Development of an Ensemble Kalman Filter for Land Surface Data Assimilation of Soil Moisture Brightness Temperatures

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1. Introduction

Over the last decade it has become increasingly clear that an accurate initialization of soil moisture is fundamentally important for skillful weather and climate predictions [1, 2]. Soil moisture influences the partitioning of the incoming energy into latent and sensible heat fluxes, which in turn exert an important control upon land-atmosphere interactions. A major obstacle to the inclusion of soil moisture information in Numerical Weather Prediction (NWP) models has been the sparse network of ground-based soil moisture measurements. The launch of the Soil Moisture and Ocean Salinity (SMOS) mission by the European Space Agency (ESA) in November 2009 will provide a first opportunity to examine global L-band soil moisture brightness temperatures.

In an effort to improve the representation of the land-surface in their operational NWP models, the Meteorological Research Division of Environment Canada is currently developing the Canadian Land Data Assimilation System (CaLDAS). The core component of CaLDAS is the external land surface model driven by three types of information: geophysical land surface characteristics, atmospheric forcing, and initial conditions. An important emphasis within CaLDAS has been placed upon the assimilation of space-based remote sensing data for soil moisture, snow parameters, and vegetation.

The Ensemble Kalman Filter (EnKF) assimilation technique has shown considerable promise as a viable assimilation approach for the initialization of soil moisture in land surface models. Numerous studies have demonstrated the positive impacts of experimental versions of the EnKF for selected case studies within the context of both real and idealized experiments [3, 4, 5, 6]. Within the science of data assimilation the key to success rests largely with the accurate specification of the input error parameters [7, 8, 9]. In particular, the calculation or specification of the model error covariances, so-called error covariance modeling, is a challenging task [8]. For these reasons during the development of CaLDAS efforts have been focused upon approaches to model background errors by perturbing both the atmospheric forcing data and geophysical fields (albedo, roughness, vegetation fraction, etc …) in order to generate a sufficient spread among ensemble members which is crucial to the optimum performance of the EnKF. A version of CaLDAS which uses the EnKF assimilation method has been coded within the Supervisor Monitor Scheduler (SMS) task sequencer environment. This study reports upon a series of soil moisture assimilation experiments using the EnKF and will point to future development directions.

2. Assimilation Experiments

To examine the performance and to determine the optimal configuration of the EnKF a series of idealized soil moisture convergence experiments were performed. The study domain selected for these experiments was the Great Lakes region of North America. An open loop simulation starting on 1 July 2007 with wet initial conditions (both soil moisture reservoirs of the ISBA land surface model set to field capacity) was integrated for the entire month of July 2007. Synthetic truth L-band brightness temperatures were generated every 6 hours from this open loop simulation using the Community Microwave Emission Model (CMEM). For the EnKF assimilation integration, each ensemble member was initialized with dry initial conditions (both soil moisture reservoirs of ISBA set to the wilting point) on 1 July 2007 and was subjected to perturbed precipitation, temperature and radiation forcing. The synthetic truth L-band brightness temperatures were assimilated and the convergence of the soil moisture was examined using a convergence index defined as the difference between the soil moisture from the EnKF integrations and the synthetic truth soil moisture, normalized by the soil moisture dynamic range.

Reasonable convergence is achieved for both superficial and root-zone soil moisture with the EnKF. The convergence of soil moisture was found to be sensitive to the number of ensemble members used and to the temporal frequency of assimilation. As expected, convergence increases as the number of ensemble members and the frequency of observations assimilated increase.

3. Future Work

A set of more realistic synthetic experiments are currently being prepared to evaluate the EnKF. For these experiments, the synthetic truth observations will be derived from a high-resolution simulation forced with higher-resolution geophysical fields than those used for the EnKF assimilation integration. We will also examine aspects related to the optimal combination of L-band satellite brightness temperatures with surface temperature and relative humidity data for an improved performance of the EnKF within an operational environment.

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