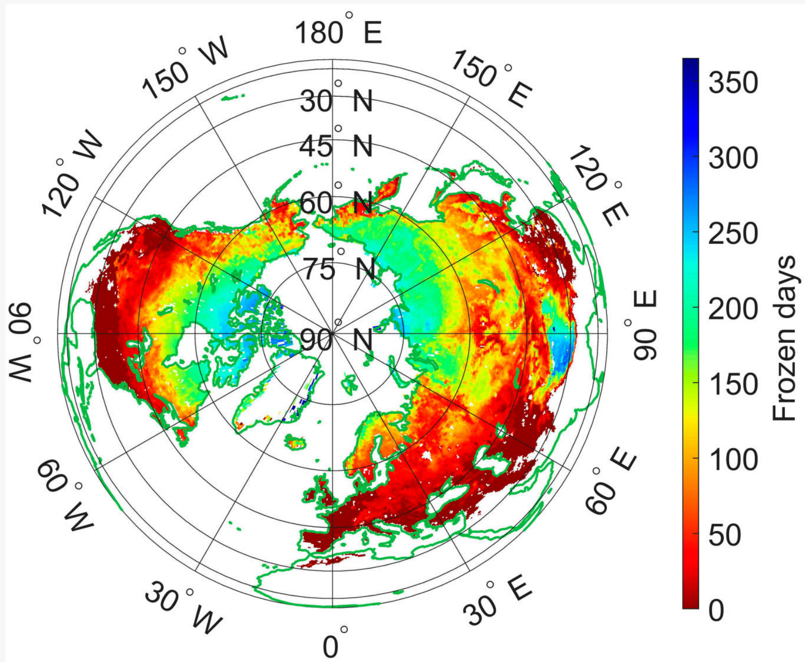
Tracking frozen ground from orbit: Dynamic parameters unlock precision in soil monitoring



Distribution of annual average frozen days (July 2017 to June 2022) from SMAP FT products

GA, UNITED STATES, November 6, 2025 /EINPresswire.com/ -- Soil freeze–thaw (FT) cycles play a crucial role in land–atmosphere energy exchange and climate regulation, yet accurate global detection remains challenging. A new study proposes a refined retrieval algorithm that leverages Diurnal Amplitude Variation (DAV) in L-band brightness temperature to capture soil FT dynamics more precisely. By introducing regionally optimized parameters rather than fixed global ones, the algorithm improves the spatial accuracy of FT classification, boosting overall classification accuracy (OA) from 54.43% to 89.36%. The enhanced approach demonstrates stronger consistency with ERA5-Land and SMAP data, offering a more reliable way to track soil freezing and thawing processes from space.

Freeze–thaw (FT) transitions in soil alter surface albedo, moisture, and heat fluxes, profoundly affecting weather patterns and hydrological cycles. However, capturing these dynamic processes is difficult because diurnal soil temperature variations and surface heterogeneity are often neglected in large-scale models. L-band microwave remote sensing provides a promising solution due to its sensitivity to soil dielectric properties and ability to penetrate snow and vegetation. Existing SMAP-based algorithms rely on globally fixed parameters, which may fail under diverse land cover and climate conditions. Based on these challenges, an improved parameter-optimization framework for soil freeze–thaw retrieval needs to be developed.

Researchers from Fudan University, the University of Twente, and Chengdu University of Information Technology have developed a dynamic parameter optimization algorithm that enhances soil freeze–thaw detection from spaceborne L-band measurements. The study, published (DOI: [10.34133/remotesensing.0806](https://doi.org/10.34133/remotesensing.0806)) on September 10, 2025, in Journal of Remote Sensing, presents a data-driven framework that adapts to regional variations in land cover, terrain, and climate to improve the accuracy of soil FT mapping using SMAP satellite data.

The research team improved the existing Diurnal Amplitude Variation–based Freeze–Thaw (DAV-FT) algorithm by introducing three dynamically optimized parameters—α, β, and γ—representing detection period, variance window, and threshold sensitivity, respectively. Through a process akin to maximum likelihood estimation, these parameters are tuned to maximize overall classification accuracy (OA) across regions. The optimized algorithm distinguishes freezing and thawing states based on annual variations in L-band brightness temperature observed by SMAP. Results show that regions with OA > 0.7 expanded from 54.43% to 89.36%, with the strongest performance in the Qinghai–Tibet Plateau, southwestern Eurasia, and southern North America. The new model also achieved high consistency with ERA5-Land (81.28%) and SMAP-FT (79.54%) datasets. Validation using 828 in situ soil temperature stations confirmed the algorithm's superior accuracy and stability, with a median accuracy of 0.92—surpassing both fixed-parameter and SMAP products.

"The dynamic parameter optimization significantly enhances our ability to capture subtle soil freeze–thaw transitions that vary across regions and seasons," said Dr. Shaoning Lv, the study's corresponding author. "By reflecting diurnal surface changes in real time, our method not only refines the retrieval accuracy of L-band data but also provides a more physically consistent understanding of land–atmosphere interactions. This represents an important step toward global-scale climate monitoring with improved temporal and spatial precision."

The improved DAV-FT algorithm provides a robust framework for continuous soil freeze–thaw monitoring across diverse terrains, offering valuable support for climate modeling, agricultural management, and hydrological forecasting. Its capacity to account for diurnal temperature cycles and regional heterogeneity makes it particularly useful for high-latitude and mountainous regions where existing algorithms struggle. By enhancing the accuracy of soil state detection from space, the method strengthens the foundation for assessing permafrost dynamics, water availability, and land–atmosphere energy fluxes—key factors in predicting climate change impacts and improving global land-surface models.

DOI
10.34133/remotesensing.0806

Original Source URL
https://doi.org/10.34133/remotesensing.0806

Funding information
This research was funded by the National Key R&D Program of China (grant no. 2022YFF0801404), the Key Research and Development and Achievement Transformation

Program of Inner Mongolia Autonomous Region, China (grant no. 2025YFDZ0007), the Yan Liyuan–ENSKY Foundation Project of Zhuhai Fudan Innovation Research Institute (grant no. JX240002), and the National Natural Science Foundation of China (grant no. 42075150).

Lucy Wang
BioDesign Research
email us here
