



# Soil Moisture: Algorithms

Eni Njoku  
Jet Propulsion Laboratory  
California Institute of Technology

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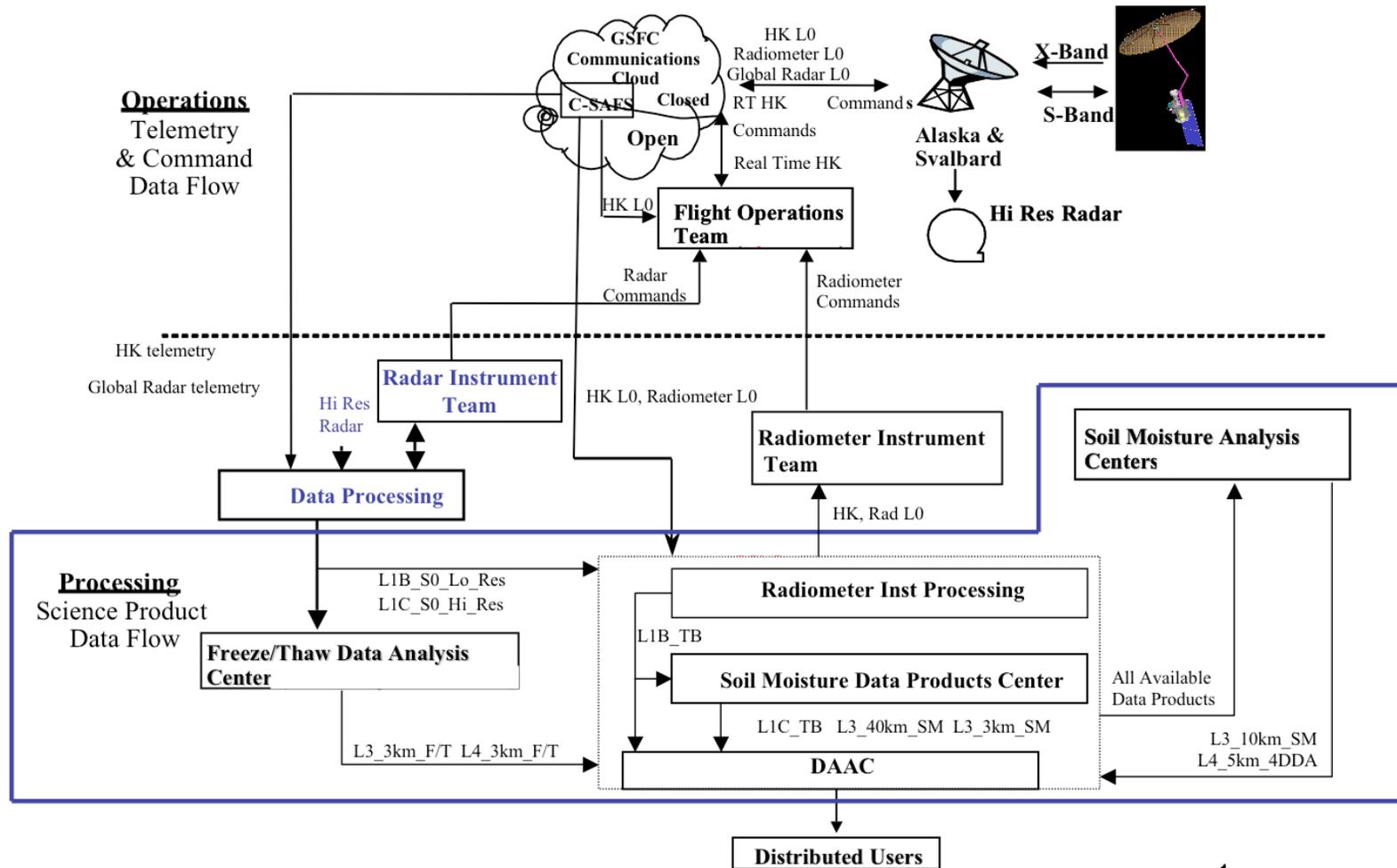
# SMAP Primary Data Products Table

## SMAP Primary Products (Hydros Heritage)

Data Product	Description
L1B_S0_LoRes	Low Resolution Radar $\sigma^0$ in Time Order
L1C_S0_HiRes	High Resolution Radar $\sigma^0$ on Earth Grid
L1B_TB	Radiometer $T_B$ in Time Order
L1C_TB	Radiometer $T_B$ on Earth Grid
L3_SM_HiRes	Radar Soil Moisture on Earth Grid
L3_F/T_HiRes	Freeze/Thaw State on Earth Grid
L3_SM_40km	Radiometer Soil Moisture on Earth Grid
L3_SM_A/P	Radar/Radiometer Soil Moisture on Earth Grid
L4_GPP	Gross Primary Productivity on Earth Grid
L4_4DDA	Soil Moisture Model Assimilation on Earth Grid

# SMAP Candidate Ground System Architecture

## Hydros Heritage



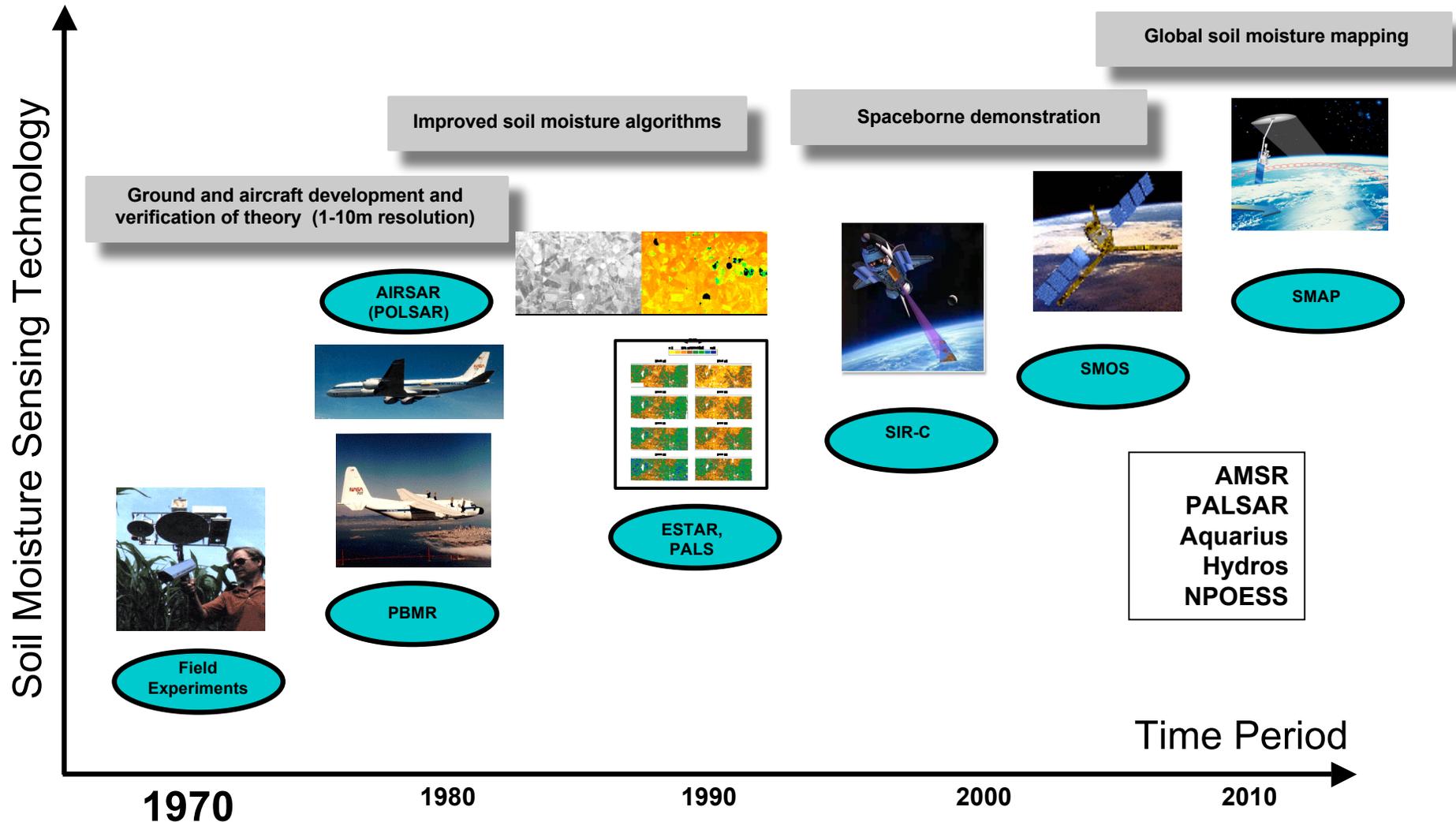
# Science Algorithm Roadmaps

## Algorithm Roadmaps (Hydros Heritage)

- Mission data products are based on algorithms (baseline and enhancements) that consist of the equations and processing steps used to generate the products
- Algorithm roadmaps describe the procedures for developing and testing the algorithms to ensure the data products meet the mission requirements
- The algorithms and computational software derived from them are developed by the science team to be used in generation of the data products
- Each science data product has a target accuracy, spatial resolution, spatial gridding (posting), global repeat, and latency requirement
- Roadmap documents were developed for each Hydros data product during Hydros Phase A

# Soil Moisture Algorithms: Heritage R&A Investments

## Evolution of Soil Moisture Mapping



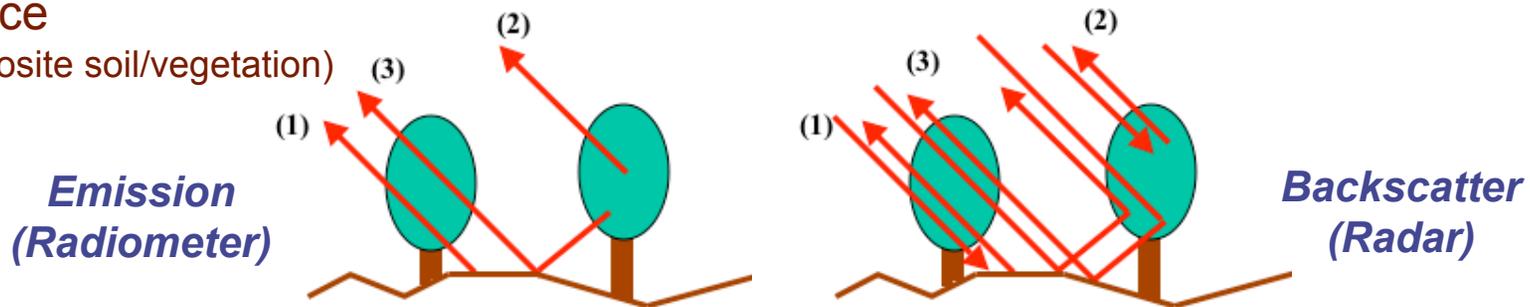
# Soil-Vegetation Surface Microwave Model

Ionosphere, Atmosphere

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Surface

(Composite soil/vegetation)



$$T_{Bp}^t = T_{Bp}^s L_p + T_{Bp}^v + T_{Bp}^{sv} \quad (\text{Emission})$$

$$\sigma_{pq}^t = \sigma_{pq}^s L_{pq}^2 + \sigma_{pq}^v + \sigma_{pq}^{sv} \quad (\text{Backscatter})$$

- Subscripts  $p, q$  : polarization ( $h$  or  $v$ )
- $L_{pq}, L_p$  : one-way vegetation attenuation factor,  $\exp(-\tau_o / \cos\theta)$
- Superscripts  $t, s, v$ , and  $sv$  indicate total, soil, vegetation, and soil-vegetation interaction terms, respectively

# Supporting Field Campaigns

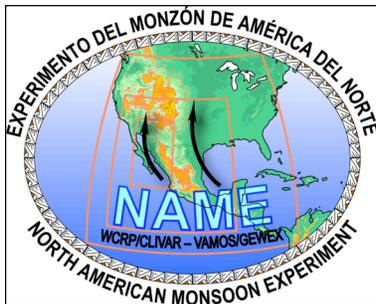
## Soil Moisture Science and Algorithm Development

### *Multi-scale soil moisture field experiments (1990-2005) using satellite, airborne, and in-situ sensing*

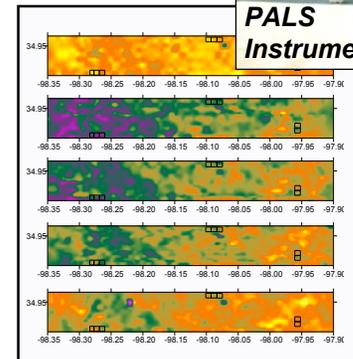
- Coordinated by NASA and USDA/ARS Hydrology Laboratory
- Included flights of ESTAR, PALS and AIRSAR L-band sensors
- Participation by university faculty and students in field measurements and data analysis



### *SMEX04/North American Monsoon Experiment (NAME)*



### *SMEX U.S. Sites*



**SMEX Airborne soil moisture mapping**



**In-situ Sampling**



**Validation Field Site at Alabama A&M with University Students Participation**



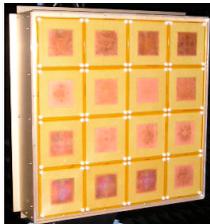
### **600+ High-Schools**

Students collect ground-truth soil moisture data. Classroom access linkages developed for soil moisture mission data.

# PALS-II: Combined Active and Passive L-band Instrument



Twin Otter



Planar antenna



Front-End Electronics Integrated with Antenna



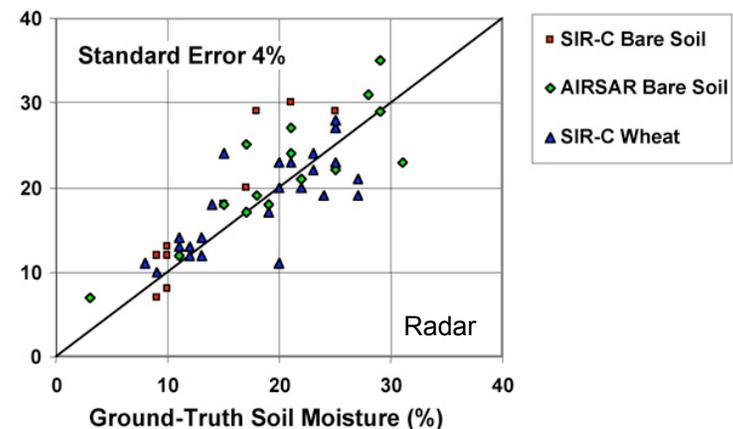
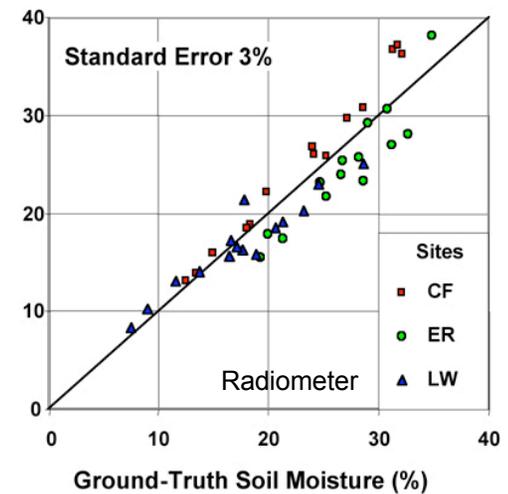
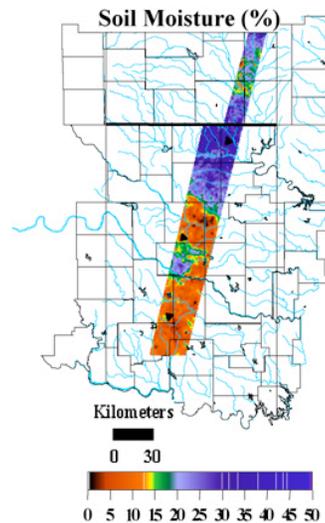
Rack equipment

- PALS-II Characteristics
  - Polarimetric radiometer (1.41 GHz)
    - V, H, +45, and -45 degree polarizations
    - Three-noise-diode design, similar to Aquarius and Hydros'
  - Polarimetric radar (1.26 GHz)
    - VV, HH, VH and HV
    - Parallel V and H receivers
  - Companion nadir-looking IR and video cameras
- CLASIC campaign on the Twin Otter in summer 2007
- High Wind Ocean Salinity Campaign for hurricanes of opportunity on the NASA P-3 in summer 2008

# Field Campaign Retrieval Results

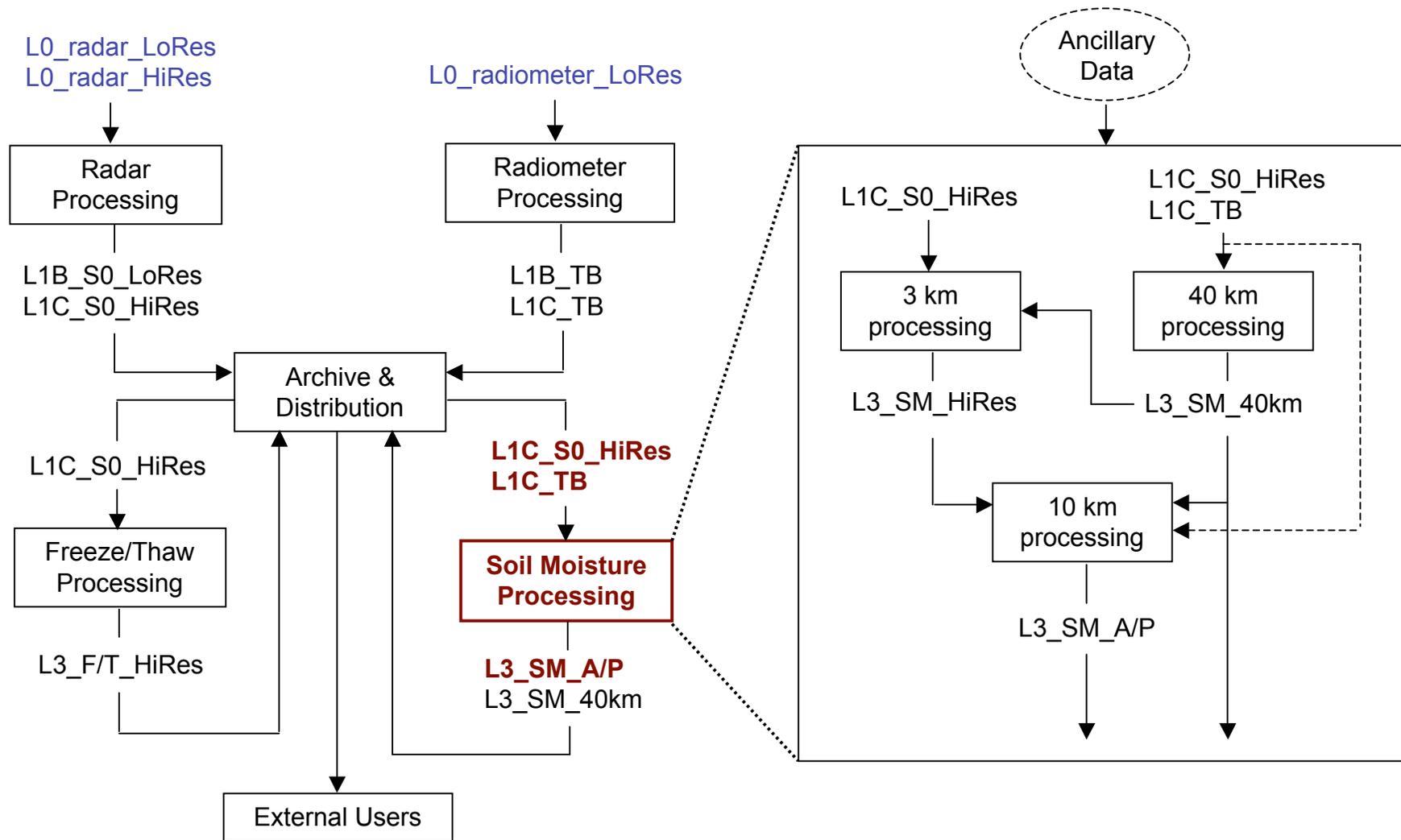
## Retrievals and Validation

- Soil moisture retrieval algorithms have been developed and validated during an extensive history of microwave modeling and field experiments (using ground-based, airborne and Shuttle instruments)
  - *MacHydro'90, Monsoon'91, Washita'92, FIFE, HAPEX, SGP'97, '99, SMEX'02, '03, '04, '05*
  - *Radiometric retrieval accuracy is greater than radar in vegetated conditions, achieving better than 4% volumetric accuracy for vegetation water contents up to  $\sim 5 \text{ kg m}^{-2}$  (mature corn crop)*
  - *Radar can achieve higher spatial resolution than radiometry using synthetic aperture processing*

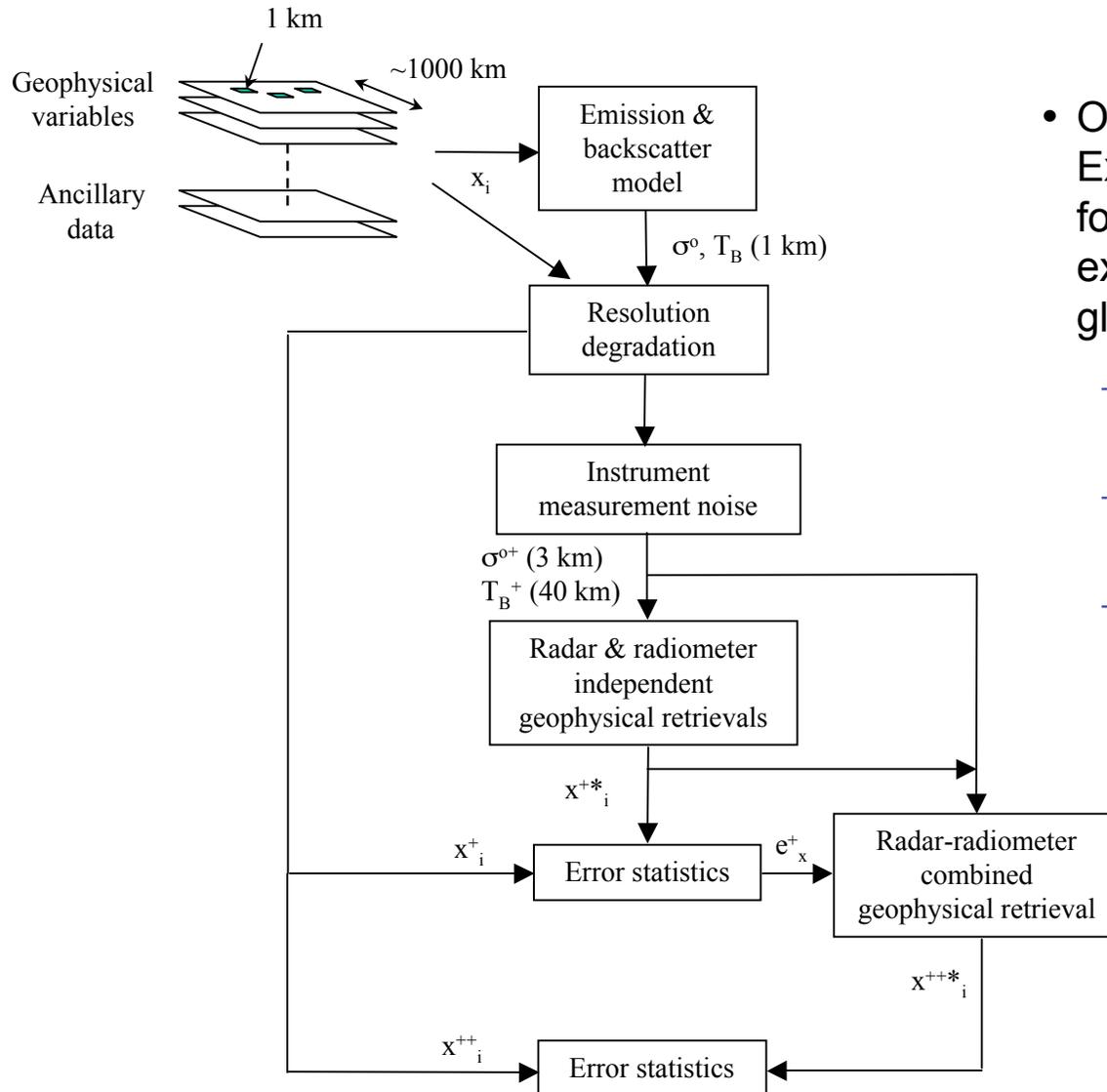


# Soil Moisture and Freeze/Thaw Algorithm Processing

(Hydros Heritage)



# Retrieval Simulation and Sensitivity Studies



- Observing System Simulation Experiments (OSSE) designed for Hydros can be improved and extended to continental and global scales for SMAP

– Improved geophysical and microwave models

– Improved instrument and orbit simulations

– Essential for informed instrument design trades and algorithm development

## Legend:

$x_i$  geophysical variables  
 $+$  simulated sensor product resolution (radar and radiometer)  
 $++$  combined retrieval resolution  
 $*$  estimated (retrieved variables)

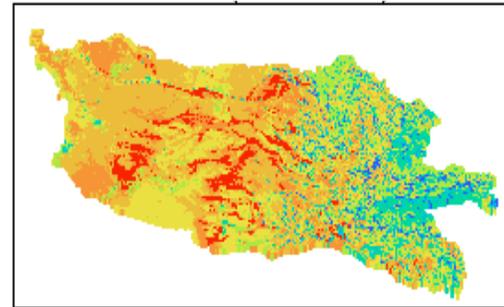
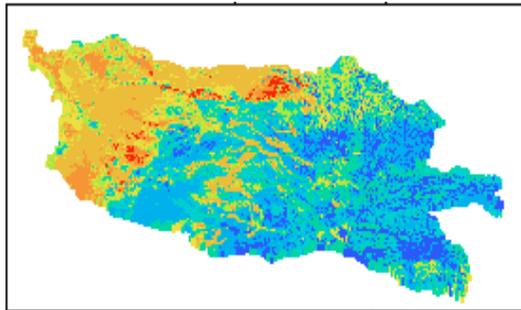
# Model-Simulated Soil Moisture

Red-Arkansas River Basin (Crow et al.)

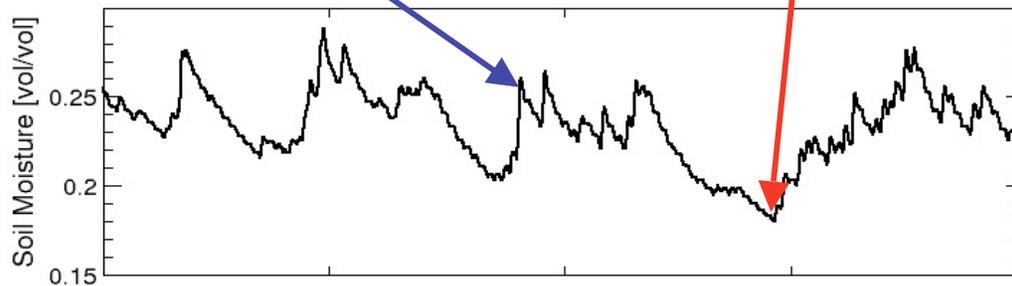
## Hydros OSSE - Geophysical simulations

Start Date: May 26, 1994 (Wet)

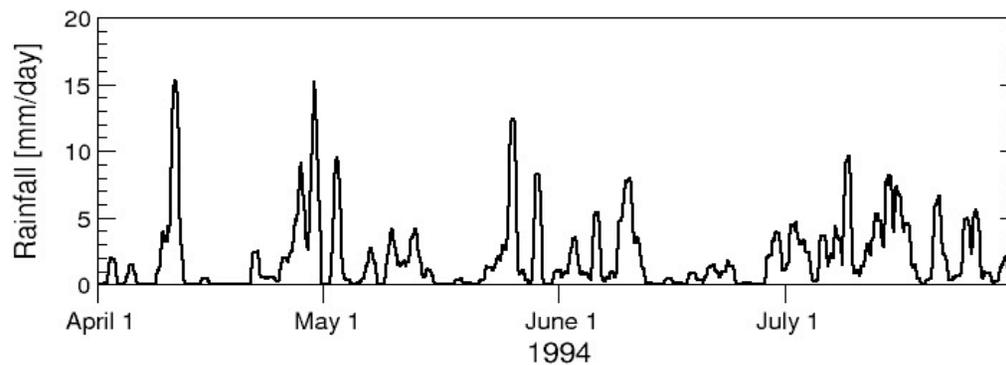
End Date: June 28, 1994 (Dry)



*Soil moisture distributions at start and end of simulation*



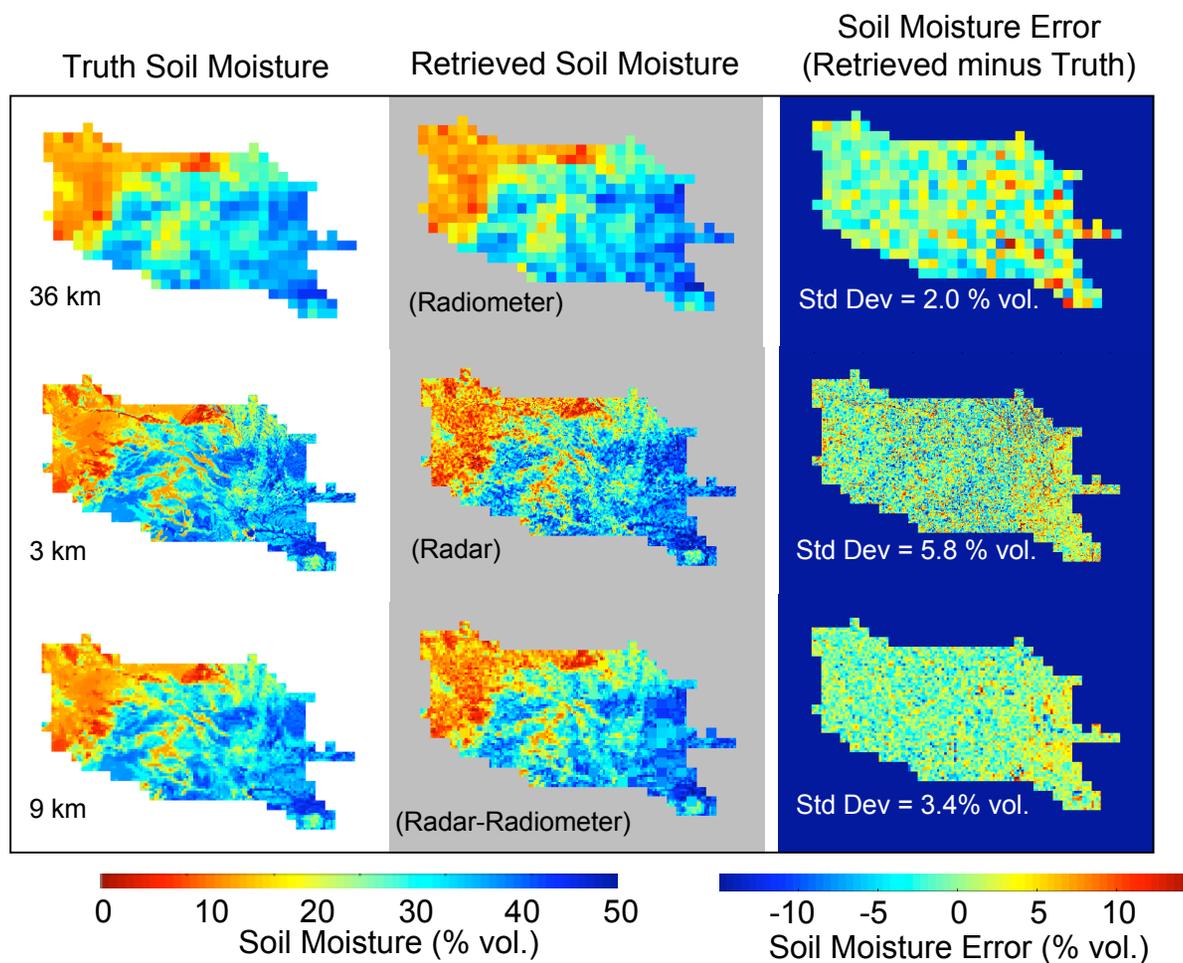
*Basin-averaged soil moisture and precipitation time series*



# Simulated Soil Moisture Retrievals

(Radiometer, Radar, and Combined Spatial Resolutions)

Hydros OSSE



# SMAP Soil Moisture Algorithms - Summary



- Soil Moisture Requirements for a spaceborne mission were articulated in NASA-sponsored community workshop (SMMWG) in Irvine in the 1990s and have not changed significantly since then - recently reconfirmed by the SMMWG meeting in March 2006
- SMAP soil moisture algorithms (Hydros heritage) were further developed during the Hydros Risk-Reduction phase and reviewed at the Hydros open science meeting (Phoenix, AZ, May 2005)
- Recent progress in soil moisture radar science and algorithms was presented and reviewed at the Hydros International Radar Workshop (Santa Barbara, CA, October, 2005)
- Soil moisture and freeze/thaw algorithms are robust - additional research will help refine and extend these algorithms for the SMAP mission