Development of a Real-time Coastal Drought Index

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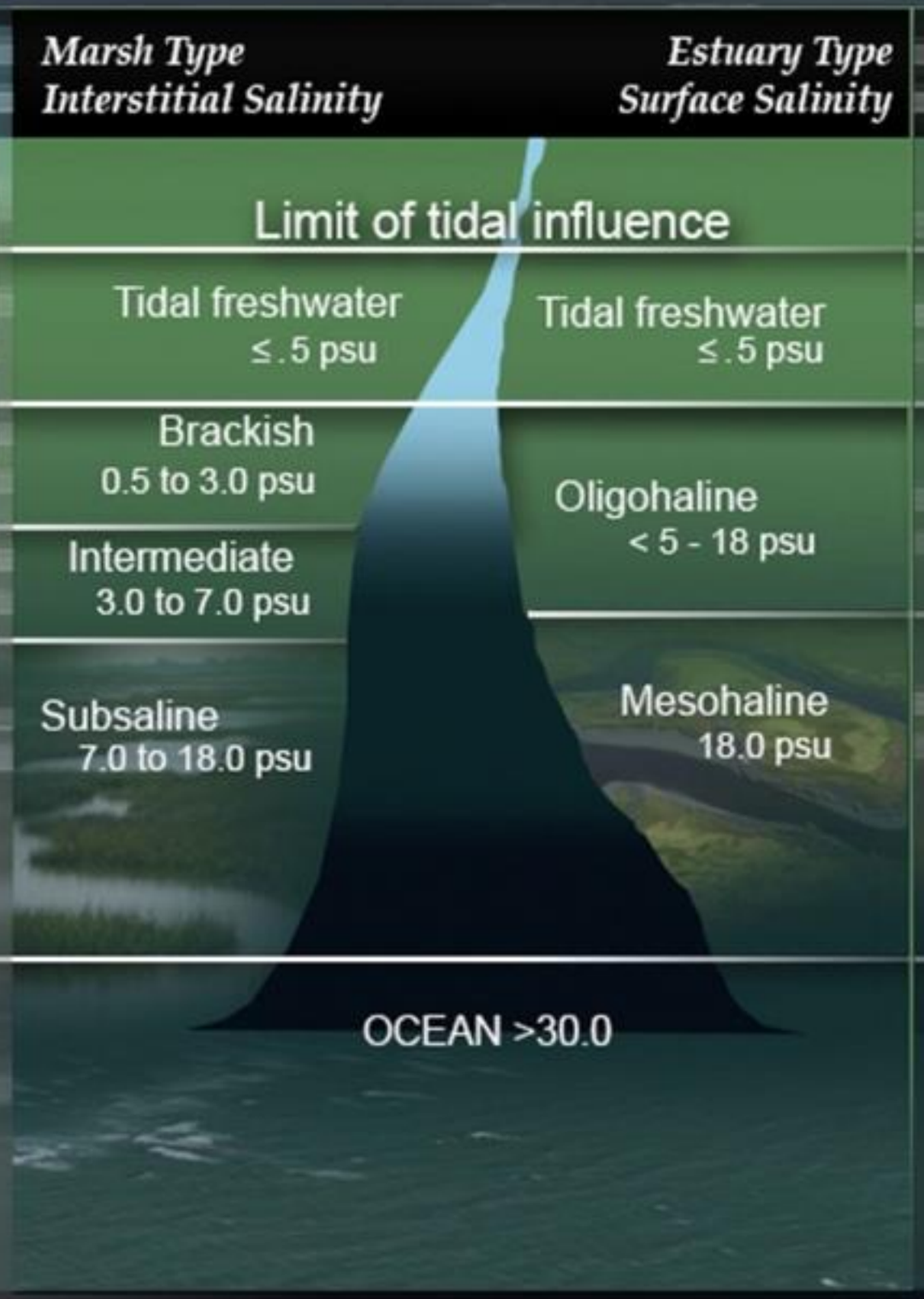
Question –
Can a drought index be developed for the coast?



…towards a Coastal Drought Index

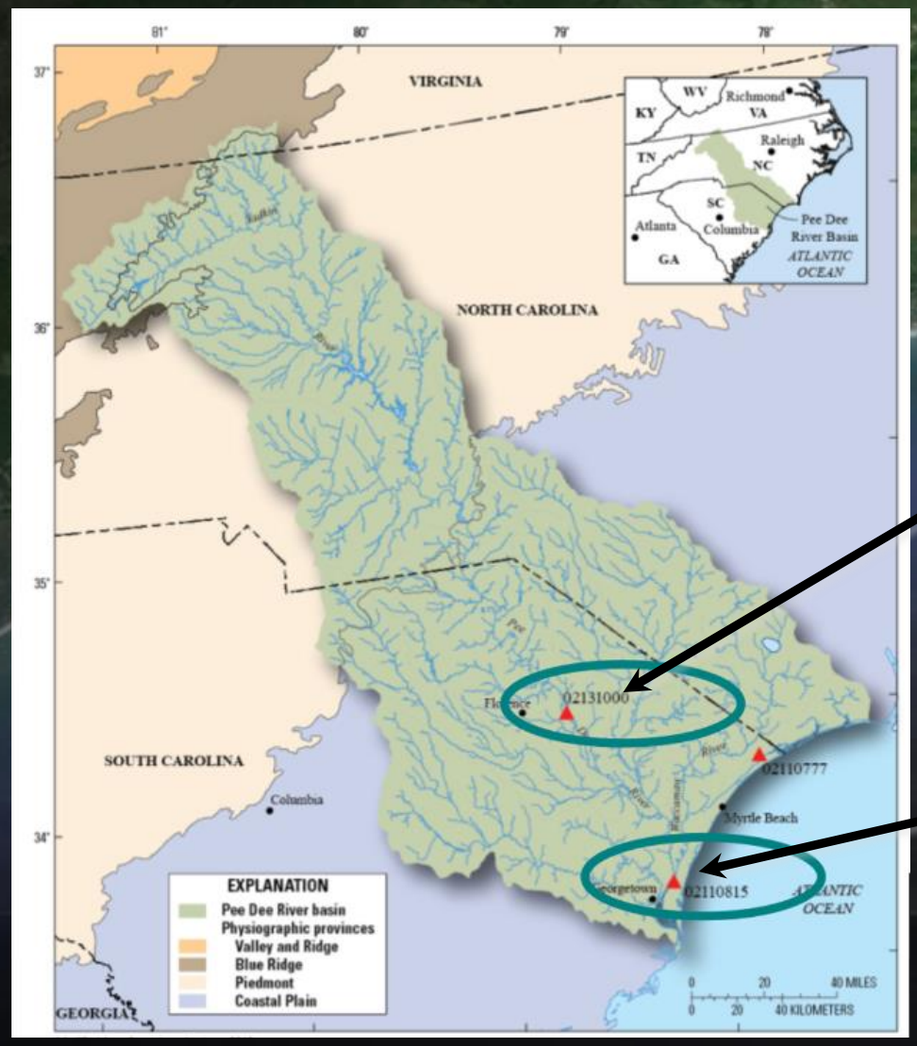
Four drought categories;

- Meteorological,
- Agricultural,
- Hydrological, and
- Socioeconomic

Addresses different sectors and spatial scales
Impossibility to devise a universal drought index

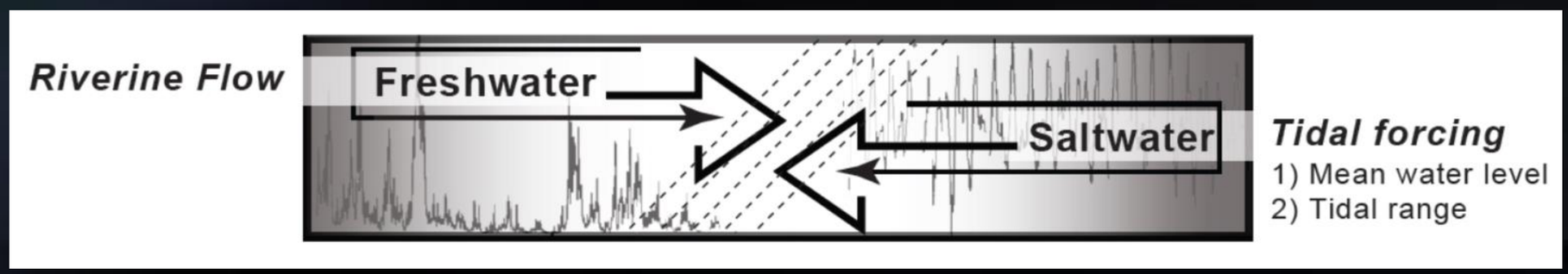
Heim, 2002

Can Salinity be Used as a Drought Index Variable?

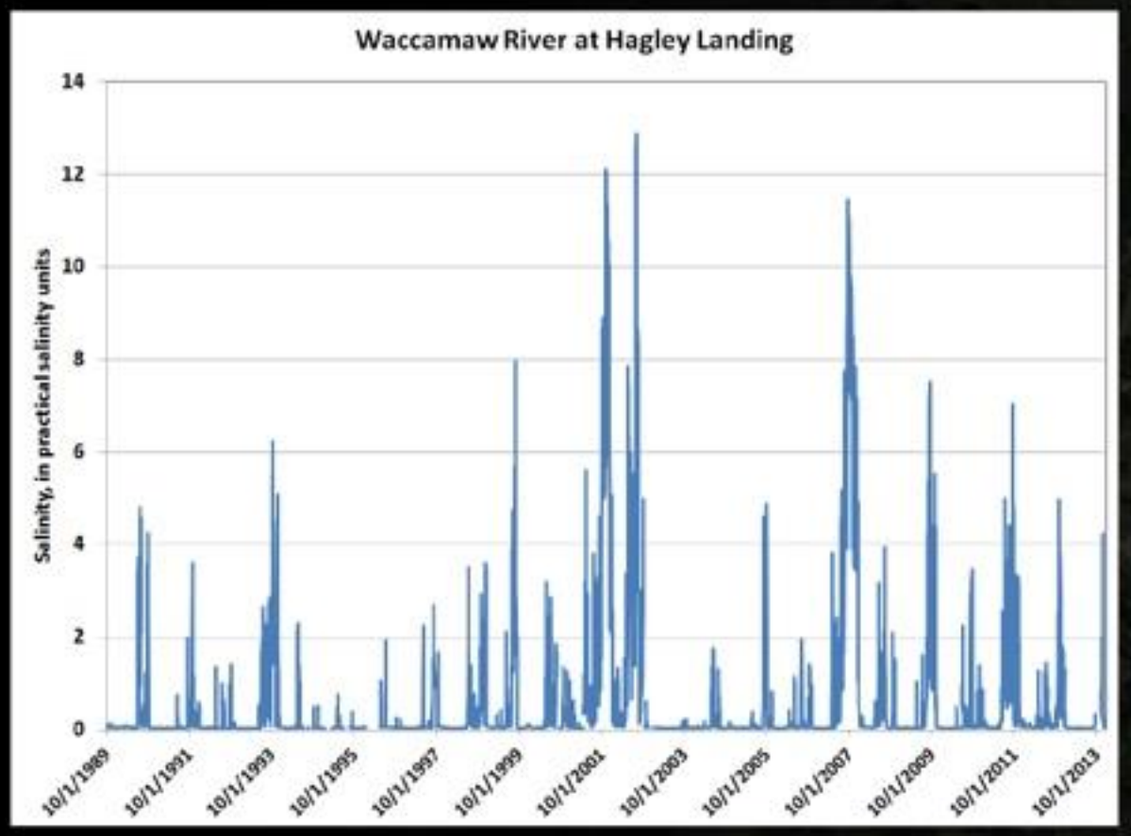


Pee Dee River

Waccamaw River



Long-term Salinity Data



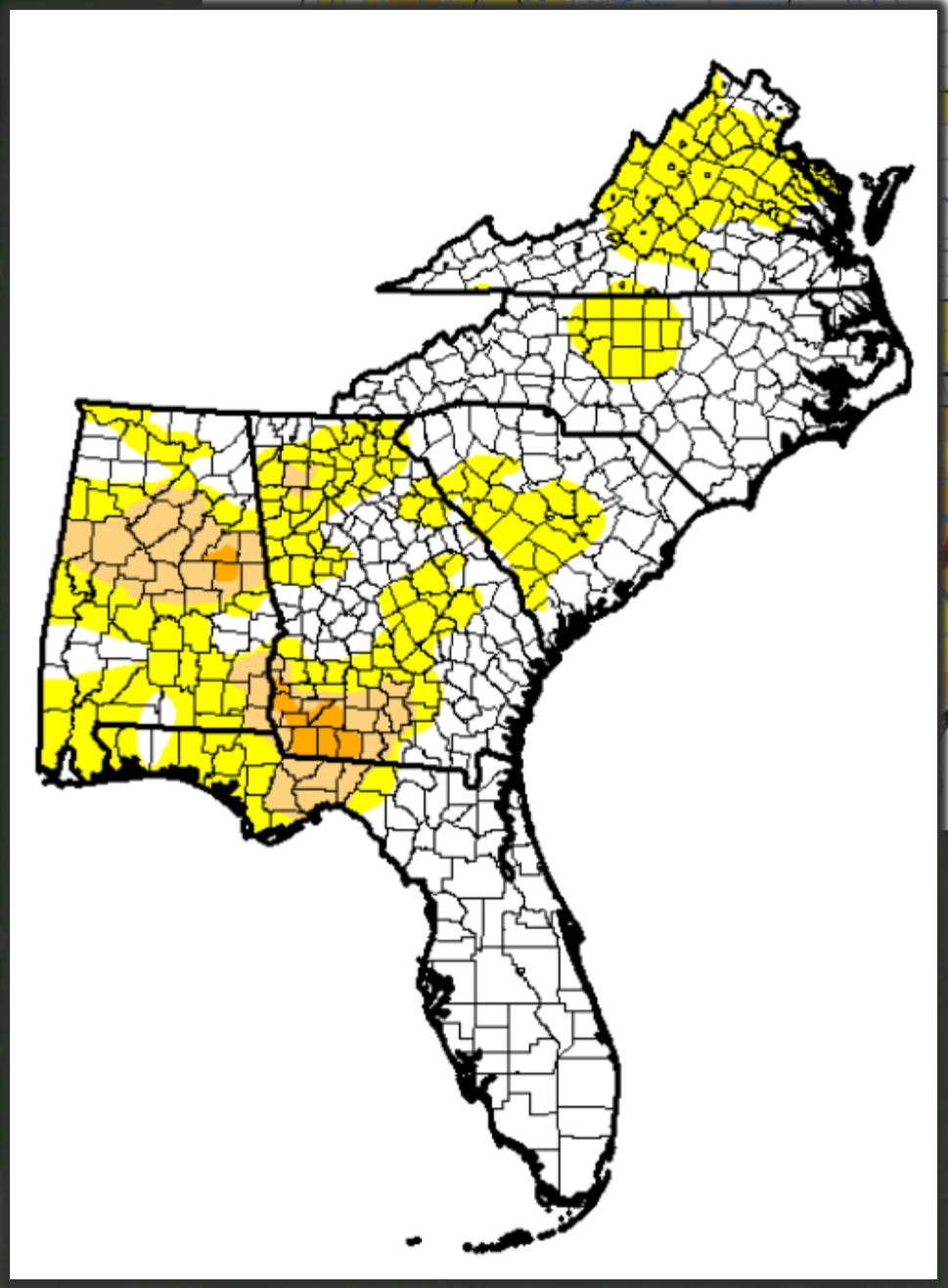
Waccamaw River at Hagley Landing (02110815)
Long period of record
1989 to present
Daily mean salinity
~8,000 data point

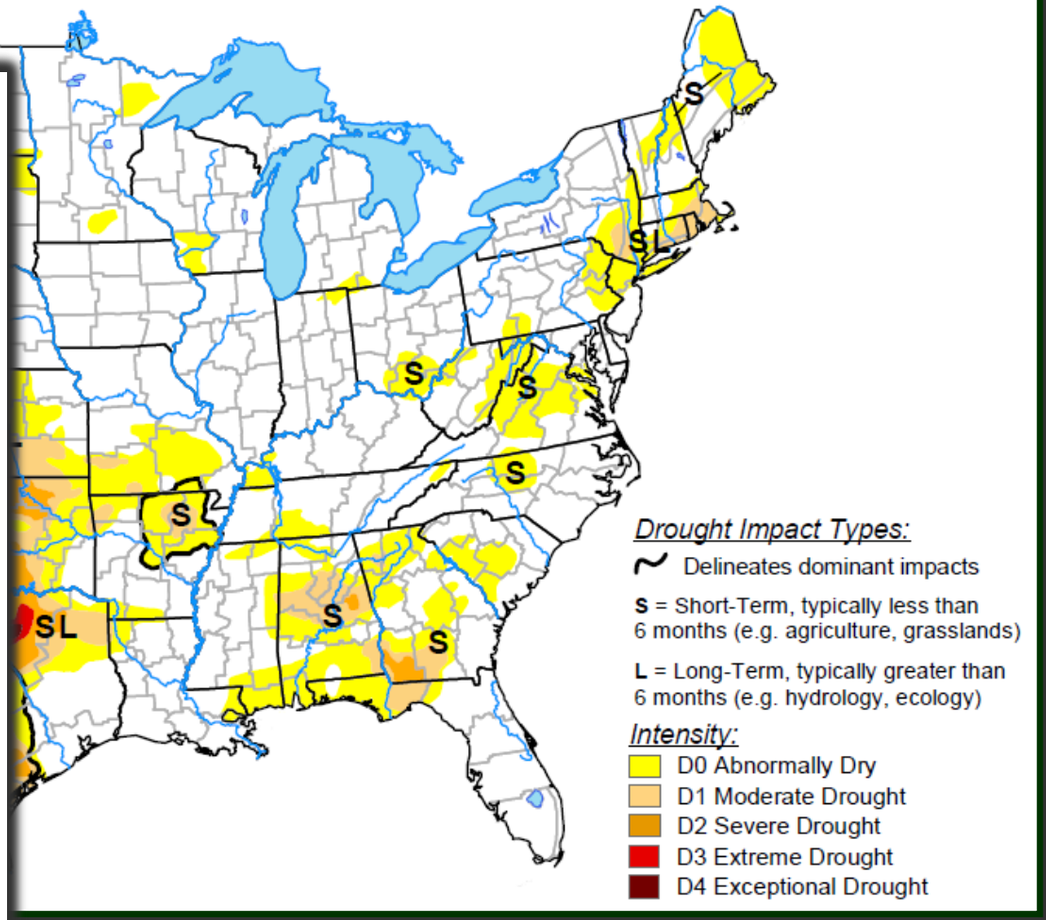
U.S. Drought Monitor

October 7, 2014

(Released Thursday, Oct. 9, 2014)

Valid 8 a.m. EDT





Drought Impact Types:

~ Delineates dominant impacts

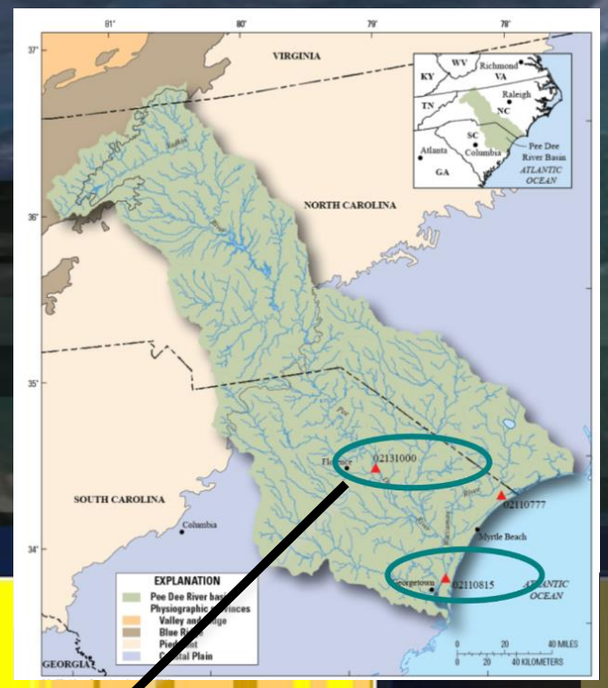
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

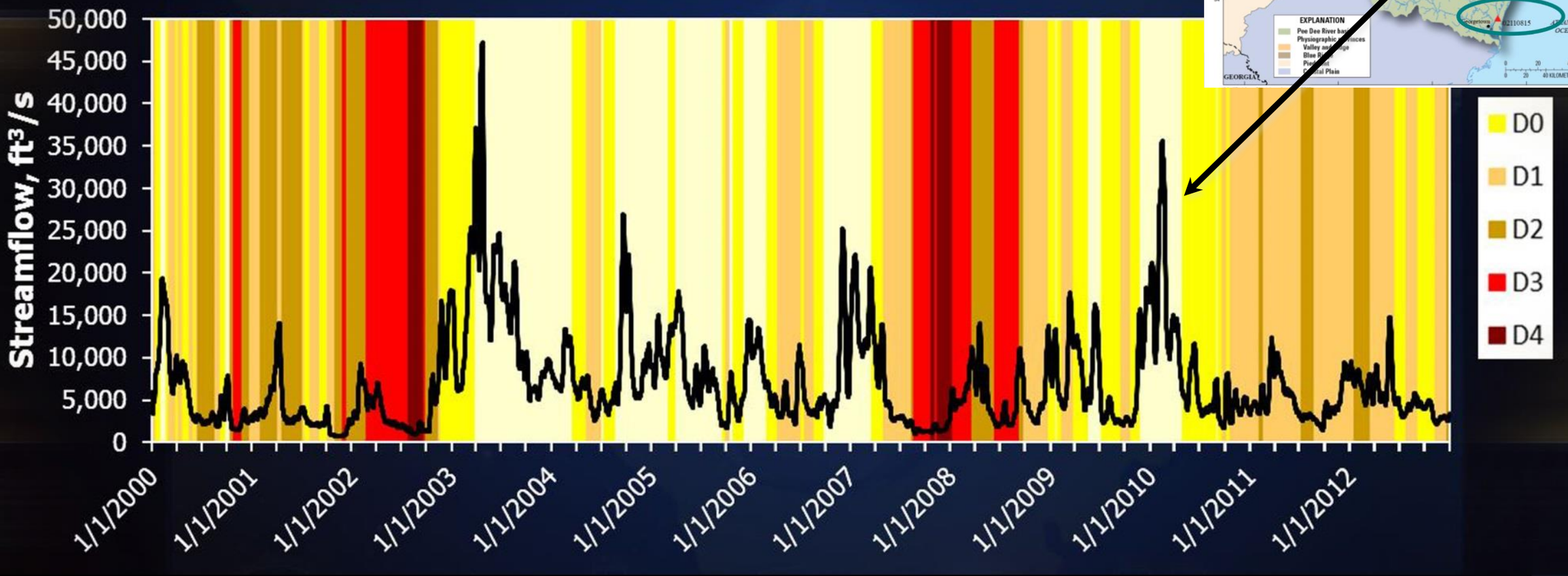
L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

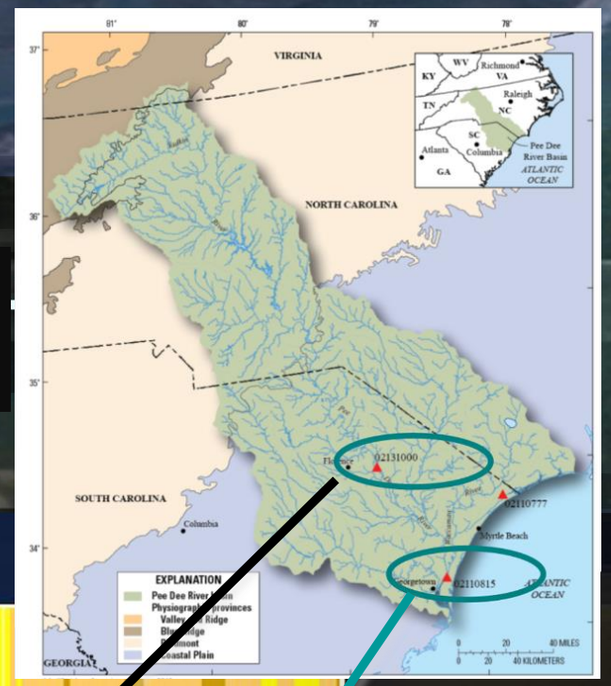
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

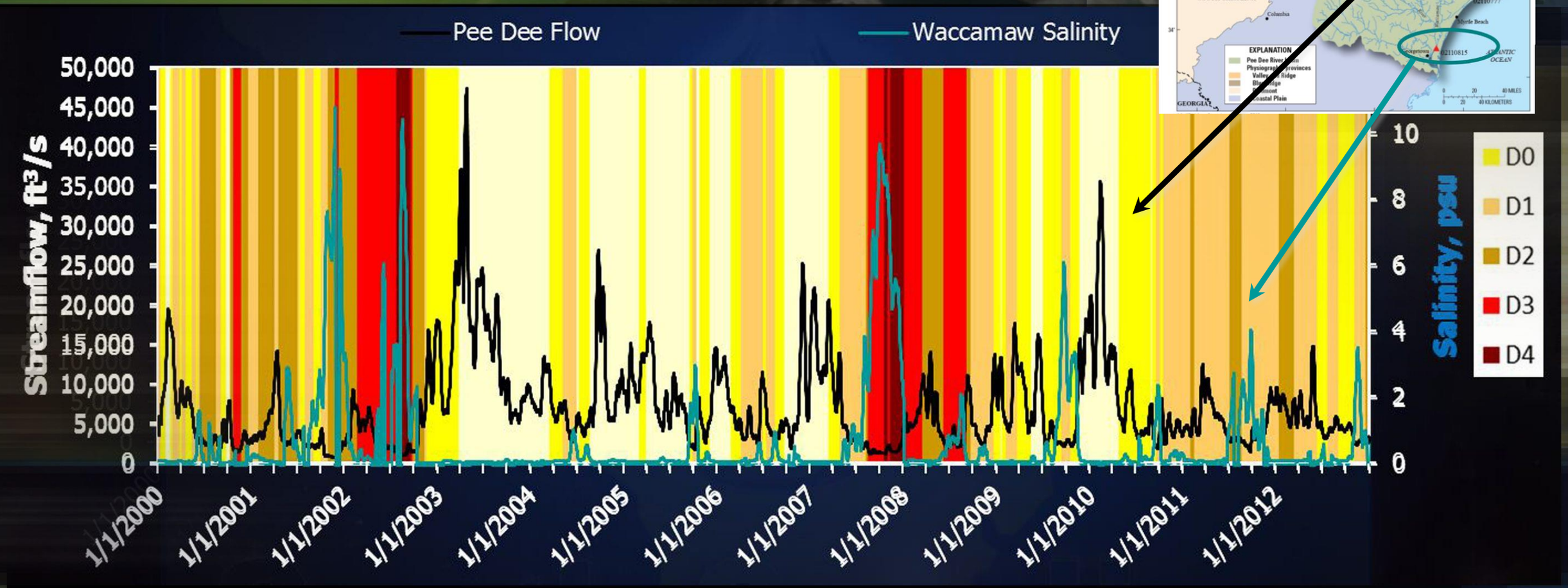
Flow and Drought Index





Flow, Salinity, and Drought Index





Coastal Drought Index Considerations

(Friedman 1957, Heim 2002)

1) Appropriate time scale for the problem
   - Responses to salinity changes – multiple time scales
   - Short-term (intake, pathogen transport) vs. Long-term (marsh conversion)

2) Quantitative measure of large-scale long-continuing conditions
   - Limited studies/data on ecological response to coastal drought

Coastal Drought Index

Criteria Considerations (continued)

3) Applicable to the problem
   - Importance of saltwater/freshwater interface position

4) Historical data for computation
   - Long-term data records available

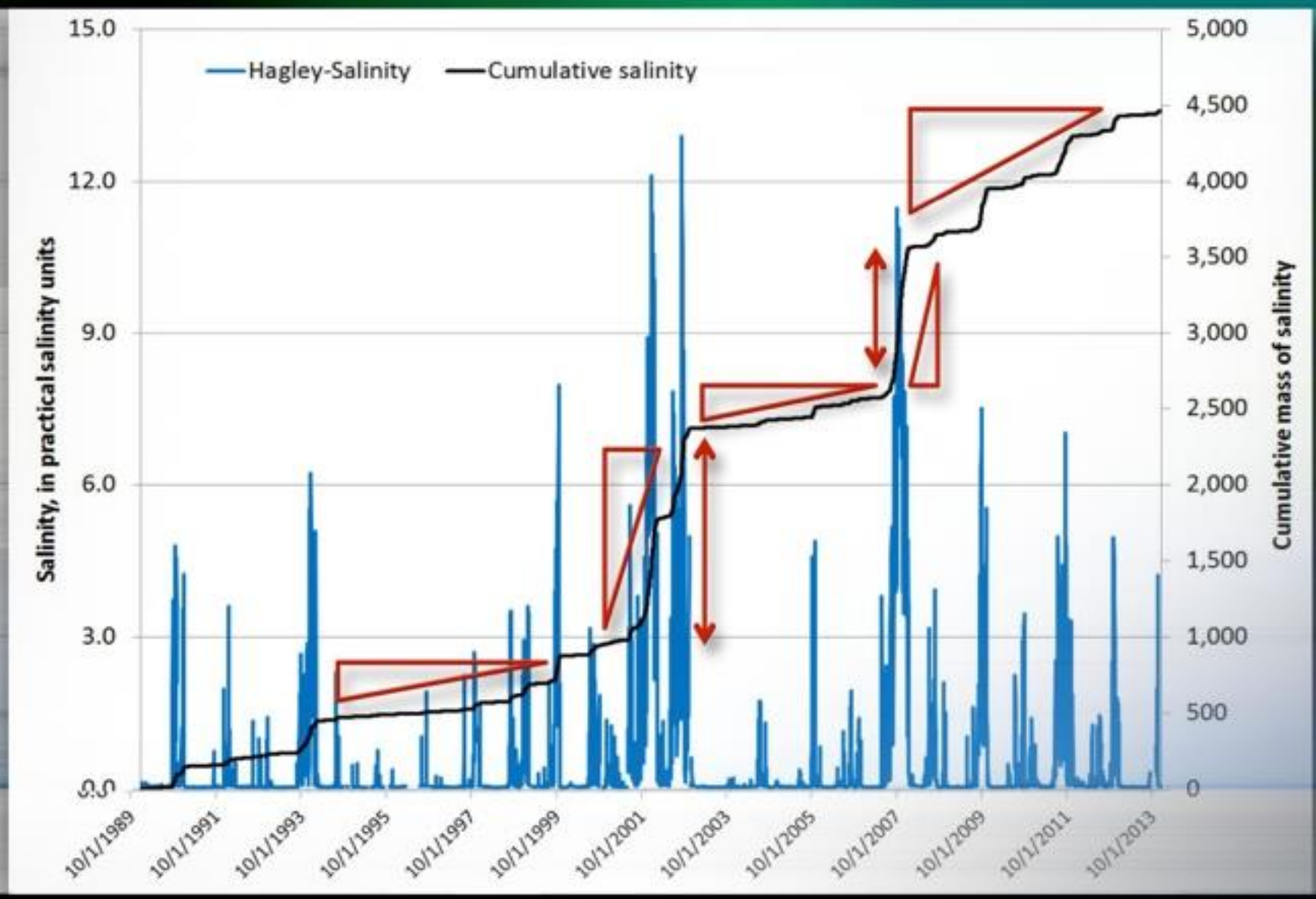
5) Computable on a near-real time basis
   - Many real-time salinity gaging sites

Index Development Approach

- Single process salinity times series to extract drought information:
  - *Single Mass Curves*
  - *Cumulative Z-scores*
  - *Time-derivative*
- Create “drought” time-series
  - *Compute frequency distribution*
  - *Use frequency distribution to set drought thresholds*

Identifying Changing Salinity Behavior

Single Mass Curve

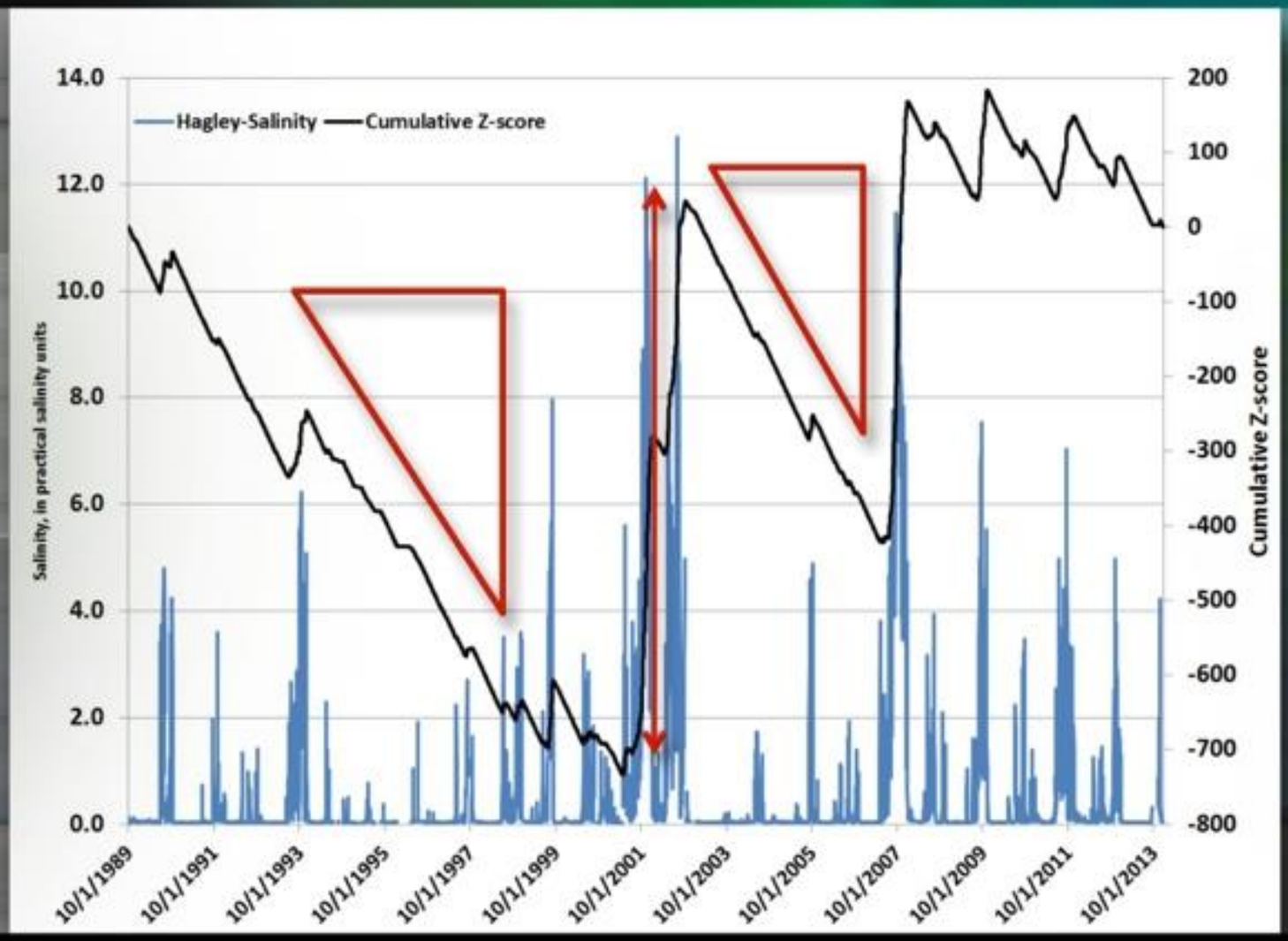


Could slope and magnitude of rises be used in an index?

Identifying Changing Salinity Behavior

Cumulative Z-score

Z-score = (x - mean)/standard deviation

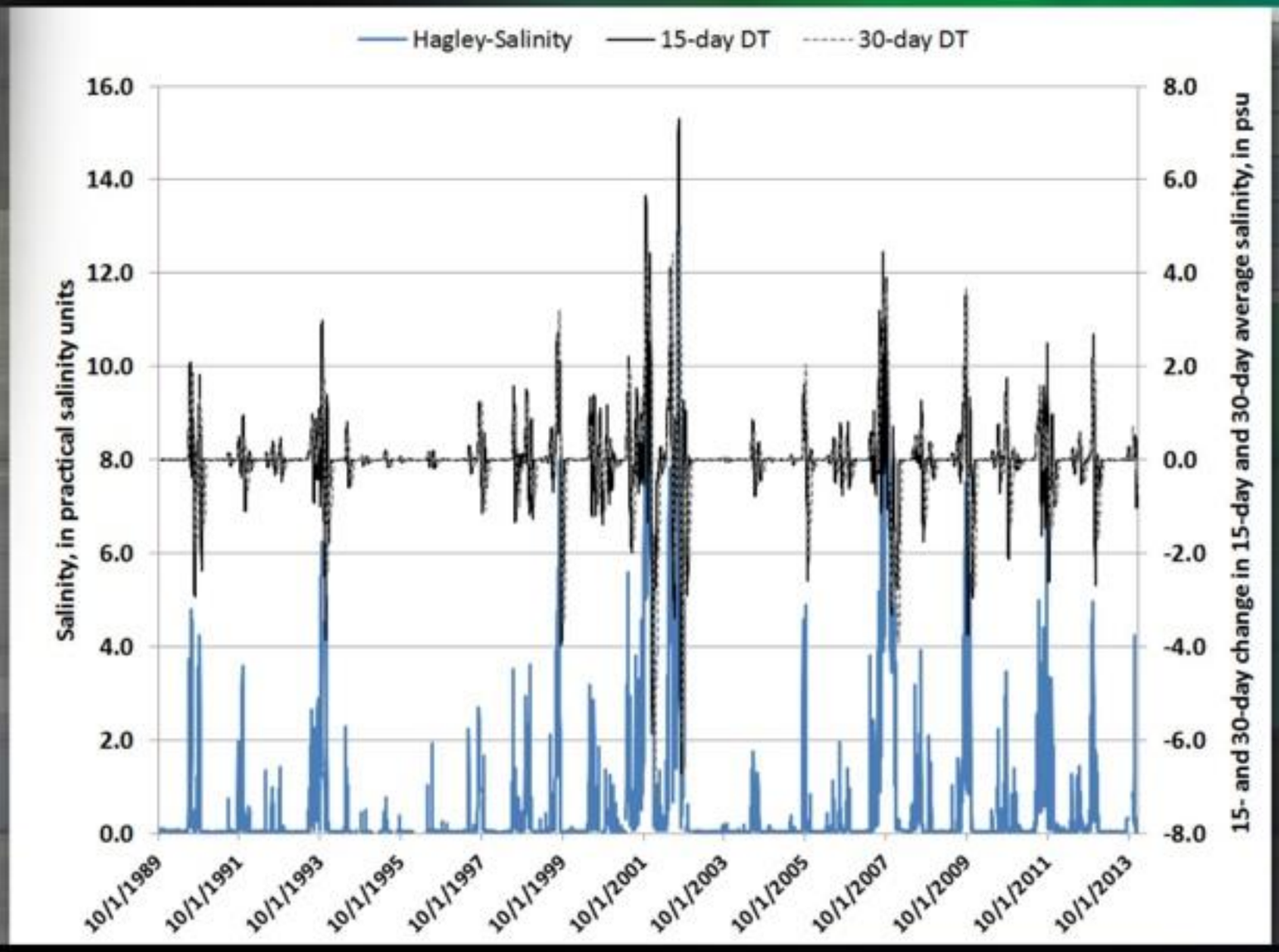


Change in slope indicates a change in salinity behavior

Identifying Changing Salinity Behavior

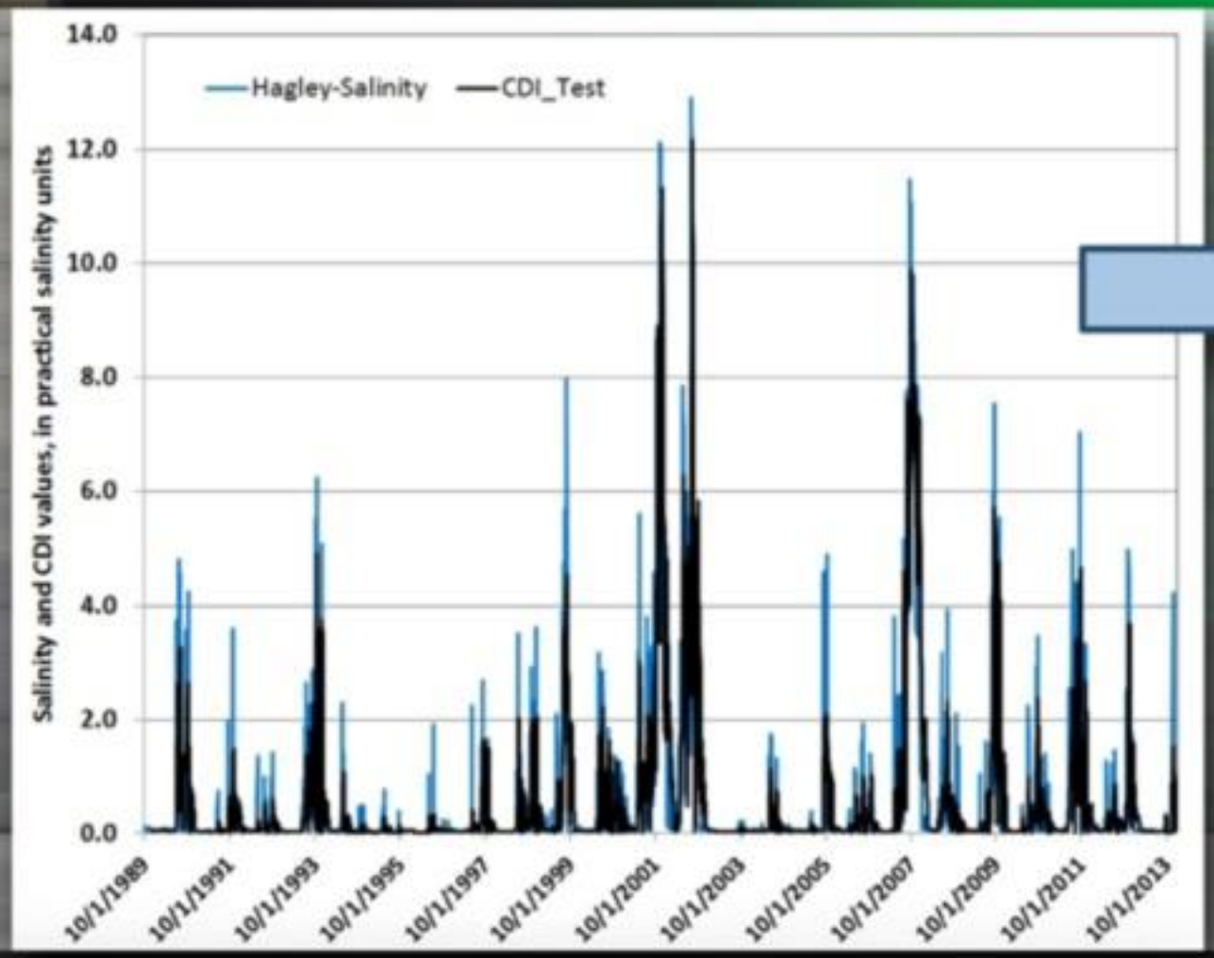
Time Derivative

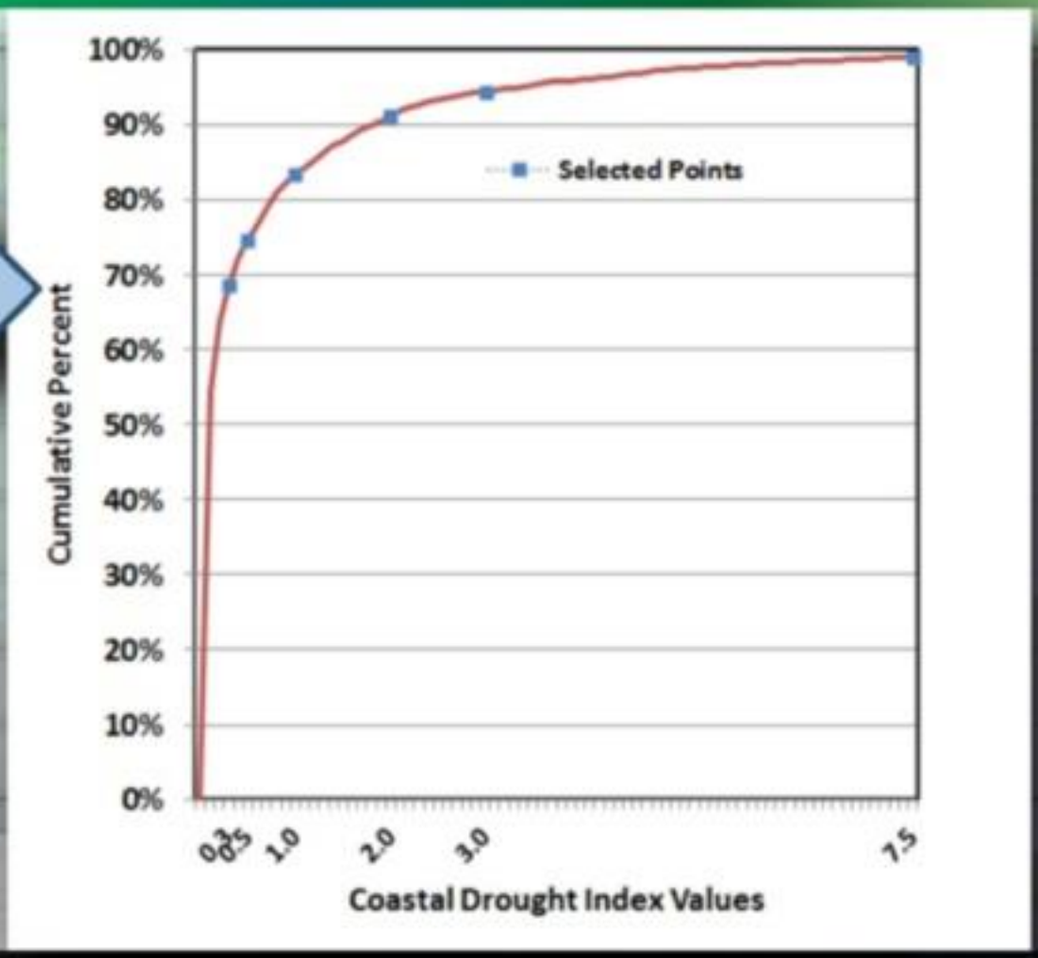
15-day DT = Average(Day16-30) - Average(Day1-15)



Sun	Mon	Tues	Wed	Thurs	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5

Preliminary Coastal Drought Index (CDI) Time Series & Frequency Curve



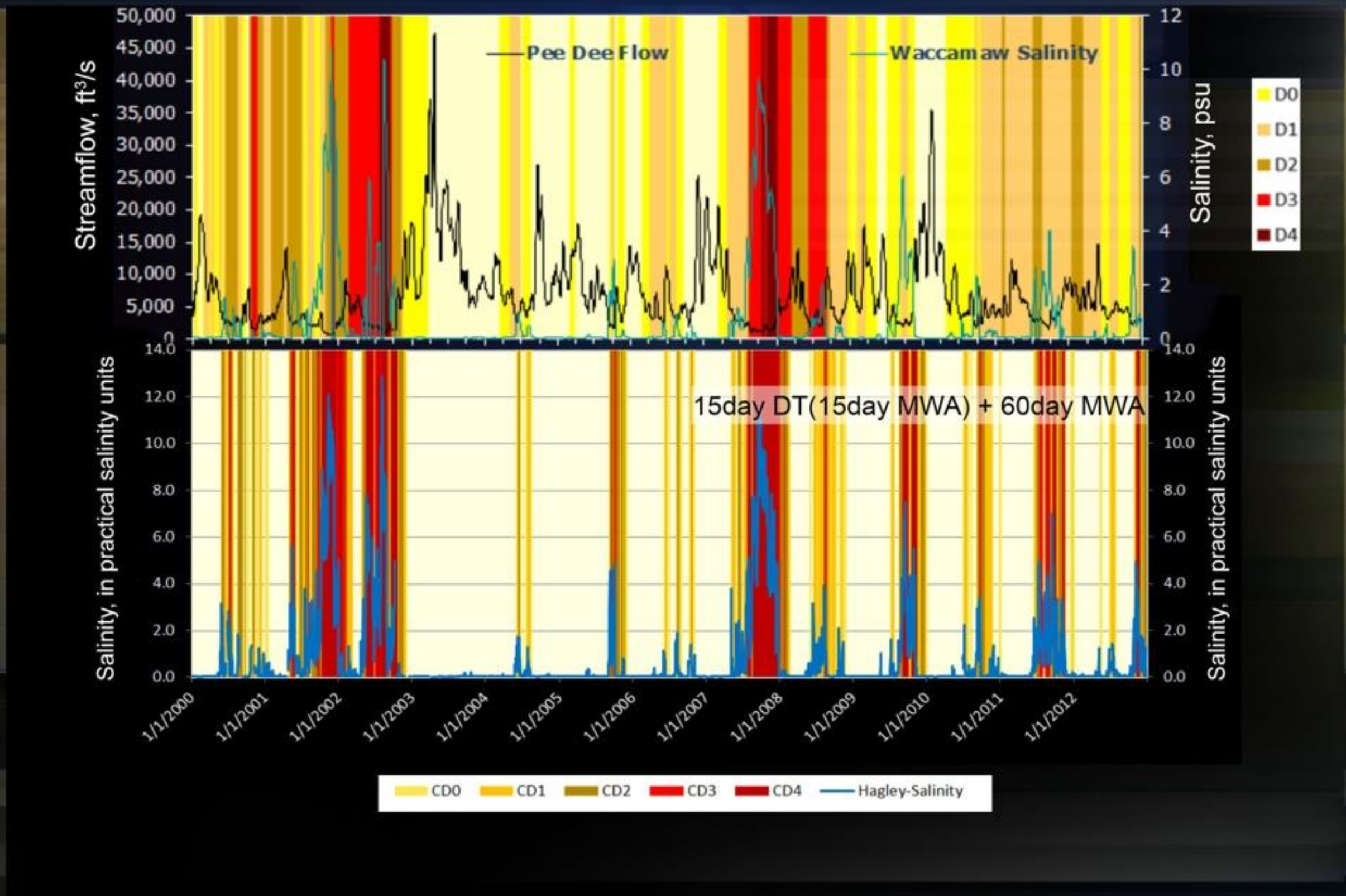


Preliminary

CDI = 60-day MWA salinity + 15-day DT

- Computed frequency distribution of CDI values
- Pick threshold values from distribution

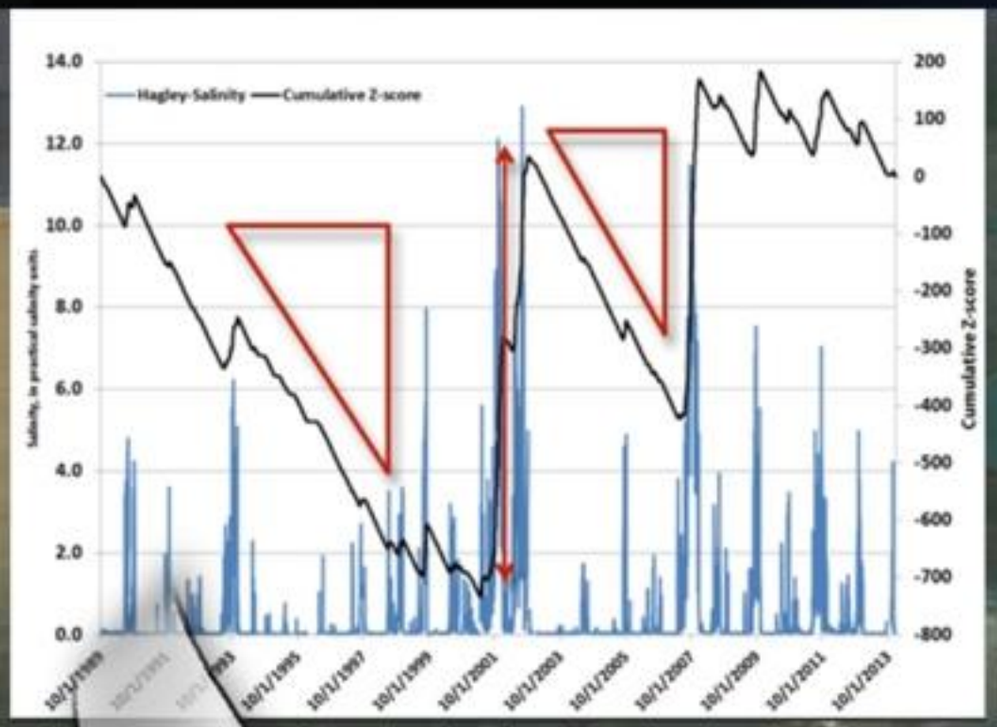
Salinity, Flow and Drought Monitor Declarations

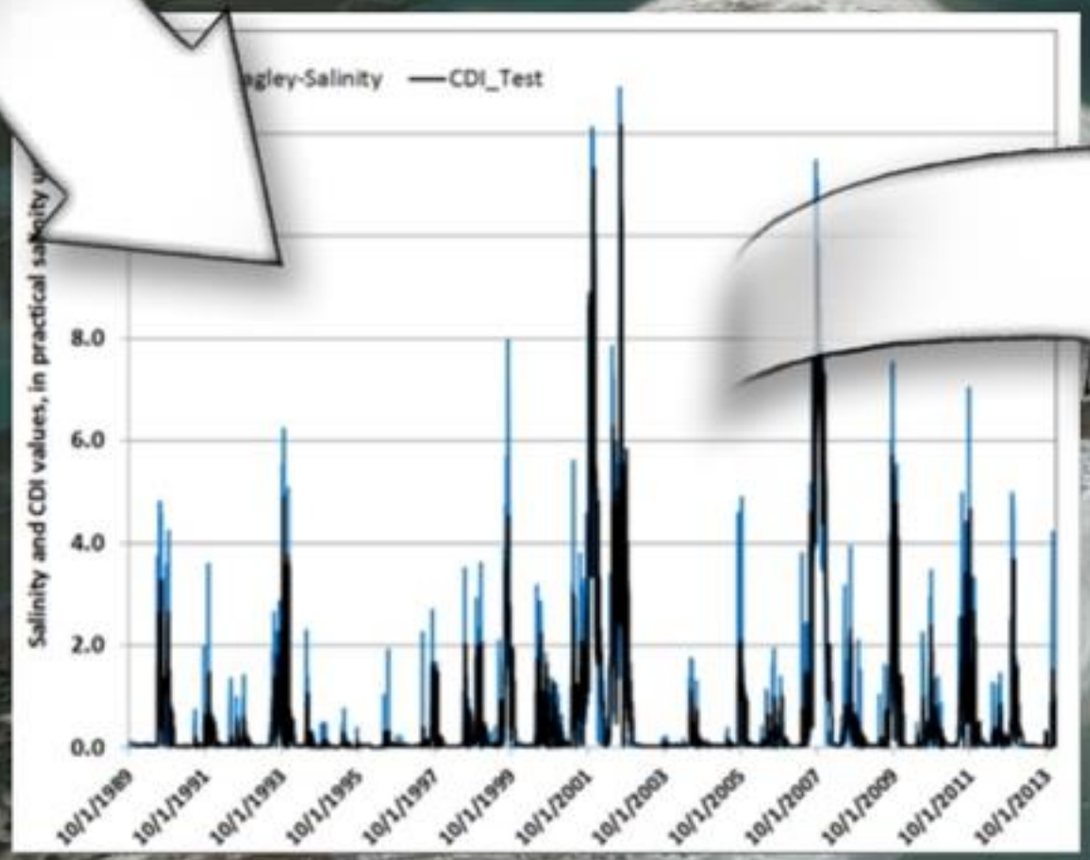


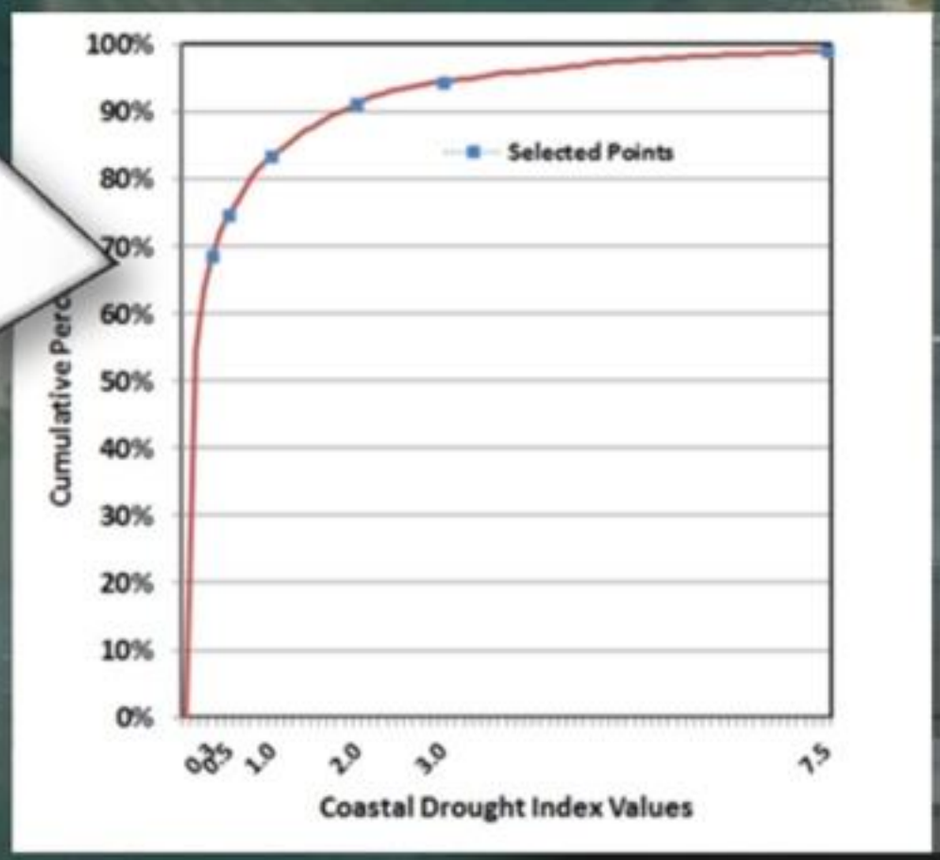
Issues to Address

- Pinball effect
- Concern for “wet” conditions
- Time scales between the CDI and environmental and ecological response variables

Where to go next?



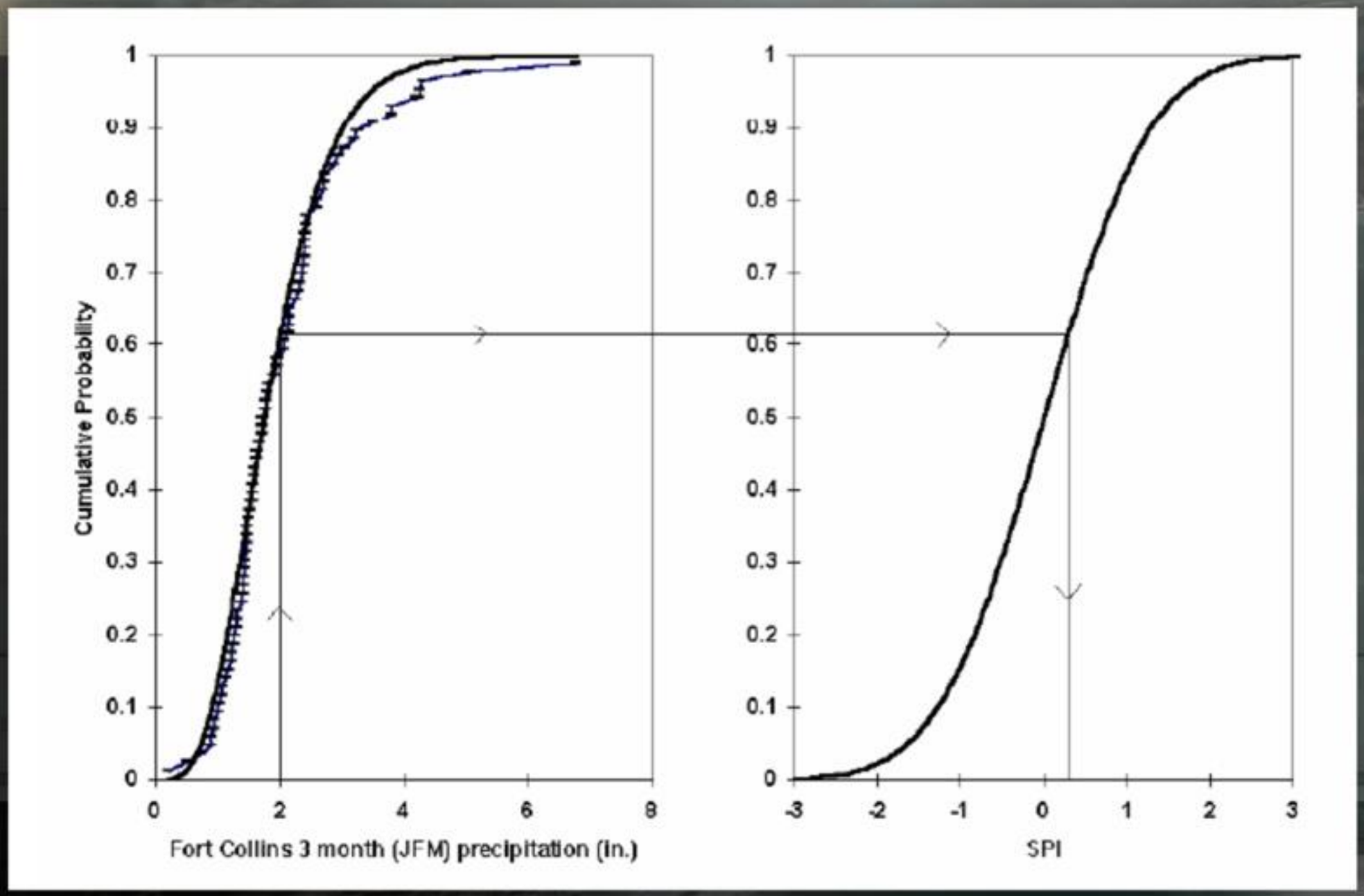




Standardized Precipitation Index (SPI)

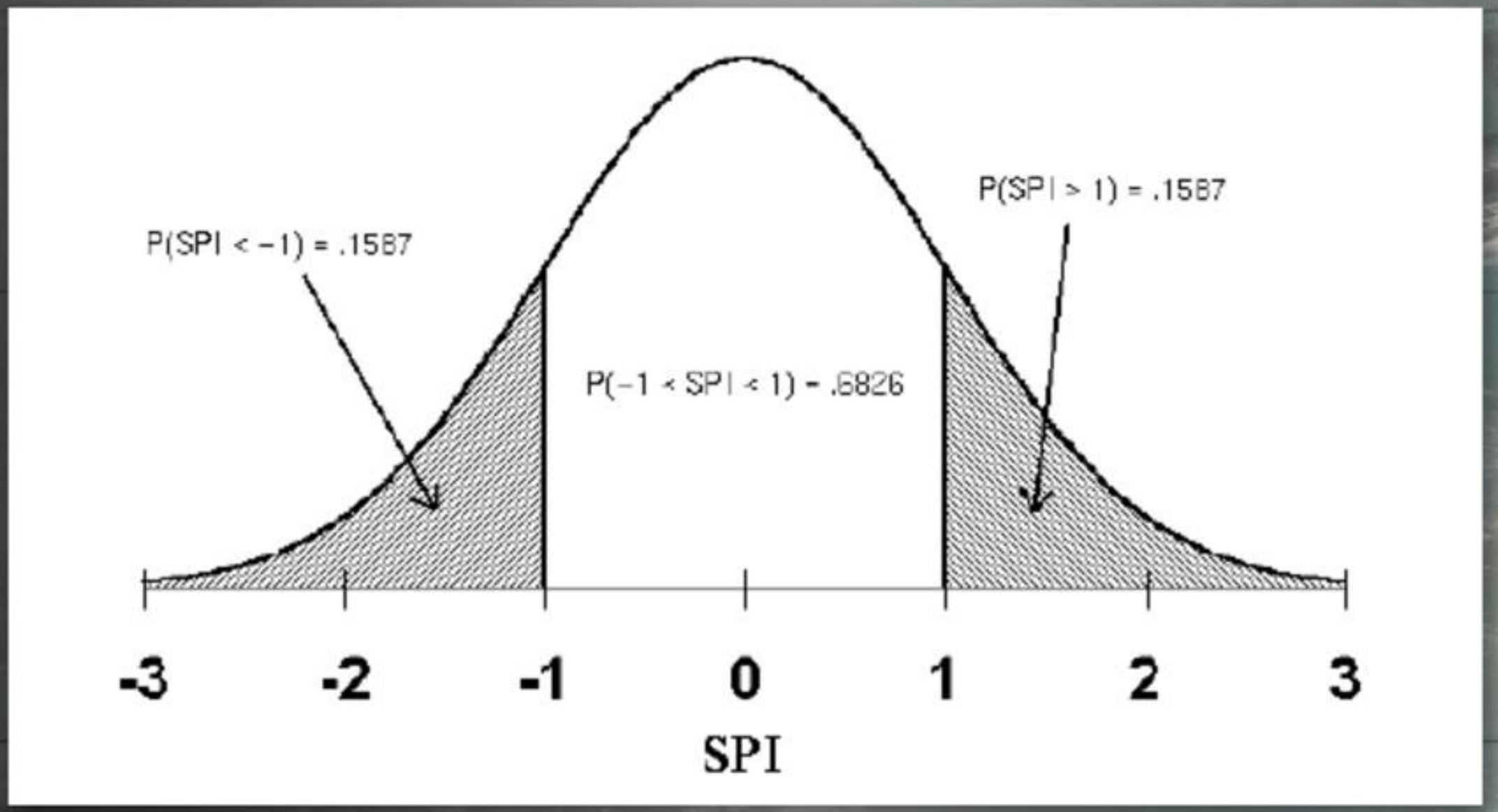
- Similarity of SPI and cumulative Z-scores
- Normalize precipitation with probability distribution
- Index values are standard deviation from the median
- Index for dry and wet conditions
- SPIs comparable for different locations

Example of equiprobability transformation from fitted gamma distribution to the standard normal distribution



From Colorado State

Standard Normal Distribution



Standard normal distribution with the SPI having a mean zero and variance of one.

From Colorado State

Benefits of a Standardize Salinity Index (SSI)

- Compute for multiple time periods
  - 1-month, 3-month, 6-months, etc.
  - Difference time periods used for different drought response variable
- Index for fresher and saltier conditions
- Real-time computation of SSI
- Challenges
  - Limited number of long-term sites
  - Missing record – estimating data gaps

SSI Computation

Murrells Inlet

Hagley Landing

Pawleys Island

Hagley

1986	5	5820
1986	6	3590
1986	7	3070
1986	8	2750
1986	9	1910
1986	10	8390
1986	11	3860
1986	12	280
1987	1	220
1987	2	150
1987	3	160
1987	4	
1987	5	
1987	6	
1987	7	
1987	8	
1987	9	340
1987	10	8300
1987	11	1820
1987	12	160
1988	1	150
1988	2	130
1988	3	150
1988	4	320
1988	5	510
1988	6	4470
1988	7	6530
1988	8	3470
1988	9	320
1988	10	790
1988	11	620
1988	12	410
1989	1	390
1989	2	
1989	3	
1989	4	
1989	5	
1989	6	220
1989	7	190
1989	8	170
1989	9	1030
1989	10	180

Input file

Hagley		SSI-1	SSI-3	SSI-6	SSI-9	SSI-12
1986	5	2.11	-99.00	-99.00	-99.00	-99.00
1986	6	1.39	-99.00	-99.00	-99.00	-99.00
1986	7	0.75	1.49	-99.00	-99.00	-99.00
1986	8	0.37	0.73	-99.00	-99.00	-99.00
1986	9	0.14	0.33	-99.00	-99.00	-99.00
1986	10	1.10	0.63	0.94	-99.00	-99.00
1986	11	0.67	0.73	0.73	-99.00	-99.00
1986	12	-0.36	0.78	0.57	-99.00	-99.00
1987	12	-0.58	0.61	0.19	0.11	0.10
1988	1	-0.29	-0.07	0.26	0.08	0.09
1988	2	-0.19	-0.51	0.33	0.13	0.09
1988	3	0.21	-0.20	0.57	0.17	0.09
1988	4	1.30	0.57	-0.07	0.25	0.08
1988	5	-0.10	0.07	-0.29	0.29	0.10
1988	6	1.66	1.20	1.09	0.71	0.30
1988	7	1.57	1.38	1.49	0.78	0.58
1988	8	0.54	1.18	1.09	0.88	0.65
1988	9	-0.76	0.59	0.75	0.72	0.65
1988	10	-0.46	-0.18	0.46	0.48	0.31
1988	11	-0.41	-0.72	0.36	0.34	0.25
1988	12	-0.19	-0.49	0.12	0.30	0.28
1989	1	0.77	-0.29	-0.29	0.27	0.29
1989	2	3.67	0.31	-0.50	0.34	0.33
1989	3	1.38	1.82	-0.31	0.16	0.33
1989	4	0.05	2.31	-0.10	-0.24	0.30
1989	5	-0.59	-0.35	0.05	-0.54	0.29
1989	6	-0.75	-0.67	-0.06	-0.46	0.03
1989	7	-1.03	-1.04	-0.55	-0.55	-0.49
1989	8	-1.01	-1.09	-0.96	-0.64	-0.86
1989	9	-0.21	-0.82	-0.89	-0.65	-0.83
1989	10	-1.06	-0.86	-1.06	-0.85	-0.84

Output file

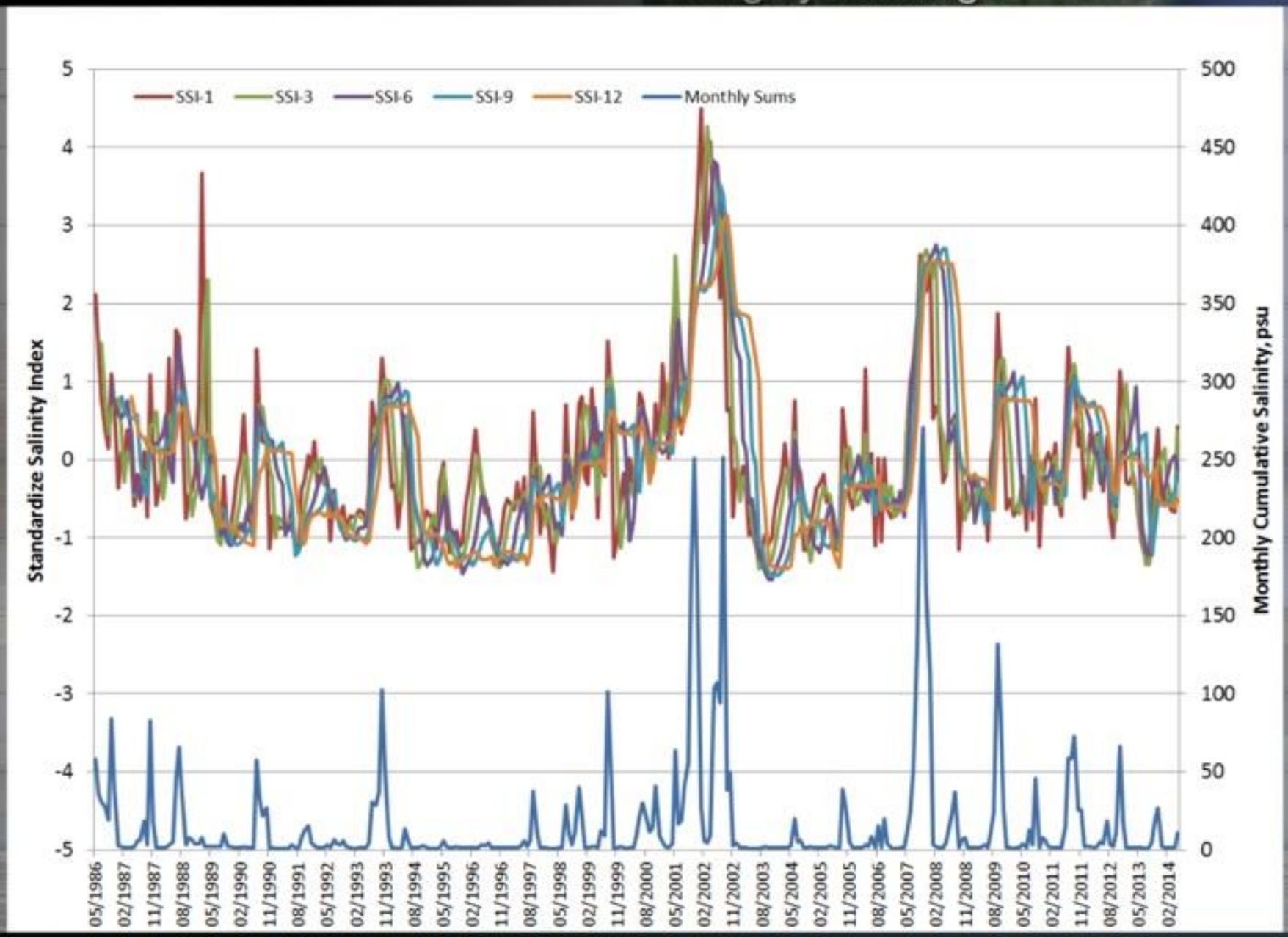
Example:

Year	Month	SSI-3	Comapred with
1986	9	JAS -1986	JAS - POR
1986	10	ASO -1986	ASO - POR
1986	11	SON - 1986	SON - POR
1986	12	OND - 1986	OND - POR
1987	1	NDJ - 1987	NDJ - POR

Monthly values

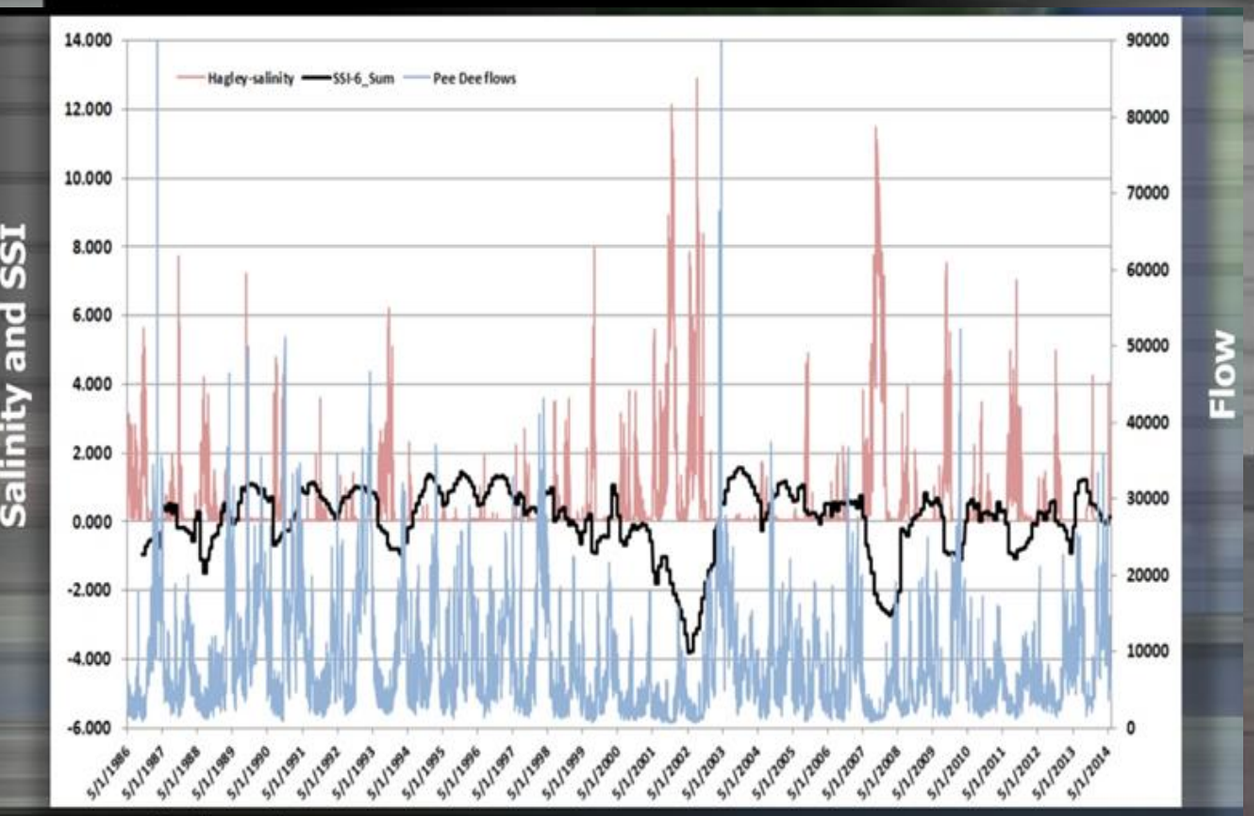
Positive SSIs – saltier conditions

Negative SSIs – fresher conditions

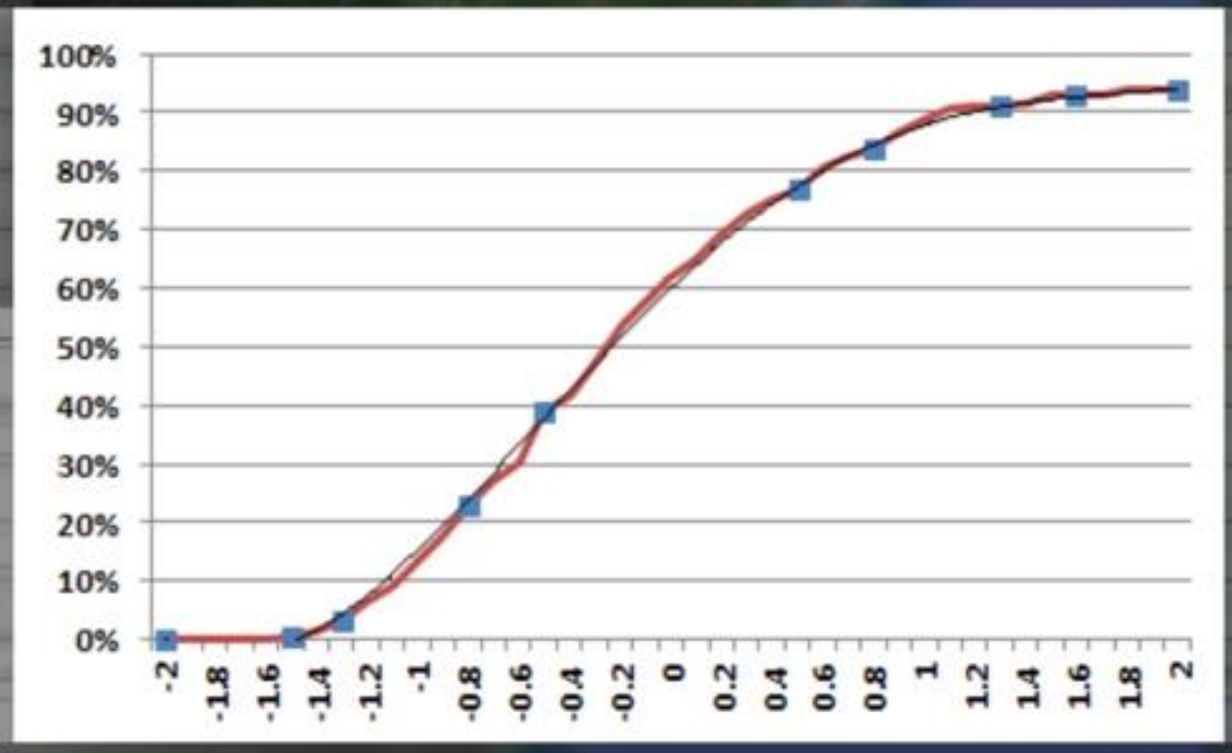


Issues with "positive" drought values

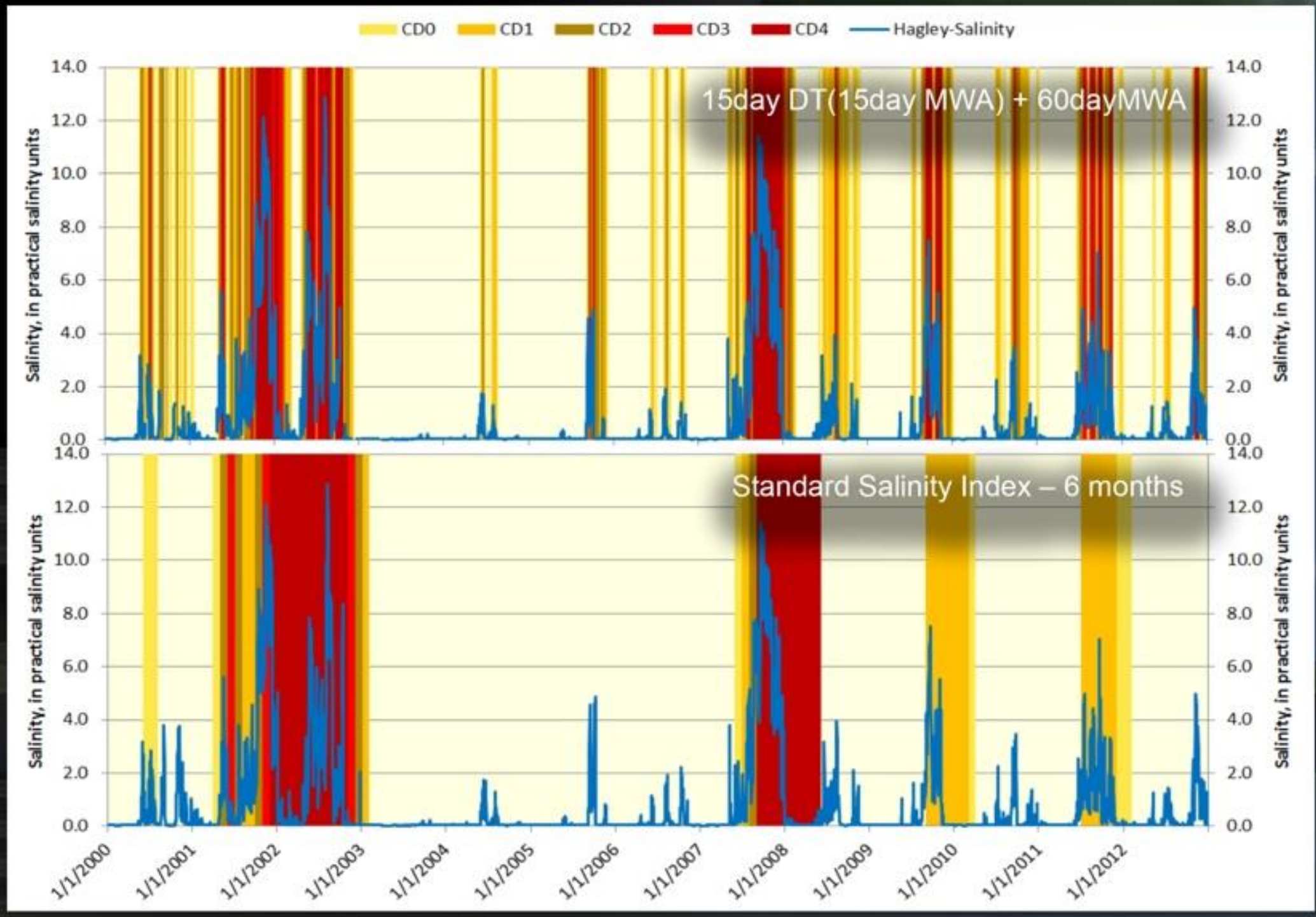
Transform SSI values into Drought Declarations



Daily values
Positive SSIs – fresher conditions
Negative SSIs – saltier conditions



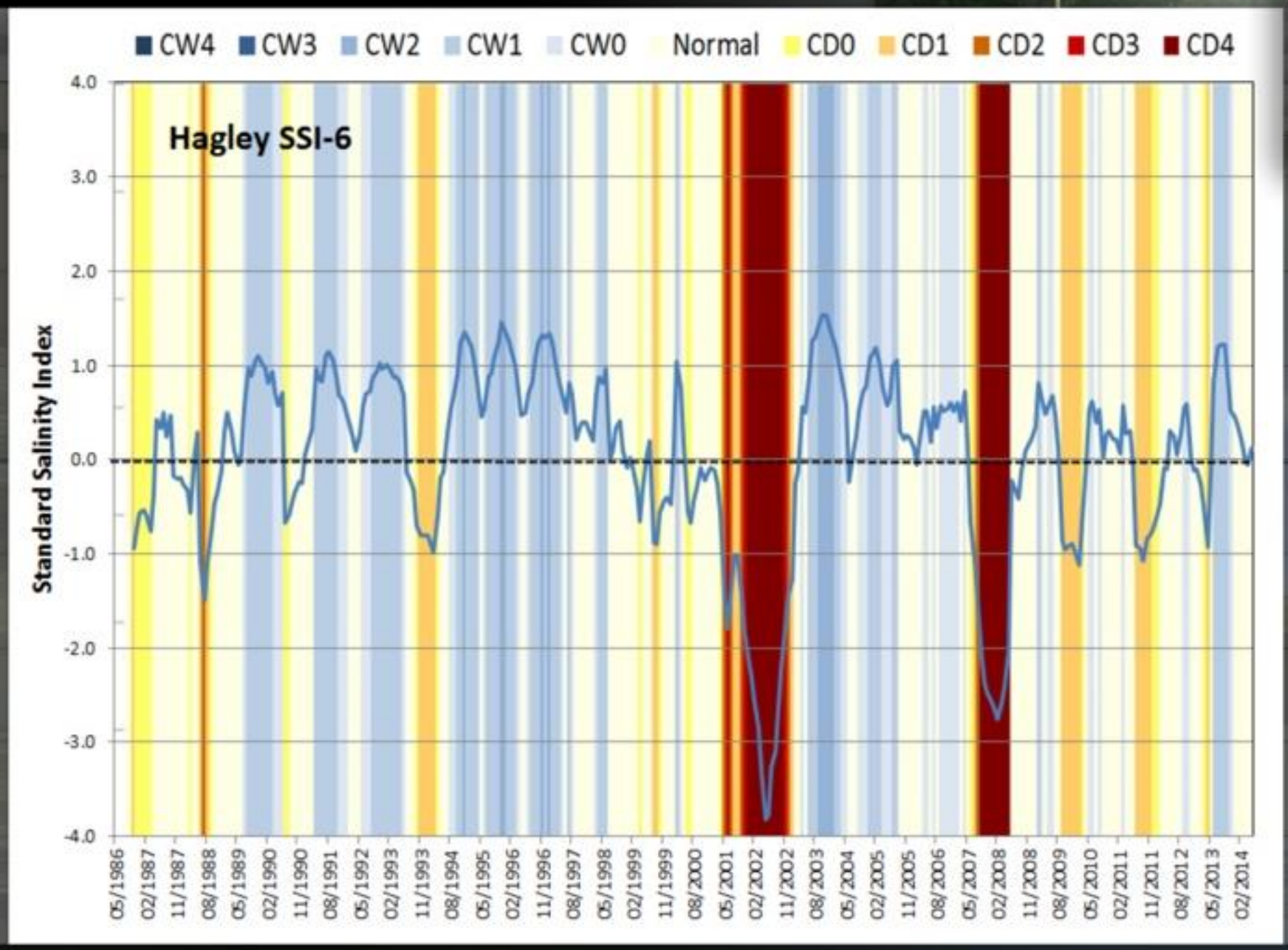
Declaration	Decsription	SSI Threshold
W4	Exceptional wet	2
W3	Extreme Wet	1.6
W2	Severe Wet	1.3
W1	Moderate Wet	0.8
W0	Abnormally Wet	0.5
N0	Normal	0
D0	Abnormally Dry	-0.5
D1	Moderate Drought	-0.8
D2	Severe Drought	-1.3
D3	Extreme Drought	-1.6
D4	Exceptional Drought	-2



SSI doesn't have the "pinball machine" effect as compared to the preliminary CDI

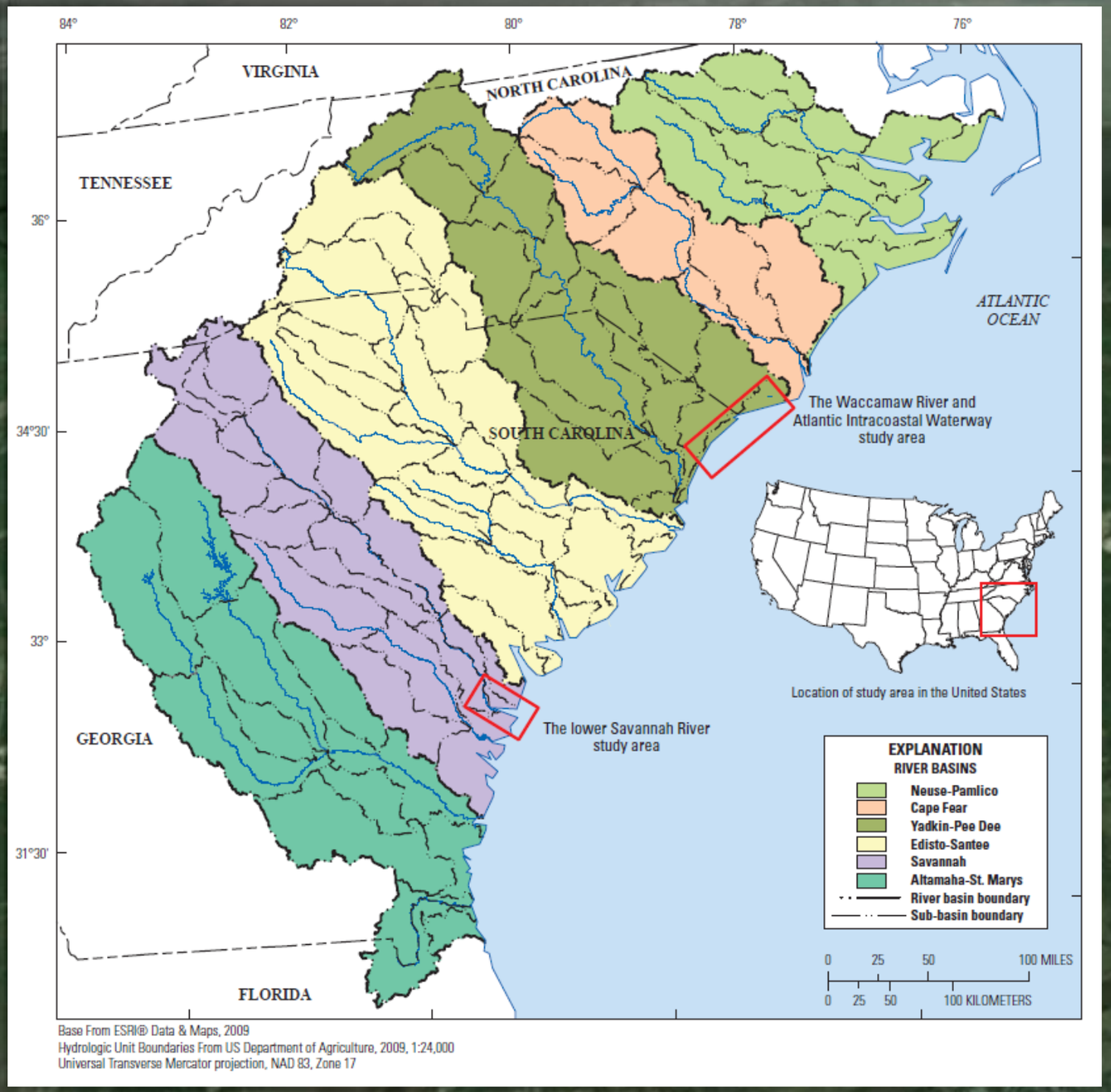
Use for Drought and Wet declarations

Declaration	Decsription	SSI Threshold
W4	Exceptional wet	2
W3	Extreme Wet	1.6
W2	Severe Wet	1.3
W1	Moderate Wet	0.8
W0	Abnormally Wet	0.5
N0	Normal	0
D0	Abnormally Dry	-0.5
D1	Moderate Drought	-0.8
D2	Severe Drought	-1.3
D3	Extreme Drought	-1.6
D4	Exceptional Drought	-2



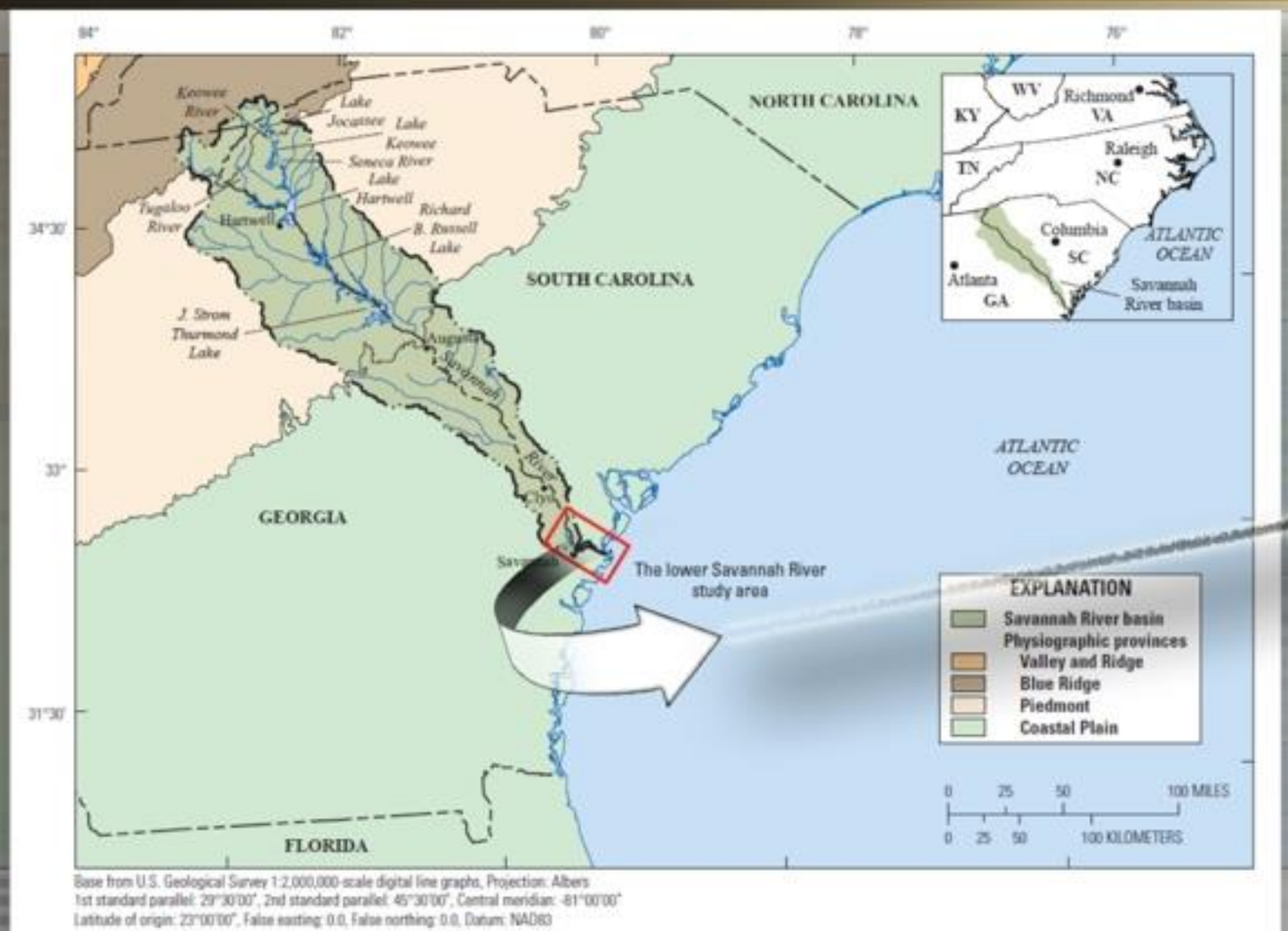
1996 - 2014

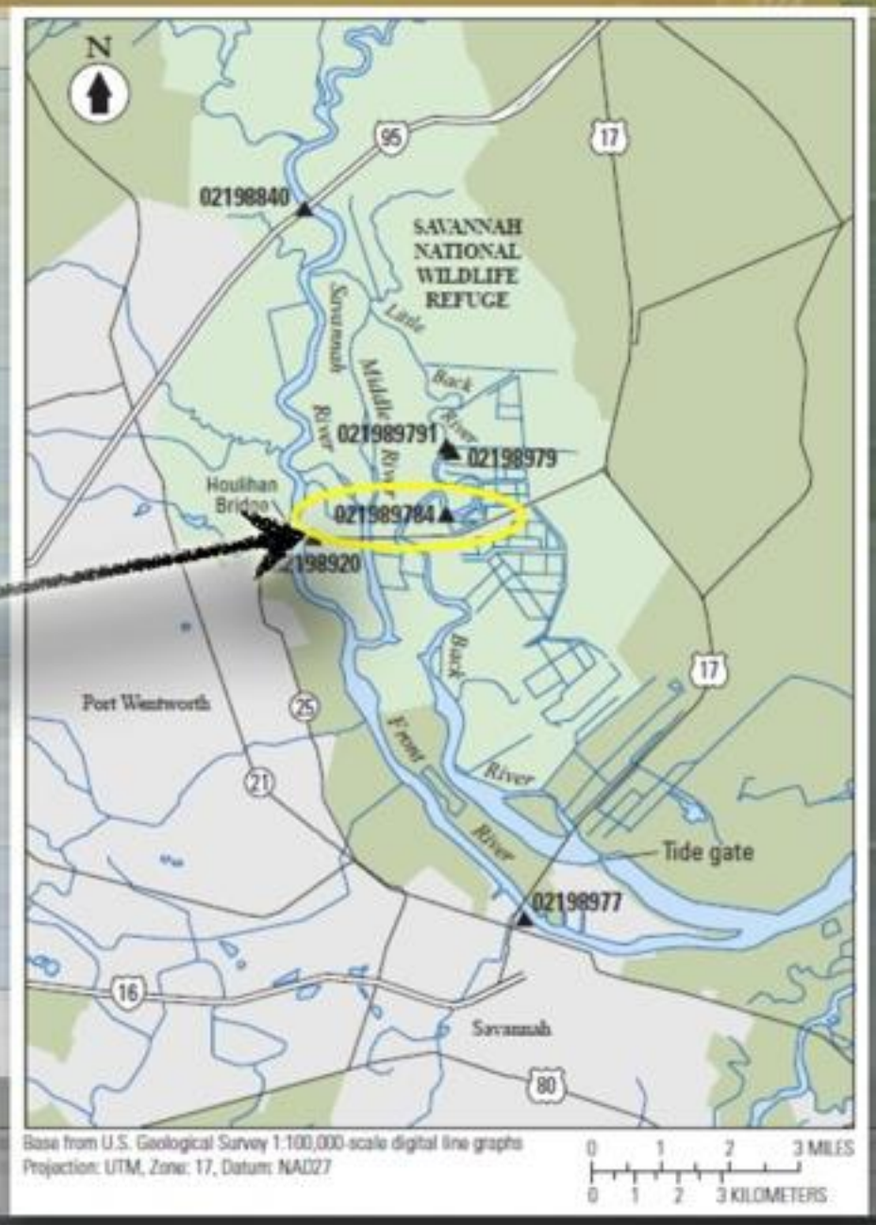
Regional Comparison



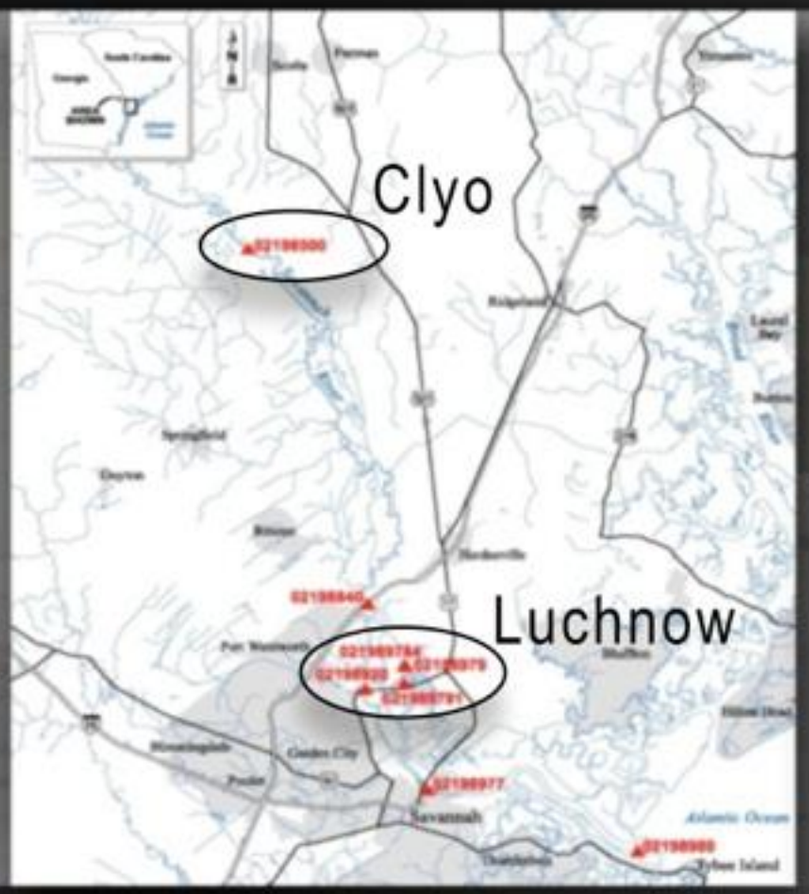
Is the CDI a site specific index or can it be used to regional comparisons?

Lower Savannah River –
Little Back River at Luchnow Canal

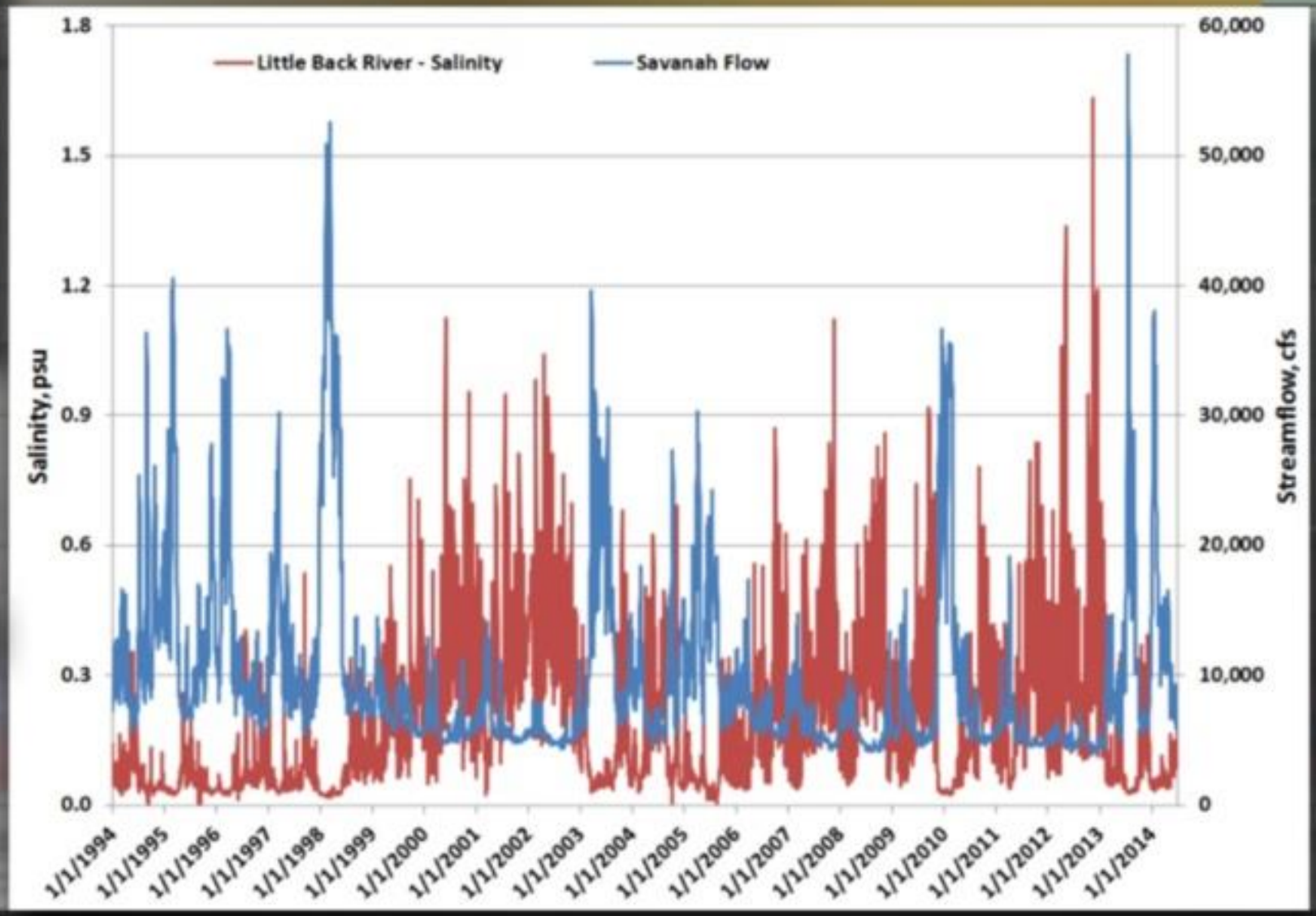




Flow and Salinity



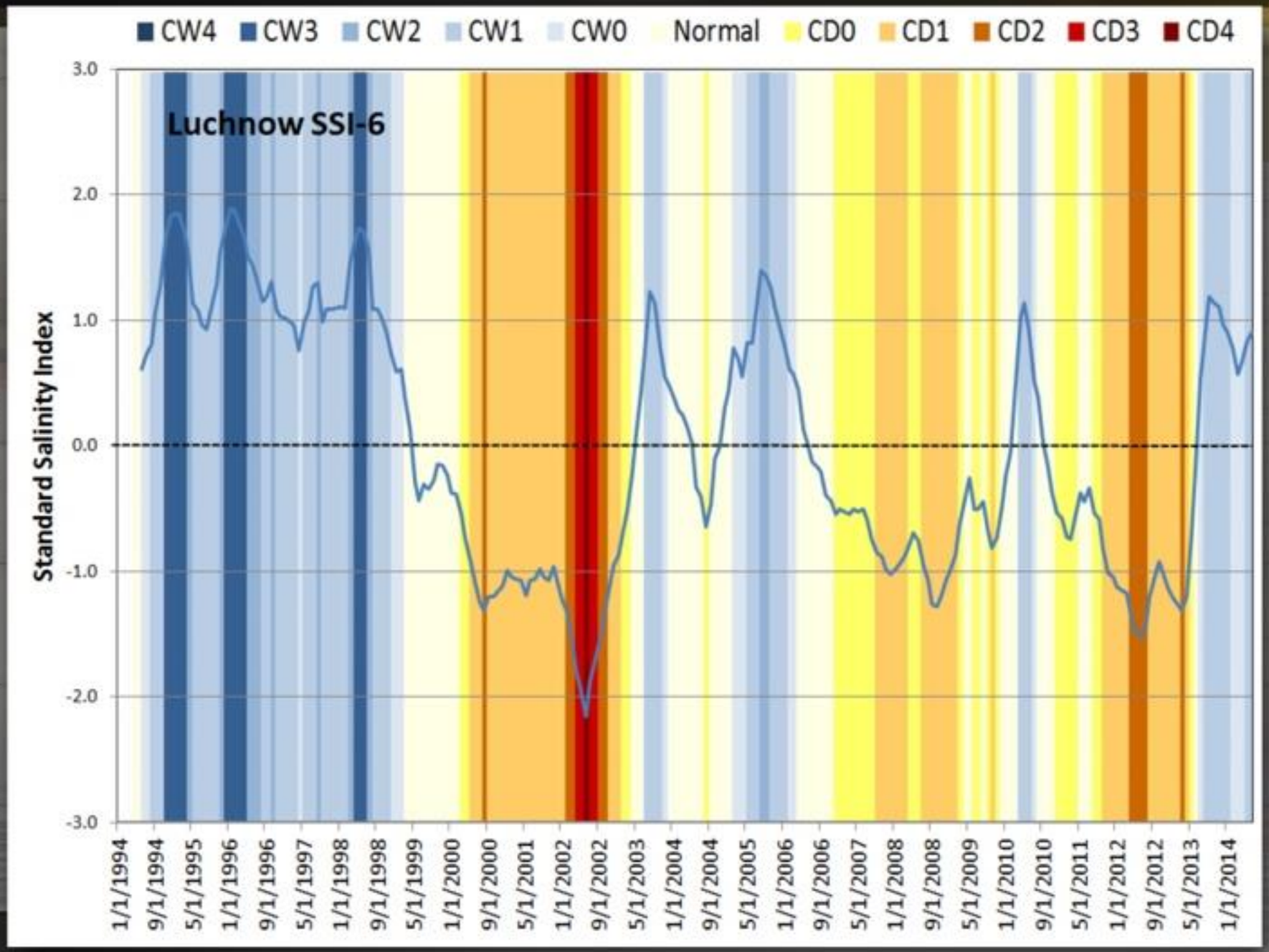
Salinity data from 1990 to present
Used data after the last harbor deepening in 1994



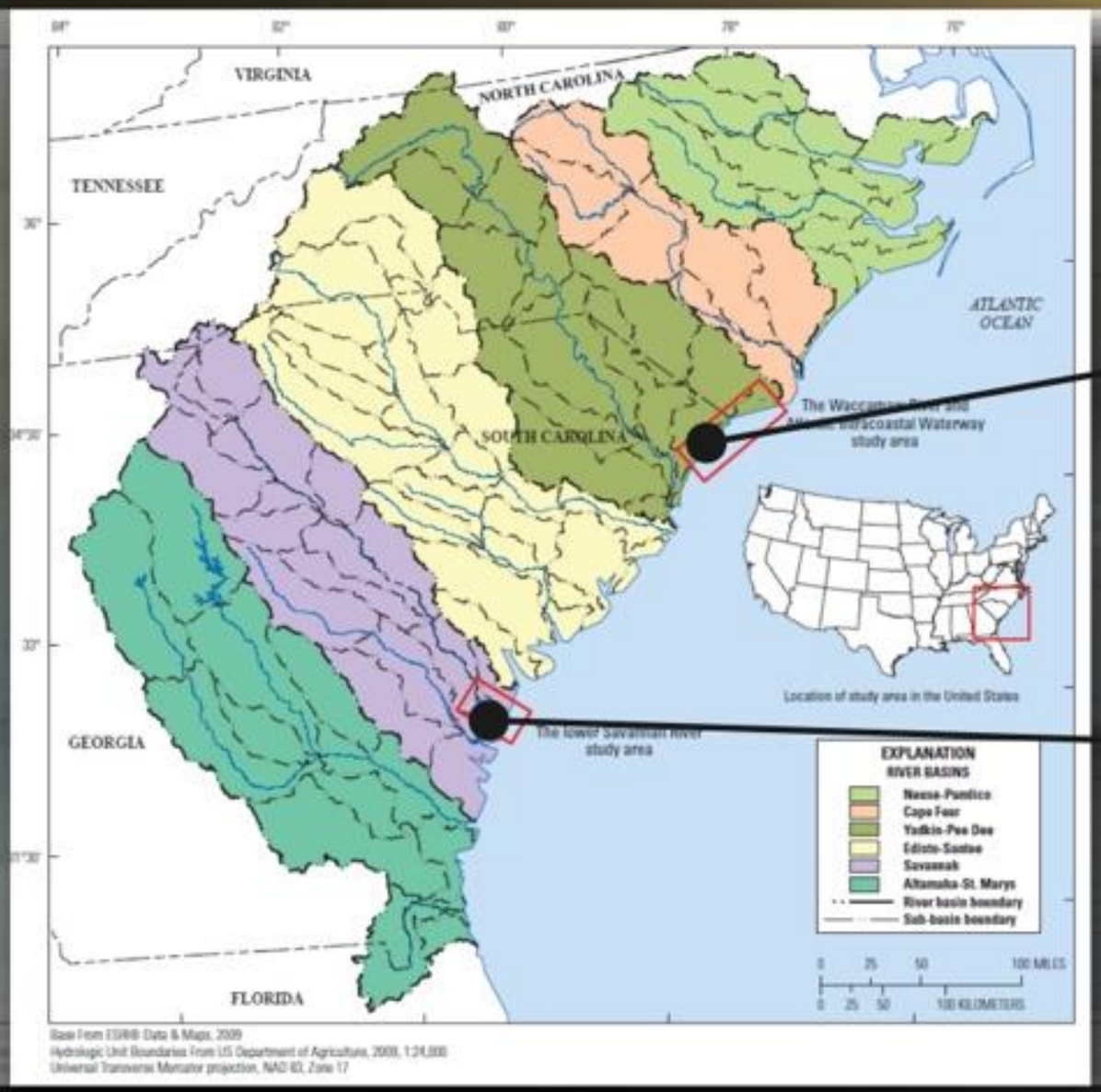
Less than 4 % missing data.
Fill with neural network model (Rsq-0.73) and linear interpolation

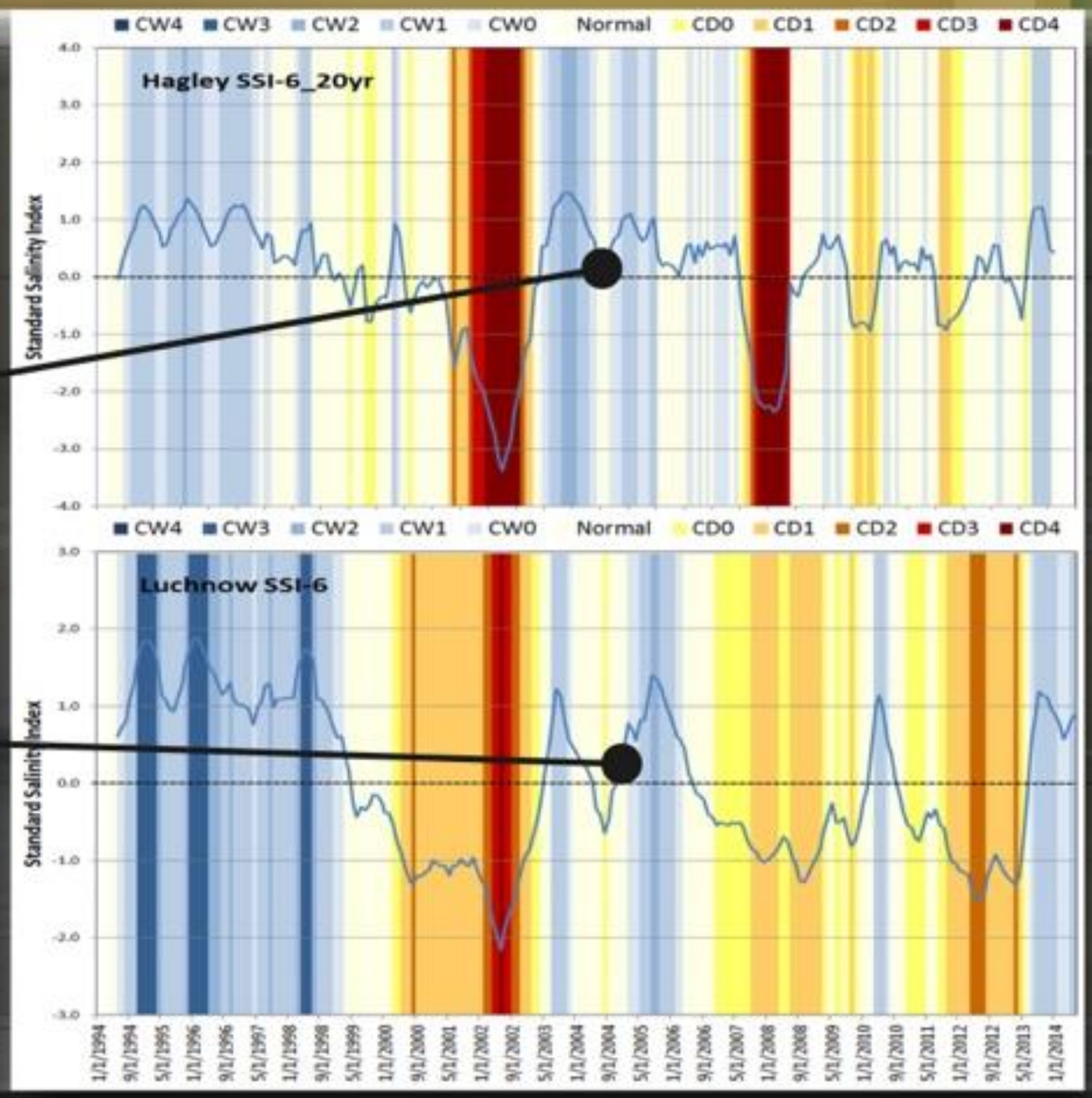
USGS

SSI-6 Declarations
Little Back River – Luchnow Canal



Can the SSI be used to compare between sites?



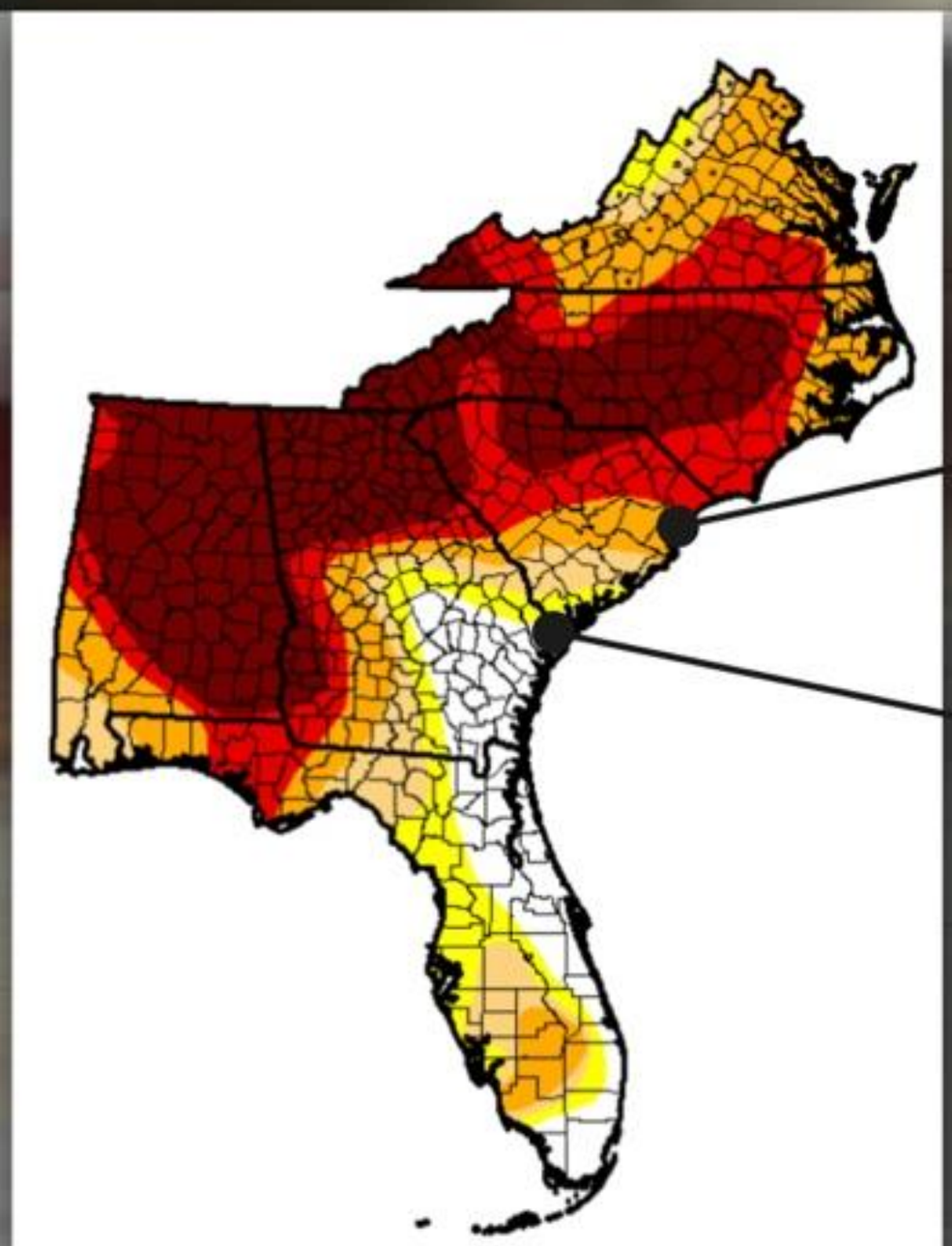


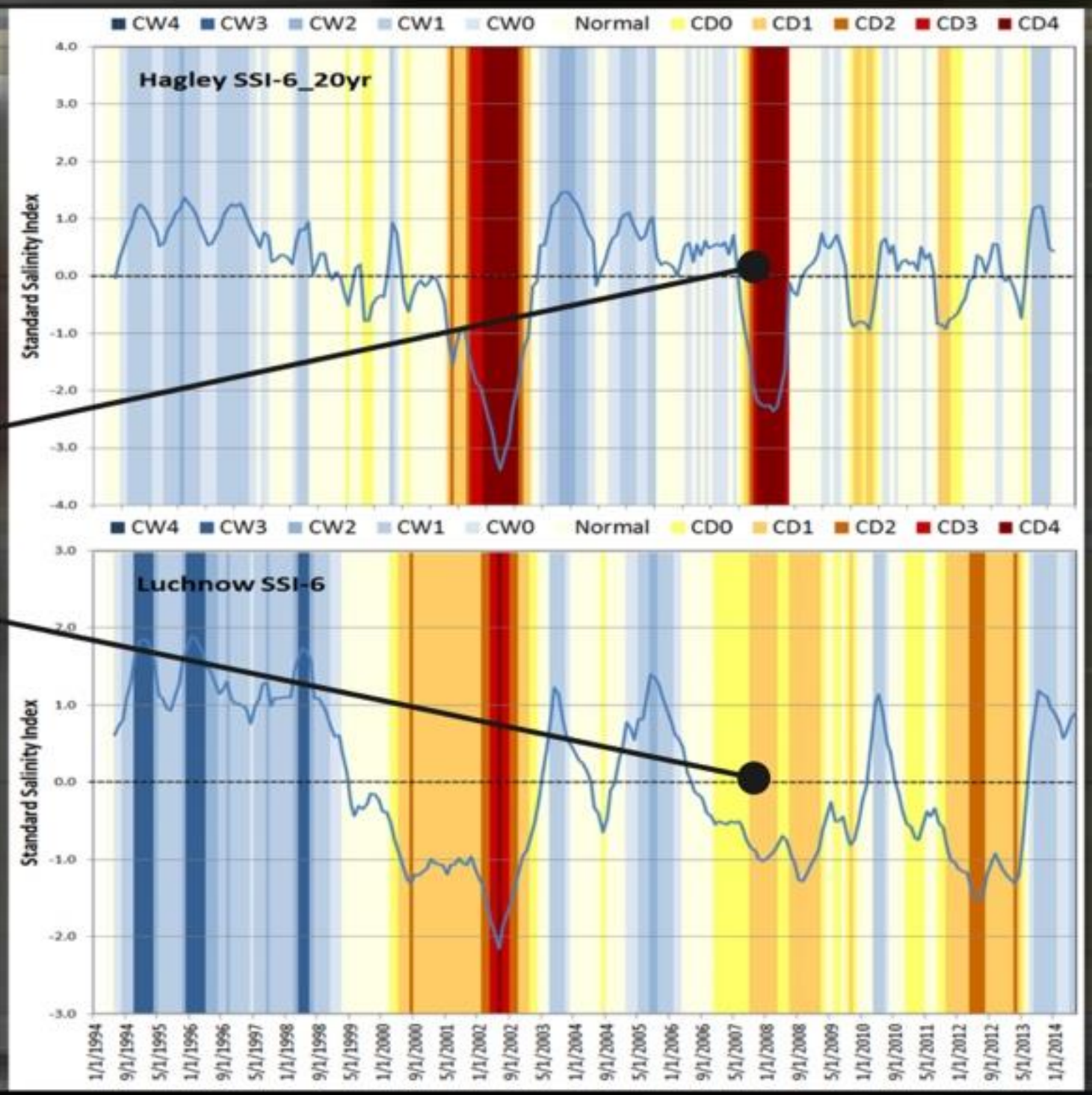
Used 20-year record (1994-2014) record to compare

USGS

USGS

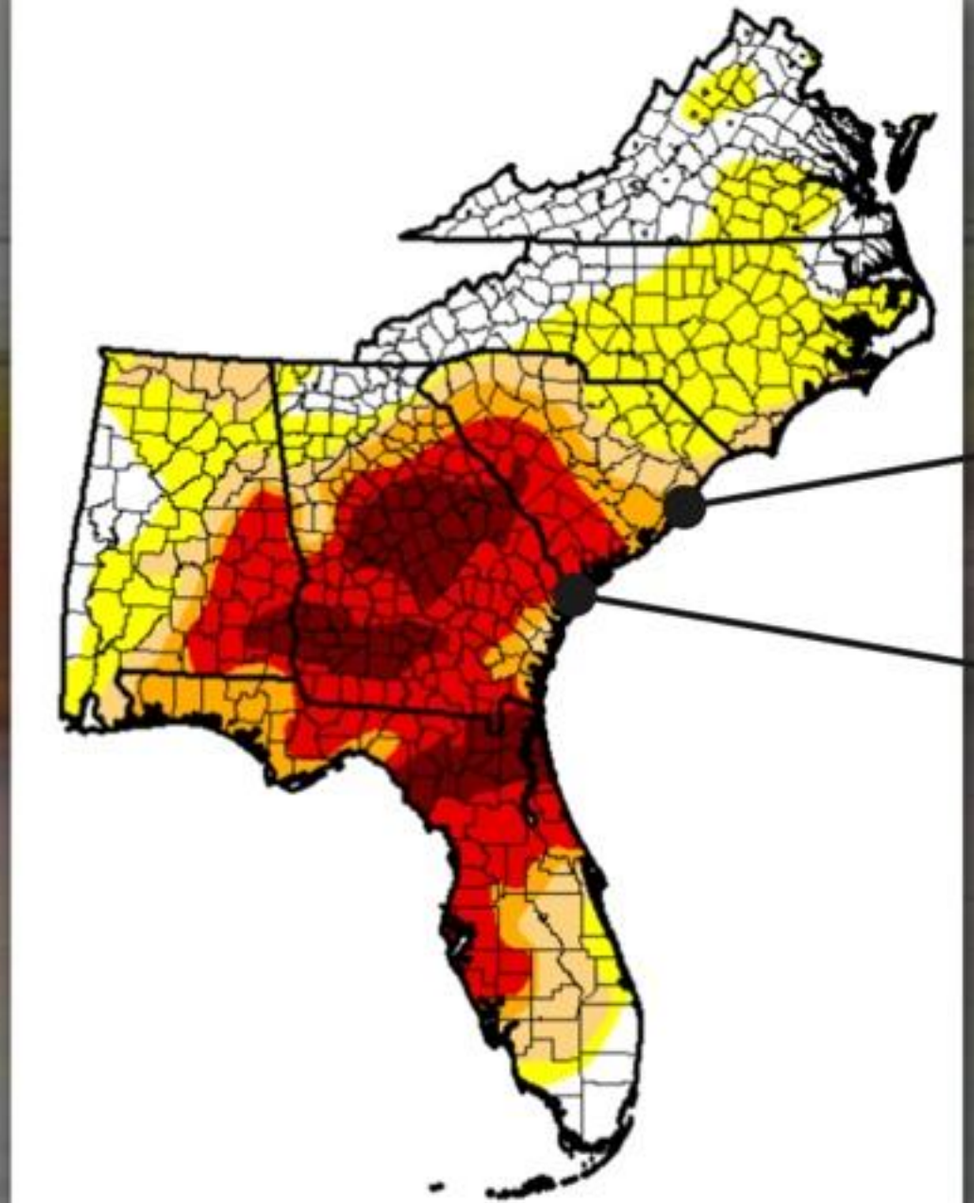
Regional Comparison
Oct. 16, 2007





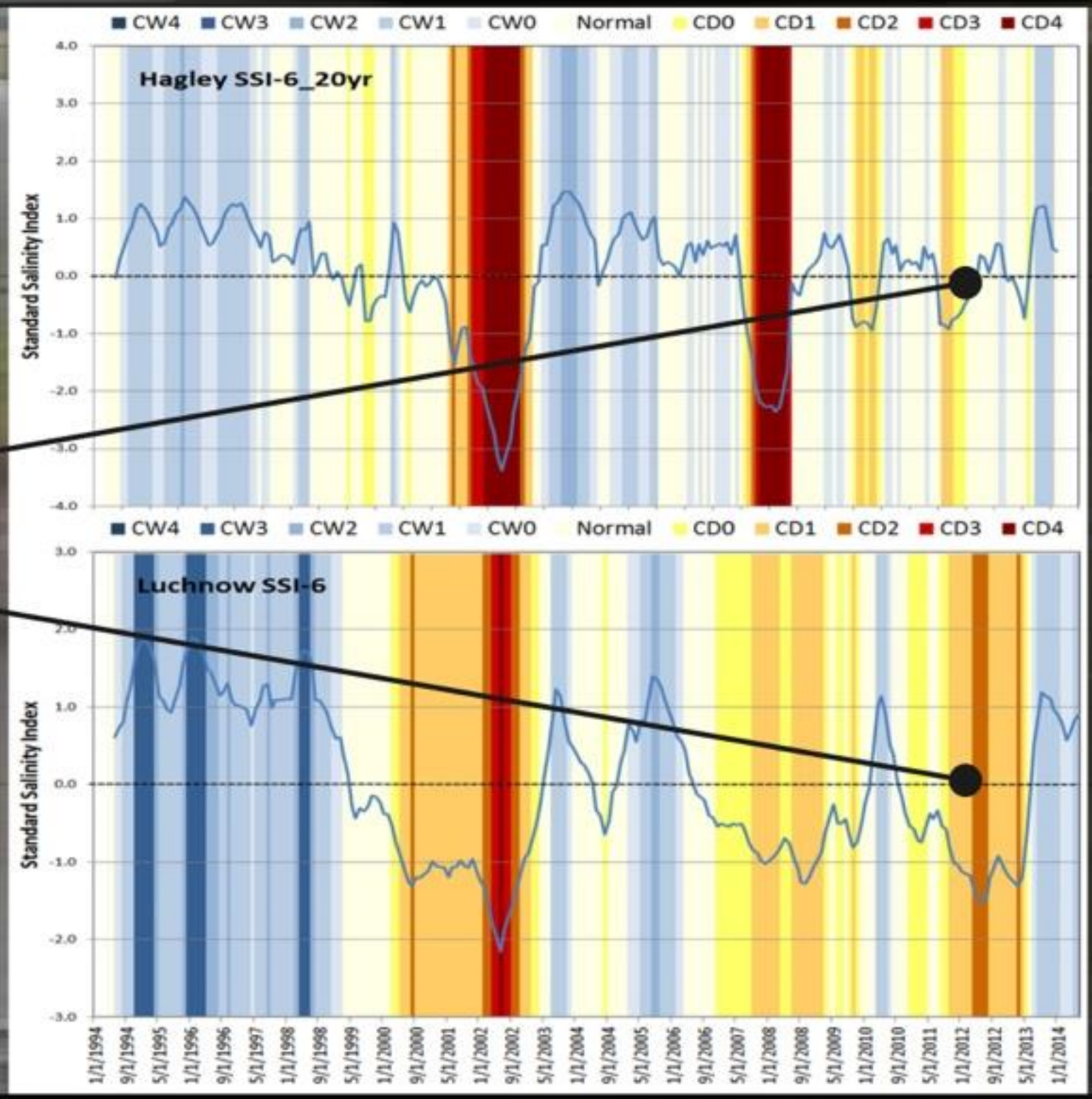
USGS

Regional Comparison
May 22, 2012



Intensity:

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



Summary

- **Modifying the Standardized Precipitation Index good approach for a Coastal Drought Index**

- **Benefits of the "Standardized Salinity Index" (SSI):**

- **Minimize the "pinball" effect of quickly changing drought declarations**

- **Computed for multiple time intervals**

  - **Correlate appropriate SSI time interval to coastal response variable**

Summary

- SSI can be used for drought and wet conditions
- Not a site specific CDI
- May be able to use different periods of salinity record
- Can be used to compare sites
- Based on established SPI computation that readily understood and accepted in the drought community

Questions?


THIS IS OUR NEW COMPANY DRESS CODE. WE CALL IT "BUSINESS DORKY."
I LIKE IT BECAUSE IT MAKES YOU LOOK POWERLESS, BORING, AND SEXUALLY IRRELEVANT.
THEY MAKE ME WEAR THIS BADGE SO I DON'T LOOK LIKE AN ASEXUAL TRESPASSER.
ACCESSORIES MAKE THE OUTFIT.
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