Second Split Workshop in Atmospheric Physics and Oceanography

PROCESSES CONTRIBUTING TO THE GLOBAL SEA LEVEL CHANGE

Student: Maristella Berta

Mentor: Prof. Stjepan Marcelja

Split, 24 May 2010

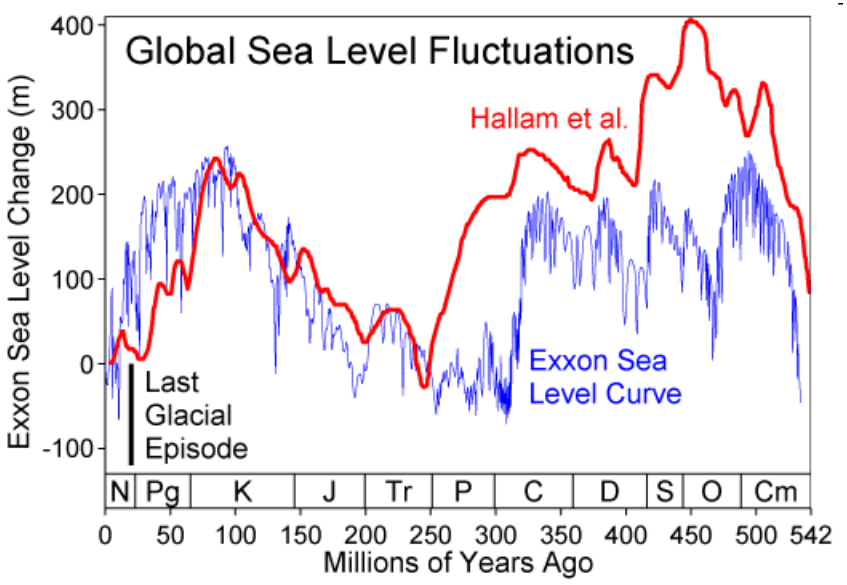
INTRODUCTION

Mean Sea Level Variability is an important indicator of changes in the Earth's climate system.

During the 20th century, sea level rose about 15-20 cm (~ 1.5-2.0 mm/yr), with the rate at the end of the century greater than over its earlier part.

Satellite measurements taken over the past decade, however, indicate that the rate of increase has jumped to about 3.1 mm/yr.

Nothing compared to sea level changes between glacial and interglacial periods, but still remains very important to determine the relevance of the causes in order to predict future scenarios because sea level rise could have dramatic impact on many coastal environments.



CONTRIBUTIONS TO SEA LEVEL CHANGE

OCEAN MASS CHANGES related to variability of continental water input

OCEAN STERIC CHANGES associated to temperature and salinity variation

Sea level change is not geographically uniform because of :

- ocean circulation changes (not uniform across the globe)
- atmospheric pressure
- vertical land movements resulting from glacial isostatic adjustment (GIA), plate tectonics and sedimentation

The main causes are attributed to reduction of land glaciers and thermal expansion. Haline contraction is supposed to have small effect on global sea level rise, but can have important effects on local sea level change.

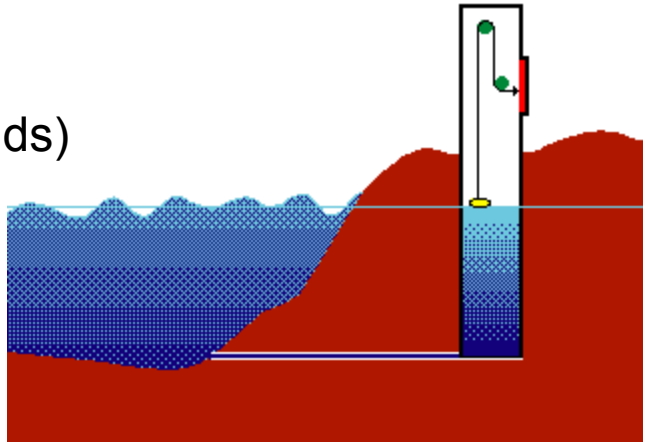
The steric component is dominant over the mass component in regional sea level variability but on a global basis it accounts for about 1/3 of total sea level increase in the past half century (Domingues et al 2008).

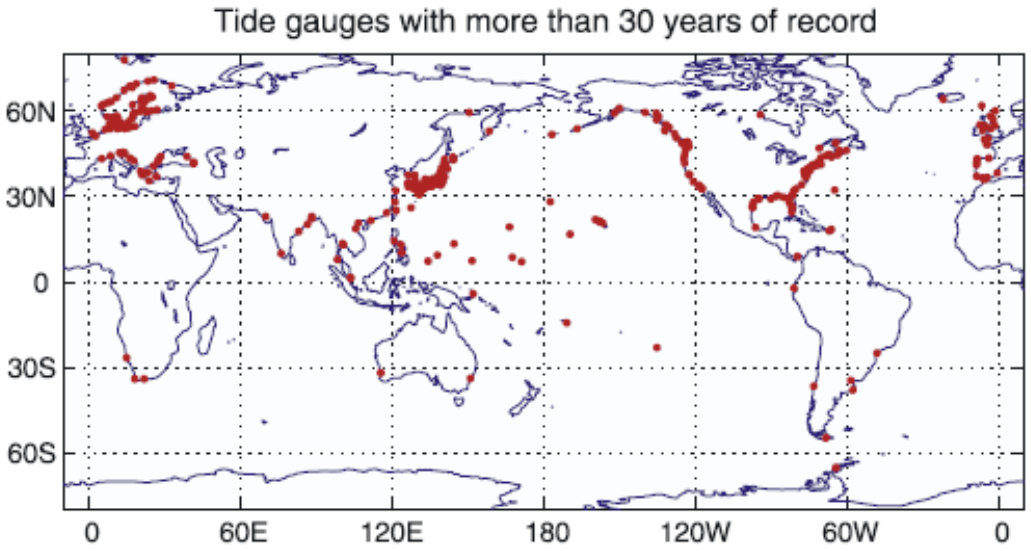
DIRECT MEASUREMENTS OF SEA LEVEL CHANGE

TIDE GAUGES provide sea level variations with respect to the land on which they lie.
Available for the last 50-100 years.

Limitations:

- poor spatial distribution (continental margin and islands)
- sensibility to land motions (not always identifiable)





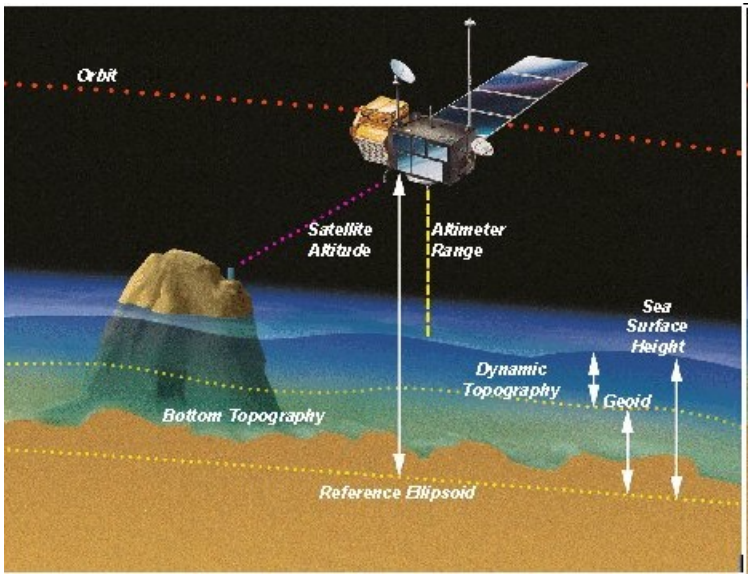
Cazenave and Nerem (2004)

SATELLITE ALTIMETRY measured with respect to the Earth's centre of mass, and thus is not distorted by land motions. Global coverage since the early 1990s.

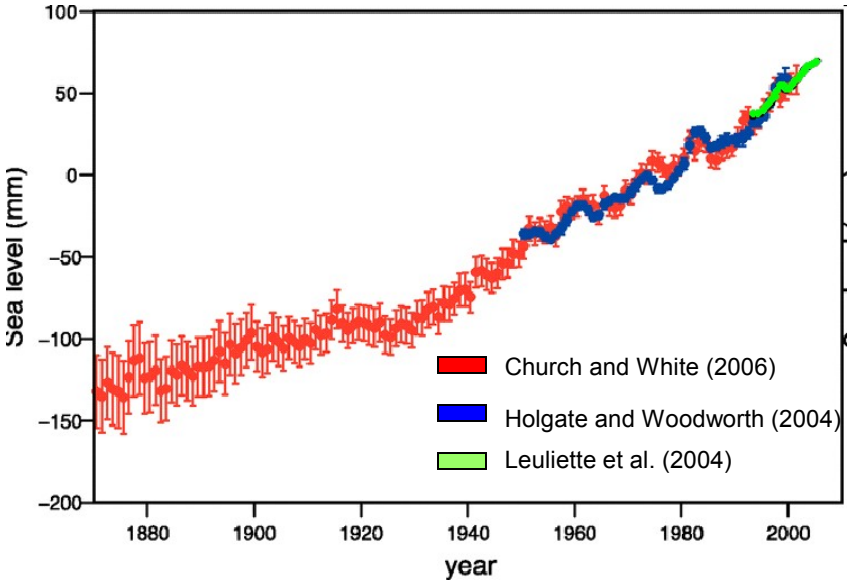
S→ distance satellite orbit - reference ellipsoid

R→ distance satellite - sea surface

SSH = S - R



SSH needs corrections related to satellite orbits error, atmospheric delay, sea state corrections, instrumental errors.



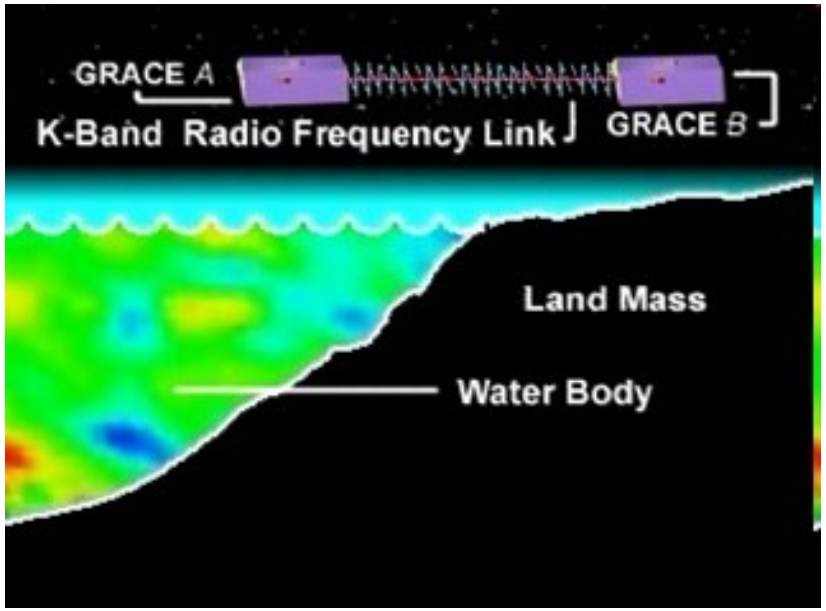
Good agreement between the two methods.

Possibility of cross validation between measurements.

IPCC Report (2007)

ESTIMATION OF CONTRIBUTIONS TO SEA LEVEL CHANGE

OCEAN MASS VARIABILITY measured by GRACE Project (Gravity Recovery and Climate Experiment) that provides accurate gravity information with a resolution of 200 km since March 2002.

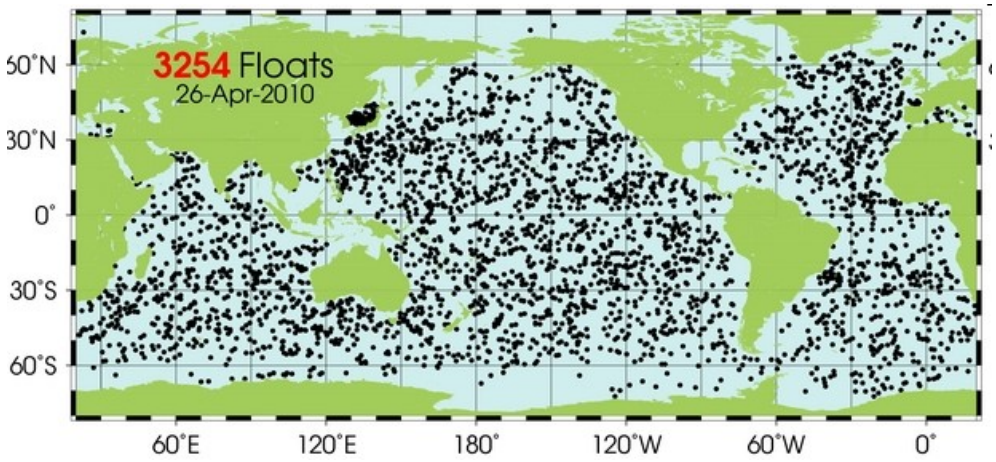


based on measurement of relative distance between twin satellites

corrections for GIA, gravity signals from land hidrology...

http://www.csr.utexas.edu/grace/

OCEAN STERIC VARIABILITY by ARGO Project (started in 2000) that provides global coverage of temperature and salinity profiles of the upper 2000 m in ocean.

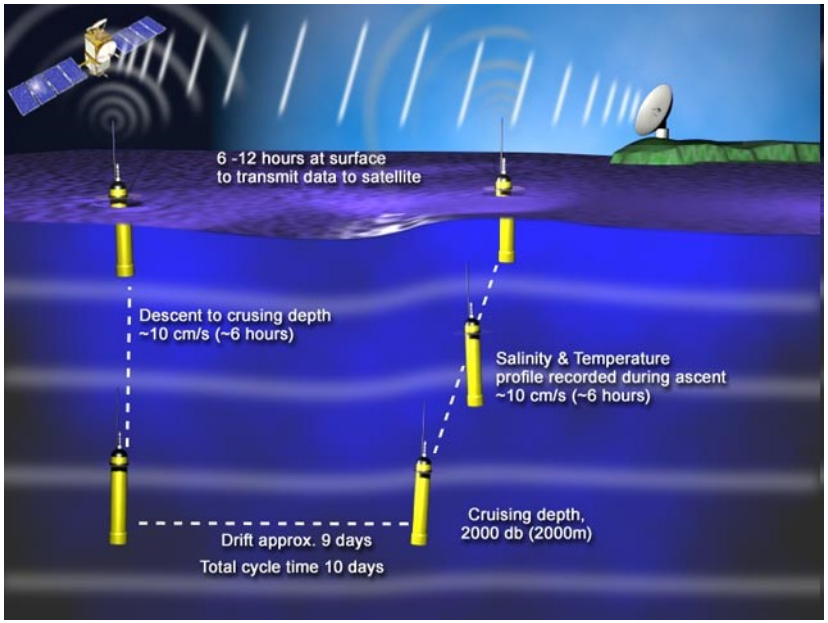


Estimation of steric component:

- distribution over depth;
- relative importance between temperature and salinity

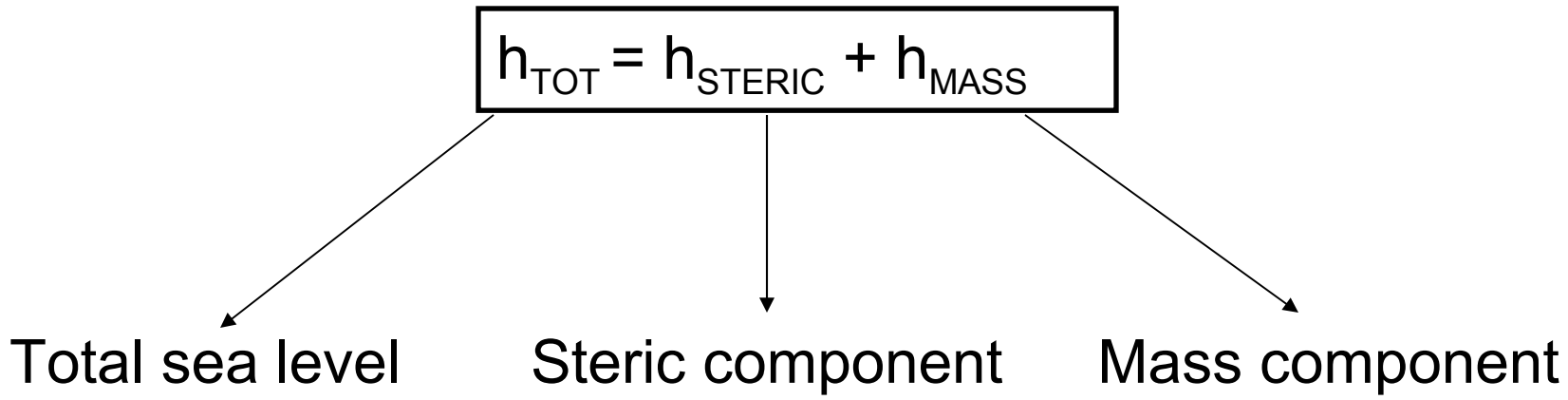
Integration of equation of state along the water column for measuring vertical expansion or contraction.

Systematic errors in pressure measurements and poor sampling during the first years of the project.



www.argo.ucsd.edu/

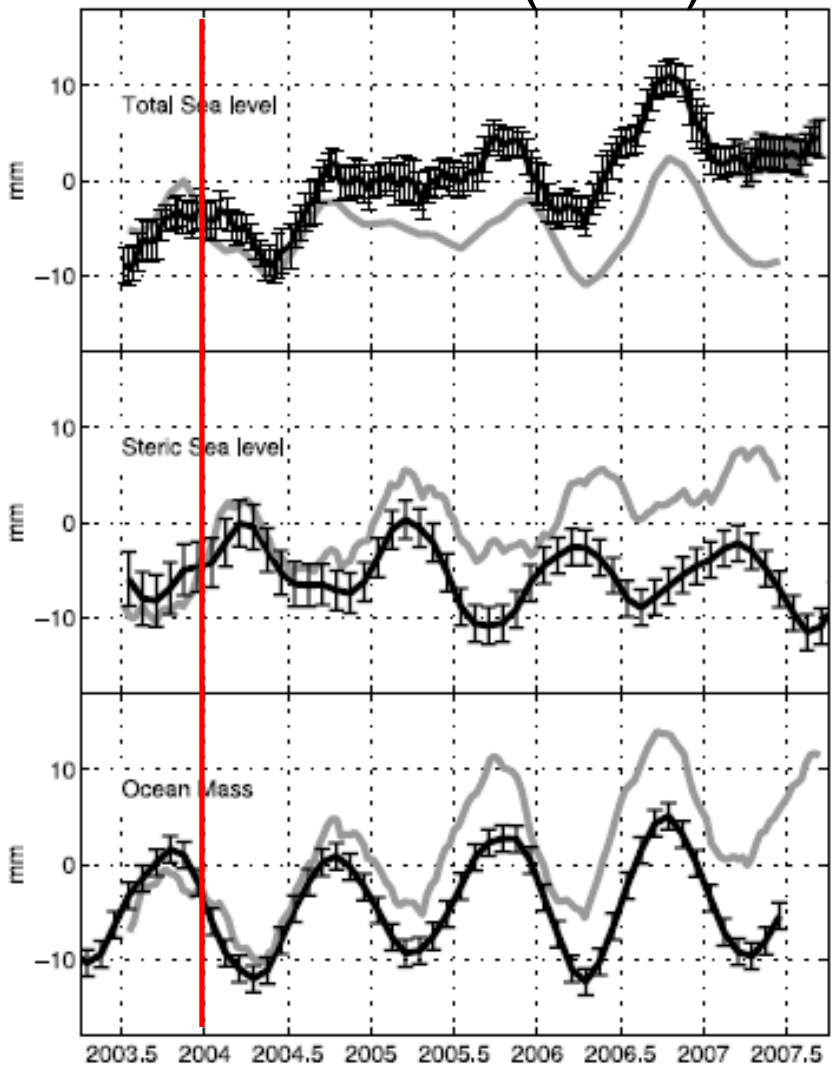
SEA LEVEL BUDGET



The sea level budget is closed observationally if RHS and LHS of the equation agree within the error estimates of each term.

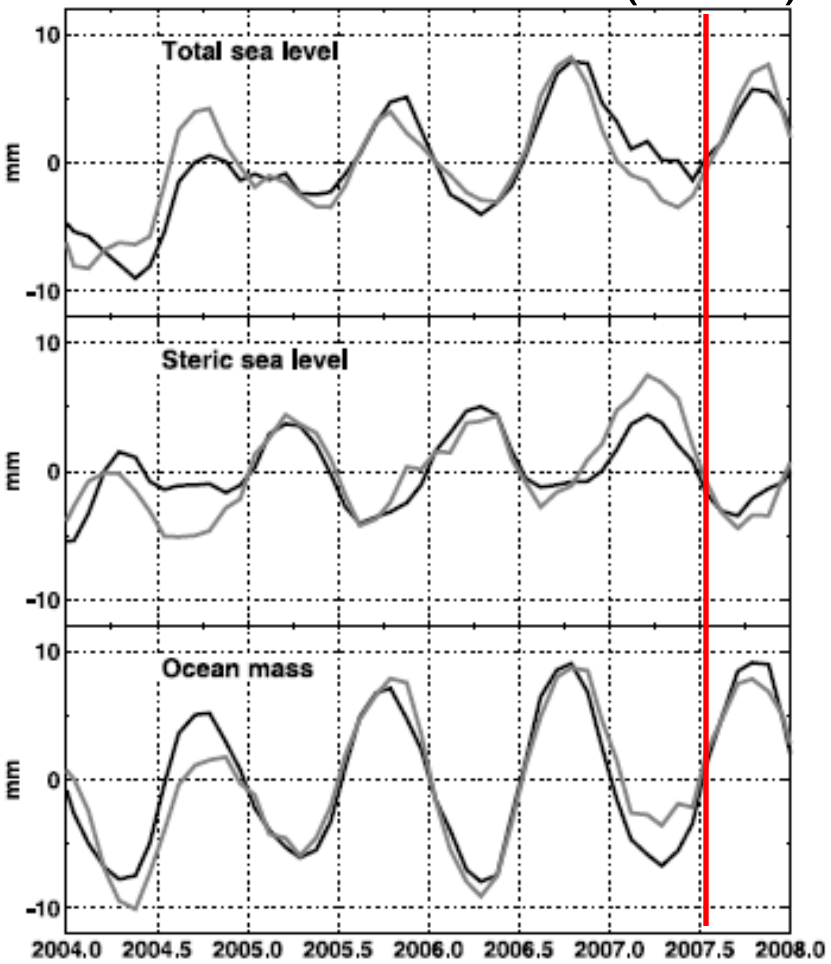
While the observations of the total sea level change (by means of satellite altimetry) are very accurate, the knowledge of the individual contributions from steric and mass effect are less well known.

Willis et al. (2008)



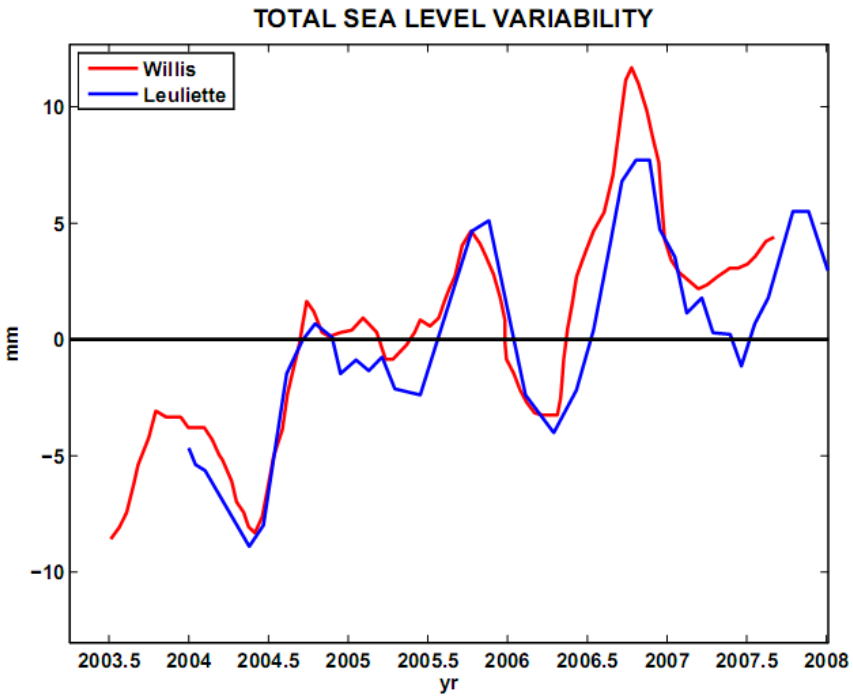
Similar fluctuations but different trend → Errors in observing systems

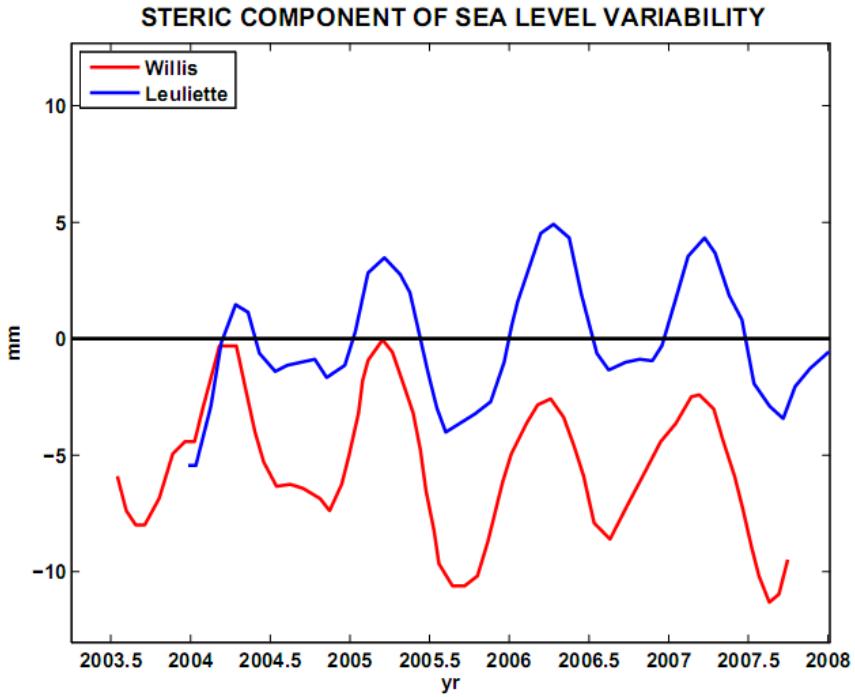
Leuliette and Miller (2009)

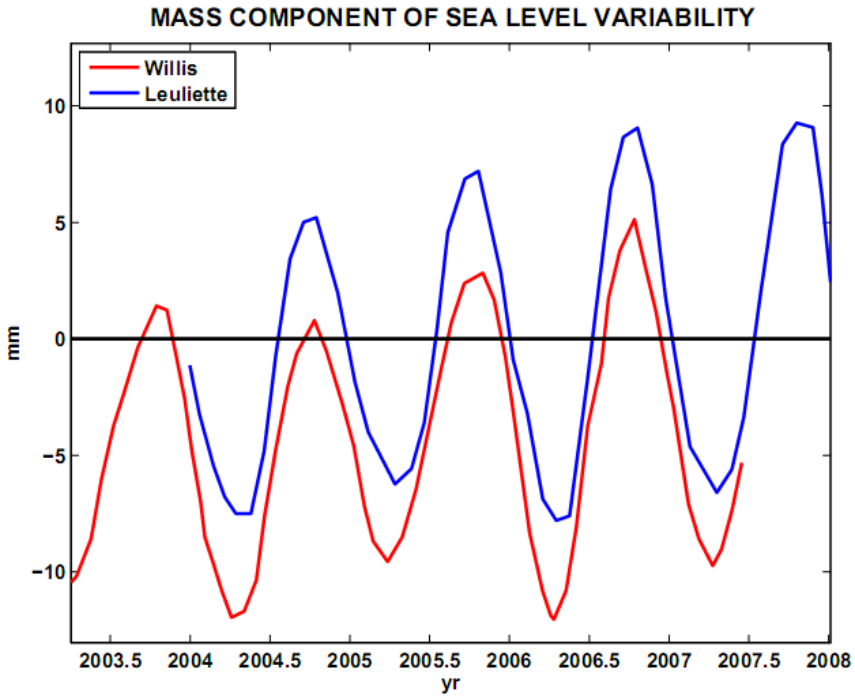


Closed budget thanks to different corrections applied to altimetric and steric components

- The main difference in the budget calculation is in the steric component.
- Willis estimate is affected by a cold-bias in Argo measurements, that have been removed in Leuliette analisys.
- Leuliette study brings the estimates of sea level change closer to the observations.
- Some discrepancies still remain in the total sea level budget and temperature changes in the deep ocean may be responsible.

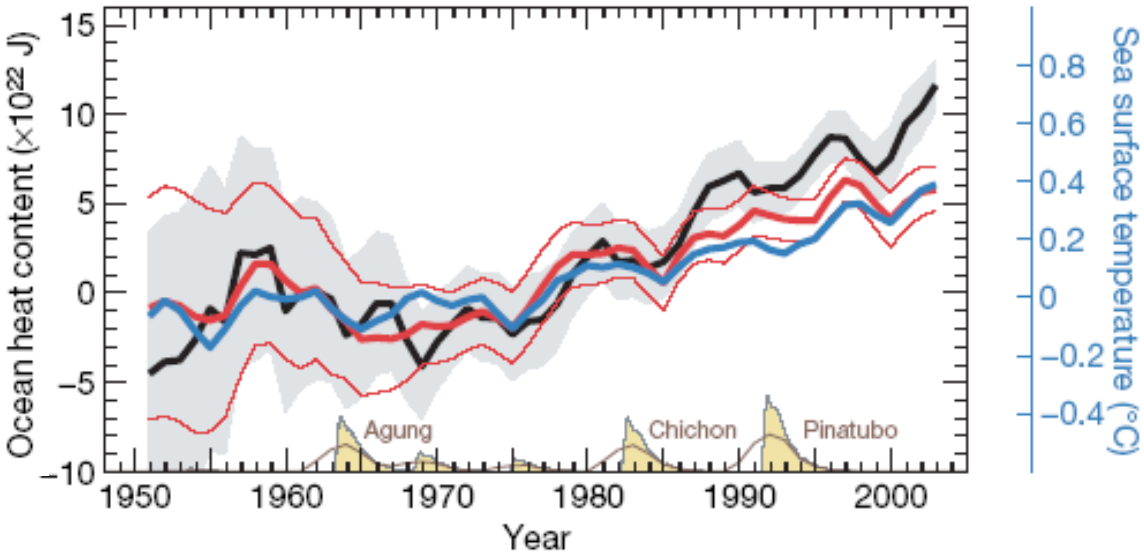






There exists a method for evaluating each component avoiding discretionary corrections and able to go back in time as much as possible from the past records?

Could it be possible to evaluate the heat content change in the ocean from the past SST distribution only, and then to estimate thermosteric sea level variability?

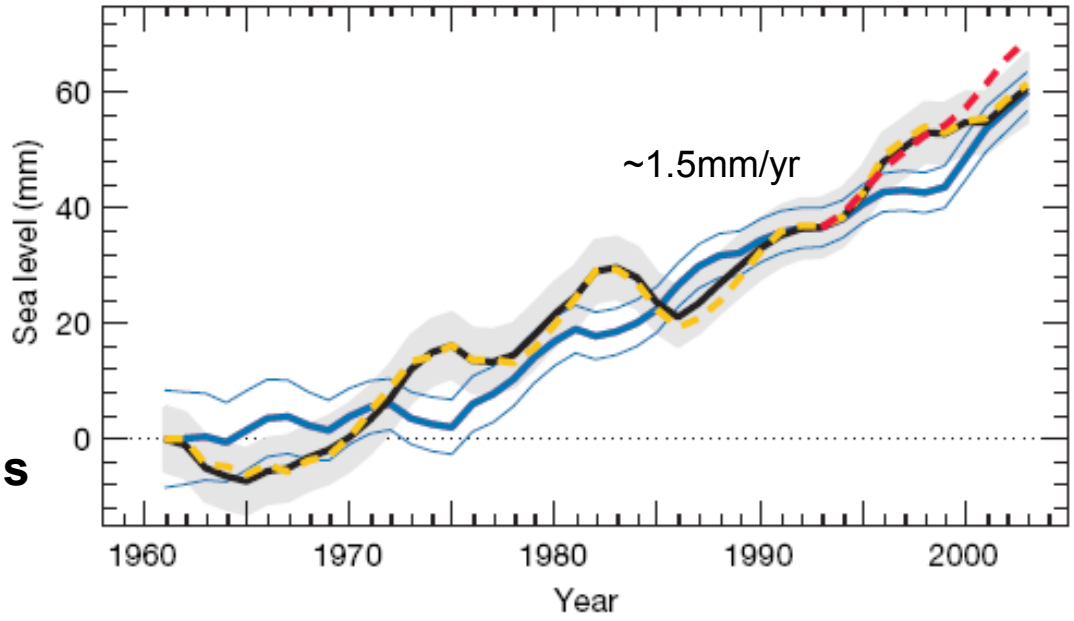


Domingues (2008)

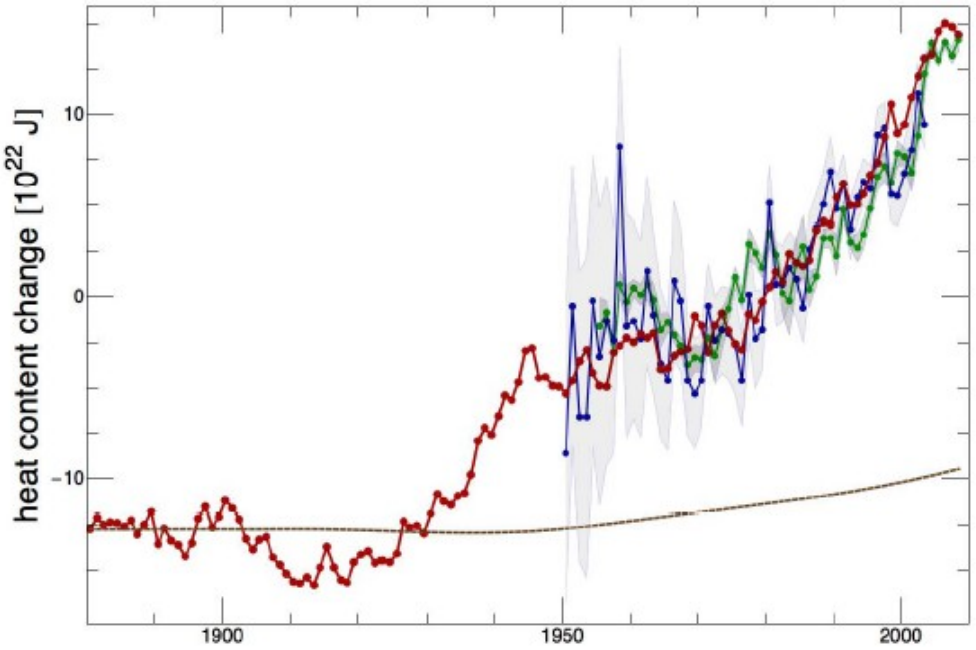
- evaluation from water column properties

- ocean heat content (700m)
- ocean heat content (100m)
- SST

- estimated global sea level
- sum of contributions (upper and deeper thermal expansion, ice sheets, glaciers and ice caps, terrestrial storage)



Improved closure of sea level budget over multi-decadal periods



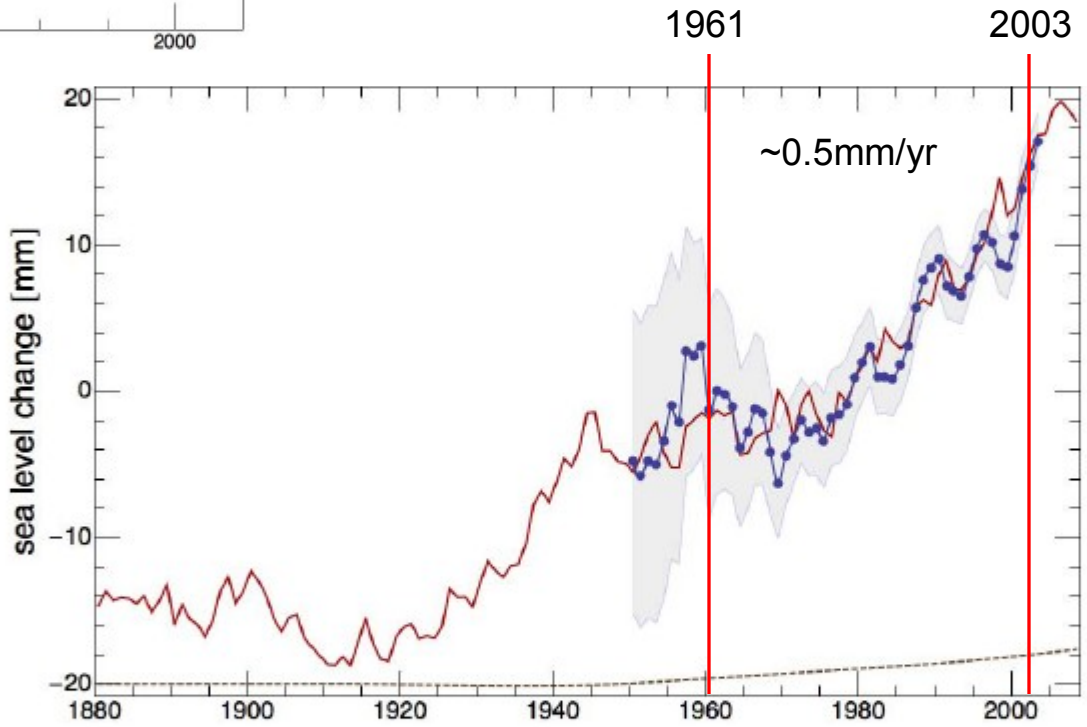
Marcelja (2010)

- single column model based on time dependent diffusion equation
- evaluation of the ocean heat content change from the past SST only (GISS) without using adjustable parameters

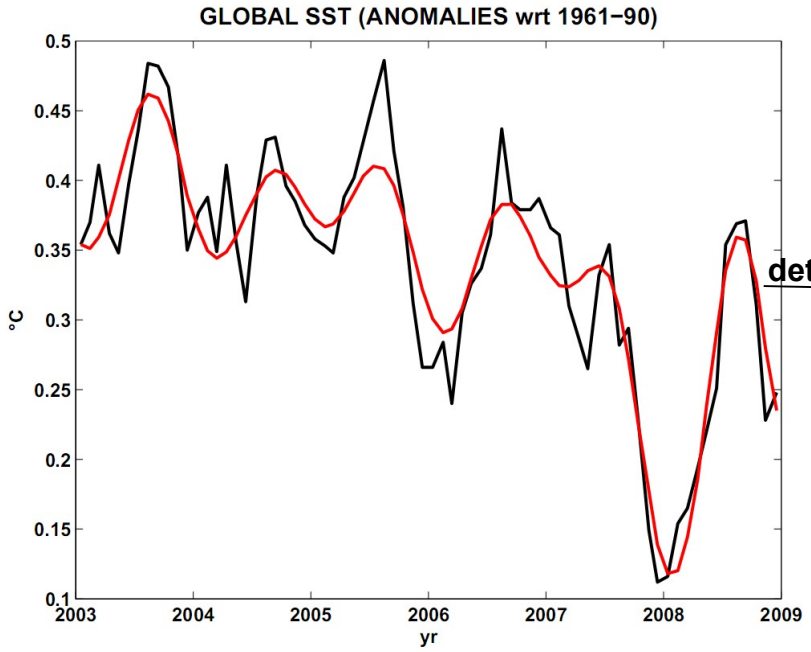
Marcelja model (700m)

Domingues estimates (700m)

Agreement with IPCC estimate



CORRELATION BETWEEN SST AND STERIC COMPONENT



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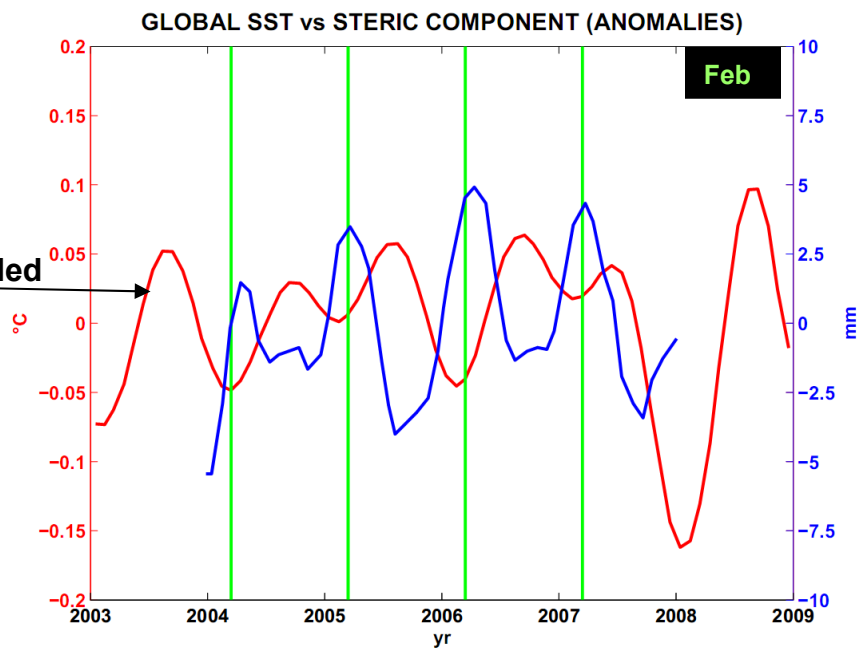

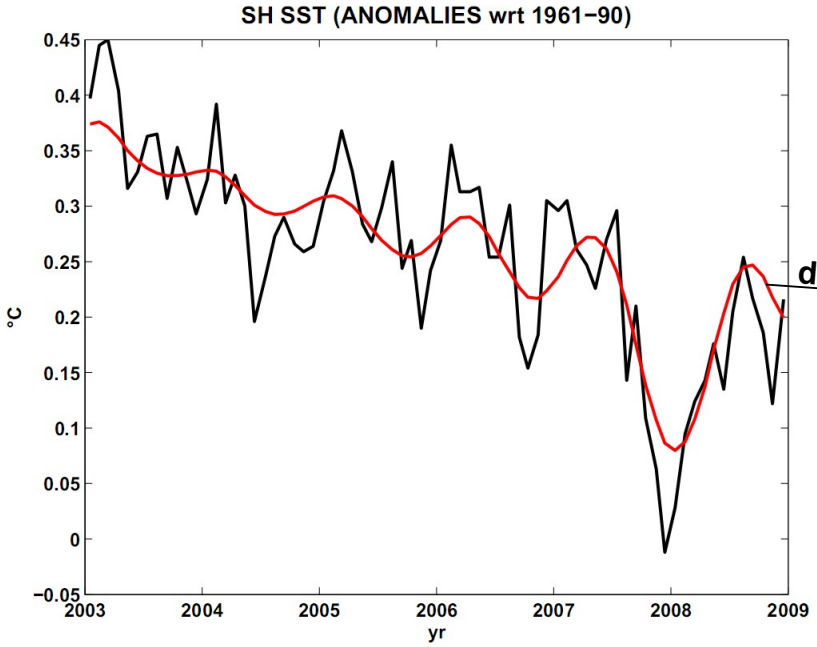

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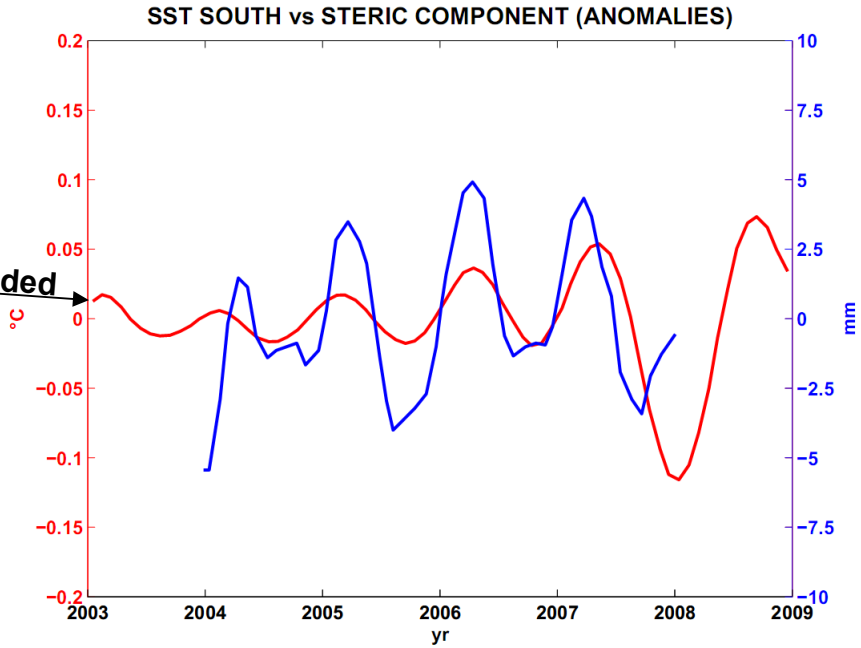
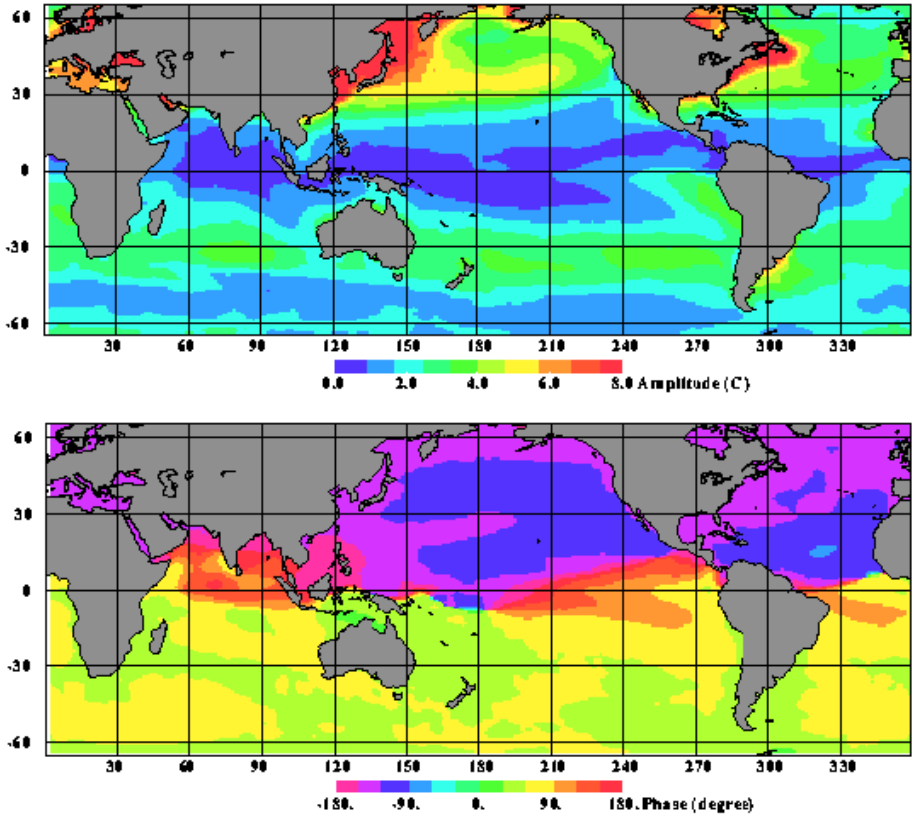
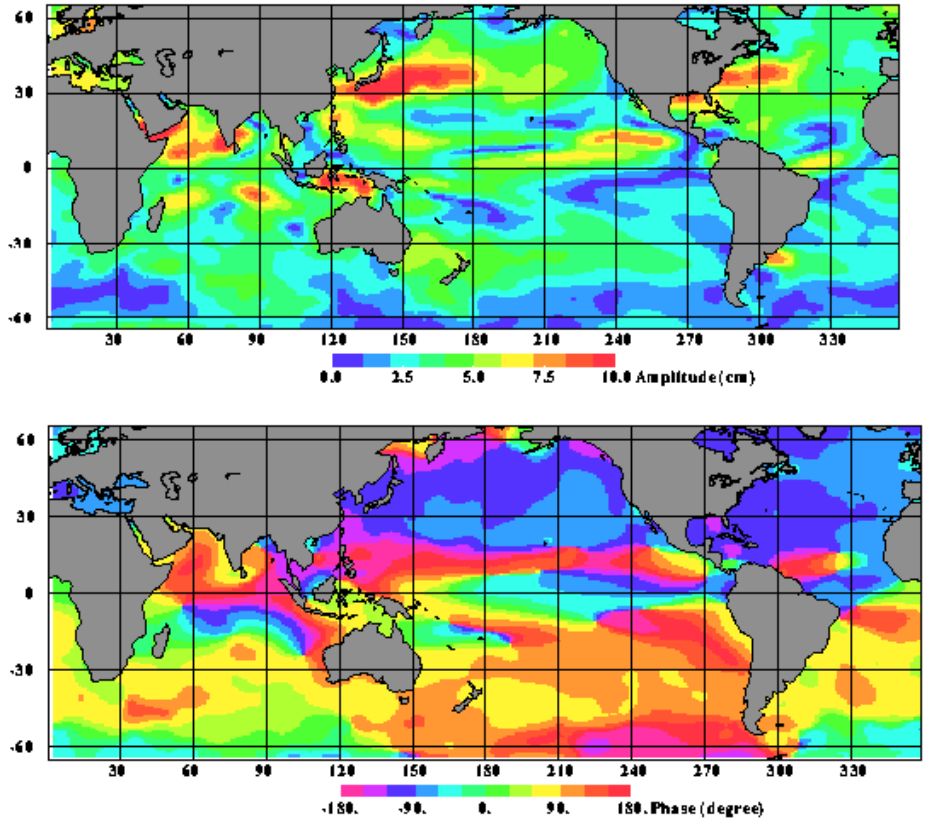


Annual SST cycle



Annual SLA cycle



- larger signal amplitude in NH (Gulf Stream and Kuroshio Current)
- NH and SH signal are shifted by 6 months
- mid-latitudes phase shift between SST and SLA of about 1 month

http://www.aviso.oceanobs.com/

CONCLUSIONS

- Why the global steric contribution should be in phase just with southern SST signal?

The Antartic Circumpolar Current (extends from the sea surface to depths of 2000-4000 m and can be as wide as 2000 km) could be an effective mechanism to redistribute water properties in the whole water column and to supply heat exchange at the surface

SH ocean MLD seasonal cycle is very deep compared to NH (de Boyer Montégut et al., 2004)

- Improving estimates of the contributions to sea level change, allows to understand the mechanisms of heat redistribution and to upgrade future projections of sea level change.