MULTI-FREQUENCY INVESTIGATION INTO SCATTERING FROM VEGETATION OVER THE GROWTH CYCLE

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ABSTRACT

This paper reports on a recent field campaign that aims to collect time-series multi-frequency microwave data over winter wheat during the entire growth cycle. The data are being collected to characterize vegetation dynamics and to quantify its effects on soil moisture retrievals. A C-band radar was recently incorporated within the existing L-band radar/radiometer system called ComRAD (SMAP's ground based simulator) and an additional VHF receiver is being constructed as well. With C-band's ability to sense vegetation details and VHF's root-zone soil moisture within ComRAD's footprint, we will have an opportunity to test our 'discrete scatterer' vegetation models and parameters at various surface conditions. The purpose of this investigation is to determine optical depth and effective scattering albedo of vegetation of a given type (i.e. winter wheat) at various stages of growth that are needed to refine soil moisture retrieval algorithms for the SMAP mission.

Index Terms— Multi-frequency, vegetation, microwave

1. INTRODUCTION

Sensing vegetation biomass and underlying soil moisture is valuable to improved understanding of the Earth's water, energy, and carbon cycles, and to many applications of societal benefit. Microwave sensors are well suited for this due to their high sensitivity to land biophysical and hydrological features. However, retrieving parameters of interest from microwave measurements is a highly difficult task due to the complexity of microwave interactions with the Earth. For example, vegetation poses a challenge for soil moisture retrieval since the emission from soil is attenuated and scattered by the vegetation while the vegetation contributes its own emission. Similarly, variations in the underlying soil moisture make retrieval of biomass a challenging task since both the soil surface and vegetation canopy contribute together to the observed brightness temperature.

Appropriate corrections for biomass must be made in order to make reliable soil moisture estimation. In a similar manner, appropriate corrections for soil moisture are needed to make reliable biomass estimation. Concurrent multi-frequency observations can be an opportunity to investigate contributions emerging from different layers of vegetation and soil. Penetration depth into vegetation and soil is directly related to frequency. Longer wavelengths (i.e. P-band) penetrate deeper into vegetation and soil, while higher frequencies (i.e. C-band) are more sensitive to volume scattering within vegetation and can provide information on upper layer of canopy.

To extend sensing capabilities of NASA's existing ComRAD instrument system (L-band radar/radiometer) within both vegetation and soil, a C-band radar was recently integrated and a VHF receiver are currently being constructed. In early April 2016, the upgraded ComRAD was deployed in a winter wheat field in Maryland USA, to collect coincident multi-frequency data sets at the SMAP's incidence angle (40°) as a time series over a long enough time period to reflect changing scene conditions.

In this study, we will present our preliminary results about the effect of vegetation growth on vegetation parameterization (effective scattering albedo [1] and opacity) in passive L-band soil moisture retrievals. In particular, the C-band radar will be used as a tool to help determine the attenuation and scattering properties of the vegetation [2] while the VHF receiver (once completed) will be employed to validate the root zone and surface soil moisture retrievals [3]. In addition, the experiment will provide a data set to investigate empirical relationships between vegetation properties at various frequencies so that future and current satellite missions with different frequencies can be more effectively utilized in an integrated fashion.

2. COMRAD INSTRUMENT SYSTEM

The ComRAD (for Combined Radar / Radiometer system) microwave instrument system used in this investigation has been developed jointly by NASA/GSFC and the George Washington University. It has been recently undergoing several upgrades to be able to collect concurrent multi-frequency observations to investigate different layers of vegetation and soil.

2.1. Original System

The original ComRAD system included a dual-pol 1.4 GHz radiometer and a quad-pol 1.24-1.34 GHz radar sharing a 1.22-m Cassegrain parabolic dish antenna and subreflector to achieve a very low loss system. Absolute accuracy and the sensitivity of the instrument were ±1 K and ±0.1 K, respectively. External calibration was achieved using cold sky and ambient microwave absorber targets for the radiometer, and flat plates and dihedral reflectors for the radar. When deployed in the field, ComRAD was mounted on a 19-m hydraulic boom truck (Fig. 1) and can operate over a range of incidence angles from 0° to 175° and a 300° range in azimuth. The mounting platform can also accommodate additional small instruments such as a CropScan visible/infrared sensor for vegetation reflectance measurements and a thermal infrared sensor for scene physical temperature.

2.2. System Upgrades

The C-band radar and the VHF receiver are currently being implemented within the existing ComRAD system to extend its sensing capabilities within both vegetation and soil. The C-band radar system uses a separate horn antenna and is configured around the same vector network analyzer that is currently used for L-band radar. The C-band radar operates in a stepped-frequency mode at 4.75-GHz center frequency for all linear polarization combinations. This new radar is used to sense vegetation dynamics (i.e., leaf area index) of crops. In addition, the recently developed 4-channel VHF receiver hardware will be integrated with the hydraulic boom truck to perform measurements of direct and reflected signals in the 240-270 MHz VHF/UHF band from MilSatCom satellites utilizing sky- and Earth-looking antennas. This will add a new capability to the existing system to penetrate denser vegetation and to respond to conditions deeper in the soil because of the use of a longer wavelength.

3. FIELD EXPERIMENT

An extensive field campaign measuring winter wheat was initiated in early April 2016, and will continue through late June, when the wheat is harvested. The location is near the heavily instrumented USDA-ARS (U.S. Dept. of Agriculture- Agricultural Research Service) OPE3 (Optimizing Production Inputs for Economic and Environmental Enhancement) test site in Beltsville, MD.

Figure 1: ComRAD instrument system.

The ComRAD microwave measurements are being made at the SMAP incidence angle of 40°, autonomously every 2 hours (weather permitting) accordingly. Various in situ sensors such as soil moisture, soil temperature, rainfall, NDVI, and leaf wetness sensors were installed by USDA to provide continuous ground truth data. These data are being supplemented by additional soil moisture data collected at least once a week by USDA personnel, along with weekly plant architectural, water content, and density measurements.

4. REFERENCES

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