“Wind Gust Climatology for Southern South Carolina and Coastal North Georgia”

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NOAA Goal: Weather-Ready Nation

NWS Charleston, SC

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About Me

- Ryan Kramer
- Penn State University, Meteorology

- Chose Charleston, SC NWS because:
  - Experience operational meteorology
  - Different style of research

Outline

- Goals
- Background
- Methods
- Results
- Conclusions
- Next Steps

Goals

- Develop guidelines an NWS Charleston, SC forecaster can use to forecast wind gusts.
  - No clear blueprint currently in place

- Base these guidelines on trends of various time scales found in an analysis of surface observations

Background

- **Wind Gust**: Rapid fluctuation in wind speed
  - 10 knot variation between wind peaks and lulls

Gusts are only reported if ≥ 14 knots

- **Land Sites**
  - Sustained Wind: 2 minute average
  - Gusts: 5 second average

- **Marine Sites (buoys)**
  - Sustained Wind: 8 minute average
  - Gusts: 5 second average

Background

- Gust Factor (G)

$$G = U_{max}/\bar{U}$$

Gust over sustained wind speed

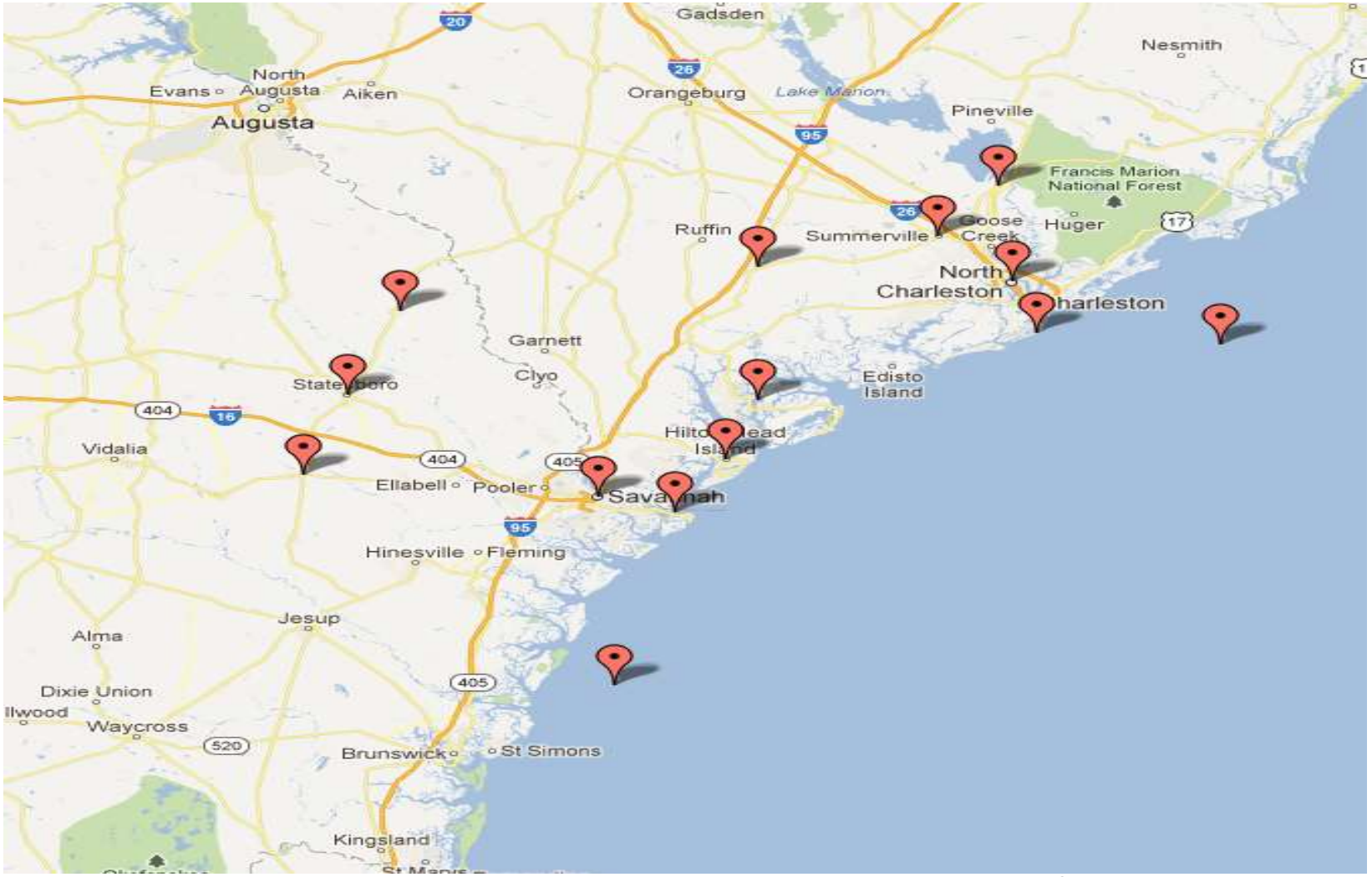
- Ex: “1.25 or 125%”
  - Should always be ≥ 1
- G multiplied by Sustained Wind = Gust

Background

- NWS Charleston wind gust forecasting:
  - Forecasters estimate G from experience
  - Forecasting Smart Tool's default value of 1.15 is applied

- Project purpose: Analyze climatological data to determine appropriate gust factor values for forecasting

Sites



google.maps.com

Methodology

- Hourly, or more, time-stamped surface observations at each location
  - Gust, sustained wind, wind direction, etc.
  - Data from Jan 1, 2007 to Dec 31, 2011

- Quality Control
  - Remove erroneous wind reports
  - Keep only data within 1 standard deviation of mean G
    - Ensure dataset representative of “fair-weather” conditions

Methodology

- Geographical Groupings
  - All-Land vs. Marine
  - Land vs. Marine/Shoreline

- Data set with 3,000 observations per location
  - Noticed a bias towards locations with many points

Wind Statistics

- Gusts found in *17%* of all land observations and *50%* of all marine observations
- Sustained winds:

All Land Sites

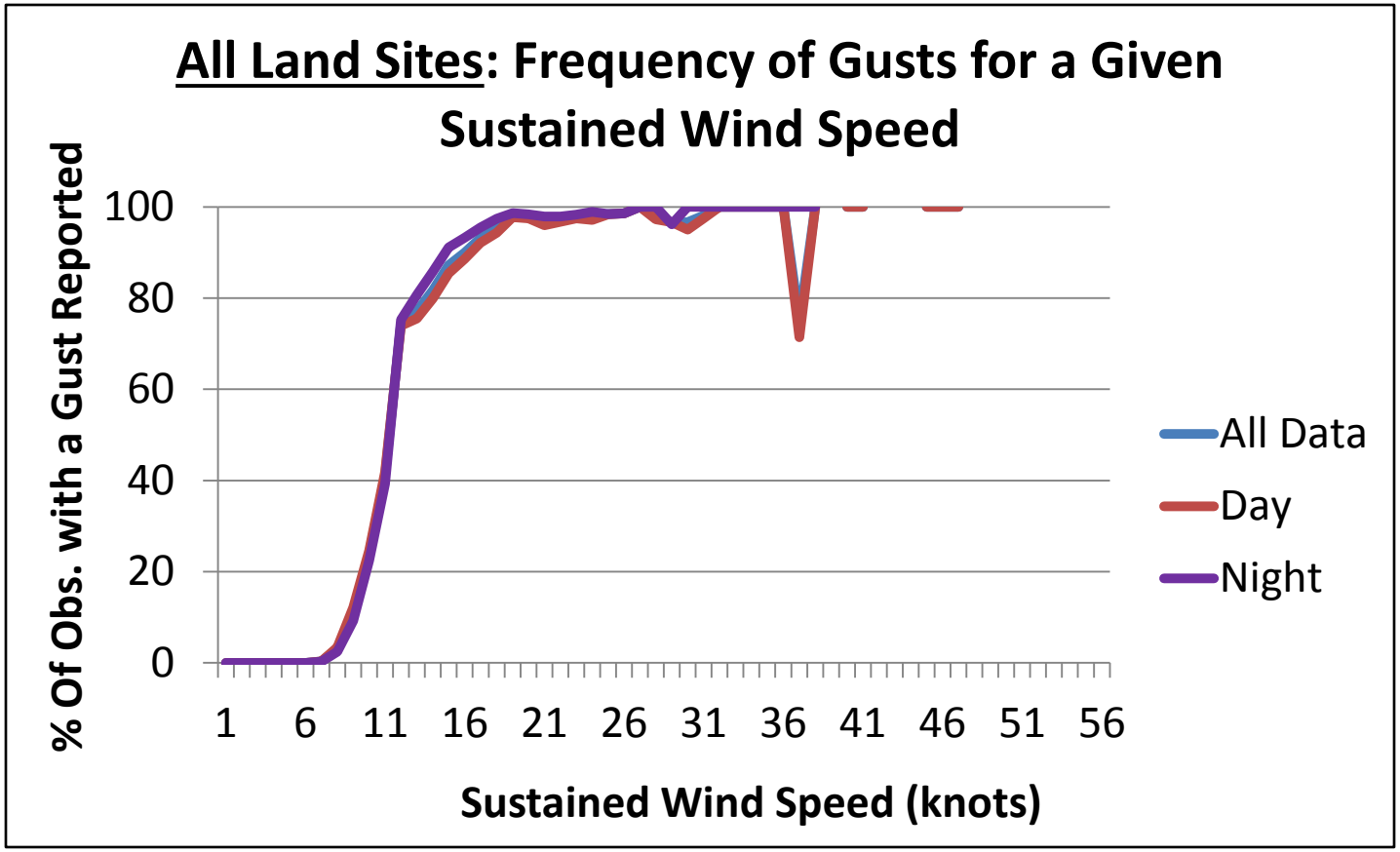
Sustained Wind	% of Obs.
< 10 knots	**82.5%**
10 – 20 knots	**16.3%**
20 – 30 knots	**1.2%**
30 – 40 knots	**.02%**
40+ knots	**.001%**

Marine Sites

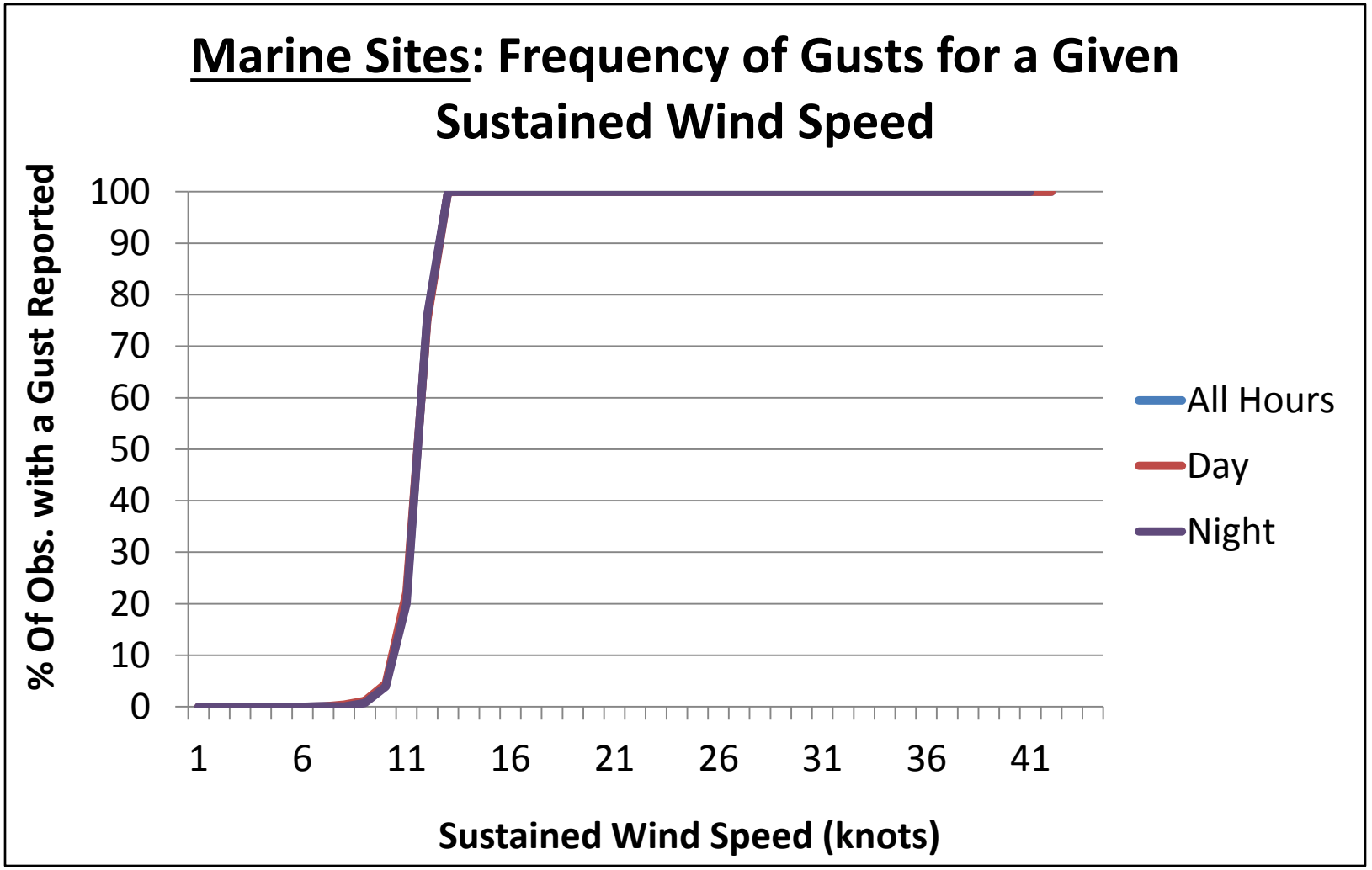
Sustained Wind	% of Obs.
< 10 knots	**35.3%**
10 – 20 knots	**53%**
20 – 30 knots	**11.3%**
30 – 40 knots	**.45%**
40+ knots	**.02%**

Wind Statistics

•How often are gusts reported when the sustained wind is X knots?

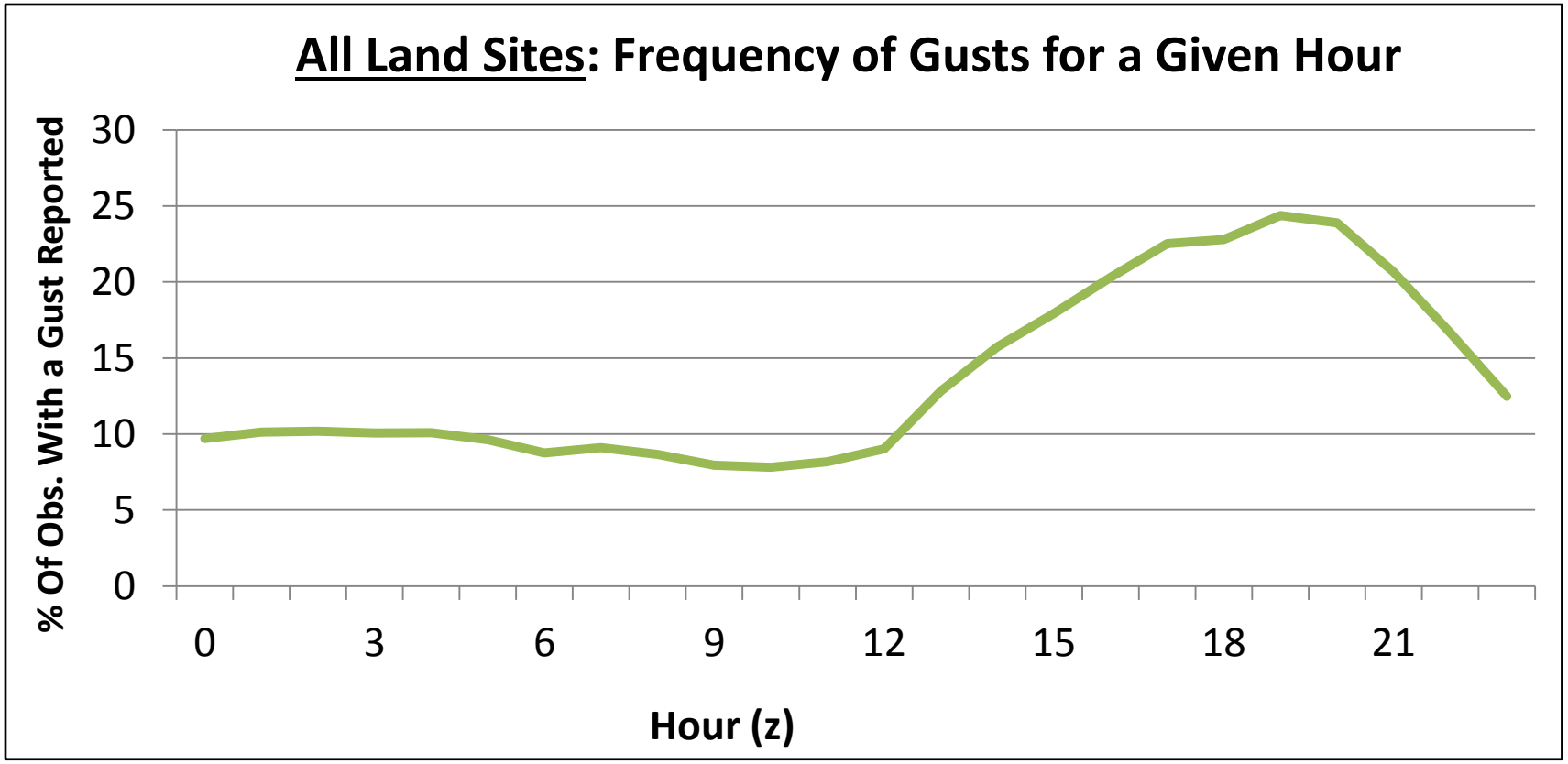


Wind Statistics

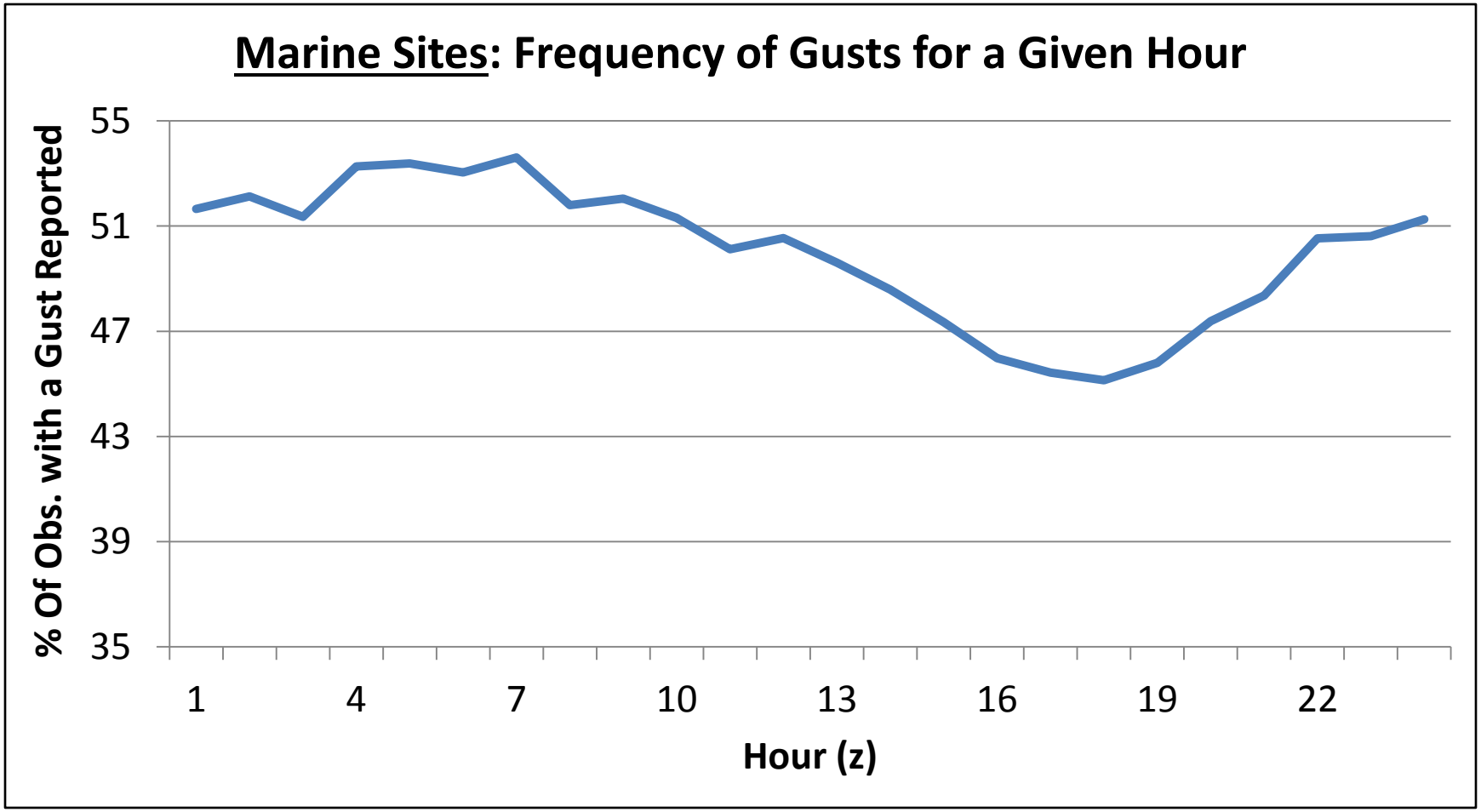


Wind Statistics

- How often do observations at hour X include a gust report?

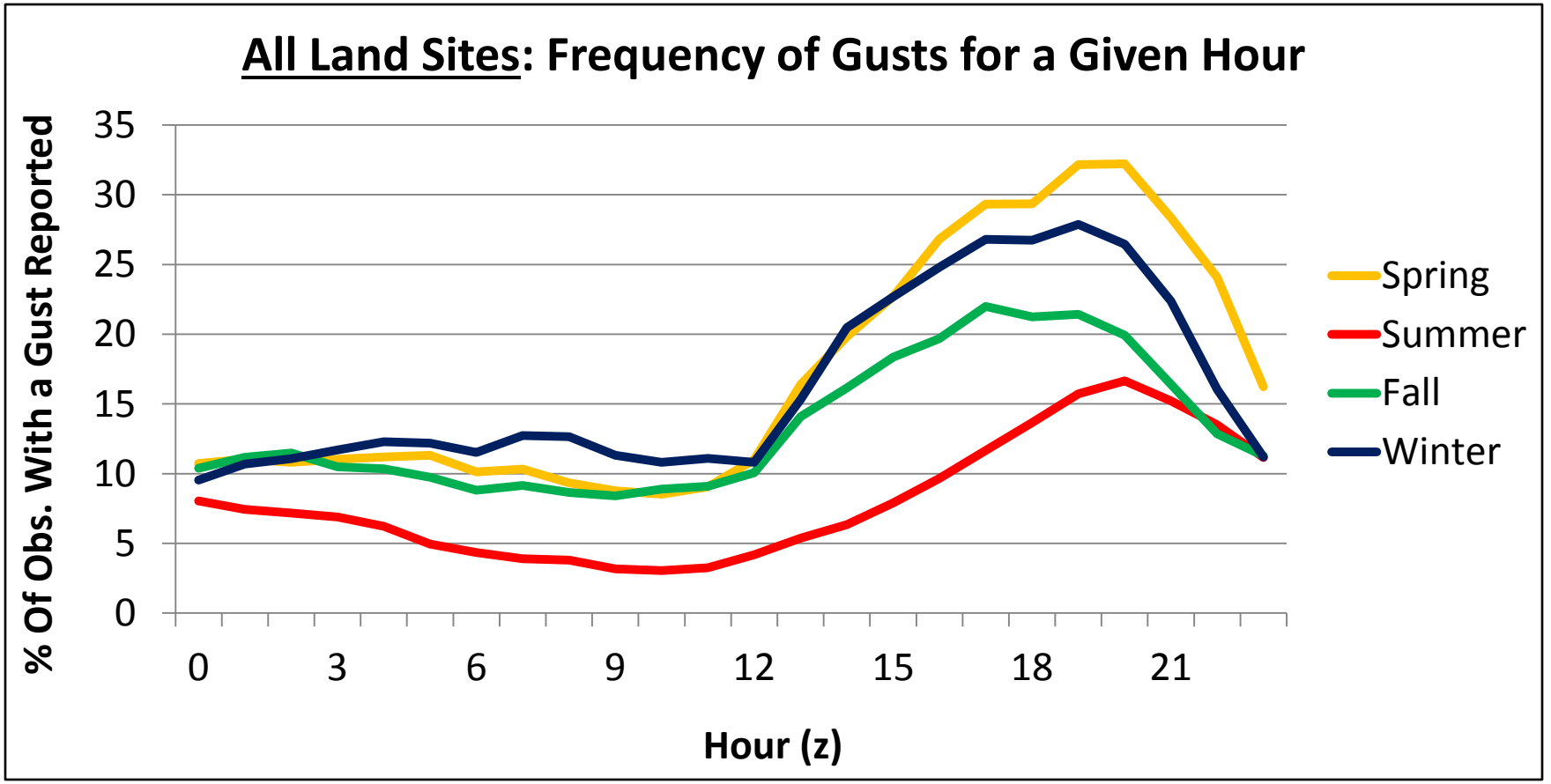


Wind Summary



Seasonal Averages

•Changes in gust frequency magnitude, and daily “peak gust time” shifts with season



Gusts vs. Sustained Wind Speeds

- Gust factors and sustained wind speed trends are **inversely related** over land
  - New grouping: Land vs. Marine/Shoreline

Land

Sustained	G
<10 knots	**1.94**
10-15 knots	**1.57**
15-20 knots	**1.43**
20-25 knots	**1.38**
25+ knots	**1.37***

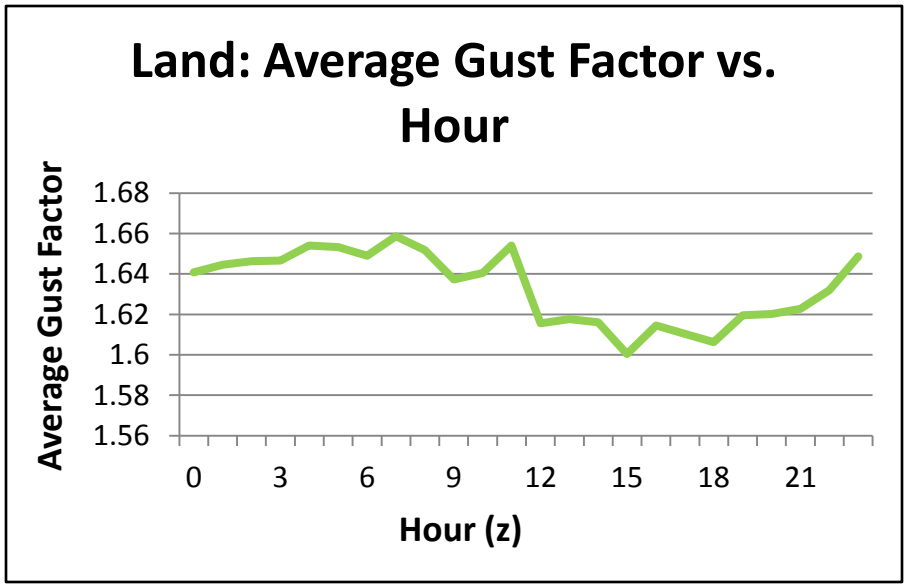
Marine/Shoreline

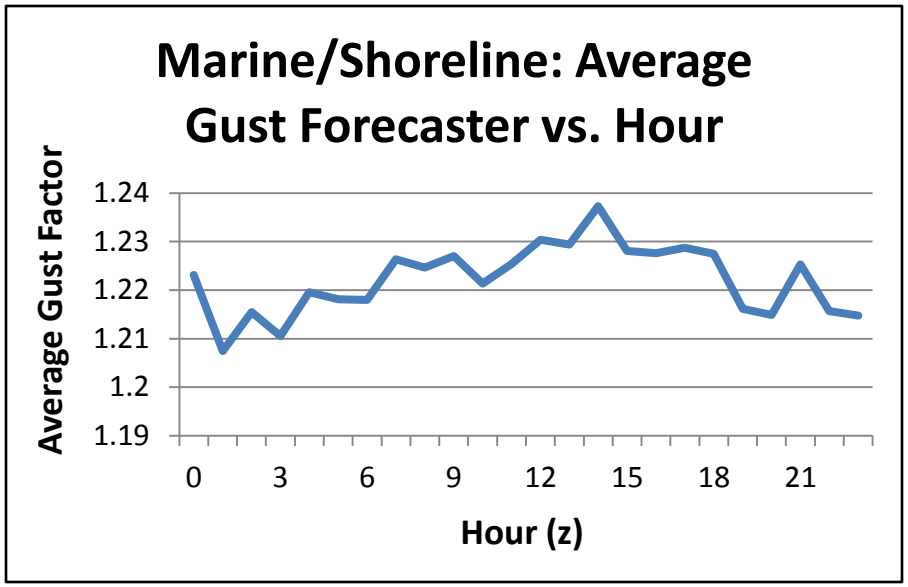
Sustained	G
<10 knots	**1.65**
10-15 knots	**1.22**
15-20 knots	**1.21**
20-25 knots	**1.22**
25+ knots	**1.23***

* Statistically insignificant number of points

Hourly Averages

- Slight diurnal variation





Gust Factor Average

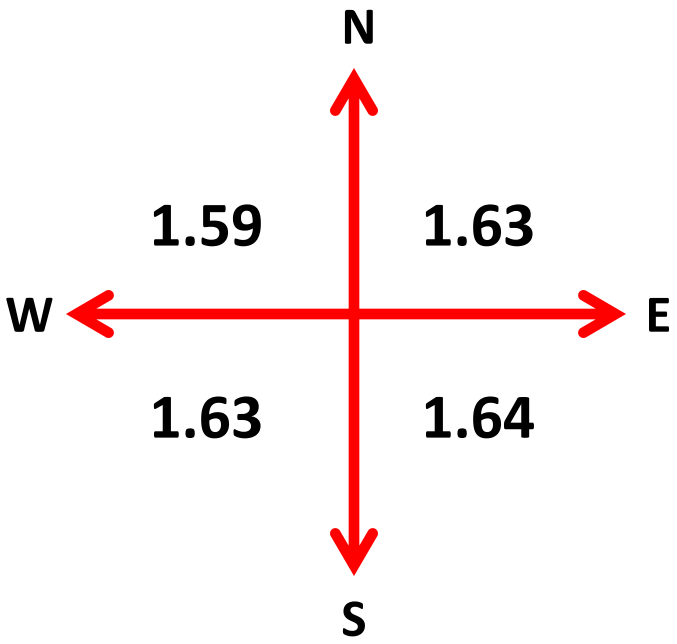
- Forecasters may want a general gust factor value they can confidently input into long-term forecasts

- Consider that the majority of observed gusts over land occur:
  - with sustained winds of 11 to 16 knots
  - from 15z to 22z

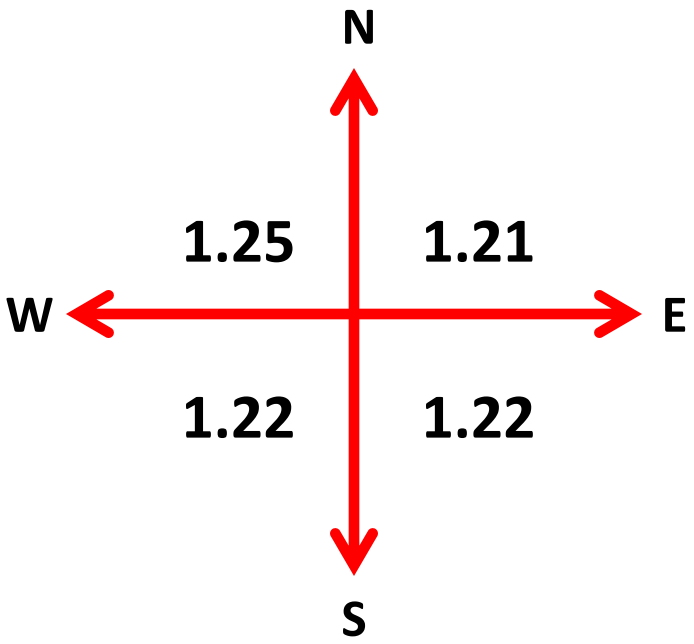
Land ≈ 1.51 **Marine/Shoreline ≈ 1.21**

Wind Direction

Land



Marine/Shoreline



Wind Direction

Ft. Pulaski

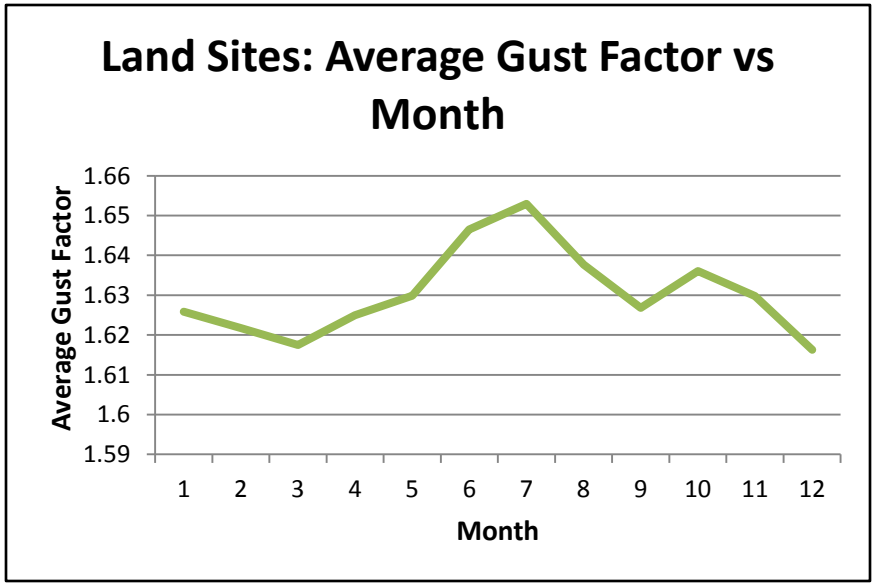
Direction	G	Sustained Wind
0-90°	1.25	15.2
90-180°	1.47	11.4
180-270°	1.45	12.1
270-360°	1.24	15.7

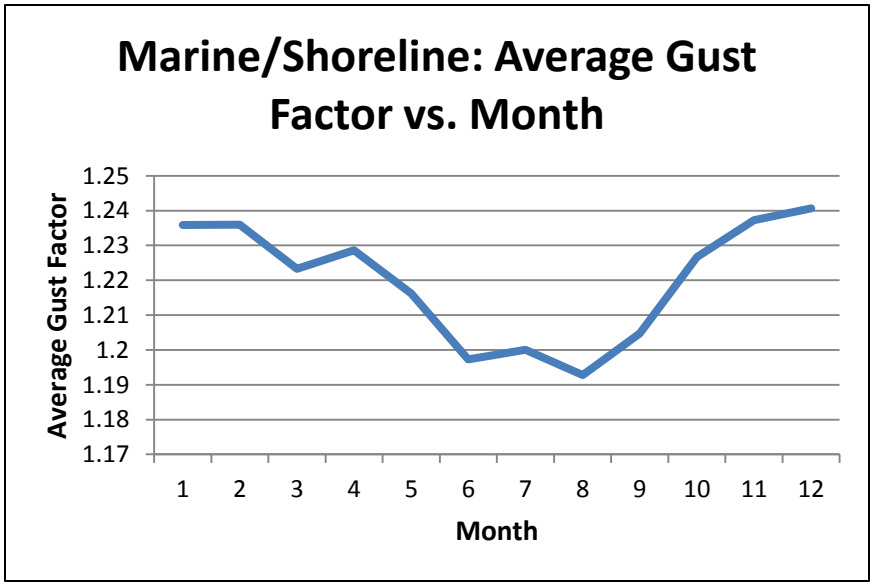
- More local variation
- Gust factor variation explained by sustained wind speed variation

google.maps.com

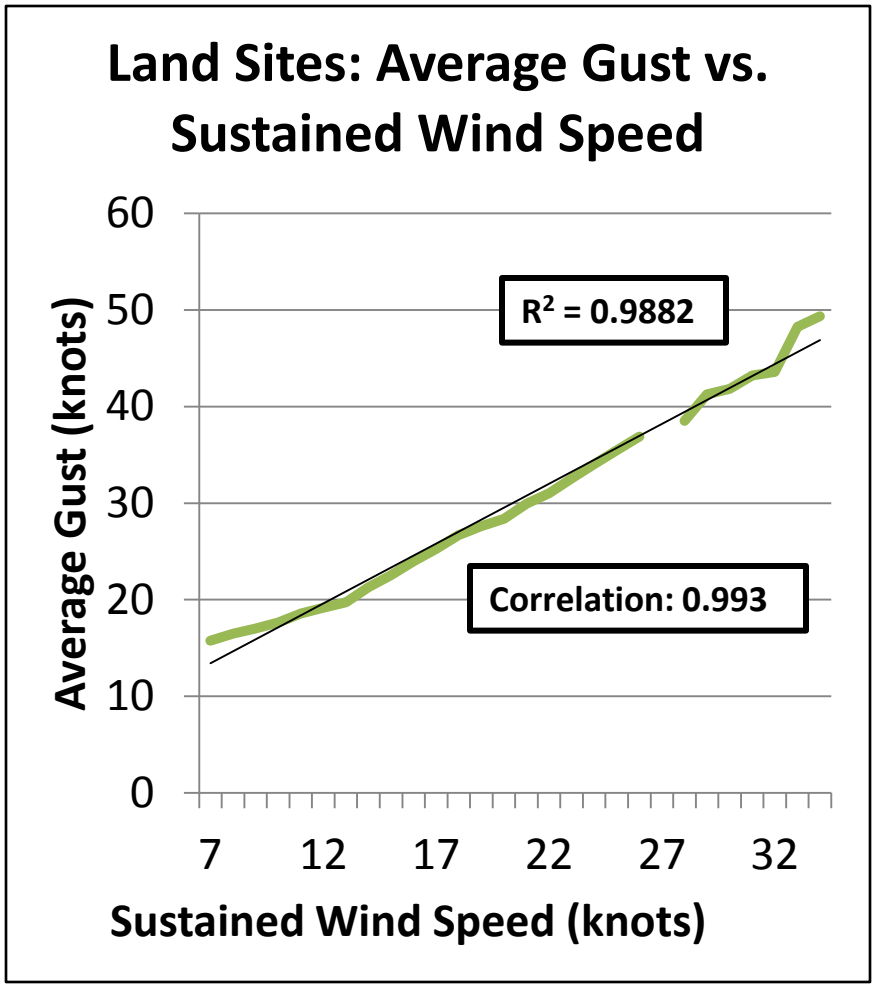
Seasonal Averages

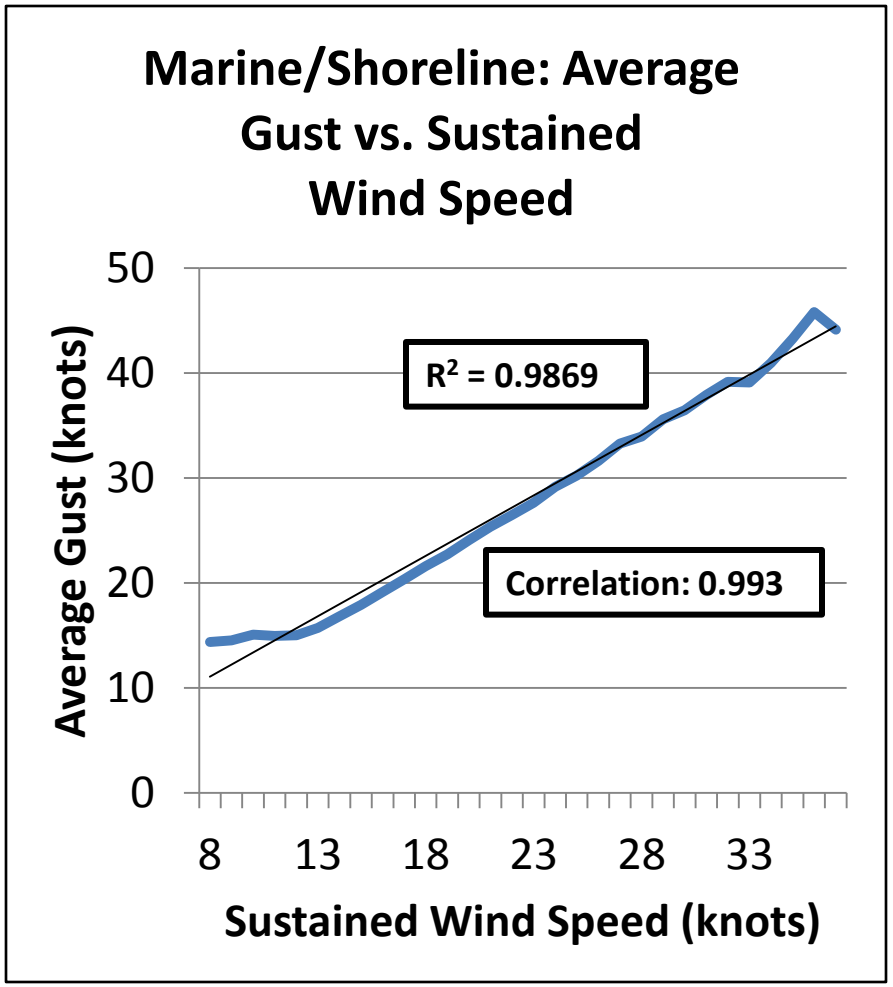
- Slight gust factor variation monthly and seasonally
  - Land and Marine/Shoreline appear inversed





Gusts vs. Sustained Wind Speeds





Conclusions

- Relationship between surface sustained wind and gusts is very strong
  - Accurate sustained wind forecast can lead to a strong gust forecast
- Over land: Gust factor decreases with increasing sustained wind speed
  - Multiple factors can cause variability in gust factor
- Most gust trends, and land vs. marine differences, explained by:
  - Surface Roughness, atmospheric turbulence
  - Boundary Layer Mixing

Next Steps

- Analyze model soundings to better compare surface winds to upper air winds
  - Atmospheric stability may also play a role in gusts
- Closer look at effects of surface roughness
  - Variation with location
- Update Smart Tool within the NWS Integrated Forecast Preparation System
  - Automatically apply trends to forecast grids

Acknowledgements

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- The rest of the NWS Charleston office
- Hollings Program Coordinators

References/Resources

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- Wieringa, J., 1972. Gust Factors Over Open Water and Built-Up Country. *Boundary-Layer Meteorology*. Volume 3, Issue 4, pp.424-441
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- National Data Buoy Center., 2012.

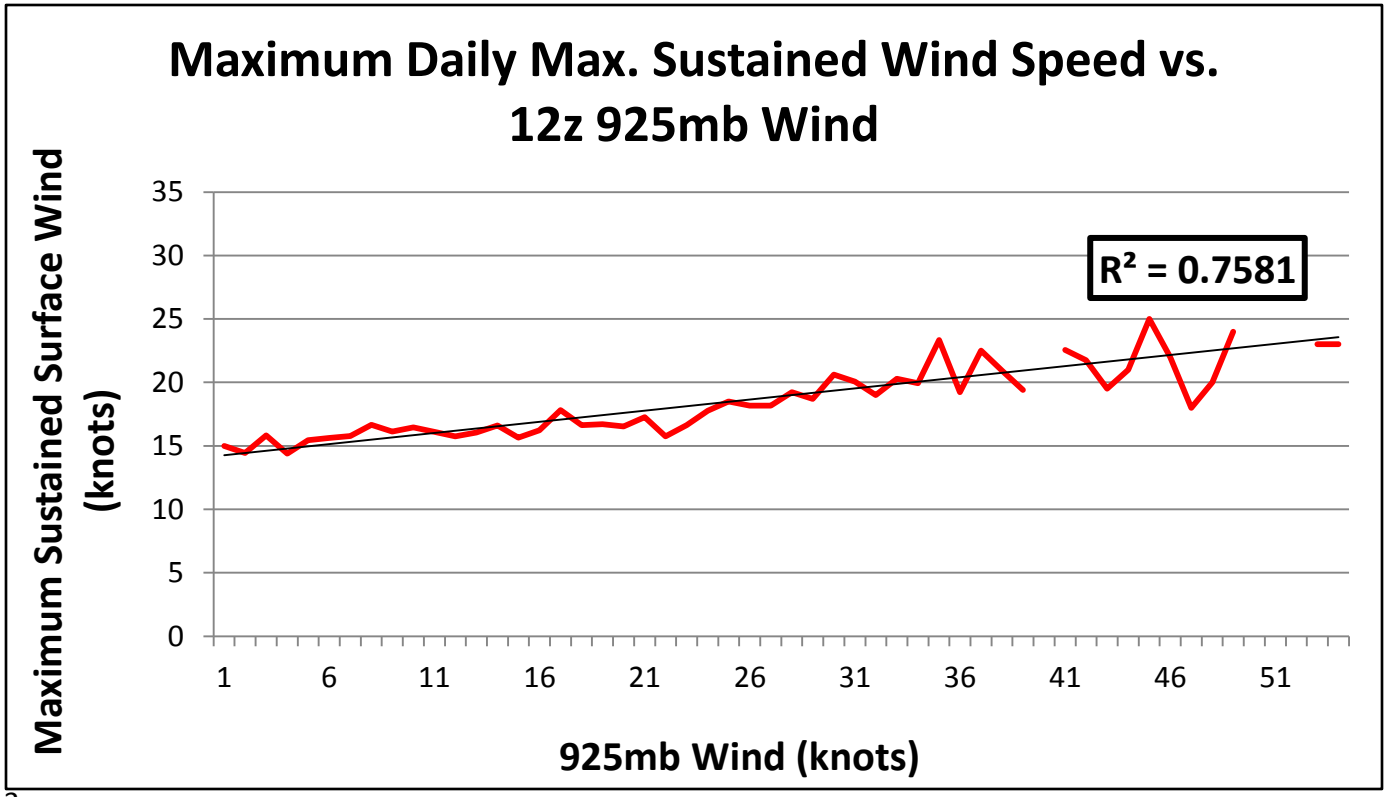
Methodology

- Gathered 12z sounding data for Charleston Air Force Base/Intl. Airport (CHS)
  - CHS is one of the surface data sites

- Saved CHS data for days with both upper air and surface data

Upper Air Analysis

- Compared winds at 850mb, 925mb, and 1000mb to surface winds



Upper Air Analysis

Max. Sfc Wind

	R^2
1000mb	.12
925mb	.76
850mb	.68

Ave. Sfc Wind

	R^2
1000mb	.05
925mb	.76
850mb	.62

12z Sfc Wind

	R^2
1000mb	.78
925mb	.89
850mb	.68

- Strongest relationship at 925mb
  - Inversion at 1000mb, 850mb too high
- Are 925mb winds a reliable indicator of surface conditions around the same time of sounding?
- No stand out trends for Gusts or Gust Factors

Addition Method

- Add a number to the sustained wind forecast to get gust forecast value

Land

Sustained Wind	Add On
<10 knots	8.2
10-15 knots	7.3
15-20 knots	8
20-25 knots	9
25-30 knots	10.8
30+ knots	12.8

Marine/Shoreline

Sustained Wind	Add on
<10 knots	5.4
10-15 knots	3
15-20 knots	3.4
20-25 knots	4.6
25-30 knots	5.9
30+ knots	7.3