The Influence of African Easterly Waves on Atlantic Tropical Cyclone Tracks and Landfall in Large Ensembles

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Research Questions

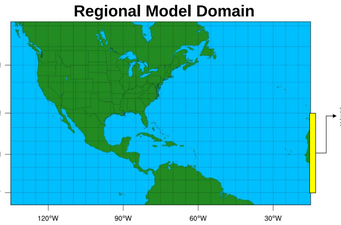
1. **How do African easterly waves (AEWs) influence Atlantic tropical cyclone (TC) tracks and landfall in large ensembles?**
2. **How do AEWs influence TC environmental favorability and steering flow?**
3. **How do TCs form in the absence of AEWs?**

Regional Climate Model Simulations

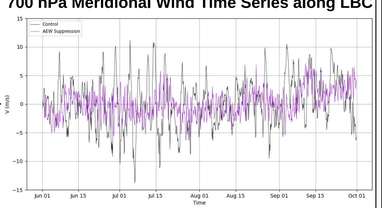
- **Weather Research and Forecasting (WRF) Model** (Skamarock et al. 2008)
  - **Resolution:** 27km (TC-permitting); 48 vertical levels
  - **Initial / lateral boundary conditions (LBC):** ERA5 Reanalysis v5 (Hersbach et al. 2020)
  - **Simulation duration:** June 1 – November 30
  - **50-member ensembles:** time-lagged (283 TB of WRF output)
- **5 Atlantic Hurricane Seasons**
  - **Above-average:** 2010 and 2005
  - **Average:** 2001 and 1992
  - **Below-average:** 1992
- **Simulations**
  - **Control:** Hindcasts of Atlantic hurricane seasons
  - **AEW suppression:** 2-10 day filter applied along eastern LBC (Experimental Approach)

Experimental Approach

Regional Model Domain



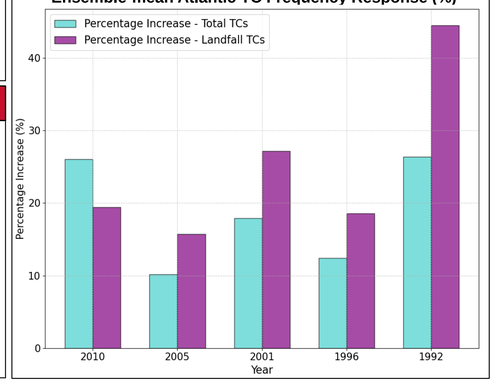
700 hPa Meridional Wind Time Series along LBC



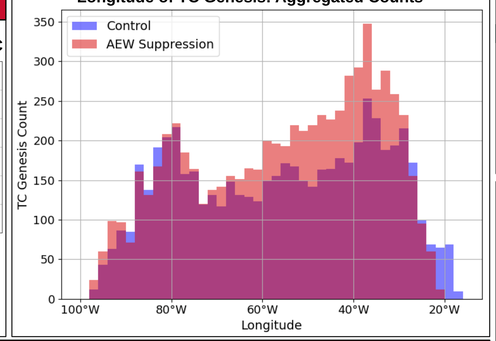
- Similar approach to previous studies investigating AEW suppression (Patricola et al. 2018; Danso et al. 2021; Bercos-Hickey and Patricola 2023)
  - Lanczos filter applied to LBC to remove 2-10 day variability of thermodynamic/kinematic variables associated with AEWs

Atlantic TC Frequency and ACE Response

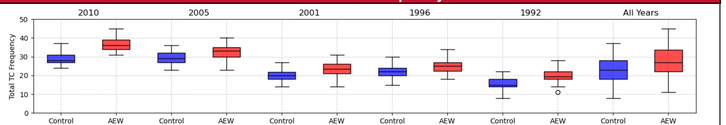
Ensemble-mean Atlantic TC Frequency Response (%)



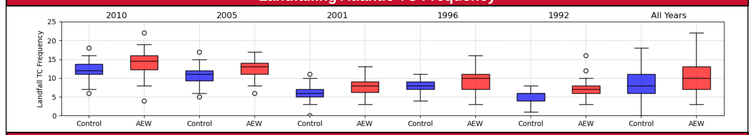
Longitude of TC Genesis: Aggregated Counts



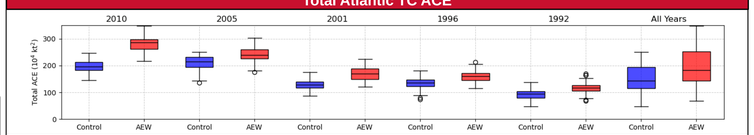
Total Atlantic TC Frequency



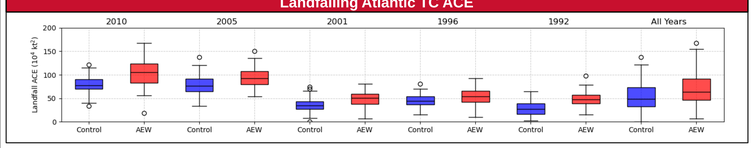
Landfalling Atlantic TC Frequency



Total Atlantic TC ACE



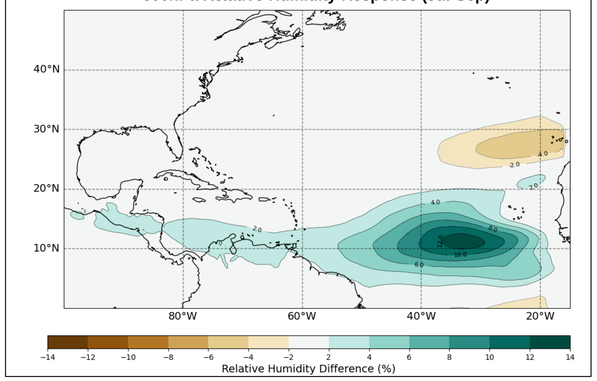
Landfalling Atlantic TC ACE



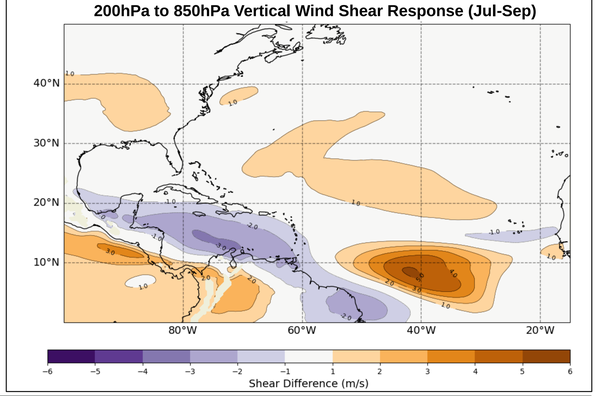
- **AEW suppression resulted in statistically significant increases in the total TC and landfalling TC frequency and accumulated cyclone energy (ACE) across all five years.**
  - The total number of Atlantic TCs increased by 10% – 26% across the five years considered, while the number of landfalling TCs increased by 16% – 44%.
- **Sub-seasonal TC frequency response to AEW suppression varied yearly.**
  - July, August, and September produced the largest responses in TC frequency (not shown).
- **Increases in TC activity and the response in the TC genesis locations both correspond strongly with increased mid-tropospheric moisture across all five years.**
  - Vertical shear response varied across years and played a minimal role in explaining the TC response to AEW suppression.

TC Environmental Favorability Response

600hPa Relative Humidity Response (Jul-Sep)

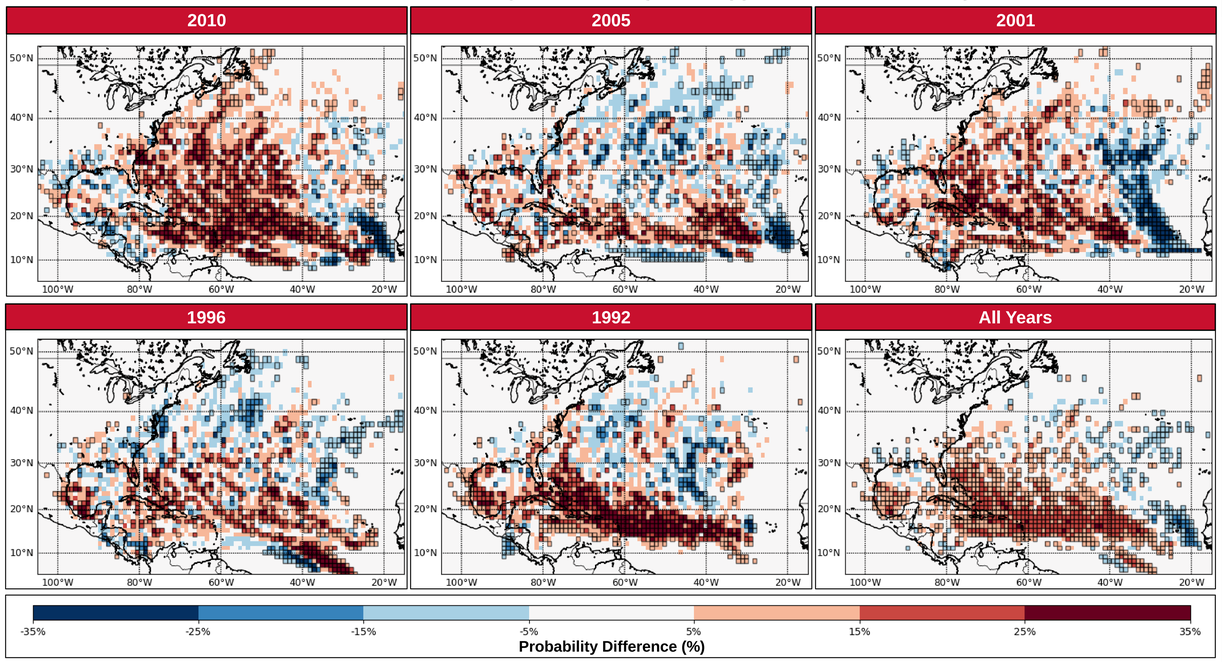


200hPa to 850hPa Vertical Wind Shear Response (Jul-Sep)



TC Tracks and Landfall Response

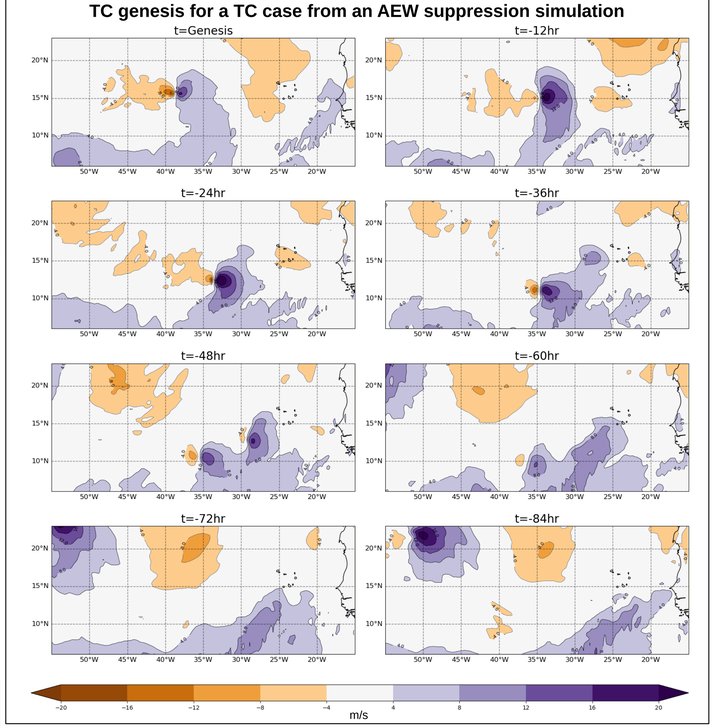
Ensemble-Mean Probability Differences (AEW Suppressed minus Control)



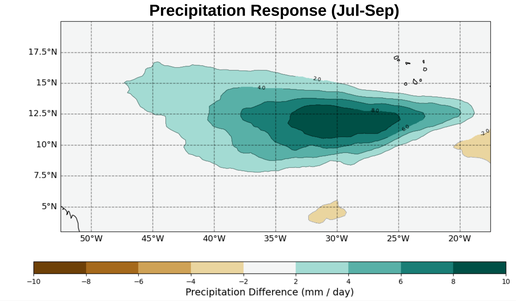
Bayesian geospatial methodology estimates probabilities of at least one TC occurring for a given year (Rhoades et al. 2021). 50-member ensembles made it possible to evaluate statistical significance (boxes = 95% confidence interval does not include zero & |Prob| > 0.05) of TC track and landfall responses.

Possible TC Genesis Mechanism in the Absence of AEWs

850 hPa meridional wind from 84 hours prior to TC genesis through the time of TC genesis for a TC case from an AEW suppression simulation



Precipitation Response (Jul-Sep)



- Preliminary analysis suggests TC precursors in absence of AEWs may be related to disturbances from the Intertropical Convergence Zone (ITCZ).
- ITCZ precipitation increased in response to AEW suppression for all years.
- **TCs can form from ITCZ wave breaking** (Agee 1972):
  - Instabilities associated with deep-layer diabatic heating result in shedding of **vortices** (Wang and Magnusdottir 2005) that can produce TCs.

Summary

Suppressing AEWs produced statistically significant increases in total Atlantic TC (10% – 26%) and landfalling Atlantic TC (16% – 44%) frequency.
- Consistent for above-average, average, and below average TC seasons.
- Supported by increased mid-tropospheric moisture, with minimal contributions from vertical wind shear.

AEW suppression produced increased TC landfalls.
- Caribbean Islands, Southwestern Gulf of Mexico, Florida, and Carolinas
- Supported by a westward shift in TC genesis, with minimal contributions from changes in bulk steering flow (not shown).

Preliminary results suggest that TCs form from disturbances associated with the ITCZ in the absence of AEWs.
- The ITCZ is shifted northward and stronger in response to AEW suppression.

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