Decadal Climate Predictions: The AMOC and the North Atlantic sector

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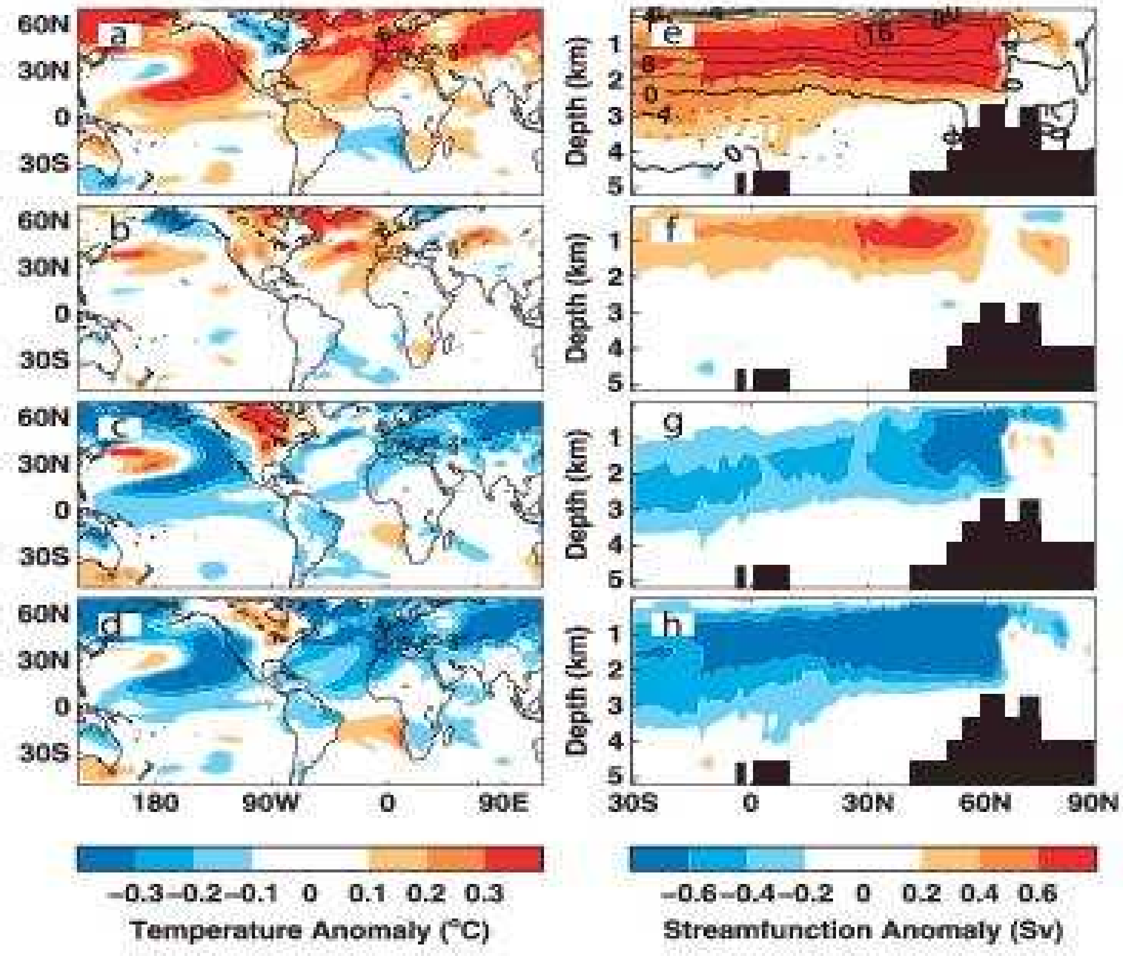
THOR

Outline

- Introduction: Atlantic Meridional Overturning Circulation (AMOC) and Atlantic Multidecadal Variability (a.k.a. AMO)
- Predictability studies using ocean initialization in the MPI-M climate model
  - North Atlantic SAT, SST
  - AMOC and heat transport
  - Deep water formation
- How robust are the AMV and AMOC/AMV relations in various models?
- Aspects of external forcing

AMOC variations and climate



Knight et al., 2005

MOC changes are associated with considerable temperature variations, in particular over the North Atlantic and Europe

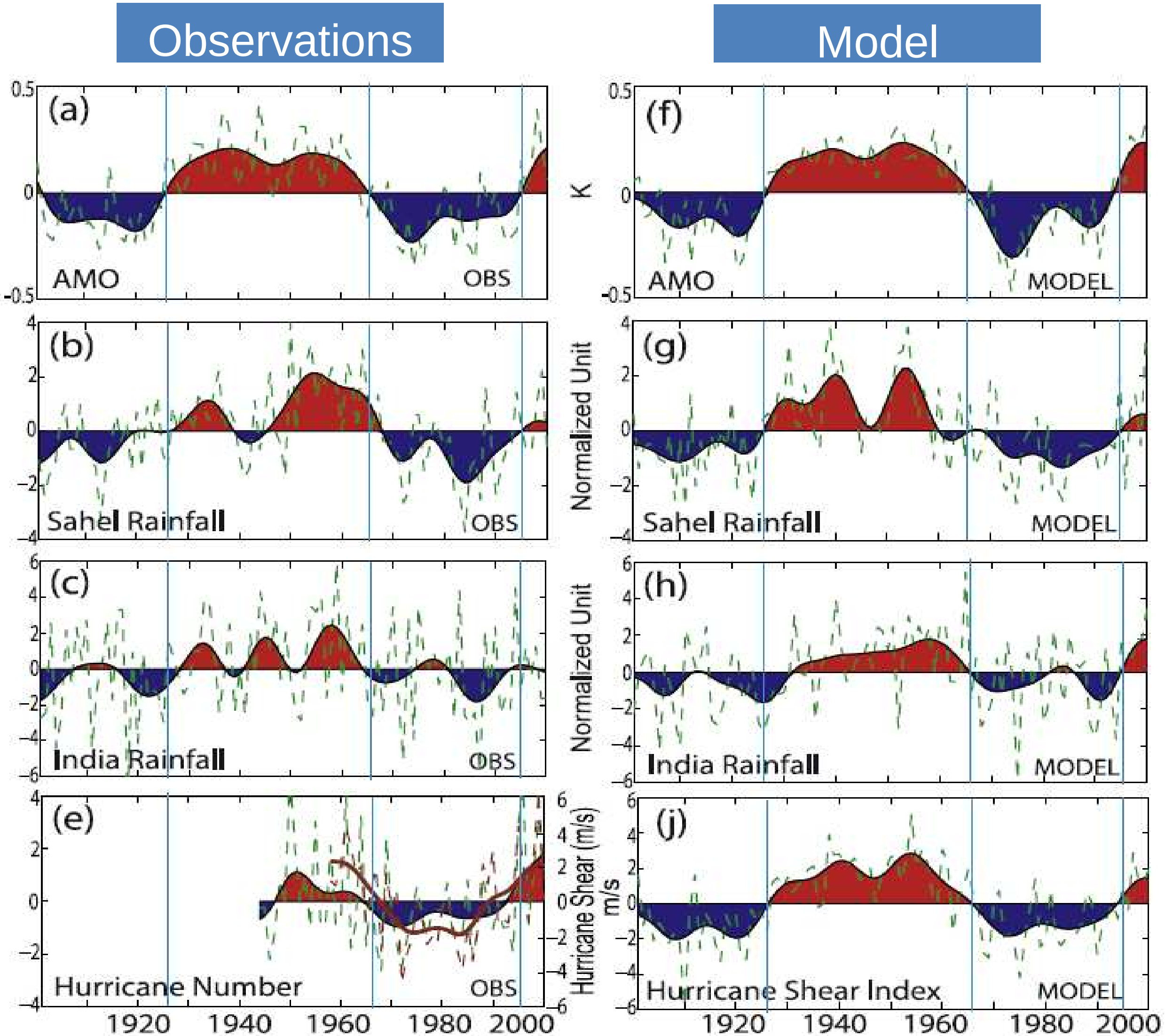
North Atlantic SST and other climate indices

North Atlantic SST

Sahel rainfall

India rainfall

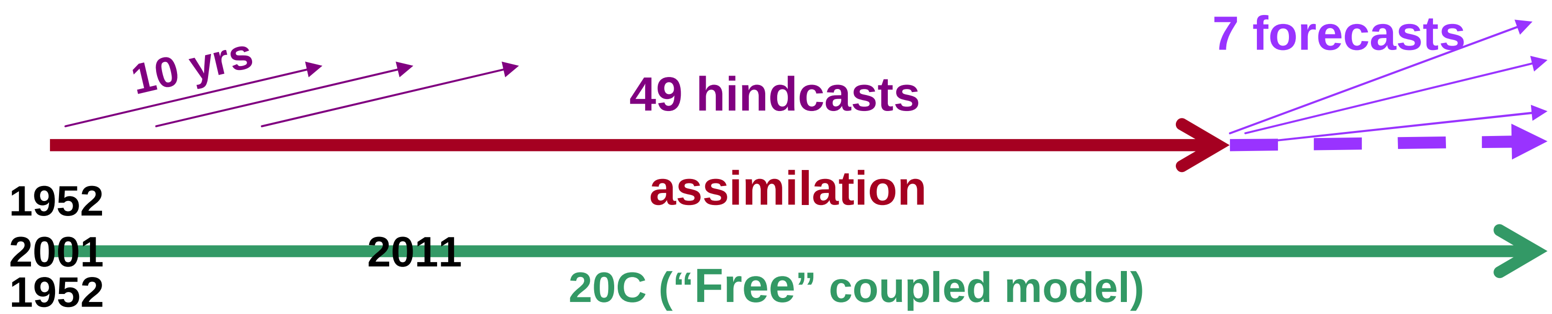
Hurricanes



Zhang and Delworth, 2006

Initialization by GECCO

- **Model: ECHAM5/MPI-OM T63L31/1.5L40 (~IPCC AR4 model).**
- **Include changes in greenhouse gases and sulphate aerosols (SRES A1B scenario).**
- **Include initial condition information: assimilate 3D T&S from GECCO (1952-2001).**
- **Use anomalies to avoid model drift.**
- **No initialization in the top ocean model layer.**



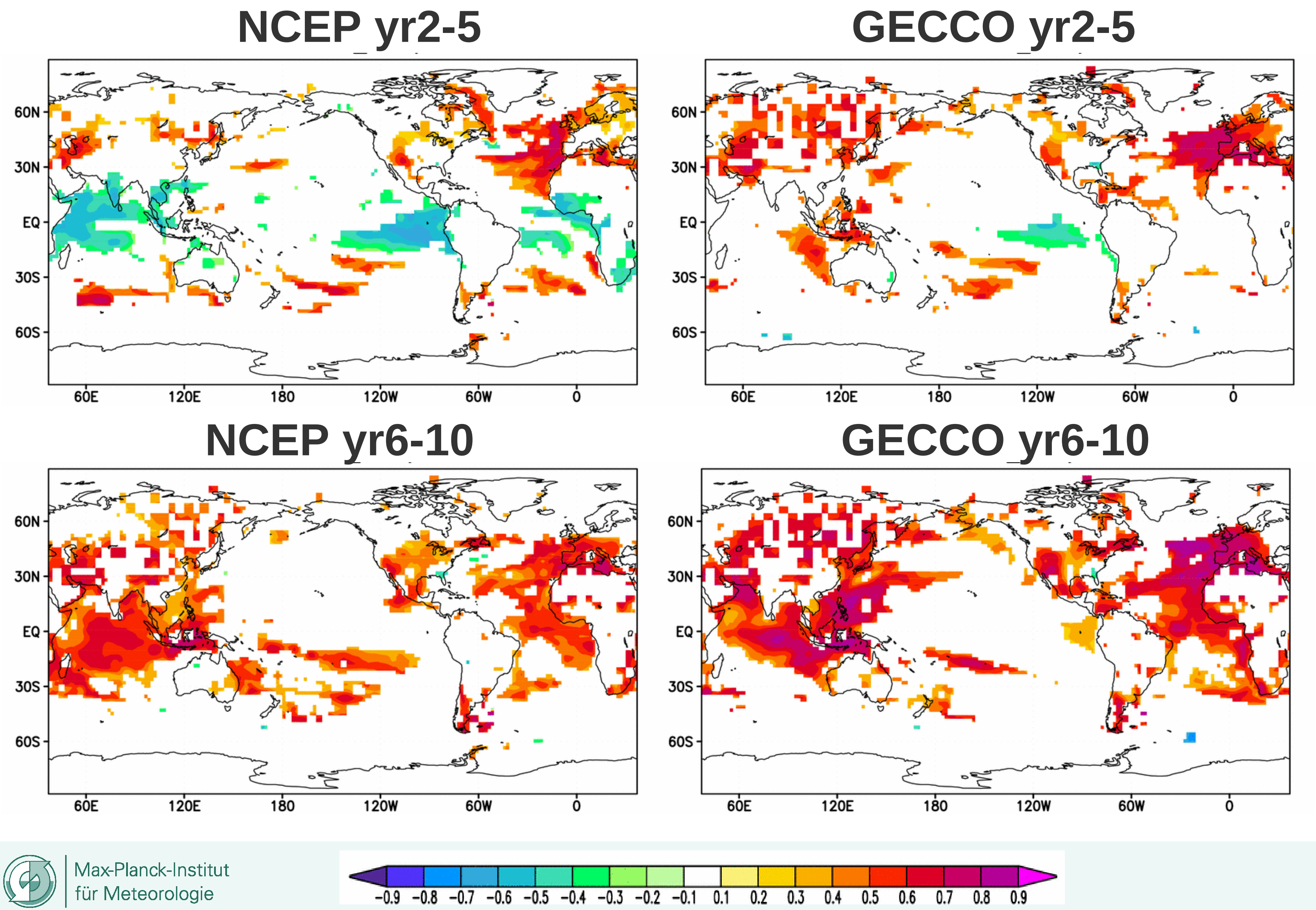
Initialization by NCEP-forced MPIOM

- **Mismatches between the ocean climates of GECCO and the MPI-OM model may lead to inconsistencies in the representation of water masses**
- **An alternative approach: ensemble of NCEP-forced integrations for the period 1948-2007**
- **The ensemble mean 3D fields of T&S anomalies are then nudged into the coupled model**

Matei et al. (2010)

Predictability of SAT and North Atlantic SST

SAT COR skill for yr2-5 and yr6-10



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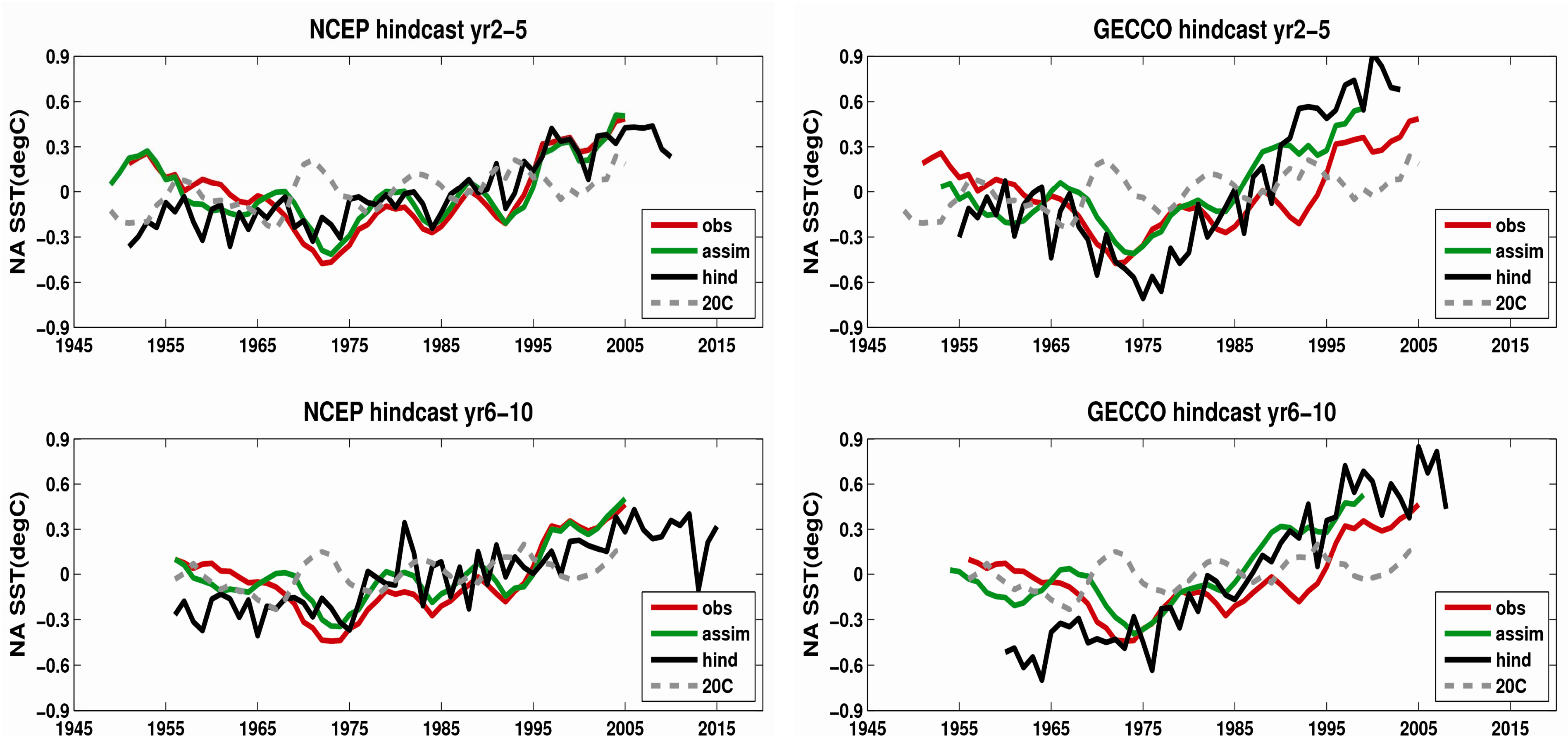
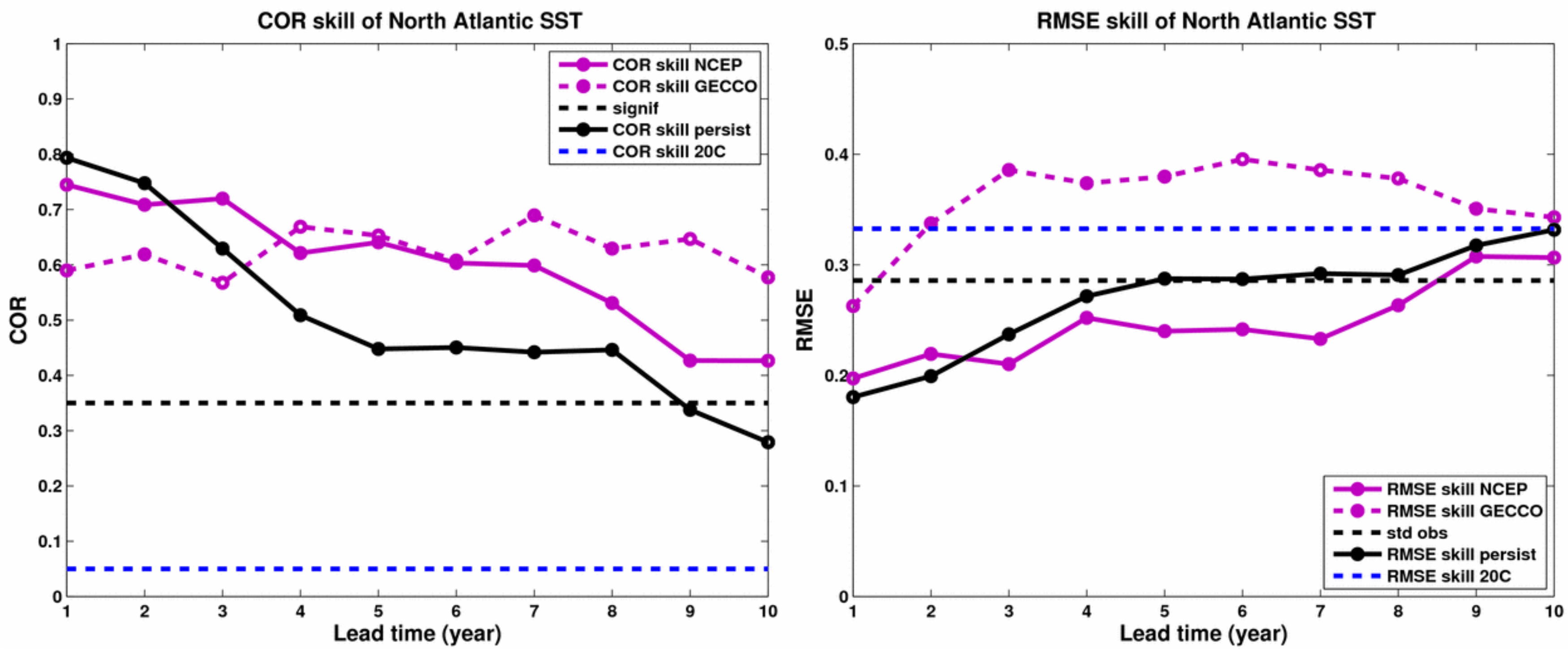
North Atlantic SST



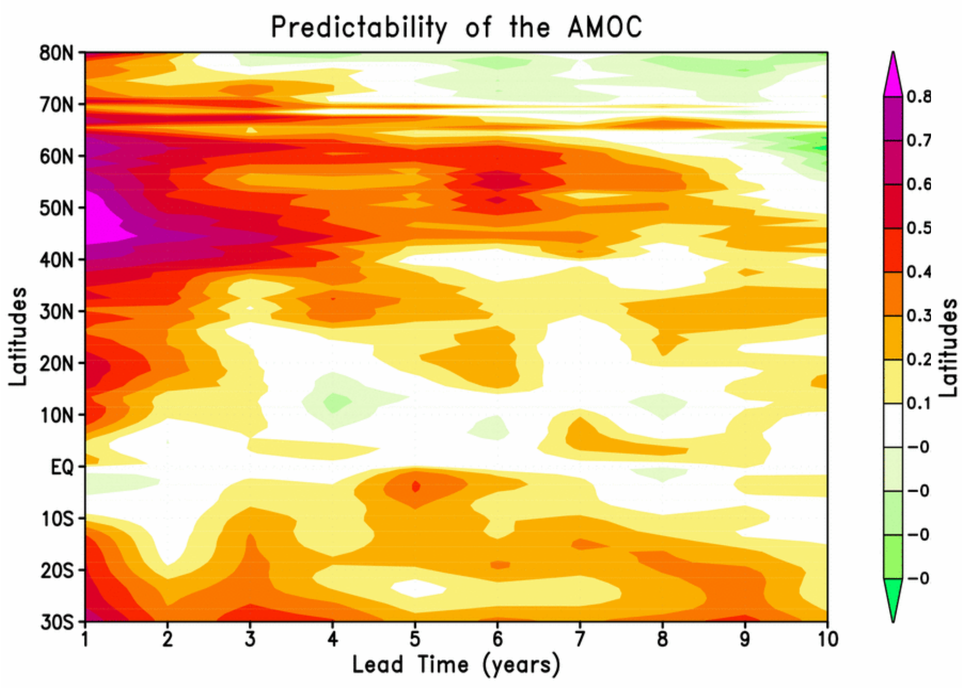
North Atlantic SST predictive skill

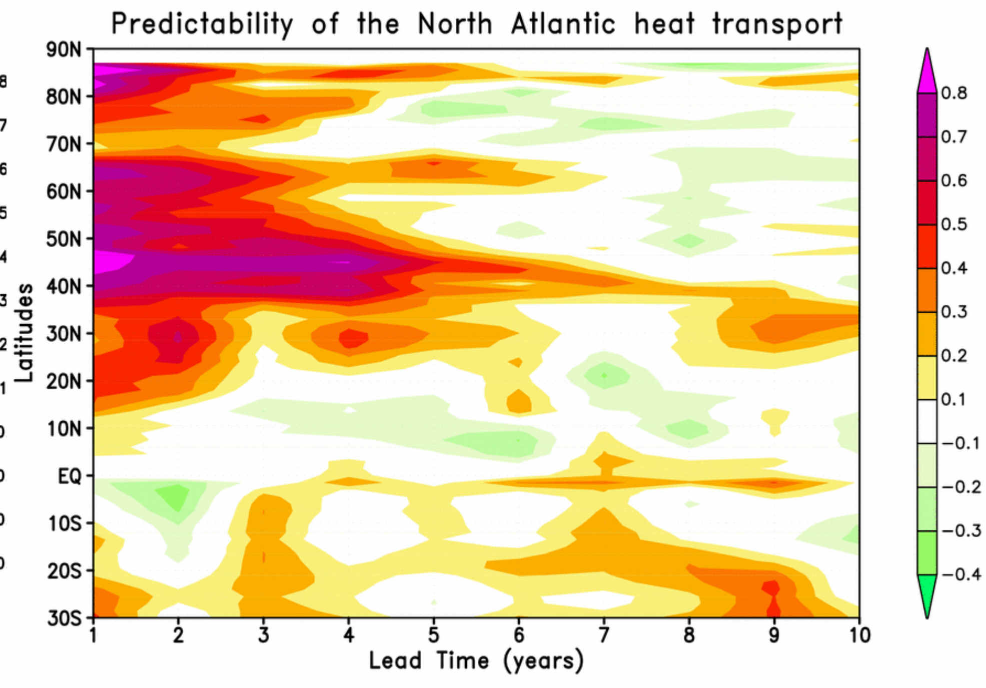


Predictability of AMOC and some of its “components”

(using NCEP-forced initialization)

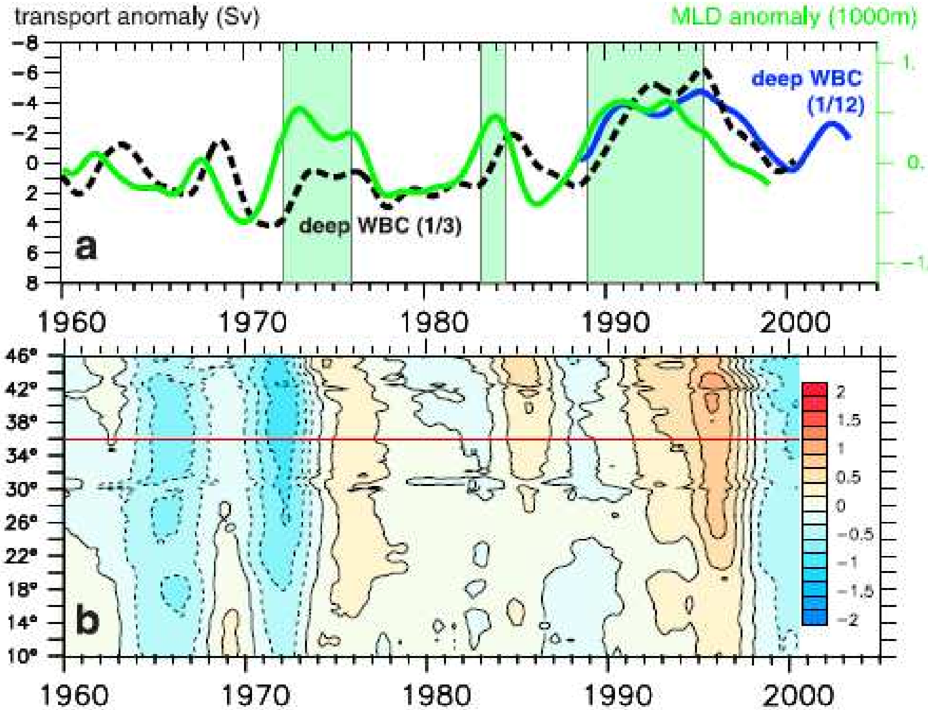
Potential Predictability of AMOC



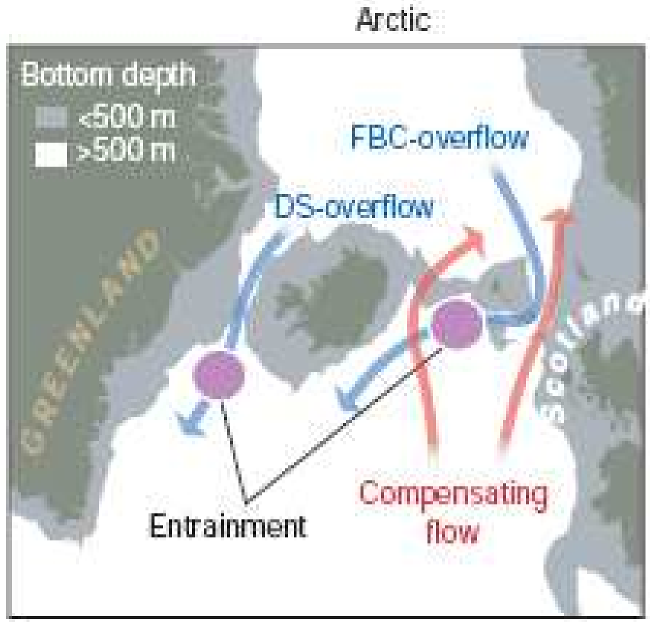


- highest predictability in sub-polar region, carries over to heat transports.
- Important role of interaction between AMOC and gyre system

Sources of AMOC variability



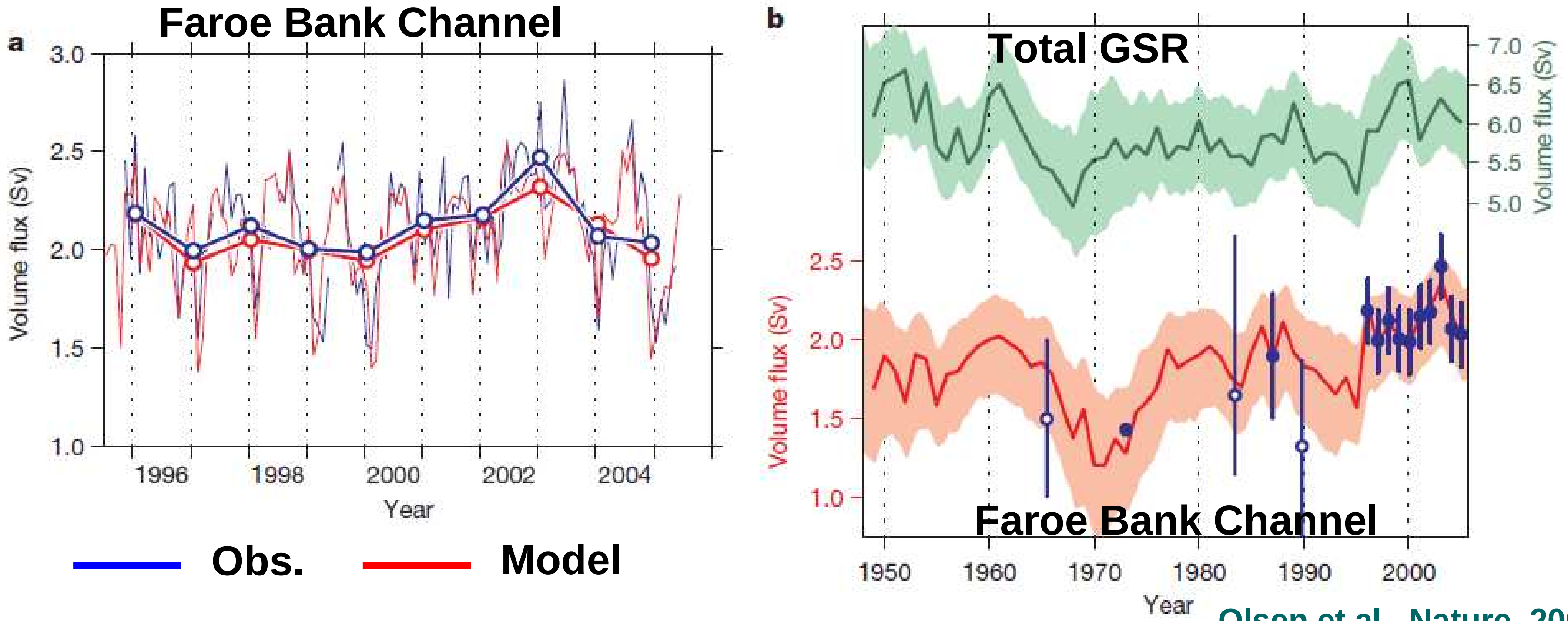
Boening et al., 2006



Hansen et al., 2005

- AMOC is modulated by variations in LSW formation and Nordic Seas overflows

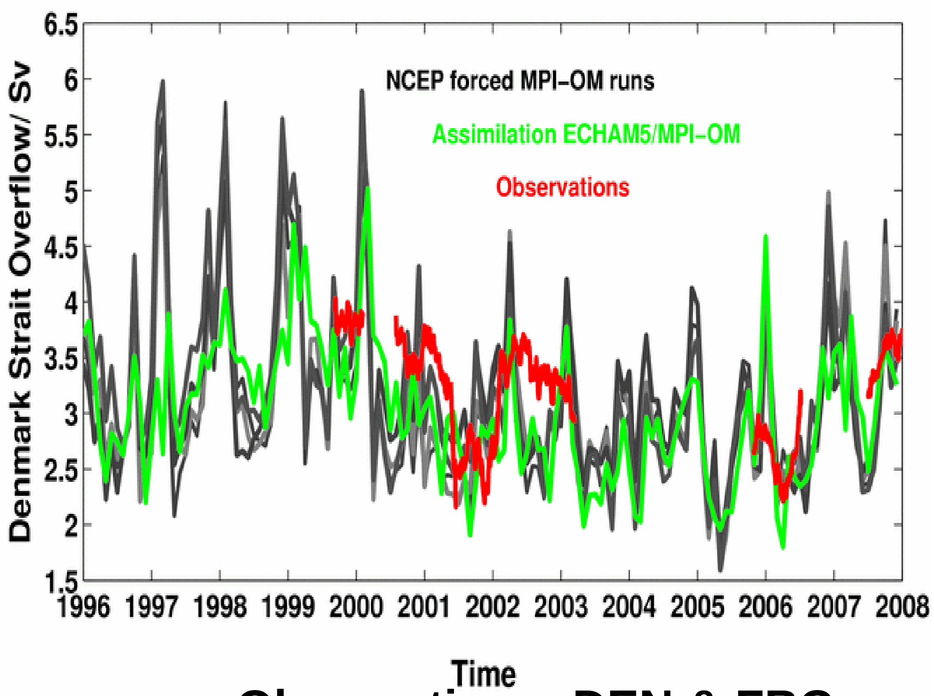
Nordic Seas Overflows

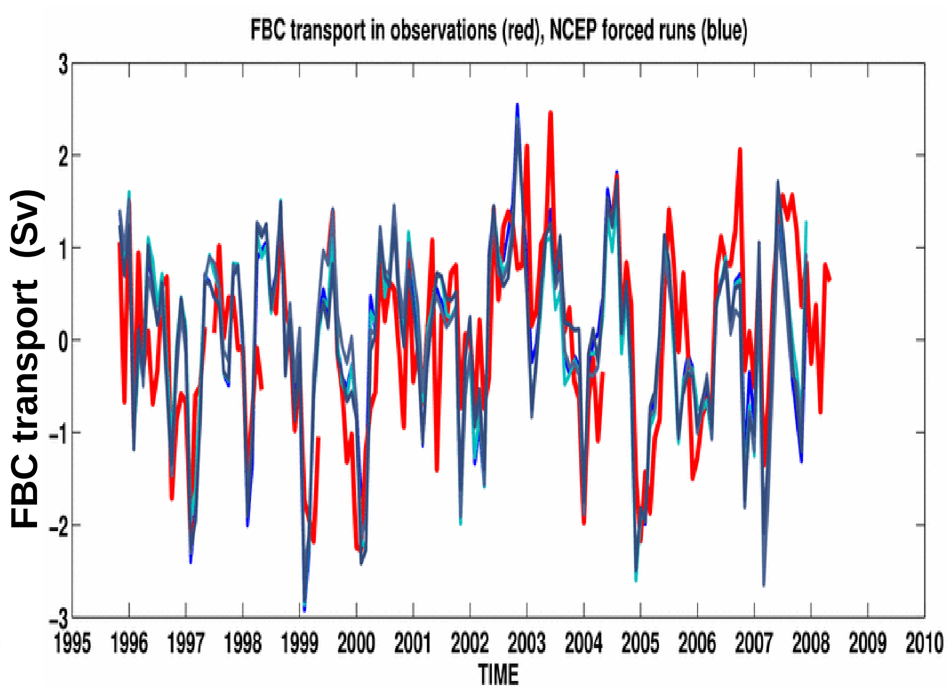


Olsen et al., Nature, 2008

- Olsen et al. showed that overflow variability can be reproduced on interannual, but also on decadal time scale in NCEP-forced ocean-only simulations.

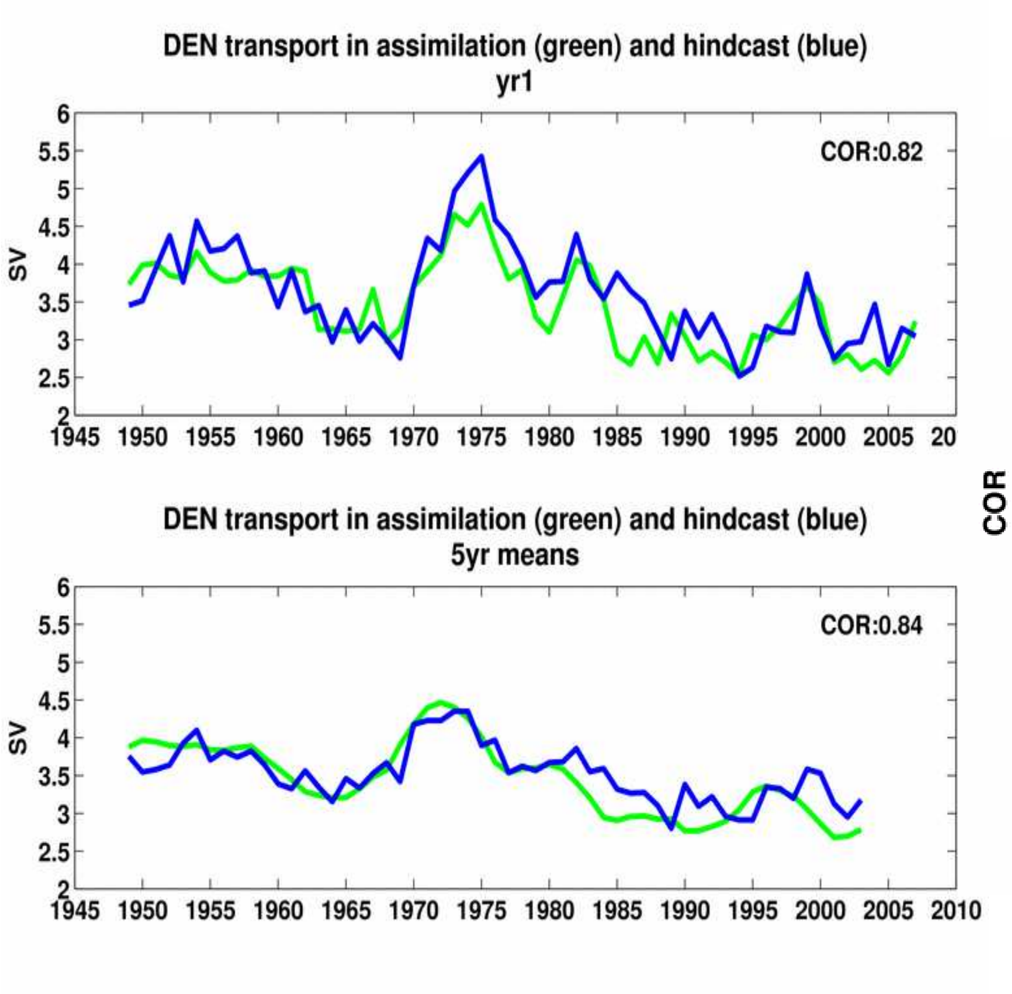
Nordic Seas Overflows NCEP-forced vs. obs.

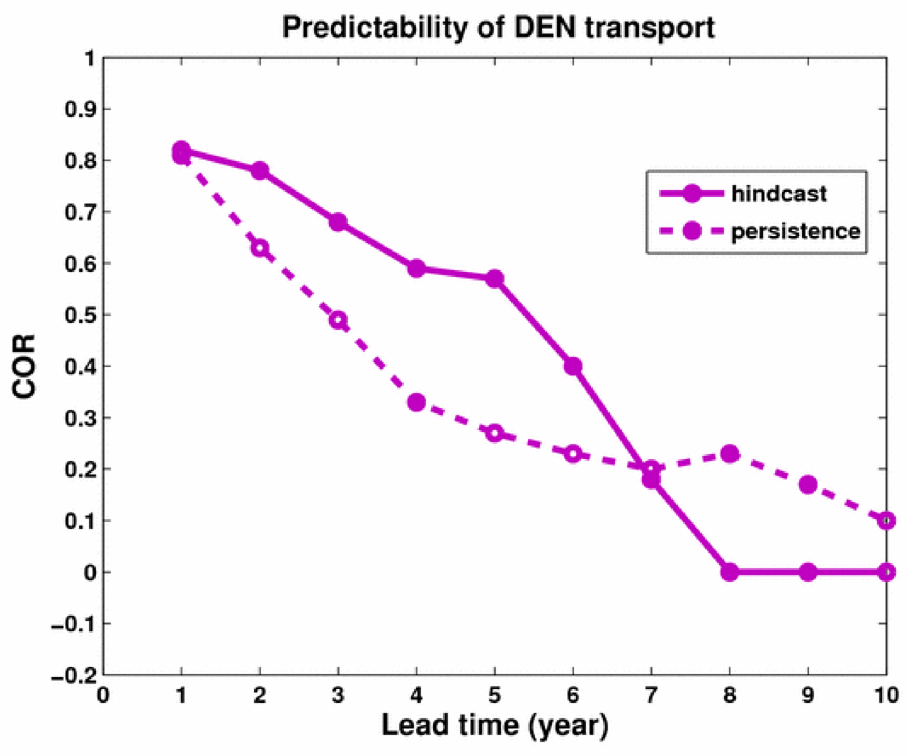




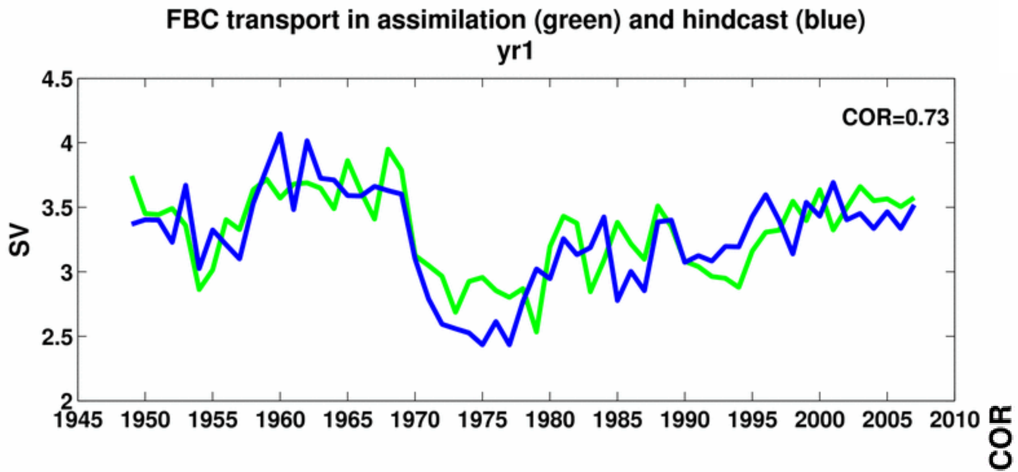
Observations: DEN & FBC overflow (R.Käse& B. Hansen)

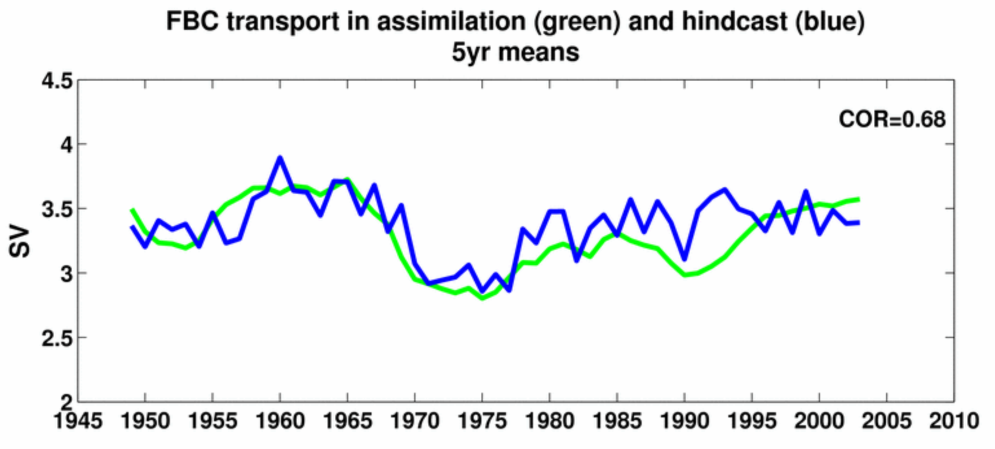
Potential Predictability of DEN overflow

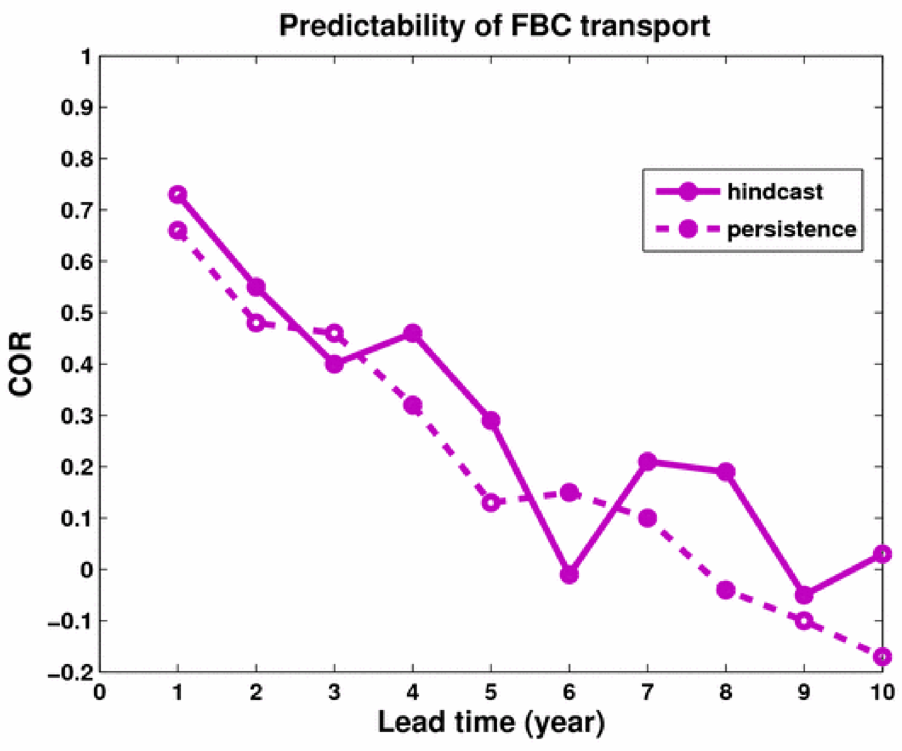




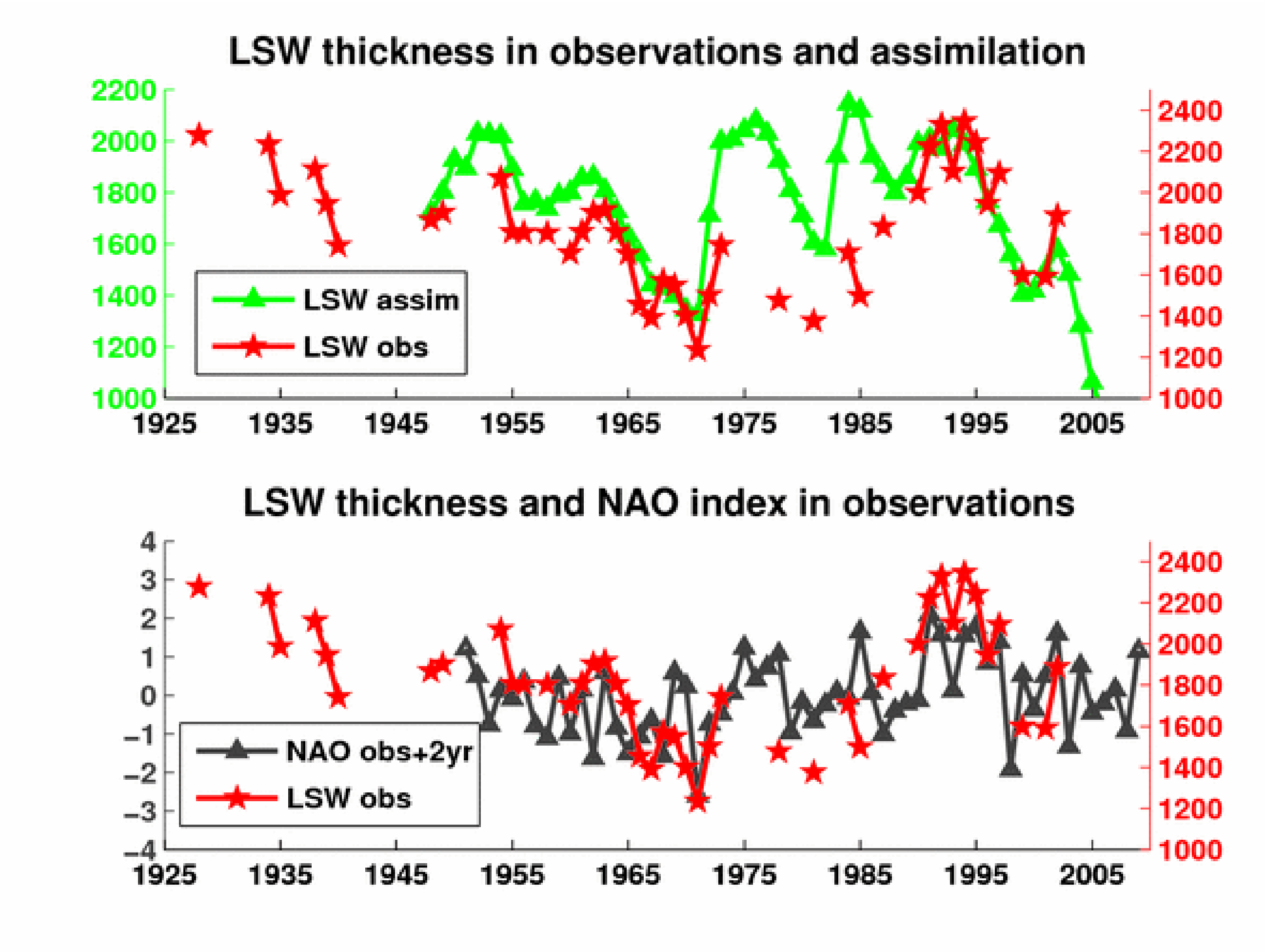
Potential Predictability of FBC overflow





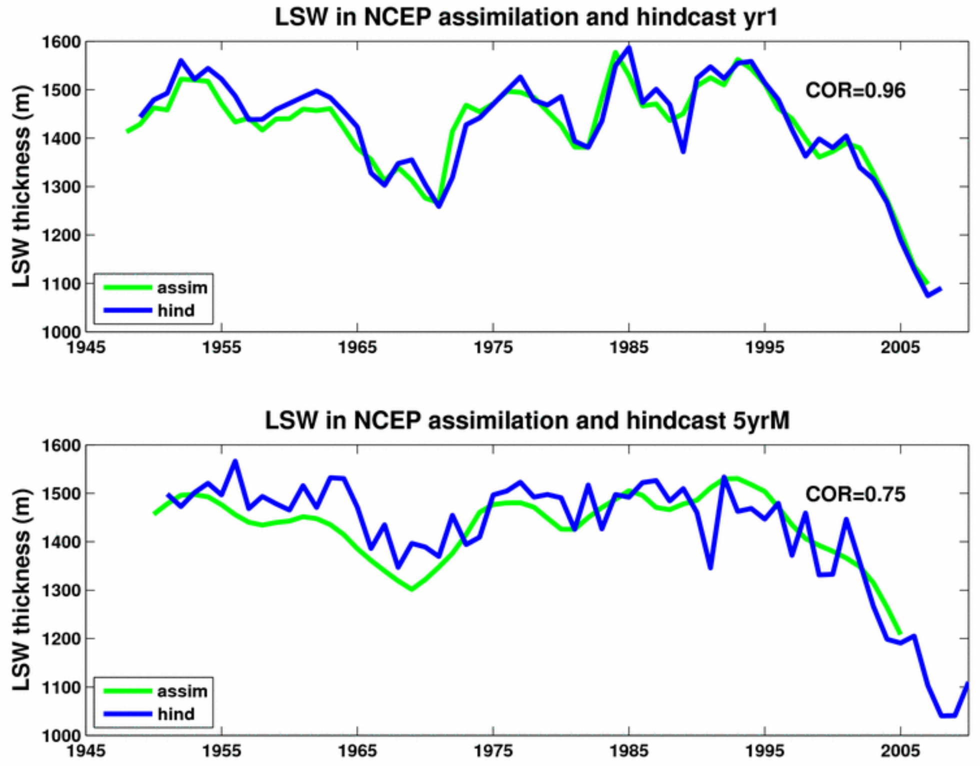


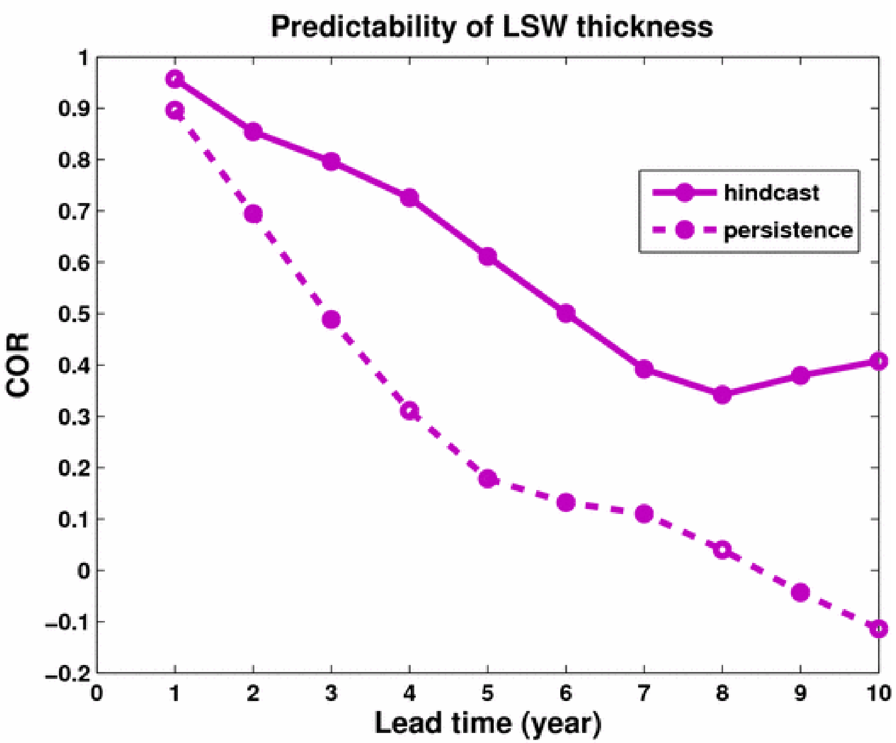
LSW thickness NCEP-forced vs. obs.



Observations: LSW (Curry et al. 2001) & NCEP/NCAR (NAO index)

Potential Predictability of LSW thickness
NCEP-forced





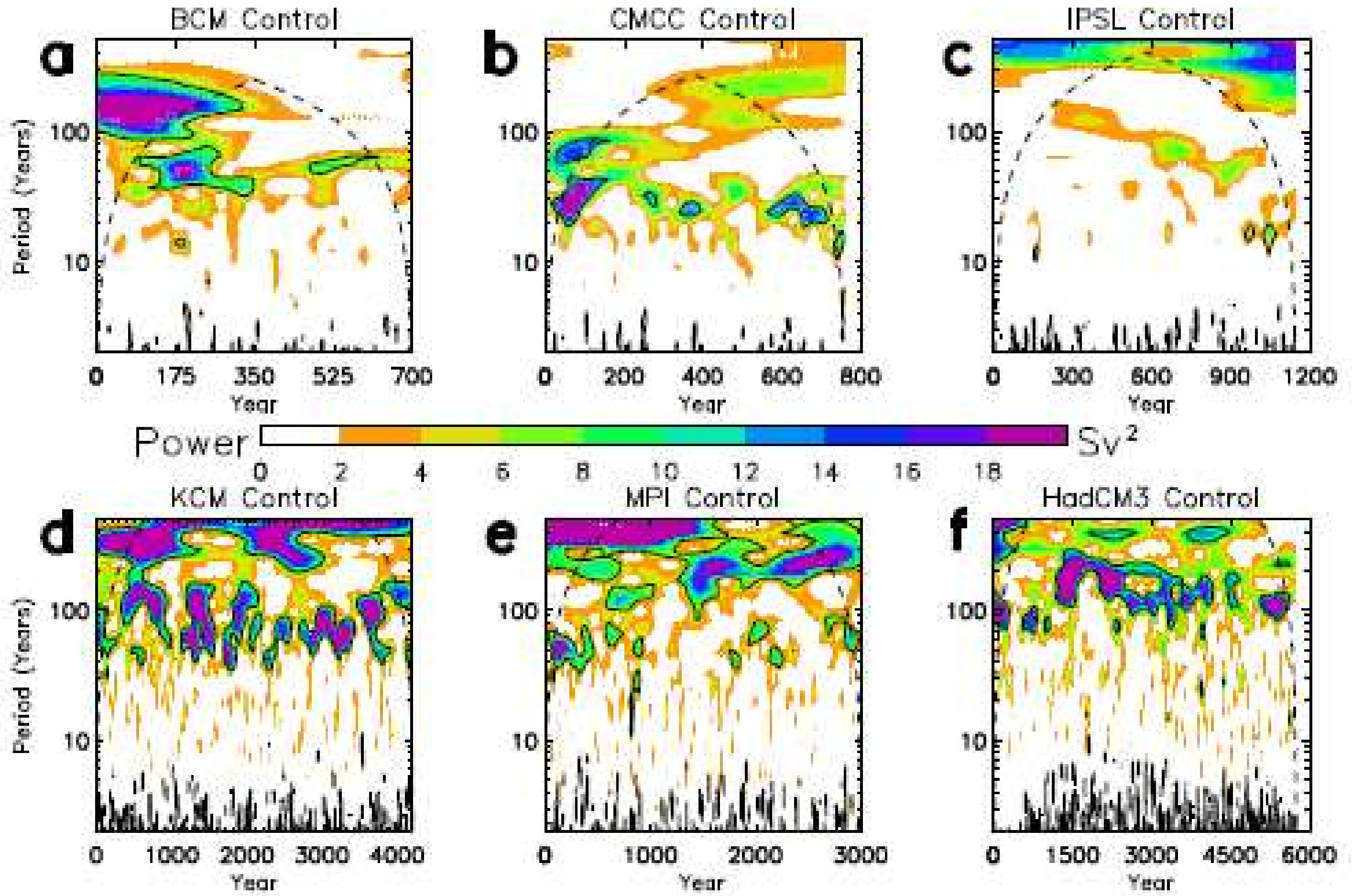
“Pre” - Conclusions

- First attempts in decadal climate prediction, based on ocean initialization, show promising results and achieve significant multi-year predictive skill for crucial climate quantities (e.g., North Atlantic surface air temperature, Atlantic MOC, deep water formation)

- However, causes for skill (or lack thereof) have not been investigated to sufficient depth; how much does the result depend on the specific period we look at?

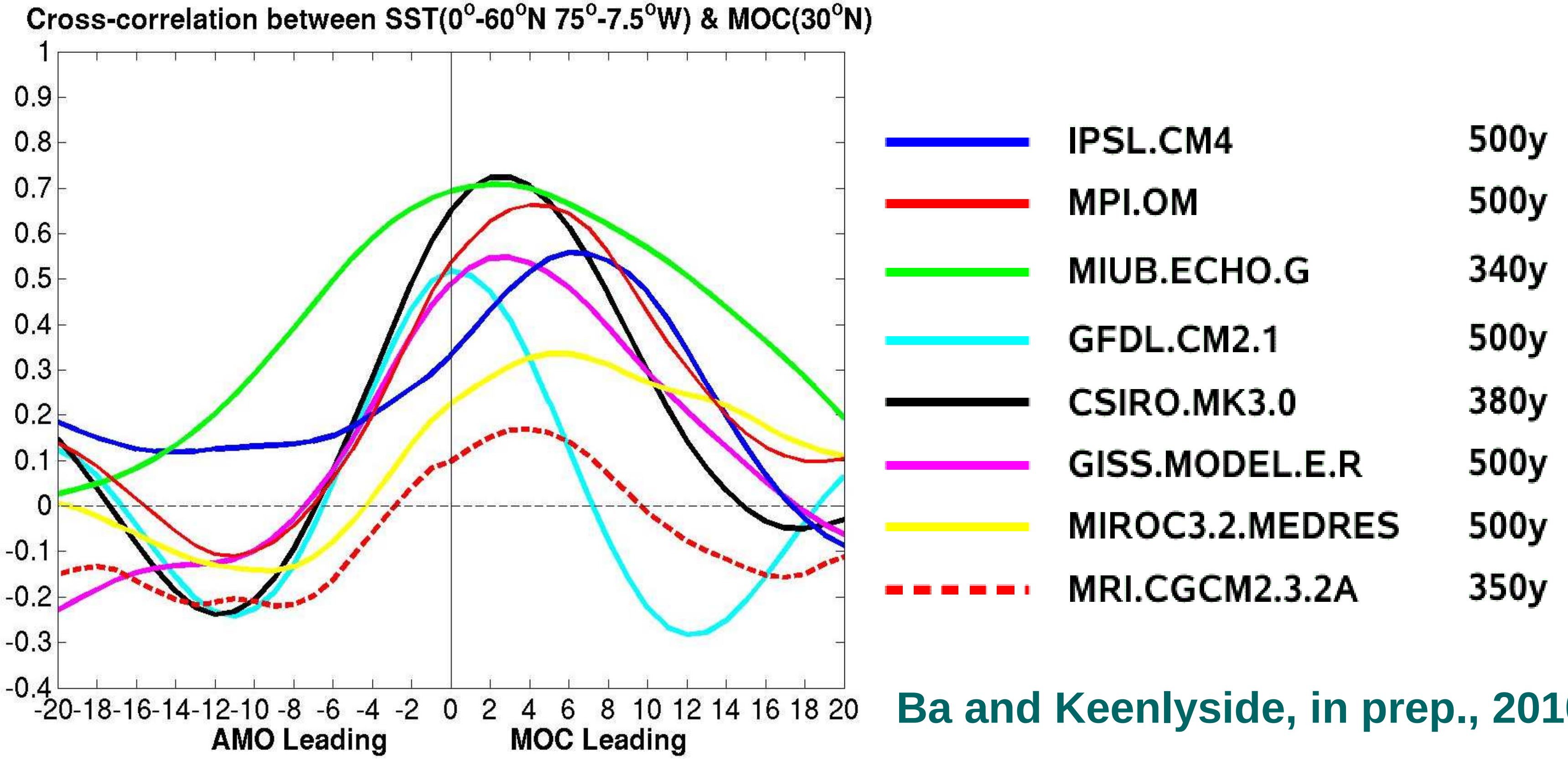
- Moreover, what about the decadal or even multi-decadal scale that looks so promising in the AMO/AMV picture?

needs for further research: decadal to centennial variability in models



Menary et al., submitted 2010

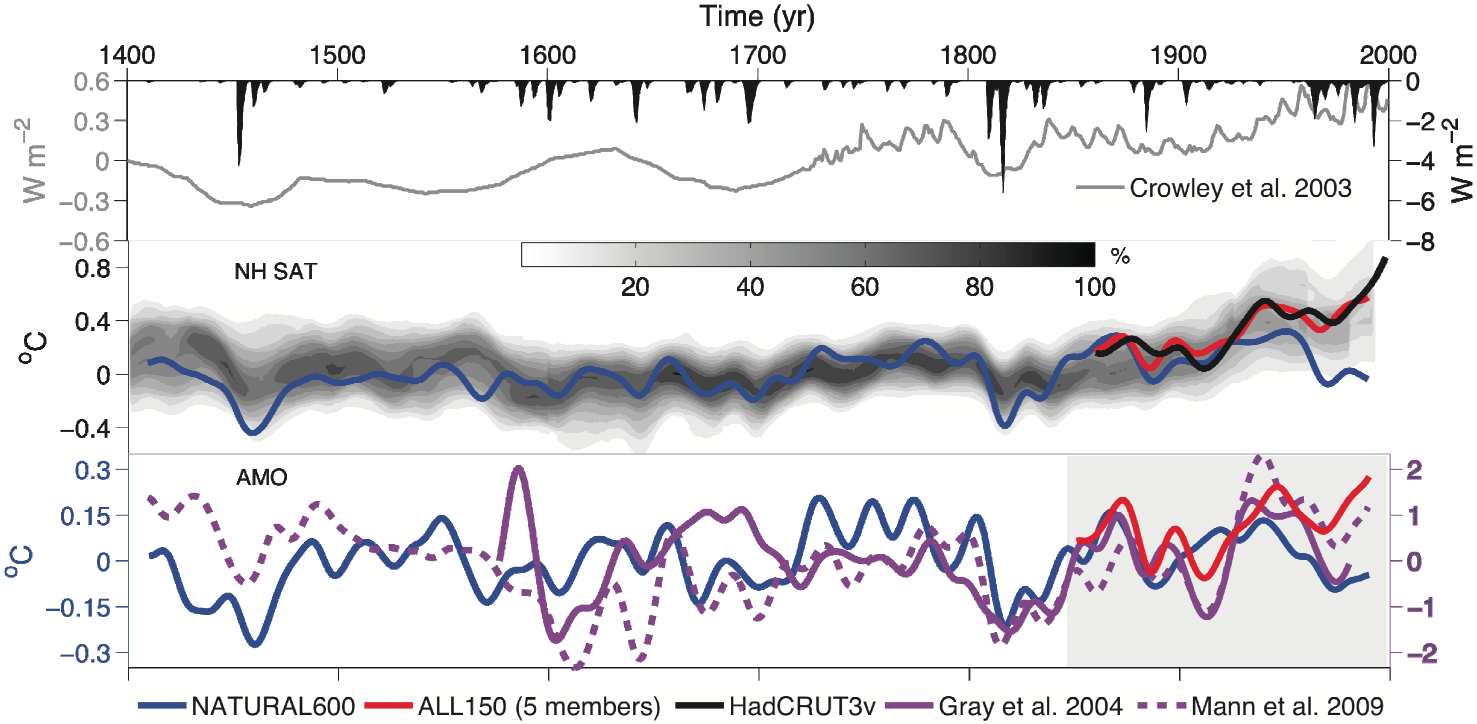
needs for further research: processes



Ba and Keenlyside, in prep., 2010

Models agree that North Atlantic SST anomalies (Atlantic Multidecadal Variability, AMV) are driven by the MOC, but there are certain differences in timing, probaly related to the representation of processes. Note: no ext. forcing!

needs for further research: internal variability vs. external forcing



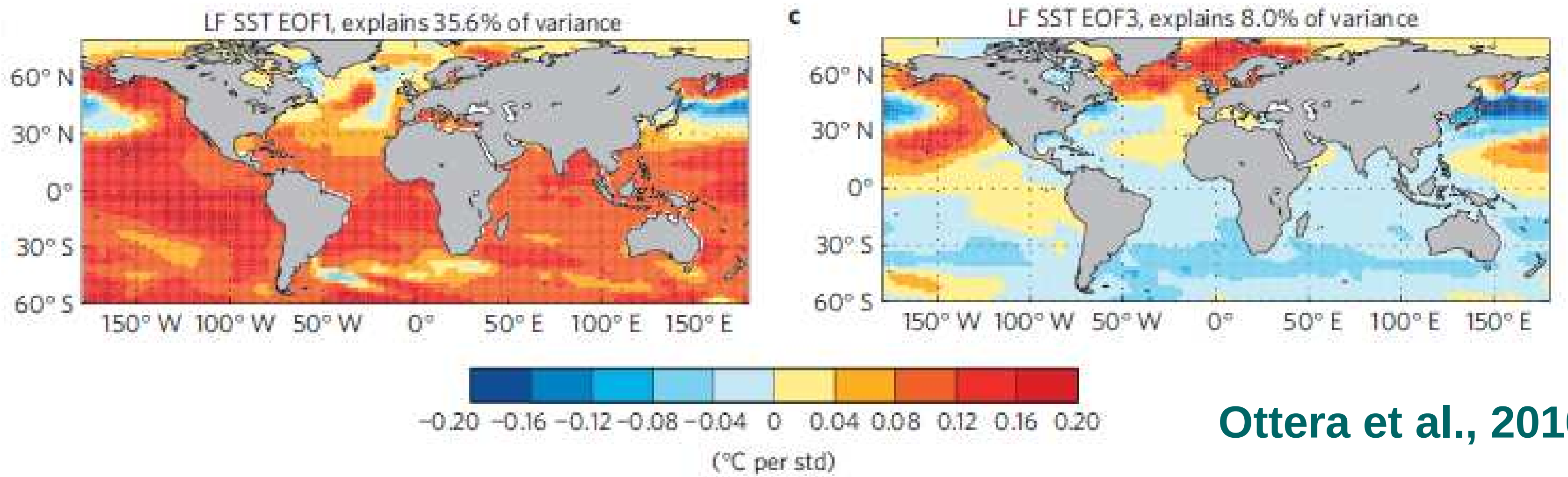
Ottera et al., 2010

model integrations over the last millennium (THOR) indicate that external forcing, such as strong volcanic eruptions, strongly influence the surface temperatures

needs for further research: internal variability vs. external forcing

Variability pattern due to external forcing

Variability pattern due to MOC changes



Ottera et al., 2010

Changes in external forcing (e.g. strong volcanic eruptions) may override MOC-driven temperature changes and imprint their signal onto the MOC. However, relative role of internal variability vs. external forcing is model dependent.

Conclusions Part II

- Variability time-scales and underlying mechanisms are different in various models. Need to identify those that appear to work in the real world (e.g. Menary et al., submitted 2010)
- Variability characteristics are not stationary (e.g. Saenger et al., 2009; Zanchettin et al, 2010)
- External forcing plays a role in shaping AMO, but also AMOC. Need to investigate mechanisms that translate forcing “events” to longer-term variations (e.g. solar forcing: Servonnat et al., 2010; volcanic forcing: Ottera et al., 2010)