Diagnosing the Role of Retrieved Cloud Properties in IR-Only Rain Detection and Quantitative Precipitation Estimation from Himawari

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Accurate rain detection from geostationary satellite infrared (IR) observations remains challenging because IR radiances provide only indirect proxies for precipitation-related processes. While brightness temperatures and spectral-parameter combinations have been widely used, they often suffer from ambiguous cloud states that lead to elevated false-alarm rates, particularly in deep but non-precipitating cloud regimes. Whether retrieved cloud properties provide independent physical constraints beyond radiance-based proxies under an IR-only sensing constraint remains insufficiently examined.

In this study, we evaluate the role of retrieved cloud properties (CPs) in IR-based rain detection using Himawari-8/9 observations over Taiwan. A controlled set of deep neural network experiments is designed to compare three feature configurations: (i) IR-only brightness temperatures, (ii) IR combined with radiance-derived spectral parameters, and (iii) IR combined with retrieved cloud properties, including cloud-top height, optical thickness, and cloud water path. Radar-based Quantitative Precipitation Estimation and Segregation Using Multiple Sensor (QPESUMS) precipitation data are used as the surface reference for training and validation. The analysis focuses on daytime conditions over Taiwan during representative rainfall events to minimize illumination-related retrieval uncertainty.

Results show that incorporating CPs shifts the model toward a more conservative operating point, substantially reducing false alarms at the default decision threshold while maintaining comparable overall skill. In contrast, spectral parameters tend to increase detection sensitivity but also expand rainfall coverage, resulting in higher false-alarm rates. Regime-based post-hoc diagnostics suggest that incorporating cloud properties (CPs) facilitates the reallocation of non-precipitating high-cloud scenes into lower-confidence regimes, leading to improved decision reliability.

Although the primary focus is rain detection, the same IR+CP configuration also yields more coherent rainfall-rate patterns and improved spatial consistency in quantitative precipitation estimation relative to IR-only baselines. These findings suggest that retrieved cloud properties provide consolidated physical constraints that complement radiance-based features, offering a pathway to improve IR-only rain detection and precipitation estimation when microwave observations are limited.

Keywords: Himawari Advanced Himawari Imager (AHI), Cloud properties (CPs),

Infrared-based Quantitative Precipitation Estimation (IR-QPE), Rain detection