CORRECTING FOR CHANGES IN THE NDBC WAVE RECORDS OF THE UNITED STATES

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Overview

- Motivation
- Data Description
- Prove hull and payload affect the wave record:
  - ANCOVA
  - Multiple Comparison Tests
- Can we fix it?
  - Option 1: Normalize the data
  - Option 2: Modify the probability distribution functions
- Conclusions

MOTIVATION

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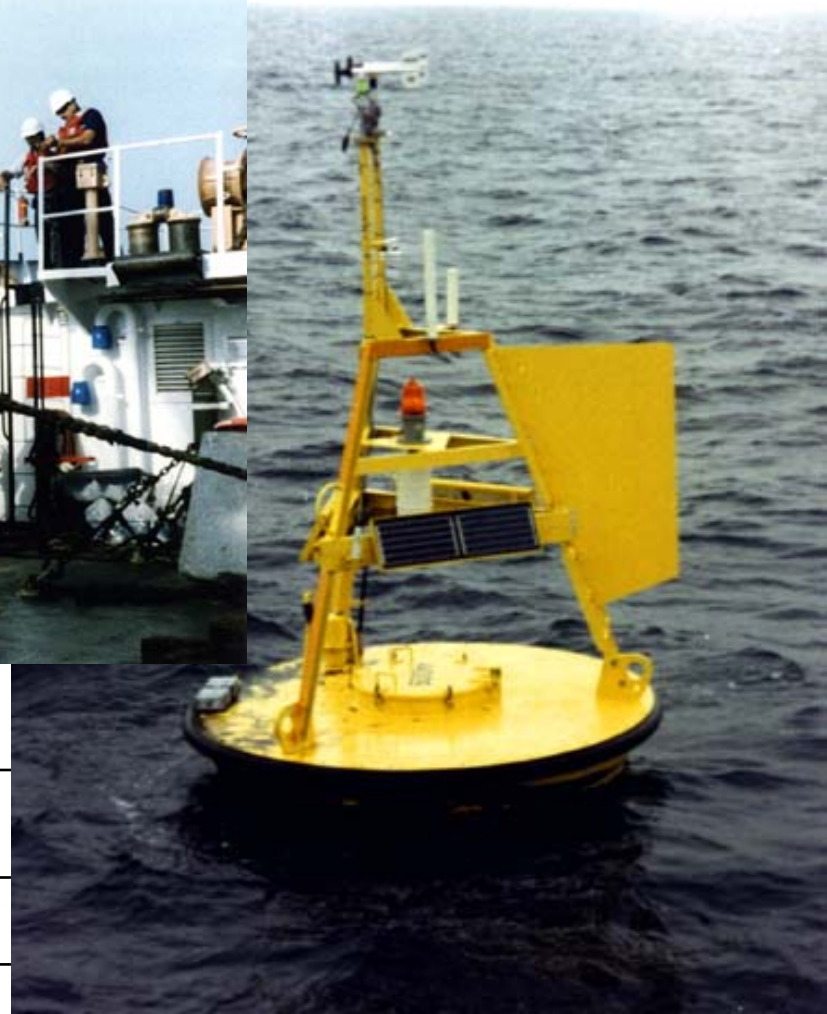
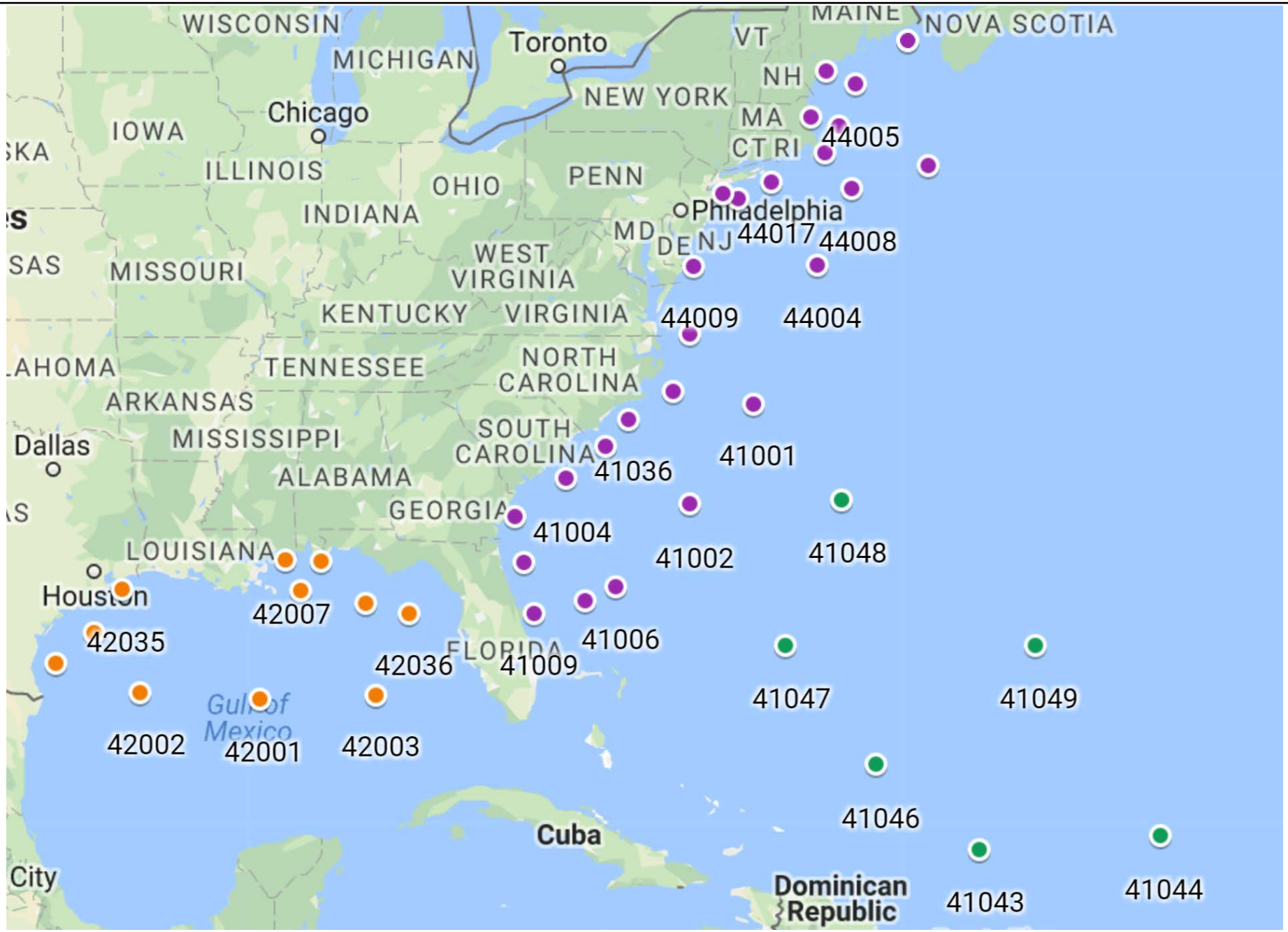


41002			
41002			
41002			
41002	Apr-1990	6N	
41002	Jul-2003	3D	

http://www.ndbc.noaa.gov/data_availability/data_avail.php

DATA DESCRIPTION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ARKANSAS
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LOUISIANA
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Houston
42007
42035
41006
FLORIDA
42036
41009
41047
41049
Gulf of
Mexico
42002
42001
42003
41046
Cuba
41043
41044
Dominican
Republic

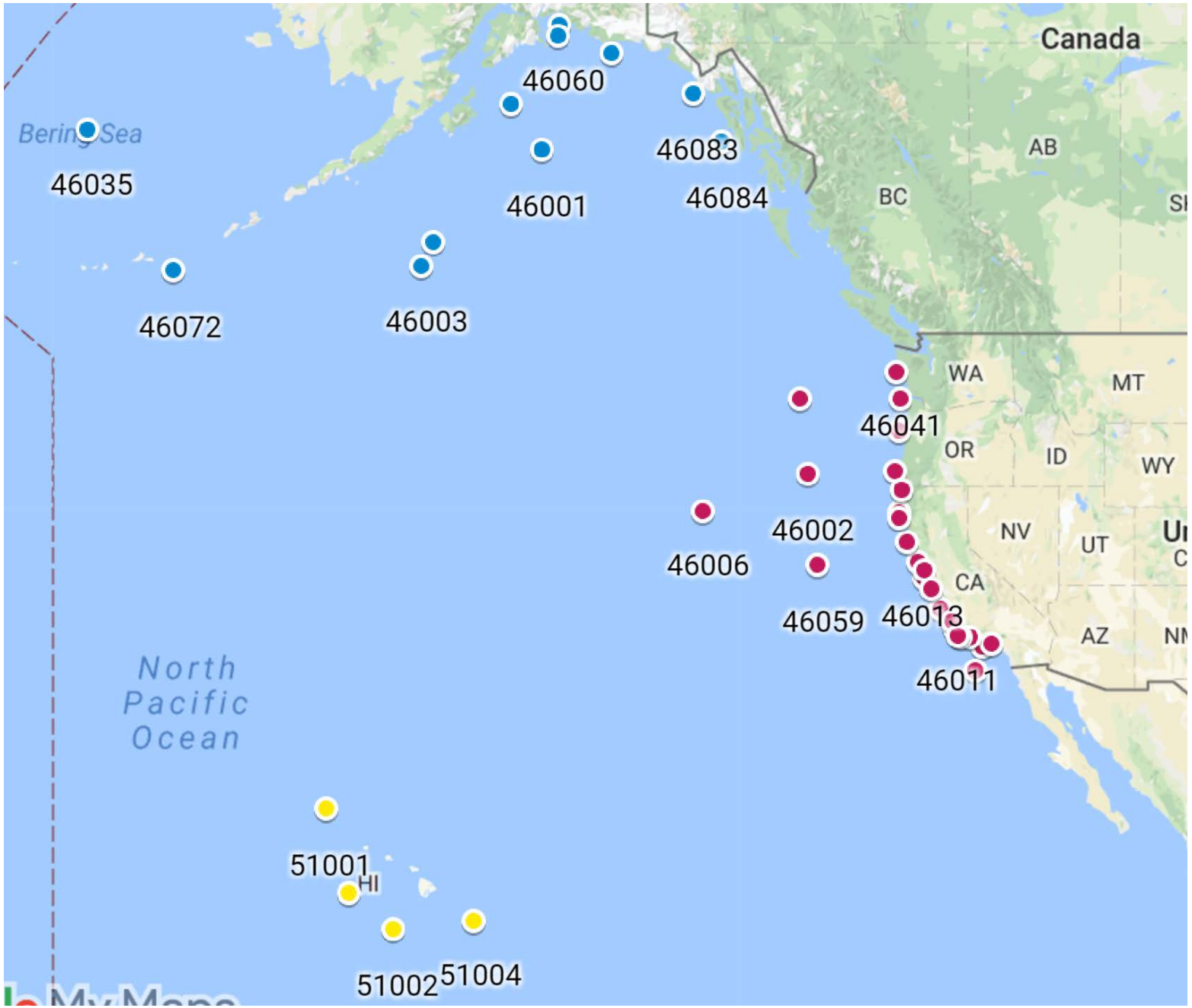
Selected Buoys

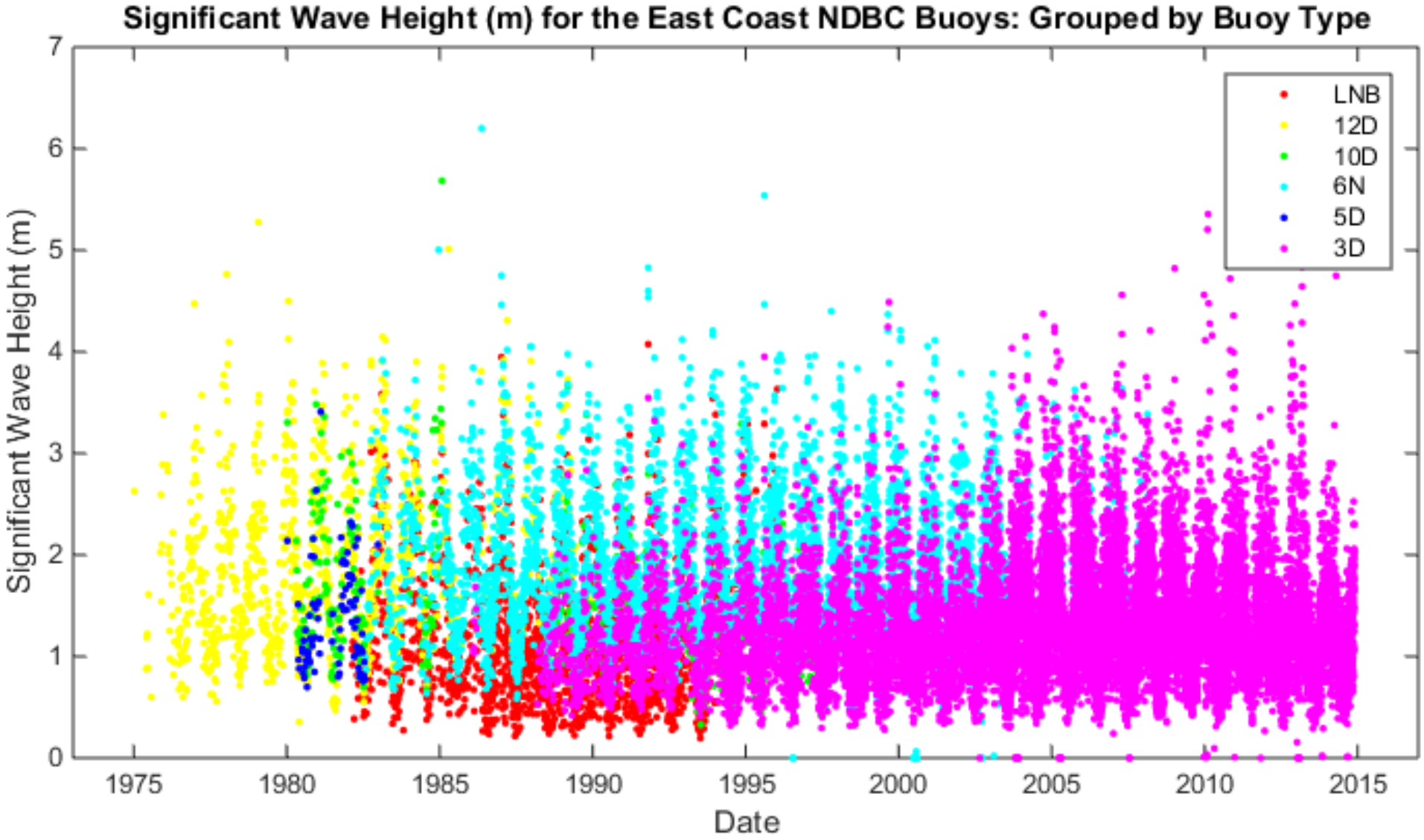
Three basic selection criteria

- NDBC Buoys
- Currently considered operational
- At least 10 years of data

Selected characteristics

- Depths ranging from 20 m to 4.5 km
- First deployments in the 1970's
- Most recent in 2002




Significant Wave Height (m) for the East Coast NDBC Buoys: Grouped by Buoy Type
Significant Wave Height (m)
Date
0
1
2
3
4
5
6
7
1975
1980
1985
1990
1995
2000
2005
2010
2015
LNB
12D
10D
6N
5D
3D

IS THE WAVE RECORD CHANGING?

Analysis of Covariance

- Combines analysis of variance and regression
- Determines if different levels of a categorical independent variable influence the population means of the dependent variable
- Controls for the effects of other continuous variables (in this work, time), which are known as covariates

Source	d.f.	Sum Sq	Mean Sq	F	P-value
Hull Type	5	341.8	68.3609	174.29	1.19E-182
Date	1	10.67	10.6723	27.21	1.84E-07
Hull Type * Date	5	84.88	16.9755	43.28	1.44E-44
Error	23035	9035.1	0.3922		

Multiple Comparison Test

- ANCOVA tests the hypothesis that the means of several groups are all equal
  - It provides no information about which groups are significantly different from each other.
- The multiple comparison test employed here is the Tukey-Kramer
  - Considered one of the most conservative
  - Tests all possible combinations of the relevant grouped variable.

	3D	5D	6N	10D	12D
LNB	0.47	0.97	0.31	0.00	0.00
12D	0.00	1.00	0.00	0.00	
10D	0.00	0.81	0.00		
6N	0.00	0.95			
5D	0.98				

CAN WE FIX IT?

Trend Analysis (First guess)

- The wave records were grouped by buoy number, hull and platform type and then normalized with a z-score

$$z = \frac{(X - \mu)}{\sigma}$$

- Force a consistent mean and standard deviation (by buoy)
- Linear models were fit to the wave record for each buoy
  - Original dataset
  - Corrected for both

Trend Analysis (Best guess?)

- The wave records were grouped by buoy number, hull and platform type and then quantile normalized
  - A technique for making two distribution have identical statistical properties

$$x_{norm} = F_i^{-1}\left(F_{ref}(x)\right)$$

- Force a consistent probability density function (by buoy)
- Linear models were fit to the wave record for each buoy
  - Original dataset
  - Corrected for both

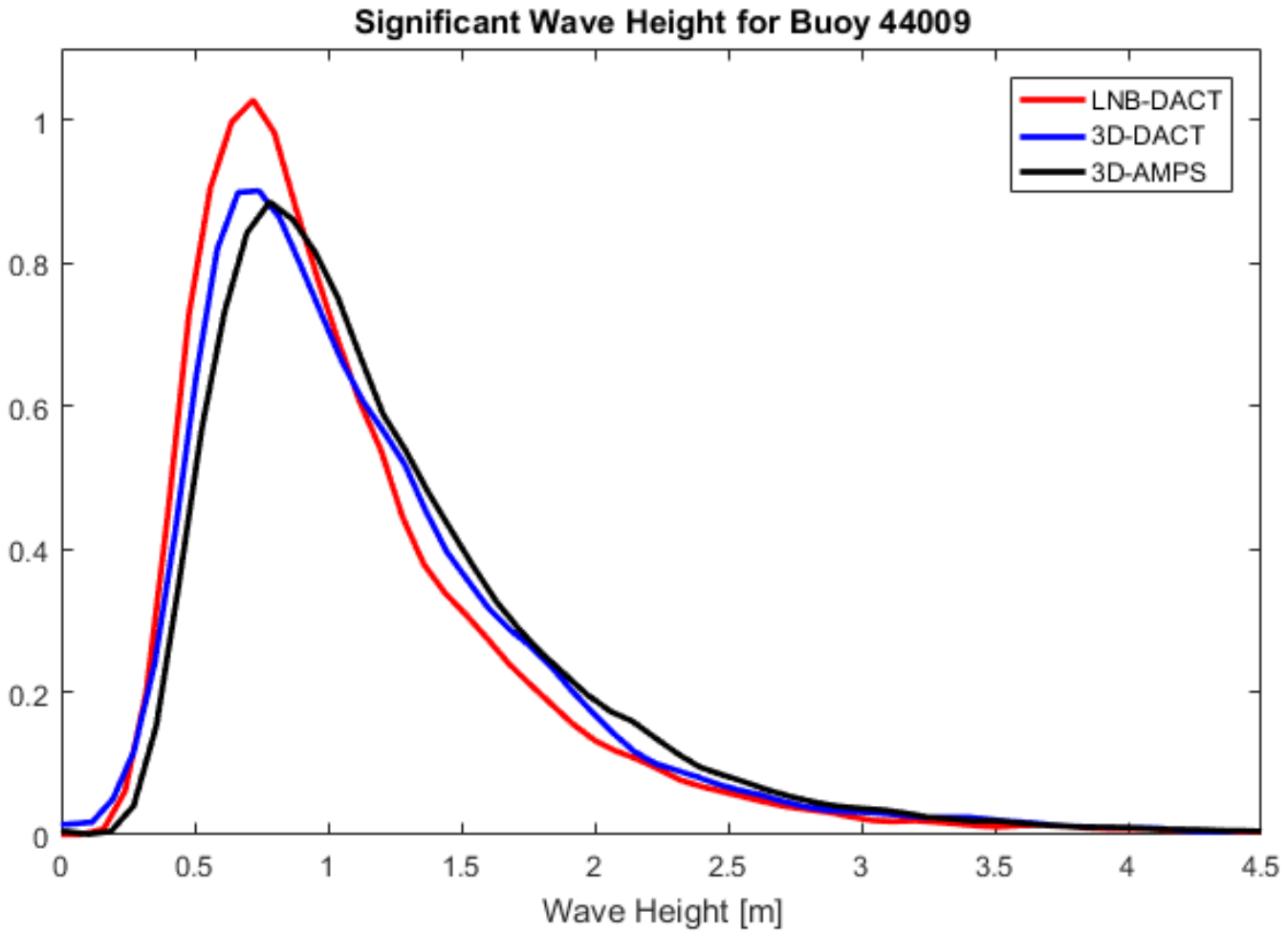
Probability Density Functions (PDFs)

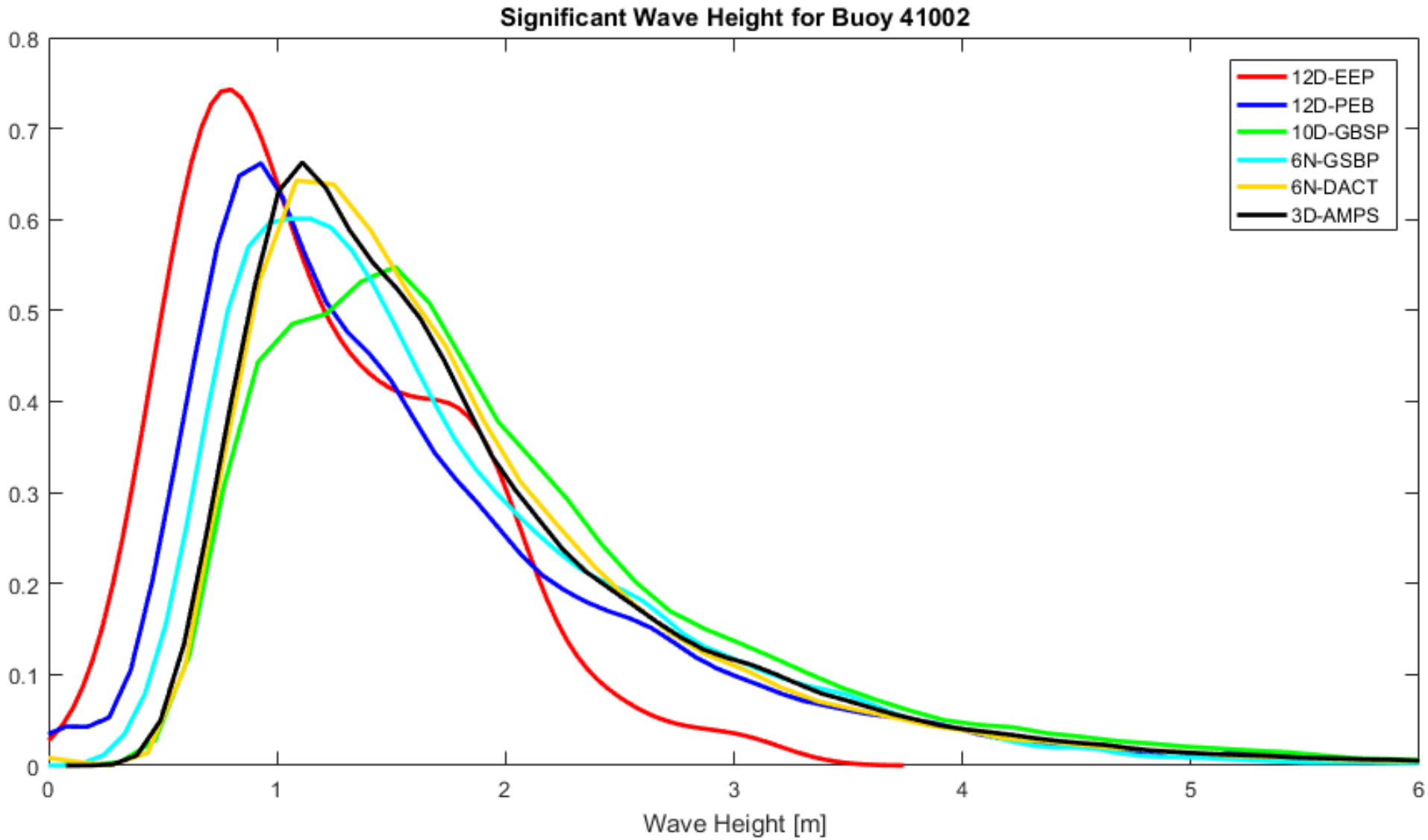
A function of a random variable, whose integral across an interval gives the probability that the value of the variable lies within the same interval.

- PDFs provide a relative likelihood of a random variable having a given value

A kernel distribution is a nonparametric representation of the pdf of a random variable.

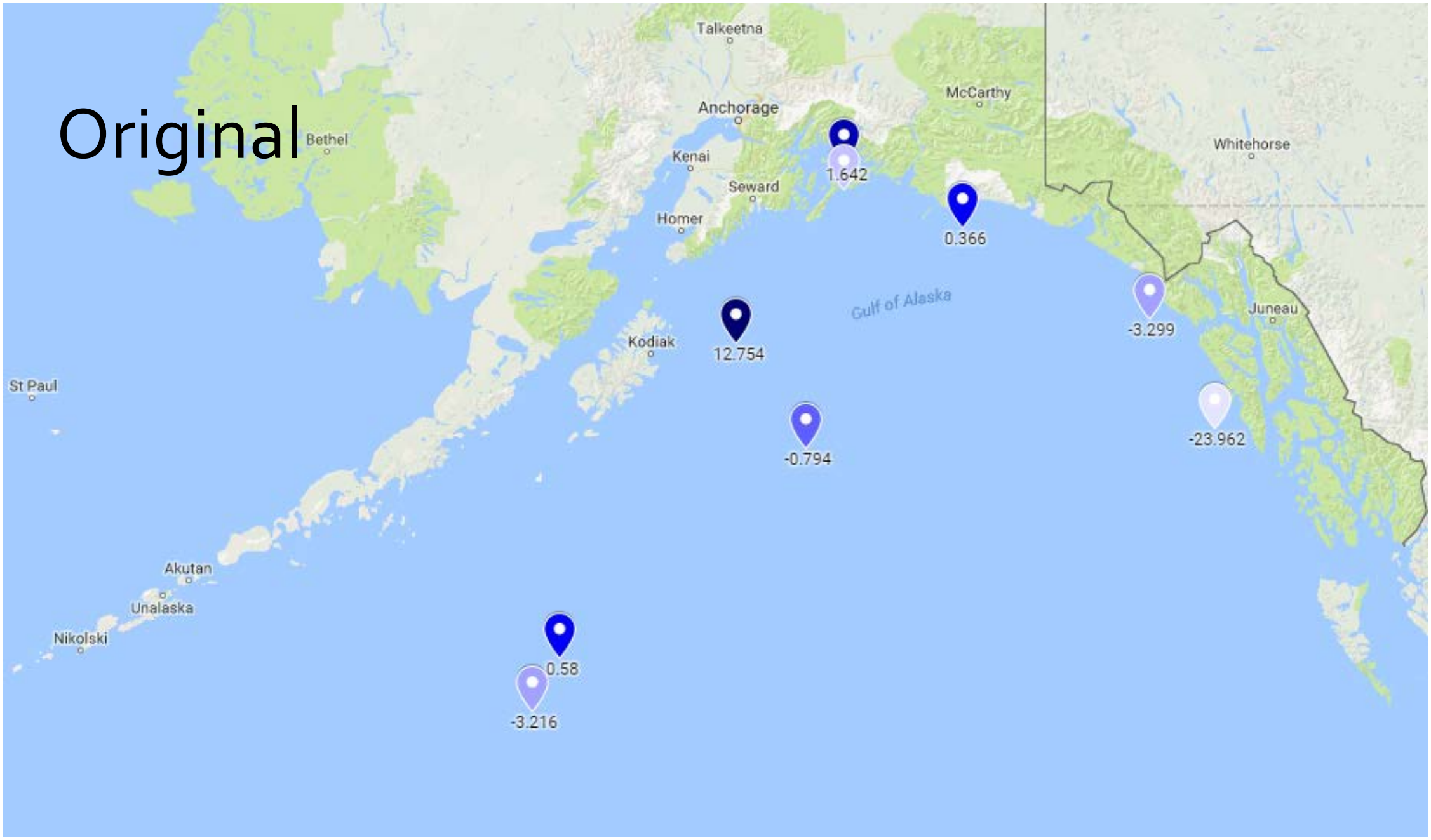
- Primarily used when you want to avoid making assumptions about the distribution of the data




Significant Wave Height for Buoy 41002
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
Wave Height [m]
12D-EEP
12D-PEB
10D-GBSP
6N-GSBP
6N-DACT
3D-AMPS

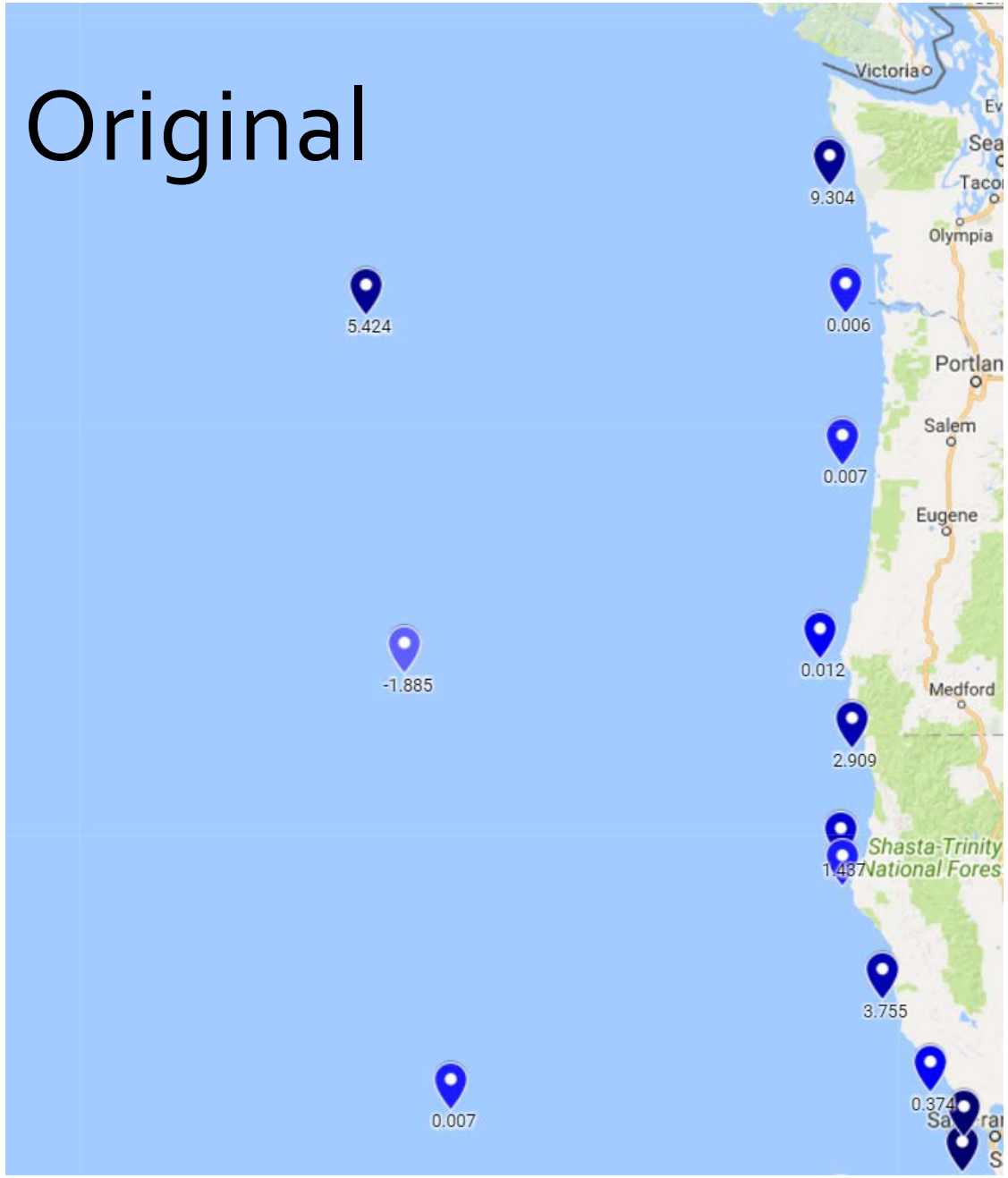
Buoy Number	Original Dataset		Linear Correction		Quantile Correction	
	Slope (n-mm/yr)	*p-Val*	*Slope (n-mm/yr)*	*p-Val*	*Slope (n-mm/yr)*	*p-Val*
Buoy 44005	-9.634	0	-1.667	0.011	3.241	0.561
Buoy 44008	7.268	0	0.792	0	-0.918	0.000
Buoy 44009	8.859	0	-1.136	0.544	2.670	0.675
Buoy 44011	2.826	0.041	1.583	0	-0.860	0.000
Buoy 44014	0.958	0.004	-0.607	0.414	0.665	0.003
Buoy 44017	2.114	NaN	-0.934	NaN	2.928	NaN
Buoy 44018	2.115	NaN	-0.935	NaN	2.928	NaN
Buoy 44025	6.935	0	0.72	0	-0.010	0.000
Buoy 44027	2.113	NaN	-0.934	NaN	2.928	NaN

Original


Talkeetna
Anchorage
McCarthy
Bethel
Kenai
Seward
Homer
1.642
0.366
Whitehorse
Gulf of Alaska
Kodiak
12.754
-3.299
Juneau
St Paul
-0.794
-23.962
Akutan
Unalaska
Nikolski
0.58
-3.216

PDF Corrected

Original



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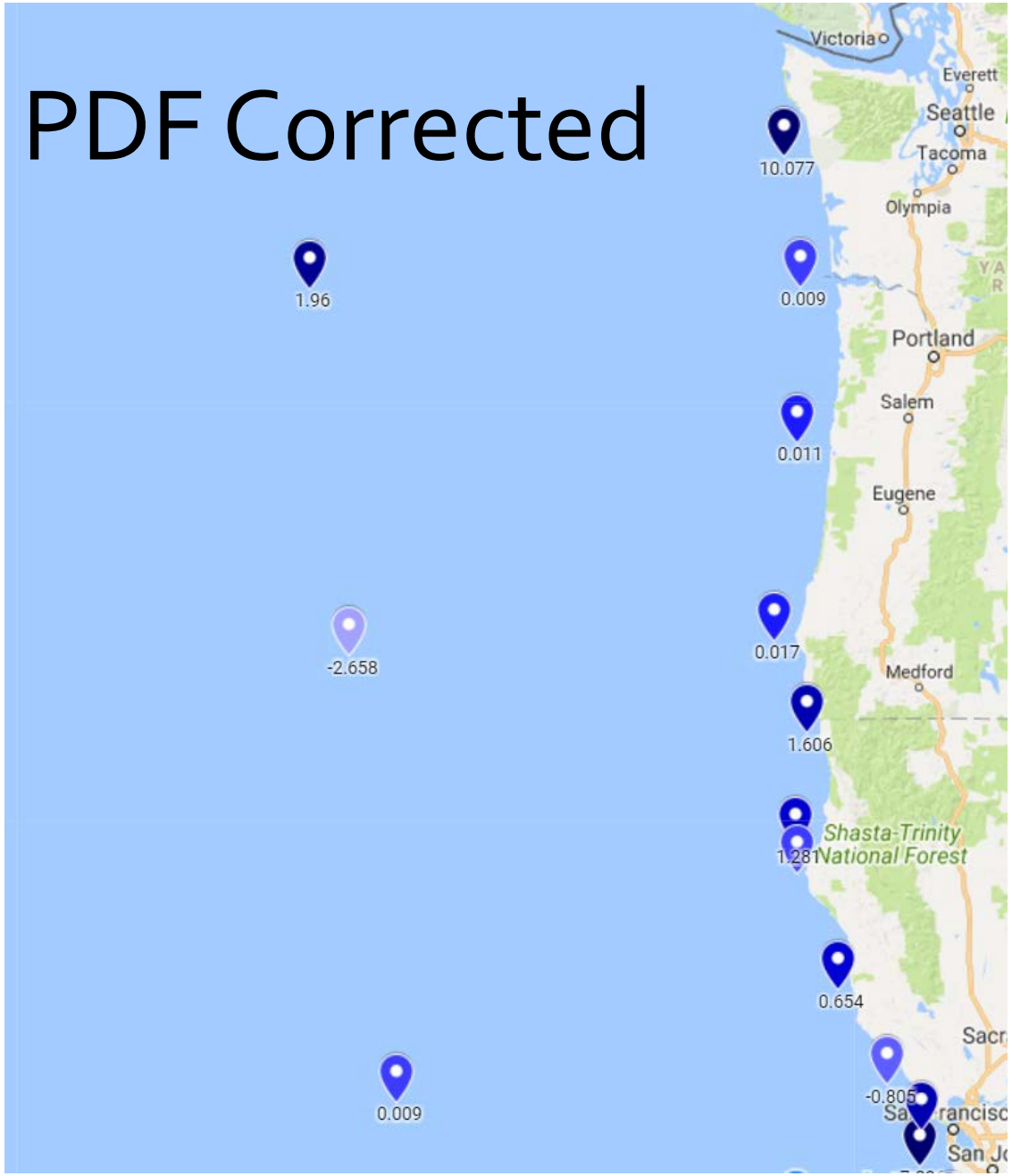

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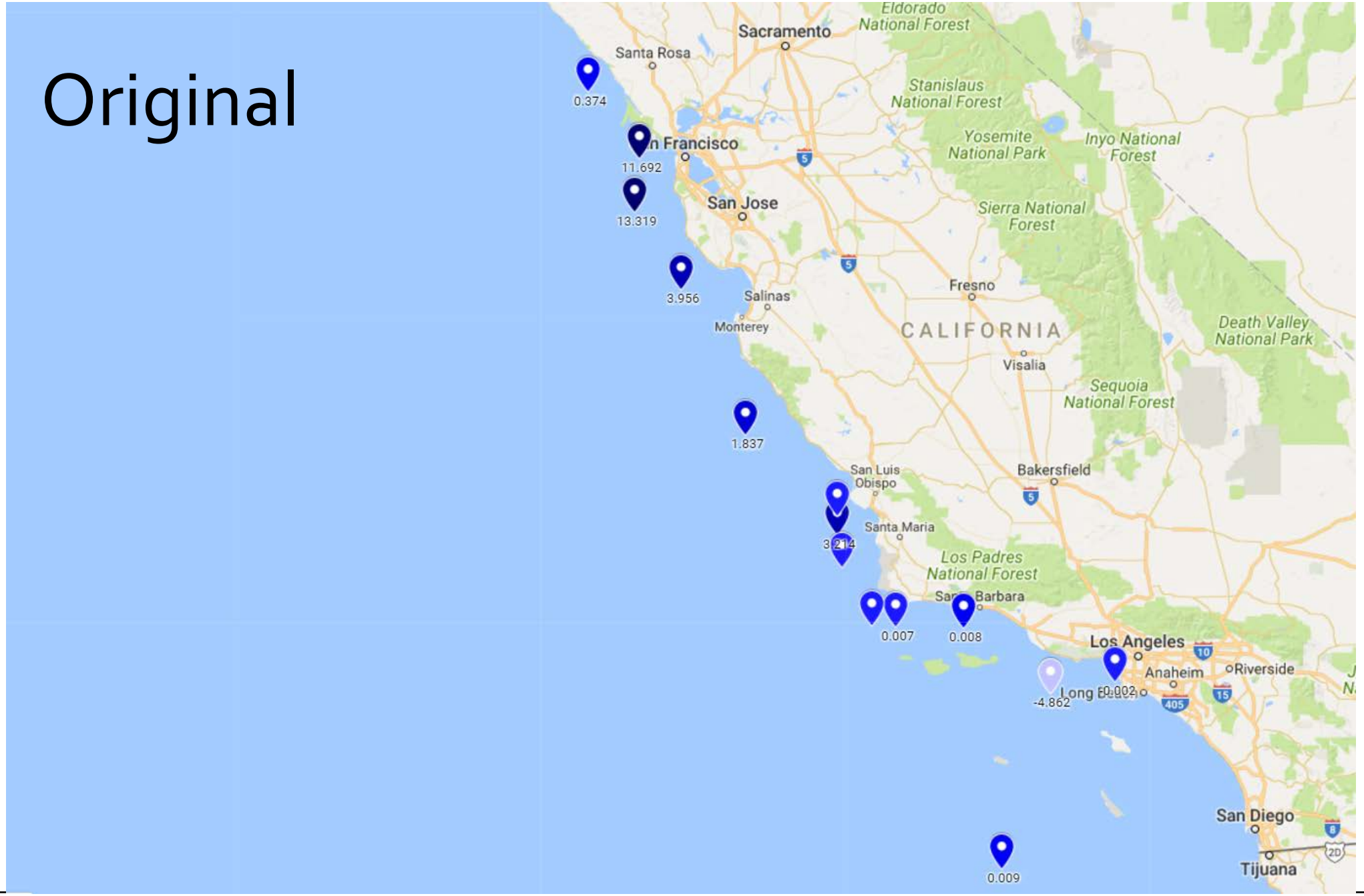
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CALIFORNIA
Visalia
Death Valley National Park
Sequoia National Forest
Bakersfield
San Luis Obispo
Santa Maria
Los Padres National Forest
Barbara
Los Angeles
Anaheim
Riverside
Long Beach
San Diego
Tijuana
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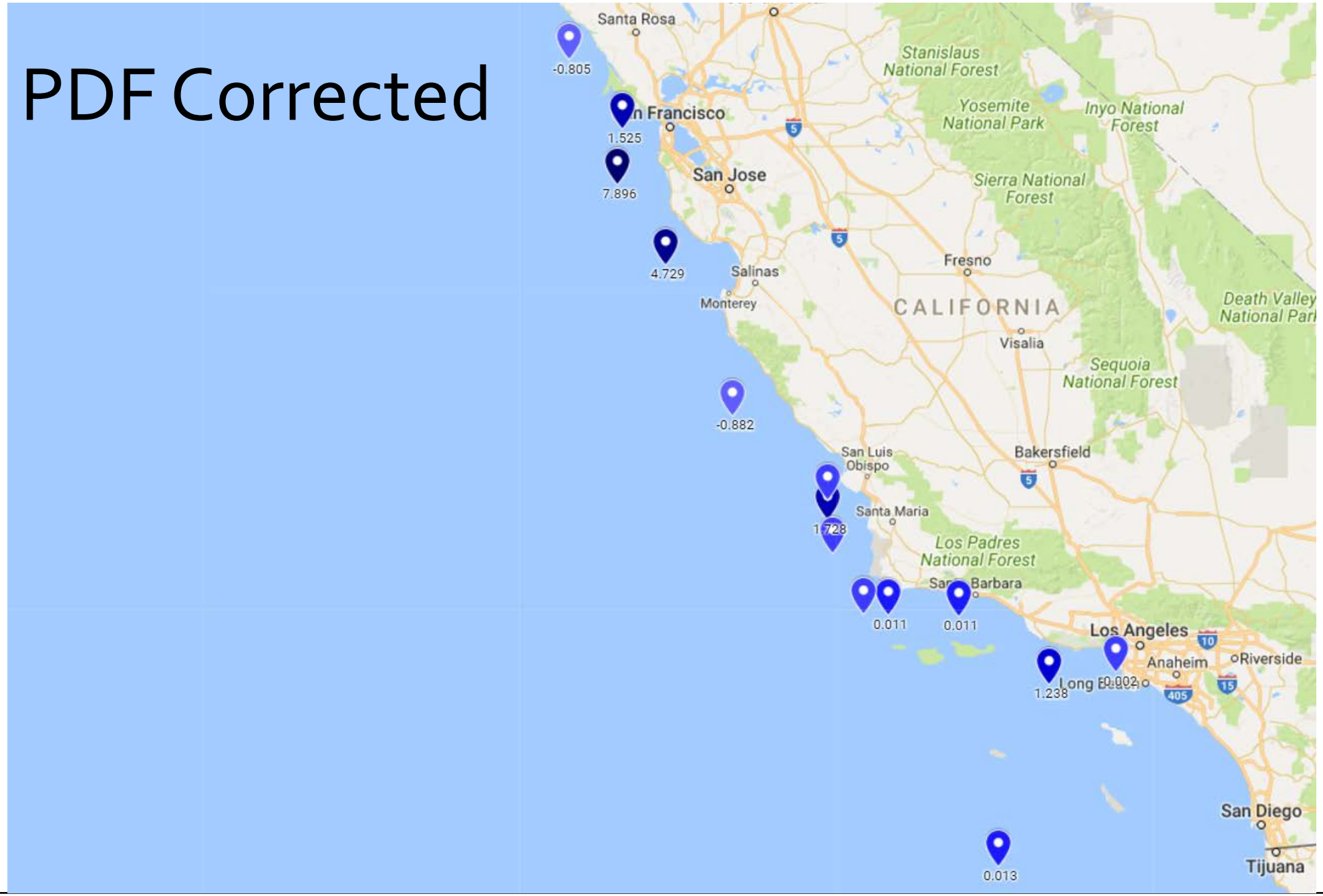

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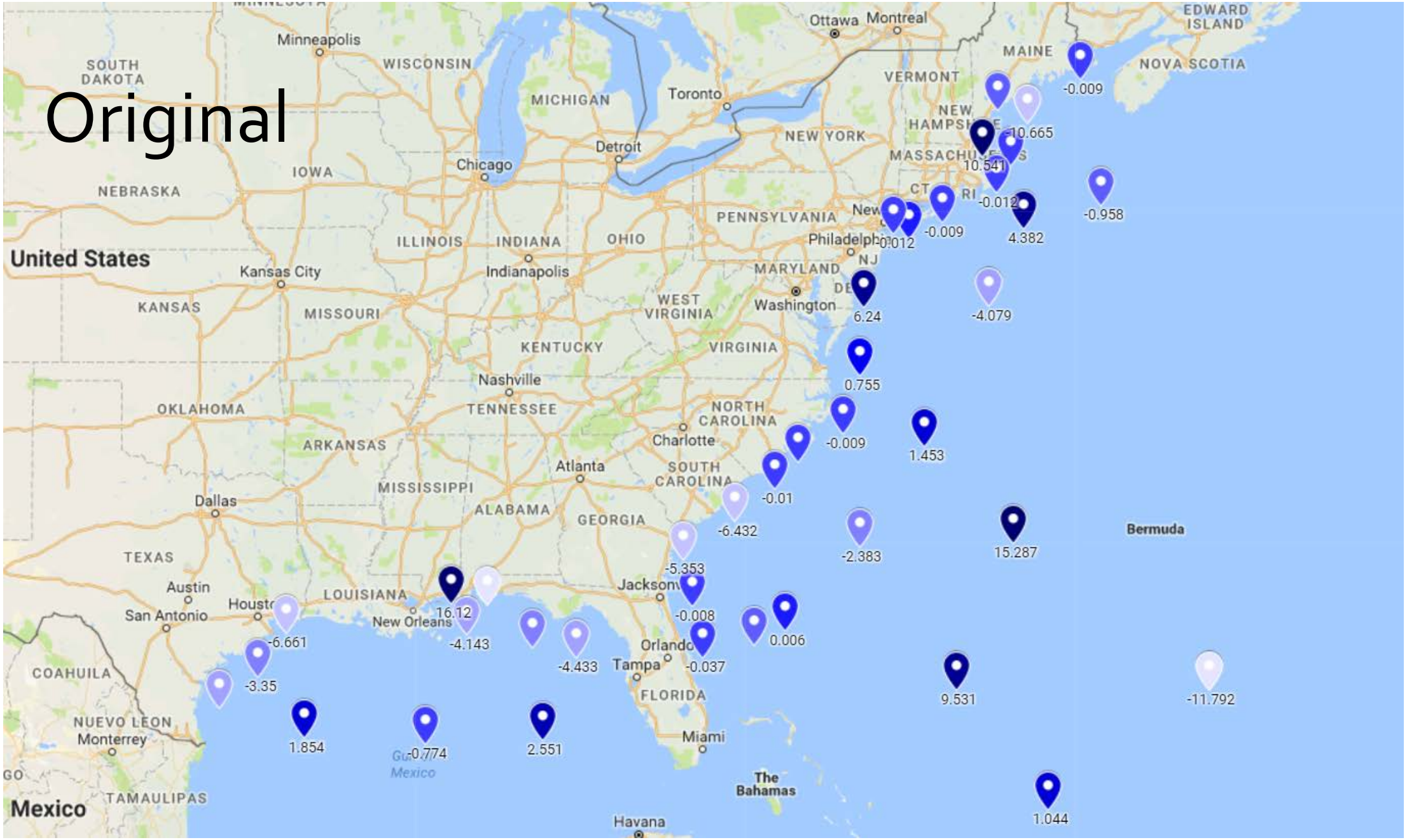
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Jackson
Orlando
Tampa
FLORIDA
COAHUILA
NUEVO LEON
Monterrey
TAMAULIPAS
Mexico
Miami
The Bahamas
Havana
Bermuda
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0.012
6.24
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15.287
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0.006
16.12
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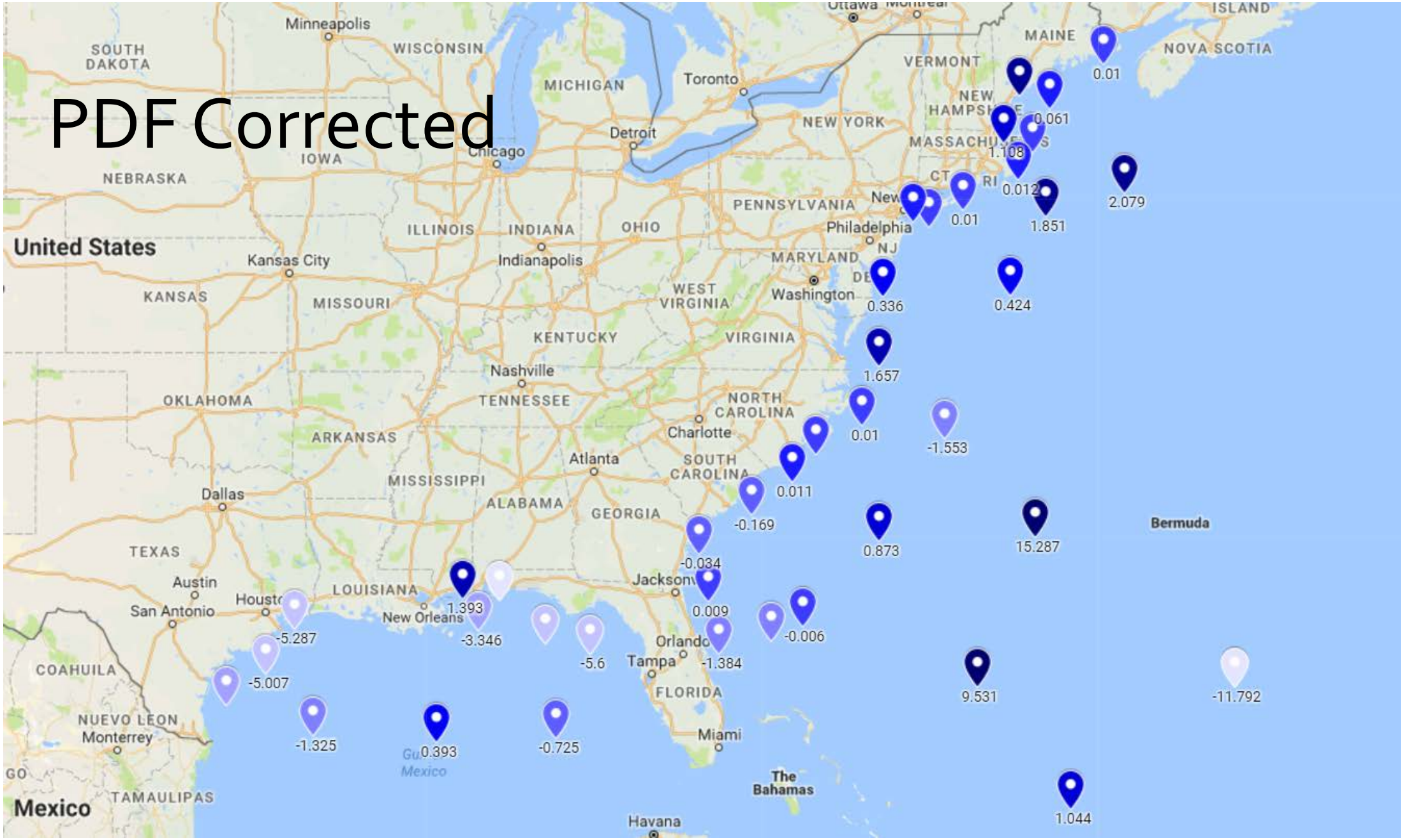
1.044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1.851
0.336
0.424
1.657
0.01
-1.553
0.011
-0.169
-0.034
0.873
15.287
0.009
-0.006
-1.384
-5.287
-3.346
-5.6
-5.007
-1.325
0.393
-0.725
9.531
-11.792
1.044

FINAL THOUGHTS

Evidence of a Recent Increase in Storminess along the New Jersey Coast

BY ELIZABETH LIVERMONT
JON K. MILLER
THOMAS O. HERRINGTON
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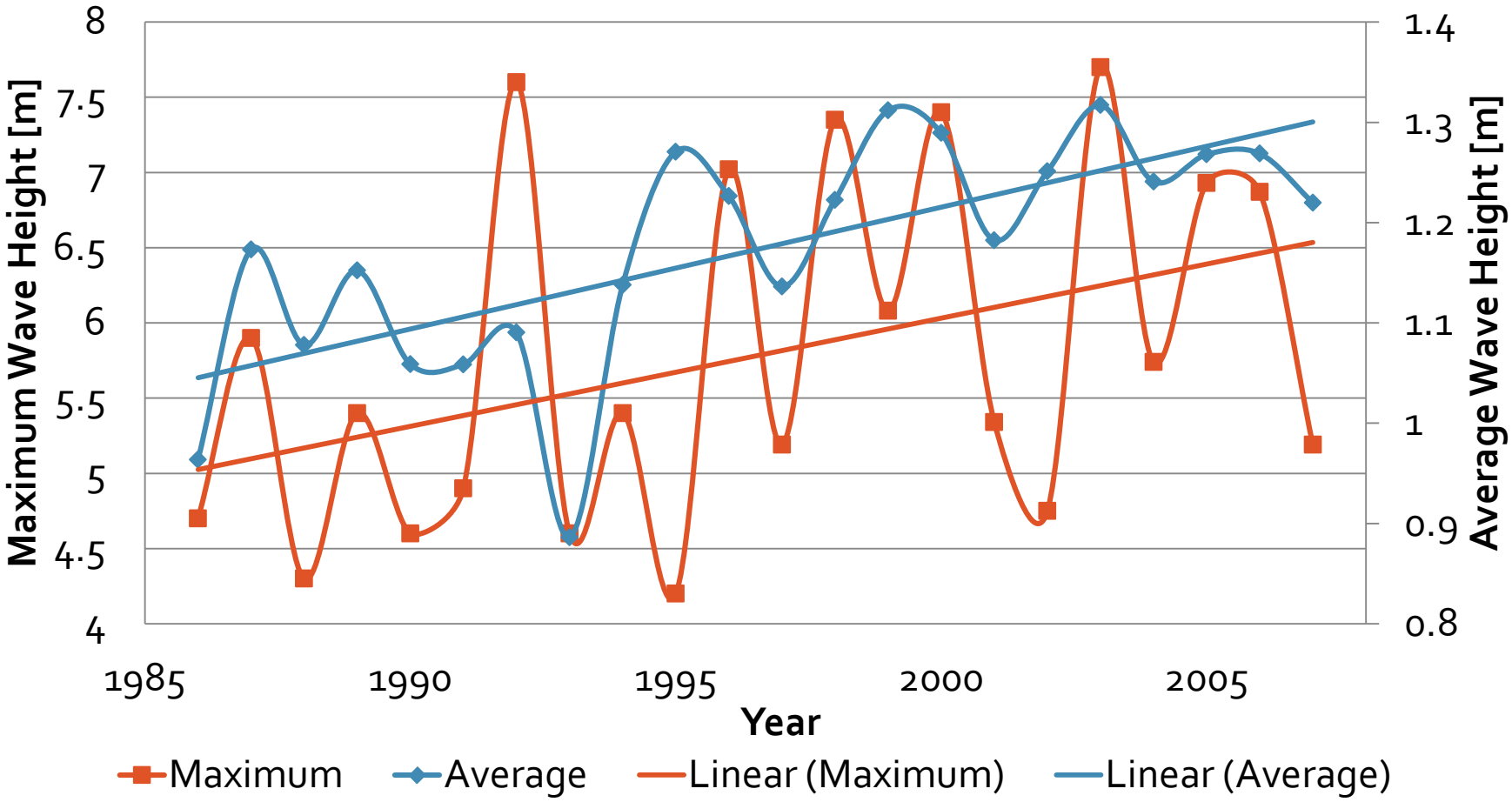
CENTER FOR MARITIME SYSTEMS
OCTOBER 16, 2008

Significant Wave Height for 44009 (From 2008)



Comparing Apples to Oranges

- NDBC maintains the historical buoy records
  - However, they are not climatological records
  - Which means it should not be used for climatological analyses
- But, as engineers any data is better than no data
- Goal is calculating reliable return periods based on observations: What's the best solution?

Conclusions

- Both hull and platform type result in significant changes to the time series, with the hull type as the more significant contributor.
- The time series were corrected to remove the influence of the modifications and then analyzed to determine if there were any long-term trends in the wave conditions.
- Overall, trends do not change utilizing quantile normalization, but are reduced in magnitude.
- It is crucial for long-term records to document the observational changes which introduce artificial trends into the data, and adjust the buoy time series prior to trend analysis.

Questions?

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