Detection and Estimation of Light Precipitation from GPM GMI

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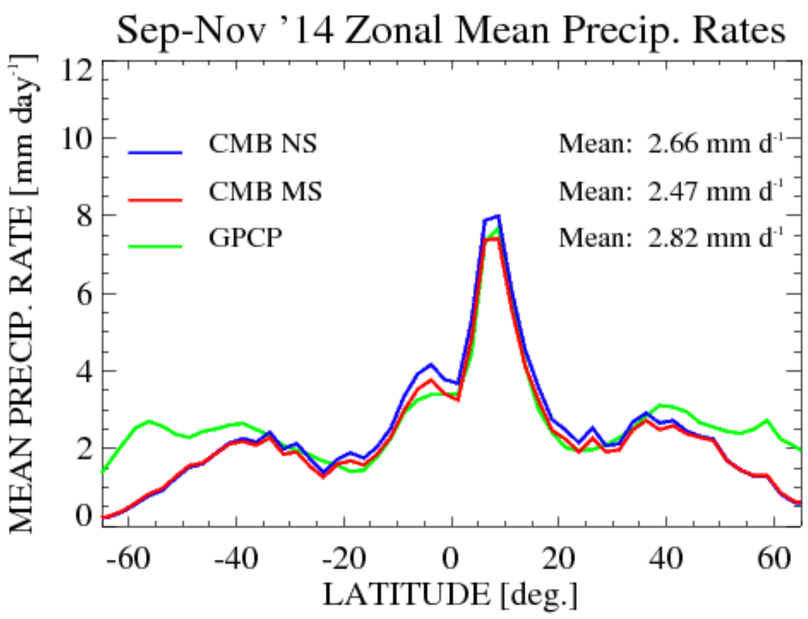
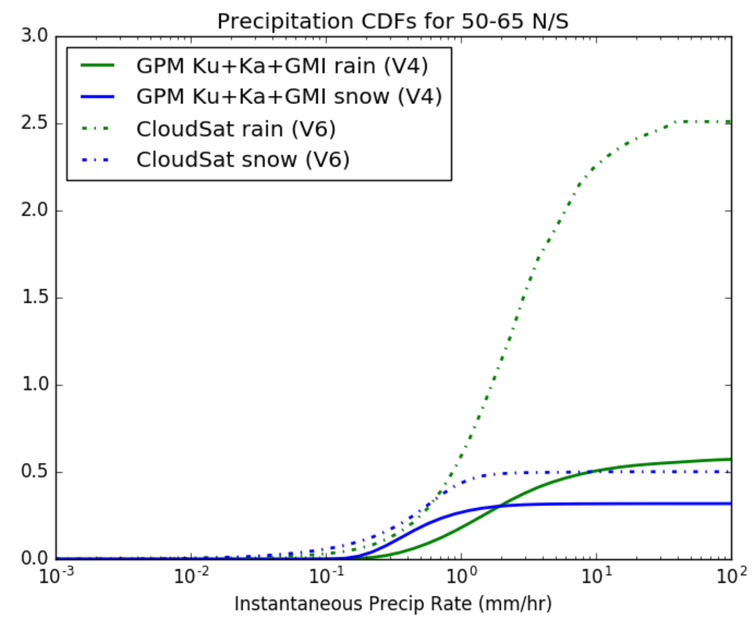


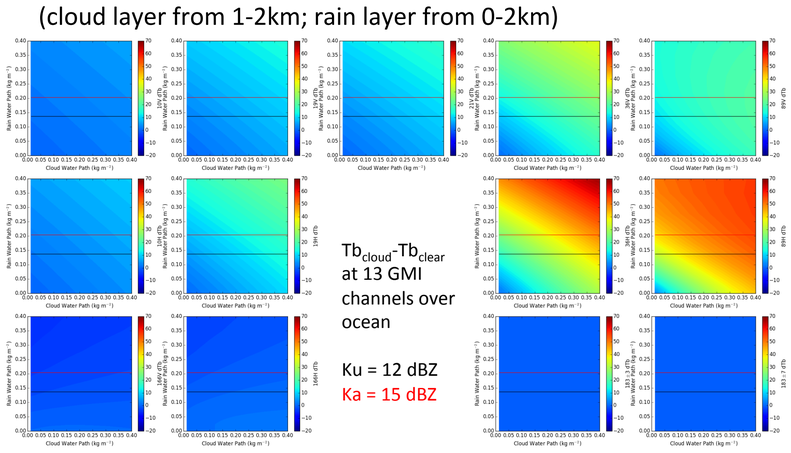
Introduction

The Global Precipitation Measurement (GPM) core satellite is intended to serve as a reference for passive microwave satellite precipitation estimates via combination of the GPM Microwave Imager (GMI) and Dual-frequency Precipitation Radar (DPR) to produce a database of precipitation profiles to be used in Bayesian retrievals. However, the minimum detectable DPR reflectivity corresponds to a precipitation rate of 0.2-0.5 mm/hr (depending on DPR mode and raindrop size distribution), and ground clutter prevents detection of shallow precipitation with echo tops less than 1-2 km above the surface. Comparisons of the GPM DPR+GMI combined algorithm show significant underestimation relative to GPCP (left) and CloudSat (right). Therefore, it is desirable to devise techniques to retrieve light precipitation from GMI observations alone.



Simulated GMI sensitivity to nimbostratus cloud

(cloud layer from 1-2km; rain layer from 0-2km)

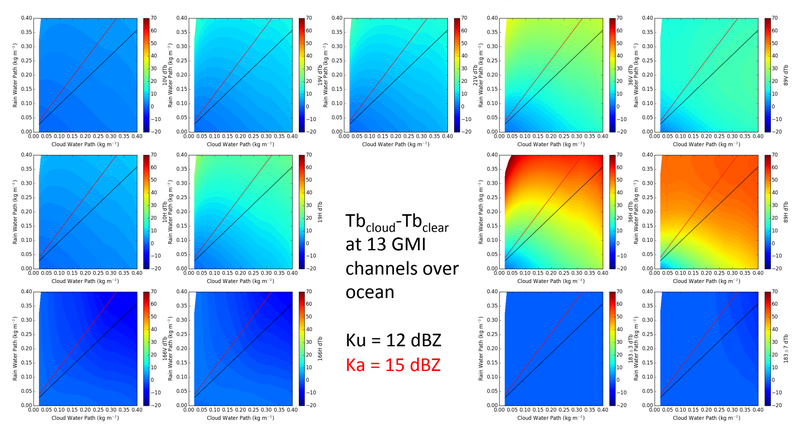


Tb_{cloud}-Tb_{clear} at 13 GMI channels over ocean

Ku = 12 dBZ
Ka = 15 dBZ

Simulated GMI sensitivity to congestus cloud

(variable cloud height, water content=0.1 g/m³)

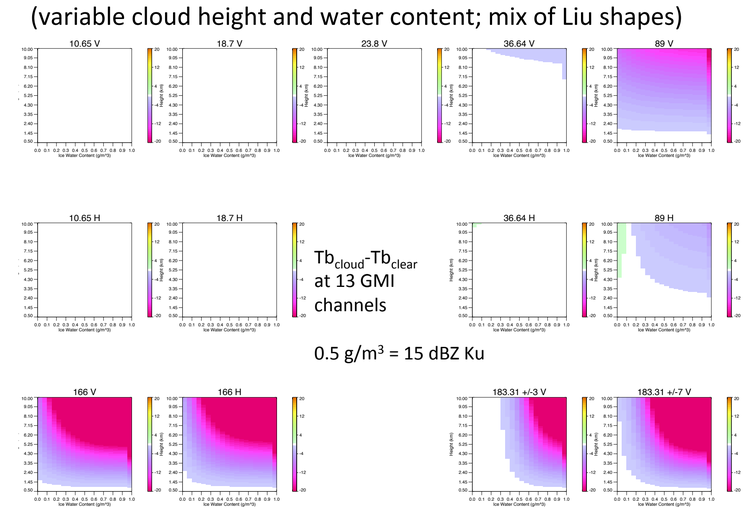


Tb_{cloud}-Tb_{clear} at 13 GMI channels over ocean

Ku = 12 dBZ
Ka = 15 dBZ

Simulated GMI sensitivity to ice cloud

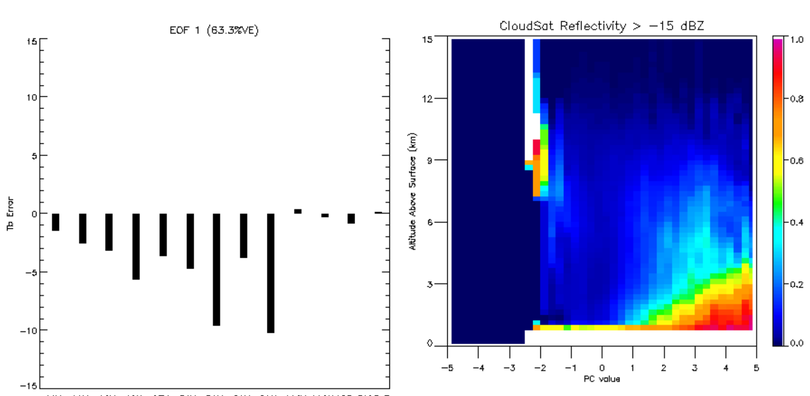
(variable cloud height and water content; mix of Liu shapes)



Tb_{cloud}-Tb_{clear} at 13 GMI channels

0.5 g/m³ = 15 dBZ Ku

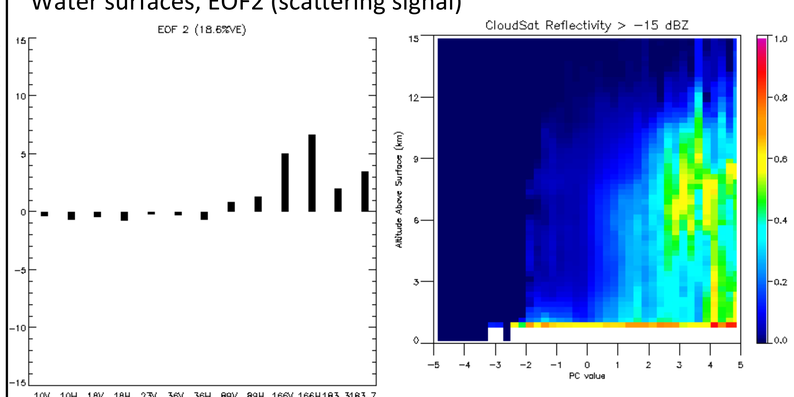
Water surfaces, EOF1 (emission signal)

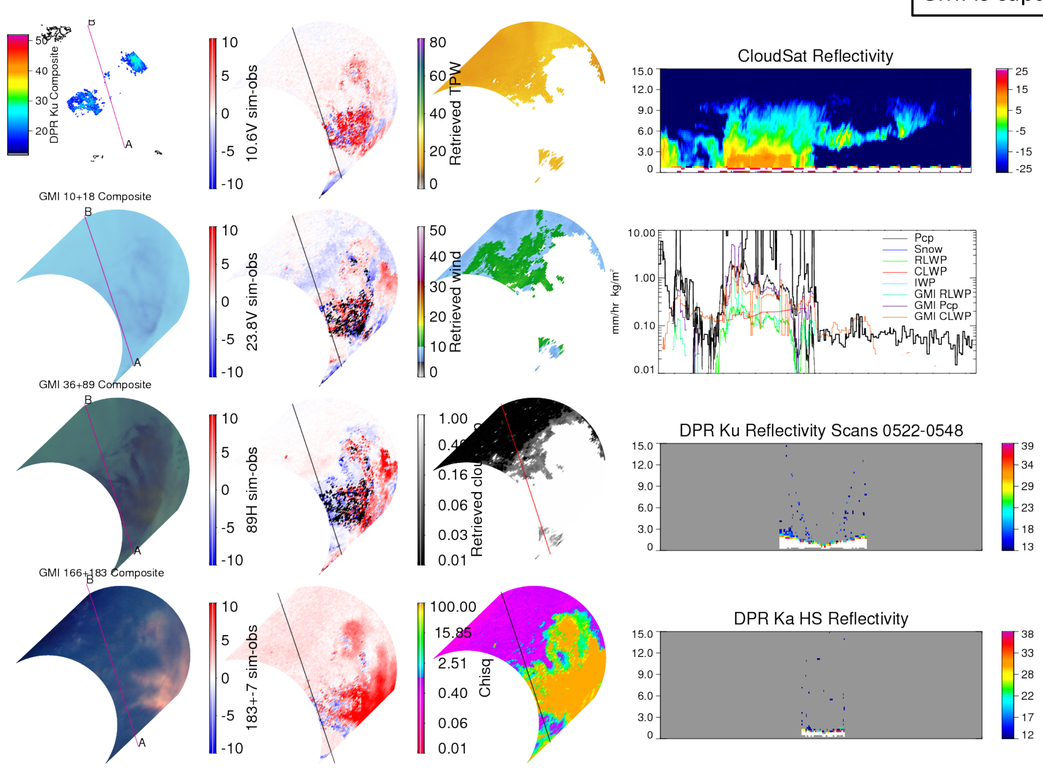


Observational basis

Starting with the database of CloudSat-DPR matchups over ocean surfaces and in pixels where DPR did not detect precipitation, we computed clear-sky Tbs at all 13 GMI channels using reanalysis data from MERRA. An EOF analysis of the Tb_{sim}-Tb_{obs} was performed, with the two leading modes corresponding to excess emission (left) and scattering (right). Next, CloudSat reflectivity profiles were analyzed to show the percentage of time echo exceeded -15 dBZ (threshold for drizzle or light snowfall) as a function of the EOF values. There is a steadily increasing occurrence and depth of echo as the value of EOF1 increases, consistent with shallow raining clouds, and increased occurrence of deep echoes with increasing values of EOF2, indicative of precipitating ice clouds. These results confirm that GMI is capable of detecting sub-DPR-threshold precipitation.

Water surfaces, EOF2 (scattering signal)

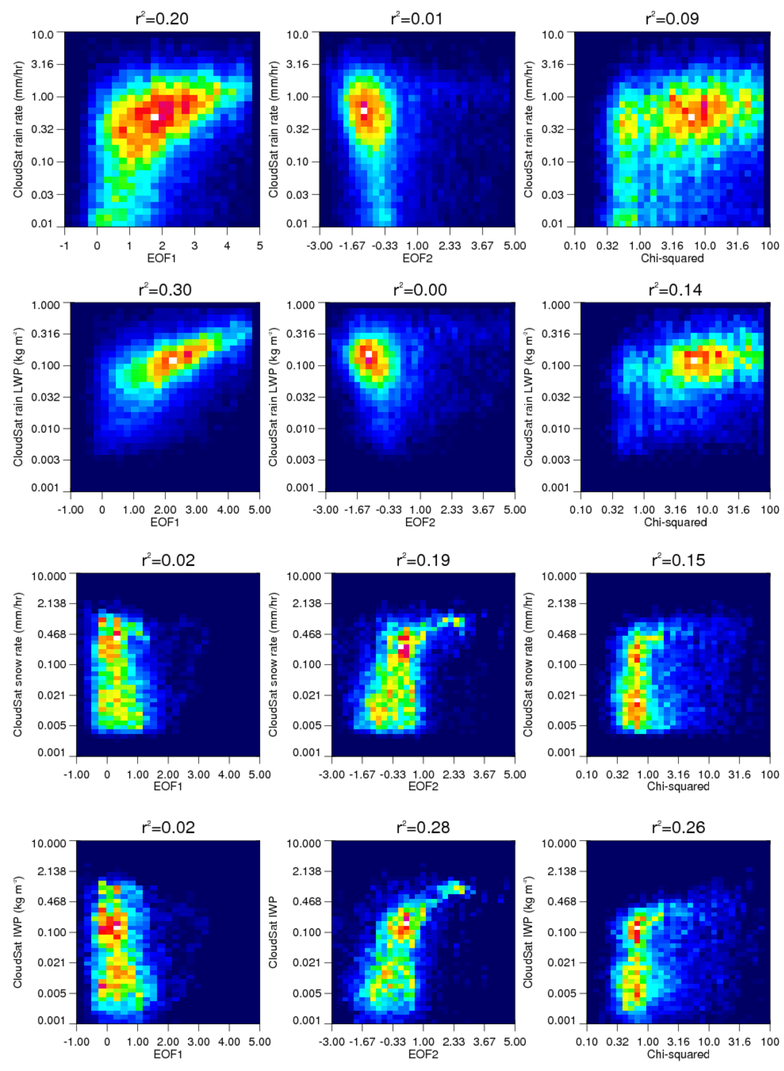


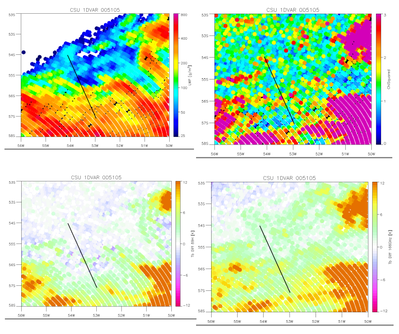


Detection Strategy

Precipitation can be retrieved directly from GMI by adding precipitation to 1DVAR retrievals such as those shown on the left; however; this requires detailed descriptions of cloud structures and computationally-intensive iterative scattering radiative transfer calculations. An alternative is to use the non-precipitation retrieval error as a proxy for precipitation guided by CloudSat statistics to ensure consistent precipitation occurrence and amounts.

The panels on the right show the correlation of CloudSat-derived rain rate, rain liquid water path, snow rate, and ice water path with the GMI EOFs described above and optimal estimation chi-squared. While chi-squared has the best correlation with all parameters, the EOFs are better at distinguishing precipitation of a given phase (rain or snow). These panels also indicate that the minimum rain rate detectable by GMI over ocean is around 0.1 mm/hr while the minimum snowfall rate is closer to 0.3 mm/hr. These statistics will be used to augment future versions of the GPROF database for passive microwave precipitation retrievals.





Optimal Estimation Retrievals

Two different 1DVAR algorithms have been developed to retrieve ocean surface winds, water vapor profiles, and cloud liquid water from GMI (Top: Munchak et al., 2016 *JTECH*; left: Duncan and Kummerow, 2016, *JGR*). The goodness-of-fit parameter χ^2 can be used as a proxy for precipitation, which is not accounted for by the forward model.

Acknowledgement

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