The sea level signature of the Atlantic meridional overturning circulation

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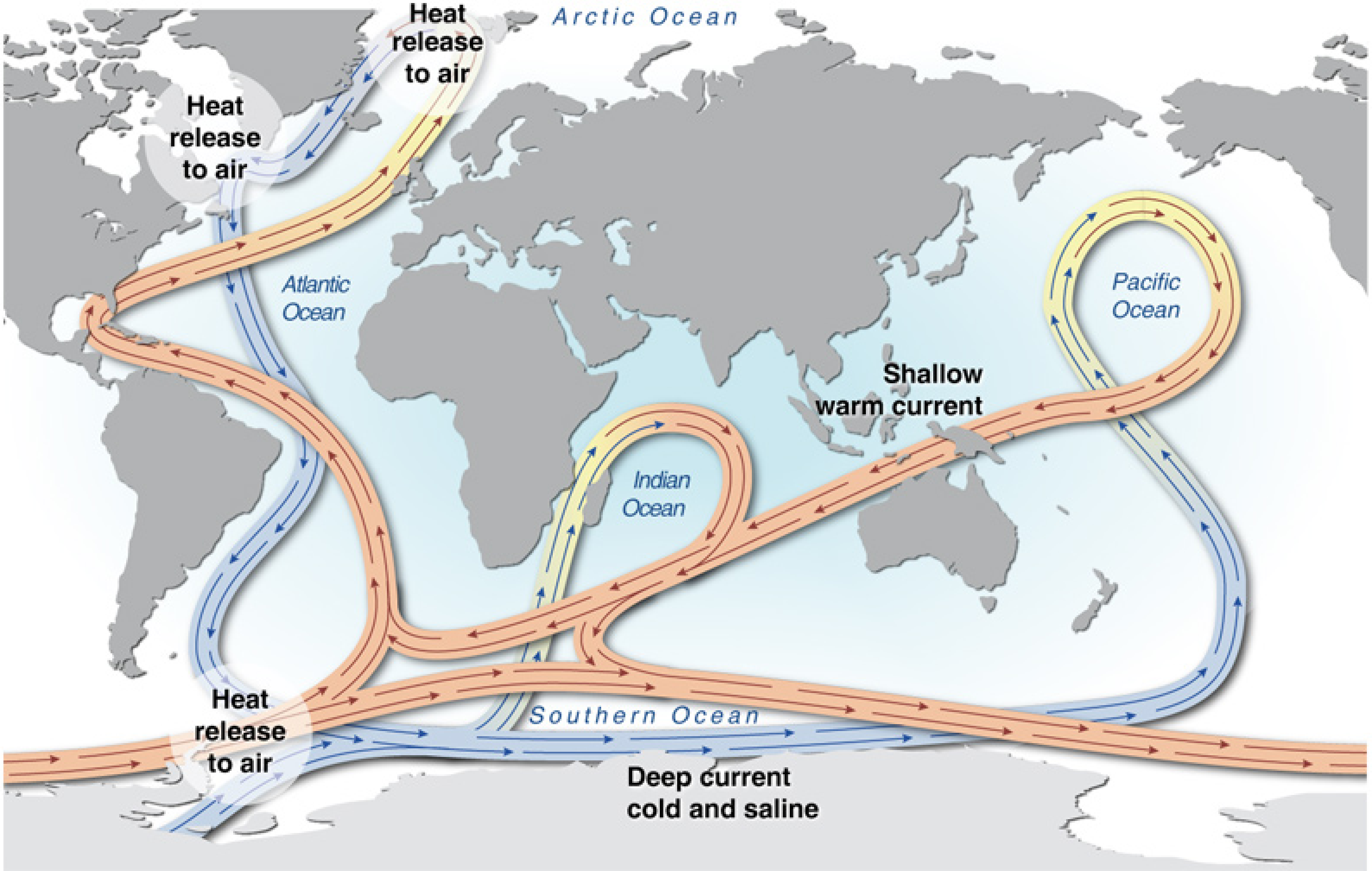
The global conveyor belt

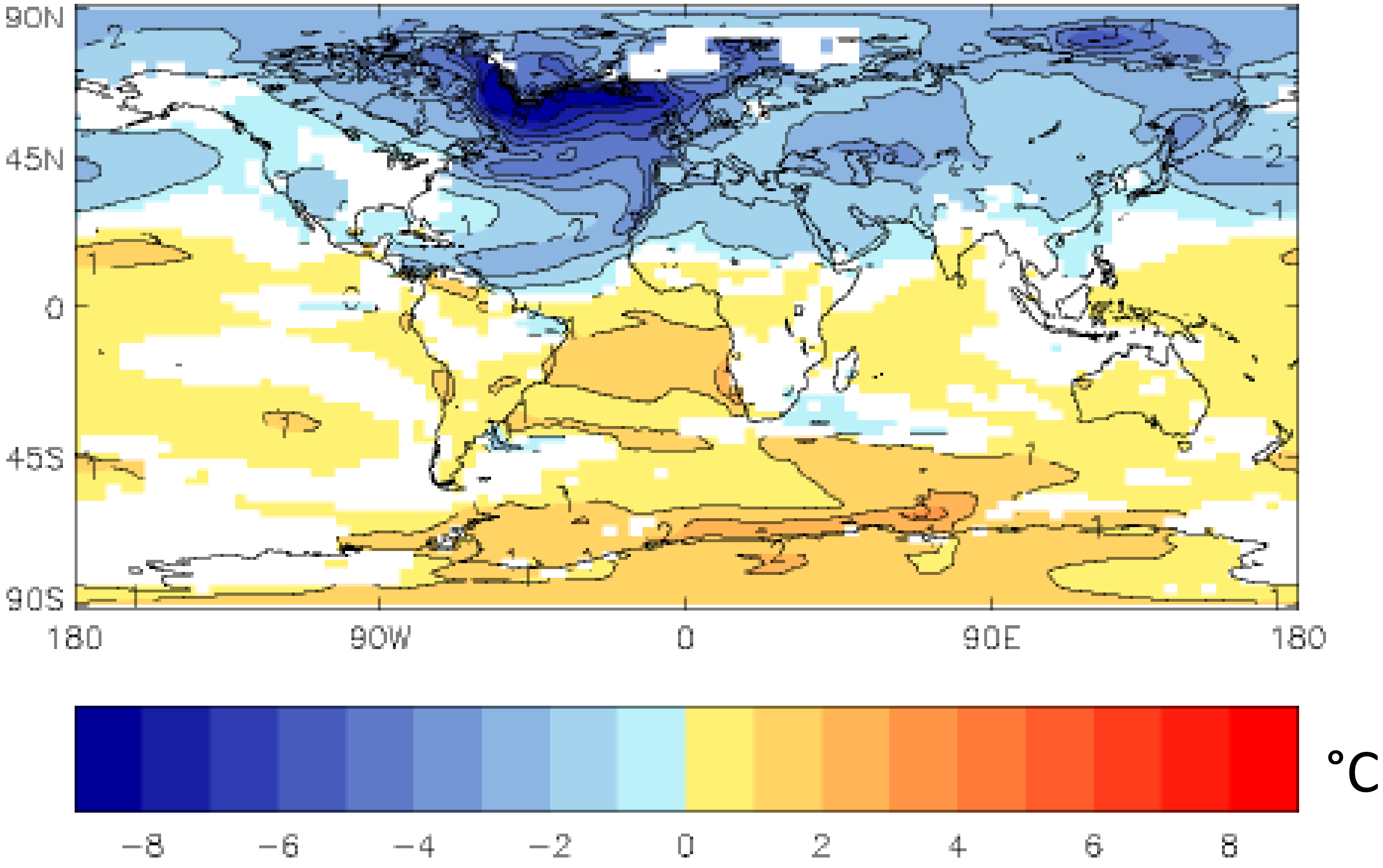


Thermohaline Circulation
Visual representation of global ocean circulation highlighting the down-welling in the North Atlantic and the return of warm surface waters from the North Pacific.

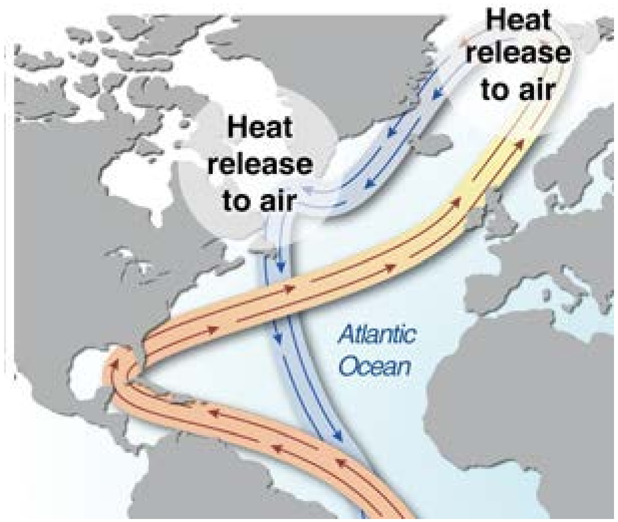
Credit: Grid Arendal and UNEP

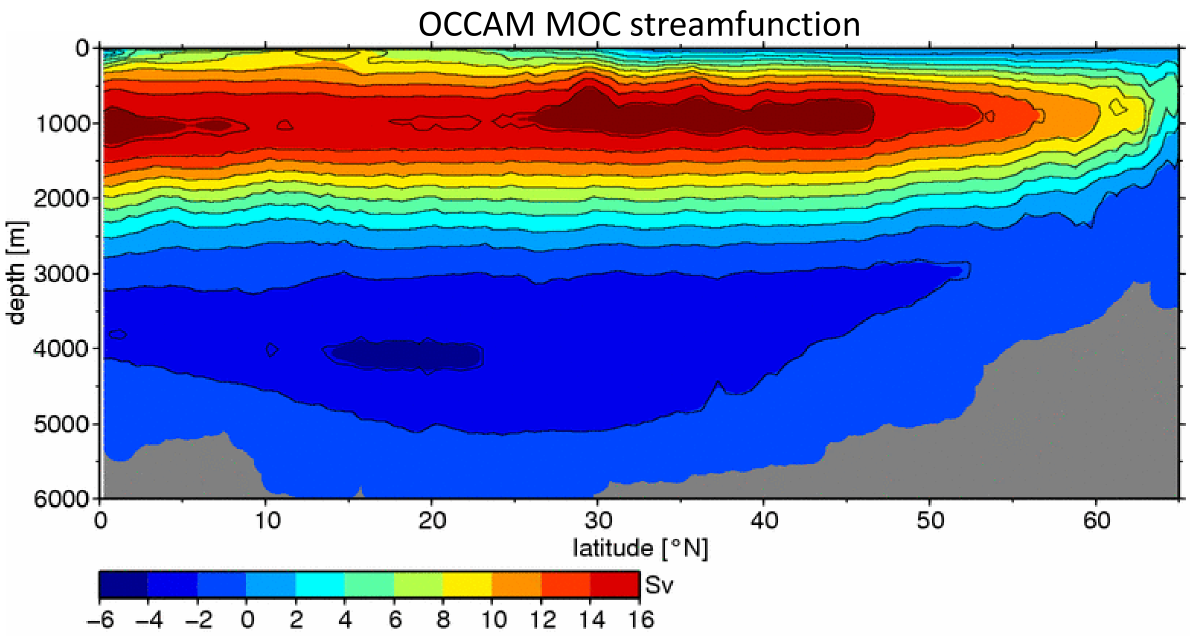
The thermohaline catastrophe

Air temperature change due to North Atlantic freshening (HadCM3 model experiment)



The Atlantic meridional overturning circulation (MOC) in the OCCAM model





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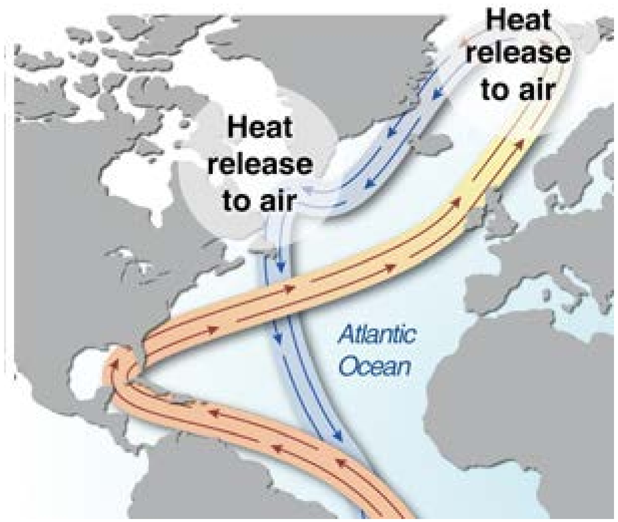
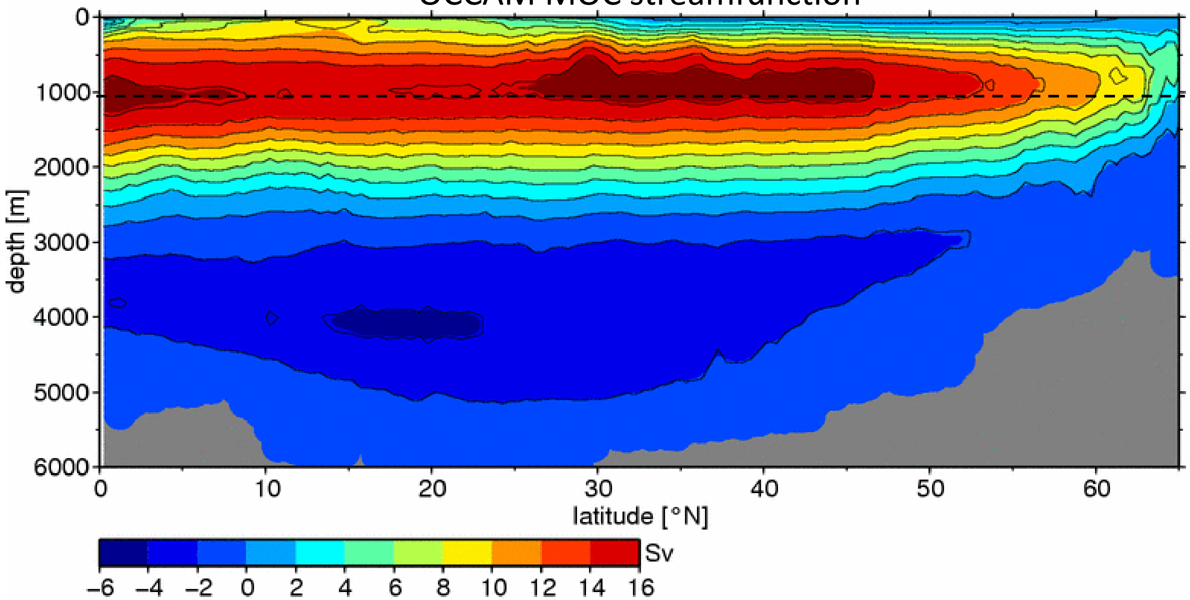
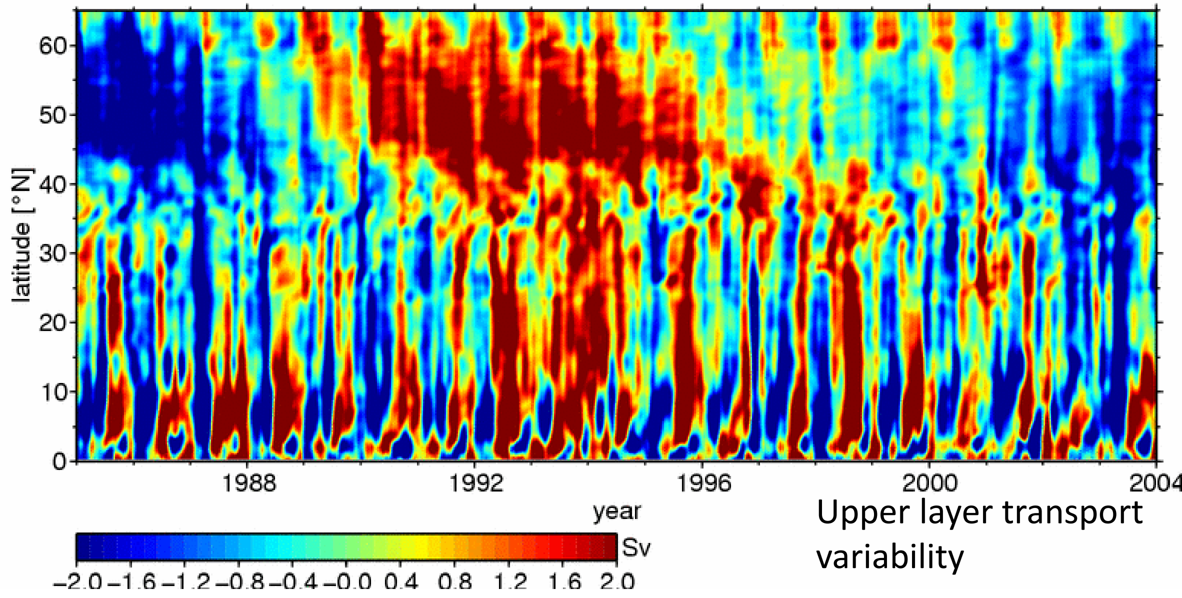


OCCAM MOC streamfunction





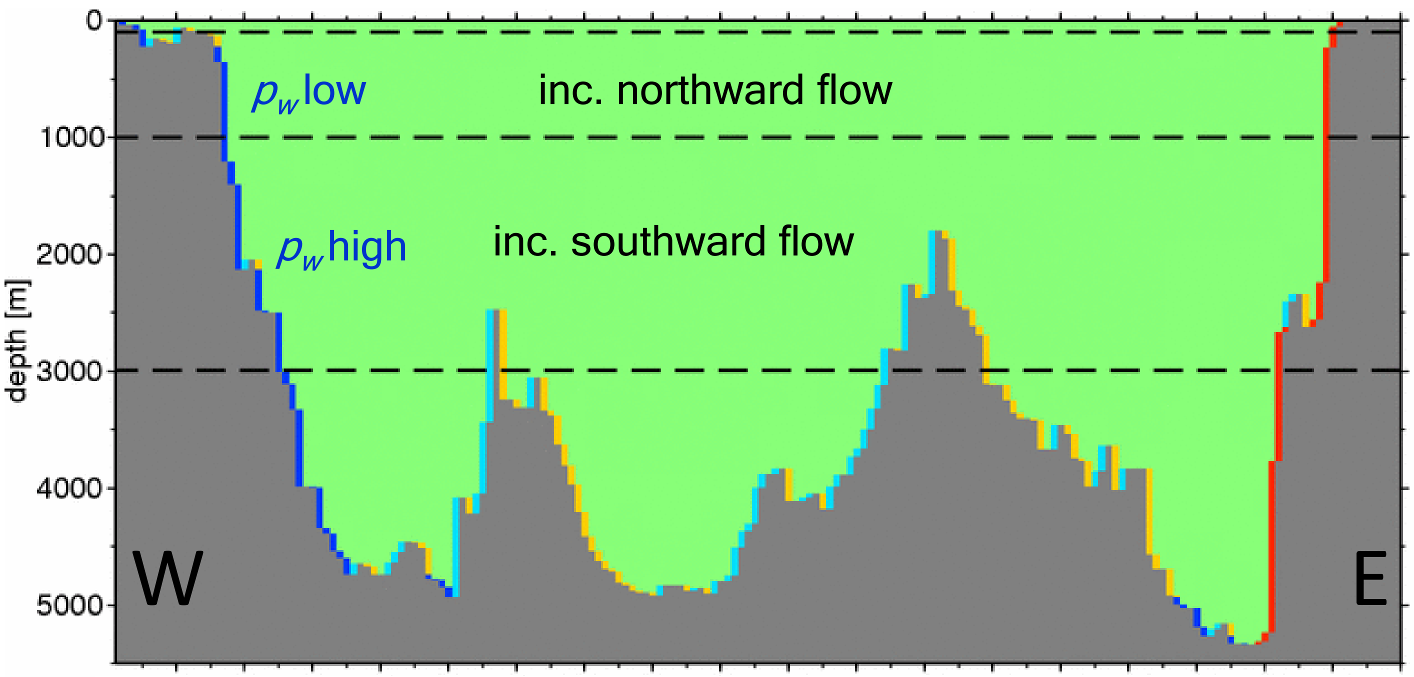
Upper layer transport variability

The Atlantic MOC - Geostrophy

At depths below the Ekman layer, the zonally-integrated northward transport is proportional to the pressure difference between the eastern and western boundaries:

$$T(z) = \frac{p_e(z) - p_w(z)}{\rho f}$$

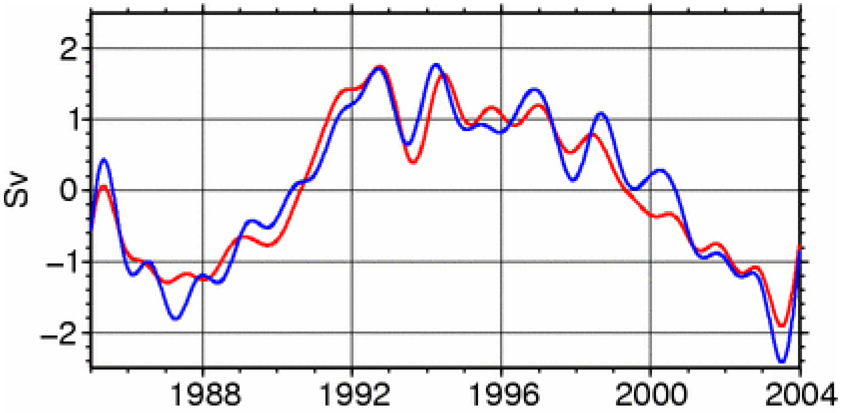
Pressure relative to the eastern boundary



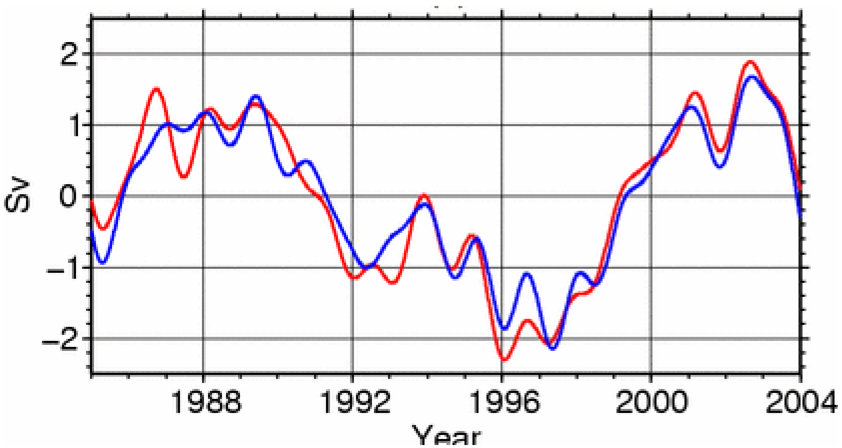
Cross-section (looking north) showing the topography of the North Atlantic at 42N

Meridional transport determined from western boundary pressure (42N)

OCCAM (100–1300 m); RMS error: 0.28 Sv



OCCAM (1300–3000 m); RMS error: 0.31 Sv



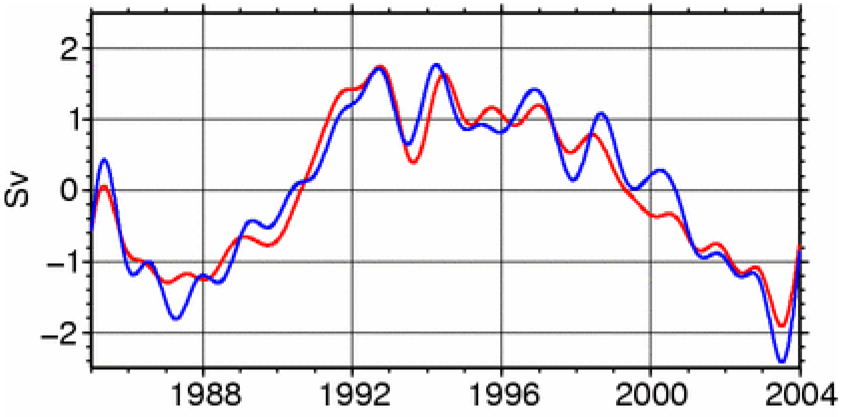
Actual

Inferred from western boundary pressure

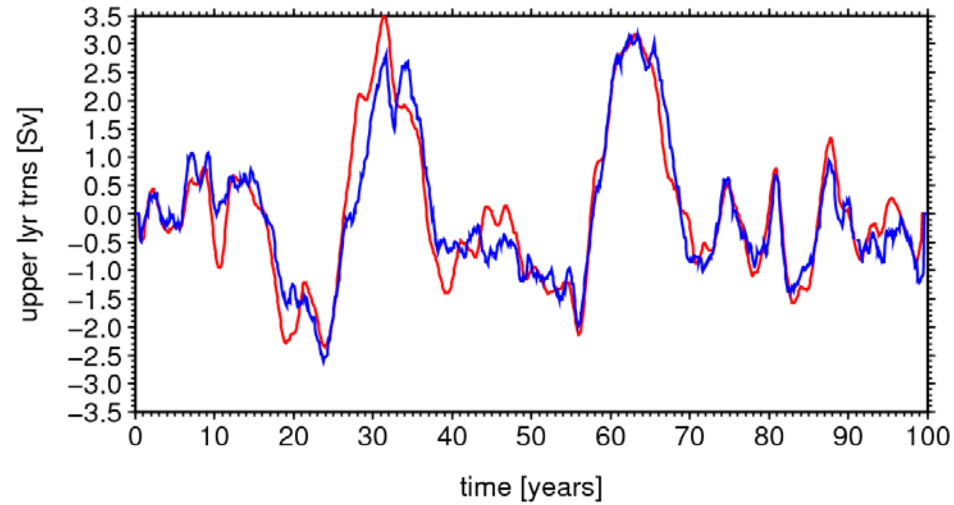
North of the Gulf Stream inter-annual meridional transport variability can largely be determined from bottom pressure on the western boundary.

Meridional transport determined from western boundary pressure (42N)

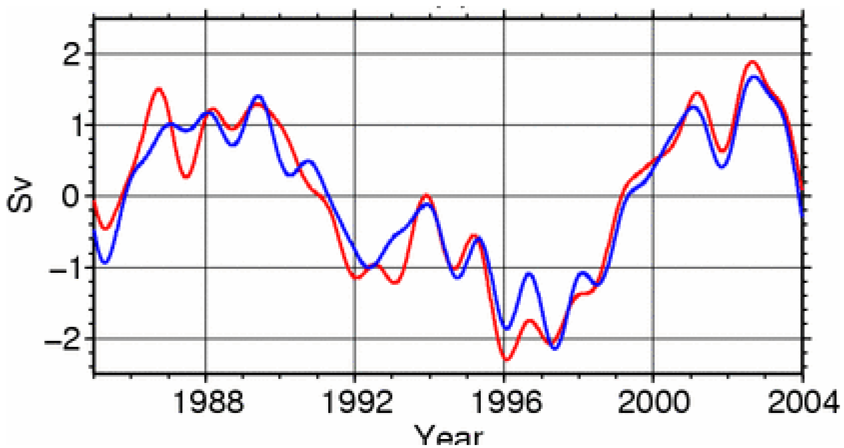
OCCAM (100–1300 m); RMS error: 0.28 Sv



HadCM3 (100–1800 m); RMS err: 0.39 Sv



OCCAM (1300–3000 m); RMS error: 0.31 Sv



Actual

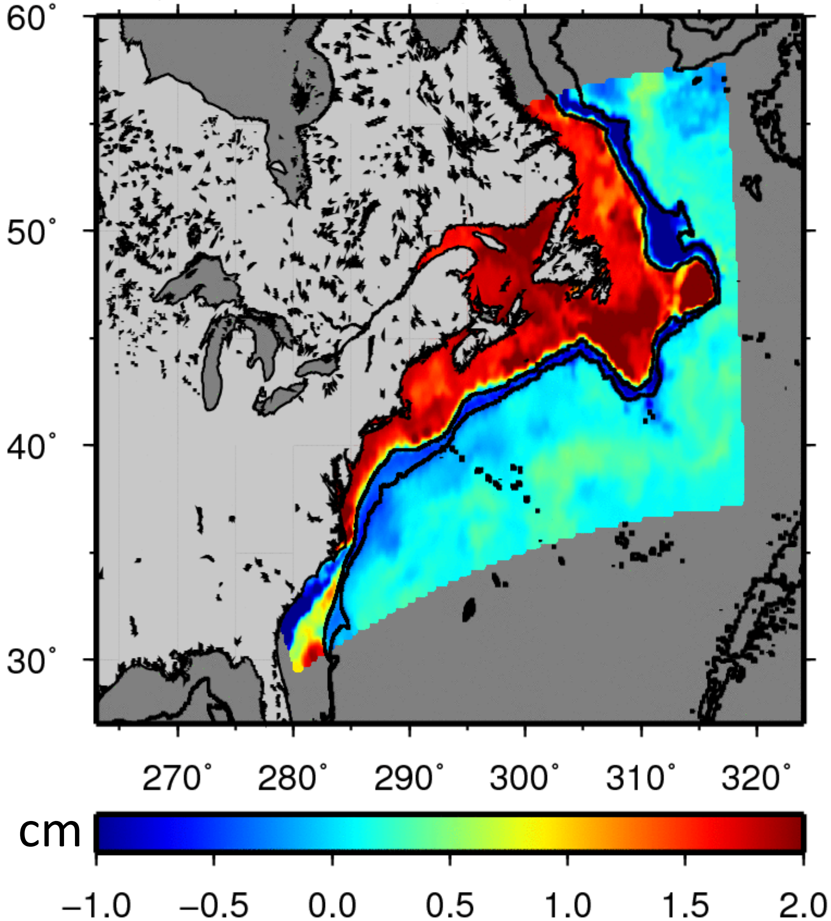
Inferred from western boundary pressure

North of the Gulf Stream inter-annual meridional transport variability can largely be determined from bottom pressure on the western boundary.

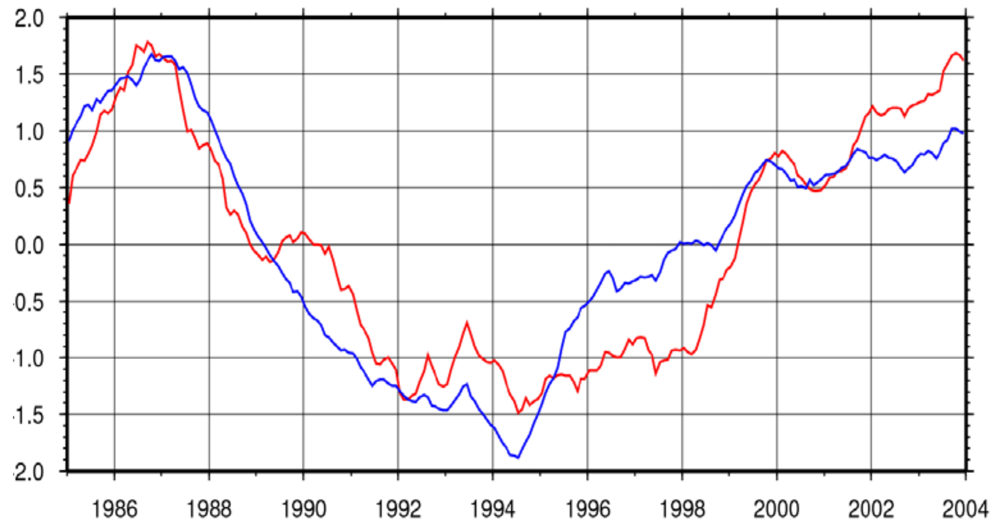
Seems to be a general result.

EOF analysis of bottom pressure

Leading EOF of interannual bottom pressure variability in OCCAM

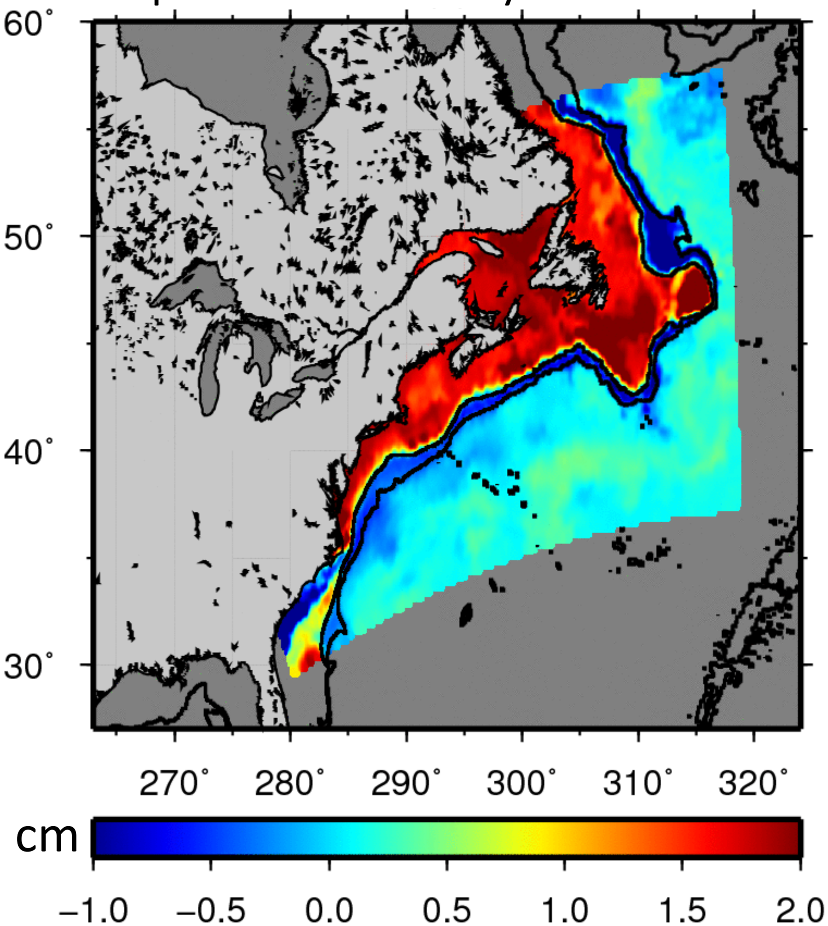


PC1 of interannual bottom pressure variability in OCCAM

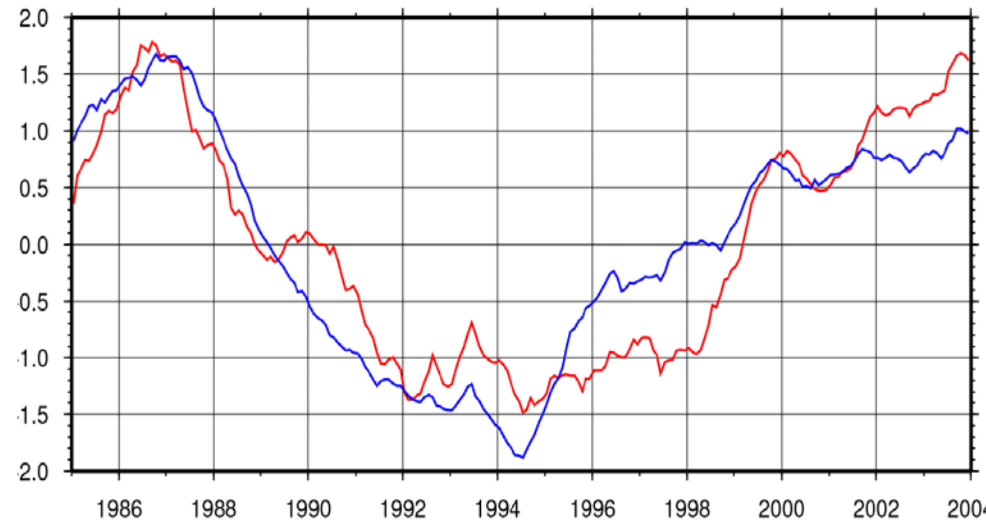


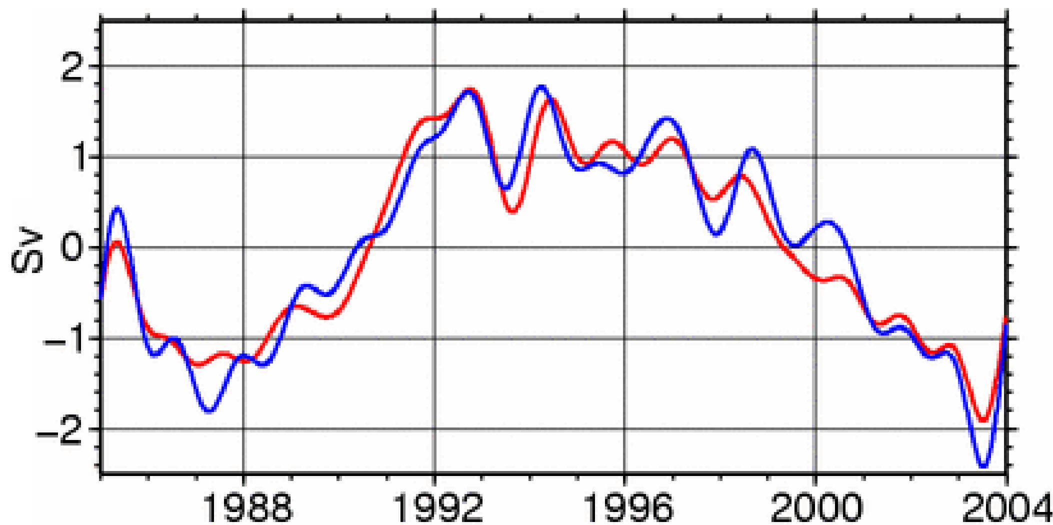
EOF analysis of bottom pressure

Leading EOF of interannual bottom pressure variability in OCCAM

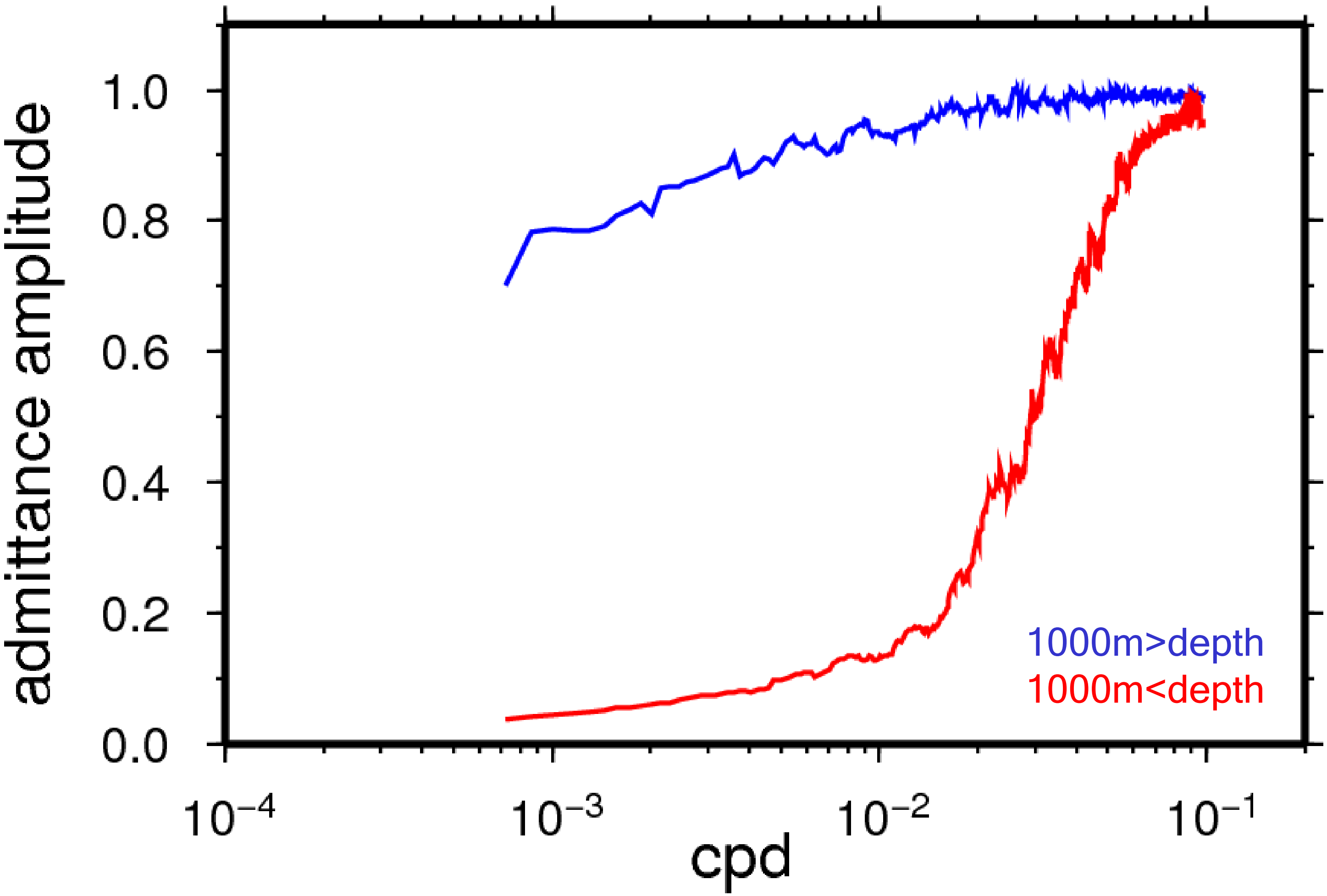


PC1 of interannual bottom pressure variability in OCCAM



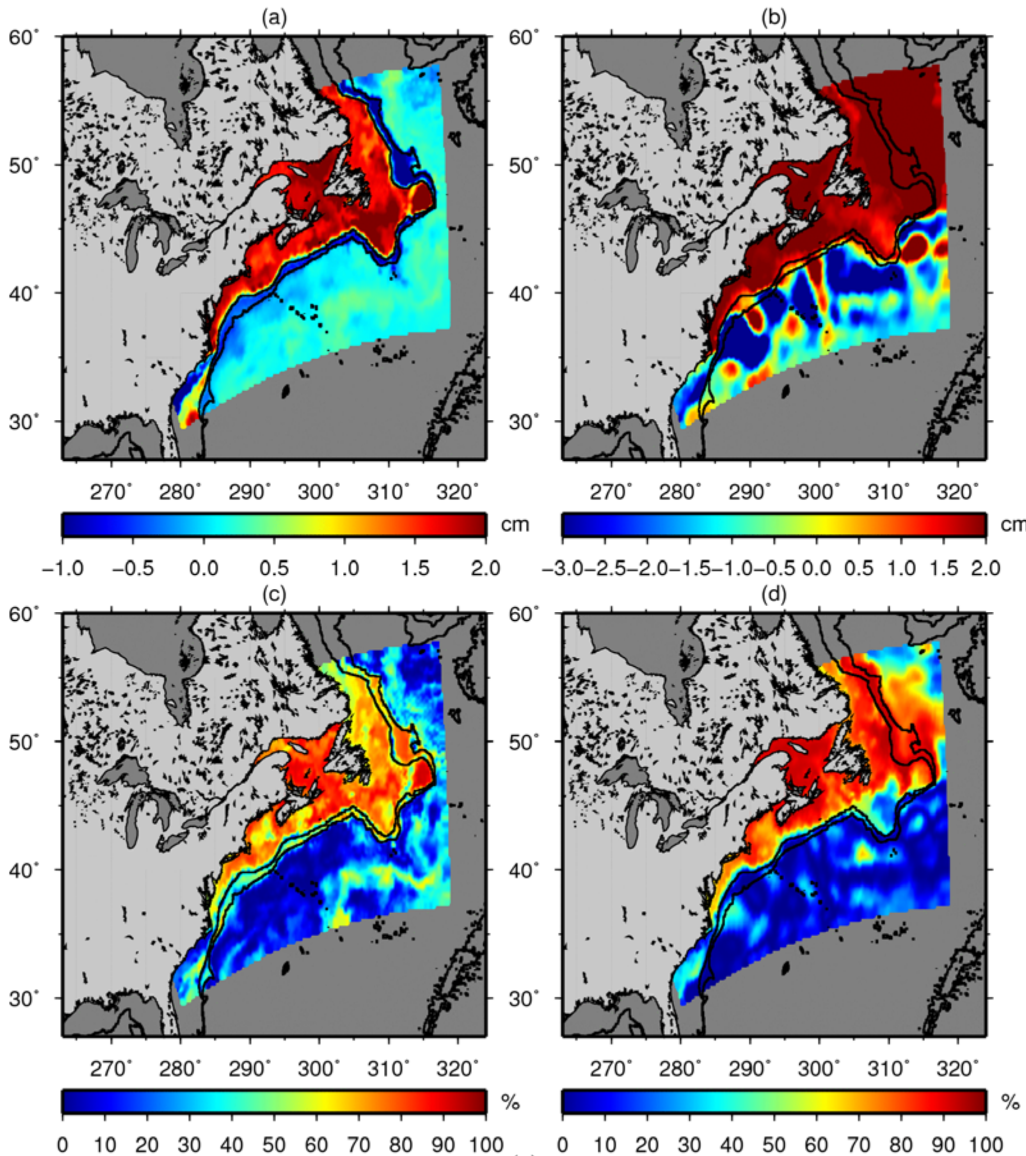


The relationship between bottom pressure and sea level



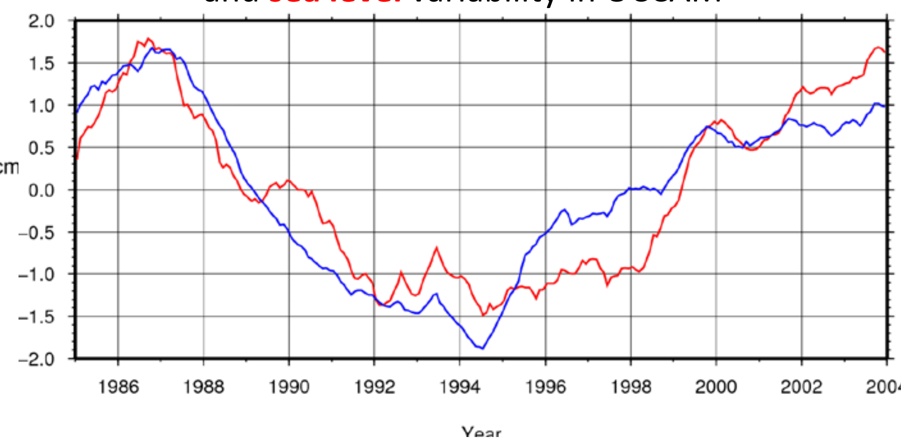
(Bingham and Hughes, GRL, 2008)

The relationship between bottom pressure and sea level



Leading EOFs of interannual bottom pressure (left) and sea level (right) variability in OCCAM.

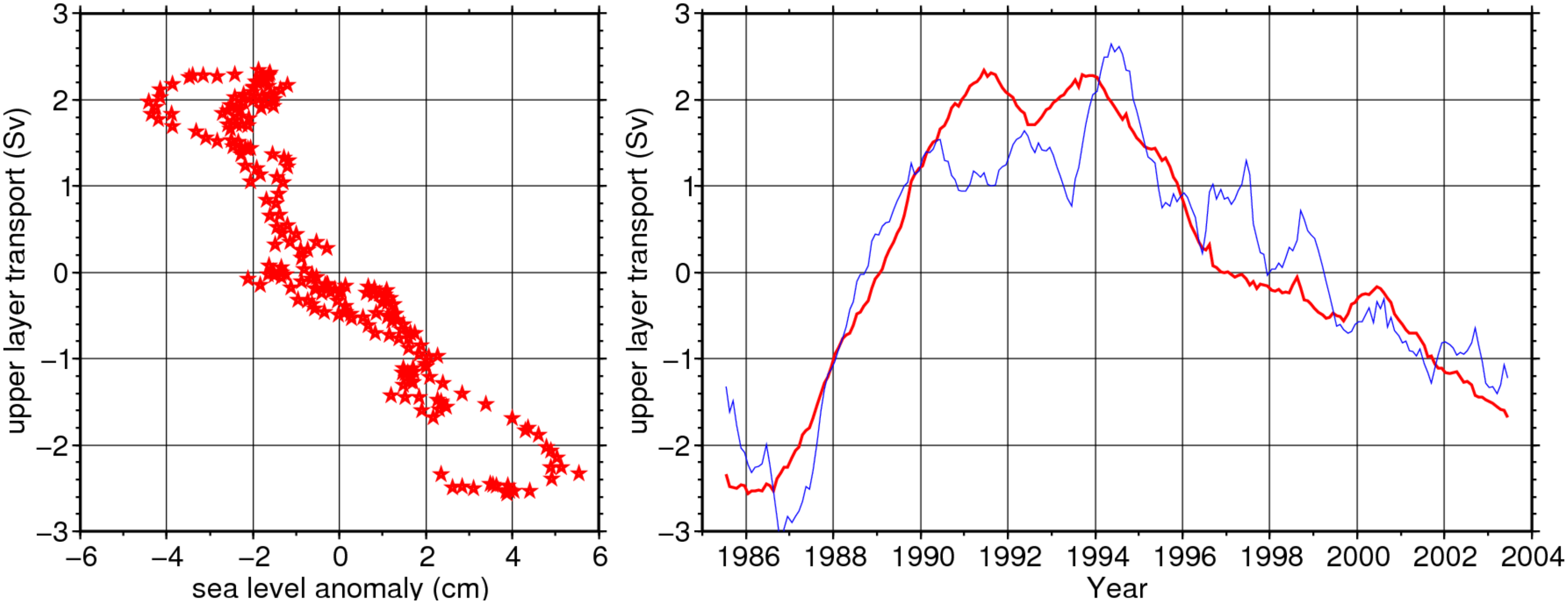
First PCs of interannual **bottom pressure** and **sea level** variability in OCCAM



Percentage of variance accounted for by the leading EOFs.

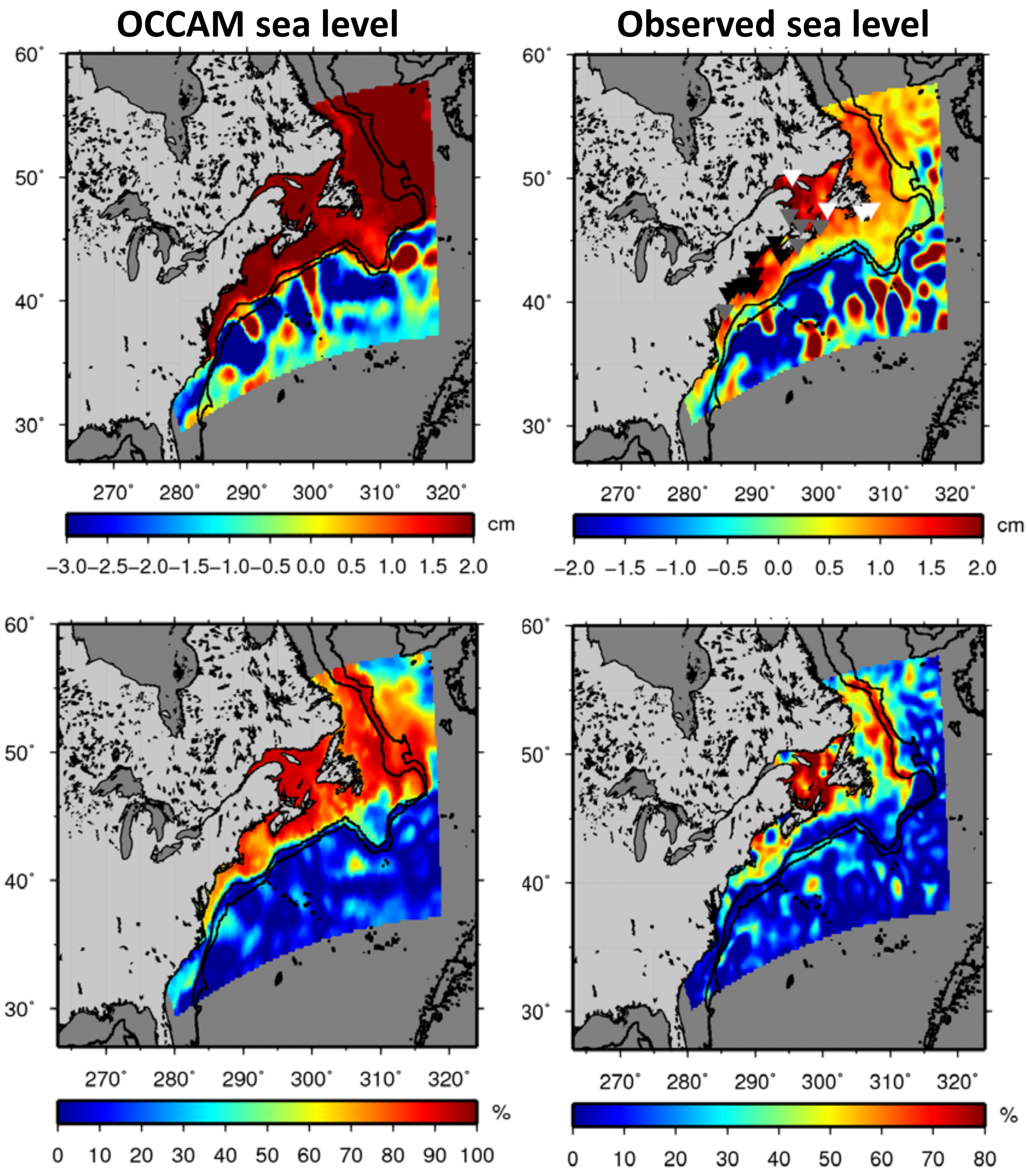
Meridional transport and western boundary sea level

Actual slope is -0.59 Sv/cm



Actual upper layer transport at 42N
Transport based on sea level regression

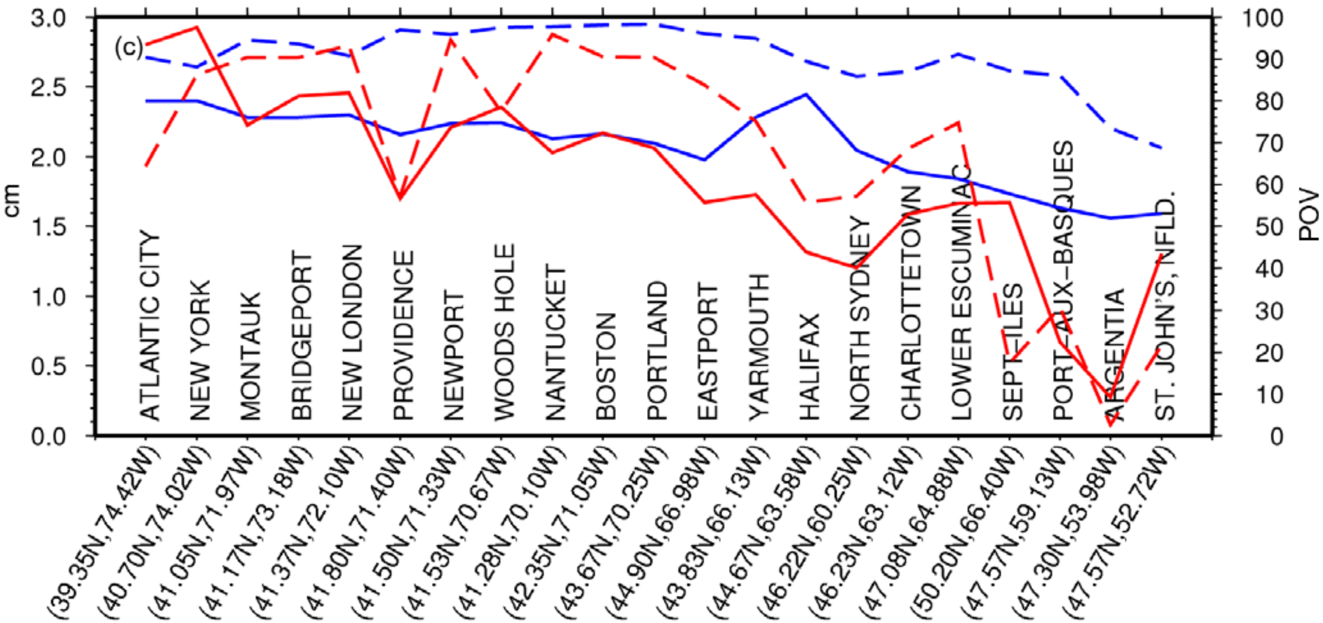
Meridional transport and western boundary sea level



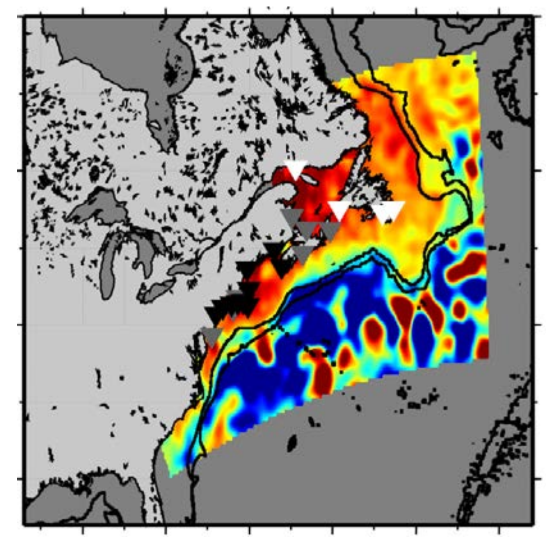
Leading interannual EOF

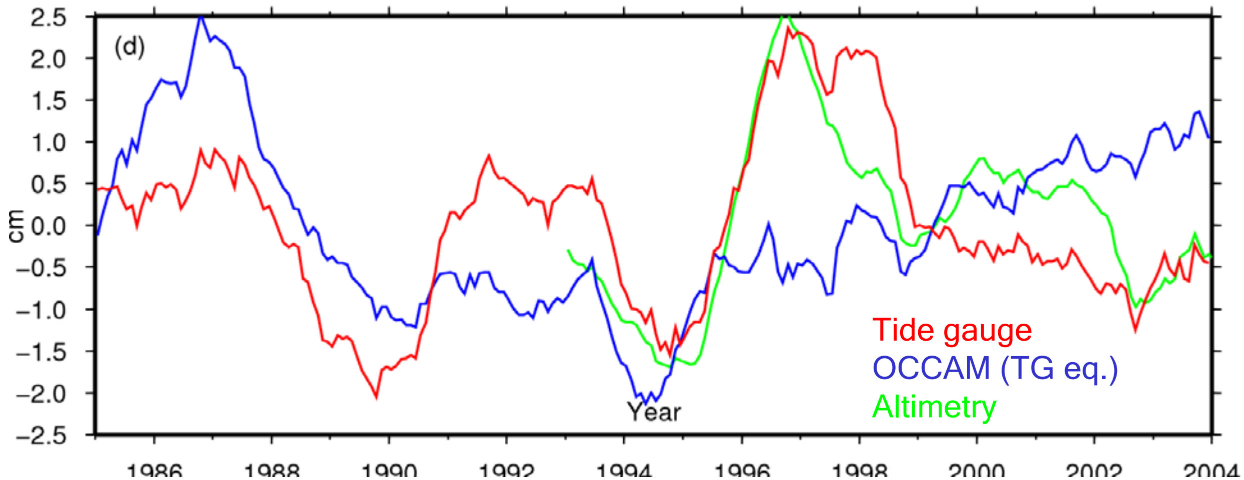
Percent of variance accounted for

Meridional transport and western boundary sea level



Leading EOF of interannual sea level variability from **tide gauges** and POV accounted for. Repeated for **OCCAM**.

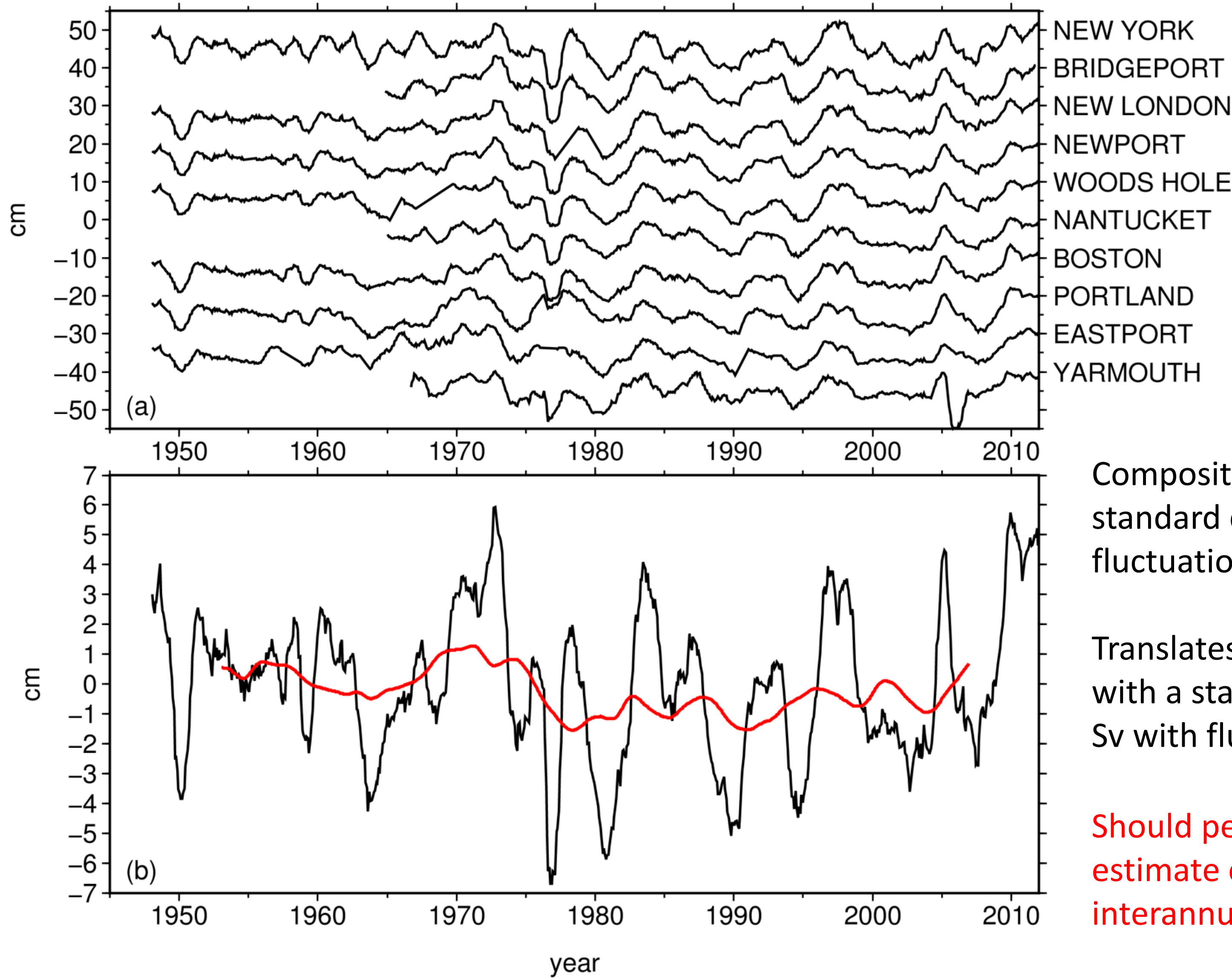




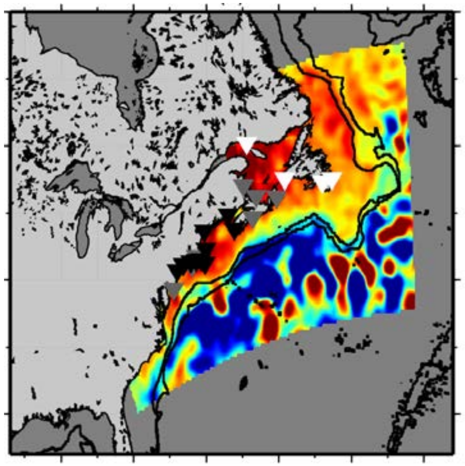
Corresponding principle components

A possible reconstruction of past MOC variability?

(Bingham and Hughes, GRL, 2009)



Tide gauges where coherent mode accounts for at least 80% of variance (black triangles)

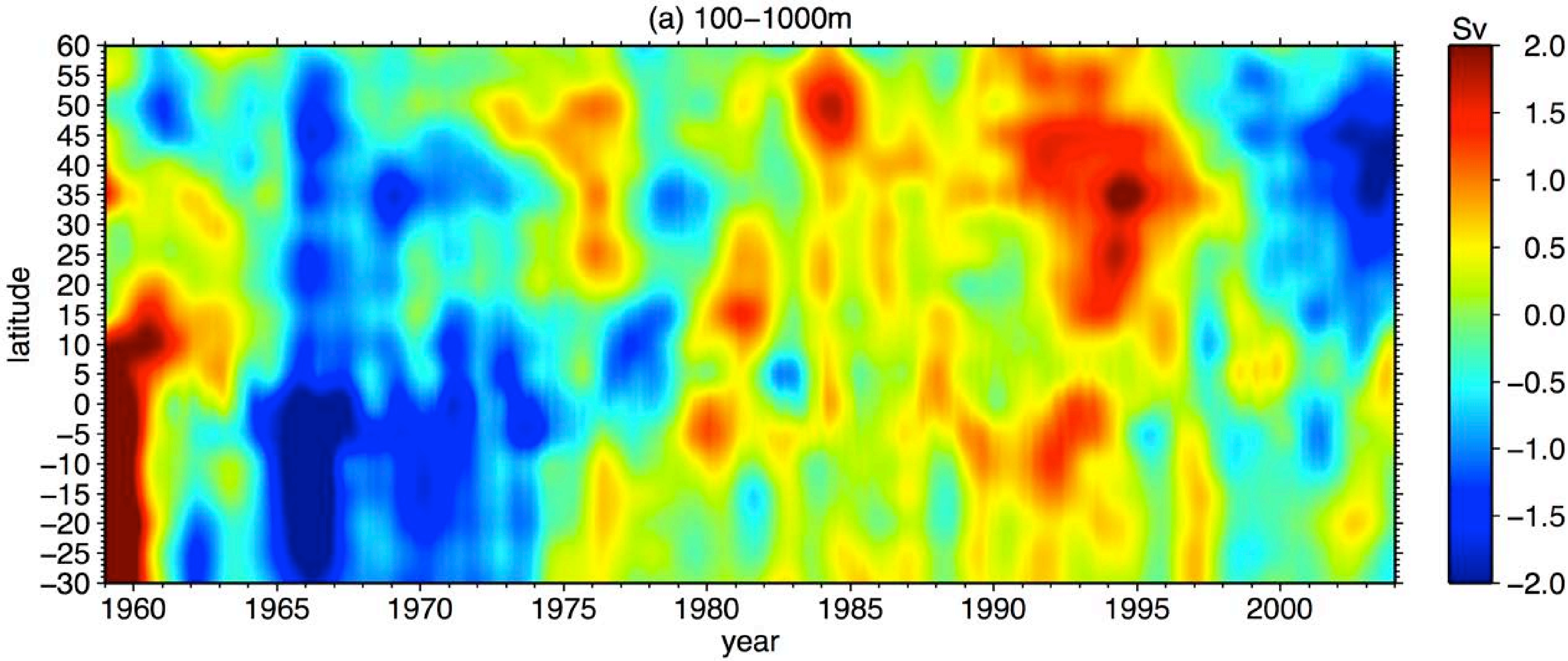


Composite TG timeseries has standard deviation of 2.5 cm and fluctuations of up to10 cm

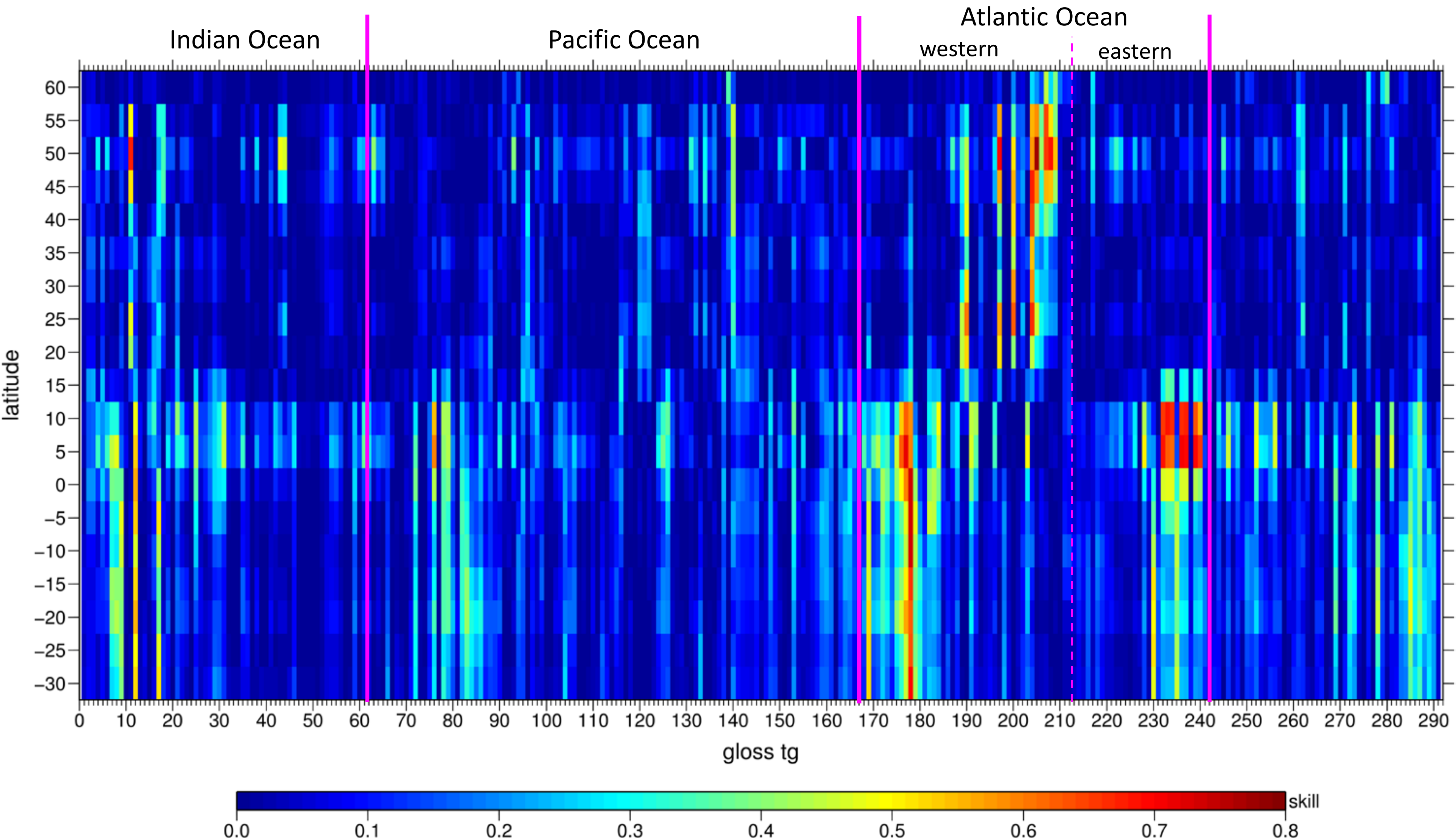
Translates to meridional transport with a standard deviation of 1.25 Sv with fluctuations of up to 5 Sv.

Should perhaps be considered an estimate of the likely range of interannual MOC variability

Inter-annual upper layer transport variability in ORCA (1958-2004)



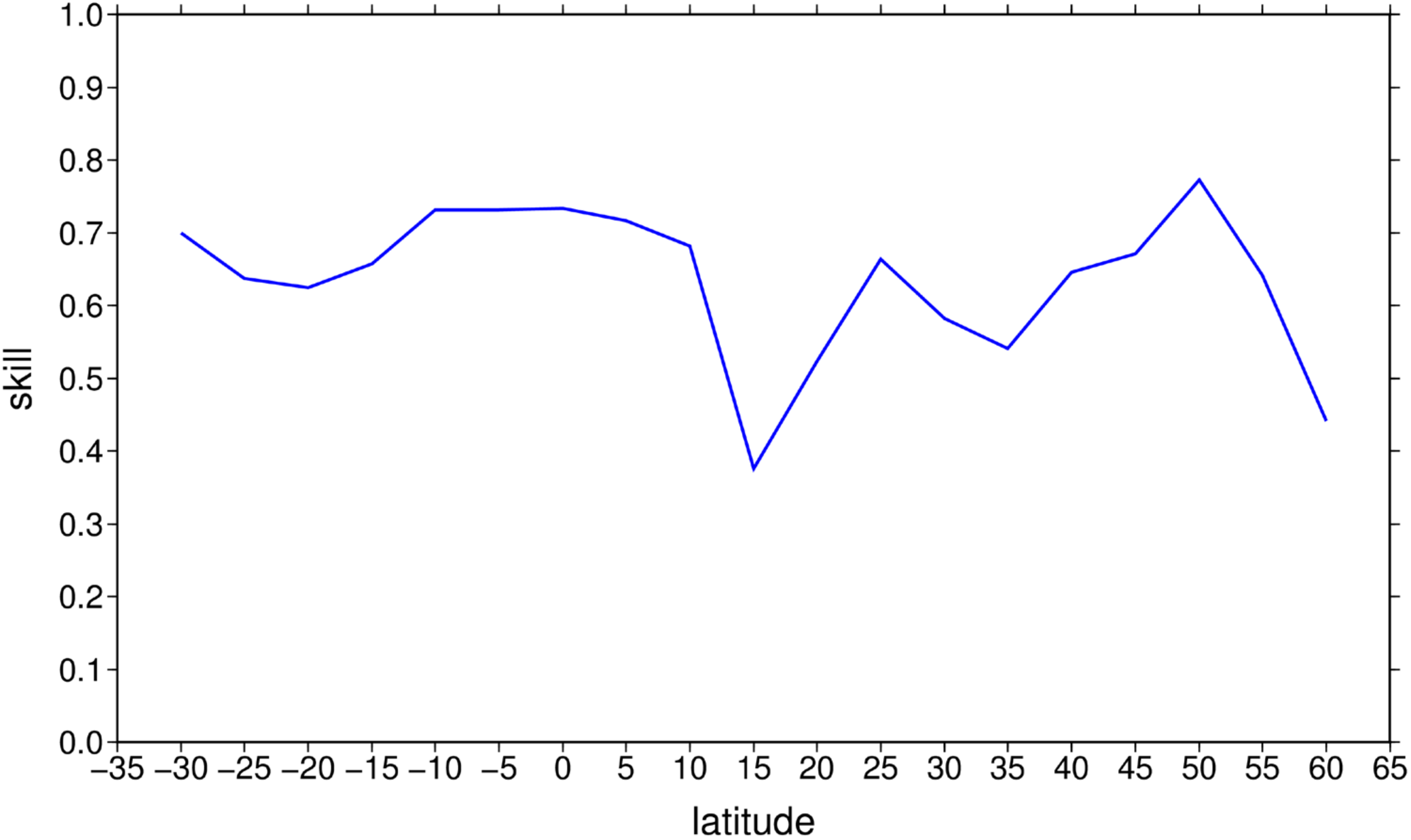
Reconstructing ORCA transport variability using sea level at GLOSS station positions



Skill of transport reconstruction: $T_i(\theta) = a_i(\theta)h_i + b_i(\theta)$

Reconstructing ORCA transport variability using sea level at GLOSS station positions

Skill of best TG transport reconstruction at each latitude



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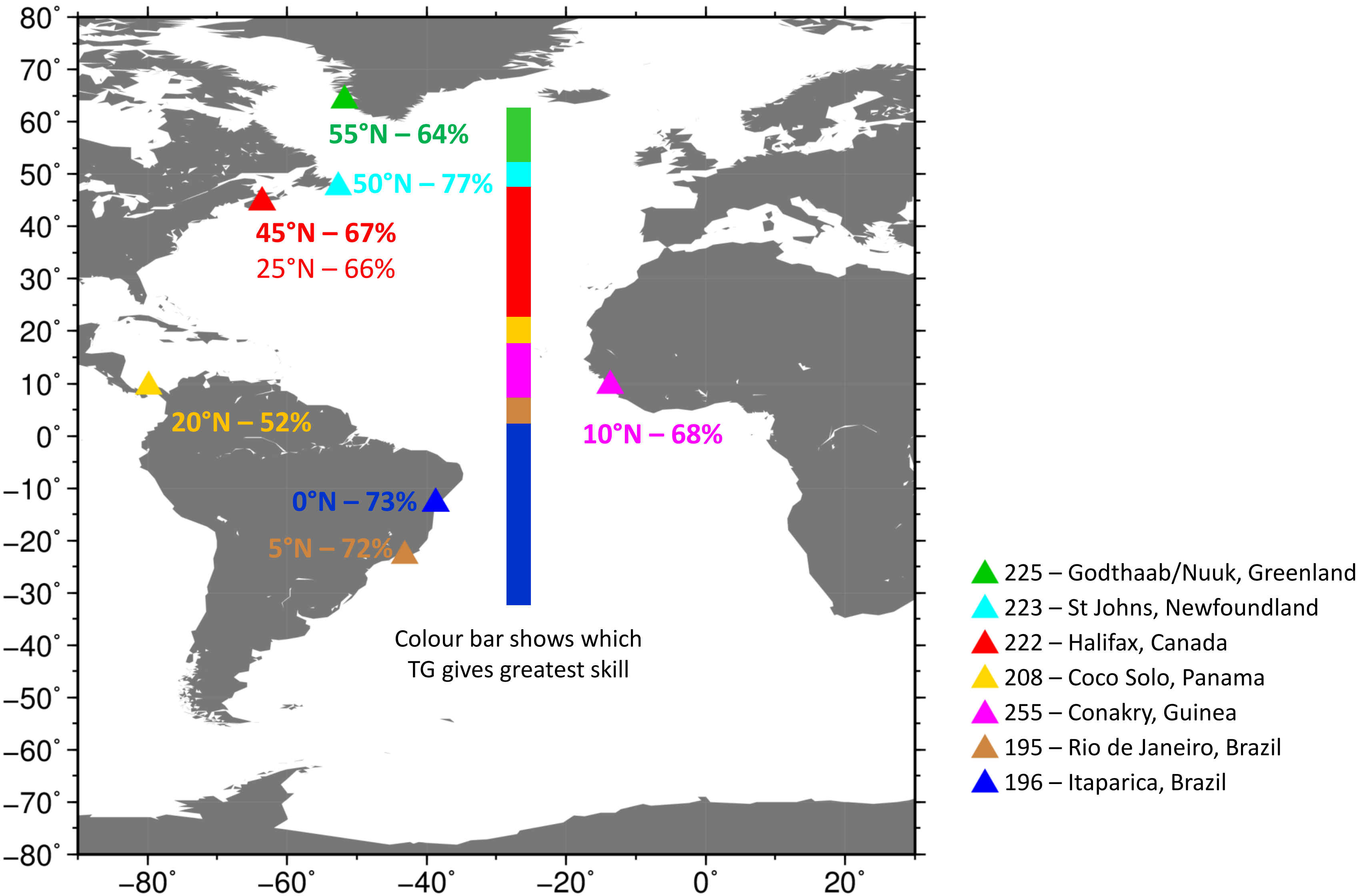
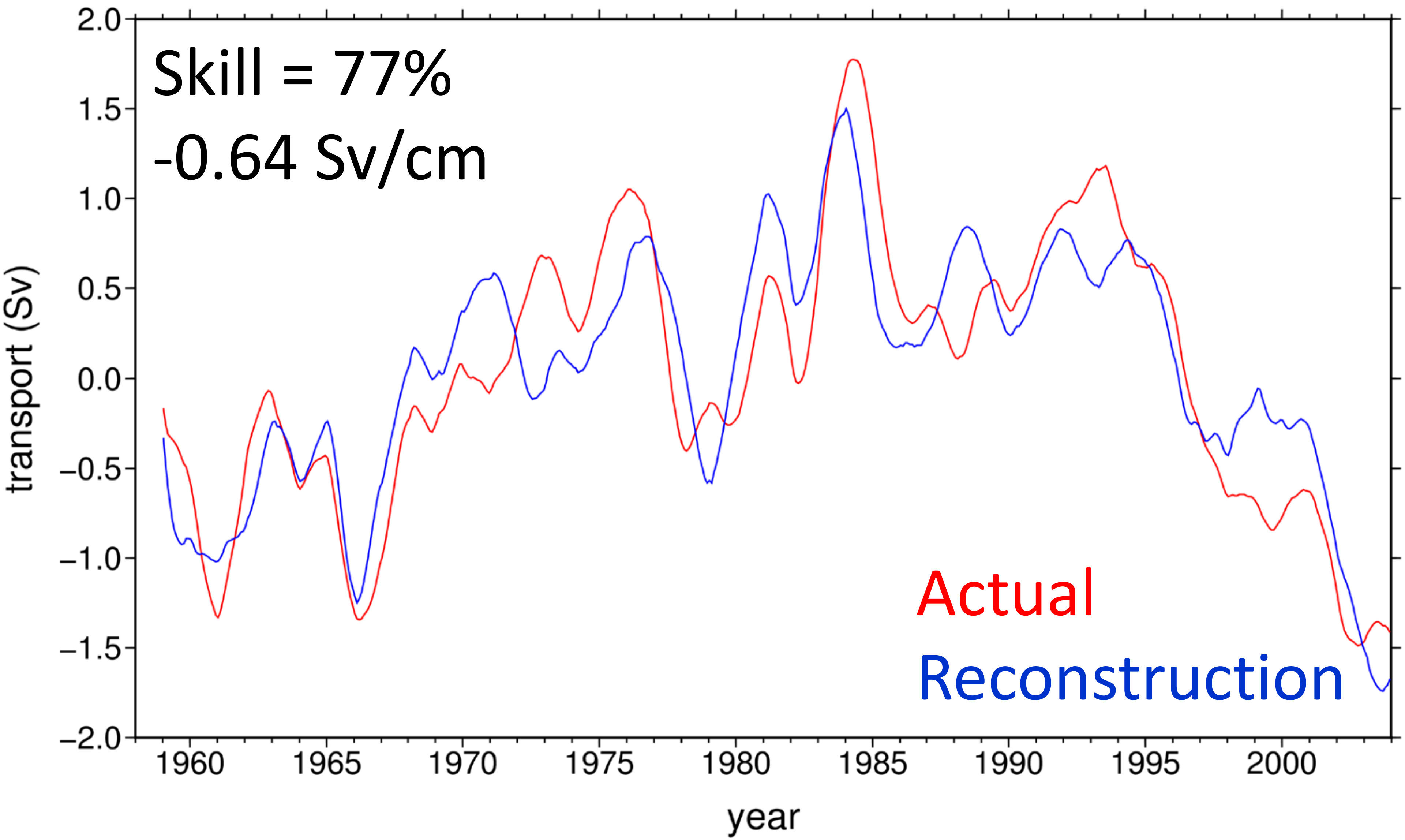
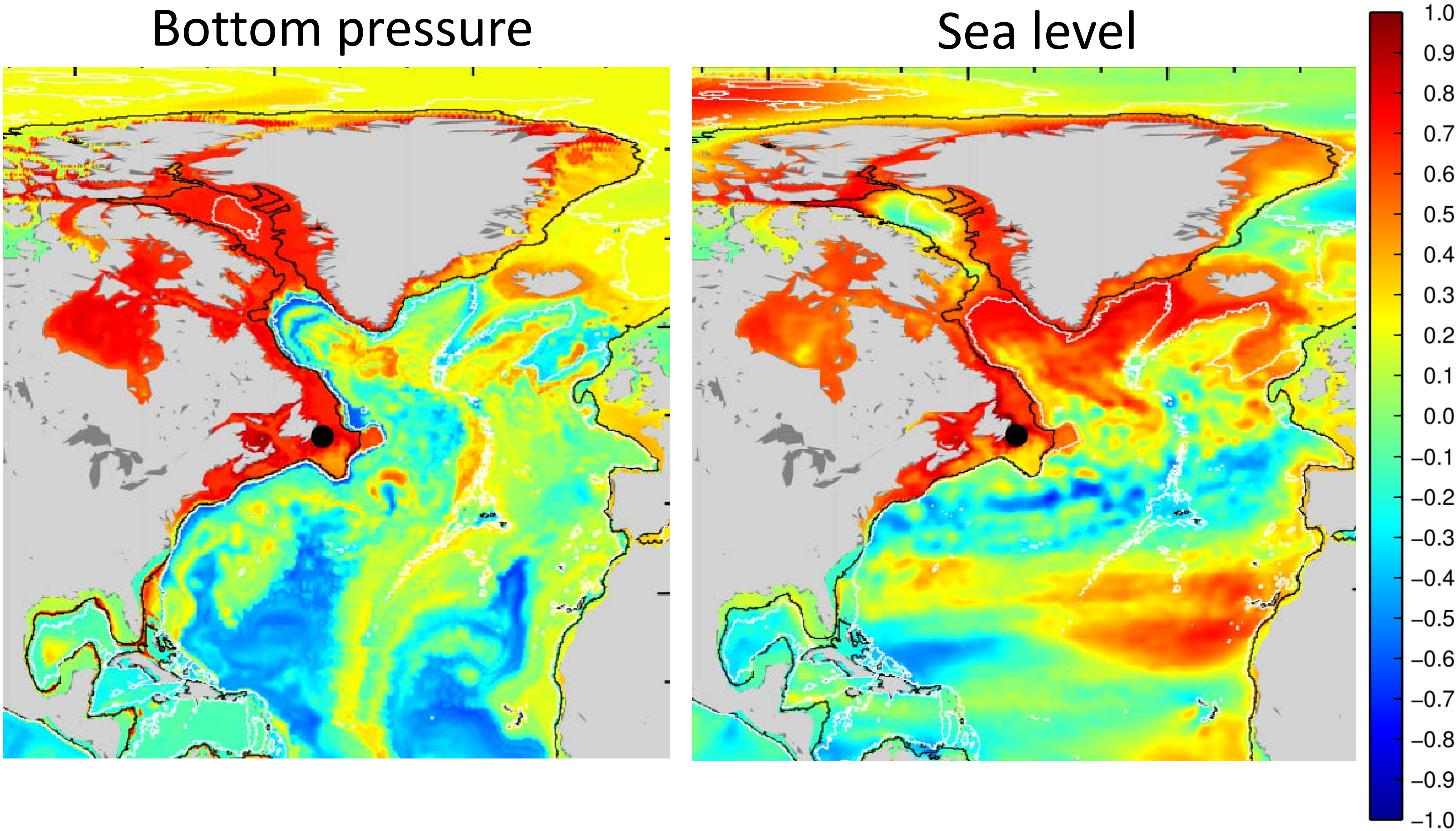


50N transport reconstruction based on St. Johns, NF sea level in ORCA

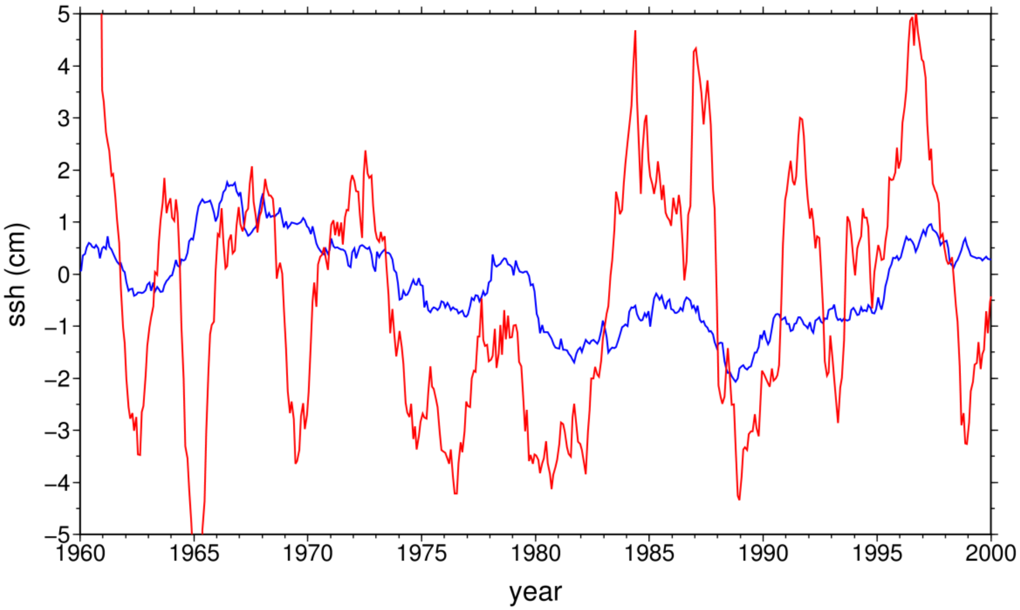


St Johns interannual correlation patterns in ORCA

Bottom pressure   Sea level

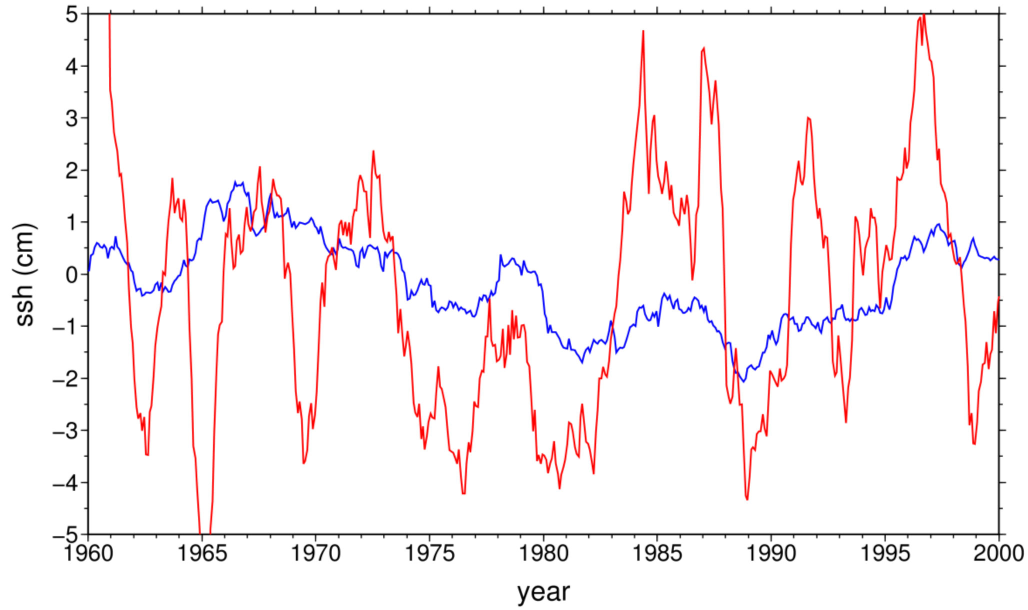


Observed vs. modelled sea level at St. Johns, NF



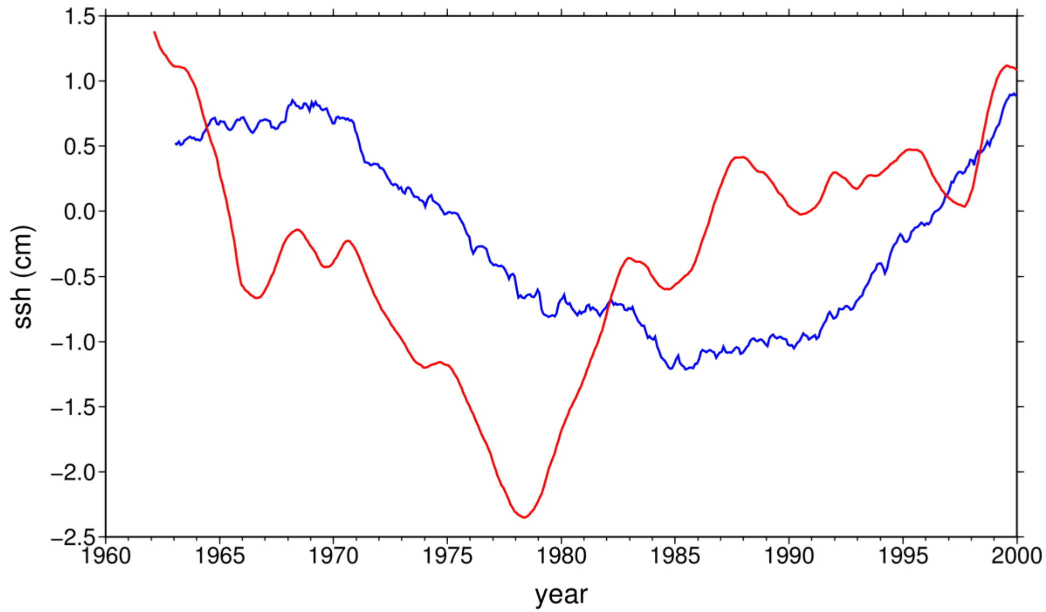
Observed
ORCA

Observed vs. modelled sea level at St. Johns, NF



Observed

ORCA

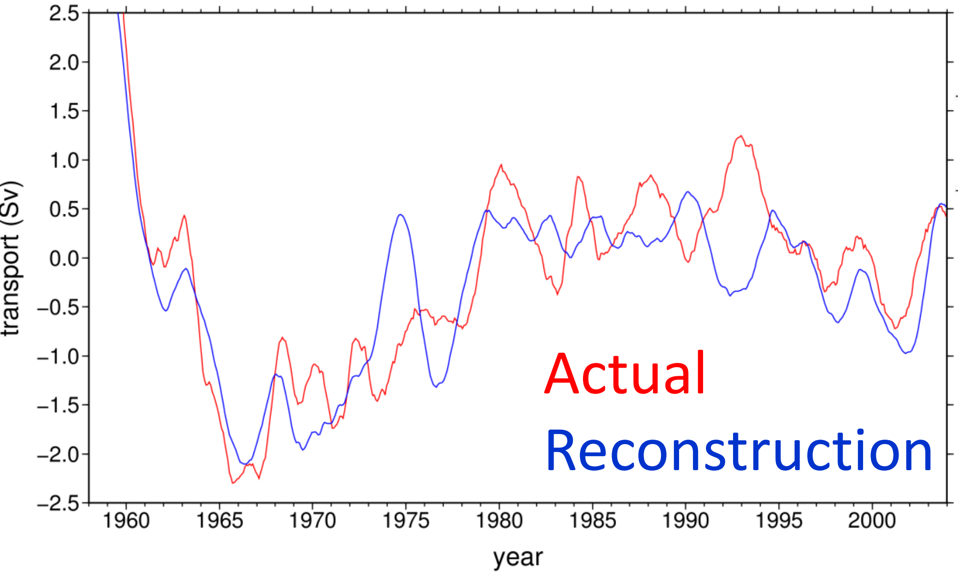


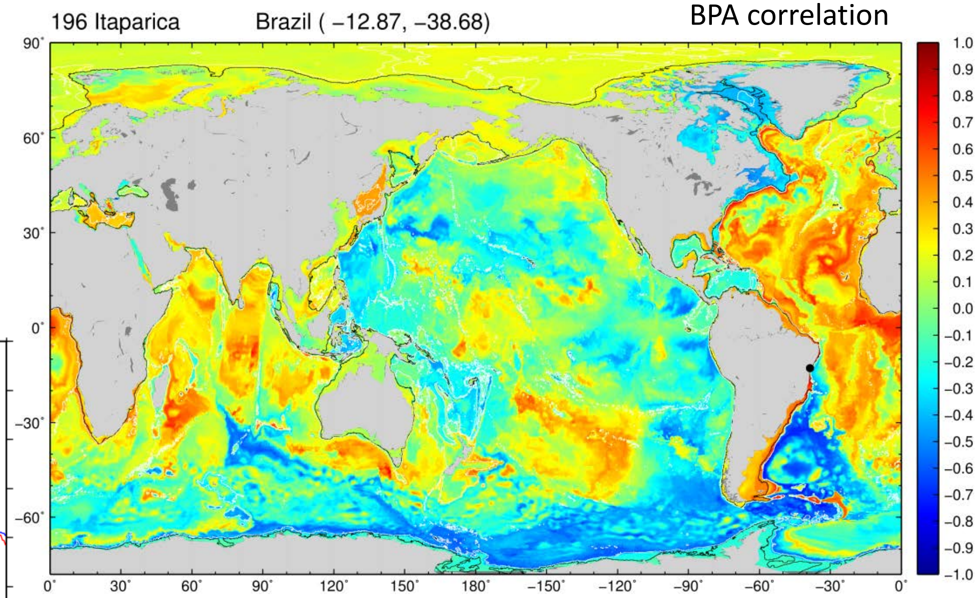
Decadal variability
(10 yr moving average)

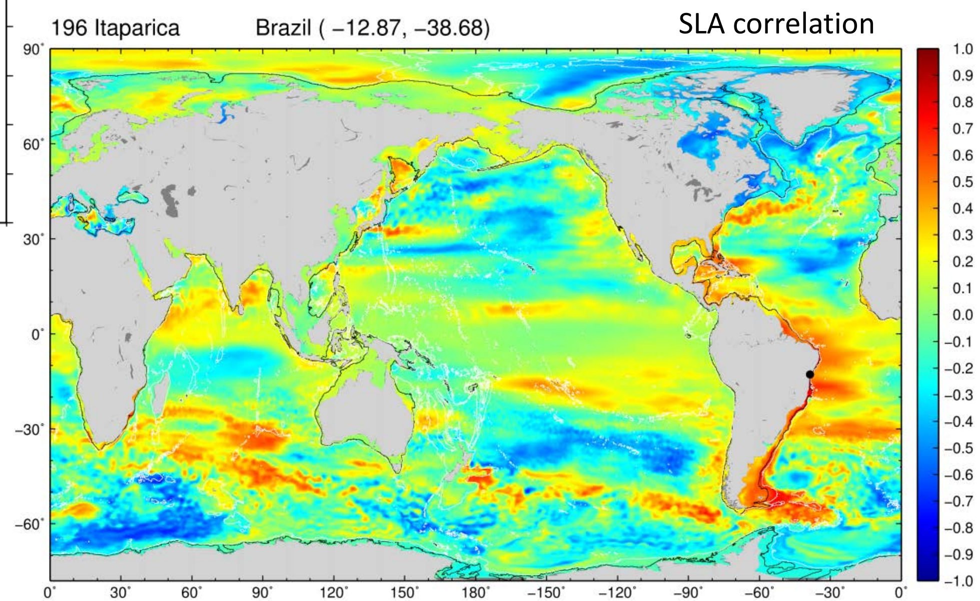
0N transport reconstruction based on Itaparica, Brazil sea level in ORCA

Skill = 73%

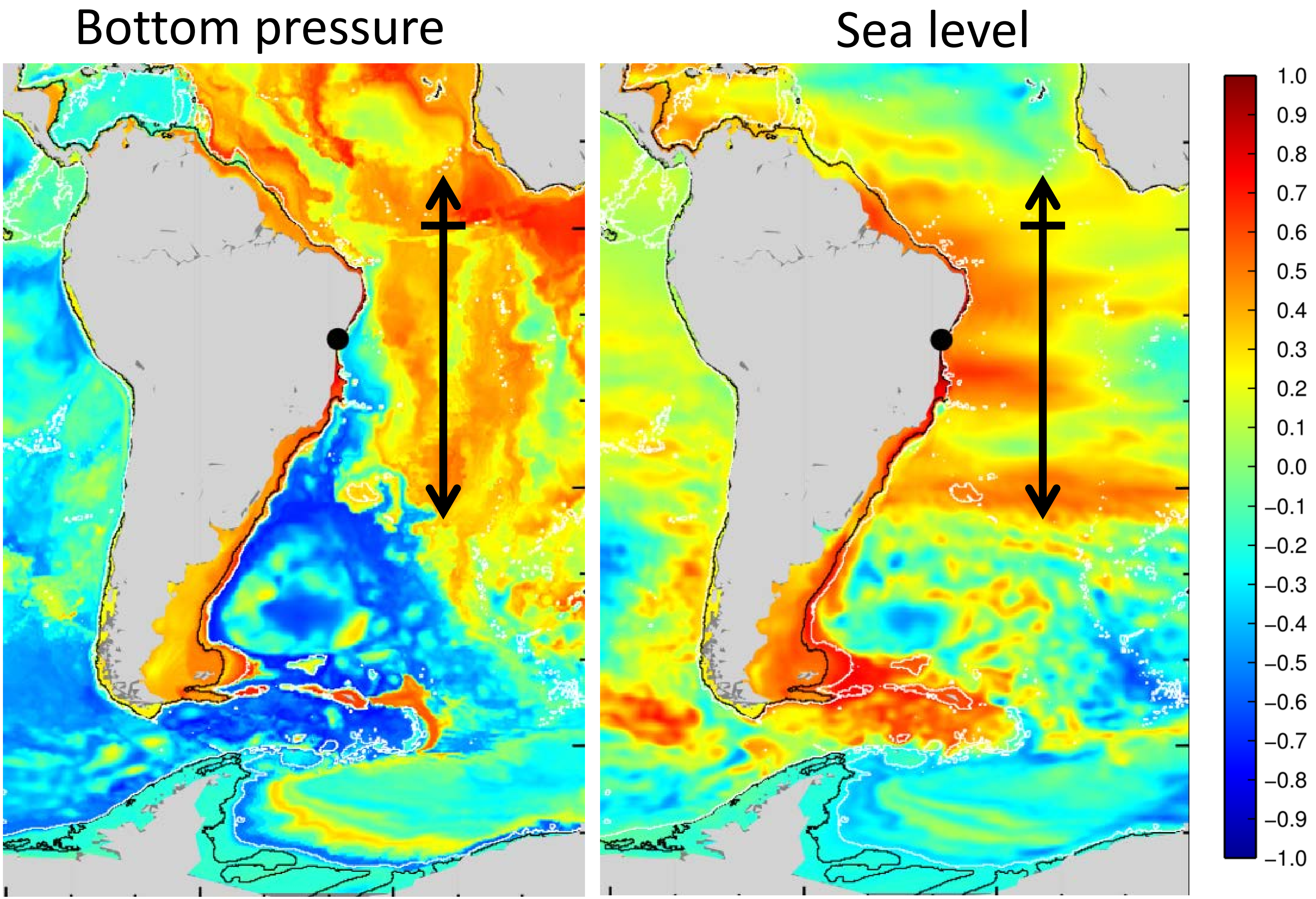
0.76 Sv/cm







Itaparica, Brazil interannual correlation patterns in ORCA



Summary

- Models show interannual Atlantic meridional transport variability can be calculated from western boundary pressure.
- This leads to a close relationship between MOC variability and sea level along the east coasts of North/South America.
- North Atlantic 2 cm sea level increase (decrease) for every 1 Sv decrease (increase) in the meridional transport strength.
- Transport at 50N can be reconstructed with 77% skill from St Johns tide gauge.
- Transport in the South Atlantic can be reconstructed with up to 73% skill using the Itaparica (Brazil) tide gauge.
- Past variations – fluctuations up 5 Sv with s.d. of 1.25 Sv.