Ocean and Climate Change, March 30, 2012, Paris

Water masses and circulation in the North Atlantic

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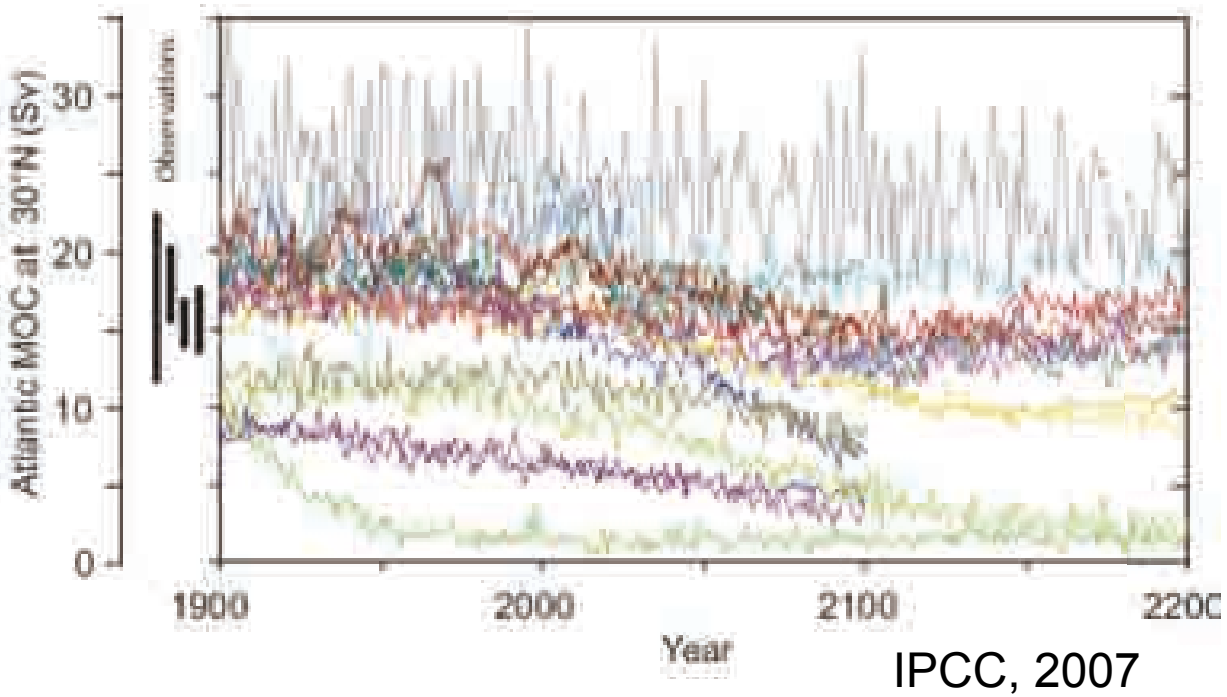
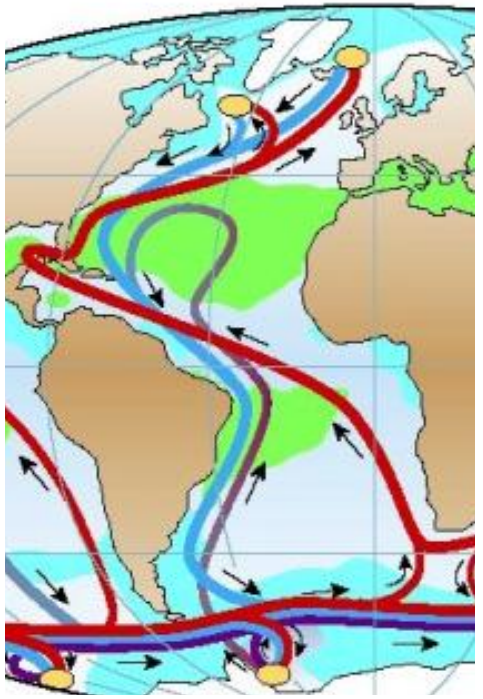
Dagmar Kieke, Christian Mertens, Achim Roessler, and Reiner Steinfeldt

Universität Bremen

- ocean and climate change: go where the big signal is



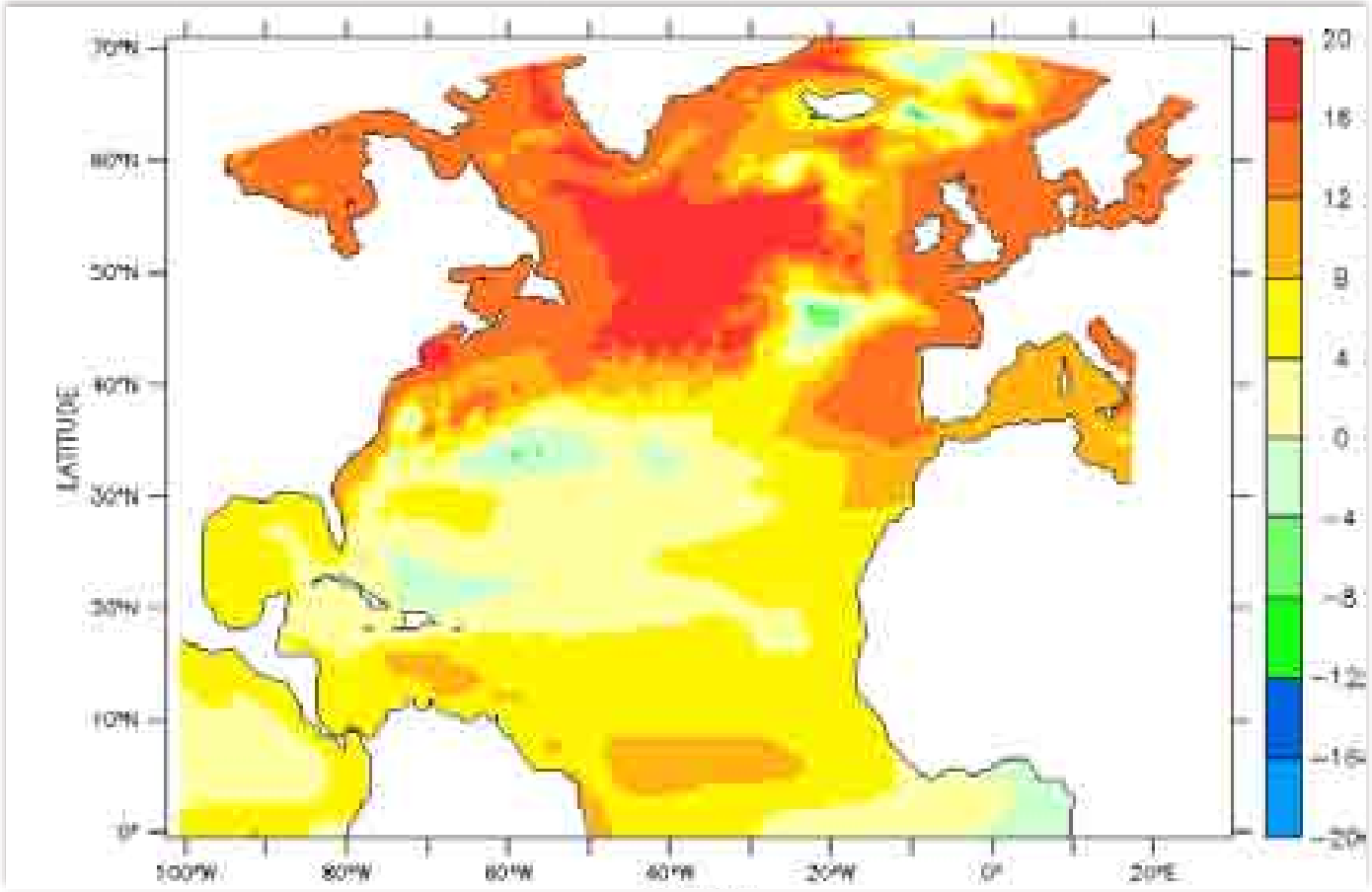
IPCC, 2007



Rahmstorf, 2002

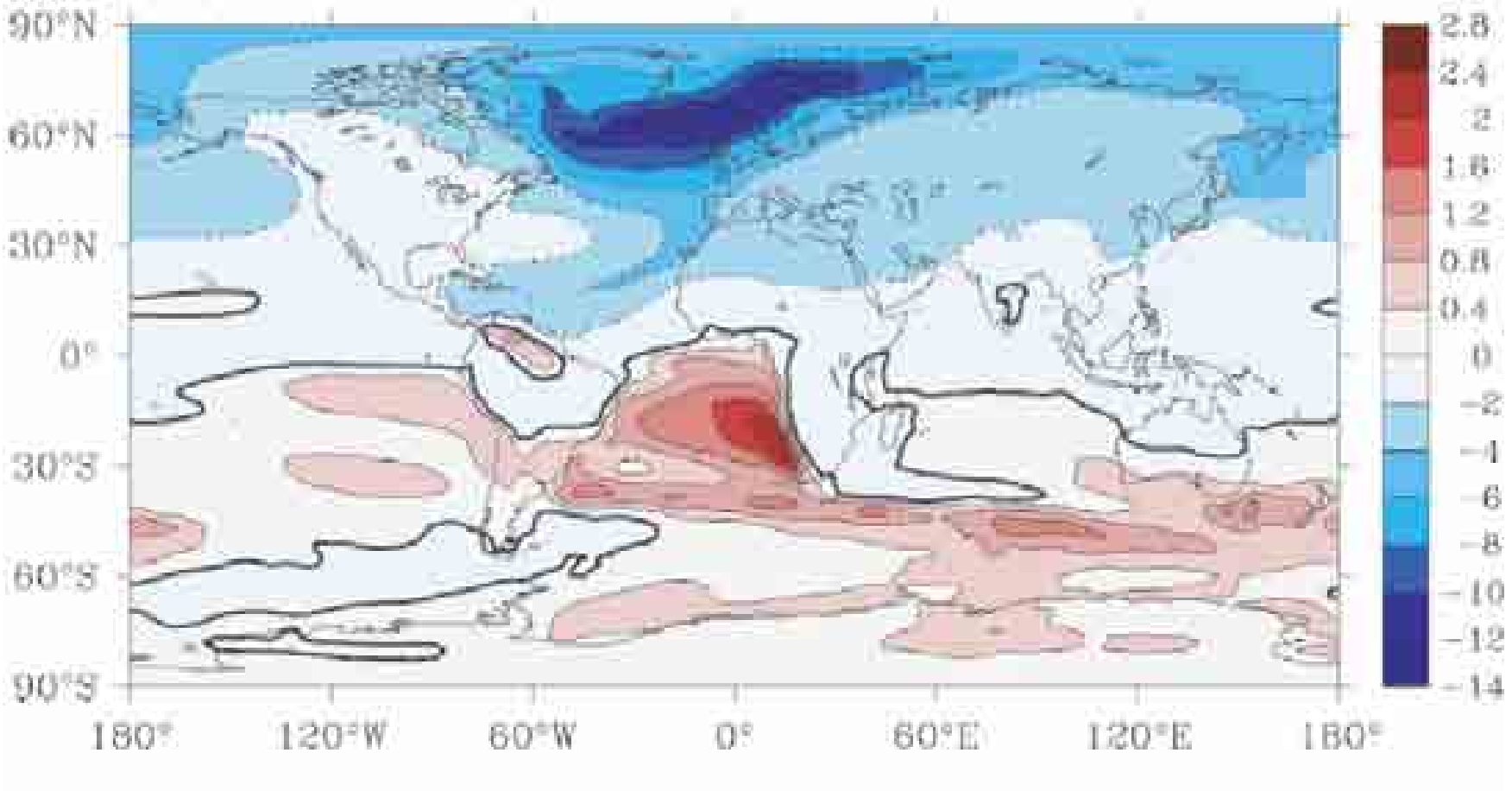
Evolution of the AMOC, 1999-2100 Scenario A1B, IPCC Report, 2007: reduction of about 30%

one key region: **subpolar North Atlantic**
SSH-changes (cm) after weakening of the AMOC by 30%
caused by circulation changes

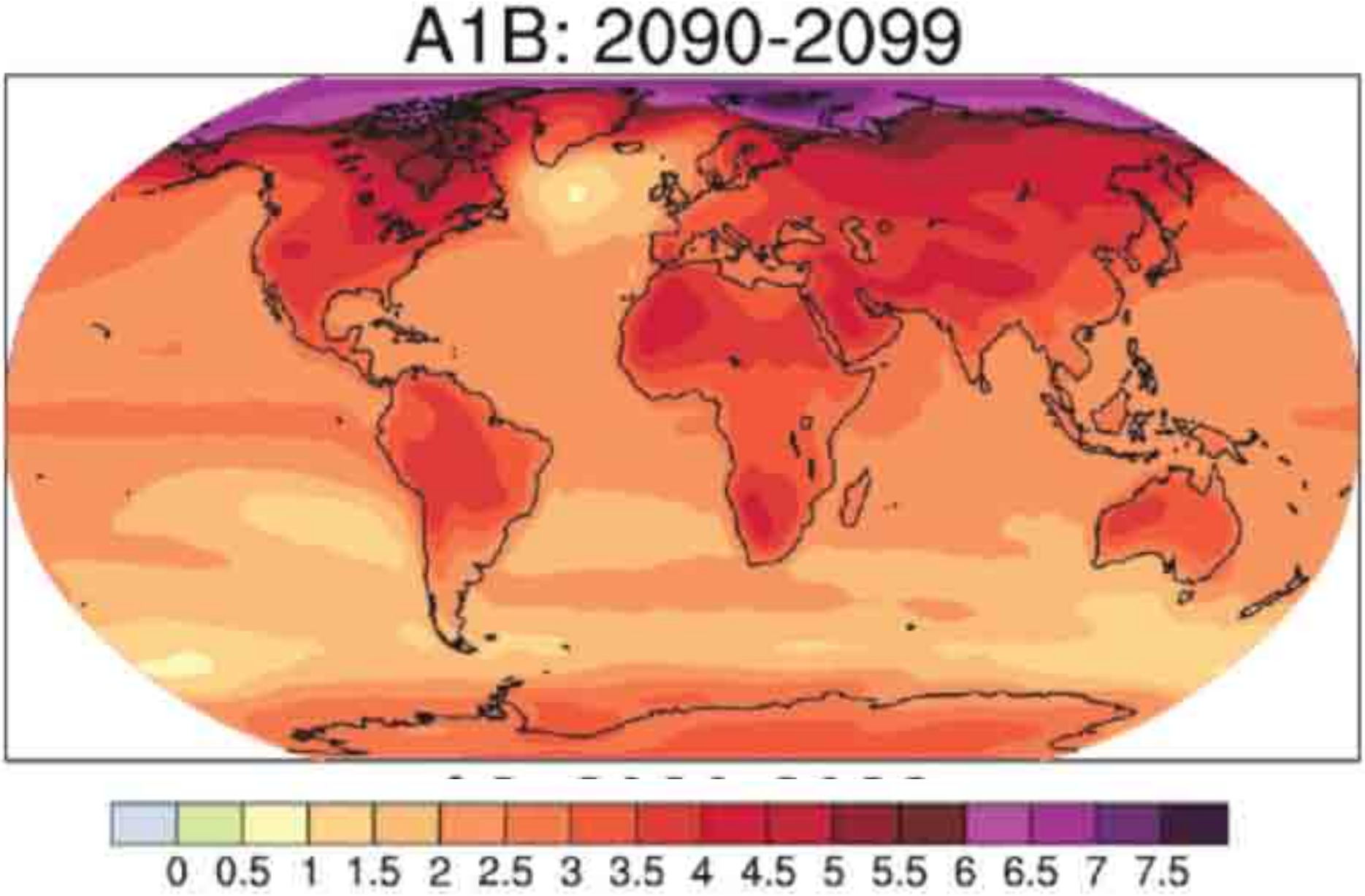


ORCA Ocean model, C. Böning, GEOMAR

Atmospheric Temperature Change after cessation of AMOC



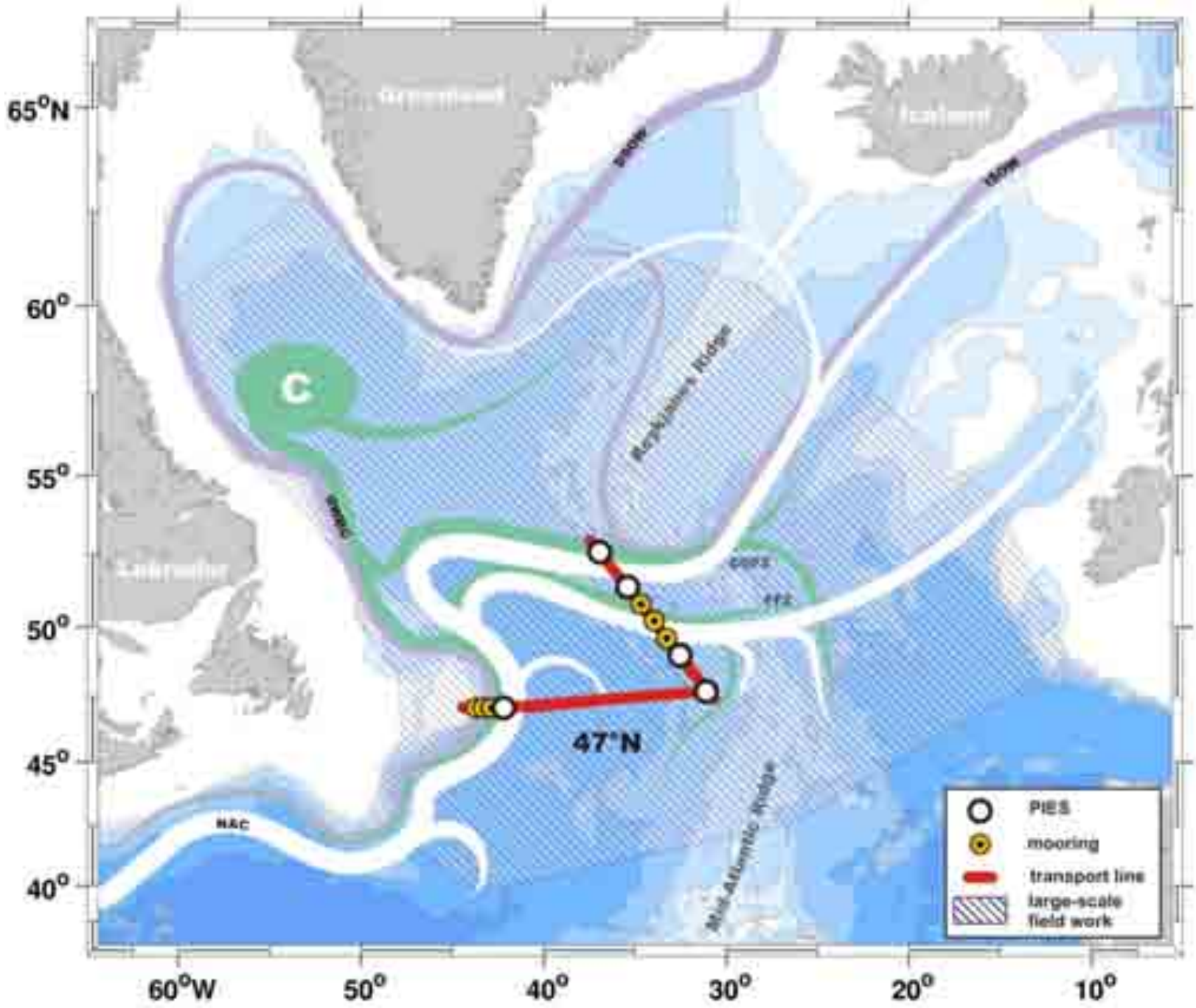
Stouffer et al., 2006

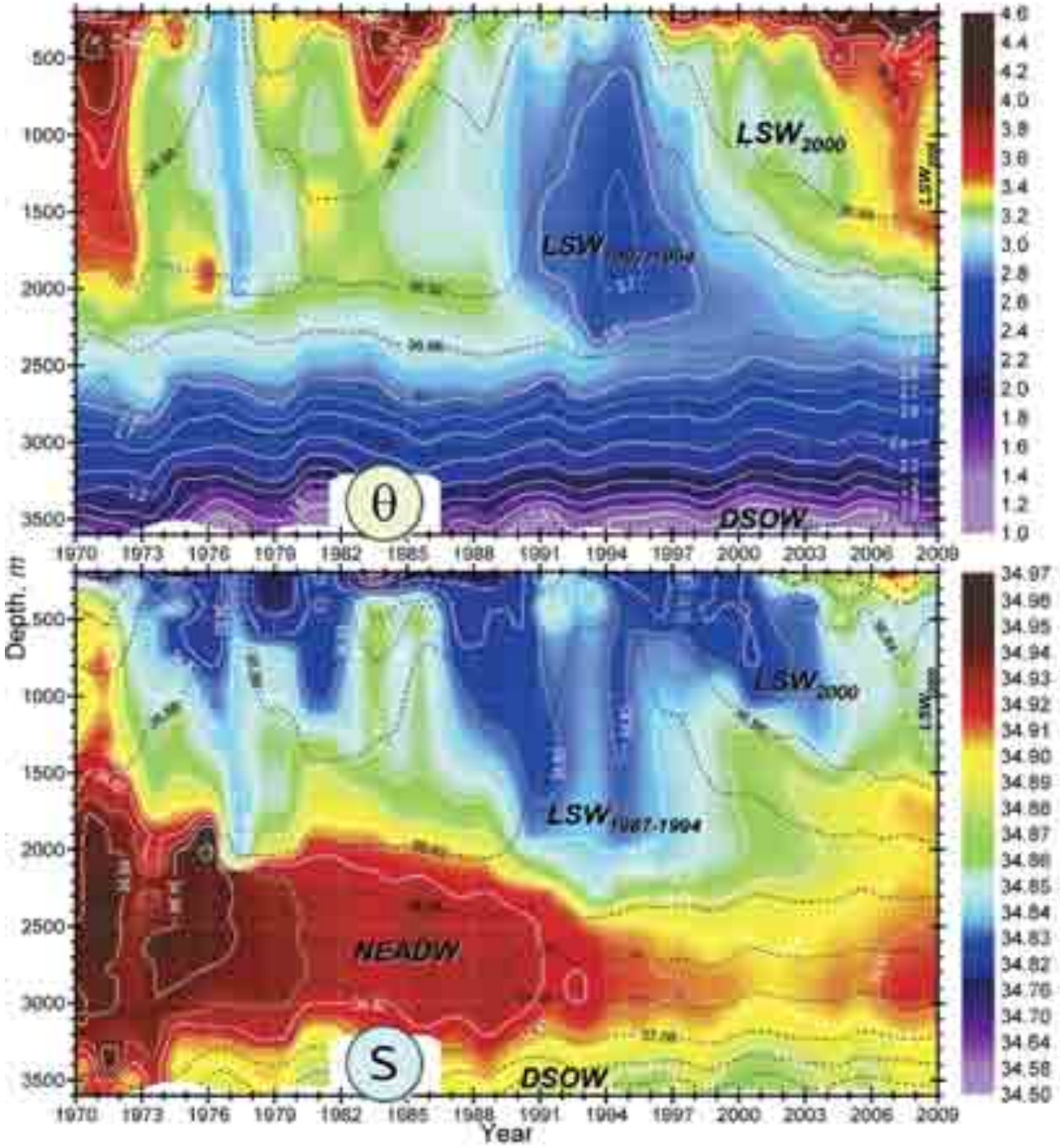


Temperature change relative to 1990. IPCC, 2007

- BUT
- variability on interannual, decadal and longer time scales dominate observations
- time series too short to separate trend from variability
- need to measure and understand variability

- LSW water mass formation changes
- Subpolar gyre: NAO, transports, water masses
- Circulation in western basin
- Circulation of newly formed deep water in the North Atlantic
- Future observations

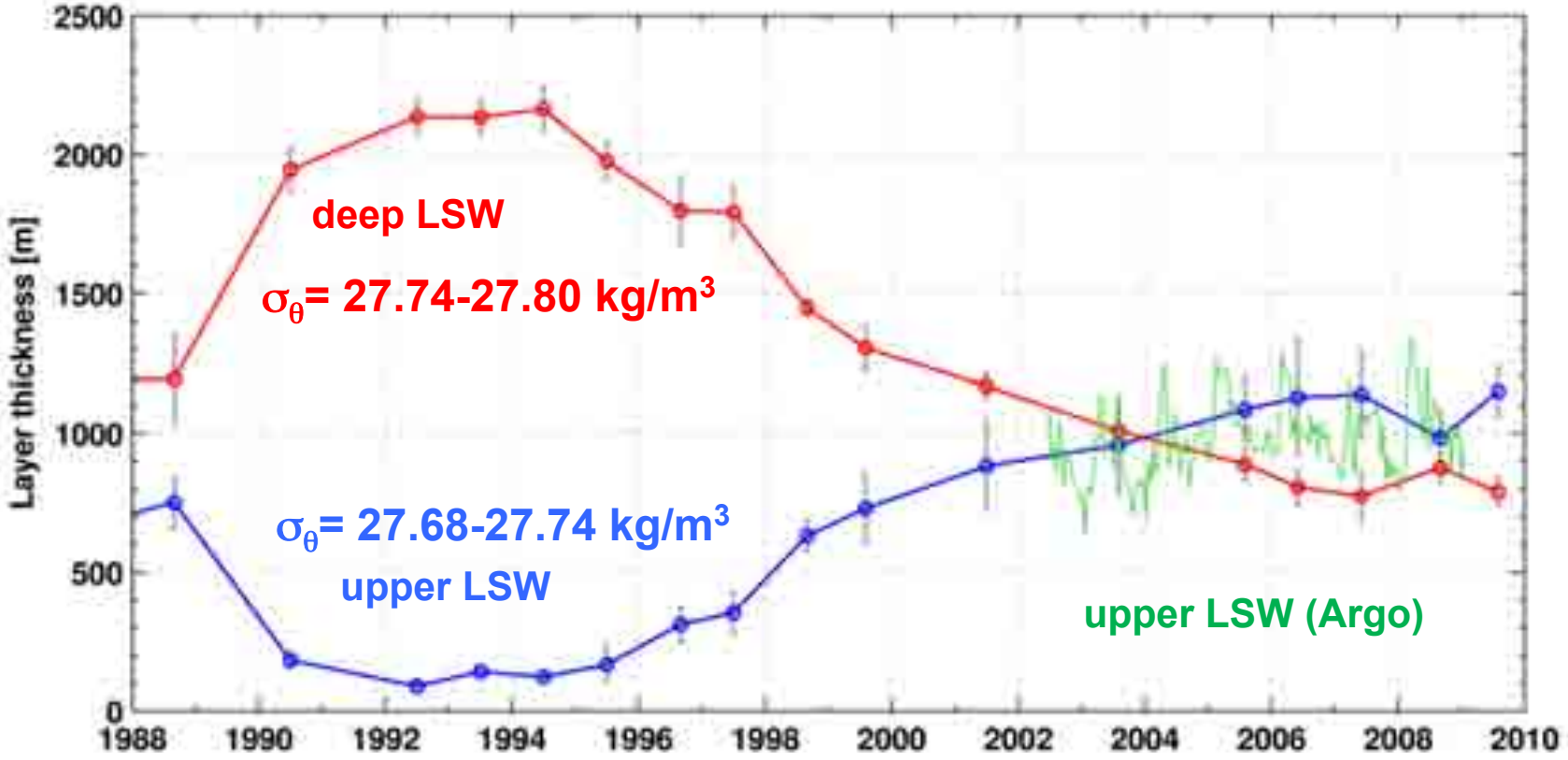

65°N
60°
55°
50°
45°
40°
60°W
50°
40°
30°
20°
10°
Greenland
Iceland
Labrador
C
Reykjanes Ridge
47°N
NAC
Mid-Atlantic Ridge
PIES
mooring
transport line
large-scale field work



Temperature and Salinity, Labrador Sea 1970-2009

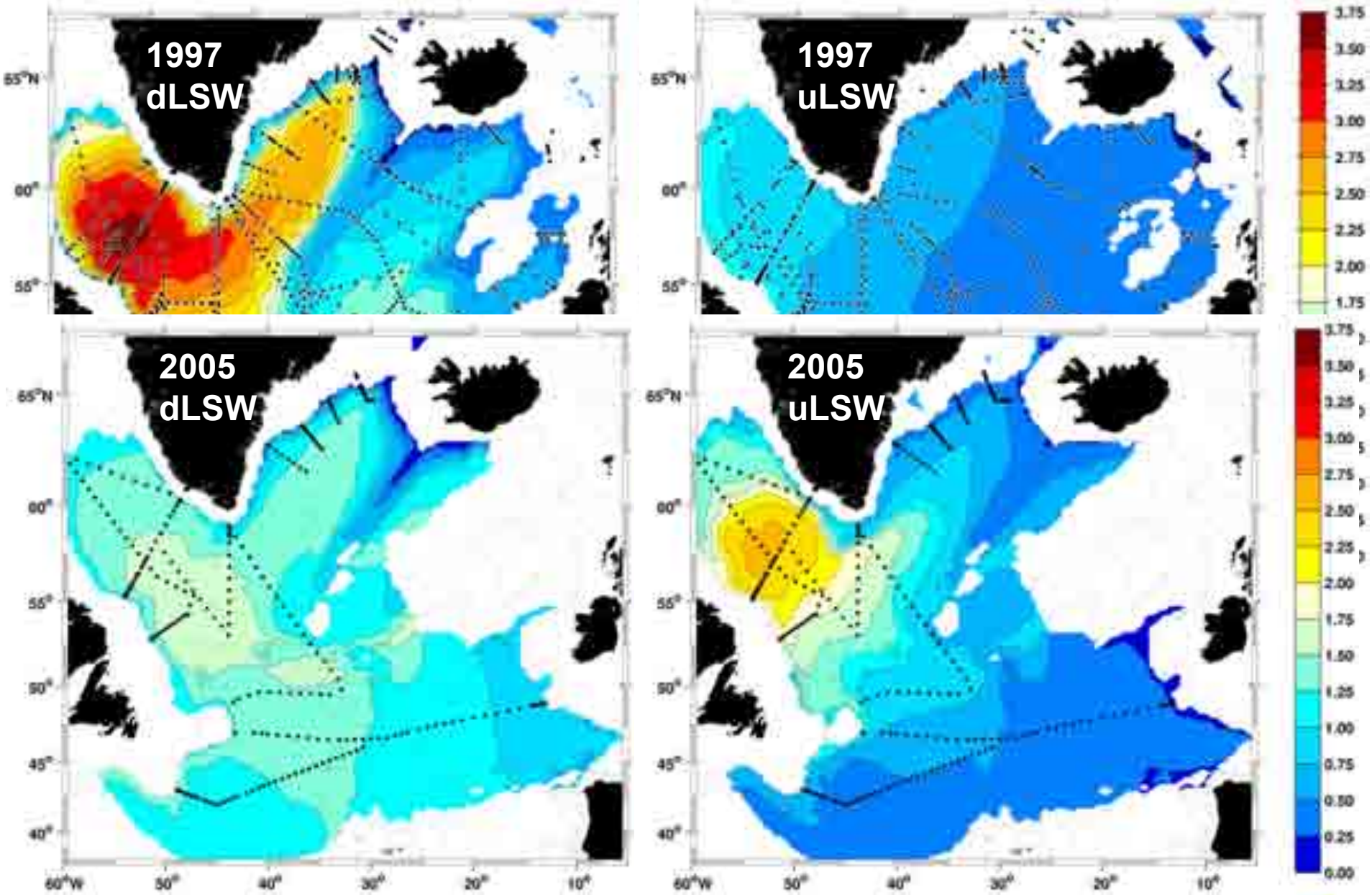
Yashayaev and Loder, GRL, 2009

Layer thickness evolution in the Labrador Sea



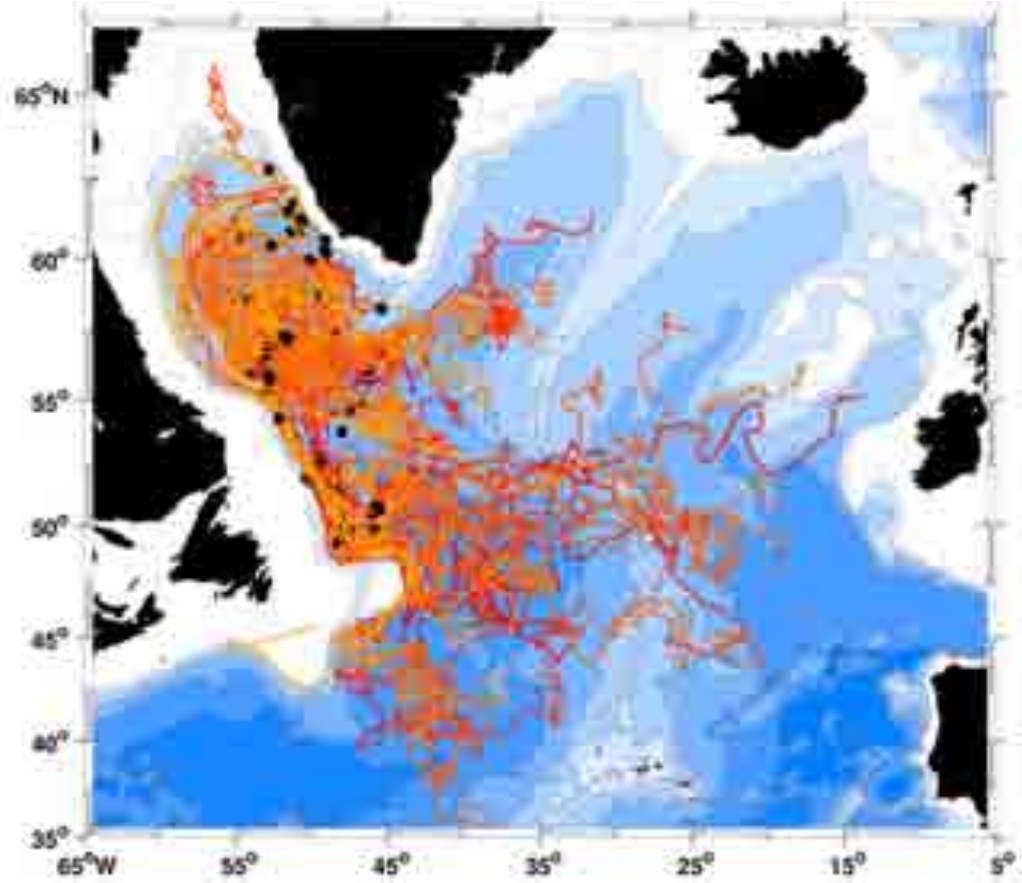
- production of different modes of LSW
- changes in the layer thickness serve as proxy for LSW formation
- increase of upper LSW, decrease of deep LSW over past 15 years

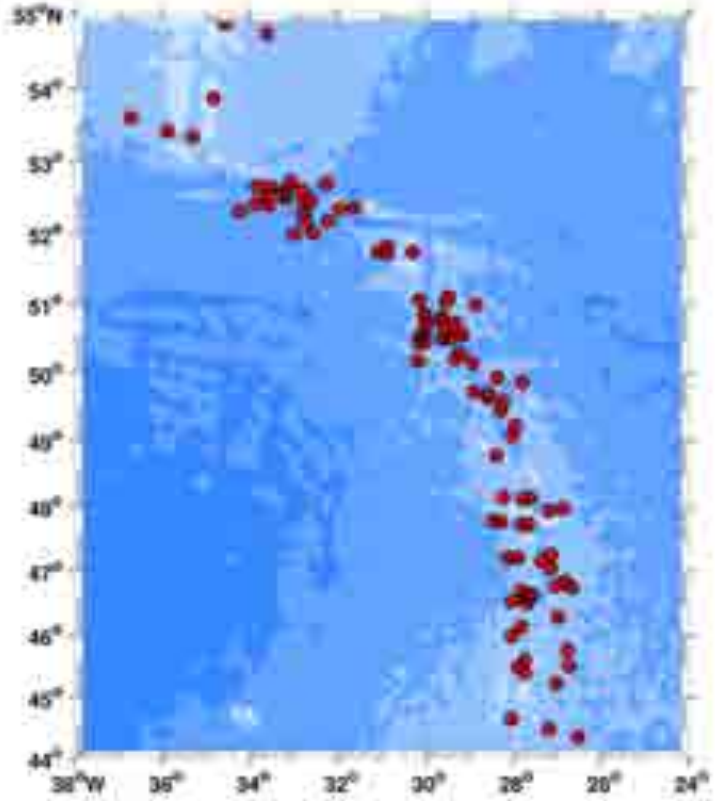
CFC-12 inventories for the subpolar gyre

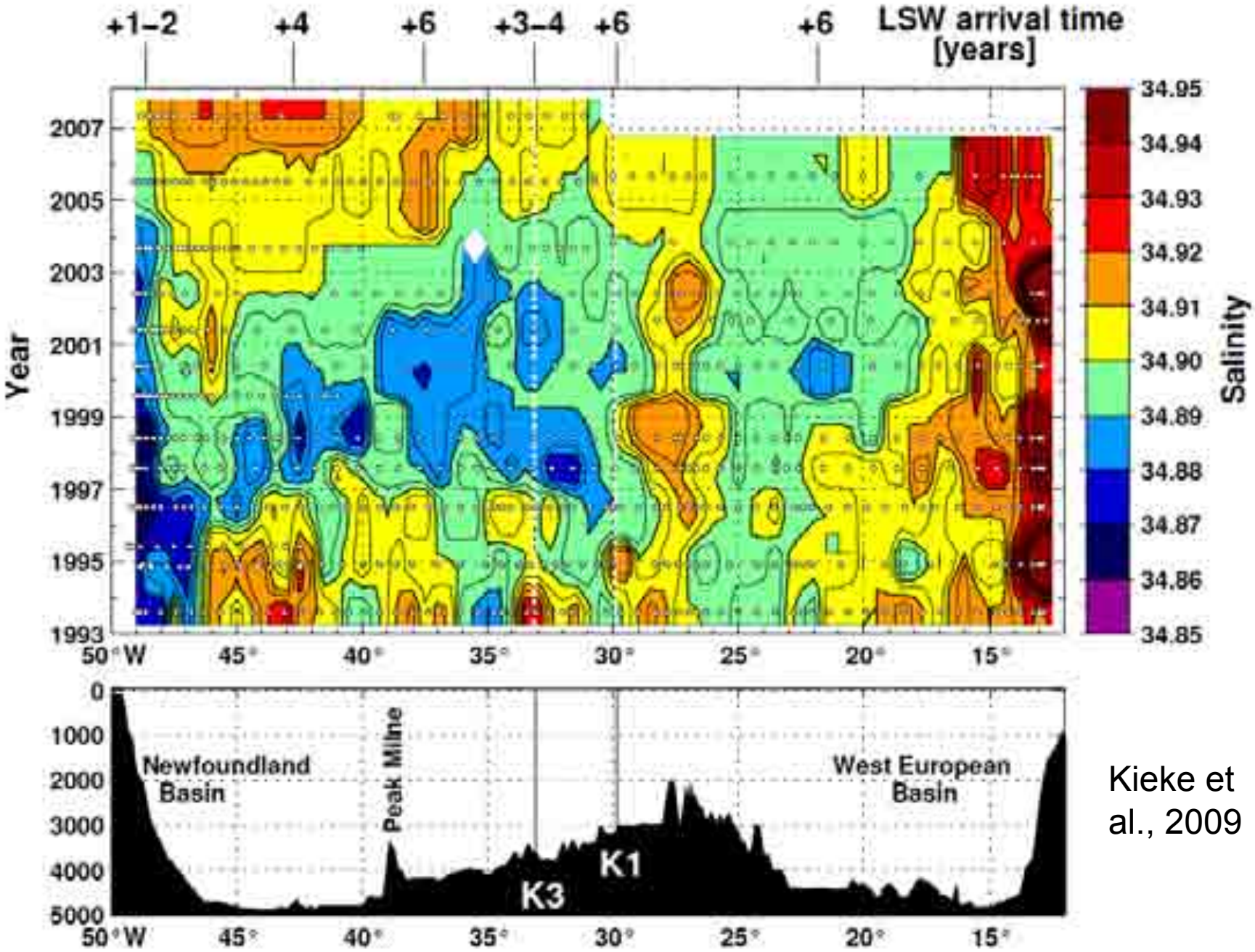


update from Kieke et al., GRL 2007

Trajectories of Argo floats crossing the MAR

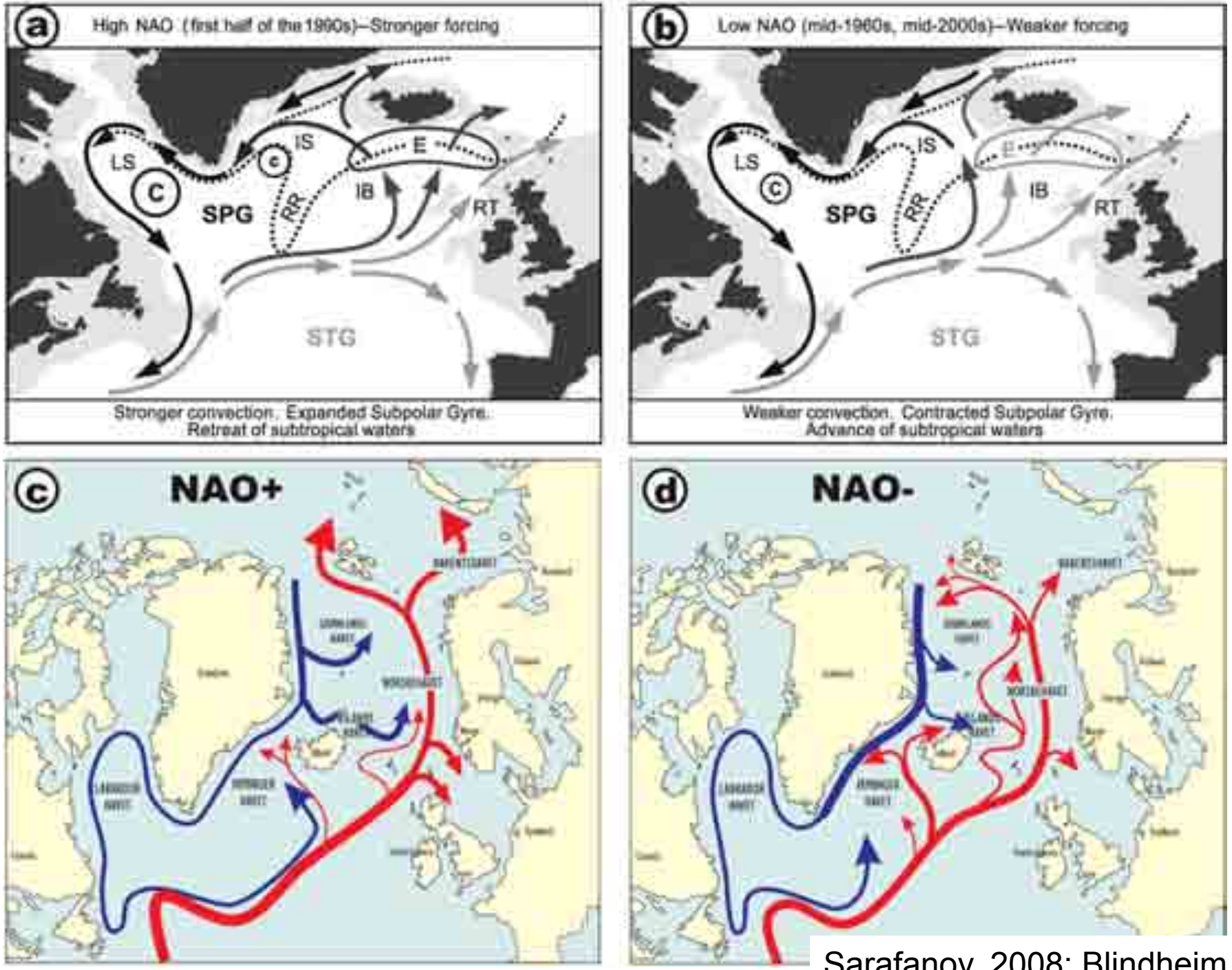




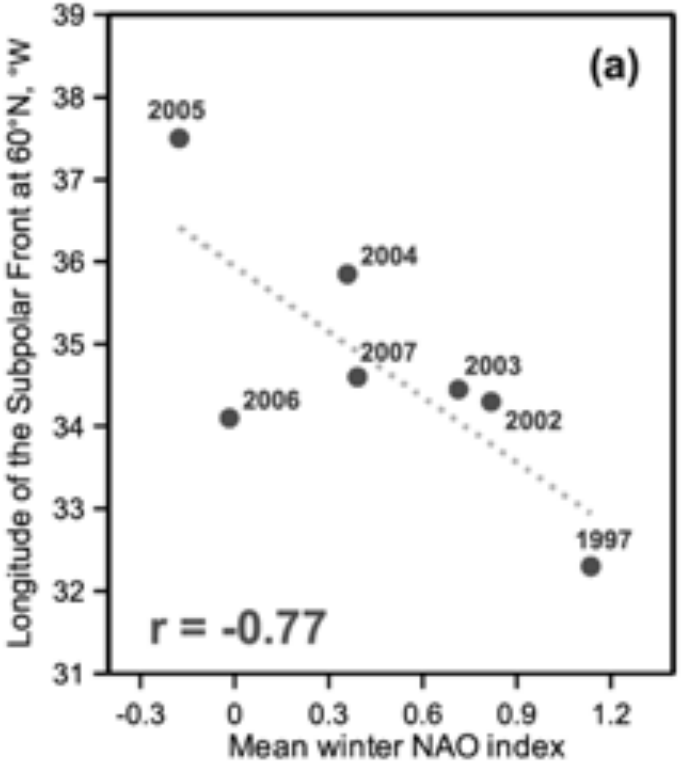


Kieke et al., 2009

- LSW water mass formation changes
- **Subpolar gyre, NAO, and AMOC**
- Circulation in western basin
- Circulation of newly formed deep water in the North Atlantic
- Future observations



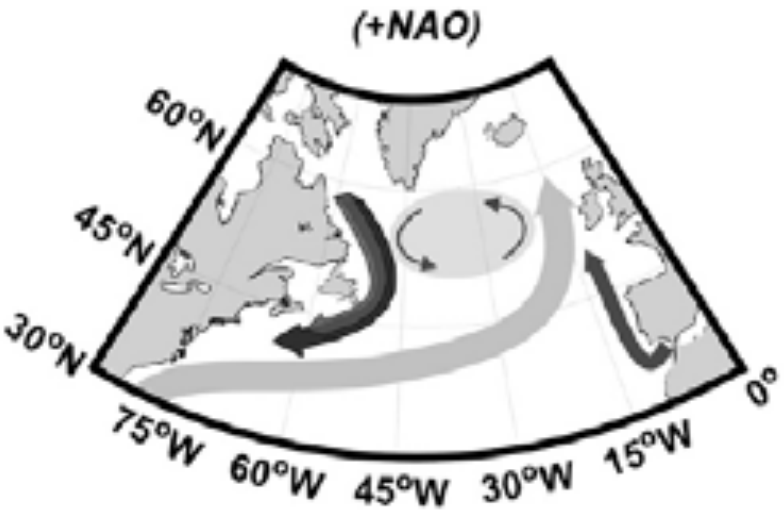
Sarafanov, 2008; Blindheim, 2001

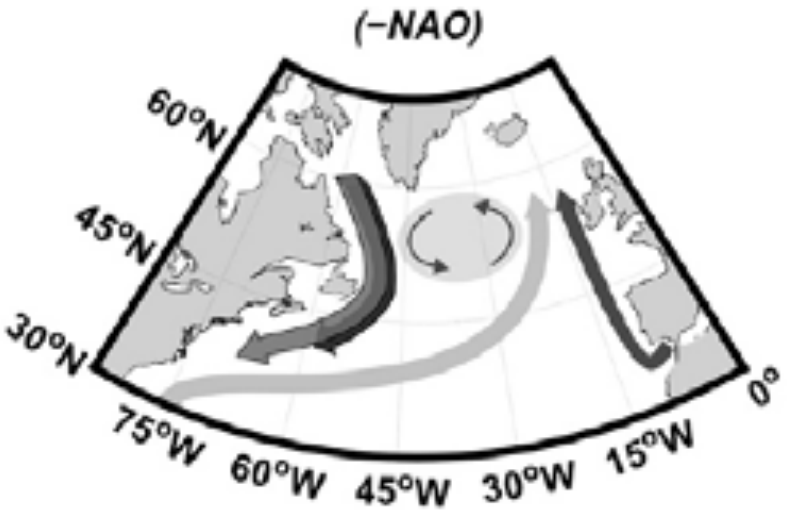


Subpolar front location at 60°N from horizontal salinity gradient in 250m depth
Versus
mean winter NAO index for 5 preceding winters

Sarafanov et al., 2008

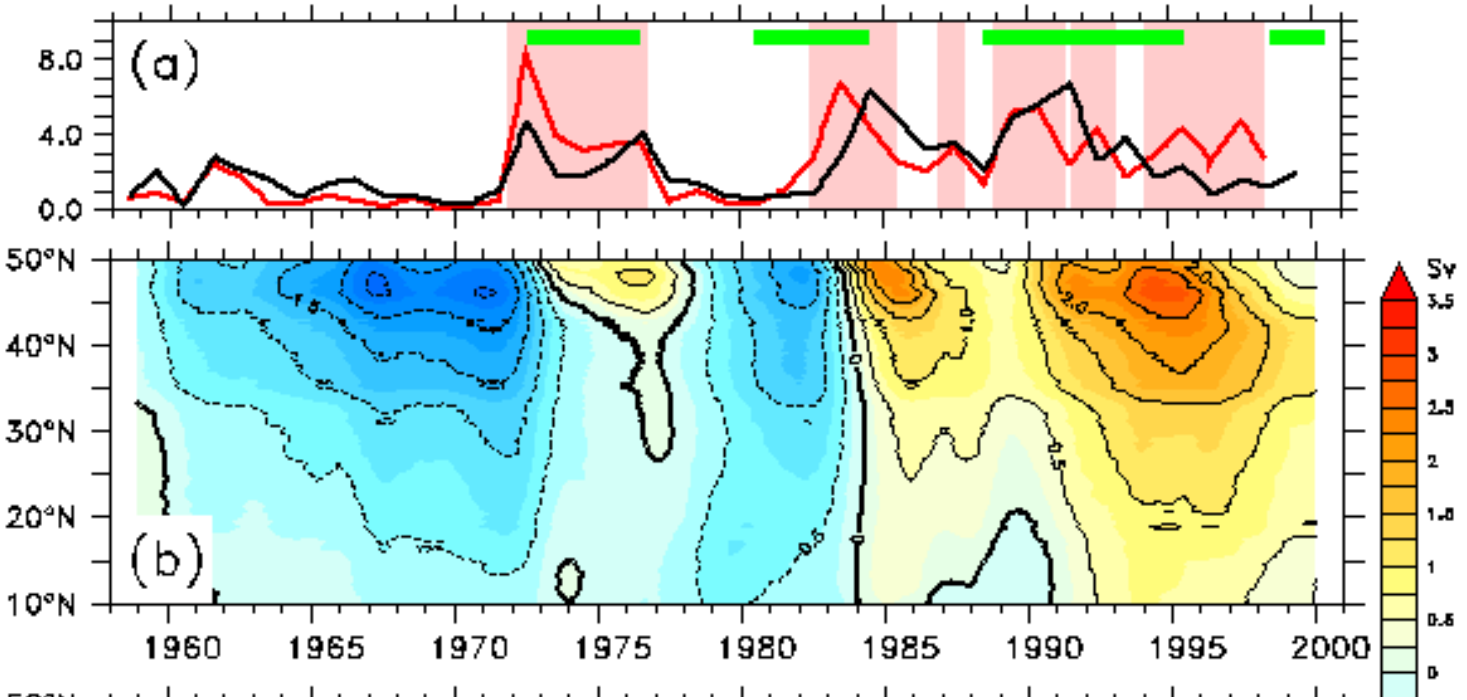
Chaudhuri et al., JPO, 2011





Effect of variable thermohaline *forcing* in isolation

ORCA-HEAT+FW: climatological wind stress; interannual heat and fw fluxes



Labrador Sea Water formation *(Sv)*

MOC anomalies

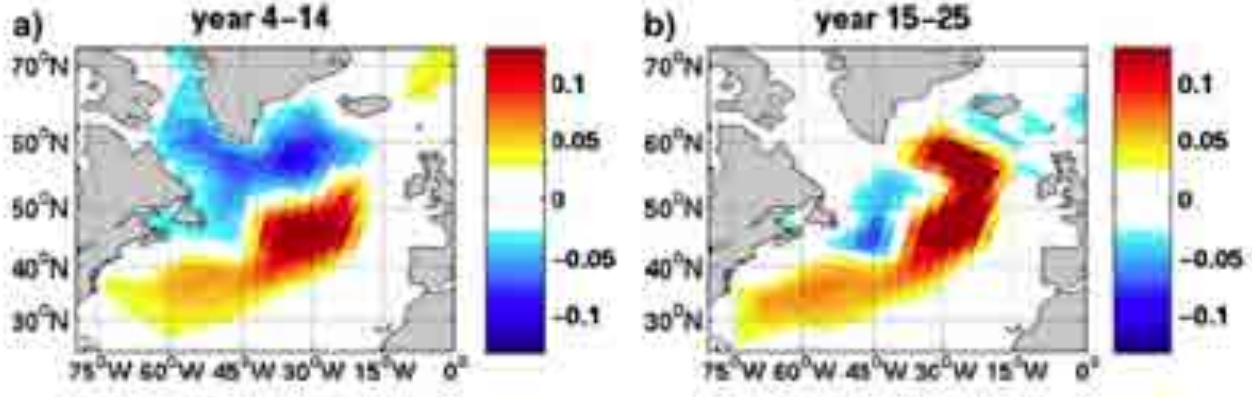
(C.I.= 0.5 Sv)

Böning and Biastoch, 2008

- Positive MOC anomalies follow periods of intensified LSW formation
- Amplitude of decadal MOC variability: ~ 2 Sv at 40°N
- from overflow another +-1-2 Sv (Latif et al., 2006)

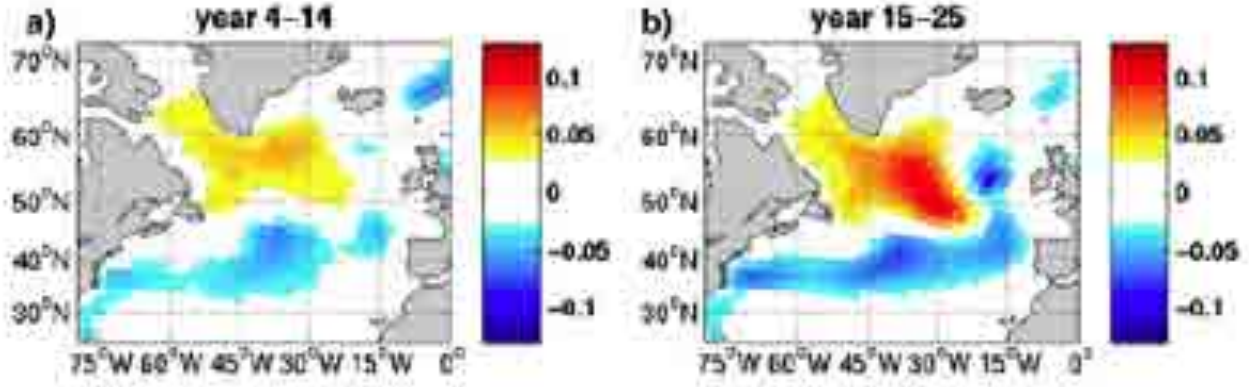
Asymmetric response to NAO+ and NAO- (Lohmann et al., 2009)

Difference SSH between NAO+ and neutral state: initial strengthening and cooling of subpolar gyre followed by warming and weakening

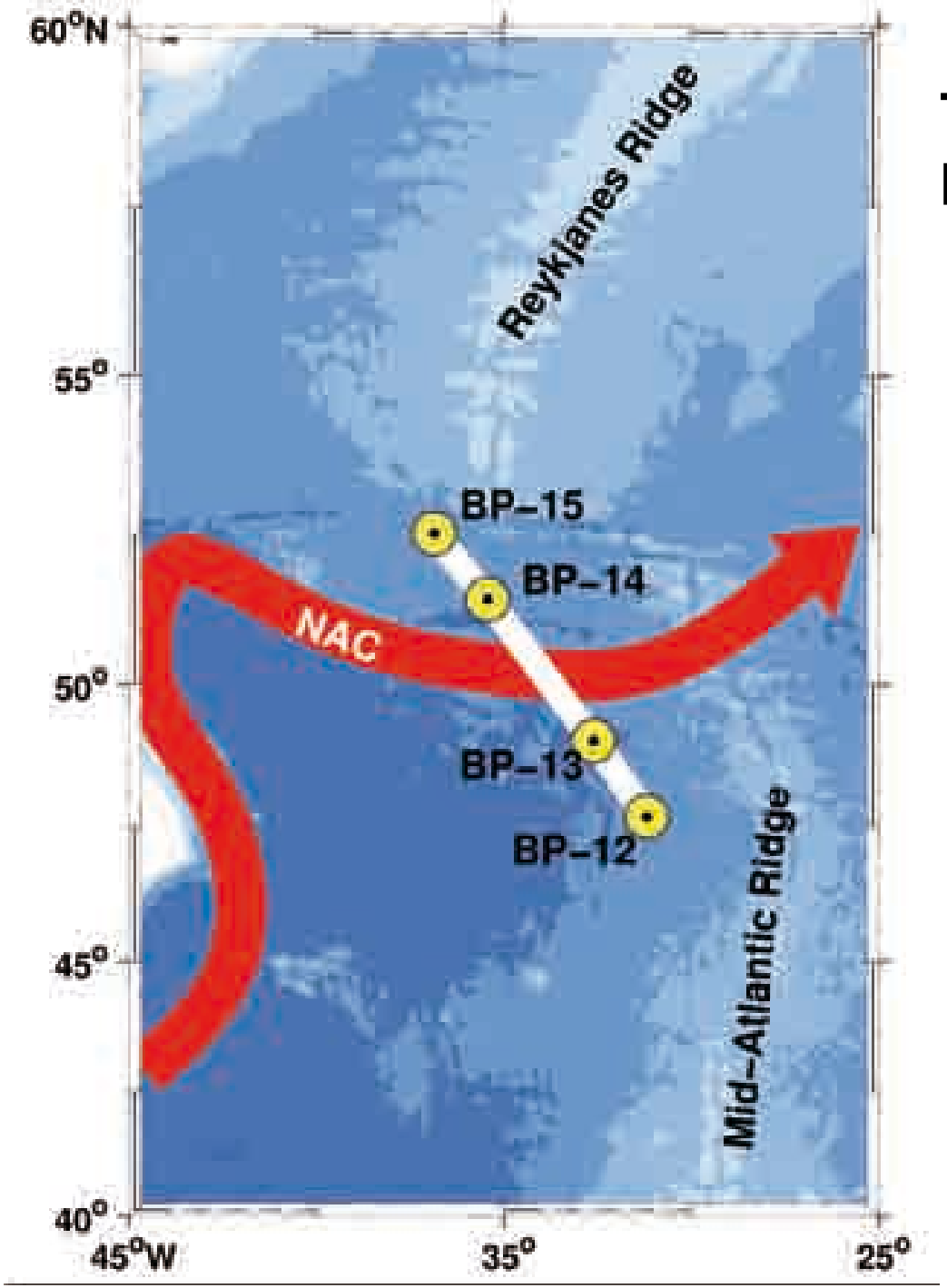


Negative: gyre strengthens

Difference SSH between NAO- and neutral state: subpolar gyre weakens



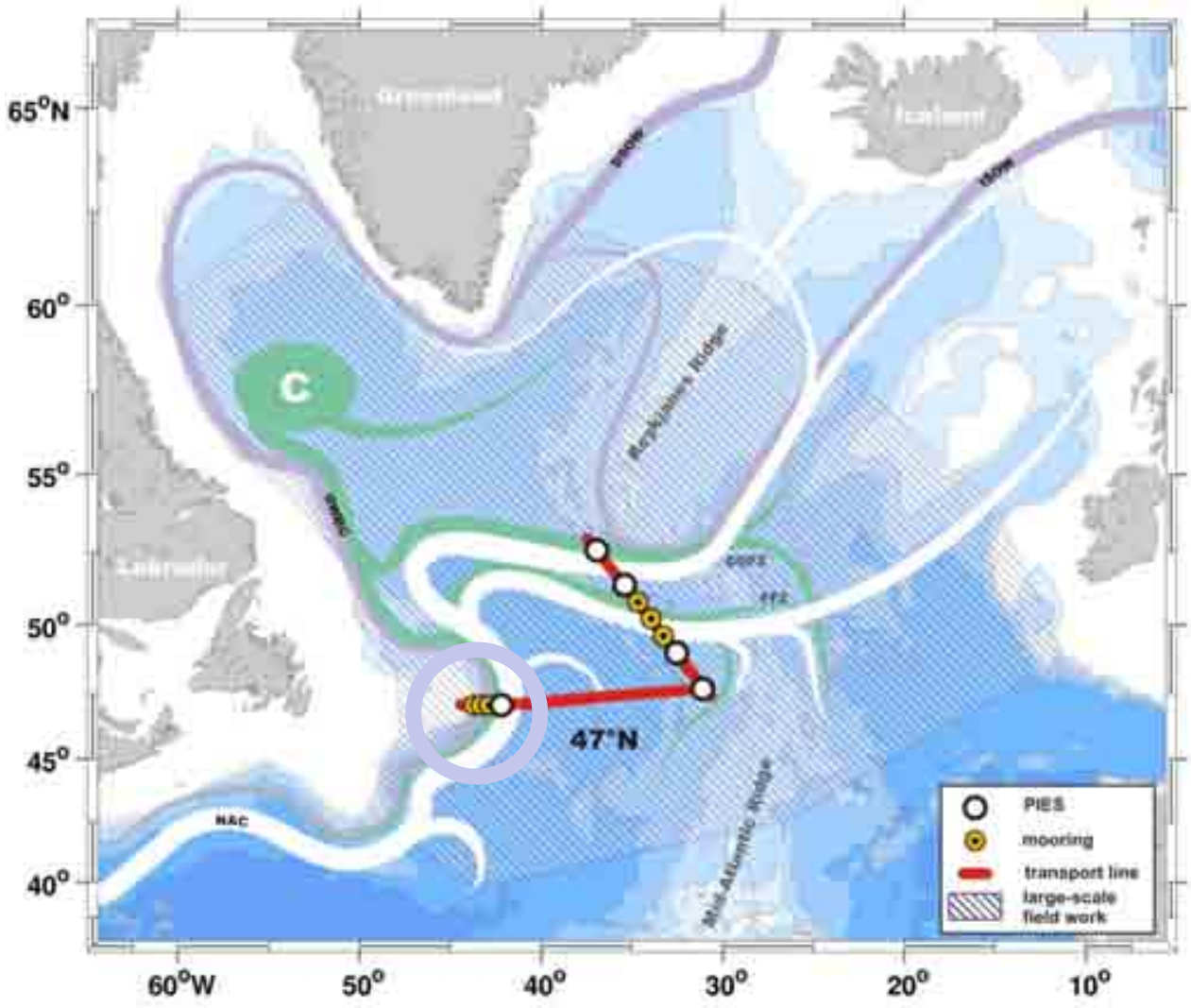
- LSW water mass formation changes
- **Subpolar gyre: transports**
- Circulation in western basin
- Circulation of newly formed deep water in the North Atlantic
- Future observations



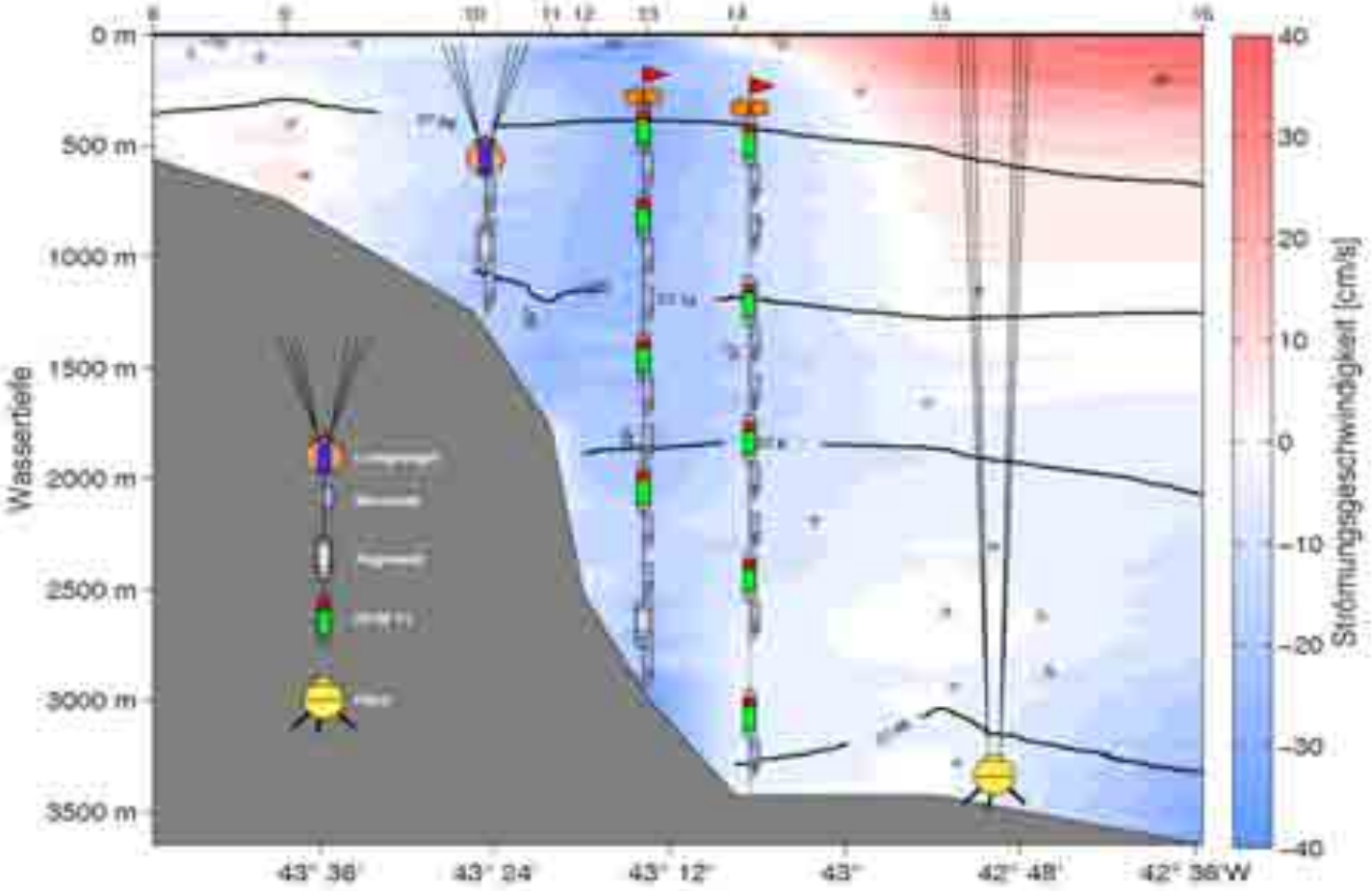
Transports across the MAR

Moored PIES 2006 – 2015

DWBC transports at 47°N

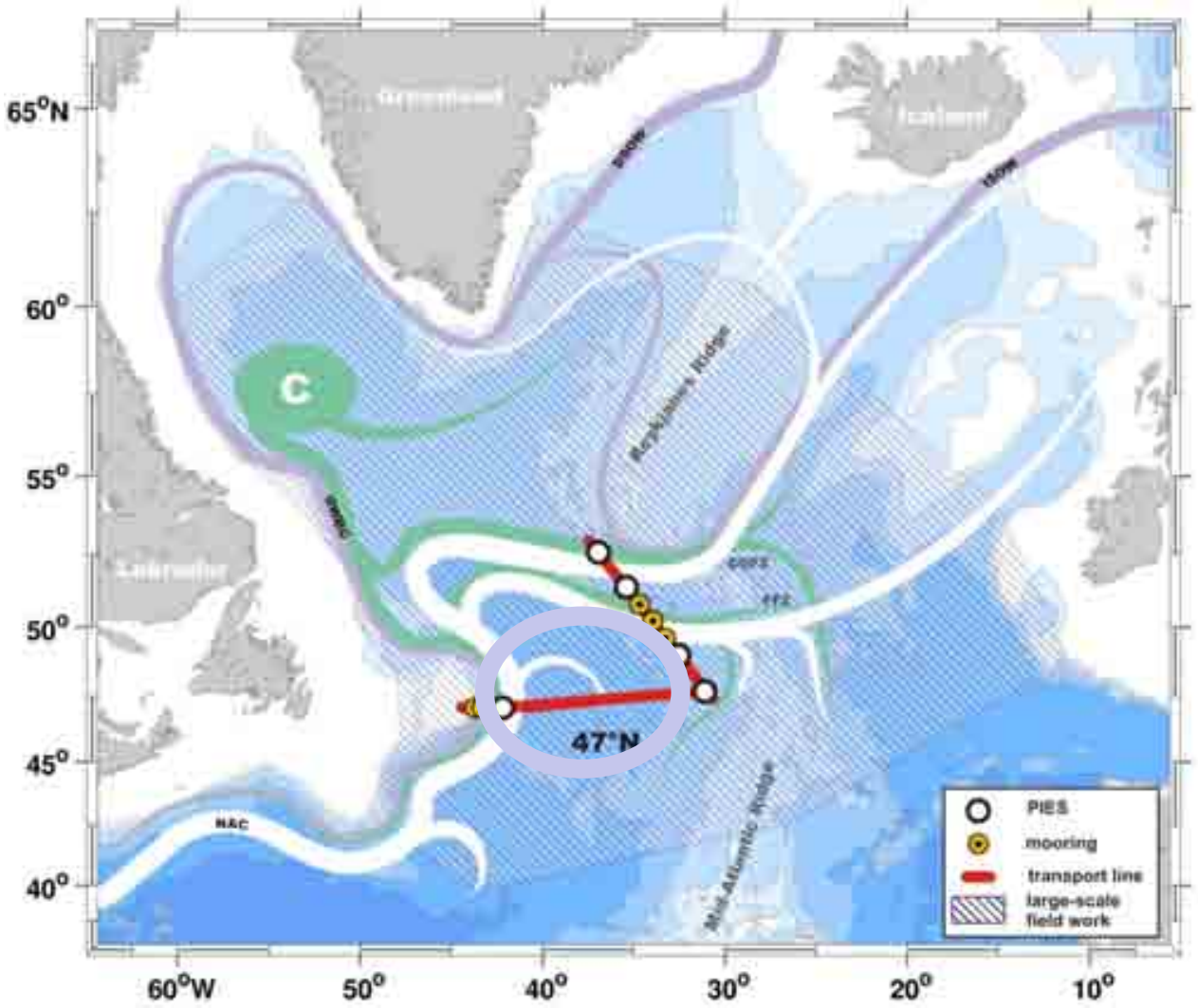


Mooring array in the DWBC area off Flemish Cap, 47°N

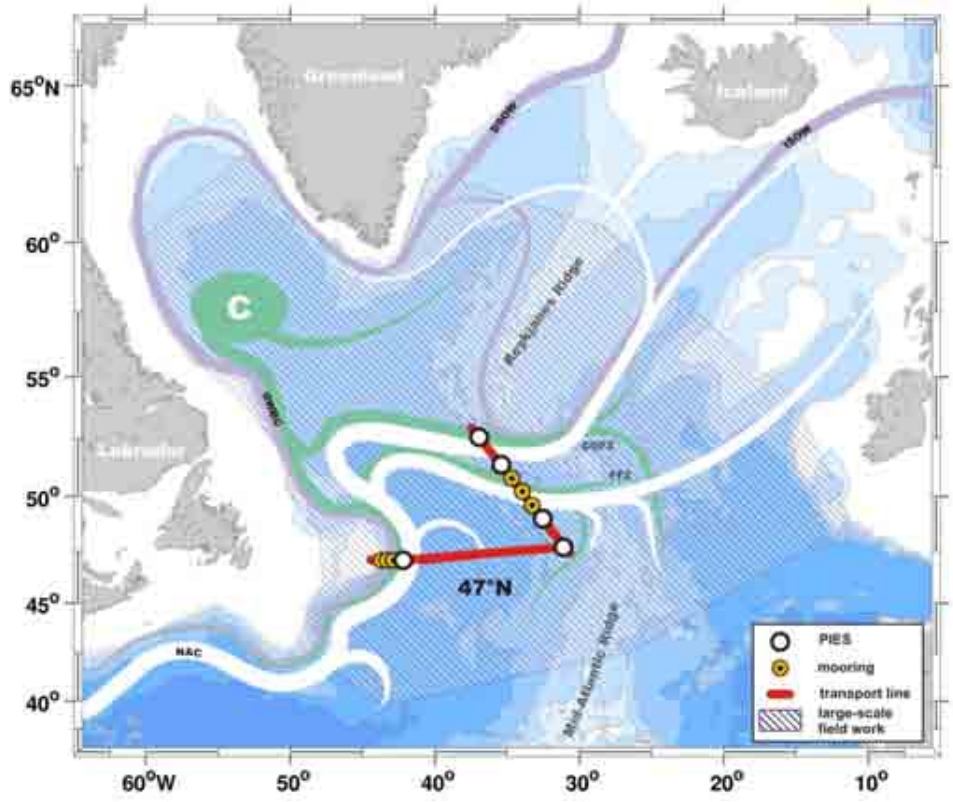


DWBC-mooring array 2009-2011
(snap-shot v-field from 2010 in the back)

Inflow and export of NAC and deep water in Newfoundland Basin at 47°N



What is the fate of the newly formed deep water south of the subpolar gyre?



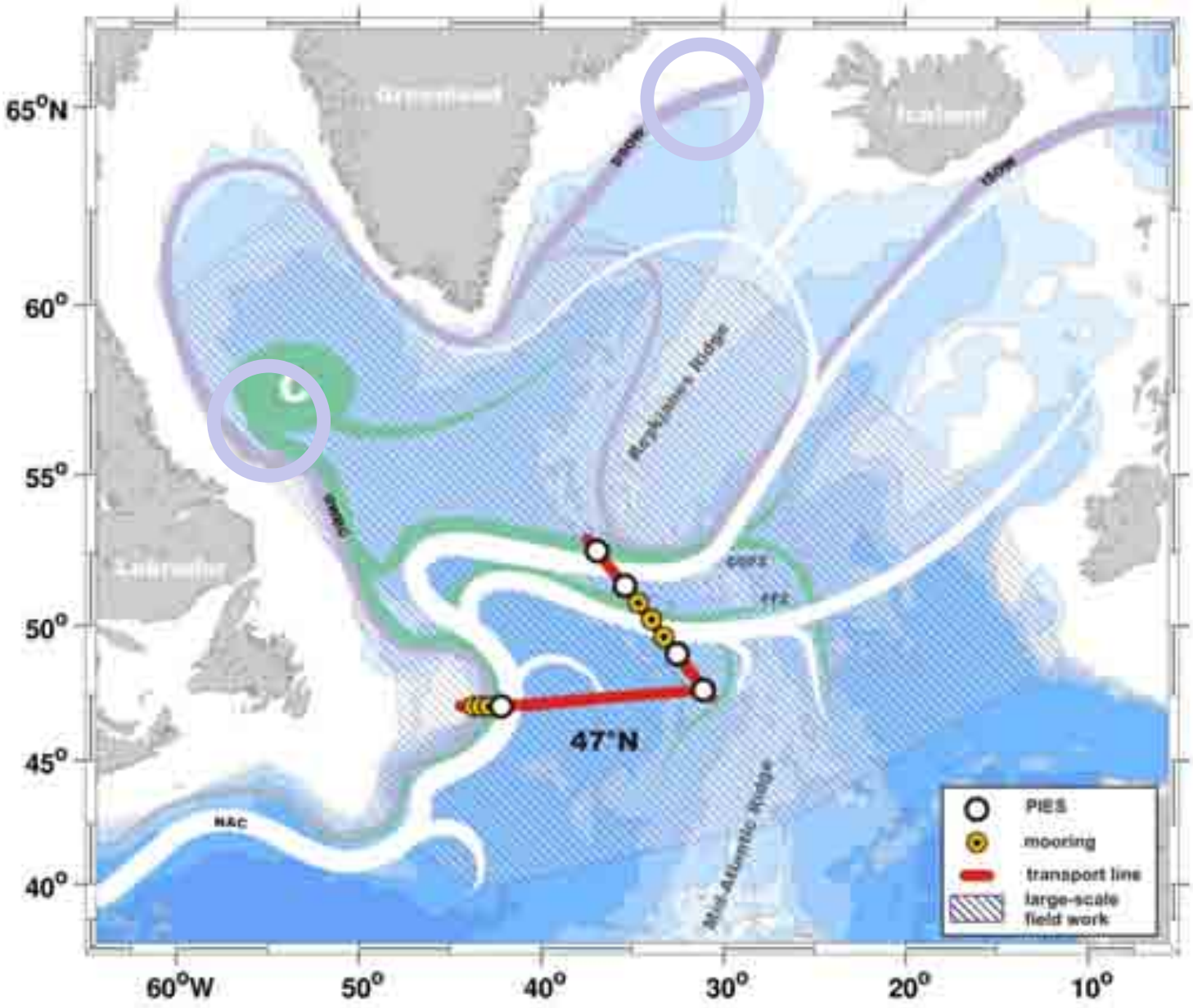
?

- *CFC data, 65°N – 20°S, 1980-2005: GLODAP, CARINA, and others: about 20.000 measure-ments on 3700 locations*

- *Calculate parameters, that are **independent of sampling date**: age and fraction of young water* (subpolar region only data 1996-99)

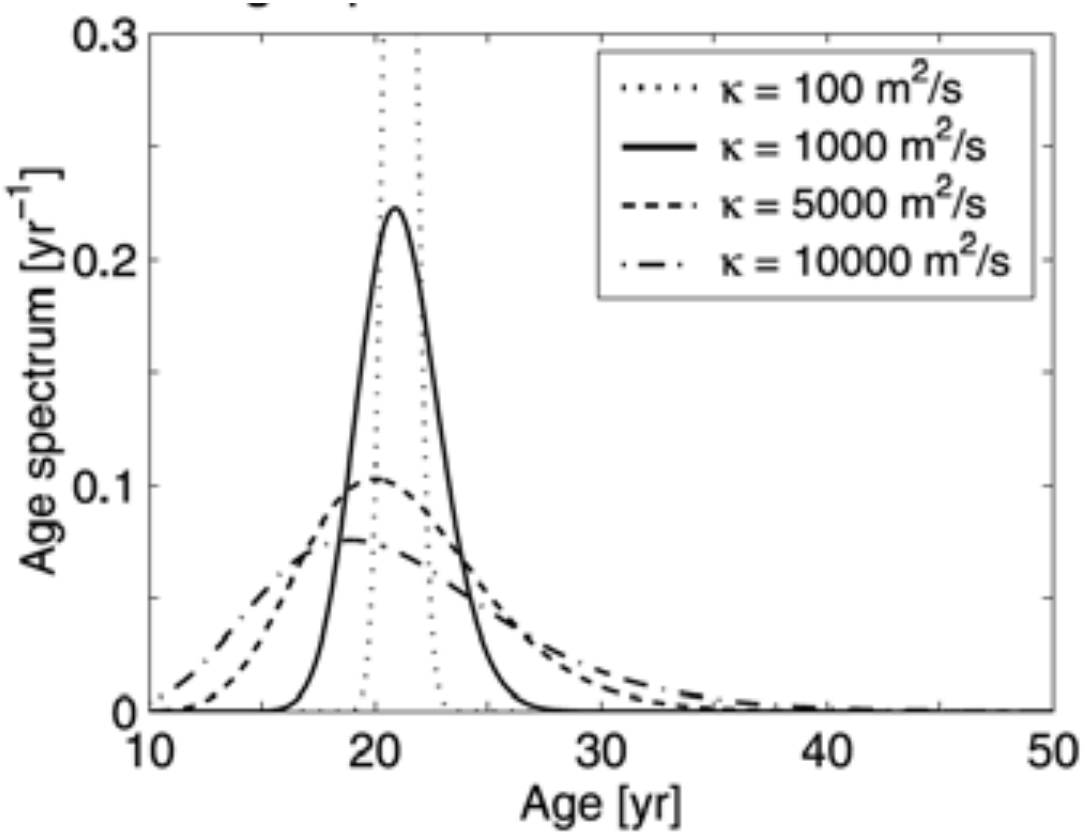
- *produce maps of ages and fractions of young water*

young water source: DSOW : 65°N LSW : 55°N



- *fraction of LSW and DSOW younger than 40 years*

- *age of LSW and DSOW*



Age spectrum, DWBC at the equator, 44°W

Without exchange with interior, fraction should be constant in DWBC

Steinfeldt and Rhein, 2004

- LSW and DSOW ages in the DWBC mostly younger than in the interior: ***DWBC fastest way and DWBC continuous***

- Zonal LSW age gradient north of 35°N smaller than south of that latitude: ***interior pathways in subpolar NA and between both gyres***

- DSOW more focused at western boundary than LSW: ***guided by topography***

- LSW and DSOW fractions in DWBC higher than in interior: ***DWBC continuous***

- Fraction decreases downstream: ***exchange with ocean interior***

- *largest along-stream age and fraction gradients in Newfoundland Basin: encounter with the NAC*

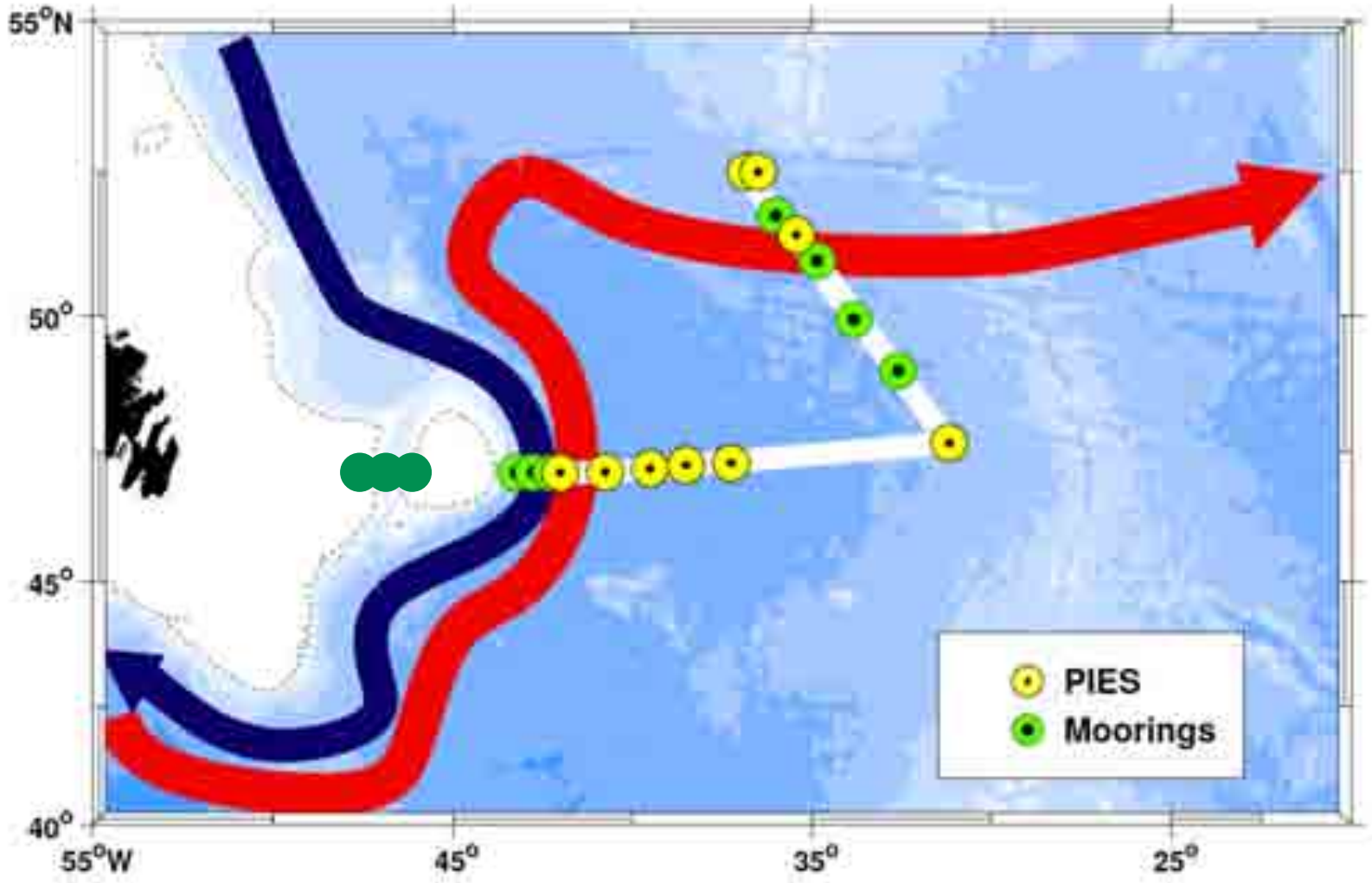
- ***small gradients** in the Labrador Sea **AND in the recirculation zone***

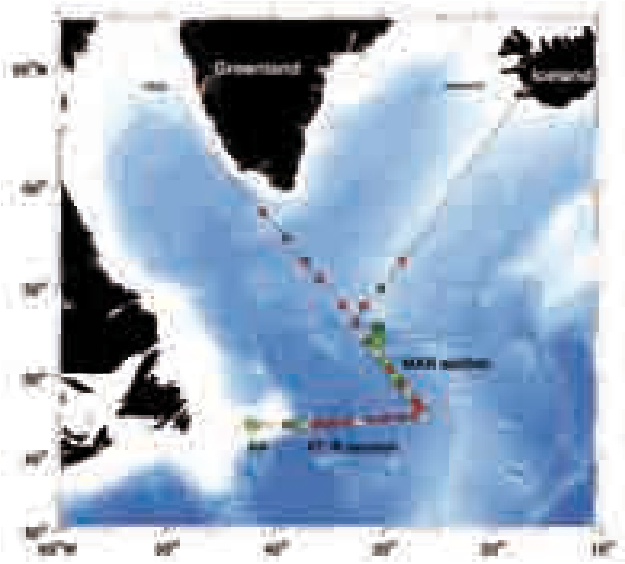
- *continuous time series of transports, formation rates, and water mass changes in key regions of North Atlantic are emerging*

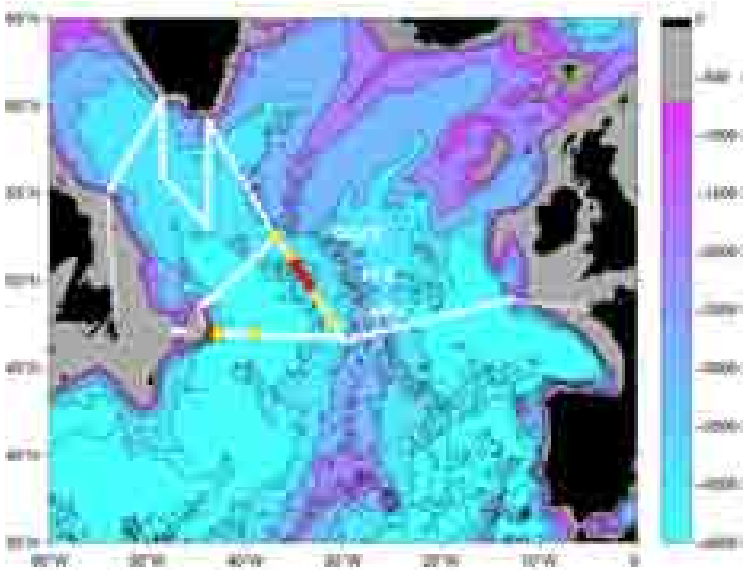
- *Intense circulation at 47°N in interior basin: mixing between old and young deep water*

- *DWBC continuous and important to transport young deep water, interior pathways between subpolar and subtropical gyre*

Midatlantic Ridge: 2006 – 2013, funding submitted till 2015 (Rhein / Klein)
47°N: DWBC 2009 – 2012, PIES full array 2013 – funding submitted till 2015 (Rhein)
Flemish Pass 2011 – 2015 funded (Kieke / Jochumsen)

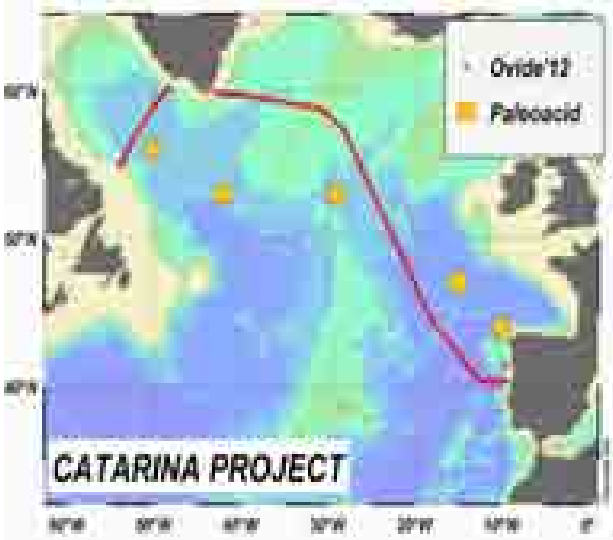






2012

Aida Rios, Vigo;



2013 , 2014

EGU 2012, Vienna
Thur, Fri: OS 1.2 The North Atlantic: Natural variability and Global Change

Conveners: Monika Rhein and Richard Greatbatch

Invited talks: Mojib Latif, Simon Josey, and Xiaoming Zhai

IFM-GEOMAR

Universität Bremen

North Atlantic Session
IUGG Meeting, July 22-26 2013,
Gothenborg, Sweden
http://www.iahs-iapso-iaspei2013.com/

Conveners:
Monika Rhein
Richard Greatbatch
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