

SOPRANE: EASTERN-NORTH ATLANTIC UNDER ALTIMETRY CONTROL

P. Bahurel (SHOM/CMO, France),
E. Dombrowsky (CLS Space Oceanography Division, France),
S. Giraud (SHOM/CMO, France),
S. Baudel (STERIA, France),
J.M. Audoubert (STERIA, France)

SOPRANE is a pre-operational ocean mesoscale forecasting system aimed at routinely providing real-time nowcast and forecast bulletins of the mesoscale ocean circulation in the Eastern North-Atlantic basin to support sea activities such as naval operations and oceanographic research cruises.

SOPRANE, a pre-operational ocean mesoscale forecasting system

The system is based on routine assimilation of TOPEX/POSEIDON and ERS-2 real time altimeter data into a quasi-geostrophic ocean model of the Eastern North Atlantic basin. The system modules include:

- operational external data acquisition and processing (altimetry, meteorology, hydrology),
- quasi-geostrophic modelling (SIMANE),
- the computation of derived oceanographic variables (temperature, salinity, sound velocity).

SIMANE is a high-resolution 10-level $1/10^\circ$ quasi-geostrophic model extending from 24°N to 54°N and from 35°W to the eastern coastal 200 m isobath. It is derived from the Blayo et al. [Blayo, 1994] North-Atlantic QG model. The model is designed to perform sequential assimilation (P. De Mey's optimal interpolation assimilation scheme SOFA) of ERS-2 and TOPEX/POSEIDON altimeter data in real time conditions, and real-time daily wind-stress forcing from the Météo-France meteorological model ARPEGE forecasts.

The system retrieves and processes Topex (JPL and NAVOCEANO) and POSEIDON (CNES) IGDRs in real time, both with a 48-hour Doris orbit provided by CNES, and ERS-2 (ESA) FDPs with a 3-day orbit provided by DEOS (Delft).

SOPRANE provides a complete depiction of the mesoscale ocean circulation from October 1992 to the present day ("hindcast" mode). Every week, a new assimilation cycle is processed with the latest altimeter tracks available in near real time (3-day latency max. for TOPEX/POSEIDON and ERS-2 data), to provide a "nowcast" bulletin. The model run provides reliable "forecasts" of ocean changes for up to two weeks.

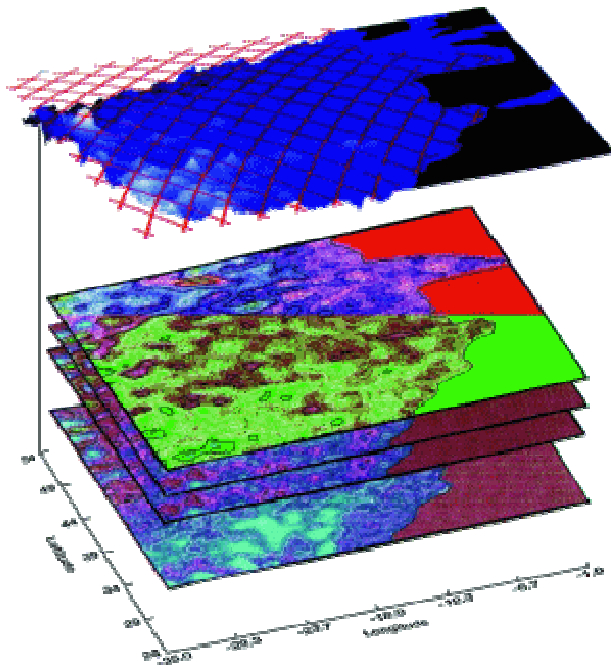


Figure 1
The SOPRANE system : Routine assimilation of TOPEX/POSEIDON and ERS-2 real time altimetry into a 10 level 1/10° quasi-geostrophic model of the Eastern North Atlantic.

Reliable forecasts of mesoscale circulation

SOPRANE was tested in summer 1997 during the ARCANE and CAMBIOS cruises, and good agreement between in situ data and model forecasts was observed. It will go into pre-operational service in April 1998. During the system validation phase (April 1997 to December 1997), the model outputs were compared to independent data sets from in situ campaigns or other QG models.

The SEMAPHORE experiment [Eymard, 1996] was used as a reference to validate the system in hindcast mode: the SIMANE model was successfully compared [Giraud, 1997] with the SEMAPHORE data set (XBTs, CTDs and drifters) and with the outputs of the [Blayo 94] North Atlantic model and the [Dombrowsky, 1994] Azores/Madeira regional model.

In addition, from April 1997 to December 1997, three assimilation experiments were performed in real time to validate the system in nowcast/forecast mode. We collaborated with scientists involved in leading oceanographic campaigns, such as J. Paillet (SHOM/CMO) and B. Le Cann (LPO) for ARCANE (in the inter-gyre region in the Eastern-North Atlantic) and F. Gaillard (LPO) for CAMBIOS (in the Azores/Madeira region). Model nowcasts and forecasts were sent from Toulouse to on-site research vessels via satellite. In-situ raw hydrological profiles or sections were received from the on-site vessels and analyzed to refine the forecast bulletin. The system appeared to be a useful tool for eddy tracking: the nowcast and forecast maps were used to optimize the measurement strategy (float deployments for example) in real time.

Figure 2 shows that SOPRANE can nowcast (and forecast), in real time, the strong current patches observed along the 24°W and 19°W sections after one month of in situ measurements, and the added value of the assimilating model compared with altimetry alone.

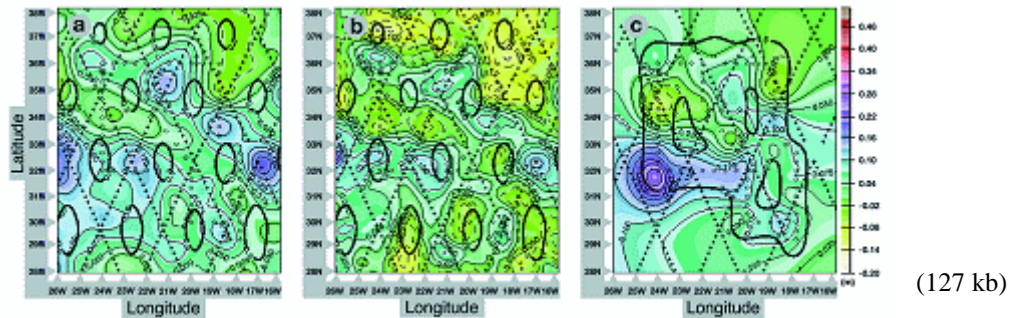


Figure 2

Three different depictions of the same situation: Total dynamic height at 100 m, in the Azores front on July 1997 (contour interval=0.25m).

- a) Altimetry alone (Optimal Interpolation of ERS-2 FDP and TOPEX/POSEIDON IGDR),*
- b) SOPRANE nowcast (assimilation of the same data into the SIMANE model), and*
- c) In Situ data (Optimal Interpolation of CTD data transmitted in real time during the CAMBIOS experiment). In the background, crosses represent the observed altimetry, and diamonds the CTD locations (bold line = 60% confidence limit of 0.1).*

Towards operational oceanography in the TOPEX/POSEIDON years

The SOPRANE project is part of a long-term program started in 1991 by the Centre Militaire d'Océanographie (CMO) and aimed at developing operational oceanography for mesoscale applications. Through this program, the strong dependence between operational oceanography and operational altimetry can be clearly observed.

SOPRANE started with the SOAP93 project, taking advantage of the availability of TOPEX/POSEIDON and ERS-1 altimeter data in the coming years. SOAP93 was a demonstration system, implemented in the Azores front region. The purpose was to perform a proof-of-concept experiment to validate the idea that real time altimetry and routine assimilation & modeling could lead to operational ocean monitoring: SOAP93 was performed continuously from 1993 to 1996 under real time conditions [Dombrowsky, 1994]. This experiment successfully demonstrated the feasibility of operational systems of this type, and helped to understand where to improve the processing system leading from satellite measurements to ocean forecast products.

The good results obtained with this preliminary system were a starting point for the SOPRANE project in 1996. After a 2-year development period, the system will go into pre-operational service in 1998, to be performed under the TOPEX/POSEIDON Extended Mission, and the ERS-2 and Geosat-Follow-On missions.

The project focuses on the improvement of operational aspects: the system is designed to be operated routinely on a weekly basis. Special attention is being paid to data handling: today, thanks to good collaboration with the French and US teams involved in IGDR data processing, the data latency of IGDR TOPEX and POSEIDON has been reduced from 10-20 days (SOAP93) to 3 days (SOPRANE), leading to a clear improvement in the system nowcasts and forecasts.

The coming years will give opportunities to work on the real time combination of multi-mission altimeter data, and to build fast, secure links between the SOPRANE assimilation system and the data providing centers. This ongoing experiment contributes significantly to the specification of future systems: the SOPRANE follow-on system (built in the framework of the MERCATOR project [Courtier, 1997]) will be based on a primitive equation model of the North Atlantic, with $1/12^\circ$ horizontal resolution. It will be operated with operational data from the EnviSat and Jason-1 missions.

References :

- Blayo E., J. Verron and J-M. Molines, 1994: Assimilation of TOPEX/POSEIDON altimeter data into a circulation model of the North Atlantic, *J. Geophys. Res.*, 99 (C12).
- Dombrowsky E. and B. Le Squère, 1994: Operational assimilation of TOPEX/POSEIDON and ERS-1 data into the French Navy's SOAP-93 forecasting system, *AVISO Newsletter 3*
- Courtier P., 1997: The MERCATOR project and the future of operational oceanography, *Biarritz International Symposium, Proceedings*, Oct.97.
- Eymard et al. , 1996: Study of the air-sea interactions at the meso-scale : the SEMAPHORE experiment, *Annales Geophysicae*, 14.
- Giraud S., S. Baudel, E. Dombrowsky and P. Bahurel, 1997: The SOPRANE project : Real-time monitoring of the North-East Atlantic - Ocean circulation Nowcast/Forecast for Oceanographic Scientific Campaigns, *Biarritz International Symposium, Proceedings*, Oct.97.