Factors Affecting Storm Surge Hazard in the Battery and Vicinity (BAV)

2013

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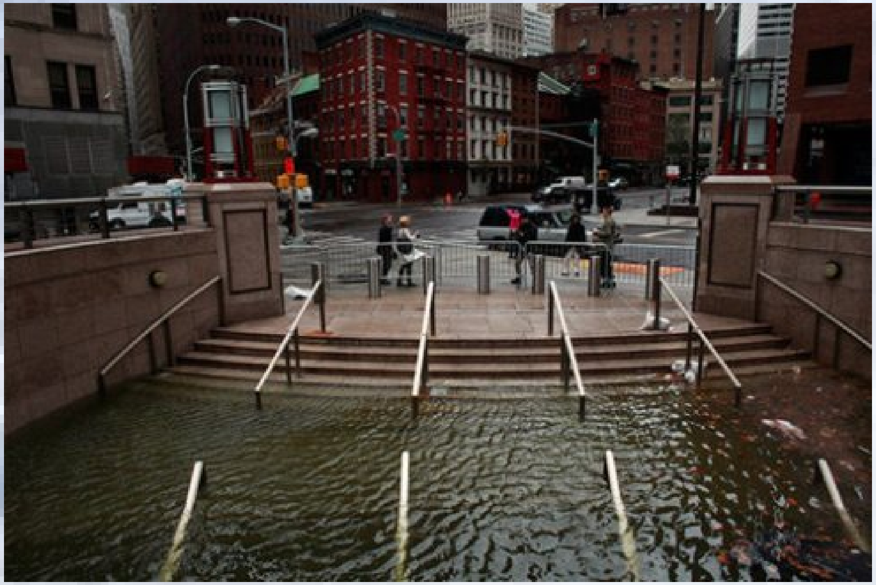
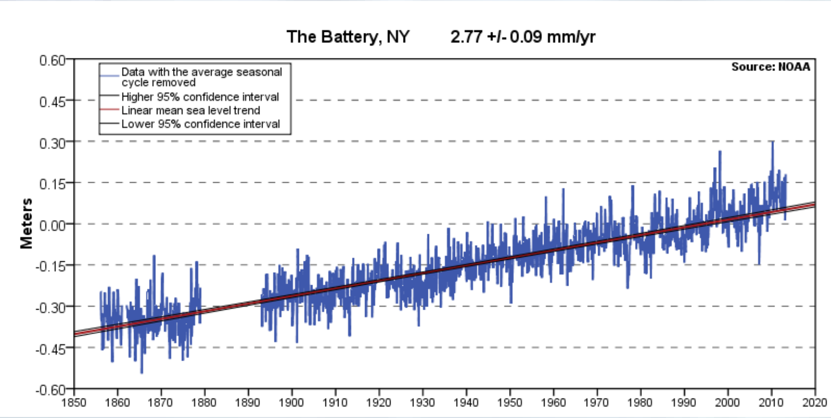
Don Resio

Introduction

- New York City at Risk
- Two of the last three years surpassed 100-year and one surpassed 500-year level



- The risk will continue to rise for this area due to SLR



Overview

- Motivation
- Conclusions
- Methodology
- Discussion
- References

Motivation

- Following Sandy and Irene questions were raised concerning common assumptions of storm frequencies and intensities in this area
- Previous studies have focused on long term warming or secular variation and not on non-secular variation
- Improved quantification of local surge hazards would allow more efficient planning
- Improved data have become available over the last five years

Motivation: Previous Studies

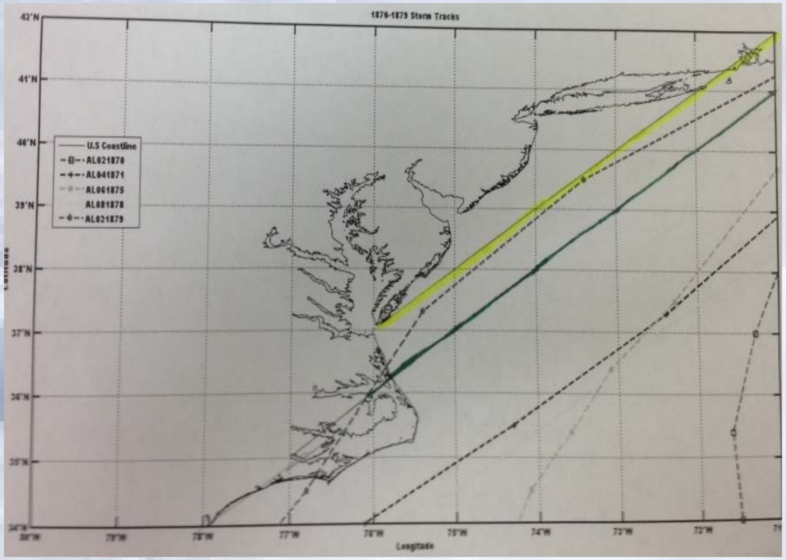
- Blumberg, Orton and Hall (Stevens Institute) are currently investigating models of synthetic storm events to quantify storm surge hazards
- Lin et Al 2012- Estimated surge hazards using synthetic storms based on climatological characteristics between (1981-2000): Sandy :500, Irene: 100
- Hwang 2012- Estimated hazards using GEV analysis on tide gauge data at the Battery
- USACE : FIMP Study was conducted but information and findings never released

Conclusions

- There is no statistically significant relationship between storm intensity and frequency
- Preliminary results suggest that storm occurrence follows a Poisson distribution through time
- A statistically significant relationship exists between intense storm occurrence and a combination of atmospheric circulation and sea surface temperature
- Multi-year variability should be included in hazard maps and may contribute to improved seasonal forecasts of regional hazard

Data

- NCEP/ NCAR Reanalysis 2 (Compo et al 2011)
- HURDAT 2 (NOAA 2013)
- NWS 38 (Ho et al 1987)
- NOAA Extended Reconstructed SST (NOAA 2013)



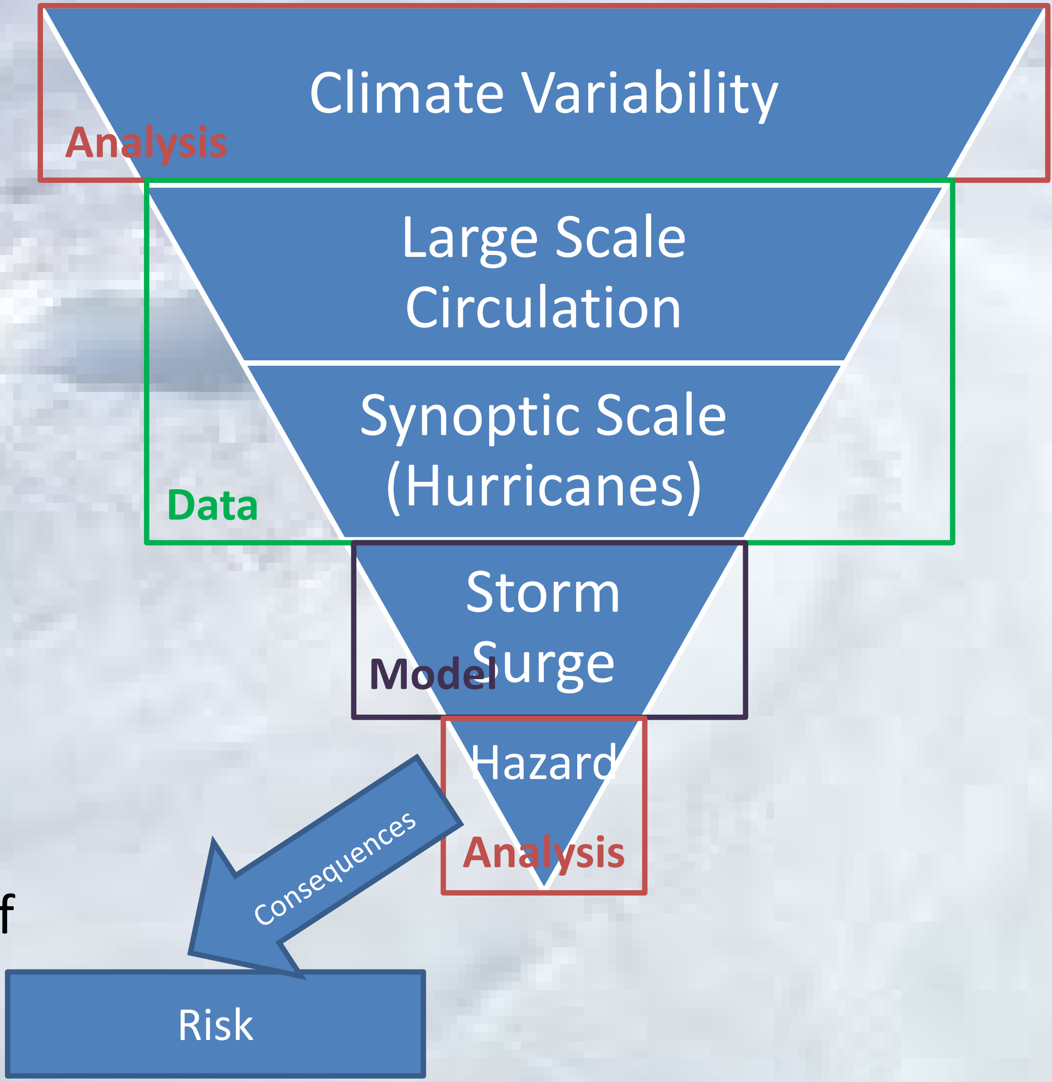
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION
NCEP

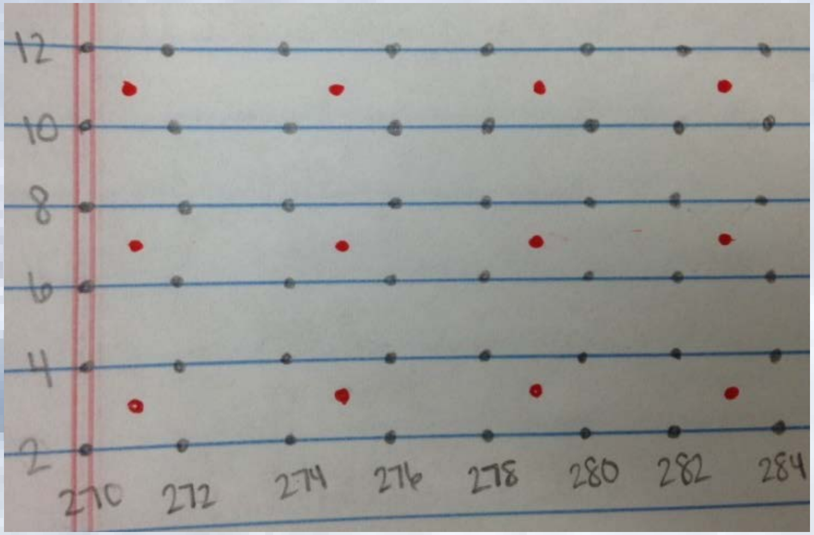
Methodology

- Investigate the presence of relationships among pressure patterns, sea surface temperature, intensity and frequency of storms through a series of chi squared tests
- Develop eigenvectors to define different pressure patterns
- Take the weightings of the eigenvectors on the pressure differences from the mean
- Compare using contingency tables
- Today we will focus on climate variability, large scale circulation, and the behavior of hurricanes



Developing Eigen Vectors

- Upscale and Limit the Pressure Data (3-59˚N and 271-17˚E)
- Calculate 5 Day Means for Each
- Form Covariance Matrix
- Calculate eigenvectors with descending % of Variance
- Use eigenvectors to calculate weightings on 5 day running average deviations



$$\mathrm{cov}(x,y)=\sum_{i=1}^{n}\frac{(x_i-\bar{x})(y_i-\bar{y})}{n-1}$$

All Storms

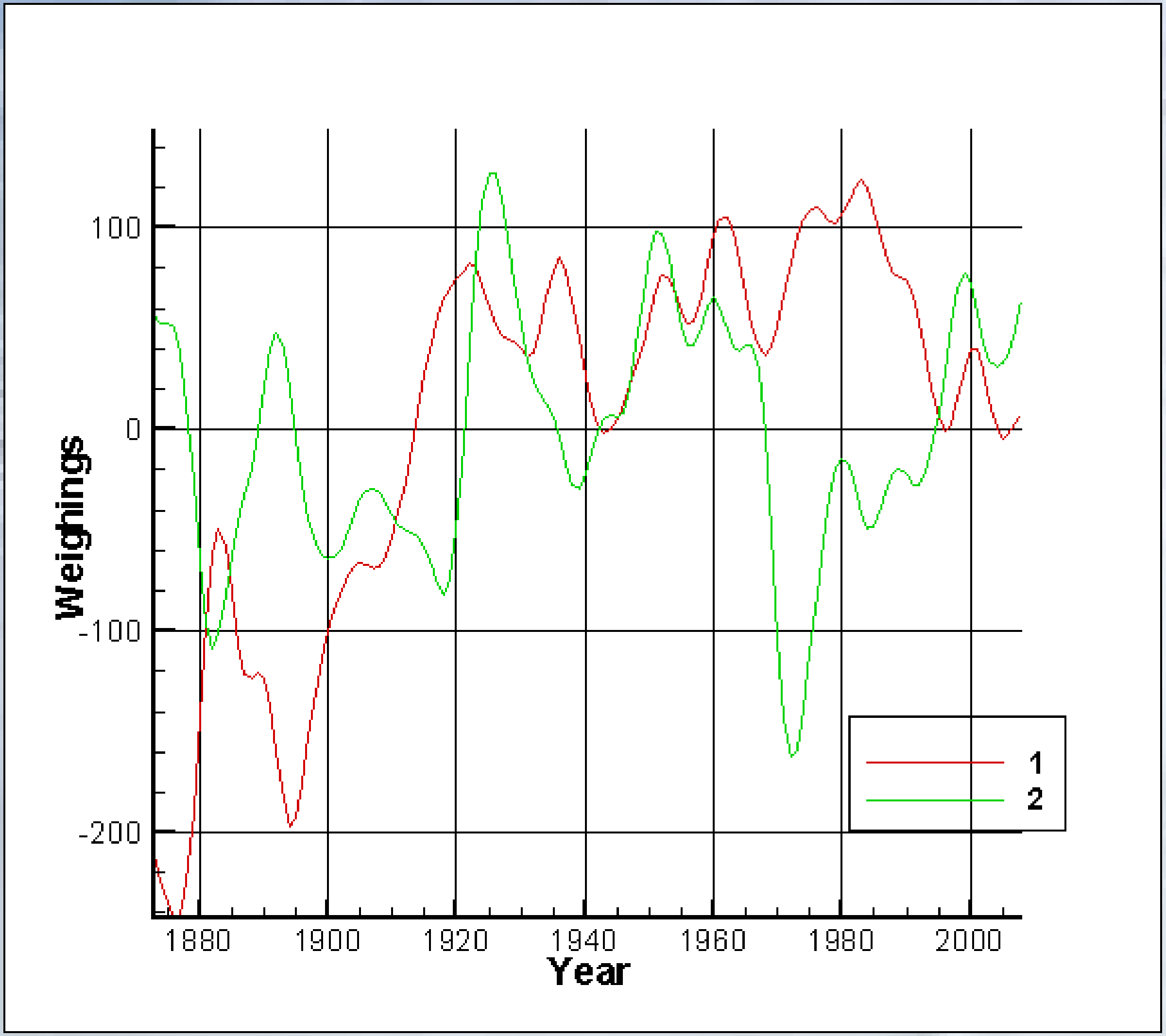
- Intense Storms: Cp ≤ 980

Storm	P Max
AL061851	----
AL031856	----
AL031858	----
AL081861	999
AL071866	----
AL061869	963
AL041877	----
AL021879	984
AL061881	----
AL041882	----
AL021886	----
AL041893	----
AL111893	----

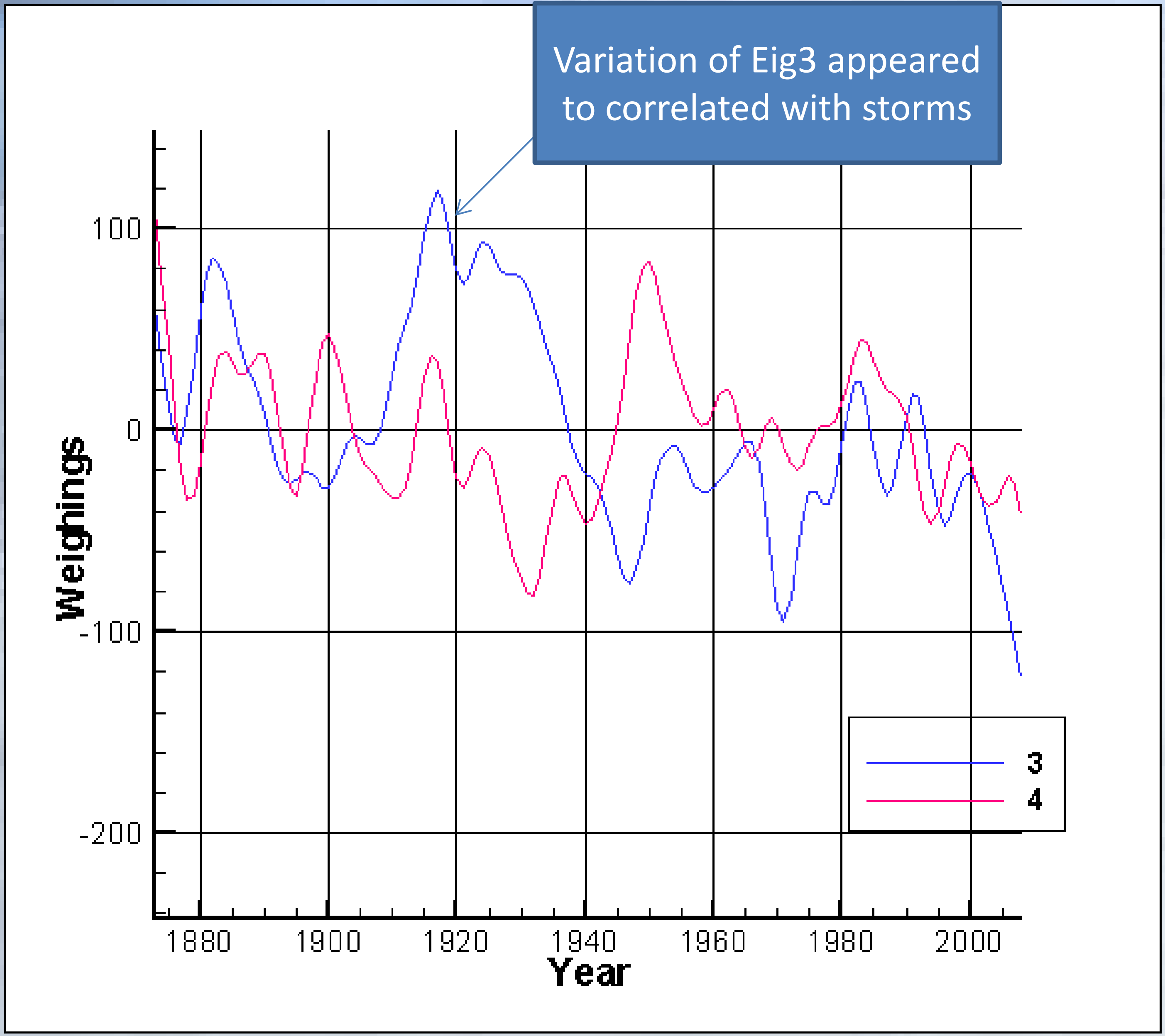
AL051894	----
AL031897	----
AL061900	----
AL041903	990
AL011907	----
AL021908	----
AL011916	990
AL031916	993
AL071934	989
AL061938	941
AL071943	----
AL031944	----
AL071944	966
AL111944	----

AL031954	976	Carol
AL021955	969	Connie
AL051960	970	Donna
AL061961	----	Unnamed
AL091971	997	Doria
AL021972	980	Agnes
AL071976	977	Belle
AL091985	951	Gloria
AL101985	1006	Henri
AL051986	990	Charley
AL031991	964	Bob
AL081999	980	Floyd
AL112000	1005	Gordon
AL012001	1004	Allison
AL022004	1012	Bonnie
AL032004	1014	Charley
AL022007	991	Barry
AL092011	958	Irene
AL182012	943	Sandy

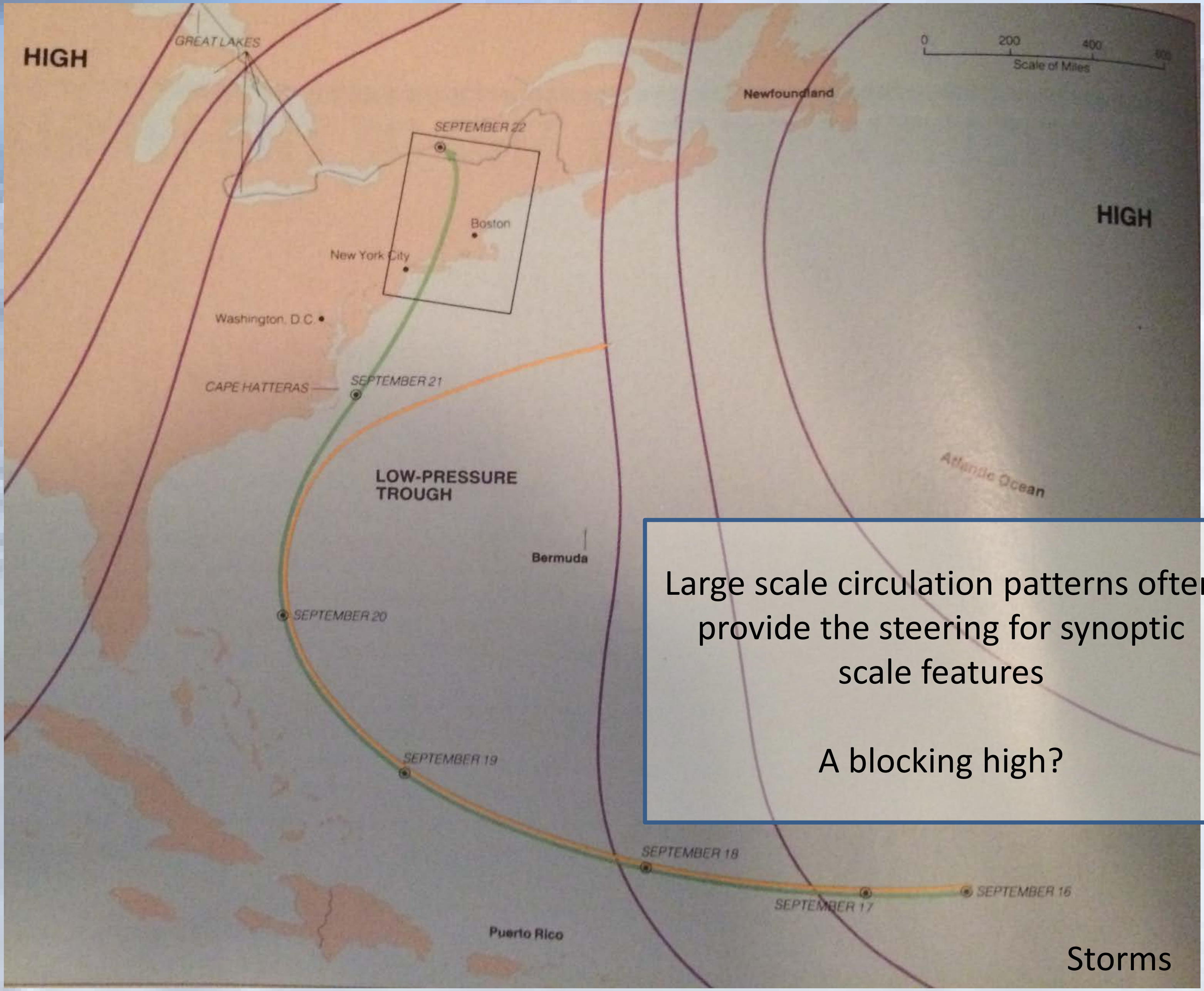
Weightings



100
0
-100
-200
Weighings
1880
1900
1920
1940
1960
1980
2000
Year
1
2


Variation of Eig3 appeared to correlated with storms
100
0
-100
-200
Weighings
1880
1900
1920
1940
1960
1980
2000
Year
3
4

1938 Storm Track

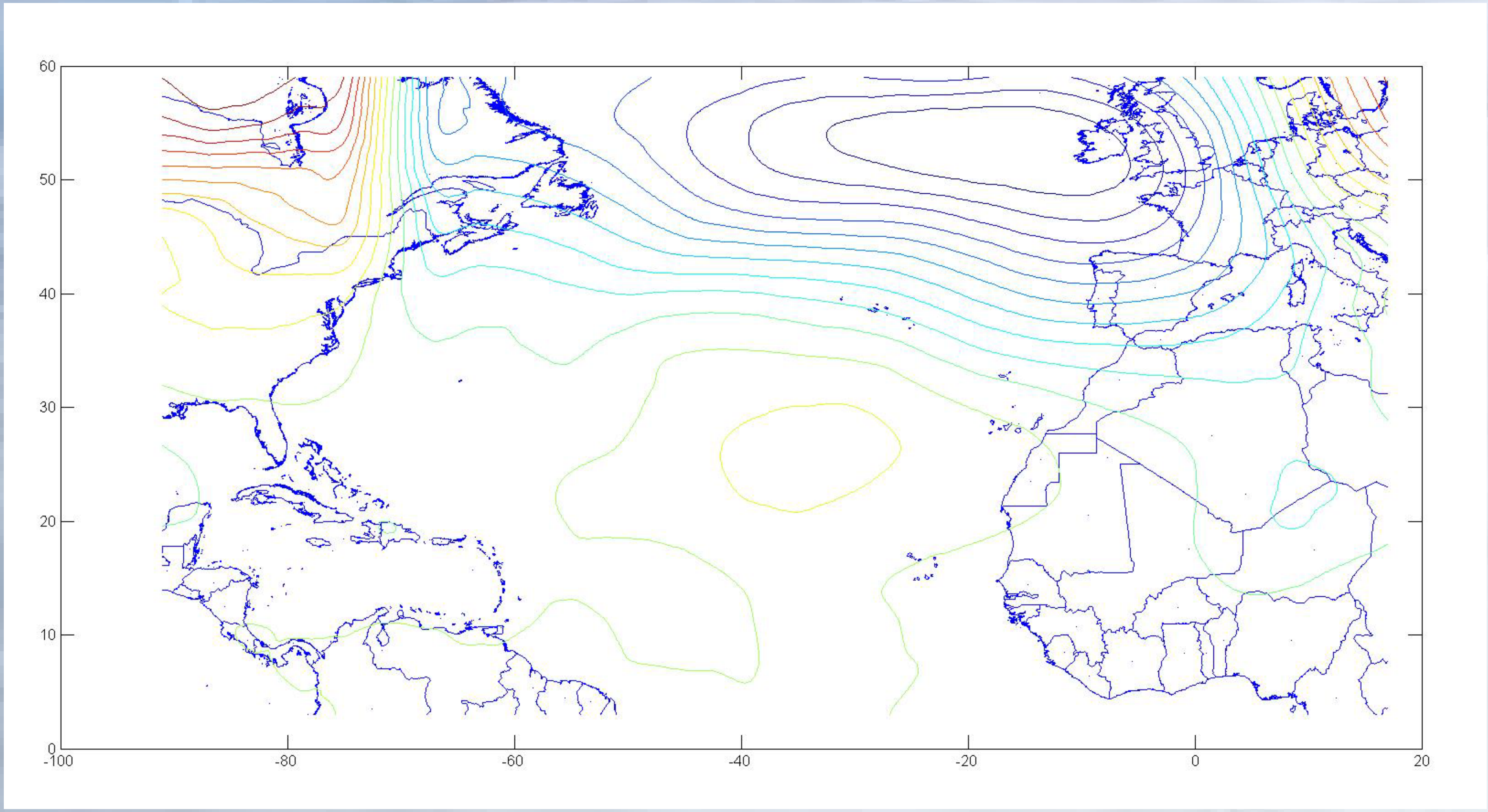


Large scale circulation patterns often provide the steering for synoptic scale features

A blocking high?

Storms

Contours of Eig 3



Test of Significance Using Contingency Table

- Develop a Contingency Table
- Form Null and Alternative Hypothesis
- H_0= No relationship
- H_a = A relationship exists
- $X^2 = \sum_{i=1}^{n} \frac{(Observed - Expected)^2}{Expected}$
- Determine Degrees of Freedom
- Compare this to Critical Value
- $X^2 \leq$ Critical Value: Do not reject null hypothesis
- $X^2 >$ Critical Value: Reject

Percentage Points of the Chi-Square Distribution

Degrees of Freedom	Probability of a larger value of x^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21

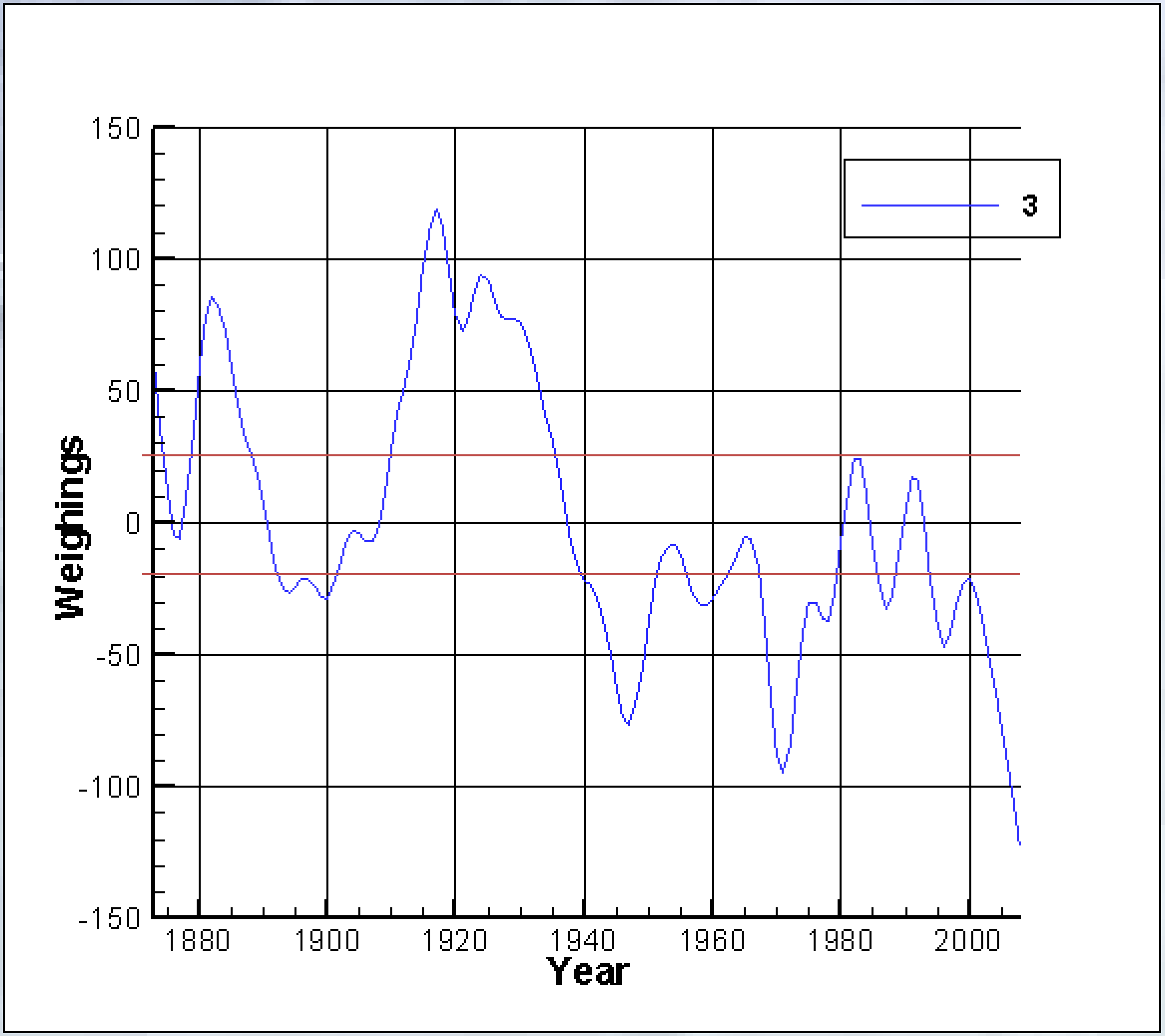
Contingency Table for Central Pressure and Frequency

Contingency Table			
	5 Year Freq. ≤2	5 Year Freq. >2	TOTALS
storms > 980	15	15	30
storms <= 980	6	3	9
TOTALS	21	18	39

- Chi Squared = 0.77; 1 Degree of Freedom
- Critical Value = 3.84
- Do not Reject Null Hypothesis (There is not significant evidence to support a relationship)

Weightings on Eigenvector 3

- In order to test relationships we partitioned weightings on Eig3 into three equal probabilities, i.e. 1/3 of the total probability falls into each class



One Dimensional Relationship of Weightings on Eig 3

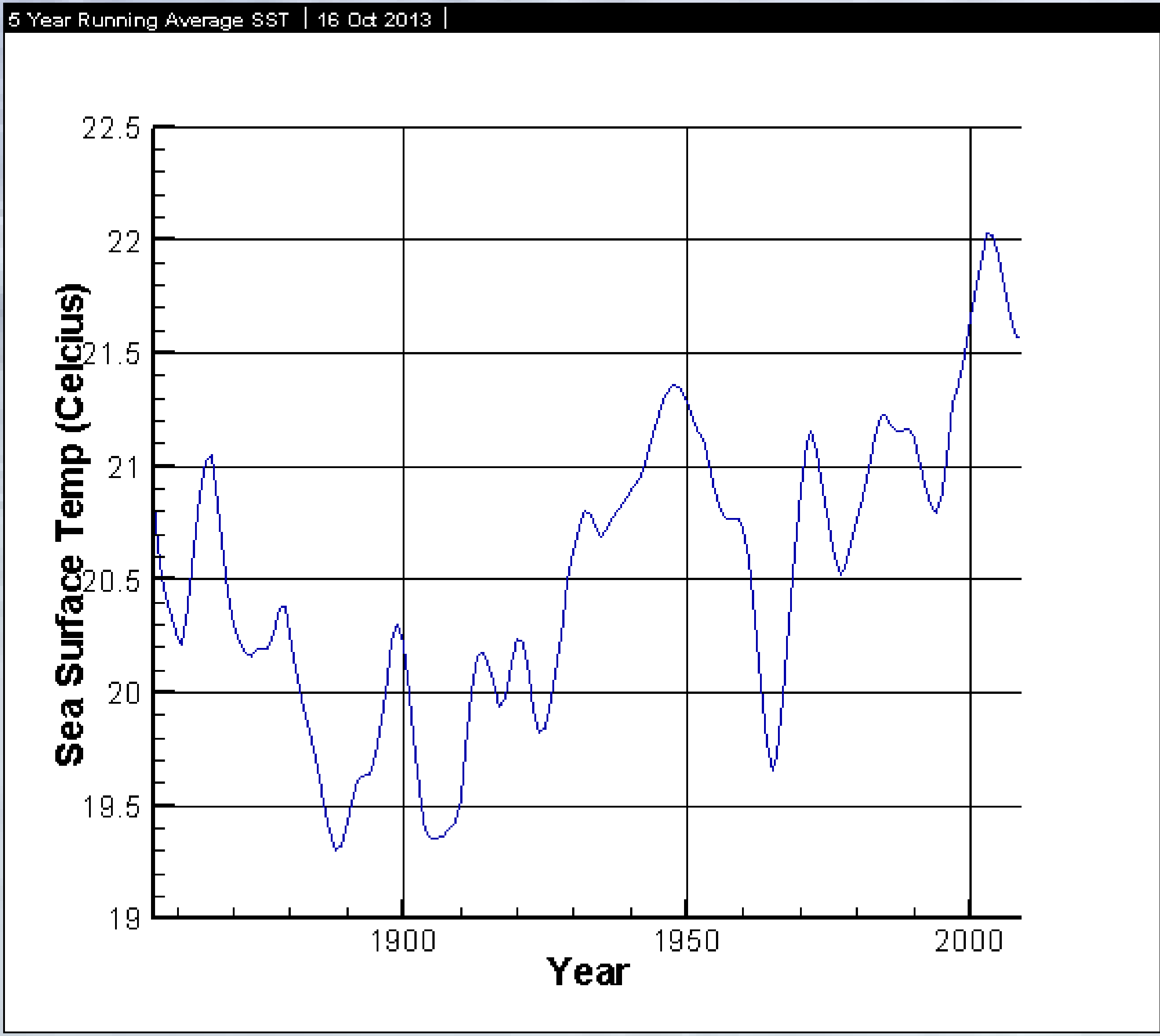
# Years With Storms in W_3 classes		
Neg W	Neutral	Pos W
19	12	8

# Years with Intense Storms in W_3 classes		
Neg W	Neutral	Pos W
6	4	0

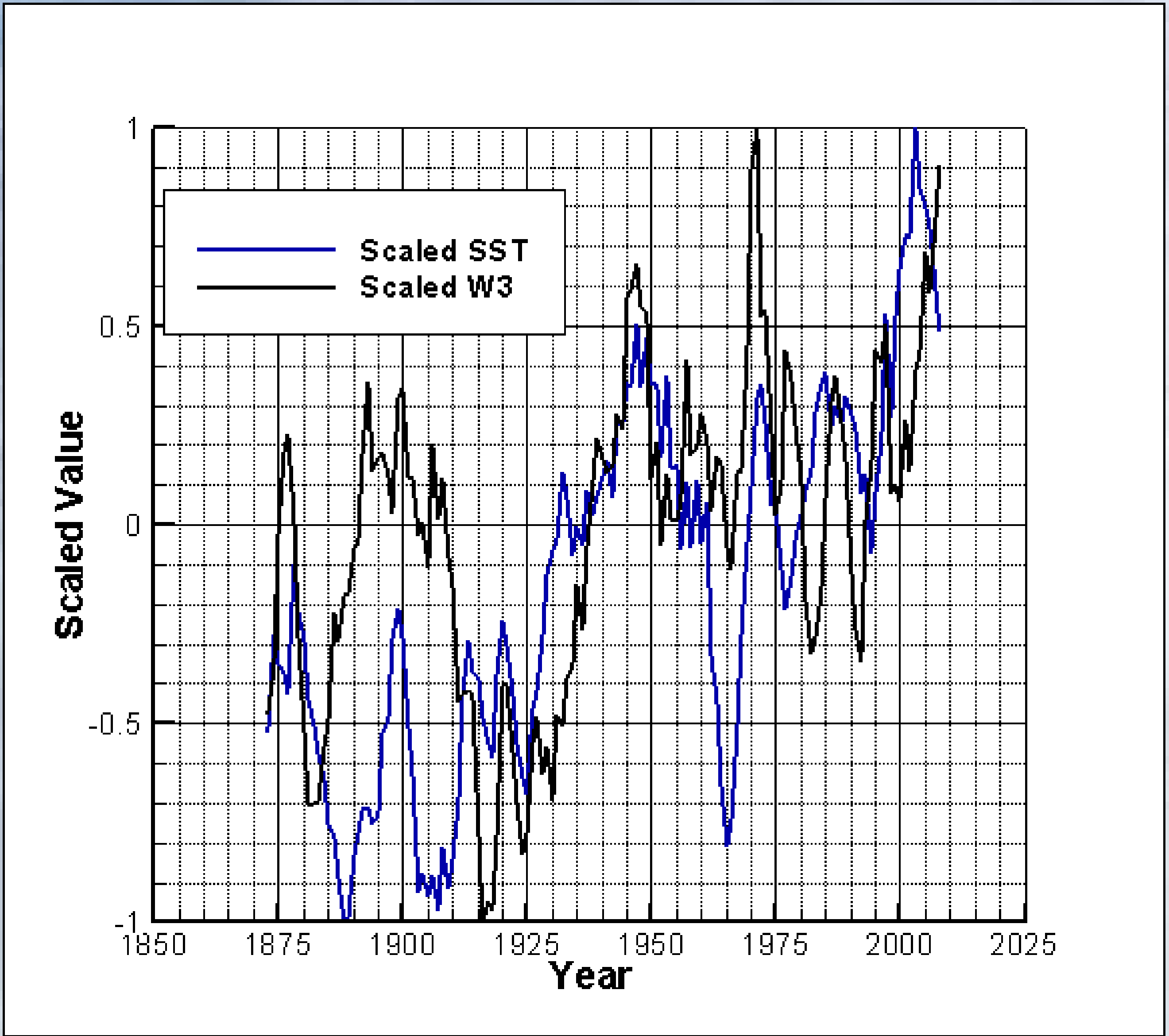
- The inverse of this pressure condition has effect on the intensity and frequency of tropical storms in the study region

Five Year Running Average Sea Surface Temperatures of Aug.-Nov.

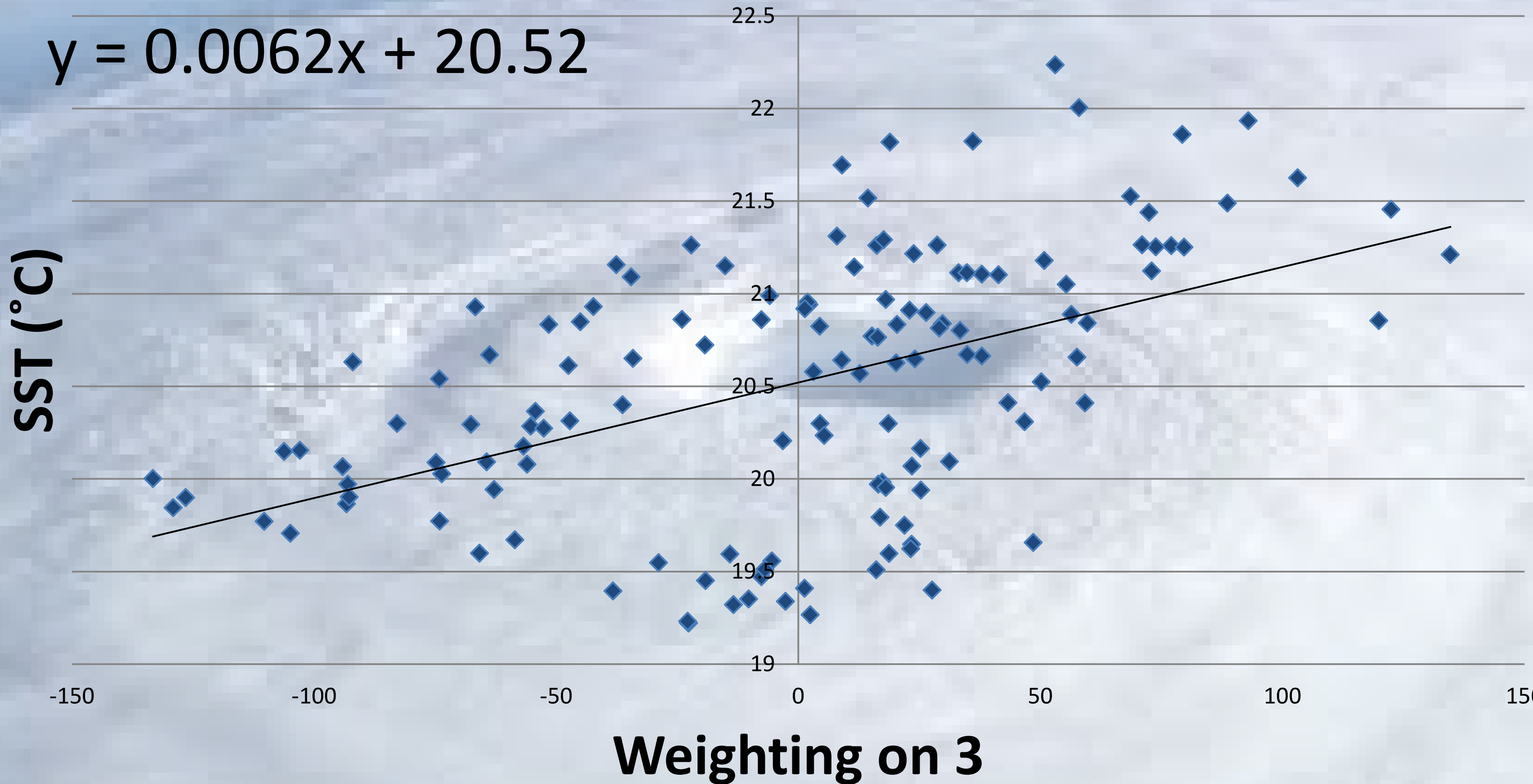
- Average: 20.51
- High > 20.86
- 2011 = 21.51
- 2012 = 21.74



Scaled Plots of SST and Eigenvector 3



SST vs. Weighting 3



- R= 0.4915
- A significant relationship exists (Above 0.01)
- Pearson and T-test

SST Vs. Weighting 3 Contingency Table of Years with High Intensity Storms

Category	Neg W_3	Neut W_3	Pos W_3
SST < 20.09	0	0	0
20.09 < SST < 20.86	2	2	0
20.86 < SST	4	2	0

- Cp < 980 for Intense Storms
- X squared =9.59, Critical Value = 9.49 (0.05)

If Sandy and Irene Were Factored In

Category	Neg W	Neut W	Pos W
SST < 20.09	0	0	0
20.09 < SST < 20.86	2	2	0
20.86 < SST	6	2	0

- Cp < 980 for Intense Storms
- X squared = 14.32 , Critical Value = 13.28 (0.01)

Discussion

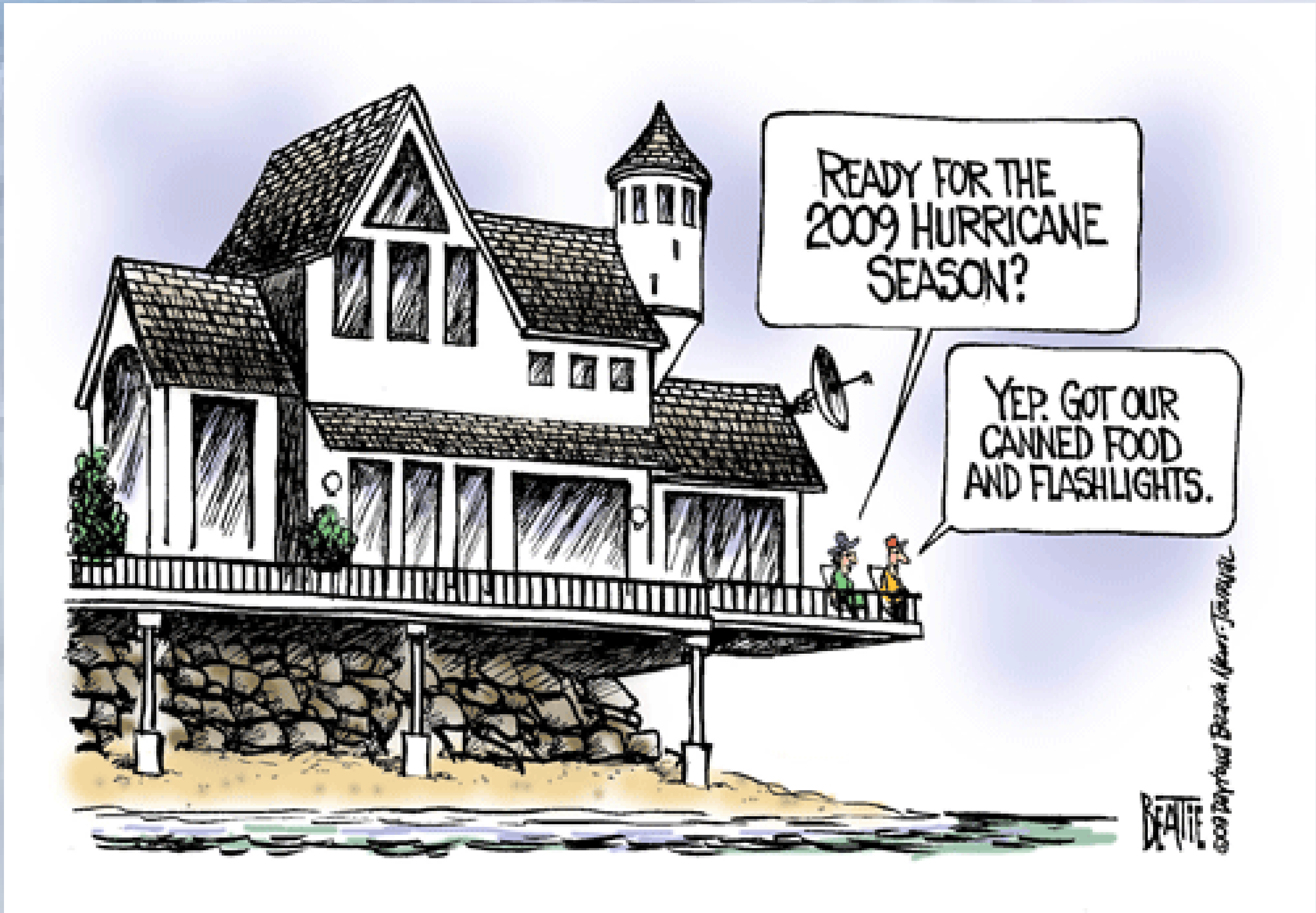
- Steering currents related to pressure patterns influence storm tracks while the sea surface temperature enables storms to develop higher intensities (E3 represents a “blocking high” pattern for negative weightings)

- This study will continue investigating additional factors influencing surge hazard with the intent of developing an improved, localized hazard prediction

Future Work

- Execute surge model simulations
- Construct surge response functions
- Estimate surge hazards and their dependence on multi-year large scale atmospheric circulation variability

Questions?


READY FOR THE 2009 HURRICANE SEASON?
YEP. GOT OUR CANNED FOOD AND FLASHLIGHTS.
BEATTIE

References

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- Credit to Luis Montoya for assistance with contouring
- Credit to Don Resio for eigenvector code