NortekUSA Wave Measurements

- Overview of NortekUSA
- Options for wave measurements
  - Equipment
  - Methodology
  - Limitations
- Tampa Bay wave data
- Discussion & Questions

NortekUSA Overview

Nortek-AS (1996)
Oslo, Norway

NortekUSA (1999)
Annapolis, MD

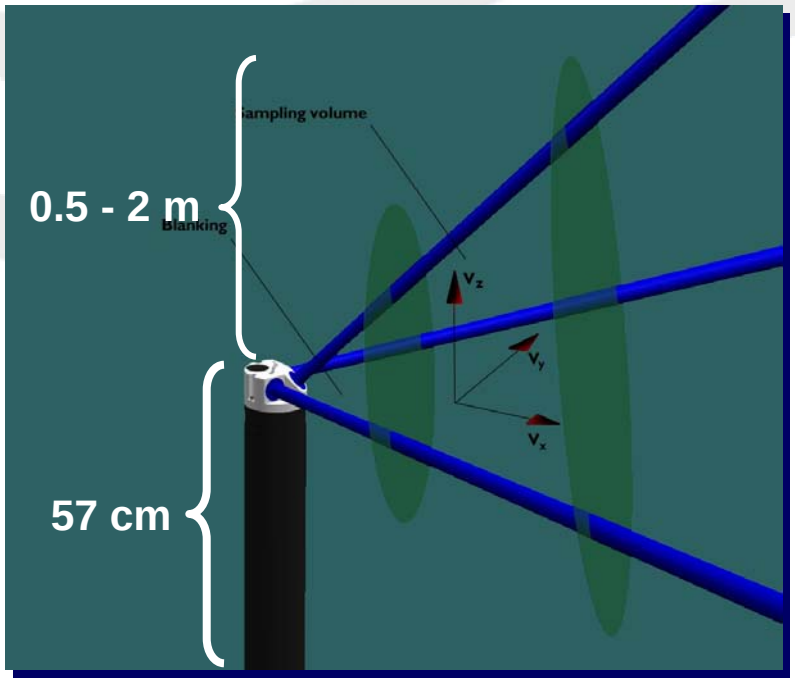
- Current Meters
- Current Profilers
- Wave Gauges
- Velocimeters
- River Measurements

Options for Wave Measurements

- Aquadopp Current Meter (PUV)
- Aquadopp Profiler (PUV)
- Vector Velocimeter (PUV)
- AWAC (AST-MLM)

Aquadopp Current Meter

- Measures current velocity in one cell
- Measures waves at 1 Hz maximum
- Optional transducer head config.



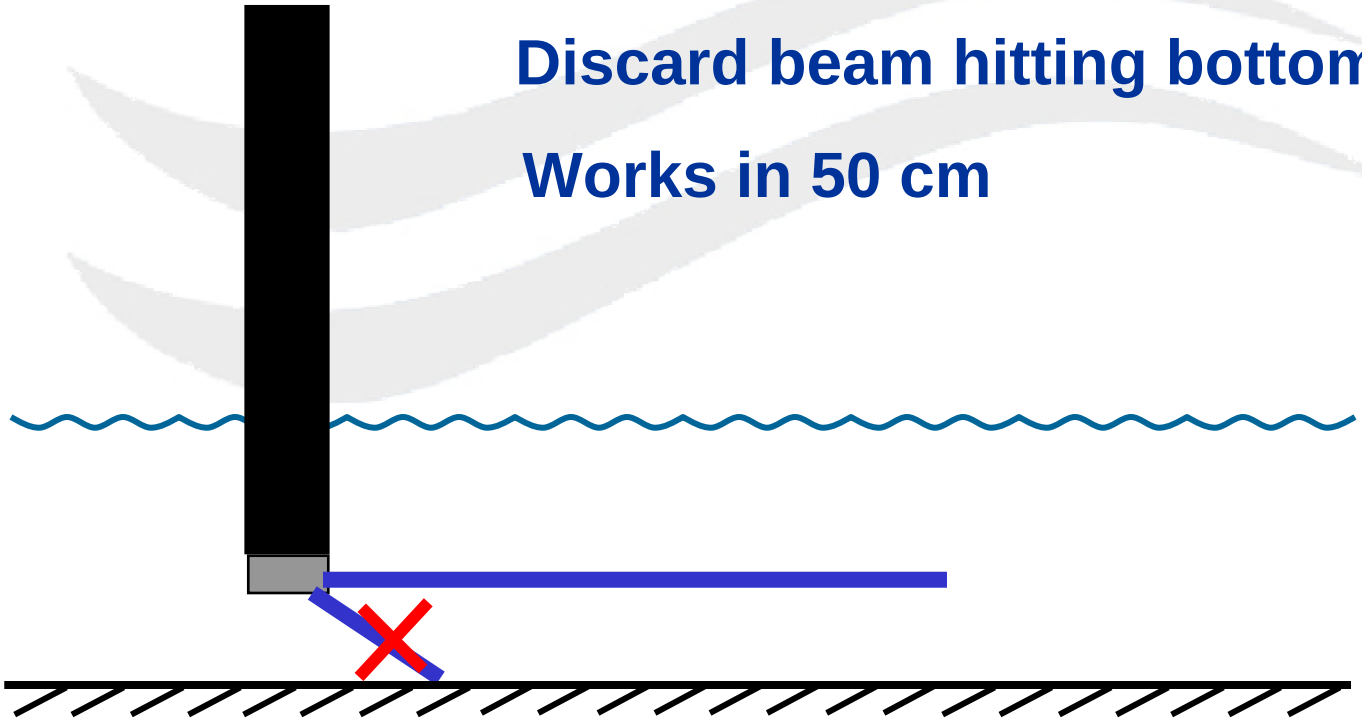
Aquadopp in Shallow Water

Turn Aquadopp upside down

Measure in XYZ coordinates

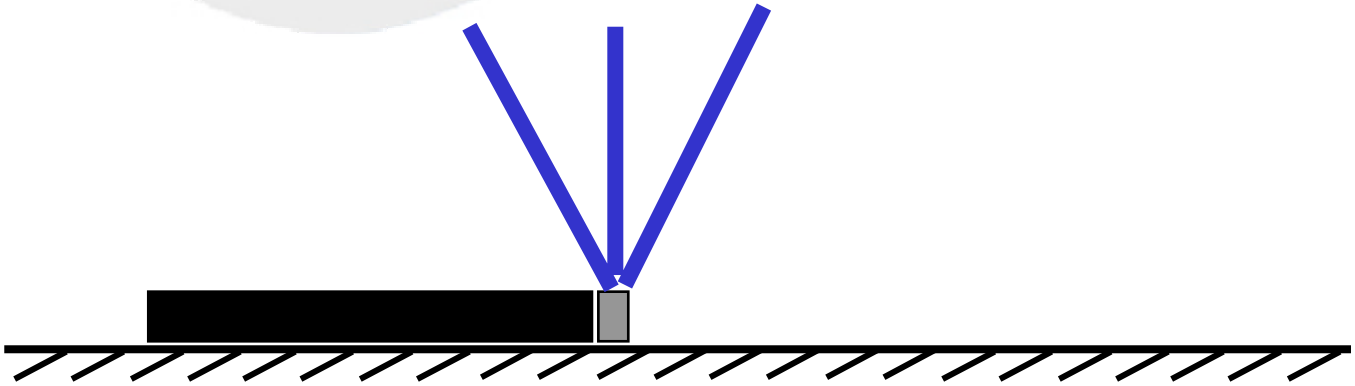
Discard beam hitting bottom

Works in 50 cm



Aquadopp in Shallow Water

- Optional “right angle” transducer
- Works in 2 m water
- Easy to deploy
- Low flow disturbance
- Upgradeable to Profiler

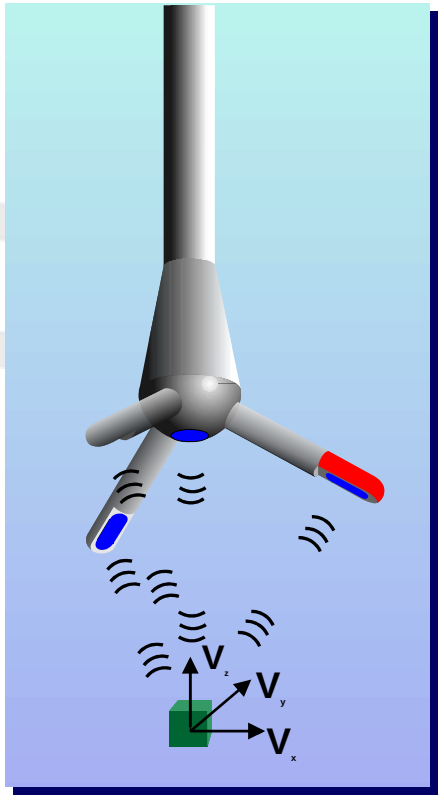


Aquadopp Profiler

- Measures velocity profile 128 cells
- Measures waves at 2 Hz maximum
- Acoustic profile range up to 50 m
- Minimum cell size 10 cm
- Optional transducer head config.
- NEW: High Resolution Profiler
  2 m range with 2 cm cells
  (firmware upgrade)

Vector Velocimeter

- Measures velocity in small cell (~1 cm^3)
- Measures at 64 Hz maximum
- Suitable for turbulence measurements
- Interface with turbidity sensor
- Study sediment suspension in sea grass

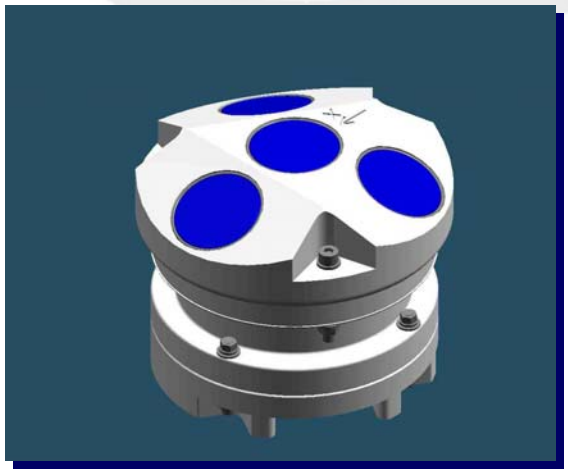


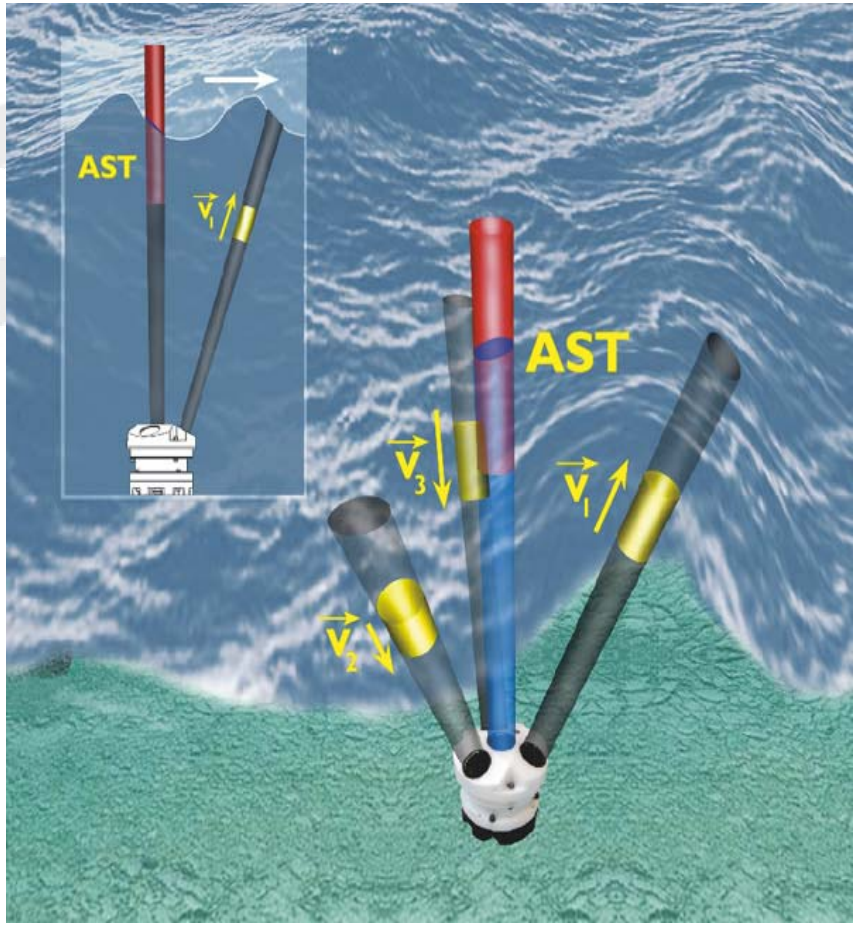
Vector Velocimeter

- **Bottom mounted**
- **Surface mounted**

AWAC

- AWAC (Acoustic Wave And Current) profiler
- Profiles current velocity in 128 cells
- Measures wave height with AST (Acoustic Surface Tracking) at 4 Hz
- Measures wave direction with MLM (Maximum Likelihood Method) at 2 Hz)
- Works well in deep water





AWAC – US Coast Guard

AWAC – US Coast Guard

PUV Methodology

PUV Wave Height: Inferred Estimates

Measure time series of pressure

Linear wave theory

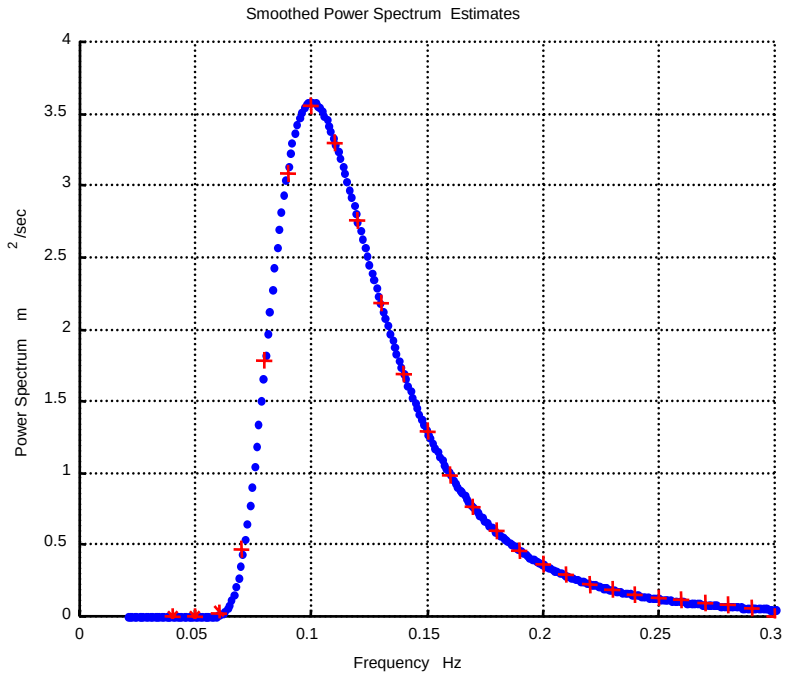
Pressure → H → **Sea Surface Height**

f(*f*, h, z)

Transform time series into power spectra

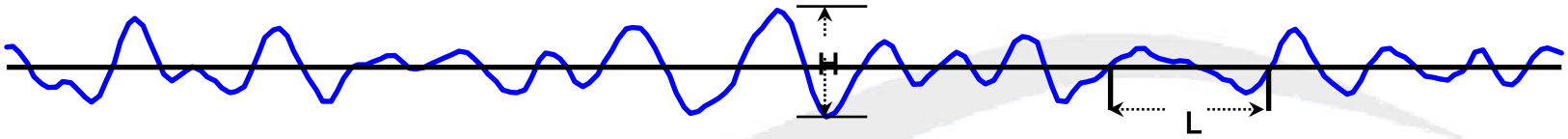
$$H_s = 4\sqrt{area}$$

- Well accepted and robust method
- Problem for transient waves
- Problem for non-linear waves



AWAC Wave Height: Direct Measurements

Measure time series of surface position (AST)



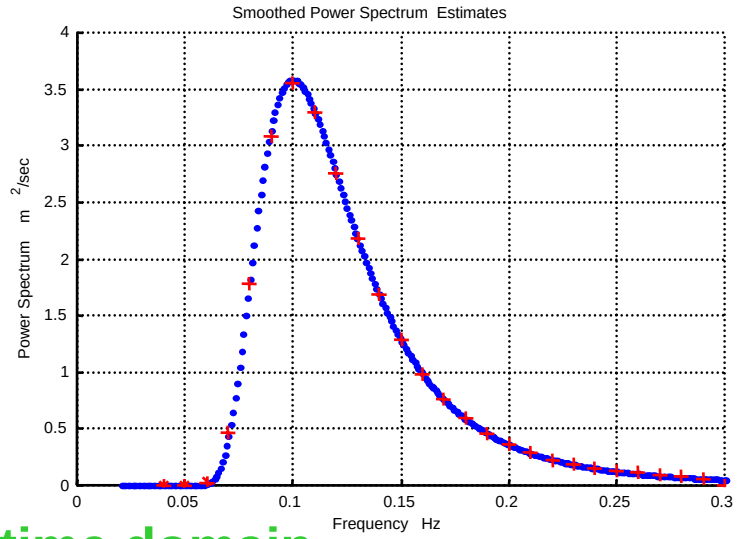
Method 1: Time Domain

H_s is the "*mean of the 1/3 largest waves in a record*"

Method 2: Frequency Domain

Transform time series into power spectra

$$H_s = 4\sqrt{area}$$

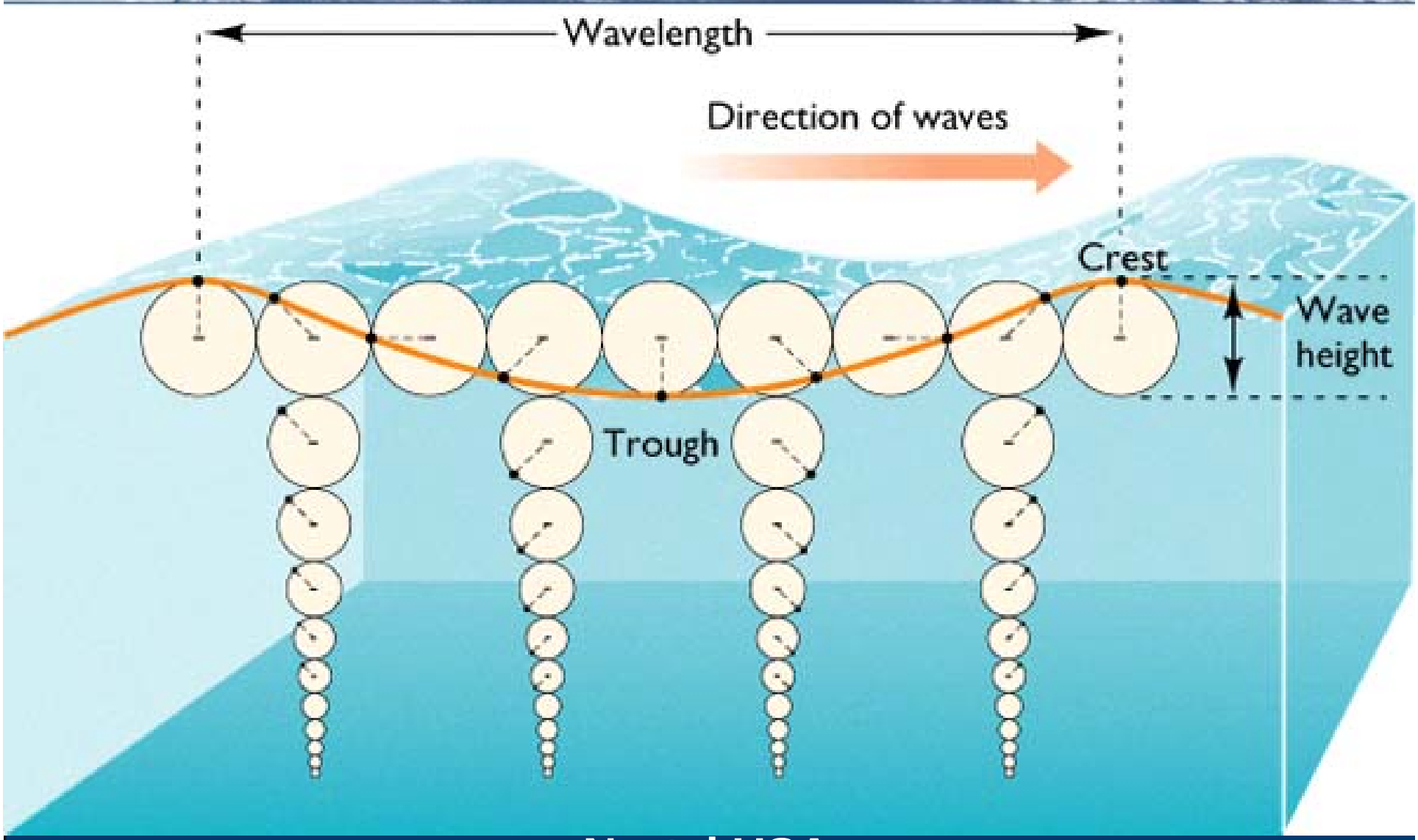


- **Direct measurement of wave height**
- **Can measure H_{max}**
- **Study non-linear/transient waves in time domain**

Wave Measurement Considerations

- **Pressure & velocity attenuation with depth (PUV vs. AST-MLM)**
- **Sampling frequency**
- **Sampling duration**
- **Trying to capture ship wakes**
- **Energy spectra and directional limitations**

Attenuation of wave properties



PUV Limitations

- **2.5 second (0.4 Hz) wave is fastest that can be measured in 3 m of water**
- **Are faster waves present in region?**

Depth	Period	Hs
20	5.8	0.75
20	6.4	0.60
20	7.2	0.35
20	8.3	0.30
20	10.1	0.20
15	5.0	0.50
15	5.5	0.40
15	6.2	0.25
15	7.1	0.20
15	8.7	0.15
10	4.1	0.40
10	4.5	0.30
10	5.0	0.20
10	5.8	0.15
10	7.1	0.10
5	2.9	0.20
5	3.2	0.15
5	3.6	0.10
5	4.1	0.07
5	5.0	0.05
3	2.3	0.12
3	2.5	0.10
3	2.8	0.05
3	3.2	0.04
3	3.9	0.03

Sampling Frequency

- Nyquist frequency is important to consider

- If you sample a 1 Hz,
  the fastest wave you can resolve is 2 sec (0.5 Hz)

- If you sample a 2 Hz,
  the fastest wave you can resolve is 1 sec (1 Hz)

- If you sample a 4 Hz,
  the fastest wave you can resolve is 0.5 sec (2 Hz)

Sampling Duration

- Combination should amount to *Well Sampled*

- 100 wave cycles sampled per burst

- Example 5 sec period requires min 8.5 minutes

	512	1024	2048
1 Hz	8.5 min	17 min	35 min
2 Hz	4.25 min	8.5 min	17 min

Sampling Duration

Ideal:

Ship wake to dominate signal

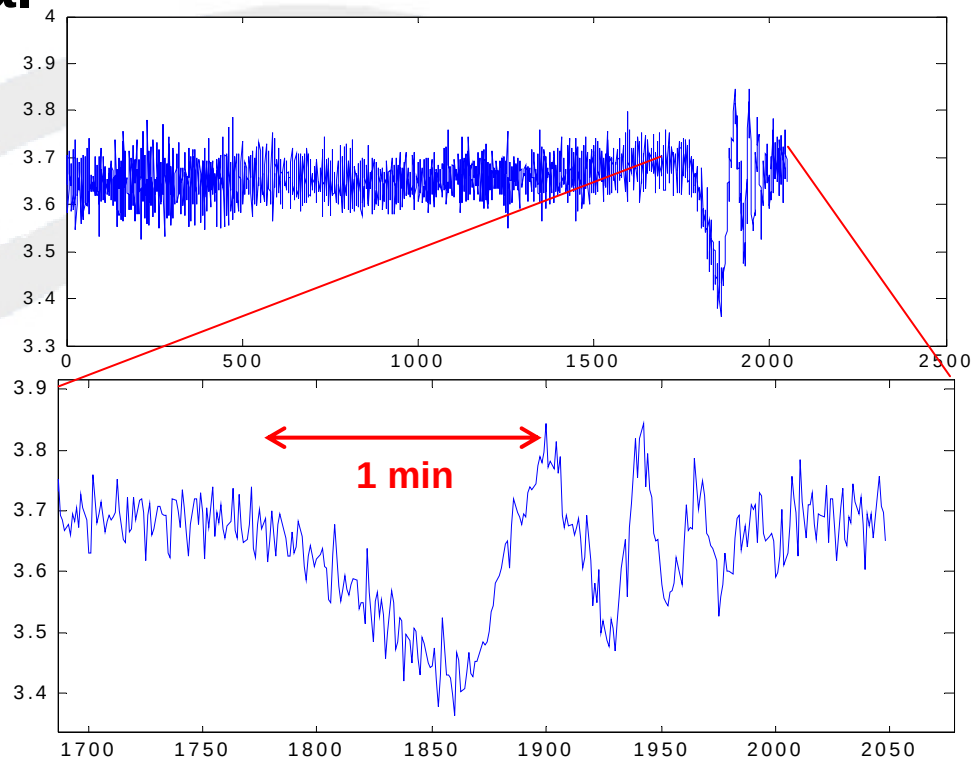
Compromise:

Long duration burst to “well sample” background waves

- vs -

Short duration burst to maximize ship wake signal

Tampa Bay AWAC Burst 391
7/22 0219 hours



Directional Limitations

Directional ability is a function of velocity and pressure (PUV) or AST (AWAC) measurements

PUV method is most limited by pressure attenuation

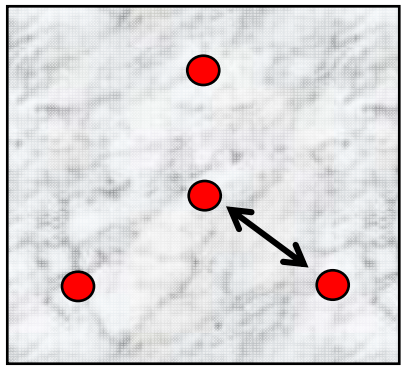
At 3 m depth, pressure attenuation limits frequency (and thus direction) resolution to 2.5 sec (0.4 Hz)

AWAC directional estimates are limited by array geometry

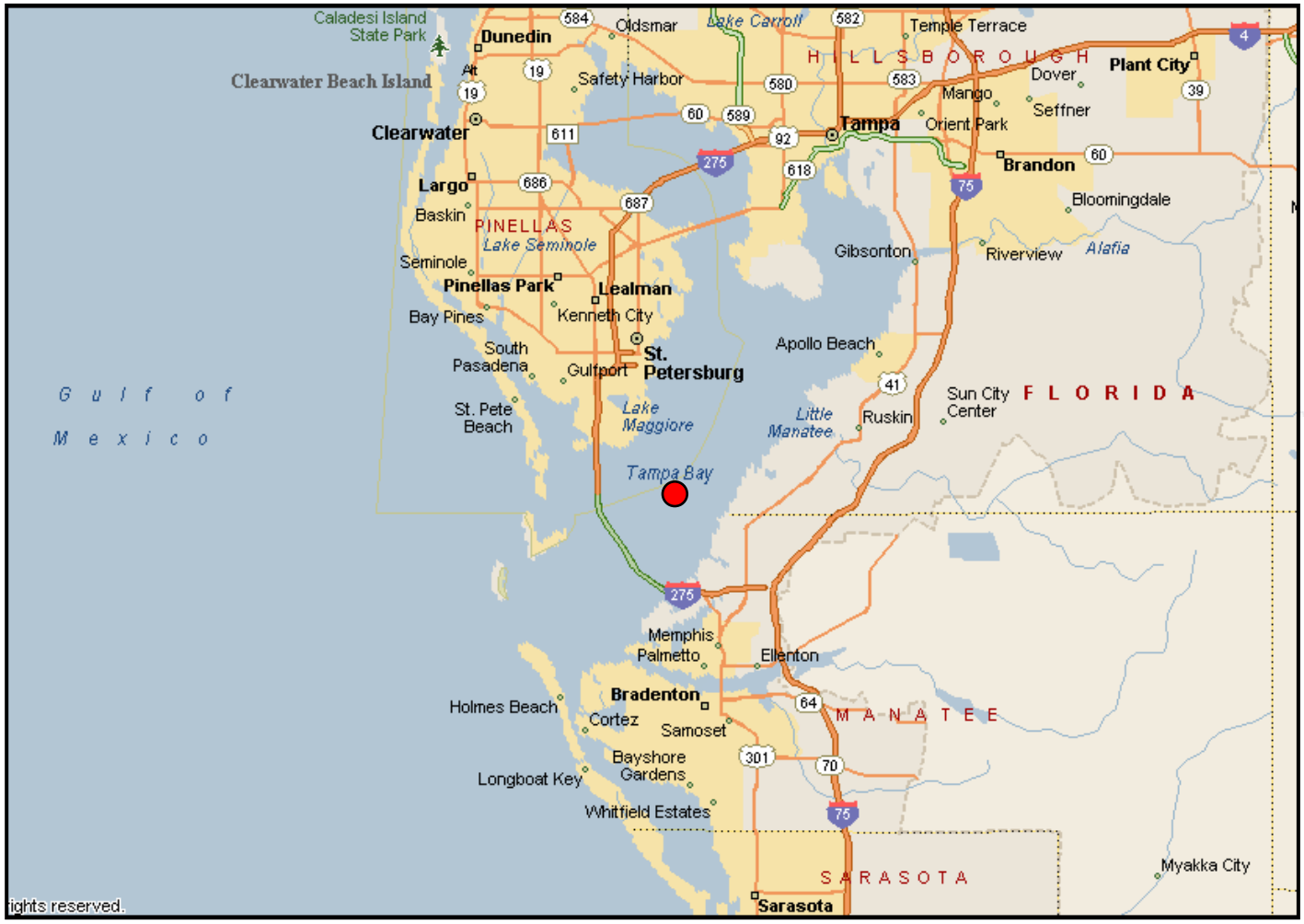
Must measure velocity at two places on each wave, so array spacing limits wave length and wave period resolution

At 3 m depth, array spacing is 0.8 m, minimum wave length is 1.8 m, and thus directional resolution is limited to 1 sec (1 Hz)

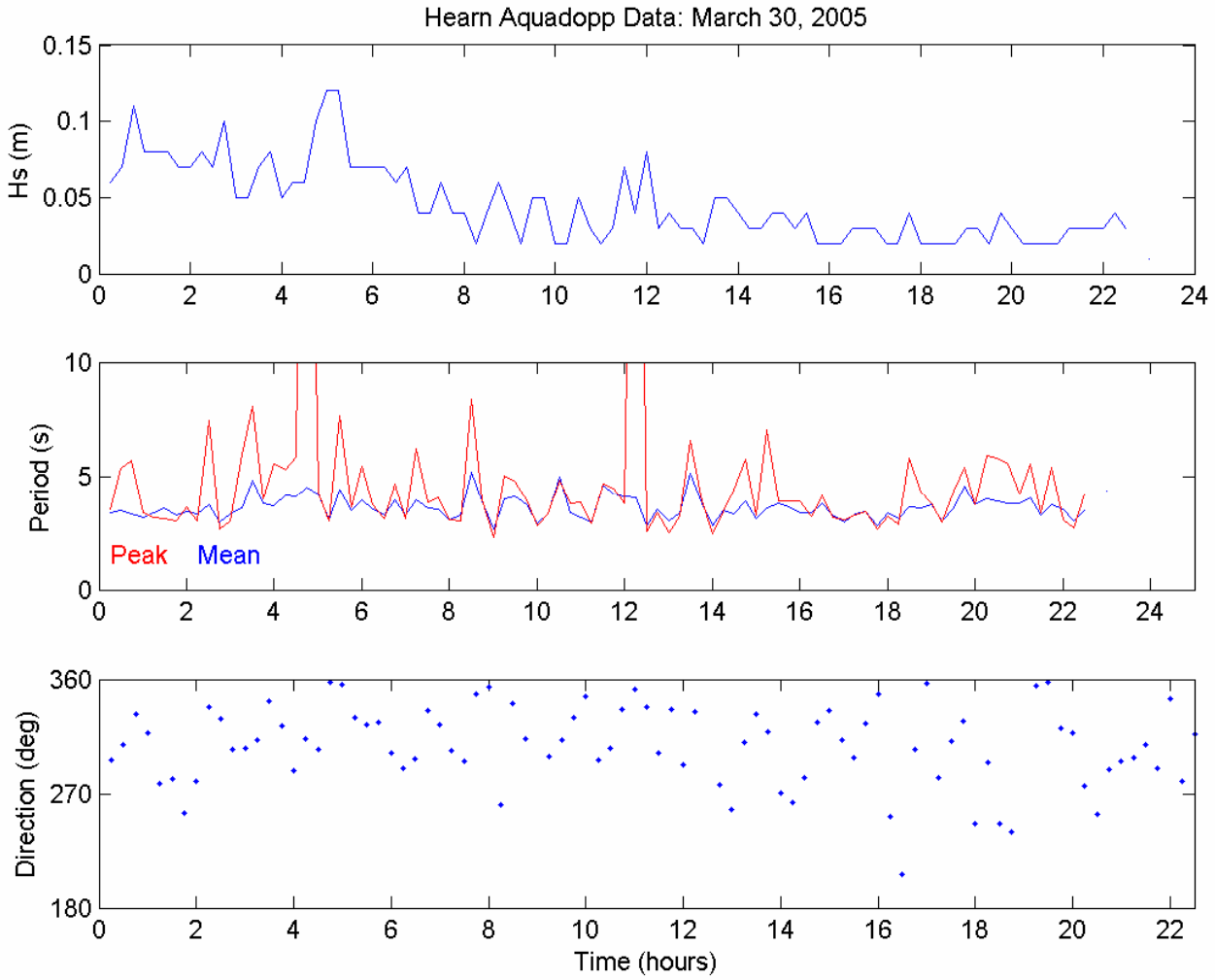
plan view



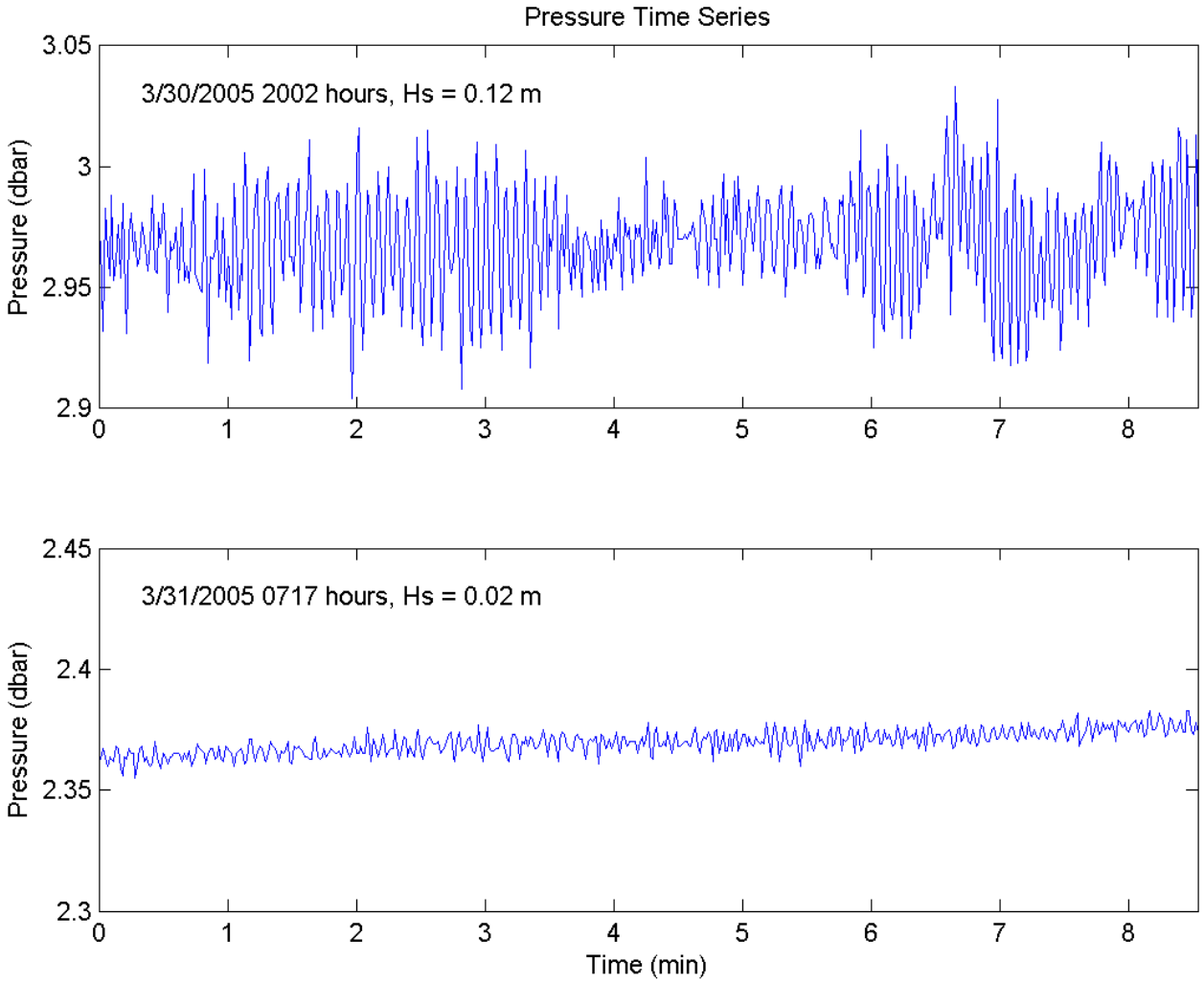
Tampa Bay Data



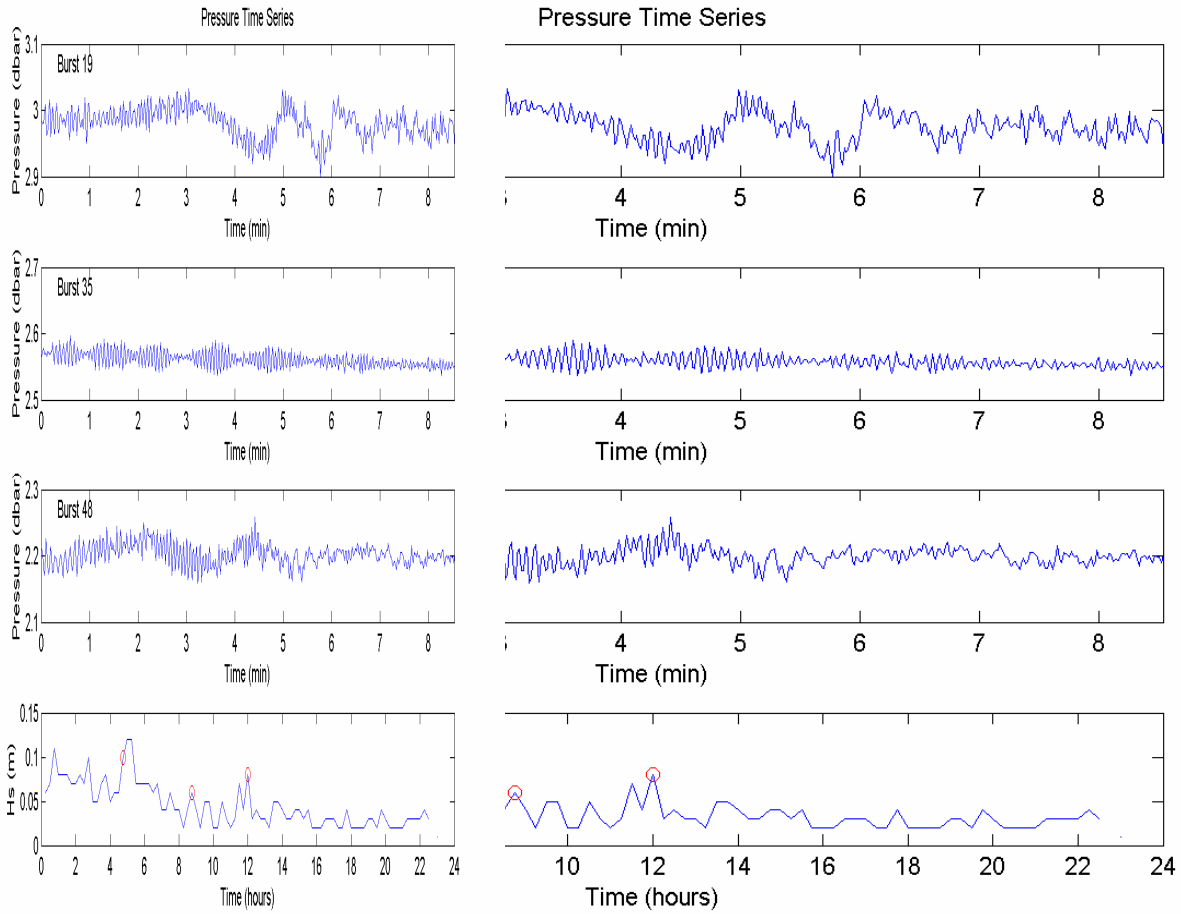
USGS Aquadopp Data



USGS Aquadopp Data



USGS Aquadopp Data

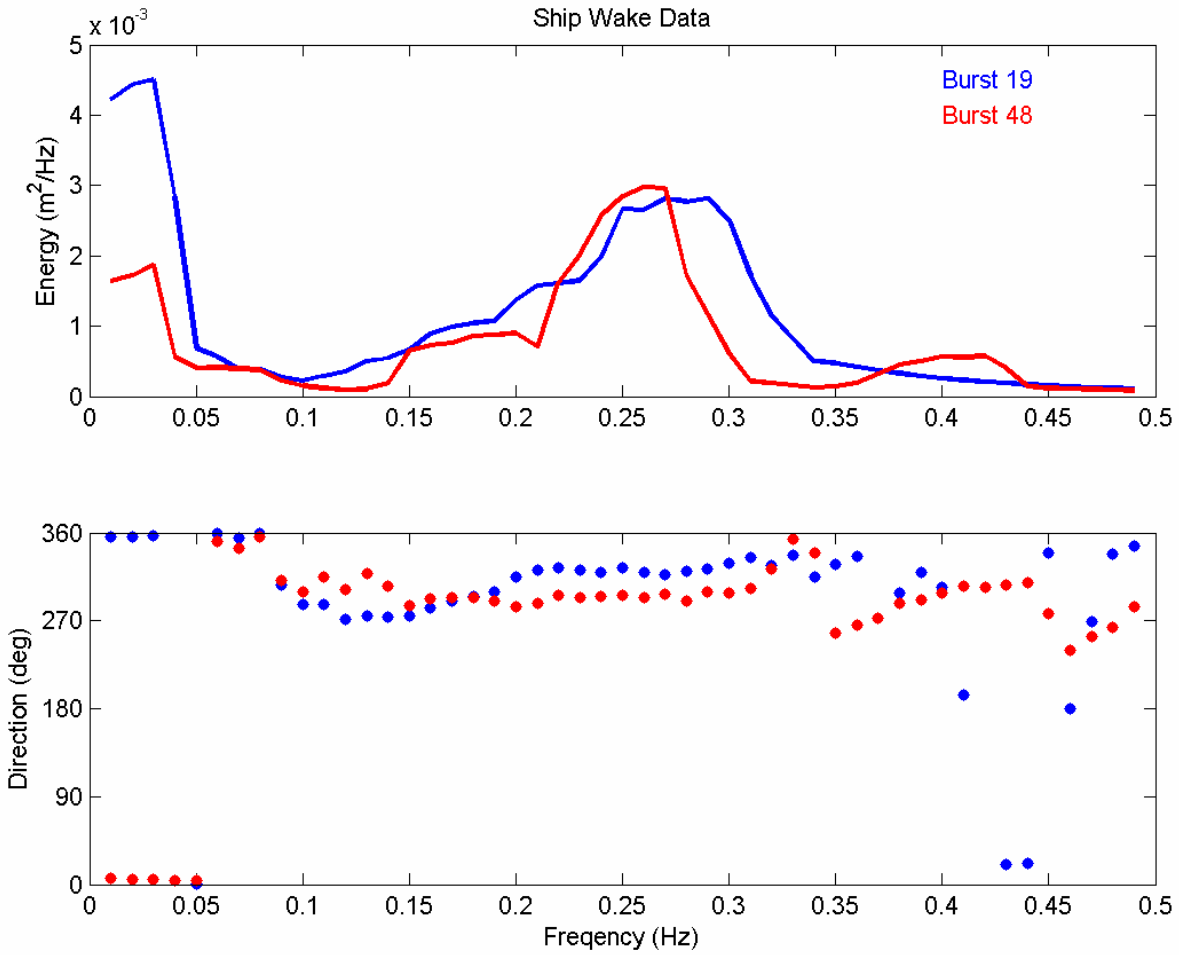


Ship Wake ?

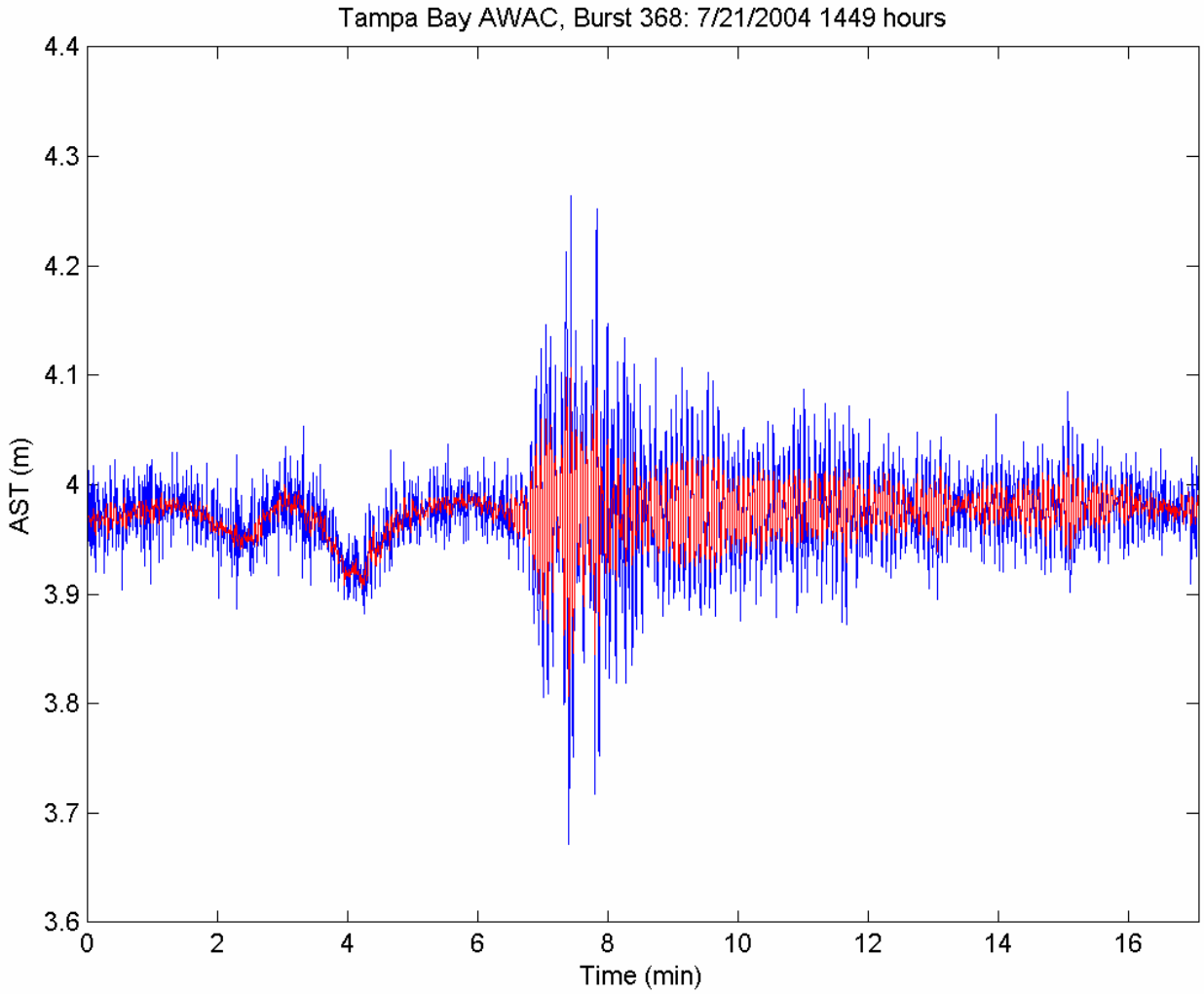
Harmonic ?

Ship Wake ?

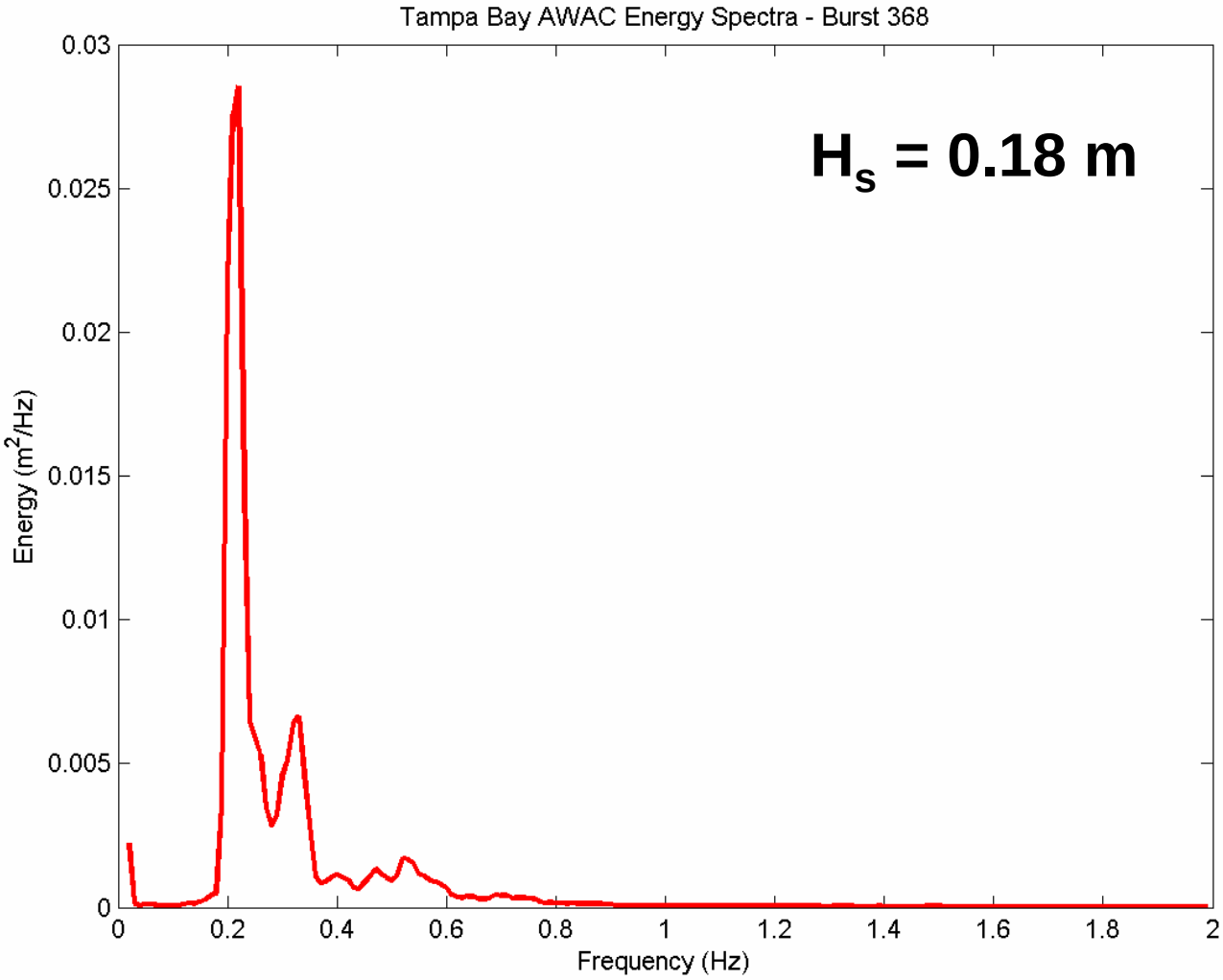
USGS Aquadopp Data



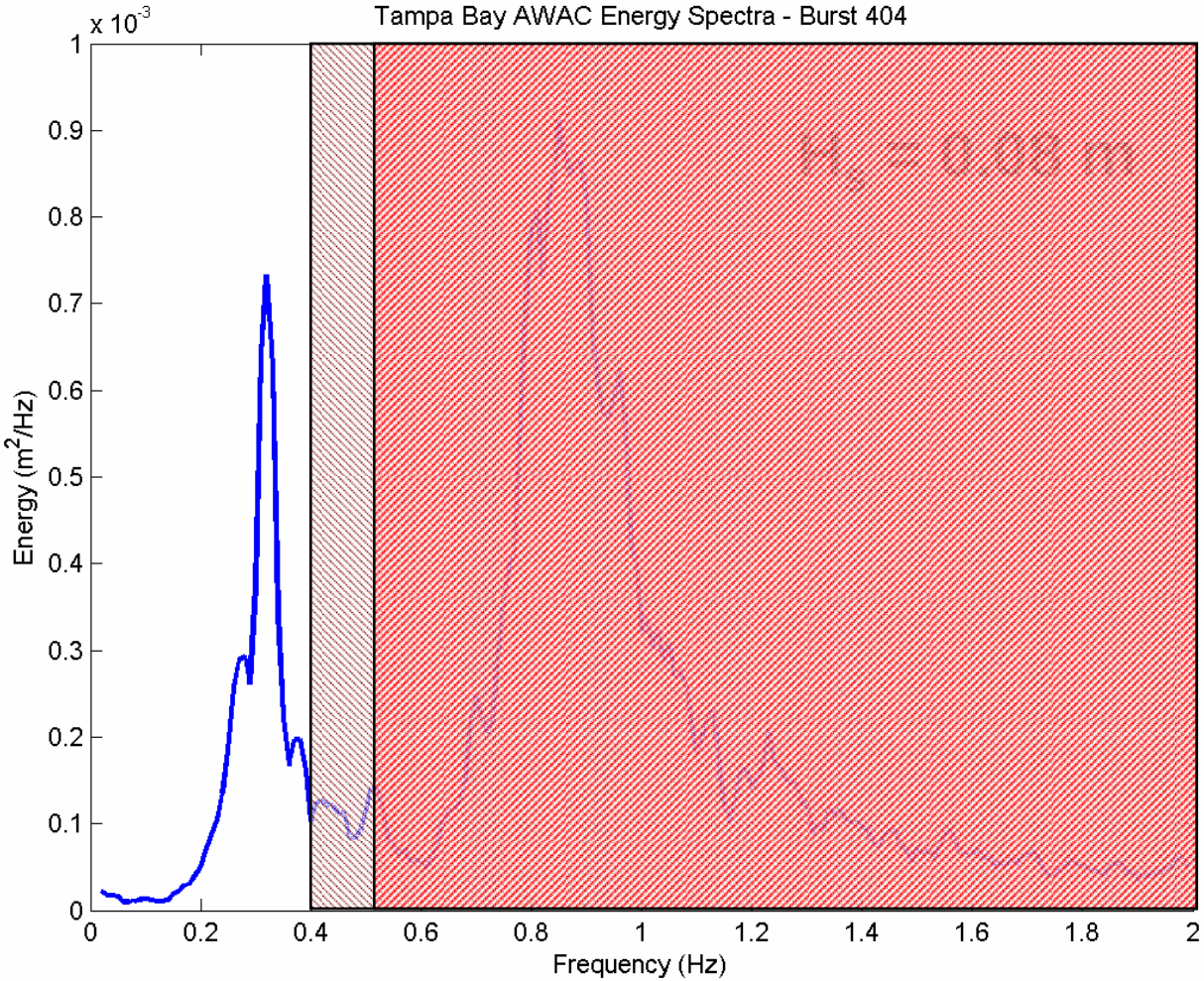
AWAC Data


Tampa Bay AWAC, Burst 368: 7/21/2004 1449 hours
AST (m)
Time (min)
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
0
2
4
6
8
10
12
14
16

AWAC Data


Tampa Bay AWAC Energy Spectra - Burst 368
H_s = 0.18 m
Energy (m^2/Hz)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Frequency (Hz)

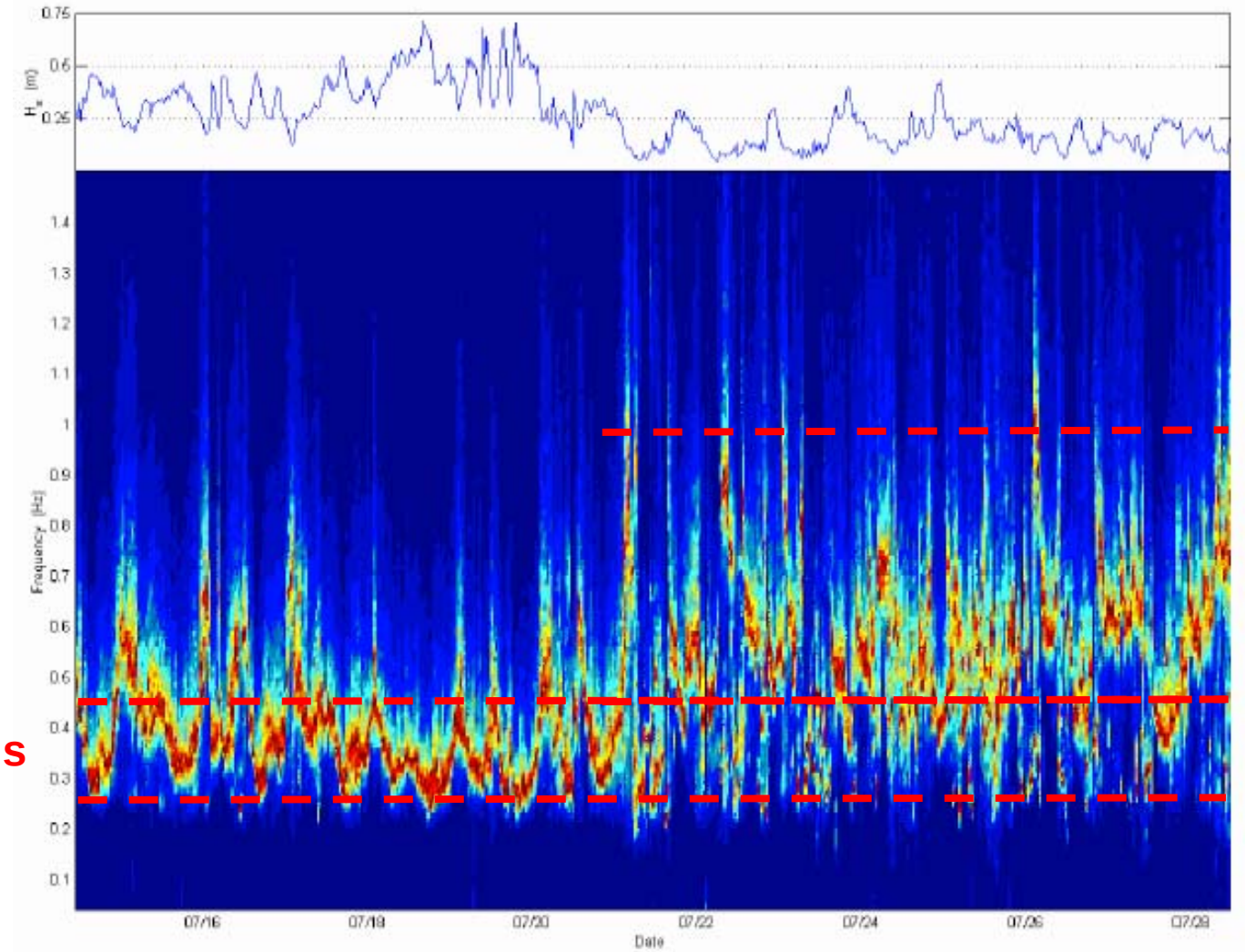
AWAC Data



Logging @ 1 Hz

Deployed in 3 m

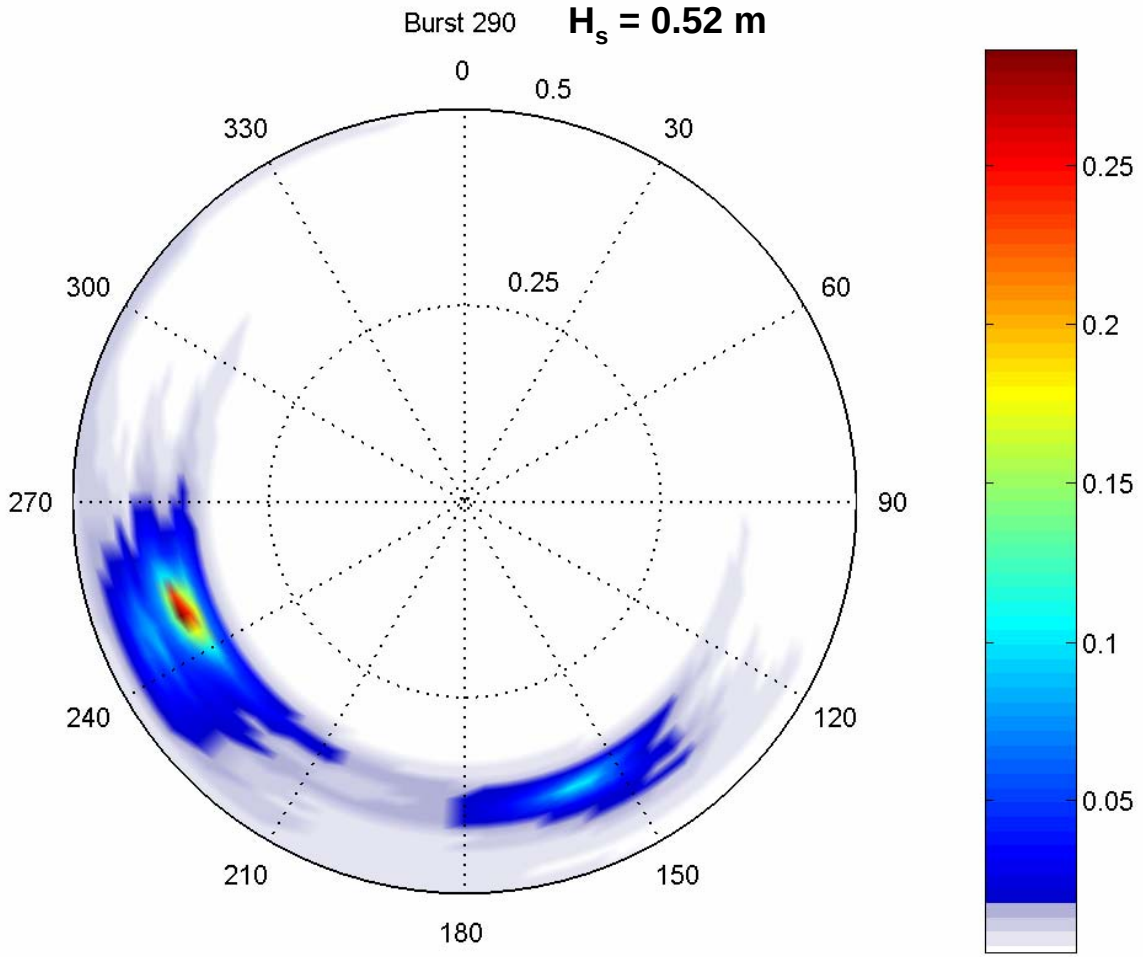
AWAC Data



1 - 2 s

2 - 4 s

AWAC Data


Burst 290
H_s = 0.52 m
0
0.5
30
60
90
120
150
180
210
240
270
300
330
0.25
0.25
0.2
0.15
0.1
0.05

Contact Information

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