Deriving Soil Moisture with the combined L-band Radar and Radiometer Measurements

[1]Jiancheng Shi, [2]K.S Chen, [3]L. Tsang, [4]T. Jackson, [5]E. Njoku, [5]J. Van Zyl , [6]P. O' Neill, [7]D. Entekhabi, [8]J. Johnson, and [9]M. Moghaddam,

[1] ICESS, University of California Santa Barbara, CA 93106, USA, shi@icess.ucsb.edu;
[2] Center for Space and Remote Sensing Research, National Central University, Chung-Li, Taiwan, 32001, Republic of China
[3] Department of Electrical Engineering, Box 352500, University of Washington, Seattle, WA 98195-2500, USA
[4] USDA ARS Hydrology and Remote Sensing Lab, USA
[5] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[6] NASA GSFC Greenbelt, MD 20771, USA
[7] MIT, 15 Vassar St. Cambridge, MA, 02139, USA
[8] Department of Electrical and Computer Engineering, Ohio State University, 2015 Neil Avenue, Columbus, OH 43210, USA
[9] Department of Electrical Engineering and Computer Science, University of Michigan, 1301 Beal Avenue, Ann Arbor, MI 48109-2122, USA

Abstract

Soil moisture is a key parameter in numerous environmental studies, including hydrology, meteorology, and agriculture. It plays an important role in the interactions between the land surface and the atmosphere, as well as the partitioning of precipitation into runoff and ground water storage. Therefore, the spatial and temporal dynamics of soil moisture are important parameters for various processes in the soil-vegetation-atmosphere-interface. The Soil Moisture Active and Passive Mission (SMAP) with both Active/Passive L-band instruments has been approved by NASA for monitoring global soil moisture and freeze/thaw. The radar operates with VV, HH, and HV transmit-receive polarizations, and uses separate transmit frequencies for the H (1.26 GHz) and V (1.29 GHz) polarizations. The radiometer operates with V, H and U (third Stokes parameter) polarizations at 1.41 GHz.

In attempt to use the active or passive microwave remote sensors for estimation of soil moisture, we are mainly facing two common problems: effects of surface roughness and vegetation cover. Natural variability and the complexity of the vegetation canopy and surface roughness significantly affect the

sensitivity of backscattering and brightness temperature to soil moisture. Backscattering and brightness temperature signals from the vegetated areas is a function of water content and its spatial distribution as determined by vegetation structure and underlying surface conditions including surface roughness parameters and dielectric properties. Due to the limited observations from either passive or active measurements alone, an ill condition, the number of measurements and equations are less than the number of unknown, is expected. It results in the uncertainties in estimation of soil moisture.

It has been realized that both radar and radiometer measurements at L-band are affected by soil moisture, vegetation, surface roughness and temperature. However, how to take each instrument's advantages and avoid its disadvantages to develop a combined active/passive technique to estimate surface soil moisture need to be explored. In this study, we evaluate whether we can improve the soil moisture estimation accuracy by adding active measurements in compared with the passive observation alone.

We first simulated a database for both active and passive signals under SMAP's sensor configurations using the radiative transfer model with a wide range of conditions for surface soil moisture, roughness and vegetation properties that we considered as the random orientated disks, needles, and cylinders. Using this database, we evaluated the relationships between each backscattering and emission components. Through analyses of these relationships, we developed a technique to estimate surface soil moisture.

PALS is a non-scanning real aperture combined microwave radiometer and radar, operating at 1.41 and 2.69 GHz (radiometer) and 1.26 and 3.15 GHz (radar) with multiple polarizations. The instrument was designed for high accuracy measurements of ocean salinity and soil moisture. The radiometer operates at V (vertical) and H (horizontal) polarizations, while the radar operates at VV, HH, and VH polarizations. For SGP'99 and SMEX'02 the incidence angles were fixed at 38° and 45°, respectively. The instrument thus samples a single footprint track along the flight path. At a nominal flight altitude of 1 km and incidence anglesthe instantaneous 3-dB footprints at the surface are approximately 330 x 470 m. We will demonstrate this technique with the model simulated data and its validation with the airborne PALS image data from the soil moisture SGP'99 and SMEX'02 experimental data with ground soil moisture measurements. The test from the SMEX02 PALS measurements performed reasonable well with the RMSE of 4.7 % for volumetric soil moisture estimation.

References:

[1] Wu, T. D., K. S. Chen, J. Shi and A. K. Fung, "A Transition Model for the Reflection Coefficient in Surface Scattering", IEEE Transactions on Geoscience and Remote Sensing, Vol. 39, No. 9, pp. 2040-2050, Sept., 2001.

[2] Chen, K. S., T. D. Wu, L. Tsang, Qin Li, J. Shi and A. K. Fung, “The Emission of Rough Surfaces Calculated by the Integral Equation Method with a Comparison to a Three-Dimensional Moment Method Simulations”, IEEE Transactions on Geoscience and Remote Sensing, 41(1):90-101, Jan. 2003.

[3] Jackson, T. J. and D. M. Le Vine, “Mapping surface soil moisture using an aircraft-based passive microwave instrument: algorithm and example,” J. Hydrology, vol. 184, pp. 85-99, 1996.

[4] Freeman, A. and S. L. Durden, “A three-component scattering model for polarimetric SAR data”, IEEE Trans. Geosci. and Remote Sens., 36(3):963-973, May 1998.

[5] Wilson, W. J., S. H. Yueh, S. J. Dinardo, S. Chazanoff, F. K. Li, and Y. Rahmat-Samii, “Passive Active L- and S-band (PALS) microwave sensor for ocean salinity and soil moisture measurements,” IEEE Trans. Geosci. Rem. Sens., vol. 39, pp. 1039–1048, 2001.