Subsurface wave measurements: Comparison tests in Lunenburg Bay, Canada and Lysekil, Sweden

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Nortek-AS

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Integrated Inductive Modem

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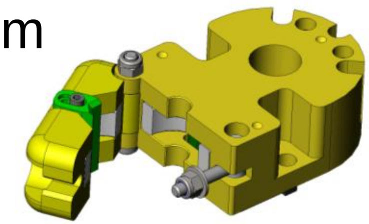
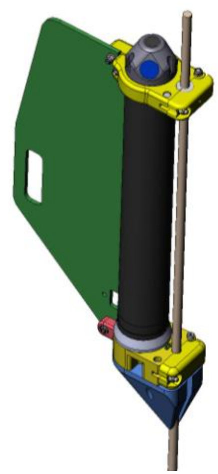
Integrated Seabird inductive modem

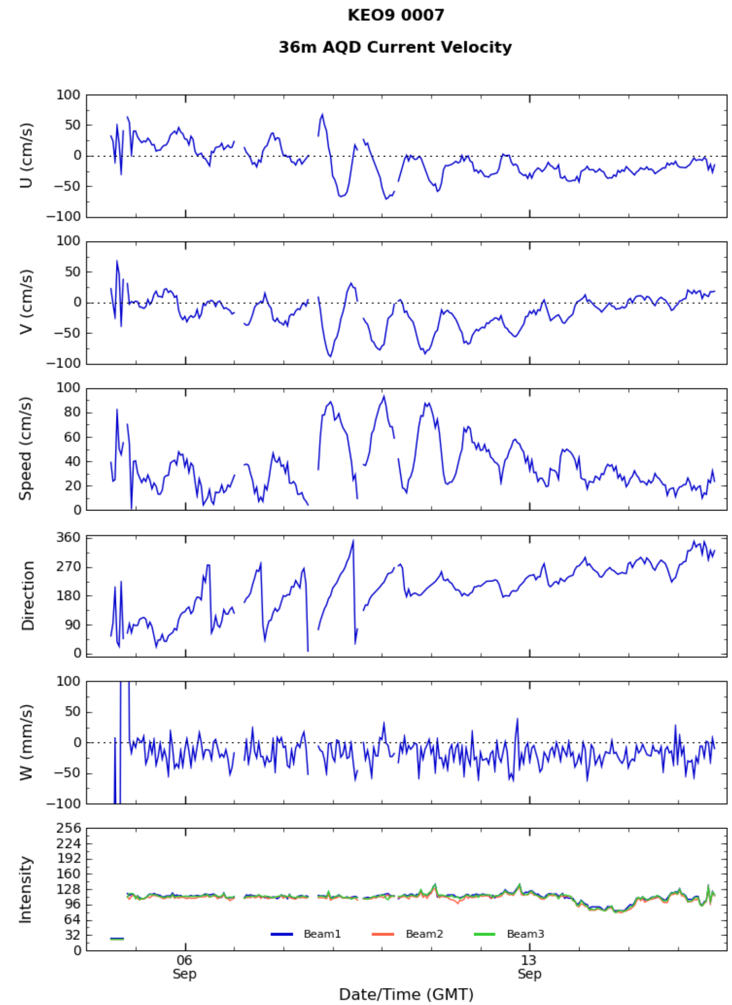


Use of mooring wire for comms

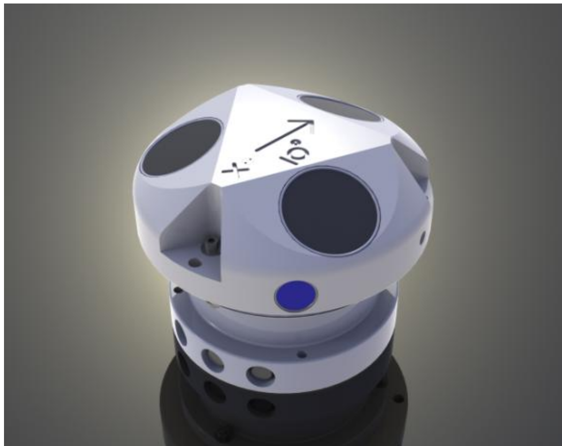
NOAA in cooperation with JAMSTEC deployed 2 Aquadopps at Kuroshio Extension Observatory (KEO)



16 and 36 meters depth.
4 Sep 2009



Zero Cell Profiler



Profilers typically have a "blanking distance" before profiling begins

Often leads to first measurements beginning 1-2 meters away from head

For those interested in boundary measurements this left a gap

New sensor head has 3 horizontally oriented transducers to measure at the head level.

NOAA deployed buoy #42007
Sept. 1, 2009

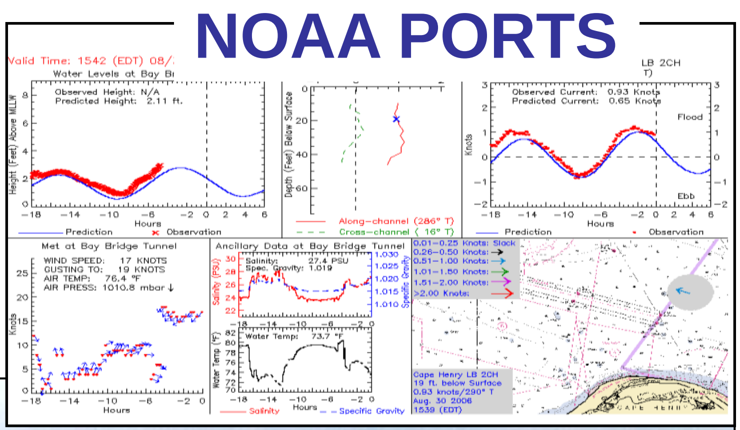
ATON Buoy

•Use existing navigational buoys

•Harbor entrance: shipping safety, oil spill response, resource management

•Real time

•Comms:
•radio/cell net/Iridium



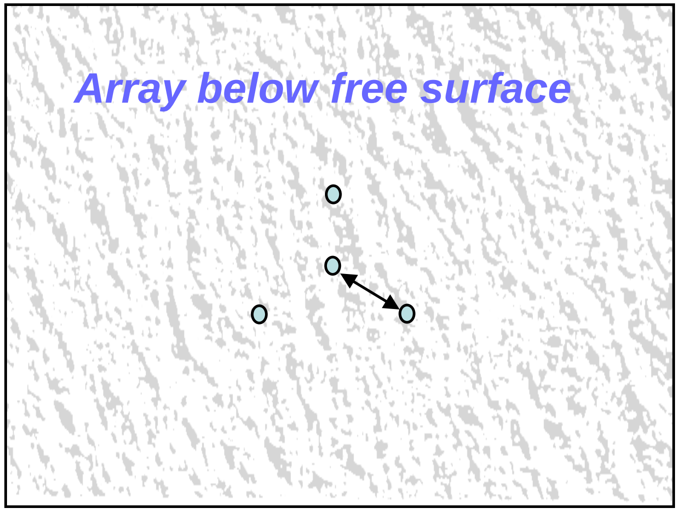
Depths limits and reasons for subsurface buoys

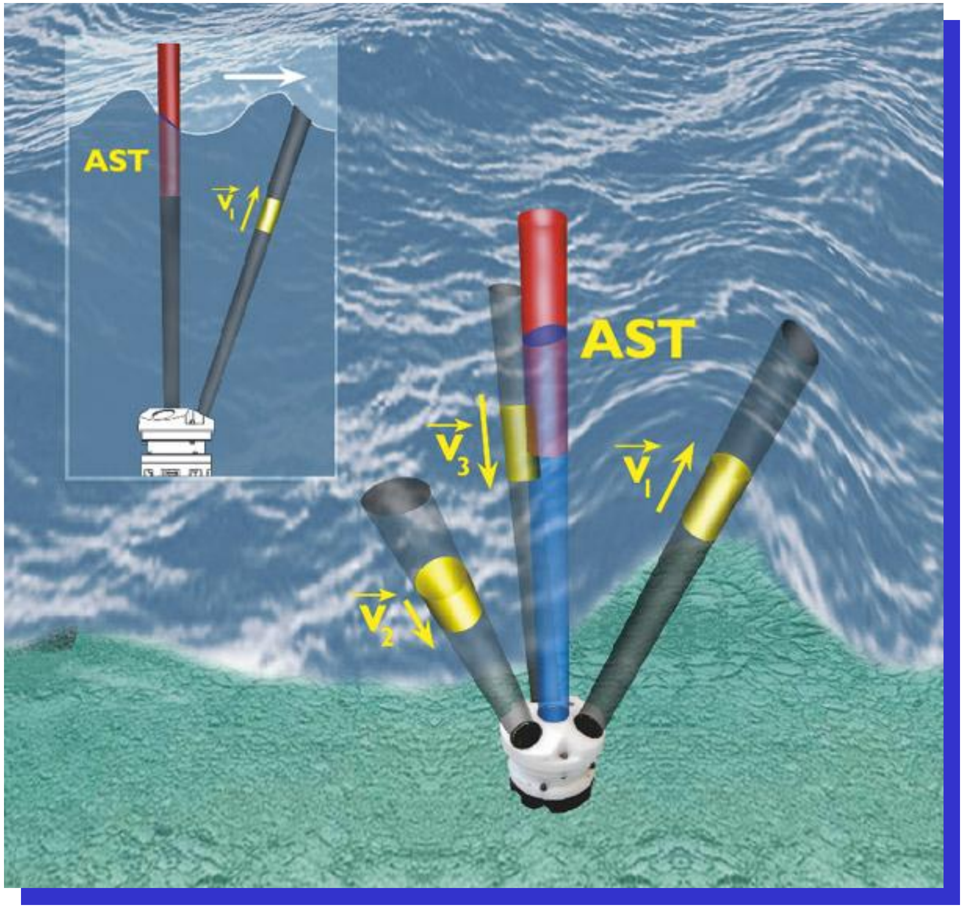
Description of the SUV solution

Comparative results of SUV with Directional Waverider

AWAC Measurement Methods

Waves measured with
- Pressure
- Orbital velocities
- Acoustic Surface Tracking (AST)

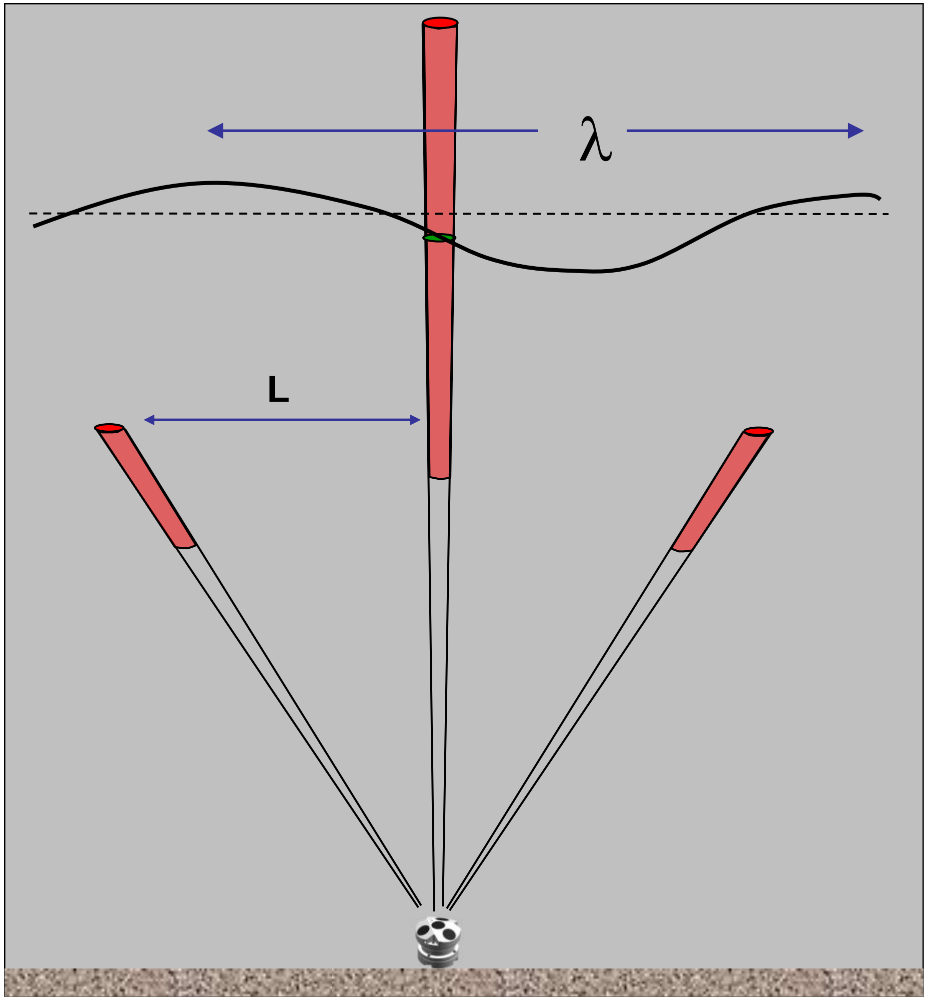




Depth Limitations for Bottom Mounted Instruments

Wavelength Must Be: $2L < \lambda$

Depth	Cutoff Freq	Cutoff Period
5	0.70	1.45
10	0.45	2.20
20	0.32	3.10
30	0.26	3.85
40	0.23	4.35
50	0.20	5.00
60	0.18	5.55



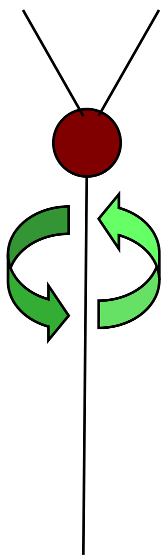
Wave Measurement Problem

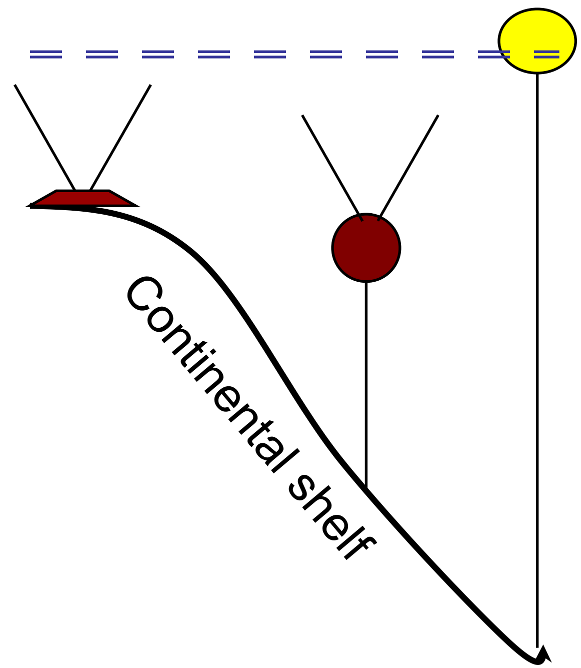
Solution: Mount AWAC on subsurface buoy

Challenge:

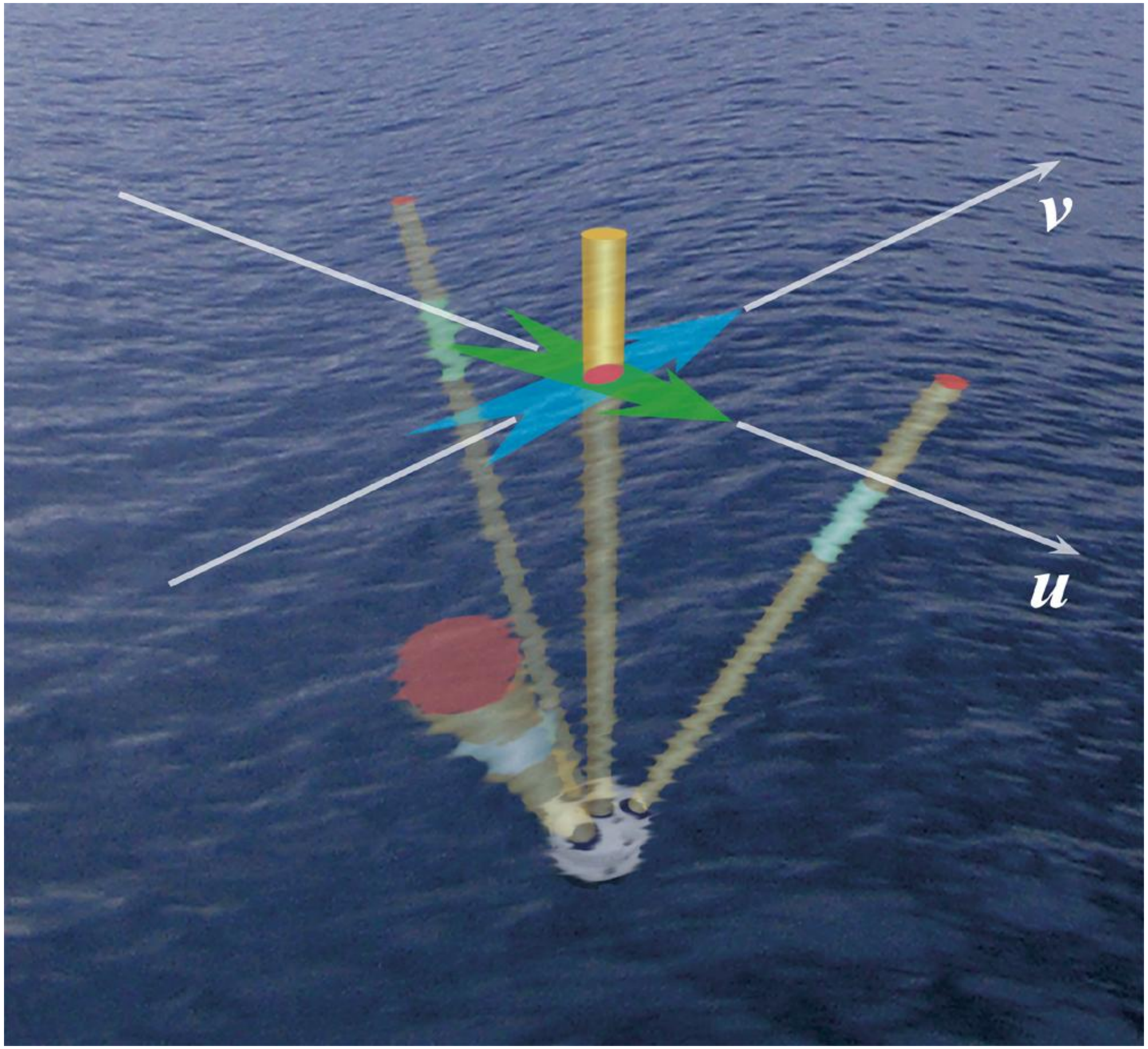
- Current profiles – no problem!
- Directional wave estimates – problem!
- Subsurface buoy moves during wave burst
- Traditional array methods no longer valid

Rotation





SUV method for buoy



Energy - Height & Period:

- **Acoustic Surface Tracking (AST)**
- **Pressure** (secondary)

Direction:

- **Measure along beam velocity**
- **Measure AWAC attitude (heading and tilt)**
- **Coordinate transform from *Beam* to *U* and *V***
- **Form a triplet with *U, V,* and AST**

Standard Triplet Analysis

$$D(f,\theta)=\frac{1}{\pi}\left[\frac{1}{2}+\sum_n\{a_n\cos n\theta+b_n\sin n\theta\}\right]$$ Fourier expansion

...Of which we obtain only the first two pair

$$a_1(f)=\frac{C_{SU}}{\sqrt{C_{SS}(C_{UU}+C_{VV})}}$$

$$b_1(f)=\frac{C_{SV}}{\sqrt{C_{SS}(C_{UU}+C_{VV})}}$$

$$b_2(f)=\frac{2\,\mathrm{Re}[C_{UV}]}{C_{UU}+C_{VV}}$$

$$a_2(f)=\frac{C_{UU}-C_{VV}}{C_{UU}+C_{VV}}$$

Mean Direction

$$\theta_1(f)=\arctan(b_1(f)/a_1(f))$$

Directional Spread

$$\sigma(f)=[2(1-r_1(f))]^{1/2}$$

$$r_1=\sqrt{a_1^2+b_1^2}$$

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Lunenburg Bay, Nova Scotia

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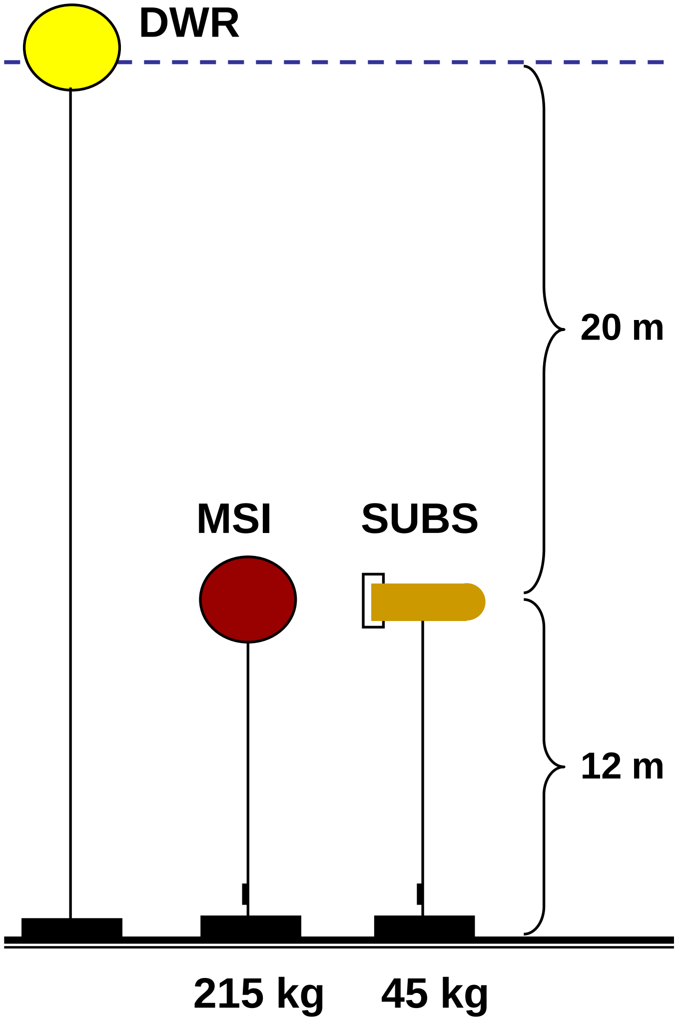
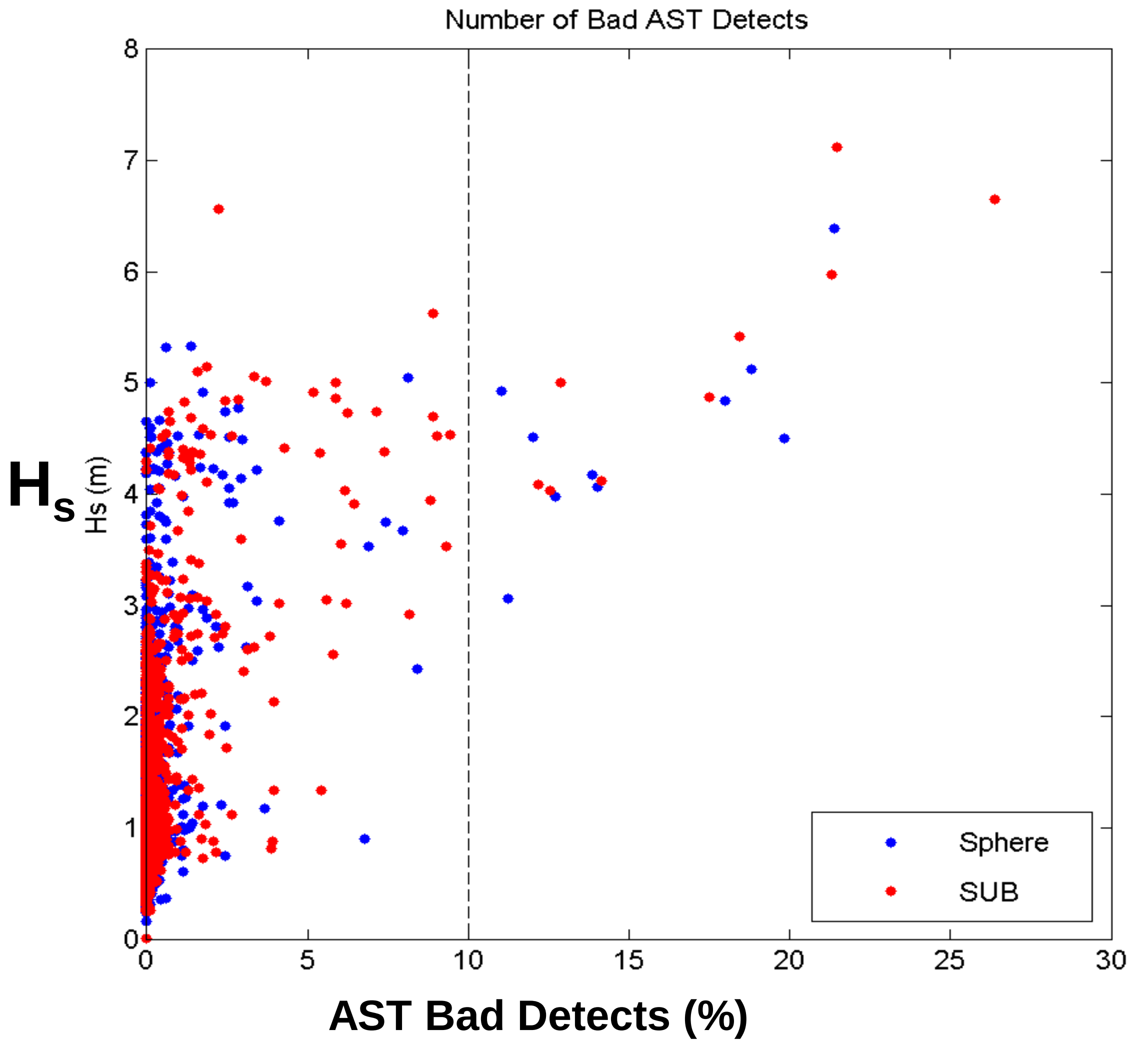
Mooring Configurations

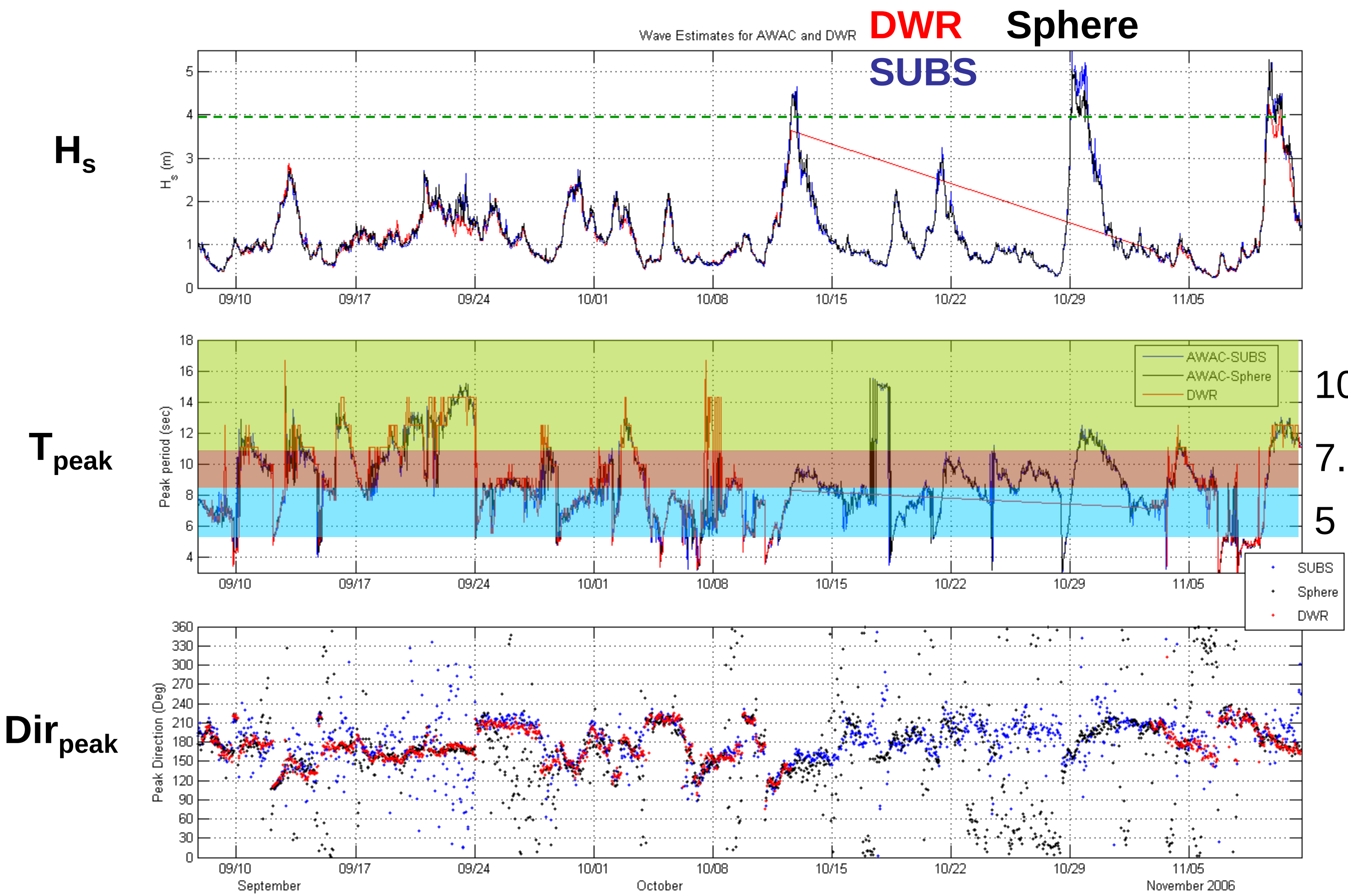


AWAC AST Data



- **MSI & SUBS perform similarly**
- **MSI: 96% AST samples have less than 1% bad detects**
- **SUBS: 93% AST samples have less than 1% bad detects**
- **Only 10 bursts (out of 1500+ bursts) have more than 10% bad detects**

Standard Results



Three Storm Events $H_s > 4$ m

10 - 33 sec

7.7 -10 sec

5 - 7.7 sec

Band Estimates: 10 – 33 seconds
Direction - Energy

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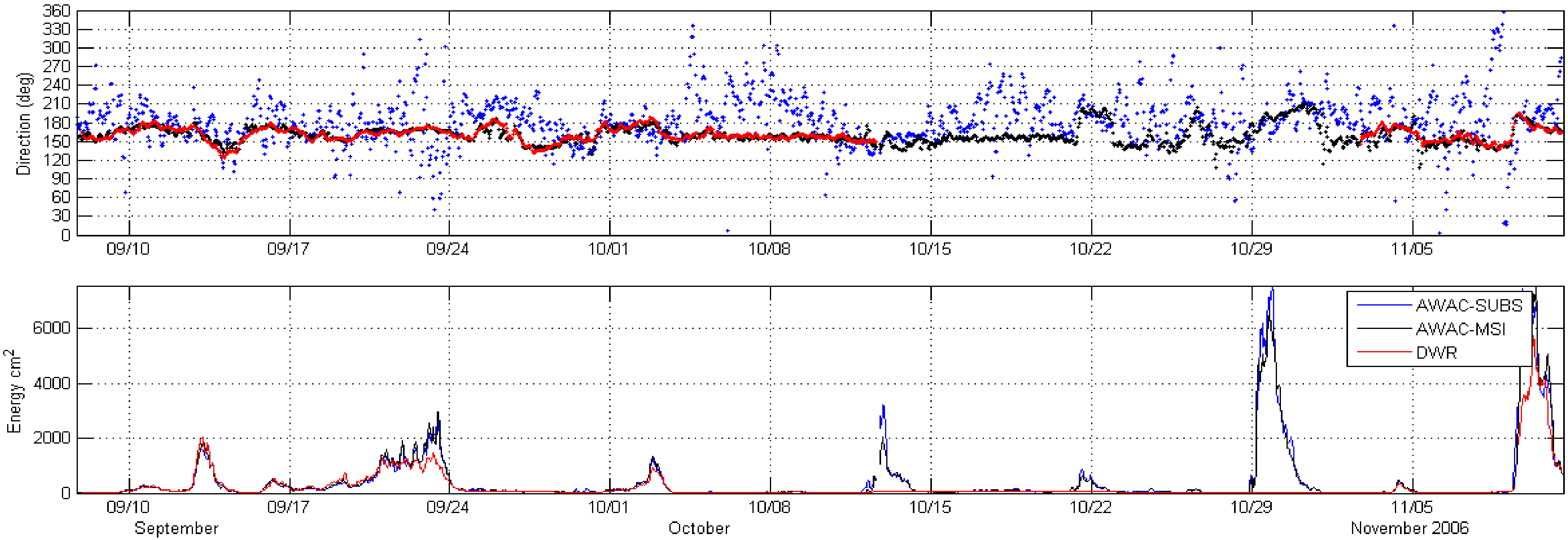
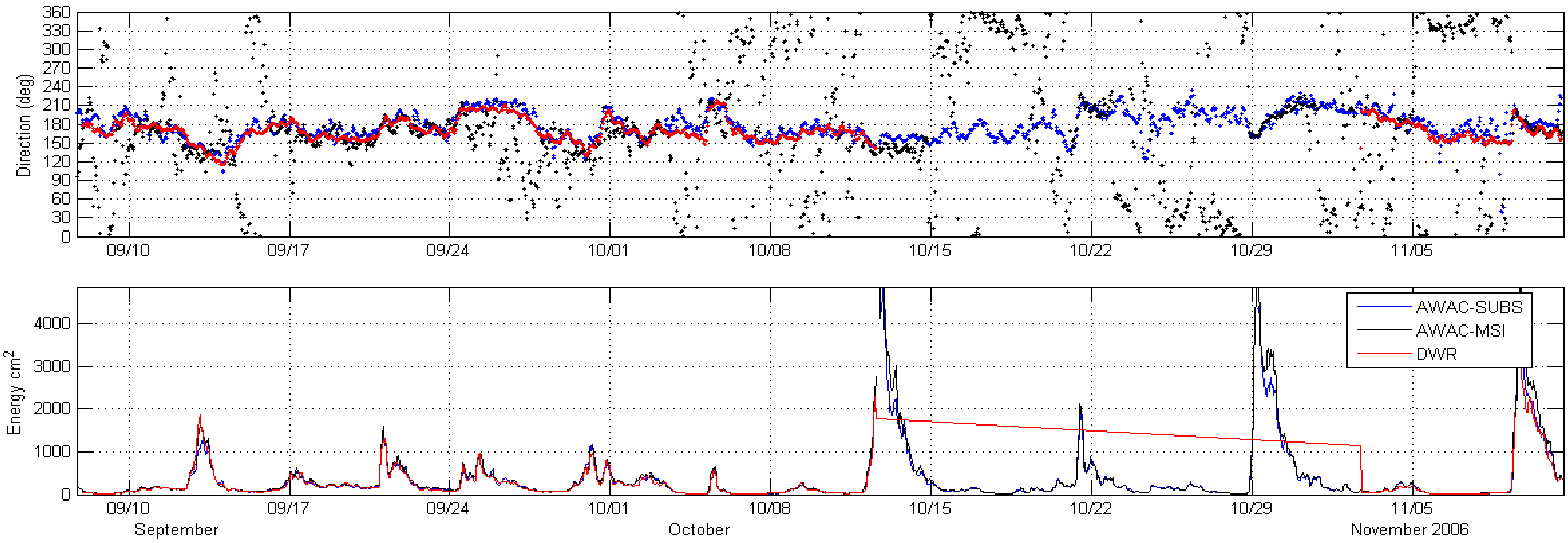
Sphere better



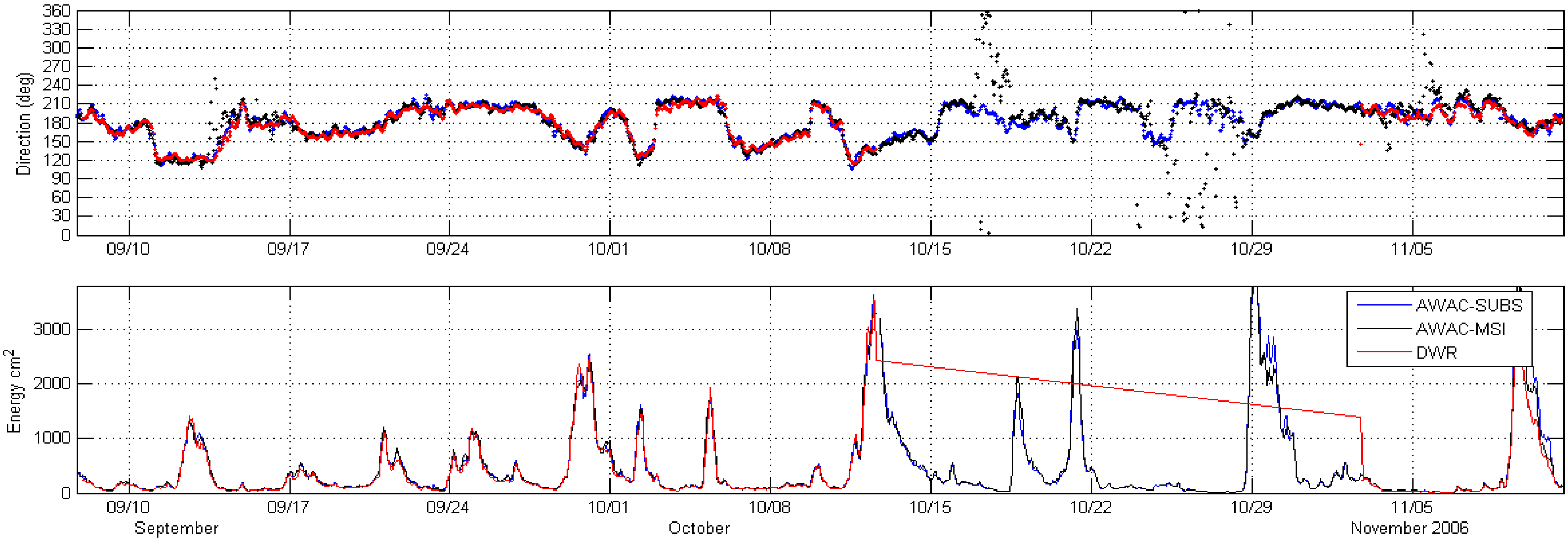
Band Estimates: 7.7 – 10 seconds Direction - Energy

SUBS better

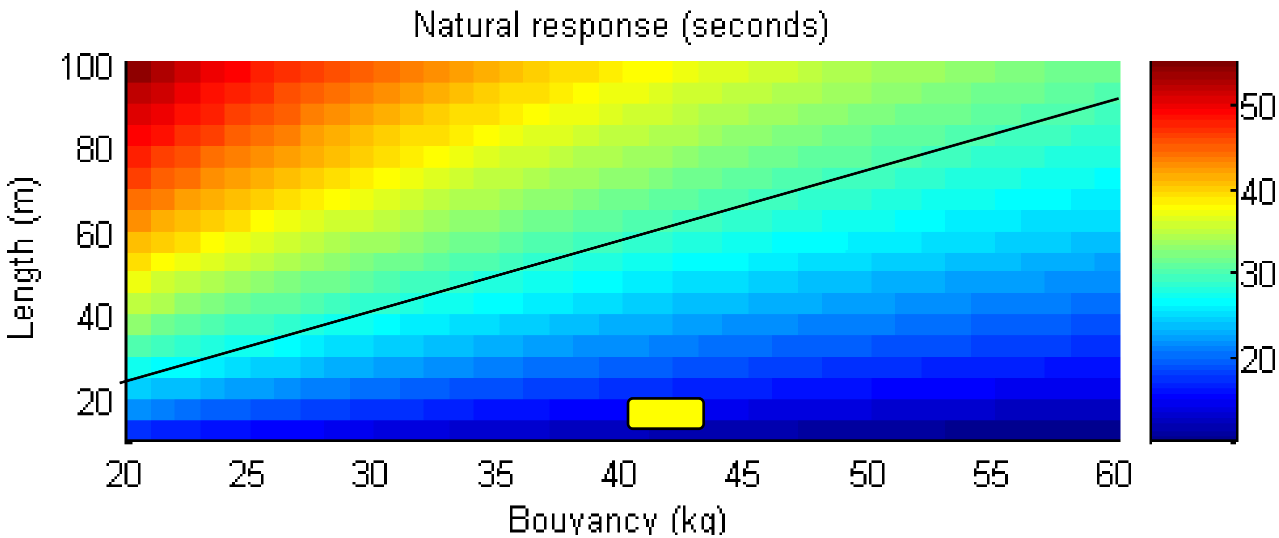


Band Estimates: 5 – 7.7 seconds Direction - Energy

Both well



SUBS Mooring response



Wave measurements
Generally 2-30 seconds

Ideally, mooring response
Should be longer than 30

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Deployment with SMHI

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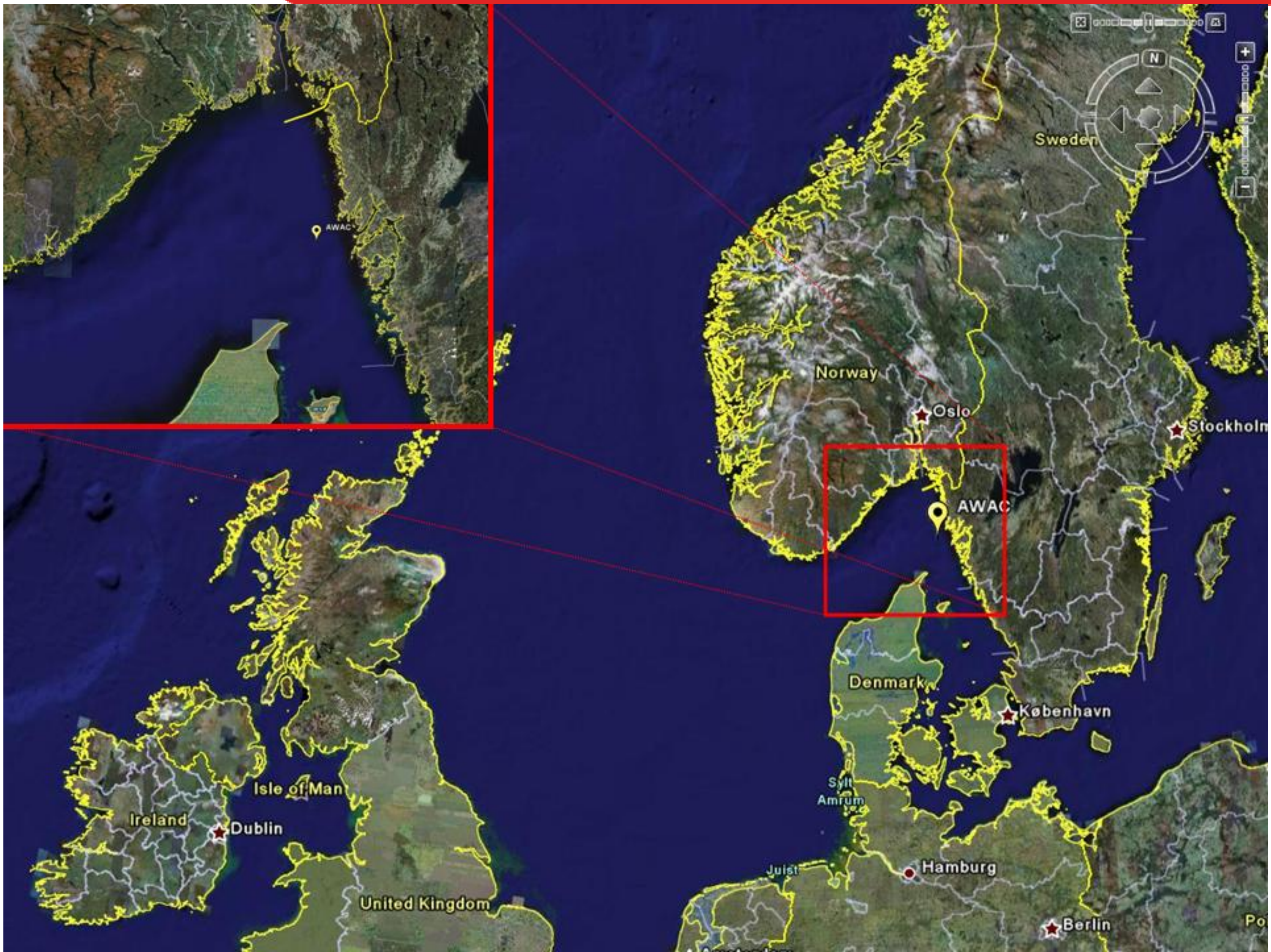
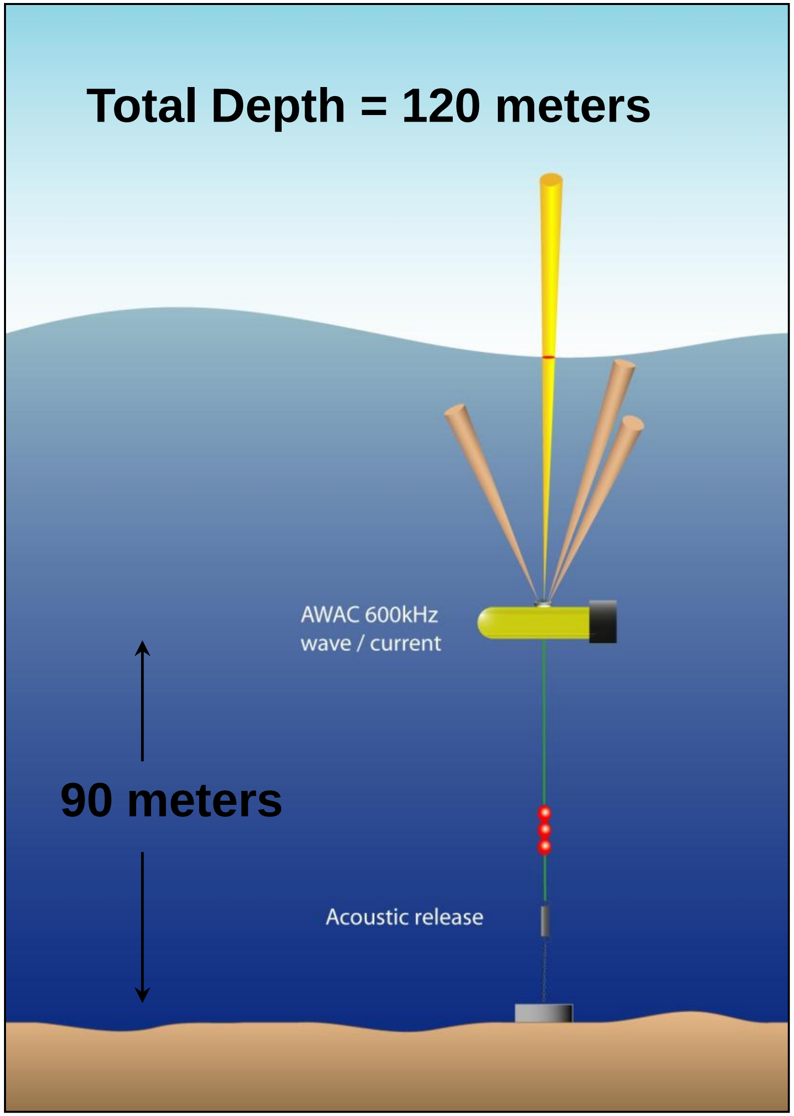


Configuration



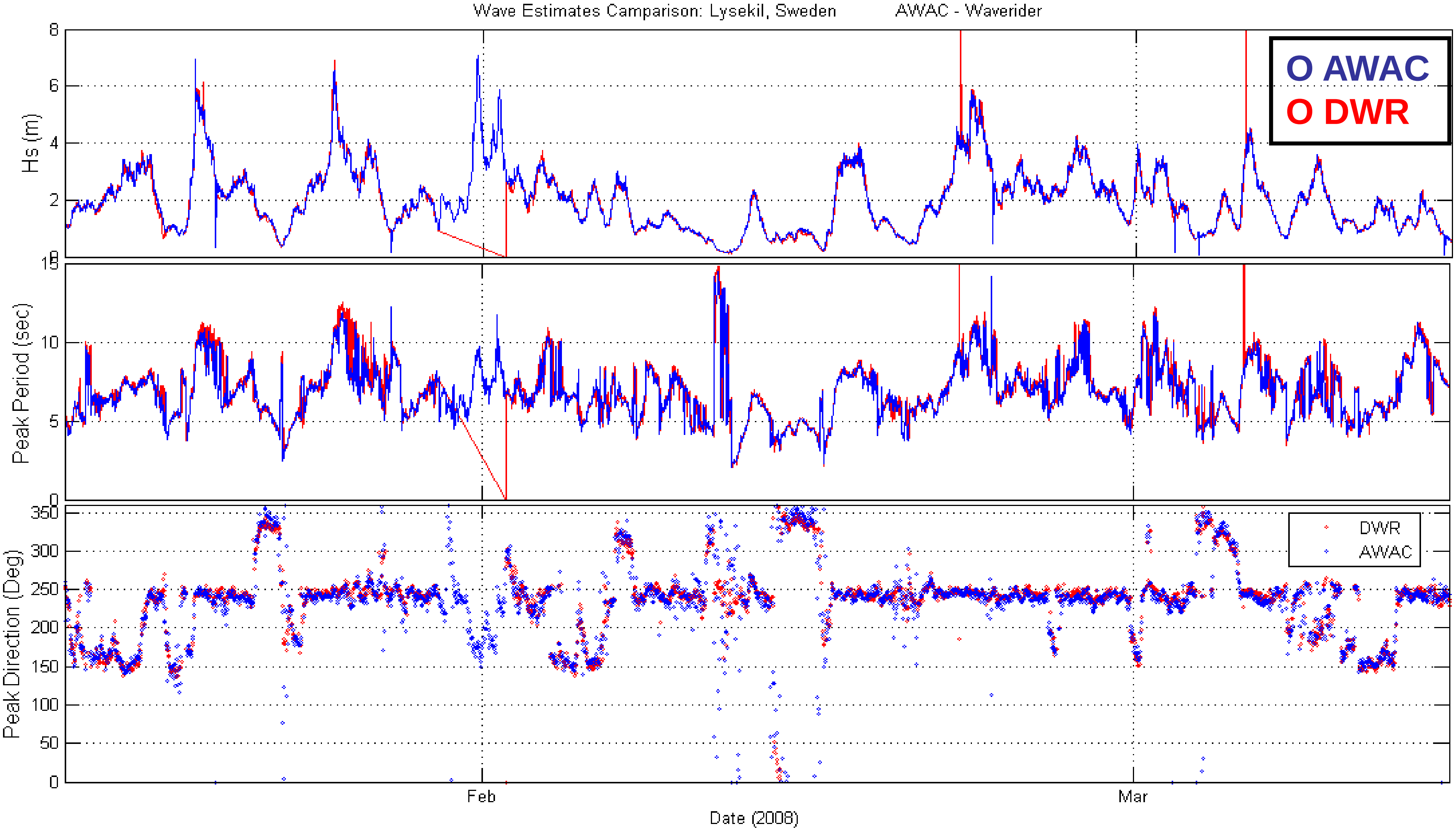
Natural response = 35 seconds

Critically damped

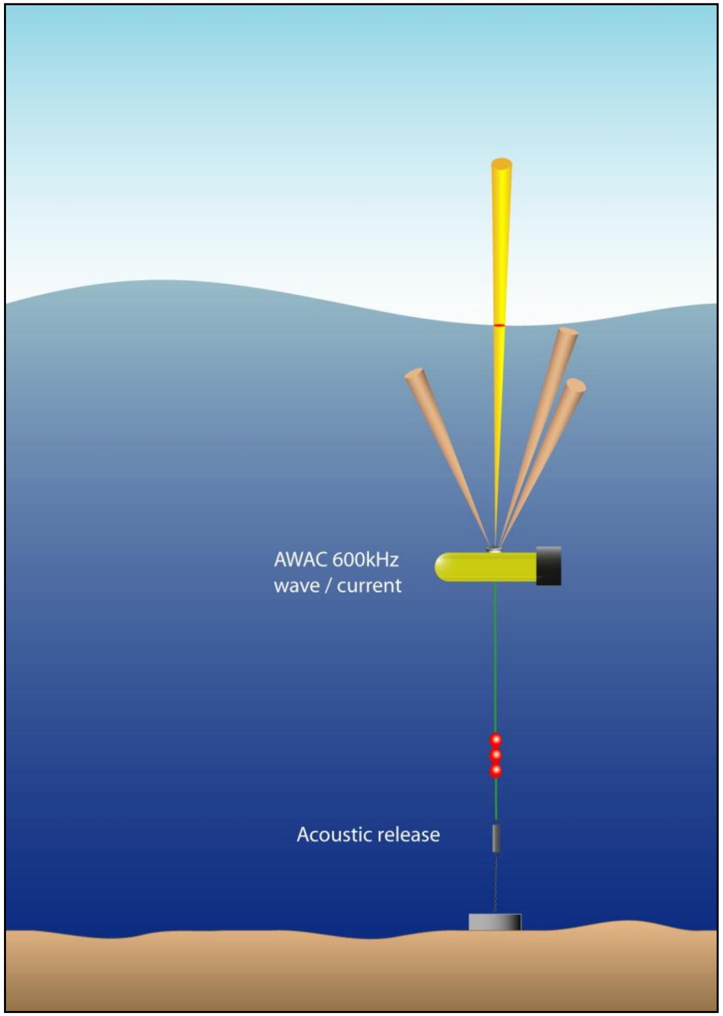
Currents ~1 m/s

Draw down
32 -> 50 meters

Wave Estimates



Summary



SUV method from a buoy shows good agreement … but attention has to paid to the buoy/mooring design.

Applications:

- **Site surveys now from a single mooring – reducing deployments costs**
- **Short moorings complicated bottom types (soft or steep)**
- **Measurements up to and through surface ice events**

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