NONLINEAR SUPERPOSITION OF LOCAL AND REMOTE INLFUENCES ON VERTICAL WIND SHEAR IN THE NORTHERN TROPICAL ATLANTIC

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MOTIVATION

Vertical wind shear over Tropical Atlantic is influenced by the remote ENSO phenomenon, with stronger vertical wind shear during El Nino Events. But we note some interesting discrepancies between observations and model simulations of this ENSO-shear relationship. Our goal is try to interpret these discrepancies and understand the nonlinear superposition of local and remote influences on vertical wind shear over the tropical Atlantic.

DATASETS

Time period:
- Atlantic hurricane season (July - October) from 1950 to 2000

Observations:
- Wind : NCEP and ECMWF reanalysis
- SST: HadISST and ERSST

Coupled simulations from IPCC-AR4:
- CCSM3 for 20th century simulation
- GFDL CM2 for 20th century simulation

Uncoupled simulations:
- CCSM3 for AMIP experiment from IPCC-AR4
- GFDL-AM2 for AMIP experiment form IPCC-AR4
- CAM3 forced by 50-year historical SST

REMOTE AND LOCAL INFLUENCES

Remote influence (ENSO influence):
- Observation: *increased* shear from the Caribbean to the west Africa during El Nino events **(Fig.1a)**
- Coupled model simulations: *increased* shear dominates the MDR during El Nino events **(Fig.1b and Fig. 1c)**
- Uncoupled model simulations: *decreased* shear dominates the MDR during El Nino events **(Fig. 1d and Fig. 1e)**

Local anomalous flow due to ENSO:
- anomalous westerlies at 200hPa in observation **(Fig.2a)**, CCSM3 simulation **(Fig.2b)** and CAM3 simulation **(Fig.2c)**
- increased trade winds at 850hPa in observation, CCSM3 simulation and CAM3 simulation (Figure not shown)

Local background flow :
- Westerlies from the Caribbean to the west Africa at 200hPa in observation **(Fig.3a)** and CCSM3 simulation **(Fig.3b)**
- Easterlies from the Caribbean to the west Africa at 200hPa in CAM3 **(Fig.3c)**
- Consistent trade windd at 850hPa in Observations, CCSM3, and CAM3 simulations (Figure not shown)

ENSO-SHEAR RELATIONSHIP

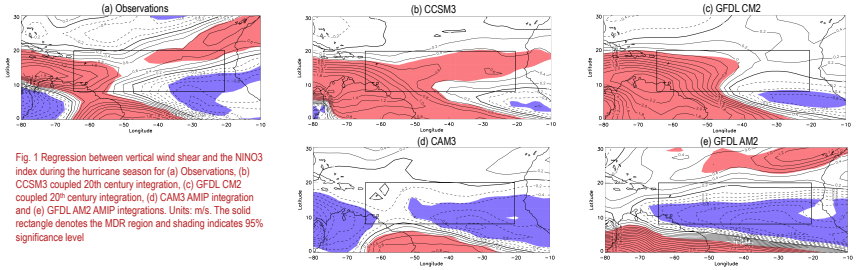

Fig. 1 Regression between vertical wind shear and the NINO3 index during the hurricane season for (a) Observations, (b) CCSM3 coupled 20th century integration, (c) GFDL CM2 coupled 20th century integration, (d) CAM3 AMIP integration and (e) GFDL AM2 AMIP integrations. Units: m/s. The solid rectangle denotes the MDR region and shading indicates 95% significance level

ENSO-U200 RELATIONSHIP

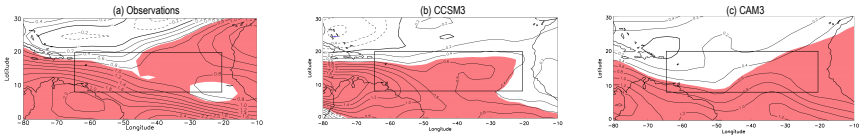

Figure 2. Regression of zonal wind at 200hPa with the NINO3 index during the hurricane season for (a) Observations, (b) CCSM3 and (c) CAM3-AMIP (Shading indicates 95% significance).

HURRICANE SEASON MEAN U200

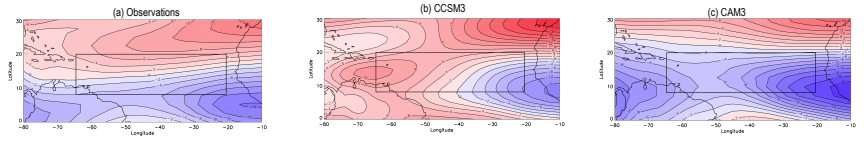

Figure 3. Hurricane-season mean zonal wind at 200hPa in (a) Observations, (b) CCSM3 and (c) CAM3-AMIP. Units: m/s.

LINEAR ESTIMATION Of ENSO-SHEAR RELATIONSHIP

Linear Estimate of Regression

- Mean shear :

$$|U_{200} - U_{850}|$$

- ENSO wind anomaly:

$$U_{200}^{reg}$$

- Estimate of ENSO shear:

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

- Estimate of ENSO shear anomaly:

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

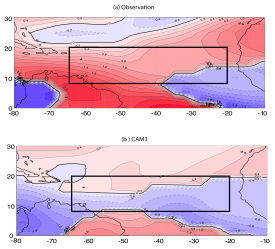

Figure 4. Regression model estimation of ENSO-induced vertical shear anomaly in (a) Observations and (b) CAM3. Units: m/s.

Fig. 4a shows the ENSO-induced vertical shear anomaly as computed using the regression model for observations. The regression model compares fairly well with observed ENSO-vertical shear relationship (Fig. 1a), although there are some differences south of 15N. In particular, the positive correlation in the western portion of the MDR and the Caribbean is captured well by the regression model.

When we apply the regression model to the CAM3-AMIP simulations (Fig. 4b), again we find good agreement with the corresponding direct estimate of the ENSO-vertical shear relationship (Fig. 1d). In particular, the regression model demonstrates a weaker vertical wind shear during warm ENSO events, especially over the Caribbean and much of the MDR region.

NONLINEAR SUPERPOSITION

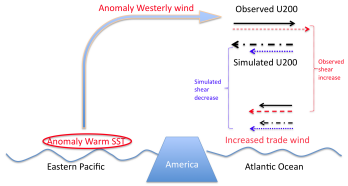

Figure 5. Schematic longitude-height section illustrating the nonlinear interaction between the remote influence of ENSO and the mean zonal wind over the western portion of the northern tropical Atlantic region. Solid arrows denote the 200hPa and 850hPa mean zonal winds in observations. The dashed arrows denote the zonal winds during a warm ENSO event in observations. The dash-dotted arrows denote the 200hPa mean zonal winds in the CAM3 simulation, and the dotted arrow denotes the zonal wind during a warm ENSO event, as simulated by CAM3.

The observed mean flow is westerly at 200hPa and easterly at 850hPa. The positive SST anomaly associated with a warm ENSO event in the Eastern Pacific induces an anomalous Walker circulation which strengthens the upper level westerlies as well as the lower level easterlies, leading to an *increased* vertical wind shear.

In the CAM3_AMIP simulation, the simulated mean upper level flow is easterly. The upper level westerly anomalies associated with a warm ENSO event weaken the upper level easterlies in the CAM3 simulation, whereas the lower level easterlies increase slightly. Thus, a warm ENSO even is associated with *reduced* vertical wind shear in CAM3.

CONCLUSIONS

- Vertical wind shear is an inherently nonlinear field.
- The mean wind and and the anomalous winds do not superpose linearly in the computation of wind shear.
- 200hPa zonal wind (U200) is the dominant contributor to variations in vertical wind shear over the Tropical Atlantic
- GCMs exhibit significant errors in the simulation of the mean U200 in the Tropical Atlantic.
- GCMs capture the relationship between ENSO and anomalous U200 fairly well.
- Due to errors in the mean state simulation, GCMs can simulate weaker vertical shear over the Tropical Atlantic associated with warm ENSO events!
- This has important implications for interpreting trends in vertical shear simulated in climate change scenarios.