Using Satellite Data to Analyze if Soil Moisture Has an Impact on Hurricane Path

[1,2]Pasquale Arnone, [1]Hassan Dashtian, [1]Dev Dev Niyogi
[1]Department of Earth and Planetary Sciences, [1]The University of Texas,
[2]Department of Natural Sciences, [2]Flagler College

TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences

FLAGLER COLLEGE

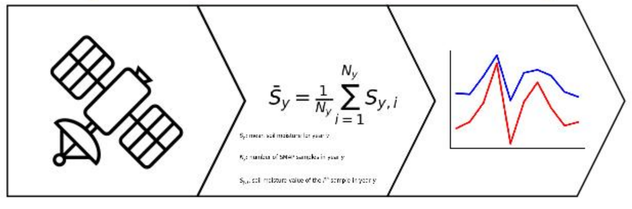
Introduction

Hurricane Helene displayed unexpected strength and path. Helene was able to retain its strength after landfall due to the Brown Ocean Effect (BOE), which replicates the ocean environment. Soil moisture (SM) is a factor of BOE, known to affect the strength and speed of hurricanes. SM's influence on the path of hurricanes remains unknown. This project seeks to find a correlation between SM and hurricane path. **It is expected that hurricanes are drawn toward lower SM concentrations**, which influenced Hurricane Helene to take an abnormal path. Neglecting SM data is common in most forecasting systems, leading to inaccurate models that fail to predict inland hurricane trajectory. Revealing this correlation could **highlight the importance of SM data for forecasting and modeling hurricane paths. This would also result in improved weather predictions, public safety, and environmental protection.**

Research Goal

This study aims to find a correlation between SM levels and hurricane path. Specifically, how **SM levels were lower the week before Hurricane Helene made landfall compared to the preceding 10 years of the same period.**

Methods



NASA's Soil Moisture Active Passive (SMAP) Level 4 SPL4SMGP v007 was used to collect SM data. The area of focus was then decided by which counties were in the direct path of Helene. The data focused on a specific time interval in 2024, along with the preceding 10 years of the same period, from **September 18 to 25** (the week before landfall). Both the rootzone SM (RSM) and surface SM (SSM) were collected and used to compare the 2024 data with that of previous years. The average data for each year was then found and tested to see if the 2024 data was significantly lower than the 10-year average. **If the P-value was < 0.05, then the value was considered significantly higher or lower.**

Figures and Results

Average SMAP Rootzone and Surface Soil Moisture (Sept 19-26, 2015-2024)

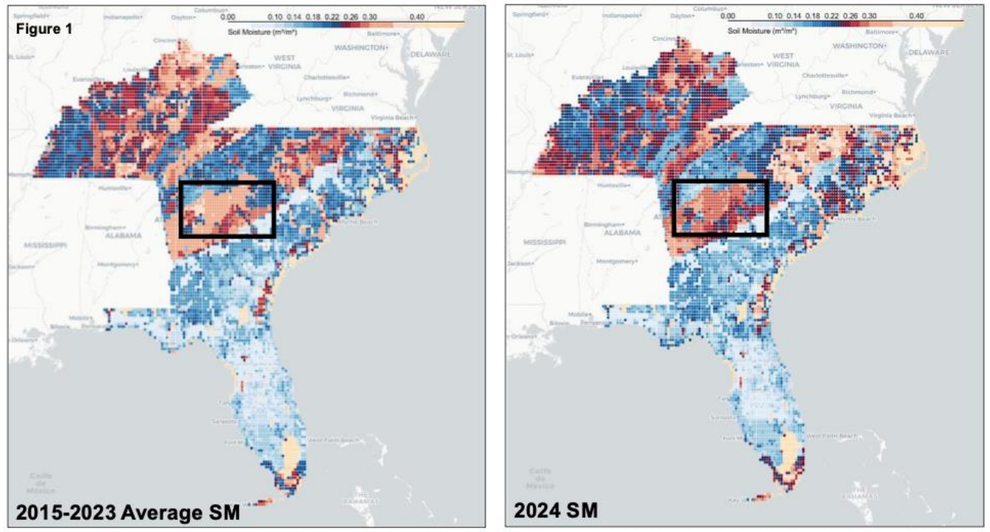


Figure 1. *2015-2023 average (left) and 2024 (right) surface SM data in Kentucky, Tennessee, North Carolina, South Carolina, Georgia, and Florida, from Sept 18-26. Data collected using NASA's SMAP Level 4 SPL4SMGP v007. Black boxes surrounding areas in Tennessee and North Carolina due to the visual change.*

KY: 2024 RSM = 0.2431 m^3 / m^3, p = 0.0128, 11.57% decrease from 2015-2023 RSM. 2024 SSM = 0.1918 m^3/m^3, p = 0.1431, 12.42% decrease from 2015-2023 SSM.
TN: 2024 RSM = 0.2535 m^3 / m^3, p = 0.1638, 5.06% decrease from 2015-2023 RSM. 2024 SSM = 0.2109 m^3/m^3, p = 0.7412, 2.27% decrease from 2015-2023 SSM.
NC: 2024 RSM = 0.2116 m^3 / m^3, p = 0.7820, 1.67% decrease from 2015-2023 RSM. 2024 SSM = 0.1965 m^3/m^3, p = 0.2928, 9.84% increase from 2015-2023 SSM.
GA: 2024 RSM = 0.2296 m^3 / m^3, p = 0.1206, 6.64% increase from 2015-2023 RSM. 2024 SSM = 0.2154 m^3/m^3, p = 0.1210, 13.43% increase from 2015-2023 SSM.
FL: 2024 RSM = 0.1837 m^3 / m^3, p = 0.3230, 6.99% increase from 2015-2023 RSM. 2024 SSM = 0.2180 m^3/m^3, p = 0.2659, 11.28% increase from 2015-2023 SSM.

Average SMAP Rootzone and Surface Soil Moisture (Sept 18-25, 2015-2024)

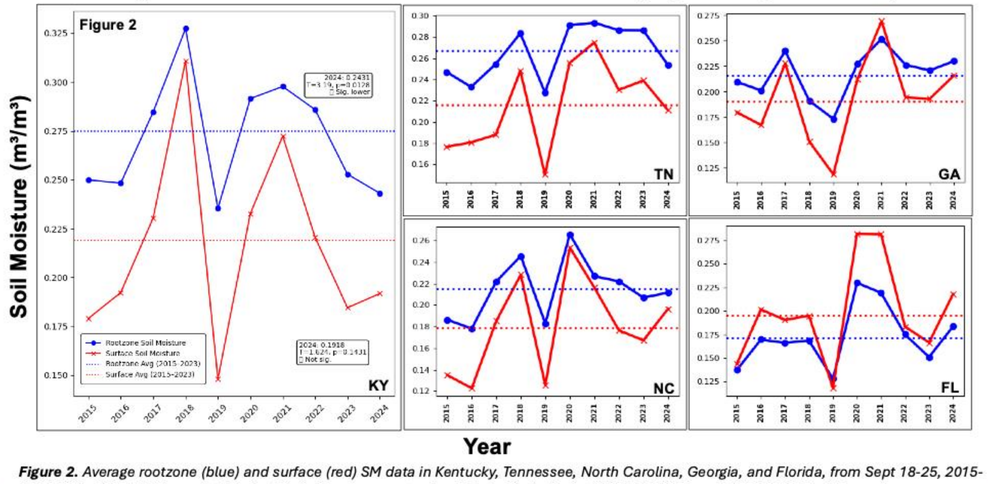


Figure 2. *Average rootzone (blue) and surface (red) SM data in Kentucky, Tennessee, North Carolina, Georgia, and Florida, from Sept 18-25, 2015-2024. With 2015-2023 average (dashed line) shown across graphs. Data collected using NASA's SMAP Level 4 SPL4SMGP v007.*

Conclusion

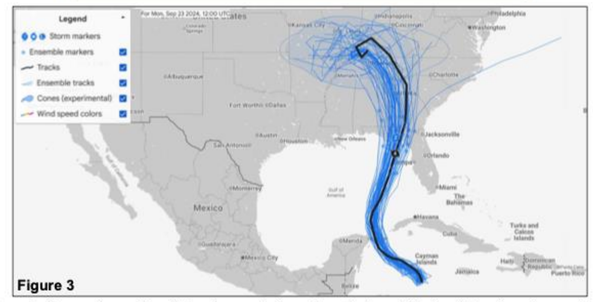


Figure 3: *Comparison of real-time forecasts from Google DeepMind and Graphcast_operational. The forecasts were done on 09-23-2024, predicting the period of Sept 25-26, 2024. This shows the majority of forecasts exhibit a large amount of variance that leads to inaccurate predictions.*

- Kentucky supported the hypothesis, showing statistically significant low RSM levels (p = 0.0128).
- Tennessee and North Carolina showed decreased RSM/SSM levels, but the values weren't significant.
- Georgia and Florida had increased RSM/SSM levels when compared to their average from 2015-'23, but the values are low compared to other areas of study.
- Low SM causes increased surface temperatures, which correlate with less dense air. This reduces the surface resistance, drawing in hurricanes.
- The use of SM could improve the accuracy of hurricane modeling.
- These findings are limited to a single hurricane, and more research is necessary to confirm a correlation.
- Expanding this study to multiple hurricanes across different years could further prove this relation.
- SM plays a vital role in the trajectory of hurricane paths. Its consideration in hurricane modeling could improve weather forecasting, environmental protection, and public safety.

Acknowledgments

This work was supported by NSF. I would also like to thank the RTX program and peers for this experience.

References

1. *Data Products | Data. SMAP.* https://smap.jpl.nasa.gov/data/
2. Hsu H, Dirmeyer PA, Seo E. 2024. Exploring the Mechanisms of the Soil Moisture-Air Temperature Hypersensitive Coupling Regime. Water Resources Research. 60(7). doi:https://doi.org/10.1029/2023wr036490
3. Entekhabi D, Njoku EG, O'Neill PE, Kellogg KH, Crow WT, Edelstein WN, Entin JK, Goodman SD, Jackson TJ, Johnson J, et al. 2010. The Soil Moisture Active Passive (SMAP) Mission. Proceedings of the IEEE. 98(5):704–716. doi:https://doi.org/10.1109/jproc.2010.2043918
4. DeMarco E. 2025 Jun 12. NASA's Hurricane Science, Tech, Data Help American Communities. NASA Science. https://science.nasa.gov/earth/nasas-hurricane-science-tech-data-help-american-communities/