A temporal variational data assimilation method suitable for deep soil moisture retrievals using passive microwave radiometer data

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A key environmental variable is deep soil moisture. Soil moisture at depth significantly impacts DoD-related trafficability, off-road mobility, hydrological stream flow estimation, counter-mine operations, target detection, background simulation, and strategic planning of mission operations. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) threshold Soil Moisture Environmental Data Record (EDR) requirement is for near-surface soil moisture estimates (Li et al., 2010). This work enhances the NPOESS Soil Moisture EDR toward objective performance at deep soil levels. Our goal is to identify a pathway to the soil moisture performance objective (soil moisture at depths between 0-80 cm) for US Army and civilian use, and to identify and mitigate algorithm impediments to its potential performance. Interactions and community involvement with a variety of agencies that will use the NPOESS surface and deep soil moisture products are also underway (Jones et al., 2010).

A temporal variational data assimilation methodology (Jones et al., 2004) is used to derive deep soil moisture profile sensitivities and tendencies for use with future NPOESS Microwave Imager Sounder (MIS) data. The MIS sensor is a low-frequency conical-scanning passive microwave radiometer. Surface soil moisture retrieval results from the Navy Coriolis WindSat instrument indicate good performance at the surface by existing passive microwave direct retrieval methods (Li et al., 2010). This work extends those surface estimates to deep soil levels, by using their temporal behaviors within a variational data assimilation system.

Our results indicate that the depth penetration of the soil moisture information with time is dependent on soil texture information, and in particular, the soil hydraulic conductivity parameter. A majority of soils show very deep soil moisture sensitivity penetration (>100 cm soil depths) after approximately 7-14 days of temporal data assimilation. Some soils require longer integration times. Examples of the deep soil moisture signal from the temporal adjoint sensitivity studies will be presented. The land surface model and its respective adjoint sensitivities are used in a 4DVAR solver. We have adopted the Fletcher non-Gaussian 4DVAR framework since soil moisture variables have skewed data distributions, and are therefore non-Gaussian. The 4DVAR solver component tests are based on lognormal probability distributions.

We have successfully completed our individual system component tests. These components include 1) a software test system, 2) a land surface model and its adjoint based on a full Richard's equation land surface model solver, and 3) a new 4D variational (4DVAR) lognormal data assimilation framework. In addition, a fourth post-processing spatial resolution enhancement component is under testing at CSU by Prof. Niemann for very high resolution disaggregation of the results using high-resolution Digital Elevation Model (DEM) data sets and land surface model-assisted methodologies. This analysis method will allow us to estimate soil moisture using NPOESS MIS data at horizontal scales of 5-15 meters. Testing at 15 meter grid spacing has shown considerable skill when compared to high-resolution observations. Additional observational verification using in situ comparisons were also performed against the land surface model outputs which are used in the initial estimation of the 4DVAR background error covariance fields (Combs et al., 2007; Lakhankar et al., 2008; 2009).

Our current focus is full system integration within targeted operational architectures. The components are being integrated into the development version of the Air Force Weather Agency (AFWA) – Land Information System (LIS). Design details of the various system components will be discussed.

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