The science of ocean predictions: issues and perspectives

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SUMMARY

1. The prediction problem definition
2. A brief history of ocean prediction science
3. The today's challenges in the coastal zones

The prediction problem definition

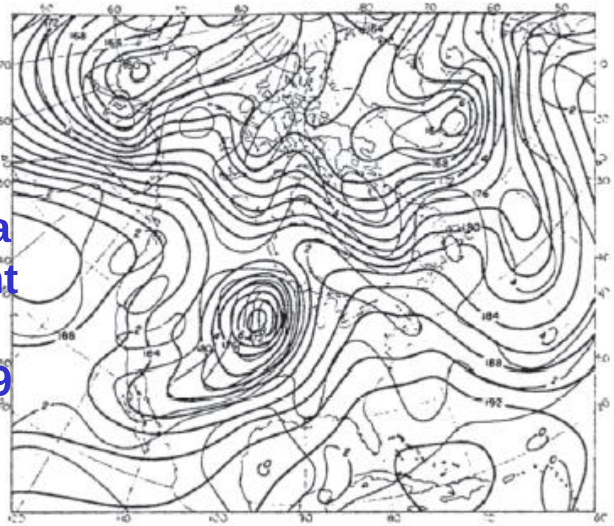
- Bjerknes (1911) defined the prediction problem the "*ultimate problem of meteorology and hydrography*"
- Bjerknes defined the prediction problem as the discovery of *"the laws according to which an atmospheric or hydrospheric state develops out of the preceding one"* and the "precalculation of future states" from gridded analyzed observations
- Two conditions should be fulfilled in order to solve the prediction problem in atmopshere 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

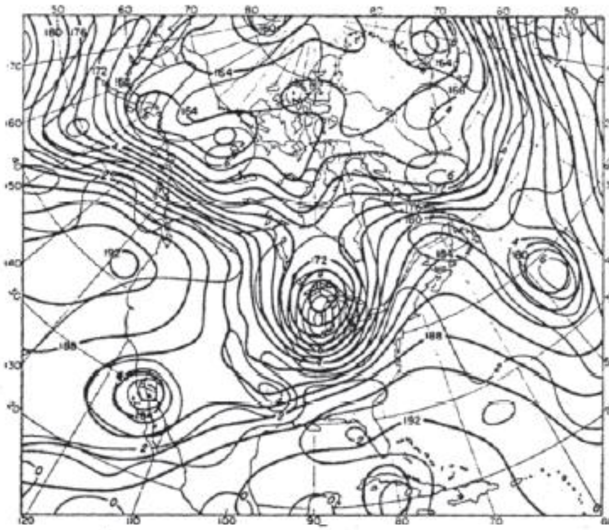
The prediction problem definition (cont.)

- In order to solve the *prediction problem* the scientific approach should consider 3 partial problems
  - **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.**

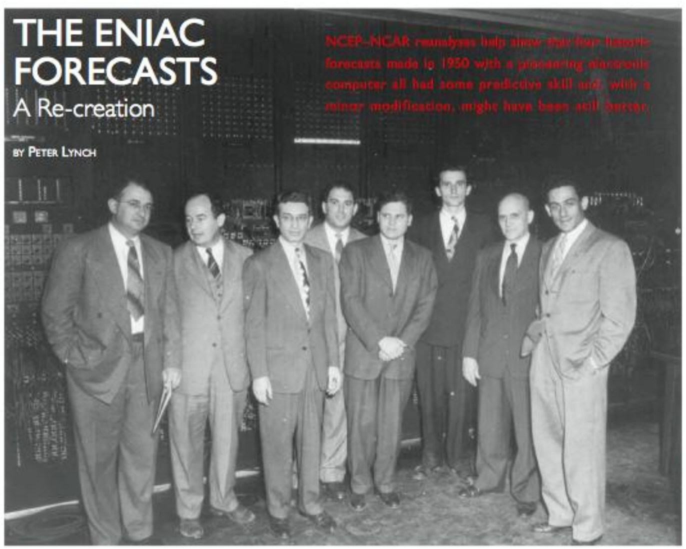
The first atmospheric prediction: Princeton 1950

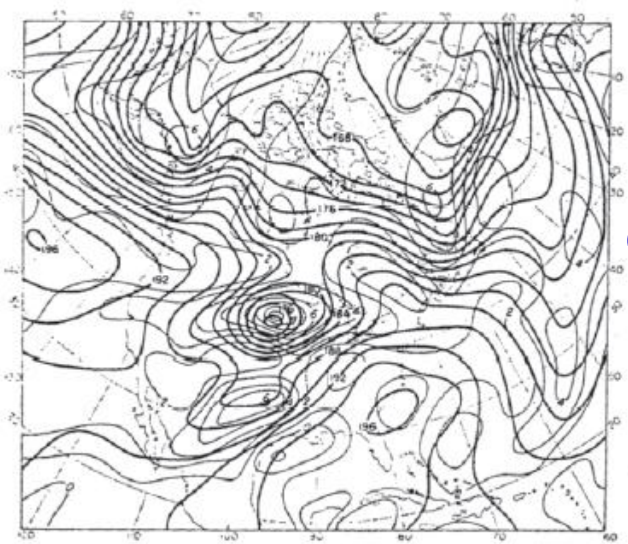
Analysis of 850 hPa Geo. Height 03:00 UTC Jan 5, 1949





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



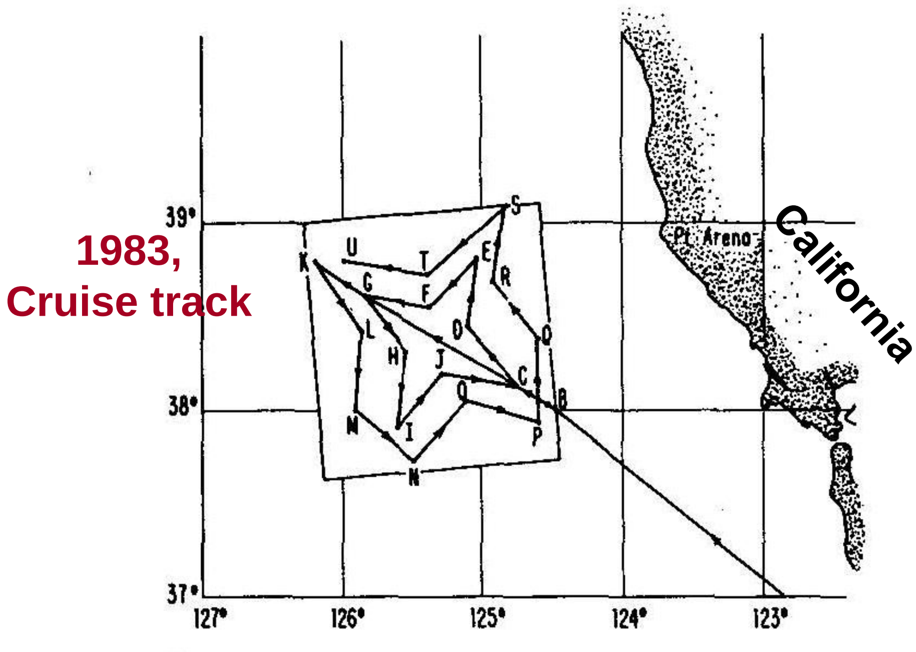


Forecast of 850 hPa Geo. Height 03:00 UTC Jan 6, 1949

The first oceanographic prediction: Harvard and Naval Postgraduate School, Monterey, 1983

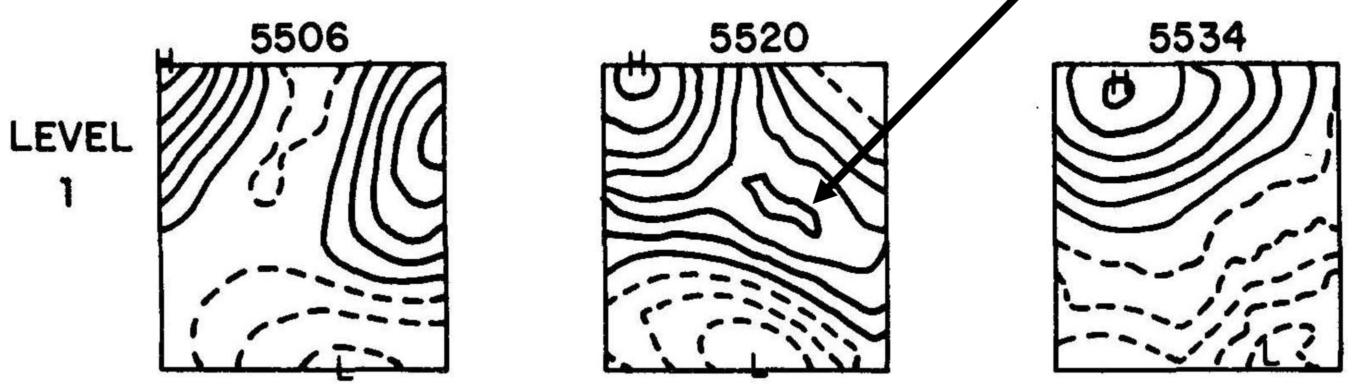
- Method was developed for a open ocean area offshore Point Arena in California
- Intensive data sets were collected for model initialization in restricted areas, as large as the computer could allow
- The forecast was released in real time
- The science question was: is it possible to forecast the highly nonlinear oceanic mesoscale flow field? If yes, for how long?

Ocean predictions: 1983, the first forecast in real time

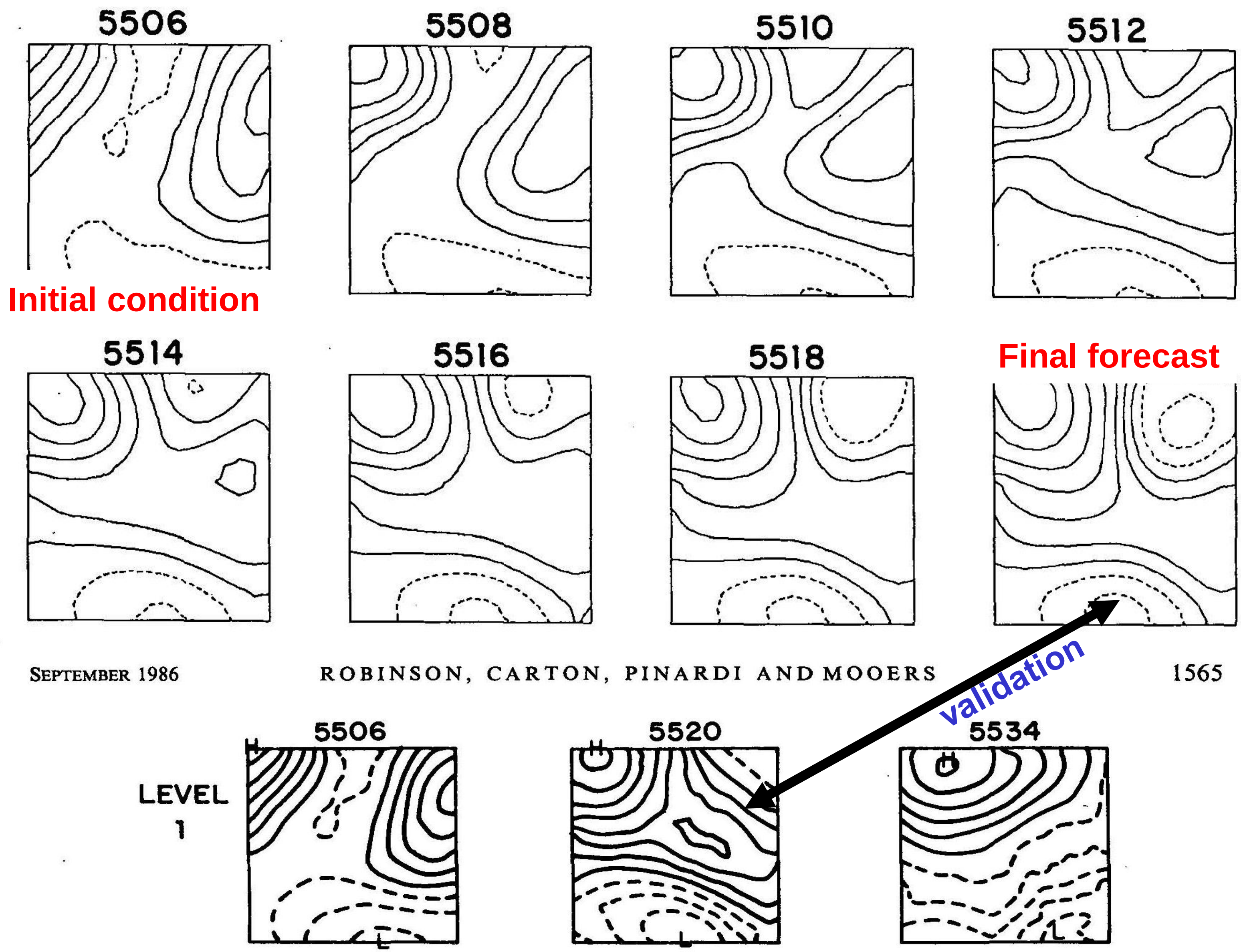


Collected data allows the calculation of an initial condition for the forecast and its validation

SEPTEMBER 1986 ROBINSON, CARTON, PINARDI AND MOOERS



Ocean predictions: 1983, the first forecast in real time



Ocean predictions: 1984, the Gulf Stream

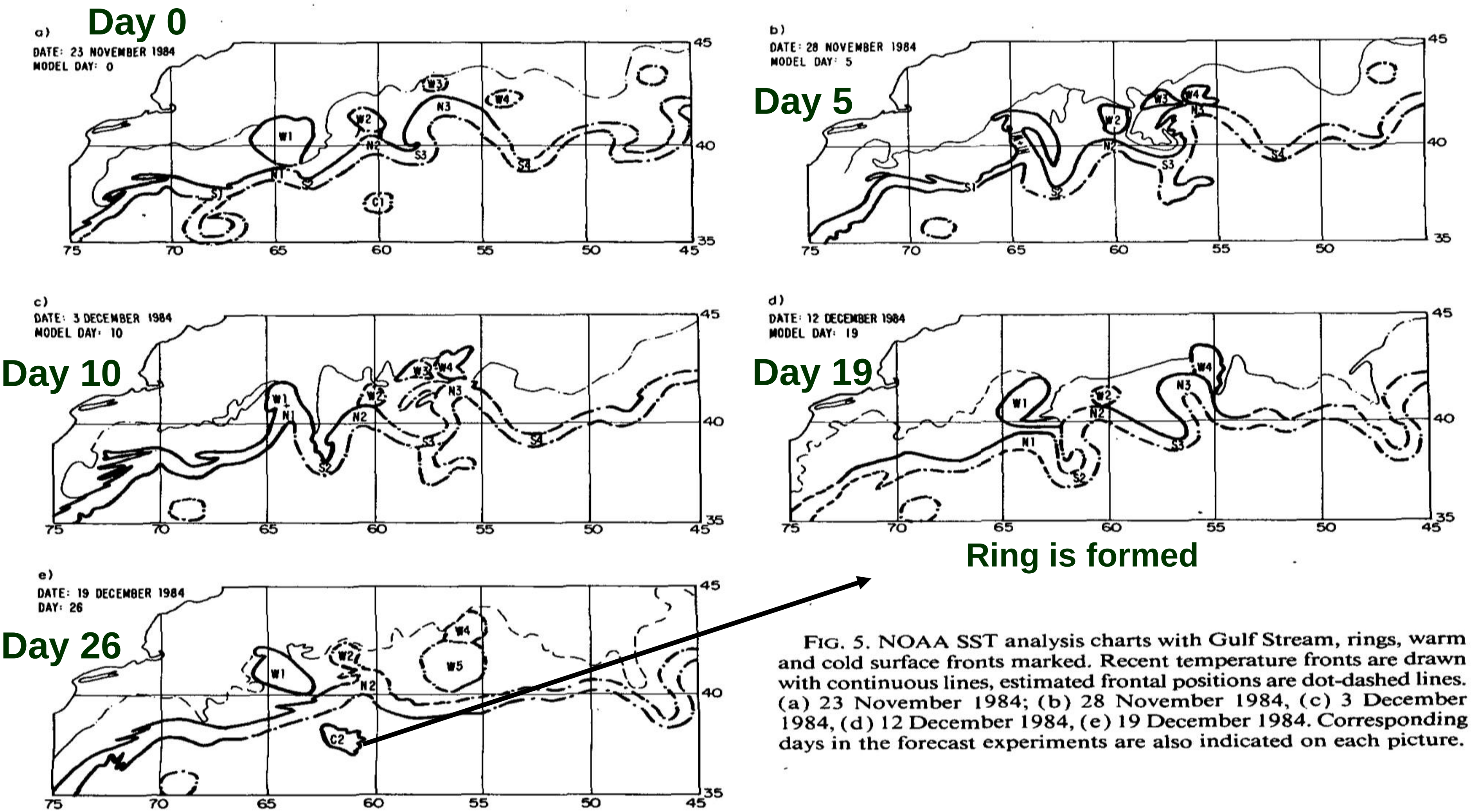


FIG. 5. NOAA SST analysis charts with Gulf Stream, rings, warm and cold surface fronts marked. Recent temperature fronts are drawn with continuous lines, estimated frontal positions are dot-dashed lines. (a) 23 November 1984; (b) 28 November 1984, (c) 3 December 1984, (d) 12 December 1984, (e) 19 December 1984. Corresponding days in the forecast experiments are also indicated on each picture.

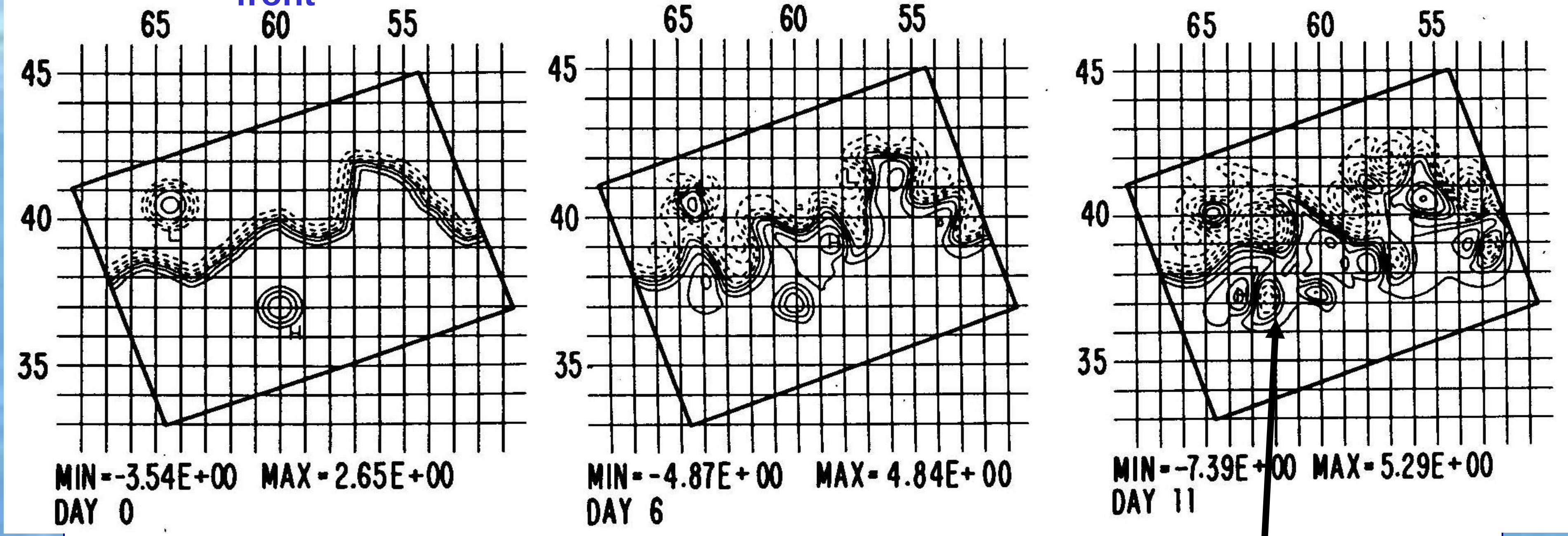
Goal: forecast the ring formation using satellite SST images information

Ocean Predictions: 1984, the Gulf Stream

Initial streamfunction representing Gulf Stream SST front

Forecast

Forecast



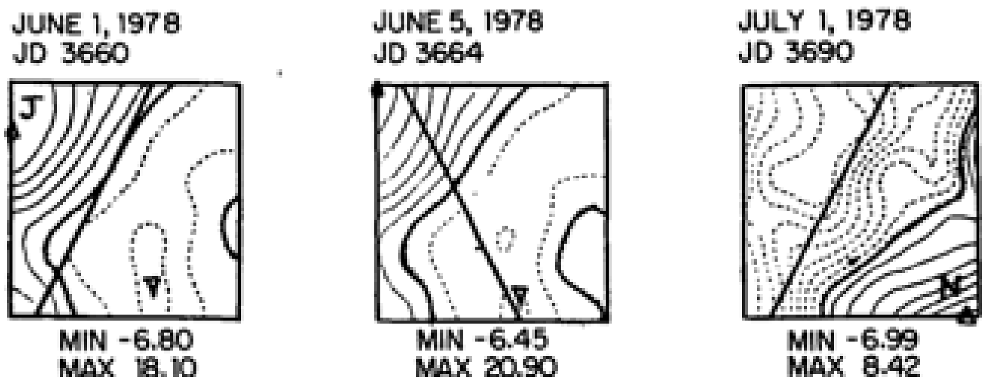
Newly born ring:
5-15 days before the observed one,
in the right position
and with the right vertical structure

1988, Journal of Physical Oceanography,
Robinson, A.R., M.A. Spall and N. Pinardi

Ocean predictions: 1983, ‘altimetry’ assimilation

1987, *Journal of Physical Oceanography,* 17(12), 2280-2293.
DeMey, P. and A.R. Robinson

Simulated altimeter Track Over realistic ocean eddy field



Mesoscale eddy field in the Atlantic Subtropical gyre

RMS error after initial assimilation of altimeter data

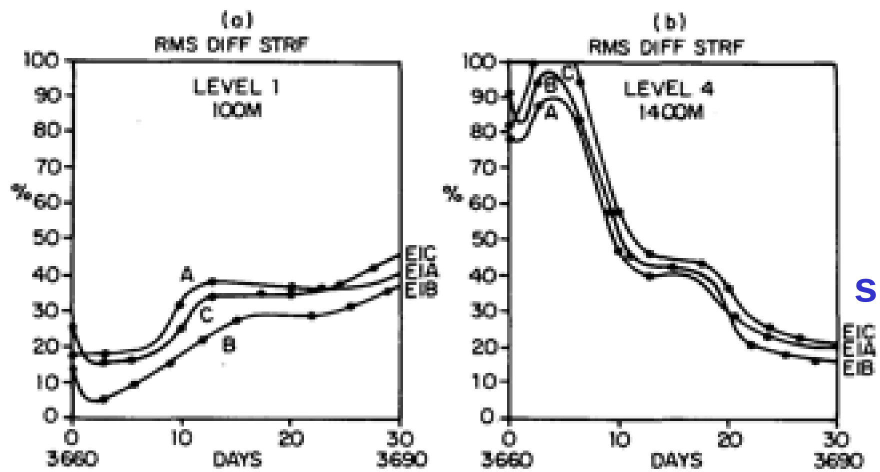
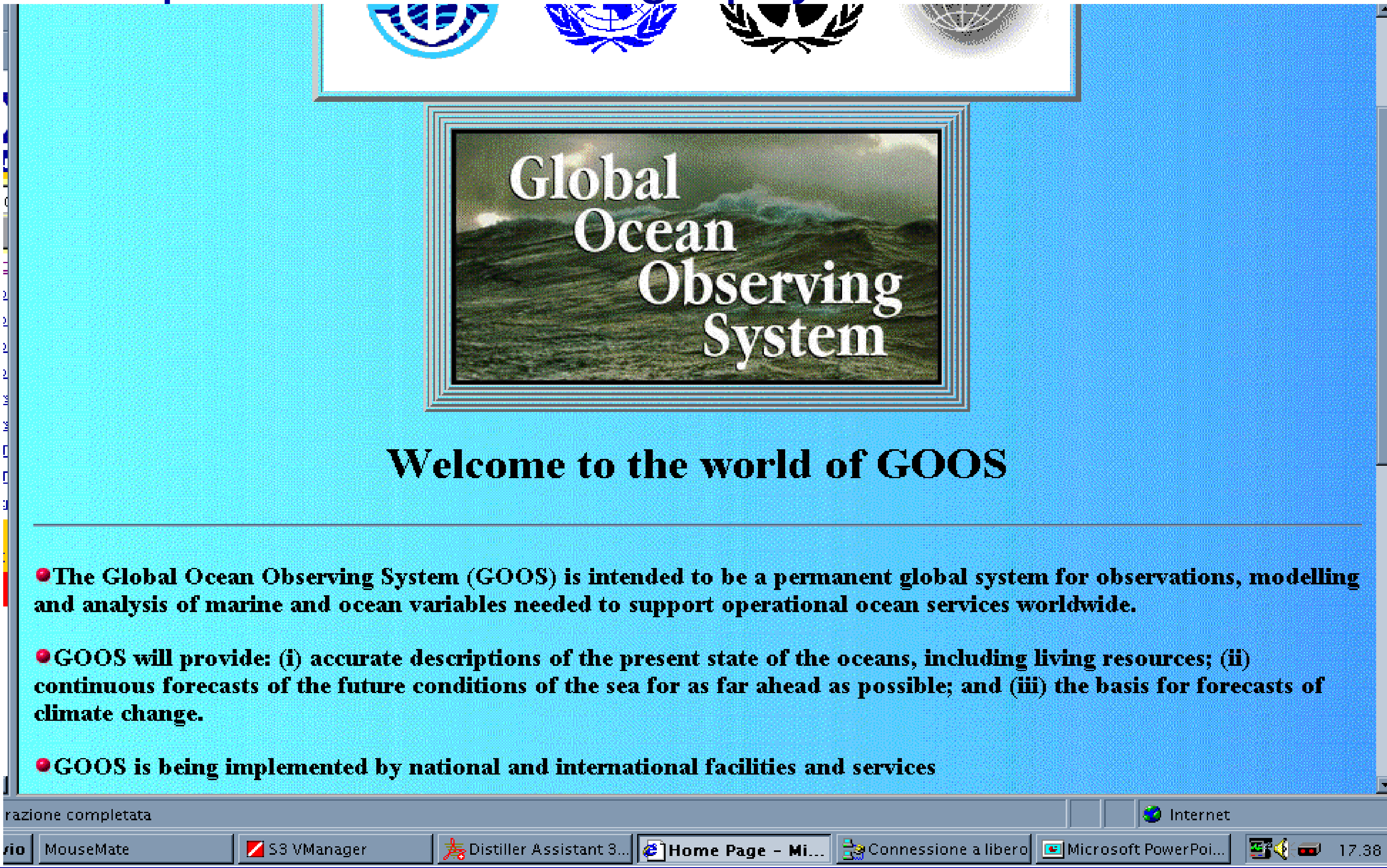


FIG. 13. Results of assimilation runs with bottom topography starting j.d. 3660. EI runs are shown. A simulated altimeter streamfunction is assimilated. Repeat cycle, revolutions per day. A: 10 days, 12 + 7/10; B: 22 days, 12 + 15/22; C: 17 days, 12 + 12/17. Inclination: 63.5°.

Extrapolation of surface information Via EOF

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/synchronously to atmospheric forecast**	**Data assimilation for optimal field estimates and uncertainty estimates**

2 pillars of Operational oceanography

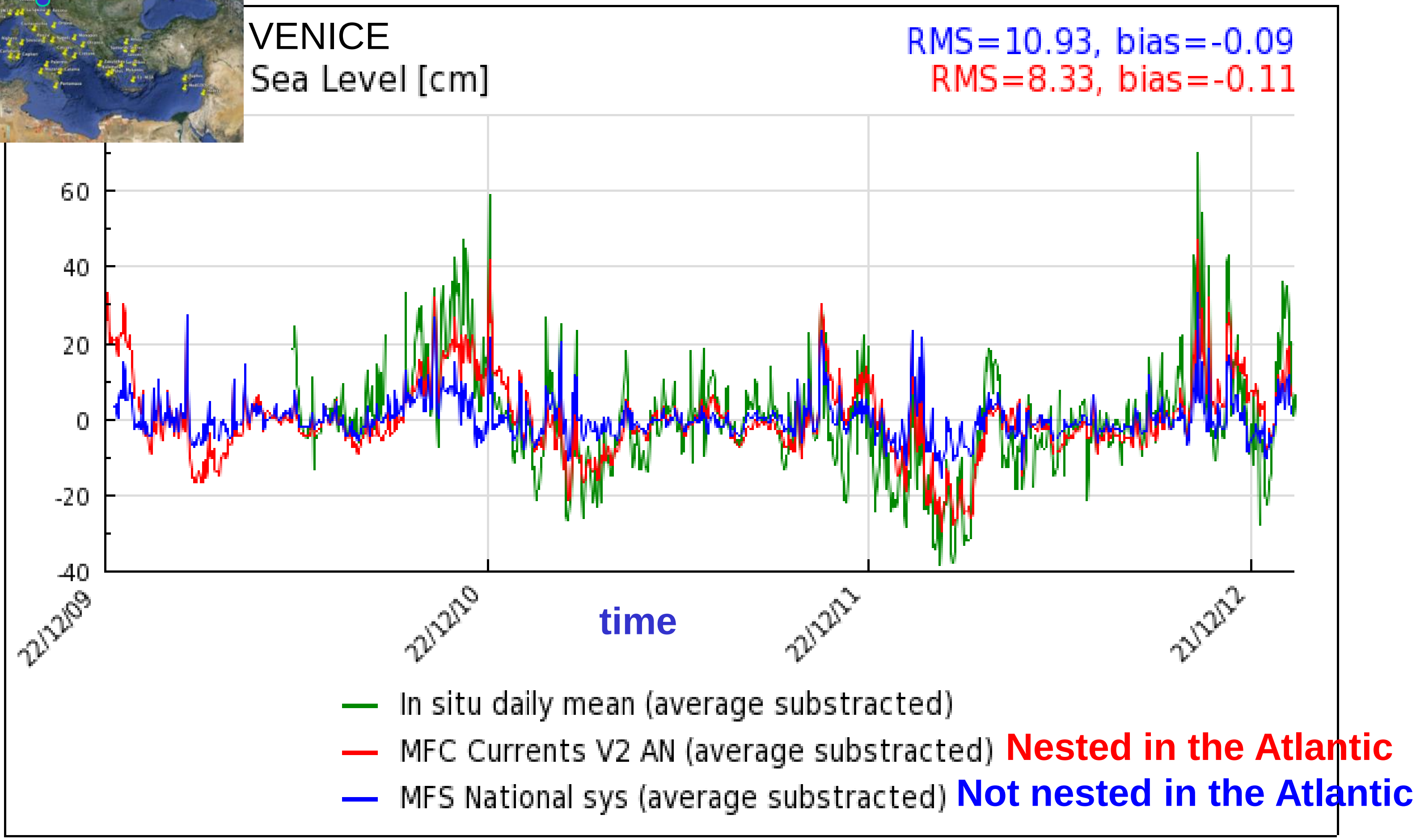
Continuos production of nowcasts/forecasts of relevant environmental state variables

The incremental approach:
from large to coastal space scales (NESTING),
weekly to monthly time scales

Challenges in coastal forecasting and operational oceanography

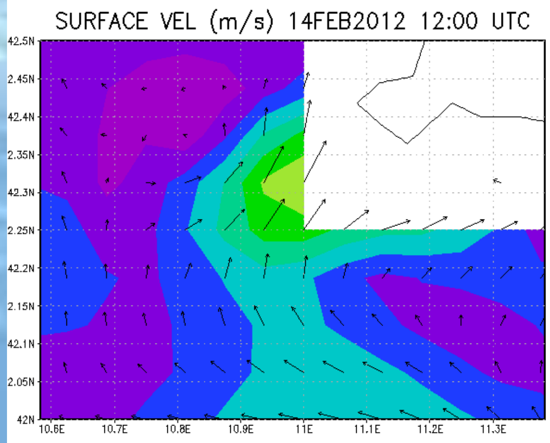
- Develop coastal forecasting systems with predictive skills up to one week
- Resolve coastal geometry and details
- Assimilate high frequency and regular coastal data sets
- Join the ‘deterministic’ with the ‘probabilistic’ approach
- Integrate land, atmosphere and sea water cycles in the coastal areas
- Develop predictive tools and methods that will extend the coastal forecasting systems into the climate prediction range for adaptation and mitigation
- Introduce a methodology that connects continuously innovative and relevant technology to user-oriented services
- Join forces between the science developers and the different operational communities (service and user oriented)

Increasing the accuracy with better models, better nesting from the deep ocean to the coasts

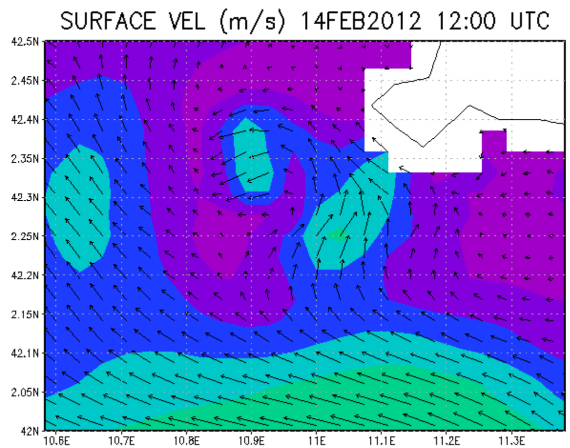


Resolve coastal geometry

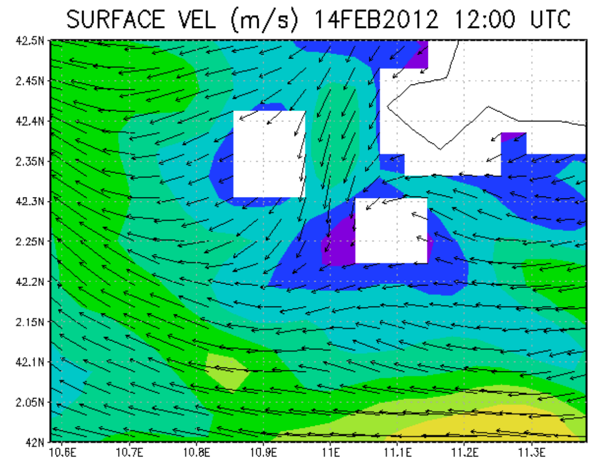
COARSE RESOLUTION MODEL

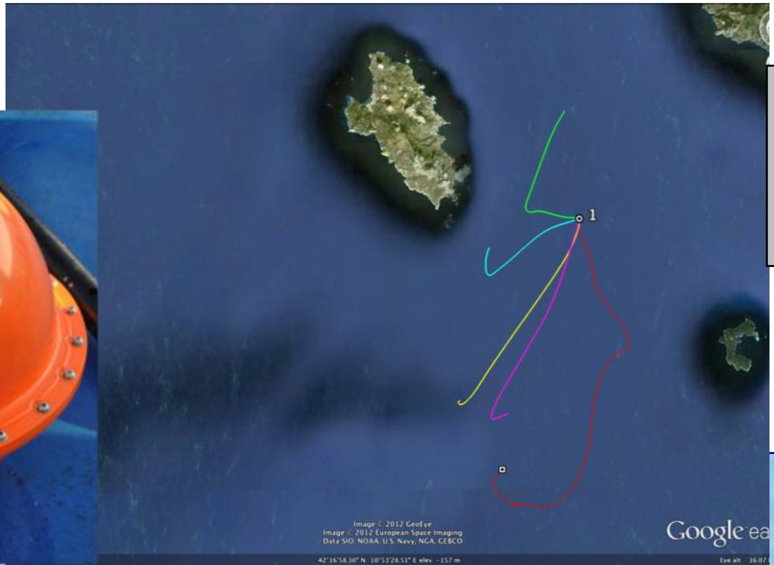


HIGH RESOLUTION MODEL ONLY



HIGH RESOLUTION MODEL AND ISLANDS

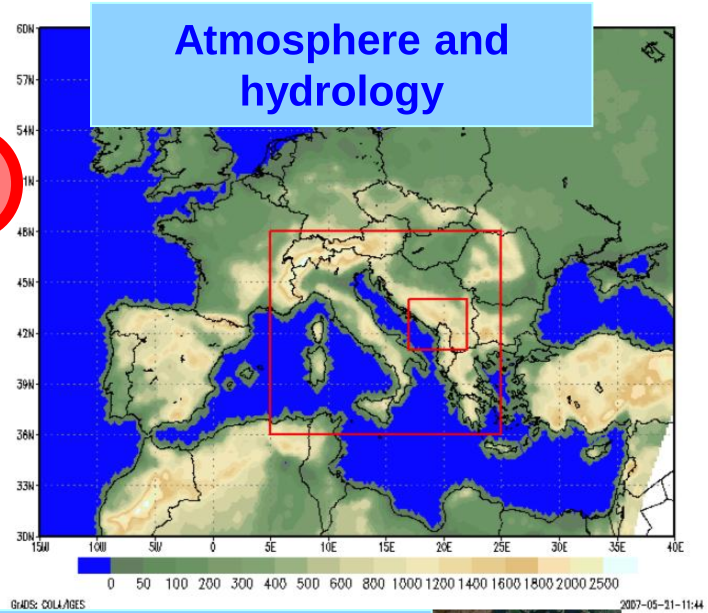




COARSE MODEL
HIGH RESOL + ISLANDS
HIGH RESOL + ISLANDS
OBSERVED TRAJECTORIES

Integrate the local water cycle models

1



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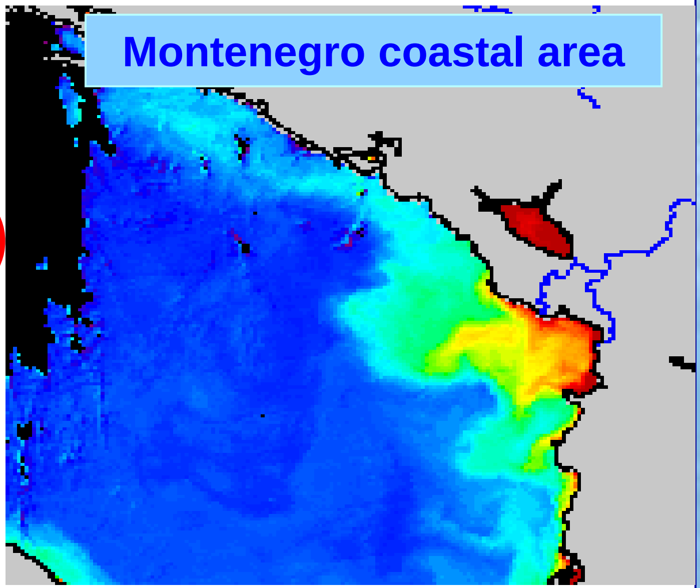

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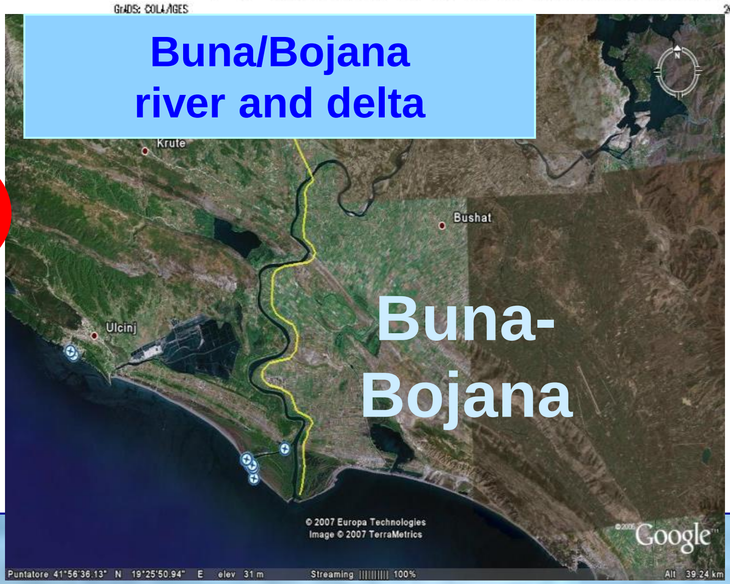
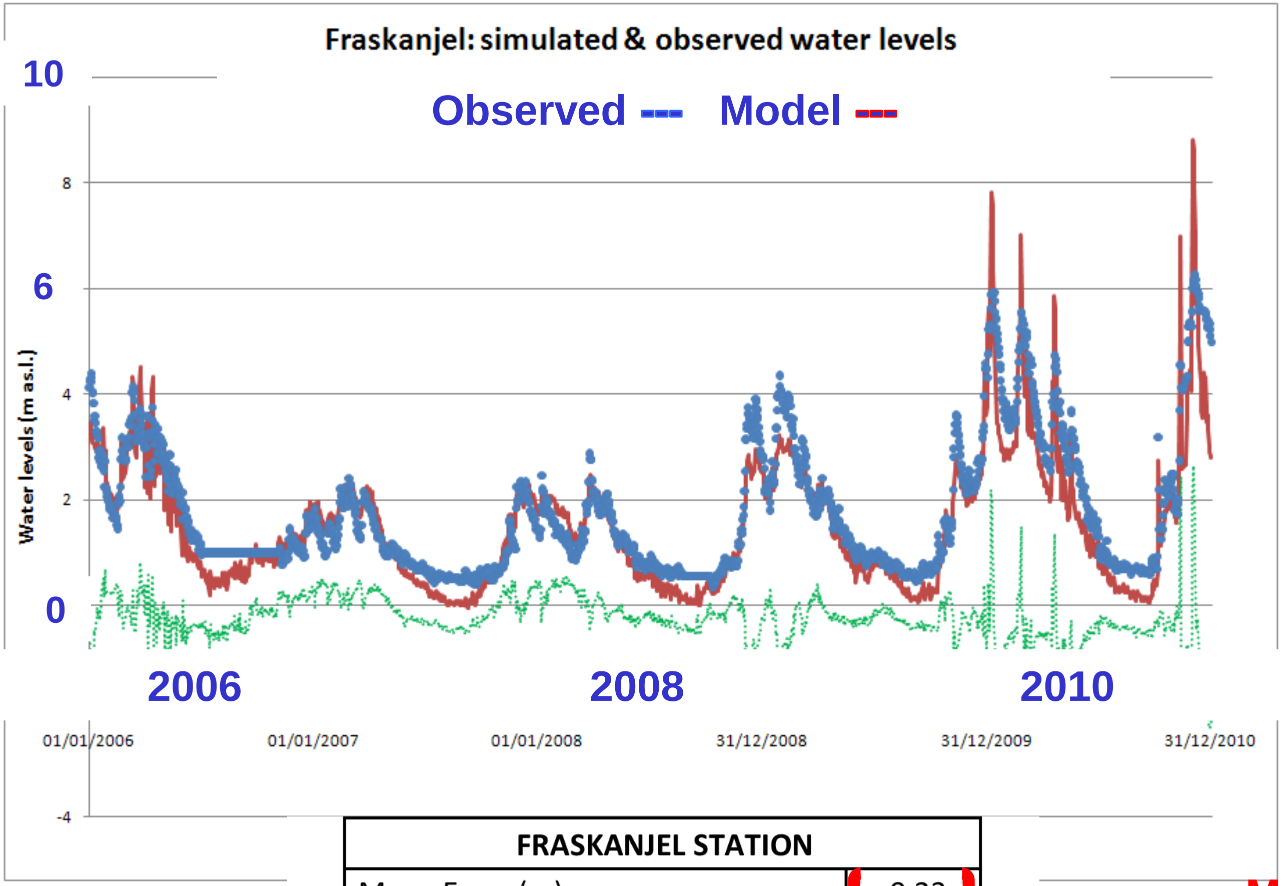


4

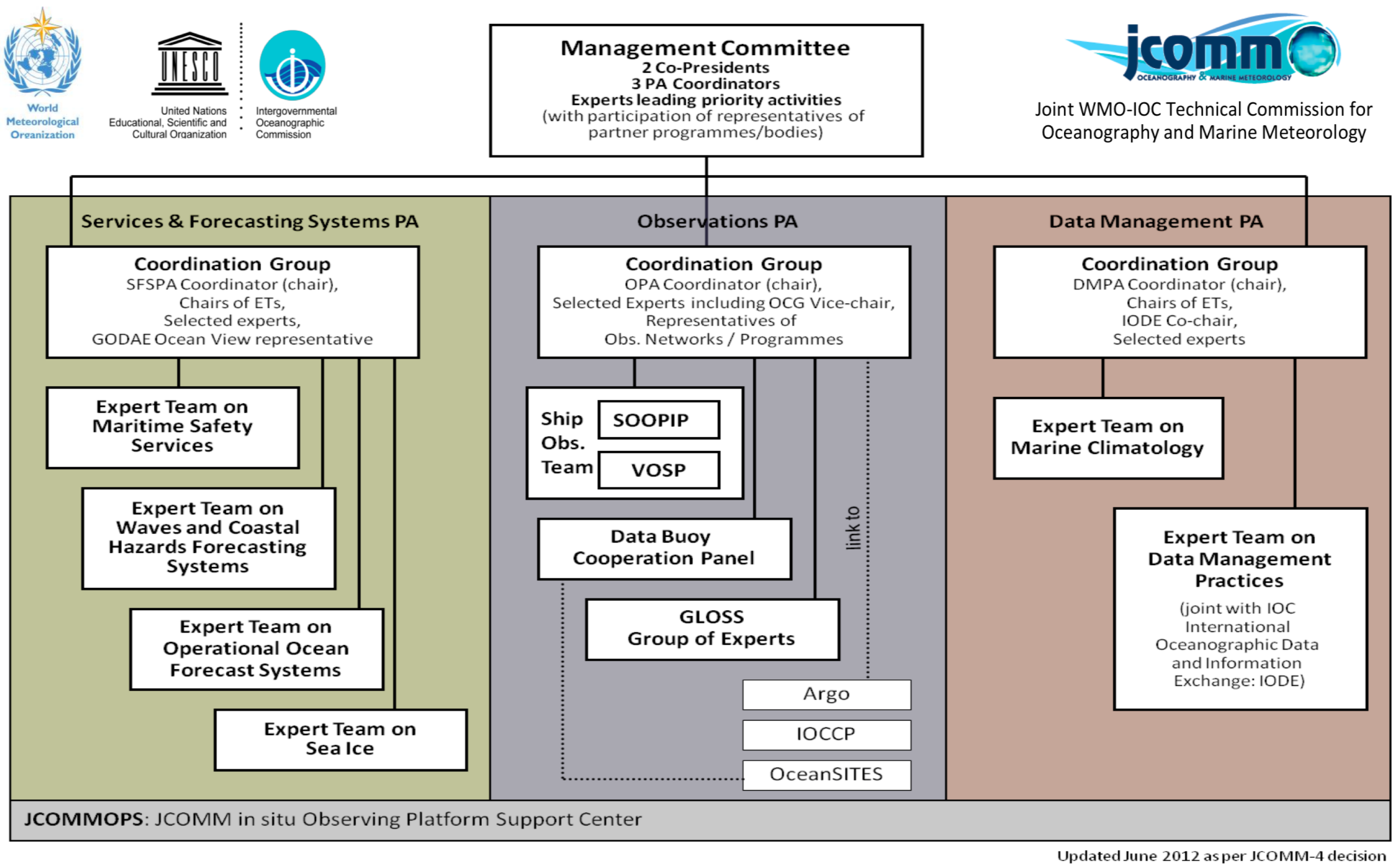
The results from model integration: river outflow for coastal models



FRASKANJEL STATION	
Mean Error (m)	-0.23
Mean Absolute Error (m)	0.38
Root Mean Square Error (m)	0.01
Standard Deviation of residuals (m)	0.01
Correlation (-)	0.83

Mean errors

JCOMM: The merging with the user community



Summary and conclusions

- Ocean prediction science is mature for the open ocean, about 30 years old now
- Operational oceanography is also mature, 20 years old and satellite data are now almost everywhere assimilated in a routine way
- Coastal predictions and science are younger, need to boost in the next decade
- Meeting with intermediate and end users is a key to success, thus interactions with hydrology and meteorology community is needed
- JCOMM-GODAE connection through the COS-TT Group is an important opportunity