Explaining Variations in Microwave Surface Emissivity from Passive Microwave Observations

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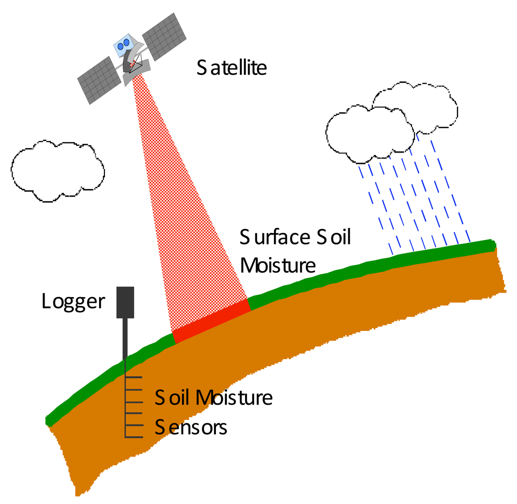


The microwave brightness temperature is a radiative transfer process of soil surface-vegetation interaction, driven by atmospheric conditions. Electromagnetic surface properties such as microwave emissivity are controlled by physical properties of the medium, such as dielectric constant, vegetation roughness and horizontal correlation length. The same physical properties that affect a TB at one channel affect the TB at another channel, so it is unreasonable to specify or modify the emissivity at one channel without changing the emissivity at all channels.

Principal Component (PC) Data Reduction

9x1 PC vector (assuming 9-channel TMI)

$\vec{u} = [E]^T \vec{x}$ ← 9x1 emissivity vector

$[\Lambda] = [E]^{-1}[S_x][E]$ — 9x9 emissivity covariance matrix

$\vec{x} \equiv [E]\vec{u}$ — Exact reconstruction if all 9 PC's are used

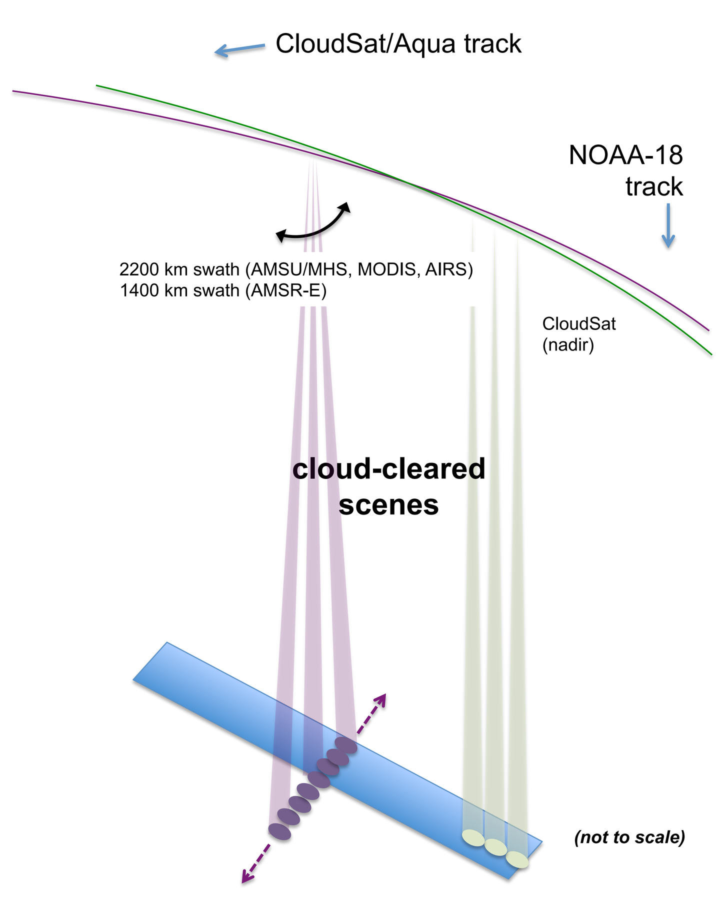
$\vec{x} \approx [E]\vec{u}$ — Approximate reconstruction if not all PC's are used

To use this formulation in practice, one would need extra information (e.g, atmospheric *p, T, q*) to calculate the emissivity PCs, or else have them tabulated. It would be useful if one could derive the emissivity PC's from some nonlinear combination of the T_B themselves

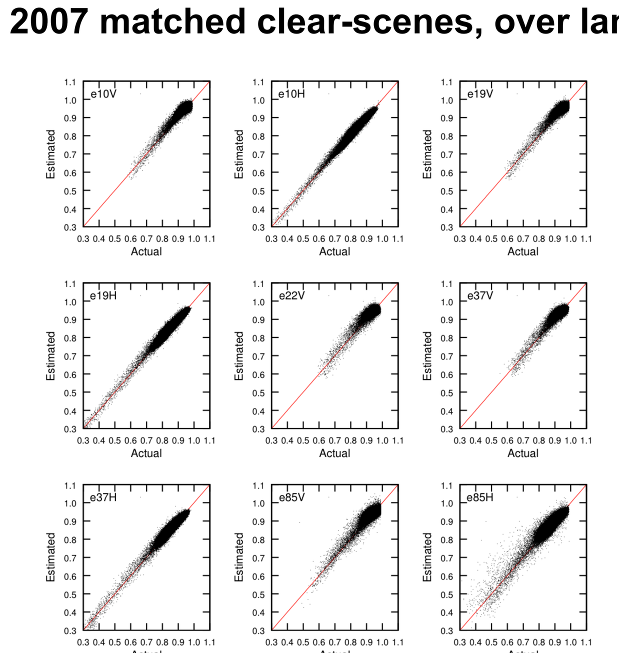
$$u'_1 = f(\vec{T}_B) = a_0 + a_1 T_{10V} + a_2 T^2_{10V} + ...$$
$$u'_2 = f(\vec{T}_B) = b_0 + b_1 T_{10V} + b_2 T^2_{10V} + ...$$
$$u'_3 = f(\vec{T}_B) = c_0 + c_1 T_{10V} + c_2 T^2_{10V} + ...$$

Then reconstruct the full emissivity vector directly from the T_B: $\vec{x} \approx [E]\vec{u}'$

The relationship is valid for cloud-free scenes and should degrade under increasingly cloudy and precipitating scenes. It is constructive to further analyze how this formulation behaves under all scenes, as shown in the example to the right.

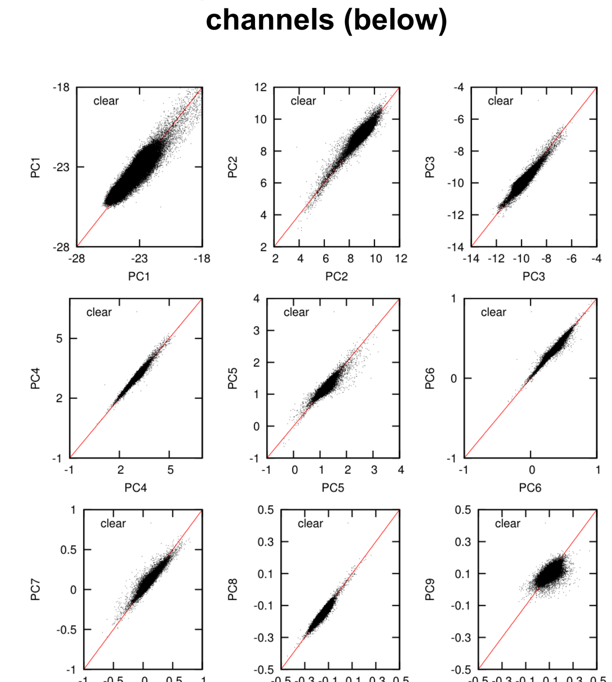


All 2007 matched clear-scenes, over land



Estimation of first 9 PC's (above)

Emissivity reconstruction at TMI-like channels (below)



Clear-Scene Observational Database (06/2006-02/2010)

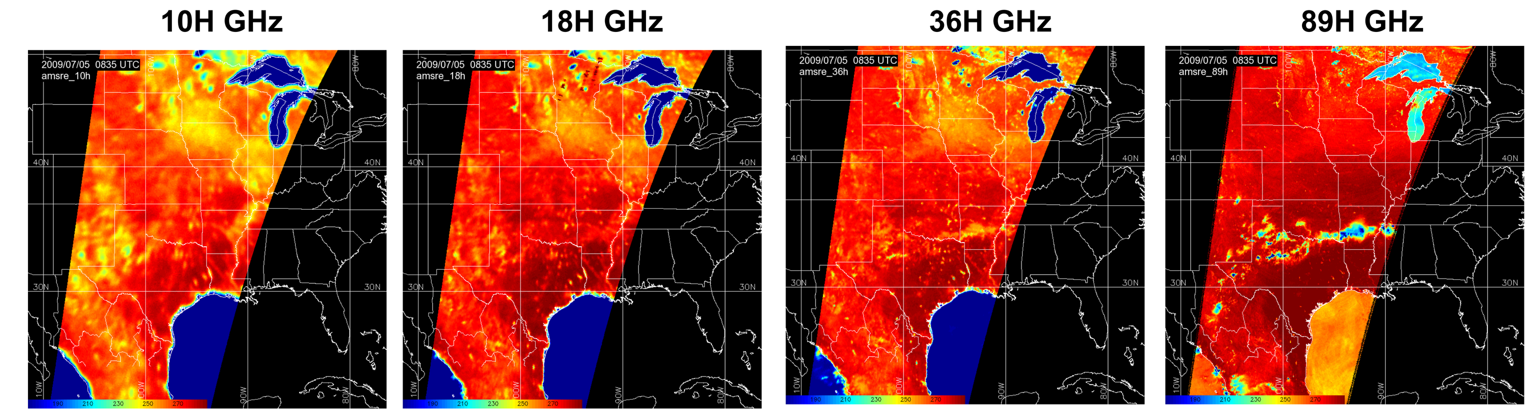
NOAA-18 within 10-km and 15 minutes of CloudSat

T_B scene is declared "clear" if no clouds detected within ±10 CloudSat-basis pixels, determined by each of 2B-GEOPROF, 2B-GEOPROF-LIDAR, and MODIS-AUX

- AMSR-E L2A (12 T_B)
- AMSU-A/MHS TB (20 T_B)
- AMSR-E 12-km ice fraction
- AIRS and ECMWF (*p,T,q*) profiles
- MODIS thermal channels (11 T_B)
- CMORPH every 3-hours, back 7 days
- NOAA IMS snow cover index
- Satellite and sun angles

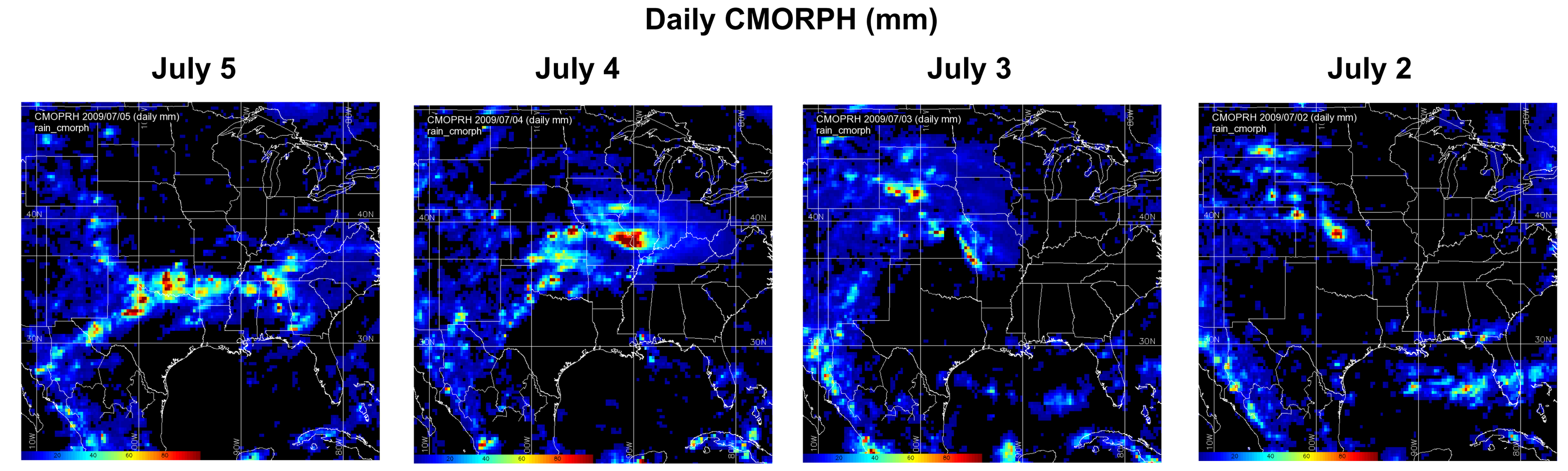
Emissivity vector estimated from non-scattering 1-D RT model using either ECMWF or AIRS atmosphere and surface temperature (inverse technique). Emissivities are categorized by surface conditions (snow cover, ice fraction, amount of previous-time precipitation, season, latitude, etc).

Example: Central US 5 July 2009 0835 UTC Aqua/AMSR-E Descending

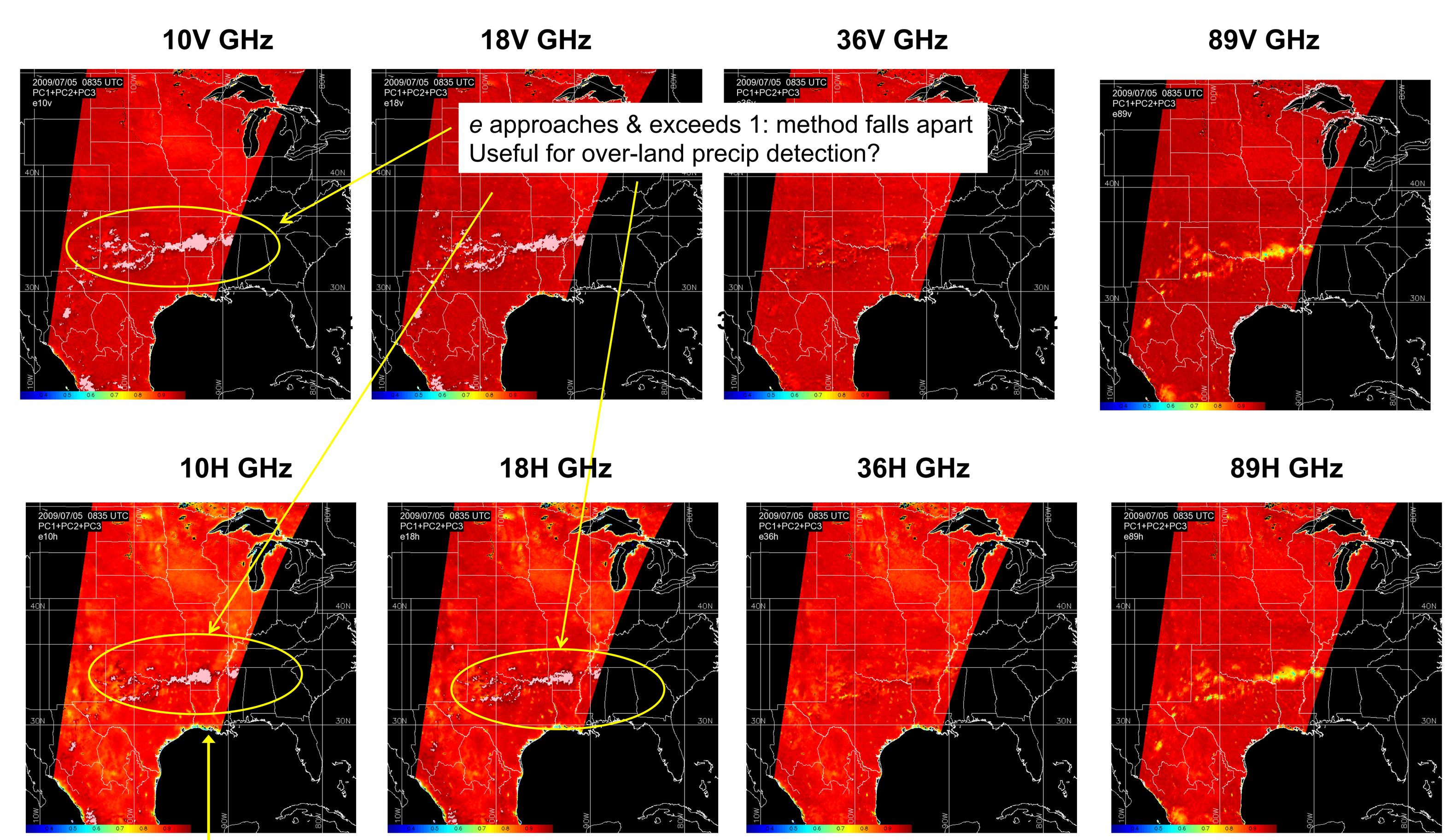


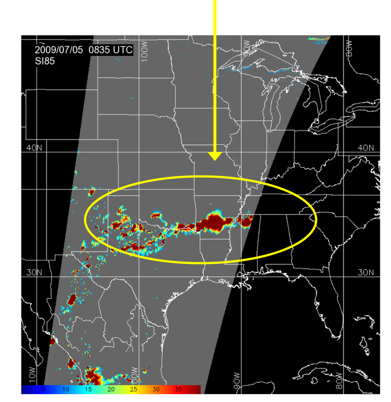
In this example, a line of convection is noted at 89 GHz along the Texas-Oklahoma border. At 10 GHz, a widespread area of TB < 240K is likely indicative of increased soil moisture or vegetated areas, and inland water and stream channels are noticeable. The precipitation totals from CMORPH for the previous four days are shown below, whose overall patterns indicate significant rainfall across the upper Midwest.

Daily CMORPH (mm)



The emissivity (e) vector reconstructed from the TB-estimated PC, (using coefficients from all clear-scene 2007 AMSR-E data over land) is shown below at 10, 18, 36 and 89 GHz. The areas of depressed 10 GHz TB noted above show reduced emissivity values ≈ 0.8 (relative to the nearby areas) and $e_V > e_H$ as expected. At 10 and also 18 GHz, both e_V and e_H approach and exceed unity in the region of most noticeable convective precipitation. This suggests that while this technique may yield realistic emissivity information in the clear and partially cloudy areas (not yet validated), it may potentially serve as a screening or detection for precipitation. The magnitude or threshold of detection is currently being analyzed.



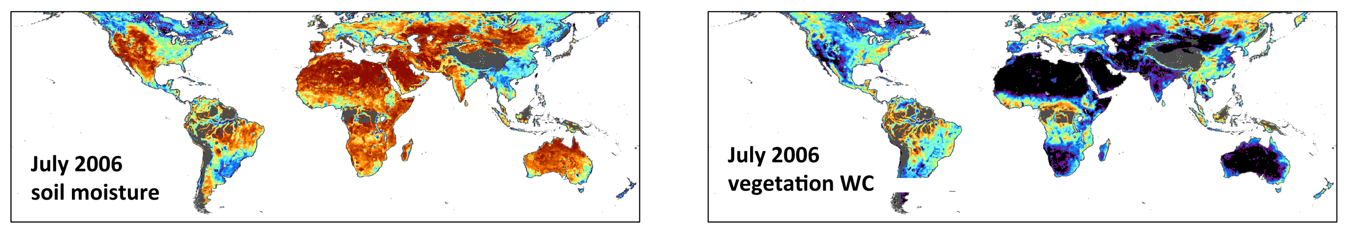


Grody (1991) developed a novel method that separated precipitating and non-precipitating observations by estimating the non-scattering contribution at the high frequency scattering-based channels with the lower frequency channels. Over land,

$$SI = 451.9 - 0.44T_{19V} - 1.775T_{22V} + 0.00574T_{22V}^2 - T_{85V}$$

In the left figure, regions of SI < 10 are shaded grey. Regions of SI > 10 are closely aligned with regions where e_{10V} exceed unity.

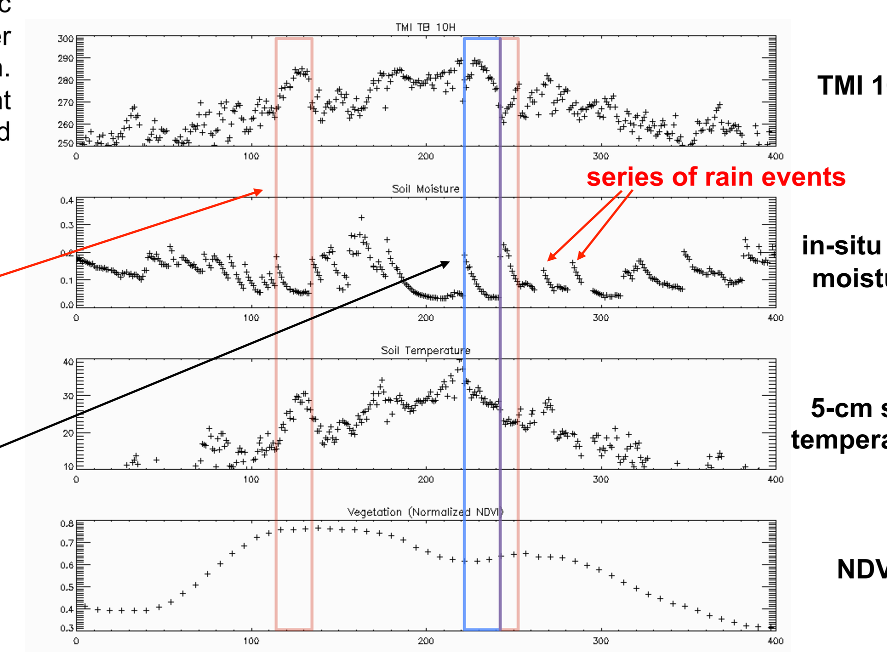
Physical modeling attempts to retrieve the underlying geophysical parameters that are consistent with the observed TB (emissivity is produced as a product in the retrieval), under rain-free conditions. While soil moisture will change abruptly with the onset of rain, knowledge of vegetation before rain events helps to reduce the uncertainty of the emissivity of rain-wetted surfaces. The skin depths are different for individual channels so it is constructive to compare observed T_B with in-situ data. Currently the physical retrieval technique of Li et al. (2010) is being adapted to work with the most recent Version 7 TMI data.



Generally, rainfall increases soil moisture, leading to an increase in the dielectric constant (increased absorption) and lower TB than would be observed without rain. However, the emissivity is also dependent upon vegetation content and structure, and near-surface temperature.

In the red region, note that the TMI 10 GHz T_B *increases* while soil moisture decreases, as the soil dries out after rain events

In the blue region, note that the TMI 10 GHz T_B *decreases* while soil moisture decreases



SGP Oklahoma site Day of Year (2003)

6 GHz

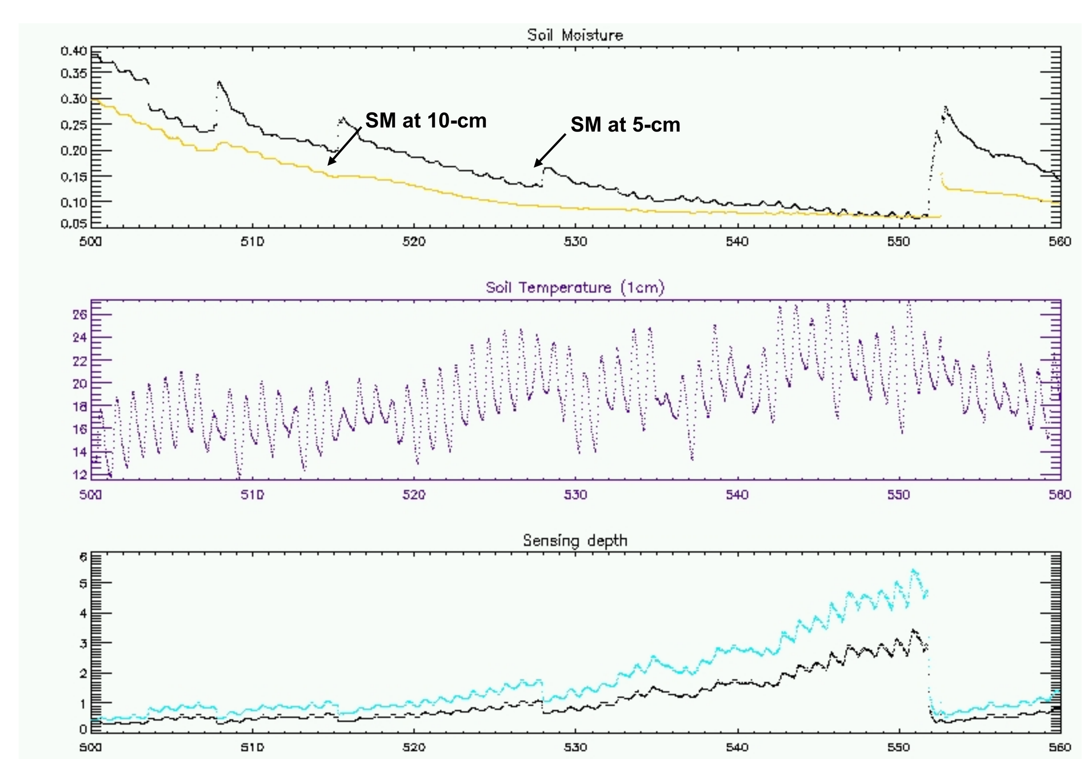
2 month period

In-situ soil moisture (top) and 1-cm soil temperature (middle)

63% temperature sensing depth

80% (blue line)

(Vol. 3 of Ulaby et. al, pg. 1533)



Southern France site Day of Year (since 2003)

Analysis of the individual PCs provides insight to the information contained in the TB observations, and can be compared with the physical modeling (above). PC1 appears to emphasize both the regions of wet soil and/or vegetation in the upper Midwest and the convective precipitation, with opposite trends (for illustration purposes, the PCs are shown everywhere, but are derived using the over-land coefficients). PC2 and PC5 (not shown) hide land-water background differences but PC5 shows coastal effects. The region of convection is best distinguished from surrounding land variations in PC3.