Changes in the Tropical Cyclone Steering Flow Along Southeast U.S. Coasts

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Introduction

The large scale environmental steering flow determines, to first order, the direction and speed of tropical cyclones. When embedded in weak steering flow, tropical cyclones may move slowly or even stall, and their impacts may be experienced for extended time periods, as was seen during Hurricane Harvey in 2017. As the hemispheric meridional temperature gradient decreases with increased anthropogenic warming, we hypothesize that the tropical cyclone steering flow may weaken concurrently, increasing the likelihood of seeing slow-moving tropical cyclones. While recent research has shown that tropical cyclone translation speeds have, on average, slowed by 10% globally from 1949 to 2016 (Kossin 2018), we analyze 38 years of large-scale deep mean steering flow and determine what changes may be observed in this steering flow during the North Atlantic hurricane season along the Southeast and Gulf coasts of the U.S.

Data and Methods

- Used ERA-Interim zonal and meridional winds between 1000 mb and 100 mb (Dee et al. 2011) and averaged winds using the deep layer mean scheme of Neumann (1988)
- Used six-hourly data during the North Atlantic hurricane season (June - November) at the locations indicated in Figure 2
- Divided data into early and late time periods of equal length: 1979-1997 (early) and 1998-2016 (late)
- Analyzed data for all points together and for smaller regions within the range of data points; later made the following regional groupings:
  - Gulf of Mexico coast: Texas, Louisiana, Mississippi, Alabama, and Florida panhandle
  - Florida Peninsula: All of Florida, except panhandle
  - Georgia/South Carolina coasts
- Removed data for points within 6 degrees of the center of an ongoing tropical storm
- Calculating a deep layer mean wind speed at a location

Figure 1: A visual representation of the deep layer mean weighting scheme described in Neumann (1988). These weights determined the significance of the wind speeds at given atmospheric levels for calculating a deep layer mean wind speed at a location.

Figure 2: A map showing all of the locations that data was obtained for. All data points chosen were within 6 degrees of the coastline stretching between the Texas-Mexico border and Myrtle Beach, SC. In addition to all points being analyzed together, red points were included in the Gulf of Mexico coast regional analysis group, green points were included in the Florida Peninsula group, and blue points were included in the Georgia/South Carolina coast group.

Figure 3: A histogram depicting changes in the normalized frequencies of wind speeds from the 1979-1997 time period to the 1998-2016 time period. Wind speeds were grouped using buckets with 1 m/s intervals. A positive value indicates a range of wind speeds being more frequent in the 1998-2016 time period, while a negative value indicates the range being more common in the 1979-1997 time period.

Figure 4: A time series showing how three day moving average wind speeds during North Atlantic hurricane seasons compared between the 1979-1997 time period and the 1998-2016 time period. Wind speeds were averaged at each time step among all data points and all years in each 19 year period.

Figure 5: Histograms depicting changes in the normalized frequencies of wind speeds from the 1979-1997 time period to the 1998-2016 time period. Each of these histograms only shows normalized frequency differences for selected months in the hurricane season. The histograms use the same 1 m/s wind speed groupings, as per Figure 3. A positive value indicates a range of wind speeds being more frequent in the 1998-2016 time period, while a negative value indicates the range being more common in the 1979-1997 time period.

Results

Table 1: Changes in the median wind speed (in m/s) between the 1998-2016 time period and the 1979-1997 time period. Negative values signify a decrease in wind speed from the 1979-1997 time period to the 1998-2016 time period, while positive values signify an increase. Statistically significant changes are bolded and colored, and if there was an increase or decrease. Statistical significance was determined using bootstrap sampling for each time period’s data as described by Wilks (2011) and then assessing the resulting 95% confidence intervals for overlaps.

Future Work

- Verify findings by analyzing tropical cyclone translation speed changes in region of interest during North Atlantic hurricane seasons
- Examine changes in jet stream positioning during North Atlantic hurricane seasons
- Analyze additional tropical cyclone basins
- Utilize climate models to determine future trends in tropical cyclone steering flow

Conclusion

- Overall, the southeastern coasts of the U.S., the deep layer mean steering flow during the North Atlantic hurricane season was weaker in the 1998-2016 time period compared to the 1979-1997 time period. This was determined using bootstrap sampling for each time period’s data as described by Wilks (2011) and then assessing the resulting 95% confidence intervals for overlaps.
- There was strong evidence that the steering flow weakened in the month of June at all considered locations and in the month of November at most considered locations
- Evidence exists that the steering flow strengthened at most considered locations in the months of July and August, although the magnitude of the strengthening isn’t as strong as the amount of weakening seen in June and November
- Data for September and October had the greatest amount of spatial and temporal variability, but mostly suggested of a slight weakening in the steering flow
- Our findings suggest that the time frame for an increased likelihood of slow-moving tropical cyclones impacting the southeastern U.S. may be expanding and that a larger percentage of slow-moving landfalling tropical cyclones may occur outside of the two months where the steering flow is usually weakest (July and August)
- One possible theory for our June and September results is that the mean position of the polar jet stream is moving north earlier than usual and then returning southward later than usual, effectively resulting in longer summers and longer periods of weak steering flow in the southeast U.S.
- It is less clear to us why the steering flow strengthened in July and August. Recent research has suggested that the jet stream has been fluctuating more frequently in the Northern Hemisphere (Trouet et al. 2018), so it may be dipping farther south during the summer and producing a slight increase in the average wind speed during months with minimal wind. However, this is slightly contradictory to our other theory and more research will need to be done for us to feel confident with this reasoning.

References

4. Kossin, J. P., et al. 2011: Interim zonal and meridional winds between 1000 mb and 100 mb (Dee et al. 2011) and averaged winds using the deep layer mean scheme of Neumann (1988)
5. Dee, D. P., et al. 2011: Remained data for points within 6 degrees of the center of an ongoing tropical storm

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