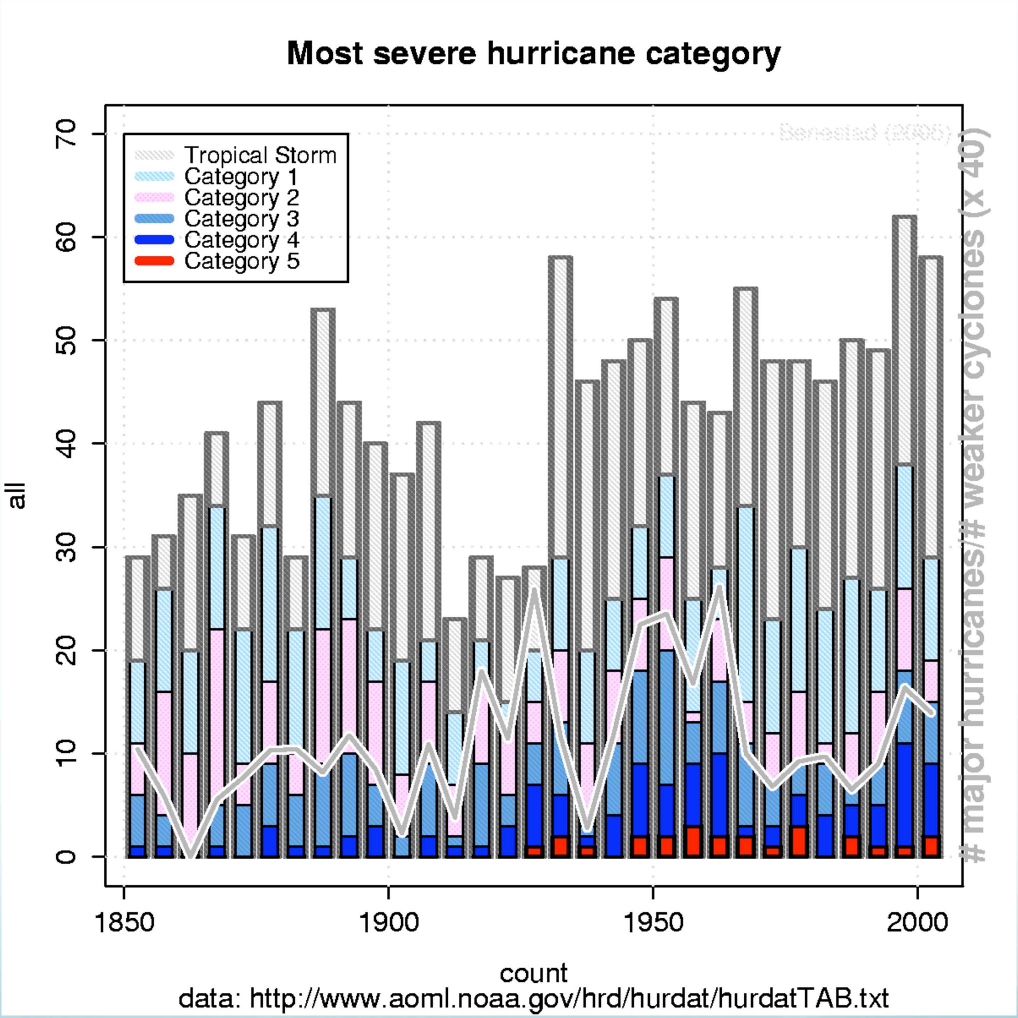
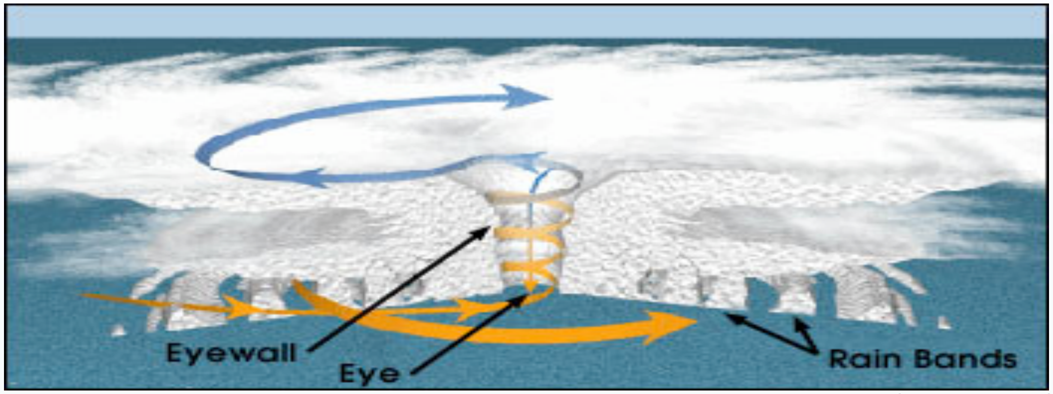
Variability in tropical storm frequency



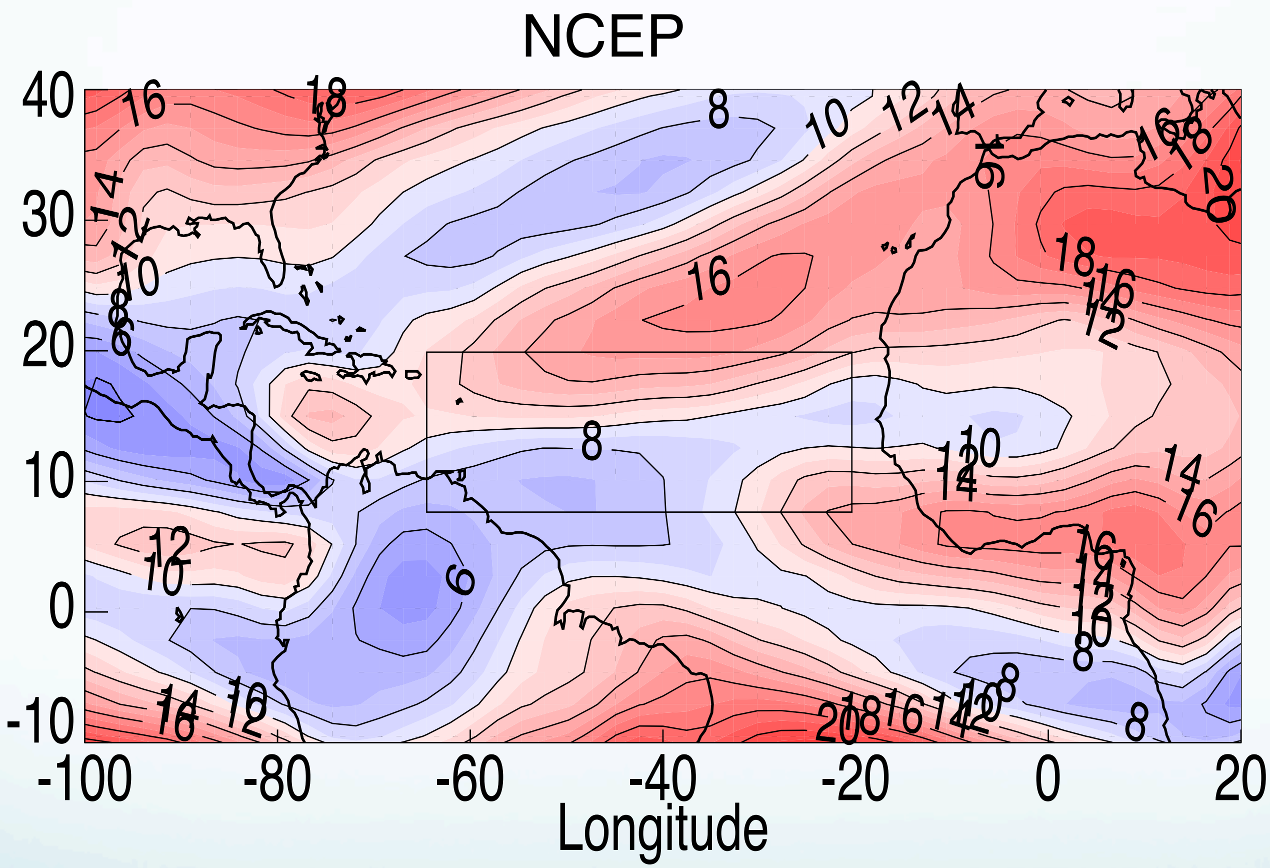
Environmental factors affecting tropical cyclogenesis



Source: NOAA

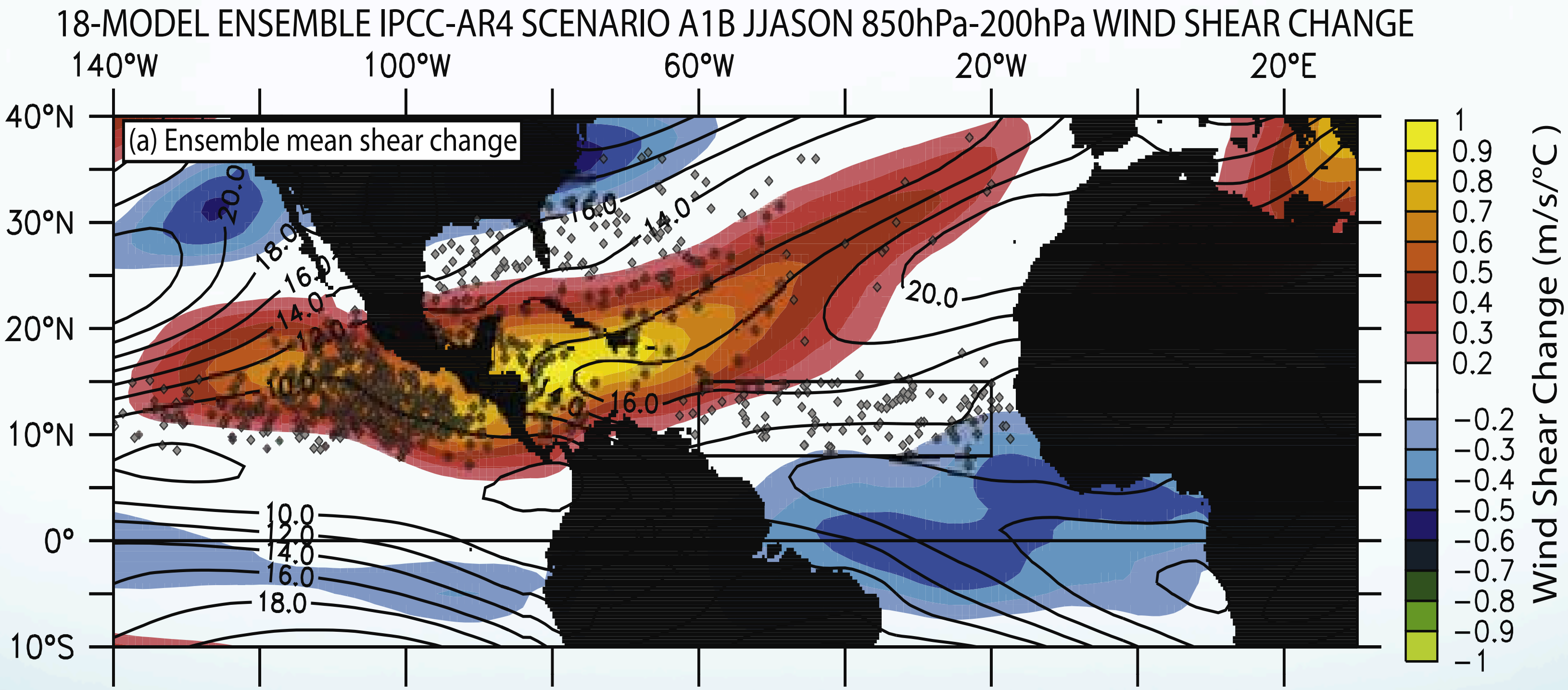
- Sea Surface Temperature >26C
- Low values of vertical wind shear between lower troposphere (850 hPa) and upper troposphere (200hPa)
- Atmospheric Instability
- Mid-troposphere humidity – sufficient moisture
- Coriolis effect
- Pre-existing disturbance

Vertical wind shear (JASO)



Blue: < 10m/s
Red: > 10m/s

Trends in tropical Atlantic wind shear (IPCC-AR4 models)

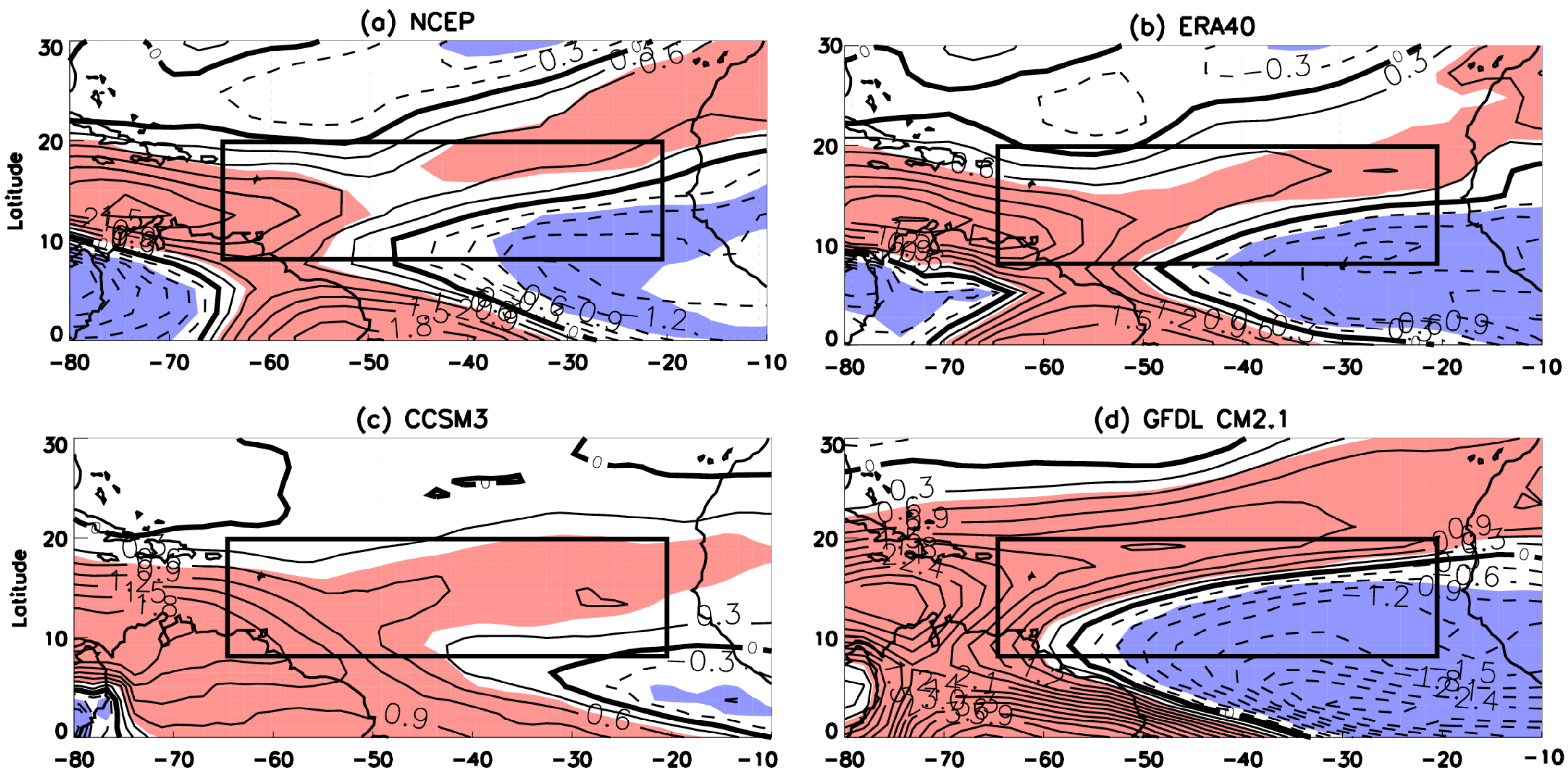


Vecchi and Soden 2007

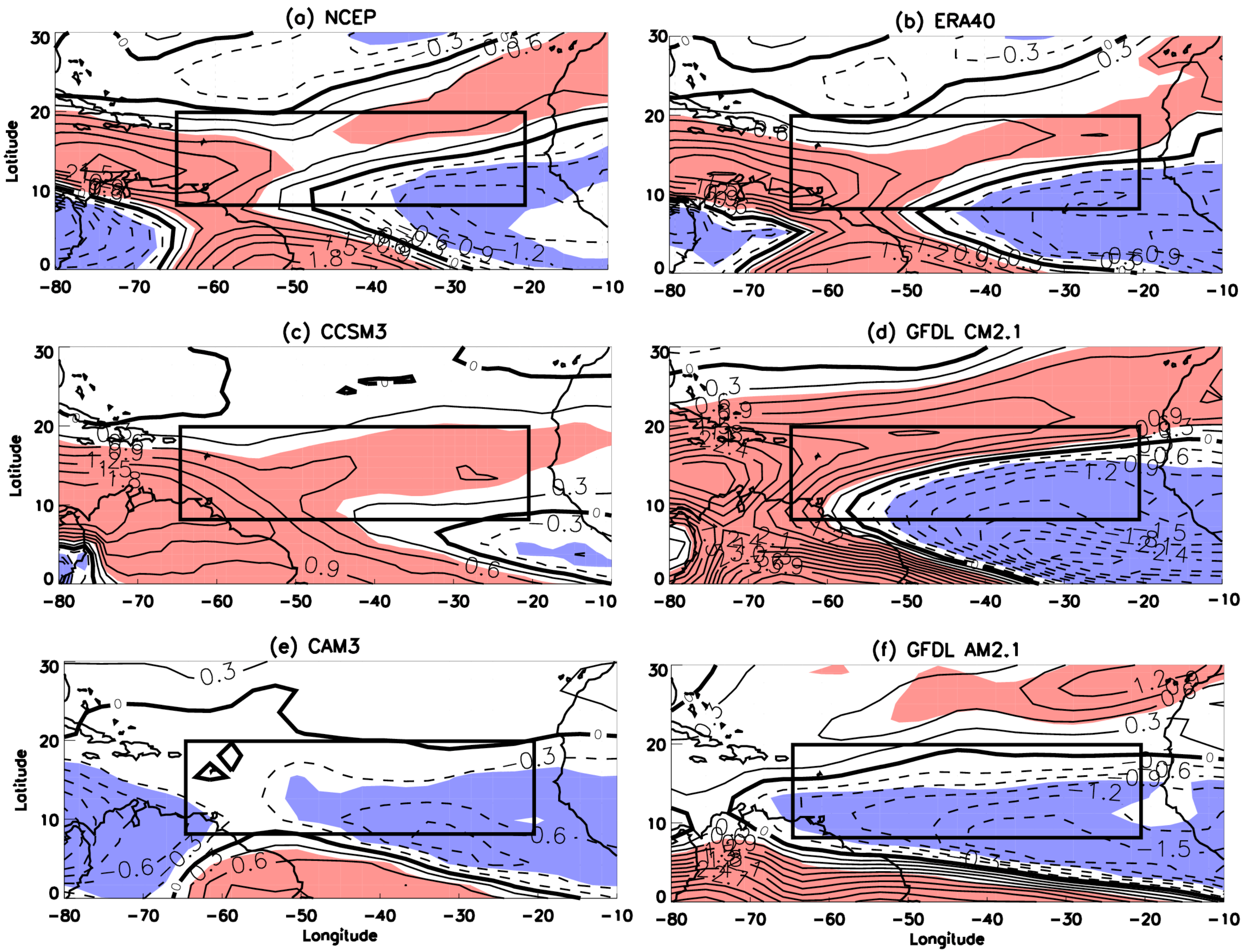
Questions

- What are the dominant modes of vertical wind shear variability over the tropical Atlantic?
- What drives tropical Atlantic vertical wind shear variability at different time scales?
  - local SST forcing
  - remote SST forcing
  - atmospheric internal variability
- How well do numerical models simulate the vertical wind shear?
  - Coupled model simulations
  - Uncoupled model simulations

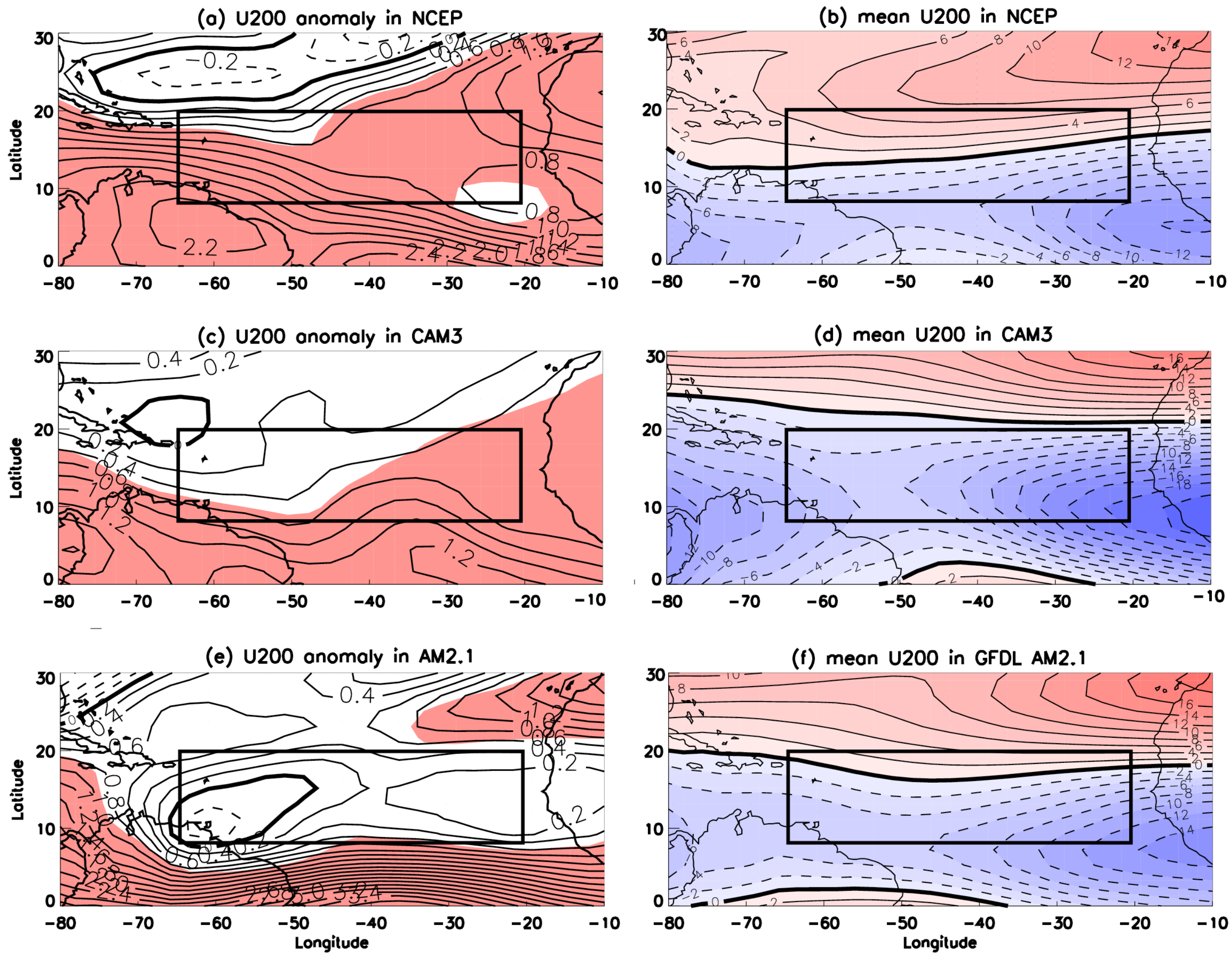
ENSO-vertical shear regression



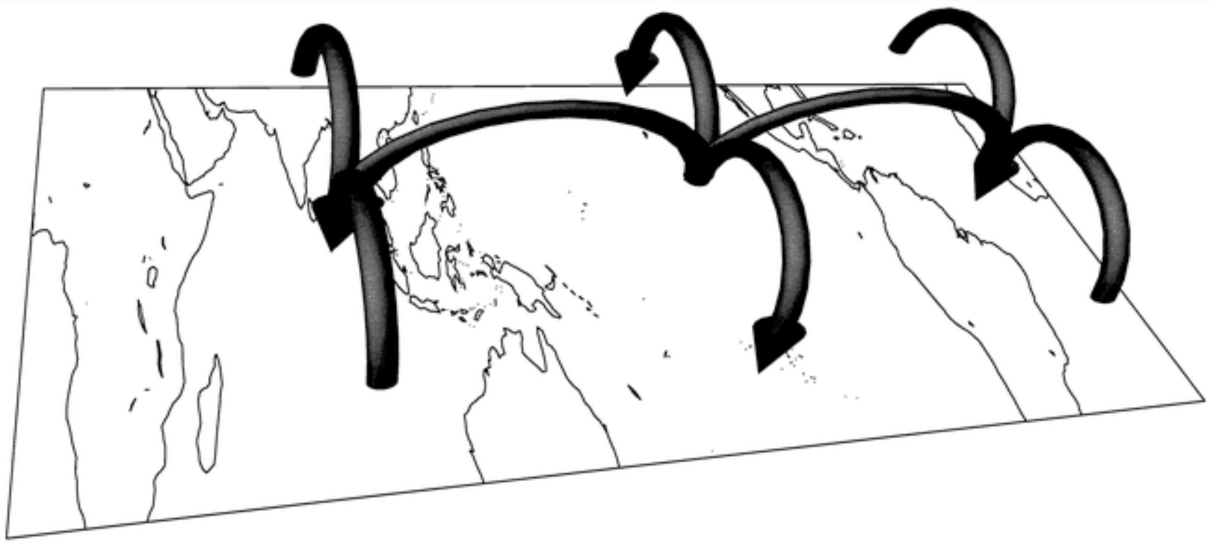
ENSO-vertical shear regression

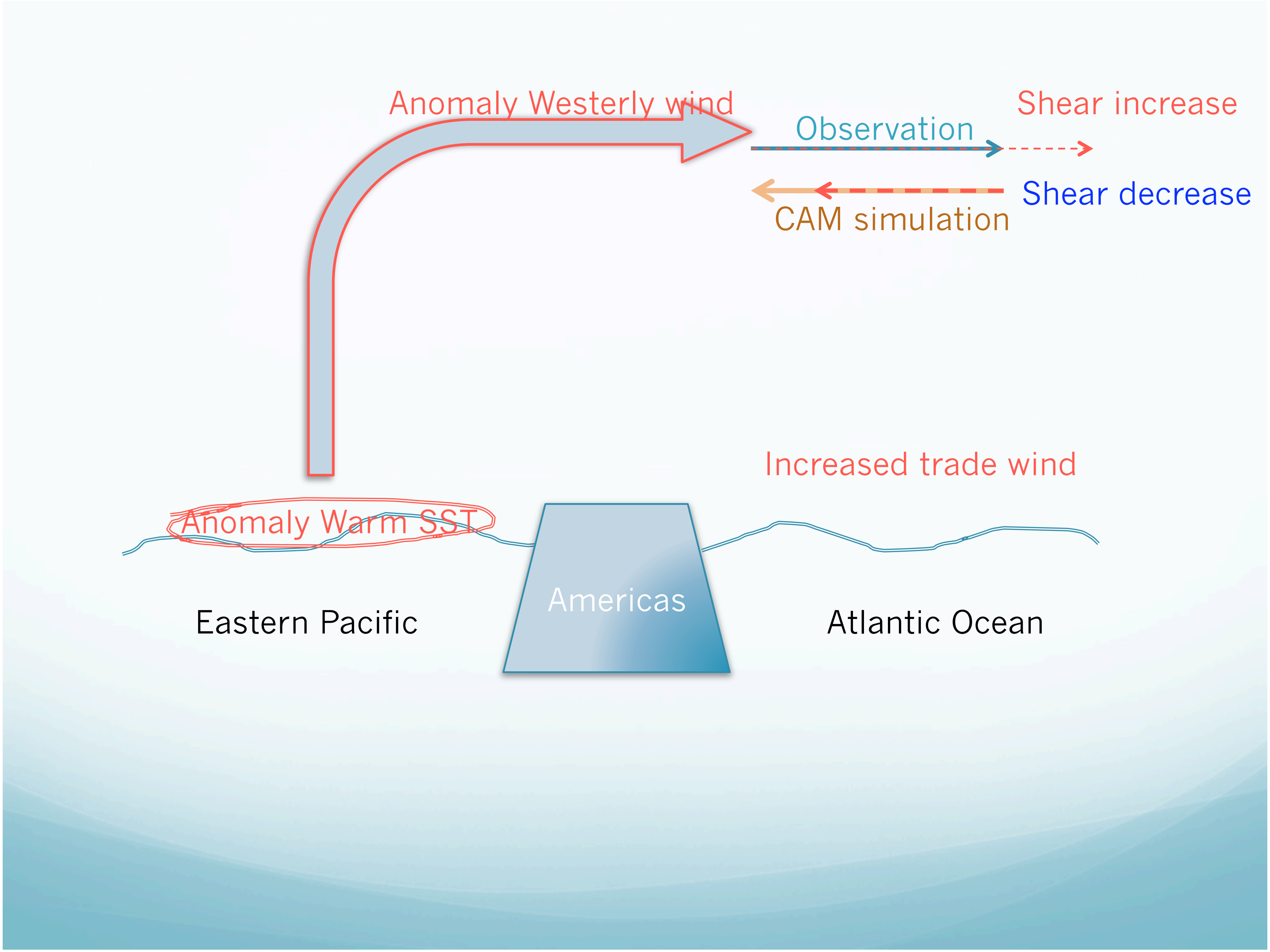


U200 anomaly and mean flow



Tropical Atmospheric Bridge
(Klein et al, 1999)



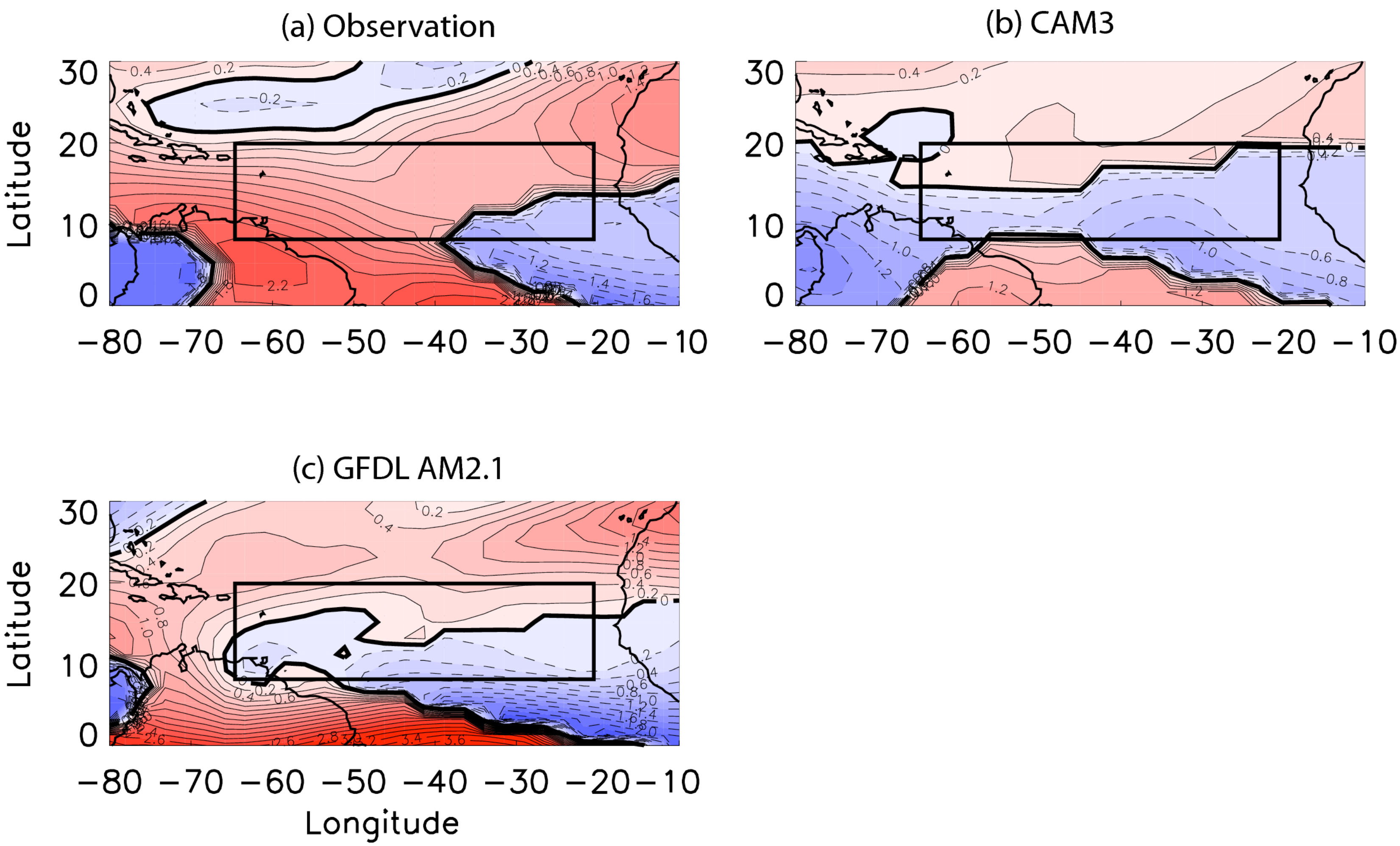

Anomaly Westerly wind
Observation
Shear increase
Shear decrease
CAM simulation
Increased trade wind
Anomaly Warm SST
Americas
Eastern Pacific
Atlantic Ocean

Simple superposition model of ENSO-vertical shear regression

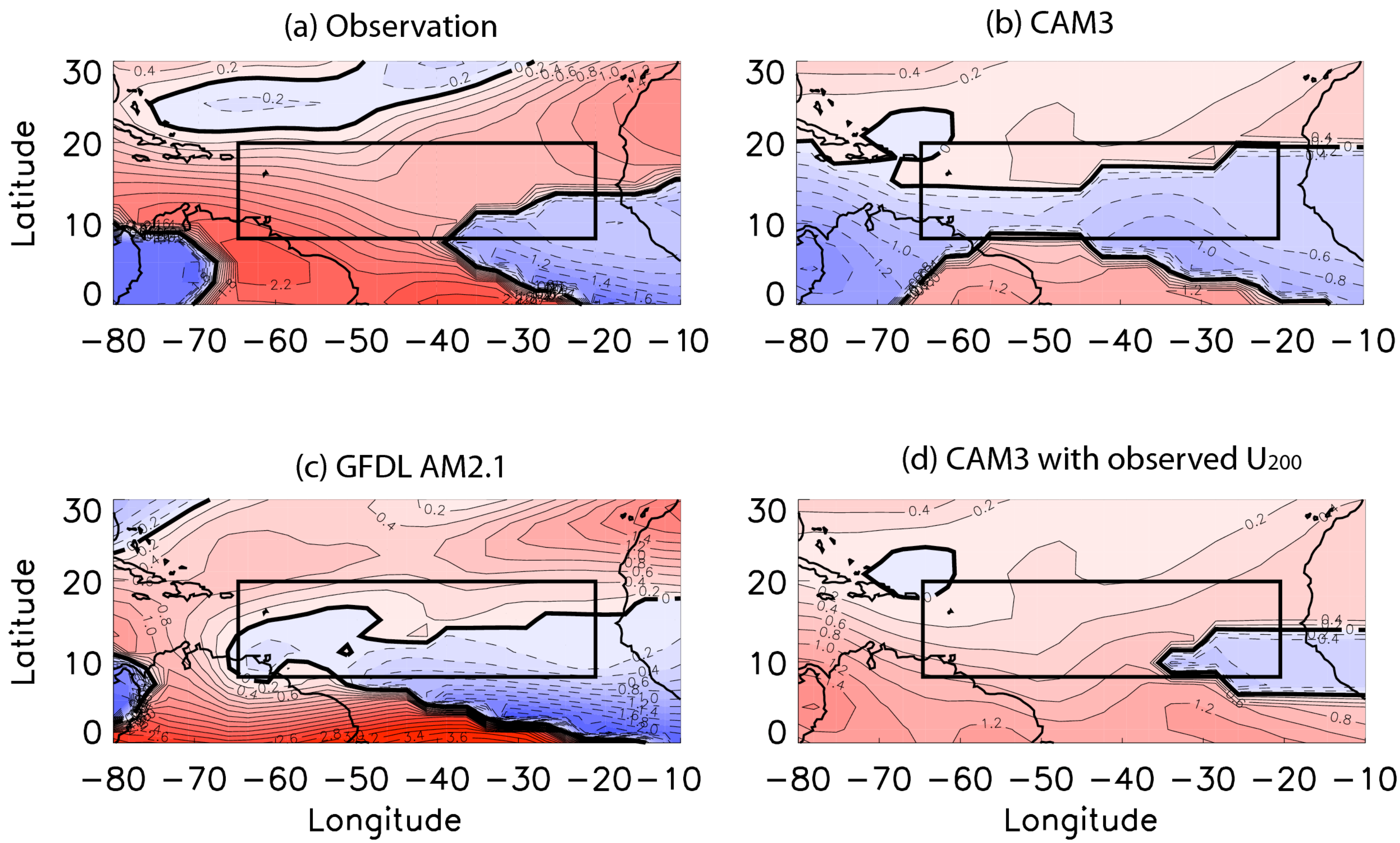
- Mean shear : $\left|U_{200} - U_{850}\right|$
- ENSO wind anomaly: U_{200}^{reg}
- Estimate of ENSO shear: $\left|(U_{200} - U_{850}) + U_{200}^{reg}\right|$
- Estimate of ENSO shear anomaly:

$$\left|(U_{200} - U_{850}) + U_{200}^{reg}\right| - \left|U_{200} - U_{850}\right|$$

Estimates of ENSO-vertical shear regression using the superposition model

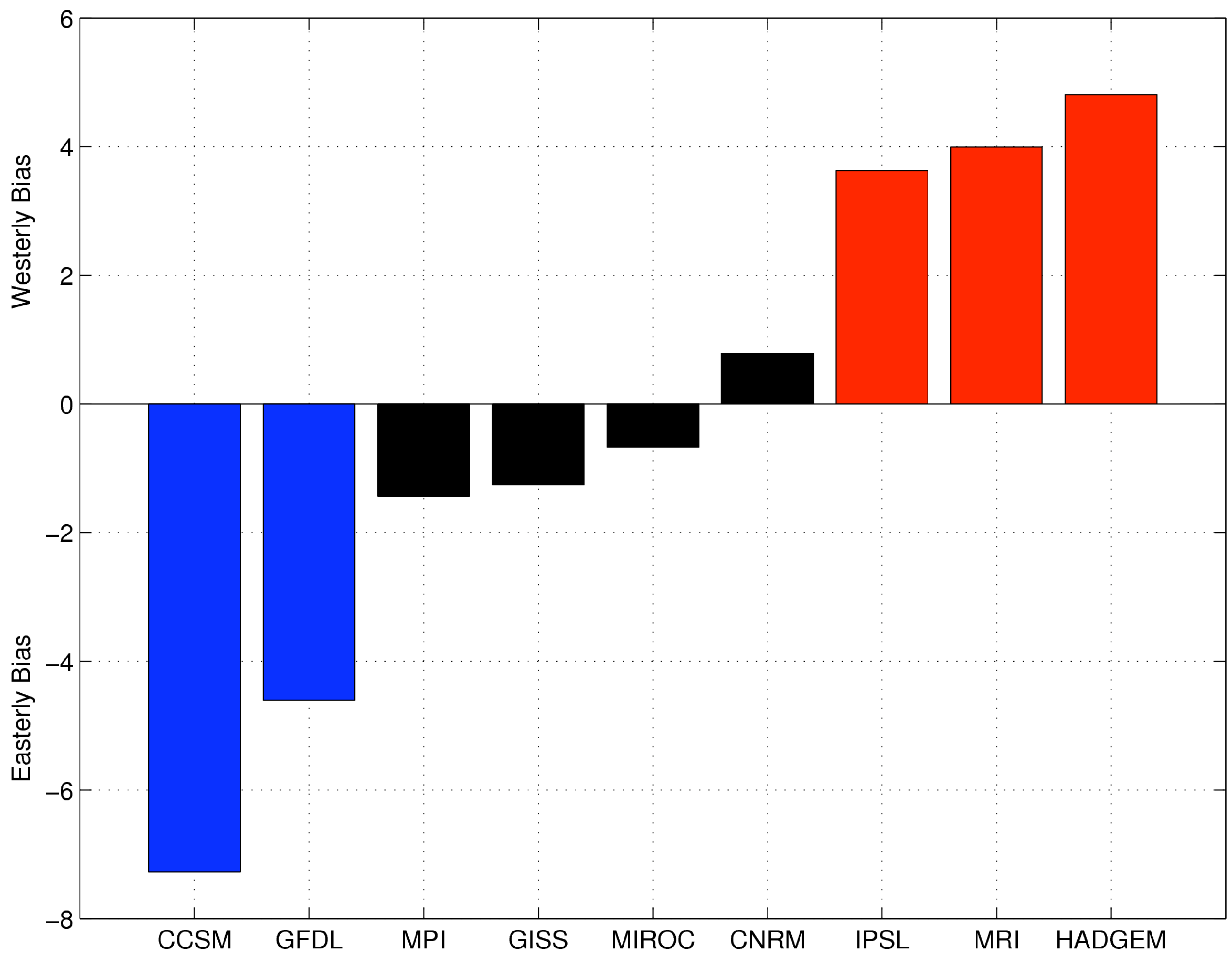


Estimates of ENSO-vertical shear regression using the superposition model

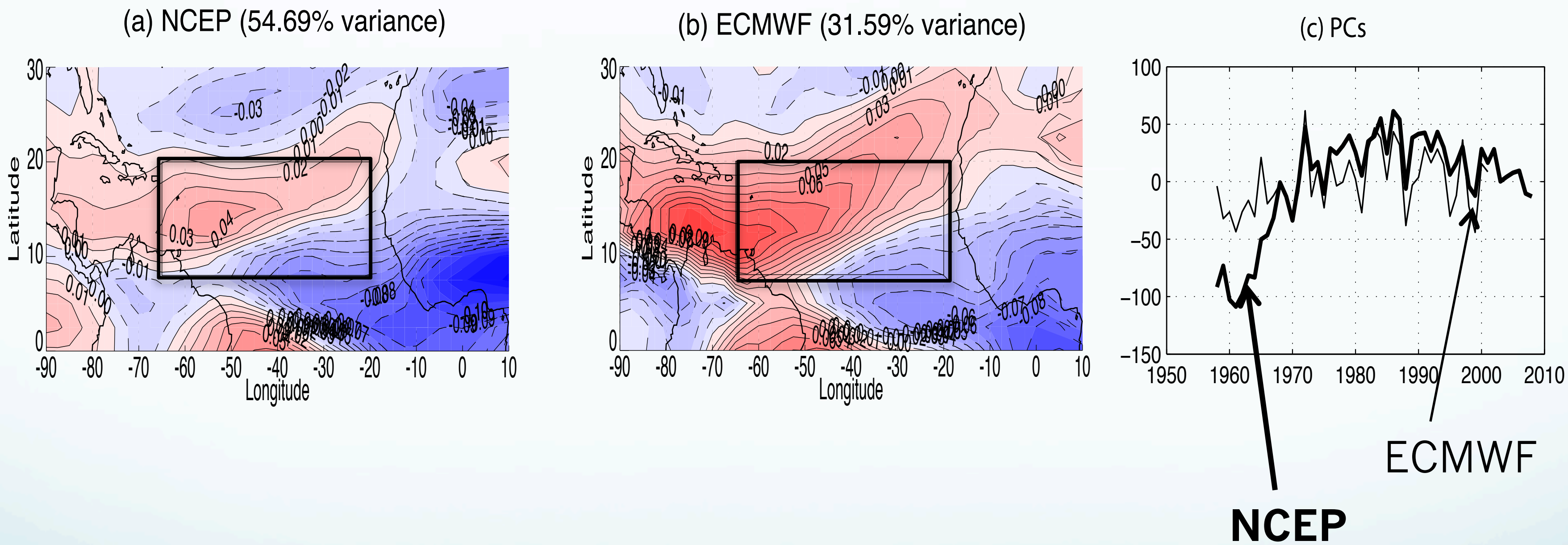


200 hPa zonal wind bias in AR4 AMIP integrations.

(ENSO-shear correlation: Red => positive, Blue => negative)

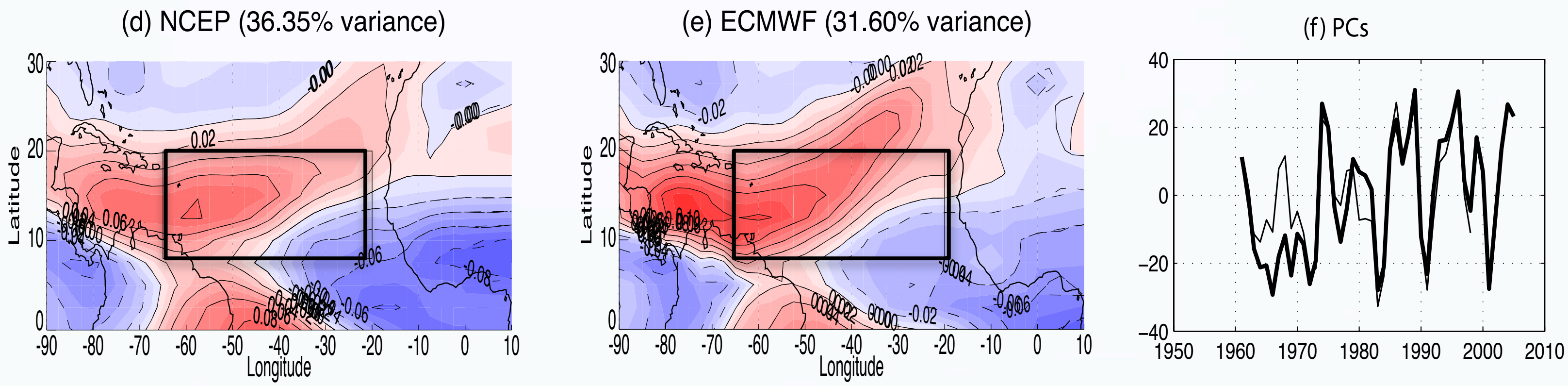


Dominant mode (EOF1) of Vertical wind shear Observations (Jul. – Oct.)



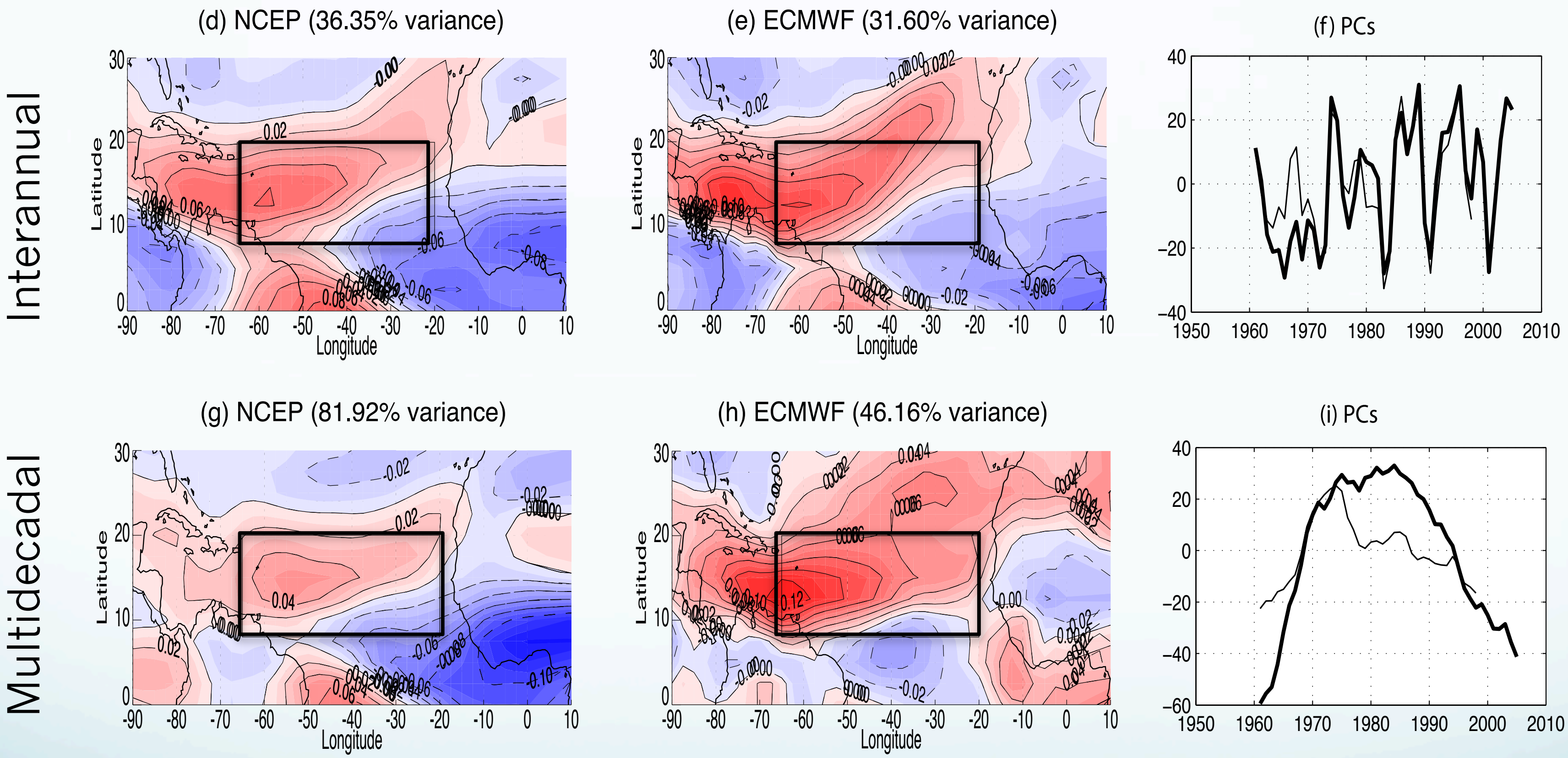
Dominant mode (EOF1) of Vertical wind shear

Interannual



Thick: NCEP
Thin: ECMWF

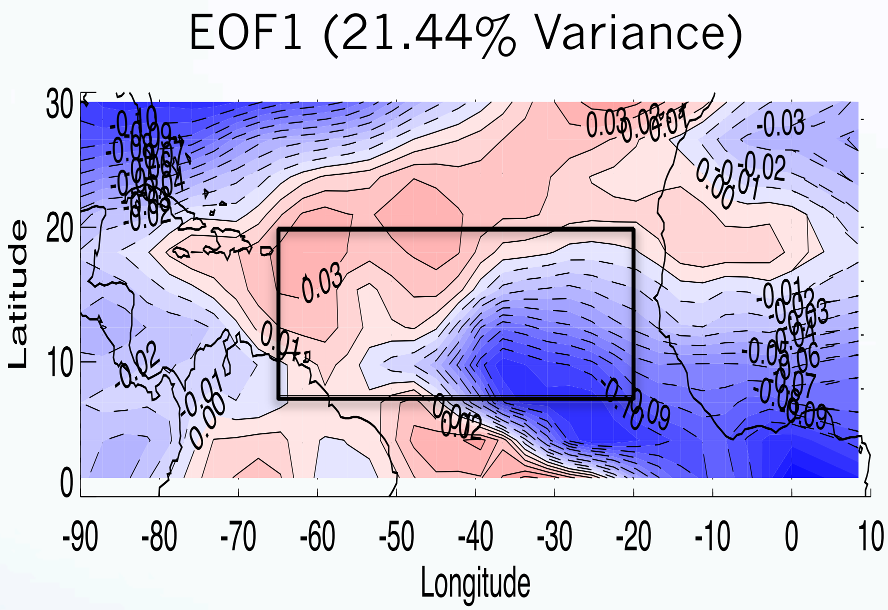
Dominant mode (EOF1) of Vertical wind shear



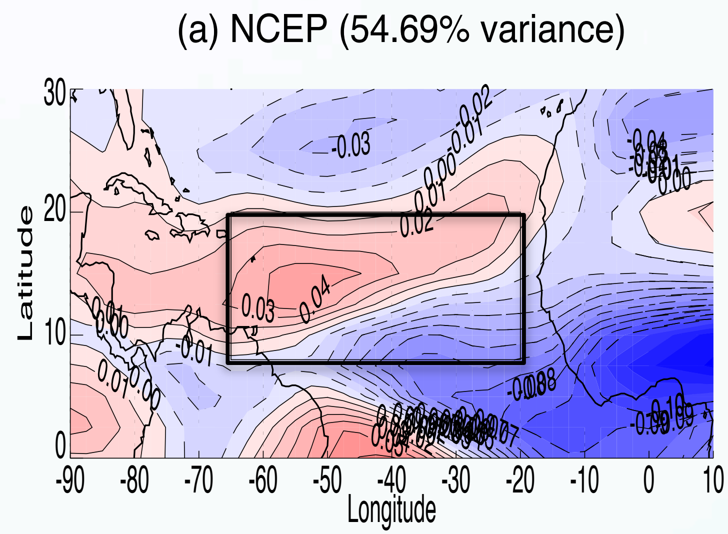
Thick: NCEP
Thin: ECMWF

An internal atmospheric mode?

CAM3 forced with observational climatology SST



Observations



Conclusions

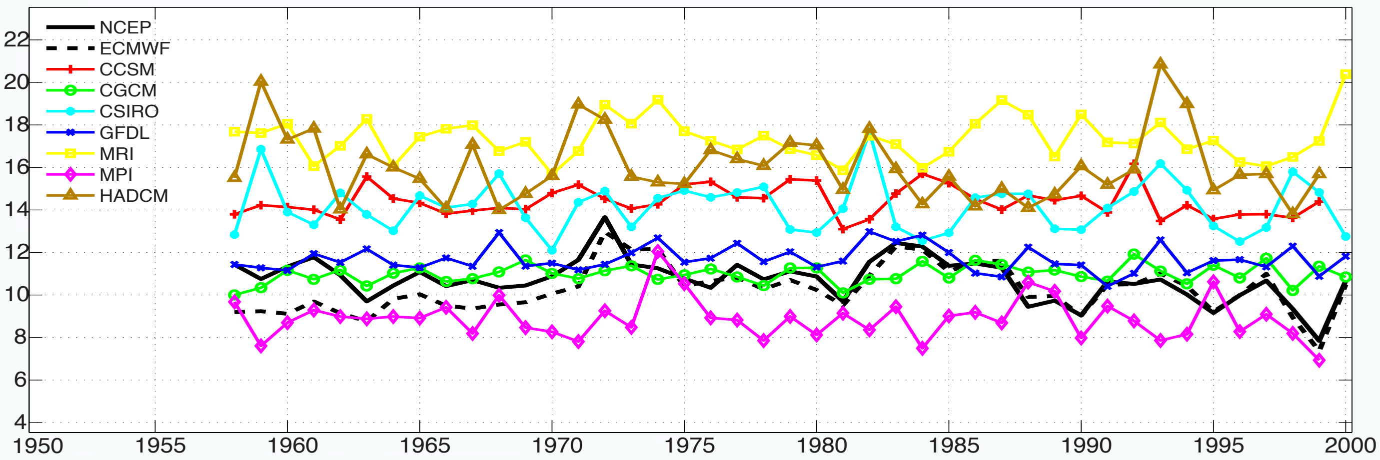
- **Simulated ENSO-Shear relationship**:
  - Coupled integrations: Well simulated (for the right reasons?)
  - Uncoupled AMIP integrations: Wrong sign in some cases!
    - Anomalous U200 is well simulated but mean U200 is not realistic.
    - Simple superposition model for estimating shear works quite well.

- **Implications for climate prediction**:
  - Vertical shear is an inherently nonlinear (threshold) quantity.
  - It is determined by the superposition of the anomalous wind on the mean flow.
  - Trends in shear cannot be compared across models without taking into account the mean flow.

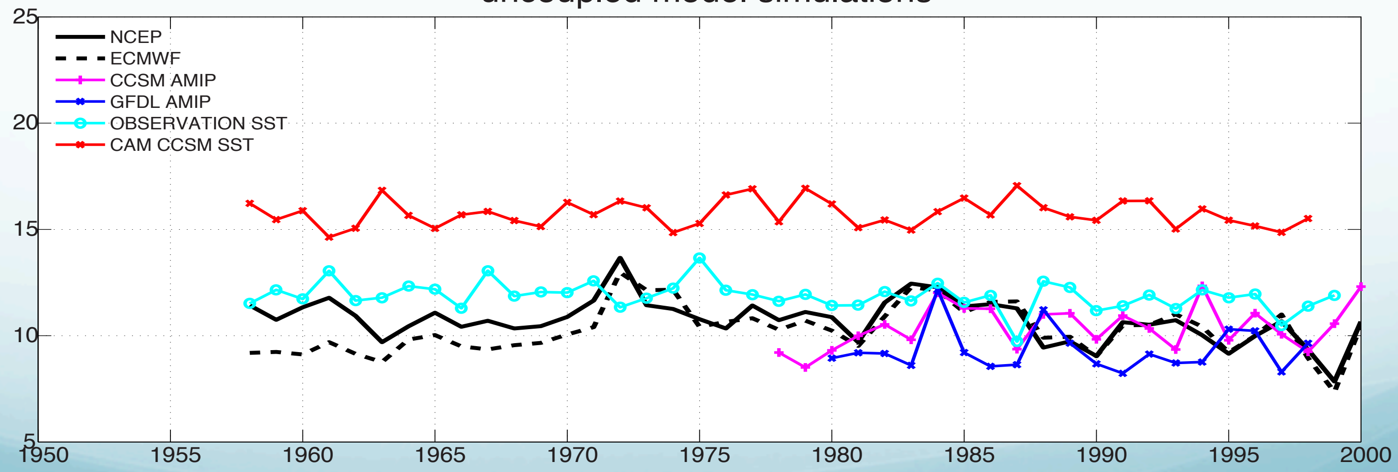
- **Vertical shear has a dipole mode over MDR**.
  - *Interannual time scale*: correlated with zonal SST gradient in Pacific ocean.
  - *Multidecadal time scale*: correlated with north Atlantic SST as well as tropical Pacific SST gradient.
  - Similar in structure to an internal atmospheric mode.

MDR averaged vertical wind shear

Coupled model simulations

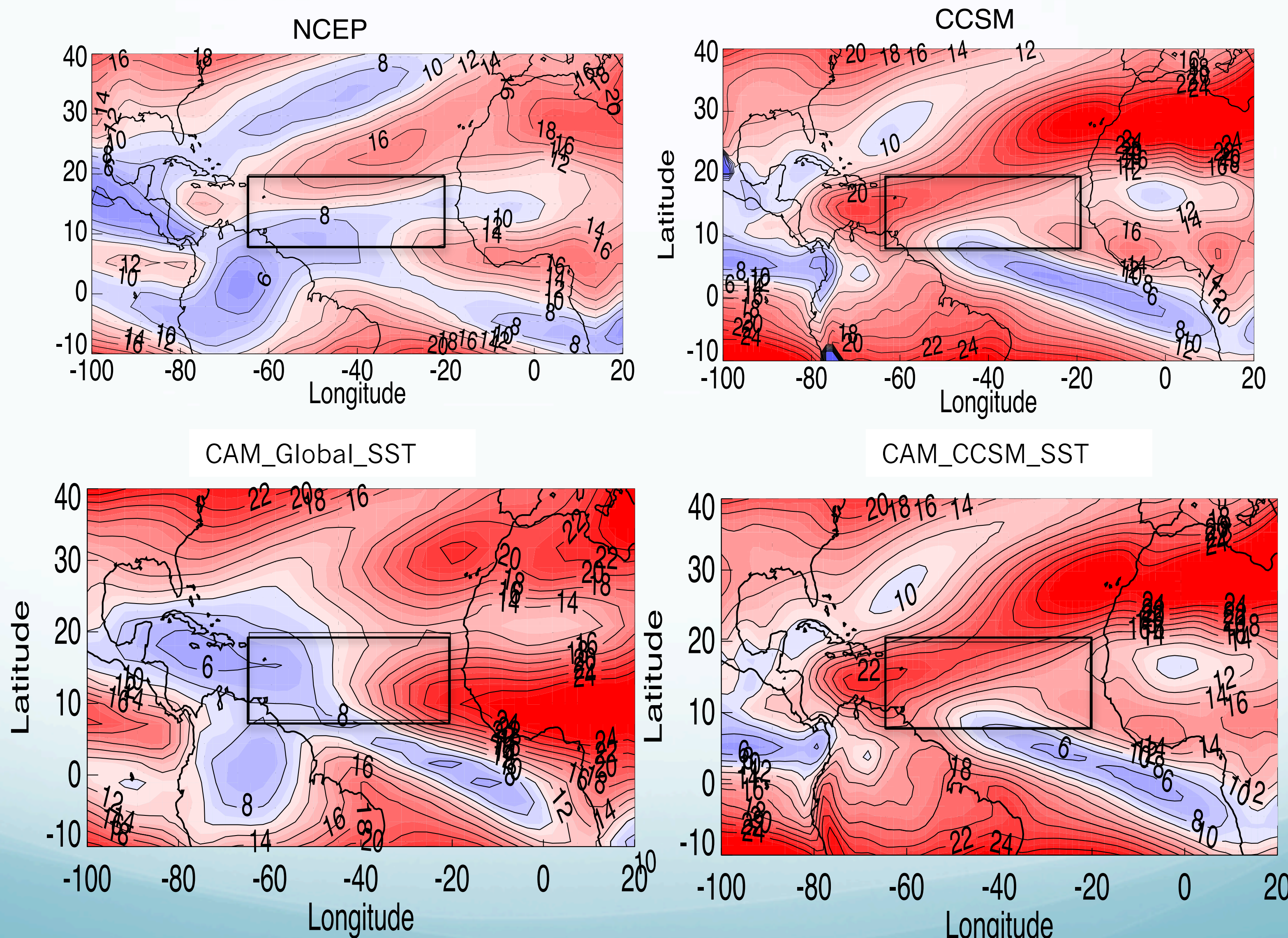


uncoupled model simulations



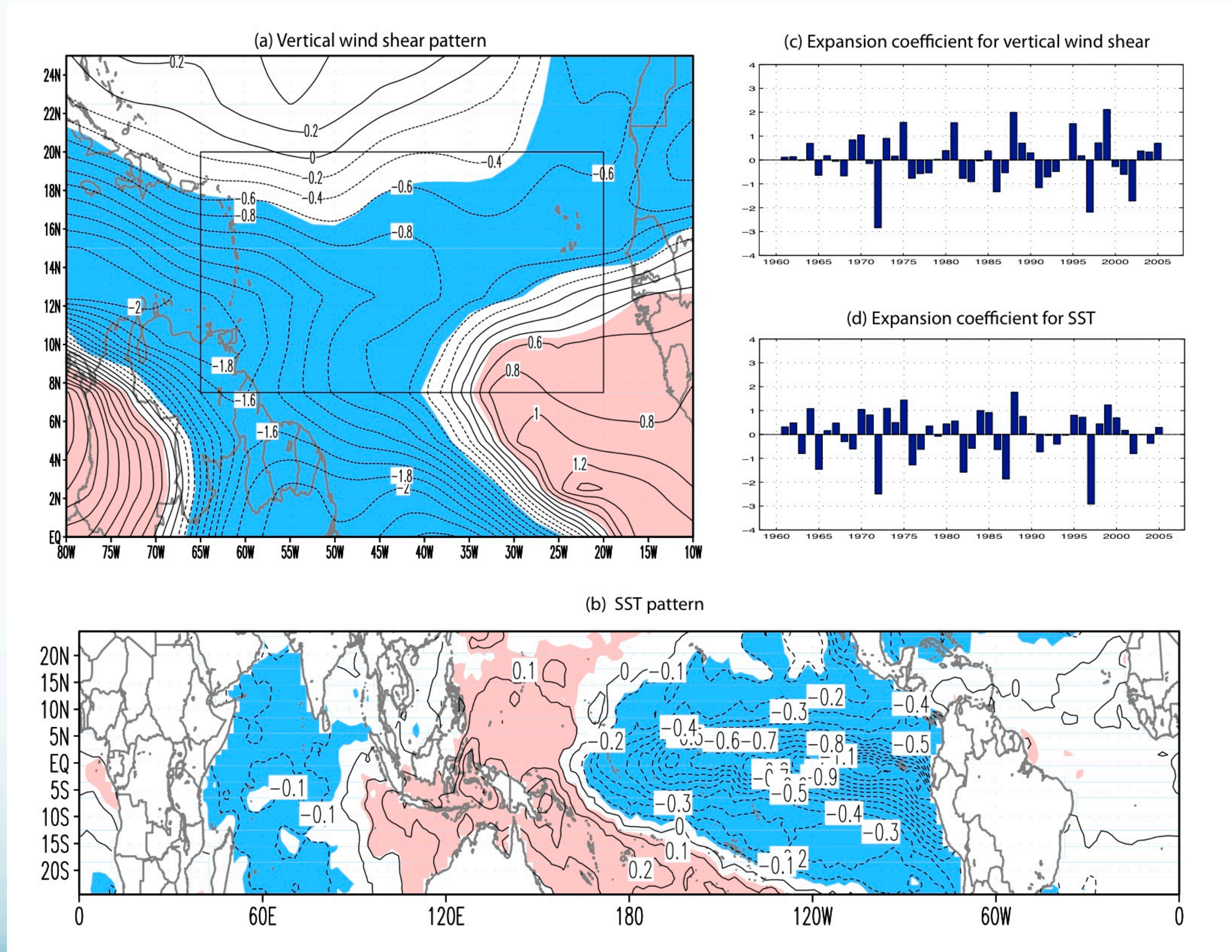
Hurricane season mean Vertical shear

Coupled and uncoupled



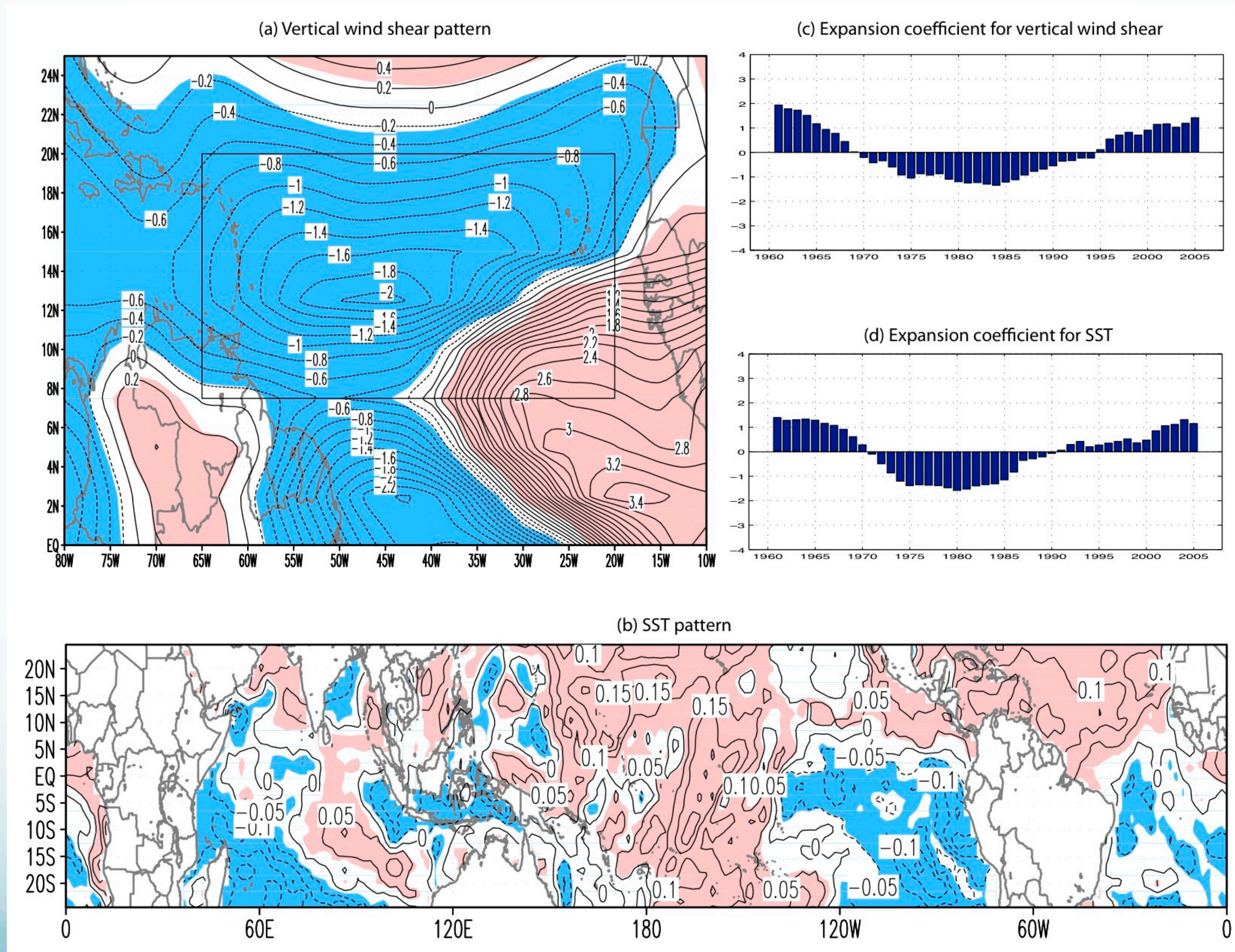
Vertical wind shear and tropical SST (SVD mode1)

- Interannual time scale



Vertical wind shear and tropical SST (SVD mode1)

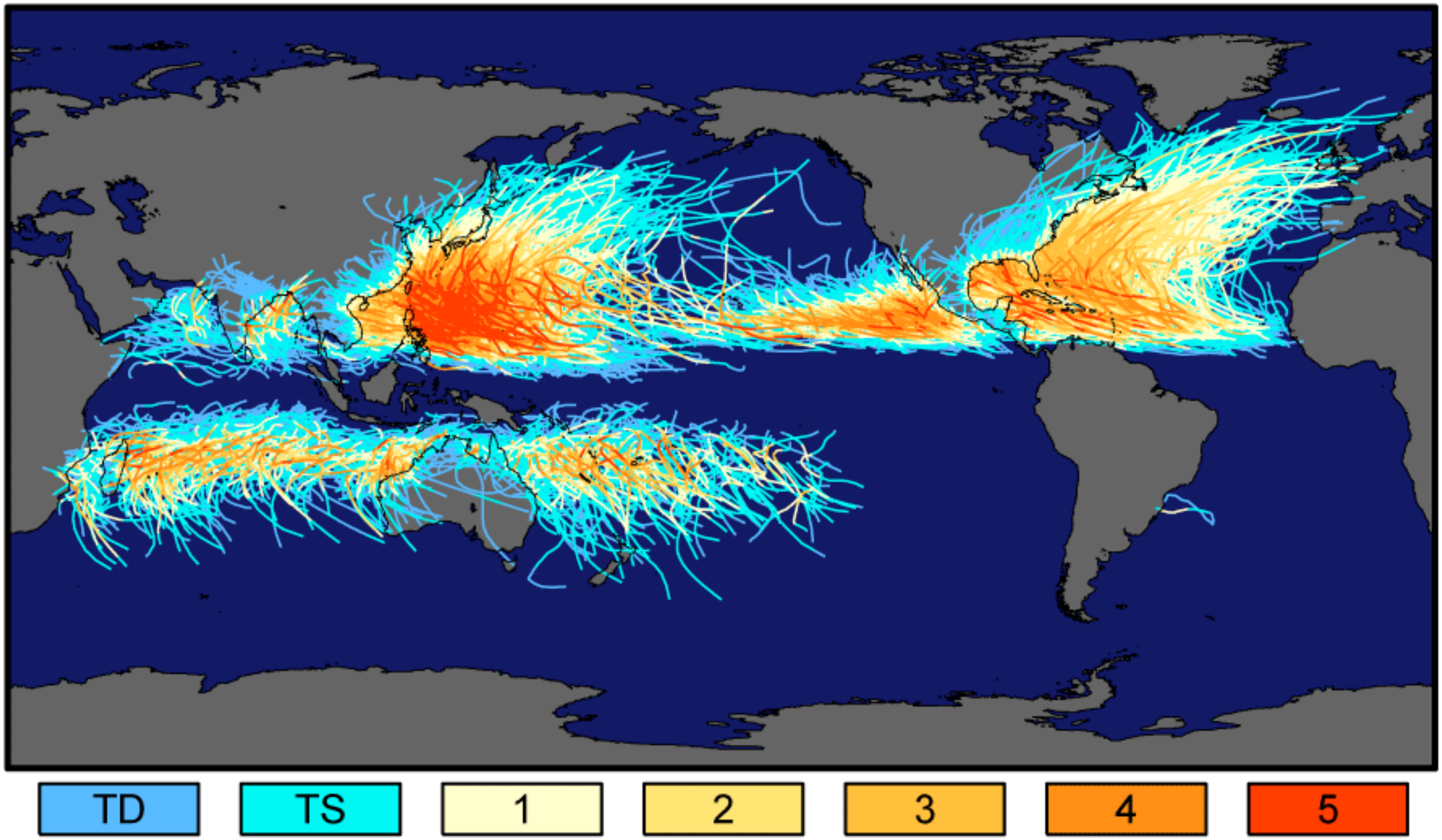
- Multidecadal time scale



Simulated vertical wind shear

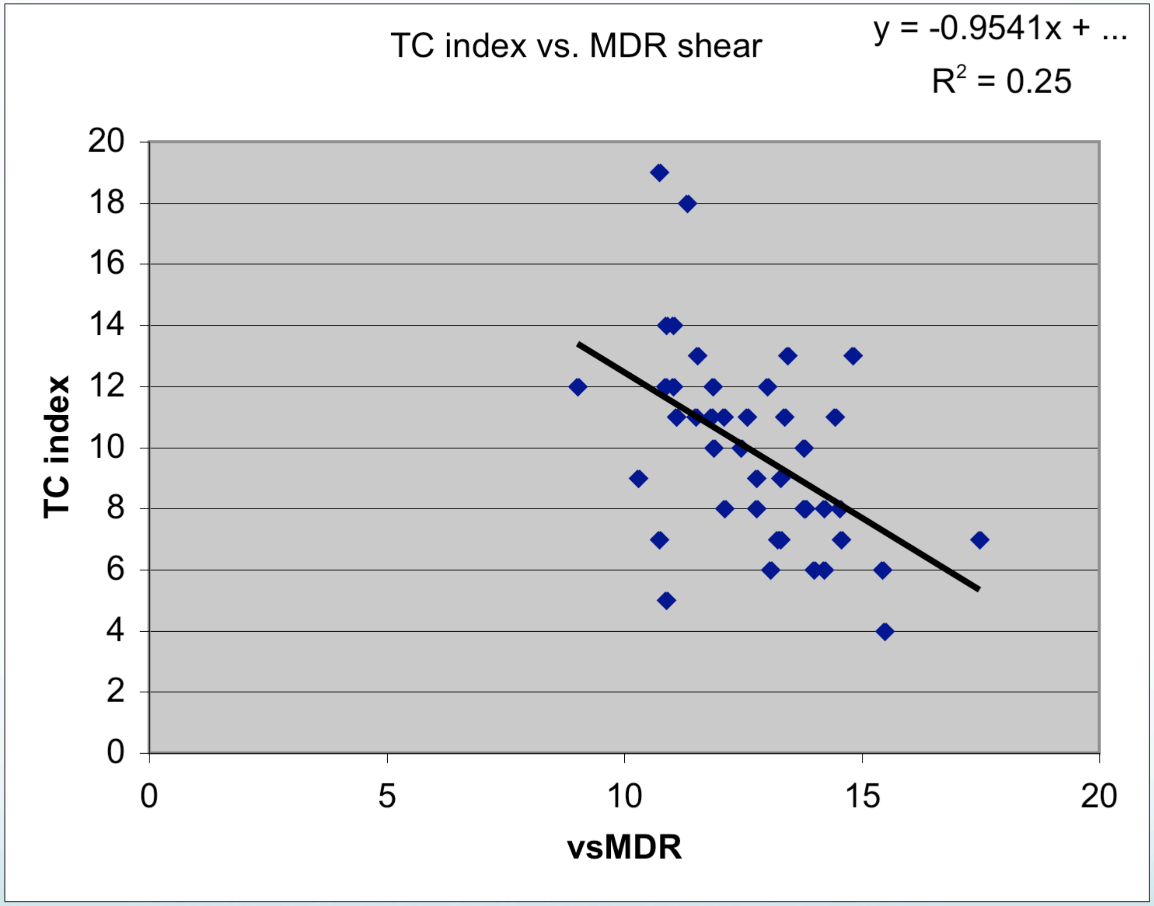
- **Coupled model simulations**
  - 20th century simulation from IPCC AR4
    - *CCSM, GFDL, HADCM3, MPI, MRI, CCCMA, CGCM* (1950 - 2000)
- **Uncoupled model simulations**
  - AMIP simulations from IPCC AR4 (20 years)
    - CCSM, GFDL
  - CAM3 forced with Global observed SST
    - *CAM-Global-SST* (1950- 1999, 5 ensembles)
  - CAM3 forced with CCSM output SST
    - CAM-CCSM-SST (1950 – 1999, 2 ensembles)

Tracks and Intensity of All Tropical Storms

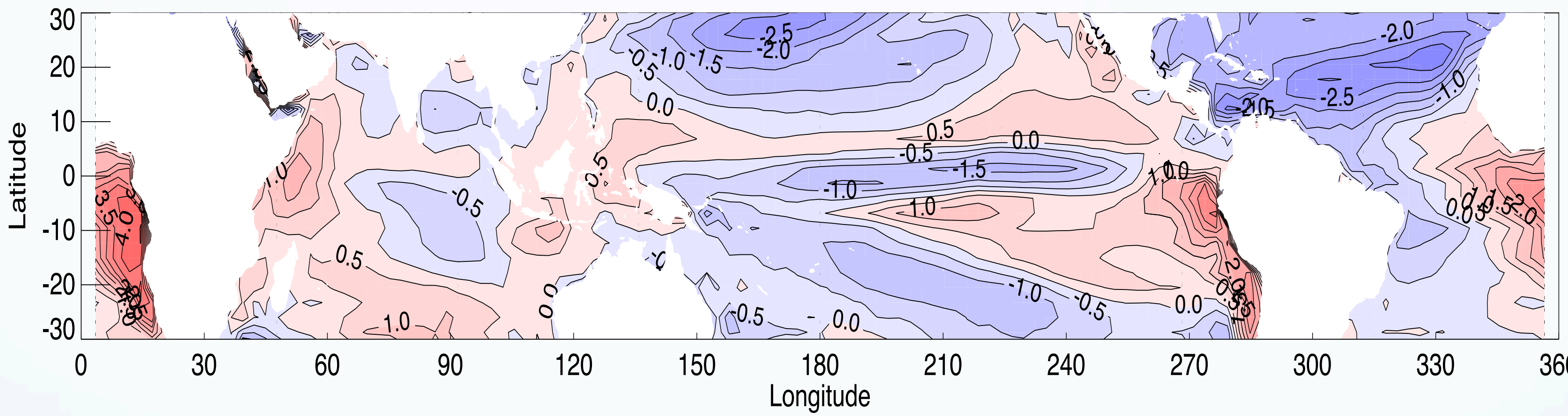


Saffir-Simpson Hurricane Intensity Scale

Count of *named storms* vs. MDR *vertical shear*



Mean SST bias (Jul. – Oct.)
CCSM – Observation



Cooler northern Atlantic SST => Stronger vertical wind shear

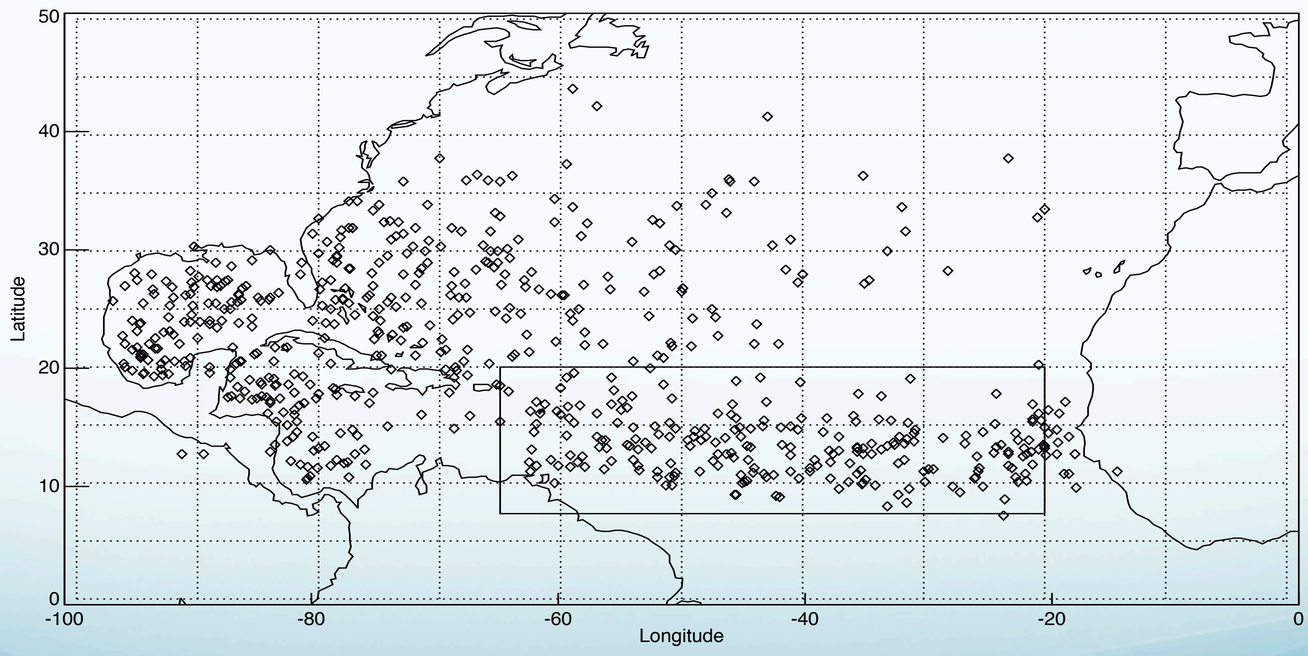
Warmer Eastern Pacific SST => Stronger vertical wind shear

Data and Method

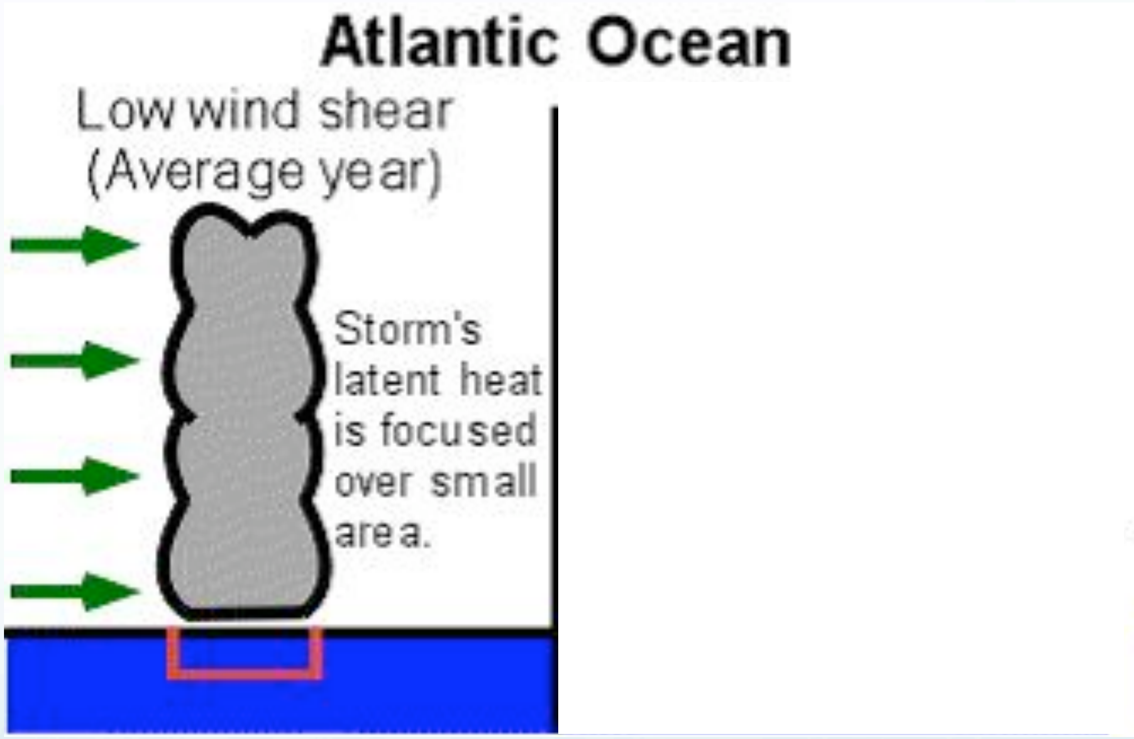
- Observational data
  - Wind:
    - ERA Interim (1989 –2009);
    - NCEP/NCAR reanalysis (1958 – 2008);
    - ECMWF ERA40 (1959 –2002)
  - SST: HadISST and ERSST
  - Hurricane track data: Emanuel
- Hurricane season: July – October
- Methods
  - EOF analysis
  - SVD analysis

Main Development Region

- Using genesis locations from 1980 to 2008
- Main Development Region (MDR): (7.5 N – 20N, 65W – 20W)

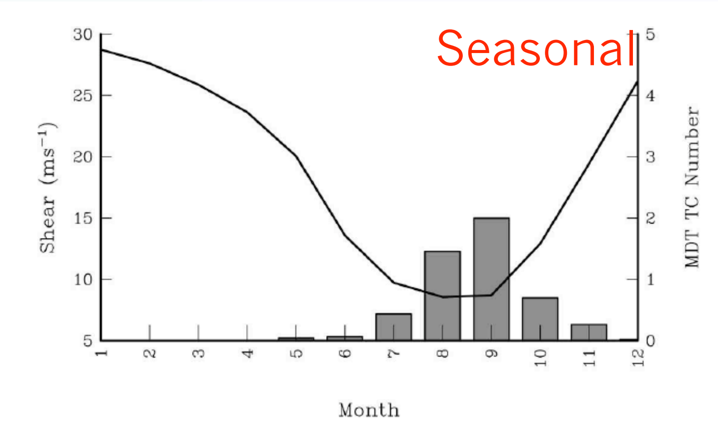


Schematic illustration of vertical wind shear and hurricane development

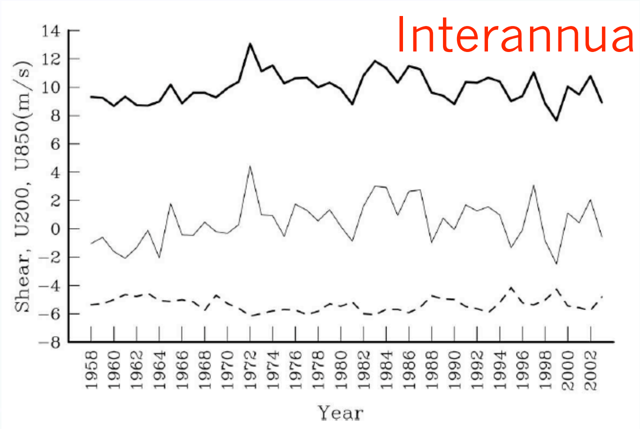


http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hurr/grow/home.rxml

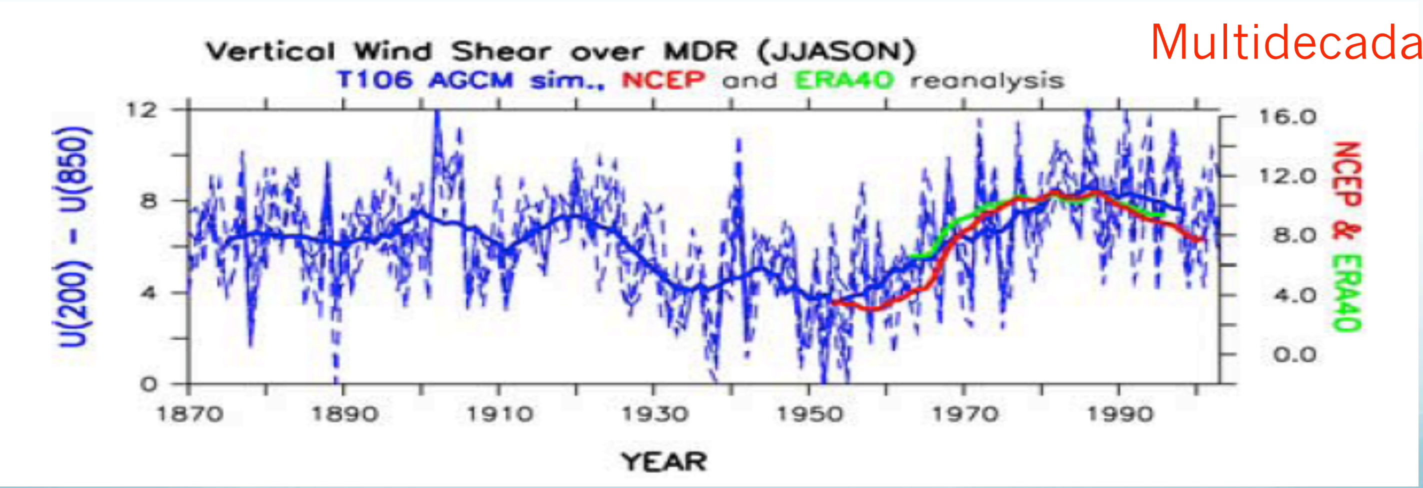
Variations of vertical wind shear



Aiyyer and Thorncroft (2006)



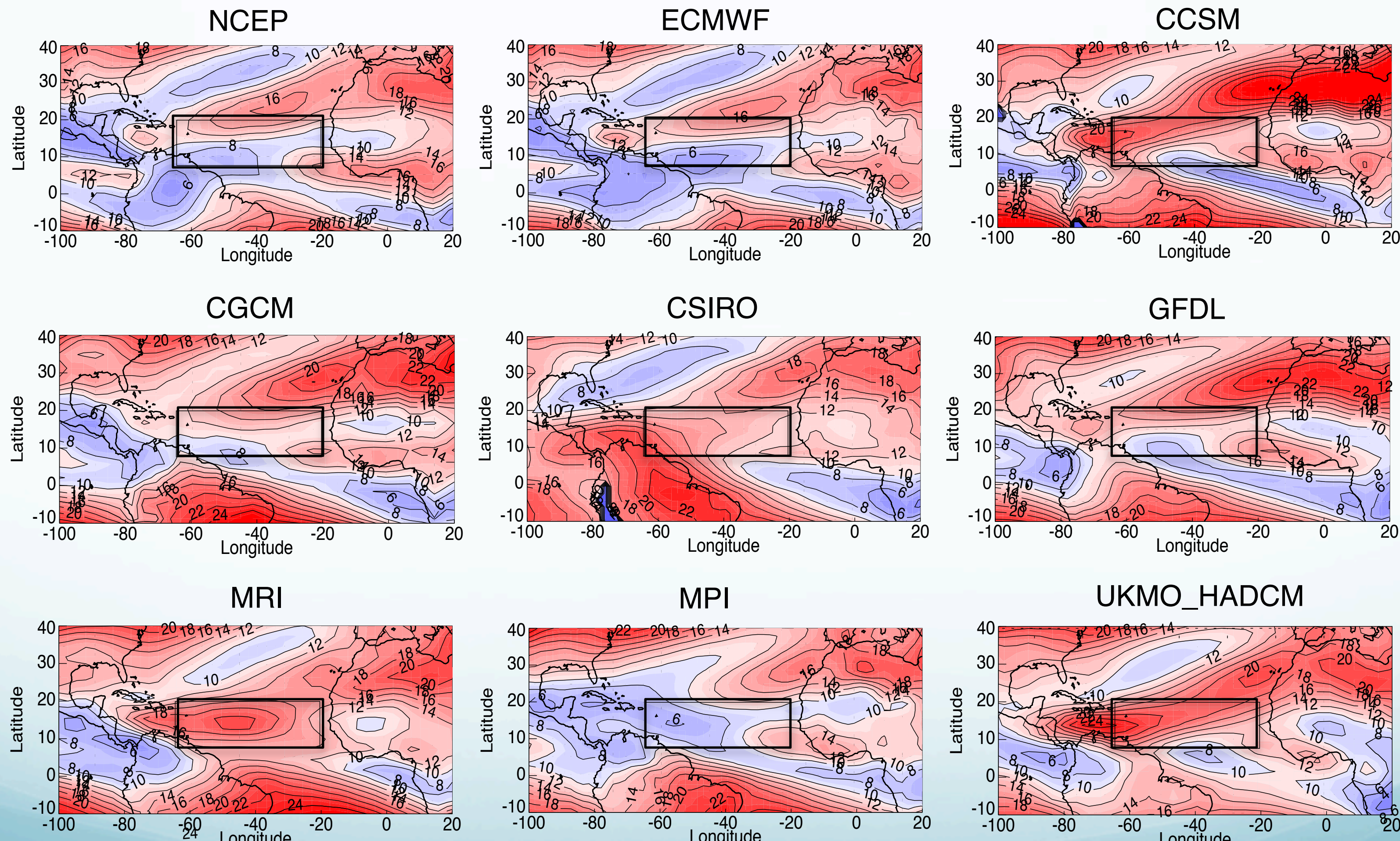
Aiyyer and Thorncroft (2006)

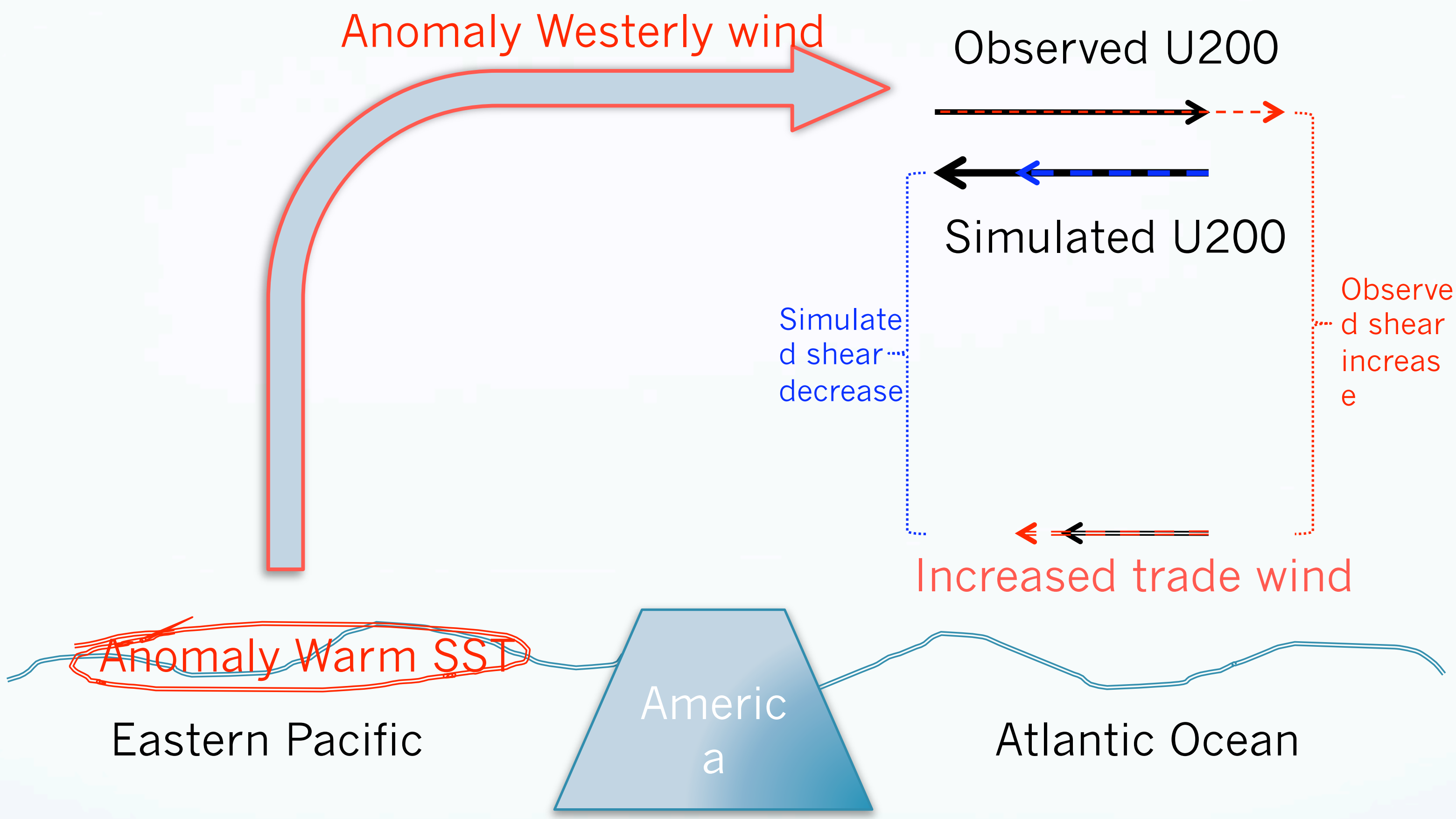


Latif et al. 2007

Hurricane season mean field

Coupled models



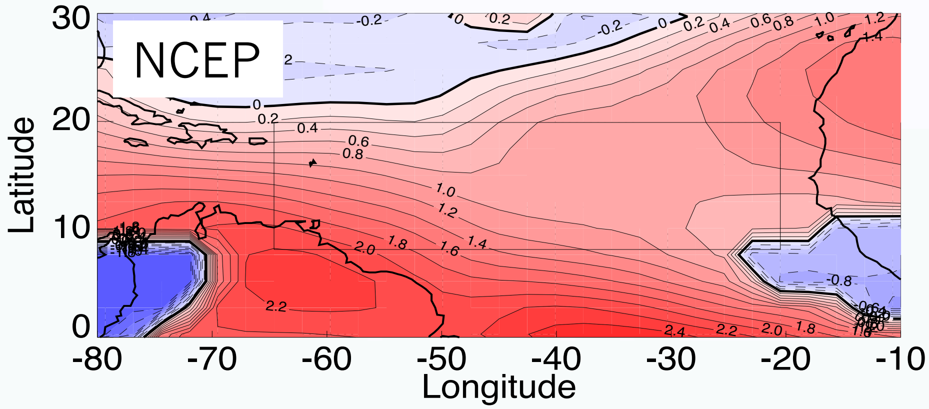

Anomaly Westerly wind
Observed U200
Simulated U200
Simulated shear decrease
Observed shear increase
Increased trade wind
Anomaly Warm SST
America
Eastern Pacific
Atlantic Ocean

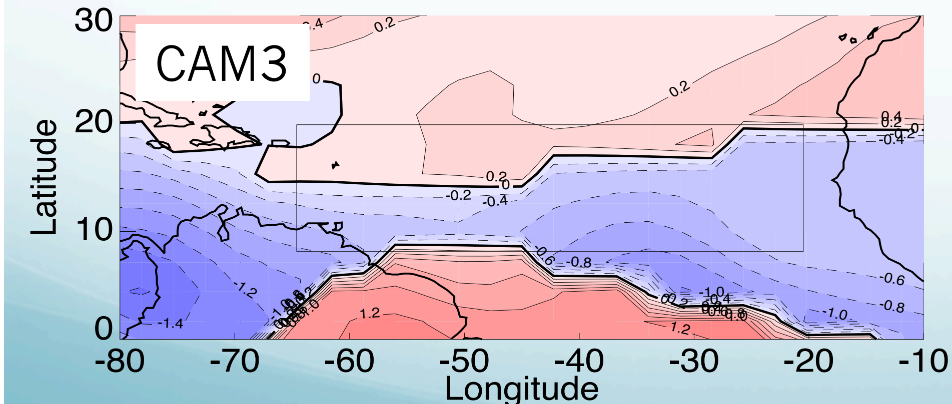
ENSO-Shear Relationship

Estimate of ENSO shear anomaly

ENSO shear Minus Mean shear

$(|(U_{200} - U_{850}) + U^{reg}_{200}|) - (|U_{200} - U_{850}|)$





Computed ENSO shear anomaly