

PERFORMANCE OF THE NORTEK AWAC IN THE BEAUFORT SEA

Wave, Ice, and Current Measurements

Successes and Issues

Bruce Magnell

Leonid Ivanov

David Szabo

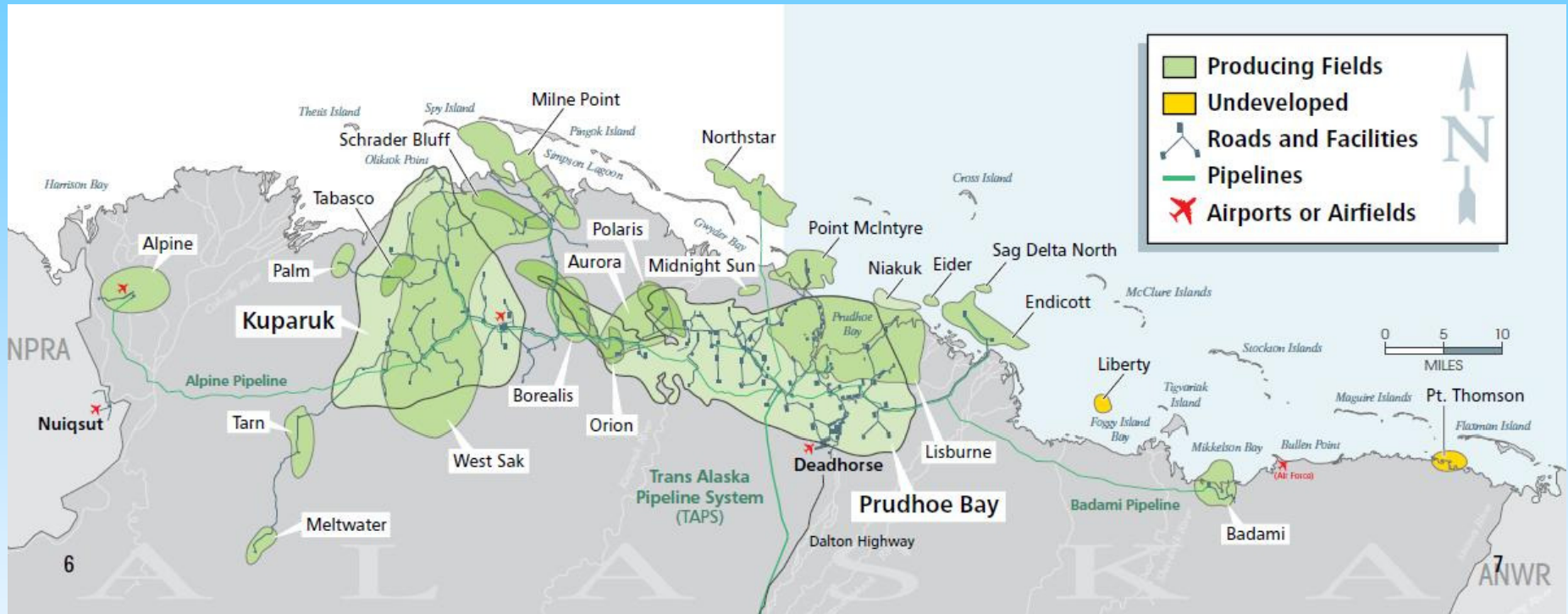
Bruce Andrews

Woods Hole Group, Inc.

Oceanography and Measurement Systems



BEAUFORT SEA MEASUREMENT PROGRAM



- 3 instrumented bottom platforms offshore Northstar Island at Prudhoe Bay in Beaufort Sea
- 1 year deployment

2008-2009 BEAUFORT SEA MEASUREMENT PROGRAM

- Obtain data for design of offshore structures and ice armoring
 - Wave data during open-water periods
 - Ice thickness data during fast-ice periods
 - Ice block thickness, size and movement during partial ice coverage periods
- Multi-year measurement program
 - Originally planned for 5 years
 - Cut back to 1 year
- Requirements
 - Under-ice measurements in shallow water
 - Multiple, redundant instruments
 - 1-year deployments
 - Small vessels

INSTRUMENTATION

- Nortek 1 MHz AWAC system
 - Acoustic Surface Tracking (AST)
 - Nortek Internal Processor (NIP)
 - 4 GB memory
 - 4 Nortek Lithium AWAC battery packs (each pack ~1800 – 2000 w-hrs)
- ASL IP-5 Ice Profiler
 - 420kHz upward-looking sonar
 - Multi-phase sampling capability

AWAC AST/NIP ADVANTAGES

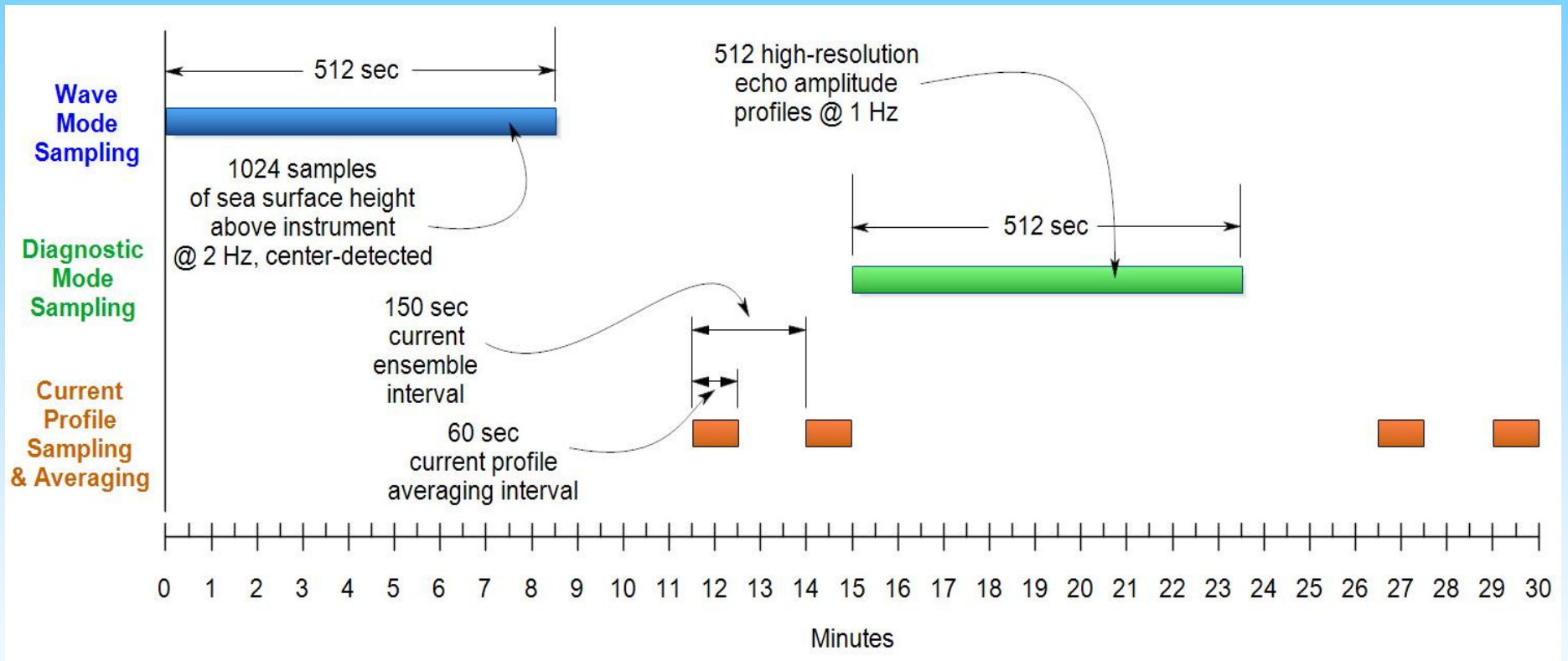
- AWAC's combination of currents, waves, and ice keel depth measurements permits analysis of ice movement
- AWAC provides directional wave data
- NIP's large data storage capacity allows long deployments with intensive sampling scheme
 - Necessary for diagnostic mode sampling (4 GB per year)
 - But power consumption and data storage requirements pose configuration challenges

BEAUFORT SEA BOTTOM PLATFORM



- Mooring Systems, Inc. TRBM
- Acoustic release
- Pop-up float and line canister
- Acoustic release hook used for deployment

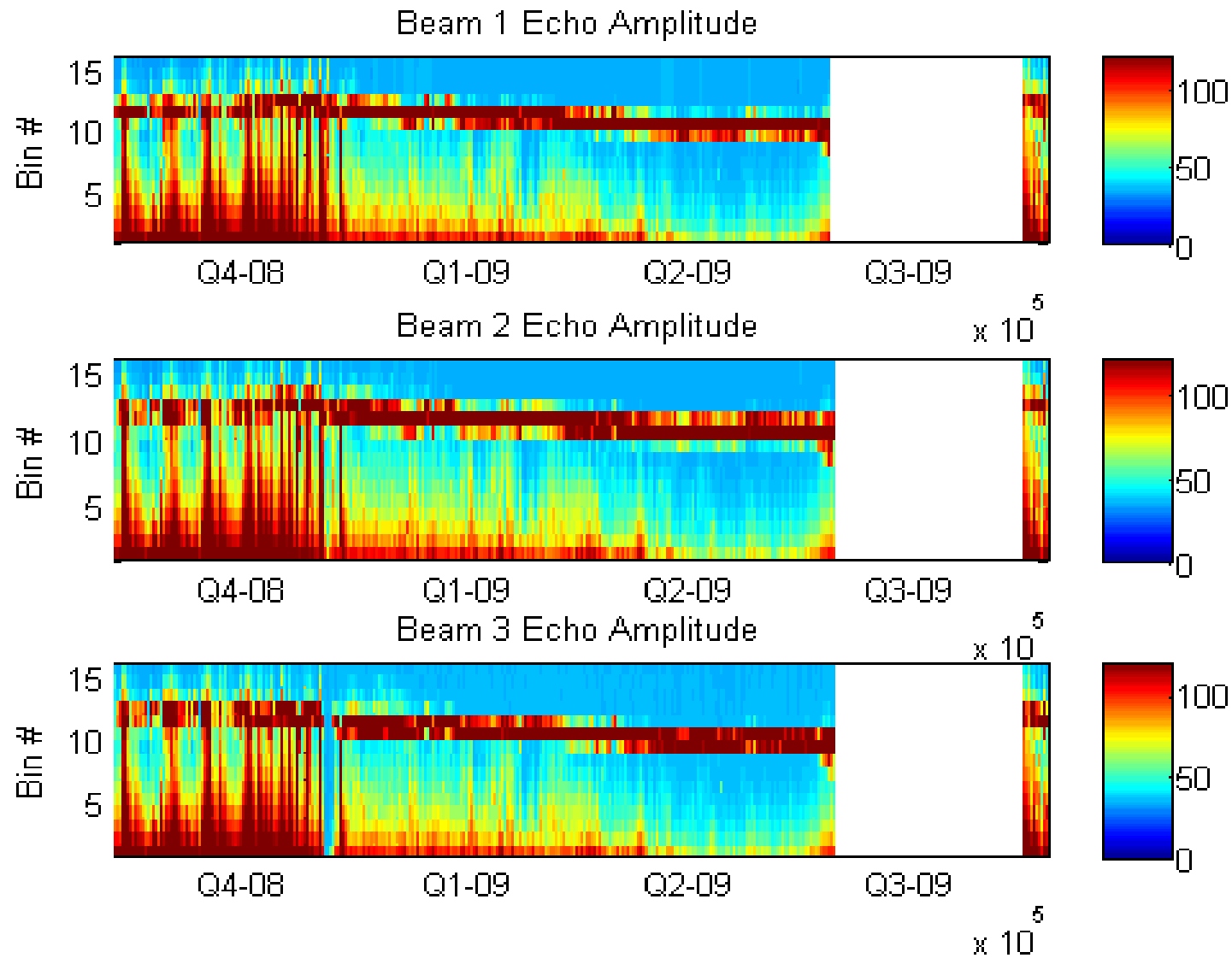
AWAC AST SAMPLING CONFIGURATION



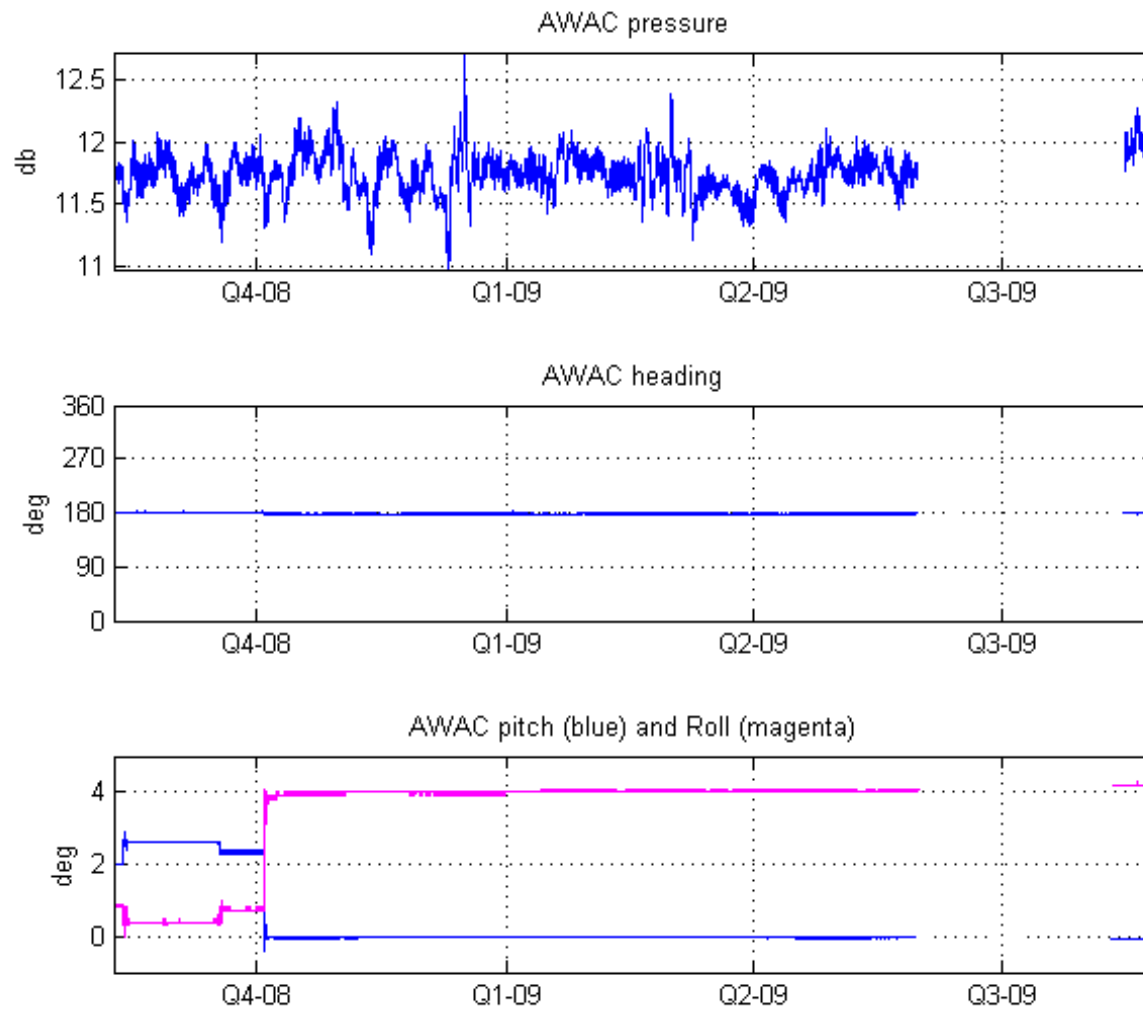
AWAC AST/NIP SUCCESSES

- AWAC's combination of current profiles and diagnostic echo amplitude profiles provided valuable data showing ice keel depth, ice block size, and ice block movement
- Diagnostic data also provided valuable insight into ice structure, water column acoustic properties, causes of bad detects, etc.
- AWAC AST provided good quality directional wave spectra most of the time

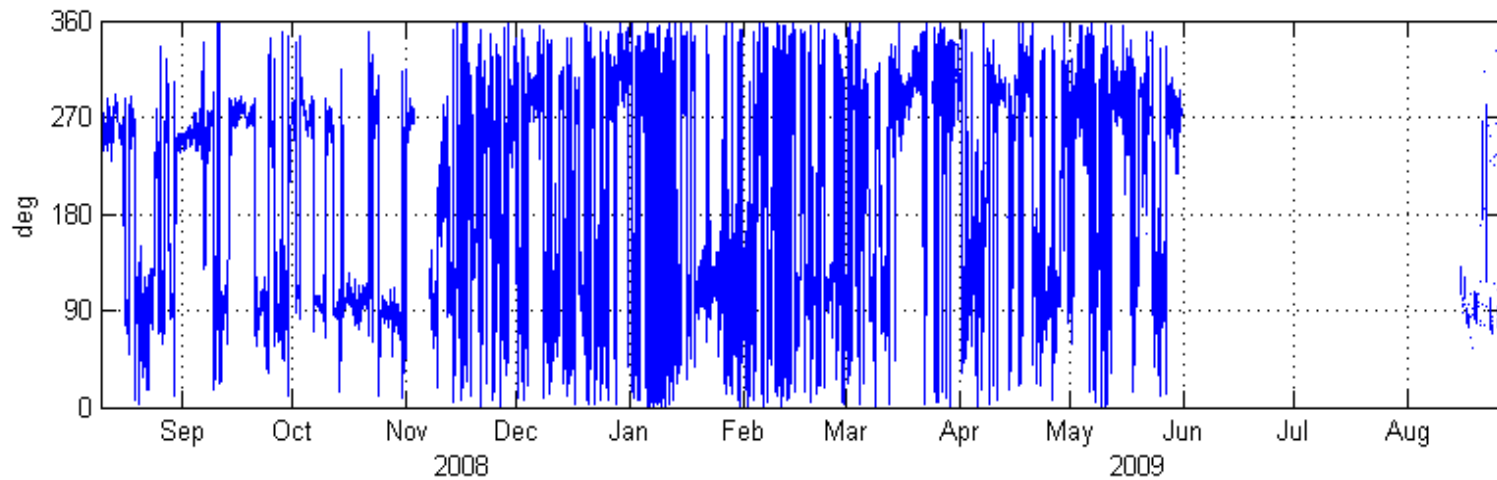
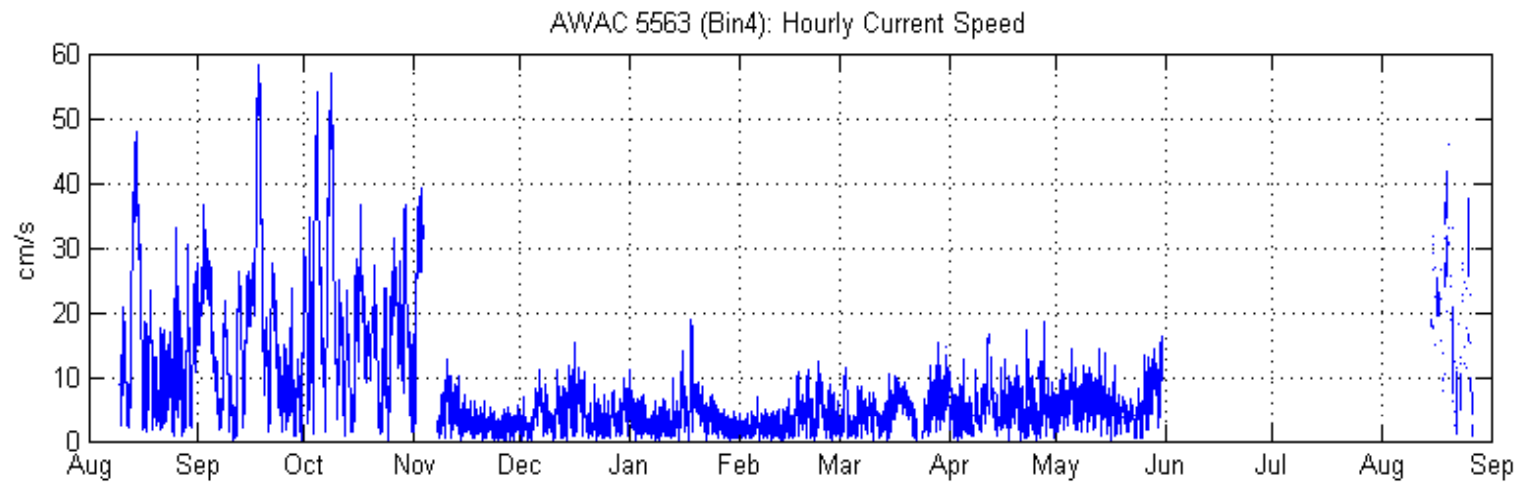
ECHO AMPLITUDE



DEPTH, HEADING, AND TILT Mooring M1



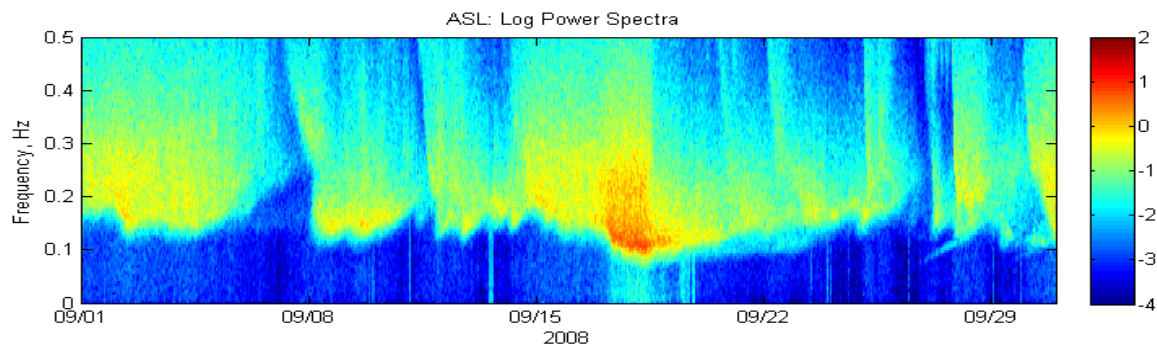
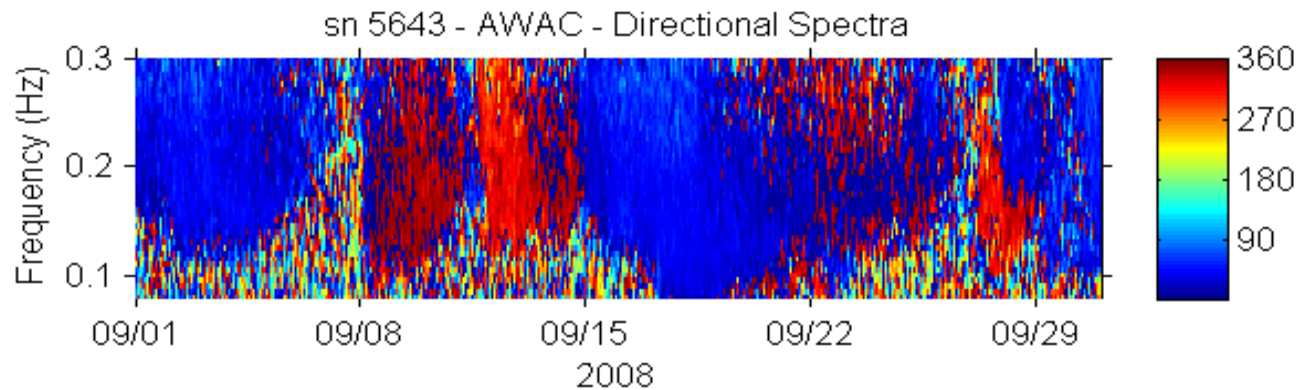
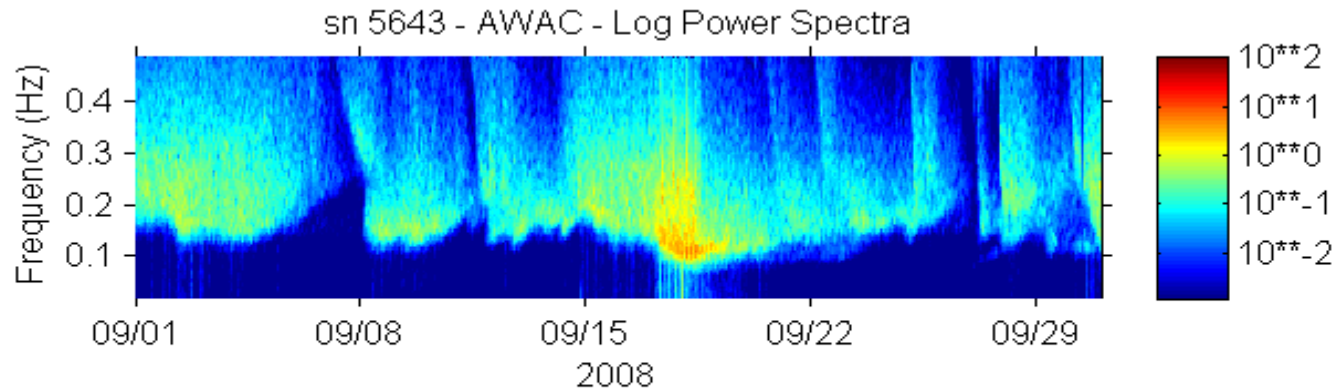
CURRENT SPEED AND DIRECTION Mooring M1



AWAC WAVE DATA

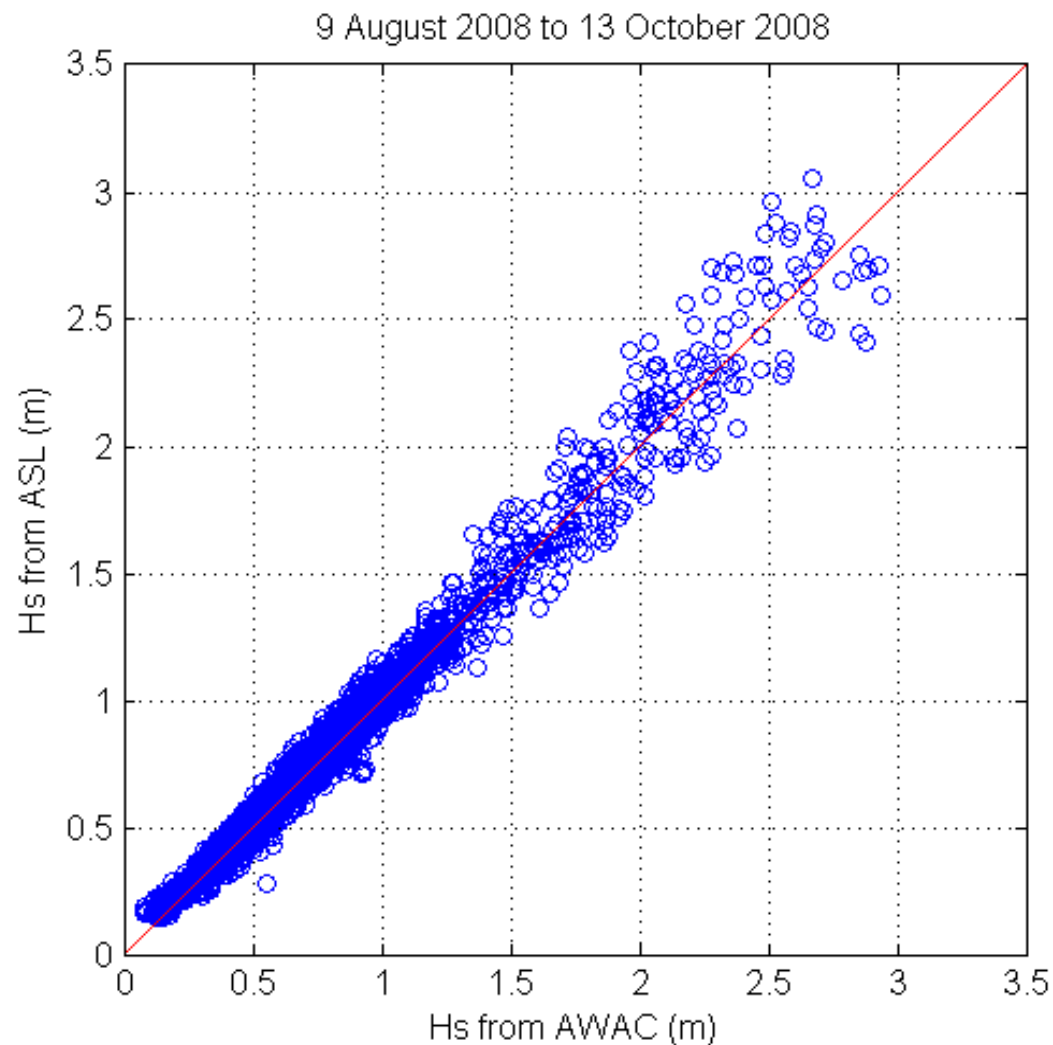
- Examples of wave directional spectra
- Intercomparison with ASL

AWAC & ASL Spectra, Mooring M1, September 2008



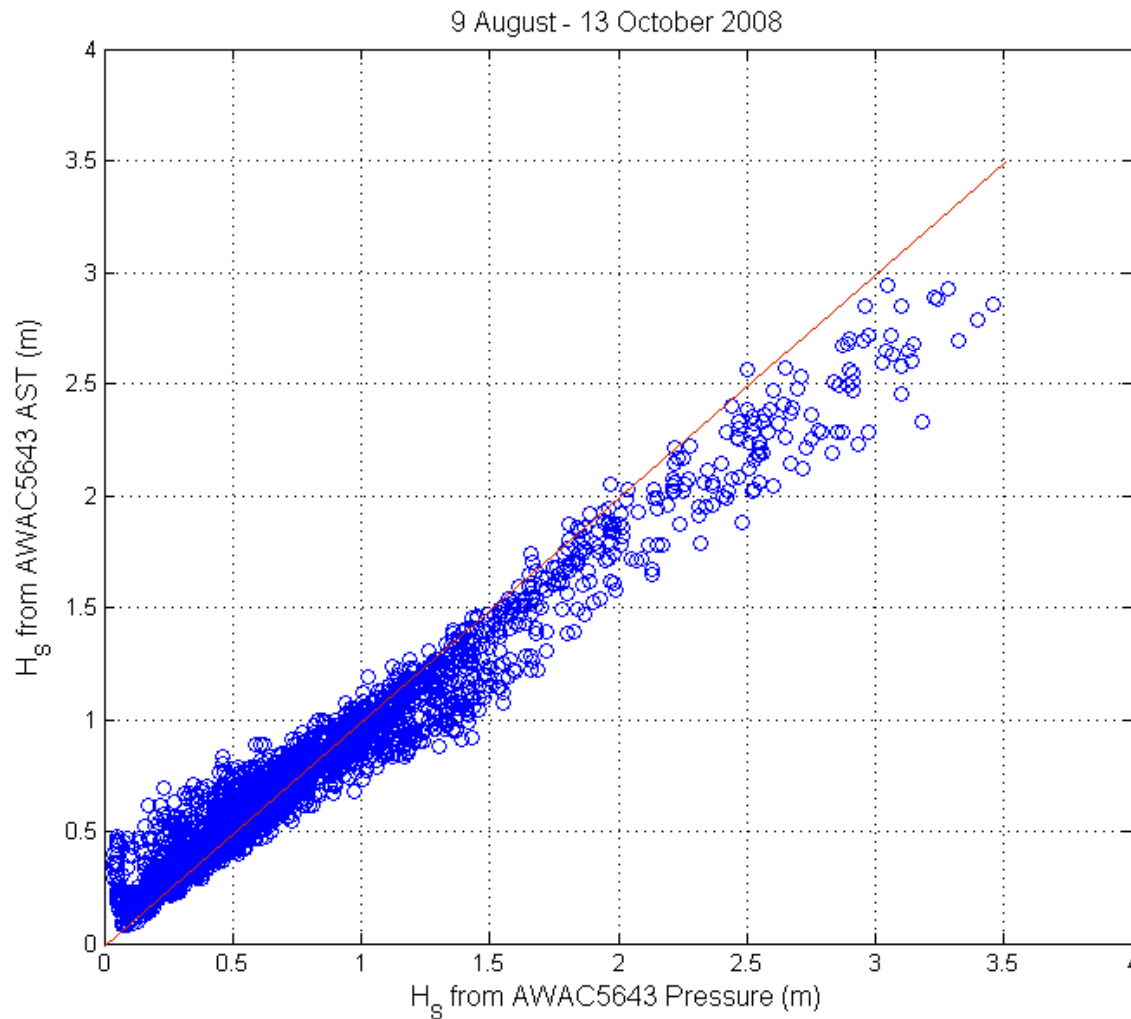
AWAC WAVES Hs

AWAC AST vs ASL IP-5 Hs at Mooring M1



AWAC WAVES

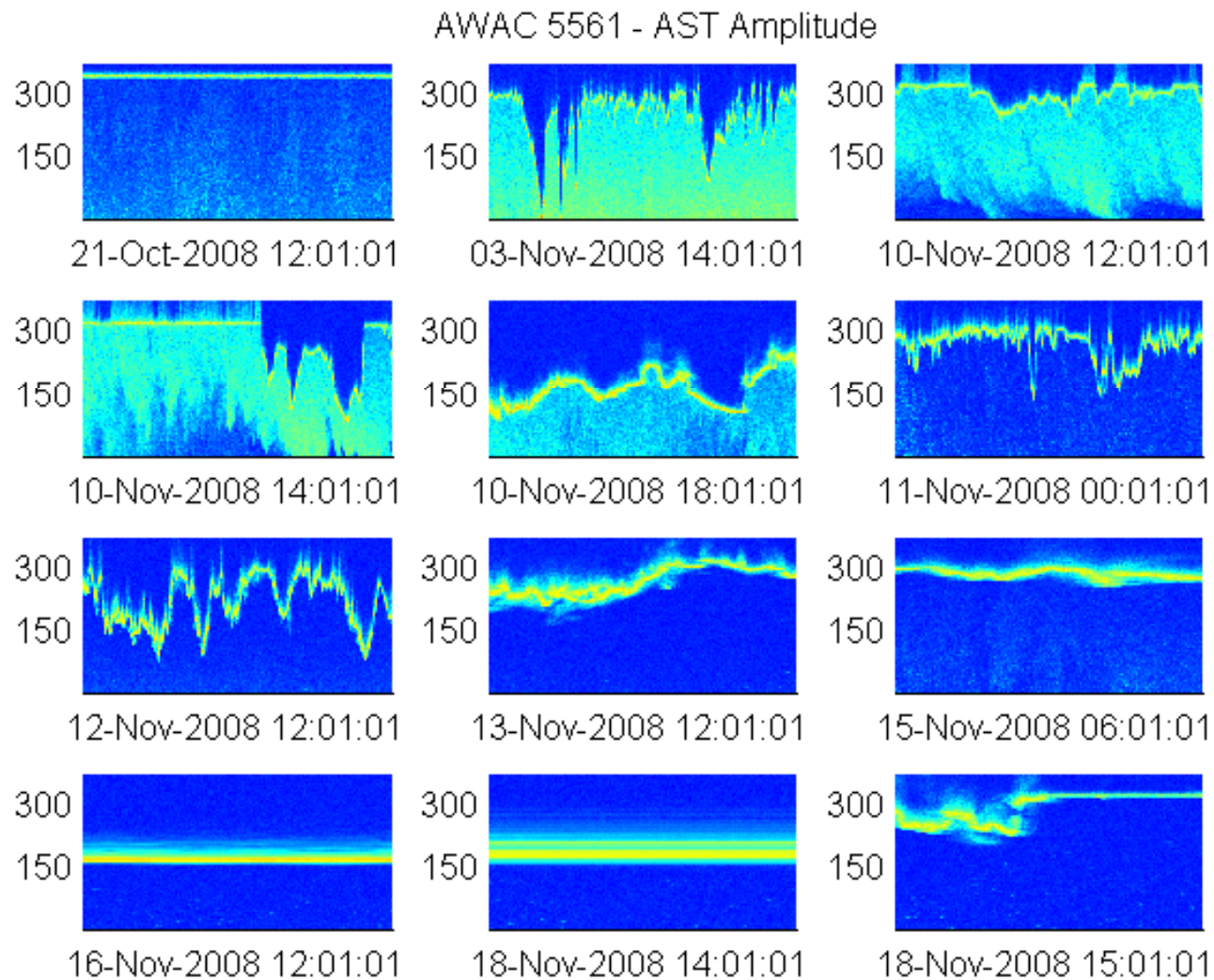
AST vs Pressure H_s at Mooring M1



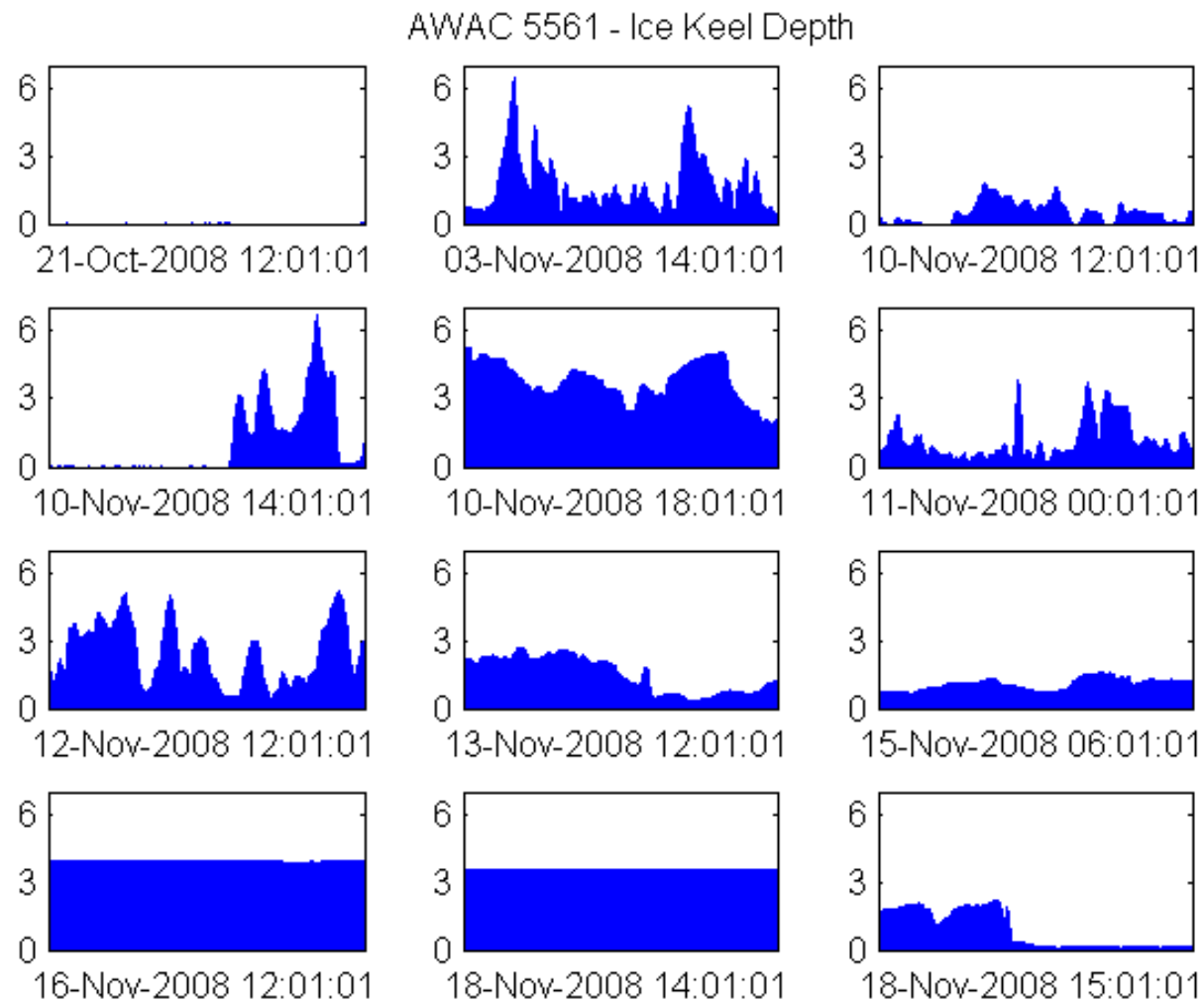
AWAC ICE DATA

- Examples of diagnostic data as used for ice keel range measurement
- Intercomparison with ASL IP-5 Ice Profiler

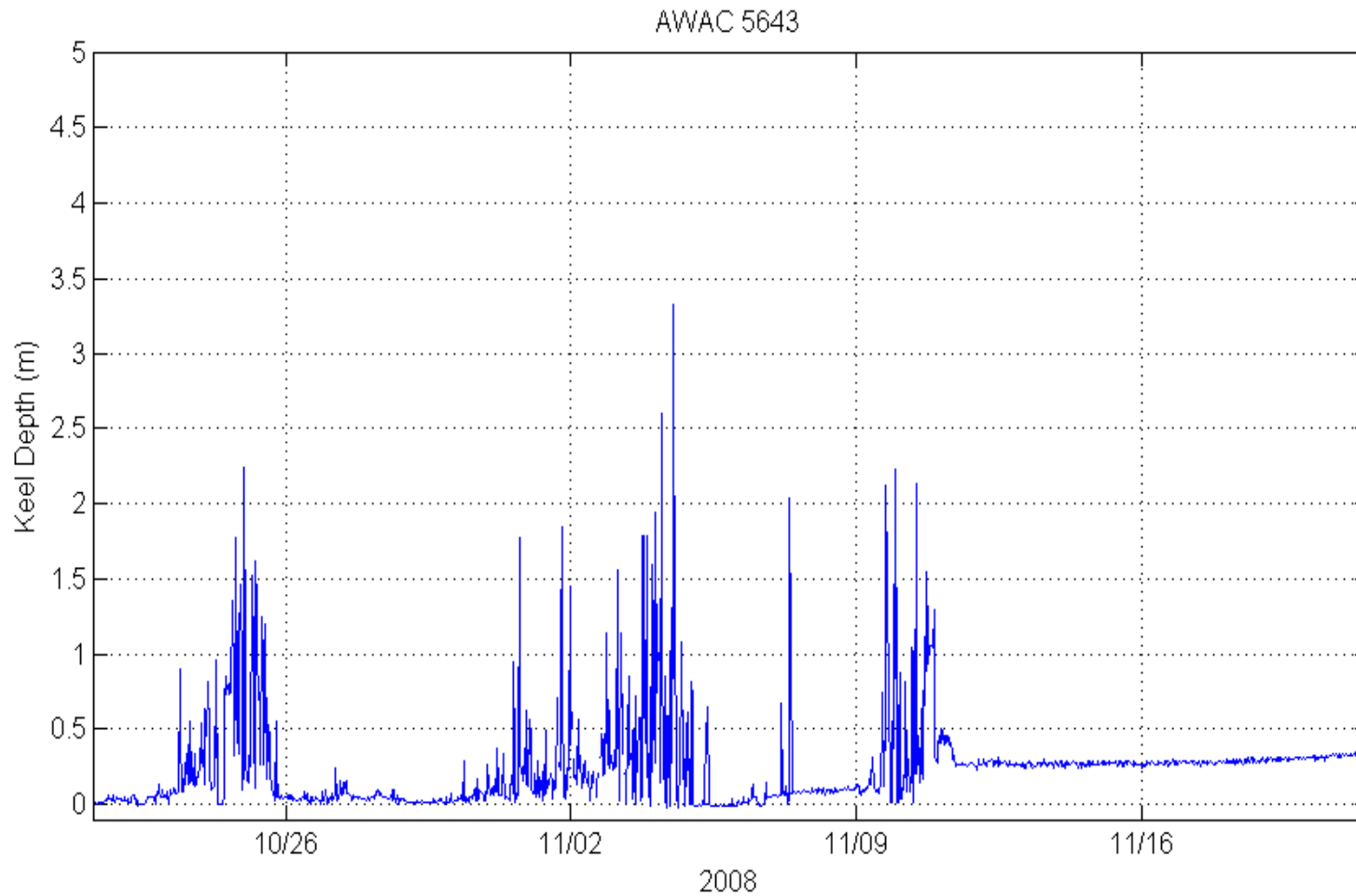
ICE KEEL DEPTH FROM DIAGNOSTIC BURSTS



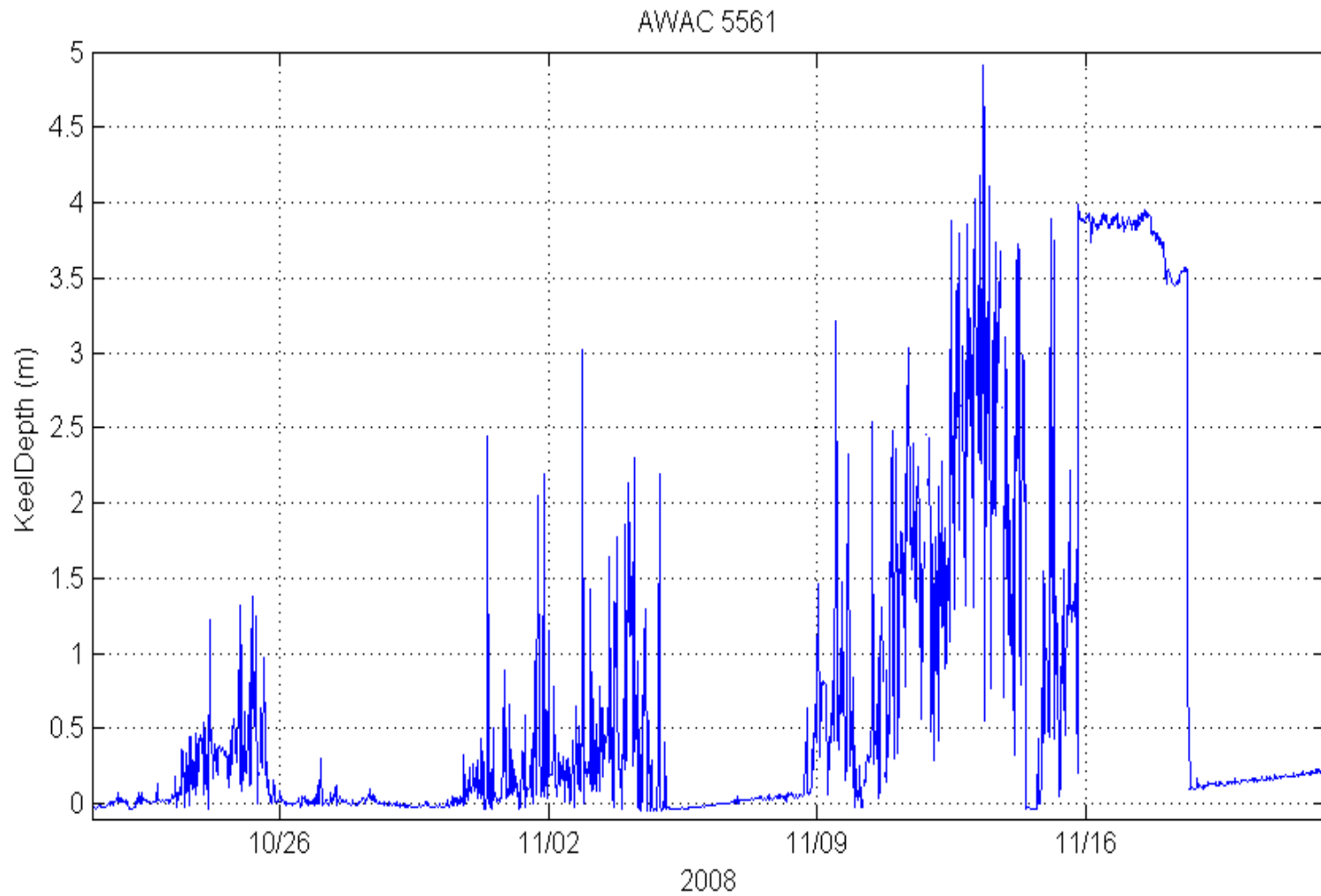
ICE KEEL DEPTH FROM DIAGNOSTIC BURSTS



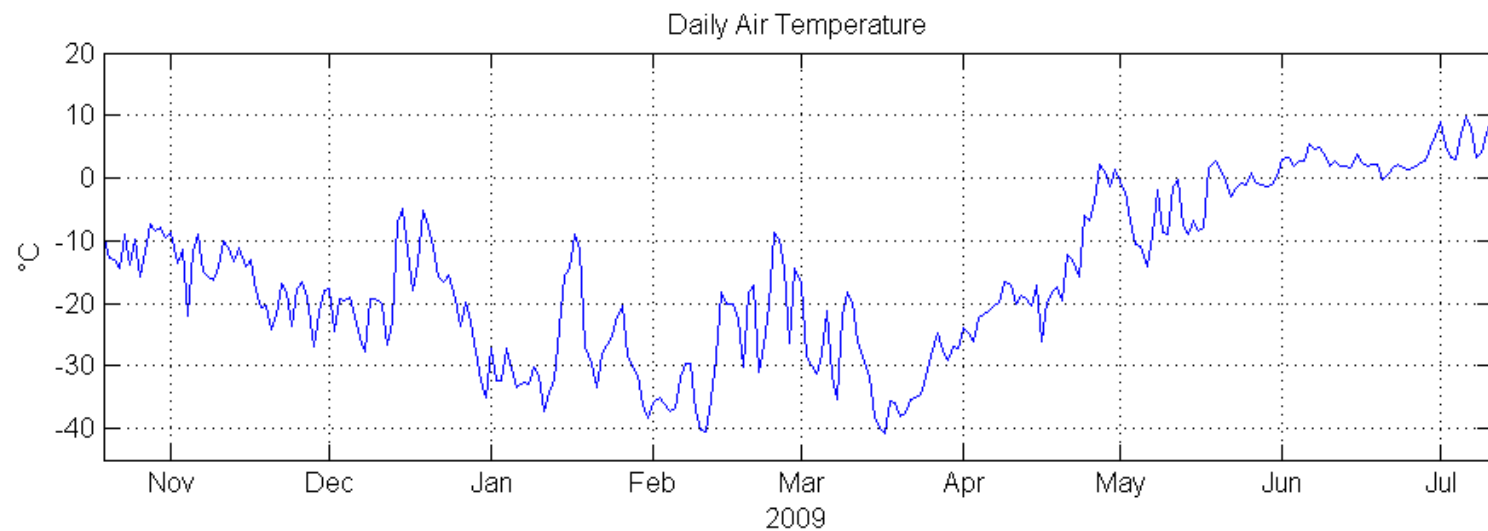
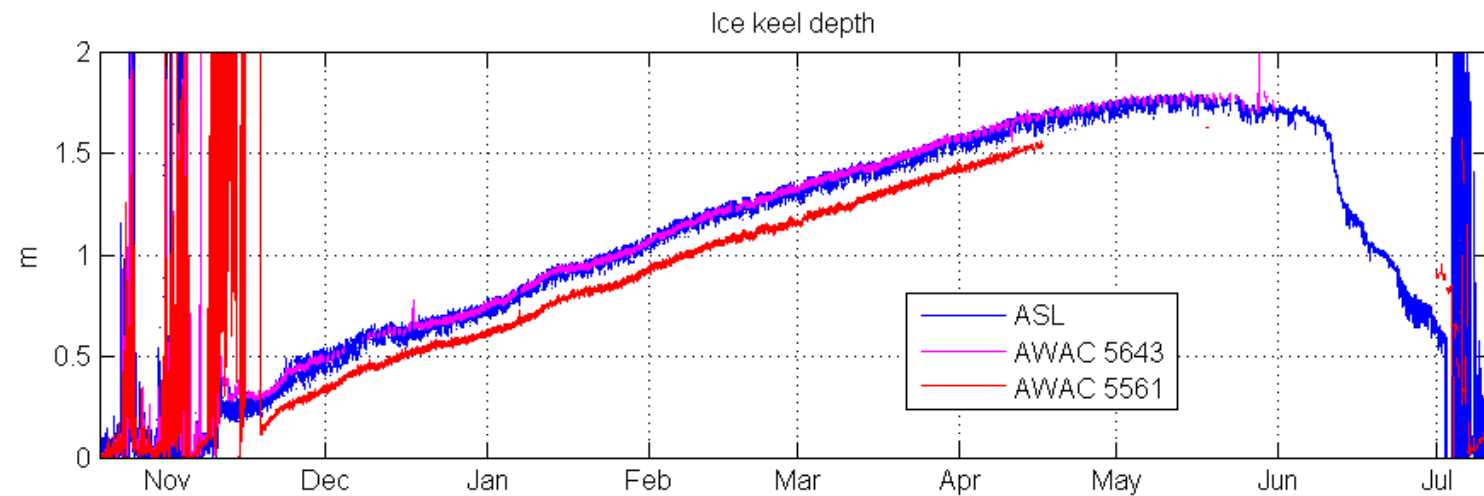
ICE KEEL DEPTH FROM DIAGNOSTIC BURSTS



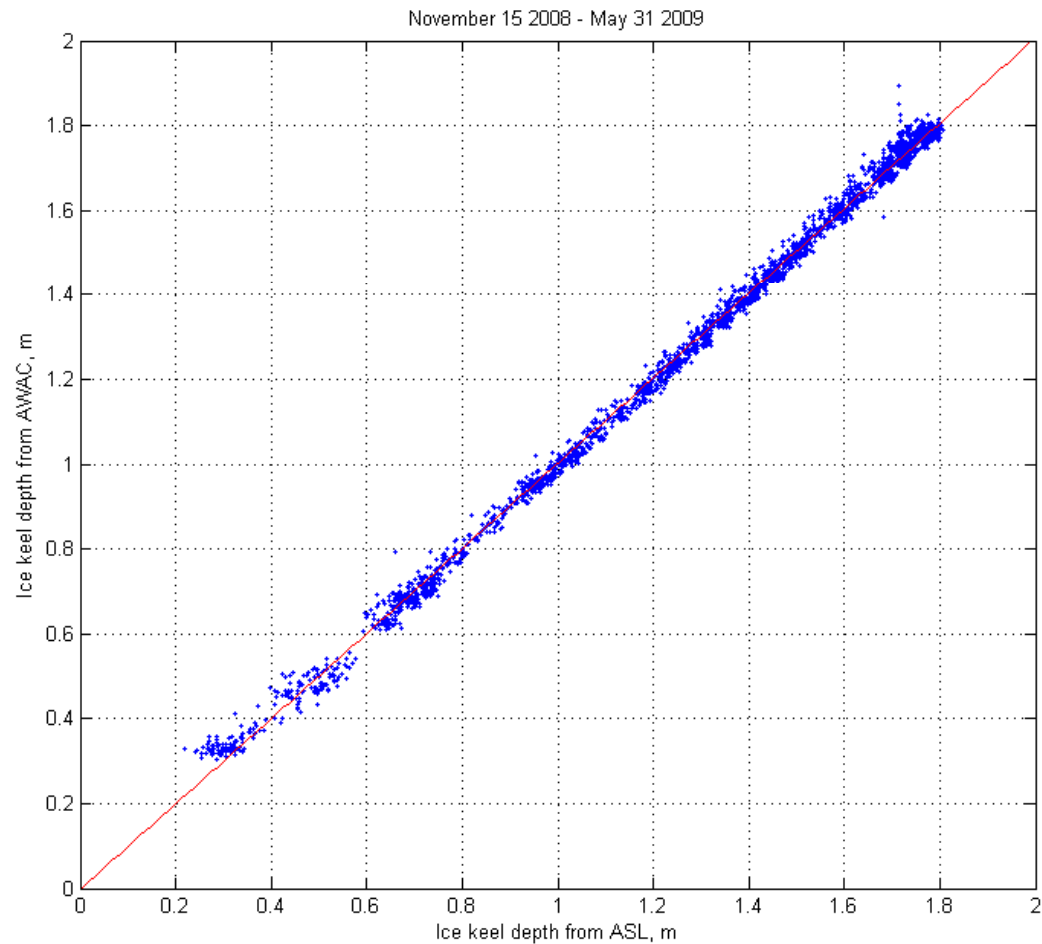
ICE KEEL DEPTH FROM DIAGNOSTIC BURSTS



ICE KEEL DEPTH FROM DIAGNOSTIC BURSTS



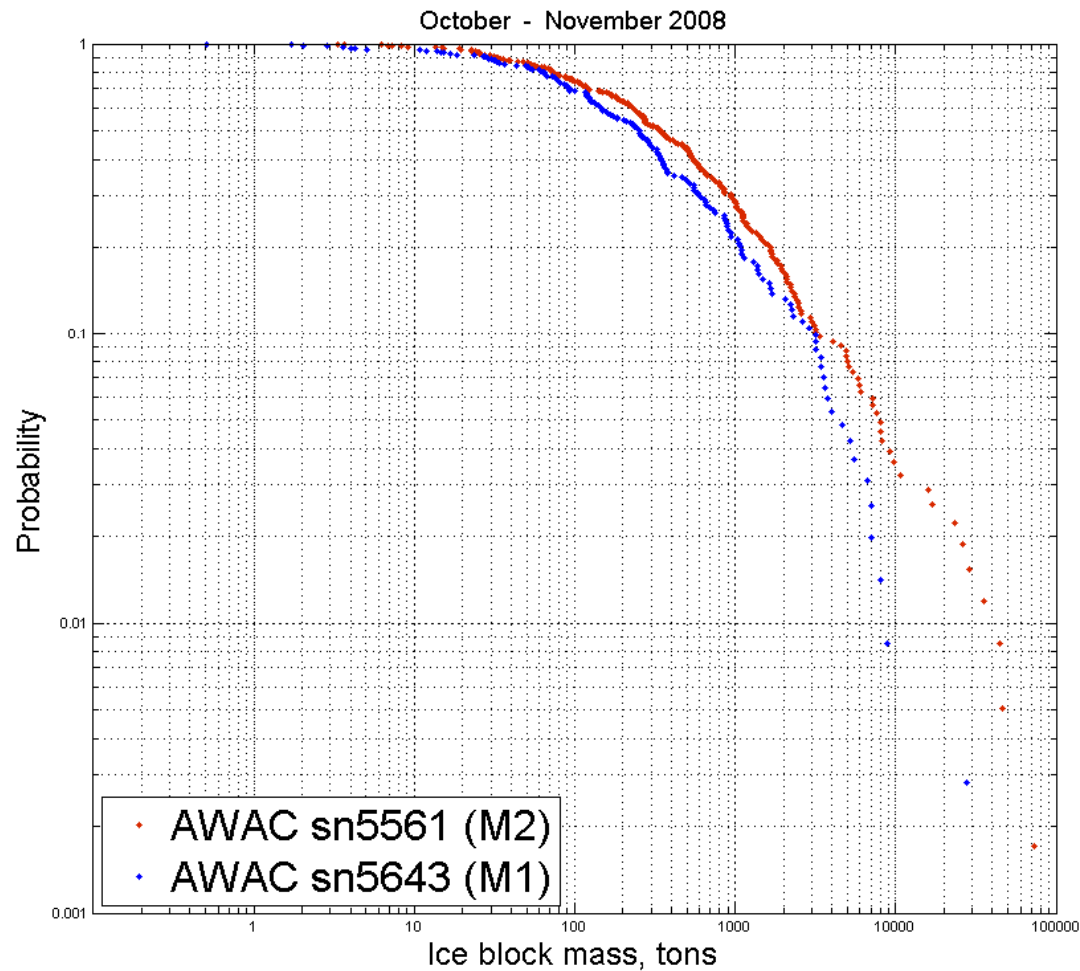
ICE KEEL DEPTH ASL vs AWAC at Mooring M1 Solid Ice



ICE BLOCK ANALYSIS

- Using detailed ice keel depth profiles within sampling bursts
 - Determine time interval for passage of individual ice blocks
 - Calculate average thickness of each ice block
 - Estimate horizontal extent of individual ice blocks using current data
 - Limitation: only measuring horizontal extent along the line of movement – assume square shape?
- Using data from multiple bursts
 - Calculate the distribution of ice block size and mass

ICE BLOCK MASS DISTRIBUTION (Assuming square blocks)



PERFORMANCE SUMMARY

- AWACs operated well - most of the time
- Obtained the data we needed – most of the time
- Missed the spring ice breakup and floating ice period
- Some problems with instrument data and processing software

PERFORMANCE ISSUES

- Unexpected short battery life
- Bad surface detection in wave crests
- Erroneous ice keel detection at ice block edges
- Wave pressure measurement noise
- Post-processing software problems

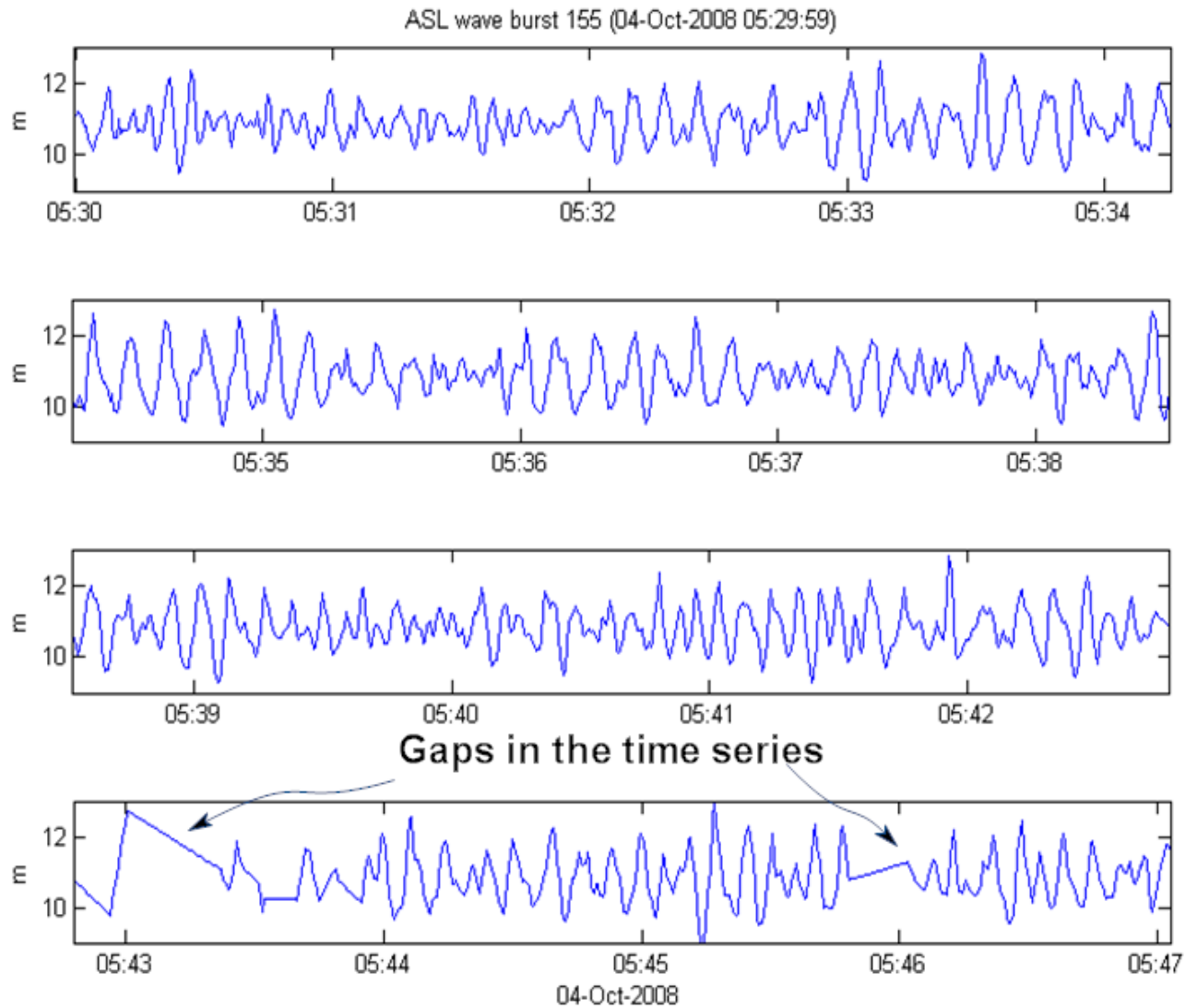
ISSUE: UNEXPECTED SHORT BATTERY LIFE

- Extended battery capacity
 - 4 large Lithium packs
 - Planned for >1-year deployment
 - Achieved < 9 months of reliable operation
 - Recovered somewhat in final summer
 - Cause: excessive internal resistance when partially discharged and cold
 - Nortek re-design to eliminate this problem

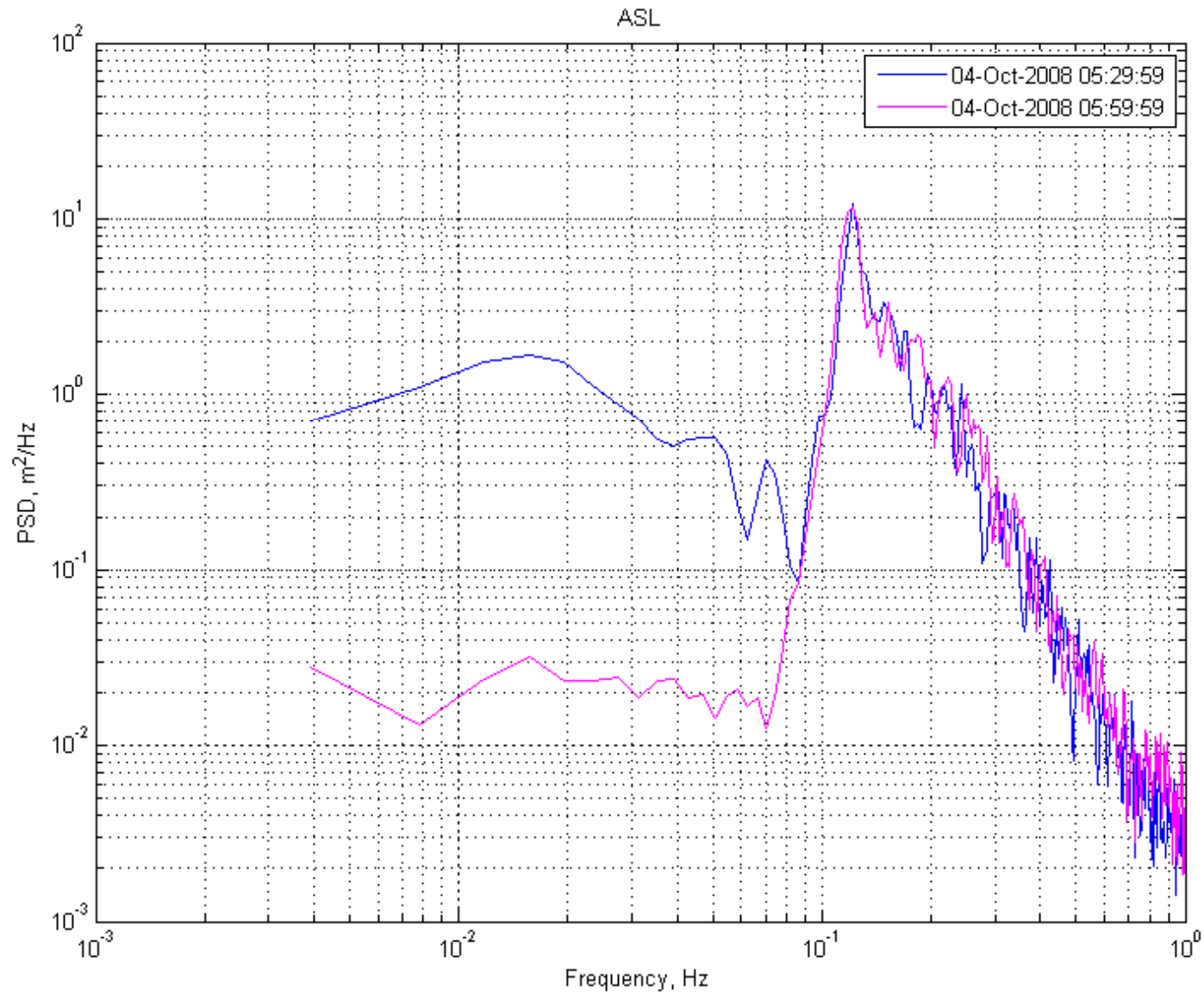
ISSUE: BAD AST SURFACE WAVE DETECTS

- The AST time series contained long gaps
 - Longer than a wave period
 - But the burst is not rejected in post-processing since the total number of bad detects is not above the threshold

BAD AST SURFACE WAVE DETECTS



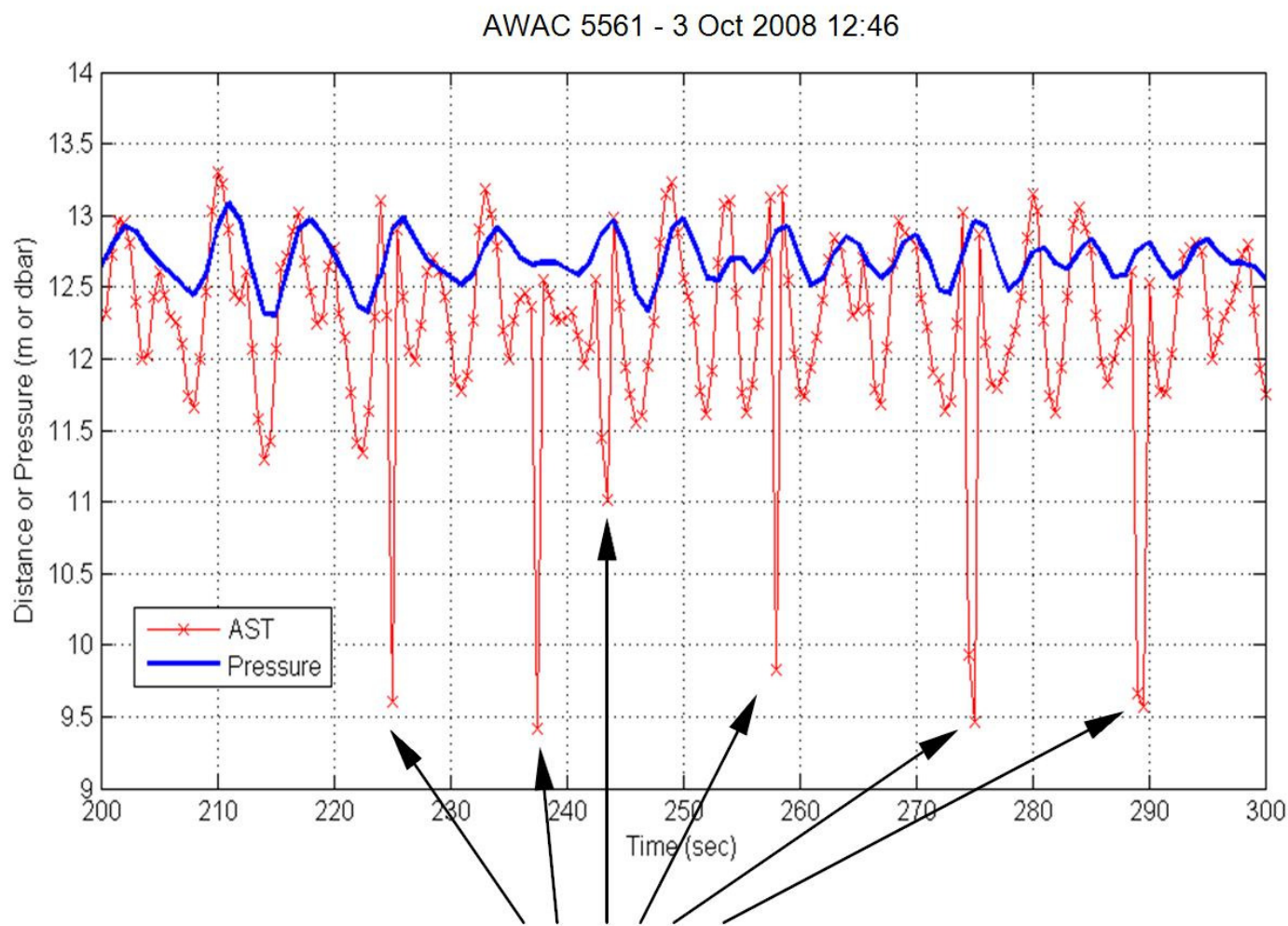
EFFECT OF BAD AST SURFACE WAVE DETECTS



ISSUE: BAD AST SURFACE WAVE DETECTS

- During high wave conditions in shallow water, the AST did not “see” some wave crests
 - Instead it picked some points deeper in the water column, causing down-going spikes in the data
 - Cause was configuration error
 - Range window too small for water depth
 - Range window was restricted to conserve power

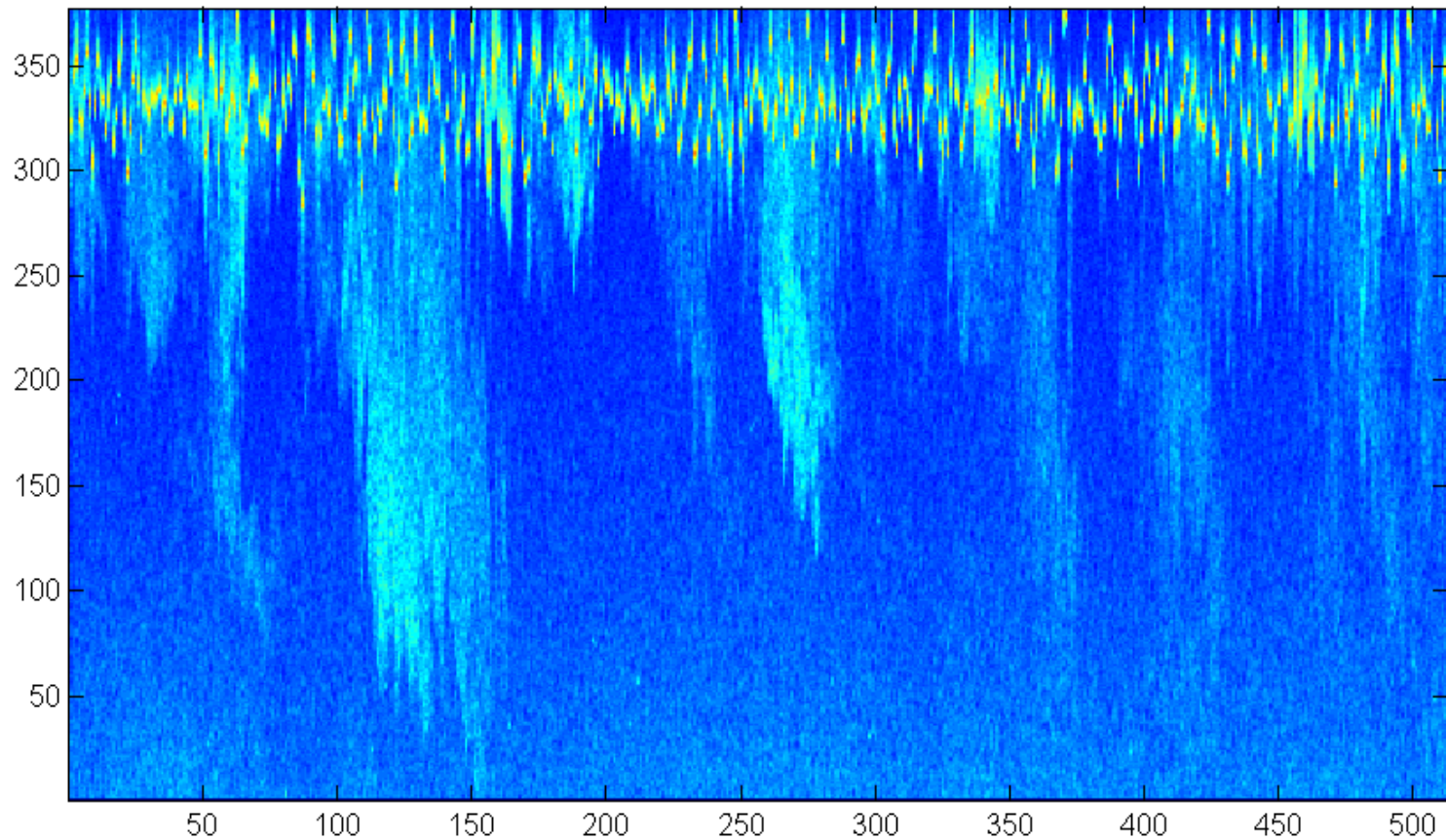
ERRONEOUS AST SURFACE DETECTS



Erroneous AST surface detects
(failure to find true sea surface and substitution of false targets)
due to 5-14mab acoustic range window limitation

ERRONEOUS AST SURFACE DETECTS

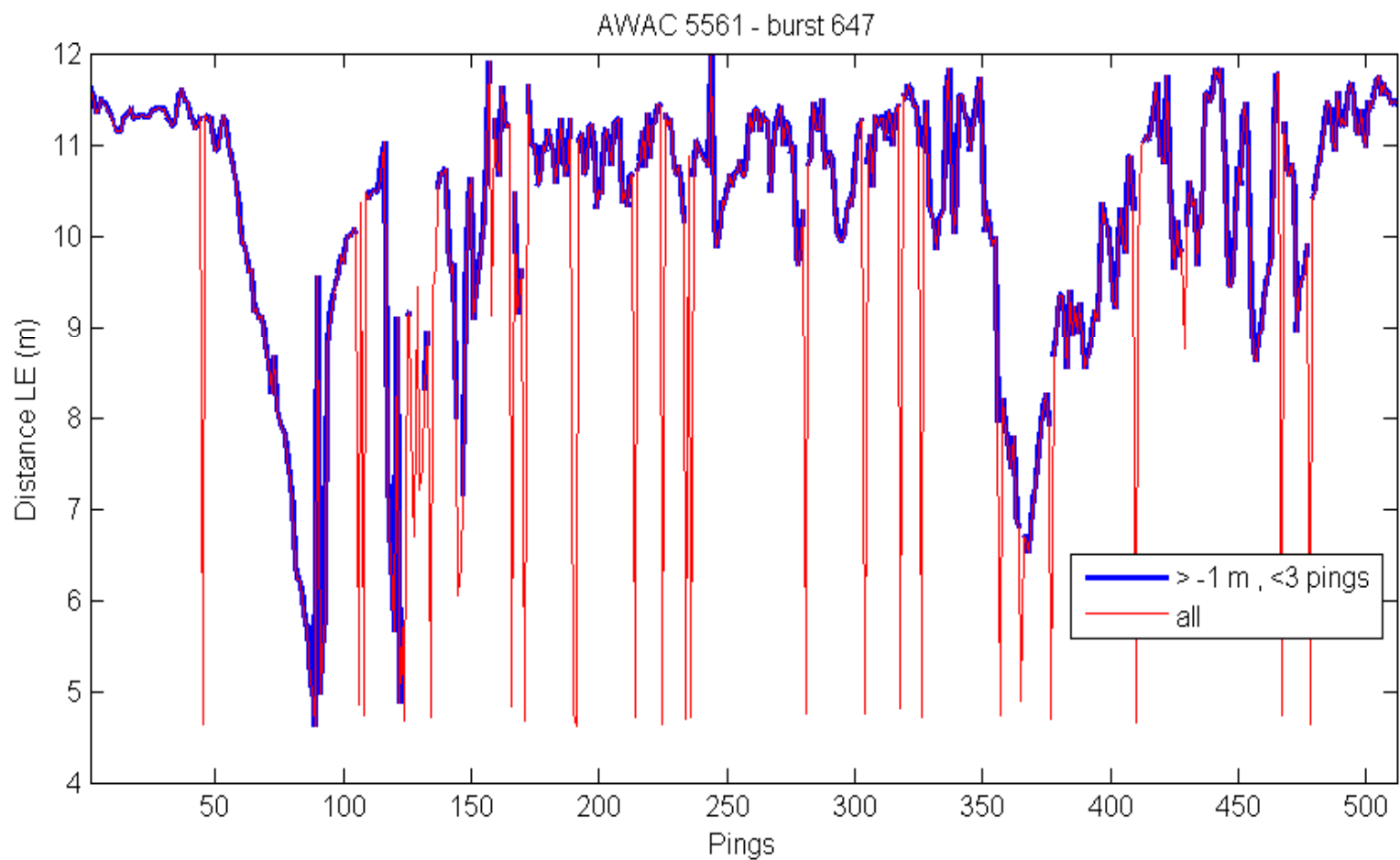
AWAC 5561 - 3 Oct - 12:31



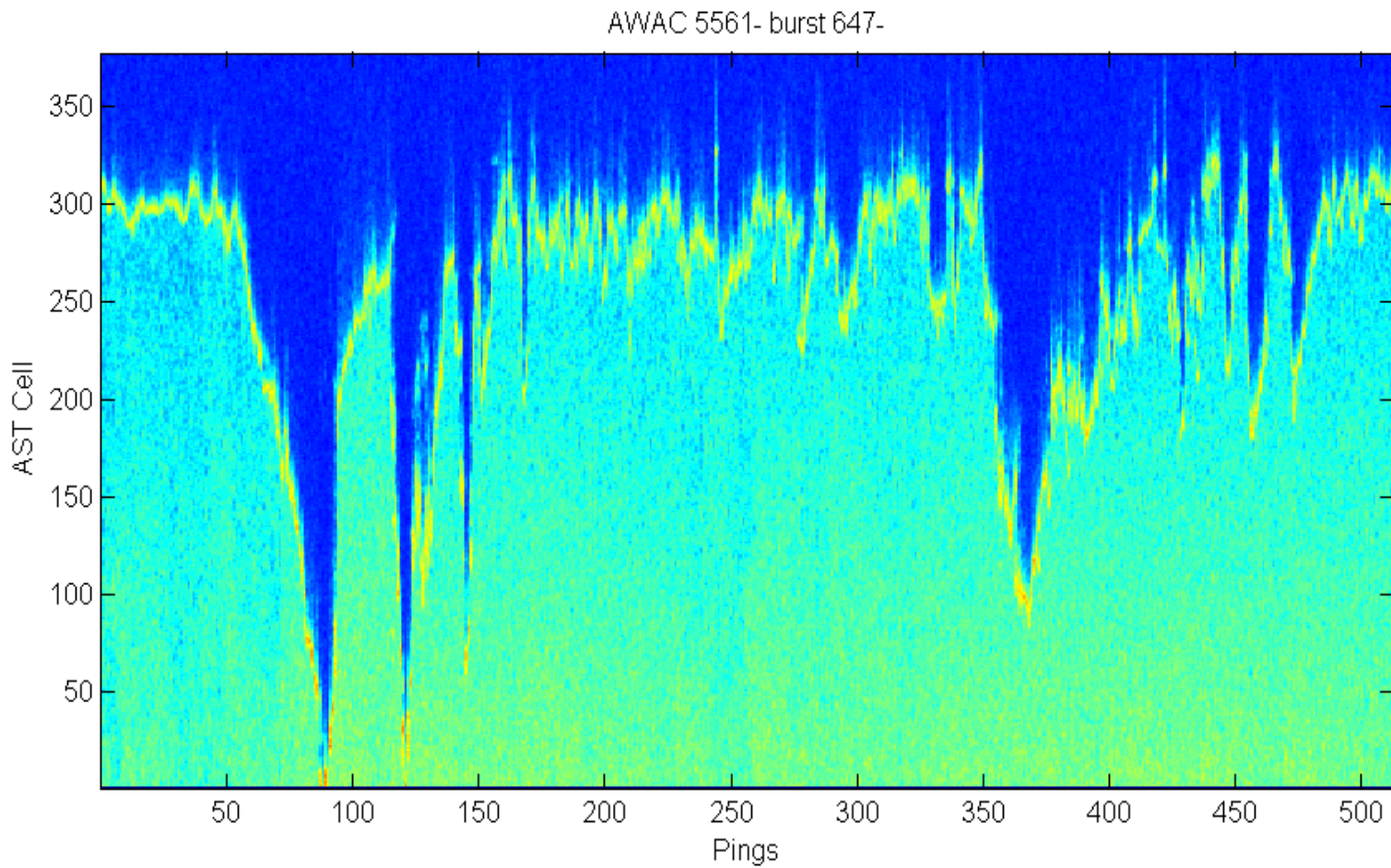
ISSUE: BAD AST ICE KEEL DETECTS

- During passage of ice block edges, the AST failed to detect the bottom of the ice
 - Instead it picked a point at the beginning of the range window, causing down-going spikes in the data
 - Bad points could be edited out in post-processing

ERRONEOUS AST ICE KEEL DETECTS



ERRONEOUS AST ICE KEEL DETECTS



ISSUE:

POST-PROCESSING SOFTWARE FOR WAVE SPECTRA FROM PRESSURE

- Software switches automatically and unexpectedly from AST to pressure if AST data quality is too low
- Software selects noise cutoff frequency for depth-corrected spectra
- H_s (total variance) is very sensitive to cutoff frequency
 - Significant overestimation of H_s when using pressure with original Nortek software
 - Causes jumps in H_s when switching from AST to pressure
 - Due to noisy pressure data

ISSUE: POST-PROCESSING SOFTWARE FOR ICE KEEL DEPTH

- QuickWave (Ice) Ver. 2.07 Beta 7
 - Decodes and processes raw binary wave and diagnostic data
 - Applies leading-edge detection method to estimate ice keel range (depth)
- Did not reject spikes in the ice keel depth
- Required manual editing of data points

RECOMMENDATIONS

- Enable current profile ensembles during wave/diagnostic bursts
 - Gaps in current profile time series make analysis difficult
- Provide ice keel velocity tracking (inverted bottom tracking)
 - Would permit direct measurement of ice movement and ice block size
- Improve AST error detection in firmware
 - Tracking and rate-of-change criteria
 - Spike detection and elimination
- Improve pressure sensor noise figure
 - Less sensitivity to spectral cutoff
 - Improved accuracy of Hs etc.

RECOMMENDATIONS

- Improve post-processing software
 - Better gap rejection in wave bursts
 - Better spike elimination in wave and ice processing
 - Active (burst by burst) cutoff frequency determination for pressure spectra
- Provide multi-phase sampling capability
 - Normal wave & current sampling when no ice is present
 - Intensive wave & ice thickness when floating ice is present
 - Reduced ice thickness sampling and no wave sampling when solid ice is present
 - Would greatly reduce power and data storage requirements
 - Would permit more and longer current ensembles