THE SCIENCE OF OCEAN PREDICTIONS AND ITS APPLICATIONS TO THE MEDITERRANEAN SEA

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SUMMARY

1. The prediction problem and history
2. The European Copernicus/GMES Marine Service
3. The Mediterranean Sea implementation
4. The downstream services

The Grand Challenges of the Earth system Science

From the Earth System Science for Global Sustainability: The Grand Challenges, ICSU, 2010

What is it that I really seek? Whither am I steering?

the thought

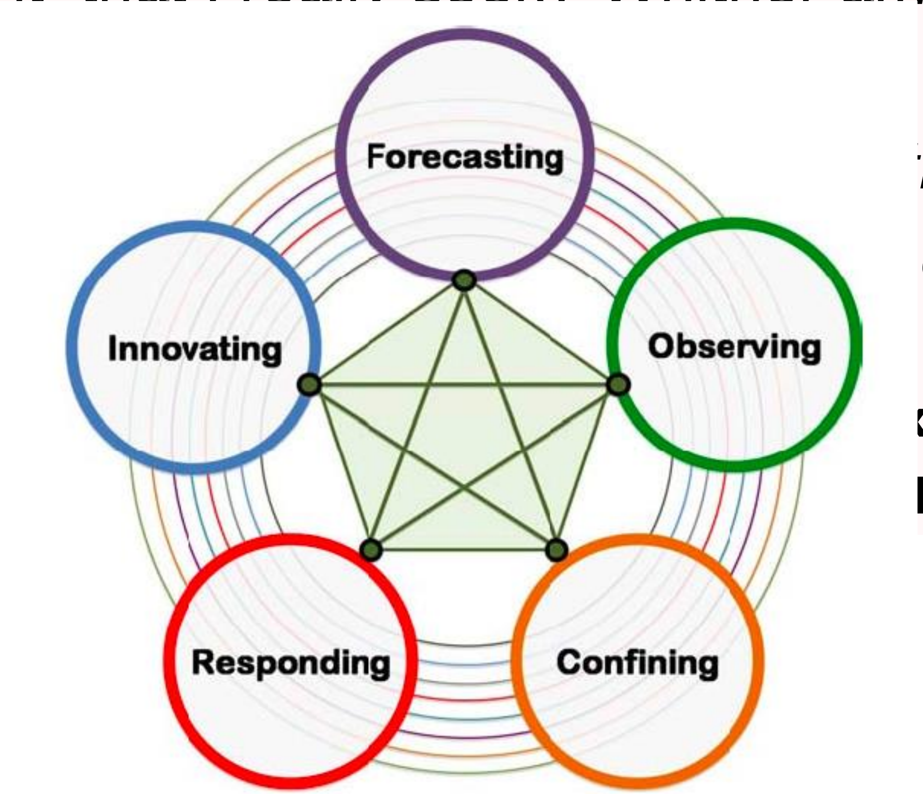
that “There

h attacking,

conditions.”

act science’,

Review, 1914



The forecasting/prediction problem definition

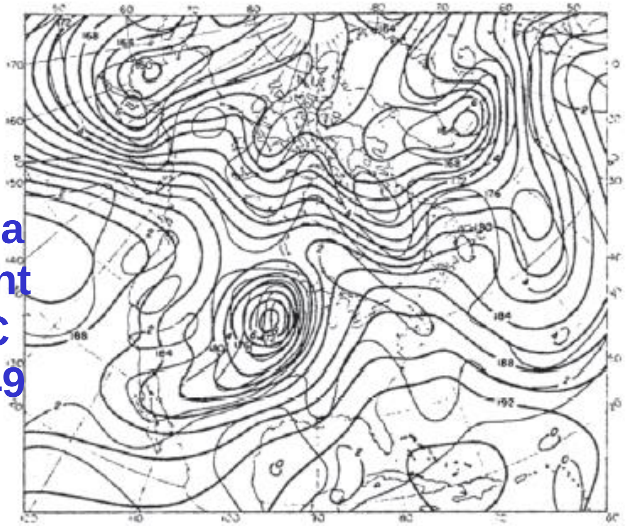
- Bjerknes defined the prediction problem as the discovery of *"the laws according to which an atmospheric or hydrospheric state develops out of the preceding one"* and the "precalculation of future states" from gridded analyzed observations
- Two conditions should be fulfilled in order to solve the prediction problem in the atmosphere and oceans
  - I- Know the present state of the system as accurately as possible
  - II- Know the laws of physics that regulate the time evolution of the basic field state variables, i.e. have predictive models for atmosphere and oceans

The prediction problem definition (cont.)

- In order to solve the *prediction problem* the scientific approach should consider 3 partial problems (the three ‘pillars’)
  - **Comp 1: The observational network**
  - **Comp. 2: The diagnostic and analysis tools/algorithms**
  - **Comp. 3: The prognostic component**
- **Comp 1: The observing network should be as comprehensive as possible in order to resolve time and space scales of motion and number of field state variables**
- **Comp. 2: The diagnostic/analysis component should be developed to bring observations into a ‘*regular grid*’ representation consistent with the prognostic component (objective analysis and data assimilation techniques)**
- **Comp. 3: the laws of physics have to be re-written in a numerical form capable to predict the future.**

The atmosphere was first: Princeton 1950

Analysis of 850 hPa Geo. Height 03:00 UTC Jan 5, 1949



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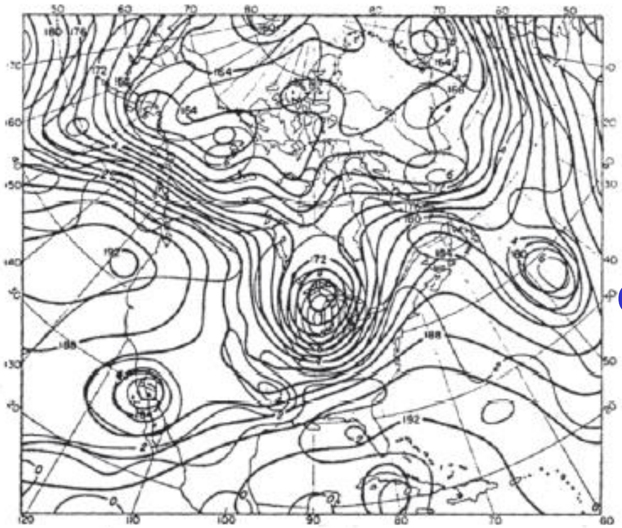
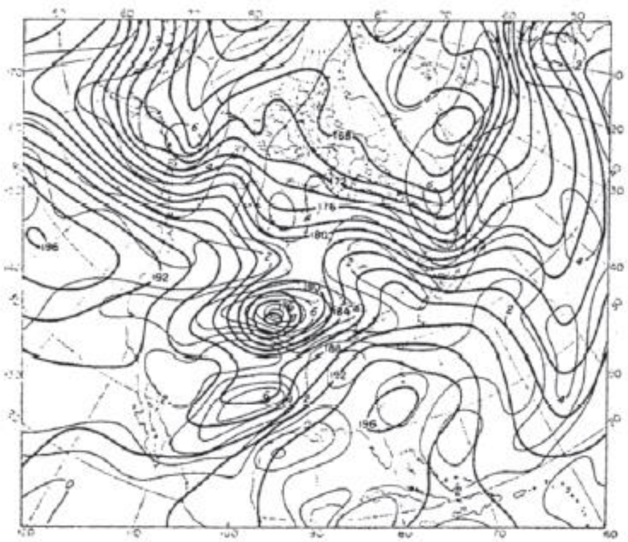


Analysis of 850 hPa Geo. Height 03:00 UTC Jan 6, 1949

The key choice: barotropic quasigestrophic numerical model

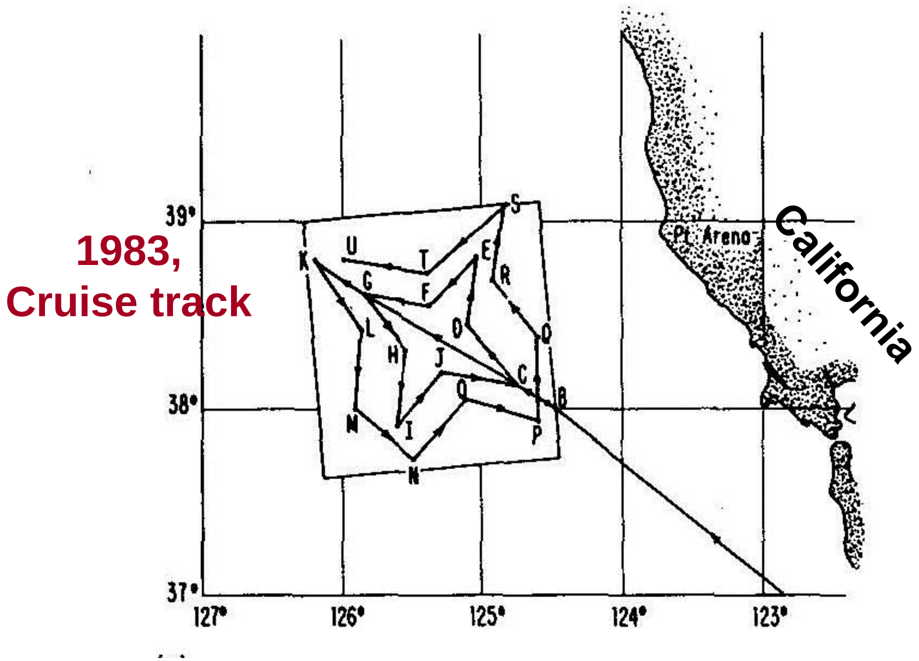
$$\frac{Dq}{Dt} = -\vec{v}.\nabla q - \beta\frac{\partial\psi}{\partial x} + diss$$

$$q = \nabla^2\psi$$



Forecast of 850 hPa Geo. Height 03:00 UTC Jan 6, 1949

The first ocean forecast: Harvard and Monterey 1983

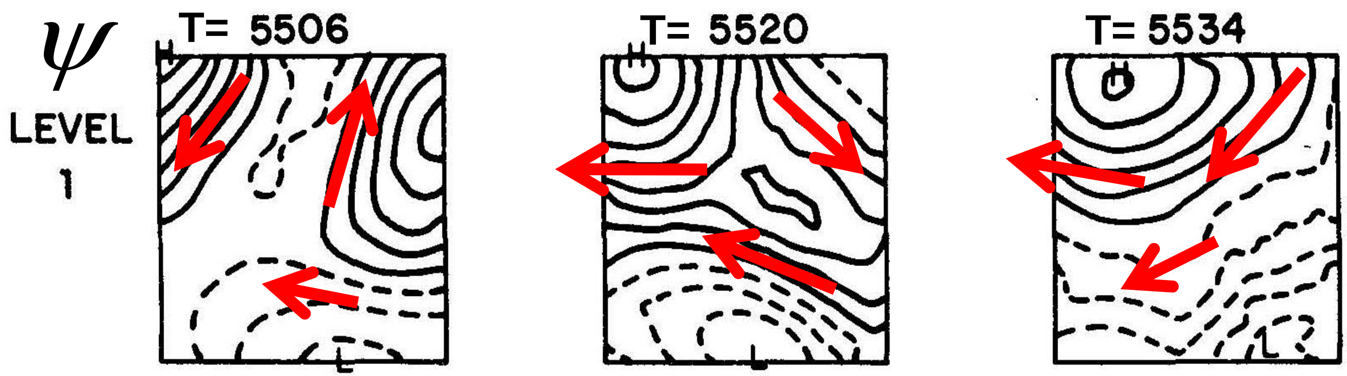


The key choice:

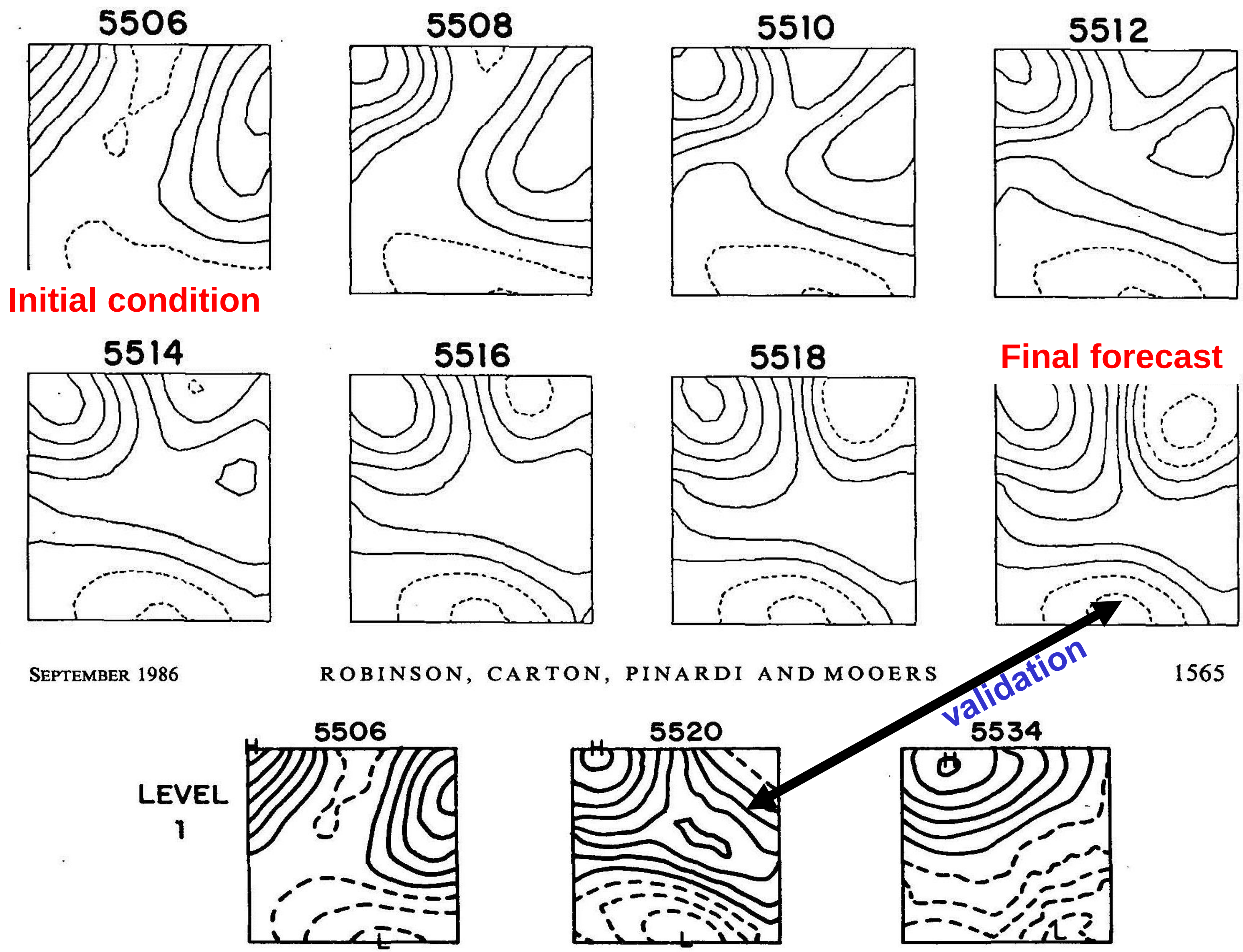
1) synoptic data for initial conditions

2) baroclinic multilevel quasigeostrophic model

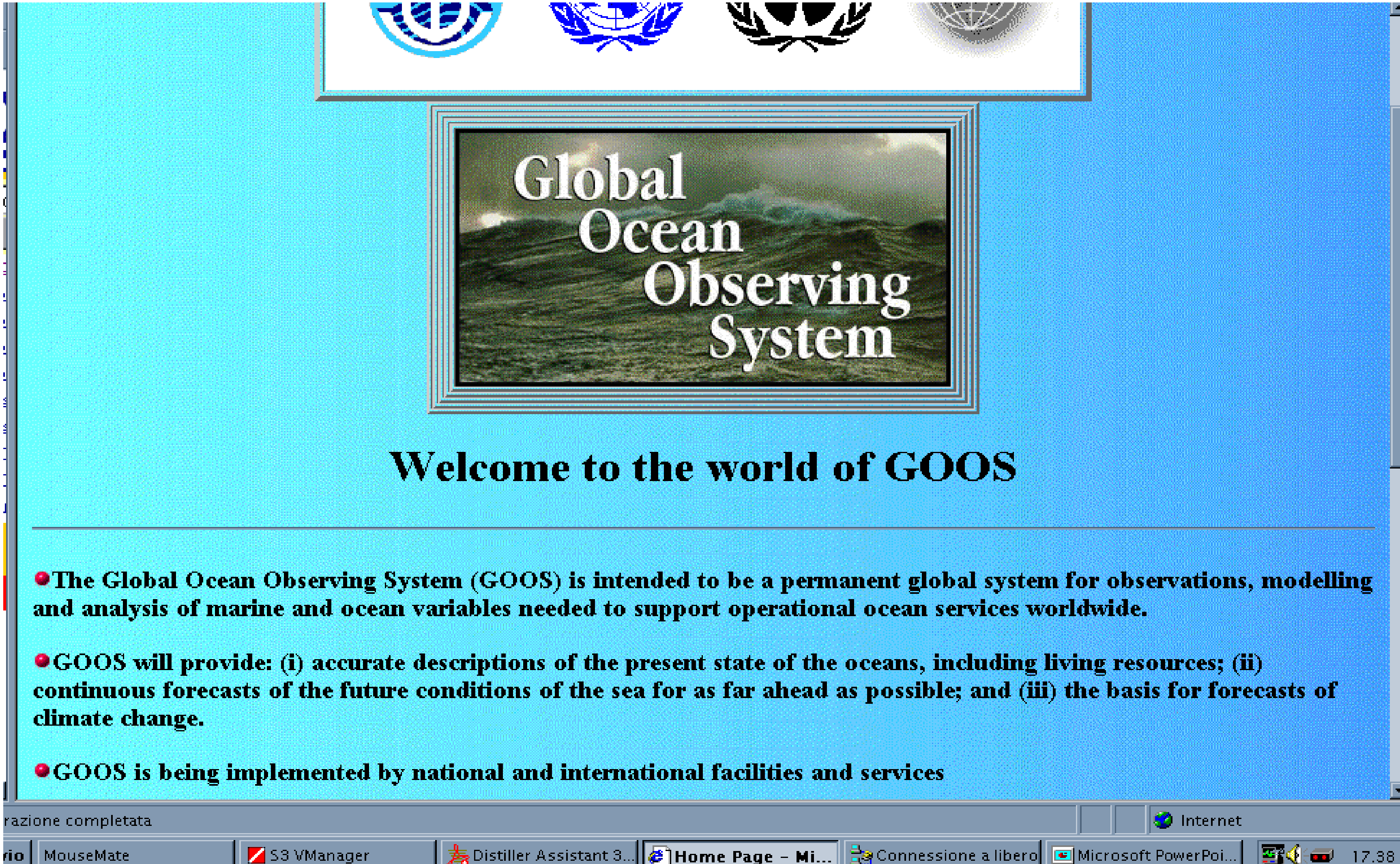
SEPTEMBER 1986 ROBINSON, CARTON, PINARDI AND MOOERS



The first ocean forecast: Harvard and Monterey 1983



Ocean predictions: operational oceanography starts in the 90s



The fusion of the science of predictions with the Operational Oceanography approach

3 pillars of prediction science

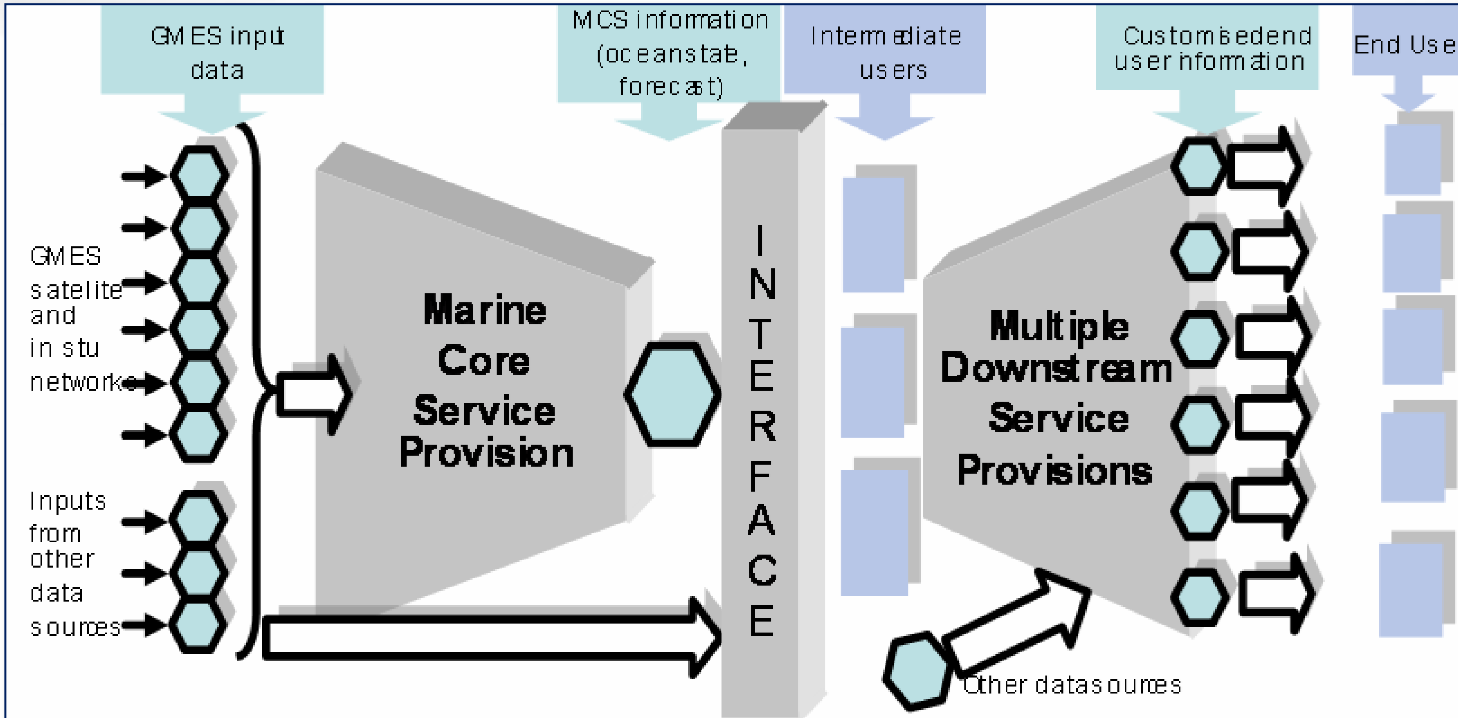
Multidisciplinary Multi-platform Observing system (permanent and relocatable)	Numerical models of hydrodynamics and ecosystem, coupled a/synchronousl y to atmospheric forecast	Data assimilation for optimal field estimates and uncertainty estimates

2 pillars of operational oceanography

Continuos production of nowcasts/forecasts of relevant environmental state variables

The service to users and the incorporation of user feedbacks to enhance product quality

The European solution: Copernicus/GMES Marine Service



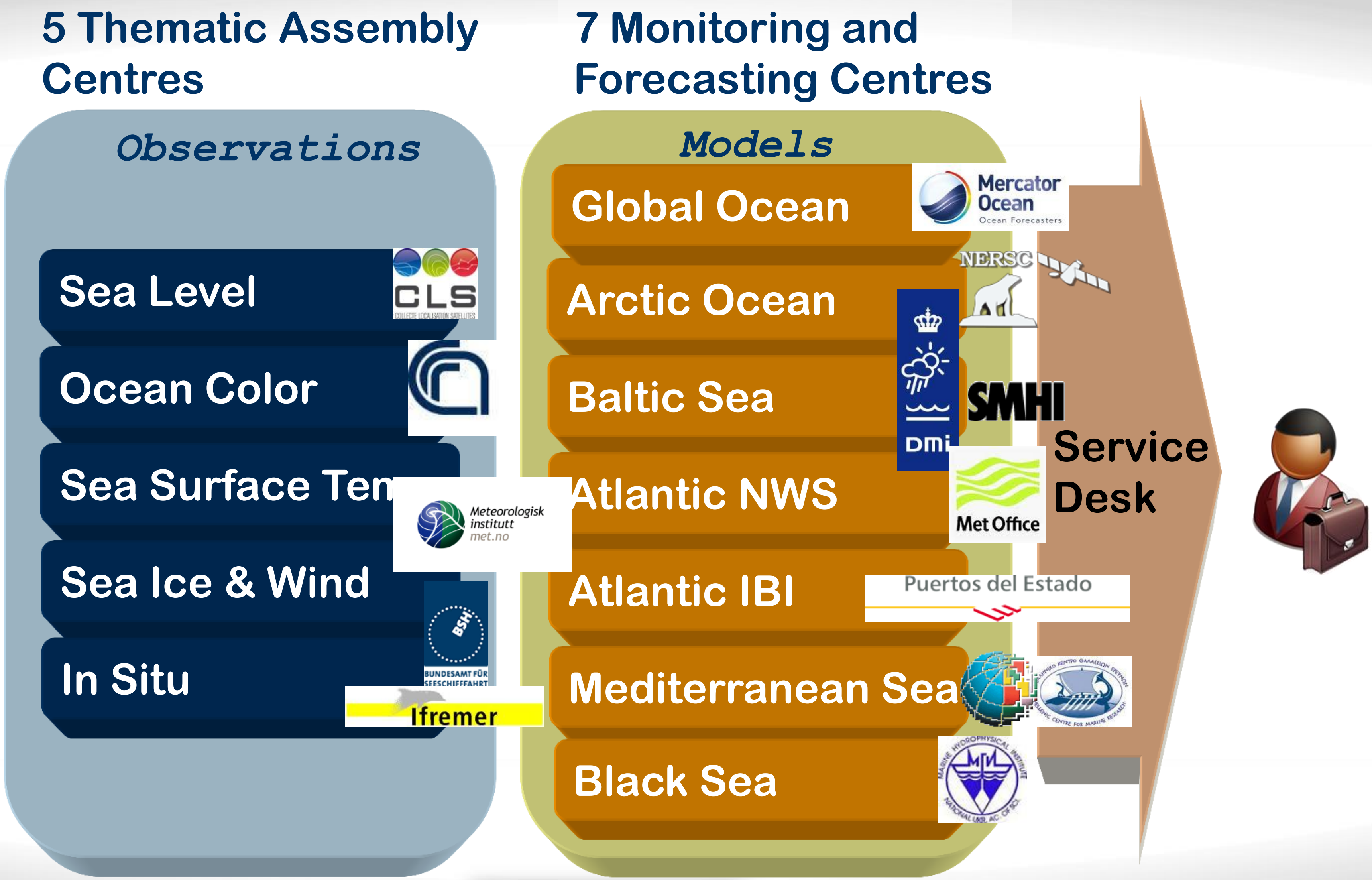
Marine Core Service Implementation Group (April 2007)

A two-fold strategy for community-defined essential state variables

❶ An operational production & service

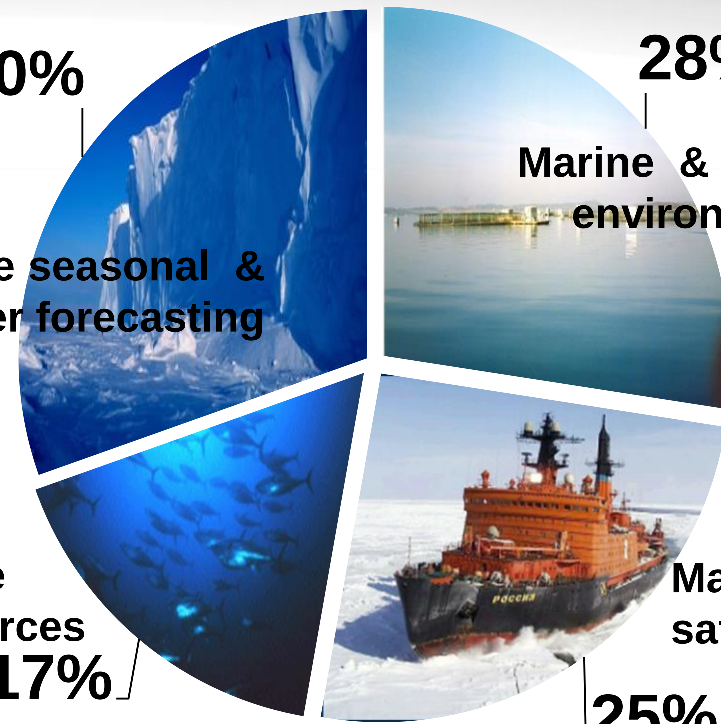
❷ A continuous dialog with users

The Copernicus/GMES Marine Service: a pan-European network organization



The Copernicus/GMES Marine Service: stakeholders and end-users

2300 Users in 92 different countries (US:141; CA:40)

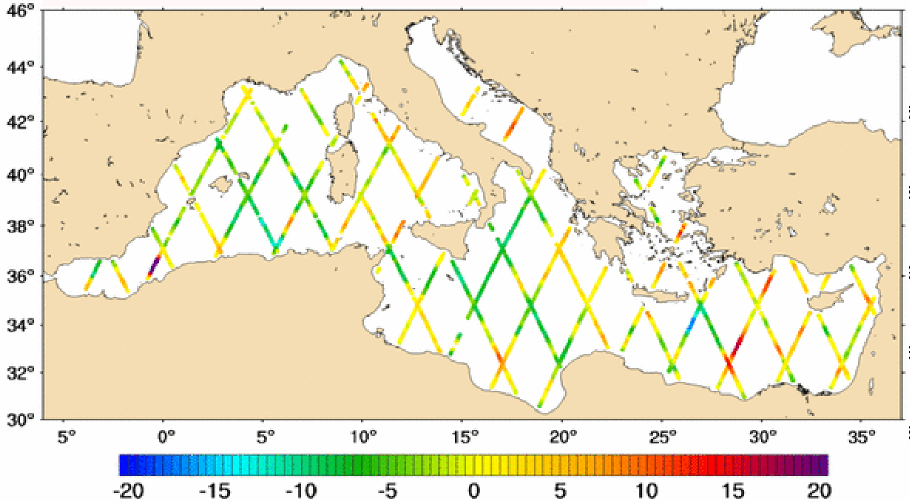


A fair repartition in application areas

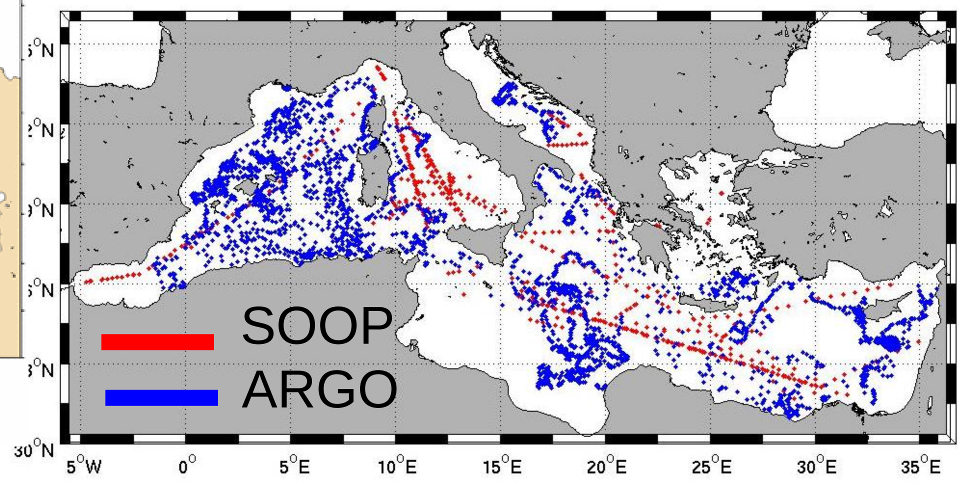
70% of users using the service in more than one sector

The Copernicus Marine Service implementation in the Mediterranean: the observational component

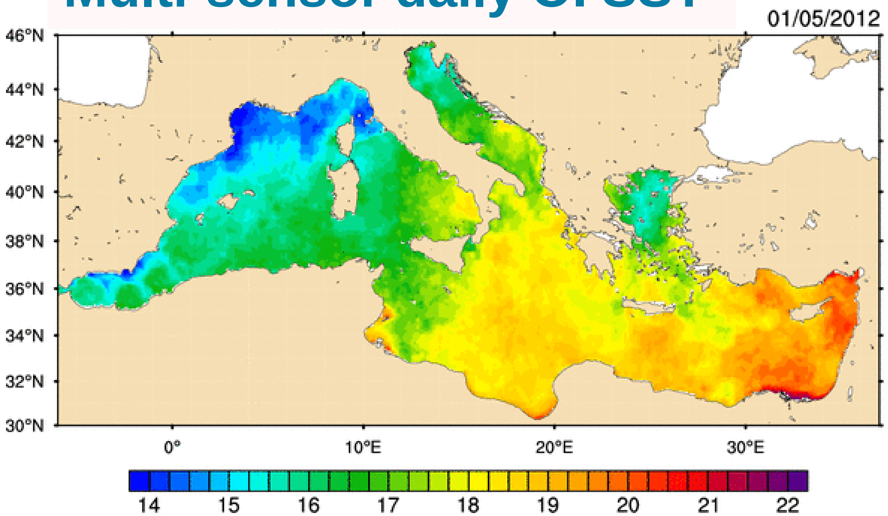
Satellite altimetry SLA



coverage for the 2008-2011



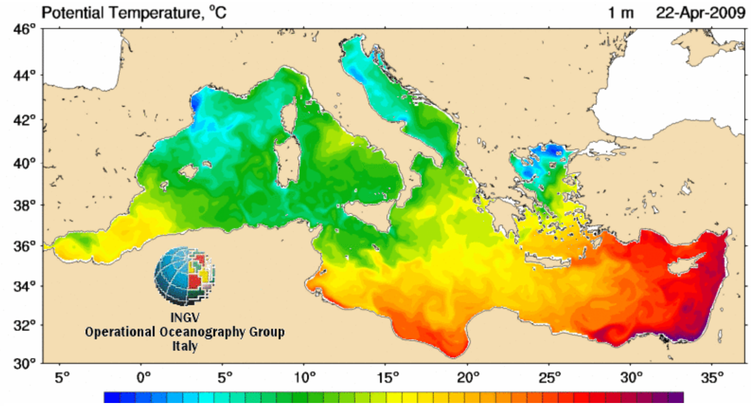
Multi-sensor daily OI SST



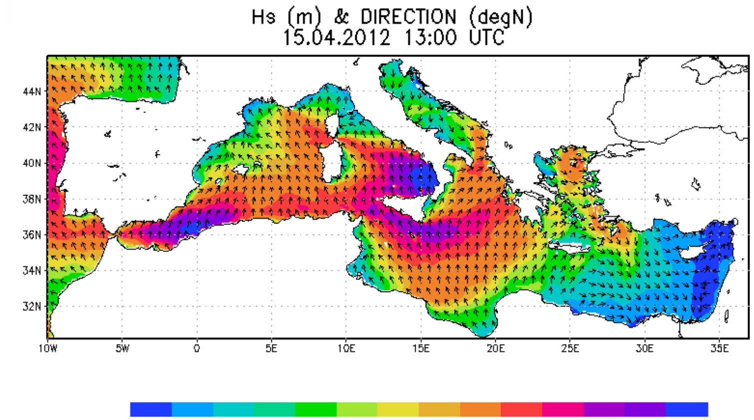
Real Time multidisciplinary coastal Buoys (sea level, T,S V, etc.)

The Copernicus Marine Service implementation in the Mediterranean: the modeling component

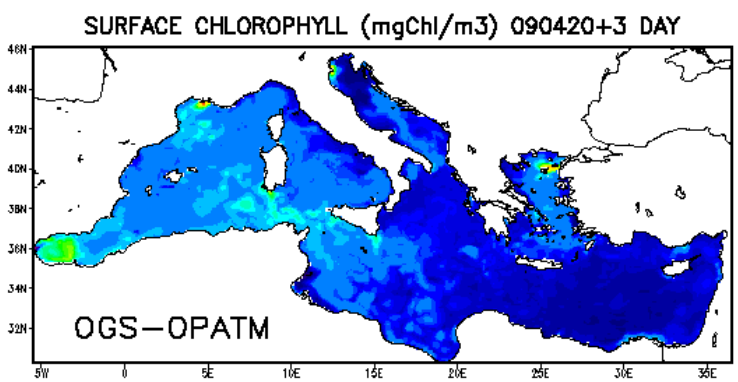
A) Hydrodynamics



B) Waves



C) Pelagic Biochemistry



The Copernicus Marine Service implementation in the Mediterranean: the analysis component

Method is variational, so-called 3DVAR

(Dobricic and Pinardi, 2008)

$$J = \frac{1}{2}\delta\mathbf{x}^T\mathbf{B}^{-1}\delta\mathbf{x} + \frac{1}{2}\left[\mathbf{H}(\delta\mathbf{x}) - \mathbf{d}\right]^T\mathbf{R}^{-1}\left[\mathbf{H}(\delta\mathbf{x}) - \mathbf{d}\right]$$

$$\delta\mathbf{x} = \mathbf{x} - \mathbf{x}_b \qquad \mathbf{d} = \left[H(\mathbf{x}_b) - \mathbf{y}\right]$$

Preconditioning is done using a control vector v defined by:

$$\mathbf{v} = \mathbf{V}^{+}\boldsymbol{\delta}\mathbf{x} \qquad \mathbf{B} = \mathbf{V}\mathbf{V}^T$$

$\mathbf{V}$ **is modelled as a sequence of linear operators:** $\mathbf{V} = \mathbf{V}_D\mathbf{V}_{uv}\mathbf{V}_\eta\mathbf{V}_H\mathbf{V}_V$.

$\mathbf{V}_V$ - **Vertical EOFs.**

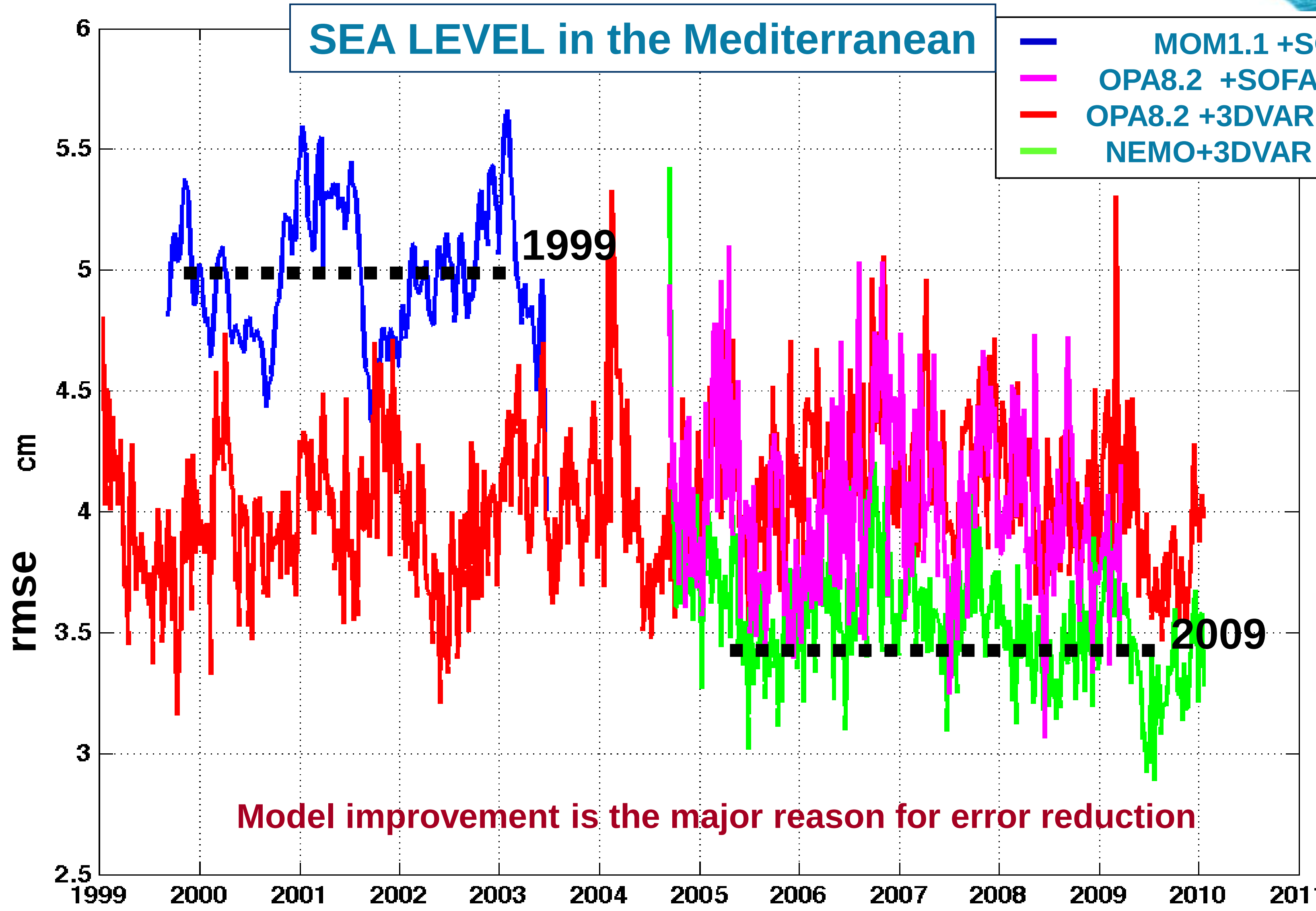
$\mathbf{V}_H$ - **Horizontal covariances.**

$\mathbf{V}_\eta$ - **Barotropic model for eta**

$\mathbf{V}_{uv}$ - **Diagnose u and v.**

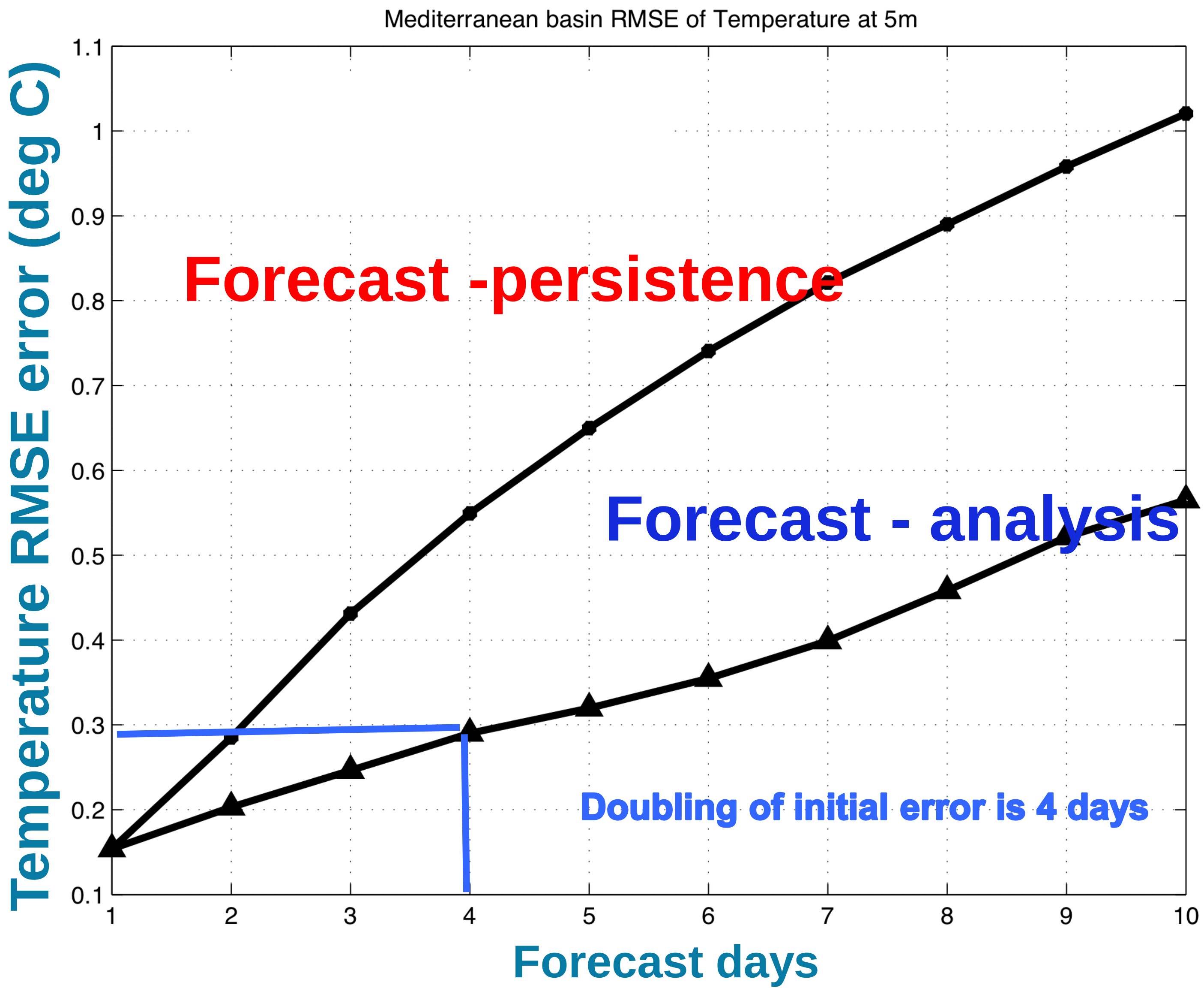
$\mathbf{V}_D$ -**Divergence damping filter.**

How did the error decrease in the last 10 years?

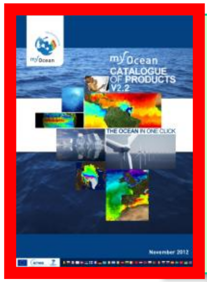


30% error decrease

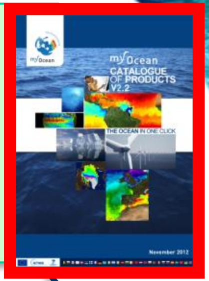
Ocean predictability for the mesoscale temperature



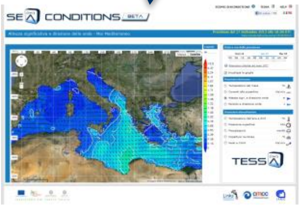
Downstream Services:
the ultimate way to assess quality of forecast

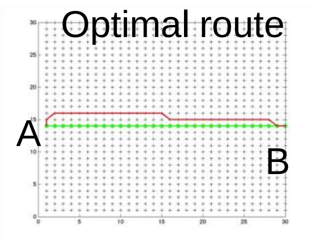


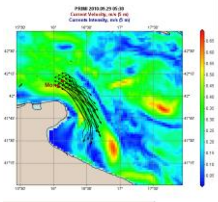
MARINE SERVICE DATA WAREHOUSE (DISCOVER, DOWNLOAD)

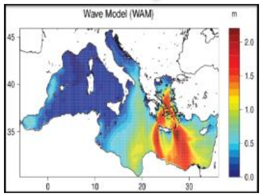


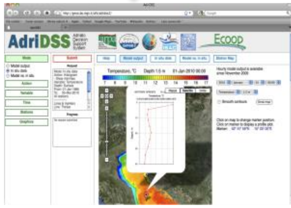
- Sea-Conditions
- DSS Oil spill
- DSS Ship routing
- DSS search and rescue
- DSS early warning
- DSS env. quality









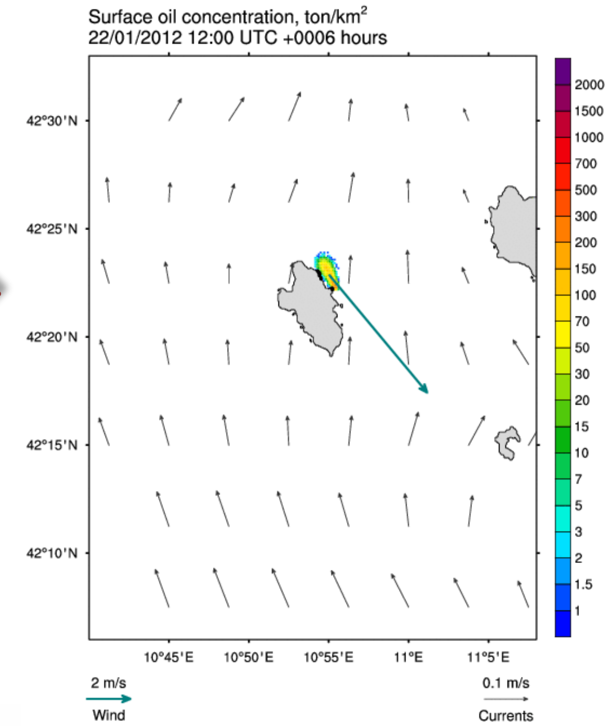


MyOcean downstream application: Costa Concordia accident response

- MyOcean – Daily scenario forecasts of the possible oil spill drift and spreading

Currents forecasted in the area → **Oil spill scenario derived locally** → **Decision support for operations**

INGV



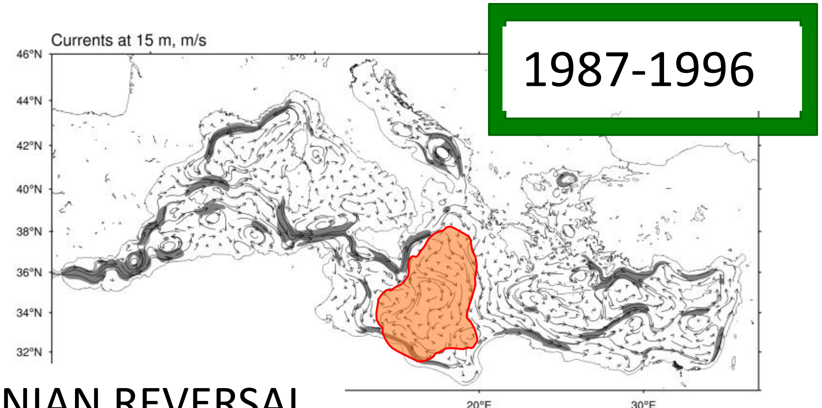
ITALIAN COAST GUARD HEADQUARTERS

Comando Generale del Corpo delle Capitanerie di Porto

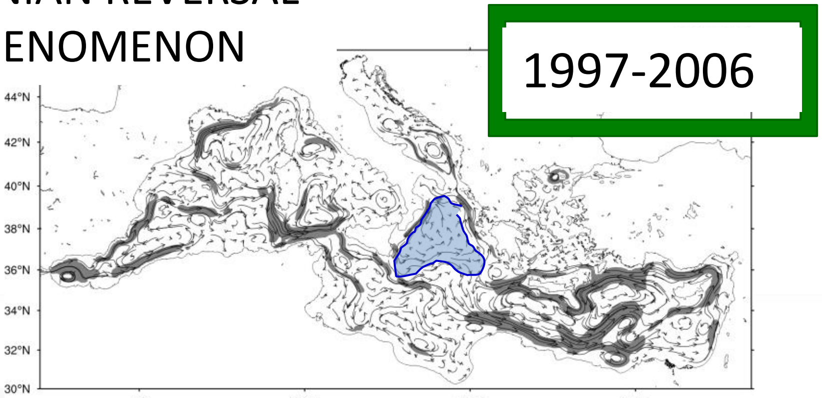
13th Jan 2012

MyOcean users:
R&D and environmental assessment community

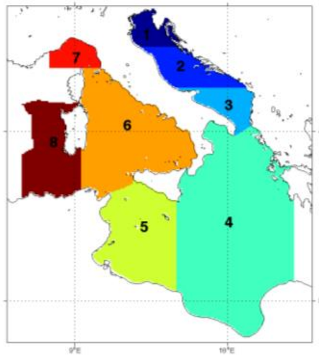
- MyOcean – re-analysis of the past twenty years Med Sea ocean state allows to assess GES



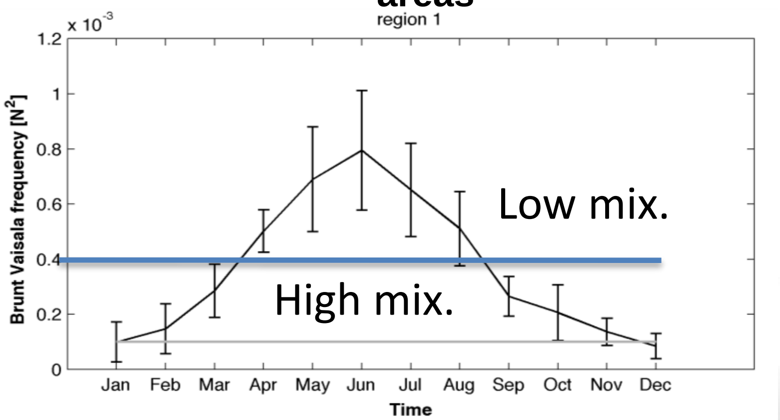
IONIAN REVERSAL PHENOMENON



Evaluation
of mixing indicator
from re-analysis
and for Italian Seas



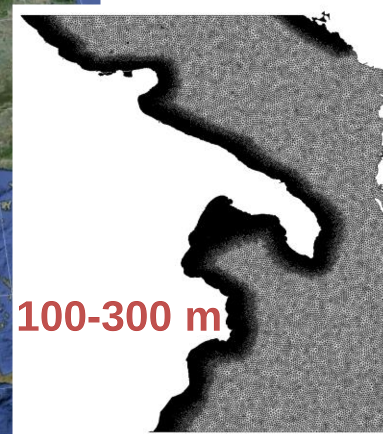
Italian Sea areas



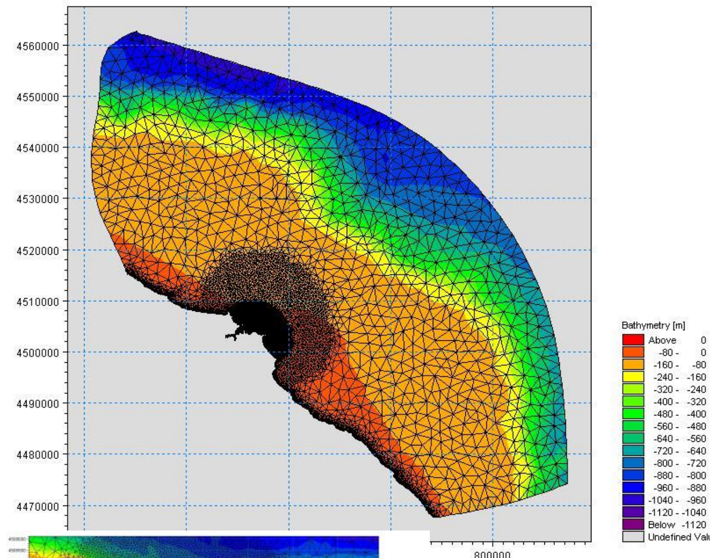
MyOcean downstream applications: modelling the ports for safe navigation

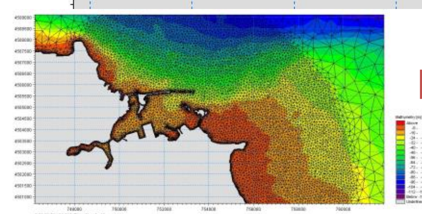
Currents forecasted in the area

MODEL GRID: 2 km



100-300 m





MODEL GRID: 10 m

Adding geometry and resolution where is needed without loosing the connection with the open sea

In conclusions

- Forecasting is at the basis of ocean innovation, responding and confining challenges in the ocean sciences.
- The Copernicus/GMES Marine Service provides a rational implementation of scientific and operational concepts at European level, the first in the world of this type
- Ocean forecasting is a reality in all European regional seas and users confirm interest in the services and products. More is needed to start new scientific and engineering integration programs