North Atlantic variability from ocean simulations with and without in situ/satellite data assimilation

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Recent climate variability studies require the combined investigation of disparate ocean in-situ/satellite data, and numerical experiments. Ocean reanalyses, where large amounts of observations are assimilated into numerical models, provide syntheses based on both types of information.

The present study is a contribution of the DRAKKAR program to OST/ST objectives. We aim at describing, comparing and assessing over 1993-2001 the variability of large-scale circulation indexes (Meridional Overturning Circulation, Meridional Heat Transport, at basin scale and along the 24°N and 48°N repeated sections) obtained from height recent model integrations. These are four 50-year global ocean/sea-ice hindcasts from the DRAKKAR hierarchy of model configurations at 2°, 1°, 1/2° and 1/4° resolution, two global ocean reanalyses performed at ESSC with the 1° and 1/4° resolution configurations, the 10-year MERA11 North Atlantic 1/3° ocean reanalysis performed by Mercator-Océan as well as its unconstrained counterpart.

Model intercomparisons are presented. Differences reveal the impact of model resolution (among the DRAKKAR hierarchy of models) and of sequential data assimilation (among the various reanalyses) on the means and variabilities of these indexes, as well as on their continuity over time and space in the case of assimilation. Complementarily, common features among this hindcast ensemble exhibits robust features of the actual ocean variability, as well as their forced character. This work should thus help assess the robustness of observation-based studies of the basin's variability.

DATASETS

MERA	1/3°	Atl. 20°S-70°N	1992-2001	Free	Mercator
MERA	1/3°	Atl. 20°S-70°N	1992-2001	Assim. - Altimetry and in situ data (T,S,surface obs.)	Mercator
DRAKKAR	2°	Global	1958-2004	Free	Drakkar
DRAKKAR	1°	Global	1958-2004	Free	Drakkar
DRAKKAR	1°	Global	1958-2004	Assim. - Hydrography	Drakkar
DRAKKAR	1/2°	Global	1958-2004	Free	Drakkar
DRAKKAR	1/4°	Global	1958-2004	Free	Drakkar
DRAKKAR	1/4°	Global	1987-2004	Assim. - Hydrography	Drakkar

See Greiner et al (2006), Drakkar Group (2007) and Smith et al (2008)

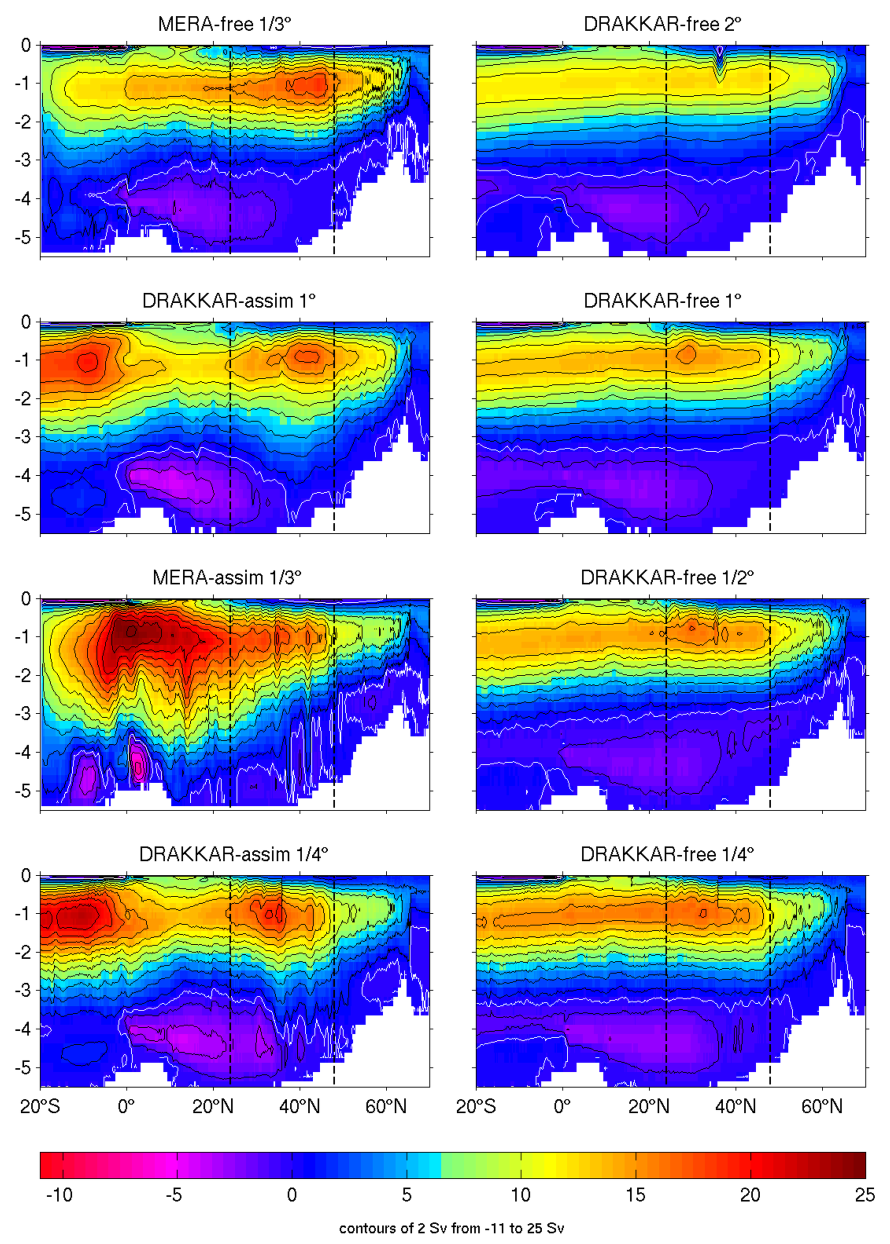
TIME-MEAN STRUCTURE OF AMOC AND MHT

Robust:
- North Atlantic MOC maxima : 900m / 30-40°N.
- Five Sv decrease of AMOC between 48°N and 60°N.
- 40-60°N : *D-free1/4°* ~ *D-assim1/4°* ~ *M-assim1/3°*
- Meridional structure of MHT in *free* runs.
- *MERA-assim* MHT fits best Ganachaud et al (2000) and Talley et al (2003) at 24°N.

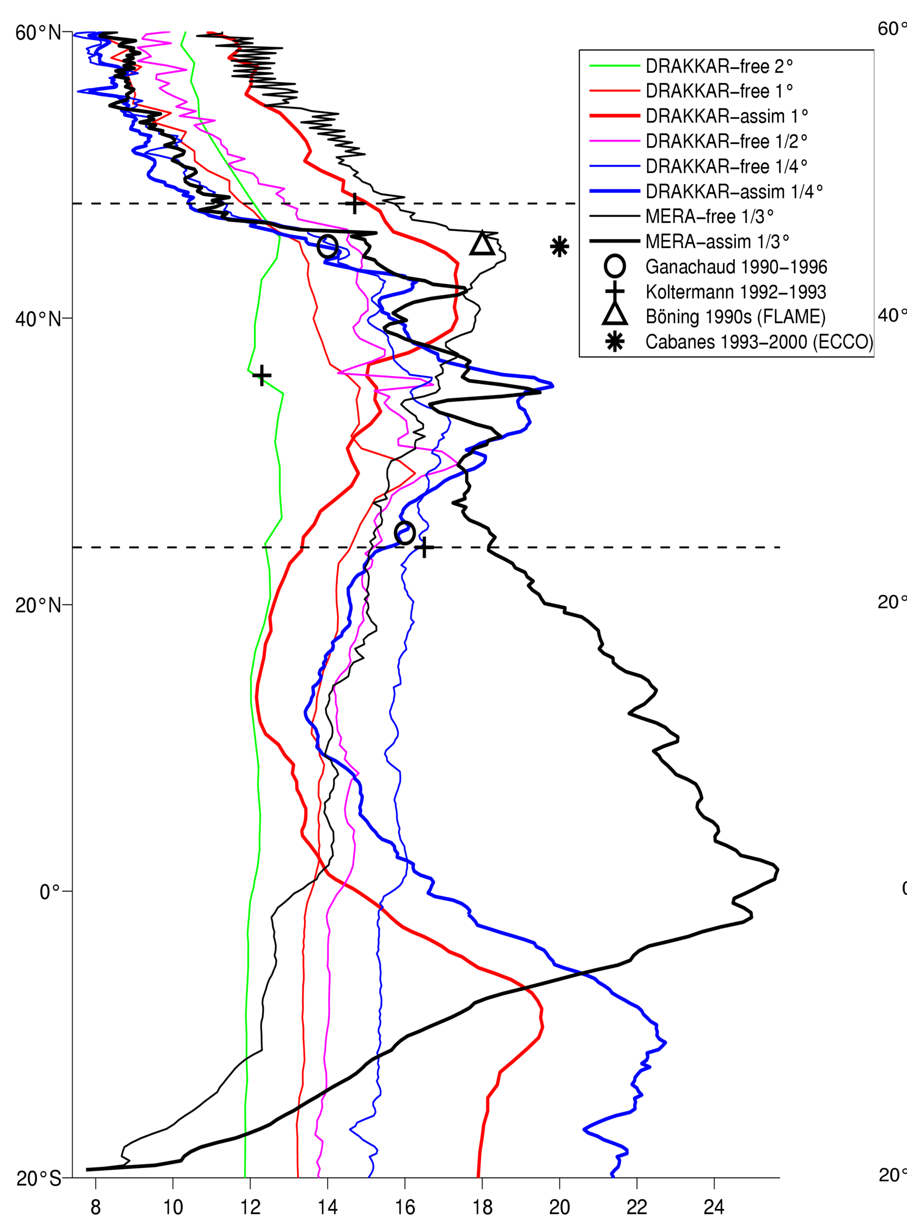
Resolution:
- Enhances mean AMOC from 12Sv (*DRAKKAR-free 2°*) to 18Sv (*DRAKKAR-free 1/4°*, as Talley et al 2003).
- Enhances MHT.
- Better fit between *free* and *assim*.
- Local MHT minima in GS/NAC at low resolution disappears with increasing resolution (more realistic NW corner).

Assimilation:
- Suspicious AMOC/MHT maxima in 20°S-5°S (*DRAKKAR-assim*) and 10°S-20°N (*MERA-assim*).
- MERA: Overall MHT increase (but same meridional structure).
- *DRAKKAR-assim 1/4°* fits *MERA-assim* north of 35°N.
- MERA-assim fits Ganachaud and Wunsch, Talley.

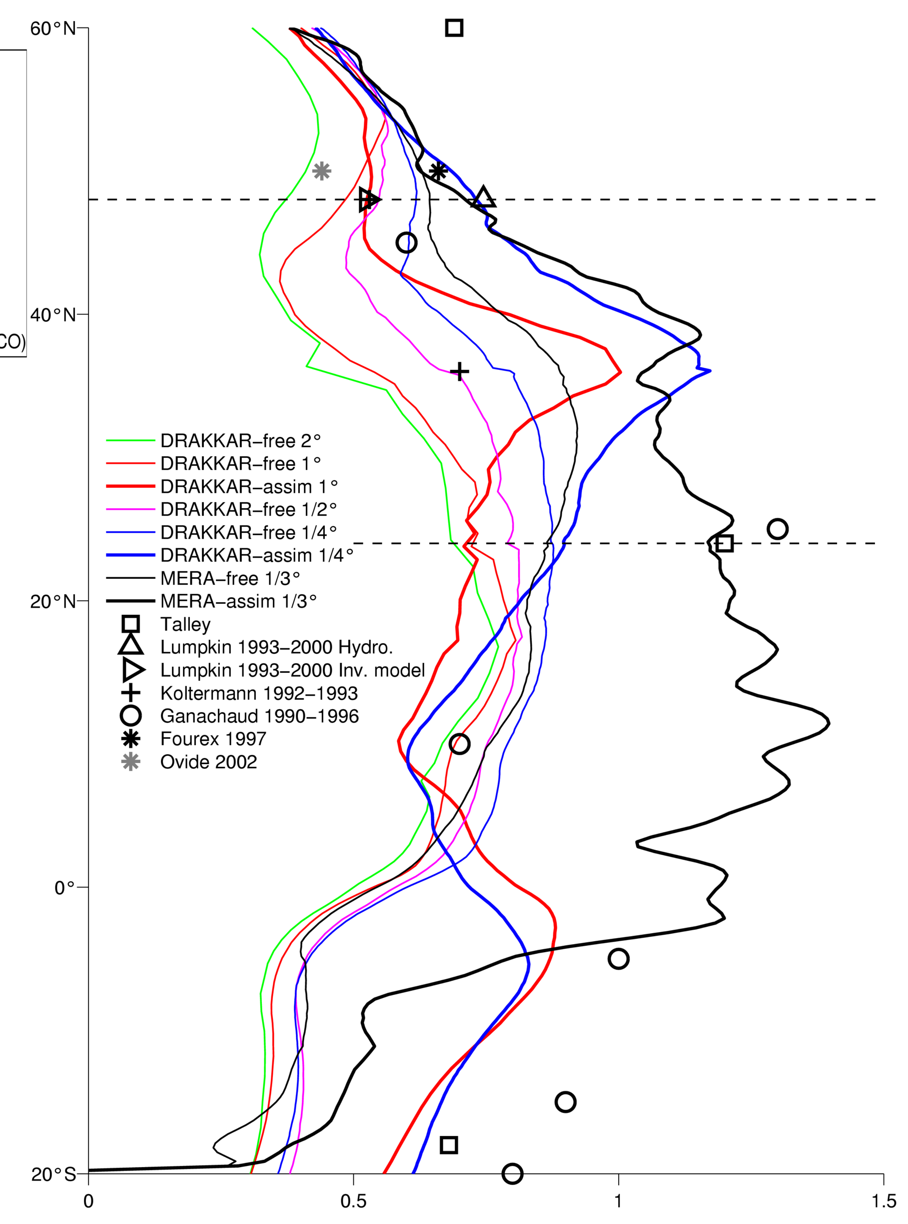
Time-mean (1993-2001) AMOC (Sv)



Time-mean (1993-2001) upper cell AMOC (Sv, 500-2000m)

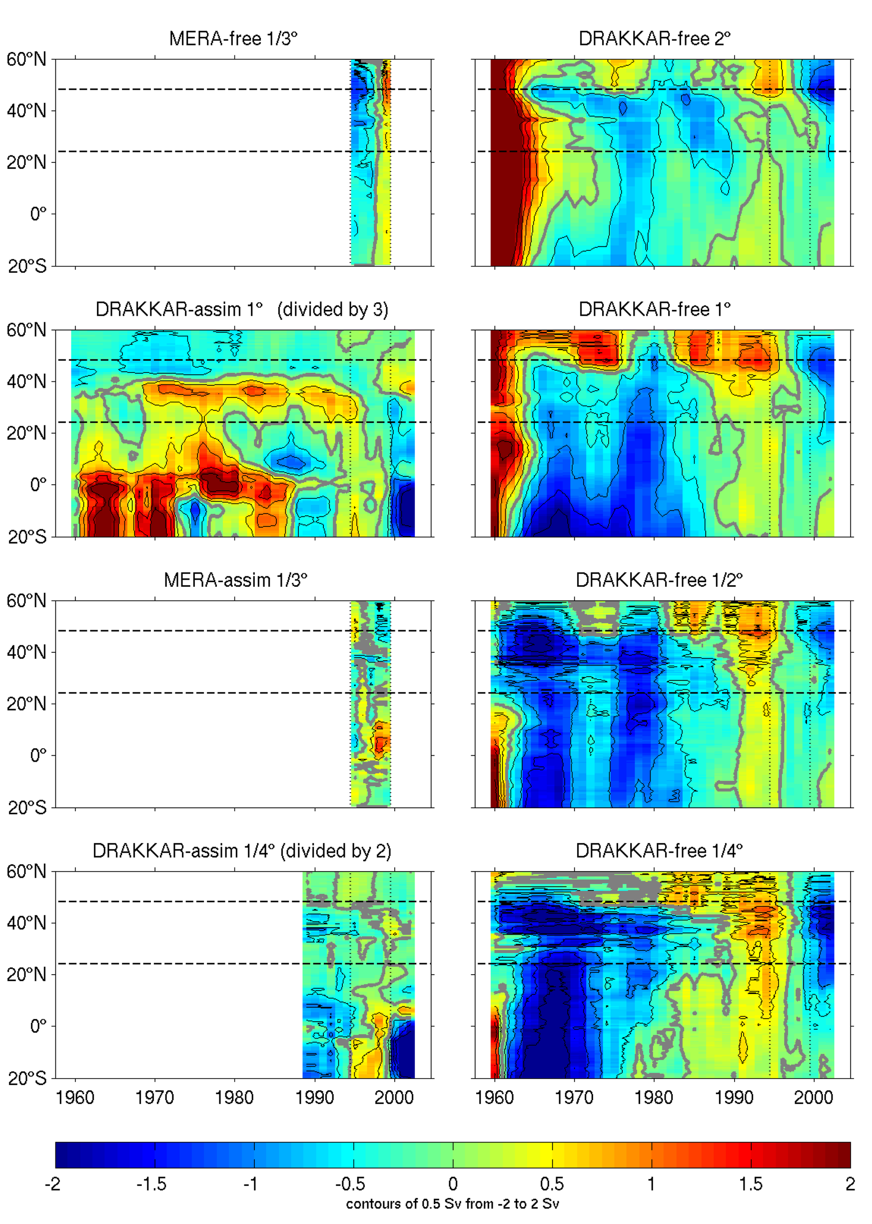


Time-mean (1993-2001) MHT (PW)

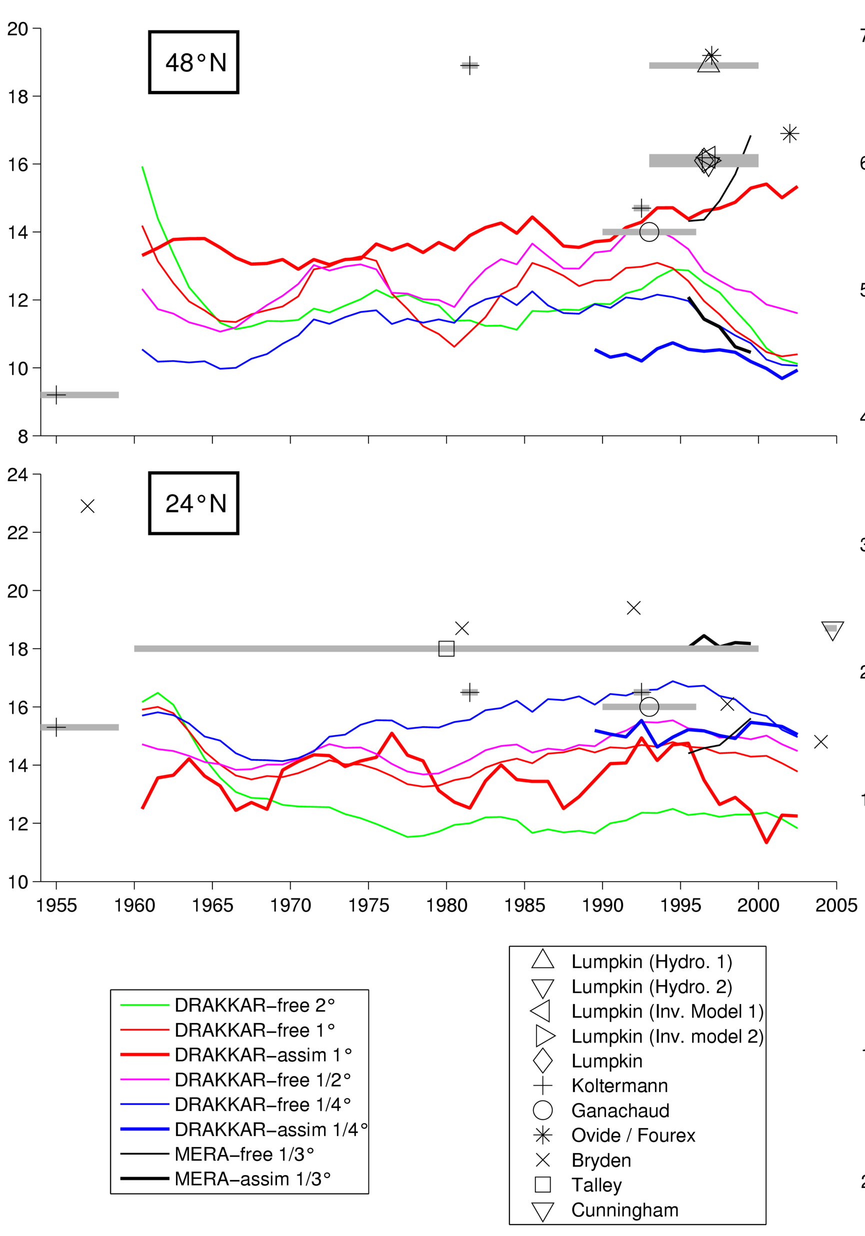


AMOC VARIABILITY

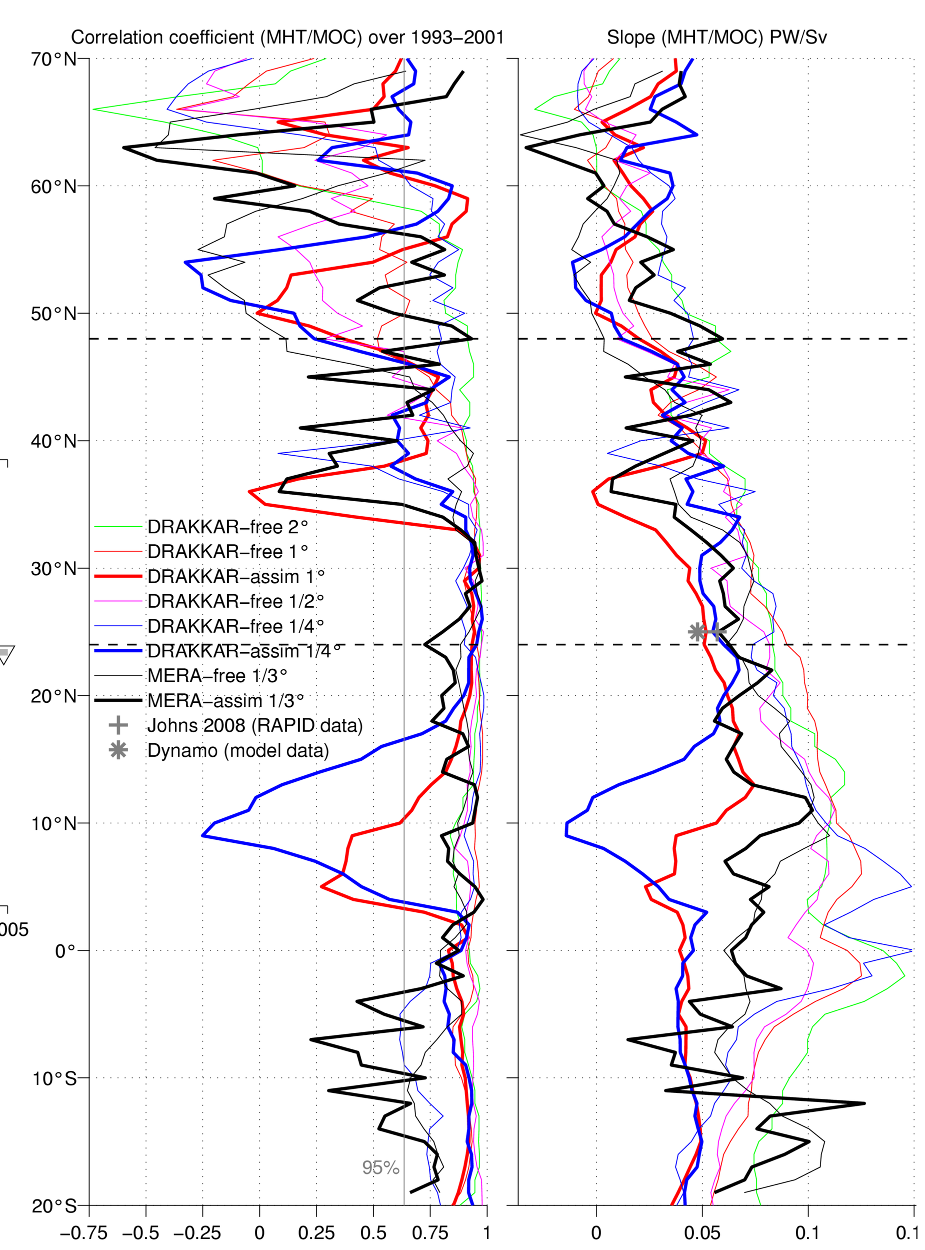
Upper cell AMOC anomaly (Sv) with respect to the common 1993-2001 period, 5-yr boxcar filtered.



Upper cell AMOC intensity (Sv) at 24°N and 48°N. 5-yr boxcar filt.
Marks = obs. estimates (gray lines show the period considered).



Coefficients and slopes of the linear regression between AMOC(t) and MHT(t) at each latitude.



Robust: - AMOC increase until the 1990s, and then decrease.

Resolution:
- Extents 1990 subpolar AMOC anomaly towards the equator.
- Moderates decadal cycle.
- Enhances MOC at 24°N.
- 1981-1992 trend closer to Bryden et al (2005).
- 1998-2004 AMOC and trend similar to Bryden et al (2005).

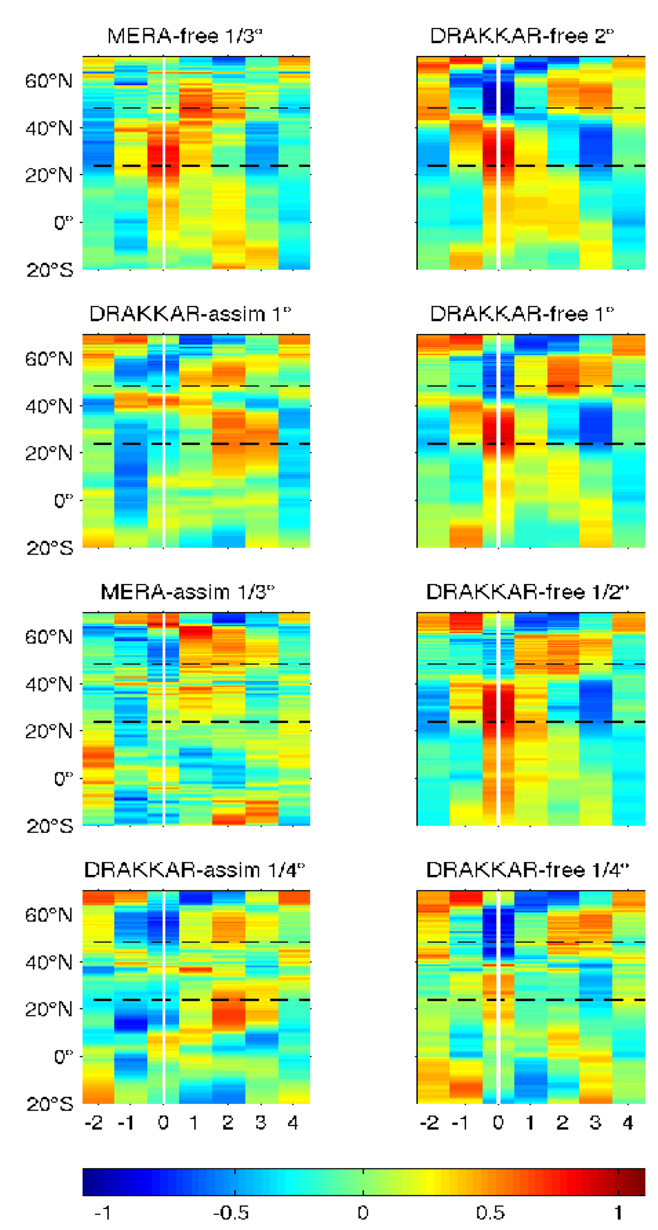
Assimilation:
- Significantly changes AMOC variability patterns.
- *D-assim1°* at 24°N -> *D-free* at 48°N

Robust:
- Strong AMOC/MHT link at 24°N.
- Strong AMOC/MHT link for hindcasts in 0°-30°N (realistic ?).
- Weak AMOC/MHT link for reanalyses in 5°-15°N.
- Northward decrease of the AMOC/MHT link.

Assimilation:
- Weakens the AMOC / MHT link.
- Reanalyses agree with link predicted by RAPID (Johns et al 2008) and simulated by Dynamo models.

LINK WITH NAO

Lagged correlation (colors) between annual NAO(t) and AMOC(t) between 1993 and 2001, computed at each latitude (ordinate). Unfiltered yearly data. Lag in years (abcissa), NAO leads for positive lags.



Robust:
- Subpolar response to NAO+ :
  - AMOC decrease at lag 0.
  - Poleward and equatorward propagation in *DRAKKAR-free/assim*.
  - AMOC increase at lag 2-3.
- Subtropical response to NAO+ :
  - AMOC increase at lag 0.
  - AMOC decrease at lag 2-3 in *FREE* runs.
- wind driven at lag 0 ?
- buoyancy driven at lag 2-3 ?

Assimilation :
- Subtropical response to NAO becomes weak or opposite to *DRAKKAR-free*.

CONCLUSIONS - PERSPECTIVES

Robust:
- Substantial inter model differences.
- Maximum AMOC in early 1990s.

Resolution:
- Increases time-mean AMOC / MHT through entire Atlantic.
- More interannual "noise".

Assimilation: - AMOC variability quite different in reanalyses, depends on assimilation method.

Further investigation is required to understand the impact of assimilation on AMOC / MHT mean structures and variabilities.

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