Validation of Aircraft and Satellite Remote Sensing of Brightness Temperatures and Derived Soil Moisture using a Hydrologic/Radiobrightness Model

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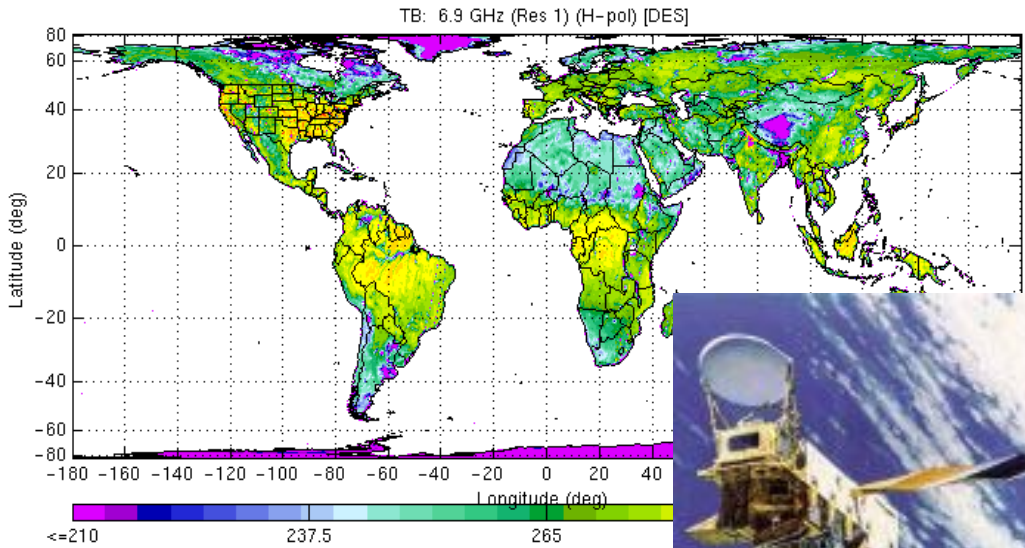
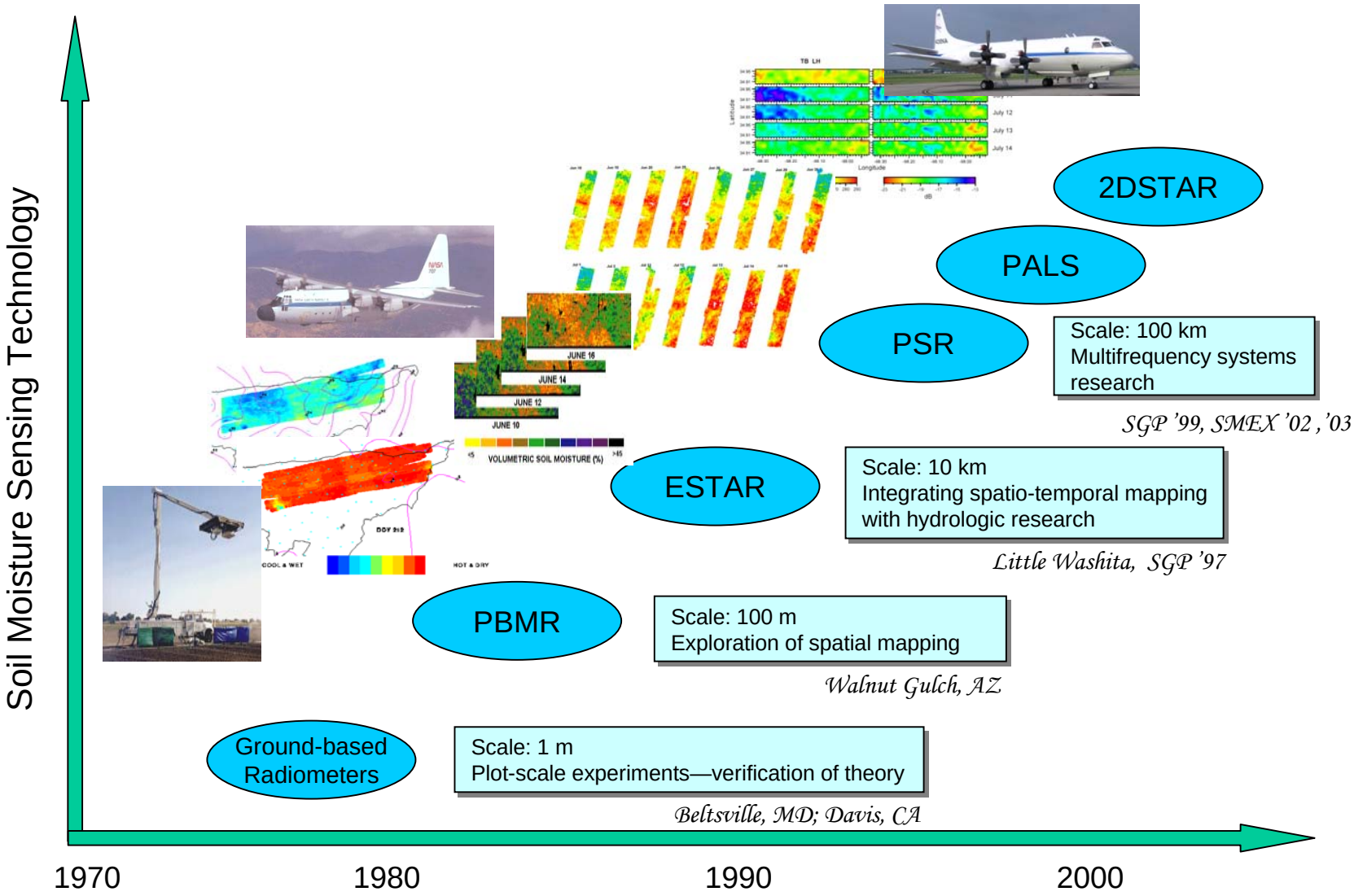
IGARSS, Toulouse, France July 21-25, 2003

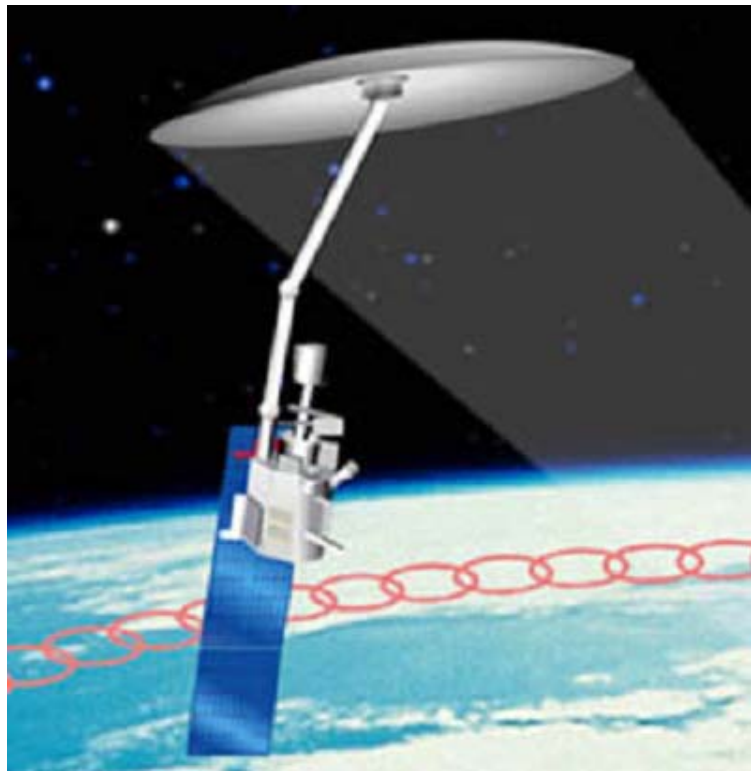


Soil Moisture: Technology Development

AMSR-E Soil Moisture



Future Soil Moisture Missions



SMOS

- Launch 2005
- L-band multiangular interferometry
- Coverage: global
- Spatial resolution: 50 km
- Revisit frequency: <3 days

HYDROS

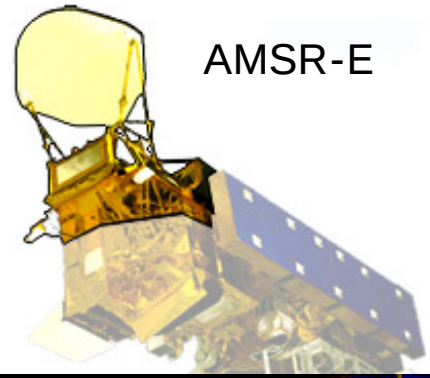
- Launch 2007
- L-band active/passive system
- Coverage: global
- Spatial resolution: 3, 10 km-radar; 40 km-radiometer
- Revisit frequency: 2-3 days

Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E)

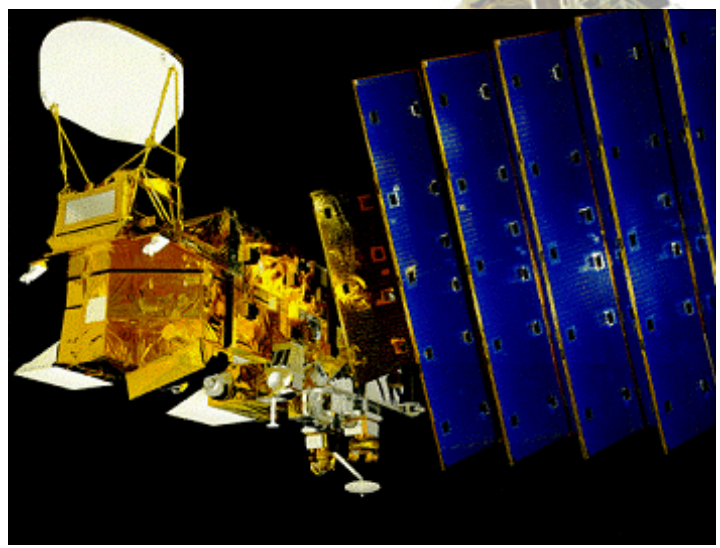
AMSR-E Soil Moisture

Sensor Specifications:

Frequency (GHz)	Polarization	Sensitivity (K)	Mean Spatial Resolution (km)	Swath (km)
6.925	V, H	0.3	56	1445
10.65	V, H	0.6	38	1445
18.7	V, H	0.6	21	1445
23.8	V, H	0.6	24	1445
36.5	V, H	0.6	12	1445
89.0	V, H	1.1	5.4	1445



Aqua



- 12 channel, 6 frequency conically scanning passive microwave radiometer
- Built by the Japanese Space Agency, NASDA

Launch:

- AMSR-E launched on Aqua on May 4, 2002
- AMSR launched on the Advanced Earth Observing Satellite (ADEOS-II) on Dec. 14, 2002

Orbit:

- Sun-synchronous
- Altitude: 803 km—AMSR, 705 km—AMSR-E
- Equatorial crossing at 1030 LST for AMSR and 1330 LST for AMSR-E
- Earth incidence angle of 55°
- T_B resampled to 25 km for soil moisture product

Objectives

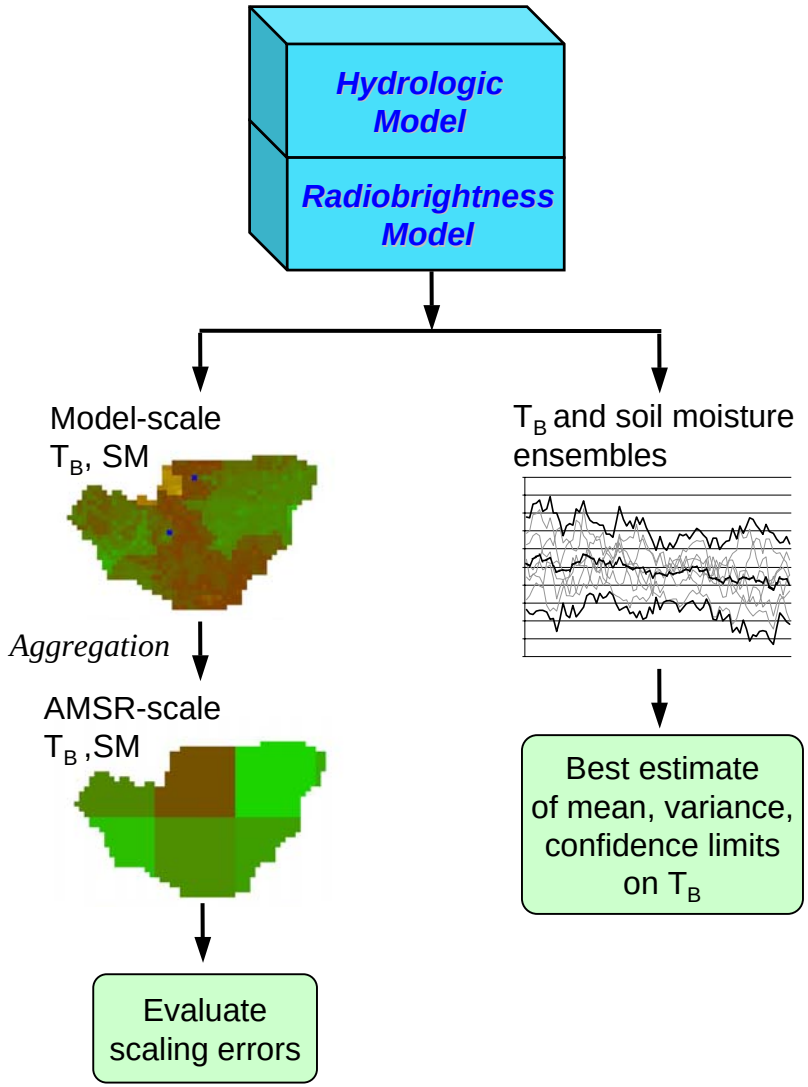
Objective:

Provide “best estimates” of footprint-scale mean brightness temperatures and EASE-grid-scale soil moisture with associated confidence limits.

Approach:

Utilize a coupled hydrologic/radiobrightness model to estimate brightness temperatures with data assimilation from *insitu* observations and airborne radiometers.

Validation is performed using data from regional experiments.

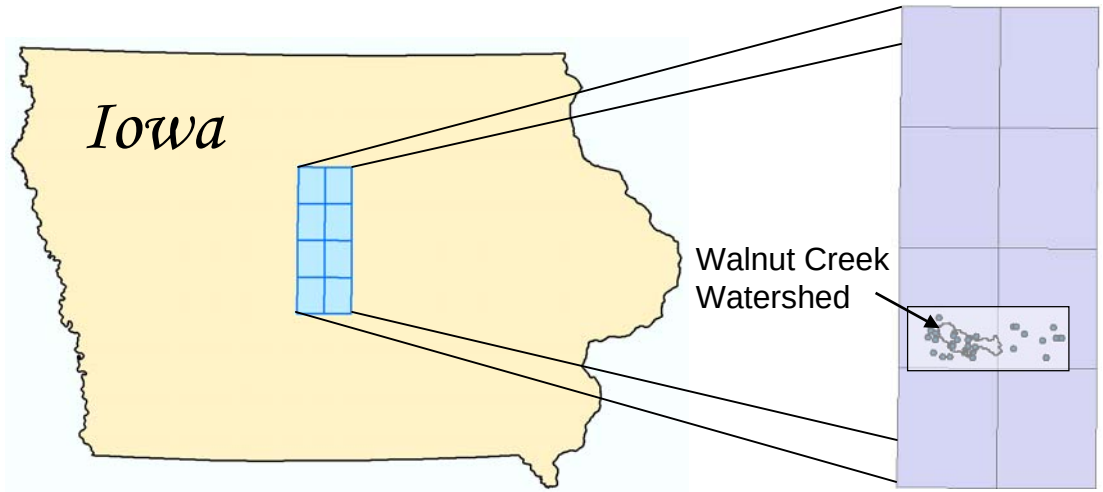


Soil Moisture Experiments in 2002 (SMEX02)

Location: Near Ames, Iowa
Time: 24 June – 13 July 2002

Regional Area:
- ~5000 km^2
- 48 ground sampling sites for measuring gravimetric soil moisture (daily, PM)

Walnut Creek Watershed Area:
- ~ 400 km^2
- 31 ground sampling sites for measuring gravimetric soil moisture, surface and soil temperatures (daily, AM), and vegetation properties (~weekly)
- Surface energy flux stations, lidar, and radiosonde measurements

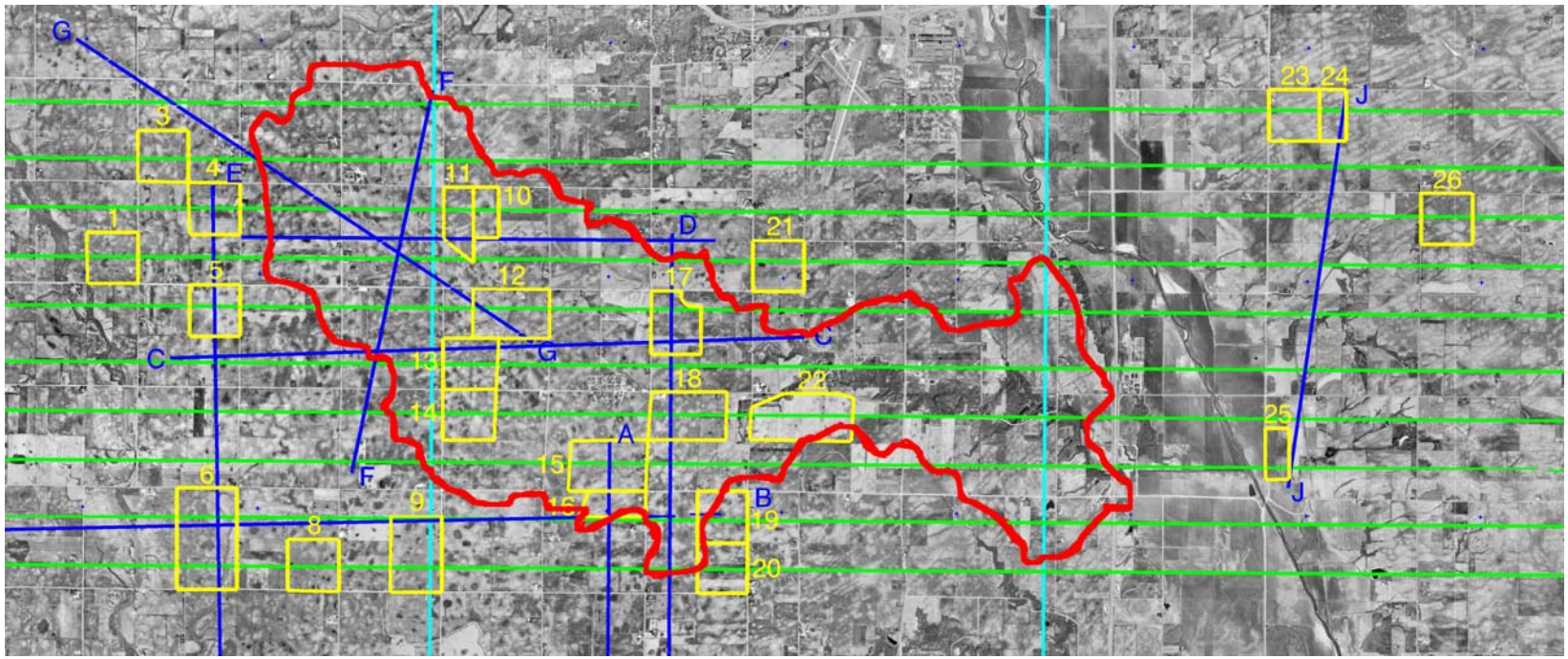


AMSR-E data resampled to EASE-Grid cells

C-band data from aircraft at 800 m resolution for regional domain

L- and S-band data from aircraft at 200 m resolution for watershed domain

Watershed-scale Sampling Sites



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AMSR-E Soil Moisture

Polarimetric Scanning Radiometer (PSR)

AMSR-E Soil Moisture

NASA P3-BB Orion Aircraft

On-board Data System

PSR Instrument

Frequency (GHz)	Beamwidth
5.82-6.15	10°
6.32-6.65	10°
6.75-7.10	10°
7.15-7.50	10°

Passive and Active L and S Band Microwave Instruments (PALS)

AMSR-E Soil Moisture

NSF C-130

PALS Instrument System

Parameter	Radiometer	Radar
Frequency	1.41 and 2.69 GHz	1.26 and 3.25 GHz
Polarization	V and H	VV, VH, HH
Sensitivity	0.2 K	0.2 dB
Incidence Angle	45 deg.	45 deg.
Spatial Resolution	~400 m	~400 m

Measurement of Surface Soil Moisture

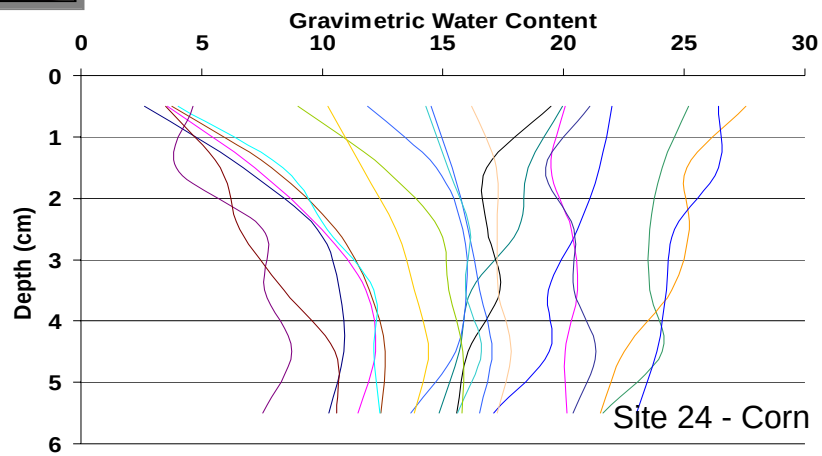
AMSR-E Soil Moisture

Soil Cores

Scoops

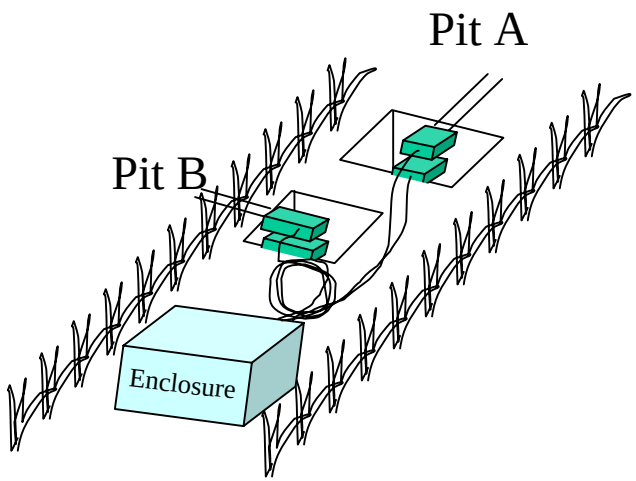
Impedance Probe

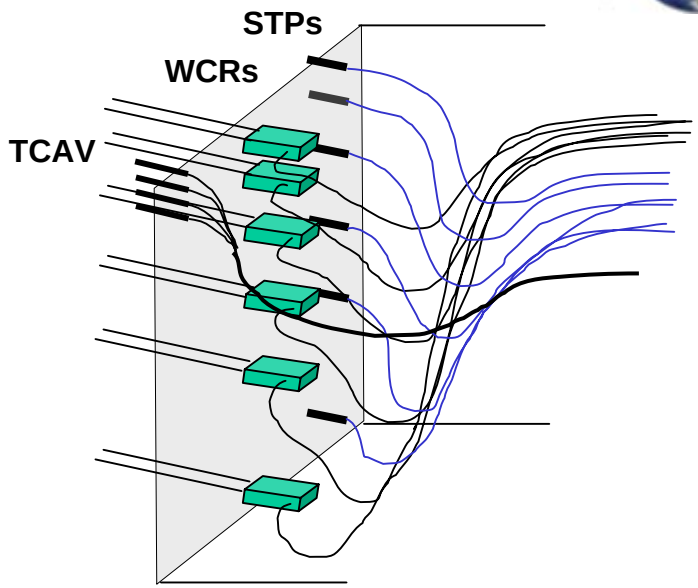
0-6 cm profiles from sliced cores collected daily each AM at 4 points.



Automated Monitoring Stations

AMSR-E Soil Moisture





Depth (cm)	Sensor	Depth (cm)	Sensor
2	WCR, STP	1	TCAV
5	WCR, STP	2	TCAV
		3	TCAV
10	WCR, STP	4	TCAV
15	WCR, STP		
20	WCR, STP		
30	WCR, STP		

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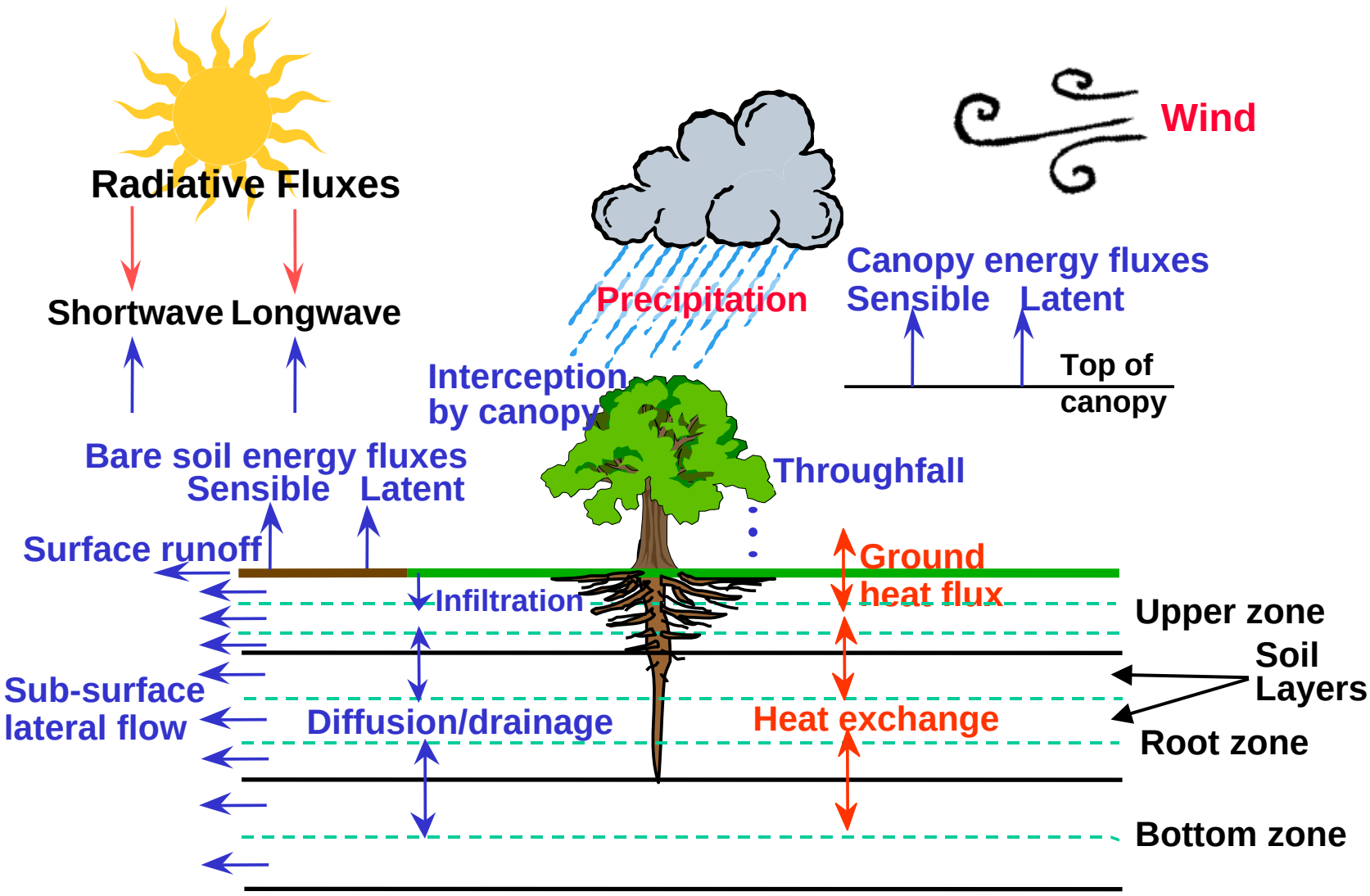
Hydrologic Model



AMSR-E Soil Moisture

Microwave Radiobrightness Model

- Based on the forward coherent wave radiative transfer model of Njoku and Kong (1977).
- Determines microwave brightness temperatures at given frequencies based on soil moisture and temperature profiles
- Soil moisture and temperature profiles are supplied by the hydrologic model or *in situ* observations
- Includes parameterizations for effects of surface roughness and vegetation
- Using Dobson dielectric mixing model in this study

AMSR-E Soil Moisture

Hydrology and Radiobrightness Modeling

- **Initialize soil moisture profile based on antecedent precipitation on day 161 (10 June)**

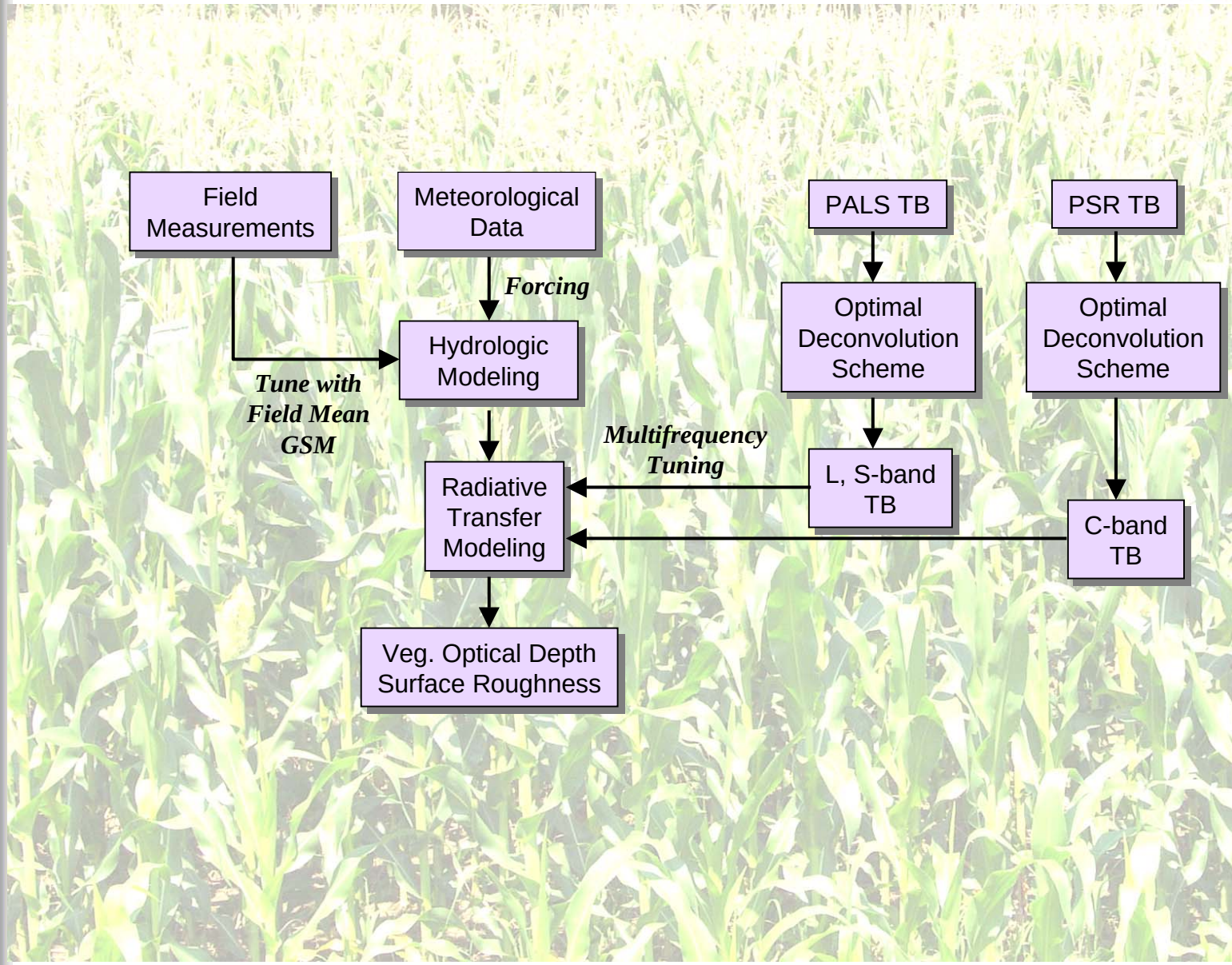
- **Run SHEELS at hourly time step, forcing with NWS North Central River Forecast Center Multi-sensor Precipitation Estimates (MPE)**

- **Other meteorological forcing obtained from USDA Soil Climate Analysis Network (SCAN) site at Ames, Iowa**

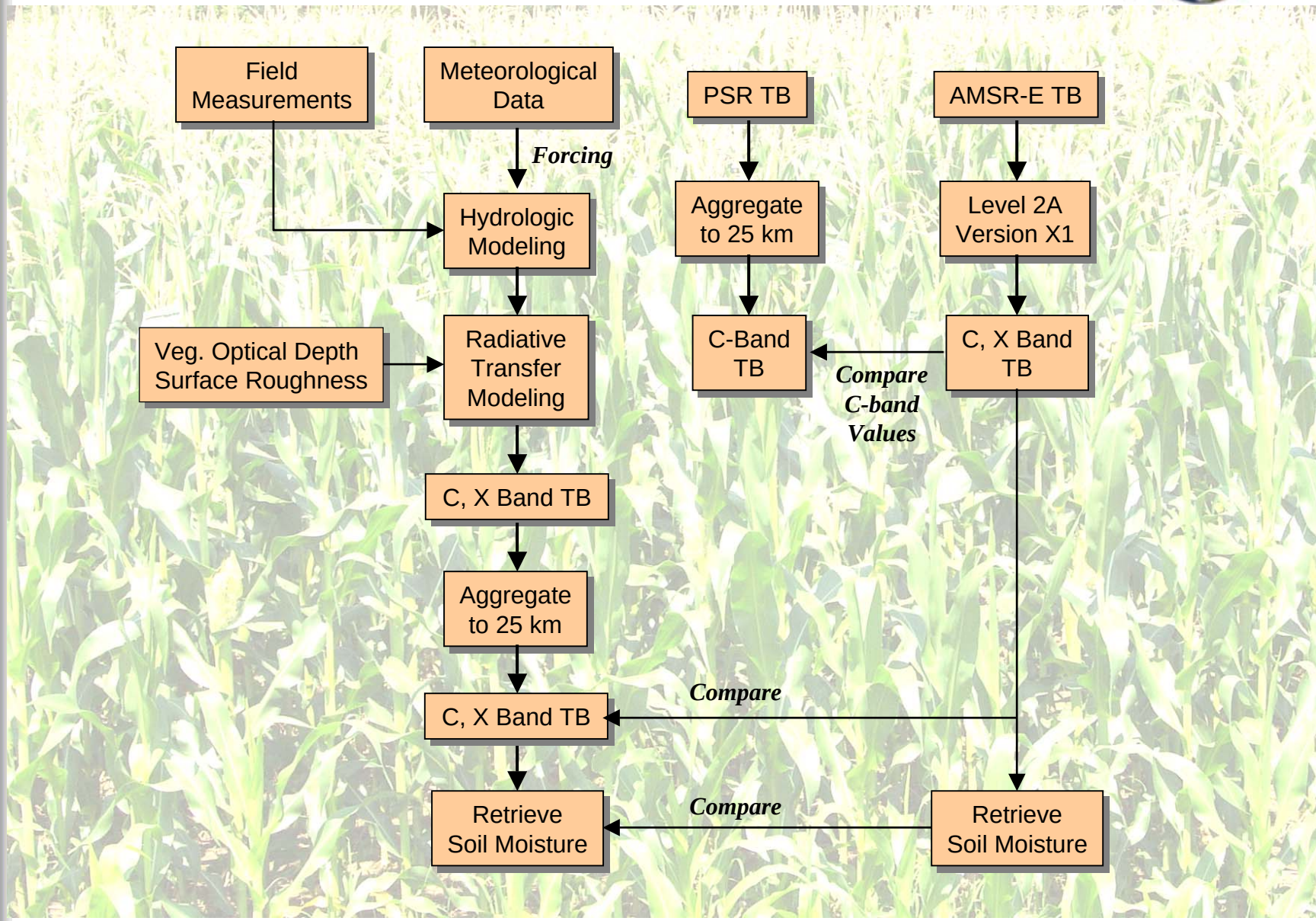
- **SHEELS soil layer configuration:**

Zone	Thickness (cm)	No. layers
Upper	6	6
Root	94	9
Bottom	50	2

Methodology: Watershed-scale Area



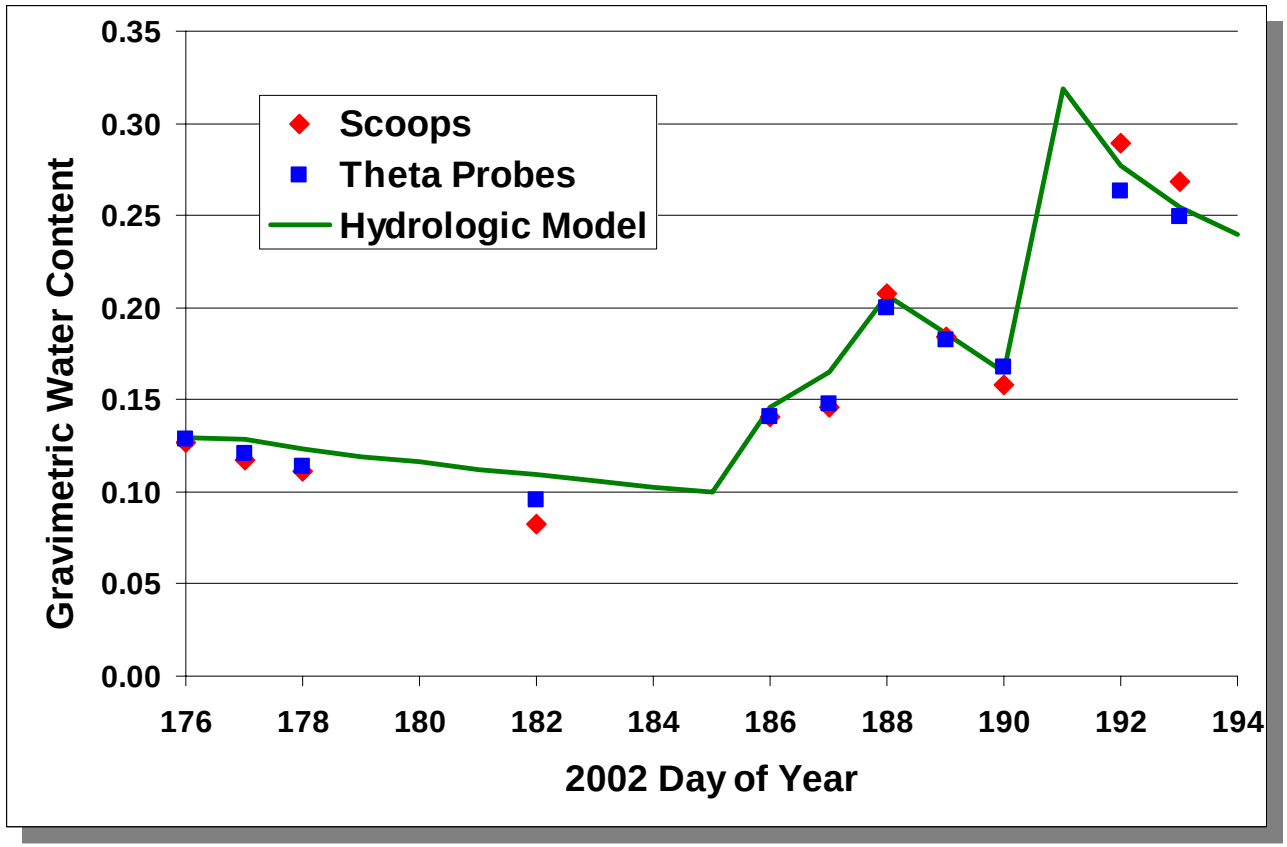
Methodology: Regional-scale Area



Observed vs. Modeled Soil Moisture (0-6 cm)

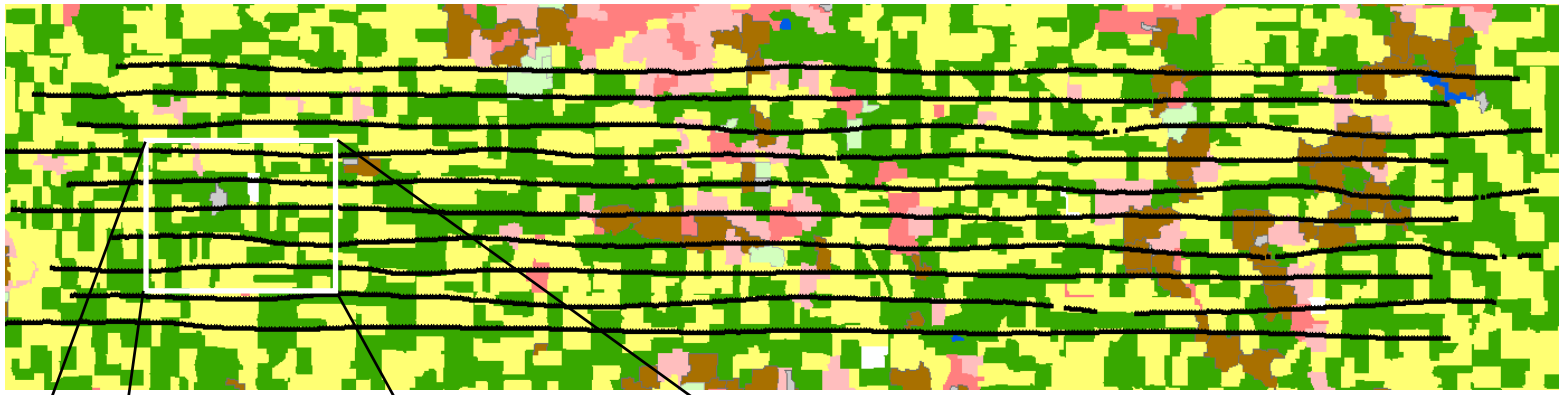
Watershed-scale Area

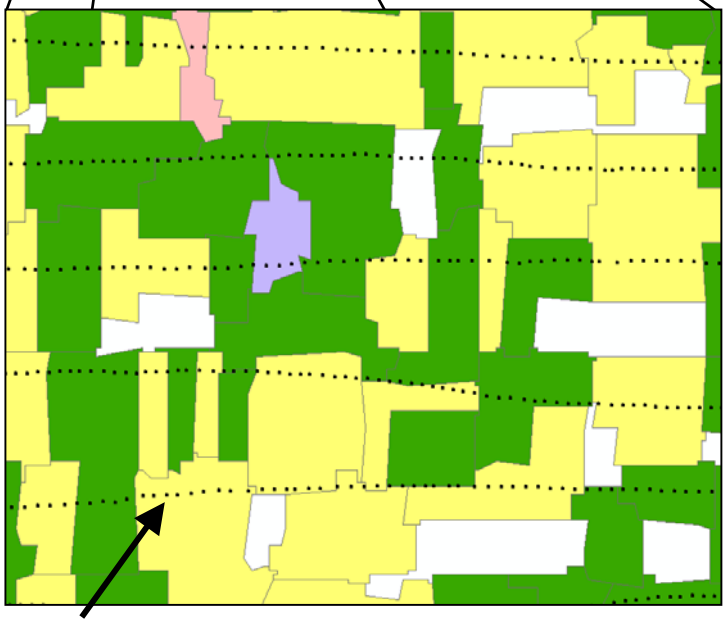
AMSR-E Soil Moisture



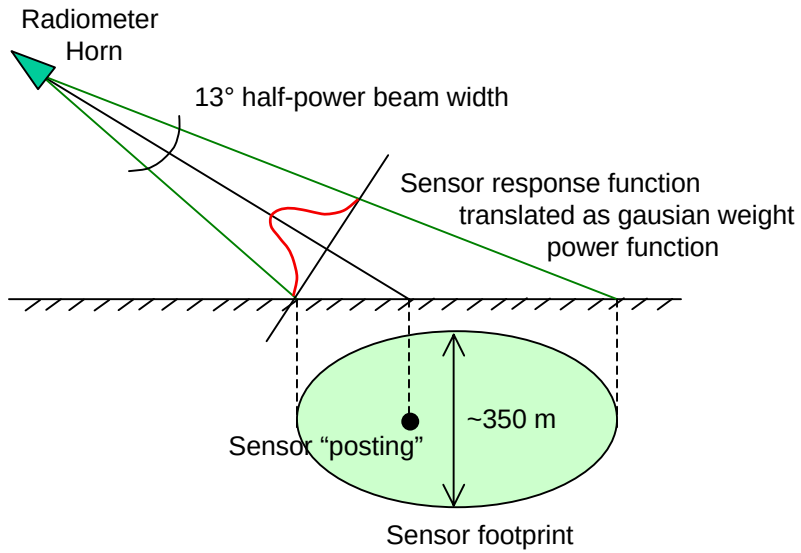
Optimal Deconvolution of Remotely Sensed Brightness Temperature

AMSR-E Soil Moisture





~100 m spacing between observations (“postings”)

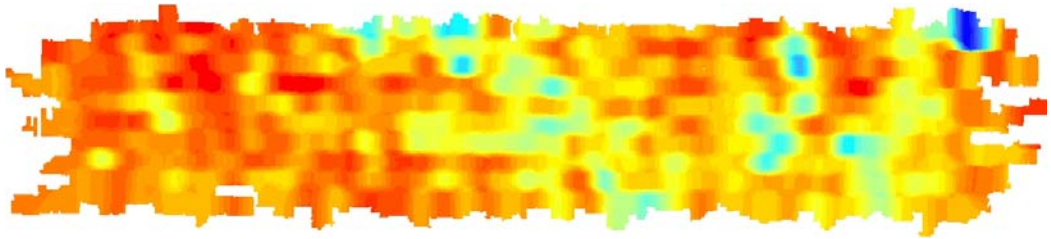


Spatial Interpolation vs. Optimal Deconvolution

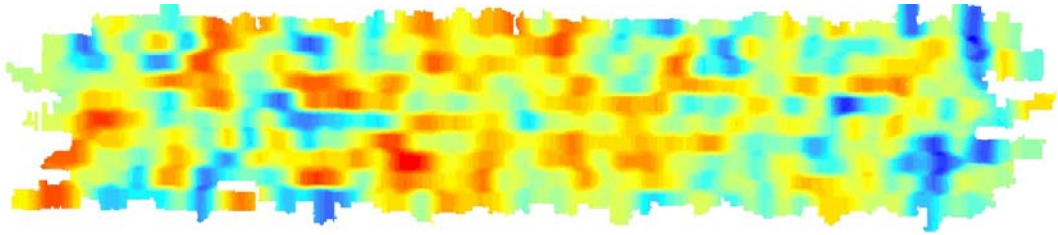
AMSR-E Soil Moisture

Kriging

July 2
Dry Case

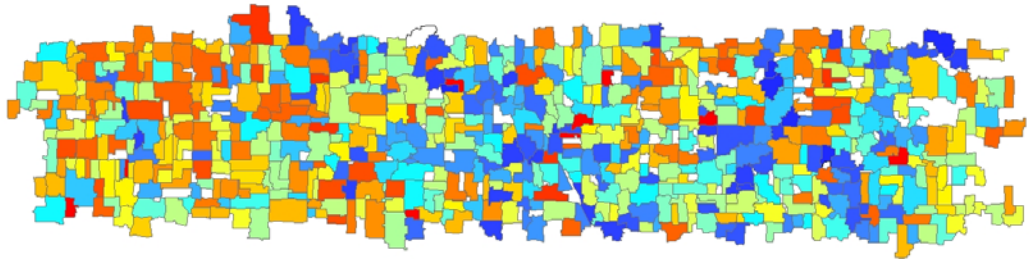


July 7
Wet Case

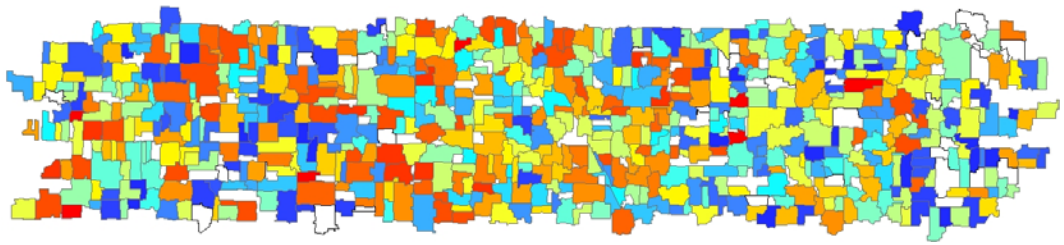


Optimal Deconvolution

July 2
Dry Case

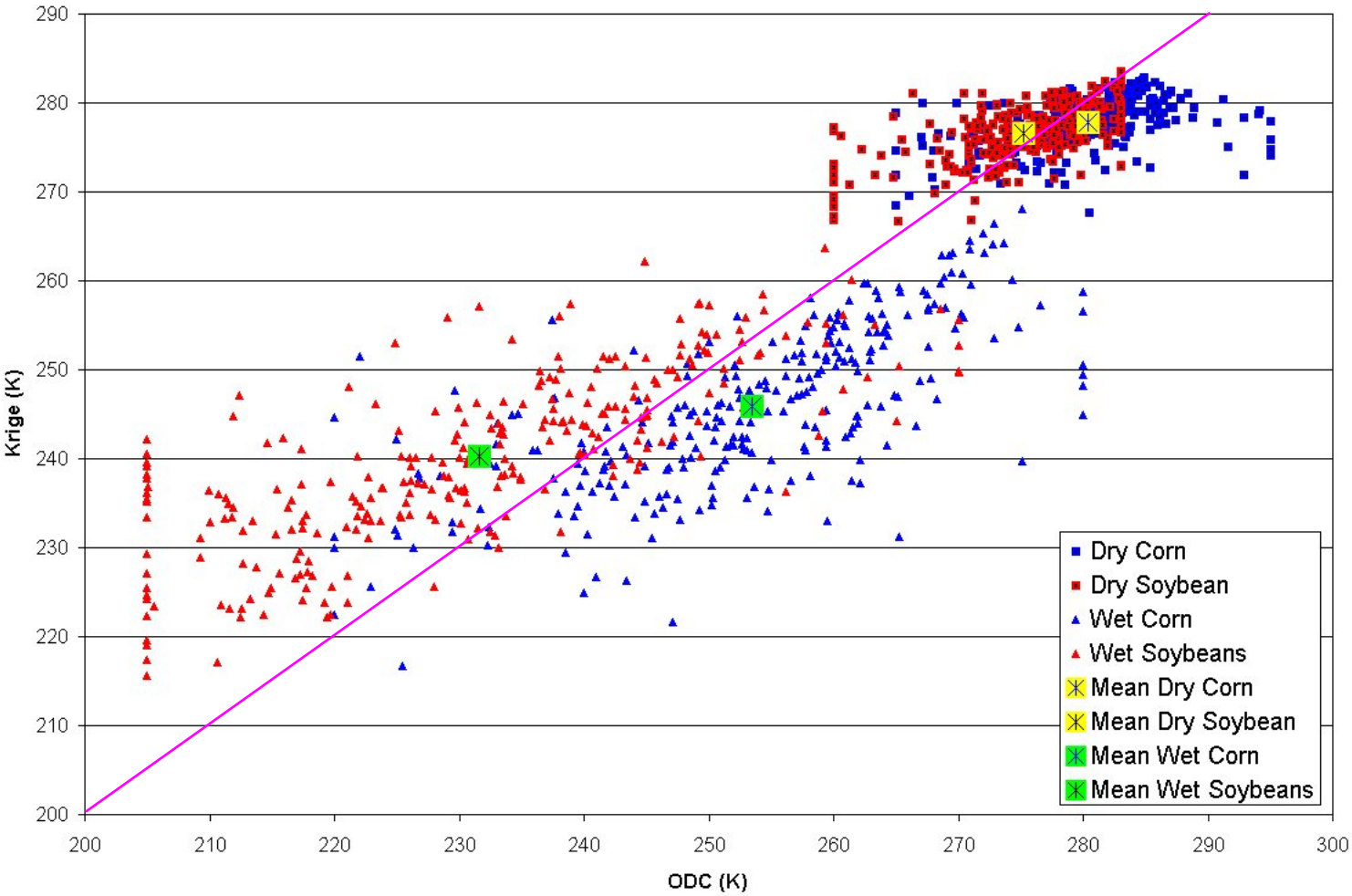


July 7
Wet Case

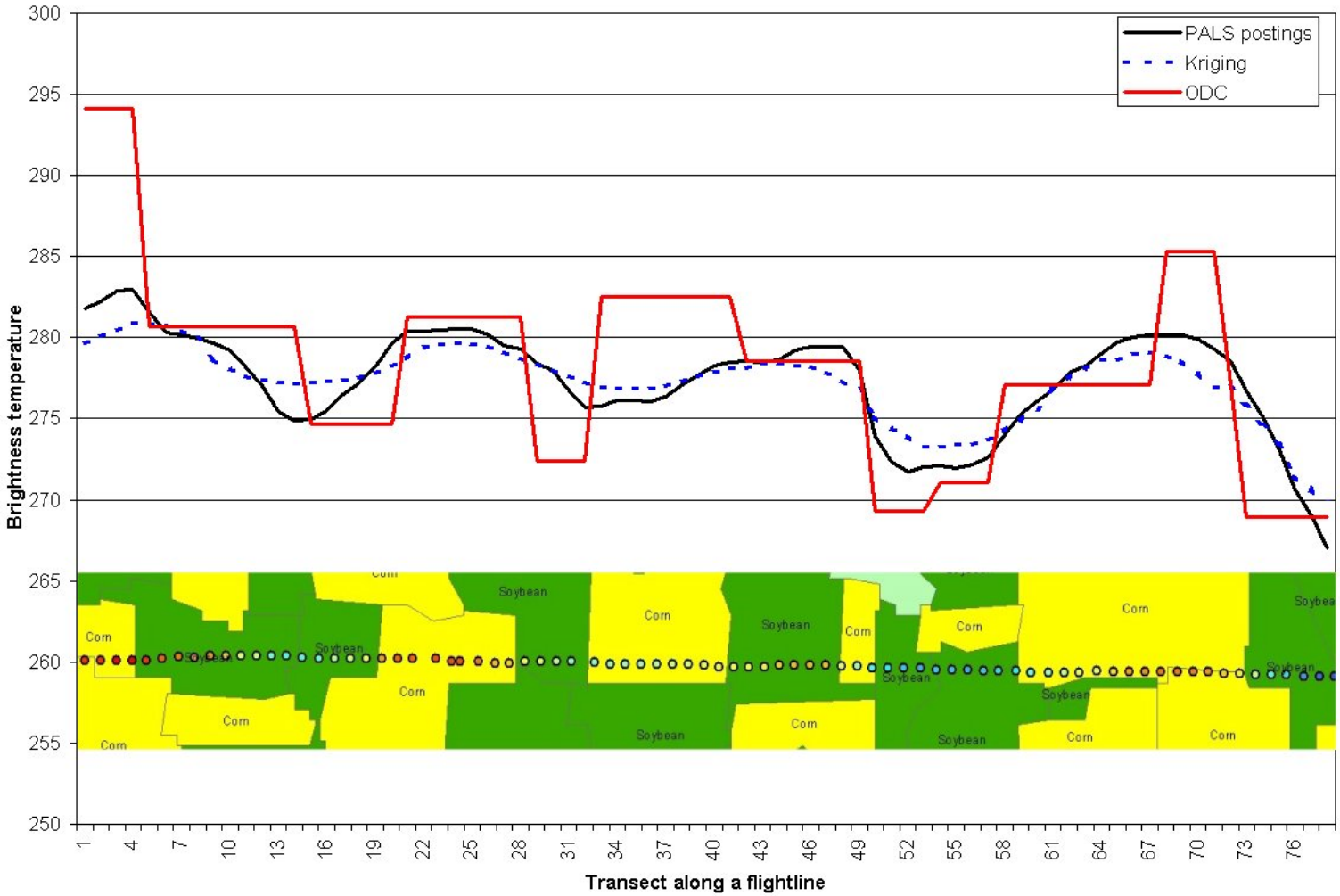


Brightness Temperatures Derived by Spatial Interpolation vs. Optimal Deconvolution

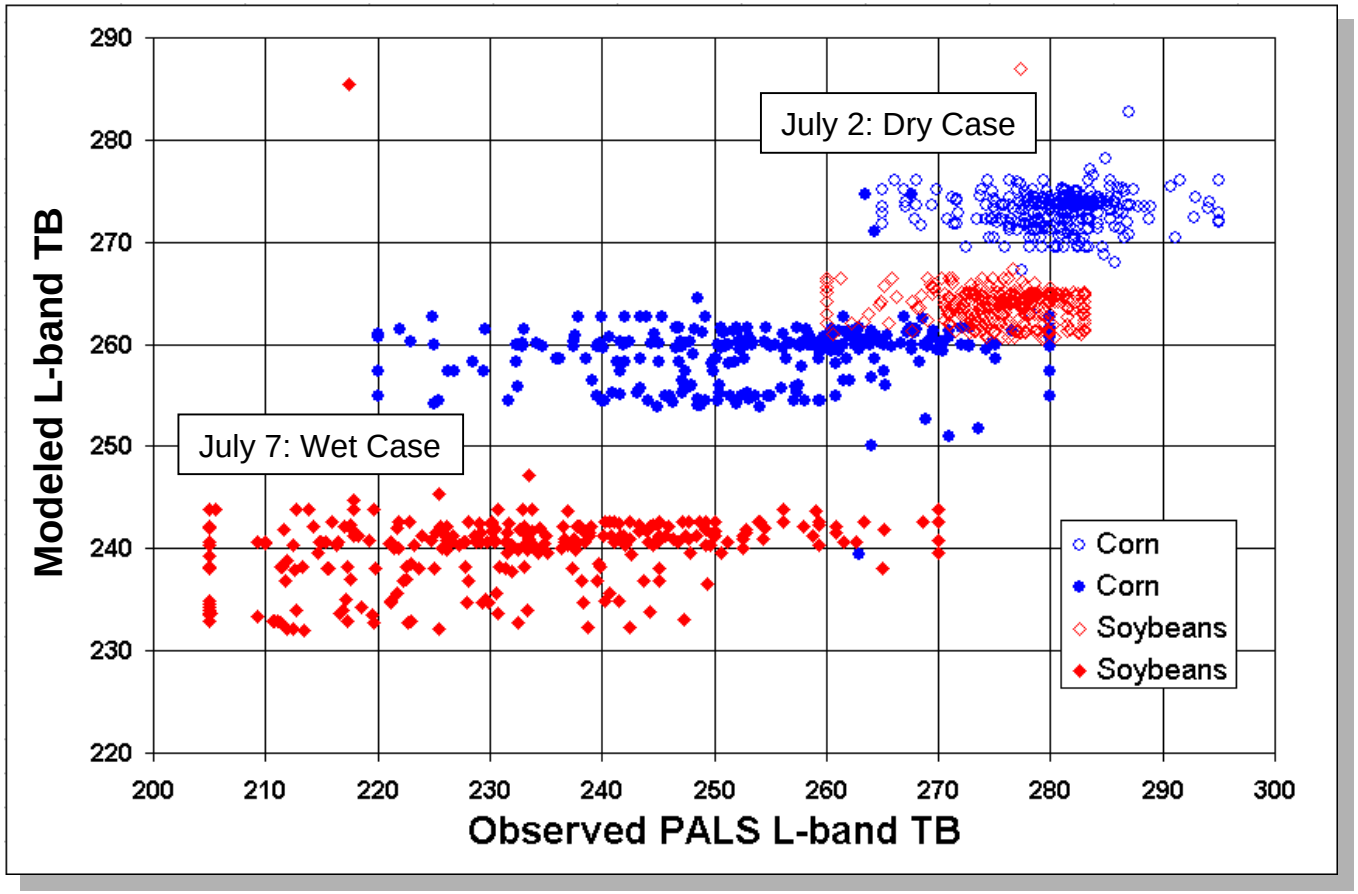
AMSR-E Soil Moisture



Comparison of Methods Along a Transect



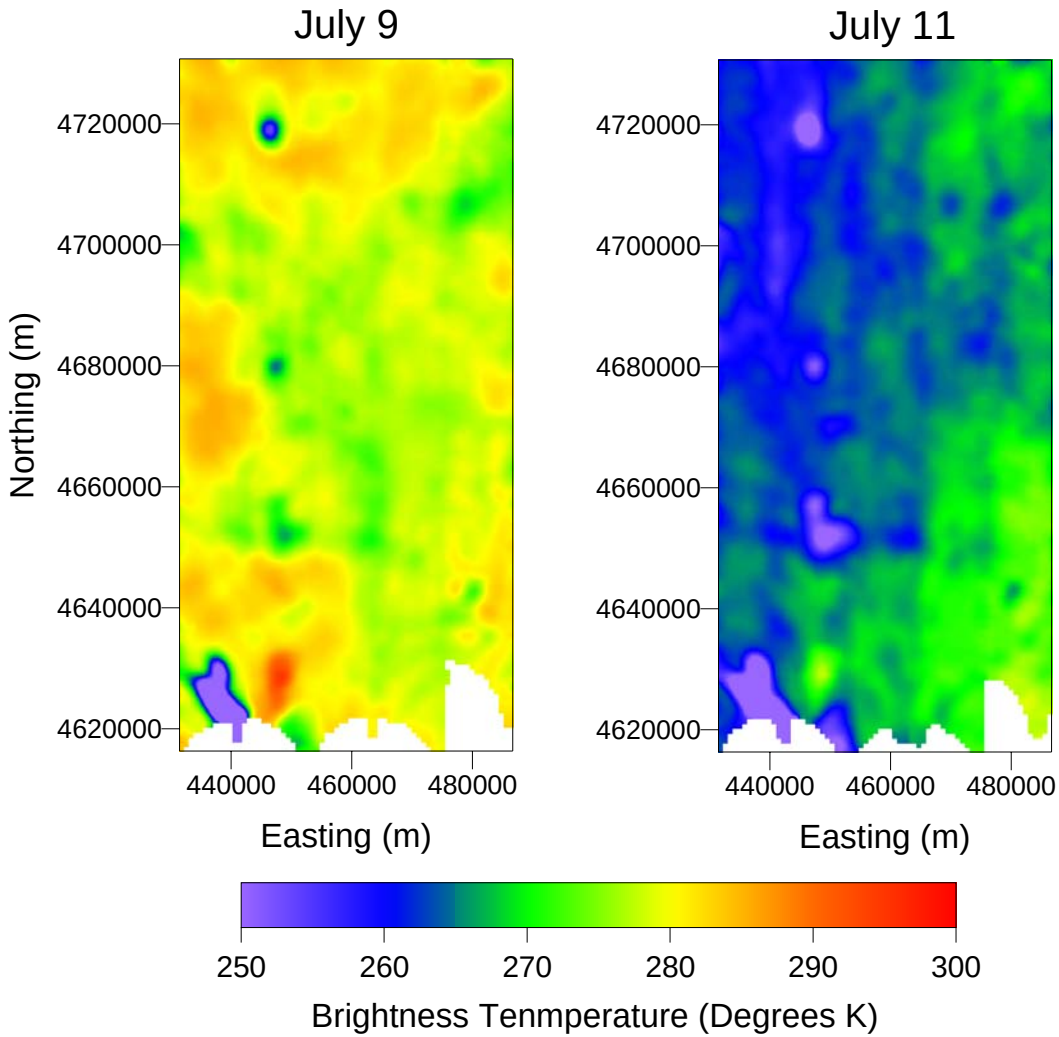
Observed PALS TB vs. Modeled TB (1.4 GHz)



AMSR-E Soil Moisture

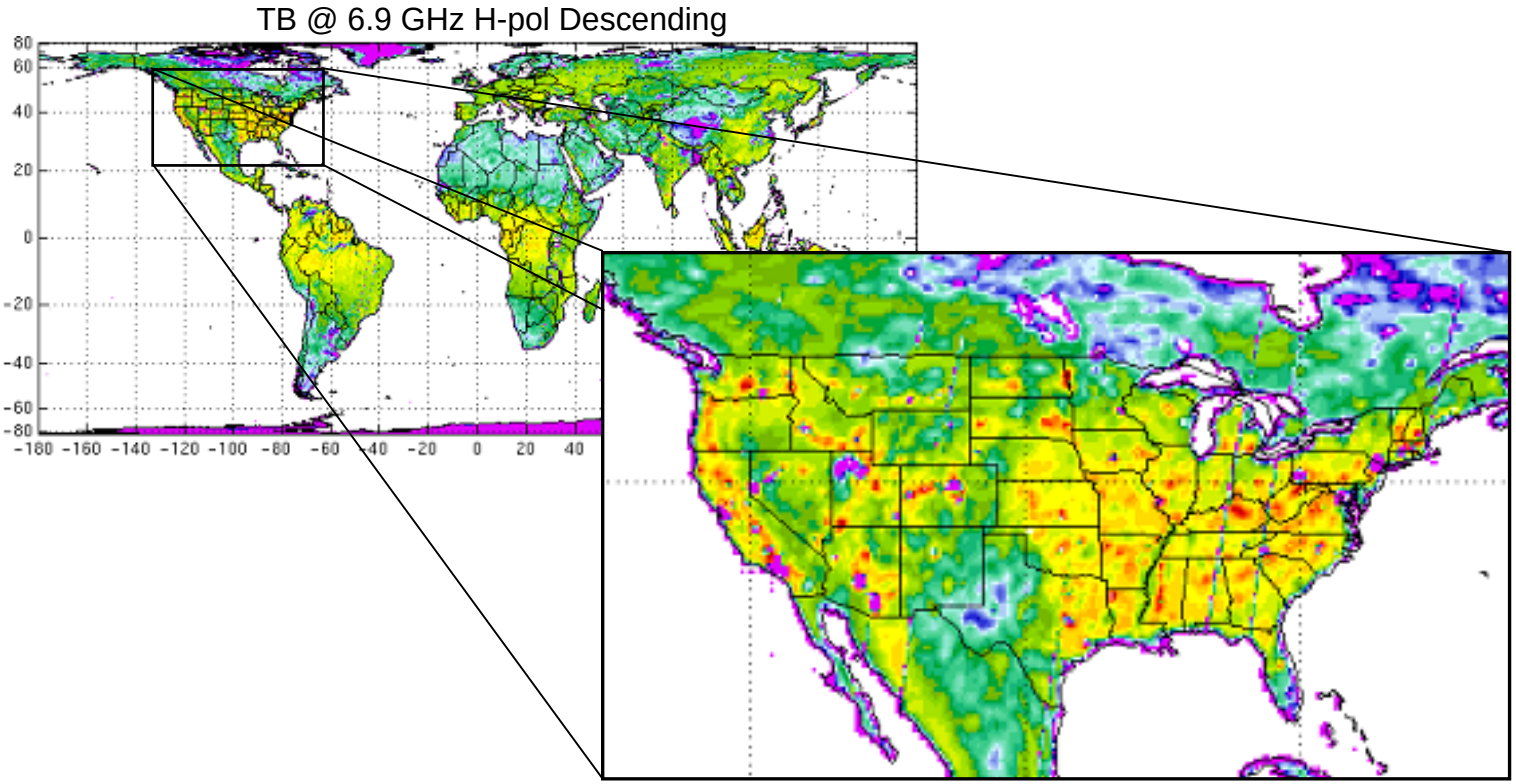
Polarimetric Scanning Radiometer (PSR)

7.32 GHz H-Pol



Images Provided by the USDA ARS Hydrology and Remote Sensing Lab

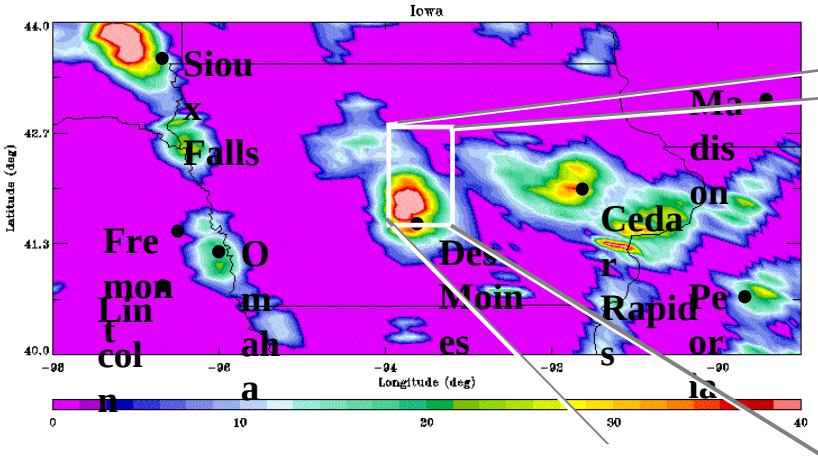
Radio Frequency Interference in AMSR-E at 6.9 GHz

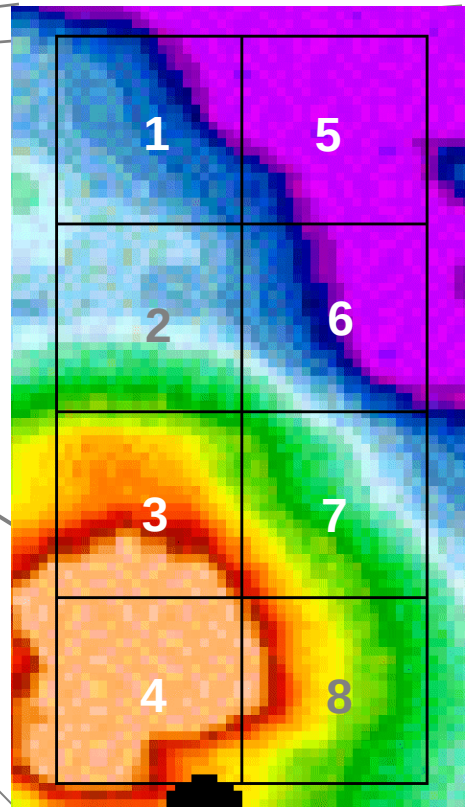


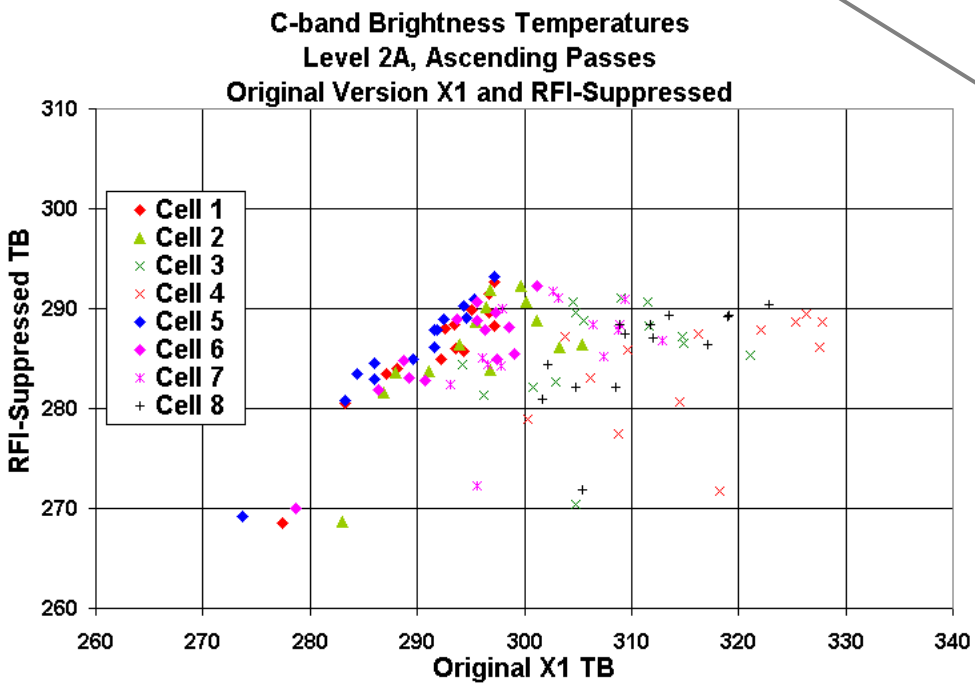
3 approaches for addressing RFI:

- Do nothing and apply mask over affected areas
- Develop/apply a RFI suppression algorithm
- Develop soil moisture retrieval algorithm exclusive of 6.9 GHz information

RFI Suppression in AMSR-E TB (6.9 GHZ)

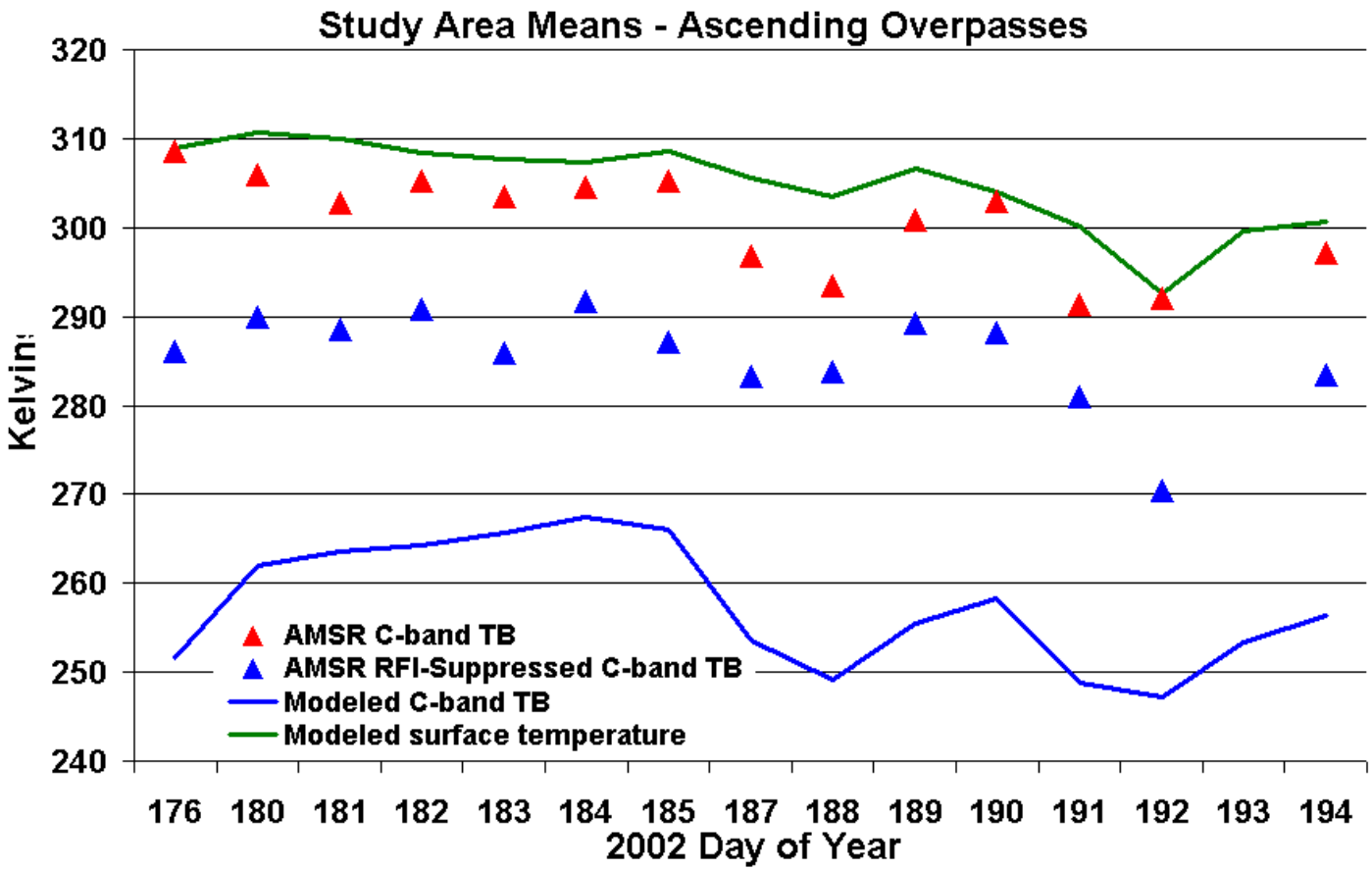






AMSR-E Soil Moisture

AMSR-E TB vs. Modeled TB (6.9 GHz)



- Mean TB for the 8-cell SMEX02 regional area
- Results for horizontally-polarized 6.9 GHz frequency
- Data are for ~ 1330 local time
- Coincident modeled surface temperatures are shown for comparison

AMSR-E Soil Moisture

Summary and Future Research

- A modeling/data assimilation system is in place to generate 'best estimates' of microwave brightness temperatures and near-surface soil moisture with which to validate AMSR-E data products.
- Uncertainties in these estimates will be determined using an ensemble simulation approach.
- The hydrologic model has been tuned such that soil moisture estimates agree well with observations at the watershed scale (400 km^2).
- An "optimal deconvolution" method has been developed to extract land cover based estimates of T_B.
- Model T_B for corn is about 10 K higher than for soybean under dry conditions and about 20 K higher under wet conditions.
- We are awaiting release of the PSR data to complete the multifrequency tuning of the radiative transfer model at the watershed scale.
- We will then run the coupled model over the regional domain in ensemble mode to generate products for AMSR validation.
- Validation of the RFI-suppression algorithm will be ongoing.
- Validation activities will be repeated to some extent with data sets generated during SMEX03.