# PALS-ADD AND AIRBORBE CAMPAIGNS TO SUPPORT SOIL MOISTURE AND SEA SURFACE SALINITY MISSIONS

*Simon Yueh[1], Steve Dinardo[1], Steven Chan[1], Eni Njoku[1], Thomas Jackson[2], Rajat Bindlish[2], Joel Johnson[3], Jeffery Piepmeier[4] and Christopher Ruf[5]*

Jet Propulsion Laboratory, California Institute of Technology[1], Pasadena, CA, USA
USDA ARS Hydrology and Remote Sensing Lab[2], Beltsville, USA
Ohio State University[3], Columbus, USA
NASA Goddard Space Flight Center[4], Greenbelt, USA
University of Michigan[5], Ann Arbor, USA

## 1. INTRODUCTION

L-band active/passive microwave remote sensing plays a critical role in soil moisture and sea surface salinity sensing, and is the primary sensor technology of the Aquarius and future Soil Moisture Active/Passive (SMAP) missions. To investigate the benefits of combining passive and active microwave sensors for soil moisture remote sensing, the Jet Propulsion Laboratory (JPL), with NASA support, designed, built and tested a precision Passive/Active L-band System (PALS) instrument to support soil moisture and ocean salinity field campaigns. From 1999 to 2002, PALS together with a large conical horn antenna was deployed on the NCAR C-130 aircraft to support three ocean campaigns, the Southern Great Plains 1999 experiment (SGP99), and the Soil Moisture Experiment in 2002 (SMEX02). The PALS data from these campaigns have been used to illustrate first attempts at joint passive and active soil moisture change detection and sea salinity retrieval.

During discussions at several science working group meetings and pre-Phase A Science Transition Team meetings in support of the SMAP mission, a number of specific questions have been identified. These include (1) the mitigation techniques for radio-frequency interference (RFI), (2) a lack of robust sets of concurrent passive and active L-band observational data including temporal change for algorithm development and validation, (3) how to relate the high resolution (10 m) to lower resolution (1 km) radar data of SMAP, (4) What effect does azimuthal orientation have on radar backscatter for different land covers and topographic conditions at the spatial resolution of SMAP?, (5) Does topography have to be accounted for in retrievals?, (6) Can soil moisture be retrieved over urbanized areas?, and (7) Under what conditions can we expect to retrieve soil moisture under forest canopies? Many of these questions need to be answered in the near-term.

For sea surface salinity sensing, there are also a number of remaining algorithm issues. These include (1) What is the sensitivity of L-band radar backscatter and radiometer brightness temperatures to ocean wind under high wind conditions (>10 m/s), (2) What is the wind direction dependence of radar backscatter and brightness temperature?, and (3) How to model and correct the sea surface roughness effects on the reflection of Sun and Galactic radiation. Timely resolution of these issues will be particularly critical for the Aquarius mission to be launched in 2010,

In this article, we will describe the upgrade to PALS completed since 2003 and will provide examples of the results from the Soil Moisture Active PassiveValidation Experiment 2008 (SMAPVEX08) and the High Ocean Wind Campaign in 2009.

## 2. PALS UPGRADE AND RFI MITIGATION

Since 2003, several upgrades, including a compact high-polarization-isolation antenna, polarimetric receivers, three-position-Dicke switching for improved calibration, have been included in the PALS instrument to support future experiments. From June 8 through July 6, 2007, the upgraded PALS system was flown on the Twin Otter to support the CLASIC conducted in Oklahoma. The radiometer data showed significant consistency with the L-band land emission model for soil surfaces published in the literature. Significant temporal (days) changes of a few dB in the radar data were observed. The change of radar backscatter appeared to correlate well with the change of in-situ soil moisture or the soil moisture data derived from the PALS dual-polarized brightness temperatures. The radar vegetation index also correlated well with the vegetation opacity estimated from the radiometer data. The CLASIC data analyses suggest complementary information contained in the surface emissivity and backscatter signatures for the retrieval of soil moisture and vegetation water content.

Although L-band radiometer observations occur within a protected portion of the frequency spectrum, evidence of RFI corruption at L-band has been reported in numerous ground and airborne campaigns. Under the support of the NASA Airborne Instrument Technology Transition program, we integrated PALS with the RFI mitigation system from the IIP "Agile Digital Detector" (ADD) to demonstrate RFI mitigation technologies for future L-band radiometry missions, and to enhance PALS capabilities in algorithm development for Aquarius and SMAP. The ADD RFI mitigation system is comprised of three distinct modules (provided by the University of Michigan, Ohio State University, and NASA Goddard Space Flight Center), with each providing information on particular aspects of the RFI environment.

## 3. SMAPVEX08 CAMPAIGN

To address the issues of RFI mitigation, mutli-temporal soil moisture algorithm, radar resolution scaling, and effects of azimuth orientation, the SMAPVEX08 was conducted in September-October 2008. The main region selected for science algorithm investigations is a mixed agriculture and forest site located east of Washington, DC on the Eastern Shore (of the Chesapeake Bay). Flight lines were designed to cover portions of Maryland and Delaware.

The PALS-ADD instrument was installed on the Twin Otter aircraft to support the SMAPVEX08 with three flights over part of the SMEX02 study site in Iowa and 8 flights over the study site in Delaware/Maryland for science data collections. The flight campaign in Delaware/Maryland started on September 29 and ended on October 13. The weather was mostly clear, and there was only one rain event on September 30. The PALS radiometer and radar data have both responded to the change of soil moisture from the rain and the subsequent soil dry-down. More detailed analyses are being conducted to address the retrieval algorithm issues indicated above.

In addition, there were 10 RFI survey flights to explore the characteristics of RFI in many metropolitan and urban areas in Washington, DC, New York, Connecticut, Pennsylvania, Atlanta, Kansas, and Virginia. The data showed that there were continuous and pulsed RFIs in many regions. Some RFIs were as significant as several hundred Kelvin, and some were as low as a few tenths of Kelvin. Preliminary analyses of the ADD data suggest that the Kurtosis technique will be quite effective to remove most of the RFI-contaminated data.

## 4. HIGH OCEAN WIND CAMPAIGN IN 2009

To address the algorithm issues for Aquarius, the PALS High Ocean Wind Campaign has been planned for Feb-March 2009 to acquire data under high wind conditions (10 m/s-30 m/s) in North Atlantic. The PALS-ADD will be installed on the NASA P-3 aircraft with about 4 to 6 data flights. In addition, we will install the JPL Ku-band Polarimetric Scatterometer (POLSCAT) on P-3 to acquire coincident surface wind speed and direction data over the sea surface. The PALS L-band data will be analyzed together with the POLSCAT wind measurements to determine the influence of wind speed and direction on the L-band radiometer brightness temperature and radar backscatter of sea surfaces.

## 5. SUMMARY

The data from the SMAPVEX08 and the PALS High Ocean Wind Campaign 2009 will prove useful to improve the algorithms for SMAP and Aquarius missions. We are in the process of upgrading PALS to a conical scanning imaging system to mimic the scanning geometry of SMAP. The upgraded PALS-ADD instrument integration will be a useful testbed to support future field campaigns for soil moisture and sea salinity missions.