

# The Science of Floods

Aneela Qureshi

Dr. John A. Knox

University of Georgia

Masters of Disaster Workshop

Macon, GA

May 24<sup>th</sup>, 2011

Unless otherwise determinable, the images in this presentation are from Christopherson's *Geosystems* (Prentice-Hall)

*Photo credit: Ben Folds, 2010*

# Types of floods

- **Flood:** overflow of water onto normally dry land
- Floods can happen in many different ways:
  - **Flash floods:** *rapid* flooding usually caused by heavy rain in short amount of time
  - **Coastal floods:** caused by windblown ocean/lake water
  - **Tropical cyclone floods** (if slow-moving or over mountains)
  - **Snowmelt floods:** caused by melting of heavy snowcover
  - **Icejam floods:** caused by ice acting as dam in frozen river
  - **Human-caused floods:** caused by dams, levees, dikes, etc. that fail (sometimes in combination with above)

# Flash Floods

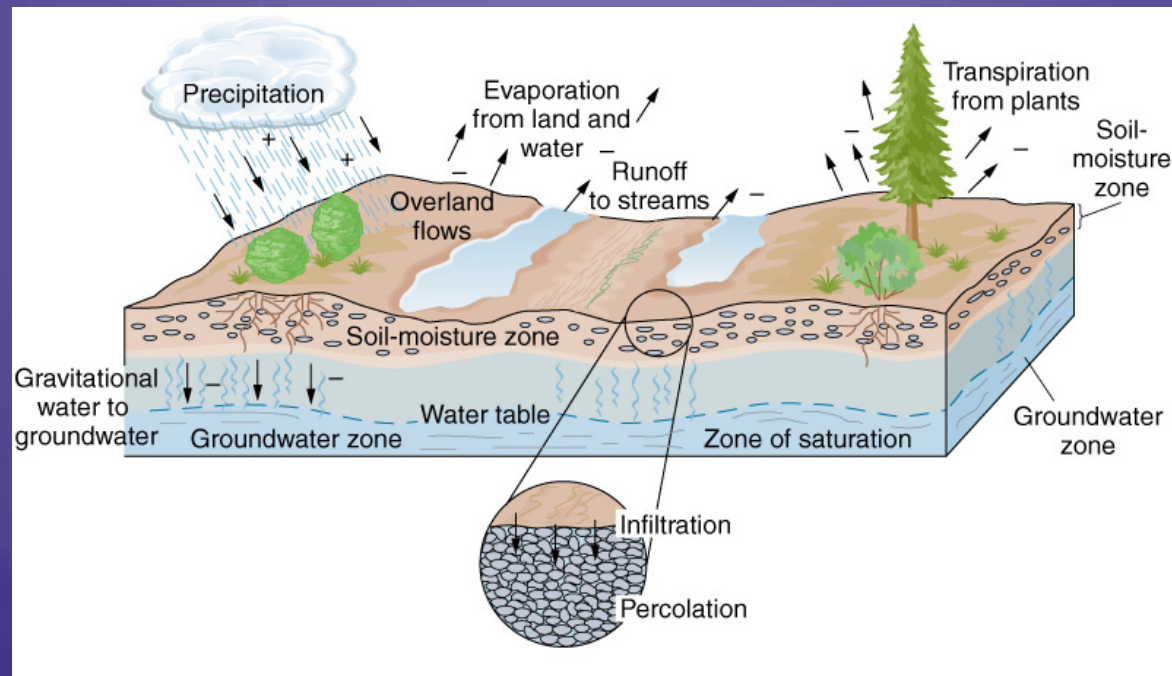
- Begin **within 6 hours** of causative event (often 3 hours)
- Causes – heavy rain, excessive runoff, icejams, dam/levee breaks
- Can cause rivers and streams to rise rapidly with little warning
- Can occur in areas with no visible streambed
- Sometimes lead to dangerous mudslides, full of mud, rocks, boulders, tree branches, etc.

# A few notable floods in U.S. history

- **10,000-15,000 years ago:** Ice sheets melt, floods of Biblical proportions carve out Scablands of Pacific NW, river valleys of East Coast, and across globe
- **1889: Johnstown, PA flood** (dam break, 2,200 dead)
- **1927: Mississippi River flood** (biggest in U.S. history)
- **1969: Hurricane Camille flood** in VA
- **1972: Rapid City, SD flash flood:** over 200 dead
- **1976: Big Thompson Canyon, CO:** 139 dead in flash flood near Boulder, <http://www.coloradoan.com/news/thompson/>
- **1993: U.S. Midwest flood** (Iowa = new Great Lake)
- **1994: Tropical Storm Alberto flood** in south Georgia
- **1997: N. Dakota snowmelt flood** (80% of Grand Forks)
- **1999: Hurricane Floyd flood** in mid-Atlantic
- **2005: Hurricane Katrina flood** (80% of New Orleans)
- **2009: Epic flooding in Atlanta**
- **2011: Historic lower Mississippi flooding**

# Physical geography of floods: hydrologic cycle

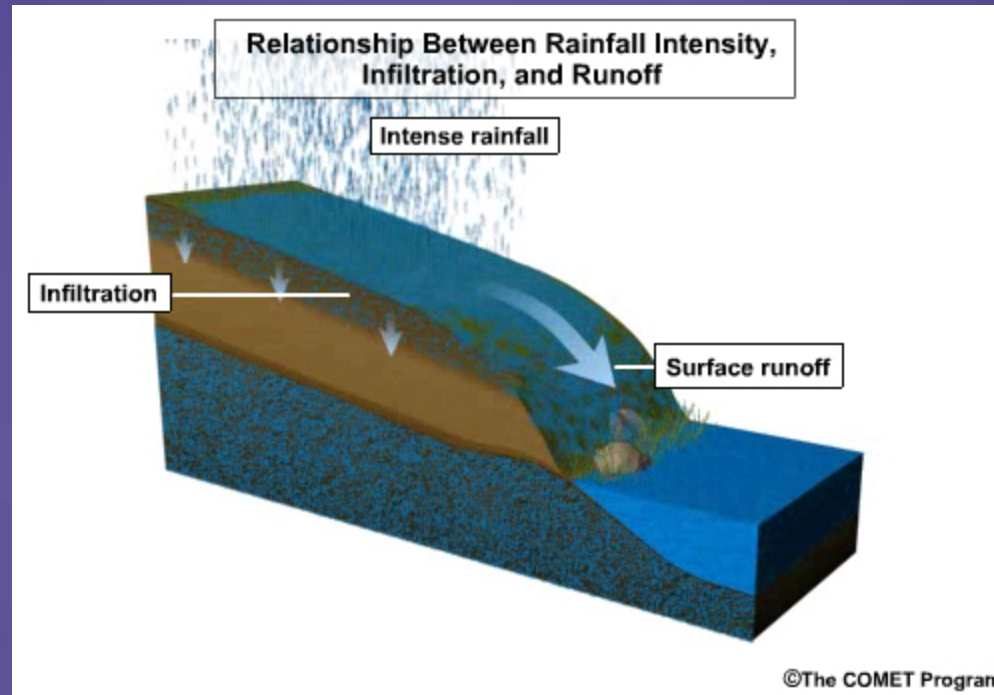
- **Hydrologic cycle:** how water moves through nature
- See [http://epa.gov/climatechange/kids/water\\_cycle\\_version2.html](http://epa.gov/climatechange/kids/water_cycle_version2.html)



# Hydrologic cycle and floods

- Key aspects of hydrologic cycle for floods and flash floods:
  - **Runoff:** precipitation lands on ground, runs downhill into streams and rivers
  - **Precipitation:** the faster it falls, more runoff
  - **Evaporation:** more when air is dry, less when moist
  - **Soil moisture:** high during wet periods, dependent on soil type
  - **Water table:** also high during (longer-term) wet periods
  - **Vegetation:** holds moisture, reduces runoff
- Bottom line: **when it rains on already-wet soils, there's more (and more rapid) runoff into rivers** (especially if there's no vegetation)

# Infiltration and Runoff: Key to floods



<http://meted.ucar.edu/>

- **Infiltration** – water entering the soil (moves through soil as **percolation**)
- Runoff – water runs over surface into streams
- When rainfall rates exceed infiltration capacity, floods can happen!

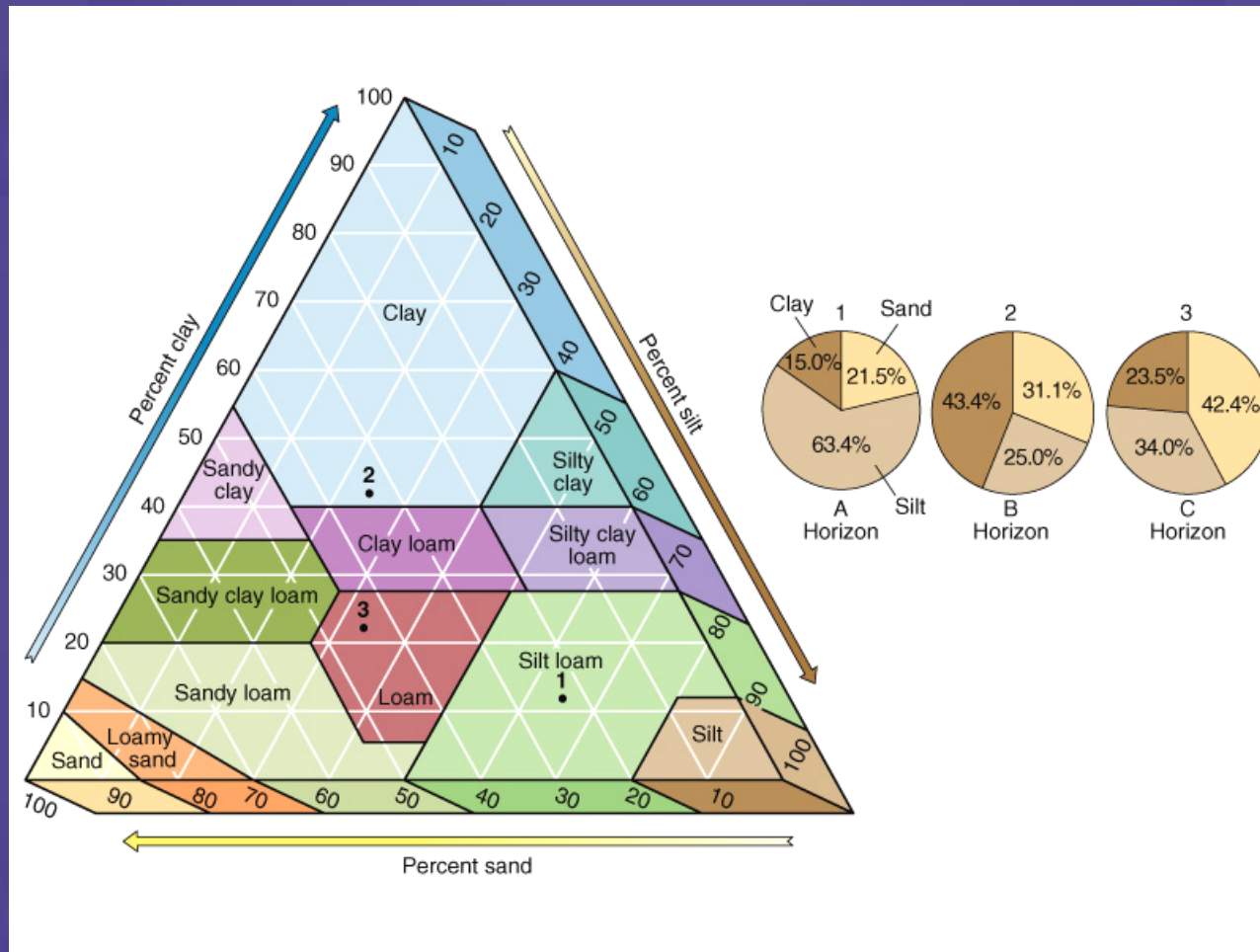
# Floods and topography



- **Steep topography promotes rapid runoff**
- Narrow river valleys at high risk of flash floods

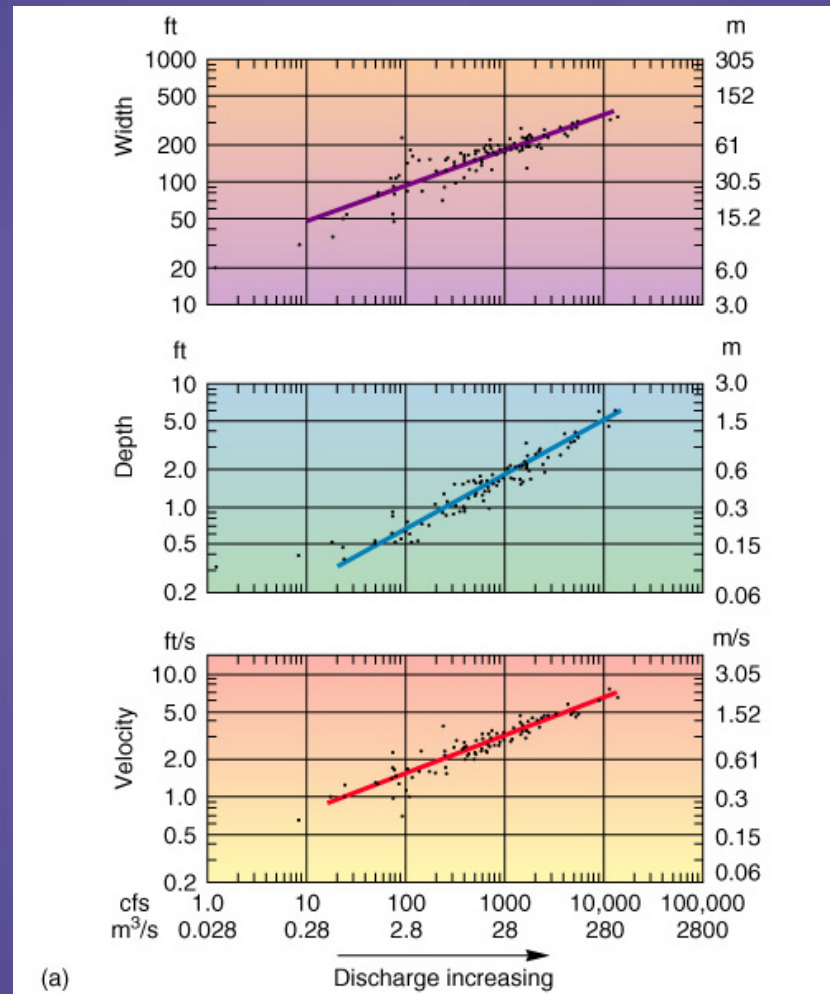


# Floods and soil type



- Sandy soils absorb water effectively
- **Clay soils promote rapid runoff** (i.e., much of eastern United States)

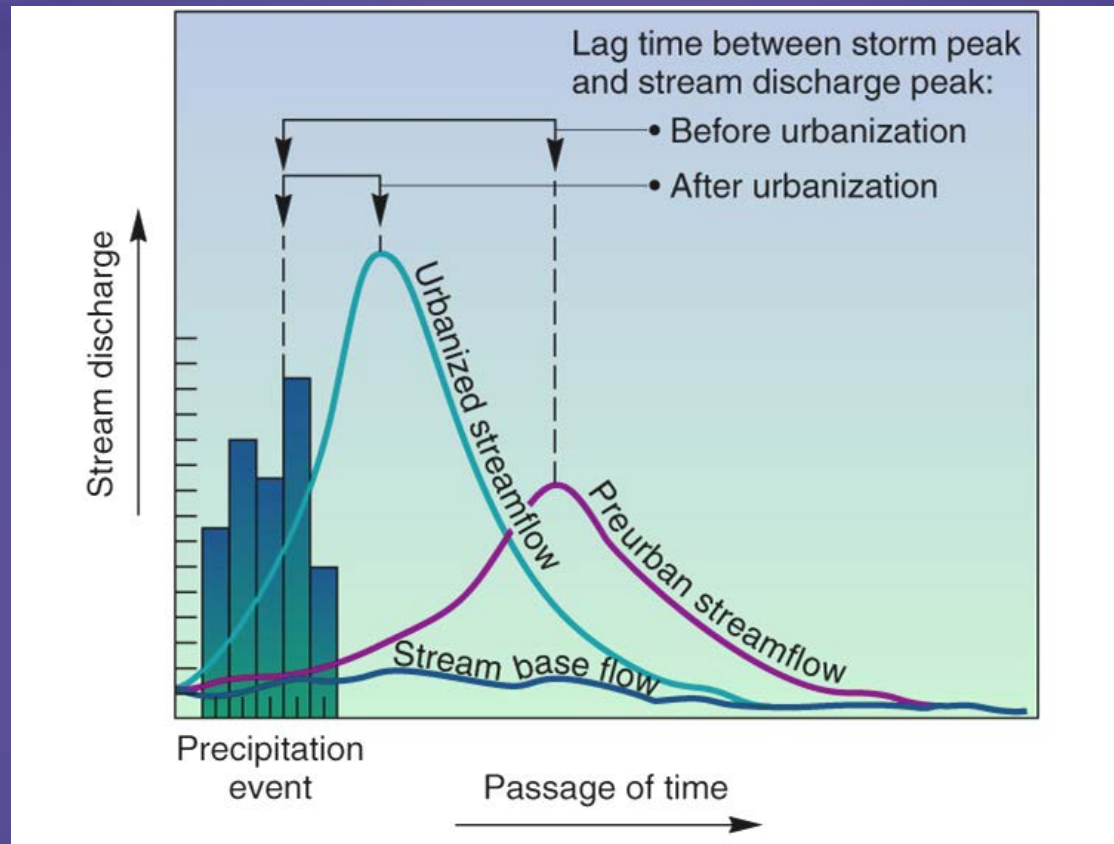
# Floods and streamflow



Data for Powder River, MT

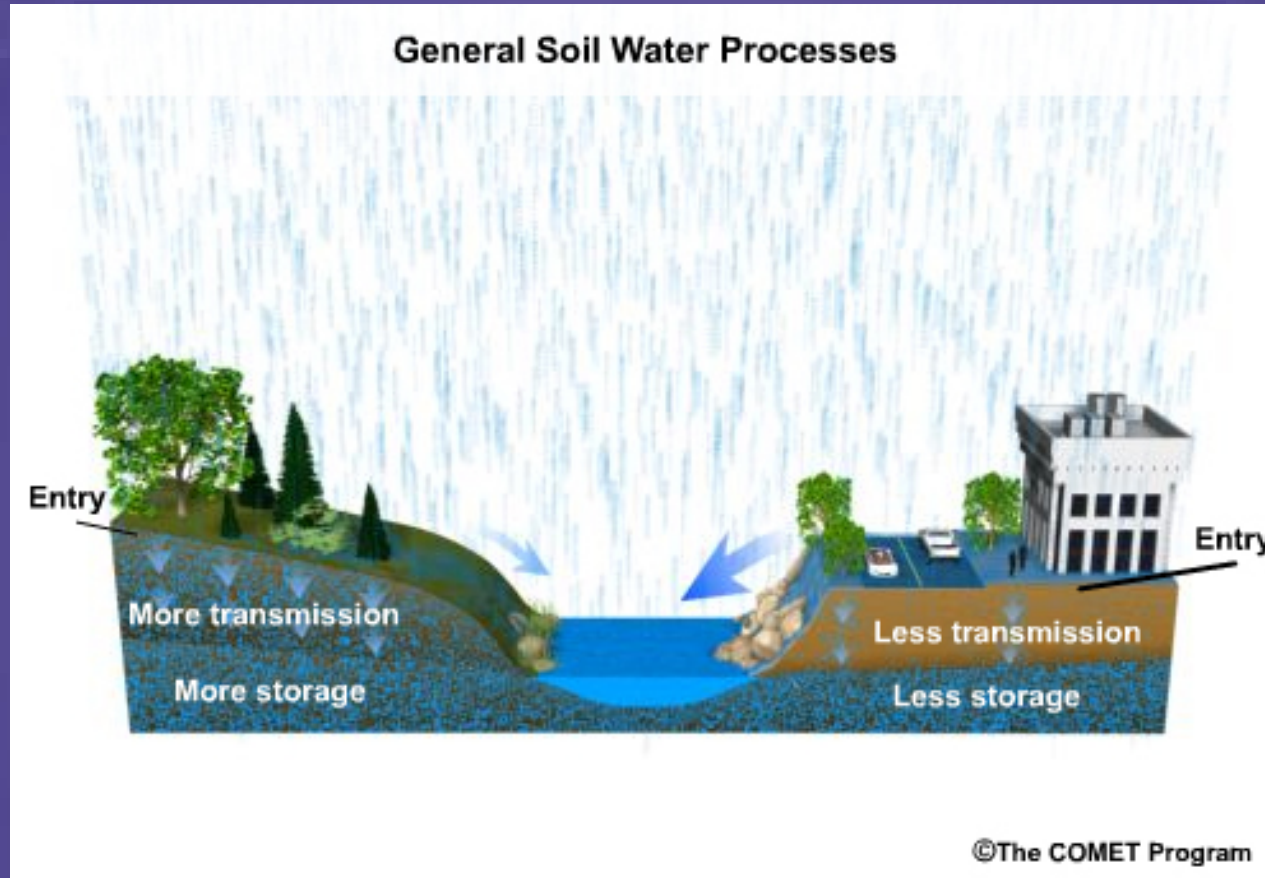
- Basic relationships: **more discharge** means a **WIDER, DEEPER, FASTER** river

# Floods and urbanization



- **Asphalt and concrete** promote much more rapid runoff than vegetated soils
- Result: rains that would have led to minor flooding in past can now lead to **faster, major urban flooding**

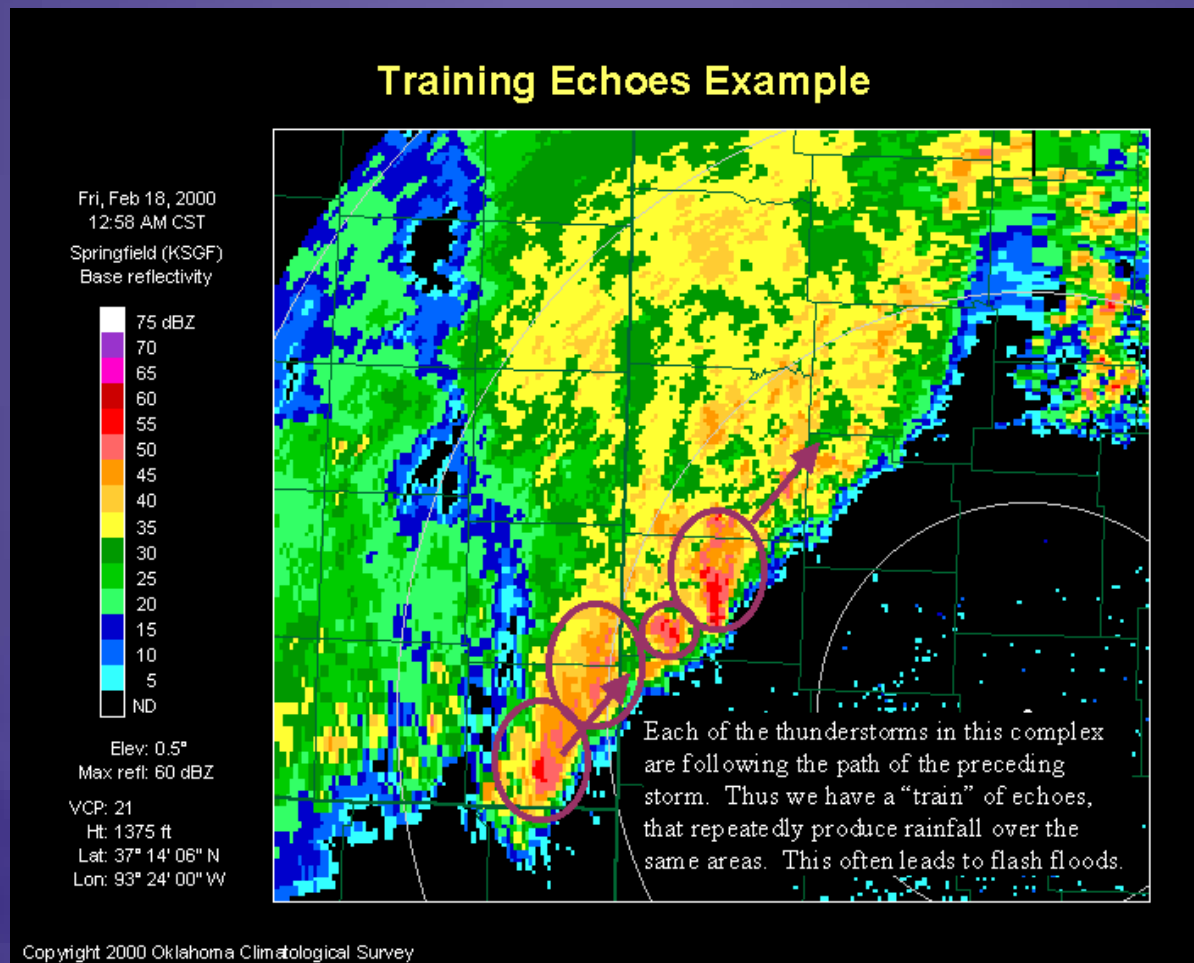
# Urban vs. Non-urban



- Urban areas – pavement allows for little to no infiltration, more runoff
- Non-urban areas – more infiltration, less runoff

# Meteorology of floods: “training” of thunderstorm cells

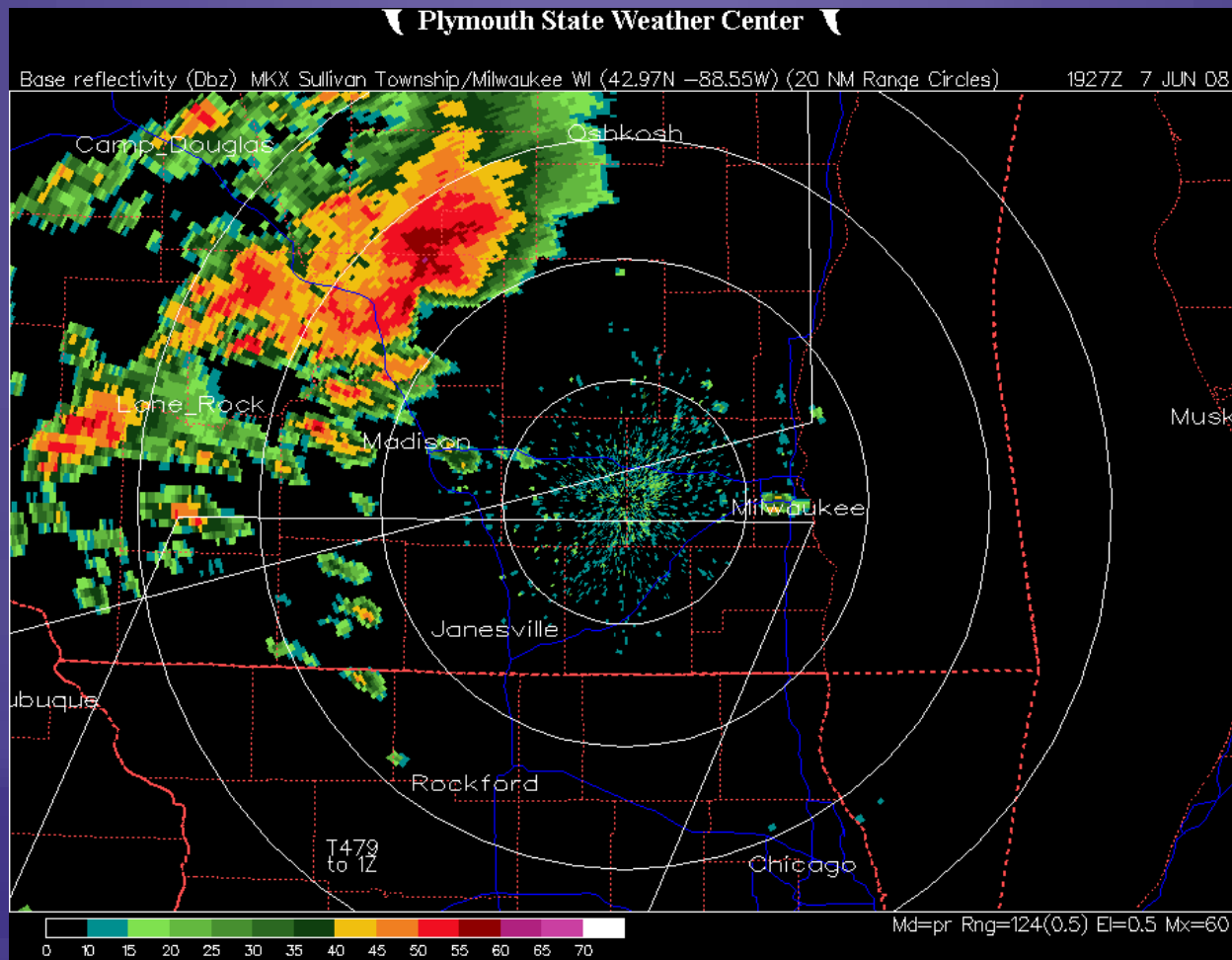
“Training” = one thunderstorm after another going over same spot



<http://okfirst.mesonet.org/train/materials/Flood/training.gif>

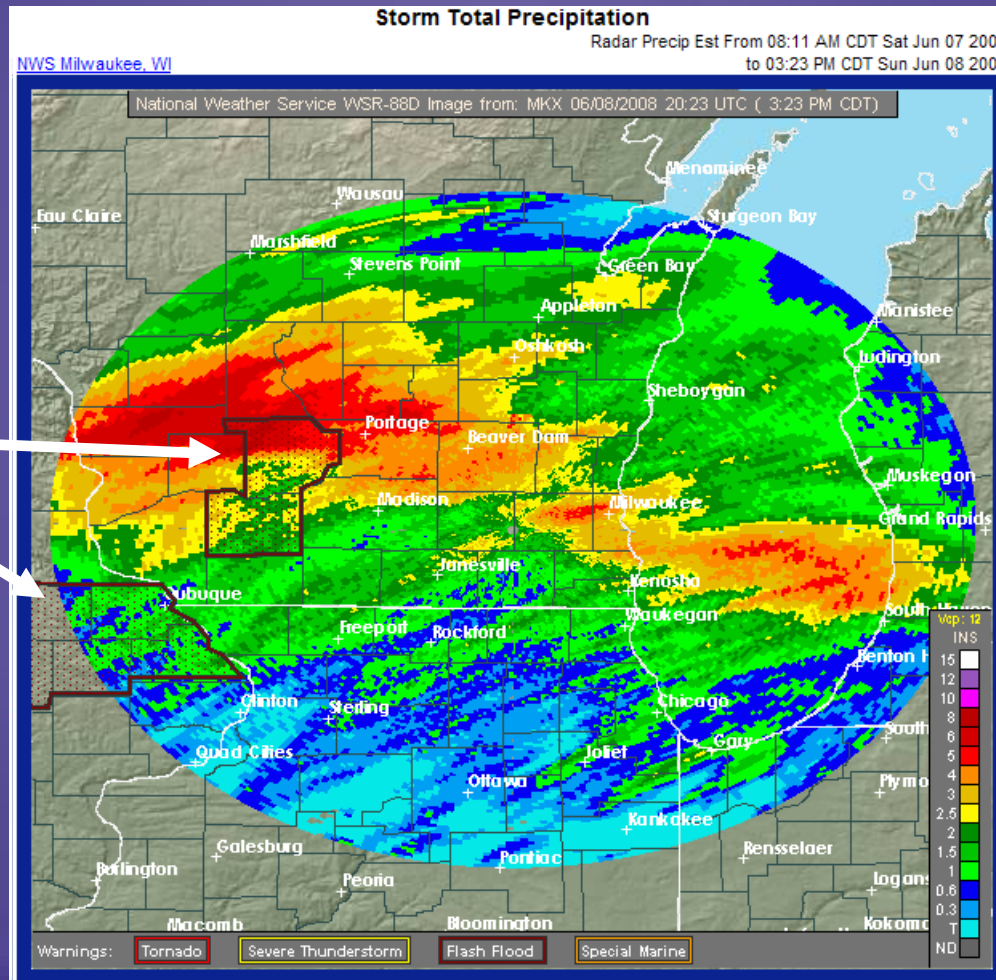
# Meteorology of floods: “training” of thunderstorm cells

“Training” = one thunderstorm after another going over same spot



<http://vortex.plymouth.edu/nids.html>

# Meteorology of floods: rainfall amounts from “training”



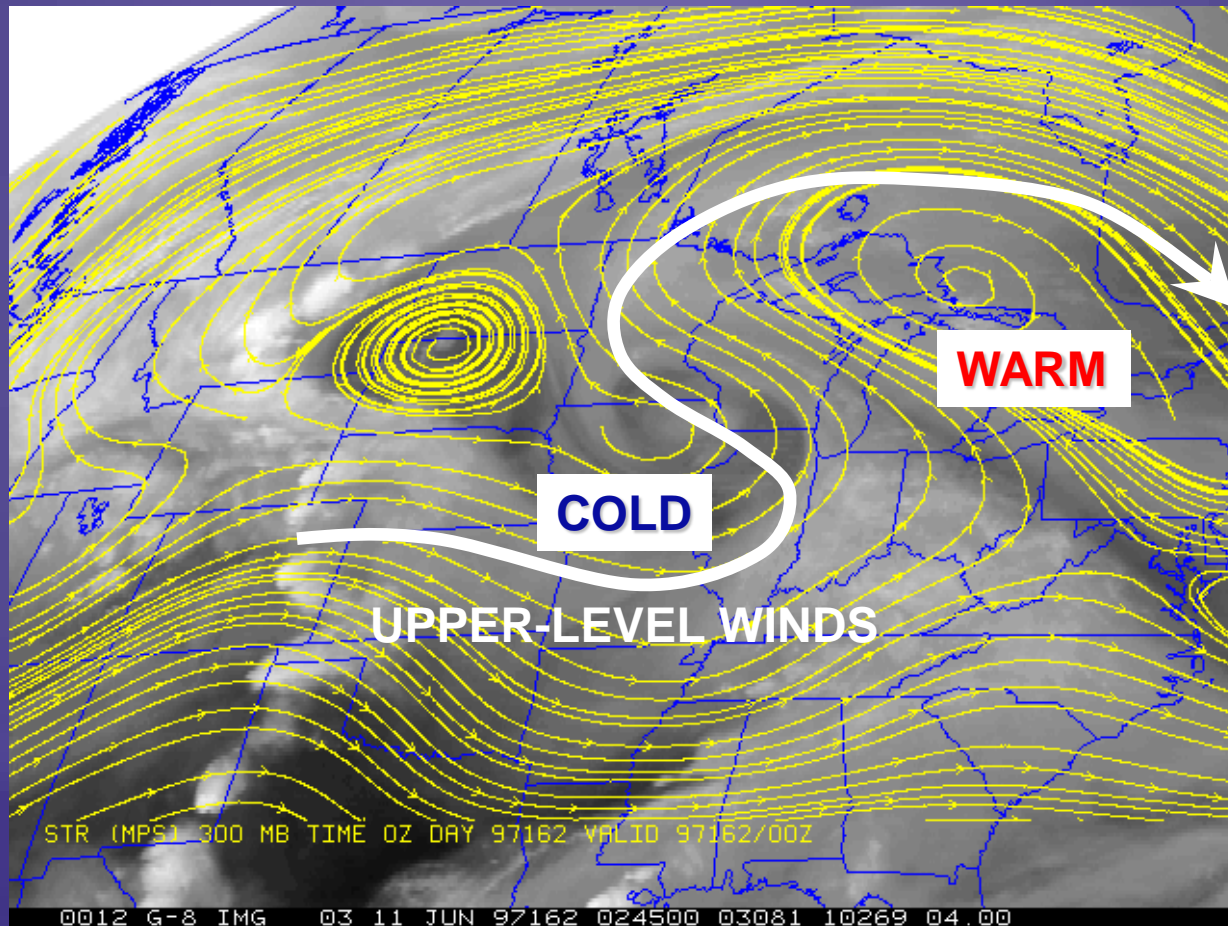
Flash  
Flood  
Warnings

Why there?  
Steep, never-  
glaciated river  
valleys in the  
“Driftless  
Area” promote  
flooding

Floods aren't  
just about the  
*amount* of  
rainfall!

# Meteorology of floods: “blocking”

“**Blocking**” = upper-level troughs and ridges “stuck” in place for weeks, focusing precipitation in the same locations



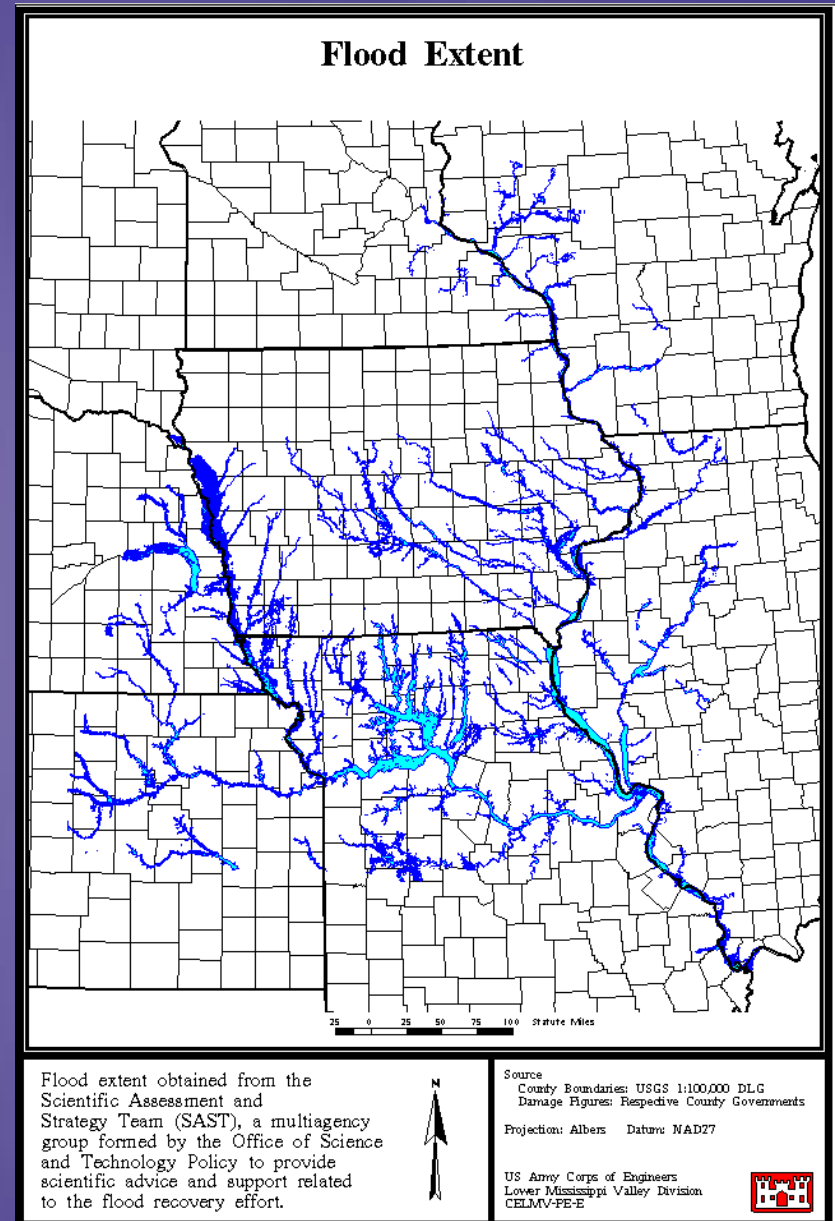
[http://cimss.ssec.wisc.edu/goes/misc/wv/June97\\_iotm.html](http://cimss.ssec.wisc.edu/goes/misc/wv/June97_iotm.html)



# “Blocking” caused 1993 upper Mississippi flood

**50 deaths,  
\$15 billion in damage**

Below: Mississippi and  
Missouri Rivers at St. Louis,  
before and during the flood



# Great Flood of 1927

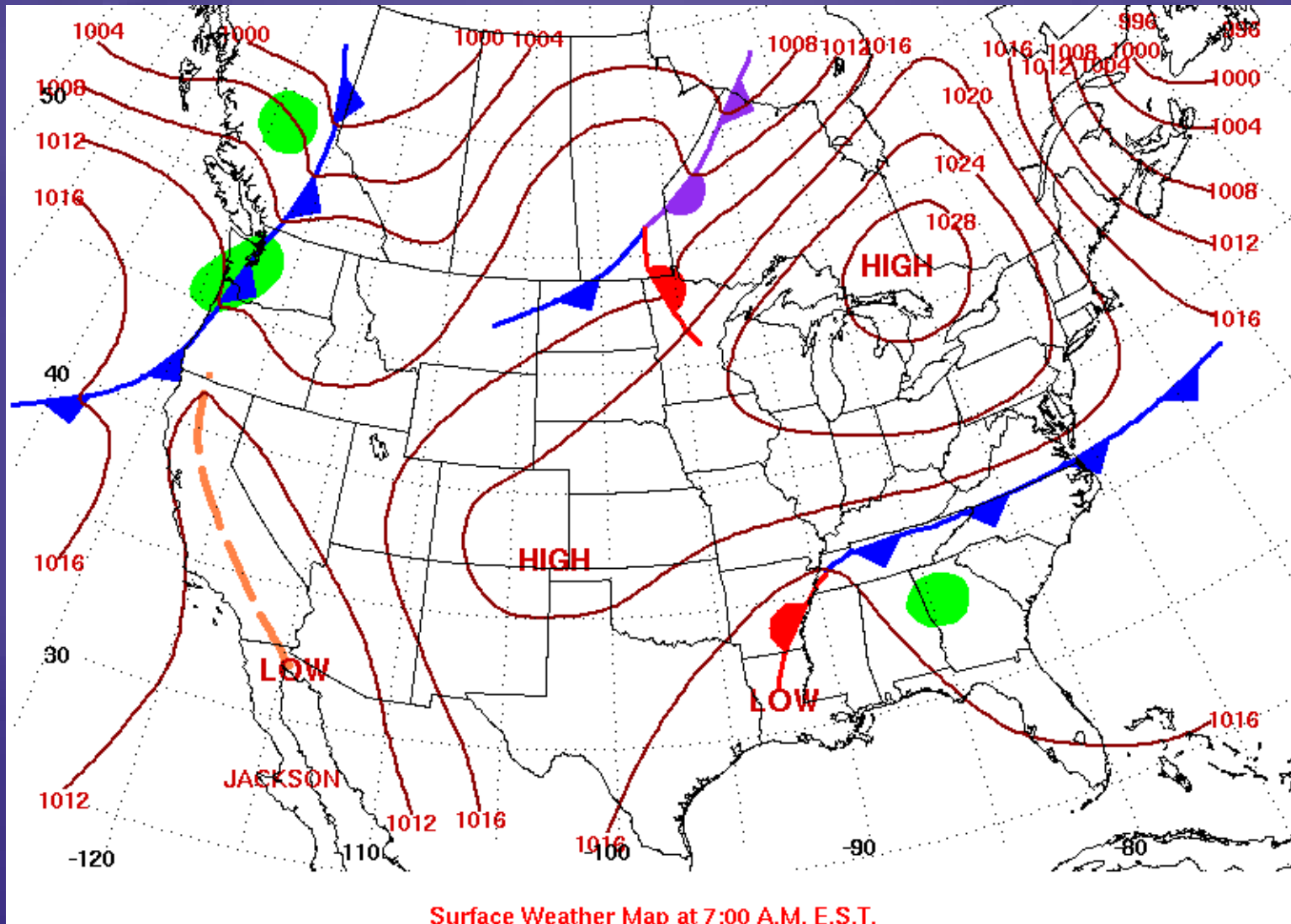
- **From Dec. 1926 through 1927**
  - 27,000 square miles flooded
  - 330,000 rescued from rooftops
  - 1 million homeless in nation of 50 million
- **Hardest hit: state of Mississippi**  
(due to crevasse failure)
  - Area 50 miles wide, 100 miles long covered with up to 20 feet of water
  - Flow of water through crevasse = double Niagara Falls
- **New Orleans leaders blew up downstream levees** to “save” city



# Sept 2009 Northern and Central GA Flooding

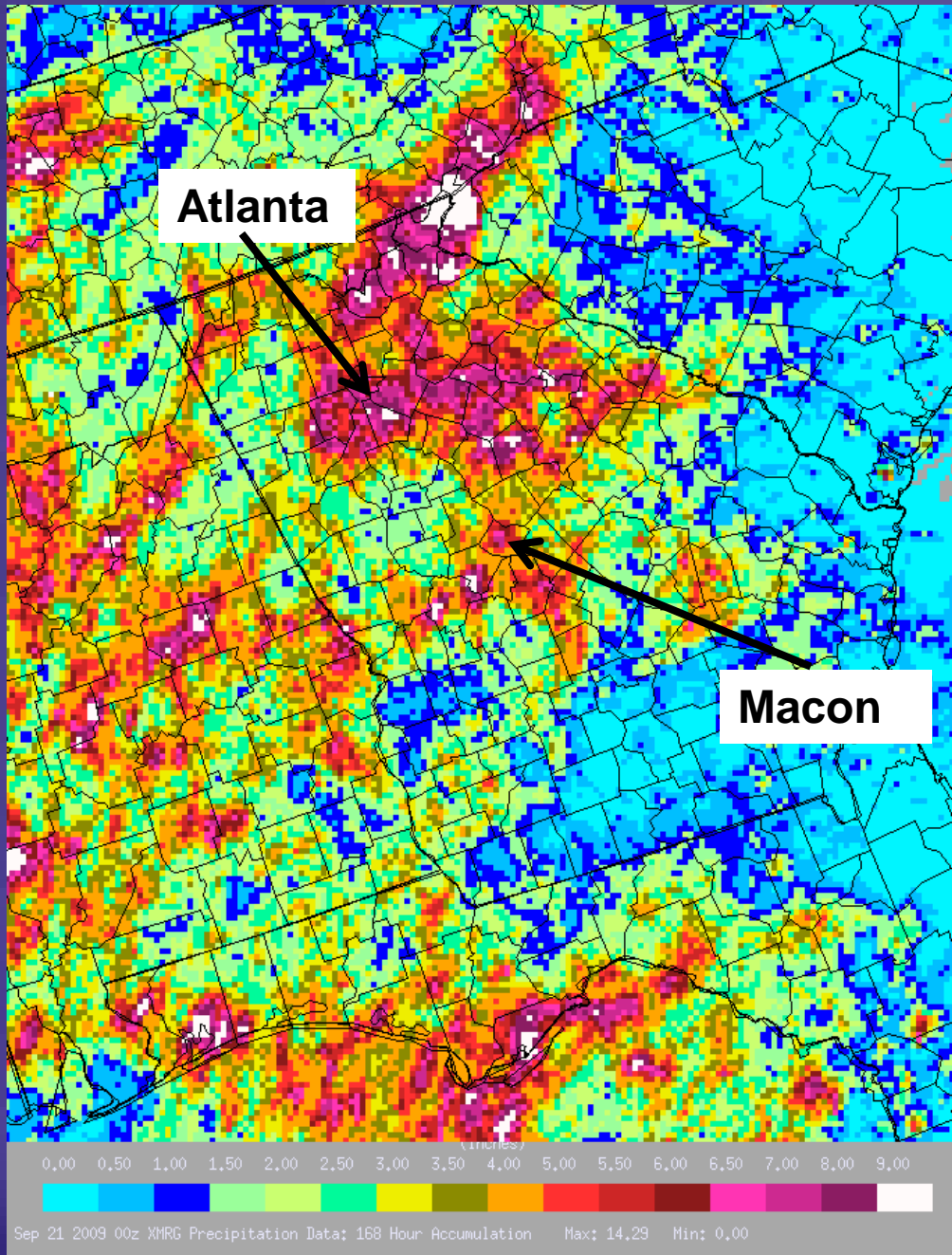
- **Meteorological conditions**
  - Persistent low pressure over the lower Mississippi Valley brought southwest flow of deep Gulf moisture across the Southeast
  - Surface high pressure along the eastern seaboard provided additional moisture from the Atlantic
  - Upper-level impulses passed over the area
  - Result: prolonged period of heavy rain across northern and central Georgia

# Surface map for 7:00 am on Sept 20



<http://www.srh.noaa.gov/images/ffc/sfc090919.gif>

# 7-day precip totals as of Sept 21 at 8:00 pm



- **Rainfall totals**
  - **Atlanta: 11.23"**
  - **Athens: 8.72"**
  - **Gainesville: 10.27"**
  - **Macon: 9.46"**

<http://www.srh.noaa.gov/images/ffc/0909207dayprecip.gif>

# Sept 2009 Northern and Central GA Flooding

- **Hydrological conditions**
  - Soil saturated across the region
  - Streams, lakes, rivers near capacity
  - Urban factors (e.g., impervious surfaces)
  - Result: Lots of runoff, nowhere for the water to go

# Sept 2009 Northern and Central GA Flooding

- Largest streamflow ever recorded on Sweetwater Creek (30.17 feet)
- Chattahoochie River – 30.55 feet
- Flood magnitudes:
  - Cobb and Douglas Counties: 500-year flood (0.2% chance of occurring in a given year)
  - Gwinnett, Dekalb, Rockdale: 100-200 year flood (1.0-0.5% chance of occurring)

# Sept 2009 Northern and Central GA Flooding

- **Impacts**

- \$500 million in damage
- Major damage to ~ 20,000 homes and businesses
- 17 counties declared federal disaster areas
- 10 deaths





Satellite  
photo of  
flooding just  
west of  
Atlanta



## Flooding on I-285

<http://media.al.com/breaking/photo/sixflagsfloodjpg-62cea29cf717a5a9.jpg>

<http://journals.ametsoc.org/doi/pdf/10.1175/2010BAMS3003.1>

Six Flags (roller coaster water slide?)



# Flash flooding event: Albert Pike Recreation Area, AR June 11, 2010

- **Widespread flash flooding** along small creeks and streams in early morning hours
- Little Missouri River **rose nearly 20 feet** in 3.5 hours
- **200-300 campers caught by surprise** by rapidly rising waters
- **Death toll 20, including 6 children**

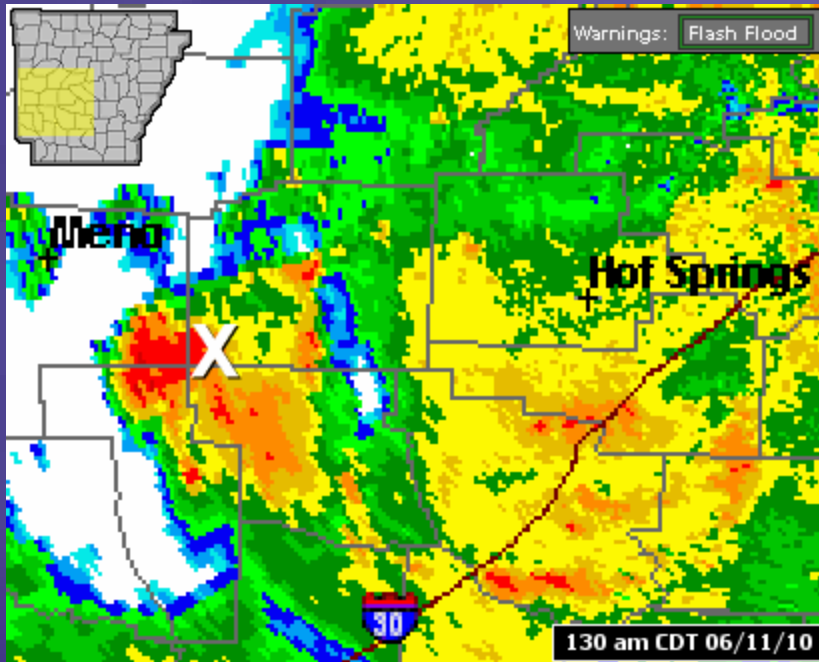


<http://www.srh.noaa.gov/lzk/?n=rain0610.htm>

# Flash flooding event: Albert Pike Recreation Area, AR June 11, 2010

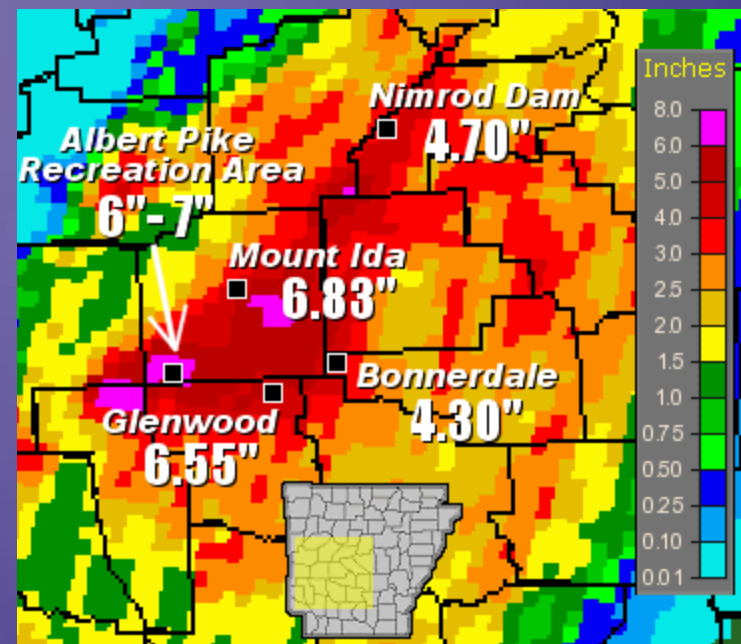


# Flash flooding event: Albert Pike Recreation Area, AR June 11, 2010



- Rainfall rates of **2-3" per hour**
- Storms continually developed and moved over Albert Pike
- Same storm system caused flash flooding in TX on June 9-10

- Rainfall rates, terrain, nature of river, time of day, and location all contributed to disaster



# Flash flooding event: Albert Pike Recreation Area, AR June 11, 2010

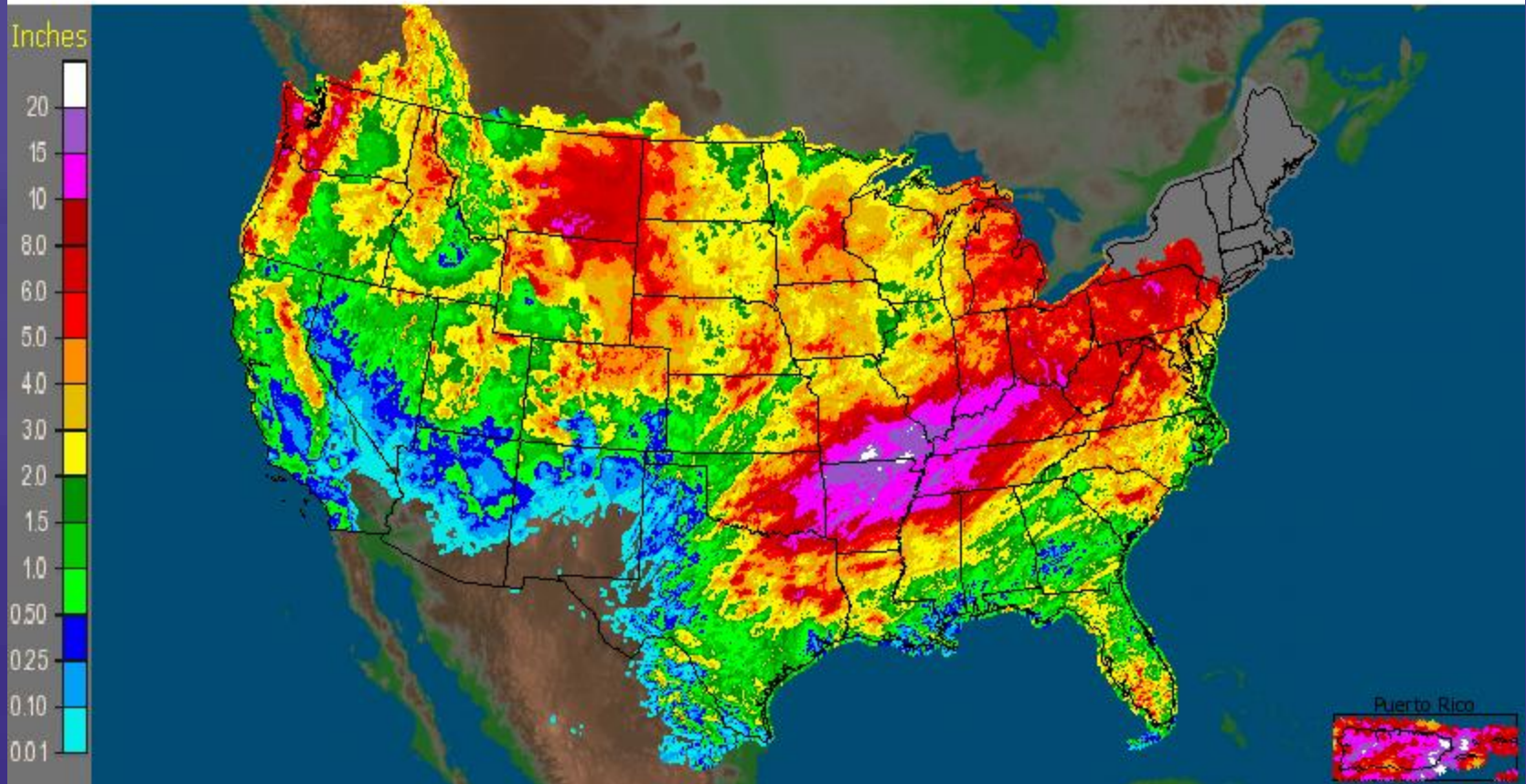


## 2011 historic Mississippi River flood

- Spring snowmelt from the upper Midwest flowed down the Mississippi
- April storm systems dumped record rainfall on the Mississippi River watershed
- Combination has resulted in historic flooding affecting several states

# 30-day observed precipitation

CONUS + Puerto Rico: Current 30-Day Observed Precipitation  
Valid at 5/22/2011 1200 UTC- Created 5/22/11 23:39 UTC



<http://water.weather.gov/precip/?yesterday=1>



# 2011 historic Mississippi River flood

- **Illinois and Missouri**

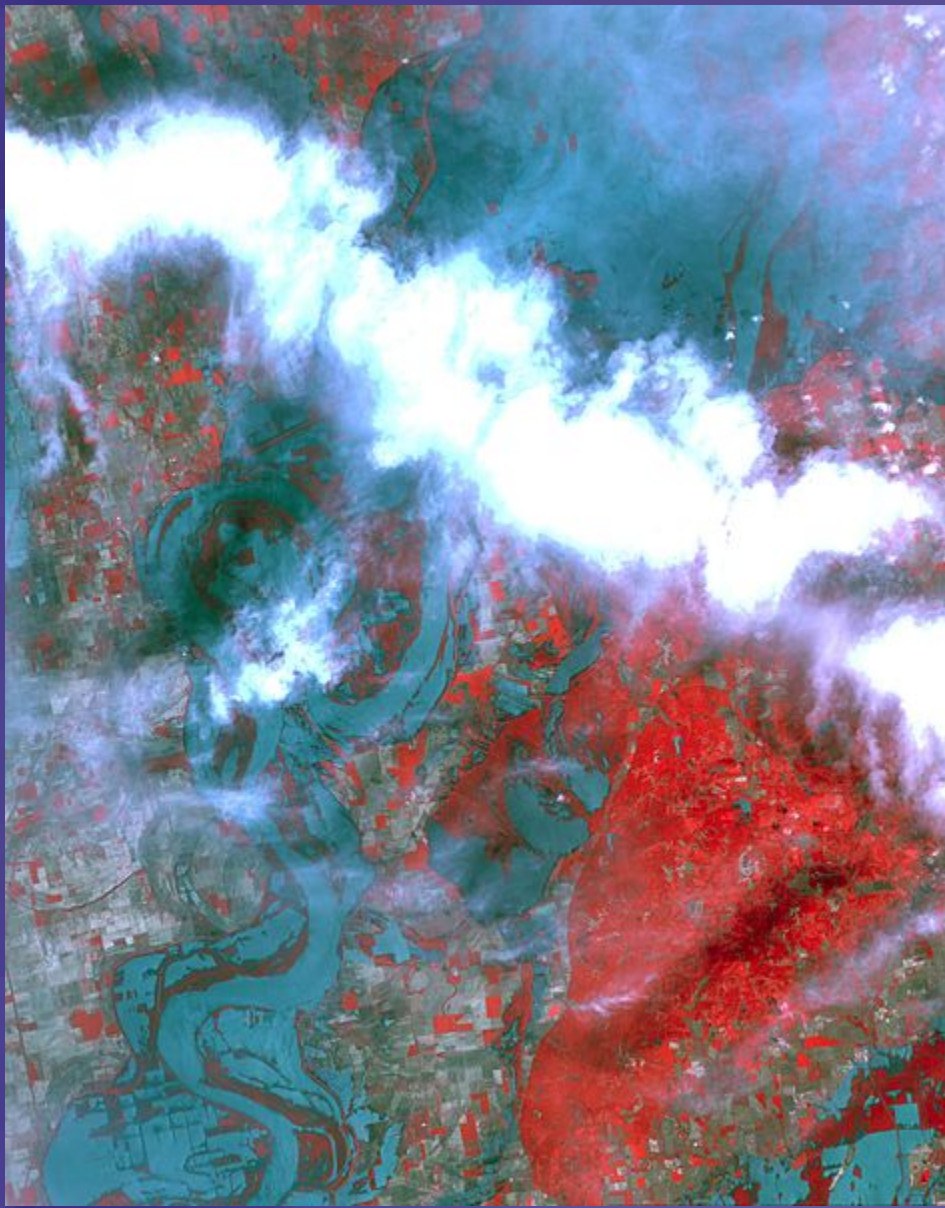
- Birds Point-New Madrid Floodway blasted open to save Cairo, IL, flooding farmland in MO and forcing 200 people to evacuate

- **Tennessee**

- 600 homes and businesses inundated in Dyersburg
- Memphis – 5000+ people evacuated

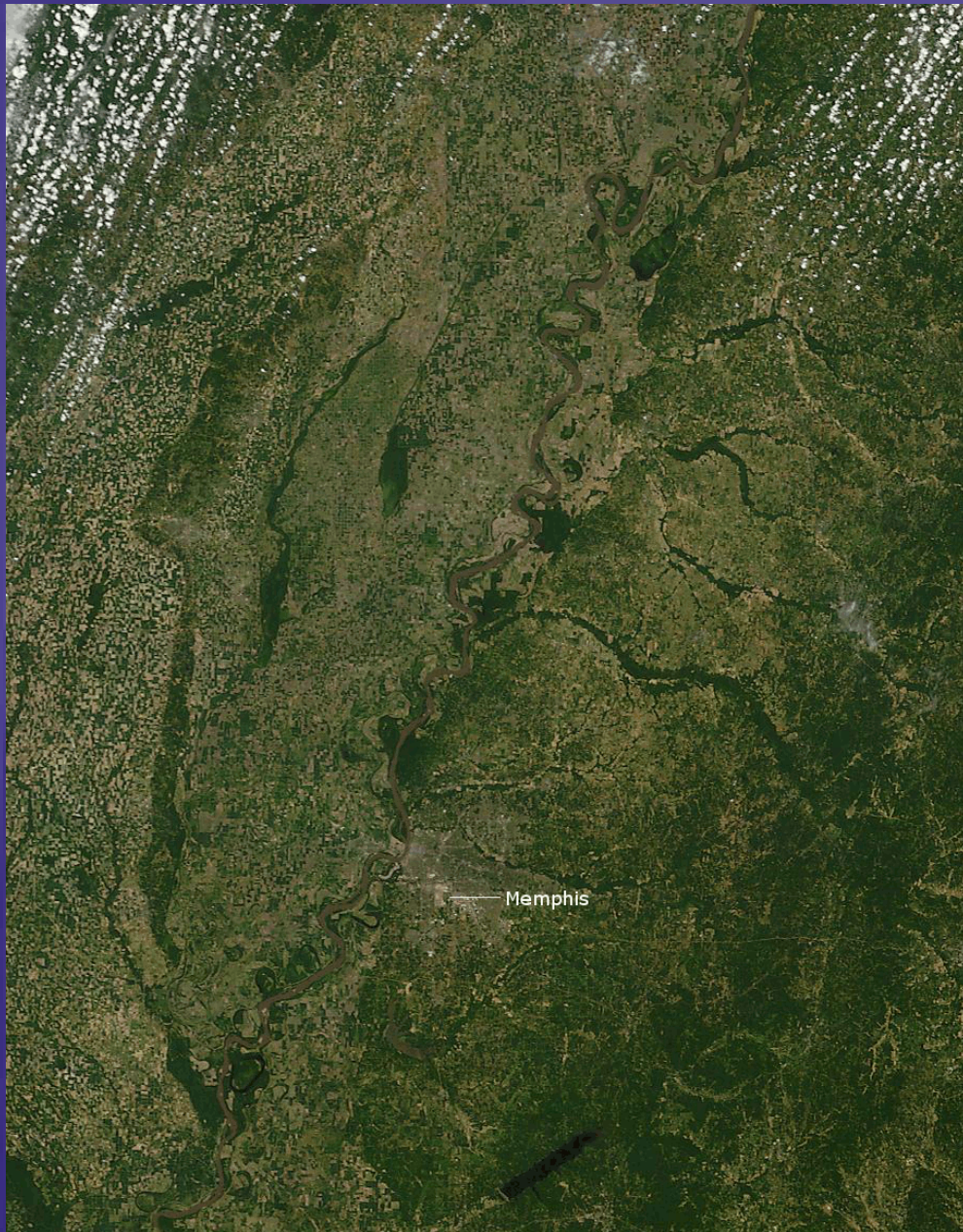
- **Arkansas**

- I-40 flooded, 8 people dead



## Missouri farmland flooding after Birds Point-New Madrid Floodway blasted open

[http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_1942.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_1942.html)



# MODIS satellite comparison of July 2010 vs. early May 2011

[http://www.srh.noaa.gov/images/meg/jul0410\\_may0411.gif](http://www.srh.noaa.gov/images/meg/jul0410_may0411.gif)

# 2011 historic Mississippi River flood

- **Mississippi**

- Casinos closed, parts of highways closed, 13 counties declared federal disaster areas, people urged to evacuate
- Gov. Barbour – “More than anything else, save your life and don't put at risk other people who might have to come in and save your lives.”

# 2011 historic Mississippi River flood

- **Louisiana**

- Morganza Spillway opened to divert water from New Orleans and Baton Rouge, resulting in extensive flooding in Atchafalaya Basin
- Bonnet Carre Spillway near New Orleans opened
- Low lying areas flooded
- Thousands evacuated in MS and LA (many ignoring evacuation orders!)

- **\$2+ billion in damages (so far!)**



**Five days after  
Morganza Spillway  
opened in Louisiana**

**114,000 cubic feet per  
second flowing onto  
floodway**

# HISTORICAL FLOODING CONTINUES...MS RIVER HAS CRESTED AT MS FORECAST POINTS

**Flood Stages**

(All Points Above Flood Stage)

- Memphis** - 34 Ft
- Helena** - 44 Ft
- AR City** - 37 Ft
- Greenville** - 48 Ft
- Vicksburg** - 43 Ft
- Natchez** - 48 Ft

## Helena

**Moderate Flooding**

- Current Stage: 50.3'
- Steady Fall
- Current Record: 60.2' 2/21/1937

## Greenville

**Major Flooding**

- Current Stage: 61.8'
- Steady Fall
- Current Record: 65.4' 4/21/1927

## Vicksburg

**Record Crest**

- Current Stage: 56.1'
- Crested
- Previous Record: 56.2' 5/4/1927

## Memphis

**Moderate Flooding**

- Current Stage: 37.8'
- Steady Fall
- Current Record: 48.7' 2/21/1937

## Arkansas City

**Major Flooding**

- Current Stage: 50.3'
- Steady Fall
- Current Record: 59.2' 4/21/1927

## Natchez

**Record Crest**

- Current Stage: 61.1'
- Crested
- Previous Record: 58.04' 2/21/1937

# Mississippi River Flooding







[http://www.srh.noaa.gov/images/jan/Weather\\_Events/2011/May\\_MS\\_River\\_Flood/Natchez/IMG\\_1821.J](http://www.srh.noaa.gov/images/jan/Weather_Events/2011/May_MS_River_Flood/Natchez/IMG_1821.J)



Photo Credit: Mike Brown, AP



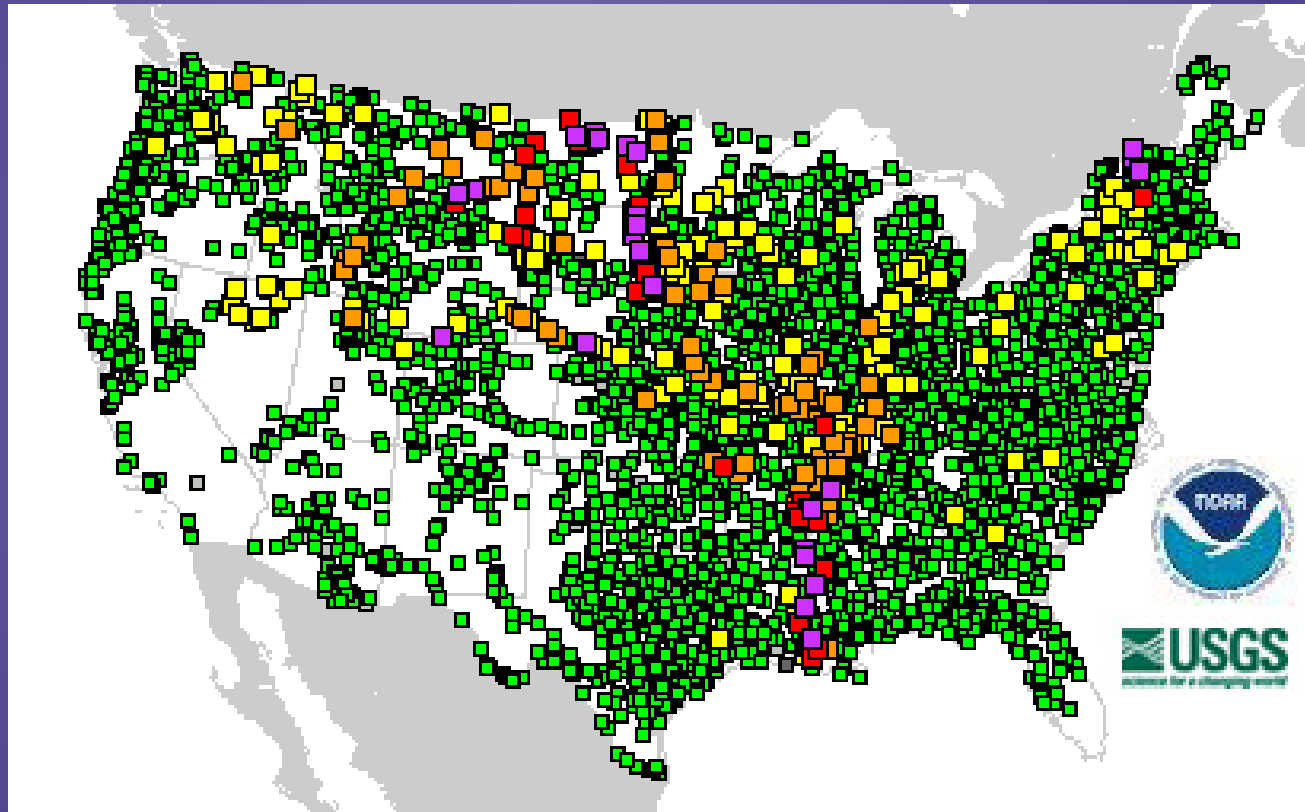
Photo Credit: Brett Duke, Times Picayun



[http://www.monstersandcritics.com/news/usa/features/article\\_1641000.php/Mississippi-Flood-Pictures](http://www.monstersandcritics.com/news/usa/features/article_1641000.php/Mississippi-Flood-Pictures)

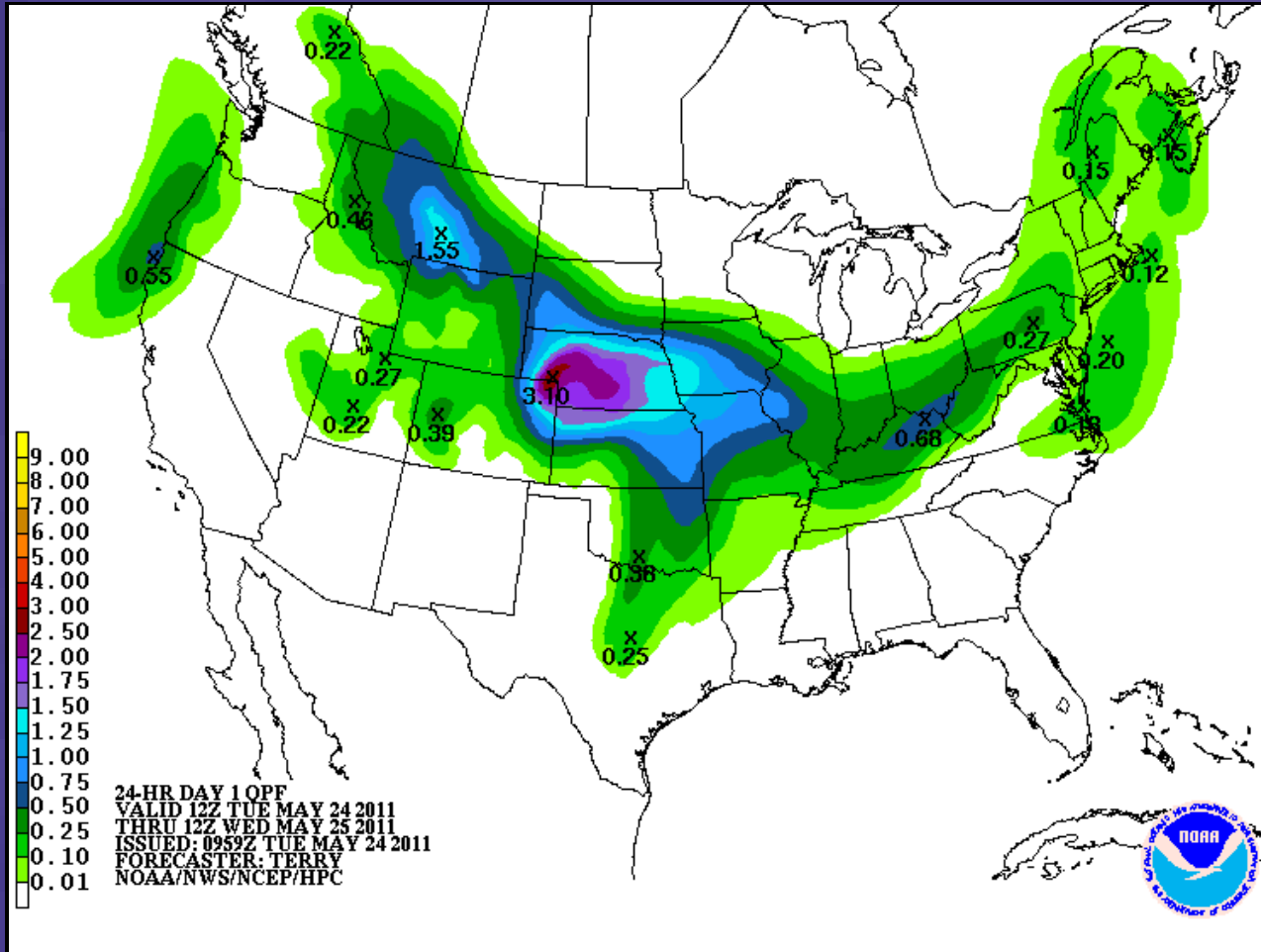
# Meteorology of floods: recent river stages

- 24 Gauges:  
Major  
Flooding
- 29 Gauges:  
Moderate  
Flooding
- 87 Gauges:  
Minor  
Flooding
- 181  
Gauges:  
Near Flood  
Stage
- 4285  
Gauges:  
No  
Flooding



Last map update: 05/23/2011 at 09:15:39 pm EDT.  
From <http://water.weather.gov/ahps/>

# Hydrometeorological Prediction Center Quantitative Precipitation Forecasts

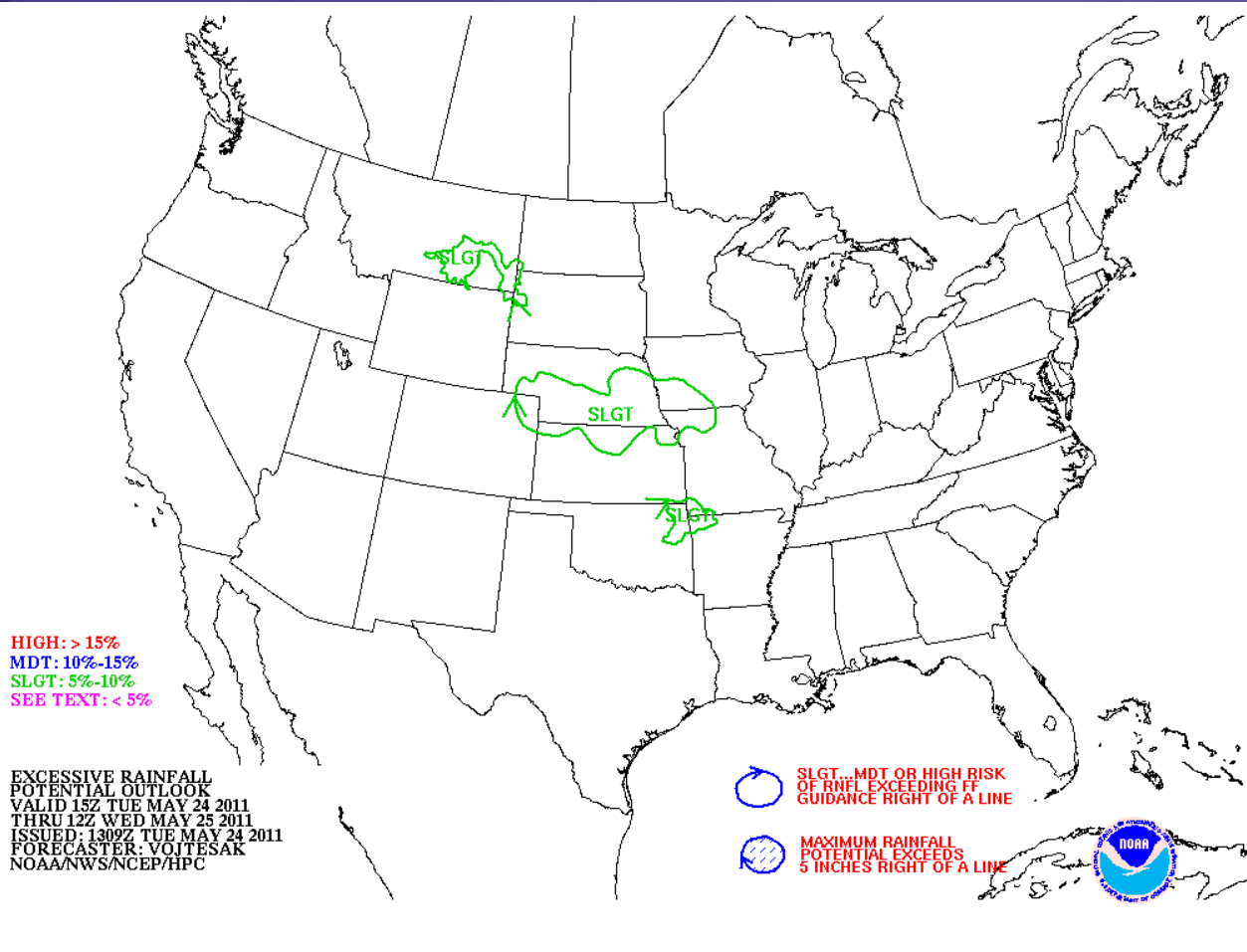


Amount of precipitation forecasted to fall in a given time period (6, 12, or 24 hours)

<http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml>

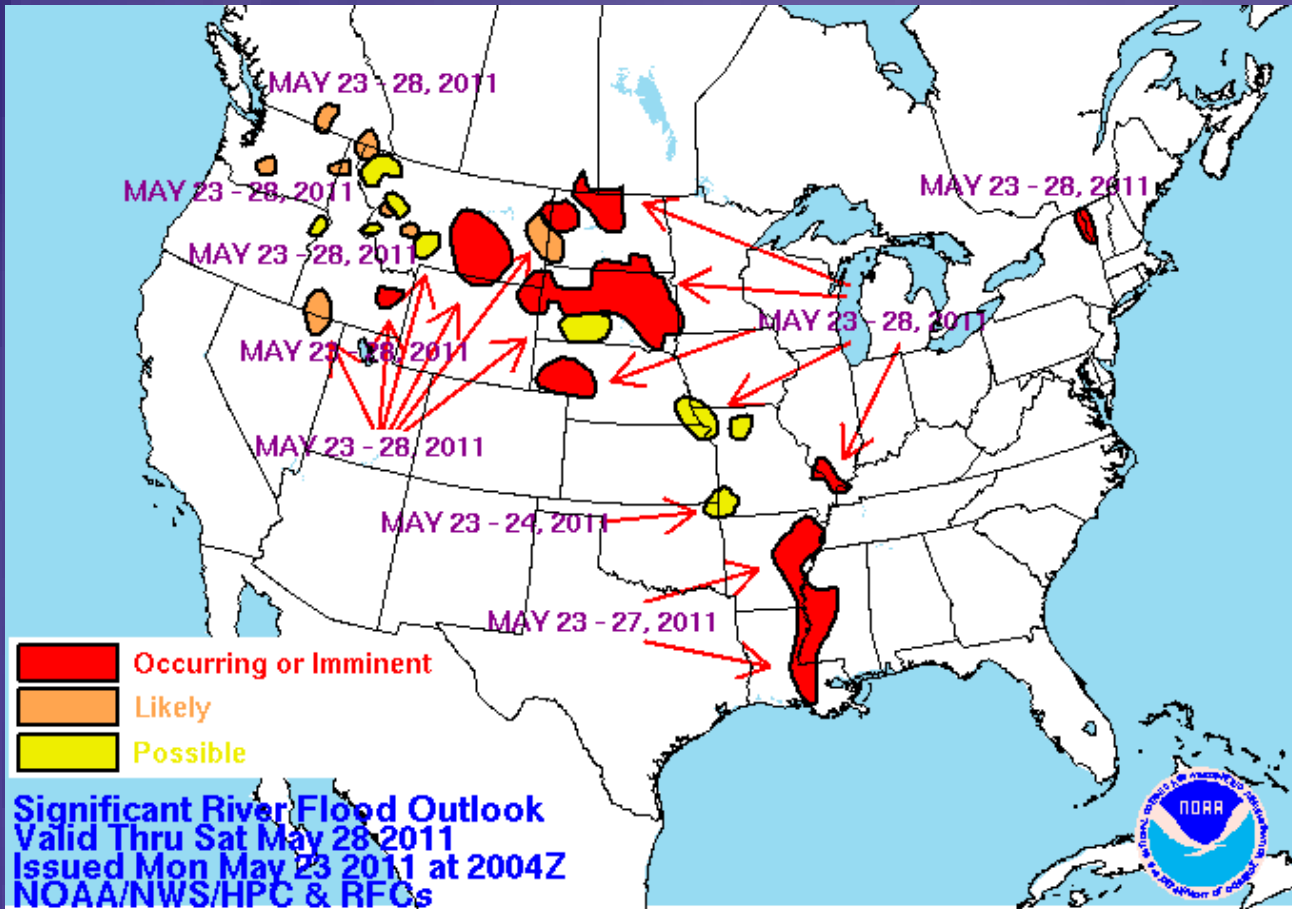
# HPC Excessive Rainfall Forecast

- Flash flooding potential
- Provides probability that precip will exceed flash flood guidance values issued by River Forecast Centers



[http://www.hpc.ncep.noaa.gov/qpf/excess\\_rain.shtml](http://www.hpc.ncep.noaa.gov/qpf/excess_rain.shtml)

# HPC Significant River Flood Outlook



Provides a national overview of areas of flooding

Local river forecasts provided by regional River Forecast Offices

GA – SE River Forecast Office in Peachtree City - <http://www.srh.noaa.gov/serfc/?n=qpfpage>

<http://www.hpc.ncep.noaa.gov/nationalfloodoutlook/index.html>

# Floods aren't always a bad thing!

- **Benefits of floods include**
  - Provide water and nutrient-rich soil for farmland
  - Recharge underground aquifers
  - Replenish wetlands
  - Provide habitat for fish to mature

# Flood safety

- **About 100 Americans per year die due to flooding** (most of any weather hazard except heat)
  - Half are in vehicles, most are males, all ages
- **Before the flood warning**
  - Know your flood risk (e.g., elevation)
  - Assemble emergency kit (food, drinking water, first aid, batteries, etc.)
- **During the flood warning**
  - Get out of low-lying areas
  - Do not drive through flowing waters
    - 6” of moving water can sweep a person off their feet, 18-24” can sweep a car, even an SUV away!
  - Take action even if sky is clear
- **After the flood:** “Move out of the floodplain!”



<http://weathereye.kgan.com/cadet/flood/rules.html>



<http://www.srh.noaa.gov/tadd/index.htm>

# Main sources of information

- Christopherson, R.W., *Geosystems: An Introduction to Physical Geography*, 7th Edition, Prentice-Hall, 2009.
- <http://meted.ucar.edu/>
- <http://www.floodsafety.noaa.gov/>