Role of Nonlinear Processes and Multi-Scale Interactions in Mid-Latitude Decadal Climate Variability

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Multi-scale problem!!!

North Atlantic Ocean — Atmosphere System:

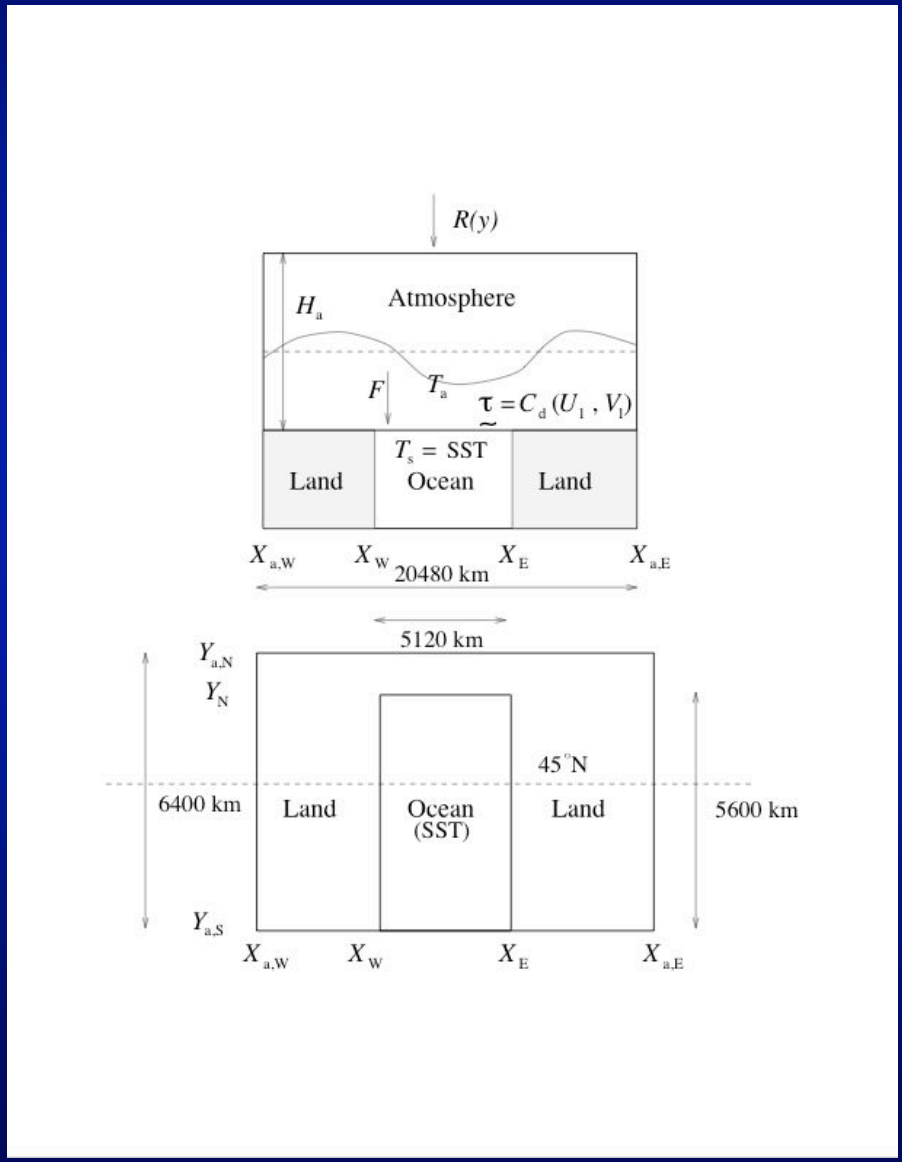
- Large-scale (1000 km) high-frequency (monthly) atmospheric patterns vs. small-scale (100 km) low-frequency (interannual) oceanic patterns associated with Gulf Stream variability
- Atmosphere: some degree of scale separation between synoptic eddies (somewhat smaller and faster) and large-scale low-frequency patterns
- Ocean: some spatial-scale separation in along-current direction ("eddies" vs. "jet")

Nonlinear problem!!!

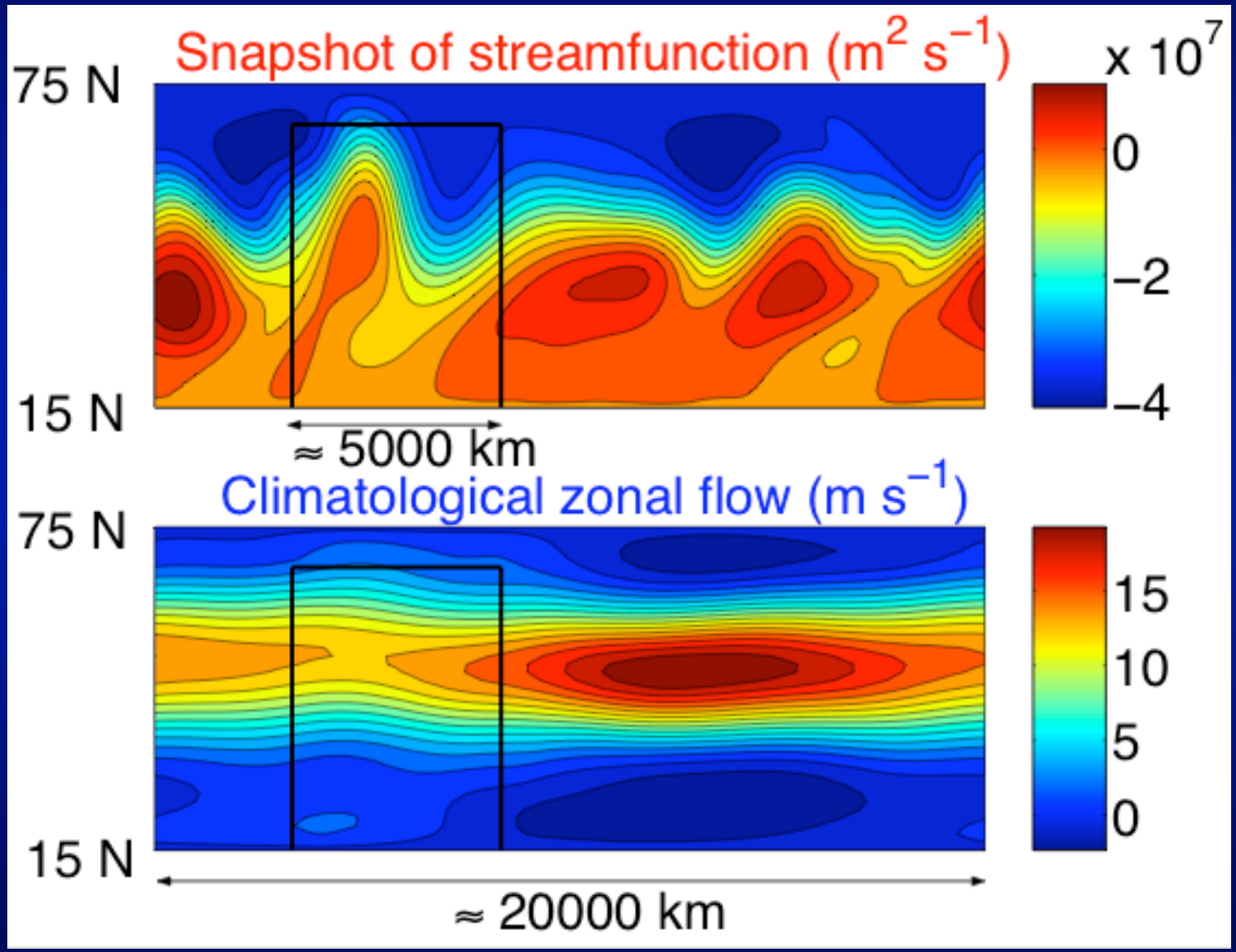
- Persistent atmospheric patterns, which are most likely to be affected by coupling, are result of complex eddy–mean flow interaction
- The region of potential coupling is also characterized by the most vigorous oceanic intrinsic variability
- Linear response of atmosphere to relatively weak SST anomalies is small. Hence, "active coupling" = "nonlinear atmospheric sensitivity to SSTA."

Coupled QG Model

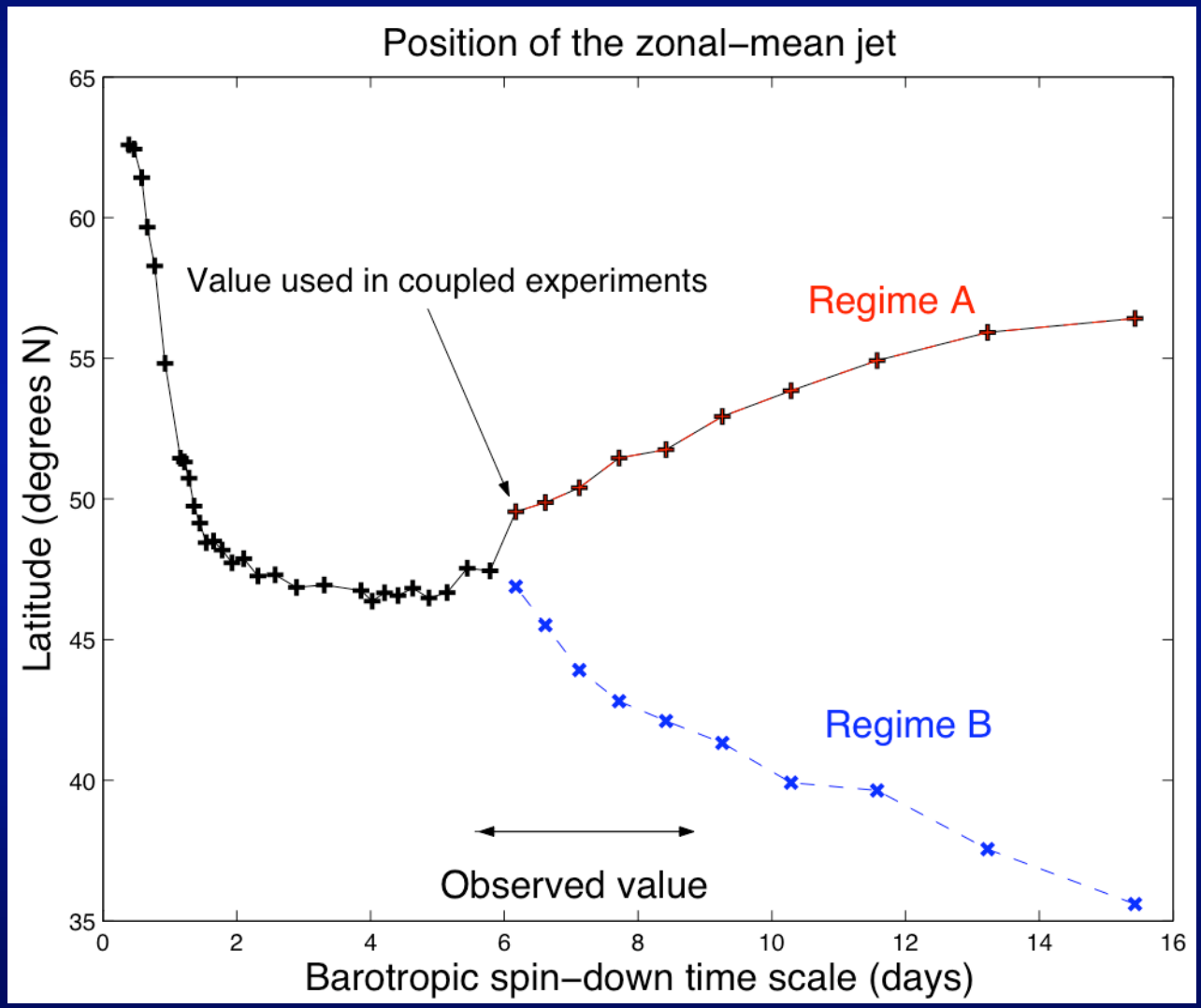
- Eddy-resolving atmospheric and ocean components, both characterized by vigorous intrinsic variability
- (Thermo-) dynamic coupling via constant-depth oceanic mixed layer with entrainment



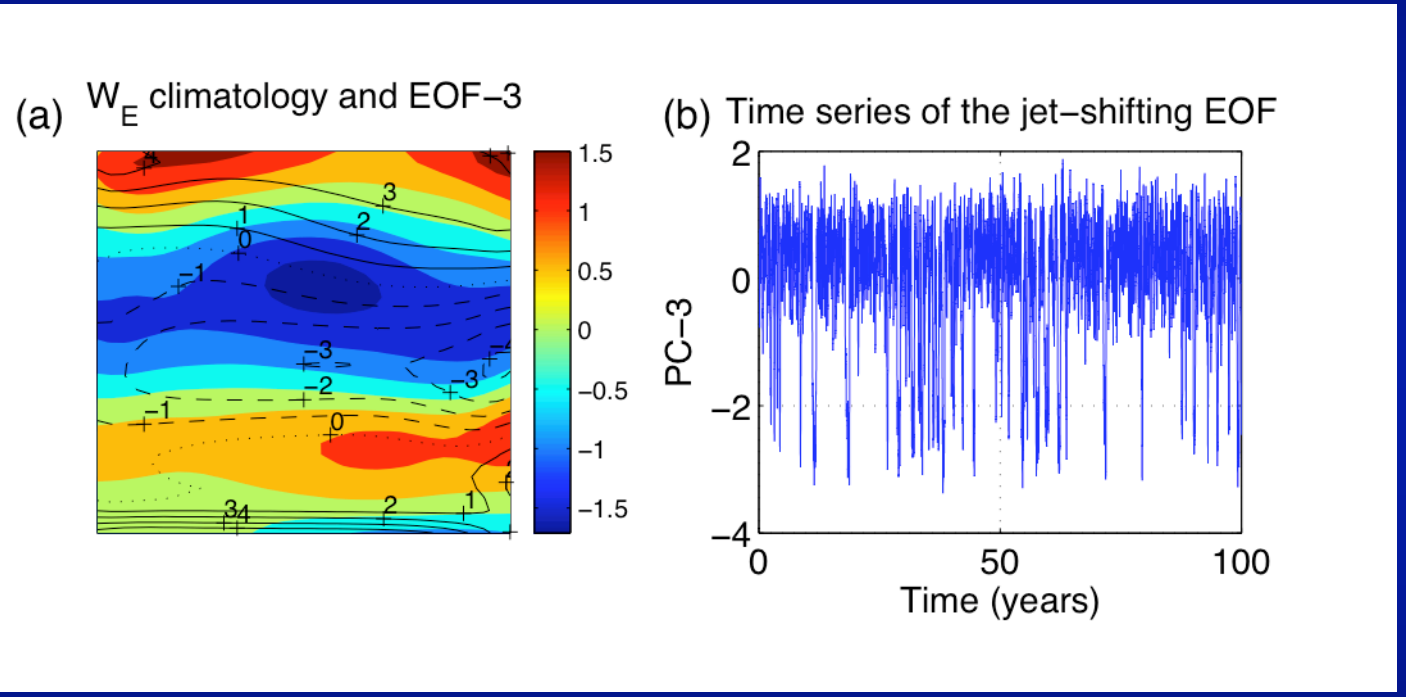
Atmospheric circulation



Zonal-jet bimodality in the model

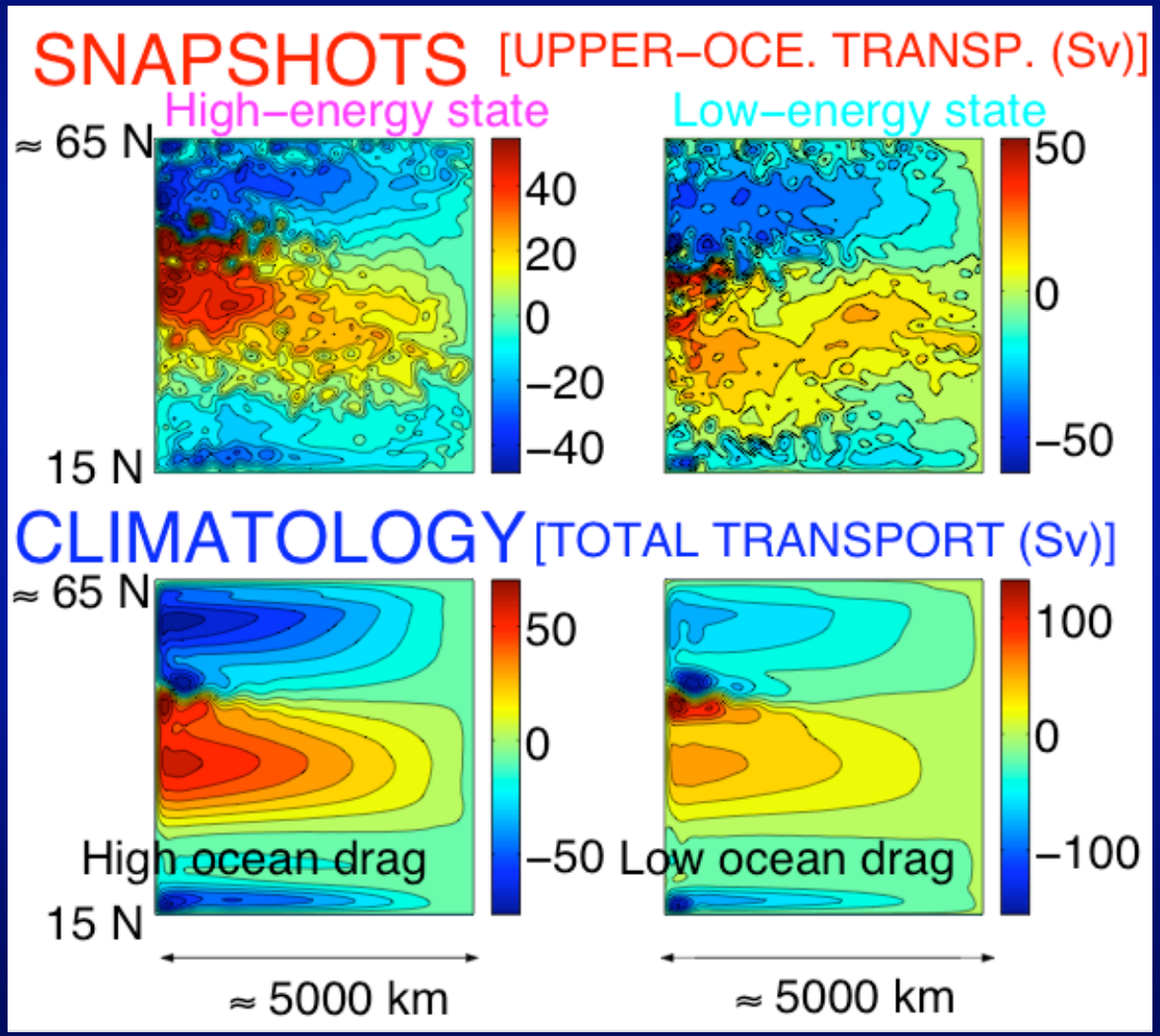


Atmospheric driving of ocean

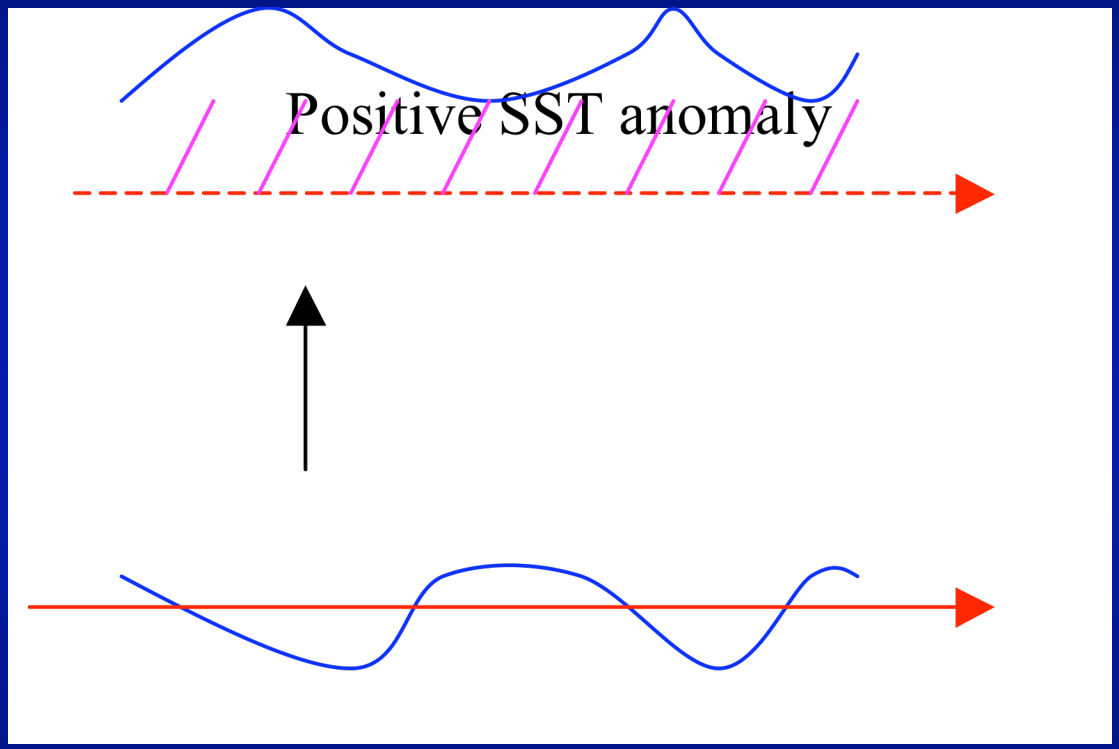


- Coupled effect: Occupation frequency of atmospheric low-latitude state exhibits (inter)-decadal broad-band periodicity

Oceanic circulation



I. O-jet's adjustment to A-jet shift



- A-jet shift (final state of O-jet as well)
- Initial state

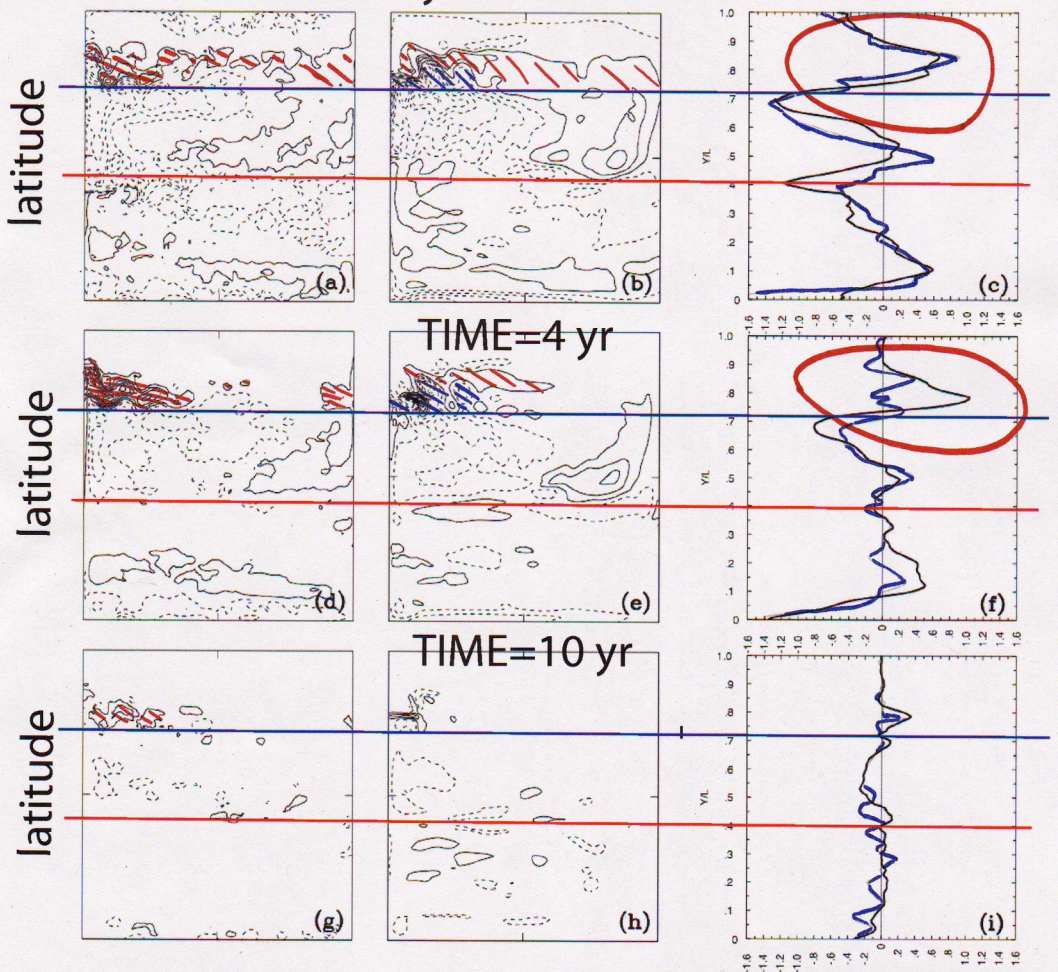
- O-jet is maintained in its transient position for a few years due to eddy forcing via rectification

SSTA RELATIVE TO FINAL
(FULLY ADJUSTED) STATE

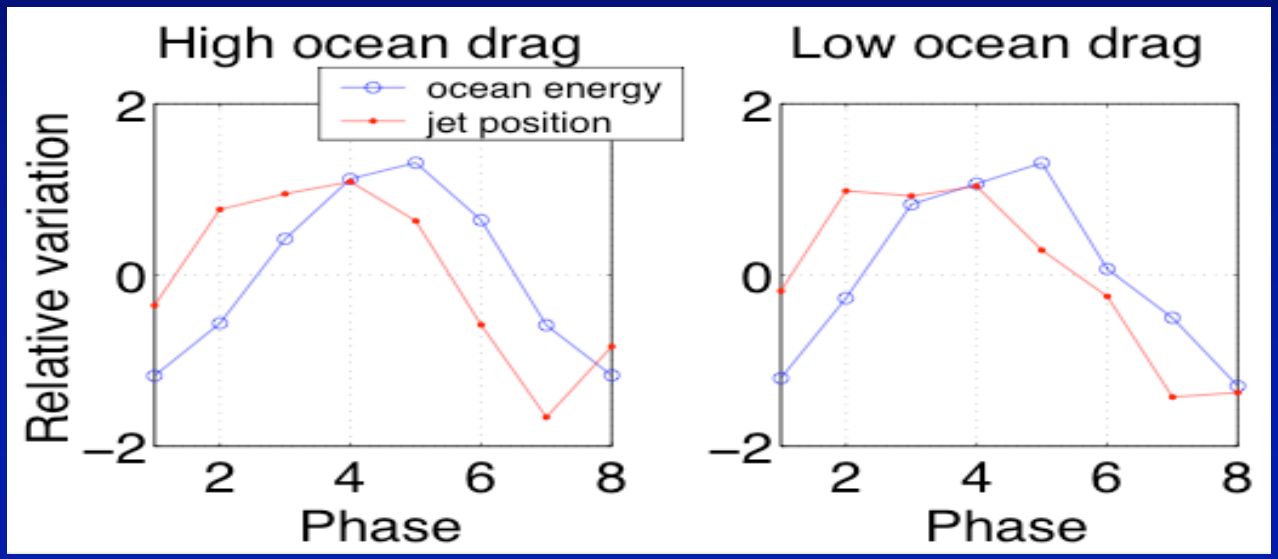
FINAL JET POSITION

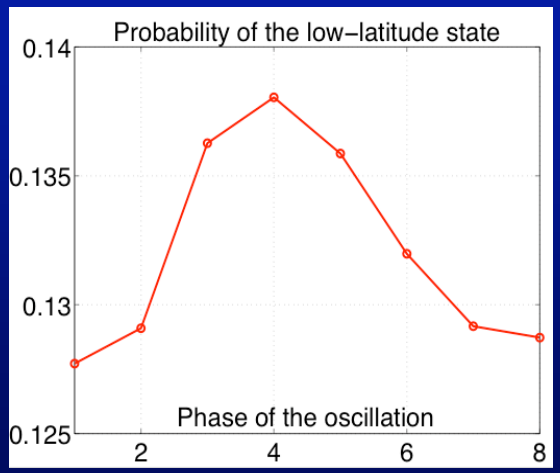
INITIAL JET POSITION

TIME=2 yr AFTER A-JET SHIFT



II. A-jet regime dependence on O-jet



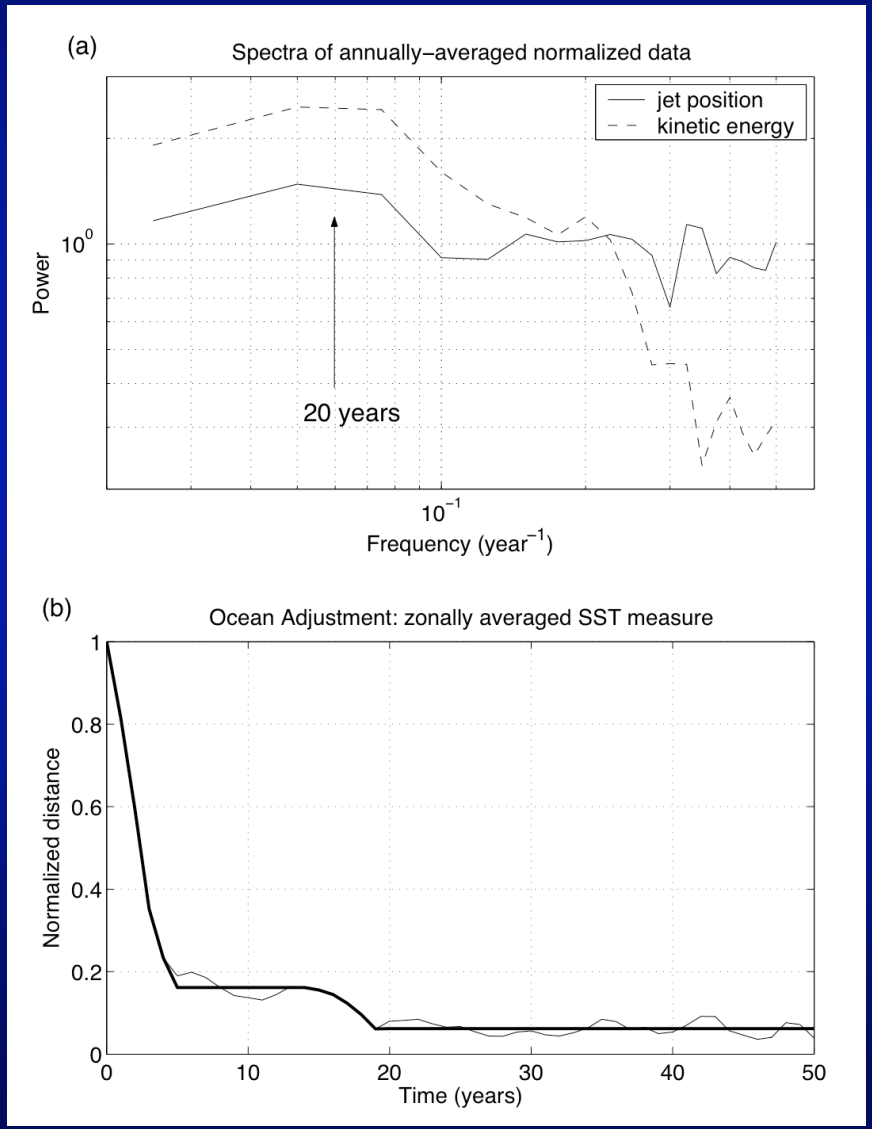


- High Ocean Energy = High-Latitude (HL) O-Jet State
- HL ocean state = A-jet's Low-Latitude (LL) state
- O-Jet stays in (transient) HL state for a few years due to O-eddies

III. Oscillation period

- Oscillation's period is of about 20 yr in low-ocean-drag case and is of about 10 yr in high-ocean-drag case

- Period scales as eddy-driven adjustment time



Summary

- Mid-latitude climate model involving turbulent oceanic and atmospheric components exhibits inter-decadal coupled oscillation
- Bimodal character of atmospheric LFV is responsible for atmospheric sensitivity to SSTAs
- Ocean responds to changes in occupation frequency of atmospheric regimes with a delay due to ocean eddy effects