Relationships between Surface Emissivity and Radar Backscatter Cross-Section: Improving Combined DPR/GMI Precipitation Retrievals

S. Joseph Munchak[1,2]*, F. Joseph Turk[3], Robert Meneghini[1], William S. Olson[1,4], Felipe Aires[5], Catherine Prigent[6]

1: NASA Goddard Space Flight Center, Greenbelt, MD, USA; 2: University of Maryland, College Park, MD, USA; 3: NASA JPL/Caltech, Pasadena, CA, USA; 4: University of Maryland Baltimore County, Catonsville, MD, USA; 5: Universite Pierre et Marie Curie, Paris, France; 6: Observatoire de Paris, Paris, France; *s.j.munchak@nasa.gov

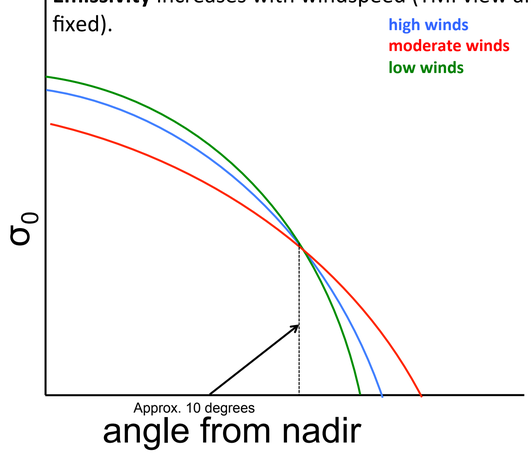
Motivation

In 15 years of observations, the TRMM PR and TMI instruments have collected data that can be used to estimate the effective surface radar reflectivity cross section (σ_0) and surface emissivity at multiple frequencies. The physical processes of emission and reflection are related, and there is an a priori expectation of an inverse relationship between the two. Knowledge of this relationship can be used to ensure consistency between estimates of path-integrated attenuation (PIA) and emissivity in the TMI-PR (or GMI-DPR) combined algorithm, and may also be used to estimate physical surface parameters (such as soil moisture or wind speed) in raining and non-raining regions.

Physical Basis

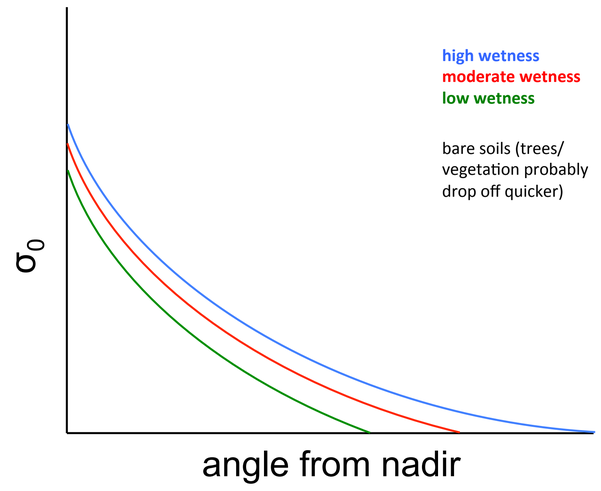
Ocean

Backscatter decreases as windspeed increases near nadir, but increases with windspeed for PR view angles past 10 degrees as a result of increased surface roughness.
Emissivity increases with windspeed (TMI view angle is fixed).

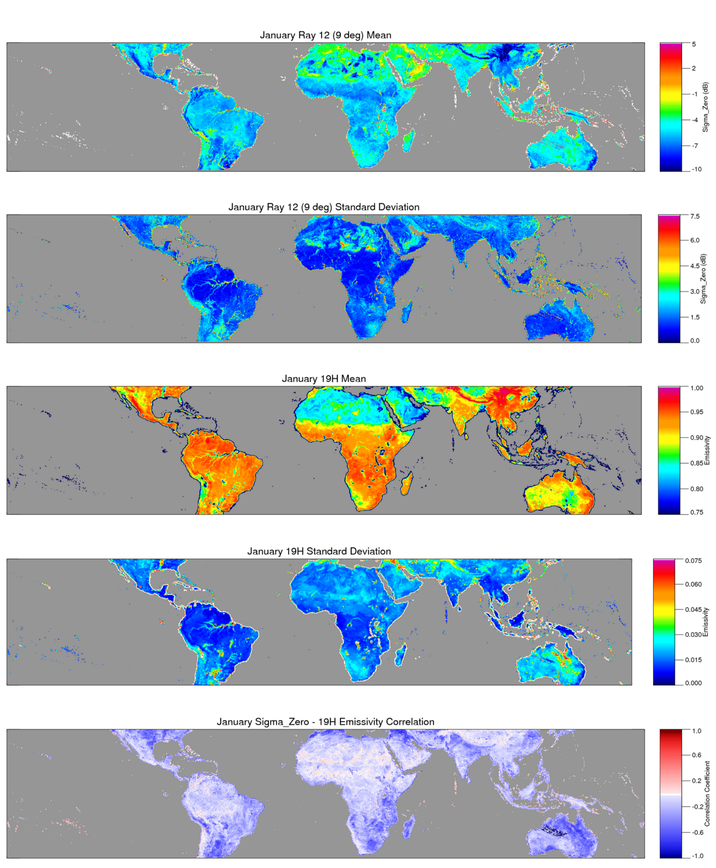


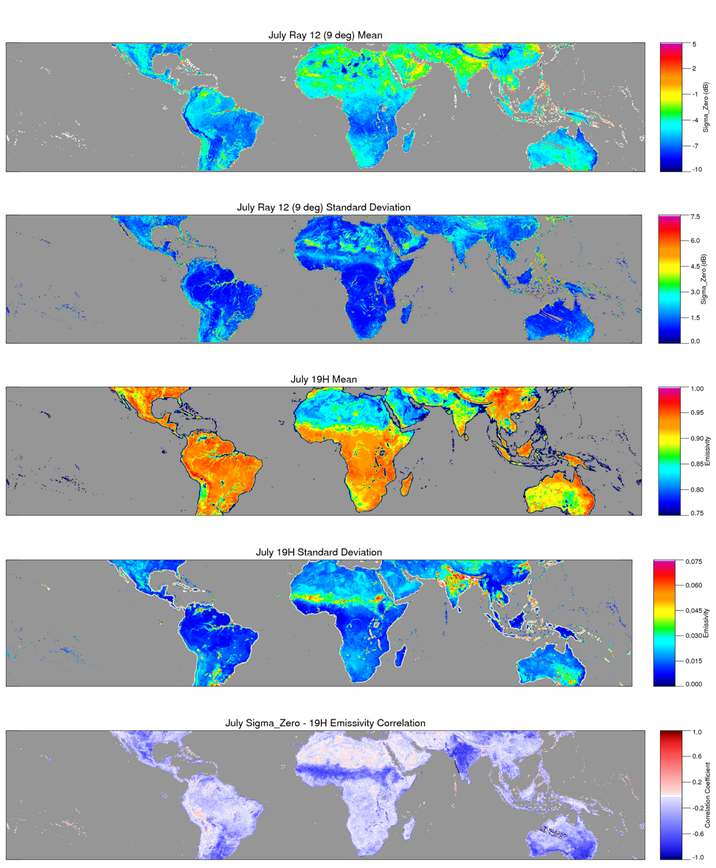
Land

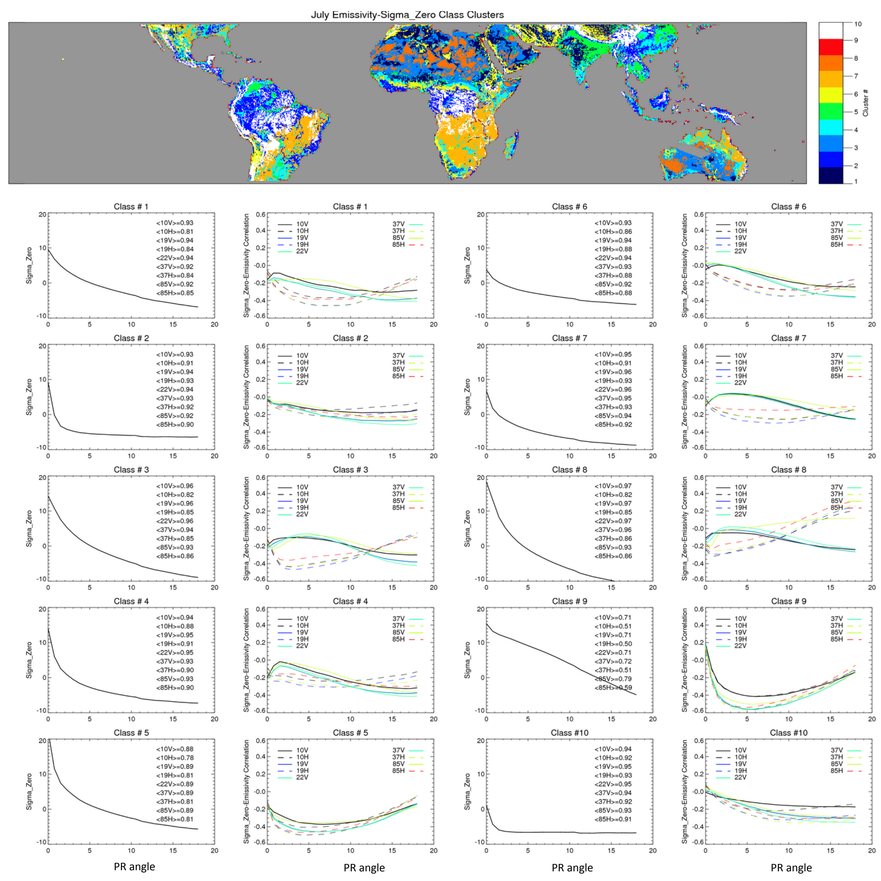
Backscatter increases with soil moisture.
Emissivity decreases with soil moisture.



Purely a cartoon, qualitative description, not to scale



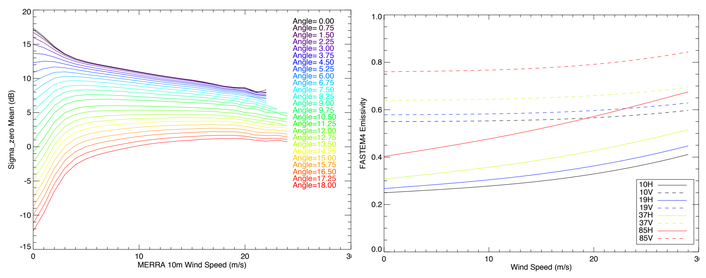


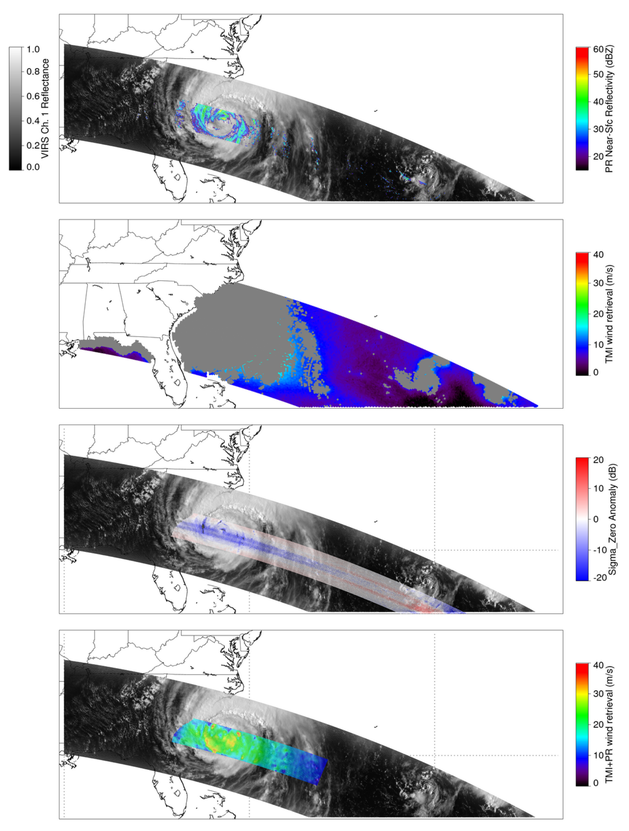


A database of co-located σ_0 and emissivity estimates is being built from the entire 15-year TRMM record. This database is precipitation and (optionally) cloud-cleared. Emissivities are estimated using the MERRA or VIRS-derived skin temperature (for cloud-cleared scenes) and MERRA atmospheric profile. For each month, the emissivity-σ_0 covariance matrix is computed for every 0.25° grid box for each PR angle bin (above images are a sample of this database).

Self-similar surfaces are identified and clustered as shown above. The emissivity spectrum and angular dependence of σ_0 display many different behaviors for the different clusters, as a result of differences in vegetation cover, surface roughness, water coverage. The angular and frequency dependence of the correlation between σ_0 and emissivity is also highly variable between the different clusters.

Water surface application: Coupled Radar-Radiometer Wind Retrieval



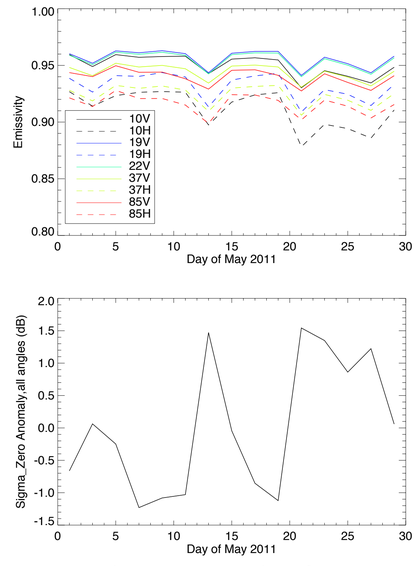


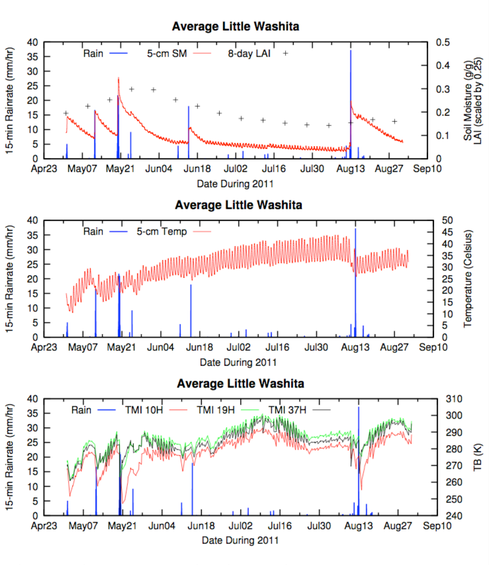
The radar reflectivity cross-section is most sensitive to wind at low wind speeds, whereas emissivity is more sensitive at high speeds. Combining both results in better constraint across full wind spectrum and improved estimates of cloud water (which does not significantly attenuate σ_0 but impacts radiometer Tbs). In raining regions, the combined approach can be used to simultaneously estimate surface wind and path-integrated attenuation from rain, although there is some ambiguity because PIA is dependent upon the rain DSD. This ambiguity should be reduced in the GPM era because DPR will provide additional constraints on the DSD and PIA.

This example retrieval of the wind field near Hurricane Irene (2011) illustrates the feasibility of such retrievals. Note that the calm eye region and surrounding eyewall windfield are represented, even in the presence of heavy rain.

Land surface application: Soil moisture

The inverse relationship observed between σ_0 and emissivity over most land areas is largely a function of soil moisture. In the plots below, the occurrence of negative emissivity anomalies and positive σ_0 anomalies is coincident with high soil moisture due to rain events. Knowledge of soil moisture (via coincident estimation from TMI or interpolation of time series) can be used to reduce the uncertainty in PIA over land, where σ_0 variability is higher than over water, and ensure consistency between the σ_0 and emissivity values used in the combined rainfall algorithm.





TRMM Observations and Surface Properties of Little Washita Watershed, OK during MC3E