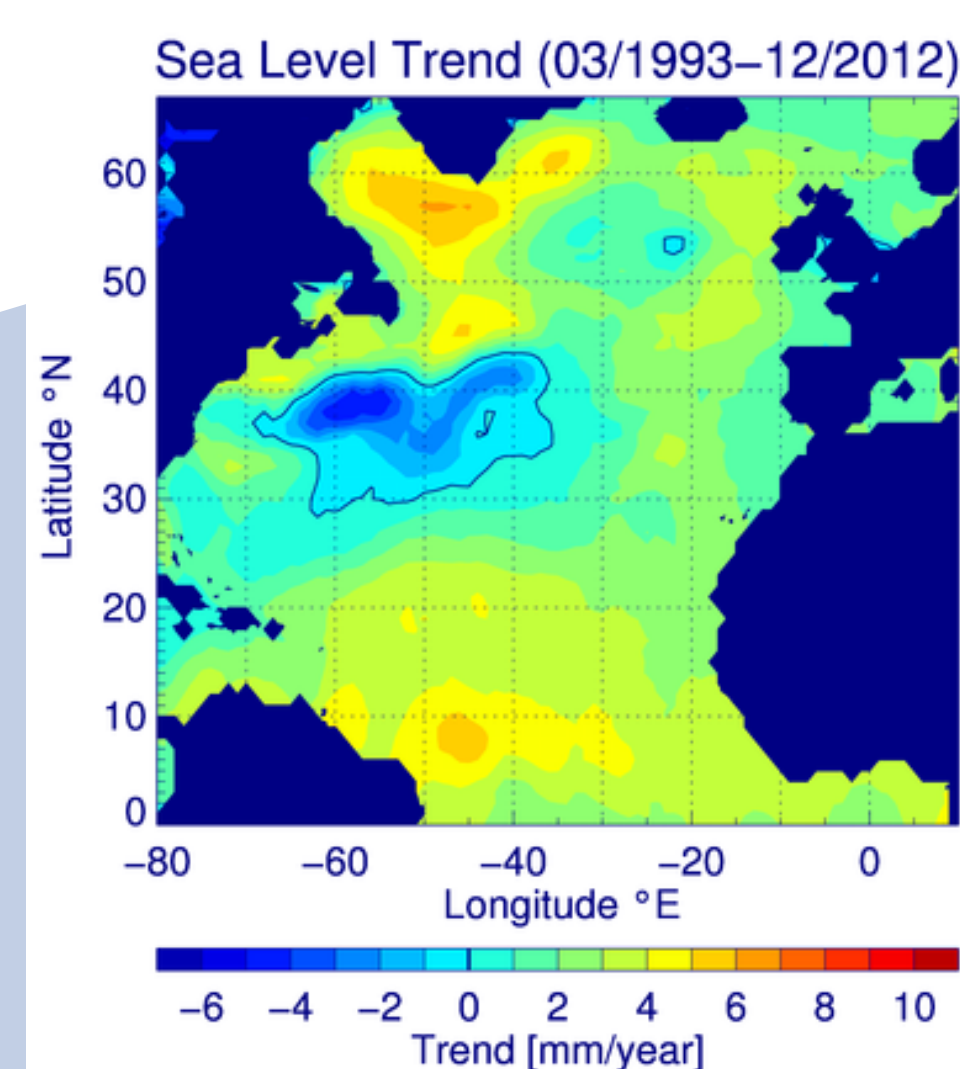


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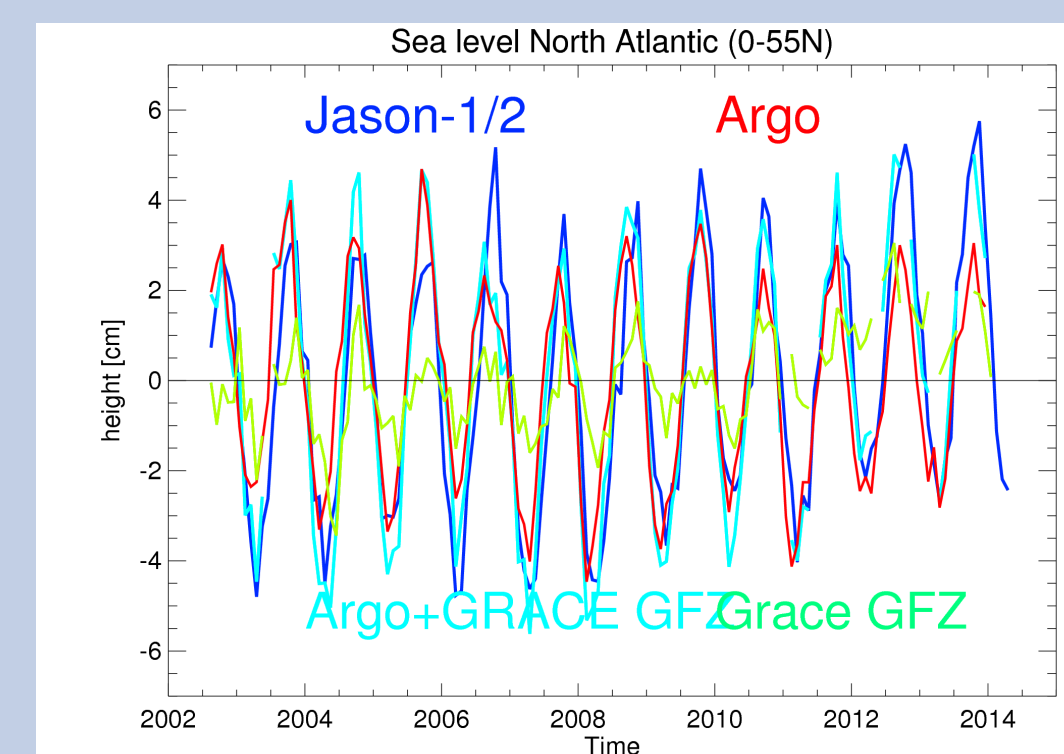
Introduction

Regional sea level changes in the North Atlantic on spatial scales greater than 500 km are studied for the period 2002 to 2013. The focus is on the relation between the total sea level and its steric and mass equivalent components. The data bases are: monthly gridded sea levels from the Jason-1/Jason-2 satellite altimeters, gridded steric sea levels from Argo floats and mass equivalent sea level from the GRACE mission.



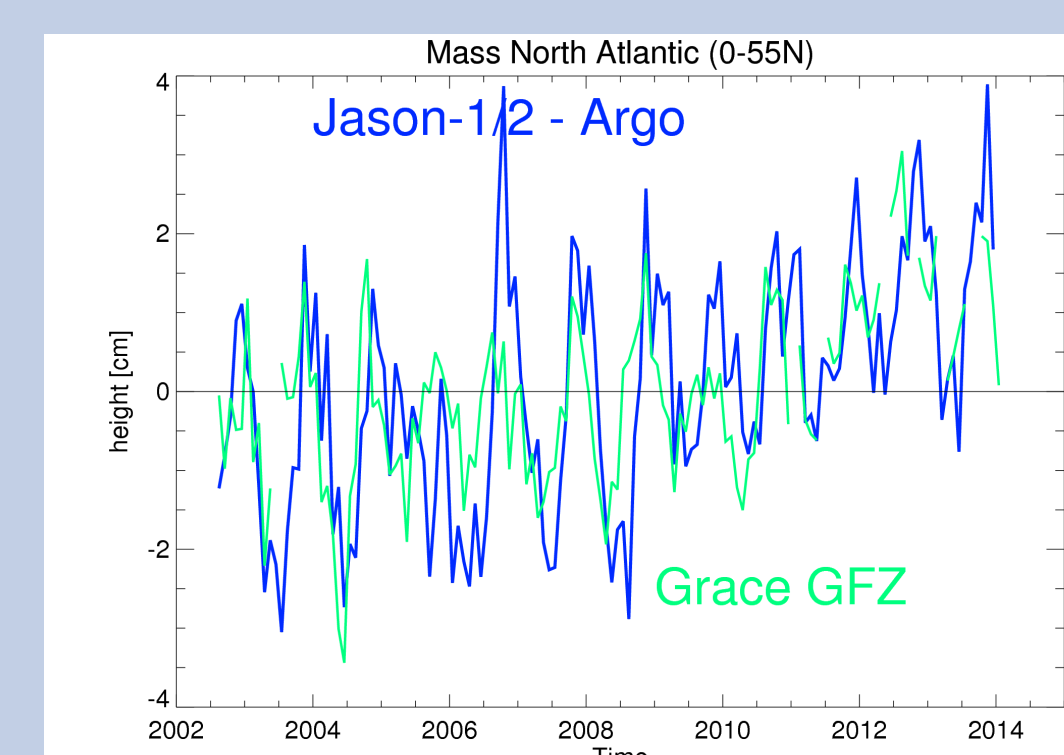
Top: 20-year sea level trends derived from altimetry. The trends are distributed nonuniform and reflect the main branches of the upper ocean circulation

Mean Sea Level and Mass Change

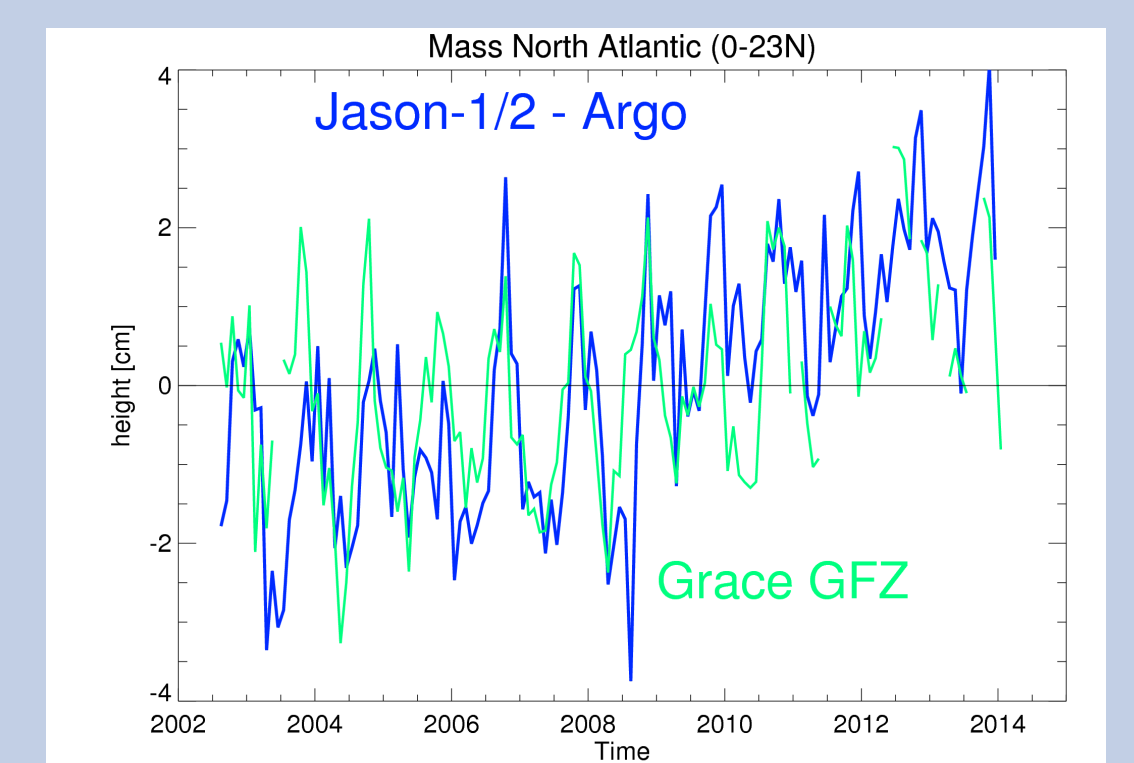


Top: North Atlantic mean sea level (0°-55°N); total (dark blue), steric (red), mass (green), sum of steric and mass (light blue).

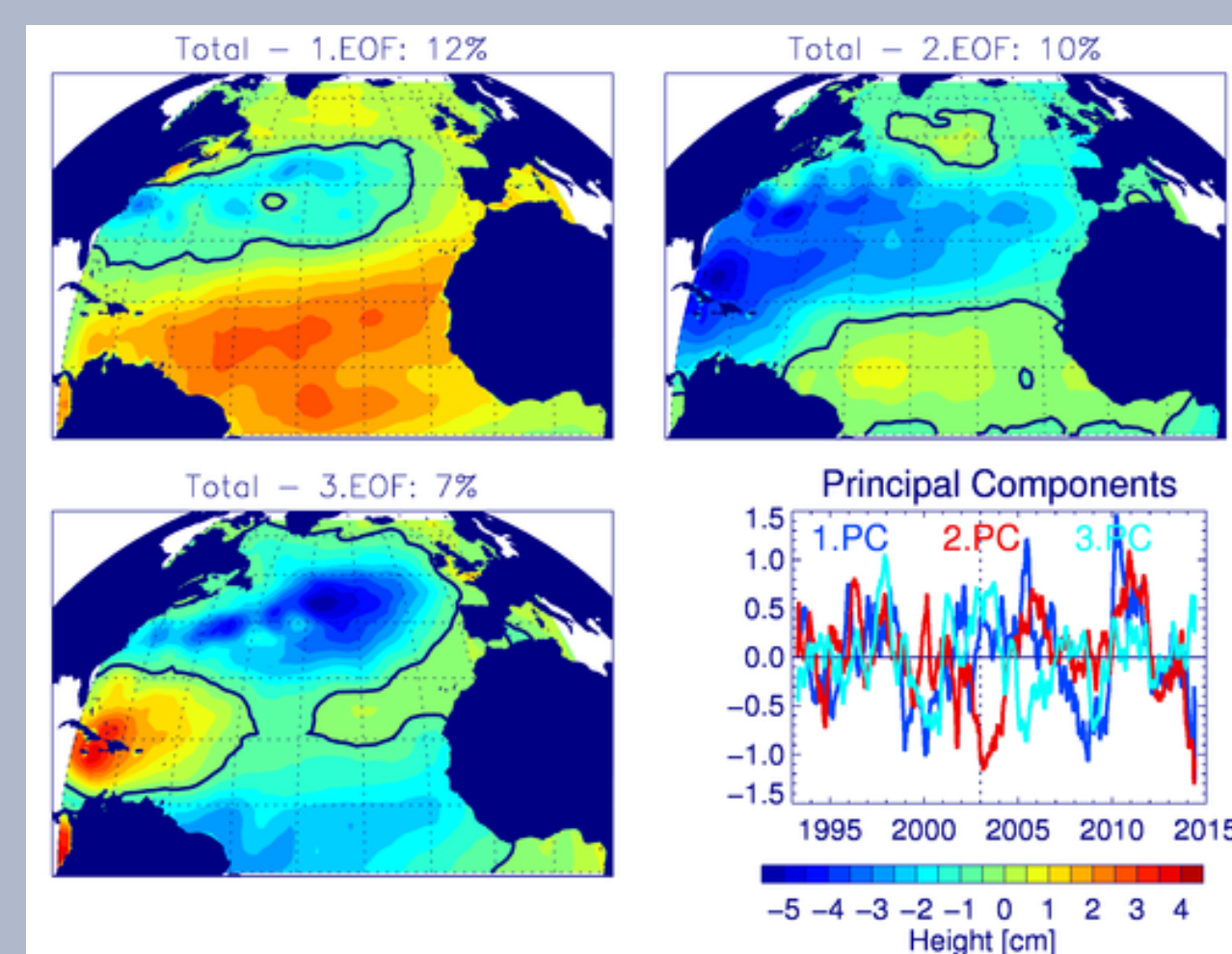
The mean sea level of the North Atlantic is dominated by the steric component. Steric and mass equivalent components are in phase. From 2009 on the mass equivalent sea level has been rising. The origin of this signal is in the Tropical Ocean. The onset coincides with a major decrease of the AMOC at 26°N.



Top: Mass equivalent sea level from GRACE (green) and from the difference of the total and steric components (blue). **Right:** For the Northern Tropics (top) and the Subtropics (bottom).

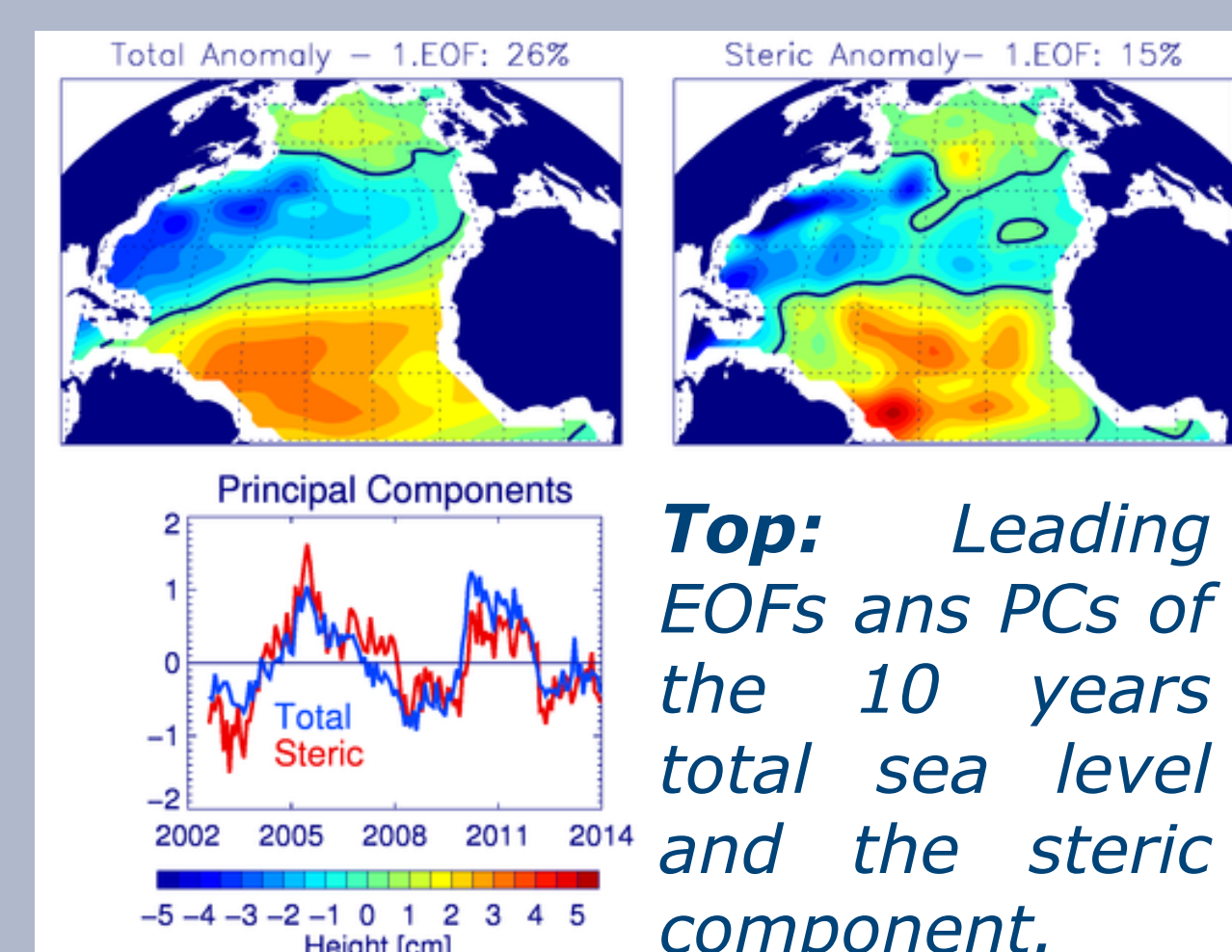


Modes of Variability

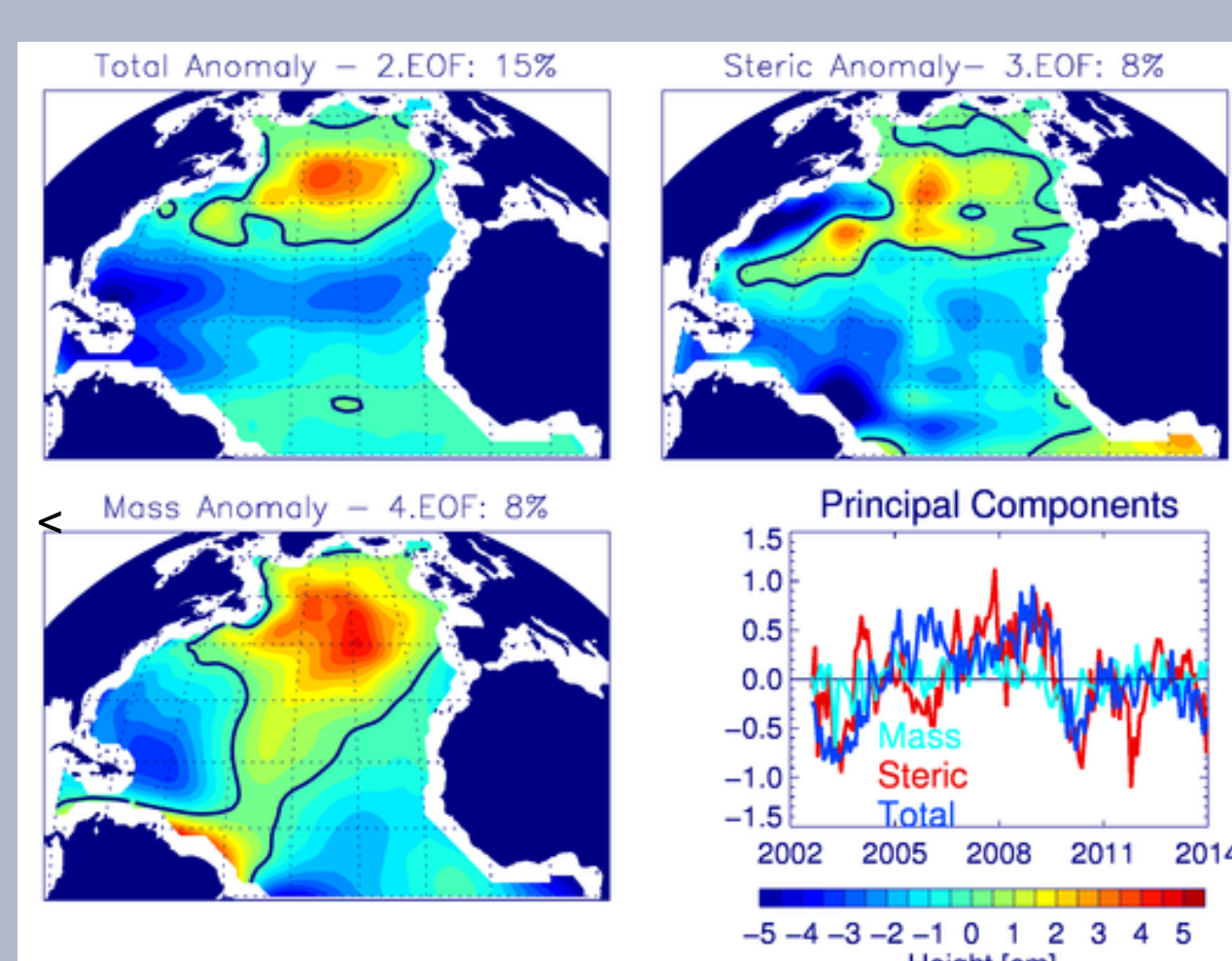


Top: Leading three Empirical Orthogonal Functions (EOFs) and corresponding Principal Components (PCs) of the 21 years sea level series (w/o annual) from altimetry.

The dominant spatio-temporal patterns are studied using Empirical Orthogonal Functions (EOFs). The first EOF from the 21 years altimetry series matches the trend pattern over the same period and is related to a weakend/strengthened subtropical gyre. It shows interannual to decadal variations. This pattern seems to be of steric origin: it is in good agreement with the EOF1 from the 10 year altimetry and the steric series.

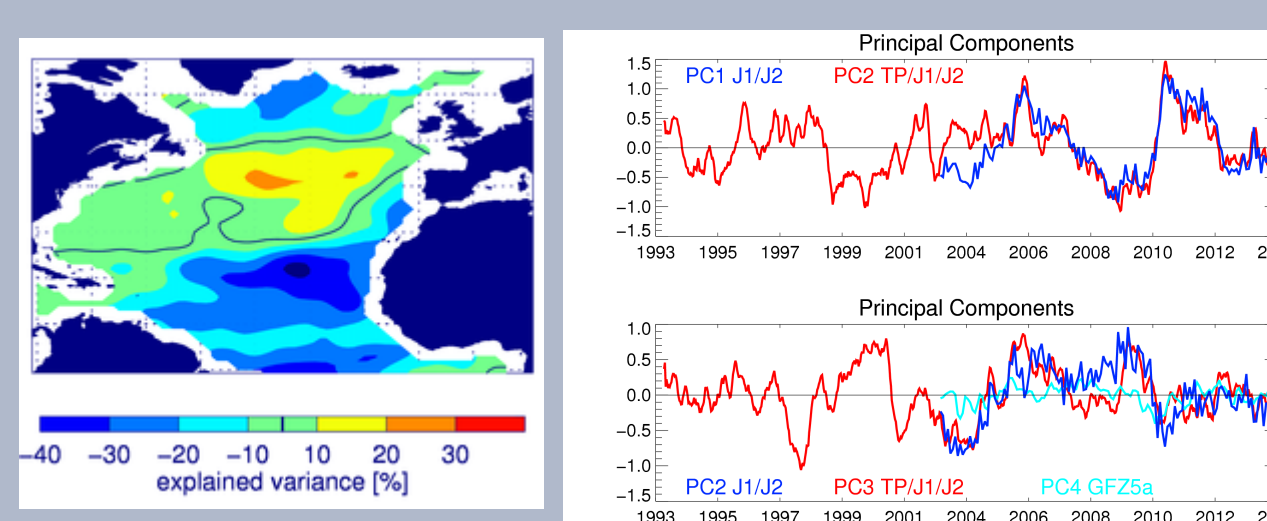


Top: Leading EOFs and PCs of the 10 years total sea level and the steric component.



Top: EOFs and PCs related to the extension of the subtropical gyre for the total, steric and mass equivalent sea level.

All three data sets exhibit a pattern that seems to be related to the extension of the subtropical gyre. It varies on intra-annual to interannual time scales. For some episodes total and steric and total and mass equivalent sea level are in phase. The abrupt reversal of the EOF1-pattern in 2010 was preceded by a change in the 'gyre mode' patterns.



Left: Regression of the cumulative PC of the 'gyre mode' from GRACE to the total sea level. **Right:** PC1 from the 21 and 10 years altimetry series (top), PCs of the 'gyre mode' from altimetry and GRACE (bottom).

Data

- all: 8/2002 to 12/2013, monthly, 1°x1° grid, filter~500km
- Jason-1/2: processed by ADS Central (<http://adsc.gfz-potsdam.de/ads>)
- Topex: included to extend the total sea level series to 21 years
- GRACE: GFZ RL05a anisotropic filter DDK1 (Kusche, 2007) (<http://icgem.gfz-potsdam.de>)
- GAD dealiasing & GIA product GFZ & geocenter motion (Swenson et al., 2008) & C20 term from SLR
- ARGO: monthly gridded T/S profiles from MetOffice Hadly Centre (EN4), 2000m reference level

Conclusions

- Good agreement between monthly sea level and its steric and mass contributions in the Tropics
- The Mass component has increased in the North Atlantic since 2009 (~4mm/year)
- The origin of this signal is in the Tropics
- The dominant mode of sea level variability is of steric origin and seems to be related to the strength of the subtropical gyre
- A 'gyre mode' related to the northeastward extension of the subtropical gyre is inherent to all three data sets