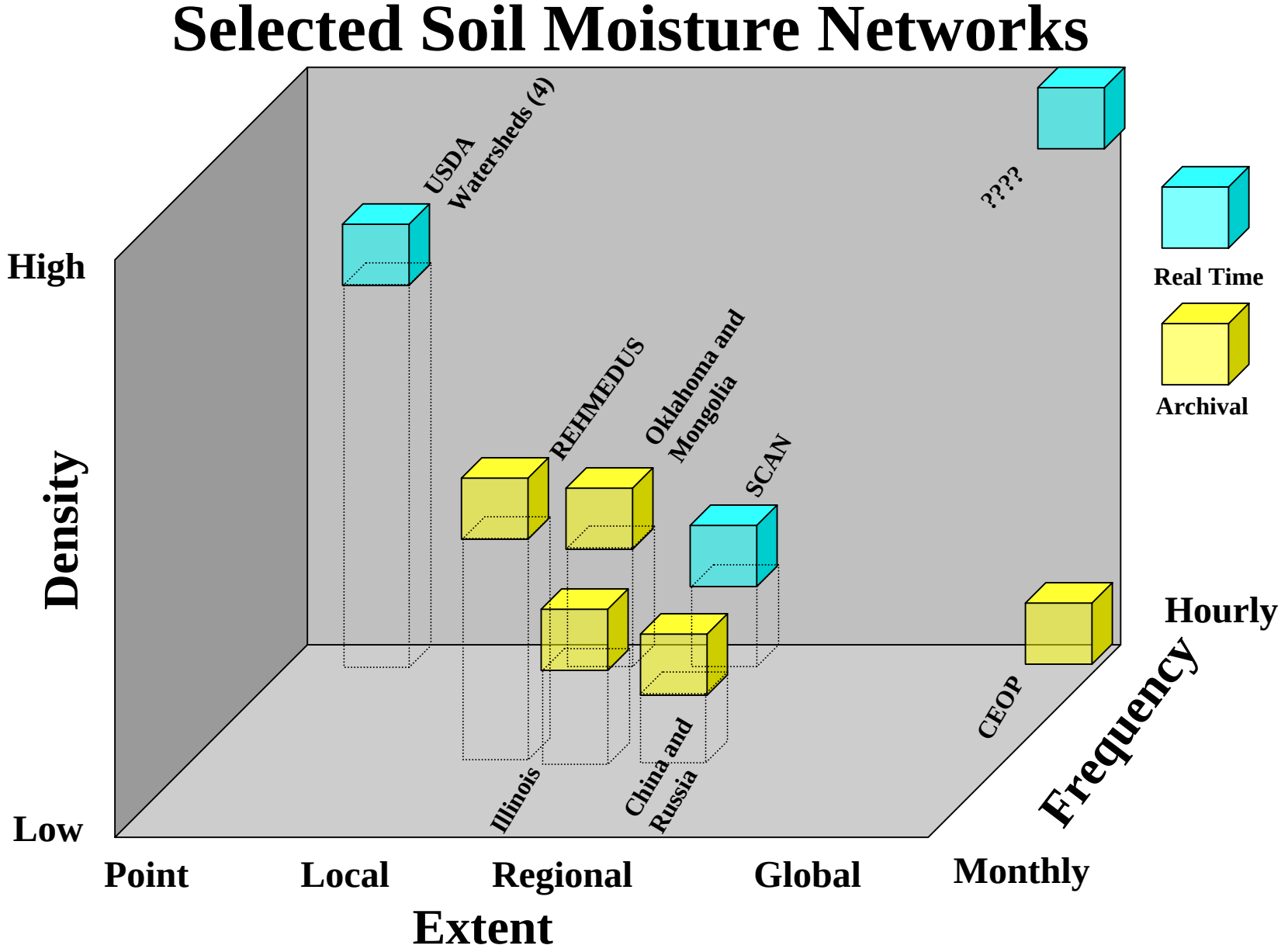
Insitu Soil Moisture Supporting Modeling and Remote Sensing

- **Take advantage of existing infrastructure**
- **Strive for consistency and standardization**
- **Link long term points to short term spatial**
- **Exploit temporal stability**
- **Consistent measurements**
- **Expand what we can**
- **5 cm!**

Insitu Soil Moisture Networks Dimensions to Consider

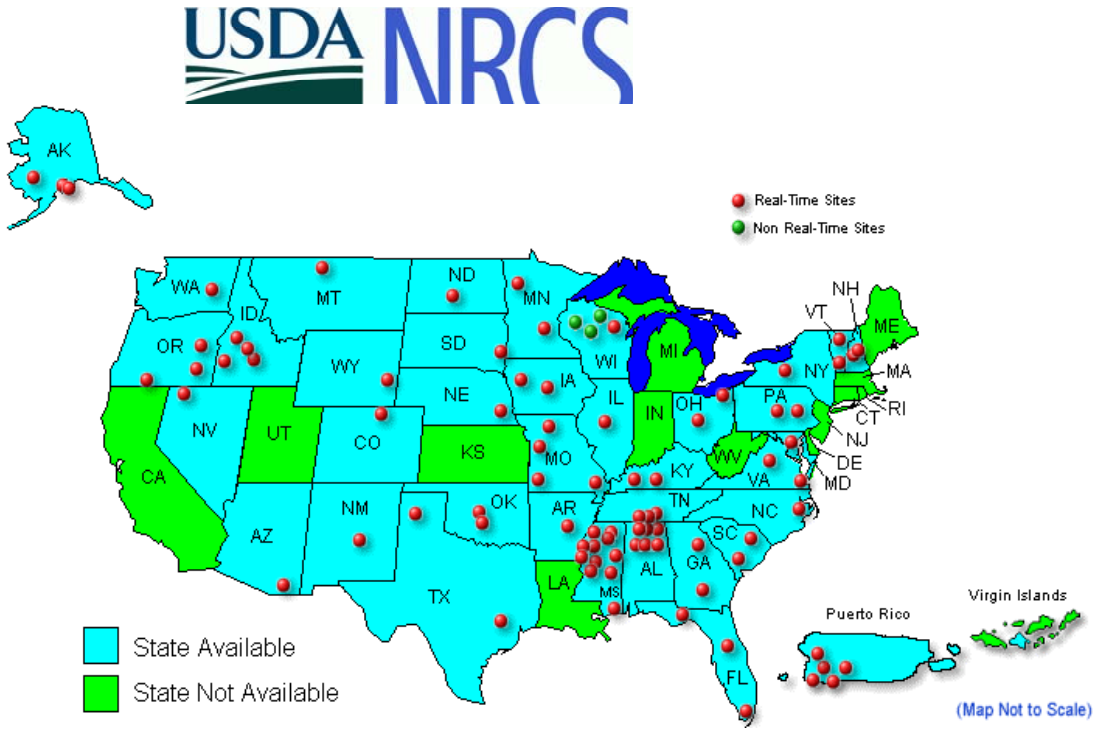
- **Extent of network**
- **Density**
- **Frequency of measurement**
- **Latency**
- **Availability**
- **Measurement Technique**


Selected Soil Moisture Networks
High
Density
Low
Point
Local
Regional
Global
Extent
Monthly
Hourly
Frequency
USDA Watersheds (4)
????
REHMEDUS
Oklahoma and Mongolia
SCAN
CEOP
Illinois
China and Russia
Real Time
Archival

Regional Extent-Low Density-High Frequency

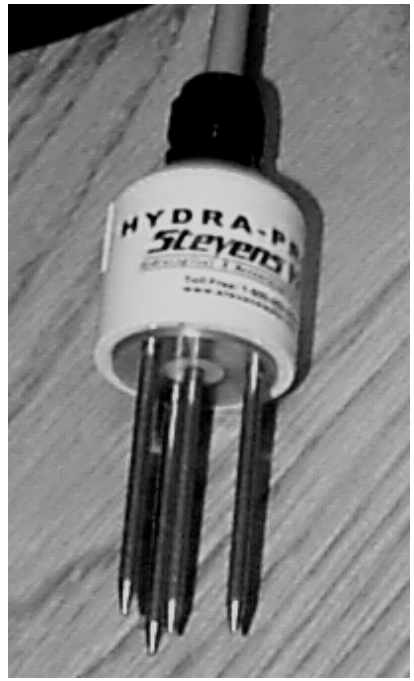
Soil Climate Analysis Network (SCAN)

- **Hourly observations**
- **80+ sites**
- **Meteor burst data transmission**
- **Web based real time**
- **Public access**
- **Wide range of users**



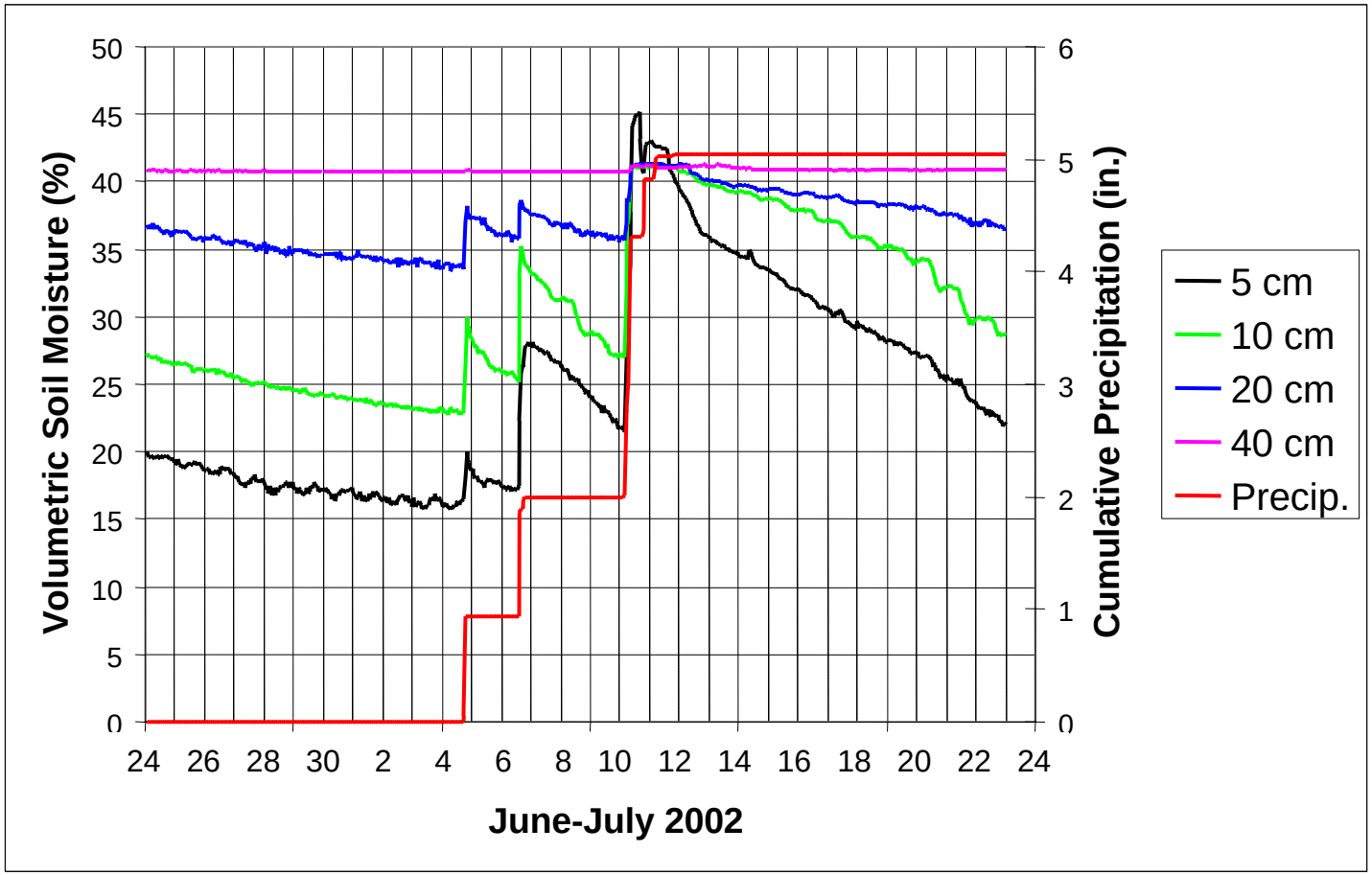
Standard SCAN Site Configuration

- Precipitation
- Air temperature
- Relative humidity
- Wind speed and direction
- Solar radiation
- Barometric pressure
- Snow water content and depth
- Soil moisture and temperature

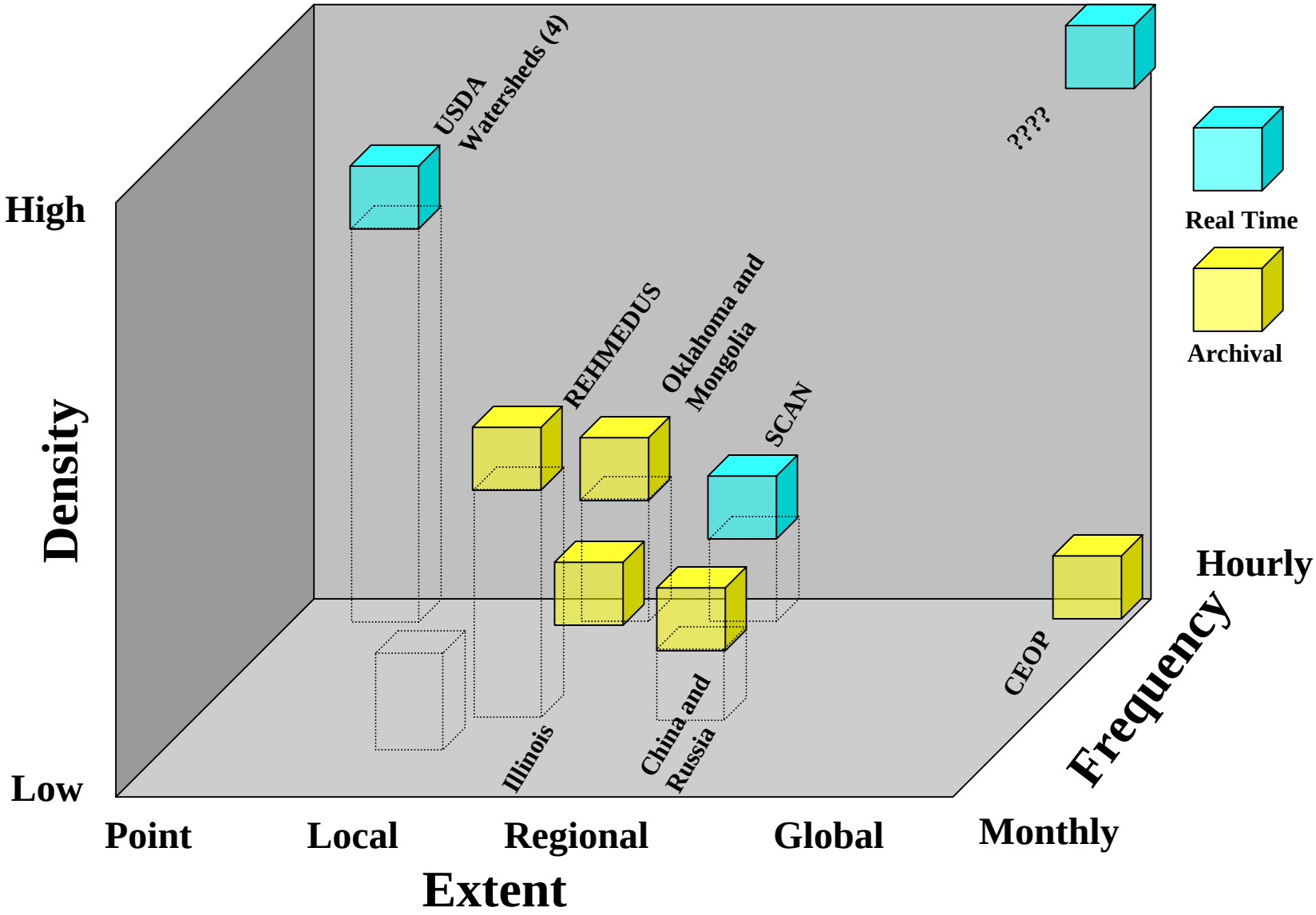


Vitel Hydraprobe

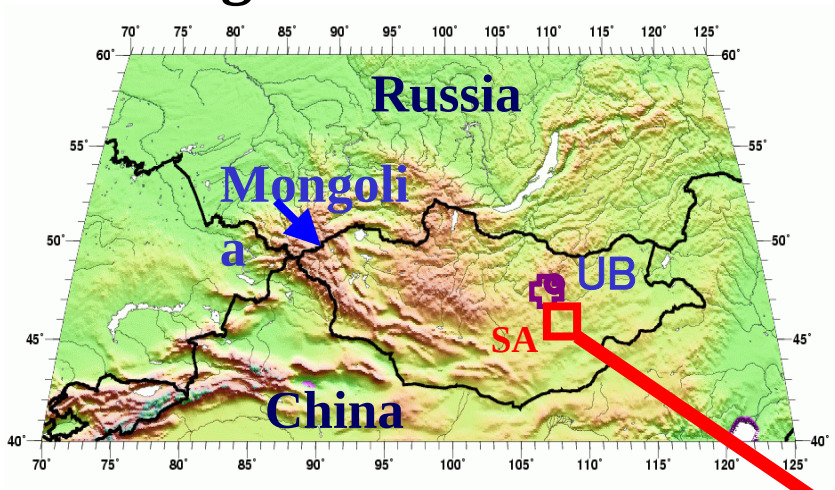
Ames, Iowa SCAN Soil Moisture

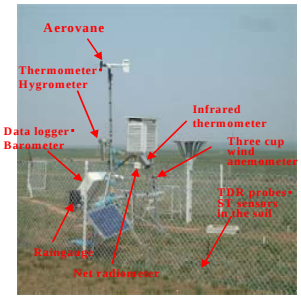


Selected Soil Moisture Networks

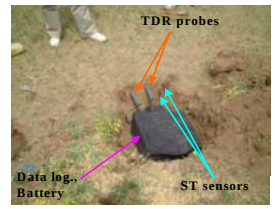


Regional Extent-Moderate Density-High Frequency

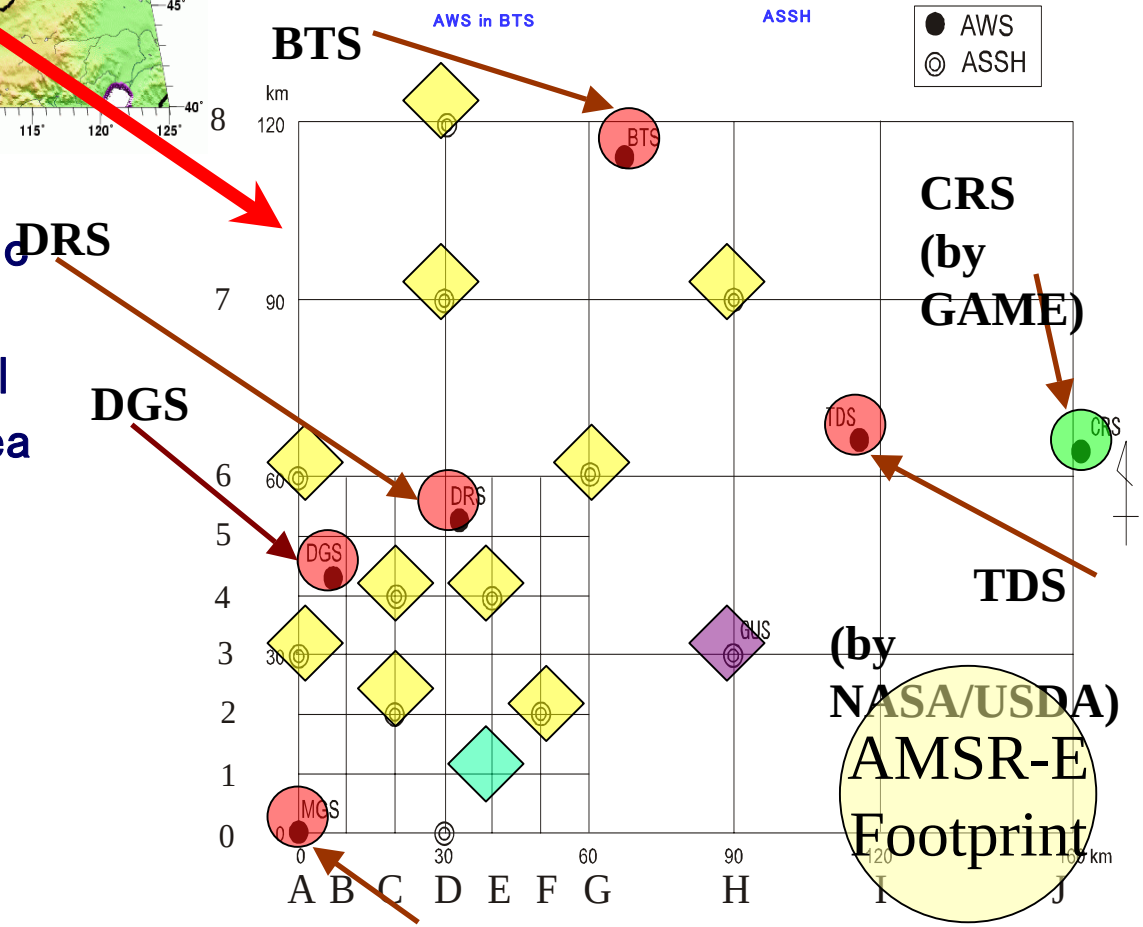




AWS



ASSH



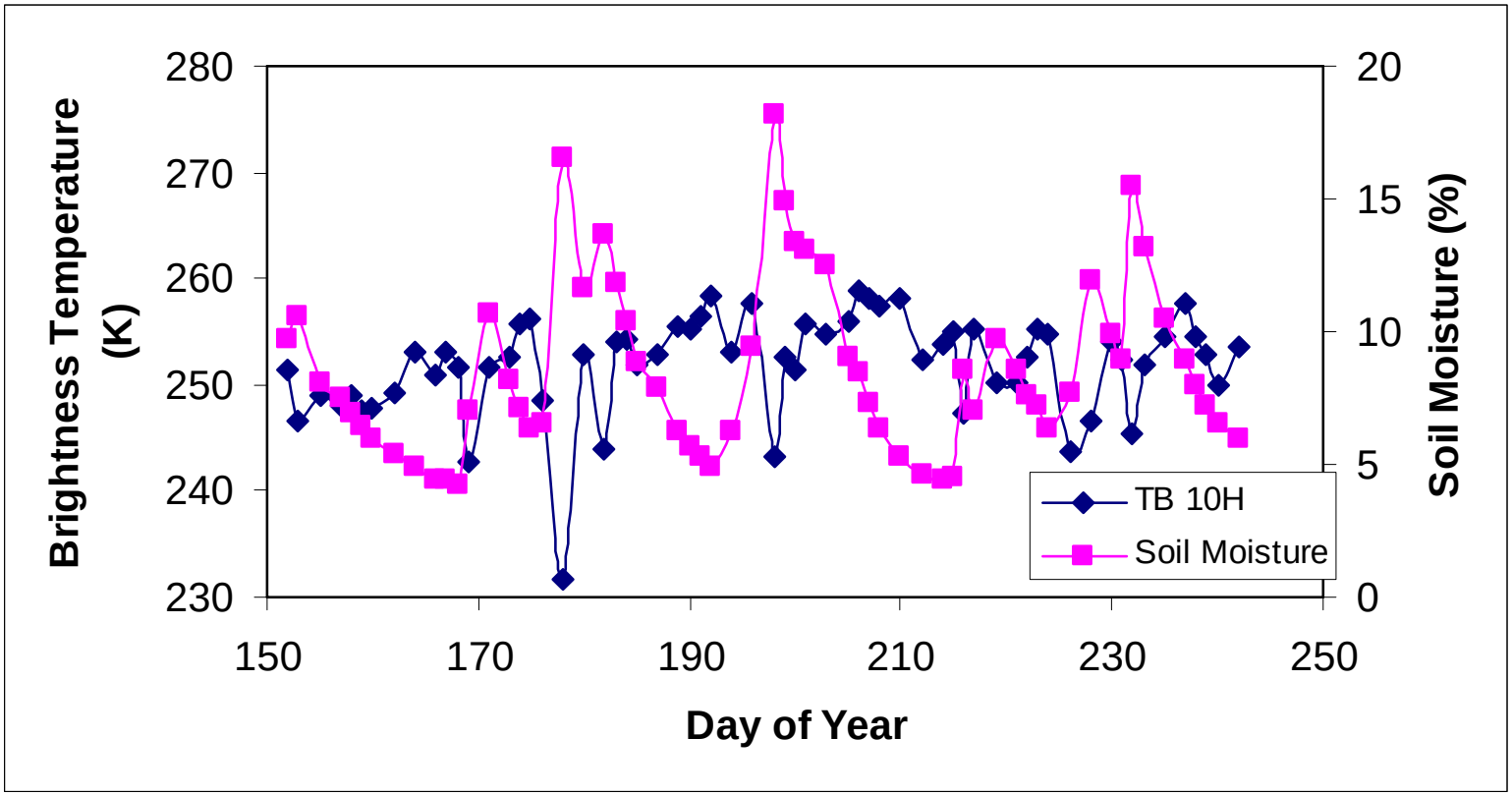
Location of AWS(Automatic Weather Station)・ASSH (Automatic Station for Soil Hydrology) in the study area and Morlinuul radar site (MRS), Oct.., 2004 (SA : Study area for also CEOP reference site, UB: Ulaanbaatar)

CEOP: Coordinated Enhanced Observing Period of GEWEX

Mongolia Match Up Data (June - August 2003)

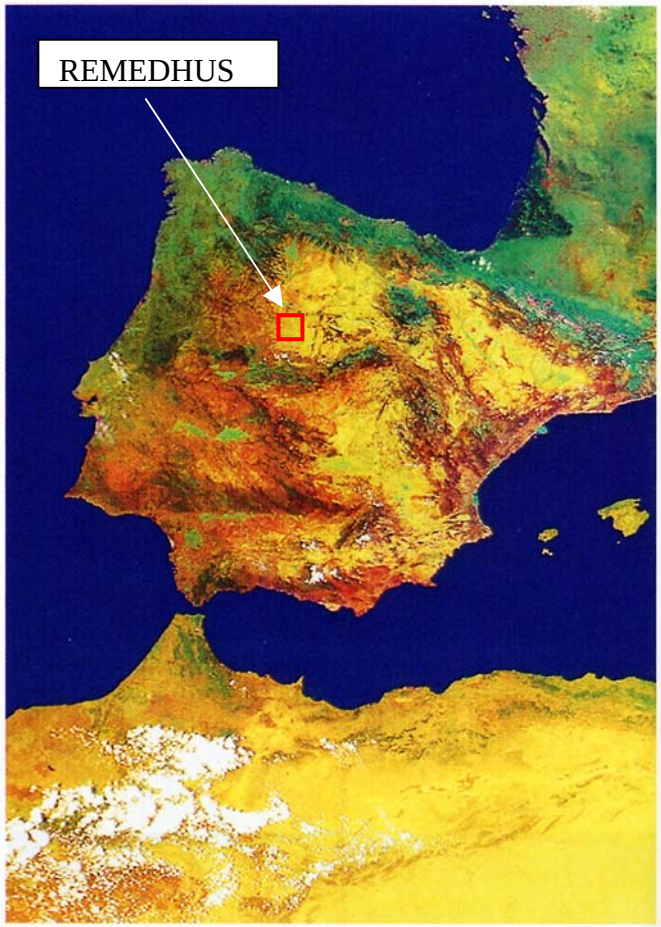
Descending

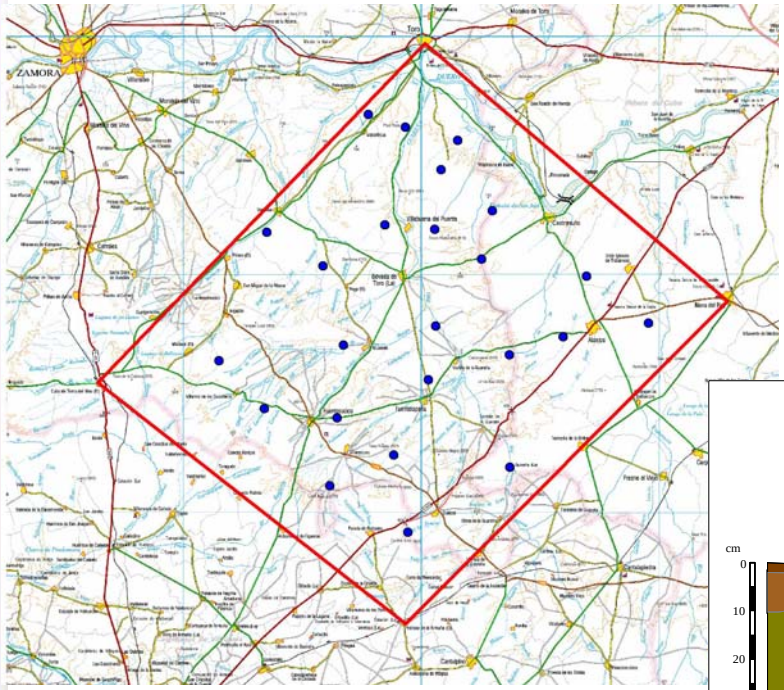
10 GHz H Brightness Temperature and 3 cm Soil Moisture

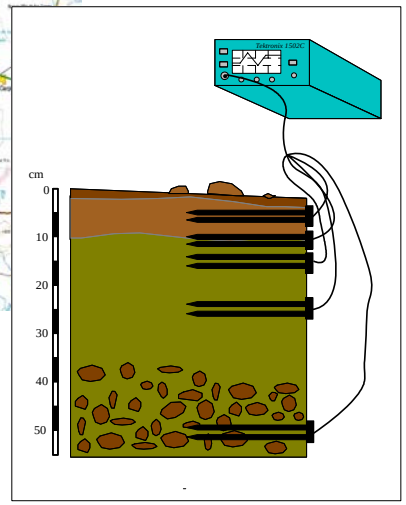


Regional Extent-Moderate Density-Low Frequency REMEDHUS* *Soil Moisture Stations Network (33 x 38 km)*

University of Salamanca

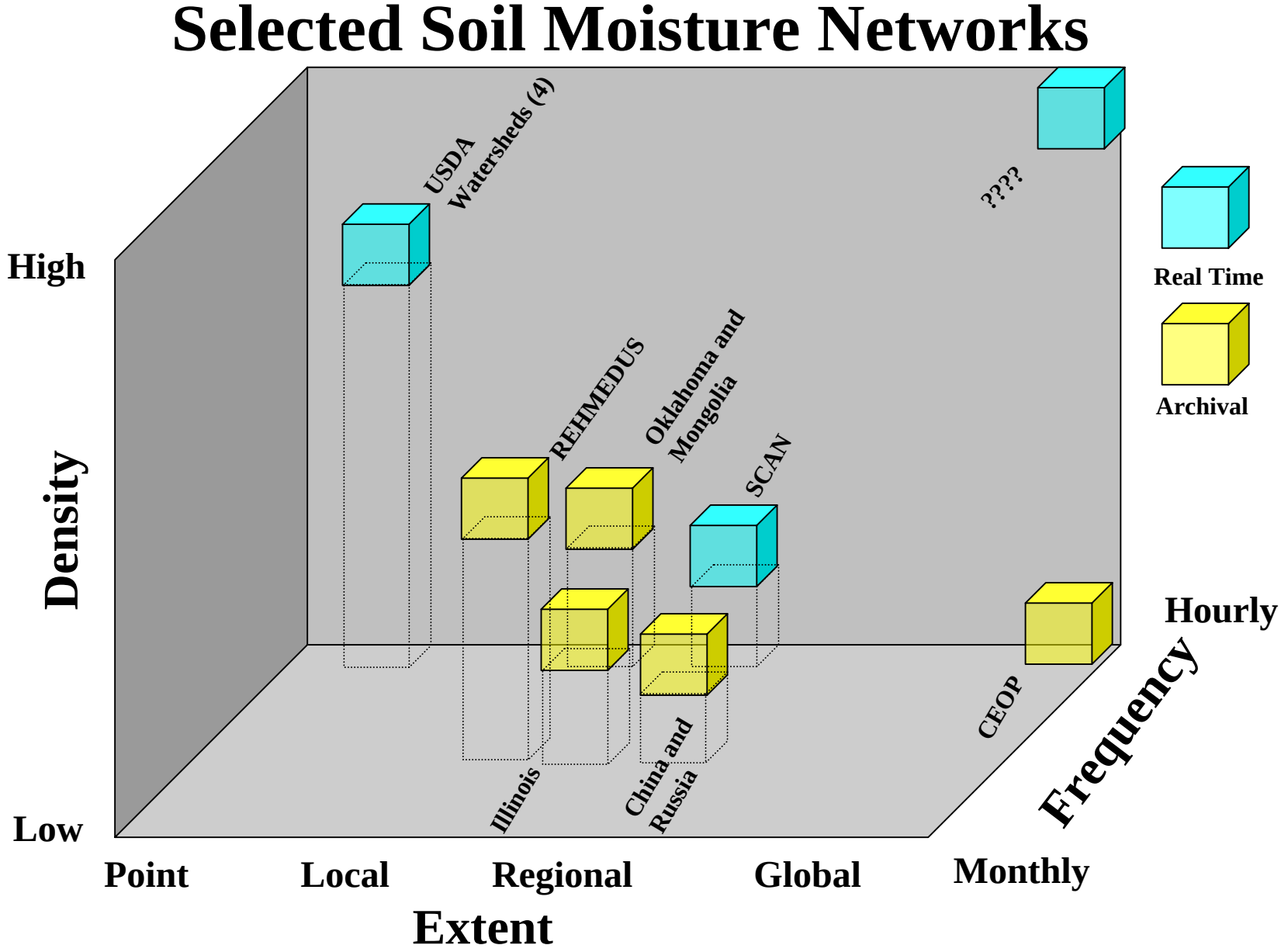






Network has been operating since June 1999 measuring soil moisture at depths of 5, 25, 50 and 100 cm at 14-days intervals using TDR probes. Vitel probes are being added for 5 cm data every 20 min.

*Red de Estaciones de Medición de la Humedad del Suelo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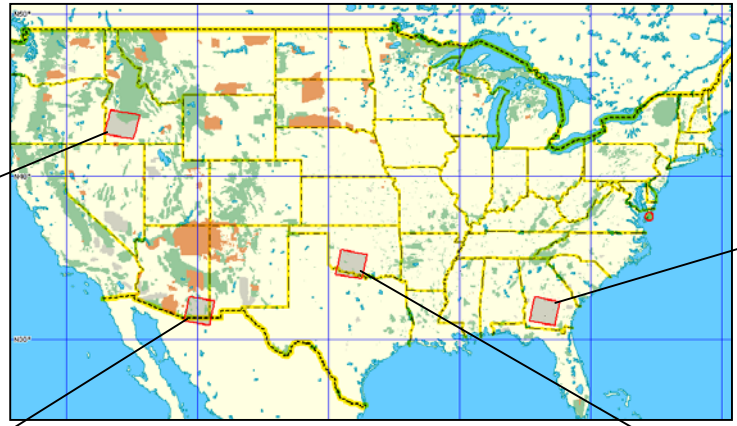
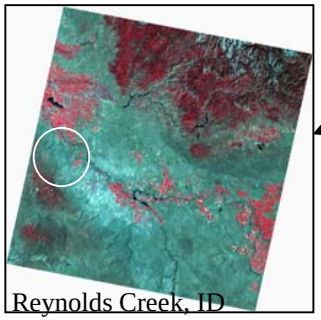
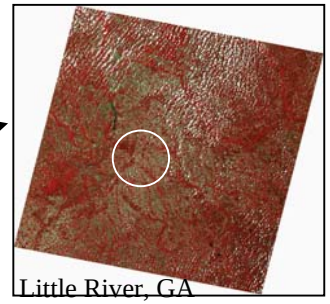
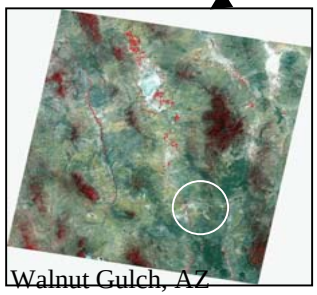
AMSR-E Soil Moisture Validation

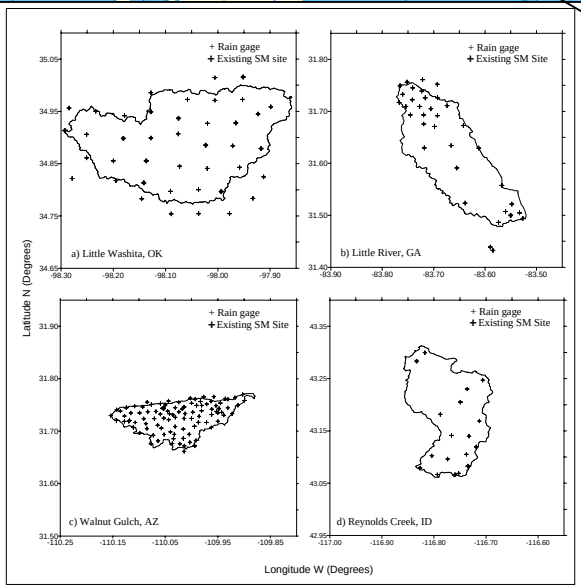
AMSR-E SMEX03,05 U.S. Soil Moisture Validation Sites

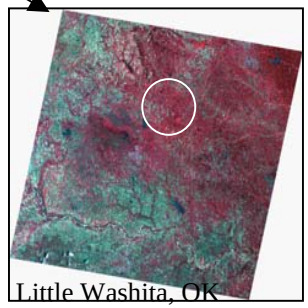




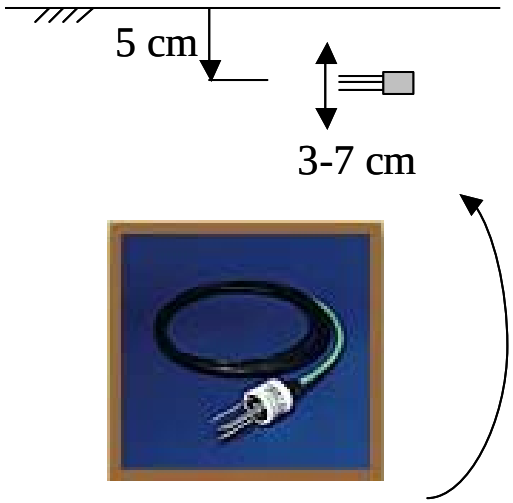




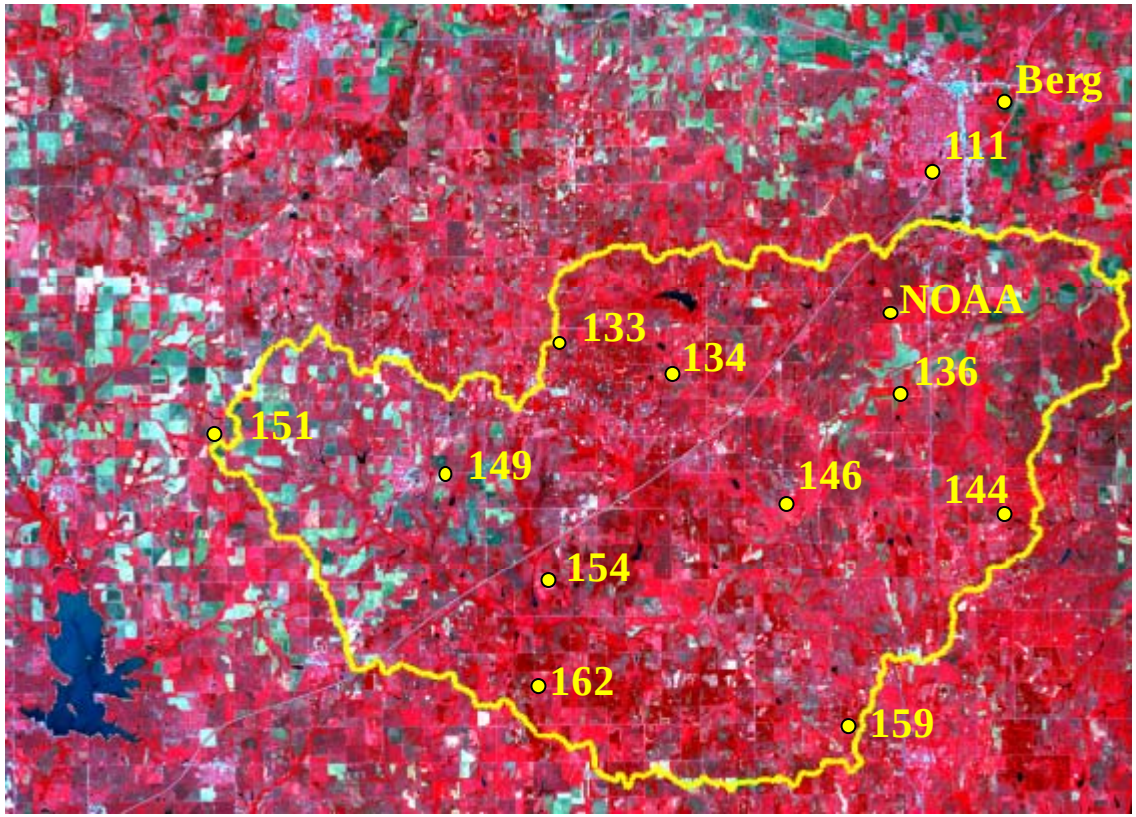




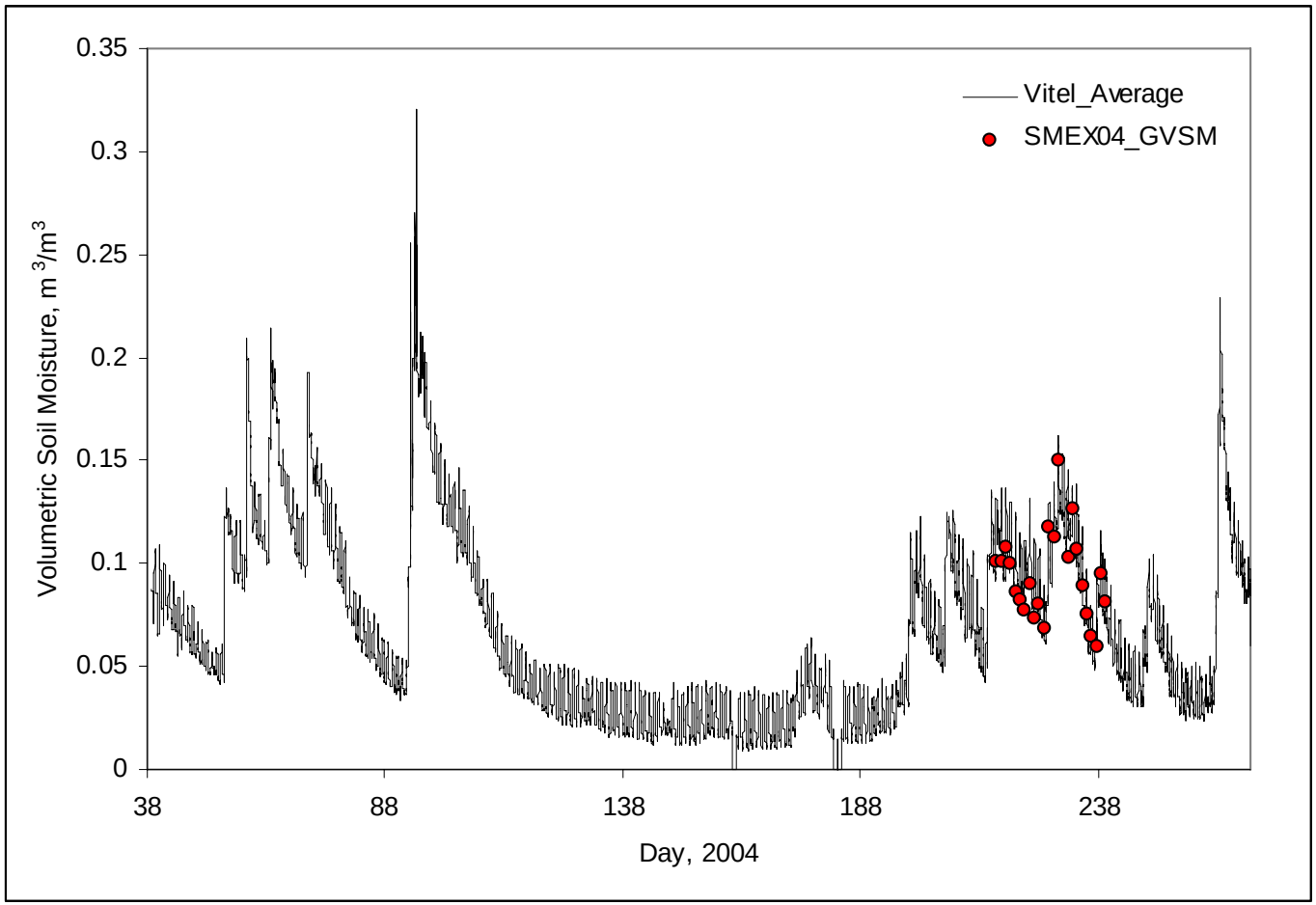
Little Washita Vitel Network



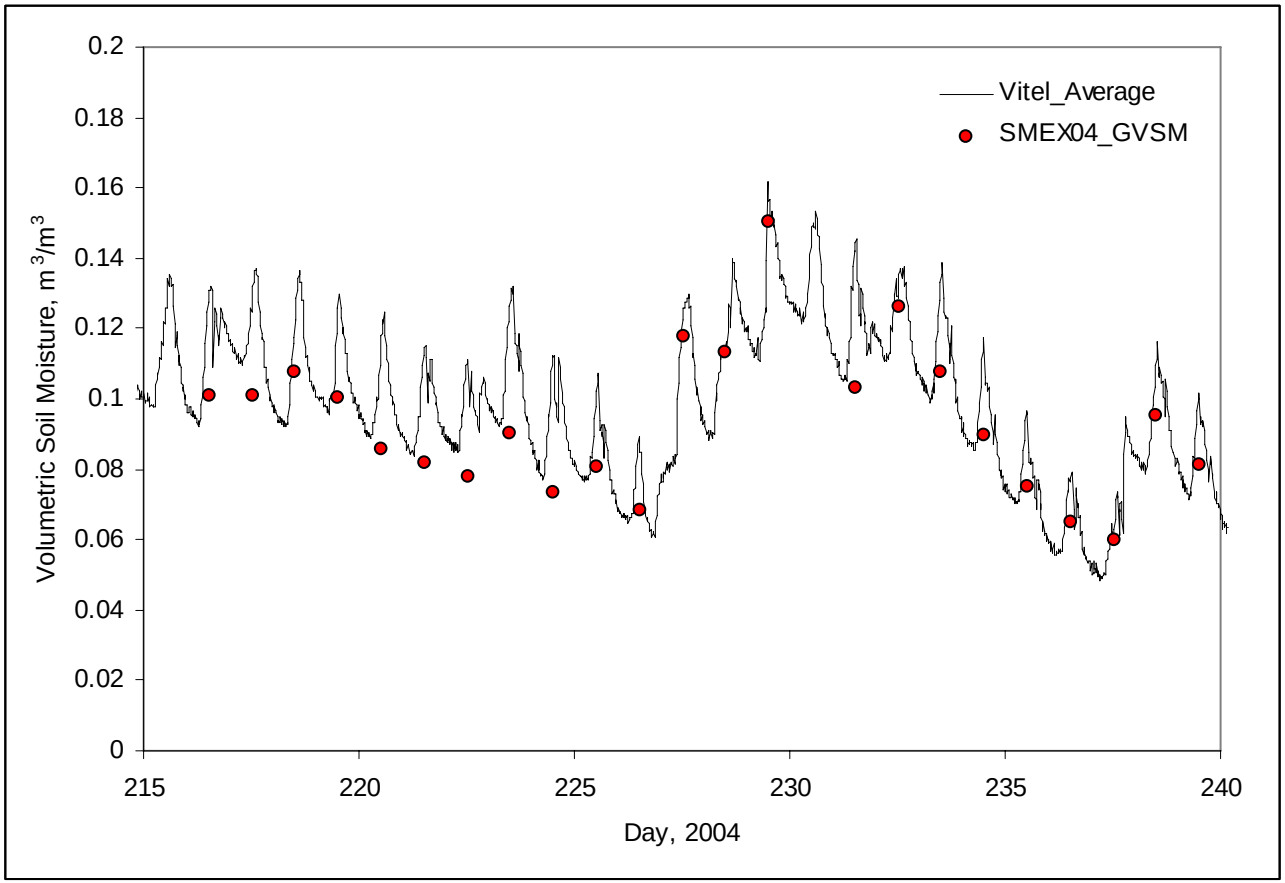
Little Washita River Washita

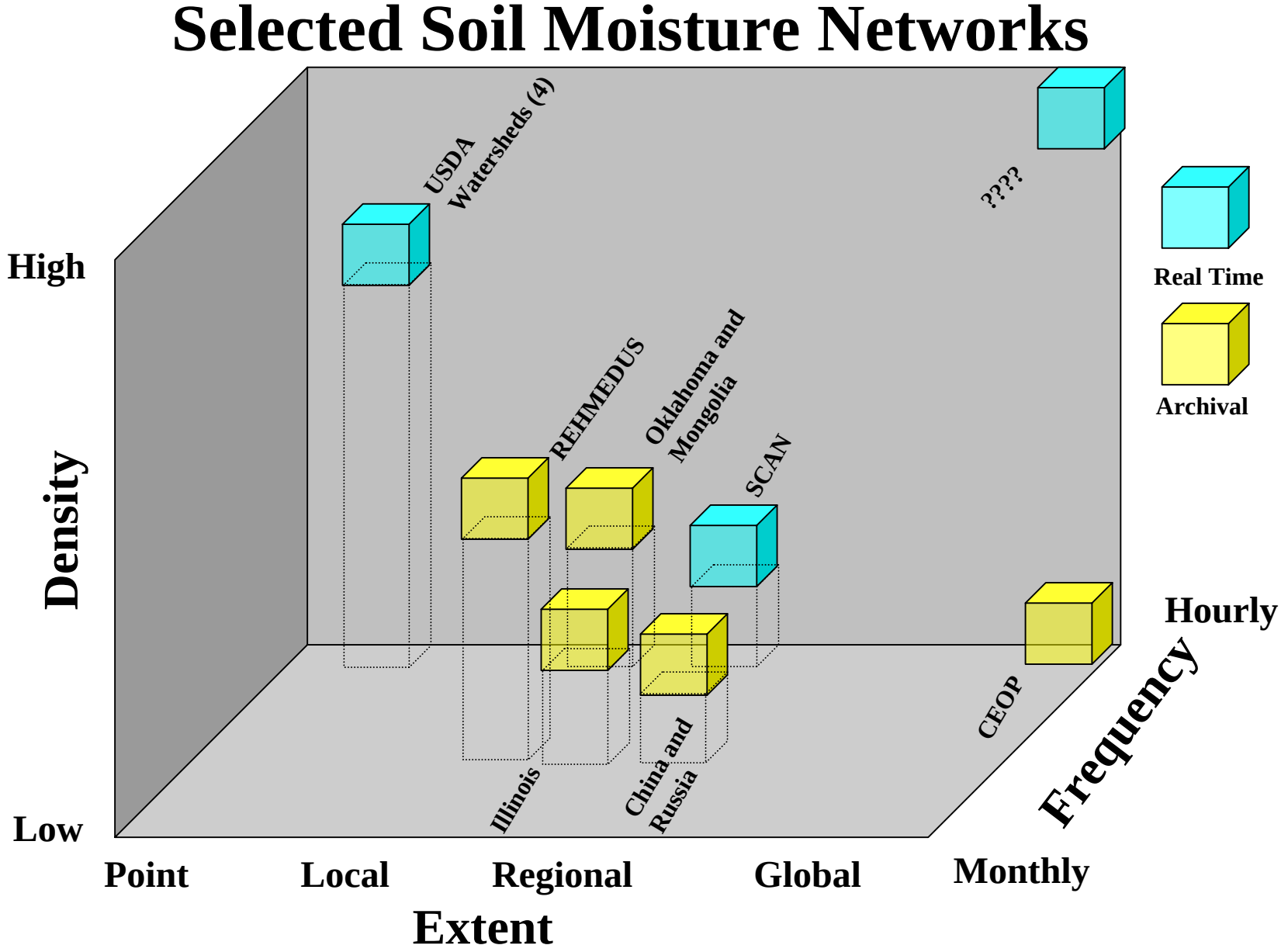


Walnut Gulch Time Series of Soil Moisture
February to September, 2004



Walnut Gulch SMEX04 Time Series of Soil Moisture

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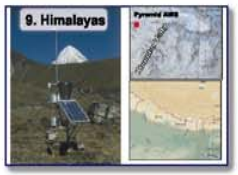
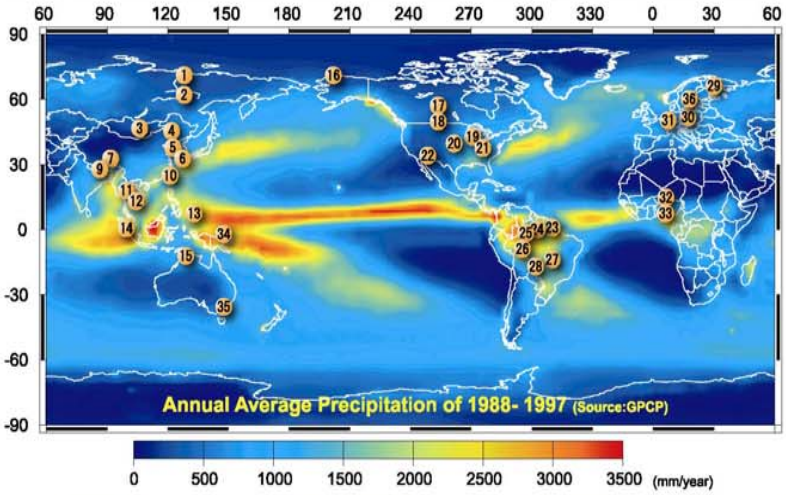
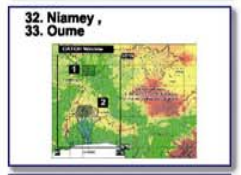
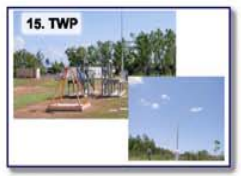
Global Extent-Low Density-High Frequency

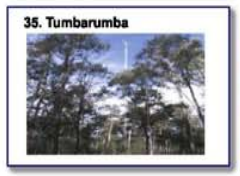
International Cooperation for the Global Coverage











Currently Available Datasets

In-Situ Data

		EOP-1		EOP-3 Frist Half				EOP-3 Second Half			
		Surface	Soil	Surface	Tower	Soil	Flux	Surface	Tower	Soil	Flux
1	Eastern Siberian Tundra										
2	Eastern Siberian Taiga										
3	Mongolia										
4	Tongue(Inner Mongolia)										
5	Korean Peninsula										
6	Korean Haenam										
7	Tibet *1) (East and West)										
8	Yangtze River										
9	Himalayas										
10	NSCSSJ										
11	Chao-Phraya river *2)										
12	North-East Thailand										
13	Western Pacific Ocean *3)										
14	Equatorial Island										
15	ARM Tropical Western Pacific (Darwin)										
16	ARM North Slope of Alaska (Barrow)										
17	BERMS (Old Black Spruce)										
18	Ft. Peck										
19	Bondville										
20	ARM Southern Great Plains										
21	Oak Ridge										
22	Mt. Bigelow										
23	Caxiuana										
24	Santarem										
25	Manaus										
26	Rondonia										
27	Brasilia										
28	Pantanal										
29	Sodankyla										
30	Lindenberg										
31	Cabauw										
32	Niamey										
33	Oueme										
34	ARM Tropical Western Pacific (Manus)										
35	Tumbarumba										
36	Norunda										

Stored in our server

Not provided

Are Single Point Sites Useful for Soil Moisture?

- **A single point observation of soil moisture is unreliable at scales beyond its measurement.**
- **The spatial domain that such a measurement represents is quite small.**
- **The spatial variability of soil/vegetation/topographic factors that influence the value is significant and cannot be inferred with precision without very detailed studies.**
- **It is possible but difficult to establish scaling functions (TS) through shorter term intensive studies.**

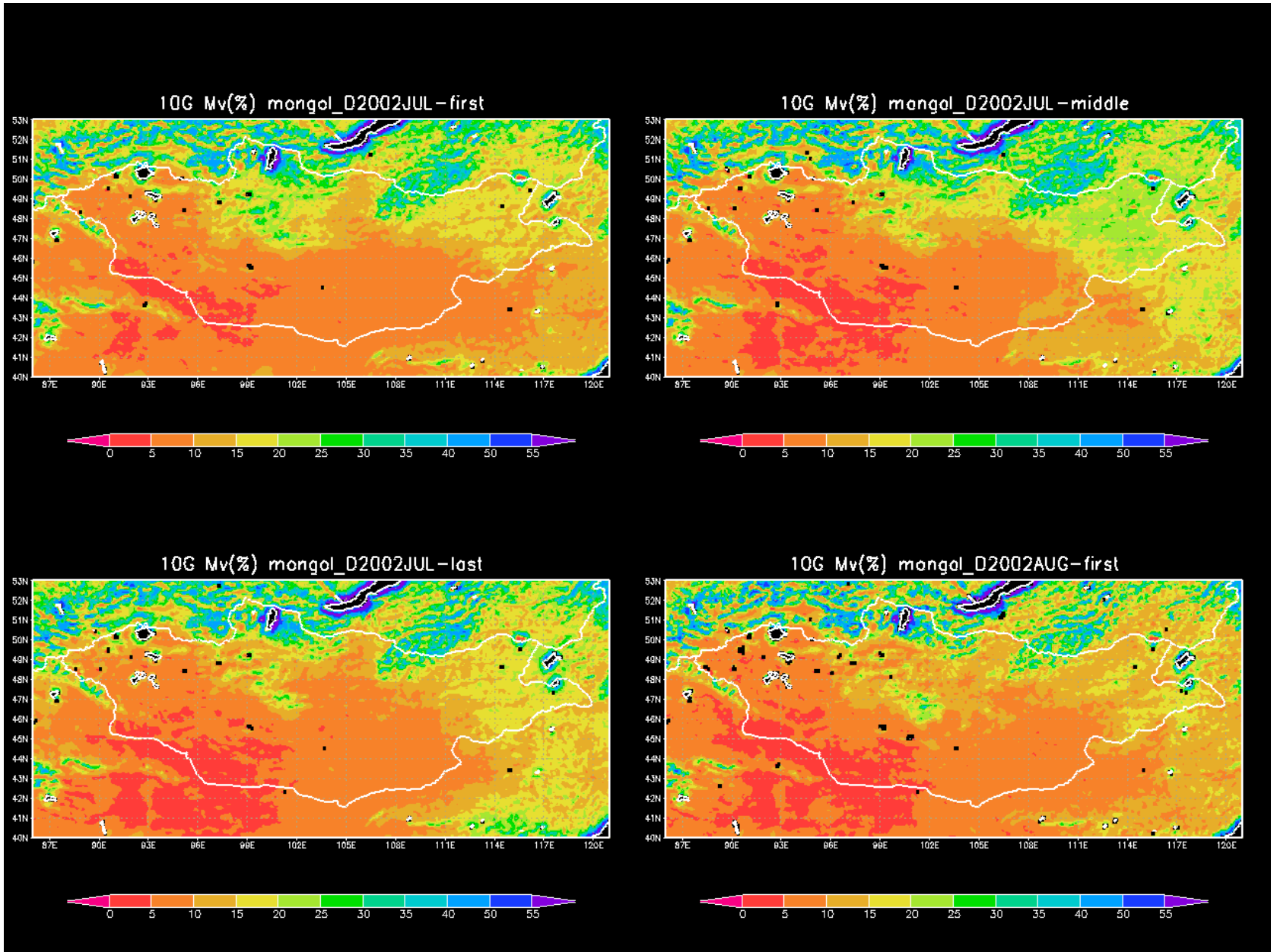
Some Problems With Historic Soil Moisture Sampling Programs

- **Satellite sensors observe a 5 cm depth (at best). Traditional programs have started at 15 cm.**
- **Measurements have been made using a variety of methods (NP, Grav., TDR) that required a revisit for each observation resulting in one measurement every two weeks.**
- **Few have provided anything resembling real time observations.**
- **Some decisions on instrumentation limit the data quality, processing, etc.**

Current Satellite Based Soil Moisture Products

- **NOAA Extreme Events**
- **NASA Aqua AMSR-E**
- **JAXA Aqua AMSR-E (4 algorithms)**
- **AMSR-E soil moisture quality evaluations have been hampered by instrument calibration issues and RFI**

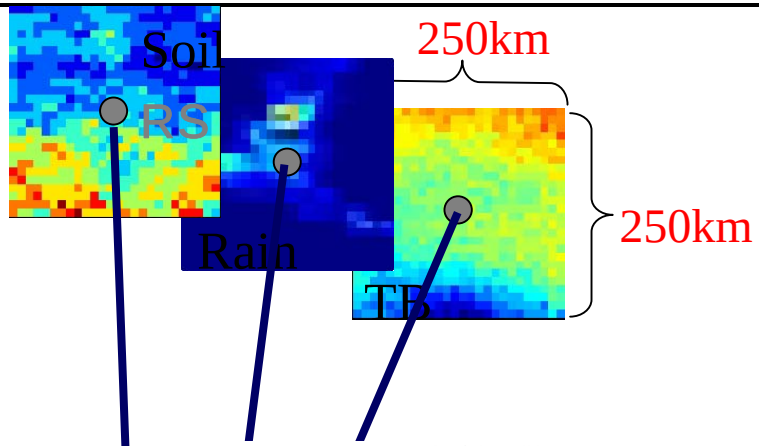
10 days averaged soil moisture map at 10G version



Satellite datasets for CEOP

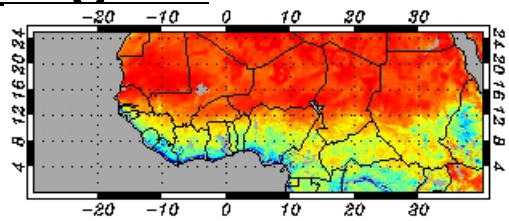
At 3 type scales

1.Reference site:35 Points

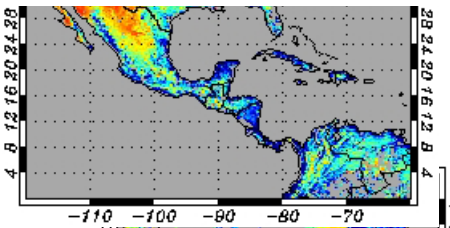


2.Monsoon Region

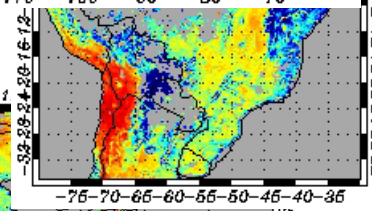
>West African



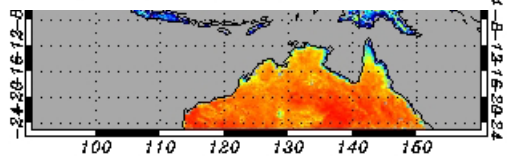
>North American

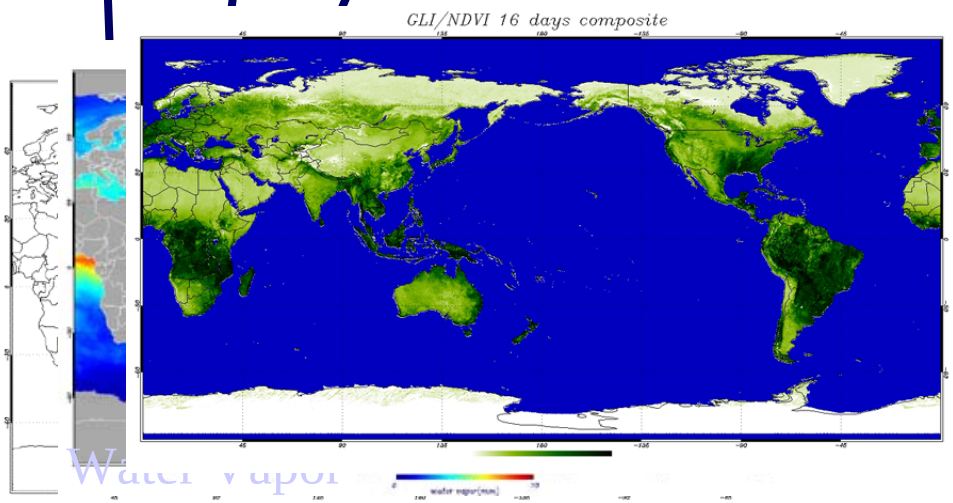


>South American



>Asia- Australian

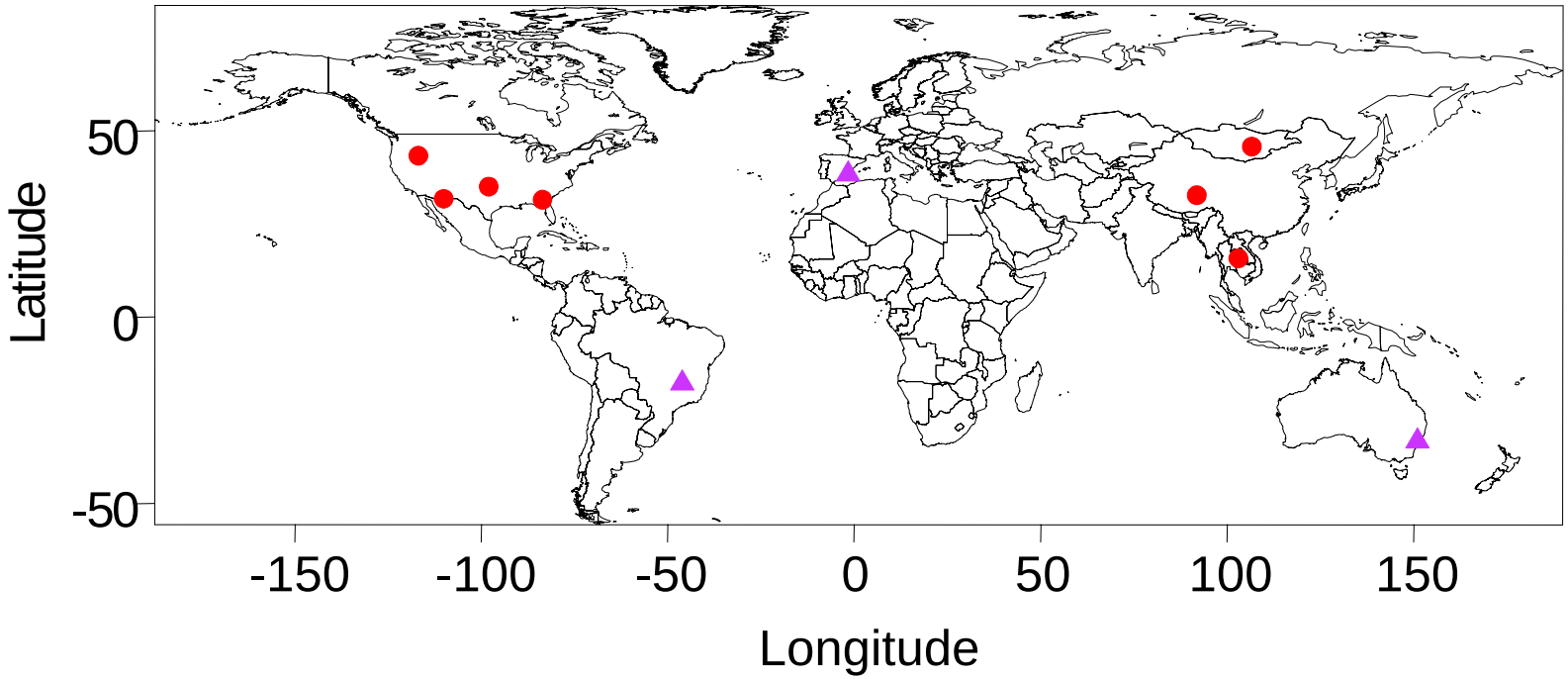




3.Global

AMSR-E Soil Moisture Validation

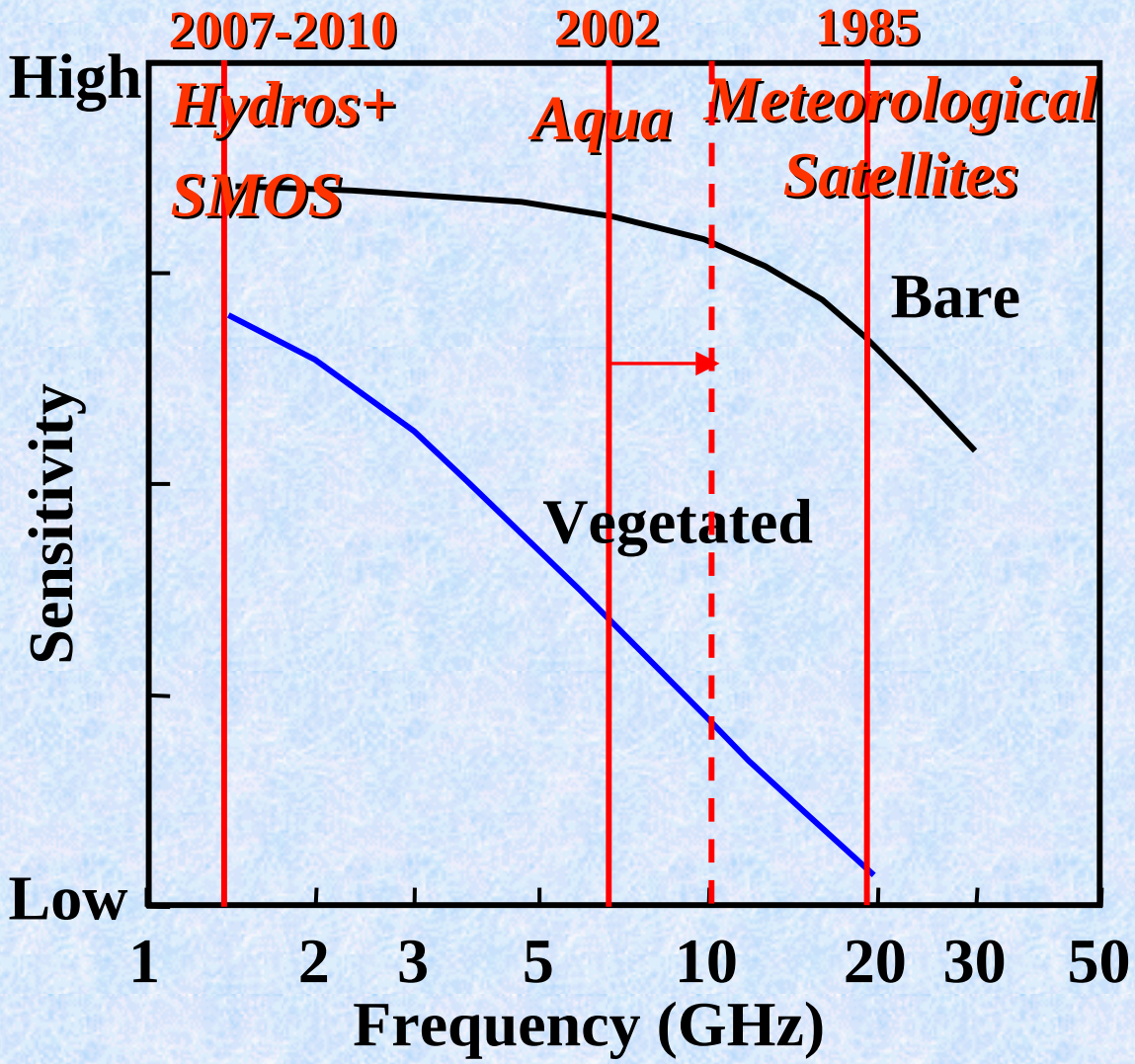
Aqua and Adeos-2 AMSR Soil Moisture Validation Sites



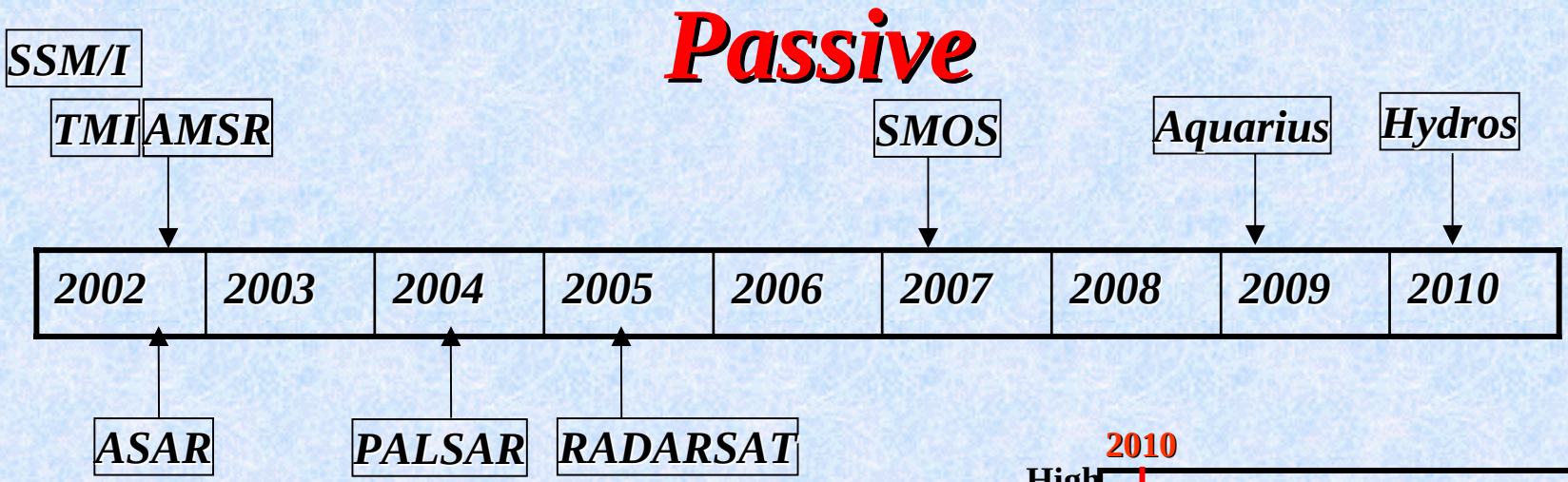
Global distribution of cooperative validation sites for Aqua/AMSR-E (U.S.: Oklahoma, Idaho, Georgia, Arizona) and Adeos-2/AMSR (Mongolia, Tibet, Thailand). Red circles represent existing facilities. Triangles are potential sites that may be developed through existing and cooperative programs.

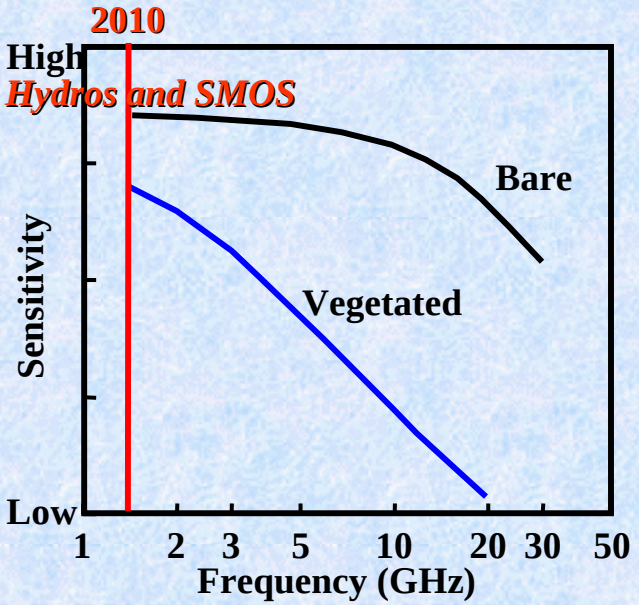
Global Soil Moisture Monitoring Today and Tomorrow

- Limited by using non-optimal satellites developed for other applications
- A low frequency instrument is needed



Microwave Satellite Timeline



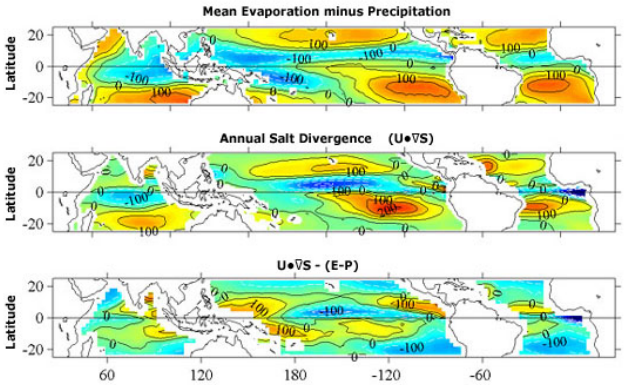


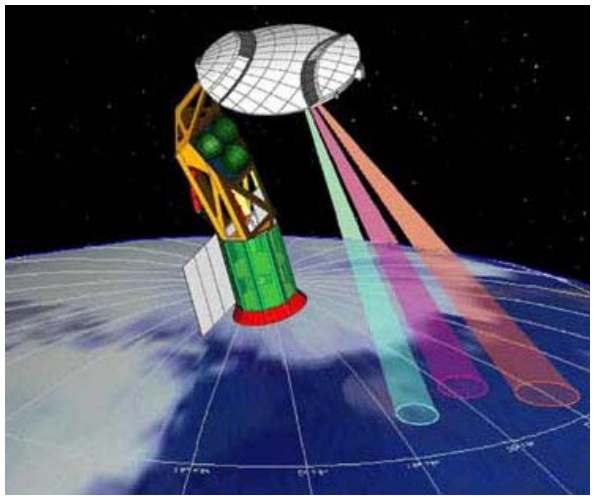
Soil Moisture and Ocean Salinity Mission (SMOS)

- 1.4 GHz, 50 km footprint, three day global coverage
- Launch 2006 by ESA
- Utilizes synthetic aperture antenna design

AQUARIUS

Aquarius is a focused satellite mission to measure global Sea Surface Salinity (SSS). Scientific progress is limited because conventional in situ SSS sampling is too sparse to give the global view of salinity variability that only a satellite can provide. Aquarius will resolve missing physical processes that link the water cycle, the climate, and the ocean.





Science Objectives	Science Measurement Requirement	Instrument Functional Requirement	Mission Functional Requirement
Discovery and Exploration SSS mapping of unmeasured regions and features unknown to science	Global coverage Mean and Variability Seasonal cycle	Measure seawater emissivity sensitive to salinity (Lband)	Polar orbit Baseline mission life: 3 years to ensure statistical confidence of seasonal cycle and track interyear changes. Minimum mission life: 1 year
Water cycling	Resolution: Baseline: 100km Minimum: 200 km	~3 meter aperture	Low Earth Orbit @ 600 km altitude
Ocean Circulation and Climate Tropics: Airsea interaction and climate feedback MidLatitude: Subduction and mode water formation HighLatitude: Deep water formation, and convection	Time scale: Monthly (science product) 8 days (obtain multiple samples and reduce random monthly error by averaging)	Relative stability 0.15 K for 8 days	„300 km swath to obtain global coverage within 8 days (from both ascending and descending orbits)
	Accuracy: Baseline: 0.2 psu Minimum: 0.2 psu, tropics 0.3 psu, high latitudes	Measure ocean Tb to <0.2 K RMS error per observation	6 a.m. sunsynchronous orbit to avoid sun glint error. Stable thermal environment. Error corrections per observation: Surface roughness to 0.15 K rms Geophysical errors per observation <0.5 psu Random errors to 0.3 psu

Item Value	Summary/Units
Sensor type	Radiometers at 1.413 GHz Scatterometer at 1.26 GHz
Number of channels	3 antenna feeds, 3 polarimetric radiometers, 1 polarimetric scatterometer
Size	3 m x 6 m_ 4 m, antenna deployed
Optical layout	3 antenna beams at 23.3˚ , 33.7˚ , 41.7˚ incidence angles to shadow side of orbit
Footprint sizes	62 _ 68 km, 68 _ 82 km, 75 _ 100 km
Radiometer NEDT 12 sec integration	0.05 K


MIT ▪ NASA ▪ GSFC ▪ JPL ▪ CSA
HYDROS
CARBON CYCLE
WATER CYCLE
ENERGY CYCLE
Soil Moisture • Freeze/Thaw

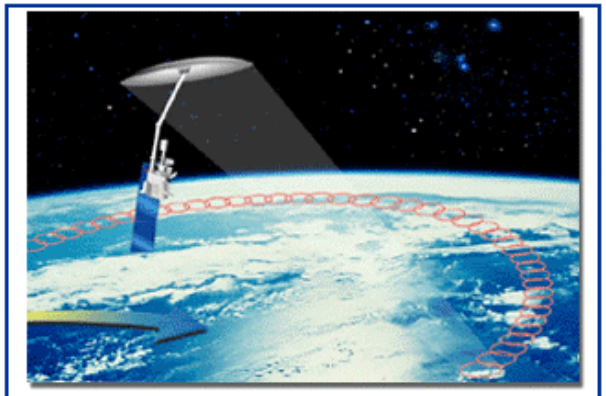
HYDROS

A NASA EARTH SYSTEM SCIENCE PATHFINDER
HYDROSPHERE STATE MISSION

MISSION | SCIENCE | SPACECRAFT | INSTRUMENTS | TEAM | LIBRARY | EDUCATION/OUTREACH | INTRANET

OUR MISSION:

HYDROS provides the first global view of the Earth's changing soil moisture and surface freeze/thaw conditions, enabling new scientific studies of global change and atmospheric predictability, and making new hydrologic applications possible.

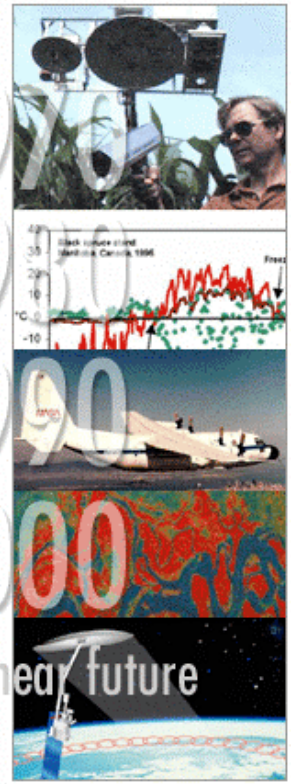


INSTRUMENT:
- **L band: Passive and active**
- **Antenna technology to provide 10 km resolution**

PARTNERS:

NASA, MIT, JPL, DOD, IPO, Italy, Canada, and Science Team

Microwave Measurement of Soil Moisture and Freeze/Thaw Timeline



HYDROS will provide:

- Global maps of the primary land surface controls of processes that link the water, energy and biogiochemical cycles.
- Land state initial and boundary conditions to improve the forecast skill of numerical weather predictions.
- Information to advance critical hydrologic applications including flood and drought forecasting and wetland monitoring.

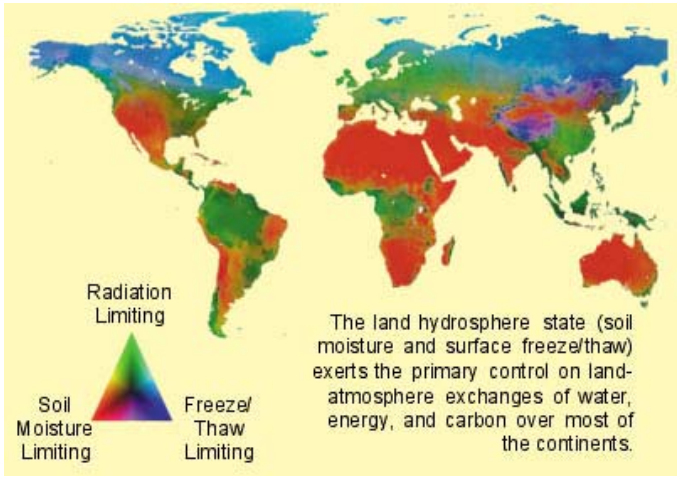
News and Highlights

HYDROS is one of three potential new Earth Science missions selected under the ESSP-3 Announcement of Opportunity.

HYDROS is currently in Formulation Phase. Launch will occur in 2010 and there will be two years of operation.

HYDROS

The Hydrosphere State Mission - A NASA Earth System Science Pathfinder | HYDROS will provide the first global views of Earth's changing soil moisture and land surface freeze/thaw conditions, leading to breakthroughs in weather and climate prediction and in the understanding of processes linking water, energy, and carbon cycles.



MEASUREMENT REQUIREMENTS:

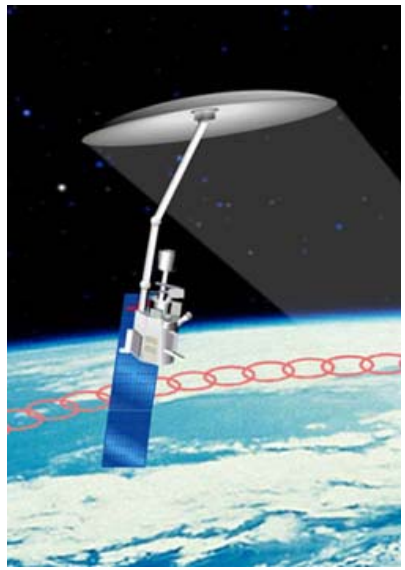
- **Spatial Resolution:**
  - Hydroclimatology soil moisture at 40km
  - Hydrometerology soil moisture at 10km
  - Freeze/thaw condition at 3km
- **Temporal Sampling:** Global in 2-3 days (2 days Above 50N)
- **Mission Duration:** 2 years

INSTRUMENT:

- L-band active/passive system
- Wide swath (1000 km) with constant look angle (39°)

	Radar		Radiometer
Polarization	VV, HH and HV		V, H and U
Resolution	3 km	10 km	40 km
Relative Error	1.0 dB	0.45 dB	0.64º K

- **Launch Date: June 2006**



- Dara Entekhabi - PI (MIT)

Partner	Role
MIT	Mission Science
JPL	Project Implementation; Science Products
GSFC	Radiometer; Science Products, DAAC
ASI	Radar Components
CSA	Antenna Components
IPO	Ground Data Systems
DoD	Reflector Assembly
Science Team	Science Data Products

What Needs to Be Done?

- **Commits to a global network of in-situ soil moisture measurements (Lead international agency, coordination-workshop?, standards, $)**
- **Commits to developing a quasi-operational soil moisture data product (Quality and relevance of current products, white paper, international support for planned dedicated missions)**