Variability of the Atlantic Meridional Overturning Circulation observed at 16°N

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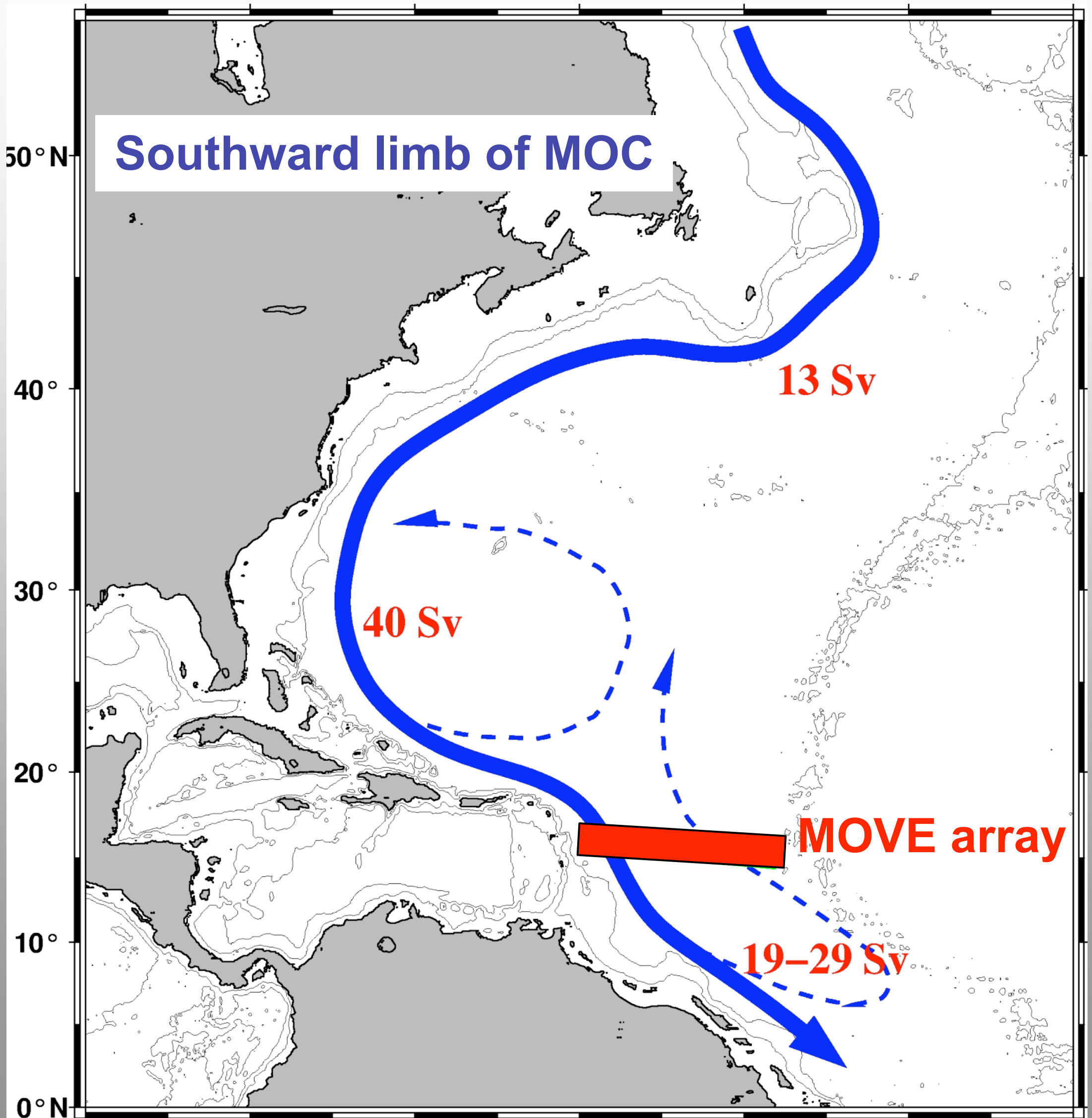
(and contributions from Torsten Kanzow)

MOVE PROJECT:

- ***9.5 years of continuous NADW transport data***
- ***decreasing MOC intensity with 85% certainty, 3Sv/10years***
- ***trend roughly agrees with decadal variability in some models***
- ***origin is weakening shear in upper NADW, transport decrease is concentrated in LSW***
- ***overall sinking trend in all NADW isopycnals***
- ***possible 3-4 year cycle in southward transport***

MOVE (Meridional Overturning Variability Experiment)

Monitoring transport of southward NADW between western boundary and Mid-Atlantic Ridge



Assumptions:

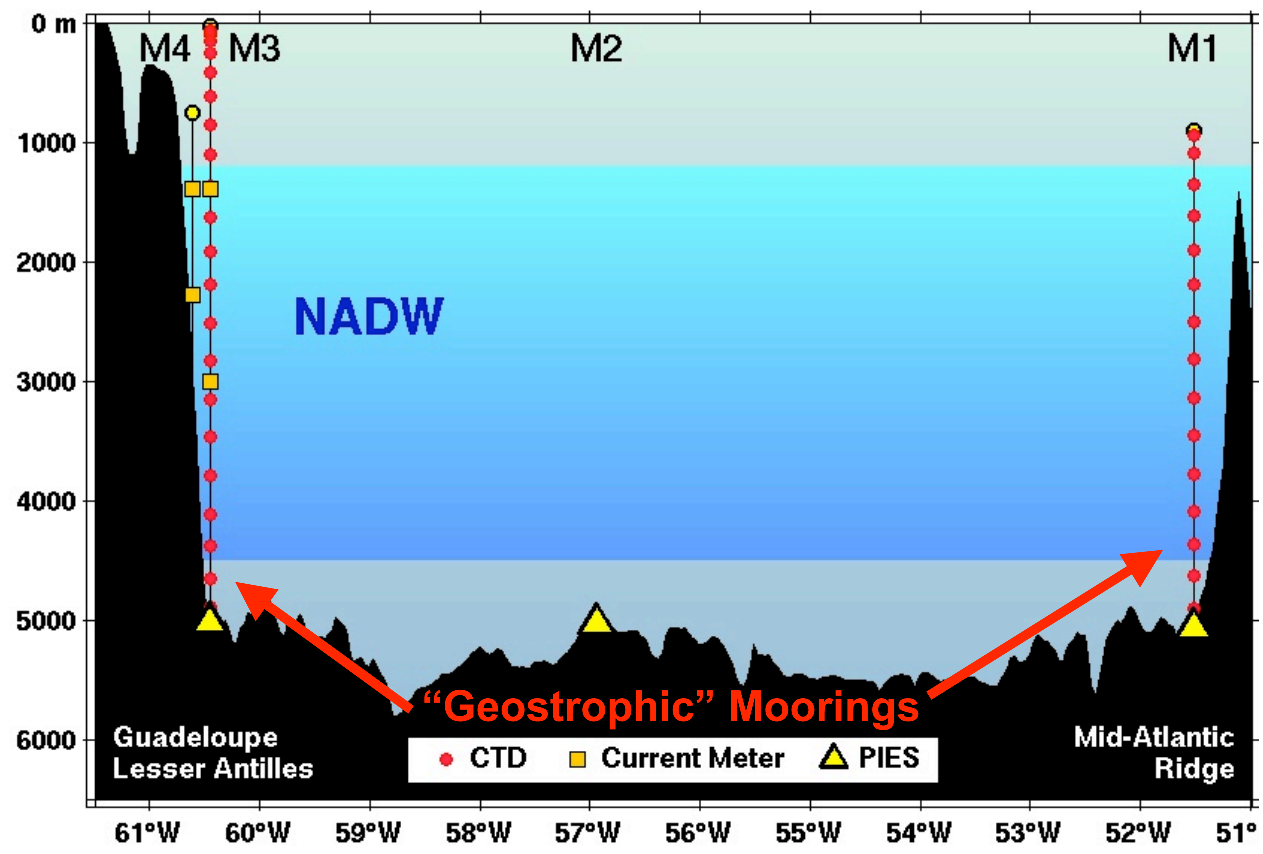
1) **Balances northward thermocline transport** (mass balance)

2) **Little transport east of MAR** (reasonable based on CFC and model data, since 2006 full-basin coverage with German mooring in east)

Recent sparse array design

Integrate NADW flow over 1000km with "geostrophic" end-point moorings

- *Internal transport:* sheared thermal wind part
- *external transport:* from bottom pressure gradient
- *boundary transport:* from current meters on slope

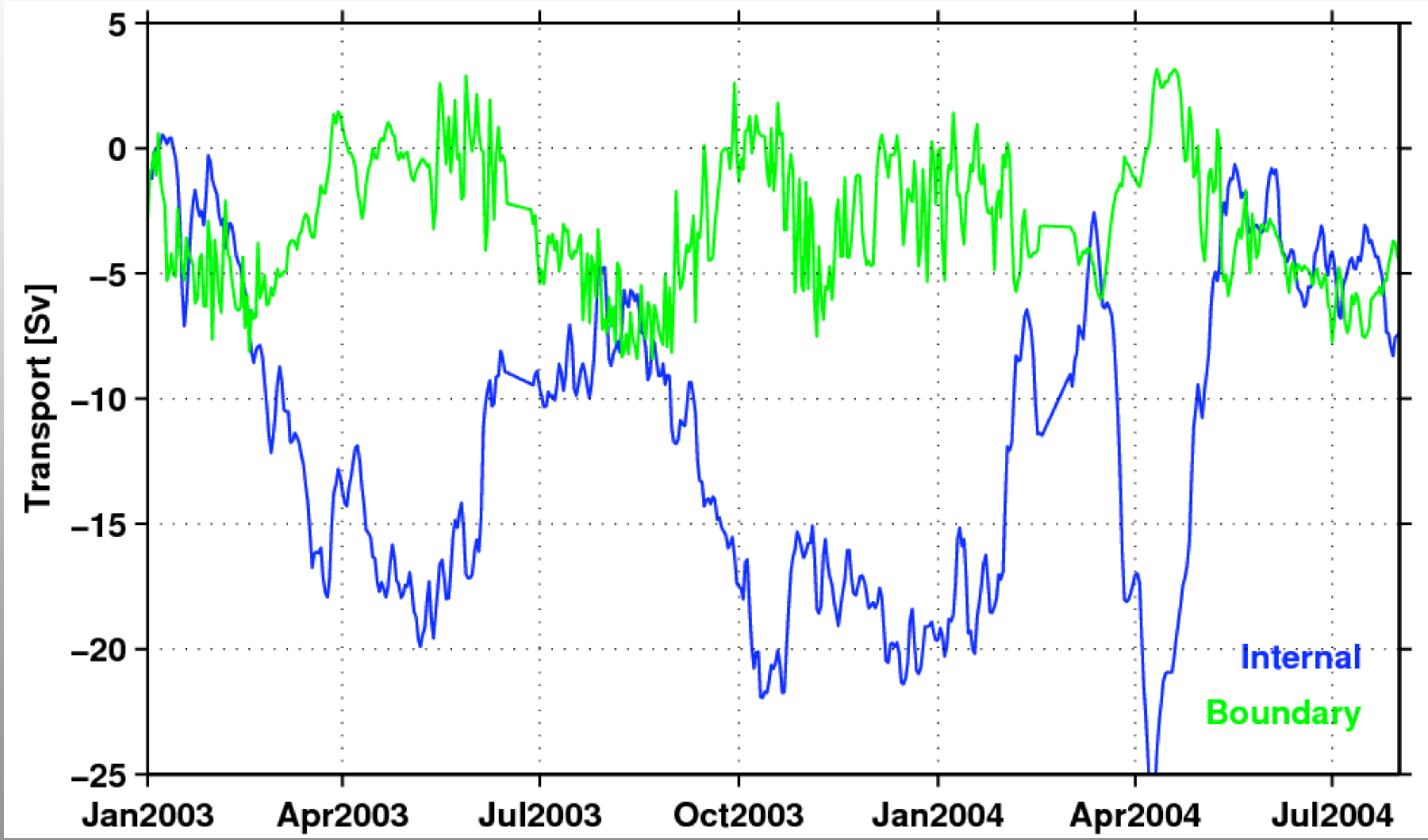


Started in 2000 as German CLIVAR project, now NOAA funded.

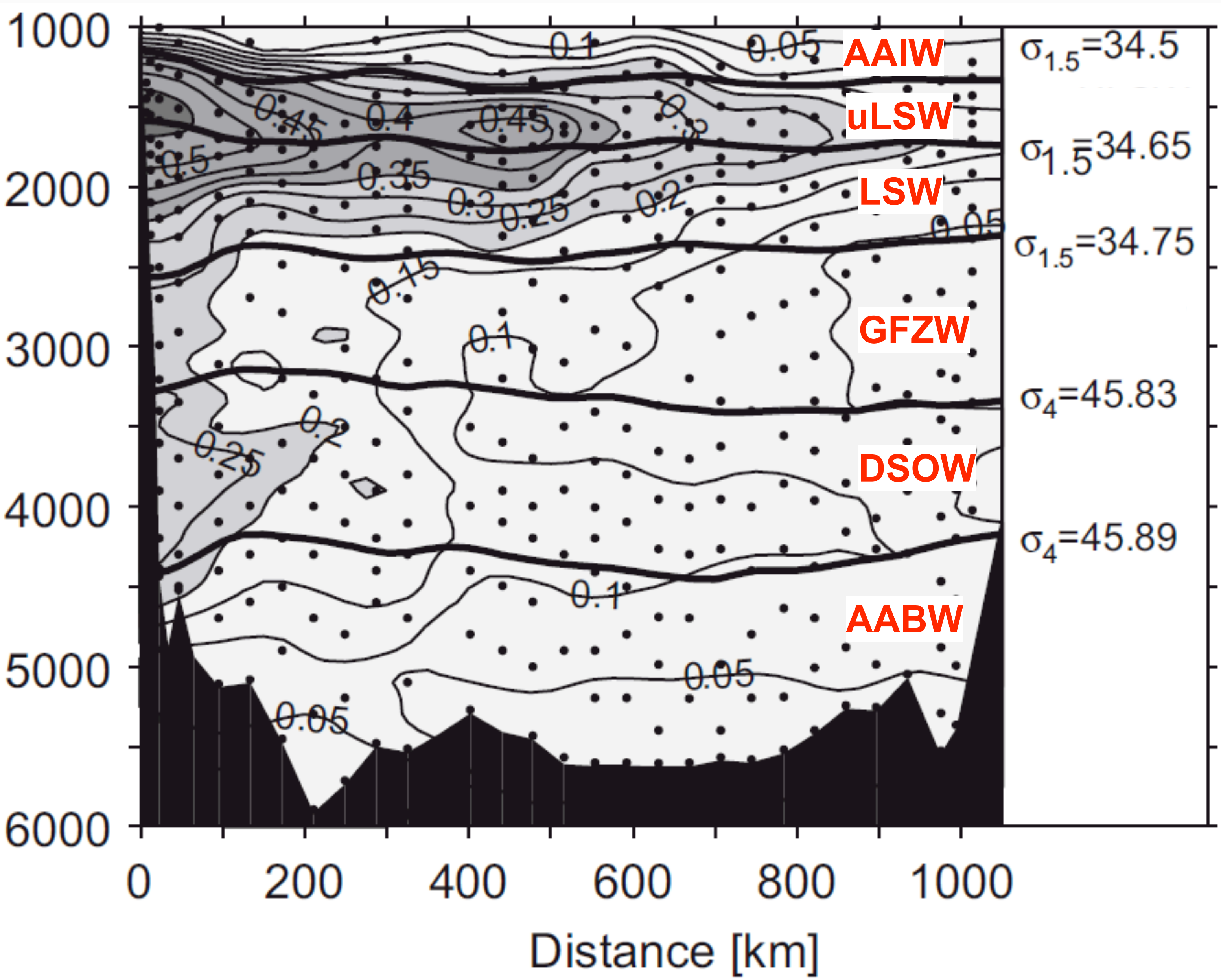
- have demonstrated the accuracy (Kanzow et al)
- started with more moorings, now achieving same with sparse array
- 9 ½ years of data now, 98% data return on internal/boundary transport

Boundary current variability

is compensated by interior changes
→ probably meandering of the boundary current

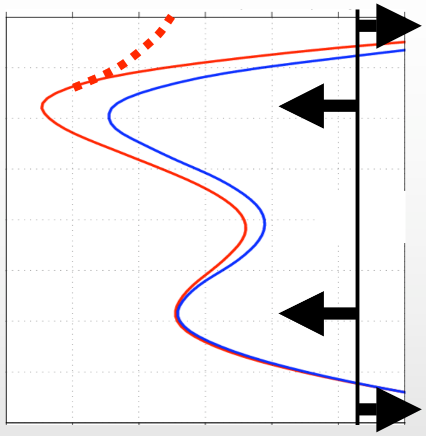


CFC-12 along 16°N from Steinfeld et al 2007

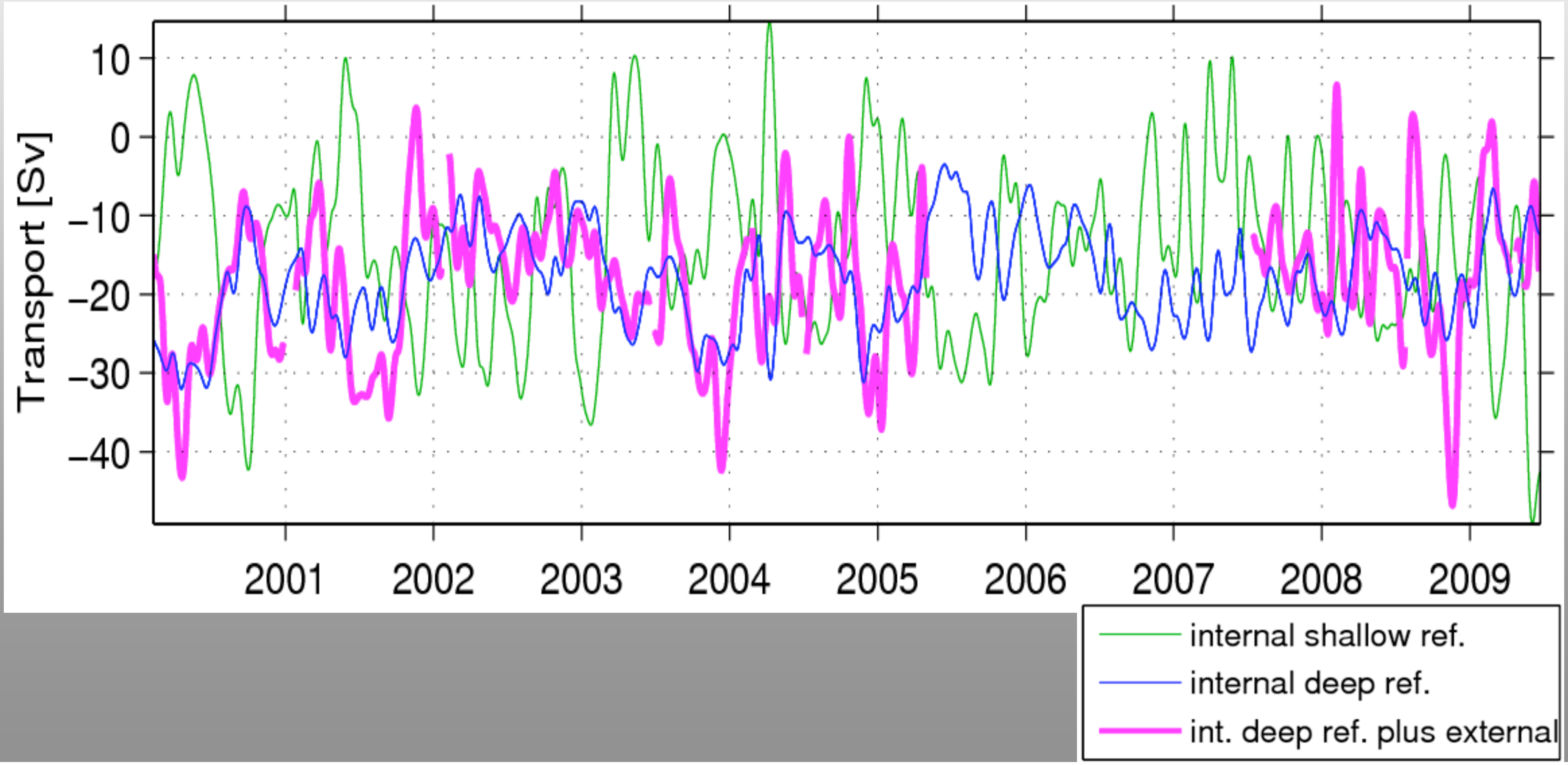


We will use these isopycnals..

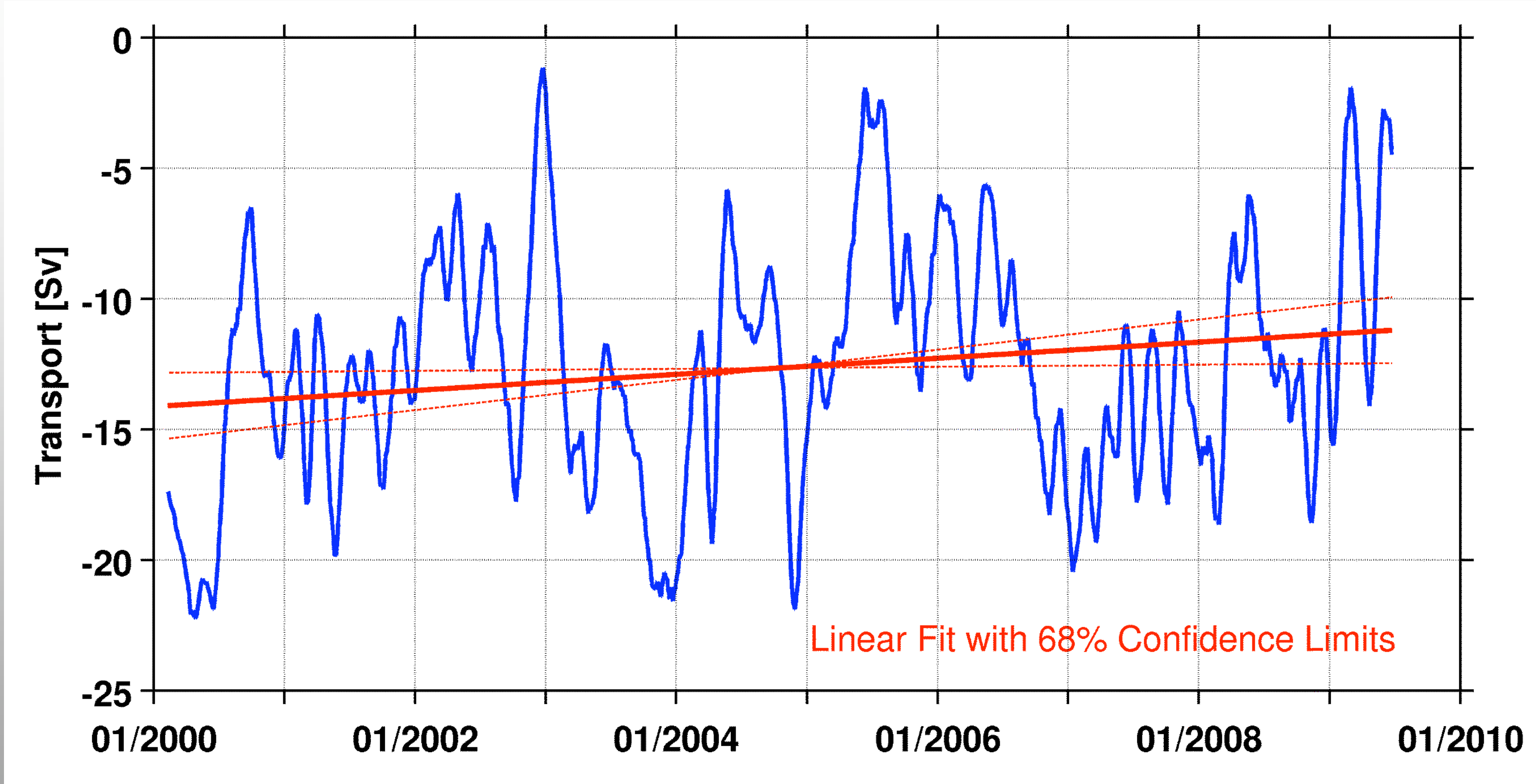
Deep reference level for geostrophic flow



- **on LONG TIME SCALES watermass boundaries must be zero-flow levels, i.e. 1200db (AAIW-NADW) or 4700db (NADW-AABW)**
- **on intra-annual time scales, total variability is known from bottom pressure, and agrees well with 4700 level-of-no-motion (implies large flow variability at 1200db, much less at 4700db)**



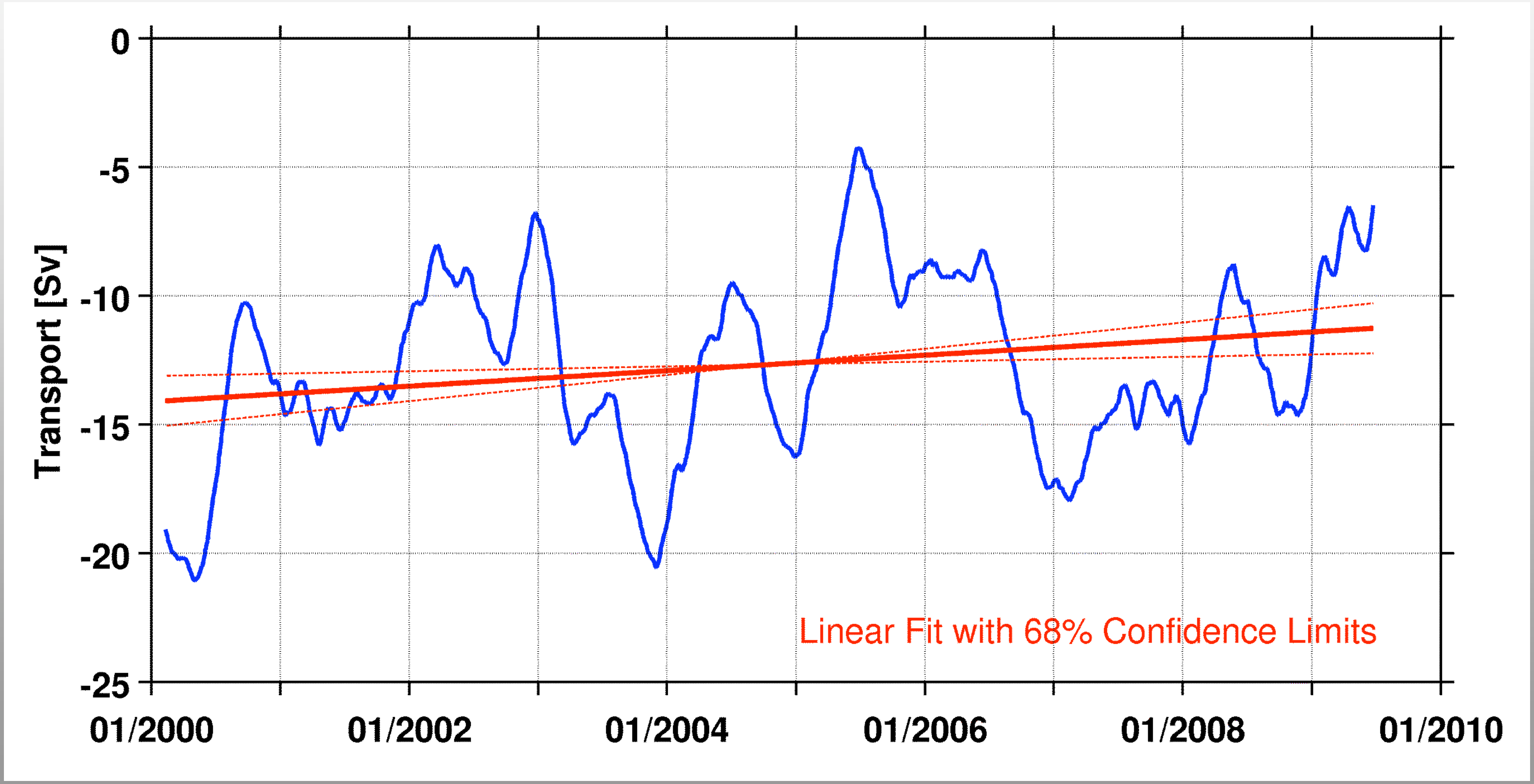
Internal transport rel 4700db plus boundary transport



- **Trend = +0.31 Sv/a → MOC decrease of 3Sv over measurement period**
- **85% certain trend > 0**
- **45 degrees of freedom**

Internal transport rel 4700db plus boundary transport

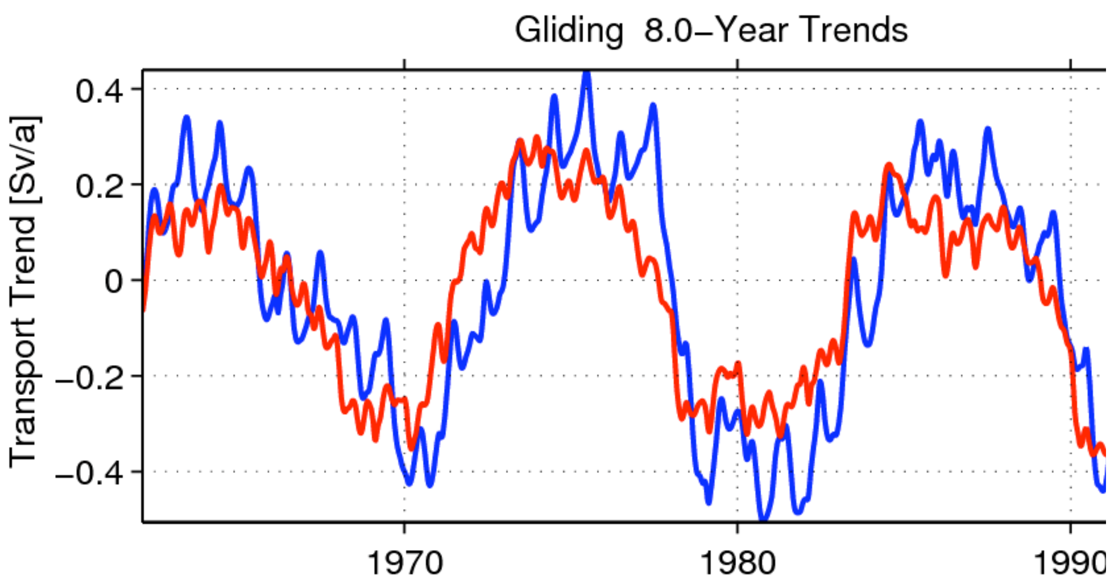
(filtered to 120 days)

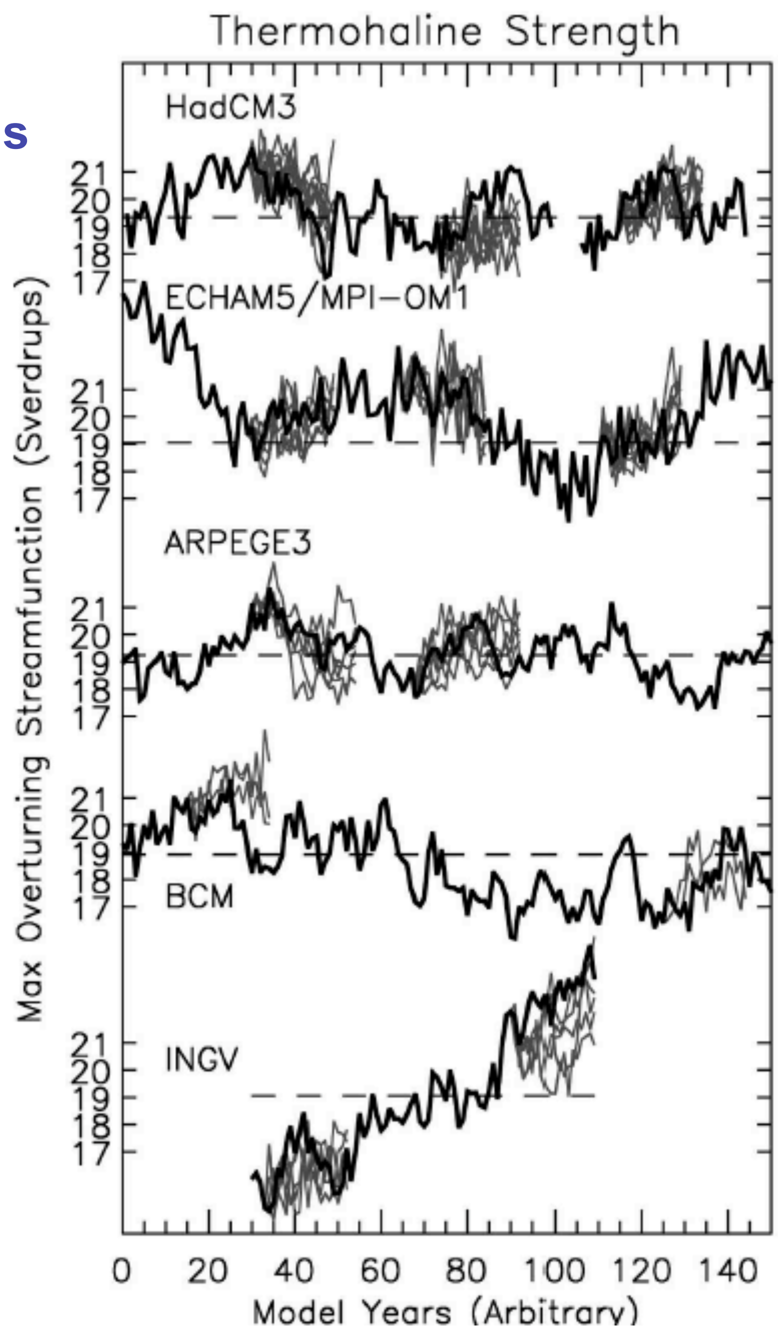


Internal variability in models has similar magnitude

Some coupled models show 1.5-2Sv/10yrs

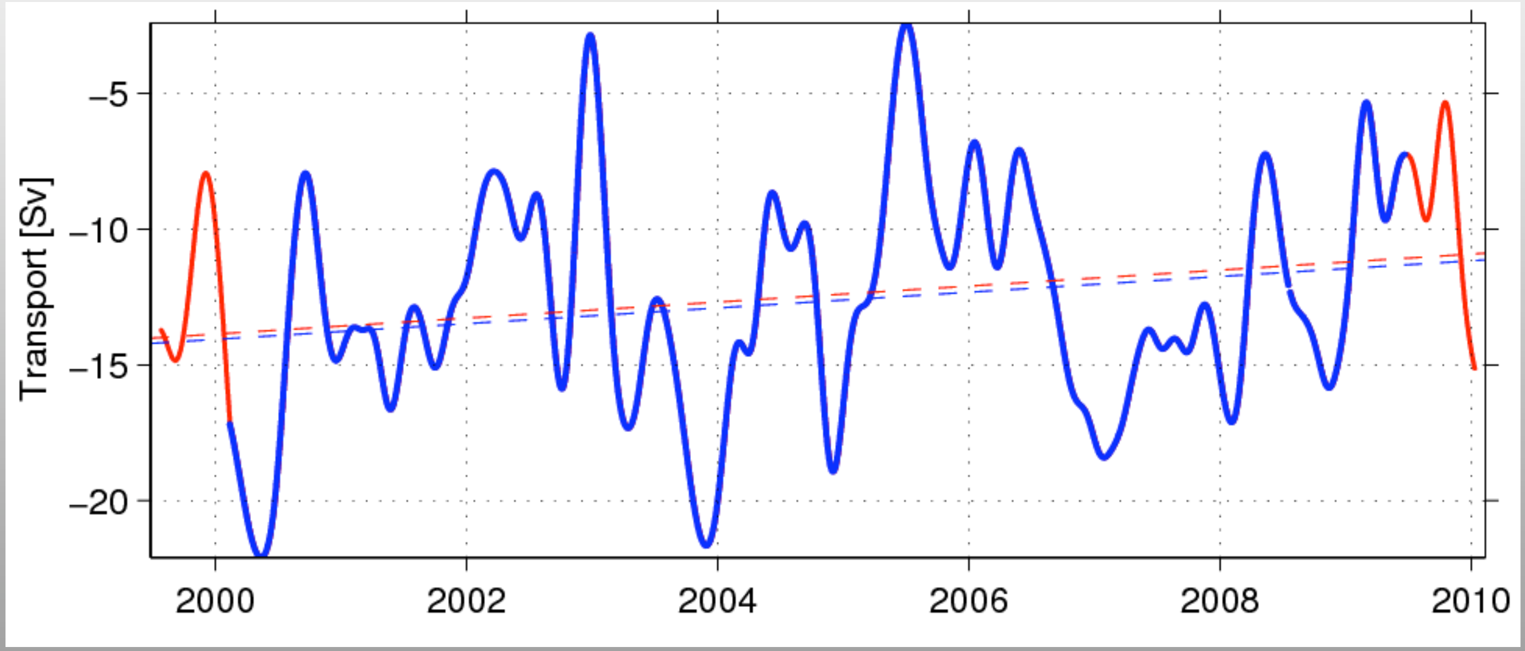
FLAME model has 3Sv/10yrs





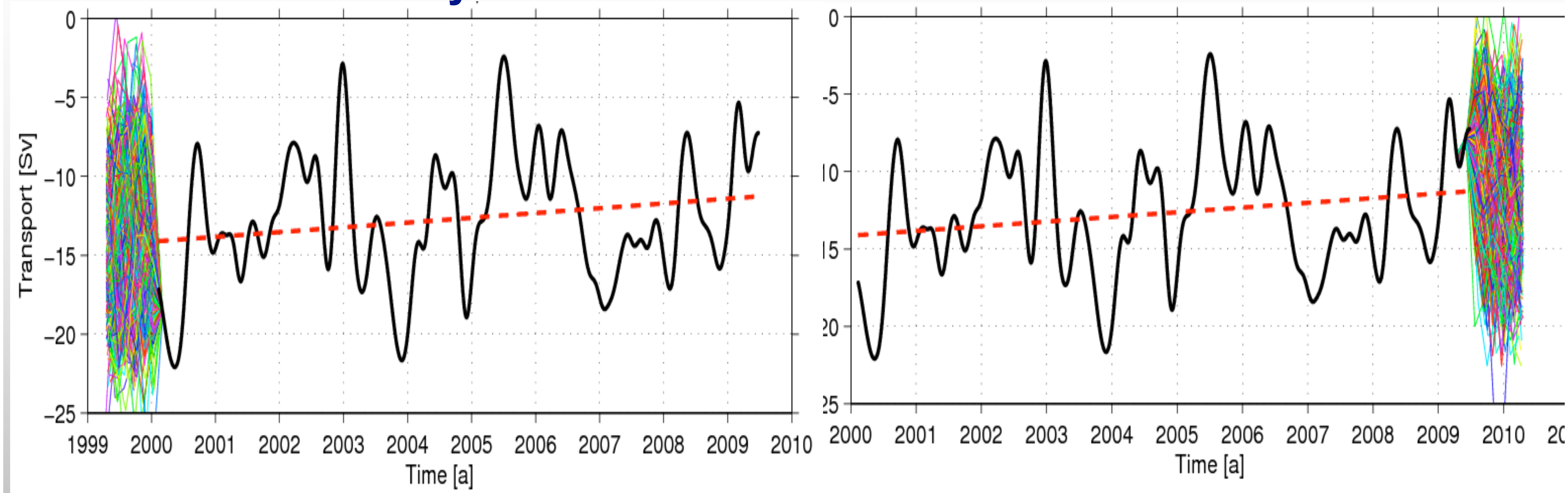
Sensitivity of trend to end effects

Internal transport rel 4700db with artificial (mirror image) extension by 6 months

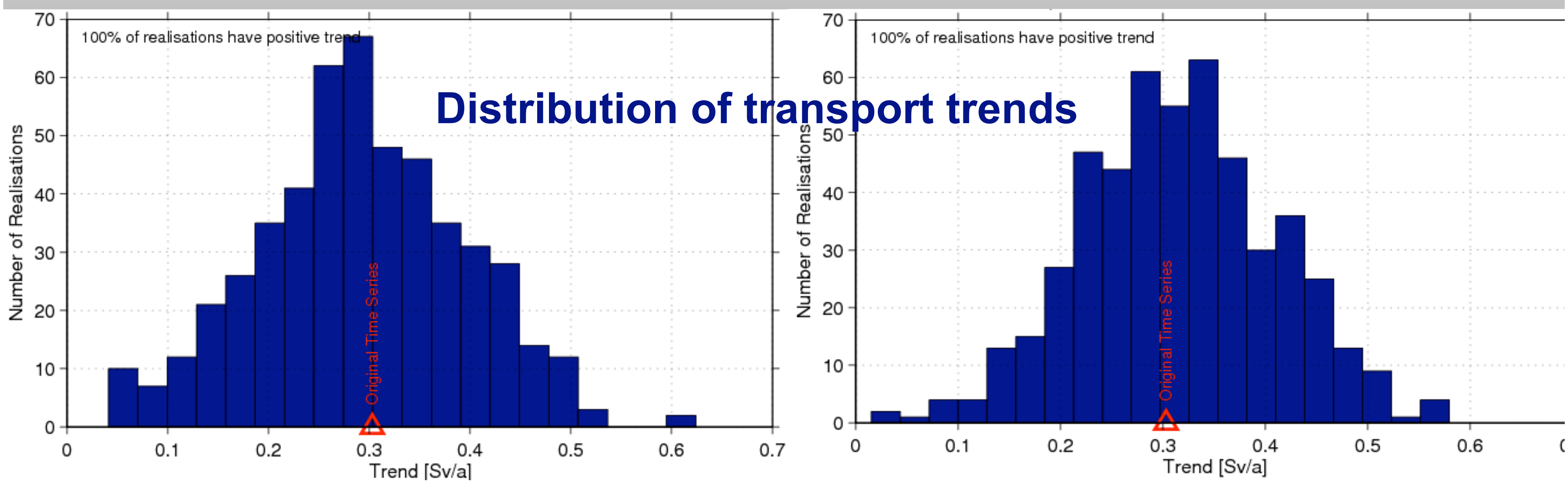


Sensitivity of trend to end effects

1-year extensions with AR2 ensembles



Distribution of transport trends



Other sensitivities of transport trend

- Trend not sensitive to cruise CTD calibration errors, since difference between 2 moorings is taken

- errors in single instruments stand out and can be corrected or omitted

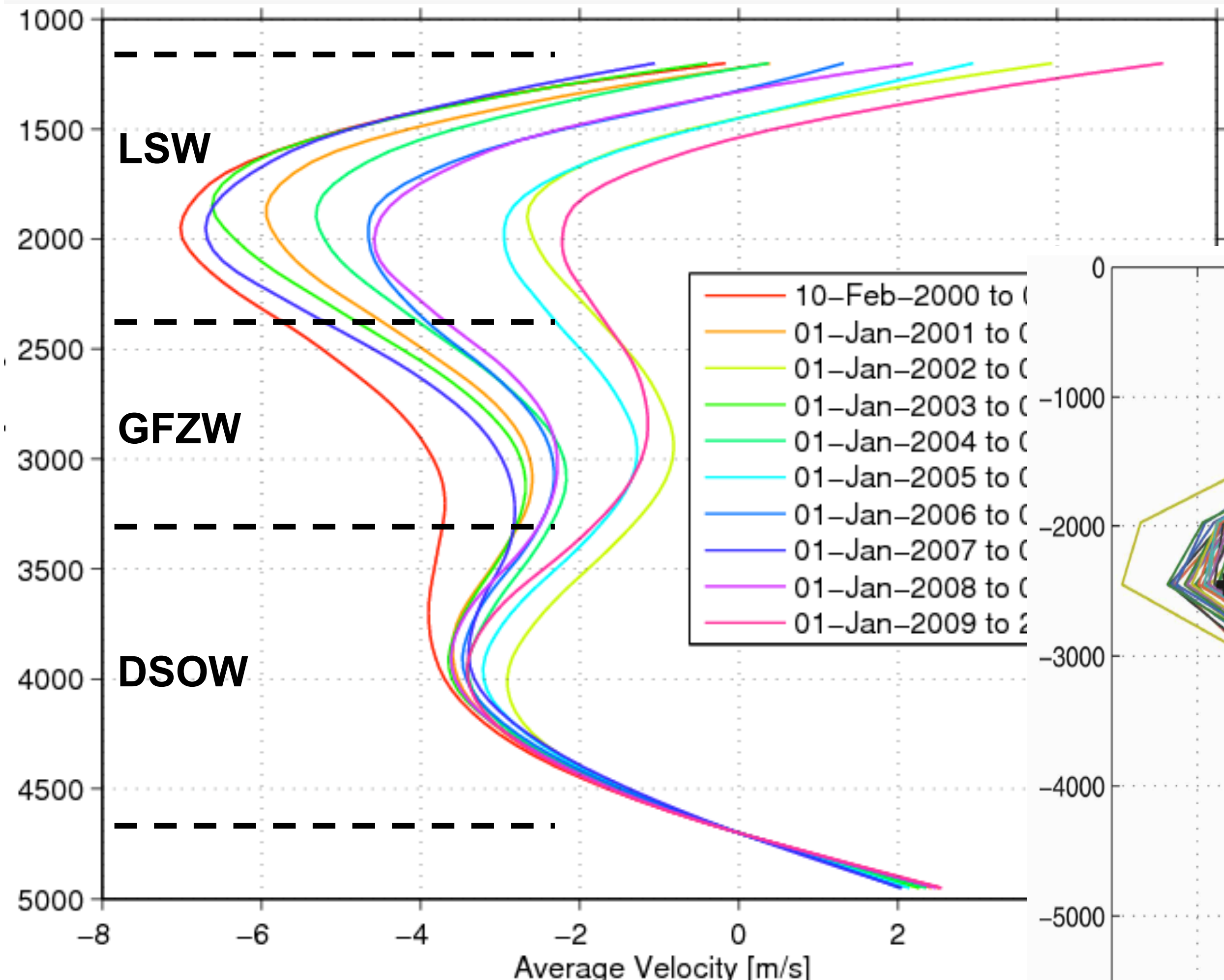
- Trend not sensitive to range of deep water layer integrated over, or even to trends in that layer thickness

- Trend also not sensitive to isobar chosen for reference level. There has to be a zero-velocity depth in the mean shear profile (opposing water masses) – can choose ANY here

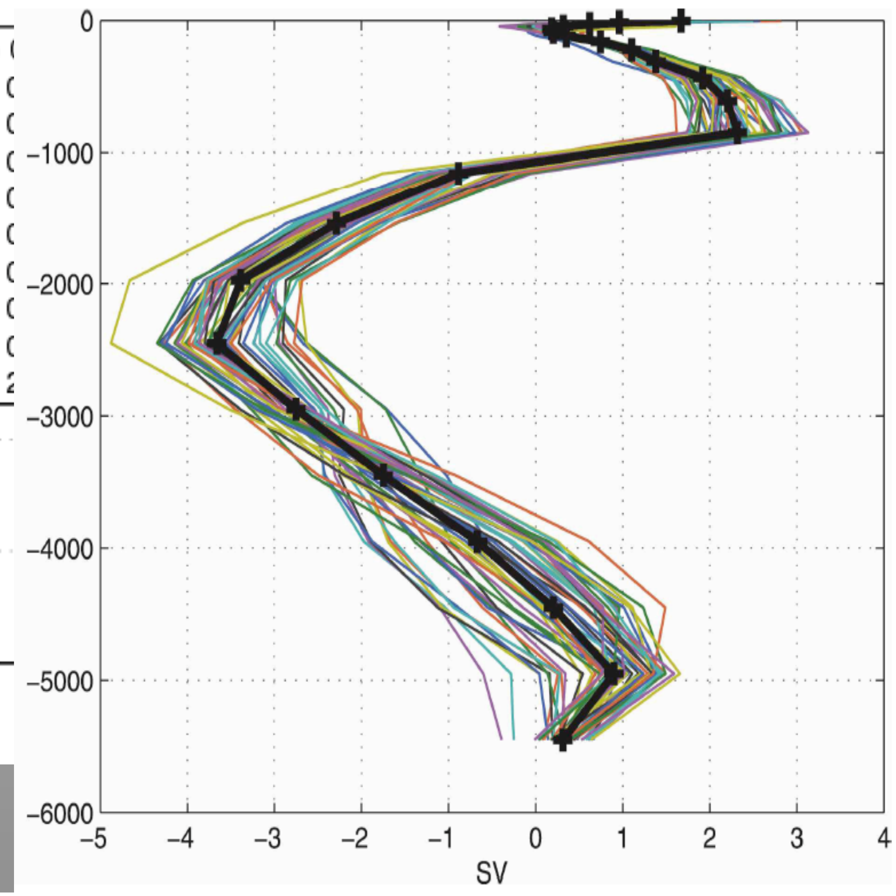
- Only sensitivity found is to SINKING reference level: if level-of-no-motion descended by 100db, this could cancel the transport trend
  → will show below that this leads to unrealistic changes over depth

Annual mean shear profiles

Large interannual changes in amplitude and shear in upper NADW
(variability at 1200db is real) - often LSW core is less pronounced

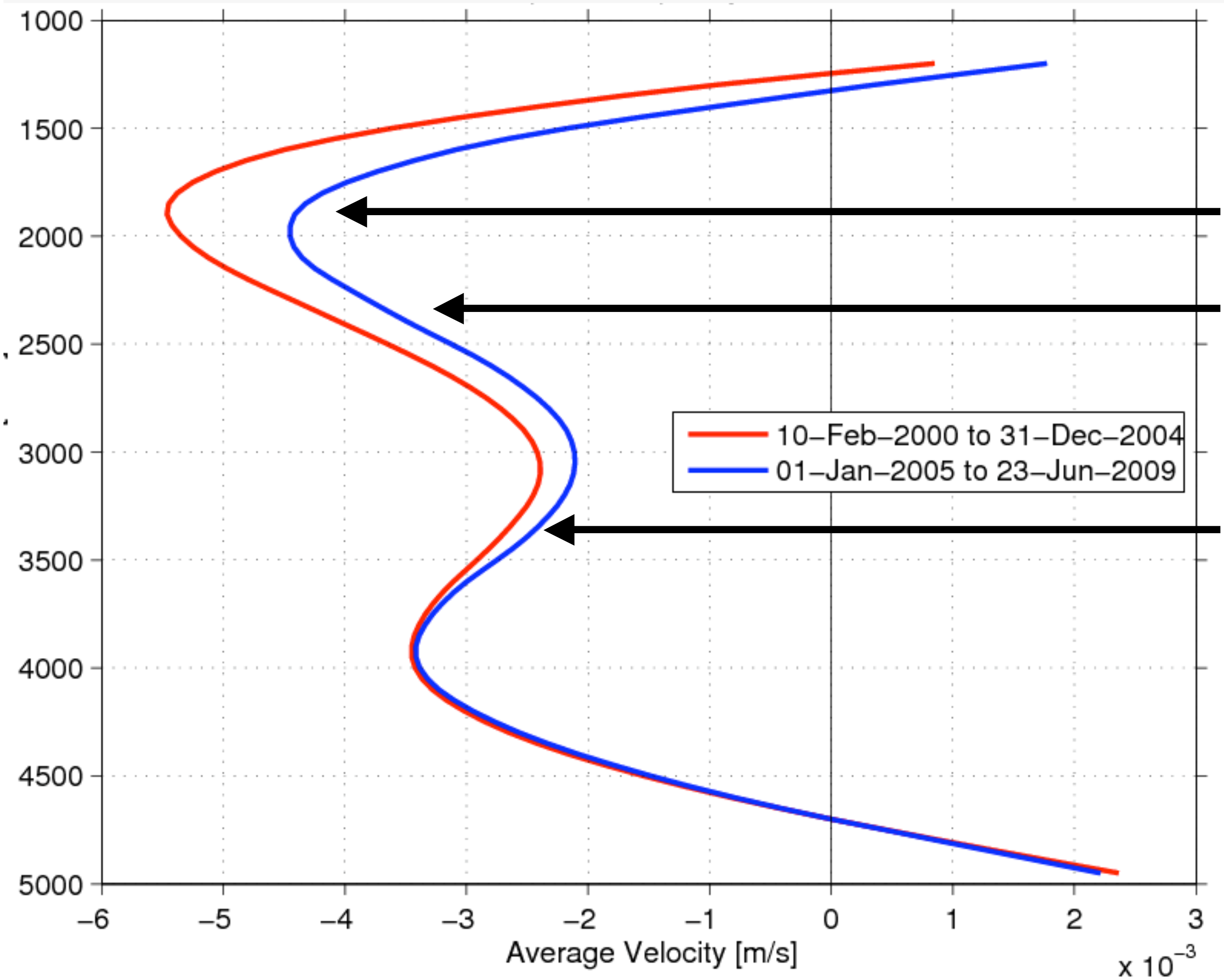


Reminiscent of Wunch&Heimbach profiles



Trends in isopycnal slopes/vertical shear

show weakening upper shear, lowering LSW core, and stronger 3500db shear, all leading to lesser NADW flow amplitude.



Isopycnal slopes from west to east:

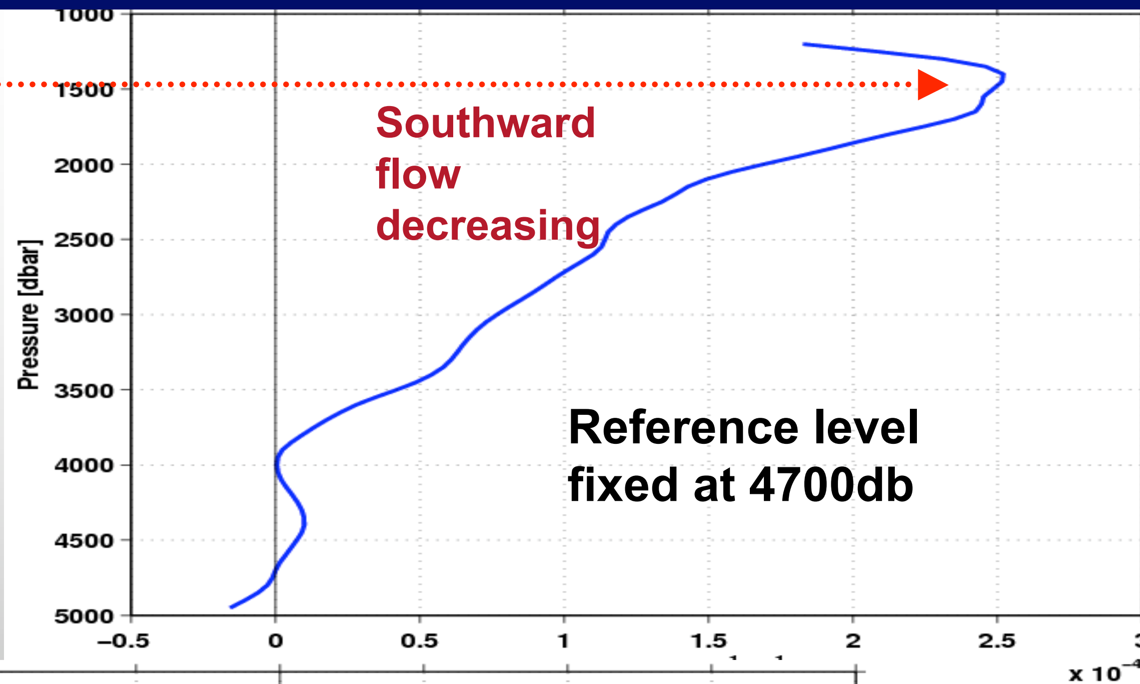
Level, but changing to downward

Sloping up, flattening

Sloping down, steepening

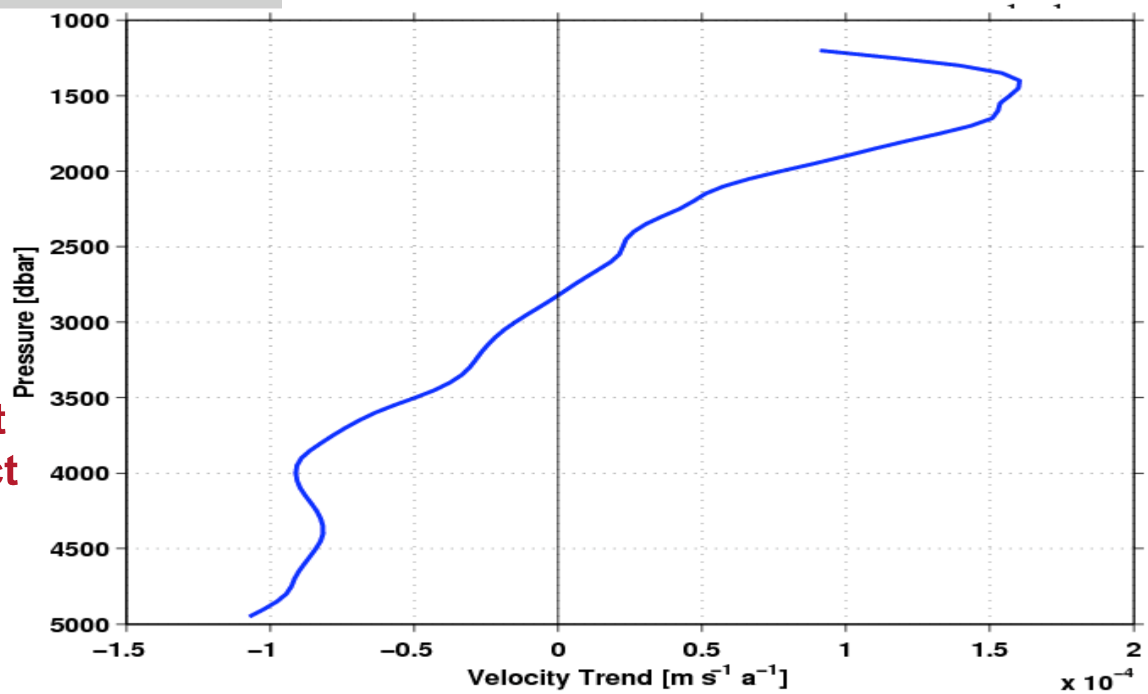
Vertical distribution of transport trend

Maximum at LSW CFC core



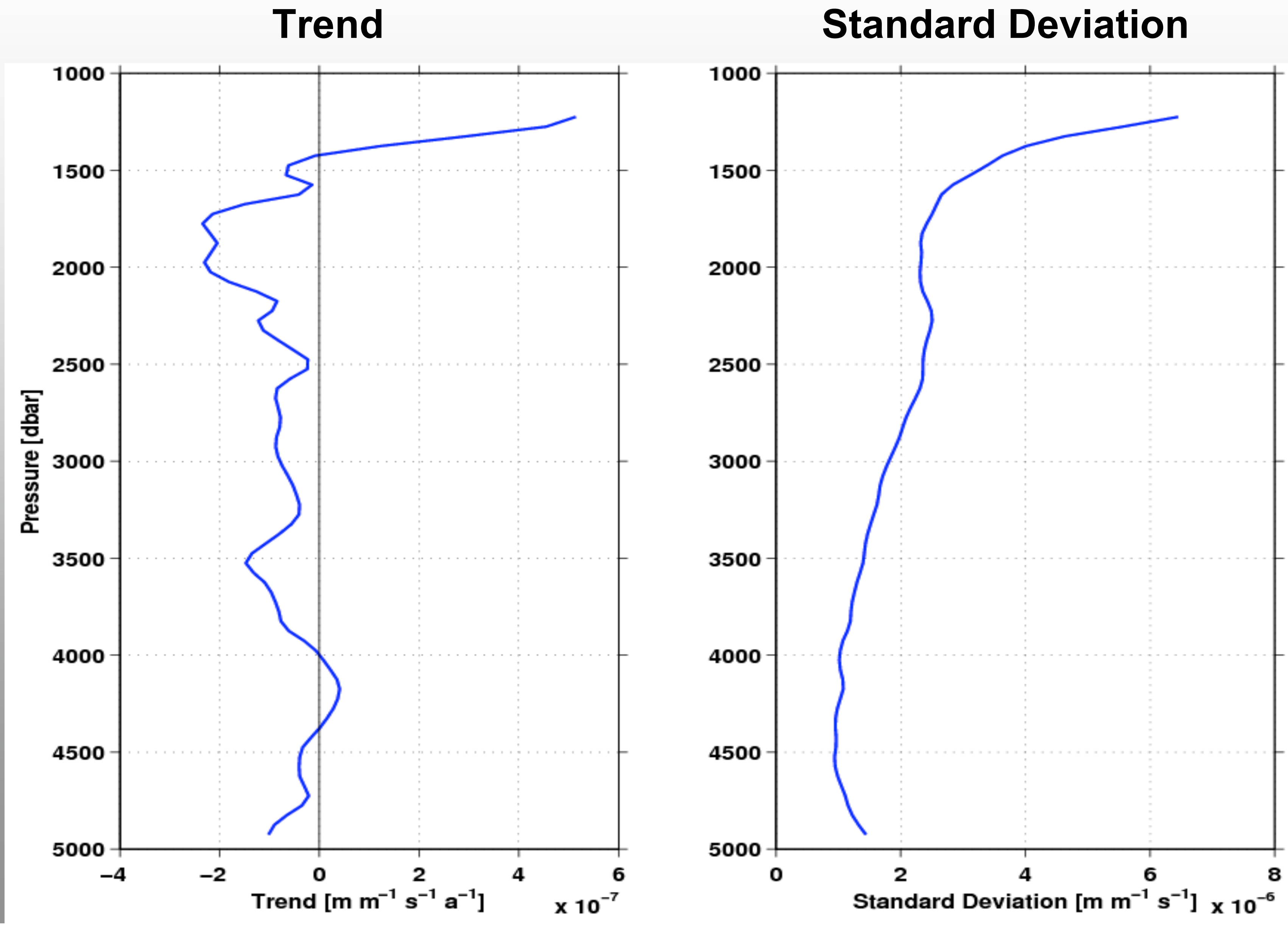
Reference level changing linearly from 4600db to 4700db

(would imply different behaviour of 3 distinct water masses)

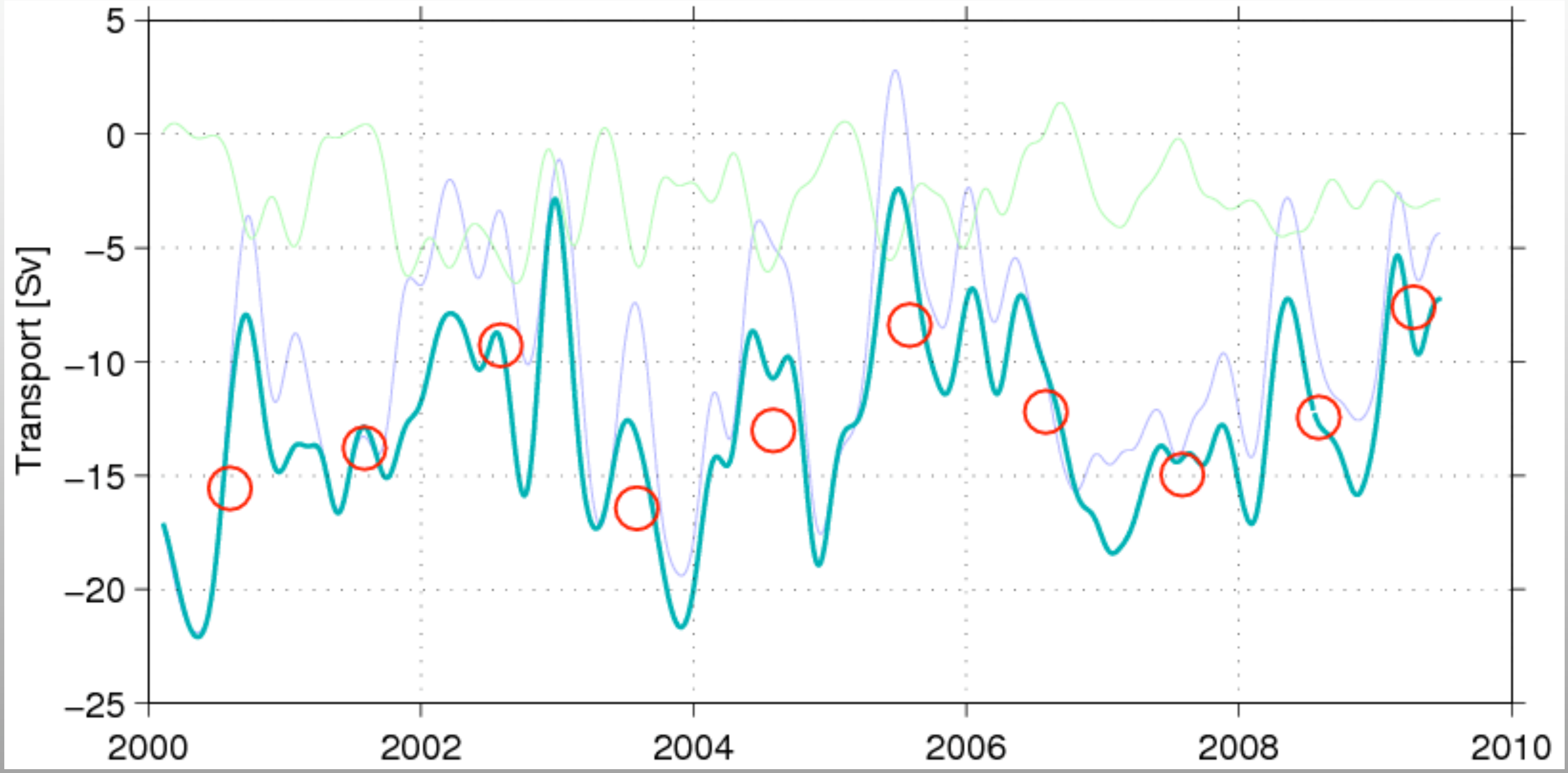


Vertical distribution of shear variability

Most of the changes observed are in the upper NADW layers



Hint of 3-4 year cycle in deep transport ??

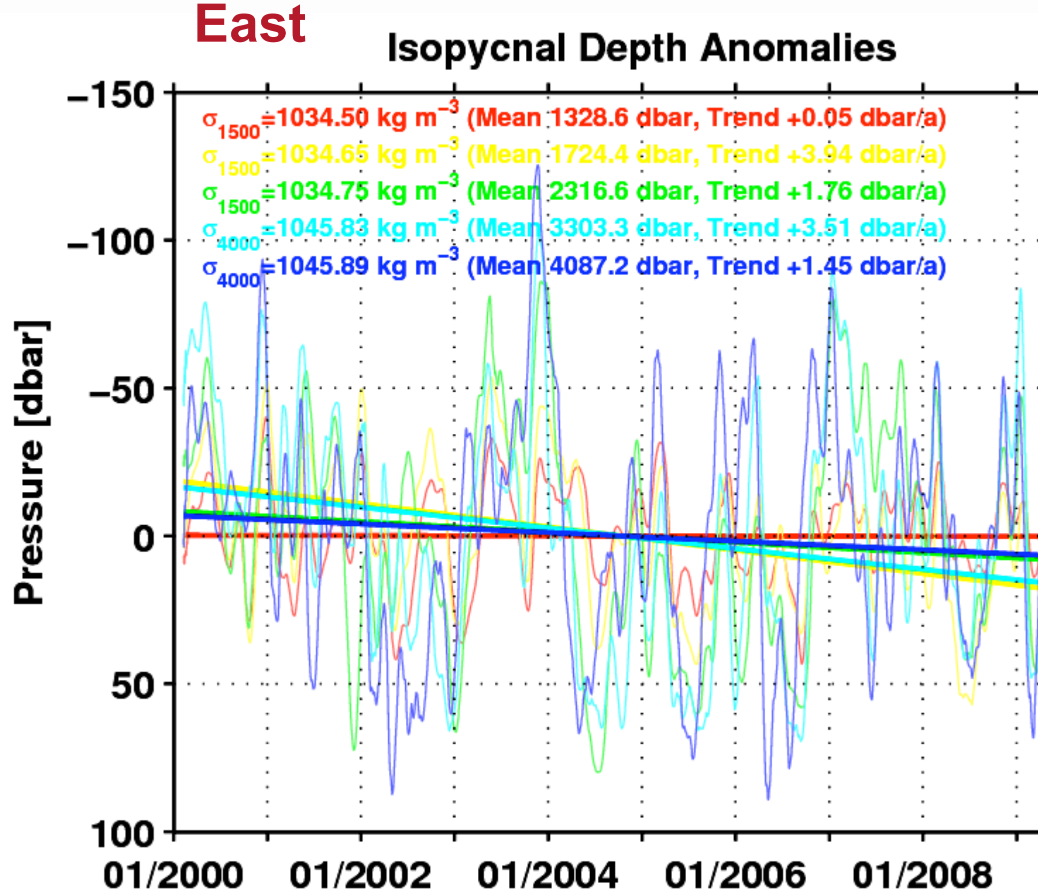


Many isopycnals appear to be sinking

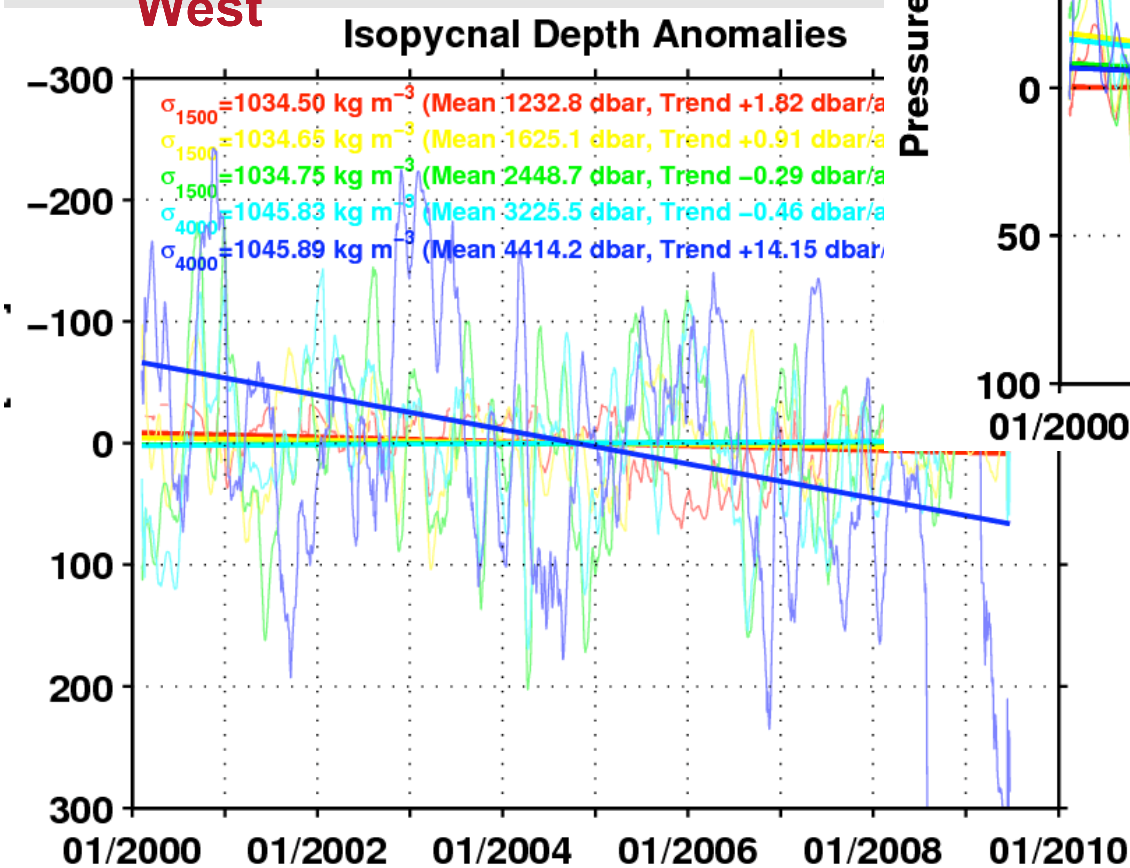
by meters per year

Change in volume of water masses ?

East



West



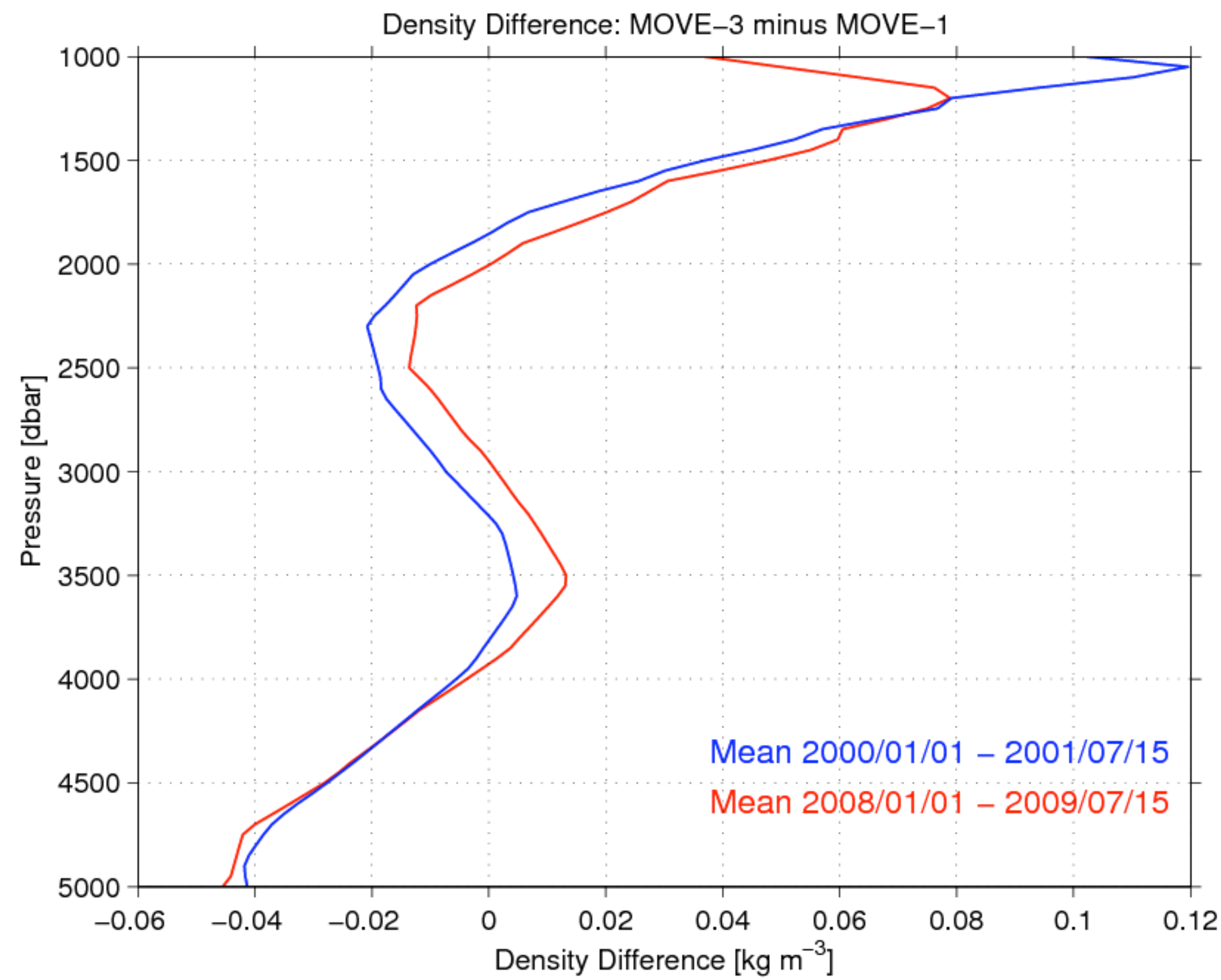
Required density accuracy (observations/assimilation)

The density changes are tiny….

Horiz. differences are 0.02-0.04 σ-units,

But changes over 8 years are 0.003-0.006 in σ, giving 3-6Sv transport change.

This requires measuring S and T to 0.003-0.006psu and 0.003-0.006°C



Assimilation runs usually assign much larger errors to hydrographic data, thus are never constrained enough to capture MOC changes… May need to assimilate transports or isopycnal depths.

Summary

- southward MOC transport weakening with 3Sv/10yrs
  - trend is not sensitive to processing/assumptions, and 85% certain
  - shear and transport changes are concentrated in LSW layer
  - a consistent picture is emerging
- indications of 3-4 yr period in transport
- isopycnals are generally descending over 10 years

- need to merge with RAPID and higher-lat observations to address connectivity of MOC changes
- MOVE data are available now for model applications - need to study better ways to constrain models with them
- future MOVE data will be available on a routine&sustained basis