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Resolving fine-scale precipitation patterns from microwave satellite observations: geometrical considerations and physical limitations

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The GPM-era NASA multi-satellite precipitation product IMERG aims at providing quasi-global continuous precipitation estimates with high spatial and temporal resolution. While the TRMM-era product (TMPA) provided 3-hourly estimates on a 0.25° grid, IMERG provides half-hourly estimates on a 0.1° grid. Resolving precipitation patterns at this scale from passive instruments introduces additional challenges that need to be addressed. Two such challenges are considered in this work.

The multisensor product IMERG partially relies on observations from conical-scanning passive microwave imagers. It was demonstrated in Guilloteau et al. (2017) that the state-of-the art Bayesian algorithm GPROF that retrieves instantaneous near-surface precipitation rates from the GPM Microwave Imager (GMI) produces smooth estimates, filtering out spatial variability at scales finer than 20 km over oceans and finer than 40 km or 80 km over land. This result may at first appear surprising considering that the retrieval over land mostly relies on the high-frequency channels (>80 GHz), whose nominal resolution is around 5 km, while over ocean the retrieval mostly relies on the low-frequency channels (<40 GHz), whose nominal resolution is between 15 km and 30 km.

In fact, high frequency microwave channels do not respond directly to near-surface precipitation, but to the presence of ice in the upper levels of the clouds. We demonstrate that GMI 89 GHz brightness temperature responds to ice above 6 km altitude, and up to 12 km altitude for the most intense deep convective systems over land. Consequently, for highly vertically developed systems, the angle and direction of the observation affect the microwave brightness temperatures. This is prone to weaken the empirically constructed statistical relations between microwave brightness temperatures and surface precipitation rates. Moreover, strong local variability may give rise to complex observation geometry, particularly at the edges of precipitating systems. For example, the parallax shift is a simple geometrical effect, which can be corrected only if the vertical distribution of the hydrometeors is known. We propose here a simple statistical correction of the parallax shift for the 89 GHz channels. Other effects such as inhomogeneous beam filling are more challenging to correct for.

Finally, over land, the main limitation for resolving fine-scale patterns of surface precipitation from passive microwave is the variable relation between the clouds‘ ice content and instantaneous precipitation. We explore how integration over time affects this relation and what are the consequences from the perspective of half-hourly accumulated IMERG estimates.

Reference:

Guilloteau, C., Foufoula-Georgiou, E. and Kummerow, C.D., 2017. Global Multiscale Evaluation of Satellite Passive Microwave Retrieval of Precipitation during the TRMM and GPM Eras: Effective Resolution and Regional Diagnostics for Future Algorithm Development. Journal of Hydrometeorology, 18(11), pp.3051-3070, doi:10.1175/JHM-D-17-0087.1