High Resolution Radiometric Soil Moisture Imaging during CLASIC 2007

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MOTIVATION

- Variations in surface water stores within the topmost layer of the vadose zone have a strong impact on the surface moisture and energy fluxes in the boundary layer and on convection and cloudiness.
- During CLASIC 2007 the CU CET operated the PSR/CXI scanning C- and X-band radiometer on board the NASA P-3B aircraft. The observation domain included a large region of central Oklahoma.
- The PSR provided high resolution microwave thermal emission maps at C- and X-band subsequently used to map near-surface soil moisture.

EXPERIMENT

- Cloud and Land Surface interaction Campaign (CLASIC 2007)
- Period: June 10-July 2, 2007
- Location: Central Oklahoma

GOALS

- Advance understanding of how land surface processes influence cumulus convection
- Demonstrate C-band airborne soil moisture imaging for cloud and convection studies

Fig. 1 NASA P-3B platform and PSR/CXI instrument during CLASIC 2007.

PSR/CXI System

INSTRUMENT DESCRIPTION

- Operational airborne microwave imaging radiometer
- Dual-band dual-polarization (full Stokes on two channels, see Fig. 2) conical-scanned system with proven multiple aircraft capability.
- Internal noise diode relative calibration and external blackbody target absolute calibration.

PSR Sampling Characteristics for CLASIC

Incidence Angle	55º
Flight Altitude	25,000' AGL (7.6 km)
Scan Period	6 sec
Sampling Interval	48 msec
C-band 3-dB Footprint	3.1 km
X-band 3-dB Footprint	2.1 km
ΔT_{RMS}	0.06 K
Swath Width	21.8 km
Grid size	255 x 185 km

Center Frequency (GHz)	Bandwidth (MHz)	Polarization
C-Band Radiometer		
6.000*	200	v,h
6.500*	200	v,h
6.925*	200	v,h
6.925	200	U,V
7.325*	200	v,h
C-Band Spectrometer		
Selectable ~5.5 to ~7.6 GHz	100 MHz Linear 10 MHz Liner 10 MHz Logarithmic	v,h
X-Band Radiometer		
10.64	80	v,h
10.69	21	v,h
10.75	100	v,h
10.70	200	v,h,U,V

Fig. 2 PSR/CXI radiometer channel specifications. Channels used in CLASIC 2007 soil moisture retrievals are indicated by asterisks.

SUBBAND-BASED RFI MITIGATION

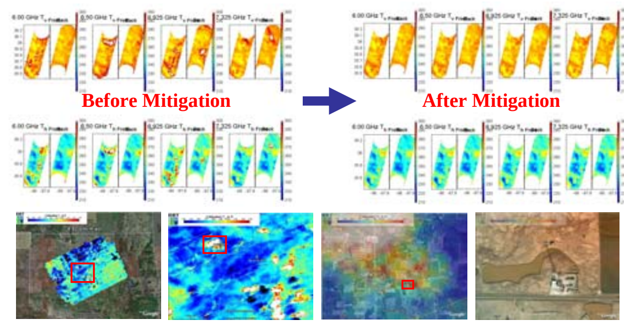


Fig. 3 Comparison of PSR C-band brightness maps over Oklahoma (SGP 99, July 14, 1999) before and after application of four-subband RFI mitigation algorithm. Lower: Progression of images revealing one interfering source on July 11, 2007.

RETRIEVAL ALGORITHM

ALGORITHM

$$T_B = \left\{\left[T_{soil} e_{soil} + (1-e_{soil}) T_{B\downarrow}\right] e^{-\tau_c} + \left(1-e^{-\tau_c}\right) T_c\right\} e^{-\tau_{a\uparrow}}$$

$$T_{B\downarrow} = \left(1-e^{-\tau_c}\right) T_c + e^{-\tau_c}\left(1-e^{-\tau_{a\downarrow}}\right) T_{MR}$$

$$e_{soil} = 1 - \frac{\sqrt{\epsilon_r}-1}{\sqrt{\epsilon_r}+1}$$

$$\epsilon_r = f(VSM\%)$$

Inversion of above RT model follows Jackson [1995]

DATA SOURCES

- *In situ* air/canopy and soil temperature data from the Oklahoma Mesonet
- 8-day average NDVI data from the SeaWiFS sensor on board the NASA Sea Star satellite
- National Weather Service NEXRAD for validation of SM products using antecedent precipitation

PRODUCTS

Calibrated soil moisture maps representative of the top 5-10 cm of soil. Draft products were available within 24 hours of some flights for mission planning.

ANCILLARY DATA

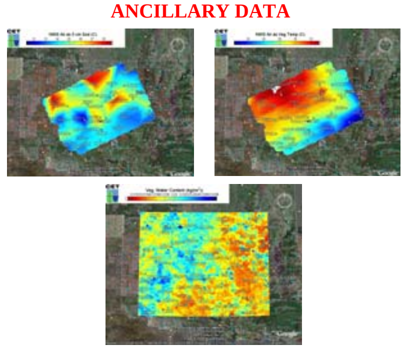


Fig. 4. Top: Spatially and temporally interpolated Oklahoma Mesonet 5-sm soil (left) and air/canopy (right) temperatures. Bottom: SeaWiFS 8-day composite VWC image.

SOIL MOISTURE RETRIEVAL ALGORITHM

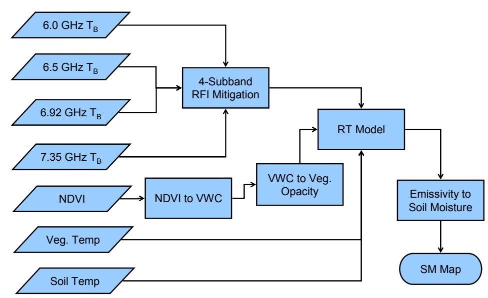
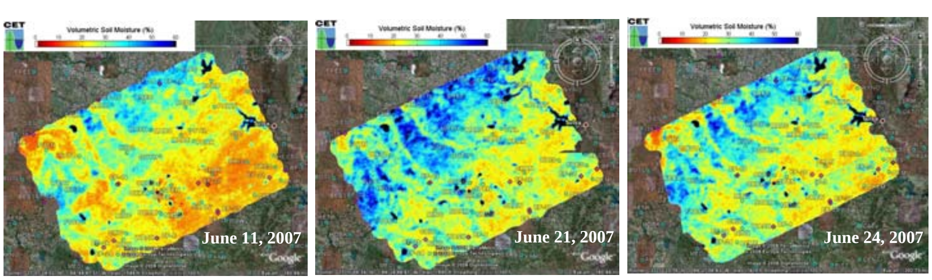


Fig. 5. Block diagram of algorithm used to retrieval soil moisture from PSR C-band brightness and ancillary data. The algorithm produces RFI-free brightness temperature maps, then SM upon subsequent to application of Jackson's retrieval algorithm.

CLASIC 2007 SOIL MOISTURE MAPS

Eight regular imaging sorties were flown on the following days: 6/11, 6/19, 6/20, 6/21, 6/23, 6/24, 7/1, and 7/2/07.

Fig 6. The three images to the right show PSR SM maps retrieved on 6/11, 6/21, and 6/24. Widespread moistening to near saturation and subsequent drydown is apparent.



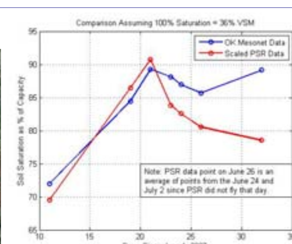


Fig. 7. Preliminary comparison between scaled domain-averaged PSR SM and Oklahoma Mesonet soil wetness data.

CONCLUSIONS

- Regular PSR overflights of the CLASIC 2007 domain along with ancillary data provided soil moisture maps for ~20% of the area of Oklahoma with high (~3 km) spatial resolution.
- Rapid data processing and RFI mitigation demonstrated the utility of high resolution C-band airborne imagery for operational soil moisture imaging even over moderately populated areas.
- The PSR soil moisture products compare favorably to soil wetness data from the Oklahoma Mesonet and (not shown) integrated antecedent precipitation observed using NEXRAD radars.
- An increasing and high amount of soil moisture over most of the CLASIC domain was observed throughout the IOP window, supporting the hypothesis of moisture recycling during CLASIC.

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