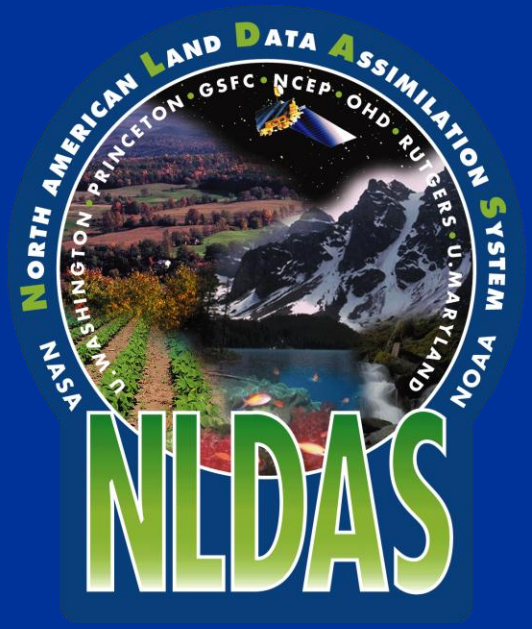
Application of NARR-Based NLDAS Ensemble Simulations to Continental-Scale Drought Monitoring



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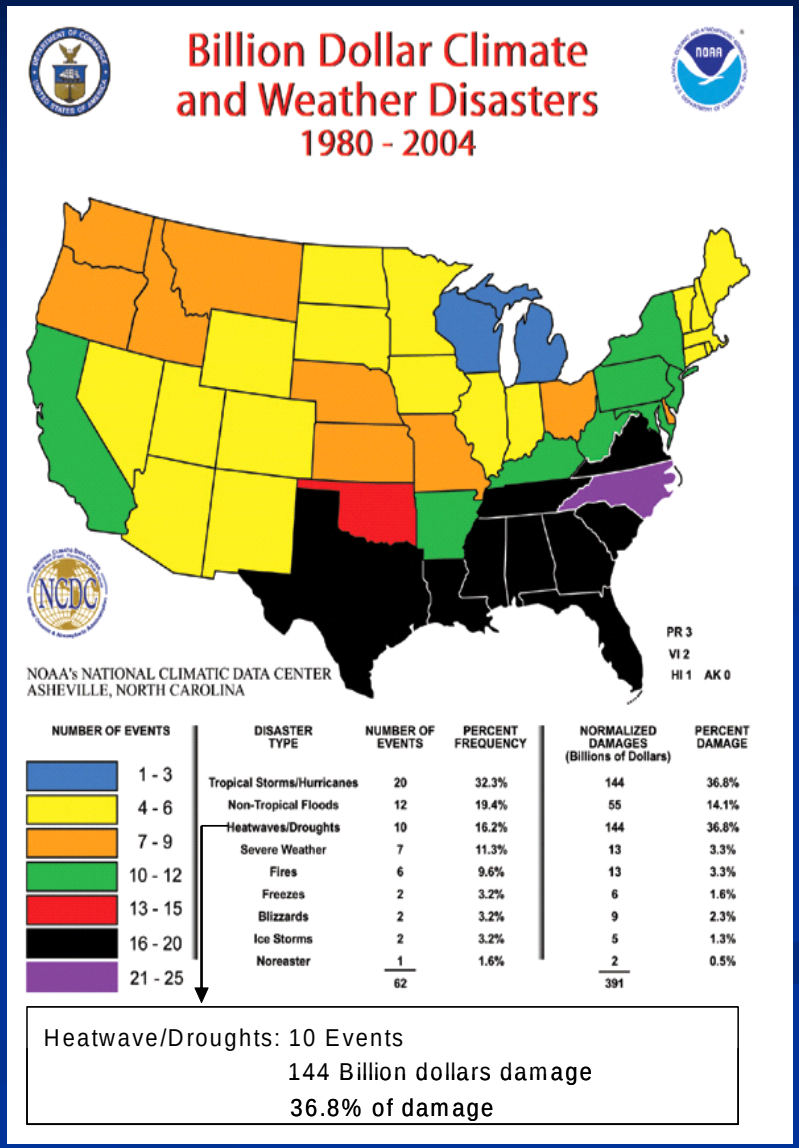
Introduction

- Droughts cause billions of dollars in damage each year
- More effective identification of droughts would directly benefit resource managers, and reduce drought impacts
- The multifaceted nature of droughts (meteorological, hydrological, and agricultural) coupled with largely varying population densities, topography, and land use across North America causes considerable difficulty in creating a single universal drought index



Introduction

- Numerous drought indices currently exist, each with its own inherent strengths and weaknesses:

  - Palmer Indices – PDSI, PHDI, Z-Index (Palmer 1965)

  - SPI - Standardized Precipitation Index (McKee et al. 1993)

  - Total Water Deficit – Hydrological drought (Dracup et al. 1980)

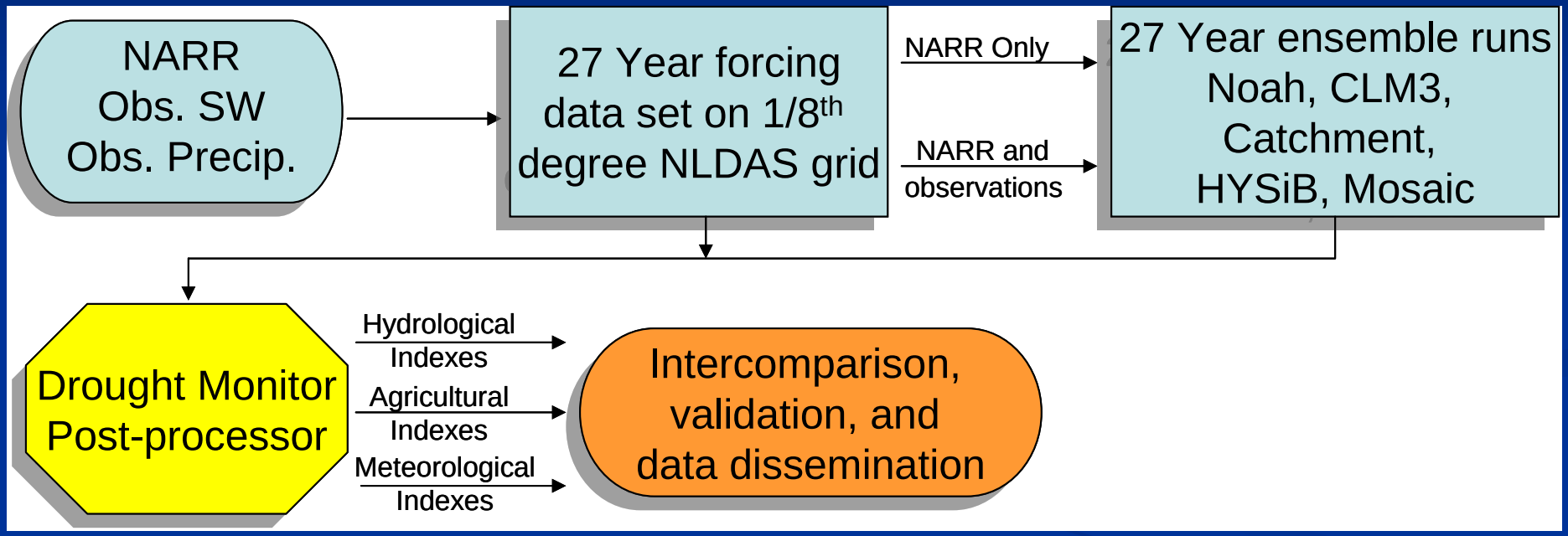
  - VHI – Vegetation Health Index (Kogan 1997)

- Difficult to calibrate and improve upon certain indices due to a lack of long term soil moisture observations on large scale
- Land surface models driven by modeled/observed forcing have become a valuable tool in the simulation of land surface states (Huang et al. 1996)
- Land Data Assimilation Systems (LDAS) offer high quality soil moisture fields with good spatial and vertical resolution and are a potentially useful tool in monitoring droughts (Sheffield et al. 2004)
- Combine modeling infrastructure of North American LDAS (NLDAS) with long term (27 years+) forcing fields of North American Regional Reanalysis (NARR) to form a NARR-based NLDAS drought monitor

Project Goals

- Construct and validate 1/8th degree forcing dataset based on NARR, supplemented with observed precipitation, and bias corrected with observed radiation
- Investigate optimal NLDAS forcing methodology using Noah and CLM3 LSMs
- Using optimal forcing methodology, execute two separate 1/8th degree 27 year-long ensemble runs using Noah, CLM3.5, Mosaic, HySSiB, and Catchment LSMs; one set forced with NARR-only data, and another forced with NARR and observed data
- Intercompare model output and validate against land surface observations
- Construct and execute drought monitor processing system using individual as well as ensemble output
- Analyze drought monitor output to determine effect of model selection and NARR climatology length on drought characterization, and to determine performance versus existing drought monitoring systems
- Transition system to real-time operations, disseminate data into existing drought monitoring efforts where possible

Project Flowchart



NLDAS Forcing Dataset

- Compatible with current NLDAS systems
  - Standard NLDAS 1/8th degree North American domain
  - 1979-Present, Hourly temporal resolution
  - Consists of model data base and observation overlay/bias correction
- NARR (and R-CDAS) model data base
  - 3 hourly, 32km, 1979 – Present over North America
  - Used as the backbone of new NLDAS forcing data set
- NESDIS/UMD Observed Short Wave Radiation
  - 1/8th degree hourly GOES-based from 1996-2000 used to bias correct NARR shortwave radiation data
  - Hourly correction developed for each month and applied to NARR
- CPC Observed Rain Gauge Data
  - Daily 1/8th degree PRISM 1979-Present (Schaake IDW)
  - Hourly Precipitation Data Set (HPD), 2 x 2.5 degree, 1979-Present
  - Hourly 4km Stage2 Doppler/Gauge data, 1996-Present
  - 30 Minute CMORPH satellite precipitation data, 2002-Present

Forcing Methodology Study

- Ongoing NLDASE project highlighted need for LDAS forcing methodology investigation
- Use of 2m/10m fields versus lowest model level fields (with variable forcing height) can greatly impact simulation of surface fluxes
- Multi-model investigation
  - Noah and CLM3 LSMs
  - 1996-2005 with 5 year recursive spin-up
- Validation against OK Mesonet and SCAN
- Result will impact subsequent drought monitoring simulations

Multi-Model Ensemble Simulations

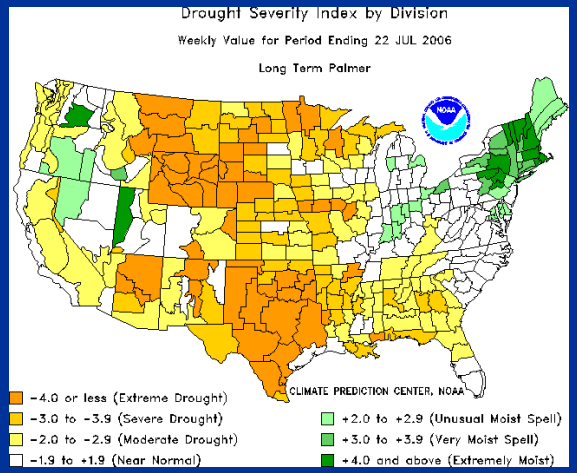
- Multi-model output will form base of drought monitor, and aid in LSM improvement as current NLDAS runs have done
- Two sets of simulations: NARR-only forcing and NARR + observation forcing, both using optimal forcing methodology
- Noah, CLM3, HySSiB, Catchment, Mosaic LSMs
- 27 Years (1979-Present) with 5 year recursive spin-up (using mean climatological forcing)
- 3-hourly output on 1/8th degree NLDAS grid
- Runoff routing scheme applied to each LSMs output to calculate stream flow (Lohmann 1998b)
- Ensemble mean and individual LSM output intercompared and validated against observations and CPC 50 year LDAS simulation (Noah LSM)

Drought Monitor Processing System

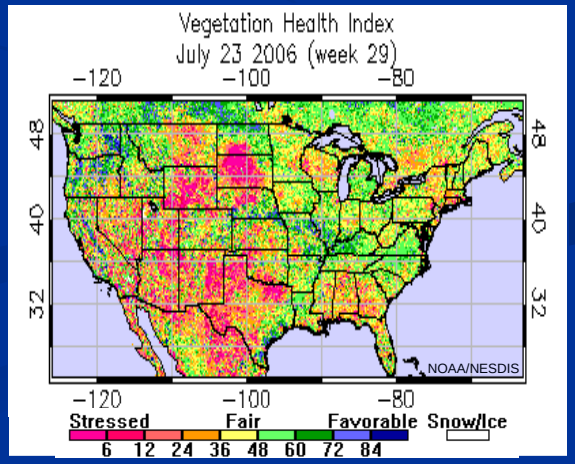
- Drought monitor will compute several drought indices from NLDAS LSM output, NARR land surface states, and forcing data
- Both standard and new NLDAS-based drought indices will be computed

	Drought Index	Drought Type	Required NARR/NLDAS Monitor Data	Comparison Data
Standard Indices	Wtd/UnWtd PDSI	Meteorological	Forcing	NCDC PDSI
	SPI	Meteorological	Forcing	U. Nebraska SPI
	PHDI	Hydrological	Forcing	NCDC PHDI
	TWD	Hydrological	Streamflow Output	USGS Streamflow
	Palmer Z	Agricultural	Forcing	NCDC Palmer Z
	VIC Percentile	Agricultural	LSM Soil Moisture Output	U. Washington
Experimental LDAS Indices	LDAS PDSI	Meteorological	LSM Output and Forcing	NCDC PDSI
	LDAS PHDI	Hydrological	LSM Output and Forcing	NCDC PHDI
	LDAS Palmer Z	Agricultural	LSM Output and Forcing	NCDC PHDI
	CLM3 VHI	Agricultural	CLM3 LAI/NDVI Output	NOAA VHI

Self Calibrating (duration and climate characteristic parameters)



Examples of Palmer Drought Severity and Vegetation Health Indices that will be used as comparison data for NARR-based monitor.



Analyze Drought Monitor Index Output

- How does the characterization of drought vary by LSM?
- What impact does use of the ensemble mean have on drought detection?
- How do drought indices produced by the ensemble LSMs compare to drought index values produced directly from NARR land surface fields?
- Can an NARR/NLDAS system produce standard and experimental-LDAS drought index fields which capture the same droughts detected by established measures such as PSDI and US Drought Monitor?
- How does climatology-length affect drought characterization, and does the NARR offer a suitably accurate and lengthy record of forcing data to serve as the base of a drought monitor?

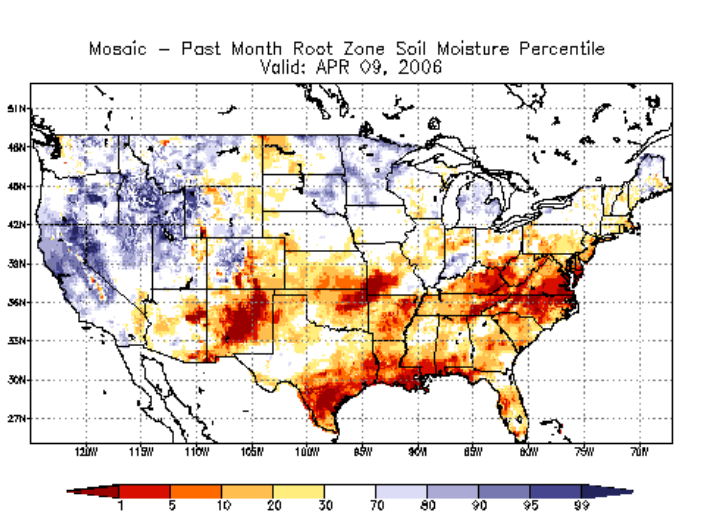
  - SPI and soil moisture percentiles will be calculated from full 50+ year CPC simulation as well as 27 year subset to gauge impact of climatology length on indices, and results will be used to guide interpretation of NARR/NLDAS-based values.

Real-time Operations and Data Dissemination

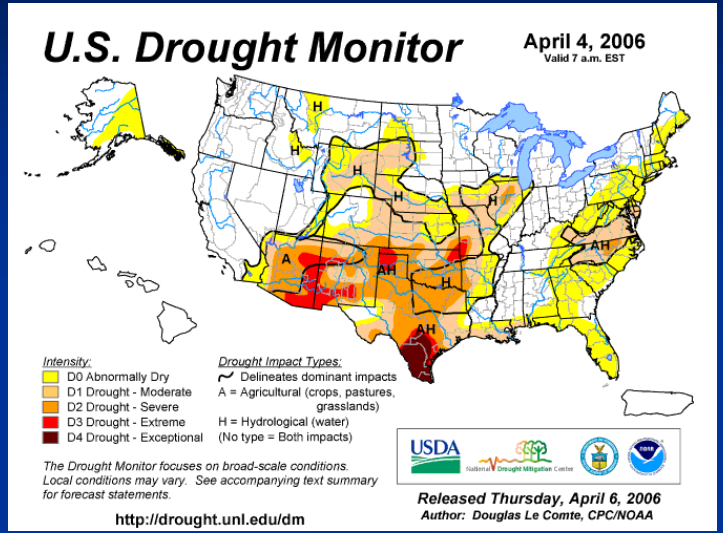
- Real-time drought monitor will mirror retrospective efforts
  - 1/8th Degree forcing creation
  - Multi-model ensemble runs
  - Computation of drought indices
  - Data display on web
  - Pilot drought monitor underway using existing NLDAS output

NLDAS Experimental Drought Monitor

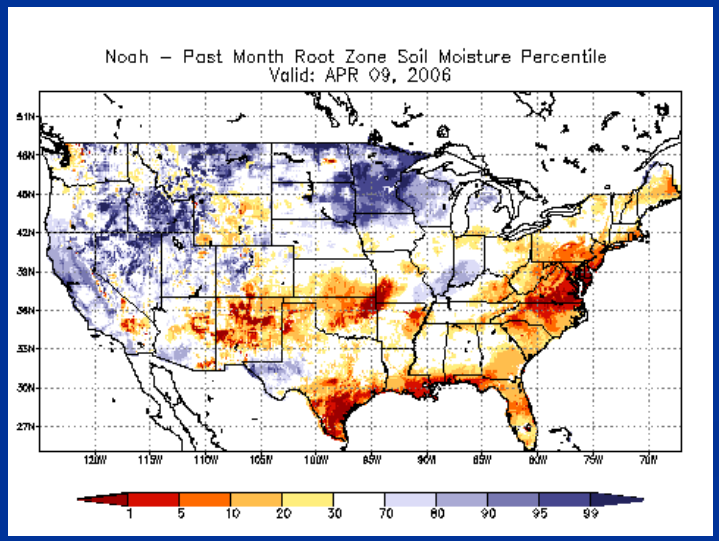
NLDAS – Mosaic LSM Output



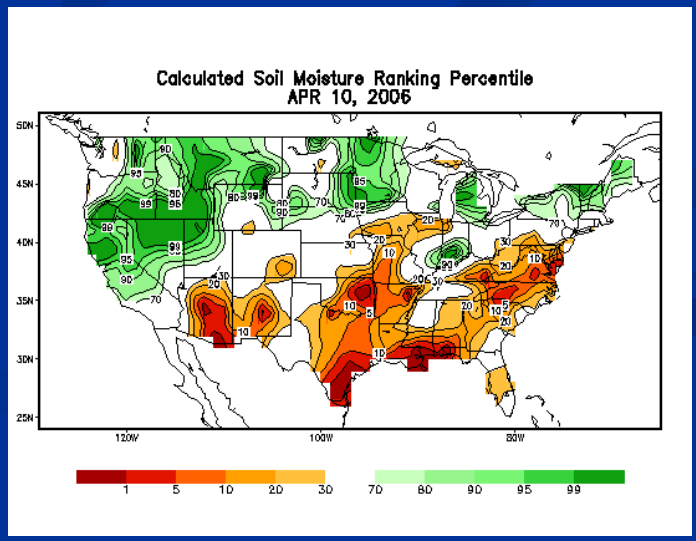
NDMC – Weekly Drought Monitor



NLDAS – Noah LSM Output

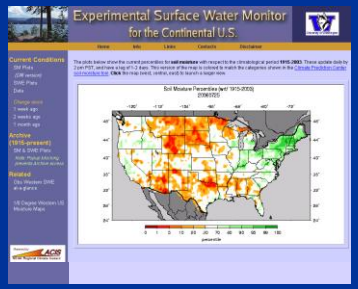


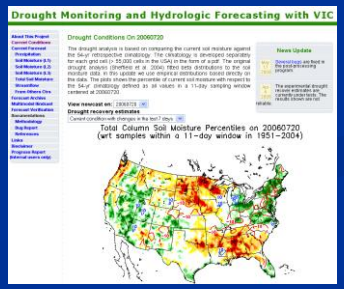
CPC - Leaky Bucket Model

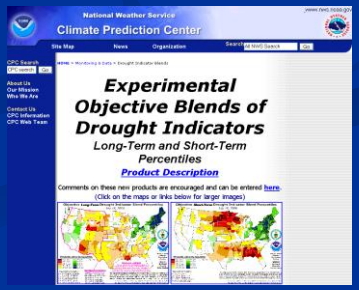


NLDAS Experimental Drought Monitor Methodology

- Mean root zone and total column soil wetness values were computed for each day of the year from the 1997-2006 NLDAS Mosaic and Noah output (1996 discarded due to spin-up) and stored in mean daily climatology files
- Anomalies are computed by comparing the near real-time data (past week/month) to the same section of the year in the mean climatology files
- Percentiles are computed by ranking the current soil wetness values (past week/month) against values from +/- 5 surrounding days over the past 9 years.
- Shell/GrADS scripts create visual output and copy images to LDAS website
- Modeled after existing websites (U. Washington, Princeton, and CPC)
  - http://www.hydro.washington.edu/forecast/monitor/index.shtml
  - http://hydrology.princeton.edu/forecast/
  - http://www.cpc.ncep.noaa.gov/soilmst/





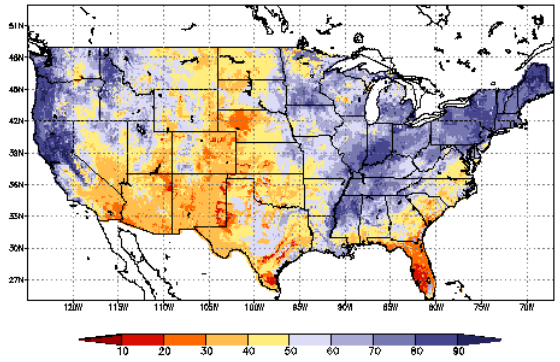
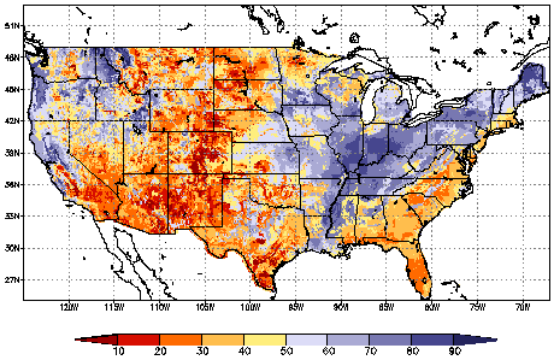


NLDAS Experimental Drought Monitor

URL: http://ldas.gsfc.nasa.gov/monitor/

Experimental NLDAS Drought Monitor

NOTE: This page is best viewed with a screen resolution of at least 1024x768

MOSAIC LSM OUTPUT	NOAH LSM OUTPUT
Root Zone (0 - 40 cm) Soil Moisture	Root Zone (0 - 40 cm) Soil Moisture
Current Conditions (Soil Wetness %)	Current Conditions (Soil Wetness %)
Past Week Soil Moisture Anomaly	Past Week Soil Moisture Anomaly
Past Month Soil Moisture Anomaly	Past Month Soil Moisture Anomaly
Past Week Soil Moisture Percentile	Past Week Soil Moisture Percentile
Past Month Soil Moisture Percentile	Past Month Soil Moisture Percentile
Mosaic Total Column Soil Wetness (%) Valid: APR 09, 2006  CLICK ONE OF THE LINKS TO BEGIN	Noah Total Column Soil Wetness (%) Valid: APR 09, 2006  CLICK ONE OF THE LINKS TO BEGIN

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- Anomalies are computed by comparing the near real-time data (past week/month) to the same time of the year in the mean climatology files
- 365 daily data distributions were also developed from the historic data using an 11-day data window (11 daily mean values)
- Percentiles are extracted by comparing (# greater/less than) the current soil wetness values (past week/month) with the empirical distributions
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Possible Collaborations

- US Drought Monitor
  - Source of objective drought data
  - Single model or ensemble-based
  - Assessment of all three types of droughts
- NIDIS
- Ongoing drought research at NOAA NCEP, University of Washington, and Princeton University
- Other research programs