



Nortek Ice Measurements

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True innovation makes a difference

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Collaborative Customers





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- Climate research
- Engineering studies
 - Oil platforms
 - Renewable energy systems
 - Coastal structures
- Ice presence
- Ice thickness
 - Mean thickness
 - Max ice keel depth



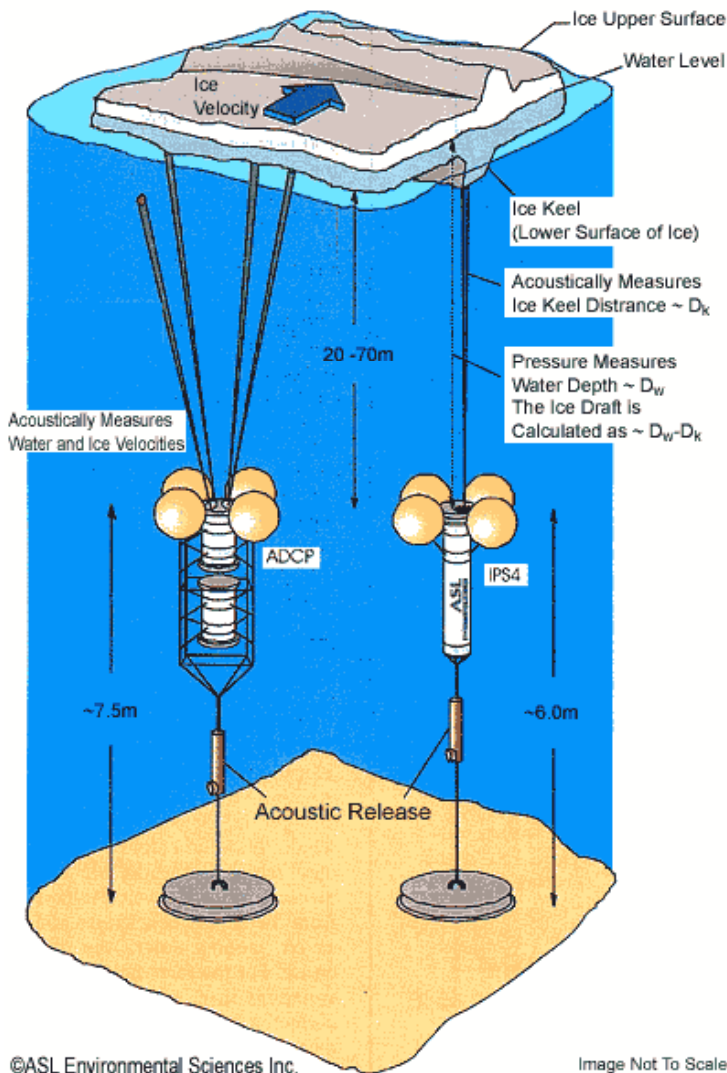
Other techniques for measuring ice

- Satellite – Good spatial coverage but misses subsurface ice features (ice keels).
- Ice “buoys” – mounted on ice surface with staff extending several meters below buoy for an upward looking ultrasound distance measurement. Moves with ice, susceptible to damage, sometimes expendable.
- Subsurface buoy with bottom mounted echo-sounder to measure distance. Often an ADCP is added for ice velocity and current profiles.



Traditional Measurements

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- Requires two independent instruments
- Balancing measurement schedules to avoid interference
- Dual systems has greater weight meaning greater buoyancy
- Bottom track method may not be optimized for ice
- Ice free events may have wave events of interest

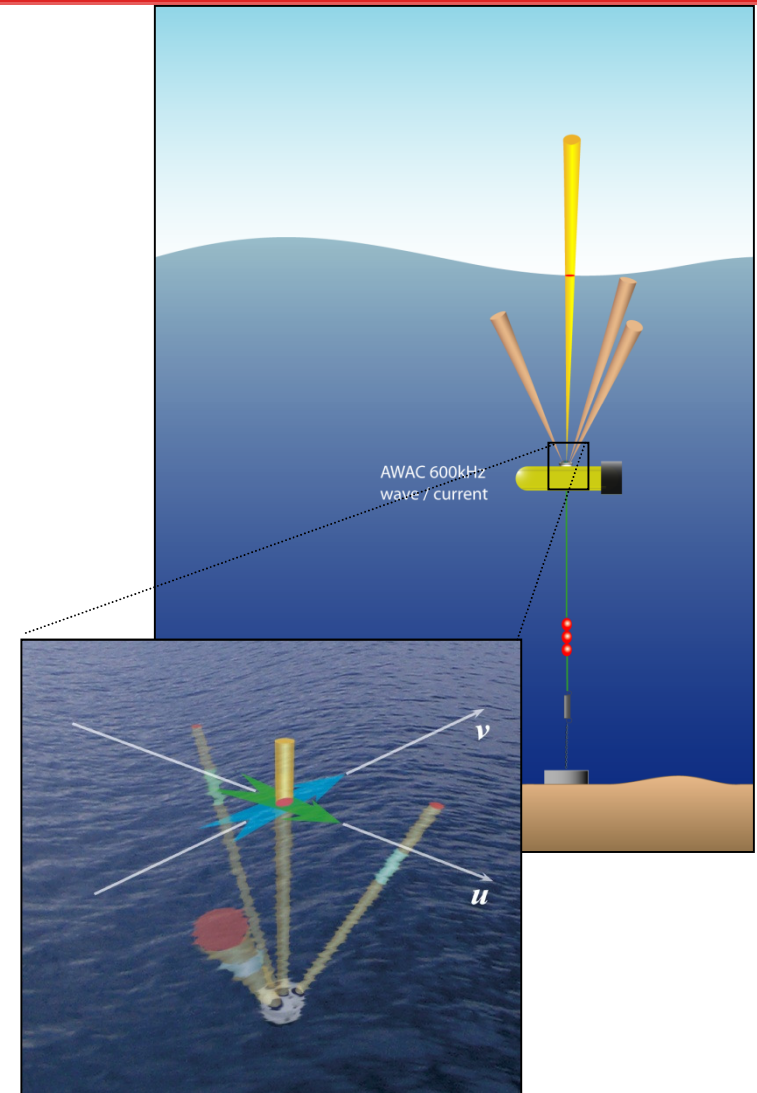


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- Ice measurements born out of the wave measurement expertise and technology
- Great success measuring waves from subsurface buoys
- Nortek uses a patented measurement method called SUV to measure waves from rotating platforms (subsurface buoys)
- SUV is a triplet wave measurement that uses the AST and transformed U and V velocity



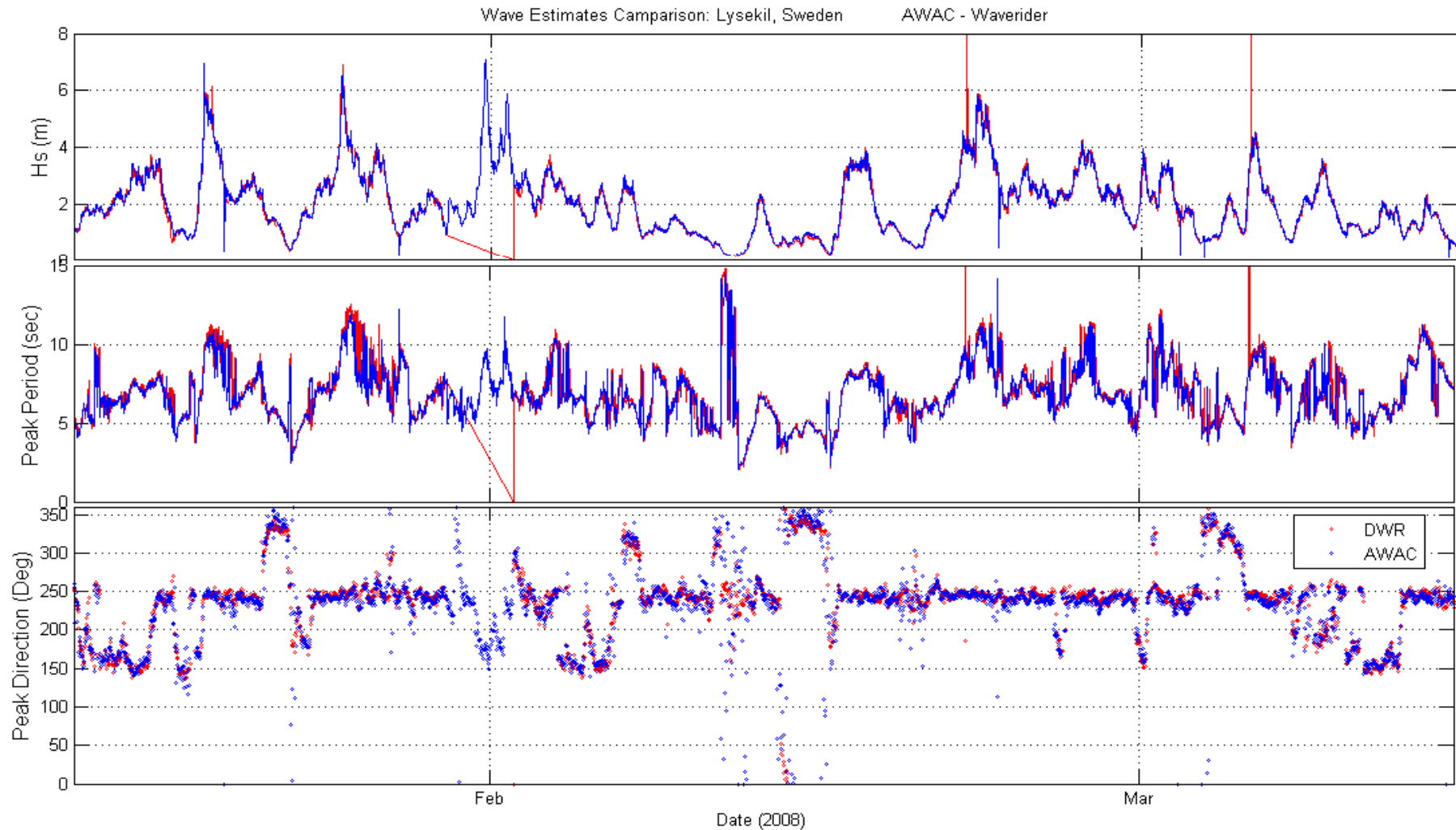


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Wave comparison – AWAC/SUV and Waverider: Lysekil Sweden





Technical Challenges

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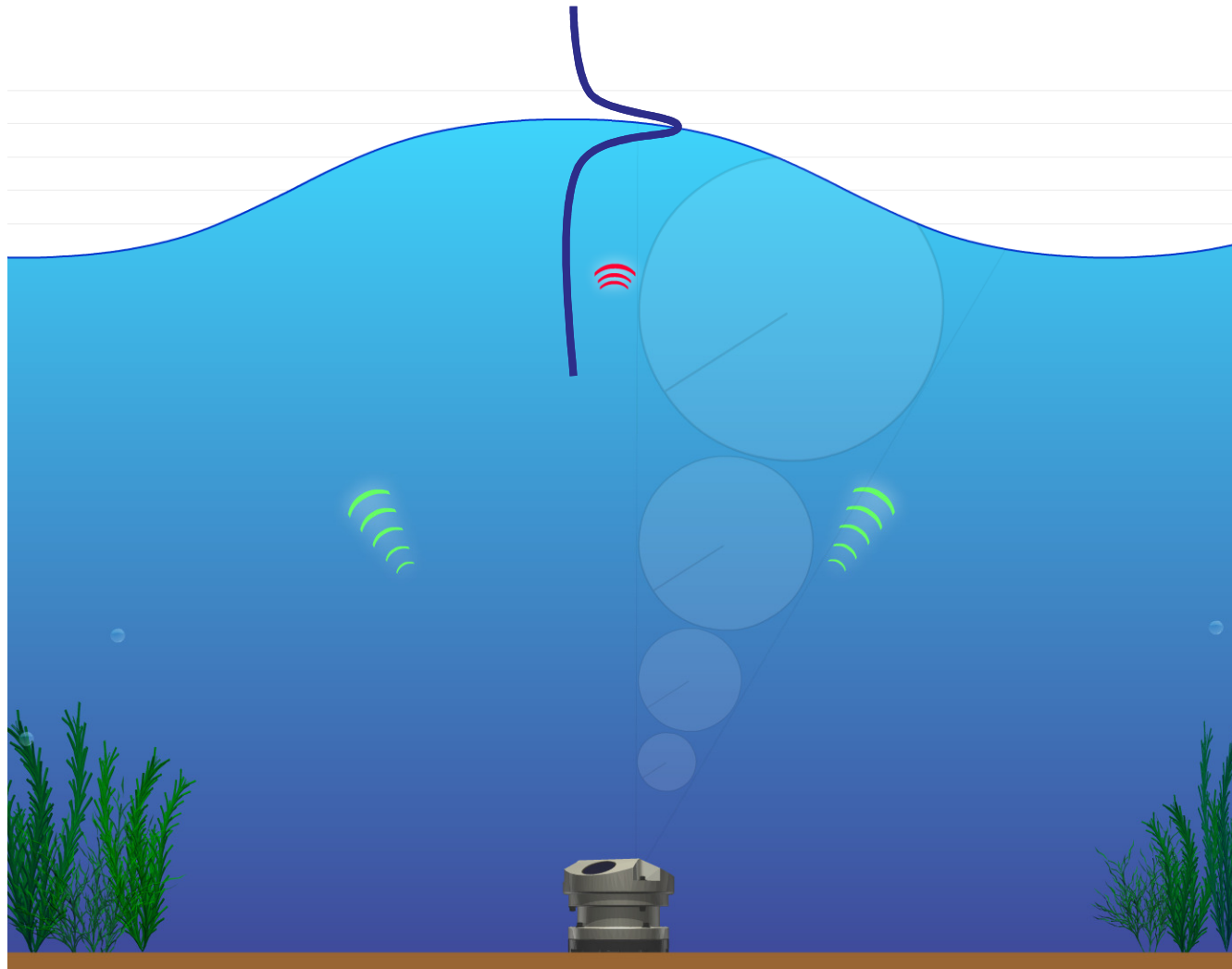
- Ice does *not* have the same characteristics as the ocean surface
- An AST ping will have multiple returns – some from the water/ice interface, some from the ice/air interface, and a variety of returns from variable surfaces
- Standard surface detection algorithm (max peak) not well suited for ice
- A leading edge type algorithm is the most promising



AST Detection for Ice

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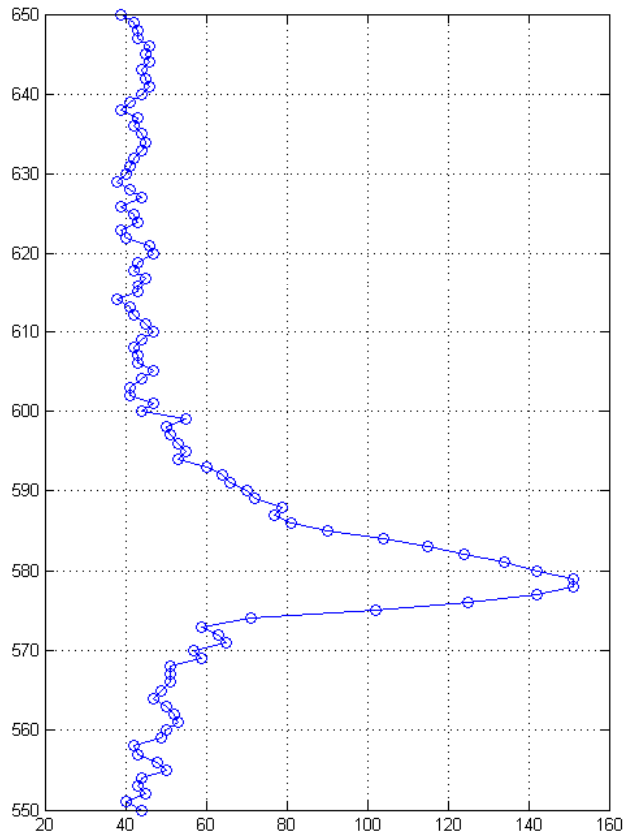


AST Detection for Ice

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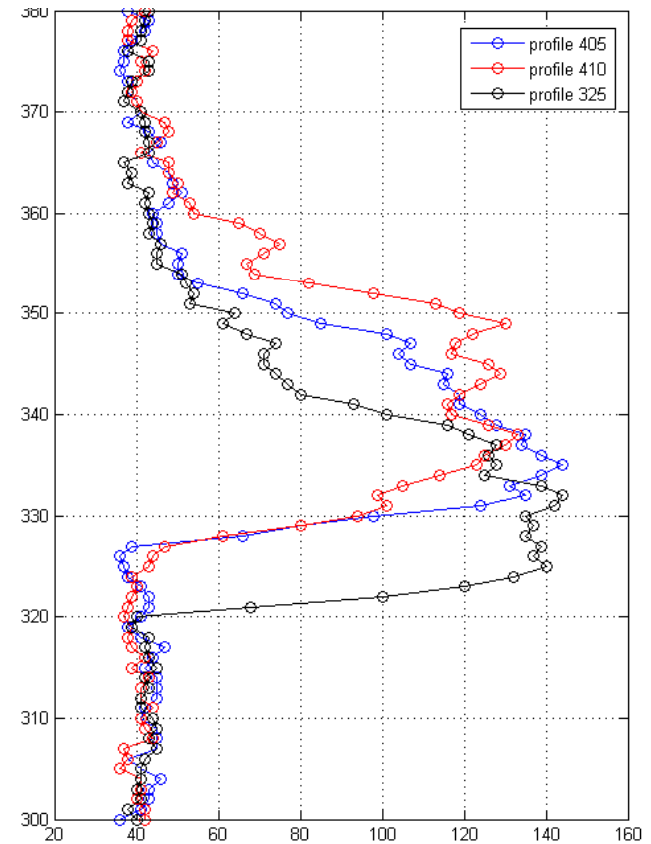
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Water-air interface



Max Peak

Water-ice interface



Leading Edge



Testing & Evaluation

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- Tested locally in the Oslo Fjord during winter of 2007
- Tested shallow water at Sintef Ice test tank facility Trondheim
- Alaska: Two users each with 2 AWACs collecting data for 2008-2009 winter
- Testing Oslo Fjord 2009 for ice velocity measurements

What have we learned?



Lessons Learned

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Error Sources:

- Peak - Surface detection needs leading edge detection
- Pressure sensor - existing 0.5% : 25 cm for 50 meter sensor
- Temperature compensated 0.1%: 5 cm for 50 meter sensor
- Density gradient effects on pressure: negligible
density(T,S): rho(-2 C, 33 ppt) = 1026.6 kg/m³
 rho(4 C, 32.5 ppt) = 1025.8 kg/m³
- Speed of sound variations within water column: can be important
estimated at AWAC (salinity estimate, temperature, pressure)
- Atmospheric variations: can translate into as much as 50 cm
can be correct for in post processing.

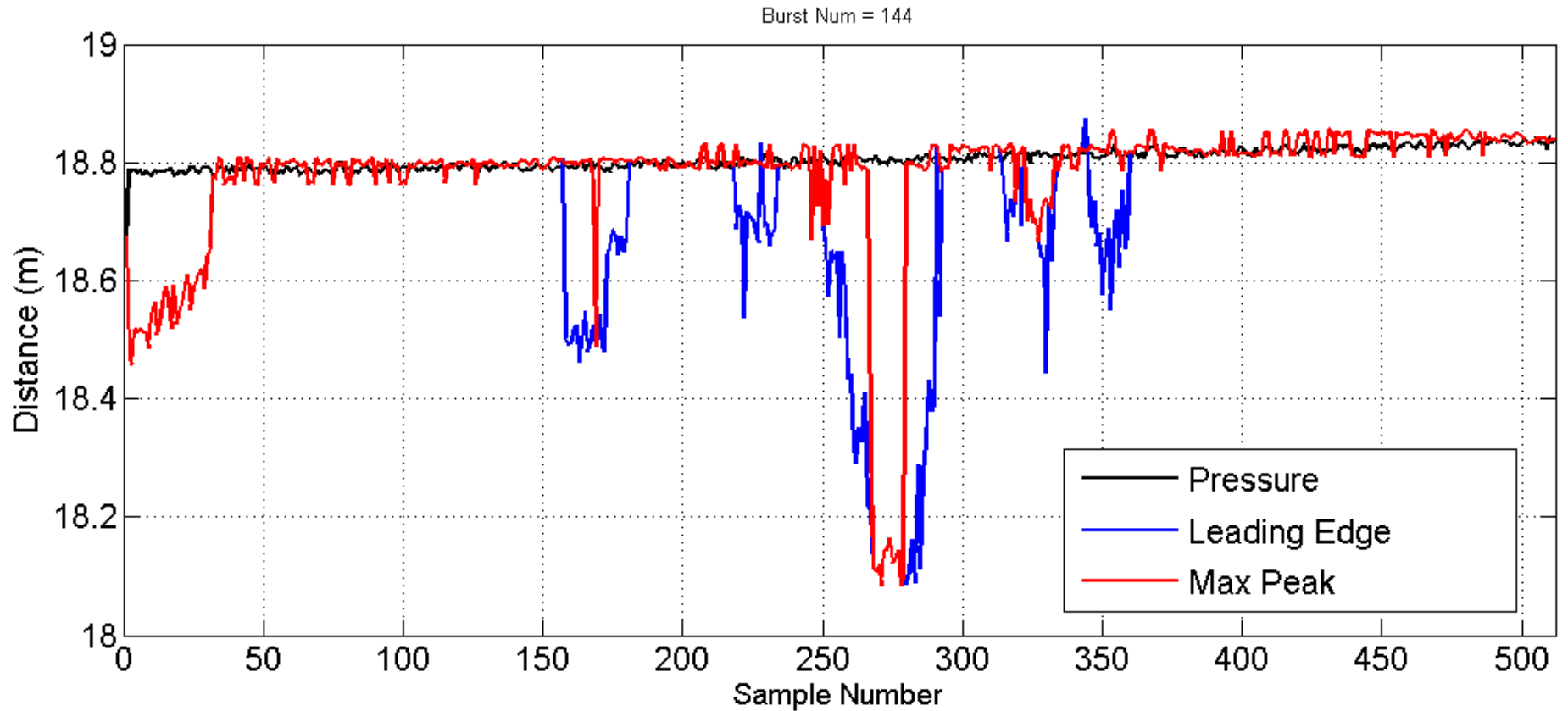


Peak Detection

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AST data from 1 MHz AWAC: Alaska



1.0% round-trip error: 50 cm for 50 m sensor

This uncertainty is common to all acoustic methods

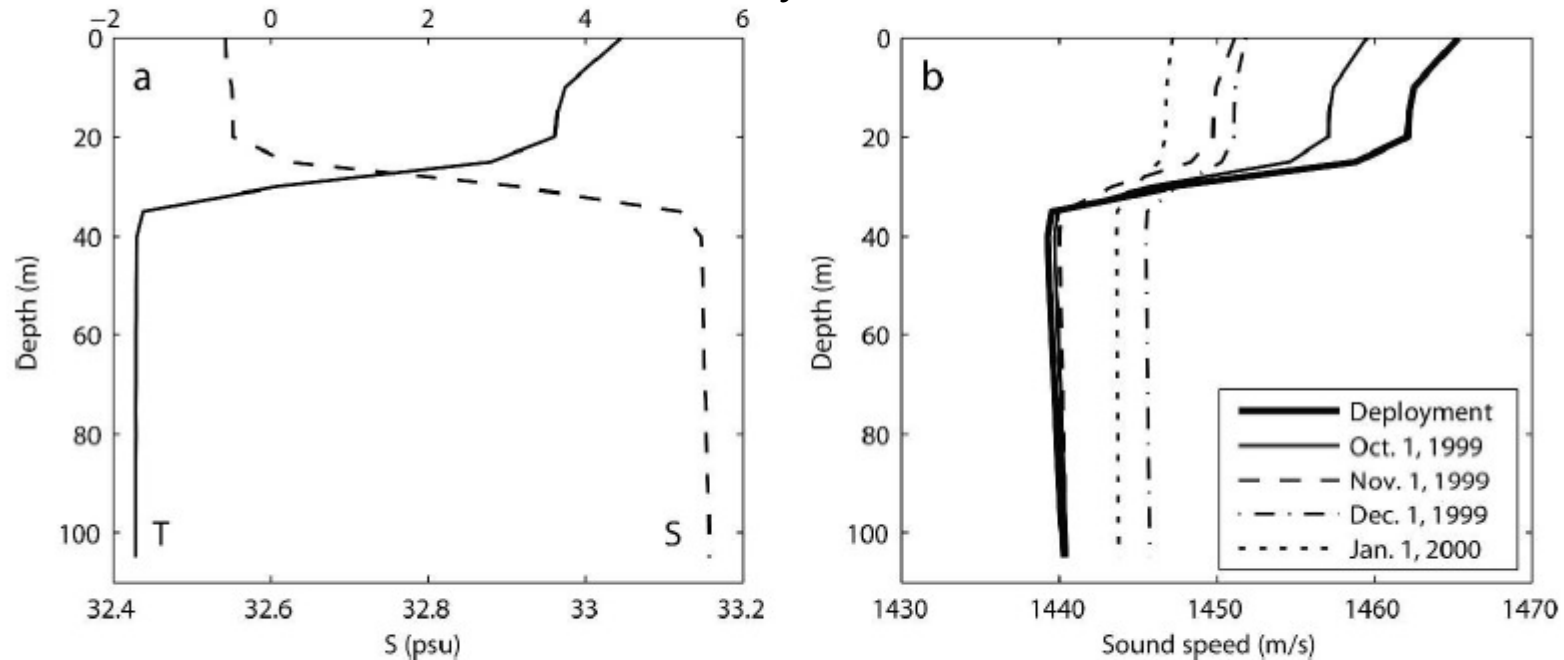


FIG. 16. Thermocline sound speed correction. (a) Vertical profiles of temperature (solid line) and salinity (dashed line) at the mooring site on 16 Sep 1999. (b) Vertical profile of sound speed calculated from the temperature and salinity data for 16 Sep 1999 (thick line) and sound speed profiles inferred using thermocline correction (thin solid and dashed lines). See text for details.

Source: "Ice-Draft Profiling from Bottom mounted ADCP", Andrey Shcherbina, Daniel Rudnick, Lynne Talley

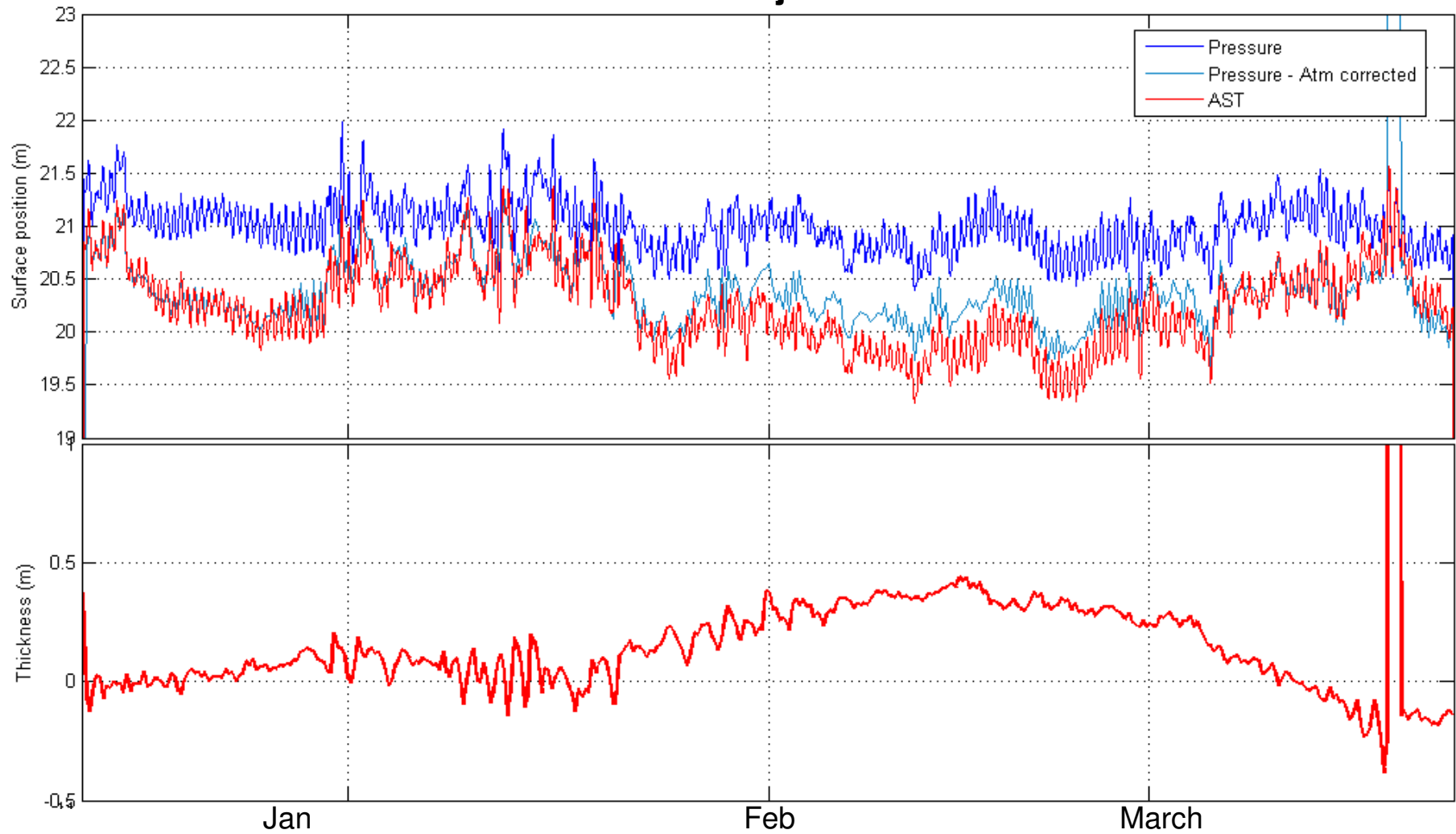


Atmospheric Correction

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Ice Draft: Oslo Fjord 2007



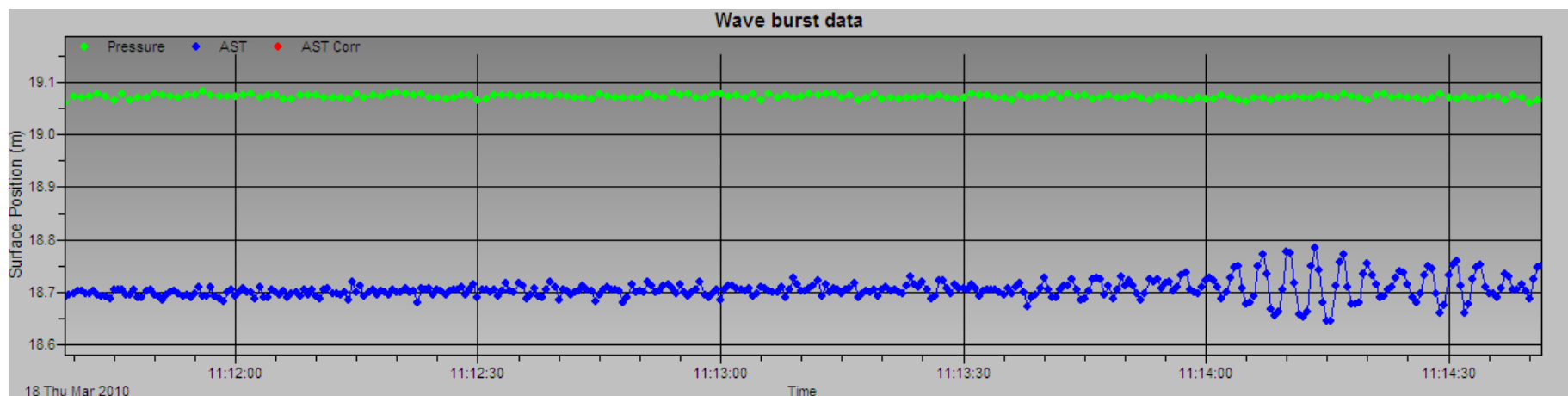


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What is New

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- New firmware with ice mode
- Check box in software to enable ice measurements
- When ice mode is enabled, AST alternates between max peak and leading edge detection. Allows for measurement of both waves and ice.
- Distance measurements to air for both methods similar (no apparent bias). This means full sampling rate can be used for wave processing.

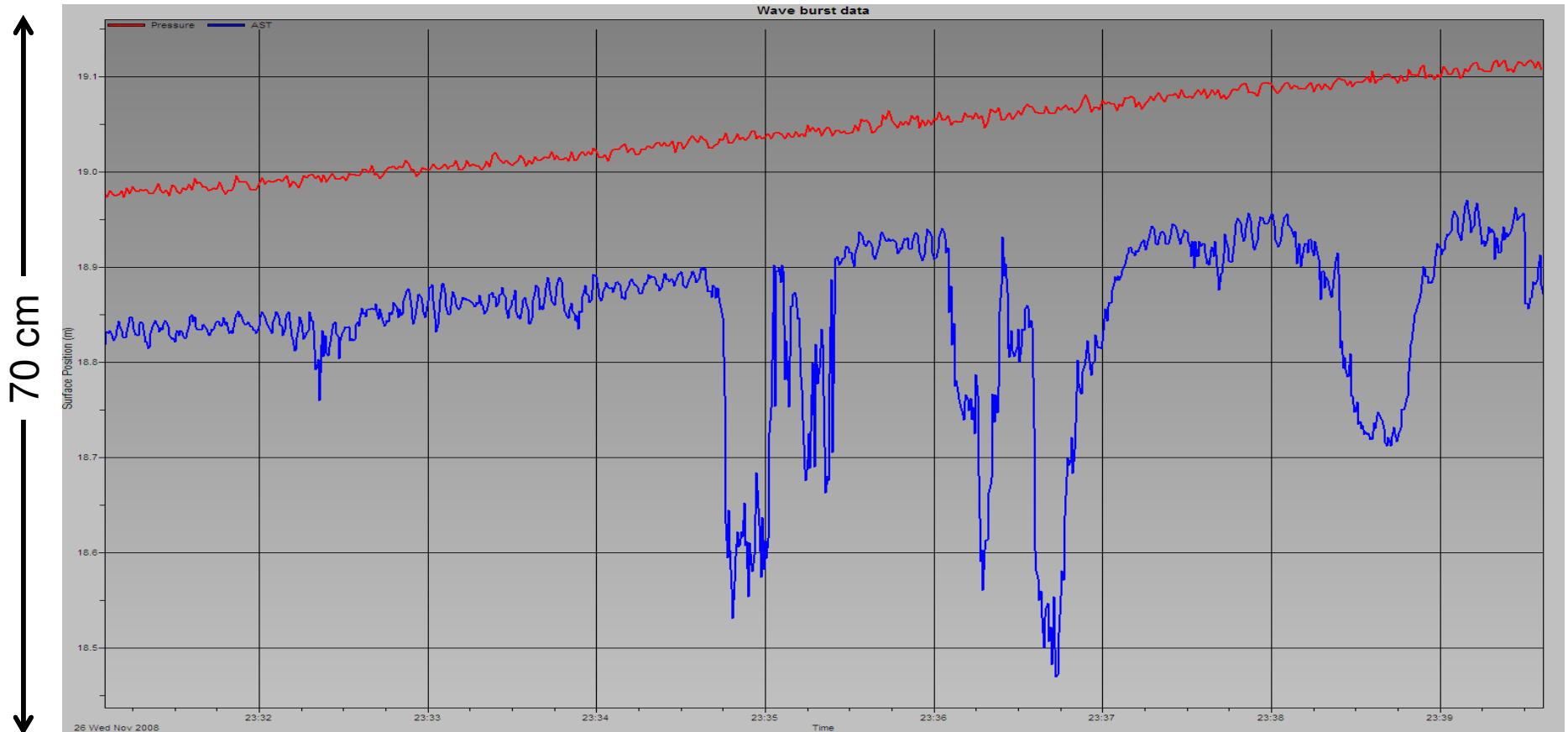




Ice Data

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8 minutes



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Applications

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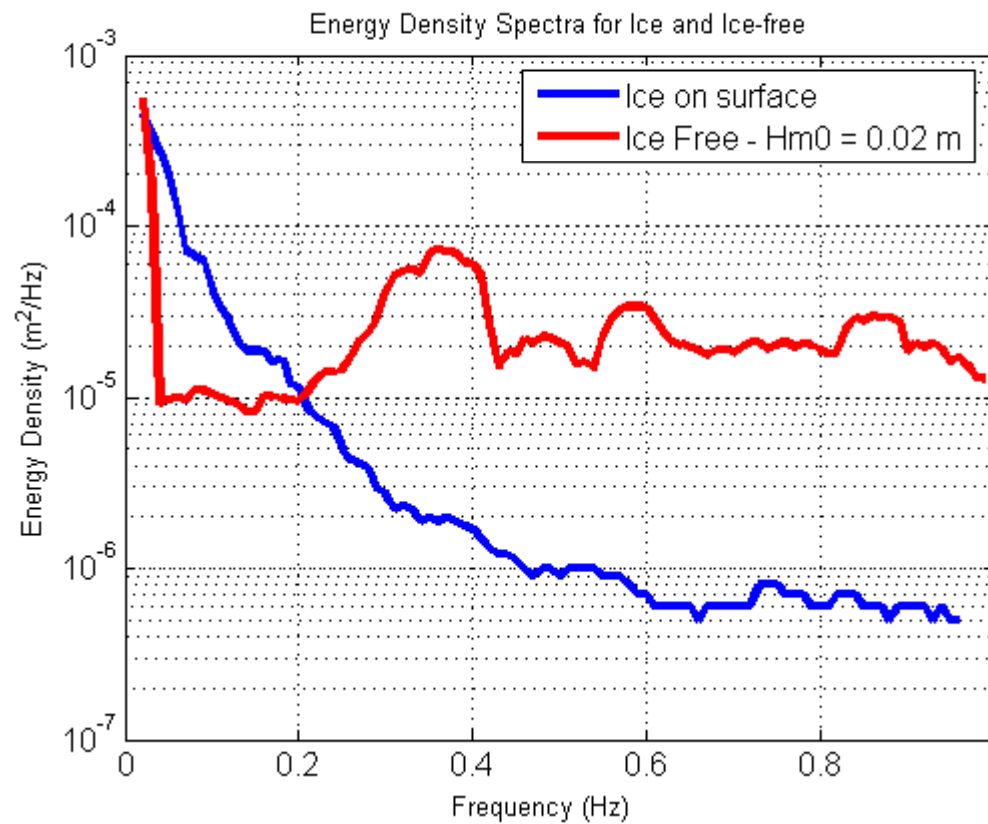
Coastal Engineering

- Shoreline erosion
- Damage to coastal structures



Climate Studies

- Ice modeling
- Atmospheric/Ocean coupling modeling



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