Using ARGO and altimetry to assess the quasi stationary circulation in the North Atlantic

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Summary

The goal of the present study is to combine the available data from **ARGO** (**A**rray for **R**eal-Time **G**eostrophic **O**ceanography) profiling buoys and satellite altimetry provided by Aviso for the years 2005 and 2006 into an **I**nverse **F**inite **E**lement **O**cean **M**odel (**IFEOM**) to produce and improve the estimates of the circulation for the North Atlantic. The model solves for temperature and salinity fields that are close to ARGO, respect quasi-stationary tracer balances, and simultaneously produces estimates of the circulation. The experiments with and without MADT (seal level anomaly + Rio05) and ARGO temperature and salinity included into IFEOM as a weak constraint have been carried out, respectively. The variability of the North Atlantic Ocean circulation is compared between the years 2005 and 2006. We show, that including altimetry improves the circulation pattern.

Model and Data

In this study a 3DVAR data assimilation is performed. The model solves the stationary momentum equations for velocity field and sea surface height, and treats the advective-diffusive tracer balances as soft constraints. IFEOM seeks for the temperature (***T***) and salinity (***S***) fields which give minimum to its objective function. The latter penalizes residuals in the tracer equations (1), deviations of model variables from data available (2) and also misfit between diagnosed deep pressure gradient and the pressure gradient of the prognostic run of the model (3). IFEOM was used to reconstruct the large-scale ocean circulation for the years 2005 and 2006 with a surface elevation close to the dynamic topography provided by Aviso (***ALT***). The data on T and S include Gouretsky and Koltermann (***GUR***) climatology and ARGO buoy data for the corresponding year. All ARGO T and S data for one corresponding year are used for assimilation. To remove the annual cycle of T and S, the Levitus climatology (WOA05) is subtracted on a monthly basis and the annual mean of this climatology is added back afterwards. Altimetry data is taken from Aviso.

Absolute Dynamic Topography, the sum of sea level anomaly (SLA) and mean dynamic topography (MDT, Rio05) is used.

Four model set ups are performed, the assimilation of:

- **I** GUR,
- **II** GUR + ALT,
- **III** GUR + ARGO,
- **IV** GUR + ARGO + ALT.

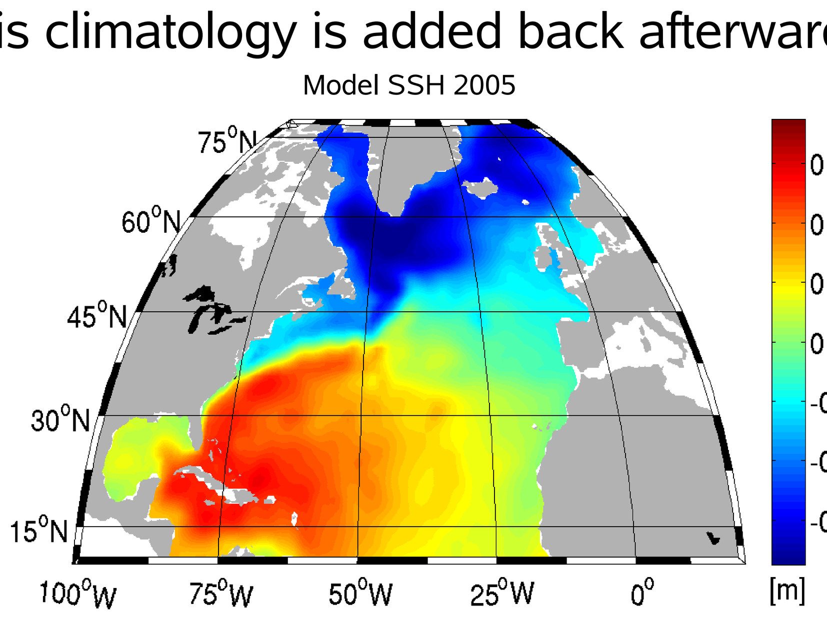

Figure 1: Sea surface height (SSH), produced after assimilation of (GUR, ALT and ARGO)

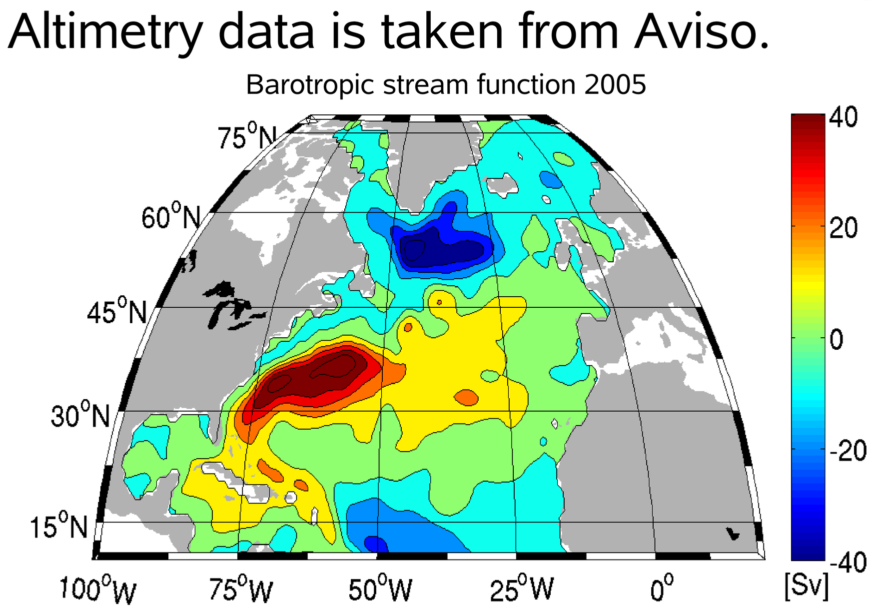

Figure 2: Barotropic stream function, produced after assimilation of (GUR, ALT and ARGO)

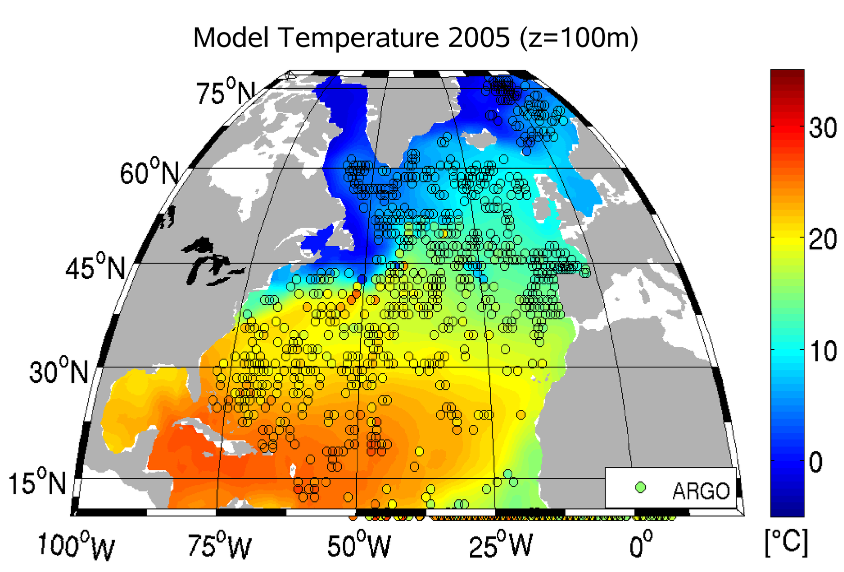

Figure 3: Model temperature, produced after assimilation of (GUR, ALT and ARGO)

Model results

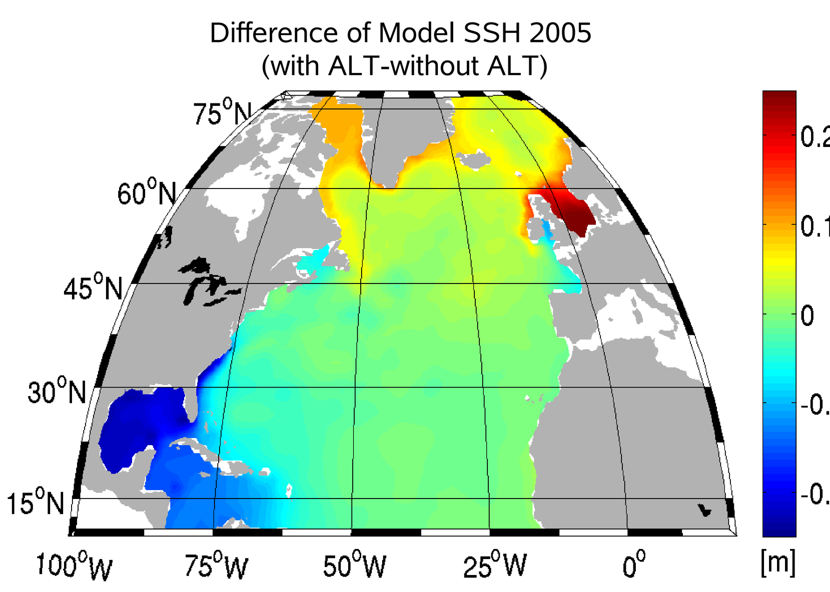

Figure 4: Difference of sea surface height, produced after assimilation of (GUR) and (GUR and ALT)

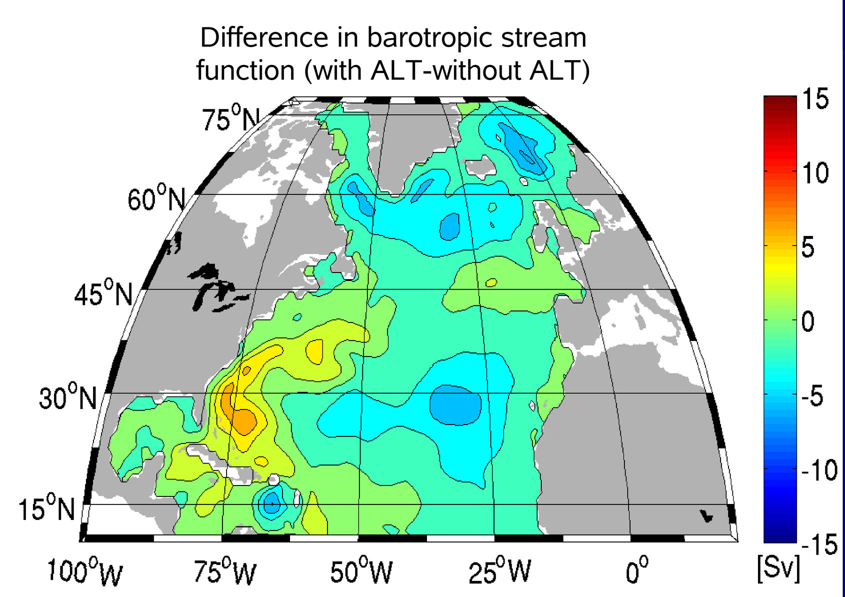

Figure 5: Difference of barotropic stream function, produced after assimilation of (GUR) and (GUR, and ALT)

Assimilation of ALT changes the model topography on large scales (Fig. 4), which also improves the circulation patterns (Fig. 5).
The assimilation of ARGO changes T and S substantially on regional scales (Fig. 6). The barotropic response is strong (Fig. 7).

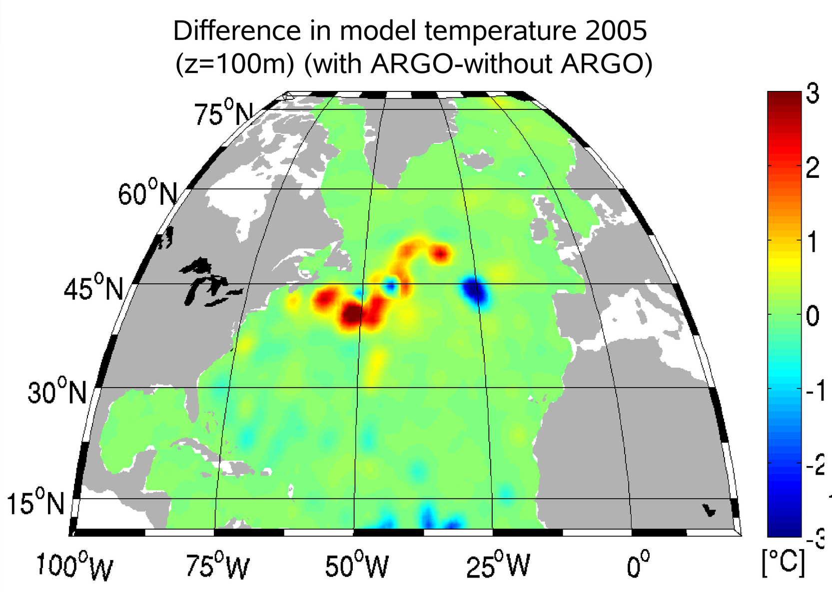

Figure 6: Difference of temperature, produced after assimilation of (GUR) and (GUR and ARGO)

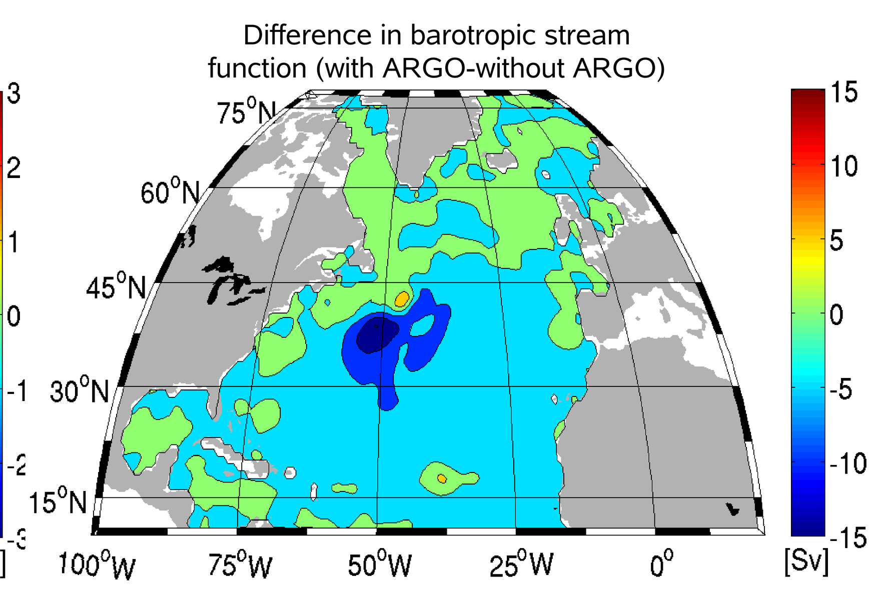

Figure 7: Difference of barotropic stream function, produced after assimilation of (GUR) and (GUR and ARGO)

Model quality

The standard deviations of various differences (Fig. 8) show that the assimilation algorithm is working well. Assimilation of ALT does not change T and S into the direction of ARGO. Similarly ARGO does not improve model topography. The combination works successfully.

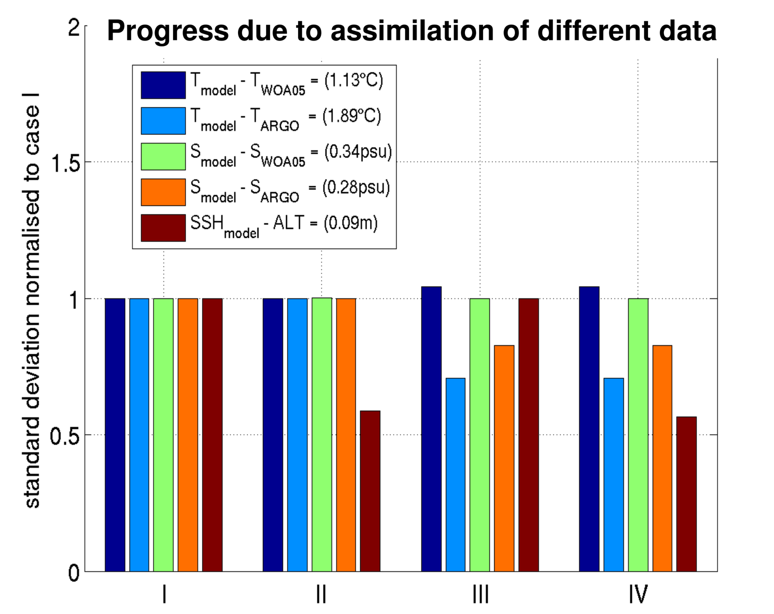

Figure 8: Standard deviations for all model set ups I to IV. Case I to II +ATL; case I to III +ARGO; case I to IV +ALT+ARGO

Annual variability

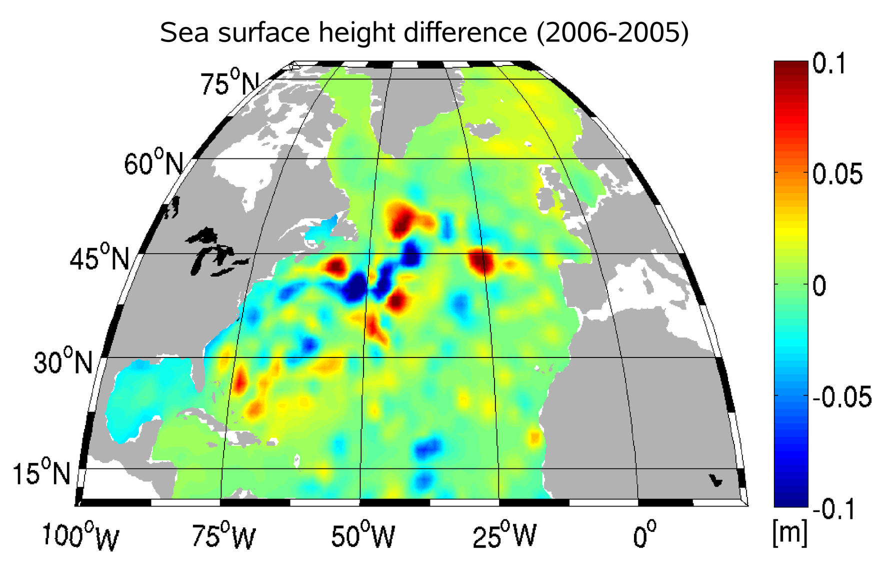

Figure 9: Sea surface height difference between 2005 and 2006 after including (GUR, ALT and ARGO)

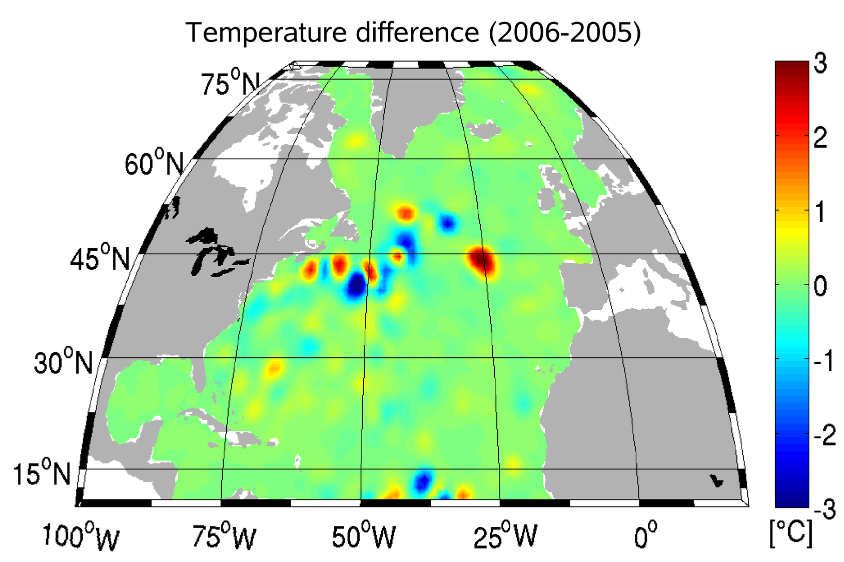

Figure 10: Temperature difference (z=100m) between 2005 and 2006 after including (GUR, ALT and ARGO)

The differences in sea surface height between 2005 and 2006 (Fig.9) are mainly captured due to ARGO, so the smaller scale variability from ALT is suppressed. The effect of assimilating altimetry data is mostly large on scales. Here the effects due to the assimilation of ARGO and altimetry are present. The changes produced by altimetry (compare to Fig. 4) and the changes coming from ARGO (Fig.10 and 11) are well seen.

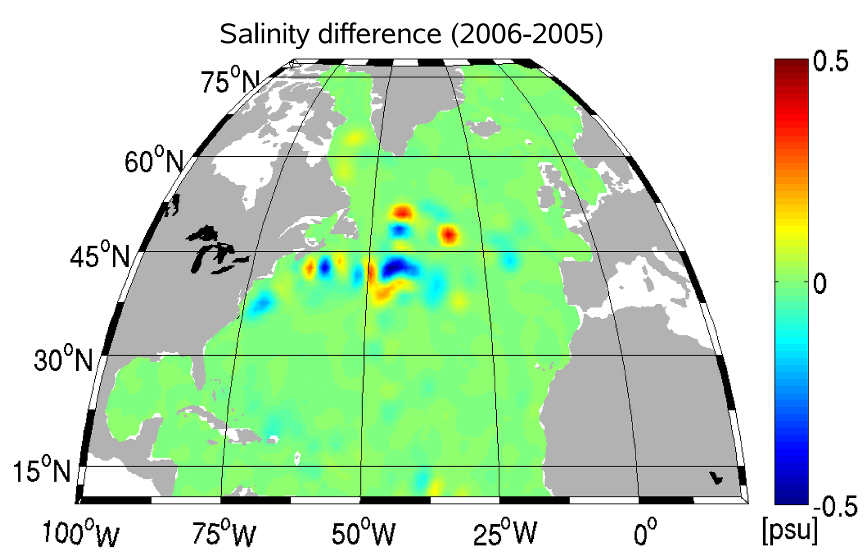

Figure 11: Salinity difference (z=100m) between 2005 and 2006 after including (GUR, ALT and ARGO)

Comparison to ARGO velocities

The patterns of the modelled velocities for the case IV are also visible by comparison to the YoMaHa'07 dataset (Fig. 12 and 13). There are larger velocities in the Gulf stream region and the North Atlantic subpolar gyre.

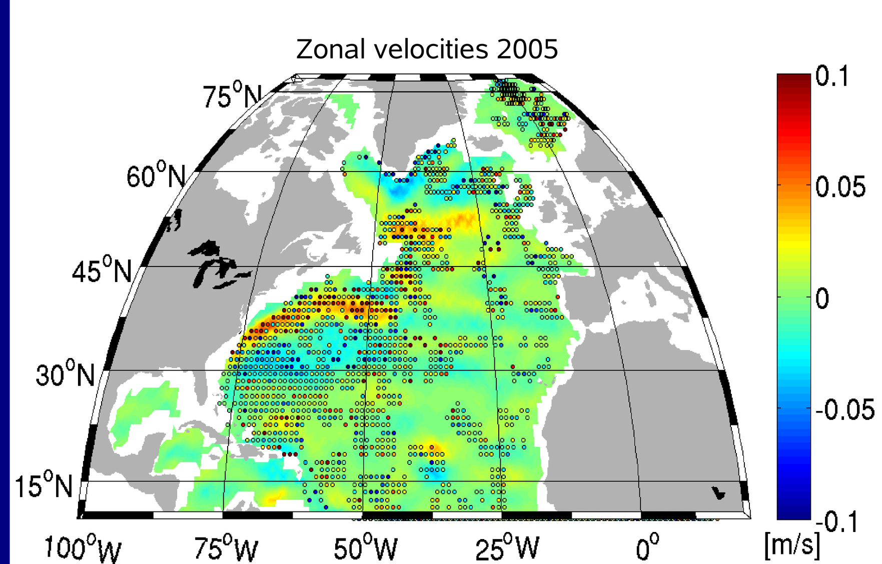

Figure 12: Zonal velocities at 1000m depth. Background: model output (GUR,ARGO and ALT); dots: YoMaHa07 dataset (modified)

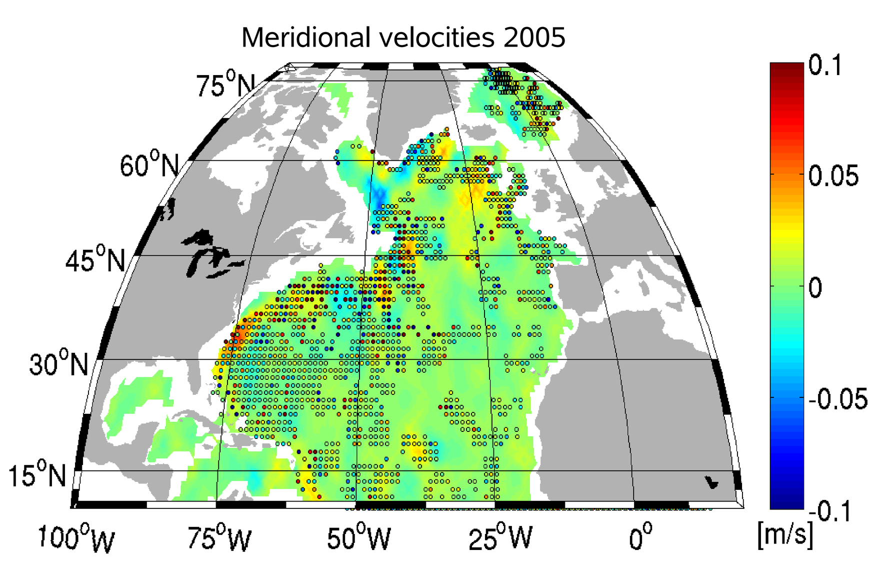

Figure 13: Meridional velocities at 1000m depth. Background: model output (GUR,ARGO and ALT); dots: YoMaHa07 dataset (modified)