Oceanic control of multidecadal variability in the North Atlantic

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Abstract

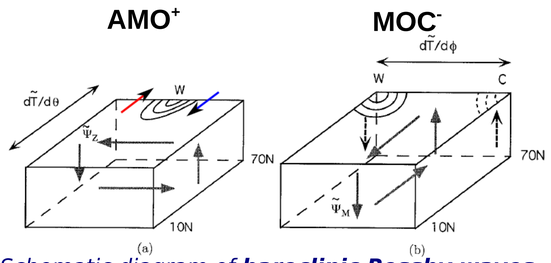
The origin of multidecadal variability in the North Atlantic (AMO/AMV) has not yet been settled, and a wide range of hypothesis have been proposed in various coupled model simulations but none allow a straightforward comparison or validation with (maybe too short) observations.
On the other hand, multidecadal variability appears spontaneously in idealized ocean simulations forced by prescribed surface buoyancy flux, through baroclinically-unstable Rossby waves. Such mechanism was also found in more realistic North Atlantic configurations (OPA ORCA2°), with and without eddies, with and without atmospheric coupling. The signature of this mode in the more realistic simulations is compa rable to the signature of the AMO in the observations, as far as it can be identified and distinguished from global warming. We review several results from the most idealized studies to the more realistic in ocean and coupled GCMs to support the relevance of such a mechanism for the Atlantic Multidecadal Oscillation.

The prototype: flat bottom ocean basin under constant heat/buoyancy flux at low resolution

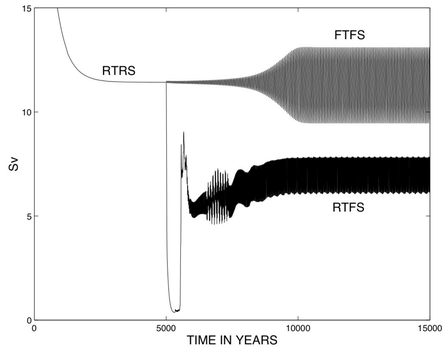
►critical influence of surface forcing for oceanic decadal variability: constant heat/buoyancy flux vs surface restoring

►driving mechanism identified as large-scale baroclinic instability (possibly due to displacement of maximum growth rate by eddy diffusivity/viscosity) [Colin de Verdière&Huck 1999]

►weak growth rate O(yr^{-1}) makes large-scale instability very sensitive to surface boundary condition



*Schematic diagram of **baroclinic Rossby waves** mechanism [teRaa&Djkstra 2002, Sévellec&Huck 2015]*



Influence of surface forcing on idealized ocean model decadal variability: RT=SST restoring, FT=constant heat flux, RS=SSS restoring, FS=constant freshwater flux [Arzel&al.2006]

Multidecadal variability of the overturning circulation in presence of eddy turbulence - flat bottom ocean basin

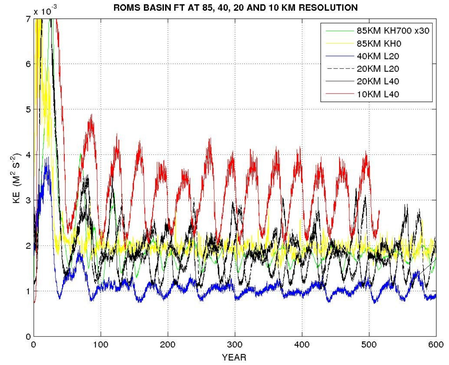
sensitivity of previous oscillations to sub-grid-scale processes parameterization is a troublesome issue => a series of numerical simulations with resolution increasing from 160km to 10km, several centuries long, initialized from previous resolution final state, performed with ROMS

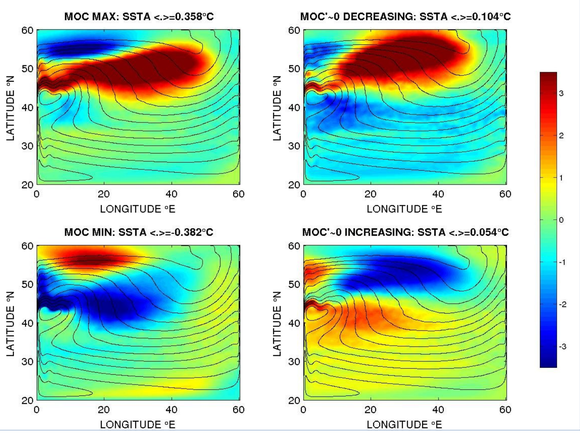
►multidecadal variability is a generic ubiquitous feature

►mean circulation and spatial structure of the variability are largely modified, but there is no clear influence of the resolution on the main oscillation period

►interdecadal variability appears even more robust to low vertical diffusivity and overturning when mesoscale eddies are resolved

►mechanism previously proposed for these oscillations, involving westward-propagating baroclinically unstable Rossby waves in the subpolar region and its feedback on the mean circulation, appears unaffected by mesoscale turbulence and is simply displaced following the polar front

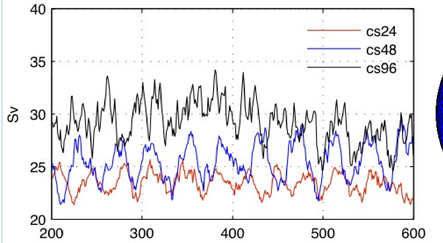


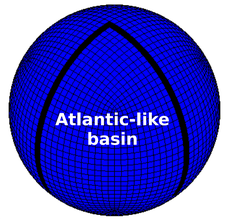


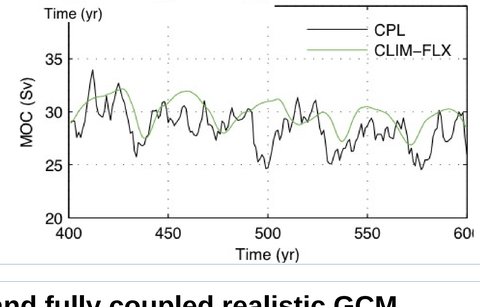
SSTA (upper 100m) associated with 4 consecutive phases of the 30-yr period oscillations for the 10-km experiment with Kv=3 10^{-5} m^2/s: (top left) when MOC is maximum, (top right) when MOC anomaly is small and decreasing, (bottom left) when MOC is minimum, and (bottom right) when MOC anomaly is small and increasing. Background mean SST appears as black contours and gives some insight on upper circulation[Huck et al. 2015 JPO]

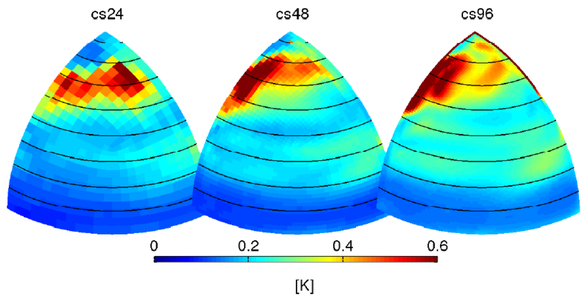
Oceanic control of multidecadal variability in an idealized coupled GCM

MIT coupled ocean-atmosphere-ice GCM in the Double-Drake configuration: flat-bottom aquaplanet geometry with 2 Pacific- and Atlantic-like basins, run at 4° (Buckley et al. 2012), 2° and 1°
►spontaneous multidecadal AMOC variability on 30-40 yr time scale in all simulations
►disruptive effect of NAO-like intrinsic atmospheric variability at higher resolution
►ocean-only 1° simulation forced by climatological fluxes show more regular multidecadal oscillations



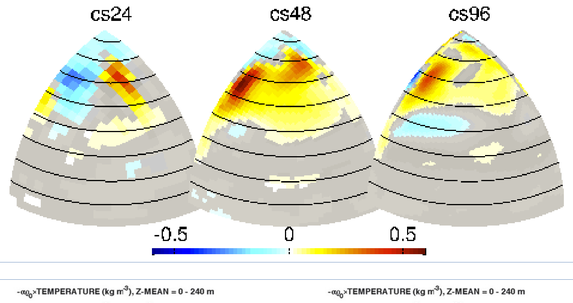






↑Standard deviation of annual-mean SST for the 4° (cs24), 2° (cs48) and 1° (cs96) resolutions [Jamet et al. 2015]

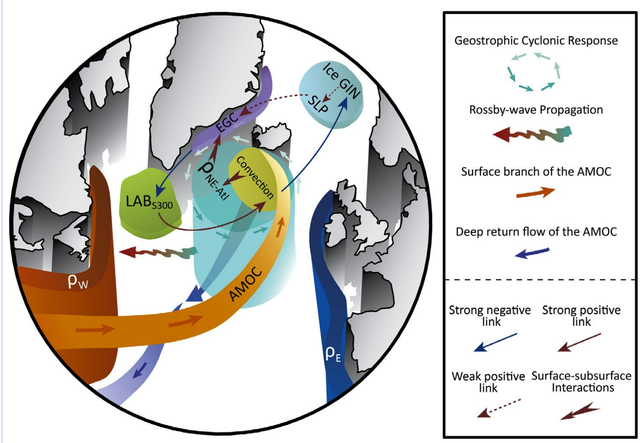
Yearly SSTA (K) associated with one standard deviation of the yearly MOC index at lag 0 (grey-shading when not statistically significant at 5%)↓



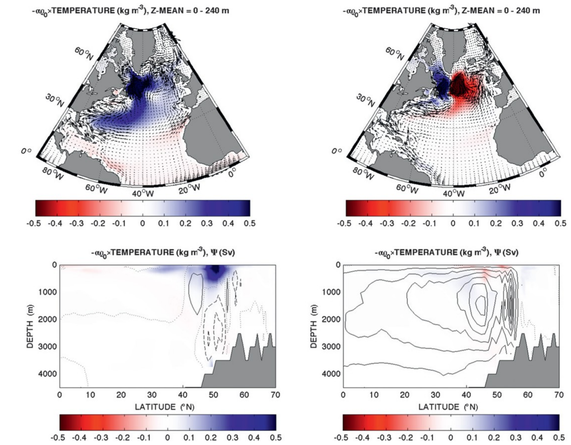
OGCM and fully coupled realistic GCM

►leading interdecadal eigenmode of the Atlantic meridional overturning circulation in global ORCA2° OGCM (NEMO) has 24-yr period and show westward propagating SSTA similar to idealized models oscillations [Sévellec & Huck 2015]

►this ocean mode is involved in IPSL fully coupled model decadal variability



Schematic of variables and interactions involved in North Atlantic 20-year cycle in IPSL-CM5A [Ortega et al. 2015]



Spatial structure of least-damped eigenmode of tangent linear model with 24-yr period, 2 phases 6-yr apart : (top) upper 240m temperature and surface currents, (bottom) zonally-averaged temperature and meridional streamfunction [Sévellec&Fedorov 2013]

More generally

►large scale baroclinic instability of the mean oceanic circulation may be a source of interannual variability [Hochet et al. 2015]

►ocean modes may be the only source of decadal predictability

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