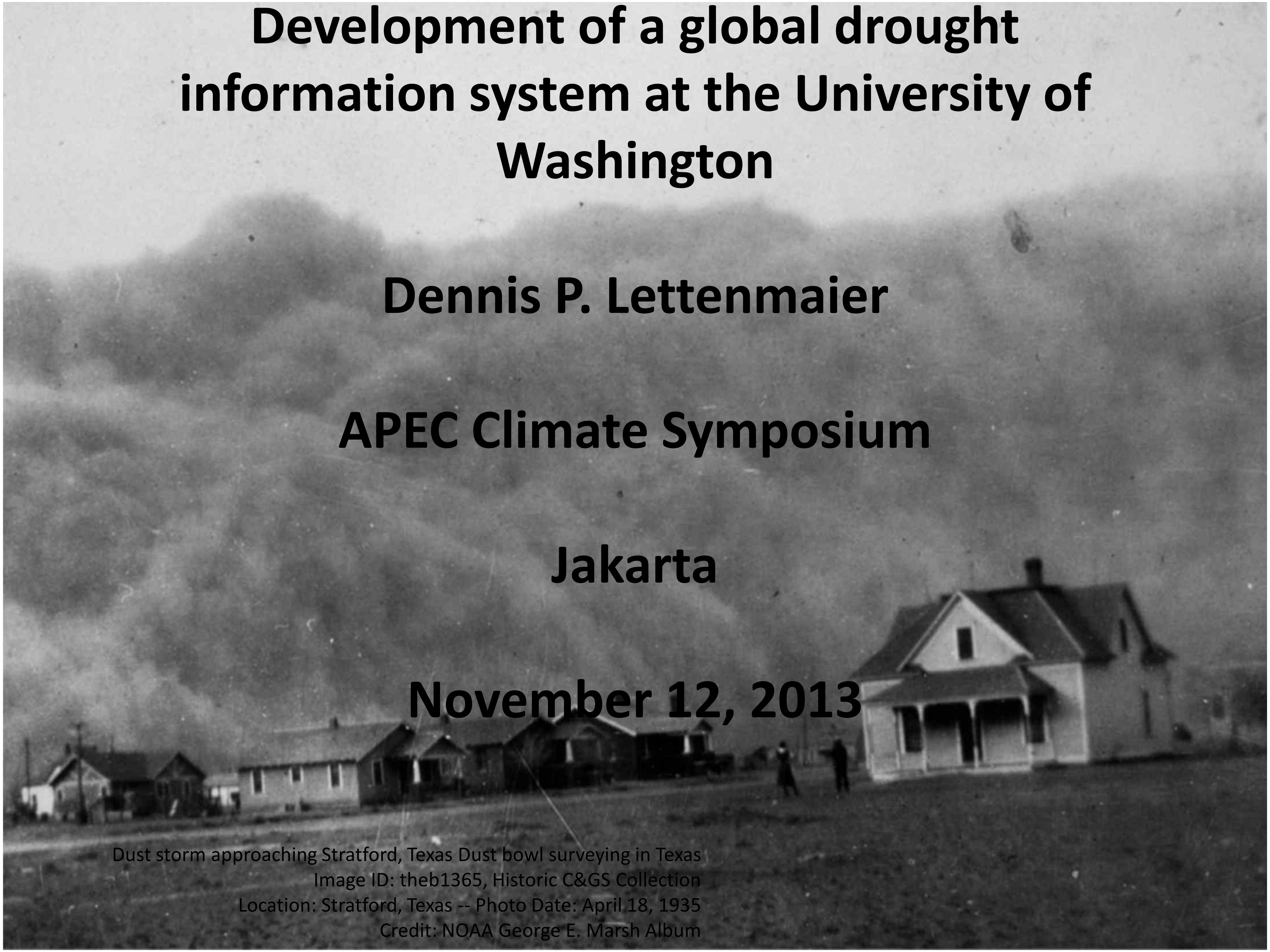
Development of a global drought information system at the University of Washington

Dennis P. Lettenmaier

APEC Climate Symposium

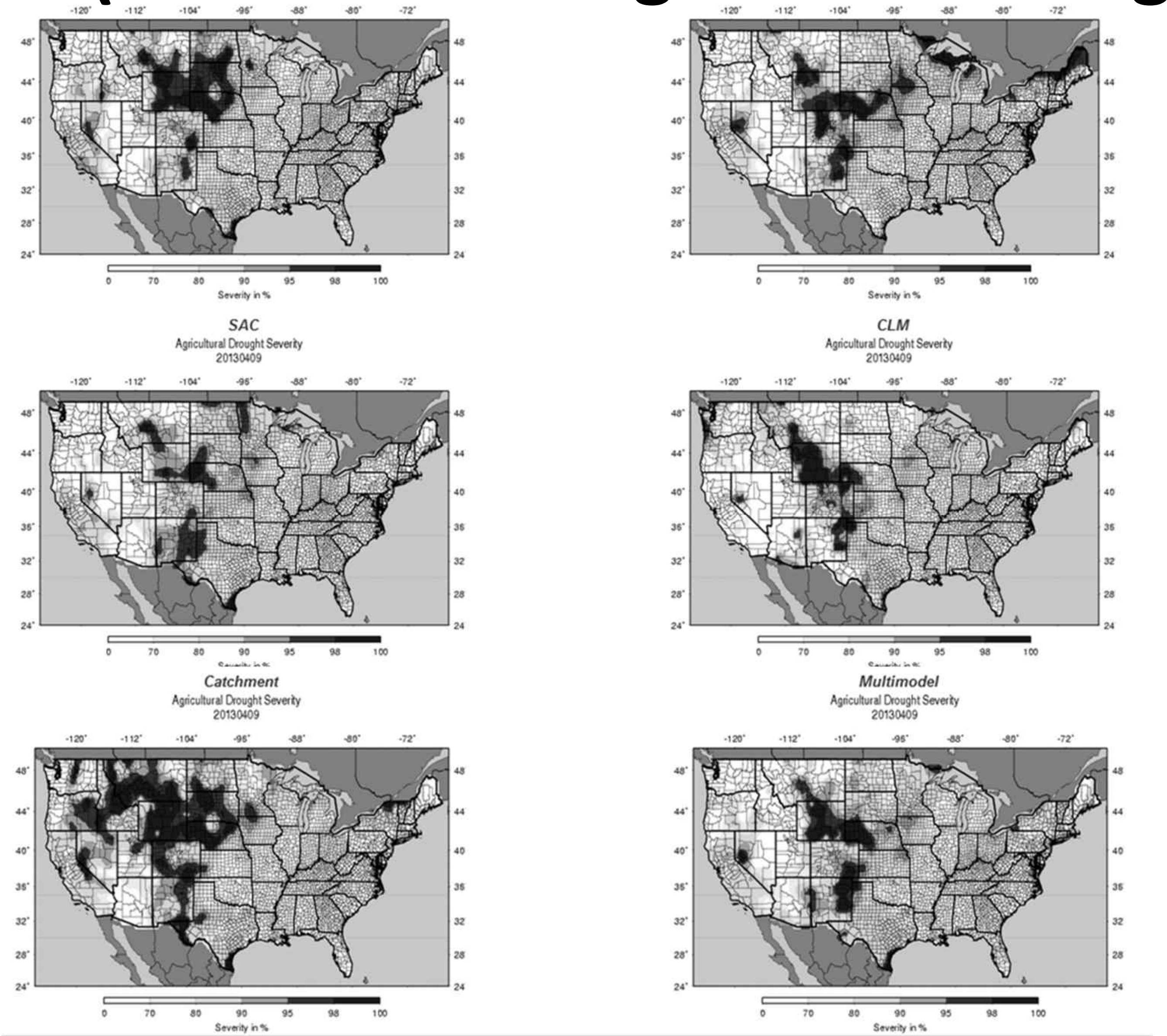
Jakarta

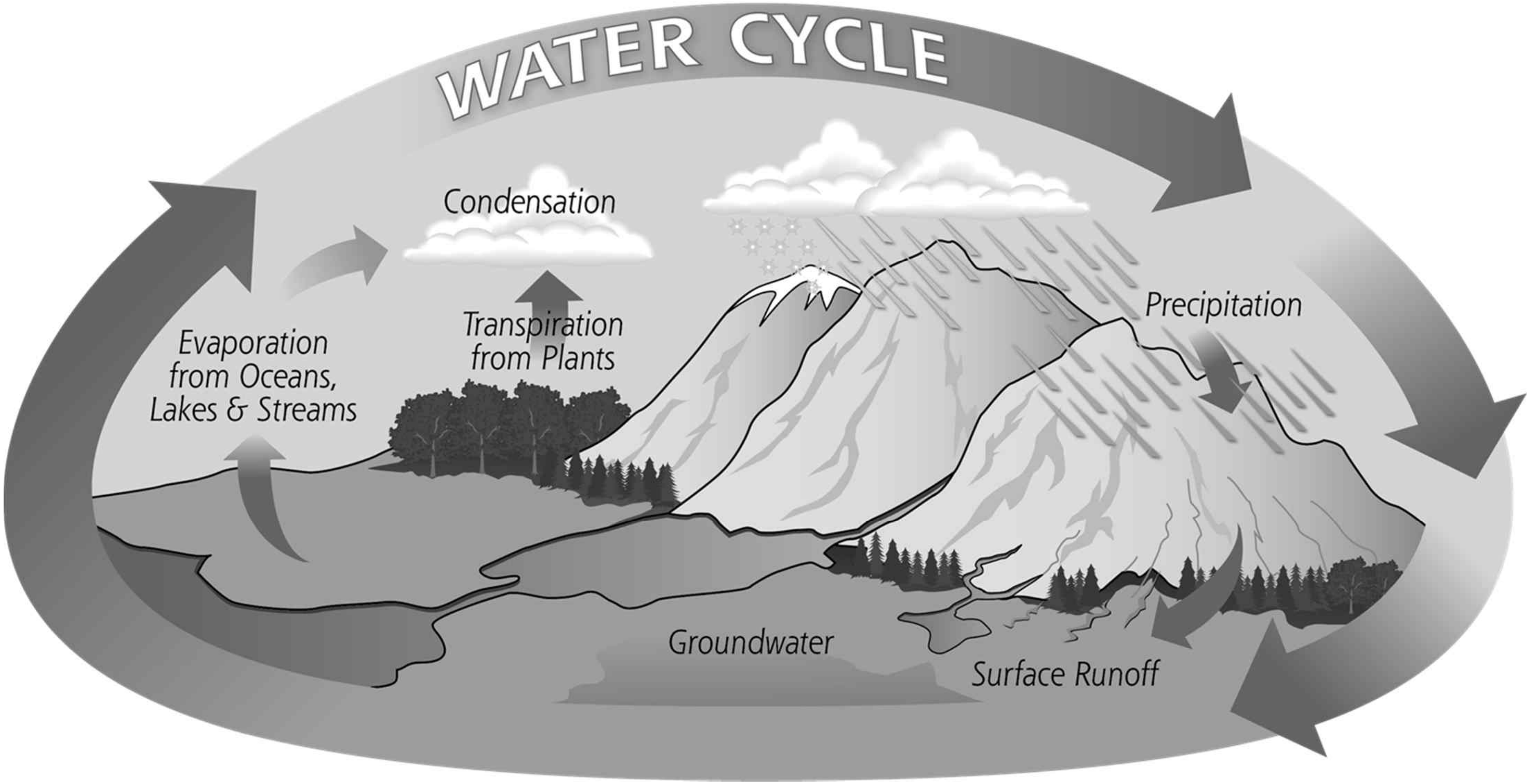
November 12, 2013



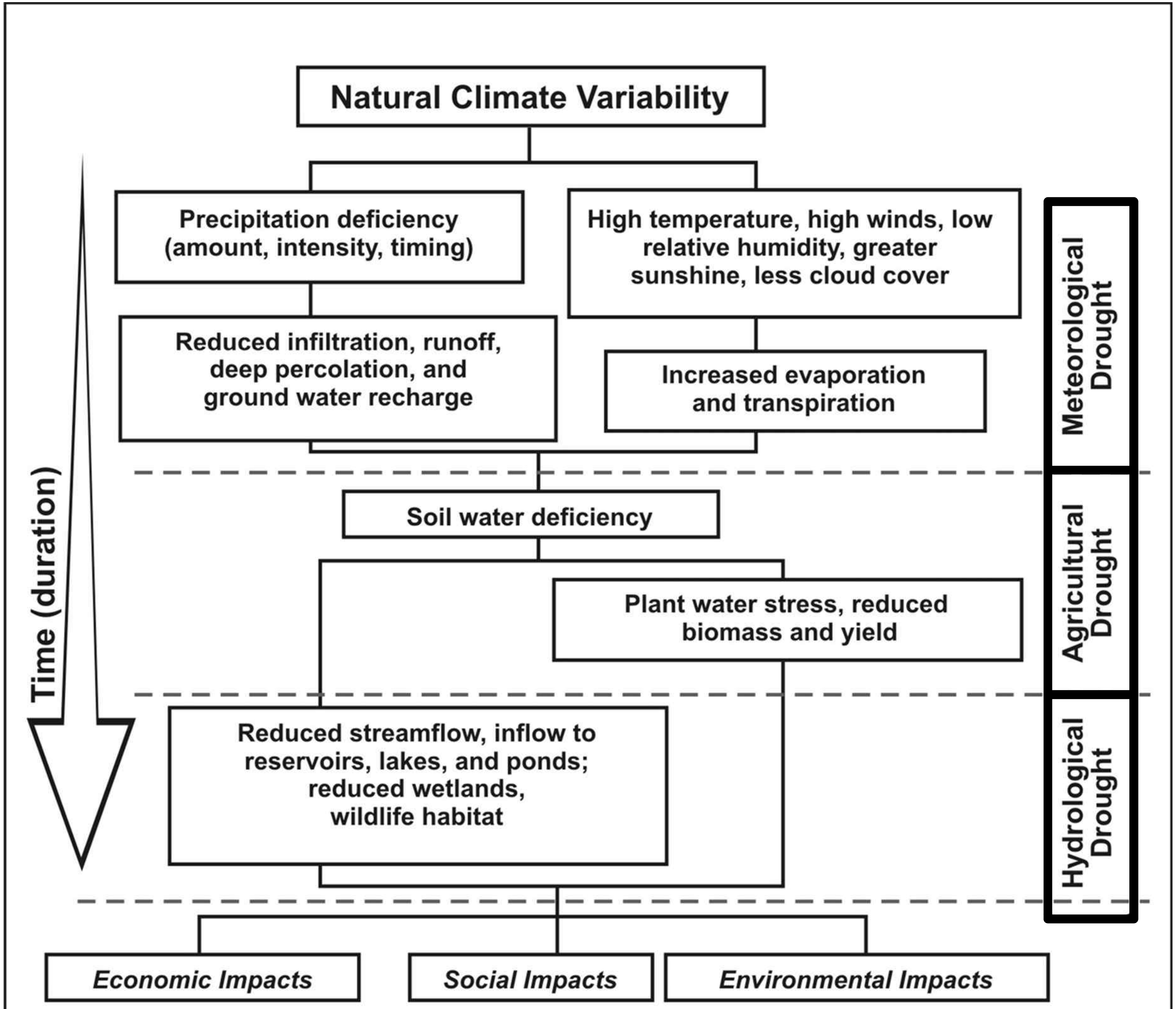
Dust storm approaching Stratford, Texas Dust bowl surveying in Texas
Image ID: theb1365, Historic C&GS Collection
Location: Stratford, Texas -- Photo Date: April 18, 1935
Credit: NOAA George E. Marsh Album

University of Washington Surface Water Monitor (real-time drought monitoring)



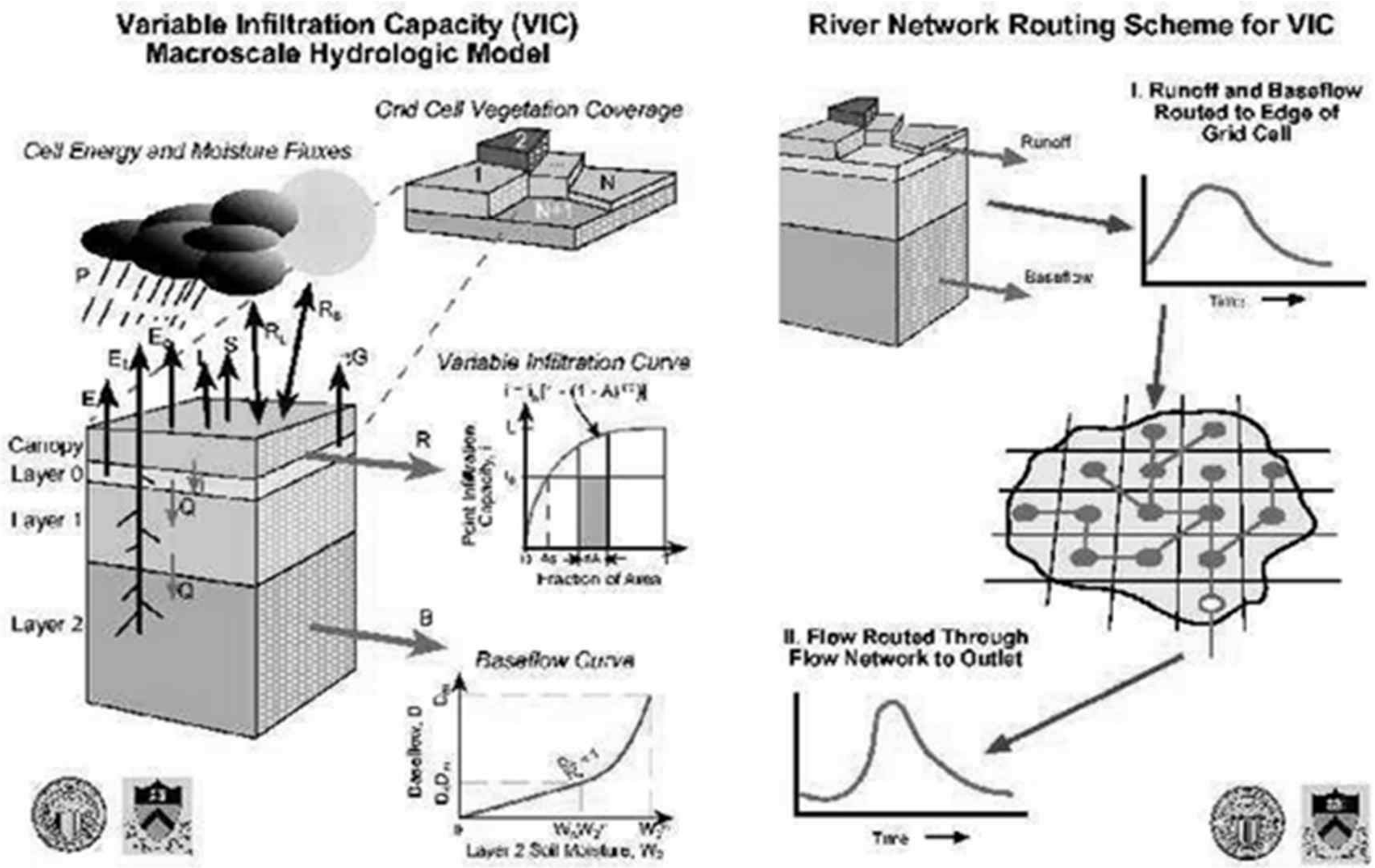


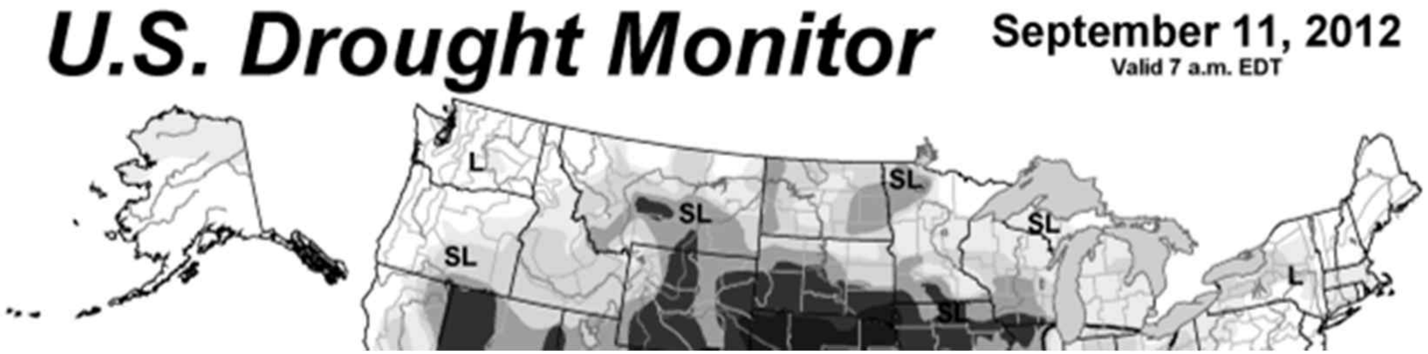
Source: NASA Precipitation Measurement Missions
http://pmm.nasa.gov/education/sites/default/files/article_images/Water-Cycle-Art2A.png



(Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.)

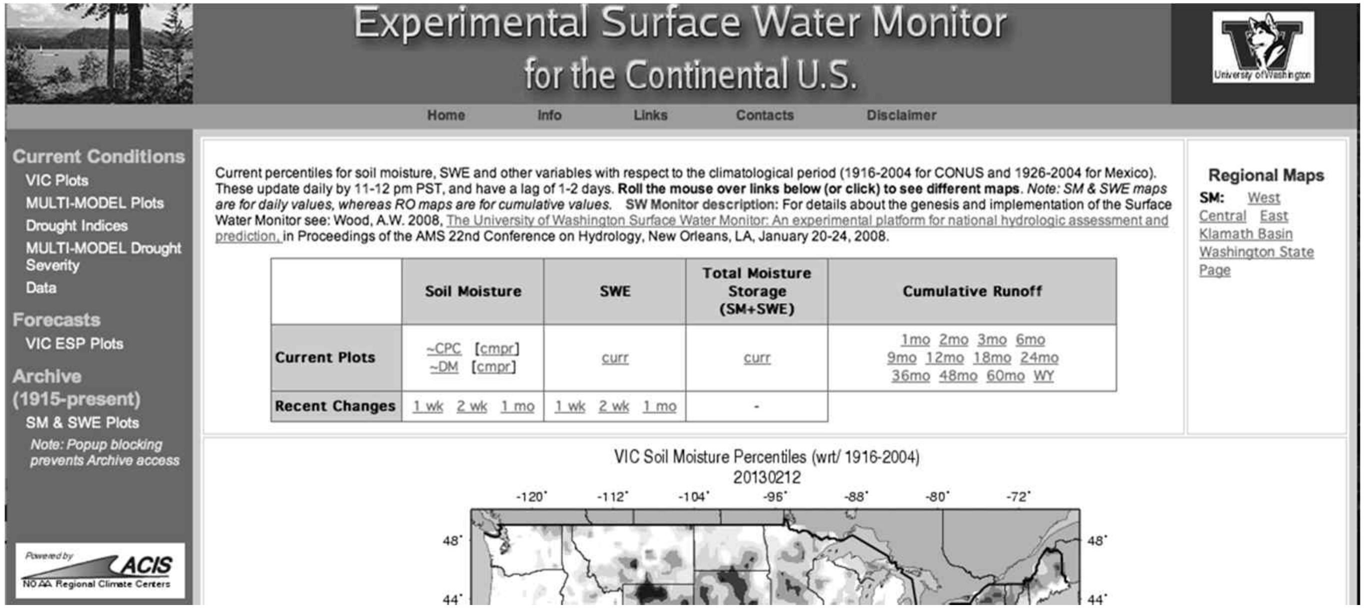
Variable Infiltration Capacity (VIC) macroscale hydrologic model

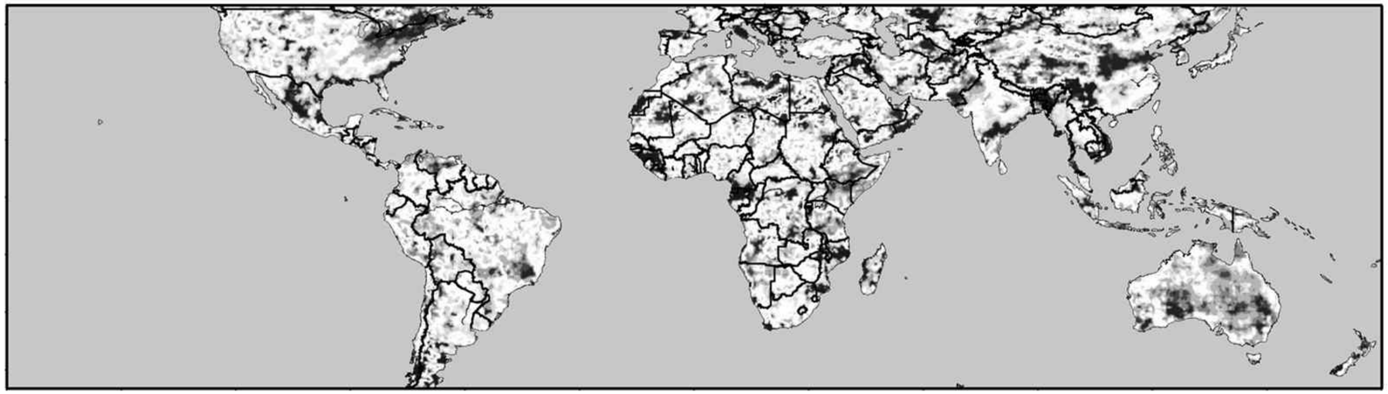




2012 US Drought

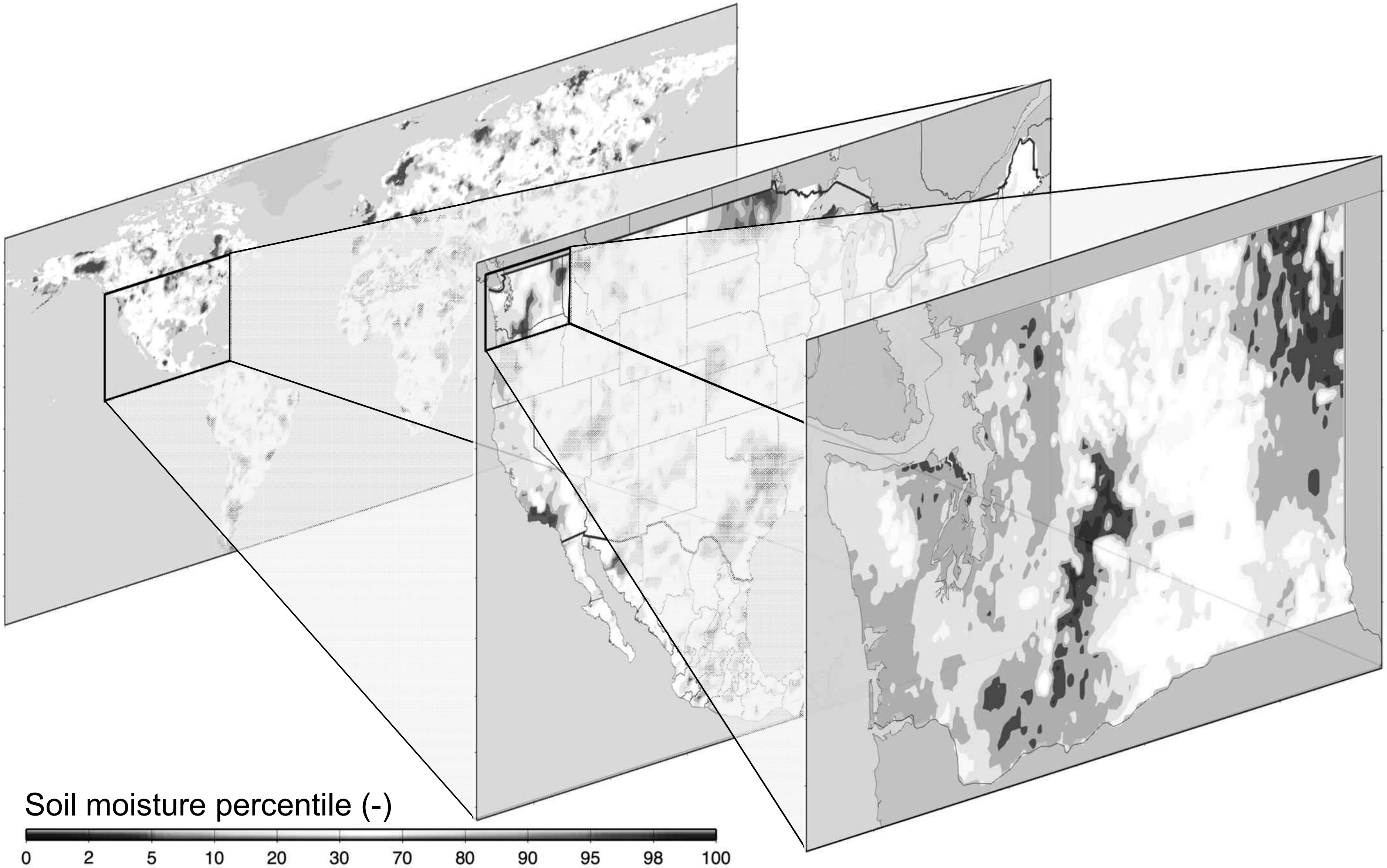
Drought Monitoring at the UW CEE Land Surface Hydrology Group

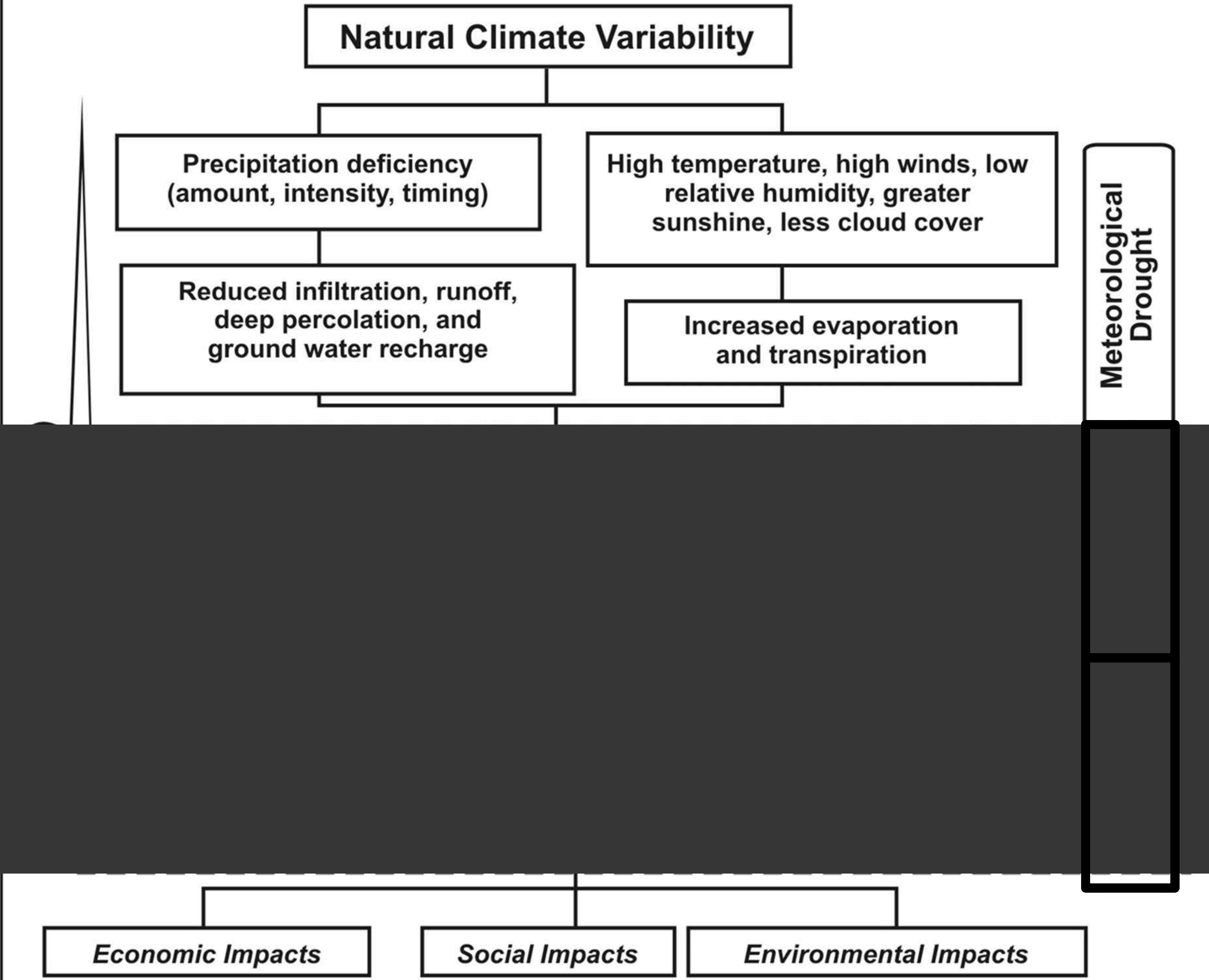




Development of a Global Drought Information System

SW Monitor: Regional to global





(Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.)

Drought severity classifications

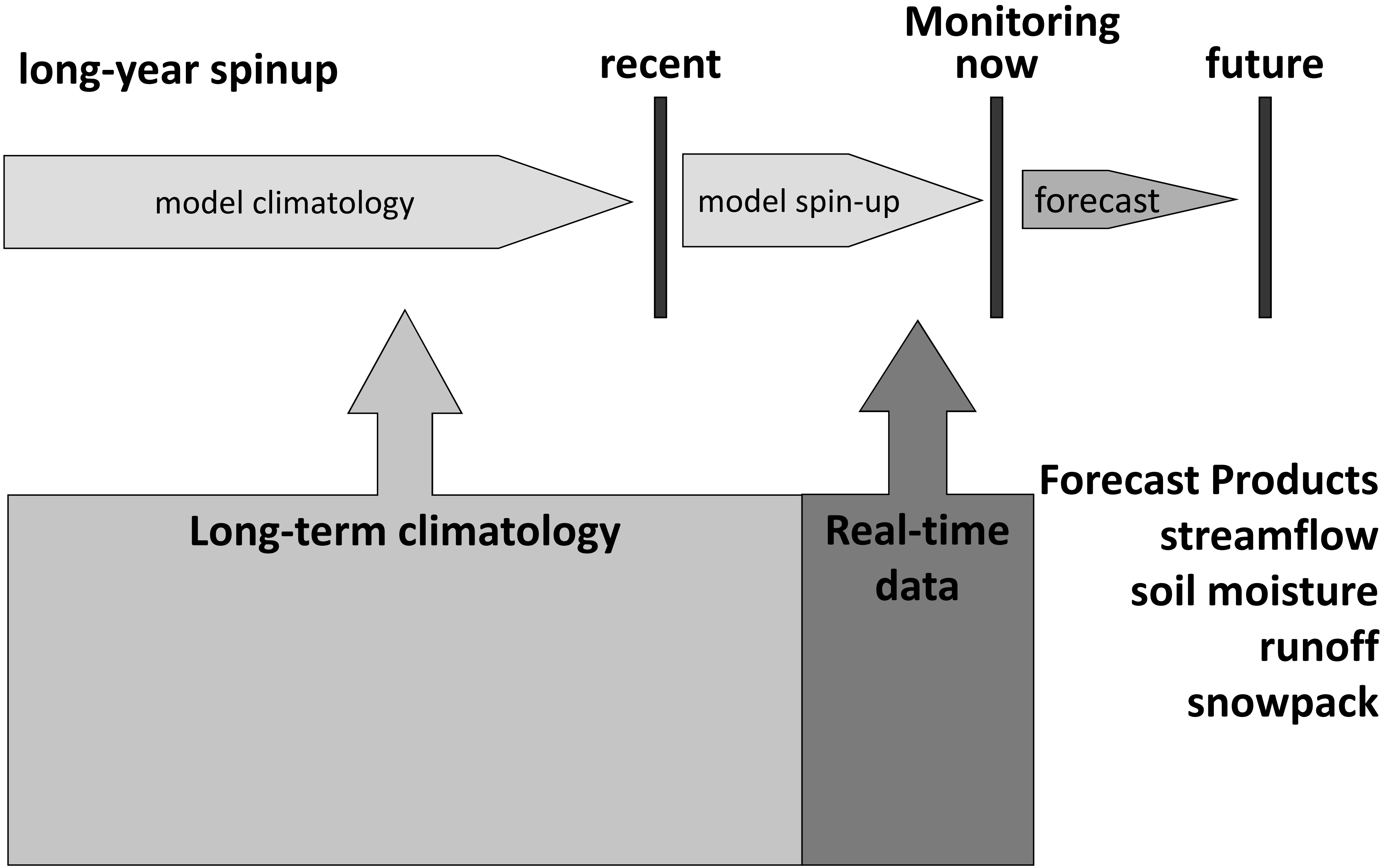
Standardized Precipitation Index (SPI)	**Standardized Runoff Index (SRI)**	**Soil Moisture Percentile (SMP)**	**Drought Severity Class**
0.50 to 1.0	0.50 to 1.0	0.50 to 1.0	**1**
0.35 to 0.50	0.35 to 0.50	0.35 to 0.50	**2**
0.20 to 0.35	0.20 to 0.35	0.20 to 0.35	**3**
0.10 to 0.20	0.10 to 0.20	0.10 to 0.20	**4**
0.05 to 0.10	0.05 to 0.10	0.05 to 0.10	**5**
0 to 0.05	0 to 0.05	0 to 0.05	**6**

Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

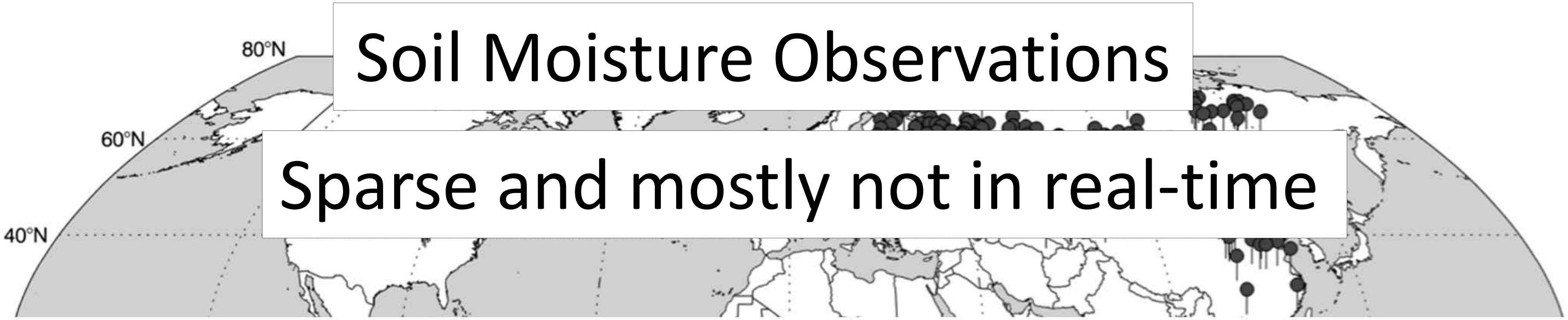
9

Simulations



Soil Moisture Observations

Sparse and mostly not in real-time

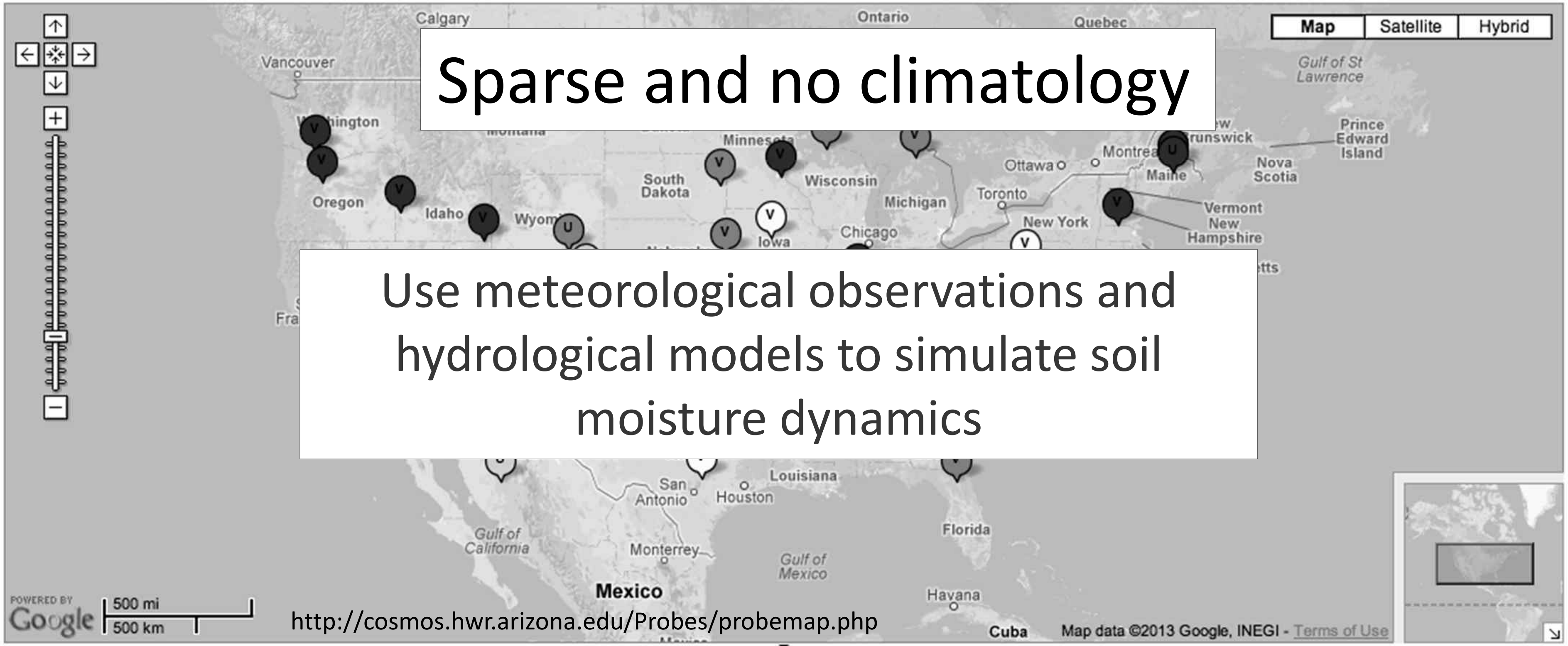


Location of COSMOS Probes

Click on balloons for site descriptions and data access. Station List Diagnostics Utilities

Sparse and no climatology

Use meteorological observations and hydrological models to simulate soil moisture dynamics



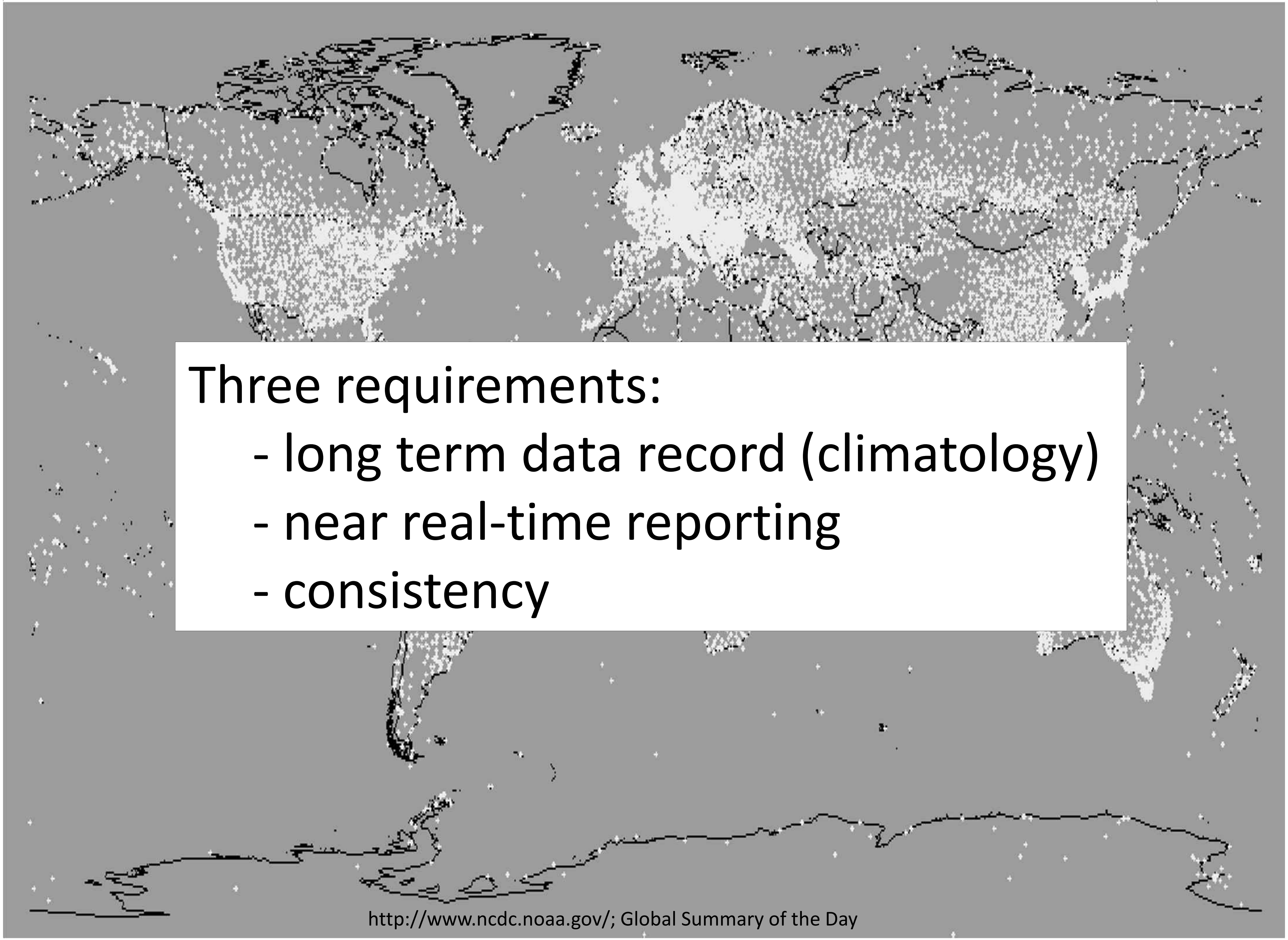
http://cosmos.hwr.arizona.edu/Probes/probemap.php

Soil Moisture (V=Volumetric, G=Gravimetric, U=Uncalibrated)

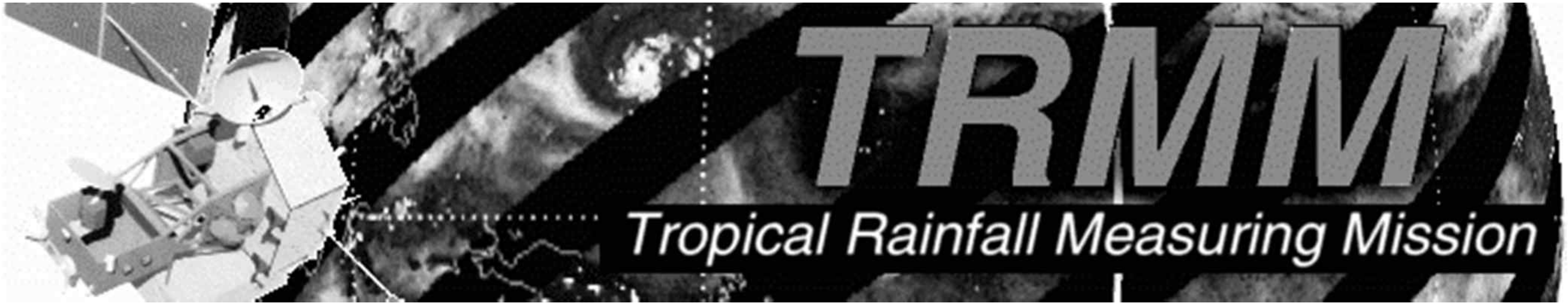
0 - 05% 05 - 15% 15 - 25% 25 - 35% > 35%

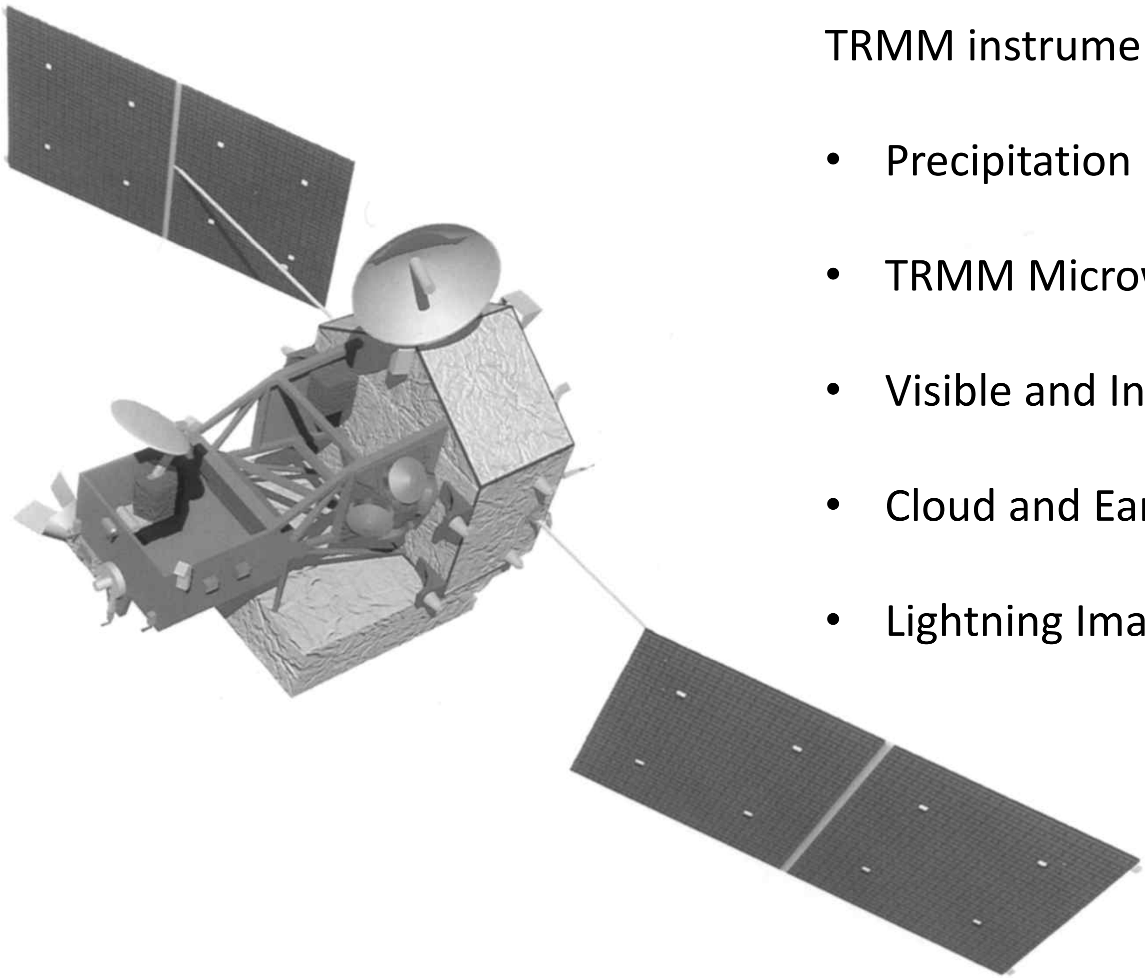
Three requirements:

- long term data record (climatology)
- near real-time reporting
- consistency



http://www.ncdc.noaa.gov/; Global Summary of the Day





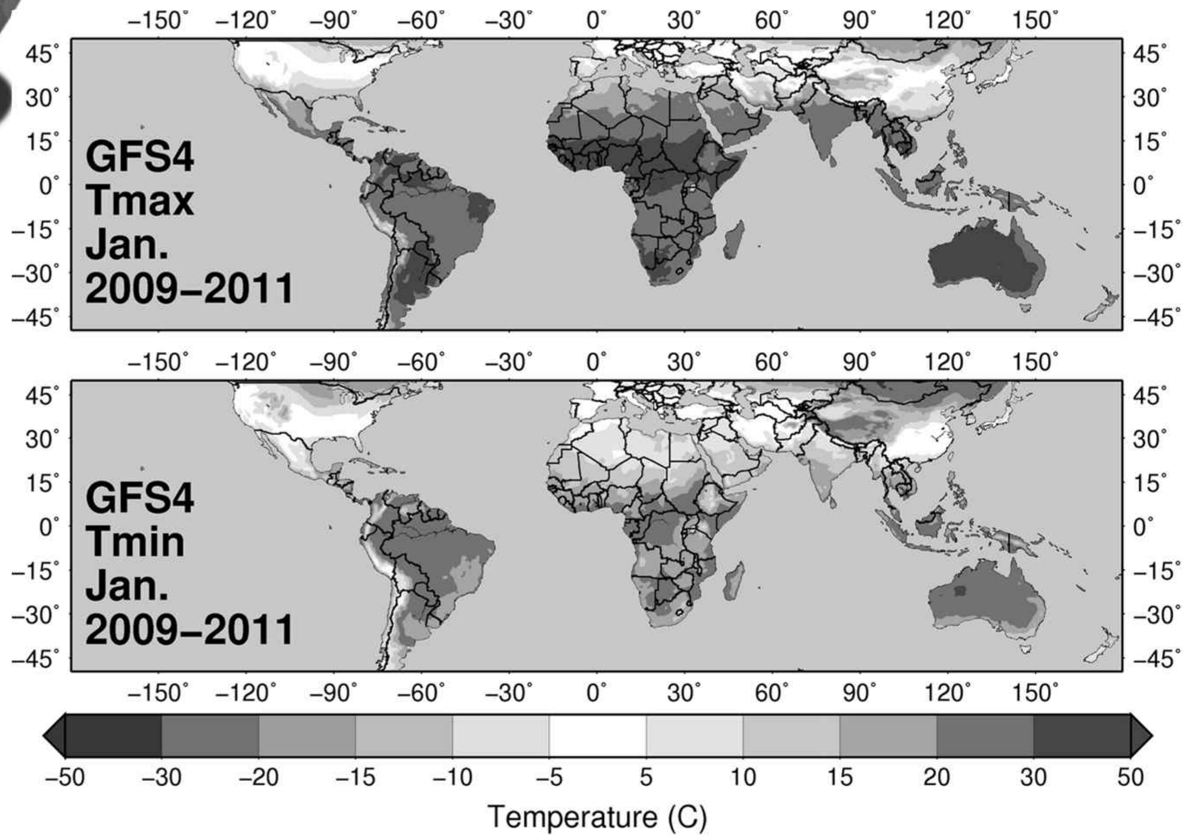
TRMM instruments:

- Precipitation Radar (PR)
- TRMM Microwave Imager (TMI)
- Visible and InfraRed Scanner (VIRS)
- Cloud and Earth Radiant Energy Sensor (CERES)
- Lightning Imaging Sensor (LIS)

http://trmm.gsfc.nasa.gov/

GFS

Global Forecast System



http://www.emc.ncep.noaa.gov/

Forcing data

Precipitation data sets used:

Sheffield et al: 1948-2008 (T and P) **(SH)** — Station-based: climatology

TRMM V7:

- Research product **RP**: 1/1/1998-6/30/2013 — Satellite + stations: spinup
- Real-time product **RT**: 3/1/2000-current — Satellite only: real-time
  - available in near real-time

Temperature data sets used:

Sheffield et al: 1948-2008 — Station-based: climatology

NCEP/NCAR Reanalysis: 1979-2011 — Model + stations: spinup

GFS 4: 2009-current — Model + stations: real-time

- available in near real-time

For the purpose of this presentation, *current* is 10/01/2013. However, the **RT** and GFS4 datasets can be updated daily.

The challenge

- The climatological period, used to determine the soil moisture percentiles for each grid cell for a given date, is based on the period 1960-2008 (Sheffield data set)
- Because soil moisture conditions in the real-time simulations are compared with those from the climatological period, systematic differences between the forcing datasets must be avoided
- Correct the precipitation and temperature data sets used for the post-2008 period so that they match the Sheffield data set (in a statistical sense) for any overlapping period

Forcing data

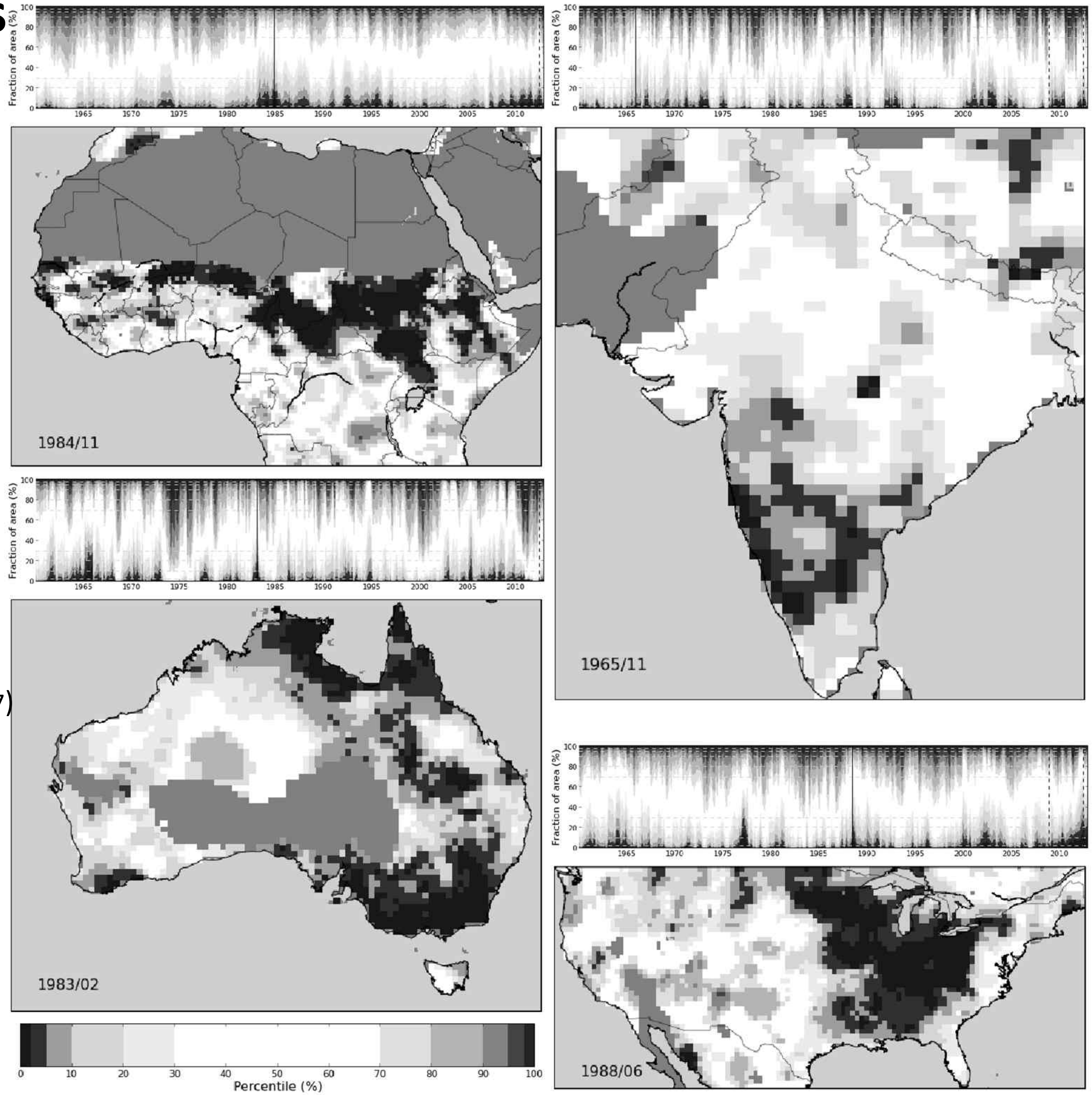
- Wind speed values are climatological values based on a reanalysis
- All other meteorological forcings needed to drive the models are estimated from the daily temperature range and precipitation
  - downward shortwave radiation
  - downward longwave radiation
  - humidity

Selected droughts

Multimodel estimates

VIC / Noah / SAC

GDIS simulates historic droughts



VIC estimates (Sheffield and Wood 2007)

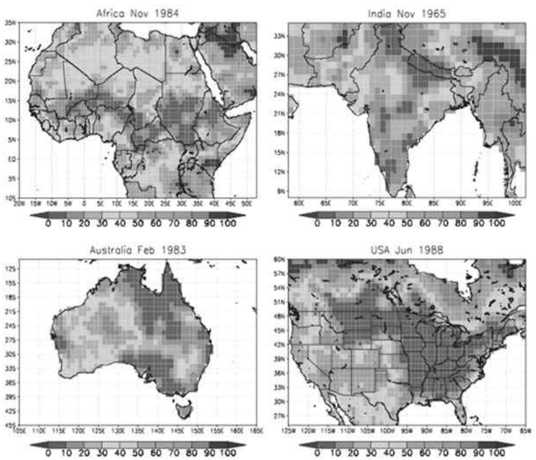
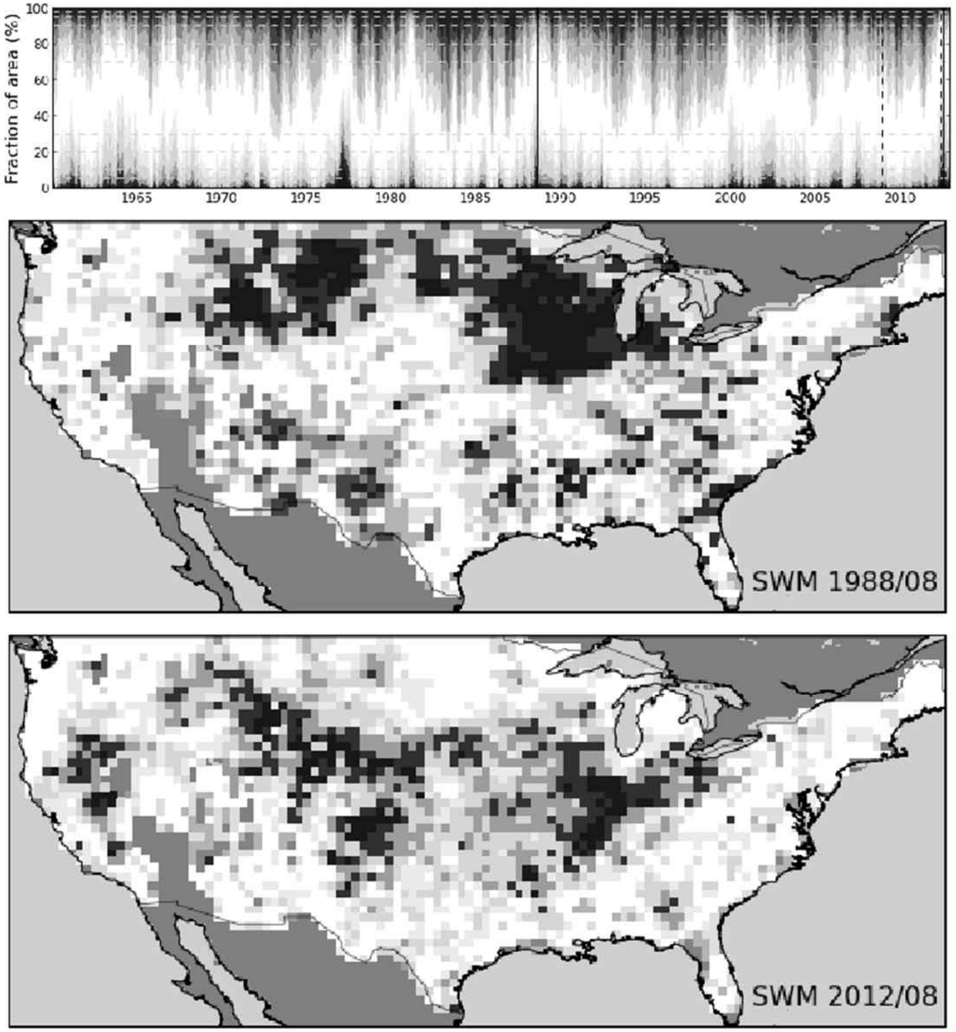
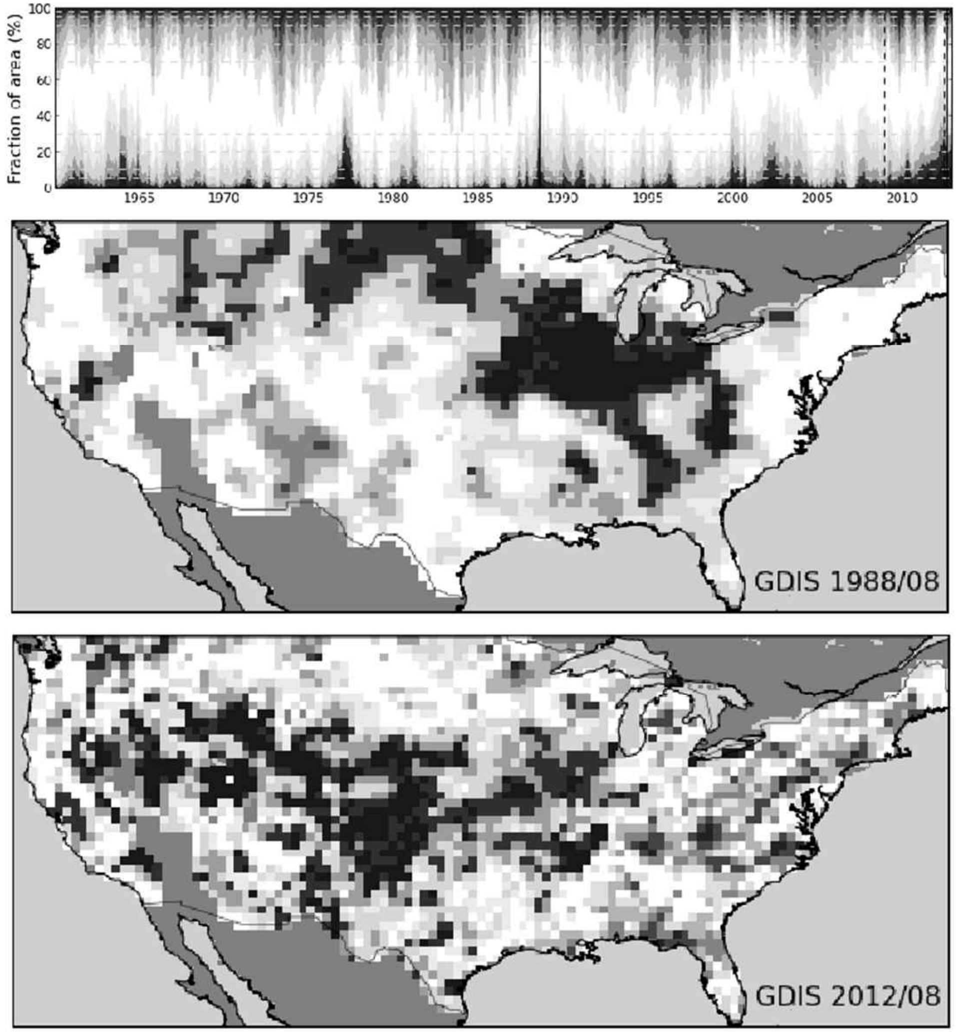


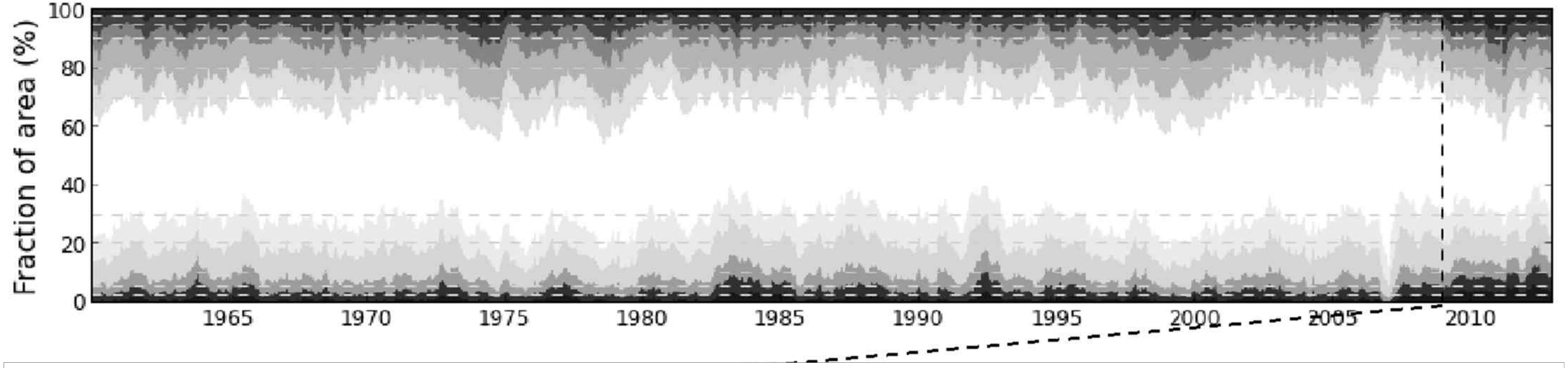
Figure 11. Examples of monthly soil moisture quantiles for four major regional droughts: (a) the Sahel, 1983–84; (b) northeast India, 1965–1966; (c) Australia, 1983; (d) USA, 1988.

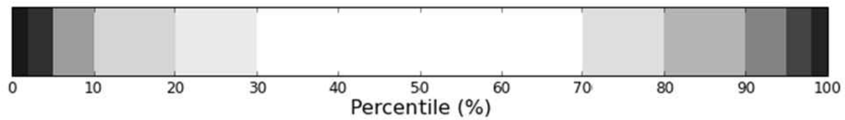


US Surface Water Monitor

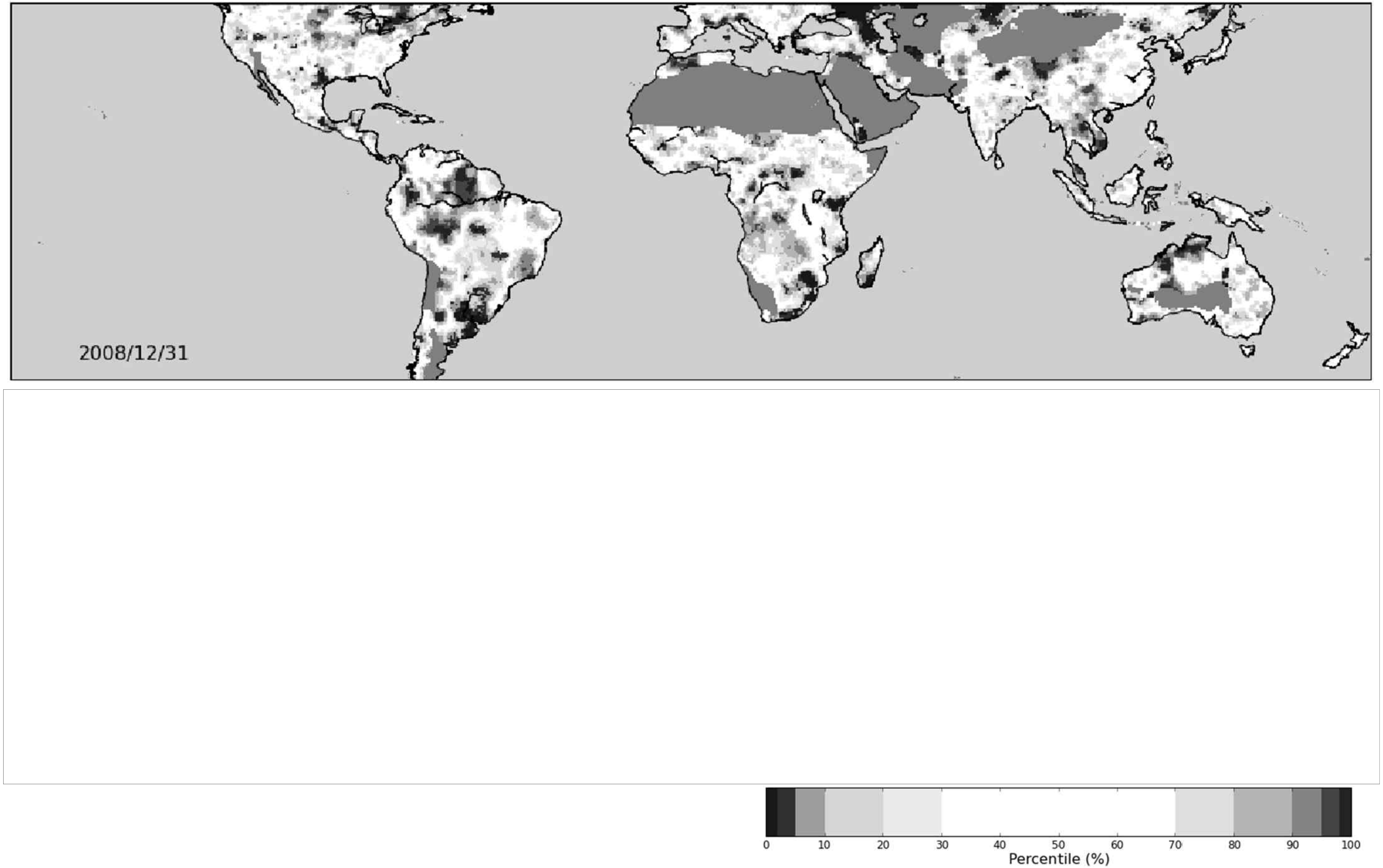


Global Drought Information System

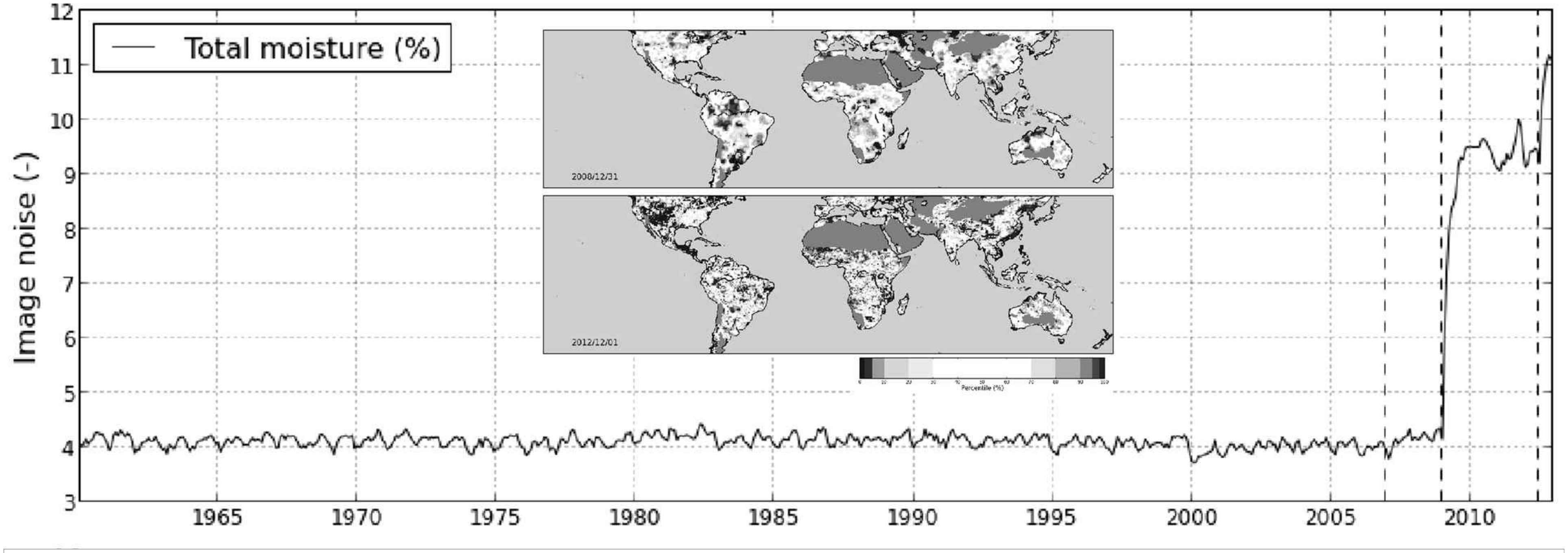




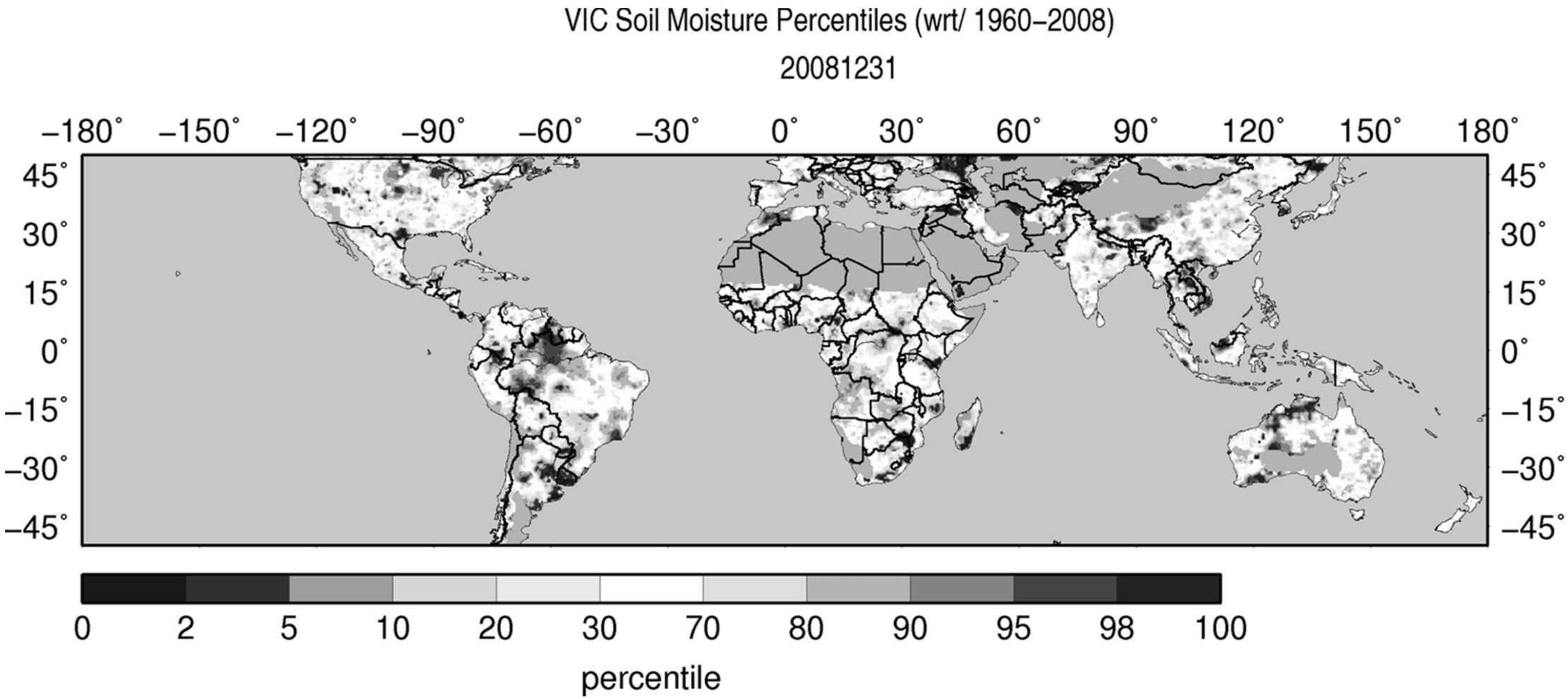
Global area in each drought category



2008/12/31
0
10
20
30
40
50
60
70
80
90
100
Percentile (%)

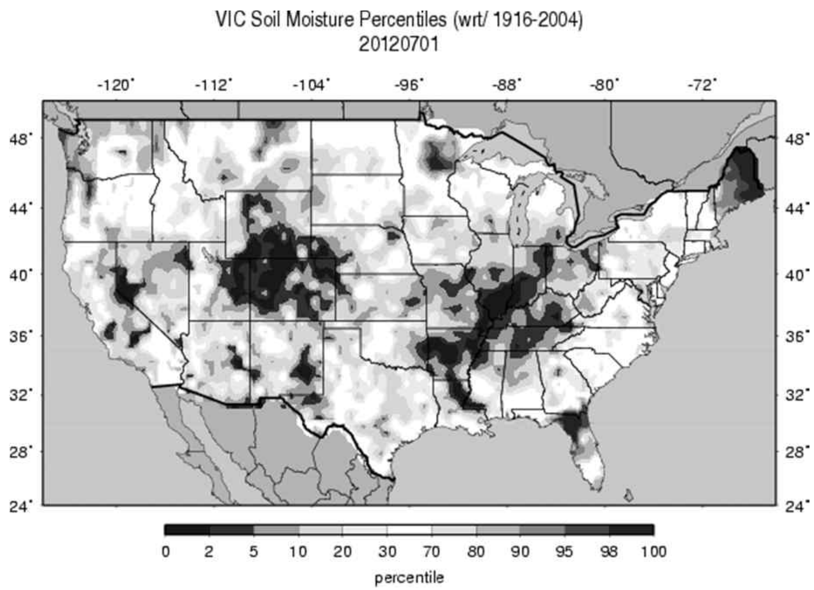

Total moisture (%)
Image noise (-)
2008/12/31
2012/12/01
Percentile (%)
12
11
10
9
8
7
6
5
4
3
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Soil moisture state (percentile) at the end of the retrospective period – based on Sheffield et al. (2006)



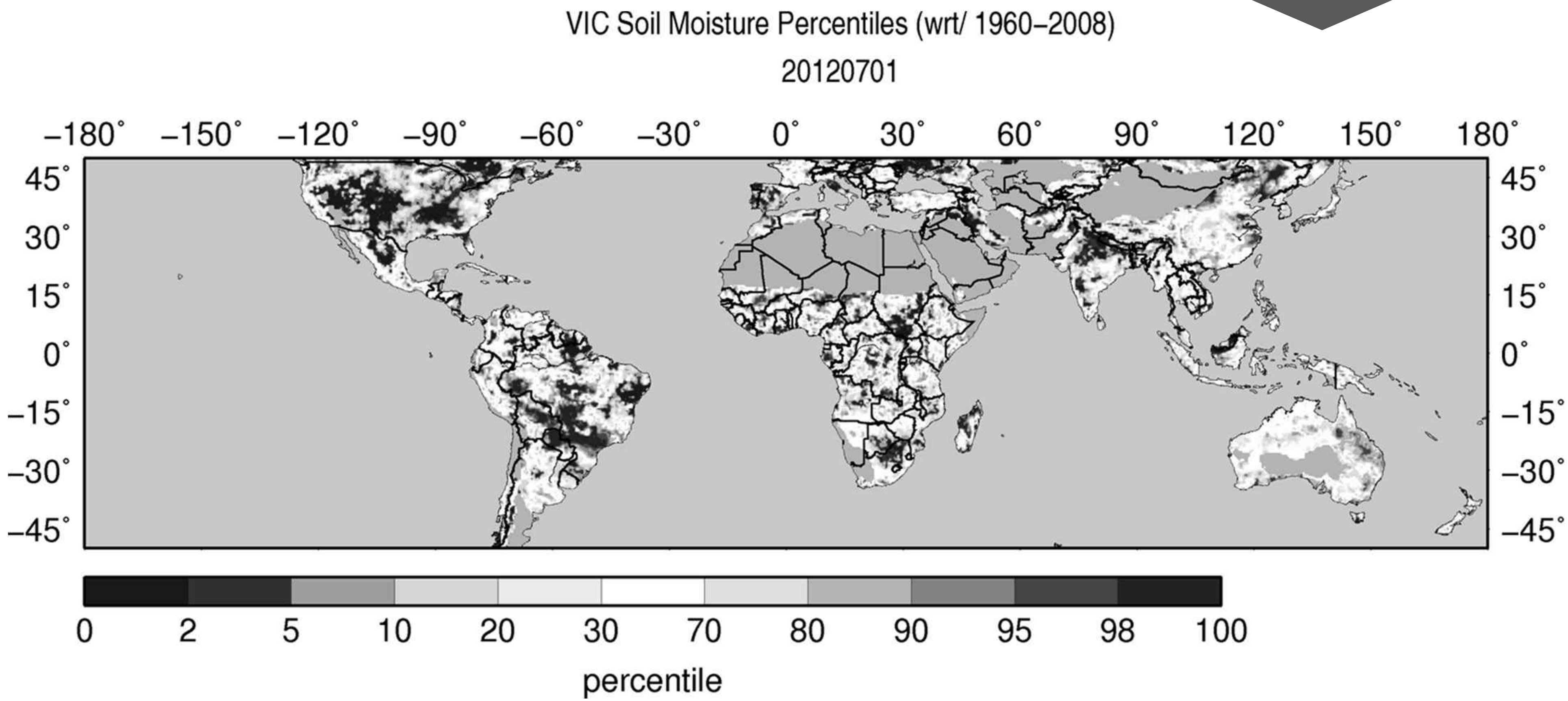
From January 1, 2009 the inputs for the global drought monitor are based on TRMM-TMPA precipitation forcings and analysis temperature fields

July 1, 2012

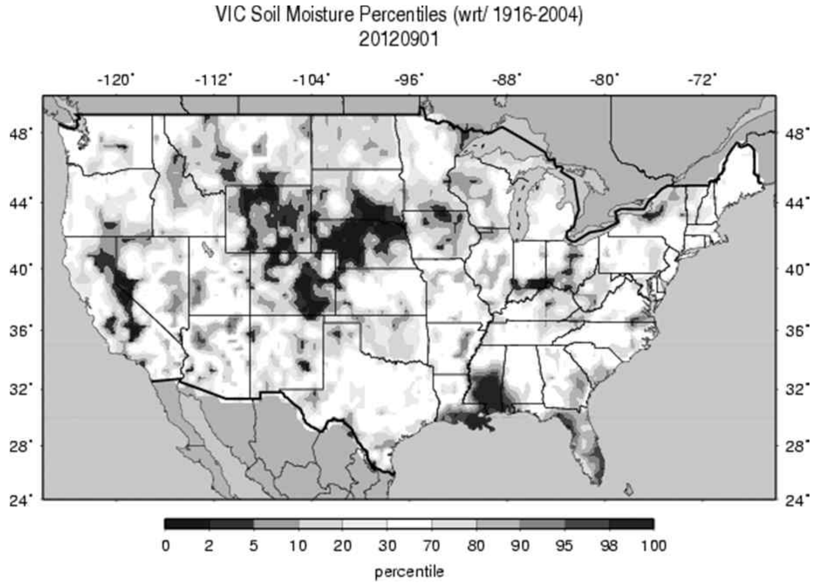


US Surface water monitor
(station-based)

Global drought monitor
(satellite-based)

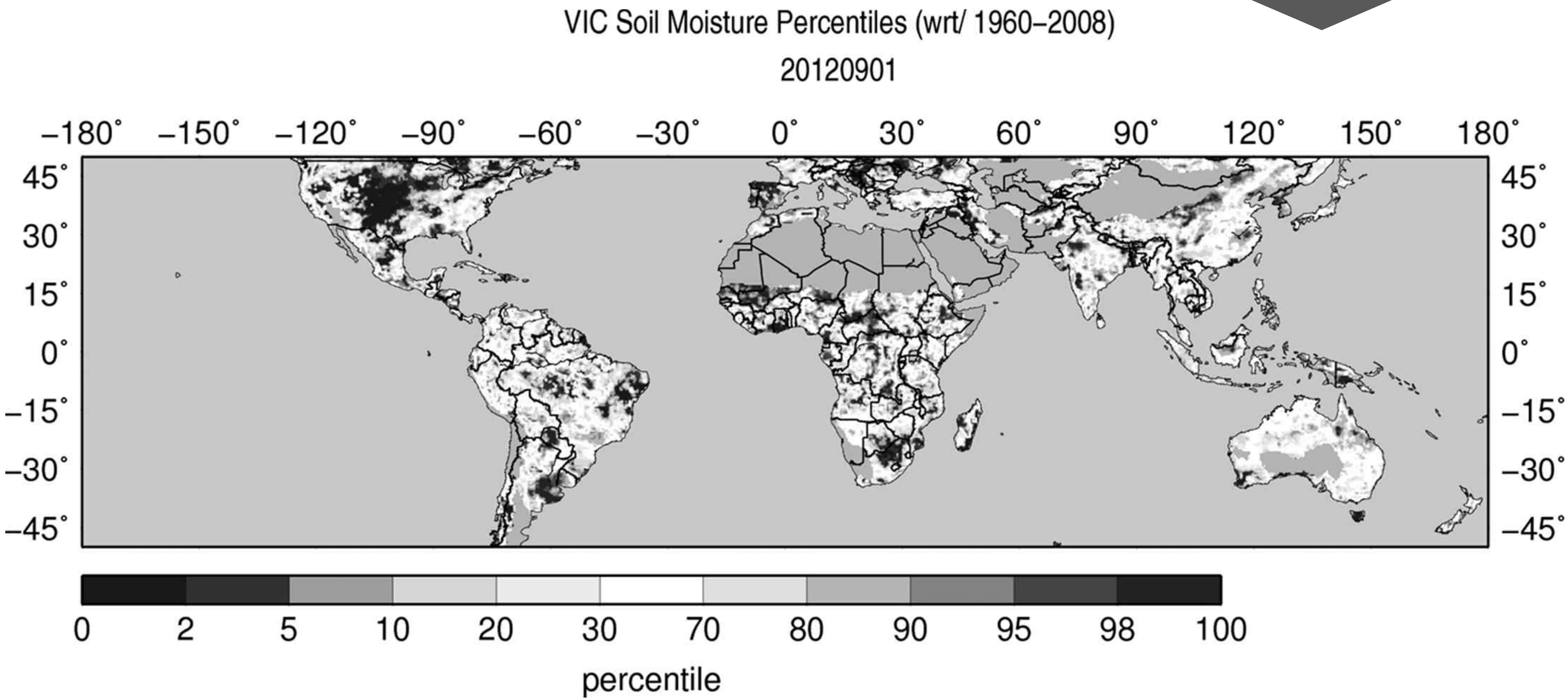


September 1, 2012

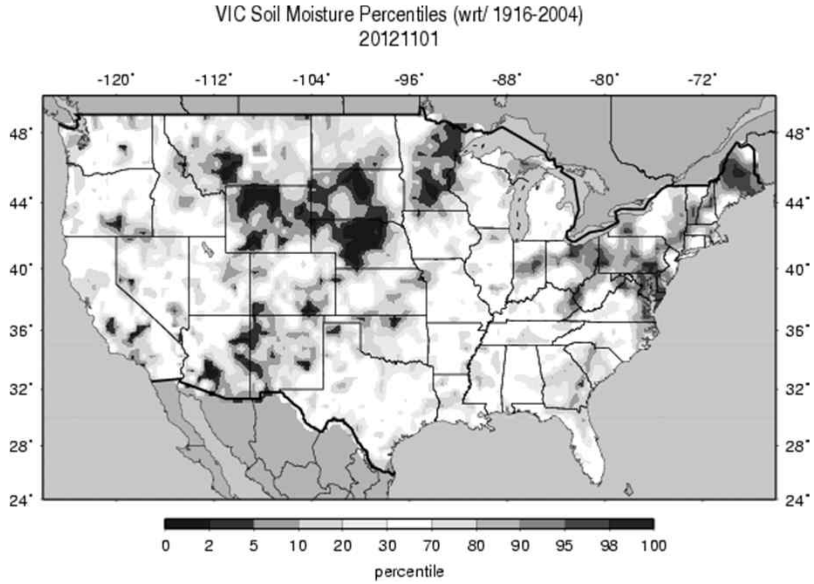


US Surface water monitor
(station-based)

Global drought monitor
(satellite-based)

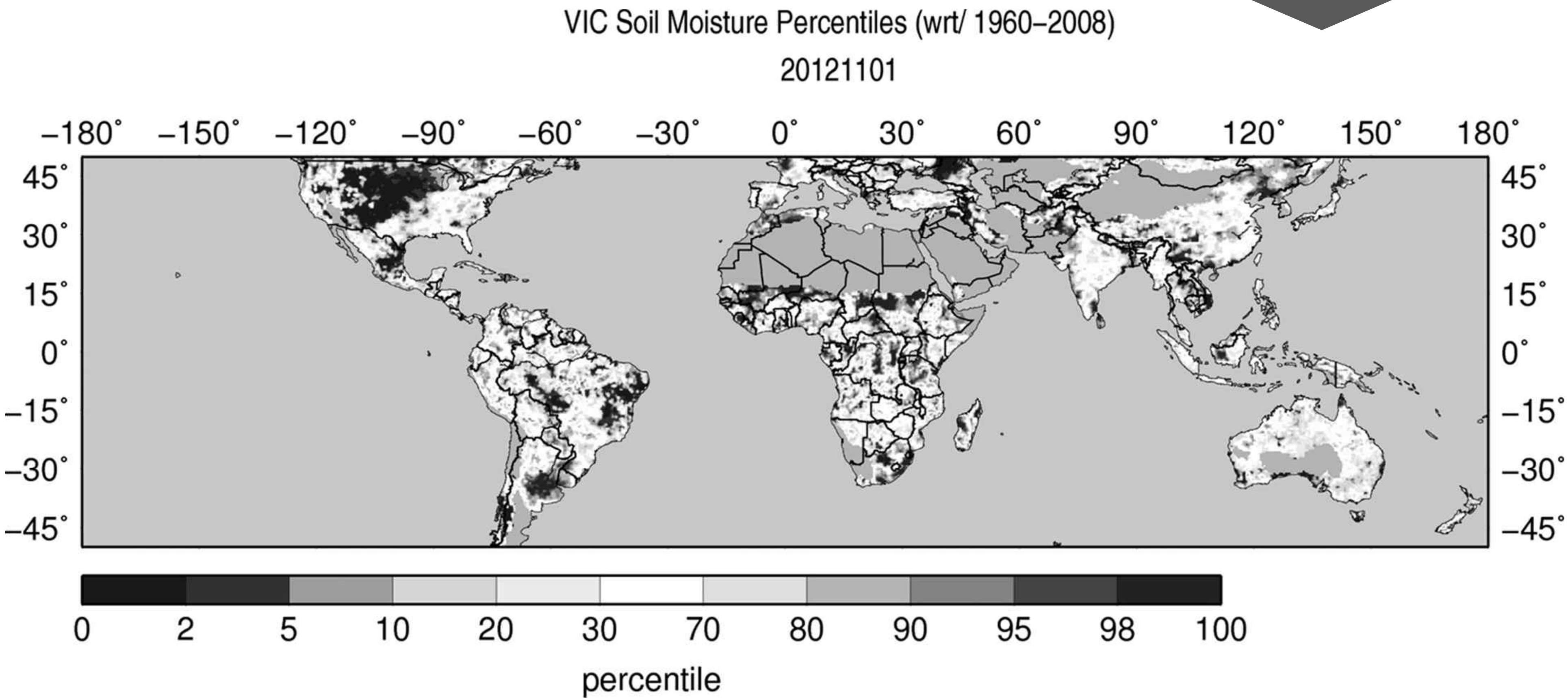


November 1, 2012

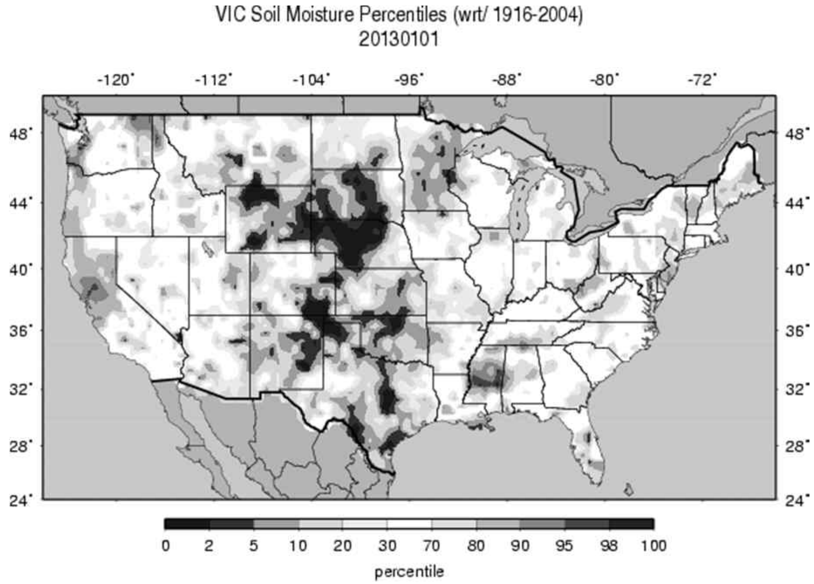


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

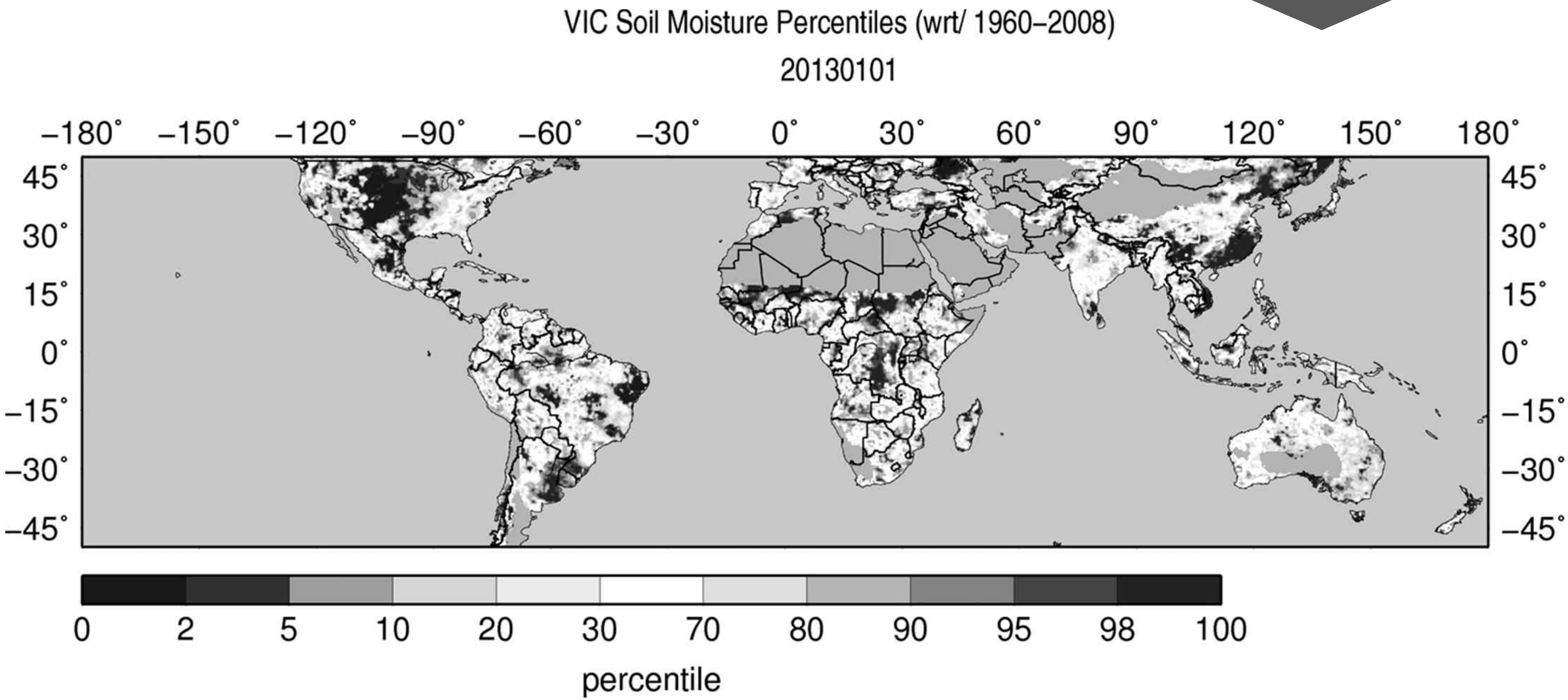


January 1, 2013

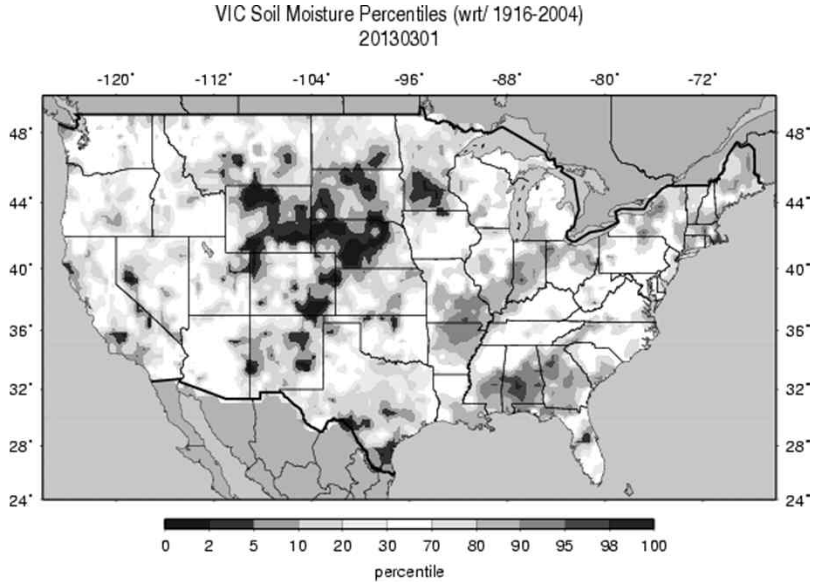


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

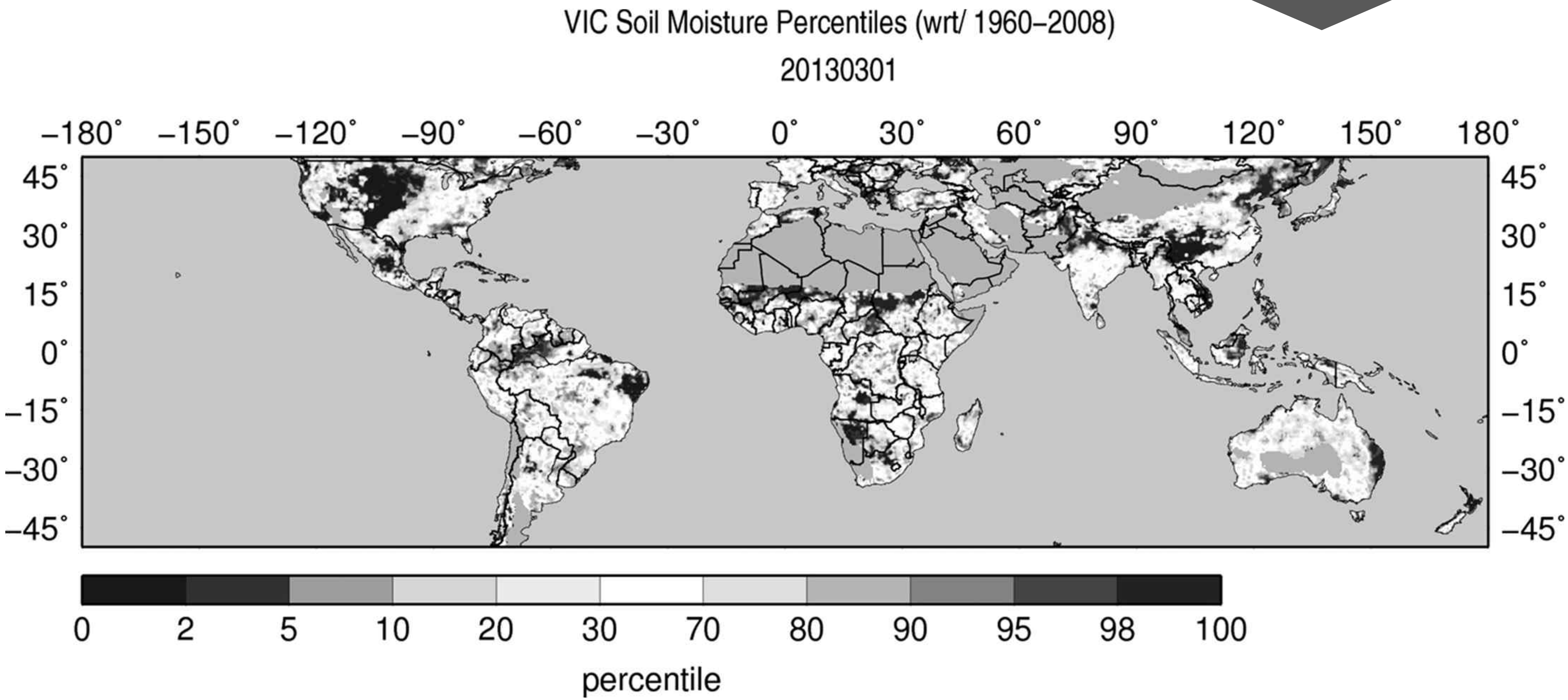


March 1, 2013

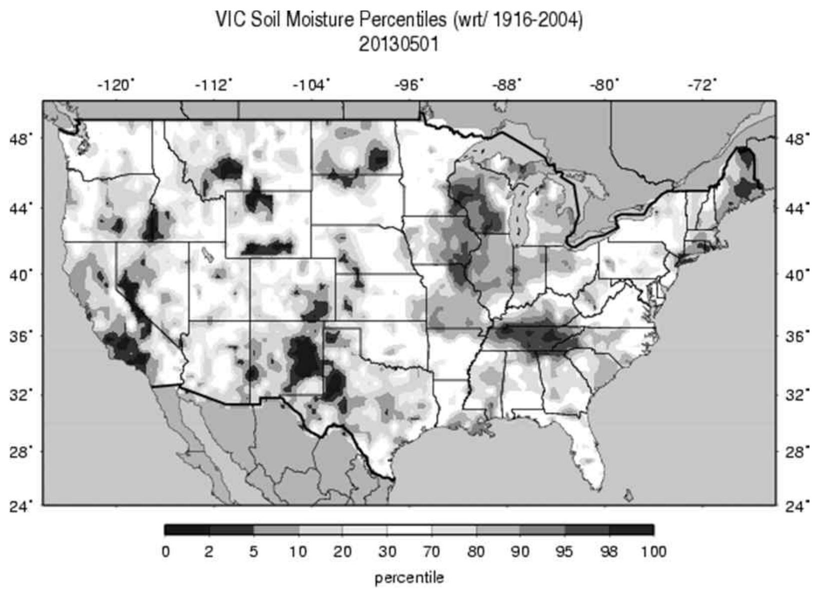


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

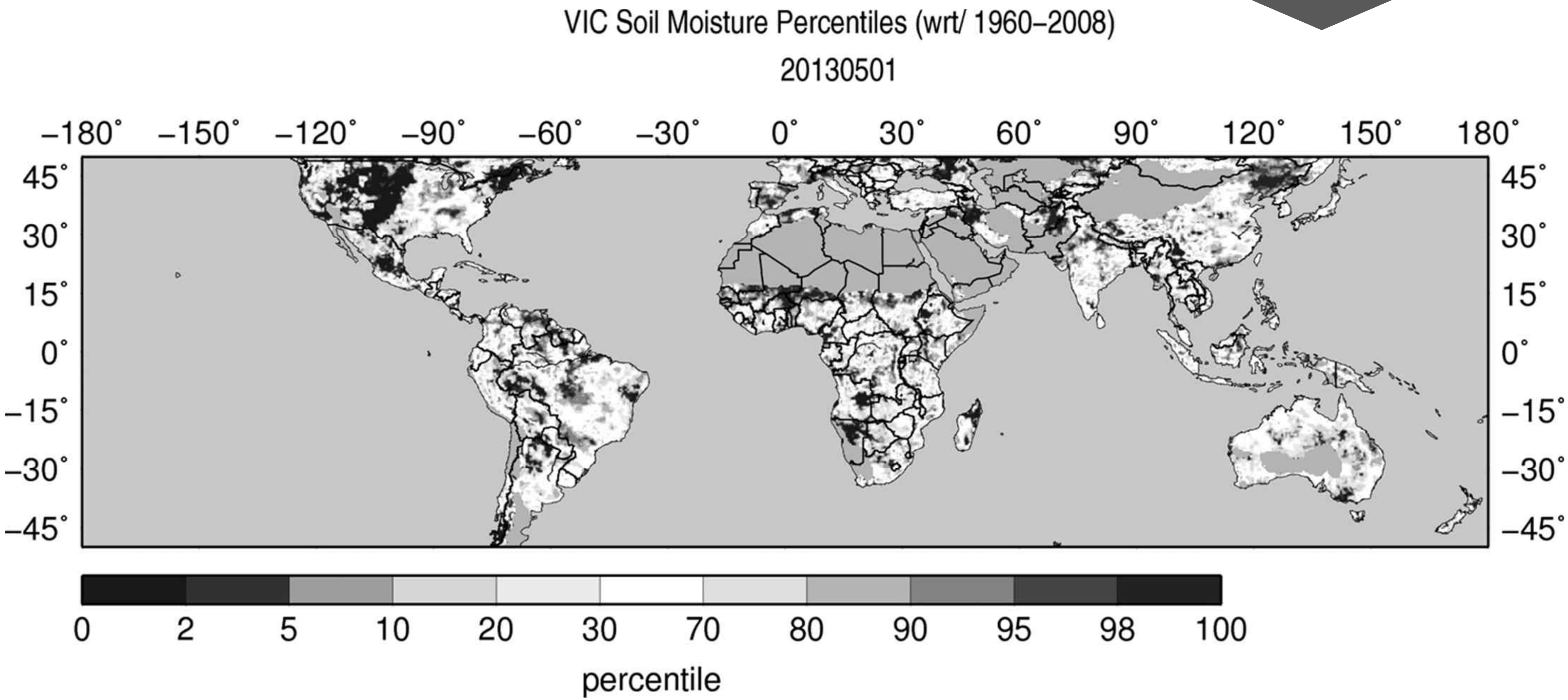


May 1, 2013

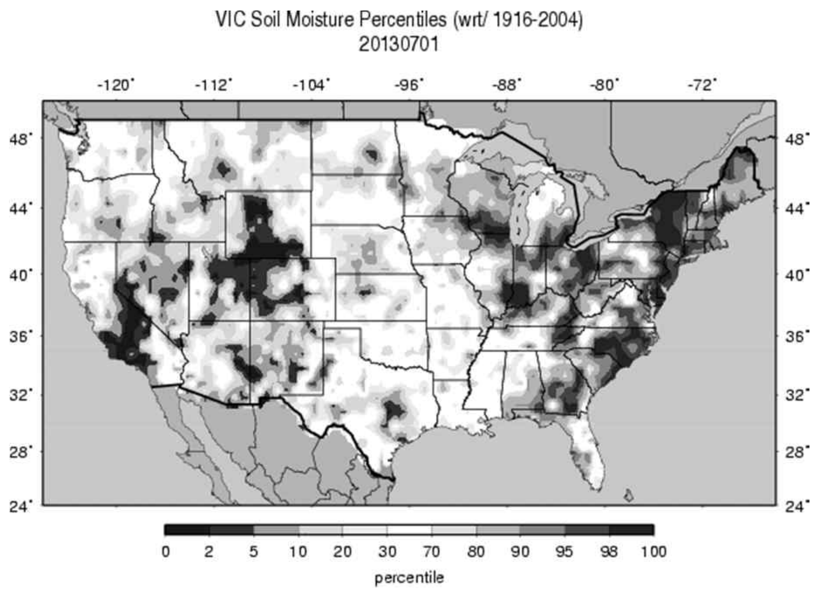


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

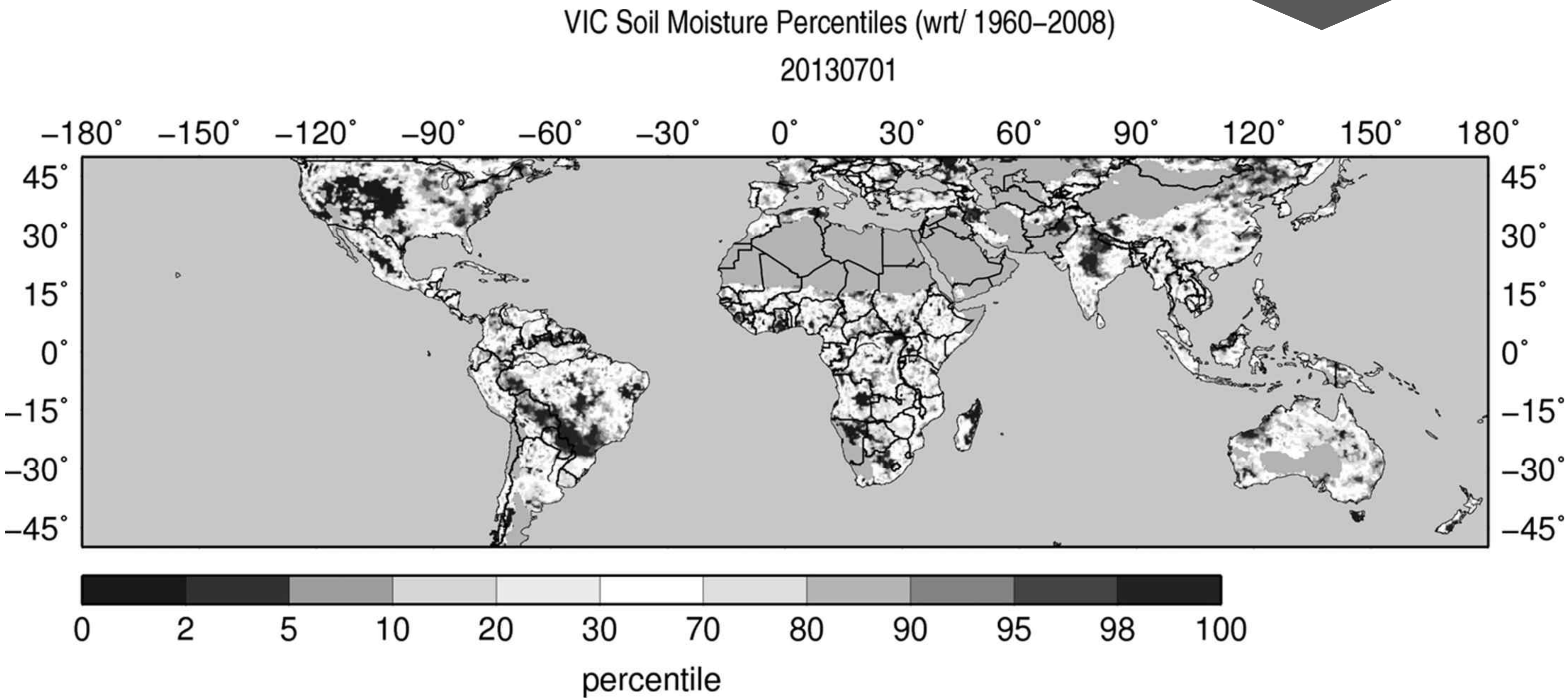


July 1, 2013

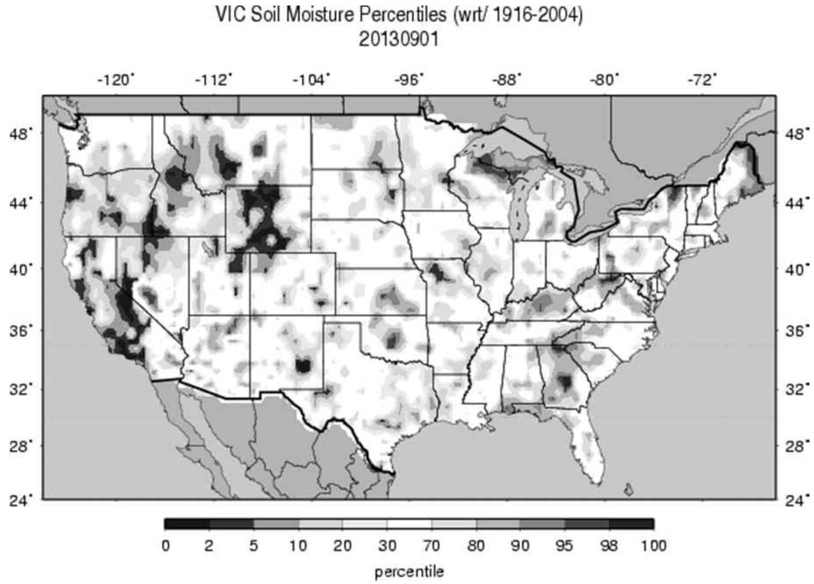


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

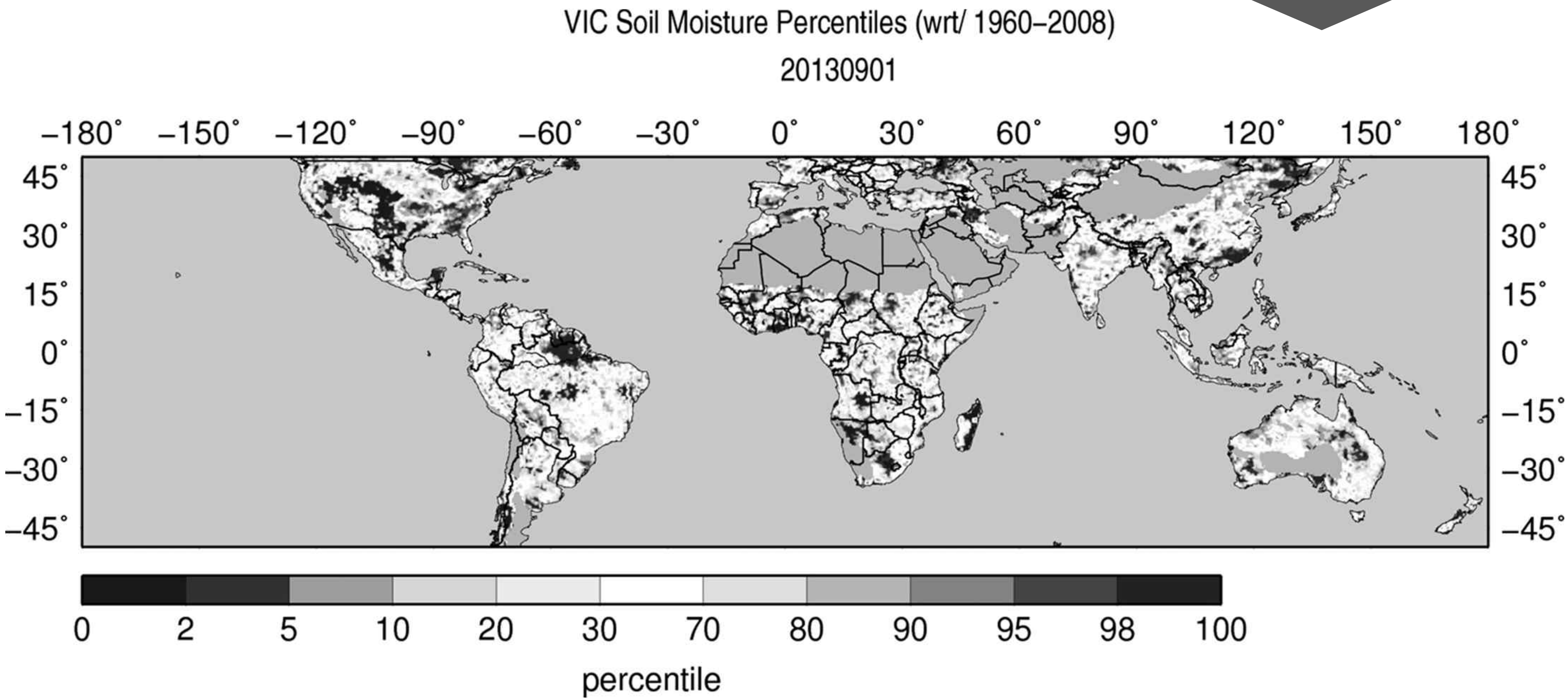


September 1, 2013

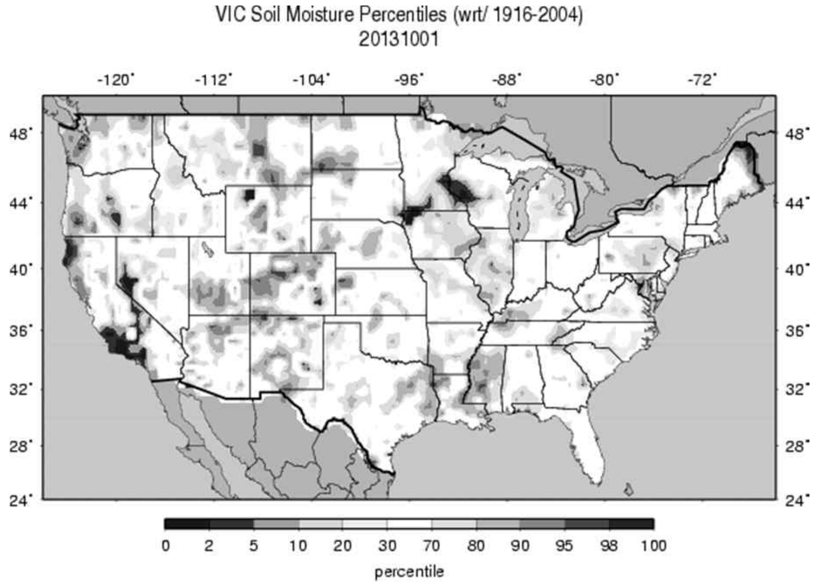


US Surface water monitor (station-based)

Global drought monitor (satellite-based)

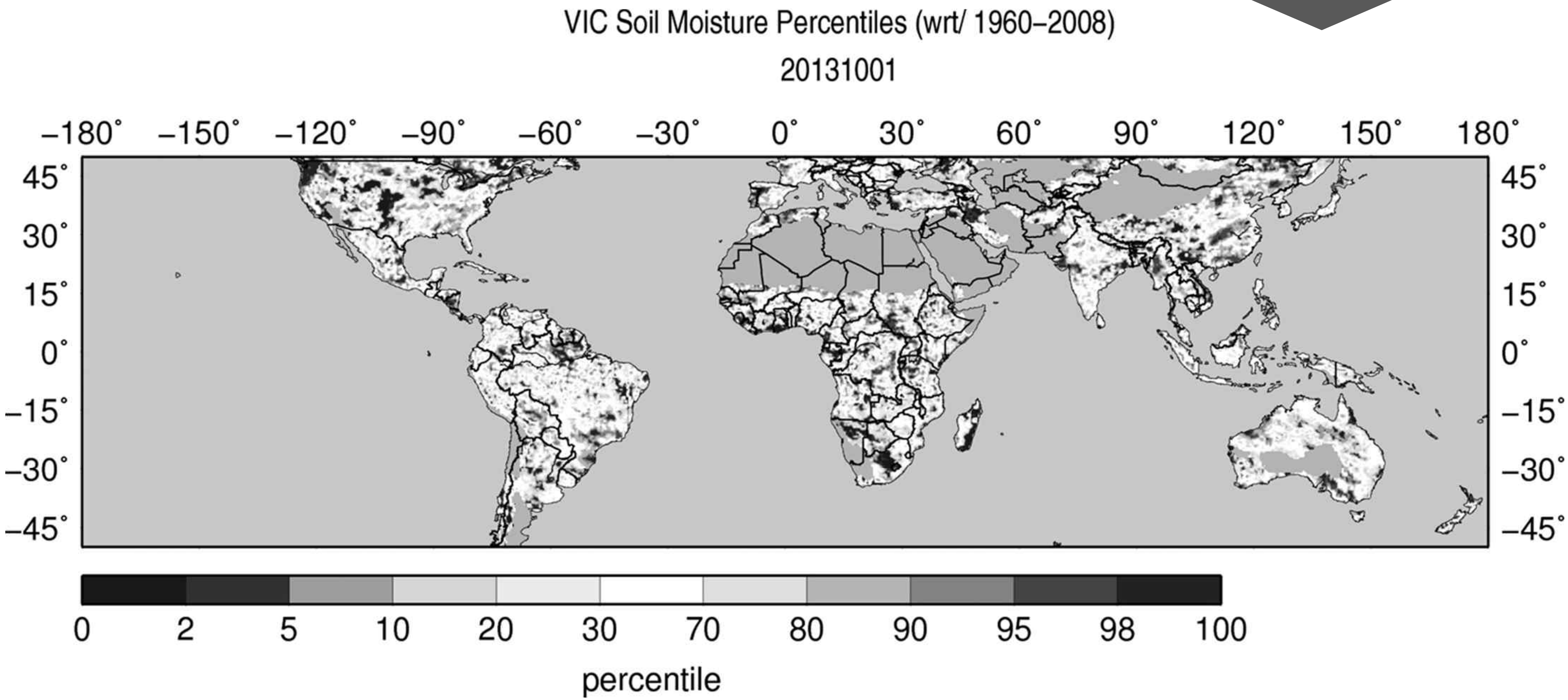


October 1, 2013

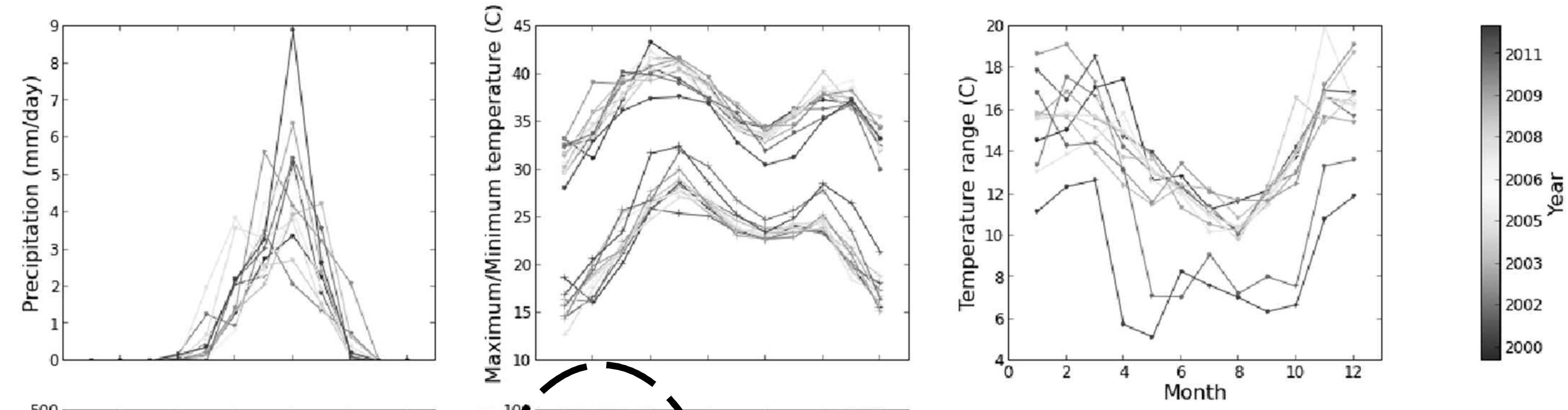


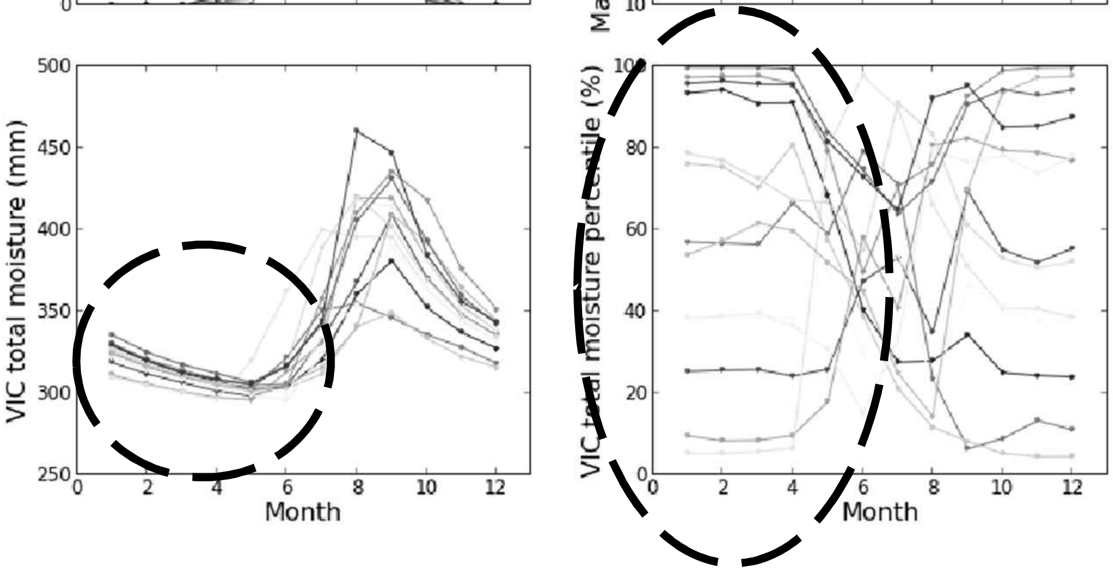
US Surface water monitor (station-based)

Global drought monitor (satellite-based)



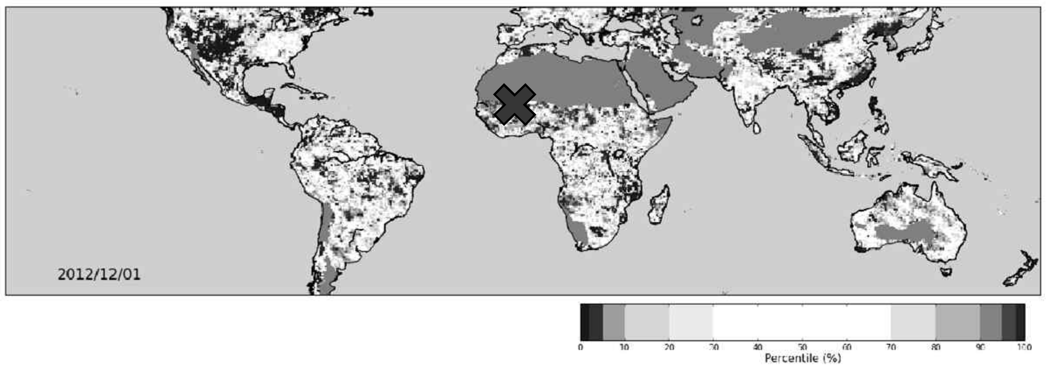
- **Systems provide soil moisture progressions for the United States that are qualitatively similar**
- **However, the systems differ in the drought intensity that they indicate** **(different reference periods are unlikely to be able to explain all of this difference)**
- **In certain regions (e.g. Sahel) there is a persistent wet bias**
  - **In areas with small dynamic ranges of soil moisture, small, but systematic changes in the forcings between the reference and satellite period can lead to large differences in percentiles (see next slide)**





Can lead to large changes in percentiles

Small changes in absolute soil moisture in areas/periods with a small dynamic range



Conclusions

1) **Global multimodel drought nowcasting is entirely feasible now**
2) **Consistent forcings are essential**
   a. **Droughts only make sense when expressed relative to a climatology – hence climatically consistent near real-time data are essential**
   b. **There is a need for improved methods that combine long-term historical records, which provide temporal continuity but have poor spatial coverage, with new observing and modeling platforms that provide great spatial detail, but lack a long-term climatology.**

A prototype Global Drought Information System based on multiple land surface models

Bart Nijssen, Shraddhanand Shukla, Chiyu Lin, Huilin Gao, Tian Zhou, Justin Sheffield, Eric F. Wood, Dennis P. Lettenmaier

Journal of Hydrometeorology, in revision