Thermodynamic Feedbacks in Tropical Coupled Variability

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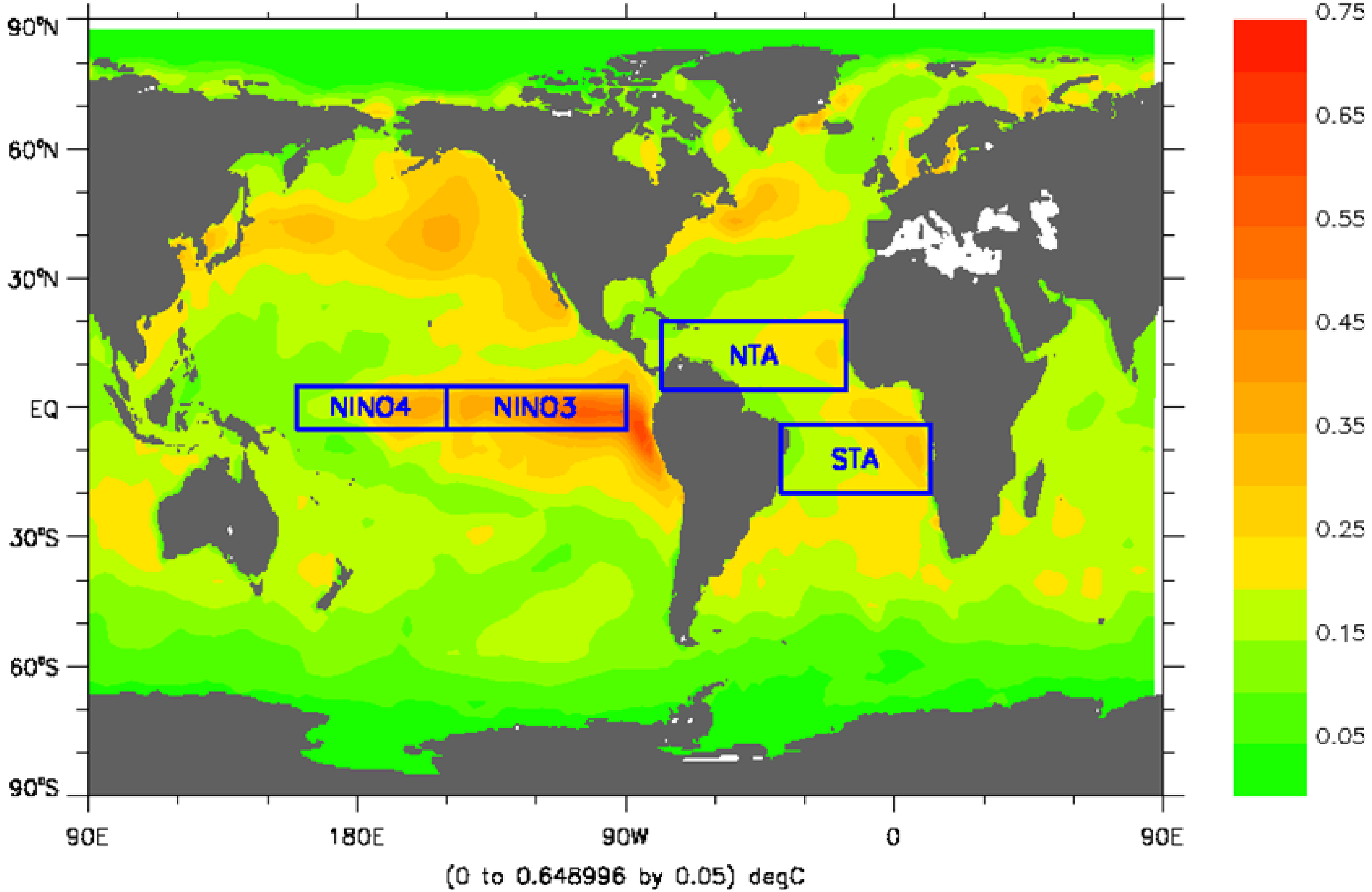
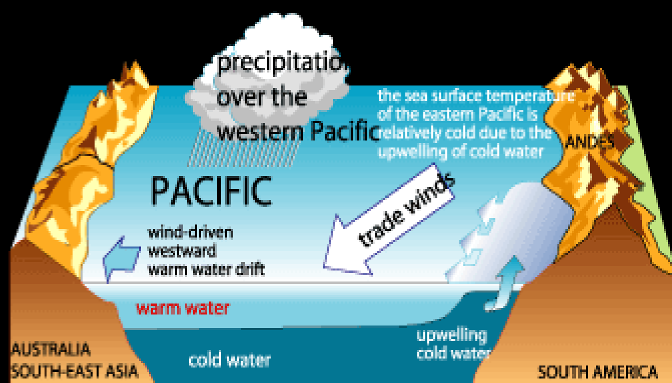
SST standard deviation (timescales < 6 yrs)

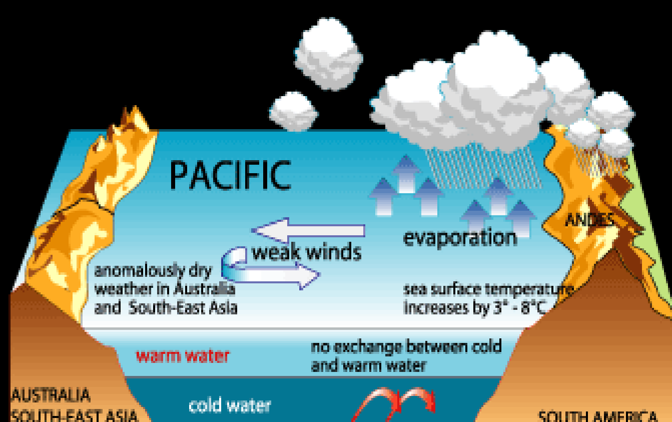


"El Niño"
interactions between the atmosphere
and the ocean

normal weather situation

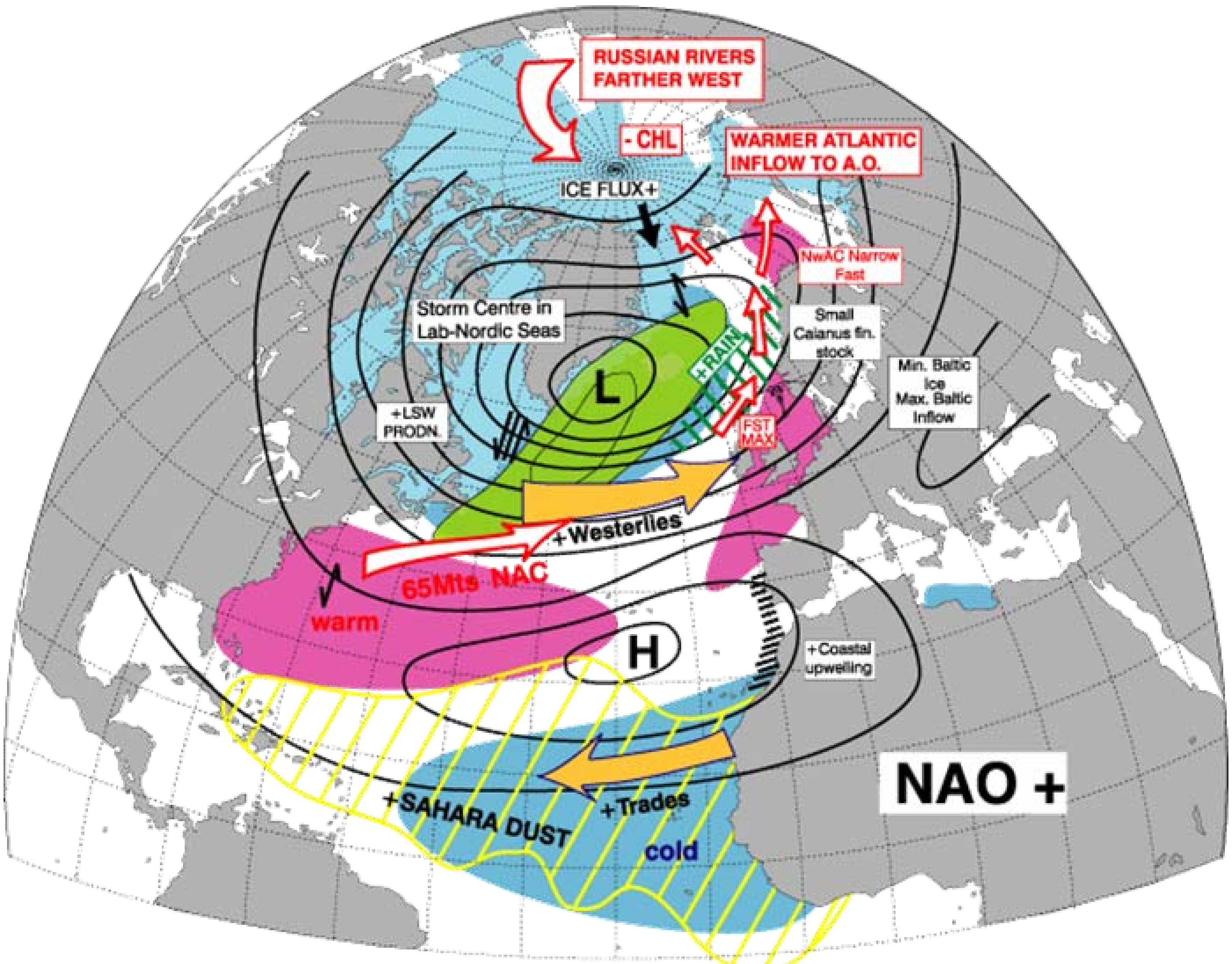


El Niño weather situation



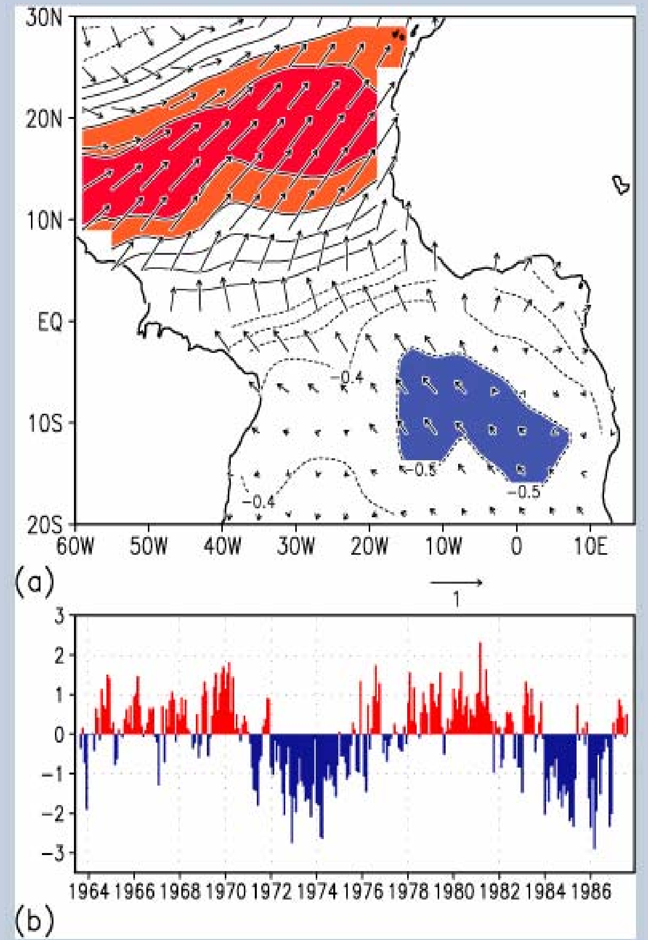
due to the lack of nutrient-rich upwelling water fish populations migrate to other regions

NAO


RUSSIAN RIVERS FARTHER WEST
- CHL
WARMER ATLANTIC INFLOW TO A.O.
ICE FLUX+
NwAC Narrow Fast
Small Calanus fin. stock
Storm Centre in Lab-Nordic Seas
+RAIN
L
Min. Baltic Ice Max. Baltic Inflow
+LSW PRODN.
FST MAX
+Westerlies
65Mts NAC
warm
H
+Coastal upwelling
NAO +
+SAHARA DUST
+Trades
cold

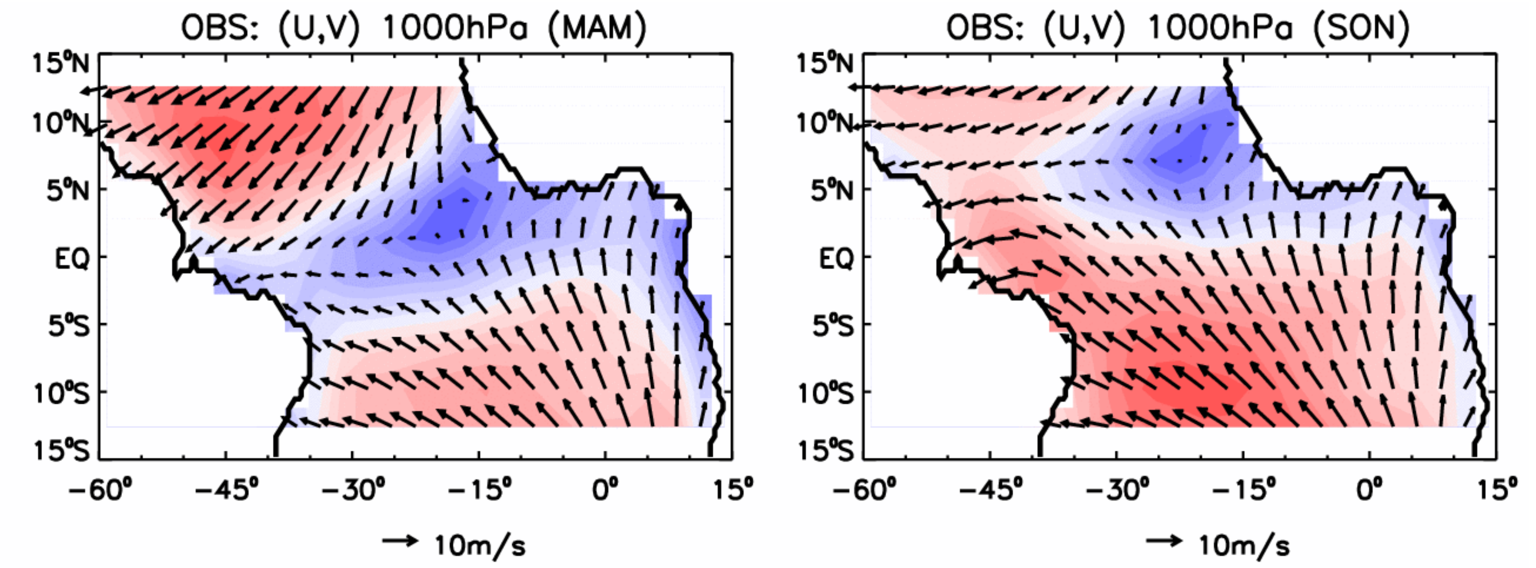
Tropical Atlantic Climate Variability

An Atlantic Dipole ?

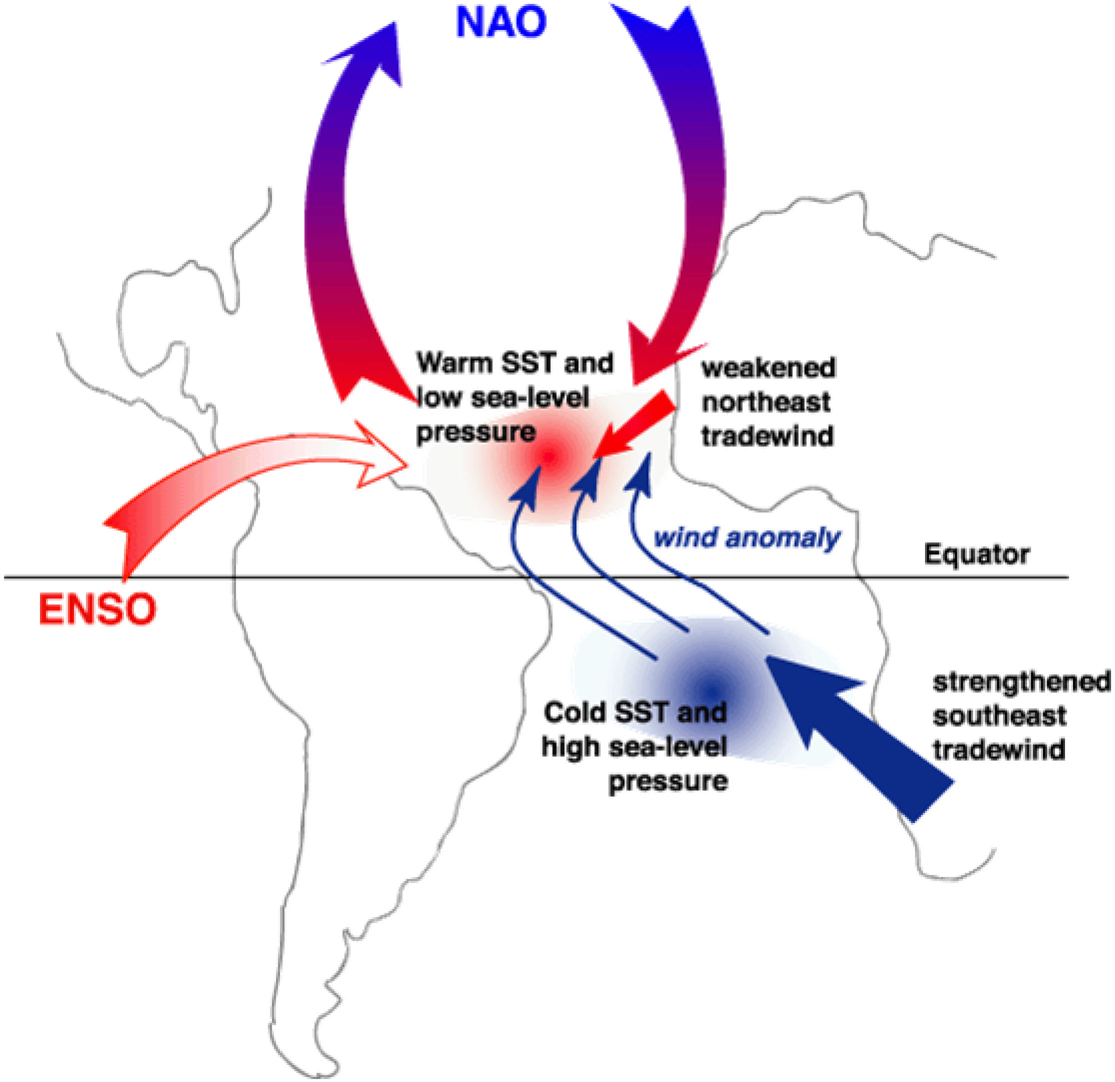


The dominant joint patterns of sea surface temperature and surface wind stress variability over the Atlantic for the period September 1963 to August 1987 and the associated time series. The time series show a dominant signal at lower frequencies but as well, there are seasonal and interannual fluctuations (Nobre and Shukla, 1996, J. Climate, 9, 2464-2479).

Mean 1000hPa wind (March-April-May)



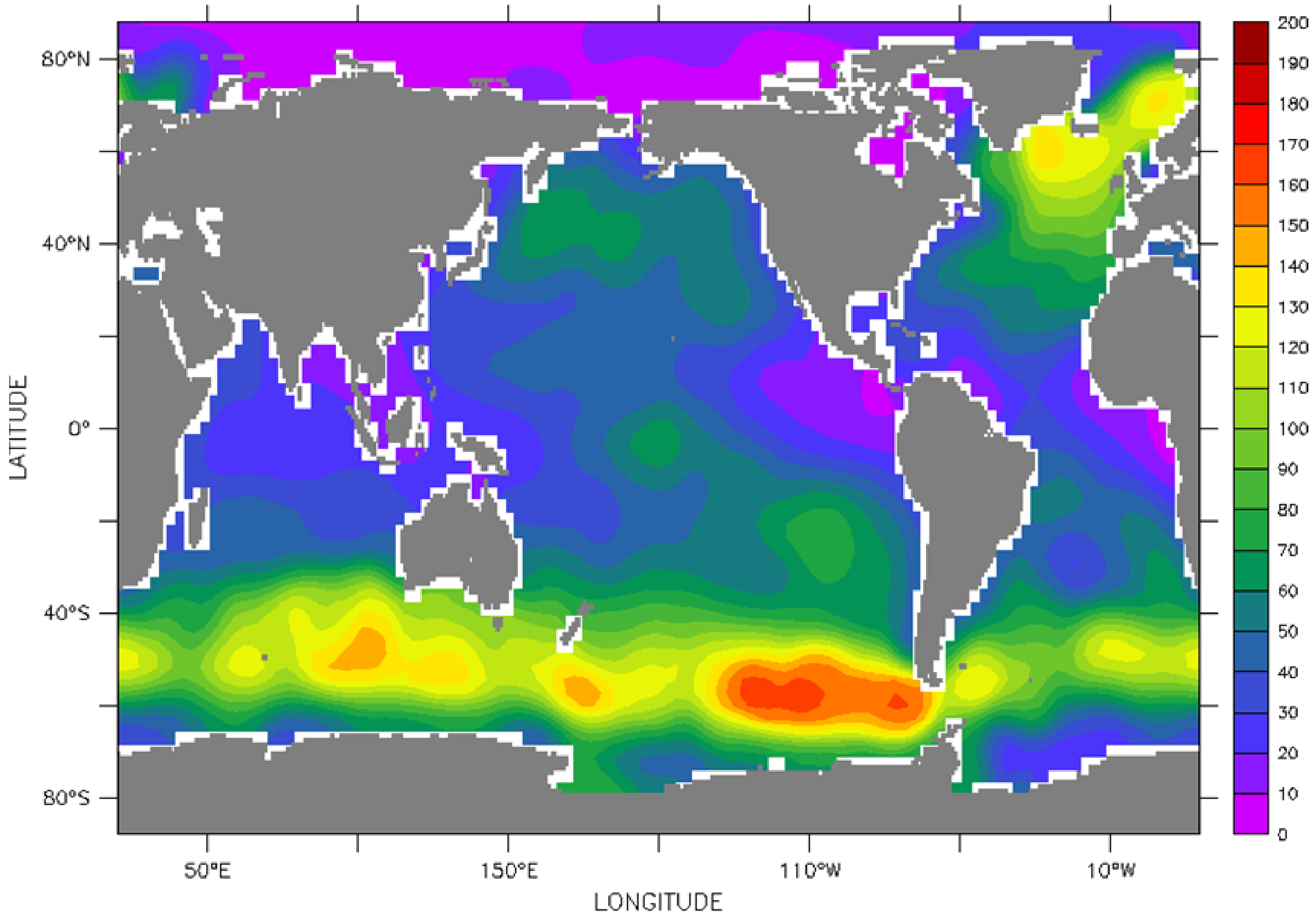
TAV


NAO
Warm SST and
low sea-level
pressure
weakened
northeast
tradewind
ENSO
wind anomaly
Equator
Cold SST and
high sea-level
pressure
strengthened
southeast
tradewind

Slab ocean/Mixed Layer

$$\frac{\partial T_o}{\partial t} = \frac{F}{\rho_w C_w H} + Q,$$

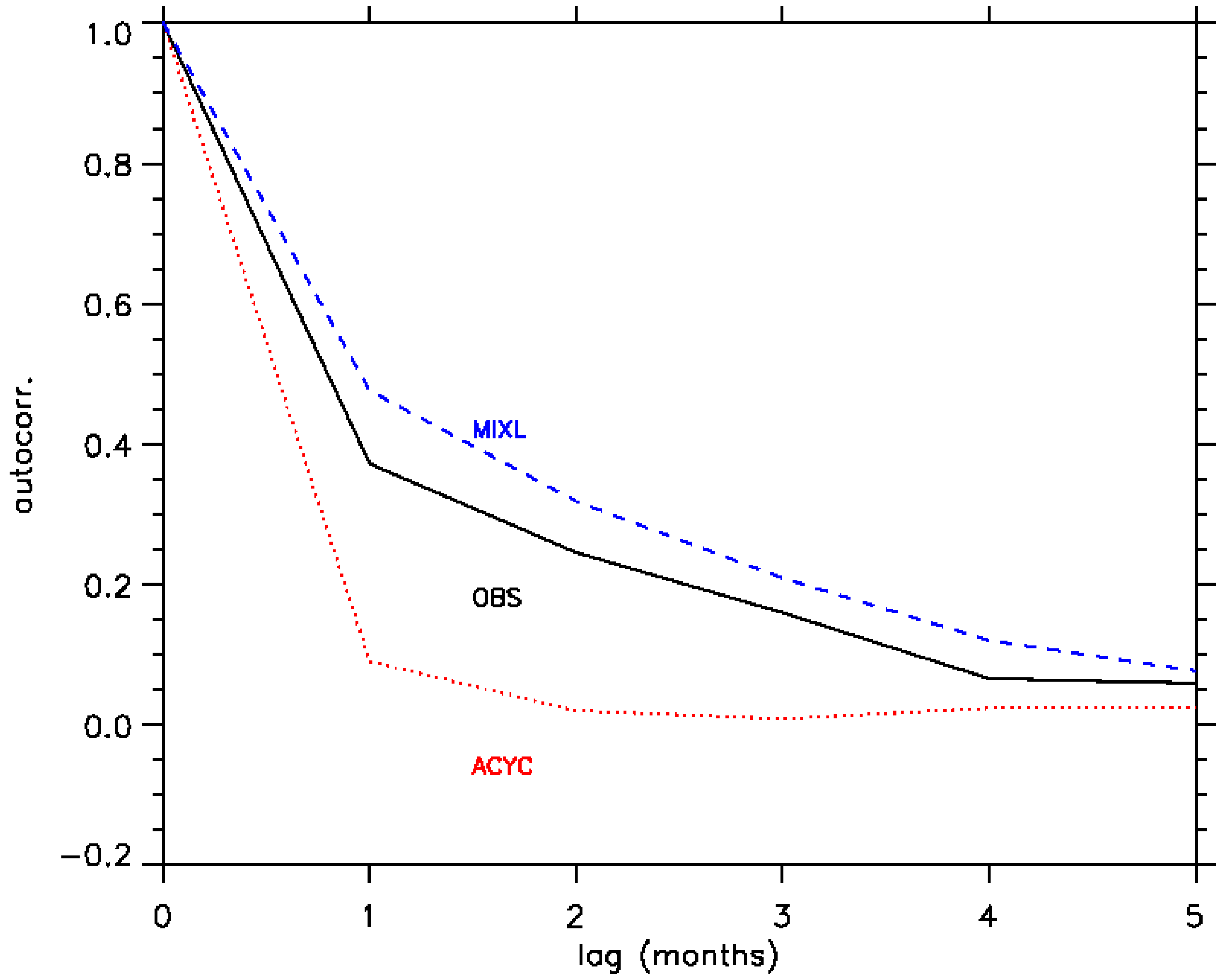
Annual-mean mixed layer depth (Levitus)



MLD

Lag-1 autocorrelation of PC1 of sfc. Pressure over the Tropical Atlantic

(Saravanan & Chang, *Geophys. Res. Let.*, 2000)



- **Dynamic coupling**
  - **Momentum exchange between atmosphere and ocean**
  - **Bjerknes feedback (ENSO, Atlantic ‘Nino’)**
  - **Predictability on seasonal-to-interannual timescales**
- **Thermodynamic coupling**
  - **Heat exchange between atmosphere and ocean**
    - *Hasselmann, 1976*
  - **Reduced thermal damping effect**
    - *Barsugli & Battisti, 1998; ...*
  - **Wind-Evaporation-SST (WES) feedback**
    - *Xie & Philander, 1994; Chang et al., 1997*
  - **Predictability?**

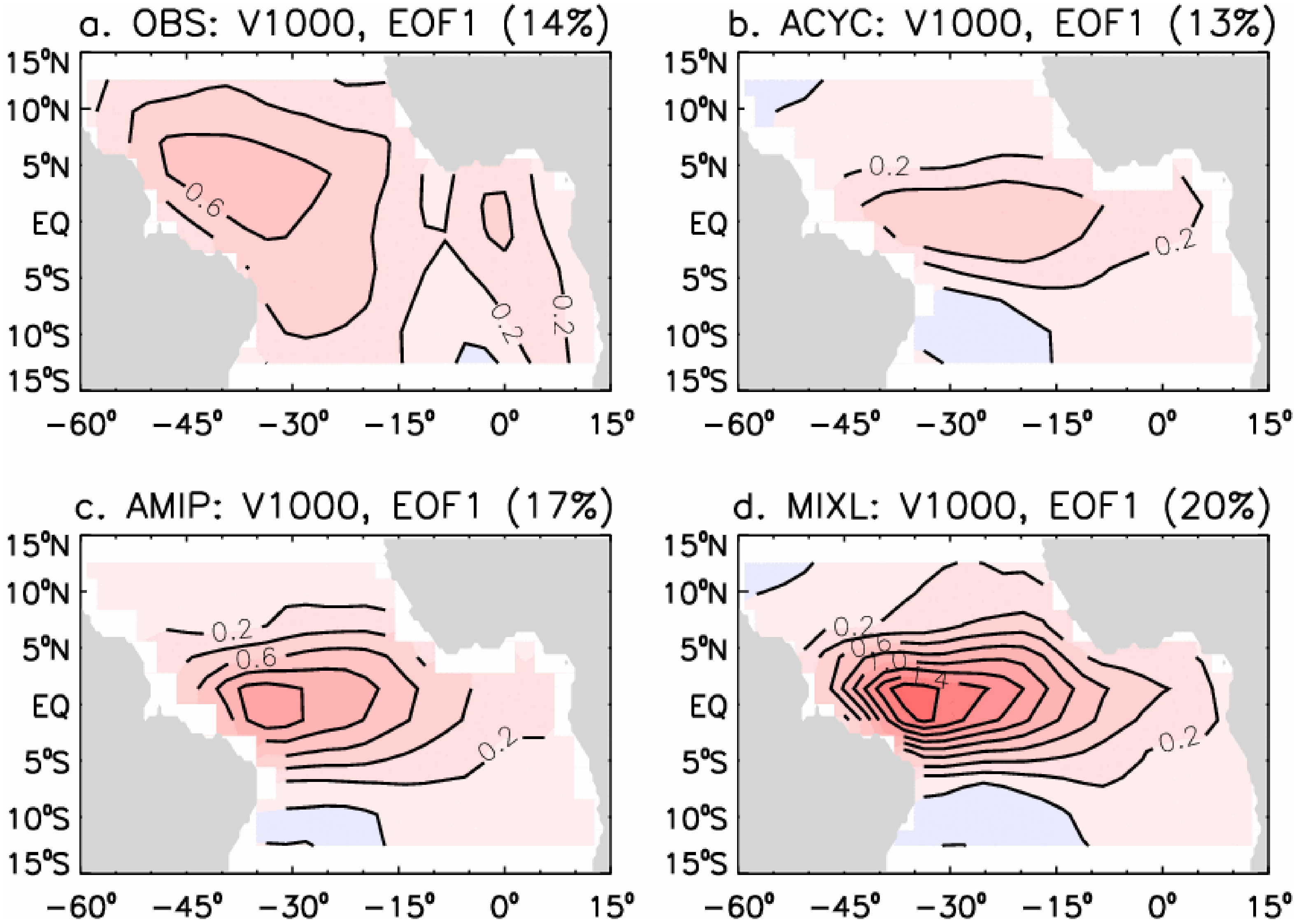
Models

- **CCM3: Community Climate Model, version 3**
  - **Atmospheric general circulation model**
  - **T42 resolution (2.8 degrees latitude/longitude grid)**
  - **18 vertical levels**
- **SOM: Slab ocean model**
  - **Thermodynamic representation of ocean**
  - **Spatially varying slab depth (Annual mean from Levitus)**

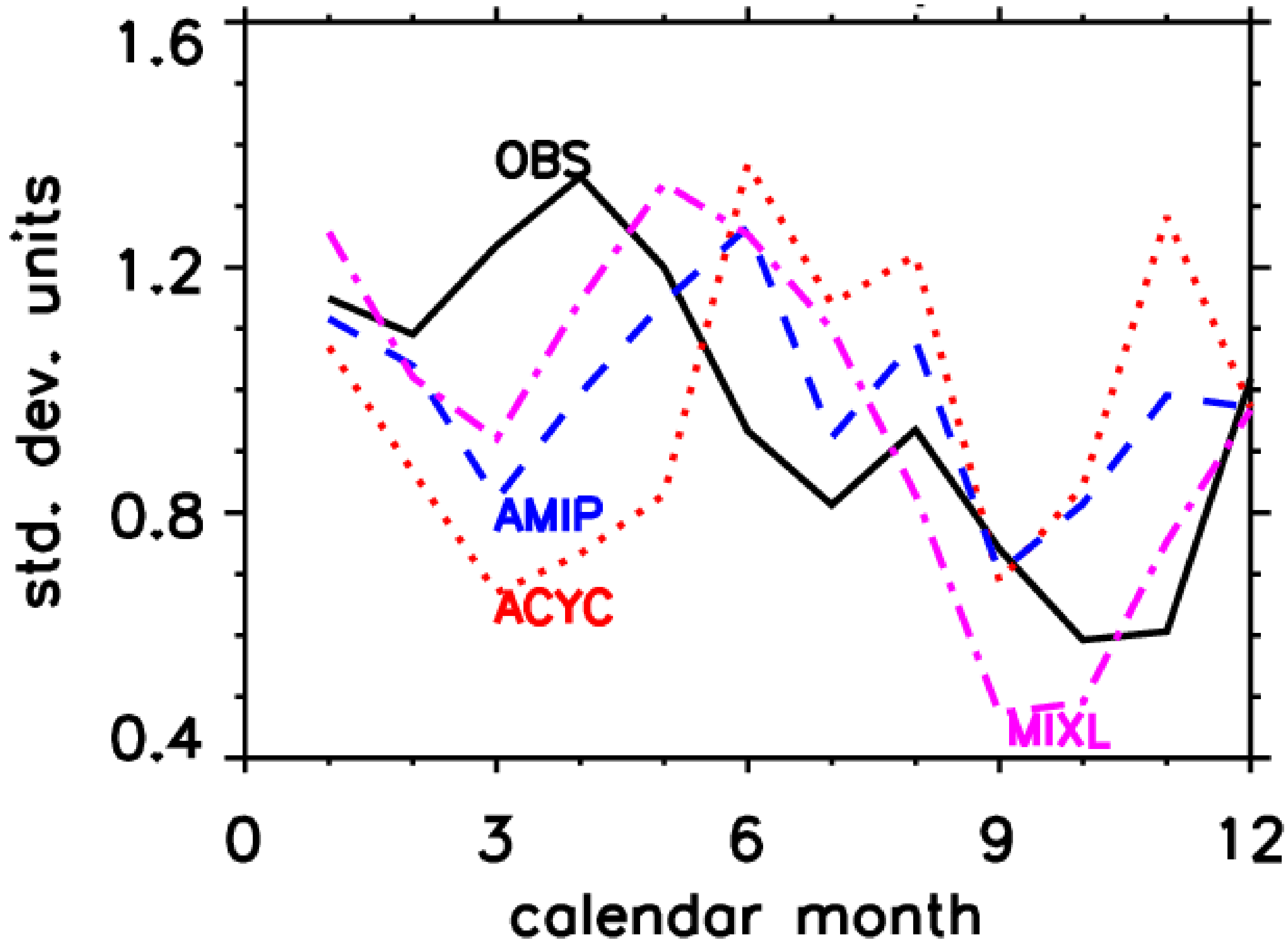
Hierarchical modeling experiments

- **ACYC**
  - **Control integration of CCM3 with repeating annual cycle of SST (100 yrs**
- **AMIP**
  - **CCM3 integration forced by observed SST from 1950-1999 (50 yrs)**
- **MIXL**
  - **Control integration of CCM3 coupled to slab ocean model (100 yrs)**

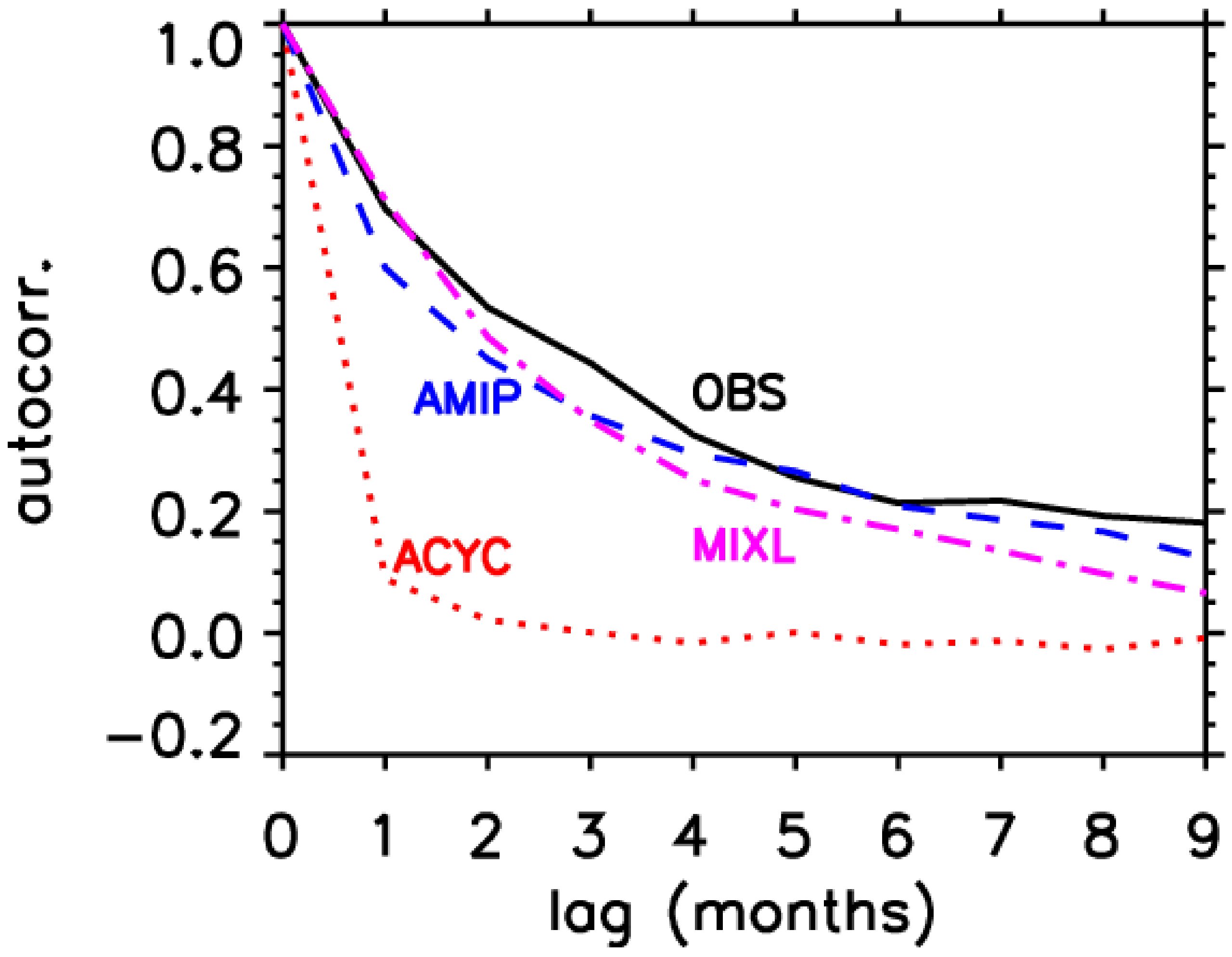
EOF1 of 1000hPa meridional wind (V)



Seasonal amplitude of EOF1 of V1000



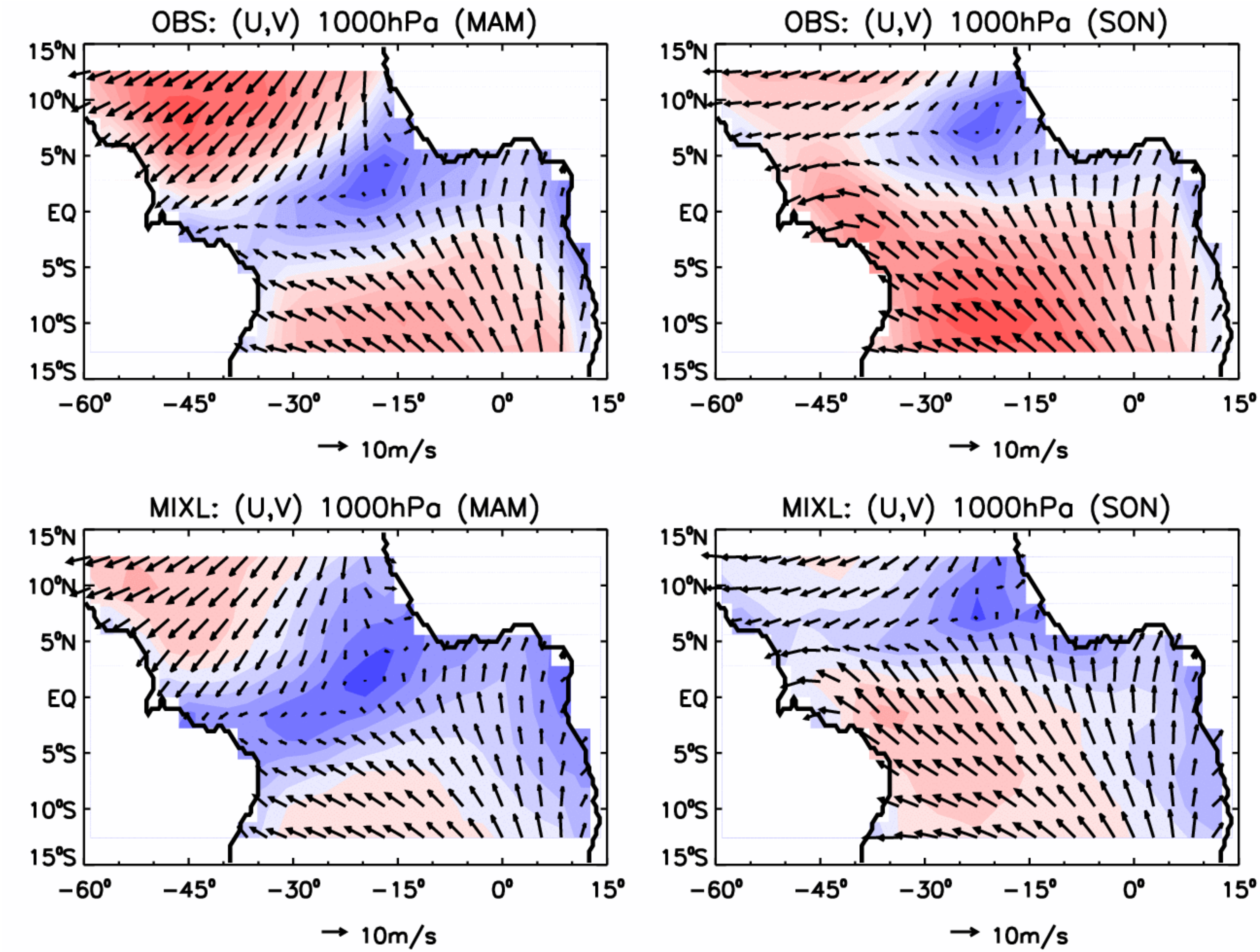
Autocorrelation of EOF1 of V1000



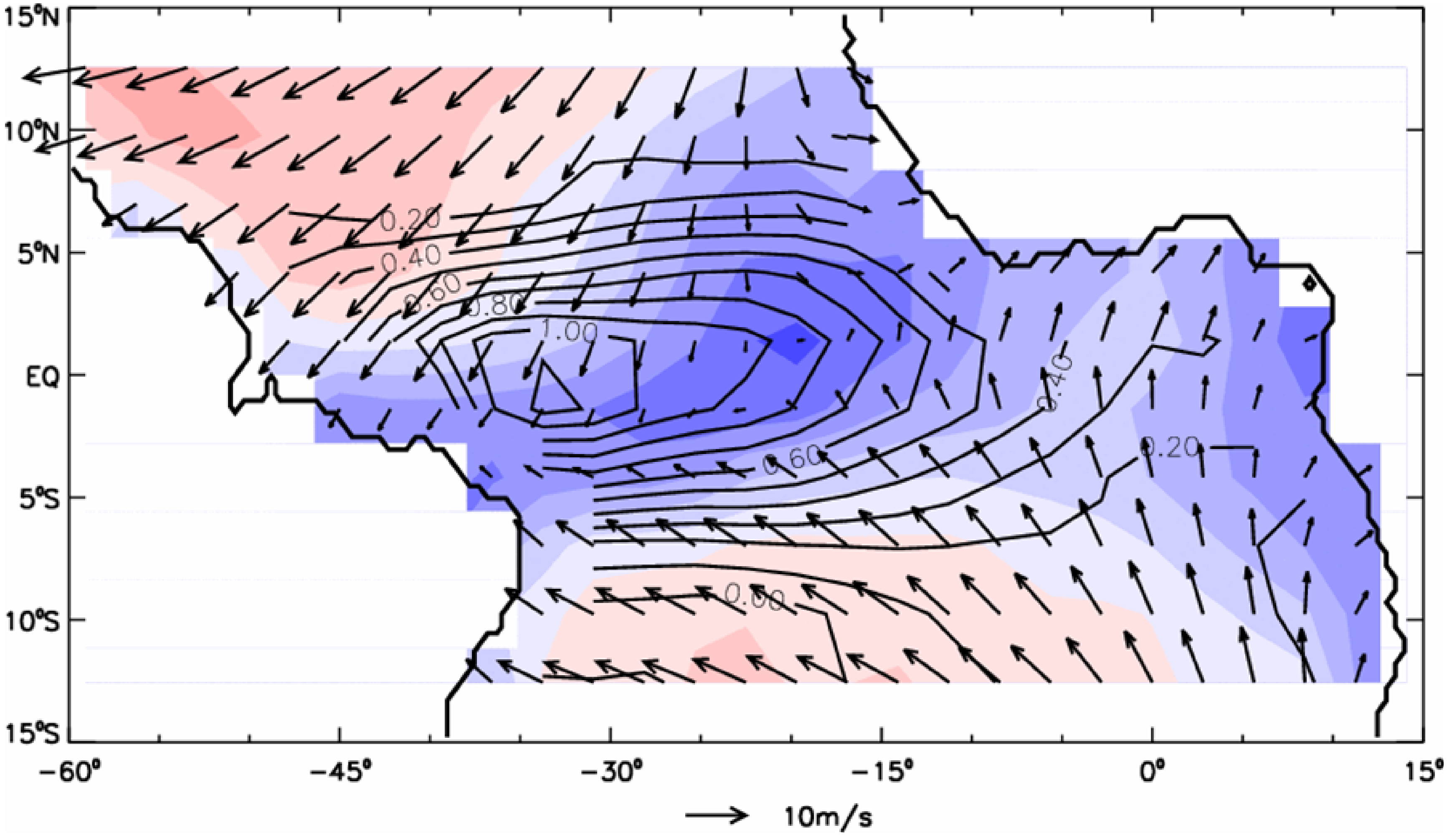
Mean 1000hPa wind (March-April-May)

OBS

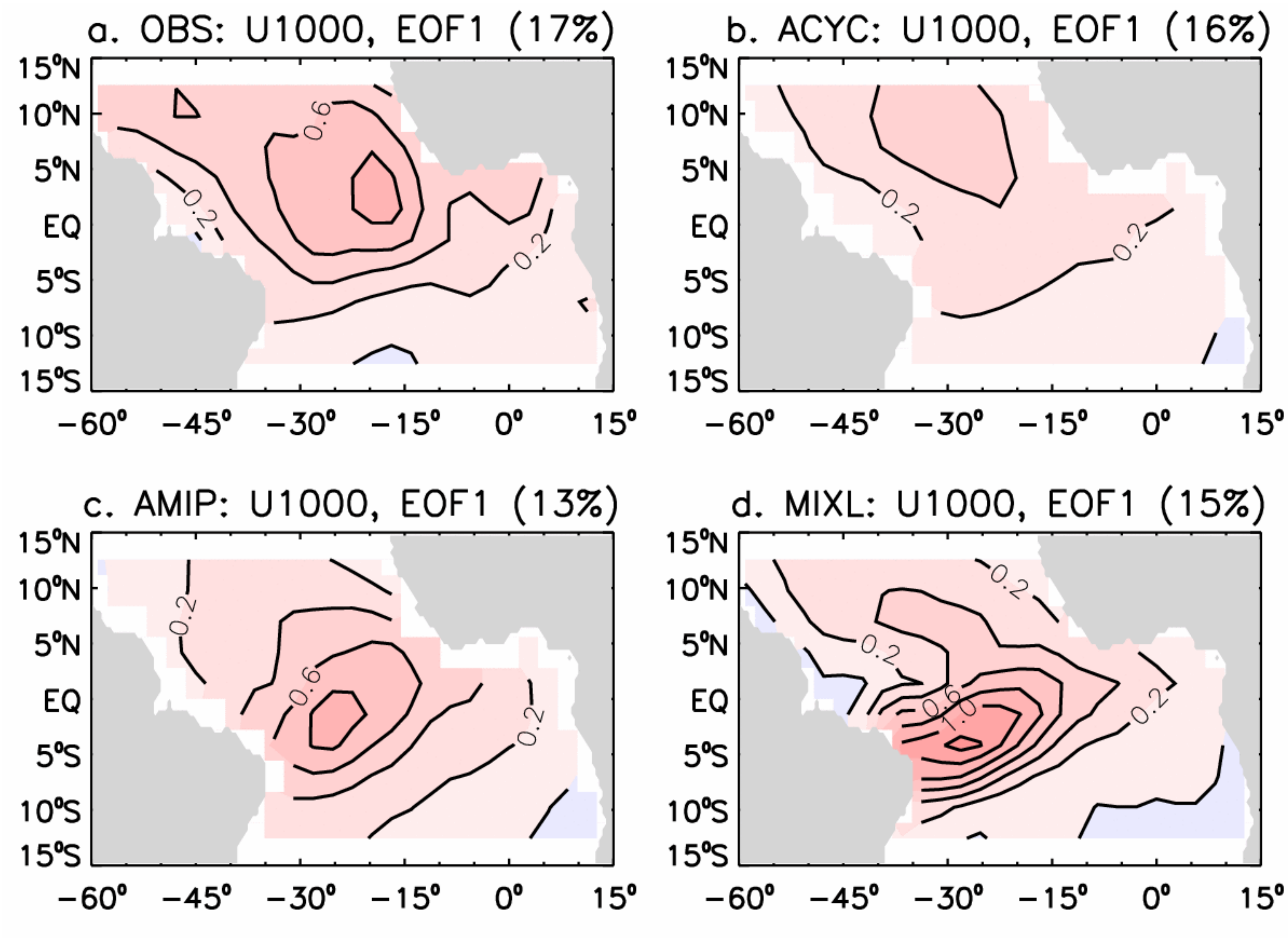
MIXL



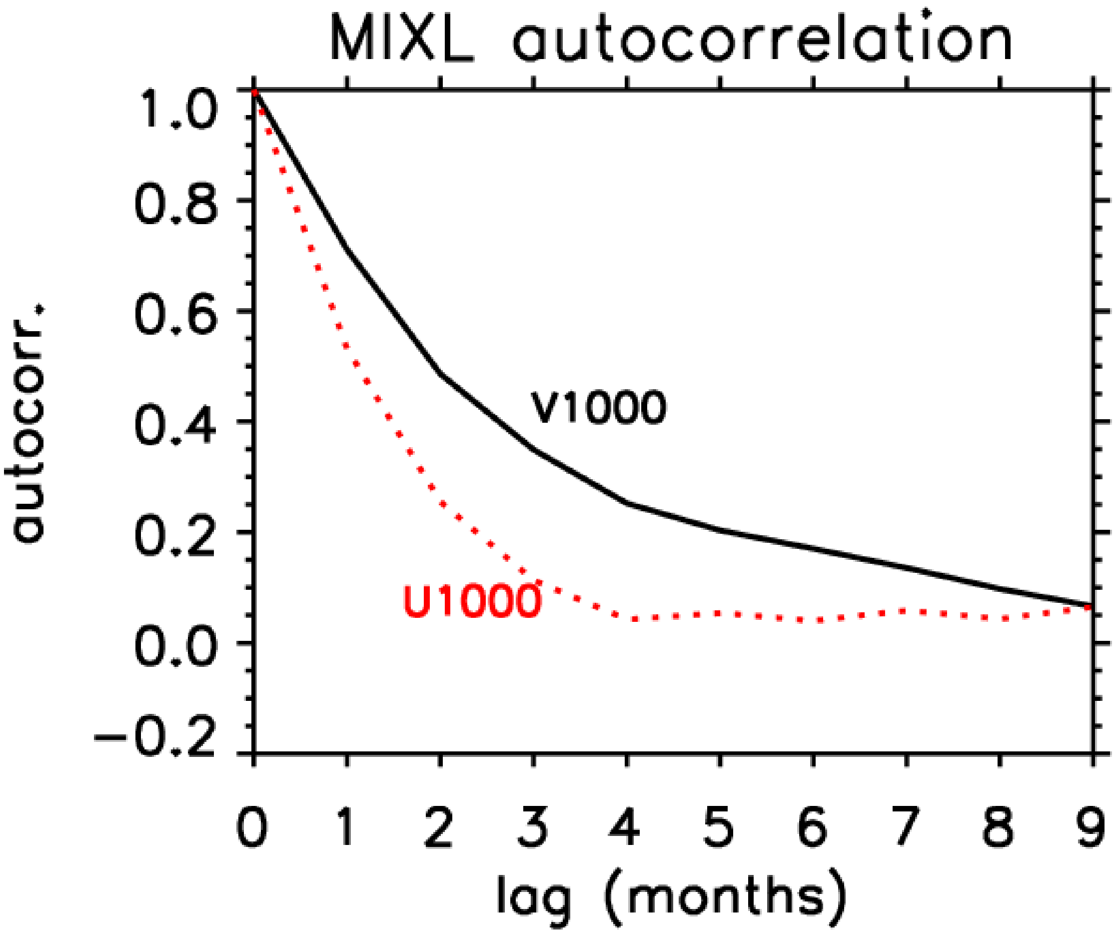
AMIP: 1000hPa wind(color) and EOF1 of V1000 (March-April-May)



EOF1 of 1000hPa zonal wind (U)



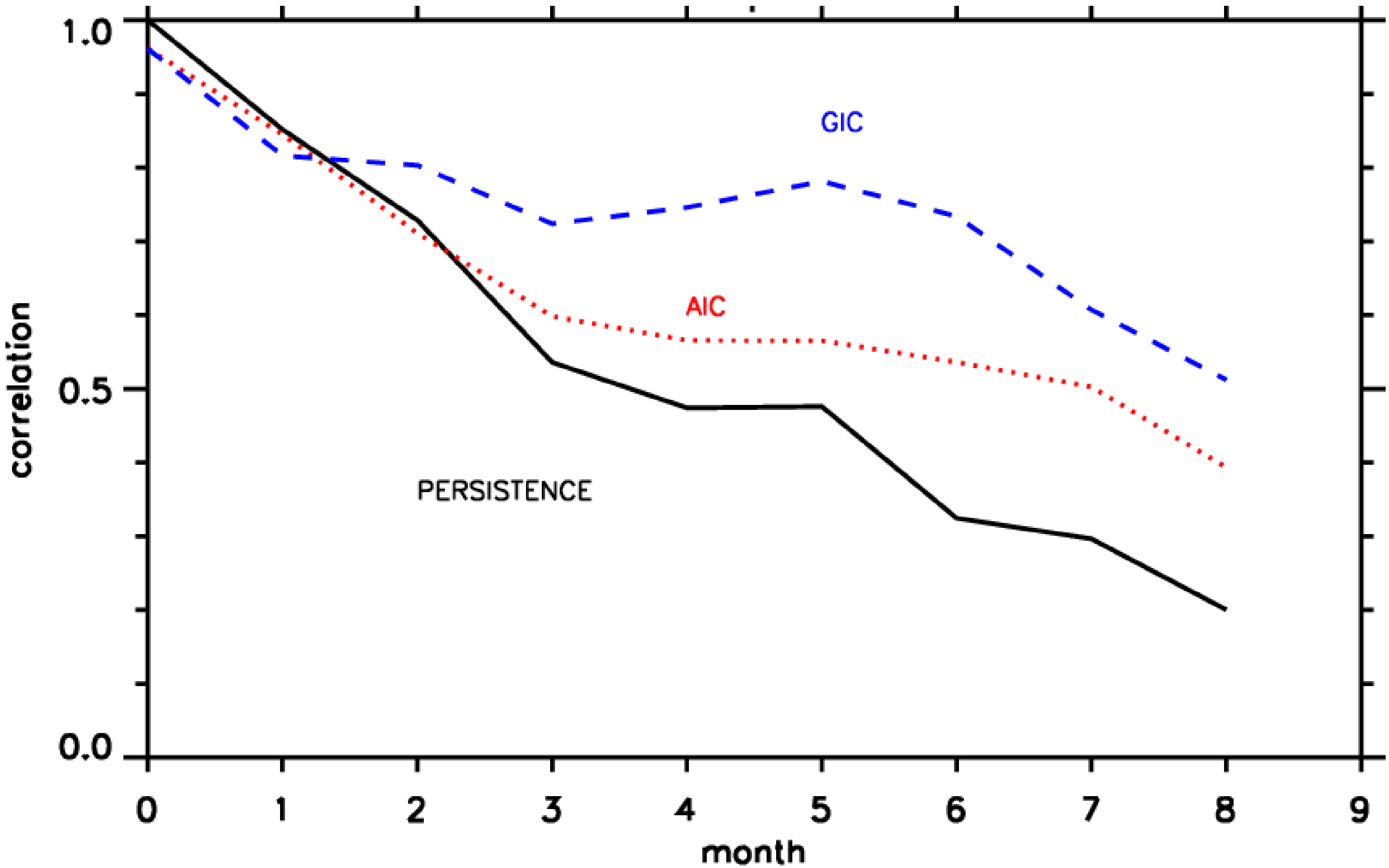
Autocorrelation of U vs. V



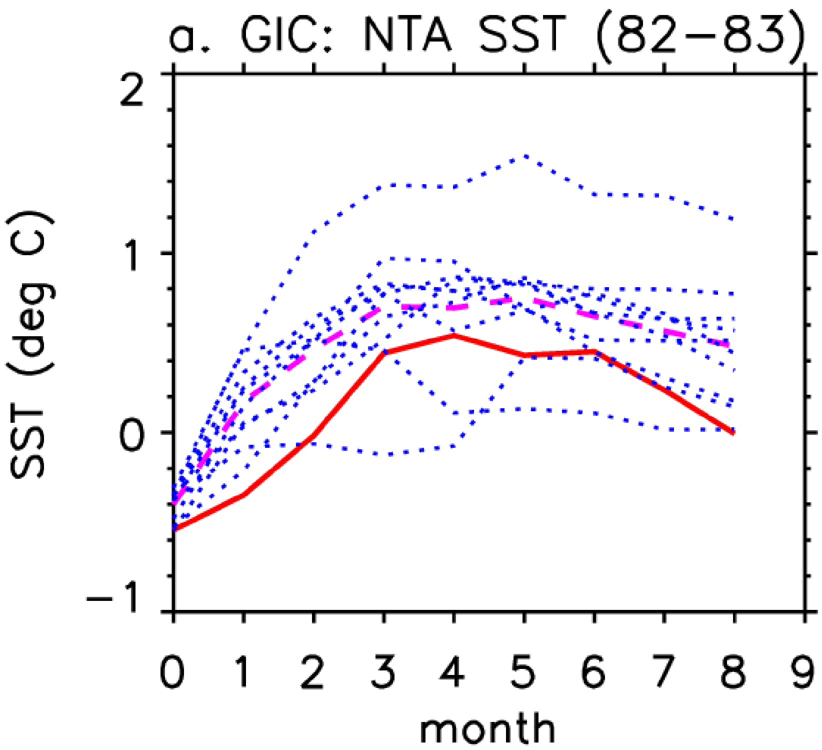
Forecast experiments

- **GIC: Global Initial Conditions**
  - **CCM3+slab ocean initialized with observed December atmospheric and SST global initial conditions**
  - **10 member ensemble, each 9 months long, for the period 1959-1997.**
- **AIC: Atlantic Initial Conitions**
  - **As above, but observed SST initial conditions used in the Atlantic basin only, with climatological SST specified elsewhere.**

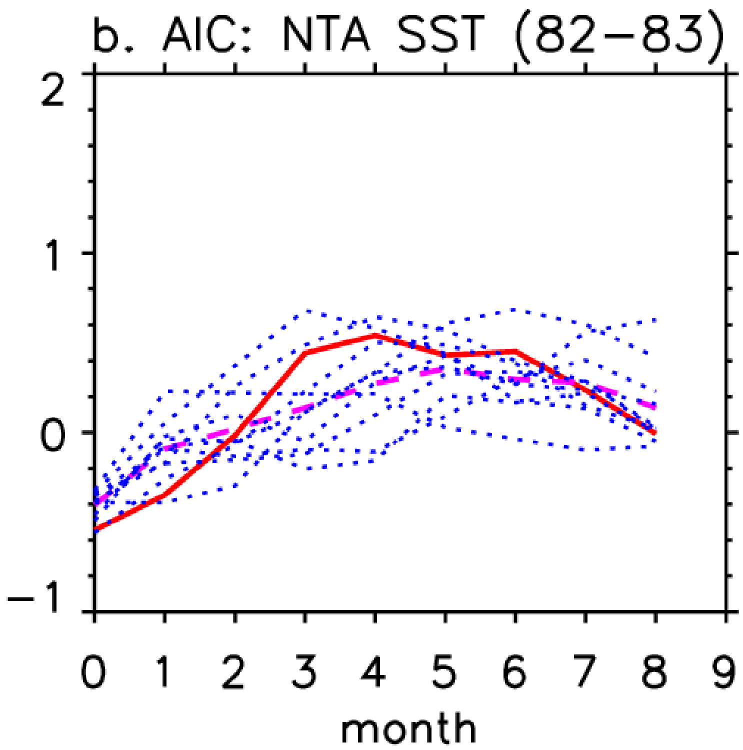
Correlation skill of NTA SST prediction (1959-1997)



Forecasting North Tropical Atlantic SST during the 1982-83 ENSO warm event



Global Initial Condition



Atlantic Initial Condition

SST damping vs. WES feedback

- **Away from the equator, mean surface winds tend to damp SST anomalies, acting as a negative feedback**
  - **F = κ (SAT – SST) (Haney, 1971; Hasselmann, 1976)**
  - **For a 30m mixed layer, if κ = 40 W/m2K, damping timescale of SST anomalies is 1-2 months**
- ***Absolute* strength of positive WES feedback depends upon windspeed anomalies**
- ***Relative* strength of the WES feedback would depend upon the ratio of the anomalous windspeed to the mean windspeed**
  - **This ratio tends to be highest in the ITCZ regions!**

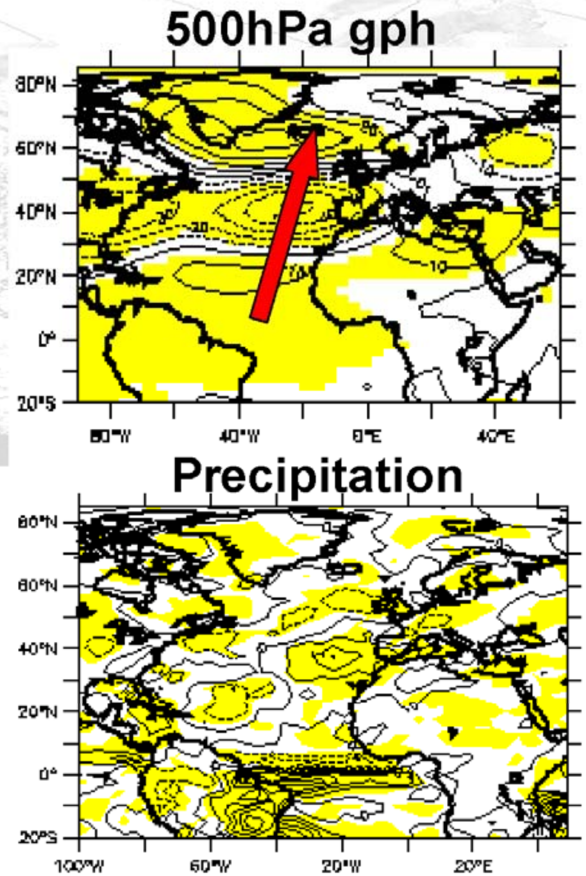
Conclusions

- Thermodynamic coupling results in significant amplification of variability in the deep tropics over the Atlantic Basin
  - It occurs in regions of surface convergence and low windspeed
  - It is anisotropic, affecting the meridional wind more than the zonal wind
  - Not reduced thermal damping (Barsugli & Battisti, 1998)
  - Indicates possible role for WES feedback
- Thermodynamic coupling results in significant forecast skill in the North Tropical Atlantic
  - Beats persistence for lead times of up to 6-8 months.
  - Significant skill is obtained even with Atlantic-only SST initial conditions, i.e., without the remote influence of ENSO.

Tropical Atlantic influence on Europe

Atmospheric response to Atlantic SST anomalies during DJF 1987/88

- SST anomalies in tropical Atlantic induce southward shift of ITCZ
- Diabatic heating anomalies associated with displaced ITCZ excite a Rossby wave response that propagates to N. Atlantic



(Ensemble mean response in HadAM3 model; ens size 10)

Mathieu & Sutton, 2003

Annual-mean mixed layer depth (Levitus)