Extremes in North Carolina- Weather Whiplash and ENSO Events

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Additional Figures:

Background

- Weather whiplash is a recently introduced term describing rapid transitions between temperature and precipitation extremes over relatively short periods.[2]
- Weather whiplash events have been linked to changes in agricultural yields, increased flood frequency, degraded water quality and heightened public health risks.[4]
- Climate change is projected to bring about increases in extreme heat and heavy precipitation events globally, including North Carolina.[1]

Purpose
Determine if the frequency of seasonal temperature and annual precipitation extremes has increased across NC, and if ENSO is a potential causal factor.

Data and Methods

- Hourly air temperature and precipitation data were analyzed from nine NC ECONet[4] stations between 2010 and 2025 (Figure 1). Precipitation patterns were aggregated to an annual basis for WWI comparison.
- To distinguish extremes, 24-hour temperature departures were calculated and instances above the 95th percentile were recorded. For precipitation, the Weather Whiplash Index (WWI) was calculated using the methodology from [Loecke, 2017][3]. A second method for WWI using the 20th/80th percentiles from [Cheng, 2022][1] was also examined.
- Positive WWI is indicative of a shift from drought conditions the previous fall/winter to a pluvial spring. Negative WWI is shifting from a pluvial fall/winter to drought conditions in the spring.
- ENSO values were plotted on top of the statistically significant (95th percentile) temp departures for each season, and were separately plotted on top of the yearly WWI value.

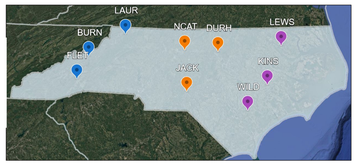

Figure 1: Selected ECONet Stations for Study

Results

Temperature

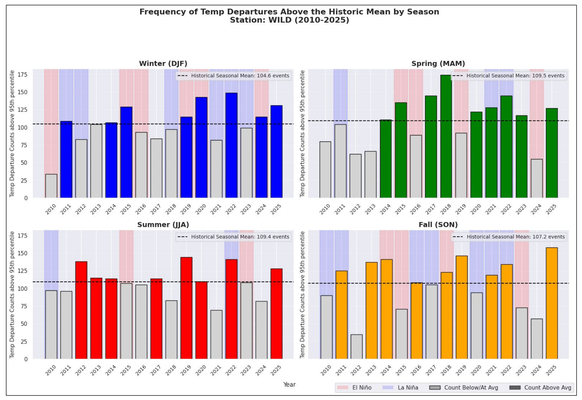

Figure 2: WILD station temperature departures above 95th percentile by season, with ENSO events highlighted in red and blue, respectively.

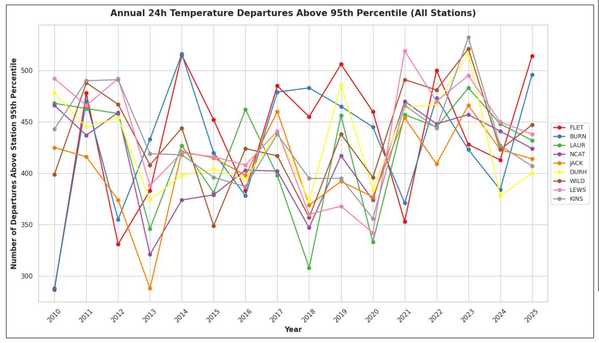

Figure 3: Annual 24 hour temperature departures for all stations

- No stations showed statistically significant growth of temperature departures above the 95th percentile (figure 3).
- Positive ENSO values are associated with El Nino (figure 4), which brings cooler, wetter conditions in the winter and warmer, pluvial springs. Negative values are indicative of La Nina, which is associated with warmer and drier winter and spring months.
- Dry to wet events (figure 5) are defined as the occurrence of two consecutive years during which the annual total precipitation falls under the 20th percentile of the baseline climatology (in the first year) and subsequently exceeds the 80th percentile of the same reference (in the following year).
- JACK was the only station to show statistically significant growth (p=0.0314) of WWI over time (figure 6).

Precipitation

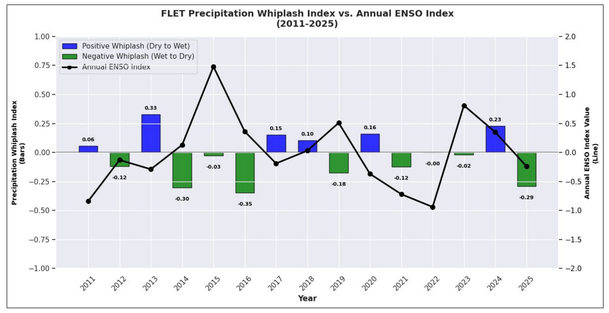

Figure 4: Example of WWI overlaid with ENSO values for FLET

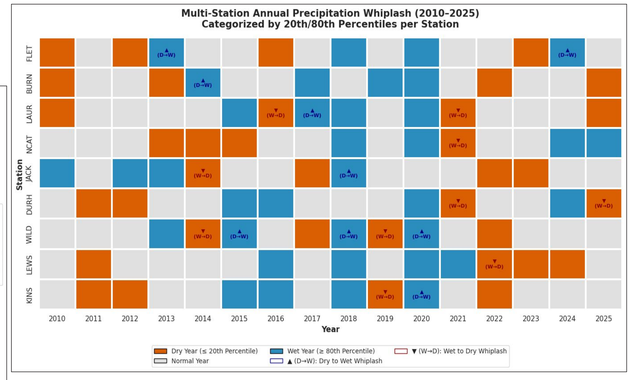

Figure 5: 20th/80th percentile whiplash patterns by station, using method from [Cheng, 2022][1]

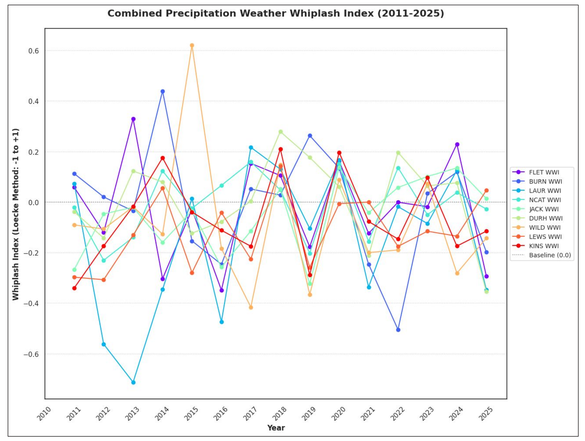

Figure 6: Annual Weather Whiplash Index trends for all stations

Conclusions

- Seasonal temperature extremes over the past 15 years do not show any statistically significant increase in frequency across the sites selected. They also do not have statistical significance in connection to ENSO events.
  - This may be due to the short time period and limited number of stations that this project examined.
- No statistical connection exists between ENSO events and the WWI.
- Annual rainfall extremes across NC do not show signs of an increase in frequency over time.
- Due to the lack of statistical significance relating to WWI and temperature departures, ENSO anomalies are not a good predictor of future weather whiplash events in NC.

Recommendations

- More data collected across more locations is needed to clarify if temperature and precipitation whiplash frequency are increasing, and if trends can be tied to larger scale anomalies like ENSO.
- A longer time scale dataset would be useful in analyzing the impacts of Weather Whiplash events.
- Research of regional scale whiplash events is limited, with many studies focusing on global and continental scales. The lack of relevant studies on this topic makes it difficult to quantify results.
- Supplementing this research by combining outside datasets with the ECONet may prove useful in connecting Weather Whiplash to ENSO events.

Sources

1: Cheng, L. and Z. Liu, 2022: Detectable increase in global land areas susceptible to precipitation reversals under RCP8.5 scenario. *Earth's Future*, **10**, e2022EF002948, https://doi.org/10.1029/2022EF002948.
2: Lee, C. C., 2022: Weather whiplash: Trends in rapid temperature changes in a warming climate. *Int. J. Climatol.*, **42**, 4214-4222, https://doi.org/10.1002/joc.7458.
3: Loecke, T. D., A. J. Burgin, D. A. Riverois-Iregui, A. S. Ward, S. A. Thomas, C. A. Davis and M. A. St. Clair, 2017: Weather whiplash in agricultural regions drives deterioration of water quality. *Biogeochemistry*, **133**, 7-15, https://doi.org/10.1007/s10533-017-0315-z.
4: Saia, S. M., S. P. Heuser, M. D. Neill, W. A. LaForce IV, J. A. McGuire, and K. D. Dello, 2023: A technical overview of the North Carolina ECONet. *J. Atmos. Oceanic Technol.*, **40**, 701–717, https://doi.org/10.1175/JTECH-D-22-0079.1.