Latest Improvements on Microwave Emissivity Models for GPM Applications

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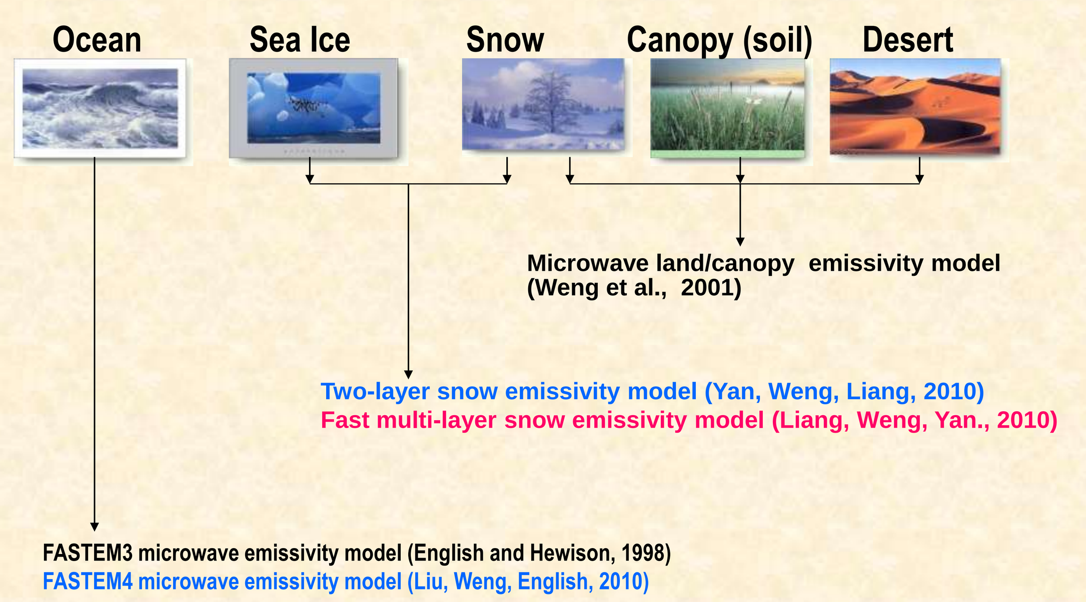
Abstract

Satellite microwave(MW) observation is a primary data source for global precipitation estimation. While water-vapor channels provide direct information about the water contents of upper atmospheric layers, window channels, which are characterized by underlying surfaces, play essential role in studying the water vapor exchange between the atmosphere and the underlying surfaces. More and more efforts have been made to assimilate the window channel data into NWP systems. TMI, SSM/I, SSMIS, and AMSU data of window channels are now routinely used for global precipitation retrievals, where surface emissivity is one of the most sensitive parameters affecting the retrieval quality and precipitation estimation result. This study shows our latest efforts in improving surface microwave emissivity models, and in particular the modeling over ocean, bare soil and vegetations.

Surface Microwave Emissivity Models



Highlights of Model Improvements

❑**Open water** – Quasi-specular fast model (FASTEM)

- **Improvement of surface roughness by accounting for surface layer wave and turbulent instabilities and wave developing stages FASTEM4,** Liu, Weng, and English, TGRS, 2011
- **Improvements at low frequencies below 20 GHz and high frequencies above 85 GHz FASTEM5,** Liu, Weng, and English, 2011

❑**Bare soil** – Coherent reflection and surface roughness correction

- **Improvement of soil dielectric model by accounting for the effect of bond-water in lower frequency range and the effect of soil texture on soil static conductivity**
- **Improvement of soil roughness correction as the function of angular and surface correlation length in the range of 1GHz to 200GHz**
- **Implementation of ORNL global soil texture and water-holding map** Chen and Weng, 2011

❑**Canopy** – Four layer scattering model

- **Improvement of multi-scattering parameterization**
- **Implementation of IGBP surface type classification and global mapping,** Chen and Weng, 2011

❑**Snow/desert** – Random condensed media model

- **Two-layer snow microwave emissivity model** Yan, Weng, and Liang, 2010
- **Desert microwave emissivity library** Yan and Weng, TGRS,2011

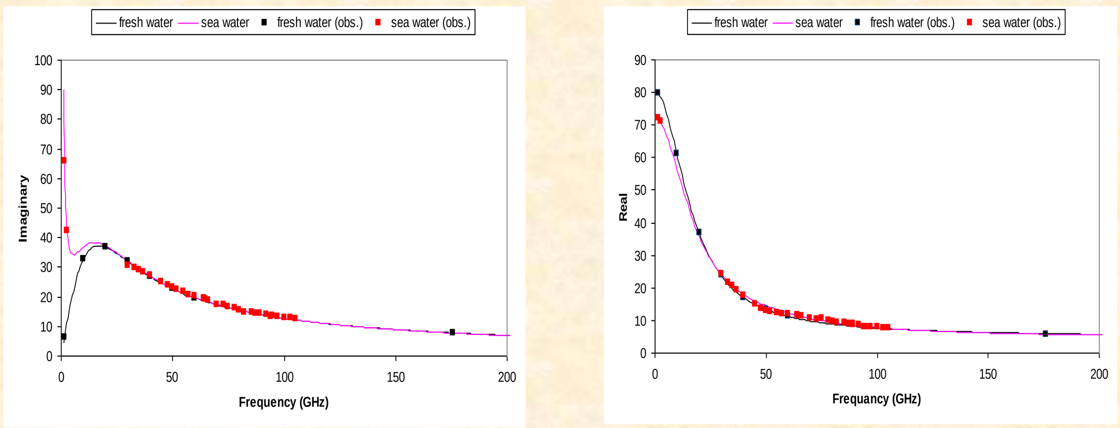
Ocean Surface Microwave Emissivity Modeling

Ocean Water Dielectric Constant

By neglecting intermolecular interaction, Debye (1929) proposed an approximate equation to describe the dielectric constant of liquid water. The intermolecular interaction was considered as the second polarization in a double Debye model (Ellison et al., 2003).

$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_1}{1 + j2\pi f\tau_1} + \frac{\varepsilon_1 - \varepsilon_\infty}{1 + j2\pi f\tau_2} + j\frac{\alpha}{2\pi f\varepsilon_0}$$

The parameters of the equation are a function of sea surface temperature or salinity or both. By fitting to measurements between 1.4 and 410 GHz, we have validated and extended the model to 200GHz.

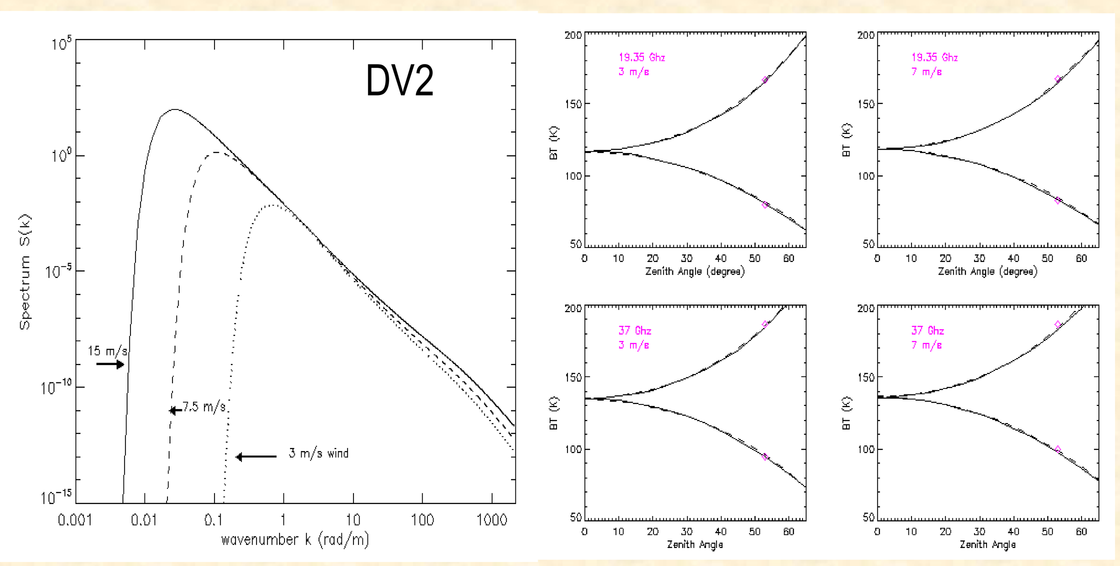


Ocean Surface Roughness

Sea surface roughness is mainly driven by surface wind vector, but using wind vector alone cannot fully describe the surface roughness since sea surface boundary stability and wave development stage affect the roughness, too.

The full wave model developed by Durden and Vesecky (1985) was modified and improved (referred to as DV2).

Omni-directional spectrum

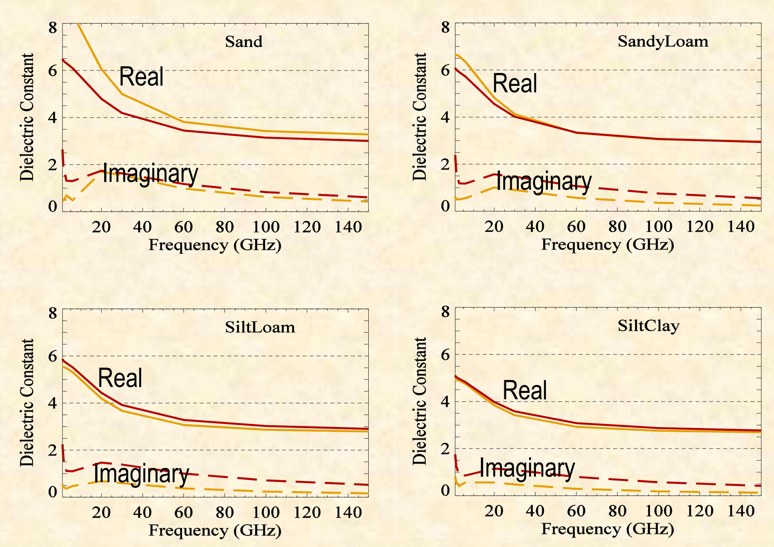


Variation of the surface brightness temperature at 19.35 GHz and 37 GHz to zenith angles. The sea surface temperature is 12 °C and the salinity is 35 ‰. Solid and dashed lines represent detailed two-scale and fast emissivity model simulations.

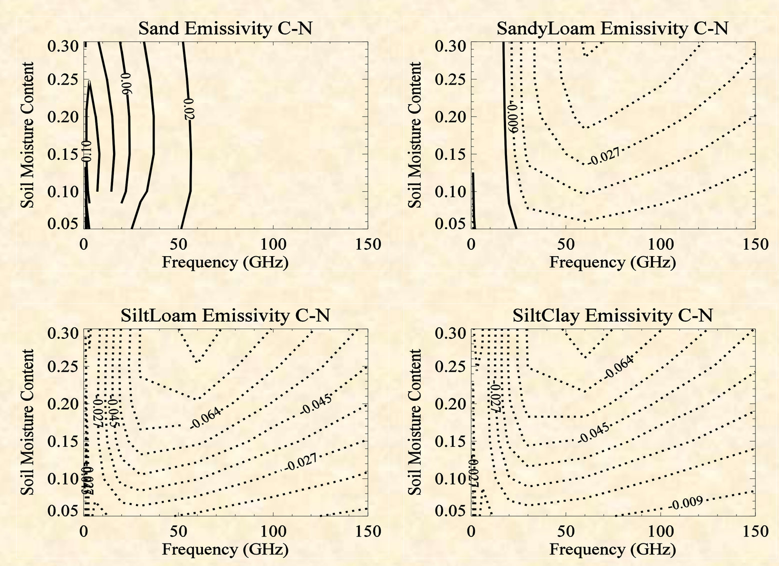
Land Surface Microwave Emissivity Modeling

Soil Dielectric Constant

- ○ Different mixing formulations for the real and imaginary parts
- ○ Different models for the lower and higher frequency bands
- ○ Bound-water effect on lower frequency range

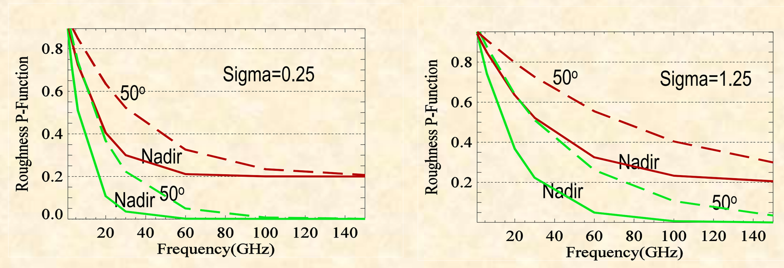


Effects of the New Soil Dielectric Constant Model on Surface Emissivity by Soil Types

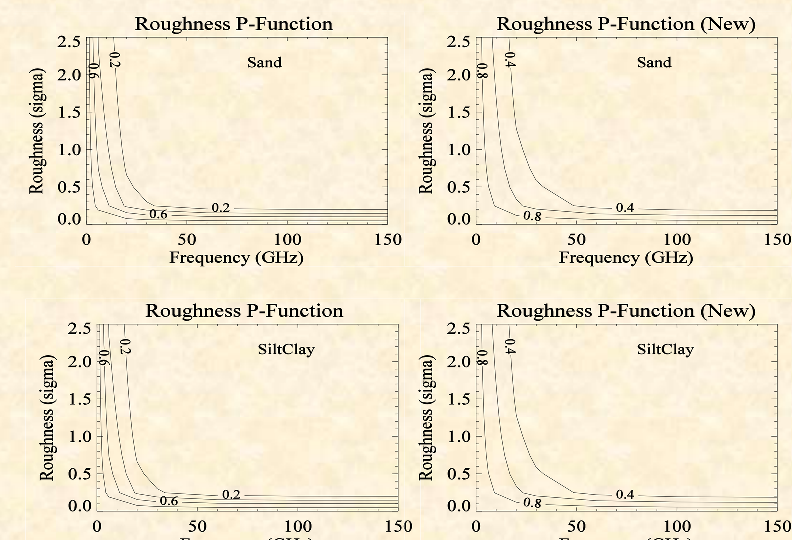


Soil Roughness Corrections

○ New model with proper asymptotic polarization properties at extreme low and high frequencies and with angular dependency of polarization

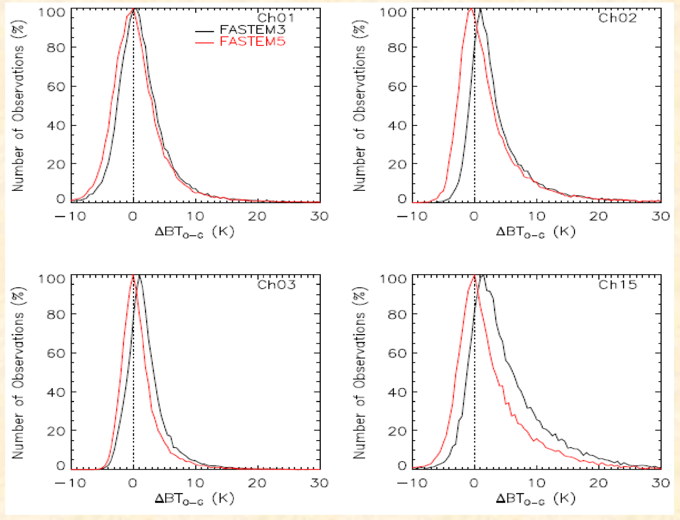


○ Soil-type dependency of polarization correction



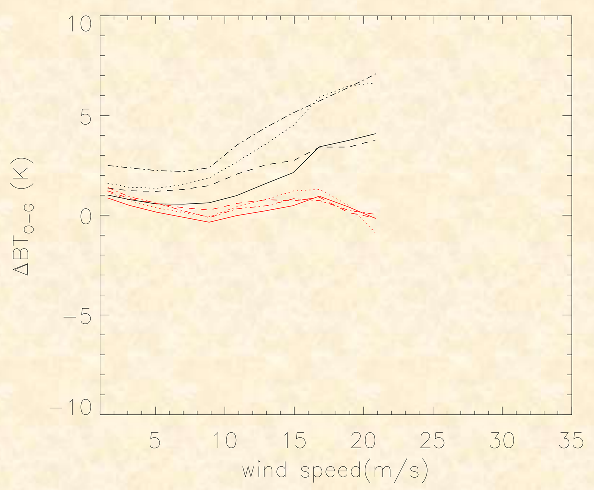
Results

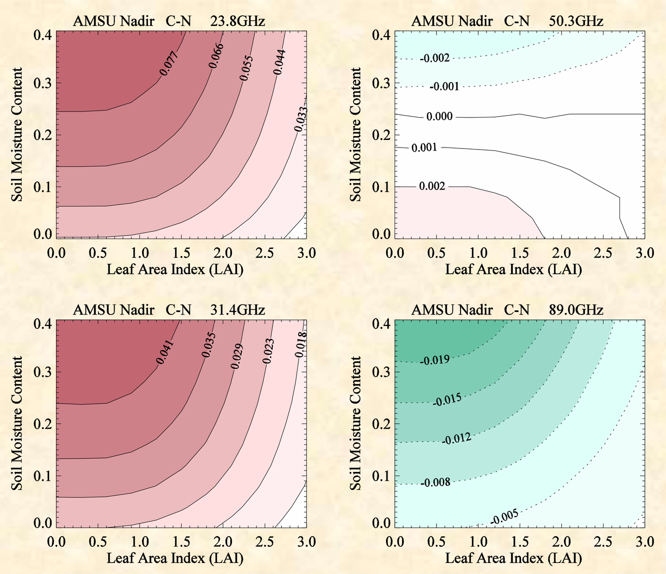
FASTEM5 has been validated using ECMWF model data and the collocated satellite measurements. The model is tested using the NCEP GSI DATA Assimilation System GSI (see the following figures).



Observed – simulated BT for AMSU-A Channels 1, 2, 3, and 15.

Variations of the Observed – simulated BT for AMSU-A Channels 1, 2, 3, and 15 to ocean surface wind speeds. The black lines are using FASTEM3 and red lines are using FASTEM5.





AMSU Emissivity difference (Current minus New Model), which is averaged over horizontal and vertical by the angular weights.

Summary

1. The emissivity is very sensitive to the real part of dielectric constant, which actually determines volume scattering process in most emissivity models. Our new soil dielectric model shows significant improvements in low frequency bands (f < 50GHz).
2. Over smooth and moderately rough surfaces, soil roughness correction is very sensitive to the specification of roughness parameter, but approaches a saturated value when roughness variation becomes larger than 0.3-0.5.
3. For a specific land surface, roughness correction is very sensitive in low frequency bands, but doesn't vary so much when frequency is larger than 50GHz, which depends on the asymptotic property of soil model. Our new soil roughness correction model shows significant promising improvements in both low and high frequency ends over the range 1GHz-200GHz.

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