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# Inter-Comparison of Data Between Sonic and Propeller Anemometers

2013 Summer Internship  
National Data Buoy Center  
Hunter Greene

Mentors: Regina Moore, Pete Lessing,  
and James Elliott

# My Background

- Senior at Mississippi State University
- Seeking B.S in Geosciences
  - Concentration: Professional Meteorology

## Mentors:

- Regina Moore- NDBC Engineer
- Pete Lessing- NDBC Engineer
- James Elliott- NTSC Engineer

# National Data Buoy Center (NDBC)

- Designs, develops, operates, and maintains a network of data collecting buoys and coastal stations.
- Serves as a data assembly center for receiving, quality controlling, and disseminating measurement data.



# Anemometers

## Propeller Anemometer

- Wind turns the propeller
- Connected to a weather vane
- Weather vane keeps anemometer properly aligned
- Propeller blades indicate wind speed while the weather vane shows direction

## Sonic Anemometer

- Based on time of flight of sonic pulses (ultrasonic sound waves) between pairs of transducers
- Measurements between transducers are combined and calculated to produce a single wind vector

# Anemometers

## Propeller Anemometer

RM Young Model 05103



- Accurate data
- Main issues are maintenance and longevity

## Sonic Anemometer

RM Young Model 85106



- How accurate is the data?
- Requires less maintenance
- Lower threshold speed

# Anemometers Used for Study

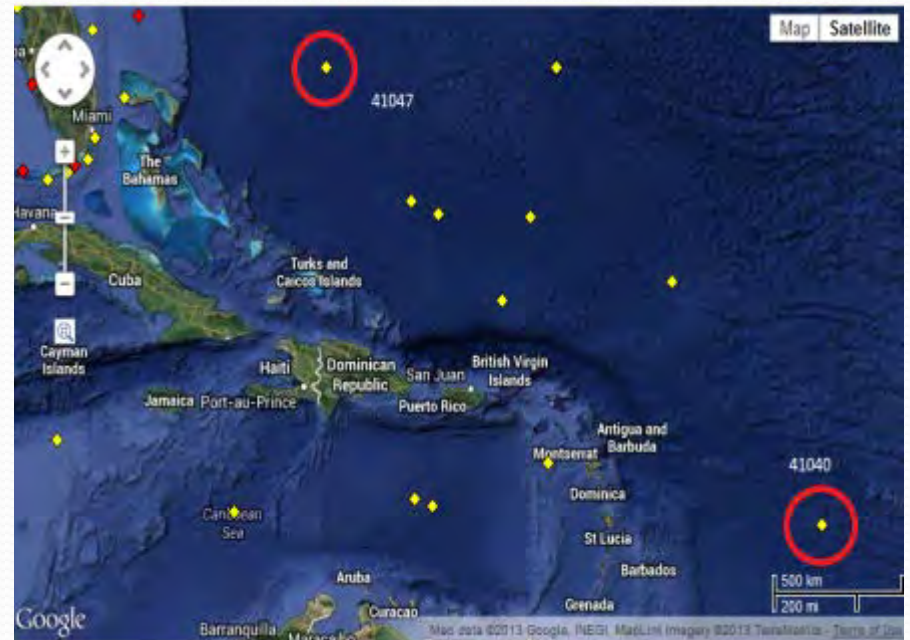
Data taken around Hurricane Isaac (8/27/12 – 9/4/12) @ NDBC

- Test Stand Propeller and Sonic Anemometers
- OSTF1 Propeller and Sonic Anemometers



Data taken from 6/10/13 – 6/17/13

- Buoy #41047
- Buoy #41040



# Methods

- Imported large .txt files(nearly 700,000 lines) into Excel, where raw data was organized using VBA scripting to make the data more readable.
- Computed differences between wind speed and direction measurements taken by propeller and sonic anemometers simultaneously.
- Transferred calculated data from Excel to Matlab where further statistical analysis was performed.
- Drafted scripts in Matlab to create informative charts and graphs of calculated data.

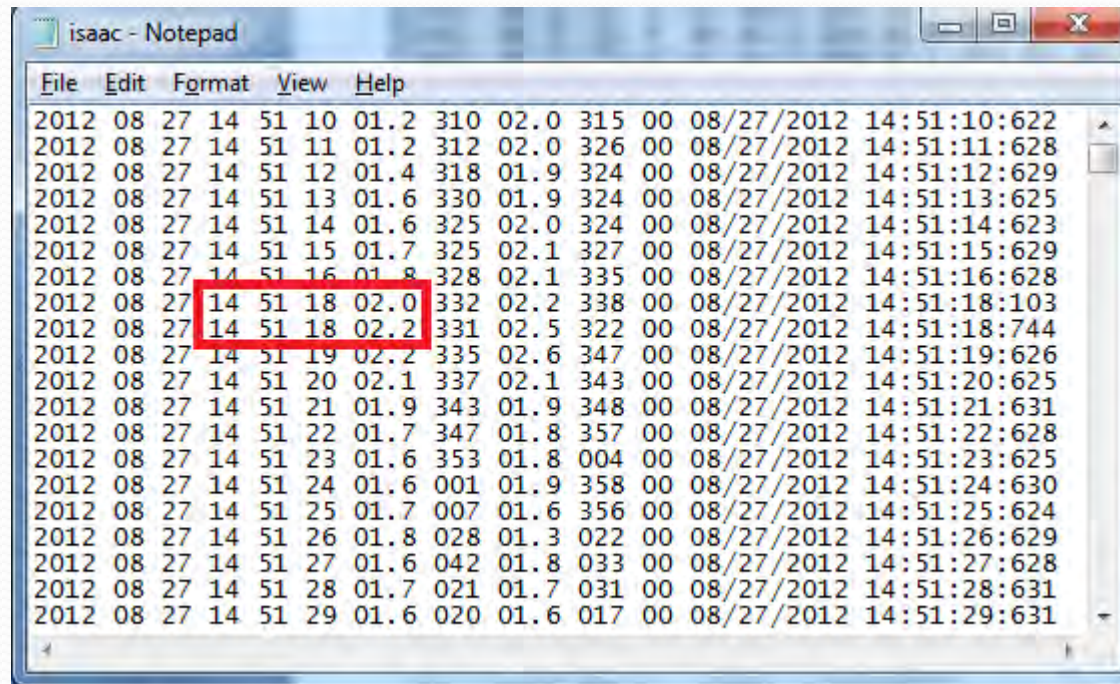
# Glitches in the System

- Missing 3 minutes and 15 seconds (195 data points) starting at 9/2/2012 @ 03:03:24 and skipping to 03:06:39.
- Likely a power failure

File	Edit	Format	View	Help								
2012	09	02	03	02	59	00.0	145	00.5	124	00	09/02/2012	03:02:59:624
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2012	09	02	03	03	02	00.0	145	00.8	111	00	09/02/2012	03:03:02:622
2012	09	02	03	03	03	00.2	142	00.7	117	00	09/02/2012	03:03:03:627
2012	09	02	03	03	04	00.0	137	00.8	123	00	09/02/2012	03:03:04:623
2012	09	02	03	03	05	00.3	135	00.8	111	00	09/02/2012	03:03:05:621
2012	09	02	03	03	06	00.3	135	00.8	122	00	09/02/2012	03:03:06:620
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2012	09	02	03	03	08	00.3	135	00.7	129	00	09/02/2012	03:03:08:618
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# System Limitations



File	Edit	Format	View	Help								
2012	08	27	14	51	10	01.2	310	02.0	315	00	08/27/2012	14:51:10:622
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2012	08	27	14	51	16	01.8	328	02.1	335	00	08/27/2012	14:51:16:628
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2012	08	27	14	51	18	02.2	331	02.5	322	00	08/27/2012	14:51:18:744
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2012	08	27	14	51	24	01.6	001	01.9	358	00	08/27/2012	14:51:24:630
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2012	08	27	14	51	28	01.7	021	01.7	031	00	08/27/2012	14:51:28:631
2012	08	27	14	51	29	01.6	020	01.6	017	00	08/27/2012	14:51:29:631

- In this image, **2 data points were recorded** at the 18 second mark on 8/27/12 @ 14:51:18.

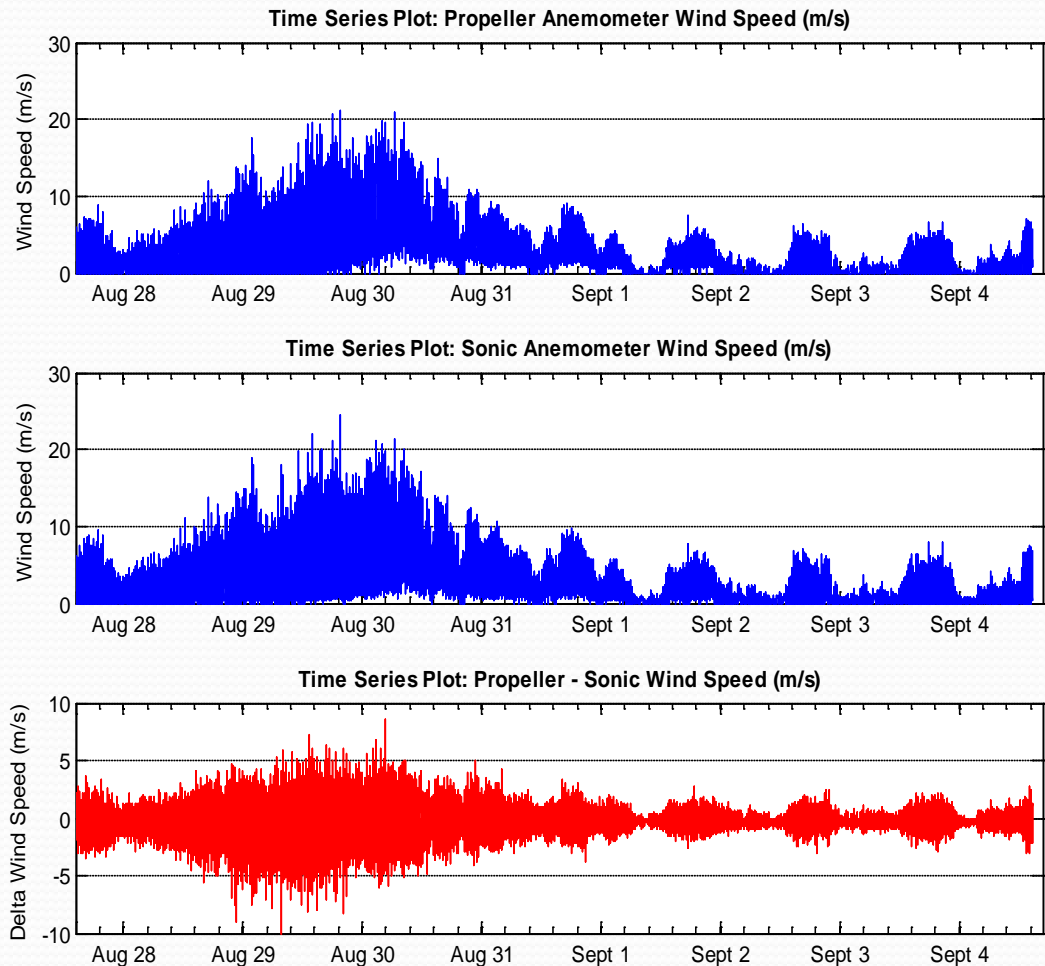
# System Limitations

```
isaac - Notepad
File Edit Format View Help
2012 08 27 15 01 07 03.0 321 03.7 308 00 08/27/2012 15:01:07:625
2012 08 27 15 01 08 03.1 320 03.9 318 00 08/27/2012 15:01:08:628
2012 08 27 15 01 09 03.1 337 03.6 331 00 08/27/2012 15:01:09:622
2012 08 27 15 01 10 02.9 333 03.3 330 00 08/27/2012 15:01:10:621
2012 08 27 15 01 11 02.8 332 03.6 319 00 08/27/2012 15:01:11:625
2012 08 27 15 01 12 02.9 314 04.0 314 00 08/27/2012 15:01:12:627
2012 08 27 15 01 13 02.8 332 03.9 319 00 08/27/2012 15:01:13:618
2012 08 27 15 01 14 03.0 327 03.7 323 00 08/27/2012 15:01:14:625
2012 08 27 15 01 15 03.3 325 03.6 327 00 08/27/2012 15:01:15:630
2012 08 27 15 01 16 02.8 328 03.3 340 00 08/27/2012 15:01:16:622
2012 08 27 15 01 17 02.3 331 02.2 333 00 08/27/2012 15:01:17:629
2012 08 27 15 01 19 01.7 327 01.6 318 00 08/27/2012 15:01:19:096
2012 08 27 15 01 19 01.3 328 01.3 308 00 08/27/2012 15:01:19:730
2012 08 27 15 01 20 01.0 329 00.9 309 00 08/27/2012 15:01:20:622
2012 08 27 15 01 21 00.7 334 01.0 334 00 08/27/2012 15:01:21:625
2012 08 27 15 01 22 00.6 336 01.0 331 00 08/27/2012 15:01:22:621
2012 08 27 15 01 23 00.4 337 01.2 342 00 08/27/2012 15:01:23:628
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2012 08 27 15 01 25 00.4 337 01.4 339 00 08/27/2012 15:01:25:620
2012 08 27 15 01 26 00.5 338 02.0 008 00 08/27/2012 15:01:26:622
```

- In this image, the same problem occurs exactly 10 minutes and 1 second later. You can see there are **2 data points recorded** at the 19 second mark on 8/27/12 but @15:01:19.
- Occurs every 10 minutes and 1 second throughout the file regardless if the hour or day changes.

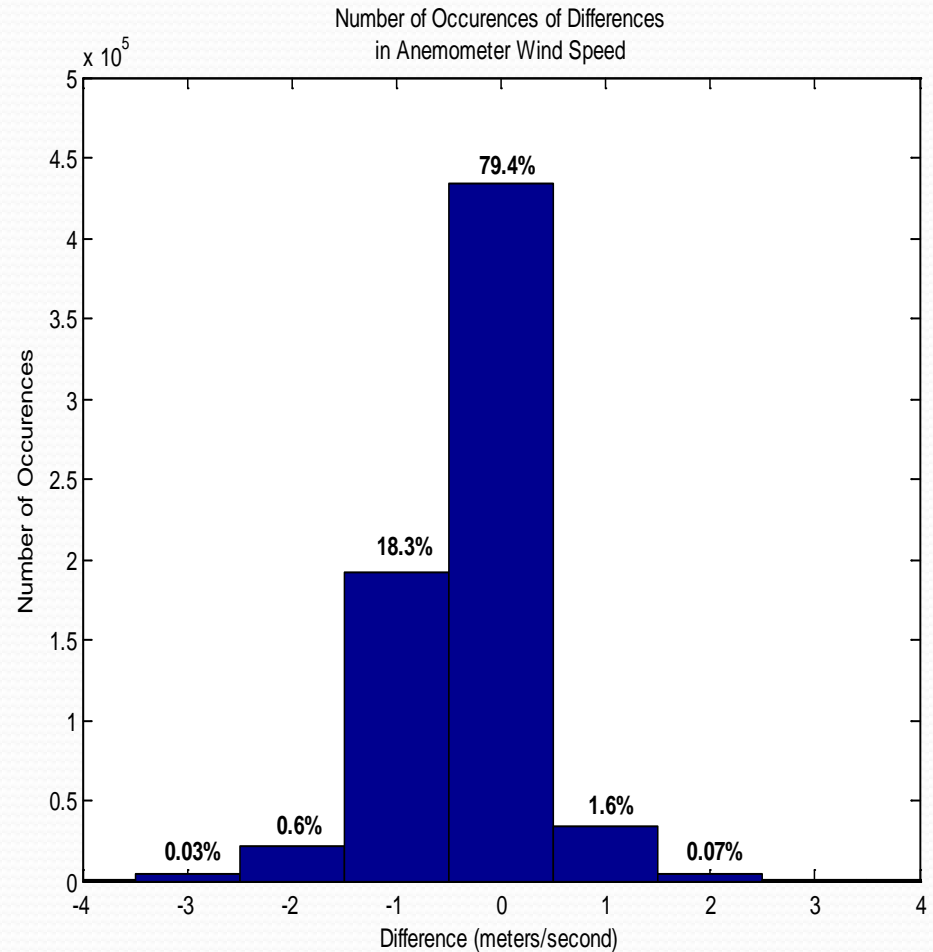
# Time Series Results

- 3 Time Series Plots from Isaac
- 3<sup>rd</sup> plot shows absolute error between anemometers
- Data collected every second from 8/27/12 at 14:37:31 UTC to 9/4/12 at 15:06:35 UTC.



# Time Series Results

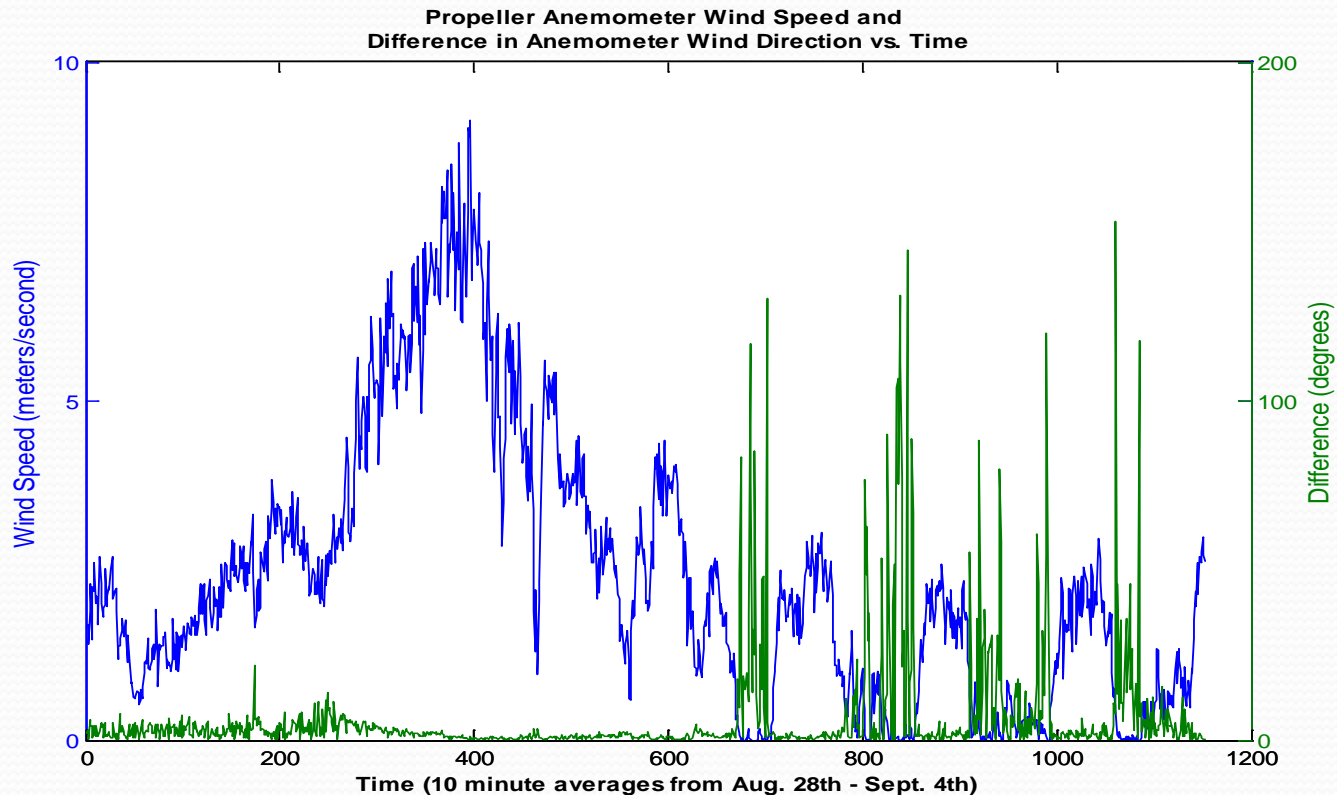
- 8 bin histogram showing distributions of the absolute error in wind speed from Isaac Time Series Data.



# Average Time Series Results

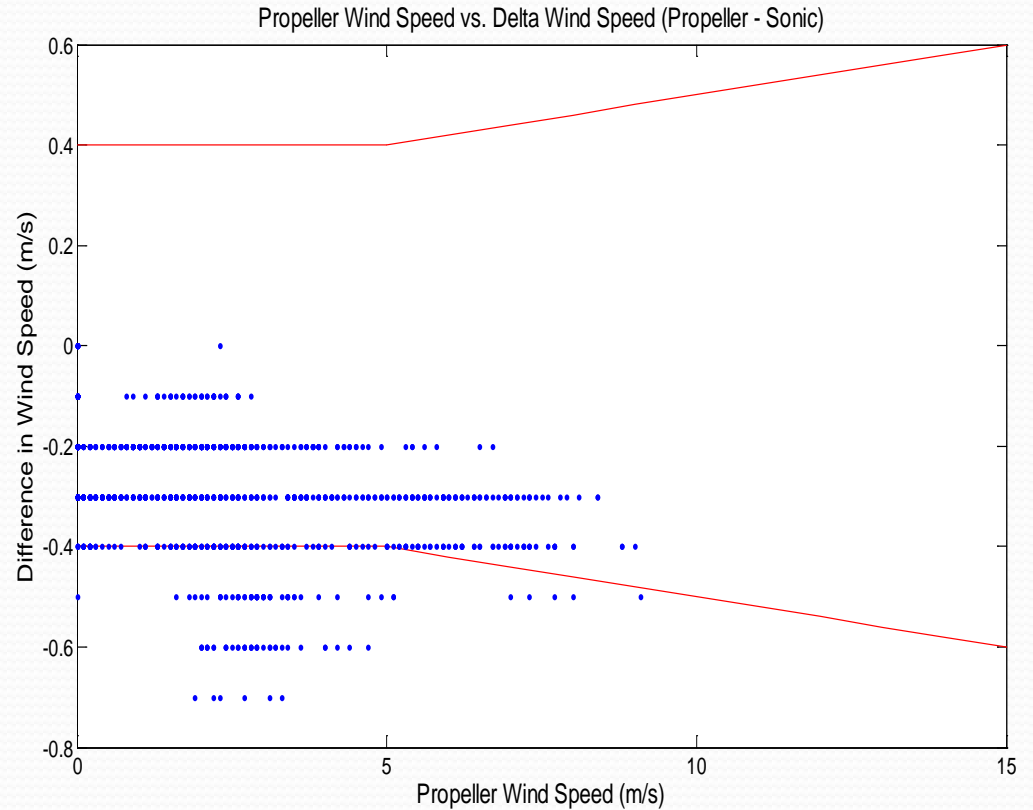
- 2 y-axis plot with blue showing wind speed, and green showing difference in observed direction.

- Differences in measured direction have a tendency to increase when the measured wind speed is at or near 0.



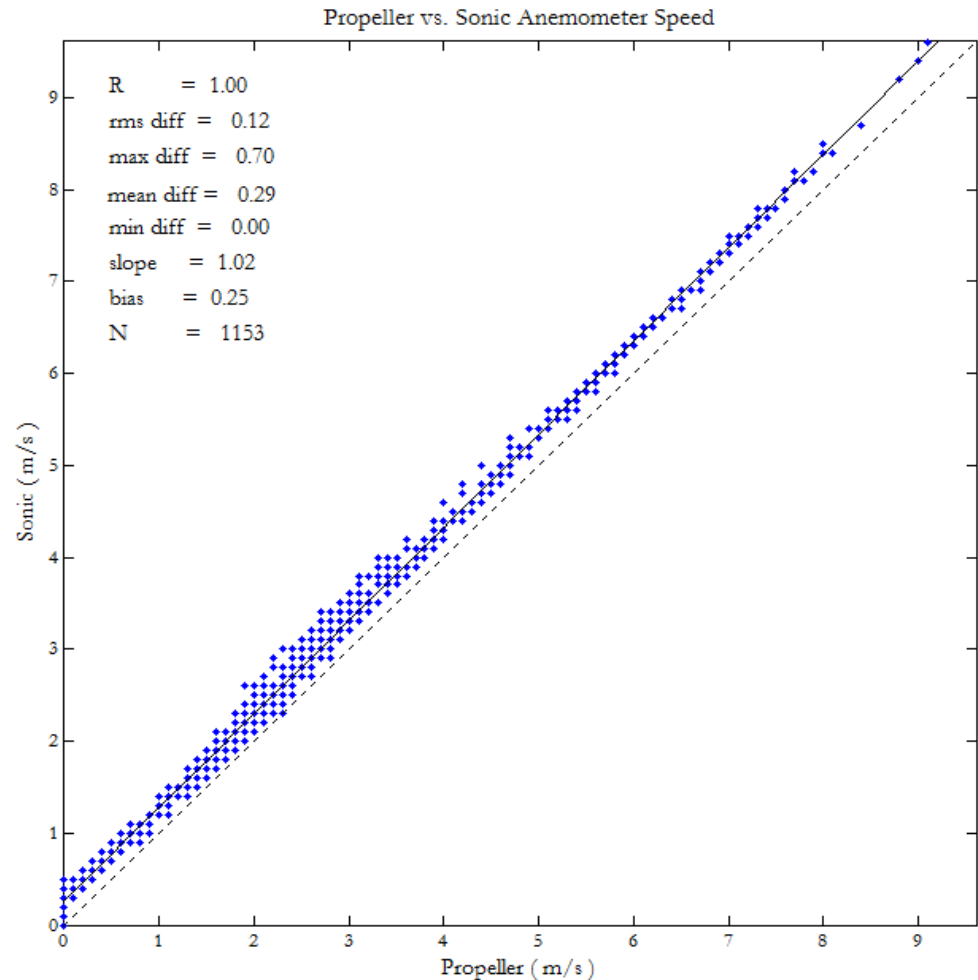
# Average Time Series Results

- Error bar plot showing absolute error in wind speed between anemometers from the averaged Time Series Data.
- 1014 data points



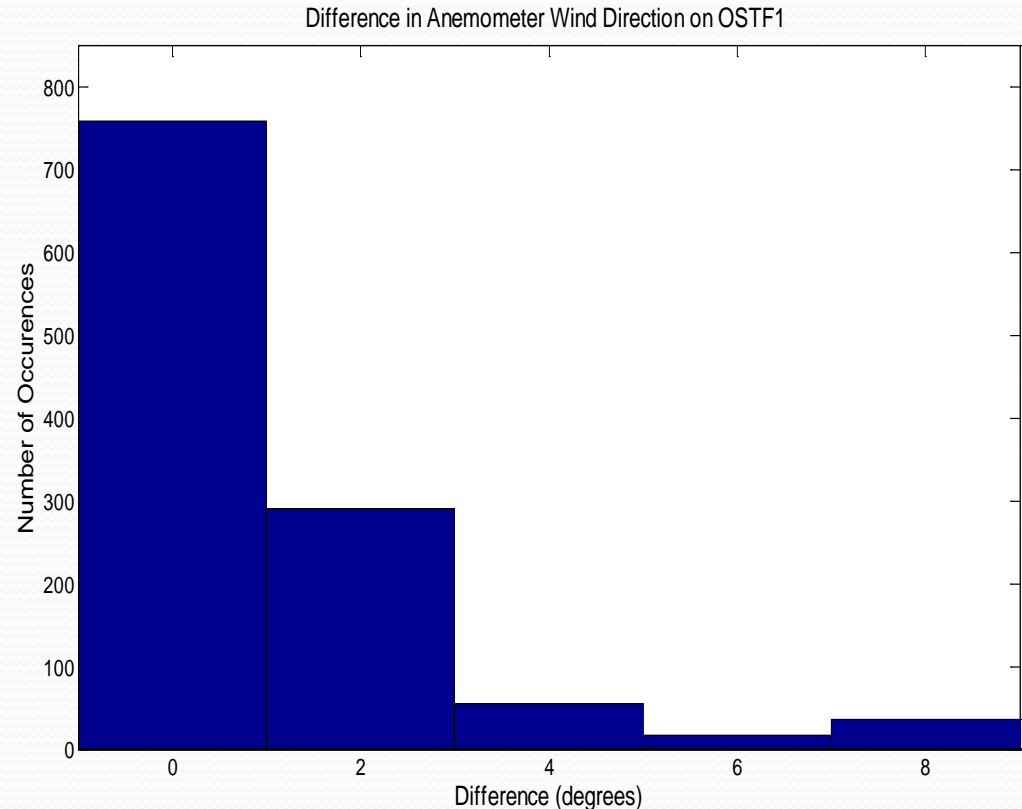
# Average Time Series Results

- Comparing Anemometer Speeds from the averaged Time Series Data
- Near perfect correlation
  - $R = +1.0$
- Slight bias with Sonic always measuring about 0.25 m/s faster than Propeller
- Maximum difference is 0.70 m/s



# OSTF1 Data Results

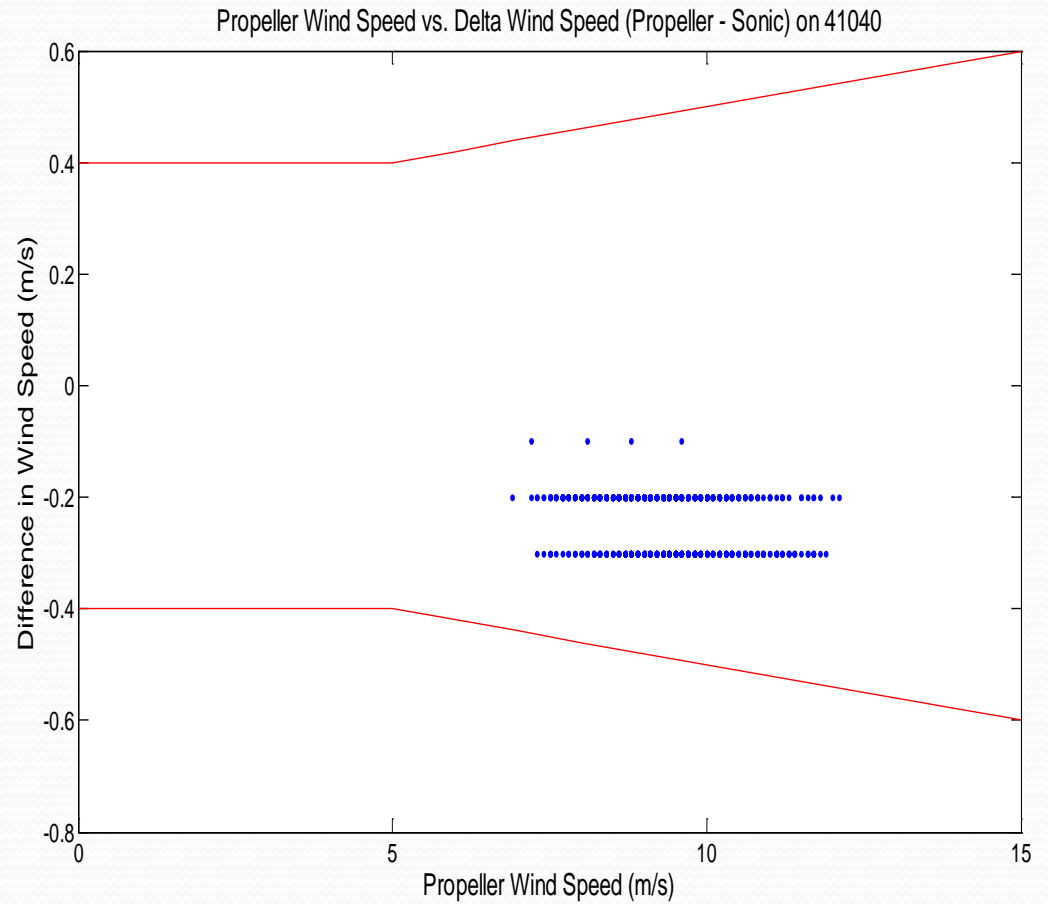
- Histogram showing distributions of the absolute error in wind direction between anemometers on sensor test facility (OSTF1)





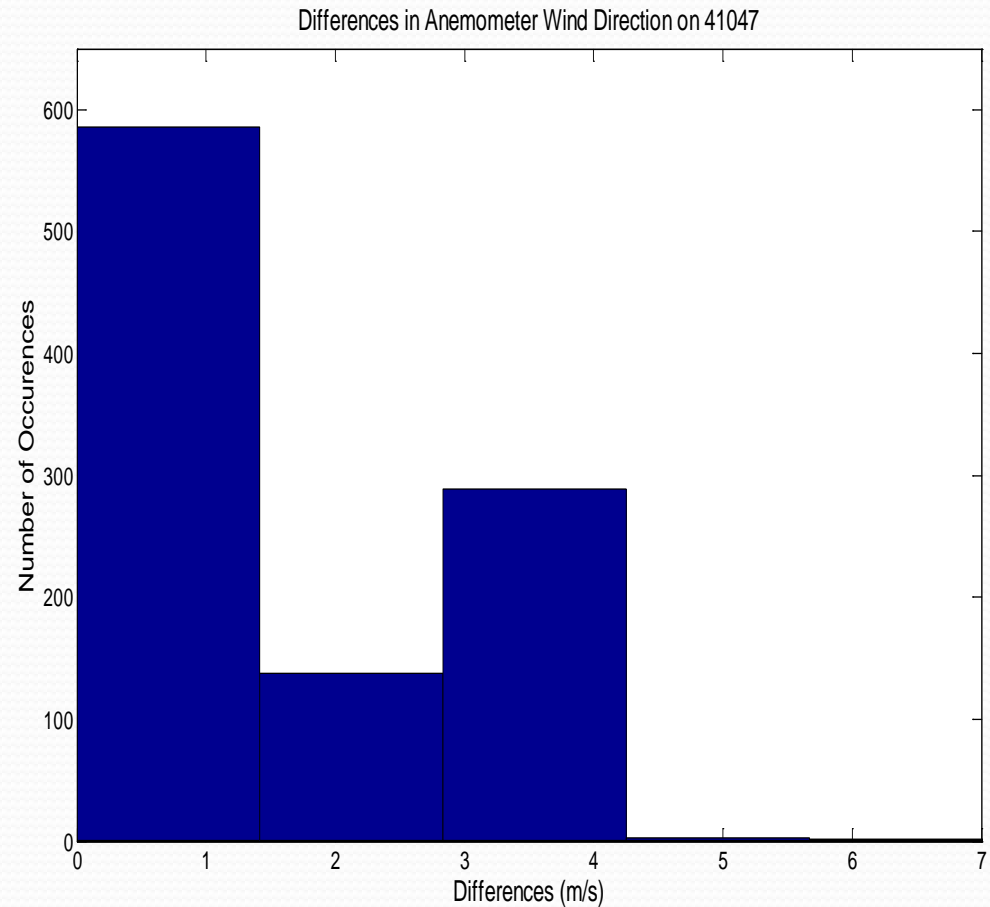
# Real Time Data Results

- Error bar plot showing absolute error in wind speed between the sonic and propeller anemometers on 41040
- 1014 data points



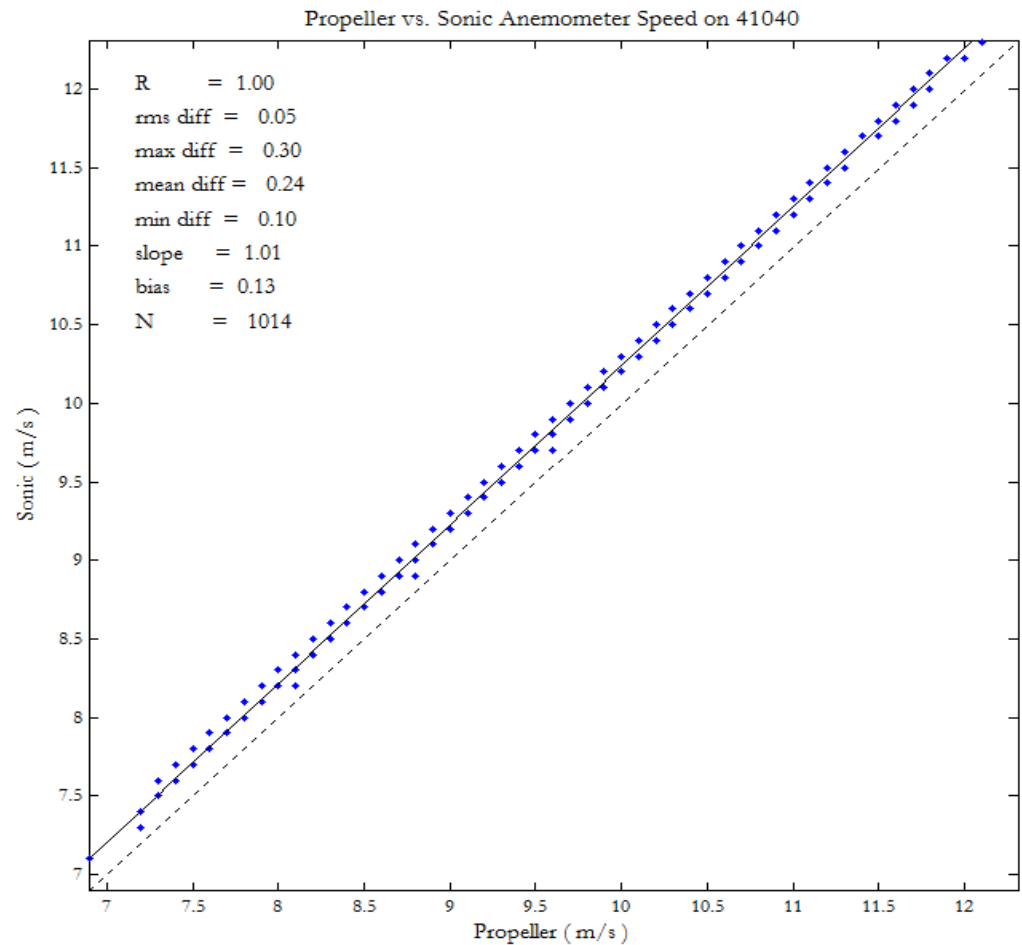
# Real Time Data Results

- Histogram showing distributions of absolute error in wind direction between the propeller and sonic anemometers on 41047



# Real Time Data Results

- Comparing Anemometer Speeds on 41040
- Biased towards Sonic Anemometer by 0.13 m/s
- Near perfect correlation
  - $R = +1.0$
- Maximum difference is 0.30 m/s



# Conclusions

- With the exception of one glitch, no data was lost during the week of Hurricane Isaac from the Time Series Data.
- Raw Time Series Data has much larger differences than averaged data.
  - Consequence of “smoothing effects” caused by averaging.
- The sonic anemometer on average is slightly faster than the propeller anemometer (possibly due to threshold speeds).
- The difference in direction between anemometers increases dramatically when the measured propeller wind speed is less than 1 m/s.
  - 99% chance that if the difference in wind direction between anemometers is greater than the standard deviation of the delta, then the measured propeller speed is less than 1 m/s.

# Content/Skills Learned

- Value of NDBC
- Matlab
- Excel
- Statistical/Comparative analysis techniques
- Graphing/plotting

# Challenges

- New to Matlab
- Going from meteorology to engineering
- Work environment
- Thinking on my own

# Final Thoughts

- Value of Internship
- Cool meetings
- Connections
- Career Outlook

# Acknowledgements

- NDBC
- Mississippi State/NGI