Hydrodynamic forecasting systems: state of the art and future steps

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Topics

- Historical evolution
- GODAE Ocean view
- Status of the art
- Data & products → emergencies
- Global-regional-coastal
- Evolution steps
- Conclusion

Evolution of the prediction systems

- Operational evolution of global and regional ocean forecasting systems has been extremely significant during the last ten years
- Several systems have been set up and developed pre-operationally and the majority of these are now fully operational, providing medium- and long-term forecasts of the most relevant ocean physical variables

"**operational**" → to describe whenever the processing is done in a routine and regular way, with a pre-determined systematic approach and constant monitoring of performance. (GODAE Strategic Plan 2000)

GODAE OceanView

GODAE and GODAE OceanView

- GODAE (Global Ocean Data Assimilation Experiment) has given national groups the opportunity to **collaborate** and has provided a firm base for the development of a global ocean forecasting system;
- GODAE aimed to develop a global system of observations, communications, **modelling and assimilation** to deliver regular, comprehensive information on the state of the oceans in a way that would promote and engender wide utility and availability of this resource for maximum benefit to society (Smith, 2006);
- At the end of the 10-year GODAE project (Smith 2006 and Bell 2009), GODAE evolved into GODAE OceanView, https://www.godae-oceanview.org, which continues to foster the development and operation of global and regional ocean forecasting systems providing coordination and leadership in consolidating and improving ocean analysis and forecasting systems.

GODAE and GODAE Ocean view

https://www.godae-oceanview.org/

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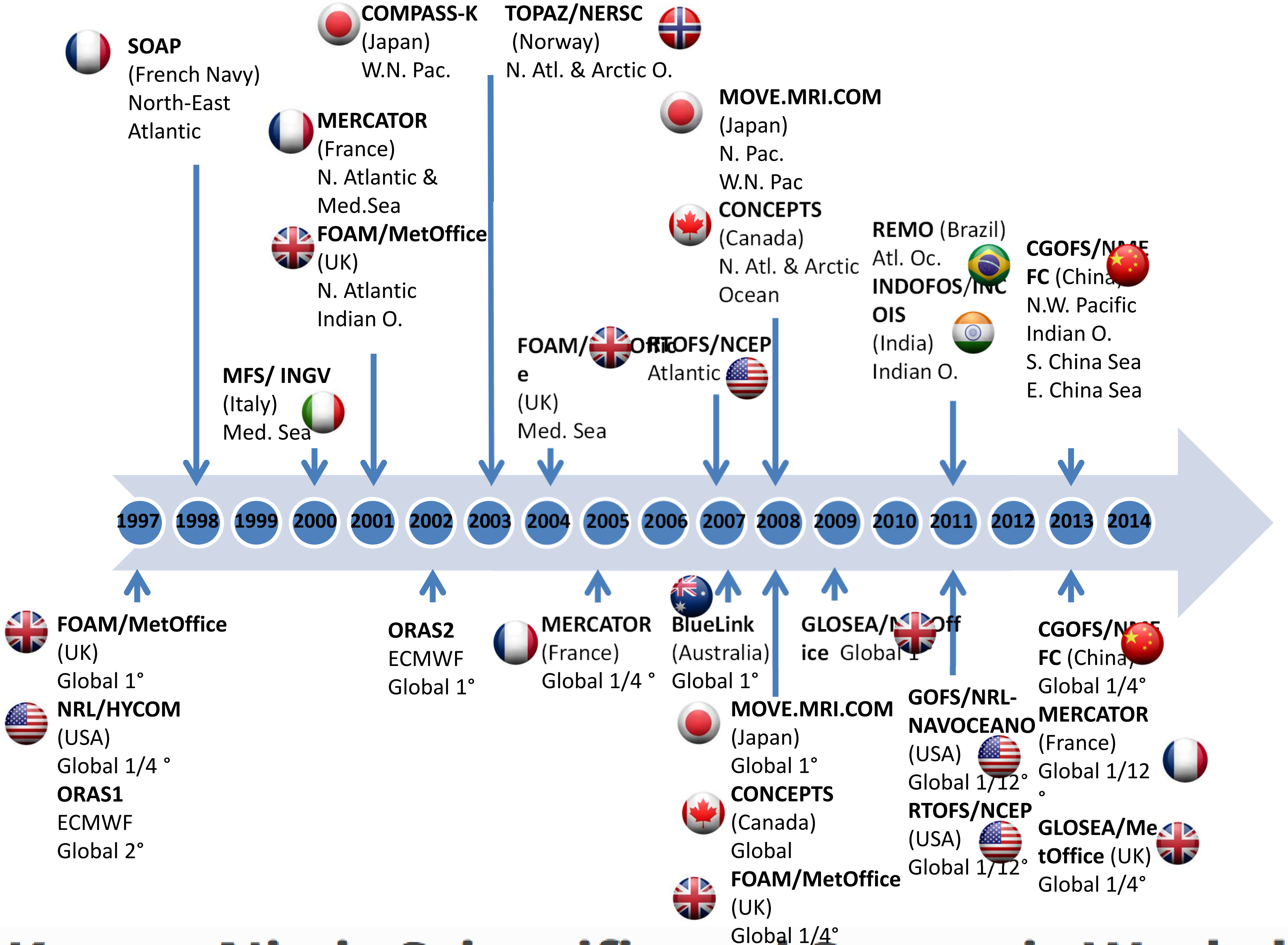
Requirements the forecasting systems should fulfill

- “Operational oceanography is the provision of **scientifically based** information and forecasts about the state of the sea (including its chemical and biogeochemical components) on a **routine** basis, and with sufficient speed, such that **users can act** on the information and make decisions before the relevant conditions have changed significantly, or became unpredictable”. N. C. Fleming 2002

Marine prediction systems evolution

- development/implementation/operation of a forecasting system is the result of a balance between **science** and **technology**
- The evolution of these two aspects together with the **funding** strategies, at national and international level, and the consideration of **user needs**, can explain the evolution shown in the previous picture.

Tonani et al., in press, JOO



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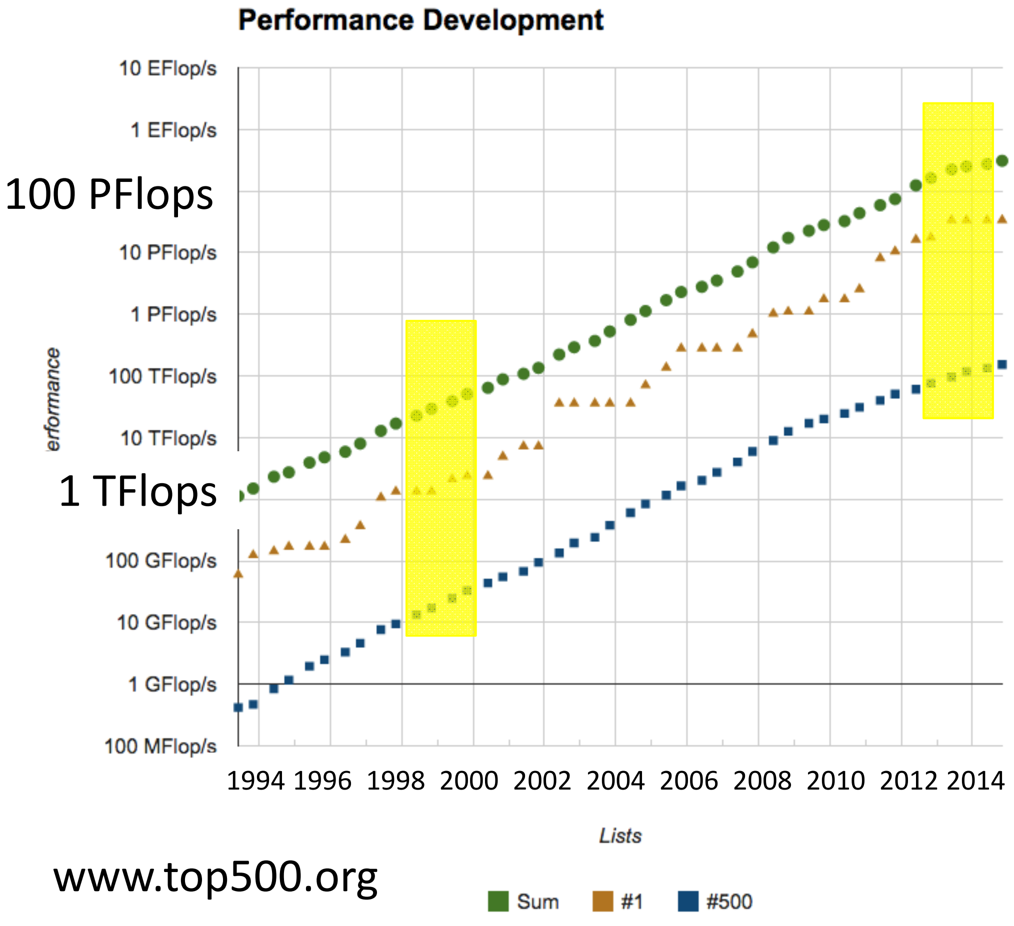
Evolution of the ocean prediction systems

- Since the beginning of the 1990s more and more systems have been developed in different countries

- All the forecasting systems are continuously evolving in an attempt to provide increasingly more accurate products

Computer power



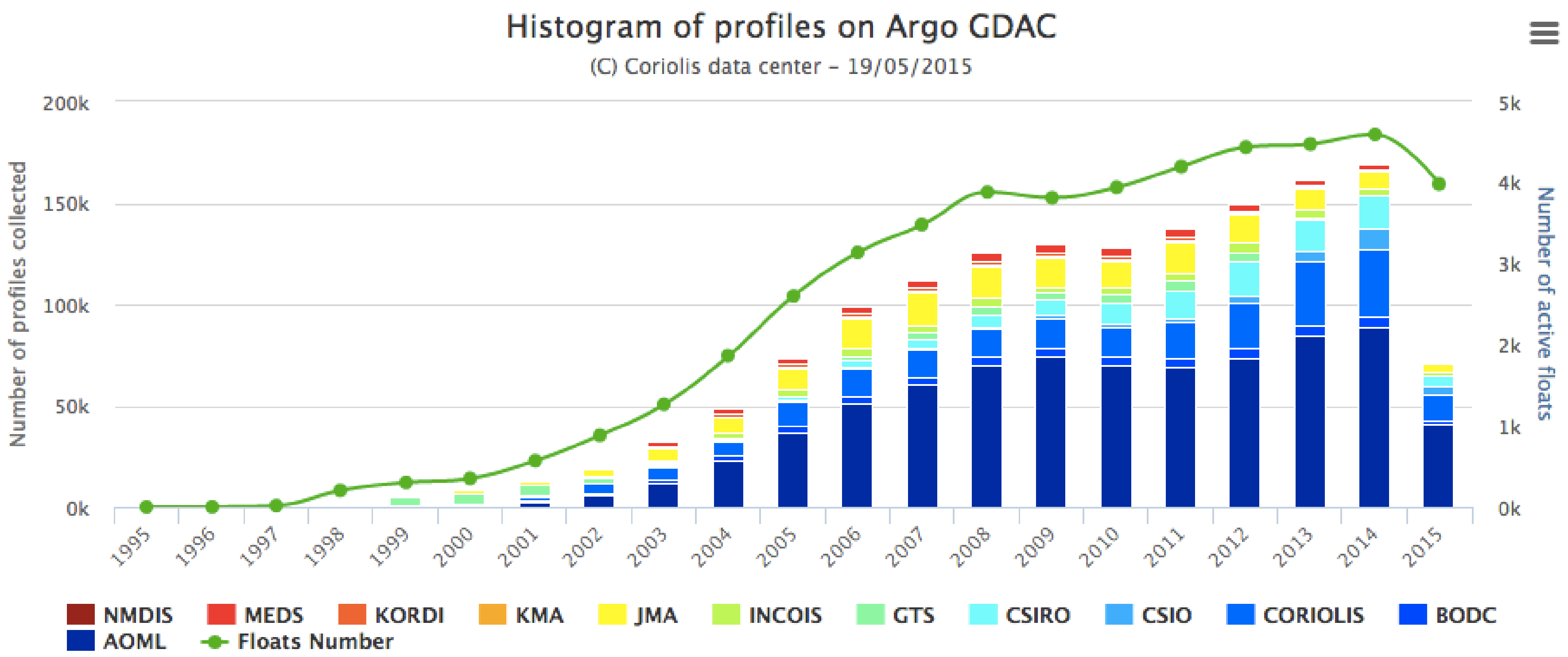
www.top500.org

→ High resolution global and regional forecasting systems operationally in near real time

→ Models: include different parameterizations, more accurate advection scheme, more complex vertical mixing parameterizations or new vertical coord, ……

→ Higher complexity for DA schemes, more assimilated data

In situ obs: Argo



http://www.argodatamgt.org/Monitoring-at-GDAC/Active-floats-statistics

→ Datasets suited for the needs of operational forecasting systems (Cabanes et al., 2013)

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Global and regional fcst systems

- At present there are many **well consolidated global and regional systems** developed by different centres using ocean models with increased **complexity** and **data assimilation** techniques that are able to properly predict the main ocean variability at different spatial and temporal scales.

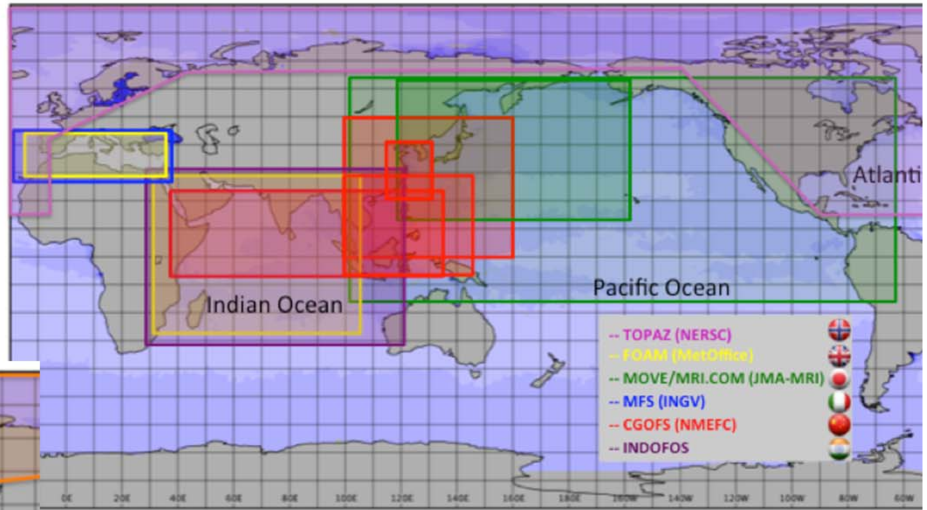
Global systems

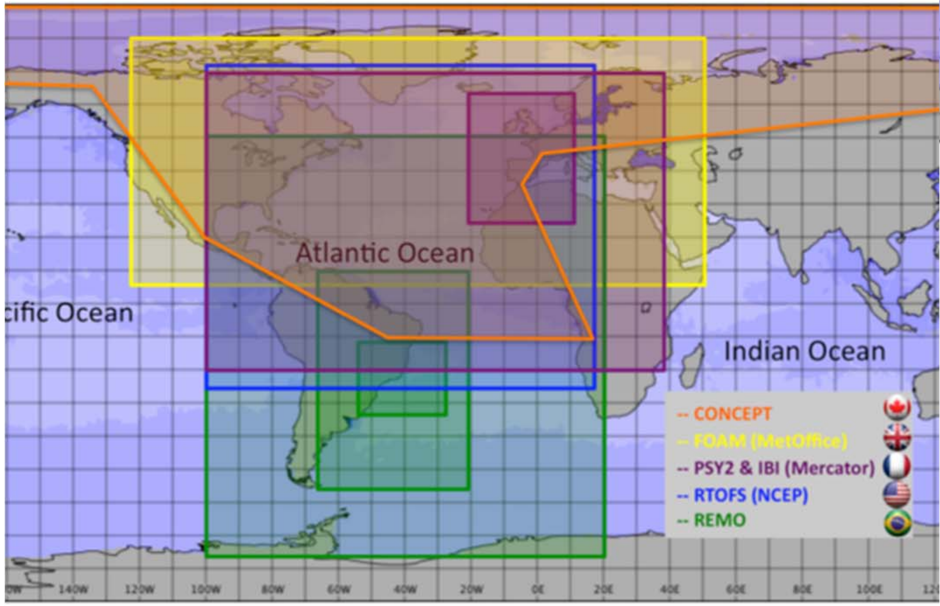
System	Grid Resolution		MODEL		DATA ASSIMILATION	ADDITIONAL INFO/ OTHER COMPONENTS
	horiz.	# vert. levels	OGCM	ICE		
ECCO-NRT (ECCO)	0.3-1°	46 z	MITgcm		Kalman filter & RTS smoother	
MOVE/MRI.COM-G (JMA/MRI)	0.3-1°	50 hybrid	MRI .COM 2	Monthly Climatology	MOVE(3DVAR)	
ECMWF (ECMWF)	1°	42 z	NEMO		NEMOVAR (3DVAR)	Wave model (WAM)
BlueLink/OceanMAPS (Bureu of Meteorology)	1° (1/10°)	47 z	OFAM2 (MOM4)		BODAS (ensenble OI)	
FOAM (MetOffice) GLOSEA (MetOffice)	1/4° 1/4°	75 z 75 z	NEMO 3.2 NEMO 3.2	CICE CICE	NEMOVAR (3DVAR)	Coupled ocean-atm-ice (GloSEA)
CONCEPT (Canada)	1/4°	50 z	NEMO 3.1	CICE	SAM2-ice 3DVAR	
CGOFS (NMEFC)	1/4°	50 z	MOM4		3DVar	Wave model (NWW3)
PSY3 (Mercator-Ocean) PSY4 (Mercator –Ocean)	1/4° 1/12°	50 z partial step	NEMO 3.1	LIM2_EVP	SAM2V1-3DVAR large scale T&S bias correction	BioGeoChemical (PISCES ¼)
GOFS (NRL/NAVOCEANO)	1/12.5°	32 hybrid	HYCOM		NCODA(3DVAR)	
RTOFS (NCEP)	1/12°	32 hybrid	HYCOM	Energy Loan	NCODA(3DVAR)	

Regional systems

These systems differ from global

- Model domain and grid resolution

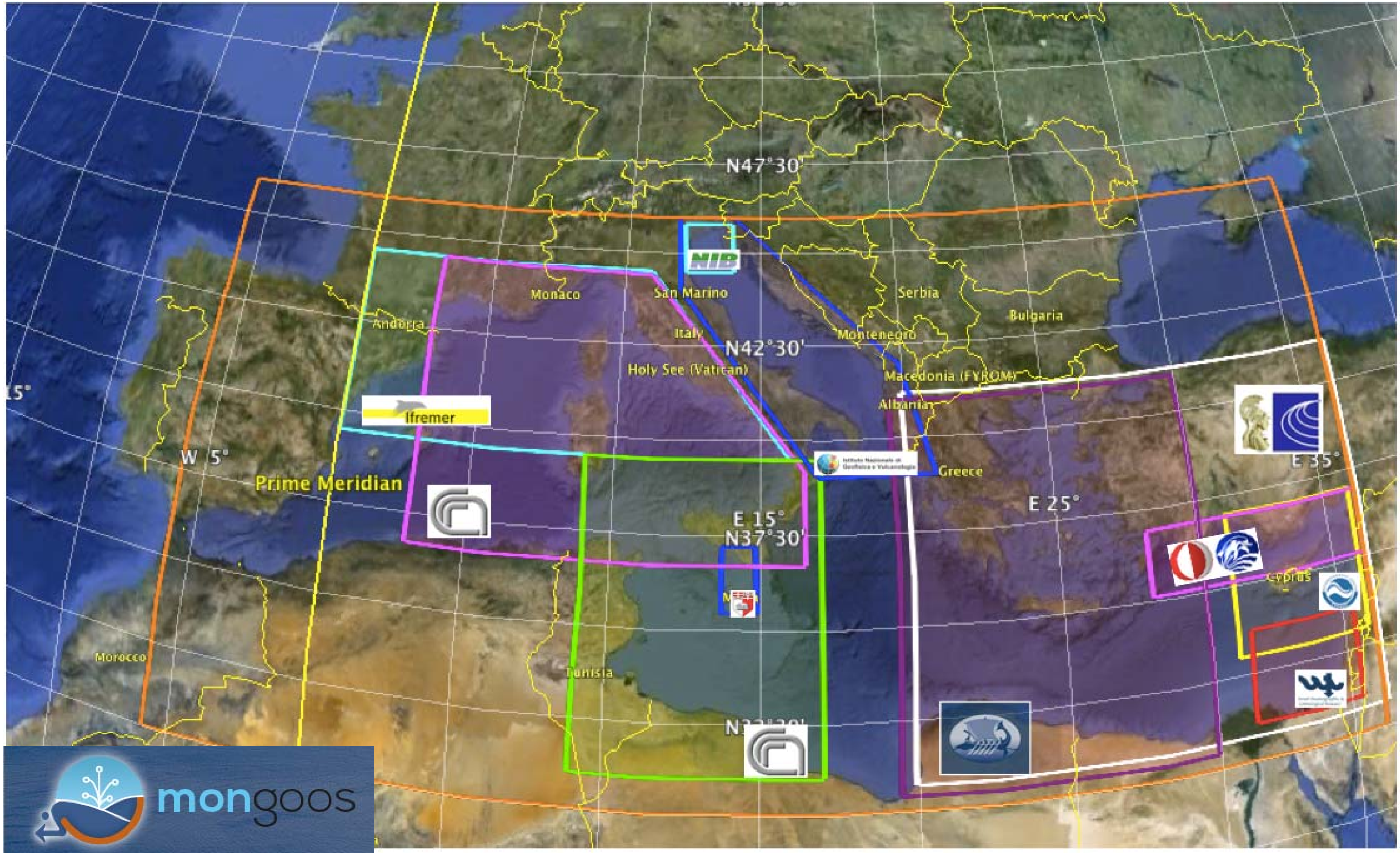




Tonani et al, in press, JOO

- Model parameterization tuned up to simulate the characteristic processes of that region
  - ✓ Ocean dynamics
  - ✓ Mesoscale circulation
  - ✓ Fronts
  - ✓ Air-sea interaction processes
  - ✓ Exchange at straits ..

From regional to coastal scale



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Data & Products service

- All the prediction systems produce data on global or regional scales, providing **real-time forecast, analysis and hindcast** fields on the model grid (native grid) or on an interpolated regular grid.
- The amount of data generated is very large and needs to be managed by data services systems that will **facilitate the user's** ability to discover, evaluate, visualize, download and analyse all the available products (Blower 2009).
- The capability to discover, visualize and download the forecasting products is fundamental to reach the oceanographic community and in general the users.

Data & Products service

- The operational products of the prediction systems are therefore **available** for different types of users and not only for the research community.
- The management of many emergencies in the last years **has relied on this products**

Deepwater Horizon Oil Spill Accident
Gulf of Mexico
April 20th, 2010

(Liu 2011)

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Accident at the Fukushima Daichii nuclear plant

March 11th, 2011

(Masumoto et al., 2012 and Zulema et al. 2014)

Grounding of the Costa Concordia

January 13th, 2012

(De Dominicis et al. 2014)

Products & Emergencies

- These products have been used to initialize and provide lateral boundary information to the **high resolution ocean models implemented in the area** of these incidents.
- In some cases the systems also provided the currents fields to force the **oil spill** or the **radioactive dispersion** modelling.
- More than one prediction system has been used in all of these examples enabling the development of **ensemble products** than were proved to be very useful for the assessment of the uncertainties.

Emergencies→ lesson learned

- These examples underline the importance of using **multiple systems** with different characteristics implemented in the same area
- Moreover the **high-resolution** of these products is very important, both in space and time in order to solve the ocean dynamics in areas of high variability.
- These few examples prove that the important step to reach the users has been accomplished.
- The interaction with the users for operational oceanography products is extremely important because the **users feedback and requirements** can provide a unique contribution to the development of new systems and new products

Future developments

All the systems have planned several improvements/developments for the next few years that affect all the components of the ocean forecasting systems:

- higher model grid resolution (horizontal and/or vertical);
- development of a biogeochemical model coupled with the physical system;
- implementation of coupled ocean-wave-ice-atmosphere forecasting systems;
- improvement of the data assimilation scheme in order to adapt to the new forecasting systems characteristics;
- assimilation of new observations types;
- introduction of the ice component into the systems that do not have it yet;
- resolution of the tidal signal;
- better diagnostic protocols;
- Nesting global-regional-.coastal

Conclusion

- The **complexity of the models has been increased**: the models are now able to resolve more processes like tides and waves and are associated with more accurate data assimilation schemes.
- Product services have been developed and now the products of almost all the systems are **available in near real-time**.
- Further **scientific work** is needed to understand better the processes that connect the different models (ocean-wave-atmosphere-ice).
- The importance of coupling **biogeochemical** systems with physical ones has been stressed
- Examples of **ensembles** have been provided but this line of research needs to be further investigated.
- The products should be **delivered to the users** efficiently and should be provided with an adequate spatial and temporal resolution.
- The **user/production interaction** has to be taken into account as leading criteria for the future developments