A Comparative Analysis Of The Consecutive Rapid Intensification Of North Atlantic Hurricanes (2024)

Diego Xiao Barbero [1] ; Marley Majetic, M.S [2]

[1] Department of Earth, Oceanic, and Atmospheric Science, Florida State University, Tallahassee, Florida 32306
[2] Department of Science and Math, Tallahassee State College, Tallahassee, Florida 32304

Introduction

- The **increased frequency of hurricane rapid intensification (RI)** events in the past decade presents a **critical challenge to hurricane forecasting.**[1,2]
- While **low vertical wind shear** and **high sea surface temperatures (SSTs**) have already been known to support RI,[1,2] the **specific numerical thresholds** that trigger multiple, consecutive RI cycles in a single hurricane **remain poorly quantified** under modern methods.
- This study conducts a comparative analysis of two major North Atlantic hurricanes from 2024 to identify atmospheric and oceanic conditions that enable successive RI episodes.

Methods

- Dataset analysis was performed with **Python**, utilizing satellite **EUMETSAT GOES-16 hourly sub-skin SST** datasets[3] and **CIMSS/UW–Madison GOES-EAST wind shear imagery**[4].
- Figures 1–3 use hourly SST data during the intensification (dotted boundaries) periods of each corresponding hurricane.
- Any **gaps in data were reconstructed using longer-term regional means** to preserve a large-scale SST visualization.

Limitations

- The ability to triangulate exact environmental thresholds is **hindered by lack of consistent, reliable hourly SST data**.
- **Infrared satellite readings cannot penetrate thick hurricane cloud cover** over the ocean, creating data gaps.
- **Data Interpolating Empirical Orthogonal Functions (DINEOF)**[5] gap-fill data to produce hourly, high-resolution estimates but remain only reconstructions.
- **No known satellite system has capabilities for all-weather, hourly SST measurements at a high spatial resolution.**

References

[1] **Kaplan, J., & DeMaria, M.** (2003). Large-scale characteristics of rapidly intensifying Atlantic tropical cyclones. *Weather and Forecasting*, *18*, 1093–1108.
[2] **Zeng, Z., Wang, Y., & Wu, C.-C**. (2007). Environmental dynamical control of tropical cyclone intensity: An observational study. *Monthly Weather Review*, *135*, 38–59.
[3] **EUMETSAT OSI SAF**. (2024). *GHRSST GOES-16 ABI L2P sea surface temperature* [Data set]. https://osi-saf.eumetsat.int/
[4] **CIMSS, University of Wisconsin–Madison**. (2024). *SATCON wind shear analysis* [Data set]. https://tropic.ssec.wisc.edu/
[5] **Alvera-Azcárate, A., Barth, A., Rixen, M., & Beckers, J.-M**. (2005). Reconstruction of incomplete oceanographic SST fields using EOFs. *Ocean Modelling*, *9*, 325–346.
[6] **Aumann, H. H., Ruzmaikin, A., & Teixeira, J**. (2008). Frequency of severe storms and global warming. *Geophysical Research Letters*, *35*(19), L19805. https://doi.org/10.1029/2008GL034562
[7] **Climate Reanalyzer**. (2024). *Daily sea surface temperature — Gulf of Mexico* [Map]. University of Maine Climate Change Institute. https://climatereanalyzer.org/clim/sst_daily/?dm_id=gomex
[8] **Mainelli, M., DeMaria, M., Shay, L. K., & Goni, G**. (2008). Oceanic heat content and operational forecasting of category-5 Atlantic hurricanes. *Weather and Forecasting*, *23*, 3–16.

Results

Figure 1.

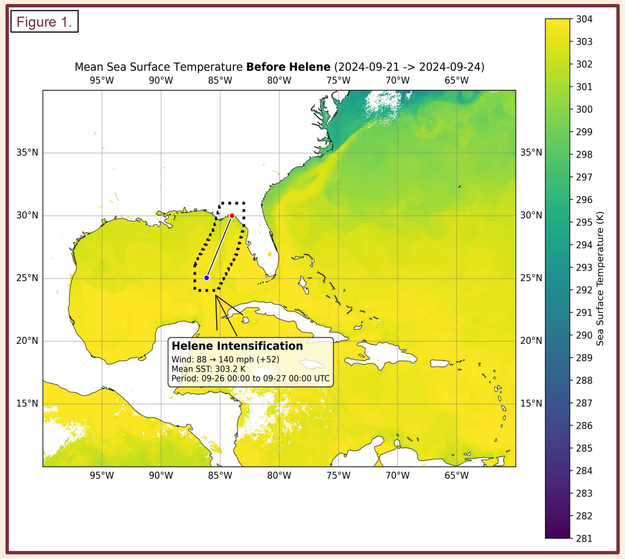


Figure 2.

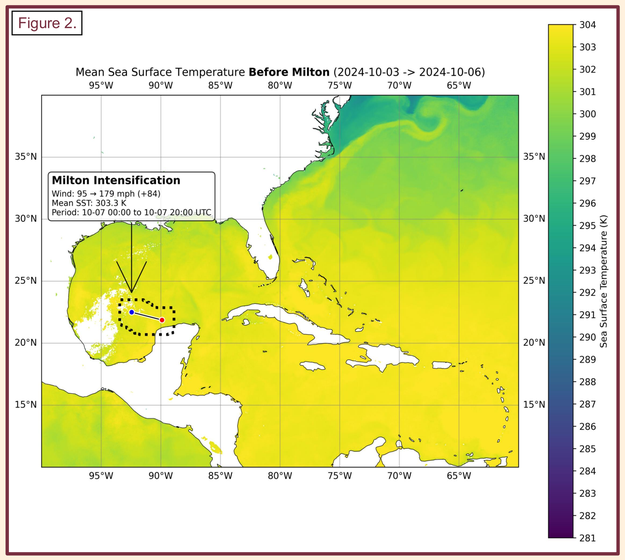


Figure 3.

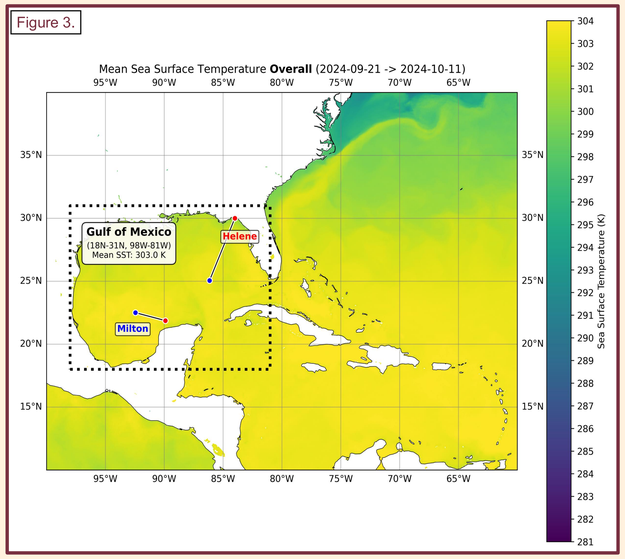


Figure 4. **Hourly Timelapse** of SSTs with a Hurricane Track Overlay[6]

Fig 5-9. **Interactive Mean** SST Temperature Before & After Imagery

Figure 10. **Deep Layer Wind Shear (kts) at 00:00 UTC on 09-26-2024**
5-10kts at Helene's location. Usually favorable conditions for intensification.

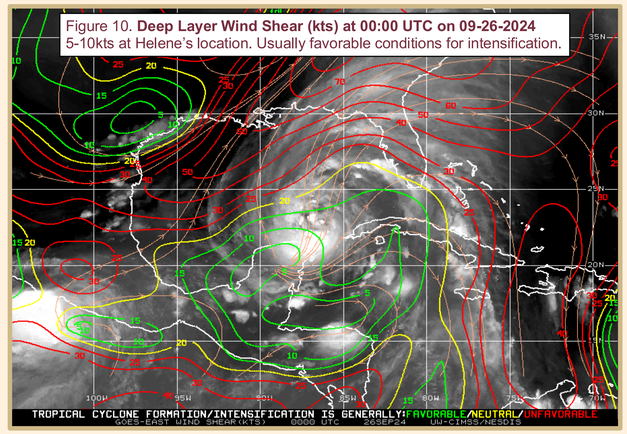
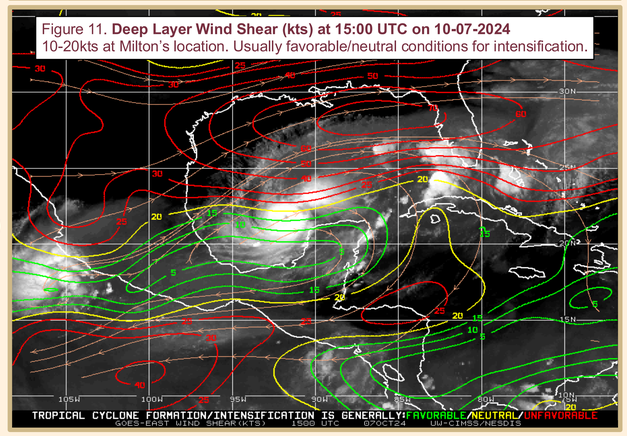


Figure 11. **Deep Layer Wind Shear (kts) at 15:00 UTC on 10-07-2024**
10-20kts at Milton's location. Usually favorable/neutral conditions for intensification.



Resultant Analysis

- Sub-skin Sea Surface Temperatures exceeding **303° K (≈ 30°C)** were associated with **more extreme and intense rapid intensification cycles.**
- Low Deep-Layer wind shear values ranging between **5-15kts (≈ 8-17mph)** allow hurricanes to **intensify without structural disruption.**
- Hurricane Milton and Helene remained in spatially extensive regions of record-high[7], sea surface temperatures throughout their intensification periods.

Conclusion

- **The 2024 Atlantic hurricane season took place during a period of exceptionally warm global and regional ocean temperatures**[7], which is important context for why this extreme intensification behavior could have happened.
- Results show that consecutive rapid intensification **events were consistently associated with persistent elevated sea surface temperatures and sustained low deep-layer wind shear**.
- Although data limitations hindered the ability to most-precisely identify environmental thresholds, the findings still highlight how oceanic heat and low vertical wind shear can influence hurricanes. This emphasizes the need for improved high-resolution, all-weather ocean observations in research.

Future Work

- Future research should **prioritize in-situ observations** alongside improved remote sensing capabilities.
- Using **extensive oceanic buoy data and airborne probes** ahead of storms would **allow surface and subsurface conditions hidden by clouds to be captured.**
- New satellite technology with high-resolution, cloud-penetrating thermal sensing could **reduce reliance on interpolation.**[8]