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A VARIATIONAL ASSIMILATION METHOD FOR SOIL MOISTURE ESTIMATION USING ACTIVE MICROWAVE DATA

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Abstract:

Microwave remote sensing systems are used to measure soil moisture on the basis of a large contrast that exists between the dielectric constant values for dry and wet soils. The potential of synthetic aperture radar (SAR) in spatial soil moisture monitoring depends on the ability of the applied methodology to define the complex relationship that exists between the backscattered energy and the characteristics of topographic and land-cover conditions. The backscattering signal from vegetated areas depends on: soil moisture content, surface roughness, and the vegetation canopy overlying the soil. However, instrument characteristics such as, angle of incidence, polarization, and frequency play important role on the performance of soil moisture estimation.

This work focuses on development of a variational data assimilation method for soil moisture estimation because of its general flexibility to treating any type of observation in conjunction with complex models. An inherent feature of the variational method is that it requires the availability of adjoint models, which is used within the variational data assimilation approach [1]. In this study, a microwave observational operator and its adjoint will be developed and tested (i.e., designed to work in concert with a suitable soil and land model).

The active microwave observational operator is complex, and before it is applied to the variational retrieval of soil moisture in conjunction with a soil and land model, we first focus on the adjoint development and on the related analysis of control parameters under a variety of conditions. This type of analysis relates directly to the sensitivity of microwave radiance observations to properties of the medium that is being observed. The adjoint sensitivity analysis is inherently independent of the data assimilation problem and the associated specification of the background covariance. The adjoint sensitivities have an ability to attribute cause and effect in a multivariate analysis.

The active microwave observational operator is an extension of the Integral Equation Model (IEM) [2] to make it more suitable to land surface model data assimilation use. In this study, the adjoint model is developed, and the information content of active microwave measurements sensitive to the land surface and soil parameters is analyzed. Various observational operator results and sensitivity analyses will be presented, demonstrating significant effectiveness of the operator for soil moisture data assimilation studies. This study focuses on the use of active satellite microwave observations (RADARSAT-1, 2 and ERS-1, 2). In constructing the adjoint of the forward model, all input variables and parameters were treated as candidate control variables. The base states were selected to be representative of nominal conditions. In addition, two linear perturbation model variants are also defined for better physical insight: a polarization (VV, HH, VH) difference perturbation operator and a frequency (1.8 GHz and 5.3 GHz) difference perturbation operator. The perturbation analysis of all input variables allows a relative variable response ranking to be performed. A comprehensive linear perturbation analysis is used to select five control variables (surface roughness, surface height, soil moisture, soil temperature, soil composition). The relative component strength analysis is used to deducing dominant control variable. The analysis indicates that the sensitivity ranking of the control variables is sensitive to the linear operator measure (e.g., frequency differences, and polarization difference).

Reference:

[1] A. S. Jones, T. Vukicevic, and T. H. Vonder-Haar, "A microwave satellite observational operator for variational data assimilation of soil moisture," *Journal of Hydrometeorology*, vol. 5, pp. 213-229, 2004.

[2] A. K. Fung, Z. Li, and K. S. Chen, "Backscattering from a randomly rough dielectric surface," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 30, pp. 799-808, 1992.