



Masking Effects of Surface Features – How Global Microwave Emissivities Place Measurable Bounds on the Problem



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Introduction

Microwave remote sensing from satellites is a valuable tool for observing Earth. Microwave satellite products showing such varied parameters as total precipitable water, precipitation, and sea ice are routinely produced and used by forecasters worldwide. Many satellite microwave retrievals are possible over ocean and not over land due to the complex, variable and poorly known microwave emissivity of land (and snow and ice) surfaces (Jones and Vonder Haar, 1997).

Modern weather satellites measure passive microwave radiation in the range from 6 to 183 GHz. Physical models have existed for decades which specify the dielectric properties of seawater in this frequency range as a function of a few variables such as sea surface temperature, wind speed, and salinity.

Knowledge of the viewing angle allows the dielectric properties to be converted into emissivity at vertical and horizontal polarizations. Over oceans, the surface emissivity ranges from about 0.5 to 0.7. Over land and ice, the surface is more complex due to variable surface types and vegetation. A typical emissivity value over land might be 0.95, much higher than over ocean. The higher emissivity itself makes it more difficult to sense atmospheric phenomena over land, since the surface appears radiometrically brighter. In addition, time-dependent changes in the surface, such as soil moisture and the seasonal cycle of vegetation, affect the emissivity.

GOALS

Our goals are to:

1. Conduct an error analysis of the MEM model via creation of a Global Microwave Surface Emissivity Validation Atlas (GMSEVA).
2. Generalize the error characterization approach to future NESDIS/NWS Observational Operator (OO) needs including new microwave sensors.
3. A parallel goal is to perform a simultaneous retrieval of water vapor, cloud and temperature profiles over land (Forsythe et al., 2005).

Physical Basis

The retrieval is a 1D variational (1DVAR) physical retrieval using NOAA AMSU-A and AMSU-B satellite data. AFWA AGRMET land surface model data is used as a first guess as well as NOAA GDAS atmospheric model output data.

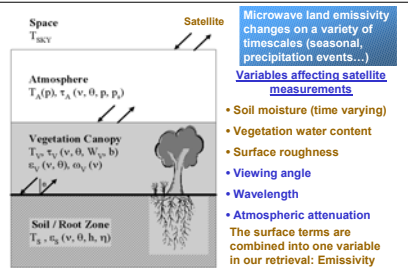
$$\Phi = (x - x_a)^T S_a^{-1} (x - x_a) + [y - F(x)]^T S_y^{-1} [y - F(x)]$$

Cost of retrieved atmosphere versus background atmosphere Cost of satellite measurements versus calculated radiances

- Physical Basis: Minimize cost function**
- Retrieval iterates [a] radiative transfer model to minimize cost. Analytic Jacobian implemented for speed.
 - Physical retrieval allows new instruments to be added easily

Key Feature: Can be Forecast Model Independent

Properties of Microwave Emissivity



Typical land value: 0.95
Typical ocean value: 0.5
(Greater dynamic range than infrared emissivity)

$$\text{Emissivity} = \frac{\text{Emitted Radiation at } \lambda}{\text{Blackbody Radiance at } \lambda}$$

Measured from satellite

Function of skin temperature

- If we could measure radiation only from surface, and independently measure surface temperature, we could measure emissivity.
- But clouds and the atmosphere affect our measurements... so we retrieve them simultaneously with emissivity via an optimal estimation approach

RESULTS

The impact of the AMSU-B Antenna Pattern Correction (APC) over ocean surfaces can be considerable (e.g., 0-15% bias adjustments in the upper tropospheric water vapor fields) (Nielsen et al., 2005).

AMSU-B APC 1DVAR Impacts Ocean 1DVAR Retrieval Validation

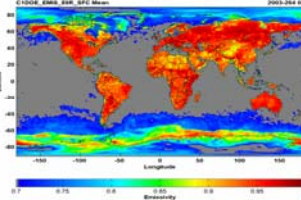
AMSU-B APC

Retrieved Variable	Mean Retrieval Difference (with APC - without APC) (variable units)	Mean Difference (%)	
Surface temperature	0.02 K	0.1	
23 GHz emissivity	-0.007	-1.4	noticeable impact over oceans
31 GHz	-0.007	-1.3	
50 GHz	-0.007	-1.3	
89 GHz	-0.007	-1.1	greatest impact
183 GHz	-0.007	-0.9	
300 hPa mixing ratio	0.002 g/kg	10.6	
500 hPa	0.013 g/kg	14.8	
700 hPa	0.061 g/kg	2.3	
850 hPa	0.430 g/kg	6.9	
1000 hPa	0.750 g/kg	5.7	
200 hPa temperature	0.36 K	0.2	
500 hPa	0.37 K	0.1	
700 hPa	0.41 K	0.1	
850 hPa	0.34 K	0.1	
1000 hPa	0.32 K	0.1	

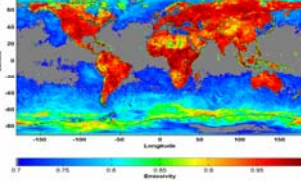


CSUCIRA Dr. Andrew S. Jones JCSDA Science Workshop on Satellite Data Assimilation, 20-21 April 2005

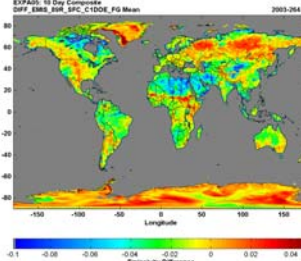
89 GHz



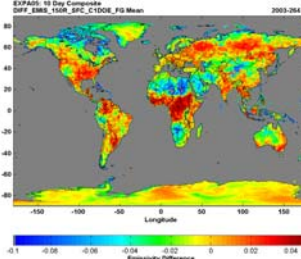
150 GHz



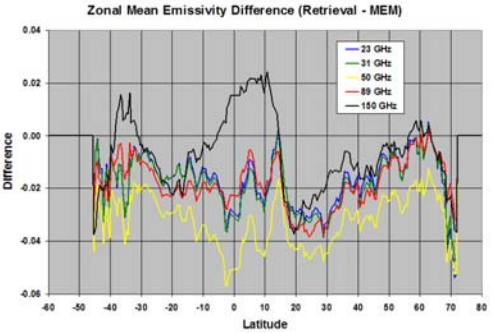
89 GHz Difference (Retrieval - MEM)



150 GHz Difference (Retrieval - MEM)



The microwave emissivity results are intercompared to the NOAA Microwave Emissivity Model (MEM) (Weng et al., 2001). Differences can be locally large (> 0.1). Most of the biases are in the desert regions, and in low vegetated tundra regions. Littoral and riverine areas are also poorly represented in the MEM model output. These results will be used to improve the MEM performance.



The results show lower emissivities in the desert regions and in the low vegetated tundra regions, and in ice conditions. High emissivities exist in heavily vegetated regions. Gray regions denote either the lack of satellite data or the presence of precipitation. Emissivities below 0.7 are also gray.

The emissivity results show good agreement with the MEM ($|\Delta\epsilon| < 0.02$) in 39-63% of the areas, depending on frequency. All frequencies are simultaneously in good agreement in approximately 15% of the areas. There are substantial challenges for the MEM to overcome. This includes a strong positive bias in deserts and regions of low vegetated tundra, especially in the Sahara Desert and the Middle East in general at the higher frequencies. Littoral and Riverine areas are also poorly represented. This is primarily a problem with mixed pixels that contain surface water features and poorly known fractional vegetation amounts. Local emissivity bias differences can be substantial ($|\Delta\epsilon| > 0.1$).

The global average difference at 50 GHz tends to be larger than the other frequencies. Only 39% of the 50 GHz emissivities were in good agreement. This can also be seen in the zonal mean microwave emissivity results above.

Conclusions

The system is capable of retrieving microwave emissivity globally in near real time. The primary focus of the work will be to facilitate continued microwave emissivity intercomparison studies, validation against other sources, and the application of this new data source toward atmospheric profile retrievals over land surfaces.

In the future, these results will be used for continued atmospheric profiling improvements over land surfaces within traditional satellite retrieval systems, and in more advanced data assimilation systems. In the short-term it may be possible to generate simple static bias adjustments to the operational MEM to improve current use of microwave data over land. Longer-term this work will lead toward a dynamic near real-time emissivity product which should result in improvements for changing snow and ice conditions, and in operational MEM quality monitoring. Also future studies will include additional microwave sensors, e.g., the CORIOLIS WindSat and the DMSP SSMIS, to expand the scope of this study. As a result of this work, microwave satellites will become more useful over land, thus expanding their current operational use by 25%.

References

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