Boundary wave propagation, bottom pressure signals and their link to overturning variability in the North Atlantic

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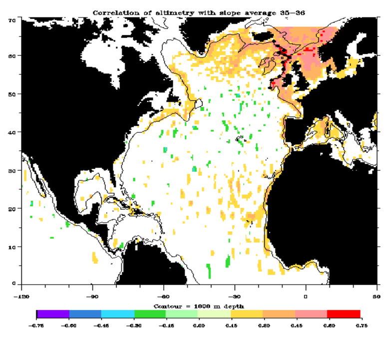
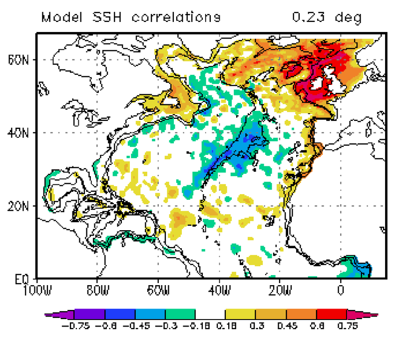
1. How changes in the high latitude forcing communicate over the ocean?

Downstream response at lower latitudes along the western boundary involving:

- rapid response: wave propagation against the sidewalls and along the equator – Kelvin waves, coastal trapped waves (Huthnance, 1978, JPO; Kawase, 1987; Johnson & Marshall, 2002, JPO)
- an intermediate response involving changes in local circulation
- slower response: advection along western boundary and evolution of dense water masses



Correlation of altimetry (Hughes & Meredith, Phil. Trans. Roy. Soc., 2006)



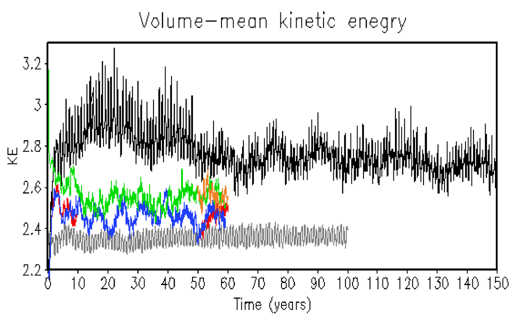
Model SSH correlation high-pass filtered

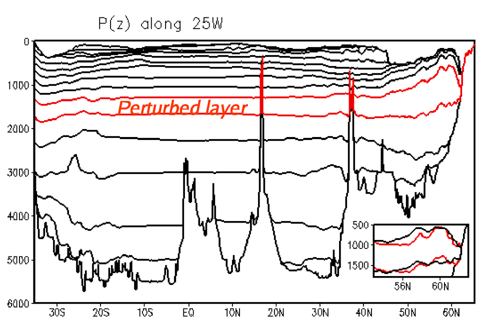
2. Model Studies

Model simulations carried out using a 16 layer isopycnic model (MICOM).

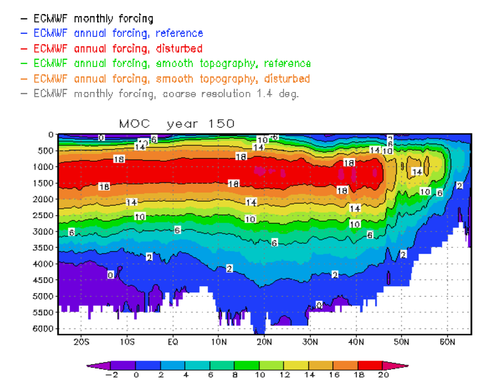
Resolution is 0.23° (26 km at the equator & 13km at 60°N). Model initialised from Levitus and run for 150 years, forced by ECMWF monthly-mean winds and surface fluxes. Parallel run is performed, forced by annual mean forcing, and a twin experiment involving extra thermohaline forcing is run from year 50.

The twin perturbation experiment is run for 10 years, with deep interface raised 50m per 5 days over the northern relaxation zone. Advection is monitored by a transient model tracer, released in the Labrador Sea, when the perturbed buoyancy forcing starts.

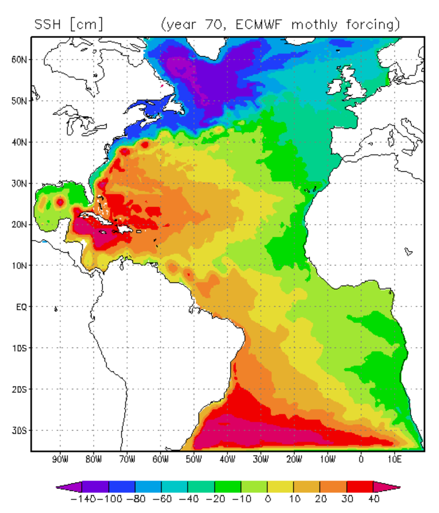




Model layer interfaces along 25°W.

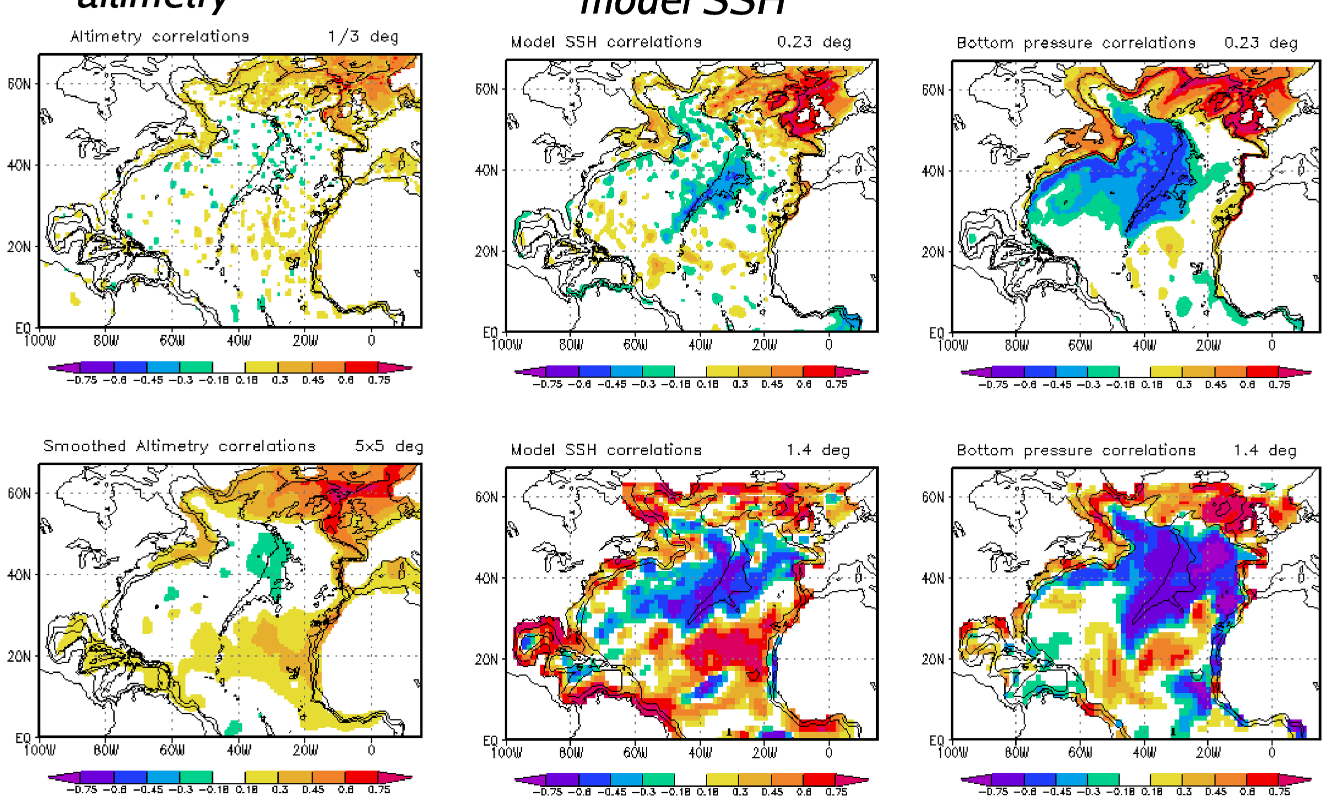


Overturning streamfunction



Model Sea-surface height

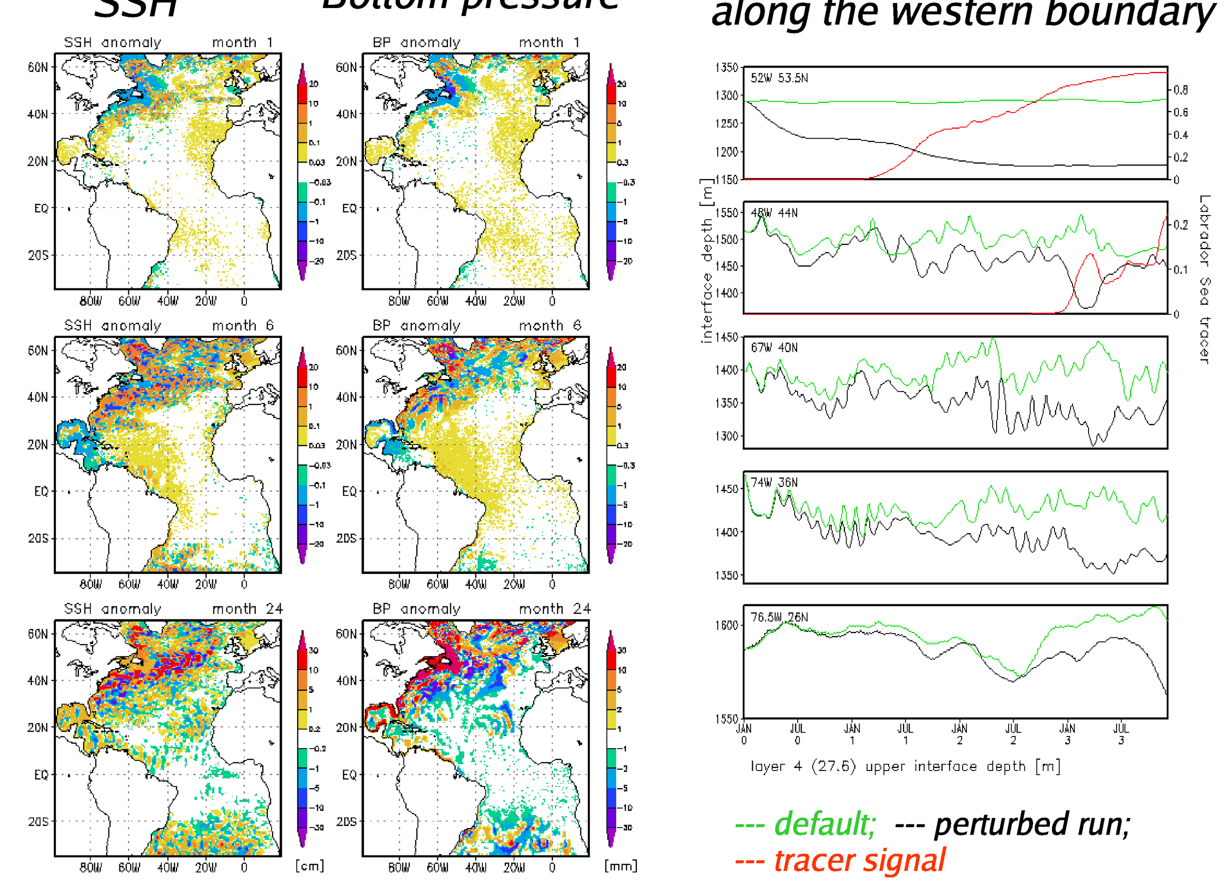
3. SSH and bottom pressure correlations



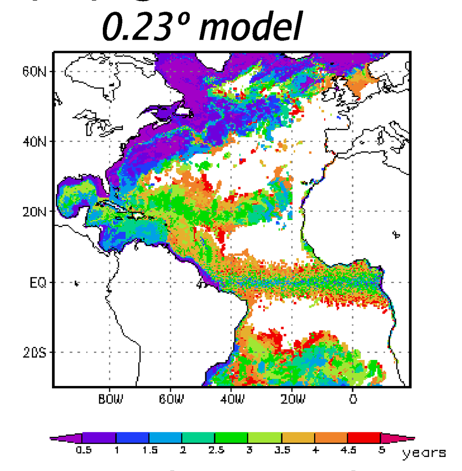
Correlations with mean SSH/BP along 1000m west of Scotland

- coherent, highly correlated signals along the coast
- negative correlations in the centre of subtropical gyre
- positive correlations around 20°N – Rossby waves generated at the eastern boundary
- higher correlations in case of coarse resolution and smoothed altimetry

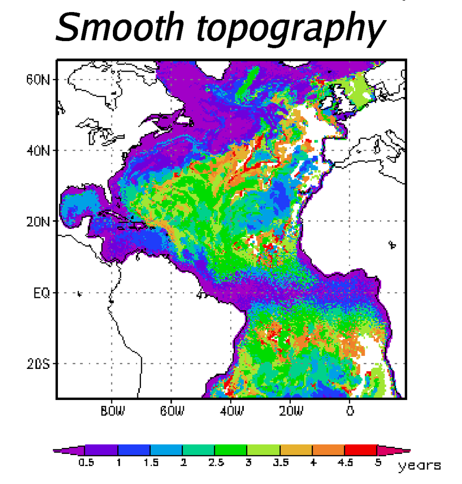
4. Propagation of wave signals in the model



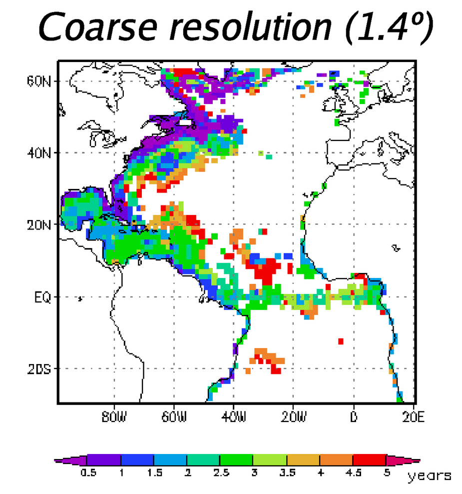
Time of BP anomaly propagation 0.23° model



Smooth topography



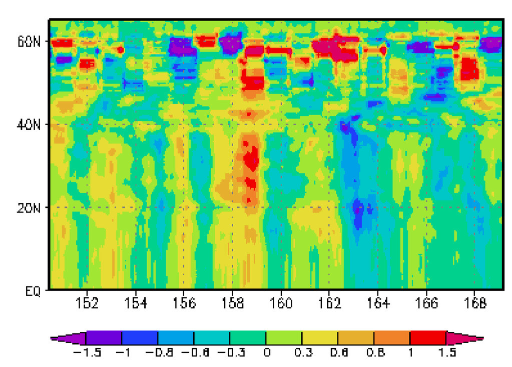
Coarse resolution (1.4°)

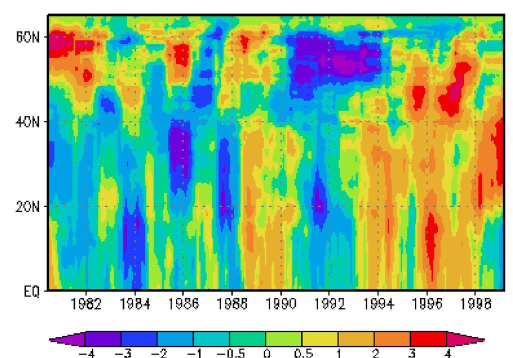


- boundary wave propagation on time scale of months to years
- connected to interior via equatorial Kelvin waves and basin-wide Rossby waves
- similar structures of SSH and bottom pressure anomalies, but highest anomalies of BP along western boundary

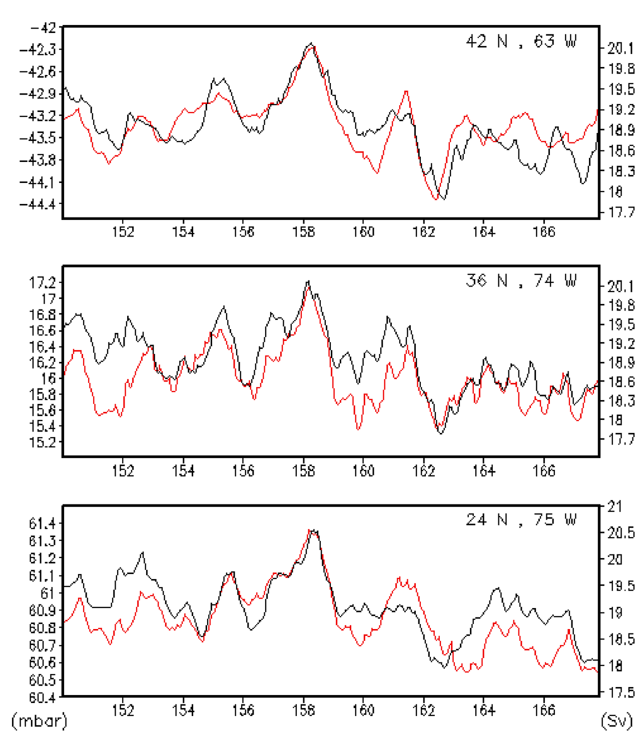
5. Overturning and bottom pressure variability

Upper transport variability





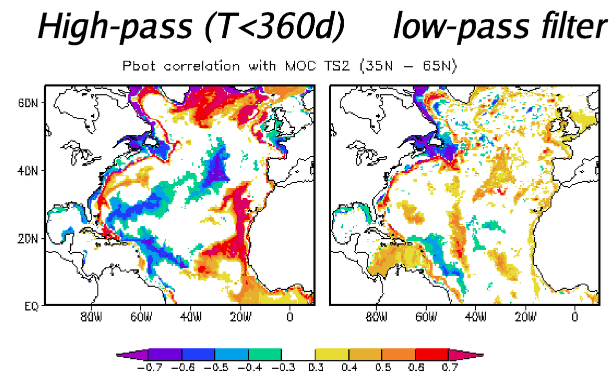
Timeseries of upper transport and WB bottom pressure



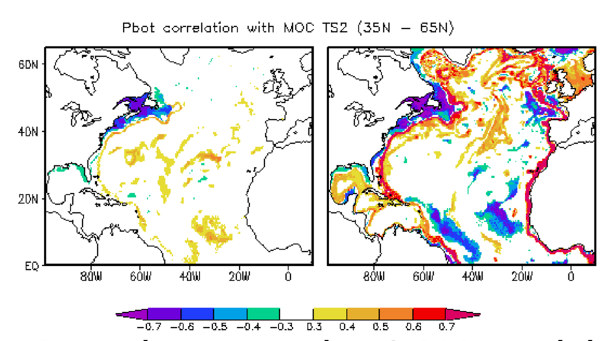
--- transport; --- bottom pressure

Bottom pressure correlations with upper transport (35° N – 65° N)

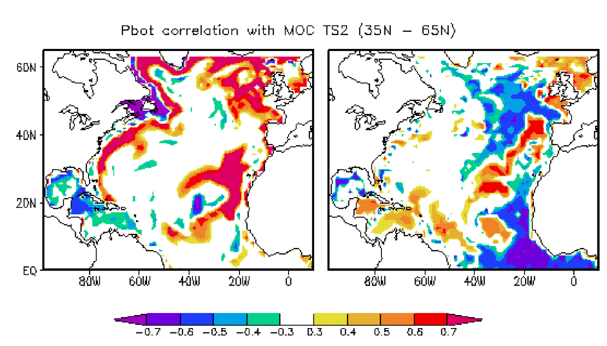
High-pass (T<360d) low-pass filter



Monthly forcing, 0.23° model



Smooth topography, 0.23° model



Monthly forcing, 1.4° model

- transport variations of 1 – 2 Sv in mid-latitudes and 2 – 4 Sv at high latitudes
- externally forced variability dominates longer term transport variations
- highly correlated overturning and WB bottom pressure variations
- different response over the shelf (negative correlations) and along the continental slope (positive correlations)

6. Conclusions

- Boundary wave propagation on time scale of months to years
- Connected to interior via equatorial Kelvin waves and basin-wide Rossby waves
- Waves modified by the topography and stratification
- Wave signals associated with changes in basin-wide overturning of typically 1 – 3 Sv, occurring prior any deep advective signal
- Externally forced variability dominates longer term transport variations
- Coherent, highly correlated signals of SSH and bottom pressure along the coast
- Significant correlations of the overturning and bottom pressure along western boundary

References:

Bingham R., Roussenov V., Hughes C. and Williams R,, 2007: Meridional coherence of the North Atlantic meridional overturning circulation. Geophysical Research Letters, submitted.

Roussenov V., Williams R., Hughes C. and Bingham R., 2007: Boundary wave propagation, bottom pressure signals and their link to overturning variability in the North Atlantic. JGR, to be submitted.