The Impacts of Climate Change and Climate Variability on Erosion Index in the Southeastern United States

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Motivation

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"As climate changes, the main changes in precipitation will likely be in the intensity, frequency, and duration of events, but these characteristics are seldom analyzed in observations or models."

Bulletin of the American Meteorological Society

September 2003

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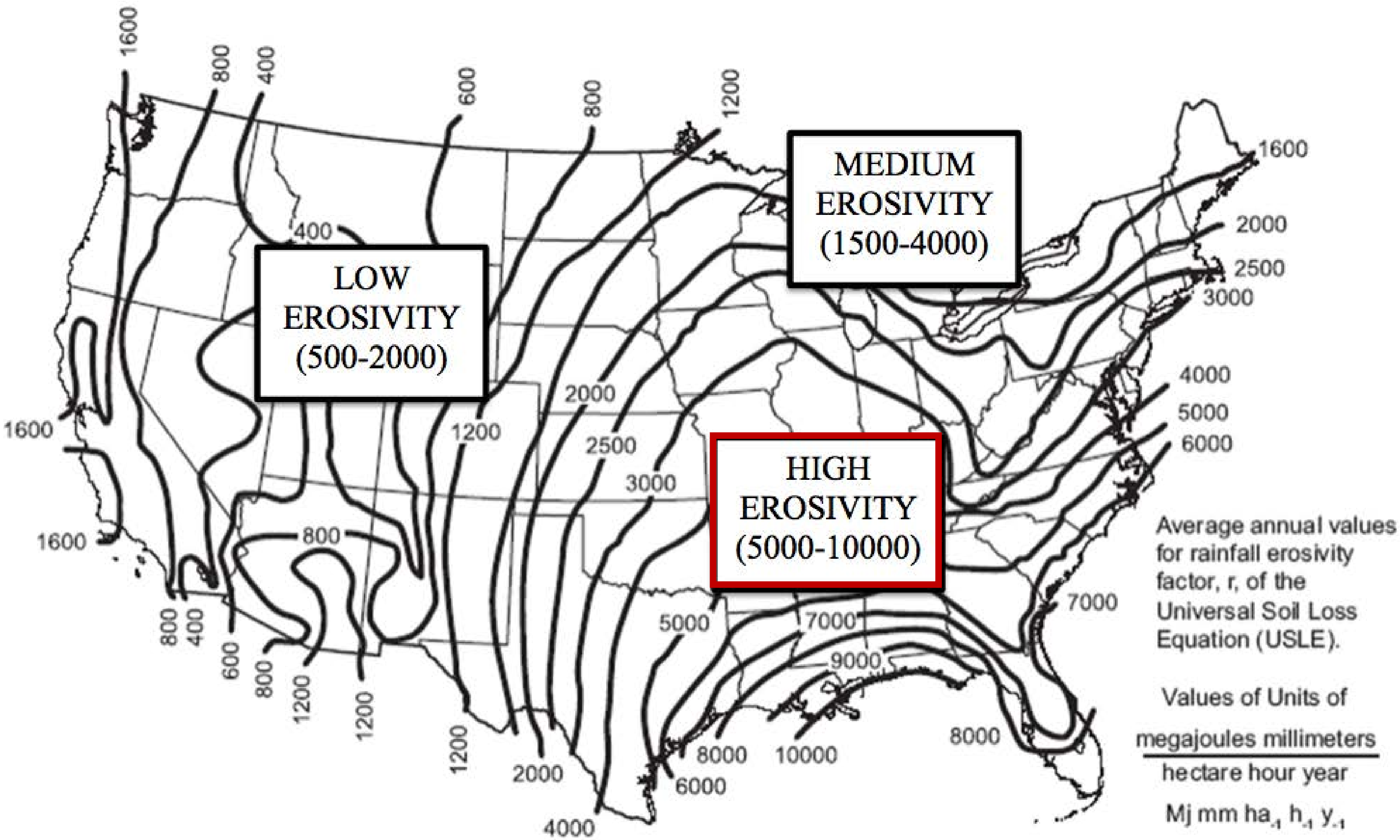
INTRODUCTION


Study Area


LOW
EROSIVITY
(500-2000)
MEDIUM
EROSIVITY
(1500-4000)
HIGH
EROSIVITY
(5000-10000)
Average annual values for rainfall erosivity factor, r, of the Universal Soil Loss Equation (USLE).
Values of Units of
megajoules millimeters
hectare hour year
Mj mm ha-1 h-1 y-1

Erosion Index (EI)

Definition: a statistical reflection of how total kinetic energy (E) and peak intensity (I30) interact within a storm

Calculation Requirements:

- High Temporal Resolution Precipitation Data
- Ideally Fixed-Intensity Data not Fixed-Interval Data

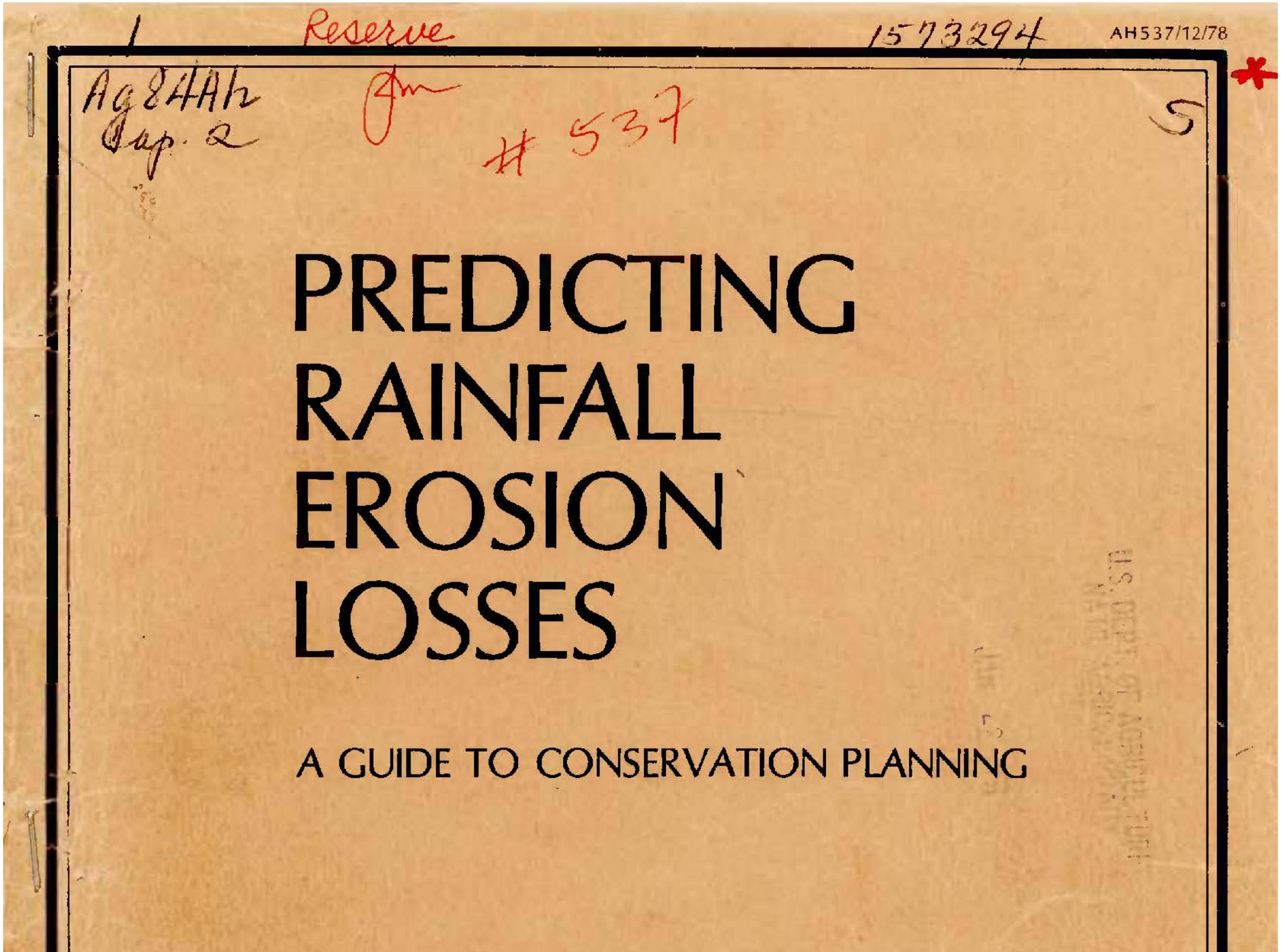
$$e_{t,t+1} = 916 + 331\, log_{10}\, i_{t,t+1}$$

$$for \begin{cases} i & \leq & 3.0\ inches\ h^{-1} \\ I_{30} & \leq & 2.5\ inches\ h^{-1} \end{cases}$$

$$E_s = \frac{\sum_{t=1}^{m} e_{0,t} + e_{t,t+1} + \cdots + e_{m-1,m}}{100}$$

$$EI = \sum_{s=1}^{n} (E_s \cdot I_{30s}) + (E_{s+1} \cdot I_{30s+1}) + \cdots + (E_n \cdot I_{30n})$$

AH537 / Wischmeier and Smith 1978


Reserve

1573294

AH537/12/78

Ag84Ah
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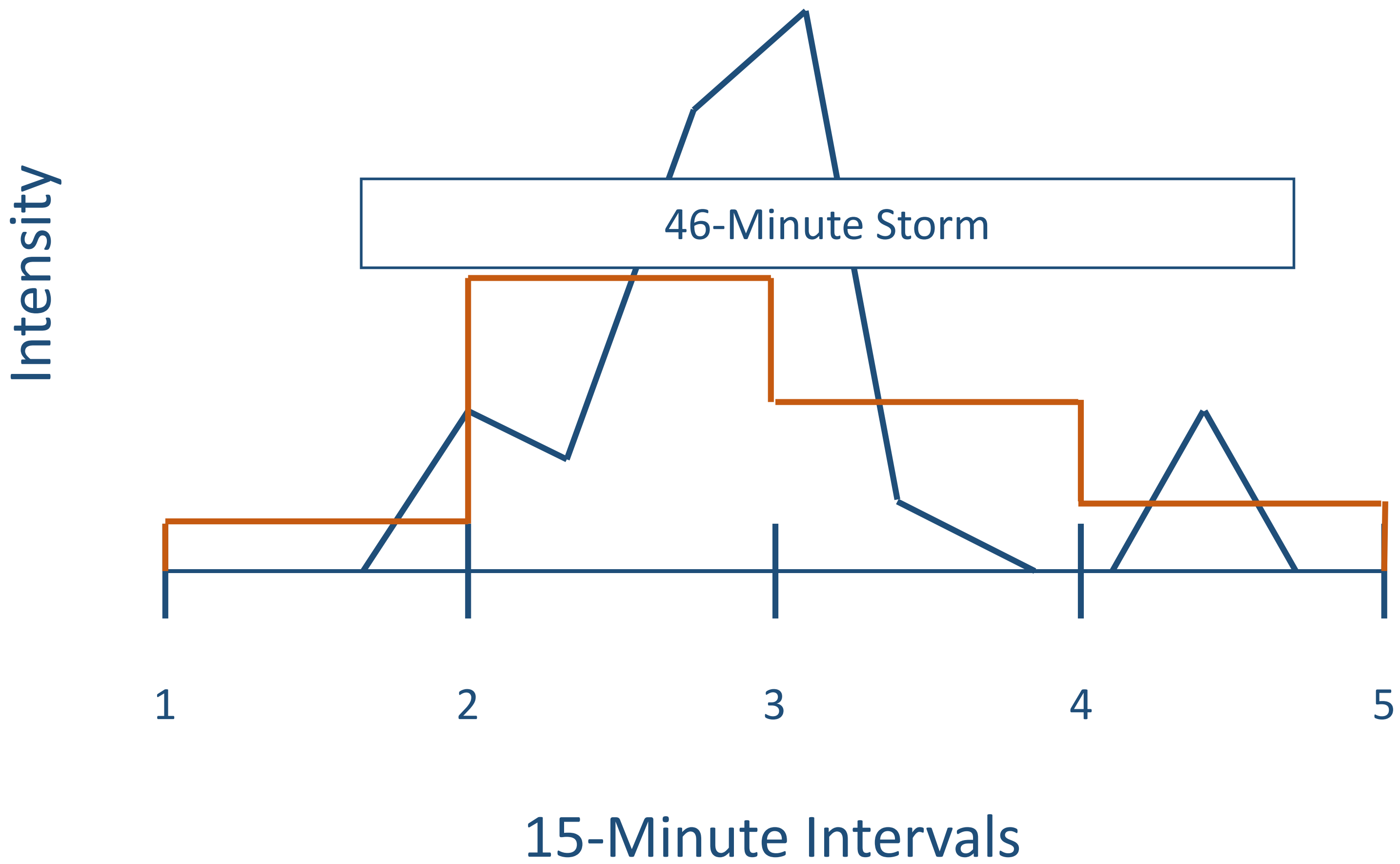
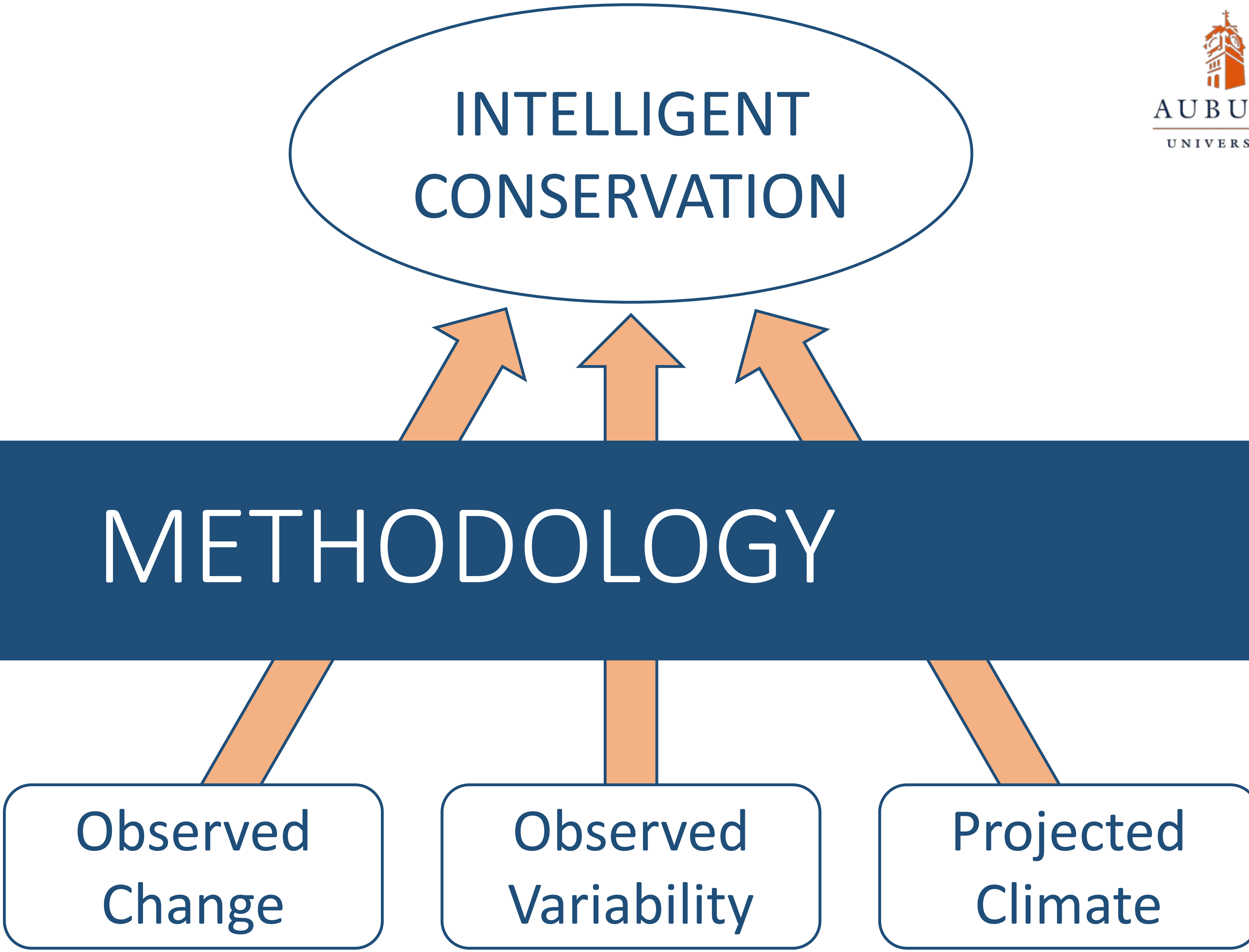
#537

PREDICTING
RAINFALL
EROSION
LOSSES

A GUIDE TO CONSERVATION PLANNING

Fixed-Intensity vs. Fixed Interval




INTELLIGENT CONSERVATION
METHODOLOGY
Observed Change
Observed Variability
Projected Climate

Data Processing

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- **Raw Data**
  - NOAA NCDC DSI-3260 (>600 Quarter-Hour Stations)
  - Gaps and Accumulations (Two Types of Data Problems)
  - More than 13,000 Station Years and 2.5 Million Storms
- **Storm Separation**
- **Station Screening**
- **Water Balance**
- **EI Calculation**
- **Statistical Analysis**

Storm Separation

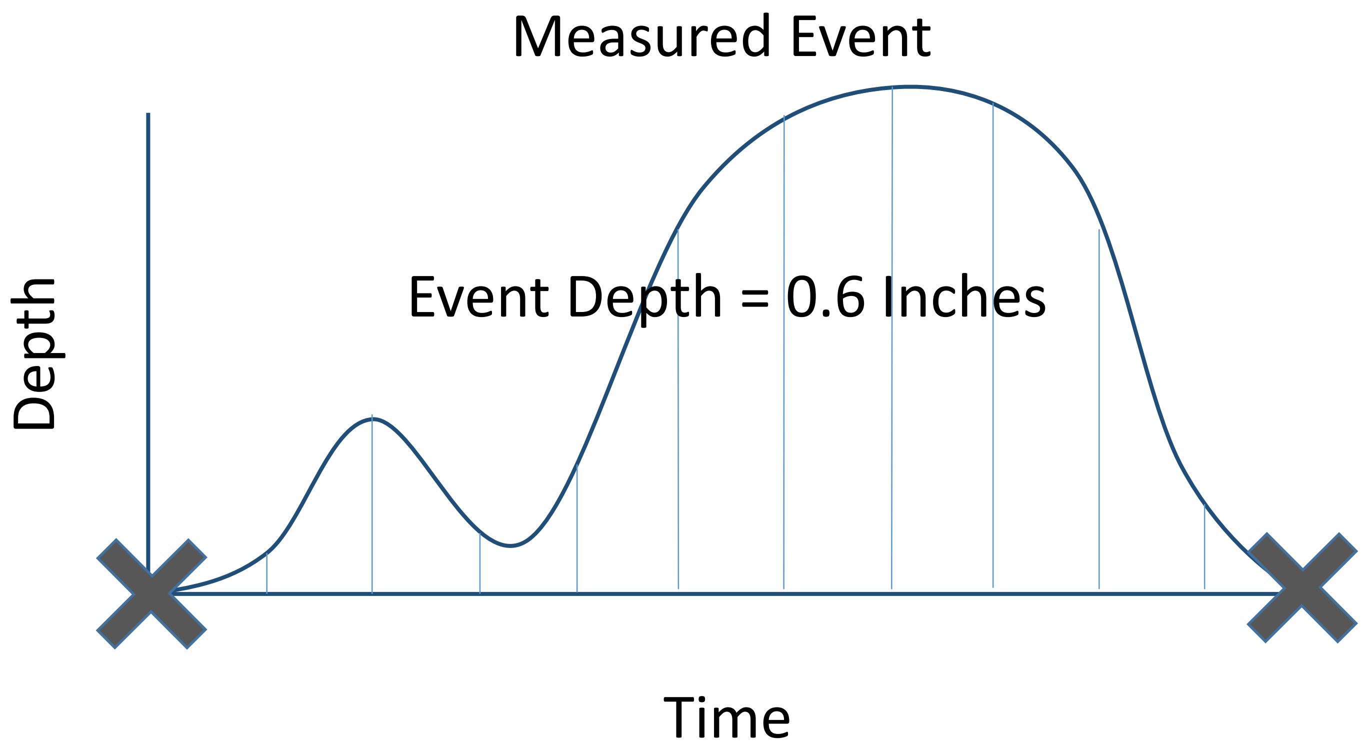
- **IDENTICAL to AH537**
  - A break between storms is a period of 6 hours or more with less than 0.5 inches of precipitation.

- **DIFFERENT from AH537**
  - AH537 omits storms less than 0.5 inches unless the intensity is at least 0.95 inches per hour.
  - Data includes accumulations (definition next slide)
  - Accumulations are assumed to be separate storms

Bands of precipitation, although technically part of the same storm system, are treated as separate systems. So, it is uncommon to see durations longer than 48 hours using this method.

Accumulations

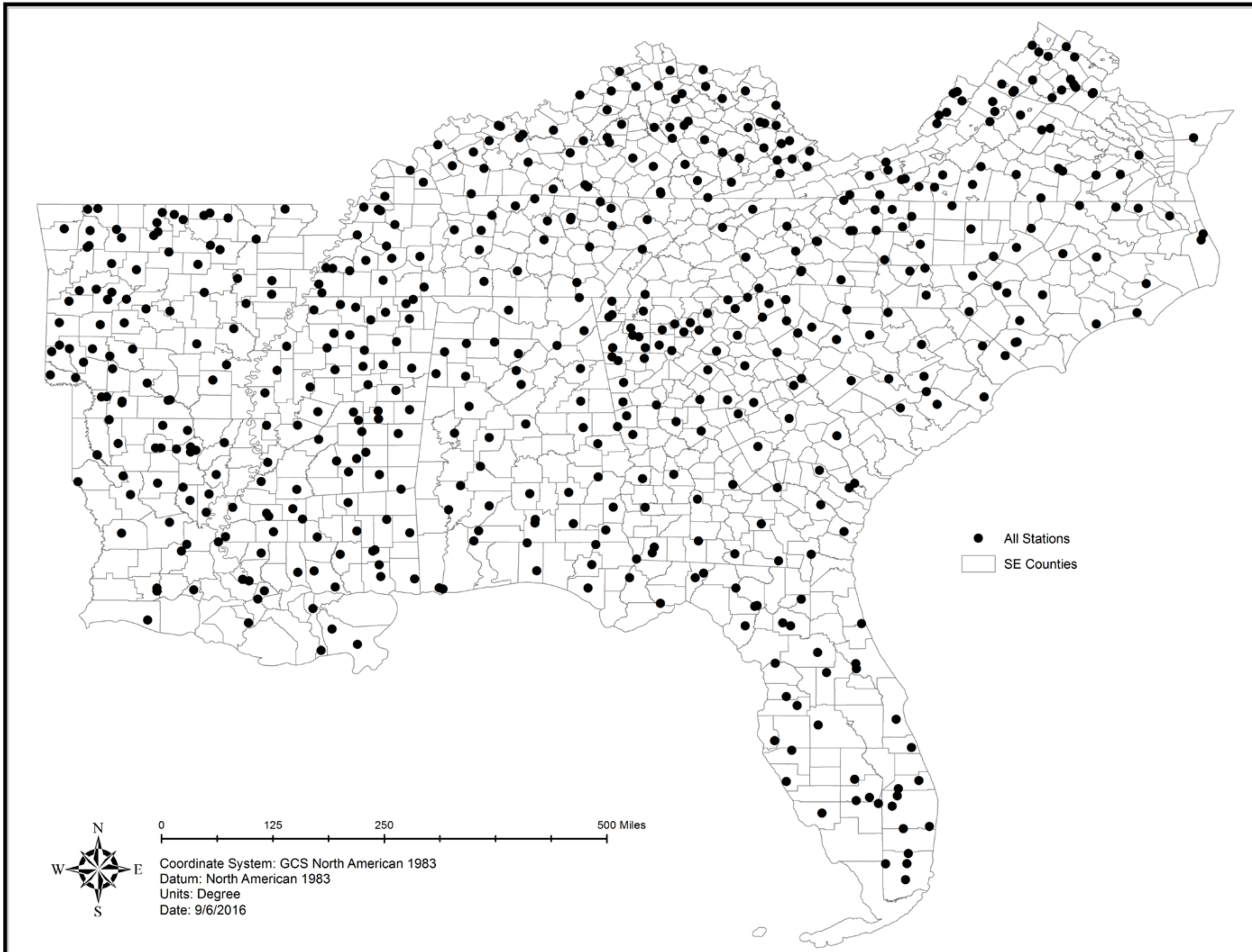
An event with known beginning and ending times and total depth without knowledge of distribution.

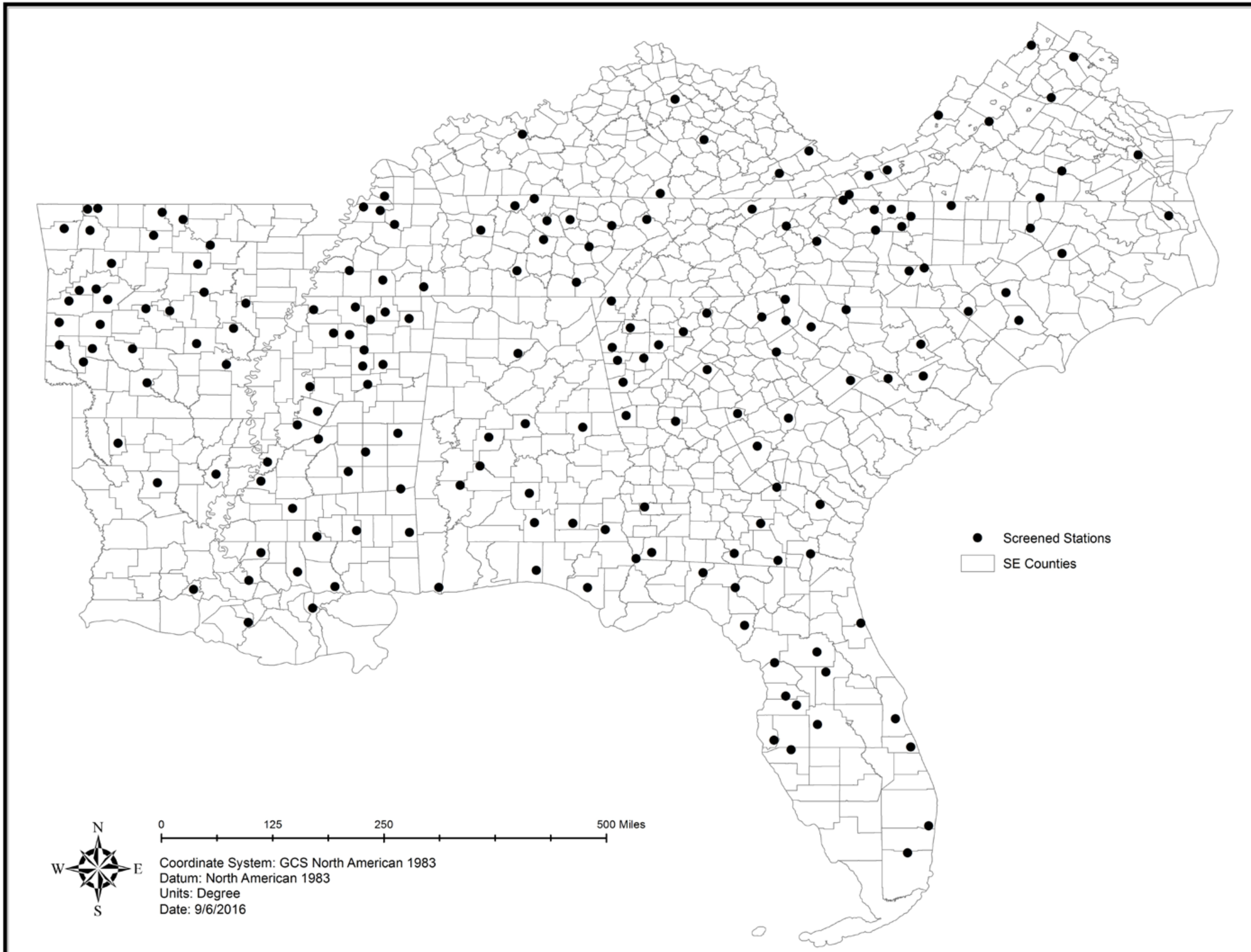


Station Screening

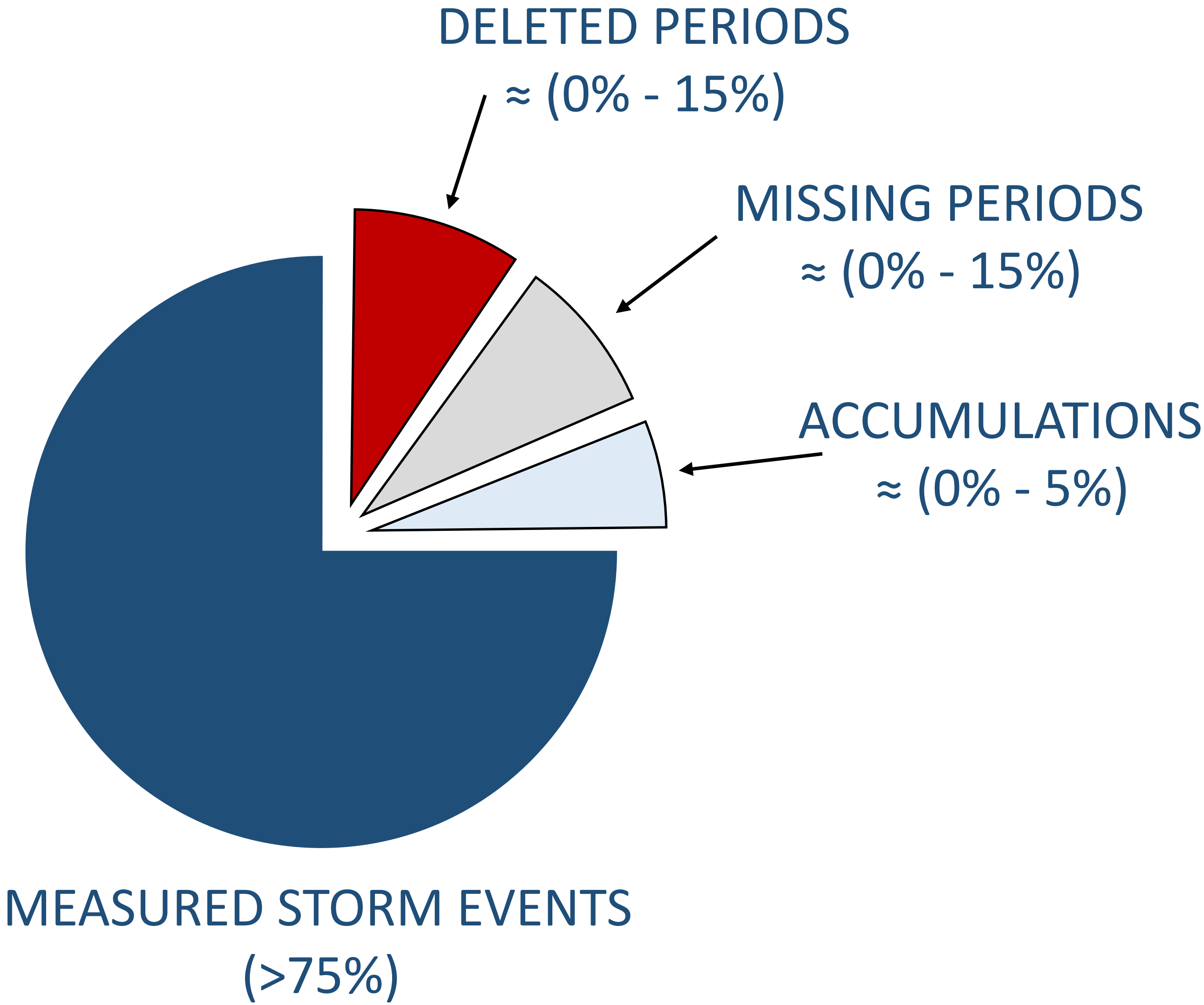
- **Qualitative Screening**
  - Check for erroneous values (inherent and introduced)
  - Less than 0.1% of data (and total depth) removed
  - Insignificant impact on results

- **Quantitative Screening**
  - Reduce 'gaps' in the data (missing and deleted periods)
  - Determined by water balance performance
  - Significant impact on results
  - About 60% of more than 600 stations do not meet the minimum quantity to be used in this study
  - NOAA uses a similar method for climate normals

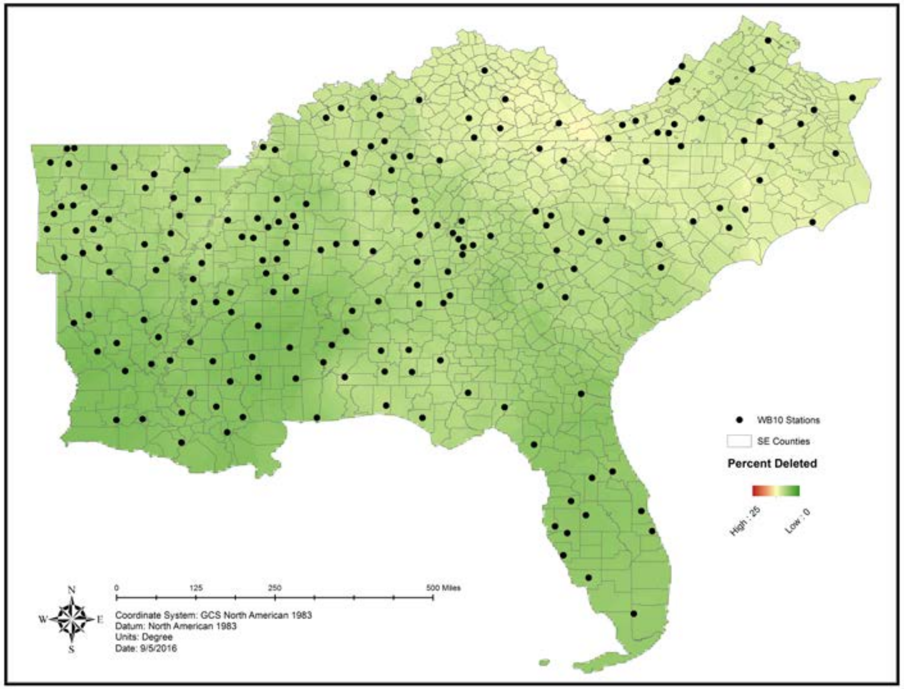

All Stations
SE Counties
0
125
250
500 Miles
N
W
E
S
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/6/2016


Screened Stations
SE Counties
N
S
W
E
0
125
250
500 Miles
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/6/2016

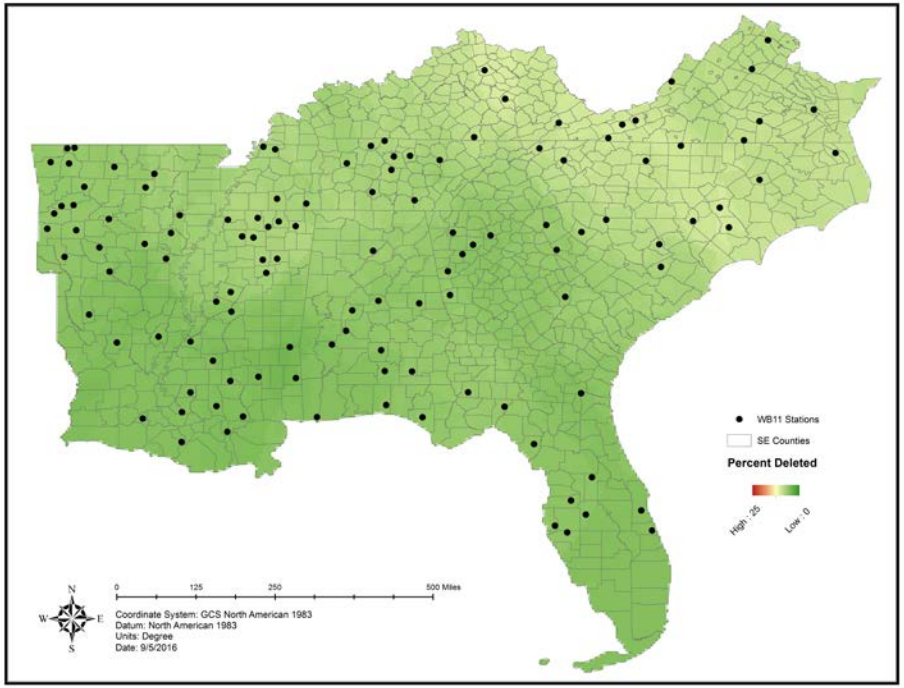
Water Balance



SCREENING METHOD ID	MEAN		MEDIAN		ST. DEV.		NUMBER OF STATIONS
	-	+	-	+	-	+	
20.10.60	-7.92	-6.03	-8.23	-5.81	3.96	4.15	286
20.11.30	-7.05	-5.27	-7.40	-5.56	4.09	4.13	179
20.11.60	-7.05	-5.27	-7.40	-5.56	4.09	4.13	179
20.11.90	-6.93	-5.17	-7.30	-5.47	4.04	4.12	178
25.10.60	-7.41	-5.40	-7.86	-5.26	3.45	3.53	174
25.11.60	-6.67	-4.99	-6.49	-4.65	3.42	3.42	82
30.10.60	-6.58	-4.77	-6.35	-4.59	2.99	2.99	73
20.12.60	-5.40	-4.32	-4.88	-3.57	3.44	3.53	34
30.11.60	-6.48	-4.86	-6.75	-4.77	2.82	2.83	26



WB10 Stations
SE Counties
Percent Deleted
High : 25
Low : 0
0
125
250
500 Miles
N
W
E
S
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/5/2016



WB11 Stations
SE Counties
Percent Deleted
High : 25
Low : 0
0
125
250
500 Miles
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W
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S
Coordinate System: GCS North American 1983
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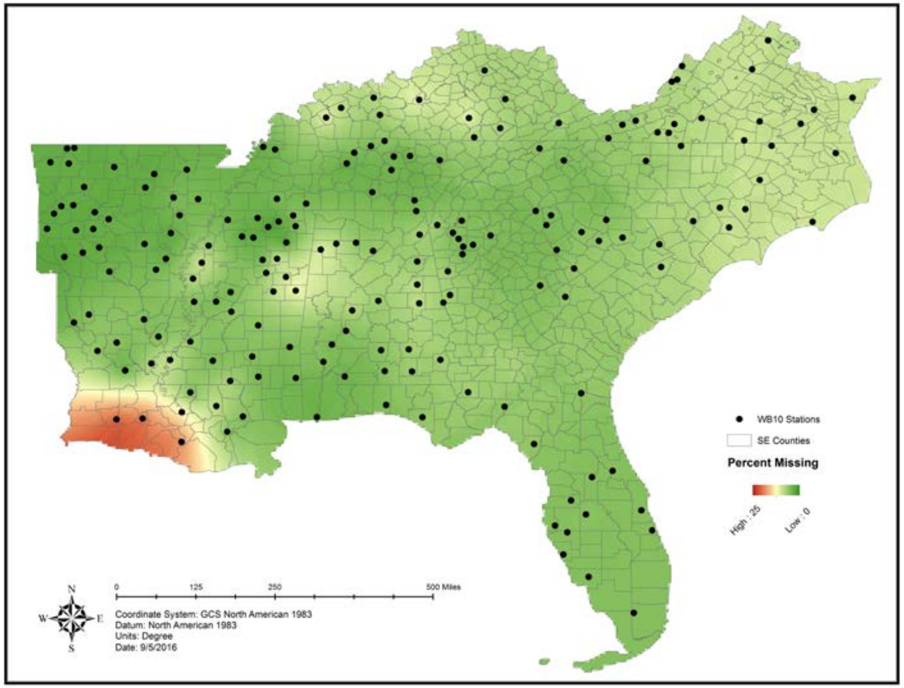

WB10 Stations
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Percent Missing
High : 25
Low : 0
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125
250
500 Miles
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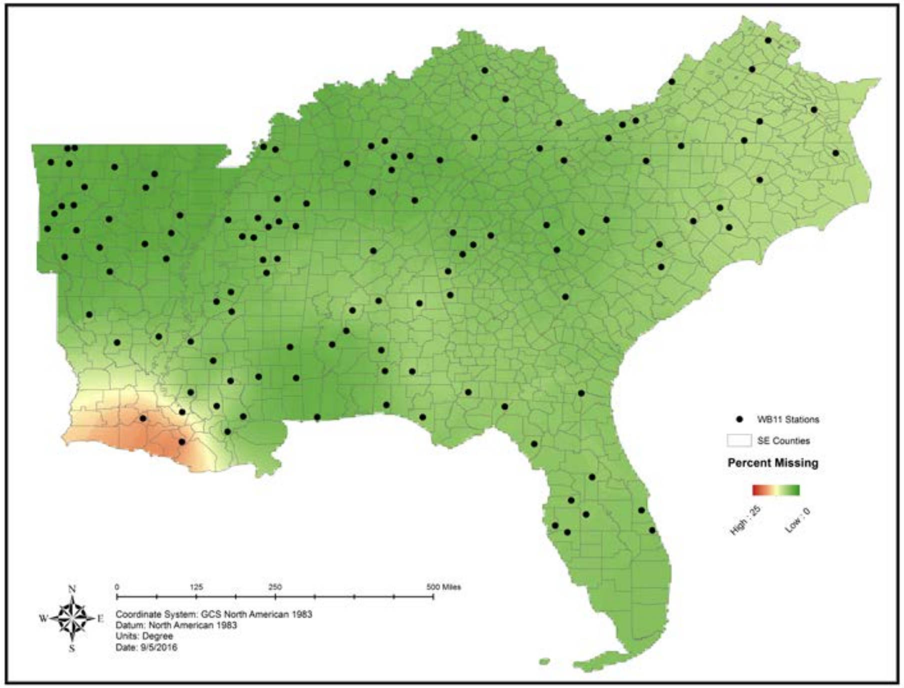

WB11 Stations
SE Counties
Percent Missing
High : 25
Low : 0
0
125
250
500 Miles
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Coordinate System: GCS North American 1983
Datum: North American 1983
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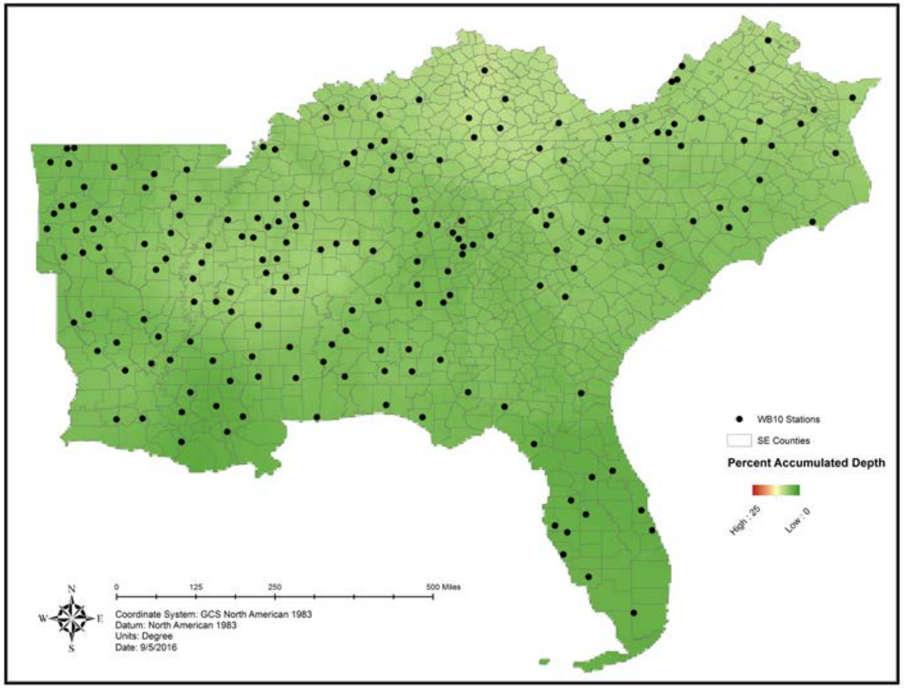
WB10 Stations
SE Counties
Percent Accumulated Depth
High : 25
Low : 0
N
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125
250
500 Miles
Coordinate System: GCS North American 1983
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Units: Degree
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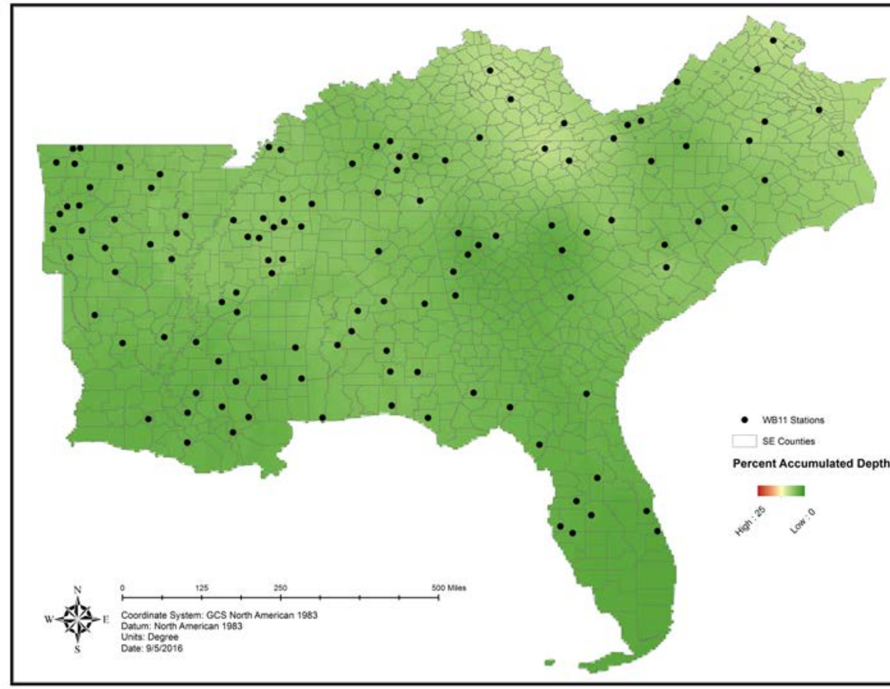
WB11 Stations
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Percent Accumulated Depth
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Low : 0
N
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125
250
500 Miles
Coordinate System: GCS North American 1983
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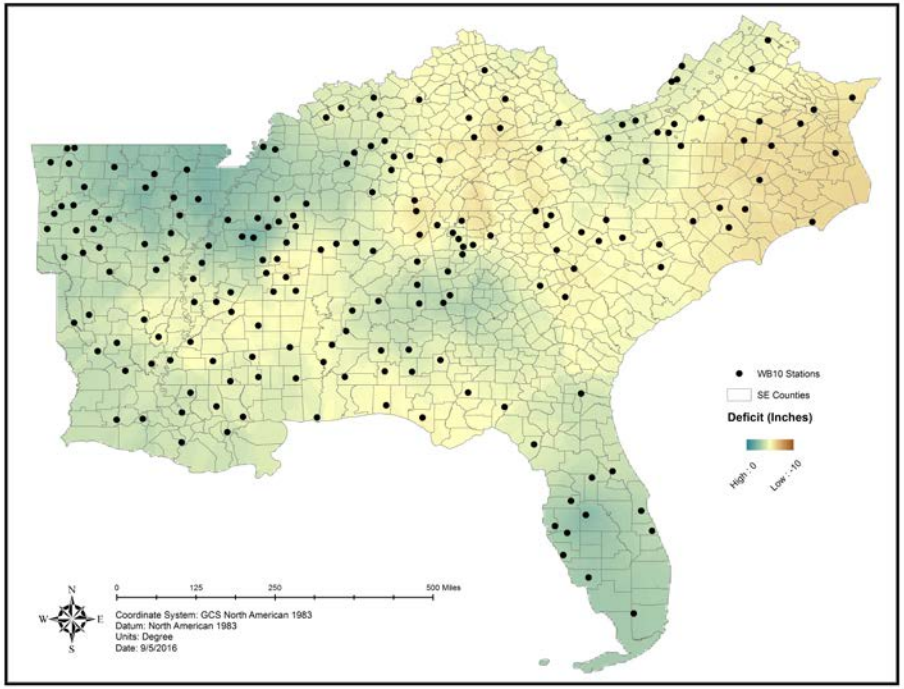
WB10 Stations
SE Counties
Deficit (Inches)
High : 0
Low : -10
0
125
250
500 Miles
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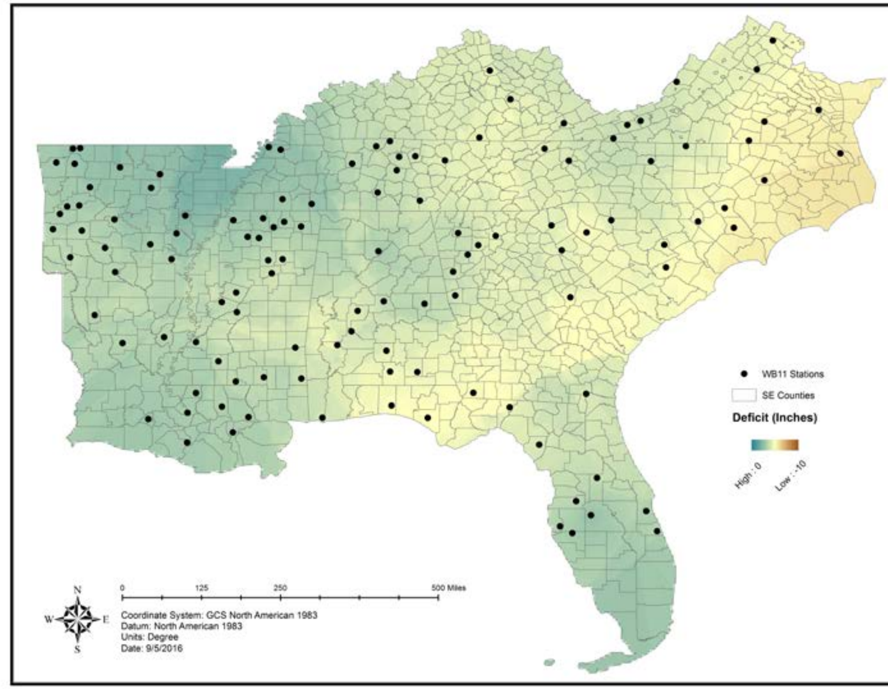
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/5/2016


WB11 Stations
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Deficit (Inches)
High : 0
Low : -10
0
125
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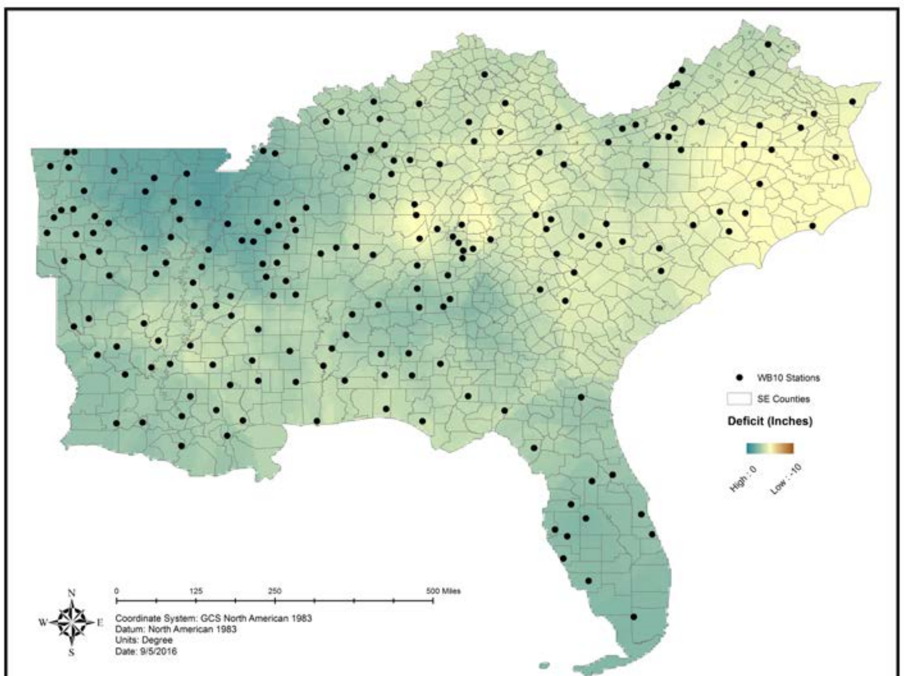
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500 Miles
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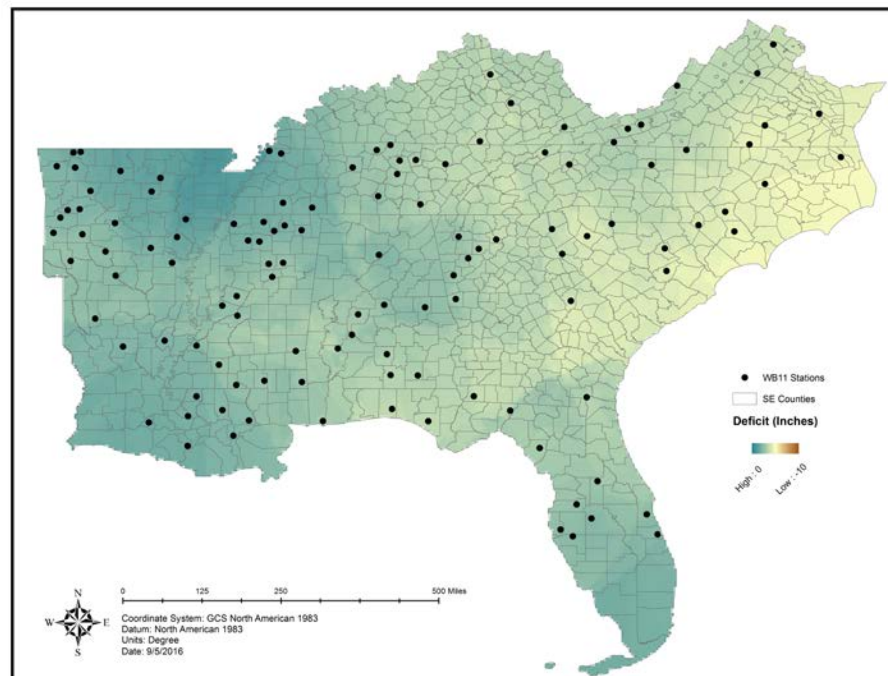
WB11 Stations
SE Counties
Deficit (Inches)
High : 0
Low : -10
0
125
250
500 Miles
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S
Coordinate System: GCS North American 1983
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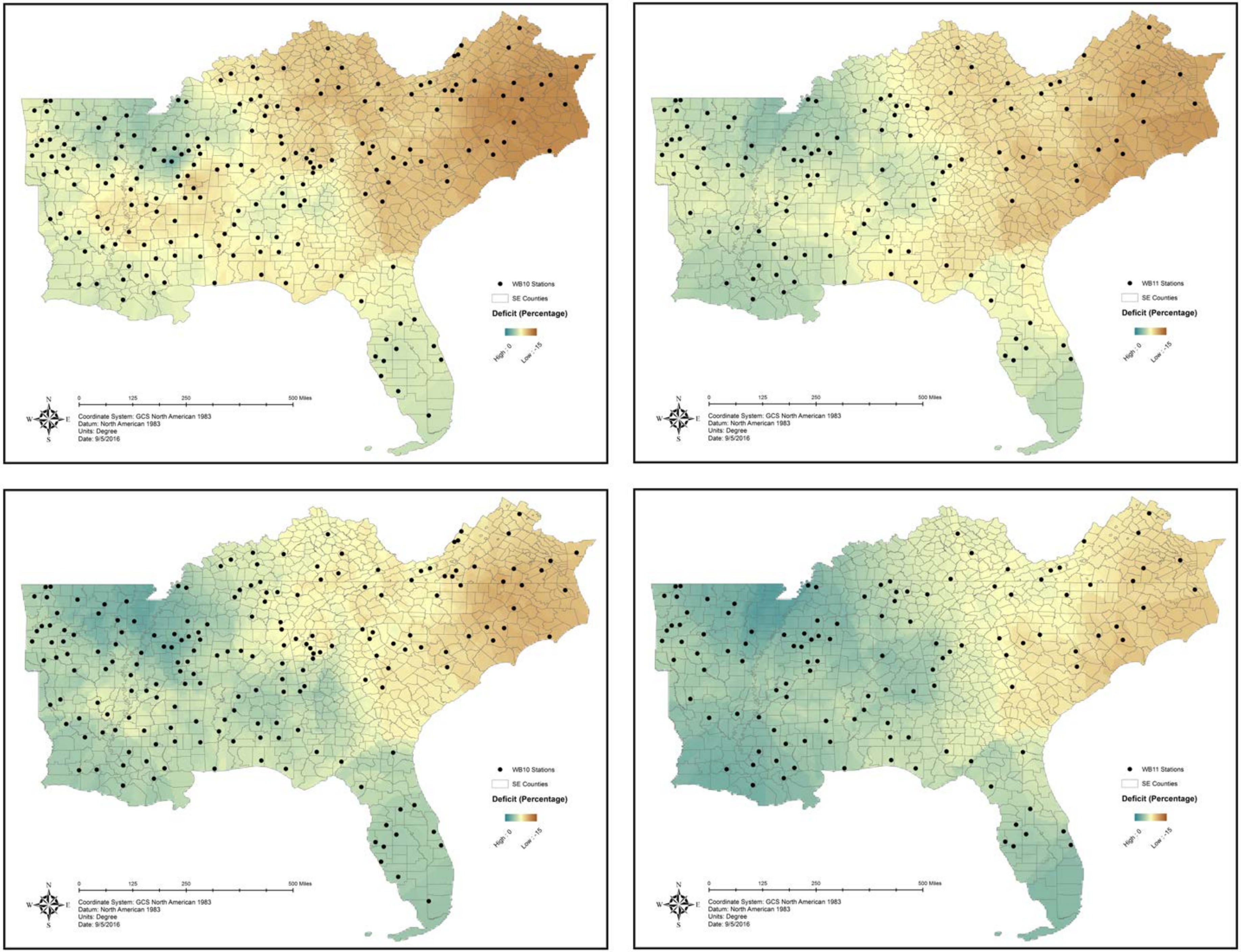
Units: Degree
Date: 9/5/2016


WB10 Stations
SE Counties
Deficit (Percentage)
High : 0
Low : -15
0
125
250
500 Miles
N
S
W
E
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/5/2016
WB11 Stations
SE Counties
Deficit (Percentage)
High : 0
Low : -15
0
125
250
500 Miles
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E
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Datum: North American 1983
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Date: 9/5/2016
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SE Counties
Deficit (Percentage)
High : 0
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125
250
500 Miles
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WB11 Stations
SE Counties
Deficit (Percentage)
High : 0
Low : -15
0
125
250
500 Miles
N
S
W
E
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/5/2016

EI Calculation

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- **IDENTICAL to AH537**
  - Intensity (i) is limited to 3 in/hr (raindrop limitation)
  - I30 is limited to 2.5 in/hr (ponding in the southeast)
- **DIFFERENT from AH537**
  - EI is calculated for all storms (no restriction)
  - Accumulations are included (separately for comparison)
- **OPTIONAL ADJUSTMENTS (Not Applied)**
  - Adjustment factor of 1.04 for I30 values
  - Adjust for Missing, Deleted, and Accumulated Data

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RStudio

File Edit Code View Plots Session Build Debug Tools Help

Go to file/function Addins

Annual EI.Rmd | all.data | Water Balance.Rmd | Moving.NORM | ALNORM7100 | State.NORM | ALMETA

Filter

RESULTS

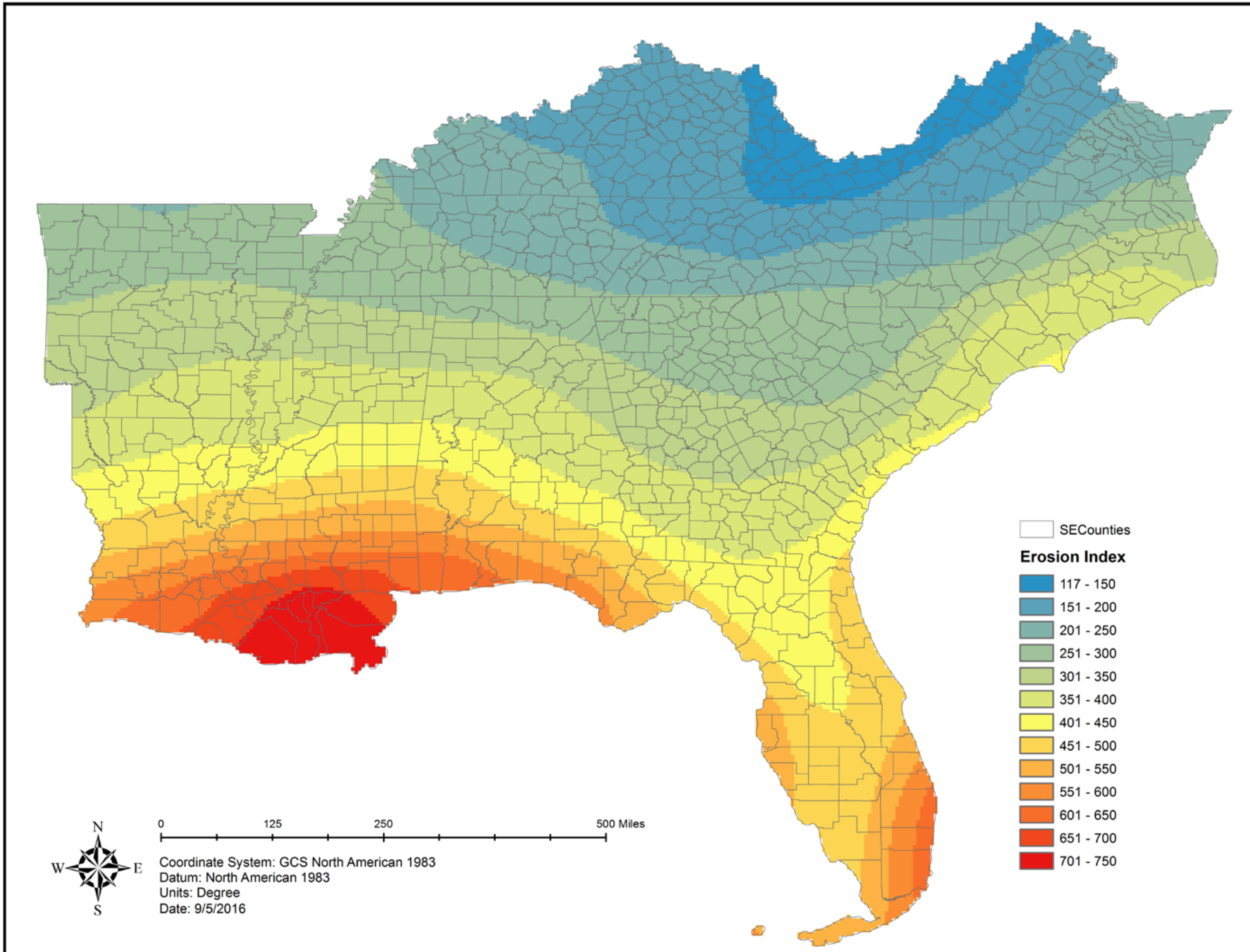
	State.ID	Station.ID	Year	Month	Day	Time.Begin	Duration..HR.	Depth..IN.	Original.Depth..IN.	Removed.Depth..IN.	Kinetic.Energy..100.FT.TONS.ACRE.	I30..IN.HR.	EI
1	1	800	1976	9	3	2300	0.50	0.3	0.3	0	2.552127	1.2	3.0625529
2	1	800	1976	9	4	1530	0.50	0.3	0.3	0	2.552127	1.2	3.0625529
3	1	800	1976	9	6	1345	6.25	1.1	1.1	0	9.783896	2.4	23.4813499
13	1	800	1976	11	27	1400	0.50	0.2	0.2	0	1.568564	0.8	1.2548510
14	1	800	1976	11	27	1445	4.75	3.2	3.2	0	31.796406	2.5	79.4910162
15	1	800	1976	11	28	815	13.25	3.6	3.6	0	30.501465	2.5	76.2536624
16	1	800	1976	12	6	1500	0.50	0.2	0.2	0	1.568564	0.8	1.2548510
17	1	800	1977	1	6	2100	2.00	0.7	0.7	0	5.689255	1.2	6.8271058
18	1	800	1977	1	9	2015	4.00	1.3	1.3	0	11.068009	2.0	22.1360185
19	1	800	1977	1	14	645	3.50	1.2	1.2	0	9.610664	1.2	11.5327970
20	1	800	1977	2	24	30	1.00	1.6	1.6	0	16.221749	2.5	40.5543729
21	1	800	1977	2	27	515	4.50	0.9	0.9	0	8.054946	2.4	19.3318704
22	1	800	1977	3	4	630	2.50	1.3	1.3	0	11.940354	2.5	29.8508860
23	1	800	1977	3	5	415	1.50	0.3	0.3	0	2.352846	0.8	1.8822765

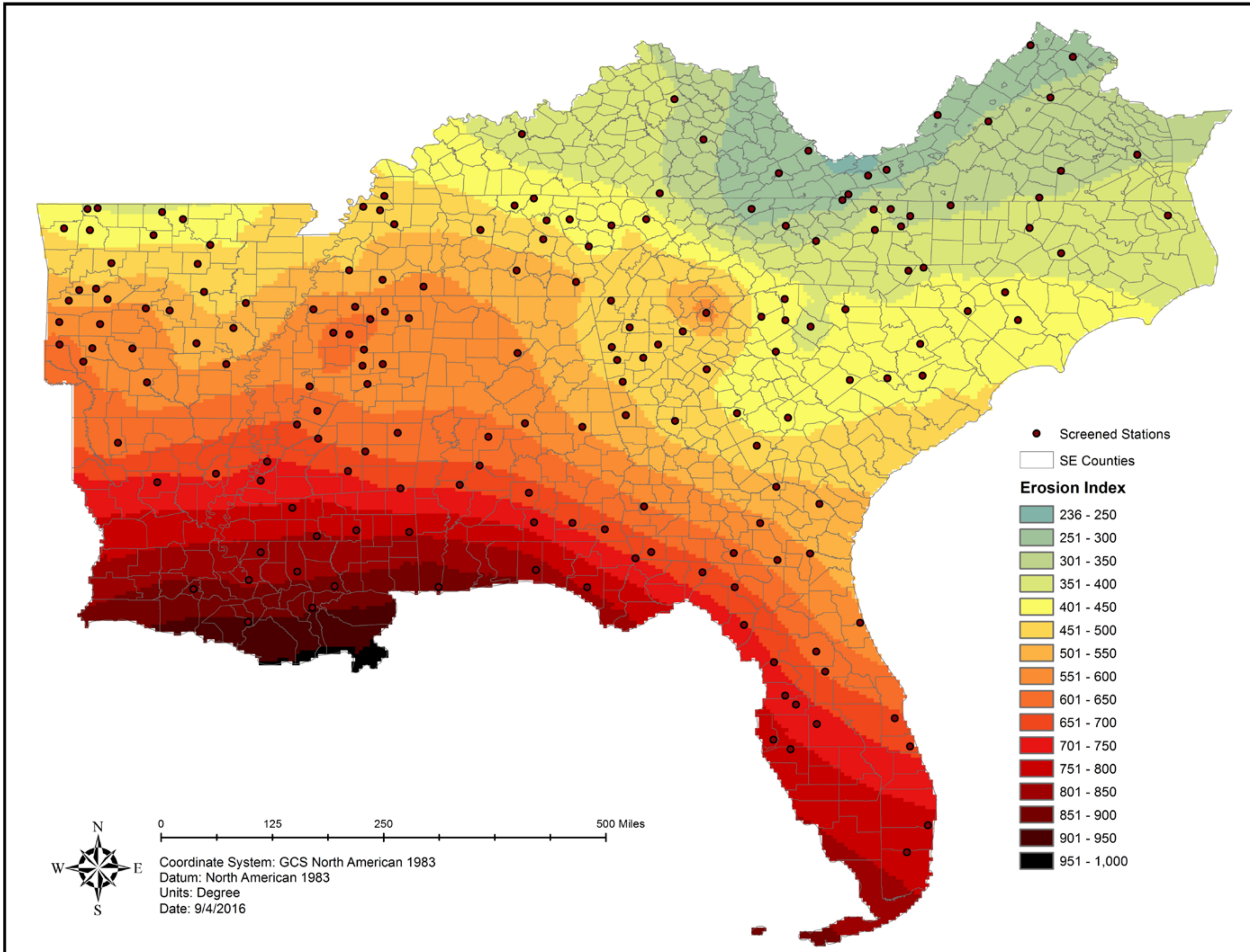
Showing 1 to 23 of 2,505,942 entries

Annual EI

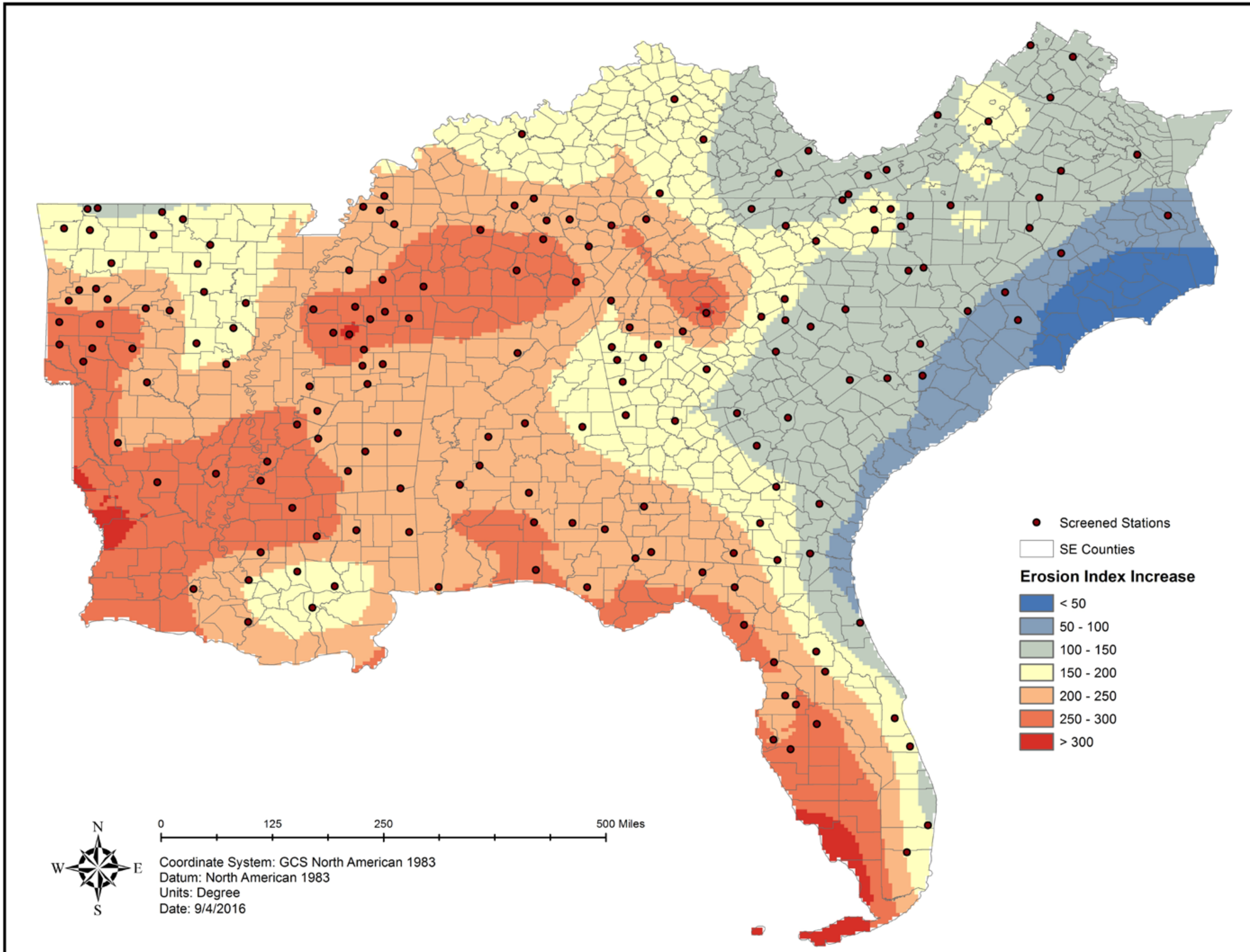
- **Sum of Storm EI for Each Year at a Given Location**
  - Usually 30 – 1000 for Most Years
  - Can be as High as 1500 or More
  - AH537 Data from 1930's – 1950's
  - New Data from 1970 – 2010

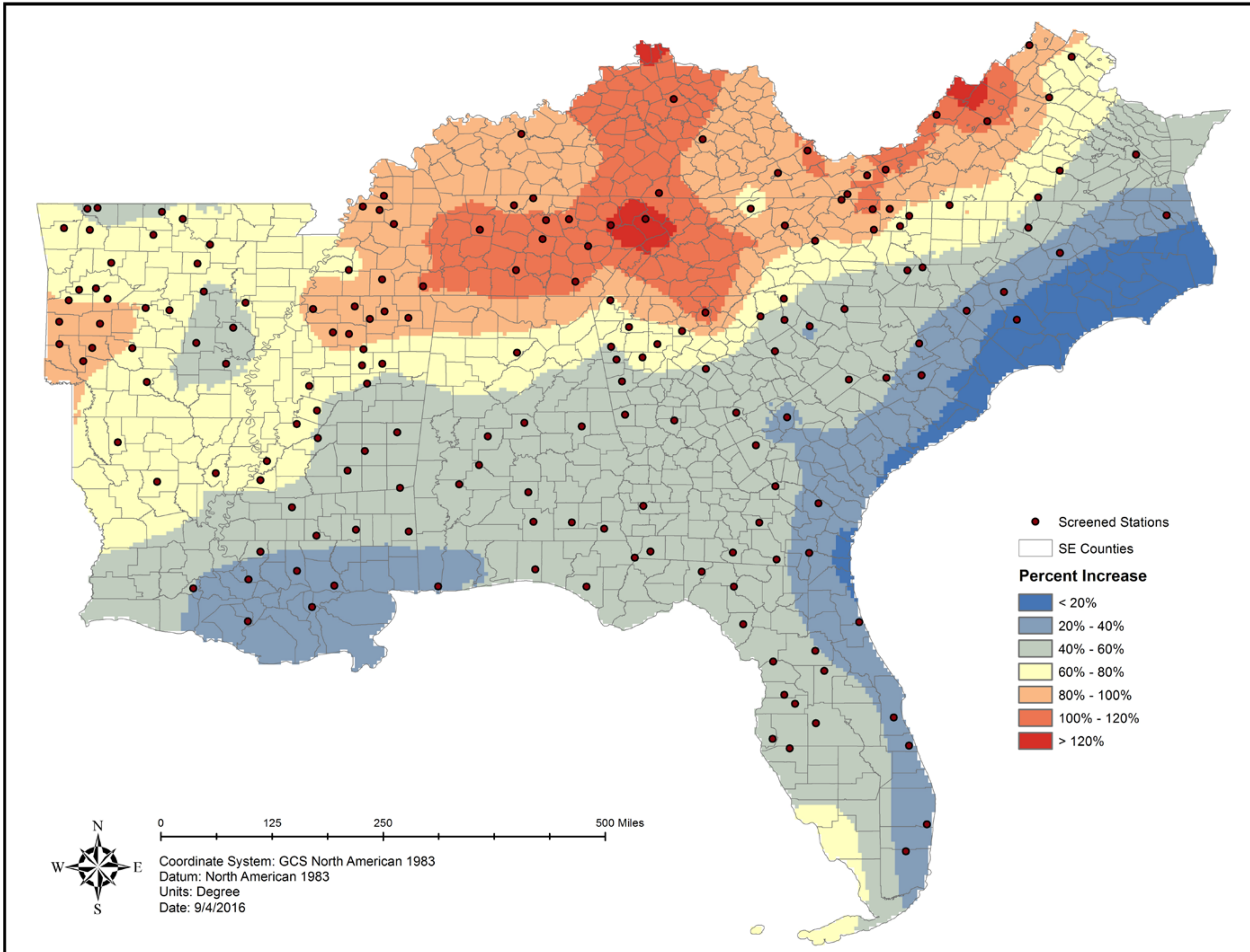
- **Analysis To Date**
  - 50%, 20%, and 5% Probabilities Analyzed (AH537)
  - Mean, SD, Minimum, and Maximum EI Values
  - Absolute Increase
  - Relative Increase


SECounties
Erosion Index
117 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
501 - 550
551 - 600
601 - 650
651 - 700
701 - 750
0
125
250
500 Miles
N
S
E
W
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/5/2016



Screened Stations
SE Counties
Erosion Index
236 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
501 - 550
551 - 600
601 - 650
651 - 700
701 - 750
751 - 800
801 - 850
851 - 900
901 - 950
951 - 1,000
N
W
E
S
0
125
250
500 Miles
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/4/2016


Screened Stations
SE Counties
Erosion Index Increase
< 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
> 300
0
125
250
500 Miles
N
W
E
S
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/4/2016


Screened Stations
SE Counties
Percent Increase
< 20%
20% - 40%
40% - 60%
60% - 80%
80% - 100%
100% - 120%
> 120%
N
W
E
S
0
125
250
500 Miles
Coordinate System: GCS North American 1983
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Units: Degree
Date: 9/4/2016

Single Storm EI

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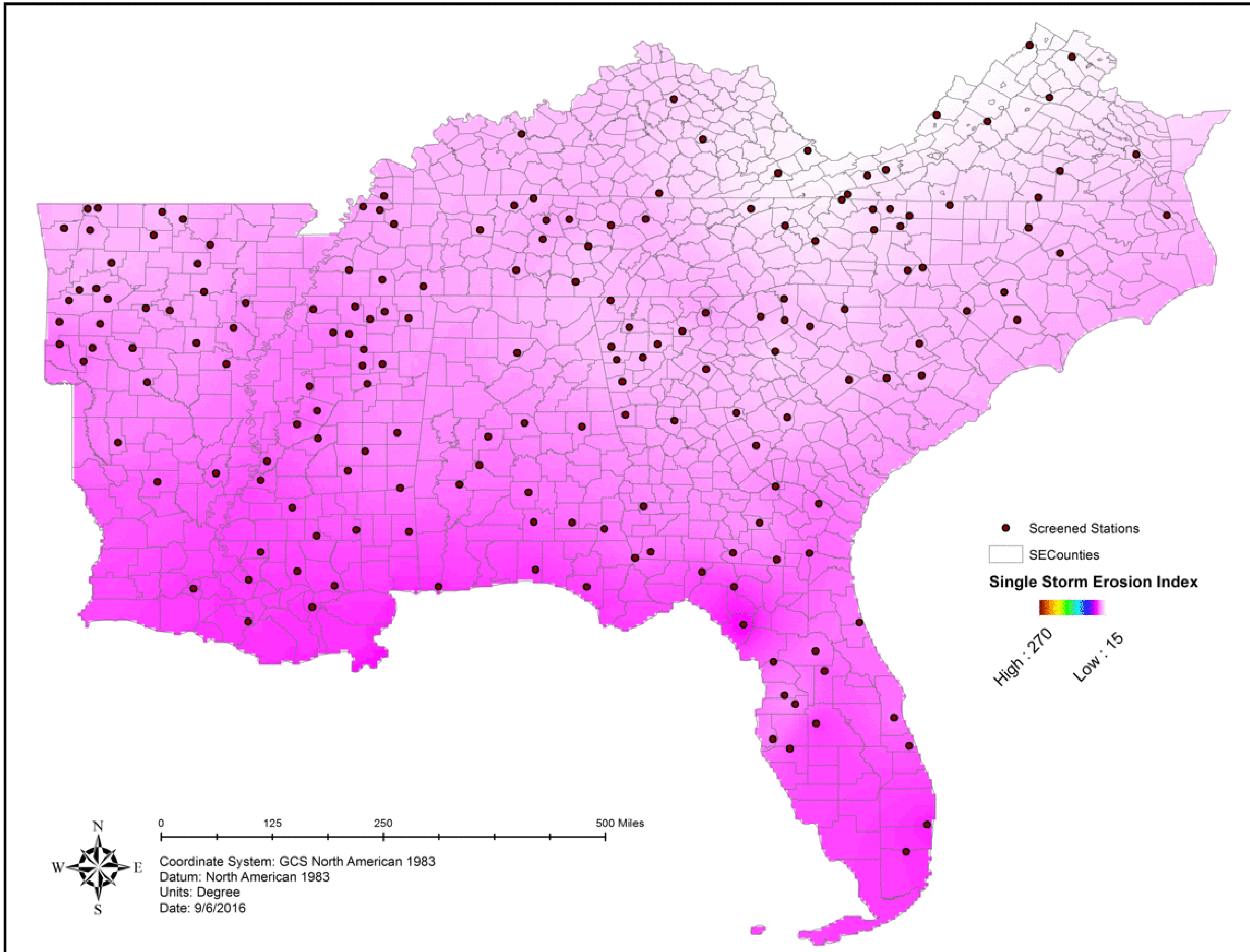
- **All Storms at a Location**
  - Usually Less Than 50 for Most Storms
  - Can be as High as 300 or More
- **Analysis To Date**
  - Probability of Exceedance
  - 1, 2, 5, 10, and 20-year Return Periods (AH537)
- **Frequency vs. Severity (In Progress)**
  - Compare with AH537 Storm Probabilities
  - Frequency of Large Storms Expected to Increase
  - Severity of Large Storms Expected to Increase



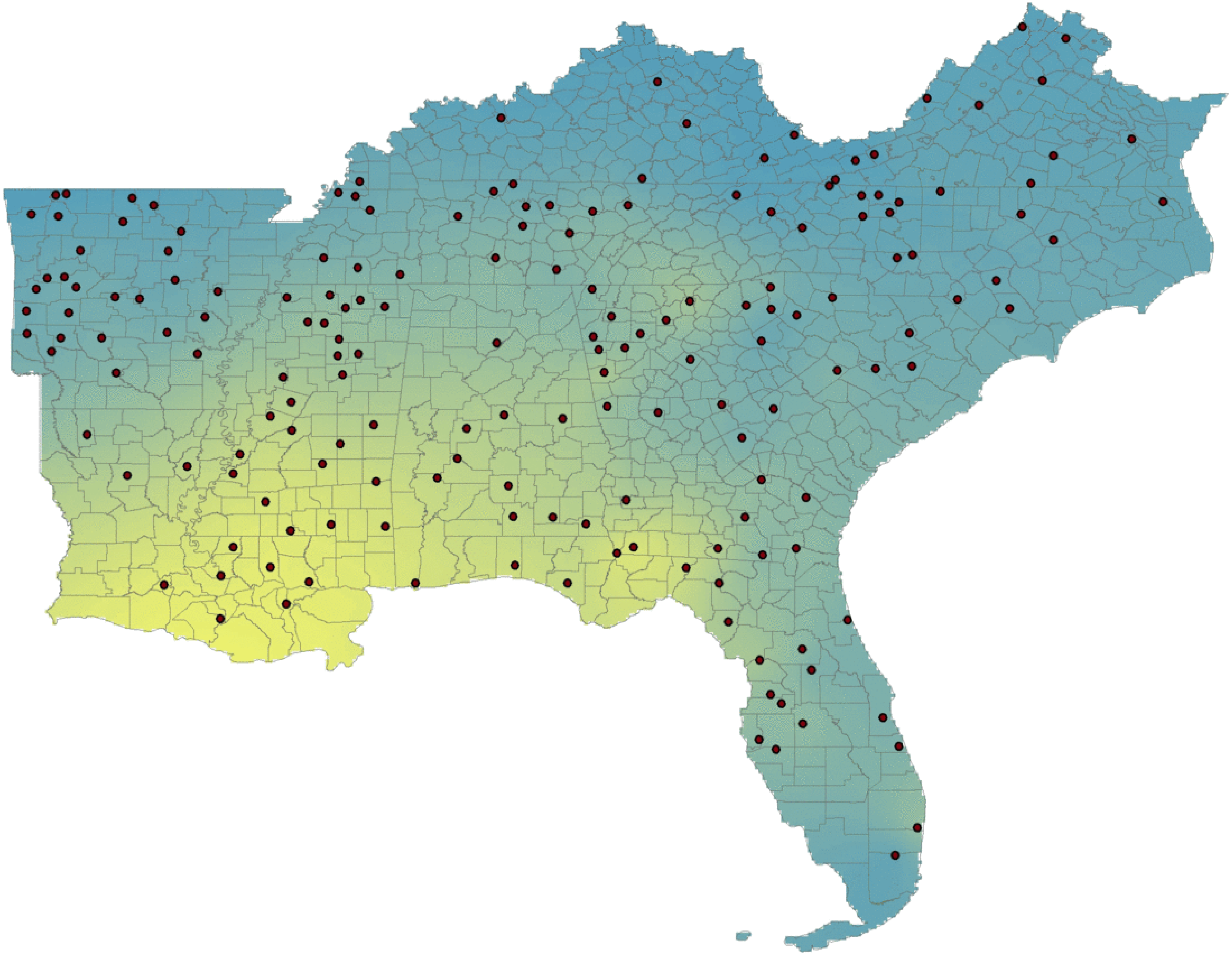
Screened Stations
SECounties
Single Storm Erosion Index
High : 270
Low : 15
0
125
250
500 Miles
N
W
E
S
Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree
Date: 9/6/2016

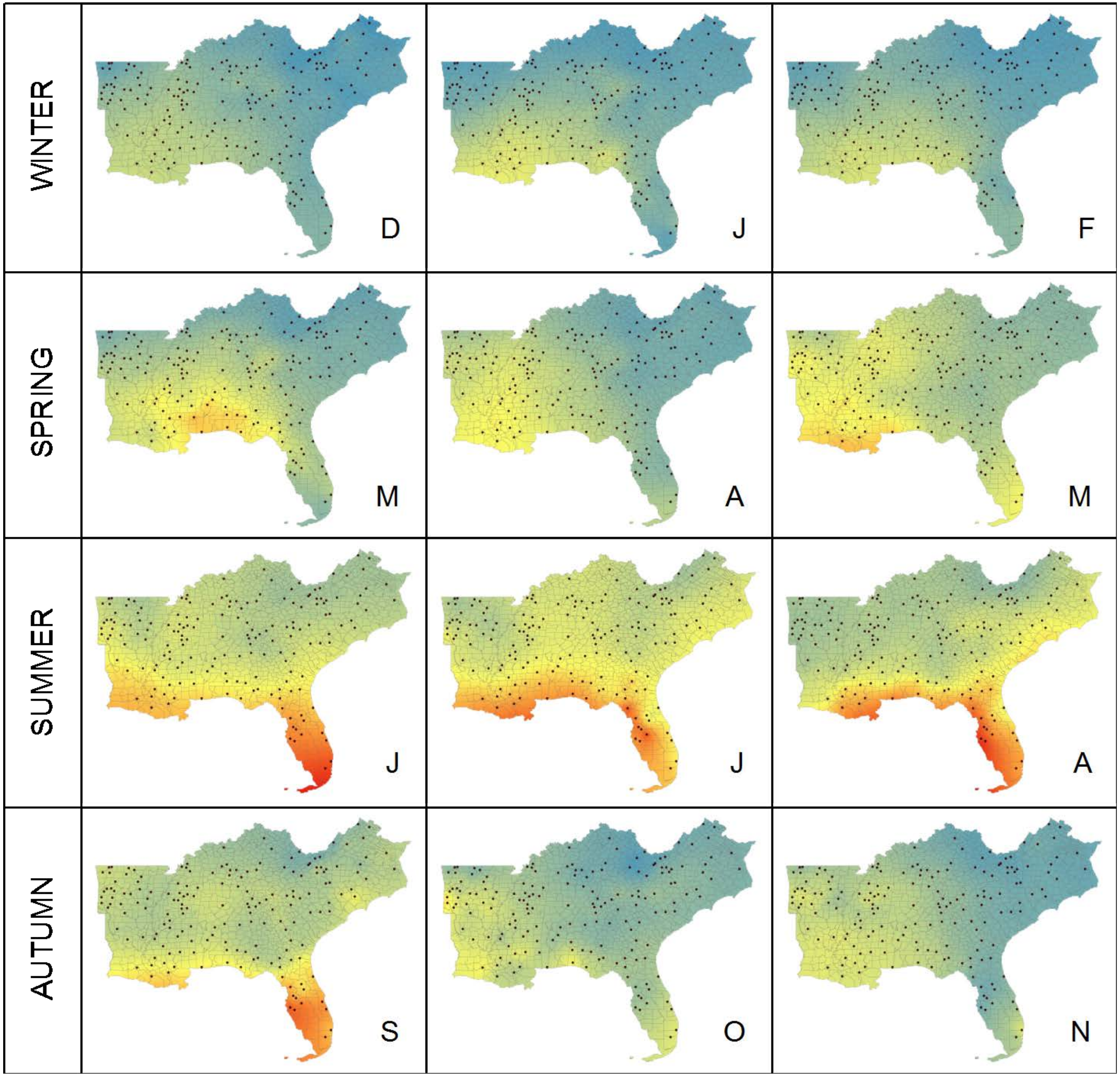
Monthly EI

- **Sum of Storm EI for Each Month at a Given Location**
  - April – October is Higher in the Southeast
  - Can be as High as 300 or More

- **Analysis To Date**
  - 50%, 20%, and 5% Probabilities Analyzed (AH537)
  - Mean, SD, Minimum, and Maximum EI Values

- **Intra-Annual and Inter-Annual Variability**
  - Precipitation Amounts vs. Energy Density
  - ENSO Driven EI and Precipitation Patterns





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CONCLUSION

Take-Aways

- **DSI-3260 Data Quality:**
  - Screening enables the use of about 40%
  - Less if years must be consecutive (for trend analysis)
- **EI for the Southeast:**
  - Annual EI (Increased 3%-132%; 62% on Average)
  - Storm EI (EI Change Driven by Frequency, Severity, or Both)
  - Monthly EI Variability Provided at High Resolution
- **Consistency with Existing Literature:**
  - Nearing et. al (2004) Predicted 17%-58% Magnitude Changes
  - McGregor et. al (1995) Observed 30% Increase in EI
  - Trenberth et. al (2003) Predicts 7% Intensity Increase K^{-1}

Contact: rpm0010@auburn.edu

Future Work

- **Observed Change Effect on EI**
  - Trend Analysis of EI (Change vs. Variation & How Much)
  - Annual Change, Monthly Change, Duration Change

- **ENSO Driven EI**
  - Significance of El Nino and La Nina on EI
  - Trend Analysis of ENSO Effect on EI by Duration
  - GAM Analysis

- **Projected Change Effect on EI**
  - Train Artificial Neural Network (ANN) with New EI
  - Run ANN for All NARCCAP Models

ADDITIONAL SLIDES

Workflow

By the Numbers:

11 Tar-Z Files (1 per State)

2 Data Types (QPCP and QGAG)

1,348,610 QPCP Records Extracted

1,348,240 QPCP Records Processed

3,620,570 Continuous Events

148,591 Recorded Months

148,035 Measured Months

79,470 Accumulation Events

42,911 Deleted Periods

35,016 Missing Periods

123 Unmatched Deleted Periods

77 Unmatched Missing Periods

7 Unmatched Accumulations

3,339,113 Continuous Measured Events

2,507,300 Individual Storm Events

1 Erroneous Station-Month

9 Screening Methods

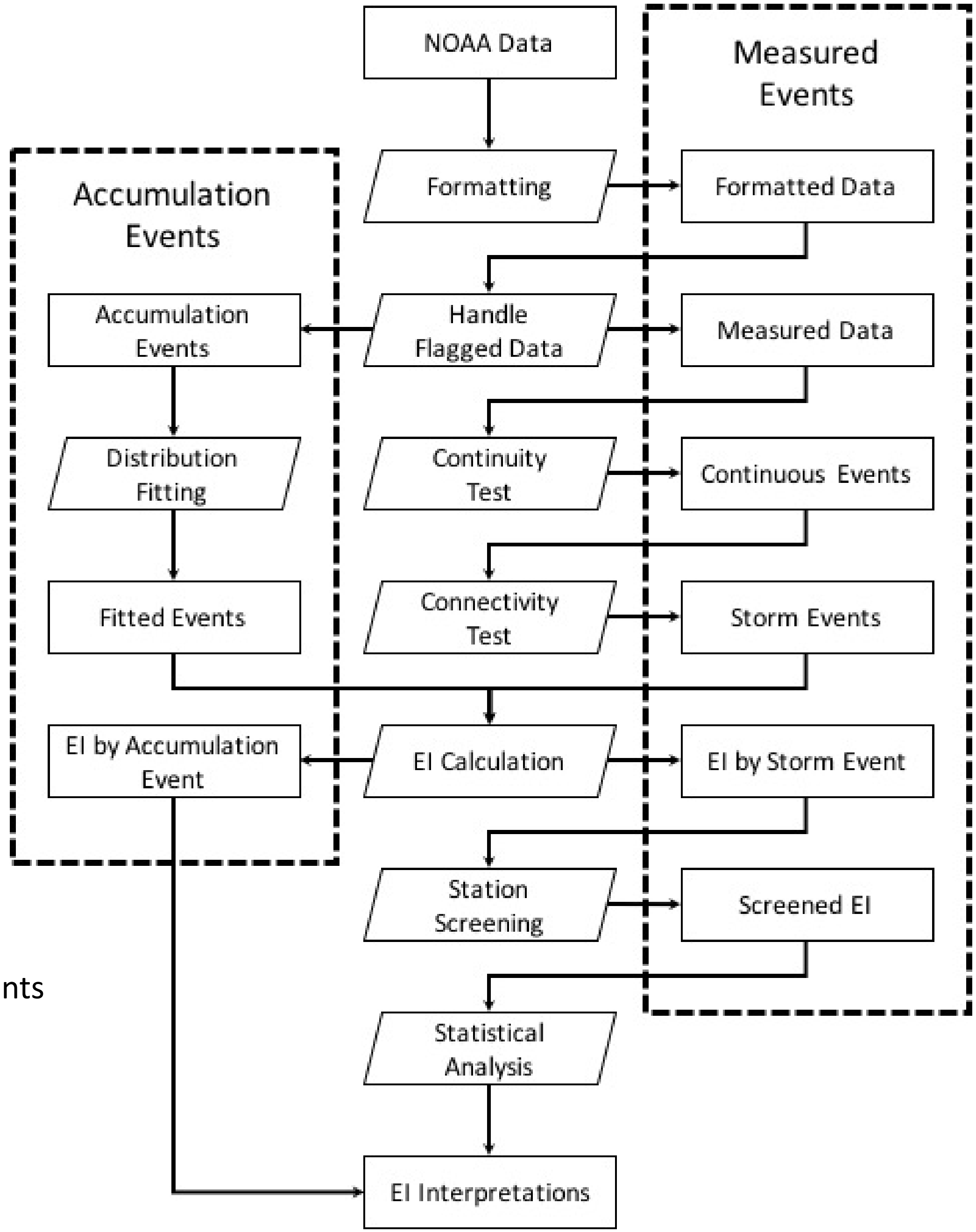

Chart readings		For each increment			Energy	
Time	Depth (inch)	Duration (minute)	Amount (inch)	Intensity (in/hr)	Per inch	Total
4:00	0					
:20	0.05	20	0.05	0.15	643	32
:27	.12	7	.07	.60	843	59
:36	.35	9	.23	1.53	977	225
:50	1.05	14	.70	3.00	1074	752
:57	1.20	7	.15	1.29	953	143
5:05	1.25	8	.05	.38	777	39
:15	1.25	20	0	0	0	0
:30	1.30	15	.05	.20	685	34
Totals		90	1.30			1,284

Kinetic energy of the storm $= 1{,}284(10^{-2}) = 12.84$

The energy per inch of rain in each interval (col. 6) is obtained by entering table 19 with the intensity given in column 5. The incremented energy amounts (col. 7) are products of columns 4 and 6. The total energy for this 90-minute rain is 1,284 foot-tons per acre. This is multiplied by a constant factor of 10^{-2} to convert the storm energy to the dimensions in which **EI** values are expressed.

The maximum amount of rain falling within 30 consecutive minutes was 1.08 in, from 4:27 to 4:57. I_{30} is twice 1.08, or 2.16 in/h. The storm **EI** value is $12.84(2.16) = 27.7$. When the duration of a storm is less than 30 minutes, I_{30} is twice the amount of the rain.

The **EI** for a specified time is the sum of the computed values for all significant rain periods within that time. The average annual erosion index for a specific locality, as given in figures 1 and 2, is the sum of all the significant storm **EI** values over 20 to 25 years, divided by the number of years. For erosion index calculations, 6 h or more with less than 0.5 in of precipitation was defined as a break between storms. Rains of less than 0.5 in, separated from other showers by 6 h or more, were omitted as insignificant unless the maximum 15-min intensity exceeded 0.95 in/h.

Recent studies showed that the median dropsize of rain does not continue to increase for intensities greater than about 2.5 to 3 in/h (*7, 15*). Therefore, energy per unit of rainfall also does not continue to increase, as was assumed in the derivation of the energy-intensity table published in 1958 (*62*). The value given in table 19 for rain at 3 in/h (7.6 cm/h in table 20) should be used for all greater intensities. Also, analysis of the limited soil loss data available for occasional storms with 30-min intensities greater than 2.5 in/h showed that placing a limit of 2.5 in (6.35 cm)/h on the I_{30} component of **EI** improved prediction accuracy for these storms. Both of these limits were applied in the development of figure 1. They slightly lowered previously computed erosion index values in the Southeast, but average-annual **EI** values for the U.S. mainland other than the Southeast were not significantly affected by the limits because they are rarely exceeded.

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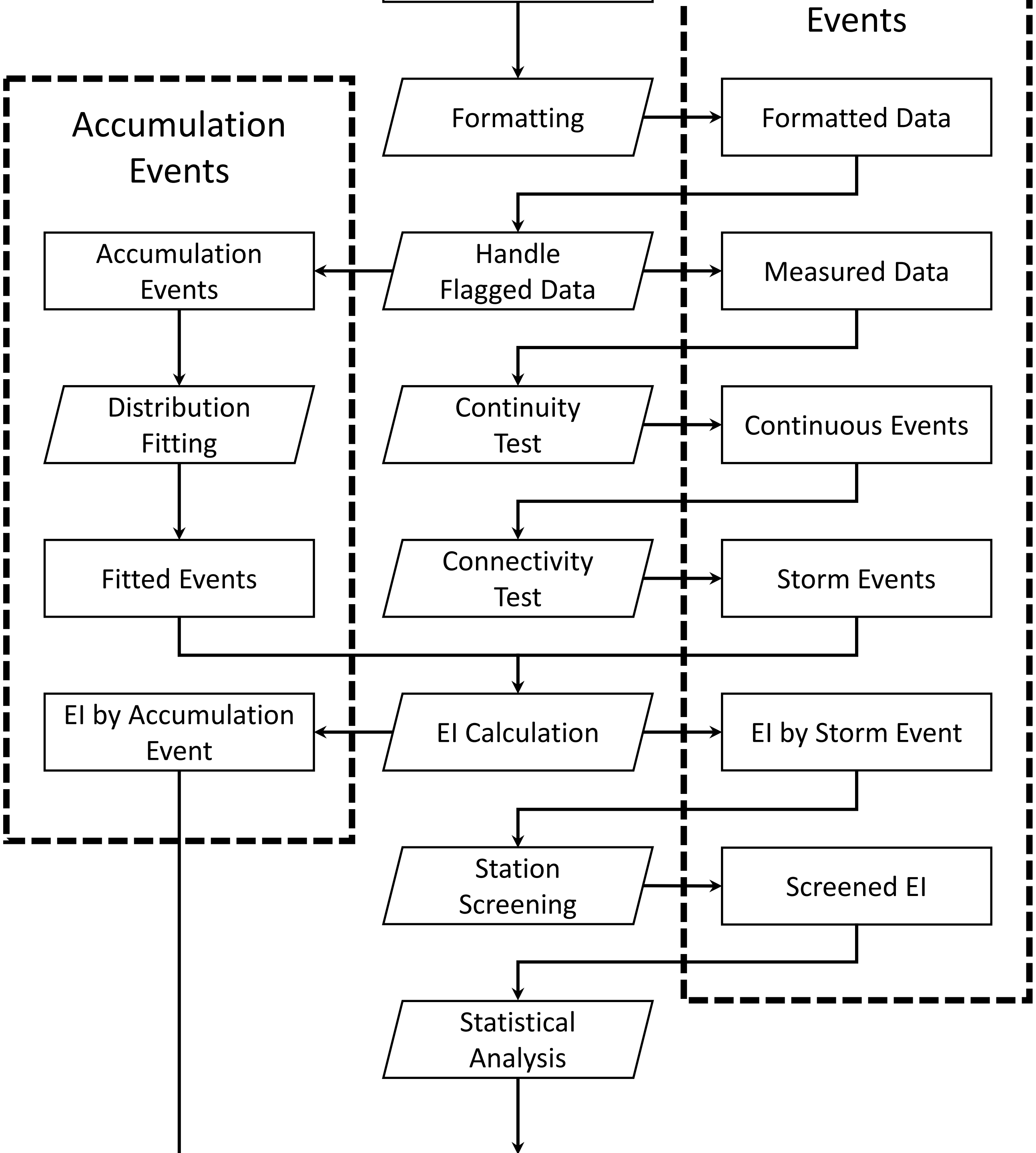
TABLE 17.—*Observed range and 50-, 20-, and 5- perce* *key lo*

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
Alabama:				
Birmingham	179-601	354	461	592
Mobile	279-925	673	799	940
Montgomery	164-780	359	482	638
Arkansas:				
Fort Smith	116-818	254	400	614
Little Rock	103-625	308	422	569
Mountain Home	98-441	206	301	432
Texarkana	137-664	325	445	600
California:				
Red Bluff	11-240	54	98	171
San Luis Obispo	5-147	43	70	113
Colorado:				
Akron	8-247	72	129	225
Pueblo	5-291	44	93	189
Springfield	4-246	79	138	233
Connecticut:				
Hartford	65-355	133	188	263
New Haven	66-373	157	222	310
District of Columbia ..	84-334	183	250	336
Florida:				
Apalachicola	271-944	529	663	820
Jacksonville	283-900	540	693	875
Miami	197-1225	529	784	1136
Georgia:				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 18.—*Expected magnitudes*

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
Alabama:					
Birmingham	54	77	110	140	170
Mobile	97	122	151	172	194
Montgomery	62	86	118	145	172
Arkansas:					
Fort Smith	43	65	101	132	167
Little Rock	41	69	115	158	211
Mountain Home	33	46	68	87	105
Texarkana	51	73	105	132	163
California:					
Red Bluff	13	21	36	49	65
San Luis Obispo	11	15	22	28	34
Colorado:					
Akron	22	36	63	87	118
Pueblo	17	31	60	88	127
Springfield	31	51	84	112	152
Connecticut:					
Hartford	23	33	50	64	79
New Haven	31	47	73	96	122
District of Columbia	39	57	86	108	136
Florida:					
Apalachicola	87	124	180	224	272
Jacksonville	92	123	166	201	236
Miami	93	134	200	253	308
Georgia:					
Atlanta	49	67	92	112	134
Augusta	34	50	74	94	118
Columbus	61	81	108	131	152
Macon	53	72	99	122	146
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



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