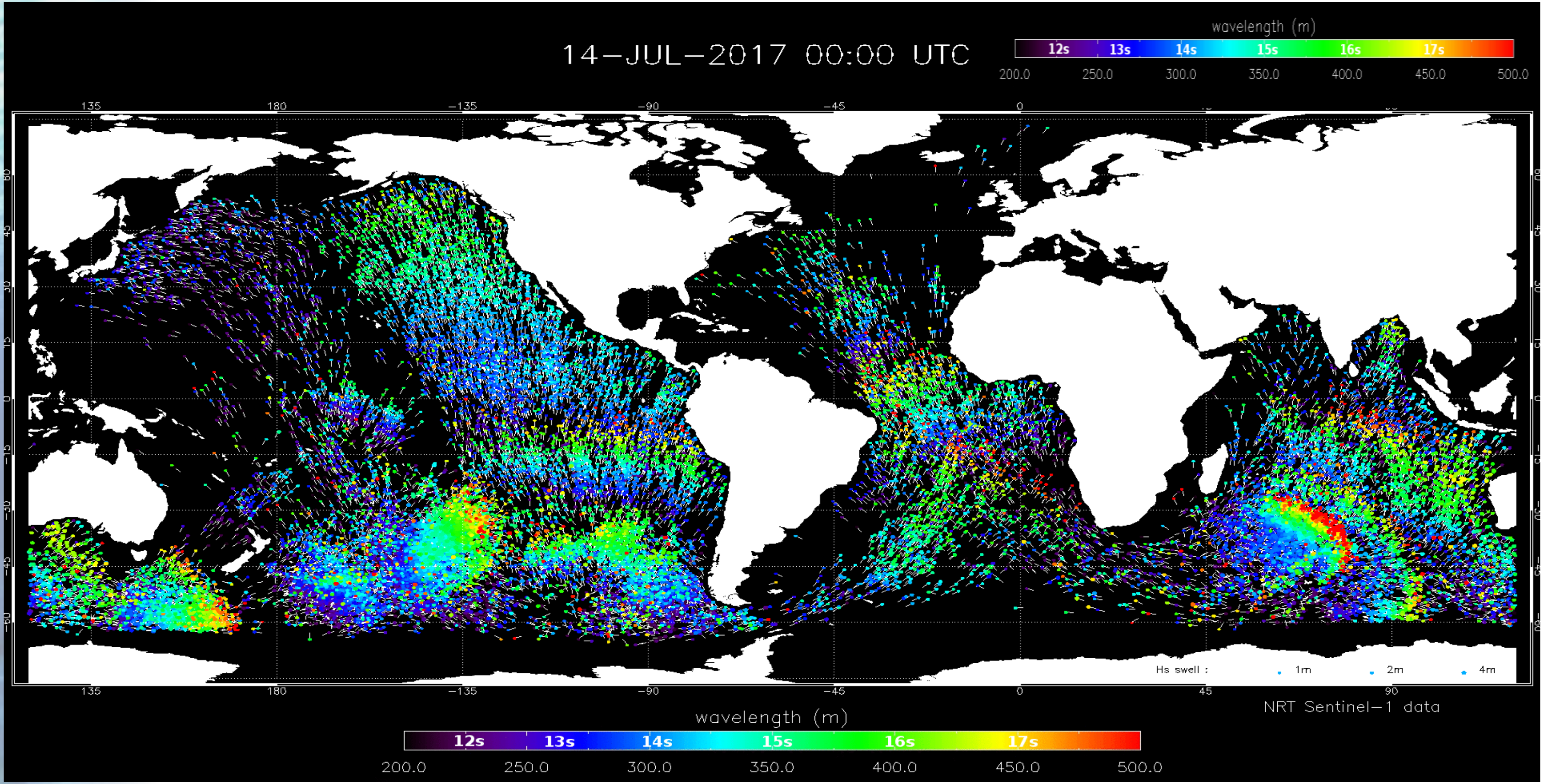
Sentinel-1 Wave spectra



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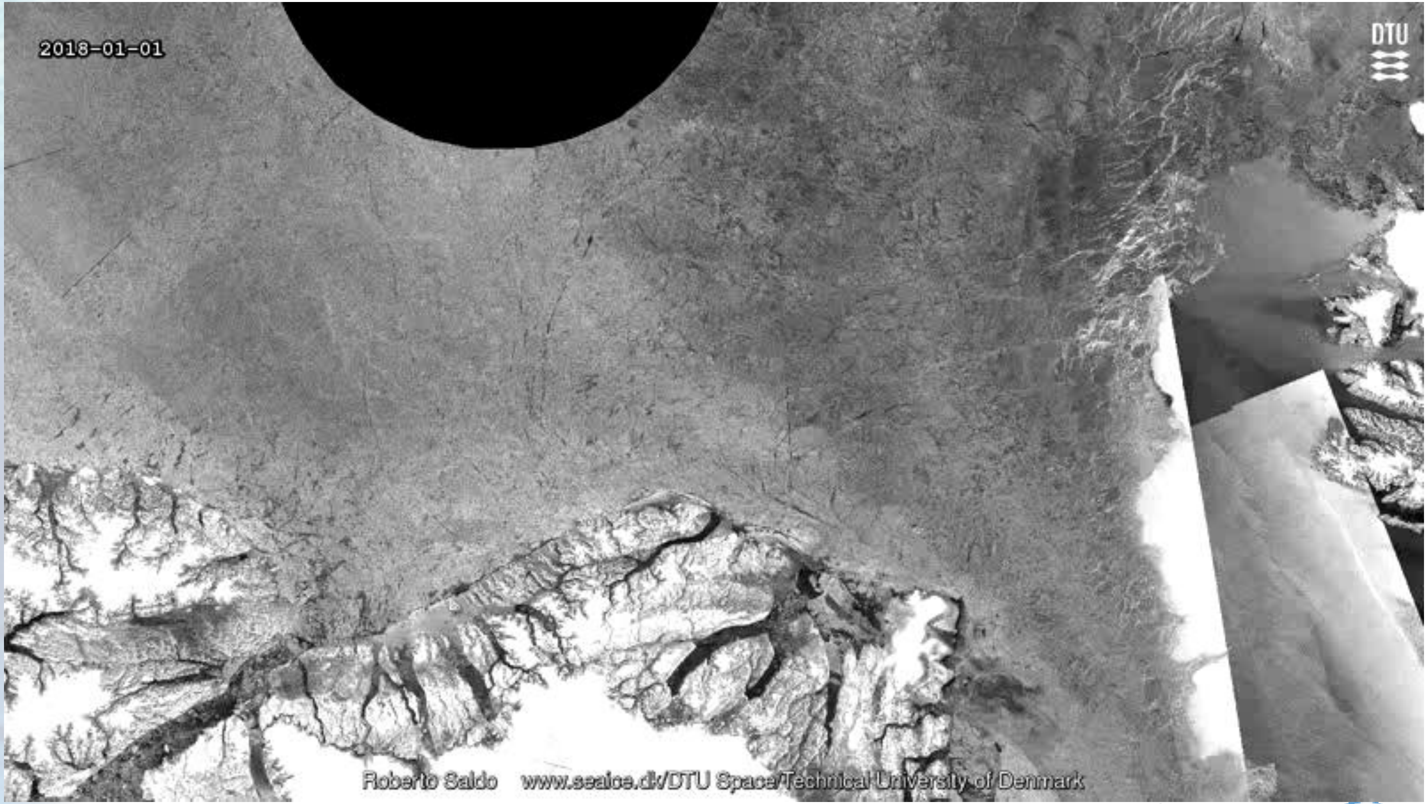
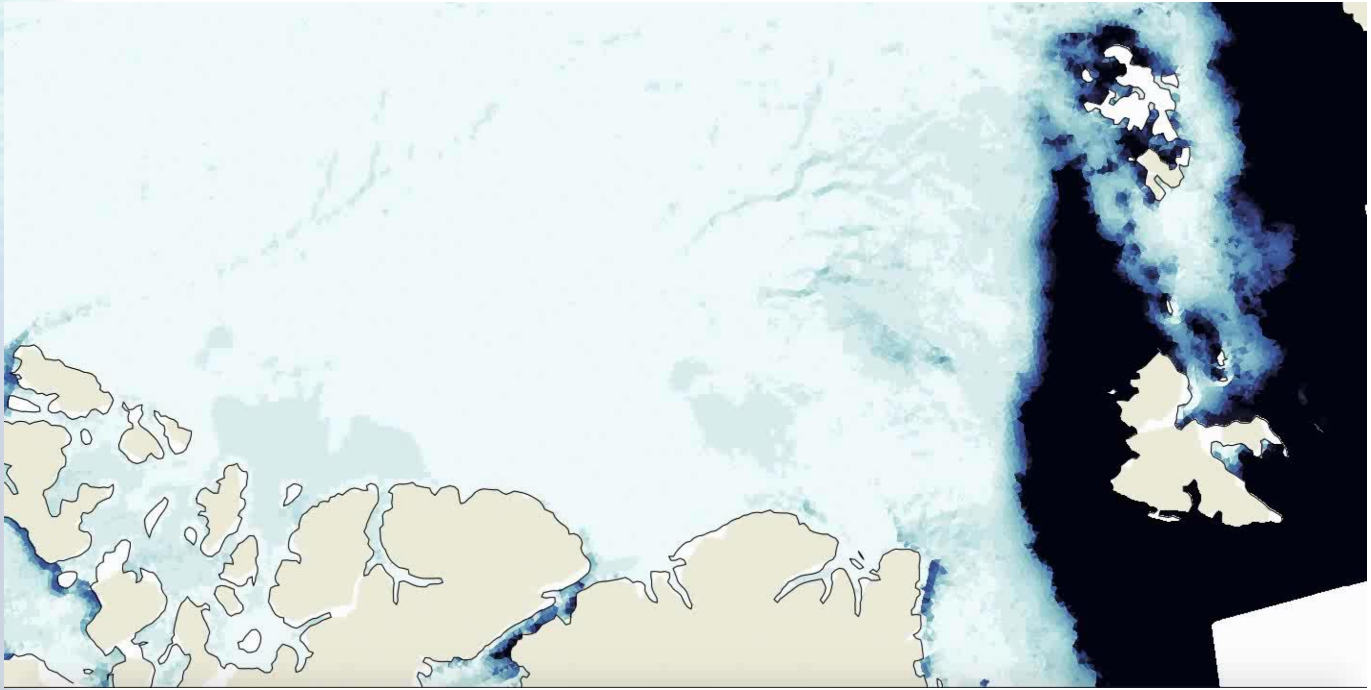
SAR animation from North Greenland polynya last winter (2018-01-01 to 05-05)



n e X t S I M   s i m u l a t i o n



- **neXtSIM stand-alone at ~7km mesh size**
  - Maxwell-EB rheology (Dansereau et al. 2016)
  - Lagrangian triangular mesh

Daily assimilation of

OSI-SAF concentrations

SMOS ice thickness

What's next ?

The Copernicus Marine Service of Tomorrow

Strategy of service

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Consolidate the positioning of Copernicus Marine Service as “the” world-leading reference source of information in the marine domain

Maintaining the excellence of a cutting-edge service capacity, reinforcing a pan-European network of highly-skilled providers of data and information, and developing further the marine value and identity to reach users beyond the known horizon.

⇒ **Focus on service uptake and sustained engagement of users, and develop confidence and secure users loyalty with intensified training activities**

⇒ **Re-enforce the «marine identity» to reach downstream service operators (Private/Public) beyond the known community,**

⇒ **High space/time resolution integrated blue-green-white ocean monitoring and forecasting system (real time, reanalyses)**

⇒ **Enhance operational interfaces with other Copernicus Services and EMODnet to foster cross-fertilization**

SEA ICE MONITORING
MARINE FOOD
WATER QUALITY
NATURAL RESOURCES & ENERGY
COASTAL MONITORING
SAFETY & DISASTER
MARINE NAVIGATION
SCIENCE & CLIMATE
SOCIETY & EDUCATION
MARINE CONSERVATION & POLICIES

What is needed ?

Requirements

for

the Copernicus Marine Service

A user driven service

CMEMS is a user driven service and user needs are regularly gathered by Mercator Ocean International and its CMEMS partners.

The constant dialogue with user communities helped in identifying overarching themes for the Service Evolution:

- 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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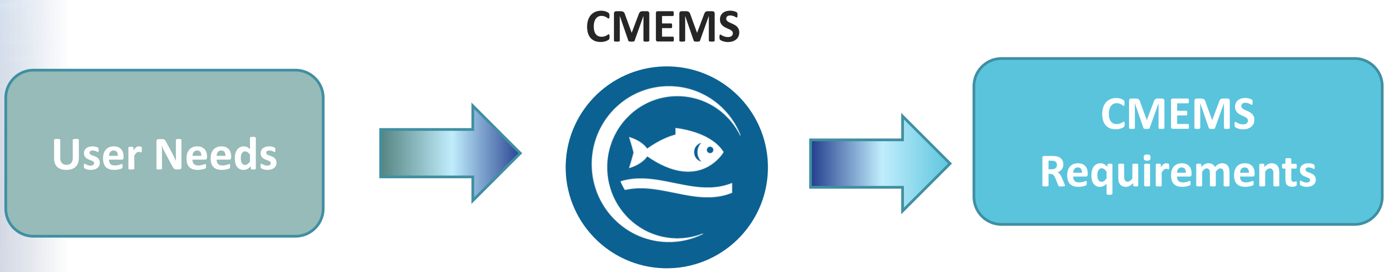
From User requirements to observation requirements

User requirements do not translate directly into observation requirements. They **must go through the added value chain of the service**.



To this end **new scientific and technological advances** in the fields of Earth observation, numerical modelling, and data processing techniques are **taken into account to define the requirements** needed for a correct evolution of the service.

Post 2021 Service priorities: needs and responses

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HR Physics and Sea Ice

Biology

Coastal

Climate

- **Marine Safety and maritime transport** : operational, global, Arctic, increased product accuracy, increased operational data access and user support.

- **Marine Resources**: reach for biology the level of excellence CMEMS has now for "Marine Physics" : better support fisheries management, development of sustainable aquaculture and living resources protection. Higher trophic levels in CMEMS BGC models.

- **Marine & coastal environment** : Encourage co-production between MS services and a re-enforced EU Marine Service.

- **Climate** : Transform the high level CMEMS expertise on the ocean into a strong assessment capacity on the ocean climate, on CO_2 & blue carbon assessment, develop new capabilities for long term projection & scenarios for the evolution of the coastal ocean and marine ecosystems.

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CMEMS requirements – satellite observing systems

Based on user requirements and the evolution of the CMEMS for the next decade, the main CMEMS recommendations for the evolution of the Copernicus Satellite Component are as follows:

- Ensure a **continuity of the present capability** of the Sentinel missions (S1, S3, S6) (+ S2)
- Develop **new capabilities for wide swath altimetry**
- Fly a **European microwave mission for high spatial resolution observations of ocean surface temperature and sea ice** concentration.
- Fly a **geostationary ocean colour mission** over Europe to strongly improve the time resolution of ocean colour observations over European seas.
- Ensure **continuity (with improvements) of the Cryosat-2 mission** for sea ice thickness monitoring and sea level monitoring in polar regions.
- R&D actions should be developed to advance our capabilities to observe **sea surface salinities and ocean currents** (e.g. SKIM) from space.

+CMEMS Requirements for Polar/Snow monitoring (June 2016). Participation of MOI/CMEMS experts in the EU Polar Expert Group [PEG-I/PEG-II reports]. The EG recommends to retain as first priority the **Copernicus Imaging Microwave Radiometer (CIMR).**


European Commission

CMEMS requirements for the evolution of the Copernicus Satellite Component

Mercator Ocean and CMEMS partners

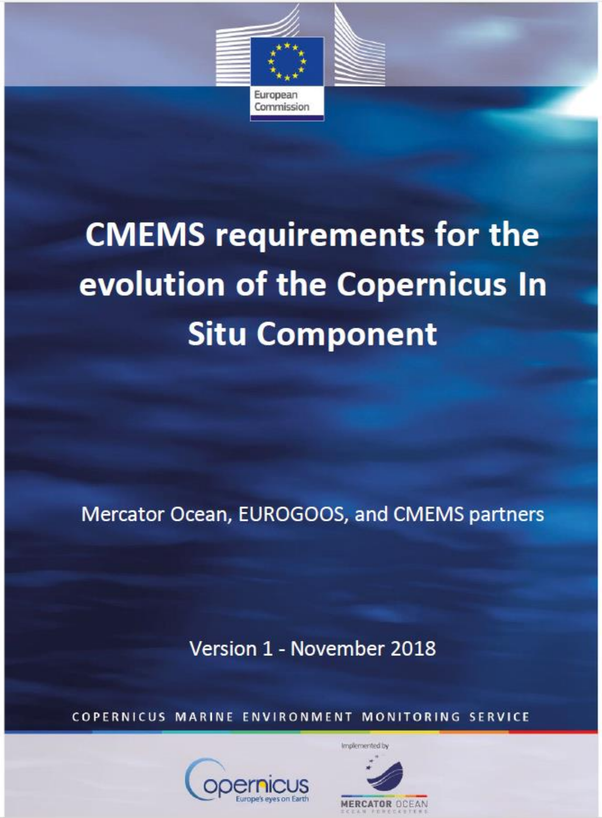
February 21, 2017

COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

European Commission | Copernicus

In-situ requirements for CMEMS have been previously gathered in the framework of the GISC project lead by the European Environmental Agency (2012).

Latest updates have been collected during a **dedicated workshop**, held **in Toulouse** on July 3rd 2018, and organized by Mercator Ocean International in collaboration with EUROGOOS that brought together all **CMEMS TACs and MFCs, ROOSes representatives and EUROGOOS Task Team members**.


European Commission

CMEMS requirements for the evolution of the Copernicus In Situ Component

Mercator Ocean, EUROGOOS, and CMEMS partners

Version 1 - November 2018

COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

Implemented by

opernicus Europe's eyes on Earth

MERCATOR OCEAN

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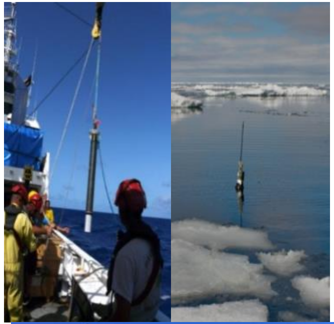
CMEMS Requirements & Recommendations

- **Critical gaps** for **biogeochemical** observations (e.g. carbon, oxygen, nutrients, chl-a).
- Identified also gaps in sampling for **physical** observations(e.g. currents, temperature, salinity, sea level)
- In terms of platforms priorities to :

✓ **Sustain** the global **Argo** array, consolidating its regional components, and implementing its extensions (BioGeoChemical Argo and Deep Argo);

✓ Improve EuroGOOS **ROOSes** and key observing systems (e.g. FerryBoxes, gliders, tide gauges, high-frequency radars, etc).

- **Data harmonization** and their access need to be improved as well.
- A specific effort for the **Arctic region** is needed; there are **severe limitations** with measurements **over the seasonal ice zone**, which is growing broader and none of the platforms available today can collect data there.
- Development of a **dedicated network** able to collect **Fiducial Reference Measurements** for all the ocean variables estimated by the Copernicus Satellite component is also important for CMEMS, since these data are also **used for the development of new products and their validation**.



Conclusions

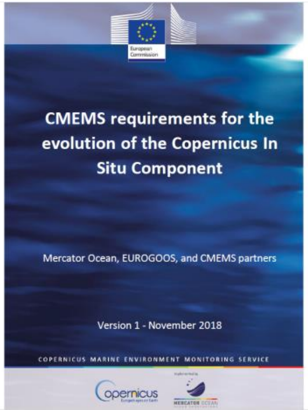
Copernicus & Copernicus Marine Service: a successful initial phase. Operational and state of the art service, user uptake, innovation.

Change and transformation in CMEMS is inextricably linked to the supply of data and the proper specification of requirements. This core dependency must be managed strategically to ensure the requirements of the future are in the observing plans of today.

Future service evolution requires 1/ **continuity** and 2**/ significant improvements of ocean observing capabilities** :

- Satellite :
  - **High space and time resolution.**
  - **Improve monitoring of Polar Seas.**
- In-situ observing systems:
  - **Major sustainability (Argo)and sampling gaps (biogeochemistry, deep ocean).**
  - **Improve the data access.**

Summary of recommendations are reported in dedicated OceanObs19 Paper



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Thanks for Your attention