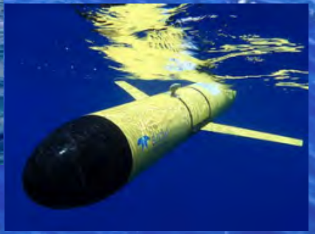
Studies of Regional Ocean Dynamics and Variability

What processes drive the regional changes of ocean circulation and sea level in the Atlantic and Arctic oceans?



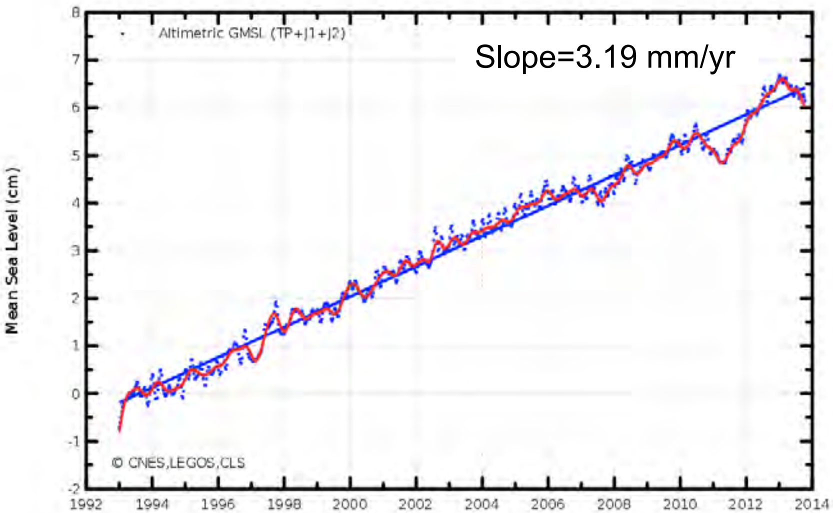
Presenter: Denis L. Volkov

AOML Program Review

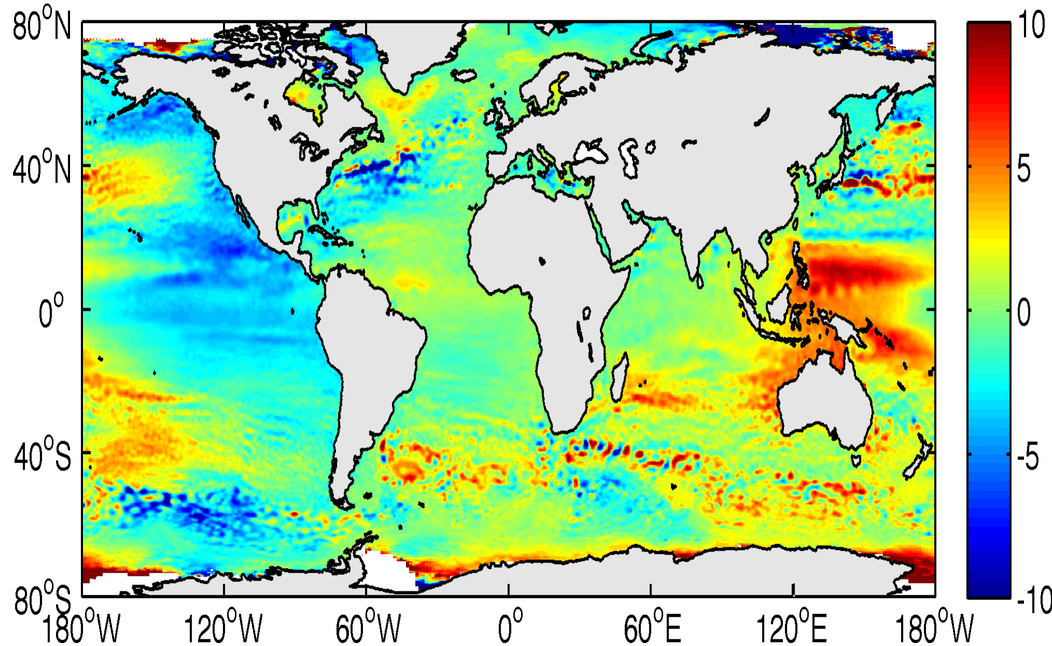
4-6 March 2014

Global and Regional Sea Level Change

Altimetric global mean sea level (GMSL) in 1993-2013. The annual and semi-annual signals are removed and a 6-month filter is used to obtain the red curve. The data are corrected for postglacial rebound. Credits: CLS/ CNES/LEGOS.

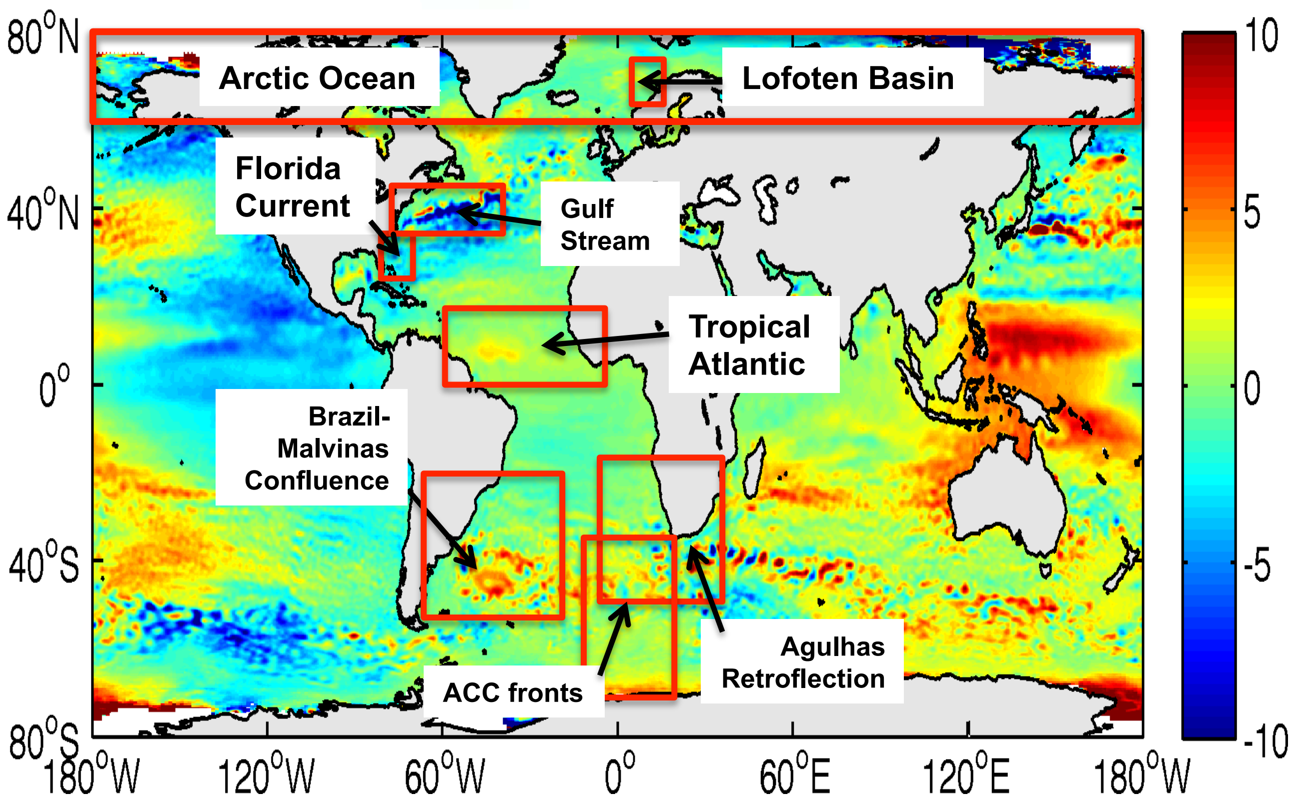


Jan 1993 – Dec 2012 linear trend of SSH (mm/yr)



- Global mean sea level has been rising at the rate of 3.19 mm/year over 1993-2013
- Sea level change is the net result of many evironmental processes
- Sea level change is not uniform; regional differences are caused by ocean dynamics

Objectives

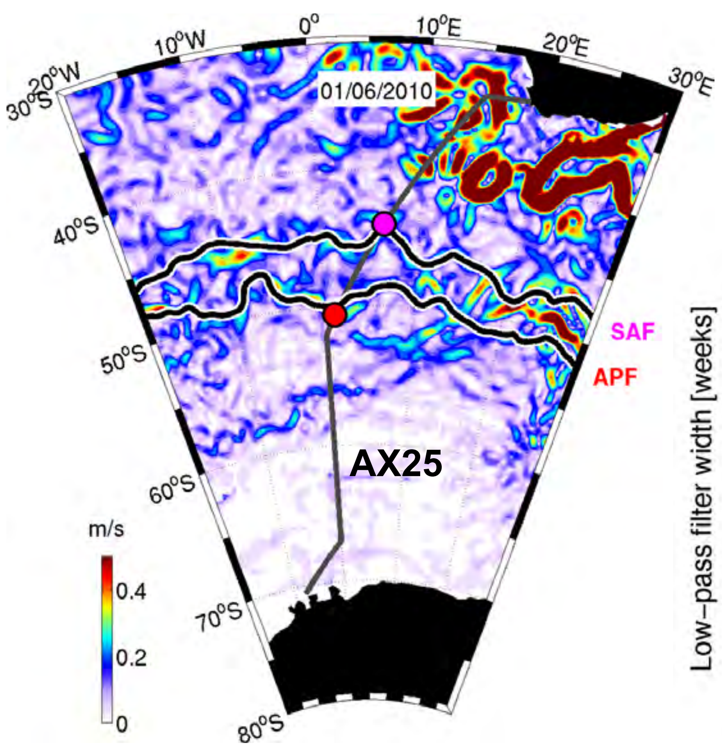


Linking regional and large-scale processes supports NOAA's objective for scientific understanding of the changing climate system and its impacts

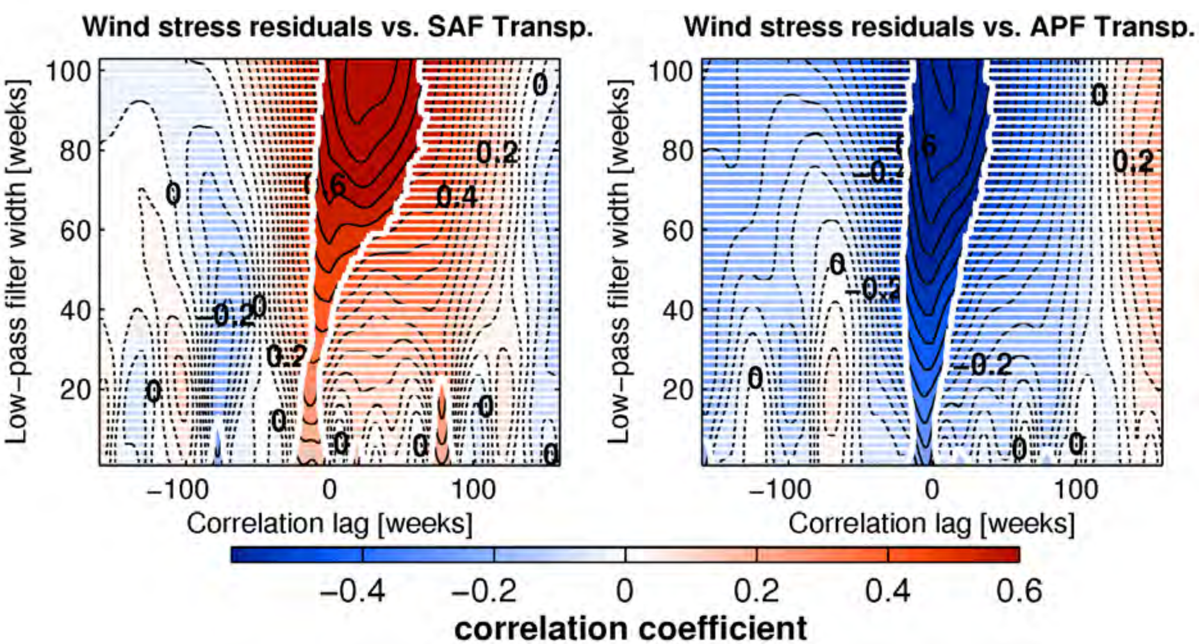
- Variability of the ACC fronts south of Africa
- Variability in Agulhas Retroflection and in the South Atlantic subtropical gyre changing
- Can we predict the variability of the Florida Current?
- How well do the climate models reproduce the Gulf Stream?
- What drives the mesoscale variability of sea level in the Lofoten Basin?
- What drives the nonseasonal variability of the Arctic Ocean mass and sea level?

Antarctic Circumpolar Current (ACC) Fronts

Absolute surface velocity (m/s) and location of fronts

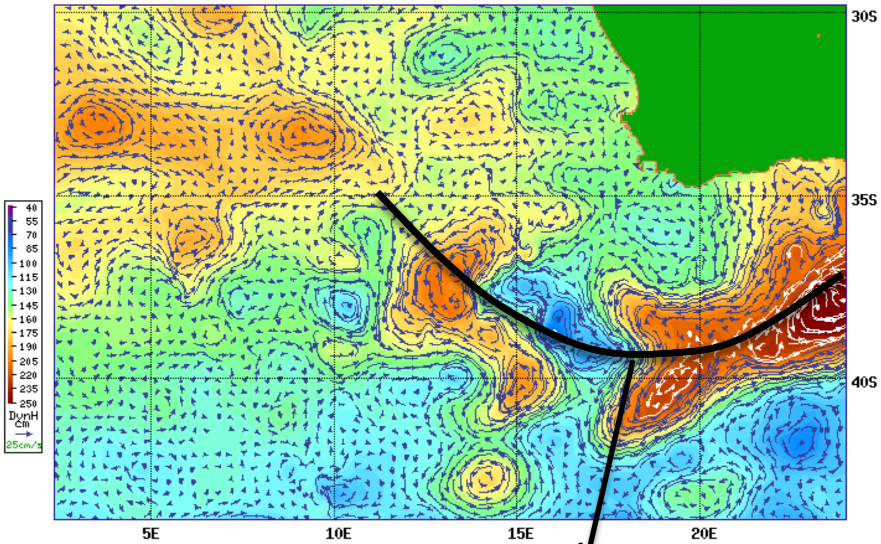


- The variability of local wind field modulates the structure of the ACC south of Africa
- Stronger westerly winds are associated with a warmer ACC and smaller (larger) Sub-Antarctic Front (Antarctic Polar Front) transport
- The Sub-Antarctic Front (Antarctic Polar Front) location south of Africa is not linked to the local wind forcing



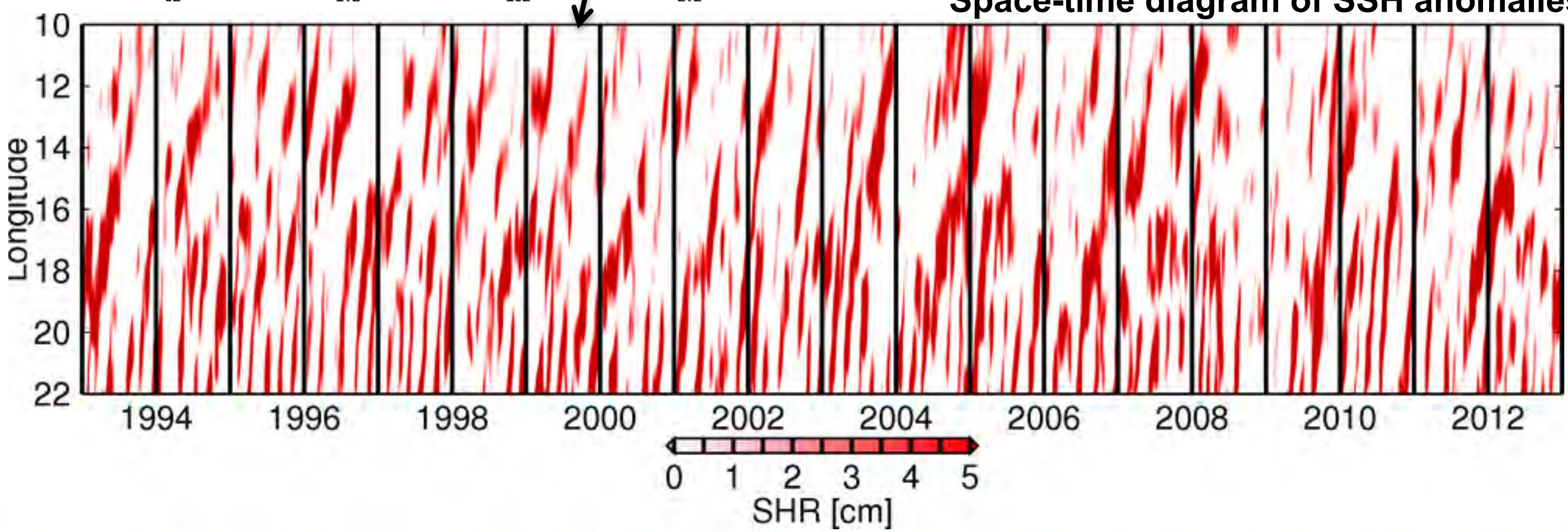
 Domingues et al. (2014)

Agulhas Current and Rings

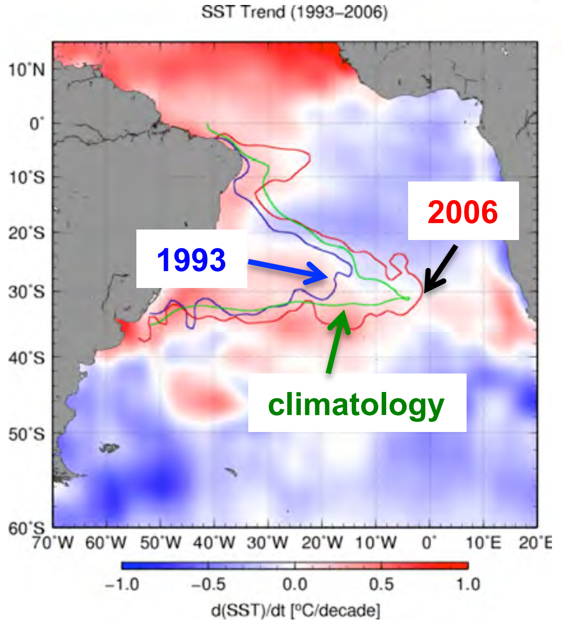


- Inter-basin water exchange between the Indian and Atlantic oceans is dominated by shedding of Agulhas rings (~1 Sv)
- Ring shedding events are subject to interannual variability: 2001 low number (3) of rings; 6 rings shed in 1997, 2002, 2004, 2010
- Do numerical models adequately reproduce the shedding of rings?

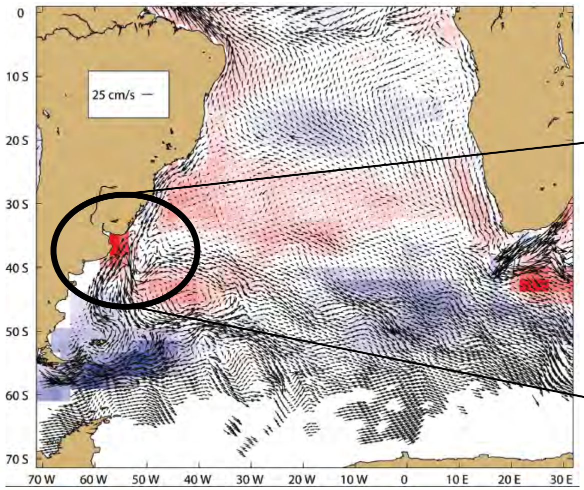
Space-time diagram of SSH anomalies



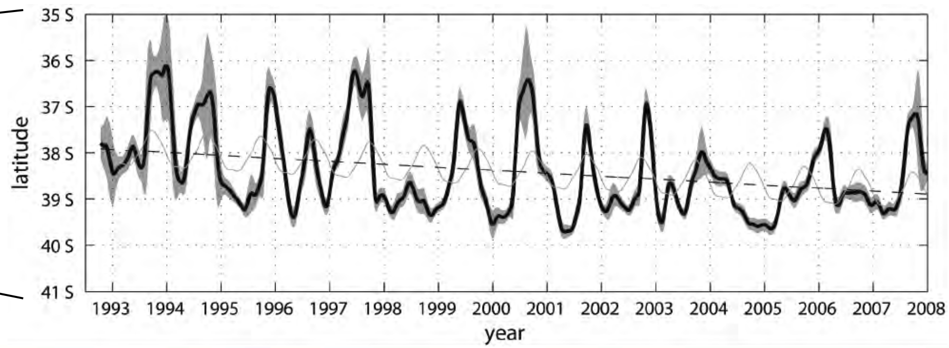
South Atlantic Subtropical Gyre and Brazil-Malvinas Confluence



- Observed long-term expansion of the subtropical gyre
- The expansion is reflected in the trends of sea surface temperature, sea surface height, eddy kinetic energy, and wind stress curl (WSC).
- In 1993-2007 the Brazil-Malvinas Confluence Front shifted southward by ~1 degree
- There is also a transition of dominant periodicity in the location of the Brazil-Malvinas Confluence front from annual to bi-annual
- The expansion of the gyre means more subtropical water is advected to subpolar regions

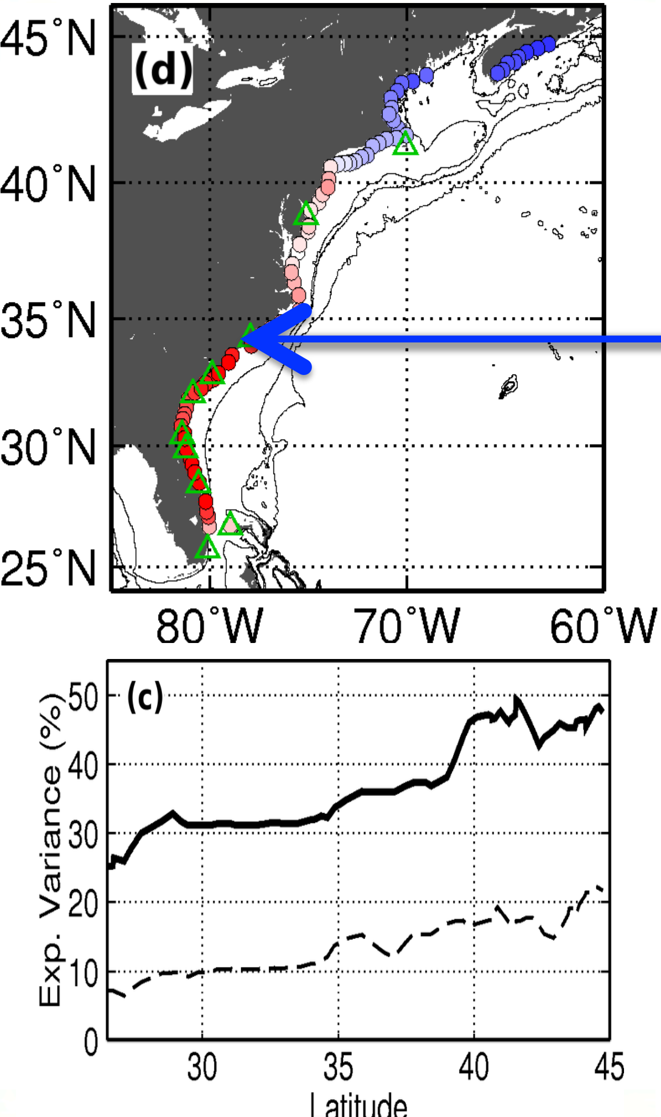


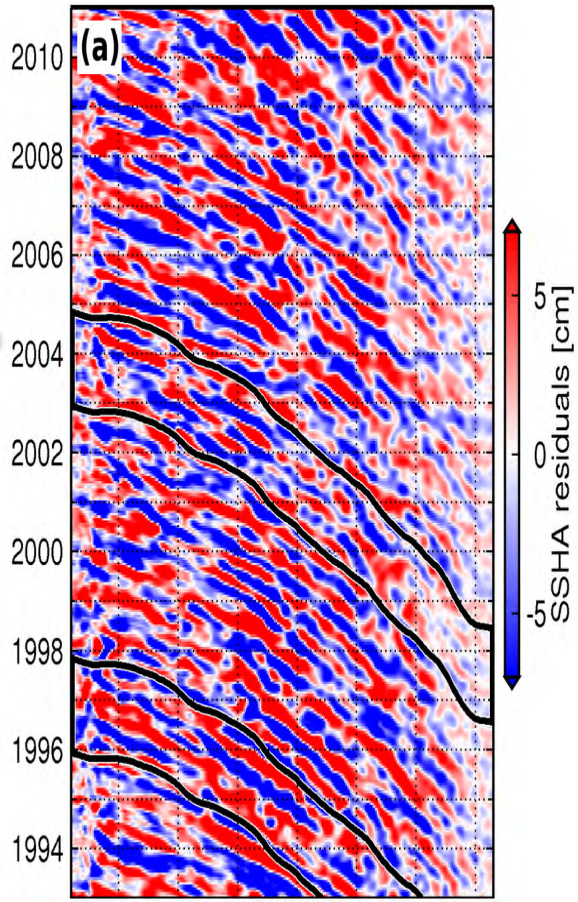
Meridional excursions of the Brazil-Malvinas Confluence Front



Lumpkin and Garzoli (2011), Goni et al. (2011)

Florida Current relation to coastal sea level

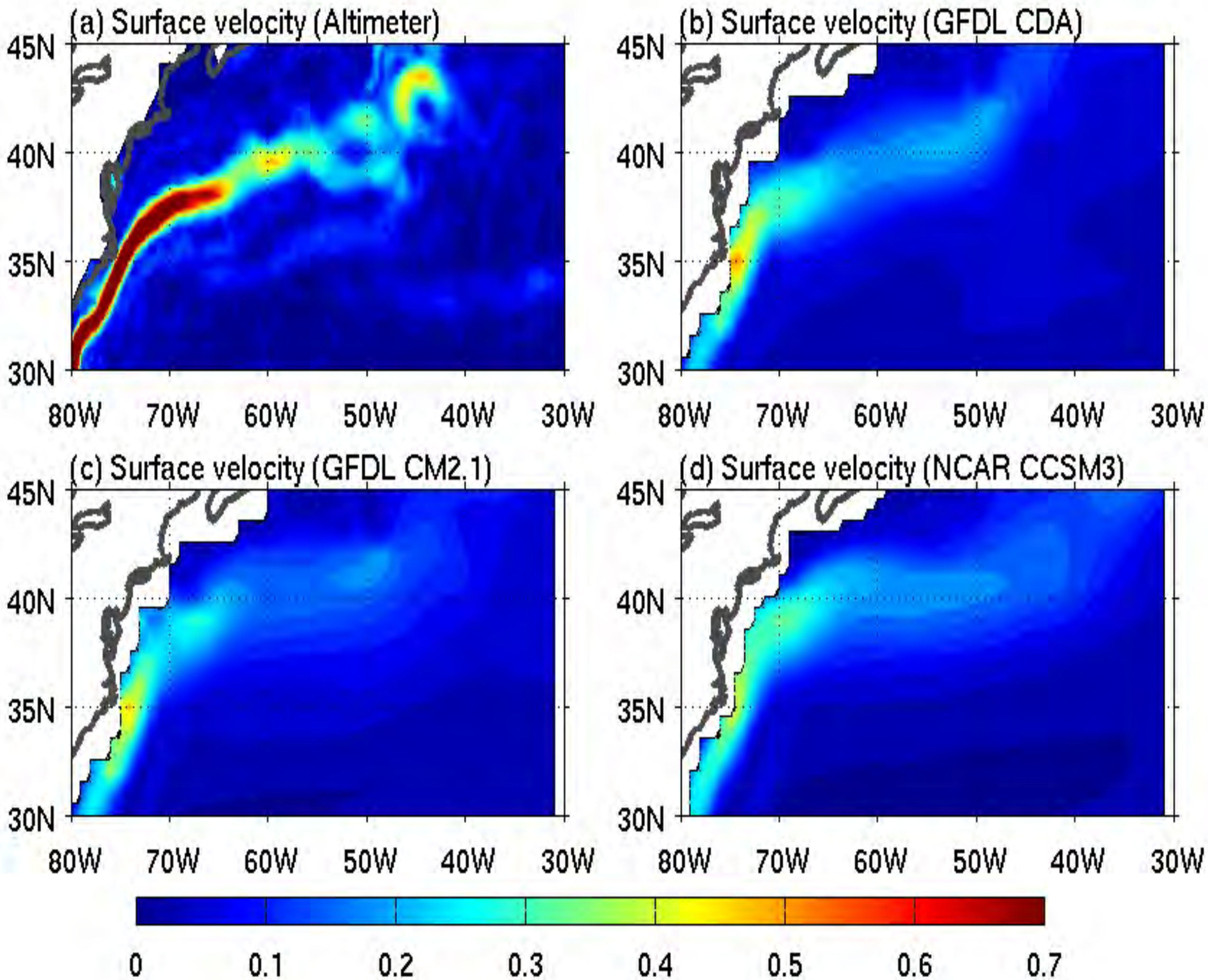




- Variability of the FC transport is correlated with SSH anomalies propagating westward across the Atlantic Ocean (lag ~6 yrs)
- Sea level anomalies that reach the east US coast can be used to explain (and eventually predict) up to 50% of Florida Current transport

Time-longitude diagram of SSH anomaly along 34N: westward propagating anomalies are correlated with the FC transport (lag ~6 yrs)

Gulf Stream in Climate Models

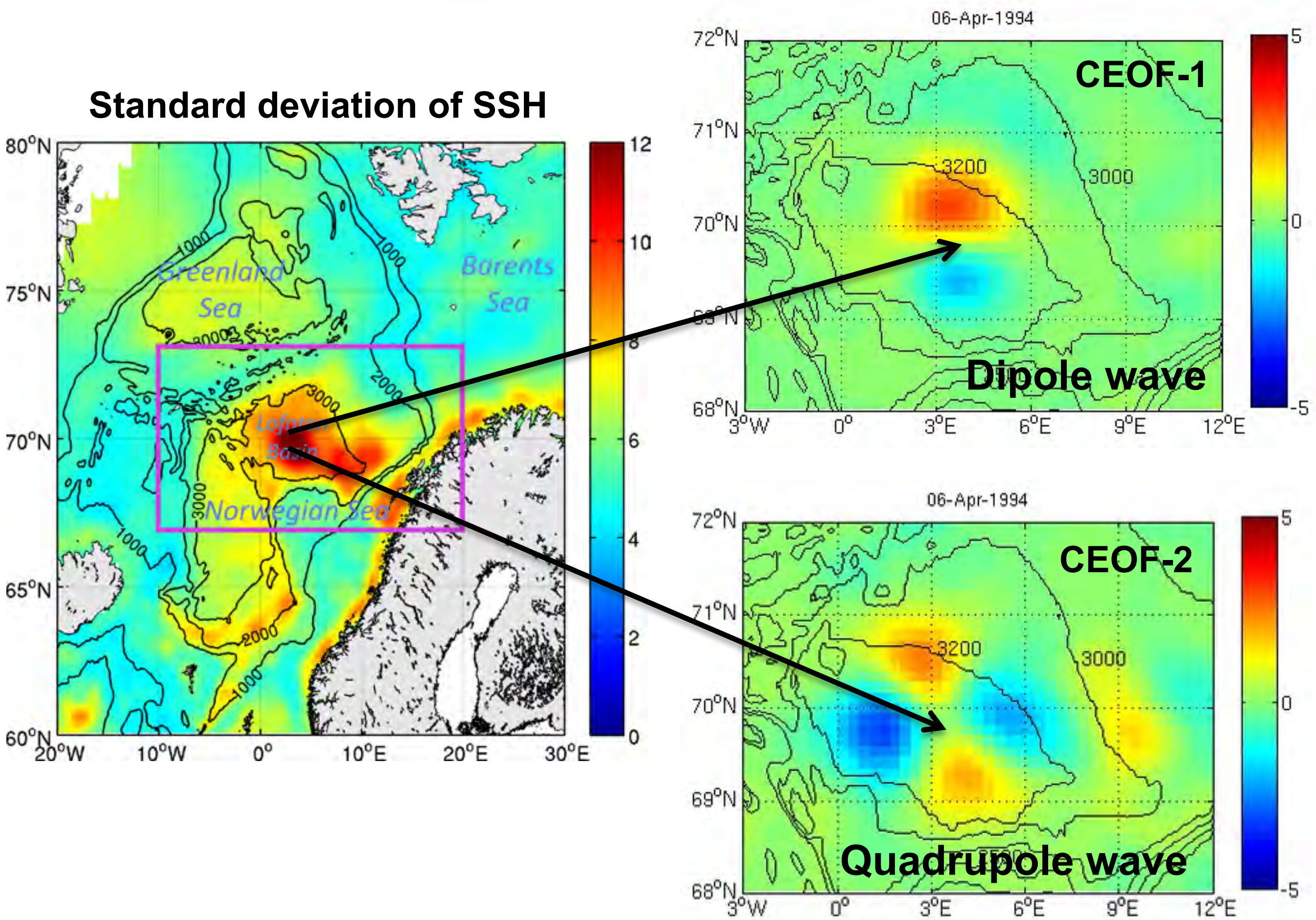


- The Gulf Stream (GS) from climate models is too weak and wide compared to observations
- The weak GS in models is unable to adequately simulate heat transport to mid-latitudes
- **Implications:** heat released to the atmosphere at mid-latitudes is underestimated by models

 Dong and Kelly (2013)

Dynamics of the Lofoten Basin in the Norwegian Sea

Reconstructed SSH anomalies

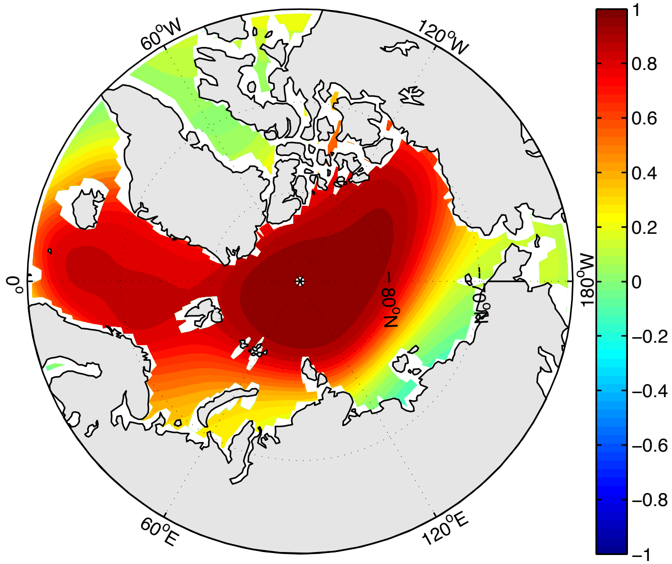


- Observed a cyclonic propagation of SSH anomalies around the center of the Lofoten Basin
- The propagation is characterized by the dipole and quadrupole wavelike modes that explain over 2/3 of the high-frequency SSH variance in the center of the LB
- The cyclonic propagation of SSH anomalies is a manifestation of barotropic topographic Rossby waves

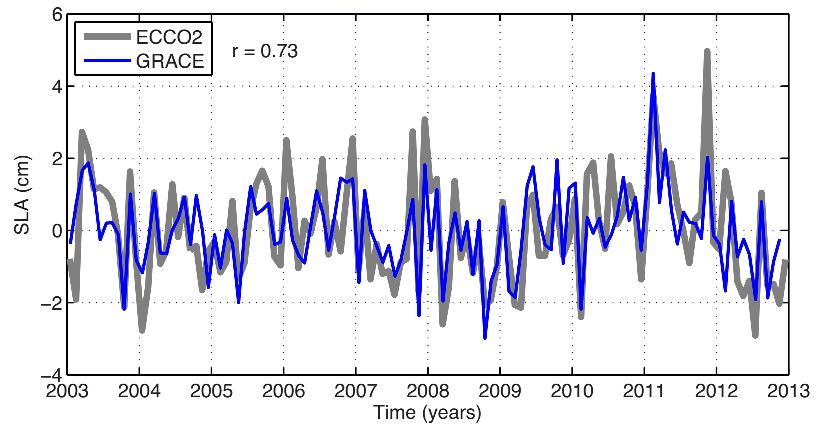
Future research:
how do the dynamic processes in the LB affect the poleward heat transfer?

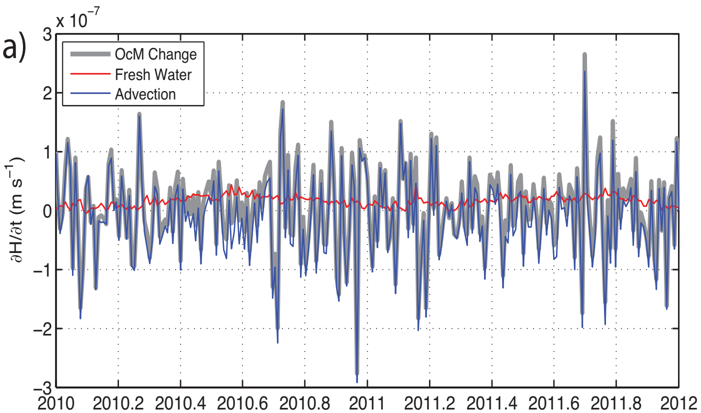
Non-seasonal Variability of the Arctic Ocean Mass

EOF-1 of the mass-related sea level (explain ~70% of variance)



Arctic Ocean mass in GRACE and ECCO2 data





ECCO2 ocean model result: The time change of the Arctic Ocean mass (gray), net transport across 65°N (blue), the contribution of fresh water fluxes (red)

- The non-seasonal variability of the mass-related sea level is almost uniform over the Arctic Ocean and Nordic seas
- The non-seasonal variability of the Arctic Ocean mass is due to divergence/ convergence; the contribution of fresh water fluxes is small
- Dominant forcing mechanism – Ekman dynamics induced by winds over the northeastern North Atlantic, Nordic and Bering sea

Summary

- Showed the importance of sustained in situ observations and their synergy with satellite observations and ocean numerical model output
- Identified the variability of mesoscale features that could be linked to larger-scale ocean changes (e.g. AMOC, South Atlantic subtropical gyre): ACC frontal variability, Agulhas rings, Florida Current transport variability, topographic Rossby waves
- Showed the value of data analysis to assess numerical model outputs

Future work

- Continue studies on regional ocean dynamics synthesizing satellite and hydrographic data, and ocean models
- Investigate the role of mesoscale processes in modulating the meridional heat transport
- Investigate the sensitivity of regional sea level to the variability of heat advection and wind forcing
- **Assess the role of regional dynamic processes in the AMOC variability**

Thank you very much

Questions?



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