NPOESS Soil Moisture Satellite Data Assimilation Research using WindSat Data

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INTRODUCTION

The primary objective of this work is to enhance the utility of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) soil moisture data by converting passive microwave sensor data records (SDRs) to soil moisture depth profiles using satellite data assimilation techniques. Other objectives are: mitigating the impacts of radio frequency interference (RFI) noise and improving the understanding of surface masking effects.

CORIOLIS WindSat passive microwave data are used as a surrogate for future NPOESS passive microwave sensor data. These substitute data allow the data assimilation techniques to be tested.

As part of this study we are also conducting validation activities for proper use of the satellite data assimilation techniques and for estimating the performance of the deep soil moisture method.

GOALS

This work is used to develop:
1) a four-dimensional data assimilation (4DDA) methodology to retrieve deep soil moisture profiles using the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and other associated data,
2) a discrete Backus-Gilbert (DBG)-based methodology for reducing the radio frequency interference impacts at 6 and 10 GHz, and
3) a methodology for better spatial mapping of the masking effects caused by surface features (i.e., vegetative cover and surface roughness.

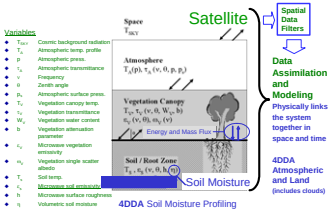
APPLICATIONS

This work contributes to several areas of interest:

1. More accurate probability estimates of mobility and trafficability
2. Improved hydrologic forecasting capabilities
3. Improved NWP land surface initialization
4. Better understanding of atmospheric/land interactions
5. More accurate agricultural assessments

SOIL MOISTURE PHYSICS

Microwave Soil Moisture Physics



4DDA DEEP SOIL MOISTURE ESTIMATES

Direct remote sensing: Only Surface Soil Moisture
4DDA methods: Soil Moisture Profiles (up to 1m depths)

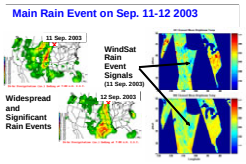
What makes this possible?
1. Diurnal soil moisture signal in land/atmos. physics
2. Use of temporal nature of the satellite data sets
3. Availability of good land surface models that can characterize the diurnal effects as a function of soil moisture

How long does it take to get results using the 4DDA method?
This is an open research question, however research literature indicates that a ~3 day integration time is required. Some aspects of the 4DDA method would be more immediate (for example, near the surface, new data impacts would be nearly immediate).

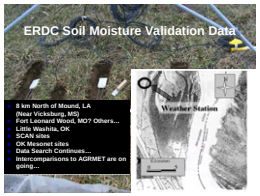
How is the WindSat data used? WindSat is sensitive to surface soil moisture variations. By matching those variations to the atmospheric/land surface model system, the soil moisture information in deeper levels can be inferred through its impact on the diurnal land/atmos. physics.

4DDA SOIL MOISTURE EXPERIMENT

Our case study is selected for the month of September 2003. This month had good WindSat data coverage, availability of in situ soil moisture data sets, and wide-spread rain events which were easily observed by WindSat.

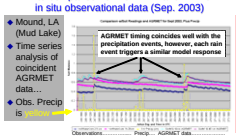


CAL/VAL

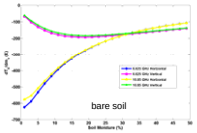


OK Mesonet
Soil Moisture
Site Locations

Intercomparison of AGRMET and ERDC in situ observational data (Sep. 2003)

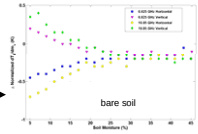


RADIATIVE TRANSFER SENSITIVITIES

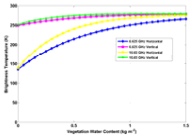


The CSU Microwave Land Surface Model (MWLSM) sensitivities to soil moisture are quite large

An intercomparison of the MWLSM to the NPOESS CMIS Model (CM) shows normalized sensitivity differences < 0.75 K.

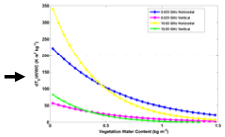


VEGETATION IMPACTS

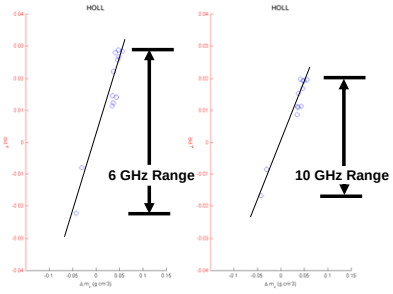


Vegetation masking effects such as vegetation water content reduce the brightness temperature information content

The sensitivity to vegetation water content is greatest at low vegetation amounts. The 6H and 10H channels are the most useful to mitigate the vegetation impacts.



6 GHz vs. 10 GHz



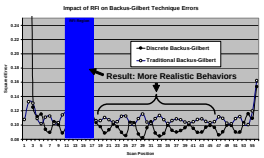
Frequency Polarization Ratio Perturbations (ΔPR) vs. AGRMET Soil Moisture Perturbations (Δm_v): (left) 6 GHz, (right) 10 GHz.

WindSat observational results show that the 6 GHz channels are approximately 43% more sensitive to soil moisture than the 10 GHz channels.

This result was obtained by comparing temporal perturbations of the normalized polarization ratios (PR) to AGRMET model soil moisture values for the HOLL site location (one of the RFI-free sites in OK) (Rapp, 2006). The AGRMET soil moisture temporal perturbation range for HOLL was ~10% in absolute SM units, or ~25% of the expected dynamic soil moisture range for the site. Larger rainfall events may have different frequency-dependent soil moisture responses due to soil saturation and surface flooding effects, etc.

ISOLATION OF RFI IMPACTS

The goals of satellite spatial filters such as the Backus-Gilbert (BG) technique are to enhance the satellite data spatial resolution and/or to improve the sensor spatial coregistration behaviors. Spatial coregistration is beneficial since spatial resolution is a function of sensor frequency (lower frequency data results in a larger footprint size). The BG methods rely upon precomputed coefficients that create modified data at a resolution different from the original sensor resolution. However in radio frequency interference (RFI) contaminated environments, the data error characteristics are dynamic. Thus a new dynamic Discrete Backus-Gilbert (DBG) method has been created for use in RFI noise environments. The improvement using DBG is shown below.



Horizontal Cross-track Scan Position

CONCLUSIONS

Conclusions

1) **6 GHz data has been shown to have approximately 43% more value than the 10 GHz data sets** at the HOLL OK mesonet site.
2) A new approach has been created to use RFI-impacted microwave radiometer data (Stephens and Jones, 2002; 2006a; 2006b).
3) The 4DDA experiment using WindSat observations is in its last research phase. The WindSat observational operator is using the radiative transfer model (RTM) parameters from Rapp (2006) study. Initialization is now complete for all 4DDA fields for the Sep. 12-13 and Sep. 17-19 WindSat experiments. We are currently diagnosing 4DDA minimization cycle-script behaviors.
4) **The primary future research needs are…**
   a) Refinement of RTM calibration procedures in preparation for a future NPOESS soil moisture sensor is needed. (We found polarization ratios and the AGRMET data set particularly useful for the model calibration/ phenomenology studies – we also expect our new global microwave emissivity retrieval capabilities to be useful in future work).
   b) Re-examination of systematic RTM bias sources is needed. Root-mean-square (RMS) RTM errors were on the order of 4-6 K, indicating that additional RTM calibration improvements are possible. Most of our WindSat work to date has focused on RMS error analysis and related physical phenomologies. Our initial results indicate that additional emphasis should be given to reducing systematic RTM errors.
   c) Longer time-domain analysis on the order of ~6-12 months is needed to capture more of the soil moisture dynamic range and associated event behaviors within the RTM calibration process.

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