Nonlinear Mechanisms of Interdecadal Climate Modes

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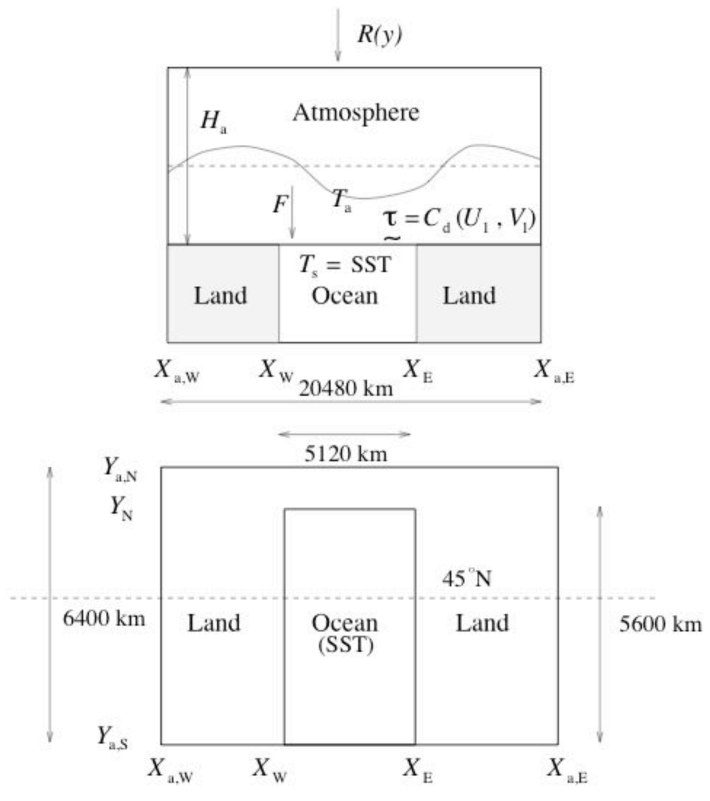
North Atlantic Ocean–Atmosphere Co-Variability: A Nonlinear Problem

- Persistent atmospheric patterns, which are most likely to be affected by coupling, are result of complex eddy–mean flow <u>interaction</u>
- The region of potential coupling is also characterized by vigorous oceanic <u>intrinsic variability</u>
- Linear atmospheric response to weak SSTAs is small. Hence, “active coupling” = “nonlinear atmospheric sensitivity to SSTA.”

Coupled Models

(1) Quasi-geostrophic atmospheric and ocean components, both characterized by vigorous intrinsic variability

(2) The same atmospheric model coupled to a coarse-resolution, primitive-eqn. ocean



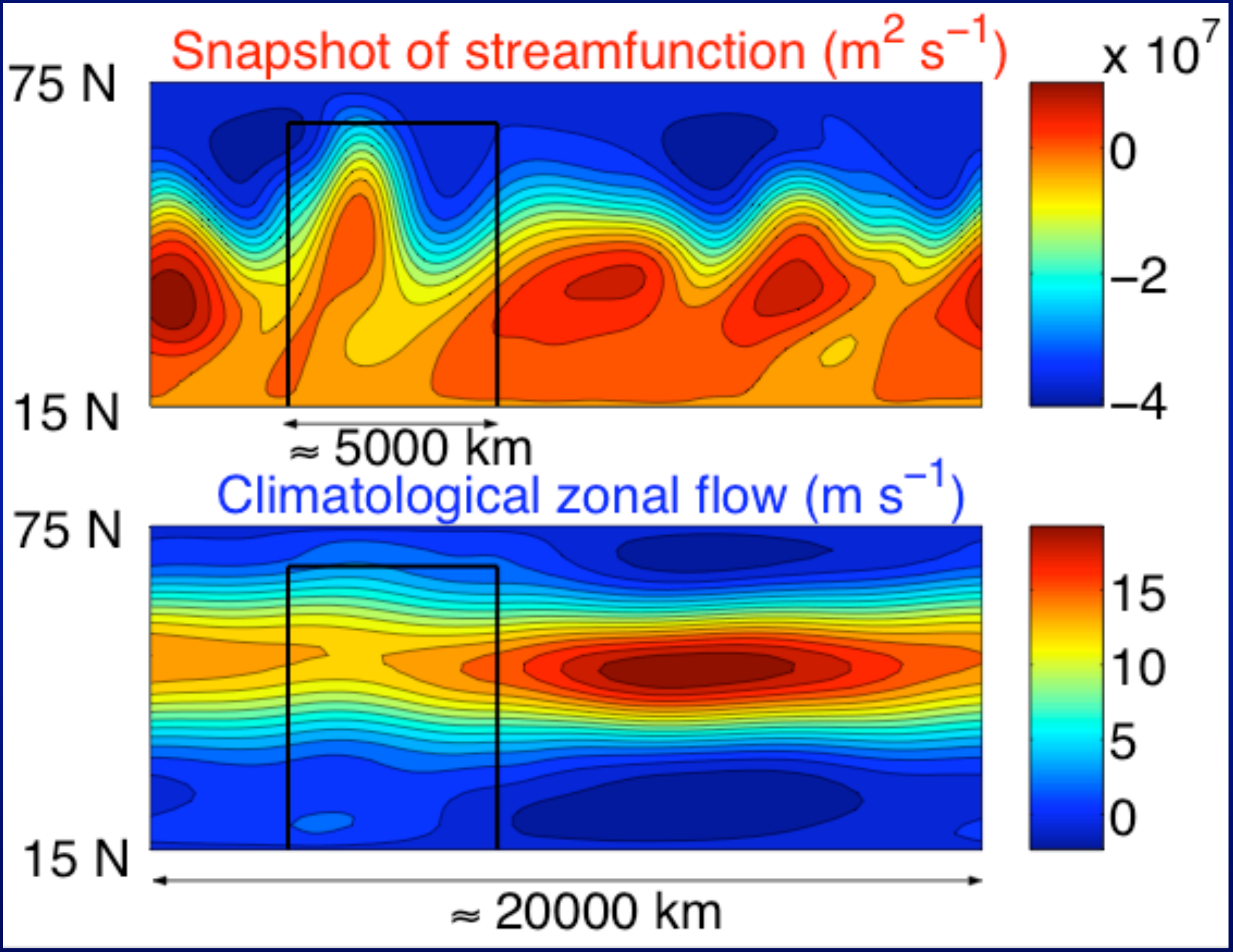
Observational Analyses

- NCEP/NCAR Reanalysis (Kalnay 1996) zonally averaged zonal wind data set: 58 Northern Hemisphere [10N–70N] winters (Dec–Mar)
- Sea-surface temperature (SST) observations (annual means, same period)
- Upper ocean heat content data [1965-2006] (Lyman et al. 2006)

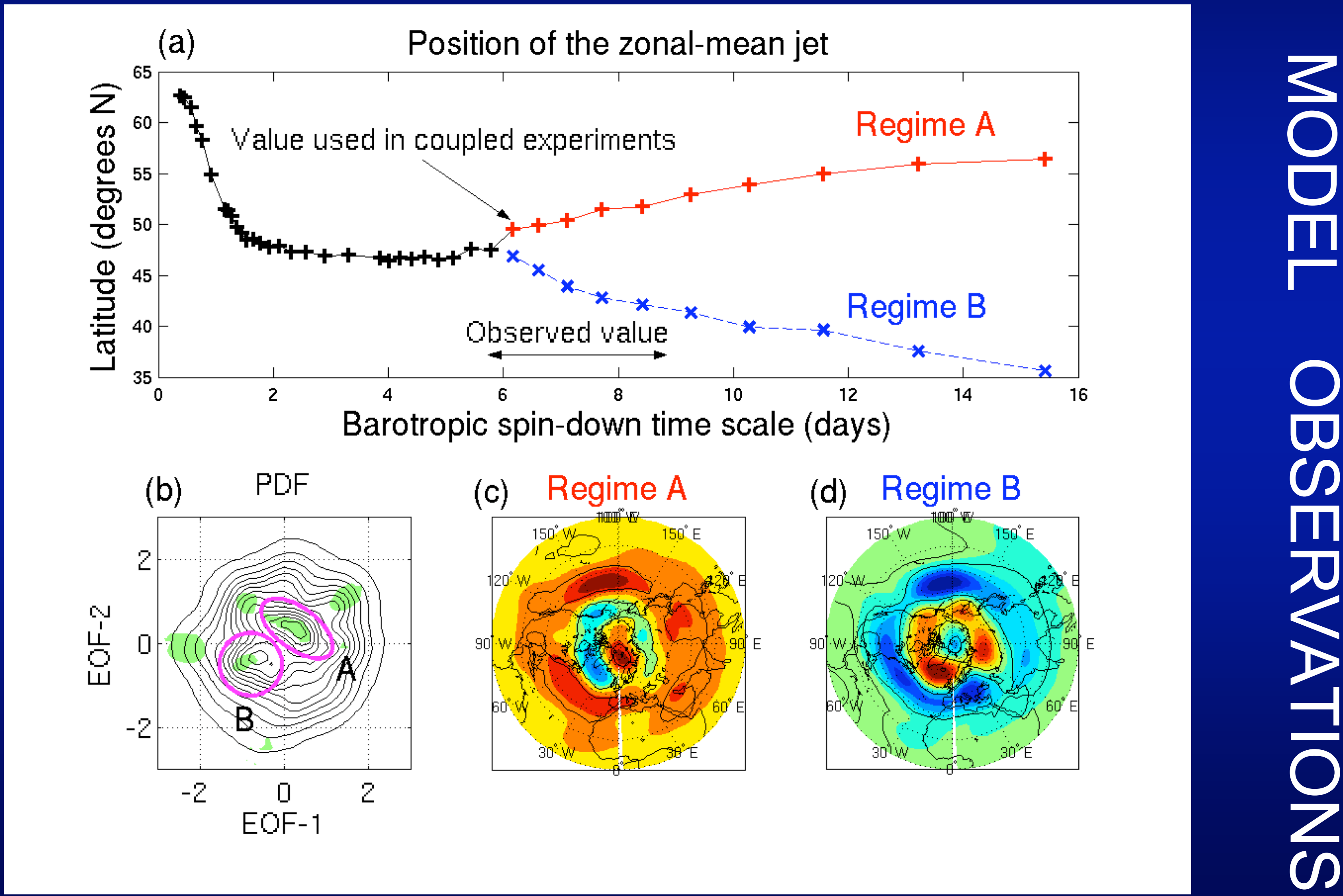
Methodology

- Study non-linear aspects of atmospheric intrinsic variability by identifying patterns characterized by anomalous persistence (time scale longer than about a week)
- Identify long-term (decadal and longer) changes in the probability of such states
- Connect the latter changes with the changes in boundary forcing (e.g., SST), as well as with the upper-ocean (inter-)decadal variability

Atmospheric circulation in a model

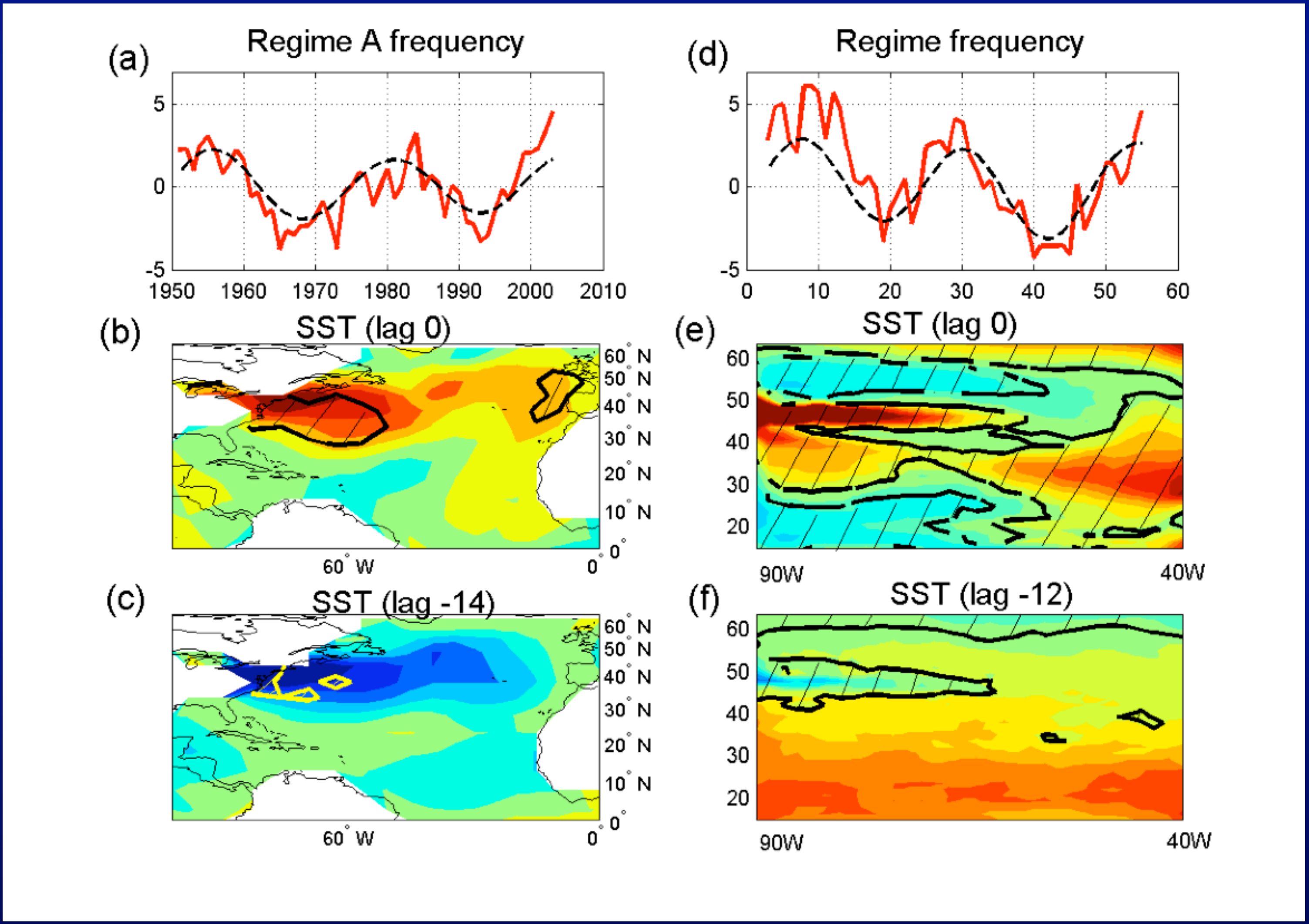


Atmospheric bimodality in models and observations



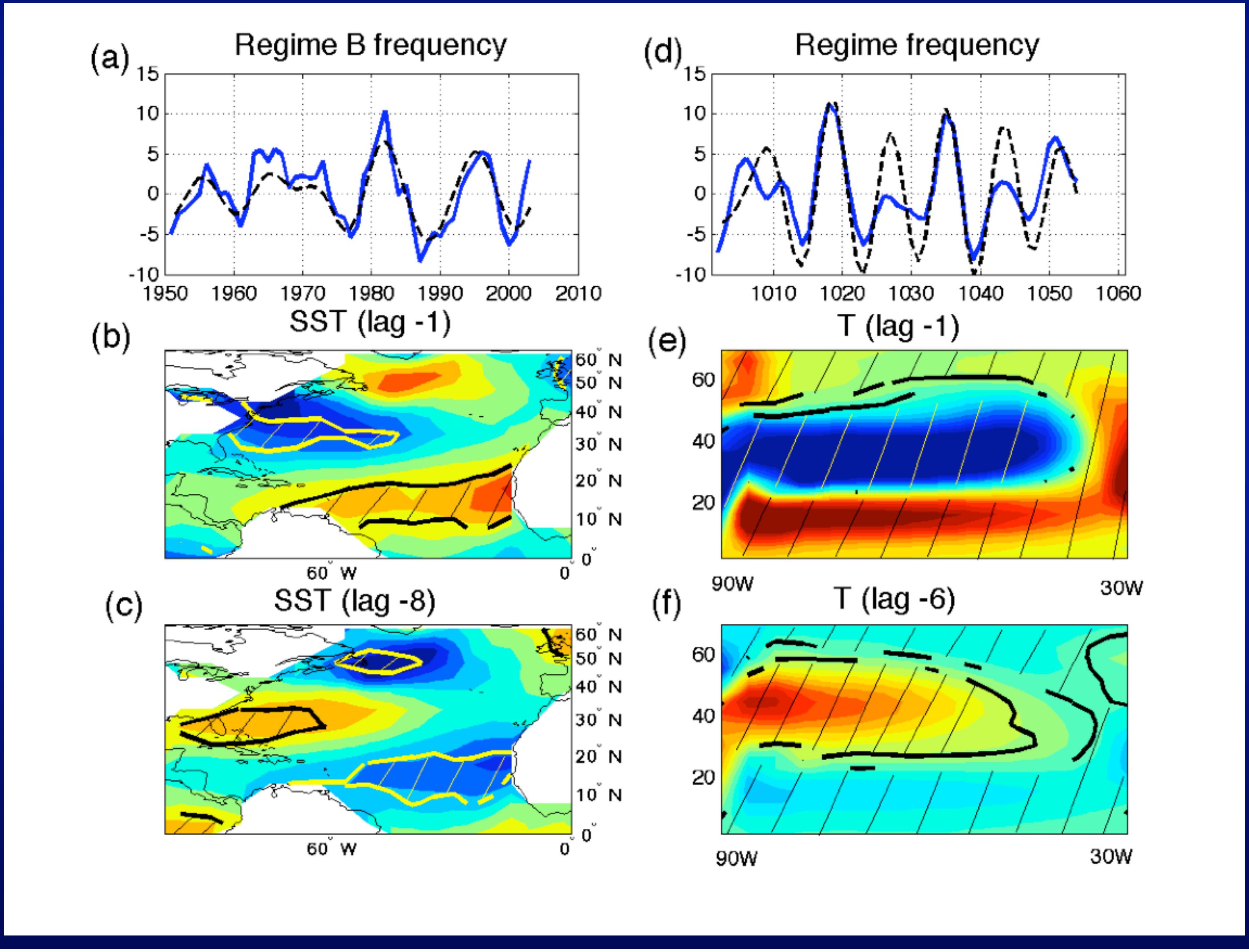
20–25-yr Coupled Mode

OBSERVATIONS COUPLED QG MODEL



10–15-yr Mode

OBSERVATIONS   COUPLED OPE MODEL

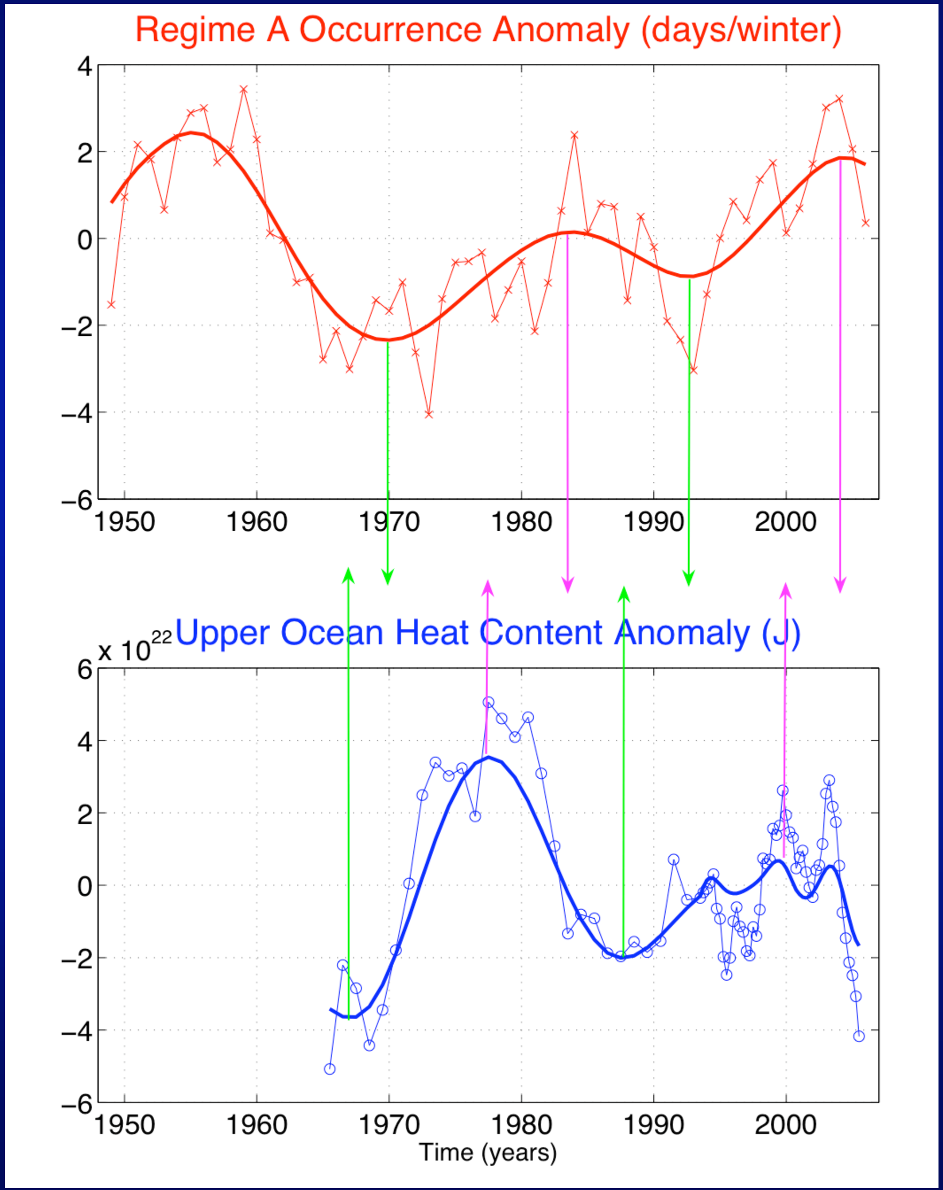


Observations of OHC Variability

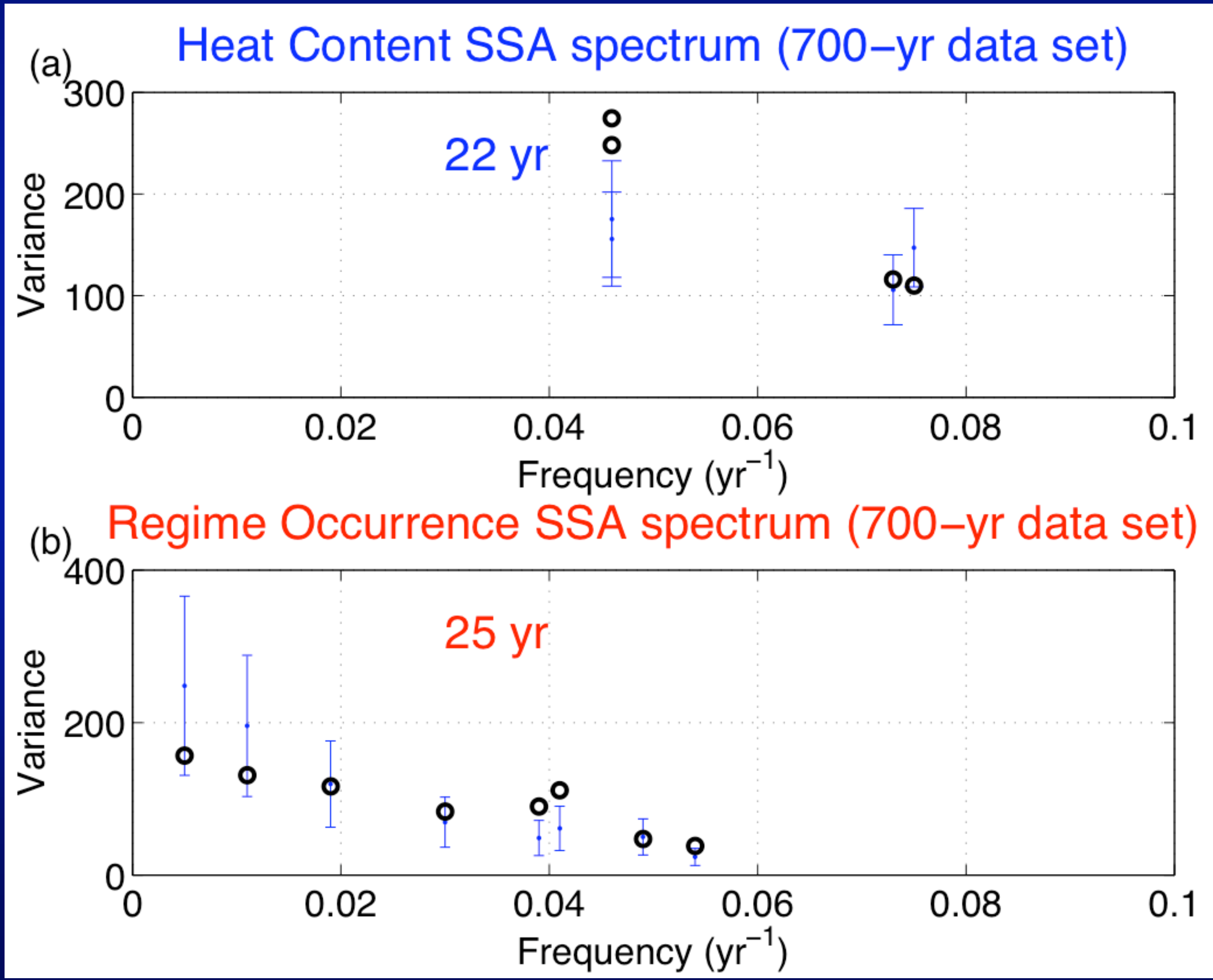
Observational record is relatively short, <u>BUT</u>

- Both Regime A and OHC time series exhibit bi-decadal variability

- OHC <u>leads</u> changes in regime occurrences by a few years



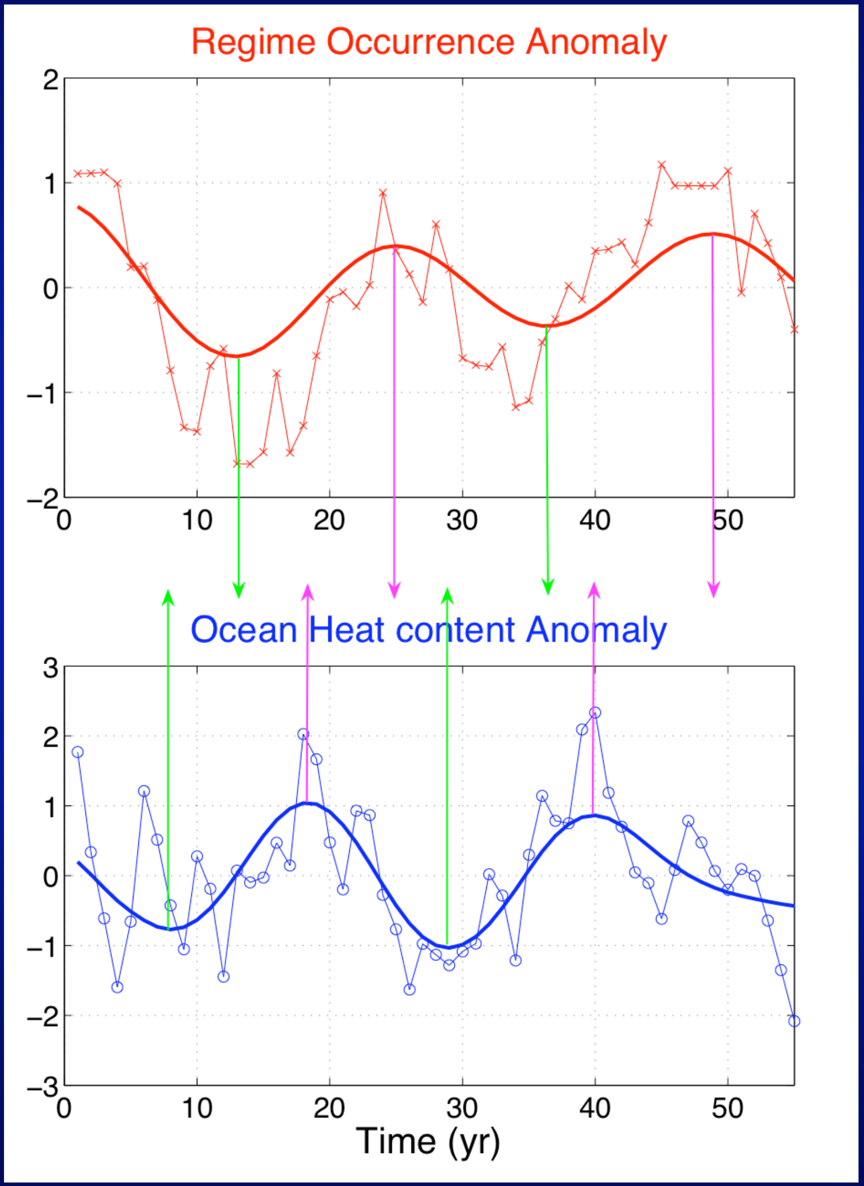
OHC variability in a CQG model–I



OHC variability in a CQG model–II

Observational result applies to CQG model variability as well:

<u>In a bidecadal coupled oscillation, OHC leads regime occurrence frequency by a few years</u>



Summary

- There is a mounting evidence for a (bi-)decadal coupled climate signals with centers of action in the North Atlantic Ocean
- Its signatures are found in the NH zonal wind and SST data, as well as in the global upper-ocean heat content data
- Prototype coupled models exhibit oscillations that reproduce time scales and phase relations between key climate variables
- Bimodal character of atmospheric LFV is res-ponsible for atmospheric sensitivity to SSTAs

Selected references

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