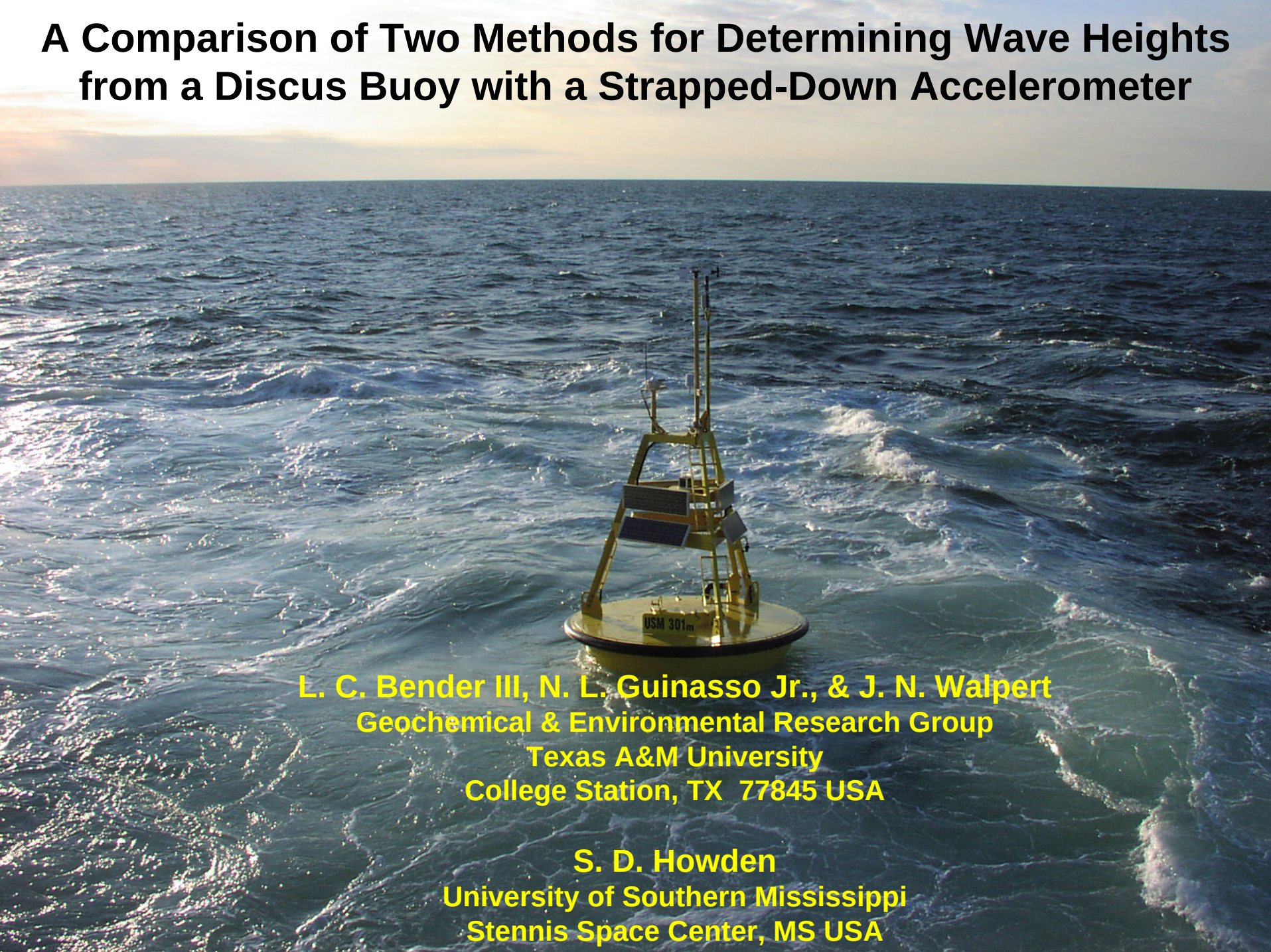
A Comparison of Two Methods for Determining Wave Heights from a Discus Buoy with a Strapped-Down Accelerometer



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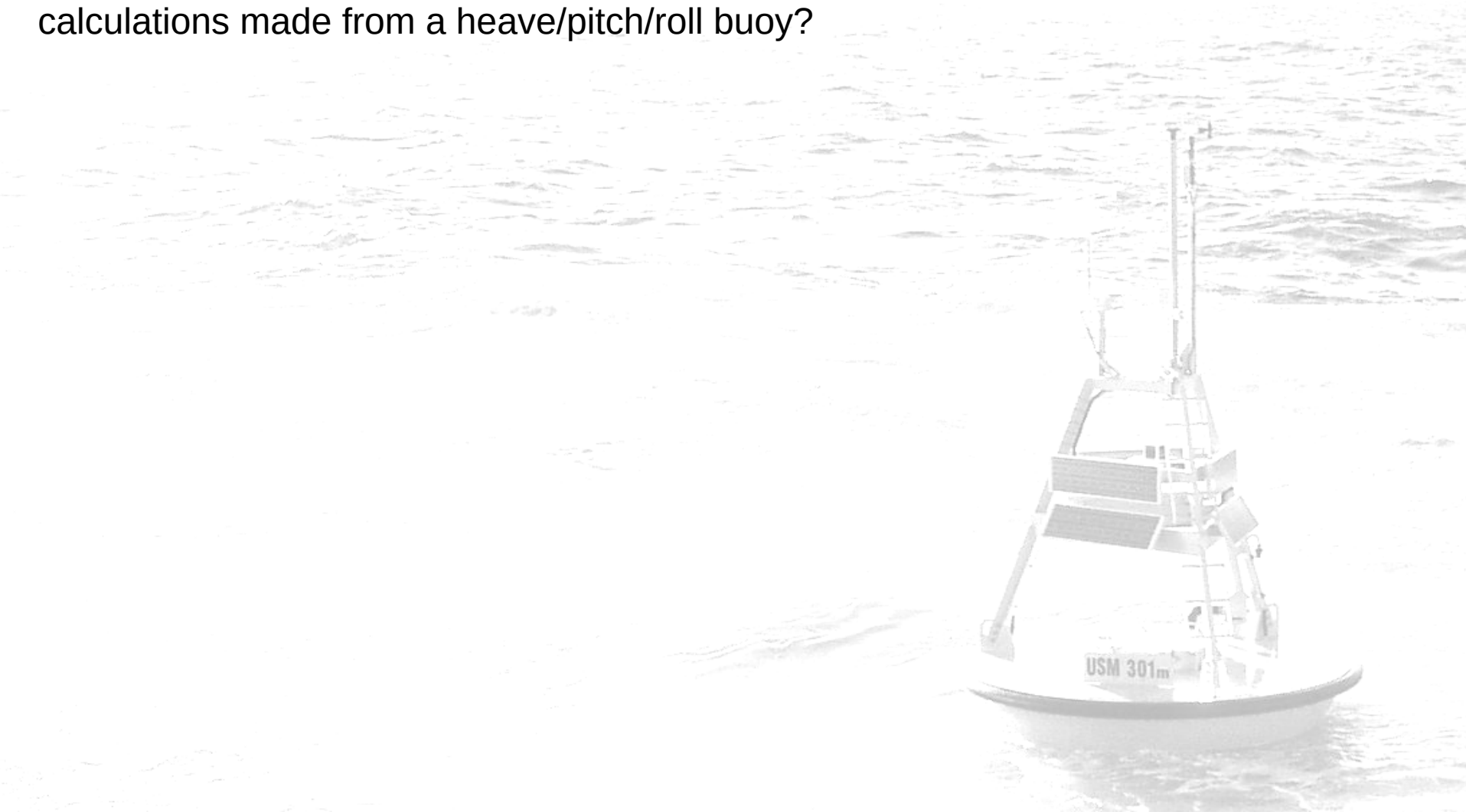
Motivation

How does one get wave heights and directions from a heave/pitch/roll buoy equipped with an accelerometer and a tilt sensor?

Why should the buoy heel make a difference in the wave height calculations made from a heave/pitch/roll buoy?



Methodology

Instrumentation

- Crossbow 3D accelerometer => a_x, a_y & a_z
- Honeywell HMR compass => heading, pitch & roll
- All the raw data was saved on board.

Platforms

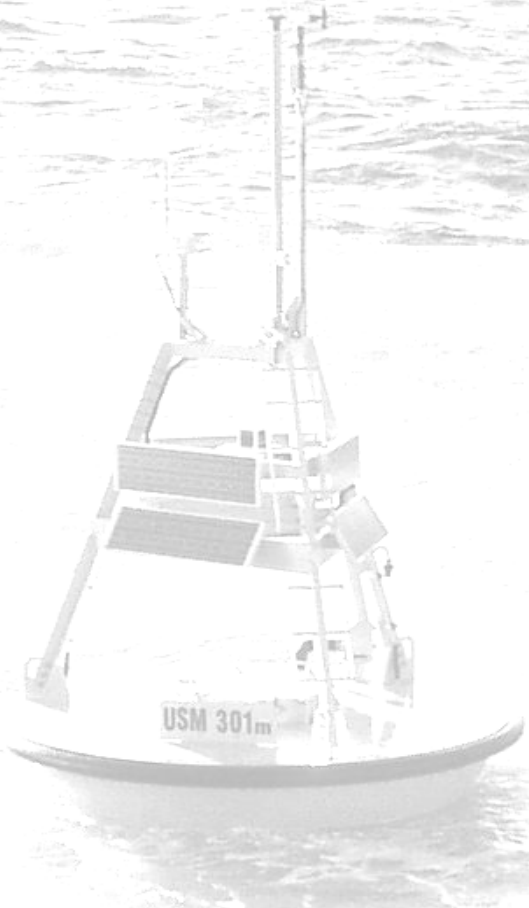
- 3-m discus buoy
- 2.25-m discus buoy

Hurricanes

- Katrina – August 29, 2005
- Ike – September 12, 2008

Test

- OWIF at NDBC



Summary of Conclusions

•Wave heights from a strapped-down 1D accelerometer can be overestimated during storm events
  - •if the buoy is small: 3m discus
  - •if the buoy is heeled: >6^{o}
  - •if the buoy is in shallow water: <100m

•A strapped-down 3D accelerometer can give comparable wave heights to an internally gimbaled accelerometer if the orientation of the strapped-down accelerometer is properly accounted for.

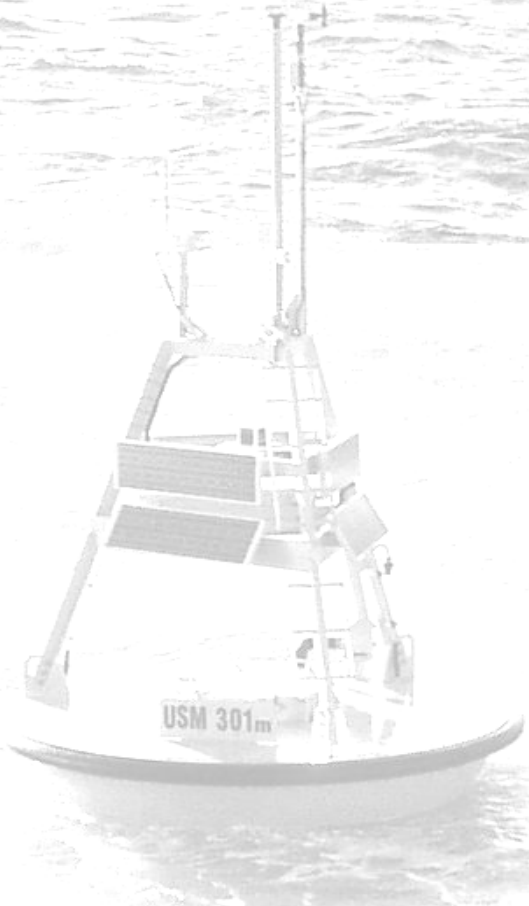
•Using a heave/pitch/roll buoy with a strapped-down 1D accelerometer to report on individual, large wave events in shallow water is not for the faint of heart.

What does an accelerometer measure?

- Acceleration?
- Force!
- => A Gravity Offset
- Orientation is important
- “Contamination” of g into three axes
- Buoy heel becomes an issue for a strapped-down1D accelerometer.

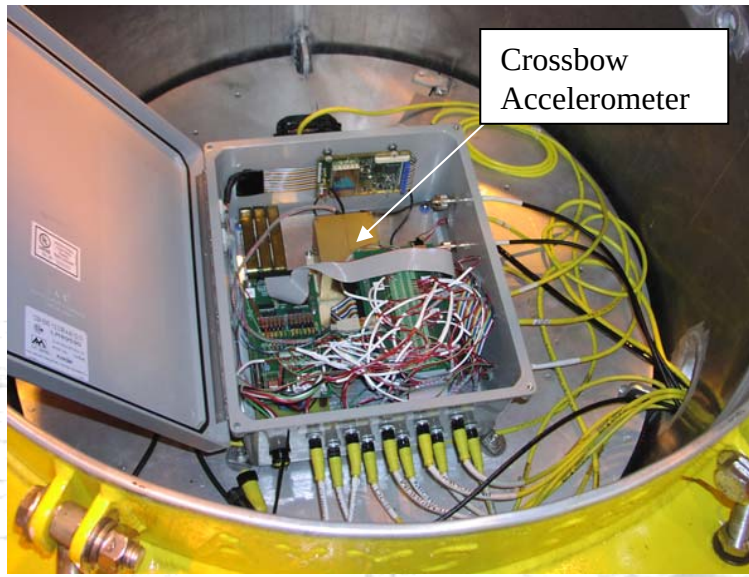
Confirmation

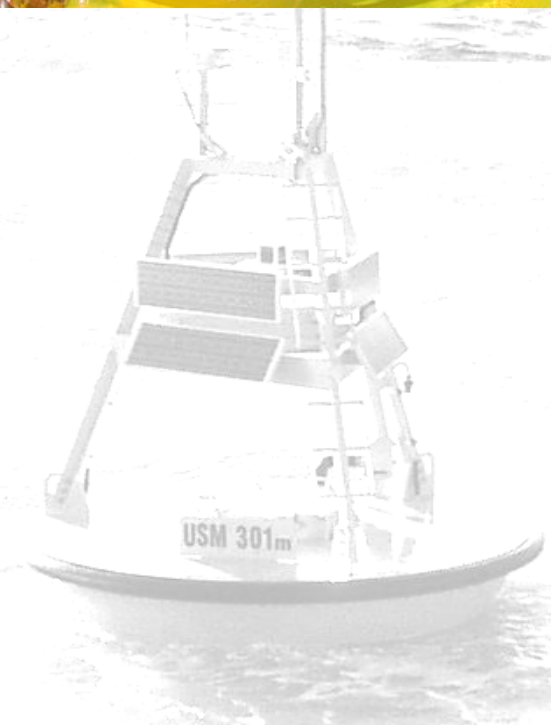
- Two buoys and two hurricanes
- One test
- A theoretical model



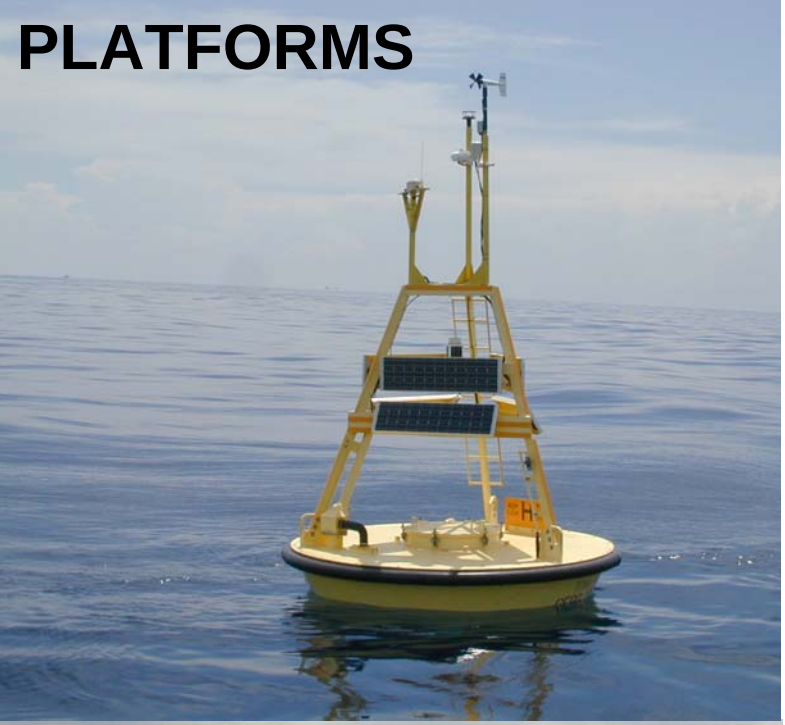
INSTRUMENTATION

- **Crossbow IMU400/440 accelerometer**
  - **3-axis linear acceleration**
  - **Pitch, roll & yaw rate**
- **Honeywell HMR 3300 compass**
  - **Heading, pitch and roll**

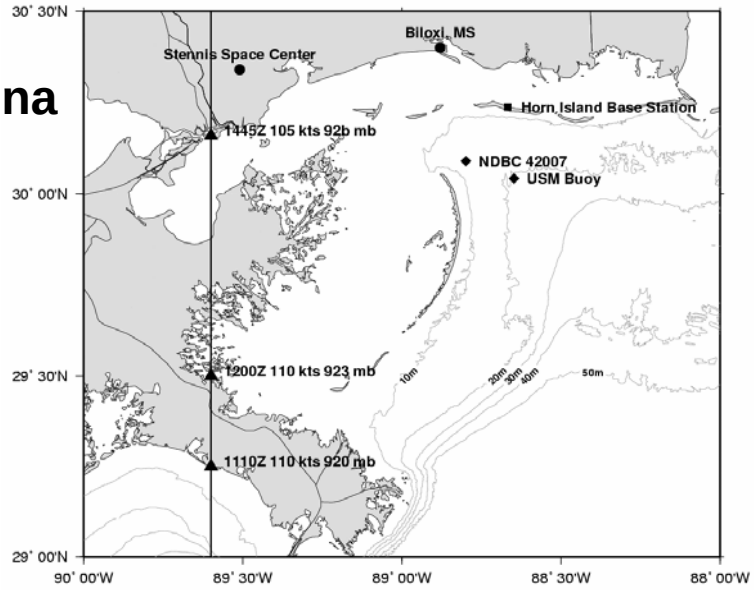




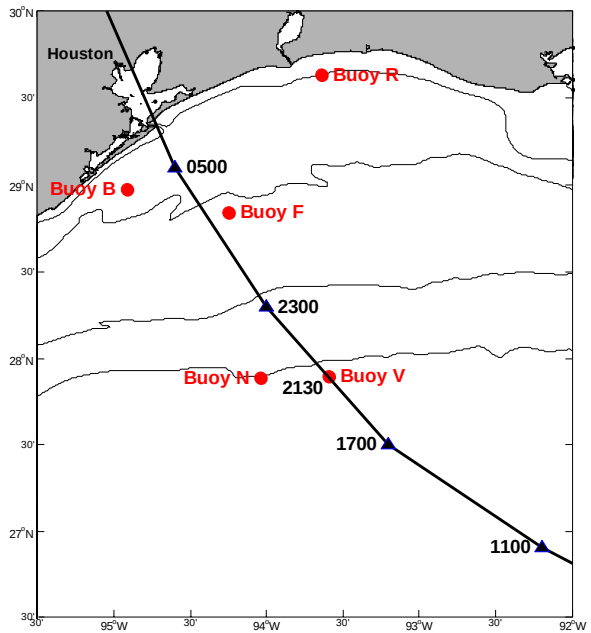
PLATFORMS



Hurricane Katrina



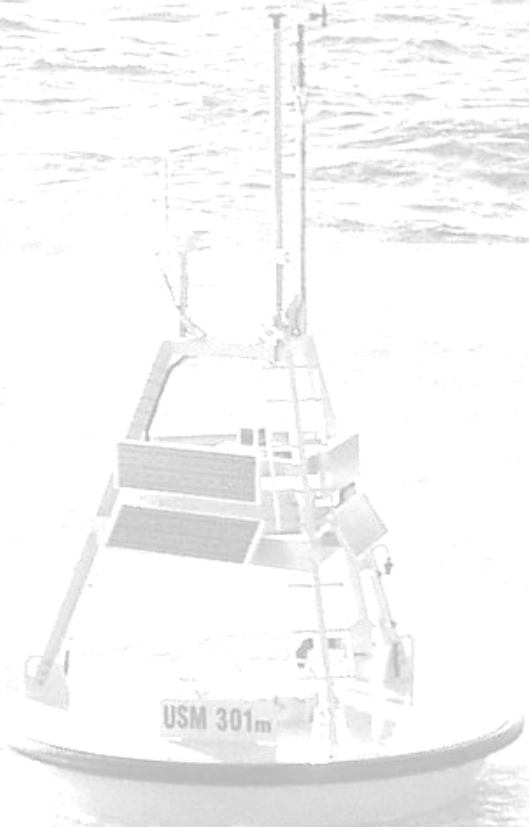
Hurricane Ike



Remove the Gravity Offset

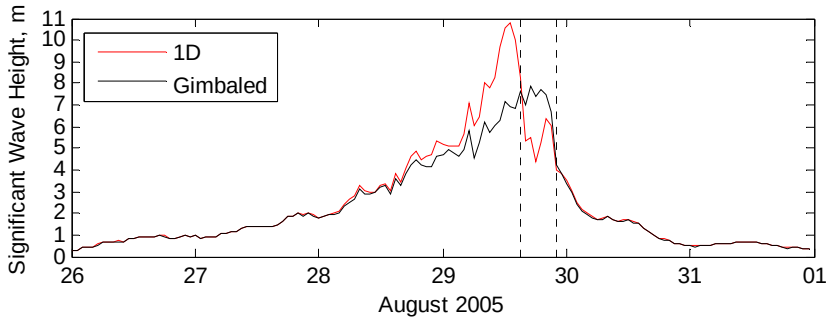
I. Strapped-down 1D accelerometer only.
   Assume the tilt is small.
   Subtract 1g from the measurements,
   Instead of subtracting the component of gravity.

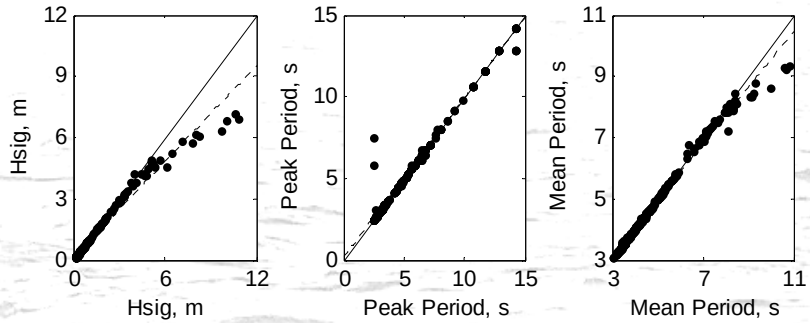
II. Strapped-down 3D accelerometer with pitch, roll & heading.
   Mathematically gimbal to get earth-referenced vertical acceleration.
   or
   z-axis only => 1D



Hurricane Katrina

3m discus
19m depth

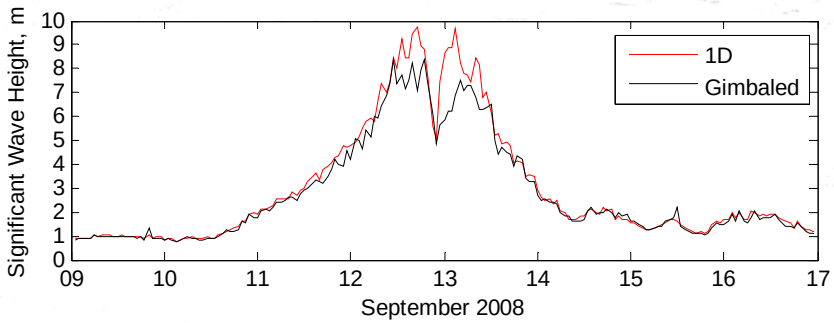


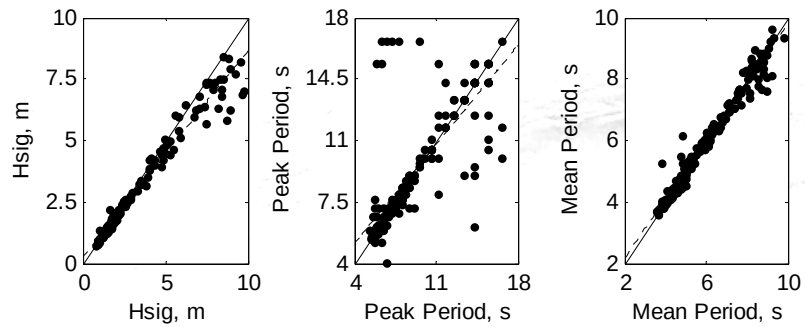


Horizontal axes – 1D
Vertical axes – Mathematically Gimbaled

Hurricane Ike

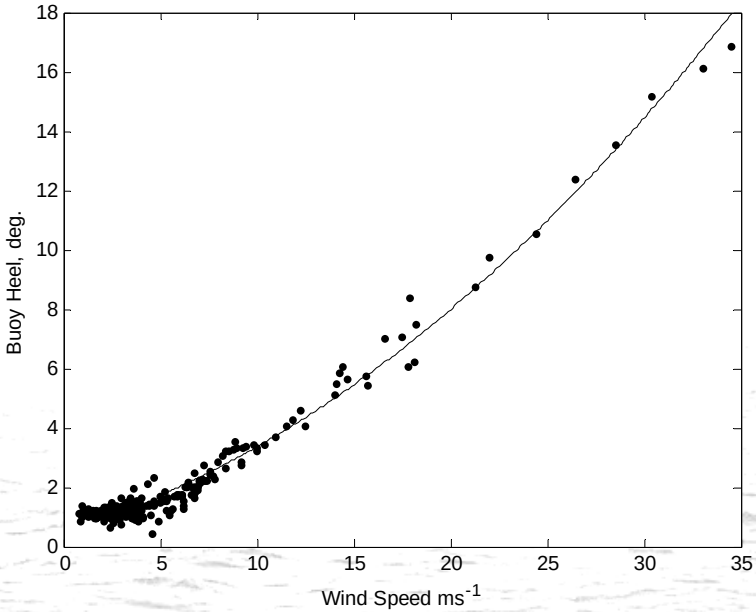
2.25m discus
89m depth





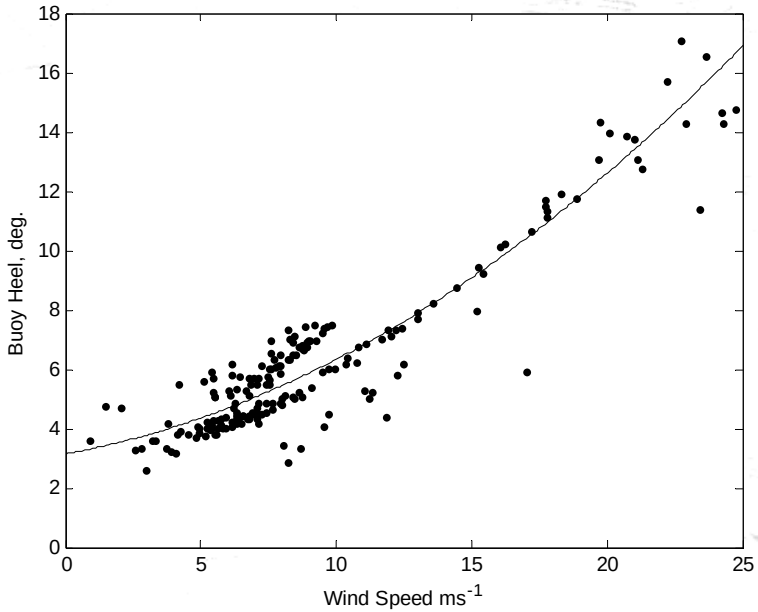
Horizontal axes – 1D
Vertical axes – Mathematically Gimbaled

Hurricane Katrina

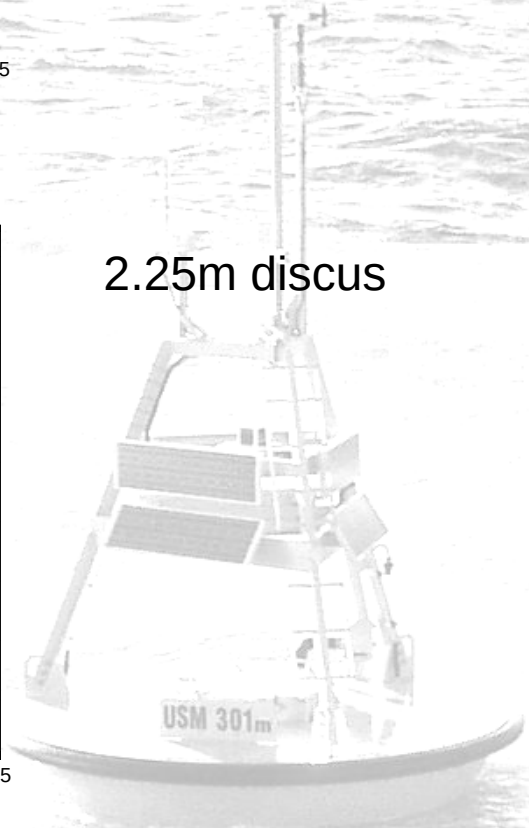


3m discus

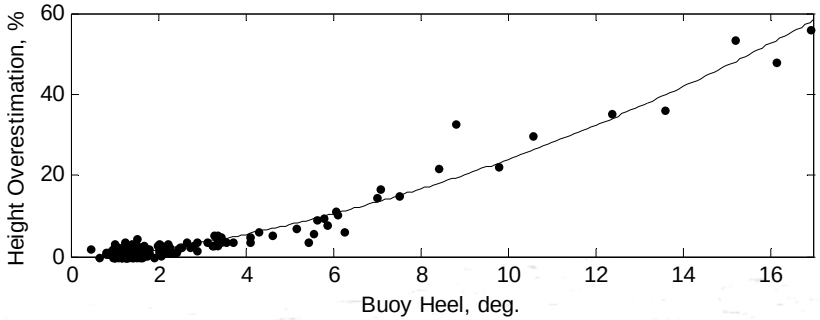
Hurricane Ike

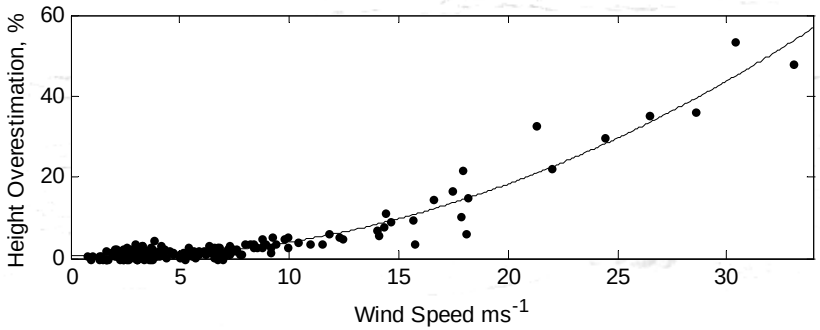


2.25m discus

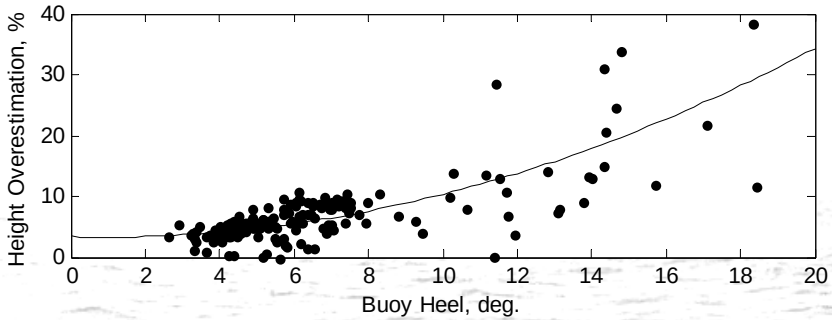


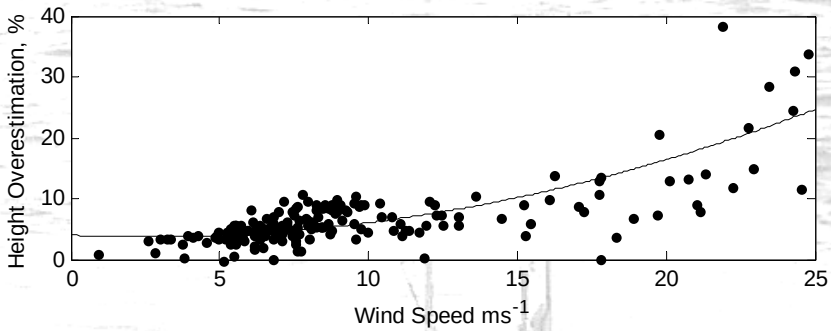
Hurricane Katrina

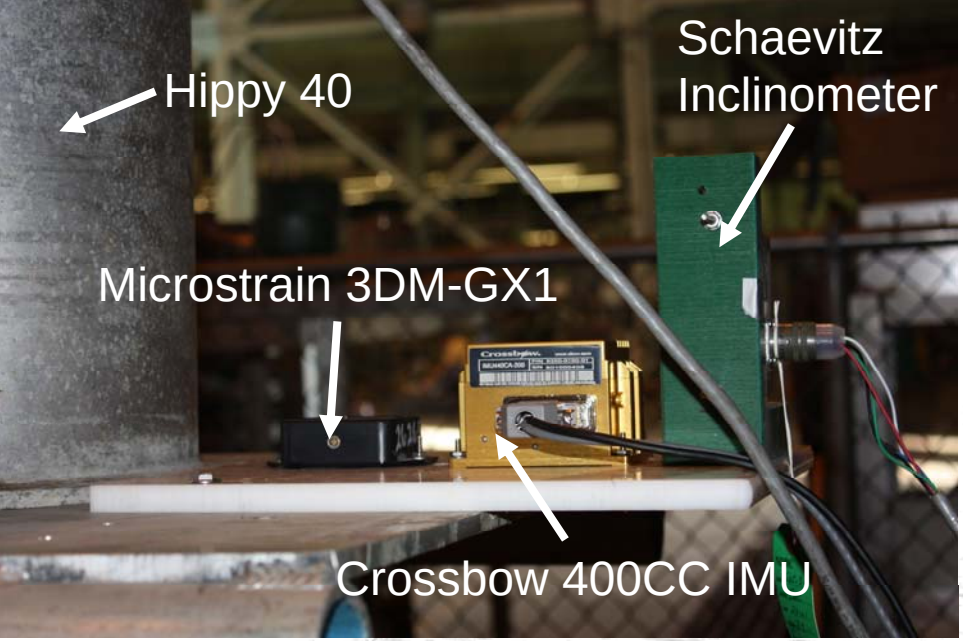


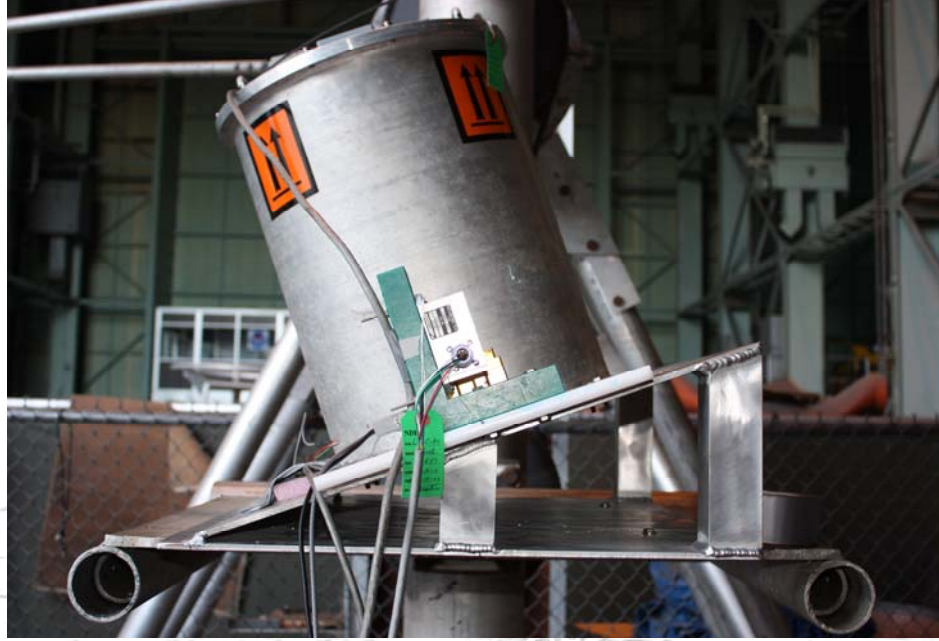


Hurricane Ike







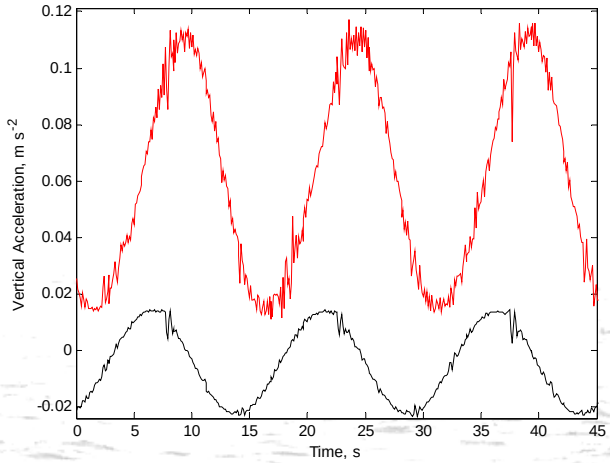


1m arm => H_S = 2.83 m

A series of 38 runs
Periods: 6, 9, 12, 15, 18, 21 s
Tilts: 0, 8, 24 deg.
Heel: 0, 20 deg.

15s period, 8^{o} tilt, 20^{o} heel

H_S = 7.36m

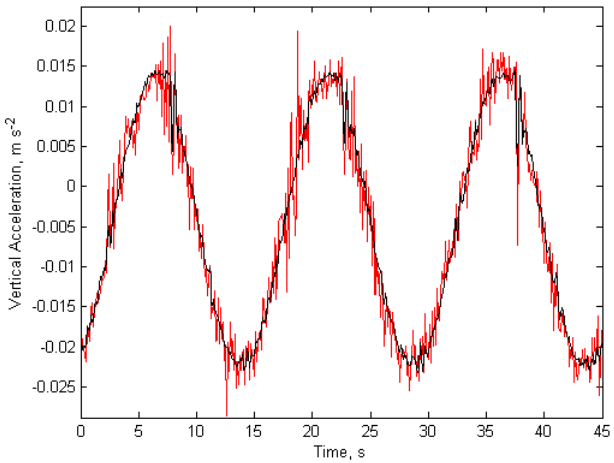


Z-axis Crossbow

Hippy 40

H_S = 2.75m

H_S = 2.72m



Mathematically Gimbaled Crossbow

Hippy 40

H_S = 2.75m

Summary of Conclusions

•Be a discriminating user of buoy wave heights.

•Shallow water, smaller diameter buoys with a strapped-down 1D accelerometer can be significantly affected if the buoy is heeled.

•Deep water discus buoys with large diameter hulls and strapped-down 1D accelerometers are largely unaffected if the buoy is heeled.

•A strapped-down 3D accelerometer with pitch, roll and heading data can give comparable wave heights to an internally gimbaled accelerometer.

•Using a heave/pitch/roll buoy with a strapped-down 1D accelerometer to measure individual, large wave events in shallow water can lead to overestimated wave heights.

Questions?