USGS
science for a changing world

Overview of the Development of the USGS Real-time Salinity Drought Index

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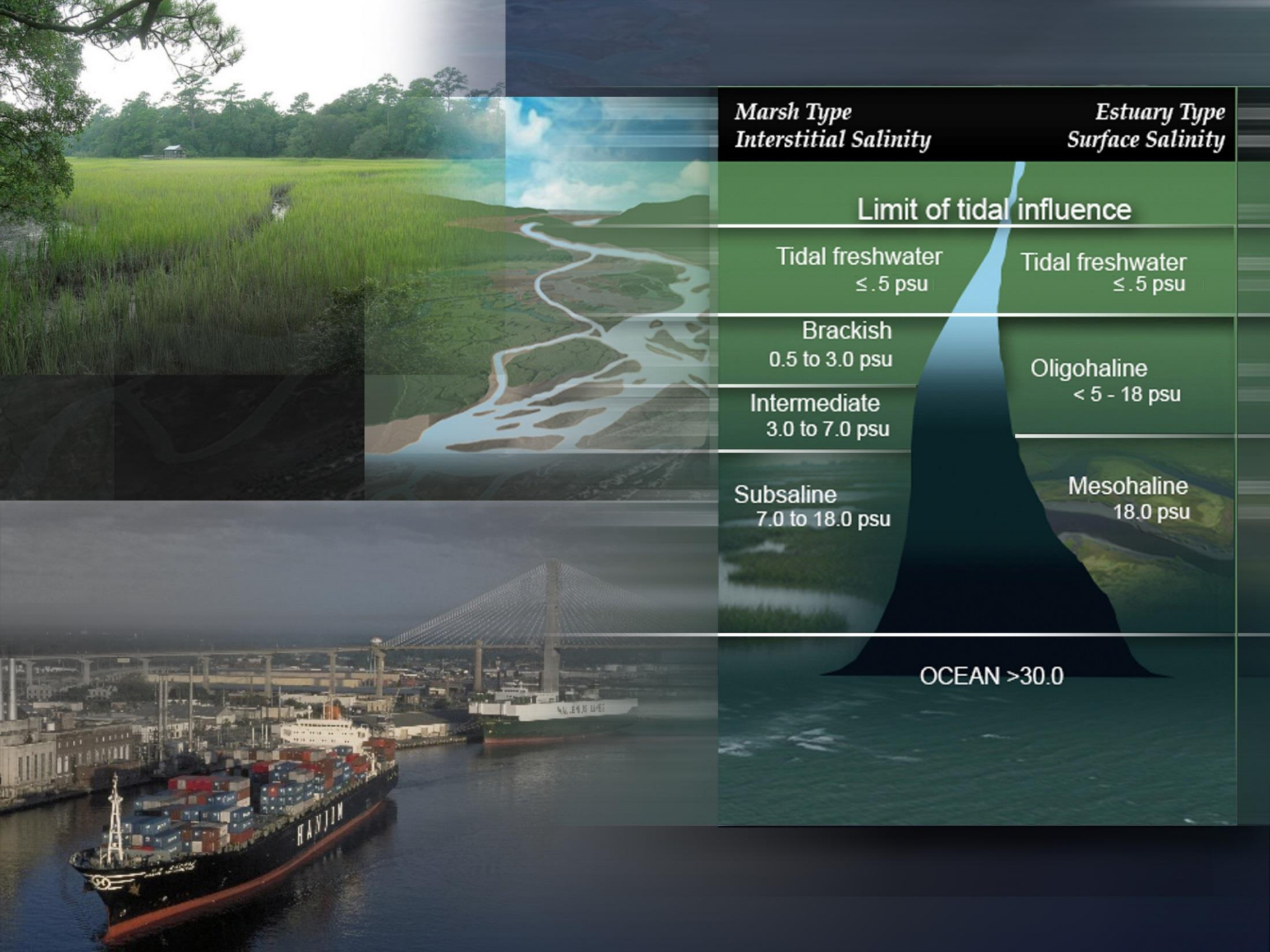
NIDIS Coastal Drought Monitoring Knowledge Assessment Workshop:
USGS Real-Time Salinity Drought Index

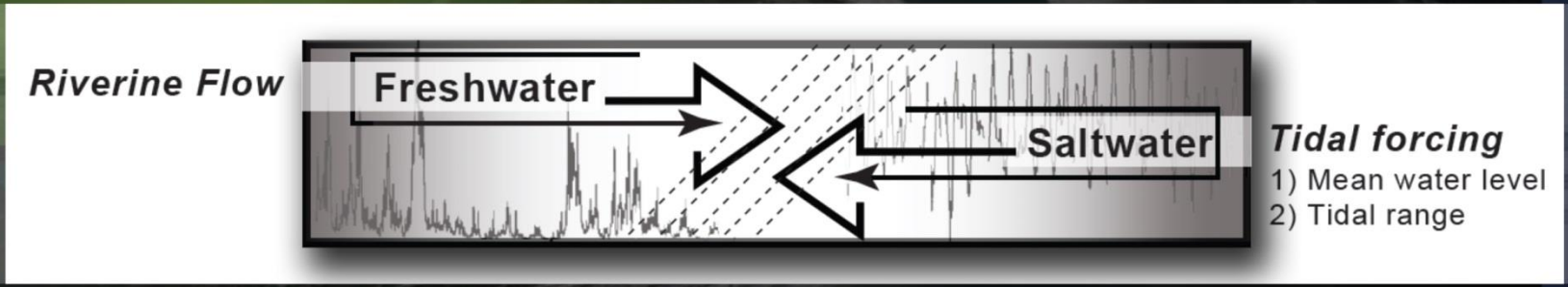
January 7, 2014

Outline

- Conceptual model of salinity intrusion
- Look at some data
- Drought and salinity intrusion
- Coastal Drought Index (CDI) considerations
- Preliminary CDI computation
- Potential beyond the Carolinas
- Summary


Marsh Type
Interstitial Salinity
Estuary Type
Surface Salinity
Limit of tidal influence
Tidal freshwater
≤ .5 psu
Tidal freshwater
≤ .5 psu
Brackish
0.5 to 3.0 psu
Oligohaline
< 5 - 18 psu
Intermediate
3.0 to 7.0 psu
Subsaline
7.0 to 18.0 psu
Mesohaline
18.0 psu
OCEAN >30.0
HANJIN

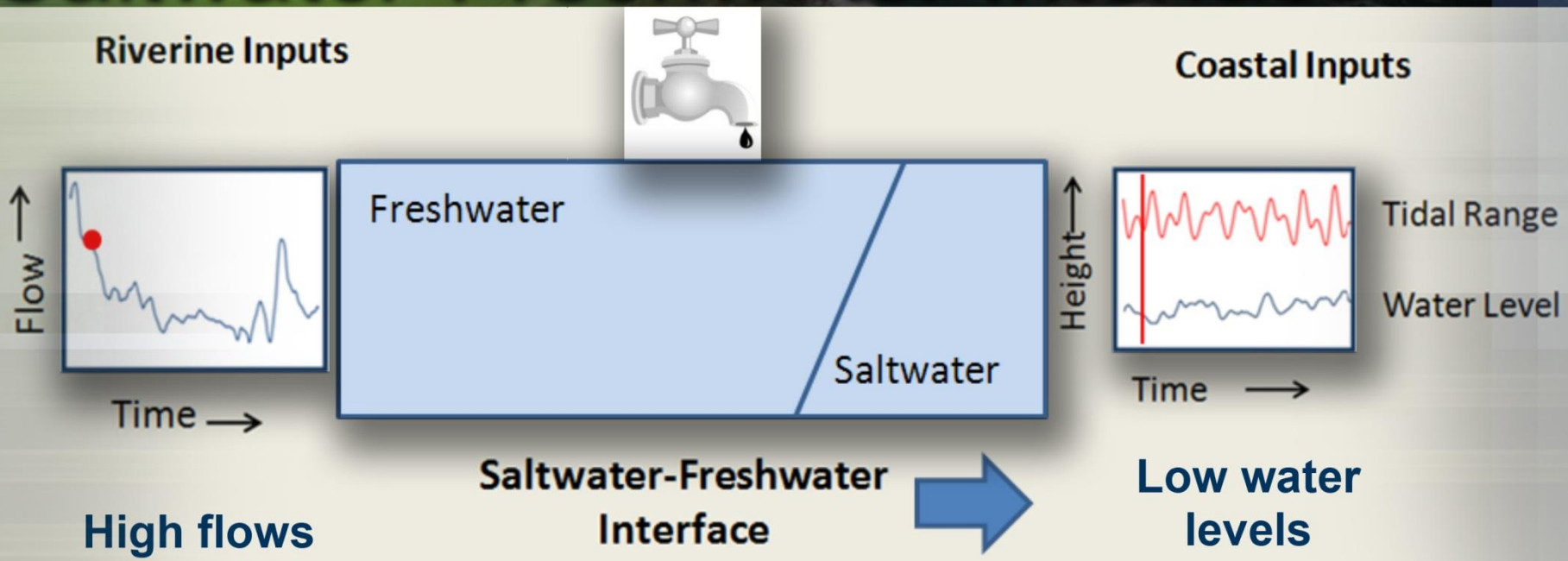
Short Review Salinity Dynamics



"…estuaries may never really be steady-state systems; they may be trying to reach a balance they never achieve."

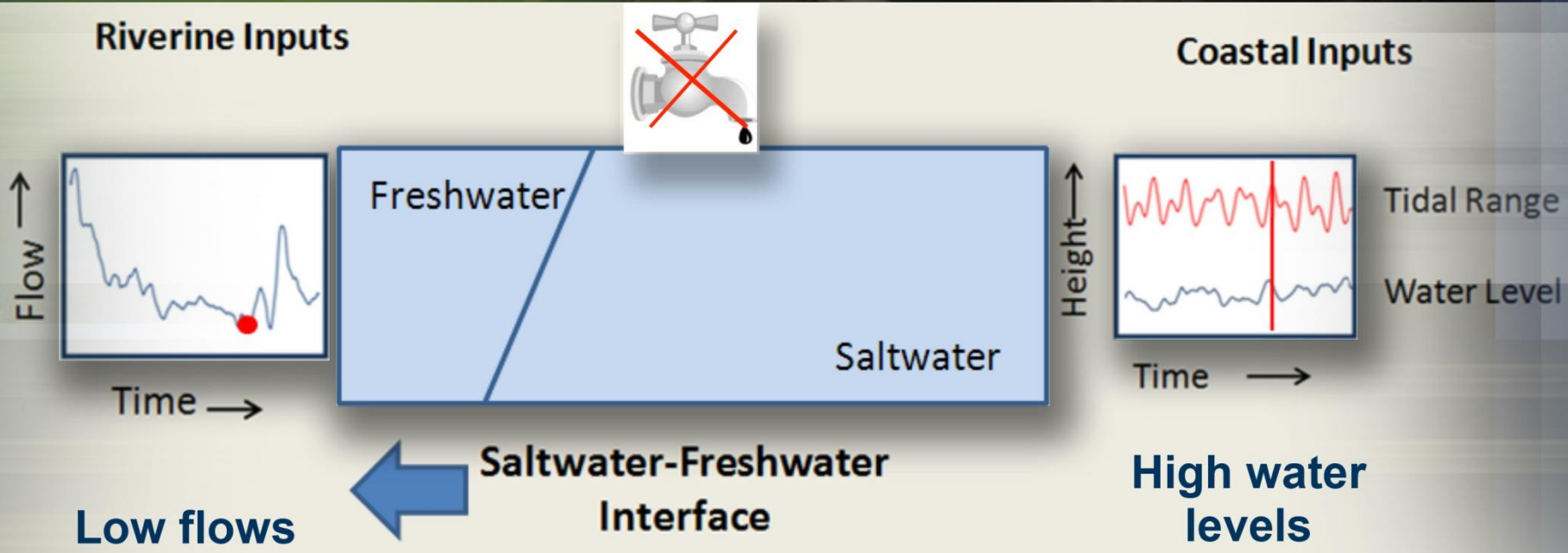
Keith Dyer, from Estuaries – A Physical Introduction (1997)

Saltwater-Freshwater Interface



Tidal Marshes
Critter Communities

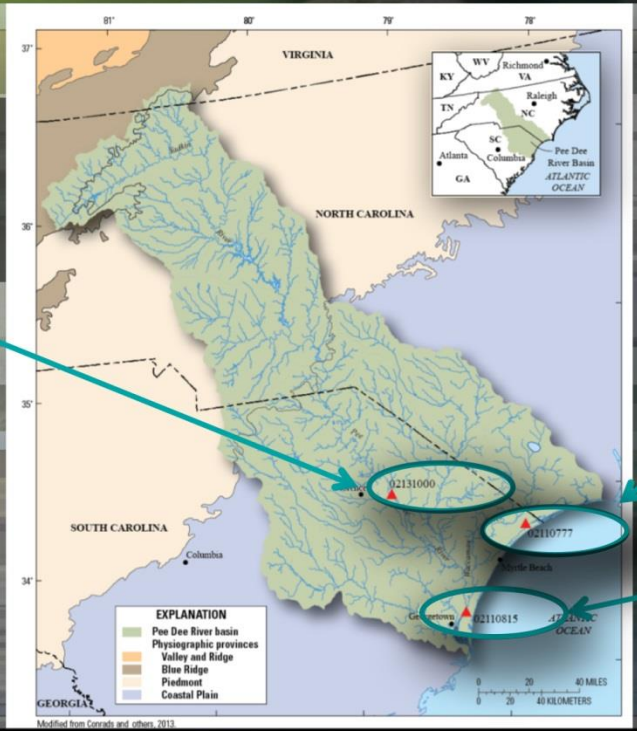
Saltwater-Freshwater Interface



Tidal Marshes
Critter Communities

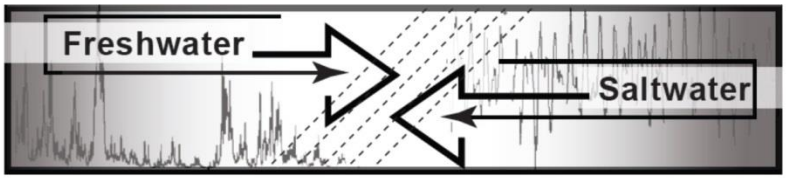
Example of Data: Yadkin-Pee Dee Basin

Pee Dee River Flows

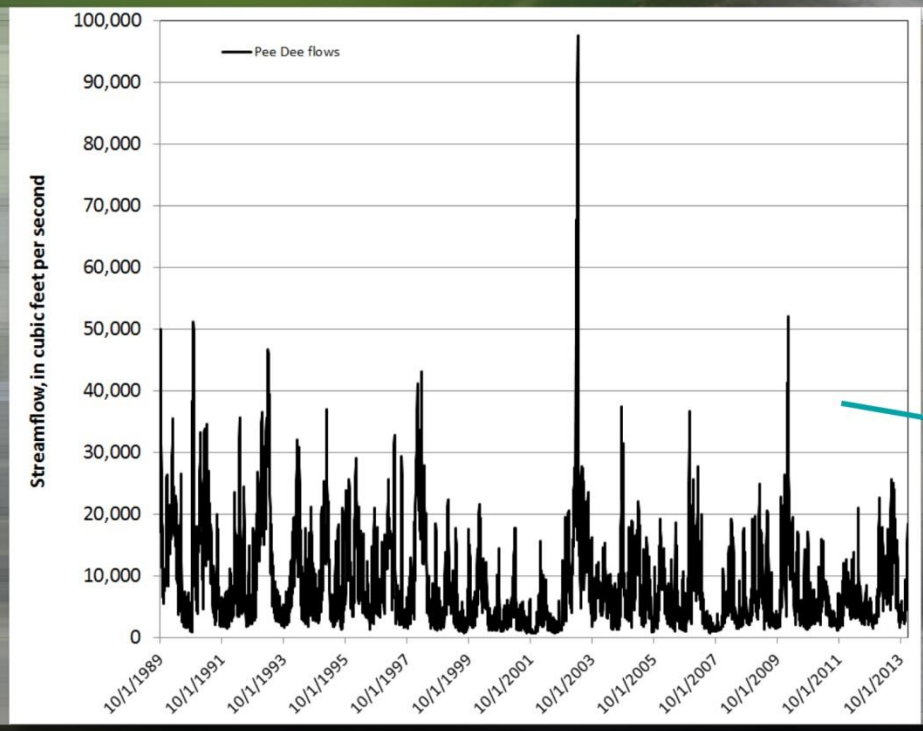


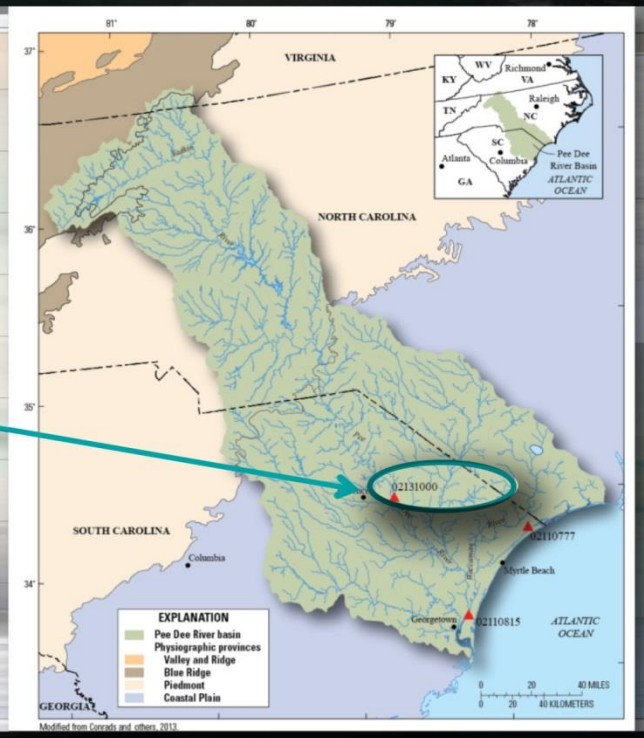
Little River Inlet Water Levels

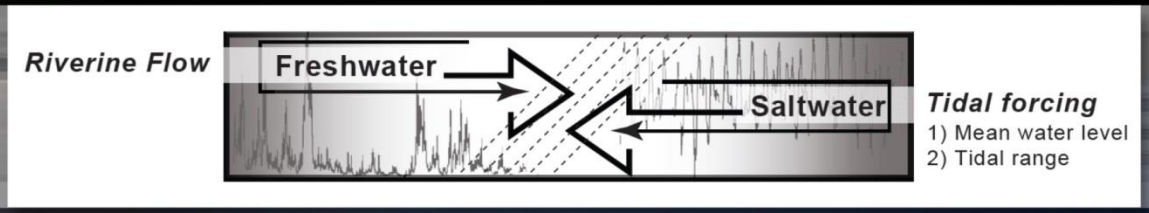
Waccamaw River Salinity



Example of Data: Streamflow

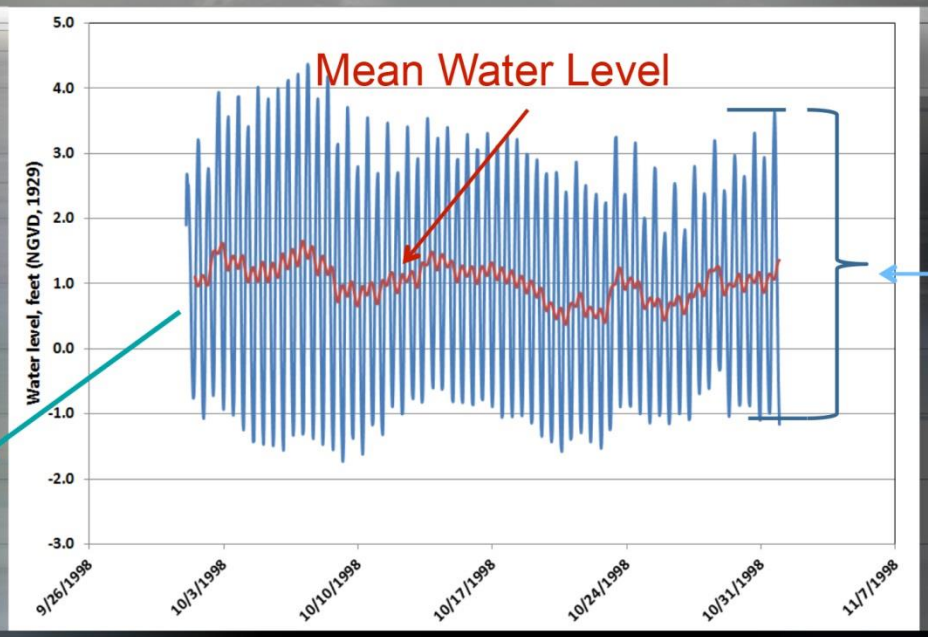




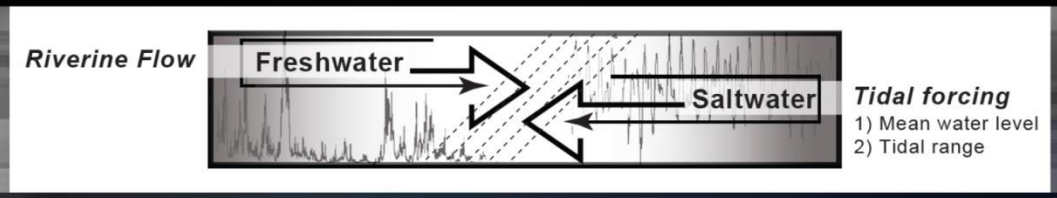


Example of Data: Water level

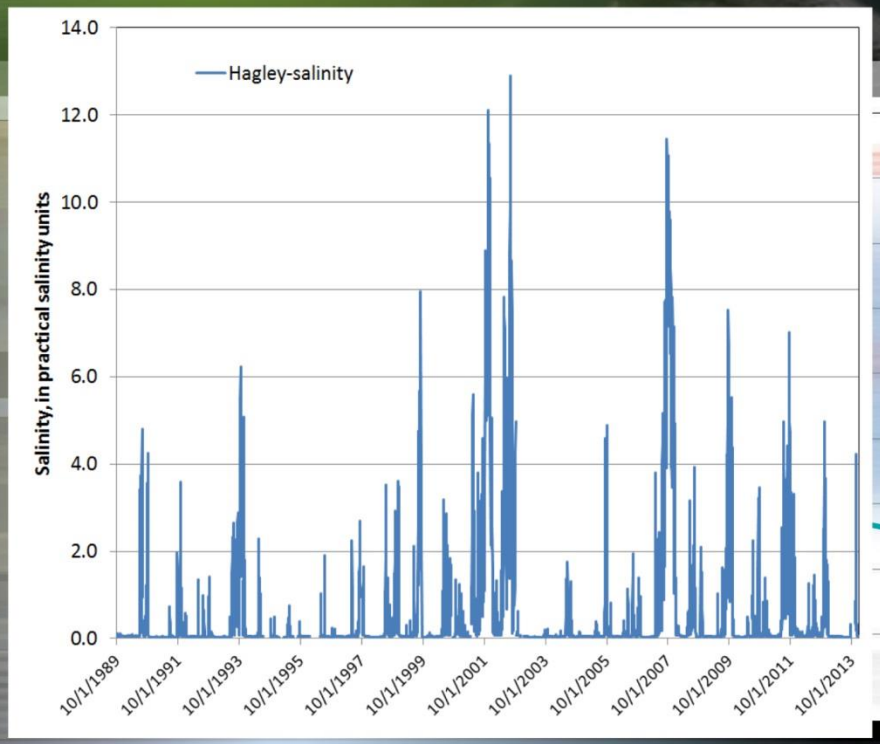
Two signals: Mean water level & Tidal Range

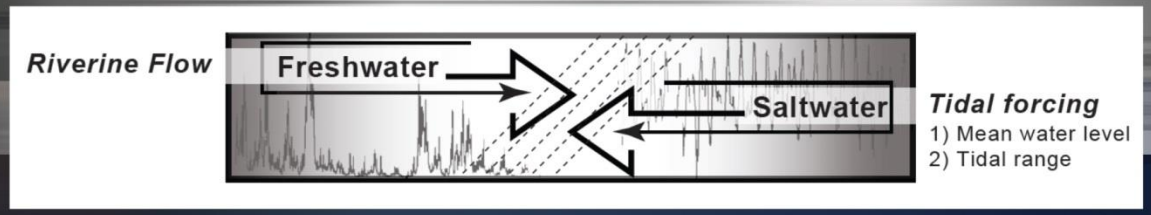


Tide Range

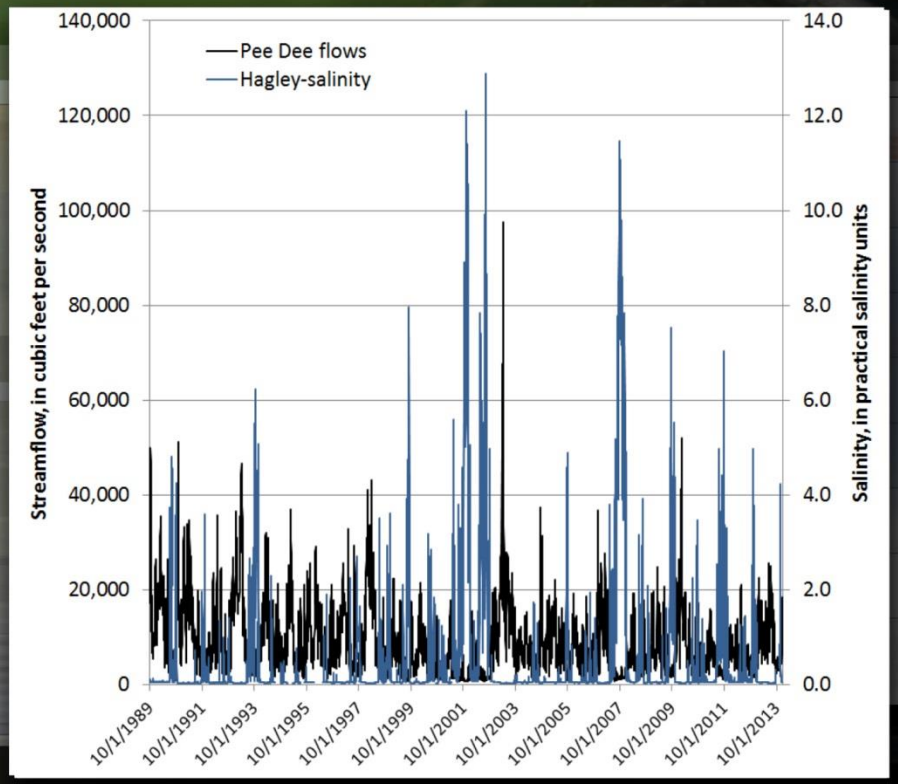


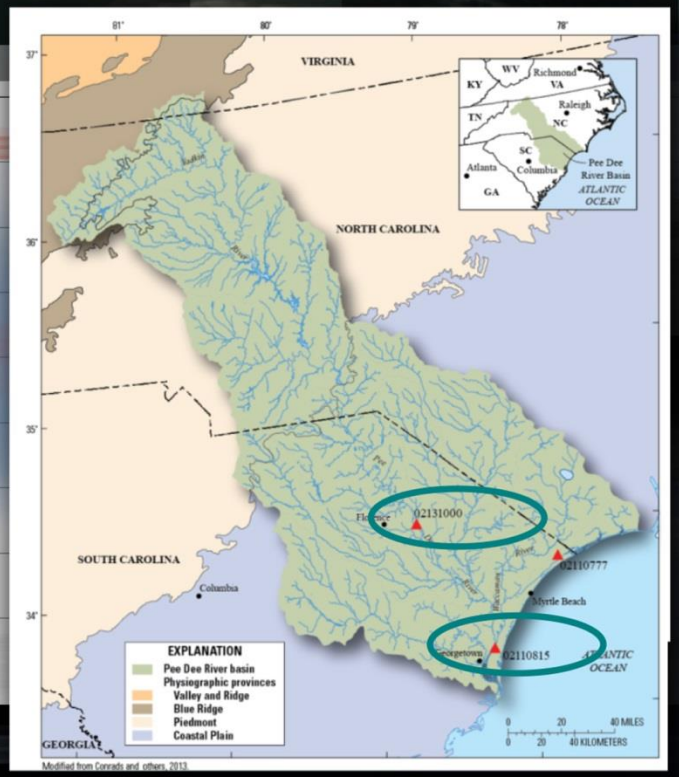
Waccamaw River Salinity

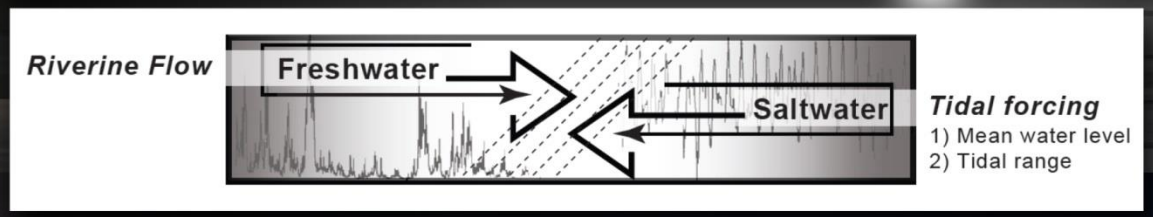




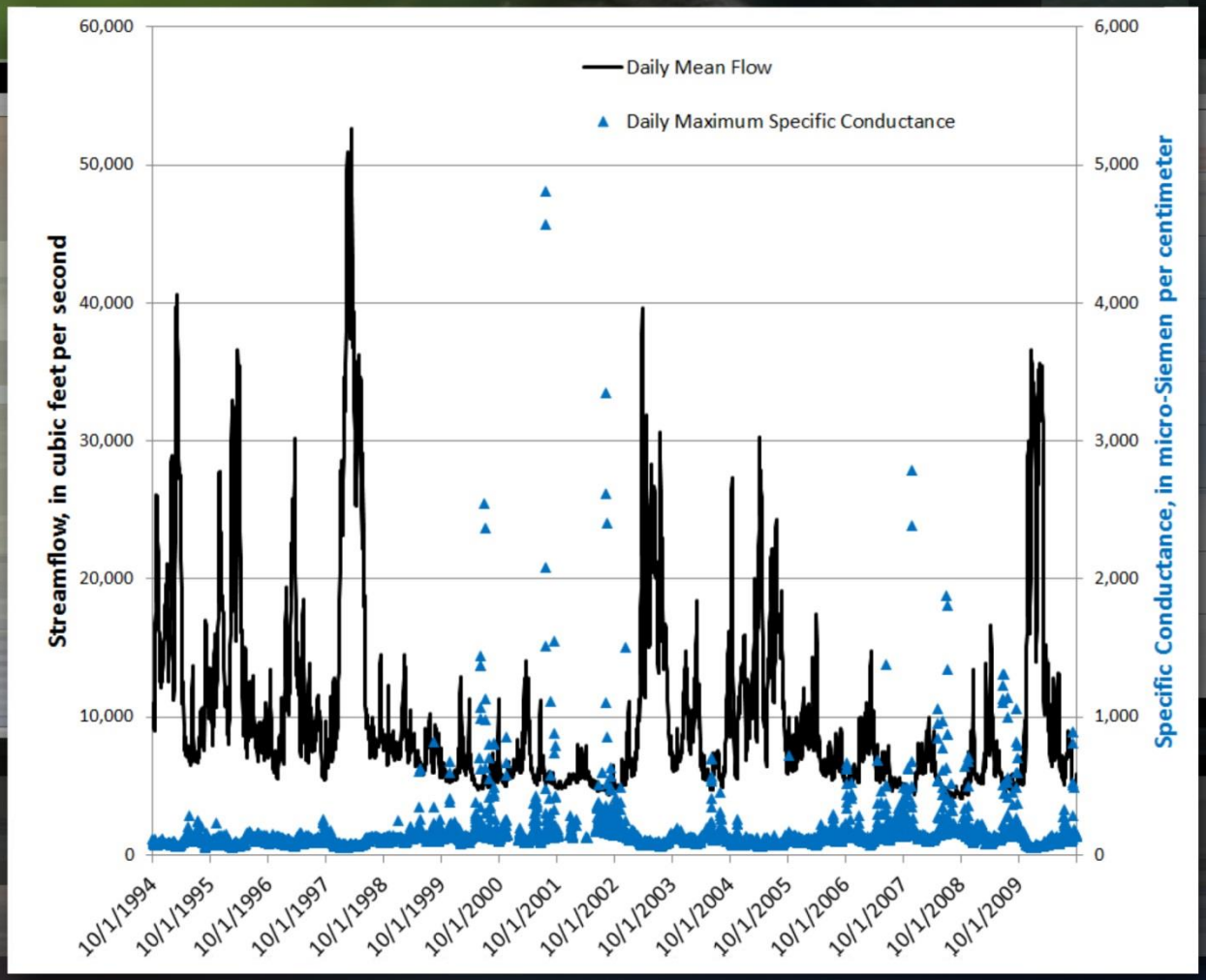
Flows and Salinity



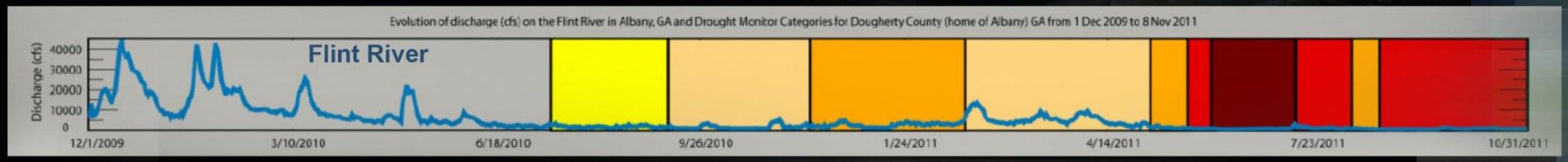




Savannah River at I-95



Flow and Drought Index



A look at drought declarations in the Yadkin-Pee Dee Basin

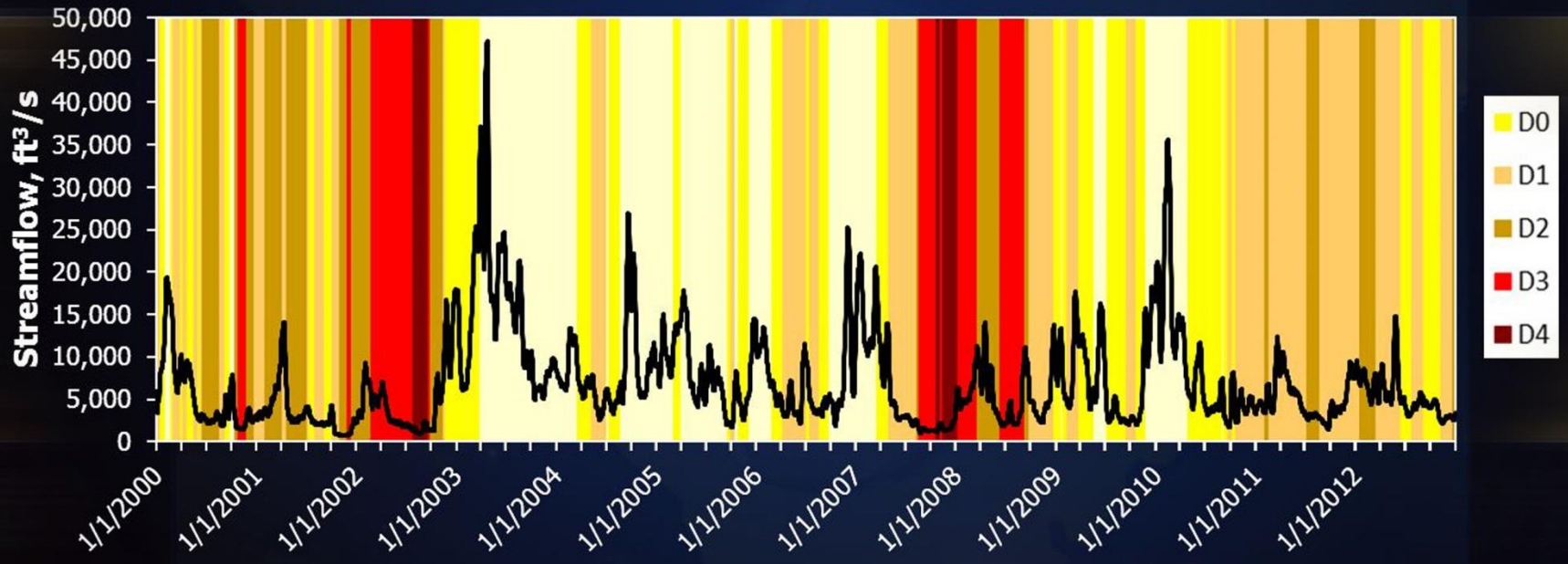
Intensity:

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

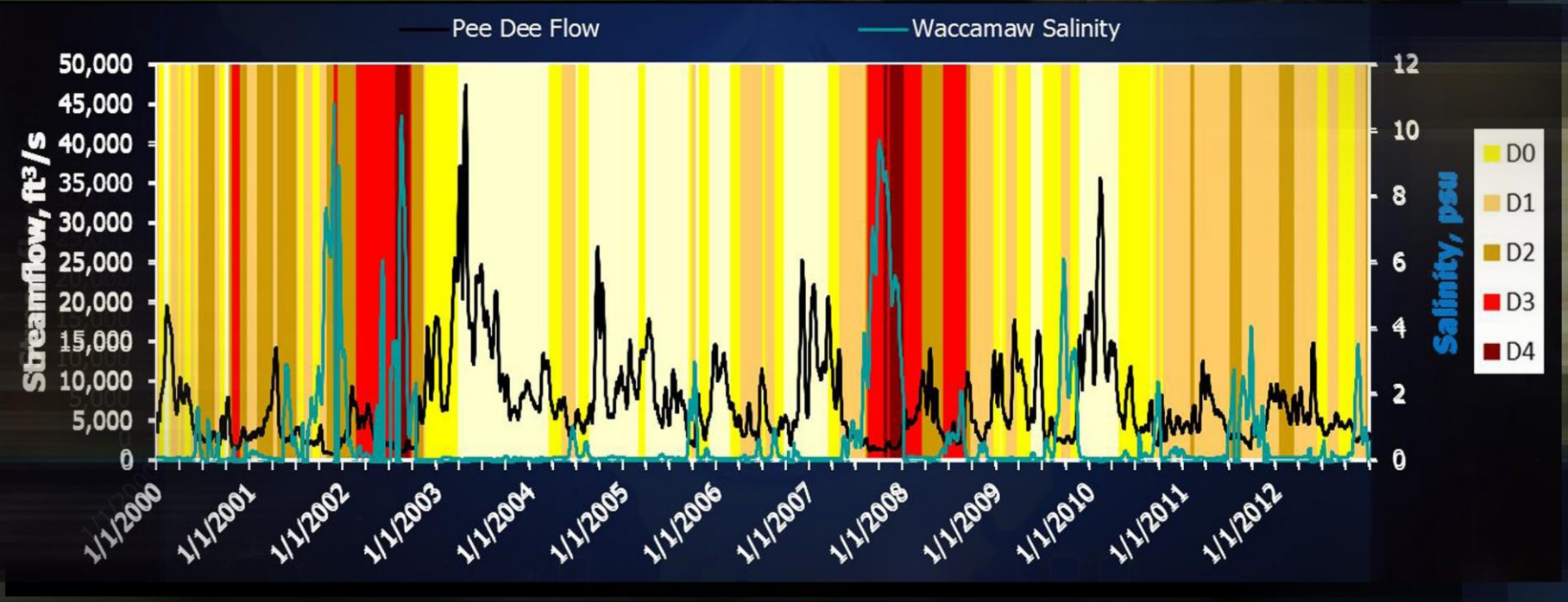
Computed a weekly drought index for the basin aggregated by declarations for each county

Plot declarations with 7-day average flow & 7-day average salinity

Flow and Drought Index



Flow, Salinity, and Drought Index



…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

Drought Index Criteria

1) Appropriate time scale for the problem
2) Quantitative measure of large-scale long-continuing conditions
3) Applicable to the problem
4) Historical data for computation
5) Computable on a near-real time basis

Friedman 1957; Heim, 2002

Coastal Drought Index

Criteria Considerations (continued)

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

Coastal Drought Index Challenges

Broader Picture

Generalized regional index or site specific index

Different estuaries
- Tidal sloughs
- Tidal rivers

Regulated vs. unregulated rivers

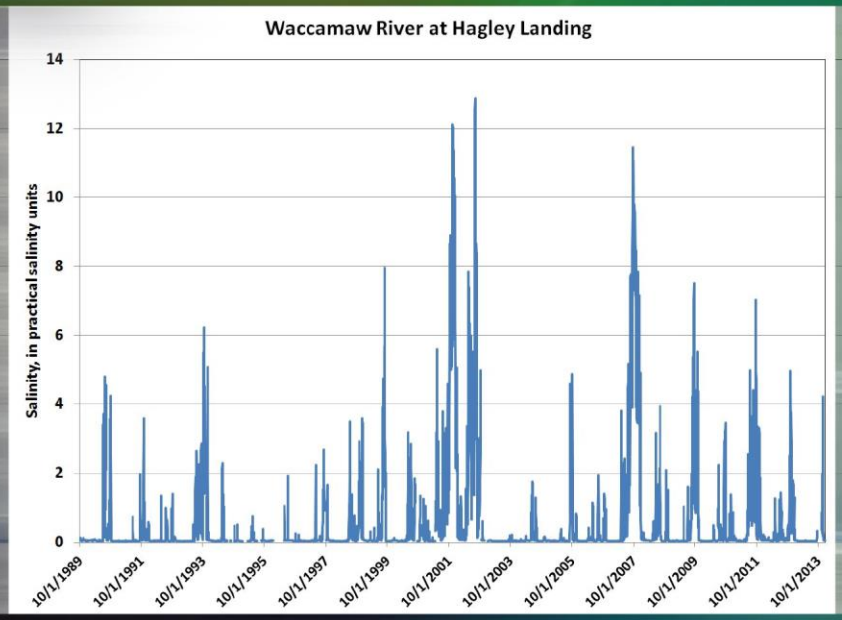
Appropriate temporal scale

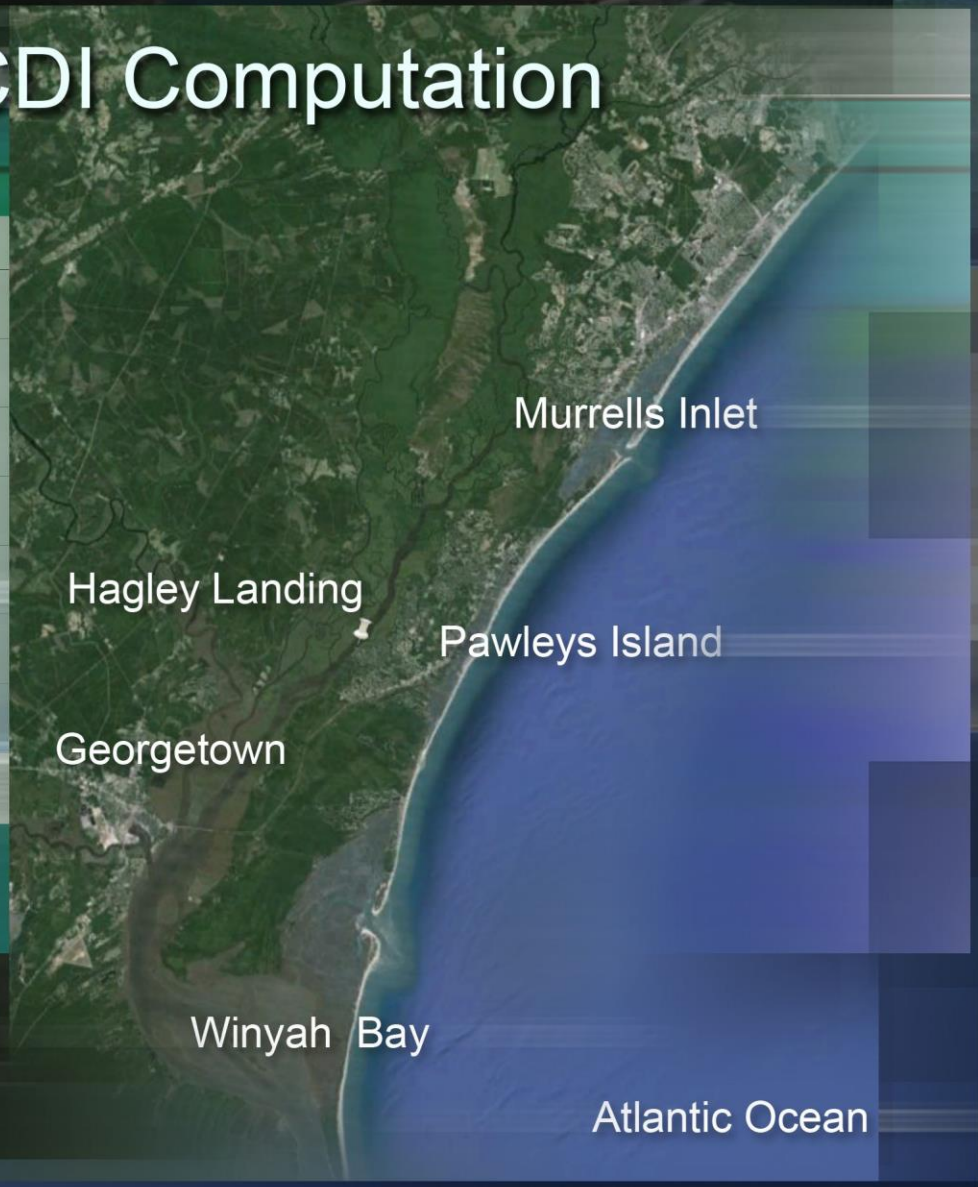
Coastal Drought Index Challenges

Site Specific Index

- Differentiating aspects of the salinity signal
  - Periodic, episodic, chronic
- Index classes clearly defined
  - Correlate to environmental response
- Physics of the index is understandable
- Real-time computation of coastal drought index

A Preliminary CDI Computation





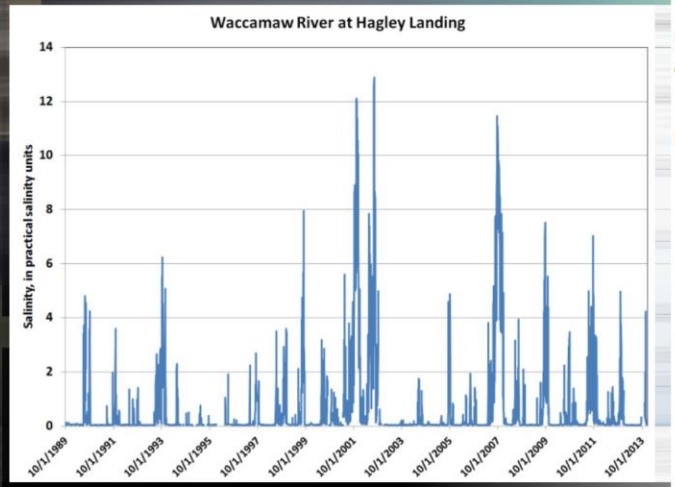
Long period of record
1989 to present
Daily mean salinity
~8,000 data point

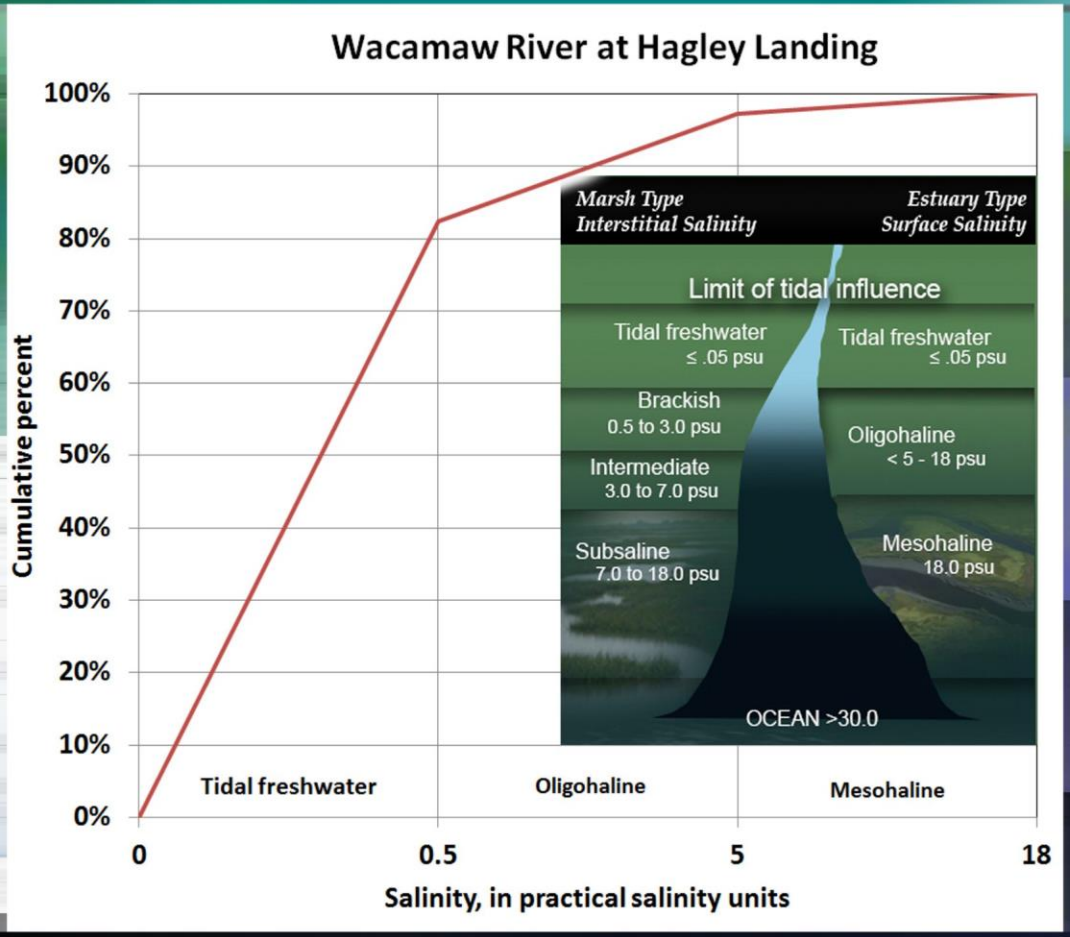
Estuarine Type

82% Tidal Freshwater

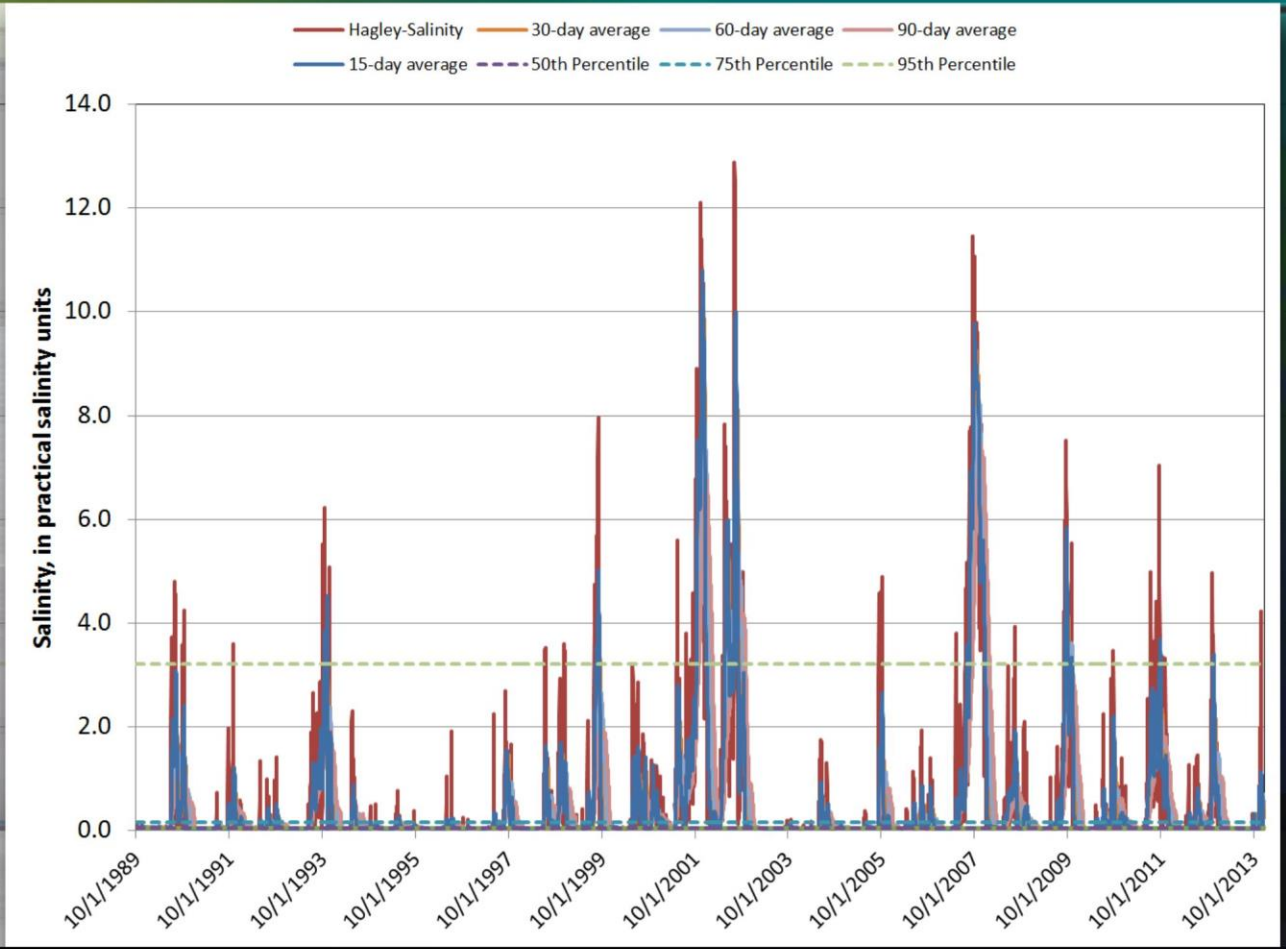
15% Oligohaline

3% Mesohaline

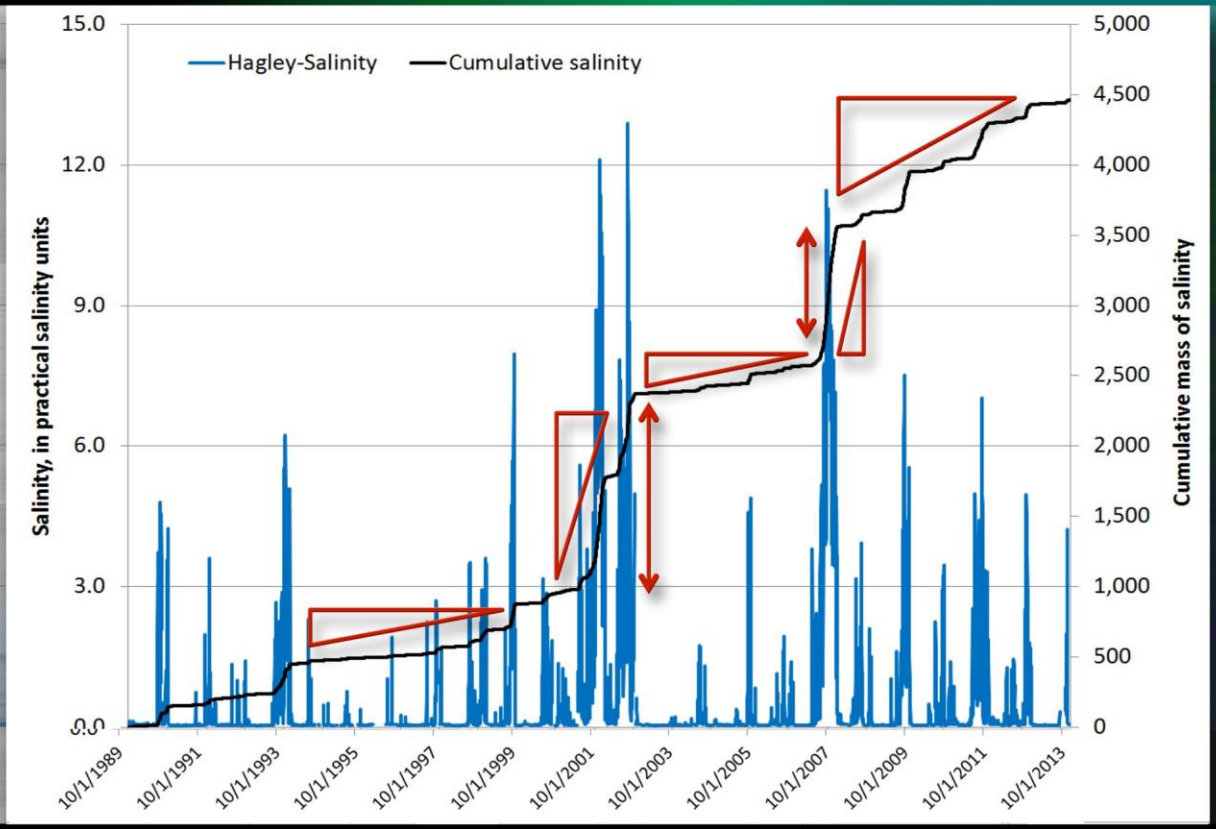




Running Averages & Percentile



Identifying Changing Salinity Behavior
Single Mass Curve

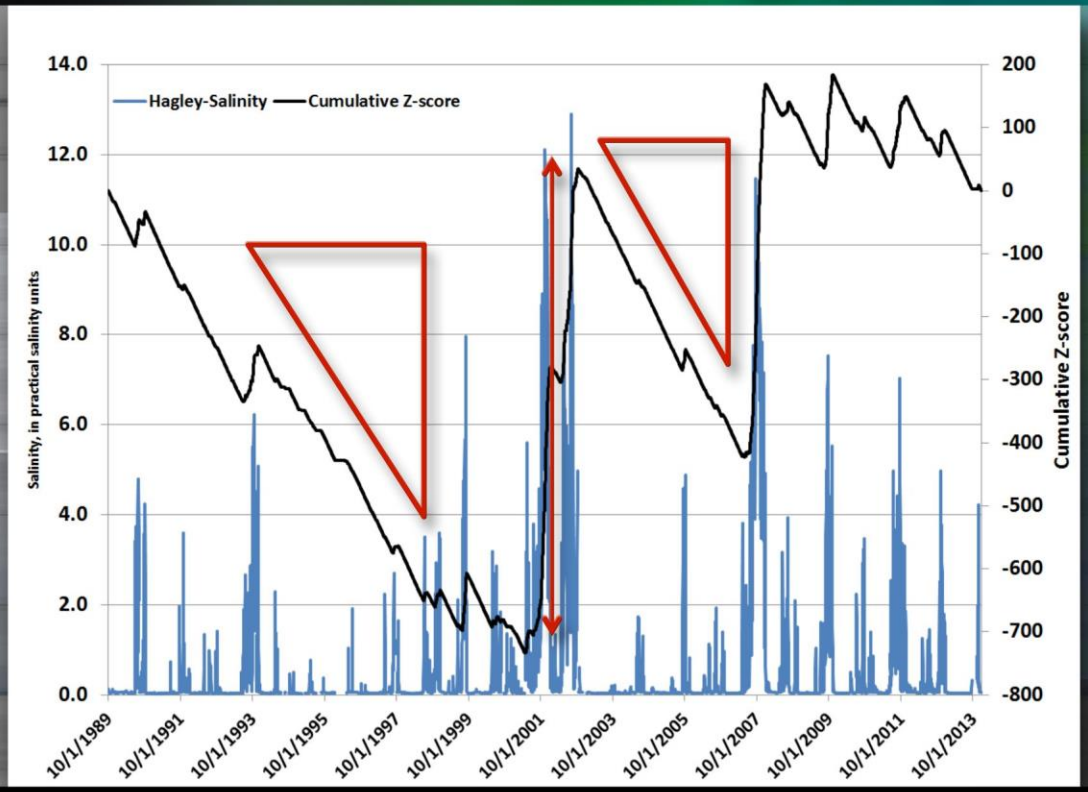


Could slope and magnitude of rises be used in an index?

Identifying Changing Salinity Behavior

Cumulative Z-score

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

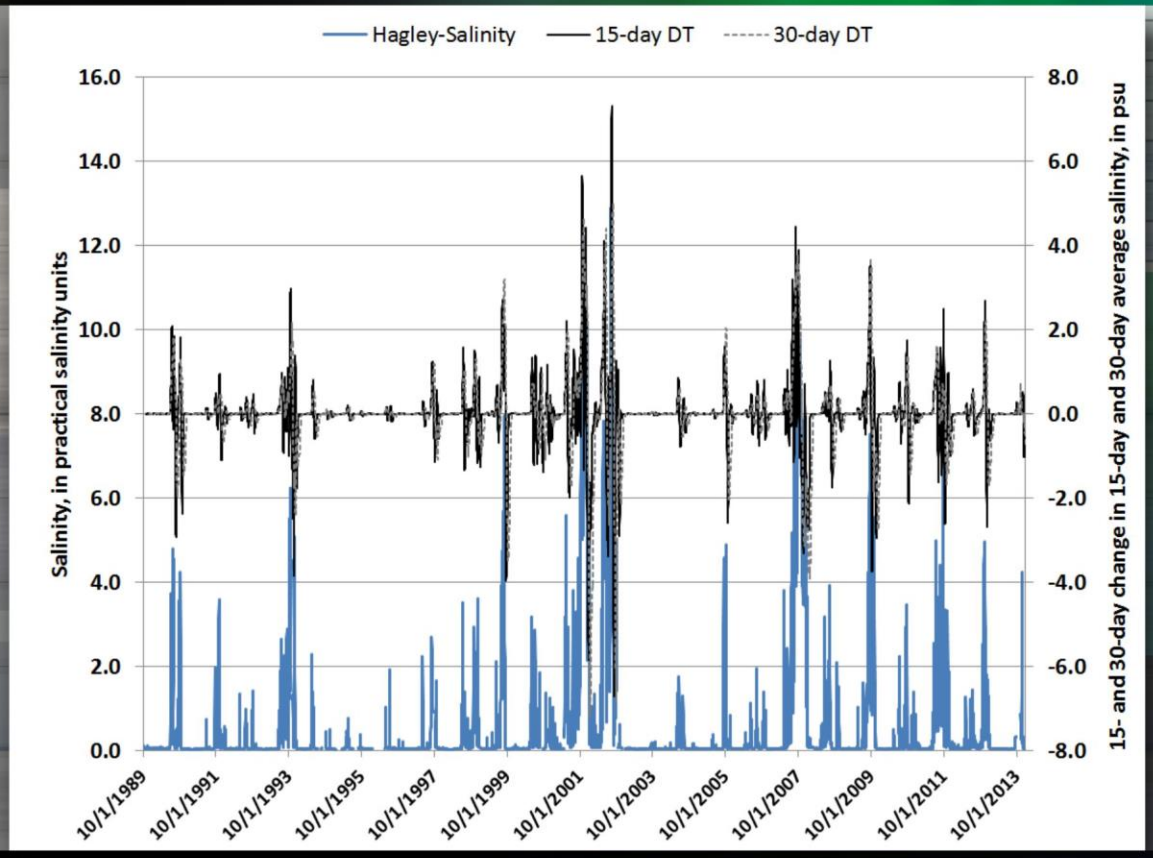


Change in slope indicates a change in salinity behavior

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) Hagley Landing

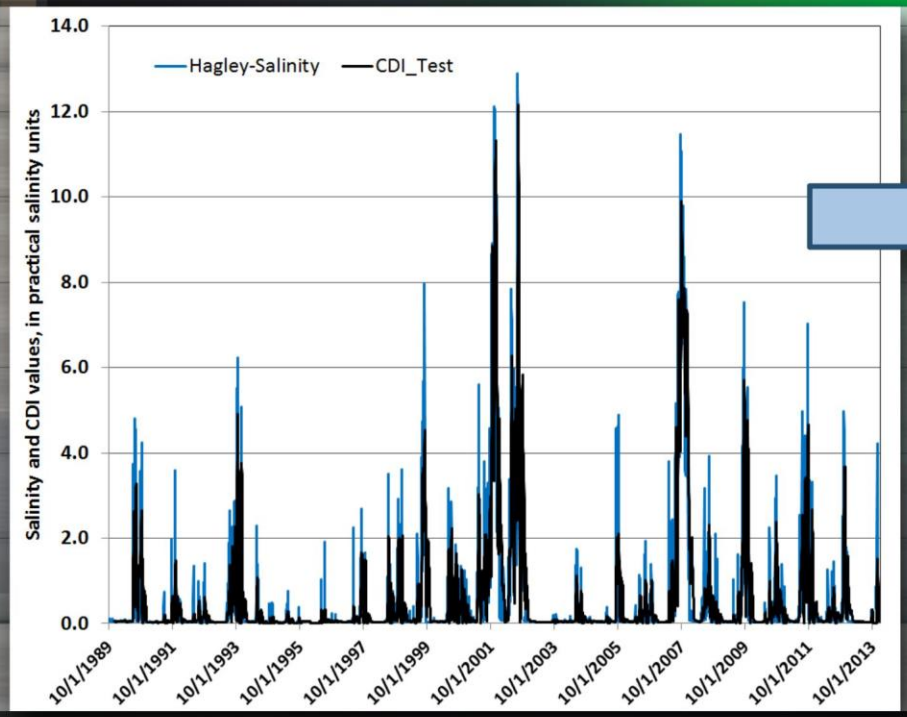
Combination of average salinity and time derivative:

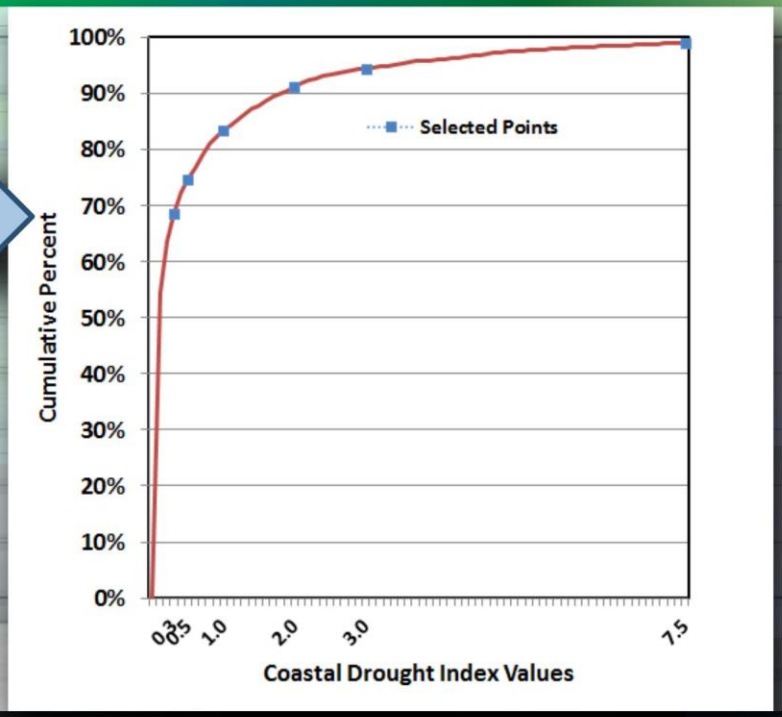
- 60-day average salinity
- 15-day change in 15-day average salinity

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

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

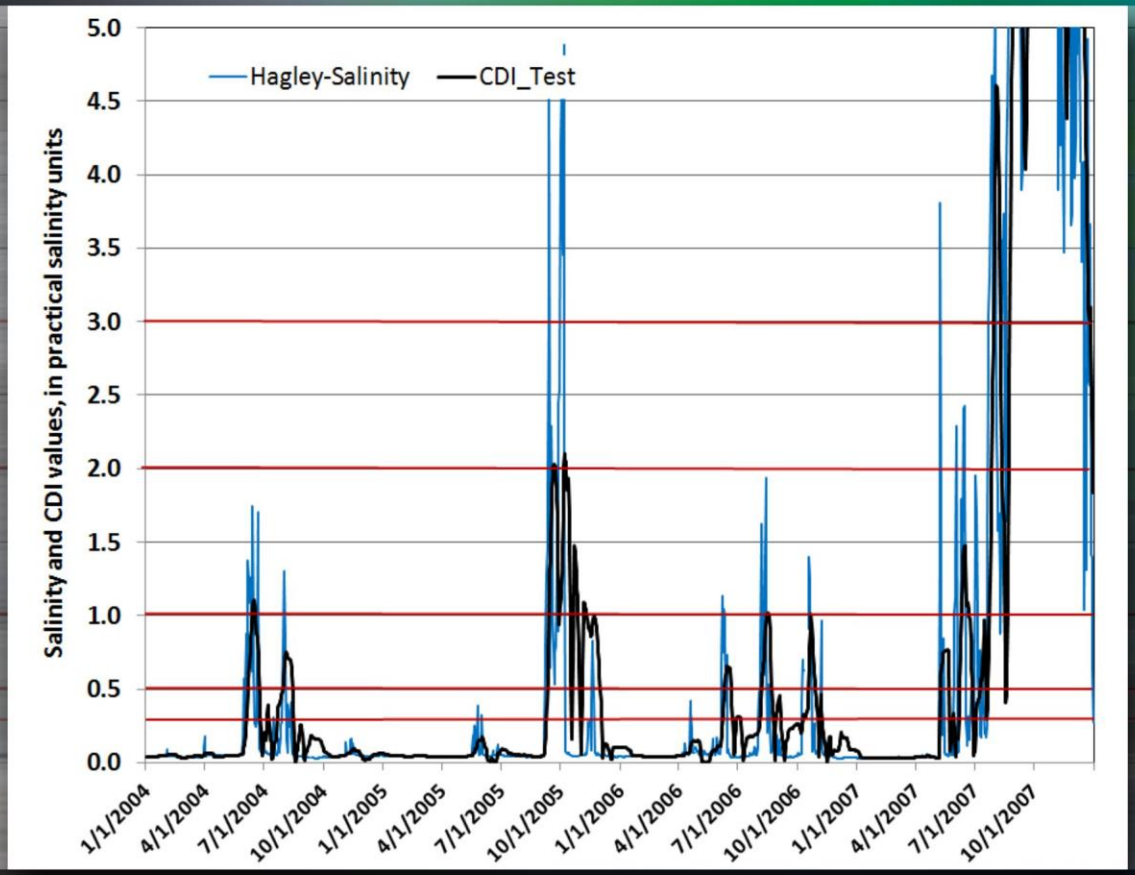
Preliminary Coastal Drought Index (CDI) Time Series & Frequency Curve





Preliminary

Preliminary Coastal Drought Index (CDI) Close up



CD4

CD3

CD2

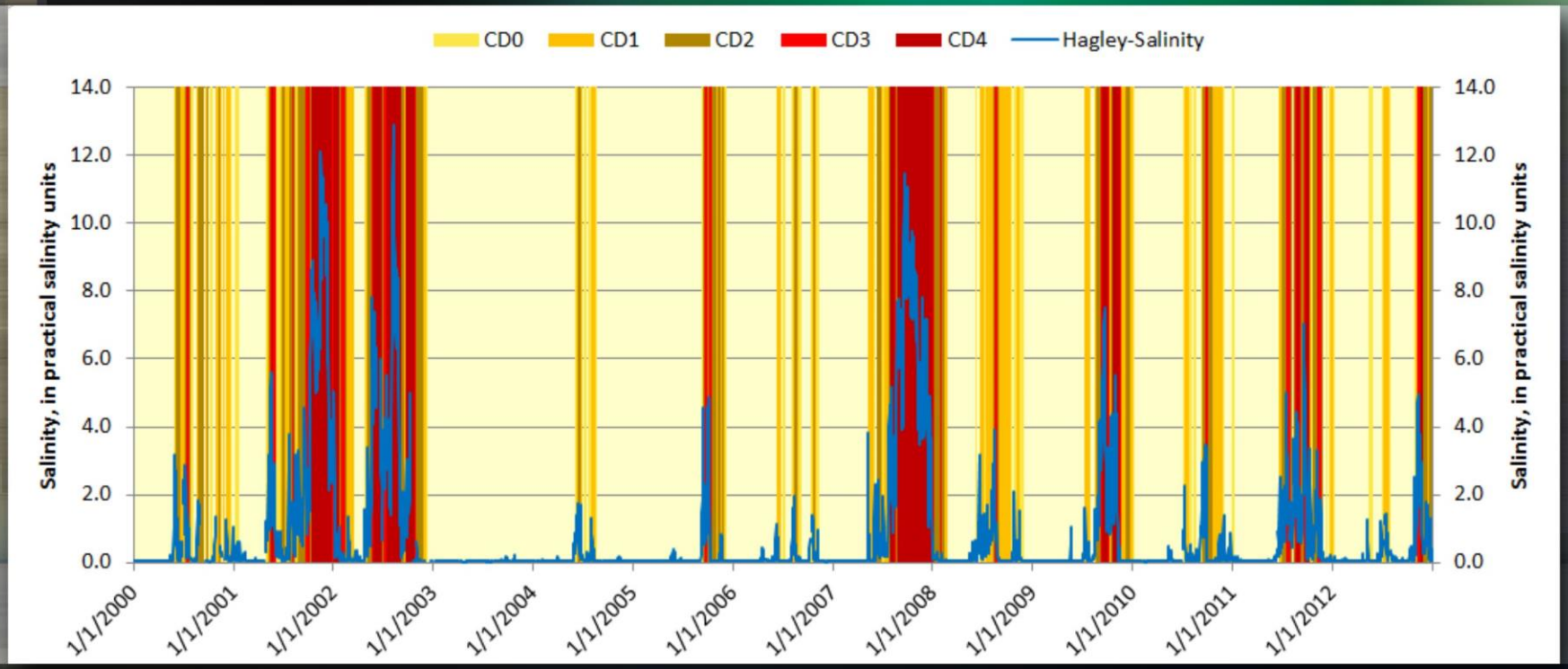
CD1

CD0

Normal

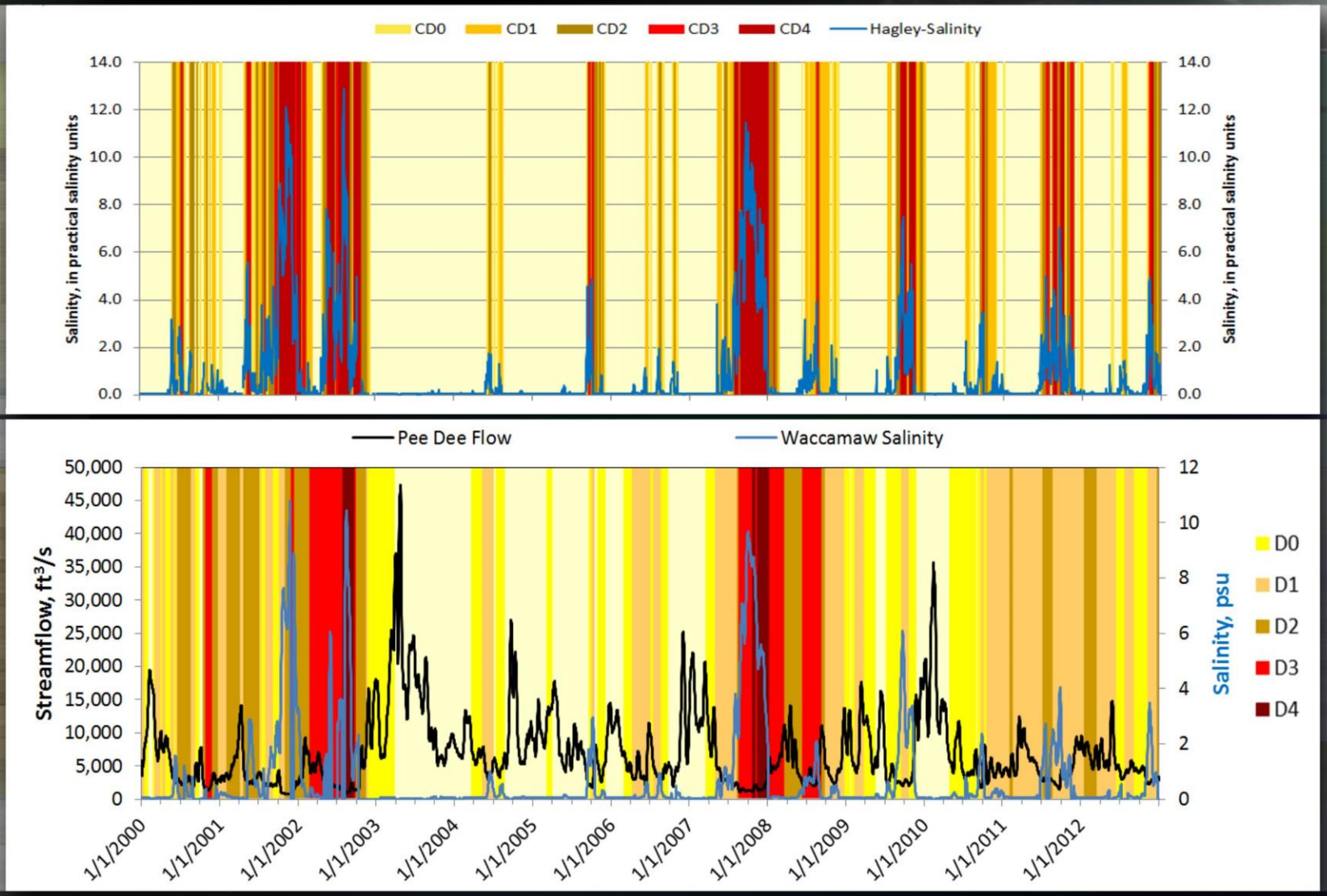
Preliminary

Preliminary Coastal Drought Index (CDI) 2000-2012



Preliminary

Drought Monitor & Preliminary CDI

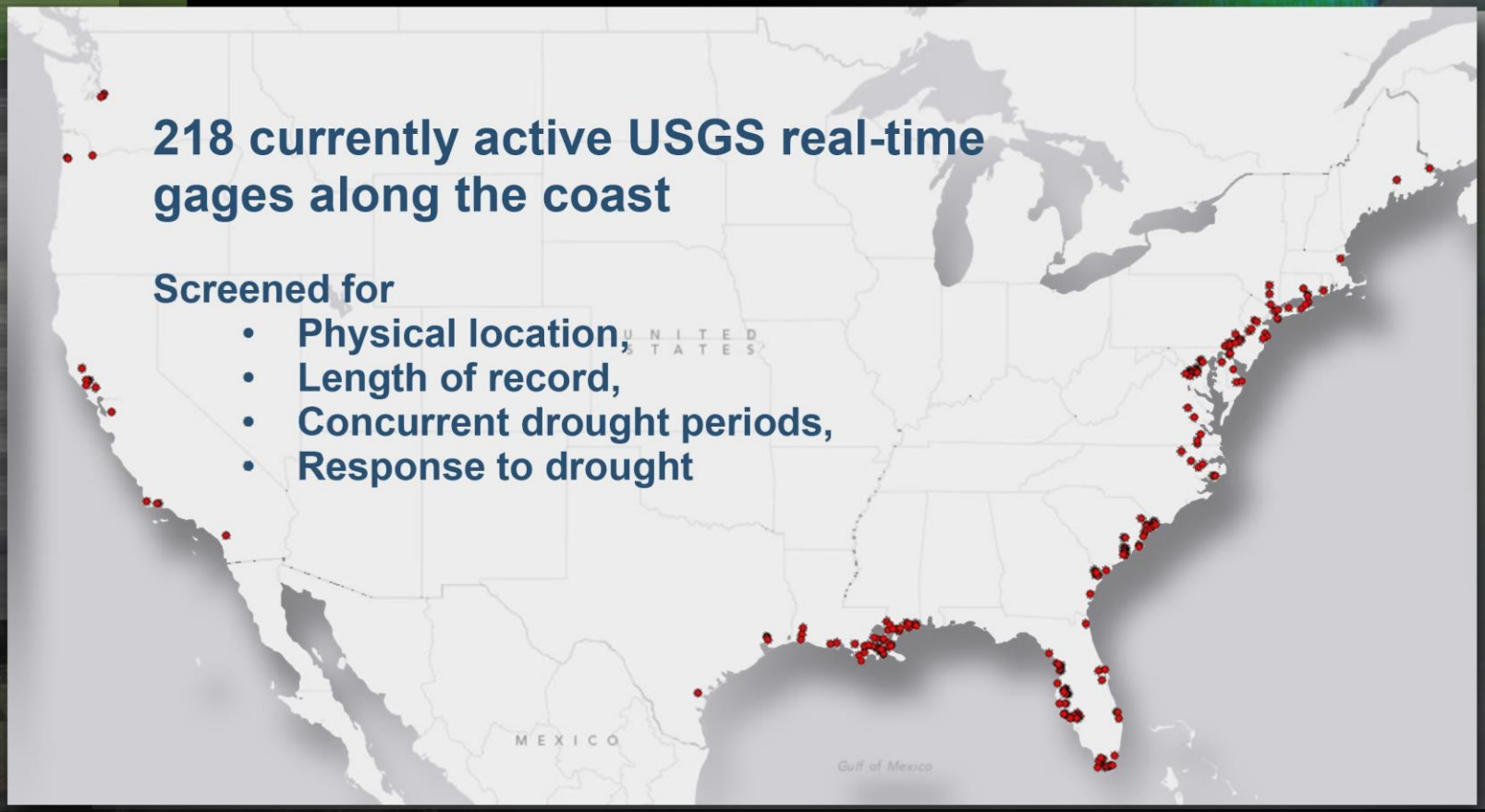


Preliminary

Thoughts on Preliminary CDI

- CDI can refine timing issues of upstream Drought Monitor declarations
- Time derivatives can address onset and recession of drought timing
  - Use different DTs
- Include elements from other analysis, for example cumulative Z-scores
  - Include other parameters, for example flows
- Cascading computation with logic statements
- Missing data – limit periods for analysis or estimate missing data?

Potential Beyond the Carolinas

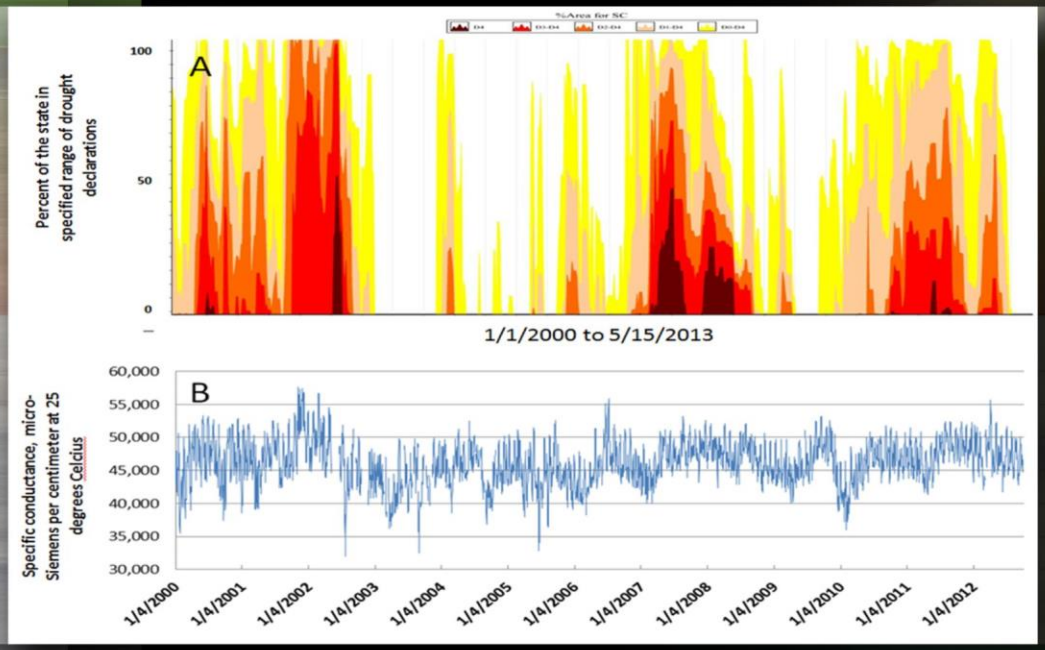


218 currently active USGS real-time gages along the coast

Screened for

- **Physical location,**
- **Length of record,**
- **Concurrent drought periods,**
- **Response to drought**

Station Evaluation



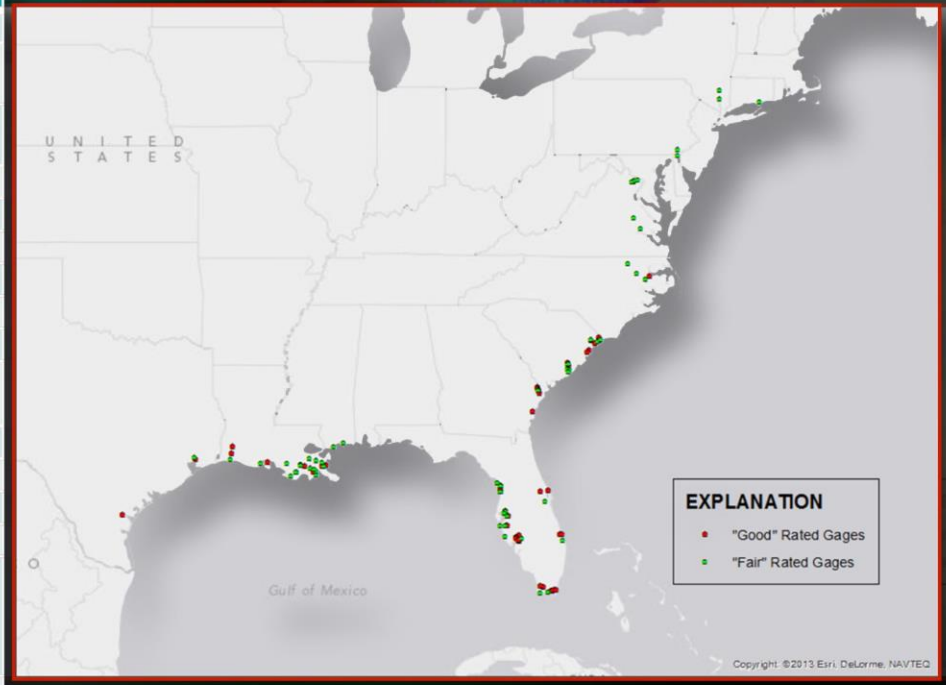
Response to drought

Physical location

Potential USGS Coastal Drought Index Sites

Table 2. Summary of visual match ratings

State	Total number of SC stations	Visual Match Ratings Summary		
		Good	Fair	Poor
CA	11	0	0	11
CT	3	0	1	2
FL	62	22	19	21
GA	6	4	1	1
LA	33	7	16	10
MA	1	0	0	1
MD-CD-DE	17	0	2	15
ME	2	0	0	2
MS	10	0	2	8
NC	6	1	3	2
NJ	6	0	0	6
NY	11	0	2	9
OR	3	0	0	3
PA	6	0	0	6
RI	1	0	0	1
SC	24	10	9	5
TX	4	2	1	1
VA	9	0	6	3
WA	3	0	0	3
Totals	218	46	62	110



108 Fair or Good Sites

Summary

- Relation between upland flow and drought declarations and salinity dynamics
- Salinity can be used for coastal drought index (CDI)
- Challenge of correlating CDI with coastal response variables
- Data networks available to support real-time coastal drought index sites

Discussion

Insert picture
of coastal drought here