

Temperature of the surface of the North Sea along the Danish and Norwegian coasts, simulated with a resolution of 1/36°. Note the contrast between the relatively warm water mass in the North Sea and the cold water mass in the Baltic Sea, which meet in the Skagerrak Strait.

Global to Regional Oceanographic Modelling

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USING DEISA COMPUTING RESOURCES, PIERRE BAHUREL AND HIS TEAM FROM MERCATOR OCEAN IN FRANCE HAVE, TOGETHER WITH ESEOO IN SPAIN, DEVELOPED NEW OCEANOGRAPHIC MODELS THAT WILL HELP US TO UNDERSTAND THE EVOLUTION OF THE CLIMATE OVER THE LAST DECADES AND TO PROVIDE AN OCEAN ANALYSIS AND FORECASTING SERVICE ON A DAILY BASIS. A SUPERCOMPUTING INFRASTRUCTURE IS ESSENTIAL FOR OCEANOGRAPHIC MODELLING IN ORDER TO GENERATE EVER MORE REALISTIC SIMULATIONS OF THE OCEAN'S BEHAVIOR.

Mercator Ocean was founded, as a consortium company, in 2002, with the aim of establishing an operational system for describing the state of the ocean at any given time and place on the planet.

"The ocean is an integral part of our environment, upon which many depend for survival, and it is a basic element of the Earth's climate. It is also an important site of transit for both goods and people", points out Pierre Bahurel, head of Mercator Ocean.

"Therefore, understanding both the state of the ocean and the ways in which it might change is crucial. Operational oceanography is essential for many scientific activities in the fields of oceanic physics, marine biology, and meteorology, and it has also practical benefits for the security and the improvement of maritime transportation", continues the French researcher.

Global and regional oceanographic modelling

In collaboration with ESEOO in Spain, Mercator Ocean launched the GROM

project in 2006, with the general aim of developing global and regional operational oceanographic models.

"The project we are currently working on is to build and validate new ocean model configurations on a global to regional scale, with which we can simulate mesoscale or sub-mesoscale physical processes such as eddies, meanders, fronts or currents", explains Yann Drillet, ocean modeller at Mercator Ocean.

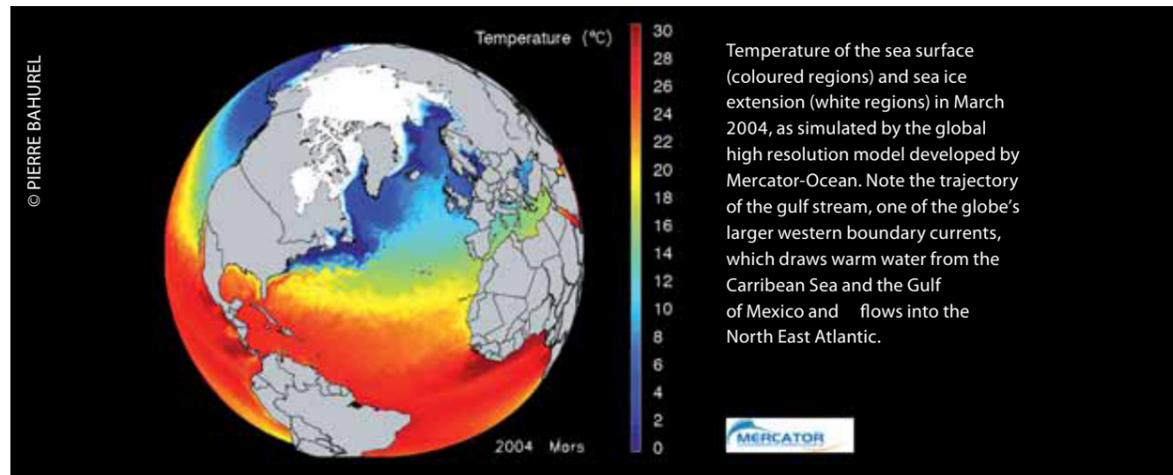
Mercator Ocean's team uses two types of models to conduct its research. The first one is called an "eddy-permitting" model, which allows a realistic representation of the main ocean currents. The second model is called "eddy-resolving", and offers finer representations of a number of mesoscale features of the ocean, essential for operational forecasting and for many activities (such as pollution detection and forecasting, ship routing, offshore fishing and halieutic resource management) for which the impact of these mesoscale processes is crucial.

"Our final goal is to develop a global eddy-resolving model (1/12°)", says Bahurel. Such a model is essential for understanding the evolution of the

climate over the last decades and for providing an ocean analysis and forecasting service on a daily basis. We are also working on a better resolution for regional eddy-resolving models (1/36°) in specific areas, capable of representing sub-mesoscale and high frequency physical processes such as tides and storm waves, and providing useful large ocean forcings to scientists or operators involved in coastal oceanography", he explains.

Modelling the ocean requires high computation capacities

Modelling the ocean requires, however, very high computation capacities. In order to validate the simulations both physically and statistically, Mercator Ocean's team needs to know the model's behavior over relatively long periods – and each year simulated requires tens of thousands of computing hours. Physical processes in the ocean, such as mesoscale phenomena or "mixing" are often very complicated to model, and others such as tides and storm waves, considerably increase the computation needs. >>>



Temperature of the sea surface (coloured regions) and sea ice extension (white regions) in March 2004, as simulated by the global high resolution model developed by Mercator-Ocean. Note the trajectory of the gulf stream, one of the globe's larger western boundary currents, which draws warm water from the Carribean Sea and the Gulf of Mexico and flows into the North East Atlantic.

By making available to Mercator Ocean some 450000 CPU hours on the ECMWF IBM, the DEISA Extreme Computing Initiative (DECI) made possible some major achievements within the GROM project:

"These computation capacities have enabled us to carry out interannual simulations, which are crucial for testing the validity of our models, for setting up systems of operational oceanic forecasting, and for deepening our understanding of the ocean more generally. Thanks to DEISA, we have been able to develop new models starting from the global eddy-permitting model to the regional eddy-resolving models", explains Drillet.

The results obtained by Mercator Ocean with the help of DEISA have proved extremely innovative and promising:

"We have been able to develop a global eddy-permitting model (1/4°) that allows us to represent an excellent degree of variability and eddy kinetic energy in all the oceans of the globe", begins Drillet.

"We have also been able to study for the first time the coupling between sea ice and a global eddy-permitting ocean", he adds. "Understanding this coupling is essential to efforts to realistically simulate circulation in the high latitude ocean, which has consequences for large-scale ocean circulation and deep water formation. An important aspect of the ocean forecasting is to provide information on sea ice-free transport pathways particularly in the Artic Ocean and in the Canadian straits".

Considerable achievements have also been made at a more regional level,

especially in the North Atlantic area: "We have managed to represent correctly the Gulf Stream pathway and in particular the separation of the current from the coast at Cap Haterras to become a zonal jet in the Atlantic", says Drillet. According to the researcher, "the eddy-resolving simulation obtained (1/12°) is the most realistic simulation ever produced".



Photo of Pierre Bahurel, head of Mercator Ocean (on the right) and Yann Drillet, Ocean Modeller at Mercator Ocean.

"The accuracy of these simulation results in the key area of the North Atlantic region is new for to the entire physical oceanographic modelling community", points out Drillet.

"It allows us to represent the position and the intensity of the Gulf Stream and its North Atlantic current extension, which has a strong influence on oceanic and atmospheric properties", says Bahurel.

"It also enables us to represent the cold and warm eddies that are formed in this current and which transport temperature and salinity properties in the Sargasso Sea in the south and along the North American coast", adds Drillet.

"We have also developed a regional model within the North East Atlantic and the Western Mediteranean Sea areas,

which allows us to refine locally the modelling process. It makes it now possible to introduce new physical phenomena, such as tides, into these models, and to get a better representation of the level of fresh water penetration from rivers into the ocean. This vastly improved the quality of our simulations, and created many new potential applications, especially on the continental shelf where human and biological activities are more important", says Bahurel.

First steps towards finer resolutions

The final goal for Bahurel's team remains the development of a global eddy-resolving model with a resolution comparable to that realised in regional models (1/12°). This model is now under development but it is still too large for the computation facilities currently available.

"The process of improving the horizontal resolution in the ocean modelling is not complete. One of our objectives is to be able to simulate sub-mesoscale processes or coastal phenomena with a resolution of 1km. This will be soon possible with regional models thanks to progress in the level of computational power", says Bahurel.

"At the global scale, ocean observations have to be improved in terms of resolution, global coverage and real time distribution. Given that the atmosphere is the ocean's engine, we will also have to improve our knowledge of this component. It is crucial for the future development of our environment monitoring and forecasting capabilities", concludes Bahurel. ■