Investigating the Predictability of Tropical Cyclogenesis through a Comparison of African Easterly Wave Seasons

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Background

What is known

- African Easterly Waves (AEWs) are westward-propagating disturbances that form from instability of the African Easterly Jet
- AEWs are the primary initial disturbance that precedes tropical cyclone (TC) development in the Atlantic basin[1]
- The direct link between AEW trends, environmental conditions, and TC genesis has been looked at, but no widely accepted conclusions[2,3]
- Some studies have suggested AEWs are not necessary for TC genesis[4]
  - However, other studies have shown that AEW strength over Africa and other characteristics (like moisture) could be predictive of downstream development[2,5]

Goals

Groupings of AEW seasons are compared to each other and to the overall AEW climatology to investigate interseason variability of AEW attributes and associated environmental conditions to determine:

1. **Causes of seasonal variability in AEW activity and TC activity**
2. **Trends of AEW characteristics in the context of large-scale natural climate phenomenon such as ENSO**

Methodology

Data

- ECMWF ERA5 data spanning from 1979 to 2022

AEW Tracking

- AEWs are tracked using the Lawton et al. (2022) track database, which utilizes 700hPa curvature vorticity[6]
- This database has been validated against other wave trackers and is able to capture the majority of AEWs and accurately represent their climatology

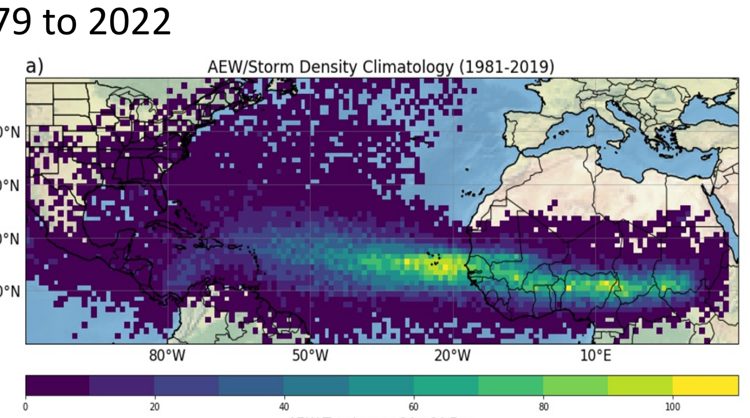

Figure 1: from Lawton et al. (2022), number density of AEWs in ERA5 across a 1981-2019 climatology for July-September. *© Copyright 2022 AMS.*

- **Developing AEWs:** AEWs that develop into TCs
- **Non-Developing AEWs:** AEWs that do not develop into TCs

Year Groupings & Environmental Conditions

- Created xarray datasets of year groupings: active years, inactive years, El Niño years, & La Niña years
  - Active & Inactive groupings based on TC activity in Main Development Region (MDR)
    - Active threshold: minimum nine TCs formed in MDR
    - Inactive year threshold: maximum two TCs formed in MDR
  - El Niño & La Niña groupings based on Climate Prediction Center's Oceanic Niño Index historical records
- Analyzed environmental conditions of year groupings and differences between them

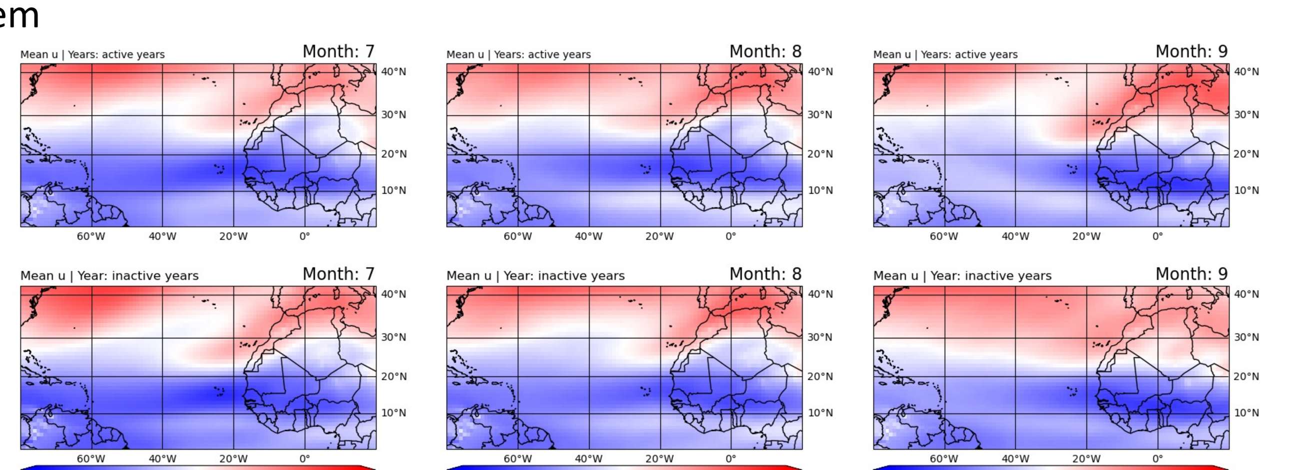

Figure 2: Example of year grouping plots; 600-700 hPa u (AEJ) for active and inactive years.
Year grouping difference plots in Figure 2 can be seen in **Figure 7**

AEW Statistics

- All AEW statistics plots show a probability density function (PDF)
- **AEW Strength:** 700 hPa curvature vorticity averaged within 600km of the AEW center

AEW Climatology

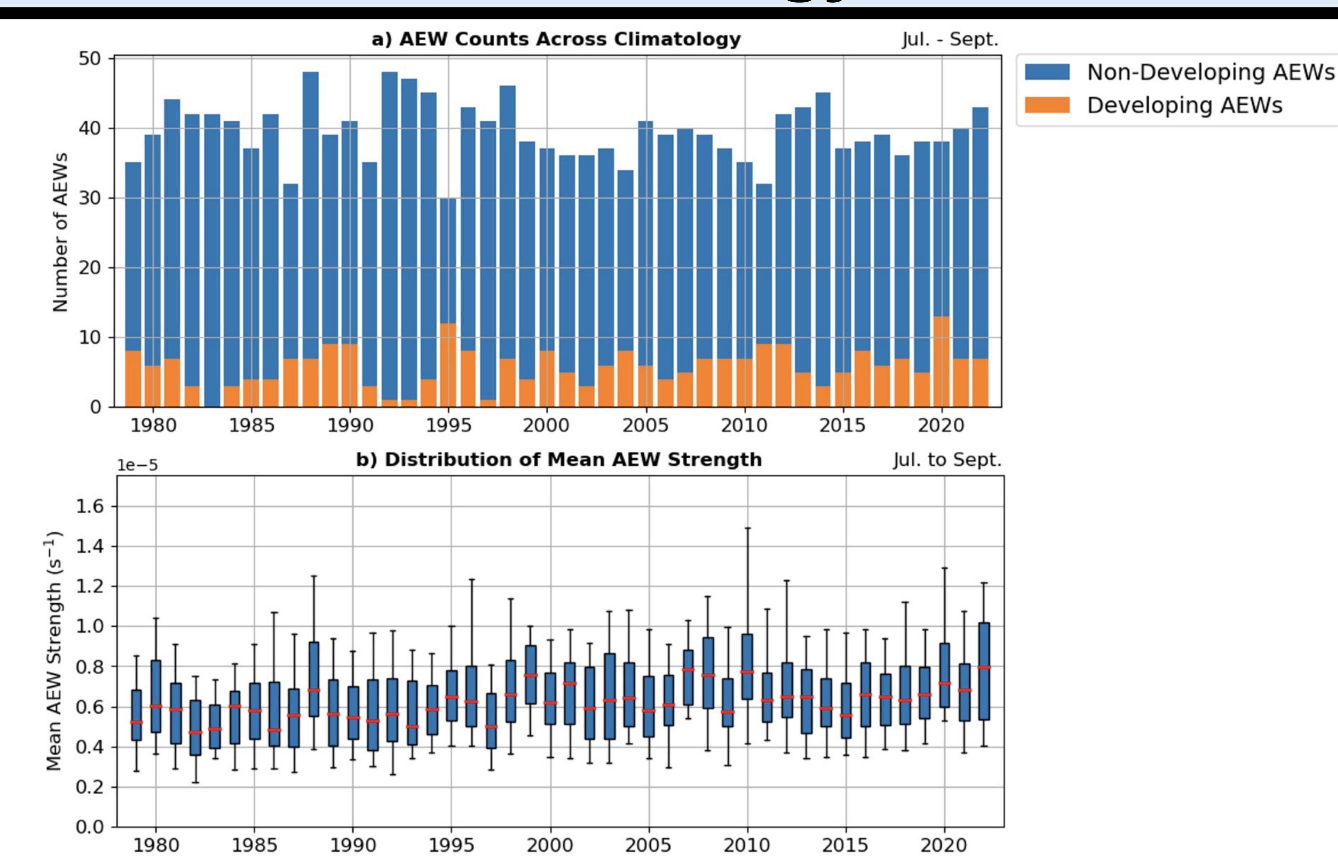

Figure 3: Climatological statistics for a) AEW counts and b) the distribution of mean AEW strength for the years 1979-2022. Blue bars are counts for non-developing AEWs, and orange bars are those for developing AEWs. The bar and whisker plots in b) have a red line indicating a year's median value, blue bars spanning the 25%-75% quartiles, and whiskers spanning the 5% to 95% quartiles.

- In ERA5 data, Figure 4 shows that years of high AEW counts **do not necessarily align** with years with high percentages of AEWs that develop into TCs
  - Suggests that perhaps neither the number nor strength of AEWs are measures indicative of the future development of TCs[7]
- Previous focus on mean climatology has been too broad, need to look at interseason variability of environmental conditions for better understanding of active/inactive seasons

Active and Inactive TC Years

Active years: 1989, 1990, 1995, 2004, 2010, 2020
Inactive years: 1983, 1985, 1986, 1992, 1997, 2002

Developing AEWs

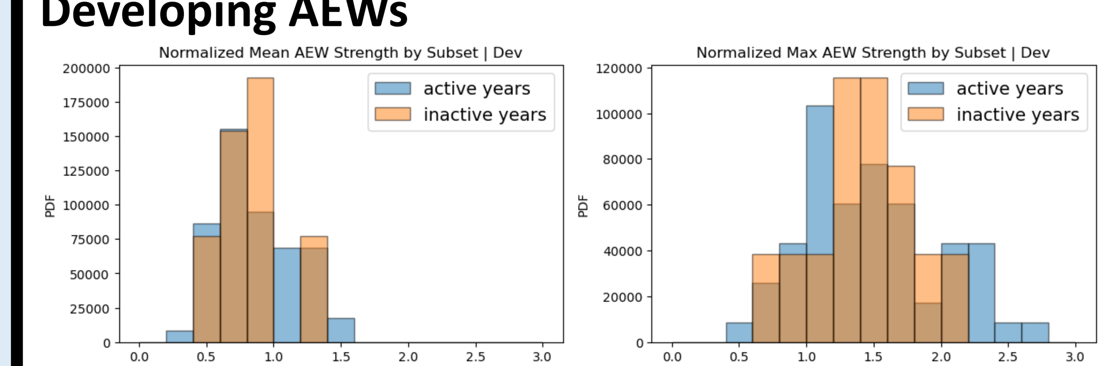

Figure 4: Developers normalized mean and max AEW strength for active and inactive years.

- Max AEW strength was higher in active years
  - Active years driven by a few stronger AEW cases

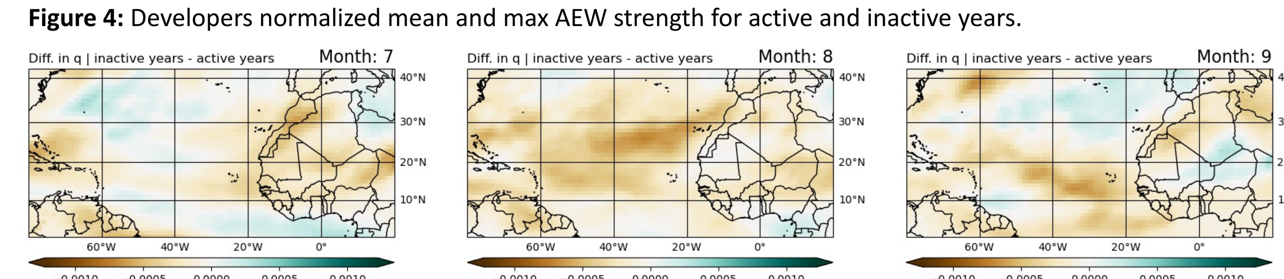

Figure 5: Difference in 400-700 hPa averaged specific humidity (mid-level) between inactive and active years.

- High values of mid-level moisture in MDR may support development of AEWs during active years

Non-Developing AEWs

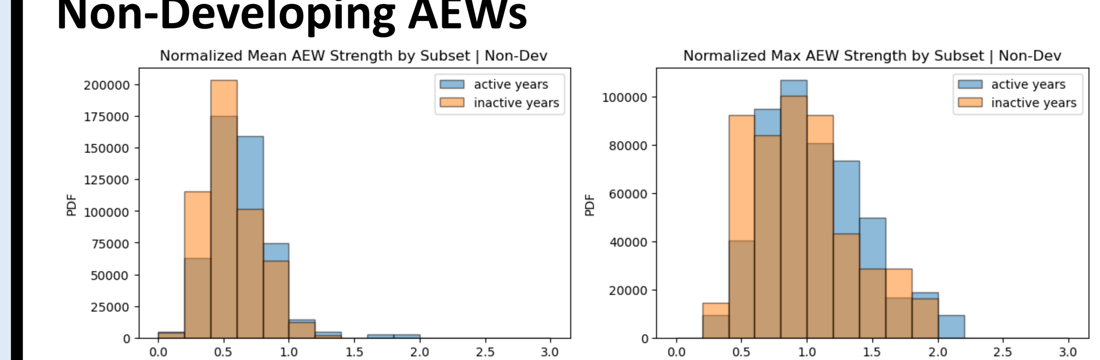

Figure 6: Non-developers normalized mean and max AEW strength for active and inactive years.

- Mean strength was higher during active years for non-developers
- Equatorward shift of AEJ during inactive years

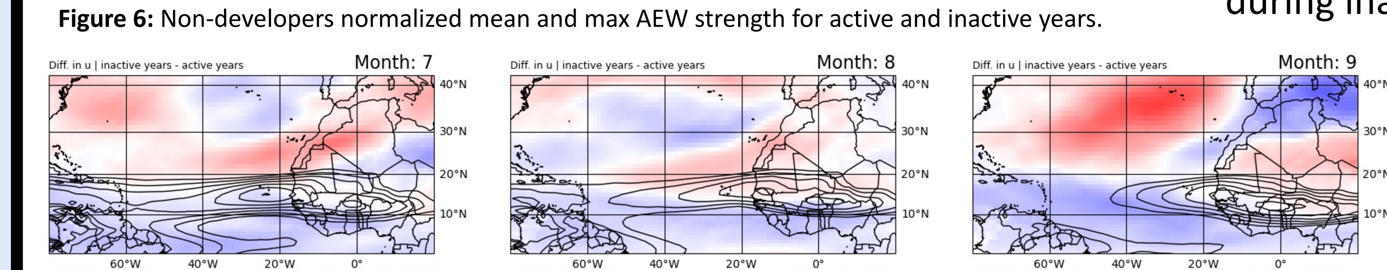

Figure 7: Difference in 600-700 hPa u (AEJ) between active and inactive years with contours of AEJ during inactive years. Contours range from -6 m/s to -20 m/s at 1 m/s intervals.

- More northern AEJ during active years connected to stronger non-developing AEWs

*Analysis also conducted including borderline inactive years, no significant differences found

El Niño and La Niña Years

El Niño years: 1982, 1987, 1991, 1997, 2002, 2004, 2009, 2015
La Niña years: 1988, 1998, 1999, 2000, 2007, 2010, 2011, 2020

Developing AEWs

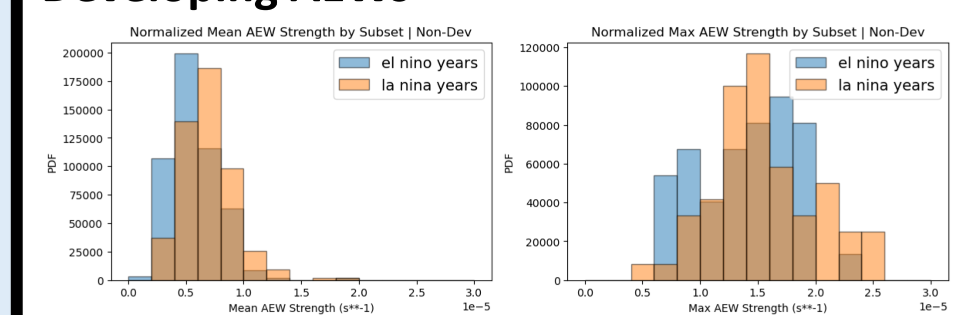

Figure 6: Developers normalized mean and max AEW strength for El Niño and La Niña years.

- Developing AEWs are stronger during La Niña years
  - Known ENSO teleconnection of wind shear in Caribbean during El Niño
  - Suggests effects of ENSO in Eastern Atlantic as well

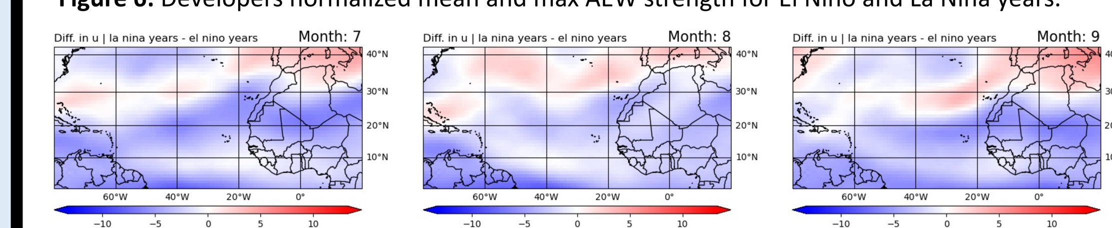

Figure 8: Difference in 200-300 hPa u (upper-level winds) between La Niña and El Niño years.

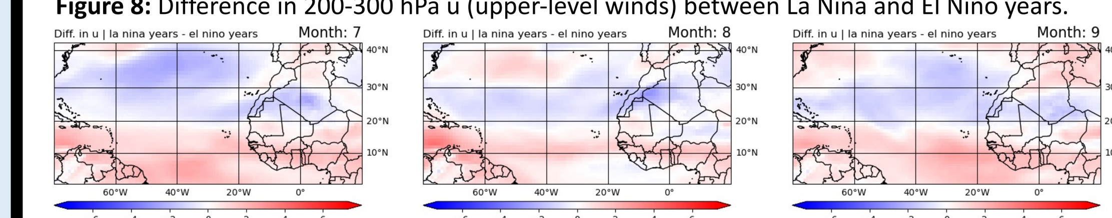

Figure 9: Difference in 800-900 hPa u (lower-level winds) between La Niña and El Niño years.

- Upper and lower-level winds analyzed to assess wind shear
  - Difference between levels (the wind shear) is greatest during El Niño years
- Greater wind shear during El Niño years supports the finding that developing AEWs are weaker during El Niño years

Non-Developing AEWs

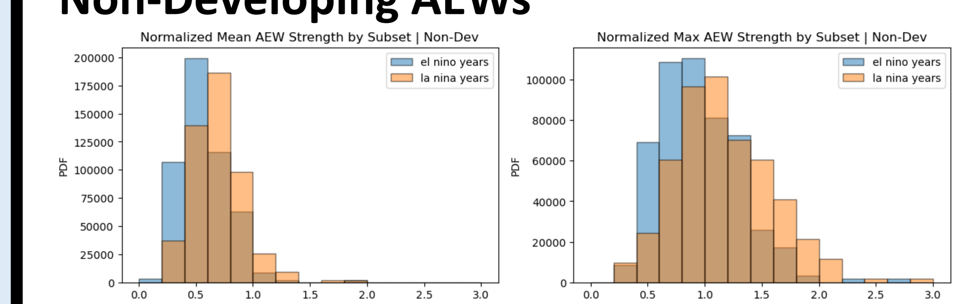

Figure 10: Non-developers normalized mean and max AEW strength for El Niño and La Niña years.

- Non-developing AEWs were on average stronger in La Niña years
- Max wave strength also higher in La Niña years

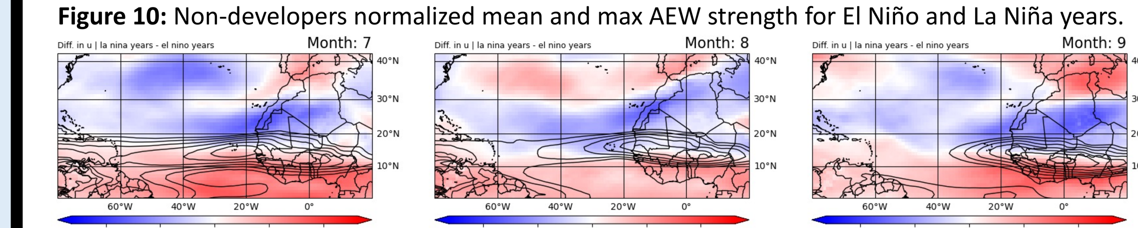

Figure 11: Difference in 600-700 hPa u (AEJ) between La Niña and El Niño years with contours of AEJ during El Niño years. Contours range from -6 m/s to -20 m/s at 1 m/s intervals.

- AEJ shifted south during El Niño years
- Stronger and more northern AEJ during La Niña connected to stronger non-developing AEWs

*Analysis also conducted including other ENSO year groupings (stronger, weaker, Top 4), no significant differences found

Conclusions and Future Work

Summary

- The effects of ENSO stretch eastward in the Atlantic Basin to the location of the AEJ, which affects the development and non-development of AEWs.
  - Expands our understanding of the relationship between ENSO and TCs
- Development of AEWs is associated with the location of the AEJ, perhaps more so than the number of AEWs in a season or the strength of AEWs.
- The lead time for tropical cyclogenesis prediction could increase
- A stronger, more northern AEJ during La Niña has been found before [8,9]
  - We used a more targeted AEW tracking framework & our findings align with previous work

Future Work

- Expand scope of conditions analyzed to include vorticity for insight into AEW vertical structure
- Conduct analysis for more year groupings to gather more data on tropical cyclogenesis trends related to AEWs and environmental conditions

References and Acknowledgments

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