

Deciding on Drought Triggers in the FERC dam Relicensing Process

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Kirstin Dow*

Hope Mizzell**

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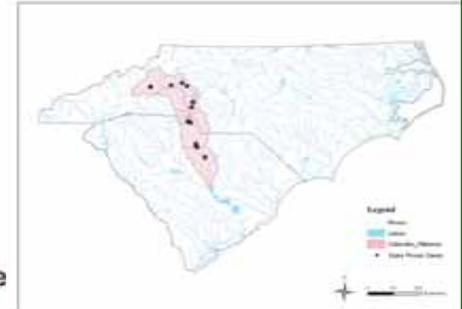
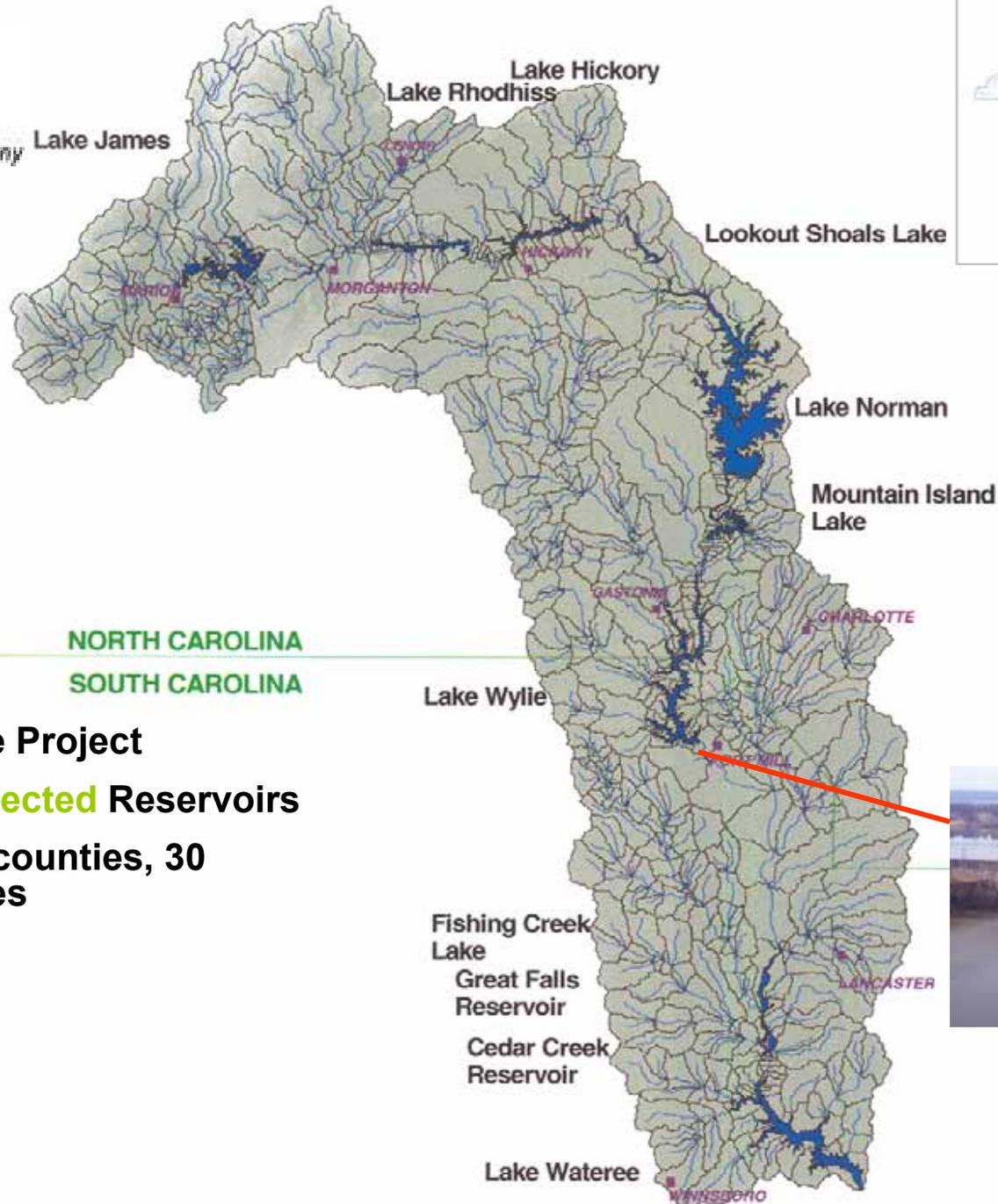
Dan Tufford***

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** SC State Climatology Office, SC DNR

*** Dept. of Biological Sciences, Univ. of South Carolina, Carolinas RISA



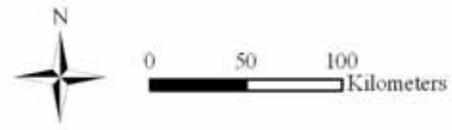
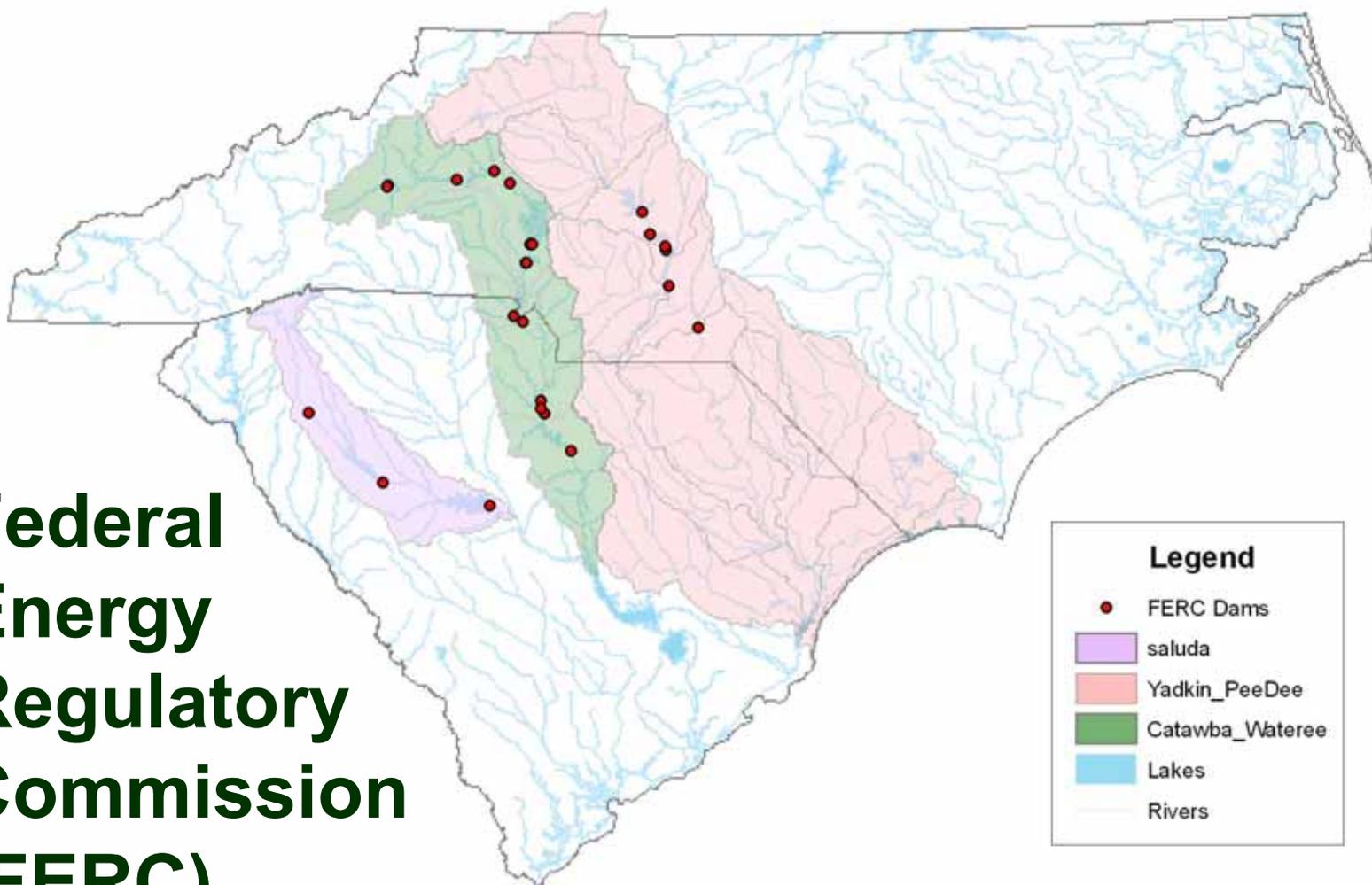


Catawba-Wateree Project

11 **Interconnected** Reservoirs

2 states, 14 counties, 30 municipalities

Federal Energy Regulatory Commission (FERC) Projects



Agencies and Interests in the FERC Relicensing Process

Federal Agencies



Licensee



Non-Agency Stakeholders



State Agencies



Study Groups

Water Quality



Hydropower



A Duke Energy Company

Water Supply



Recreation

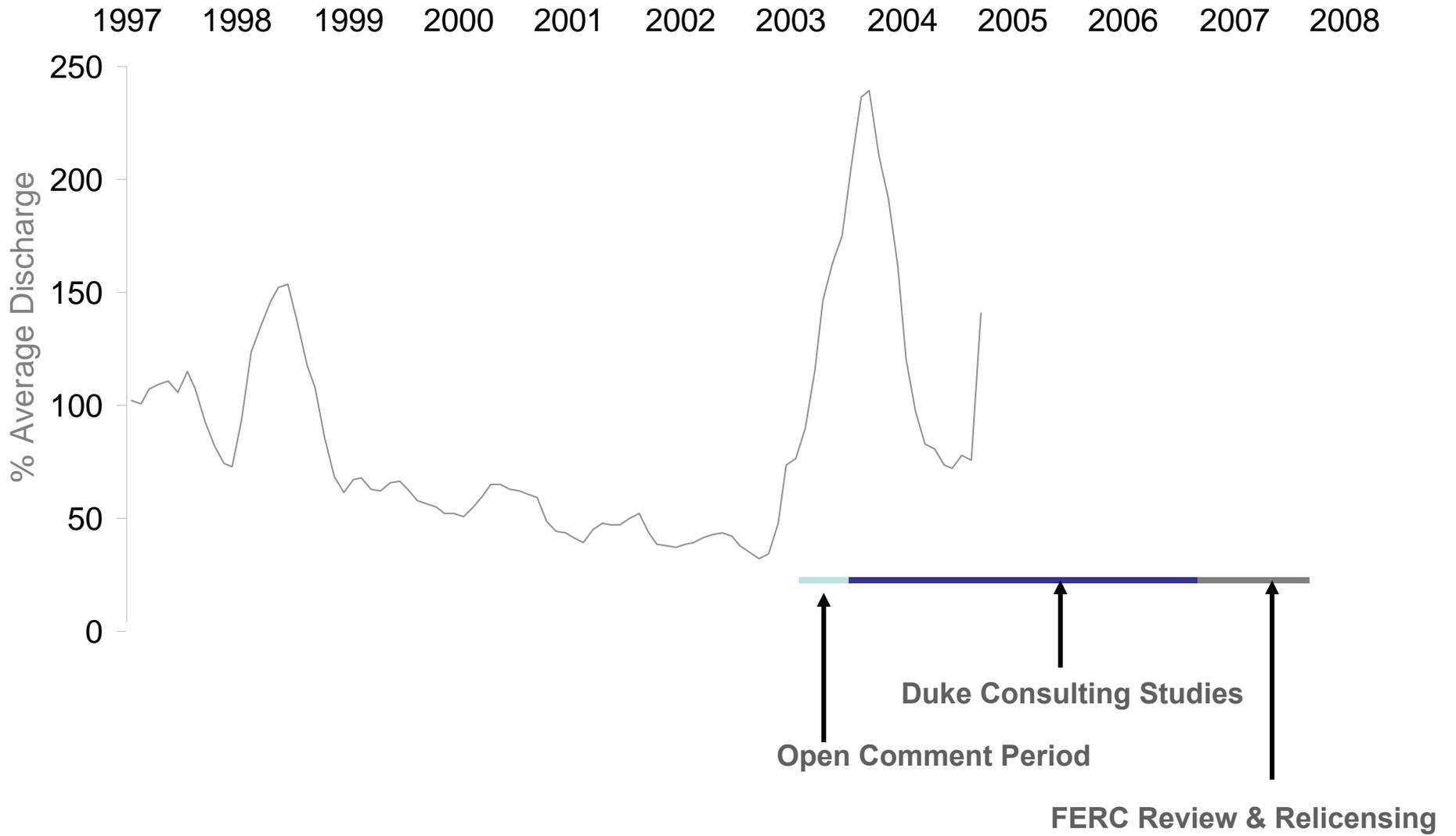


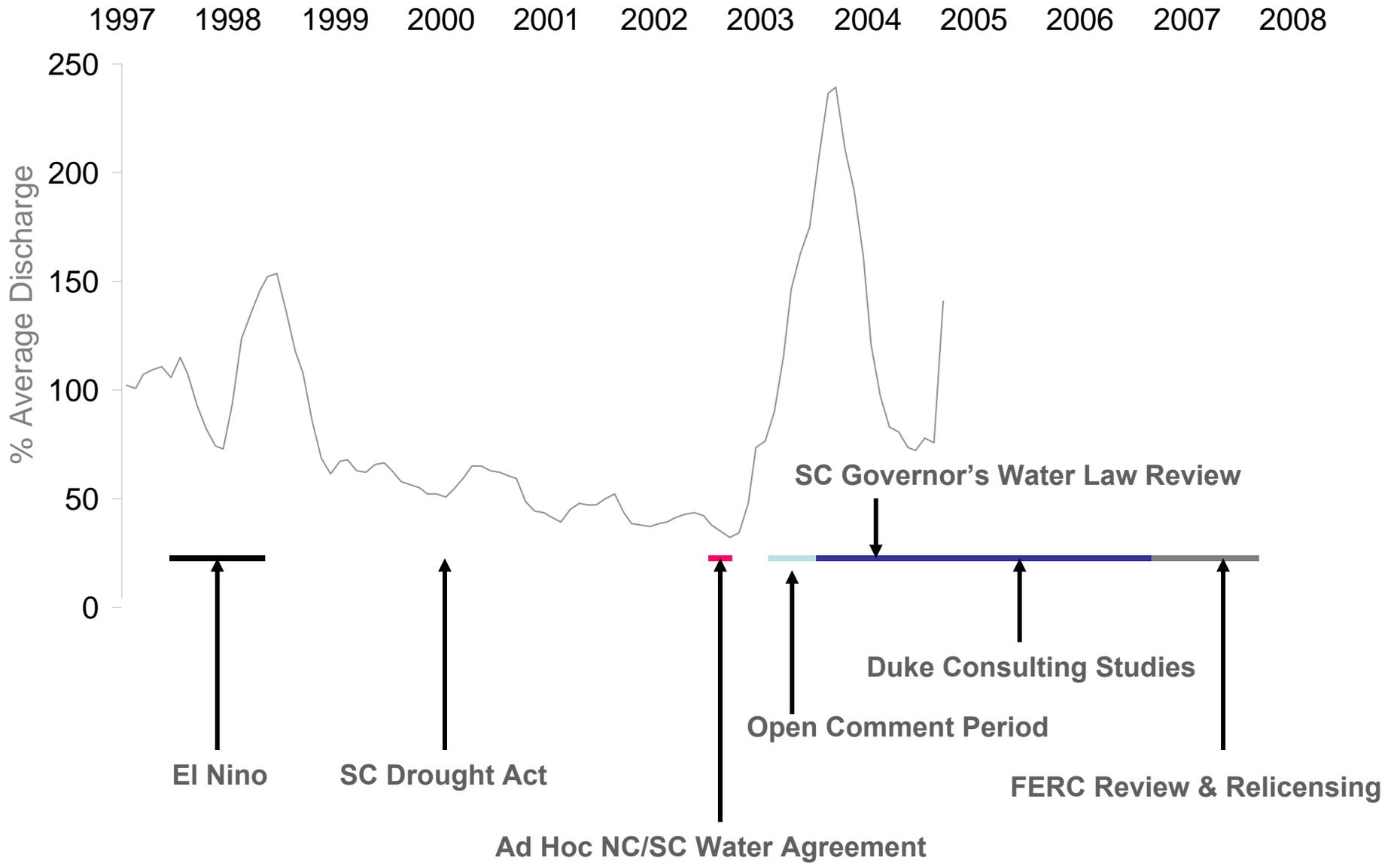
Fish and Wildlife and Habitat Enhancement and Protection



Shoreline Management







Low Inflow Protocol

Procedures for water use reductions during drought

- All Parties share responsibility to conserve water
- Triggers for drought stages (D0 – D4)
- Reductions in hydropower generation commensurate with stage
- Embrace state and local drought response laws

Catawba-Wateree Project Summary of LIP Trigger Points

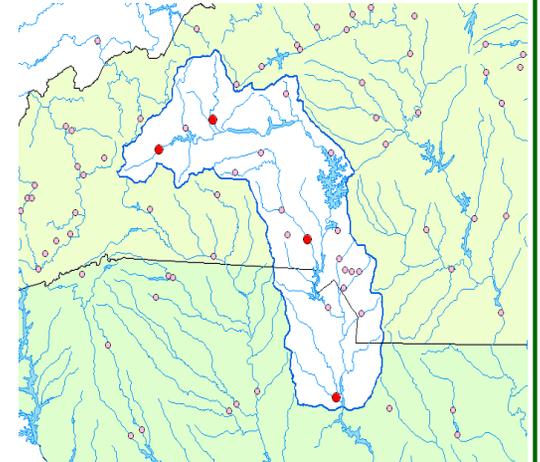
Stage	Storage Index ¹		Drought Monitor ² (3-month average)		Monitored USGS ³ Streamflow Gages
0 ⁴	90% < SI < TSI		0 ≤ DM		AVG ≤ 85%
1	75% < SI ≤ 90% TSI	A N D	1 ≤ DM	O R	AVG ≤ 78%
2	57% < SI ≤ 75% TSI		2 ≤ DM		AVG ≤ 65%
3	42% < SI ≤ 57% TSI		3 ≤ DM		AVG ≤ 55%
4	SI ≤ 42% TSI		DM = 4		AVG ≤ 40%

¹ Ratio of Remaining Useable Storage to Total Usable Storage

² 3-month numeric average of U.S. Drought Monitor

³ Sum of rolling 6-month average streamflow as percentage of period of record rolling average for same 6-month period

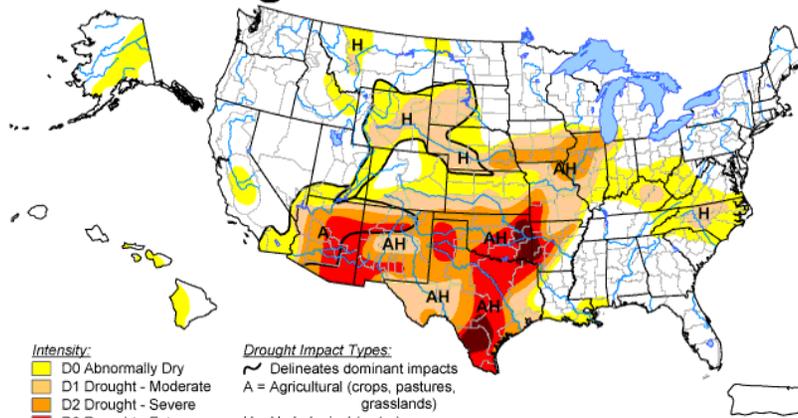
⁴ Stage 0 is triggered when any 2 of 3 trigger points are reached



U.S. Drought Monitor

March 7, 2006

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.



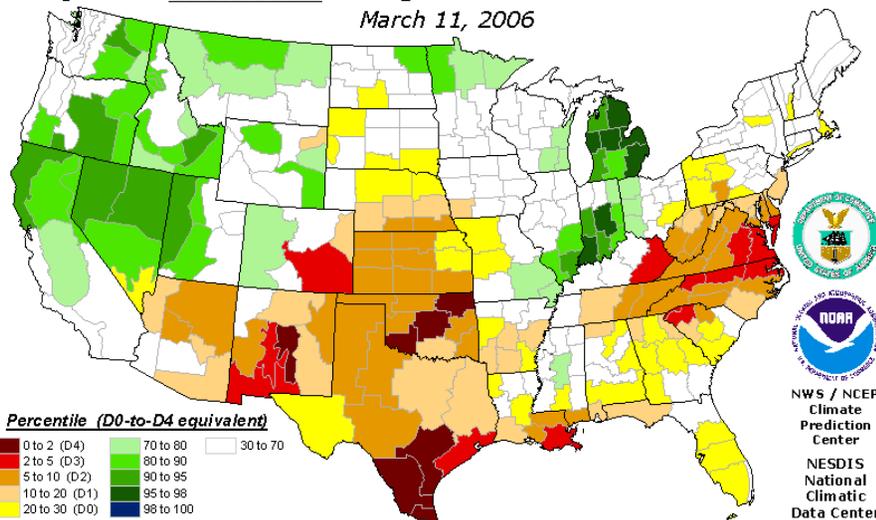
Released Thursday, March 9, 2006

Author: Brian Fuchs, National Drought Mitigation Center

<http://drought.unl.edu/dm>

Objective **Short-Term** Drought Indicator Blend Percentiles

March 11, 2006



Percentile (D0-to-D4 equivalent)



Inputs (as percentiles):

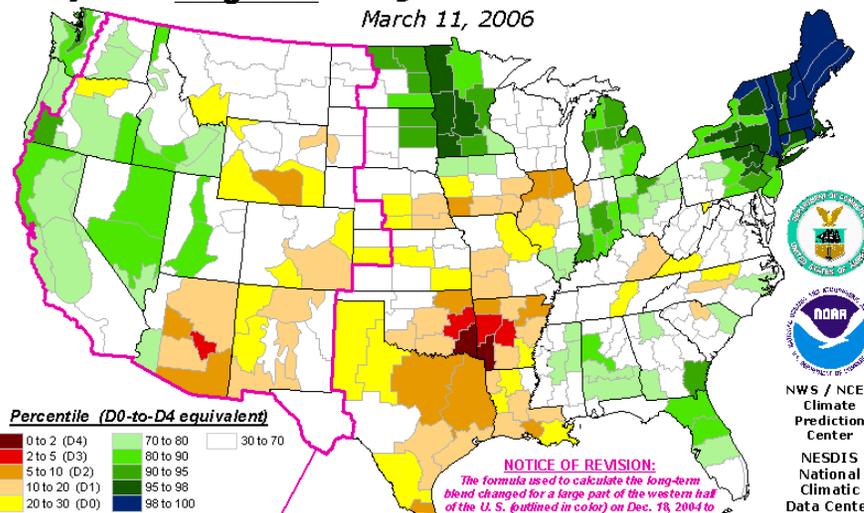
- 35% Palmer Z-Index
- 25% 3-Month Precipitation
- 20% 1-Month Precipitation
- 13% CPC Soil Moisture Model
- 7% Palmer Drought Index

This map approximates impacts that respond to precipitation over several days to a few months, such as agriculture, topsoil moisture, unregulated streamflows, and most aspects of wildfire danger. The relationship between indicators and impacts can vary significantly with location and season. Do not interpret this map too literally.

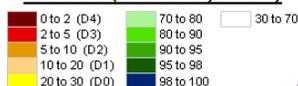
This map is based on preliminary climate division data. Local conditions and/or final data may differ. See the detailed product suite description for more details.

Objective **Long-Term** Drought Indicator Blend Percentiles

March 11, 2006



Percentile (D0-to-D4 equivalent)



Inputs (as percentiles):

- 25% Palmer Hydrologic Index
- 20% 24-Month Precipitation
- 15% 6-Month Precipitation
- 10% 60-Month Precipitation
- 10% CPC Soil Moisture Model

New Western Formulation

- 30% Palmer Hydrologic Index
- 30% 60-Month Average Z-Index
- 10% 60-Month Precipitation
- 10% 24-Month Precipitation
- 10% 12-Month Precipitation
- 10% CPC Soil Moisture Model

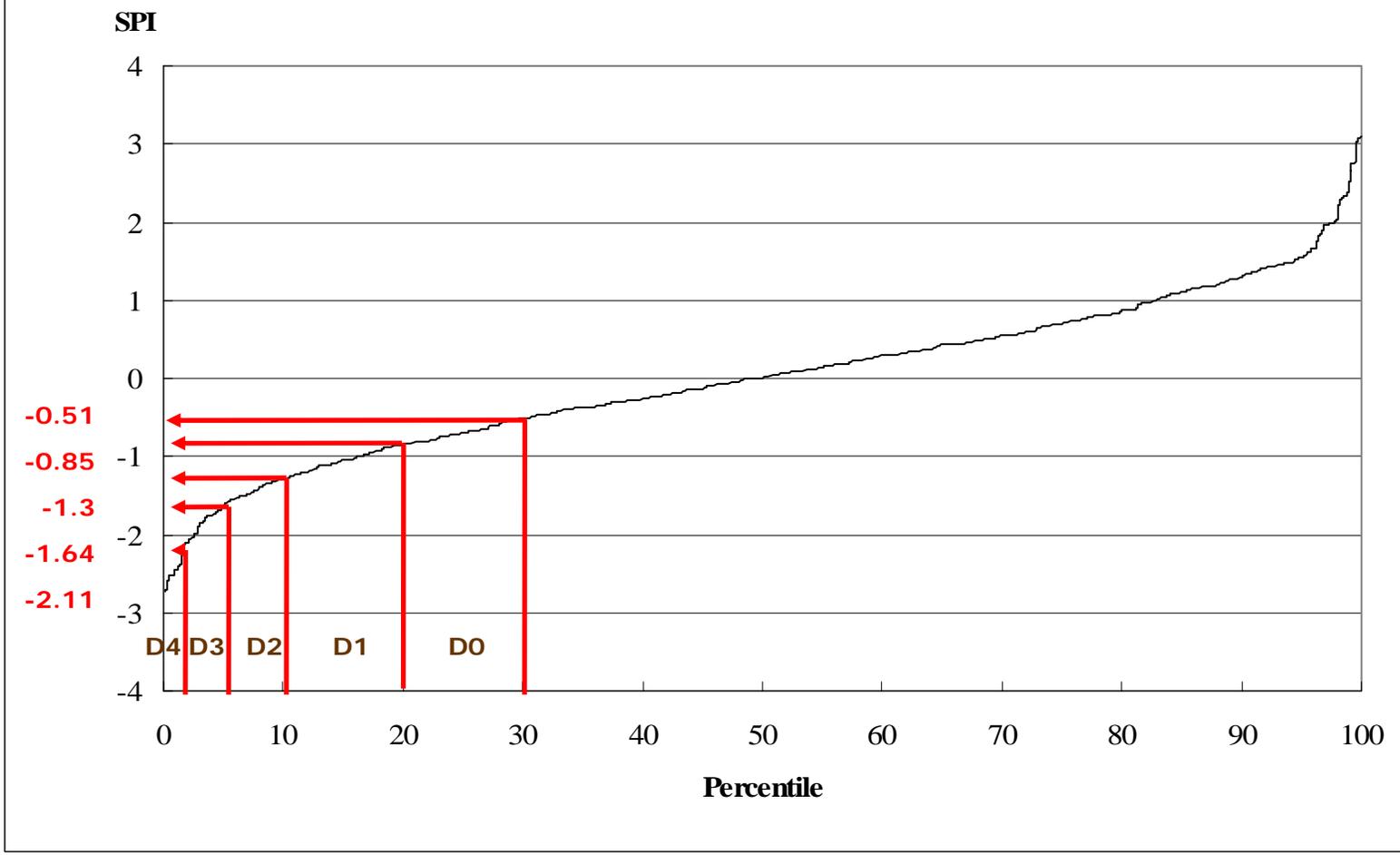
NOTICE OF REVISION:

The formula used to calculate the long-term blend changed for a large part of the western half of the U.S. (outlined in color) on Dec. 13, 2004 to better reflect the regions' water supply conditions. HOWEVER, ALL CAVEATS NOTED BELOW STILL APPLY.

This map approximates impacts responding to precipitation over the course of several months to a few years, such as reservoir content, groundwater, and lake levels. HOWEVER, THE RELATIONSHIP BETWEEN INDICATORS AND WATER SUPPLIES CAN VARY MARKEDLY WITH LOCATION, SEASON, SOURCE, AND MANAGEMENT PRACTICE. Do not interpret this map too literally.

This map is based on preliminary climate division data. Local conditions and/or final data may differ. See the detailed product suite description for more details.

6-month SPI (1954-2003)



Regional Drought Mapping Tool

Targets local-scale.

Computes suite of monthly drought indices, 1950-2004.

Based on empirical probability distributions of each index.

Allows creation of drought blends that address specific sensitivities.

PDSI, PHDI, z-index

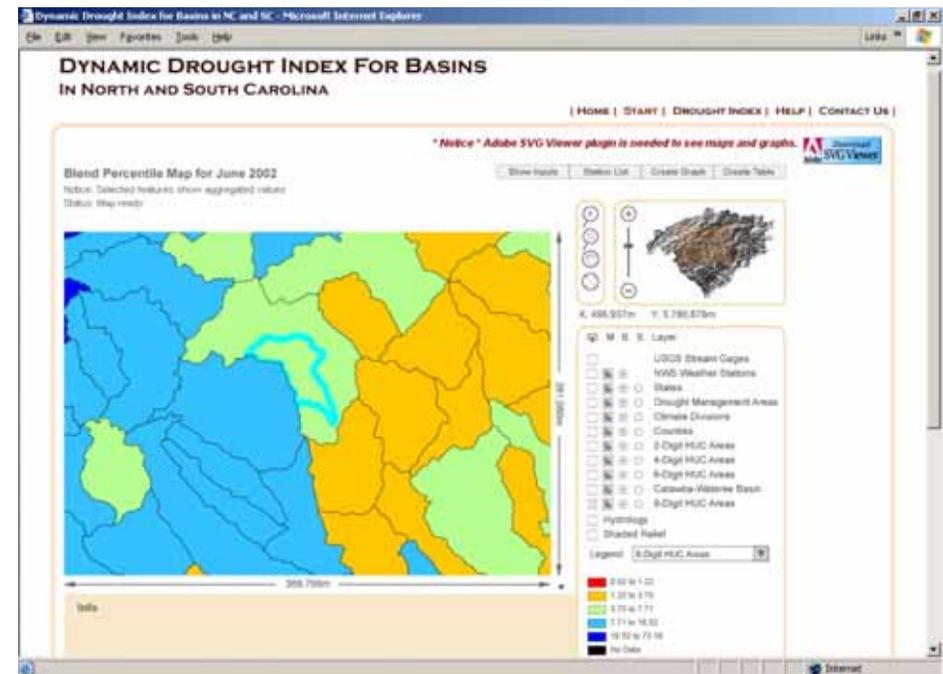
SPI (1,2,6,9,12,24-month)

Precipitation (1,3,6,12,24,60-month)

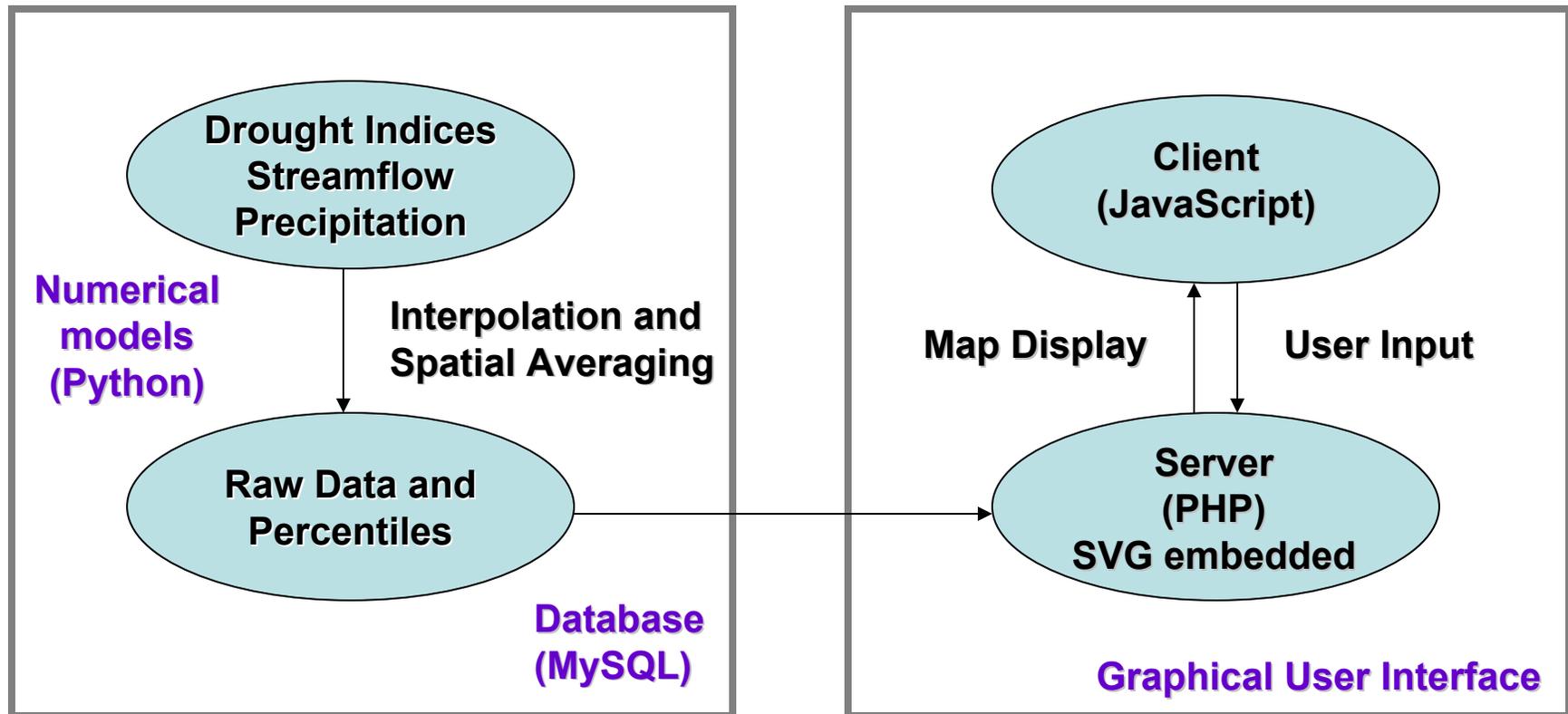
7-day Streamflow

14-day Streamflow

Streamflow (1,3,6,12,24-month)



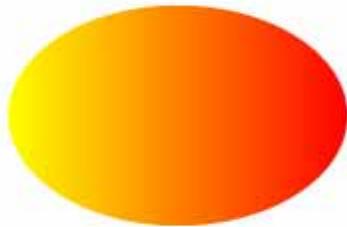
Structure



PHP – PHP: Hypertext Preprocessor
SVG – Scalable Vector Graphics

Scalable Vector Graphics (SVG)

- SVG defines vector-based graphics in XML (eXtensible Markup Language) format for the Web

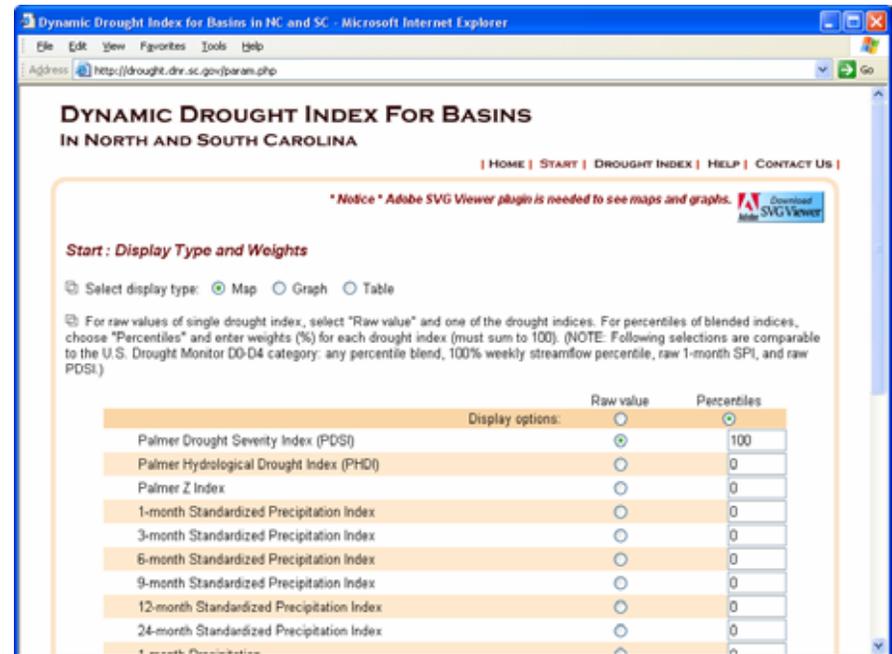


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<?xml version="1.0" standalone="no"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.1//EN"
"http://www.w3.org/Graphics/SVG/1.1/DTD/svg11.dtd">
<svg width="100%" height="100%" version="1.1"
xmlns="http://www.w3.org/2000/svg">
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<stop offset="100%" style="stop-color:rgb(255,0,0);stop-opacity:1"/>
</linearGradient>
</defs>
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style="fill:url(#orange_red)"/>
</svg>
```

Source: SVG Tutorial (<http://www.w3schools.com/svg>)

User Input

- Display type
- Input
 - PDSI, PHDI, Z Index
 - SPI in several time scales
 - Precipitation and streamflow in several time scales
- Raw data vs. percentile blend

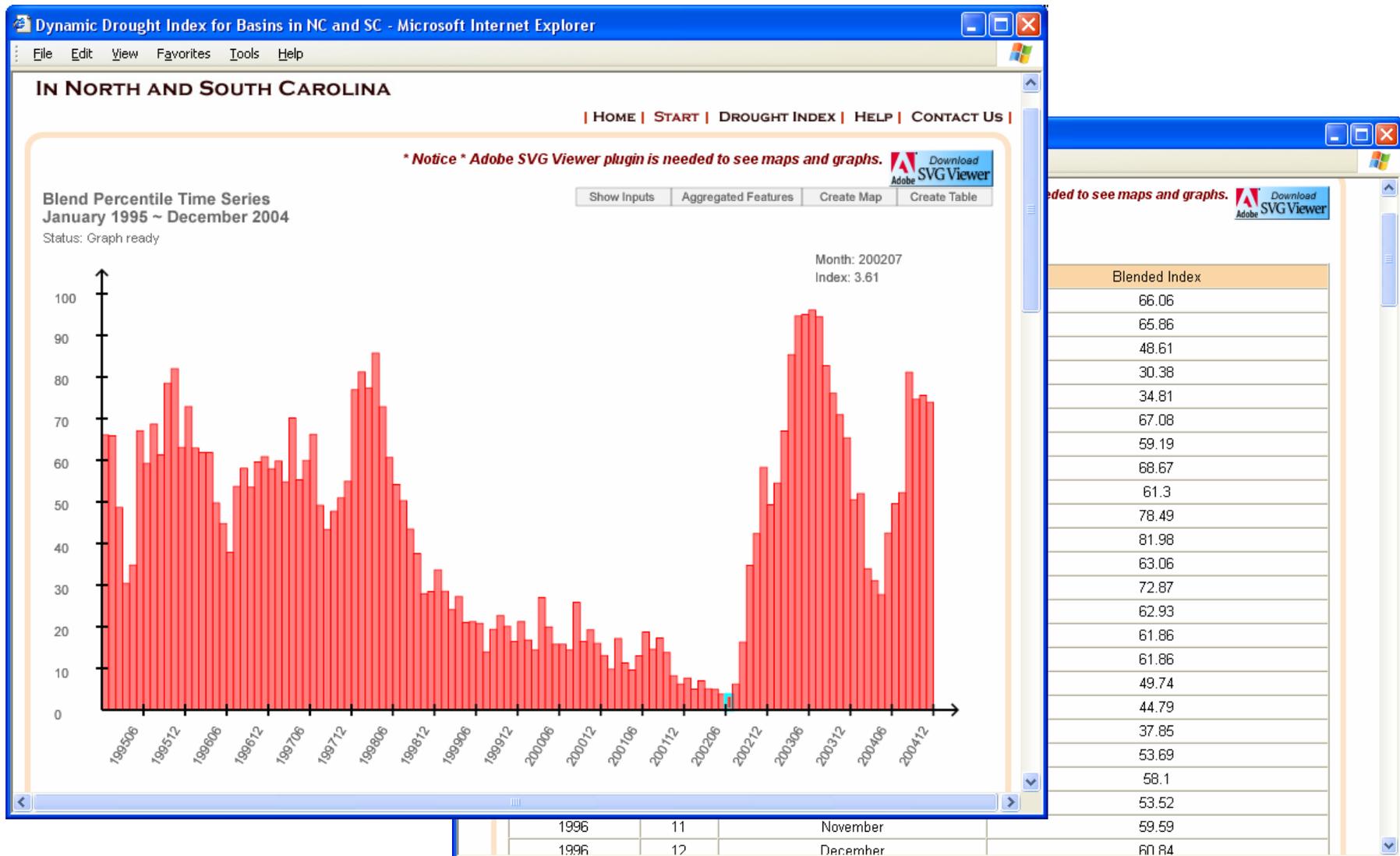


The screenshot shows a web browser window titled "Dynamic Drought Index for Basins in NC and SC - Microsoft Internet Explorer". The address bar shows "http://drought.dnr.sc.gov/param.php". The page content includes a navigation menu with links for HOME, START, DROUGHT INDEX, HELP, and CONTACT US. A notice states: "* Notice * Adobe SVG Viewer plugin is needed to see maps and graphs." Below this, the section "Start: Display Type and Weights" is visible. It contains a "Select display type:" section with radio buttons for Map (selected), Graph, and Table. A detailed instruction follows: "For raw values of single drought index, select 'Raw value' and one of the drought indices. For percentiles of blended indices, choose 'Percentiles' and enter weights (%) for each drought index (must sum to 100). (NOTE: Following selections are comparable to the U.S. Drought Monitor DD-D4 category: any percentile blend, 100% weekly streamflow percentile, raw 1-month SPI, and raw PDSI.)" Below the instruction is a table with columns for "Display options:", "Raw value", and "Percentiles".

Display options:	Raw value	Percentiles
Palmer Drought Severity Index (PDSI)	<input type="radio"/>	<input checked="" type="radio"/> 100
Palmer Hydrological Drought Index (PHDI)	<input type="radio"/>	<input type="text" value="0"/>
Palmer Z Index	<input type="radio"/>	<input type="text" value="0"/>
1-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
3-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
6-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
9-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
12-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
24-month Standardized Precipitation Index	<input type="radio"/>	<input type="text" value="0"/>
1-month Precipitation	<input type="radio"/>	<input type="text" value="0"/>

<http://drought.dnr.sc.gov/>

Tables and Graphs



Map User Input

- Classification method
 - Equal interval
 - Quantile
 - Natural break
 - U.S. Drought Monitor-comparable category
 - For any percentile blend
 - For PDSI
 - For SPI
 - For weekly streamflow percentile

The screenshot shows a web browser window titled "Dynamic Drought Index for Basins in NC and SC - Microsoft Internet Explorer". The address bar shows "http://drought.dnr.sc.gov/map.php". The page content includes a navigation menu with links for HOME, START, DROUGHT INDEX, HELP, and CONTACT US. A notice states: "* Notice * Adobe SVG Viewer plugin is needed to see maps and graphs." Below this is a "Create Blend : Map" section with the following controls:

- Select year and month: 2002 June (between January 1950 - December 2004)
- Select classification method: Quantile (dropdown menu showing options: U.S. Drought Monitor Intensity (for PDSI), Equal Interval (Minimum to maximum), Quantile, Natural Breaks (Jenks))
- Number of classes: 6
- Use same class intervals for (checkbox)

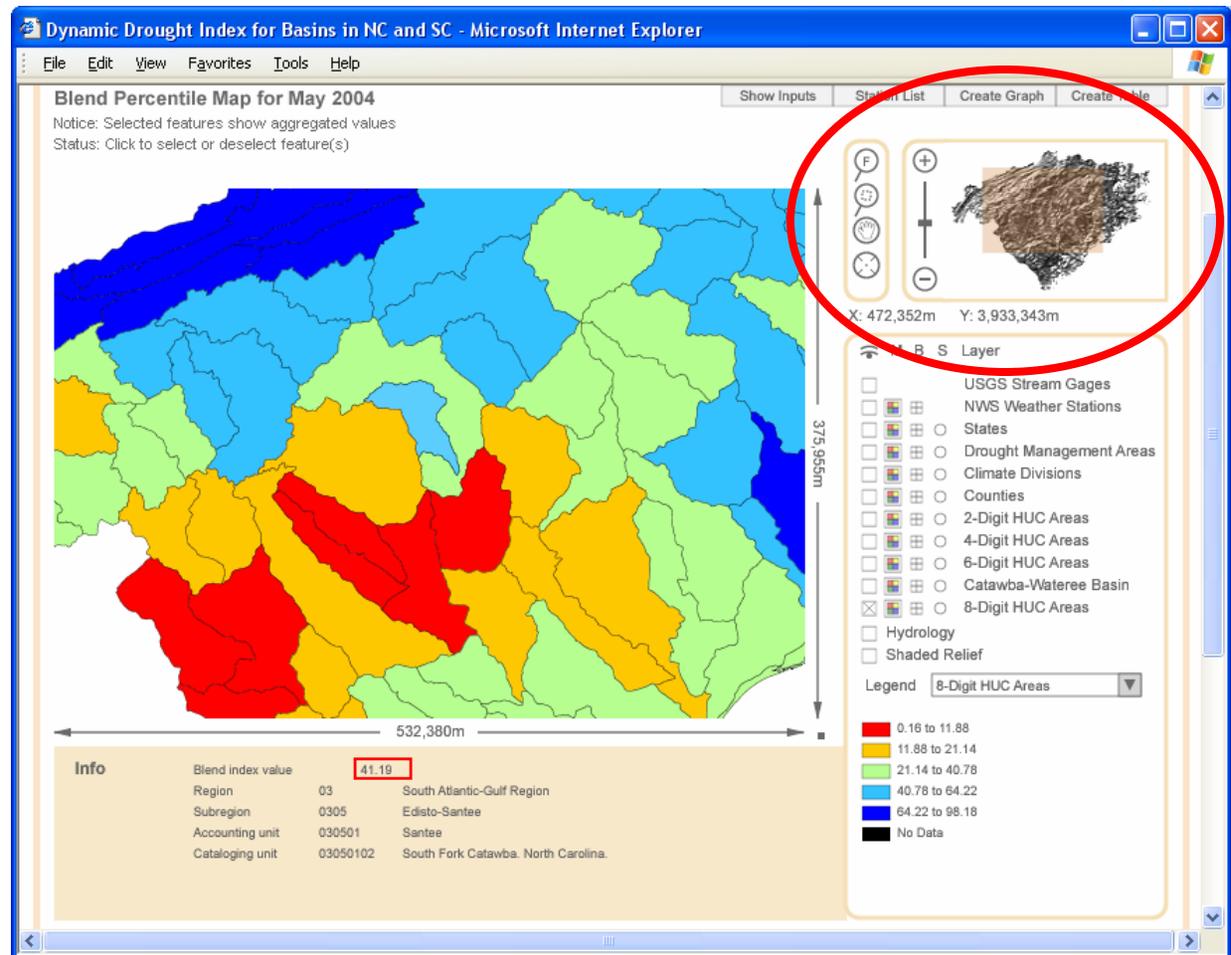
Buttons for "<< Back" and "Create Map" are visible. At the bottom, it says "Last modified: March 02, 2006", "URI: http://drought.dnr.sc.gov/map.php", and "Direct any comments or questions to rheej@sc.edu".

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

Map Navigation Tools

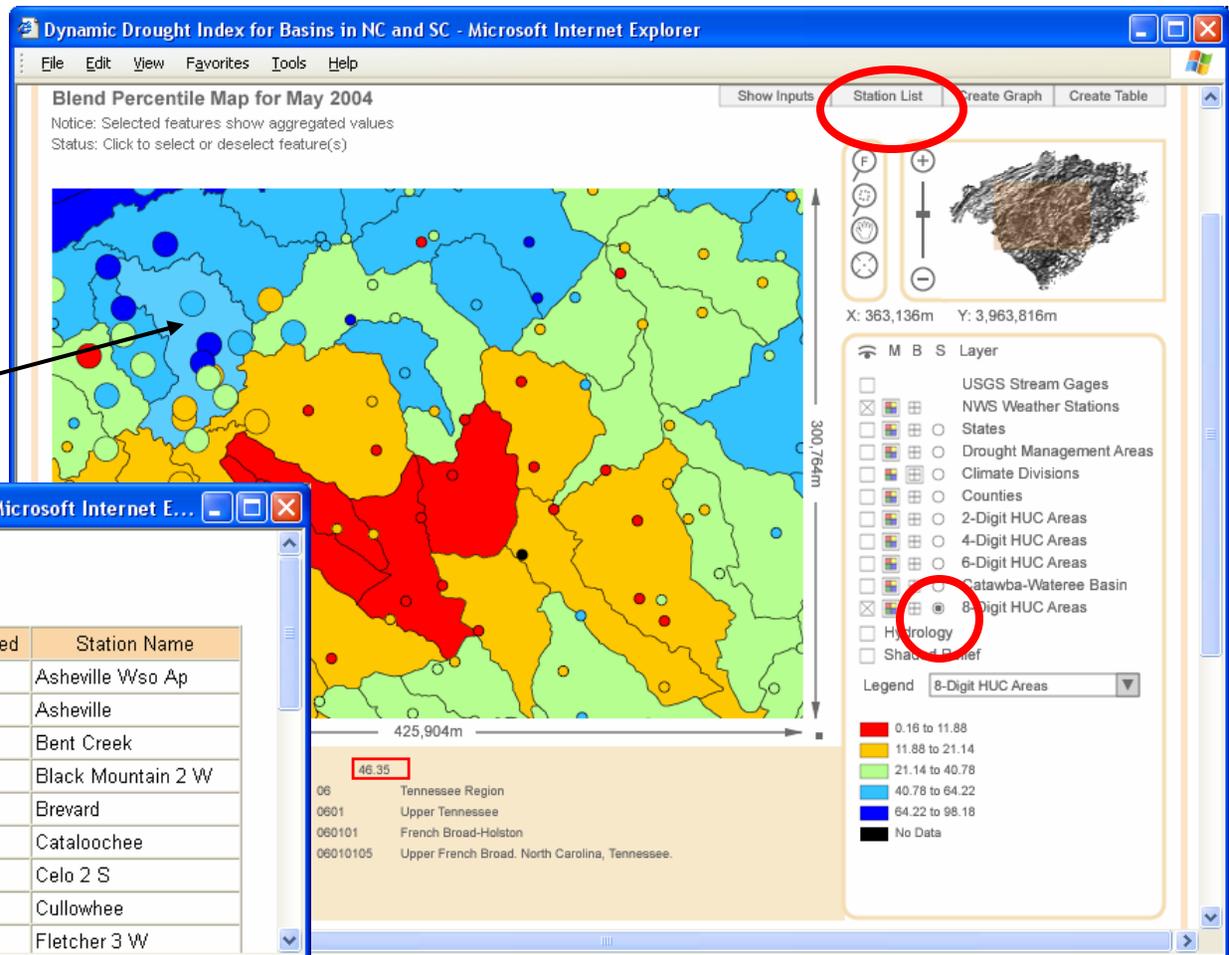
- Full view
- New map extent
- Pan
- New map center
- Zoom in & out
- Zoom slide

(JavaScript source code by
Andreas Neumann; modified
by Jinyoung Rhee)



Map Layers

- Visibility
- Choropleth map
- Boundary
- Stations used



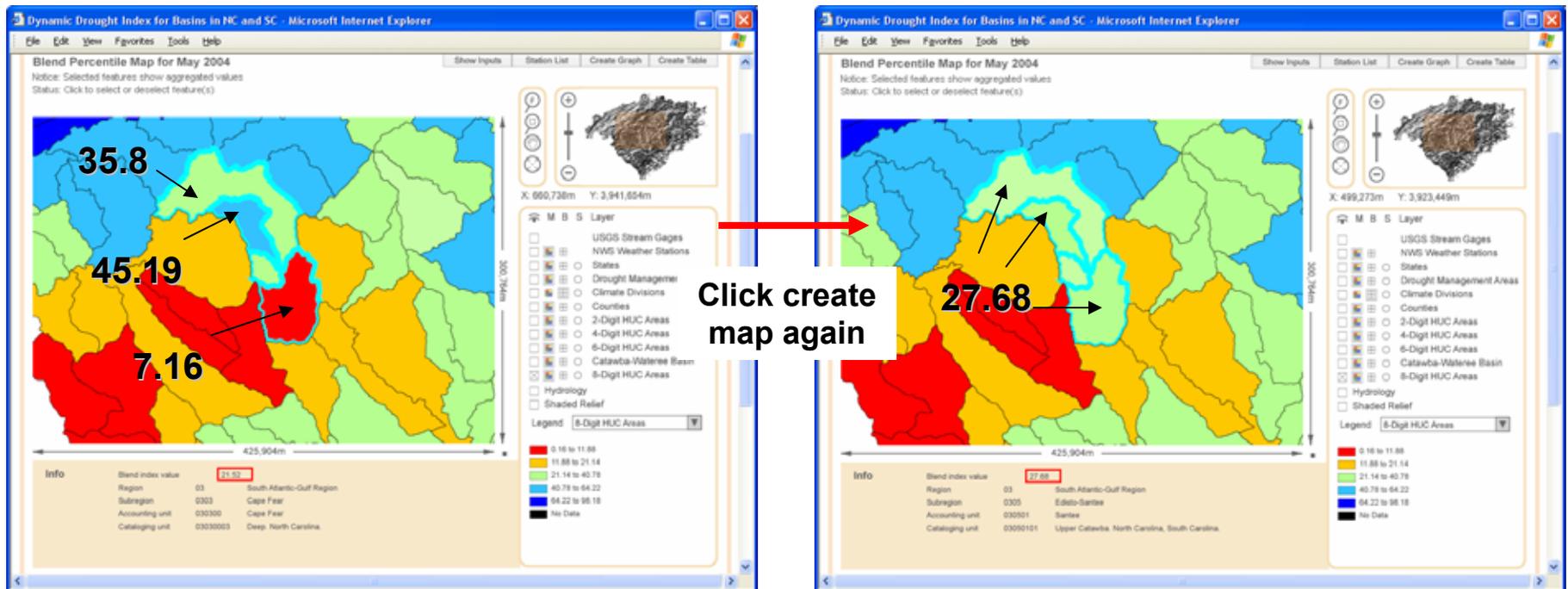
http://drought.dnr.sc.gov - Weather Station List - Microsoft Internet E...

Selected layer : 8-Digit HUC Areas
Selected number of features : 1

Feature (HUC8)	Feature Name	Station Used	Station Name
6010105	Upper French Broad	310300	Asheville Wso Ap
		310301	Asheville
		310724	Bent Creek
		310843	Black Mountain 2 W
		311055	Brevard
		311564	Cataloochee
		311624	Celo 2 S
		312200	Cullowhee
		313106	Fletcher 3 W

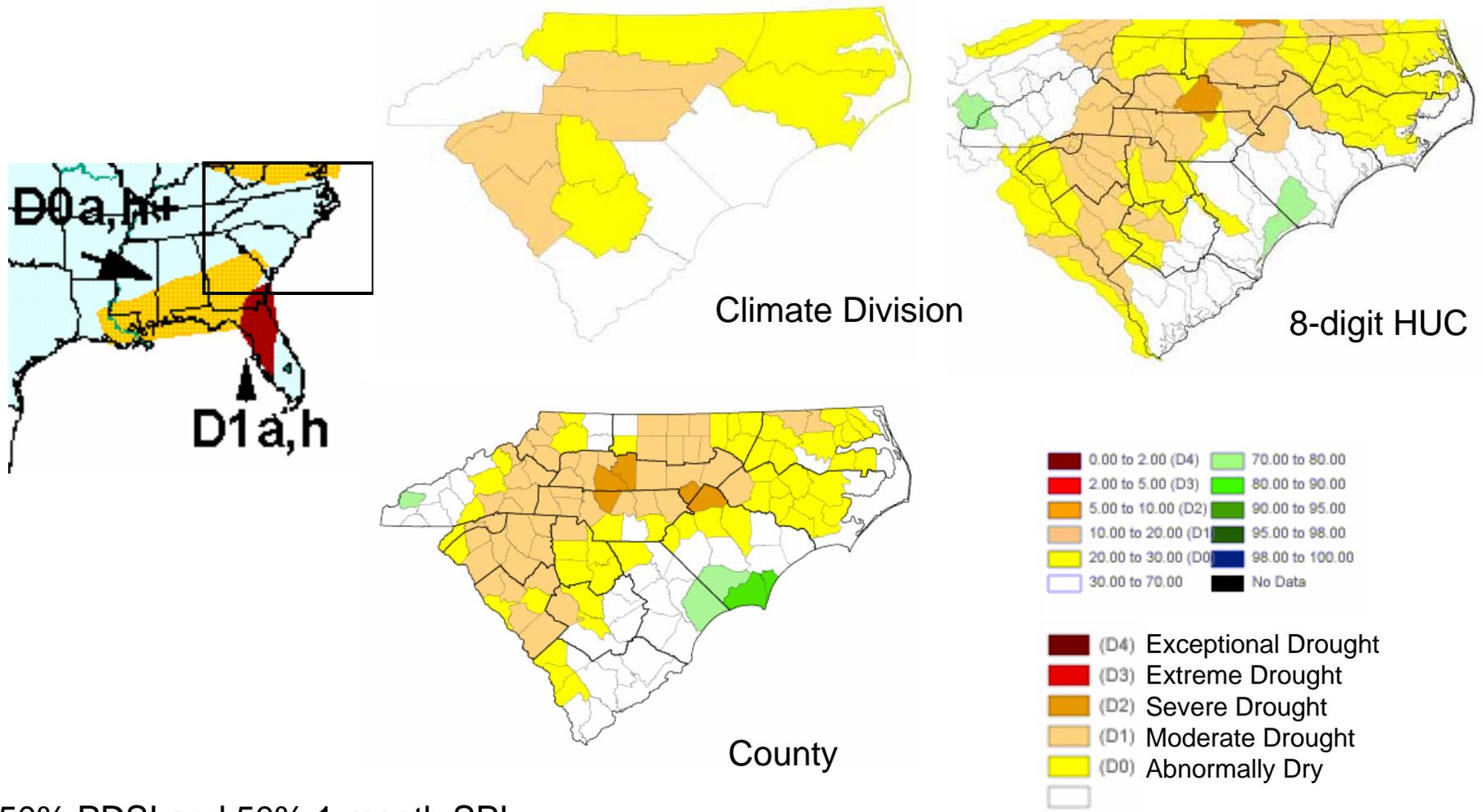
Done Internet

Layer Aggregation



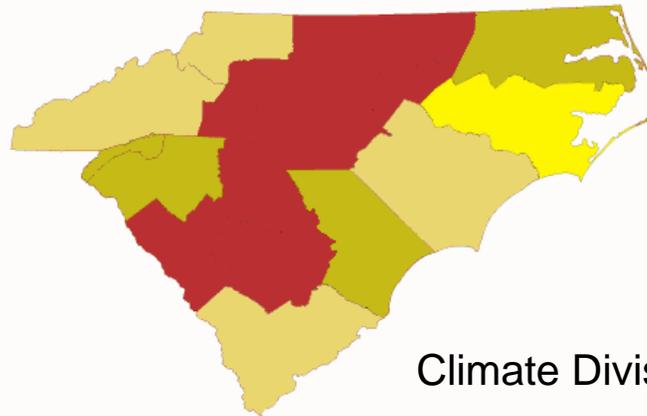
- Selected features of the same layer have been aggregated
- Aggregation is based on the number of 4 km x 4 km grids with data used for spatial averaging of each feature

Comparison: spatial variability May 1999

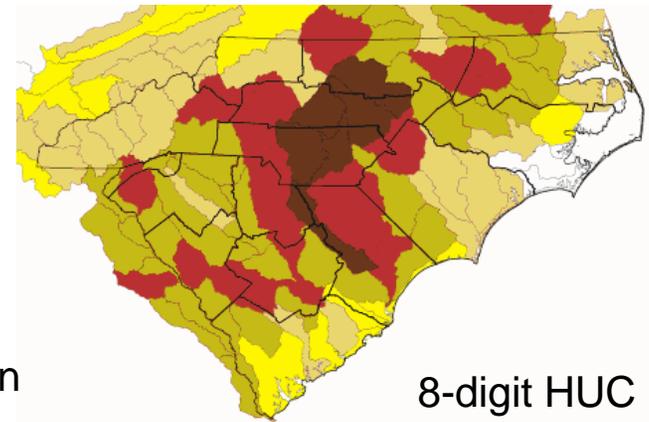


50% PDSI and 50% 1-month SPI

Comparison: spatial variability July 2002

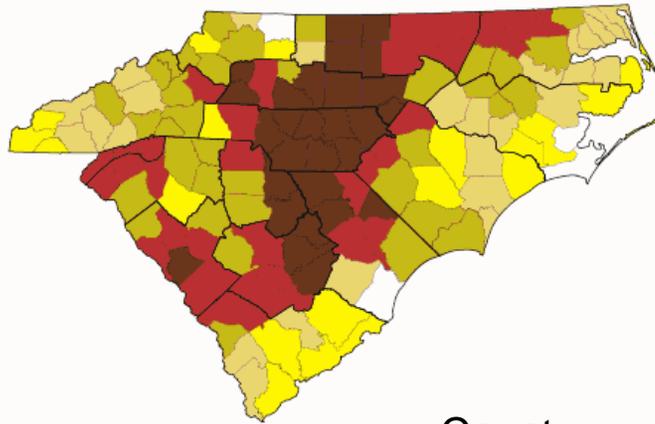


Climate Division



8-digit HUC

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



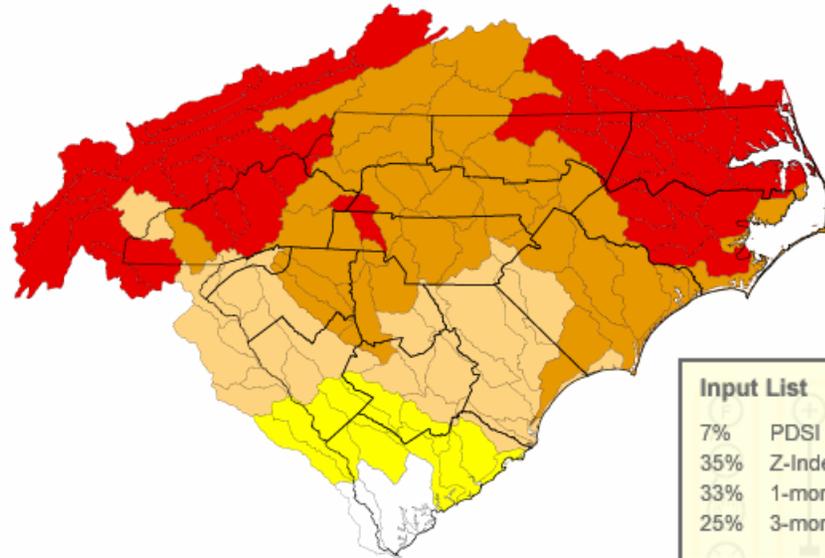
County

- | | |
|--|--|
| 0.00 to 2.00 (D4) | 70.00 to 80.00 |
| 2.00 to 5.00 (D3) | 80.00 to 90.00 |
| 5.00 to 10.00 (D2) | 90.00 to 95.00 |
| 10.00 to 20.00 (D1) | 95.00 to 98.00 |
| 20.00 to 30.00 (D0) | 98.00 to 100.00 |
| 30.00 to 70.00 | No Data |

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

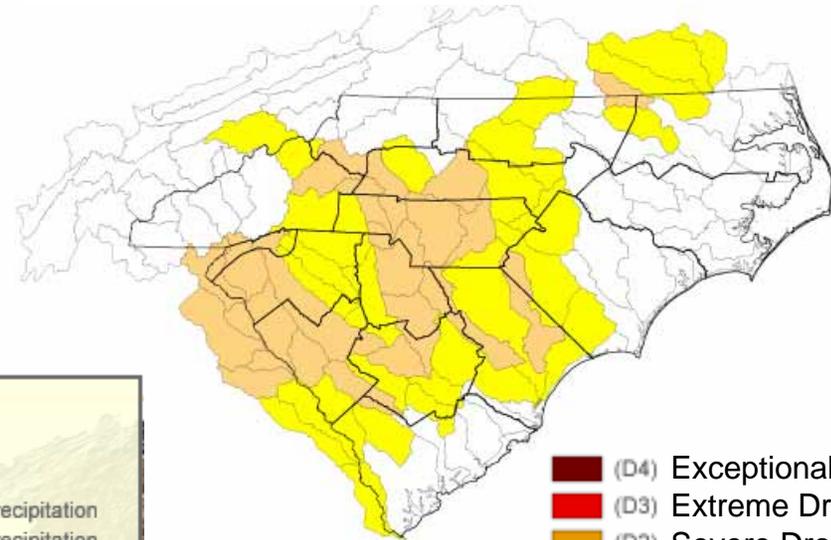
50% PDSI and 50% PHDI

Short term, December 1965



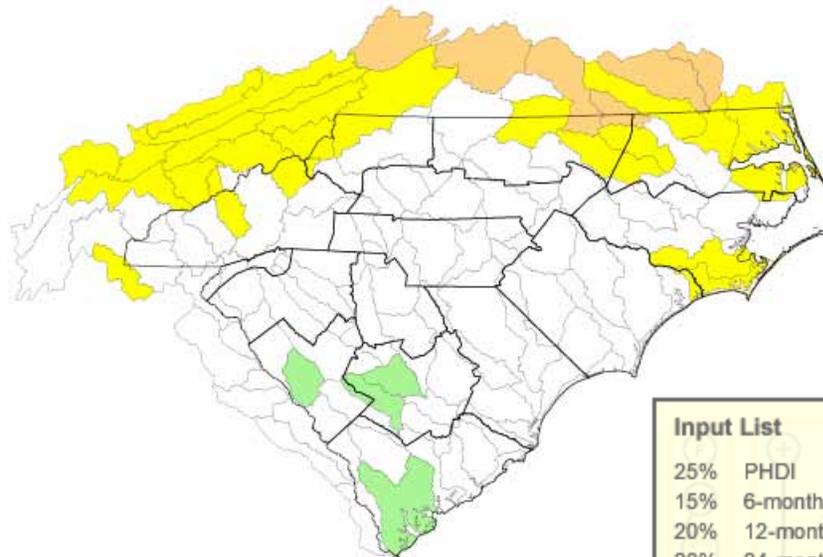
Input List	
7%	PDSI
35%	Z-Index
33%	1-month Precipitation
25%	3-month Precipitation

Short term, July 2002



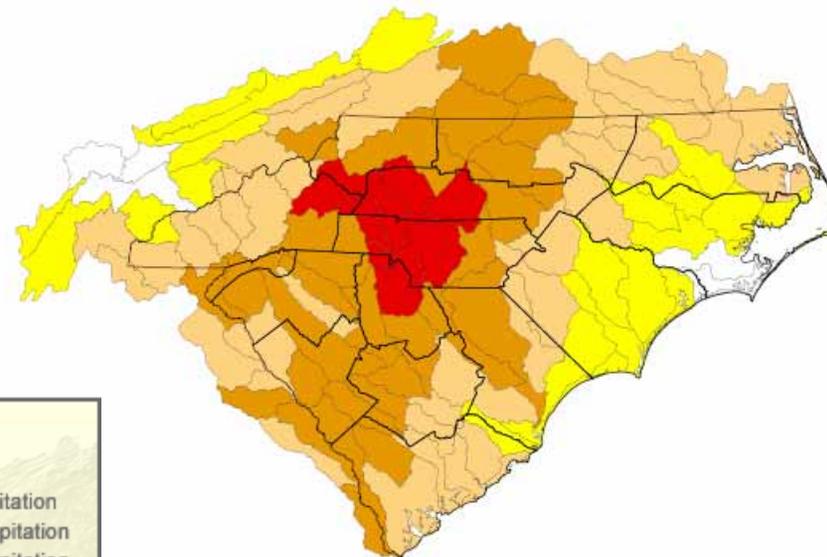
	(D4) Exceptional Drought
	(D3) Extreme Drought
	(D2) Severe Drought
	(D1) Moderate Drought
	(D0) Abnormally Dry
	

Long term, December 1965



Input List	
25%	PHDI
15%	6-month Precipitation
20%	12-month Precipitation
20%	24-month Precipitation
20%	60-month Precipitation

Long term, July 2002



Attachment G - Low Inflow Protocol (LIP) for the Catawba-Wateree Project

“In order to ensure continuous improvement regarding the LIP and its implementation throughout the term of the New License, the LIP will be re-evaluated and modified periodically. These reevaluations and modifications will be as determined by the Catawba-Wateree Drought Management Advisory Group (CW-DMAG).”



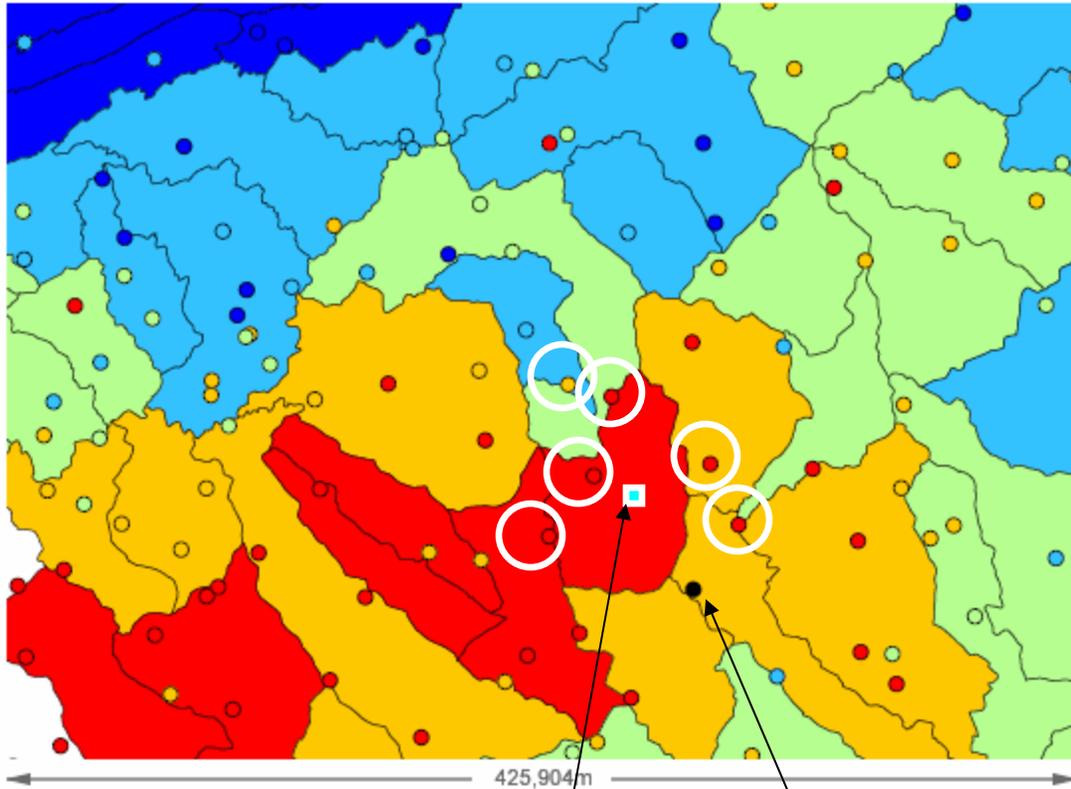
Thanks to: Lauren Gregory,
Kirsten Lackstrom, and
Ohnika Singh



Blend Percentile Map for May 2004

Notice: Selected features show aggregated values
Status: Map ready

Show Inputs Station List Create Graph Create Table



Map navigation controls including a search icon (F), a hand icon, a zoom in (+) and zoom out (-) slider, and a small inset map of the region.

X: 515,894m Y: 3,925,032m

Layer list and legend. The layer list includes:

- M B S Layer
- USGS Stream Gages
- NWS Weather Stations
- States
- Drought Management Areas
- Climate Divisions
- Counties
- 2-Digit HUC Areas
- 4-Digit HUC Areas
- 6-Digit HUC Areas
- Catawba-Wataeree Basin
- 8-Digit HUC Areas
- Hydrology
- Shaded Relief

Legend: 8-Digit HUC Areas

- 0.16 to 11.88
- 11.88 to 21.14
- 21.14 to 40.78
- 40.78 to 64.22
- 64.22 to 98.18
- No Data

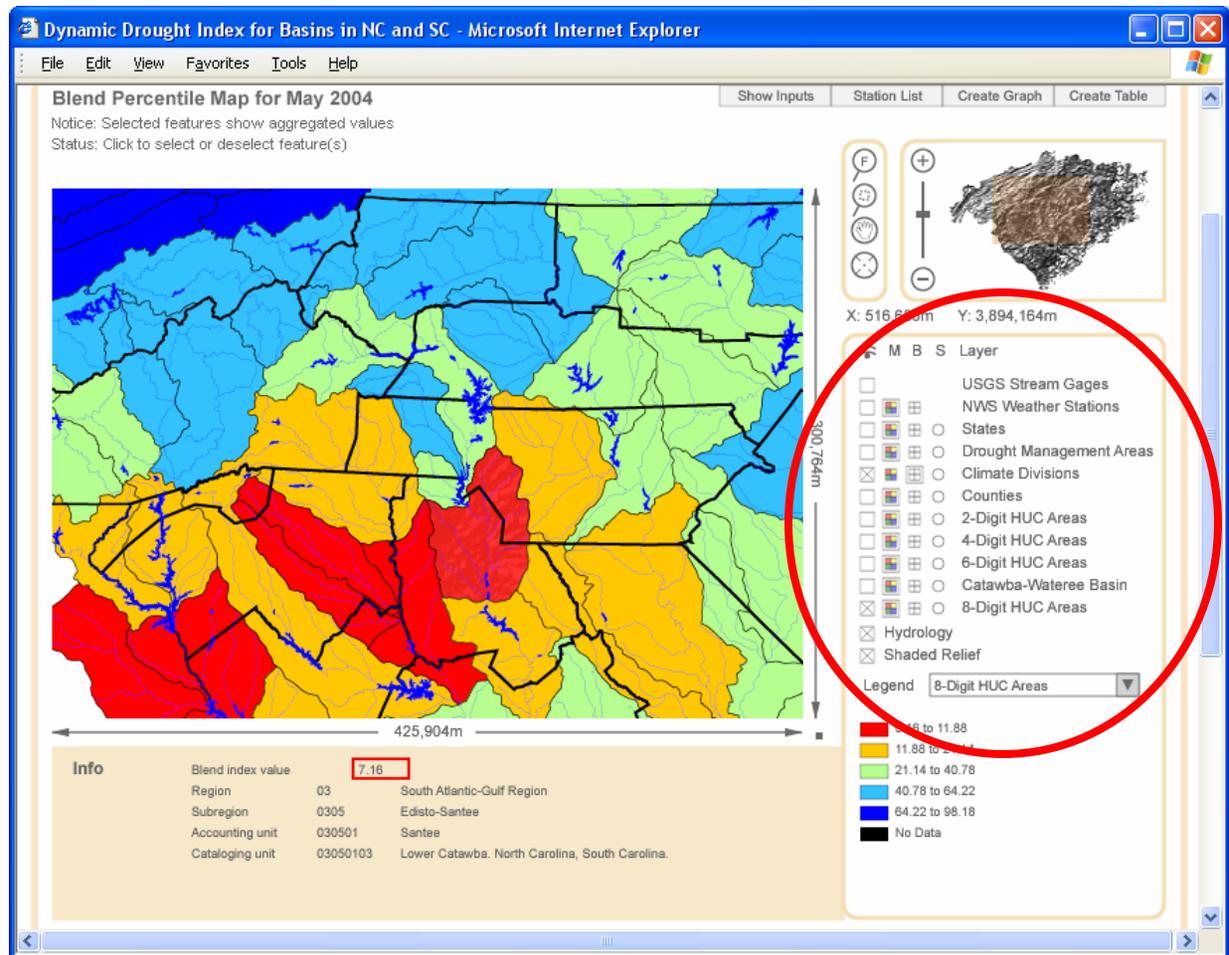
Info

4 km x 4 km grid

No data

Map Layers

- Visibility
- Choropleth map
- Boundary
- Stations used



Comparison: time scale variability January 1995 ~ December 2004

