

Transformer-Based Modeling of Global Microwave Land Surface Emissivity Using GPM

Fraser King^{1,2} and Sarah Ringerud²

¹Earth System Science Interdisciplinary Center, University of Maryland, College Park, USA

²Mesoscale Atmospheric Processes Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, USA

February 12, 2026

Abstract

Global land surface microwave emissivity estimates are critical for data assimilation, numerical weather prediction, and quantitative precipitation estimation, yet explicit calculations at multiple frequencies remains problematic. We introduce a machine learning model that converts 10.65 GHz H-polarization emissivity retrieved under clear-sky conditions into emissivity for the 12 higher-frequency channels of the GPM Microwave Imager (GMI). The model is a feature-tokenizer transformer that ingests ancillary surface variables such as skin temperature, leaf area index, soil texture, and soil moisture. Treating each variable as an individual token lets the transformer direct attention between features and learn nonlinear, spatiotemporally consistent relationships across five years of data [2015-2019]. The network reproduces channel-specific emissivities with $R^2 > 0.80$ and mean absolute percentage error $< 1\%$, and it simulates top-of-atmosphere brightness temperatures with $R^2 = 0.77 - 0.95$ and mean biases < 4 K for every channel up to 89 GHz when compared to collocated GMI observations. Using independent TELSEM2 10.65 GHz H-pol inputs produces similar skill, suggesting that the learned mapping is robust to the input source, and captures transferable physical structures. The model is lightweight and can be embedded in satellite retrieval systems, reanalysis pipelines, and Earth-system models to accelerate microwave forward modeling and improve global precipitation monitoring.