Soil Moisture Mapping During SMEX03 Using Airborne High-Resolution C- and X-band Radiometry

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BACKGROUND

Remote sensing of soil moisture can be accomplished using L-band (~1.4 GHz) microwave radiometry, as demonstrated during the 1997 Southern Great Plains Experiment (SGP97). Such measurements provide reasonable penetration of crop vegetation canopy as well as provide measurements of soil moisture at soil depths of up to ~10 cm. Radiometry using higher microwave frequencies provides progressively less penetration of vegetation and soil probing depth, but is more amenable to implementation using airborne or spaceborne antennas of practical size. The Japanese AMSR-E imaging radiometer on board the NASA EOS Aqua satellite is one such sensor capable of retrieving soil moisture using a microwave channel at 6.9 GHz with ~75 km spatial resolution. Aqua was launched in May 2002, and will provide a global soil moisture product based on AMSR-E data.

Figure 1. PSR/CX scanhead integrated on the NASA WFF P-3B during SMEX02.

The Soil Moisture Experiments in 2002 and 2003 (SMEX02/03) campaign were designed to provide early post-launch validation for Aqua via an airborne imaging study that simulates AMSR-E low-frequency microwave imagery. The airborne sensor used for the simulation is the NOAA Polarimetric Scanning Radiometer (PSR) operated on the NASA Wallops Flight Facility's P-3B aircraft (Figure 1). The PSR is the only airborne radiometer system to provide multiband polarimetric brightness imagery for a variety of scientific purposes [1,2]. It was developed at the Georgia Institute of Technology and the NOAA Environmental Technology Laboratory starting in 1995 in response to a general national need for high-resolution multiband polarimetric imagery for satellite algorithm development and calibration/validation studies.

Table 1. PSR/CX Specifications.

Frequency (GHz)	Polarization	Beamwidth(1)	ΔT_{rms}(2)
C-Band			
5.80-6.20	v,h	10º	0.3
6.30-6.70	v,h	10º	0.3
6.75-7.10*	v,h,U,V	10º	0.3
7.15-7.50	v,h	10º	0.3
X-Band			
1 0.60-10.68*	v,h	7º	0.7
10.68-10.70	v,h	7º	1.3
10.70-10.80	v,h	7º	0.6
10.60-10.80	v,h,U,V	7º	0.4

* AMSR-E frequencies

(1) Half-power beamwidth (2) 18 msec equivalent integration time, v & h

Objectives of the PSR flights during SMEX03 were several, and included:

* Providing high-resolution AMSR-E (55º incidence) underflight data at vertical and horizontal polarization,
* Developing algorithms using combined C- and X-band data for soil moisture retrieval in the presence of several types of vegetation canopies,
* Studying the detailed spatial and temporal signatures associated with soil moisture variations on a sectional (~1-km) spatial scale,
* Developing algorithms relating C- and X-band soil moisture imagery with L-band imagery for future L-band satellite development purposes,
* Developing hardware and algorithms for mitigating anthropogenic radio frequency interference in soil moisture radiometry.
* providing soil moisture data at field scale for land surface hydrology studies.

This poster provides a brief synopsis of some of the brightness imagery observed using PSR/CX during SMEX 03.

II. PSR/CX DESCRIPTION

The PSR/CX scanhead houses two thermally stabilized polarimetric radiometers that share a common dual-band lens/feedhorn antenna. Each radiometer has four subbands that provide sensitivity to both vertical and horizontal polarization, along with an analog correlator that provides sensitivity to the third and fourth Stokes parameters at each of the two primary bands. The radiometers use internal noise diodes for rapid pre-calibration, along with external views of hot and ambient blackbody targets and cold space to provide absolute radio thermal calibration.

The 3-dB beamwidths of the radiometers are 10º and 7º for C- and X-band (respectively). These beamwidths provide footprint sizes as small as 500 and 350 m (respectively) at a flight altitude of 4,000' AGL. Lower spatial resolution but with wider swath coverage is provided at higher altitudes (2.9 and 2.1 km spot sizes at 25,000' AGL, respectively).

The PSR/CX radiometers are scanned in a conical mode using a gimbal drive mechanism (the PSR "positioner"). The positioner rotates the scanhead as fast as one rotation in ~2.7 seconds. This rotation rate along with an 18 msec sample period provides near-Nyquist sampling of the scene below the aircraft at 4,000' AGL, and Nyquist sampling at 25,000' AGL. The sensitivity of the radiometers is better than 1 K for 18 msec integration time at most of the PSR/CX subbands.

The purpose of using multiple subbands for each primary PSR/CX band is to provide a means of detecting anthropogenic radio frequency interference. Such an interference detection and correction algorithm was successfully demonstrated using PSR data from the 1999 Southern Great Plains Experiment (SGP99) [3]. The algorithm works by comparing brightness temperatures in several nearby subbands through the use of a standard spectral model. If the data cannot be fit to a standard spectral model (a linear model for the case of C- and X-band observations over land) it is assumed that at least one of the subbands contains interference. The offending subband(s) can often be removed and replaced by data obtained using the spectral model.

As anticipated, interference was also observed over Georgia and Oklahoma, particularly in the AMSR-E 6.92 GHZ band. The PSR/CX subbands were able to be used to identify the general location of the interference and to select the frequency band of least contamination. Relatively few occurrences of interference were noted at X-band.

III. SMEX03 FLIGHT CAMPAIGN

Figure 3. shows flight lines in Oklahoma that were designed to provide high altitude mapping of two Regional areas (OS and ON), lower altitude mapping of the Little Washita Watershed (LW), and low altitude water calibration. The SMEX03 campaign included four low-altitude (LW) and eight high-altitude flight lines (ON/OS) designed to provide brightness imagery.

Composited PSR/CX quick-calibrated imagery for the ON region flight lines during the July 3 - July 14, 2003 period and 7.32 GHz channel are shown in Figure 3a and for the 10.7 GHz channel on figure 3b. Images for the 7.32 GHz and 10.7 GHz channels during the July 2 - July 14, 2003 period and OS Region are shown in Figure 3c and d.

Increased soil moisture is observed on July 2, 2003 in the NW corner of the OS region following a rainy day. Imagery from the following sorties indicates drying of soil in this area. Several water bodies remain in

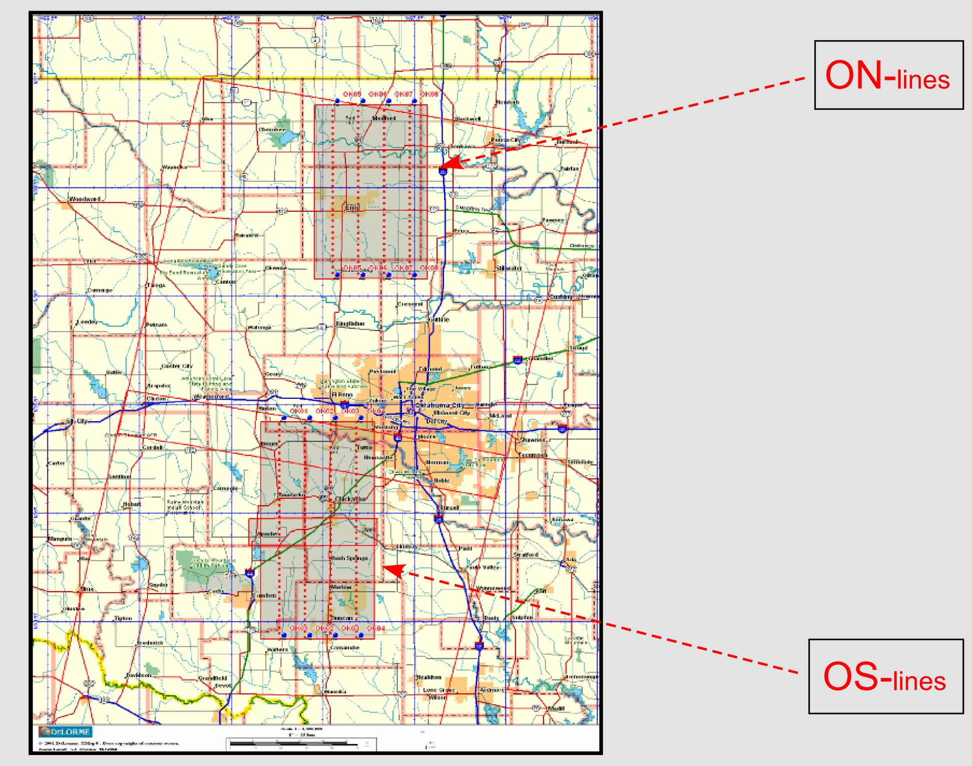

Figure 2. Oklahoma P-3B regional flight lines.

the clearly visible fixed locations. There is also an increase in brightness temperature startinf on July 11 due to a general temperature increase.

Quick-calibrated images for the ON Region (Fig.3a and b) show general drying for the first 3 days. Following the thunderstorm on the night of July 9th the PSR imagery shows cold brightness temperatures indicating presence of soil moisture. However, the next day sortie shows a rapid drying of the soil. On July 13 several spots of increased soil moisture are visible they are due to the thunderstorms of the previous night.

The interference sometimes affects an entire conical scan, producing the arc-like streaking. The calibration problem can be explained by interference during the calibration look. It seems that interference to all C-band channels, even the 7.3 GHz channel (which has historically been the cleanest) is greater this time than during SGP99.

IV. SUMMARY

The principle contributions of the PSR instrument to SMEX03 have been to provide the first high-resolution combined C- and X-band polarimetric microwave imagery over mid-season crops for AMSR-E soil moisture validation and soil moisture retrieval studies.

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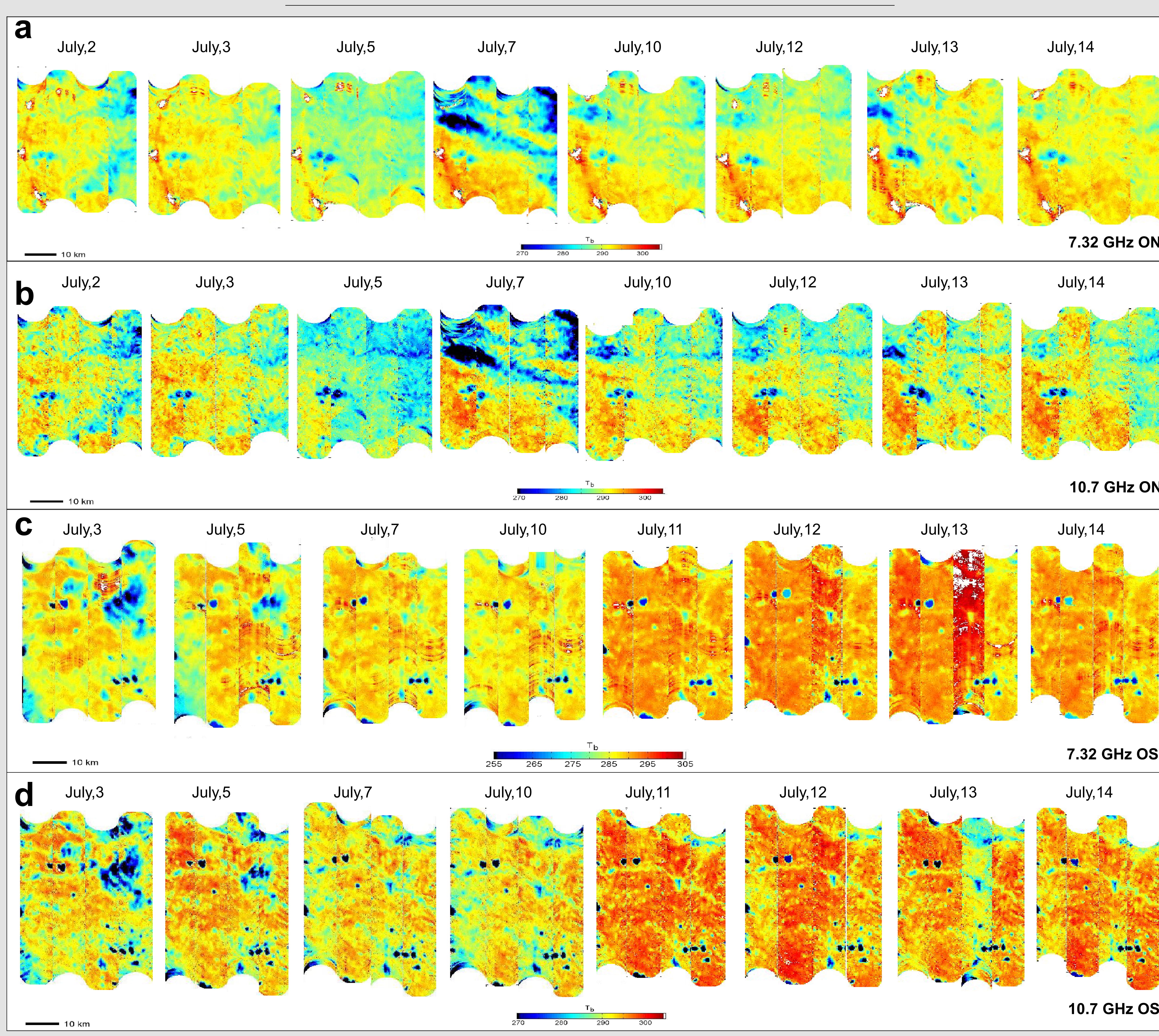

Figure 3.Time sequence of the composited quick_calibrated PSR images using four high-level flight lines for the OS Region (a and b) and for the ON Region (c and d) during July, 2003 period and for the 7.32 GHz (a and c) and 10.7 GHz (b and d) channels.

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