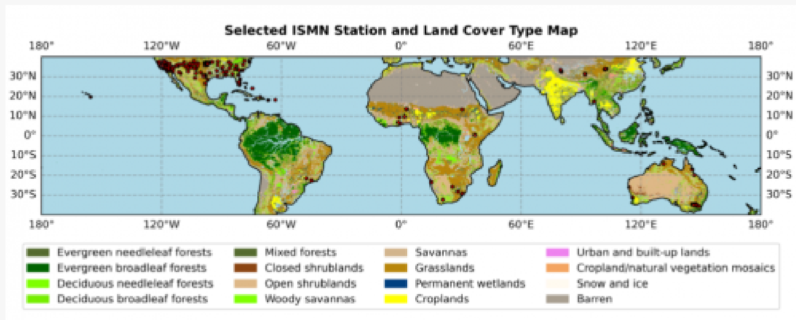
Cutting through the canopy: a smarter way to measure soil moisture via CYGNSS

FAYETTEVILLE, GA, UNITED STATES, August 1, 2025 /EINPresswire.com/ -- A new method harnessing the Cyclone Global Navigation Satellite System (CYGNSS) satellite constellation significantly improves the accuracy of soil moisture retrieval by eliminating vegetation interference and removing dependency on external datasets.



The spatial distribution of selected International Soil Moisture Network (ISMN) stations (red-filled circles) used in this study across different Land Use and Land Cover(LULC) classifications.

Soil moisture is a fundamental variable in the Earth's hydrological and climate systems, influencing everything from weather forecasting to crop management. Despite advances in satellite-based monitoring, existing systems often struggle in vegetated regions and depend heavily on supplementary data for accuracy. The spatial and temporal trade-offs in current technologies limit their effectiveness for real-time applications. Cyclone Global Navigation Satellite System (CYGNSS) offers higher revisit frequencies, but challenges persist due to vegetation attenuation and reliance on other satellite products. Due to these persistent issues, there is a critical need to develop new methods that improve soil moisture retrieval accuracy while minimizing external dependencies.

On July 14, 2025, researchers from the University of Virginia and the Gwangju Institute of Science and Technology published (DOI: 10.34133/remotesensing.0726) a novel approach in Journal of Remote Sensing that reimagines soil moisture retrieval from the CYGNSS satellite system. Originally built to monitor hurricanes, CYGNSS now proves its worth in tracking soil moisture. The team's method directly addresses longstanding limitations—vegetation signal interference and external dataset reliance—unlocking new possibilities for reliable, near-real-time land monitoring from space.

The study introduces an integrated retrieval technique combining two powerful tools: a two-step calibration to counter vegetation signal loss and an adaptive relative Signal-to-Noise Ratio (rSNR) method tailored for surface reflectivity data. This hybrid approach enhances the precision of soil moisture measurements, especially in croplands and savannahs, without relying on external satellite datasets. Compared to single-step methods, the integrated system achieved the lowest average RMSE (0.117 m^3/m^3) and bias (0.092 m^3/m^3), validating its robustness across diverse land conditions. The method also proved effective under varying land surface temperature and sand content, making it versatile for both agricultural and environmental applications. The novel method integrates a two-step calibration with an adaptive rSNR technique to retrieve soil moisture from CYGNSS data alone. First, calibration corrects raw surface reflectivity (SR) data using inland water references and vegetation attenuation models. Then, the rSNR method normalizes SR data against historical dry and wet conditions to extract relative soil moisture. The study analyzed five years of CYGNSS data (2017–2022), covering diverse vegetation and soil profiles, and validated results using the International Soil Moisture Network. Performance was benchmarked across land cover types, vegetation water content, and land surface temperature, consistently outperforming prior approaches. The integrated method excelled in sparse to moderately vegetated areas and sandy soils, where traditional retrievals often fail. However, it showed performance drops in extremely dry or densely vegetated zones—highlighting areas for future refinement. Overall, the approach delivers a significant advance in satellite-based soil moisture monitoring.

“This innovation allows us to track soil moisture more accurately and independently than ever before,” said Dr. Hyunglok Kim, co-author of the study. “Our integration method empowers researchers and decision-makers with a more reliable data source, especially in areas where vegetation complicates satellite observations. It’s a big leap toward sustainable water resource management and climate resilience.”

Researchers analyzed five years of CYGNSS satellite data, applying a two-step calibration to correct reflectivity signals for system errors and vegetation attenuation. They then used an adaptive rSNR method, modified for reflectivity data, to estimate relative soil moisture. Validation was performed using ground-based measurements from 359 International Soil Moisture Network stations, comparing satellite retrievals across diverse land covers and environmental conditions using Root Mean Square Error (RMSE), ubRMSE, and bias metrics.

This approach paves the way for a new generation of soil moisture monitoring—faster, more accurate, and globally scalable. It supports agriculture, disaster response, and climate modeling by delivering timely data without depending on external satellite products. The team plans to refine the model for extreme environments and improve calibration for dense vegetation and complex terrain. As CYGNSS continues its mission, its role in global sustainability and environmental monitoring is expected to grow.

References
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