Observing the Meridional Overturning Circulation at 26°N in the Atlantic

Johanna Baehr, Jochem Marotzke
Max-Planck-Institut für Meteorologie

Joël Hirschi
National Oceanographic Center Southampton

Klaus Keller
Pennsylvania State University

Overview

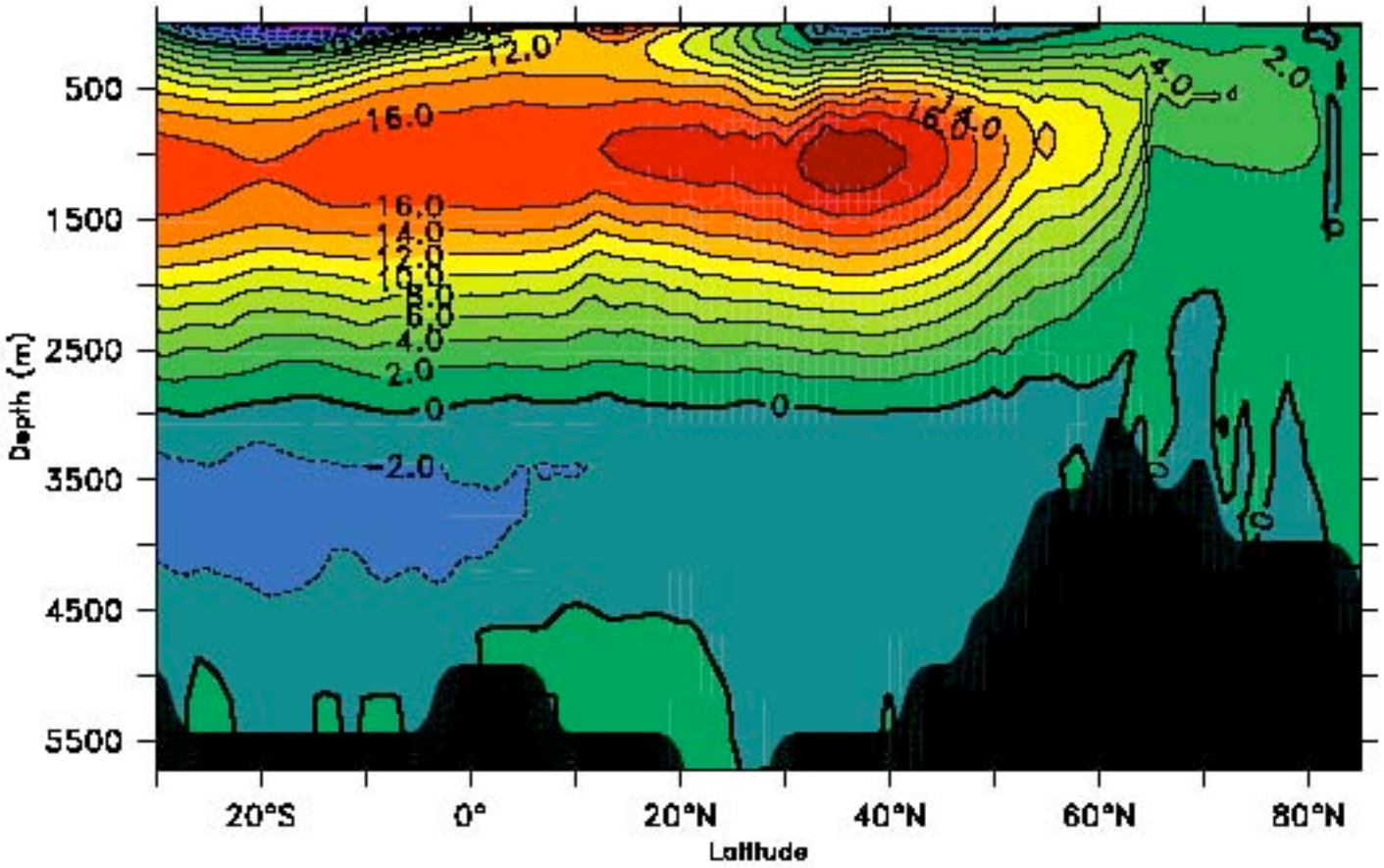
- Model based MOC monitoring array design
- RAPID UK 26°N MOC monitoring array
- Can the RAPID array detect changes in the MOC at 26°N?

Total MOC = THC + wind-driven MOC

- Meridional Overturning Circulation (MOC): Total northward/southward flow, over latitude and depth
- THC is an interpretation; MOC the observable quantity
- THC: Part of the MOC, driven by heat & water exchange with atmosphere

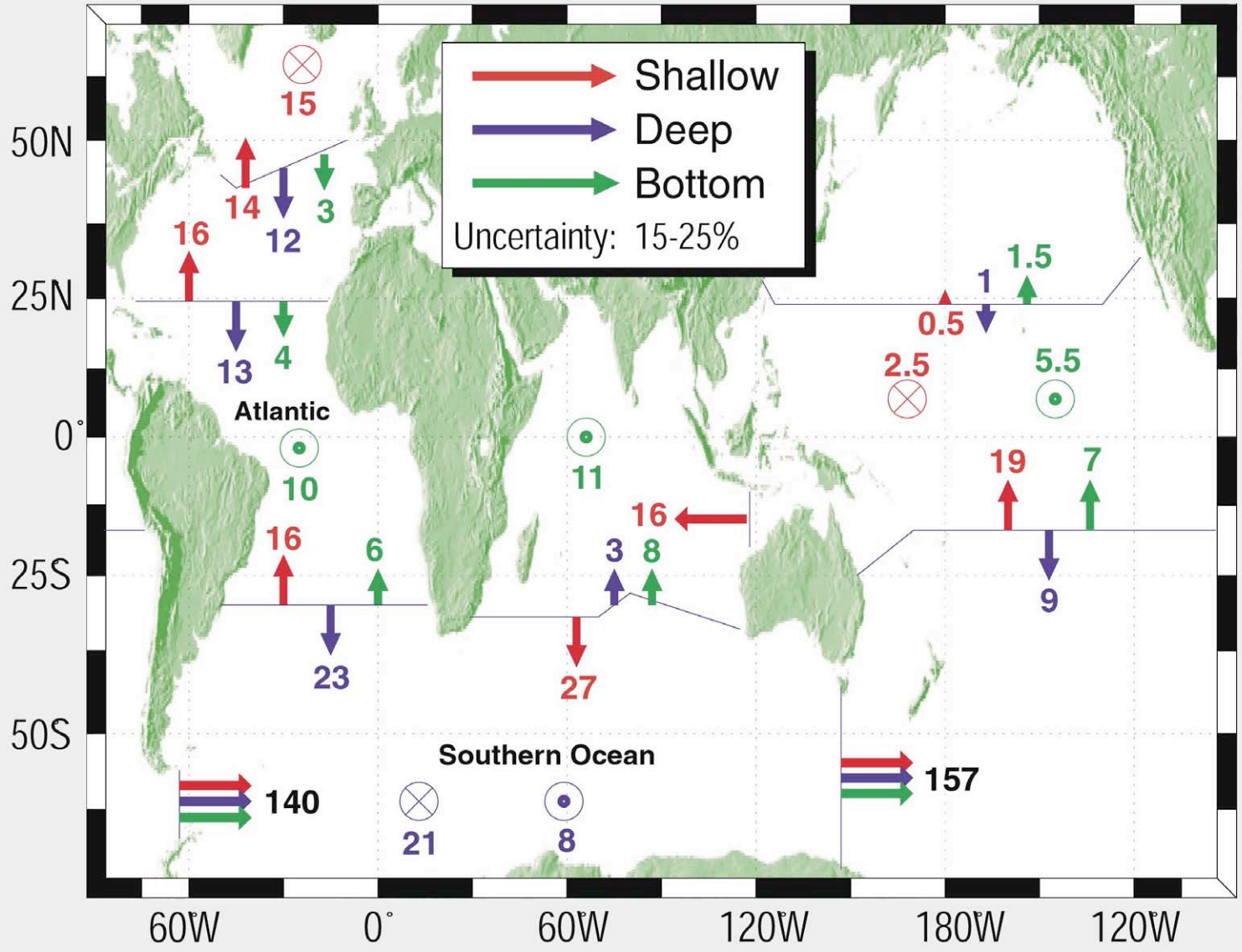
Background

MOC: zonally integrated meridional flow as a function of latitude and depth



ECHAM5/ MPI-OM

Global ocean circulation, based on Ganachaud and Wunsch (2000)



U.S. National Research Council (NRC, 2002)
Abrupt Climate Change – Inevitable Surprises

Array Design Study in FLAME

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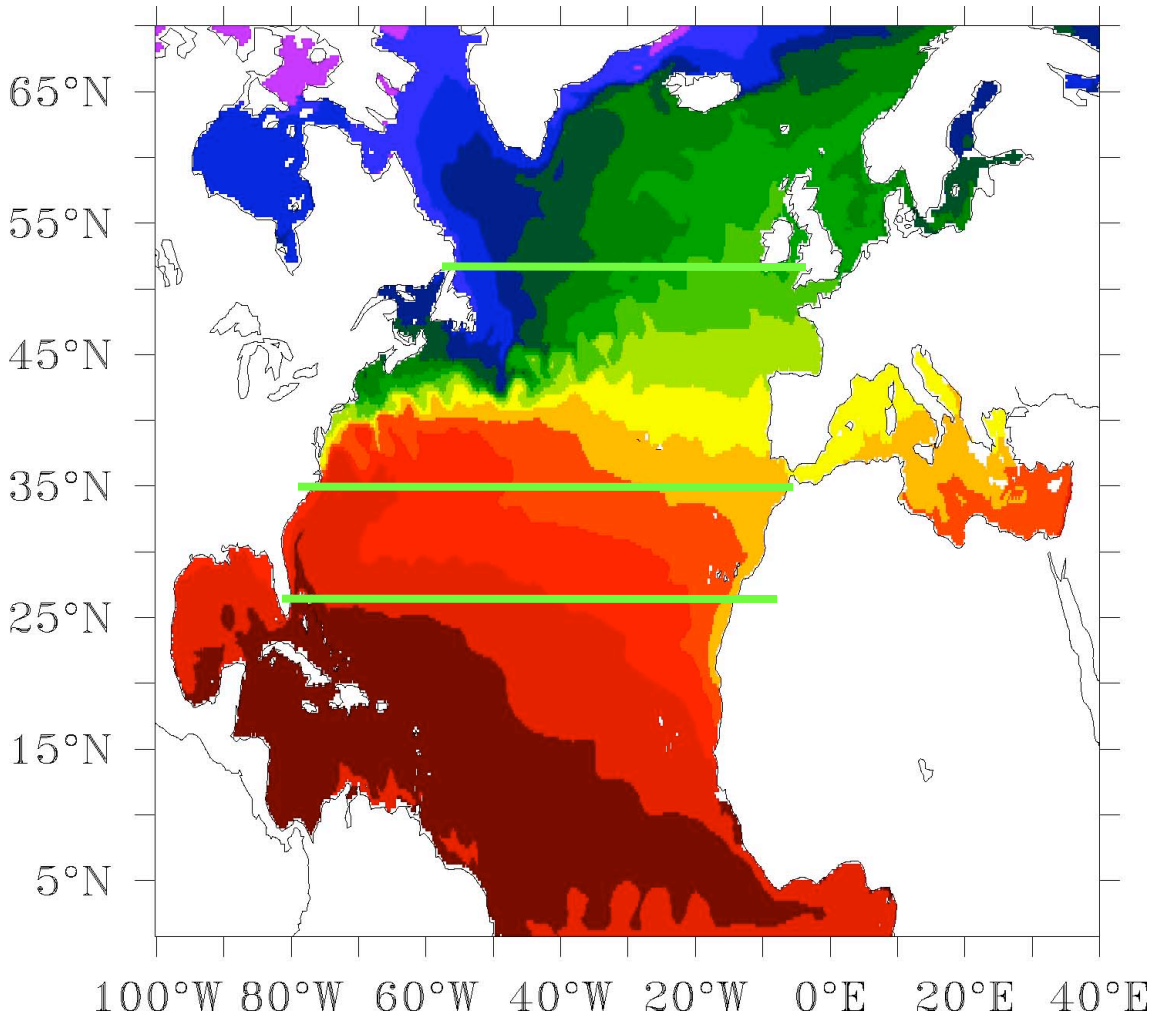
53°N

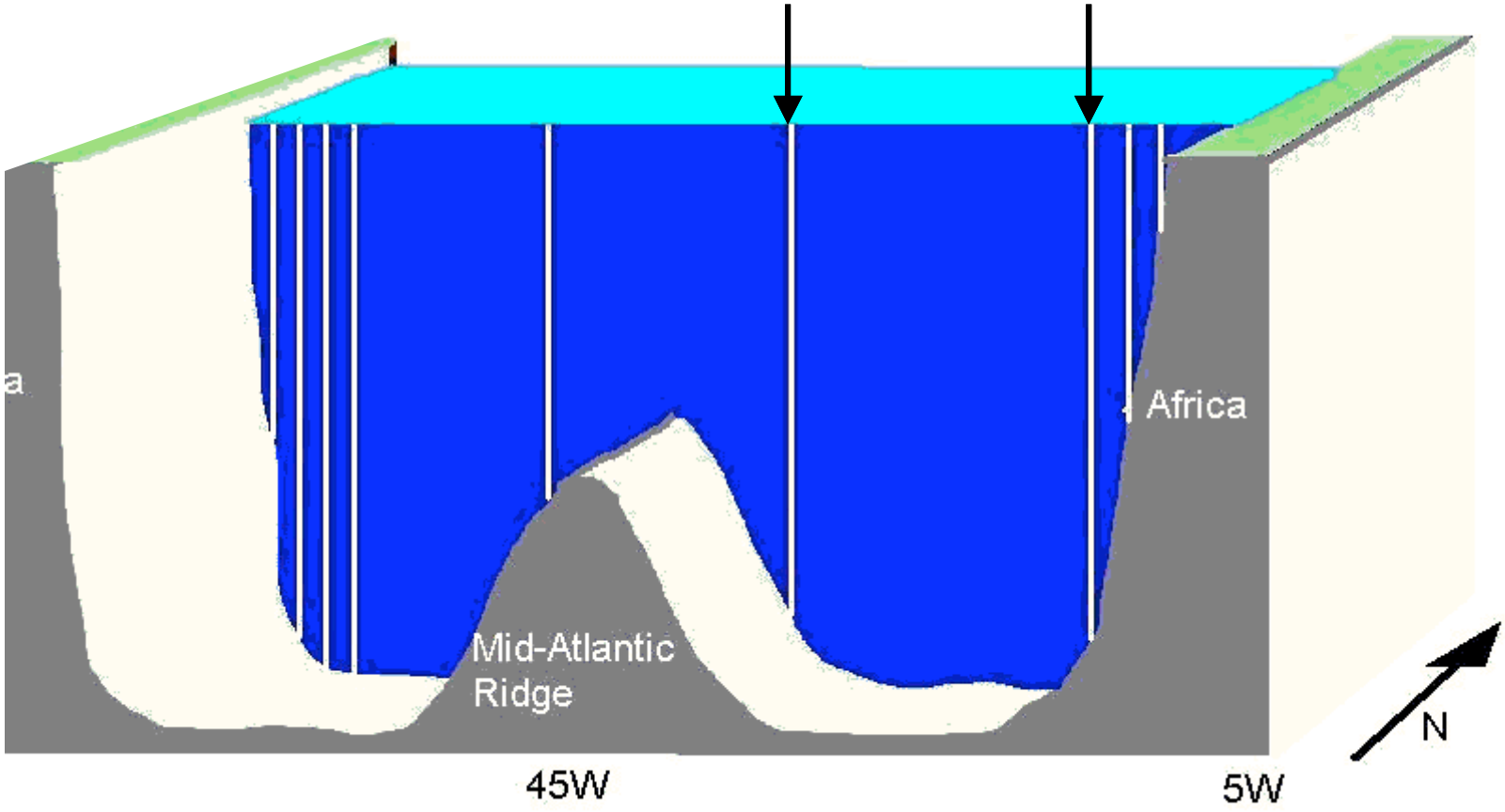
36°N

26°N



Thermal wind contribution (tw)

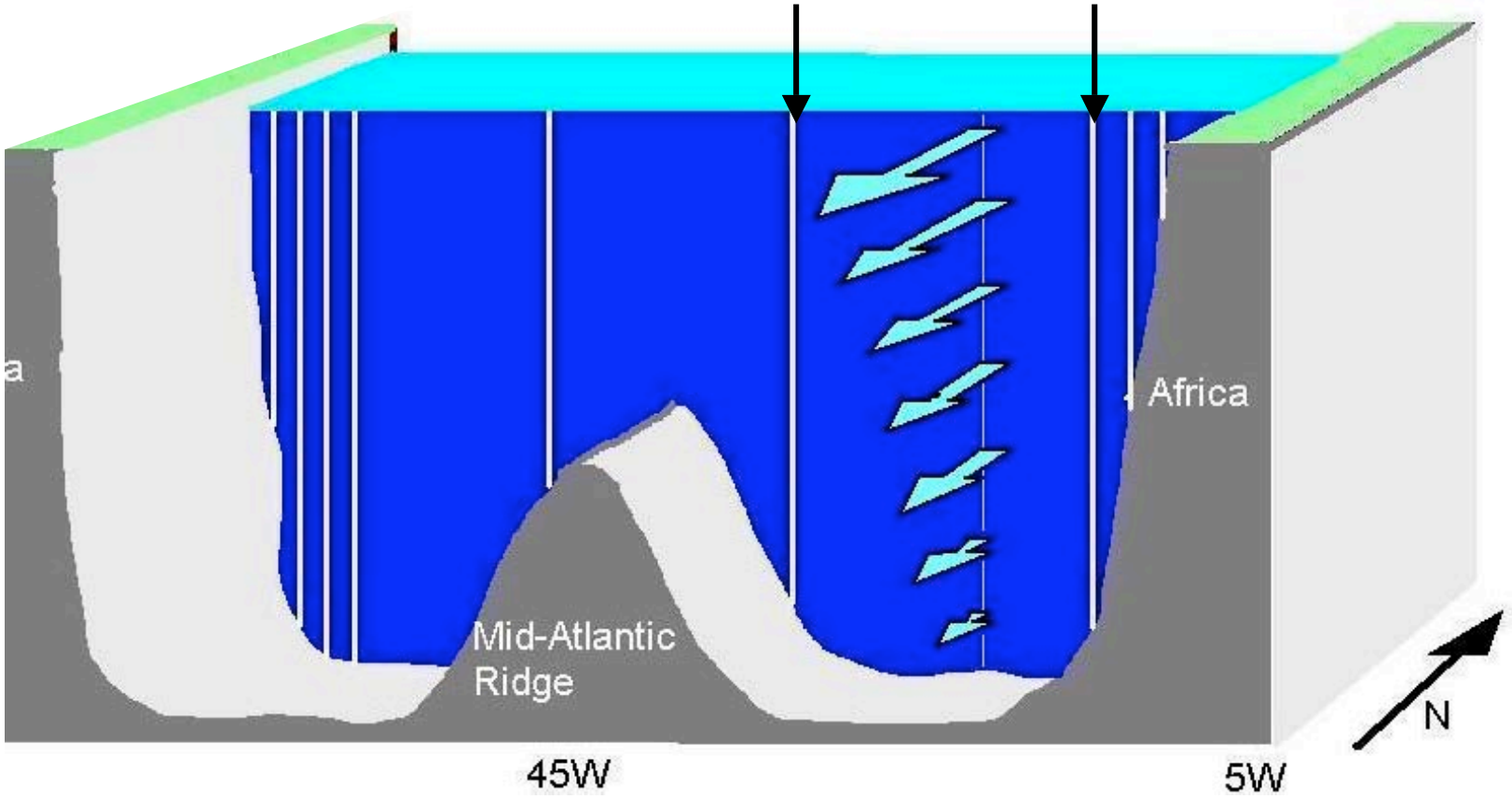
Velocities obtained between adjacent density profiles



Hirschi et al., 2003

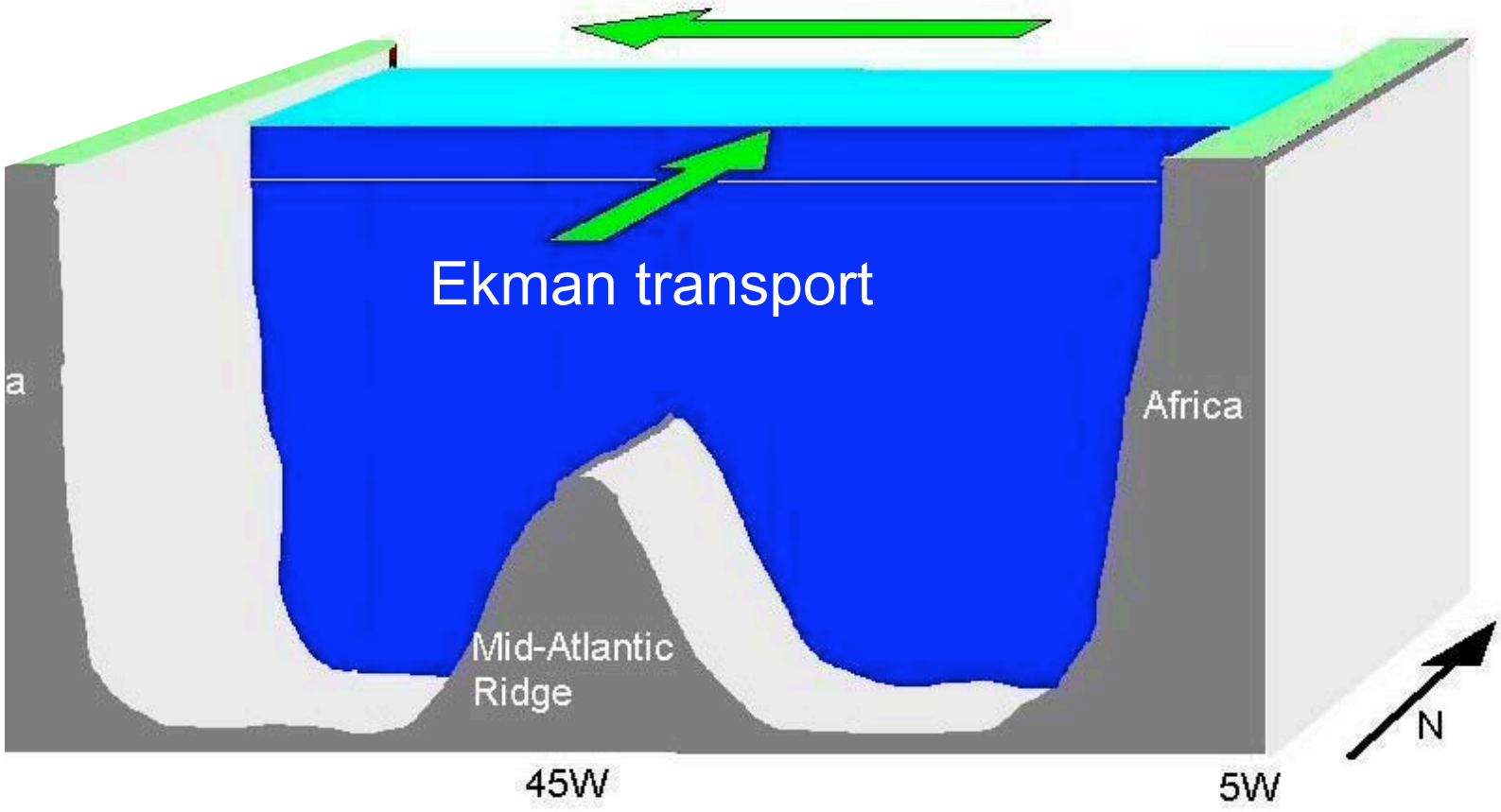
Thermal wind contribution (tw)

Velocities obtained between adjacent density profiles



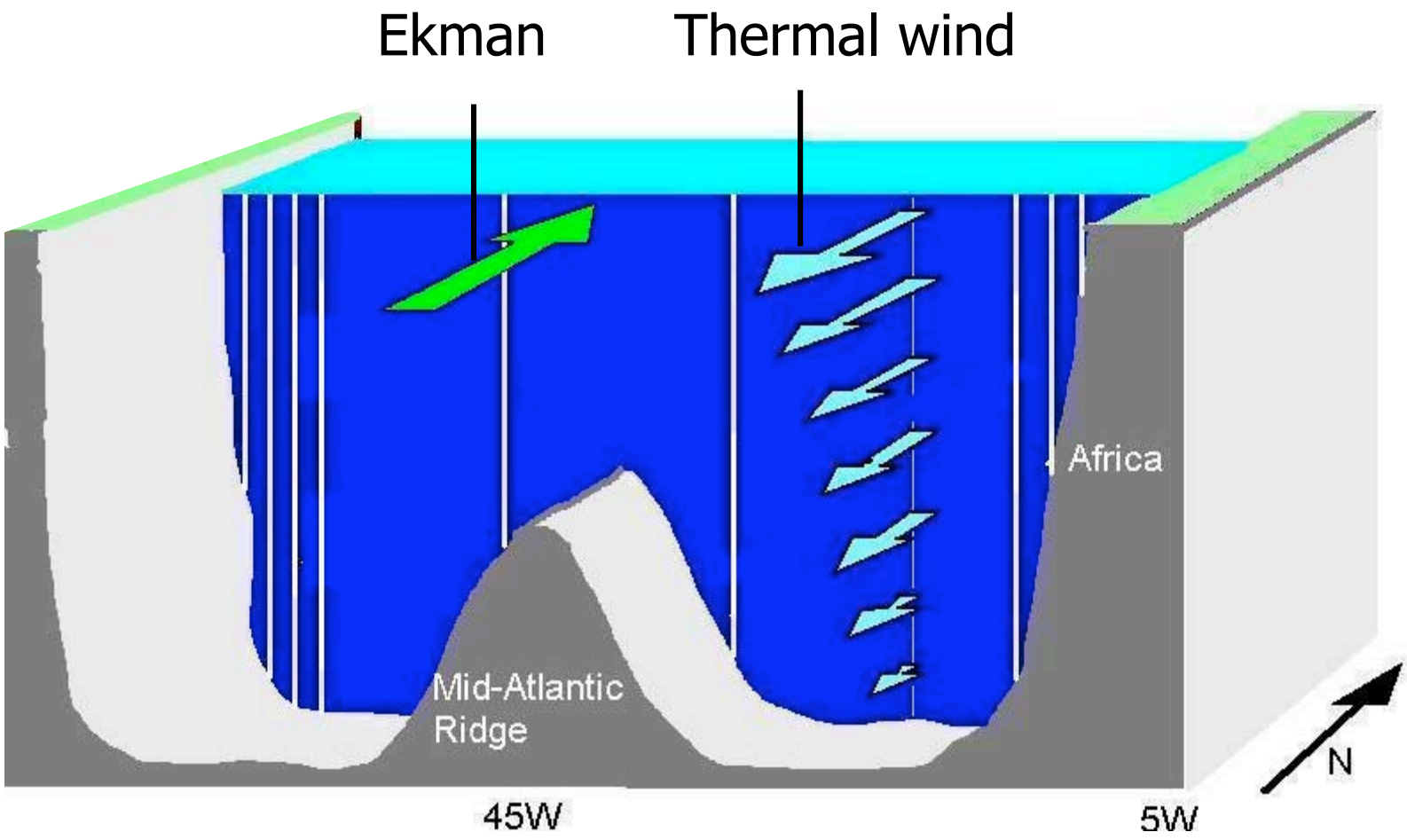
Hirschi et al., 2003

Ekman contribution (ek)



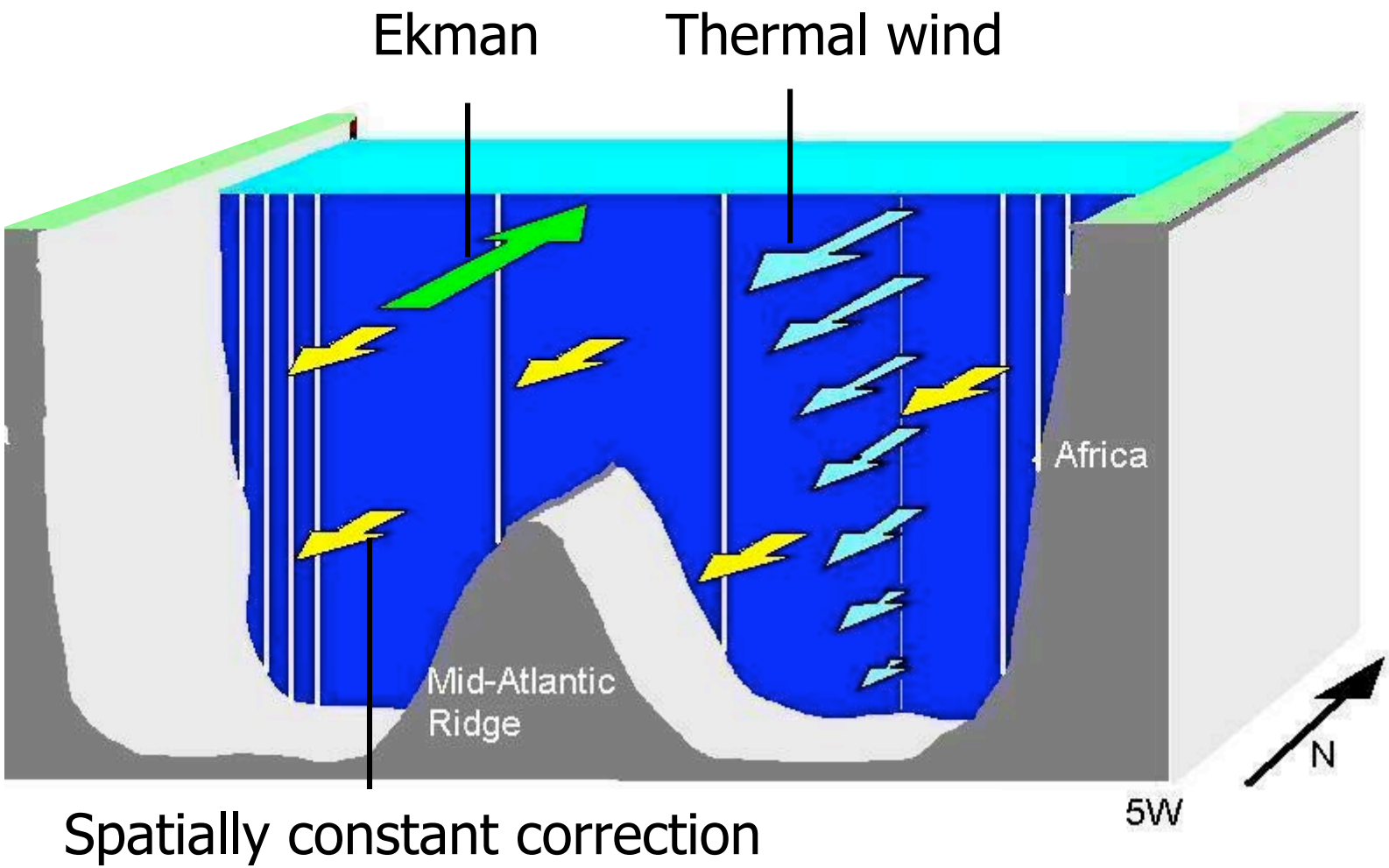
Hirschi et al., 2003

Total MOC: tw + ek



Hirschi et al., 2003

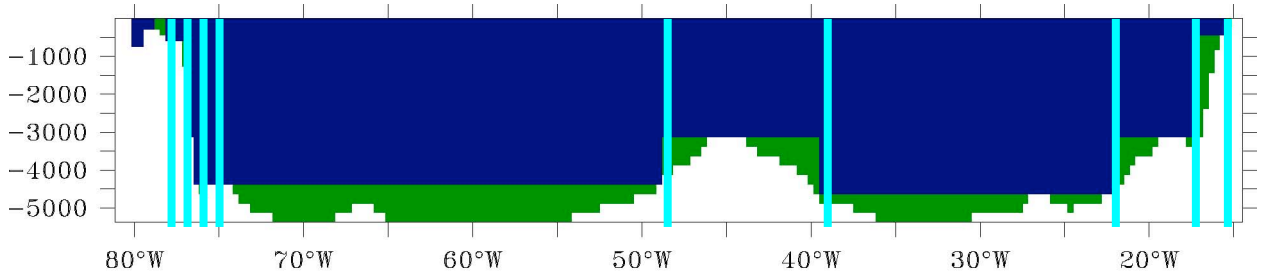
Total MOC: tw + ek + correction



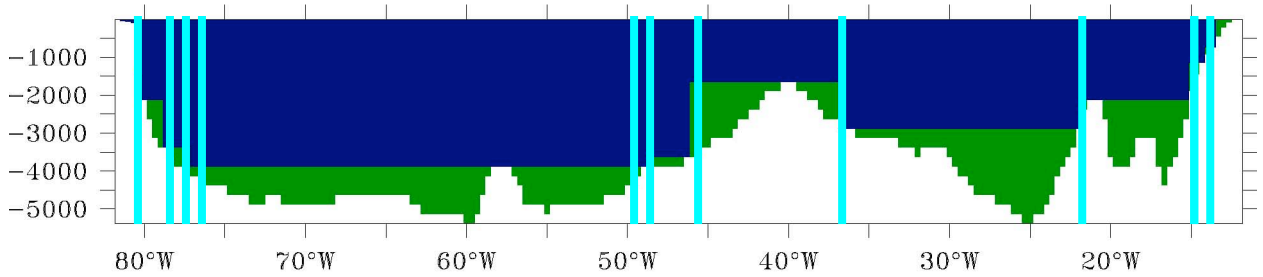
Hirschi et al., 2003

Placement of density profiles

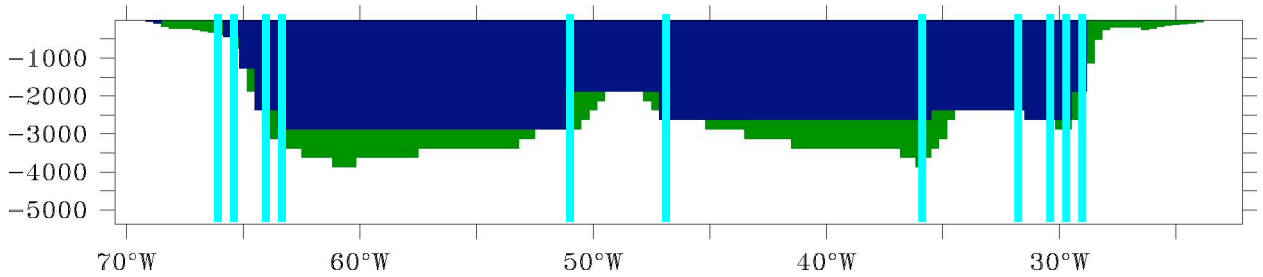
26°N



36°N



53°N



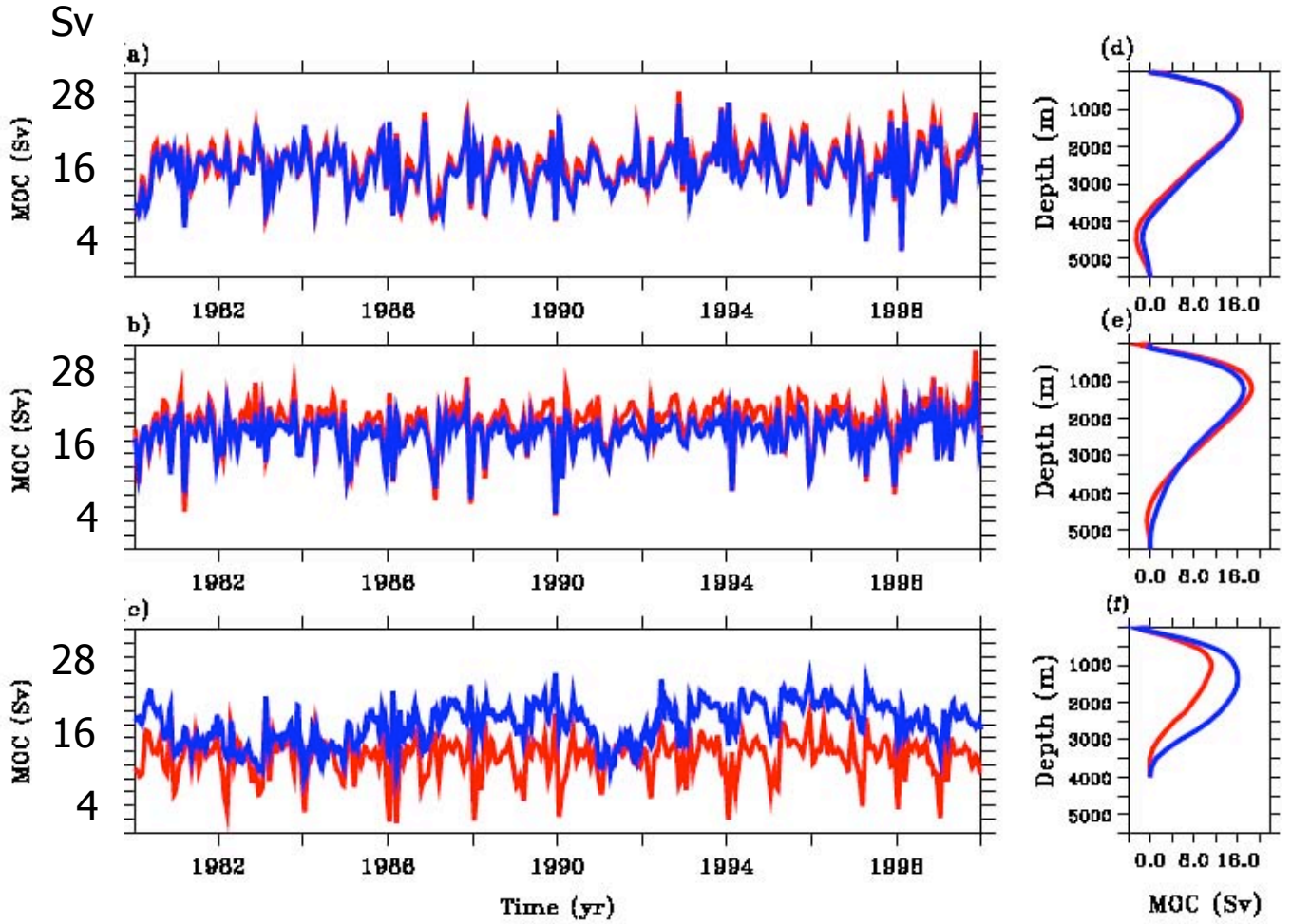
Baehr et al., 2004

MOC reconstruction based on simple array

26°N

36°N

53°N



MOC Reconstruction (tw+ek)

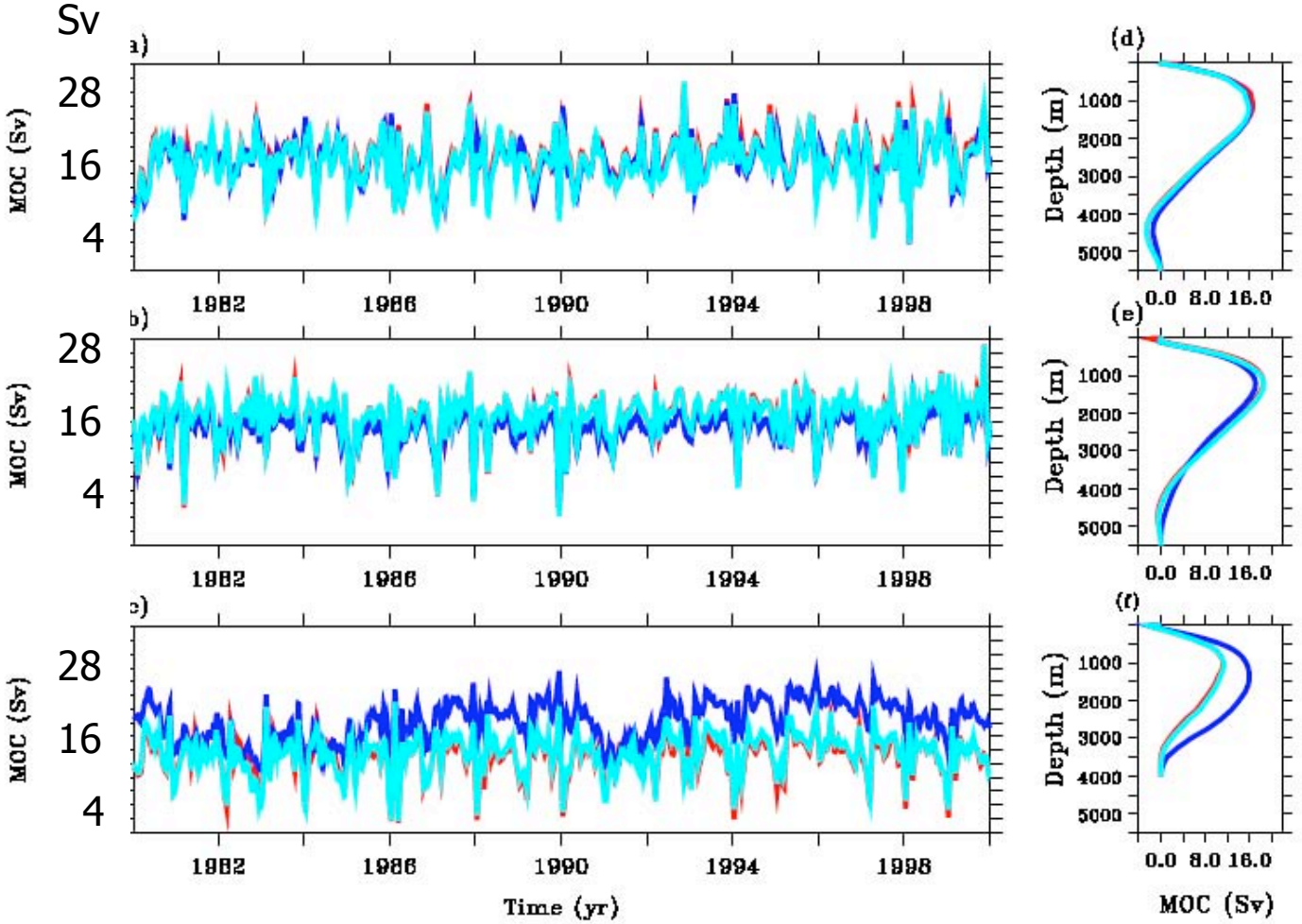
Baehr et al., 2004

MOC reconstruction based on array and bottom velocities

26°N

36°N

53°N

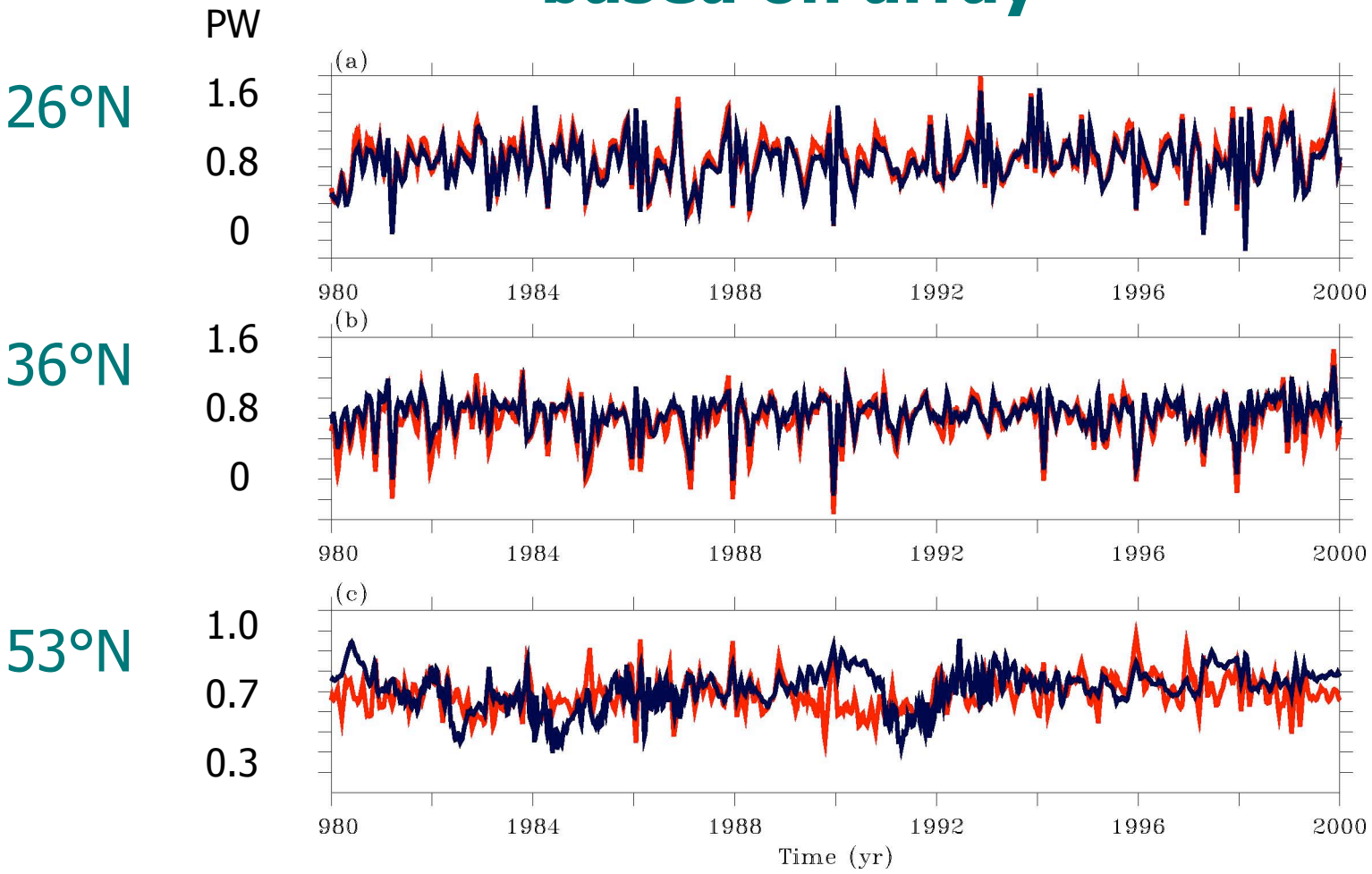


Reconstruction ($tw_{\text{incl. bottom velocities}}$+ek)

MOC — Reconstruction (tw+ek)

Baehr et al., 2004

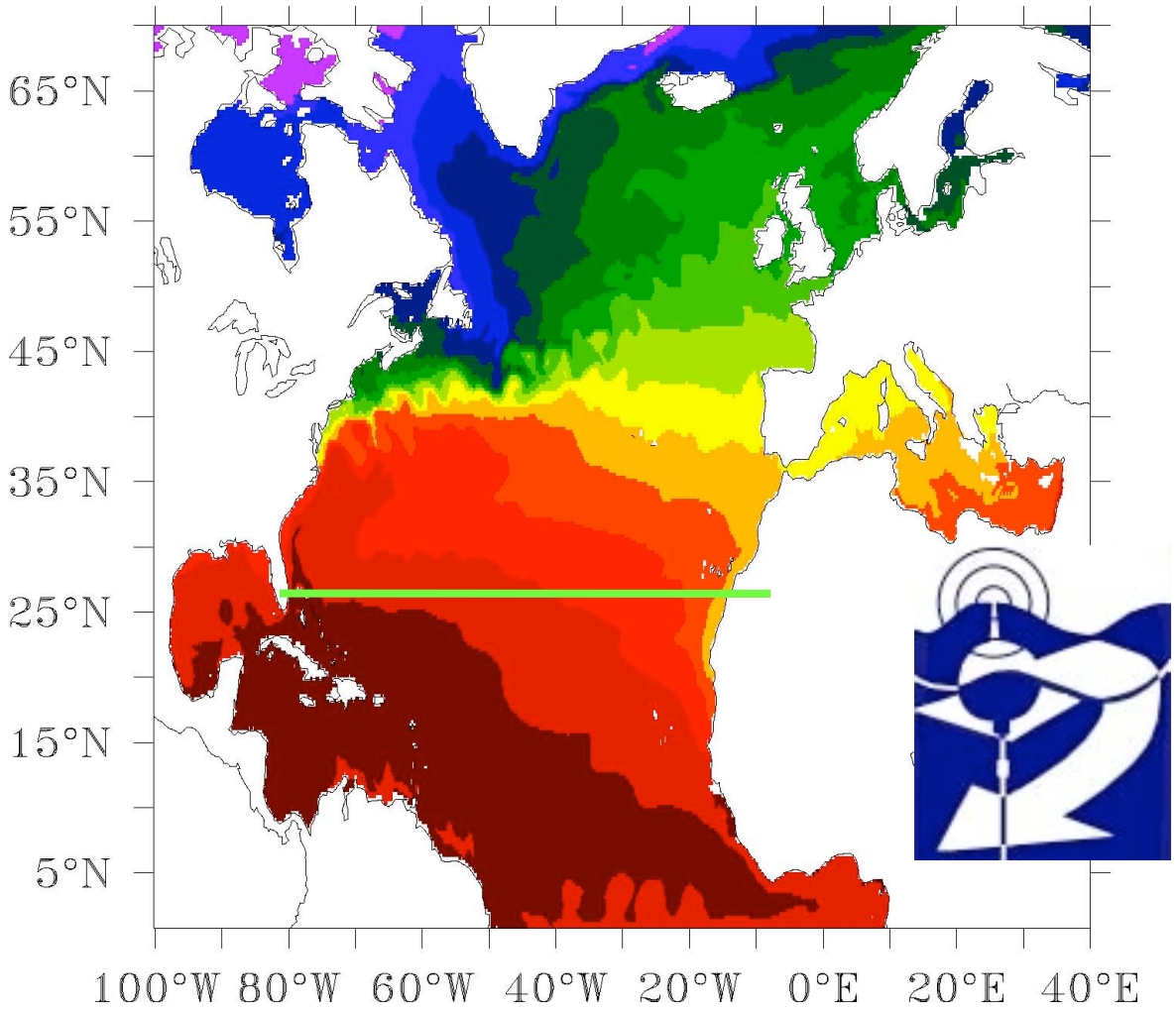
Meridional Heat Transport: reconstruction based on array



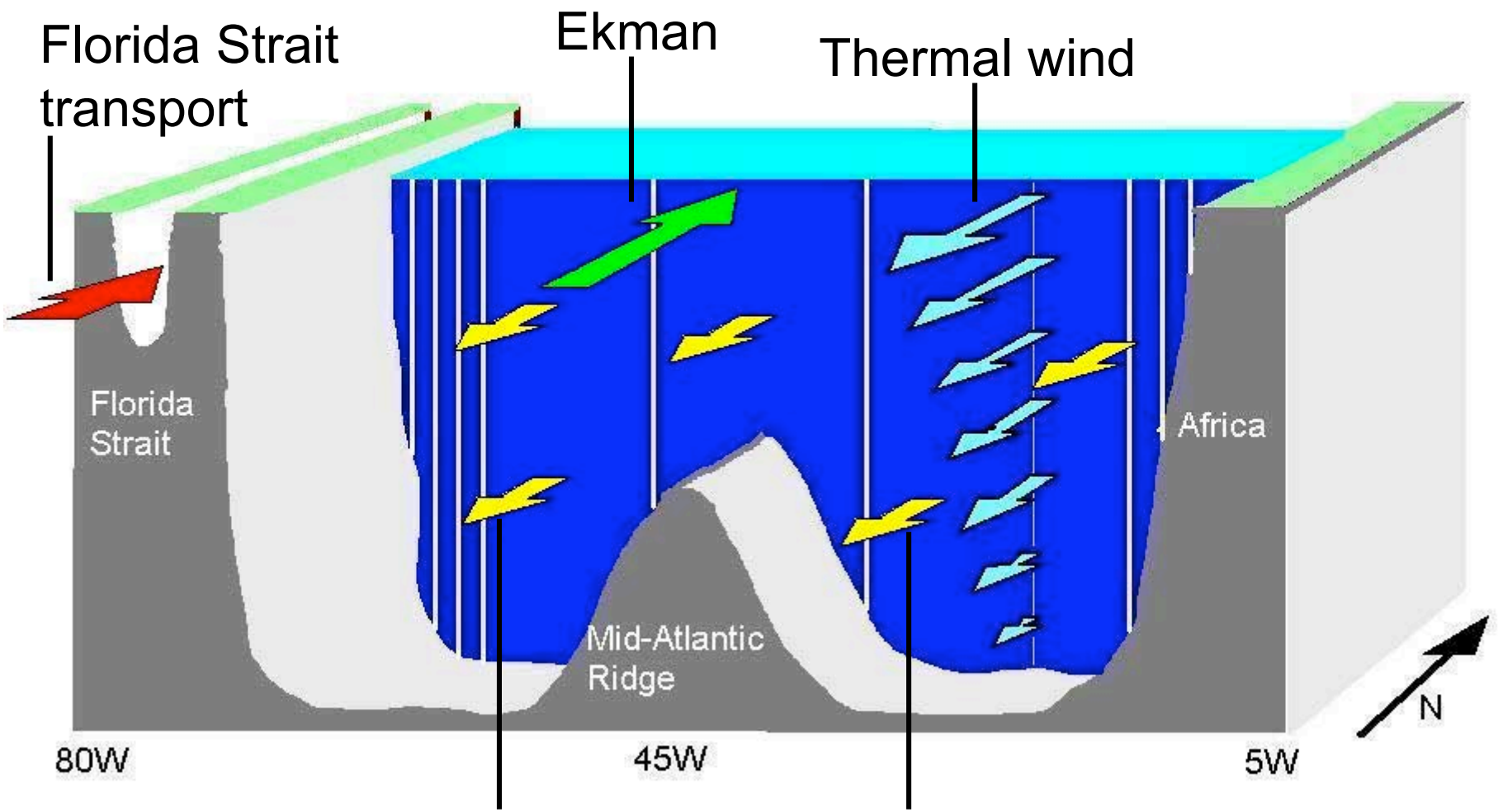
Baehr et al., 2004

Atlantic MOC at 26°N

26°N



Atlantic MOC at 26°N



Spatially constant correction for the velocity field to ensure the mass balance

Hirschi et al., 2003

26.5°N MOC RAPID project

- PIs: Jochem Marotzke (MPI & NOCS), Stuart Cunningham, Harry Bryden (NOCS)
- Funding: UK NERC, £4.0M over 5 years
- Start: 1 April 2003
- First instrument deployment: February 2004
- First instrument recovery: April 2005
- www.noc.soton.ac.uk/rapidmoc

Monitoring the Atlantic MOC at 26°N

Marotzke, Cunningham, Bryden, Johns, Baringer, Beal

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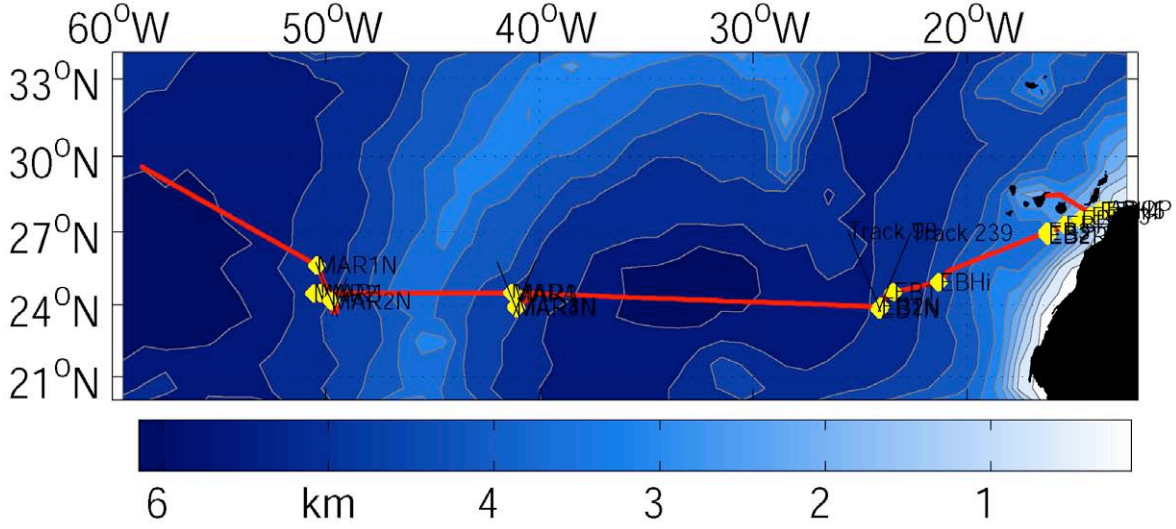
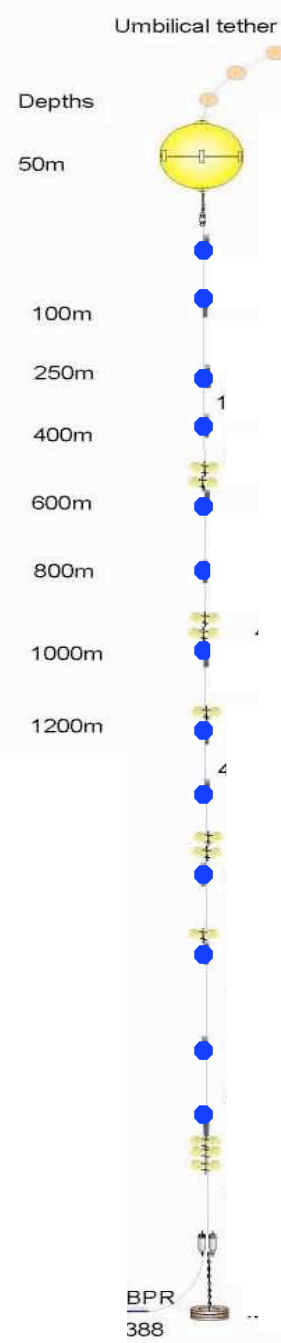
2004 mooring deployment:

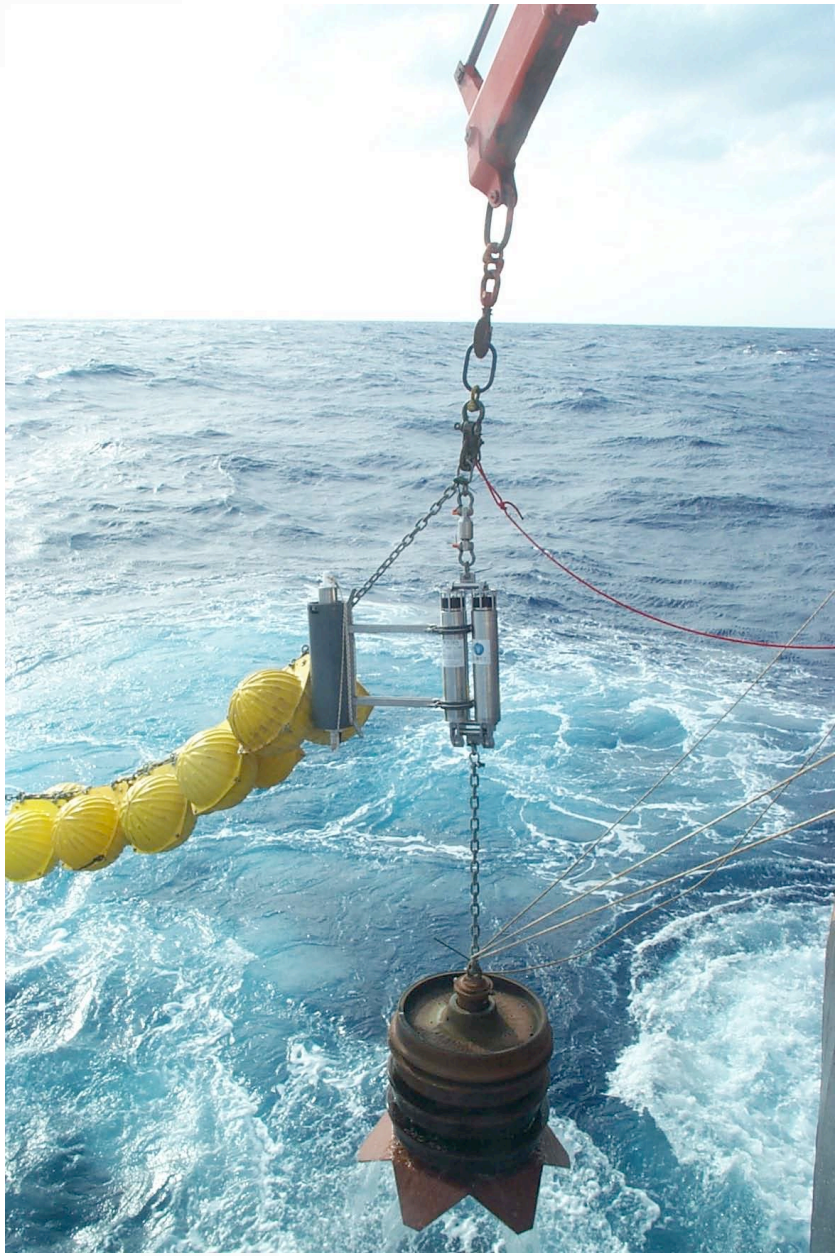
April & May 2005: First data recovery



CD170 2005 cruise track and mooring stations

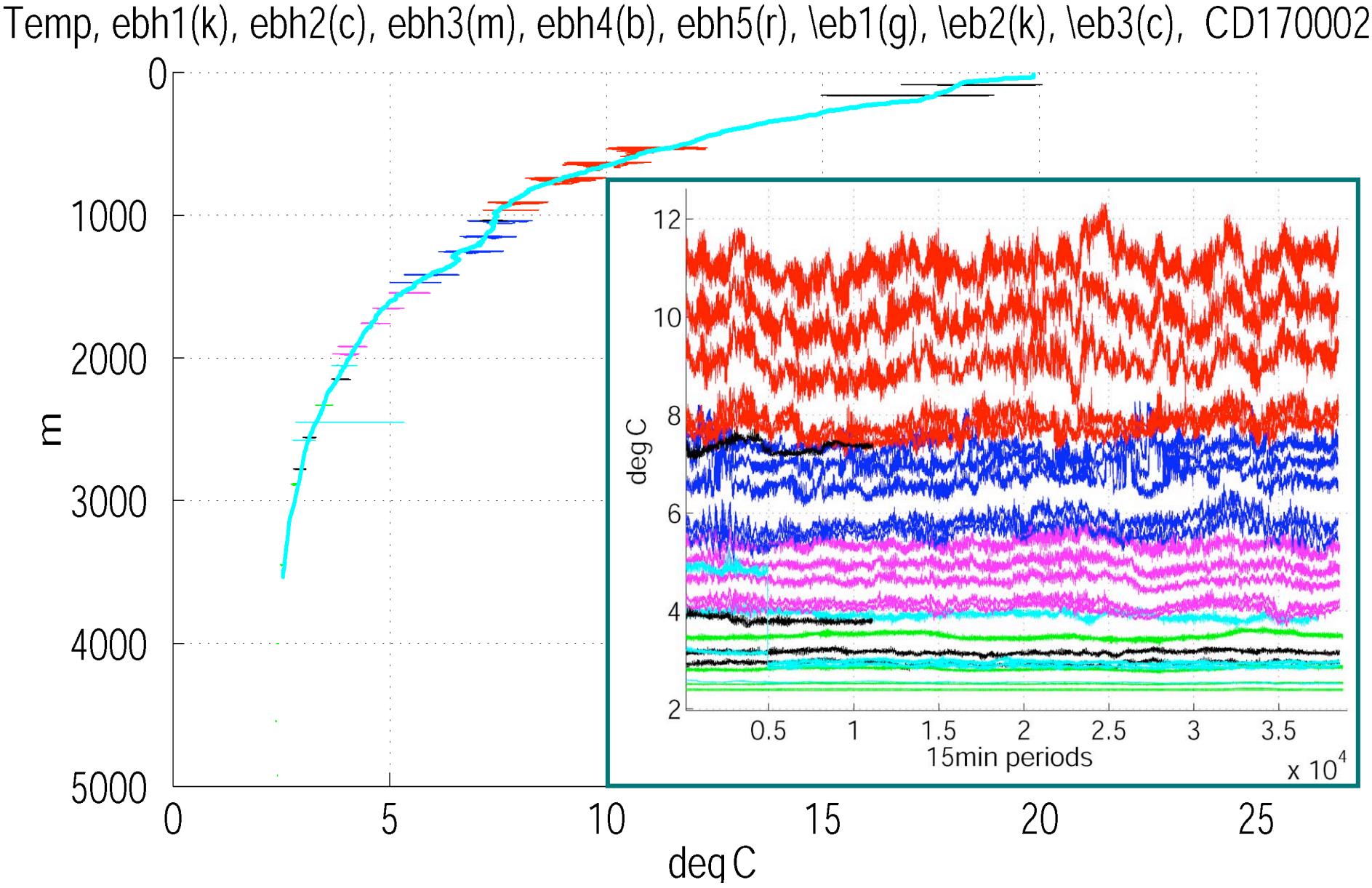
Figure 13: Mooring Diagram of EB3





RAPID 26.5N EB3 - At Sea

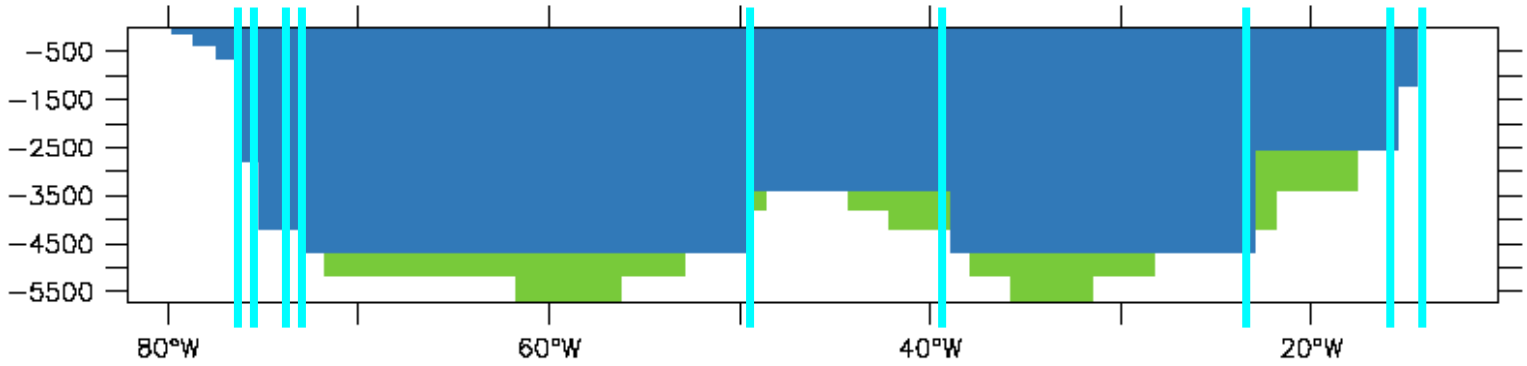
Temperature near eastern boundary



Model MOC at 26°N

ECHAM5/ MPI-OM

Simulated MOC Monitoring



ECHAM5/ MPI-OM, 26°N

MOC at 26°N

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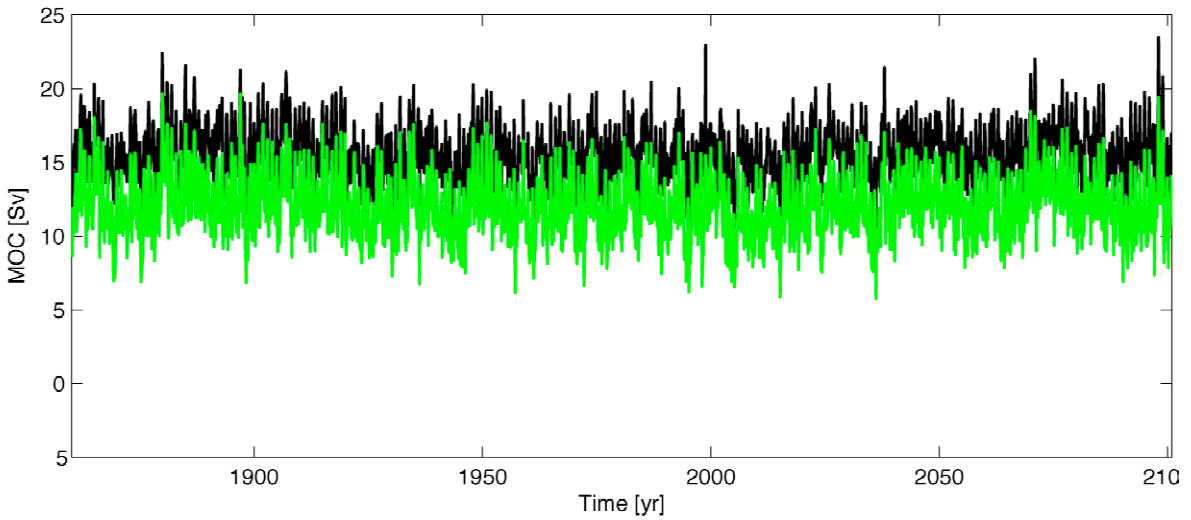
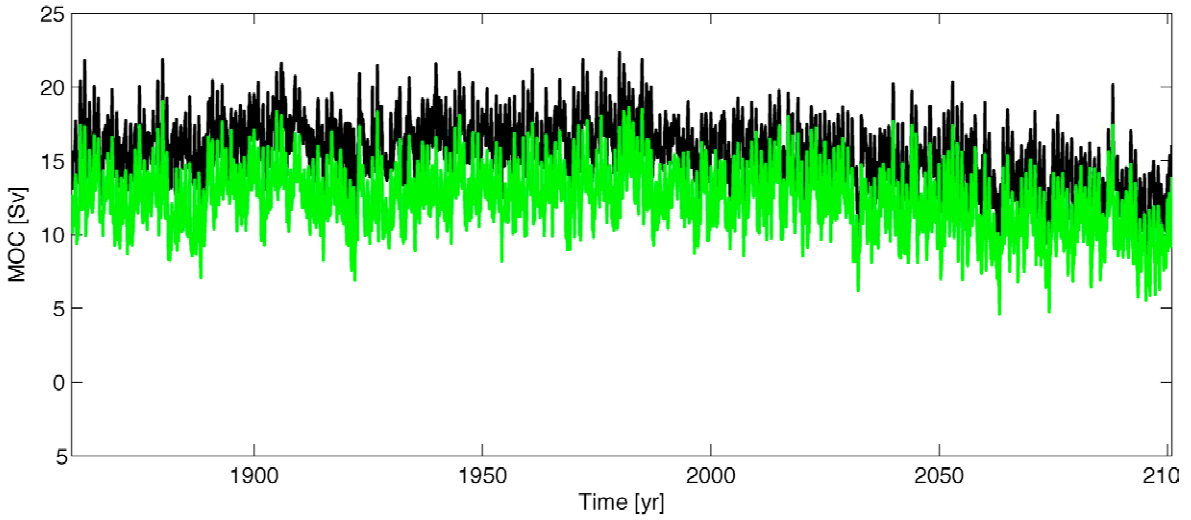
Control



Scenario

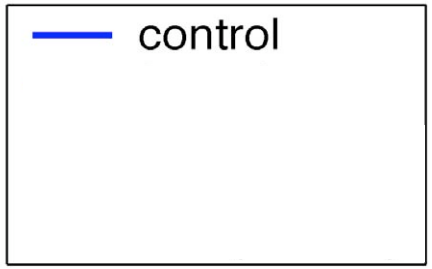


Model MOC — Reconstruction

Ein Institut der Max-Planck-Gesellschaft
An Institute of the Max Planck Society

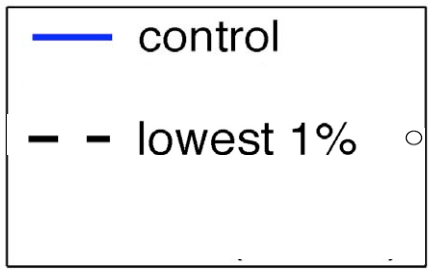
Detection

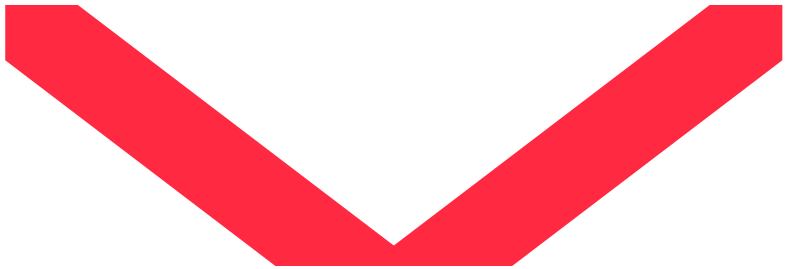
Model MOC



Detection

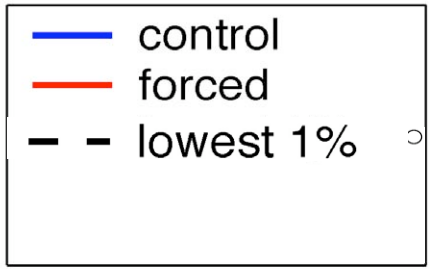
Model MOC

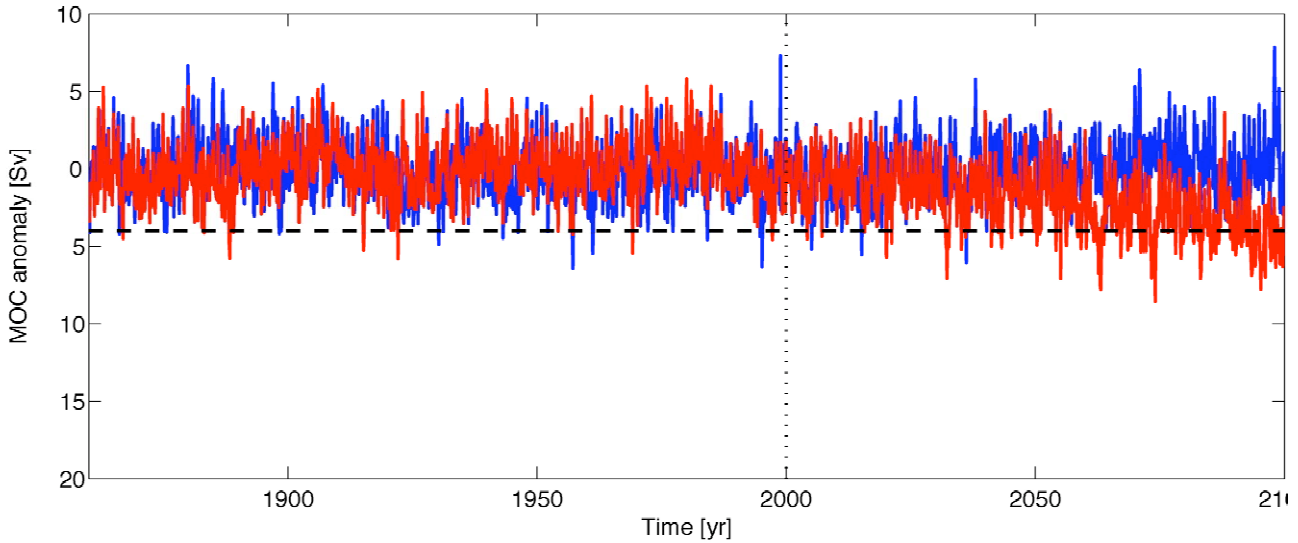




Detection

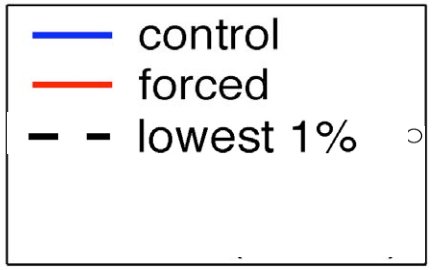
Model MOC

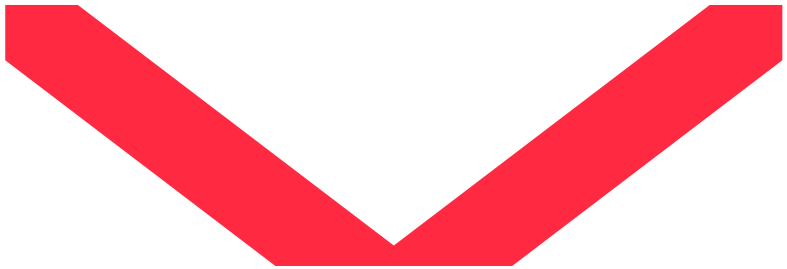




Detection

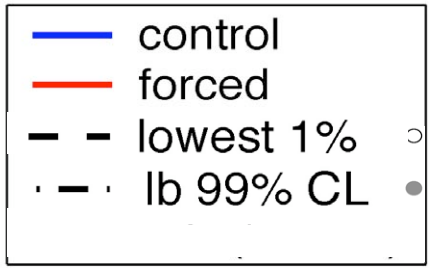
Model MOC

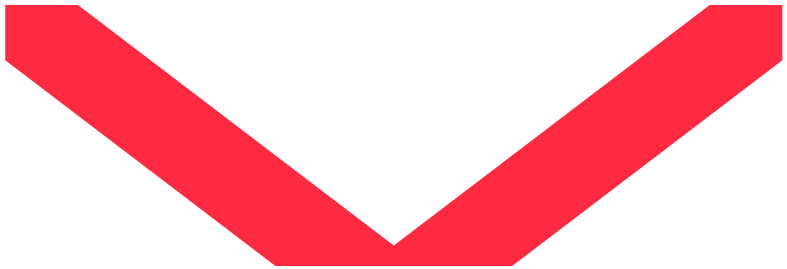




Detection

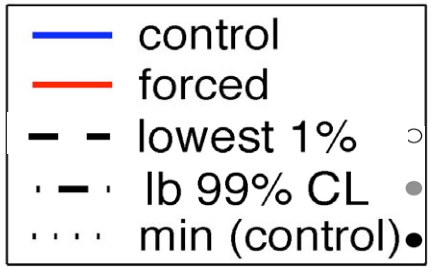
Model MOC

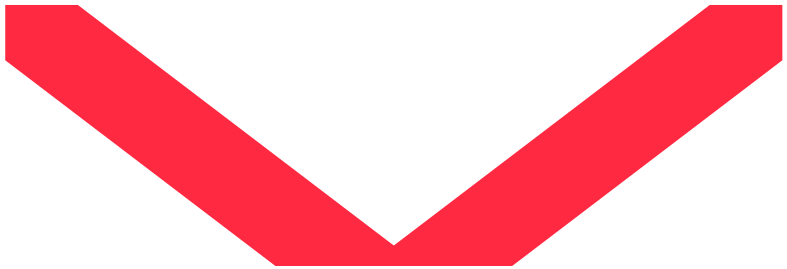




Detection

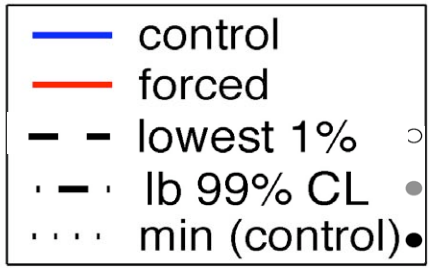
Model MOC



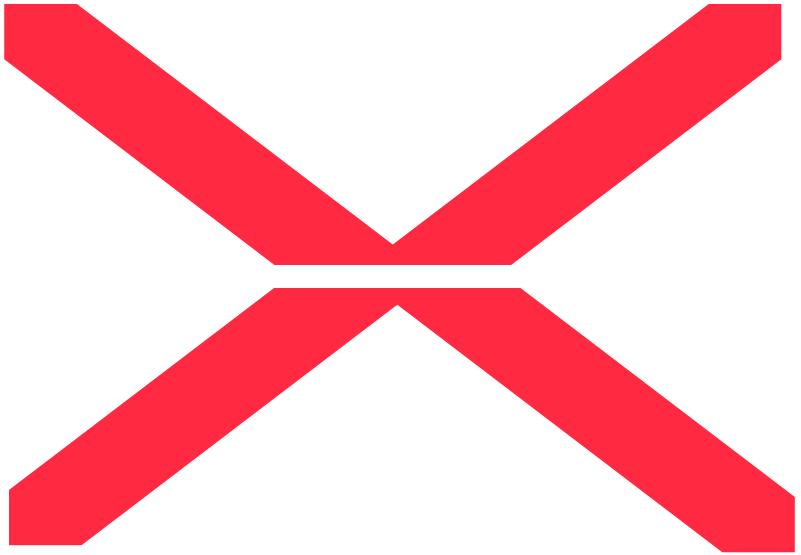


Detection

Model MOC

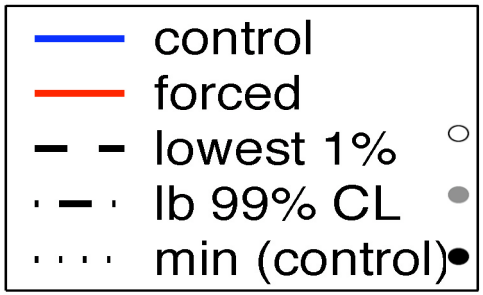


Reconstruction



Detection

Model MOC



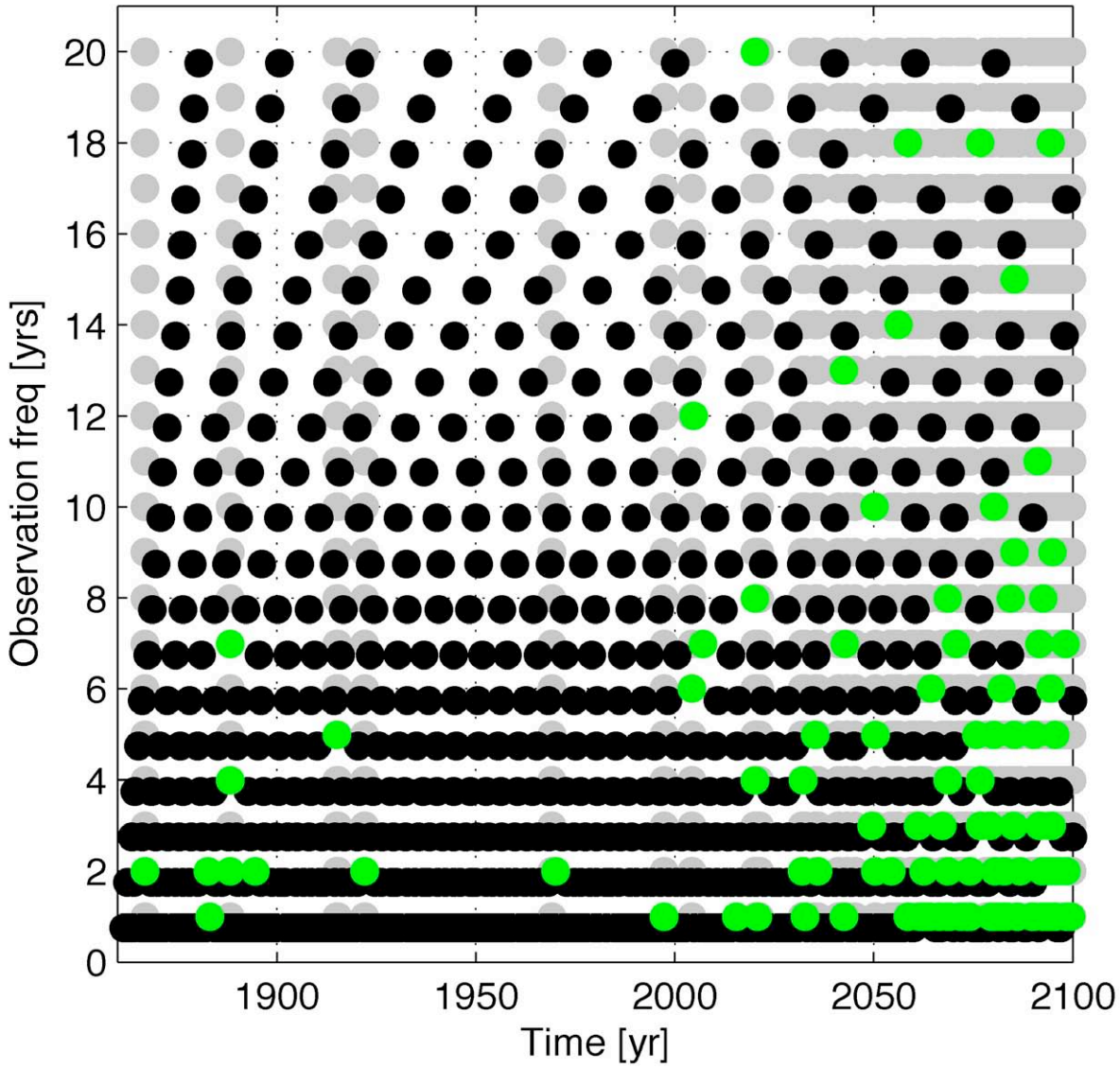
"control"

Reconstruction

"control"

Detection

- obs. frequency
- detection for continuous obs.
- detection for reduced frequency



Conclusions

- Model based array design suggests:
  - a small number of "moorings" (~ 10) is sufficient to capture the main characteristics of the MOC if bottom velocities are small.
- We expect from the RAPID array observations:
  - improved understanding of the baroclinic MOC variability at 26°N,
  - a continuous timeseries of the MOC at 26°N.
- RAPID array observations, future work:
  - signal propagation (16°N: Kiel MOVE array; 36°N: RAPID Hughes et al),
  - refine observing strategy (at 26°N and further latitudes?).
- Simple model based detection study suggests:
  - the RAPID array can detect changes in the MOC at 26°N,
  - a continuous time series is required to detect changes in the MOC.
- In reality, the detection problem consists of:
  - one short timeseries only (no "control ocean"),
  - observation error, infrequent sampling (other than at 26°N after 2004),
  - unknown autocorrelation.

Outlook

- MOC observing system design:
  - test the use of bottom pressure and sea surface height measurements.
- RAPID array observations:
  - refine observing strategy,
  - signal propagation (16°N: Kiel MOVE array; 36°N: RAPID Hughes et al),
  - further "latitudes"(?).
- In reality, the detection problem consists of:
  - one short timeseries only (no "control ocean"),
  - observation error, infrequent sampling (other than at 26°N after 2004),
  - unknown autocorrelation.