

## Enhancing Global Precipitation Retrieval with FY-3 MWHS/MWTS Radiometers Using Machine Learning and Spaceborne Radar-based References

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Satellite-based precipitation estimation plays a crucial role in monitoring the global hydrological cycle and supports operational applications such as hydrological forecasting, water resource management, and natural hazard assessment. Within the EUMETSAT H SAF (Satellite Application Facility on Support to Operational Hydrology and Water Management), the objective is to produce reliable global precipitation products derived from passive microwave radiometers onboard low Earth orbit (LEO) satellites. Achieving near-continuous spatial and temporal coverage requires a well-distributed constellation of sensors, as passive microwave radiometers—combined with advanced retrieval techniques—represent a key tool for operational rainfall and snowfall mapping.

The FengYun-3 (FY-3) satellite series, particularly the more recent missions (FY-3C launched in 2013, FY-3D in 2017, FY-3E in 2021, and FY-3F in 2023), consists of polar-orbiting meteorological satellites that significantly enhance global sampling density. Their contribution is especially valuable in regions and local times that remain under-observed. These satellites carry multi-channel passive microwave instruments, including the Microwave Humidity Sounder (MWHS) and the Microwave Temperature Sounder (MWTS), which provide regular measurements of atmospheric temperature, humidity, and precipitation. Notably, MWHS includes channels around 118 GHz, a spectral region that remains relatively underexploited for operational precipitation retrieval. These channels offer complementary information on atmospheric vertical structure, which can support advanced precipitation estimation methods when combined with other frequencies and auxiliary datasets, ultimately strengthening the reliability of H SAF operational products.

Machine Learning techniques have demonstrated strong capability in retrieving surface precipitation from passive microwave observations, owing to their ability to capture complex nonlinear relationships between multi-frequency signals and precipitation characteristics. In this study, we present the development of a retrieval algorithm that integrates observations from FY-3 MWHS and MWTS radiometers. Dual-frequency Precipitation Radar (DPR) measurements from the NASA/JAXA GPM Core Observatory (available since March 2014) and Cloud Profiling Radar (CPR) data from NASA's CloudSat mission (2006–2023) are used as physical reference datasets. For periods beyond the CloudSat mission lifetime, CPR observations from the ESA/JAXA EarthCARE mission may also be considered. DPR and CPR provide complementary insights into precipitation structure, enabling robust characterization of hydrometeors.

Supervised training is supported through the construction of spatio-temporally collocated datasets combining radar observations with MWHS/MWTS measurements. In addition, auxiliary variables derived from ECMWF model outputs are incorporated to provide further information on the atmospheric state and to enhance retrieval robustness.

The proposed retrieval framework follows a two-stage modular design. In the first stage, a neural network detects precipitation occurrence and classifies its phase (rain, snow, or mixed). In the second stage, precipitation intensity is estimated from multi-frequency observations, conditioned on the predicted phase. This modular configuration enables adaptive use of the most appropriate radar reference depending on precipitation type. Various model architectures—from pixel-based approaches to convolutional neural networks (CNNs)—are being evaluated to assess the influence of spatial context and model complexity on retrieval performance. The algorithm outputs will be validated against independent radar datasets in terms of detection skill, classification accuracy, and quantitative precipitation estimation performance.

By integrating FY-3 MWHS and MWTS observations with advanced neural network methodologies and ECMWF auxiliary information, this work aims to expand global coverage and improve the reliability of H SAF precipitation products, while also exploring the operational potential of the 118 GHz channels for precipitation retrieval.