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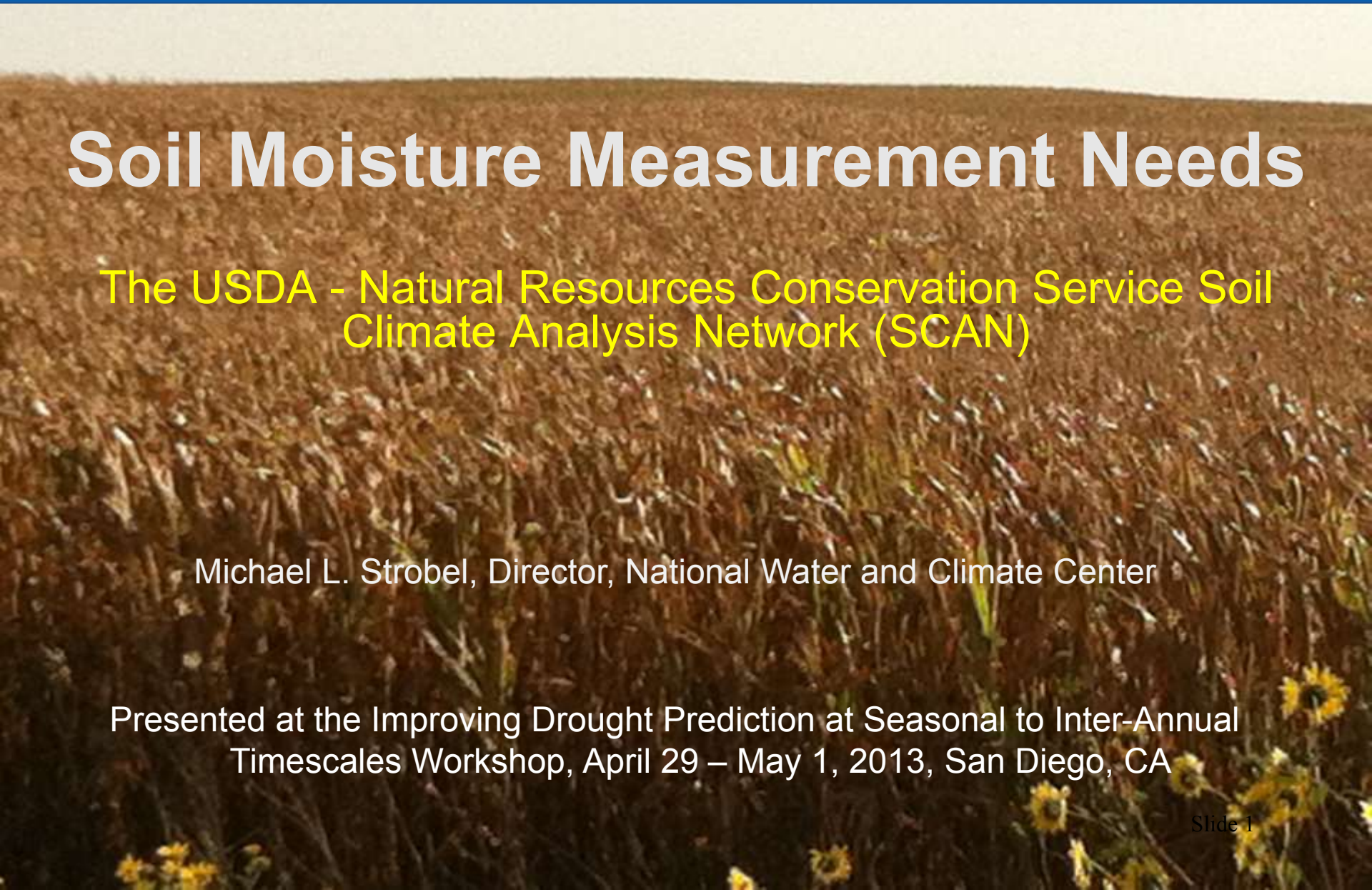
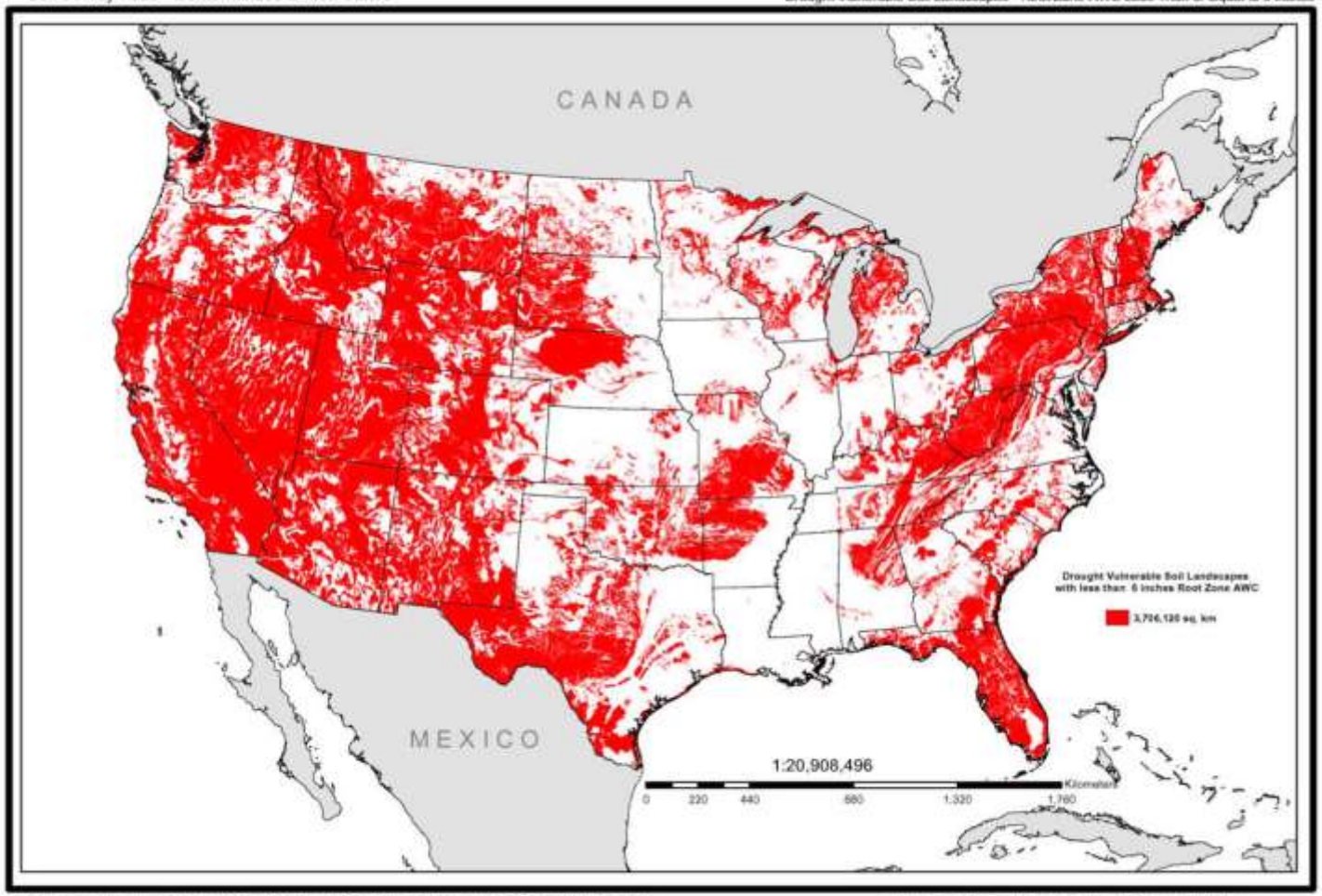


Soil Moisture Measurement Needs

The USDA - Natural Resources Conservation Service Soil Climate Analysis Network (SCAN)

Michael L. Strobel, Director, National Water and Climate Center

Presented at the Improving Drought Prediction at Seasonal to Inter-Annual Timescales Workshop, April 29 – May 1, 2013, San Diego, CA



Drought Vulnerable Soil Landscapes

Soil Moisture Measurements

- Modeled data
- Remote sensing
- In situ measurements

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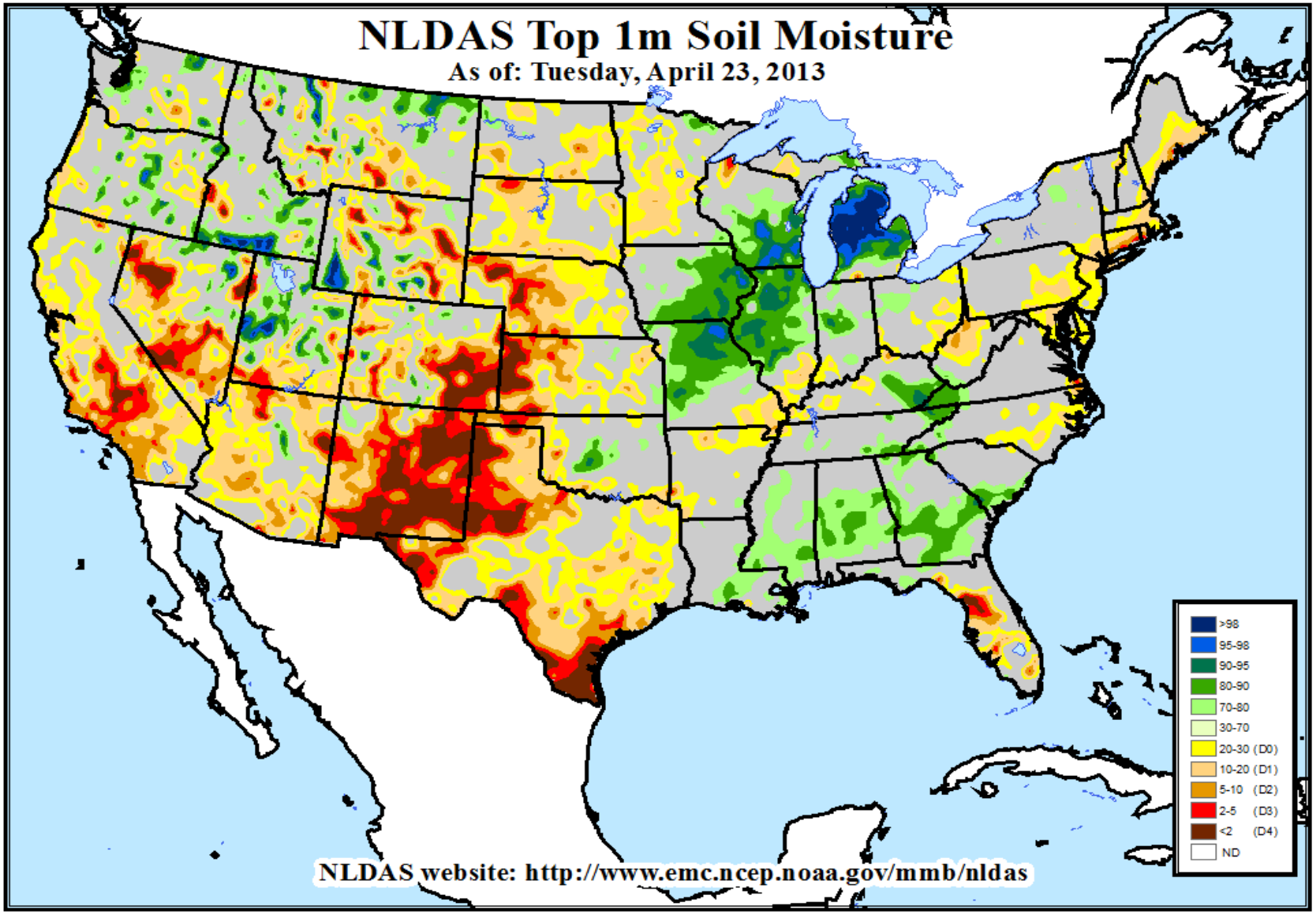


ISMN Satellite Data (http://ismn.geo.tuwien.ac.at/satellites/)

There are a large number of global soil moisture datasets that have become available from microwave radiometers (SMOS, AMSR-E, Windsat, TRMM, SMMR) and scatterometers (ERS SCAT, ASCAT).

•**SMOS Satellite**: SMOS Sensor: L-band radiometer with aperture synthesis (MIRAS) Agency: ESA Operations: launch in 2009 Resolution: 30 Revisit time: 1-2 days

•**SMAP Satellite**: SMAP Sensor: Active and passive microwave instrument in L-band Agency: NASA Operations: launch in 2014 Resolution: 10 km (active) 40 km (passive) Revisit time: 1-2 days

•**METOP Satellite**: METOP (three satellites) Sensor: C-Band Scatterometer (ASCAT) Agency: EUMETSAT in cooperation with ESA Operations: 2006-2020 Resolution: 25/50 km Revisit time: 1-2 days

•**ERS Satellite**: ERS-1 and ERS-2 Sensor: C-Band Scatterometer (SCAT) Agency: ESA Operations: 1991-2010 Resolution: 25/50 km Revisit time: 2-7 days

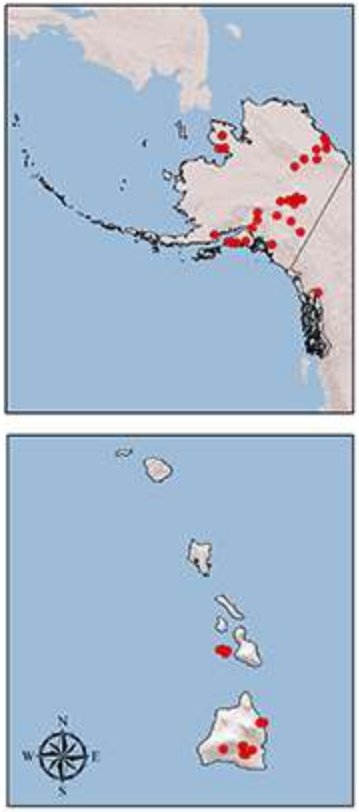
•**AQUA Satellite**: AQUA Sensor: Multi-frequency radiometer (AMSR-E) Agency: NASA in cooperation with JAXA Operations: 2002-2011, followed up by GCOM-W1 AMSR-B in 2012 Resolution: 50 km Revisit time: 1-2 days

•**Coriolis Satellite**: Coriolis WindSat Sensor: Multi-frequency polarimetric radiometer (WindSat) Agency: US Naval and Air Force Research Laboratories Operations: since 2003 Resolution: 50 km Revisit time: 1-2 days

Name	Country	Stations		Name	Country	Stations
AACES	Australia	49		MOL-RAO	Germany	2
AMMA	Benin, Niger, Mali	7		MONGOLIA	Mongolia	44
ARM	USA	25		OZNET	Australia	38
AWDN	USA	50		REMEDHUS	Spain	24
CALABRIA	Italy	5		RUSWET-AGRO	Former Soviet Union	156
CAMPANIA	Italy	2		RUSWET-GRASS	Former Soviet Union	122
CHINA	China	40		RUSWET-VALDAI	Former Soviet Union	3
COSMOS	USA	67		SASMAS	Australia	14
FLUXNET-AMERIFLUX	USA	2		SCAN	USA	182
FMI	Finland	1		SMOSMANIA	France	21
GTK	Finland	7		SNOTEL	USA	381
HOBE	Denmark	30		SWEX_POLAND	Poland	6
HSC_SELMACHEON	Korea	1		TERENO	Germany	5
HYDROL-NET_PERUGIA	Italy	1		UDC_SMOS	Germany	11
HYU_CHEONGMICHEON	Korea	1		UMBRIA	Italy	13
ICN	USA	19		UMSUOL	Italy	1
IIT_KANPUR	India	1		USCRN	USA	114
IOWA	USA	6		USDA-ARS	USA	4
MAQU	CHINA	20		VAS	Spain	3
METEROBS	Italy	1				

ISMN Soil Moisture Networks (in situ)

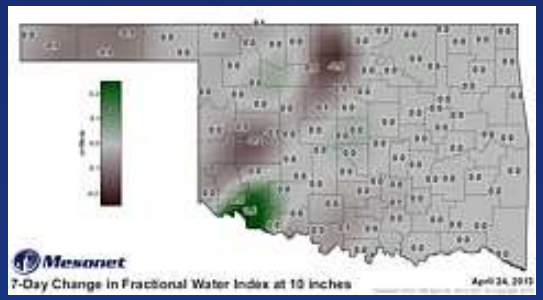
http://ismn.geo.tuwien.ac.at/networks/

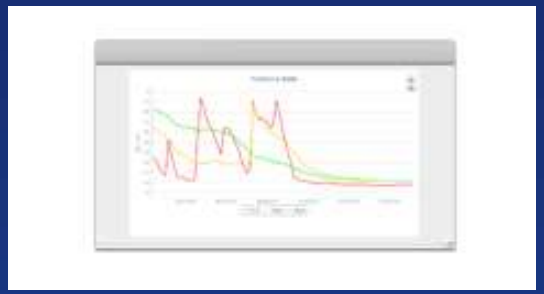


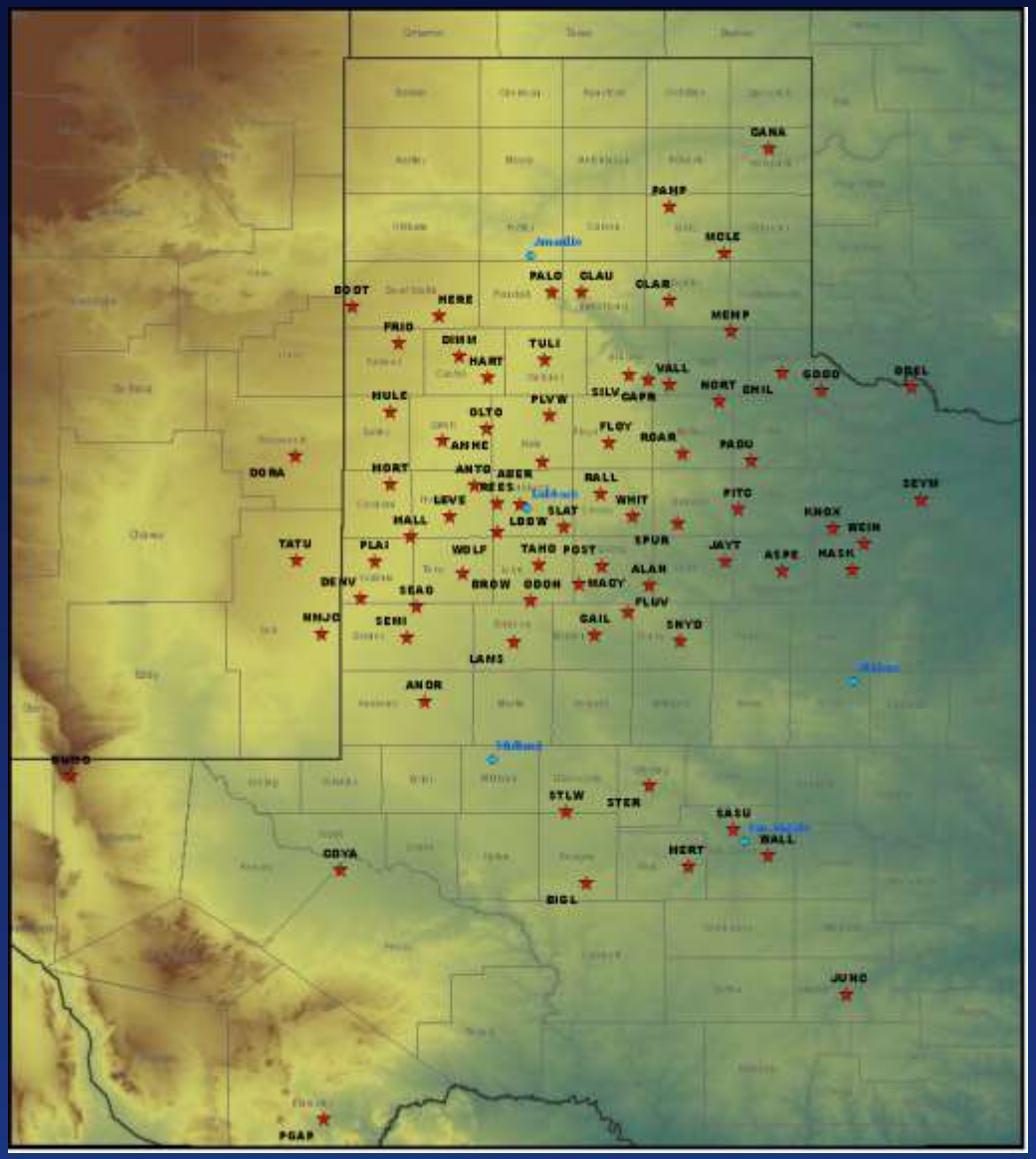
The North American Soil Moisture Database (NASMD), developed and constructed at the Texas A&M University Department of Geography's Climate Science Lab, is a harmonized and quality controlled soil moisture dataset aiding in the investigation of land-atmosphere interactions, validating the accuracy of soil moisture simulations in global land surface models as well as estimates from satellite platforms, and describing how soil moisture influences climate on seasonal to interannaual timescales

http://soilmoisture.tamu.edu/

Oklahoma Mesonet

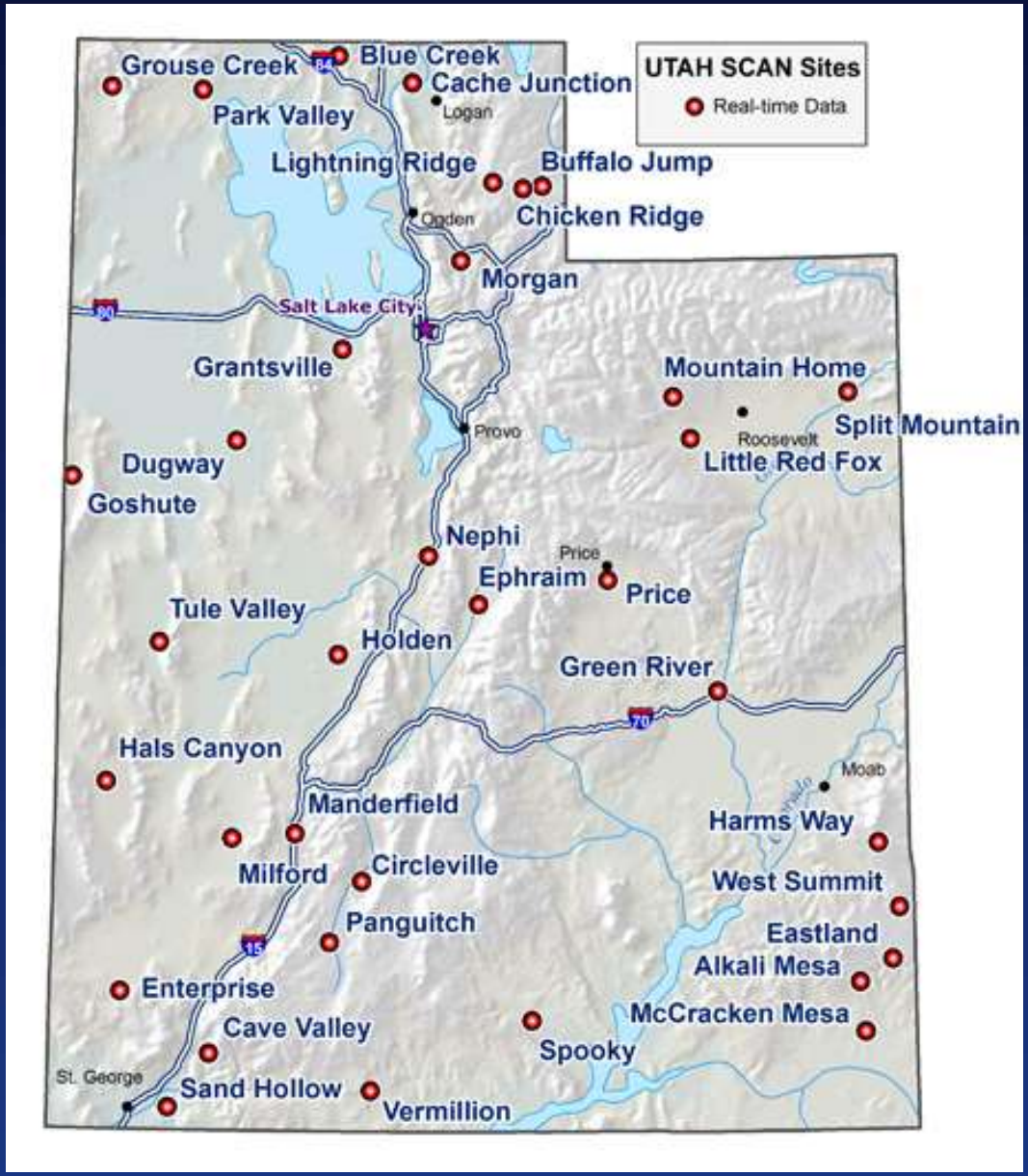






West Texas Mesonet

http://www.mesonet.ttu.edu/site_info.html


UTAH SCAN Sites
Real-time Data
Grouse Creek
Blue Creek
Cache Junction
Logan
Park Valley
Lightning Ridge
Buffalo Jump
Ogden
Chicken Ridge
Morgan
Salt Lake City
Grantsville
Mountain Home
Split Mountain
Roosevelt
Little Red Fox
Provo
Dugway
Goshute
Nephi
Price
Ephraim
Price
Tule Valley
Holden
Green River
Hals Canyon
Moab
Manderfield
Harms Way
Milford
Circleville
West Summit
Panguitch
Eastland
Alkali Mesa
Enterprise
McCracken Mesa
Cave Valley
Spooky
St. George
Sand Hollow
Vermillion

North American Soil Moisture Database (Texas A&M University) List of Networks

Alberta Agriculture and Rural Development: http://www.agric.gov.ab.ca/app21/rtw/index.jsp
AmeriFlux: http://public.ornl.gov/ameriflux
Atmospheric Radiation Measurement: http://www.arm.gov/
Agricultural Research Service: http://www.ars.usda.gov
Automated Weather Data Network: http://www.hprcc.unl.edu/awdn/
Cosmic-ray Soil Moisture Observing System: http://cosmos.hwr.arizona.edu/
Climate Reference Network: https://www.ncdc.noaa.gov/crn/
Delaware Environmental Observing System: http://www.deos.udel.edu/
Georgia Automated Environmental Monitoring Network: http://www.georgiaweather.net/
North Carolina Environment and Climate Observing Network: http://nc-climate.ncsu.edu/econet
Fluxnet Canada: http://fluxnet-canada.ccrp.ec.gc.ca/
Illinois Climate Network: http://www.isws.illinois.edu/warm/datatype.asp
Kansas Mesonet: http://www.ksre.ksu.edu/wdl
Michigan Automated Weather Network: http://www.agweather.geo.msu.edu/mawn/
Missouri Agricultural Electronic Bulletin Board: http://agebb.missouri.edu/weather
National Ecological Observatory Network: http://www.neoninc.org/
New Jersey Mesonet: http://climate.rutgers.edu/njwxnet/
NOAA Hydrometeorology Testbed Observing Networks: http://hmt.noaa.gov/
Oklahoma Mesonet: http://www.mesonet.org/
Remote Automated Weather Stations: http://raws.fam.nwcg.gov/
Soil Climate Analysis Network: http://www.wcc.nrcs.usda.gov/scan/
South Dakota Automated Weather Data Network: http://climate.sdstate.edu/climate_site/ag_data.htm
Snowpack Telemetry (SNOTEL) Network: http://www.wcc.nrcs.usda.gov/snow/
SoilScape: http://soilscape.usc.edu/
University of Alaska Fairbanks Water and Environmental Research Center: http://ine.uaf.edu/werc/
West Texas Mesonet: http://www.mesonet.ttu.edu/

Soil Moisture Monitoring

- SCAN
  - Soil Climate Analysis Network
  - Monitors lower elevation areas for climate parameters and soil moisture monitoring nationwide

SCAN

- SCAN
  - Started as a Soil Moisture/Soil Temperature Pilot Project between the National Water and Climate Center and the National Soil Survey Center in 1991 with 21 stations in 19 States
  - Full implementation of SCAN would have at least 1,000 new stations and integrate 1,000 existing partner-based stations
    - Goal will be to have new stations located on Benchmark soil series
  - Utilizes meteor burst, line-of-sight, or GOES satellite communication technology to transmit remote station data

SCAN

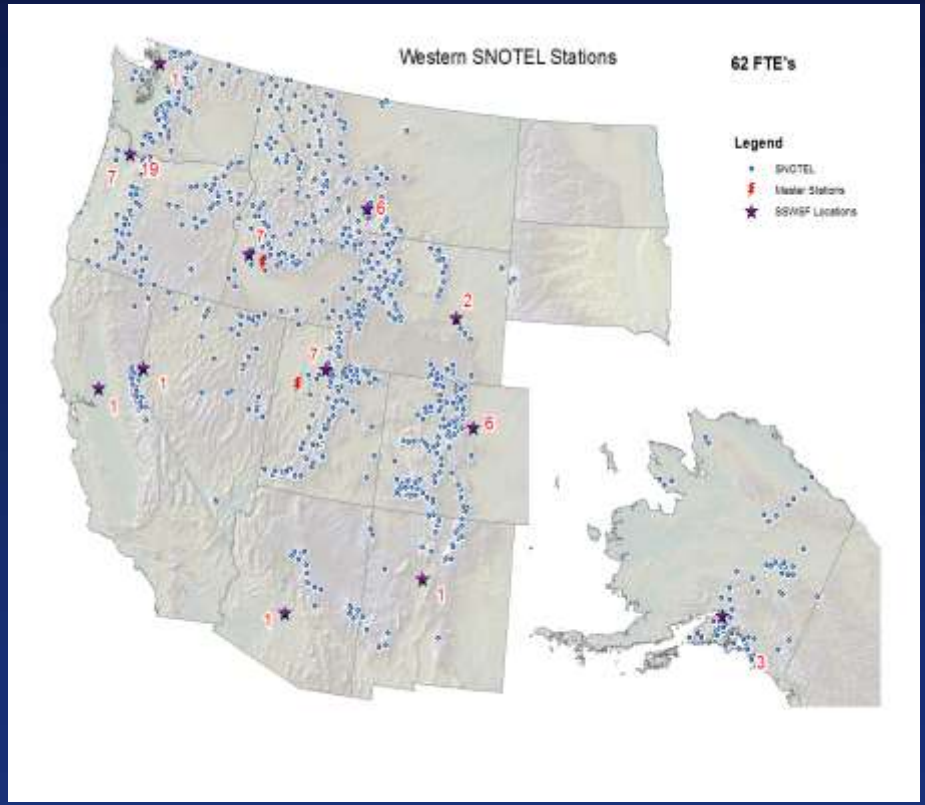
- Currently the network has 191 stations in 40 States
- Provides hourly data with
  - Precipitation
  - Air temperature
  - Relative humidity
  - Solar radiation
  - Wind speed and direction
  - Barometric pressure
  - Soil moisture and soil temperature
    - 2, 4, 8, 20, and 40 inches
    - (approximately 5, 10, 20, 51 and 102 cm)

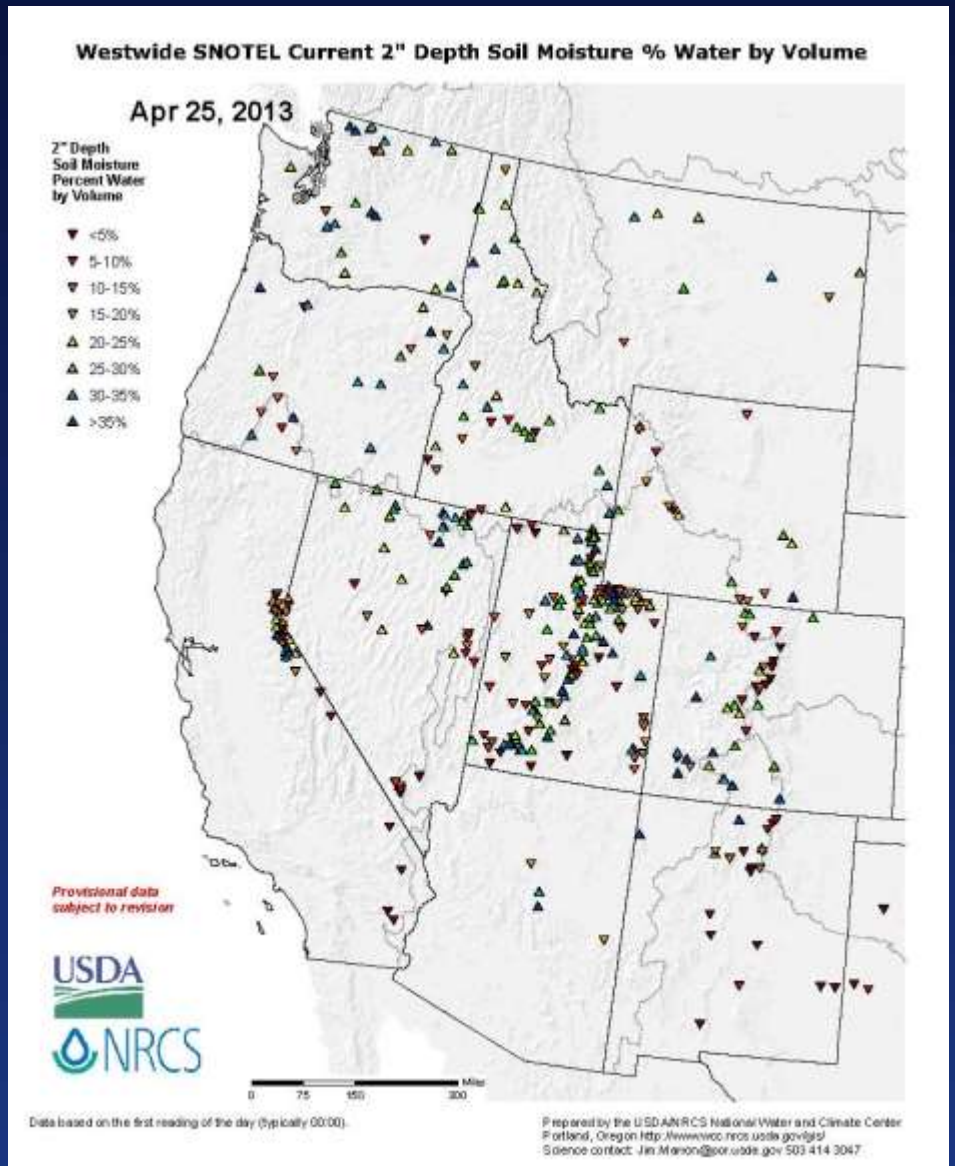
Other SCAN Data Parameters Collected at Selected Sites

- Snow water content
- Snow depth
- Net radiation
- Redox
- Additional soil moisture and soil temperature measurements
- Water level
- Surface temperature
- Water quality parameters

SNOTEL Network

- Large Automated Climate Network
  - Began in 1978
  - 860 remote stations
  - > 1,100 manual snow courses adding additional data
  - Generally in high elevation areas
  - Located in the 13 Western States including Alaska
  - Utilizes meteor burst communication technology to transmit data (Alaska uses Iridium satellite transmissions)





There are presently 408 (of 860) SNOTEL sites with soil moisture and temperature sensors. All 191 SCAN sites have soil sensors.

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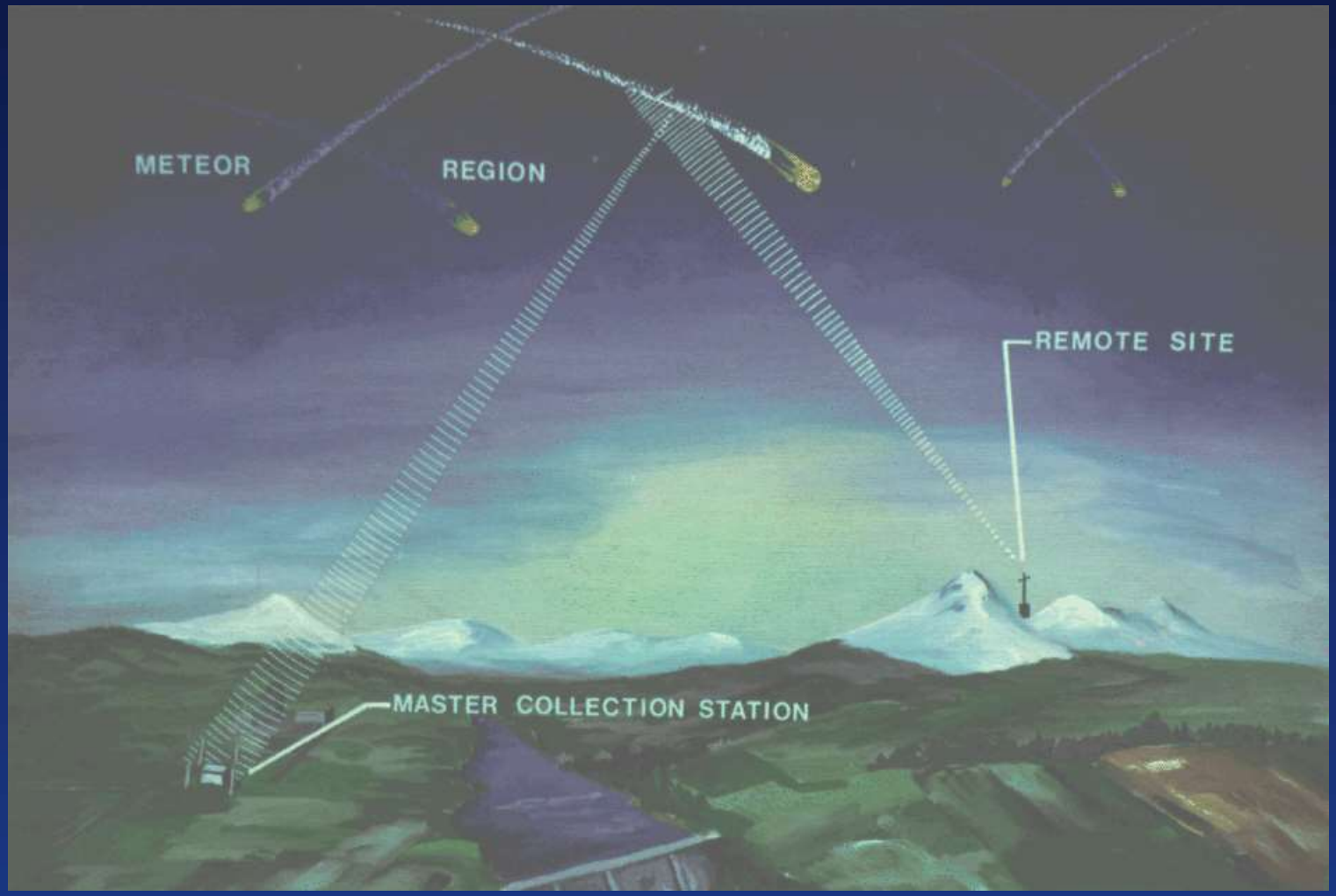
Meteor Burst Communication Technology



Meteor Burst Communication Technology

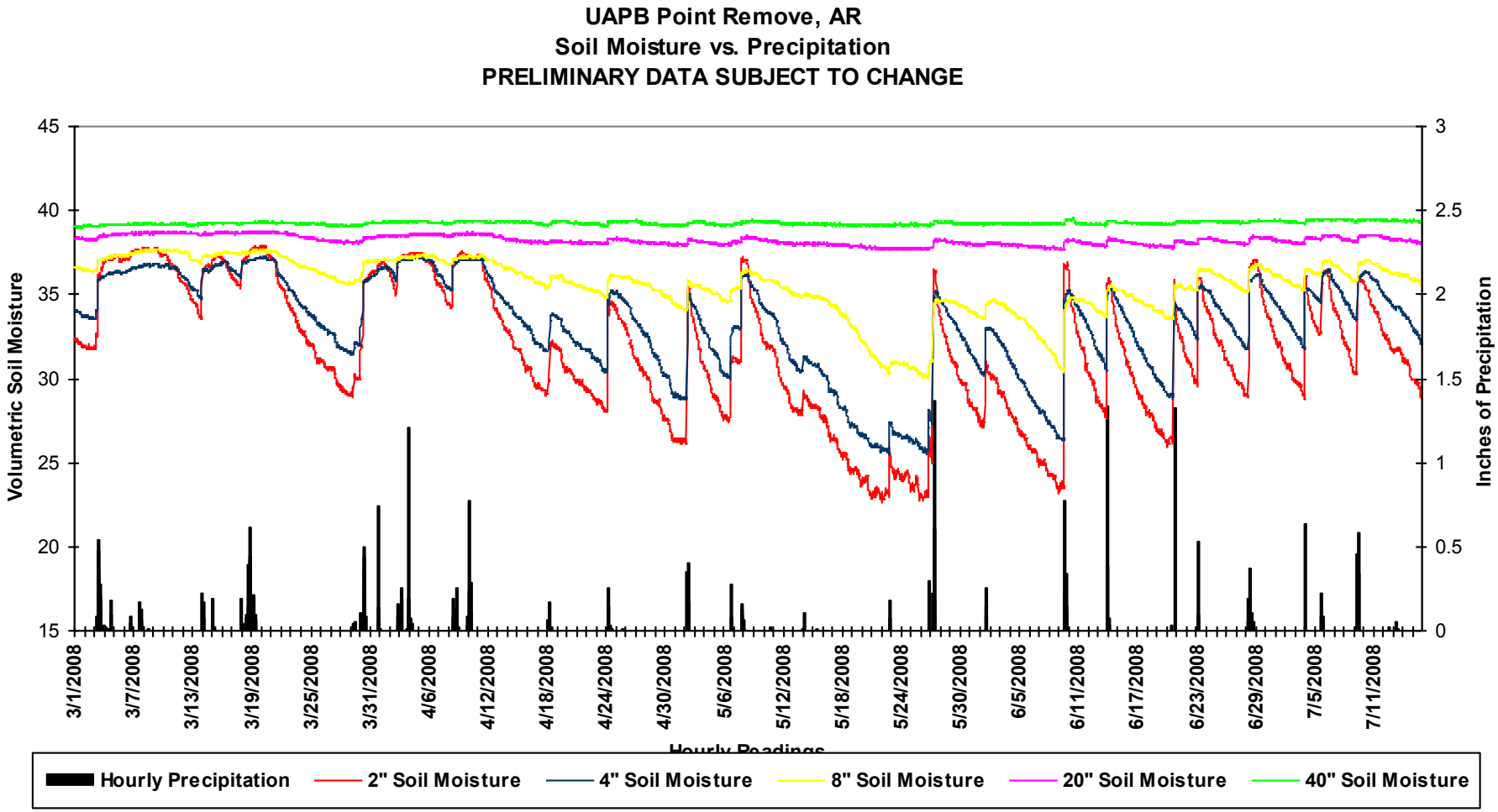
- Remote station data are transferred to the Central Computer Facility in Portland via normal telephone lines
- NRCS owns and operates five master stations and four line-of-sight master stations
  - Meteor Burst Master Stations
    - Boise, ID
    - Dugway, UT
    - Mt Gilead, OH
    - Tipton, MO
    - Stoneville, MS
  - Line of Sight Master Stations
    - Mayaguez, Puerto Rico
    - Kona, HI
    - Waimea, HI
    - Homer, AK


Dugway Master Station, Utah

SCAN Data

- All SCAN stations have full soil characterizations complete and available on the web
- All historic and real-time SCAN data are available on the web
  - http:www.wcc.nrcs.usda.gov/scan
- Special Reports
  - Special “Spreadsheet” compatible reports can be created

Soil Moisture/ Precipitation



SCAN Cooperators

- Current partners include:
  - U.S.D.A.- Agricultural Research Service
  - Mississippi State University and Extension Service
  - Alabama A&M University
  - University of Arkansas - Pine Bluff
  - University of Missouri
  - Iowa State University
  - High Plains Regional Climate Center
  - U.S.D.A.- World Agricultural Outlook Board
  - U.S.D.A.- Forest Service
  - U.S.D.A.-Natural Resources Conservation Service
  - The Nature Conservancy
  - Vermont Department of Forests, Parks, and Recreation
  - University of Alaska
  - SE Regional Climate Center
  - Others

Siting Criteria

- All stations should be located on Federal, State, county, or university lands. This will ensure long-term use of the land for monitoring purposes.
- All stations should be located in non-irrigated areas.
- First consideration be given to “Benchmark” soils.
- Consideration must be given to ensure that all Major Land Resource Area’s are represented in a given climatic region.
- The station must represent an agricultural area. Pasture, range, timber, and cropped areas must be considered first.
- When selecting a suitable location, some consideration of station security must be included.
- The first stations to be installed should be located in areas that are susceptible to drought.

Soil Moisture/Soil Temperature Measurement

- NRCS uses a capacitance type of sensor.
- Steven Water “Hydro Probe” SDI-12 is currently used
- Installed at specific depths
- Full soil description and characterization analysis are done at each location
- Description and characterization data available to users from the Web

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Soil Description

Sensor Placement and Layout

- The deepest sensor is installed first
- 40 inch installed vertically
- Hole is kept to a small size to minimize water transport

Sensor Placement and Layout

- Sensors are placed horizontally at all other depths
- Sensors are dispersed around the small hole to minimize interference
- Compact the soil as each sensor is installed making sure the sensor is inserted completely into undisturbed soil

Sensor Placement and Layout

- Sensor wires are moved to opposite side of hole and form a drip-loop
- Flex-conduit is used to protect sensor wires

Data Uses for SCAN

- Climate monitoring
- Water supply forecasting
- Drought assessment and mitigation
- Drought triggers
- Precision agriculture
- Soil survey interpretation and mapping
- Crop production forecasts
- Range production and condition
- Disease and Pest prediction/mitigation
- Provide data for NWS and other agencies for flood forecasting and reservoir management
- Climate change assessment

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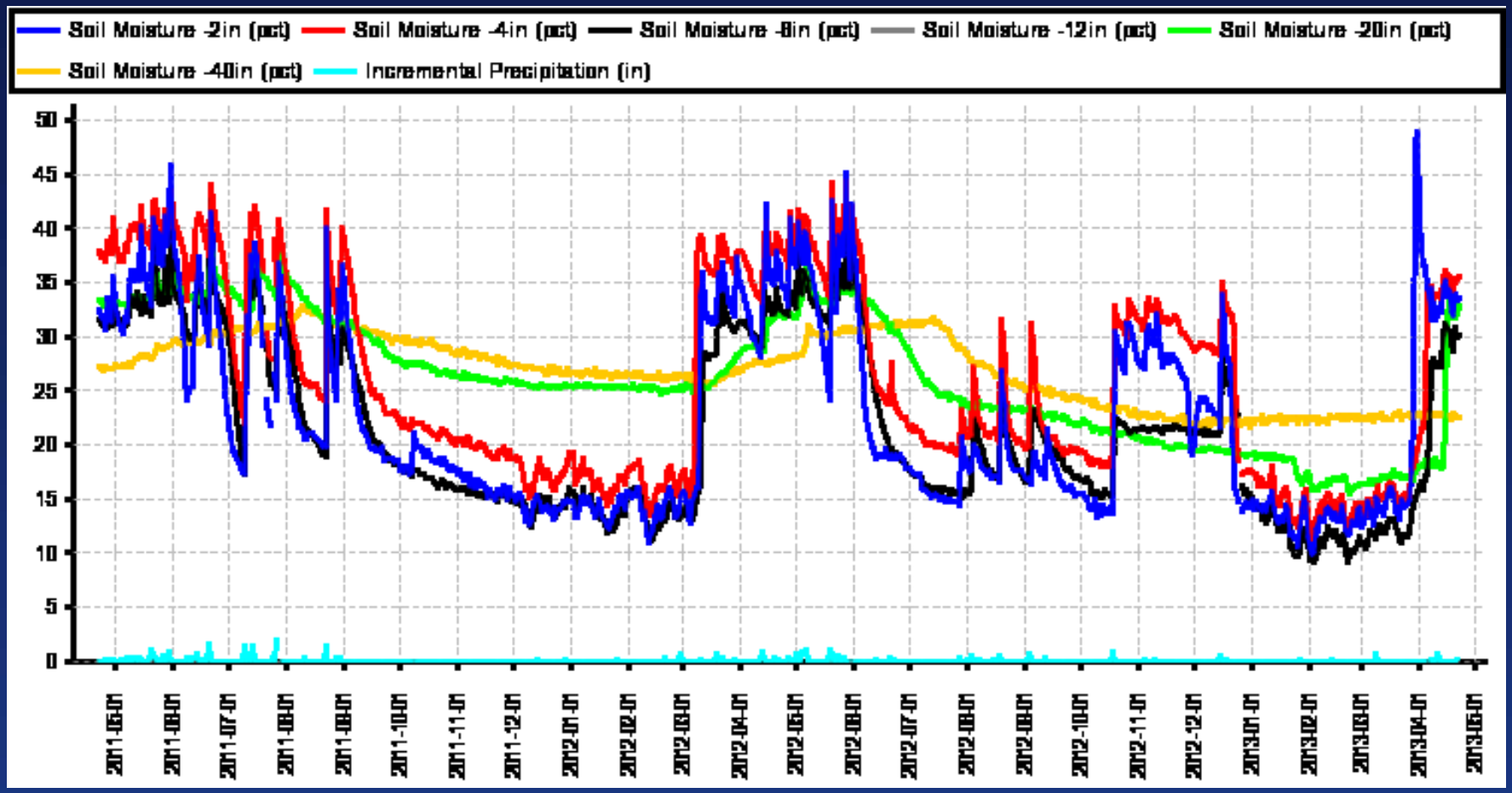
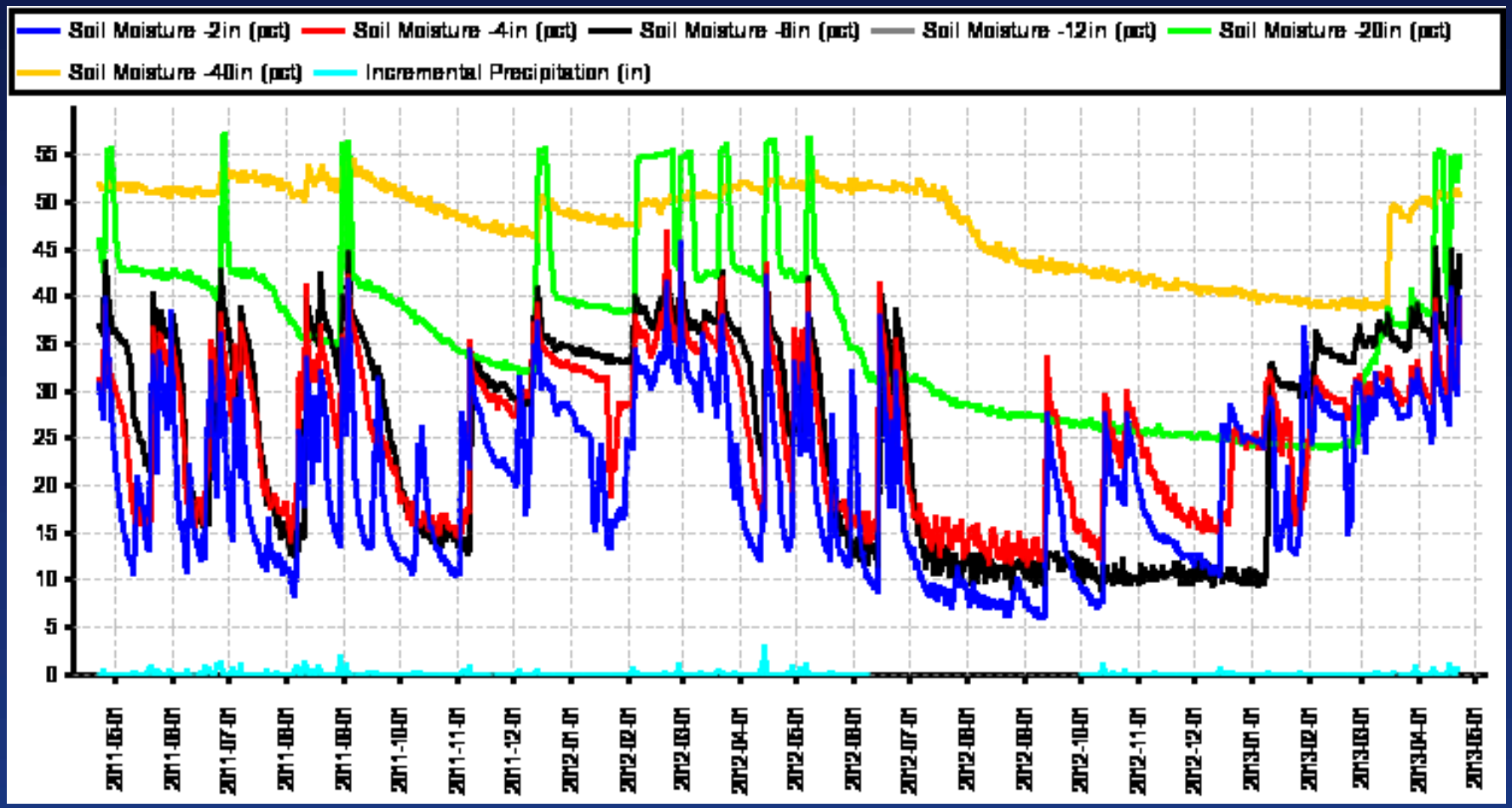
South Dakota Site - Eros Data Center (2072)

(As of: Mon Apr 22 16:12:35 CDT 2013)
Provisional data, subject to revision



Nebraska Site - Rogers Farm #1 (2001)

(As of: Mon Apr 22 16:17:31 CDT 2013)
Provisional data, subject to revision



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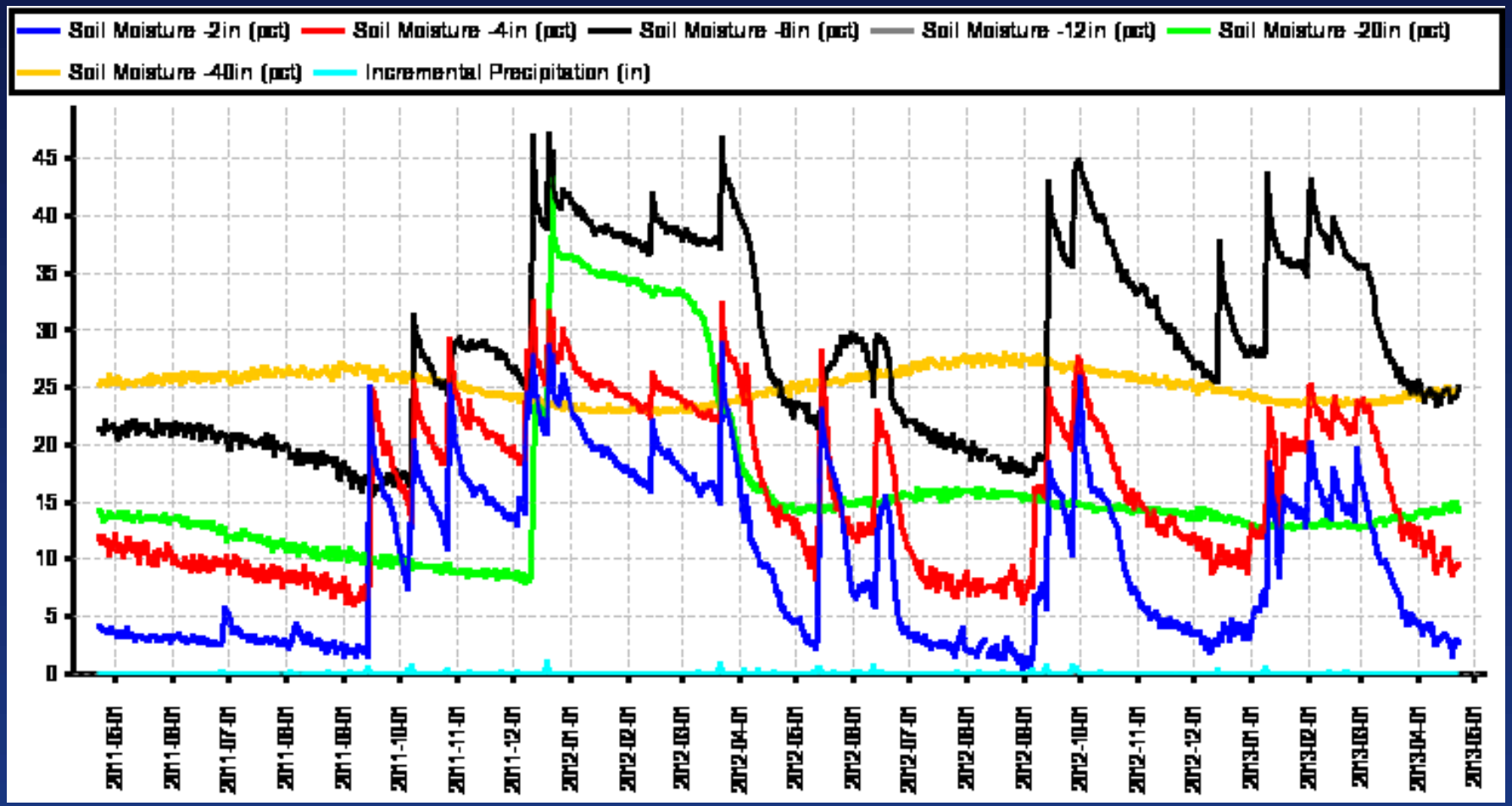
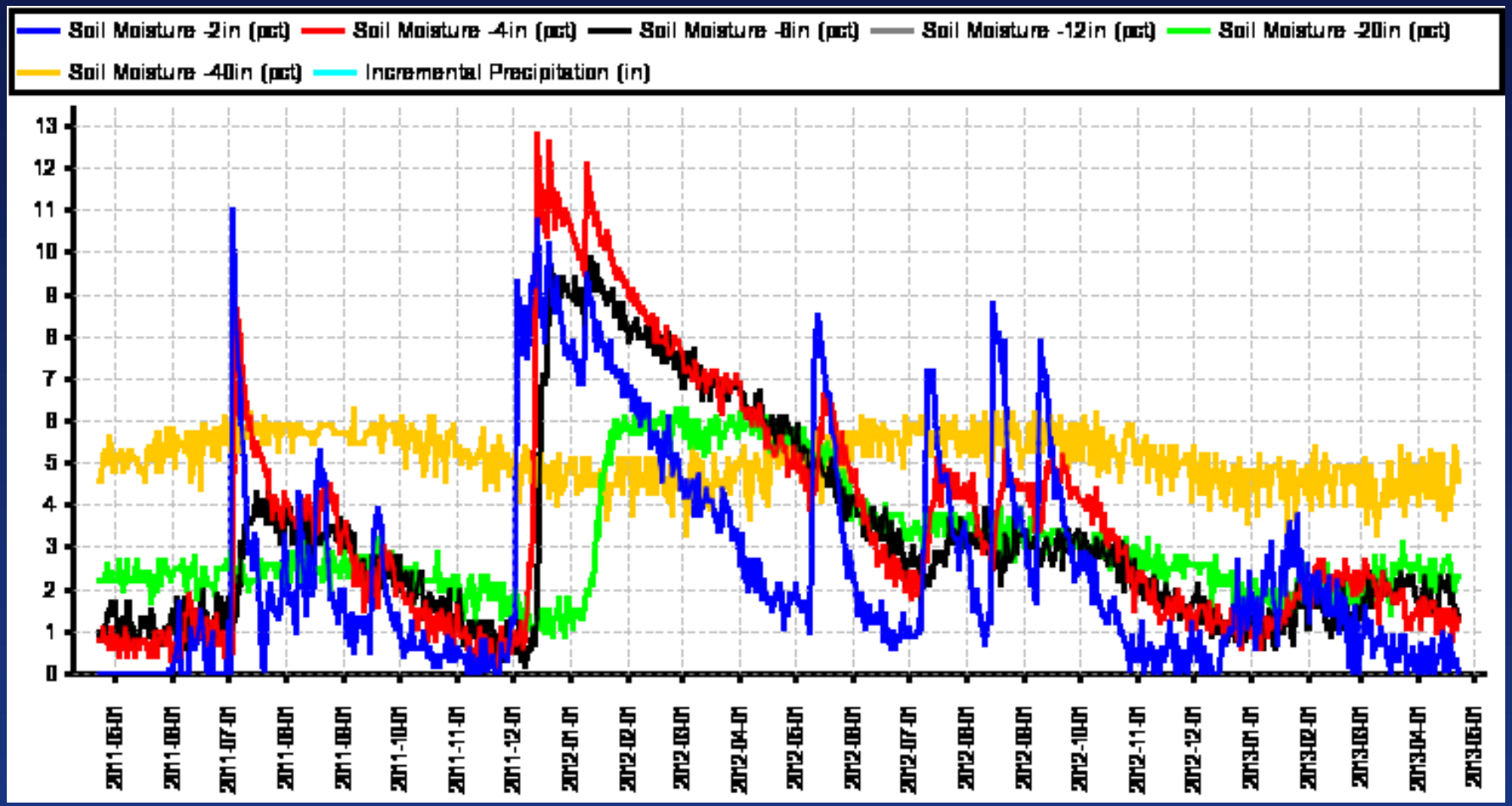
Texas Site - Bushland #1 (2006)
(As of: Mon Apr 22 16:27:32 CDT 2013)
Provisional data, subject to revision



New Mexico Site - Jornada Exp Range (2168)

(As of: Mon Apr 22 16:31:21 CDT 2013)
Provisional data, subject to revision



Summary Notes

- Need for a consistent, uniform soils network for entire country
- Many outstanding networks in existence at this time
- Present budgetary conditions emphasize the need for shared resources and coordinated efforts
- Present climatic conditions emphasize the need for soil moisture data
- Adequate data allows for assessment of drought, improved water use and precision agriculture
- Equally important with drought assessment, soil moisture is used for water supply forecasting and flood prediction
- Measurements throughout the soil profile are needed
- Need to develop better tools to provide user with spatial soil moisture modeling