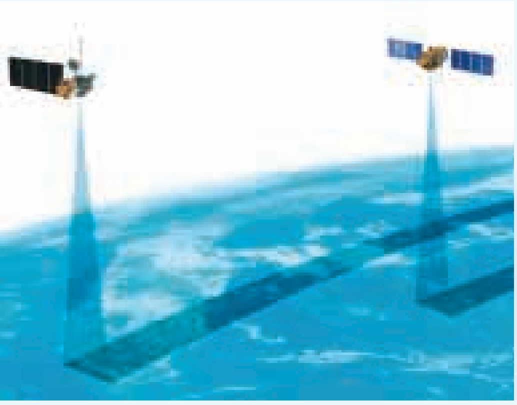
An illustration of the unique contribution of the Topex/Poseidon - Jason-1 tandem mission to mesoscale variability studies

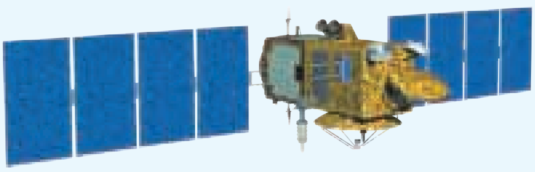
P.Y. Le Traon, G. Dibarboure
CLS, France
Pierre-Yves Le Traon - E-mail: pierre-yves.letraon@cls.fr



Artist's view of Topex/Poseidon and Jason-1 (in reality, they should be side by side)

The ocean circulation is dominated by mesoscale variability: eddies, meanders, rings, filaments, waves, and fronts are observed almost everywhere in the ocean. A better understanding of ocean circulation thus requires that we observe and model it at high spatial and temporal resolution to resolve the mesoscale variability [e.g. Wunsch, 2001]. This is also required for ecosystem modeling and for most operational oceanography applications (e.g. marine safety, pollution monitoring, offshore industry, and fisheries).

Satellite altimetry has made a unique contribution to observing and understanding mesoscale variability [see Le Traon and Morrow, 2001 for a recent review]. Two altimeter missions at least are required to monitor the mesoscale variability [Koblinsky et al., 1992]. This minimum requirement has been met since 1992 with the NASA/CNES Topex/Poseidon (T/P) and ESA ERS-1/2 altimeter missions, and their successors Jason-1 and Envisat.



However, merged T/P+ERS data have far from fully resolved the mesoscale variability. A higher spatial and temporal resolution is needed. The interleaved tandem T/P - Jason-1 mission was proposed with this idea in mind [Fu et al., 2003]. Since mid-September 2002, Topex/Poseidon has been flying midway between two adjacent Jason-1 ground tracks. This yields a track separation of 1.4° in longitude, doubling the spatial resolution that can be achieved from T/P and Jason-1 data alone. The first results from the interleaved tandem mission are presented here to demonstrate its potential for mesoscale variability studies.

Data processing

We used 32 cycles of T/P and Jason-1 IGDR data spanning the period from October 2002 to June 2003. ERS-2 Fast Delivery Products (FDP) were also used for validation purposes. All these altimeter data sets were adjusted onto Jason-1 to remove inconsistencies among missions and to reduce orbit errors. We thus get consistent sea surface height (SSH) data for the different missions.

To extract the sea level anomalies (SLA) for the different missions, we need to remove a mean profile <SSH> from the individual SSH measurements (SLA = SSH – <SSH>). The mean profile (MP) contains the geoid signal but also the mean dynamic topography (MDT) over the averaging period. For Jason, we used an MP calculated over a seven-year period (1993-1999). To get a T/P MP consistent with Jason-1 MP, an ocean variability correction was applied to T/P data using SSALTO/DUACS SLA maps.

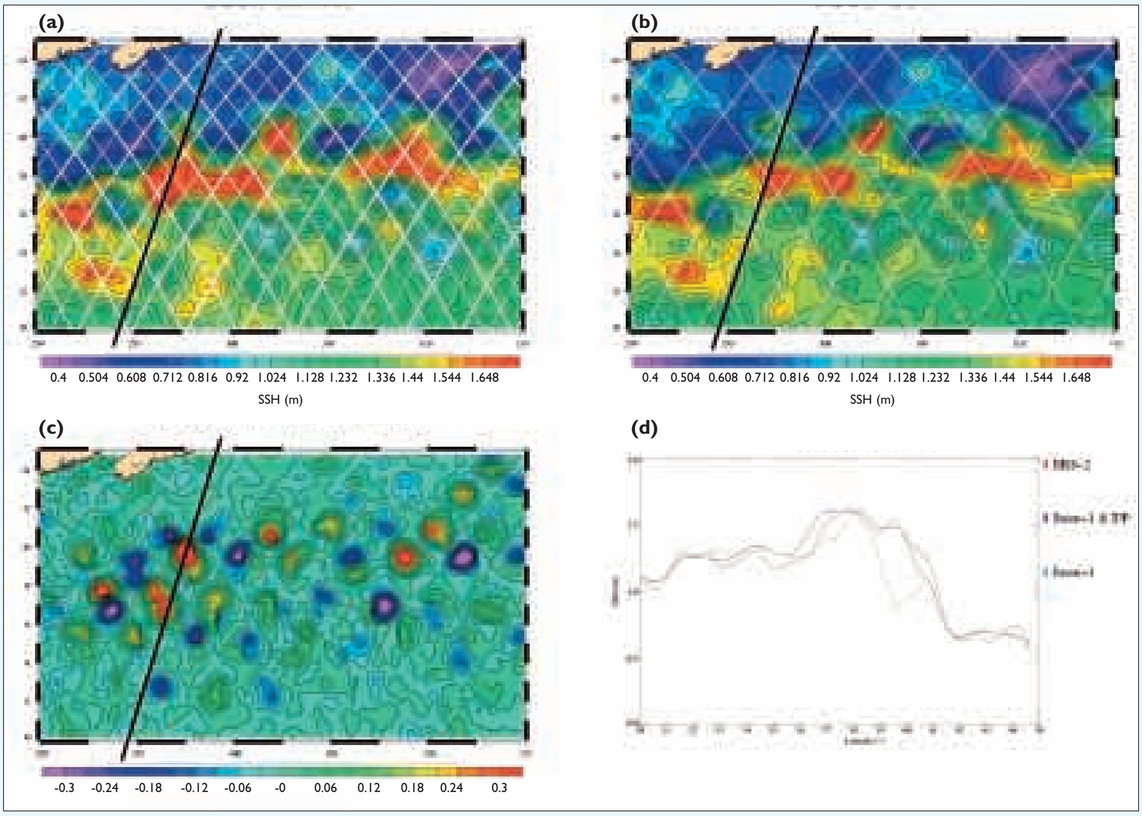


Figure 1. Absolute dynamic topography in the Gulf Stream region on December 11, 2002 derived from the combination of Jason-1 and Topex/Poseidon (T/P) (a). Jason-1 and T/P tracks are superimposed in white. (b) from Jason-1 data only. (c) is the difference between the Jason-1+T/P and Jason-1 map. Comparison with the sea level observed along an ERS track (black) (d).

A mapping method was then used to merge the SLA data from the two altimeter missions. Maps were calculated every week on a 1/3° x 1/3° Mercator grid (i.e. same resolution in latitude and longitude, that is, approximately equal to 33 km times the cosine of latitude).

Illustration of the contribution of the tandem mission for mesoscale variability studies

Monitoring of Gulf Stream meanders and eddies

Figure 1 provides an illustration of the potential of the tandem mission for better monitoring of the eddy field. The absolute dynamic topography in the Gulf Stream region on December 11, 2002, derived from the combination of Jason-1 and T/P, is shown in the figure left. A mean dynamic topography [Rio, 2003] was added to the SLA data to get the absolute dynamic topography. Jason-1 and T/P tracks are superimposed in white. The figure top right is from Jason-1 data only. The figure bottom left is the difference between the Jason-1+T/P and Jason-1 map. The Jason-1+T/P map provides a much better description of Gulf Stream eddies and meanders. Gradients are sharper and signals that are missed by the Jason-1 sampling (up to +/- 40 cm) are well reproduced with the additional sampling from T/P.

This improvement is quantified through an external comparison with the sea level observed along an ERS-2 track (black). The Jason-1+T/P map is able to reproduce most signals observed by ERS (figure bottom right), while the Jason-1 map failed to reproduce a Gulf Stream meander. The tandem mission maps are also much more consistent over time and allow us to monitor the temporal evolution of Gulf Stream eddies and meanders (see Figure 2).

Eddy Kinetic Energy and velocity mapping

Zonal (u') and meridional velocity (v') maps were derived from Jason-1 and Jason-1+T/P sea level maps (through finite centered differences). From these maps, we then computed Eddy Kinetic Energy (EKE) (EKE = $\frac{1}{2}$(<u'2>+<v'2>)). Figure 3 and Figure 4 show respectively a monthly mean of EKE from Jason-1 and from the tandem mission. The picture we get from Jason-1 alone is, as expected, far from the truth. Sampling effects are clearly visible. On the other hand, the path of the Gulf Stream is clearly seen on the EKE map derived from the tandem mission.

The same holds for the velocity field mapping. Figure 5 shows the absolute velocity field in the Gulf Stream region as derived from the tandem mission over six consecutive weeks. The MDT from Rio [2003] was used to reference the velocity anomalies. The improved sampling of the tandem mission allows us to monitor the velocity field associated with the Gulf Stream meanders and eddies. The flow is almost continuous and we do not see any apparent artifact due to sampling effects. The accuracy of the velocity field is estimated here to be about 10 to 20 cm/s, while maximum velocities can reach up to 150 cm/s. The figure shows the formation and shedding of a cyclonic ring south of the Gulf Stream and the merging of two cyclonic rings in a recirculation cell south of the Gulf Stream.

Conclusions

Results from the merging of T/P and Jason-1 have confirmed the potential of an optimized two-satellite configuration for mesoscale variability studies. Future studies should now be performed over a longer time series and should focus on velocity analysis and eddy/mean flow interaction. Similar analyses should also be performed to analyze the contribution of the tandem mission together with Geosat Follow On (GFO) and ERS-2/Envisat data. In addition to an improved understanding of the mesoscale variability, these analyses will help us to define future high-resolution altimeter missions required for operational oceanography.

Acknowledgments :

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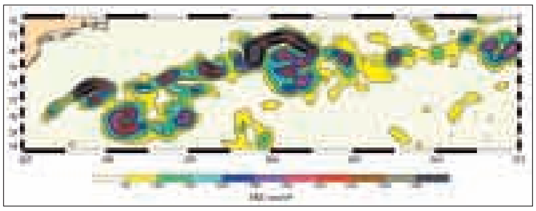

Figure 2. EKE for December 2002 derived from Jason-1 data. Units are $cm^2.s^{-2}$.

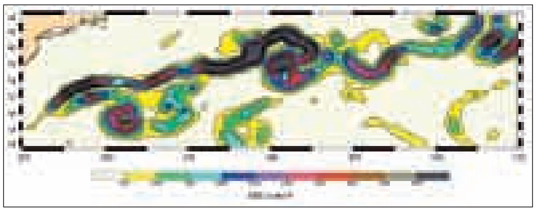

Figure 3. EKE for December 2002 derived from the tandem mission. Units are $cm^2.s^{-2}$.

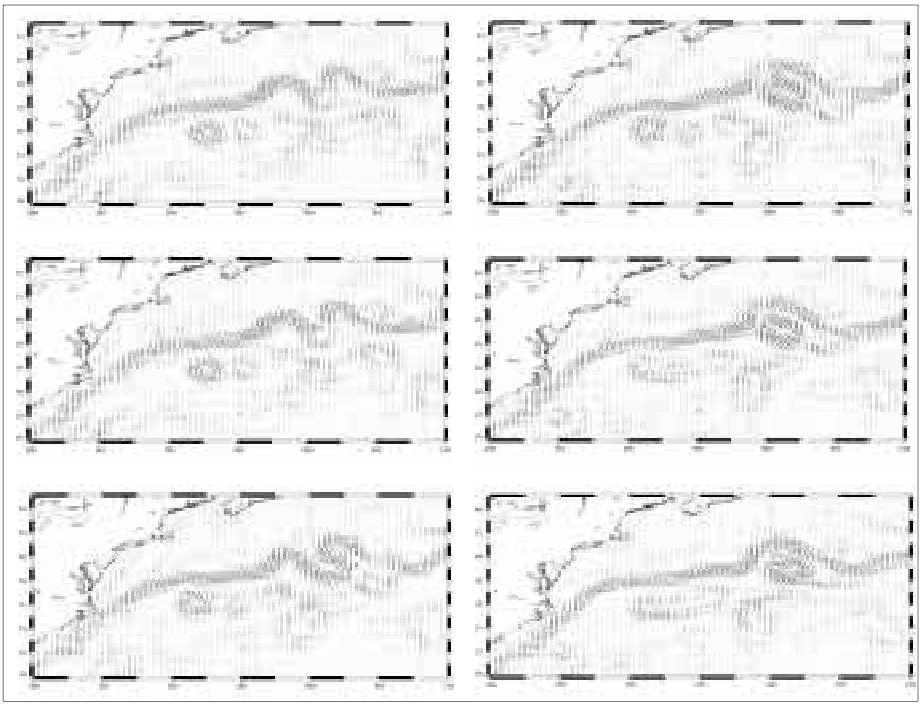

Figure 4. Snapshots of the absolute geostrophic velocities derived from the tandem mission from 2003/11/06 to 2003/12/11.

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