Atlantic Ocean: issues on model resolution and observations

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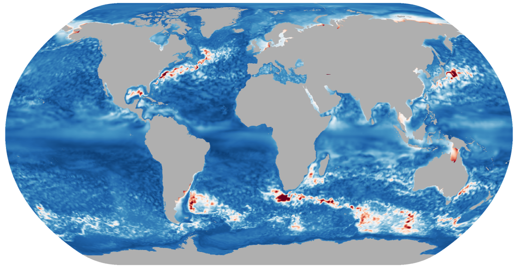
AMOC at 26. 5°N : Objective and tools

- Most numerical models, able to reproduce the mean AMOC and its variability at 26.5°N, generally underestimate the associated meridional heat transport (MHT) compared to observational estimates from the RAPID Climate Change programme

- Investigate the impact of the RAPID-like assumptions in computing transports from model output

- Different methods of calculation of the AMOC and MHT are applied to numerical results from GLOB16 and GLOB4

GLOB16	global eddying configuration: NEMOv3.4 (Madec et al. 2012) coupled to LIM2-EVP **Horizontal resolution of 1/16° (6.9 km) at the equator and 98 vertical levels** Forced by ERA-Interim reanalysis over the period 2003-2013. Initialized from WOA2013
GLOB4	global eddy-permitting configuration: NEMOv3.2 (Madec et al. 2008) coupled to LIM2-EVP **Horizontal resolution of 1/4° (27.5 km) at the equator and 50 vertical levels** Forced by ERA-Interim reanalysis over the period 1979-2012. Initialized from WOA2009
RAPID	Strength and structure of the AMOC at 26°N since April 2004, as sum of three components (McCarthy et al 2015) ○ northward transport through the Florida Straits (FS) ○ Ekman transport (Ek) derived from ERA-Interim wind stress ○ density driven transport throughout the remainder of the Atlantic from geostrophic interior flow (MO between the Bahamas and the African coast) and velocities in the western boundary region (WB from current meters between sea surface and 2000 dbar)



Iovino et al., 2016
(see my poster on Thursday)

Stepanov et al., 2016

Methods of calculation of the Atlantic Meridional Heat and Volume Transports from ocean models at 26.5°N

True method”

1.MOCmod: from simulated velocity fields as

$$\Psi(z) = \int_{x_w}^{x_e} \int_{-H}^{z} v(x,z)\, dz\, dx$$

“Observational methods” consider the interior transport as sum of the WB transport (from model velocity) and mid-ocean geostrophic component calculated as

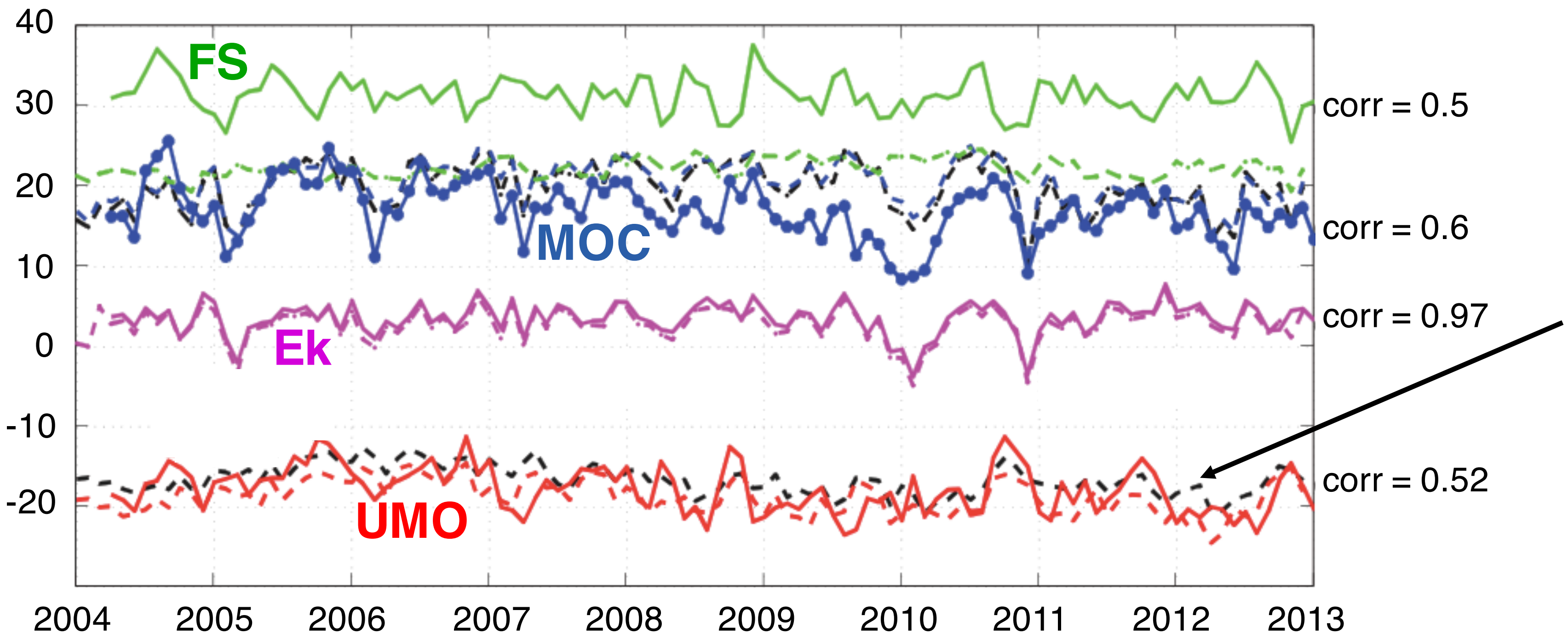
2.MOC_baro: geostrophic transport using all grid points and referenced to barotropic velocity in order to avoid uncertainties in the AMOC deep structure due to the choice of reference depths and end-point calculations.

3.MOC_bottom: geostrophic transport using all grid points and referenced to the bottom in order to evaluate the impact of uncertainties in reference depths (by comparison with #2).

4.MOC_endpoint *(closest to RAPID methodology)*: as #3, but geostrophic transport is computed using end-point geostrophy referenced to Z_0 = 4740 m in order to evaluate the impact of the end-point calculation (by comparison with #3).

Same methods are used to compute the MHT across a trans-basin section

AMOC and its components (in Sv) at 26.5ºN from RAPID array and GLOB16



RAPID: solid

GLOB16:dashed

GLOB16 with MOC_baro: black line

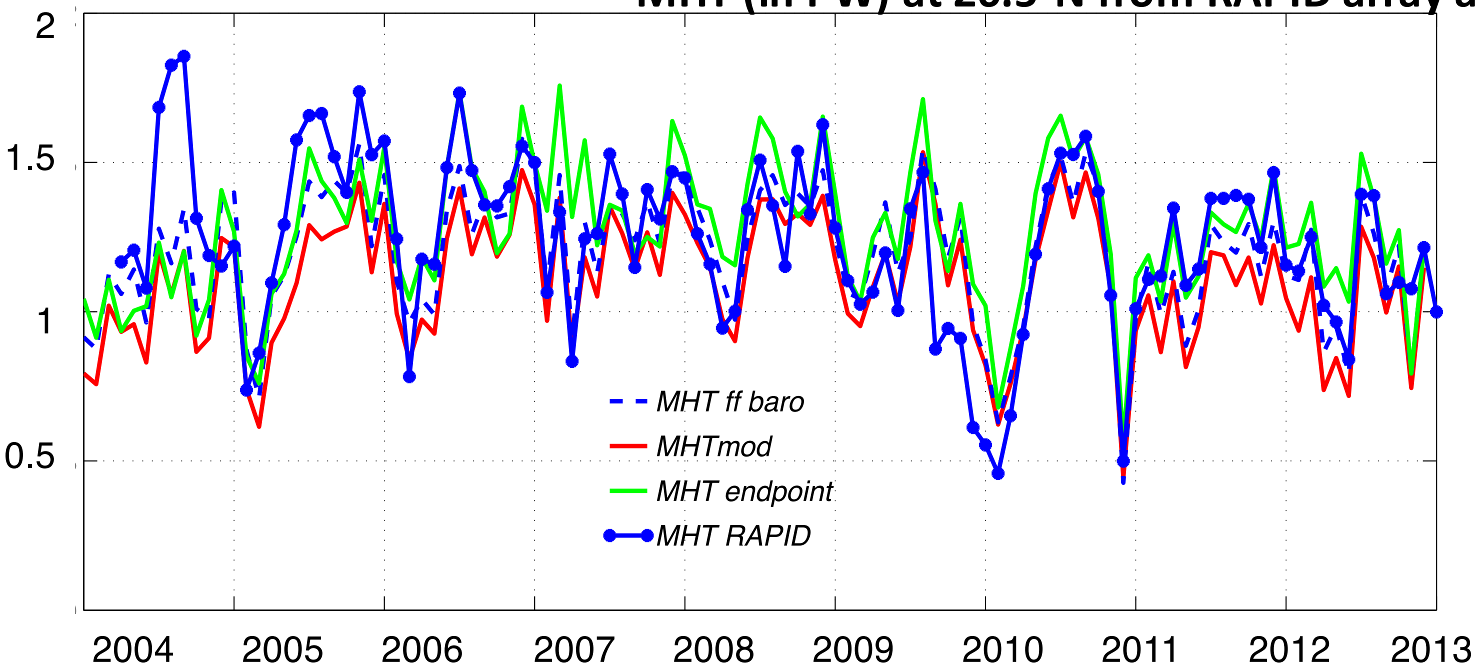
	RAPID	GLOB16	GLOB4
AMOC	15.6 ± 3.2	19.3 ± 3.1	14.3 ± 2.7
Ekman	3.3 ± 2.3	2.7 ± 2.4	2.7 ± 2.3
Gulf stream	31.2 ± 2.3	34.9 ± 2.7	32.2 ± 2.1
Upper Mid-Ocean	-18.9 ± 2.8	-19.8 ± 2.0	-21.3 ± 1.6
Throughflow	0	-1.6 ± 0.5	-0.8 ± 0.5

UMO transports (defined as the maximal southward geostrophic transport in the top ~1000m) is ~1 Sv stronger than RAPID and ~2 (3) Sv larger than the *observational* methods MOC_baro (MOC_endpoint)

2009-2013 average

Iovino et al, 2016

MHT (in PW) at 26.5ºN from RAPID array and GLOB16

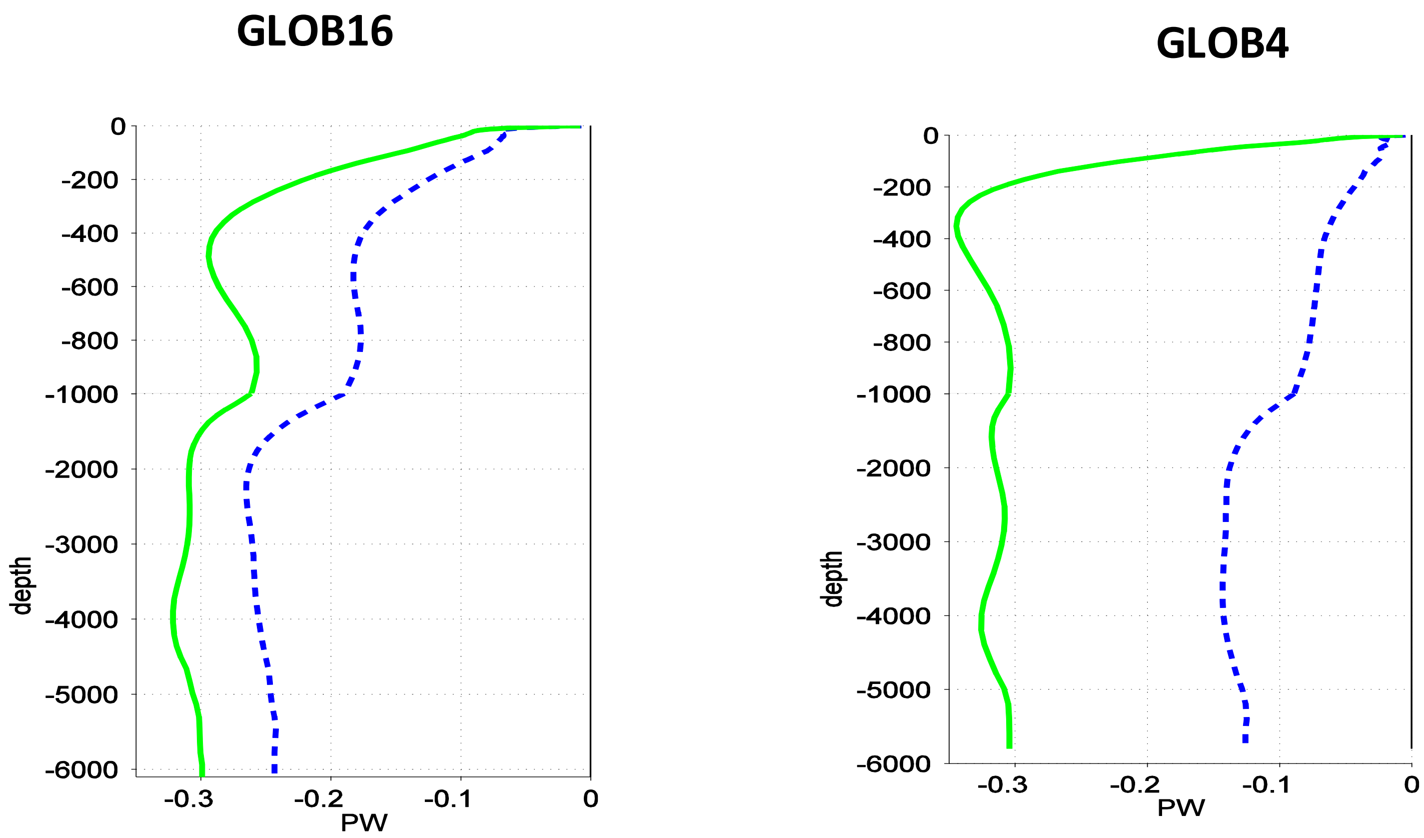


Differences come from a stronger southward heat transports in both the GLOB16 and GLOB4 MO flow

The MHT calculated with the MOC_endpoint is higher and closer to RAPID because its southward MO transport is weaker (all the other components are the same)

		2004 - 2012	
		Mean	Err (%)
GLOB16	**MOCmod**	1.10 (0.97)	
	MOC_baro	1.21	10.0 (24.7)
	MOC_bottom	1.21	10.0 (24.7)
	MOC_endpoint	1.27	15.5 (30.9)
GLOB4	**MOCmod**	0.65 (0.58)	
	MOC_baro	0.71	9.2 (22.4)
	MOC_endpoint	0.88	39.7 (43.1)
RAPID (from April 2004)		1.25	

In () MHT calculated after subtraction of gyre/eddy contributions with corresp. errors



The largest contribution to the southward MO heat transport discrepancy between MOD and OBS methods is in the first 500m

Mid-ocean heat transport differences (in PW) between *true* MOCmod (excluding eddy/gyre contribution) and *observational* methods MOC_endpoint (green line) and MOC_baro (dashed blue), averaged over the entire RAPID period and integrated downwards from the surface

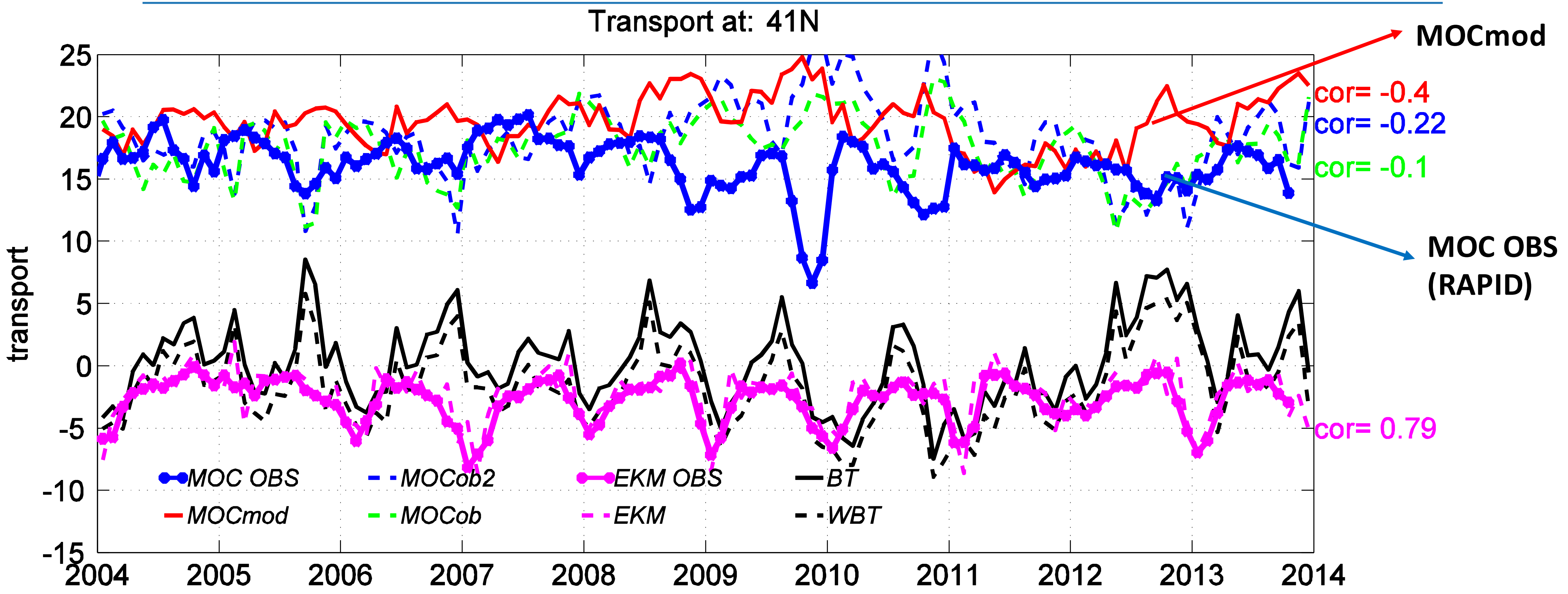
AMOC at 41°N : Objectives and methods

- ❑The Atlantic Meridional Overturning Circulation (AMOC) at 41°N from global 1/16° and 1/4° simulations compared with ARGO-based transport estimates over the 2004-2013 period (Willis,2010)

- ❑Investigate the discrepancy between the modelled and the observed AMOC seasonality at 41°N and suggest an explanation of the inverse phasing

- ❑The same different methods for calculating the transports as before

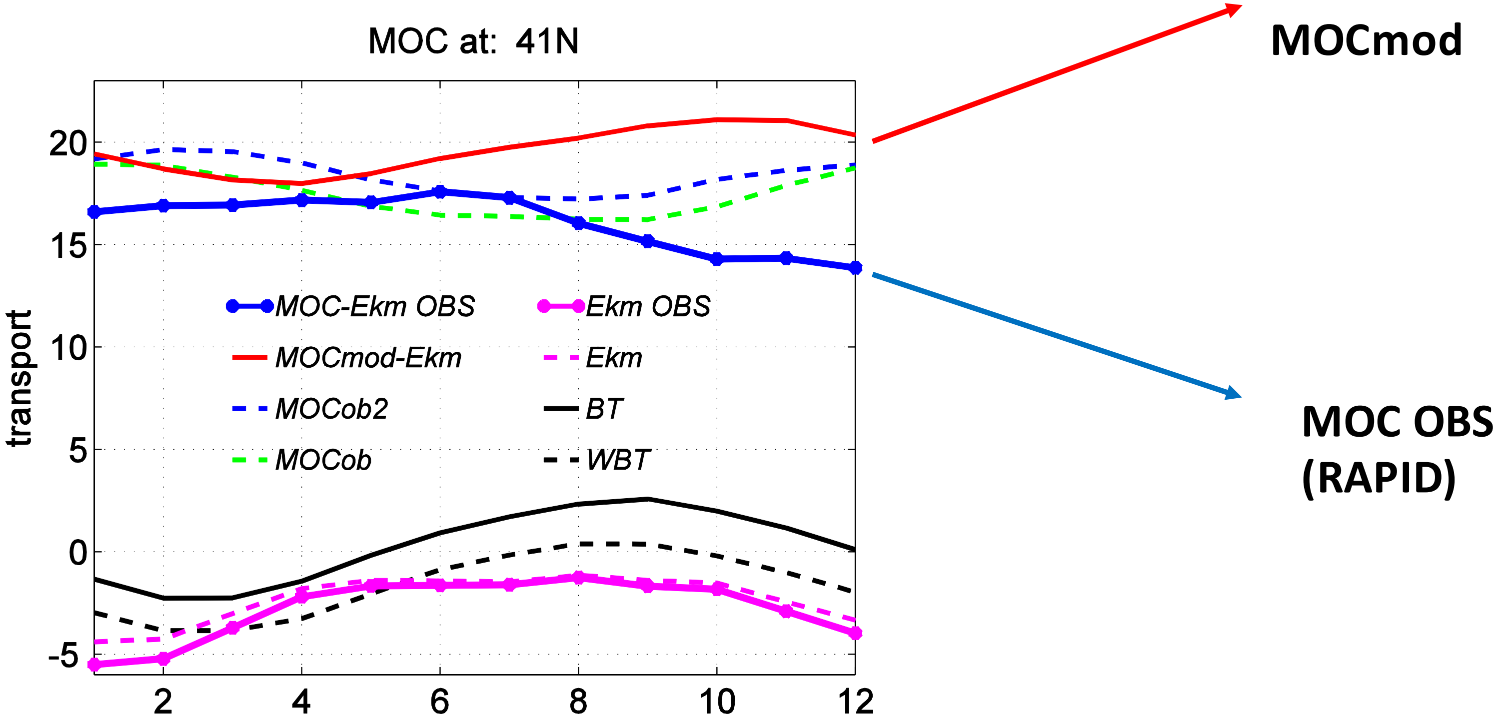
Stepanov et al., 2016



- **MOCmod is significantly anticorrelated with observations (-0.4).**
- **While the GLOB16 AMOC seasonal cycles agree with the observations at 26.5°N, we found an inverse phasing at 41°N.**

Stepanov et al., 2016

Seasonal cycle at 41°N (2004-2013)



MOCmod

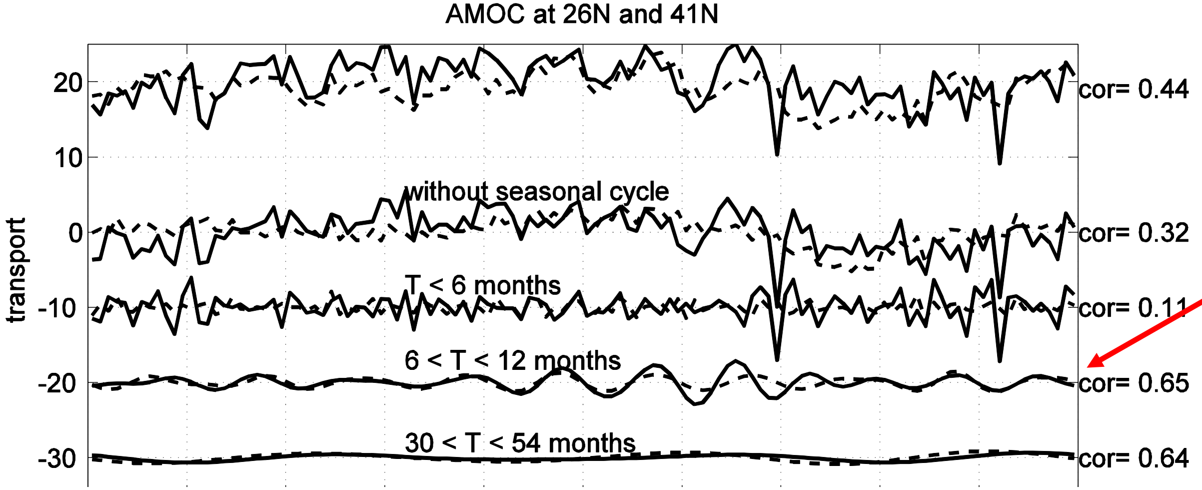
MOC OBS (RAPID)

- **Both the observed and modelled transports have well defined seasonal cycle but opposite.**
- **In GLOB16 the MOC seasonal cycle has a max in autumn and a min in spring**
- **The seasonal cycle of MOCmod is out of phase compared with the other methods (geostrophy based) but in agreement with the WBT seasonal cycle**
- **Neglecting the transport variability near the western boundary leads to a wrong representation of the seasonal cycle**

Covariability of the AMOC at 26.5°N and 41°N

GLOB16

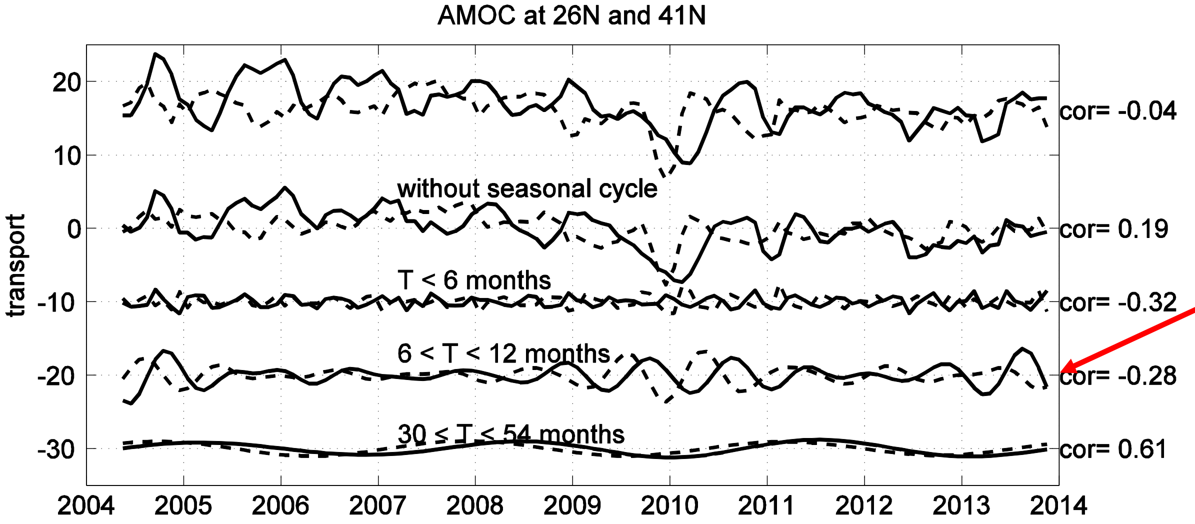
26°N (solid)
41°N (dashed)



Model AMOC at 26.5°N and 41°N is meridionally covariable at seasonal timescales, with a maximum in autumn and a minimum in spring.

Observations (RAPID/ARGO)

26°N (solid)
41°N (dashed)



RAPID (ARGO-based) transport at 26.5°N and 41°N are out of phase

Conclusions

- Similar to other model results, the modelled MHT at 26.5°N is significantly lower than the RAPID estimates, despite the higher AMOC.

- Differences in the set of MHT computations are likely linked to the poor representation of model currents near the western boundary by geostrophy. This inadequate representation of currents leads to underestimate the southward circulation in the upper mid-ocean and impacts the heat transport calculations.

- Ignoring transports near the western boundary (ARGO floats are restricted to ocean regions deeper than 2000 m) leads to the seasonal cycles of the non-Ekman component of the AMOC from the model and observations to be out of phase at 41°N.

- Similar to other model comparisons, the model output shows covariability of the AMOC between 26.5°N and 41°N at some frequency bands, while the phasing differs for the observed data.