Oceanic Influence on Seasonal Atlantic Tropical Cyclone Activity: Pacific vs. Atlantic

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Question: How does the location of tropical Pacific warming during El Niño impact Atlantic tropical cyclone (TC) activity, and through what mechanisms?

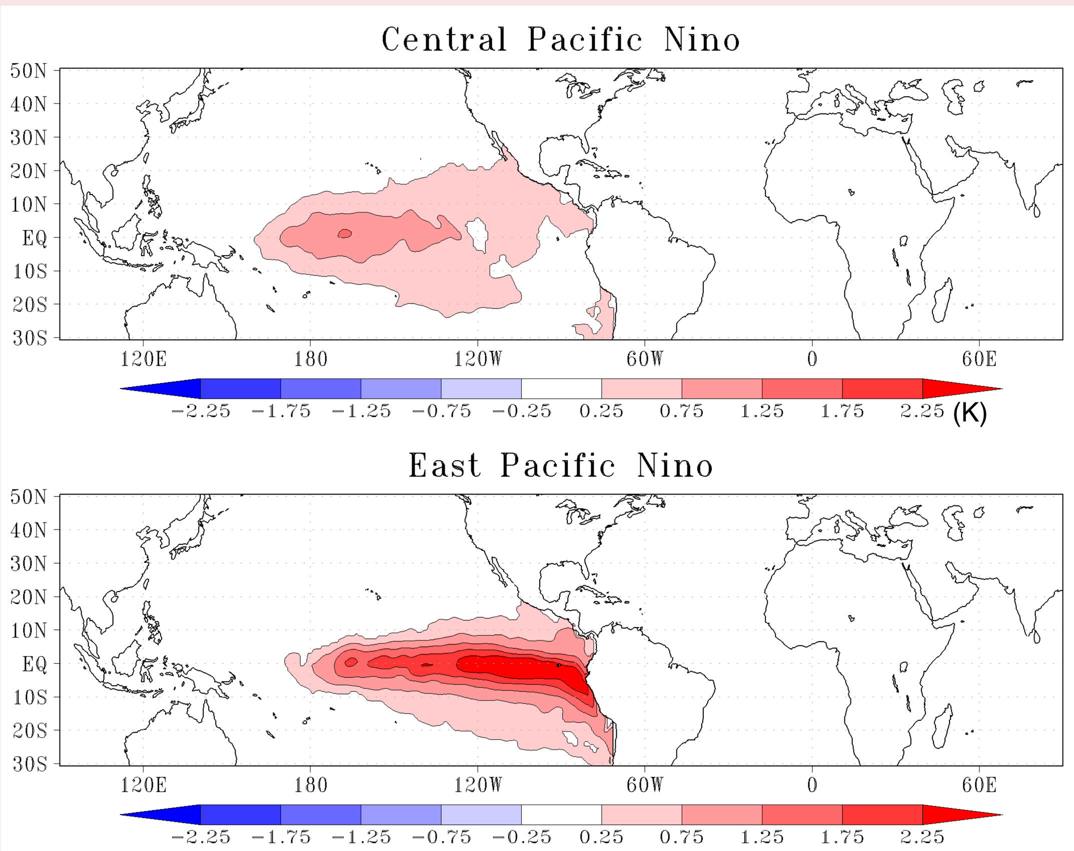


Figure 1. Sea surface temperature (SST) forcings characteristic of Central Pacific (CP) and East Pacific (EP) El Niño.

Forcing is the average deviation from the Aug-Oct mean for observed cases exceeding the 90th percentile of the Aug-Oct averaged El Niño index from the 1950-2011 period, where significant at the 5% level. EP Niño is based on the Niño 3 index; CP Niño based on the Niño 4 index excluding cases when the Niño 3 exceeds Niño 4 index. SST is from HadISST (Rayner et al. 2003)

Background and Motivation

East Pacific El Niño reduces Atlantic TC activity through increased tropical Atlantic vertical wind shear and static stability (Gray 1984; Goldenberg and Shapiro 1996; Tang and Neelin 2004).

The influence of Central Pacific El Niño on Atlantic TCs is not understood; Observationally-based studies produce conflicting results due to a short data record that is complicated by Atlantic SST variability (Kim et al. 2009; Lee et al. 2010; Larson et al. 2012).

The observed frequency and intensity of Central Pacific El Niño has increased since the 1980's and is projected to increase in the future (Ashok et al. 2007; Kug et al. 2009; Yeh et al. 2009; Lee and McPhaden 2010; Kim and Yu 2012).

Tropical Channel Model (TCM) Simulations

- Weather Research and Forecasting Model (WRF) configured as a TCM (domain in Fig. 1)
- 27 km horizontal resolution
- SST: monthly HadISST
- north/south lateral boundary conditions: 6-hourly NCEP-II reanalysis for 1996
- 6 ensemble members (May – December); initial conditions: March 15, 20, 24, 27, 30, and 31 of 1996

Simulation	Prescribed SST
climatology	1950-2011 monthly climatology
Central Pacific El Niño	monthly climatology + Central Pacific El Niño forcing (Fig. 1)
East Pacific El Niño	monthly climatology + East Pacific El Niño forcing (Fig. 1)

EP and CP El Niño reduce Atlantic tropical cyclone track density

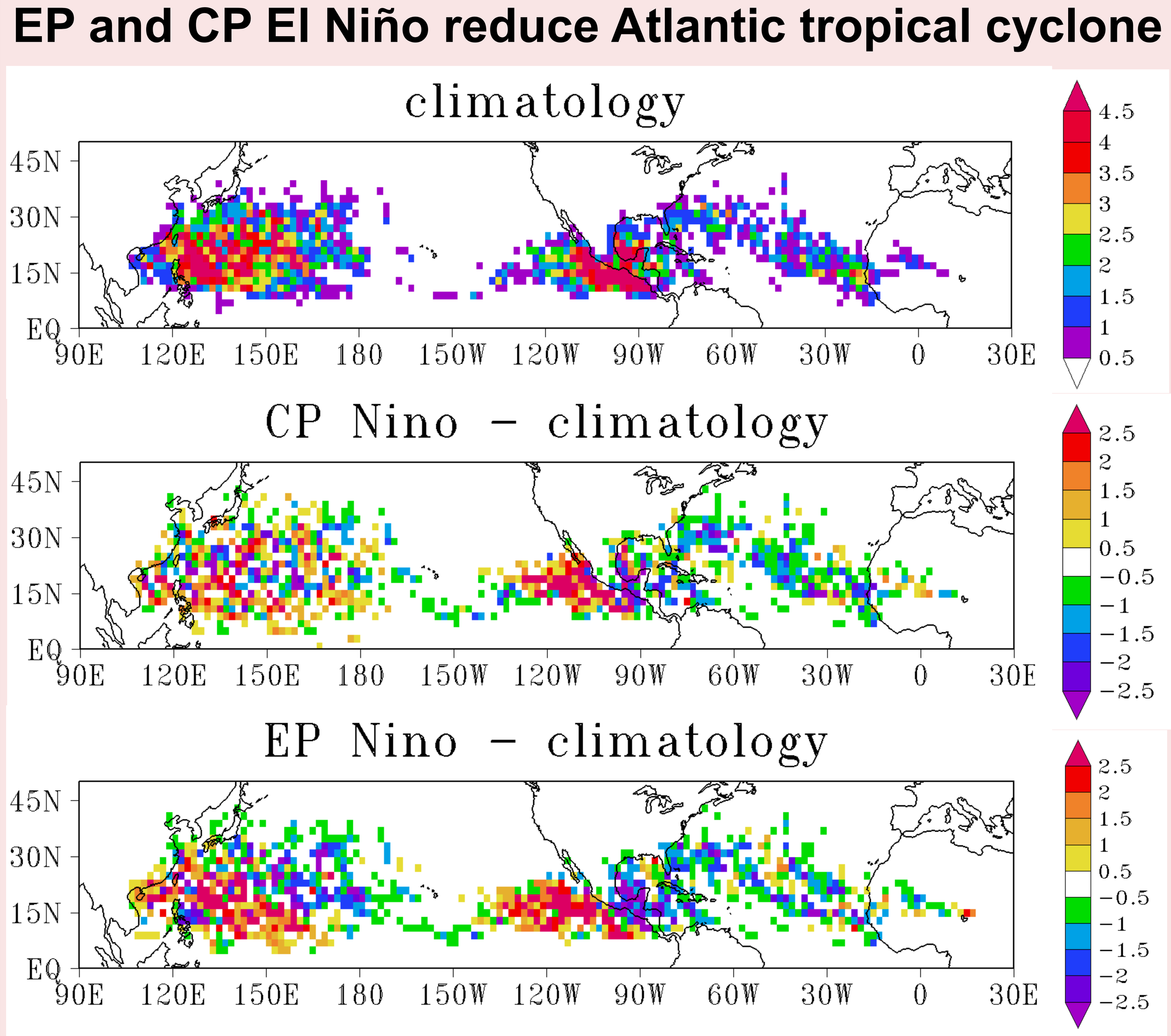


Figure 2. (*top*) TC track density (number of TCs/day) for the 6-ensemble sum from the climatology simulation during 1 May - 1 Dec. The difference in TC track density from the (*middle*) Central Pacific El Niño minus climatology and (*bottom*) East Pacific El Niño minus climatology simulations.

EP and CP El Niño significantly reduce Atlantic ACE

Seasonal TC activity is quantified by accumulated cyclone energy (ACE; Bell et al. 2000), which is the sum of the squares of the 6-hourly maximum wind speed (kt) throughout the life of a TC, for all TCs in a season: $ACE = \Sigma v^2_{max}$

	Atlantic	East Pacific	West Pacific
climatology	113	108	322
CP Niño	74 [-35%]	150 [+39%]	~~358~~
EP Niño	65 [-42%]	161 [+49%]	~~360~~

Table 1. Ensemble mean of Atlantic, East Pacific, and West Pacific ACE (10^4 knots^2) of the climatology, CP Niño, and EP Niño simulations. The mean from the El Niño experiments is significantly different (5% level, one tailed t-test) from the mean of the climatology simulation unless stricken through. Percent change from climatology in brackets.

Thresholds: SST, convection, and vertical wind shear

During CP and EP El Niño, tropical Pacific deep convection responds primarily to the moderate central Pacific warming, which is common to both El Niño types and is located east of the Western Pacific Warm Pool. In association with the deep convection response, vertical wind shear exceeds the ~10m/s threshold for TC suppression (e.g., Zehr 1992) in the Atlantic development region.

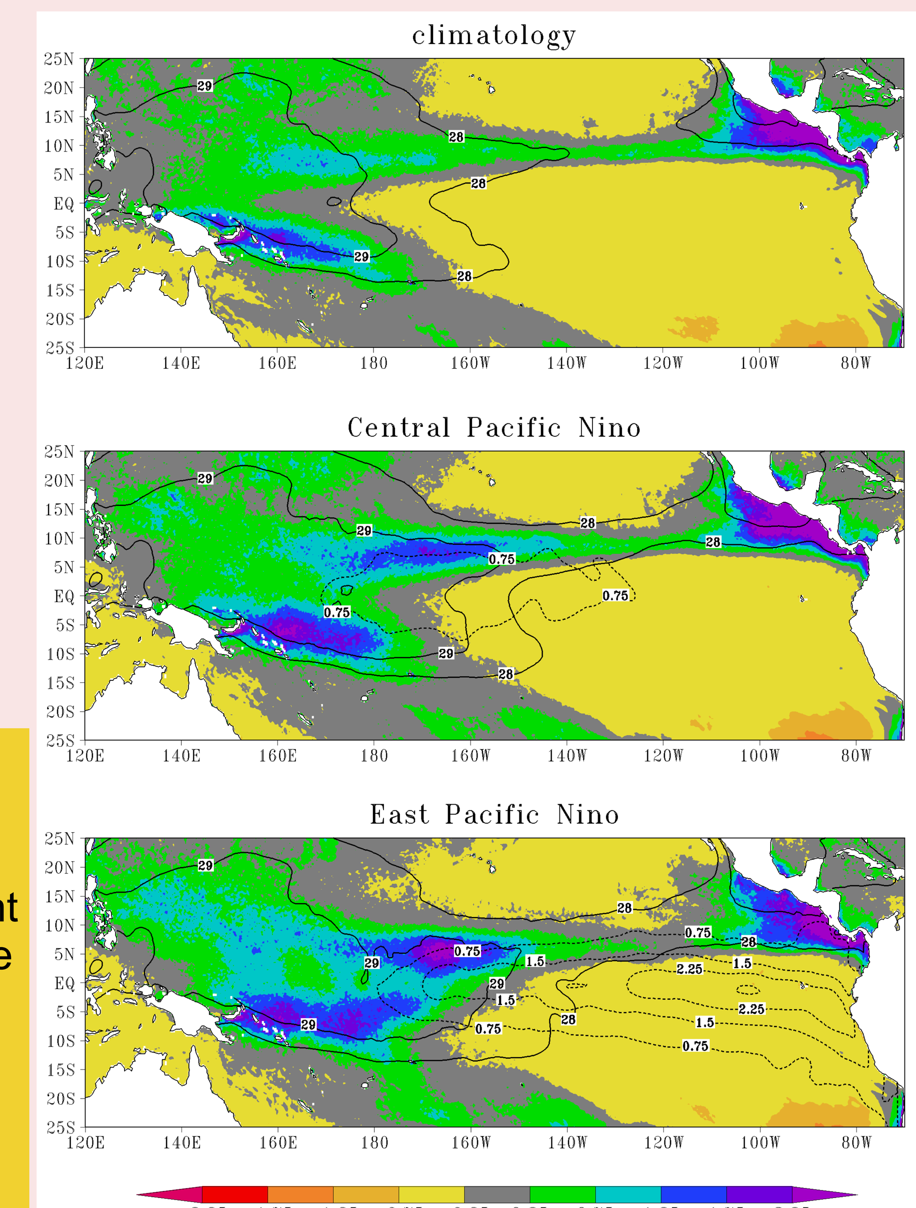


Figure 3. Vertical velocity (cm/s; shaded) at 500 hPa, SST (solid contours at 28ºC, 29ºC, and 30ºC), and deviation from Aug-Oct 1950-2011 mean SST (ºC; dotted contours) from the ensemble average of the (*top*) climatology, (*middle*) Central Pacific El Niño, and (*bottom*) East Pacific El Niño simulations, averaged Aug-Oct.

Summary

- Atlantic TC activity is significantly reduced during CP and EP El Niño.
- Atlantic ACE is insignificantly different between CP and EP El Niño because both are characterized by central Pacific warming, which triggers two thresholds: 1) SST threshold* for deep convection and 2) vertical wind shear threshold* for TC suppression.

*Thresholds depend on MDR humidity and global SST.

Question: What is the impact of *concurrent* modes of tropical Pacific and Atlantic climate variability on Atlantic TC activity?

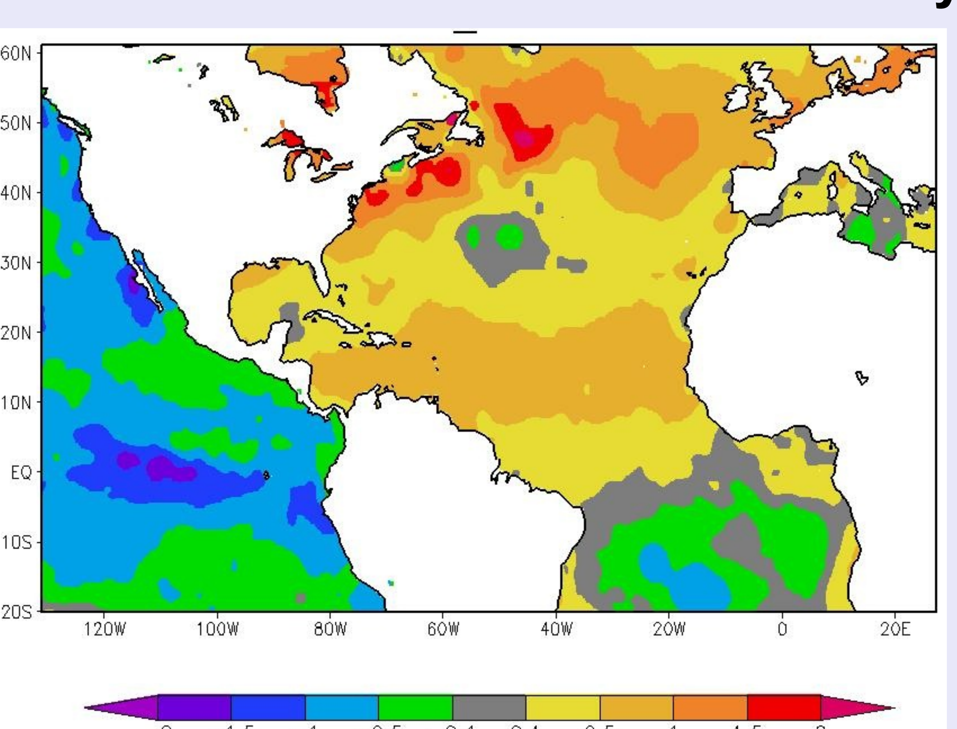


Figure 4. SST (K) anomalies characteristic of strongly positive Atlantic Meridional Mode (AMM) conditions in the Atlantic (as observed in 2005) and strong La Nina conditions in the Pacific (as observed in 1999), averaged Aug-Oct.

Background and Motivation

The Atlantic Meridional Mode (AMM) describes interannual - decadal variability in the meridional gradient of tropical Atlantic SST (e.g., Chang et al. 1997; Chiang and Vimont 2004). The positive phase is characterized by positive/negative SST anomalies in the northern/southern tropical Atlantic.

Atlantic hurricane activity is significantly correlated with the AMM on interannual and decadal timescales (Vimont and Kossin, 2007).

Seasonal predictions and future projections of Atlantic TC activity require a complete understanding of how prominent modes of climate variability influence TC activity.

Table 2. Correlations between Atlantic hurricane activity and climatic indices. (significant at 95% level, unless stricken out) [from Kossin and Vimont, 2007]

	MDR SST	AMM	AMO
unfiltered	0.45	0.64	0.44
Low-pass filtered (decadal)	0.79	0.75	0.80
High-pass filtered (interannual)	~~0.21~~	0.49	~~0.01~~

Observed influence of concurrent AMM and ENSO on Atlantic ACE

- Concurrent positive AMM and La Niña are necessary for the most active Atlantic TC seasons on average.
- Neutral ENSO with negative AMM is sufficient to largely suppress TC activity, with similar ACE compared to El Niño with negative AMM.

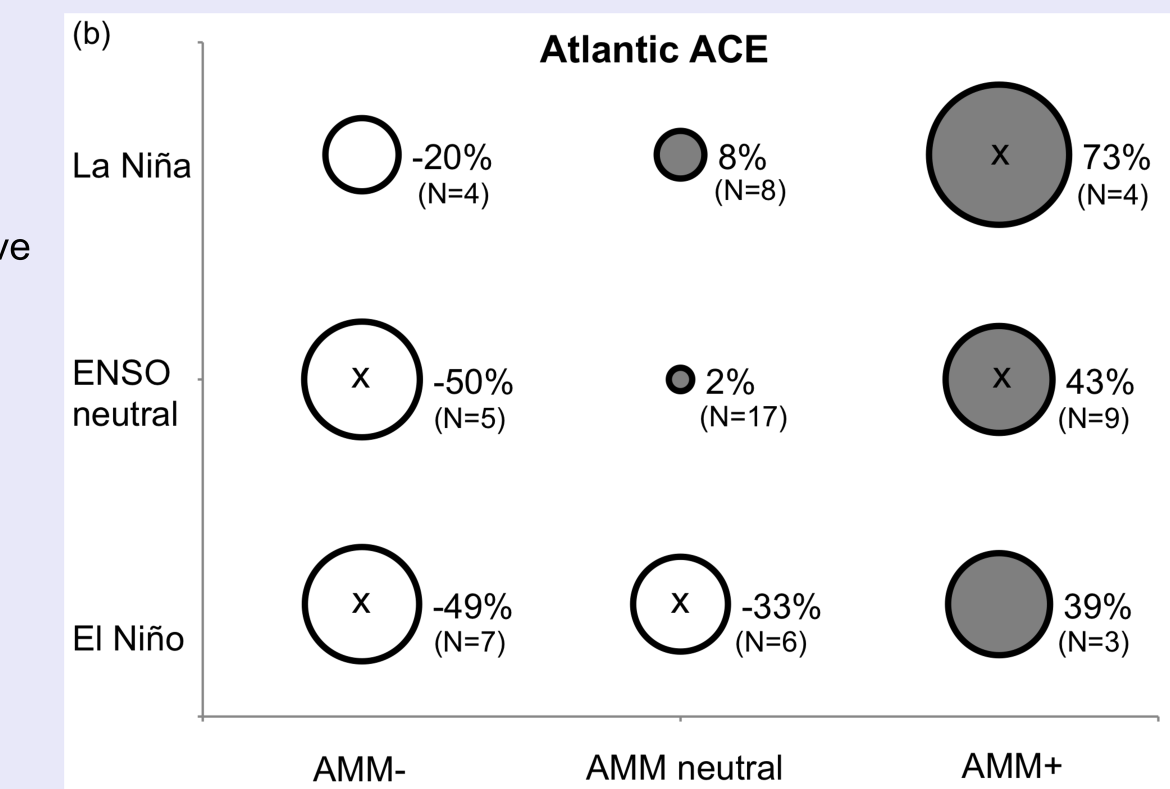


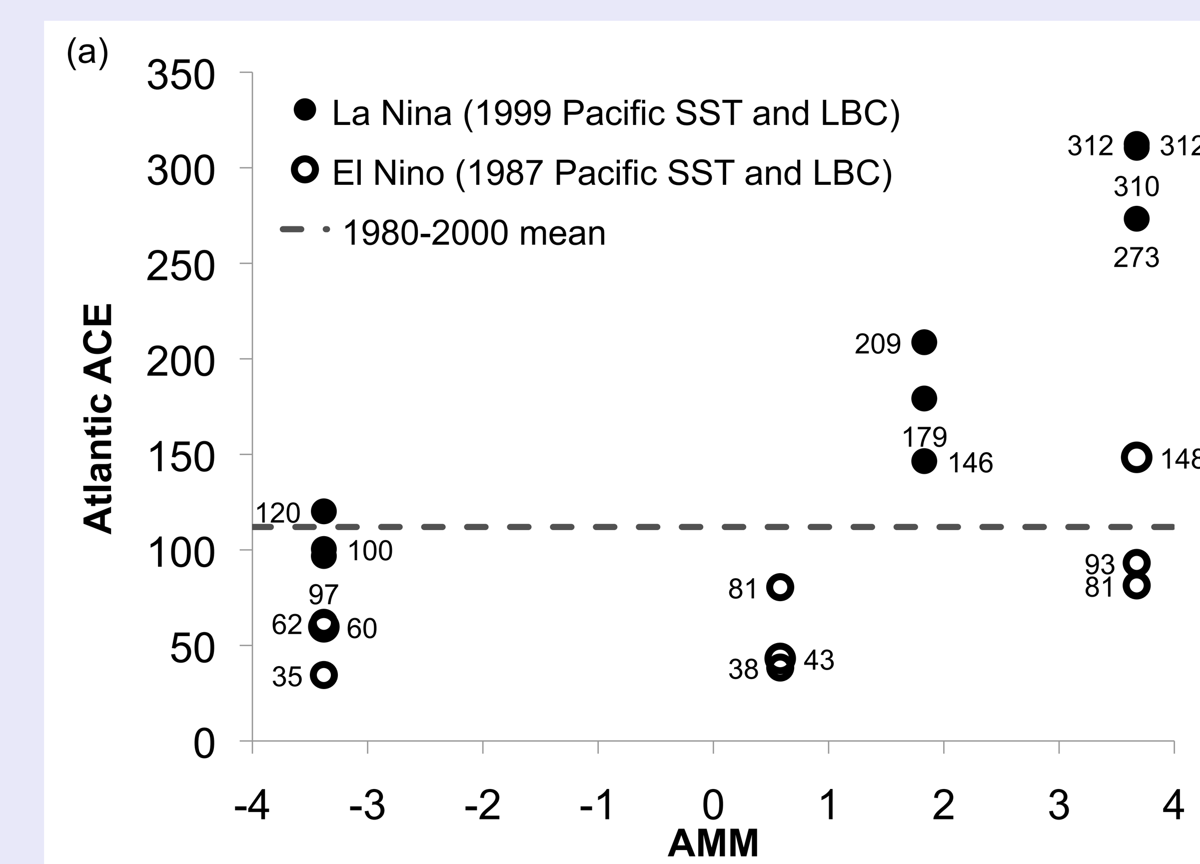
Figure 5. Average deviation from the 1950-2012 mean in observed seasonal Atlantic ACE (percent) from HURDAT for composites according to Aug-Oct averaged AMM and ENSO. A negative and positive AMM or ENSO phase is defined by the 0-25th and 75th-100th percentiles, respectively, of the Aug-Oct averaged AMM and Niño 3.4 indices during the 1950-2012 period. Deviation in ACE is proportional to the diameter of the circle (positive shaded grey) and listed to its right, and the number of occurrences, N, for each ENSO/AMM pair is in parentheses. A mark inside the circle denotes a mean ACE for the given AMM and ENSO pair that is significantly (10% level) different from the mean ACE for the set of all cases not characterized by that AMM and ENSO pair.

Regional Climate Model Simulations (WRF)

- 27 km horizontal resolution; domain in Fig. 4
- Lateral boundary conditions (LBCs): 6-hourly NCEP-II reanalysis; SST and sea ice: monthly HadISST
- control simulation: 15 January 1980 – 31 December 2000
- experiments: prescribe extreme phases of ENSO (through LBCs and Pacific SST) and AMM (through Atlantic SST)

Simulated influence of extreme concurrent AMM and ENSO on Atlantic ACE

Figure 6. Seasonal ACE (10^4 kt^2, denoted next to mark) of Atlantic TCs from RCM simulations forced by the LBCs and Pacific SST of the 1999 La Niña (filled circle) and 1987 El Niño (open circle) and Atlantic SST (corresponding Aug-Oct averaged AMM index on the x-axis), with the RCM 1980-2000 mean Atlantic ACE (dash). Each mark represents one season-long integration.



Summary

Observations and model simulations demonstrate:

- Strong concurrent positive AMM and La Niña produce extremely active Atlantic TC seasons, with ACE surpassing that of 2005, the most active recorded season.
- Phases of ENSO and AMM that individually oppose each other in their influence on Atlantic TCs together produce compensating effects and near-average Atlantic ACE.
- Concurrent El Niño and negative AMM are not required to effectively inhibit Atlantic TC activity because the threshold in vertical wind shear that suppresses TCs does not require unfavorable Pacific and Atlantic SST conditions.

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