A model assessment of boundary wave communication of bottom pressure and overturning changes for the North Atlantic

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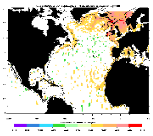
Rapid Climate Change

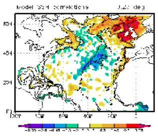
1. How changes in the high latitude forcing communicate over the ocean?

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)



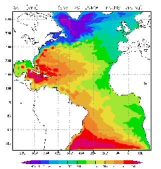
Model SSH correlation high-pass filtered

2. Model Studies

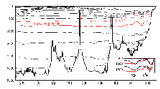
Model simulations carried out using a 16 layer isopycnic model (MICOM).

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.

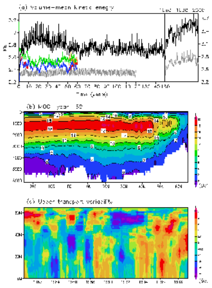
The twin perturbation experiment is run for 10 years, with deep interface raised 50m per 5 days over the northern relaxation zone. Advection is monitored by a transient model tracer, released in the Labrador Sea, when the perturbed buoyancy forcing starts.



Model Sea-surface height



Model interfaces along 25°W.

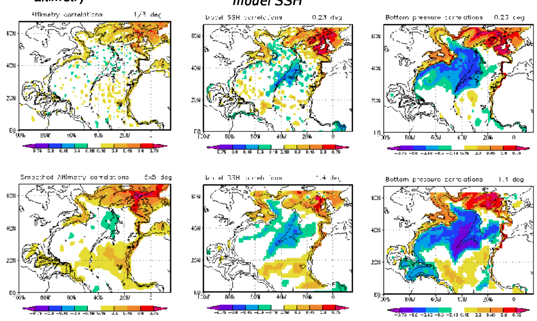


(a) Model kinetic energy: monthly forcing; annual forcing; annual forcing, smooth topography; monthly forcing, coarse resolution

(b) Overturning streamfunction

(c) Upper transport variability

3. SSH and bottom pressure correlations



Correlations of altimetry | *Correlations of model SSH* | *Bottom pressure*

High resolution model — *1980 – 2000*

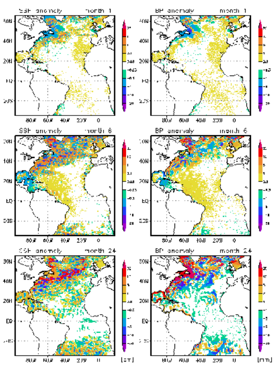
Low resolution model

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

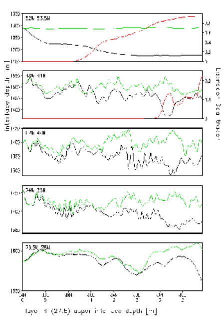
- coherent, highly correlated signals along the coast
- negative correlations in the centre of subtropical gyre
- positive correlations around 20°N – Rossby waves generated at the eastern boundary
- higher correlations in case of coarse resolution and smoothed altimetry

4. Propagation of wave signals in the model

SSH anomalies | *Bottom pressure*

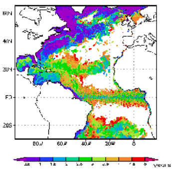


Propagation of signals along the western boundary

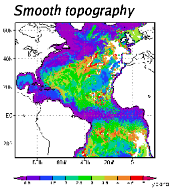


--- default; --- perturbed run; --- tracer signal

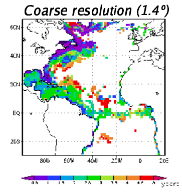
Time of BP anomaly propagation 0.23° model



Smooth topography



Coarse resolution (1.4°)

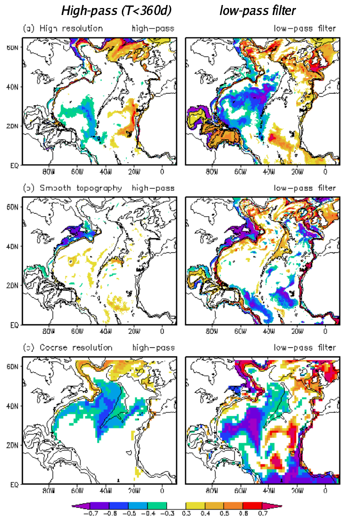


- boundary wave propagation on time scale of months to years
- connected to interior via equatorial Kelvin waves and basin-wide Rossby waves
- similar structures of SSH and bottom pressure anomalies, but highest anomalies of BP along western boundary

5. Overturning and bottom pressure variability

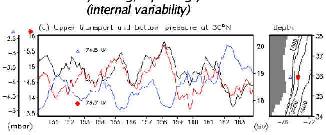
Bottom pressure correlations with upper transport (35° N – 65° N)

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

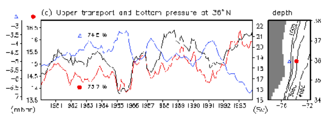


Timeseries of upper transport and bottom pressure

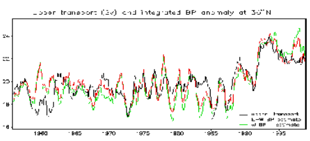
Monthly forcing, repeating year (internal variability)



Interannual monthly forcing 1980 – 2000 (externally forced variability)



Upper model transport and BP derived estimates



model transport; WB BP estimate; (E – W) BP estimate

- highly correlated overturning and western boundary bottom pressure variations
- different response over the shelf (negative correlations) and along the continental slope (positive correlations)
- externally forced variability dominates longer term transport variations
- close agreement of the model transport variations and BP derived estimates on longer timescale
- changes in overturning can be efficiently inferred from the western boundary BP variations

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
- Changes in overturning can be efficiently inferred from the western boundary BP variations

Reference: Roussenov, V., R.G. Williams, C.W. Hughes and R.J. Bingham, 2008. Boundary wave communication of bottom pressure and overturning changes for the North Atlantic. Journal of Geophysical Research, in press.