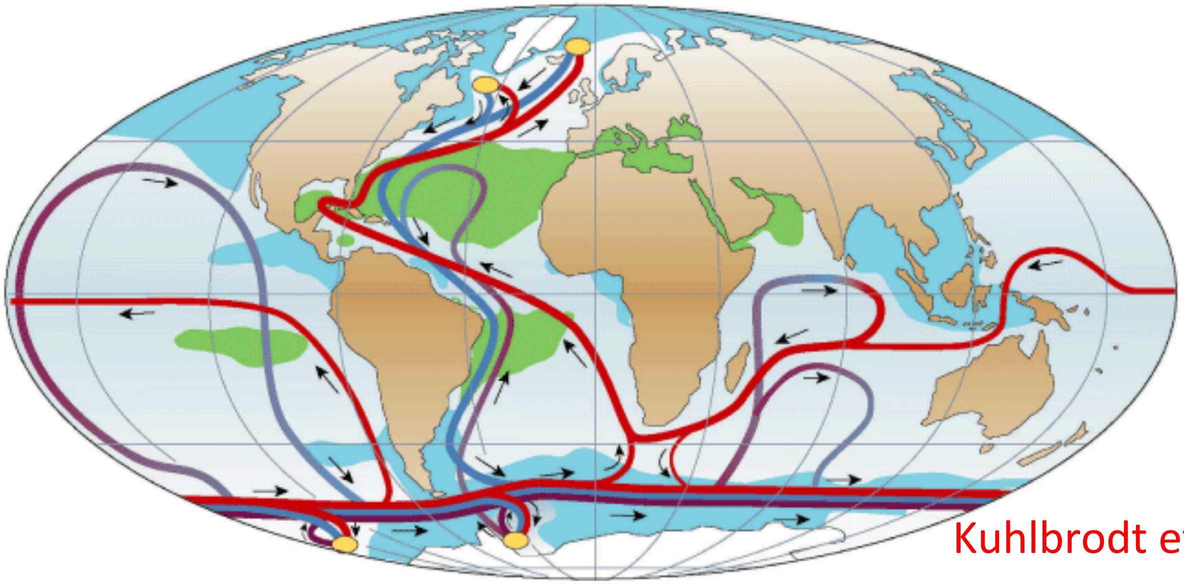
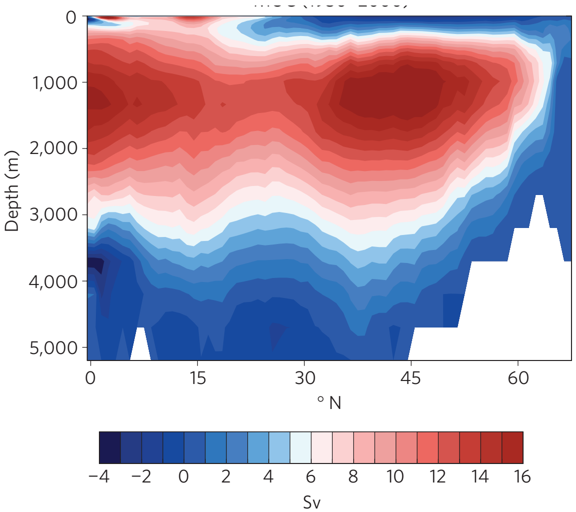
Meridional coherence and divergence of the Atlantic Meridional Overturning Circulation


Kuhlbrodt et al. (2007)

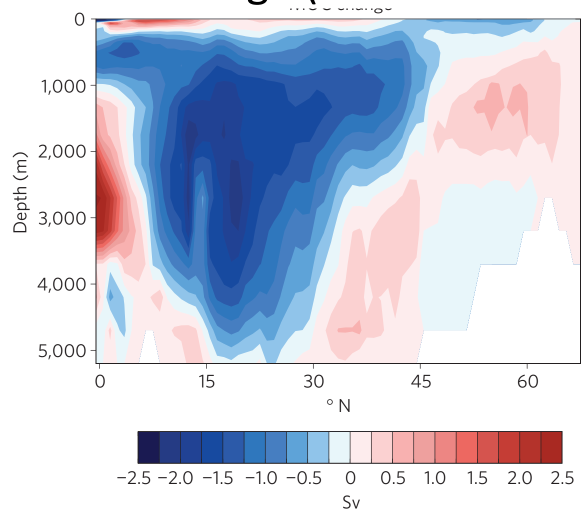
Torsten Kanzow & Johannes Karstensen (GEOMAR, Kiel, Germany)
Matthias Lankhorst & Uwe Send (SIO, La Jolla, CA, USA)
Eleanor Frajka-Williams & Stuart A. Cunningham (NOC, Southampton, UK),
Rory Bingham (Newcastle University, UK),
Chris W. Hughes (NOC, Liverpool, UK)

Coherence and divergence of MOC Changes

MOC (1950 – 2000)



MOC Change (1980-2000 minus 1950-1970)

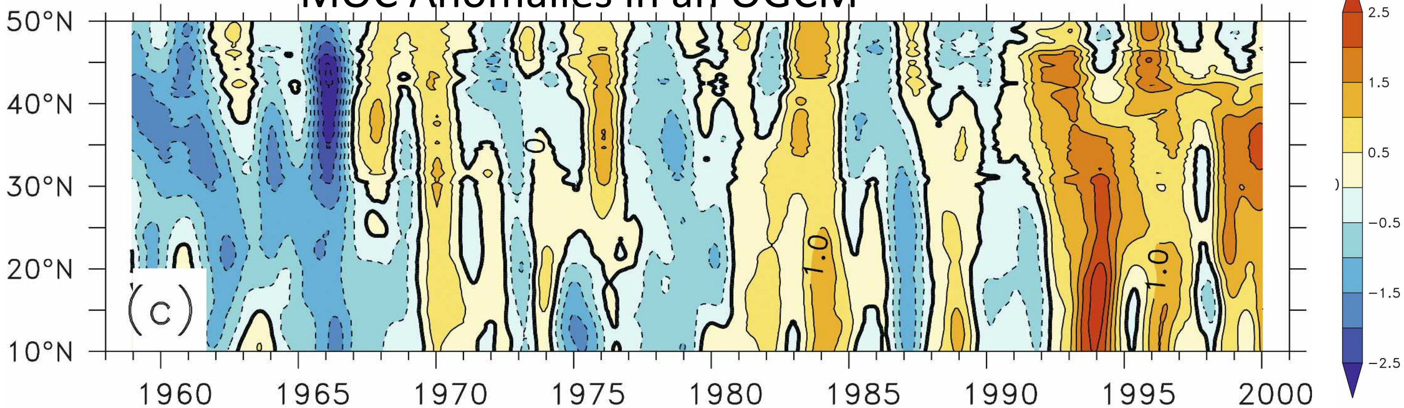


Lozier et al. (2010): Opposing decadal changes of the subtropical and subpolar MOC

➔ OGCM initialized with historical hydrographic data

➔ weakening of subtropical MOC and strengthening of subpolar MOC

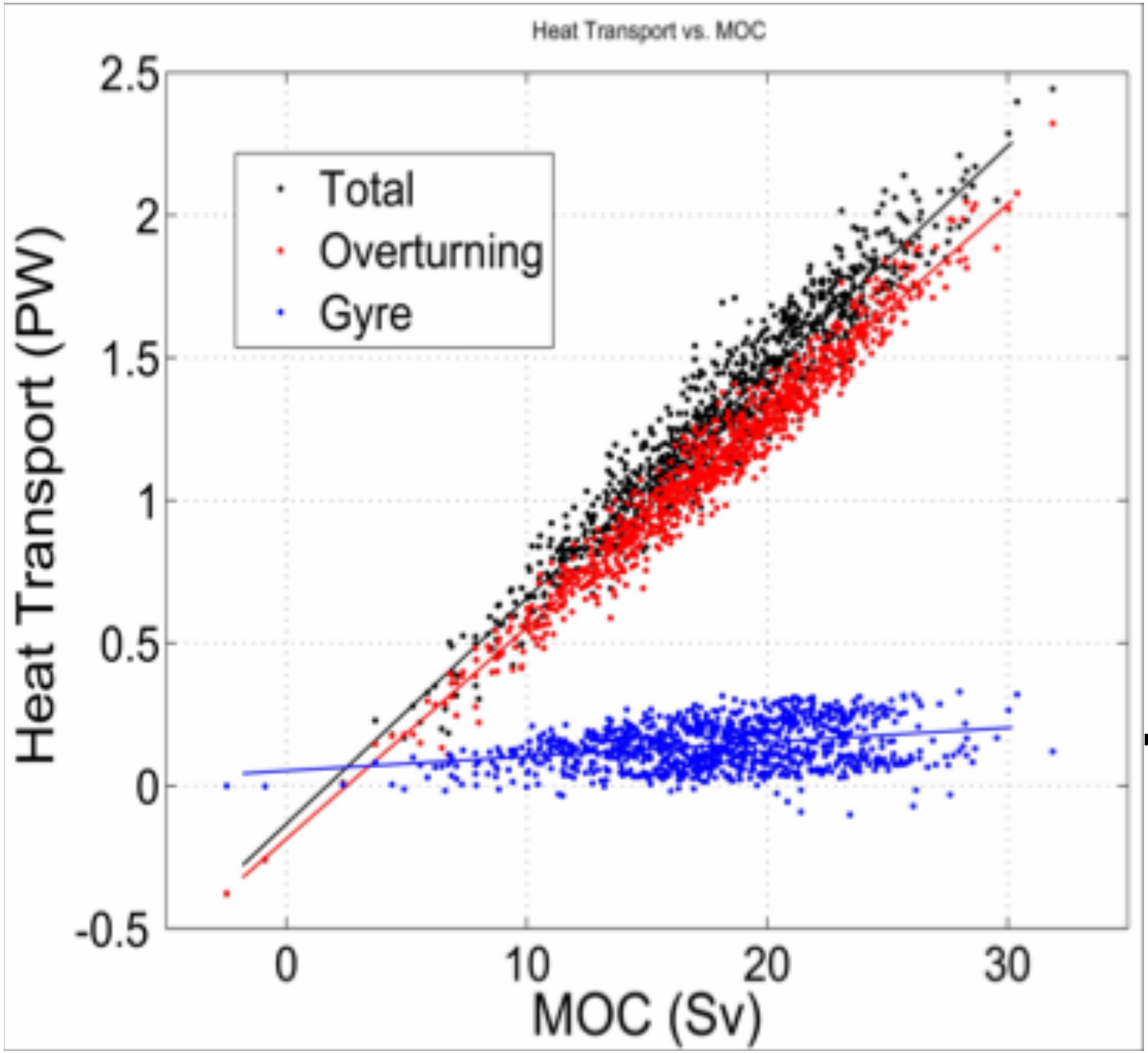
MOC Anomalies in an OGCM



Biastoch et al. (2008)

Heat Transport and MOC Variability

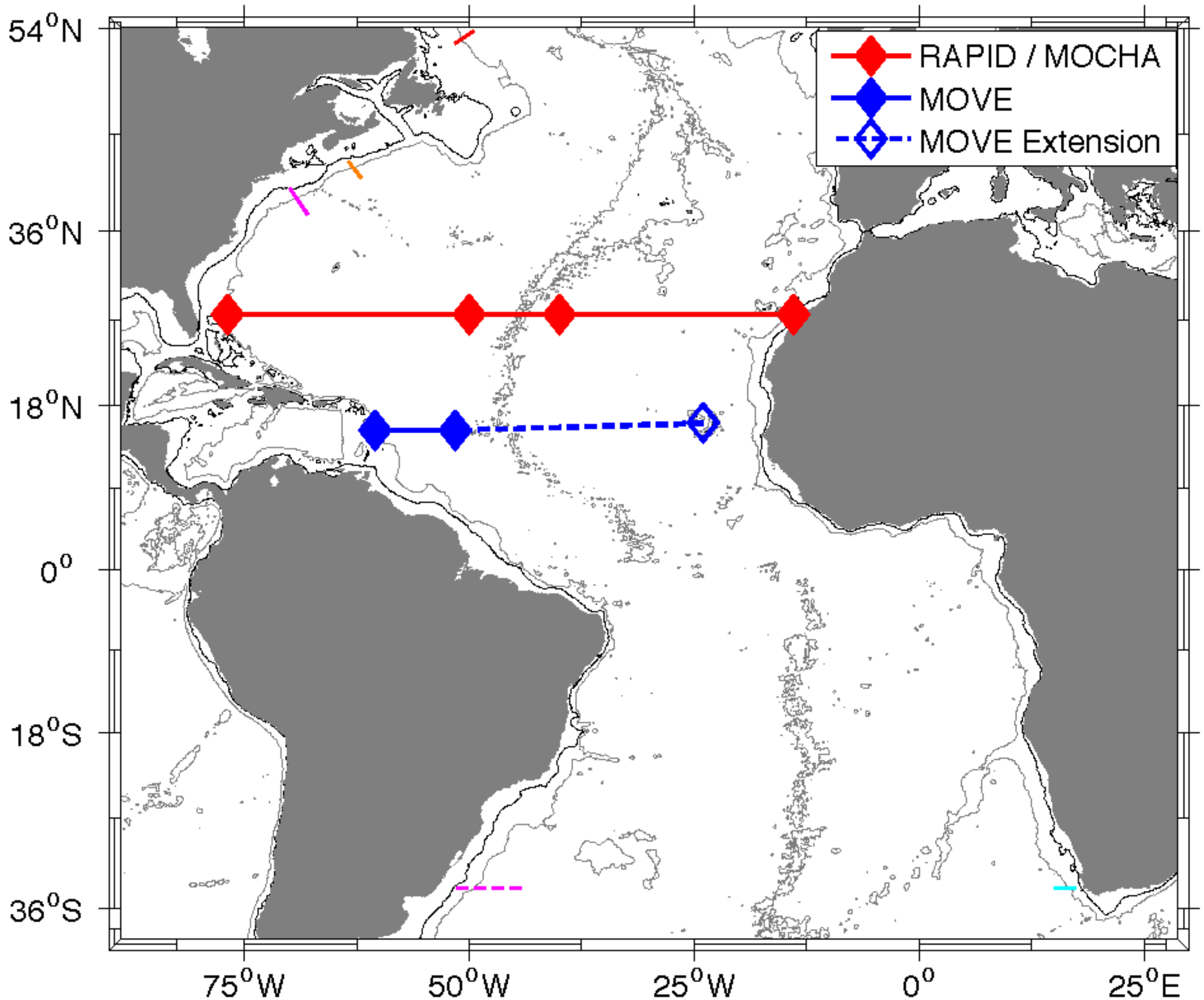
Heat transport vs. MOC and vs. horizontal gyre from RAPID (26°N)



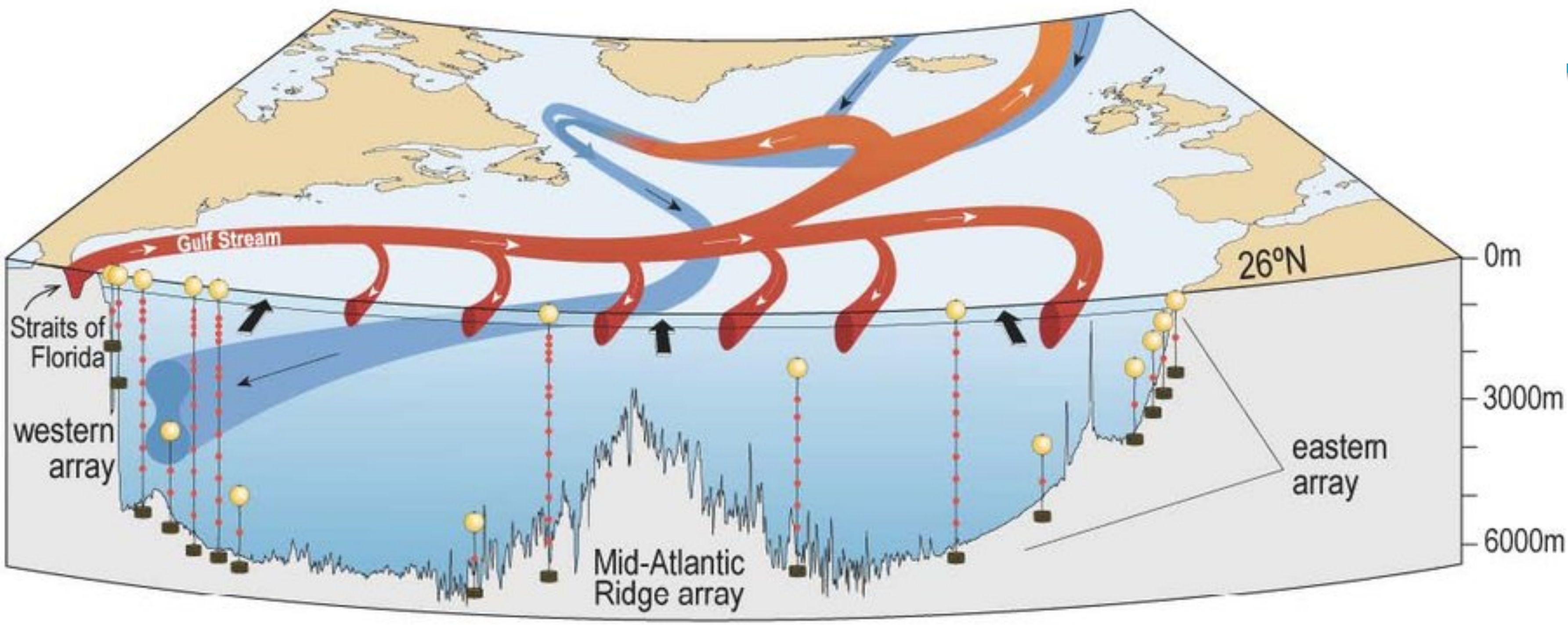
➔ MOC is main Driver of heat transport variability (Johns et al. 2011)

➔ Meridional differences in the MOC might lead to converge /divergence of heat transports.

Aim: Comparison of RAPID & MOVE NADW Transports



RAPID / MOCHA*



How?
- Gulf Stream: telephone cable (AOML, Miami)
- Ekman : scatterometer
- mid-ocean: density, current meters

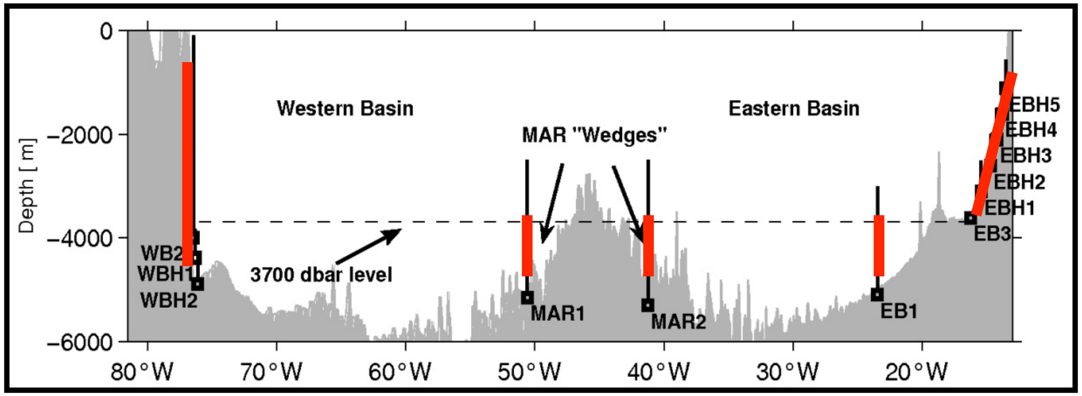
Why 26.5°N?

- Maximum heat transport
- History of measurements

* NERC / UK RAPID Climate Change Programme
NSF / US Meridional Overturning and Heat Transport in the Atlantic

RAPID / MOCHA: Methodology

1. Observations of T_{GS}, T_{EK}, T_{INT}, T_{WBW}



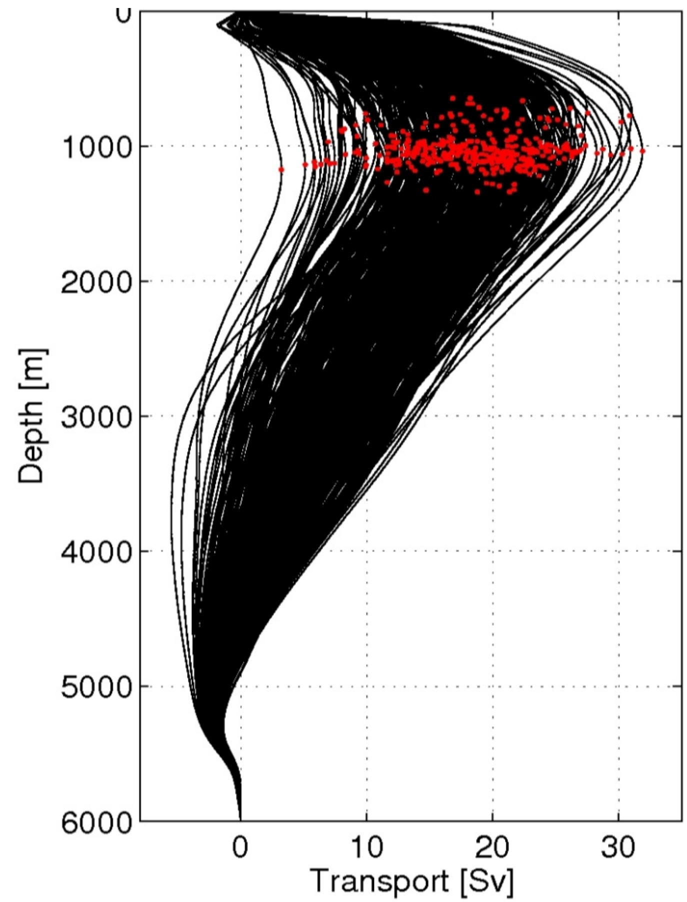
2. Prescription of mass conservation

$$\int_{Z=-H}^{Z=0} T_{EK}(z) + T_{GS}(z) + T_{MO}(z)dz = 0$$

3. Computation of reference transport (T_{COMP})

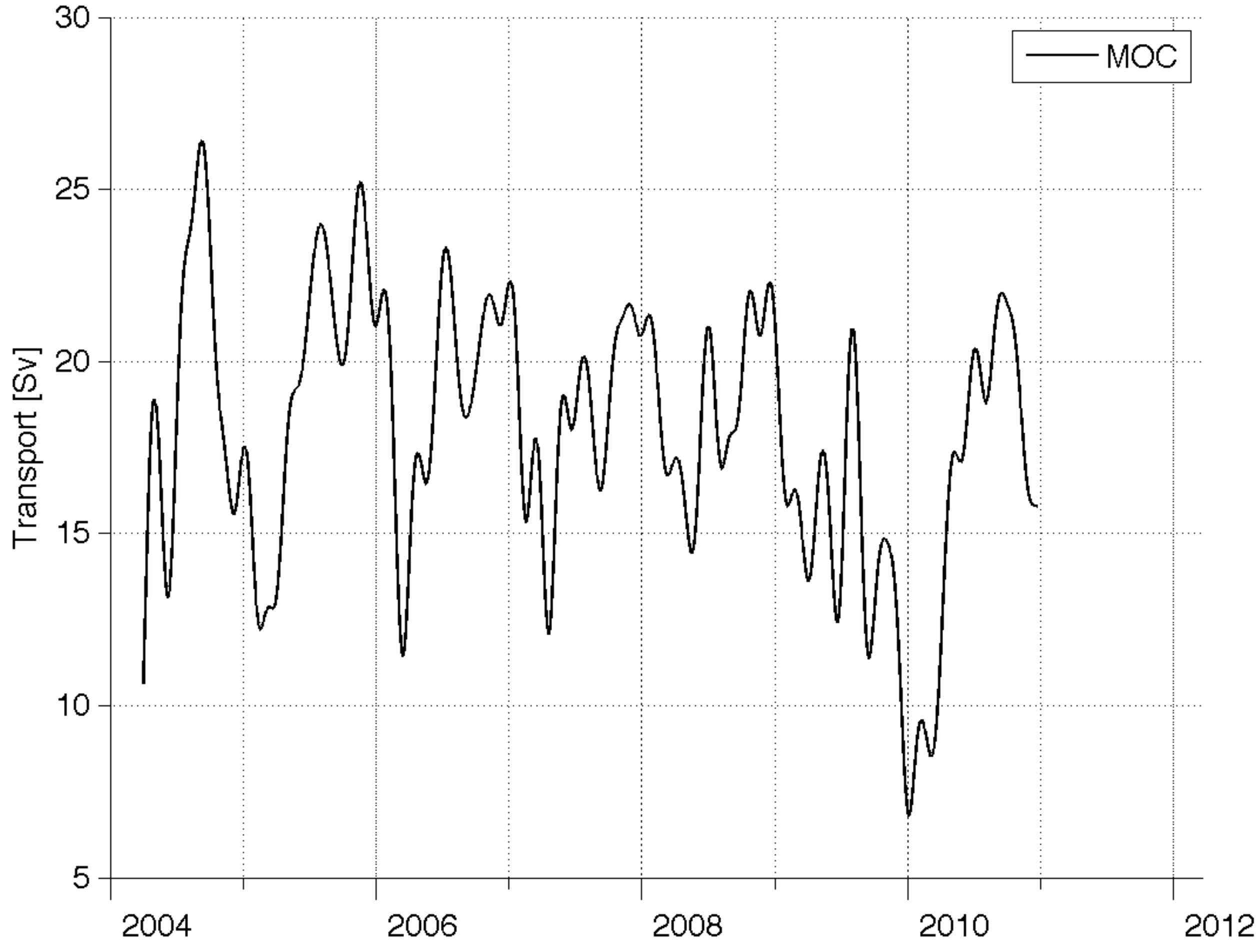
$$T_{MO}(z) = T_{WBW}(z) + T_{INT}(z) + T_{COMP}(z)$$

4. Cumulative Transport profiles

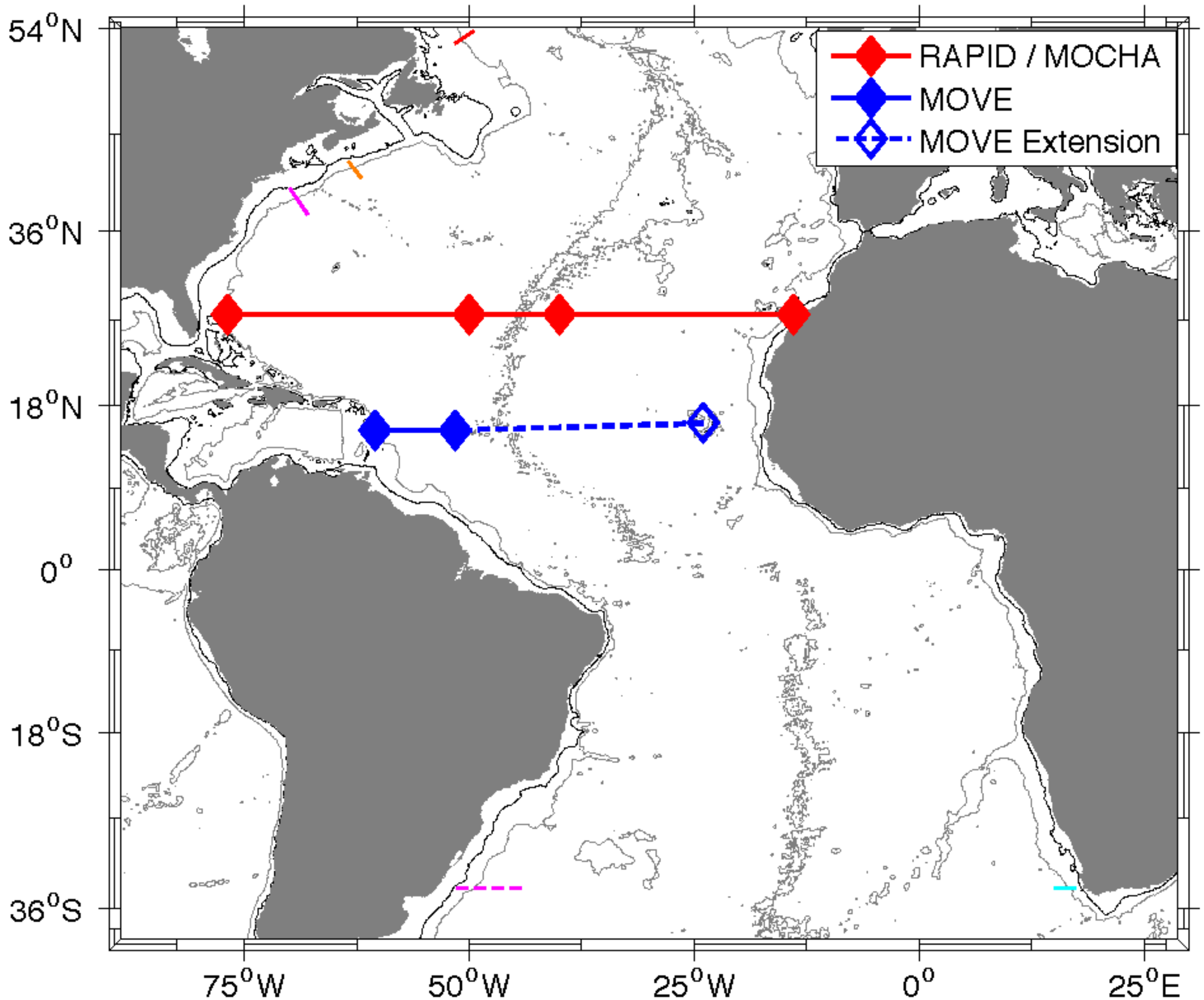


➔ AMOC definition: Maximum northward transport

MOC Time Series at 26°N (RAPID)

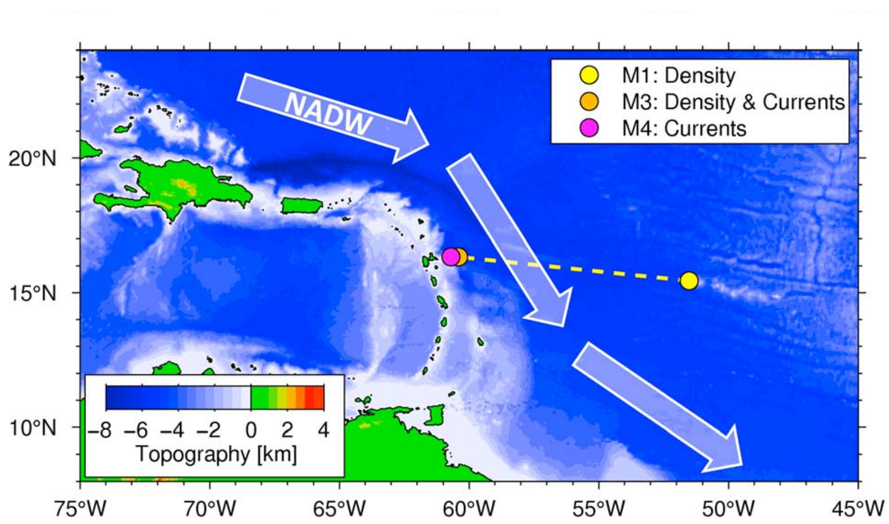


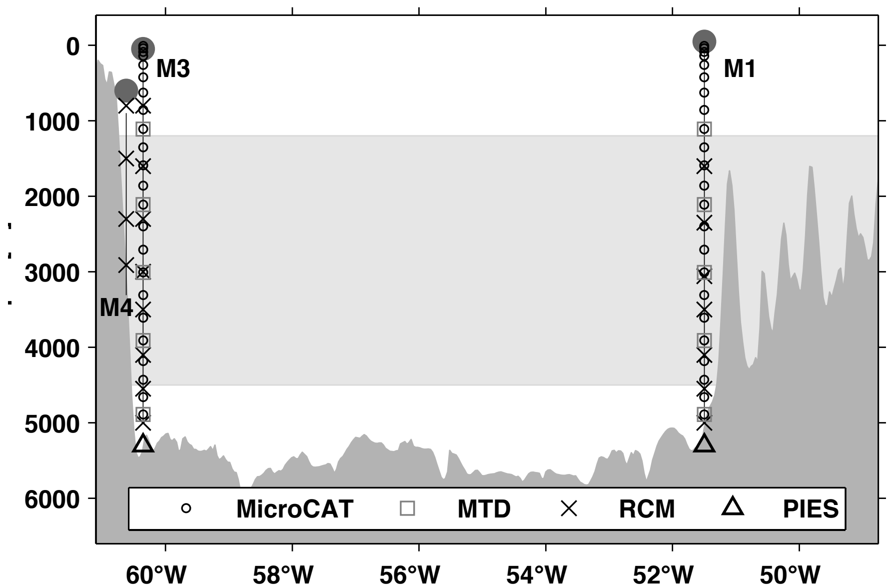
60 – day low-pass filtered



RAPID / MOCHA
MOVE
MOVE Extension
54°N
36°N
18°N
0°
18°S
36°S
75°W
50°W
25°W
0°
25°E

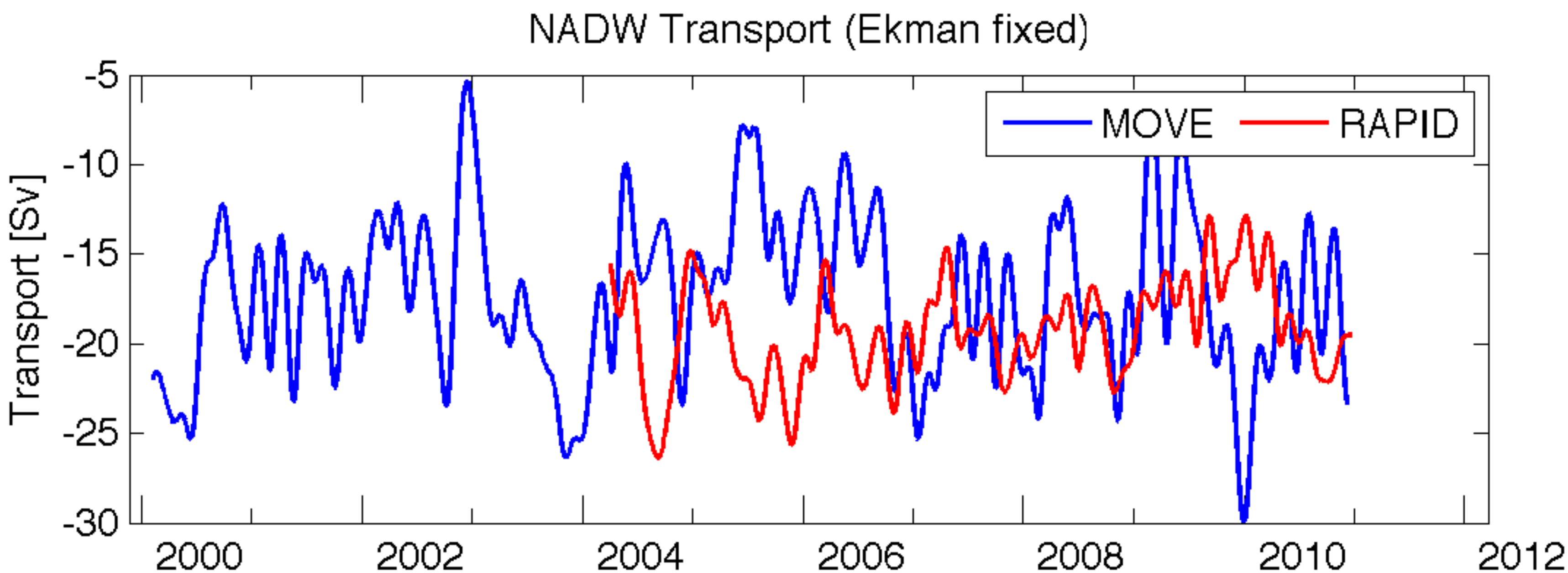
MOVE (16°N)





- Started 2000 as German project (BMBF funded); continued with NOAA funding by Prof. U. Send (Scripps, USA)
- CTD moorings (M3, M1) to infer meriodional geostrophic NADW transport relative to 4800 dbar (AABW / NADW boundary)
- Direct current meter velocity measurement (M3, M3) to derive NADW transport over Antilles continental slope

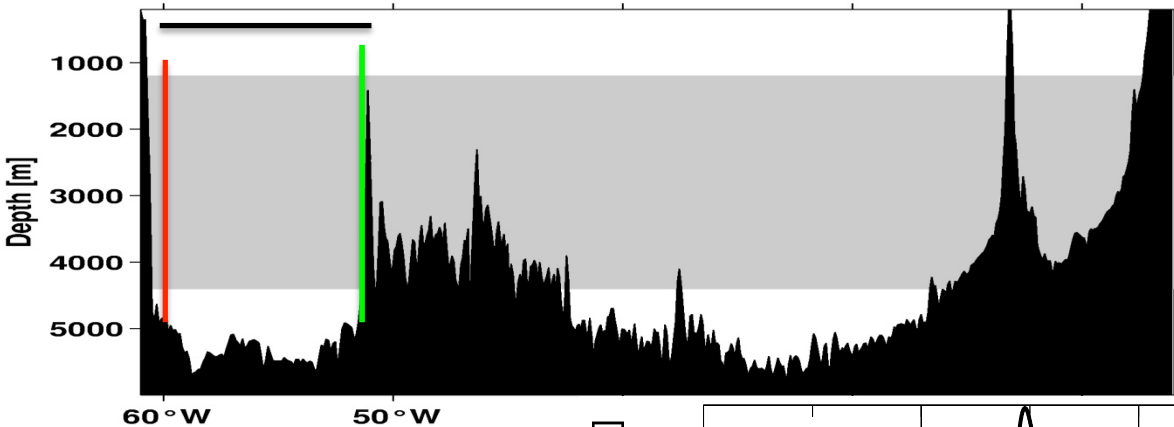
NADW Transport: MOVE(16°N) vs. RAPID (26°N)



MOVE NADW does not contain compensation for Ekman transports
➔ Remove Ekman component from RAPID

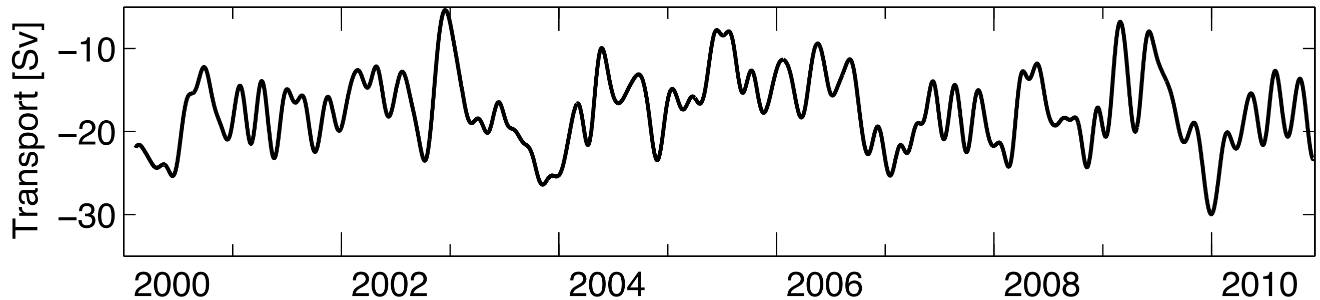
Are the huge differences in NADW transports signatures of MOC differences?

MOVE (16°N) Transport Decomposition



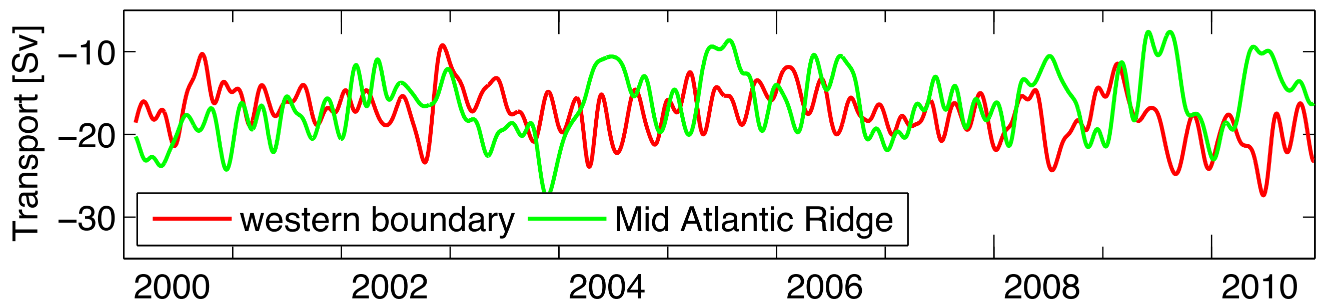
NADW Transport [Sv]

Western Boundary
->MAR



Western Boundary

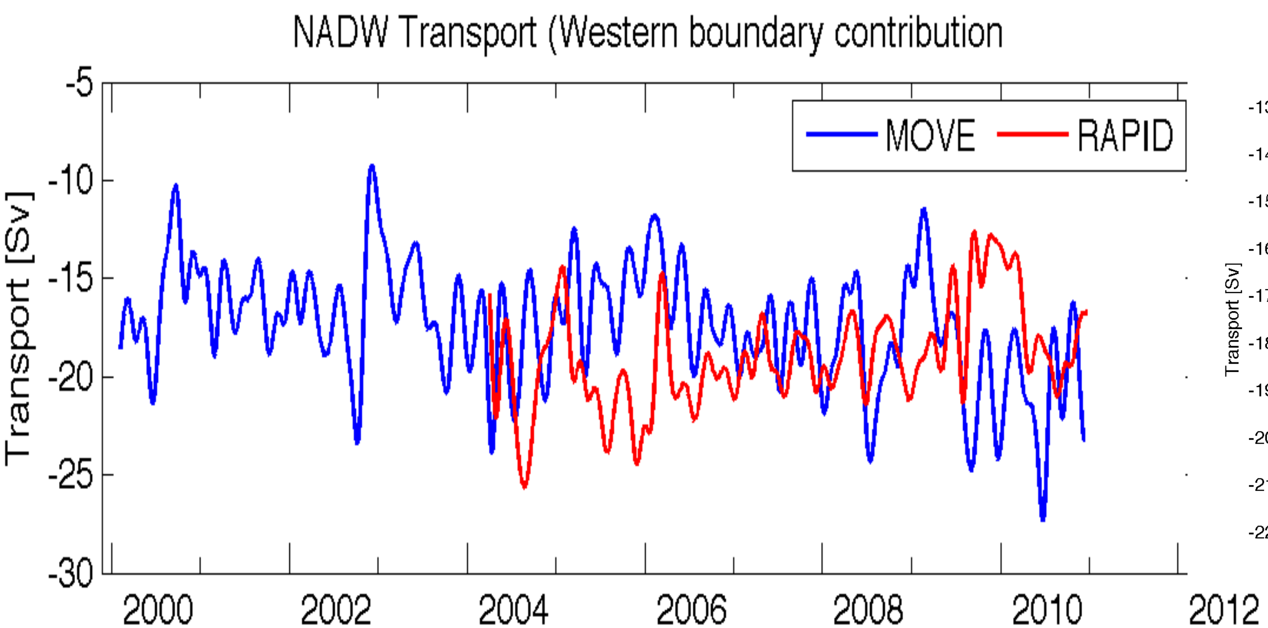
Mid-Atlantic Ridge



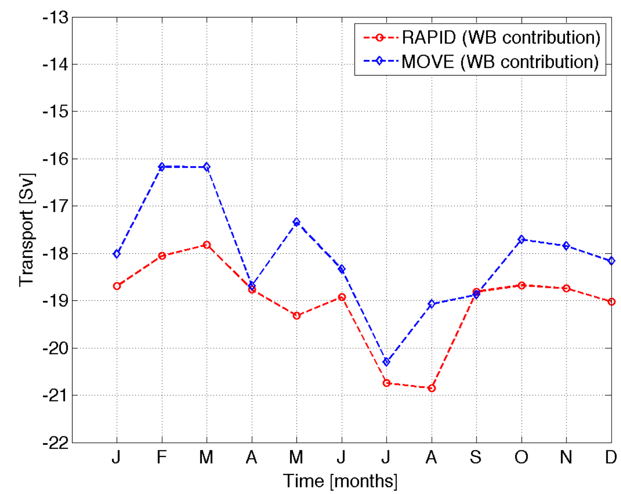
The 2009/2010 transport anomaly results from density anomaly at MAR

➔ Possibly (partly) unrelated to MOC

Seasonal Anomalies

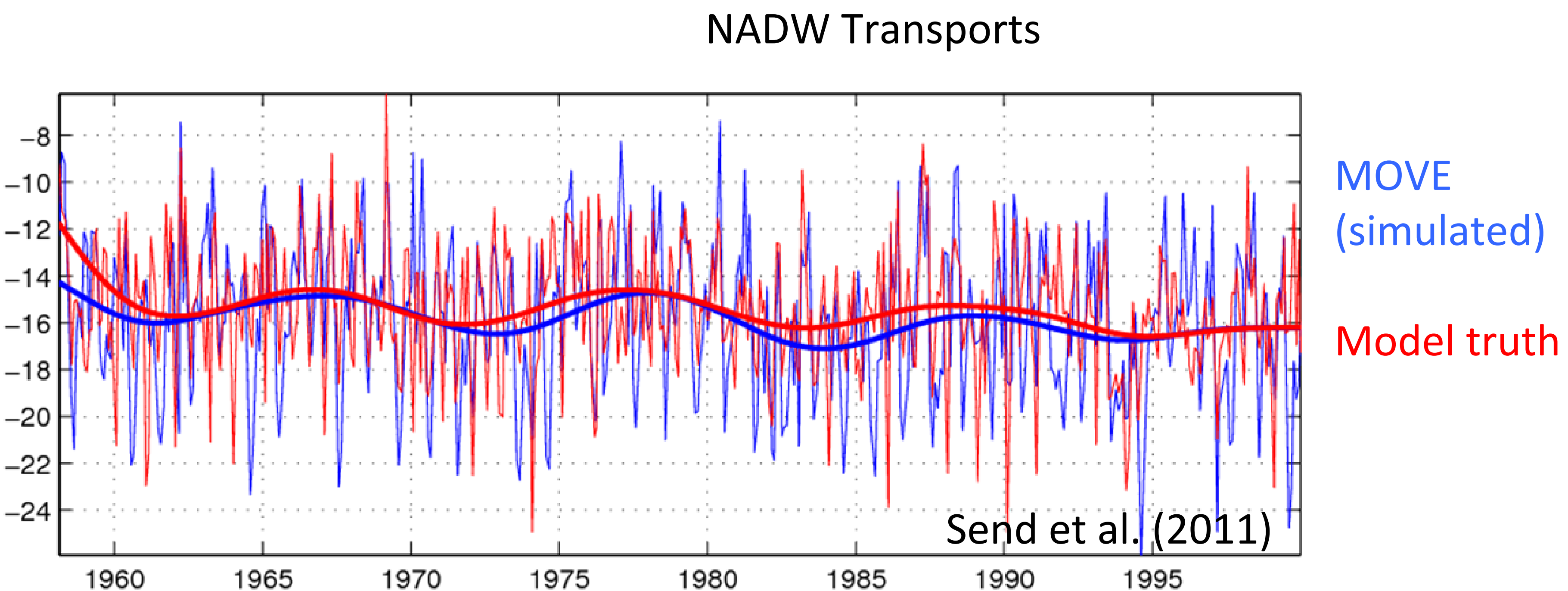


Seasonal cycle



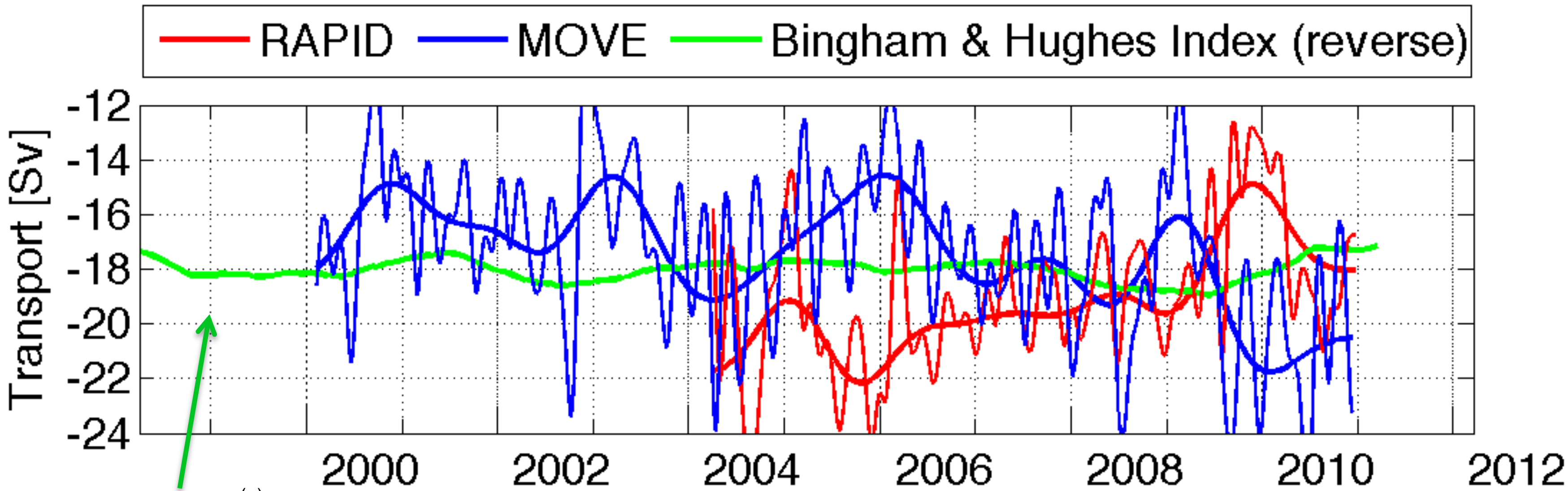
➔Eliminate eastern boundary and Mid Atlantic Ridge contributions because
(i) MOVE does not have eastern boundardy densities
(ii) Density variation might contain large eddy-related signals

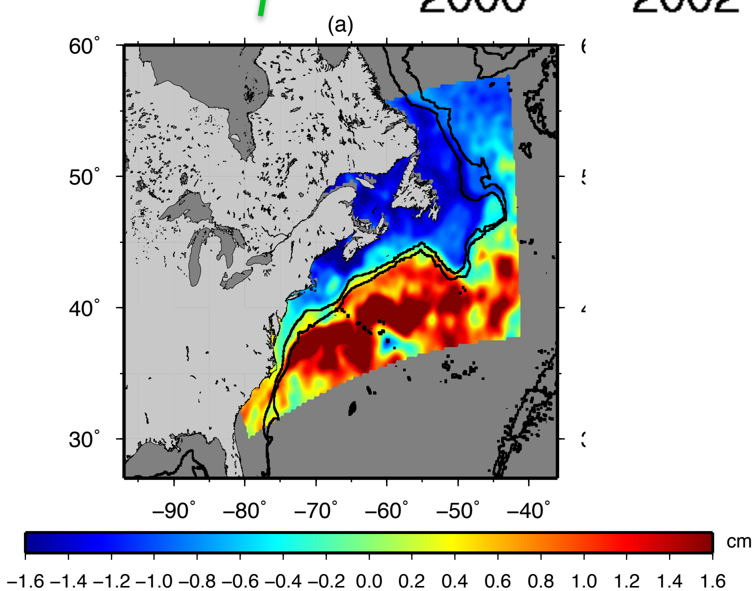
Simulation of MOVE approach to infer NADW in a numerical model (GECCO)



➔ MOVE should recover interannual NADW transport fluctuations

Interannual variability (Western Boundary contribution)

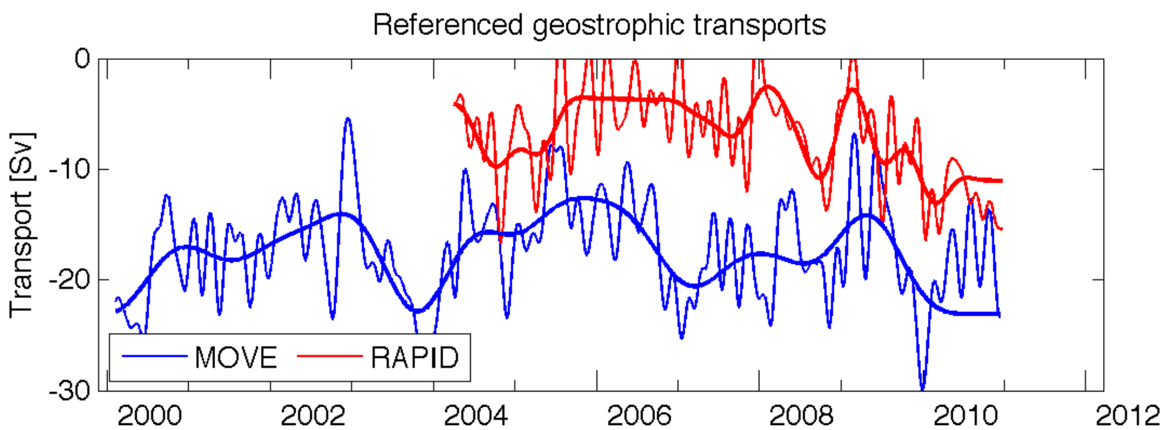


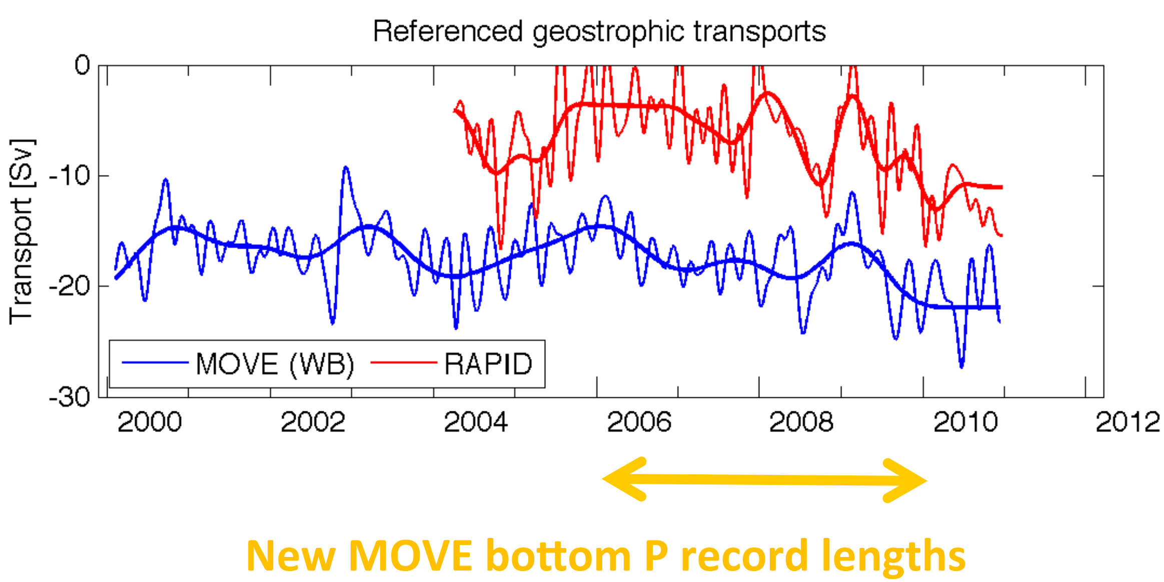


Low frequency evolutions of NADW transports (15 month low –passed) are not in phase.

➔Possibly MOC divergence and converge at interannual time scales

Interannual variability (geostrophic computation only)





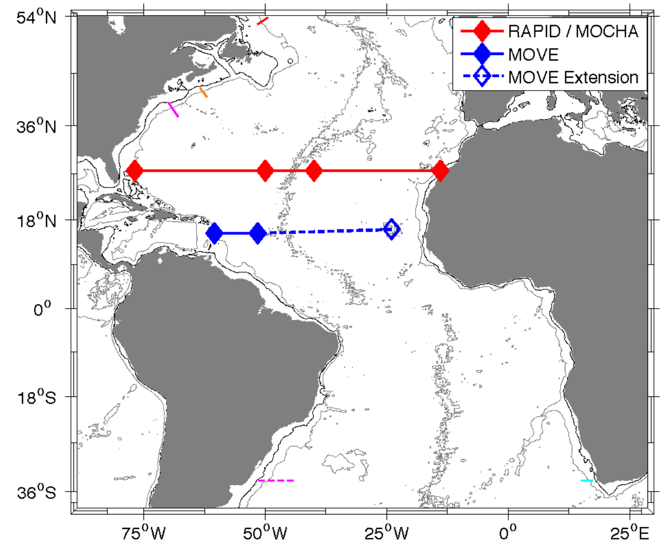
Geostrophic currents in deep water only. Does not use any shallower RAPID data, no assumption reg. mass balance at 26N.

Hints of correlation in annual-to-interannual time scales.

Perpetual question: reference level, mass balance assumptions...

Summary & Conclusions

➔ Long moored time series of NADW transports at 16°N and 26°N

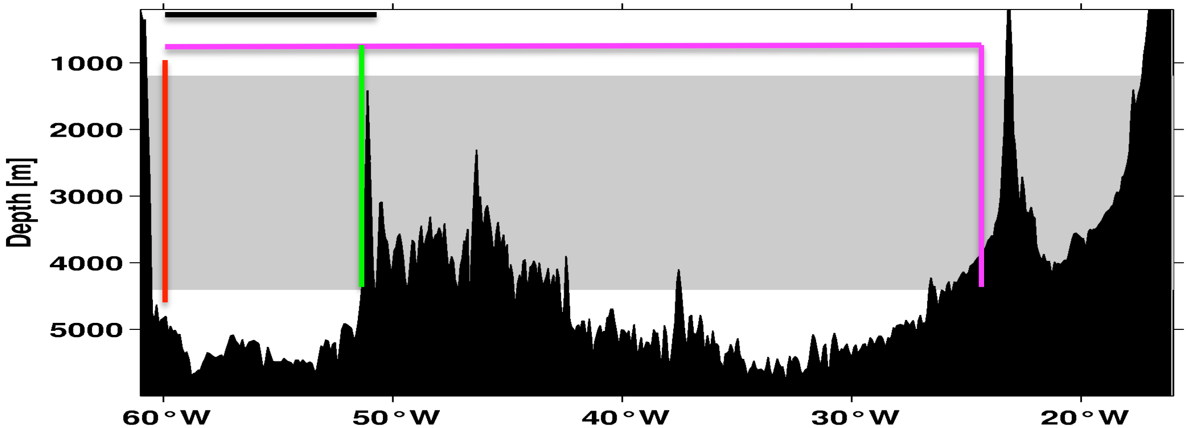


➔ Different systems not trivial to compare

➔ MOVE does not capture seasonal MOC
➔ extension required ....

➔ At short (seasonal) time scales, differences in NADW transport most likely not related to MOC divergence

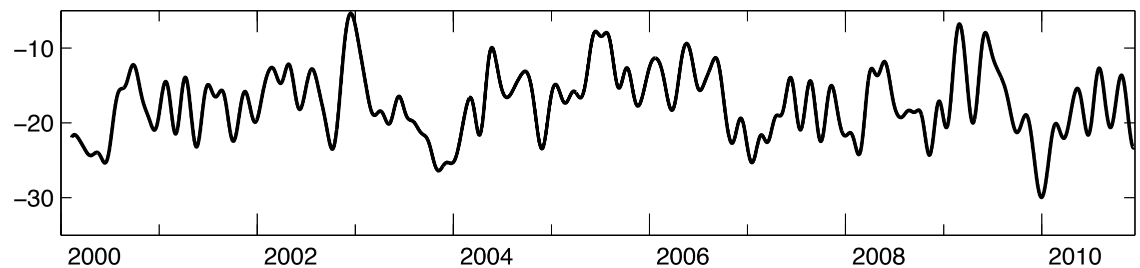
➔ Long-term evolution might represent MOC coherence / divergence, but interpretation still dependent on assumptions reg. referencing



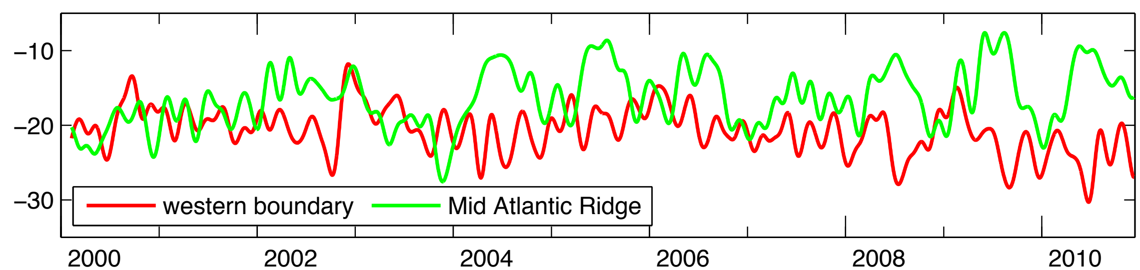
MOVE

NADW Transport [Sv]

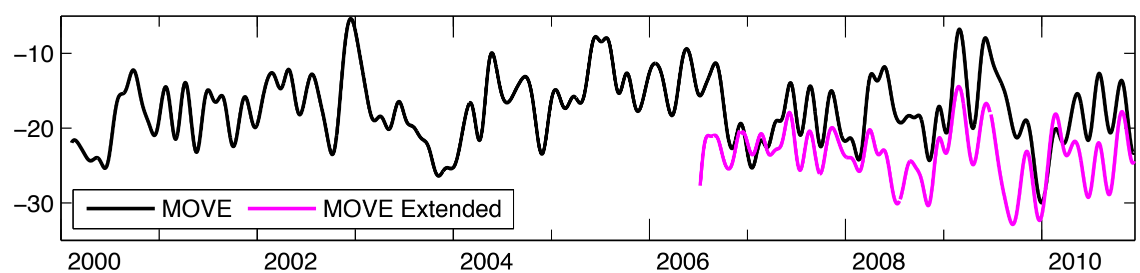
Western Boundary
to MAR



Western Boundary only
Mid-Atlantic Ridge only

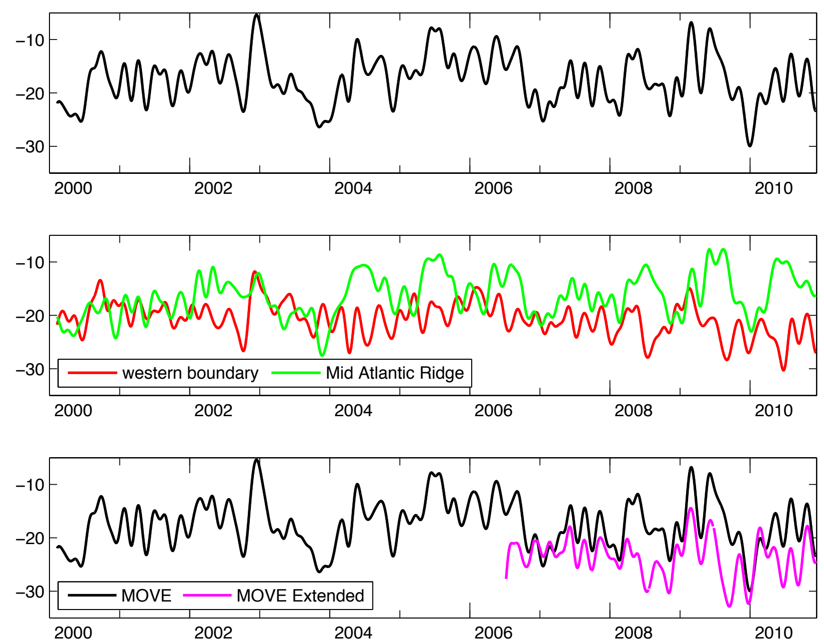


Western Boundary
to MAR
Western Boundary
to Cape Verde

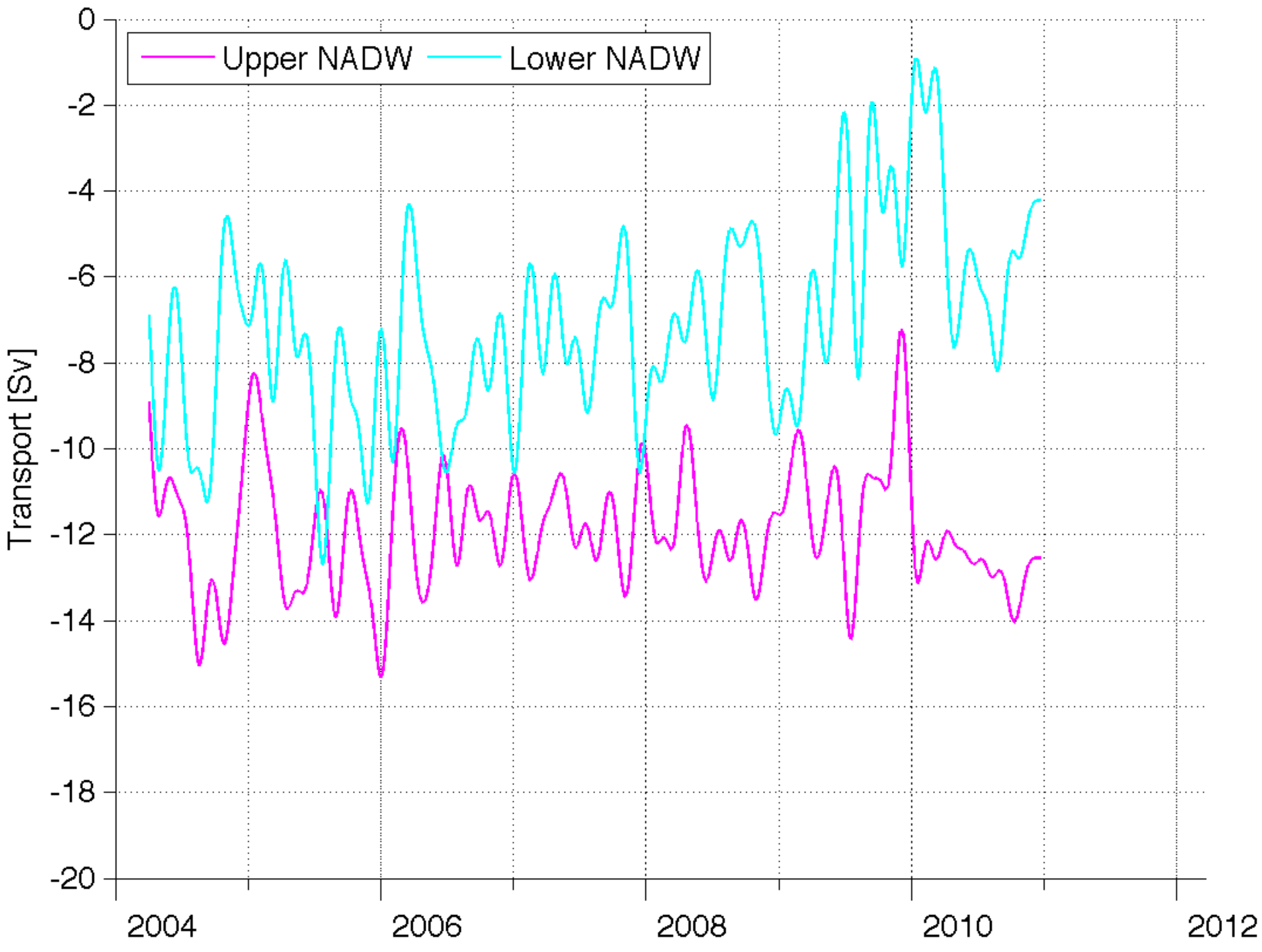


Deconstruction of MOVE

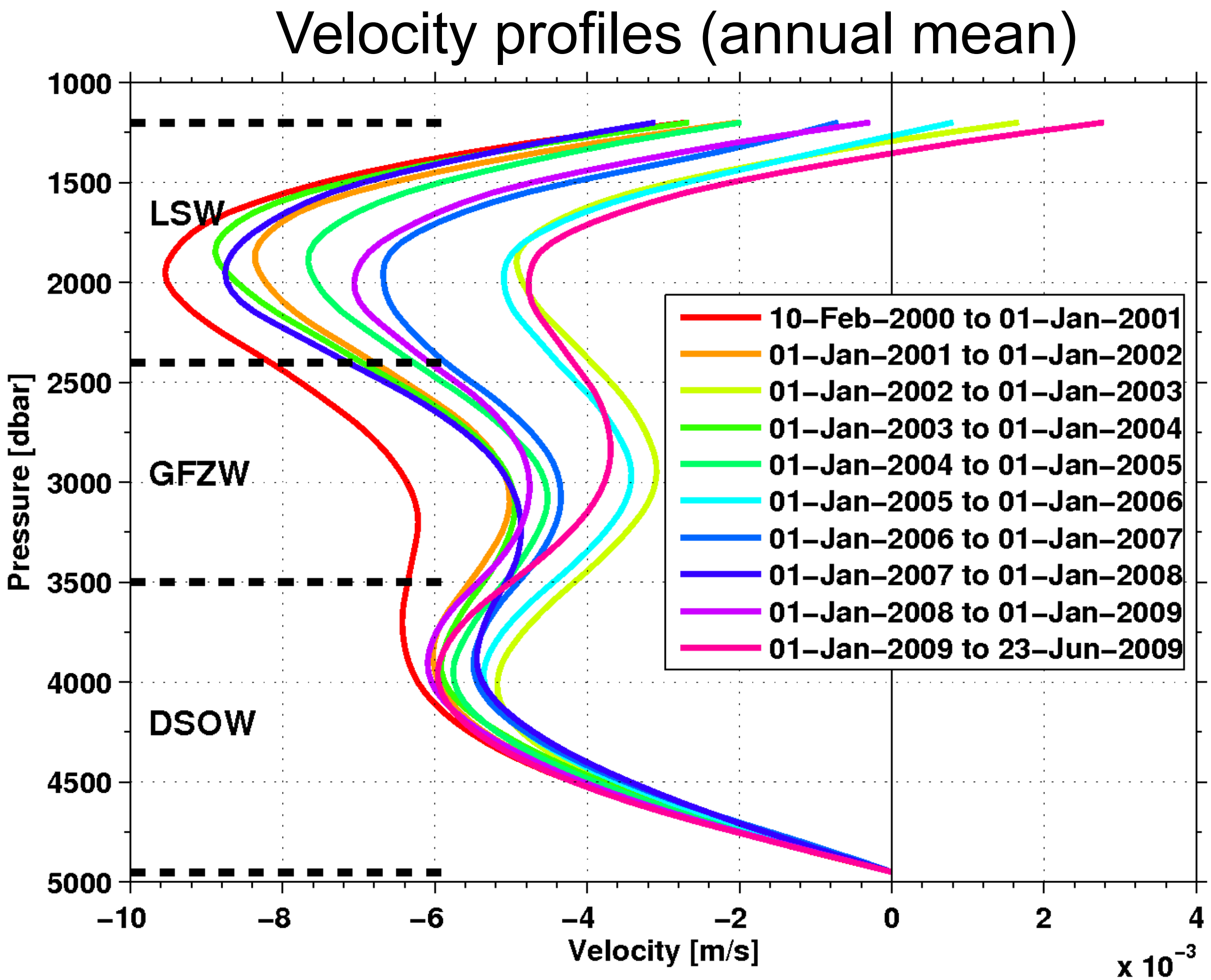
- Deconstruction of MOVE transport into WB and MAR contributions
- MAR contribution has seasonal cycle
- WB and MAR contributions appear to slowly diverge over time
- 2009/2010 event has contributions from both WB and MAR (mostly from the MAR)
- Replacing densities from MAR at depths shallower than 3500 m with densities from Tenatso (17N/24W) changes the variability substantially. This possibly indicates, that some of the variability above 3500 m observed at MAR does not correspond to a basin-wide density gradient (and should not be confused with MOC variability)



RAPID Deep Transports



MOVE



➔ Two layers of intensified southward flow

➔ Substantial year-to-year variability in vertical shear of velocity