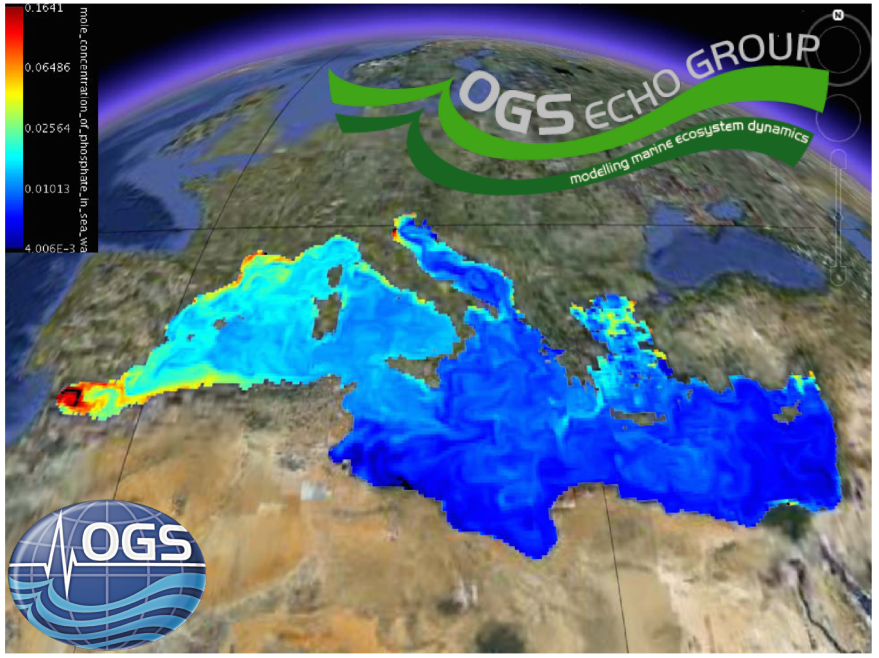
Models and Data for Blue Growth strategy: how to become aware of the EU Copernicus Marine Environment Monitoring Services (CMEMS) offer

S. Salon (OGS)

OGS – National Institute of Oceanography and Applied Geophyisics (Trieste)



The Abdus Salam International Centre for Theoretical Physics

The CODATA-RDA Research Data Science Advanced Workshops on Climate Data Sciences
ICTP, Trieste, 23 August 2019

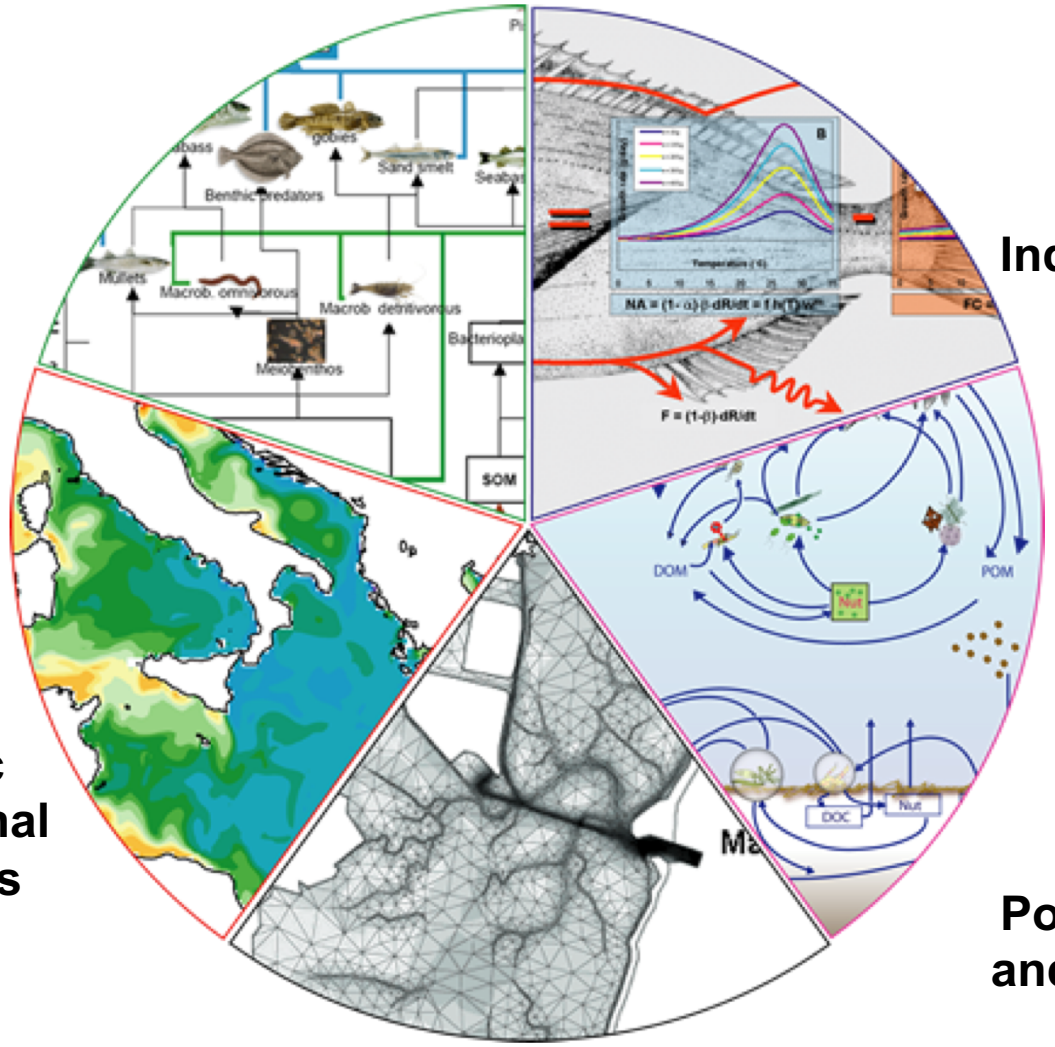
WELCOME!

ECHO group adopts a wide set of methodologies and models, based on the specific problem to be tackled:

OGS ECHO GROUP
modelling marine ecosystem dynamics

OGS

Food web models



Individual Based Model & population dynamic

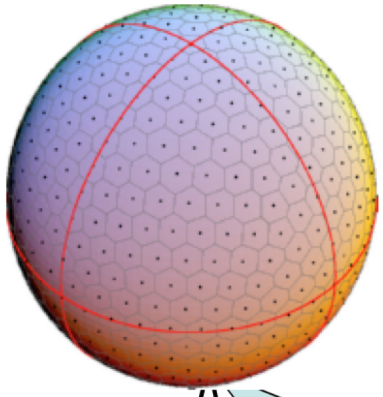
Biogeochemical models

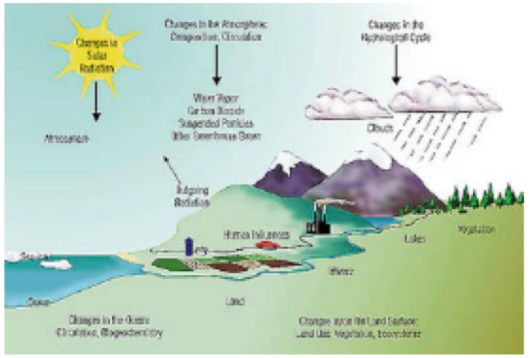
Pollutant dispersion and bioaccumulation

Hydrodynamic models at regional and local scales

Operational Oceanography models integrated in Copernicus

Challenges in ocean (and Earth System) modelling





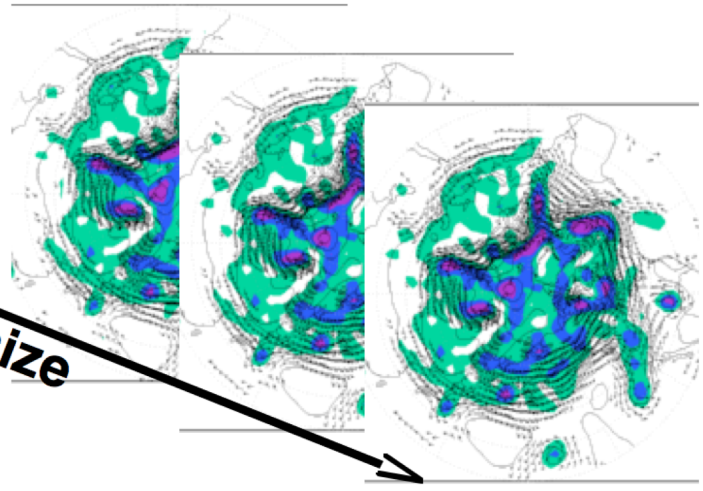
Resolution

Computing Resources

Complexity

Duration and/or Ensemble size

(Many versions of this slide exist, this one from J. Kinter's presentation to the world modelling summit 2008)



Outline

- An Ocean of data
- The EU Blue Growth strategy
- The EU Copernicus Services
- Models and BigData in Copernicus

Talk objectives

1. **Understand** the potentiality of the Copernicus infrastructure
2. **Increase** the awareness of the information provided by Copernicus
3. **Design** the most proper Copernicus information useful to analyze the case study of your interest

Europe's eyes on Earth

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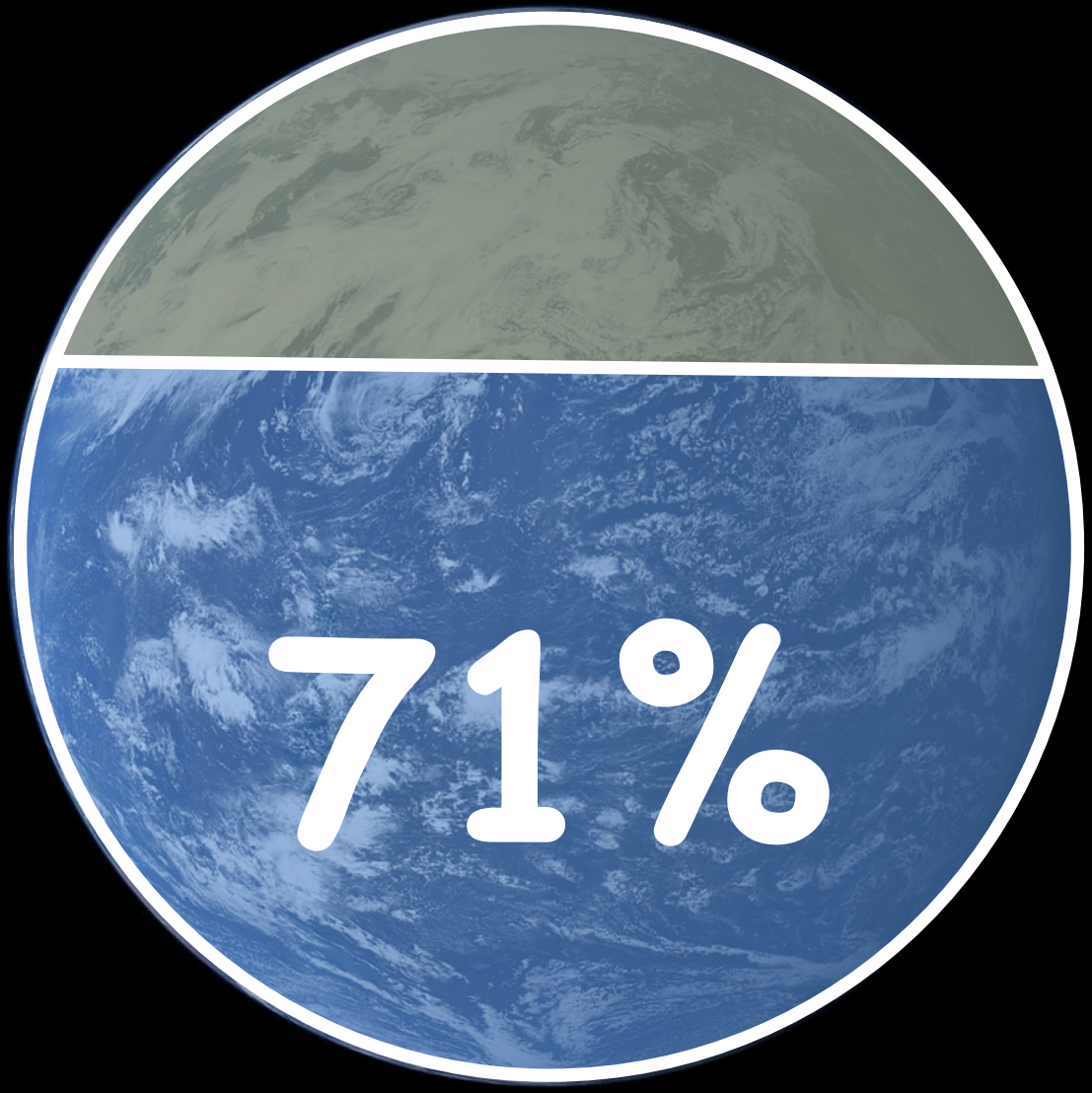
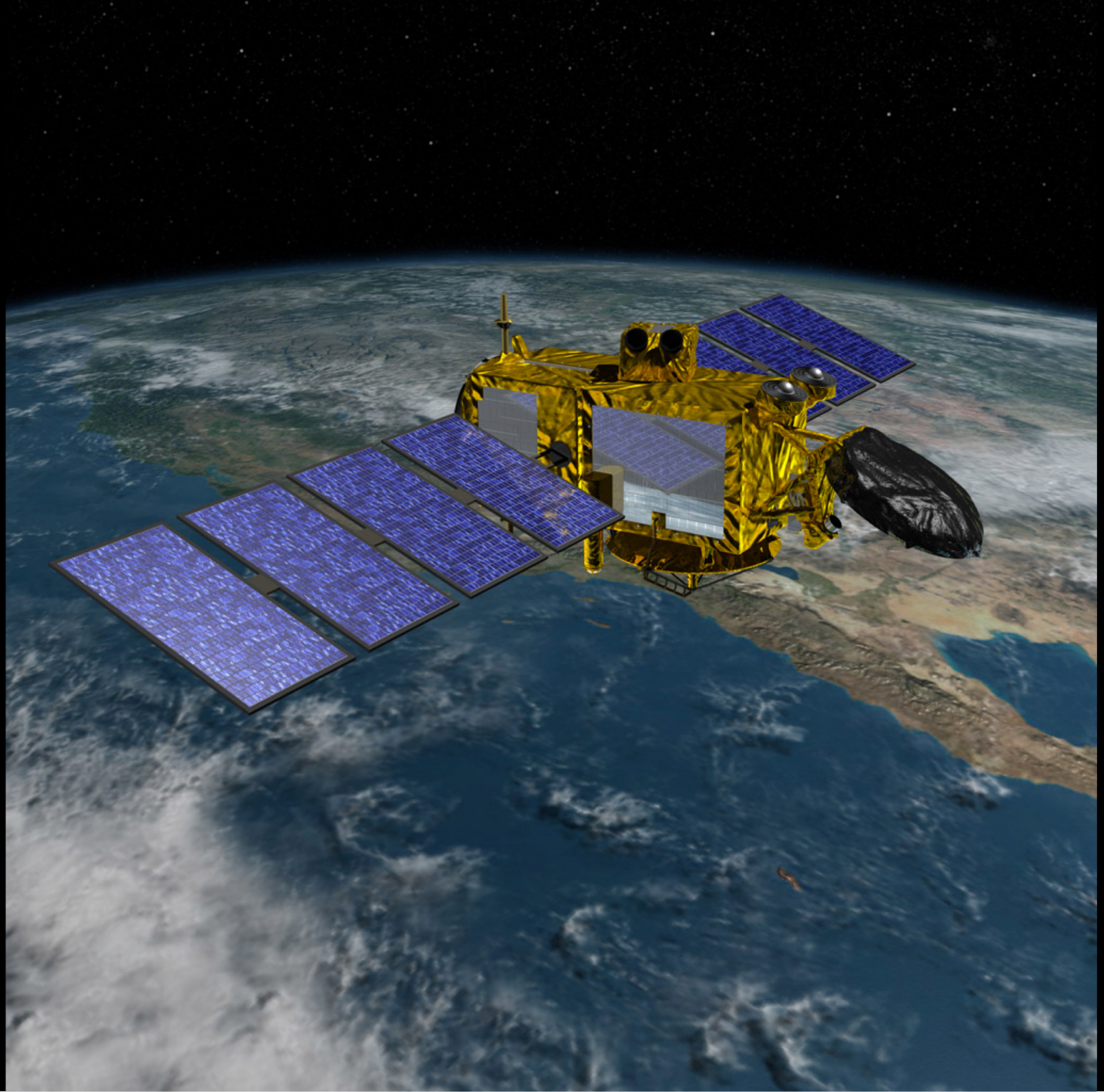
…our planet, the Earth…


71%

…but… how can we measure how our ocean changes?

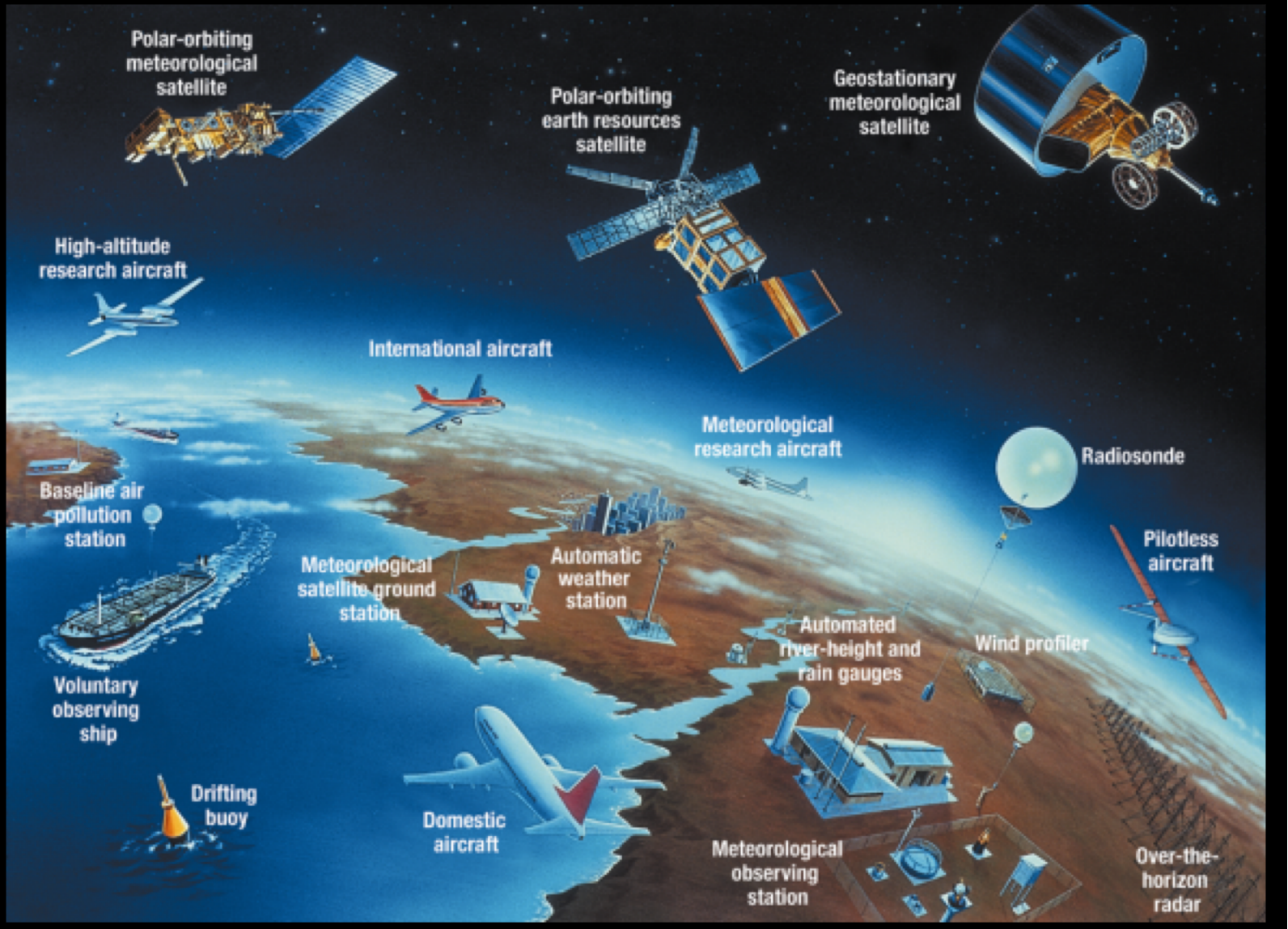
PALFINGER
PK 18500

OGS



...atmosphere
and ocean are
closely
connected...

1703

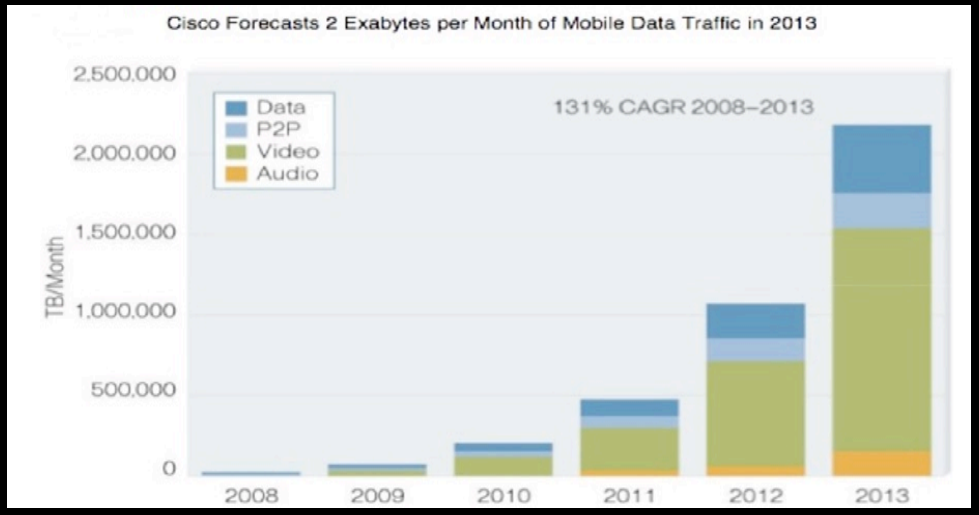

Polar-orbiting meteorological satellite
Polar-orbiting earth resources satellite
Geostationary meteorological satellite
High-altitude research aircraft
International aircraft
Meteorological research aircraft
Radiosonde
Baseline air pollution station
Meteorological satellite ground station
Automatic weather station
Pilotless aircraft
Automated river-height and rain gauges
Wind profiler
Voluntary observing ship
Drifting buoy
Domestic aircraft
Meteorological observing station
Over-the-horizon radar

天河
天河

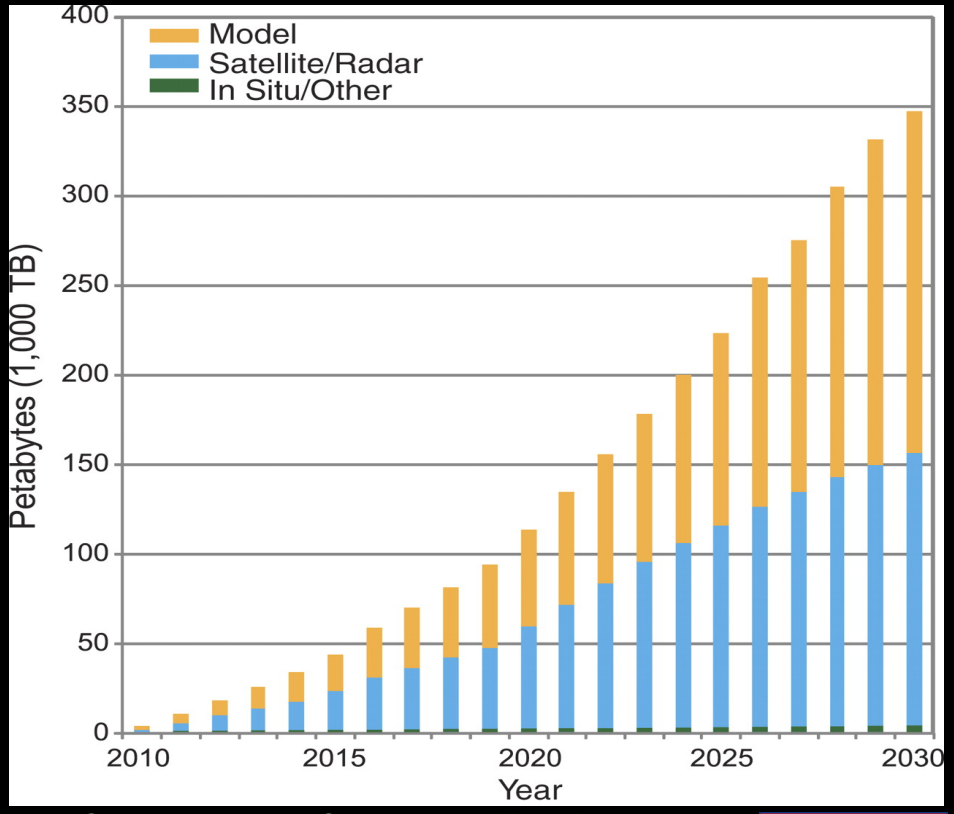
BIG
DATA
INFORMATION
TECHNOLOGIES
MANAGEMENT
ANALYSIS
STORAGE
LARGE
SETS
MILLION
SEARCH
INTERNET
PETABYTES
RESEARCH
LEARNING
DEVELOPMENT
TECHNOLOGY
SCIENCE
FUTURE
NEW
BILLION
PARALLEL
INITIATIVE
SOFTWARE
VOLUME
PROCESS
GOVERNMENT
SAN
NAS
SOCIAL
BUSINESS
DATABASES
PROCESSING
SIZE
EXABYTES
ANALYTICS
SIMULATIONS
FRAMEWORK
BETWEEN
DEFINITION
STATISTICS
VISUALIZATION
EFFECTIVE
SYSTEMS
MAKING
INTEGRATION
FACTOR
MANAGE
ONLINE
DAY
WORLDWIDE
RESULTS
YEARS
DRIVE
REPLICATION
HANDLE
SOURCES
CHALLENGES
LIMITS
COMPLEX
ANNOUNCED
PAST
CAPACITY
HAND
ONE
OUT
INCLUDE
NETWORKS
HYPOTHESIS
END
MOST
NEARLY
MAPREDUCE
CRITIQUES
APPROACH
MANY
USE
CURRENTLY
STATE
CRITIQUE
PEOPLE
TRAFFIC
TERABYTES
MARKET
RELATED
TIME
SENSOR
VARIETY
WOULD
ECONOMIC
PROJECT
ANNUAL
NOW
DISTRIBUTED
RELEVANT
USED
PER
SECOND
PRIVACY
INTERNATIONAL
IMPLEMENTATION
BECOMES
NATIONAL
FLOW
INTELLIGENCE
PROCESSES
APPROACHES
MASSIVE
USING
DETERMINE
WELL
SET
DEPARTMENT
QUERIES
HIGH
USERS
AMOUNT
REAL
STRUCTURE
WORK
RATE
APPLICATIONS
INFRASTRUCTURE
HIGHER
ALGORITHMS
COMPANIES
PRIVATE
TERMS
YEAR
CAPABILITIES
SUCCESSFUL
NEEDED
USES
COMPARED
SHARED
LESS
HUGE
EVERY
WORLD
VARIOUS
BASED
TIMES
ARCHITECTURE
PARADIGM
RECORDS
COST
FUNDING
INSIGHT
TOOLS
CENTER

Data amount produced is becoming bigger and bigger…

- The volume of **worldwide climate data** is expanding rapidly, creating challenges for both physical archiving and sharing, as well as for ease of access and finding what's needed, *particularly if you are not a climate scientist*.
- Post-processing can be synonym of Data Mining, Data Analytics
- HPC must become a necessary tool when "BigData" have to be analyzed
- **DIKW** process (Data-Information-Knowledge-Wisdom/Decision) is becoming a matter for professionals…



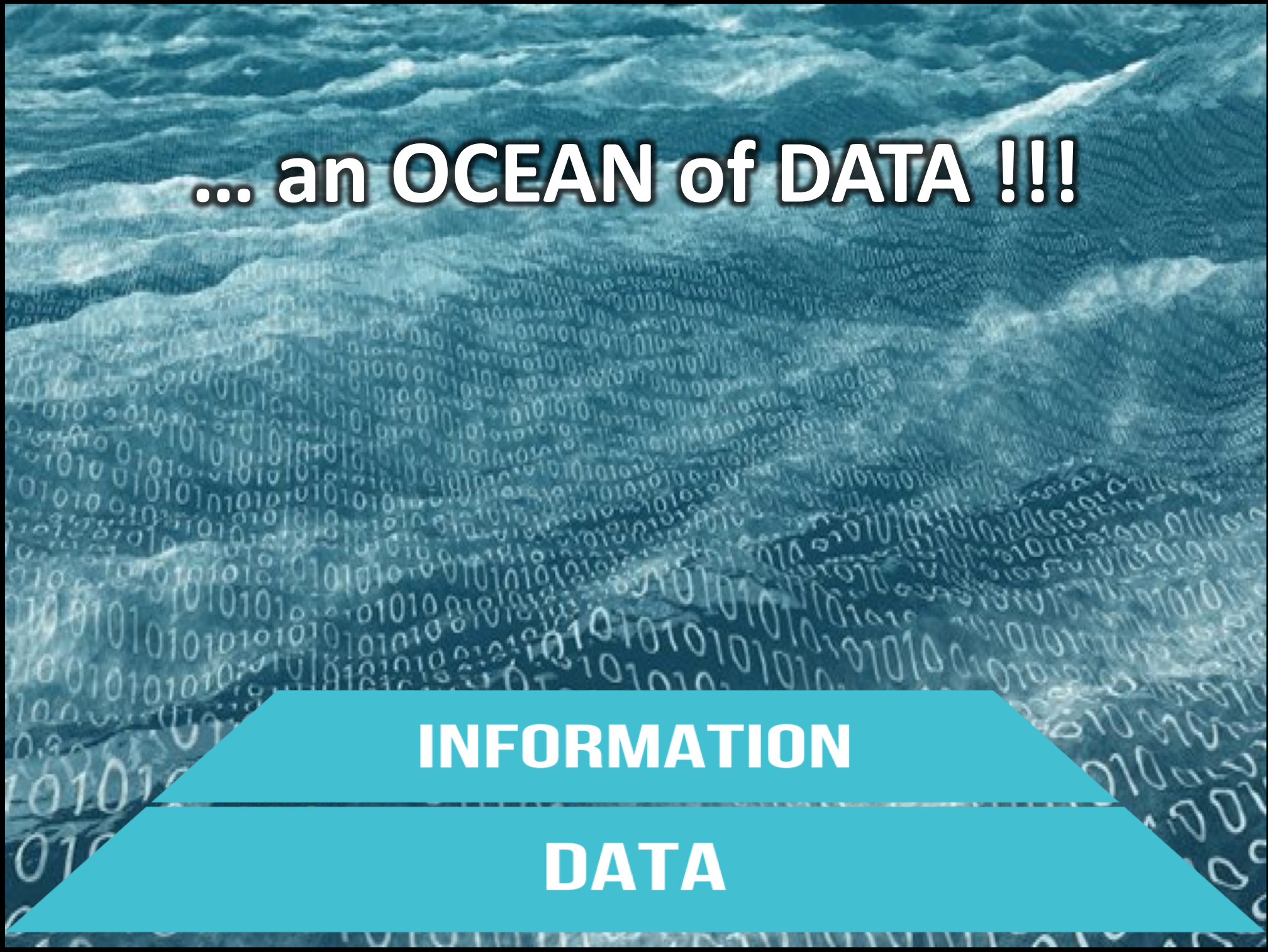
Source: Cisco (2009), then: Sule M.J., DataDay@ICTP, Sep2013

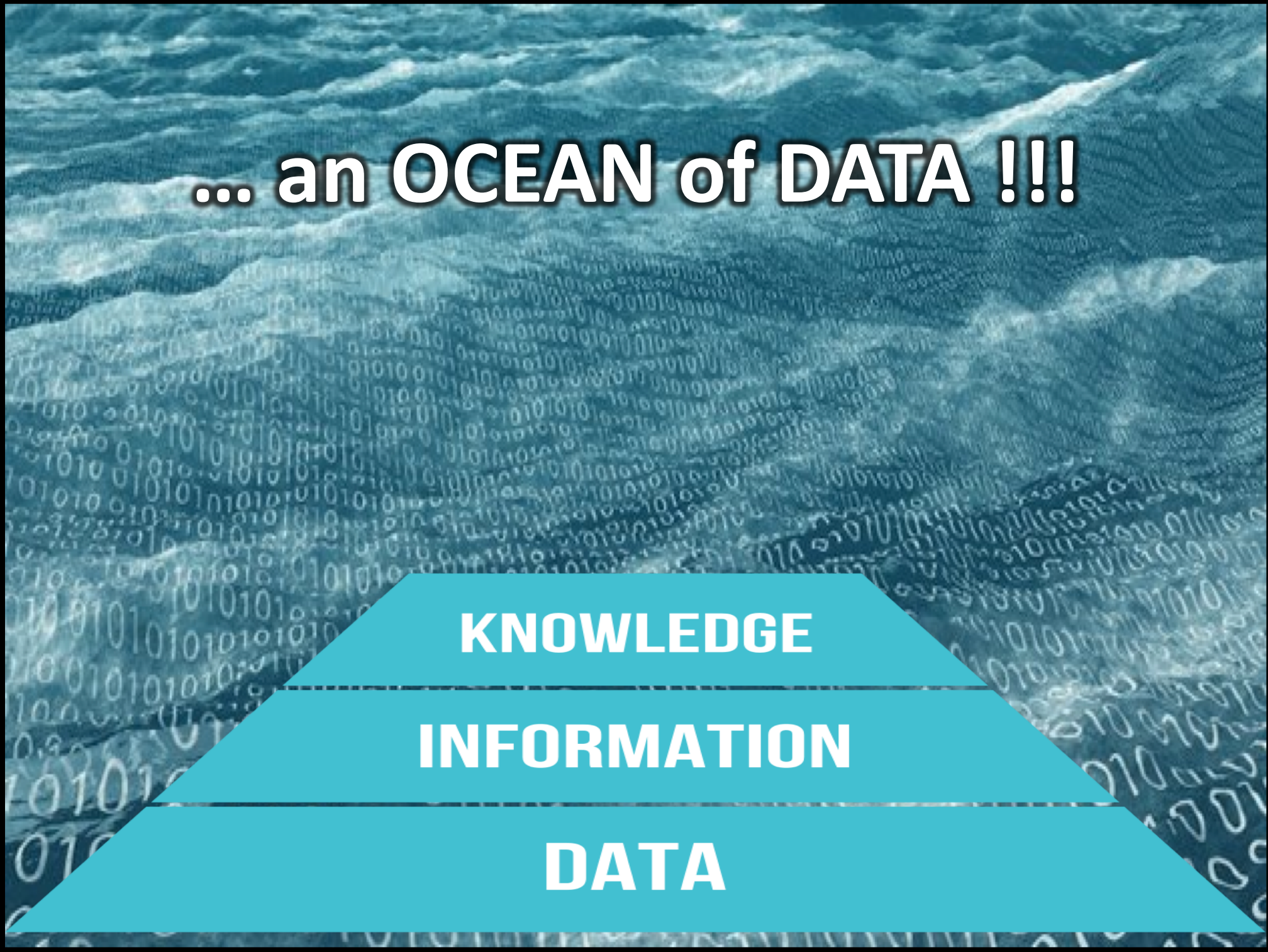


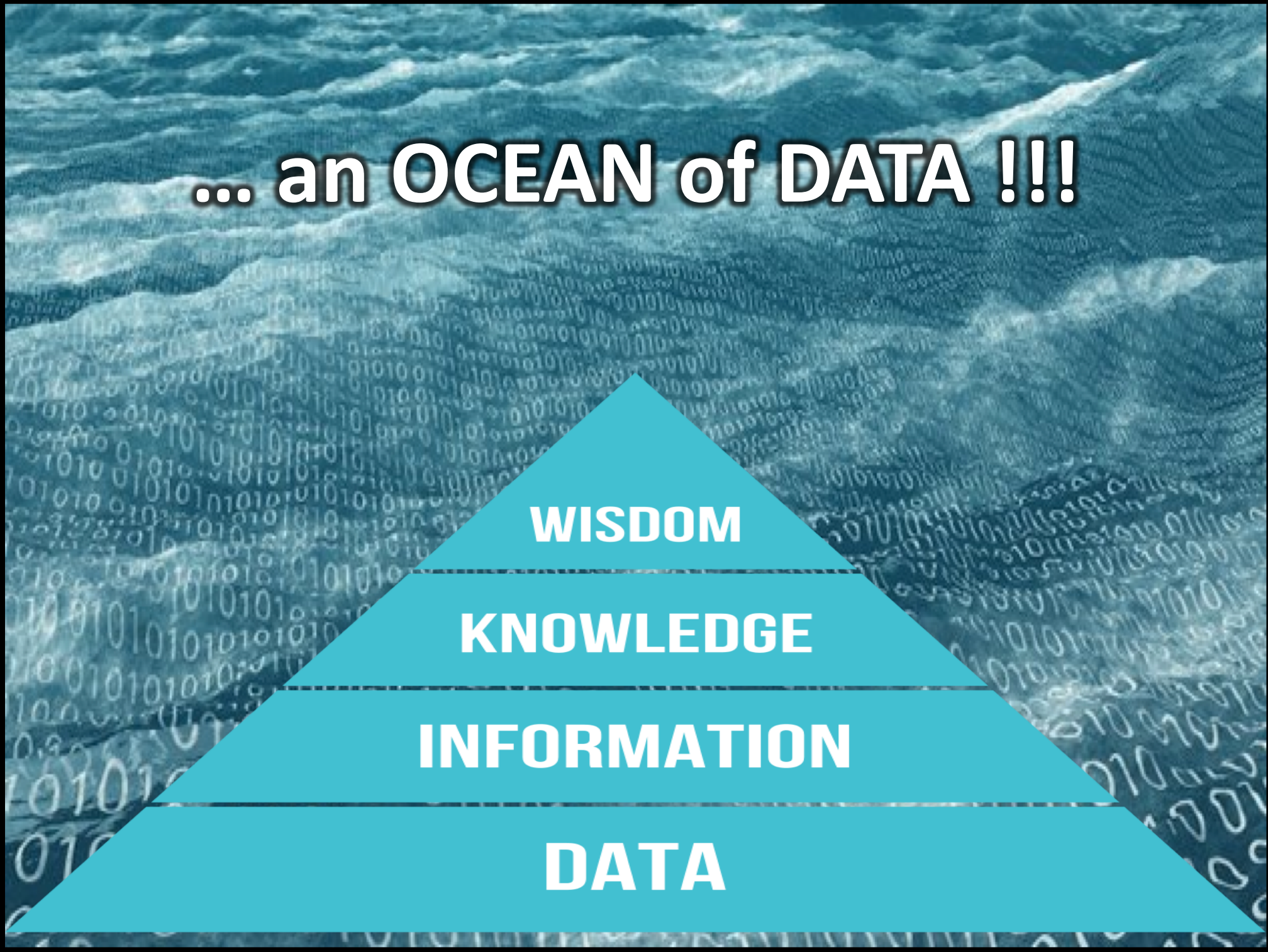
J. T. Overpeck et al. Science 2011;331:700-702

Science AAAS

… an OCEAN of DATA !!!
DATA


… an OCEAN of DATA !!!
INFORMATION
DATA

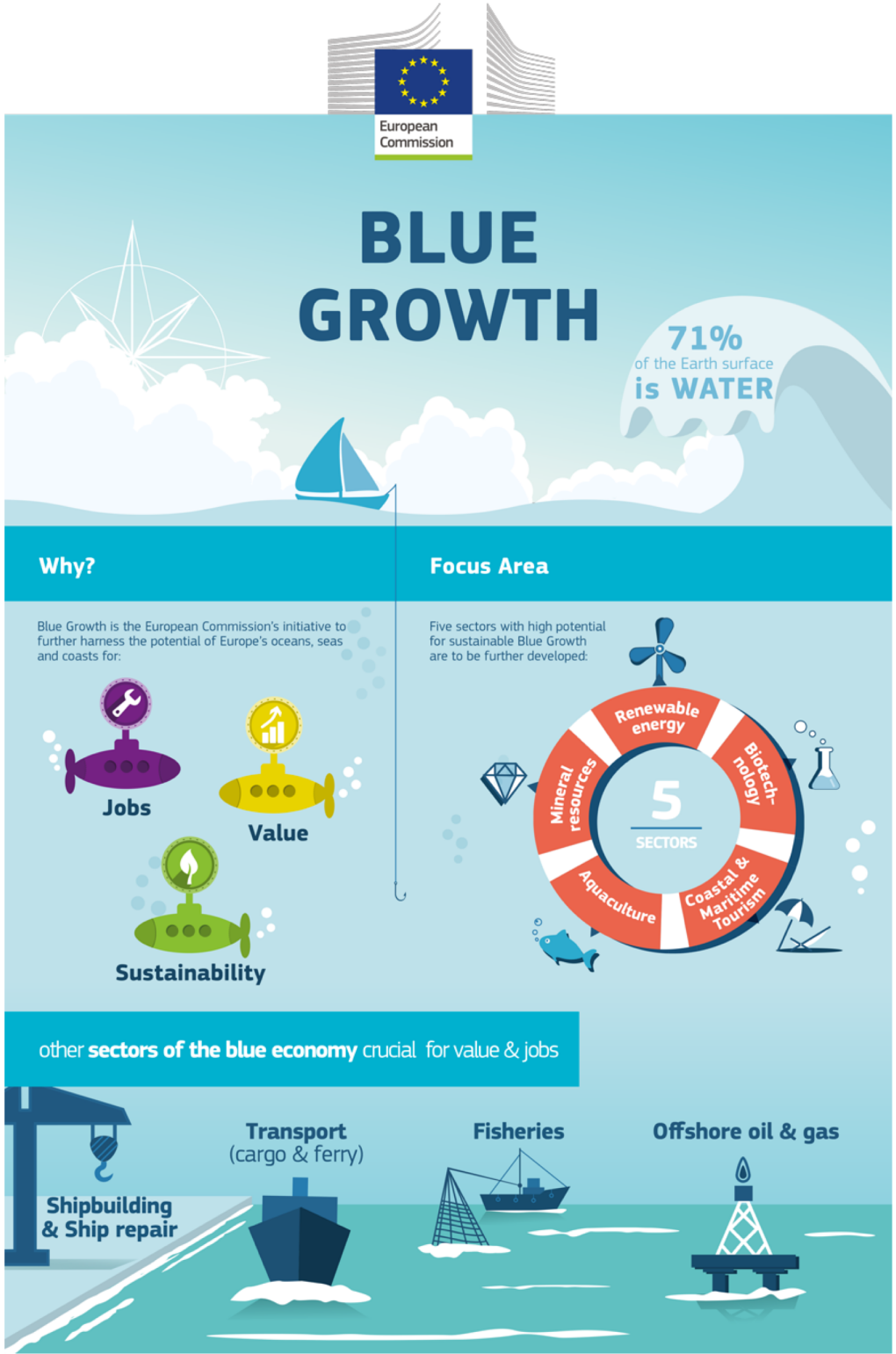

… an OCEAN of DATA !!!
KNOWLEDGE
INFORMATION
DATA


... an OCEAN of DATA !!!
WISDOM
KNOWLEDGE
INFORMATION
DATA

ACTION

Outline

- An Ocean of data
- **The EU Blue Growth strategy**
- The EU Copernicus Services
- Models and BigData in Copernicus



Blue Growth = long term strategy to support **sustainable growth in the marine and maritime sectors**.
Seas and oceans are drivers for the European economy and have great potential for innovation and growth.
BG is the maritime contribution to achieving the goals of the **Europe 2020** strategy for smart, sustainable and inclusive growth.

'blue' economy = roughly **5.4 million jobs** generating a gross added value of almost **€500 billion a year**.
=> further growth is possible in a number of **areas** which are highlighted within the strategy.

The strategy consists of three components:

1. Develop sectors that have a high potential for sustainable jobs and growth:

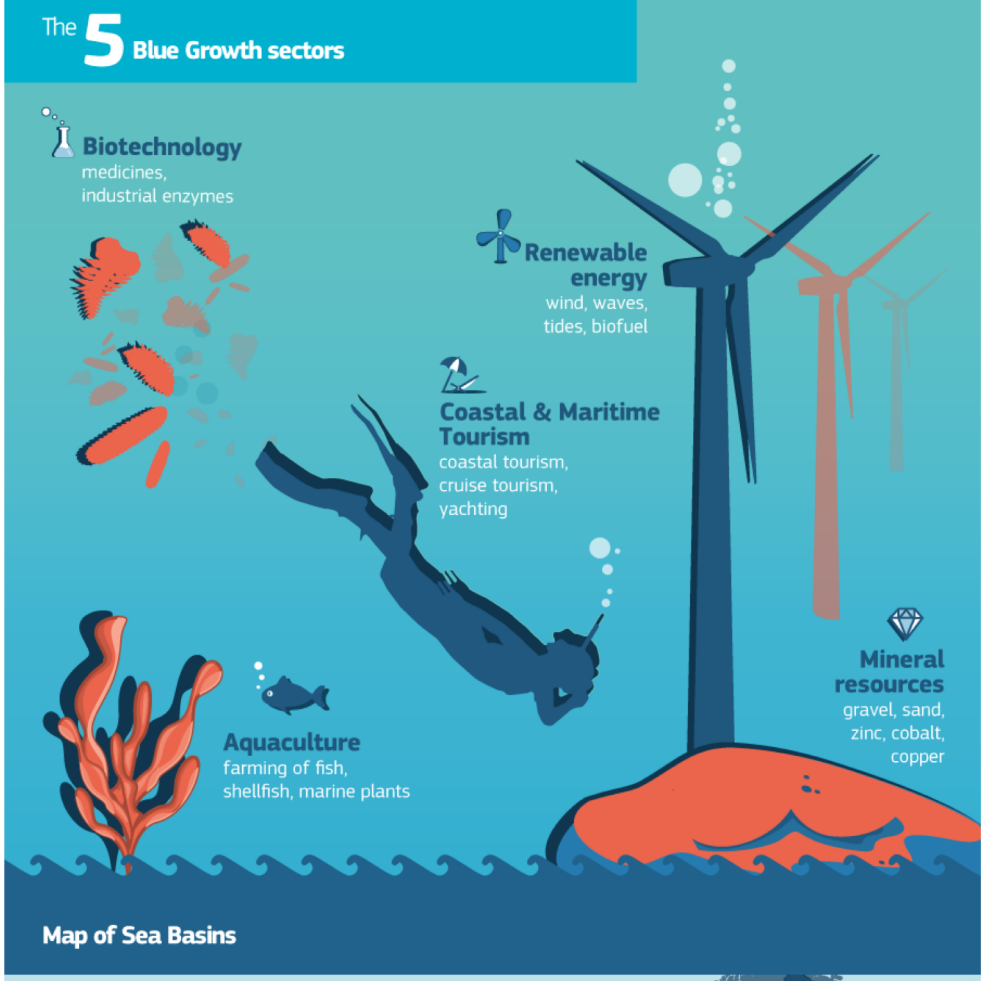
a. aquaculture
b. coastal tourism
c. marine biotechnology
d. ocean energy
e. seabed mining

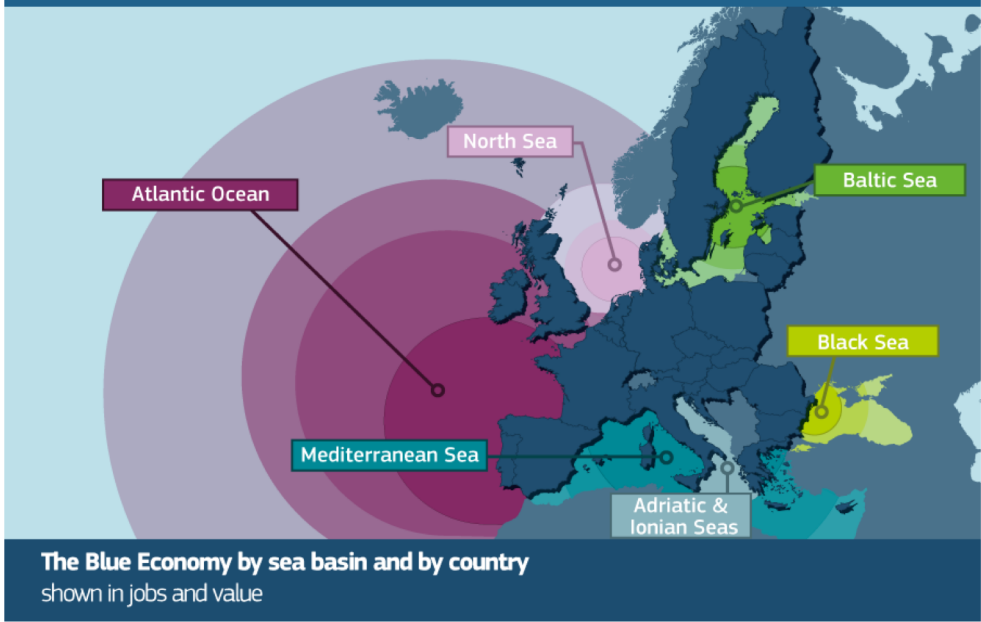
2. Essential components to provide knowledge, legal certainty and security in the blue economy:

a. **marine knowledge** to improve access to information about the sea;
b. **maritime spatial planning** to ensure an efficient and sustainable management of activities at sea;
c. **integrated maritime surveillance** to give authorities a better picture of what is happening at sea.

3. Sea basin strategies to ensure tailor-made measures and to foster cooperation between countries

a. Adriatic and Ionian Seas
b. Arctic Ocean
c. Atlantic Ocean
d. Baltic Sea
e. Black Sea
f. Mediterranean Sea
g. North Sea





Motivation
IN THE BLUE GROWTH
“WORLD”
EVERYBODY NEEDS DATA!
DATA → INFORMATION → KNOWLEDGE → WISDOM
(DIKW)

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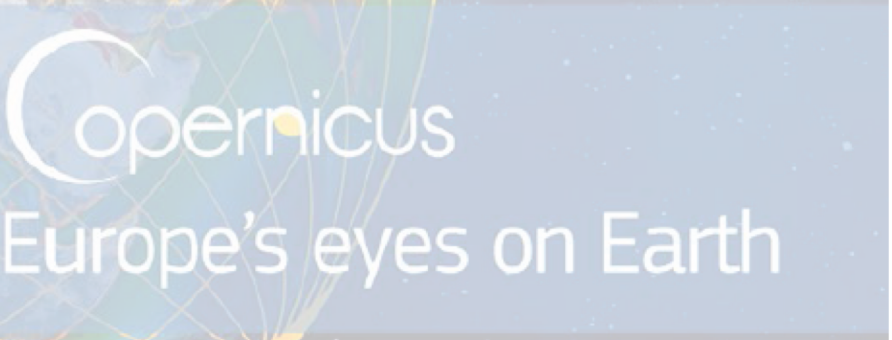
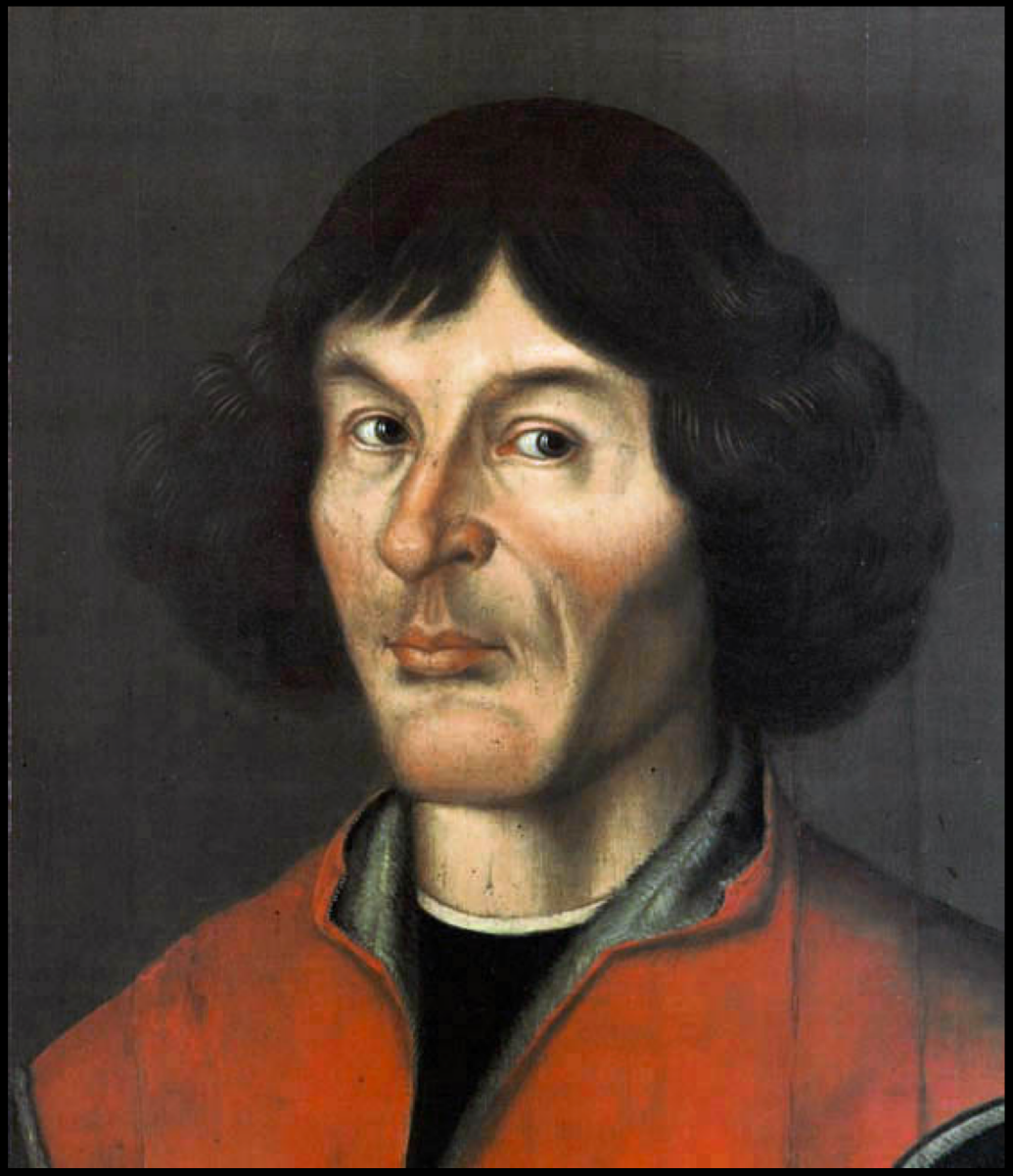


…COPERNICUS ?

COPERNICUS…?



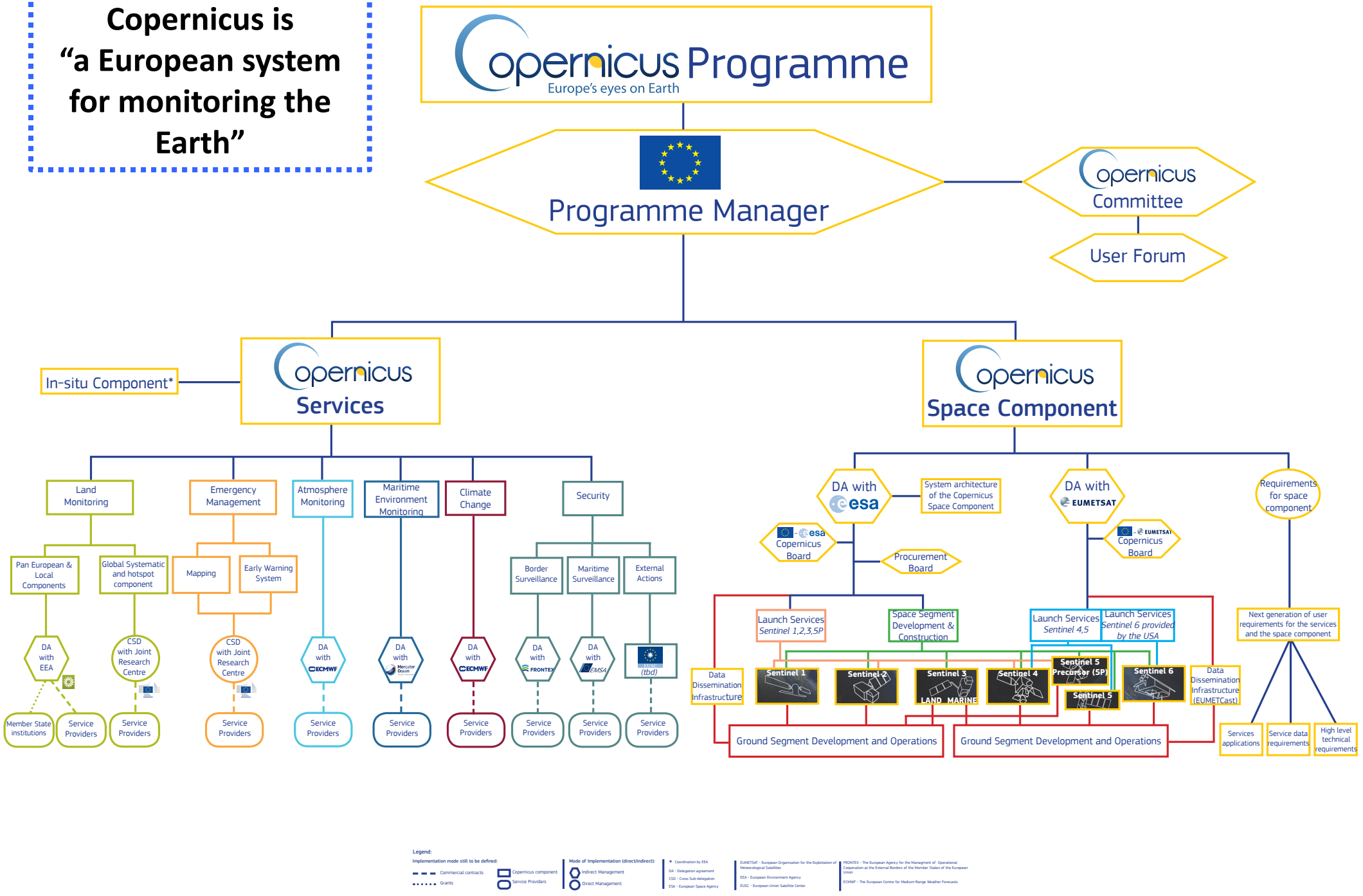
Nicolaus Copernicus (1473 –1543) was a Renaissance-era mathematician and astronomer who formulated a model of the universe that placed the Sun rather than the Earth at the center of the universe.

COPERNICUS…!

Copernicus, previously known as GMES (Global Monitoring for Environment and Security), is the European Programme for the establishment of a European capacity for Earth Observation.

1. What is the Copernicus system?
2. CMEMS within Copernicus
3. CMEMS focus on Mediterranean Sea

Copernicus is "a European system for monitoring the Earth"



Legend:
Implementation mode still to be defined:
Commercial contracts
Grants
Copernicus component
Service Providers
Mode of Implementation (direct/indirect):
Indirect Management
Direct Management
* Coordination by EEA
DA - Delegation agreement
CSD - Cross Sub-delegation
ESA - European Space Agency
EUMETSAT - European Organisation for the Exploitation of Meteorological Satellites
EEA - European Environment Agency
EUSC - European Union Satellite Center
FRONTEX - The European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the European Union
ECMWF - The European Centre for Medium-Range Weather Forecasts

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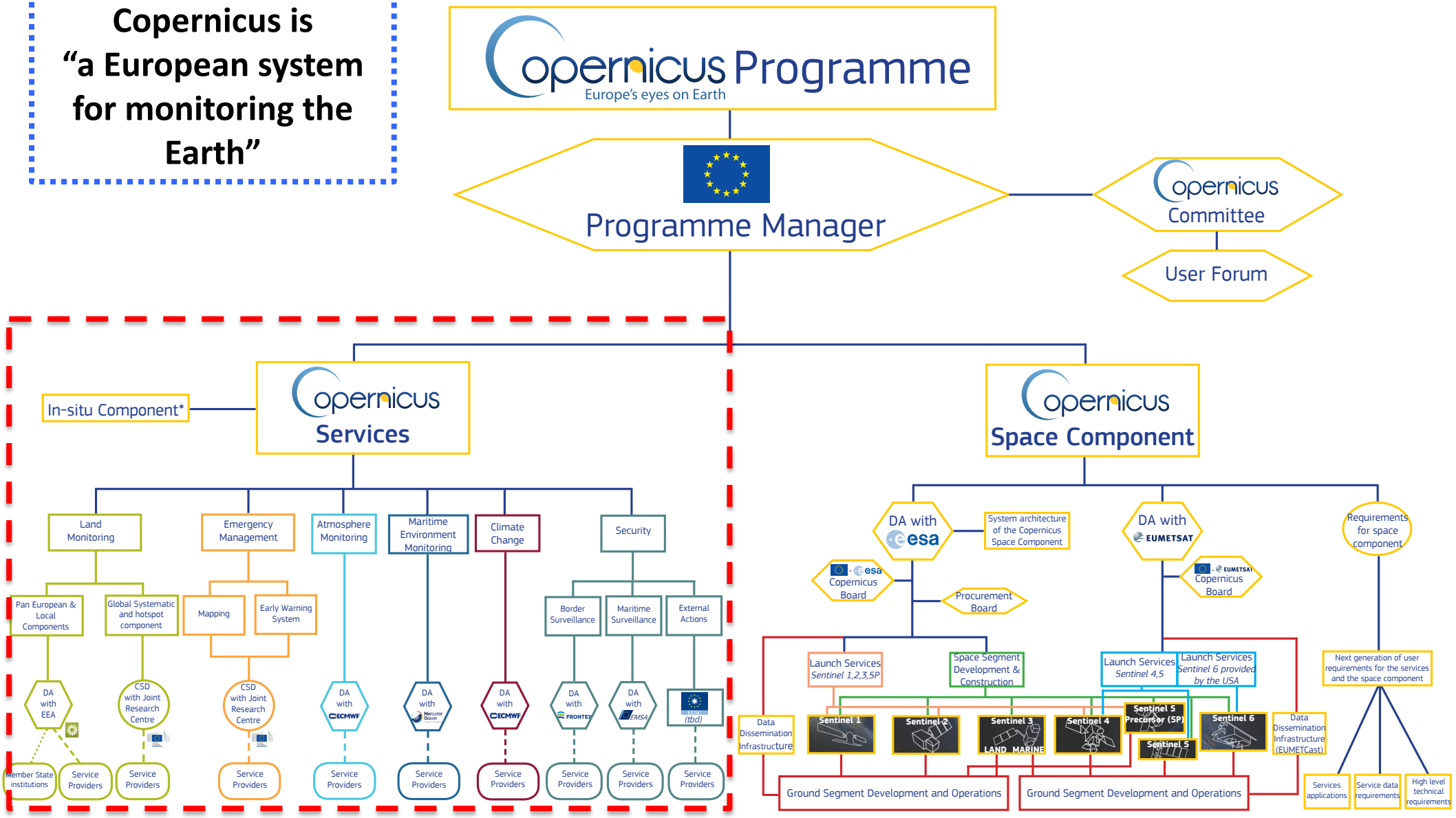

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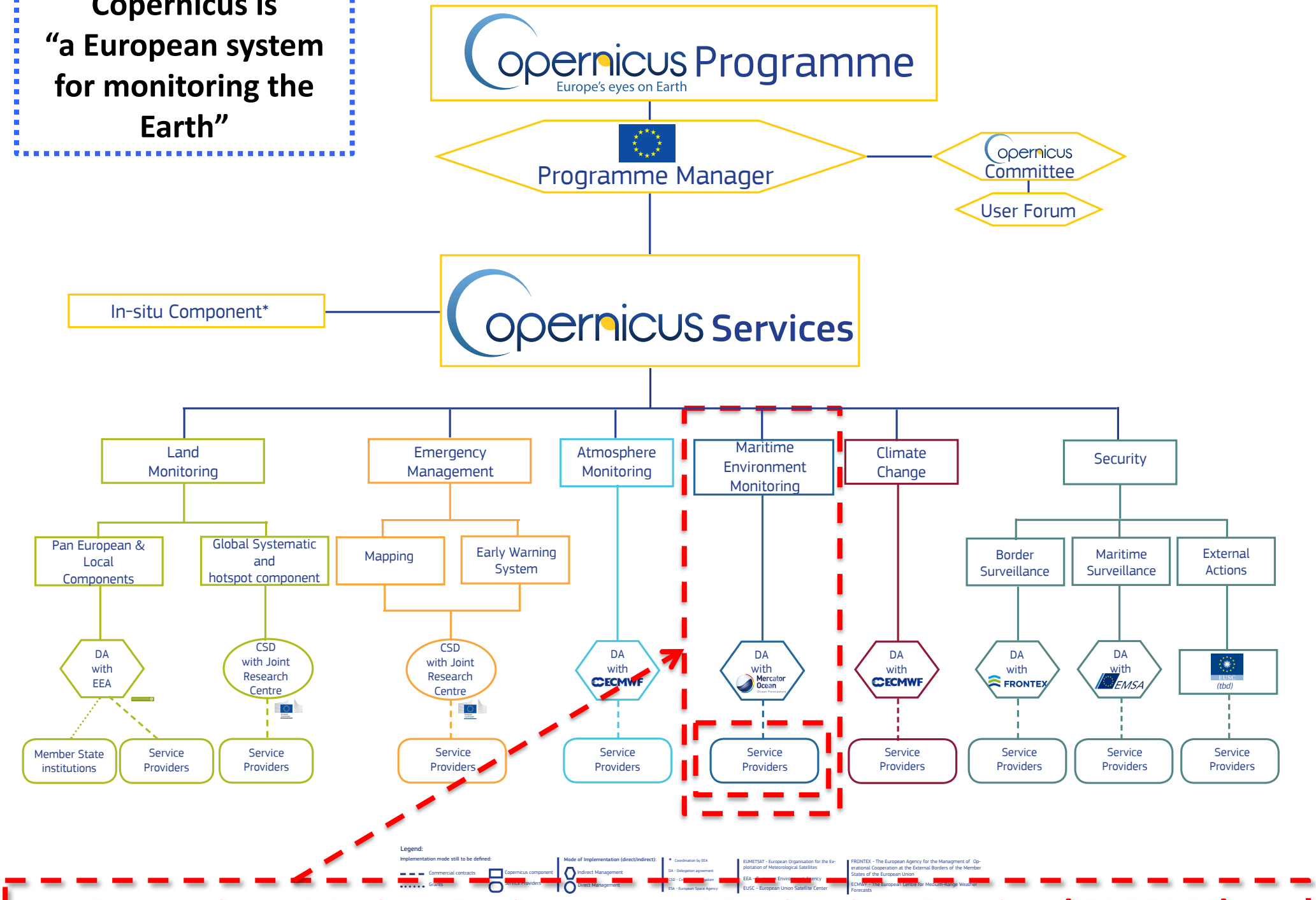

Copernicus Marine Environment Monitoring Service (CMEMS)

Copernicus is "a European system for monitoring the Earth"

Copernicus Programme
Europe's eyes on Earth

Programme Manager

Copernicus Committee

User Forum

In-situ Component*

Copernicus Services

- Land Monitoring
  - Pan European & Local Components
    - DA with EEA
      - Member State institutions
      - Service Providers
  - Global Systematic and hotspot component
    - CSD with Joint Research Centre
      - Service Providers
- Emergency Management
  - Mapping
  - Early Warning System
    - CSD with Joint Research Centre
      - Service Providers
- Atmosphere Monitoring
  - DA with ECMWF
    - Service Providers
- Maritime Environment Monitoring
  - DA with Mercator Ocean
    - Service Providers
- Climate Change
  - DA with ECMWF
    - Service Providers
- Security
  - Border Surveillance
    - DA with FRONTEX
      - Service Providers
  - Maritime Surveillance
    - DA with EMSA
      - Service Providers
  - External Actions
    - EUSC (tbd)
      - Service Providers

Legend:
Implementation mode still to be defined:
Commercial contracts
Grants
Copernicus component
Mode of Implementation (direct/indirect):
Indirect Management
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Copernicus Marine Environment Monitoring Service (CMEMS)

Copernicus Marine Environment Monitoring Service (CMEMS) is a one-stop-shop for marine data

It provides state-of-the-art analyses and forecasts daily, which offer an unprecedented capability to observe, understand and anticipate marine environment events, and reanalyses to assess decadal changes since the satellite era

Operational Oceanography User-centered Services

Why? For whom?

Safety of navigation

Coastal protection and erosion

Search and Rescue

Pollution emergencies

Climate Change

Protection&management of marine ecosystems

Off-shore activities

Military activities

Renewable energies

Fishery & acquaculture

Tourism

Harbours

Vocabulary of products and variables

1. What kind of **information** can be found?
2. How is organized the CMEMS **service**?
3. What is available for the Mediterranean and Black Seas in CMEMS **catalogue**?

Outline

- An Ocean of data
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- The EU Copernicus Services
- **Models and BigData in Copernicus**

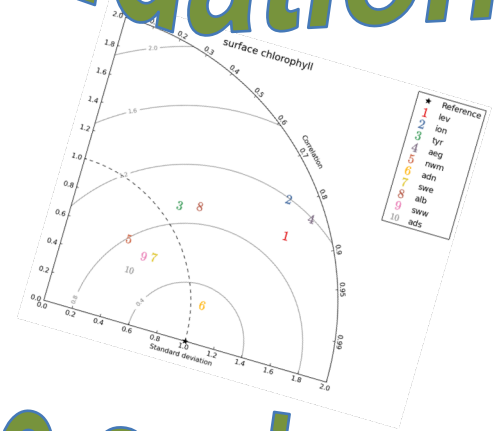
MODELS

Satellite Data

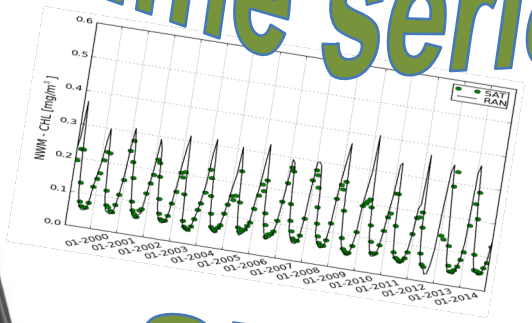
In-Situ Data

IC & BC

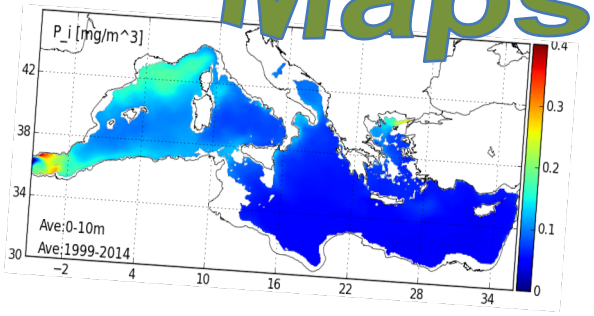
Validation



Time series

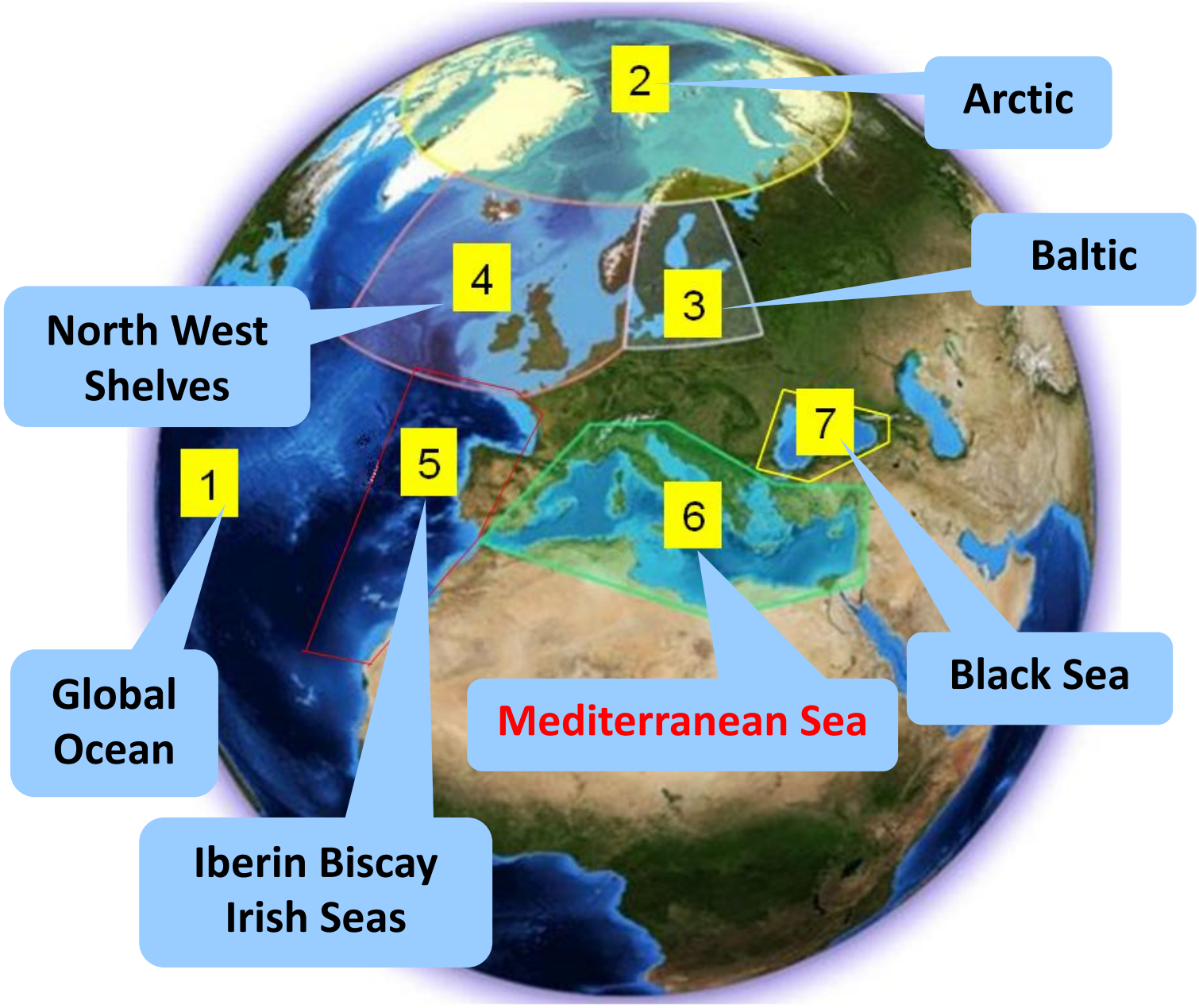


2D-Maps

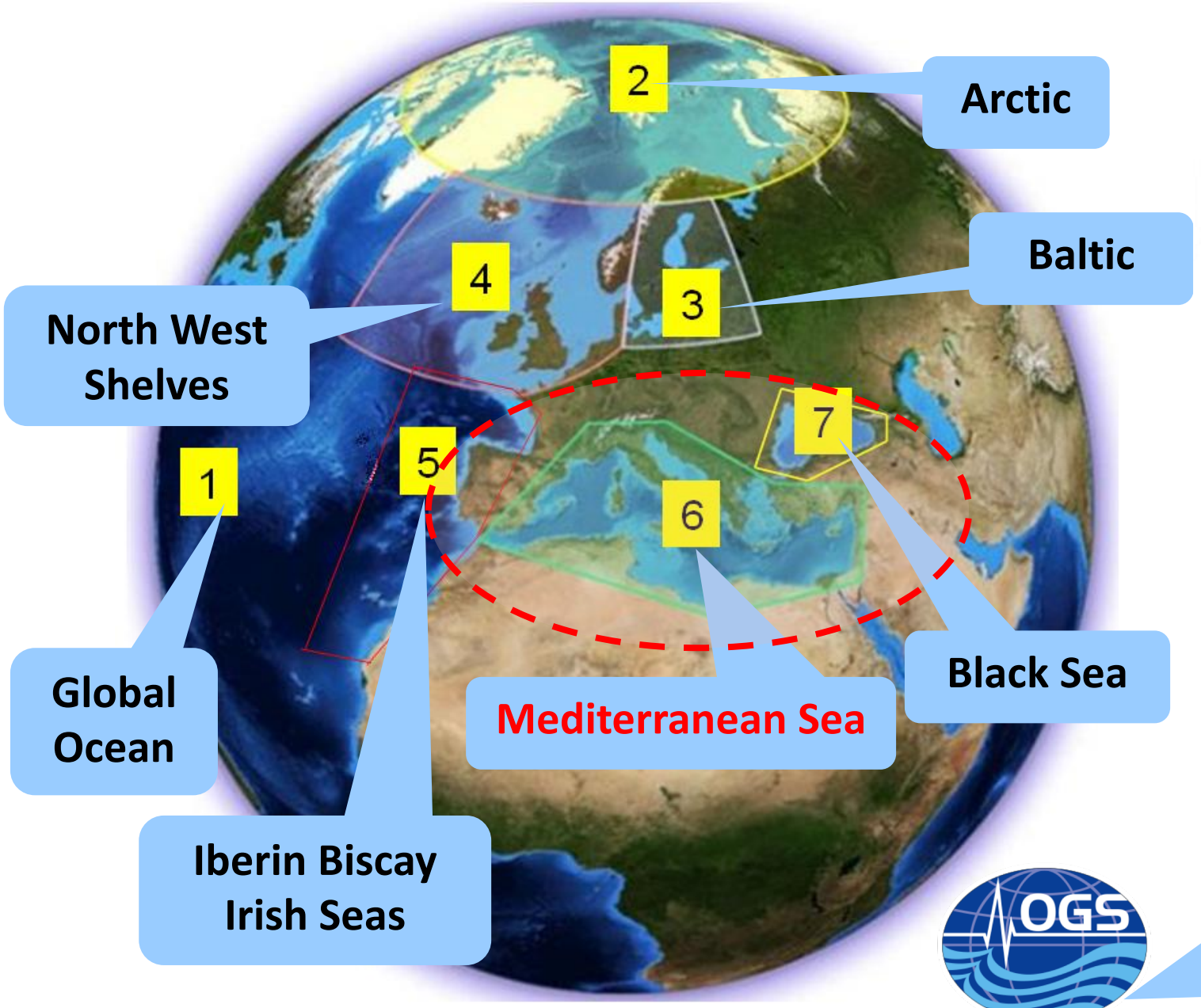


A MODEL SIMULATION IS LIKE A BLENDER…

CMEMS products for European Seas and Global Ocean

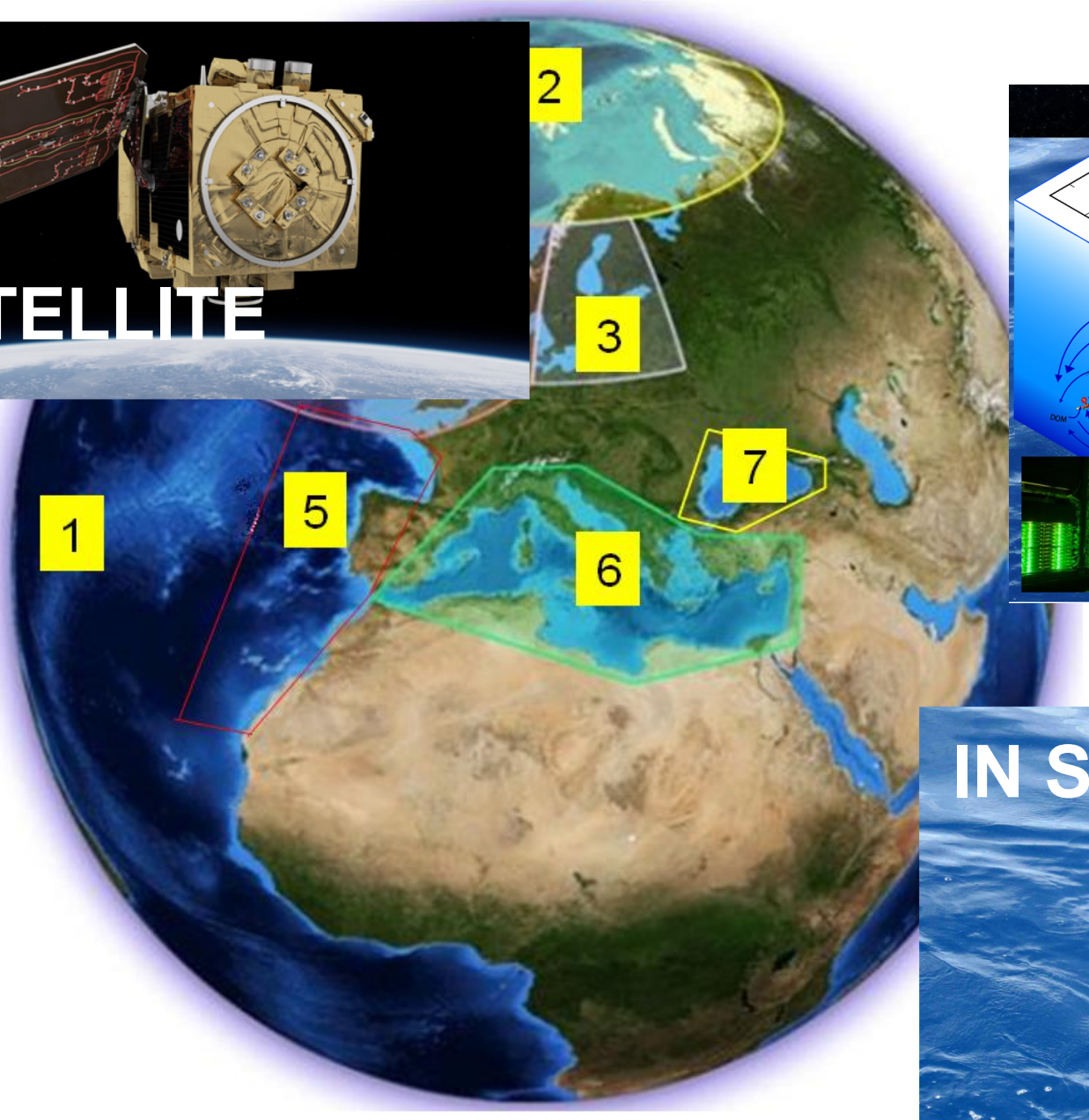


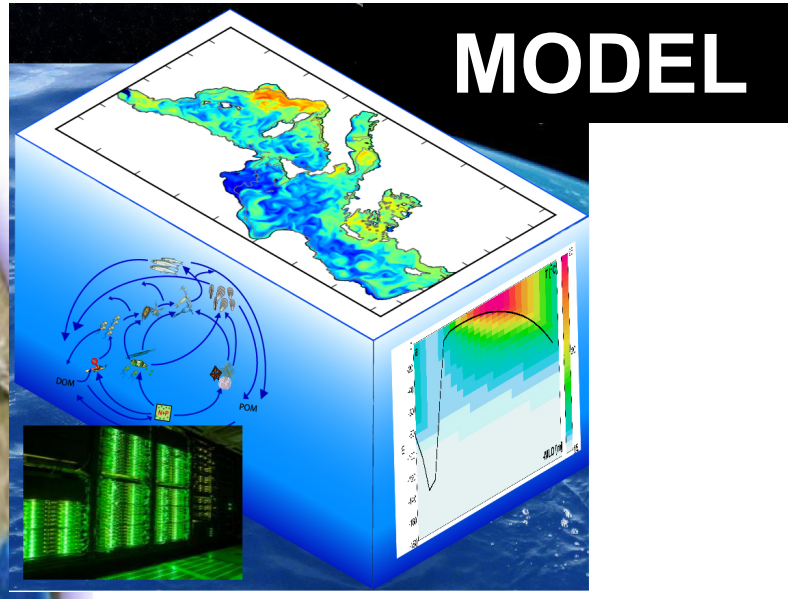
CMEMS products for European Seas and Global Ocean



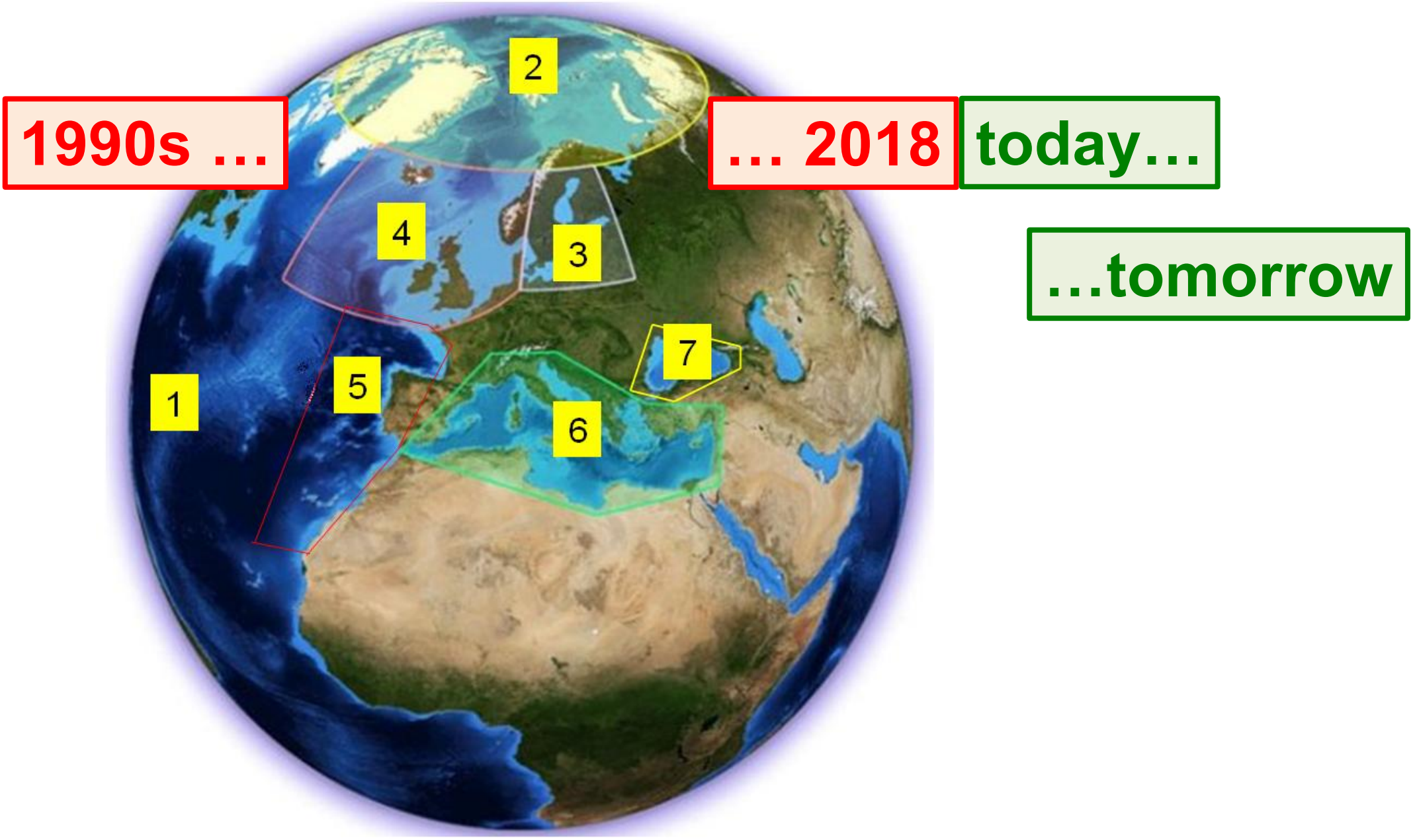
OGS provides the CMEMS products of Biogeochemistry for Mediterranean Sea

CMEMS products give info on Observation, Monitoring, Forecasting, Reprocessing and Reanalysis of Marine Data





CMEMS products give info on Observation, Monitoring, Forecasting, Reprocessing and Reanalysis of Marine Data



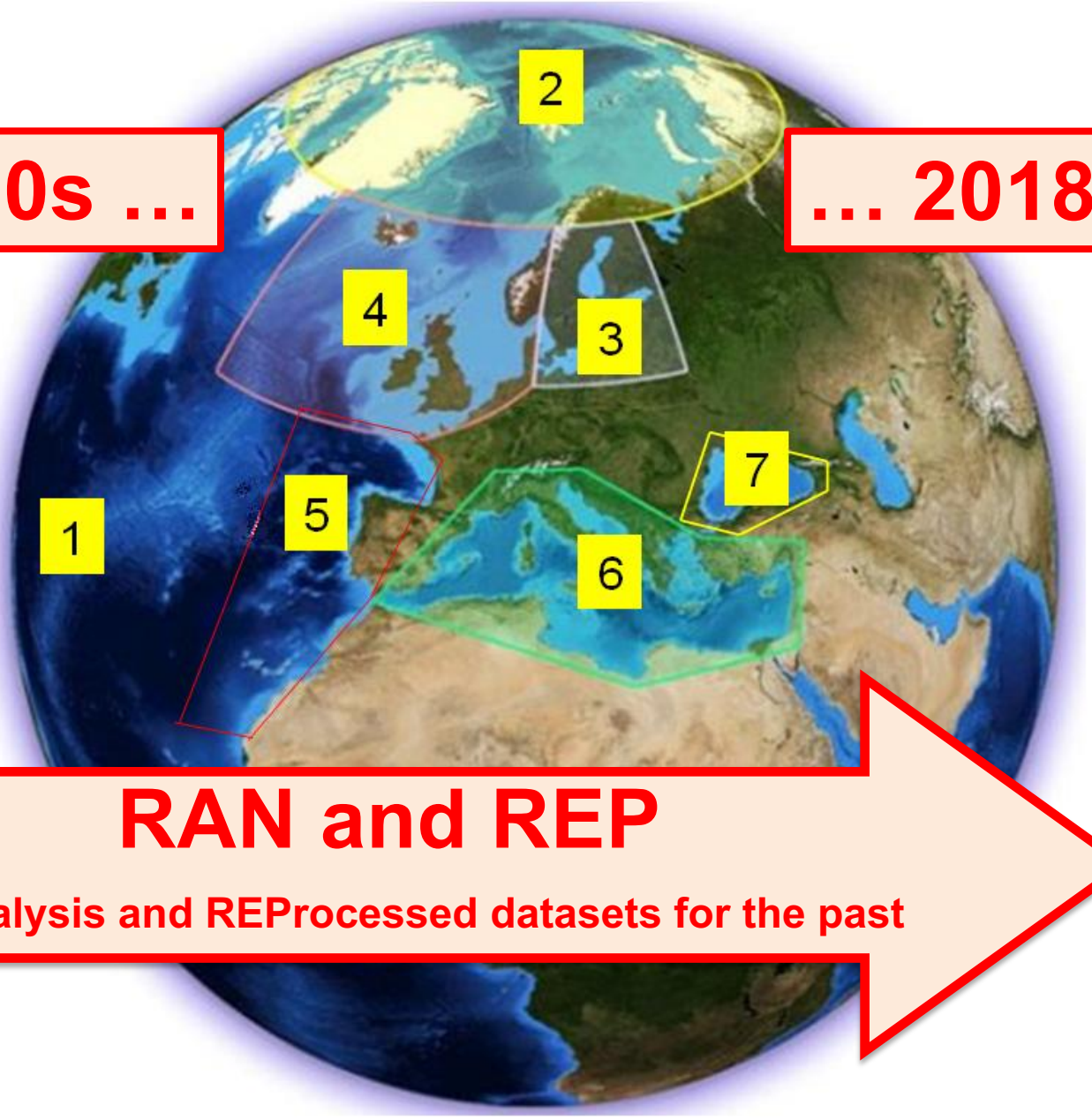
CMEMS products give info on Observation, Monitoring, Forecasting, Reprocessing and Reanalysis of Marine Data

1990s …

… 2018

today…

…tomorrow



RAN and REP

ReANalysis and REProcessed datasets for the past

NRT

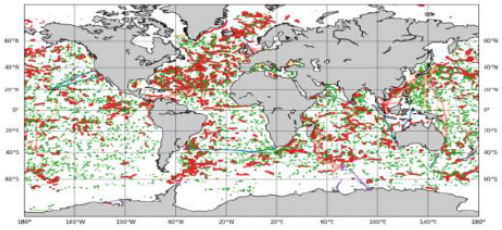
Analysis and Forecasts (5-10 days)

IN SITU products:
- area: global or regional
- spatial resolution: discrete data (L2) or spatially interpolated at 1/4deg (L4)
- update: daily/weekly (NRT) or yearly (REP)
- variables: T, S, few BIO

Marine Monitoring

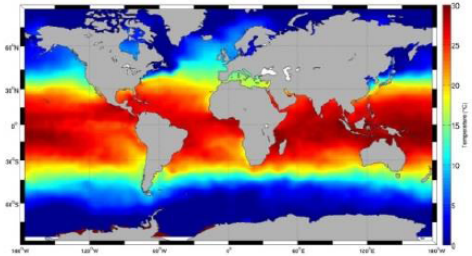
WHICH PRODUCTS IN CMEMS CATALOGUE? (2/2)

In-Situ Observations products over the GLOBAL Ocean and European Seas are sorted into 2 categories:



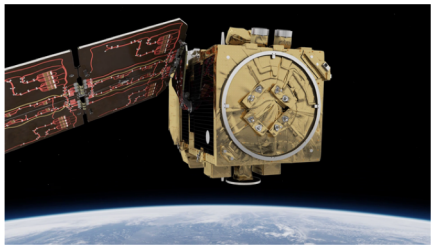
- **L2 discreet - Real Time or Reprocessed -**
  INSITU_(AREA)_TS_L2_(NRT)or(REP)_OBSERVATIONS_013_XXX

- **L4 gridded Objective Analysis - 1/4° - Real Time or Reprocessed (Global Ocean only)**
  INSITU_GLO_TS_L4_(NRT)or(REP)_OBSERVATIONS_013_XXX



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

SATELLITE products:
- **area: global or regional**
- **spatial resolution: gridded (L3) or interpolated (L4) at 1km**
- **update: daily/weekly (NRT) or yearly (REP)**
- **variables: SST, SL, WIND, CHL, OPTICS**



Marine Monitoring

WHICH PRODUCTS IN CMEMS CATALOGUE? (1/2)

OCEAN COLOUR Satellite products over the GLOBAL Ocean and all European Seas are sorted into 2 categories:

- **CHL: Chlorophyll-A**
  L3 or L4 - Real Time and Reprocessed
  OCEANCOLOUR_(AREA)_CHL_(L4)or(L3)_(NRT)or(REP)_OBSERVATIONS_009_XXX

- **OPTICS: Optical Water Properties (as Turbidity…)**
  L3 or L4 - Real Time and Reprocessed
  OCEANCOLOUR_(AREA)_OPTICS_(L4)or(L3)_(NRT)or (REP)_OBSERVATIONS_009_XXX

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

MODEL products:
- area: global or regional
- spatial resolution: gridded (L4) at different resolutions (for Med: 1/24 and 1/16deg)
- update: daily (NRT) or yearly (RAN)
- variables: PHY (T,S,current...), BIO (CHL, nutrients, pCO2...), WAV (SWH and other wave properties)

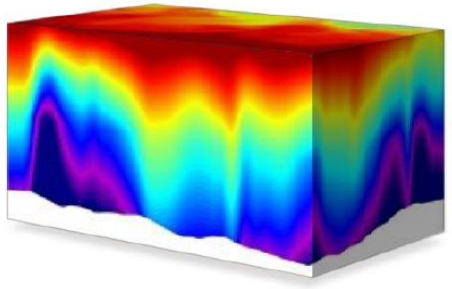
Marine Monitoring

WHICH PRODUCTS IN CMEMS CATALOGUE?

Ocean Models products over the GLOBAL Ocean and all European Seas are sorted into 2 categories:

- **REAL TIME Model Analysis and Forecast**

GLOBAL_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xxx
ARCTIC_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx
BALTICSEA_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx
NORTHWESTSHELF_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx
IBI_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx
MEDSEA_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx
BLKSEA_ANALYSIS_FORECAST_(PHY)or(BIO)or(WAV)_00x_xx



- **MULTIYEAR Model Time Series: Reanalysis of the past**

GLOBAL_REANALYSIS_(PHY)or(BIO)_00x_xxx
ARCTIC_REANALYSIS_(PHY)or(BIO)_00x_xx
BALTICSEA_REANALYSIS_(PHY)or(BIO)_00x_xx
NORTHWESTSHELF_REANALYSIS_(PHY)or(BIO)_00x_xx
IBI_REANALYSIS_(PHY)or(BIO)_00x_xx
MEDSEA_REANALYSIS_(PHY)or(BIO)_00x_xx
BLKSEA_REANALYSIS_(PHY)or(BIO)_00x_xx

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What is available for the Mediterranean and Black Seas on the CMEMS web-portal today?

…click on

http://marine.copernicus.eu

and select

SERVICE PORTFOLIO / ACCESS TO PRODUCTS

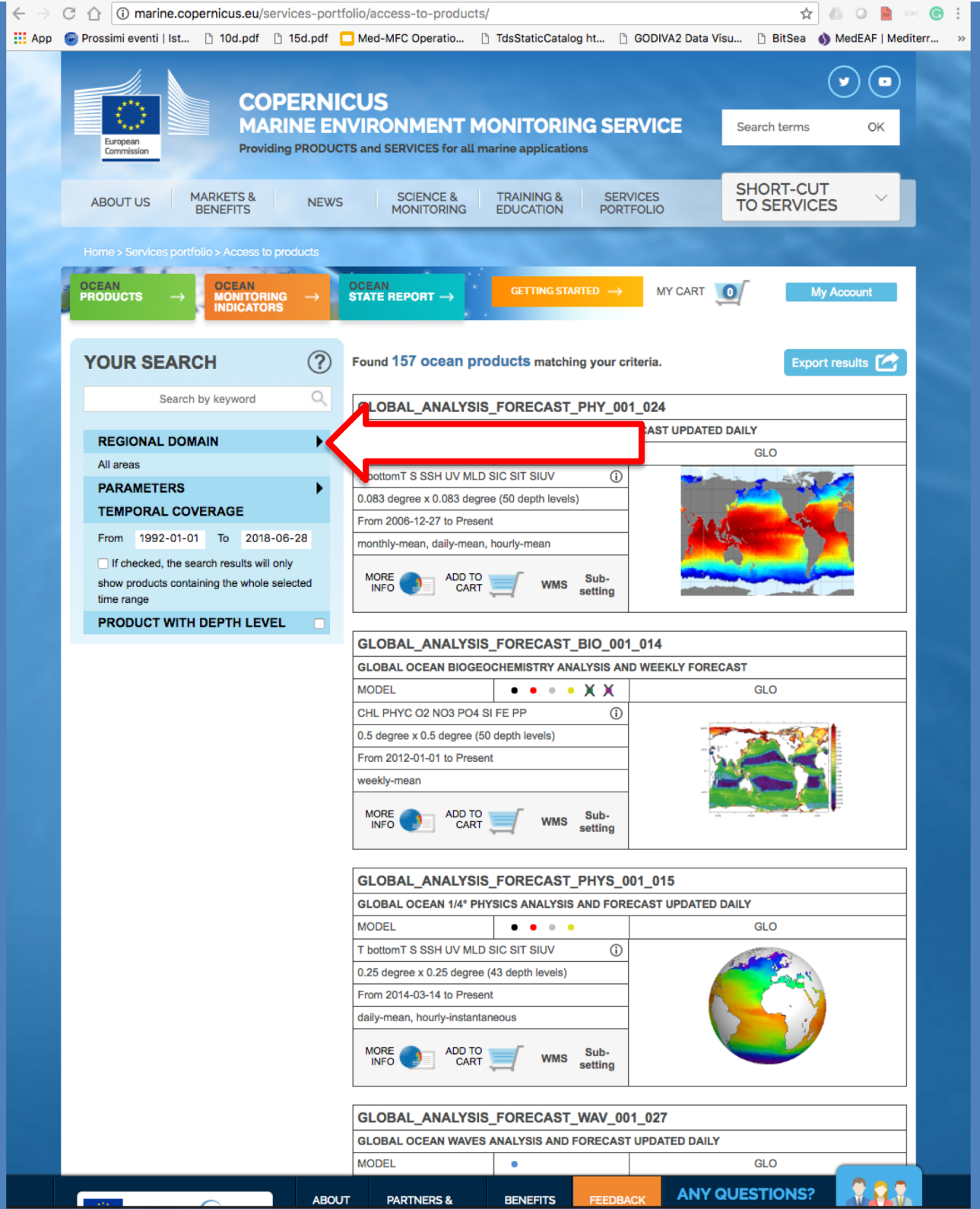
What is available for the Mediterranean and Black Seas on the CMEMS web-portal today?

…click on

http://marine.copernicus.eu

and select

SERVICE PORTFOLIO / ACCESS TO PRODUCTS



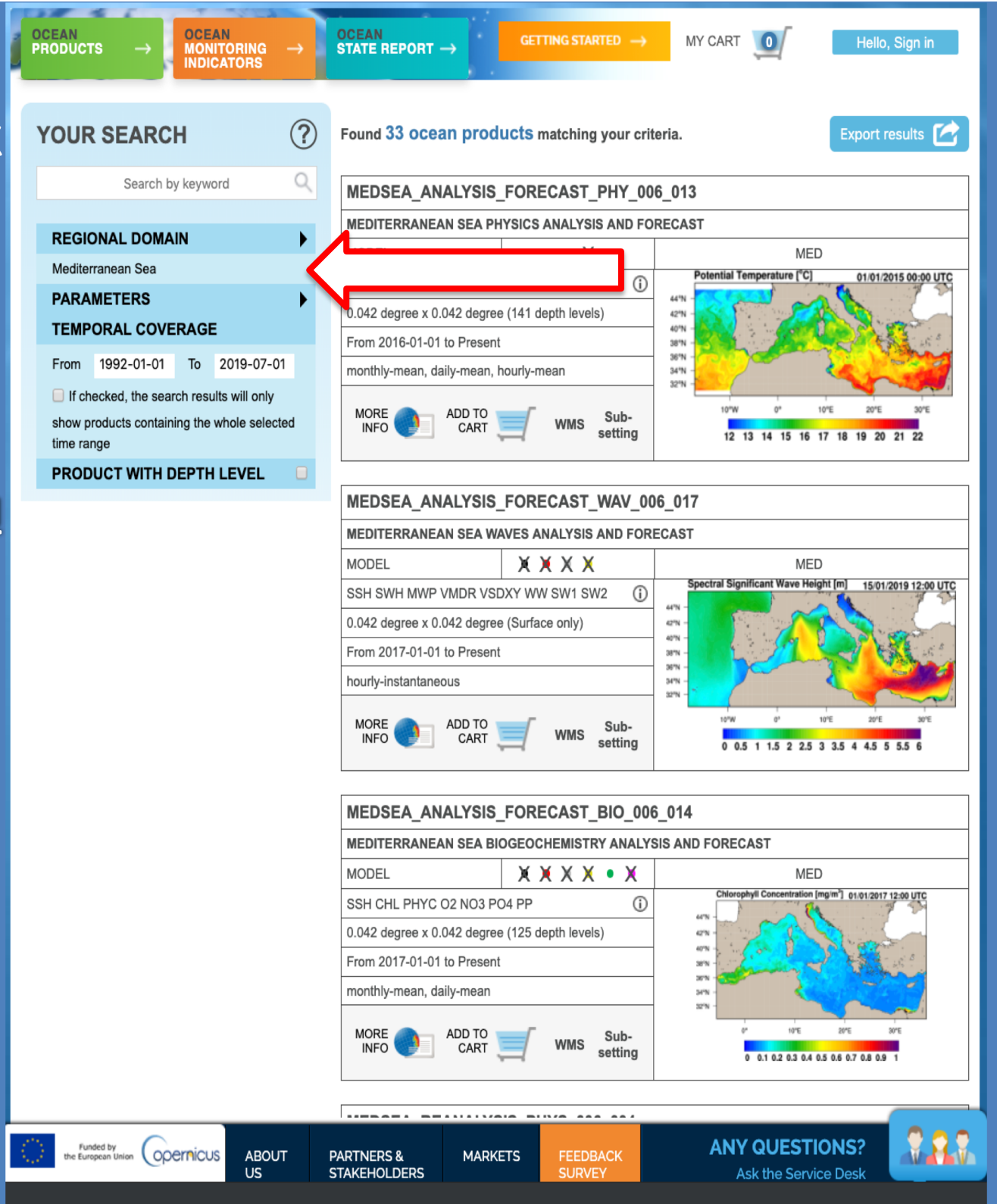
What is available for the Mediterranean and Black Seas on the CMEMS web-portal today?

…click on

http://marine.copernicus.eu

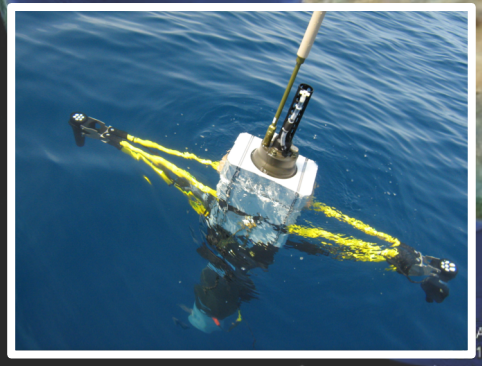
and select

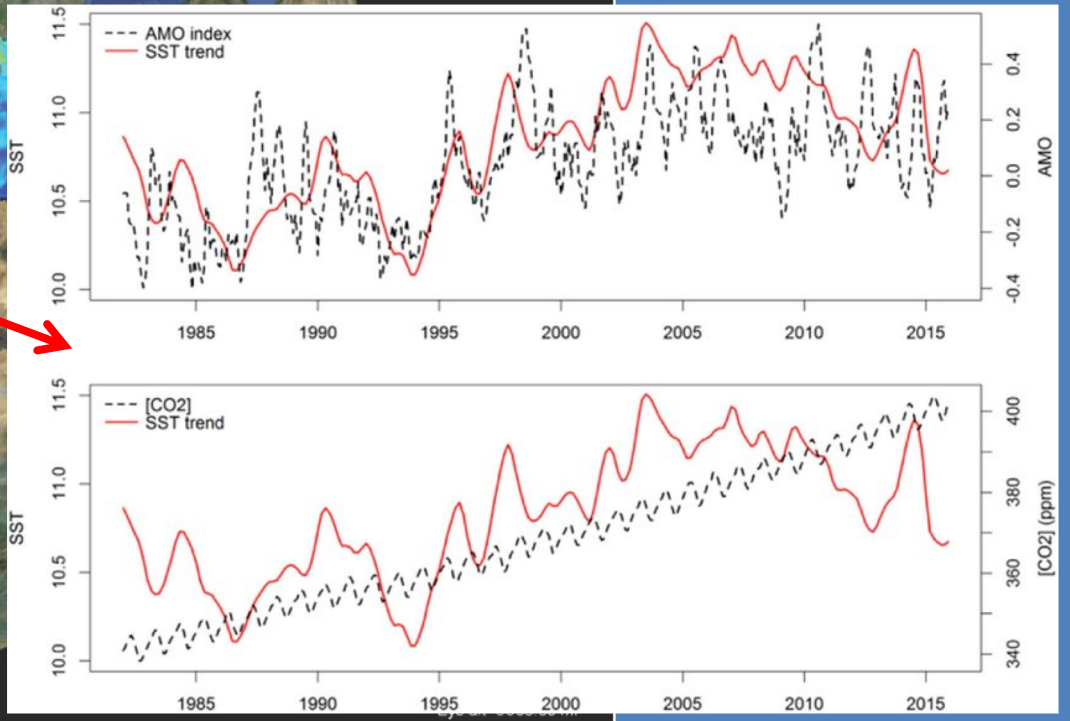
SERVICE PORTFOLIO / ACCESS TO PRODUCTS



MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

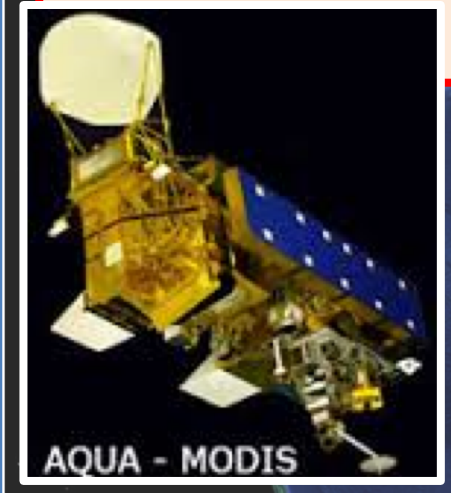
SST in the past: information from IN SITU products

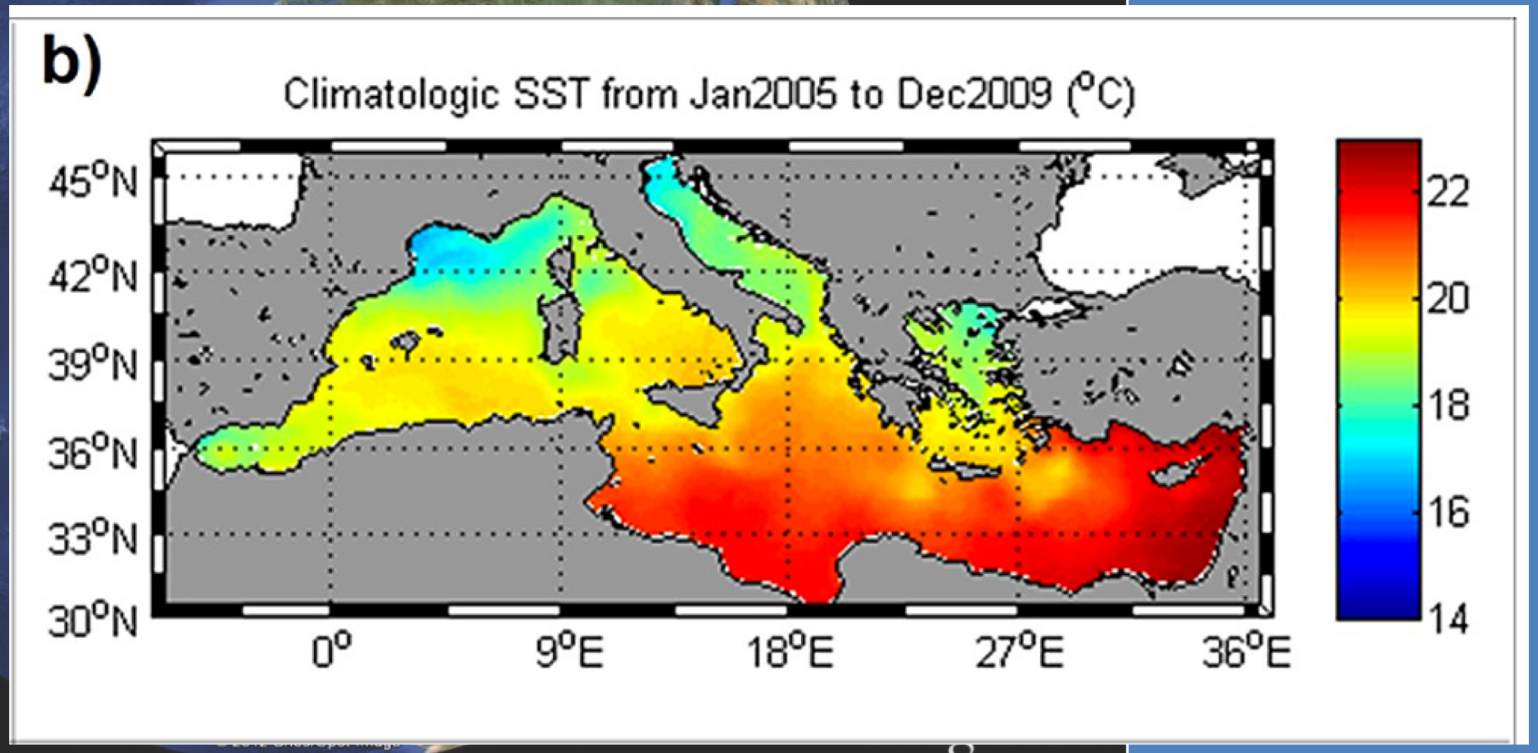




MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

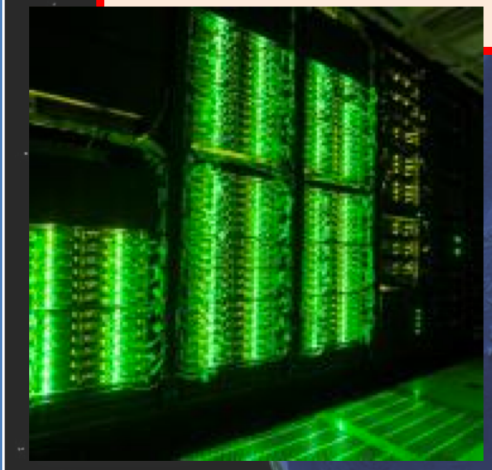
SST in the past: information from SATELLITE products (L4)

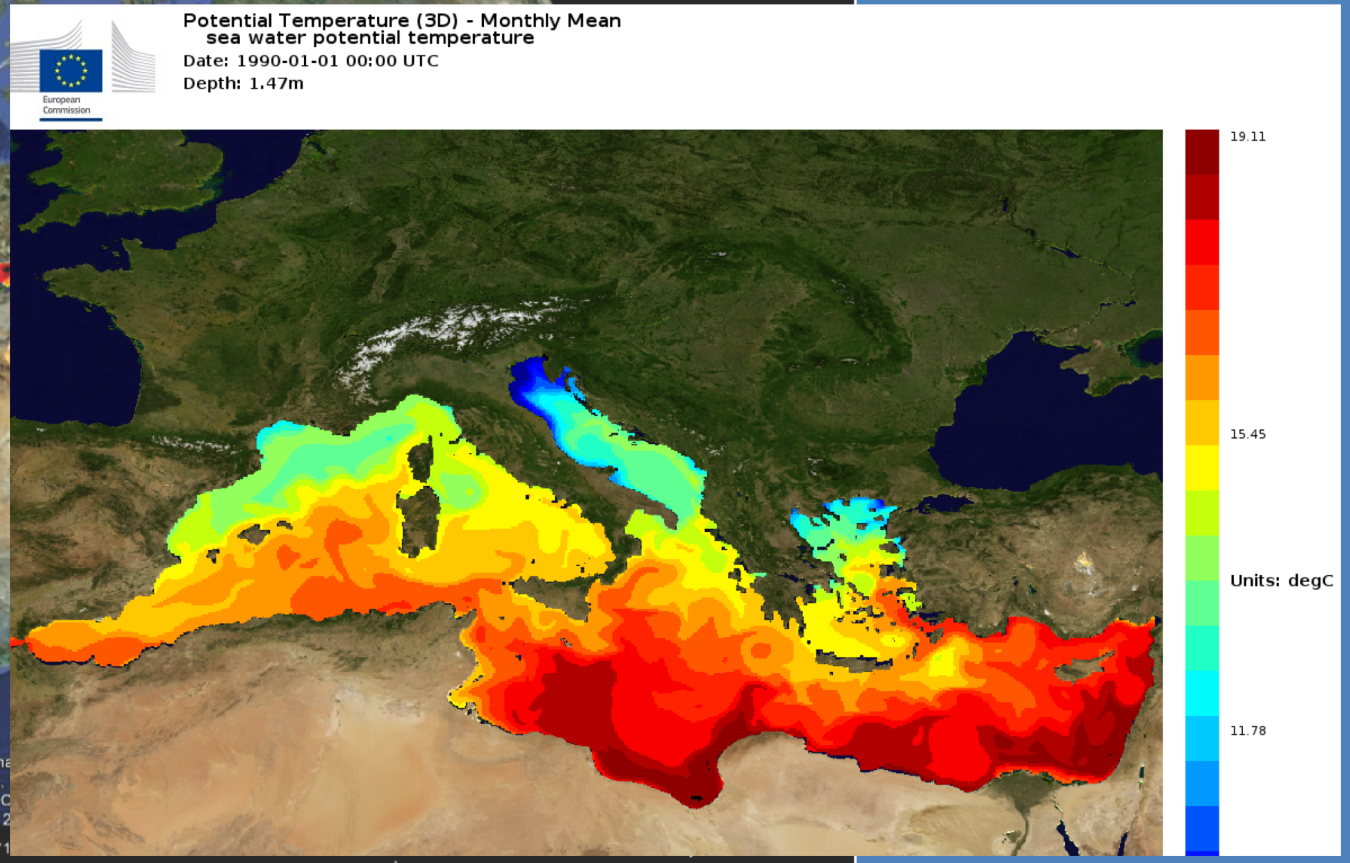




MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

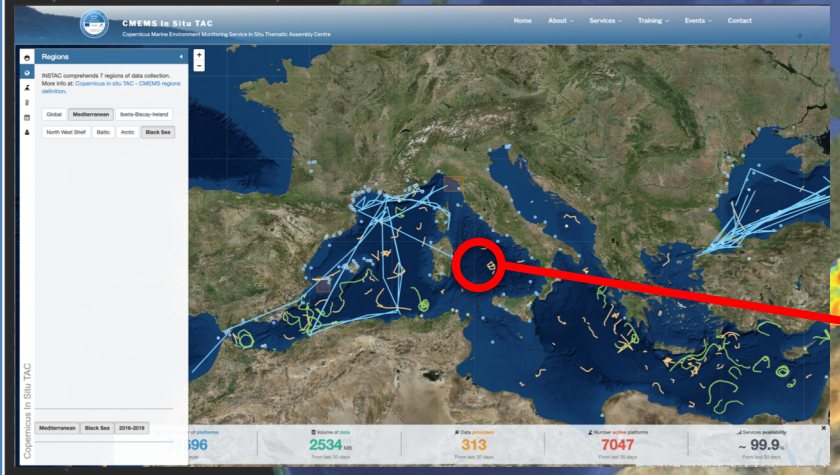
SST in the past: information from MODEL products

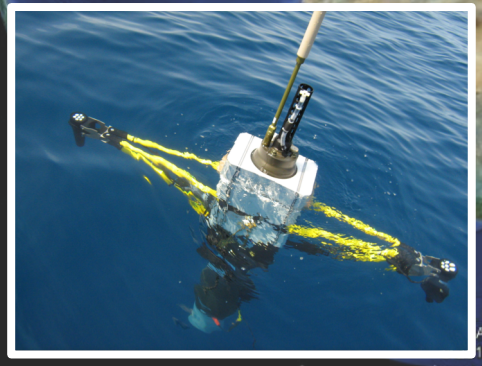




MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

SST today: information from IN SITU products





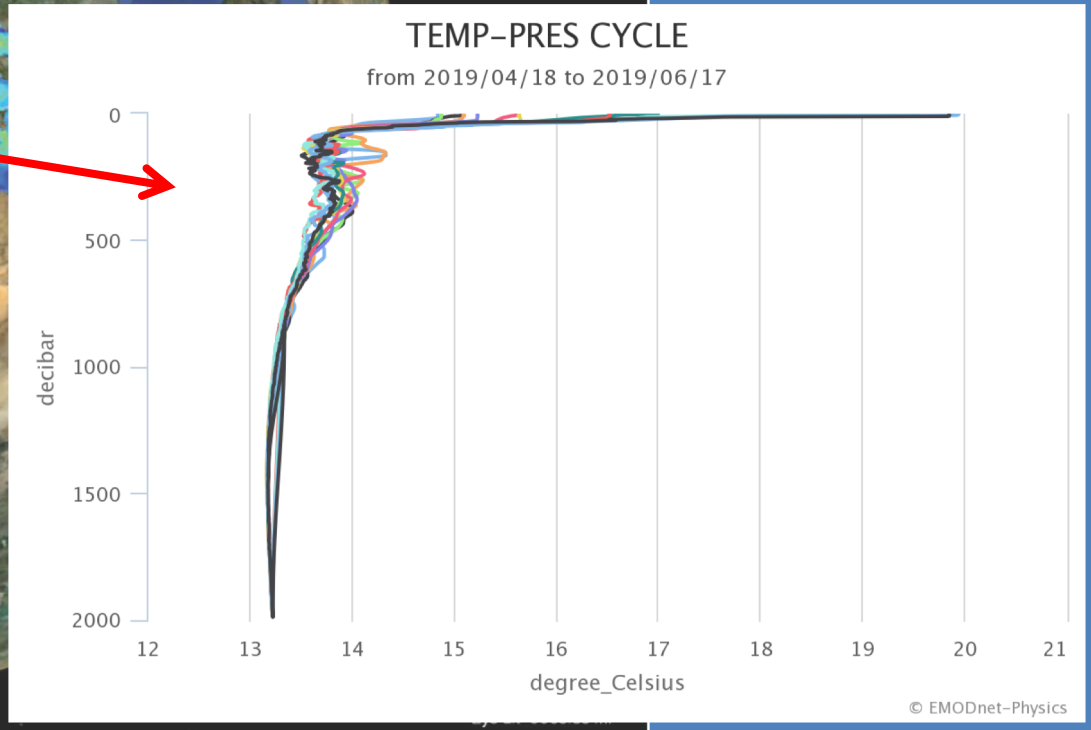
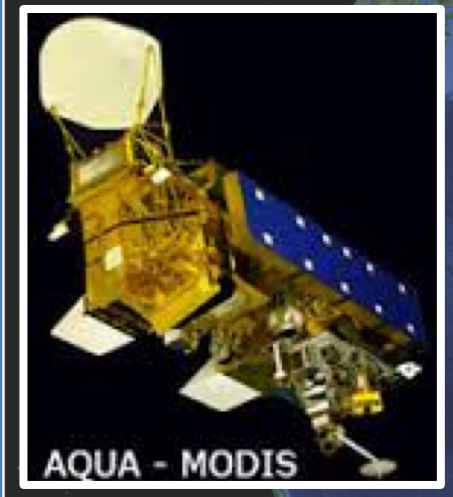
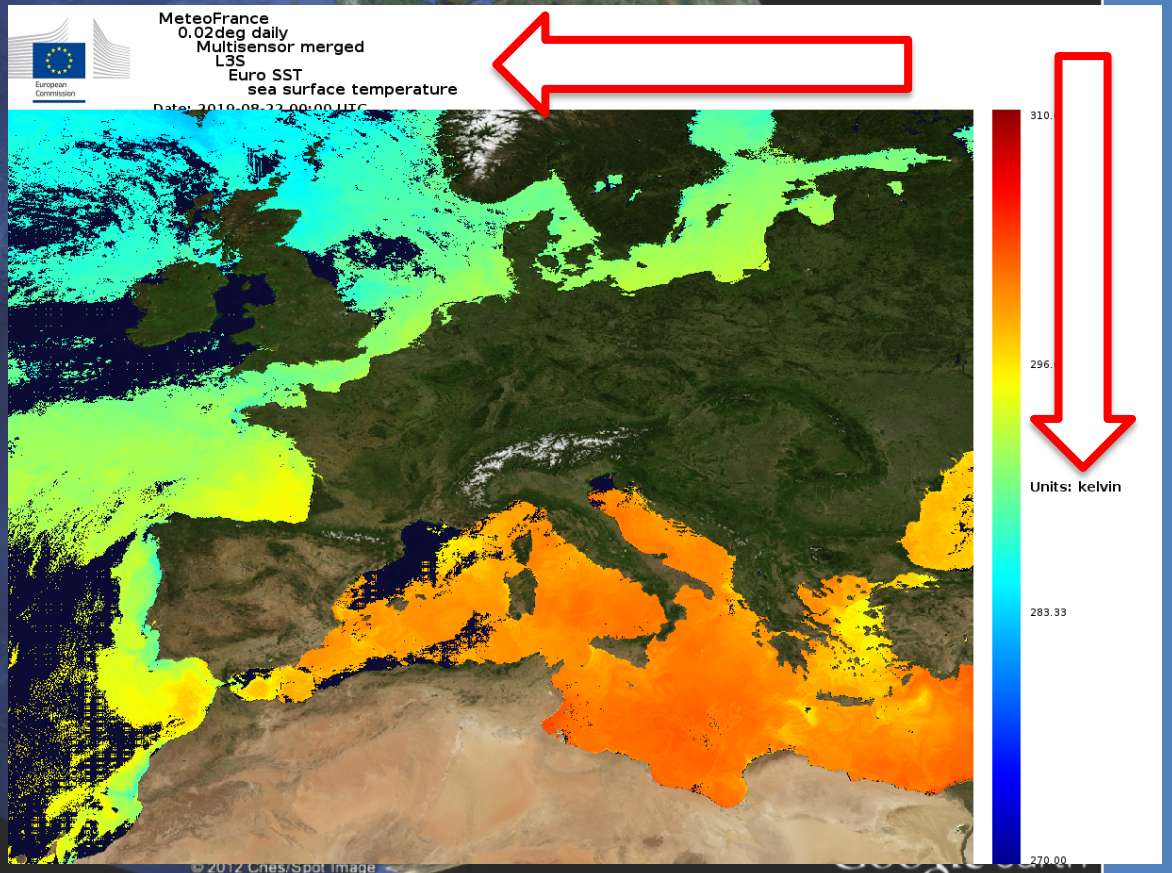


Image IBCAO
AA, U.S. Navy, NGA, GEBCO
12 Cnes/Spot Image
Image © 2012 TerraMetrics
37°33'21.51" N 0°13'44.32" W elev 942 ft

MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

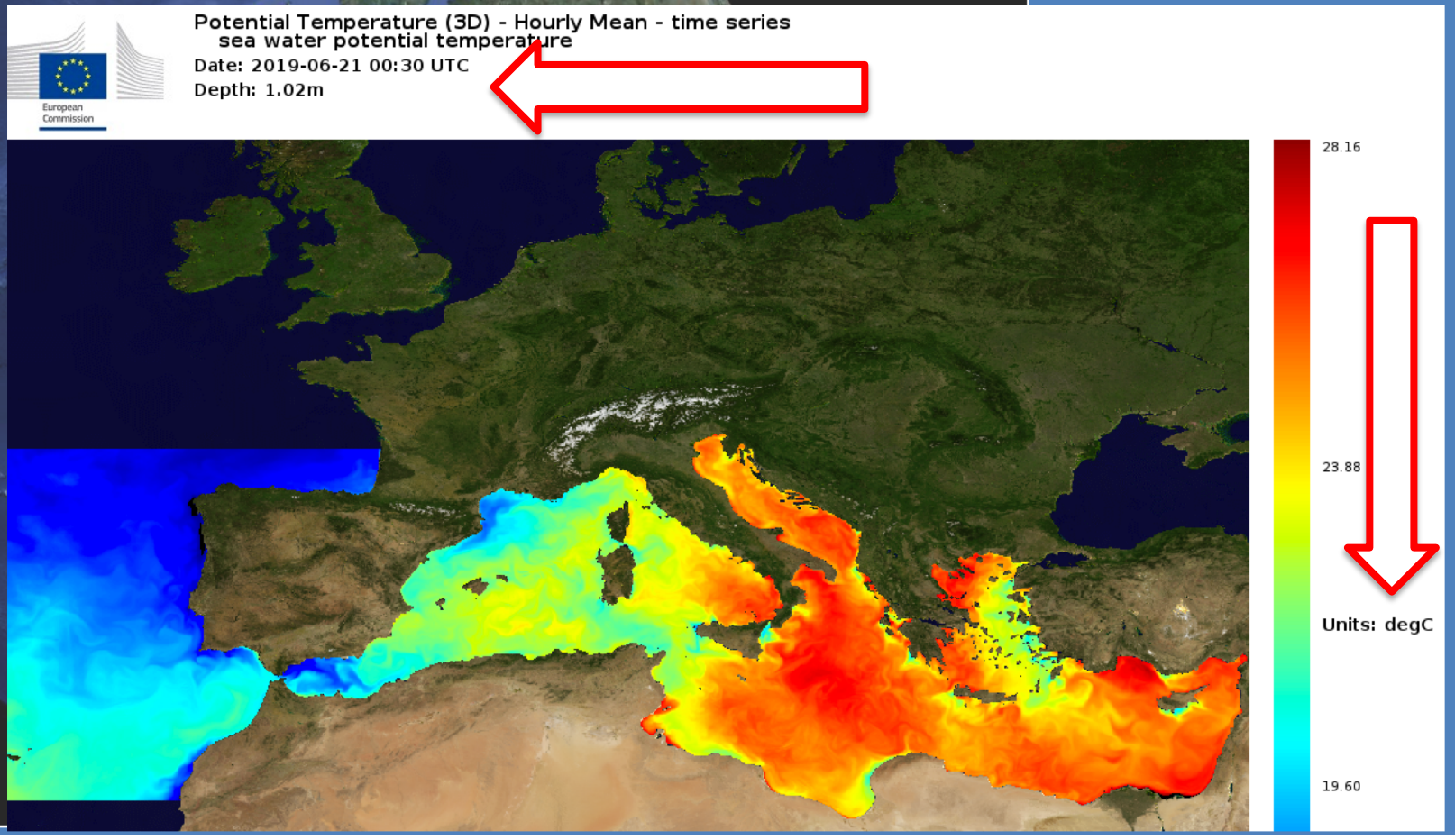
SST today: information from SATELLITE products (L3)





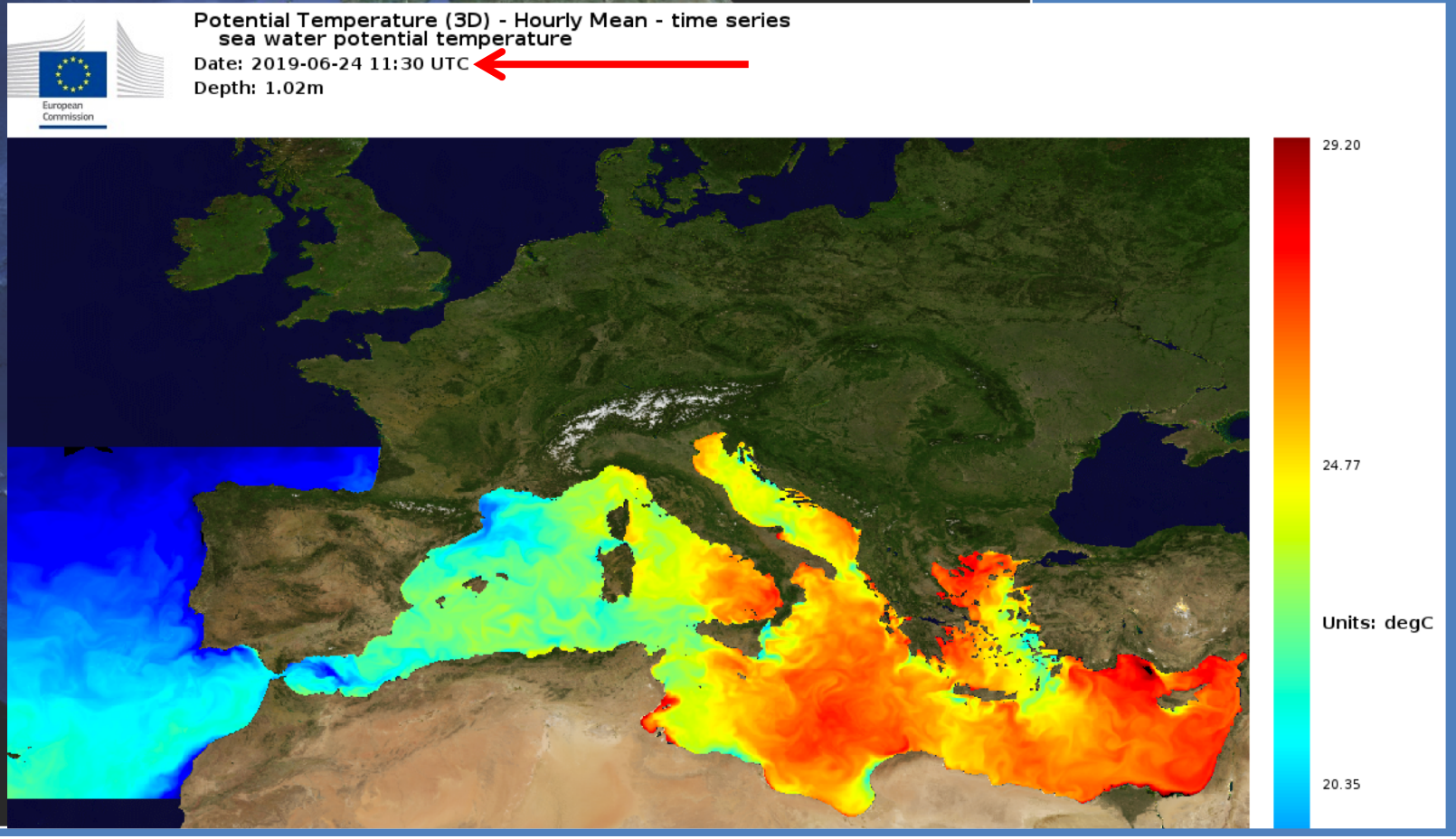
MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

SST today: information from MODEL products



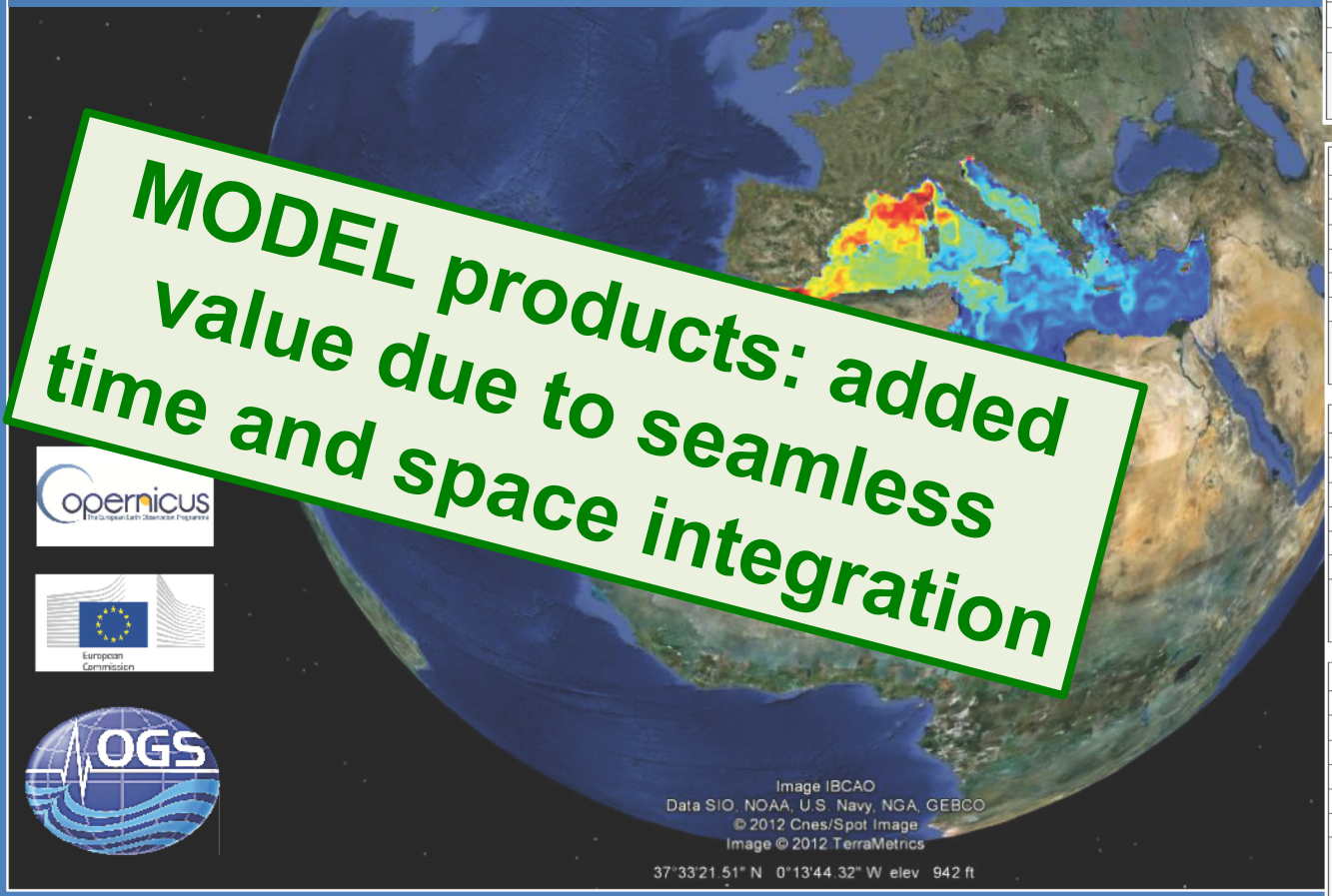
MED + BLKSEA CMEMS products	REPROCESSED / REANALYSIS	NRT-DT / ANALYSIS	FORECAST
IN SITU DATA	1+1	1+1	
SATELLITE DATA	9+8	16+17	
MODEL DATA	3+3	3+3	3+3

SST tomorrow: information from MODEL products



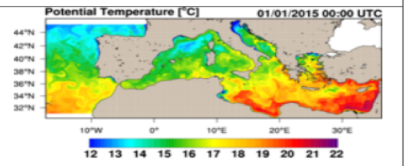
Ex: MODEL products are PHY + BIO + WAV:

- Variables **PHY**: temperature, salinity, current, SSH, Stokes drift velocity, mean wave number, MLD, bottom temperature
- Variables **BIO**: chlorophyll, nitrate, phosphate, primary production, phytoplankton biomass, oxygen, pCO2, pH
- Variables **WAV**: significant wave height, wind and primary/secondary swell wave significant wave height, periods, direction, Stokes drift velocity
- Resolution: MED=1/24° - BS=1/36° x1/27° ; hourly/daily/monthly

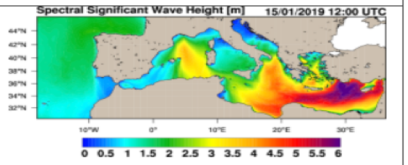


MODEL products: added value due to seamless time and space integration

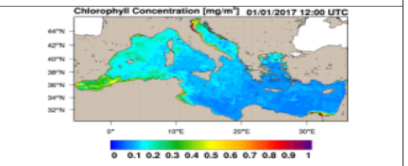
MEDSEA_ANALYSIS_FORECAST_PHY_006_013
MEDITERRANEAN SEA PHYSICS ANALYSIS AND FORECAST
MODEL | MED
T bottomT S SSH 3DUV
0.042 degree x 0.042 degree (141 depth levels)
From 2016-01-01 to Present
monthly-mean, daily-mean, hourly-mean
MORE INFO | ADD TO CART | WMS | Sub-setting



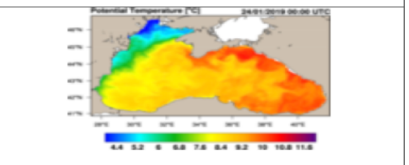
MEDSEA_ANALYSIS_FORECAST_WAV_006_017
MEDITERRANEAN SEA WAVES ANALYSIS AND FORECAST
MODEL | MED
SSH SWH MWP VMDR VSDXY WW SW1 SW2
0.042 degree x 0.042 degree (Surface only)
From 2017-01-01 to Present
hourly-instantaneous
MORE INFO | ADD TO CART | WMS | Sub-setting



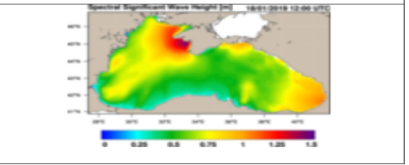
MEDSEA_ANALYSIS_FORECAST_BIO_006_014
MEDITERRANEAN SEA BIOGEOCHEMISTRY ANALYSIS AND FORECAST
MODEL | MED
SSH CHL PHYC O2 NO3 PO4 PP
0.042 degree x 0.042 degree (125 depth levels)
From 2017-01-01 to Present
monthly-mean, daily-mean
MORE INFO | ADD TO CART | WMS | Sub-setting



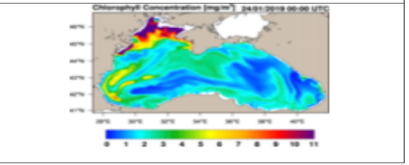
BLKSEA_ANALYSIS_FORECAST_PHYS_007_001
BLACK SEA PHYSICS ANALYSIS AND FORECAST
MODEL | BS
T bottomT S SSH 3DUV MLD
0.028 degree x 0.037 degree (31 depth levels)
From 2016-01-01 to Present
daily-mean, hourly-mean
MORE INFO | ADD TO CART | WMS | Sub-setting



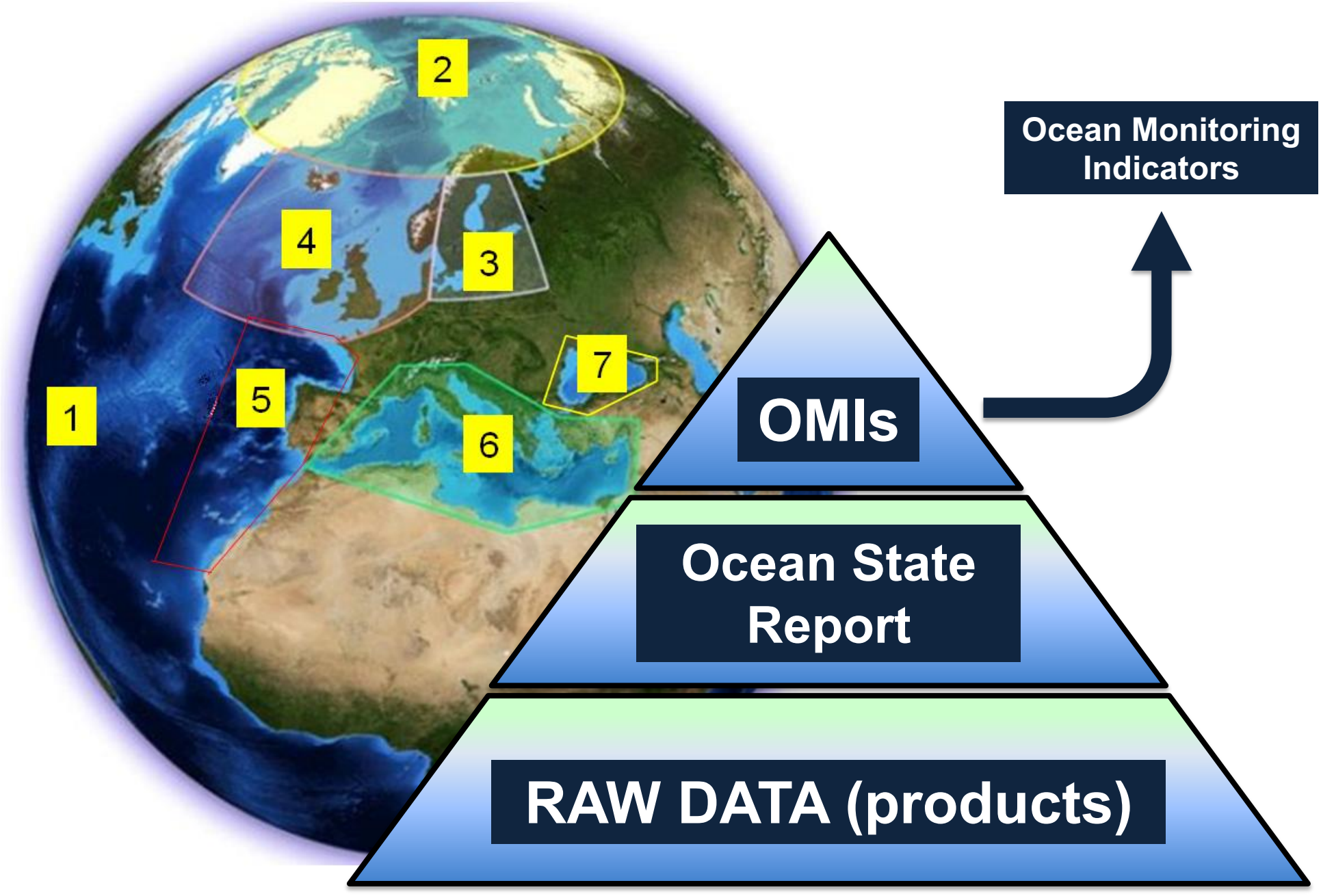
BLKSEA_ANALYSIS_FORECAST_WAV_007_003
BLACK SEA WAVES HINDCAST AND FORECAST
MODEL | BS
SSH SWH MWP VMDR VSDXY WW SW1 SW2
0.028 degree x 0.037 degree (Surface only)
From 2016-01-01 to Present
hourly-instantaneous
MORE INFO | ADD TO CART | WMS | Sub-setting



BLKSEA_ANALYSIS_FORECAST_BIO_007_009
BLACK SEA BIOGEOCHEMISTRY ANALYSIS AND FORECAST
MODEL | BS
SSH CHL PHYC O2 NO3 PO4 PP
0.045 degree x 0.045 degree (40 depth levels)
From 2016-01-01 to Present
daily-mean
MORE INFO | ADD TO CART | WMS | Sub-setting



CMEMS products: three levels of information



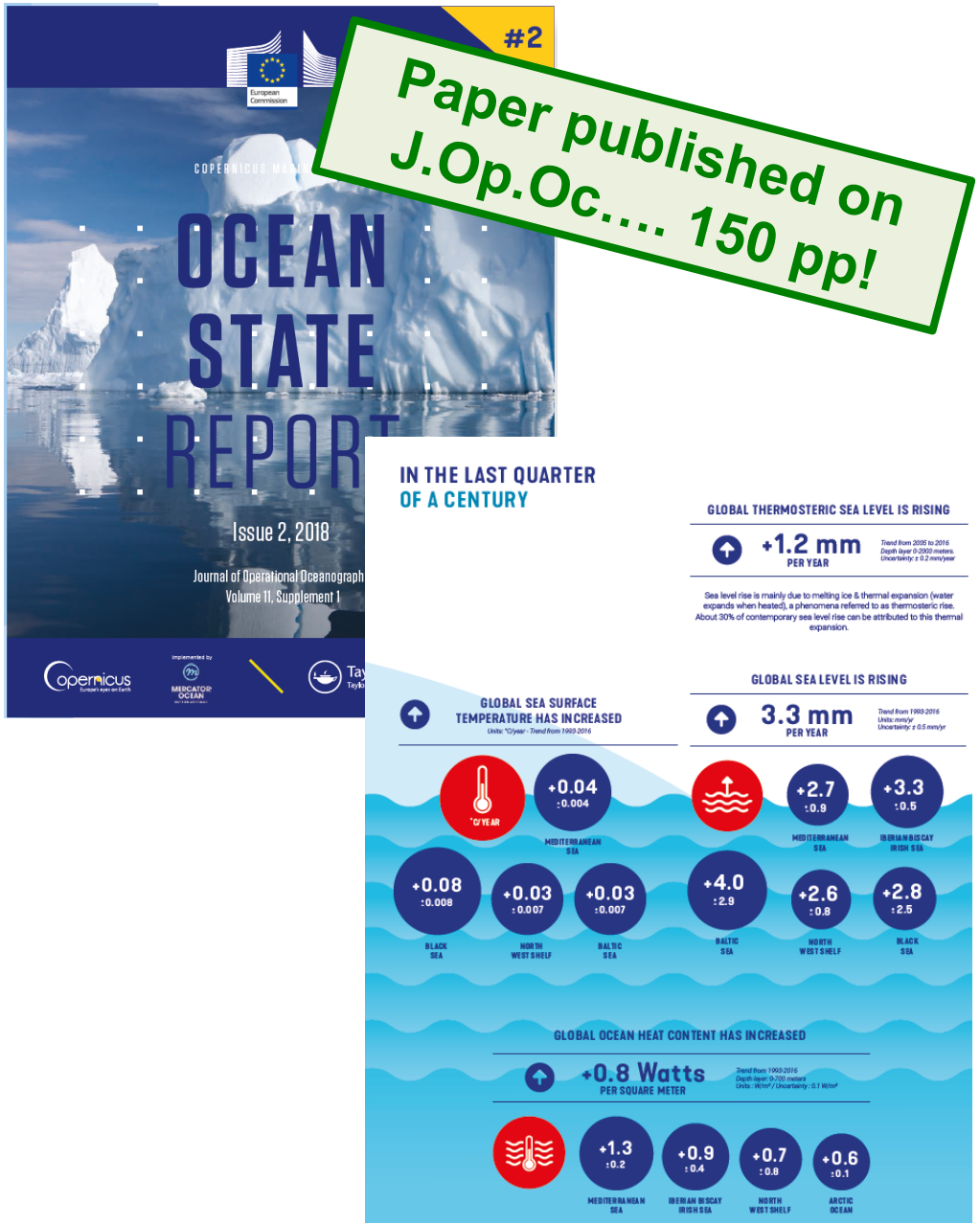
The Ocean State Report (OSR)

The CMEMS OSR is a comprehensive and state-of-the art **assessment** of the state of the global ocean and European regional seas for the ocean scientific community as well as for policy and decision-makers.

OSR provides a **4-D view**, from above and directly from the interior of the **blue, white and green global ocean and the EU regional seas**.

OSR has been conceived and intended as a **reference EU report** meant to contribute to reporting tasks and activities of EU policy makers, of environmental agencies in the EU (e.g. EEA), of Regional Sea Conventions, of EU Member States' decision makers and authorities concerned, of EU Peripheral Maritime Regions and of international organizations (e.g. IPCC, United Nations Sustainable Development Goal 14, OCDE…).

OSR aims at increasing general **public awareness** about the status of, and changes in, the marine environment.



ANOMALIES 2016

Copernicus Marine Service

2016 SELECTED ANOMALIES EUROPEAN REGIONAL SEAS

LEGEND

Symbols in RED signify a higher than average anomaly (higher than average quantity/amount)

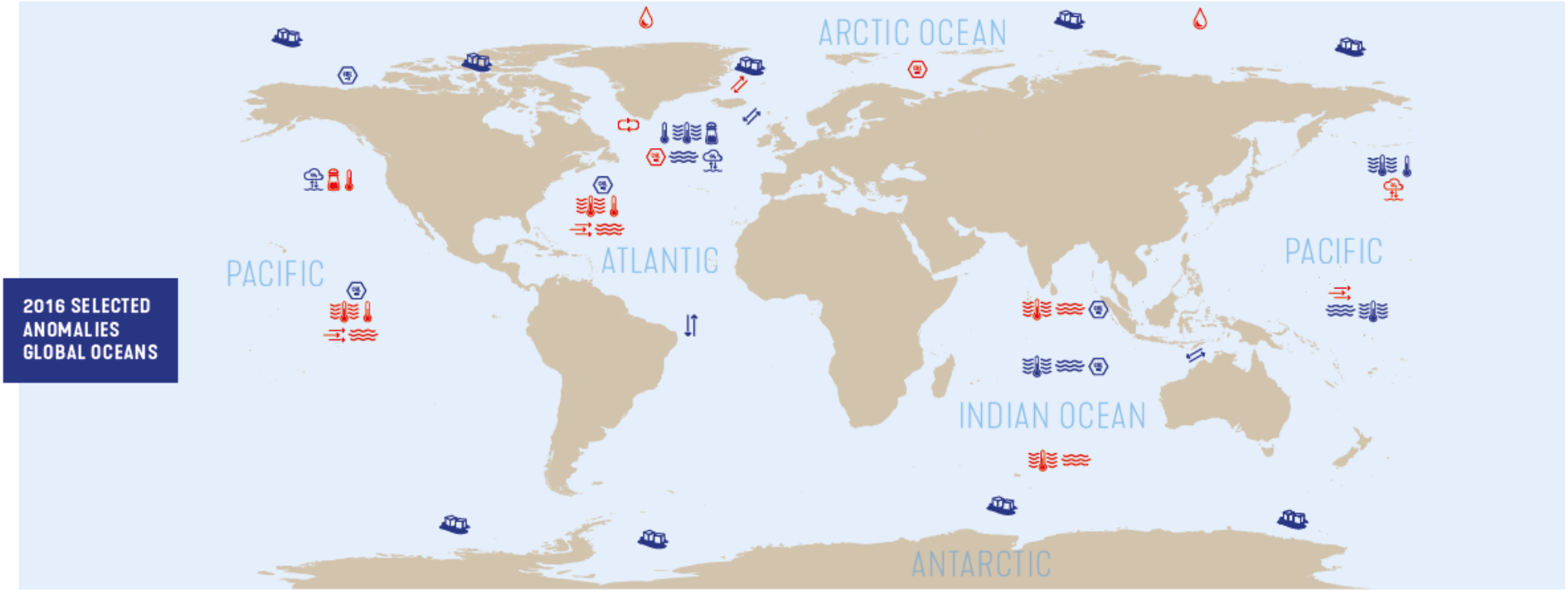
Symbols in BLUE signify a lower than average anomaly (lower than average quantity/amount)

- Ocean surface currents
- Carbon dioxide sea-to-air exchange
- Amount of oxygen
- Chl-a – Chlorophyll-a
- Significant wave height
- Ocean heat content
- Sea ice extent
- Salinity
- Temperature
- Convection
- Sea level
- Ocean transport
- Ocean freshwater content
- Extreme variability

ANOMALIES

In this report "anomaly" is defined as the difference of a measurement when compared to an average over a long time period. For example, the sea surface temperature in 2016 (in some areas) was higher than the sea surface temperature averaged over 1993 to 2014 in those same areas.

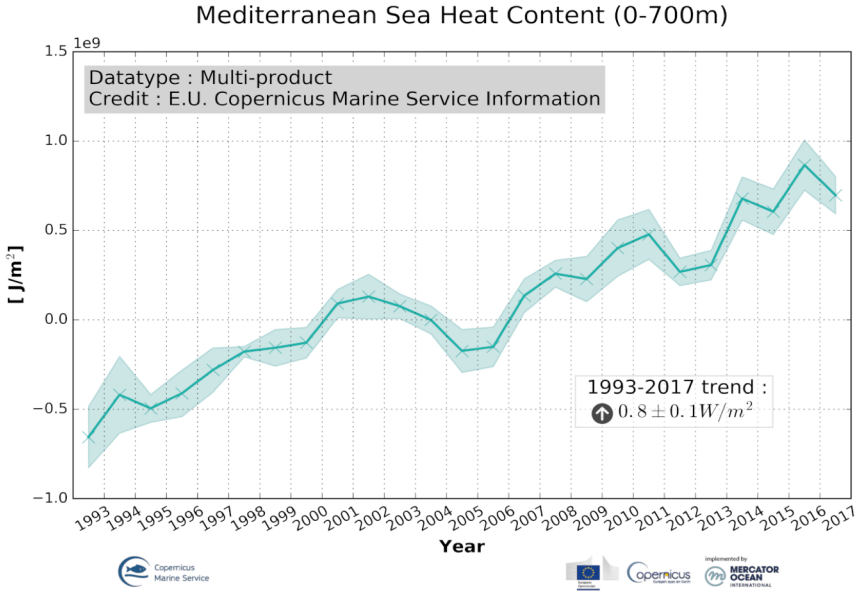
2016 SELECTED ANOMALIES GLOBAL OCEANS

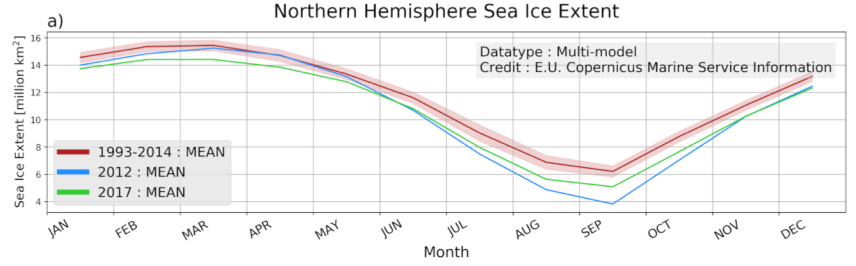


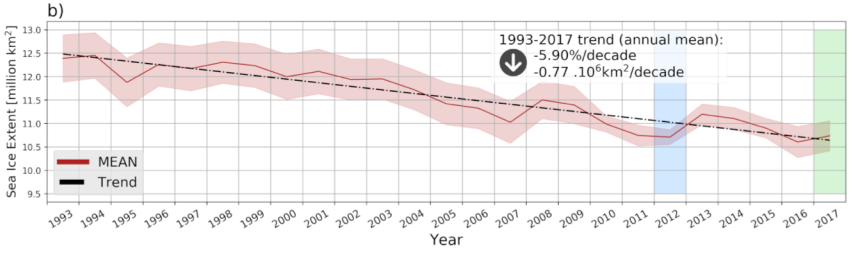
The Ocean Monitoring Indicators (OMIs)

CMEMS OMIs are free downloadable **data sets** covering the past 25 years of the **key variables used to monitor the oceanic trends in line with climate change**, including ocean warming, sea level rise and melting of sea ice. This **free and open ocean information** allows users to track the vital health signs of the ocean over the past quarter of a century.

- Ocean Heat Content: anomalies and trends, time series and maps 1993-2017
- Sea Level: averaged mean and regional trends, time series and maps 1993-2017
- Sea Ice: sea ice extent time series 1979-2017
- Next OMIs for biogeochemistry and waves





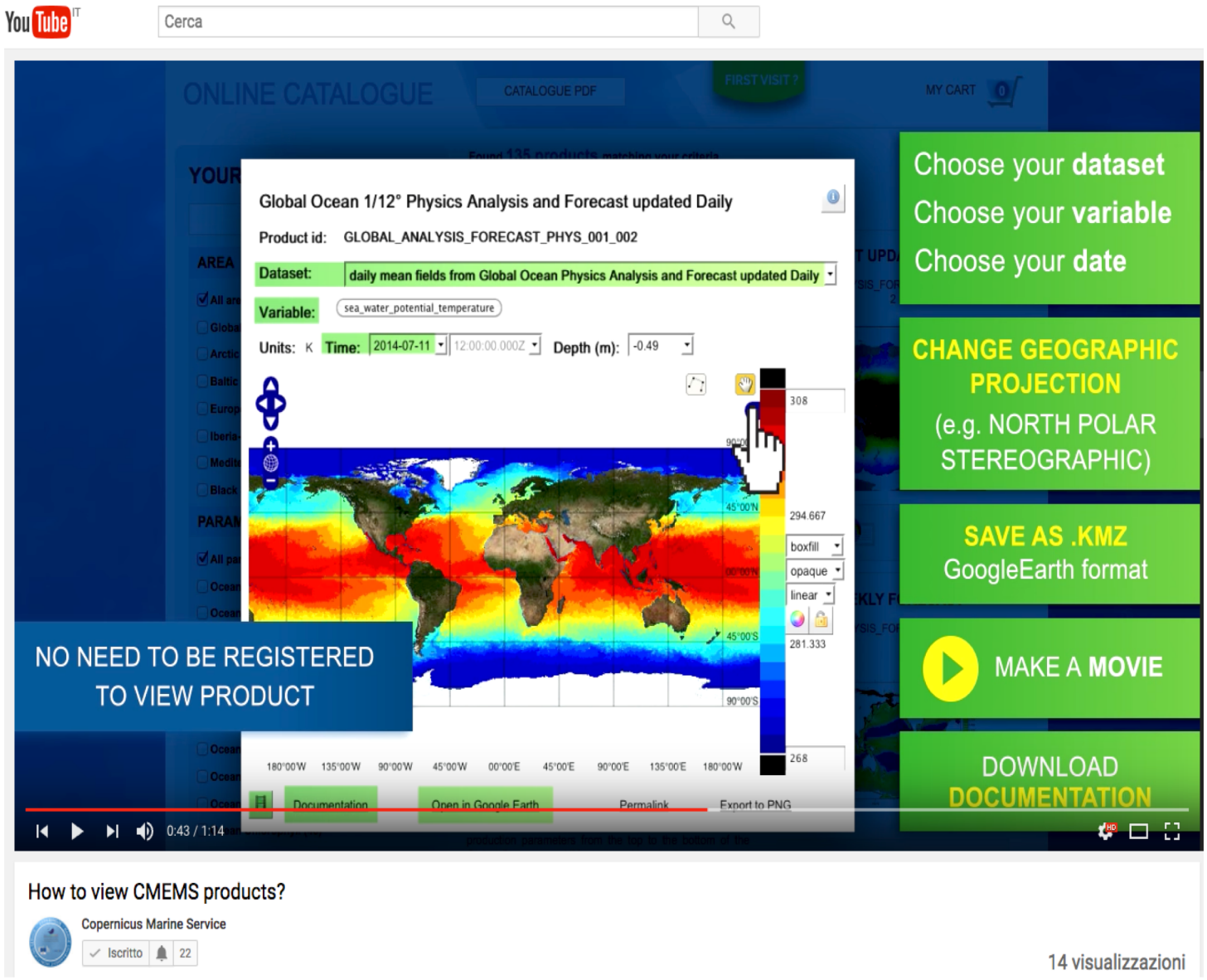


How to access and appraise data

1. **Visualize** the CMEMS data
2. **Download** the CMEMS data
3. **Manipulate** the CMEMS data

4. How to understand the **quality** of the CMEMS products?

How to visualize the CMEMS data

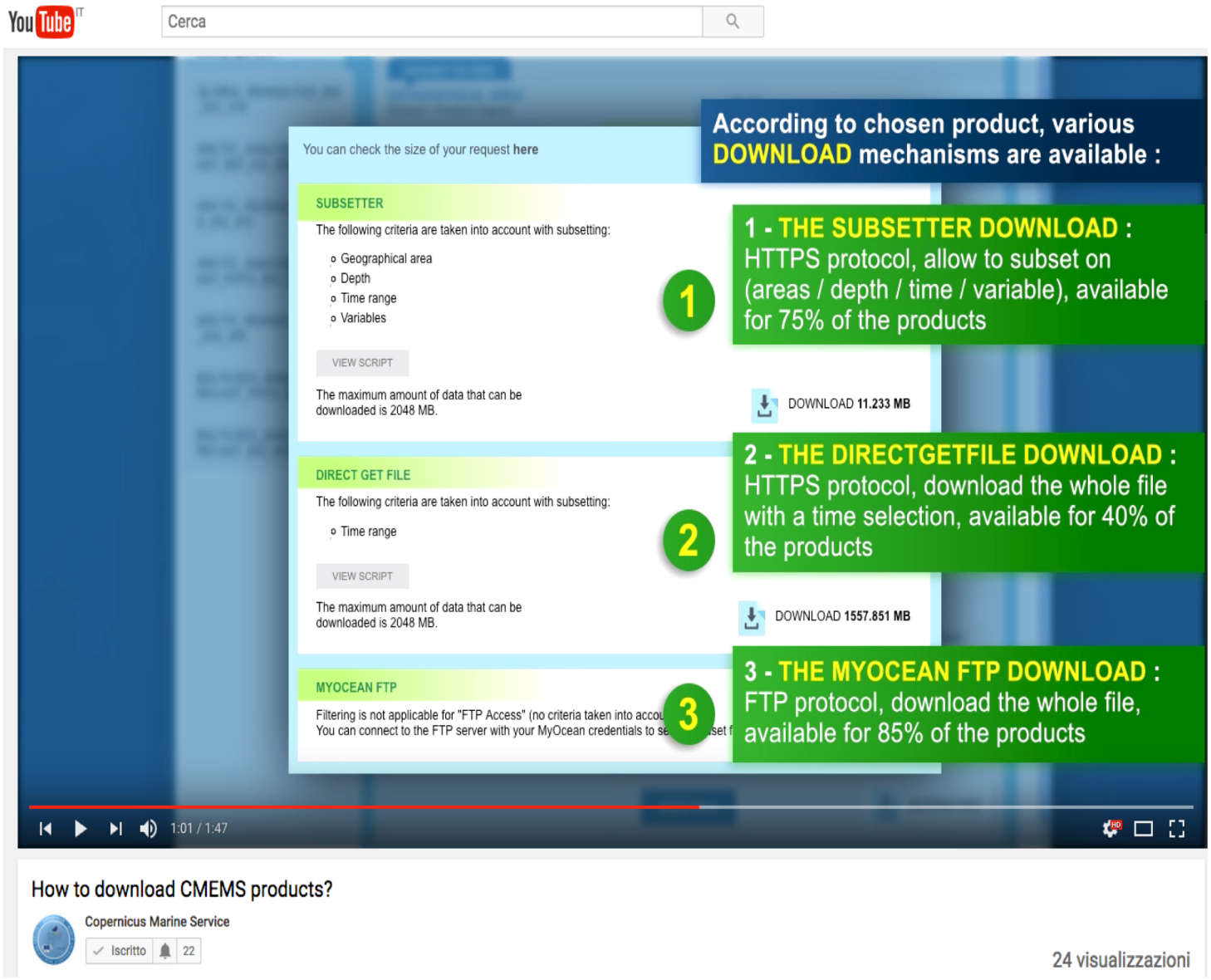


Visualizing the products through the Copernicus Web-portal

You need:
- a connection to the web and nothing more

See dedicated tutorial at http://marine.copernicus.eu/tutorials/how-to-view-products-service-release-septembre-2015/

How to download the CMEMS data



Downloading the products, then manipulating and visualizing by your own

You need:

- registration to CMEMS service
- choose among 3 different protocols
- disk space to store NetCDF file
- software that interactively visualizes NetCDF files
- NetCDF library (e.g. for Python, Fortran, Matlab)
- some computer skills ☺

See dedicated tutorial at http://marine.copernicus.eu/tutorials/how-to-download-products-service-release-septembre-2015/

Software for NetCDF files:

NetCDF: network Common Data Form (format for matrices of multivariate data organized in space and time)

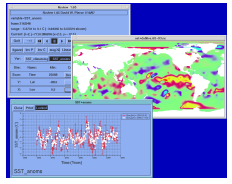
Several options for different platforms, different skills and performances

Computer software:

Ferret
http://ferret.pmel.noaa.gov/Ferret/home

IVE -The Interactive Visualization Environment
http://www.atmos.washington.edu/ive/

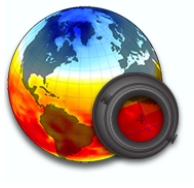
ncBrowse
http://www.epic.noaa.gov/java/ncBrowse/



NcView
ftp://cirrus.ucsd.edu/pub/ncview/

Interactively visualizing

QGIS
http://www.qgis.org/en/site/



Panoply
http://www.giss.nasa.gov/tools/panoply/

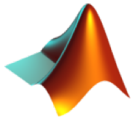
Software for NetCDF files:

NetCDF: network Common Data Form (format for matrices of multivariate data organized in space and time)

Several options for different platforms, different skills and performances

Computer Programming languages: **FORTRAN, C, visual basic**

Python
https://www.python.org/



MATLAB (**Mat**rix **Lab**oratory)
www.mathworks.com

R
www.r-project.org

GNU Octave
www.gnu.org/software/octave/

NCO
nco.sourceforge.net

GRADS
http://cola.gmu.edu/grads/

Manipulating and plotting

Appropriateness of the data given a specific investigation

Which instrument to measure the dimensions of a table?

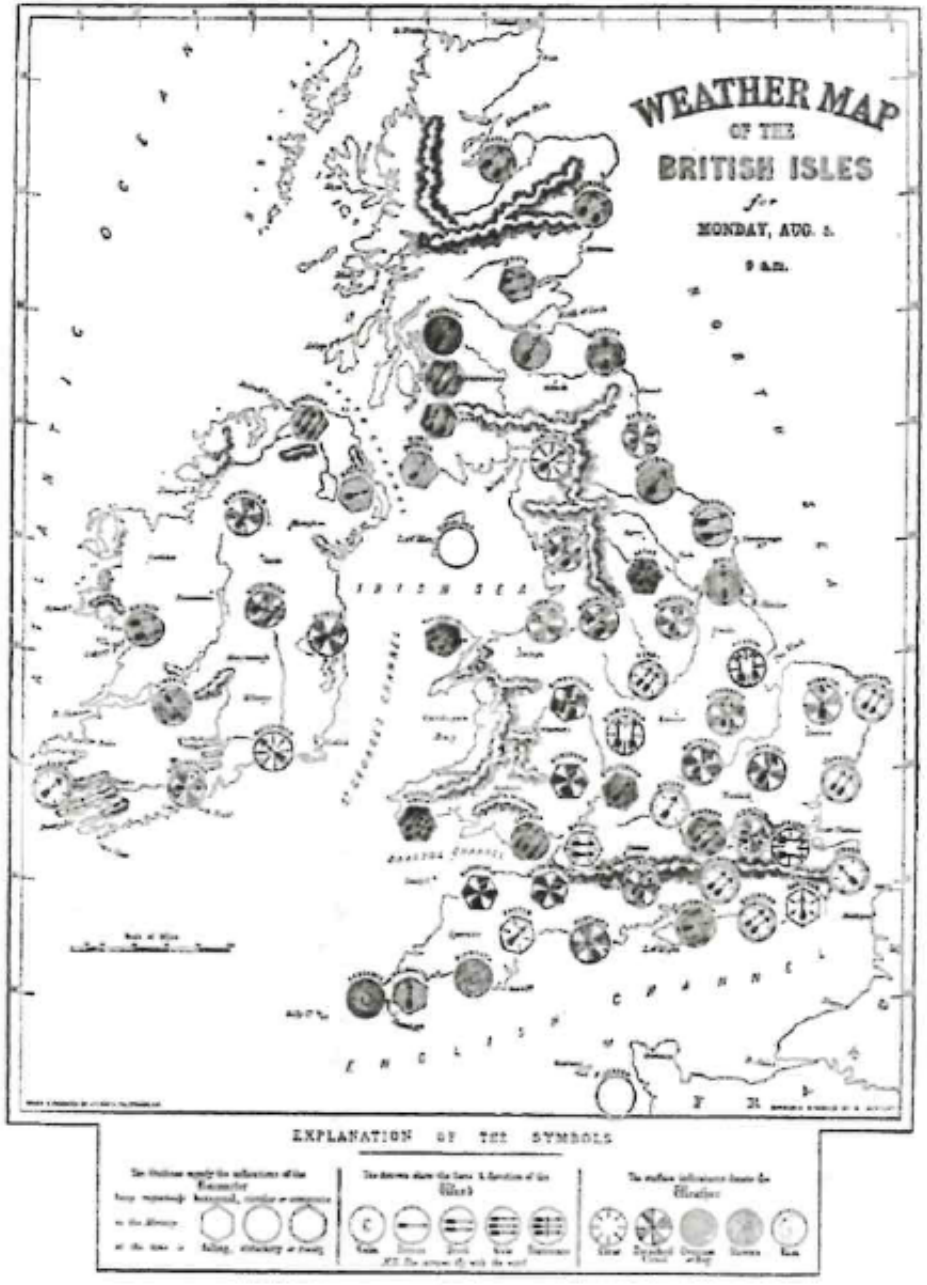
Appropriateness of the data given a specific investigation

Which instrument to measure the dimensions of a table?

.. and to monitor/predict a harmful algal bloom?

[proper assessment of nutrients, oxygen, turbidity, mixed layer dynamics, fresh water run-off, species presence/abundancy on the shelf at the proper temporal (hour/day) and spatial resolution (up to hundreds/tens of meters)]

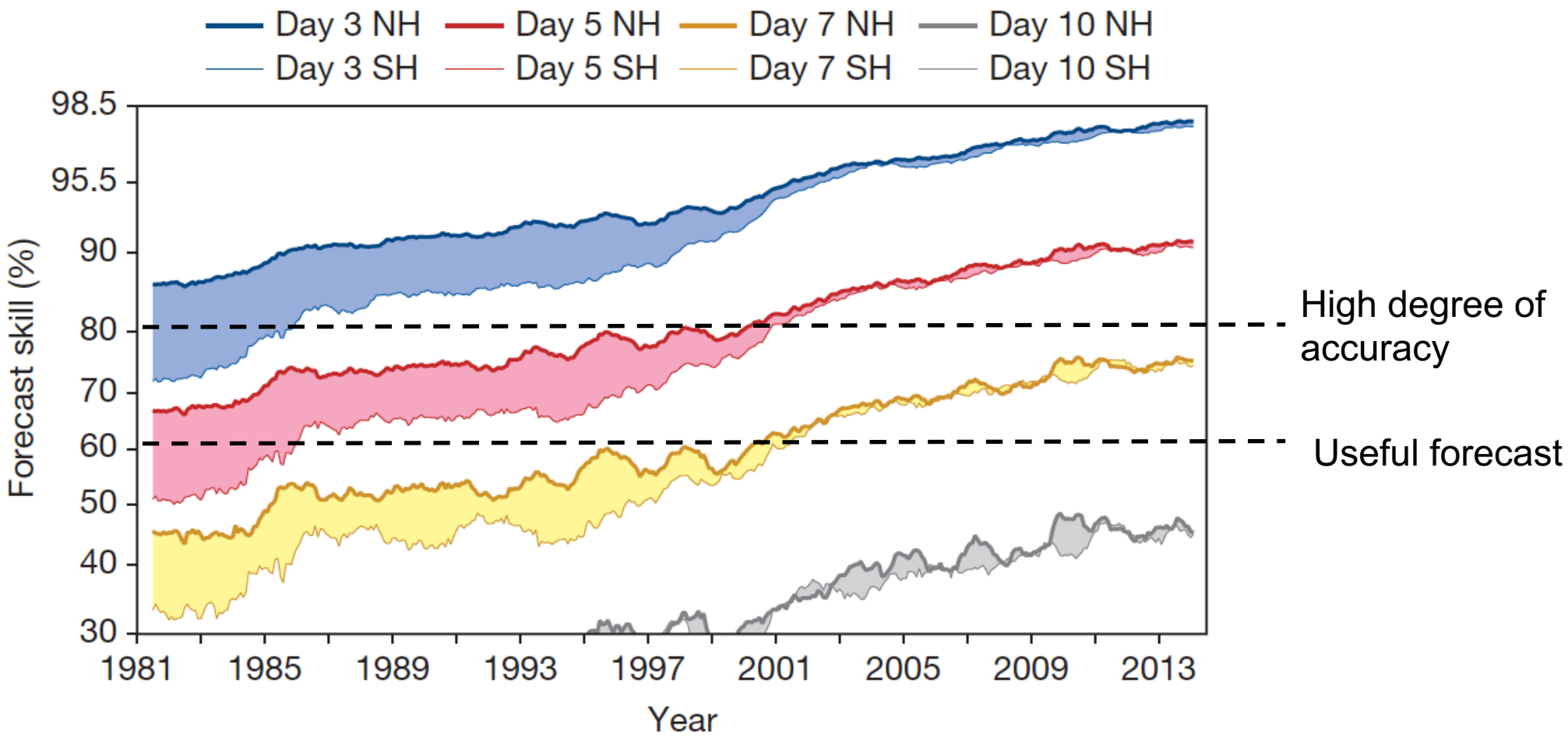
Accuracy: a measure of the quality of the variable/product values



Weather forecasts are not prophecies and dogmatic predictions. The term forecast is strictly applicable to such an opinion [probability] as is the result of scientific combination and calculation.

Robert FitzRoy, 1861

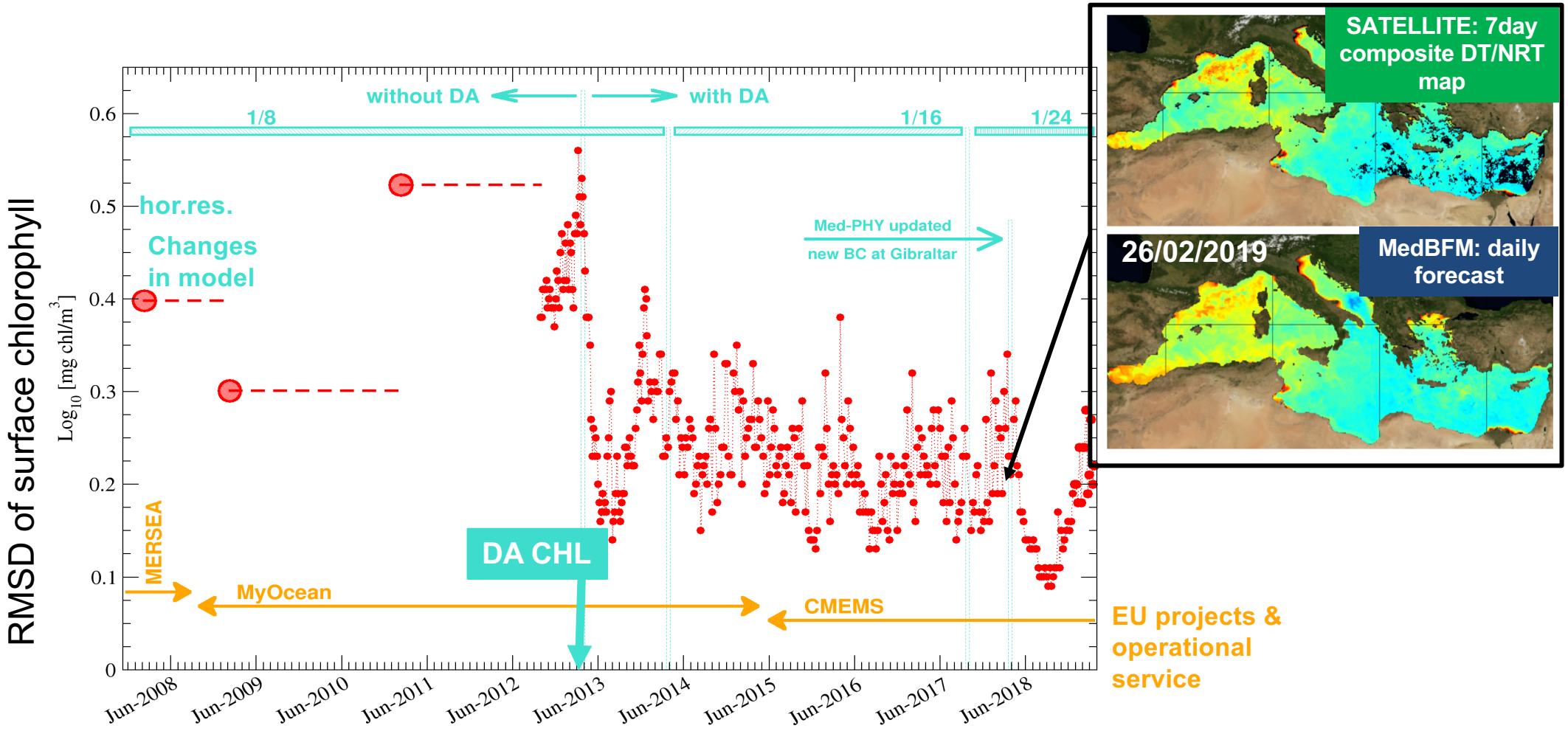
Accuracy: a measure of the quality of the variable/product values:
weather forecast skill at three-, five-, seven- and ten-day ranges



Forecast skill metric: correlation between the forecasts and the verifying analysis of the height of the 500-hPa level, expressed as the anomaly with respect to the climatological height

The quiet revolution of the weather prediction [Bauer et al., 2016]

Accuracy: a measure of the quality of the variable/product values:
History of the quality of the CMEMS Med forecast system



Skill performance of the first day of forecast of the surface chlorophyll

Salon et al., OS 2019

Accuracy: a measure of the quality of the variable/product values

skill metrics and graphical representations of the model/data - reference distance

Pearson correlation

$$r = \frac{\sum_{i=1}^{n} (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n} (O_i - \bar{O})^2 \sum_{i=1}^{n} (P_i - \bar{P})^2}},$$

Root mean square error

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}},$$

bias

$$AE = \frac{\sum_{i=1}^{n} (P_i - O_i)}{n} = \bar{P} - \bar{O},$$

Reliability index

$$RI = \exp\sqrt{\frac{1}{n}\sum_{i=1}^{n} \left(\log \frac{O_i}{P_i}\right)^2},$$

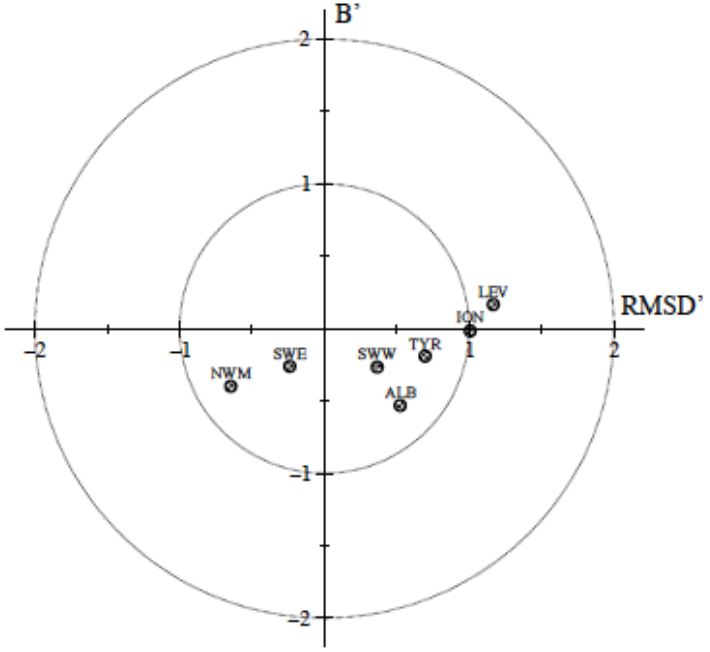
Model efficiency

$$MEF = \frac{\left(\sum_{i=1}^{n} (O_i - \bar{O})^2 - \sum_{i=1}^{n} (P_i - O_i)^2\right)}{\sum_{i=1}^{n} (O_i - \bar{O})^2},$$

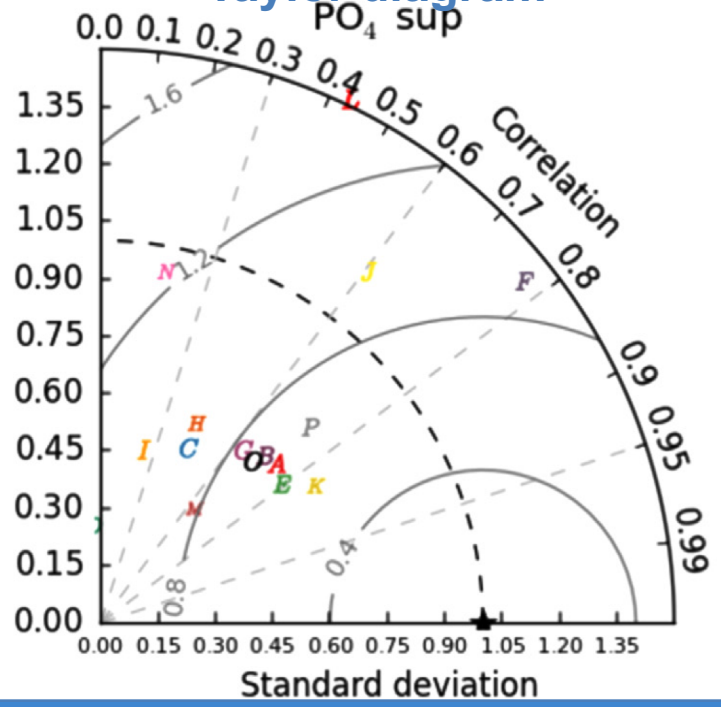
Average absolute error

$$AAE = \frac{\sum_{i=1}^{n} |P_i - O_i|}{n},$$

Target diagram

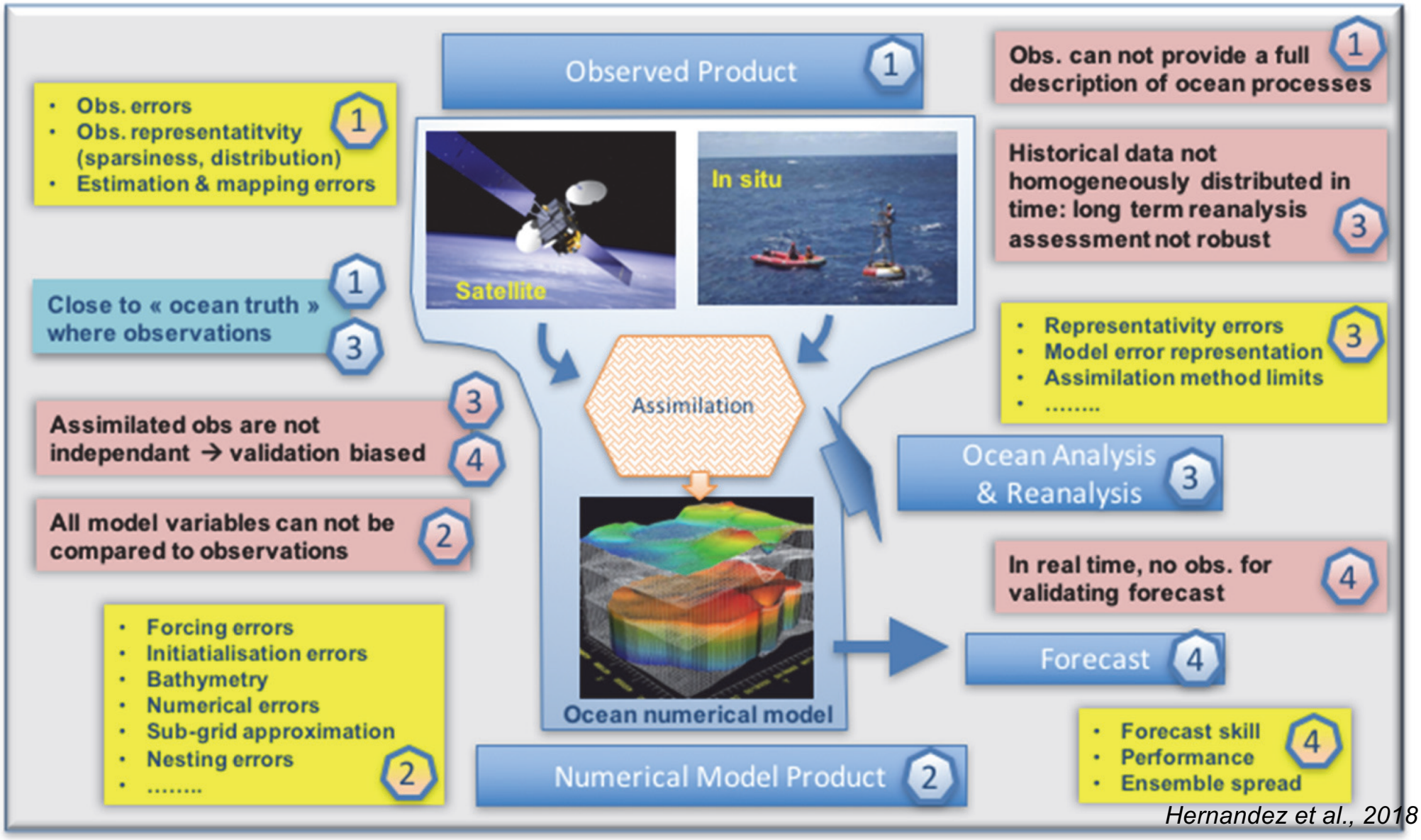


Taylor diagram



Accuracy of Ocean Forecast Monitoring products

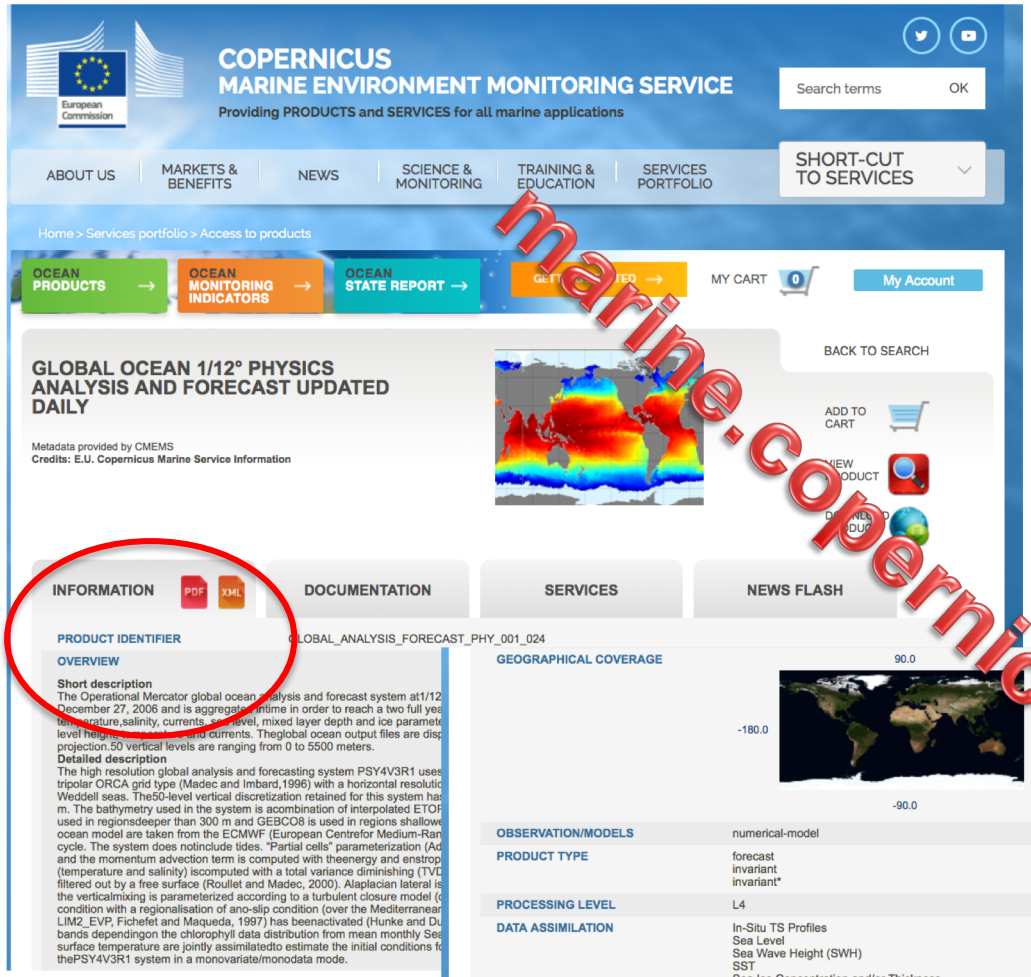
What is the true state of the ocean? critical aspects?



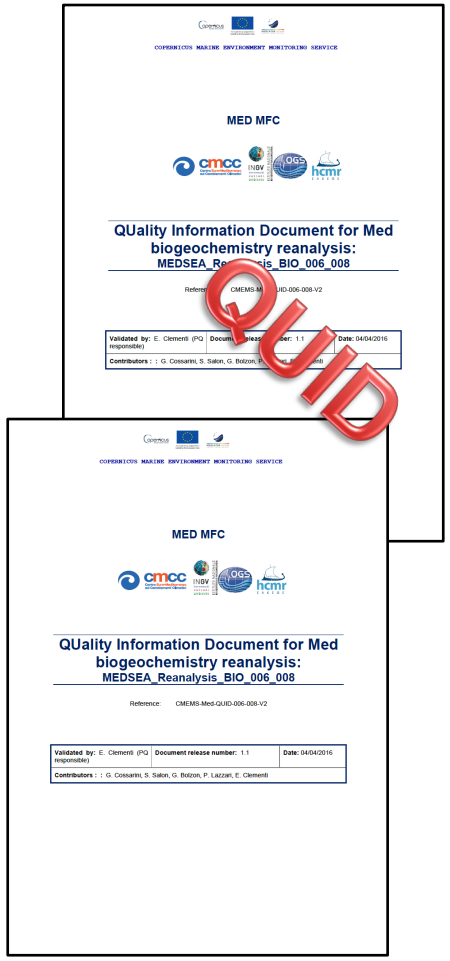
Hernandez et al., 2018

Type of products, their associated errors, positive aspects, drawbacks in using observations for the evaluation

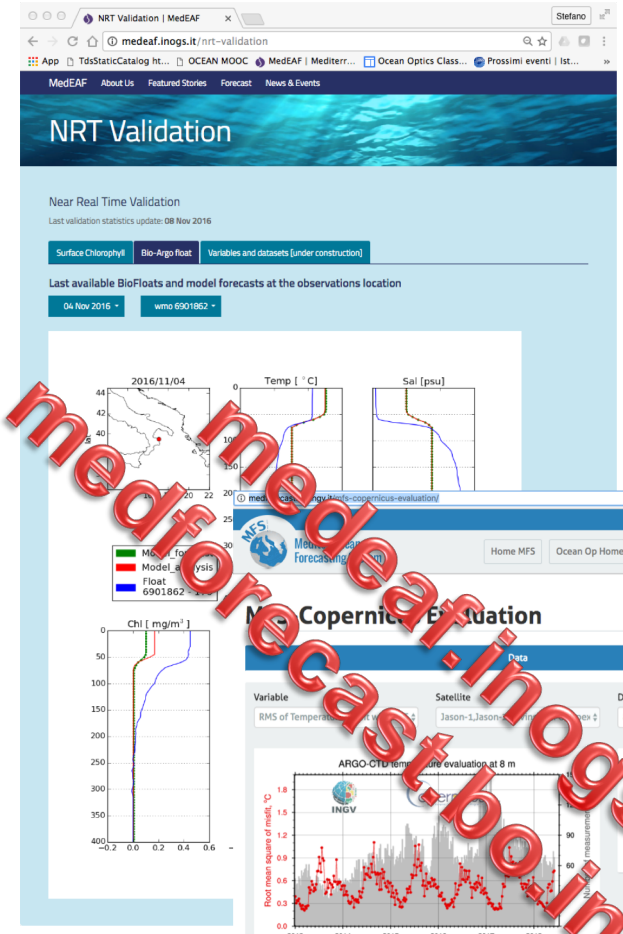
Characteristic of CMEMS products: where to find the information

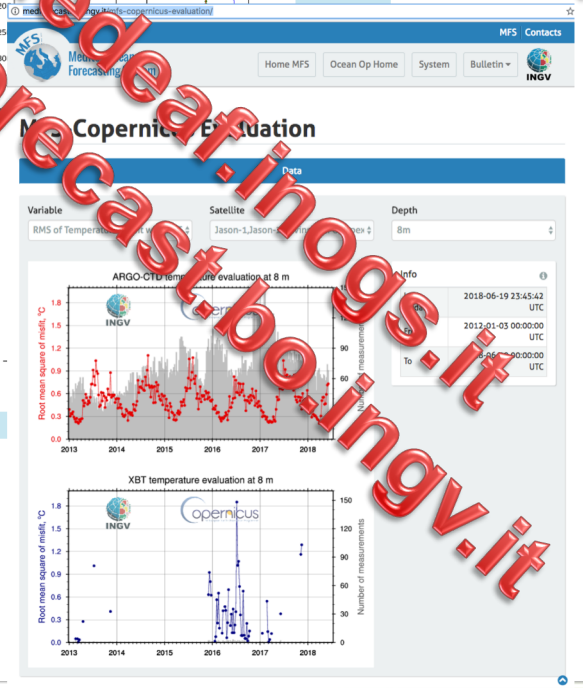


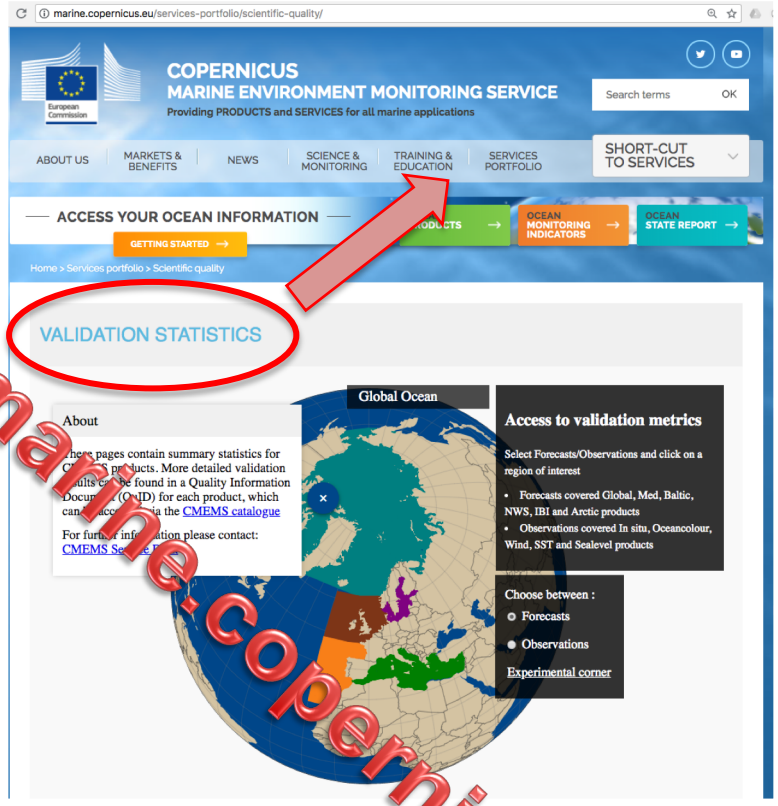
marine.copernicus.eu

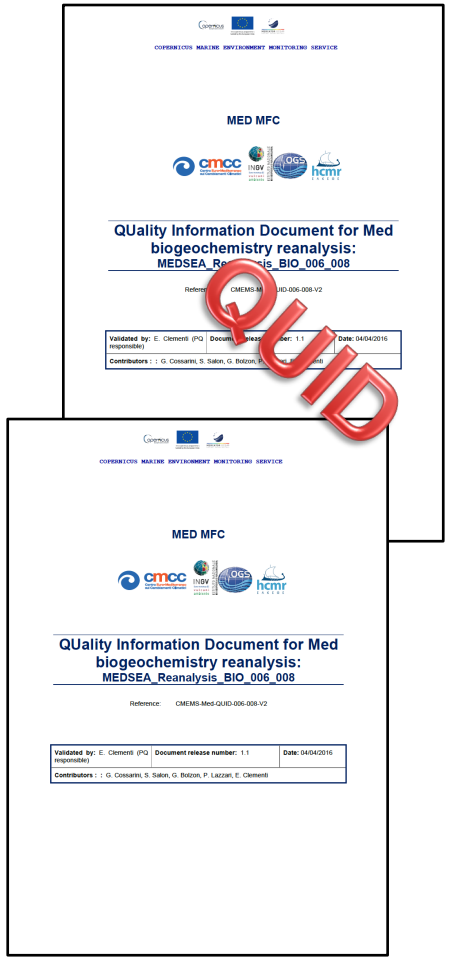


Quality of CMEMS products: where to find the information









medeaf.inogs.it
medforecast.bo.ingv.it
marine.copernicus.eu
QUID

Every day/week

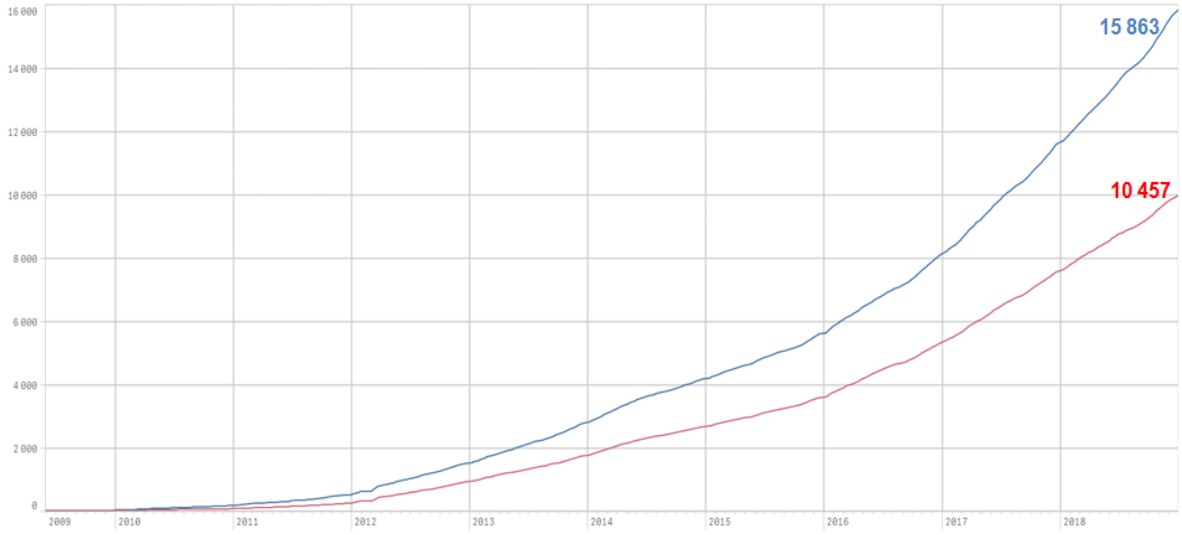
Updated statistics every 3 months

Every year: new reanalysis / new system version

Use case description

1. CMEMS Users and Markets
2. Examples of Use Cases
3. YOUR use case

Use case: growing number of the CMEMS service

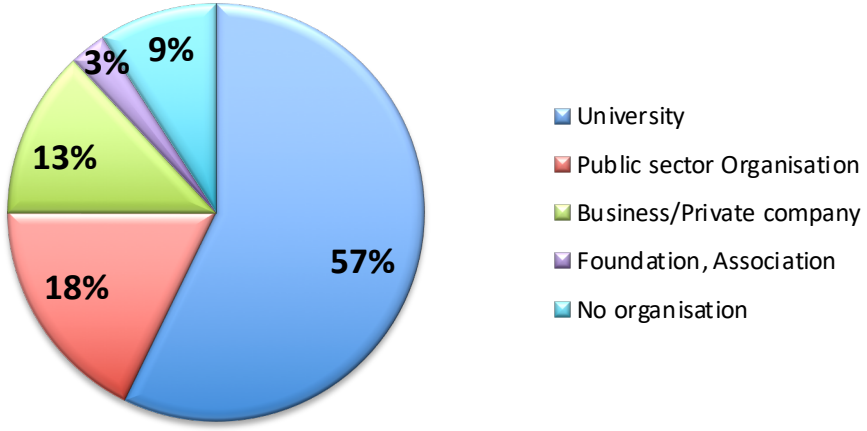


- **~ 16000** external users registered
- **> 1100** regular users
- **> 5000** downloaders
- **> 1300** TB downloaded

=> 25% users (regular) downloaded 87% of the data

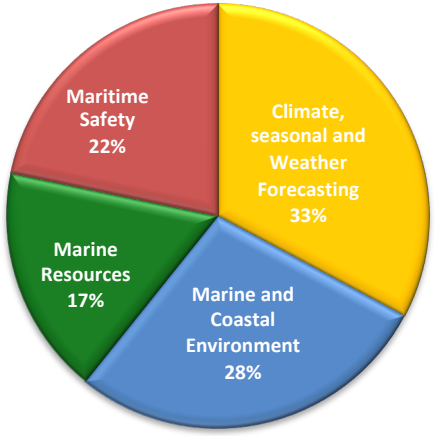
Who are the users?

CMEMS - Type of Organisation
All Subscribers (from 2009)



Which areas of interest?

CMEMS - Area of Interest
All Subscribers (from 2009)



CMEMS markets

MARKETS

COPERNICUS MARINE SERVICE SUPPORTS ALL SECTORS OF THE BLUE ECONOMY

1 POLAR ENVIRONMENT MONITORING

2 MARINE CONSERVATION & POLICIES

3 SCIENCE & CLIMATE

4 NATURAL RESOURCES & ENERGY

5 WATER QUALITY

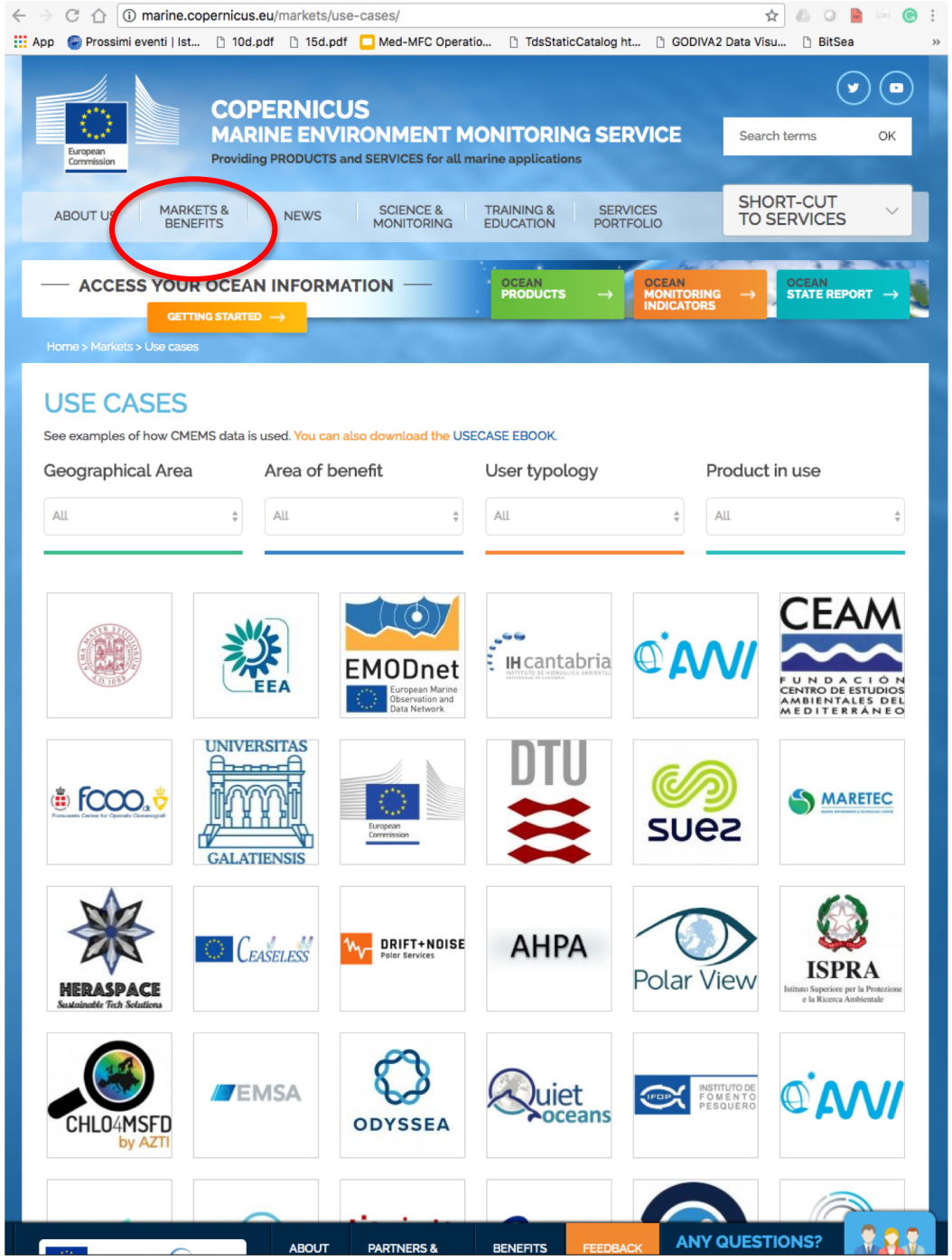
6 COASTAL MONITORING

7 SOCIETY & EDUCATION

8 MARINE FOOD

9 MARINE NAVIGATION

10 SAFETY & DISASTER



Use case: many examples of downstream applications on the CMEMS webpage

Continuous improvement based on science and users feedbacks

Design next generation of Monitoring and Forecast Systems

Downstream user applications (1/4):

Costa Concordia oil spill scenario simulation

EVENTS / AGENDA

MYOCEAN STILL ON ALERT FOR THE COSTA CONCORDIA

News - September 18, 2013

During the parbuckling of the Costa Concordia, initiated on September 16th, MyOcean currents forecasts in the Mediterranean Sea are still needed by the downstream application developed by INGV, CMCC and UniBO for preventing oil spill risks, as a support of Italian Coastguards.

When the cruiser Costa Concordia ran aground off the Italian coast in January 2012, MyOcean started to provide the Italian Coast Guard Operational Centre with daily valuable information on currents in the Mediterranean Sea (cf MyOcean news , january 2012)

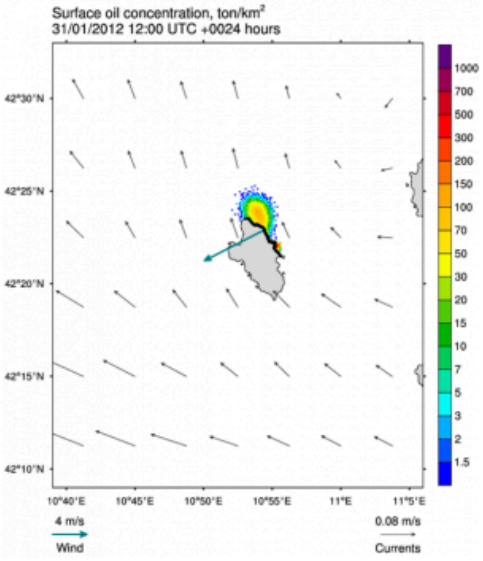
On September 16th 2013 started the parbuckling of the Costa Concordia and MyOcean service is more than ever on alert during this complex Sea operation.

A joint team of the National Institute of Geophysics and Volcanology (Istituto Nazionale di Geofisica e Vulcanologia, INGV), the Euro-Mediterranean Center on Climate Change (Centro Euro-Mediterraneo sui Cambiamenti Climatici, CMCC) and the University of Bologna have developed downstream applications (oil spill forecasting and high resolution relocatable modelling) for the Italian Coast Guards which rely on MyOcean products.

Currents forecasts in the Mediterranean Sea (cf MyOcean catalogue of product) provided by MyOcean, the Copernicus pre-operational marine service were combined with the oil spill model MEDSLIK-II in order to simulate possible scenarios of transport and dispersion of the oil in the sea. Counting on these scenario predictions allows authorities to better plan risk mitigation measures and immediately react in case a leak occurs. Data on currents and possible oil spill scenarios will continue to be provided to Coast Guard in case they will be needed during the next phases of the Concordia wreck removal.

Incredible time-lapse video of the Sea Operation (© Le Monde)

Legend: Italian Authorities also care about the environmental impact.(Illustration by courtesy of Italian Coast Guard)

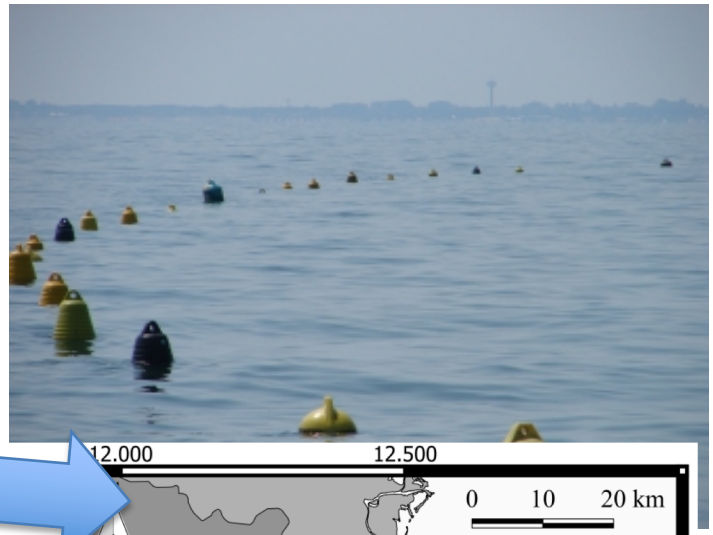


Legend: To count on predictive elements allow the Italian authorities to immediately react in case a leak occurred.(Illustration based on MyOcean data/by courtesy of INGV)

http://marine.copernicus.eu/wp-content/uploads/use-cases/costa-concordia-accident-monitoring-potential-oil-spills-1.0.pdf

Downstream user applications (2/4):

Allocating suitable zones for shellfish aquaculture in the Adriatic Sea

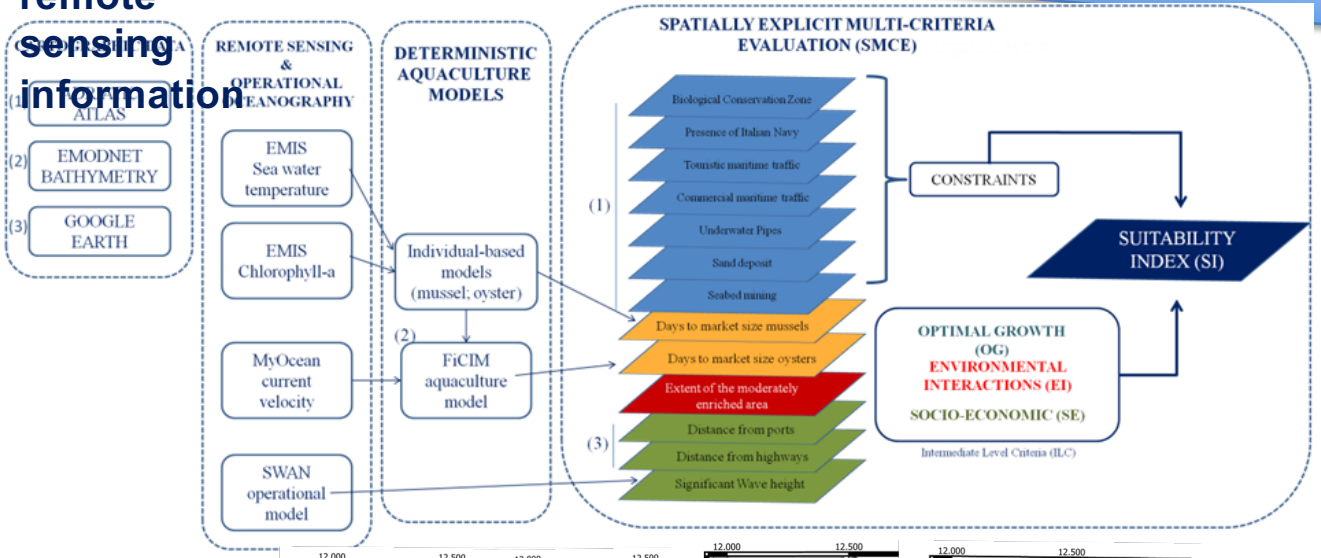


Operational oceanography & remote sensing information

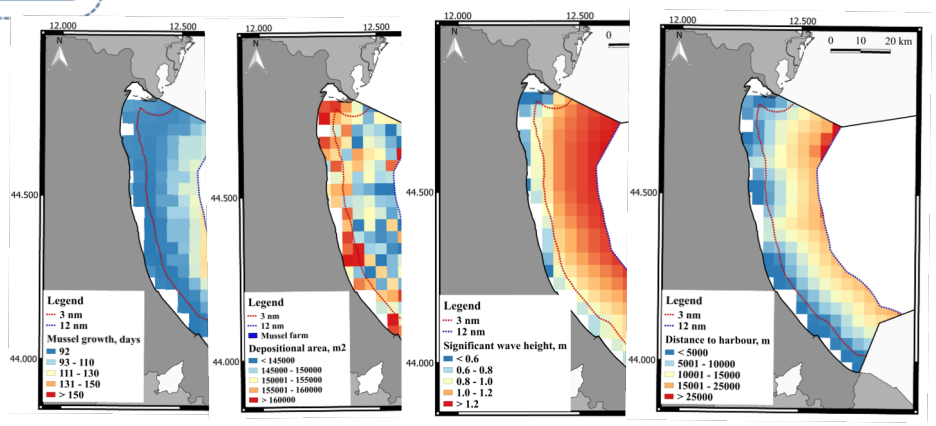
Deterministic aquaculture models

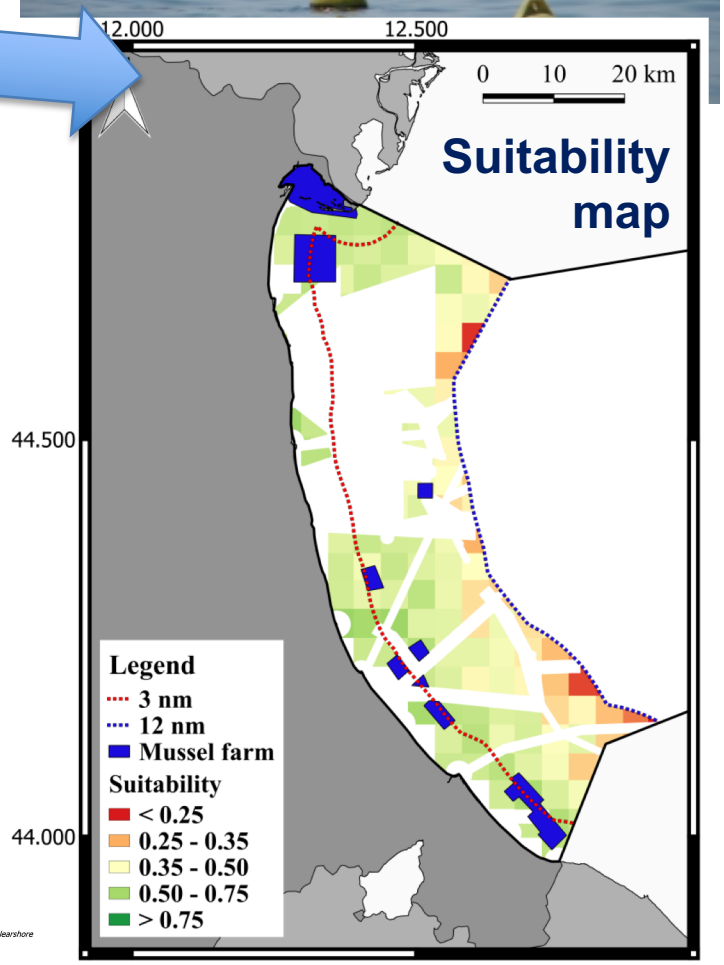
Maps for criteria

GIS



Maps for criteria



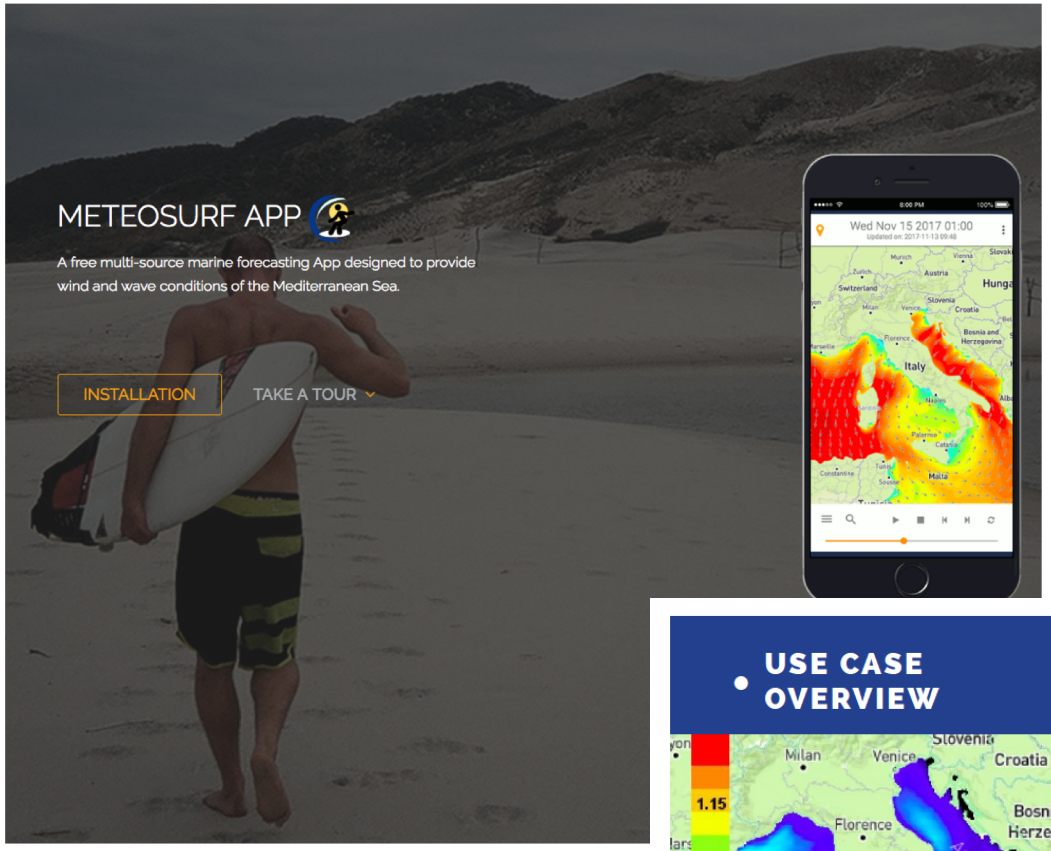


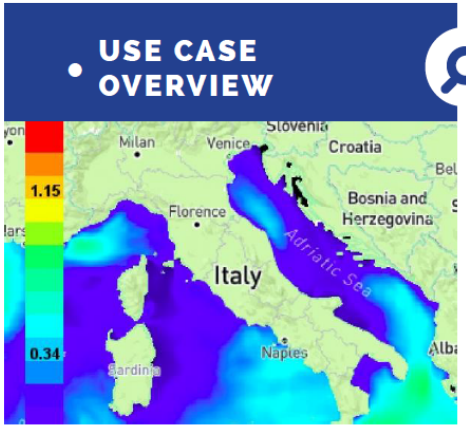
SWAN Simulating WAves Nearshore

Brigolin, D., Porporato, E.M.D., Prioli, G., Pastres, R., 2017. Making space for shellfish farming along the Adriatic coast. ICES-Journal of marine science. 10.1093/icesjms/fsx018

Downstream user applications (3/4):

MeteoSurf



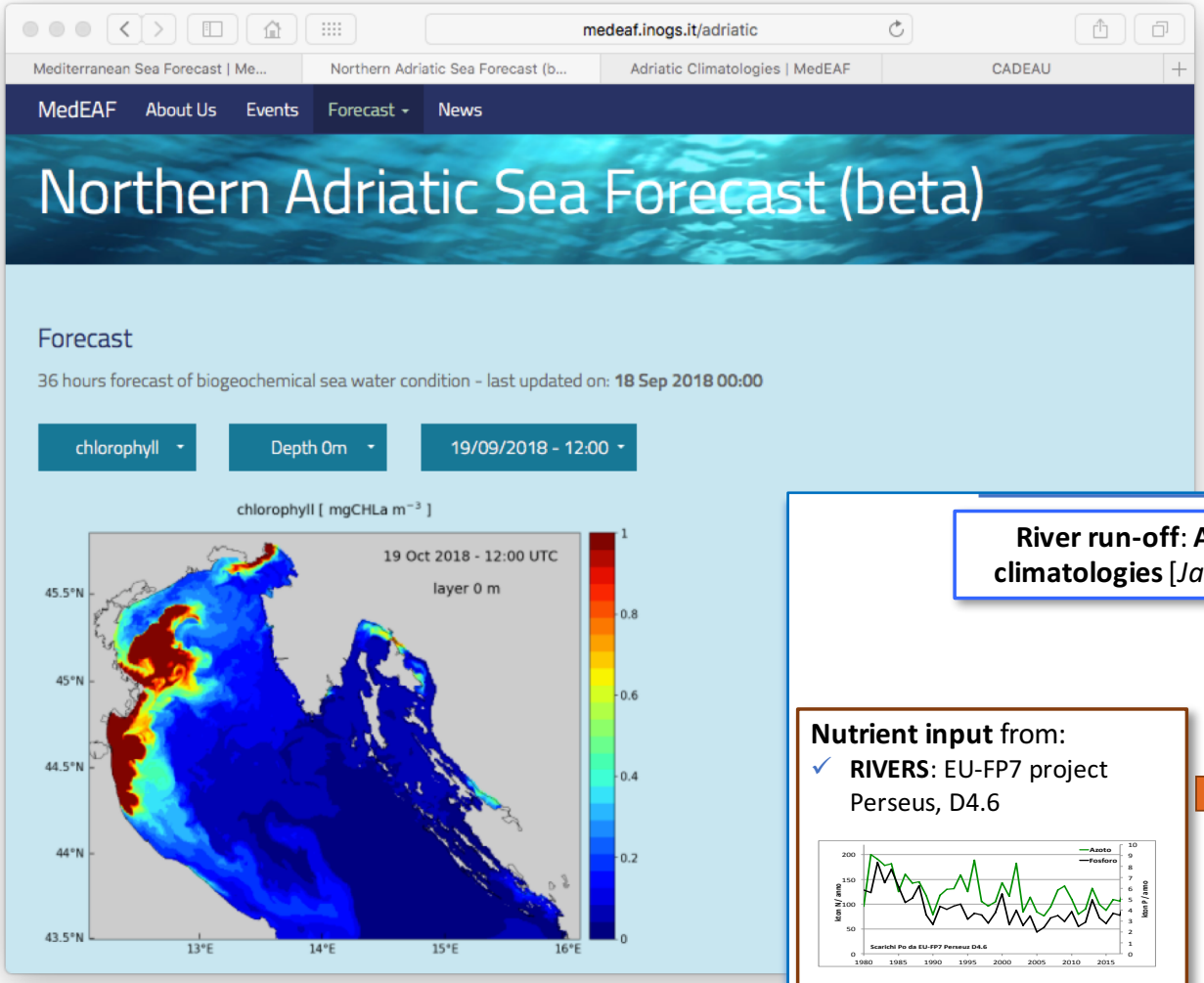


02	height	direction	(sec)	(kn)	direction
00	2.33	↘	11.17	17.33	↓
03	2.21	↘	11.17	14.26	↓
06	2.10	↘	11.17	12.07	↓
09	2.04	↘	11.17	10.96	↓
12	2.05	↘	11.17	13.49	↓
15	2.17	↘	12.28	15.53	↓
18	2.28	↘	13.51	14.77	↓
21	2.33	↘	13.51	14.40	↓
Tue 03	**Wave height**	**Wave direction**	**Period (sec)**	**Wind (kn)**	**Wind direction**
00	2.39	↘	12.28	14.94	↓

MeteoSurf is a free multi-source weather forecasting App designed to provide wind and wave conditions of the Mediterranean Sea. It is an application for smartphones and tablets, built as a Progressive Web App able to supply detailed and updated maps and data showing heights of sea waves in the Central Mediterranean. It is mainly targeted for surfers and wind-surfers. Data can be displayed as animated graphical maps, or as detailed table data. The maps refer to the whole Mediterranean Sea, while the table data is able to provide specific information for any of the major surf spots in the Med Sea. MeteoSurf shows data collected from 3 different forecasting system sources among which the Copernicus Marine Service ocean forecast model. Met-Oceanic conditions are available in the following locations: Algeria, Croatia, Cyprus, France, Gibraltar, Greece, Israel, Italy, Lebanon, Libya, Morocco, Portugal, Serbia, Slovenia, Spain, Tunisia, Turkey. Once the surfing spot has been selected, data will be prompted in a table listing the forecast for wave height, wave direction, wind speed and wind direction.

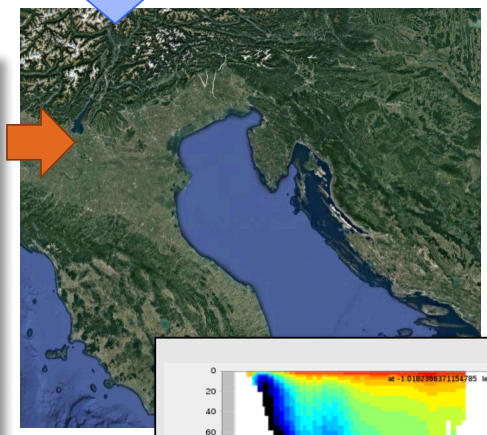
Downstream user applications (4/4):

CADEAU Northern Adriatic Sea forecast system



Downscaling from CMEMS and data integration

River run-off: **ARPAE, ARPA-FVG, climatologies** [*Janekovic et al.*, 2014]



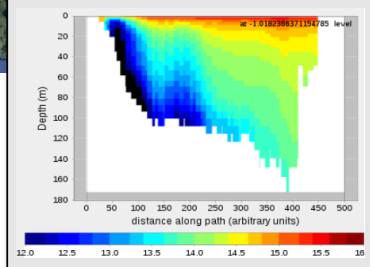
Atmospheric forcing: **ECMWF, COSMO I2**

arpae emilia-romagna

Nutrient input from:

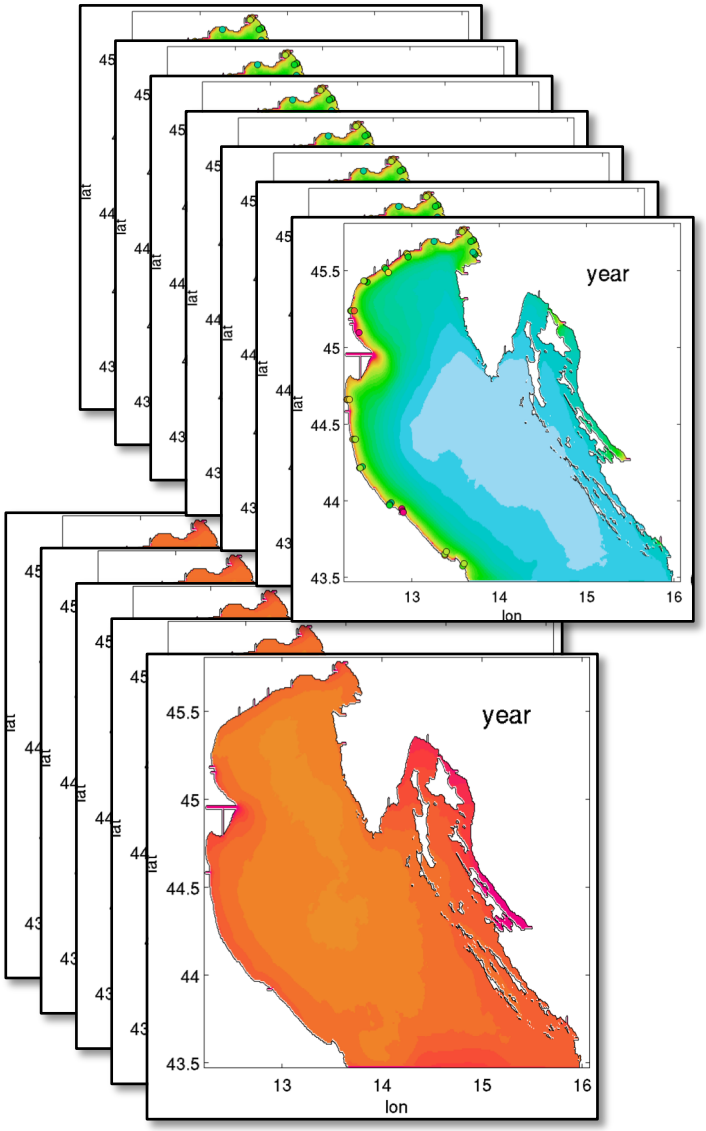
- ✓ **RIVERS**: EU-FP7 project Perseus, D4.6

- ✓ **VENICE LAGOON** [*Solidoro et al.*, 2006]
- ✓ **ATMOSPHERE** [*Ribera d'Alcalà et al.*, 2003]
- ✓ **BOTTOM REMINERALIZATION** [*Giordani et al.*, 2002; *Bertuzzi et al.*, 1997]
- ✓ **SEWAGE DISCHARGES AT SEA**: ISPRA-UWWTP



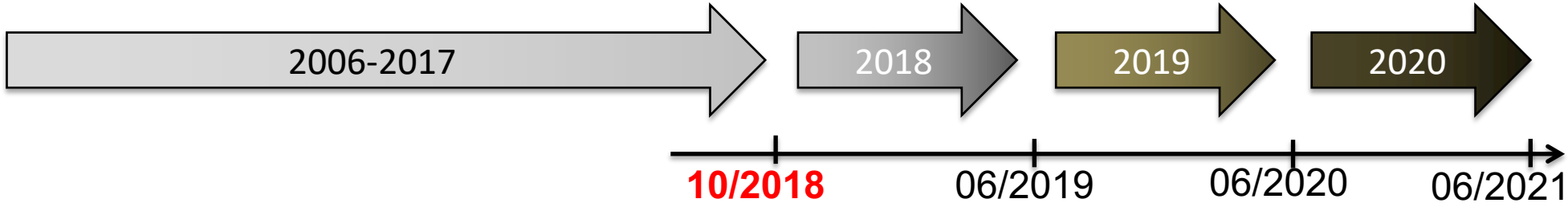
Boundary conditions for the southern open boundary (*nesting*) for physical and biogeochemical variables: **CMEMS**

CADEAU: annual bulletin of the state of the sea



High-resolution (~700 m) **physical-biogeochemical model corroborated** and **integrated** with experimental observations (ARPA, ISPRA) and satellite data (CMEMS):

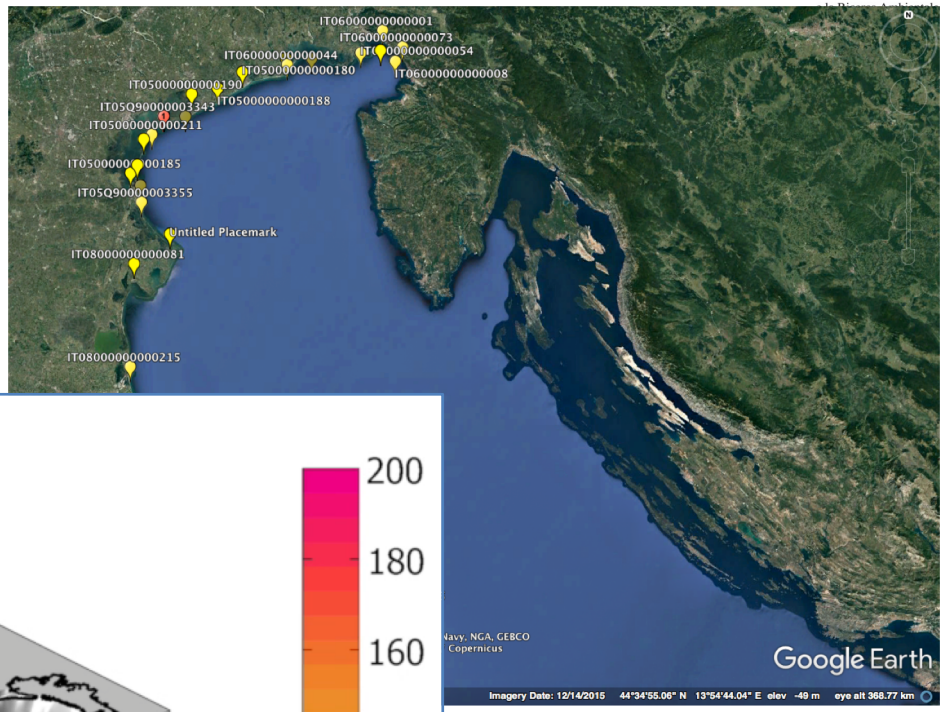
- ✓ http://www.bio.isprambiente.it/cadeau/
- ✓ **2006-2017 reanalysis** ➜ recent oceanographic/ecological state of the northern Adriatic (reference to evaluate changes);
- ✓ **annual simulations** from 2018 to 2020 ➜ bulletin of the state of the sea for the previous year and derived products;
- ✓ **simulated variables**: nitrate, phosphate, ammonia, chlorophyll, primary production, oxygen, DOC…
- ✓ **derived variables**: TRIX, impact index…

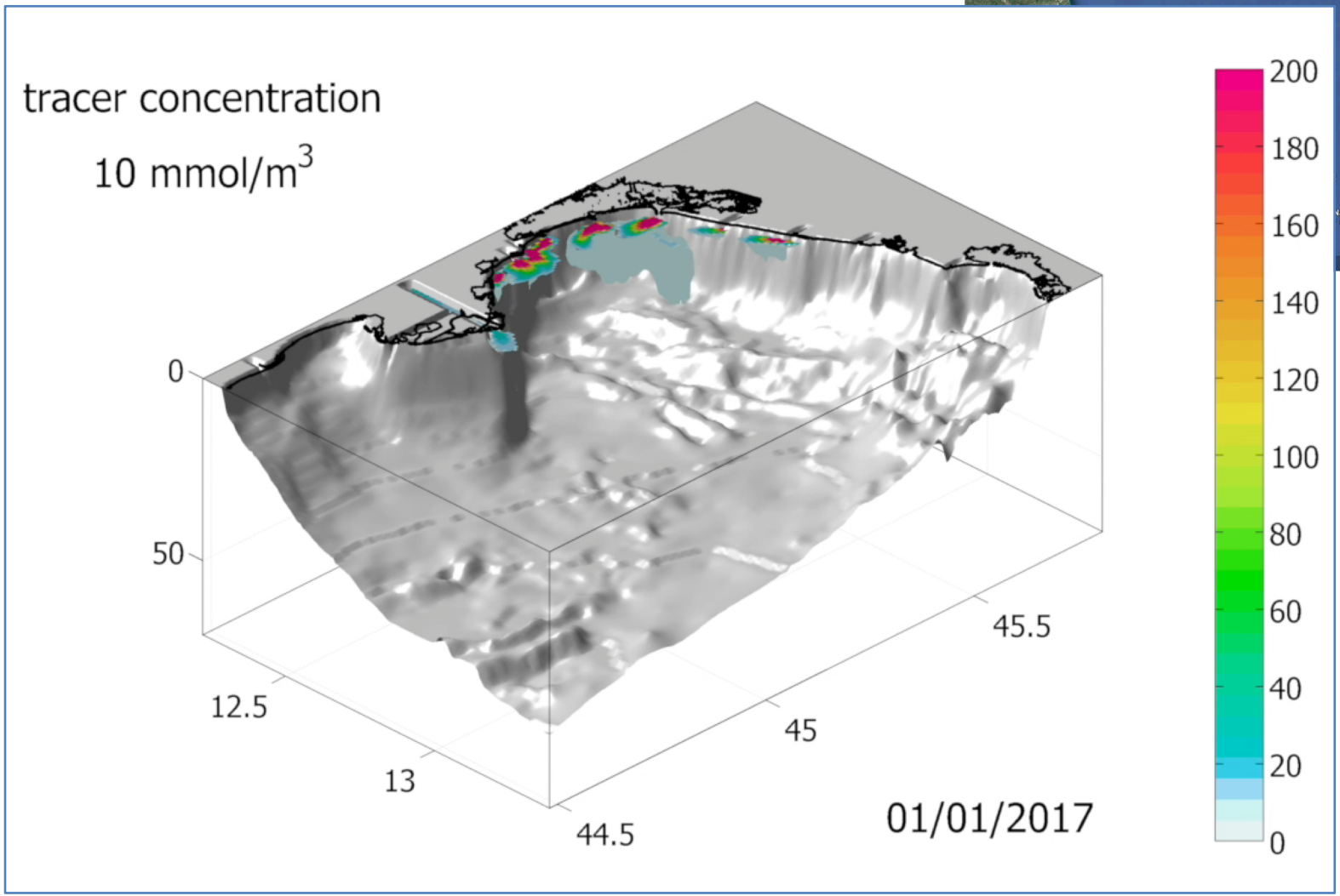


CADEAU system: water quality assessment

Simulation of **coastal sewage discharges (ISPRA dataset)**

Bathing waters case study (Chioggia):
12 sources of “escherichia coli”





Escherichia coli – like model:
first order decay law
[*Chan et al.*, 2013]

Exercise: YOUR use case

1. **Register** to the CMEMS web portal
2. **Explore** the information provided by the CMEMS web portal
3. **Explore** the products available for the Baltic Sea
4. **Select** a study site and identify one or more critical aspects regarding issues related to Ocean Health

Exercise

- Mediterranean and Baltic are two different worlds in term of biogeochemical dynamics, but some challenges they face are common: **toxic pollutants** and **harmful algal blooms** may affect ecosystem, aquaculture and tourism.
- Toxicity can be linked to algal blooms, which are operationally monitored by different research teams, usually by ships.
- Satellites may instead provide a more informative synoptic view, that can be also integrated by the forecast modelling systems, as that one managed by OGS within CMEMS.

Exercise

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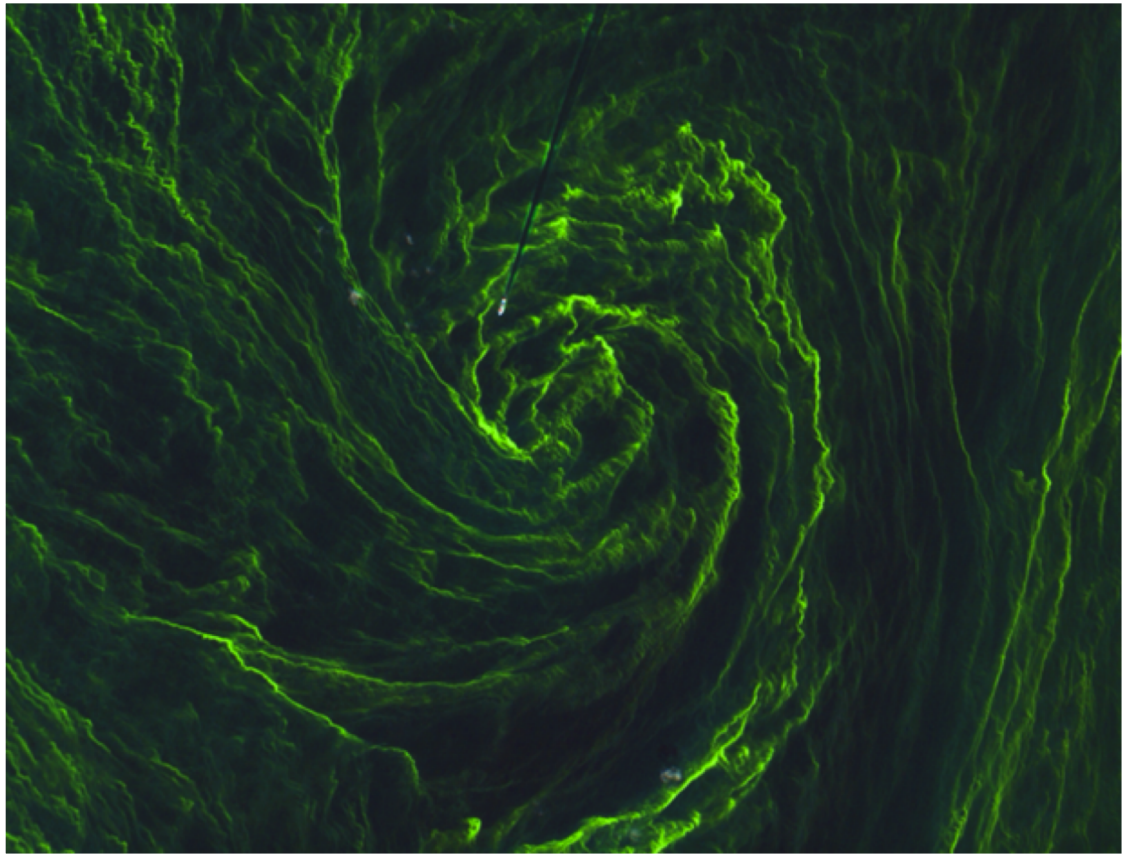
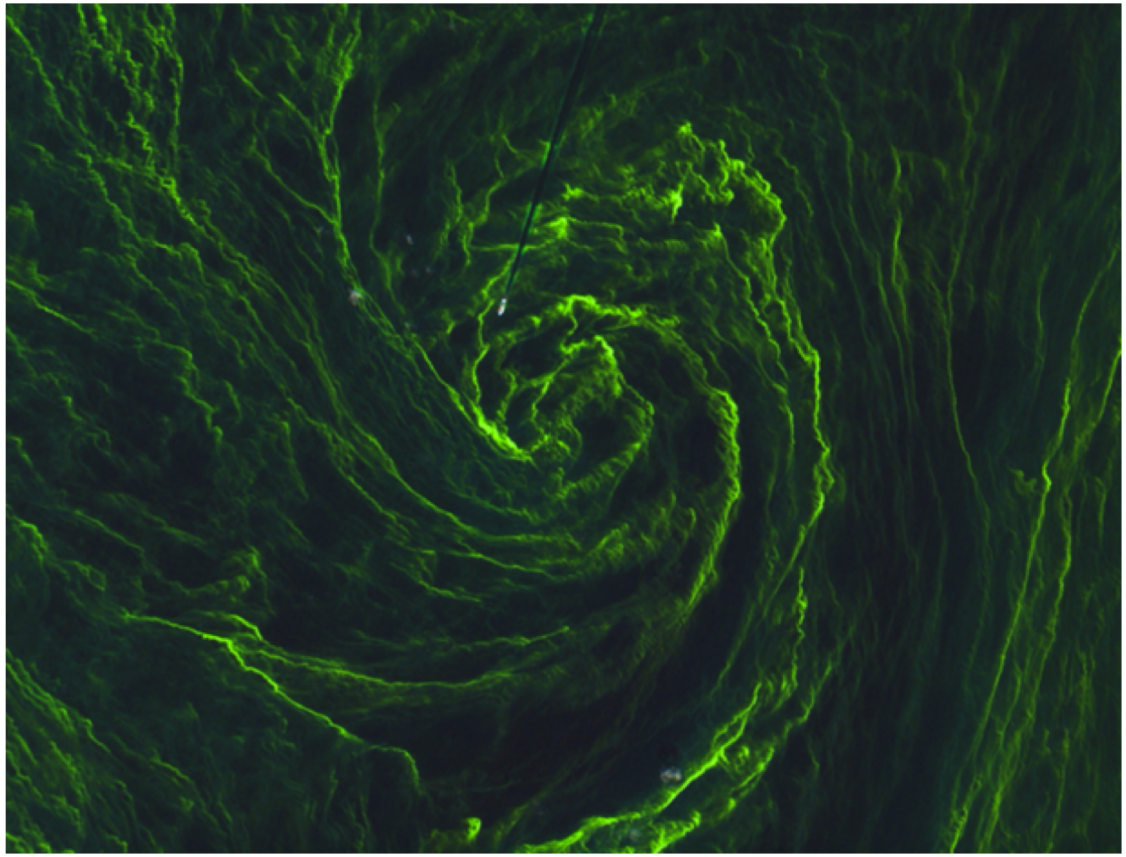


Algal bloom in the Baltic Sea (7 August 2015), with details down to 10 metres resolution. Such resolution in multiple bands allows Copernicus services to monitor biological activity in European regional seas (Sentinel-2A was optimised for land applications, but revealed itself a valuable tool for monitoring ocean colour as well).

Exercise

- Mediterranean and Baltic are two different worlds in term of biogeochemical dynamics, but some challenges they face are common: **toxic pollutants** and **harmful algal blooms** may affect ecosystem, aquaculture and tourism.
- Toxicity can be linked to algal blooms, which are operationally monitored by different research teams, usually by ships.
- Satellites may instead provide a more informative synoptic view, that can be also integrated by the forecast modelling systems, as that one managed by OGS within CMEMS.



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Stable meteo-marine conditions (warm weather and calm seas) occurred during summer 2015 increased the biological activity in the central Baltic Sea, with a specific dominance of cyanobacteria. In this area, blooms can appear as greenish streaky or vortical structures following density gradients, that may help to identify the biological activity, as specifically shown in this image.

Take home messages

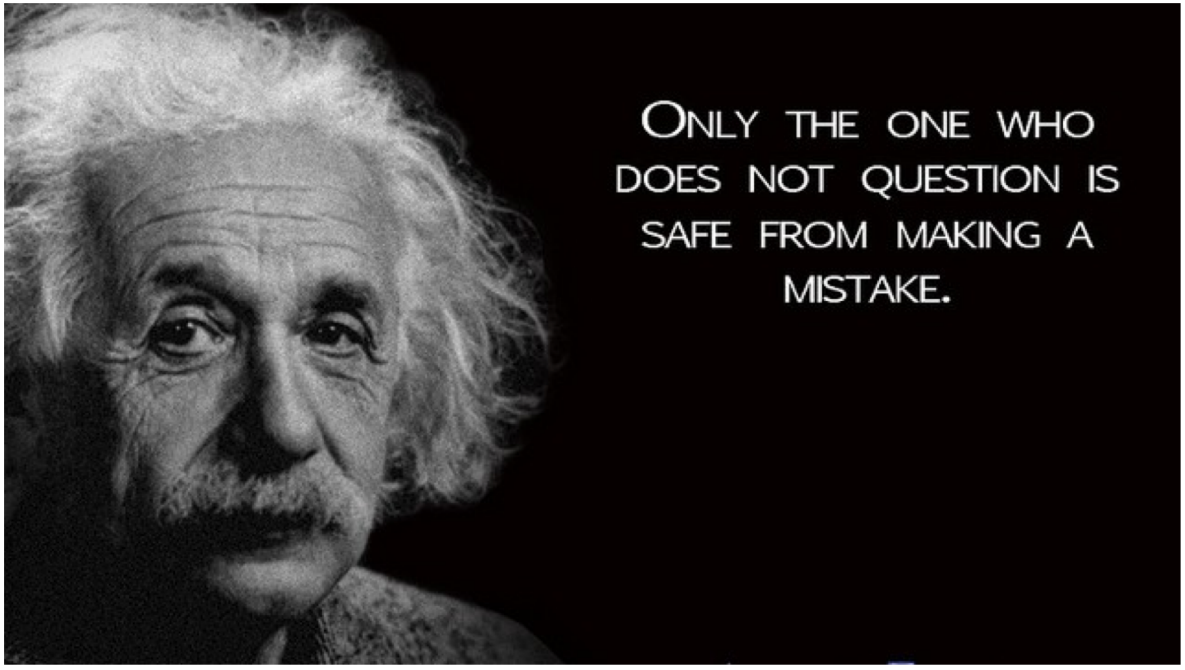
- **Blue Growth has economical and societal impacts: DATA are essential to support the sustainable development of the activities in the coastal areas**

- **Marine Copernicus (CMEMS) is a full, free and open access service that provide information and data on the status of marine environment**

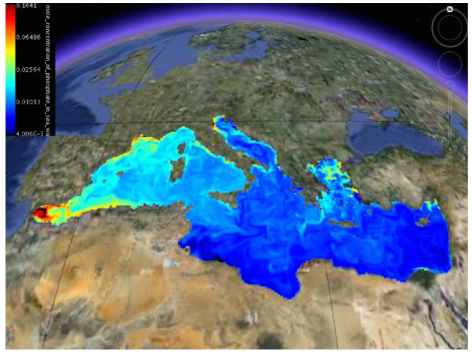
- **Information on physical, biogeochemical and wave status of the European seas and Global ocean**

- **Mix of observing and model systems spanning from the past decades to near-time forecast**

- **Knowledge of the quality and appropriateness of a CMEMS product is necessary to properly and efficiently use/exploit CMEMS information**



THANKS!



The CODATA-RDA Research Data Science Advanced Workshops on Climate Data Sciences
ICTP, Trieste, 23 August 2019