Characteristics of planetary waves in the North Atlantic from altimetry and the CLIPPER 1/6° model: Surface validation and subsurface structure

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CHARACTERISTICS OF PLANETARY WAVES IN THE NORTH ATLANTIC FROM ALTIMETRY AND THE CLIPPER 1/6° MODEL: SURFACE VALIDATION AND SUBSURFACE STRUCTURE

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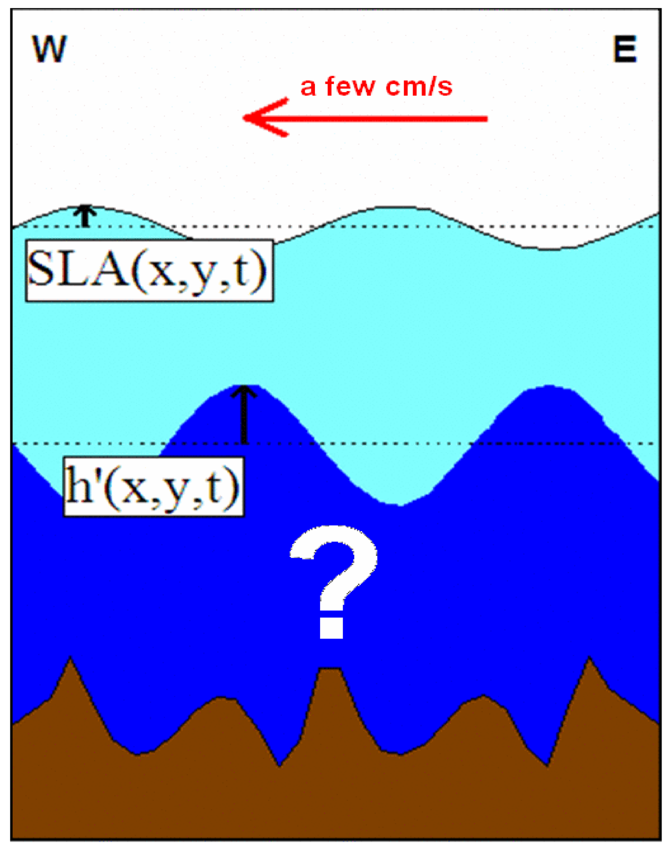
ABSTRACT

Satellite altimetry has been recording the surface signature of planetary waves in the world's oceans since 1992. These observations have highlighted the limits of standard theories about planetary waves, and stimulated the development of new ones, both of which emphazize the importance of subsurface features, i.e. the impact of baroclinic shears and bottom topography.
However, the subsurface structure of these waves is still poorly known, and realistic numerical simulations have a clear potential for such a 3D investigation. The present study focuses on the North Atlantic subtropics, and makes use of altimeter (Topex/Poseidon + ERS) sea-level anomalies (SLA) and of a 1/6° realistic Atlantic simulation performed during the French Clipper project. Westward-propagating surface structures are tracked over the period 1993-2000 from both observed and simulated SLAs. Our method, based on the Radon Transform, has been improved to extract the first baroclinic mode of the planetary waves.
This **surface validation of observed and simulated waves** is done in terms of zonal phase speeds and amplitudes, and reveals the realism of modelled waves. The same analysis is thus extended below the surface. Our analysis highlights the **complex structure of simulated waves in the vertical**, the impact of the Mid-Atlantic Ridge, and might help support theoretical investigations.



DATASETS

OBSERVATIONS

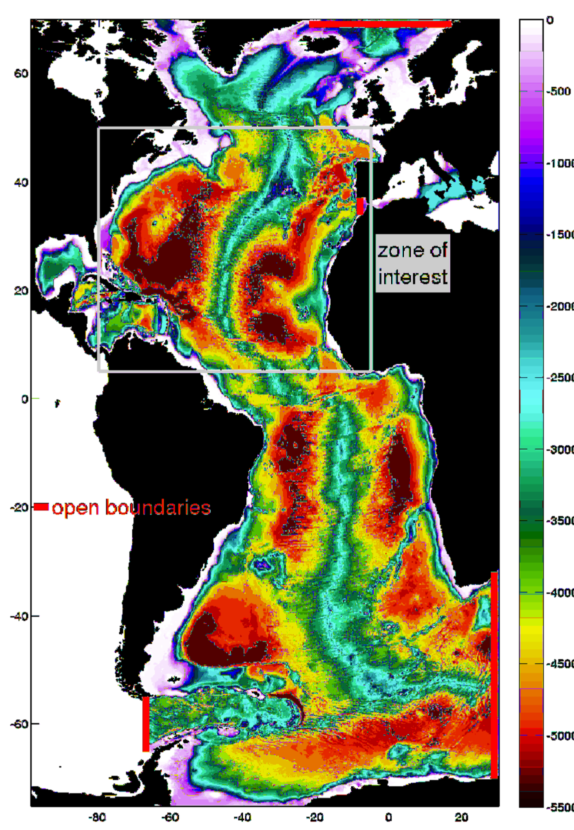
Altimeter Sea Level Anomaly (SLA) maps from merged Topex/Poseidon and ERS data distributed by AVISO.
SLA(x,y,t).
Dataset resolution = 7 days x 1/3°.

MODEL

1/6° Atlantic model based on the OPA 8.1 code.
ATL6-ERS26 simulation (Elmoussaoui et al., 2005).
Forcing: winds (ERS) + heat and salt fluxes (ECMWF).
SLA(x,y,t), depth anomalies h'(x,y,t) of 9 isopycnals located between 750m and 3250m.
Dataset resolution = 5 days x 1/6°.

Period of interest: 1993-2000.
Domain of interest: subtropical North Atlantic 15°N-40°N.

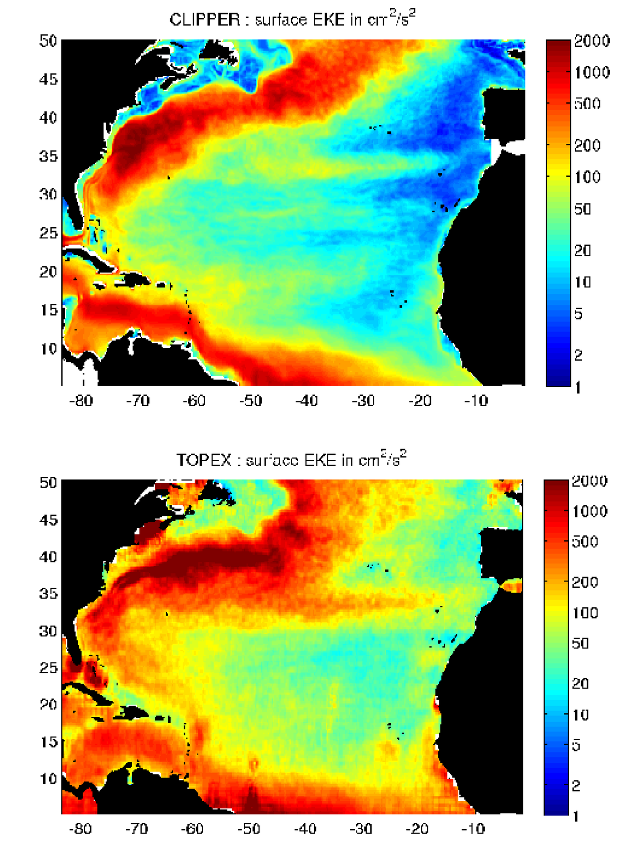
Topography of the CLIPPER model



The path of the main eddy active front is simulated correctly by the CLIPPER model in the region of interest.

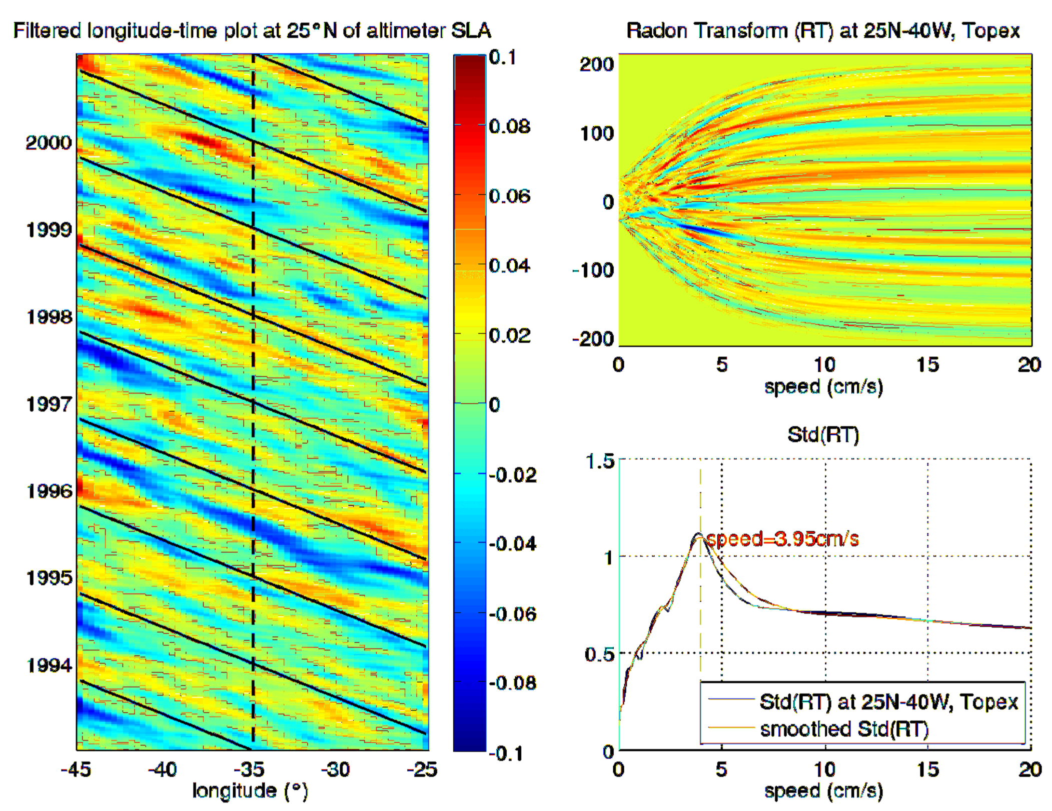
Despite a too zonal North Atlantic current, the Azores current is well located but the associated turbulence is weak.

As expected, the EKE is weaker than in reality.

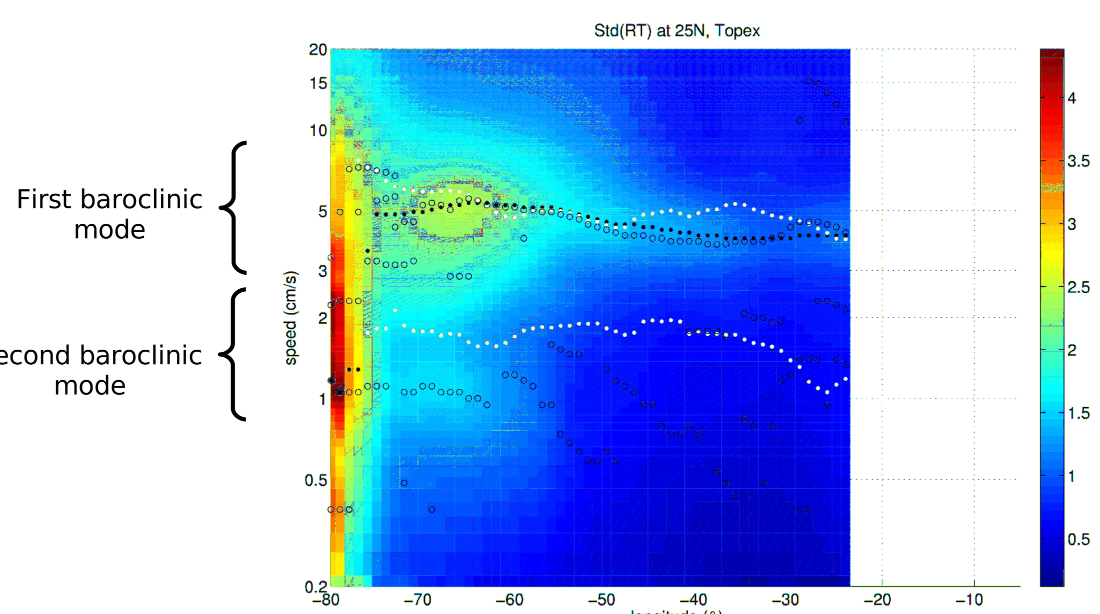


METHODOLOGY

The data processing has been applied on the surface observations, and on the surface and subsurface simulated data.
Longitude-time sections have been extracted and filtered (eastward propagating signals + non-propagating quasi-annual signal have been removed) along every latitude line.
Zonal phase speeds have been evaluated using the Radon Transform (RT). The angle of alignment in longitude-time plots can be converted into an estimate of zonal phase speed. The dominant propagating mode corresponds to a maximum of the standard deviation of the Radon Transform (Std(RT)) field. (Hill et al, 2000)
The Std(RT) field has been smoothed in the (x,y,speed) 3D space to remove grid-scale noise.



This method allows to quantify the zonal phase speeds C(x,y,z) of the dominant signal at each location (x,y,z) (black dots in the figure below). **An EOF analysis and a comparison with theoretical phase speeds (Killworth et al. 2003 - white dots) show that the dominant signal corresponds to the first baroclinic mode of Rossby waves. Phase speeds of the second and higher modes are detected too (black circles).**



PHASE SPEEDS : MODEL SKILL AT THE SURFACE

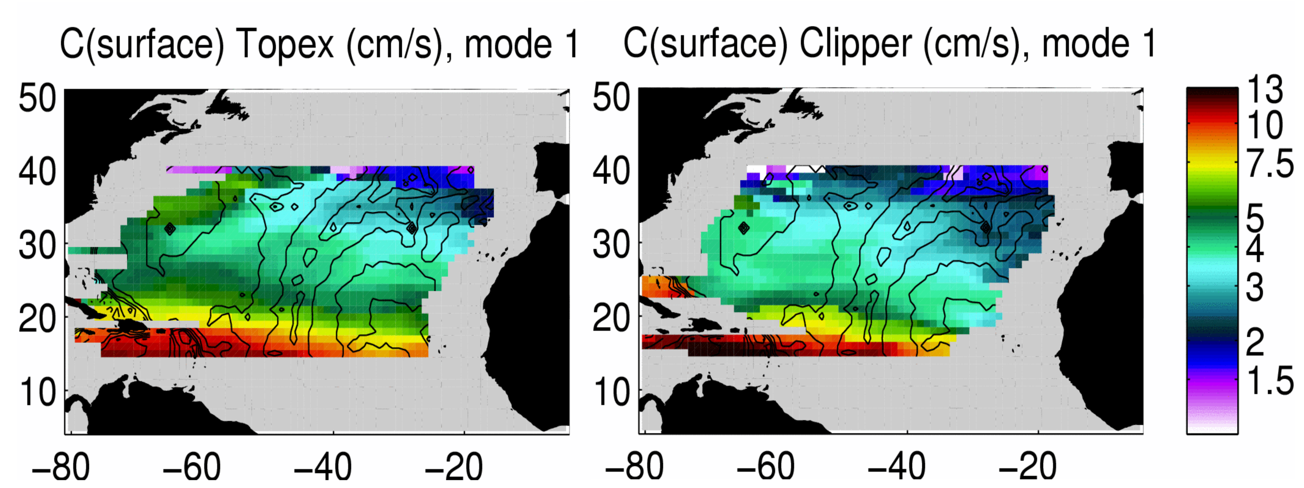
As expected from the theory, and as shown in several papers (e.g. Polito et al., 1997), observed zonal phase speeds strongly increase equatorward and slightly increase westward.

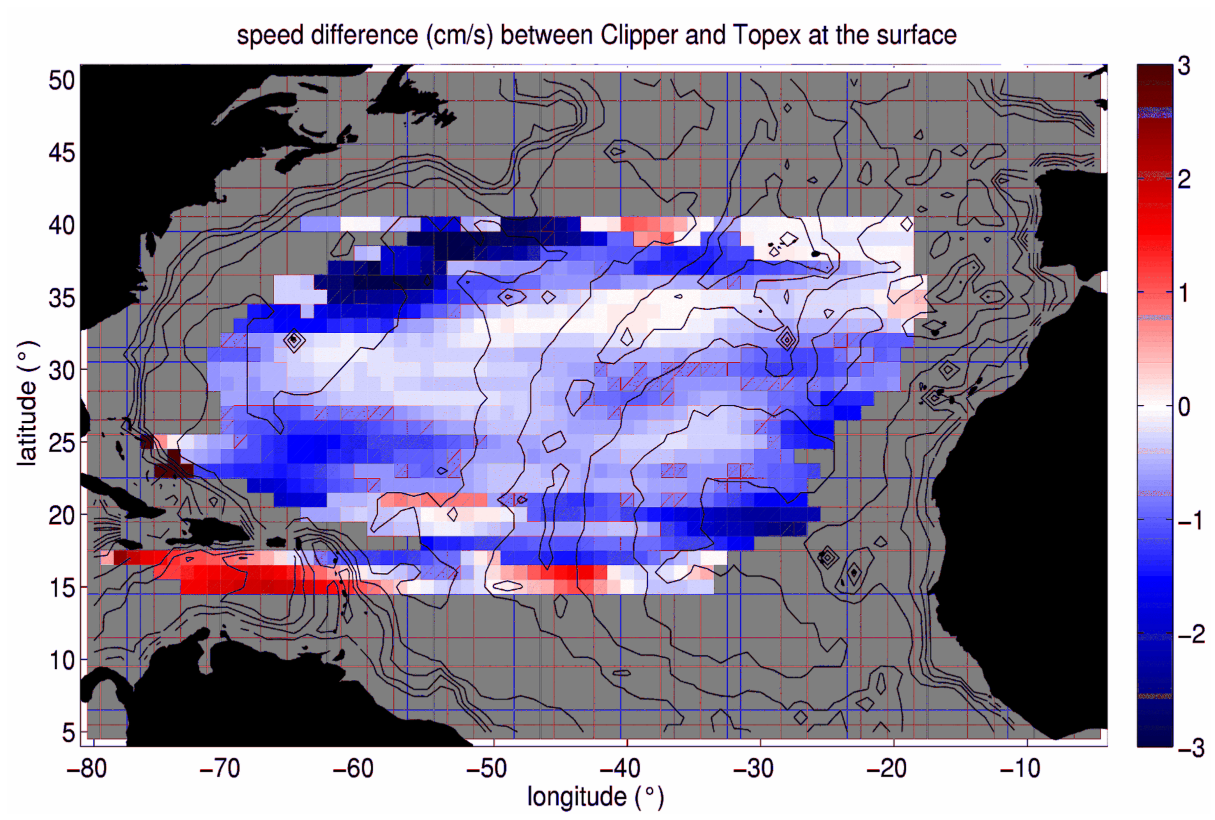
The general structure of simulated phase speeds is close to the observations. The model reproduces well the magnitude of observed phase speeds, however on average slower than observed (+/- 1cm/s of difference).

The agreement in the Azores current is very good.

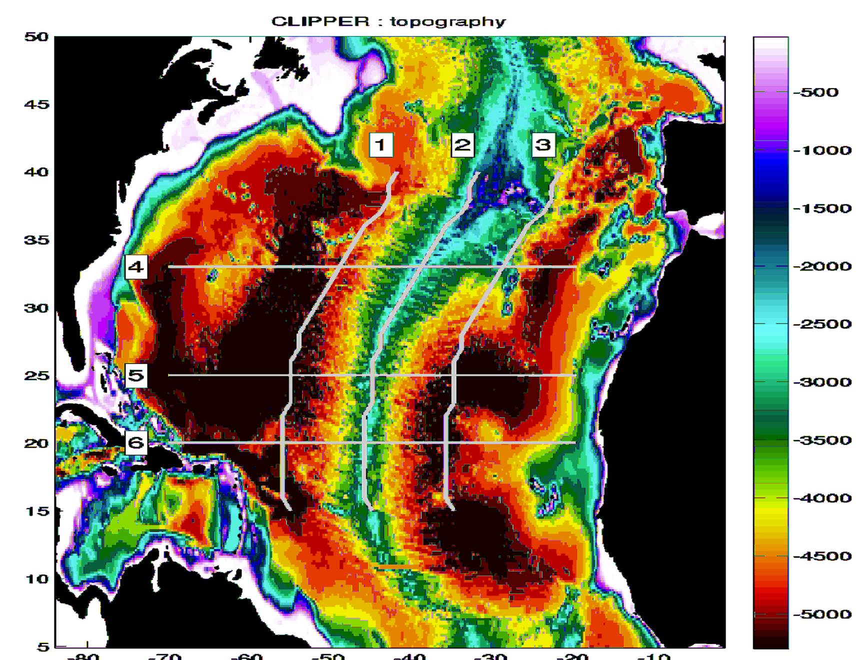
In the Gulf Stream region, which overshoots to the North in the model, the difference is particularly noticeable (2 to 3 cm/s).

Simulated zonal phase speeds are thus in good agreement with surface observations, despite a slight slow bias.





VERTICAL STRUCTURE OF SIMULATED WAVES



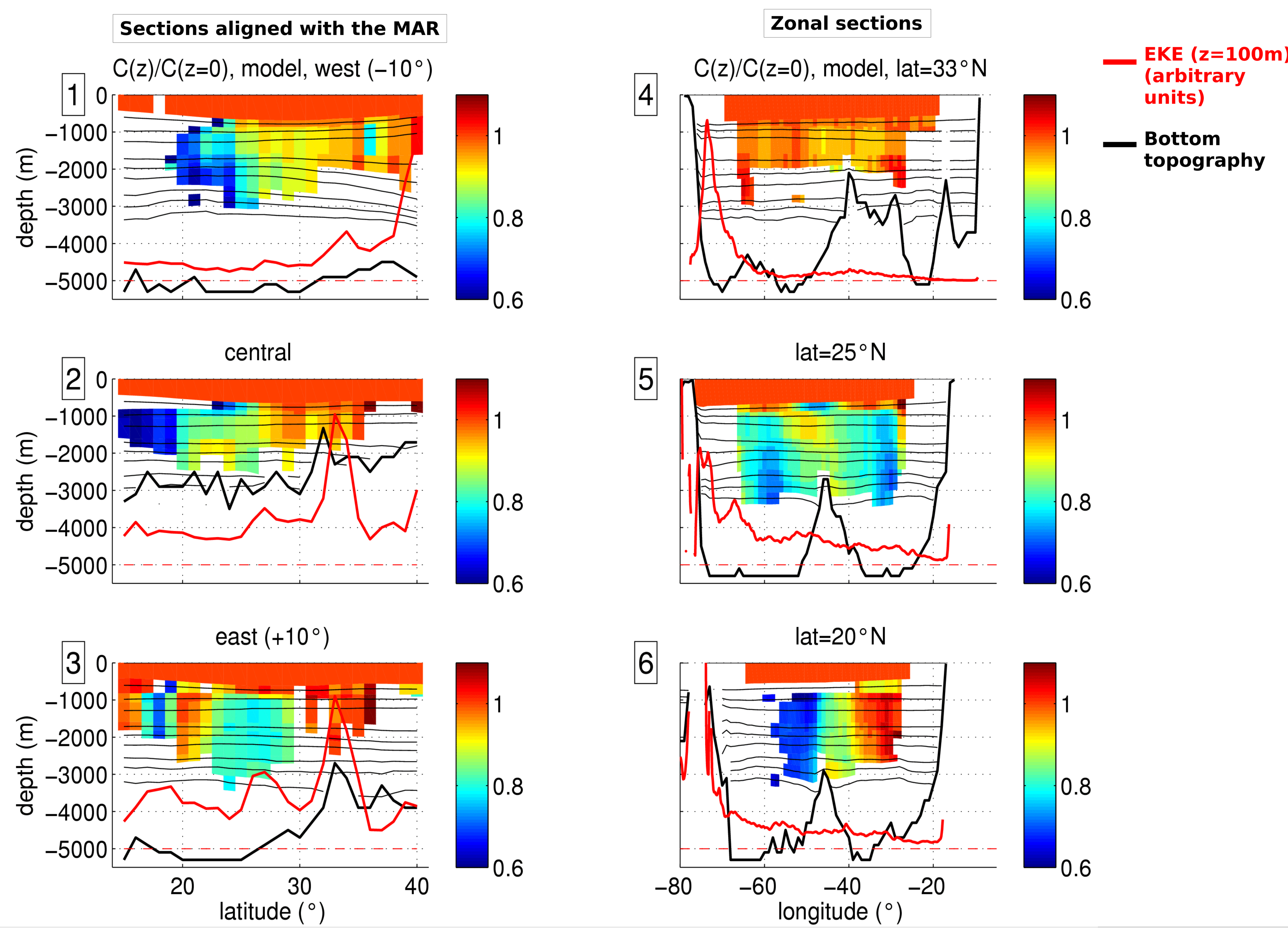
Simulated 1st baroclinic mode phase speeds C(x,y,z) exhibit a complex 3D structure (see the sections): **C(x,y,z) clearly tends to decrease with increasing depth.**

- C(z)/C(z=0) depends on longitude in the southern region (varying from ~70% to ~100% from west to east along 20°N). This zonal dependency decreases northwards.

- C(z)/C(z=0) is clearly affected by the **Mid-Atlantic Ridge (MAR)** south of about 30°N.

- C(z)/C(z=0) is maximum between 30°N and 35°N (95-100%). This region coincides with the **Azores front and its associated EKE maximum** (red line).

The **C(z) structure**, the **effect of the MAR** and the **possible link with the EKE levels** remain open questions. Further investigation is required to explain them.



CONCLUSIONS - PERSPECTIVES

Zonal phase speeds of **first baroclinic mode** of Rossby waves have been estimated in **subtropical North Atlantic** from Topex/Poseidon+ERS observations and high resolution output.

Surface : The model represents well the general structure of the Rossby wave phase speeds despite a slight slow bias.

Subsurface : Analysis of model output over the first 3.5 km shows that Rossby wave phase speeds **tend to decrease with increasing depth**.
However, this tendancy is less clear along the **Azores Front (maximum in EKE)** and might be affected by **bottom topography** as well. This features require further investigation with respect to existing theories.

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