Land Data Assimilation Systems at NCEP: Predicting Extreme Hydrometeorological Events

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Environmental Modeling Center (EMC)
National Centers for Environmental Prediction (NCEP)
NOAA/NWS

Outline

- Hydrometeorological extremes, e.g. drought, flood, and steps to increase their predictability
- NCEP Weather and Climate Modeling Suite and Noah land model
- NCEP Land Data Assimilation Systems (LDAS) and hydrometeorological prediction
- Summary

Hydrometeorological Extremes: Drought

Meteorological: Precipitation

Agricultural: Soil moisture

Hydrological: Streamflow

Drought

From Wikipedia, the free encyclopedia

For other uses, see Drought (disambiguation).

Drought is an extended period when a region receives a deficiency in its water supply, whether atmospheric, surface or ground water. A drought can last for months or years, or may be declared after as few as 15 days.[1] Generally, this occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause significant damage[2] and harm to the local economy.[3] Prolonged droughts have caused mass migrations and humanitarian crises.

Hydrometeorological Extremes: Drought

Austin American-Statesman

Monday, October 22, 2012 — Real Austin. Real News. — Breaking news at statesman.com

TEXAS IN DROUGHT

Drought loosens grip on region, rice farms

October 2012

An irrigation canal that feeds water to a field of rice on the Lehrer property is fed by the main LCRA canal in Garwood. RODOLFO GONZALEZ / AMERICAN-STATESMAN

Reservoirs not as low as year ago

Drought

Continued from A1

rice farmers harvested 180,000 acres in 2011, valued at $183 million.

"I am happy the staff is recognizing that there's a different set of hydrological conditions" from a year ago, said Ron Gertson, who leads the Colorado Water Issues Committee, which works on behalf of rice producers.

The lakes, the major reservoirs for Central Texas, remain less than half-full. Still, they're in a better situation than they were a year ago.

In September 2011, the combined storage of the lakes was 808,000 acre-feet and falling; now it's 884,000 acre-feet and holding steady. In 2011, the flow of water from tributaries feeding the lakes was a paltry 8 percent of average. Now, with a recent spate of rains, it's 37 percent of average.

Should water be released to rice farmers and dry conditions again choke the region, a 25 percent chance remains that lake levels will drop below 600,000 acre-feet of combined storage by the end of next irrigation season, according to LCRA calculations. If the lakes get that low, all customers, including the city of Austin and power plants, would face mandatory curtailments of water use.

As the board prepared to take action in September 2011, it faced a 33 percent chance of such a fate had it not cut off water for rice farmers, who pay $6.50 an acre-foot for water that can be interrupted, compared with "firm," uninterruptible water rates of $151 per acre-foot, paid by cities and industry.

Henry Ehy, executive manager for environmental and regulatory affairs at the LCRA, told the board last week that improved conditions led the staff to recommend against another water cutoff.

"We recognize the hardships on all of our customers," Ehy said.

Under the current water management plan, if the combined storage remains the same on Jan. 1, the LCRA will release 183,000 acre-feet of stored water for rice farmers. That's a curtailment compared with most years, but it's still far above what the LCRA released this year.

The authority could release more or less, depending on combined storage at the first of the year. That amount of water – 183,000 acre-feet – probably will not support the two crops that rice farmers traditionally plant, but it should be enough for one, Gertson said.

Ehy said his recommendation could change in the next month or so if weather conditions change. The board is set to take up the matter at its mid-November meeting.

The most recent drought monitor map shows Travis County to be merely "abnormally dry," not in the teeth of the worst conditions, "exceptional drought," as it was a year ago. The majority of Texas is in drought, if only mildly so.

In a briefing Tuesday, LCRA meteorologist Bob Rose backed away from earlier forecasts that an El Niño effect might lead to a wet winter. El Niño is created when temperatures across the Pacific are higher than normal. But over the past month, warming has stopped, and Rose said the Pacific is unlikely to reach the threshold for El Niño.

"It's on the warm side of neutral," he said.

"There's nothing to suggest a dry winter, but we might not have the robust rain we had been thinking of for the fall and winter," Rose continued, adding that winter temperatures are likely to be colder than average.

Contact Asher Price at 445-3643.

Rice fields operated by the Lehrer family in Garwood show healthy stalks earlier this month, a far cry from last year when some areas suffered a 75% drop in production. PHOTO BY RODOLFO GONZALEZ / AMERICAN-STATESMAN

Drought fades

Abnormally dry
Moderate drought
Severe drought
Extreme drought
Exceptional drought

Oct. 18, 2011 — 73% of state in exceptional drought

Oct. 16, 2012 — 3% of state in exceptional drought

Austin

Sources: National Drought Mitigation Center; Bob Rose, Lower Colorado River Authority

LINDA SCOTT / AMERICAN-STATESMAN

LCRA staff recommends against cutting off growers

By Asher Price
asherprice@statesman.com

In the most recent signal that drought conditions have eased since 2011, the staff of the Lower Colorado River Authority recommended last week that board members not seek emergency power from the state to cut off water next year for rice farmers.

That's a reversal from September 2011, when the LCRA's board approved an emergency plan to cut off water to rice farmers if less than 850,000 acre-feet of water was stored in lakes Travis and Buchanan, the LCRA's two main reservoirs, on March 1 of this year.

The crippling drought kept the lakes short of that level.

Some rice-producing areas in the Colorado River's lower basin saw production drop by at least 75 percent, rolling the rice economy.

Haskell Simon, a longtime emissary from the rice-growing communities of the lower basin to the LCRA, has estimated that the land devoted to the rice crop dropped from 24,000 acres in Matagorda County in 2011 to 1,500 acres this year.

According to the U.S. Department of Agriculture, Texas

Rice begins to yellow as it matures. Farmers usually plant two crops, but water levels may not support more than one.

Drought continued on A8

Hydrometeorological Extremes: Flood

2013 Colorado Flooding

Flash Flood

Flood

From Wikipedia, the free encyclopedia

For other uses, see Flood (disambiguation).

A **flood** is an overflow of water that submerges land which is usually dry.[1] The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water.[2] In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may occur as an overflow of water from water bodies, such as a river or lake, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries,[3] or it may occur due to an accumulation of rainwater on saturated ground in an areal flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals.

Predicting Hydrometeorological Extremes

Predictability

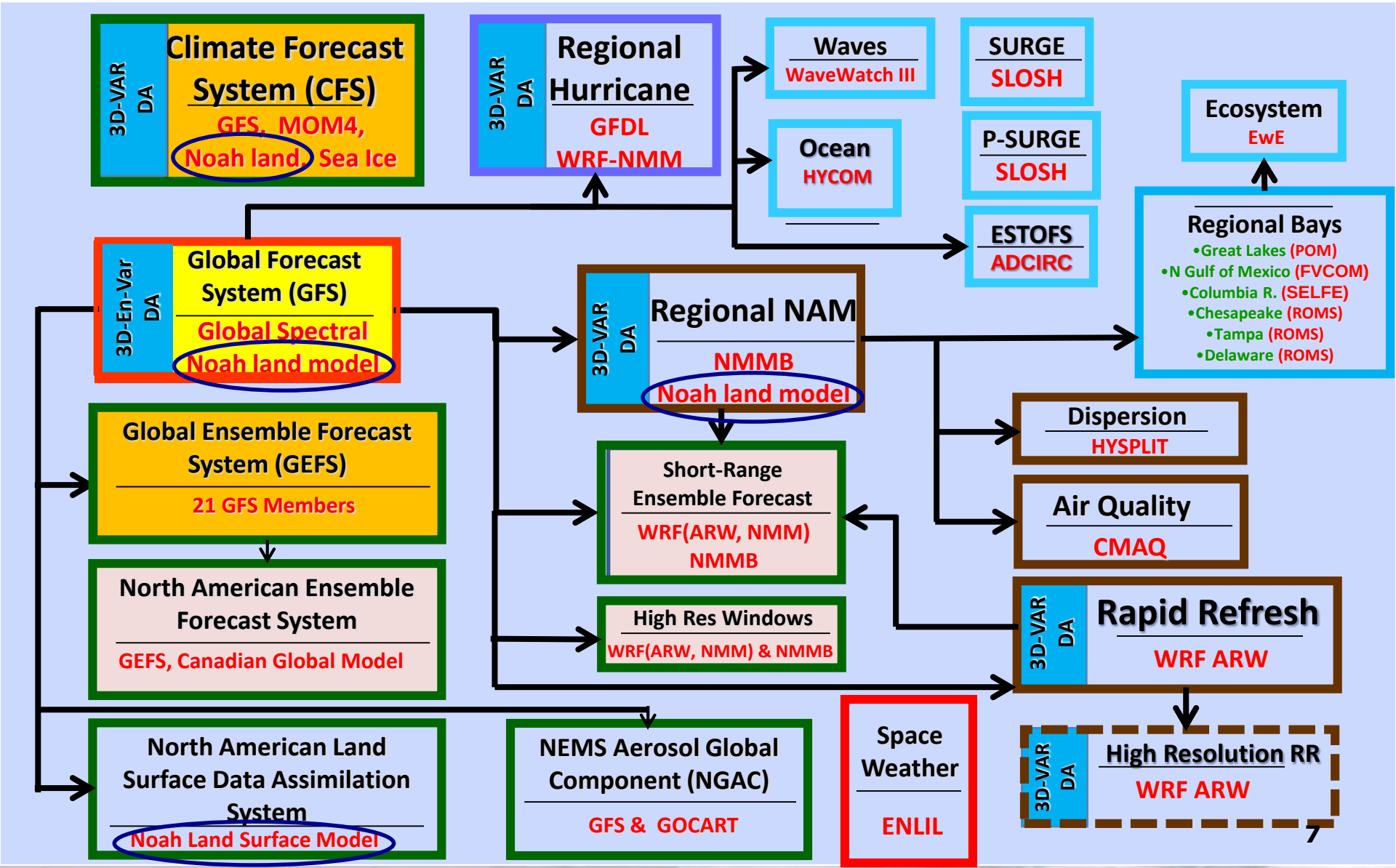
From Wikipedia, the free encyclopedia

Predictability is the degree to which a correct prediction or forecast of a system's state can be made either qualitatively or quantitatively.

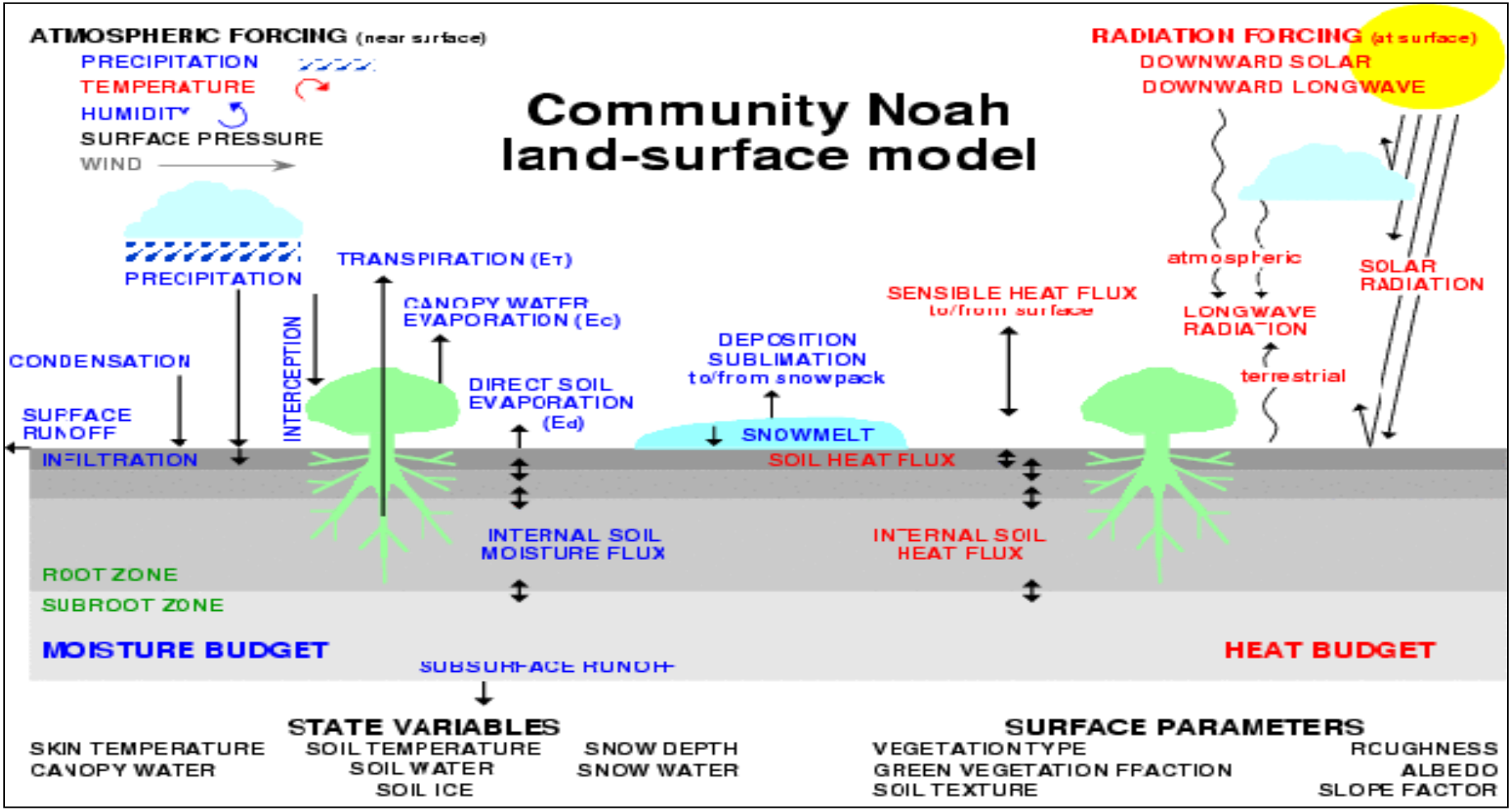
How to get there?

- Important: Potentially strong inertia in soil, e.g. soil moisture, also local land-atmosphere interaction (e.g. precip "recycling"), and large-scale/global land-atmosphere-ocean interaction.
- Land initial conditions (e.g. soil moisture), i.e. via a Land Data Assimilation System (LDAS).
- LDAS requires good forcing data, and relevant land model physics and parameters & companion land data sets including near-realtime, e.g. green veg. frac. (GVF), snow, soil moisture.
- "Parent" coupled atmosphere-ocean-land-sea ice model.

NOAA's Operational Numerical Guidance Suite (January 2014)

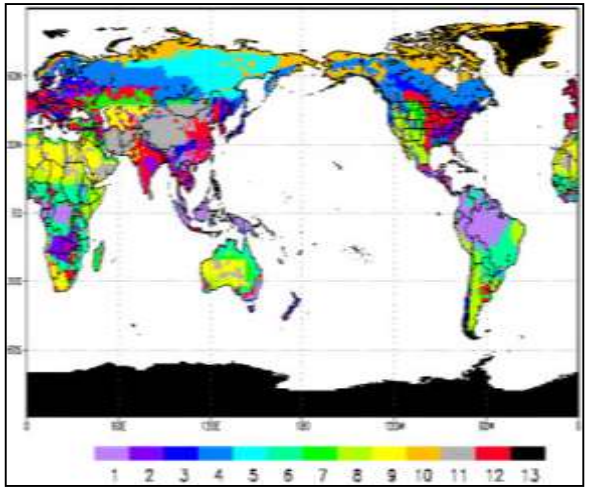


NCEP-NCAR unified Noah land model

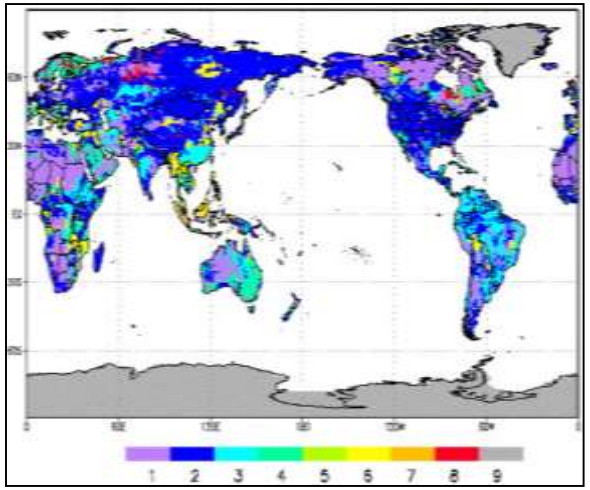


- Relevant land physics & associated parameters, provides lower boundary conditions (heat, moisture, momentum) for NAM, GFS, CFS.
- Noah partners: UT-Austin, U Ariz, U Wash, Princeton, NASA.

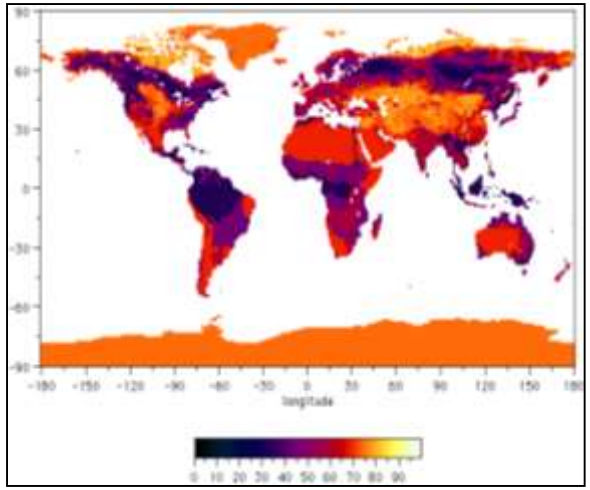
Land Data Sets



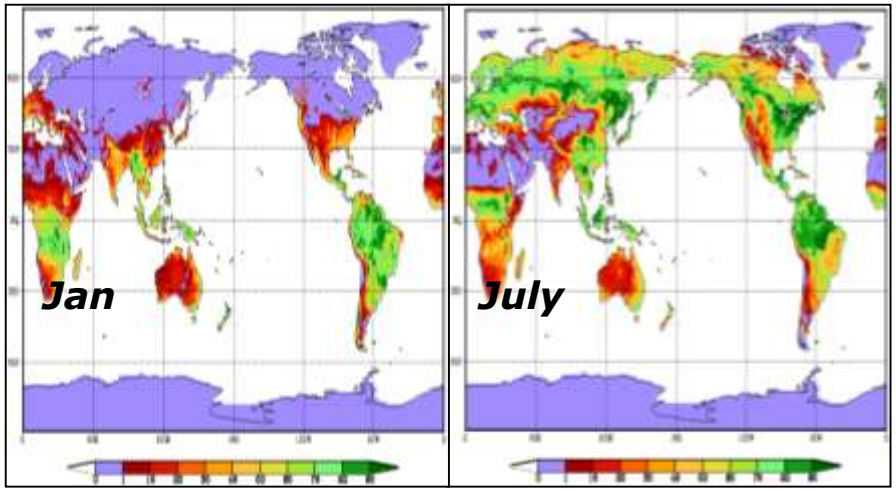
Vegetation Type



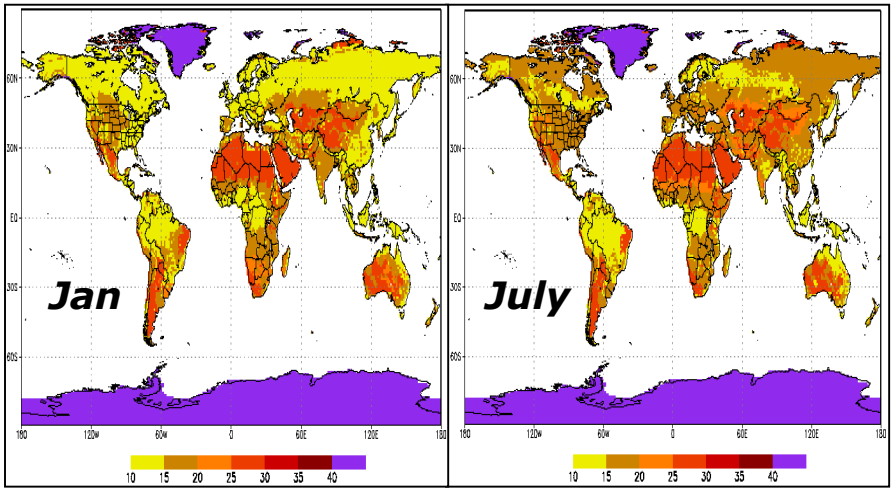
Soil Type



Max.-Snow Albedo



Green Vegetation Fraction

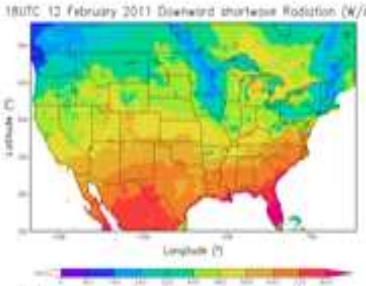


Snow-Free Albedo

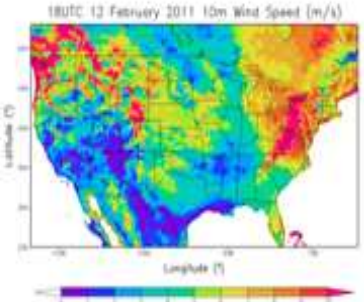
Atmospheric Forcing

- Forcing from atmospheric analysis or re-analysis system (e.g. NARR/RCDAS, GDAS, CFSR/CDAS).
- Precipitation especially important: use observations, e.g. CPC gauge-based, radar, satellite, or model.

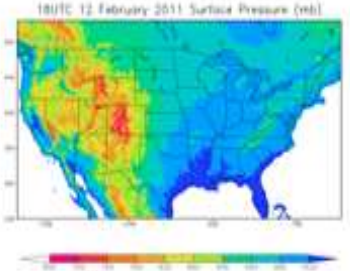
Precipitation



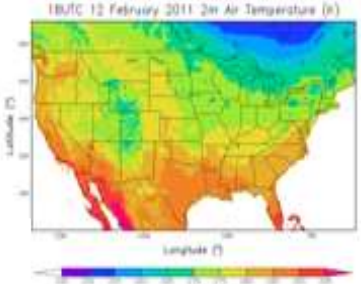
Incoming solar



Wind speed



Pressure



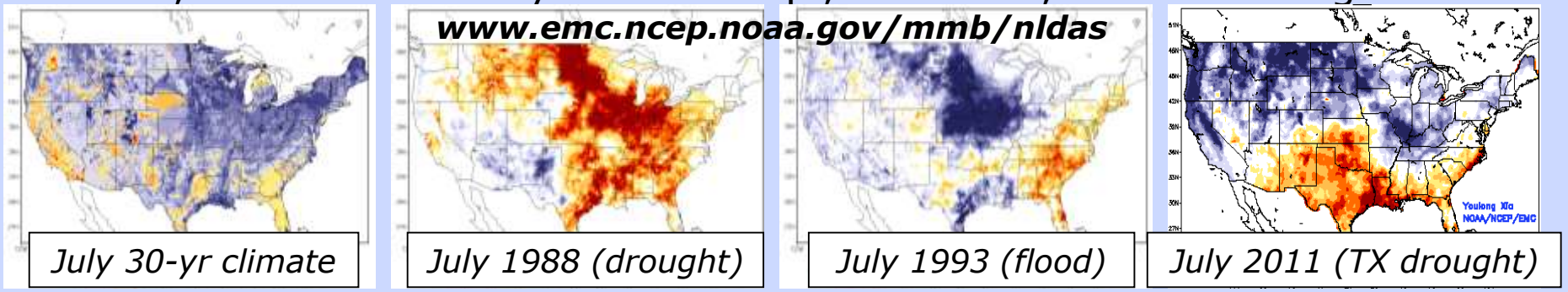
Air temperature

Downward longwave

Specific humidity

Operational North American Land Data Assimilation System (NLDAS): Monitoring

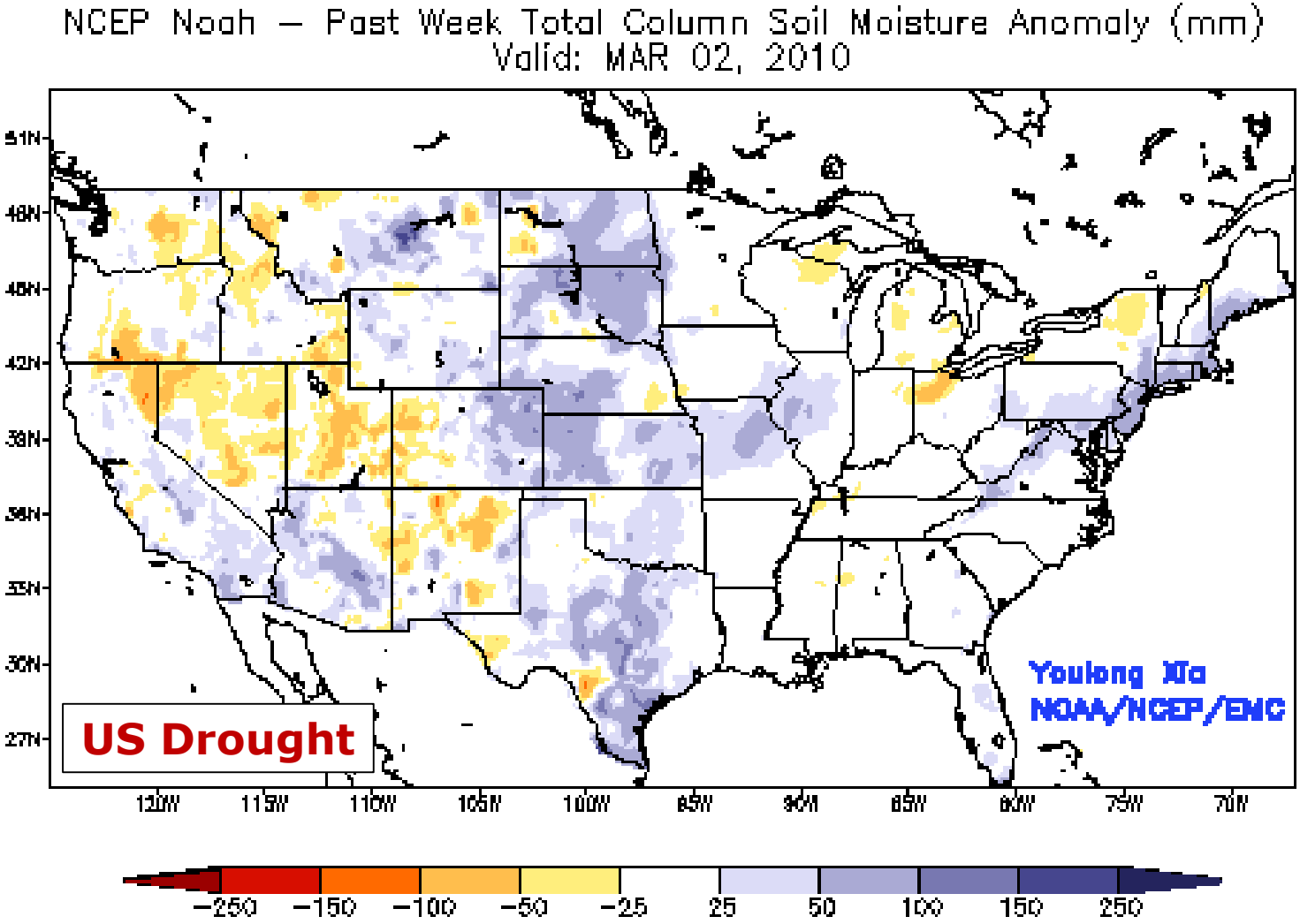
- Land models: Noah, SAC, VIC, Mosaic run in "uncoupled" mode.
- Forcing: NCEP Climate Prediction Center obs precip (gauge-based, radar/satellite disaggregatred), and atmospheric forcing from NCEP North American *Regional Climate Data Assimilation System.* Output: 1/8-deg. land & soil states, surface fluxes, runoff/streamflow.
- Climatology from land model assimilation runs for 30-years provide **anomalies** used for **drought monitoring**; supports USDM, NIDIS etc.
- Operational at NCEP Aug 2013. Future: higher resolution, land model upgrades, improved forcing, snow and soil moisture assimilation, etc.
- Research supported by NOAA Climate Prog. Office for NLDAS partners: NASA, NWS Office of Hydro. Develop., Princeton, Univ. Washington.



July 30-yr climate | *July 1988 (drought)* | *July 1993 (flood)* | *July 2011 (TX drought)*

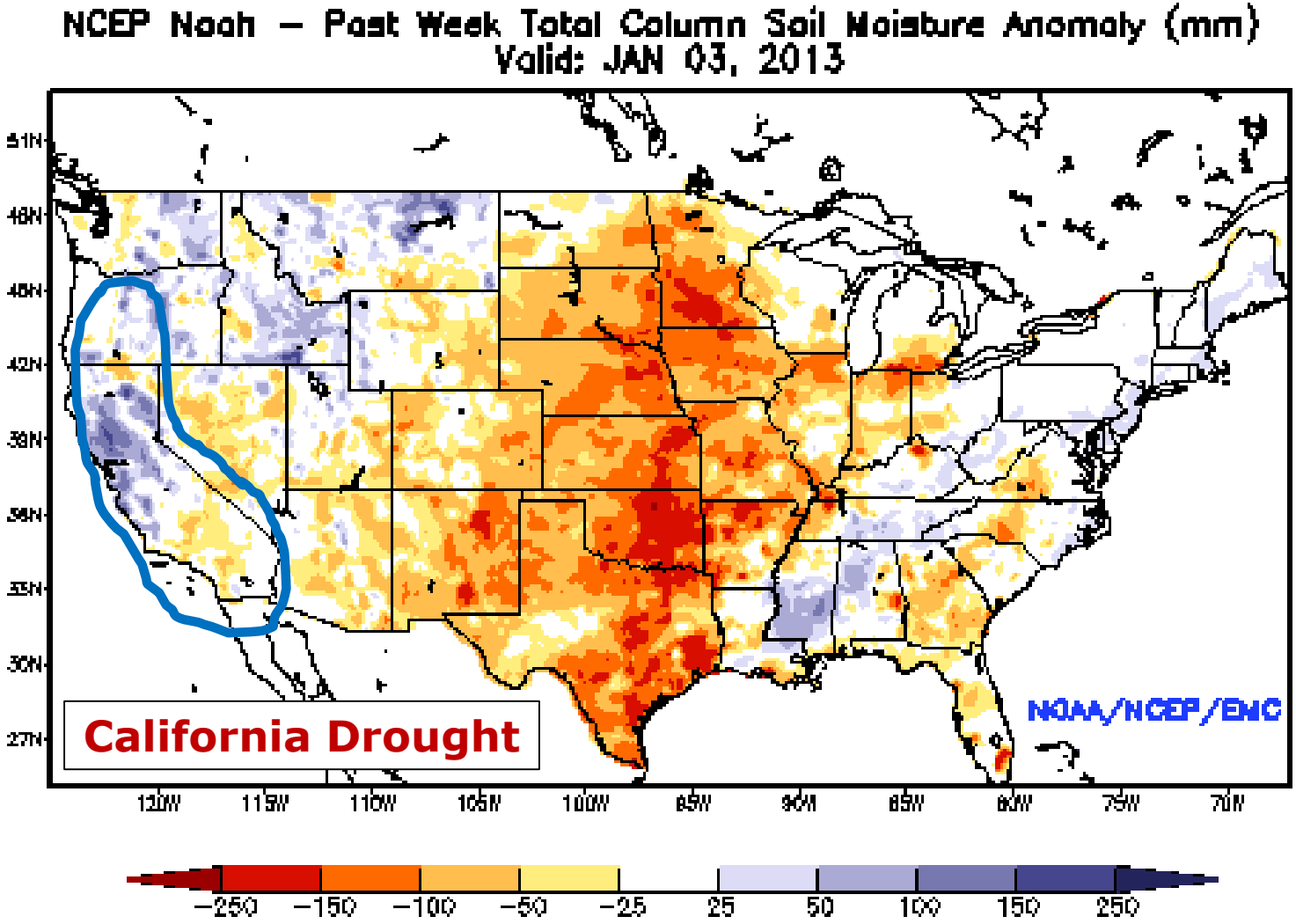
NLDAS four-model ensemble monthly soil moisture anomaly *Youlong Xia*

NLDAS Total Soil Column Soil Moisture Anomaly: March 2012 – December 2013



Youlong Xia

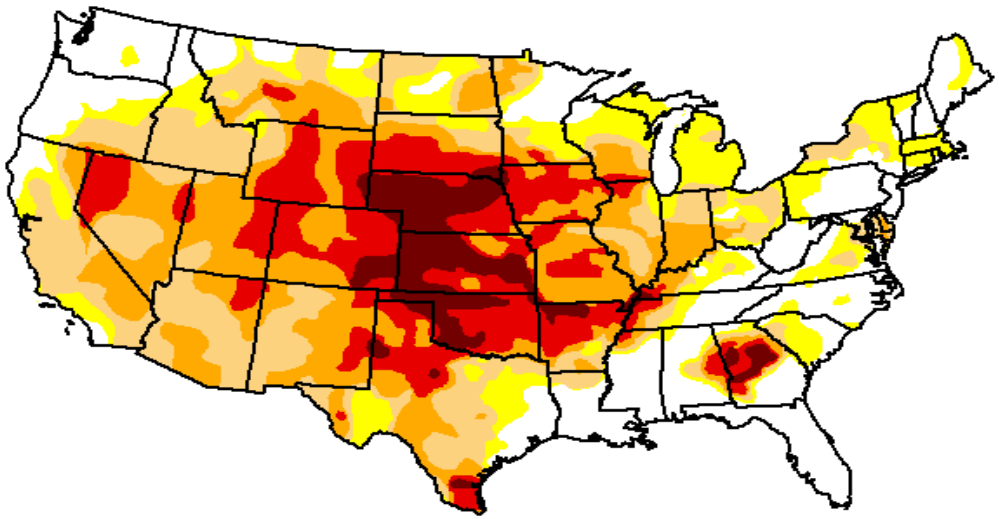
NLDAS Total Soil Column Soil Moisture Anomaly: January 2013 – August 2014



Youlong Xia

US Drought Monitor: 04 September 2012

U.S. Drought Monitor
CONUS



September 4, 2012
(Released Thursday, Sep. 6, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	22.54	77.46	63.39	42.48	21.45	6.14
Last Week 8/28/2012	22.31	77.69	62.89	42.34	23.18	6.04
3 Months Ago 6/5/2012	36.01	63.99	38.60	18.92	4.60	0.60
Start of Calendar Year 1/3/2012	50.41	49.59	31.90	18.83	10.18	3.32
Start of Water Year 9/27/2011	56.45	43.55	29.13	23.44	17.80	11.37
One Year Ago 9/6/2011	56.53	43.47	30.00	23.37	18.05	11.20

Intensity:

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

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

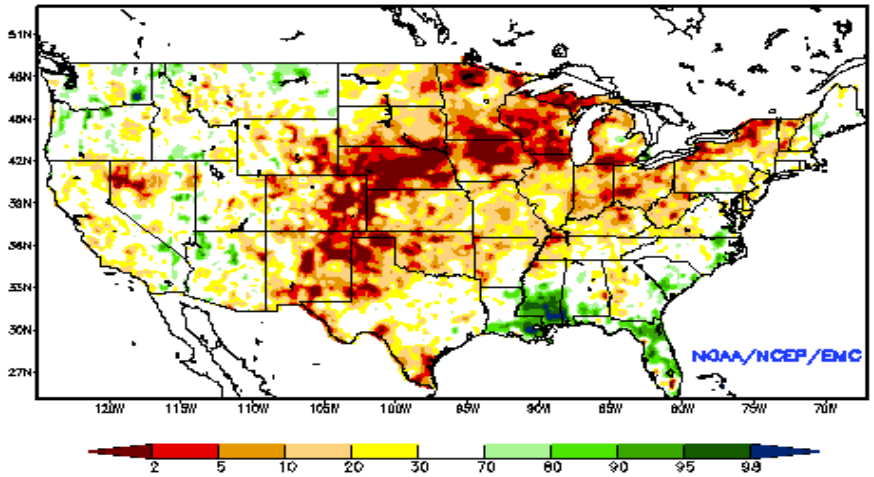
Author(s):
Brian Fuchs
National Drought Mitigation Center

USDA National Drought Mitigation Center

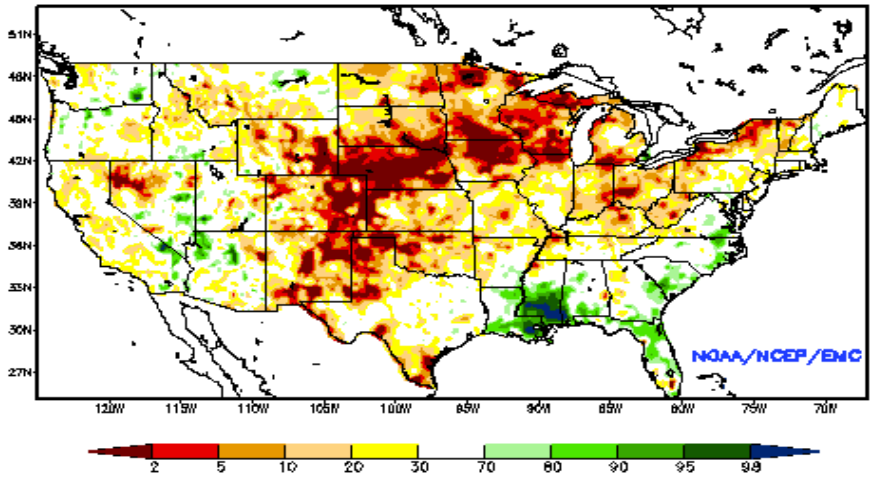
http://droughtmonitor.unl.edu/

NLDAS output: 04 September 2012

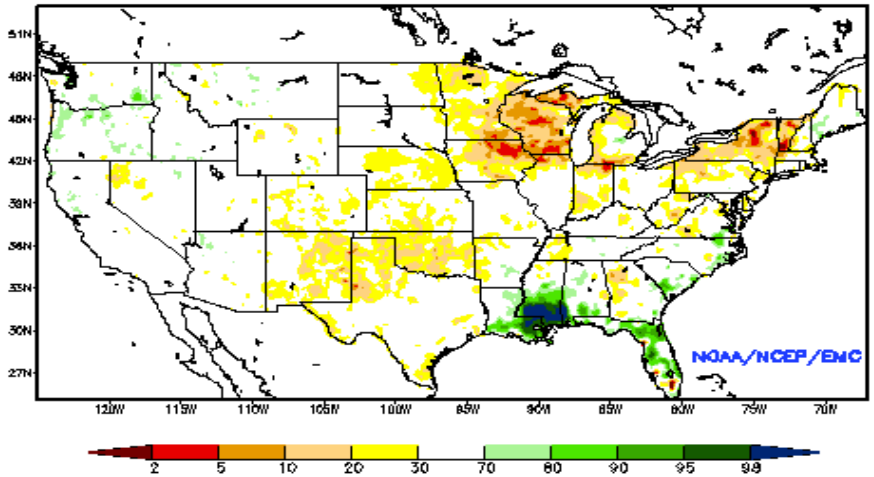
Total Column Soil Moisture



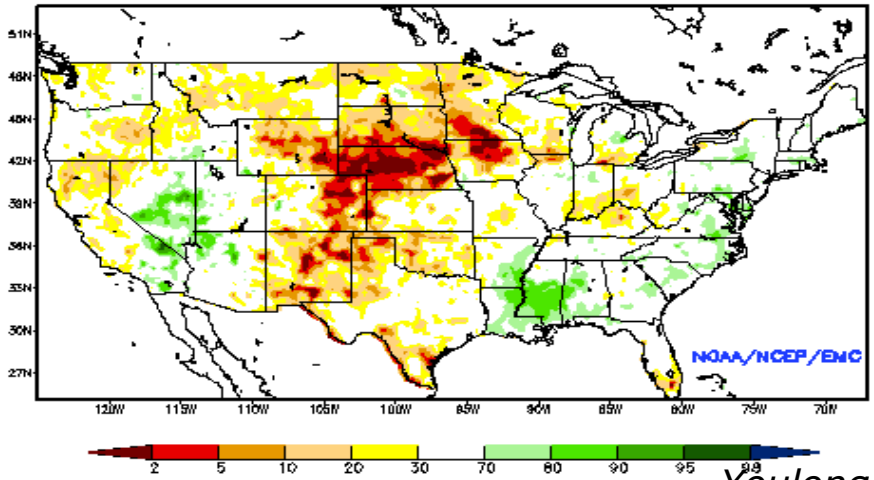
Top 1m Soil Moisture



Total Runoff

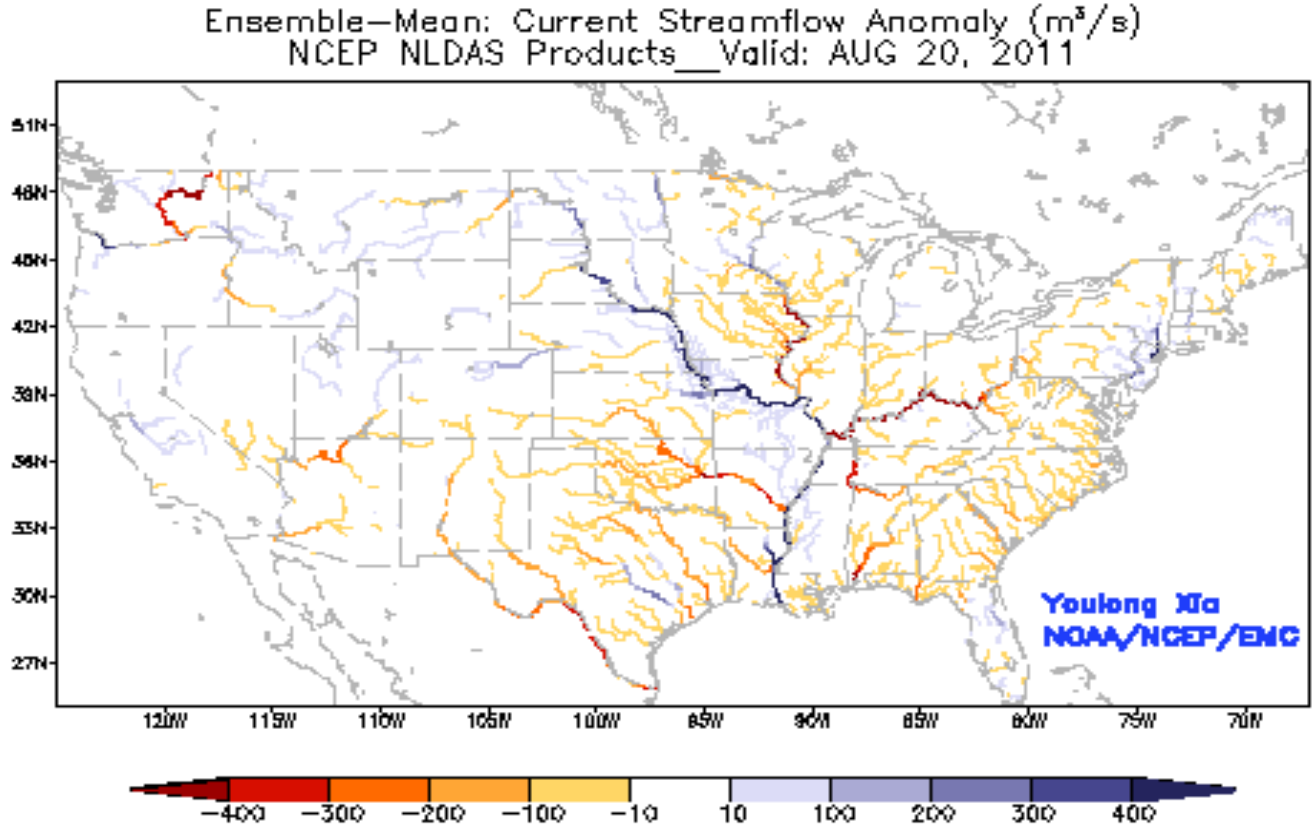


Evapotranspiration



Youlong Xia

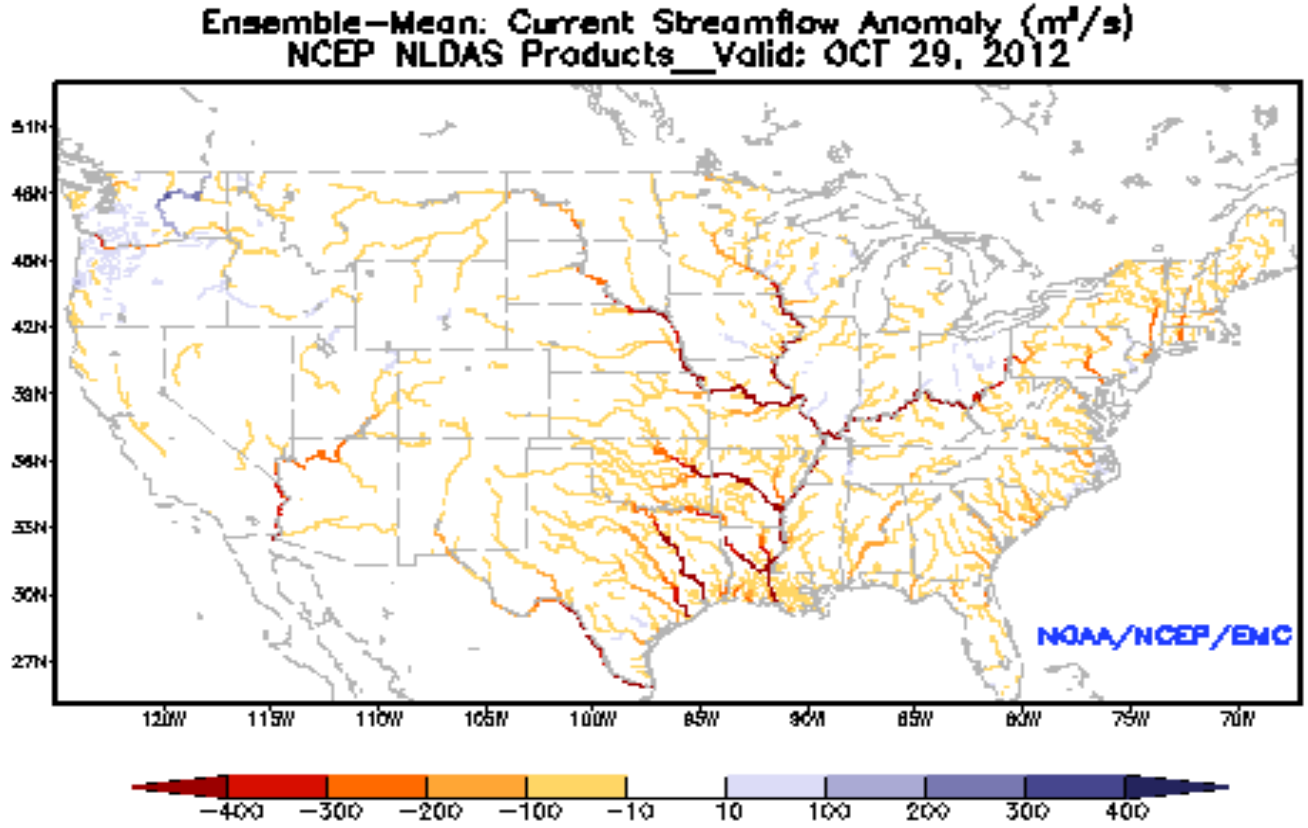
Streamflow from NLDAS routing scheme:
Hurricane Irene & Tropical Storm Lee
20 Aug – 17 Sep 2011



Ensemble mean daily streamflow anomaly (m^3/s)

Youlong Xia

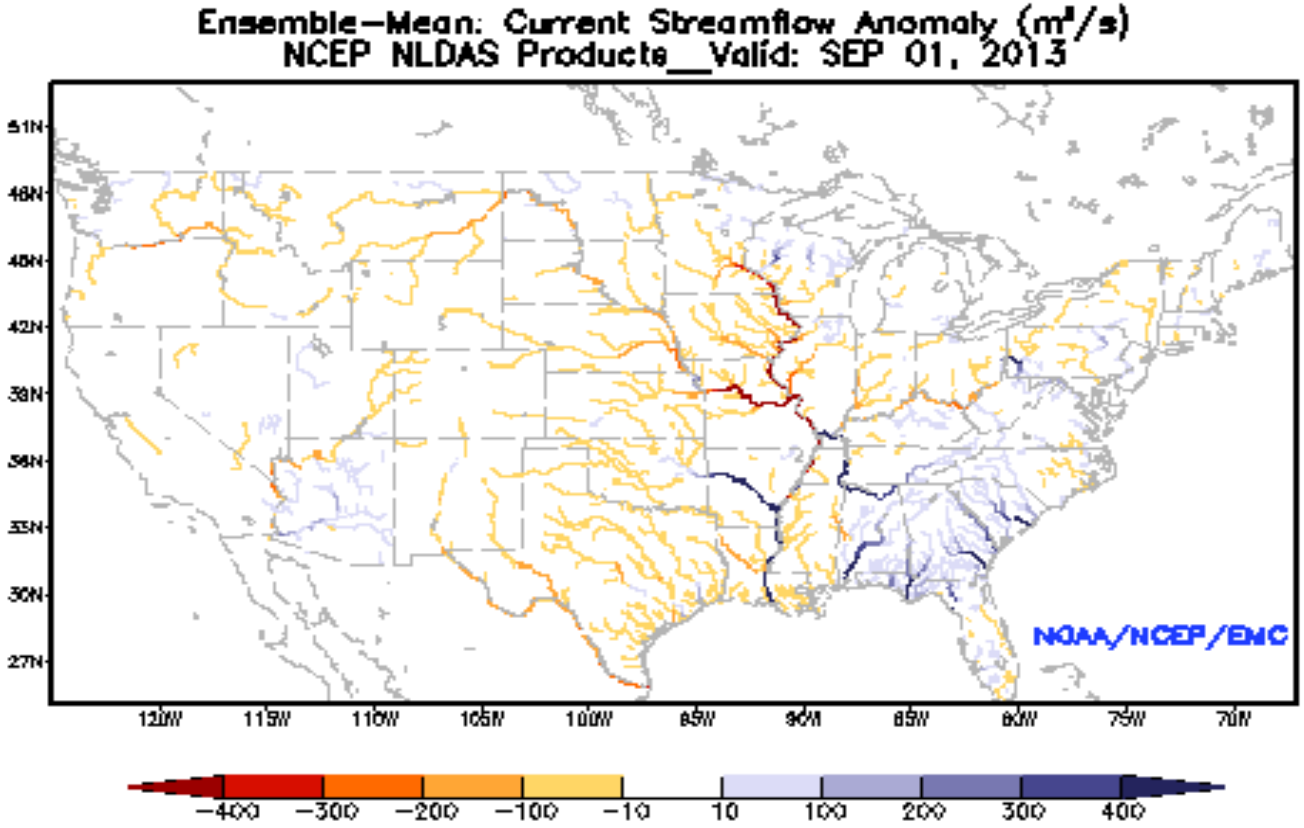
Streamflow from NLDAS routing scheme:
Superstorm Sandy
29 Oct – 04 Nov 2012



Ensemble mean daily streamflow anomaly (m^3/s)

Youlong Xia

Streamflow from NLDAS routing scheme:
Colorado Front Range Flooding
September 2013



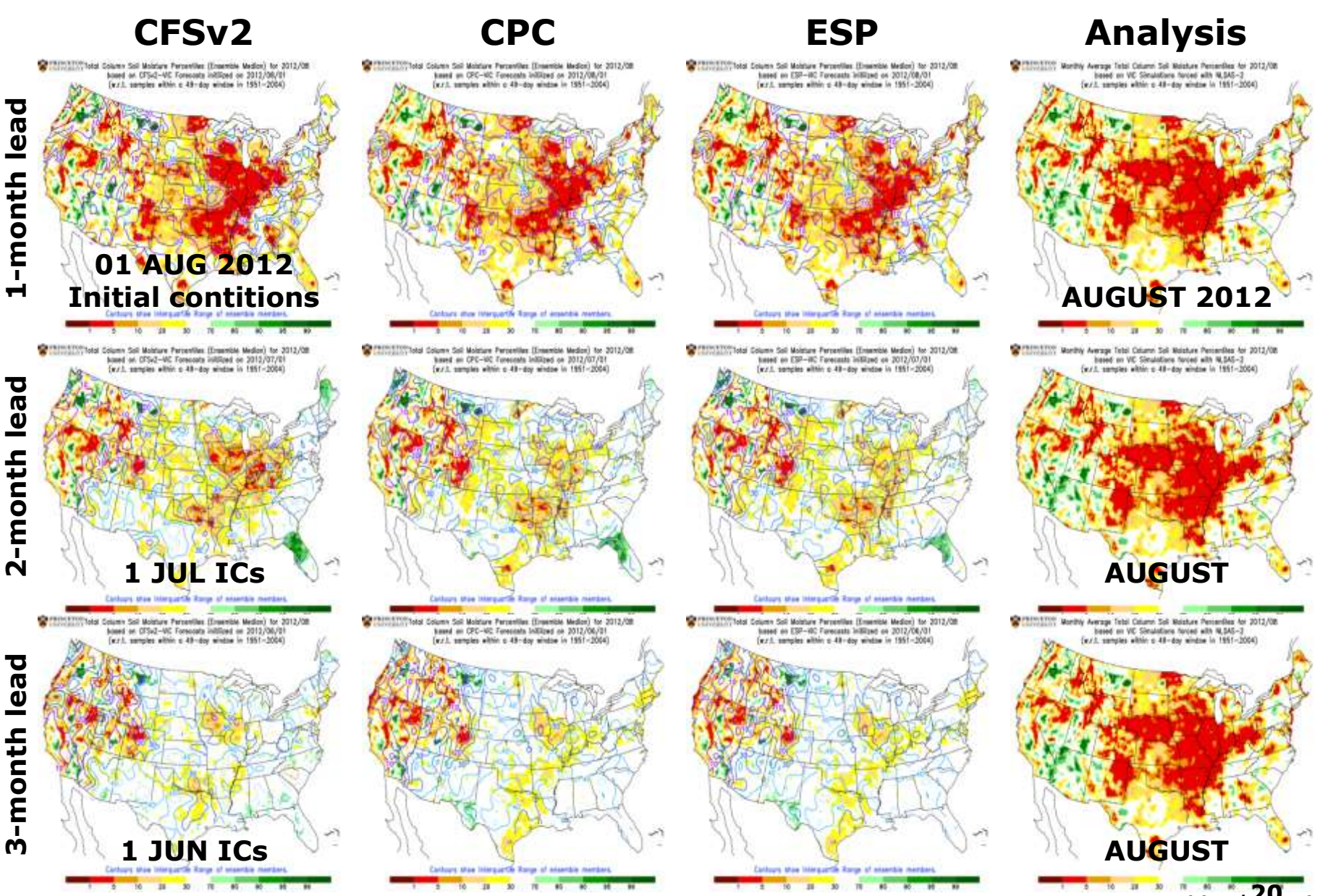
Ensemble mean daily streamflow anomaly (m^3/s)

Youlong Xia

NLDAS Seasonal Hydrological Forecast System

- System jointly developed by Princeton University and U. Washington.
- Transitioned to EMC in Nov 2009, as an experimental seasonal hydrological forecast system.
- Hydrological forecasts use downscaled/ensemble forcing from three sources: CFSv2, traditional ESP, and CPC forecasts.
- Run at the beginning of each month and forecast products are staged on NLDAS website by the 15th of each month.

NLDAS Hydro. Fcst: Drought Lead Time



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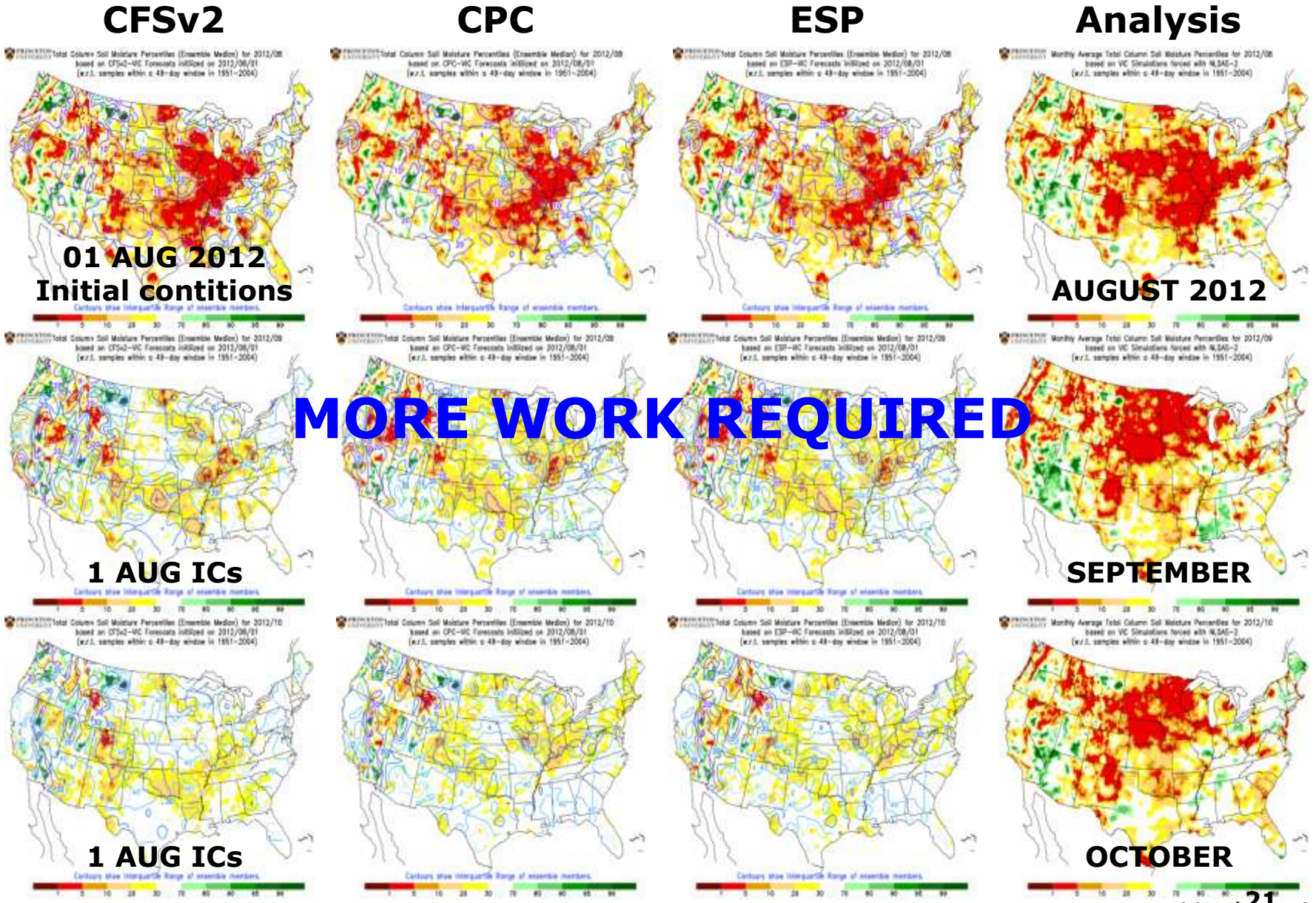
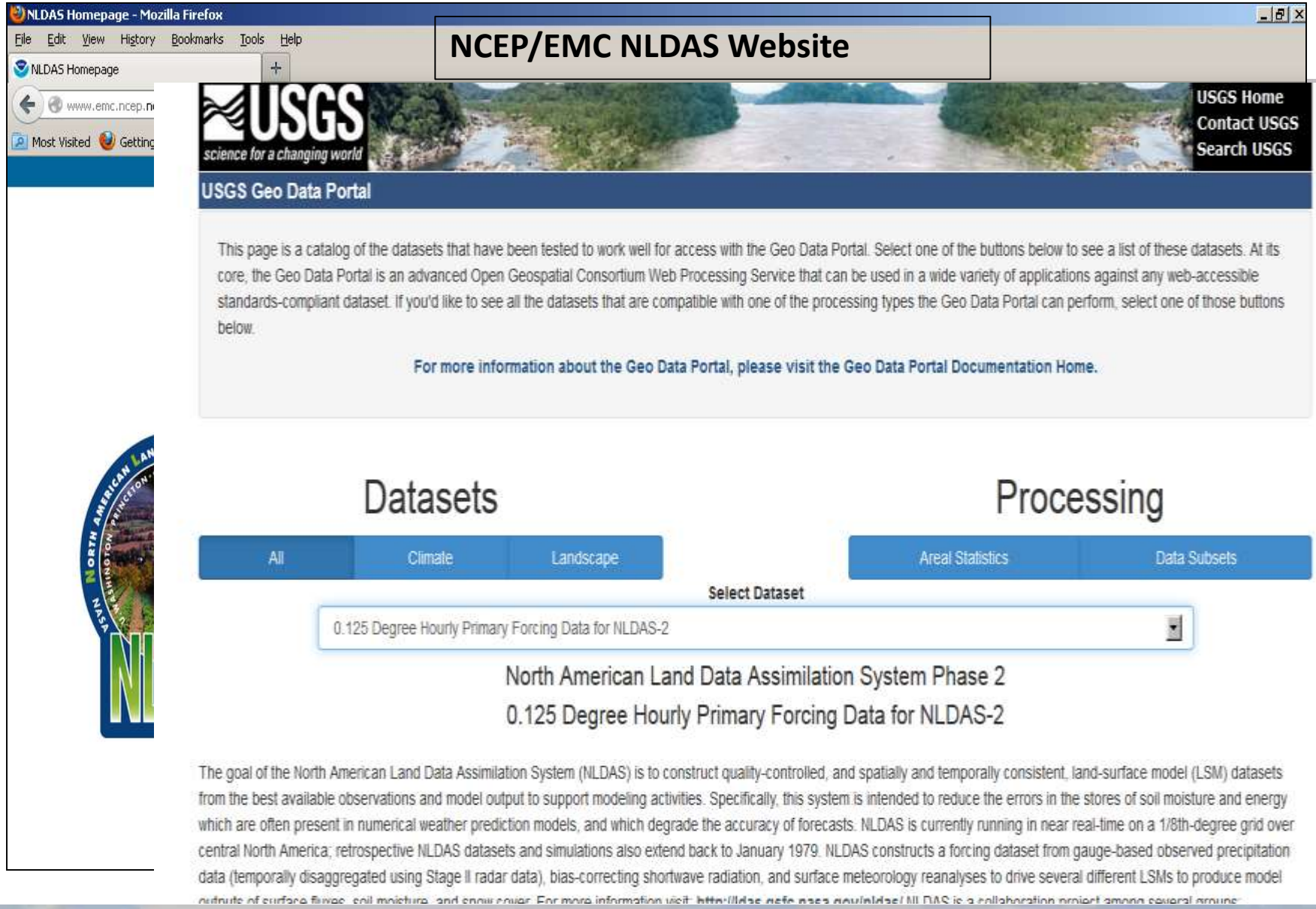
NLDAS Hydro. Fcst: Drought Persistence



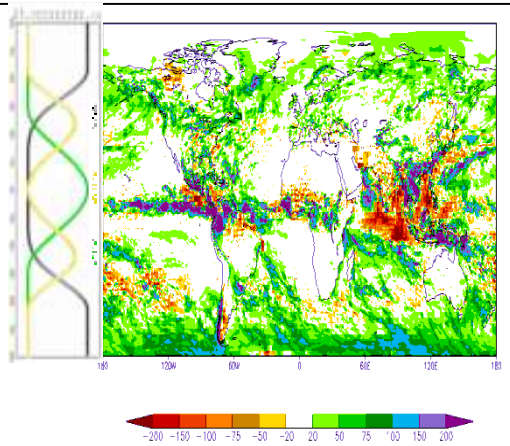
Youlong Xia

NLDAS: Web Site Information

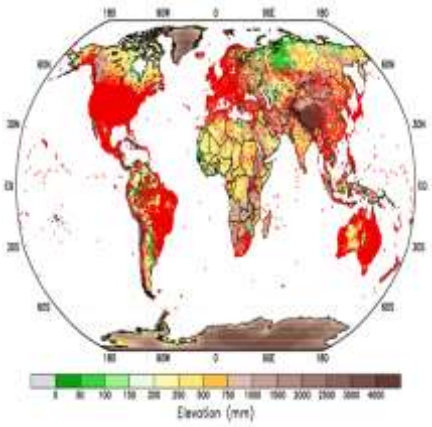


Global Land Data Assimilation System

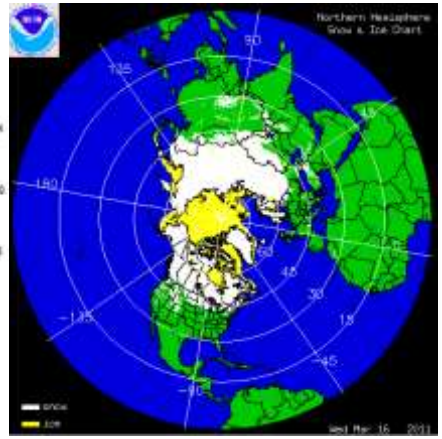
- Uses **Noah land model** running under NASA Land Information System forced with CFSv2/GDAS atmospheric data assimilation output and "blended" precipitation in a semi-coupled mode.
- **Blended precipitation** via satellite (CPC/CMAP; heaviest weight in tropics), gauge (heaviest in mid-latitudes) and GDAS (model; high latitude).
- **Snow** cycled in CFSv2/GLDAS if snow from Noah LSM within a 0.5x/2.0x envelope of observed value (IMS cover, AFWA depth).



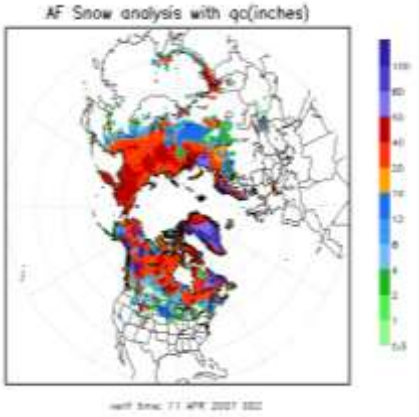
GDAS-CMAP precip



Gauge locations



IMS snow cover



AFWA snow depth

Jesse Meng

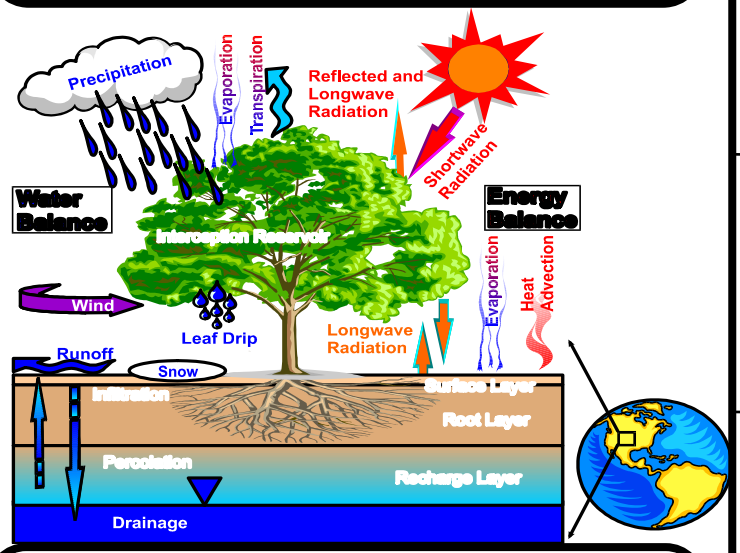
NASA Land Information System

Inputs

- Topography, Soils (Static)
- Land Cover, Leaf Area Index (MODIS, AMSR, TRMM, SRTM)
- Meteorology: Modeled & Observed (NLDAS, DMIP II, GFS,GLDAS,TRMM GOES, Station)
- Observed States (Snow Soil Moisture Temperature)

Physics

- Land Surface Models
  SAC-HT/SNOW17
  Noah, CLM, VIC, Catchment



- Data Assimilation Modules
  (DI, EKF, EnKF)

Outputs

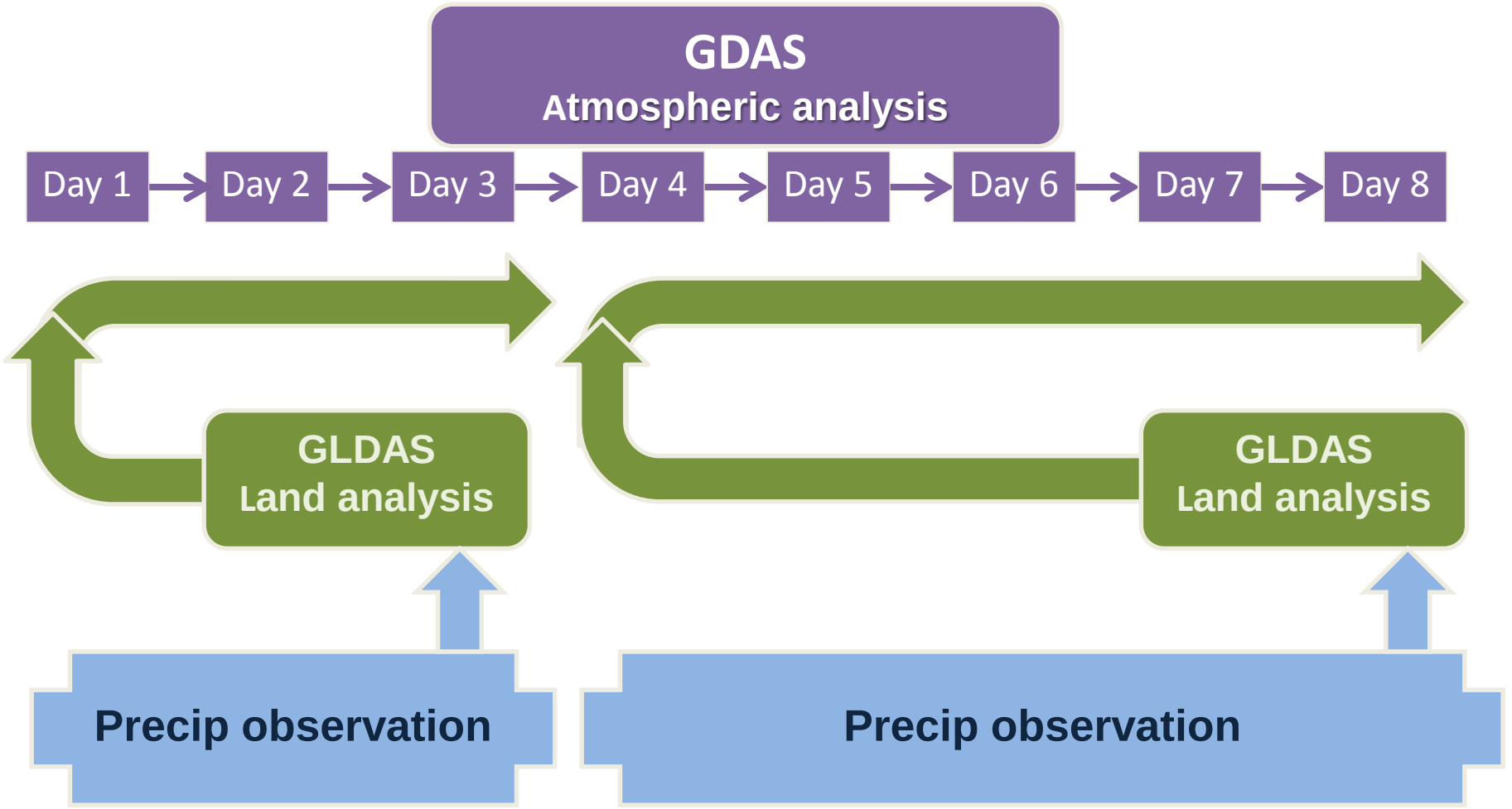
- Surface Energy Fluxes (Q_h,Q_{le})
- Soil Moisture Evaporation
- Surface Water Fluxes (e.g., Runoff)
- Surface States (Snowpack)

Applications

- Water Supply & Demand
- Agriculture
- Hydro-Electric Power, Water Quality
- Improved Short Term & Long Term Predictions

Christa Peters-Lidard et al., NASA/GSFC/HSB

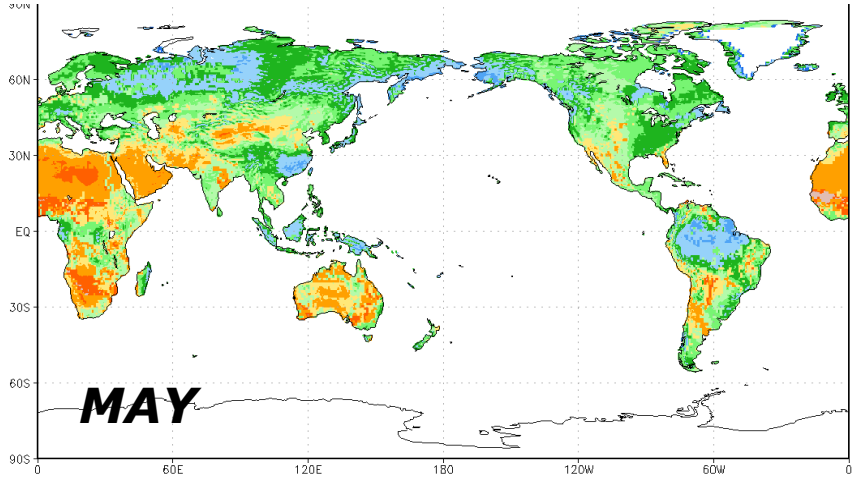
NCEP Realtime Operational GLDAS

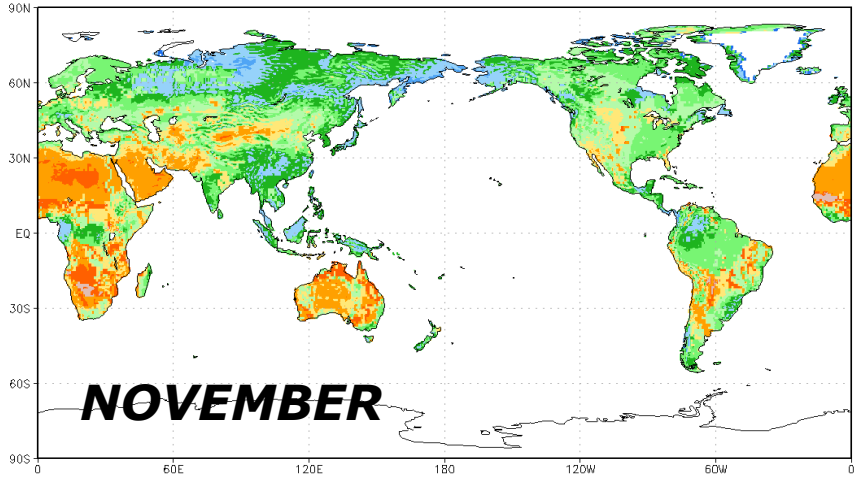


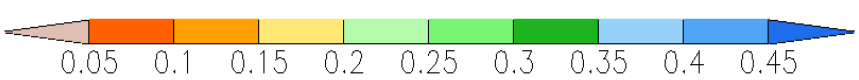
Jesse Meng

GLDAS soil moisture

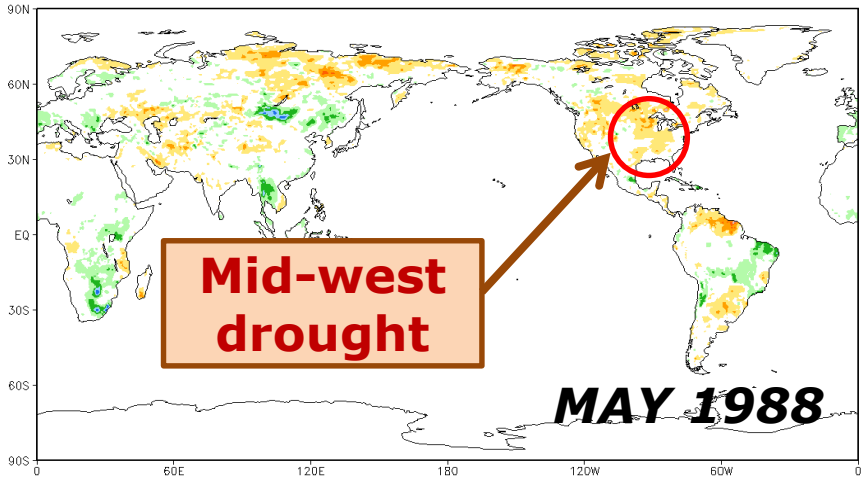
Climatology: 1980-2008

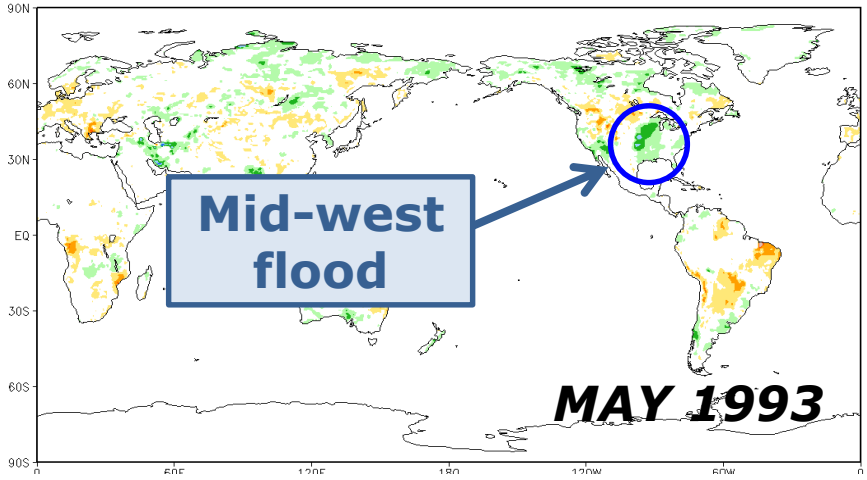


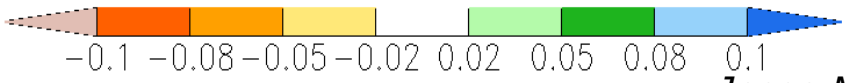




Anomalies

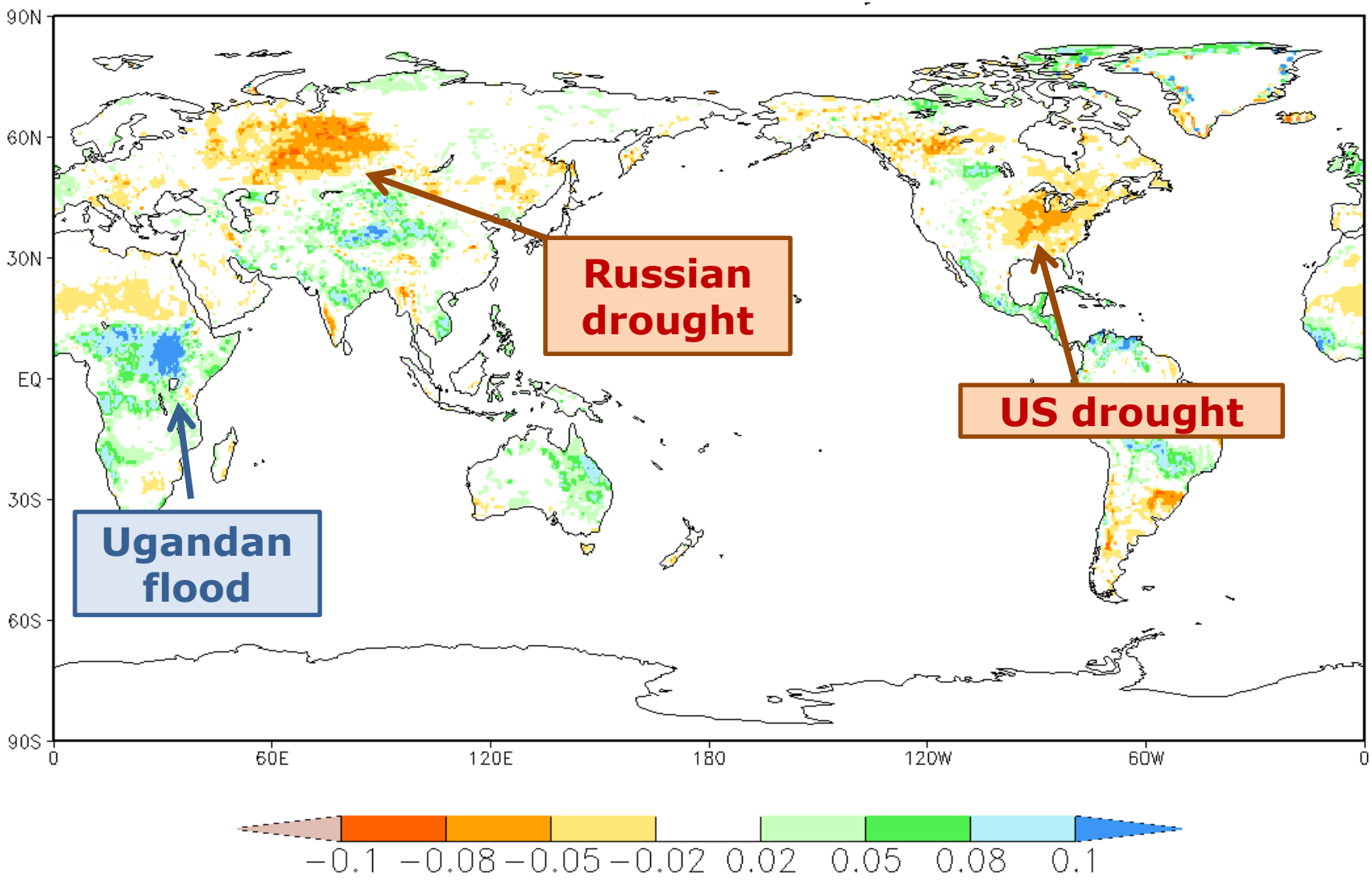






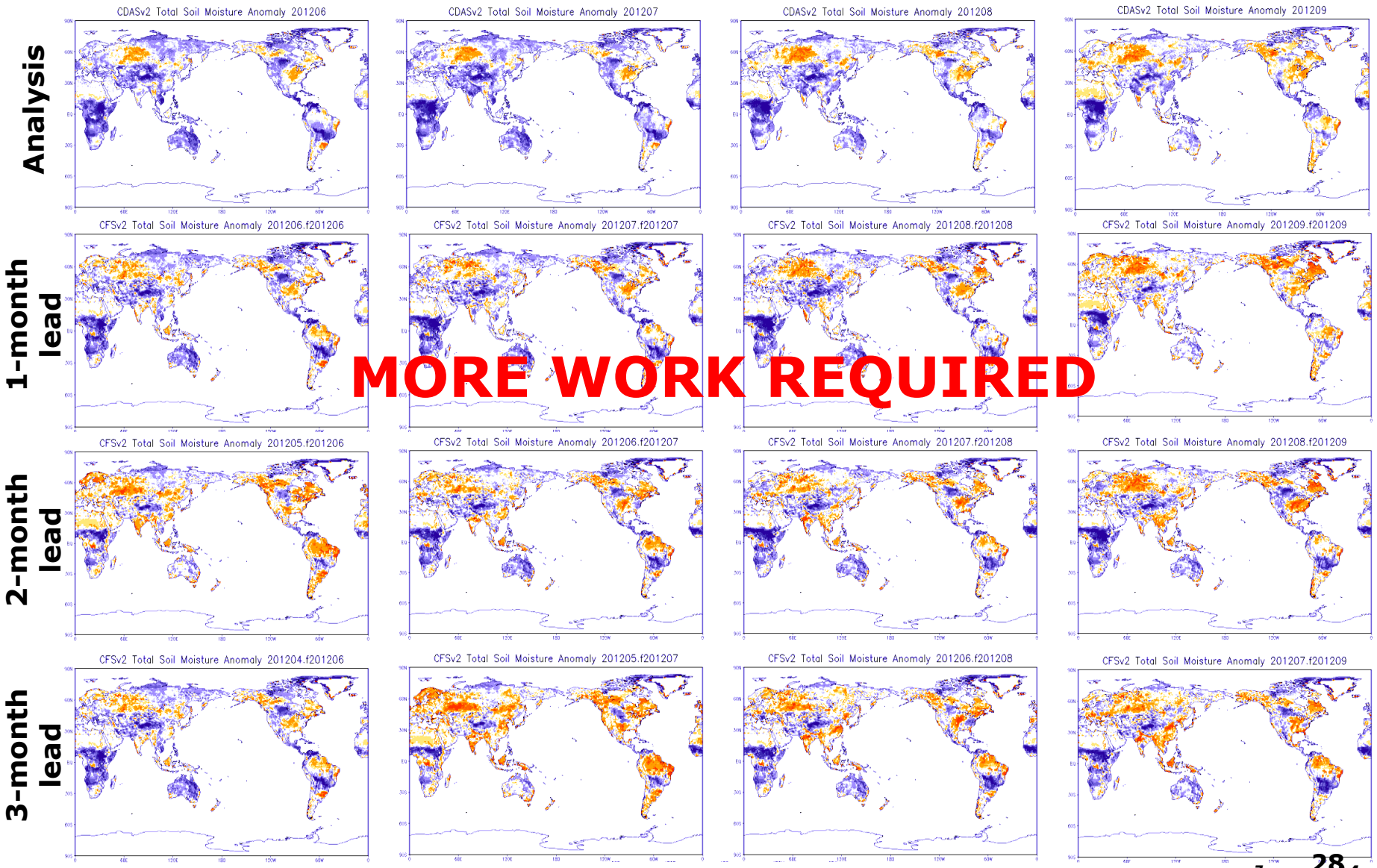
Jesse Meng

GLDAS soil moisture anomaly July 2012



Jesse Meng

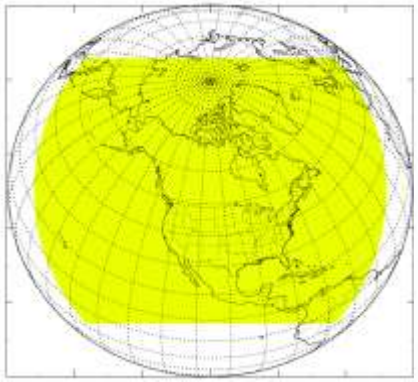
CFSv2 Total Soil Moisture Anomaly (mm)



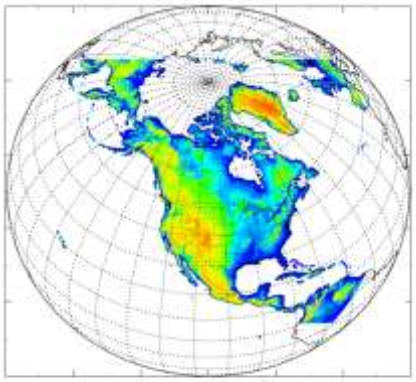
MORE WORK REQUIRED

Jesse Meng

Future NLDAS: Extend to entire North America and Mesoscale NAM domain



NAM Domain



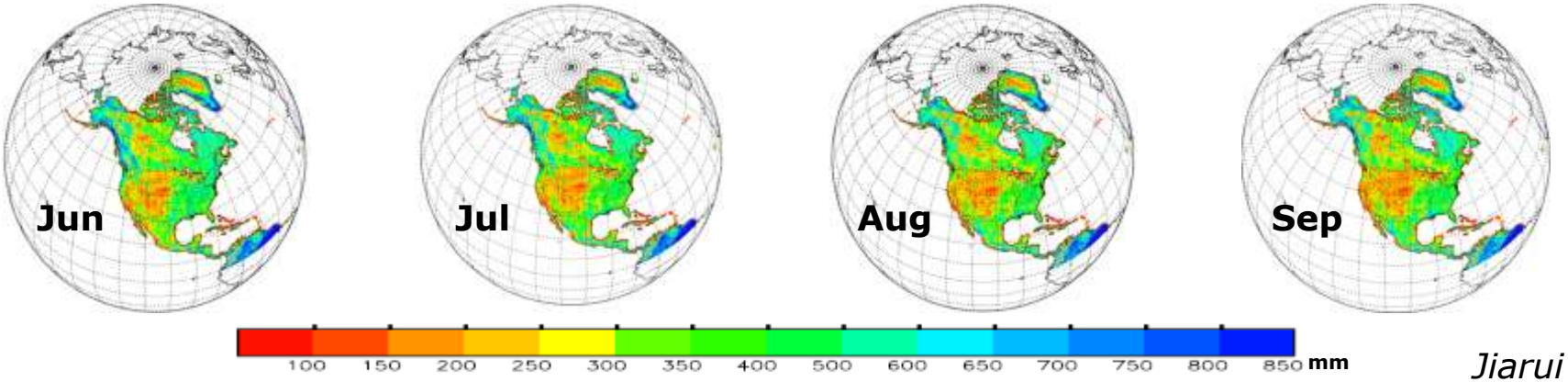
Elevation

Landcover

Configuration:

- **0.04-deg (~4km)**
- **Noah land model ver. 3.3 or later**
- **NAM/NDAS forcing**

Monthly Mean Total Soil Moisture in 2012 over NAM Domain



Jiarui Dong

Summary

- Hydrometeorological prediction of extremes (e.g. drought, flood) requires **proper initial conditions** (e.g. soil moisture memory), **correct physics** (e.g. land-surface model) & corresponding parameters, and **representative land data sets**, some near-realtime (e.g. green vegetation fraction, soil moisture, snow, etc) and some may be assimilated.
- **Improve land** data assimilation systems (LDAS) and land-surface model physics, i.e. "Noah-MP" with explicit canopy, CO2-based photosynthesis, dynamic vegetation (plant growth), groundwater, multi-layer snowpack, refine soil processes.
- **Earth-System models: Improve other components** in increasingly fully-coupled (atmosphere-ocean-land-sea ice-etc) modeling systems as they expand to make **connections** between ***Weather & Climate*** and ***Hydrology*** (including ***Water Quality***), ***Biogeochemical*** cycles (e.g. carbon, ecosystems), & ***Air Quality*** **on local as well as large scales**.

Thank you!