Initial test results using a temporal variational data assimilation method to retrieve deep soil moisture

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INTRODUCTION

Deep soil moisture data retrievals are needed to:

- accurately provide probability estimates of mobility,
- better support countermine operations,
- improve hydrological forecasting, regional Numerical Weather Prediction (NWP) performance, and boundary layer specification.

The ARL is leading a joint effort with CIRA and ERDC/GSL to develop this capability. This capability will use passive microwave data from the future operational polar-orbiting environmental satellites. Passive microwave data from the WindSat satellite are being used as a pathfinder for future microwave instruments. A four-dimensional data assimilation (4DDA) method has been created that performs a temporal assimilation analysis of the microwave sensor data to retrieve deep soil moisture.

4DDA APPROACH

4DDA SYSTEM COMPONENTS:

1. The Land Ecosystem-Atmosphere Feedback (LEAF-2) Land Surface Model (LSM).
2. The CIRA 1DVAR Optimal Estimator (C1DOE) satellite processing software that collocates several data sources onto one common grid.
3. The Fletcher non-Gaussian 4DDA MATLAB codes which are the "solver" for the 4DDA deep soil moisture retrieval system. The microwave data are used directly within this component.

The integrated system is now being implemented in the Air Force Weather Agency (AFWA) Land Information System (LIS). The 4DDA approach results in global 1-25 km soil moisture estimates. The inputs to the 4DDA system will be surface soil moisture products from available passive microwave sensors. High-resolution enhancement methods using terrain data are available to disaggregate the 4DDA output products down to 10-15 m grid scales.

4DDA DEEP SOIL MOISTURE ESTIMATES

DA methods can retrieve Soil Moisture Profiles (up to 1m depths), while direct remote sensing can only retrieve surface soil moisture.

What makes deep retrievals possible?

- Diurnal soil moisture signal in land/atmosphere physics
- Temporal nature of the satellite data sets
- 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? Our results indicate that 7-14 days of integration time is necessary to reach 1 m soil depths, however shallower depths (~ 10 cm) are reached in ~3 days of integration time or less.

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

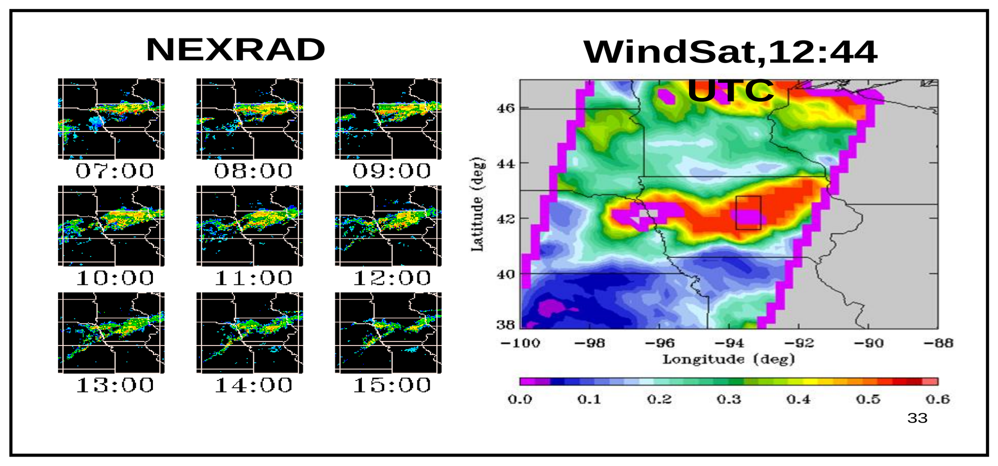

Figure 1: NRL soil moisture retrieval data from Dr. Li, 25 June 2003: (Left) Nexrad precipitation radar reflectivity data, (Right) WindSat surface soil moisture retrieval using the soil moisture EDR baseline algorithm.

Li Li (Navy Research Laboratory (NRL)) is the WindSat soil moisture EDR lead scientist. Dr. Li's algorithm results using surrogate WindSat data (Figure 1) indicate good performance using the surface soil moisture algorithm. Additional testing and science improvements to the soil moisture algorithm are underway. These data products will be used as input into the 4DDA deep soil moisture algorithm.

PHYSICAL BASIS ADJOINT SENSITIVITY RESULTS

The single-observation adjoint sensitivities are shown in Figure 2. The adjoints are integrated backwards in time from day 21 to the initial condition time, $t = 0$. The results are normalized adjoint sensitivities. These tests confirm the feasibility of the deep soil moisture 4DDA retrieval and that a temporal deep soil moisture signal is present. Initial porting tests of the system to DoD High Performance Computing (HPC) platforms is underway.

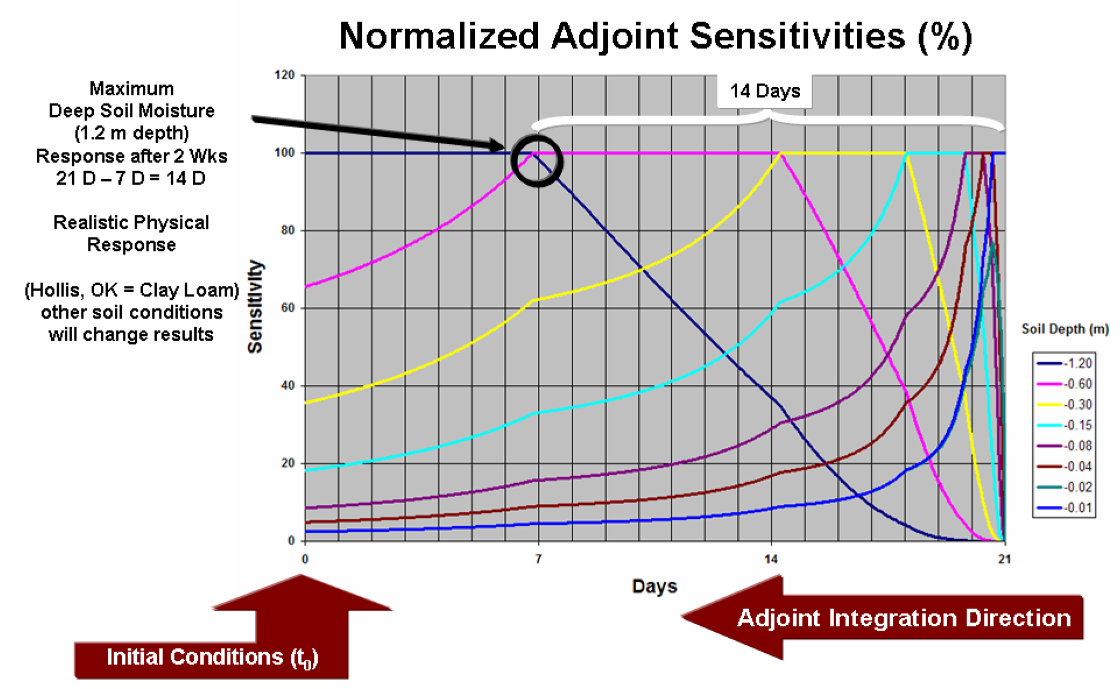

Figure 2: Normalized adjoint sensitivity results for Hollis, OK case study. Deep soil moisture at a depth of approximately 1 m has the largest sensitivity in the integration time period of 0-7 days. This indicates the strong deep soil moisture sensitivity as a function of soil depth with time.

VEHICLE TRAFFICABILITY RESULTS

Soil strength, soil slope, and roughness information at high resolution were used to estimate vehicle speeds. These results show how the satellite soil moisture information can be used with land surface model output for Army needs (Figure 3).

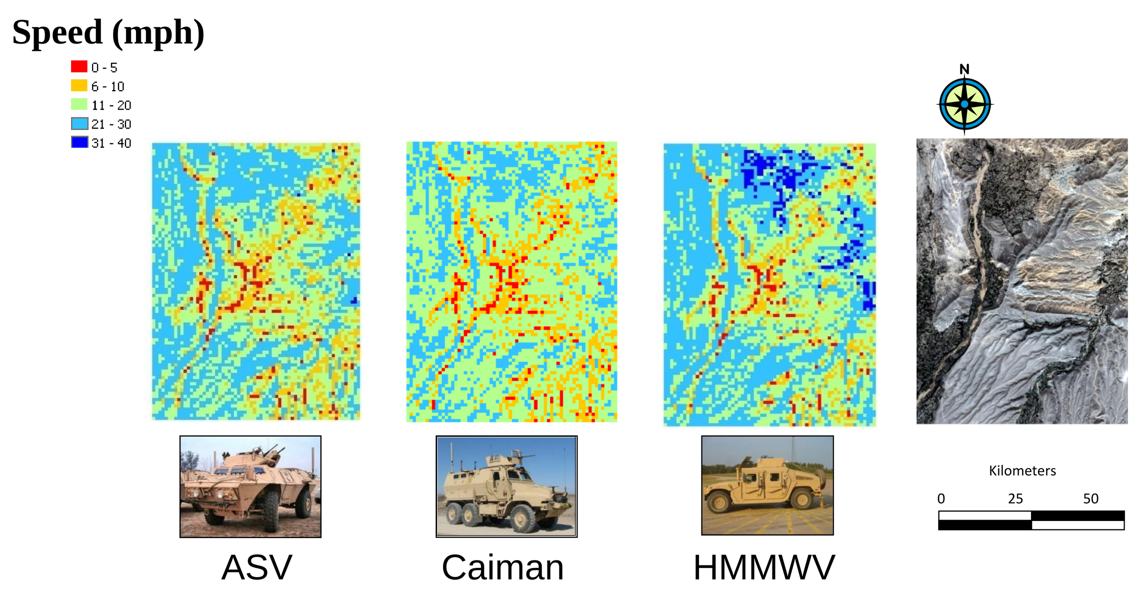

Figure 3: Mobility predictions using a two-layer NATO Reference Mobility Model for 3 vehicles from a quad in Afghanistan using WindSat and AFWA LIS data sets at 25 and 1 km resolutions.

SUMMARY

MAJOR ACCOMPLISHMENTS:

- Completed the individual component tests of the deep soil moisture methodology
- Defined the soil moisture error budget estimates
- Tested a deep soil moisture methodology

MAJOR OBJECTIVES:

1) Highest spatial resolution possible
2) Quantifiable high performance accuracy
3) Full operational support systems integration

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