MERCATOR, forecasting global ocean

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The MERCATOR investigation aims to develop operational monitoring and forecasting of the global ocean. The forecasting system is based on routine assimilation of near-real-time ocean observations in a 3D dynamical ocean model. TOPEX/POSEIDON and Jason-1 altimetry are key datasets for assimilation.
A first release of the MERCATOR system has been operating routinely since January 17, 2001, providing analysis and two-week forecasts for the North and Tropical Atlantic at medium resolution (1/3°). These ocean forecast bulletins are available at http://www.mercator.com.fr.
The target period of the investigation is the international GODAE experiment (Global Ocean Data Assimilation Experiment) covering 2003-2005, where MERCATOR will routinely run a 1/4° global ocean model providing a high-resolution picture (1/15°) of the North Atlantic and Mediterranean Sea.

Proposal objectives

The purpose of this investigation is to develop the use of altimeter data via assimilation into 3D dynamical ocean models for operational ocean applications.

The goal of the MERCATOR project is to implement an operational ocean forecasting system able to:
• simulate the global ocean with a primitive-equation high-resolution model, assimilating satellite and in-situ data to provide hindcasts and near-real-time nowcasts and forecasts of the global ocean circulation,
• provide an operational mode service (i.e., routine and near-real-time bulletins) to meets the needs of (i) research, (ii) national (military and civilian) state applications, and (iii) commercial oceanography end-users.

MERCATOR will conduct a long-term operational oceanography experiment with routine assimilation of near-real-time ocean observations into dynamical ocean models. The assimilation system will use near-real-time Jason-1 altimeter observations as input data.
The near-real-time and routine assimilation experiment got underway early in 2001 with TOPEX/POSEIDON and ERS-2 data; the target period is the intensive phase (2003-2005) of the international GODAE experiment (Global Ocean Data Assimilation Experiment).

This initiative is supported by the six French agencies involved in oceanography—the French space agency CNES, CNRS, the French national scientific research center, IFREMER, the French institute of marine research and exploration, IRD, the French development research institute, Météo-France, the French national weather serviceand SHOM, the French Navy's hydrography & oceanography department —and their subsidiaries CERFACS (European Center for Research and Advanced Training in Scientific Computation) and CLS (Collecte Localisation Satellites), with the clear ambition to develop a truly operational ocean forecasting system.

The MERCATOR forecasting system

The scientific core of the MERCATOR forecasting system consists of routine assimilation of near-real-time ocean observations in a range of 3D dynamical ocean models.

Tools

1. All MERCATOR configurations are based on the general ocean circulation OPA code developed by LODYC [Madec et al., Technical Report, LODYC, 1997].
2. The *assimilation scheme* is based on the multivariate optimal interpolation SOFA3 scheme [De Mey, 1999] developed by LEGOS to assimilate satellite altimetry, sea surface temperature and vertical in-situ temperature and salinity profiles.
3. The *core* of the system (algebraic coupling concept) is based on the PALM software developed by CERFACS [Piacentini, 1998].

Observations

MERCATOR will rely on existing data assembly centers to collect, process and validate its real-time and delayed-mode data. Input data will include forcing data, sea surface temperature, in-situ temperature and salinity vertical

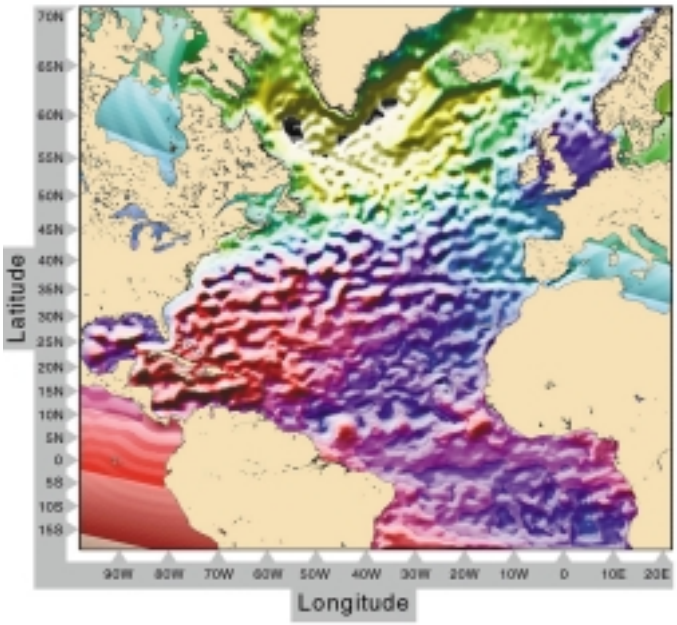

Figure 1: First Mercator bulletin. Sea surface topography in the North and Equatorial Atlantic. Two-week forecast for January 31, 2001.

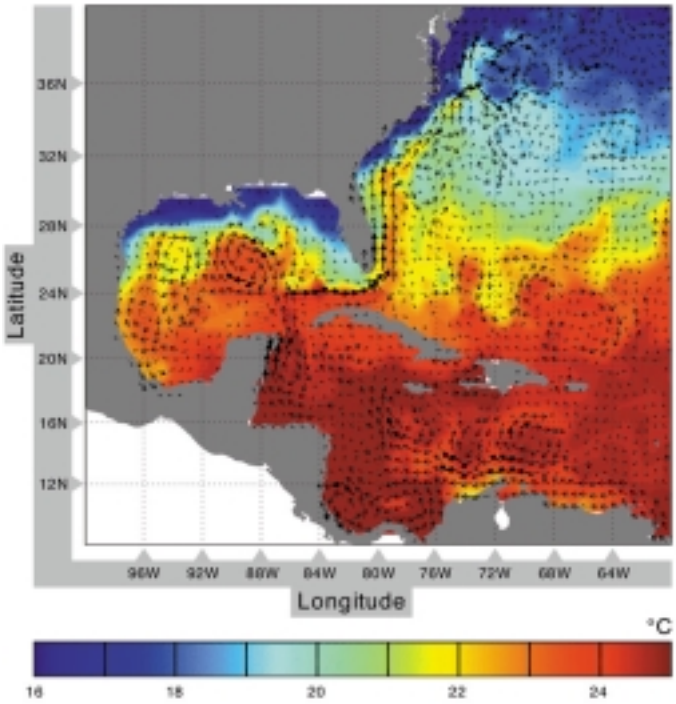

Figure 2: Surface temperature and currents in the Gulf of Mexico and Gulf Stream region. Two-week forecast for February 7, 2001. (Example of routine Mercator production).

profiles and satellite altimetry. in-situ data—from ARGO profiling floats, XBT, TAO/PIRATA/TRITON arrays, and surface drifters—will be obtained from the CORIOLIS data center.

Multi-satellite Sea Level Anomaly altimeter data (along-track and maps) will be retrieved from the SSALTO/DUACS system at CLS. All altimeter data available in near-real time will then be considered: TOPEX/POSEIDON and ERS-2, then Jason-1 and ENVISAT, maybe ENVISAT.

Model configurations

For near-real-time and routine assimilation, MERCATOR will successively experiment with three ocean model configurations:
1. a basin medium-resolution configuration (1/3° horizontal resolution, 43 vertical levels) covering the North and Tropical Atlantic; this configuration, derived from the French Clipper project, will be operated as a demonstrator to provide ocean nowcasts and forecasts in the pre-GODAE phase (2001-2002),
2. a basin very-high-resolution configuration (5-to-7 km horizontal resolution, 43 vertical levels) covering the North Atlantic and Mediterranean Sea; this configuration, to be operated during the GODAE target phase (2003-2005), will focus on mesoscale processes,
3. a global medium-resolution configuration (1/4° horizontal resolution, 43 vertical levels) covering the global ocean; this configuration, to be operated during the GODAE target phase (2003-2005), aims to provide the best ocean state estimates for global ocean analysis and boundary conditions for regional models.

Near-real-time ocean analysis and forecasts

The first prototype of the MERCATOR ocean forecasting system has been providing routine weekly ocean bulletins since January 17, 2001.
Each ocean bulletin comprises:
• global ocean analysis based on ocean observations, mainly near-real-time TOPEX/POSEIDON and ERS-2 altimetry and in-situ T and S vertical profiles,
• North and Tropical Atlantic (20°S-70°N) analysis and two-week forecast, based on routine assimilation of near-real-time altimetry into the 1/3° MERCATOR Atlantic configuration.

Figure 1 shows the first forecast generated by the MERCATOR prototype on January 17, 2001 (two-week forecast of North Atlantic sea surface topography).
MERCATOR ocean bulletins can be consulted at http://www.mercator.com.fr. Through this site, users have access to a range of maps and other information about the underlying variables of the ocean, such as velocity, salinity, temperature and sea level anomalies, which describe the ocean in all its dimensions. Information that gives us a closer insight into current and forecast ocean conditions from the sea surface to the sea floor, at regional or basin scale.

With its three-dimensional model of the ocean capable of assimilating

real-time data from satellite and in-situ observations, MERCATOR offers a uniform, synoptic view of the ocean in much the same way as meteorological models represent the atmosphere.
Figures 2 and 3 show examples of MERCATOR outputs available on line: Figure 2 is a two-week forecast of the surface temperature and current fields in the Gulf of Mexico, and illustrates the ability of this medium-resolution (1/3°) configuration to catch an interesting feature of mesoscale dynamics; Figure 3 is a vertical section of zonal velocity between Rio de Janeiro (Brazilian coast) and Cape Verde (Africa) and shows well-known surface and undercurrent features such as the Equatorial UnderCurrent (100 m; 31°W), North Equatorial Counter Current (surface to 100 m; 26.6°W) and the South Equatorial Counter Current (300 m; 35.5°W).

In the coming months and years, MERCATOR will progressively enhance the system to reach full capacity for GODAE. The next step deals with assimilation, with the implementation in fall 2001 of the multivariate version of the SOFA3 system, enabling simultaneous assimilation of horizontal along-track altimeter data (already in

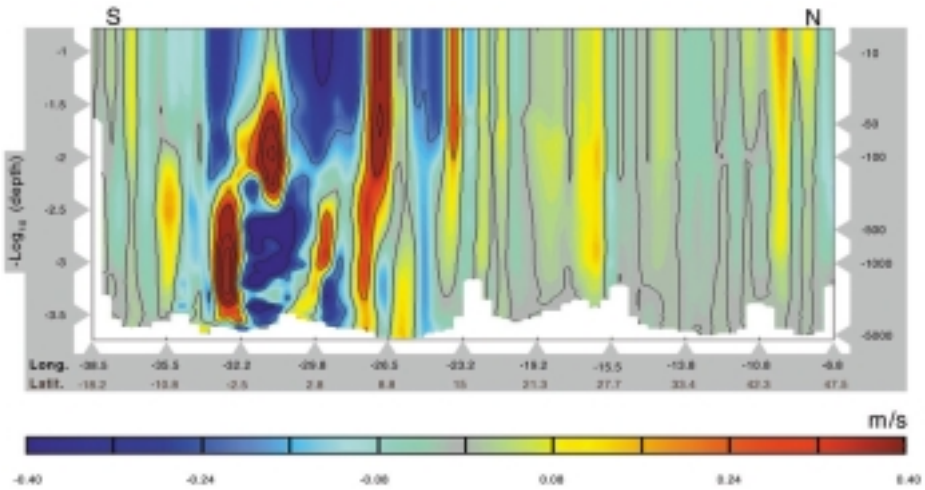

Figure 3: Vertical section of zonal velocity between Rio and Cape Verde. One-week mean analysis between January 17 and 24, 2001. (Example of routine Mercator production).

place with the monovariate scheme) and in-situ temperature and salinity vertical profiles. The assimilation of both Jason altimetry and ARGO in-situ float data is one of the key objectives of GODAE.

MERCATOR will then increase the horizontal resolution of the model with the routine operation of the high-resolution Atlantic/ Mediterranean configuration in 2002.
Model simulations (without assimilation) already show how this very-high-resolution component of the MERCATOR system will enable accurate monitoring and forecasting of mesoscale dynamics. An example of a one-year mean field of surface temperature and currents in the western Mediterranean basin is given in figure 4.
The final phase will see geographic coverage extended to the global ocean.

MERCATOR output products are and will be routinely and freely available for any scientific experiments conducted under MERCATOR and GODAE or other programs such as Jason SWT.
For operational applications, data will be disseminated through Application Centers providing direct links with end-users. Some Application Centers are already identified among the MERCATOR partners, such as the French Navy's center for naval applications and Météo-France for marine safety.
The commercial sector is more open and leading initiatives (such as service providers in fisheries and offshore) are encouraged.
Interactions with seasonal forecasting, coastal and shelf, or ecosystem modeling applications are also being discussed.

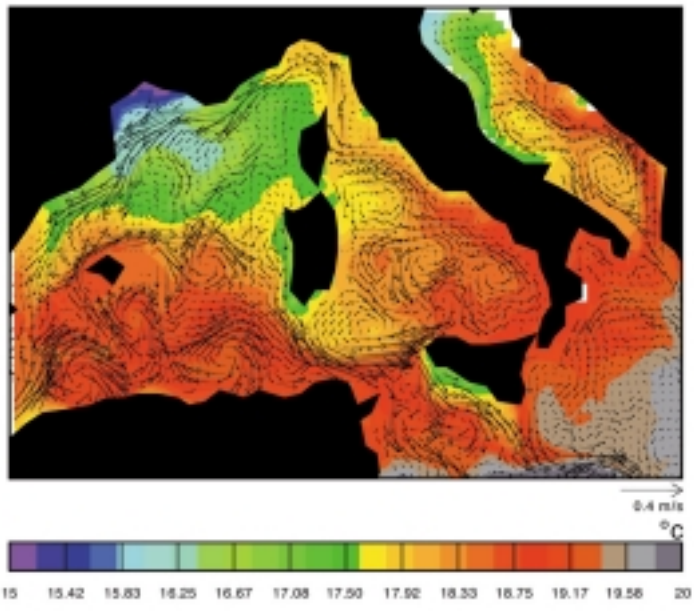

Figure 4: Surface temperature and currents in the western Mediterranean. One-year mean field without assimilation. MERCATOR high-resolution model.

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