Droughts Indicators and Triggers

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Sources / Additional Information…

- National Drought Mitigation Center (www.drought.unl.edu)
- American Meteorological Society – Applied Climatology (AMS Statement; www.ametsoc.org)
- US Drought Monitor (NOAA, USDA, NDMC, and community) (www.drought.unl.edu/dm/index.html)

"640K ought to be enough for anybody."
-- Bill Gates, 1981

Droughts are natural hazards
Droughts can affect our day to day life and the socioeconomic impacts can last for years

Drought?

Some characteristics of Drought

- **Recurring temporary event, i.e. not rare, nor random (predictable?), or a permanent feature**
- **Characteristics and impacts vary from region to region**
- **Natural hazard (but human decisions could contribute to the impacts)**
- **Deviation from normal when the regional water budget goes in the deficit**

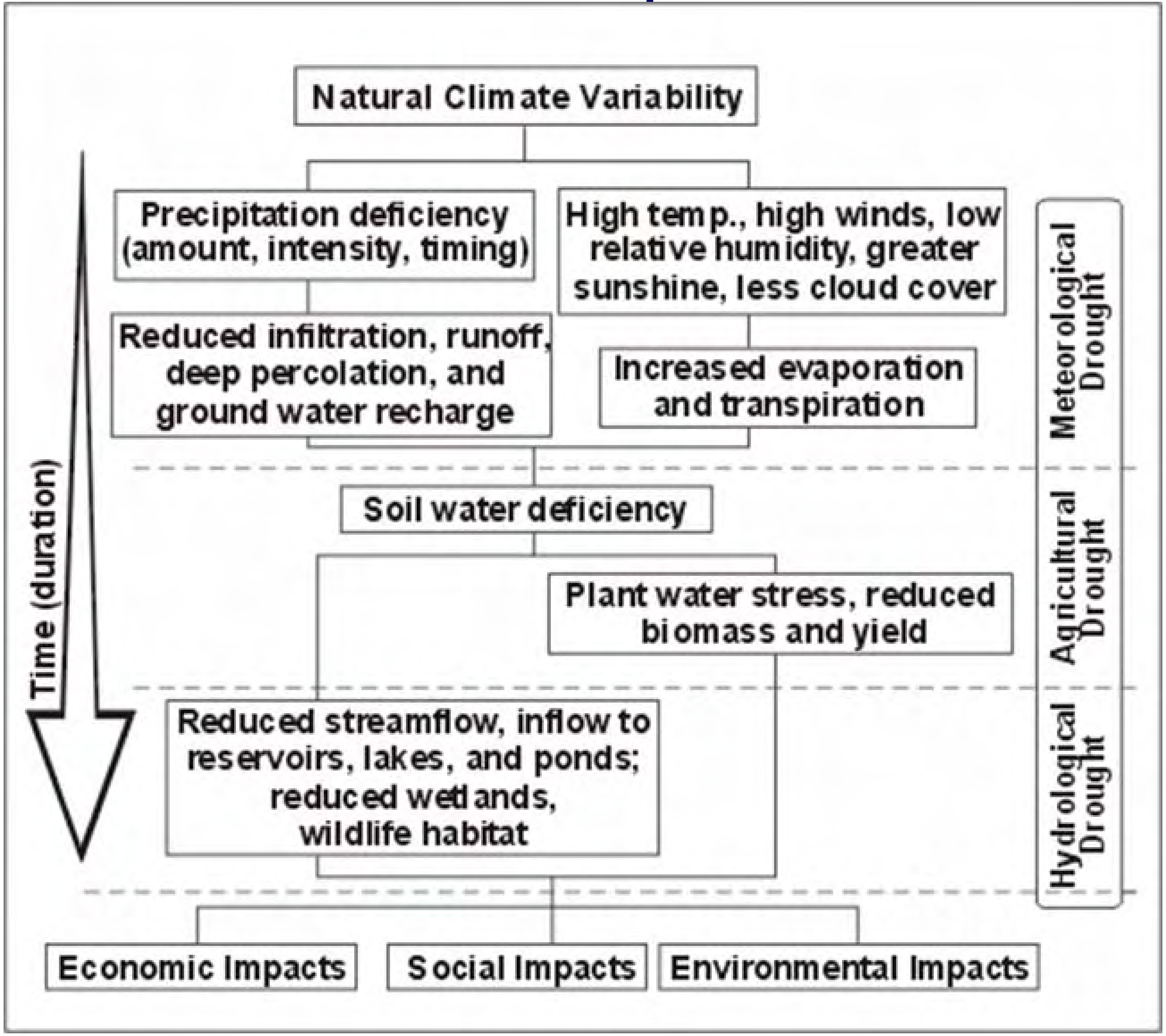
Droughts differ in terms of:

- INTENSITY
- Duration
- Spatial Extent

So what is a 'Drought'?

- Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region.
- In the most general sense, <u>drought originates from a deficiency of precipitation over an extended period of time</u>, resulting in a water shortage for some activity, group, or environmental sector.
- Whatever the definition, it is clear that drought cannot be viewed solely as a physical phenomenon.

WMO Perspective



Recent Drought Losses in the U.S.

1988: $39.2 billion nationwide

1993: $1 billion across the Southeast

1996: $10 billion across the Southwest

1998: $6-8 billion across the South

1999: $1 billion along the East Coast

2000: $1 billion each in Nebraska, Oklahoma, Texas, and Georgia

Average annual losses: $6-8 billion (FEMA)

2002 Estimated Agricultural Drought Losses

- Colorado: $1.1 billion
- Kansas: $1.4 billion
- Missouri: $460 million
- Nebraska: $1.2 billion
- South Dakota: $1.4 billion

2002 Drought Impacts

Wildfires: 7.2 million acres, $1.26 billion

Agricultural:

- Navajo Nation: 7,000 stock ponds dry
- National wheat crop lowest since 1972
- Colorado cattle breeding stock reduced 45-50%
- 1,837 counties declared “primary agricultural disaster area”
- 484 additional counties eligible

Drinking Water:

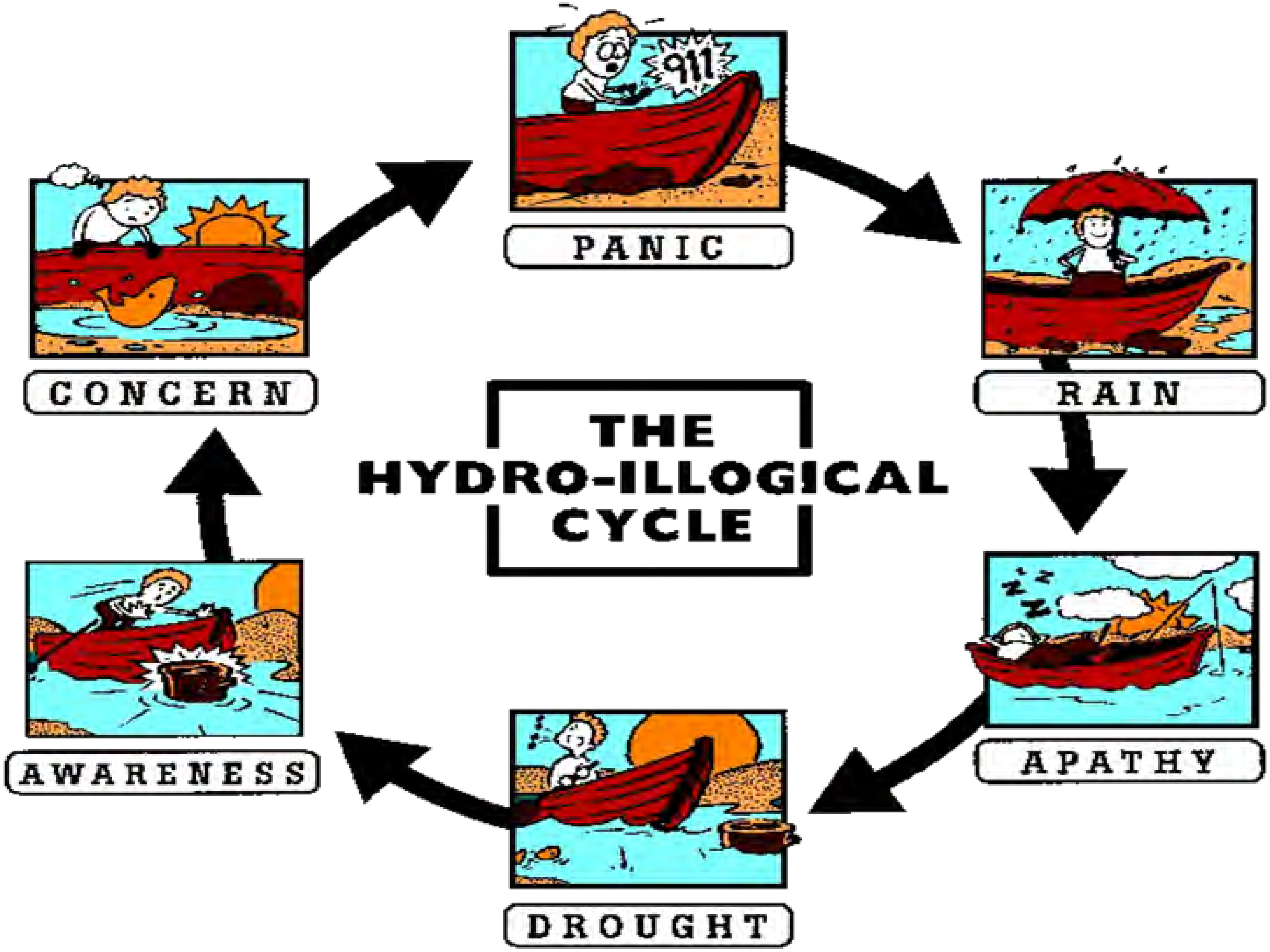
- Maine: 18,000 families had private wells go dry

Environment, Recreation and Tourism, Transportation, Public Health, Energy,…

So if the Governor's office asks.. "Should we declare drought conditions in Indiana??", what information will you seek before making your recommendation?"

Nov 2002 – "Drought brings disaster declaration for 74 Indiana counties"

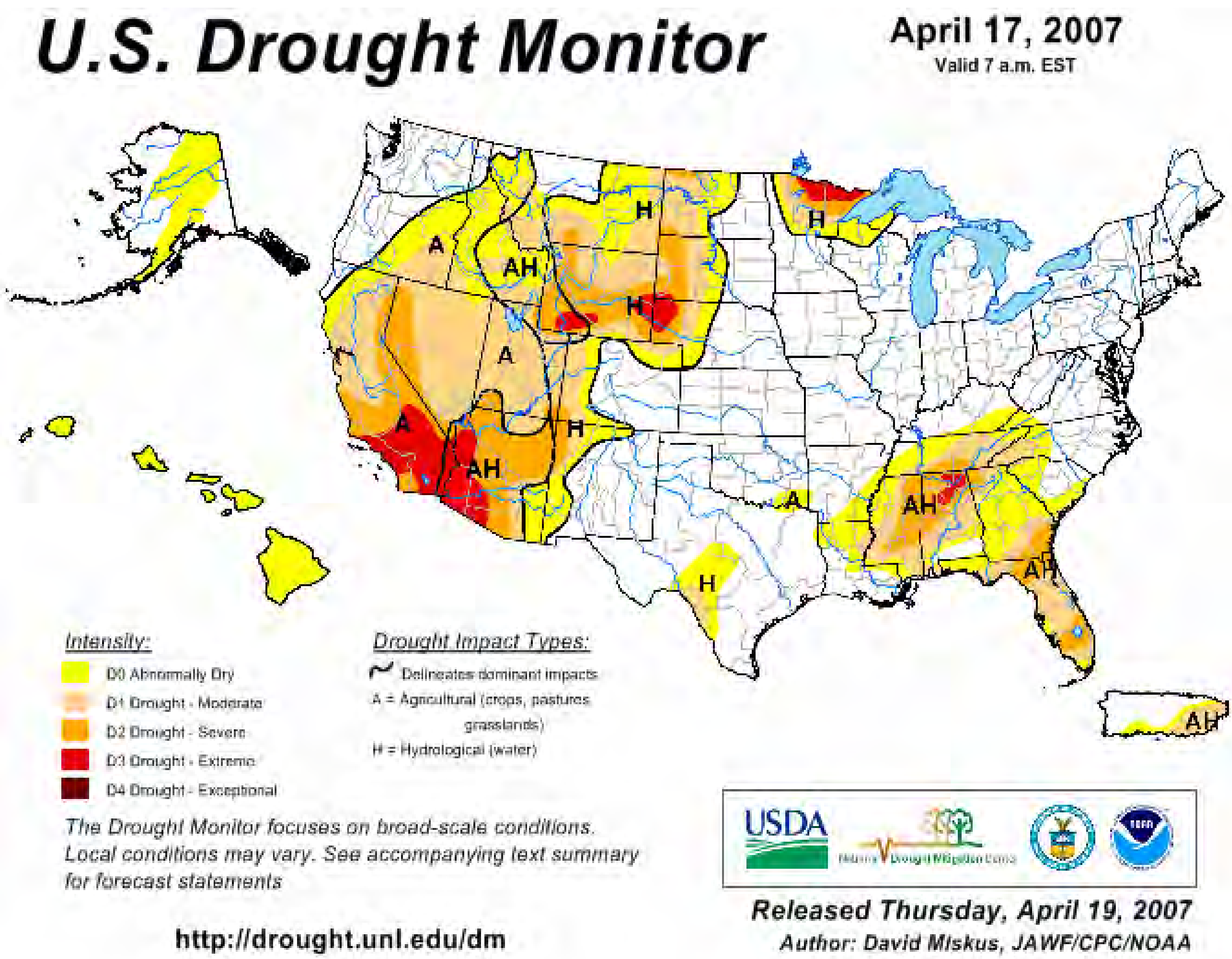
– **…FORT WAYNE, Ind. -- …The declaration, approved by the U.S. Department of Agriculture, will permit farmers in 74 of the state's 92 counties to apply for low-interest emergency loans for crop and livestock losses. Farmers in 13 counties adjacent to the disaster counties can also seek help. ….**



Courtesy: Mike Hayes, NDMC

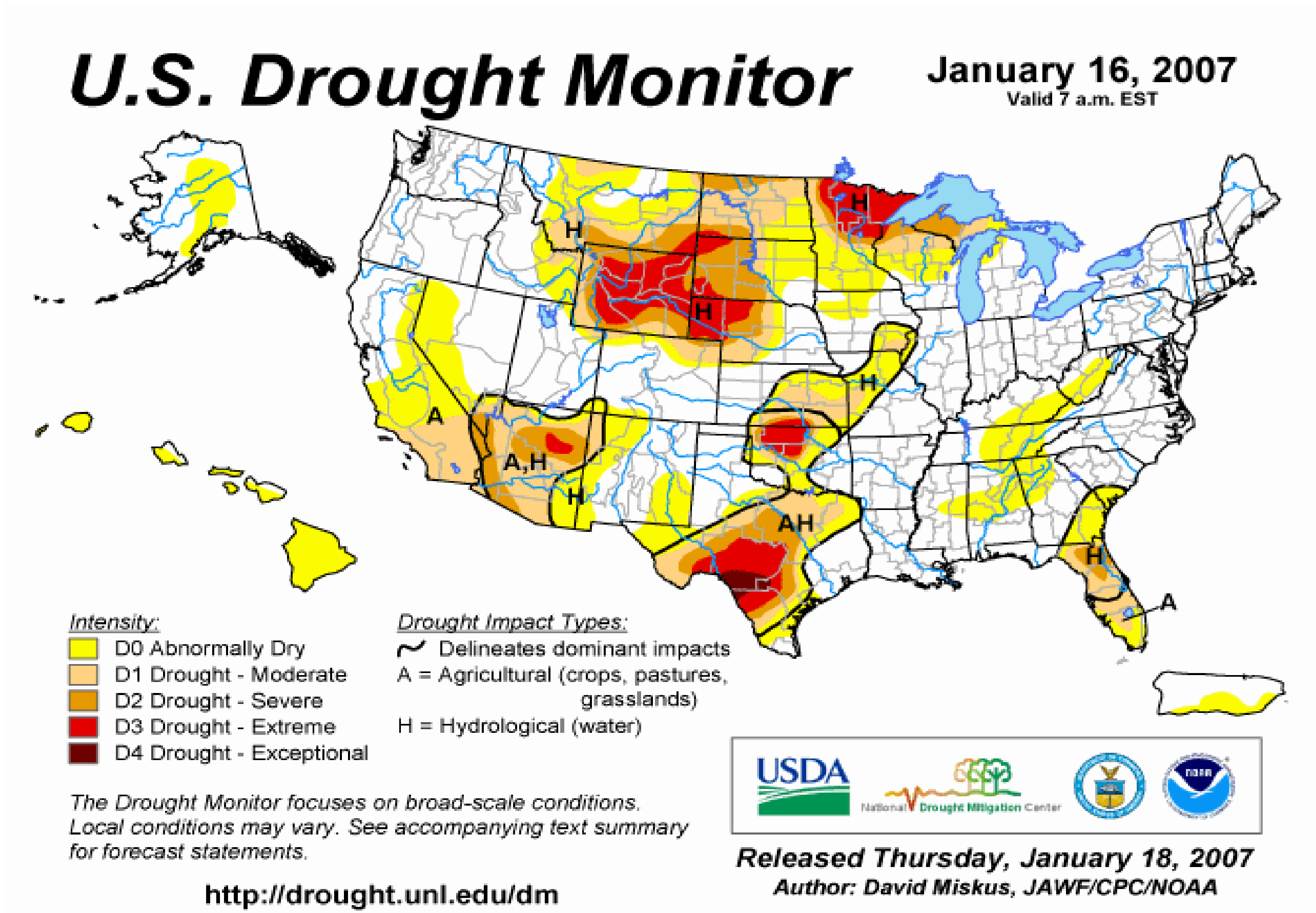
US Drought Monitor

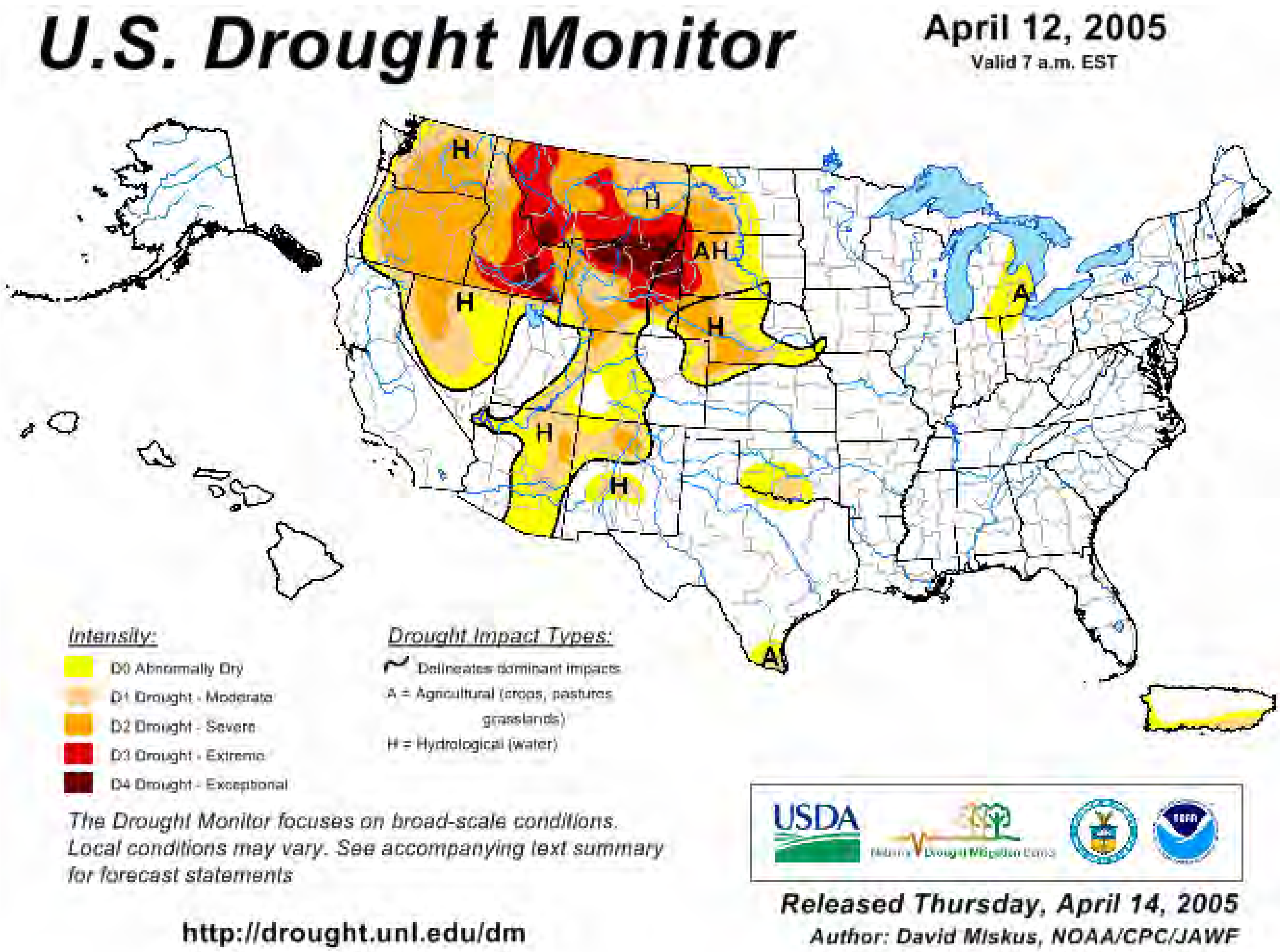
- http://www.drought.unl.edu/dm/monitor.html



U.S. Drought Monitor
April 17, 2007
Valid 7 a.m. EST
A
AH
H
A
H
H
A
AH
H
A
AH
H
AH
AH
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
http://drought.unl.edu/dm
USDA
Released Thursday, April 19, 2007
Author: David Miskus, JAWF/CPC/NOAA

http://www.drought.unl.edu/dm/6_week.gif




U.S. Drought Monitor
April 12, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
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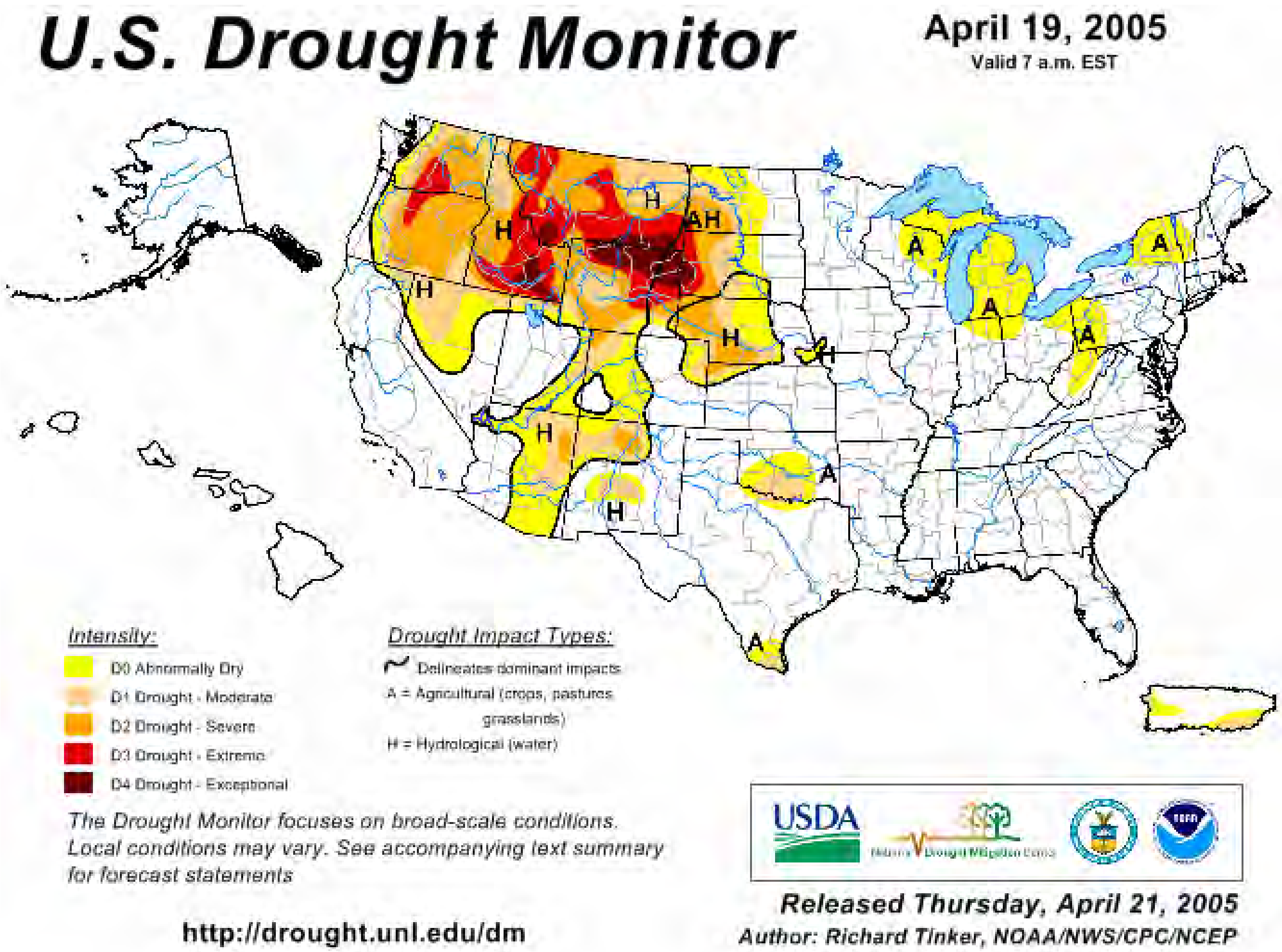
USDA
http://drought.unl.edu/dm
Released Thursday, April 14, 2005
Author: David Miskus, NOAA/CPC/JAWF



U.S. Drought Monitor
April 19, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
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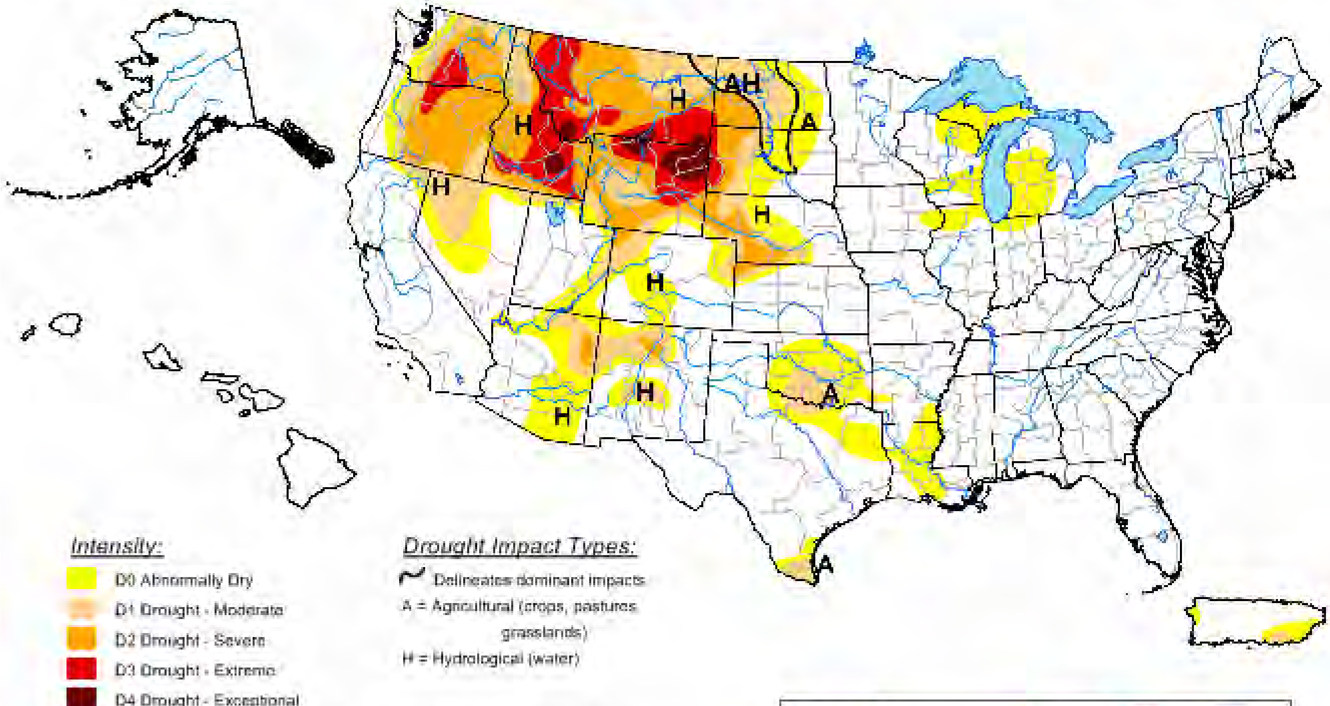
http://drought.unl.edu/dm
USDA
Released Thursday, April 21, 2005
Author: Richard Tinker, NOAA/NWS/CPC/NCEP

U.S. Drought Monitor

April 26, 2005
Valid 7 a.m. EST



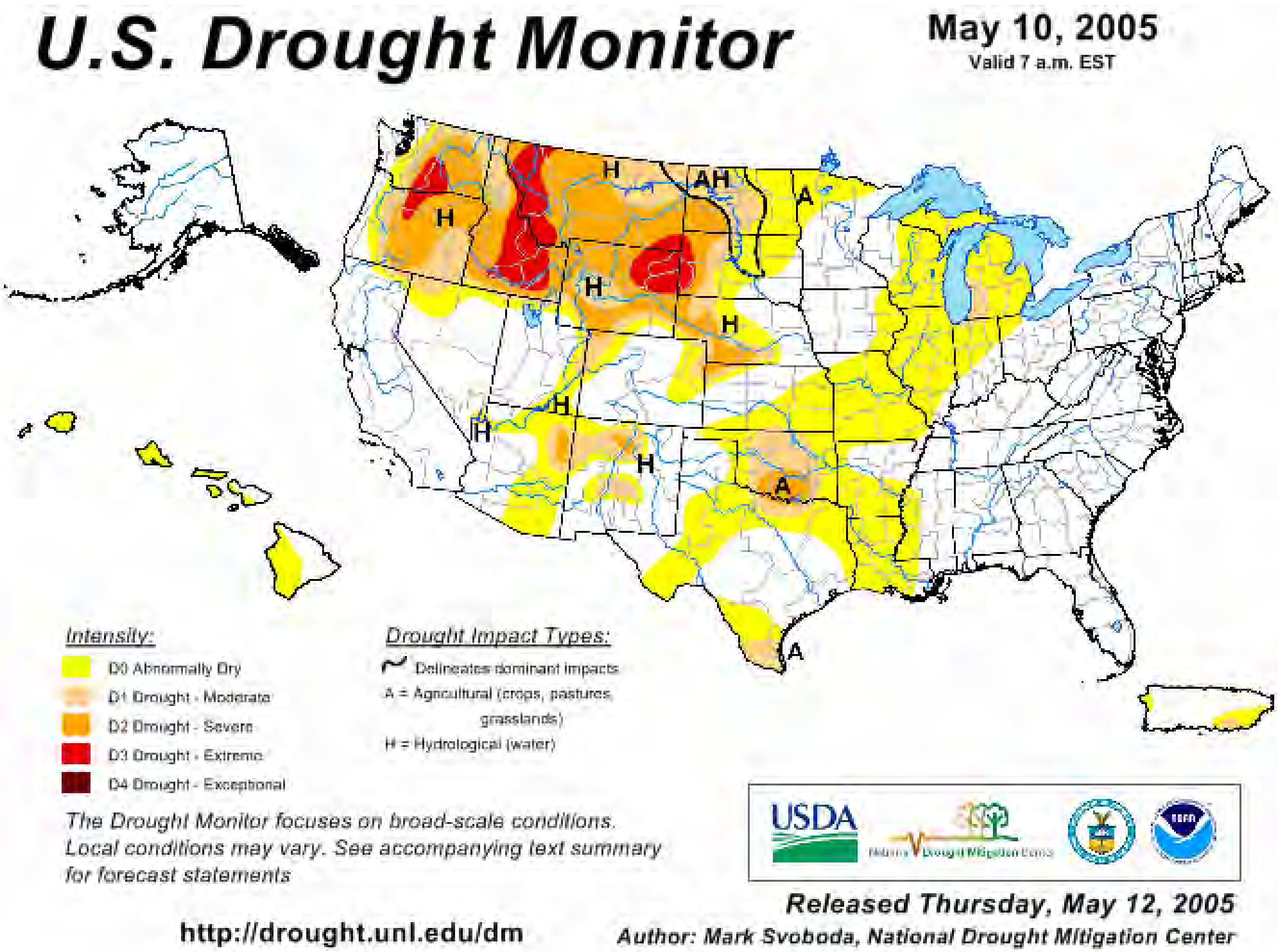
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements

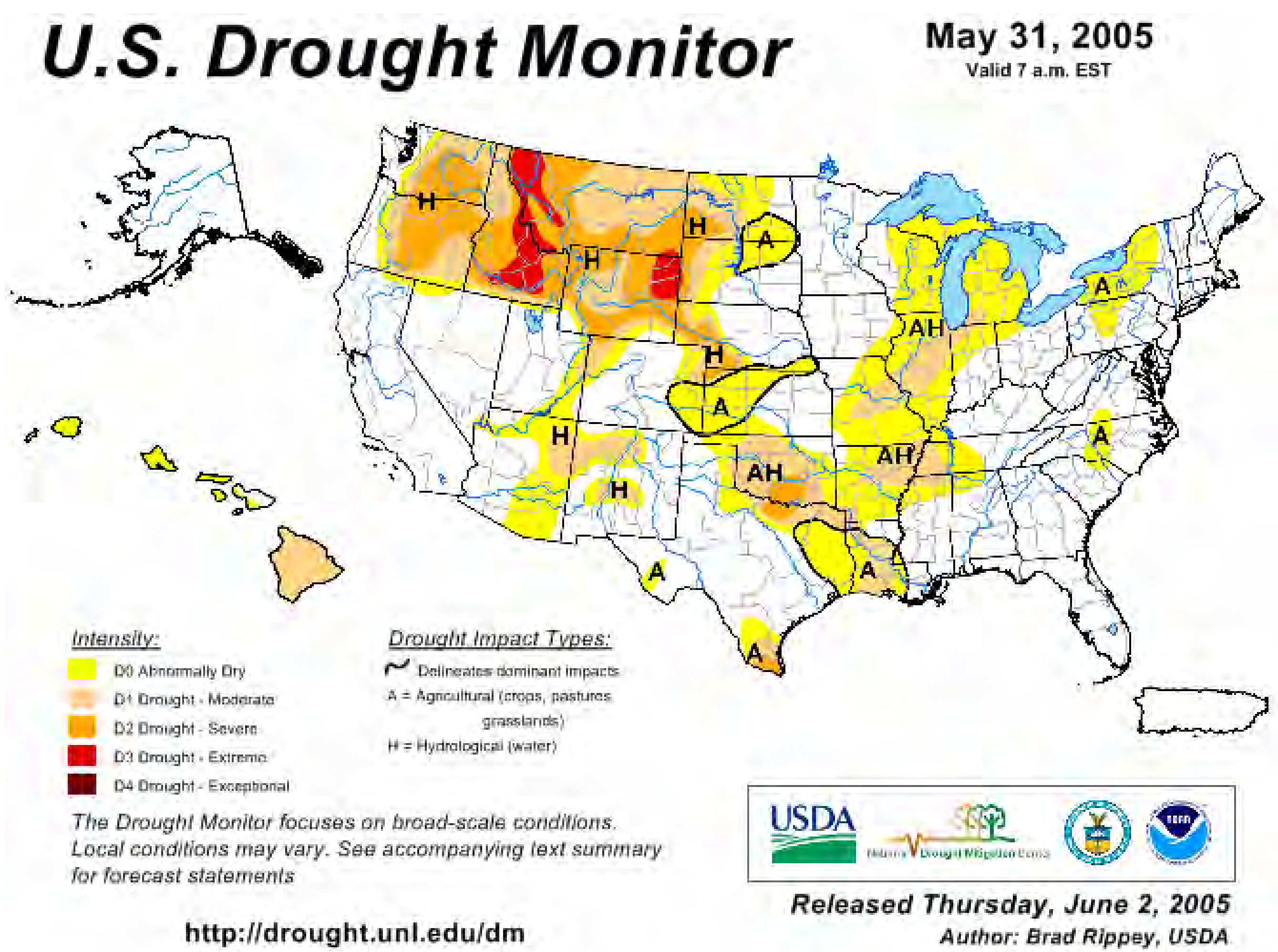
USDA

http://drought.unl.edu/dm

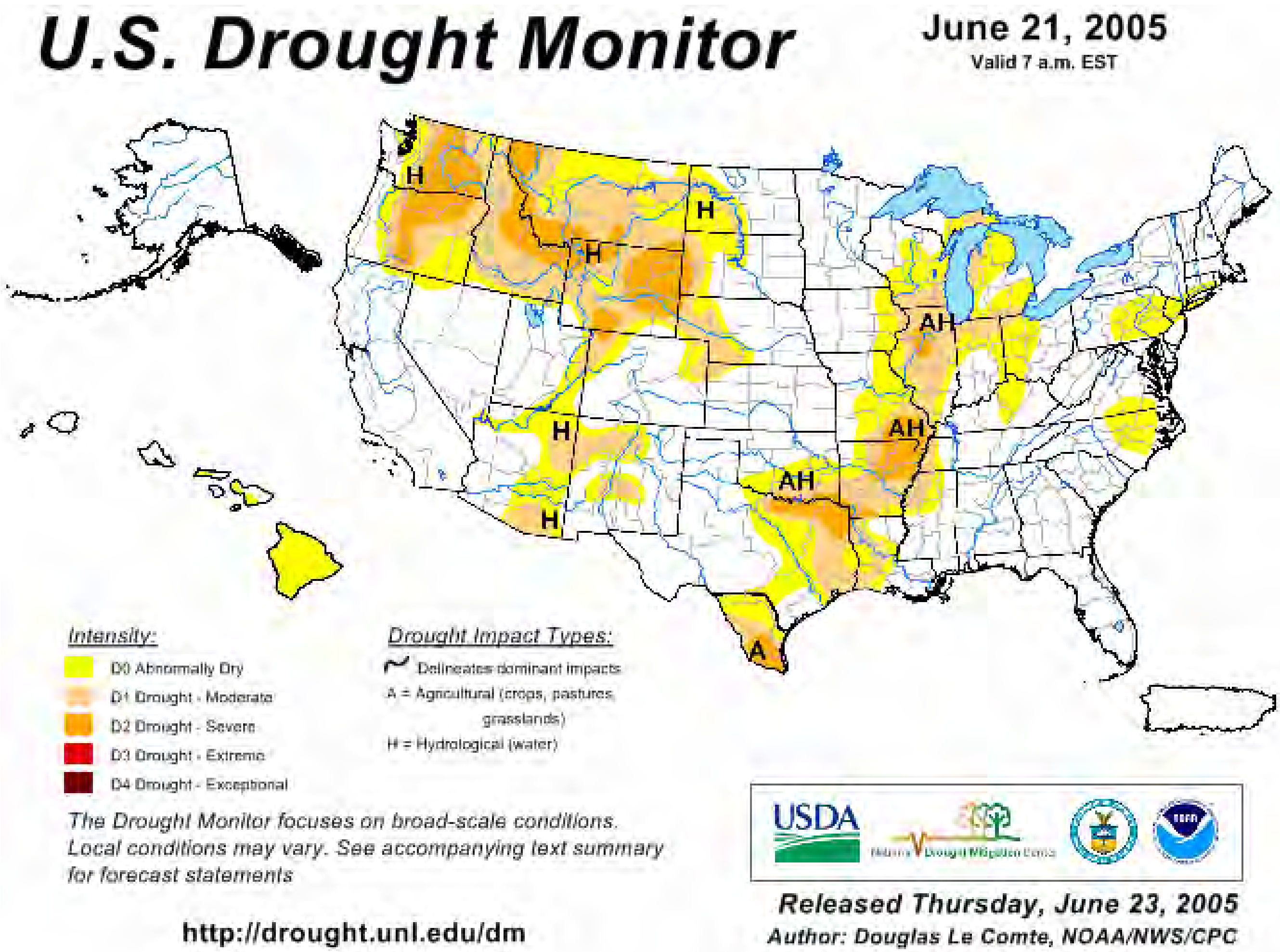
Released Thursday, April 28, 2005

Author: Richard Tinker, NOAA/NWS/CPC/NCEP


U.S. Drought Monitor
May 10, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
USDA
Released Thursday, May 12, 2005
http://drought.unl.edu/dm
Author: Mark Svoboda, National Drought Mitigation Center



U.S. Drought Monitor
May 31, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
http://drought.unl.edu/dm
USDA
Released Thursday, June 2, 2005
Author: Brad Rippey, USDA


U.S. Drought Monitor
June 21, 2005
Valid 7 a.m. EST
H
H
H
AH
H
AH
AH
H
A
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
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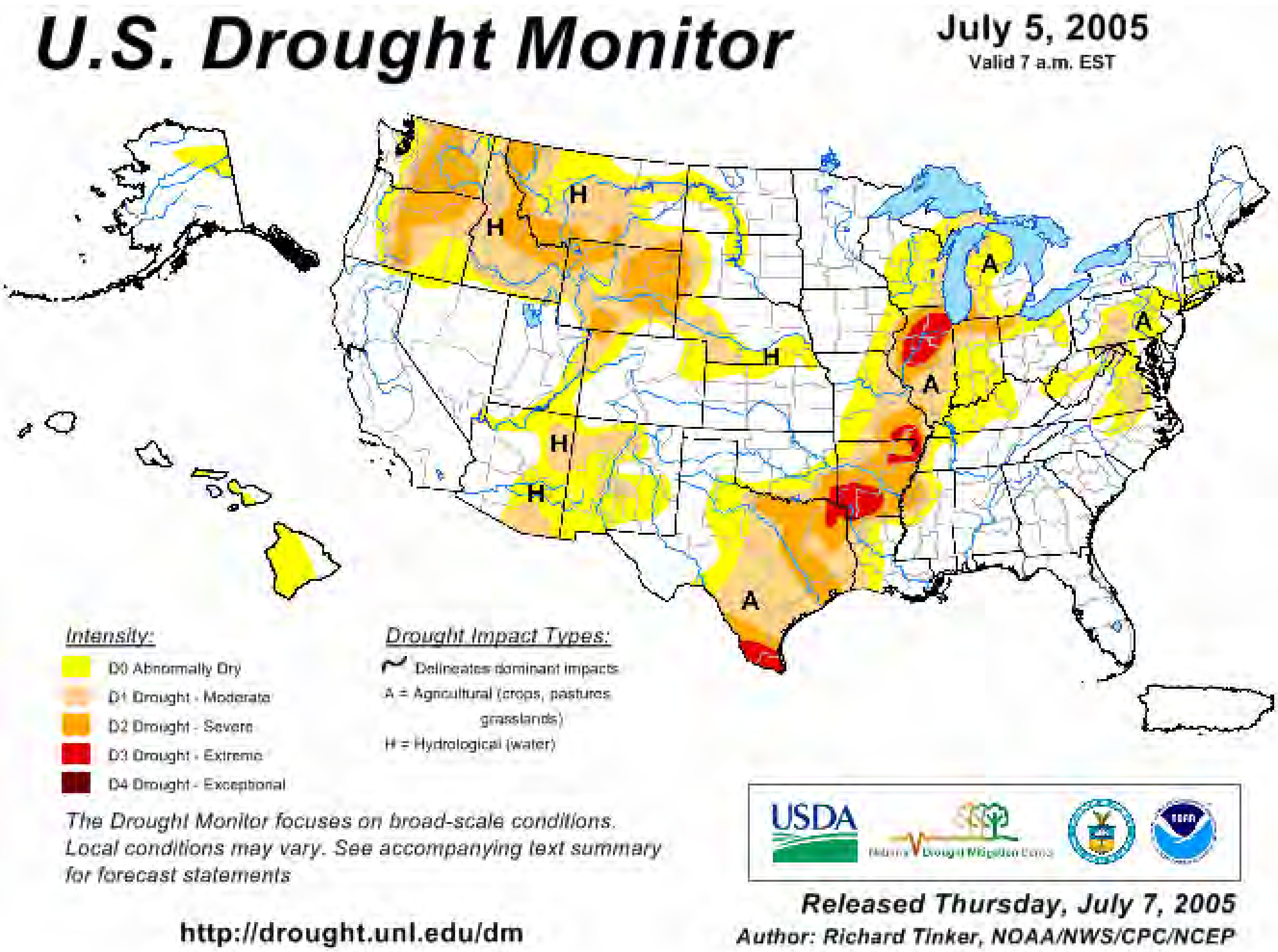
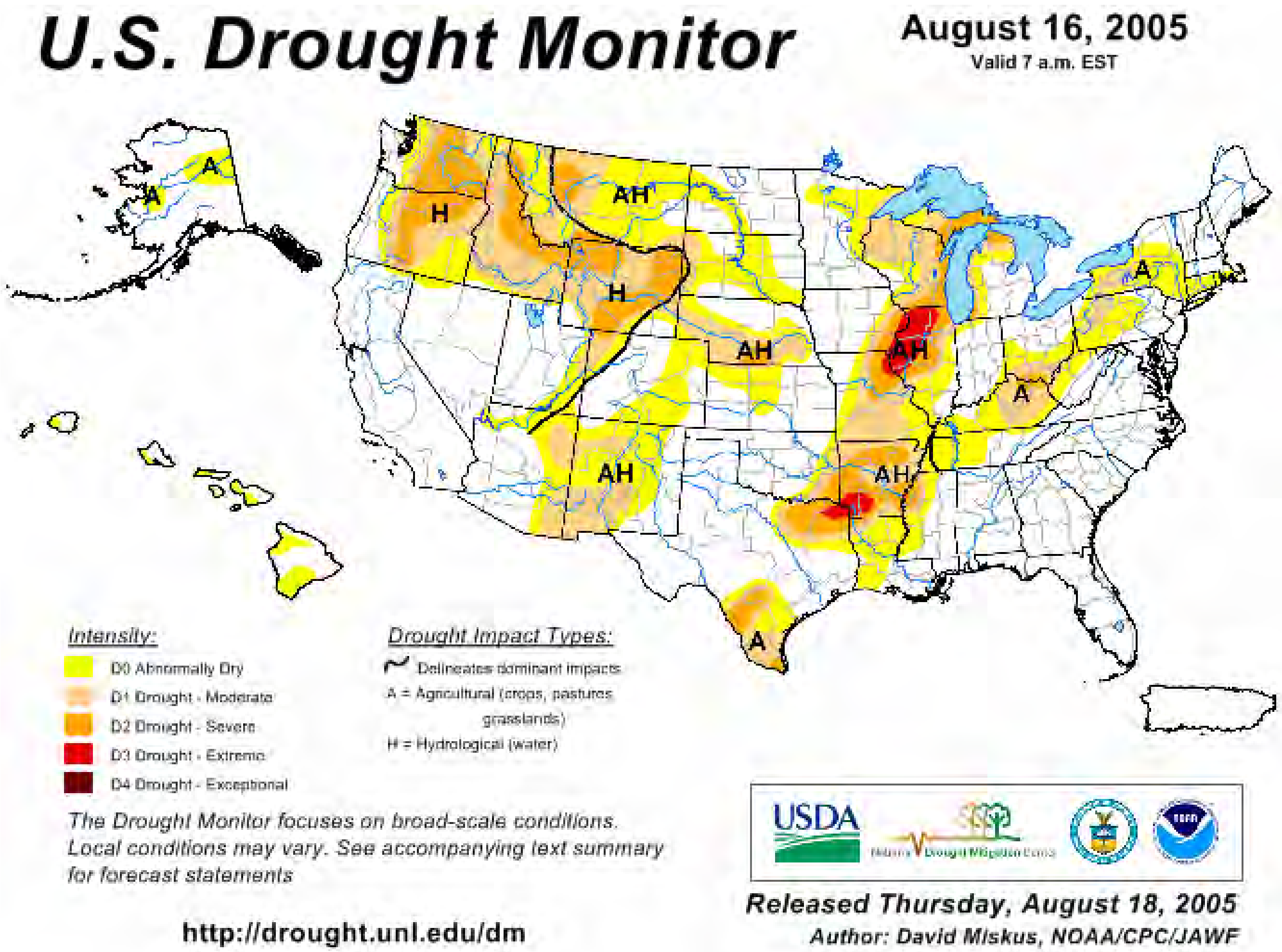
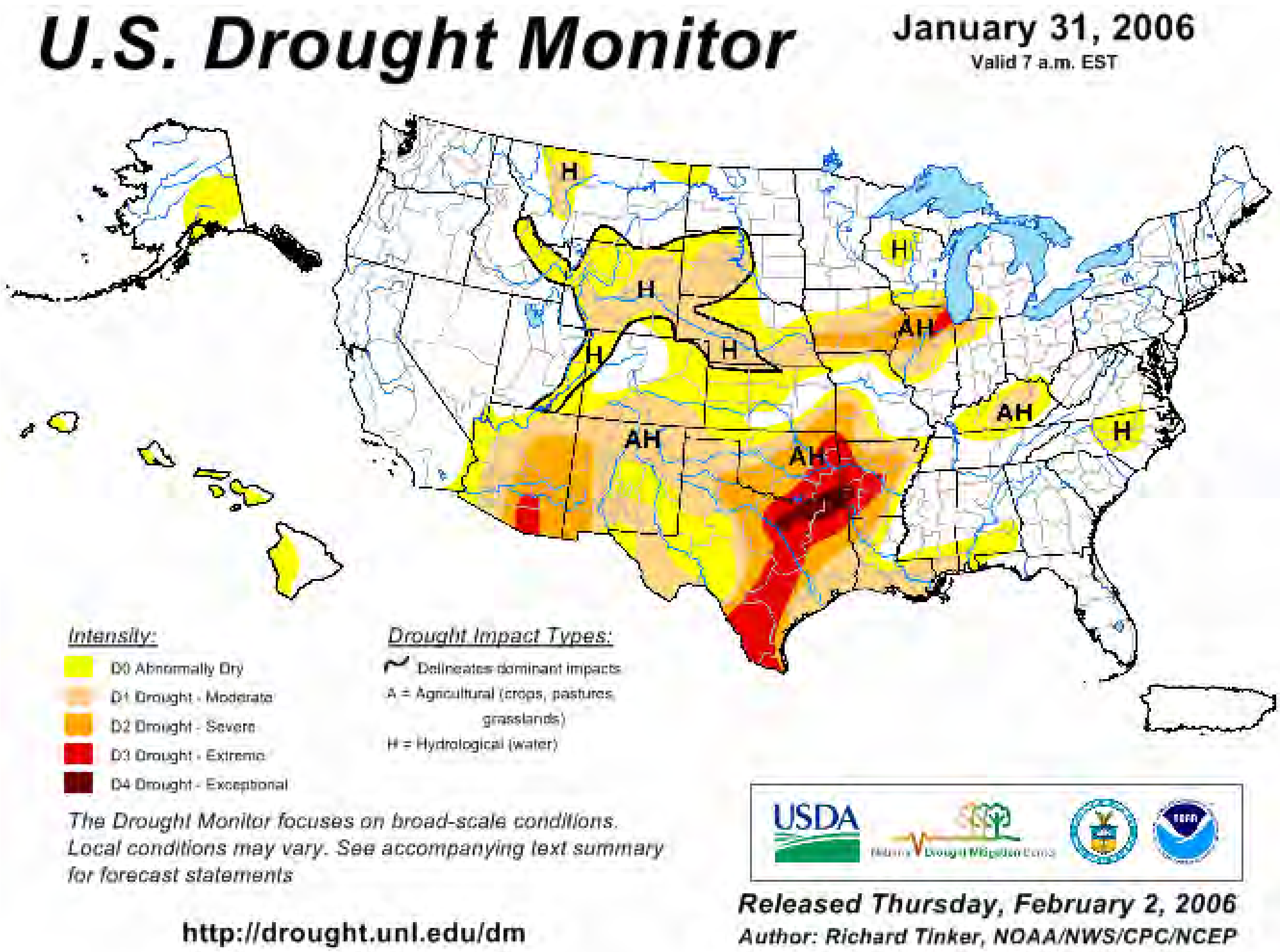
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
USDA
http://drought.unl.edu/dm
Released Thursday, June 23, 2005
Author: Douglas Le Comte, NOAA/NWS/CPC


U.S. Drought Monitor
July 5, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
http://drought.unl.edu/dm
USDA
Released Thursday, July 7, 2005
Author: Richard Tinker, NOAA/NWS/CPC/NCEP


U.S. Drought Monitor
August 16, 2005
Valid 7 a.m. EST
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
http://drought.unl.edu/dm
USDA
Released Thursday, August 18, 2005
Author: David Miskus, NOAA/CPC/JAWF


U.S. Drought Monitor
January 31, 2006
Valid 7 a.m. EST
H
H
H
H
H
AH
AH
AH
AH
H
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
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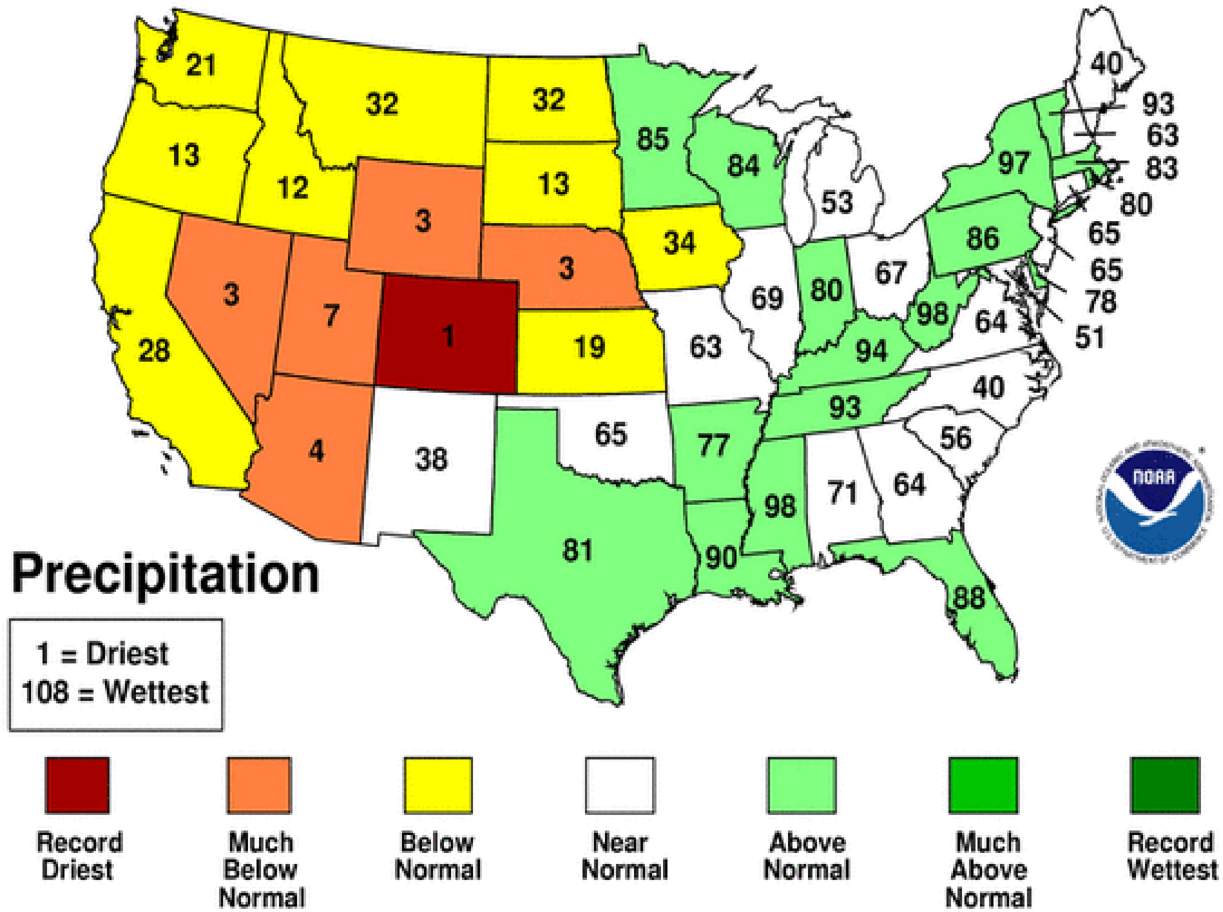
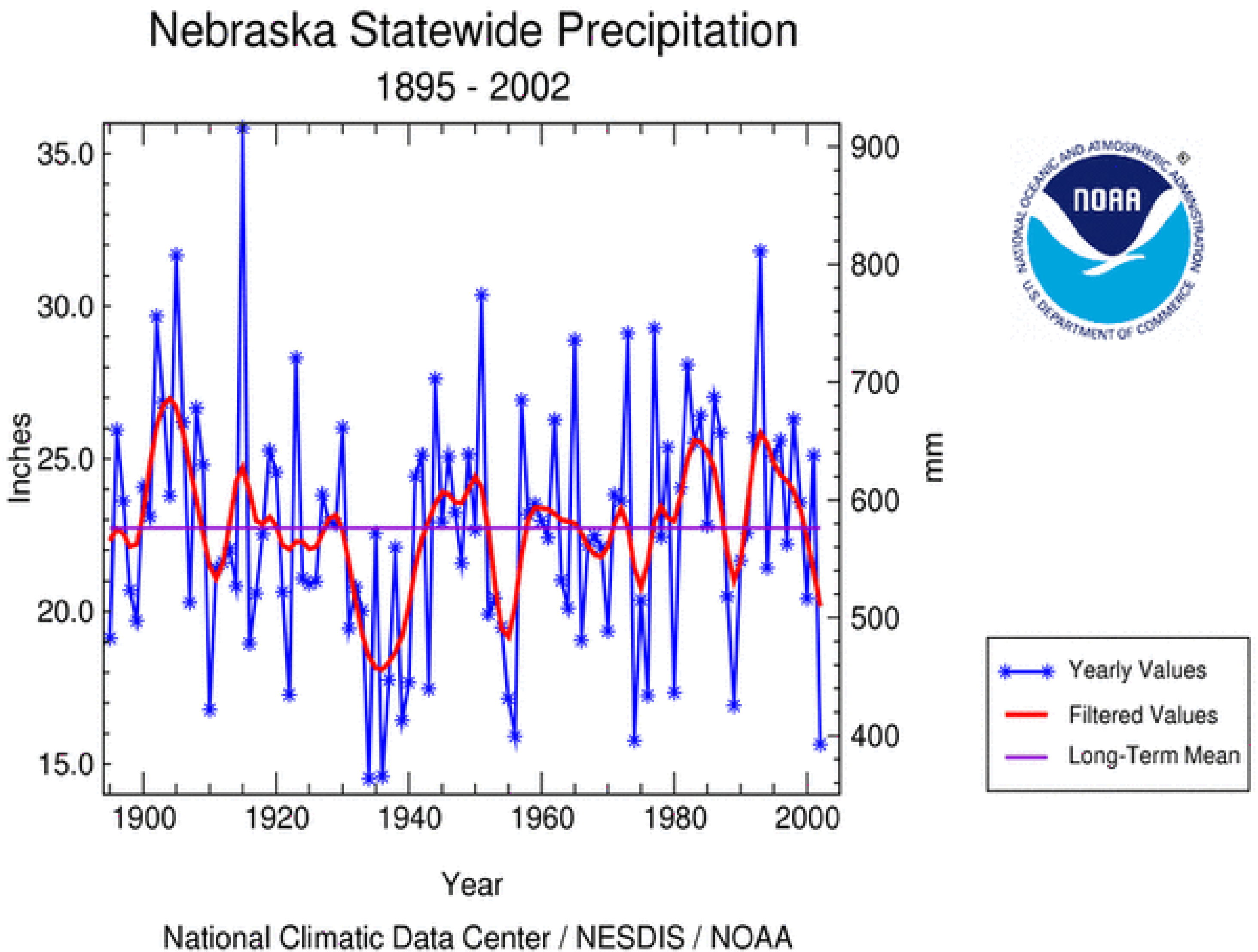
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements
http://drought.unl.edu/dm
USDA
Released Thursday, February 2, 2006
Author: Richard Tinker, NOAA/NWS/CPC/NCEP

- Methods for identifying/assessing droughts

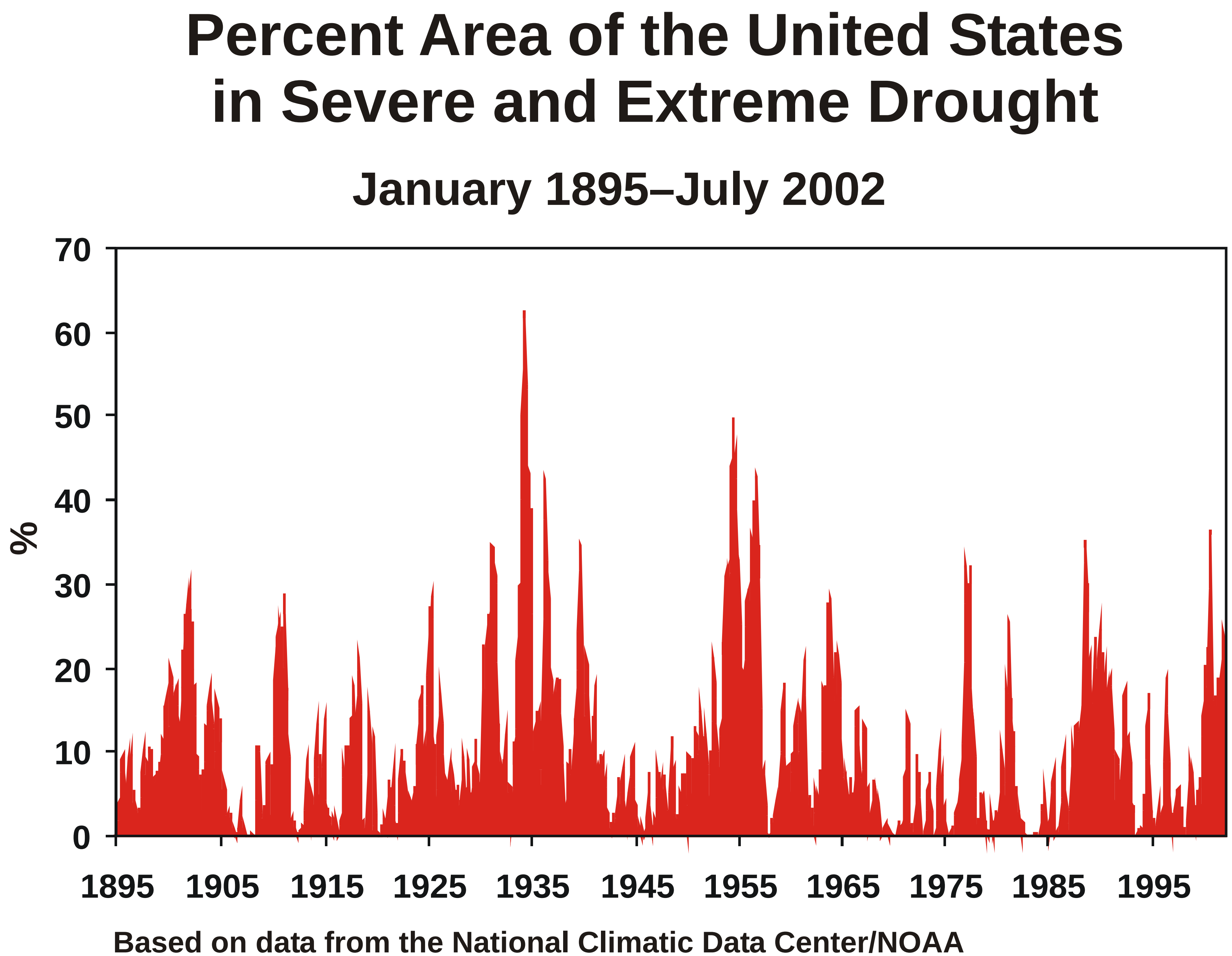
January-December 2002 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA




Nebraska Statewide Precipitation
1895 - 2002
Inches
35.0
30.0
25.0
20.0
15.0
900
800
700
600
500
400
mm
1900
1920
1940
1960
1980
2000
Year
National Climatic Data Center / NESDIS / NOAA
Yearly Values
Filtered Values
Long-Term Mean

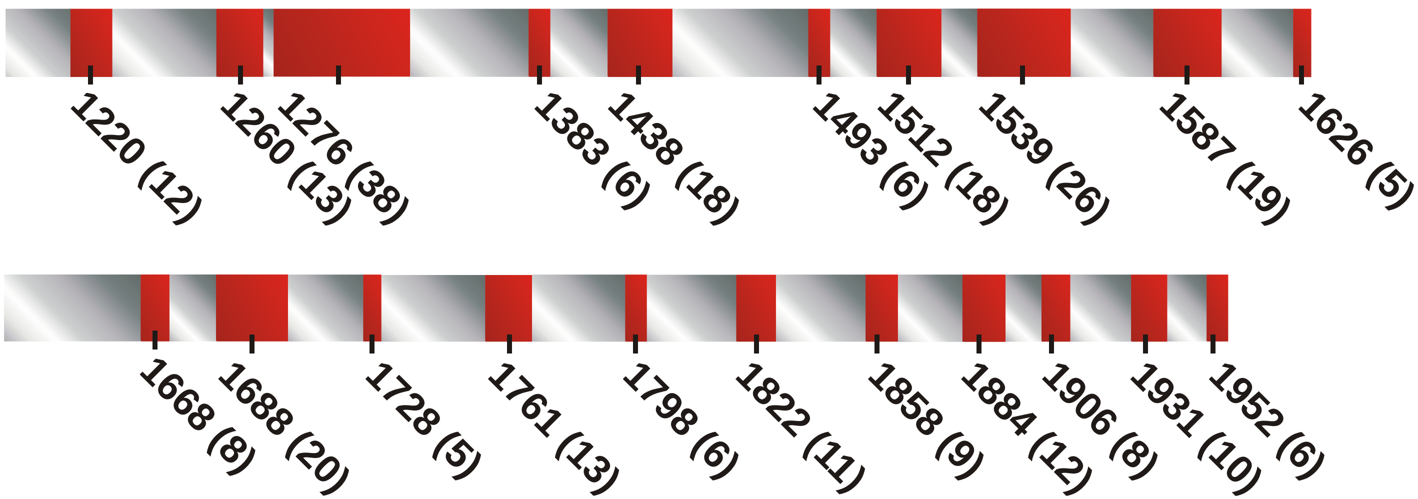
- Every year, what is the percentage of area that is typically under drought?



Percent Area of the United States
in Severe and Extreme Drought
January 1895–July 2002
%
70
60
50
40
30
20
10
0
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
Based on data from the National Climatic Data Center/NOAA

- What is the typical length or duration of the impact of a drought?

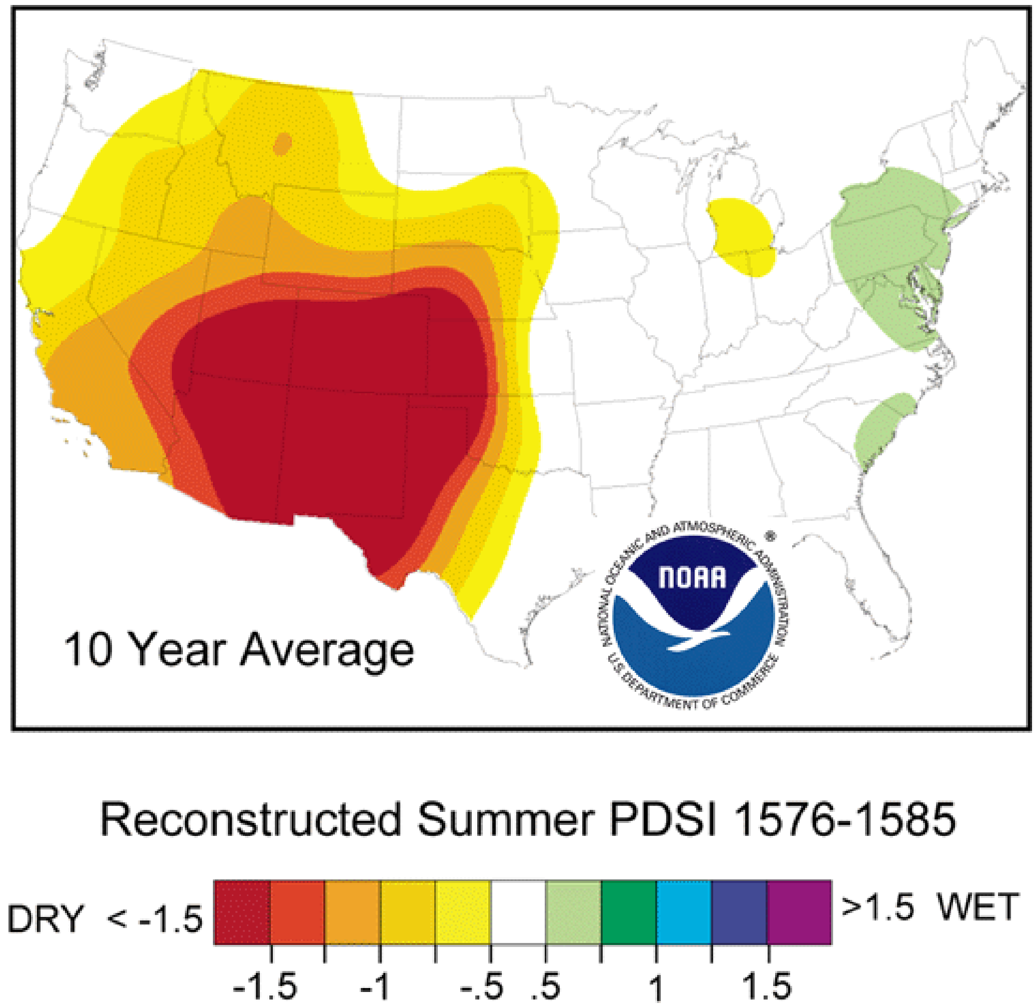
Periods of Drought in Western Nebraska
5 or More Years in Duration
1200–1960



Periods of drought shown in red. Numbers in parentheses following year indicate length of drought period.

Average duration of drought: 12.8 years

16th Century Megadrought



NOAA / NESDIS / National Climatic Data Center, Paleoclimatology Branch

What Can We Do About Drought?

- 1. Monitoring
- 2. Planning
- 3. Mitigation

Drought Differs From Other Natural Hazards

- slow onset or “creeping phenomenon”
- absence of a precise, universal definition
- impacts are nonstructural and spread over large areas--makes assessment and response difficult
- impacts are complex and affect many people

Therefore, monitoring, planning, and mitigation difficult

Key Variables For Monitoring Drought

- climate data
- soil moisture
- stream flow
- ground water
- reservoir and lake levels
- snow pack
- Evapotranspiration/ effective precipitation
- short, medium, and long range forecasts
- vegetation health/stress and fire danger
- “user input” ‘ community interaction

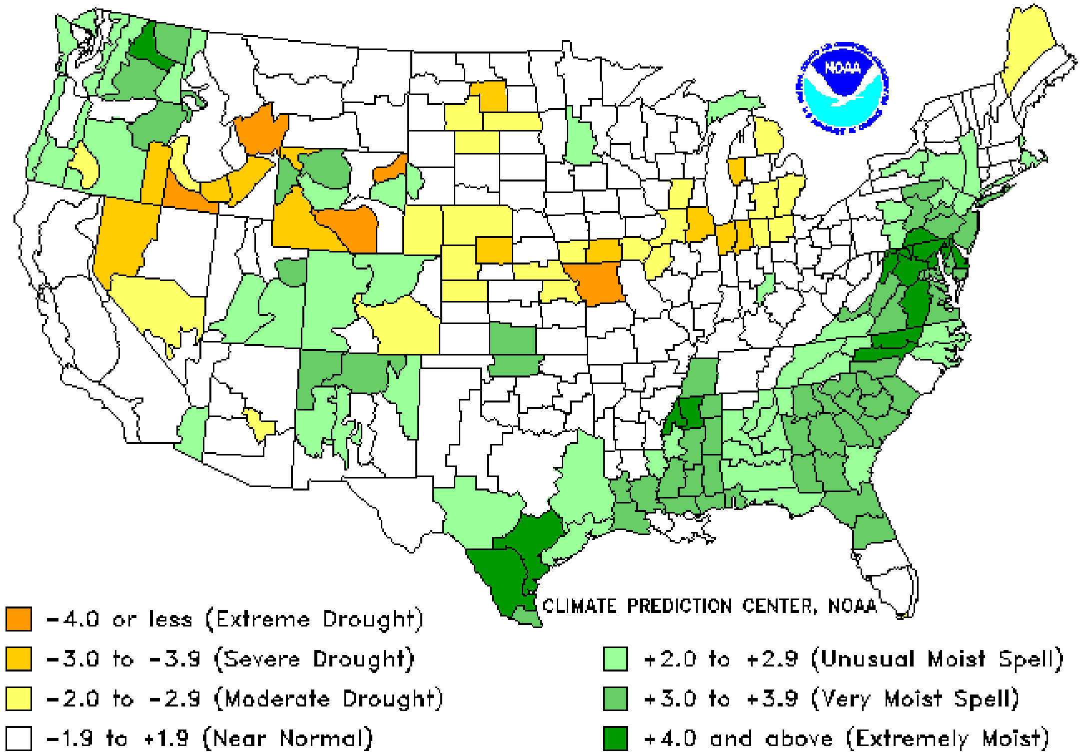
Approaches to Drought Assessment

- Single index or parameter
- Multiple indices or parameters
- Composite index

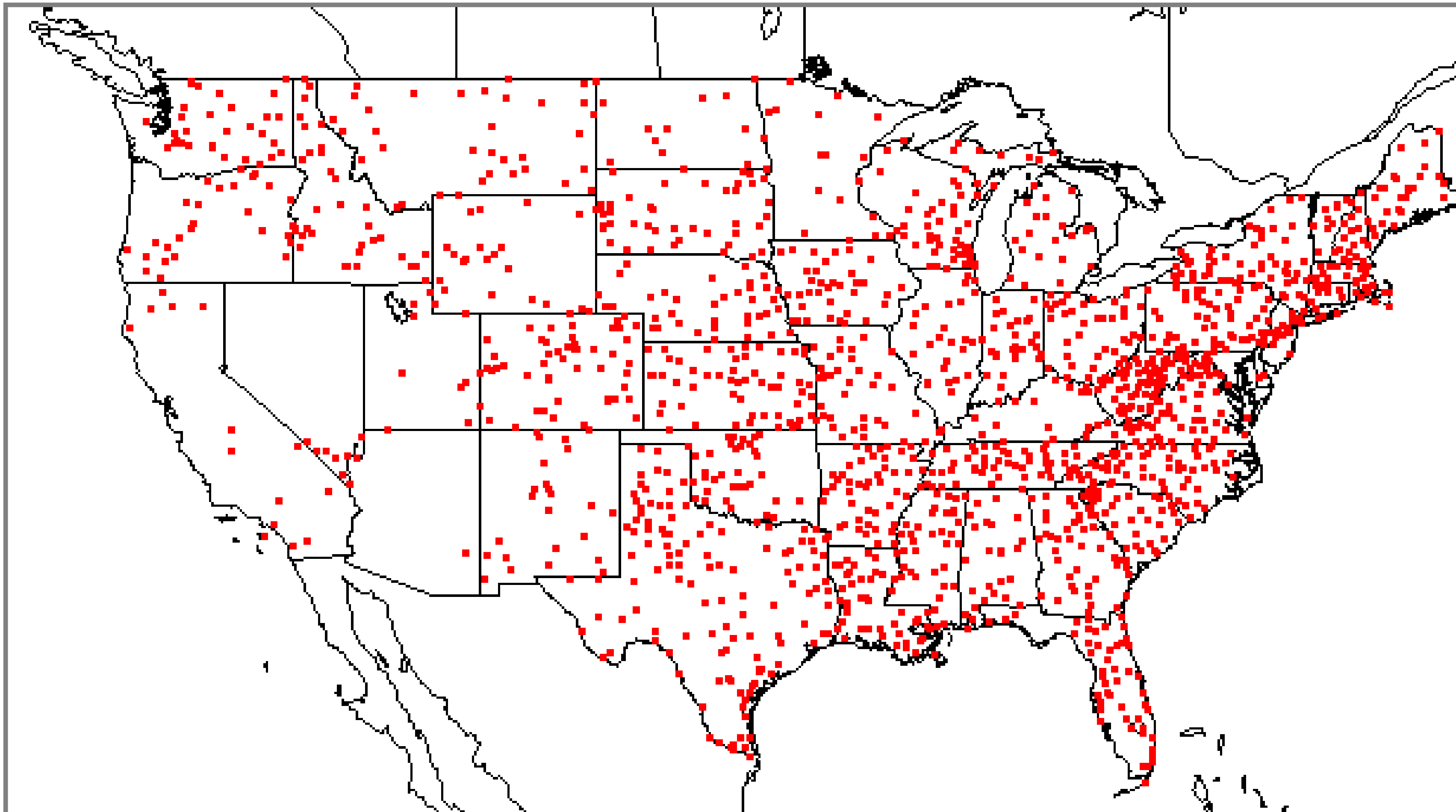
Drought Severity Index by Division

Weekly Value for Period Ending 22 MAR 2003

Long Term Palmer

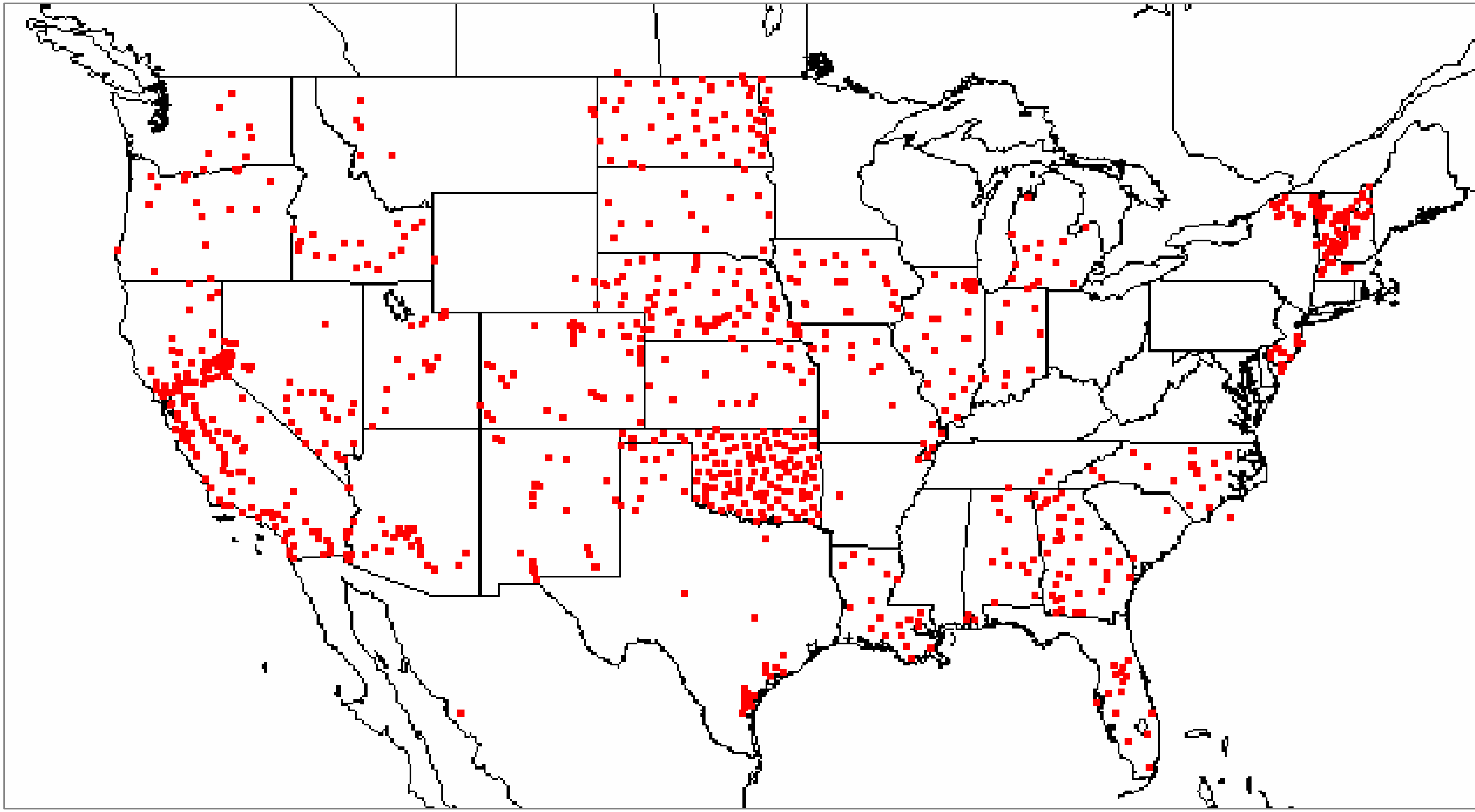


Real-Time NWS Cooperative Observer Network



www.coop.nws.noaa.gov

Automated Weather Networks



The Importance of a Drought EWS

- allows for early drought detection
- allows for proactive (mitigation) and reactive (emergency) responses
- “triggers” actions within a drought plan
- Bottom line—provides information for decision support

Components of a Drought EWS

- timely data and timely acquisition
- synthesis/analysis of data used to “trigger” set actions within a plan
- efficient dissemination or delivery system (WWW, media, extension)

An integrated climate monitoring system needs to:

- be comprehensive in scope (coupling climate, soil and water data)
- incorporate local and regional scale data
- use the best available (multiple) indices and triggering tools
- link index values or thresholds to impact sectors
- be flexible, incorporating the needs of end users

Questions addressed by monitoring

- Analyze recent events—how did we get here?
- Place current situation in a historical context—how rare is this event?
- What is the forecast and how reliable is it?
- What would it take to end the drought event?
- How can we communicate this information to decision makers to encourage positive action?

Potential Monitoring System Products and Reports

- ***Historical analysis*** (climatology, impacts, magnitude, frequency)
- ***Operational assessment*** (coop network data, SPI and other indices, automated networks, satellite and soil moisture data)
- ***Predictions/Projections*** (SPI and other indices, soil moisture, streamflow, seasonal forecasts, SST’s)

Importance of Drought Indices

- Simplify complex relationships and provide a good communication tool for diverse audiences
- Quantitative assessment of anomalous climatic conditions
  - Intensity
  - Duration
  - Spatial extent
- Historical reference (probability of recurrence)
  - Planning and design applications

Triggers: thresholds determining specific, timely actions by decision makers. Link impacts to index or indicator values.

Triggers need to be:

- appropriate
- consistent with impacts
- adaptable

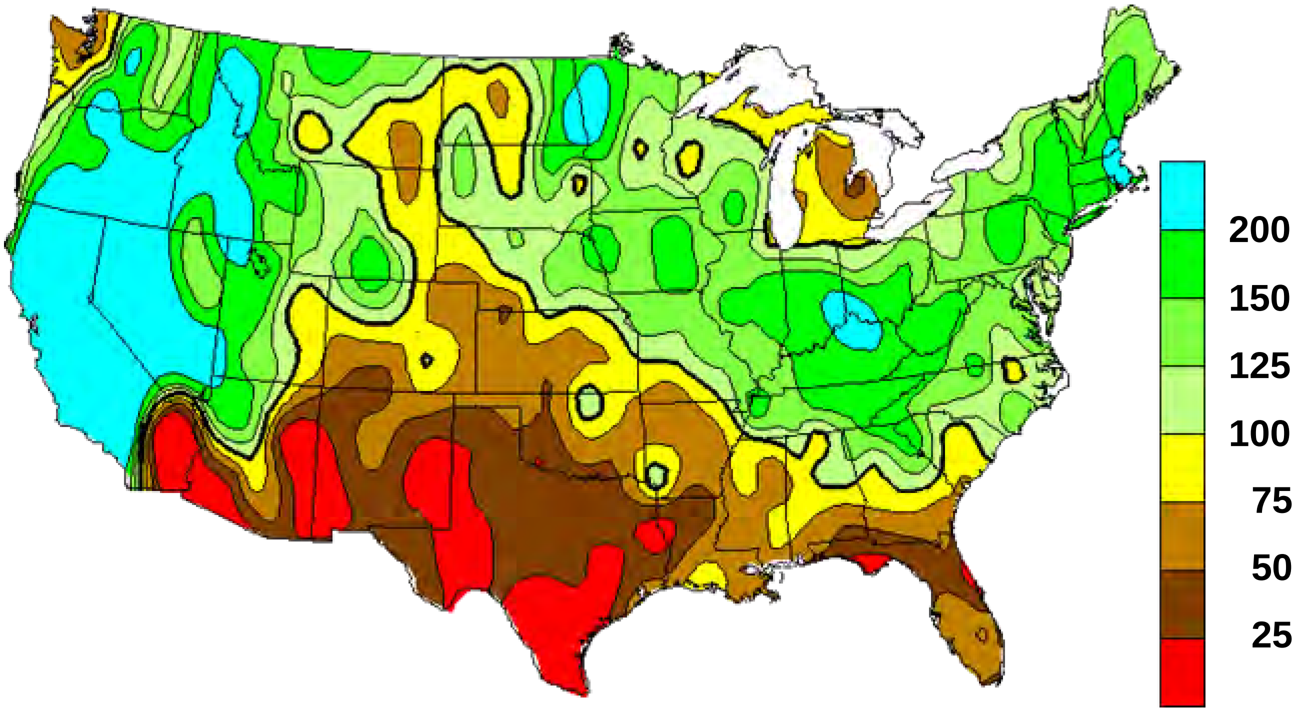
Drought Indices

- Percent of normal
- Deciles
- Palmer Drought Severity Index (PDSI)
- Crop Moisture Index (CMI)
- Surface Water Supply Index (SWSI)
- Reclamation Drought Index (RDI)
- Standardized Precipitation Index (SPI)

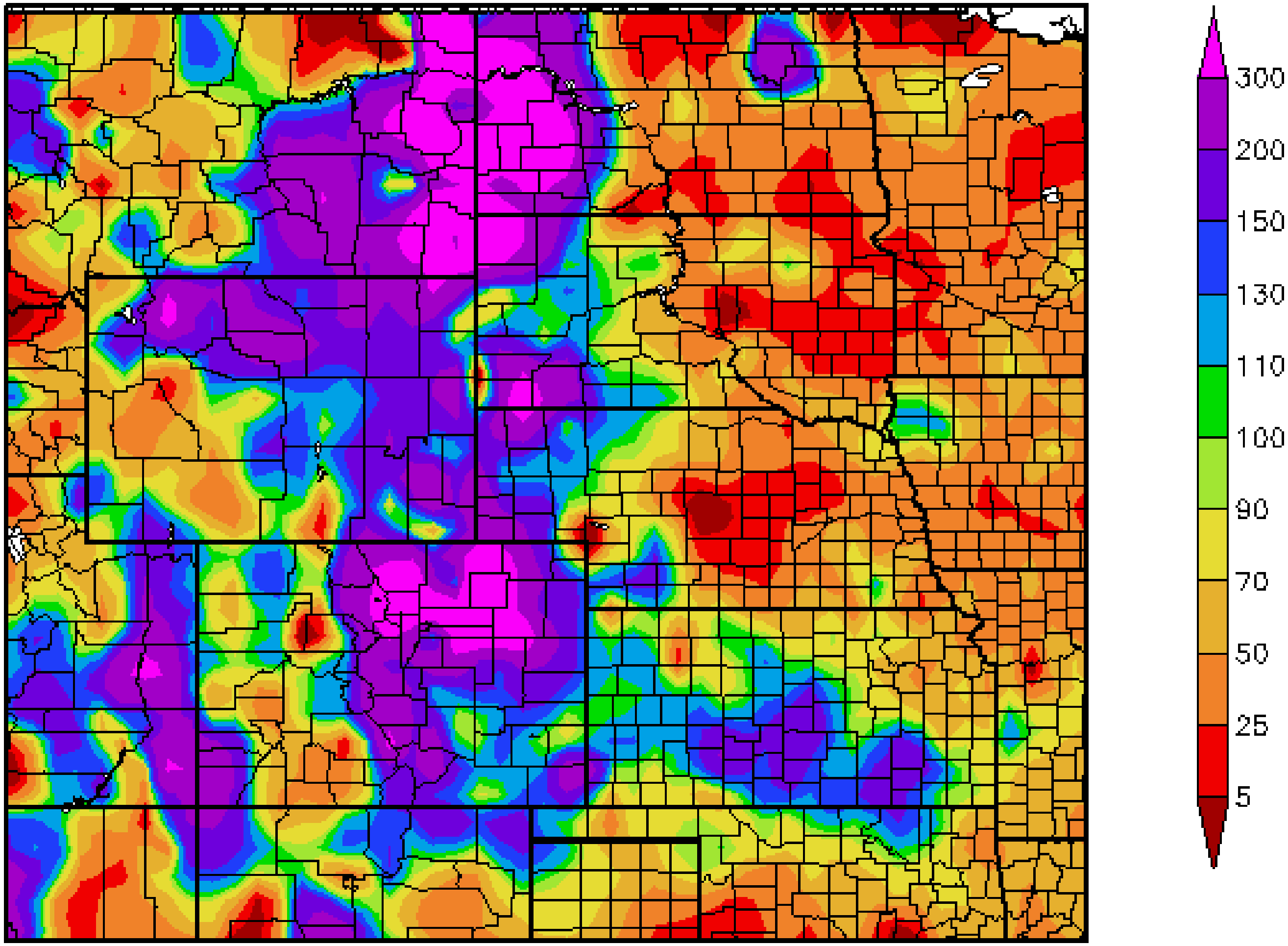
Percent of Normal: Characteristics

- simple measurement
- appeals to the public as easy to understand
- calculated by dividing actual precipitation by normal precipitation (generally a 30-year mean) and multiplying x 100%
- easily misunderstood…as the mean and the median are often not the same
- data are not normalized

Percent of Normal Precipitation
Apr. 1–Jun. 30, 1998



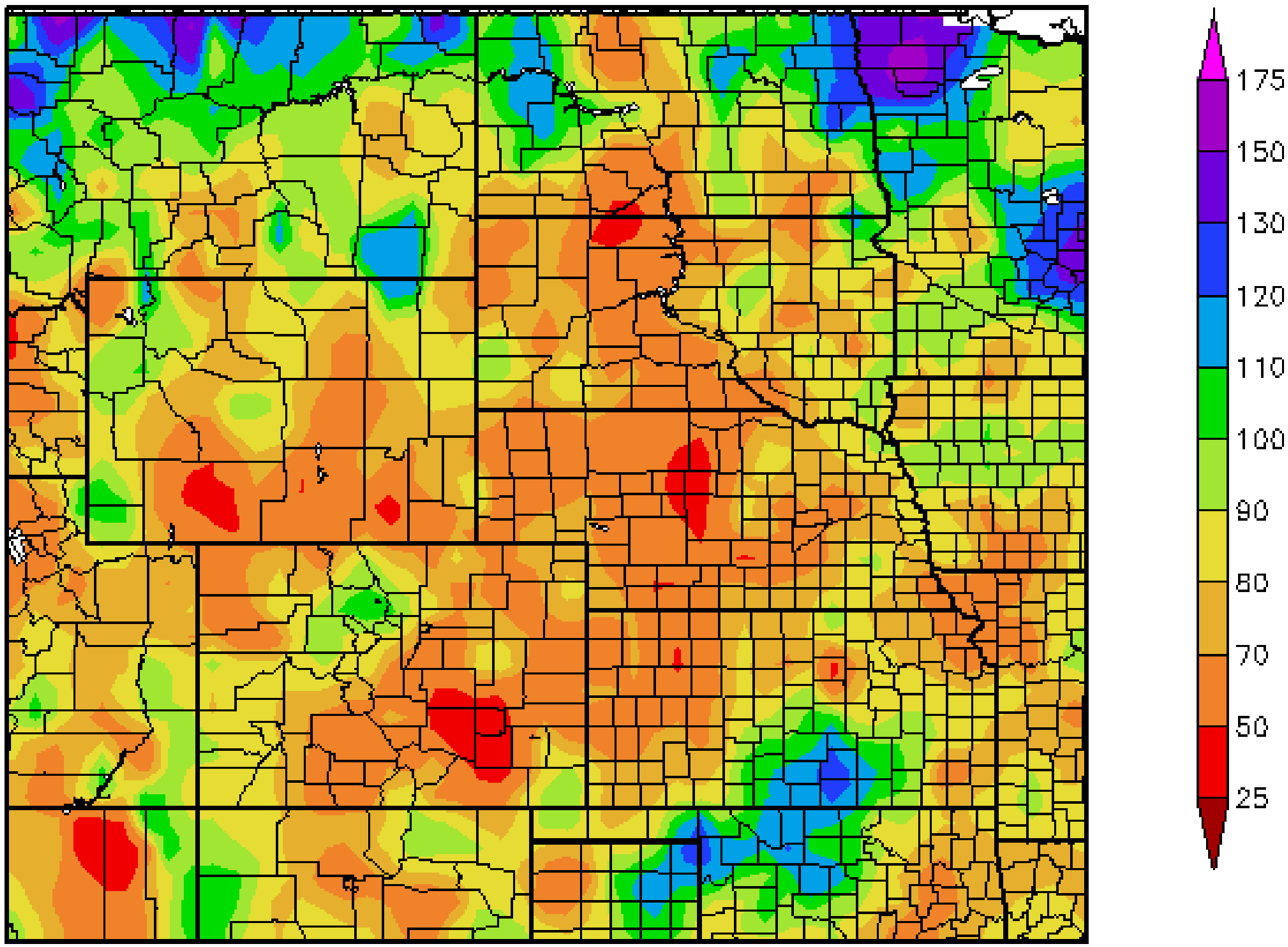
Percent of Normal Precipitation (in)
2/26/2003 - 3/27/2003



Generated 3/28/2003 at HPRCC

NOAA Regional Climate Centers

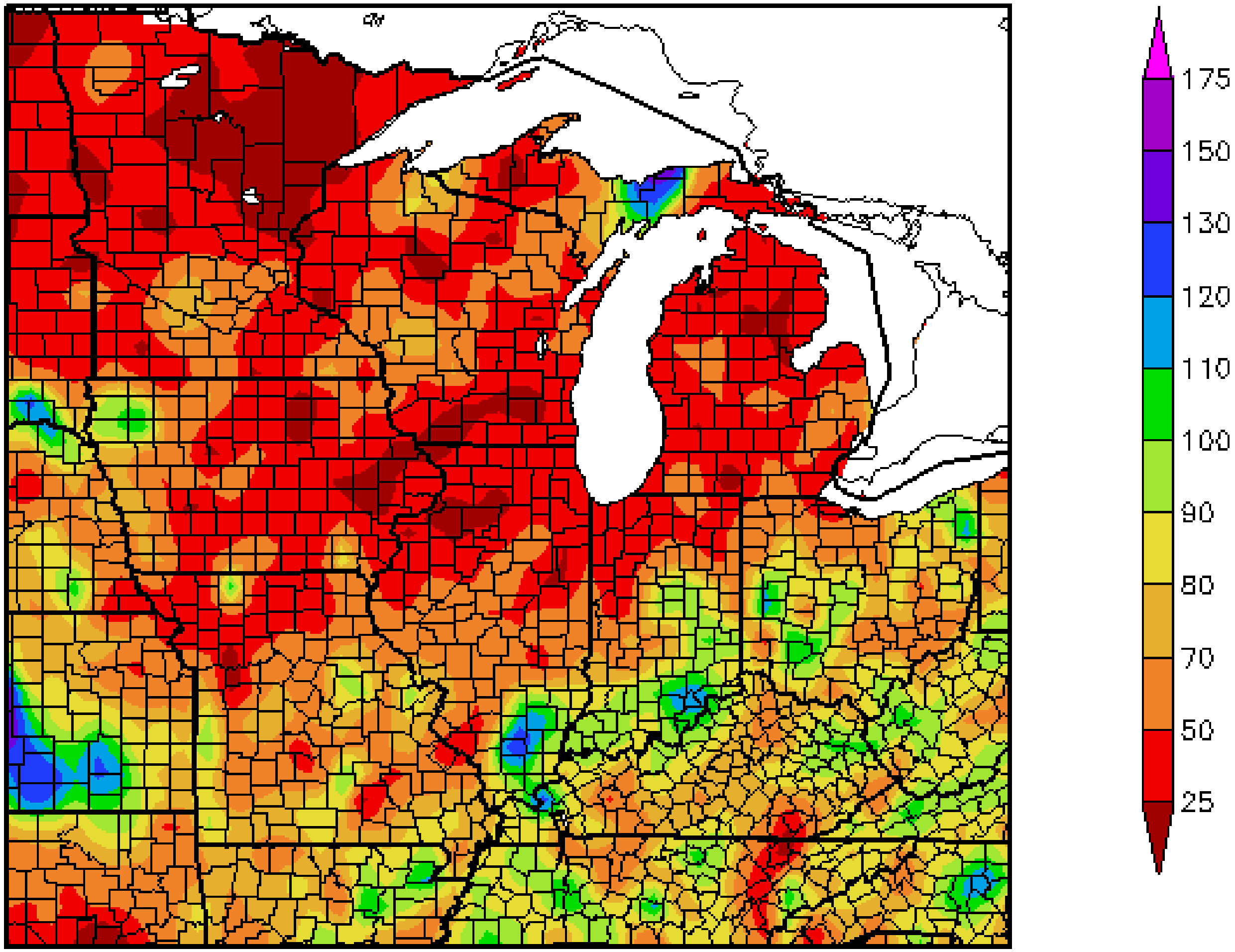
Percent of Normal Precipitation (in)
3/28/2002 – 3/27/2003



Generated 3/28/2003 at HPRCC

NOAA Regional Climate Centers

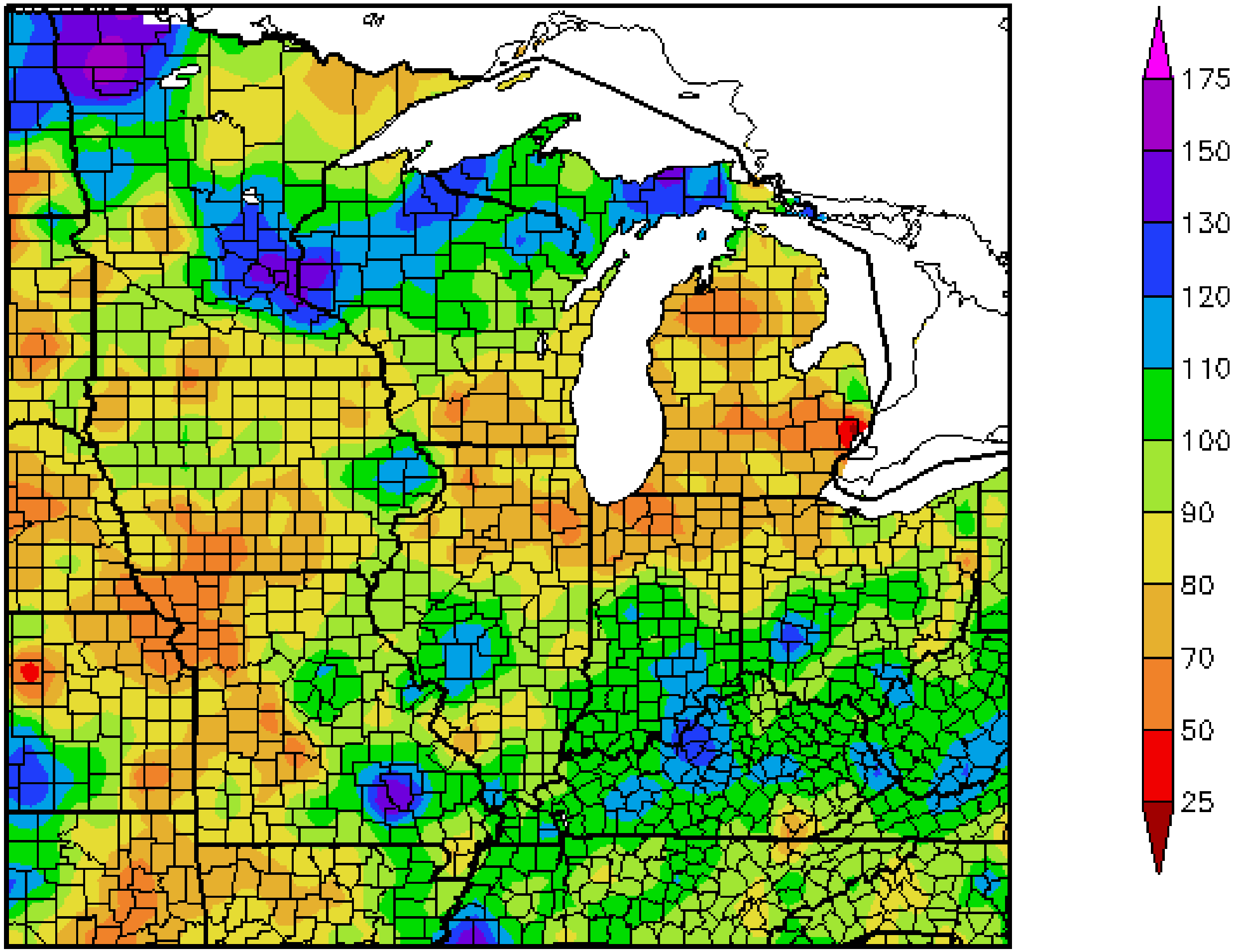
Percent of Normal Precipitation (in)
12/28/2002 – 3/27/2003



Generated 3/28/2003 at HPRCC

NOAA Regional Climate Centers

Percent of Normal Precipitation (in)
3/28/2002 - 3/27/2003



Generated 3/28/2003 at HPRCC

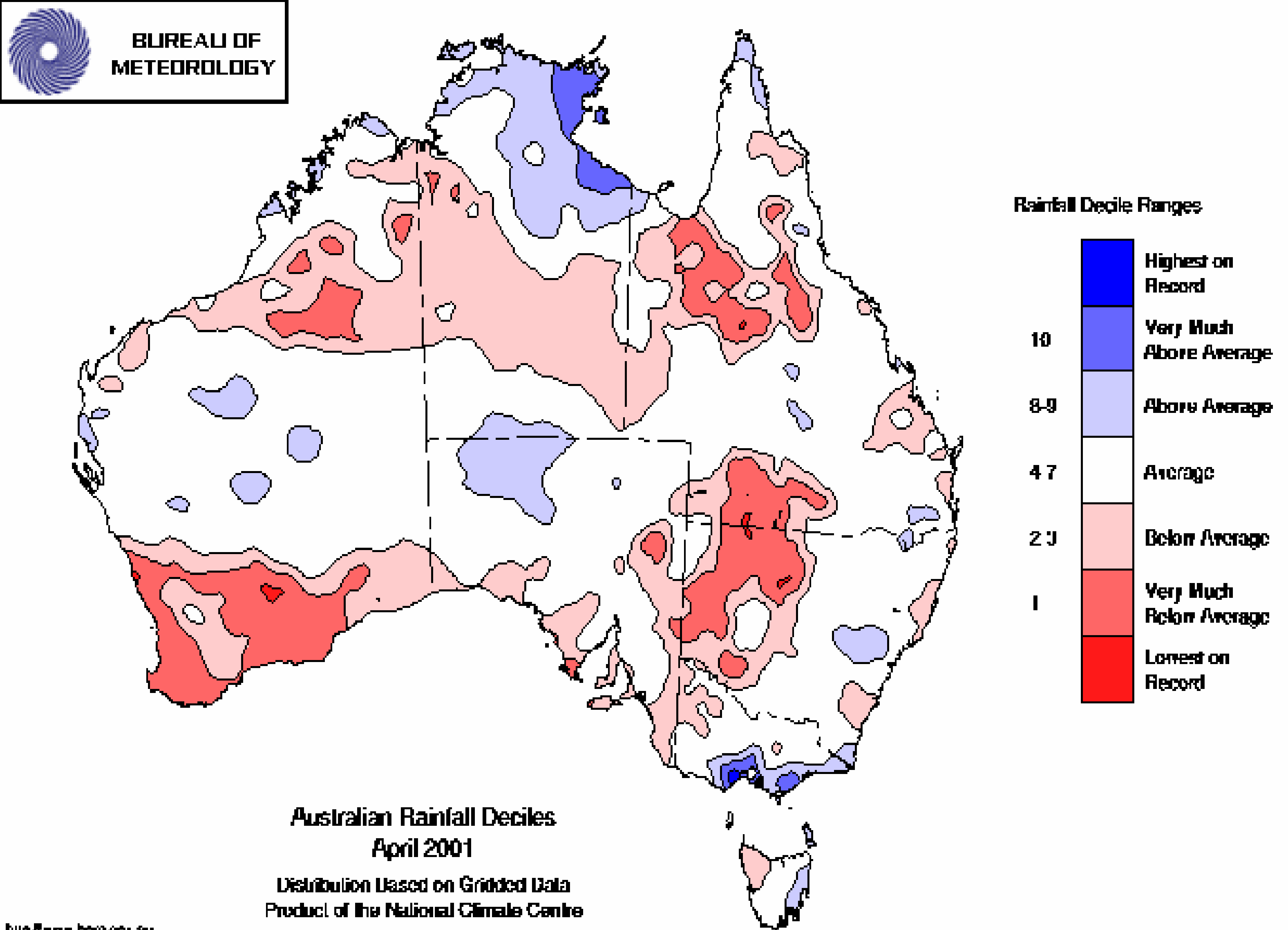
NOAA Regional Climate Centers

Decile Characteristics

- Developed in 1967 (Gibbs and Maher)
- Relatively easy to calculate
- grouped into 5 classifications (see table)
- distribution of occurrences divided into tenths
- need a long period of record to be accurate

Decile Classification for Dry and Wet Periods

Deciles 1-2	Lowest 20%	Much below normal
Deciles 3-4	Next lowest 20%	Below normal
Deciles 5-6	Middle 20%	Near normal
Deciles 7-8	Next highest 20%	Above normal
Deciles 9-10	Highest 20%	Much above normal



BUREAU OF METEOROLOGY
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
Australian Rainfall Deciles
April 2001
Distribution Based on Gridded Data
Product of the National Climate Centre
http://www.bom.gov.au

Drought Indices

- Percent of Normal
- Deciles
- Palmer Drought Severity Index (PDSI)
- Crop Moisture Index (CMI)
- Surface Water Supply Index (SWSI)
- Reclamation Drought Index (RDI)
- Standardized Precipitation Index (SPI)

What is the PDSI?

- A commonly used indicator of the status of the environmental demand for precipitation with respect to what has actually been received.
- Includes
  - average temperature
  - total precipitation
  - parameterization of soil type and
  - water holding capacity of the top layers of the soil.

Description of PDSI

- normalizes the total precipitation and average temperature to a standard 30-year period.
- applies to a regional geographical area called a “Climatological Division” (CD).
- underlying data are the averages of all of the available reporting stations for each CD for the period being

Palmer Drought Severity Index (PDSI)
(Palmer Index or Palmer Drought Index)

Characteristics

- Developed in 1965
- Supply and demand concept of the water balance equation
- Evapotranspiration calculated
- Soil component
- Calculated weekly or monthly
- Standardized for location and time ??

PDSI Limitations

- Complex
- All precipitation is treated as rain
- An inherent time scale (9 months)
- Inaccurate, underestimation of runoff
- Little use outside the United States
- Responds slowly to emerging drought conditions
- Percent time in severe and extreme categories—not probability based

PDSI

4.00
3.00 to 3.99
2.00 to 2.99
1.00 to 1.99
0.50 to 0.99
0.49 to -0.49
-0.50 to -0.99
-1.00 to -1.99
-2.00 to -2.99
-3.00 to -3.99
-4.00

CLASS

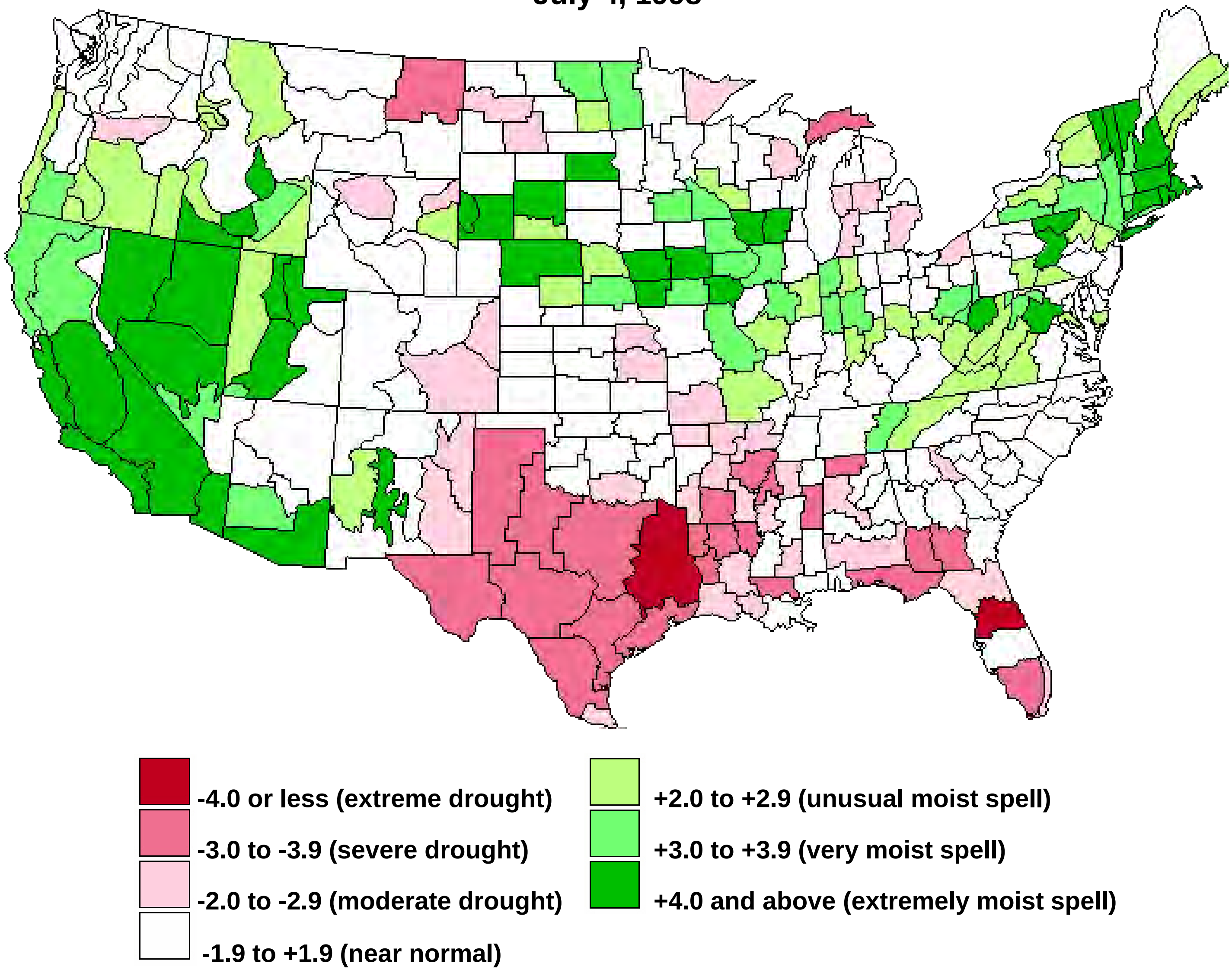
Extremely Wet
Very Wet
Moderately Wet
Slightly Wet
Incipient Wet Spell
Near Normal
Incipient Drought
Mild Drought
Moderate Drought
Severe Drought
Extreme Drought

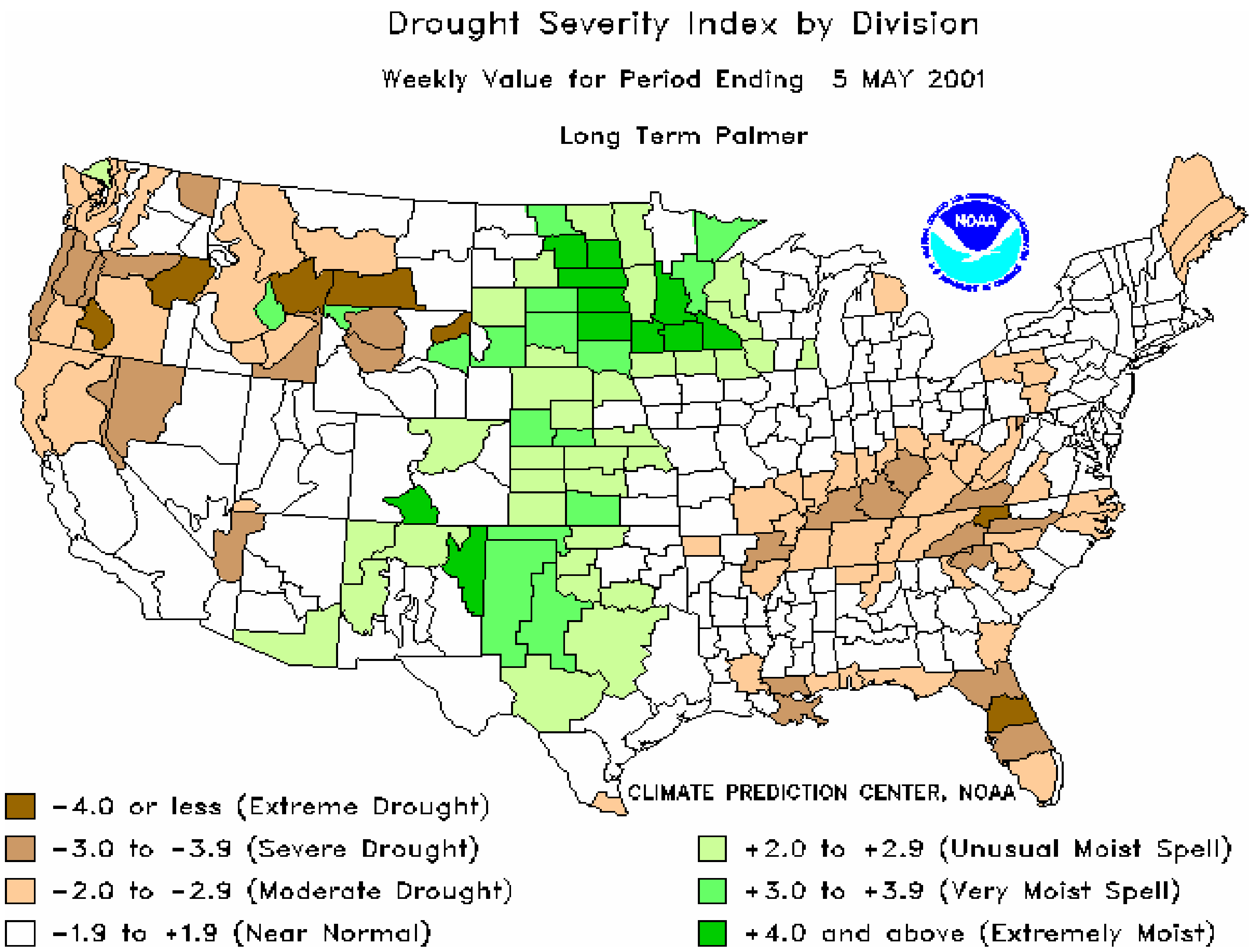
Weekly PDSI values for U.S.

- Based on available preliminary data
- Only the stations submitting data electronically are included
- The “normal” category is expanded to be between +1.99 and -1.99

Drought Severity Index by Division (Long-Term Palmer)

July 4, 1998




Drought Severity Index by Division
Weekly Value for Period Ending 5 MAY 2001
Long Term Palmer
NOAA
CLIMATE PREDICTION CENTER, NOAA
-4.0 or less (Extreme Drought)
-3.0 to -3.9 (Severe Drought)
-2.0 to -2.9 (Moderate Drought)
-1.9 to +1.9 (Near Normal)
+2.0 to +2.9 (Unusual Moist Spell)
+3.0 to +3.9 (Very Moist Spell)
+4.0 and above (Extremely Moist)

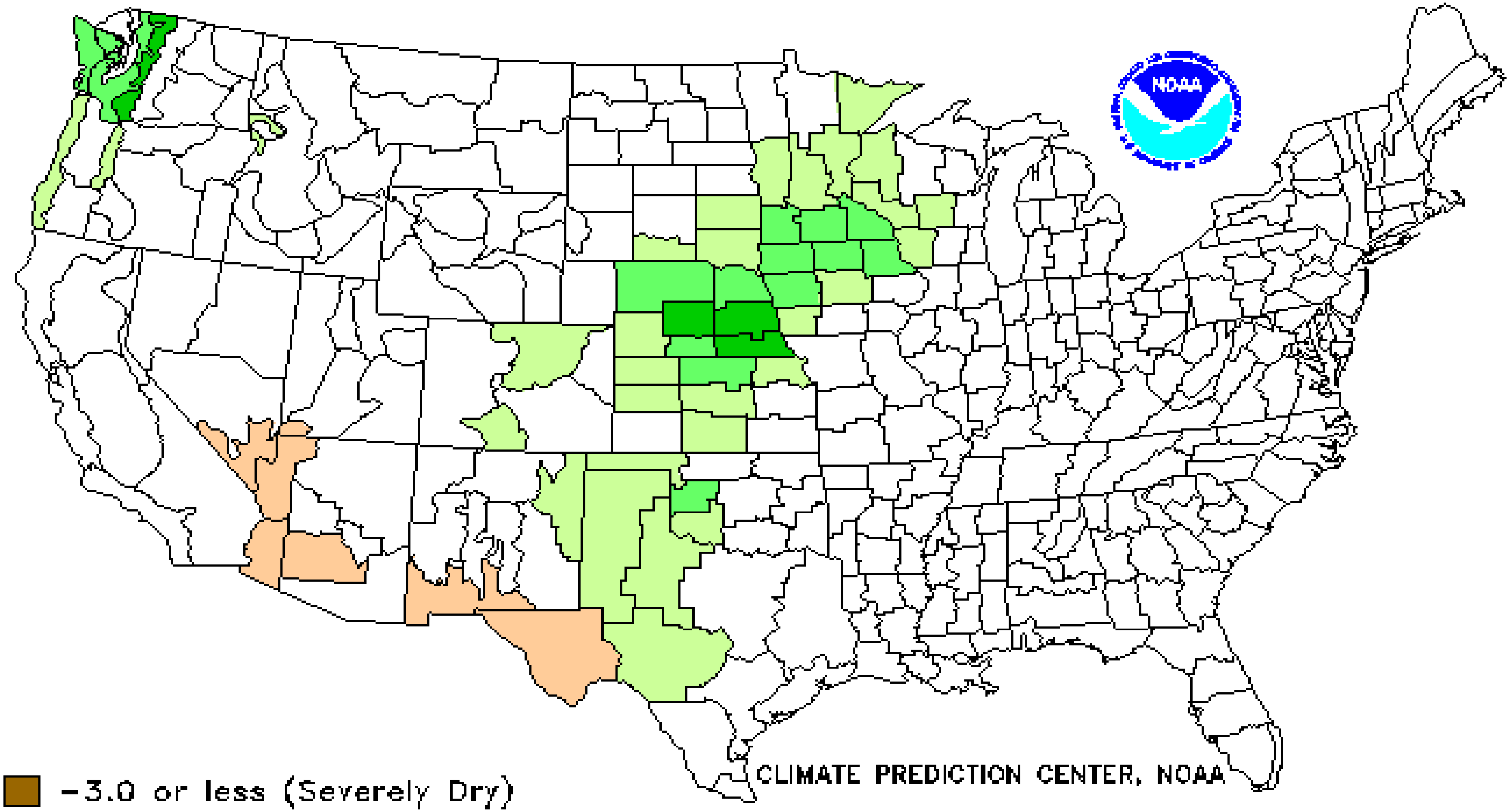
Crop Moisture Index Characteristics

- Derivative of the Palmer Drought Index
- Designed to monitor short-term moisture conditions on a weekly basis
- Looks at the top 5 feet in the soil profile
- Mainly used for agricultural purposes
- Initialized to zero each spring

Crop Moisture Index by Division

Weekly Value for Period Ending 5 MAY 2001

Short Term Need vs. Available Water in 5 Ft Profile



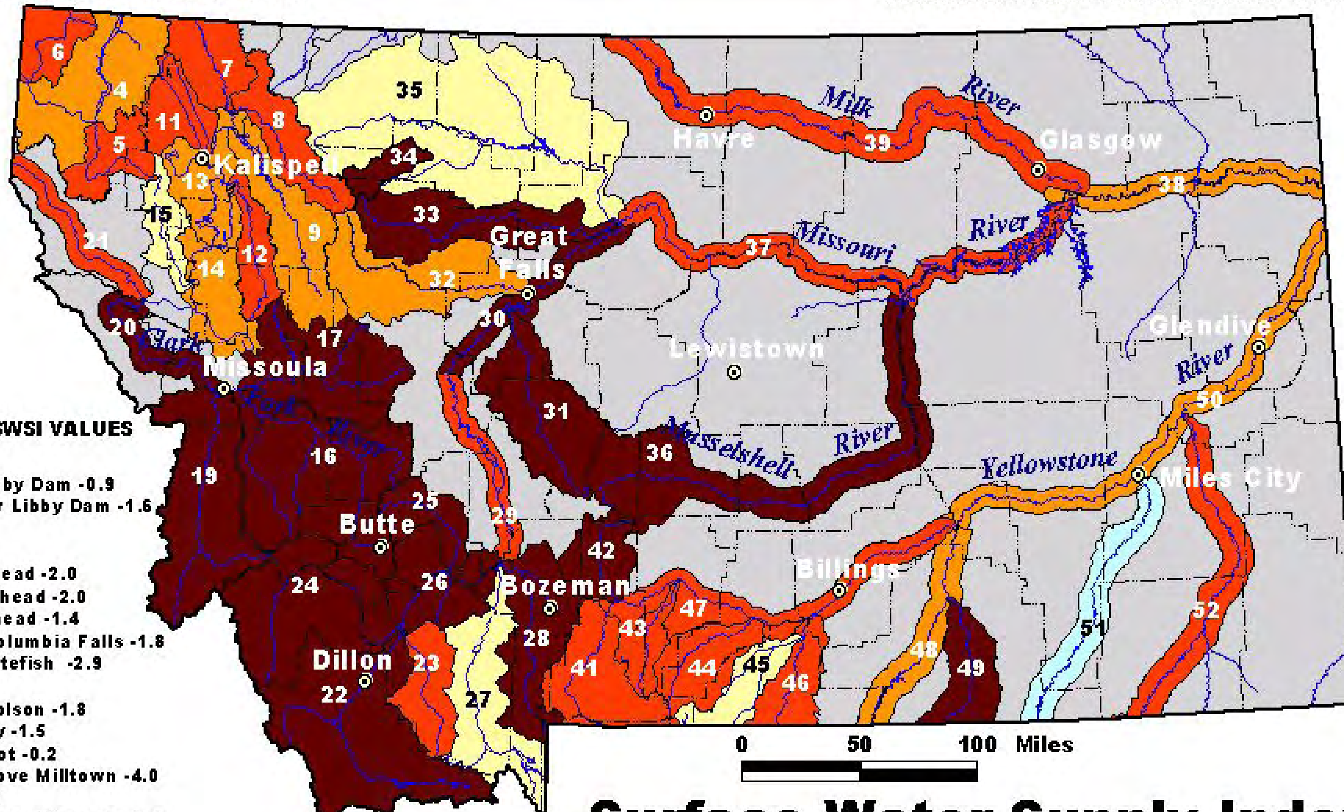
- −3.0 or less (Severely Dry)
- −2.0 to −2.9 (Excessively Dry)
- −1.0 to −1.9 (Abnormally Dry)
- −0.9 to +0.9 (Slightly Dry/Favorably Moist)
- +1.0 to +1.9 (Abnormally Moist)
- +2.0 to +2.9 (Wet)
- +3.0 and above (Excessively Wet)

Surface Water Supply Index Characteristics

- river basin (watershed) approach
- hydro/climo index developed for mountainous areas relying on snowpack for water supply
- takes into account precipitation,snowpack, reservoir and streamflow levels
- only computed seasonally
- data are normalized and a probability of non-exceedance is determined for each component
- limited comparison wise since the index is unique for each basin

UNITED STATES DEPARTMENT OF AGRICULTURE

NATURAL RESOURCES CONSERVATION SERVICE



RIVER INDEX \ SWSI VALUES

2 Tobacco -2.5
3 Kootenai to Libby Dam -0.9
4 Kootenai below Libby Dam -1.6
5 Fisher -2.1
6 Yaak -2.9
7 North FK. Flathead -2.0
8 Middle FK. Flathead -2.0
9 South FK. Flathead -1.4
10 Flathead at Columbia Falls -1.8
11 Stillwater/Whitefish -2.9
12 Swan -2.3
13 Flathead at Polson -1.8
14 Mission Valley -1.5
15 Little Bitterroot -0.2
16 Clark Fork above Milltown -4.0
17 Blackfoot -3.6
18 Clark Fork above Missoula -3.8
19 Bitterroot -3.0
20 Clark Fork below Bitterroot -3.4
21 Clark Fork below Flathead -2.6
22 Beaverhead -3.6
23 Ruby -2.7
24 Big Hole -3.9
25 Boulder (Jefferson) -4.0
26 Jefferson -3.6
27 Madison -0.6
28 Gallatin -3.3
29 Missouri above Canyon Ferry -2.5
30 Missouri below Canyon Ferry -3.2
31 Smith -3.9
32 Sun -1.6
33 Teton -4.0
34 Birch/Dupuyer Creeks -4.0
35 Marias +0.6
36 Musselshell -3.9
37 Missouri above Fort Peck -2.1
38 Missouri below Fort Peck -1.6
39 Milk -2.9
41 Yellowstone above Livingston -2.9
42 Shields -3.9
43 Boulder (Yellowstone) -2.7
44 Stillwater -2.5
45 Rock/Red Lodge Creeks -0.7
46 Clarks Fork -2.5
47 Yellowstone above Bighorn -2.8
48 Bighorn below Bighorn Lake -1.6
49 Little Bighorn -3.2
50 Yellowstone below Bighorn -1.8
51 Tongue +1.1
52 Powder -2.9

Surface Water Supply Index (SWSI) Values

Current as of September 1, 2000

SWSI VALUES
Extremely Dry -4.0 to -3.0
Moderately Dry -2.9 to -2.0
Slightly Dry -1.9 to -1.0
Near Average -0.9 to 0.9
Sighdy Wet 1.0 to 1.9
Moderately Wet 2.0 to 2.9
Extremely Wet 3.0 to 4.0
SWSI Not Applicable

NOTE: Data used to generate this map are PROVISIONAL and SUBJECT TO CHANGE.

USDA NRCS Natural Resources Conservation Service Montana

http://www.mt.nrcs.usda.gov

Reclamation Drought Index (RDI)

RDI = Supply Element + Demand Element

- RDI a function of supply, demand, and duration
- Flexibility

Reclamation Drought Index

Example

$$\left.\begin{array}{ll}\text{Precipitation Factor} & = 0.25 \\ \text{Reservoir Factor} & = 0.15 \\ \text{Streamflow Factor} & = 0.10\end{array}\right\} = 0.50$$

Temperature Factor = 0.50

Characteristics of the SPI

- Developed by McKee et al. in 1993
- Simple index--precipitation is the only parameter (probability of observed precipitation transformed into an index)
- Being use in research or operational mode in over 50 countries
- Multiple time scales allow for temporal flexibility in evaluation of precipitation conditions and water supply

How it Works

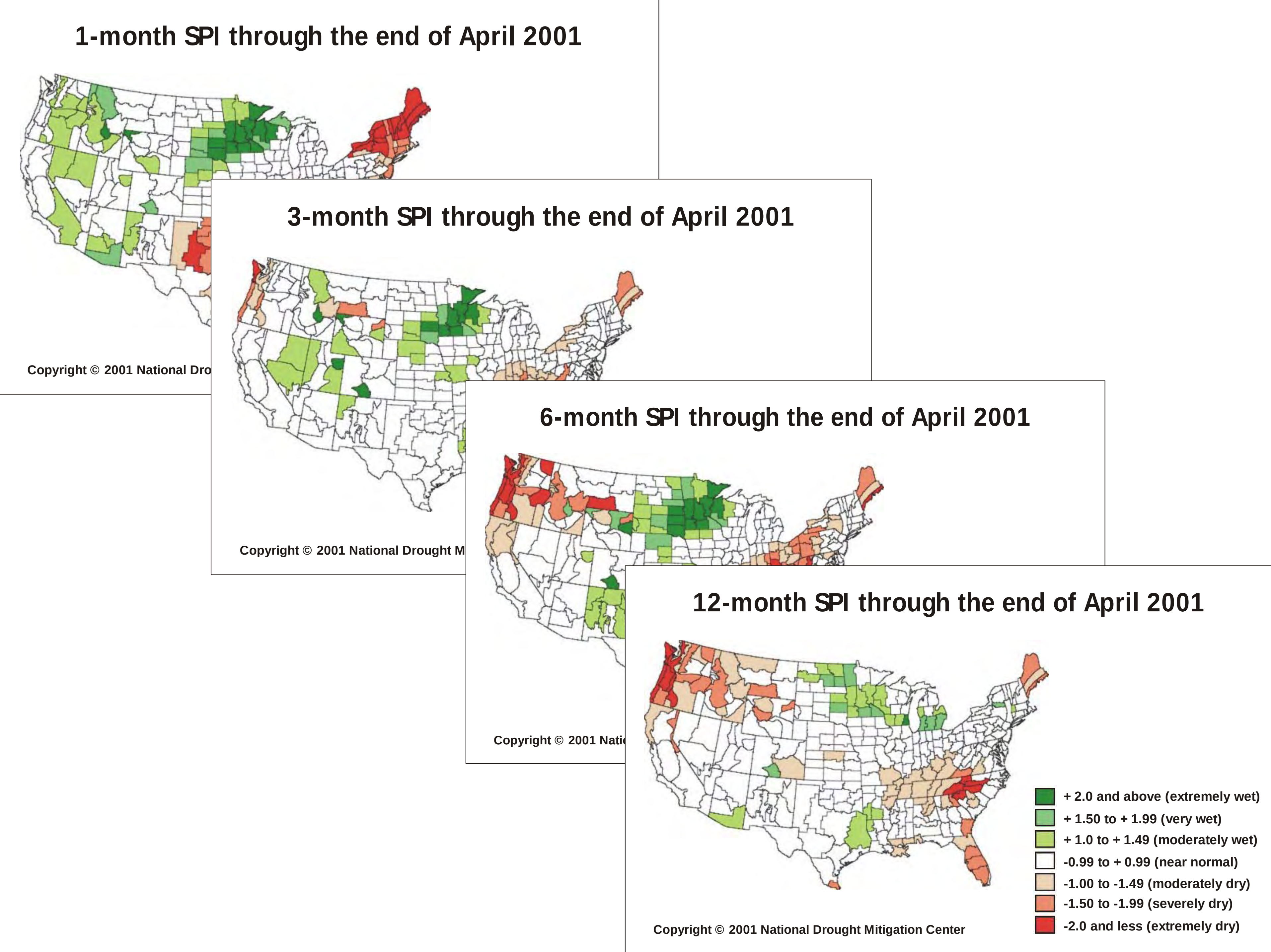
- Need 30 years of continuous monthly precipitation data
- SPI time scale intervals longer than 24 months may be unreliable
- Is spatially invariant in its interpretation
- Probability based (probability of observed precipitation transformed into an index) nature is well suited to risk management

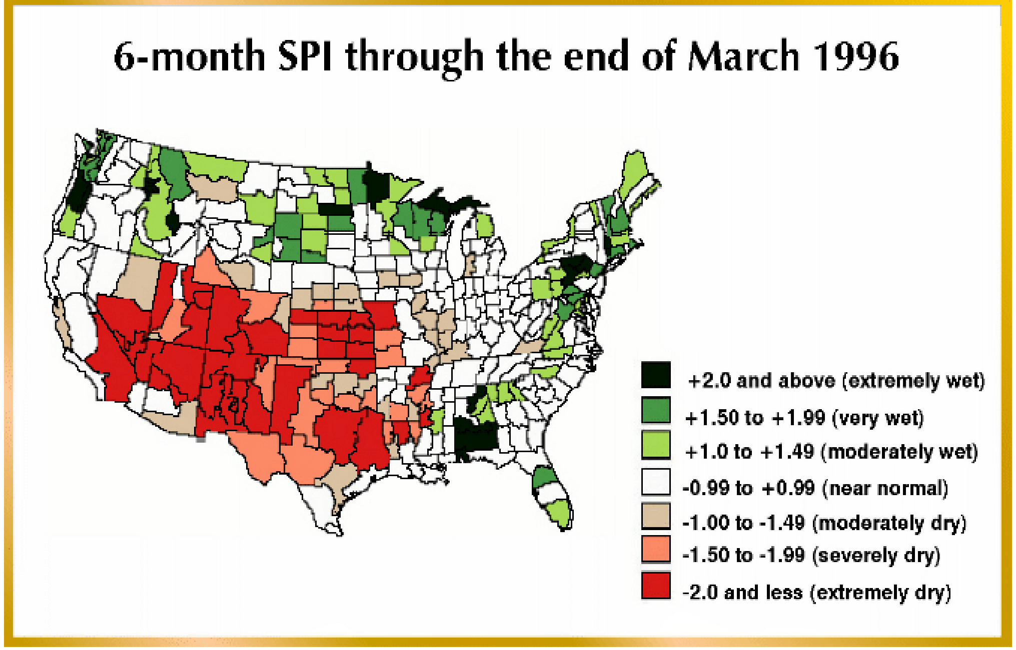
How it Works

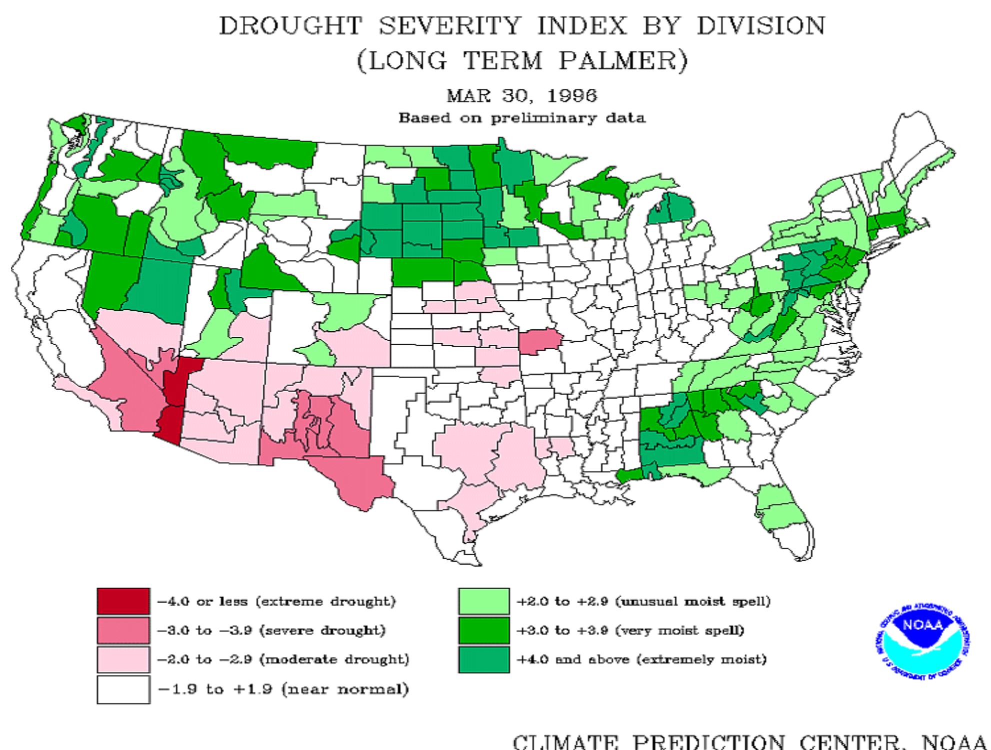
- It is ***NOT*** simply the “difference of precipitation from the mean… divided by the standard deviation”
- Precipitation is normalized using a probability distribution so that values of SPI are actually seen as standard deviations from the median
- Normal distribution allows for estimating both dry and wet periods
- Accumulated values can be used to analyze drought severity

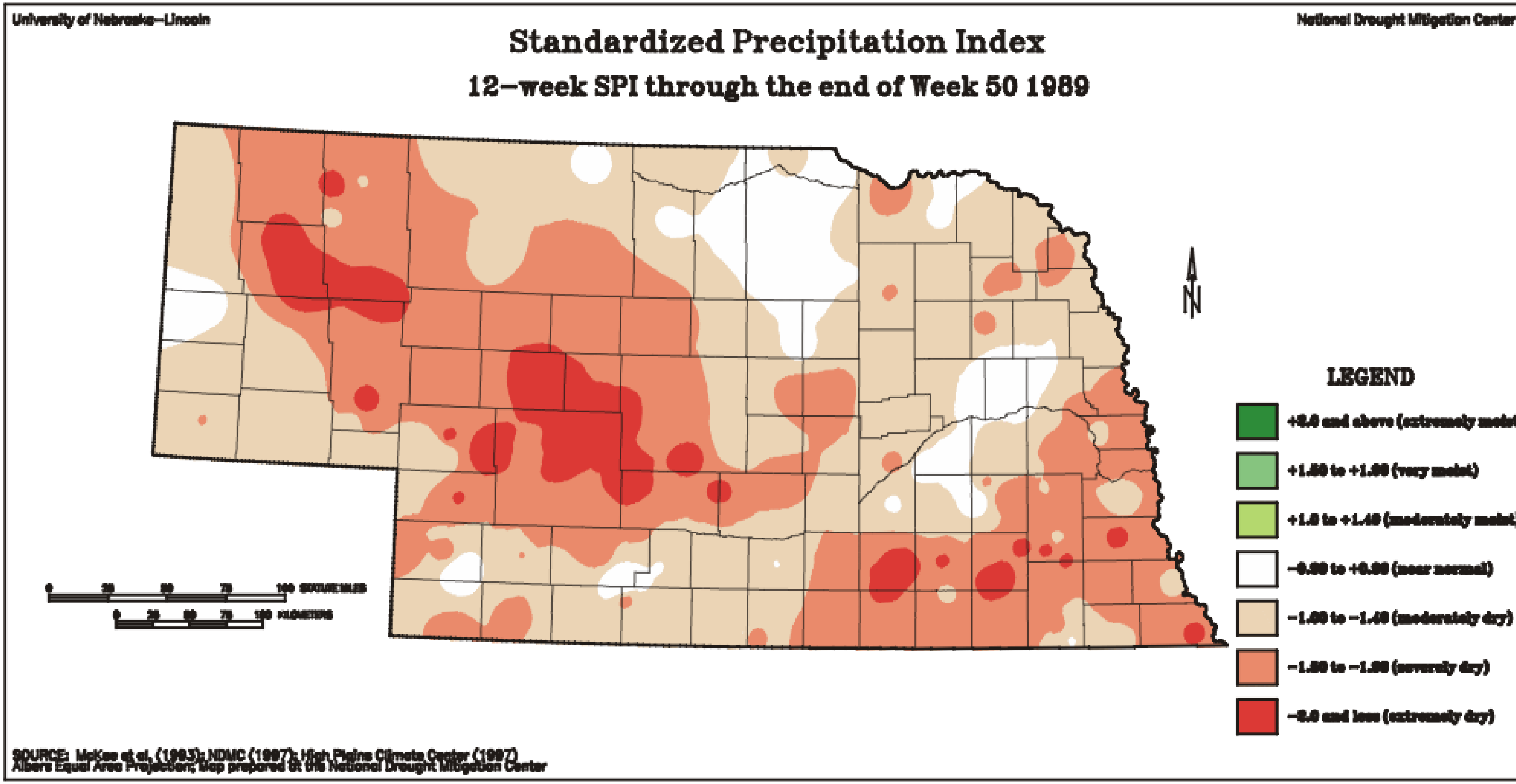
Probability of Recurrence

SPI	Category	# of times in 100 yrs.	Severity of event
0 to -0.99	Mild dryness	33	1 in 3 yrs.
-1.00 to -1.49	Moderate dryness	10	1 in 10 yrs.
-1.5 to -1.99	Severe dryness	5	1 in 20 yrs.
< -2.0	Extreme dryness	2.5	1 in 50 yrs.

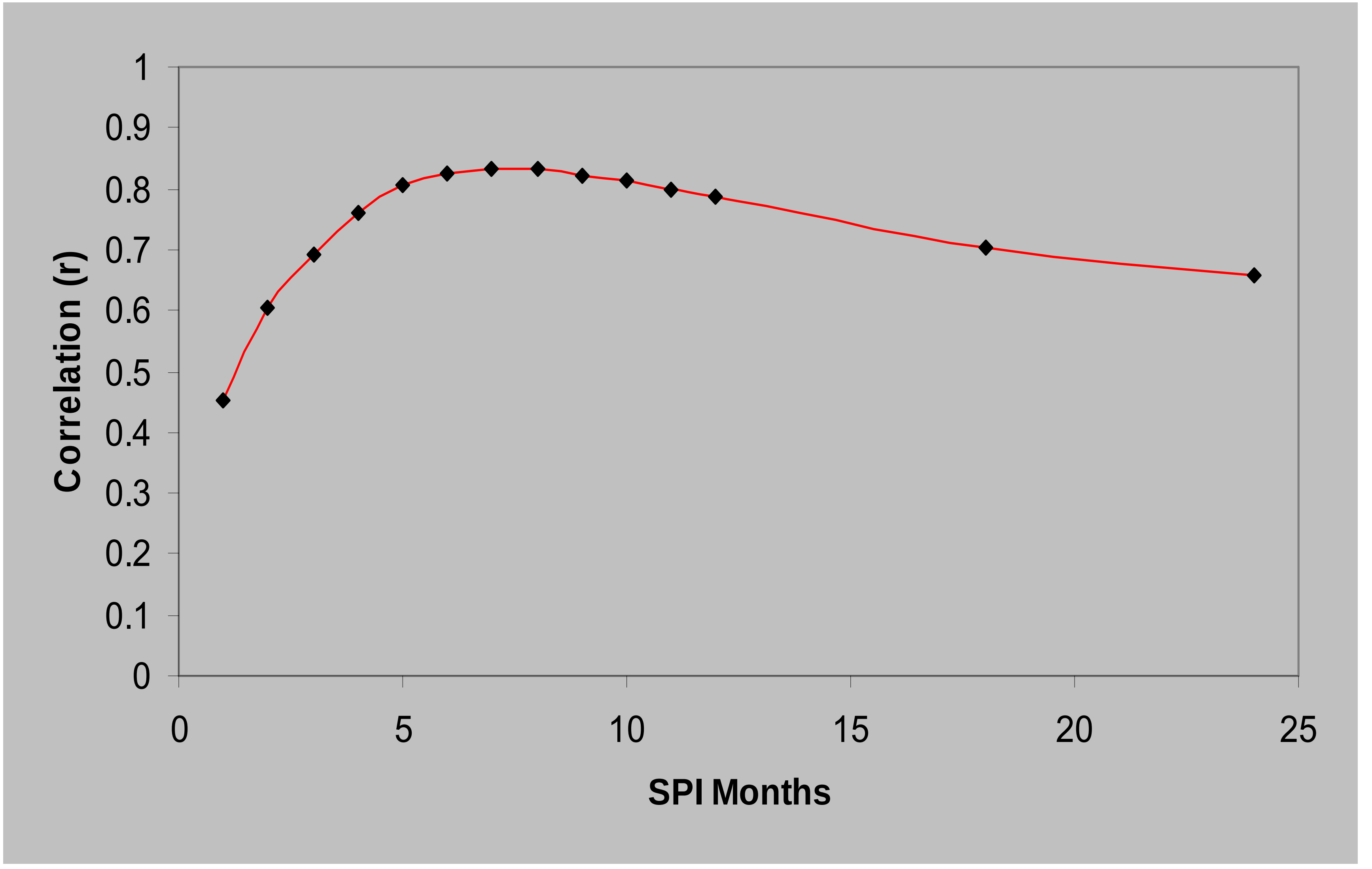

1-month SPI through the end of April 2001
3-month SPI through the end of April 2001
6-month SPI through the end of April 2001
12-month SPI through the end of April 2001
+ 2.0 and above (extremely wet)
+ 1.50 to + 1.99 (very wet)
+ 1.0 to + 1.49 (moderately wet)
-0.99 to + 0.99 (near normal)
-1.00 to -1.49 (moderately dry)
-1.50 to -1.99 (severely dry)
-2.0 and less (extremely dry)
Copyright © 2001 National Drought Mitigation Center

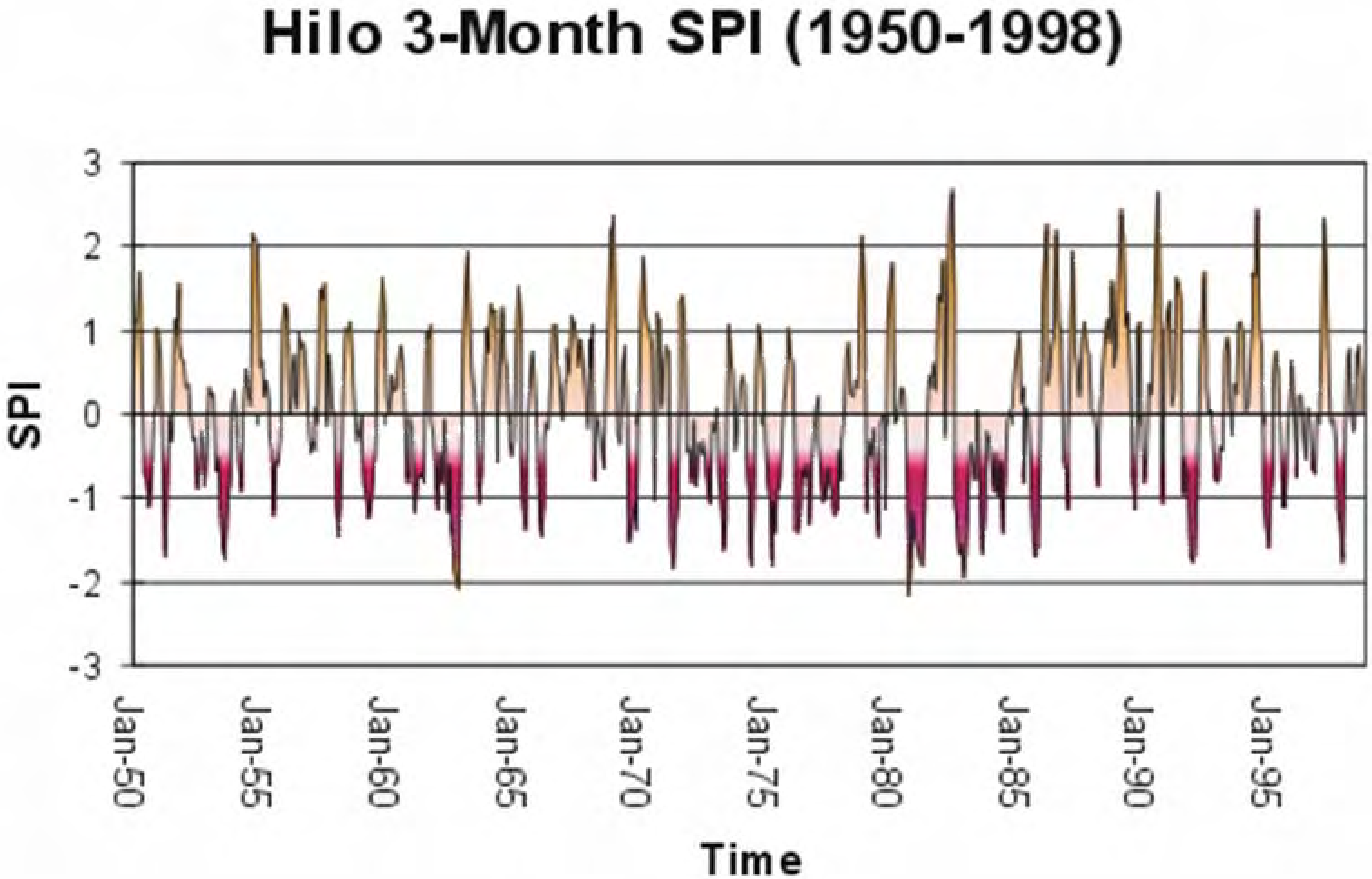

6-month SPI through the end of March 1996
+2.0 and above (extremely wet)
+1.50 to +1.99 (very wet)
+1.0 to +1.49 (moderately wet)
-0.99 to +0.99 (near normal)
-1.00 to -1.49 (moderately dry)
-1.50 to -1.99 (severely dry)
-2.0 and less (extremely dry)

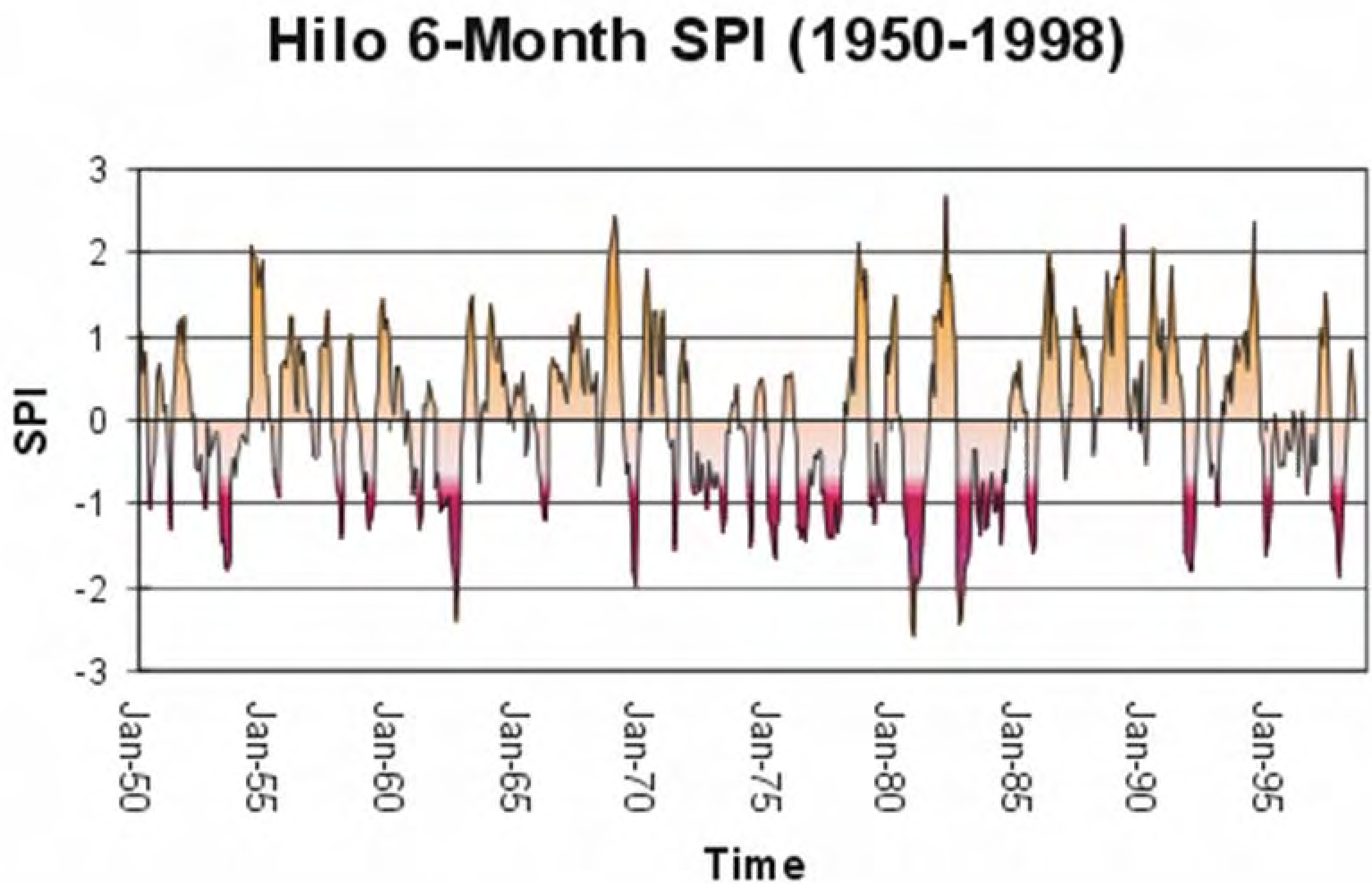

DROUGHT SEVERITY INDEX BY DIVISION
(LONG TERM PALMER)
MAR 30, 1996
Based on preliminary data
−4.0 or less (extreme drought)
−3.0 to −3.9 (severe drought)
−2.0 to −2.9 (moderate drought)
−1.9 to +1.9 (near normal)
+2.0 to +2.9 (unusual moist spell)
+3.0 to +3.9 (very moist spell)
+4.0 and above (extremely moist)
NOAA
CLIMATE PREDICTION CENTER, NOAA

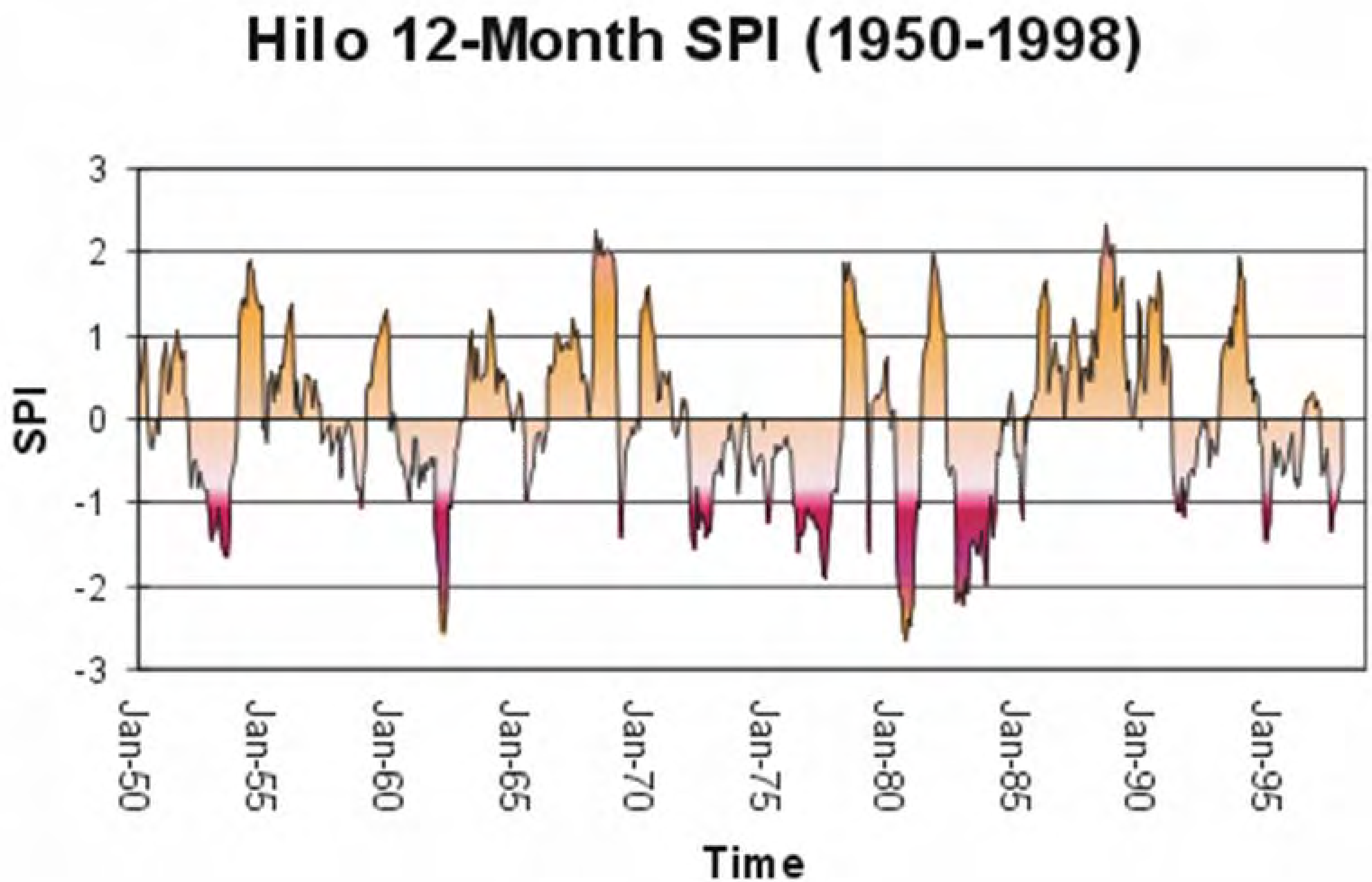

University of Nebraska–Lincoln
National Drought Mitigation Center
Standardized Precipitation Index
12–week SPI through the end of Week 50 1989
LEGEND
+2.0 and above (extremely moist)
+1.50 to +1.99 (very moist)
+1.0 to +1.49 (moderately moist)
−0.99 to +0.99 (near normal)
−1.00 to −1.49 (moderately dry)
−1.50 to −1.99 (severely dry)
−2.0 and less (extremely dry)
N
0 25 50 75 100 STATUTE MILES
0 25 50 75 100 KILOMETERS
SOURCE: McKee et al. (1993); NDMC (1997); High Plains Climate Center (1997)
Albers Equal Area Projection; Map prepared at the National Drought Mitigation Center

Correlation between the PDSI and different SPI series as a function of the time scale of the SPI

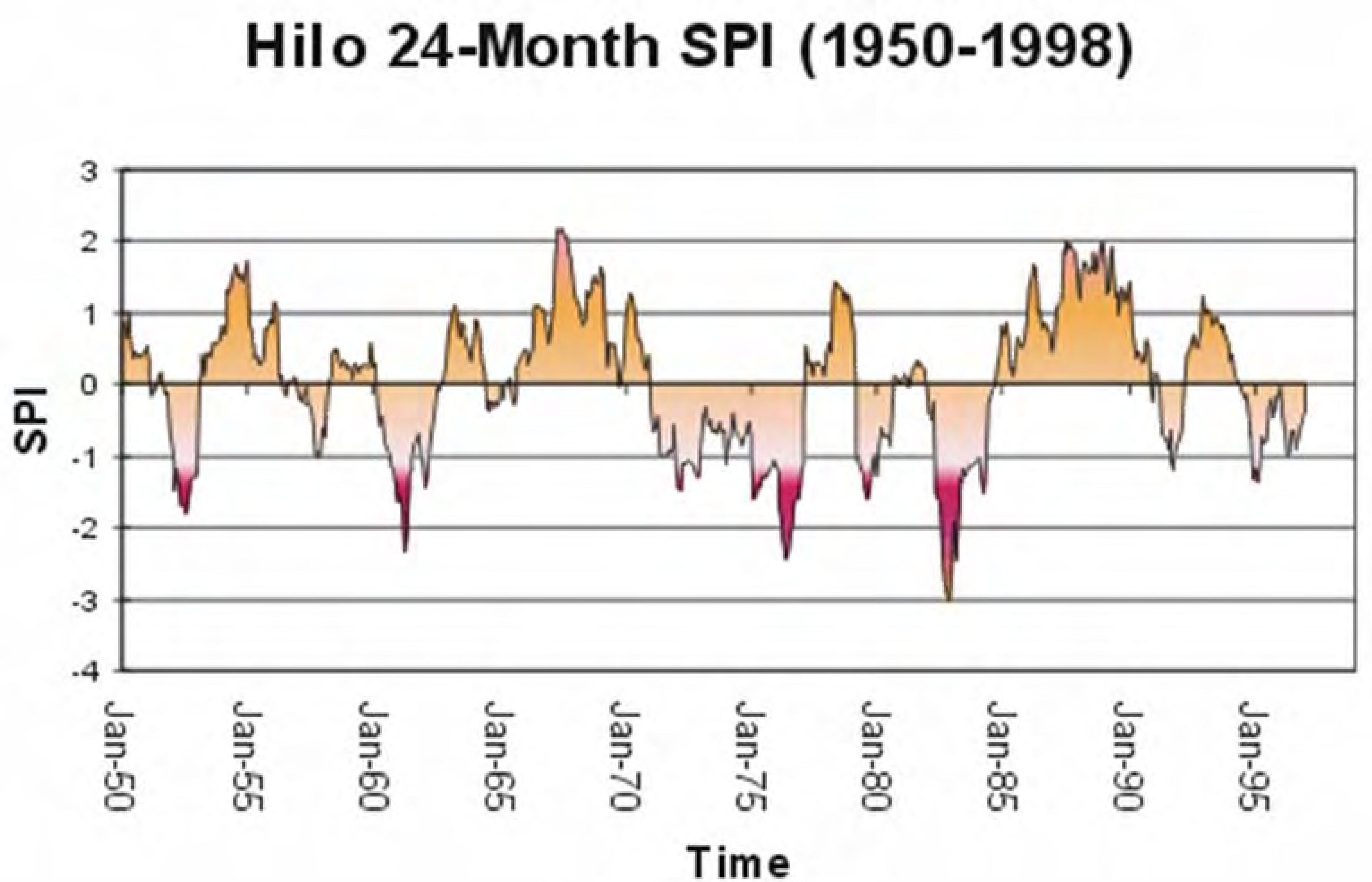



Hilo 3-Month SPI (1950-1998)
SPI
3
2
1
0
-1
-2
-3
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Time


Hilo 6-Month SPI (1950-1998)
3
2
1
0
-1
-2
-3
SPI
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Time



Hilo 12-Month SPI (1950-1998)
3
2
1
0
-1
-2
-3
SPI
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Time


Hilo 24-Month SPI (1950-1998)
SPI
3
2
1
0
-1
-2
-3
-4
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Time

Considerations for Selecting a Specific Trigger or Index:

- Is the information readily available?
- Can an index/trigger be calculated in a timely manner? Is the information likely to remain available over time?
- Is the information likely to remain available over time?
- Can the index/trigger be meaningfully correlated to actual conditions?

Critical Observations:

1) No single parameter is used solely in determining appropriate actions

2) Instead, ***different*** thresholds from ***different*** combinations of inputs is the best way to approach monitoring and triggers

3) Decision making (or “triggers”) based on ***quantitative values*** are supported favorably and are better understood

Triggers: State of South Carolina

Incipient Drought Alert Phase:

PDSI -.50 to -1.49
CMI 0.00 to –1.49
SPI -1.0 to –1.49
KBDI 300 to 399
Drought Monitor D0
ADS is 111-120% of the minimum flow for 2 consecutive weeks SWL in aquifer is between 11 to 20 ft. above trigger level for 2 consecutive months

Moderate Drought Alert Phase:

PDSI -1.50 to –2.99
CMI -1.50 to –2.99
SPI -1.50 to –2.00
KBDI 400 to 499
Drought Monitor D1
ADS 101-110%/SWL 1-10 ft above trigger level

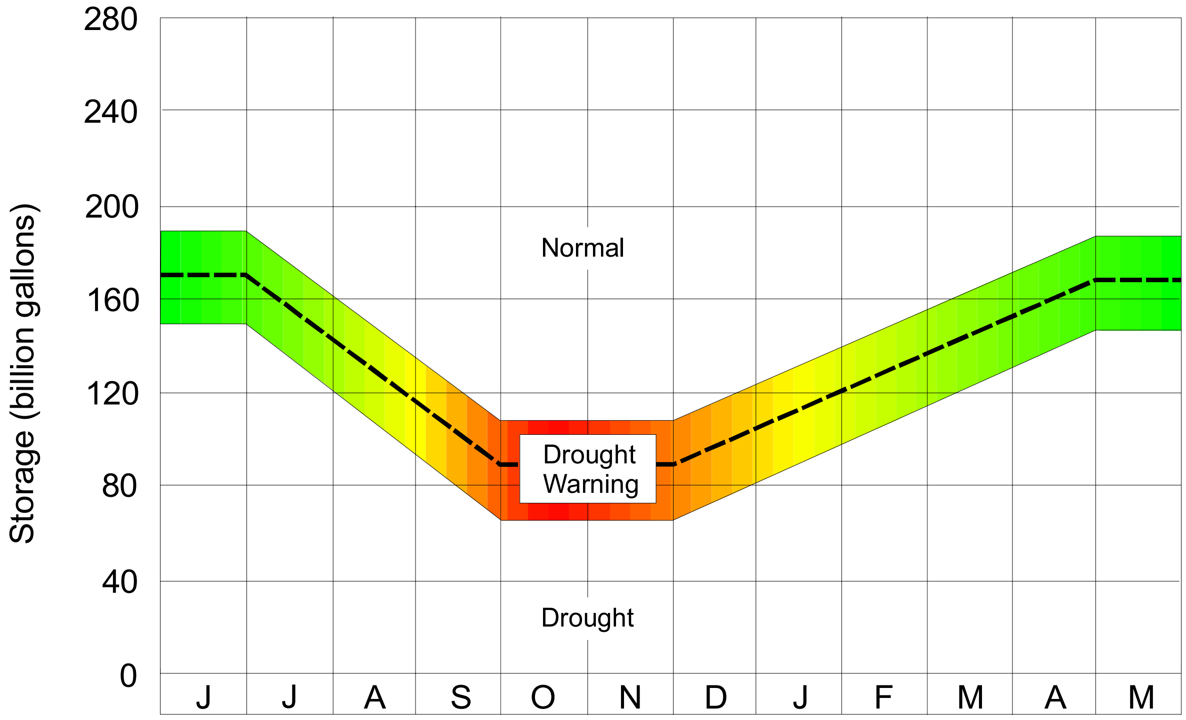
Colorado’s Drought Severity Triggers

Index Trigger	Response
>0	Normal conditions
0 to -1	Normal conditions
-1 to -2	Phase 1
-2 to -3	Phase 2
<-3	Phase 3

Triggers: Denver Water

If predicted or actual July 1 storage is below…	Declaration would be...
80 percent full	Mild drought
60 percent full	Moderate drought
40 percent full	Severe drought

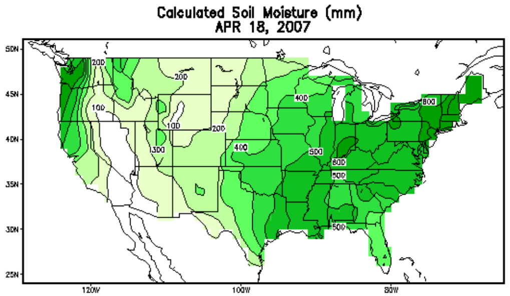
Trigger: Operation Curves for Cannonsville, Pepacton, and Neversink Reservoirs



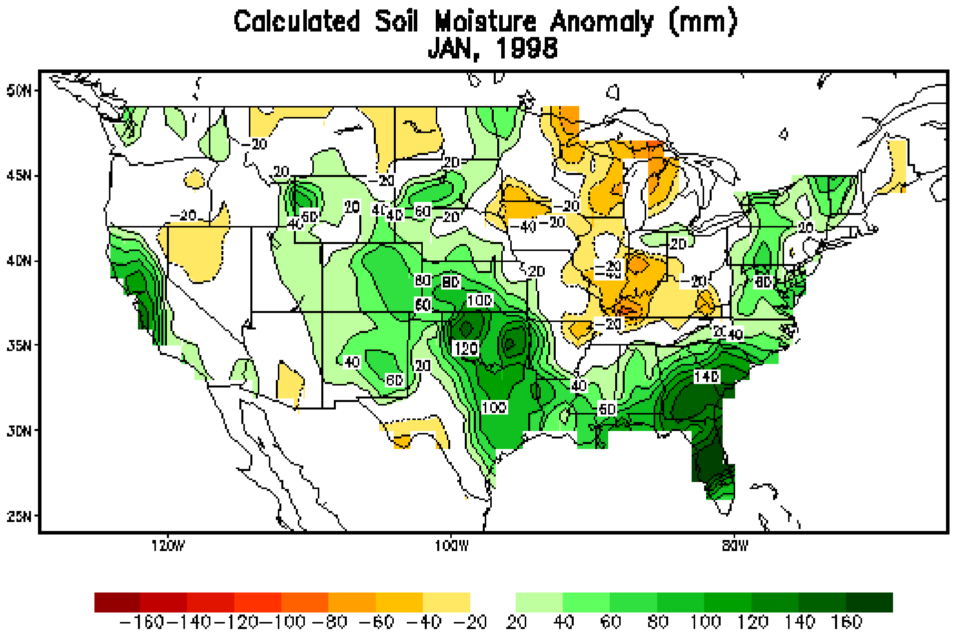
Considerations for selecting a specific trigger or index:

- Is the information readily available?
- Is the information likely to remain available over time?
- Can an index/trigger be calculated in a timely manner?
- Is the information reliable?
- Can the index/trigger be meaningfully correlated to actual conditions?

Soil Moisture forecasting



- Soil moisture outlook from CPC and Anomaly from 1998-2007
- Lowest soil moisture in Dec-Jan 1999-2000 in Indiana
- http://www.cpc.ncep.noaa.gov/soilmst/img/loop_wanom.gif



SIMBAL – Soil Moisture Balance model

Designed for simulation of field tiled soils that are poorly drained with perched water tables, a common situation in Indiana. This feature is not usually found in soil moisture models. The model can also be run
in well drained soil mode (no water table, no field tiles).

Initialization parameters

- corn phenology (silking date, observed or projected)
- soil profile depth (up to 10 six-inch layers)
- initial soil moisture content in each six-inch layer
- soil water characteristics (field capacity, wilting point)
- for soils with water table and field tiles
    - initial water table depth and field tile depth

SIMBAL model (continued)

Daily inputs

precipitation
evaporation (measured or modeled)

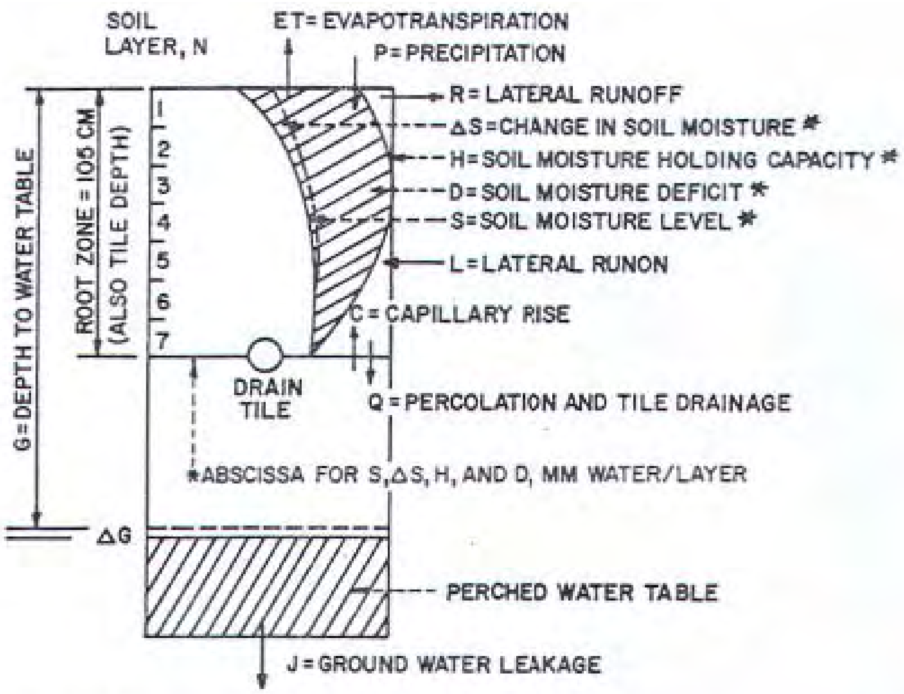


FIG. 1. Schematic profile of a poorly-drained soil, water balance components, and soil moisture expressions. Solid arrows are used for vector water balance components. Dashed arrows are used to identify the volumetric soil moisture scalars of S, ΔS, H and D, plotted on the abscissa (105 cm root and tile depth) against the respective soil layer N as the ordinate.

SIMBAL model (continued)

Daily Outputs

- precipitation and evaporation (from input)
- calculated corn evapotranspiration
- capillary flow from water table (poorly drained model)
- field runoff
- soil moisture content in each six-inch layer and profile total
- total soil profile moisture deficit
- percolation into water table (poorly drained model)
- water table depth (poorly drained model)
- tile drainage (poorly drained model)
- corn stress factor (0 to 1, < 0.5 indicates stressed crop)

SIMBAL model (continued)

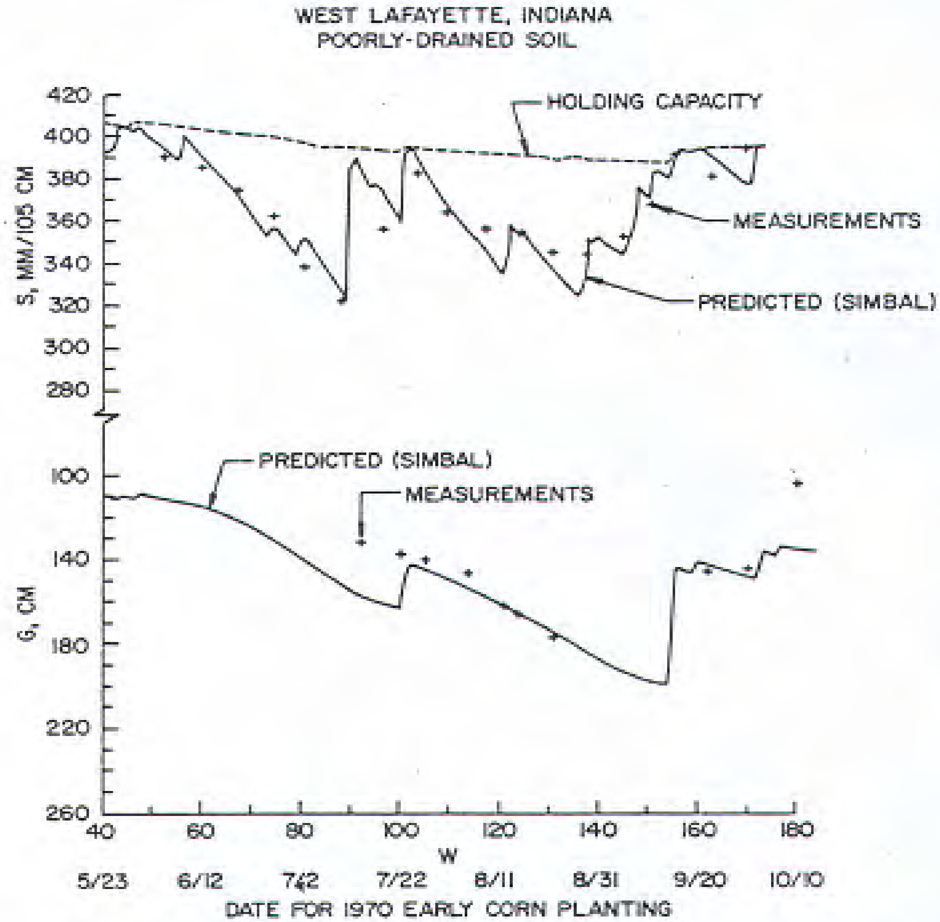


FIG. 5. Independent comparison of modeled (SIMBAL) and measured total soil moisture (S) in the top 105 cm and depth (G) to perched water table for early planted corn on PD soil (Typic Argiaquoll) in 1970. Day (W) is identified from silk date = 100.

SIMBAL model (continued)

Well drained soil verification
Castana IA

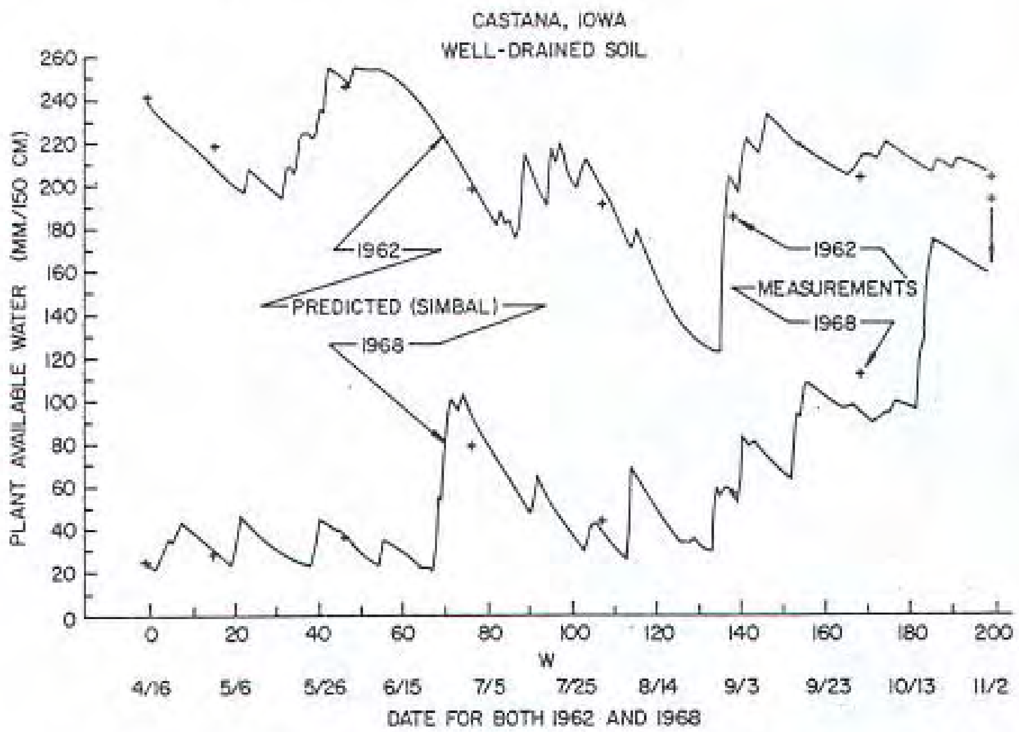


FIG. 6. Independent comparison of modeled (SIMBAL) and measured plant available soil moisture, millimeters in top 150 cm for corn, for driest (1968) and wettest (1962) years of record for WD soil (Typic Udorthent) Castana, Iowa. Corn silking date (W = 100) for both years was 25 July. Soil moisture measurements from Shaw *et al.* (1972).

Indiana Drought Region

- 3 drought regions from 9 NCDC Climate Divisions.

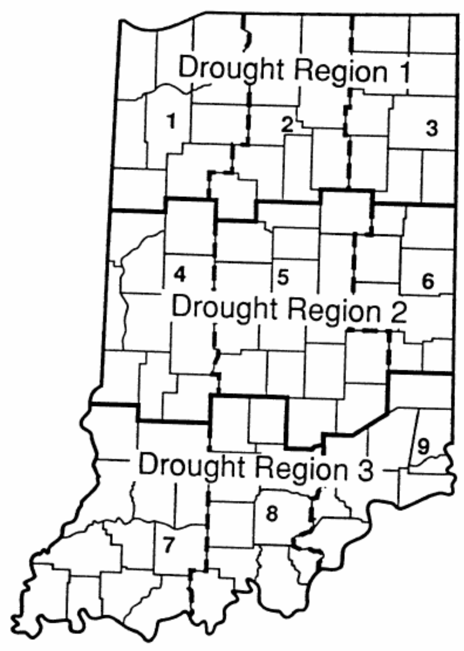


Figure 1. Indiana drought regions.

Developing drought indices for Indiana – Underway

- Use daily precipitation, temperature and stream flow to develop drought index in Indiana
- The time series for precipitation data is

  3-,6-,9- and 12- month (1985-1988).
- Time series for temperature data is 1,2,3,4 month duration between April to October only (1950-1988).
- Daily stream flow from USGS were used to calculated average monthly flow

continue

- **PHDI** > monthly index
  - Precipitation
  - Evapotranspiration
  - Soil water recharge
  - Runoff and water loss from soil

  (1931-1988)

Drought level in Indiana

- Drought watch

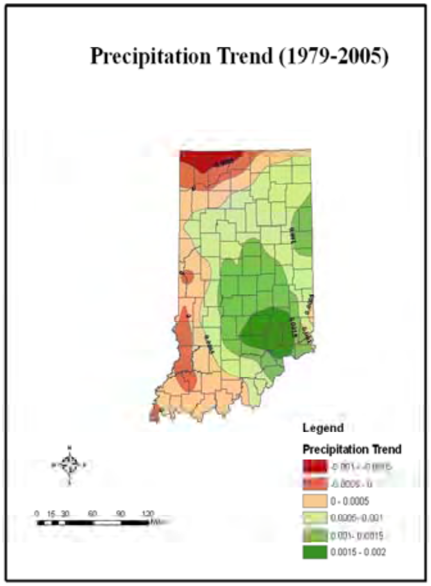
  > 75% level from mean value

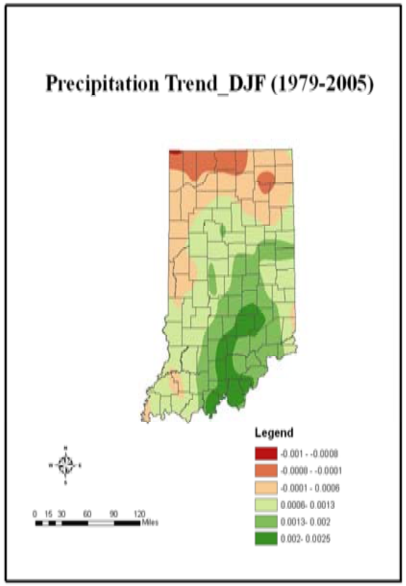
- Drought warning

  > 90% level from mean value

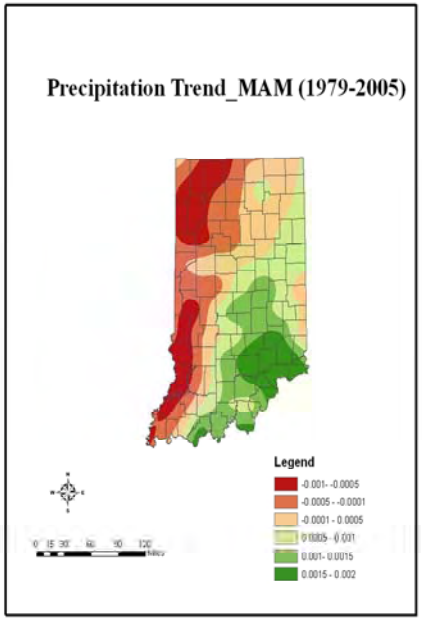
- Drought emergency

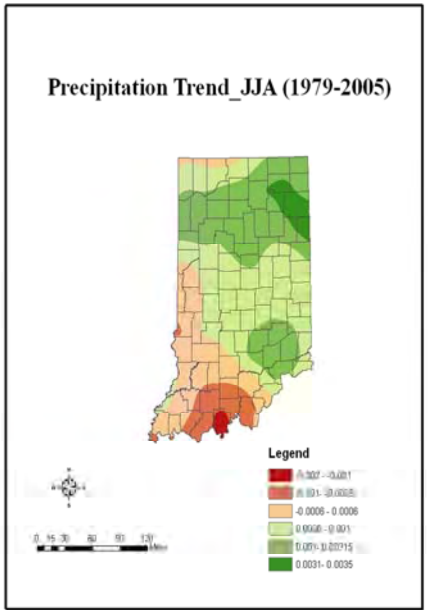
  > 95% level from mean value

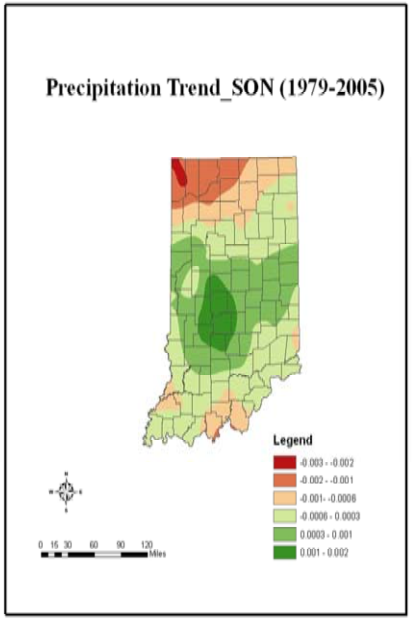




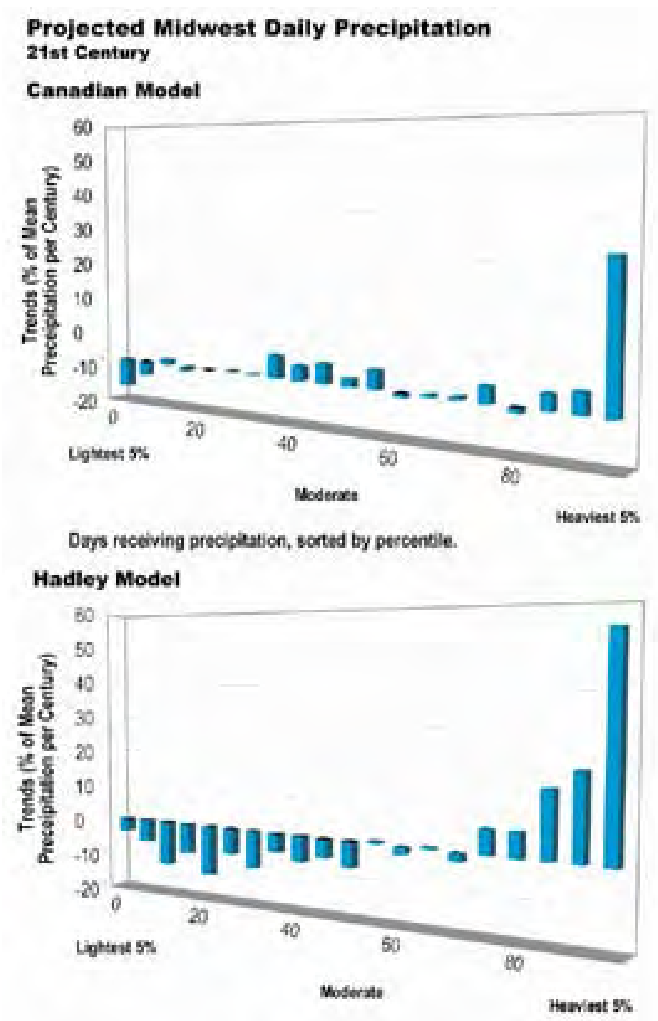
Drought or precipitation deficit tend to exist in northern and western part of Indiana and moving counter clockwise for seasonal trend



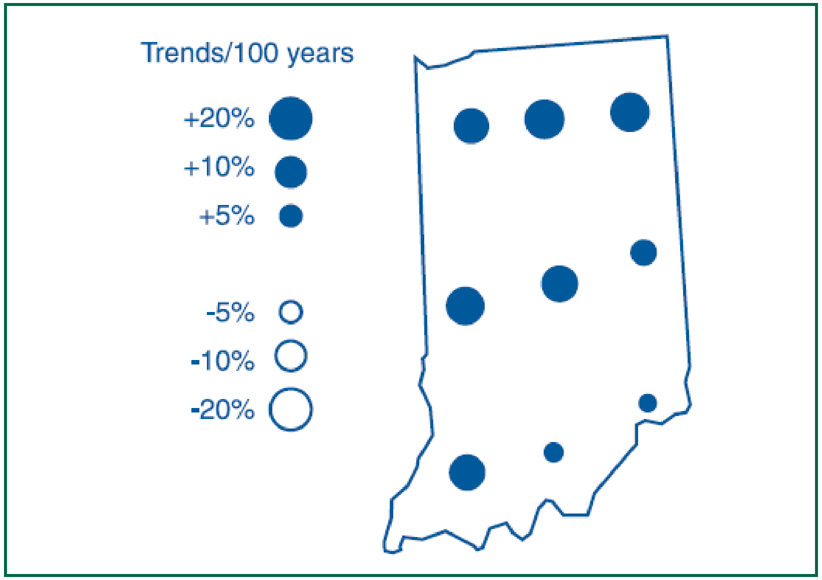




Projected Precipitation in Midwest and Indiana from IPCC model

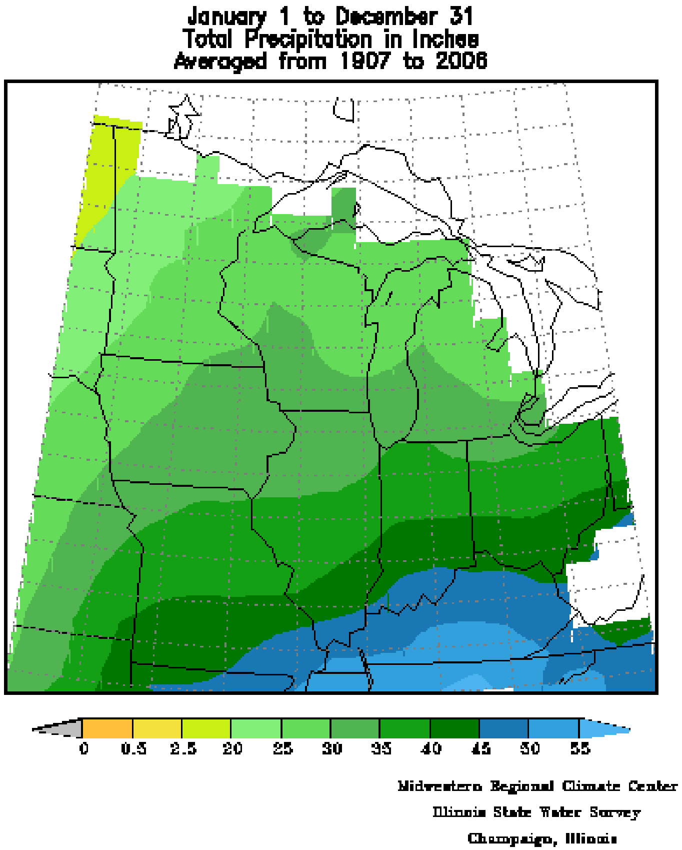


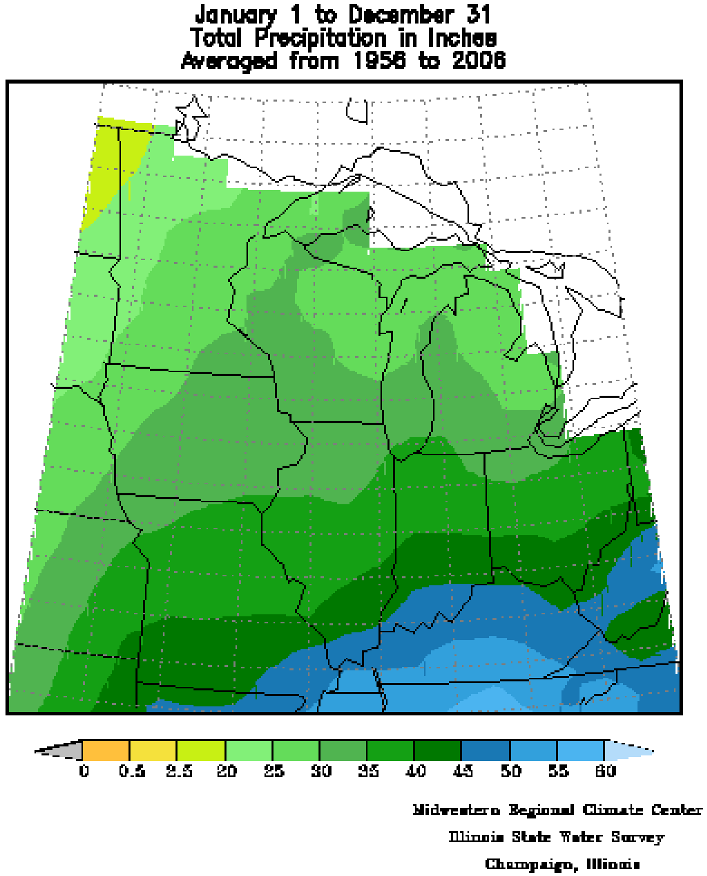
Precipitation Trends From 1900 To Present



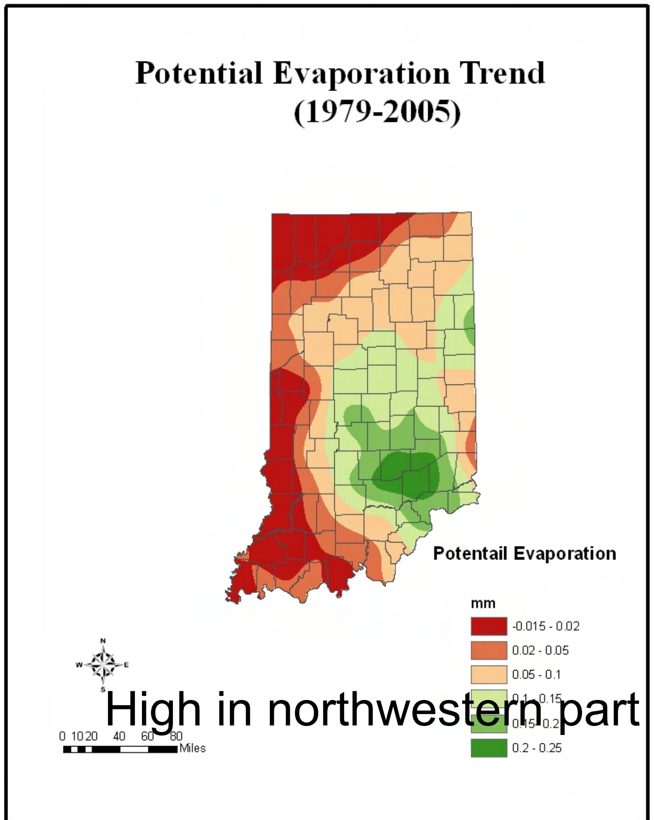
Source: Karl et al. (1996)

Precipitation Average 100 and 50 year for Midwest

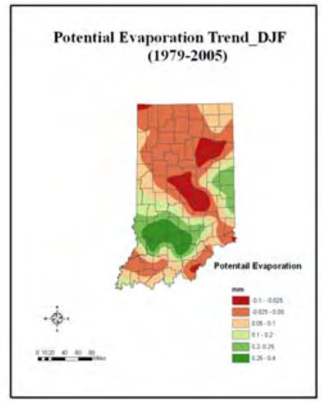


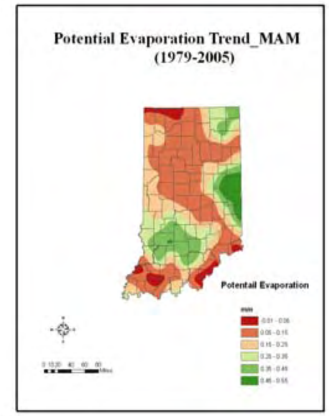


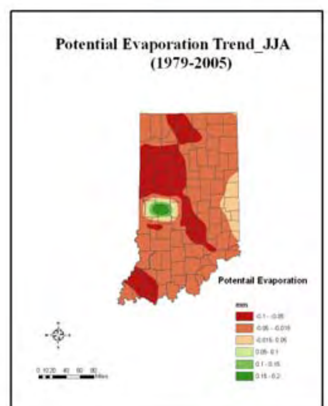
Evaporation Trend in 50 years

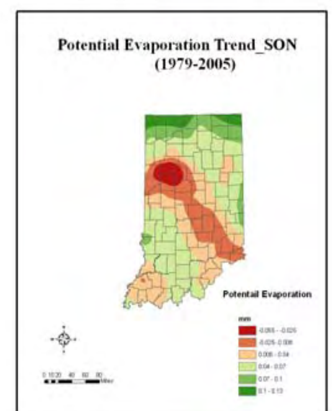


High in northwestern part









State of Illinois

State of Illinois, the criteria that discriminate precipitation droughts can be defined as following:

A 3-month precipitation drought exists if the state average is <= 60% of the mean value.

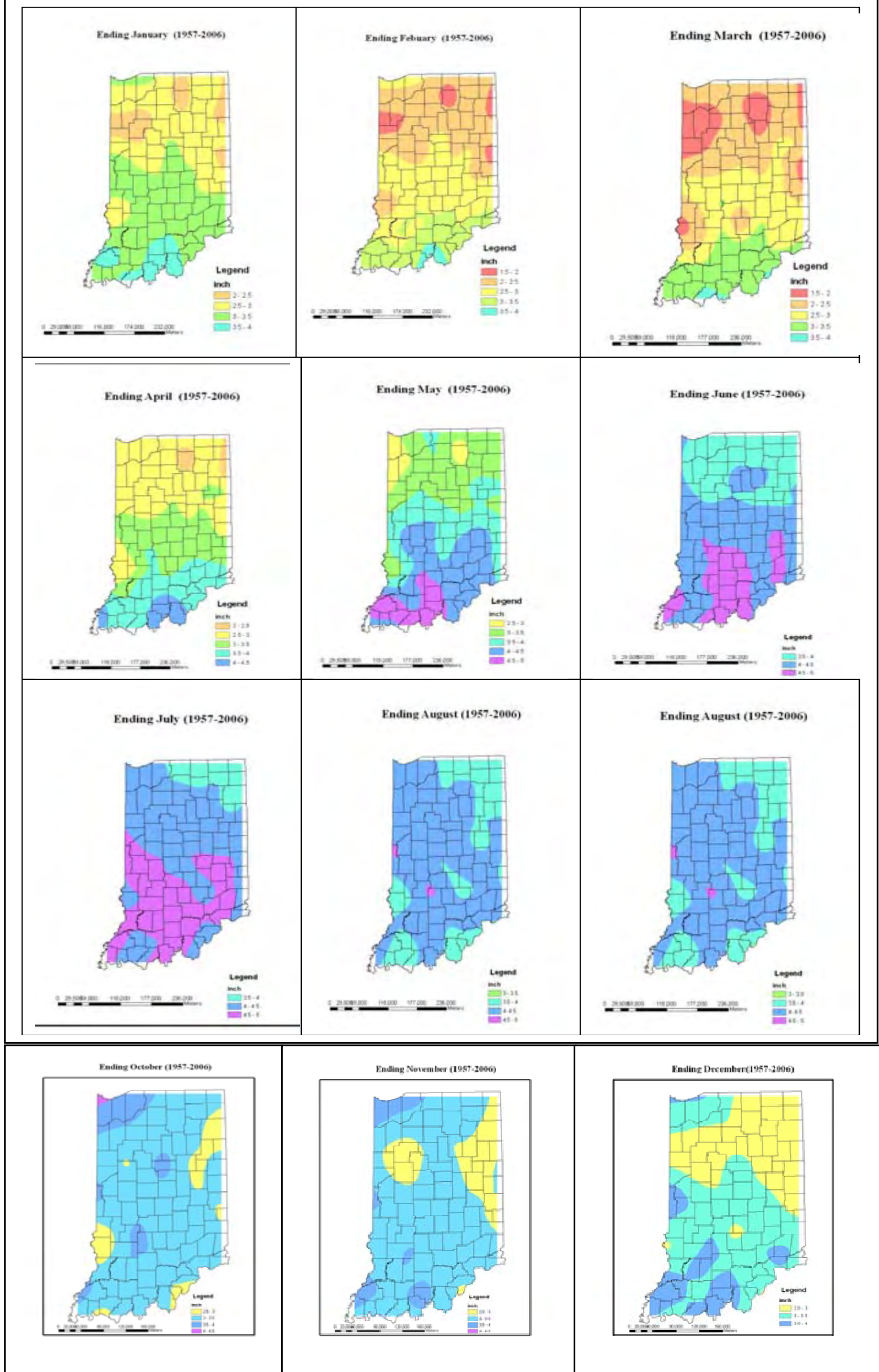
A 6 month precipitation drought exists if the state average is <=70% of the mean value.

A 12-month precipitation drought exists if the state average is <= 80% of the mean value.

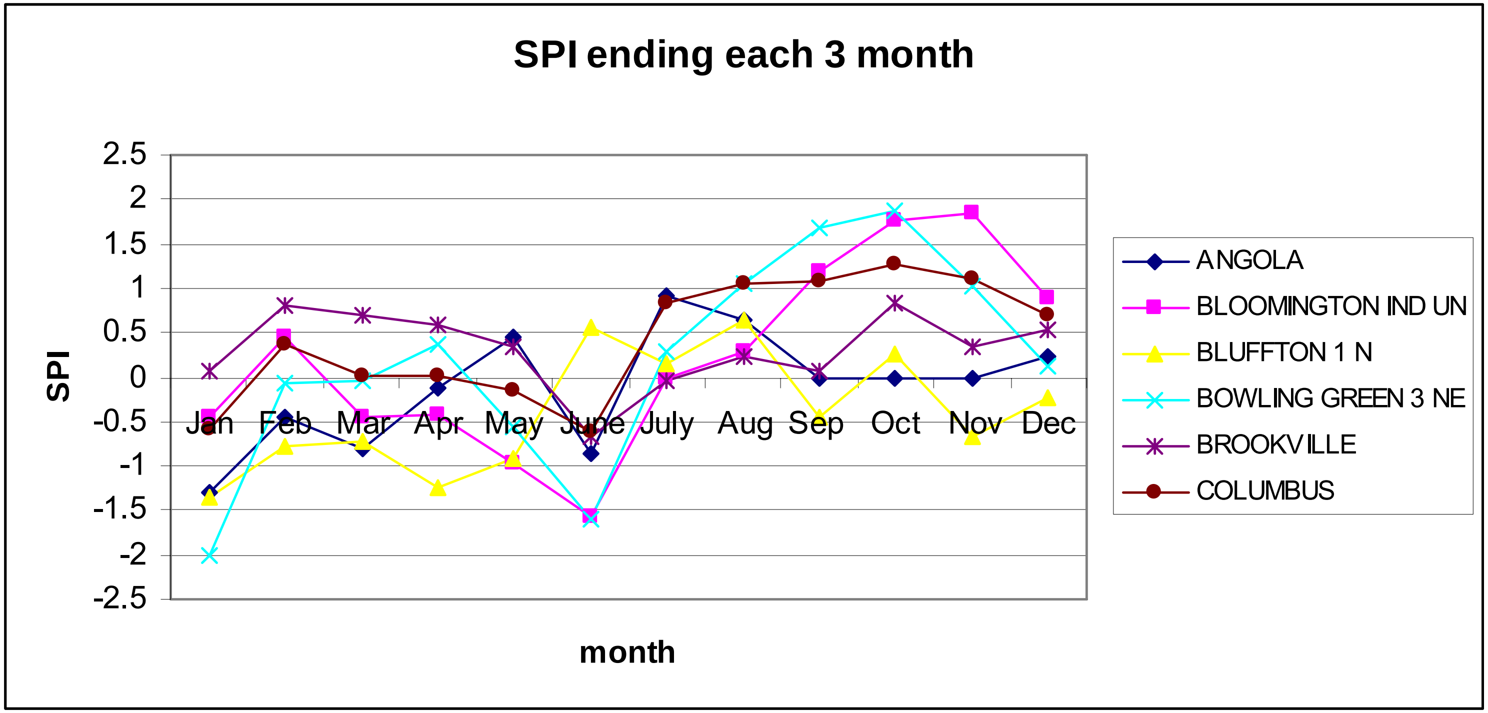
A 24-month precipitation drought exists if the state average is <=90% of the mean value.

A 30-month precipitation drought exists if the state average is <= 95% of the mean value.

Base Mean Map has been developed to compare with average precipitation to determine drought from precipitation deficit

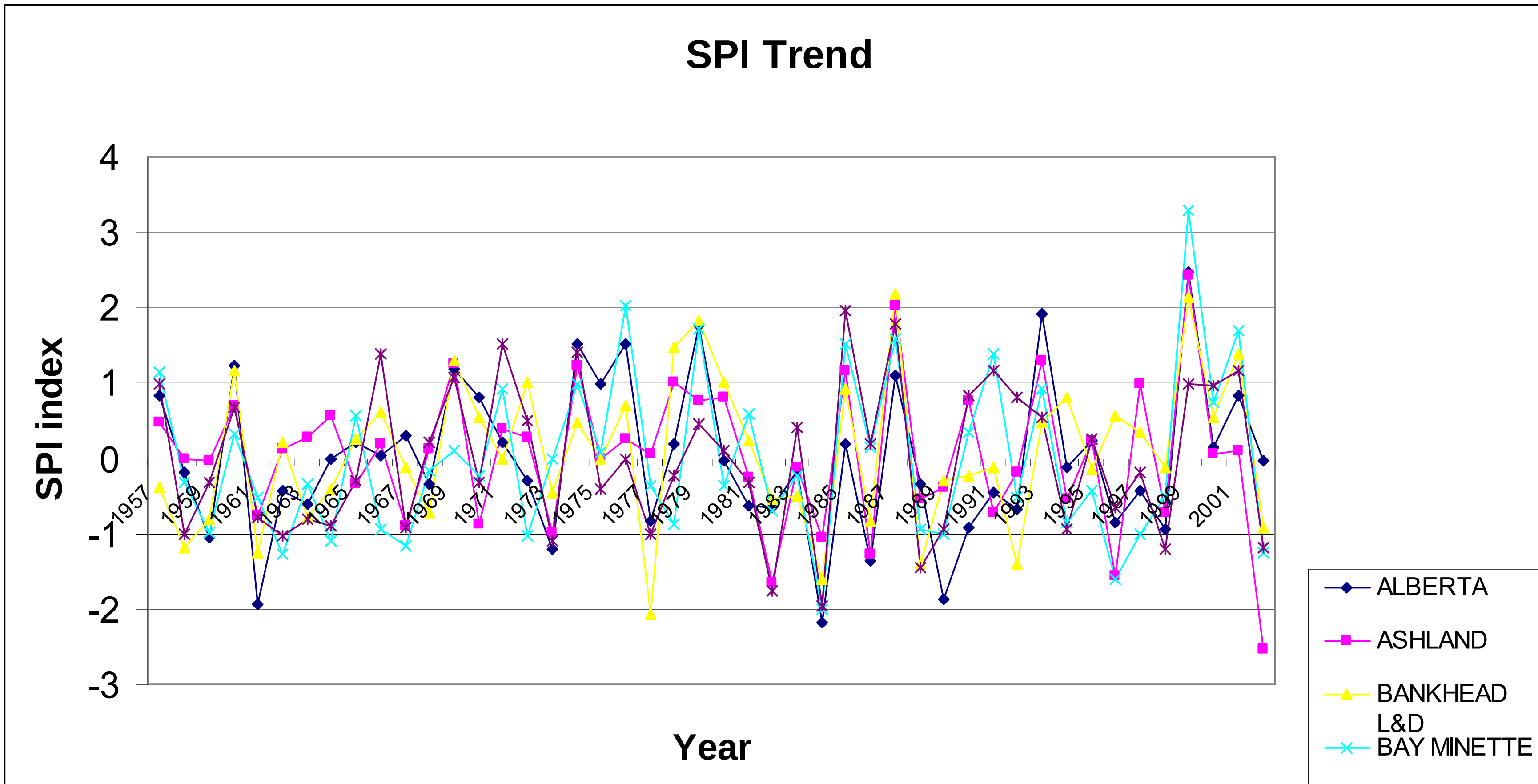


Indiana droughts responses are generally short term in Indiana



50 years average SPI index do not show / capture droughts in Indiana

(Burke et al. 2001)



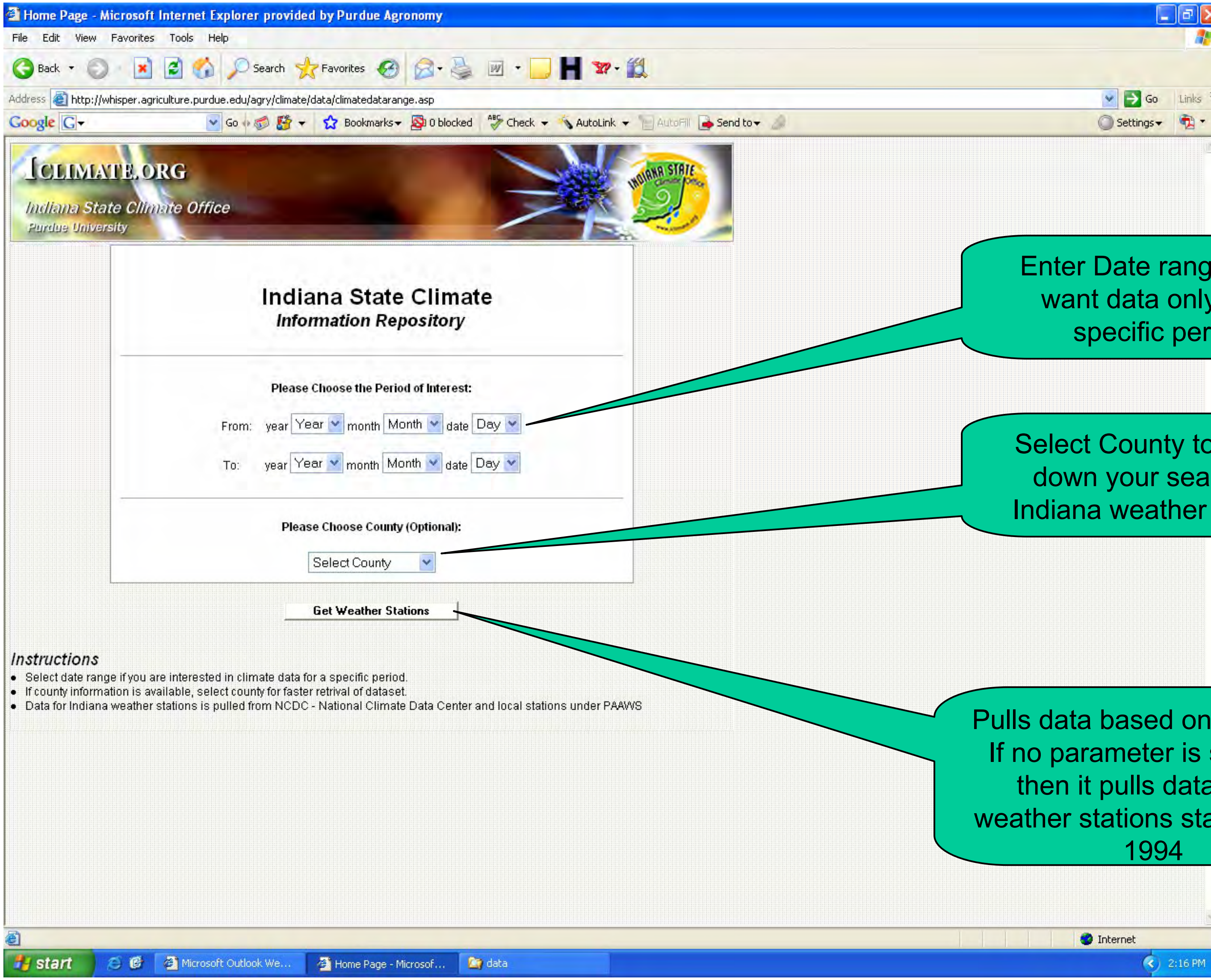
Drought Mitigation

- Pre-impact, pro-active
- Addresses at-risk sectors, population groups, and regions
- Actions aimed at reducing impacts, need for government intervention
- Initial costs of mitigation may be greater than response actions
- Paradigm shift

Categories of Drought Mitigation Actions

- Drought planning
- Improved monitoring
- Water supply augmentation
- Demand reduction/water conservation
- Public awareness/education programs
- Water use conflict resolution
- Legislation/policy changes
- Technical assistance on water management

Initialization Page -

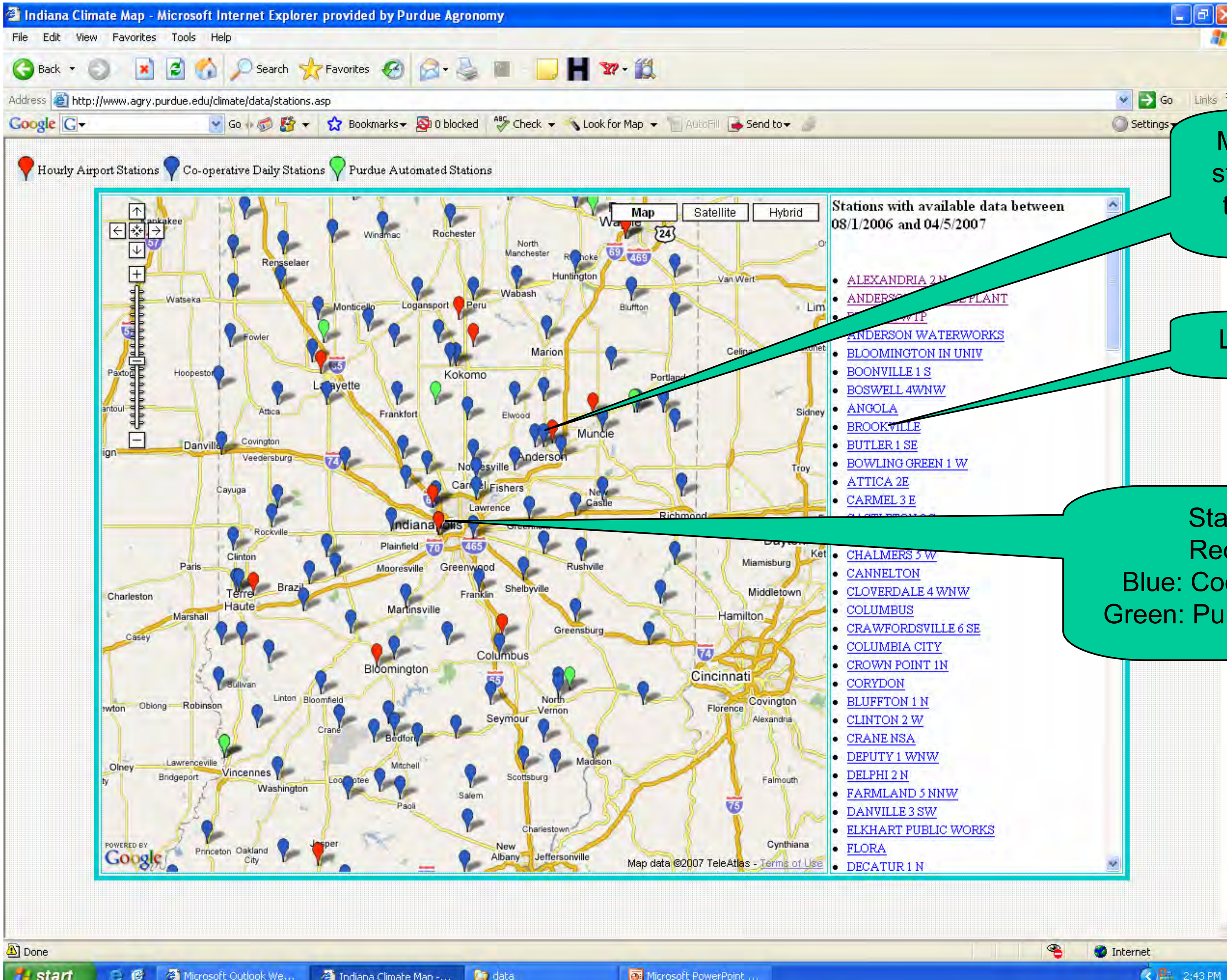


Enter Date range if you want data only for a specific period

Select County to narrow down your search for Indiana weather stations

Pulls data based on selection. If no parameter is selected, then it pulls data for all weather stations starting from 1994

Indiana Weather Stations Mapped -



Maps all Indiana weather stations which has data in the specified date range selected

Lists all stations mapped

Station Color Coding
Red: Hourly Stations
Blue: Cooperative Daily stations
Green: Purdue Automated Stations

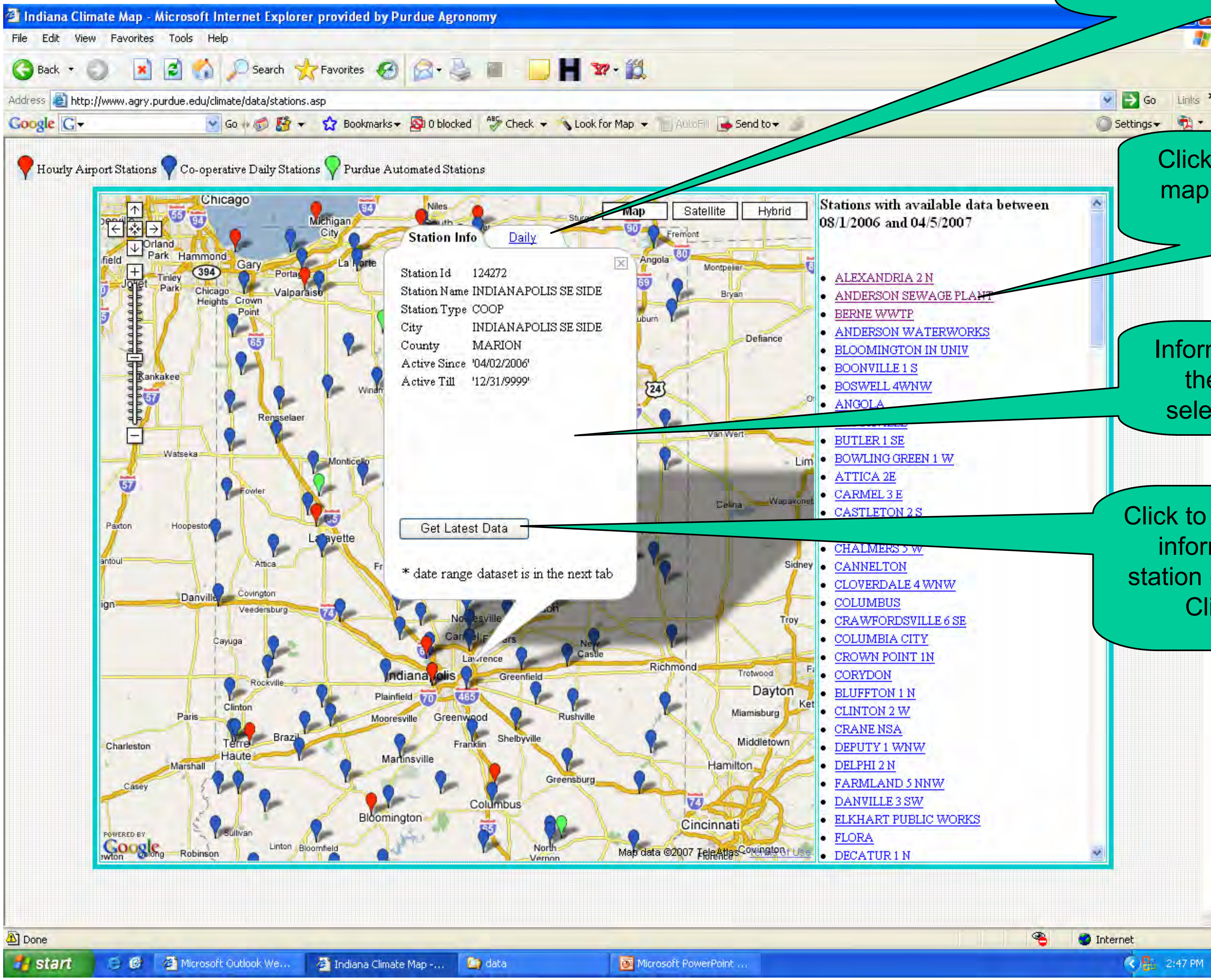
Station details -

Tabs to download data for specified date range

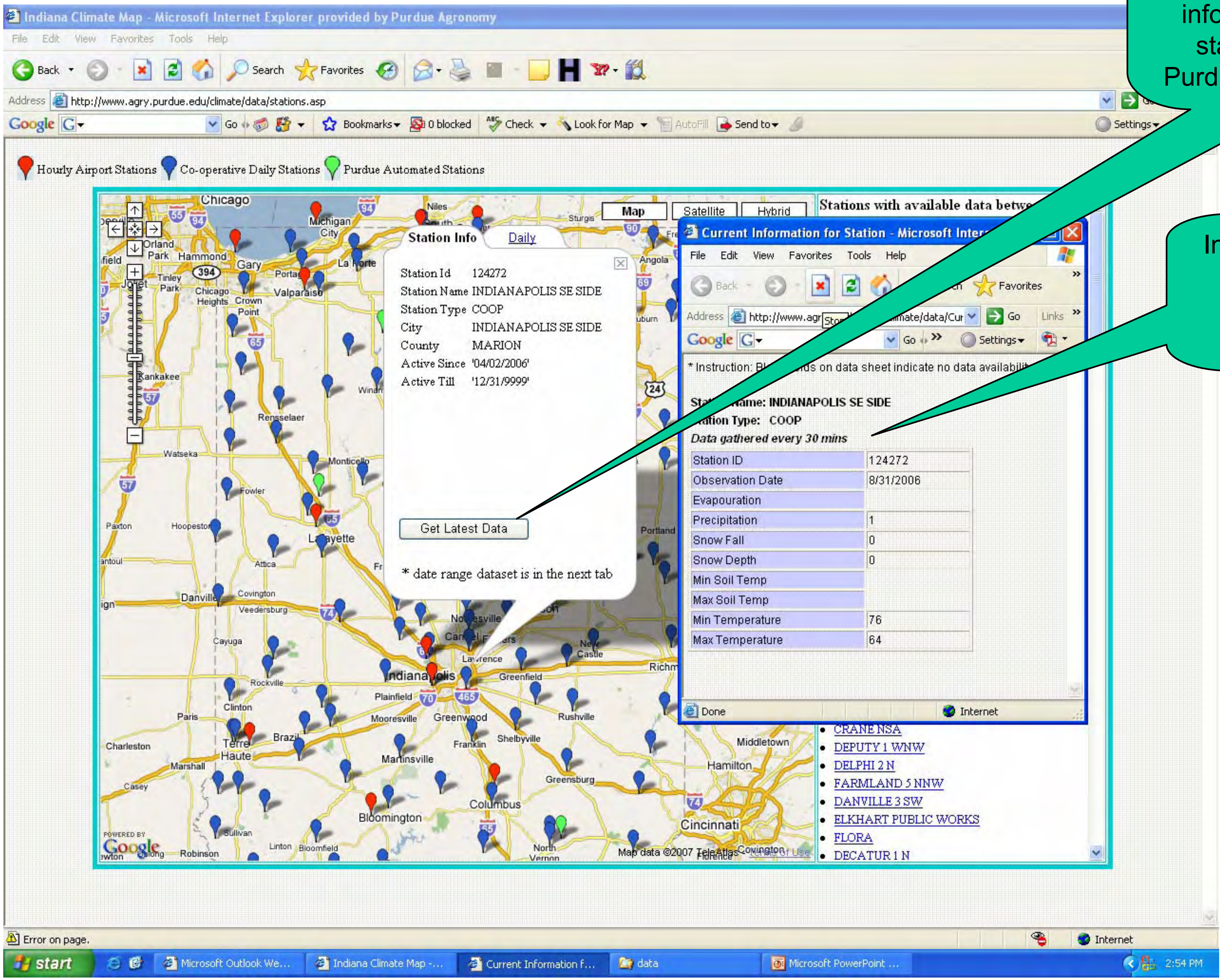
Click on a station icon (on map) or select the station from the sidebar

Information window shows the details specific to selected weather station

Click to get the latest weather information for selected station (as present in Purdue Climate Database)



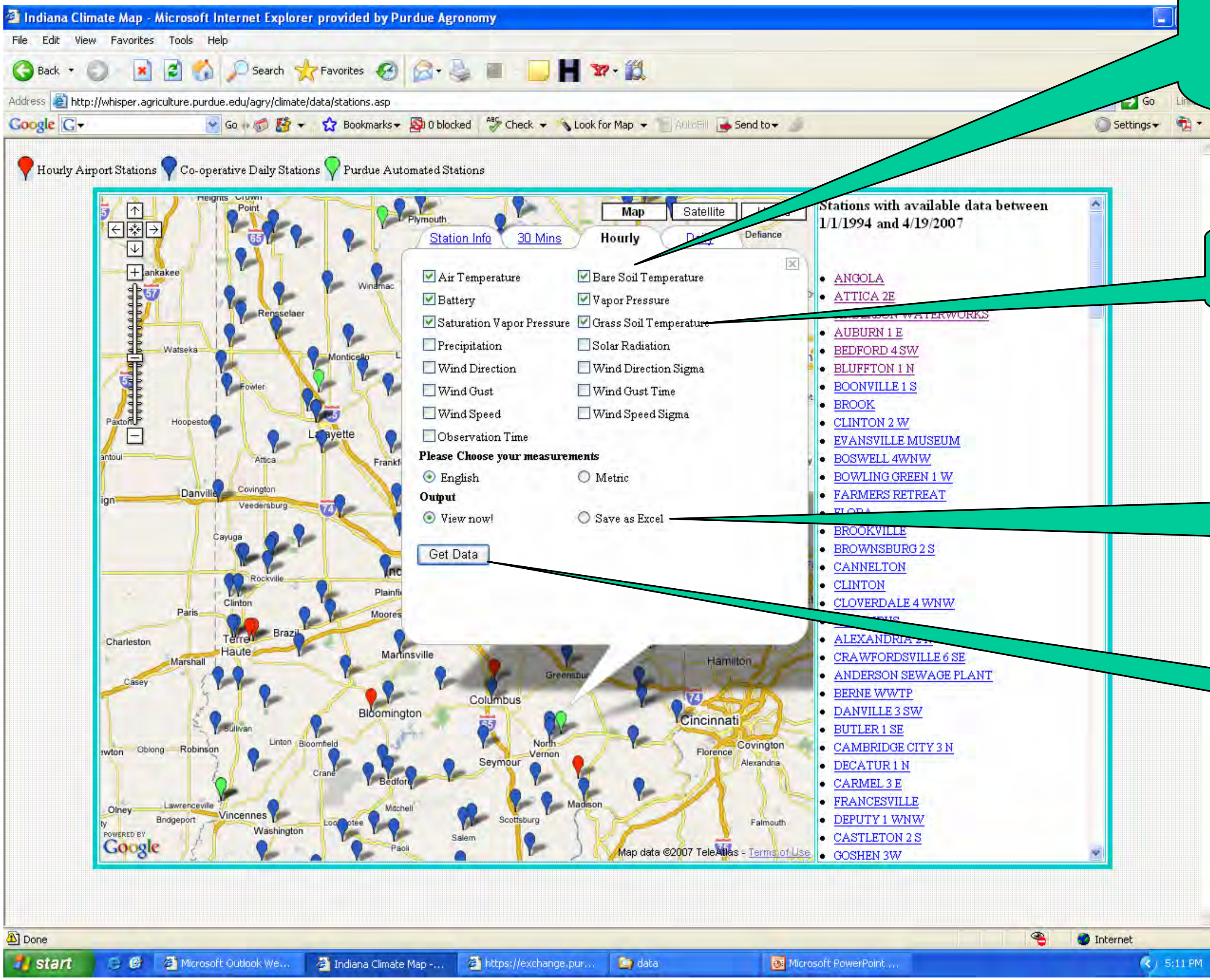
Latest weather information for selected station -



On clicking “Get Latest Data” adjacent window open up to show latest information for selected station (as present in Purdue Climate Database)

Information window shows the latest weather information for selected weather station

Select Parameters to download weather information -



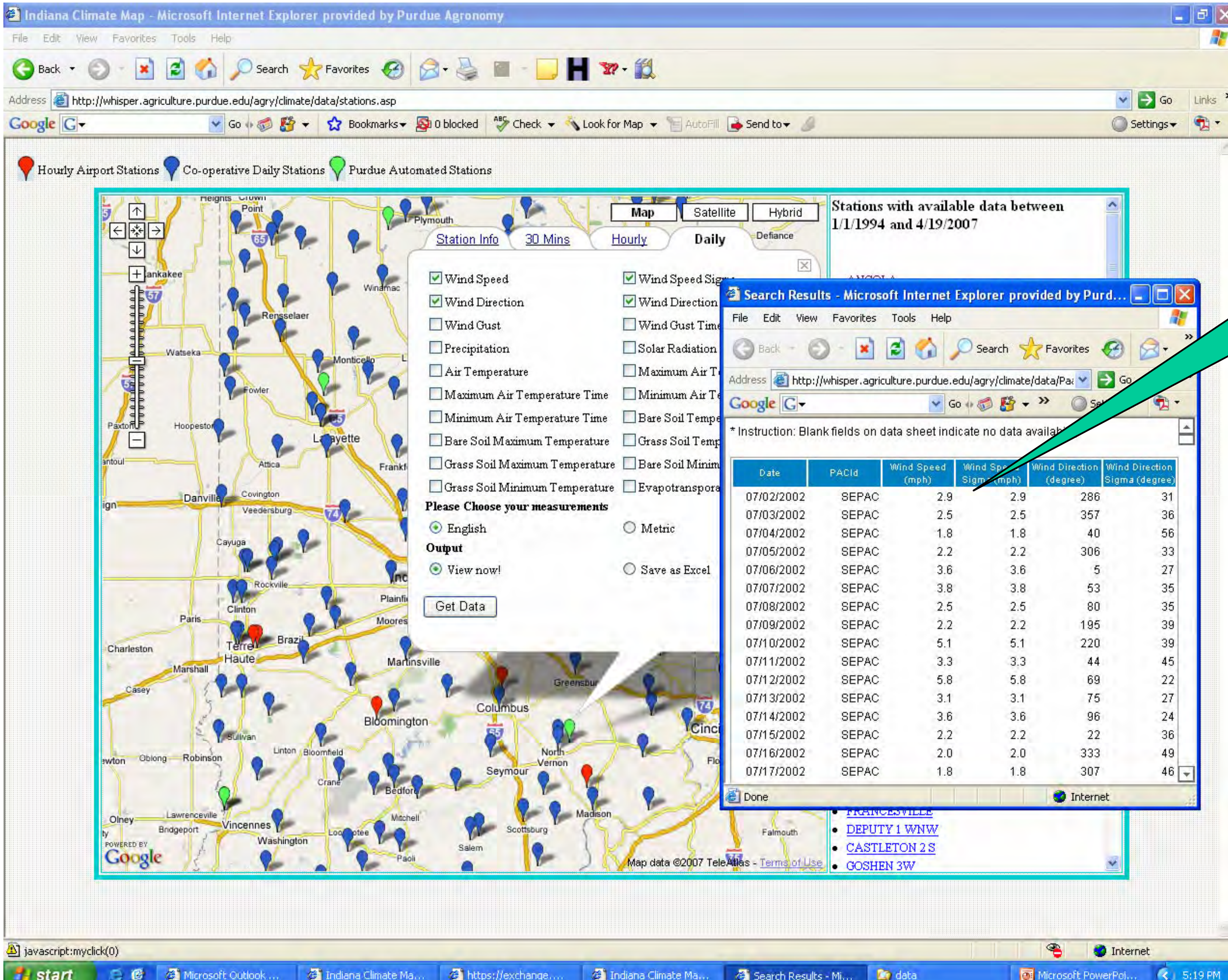
Select the tab corresponding to the type of data available for the station (30 Mins, Hourly, Daily)

Check parameters that you need in the dataset

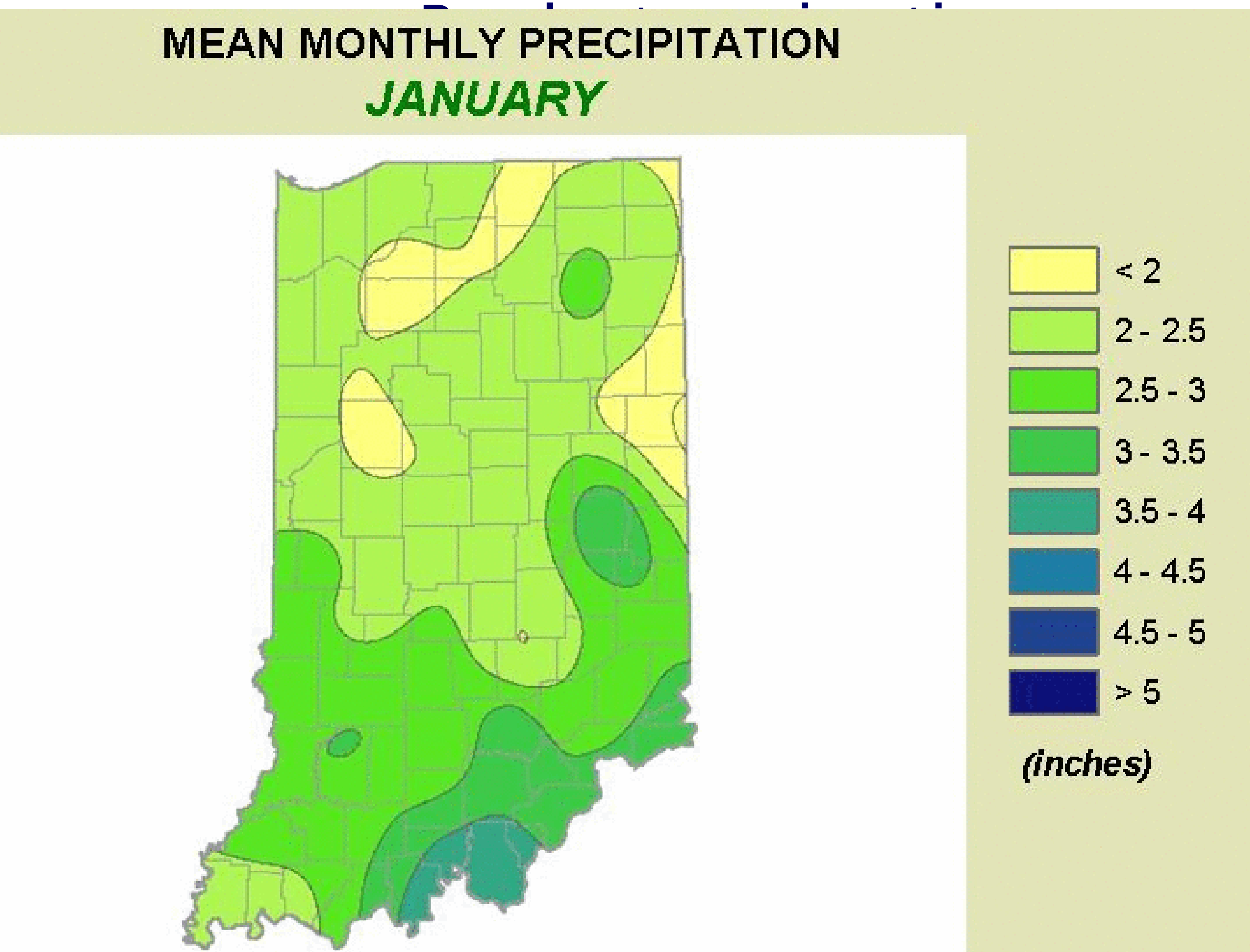
Select to download data into an excel sheet or view on web page

Hit Get Data to pull data for selected parameters

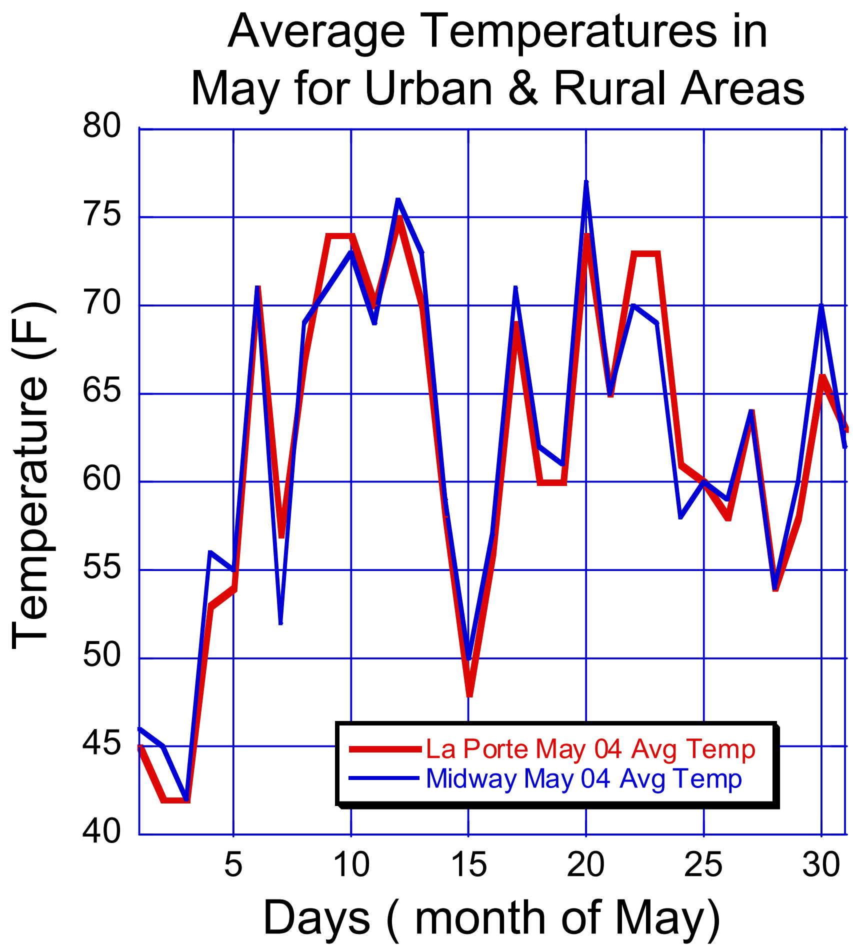
Download weather information for selected station -

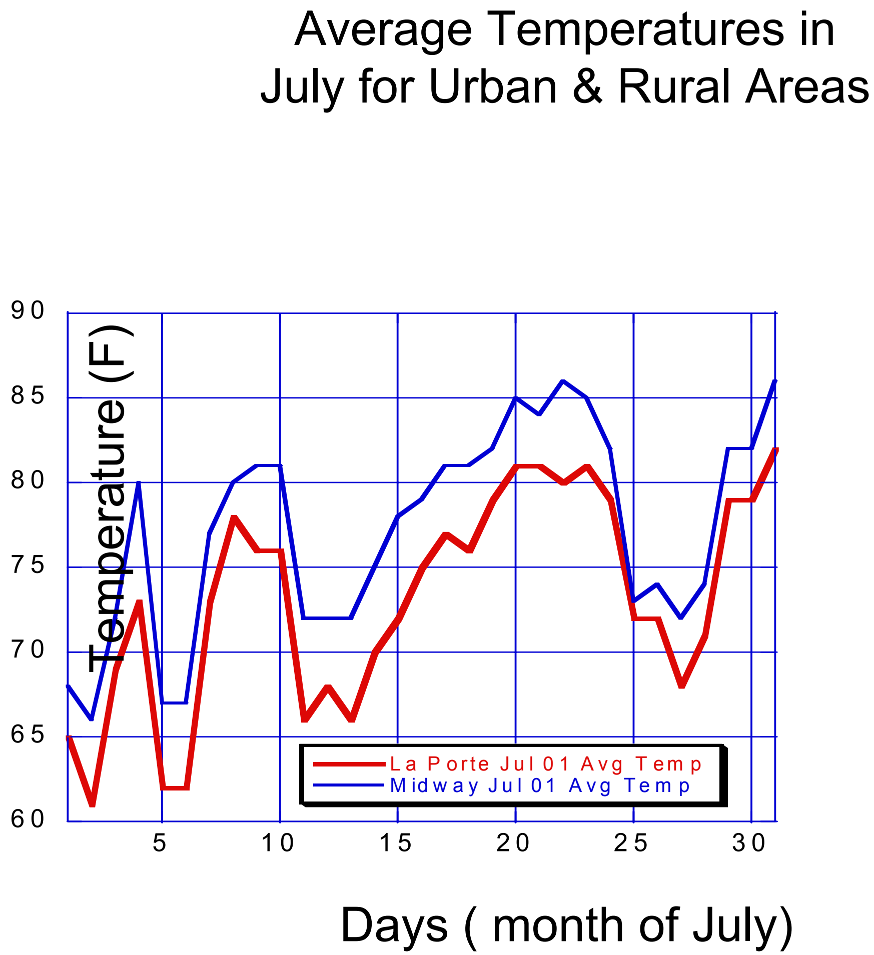


Data downloaded for the selected parameters


MEAN MONTHLY PRECIPITATION
JANUARY
< 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5
4.5 - 5
> 5
(inches)

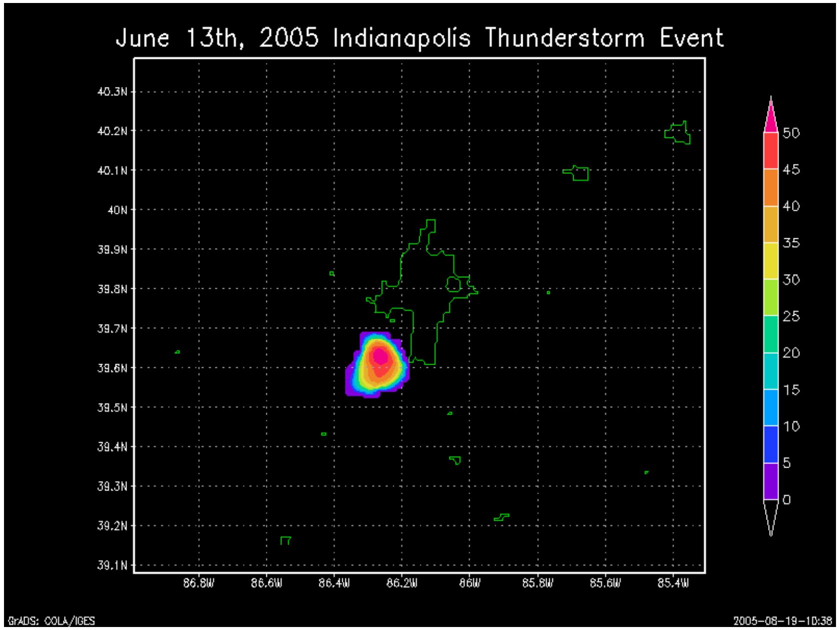
Urban Rural Analysis

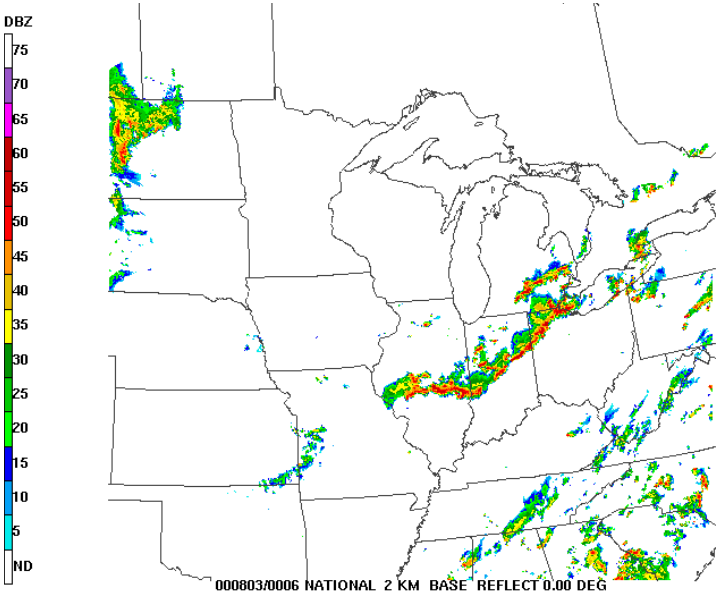


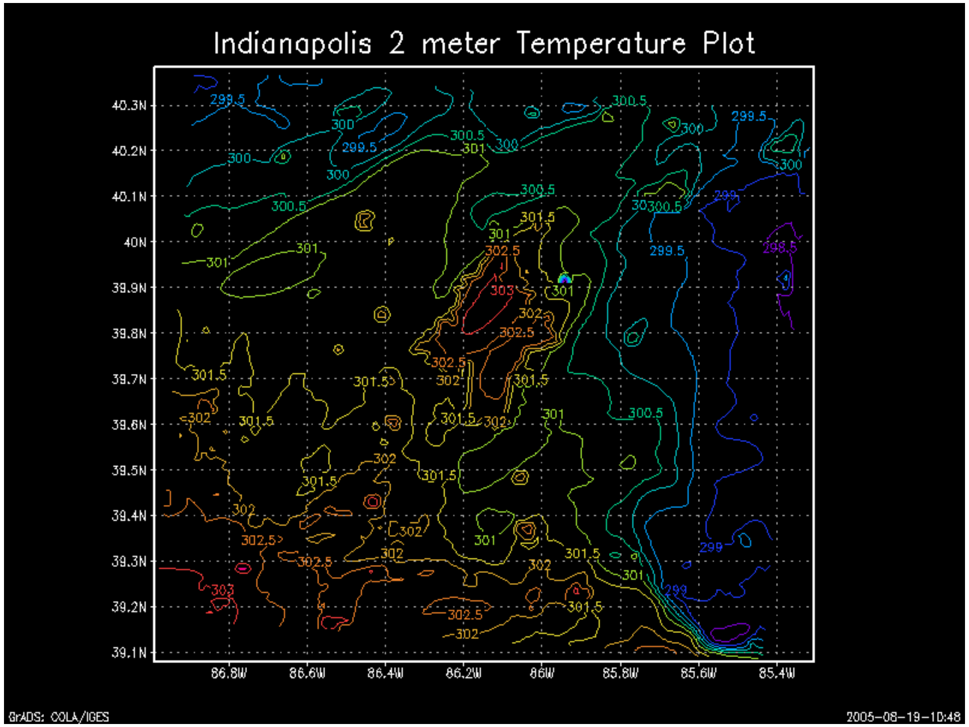


Urban impacts on Climate

- **Research is currently underway determining the effect of urban areas on storm development and regional climate**

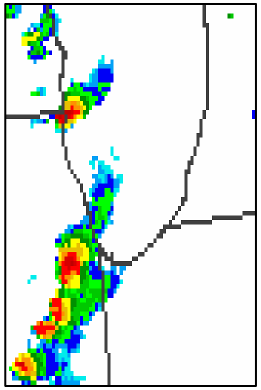






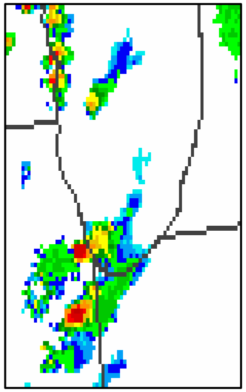
Urban Rural Analysis

Chicago / Gary Thunderstorm Case: May 24, 2004 (UTC)



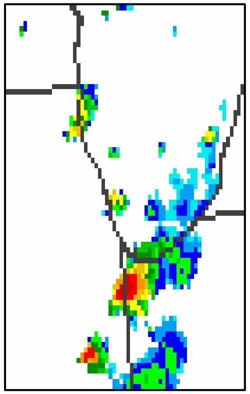
UTC 0130

Thunderstorm approaches Chicago



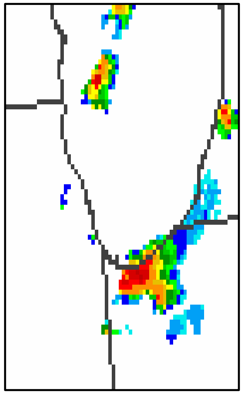
UTC 0203

Thunderstorm Splits in Chicago



UTC 0232

Thunderstorm re-merges outside Chicago

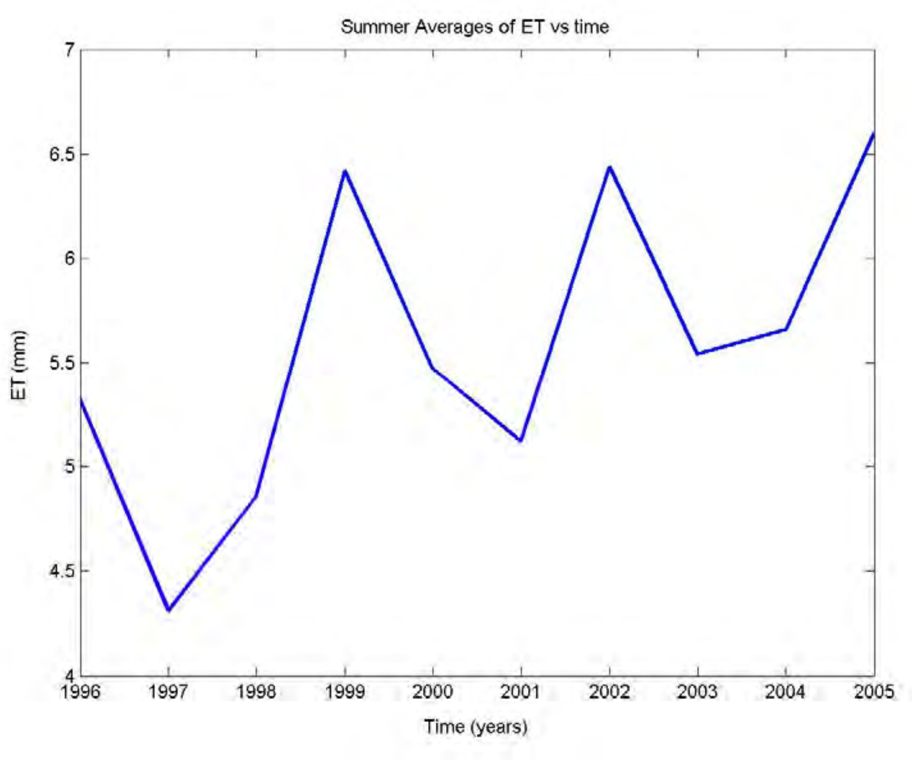


UTC 0300

Thunderstorm hits La Porte

Indiana Evapotranspiration Analysis

- **Using data from 16 airport sites around Indiana**



Average ET for the Summer Months from 1996 – 2005 for all 16 counties in Indiana

Counties from which data was taken

La Porte Anomaly

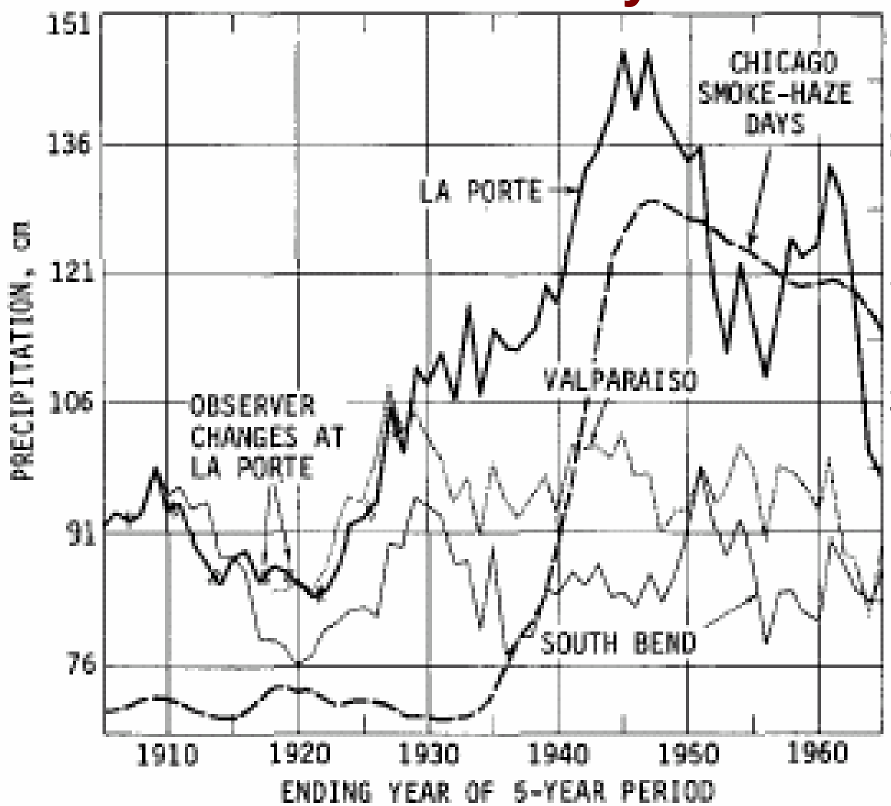
- **From 1929-1964 La Porte, Indiana weather records show unusual patterns in thunderstorms, hail, and rain data.**
- **30-40% more precipitation than surrounding areas**

La Porte Anomaly

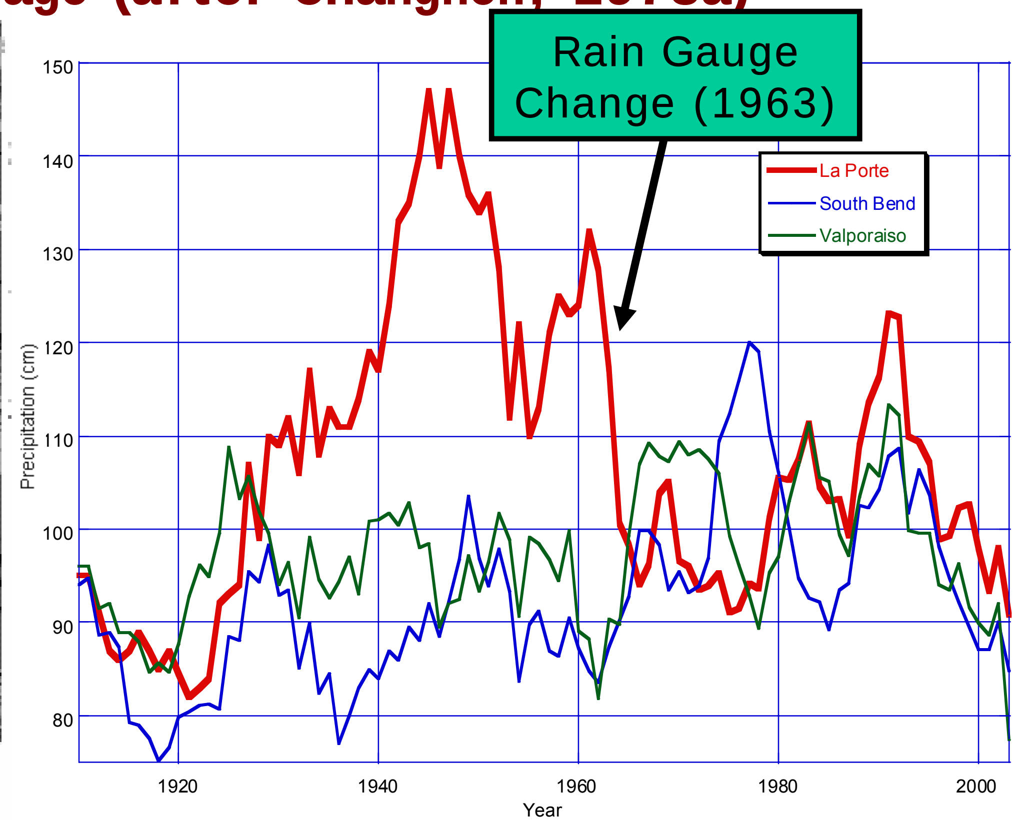
- **Factors: Chicago, Urban area, Industry**
- **If the data is accurate La Porte can only be a small scale phenomenon**
- **The disappearance of the anomaly could be the movement or reduction of atmospheric particulates**

Analysis 1 (1905-2003)

- **Five-year moving averages of annual precipitation at La Porte and two other area stations, and 5-year totals of smoke-haze days at Chicago (after Changnon, 1973a)**

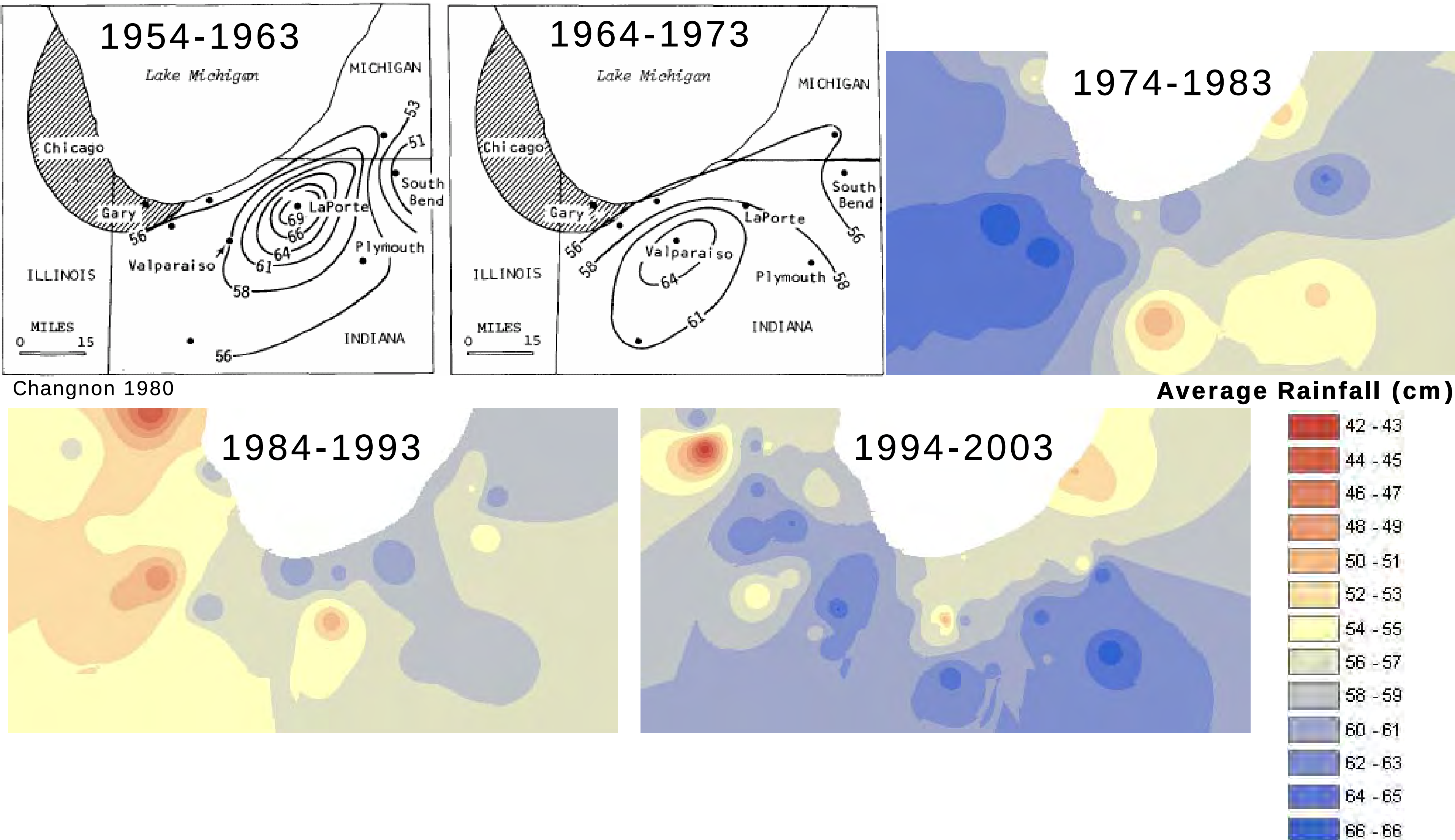


Changnon, 1980



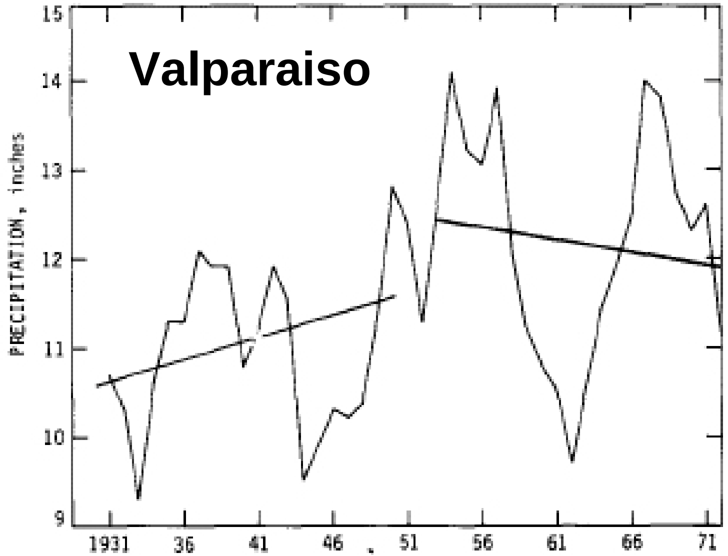
Analysis 2 (10 year periods)

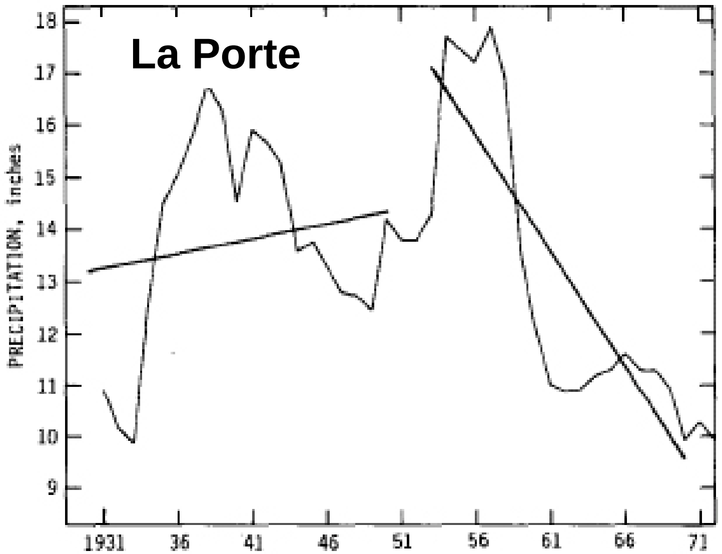
Average warm season rainfall patterns

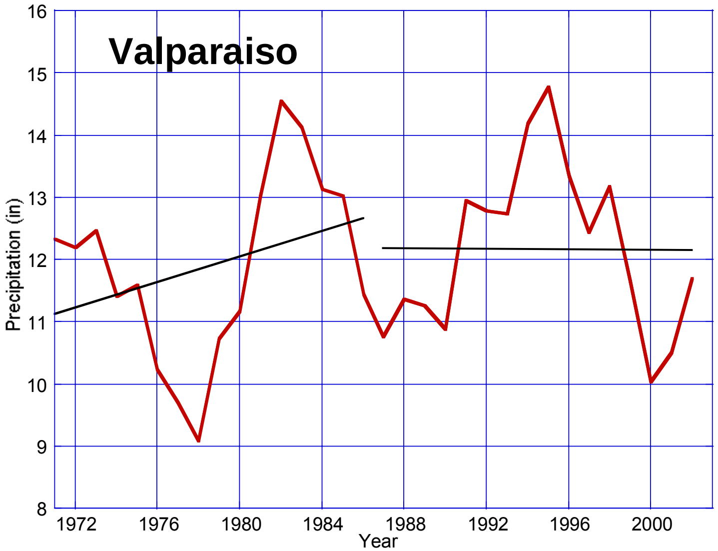


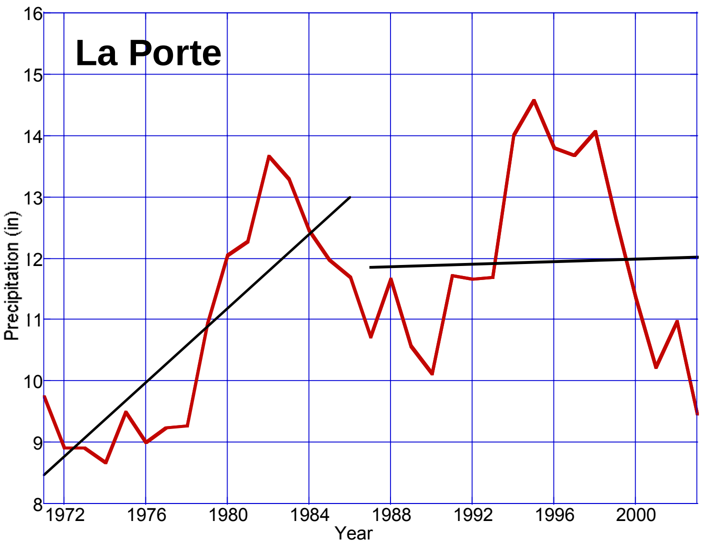
Analysis 3 (1931-1972 and 1973-2003)

- Five year moving averages of summer rainfall



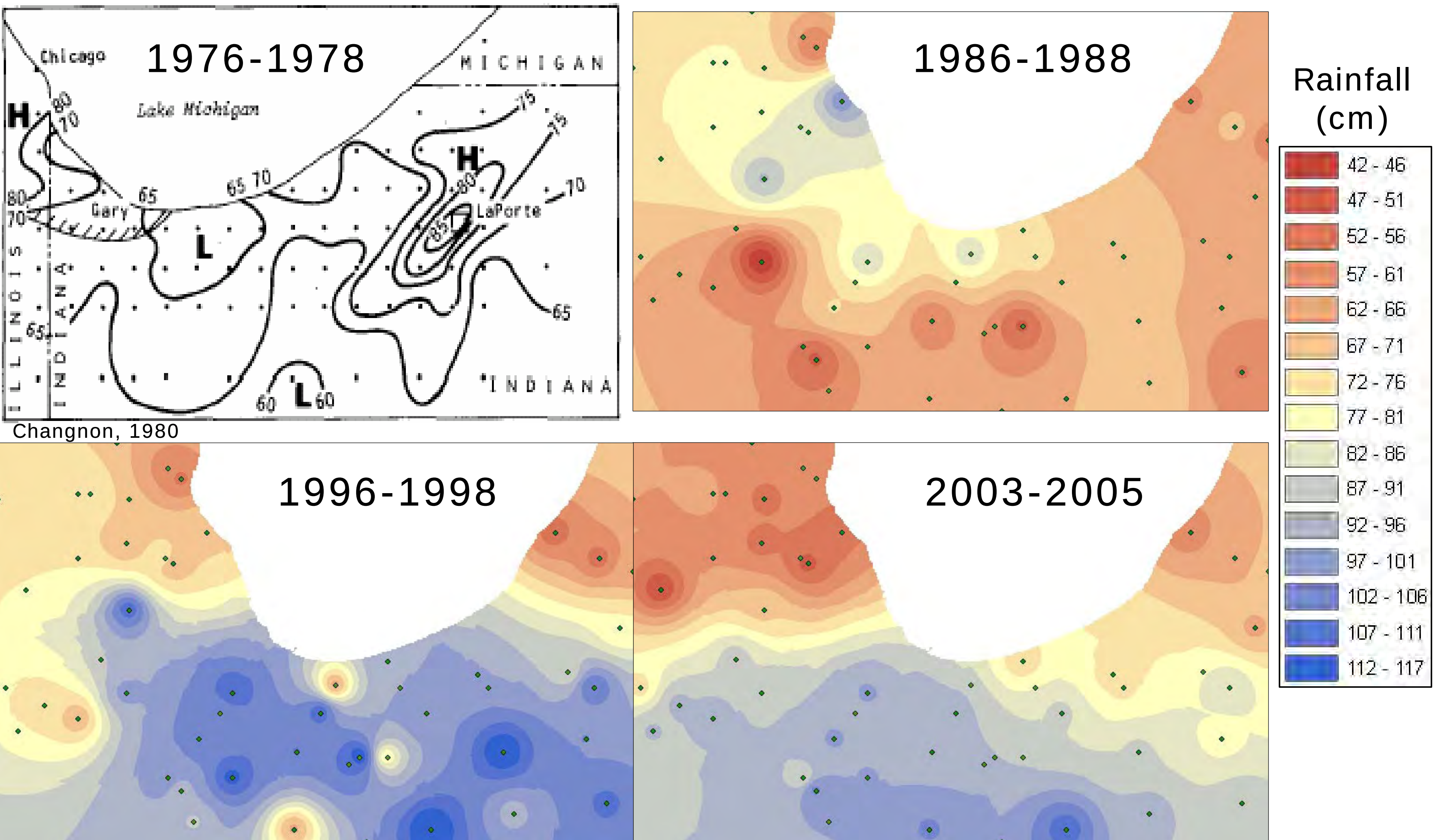






Analysis 4

Isohyetal pattern based on all network storms with point amounts ≥ 2.54 cm, 1976-1978



PRODUCTS: tables

Text files

Individual stations

West Lafayette 6 NW
COOP ID: 129430
Latitude: 40.48 N
Longitude: 87 W

YEAR	JAN	FEB	MAR
1974	338	180	518
1975	383	231	176
1976	167	230	358
1977	109	121	489
1978	159	24	252
1979	304	54	359
1980	87	206	384
1981	22	197	27
1982	426	103	400
1983	62	97	166
1984	61	99	229
1985	195	322	345
1986	9	145	172
1987	144	12	138
1988	134	165	279

Whole network

PRECIPITATION (1974 - 2003)

STATION NAME	CD	LATITUDE	LONGITUDE	ELEVATION	JANUARY	FEBRUAR
BEDFORD 4 SW	8	38.83	-86.52	167.60	2.52	2.78
BLOOMINGTON INDIANA UNIV	8	39.17	-86.52	253.00	2.70	2.78
BOWLING GREEN 3 NE	4	39.42	-86.97	210.30	2.44	2.46
BROOKVILLE	9	39.42	-85.02	192.00	2.88	2.67
COLUMBIA CITY	3	41.15	-85.48	259.10	2.62	2.62
COLUMBUS	5	39.20	-85.92	189.30	2.14	1.84
CRANE NAVAL DEPOT	7	38.87	-86.93	222.50	2.98	2.88
DECATUR 1 N	3	40.85	-84.93	249.90	1.86	1.67
ELWOOD	5	40.28	-85.83	256.00	2.23	1.96
ENGLISH	8	38.28	-86.47	155.40	3.58	3.56

Year: 1997 West Lafayette
Hour: CST

Time mo/dy:hr	Air Temp F	Td F	WB Temp F	RH %	Wind S mph	Wind D deg
01/01:00	37	35	36	92	10	120
01/01:01	39	35	37	85	7	110
01/01:02	37	35	36	92	8	110
01/01:03	37	37	37	100	10	120
01/01:04	39	37	38	92	7	130
01/01:05	39	37	38	92	8	200
01/01:06	39	39	39	100	10	250
01/01:07	39	39	39	100	10	180
01/01:08	41	39	40	92	9	240
01/01:09	41	39	40	92	8	240

Combination of variables

PRODUCTS: tables

	A	B	C	D
1	West Lafayette 6 NW			
2	COOP ID: 129430			
3	Latitude: 40.48 N			
4	Longitude: 87 W			
5				
6	YEAR	JAN	FEB	MAR
7	1974	338	180	518
8	1975	383	231	176
9	1976	167	230	358
10	1977	109	121	489
11	1978	159	24	252
12	1979	304	54	359
13	1980	87	206	384
14	1981	22	197	27
15	1982	426	103	400
16	1983	62	97	166
17	1984	61	99	229
18	1985	195	322	345
19	1986	9	145	172
20	1987	144	12	138
21	1988	134	165	279
22	1989	157	75	156
23	1990	123	601	516
24	1991	136	38	500
25	1992	120	197	293

- Spreadsheets

Same as text files

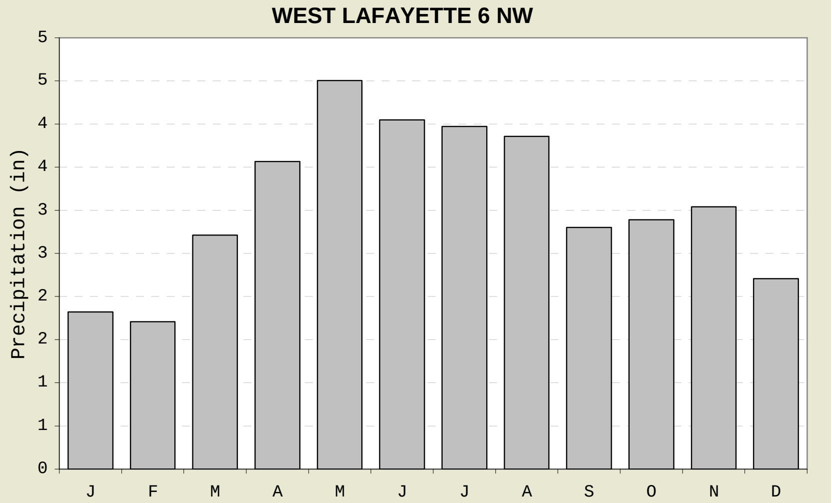
+

Summary Statistics

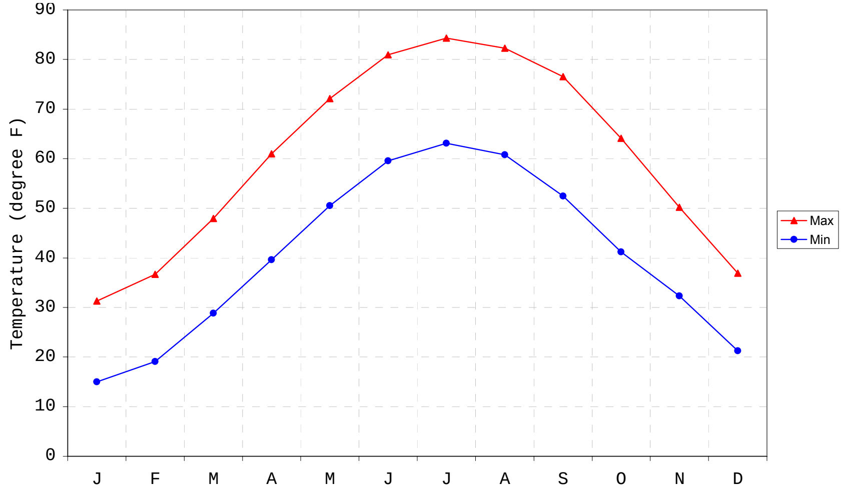
2001	62	356	46	281	292	228	499
2002	224	292	281	539	442	408	342
2003	107	115	68	274	680	383	790
Average	**1.82**	**1.71**	**2.71**	**3.57**	**4.51**	**4.05**	**3.97**
Summary Statistics							
Mean	3712.3		St. Dev.	532.5472		Range	2145
St. Error	97.22937		S. Var.	283606.5		Minimum	2787
Median	3773		Kurtosis	-0.49245		Maximum	4932
Mode	4105		Skewness	0.328844		Sum	111369

PRODUCTS: graphs

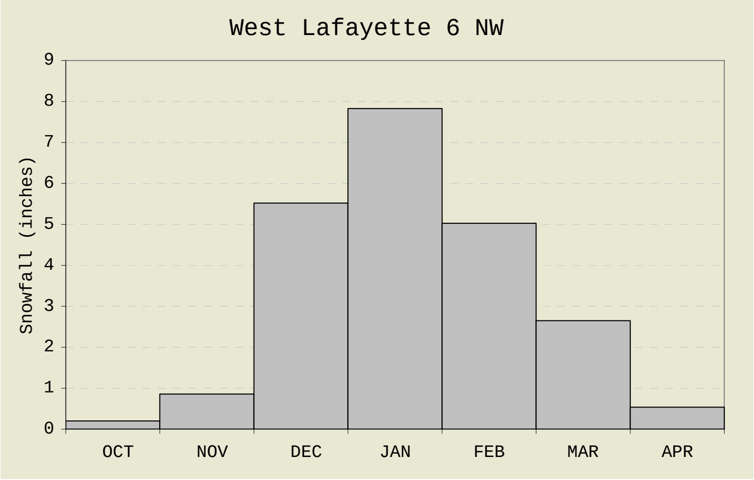
Mean monthly precipitation



Mean max & min temperatures

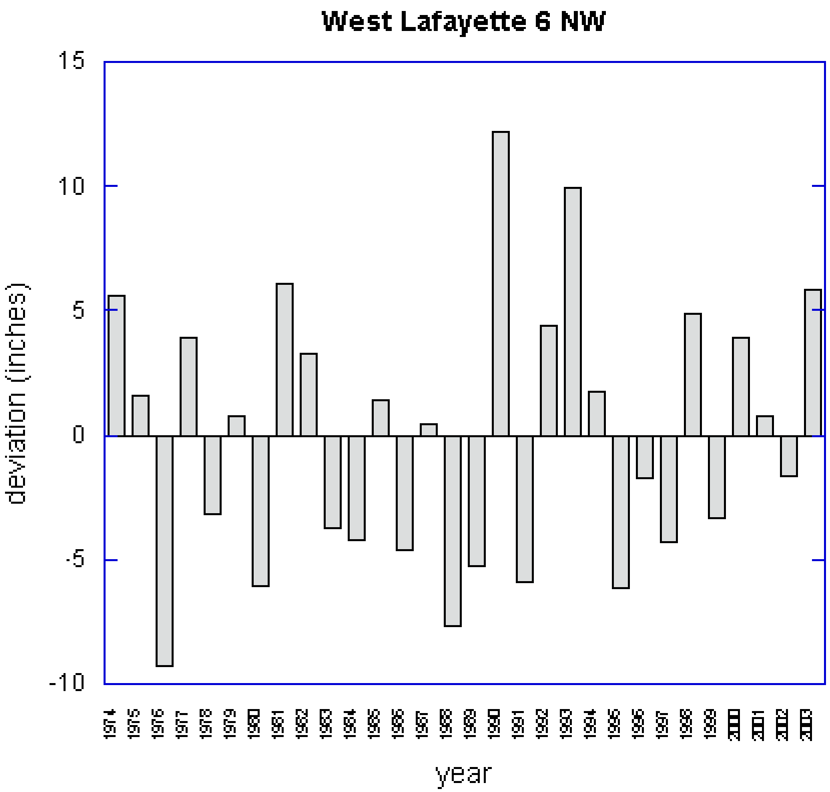


Total monthly snowfall

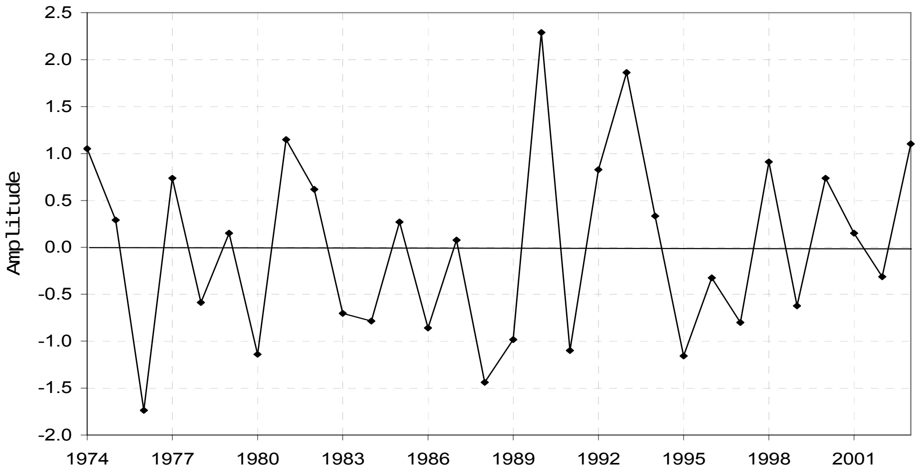


PRODUCTS: graphs

Deviation from the mean
(1974 – 2003)

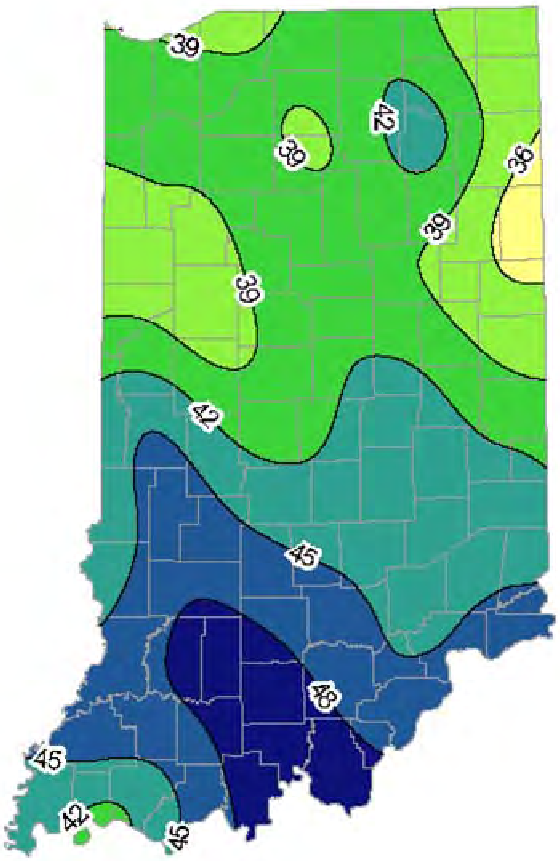


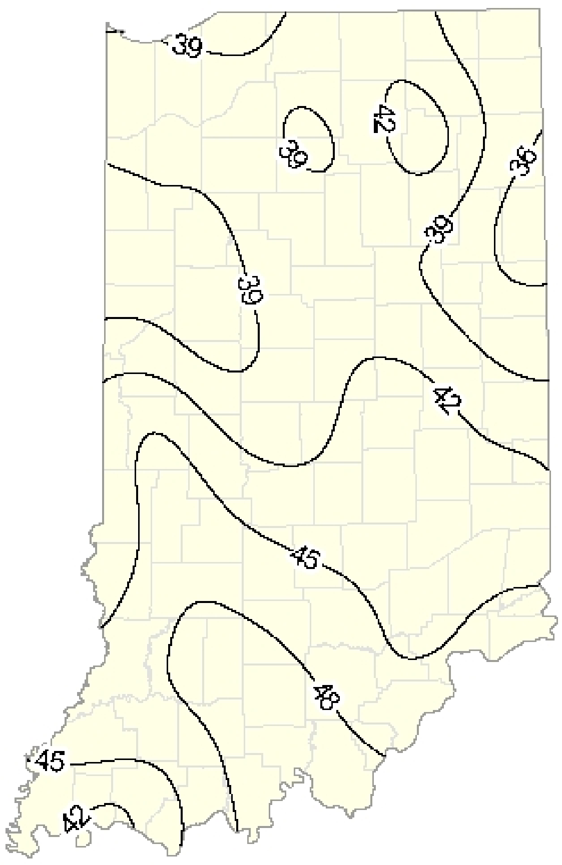
Standardized rainfall anomalies
(1974 – 2003)



PRODUCTS: maps

Color maps, contour maps

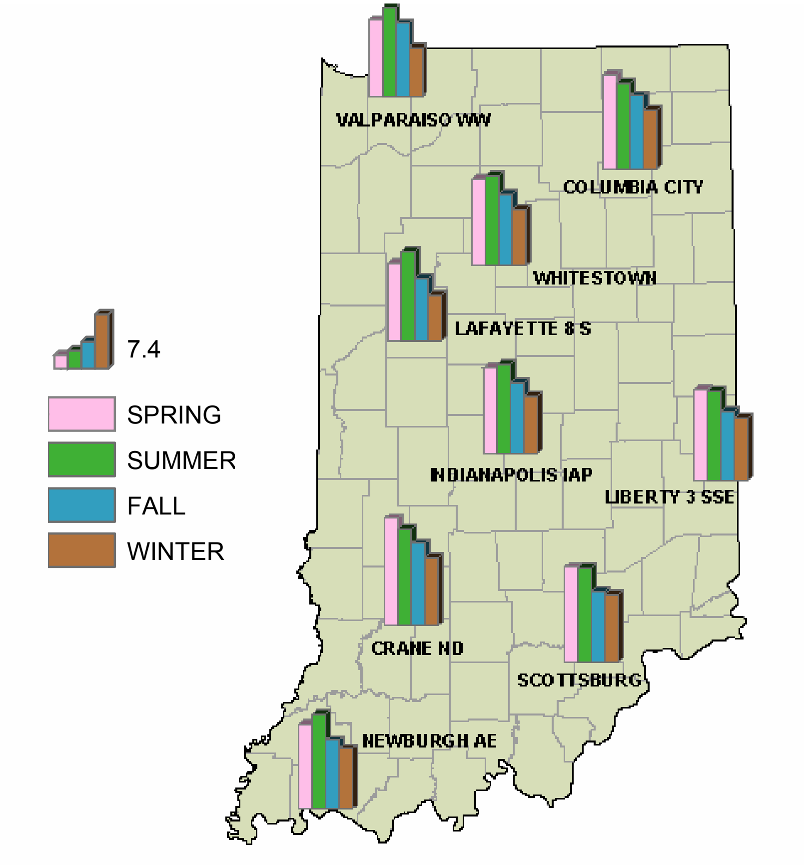




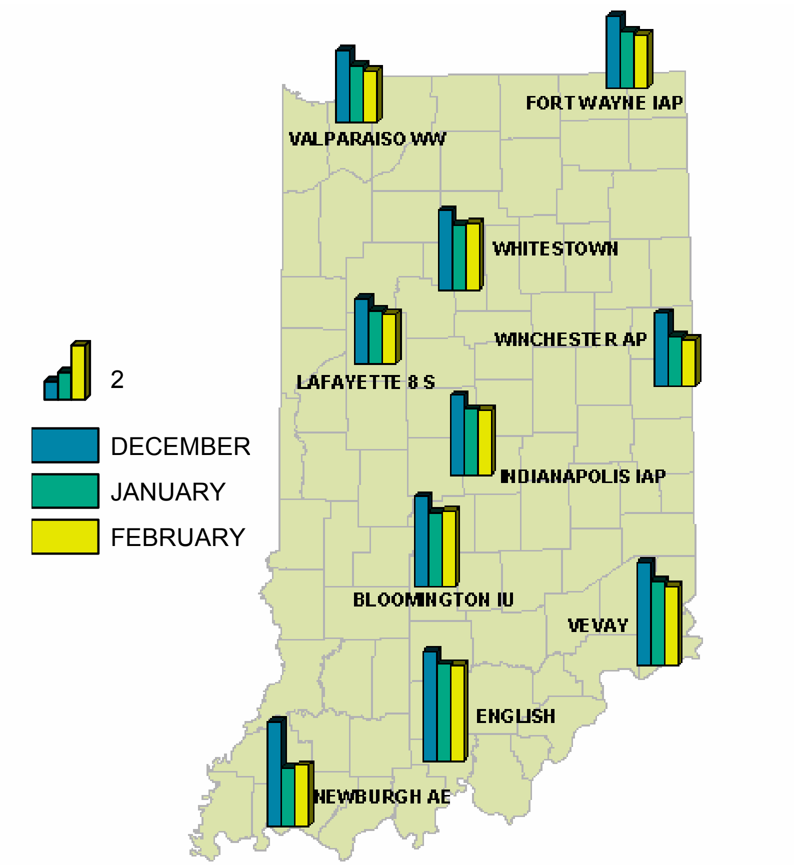
Mean annual precipitation (1974 – 2003)

PRODUCTS: maps

Seasonal maps displayed as chart maps for selected stations (the same can be done for individual months)

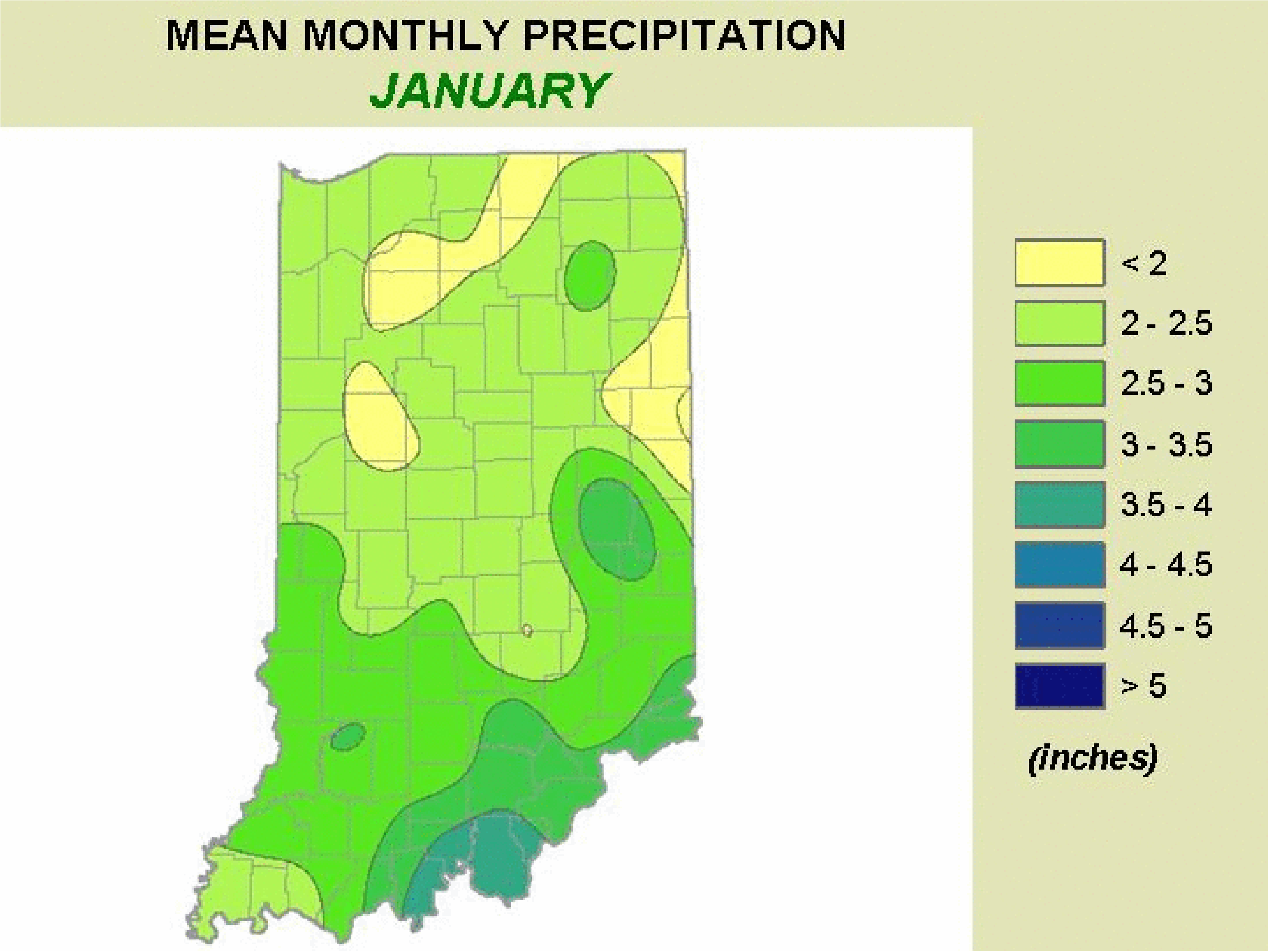


Seasonal precipitation (1974 – 2003)

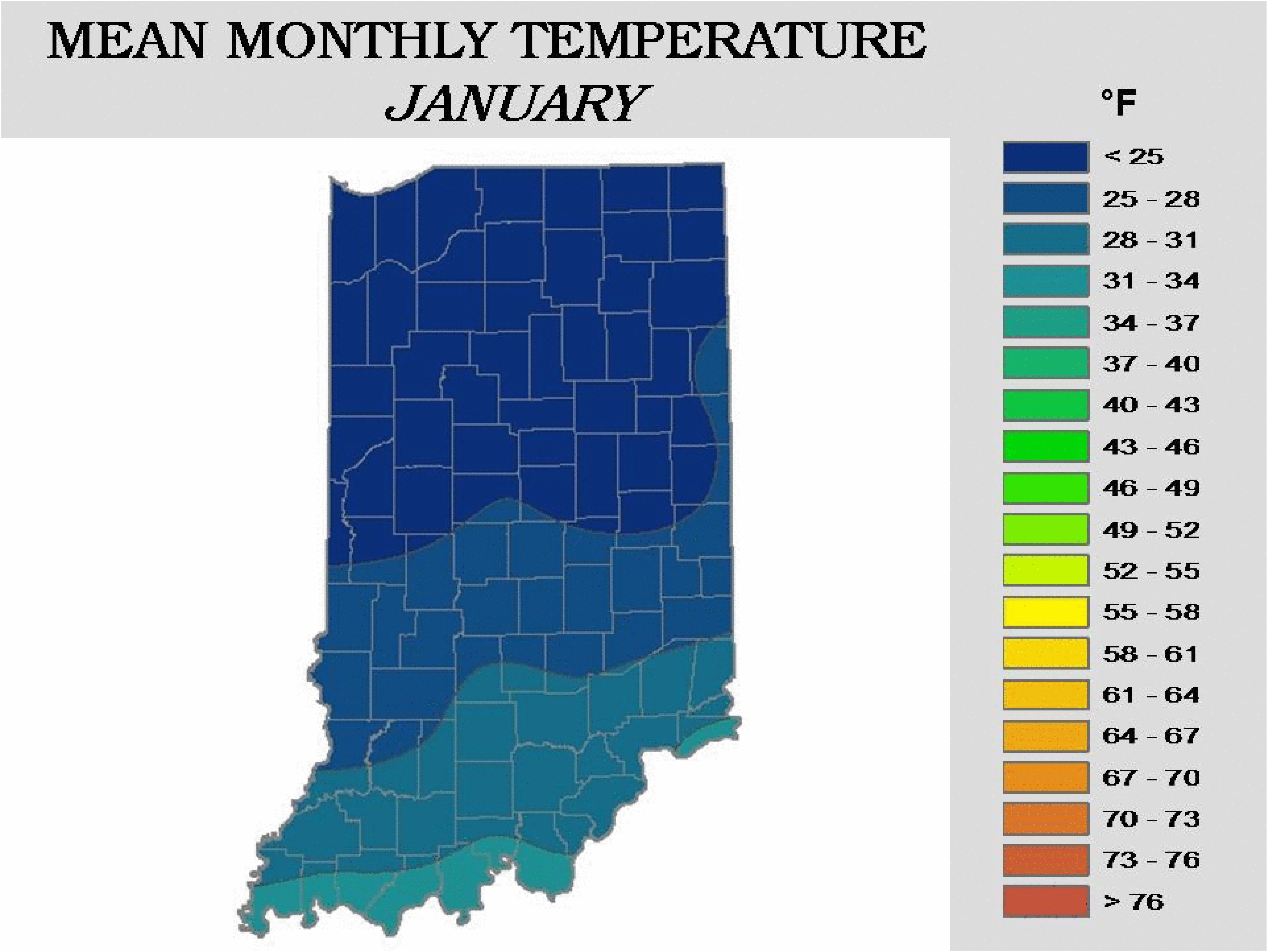


Winter precipitation (1974 – 2003)

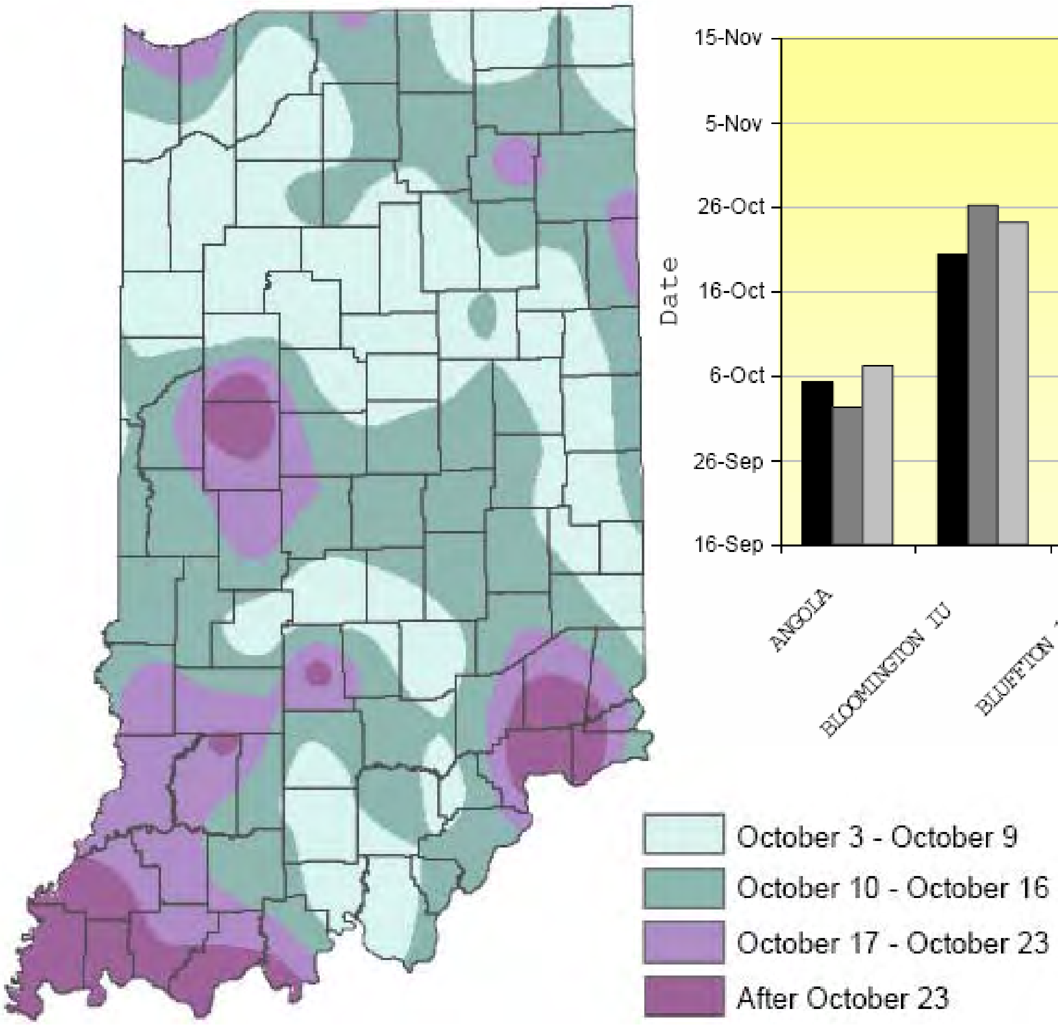
PRODUCTS: animations

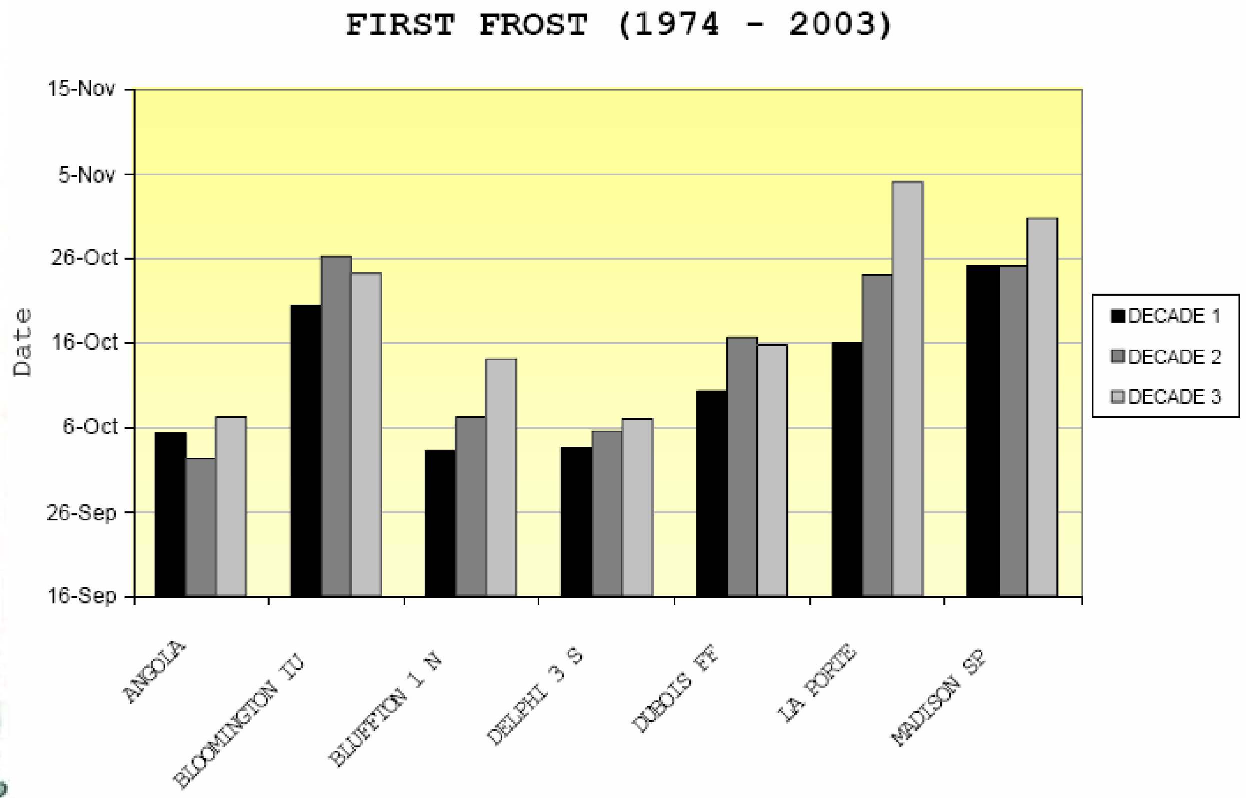


PRODUCTS: maps



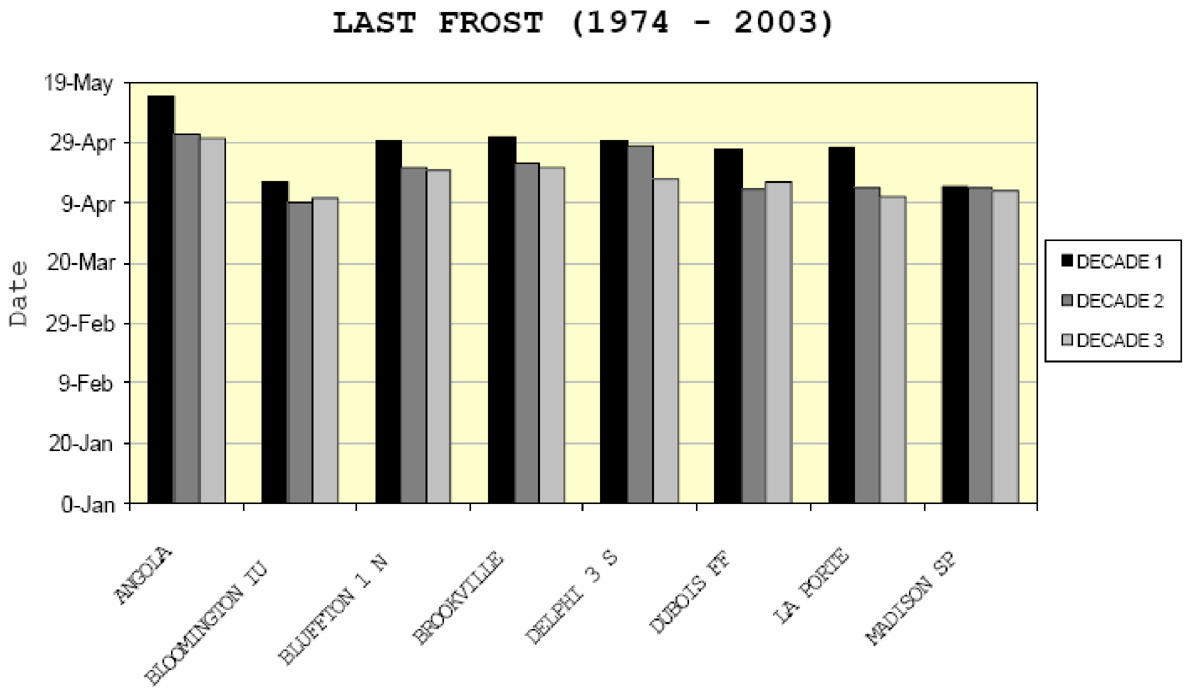
Indiana First Frost Dates

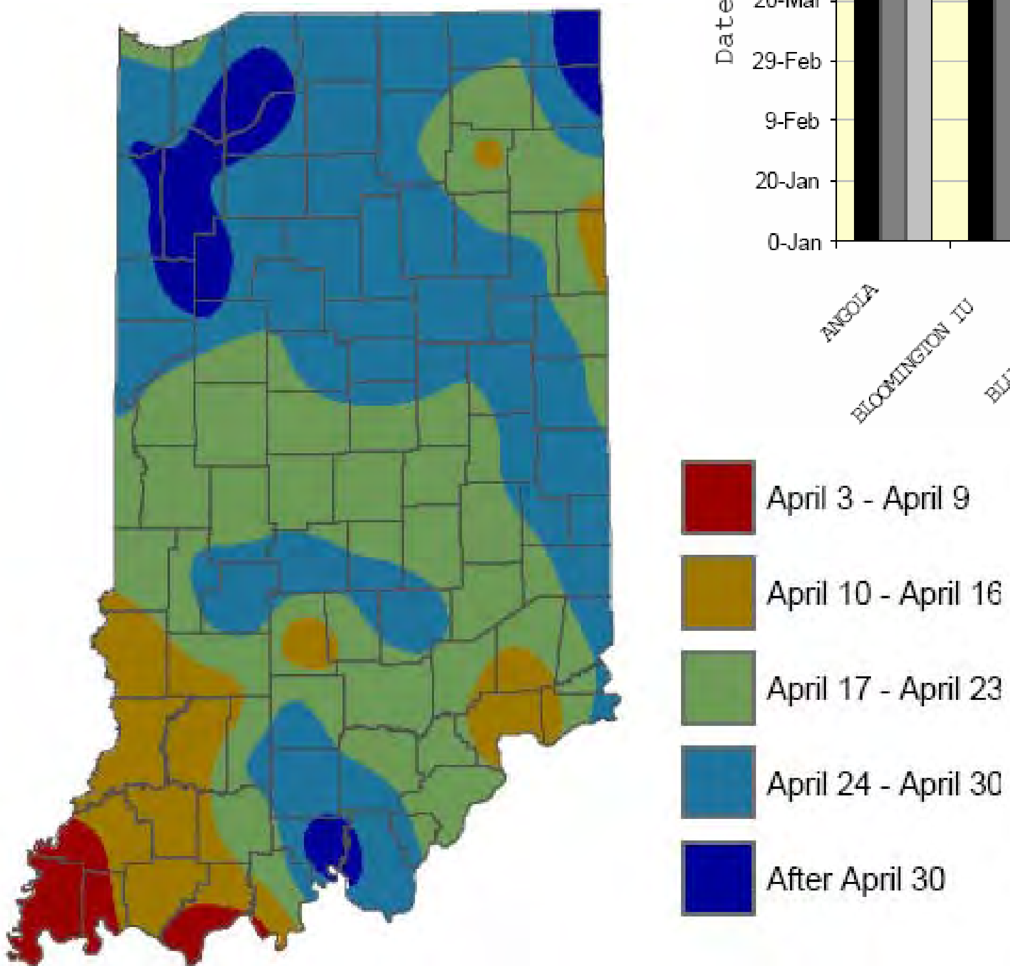




The first frost is occurring later.

Indiana Last Frost Dates





The last frost is occurring earlier.

Public Health Impacts

- Water Quality and Quantity Impacts
- Mental Health and Stress Impacts
- Dust and Windblown Agent Impacts
- Wildlife Intrusion Impacts
- Nutrition and Hygiene Impacts

Press Releases from South Dakota State University

- Drought among the factors adding stress to families
- Stress from drought issues can affect physical health
- Farming, ranching, and stress: adult depression
- Farming, ranching, and stress: recognizing and addressing your child's fears
- Farming, ranching, and stress: just for kids—watching the news

Selected Nebraska Mitigation Actions Helpful in 2002

- Vulnerable Water Systems Identification, Assistance, and Workshops
- Hay and Farm Crisis Hotlines
- UNL Extension Drought Website
- Improved Soil Moisture Monitoring

http://drought.unl.edu/dm

National Drought Mitigation Center

- Even though droughts are infrequent in Indiana they will occur

- The solution is excellent monitoring
  - Reassess the drought plan
  - Support CoCoRaHS
  - Pursue ET mapping and hydrological budgeting

  - Set up LDAS (SIMBAL, NOAA, etc)
  - Whole technical workshops on water stresses
  - Support dedicated students to work with this group

  - Official water plan that is technically sound and defensible will emerge