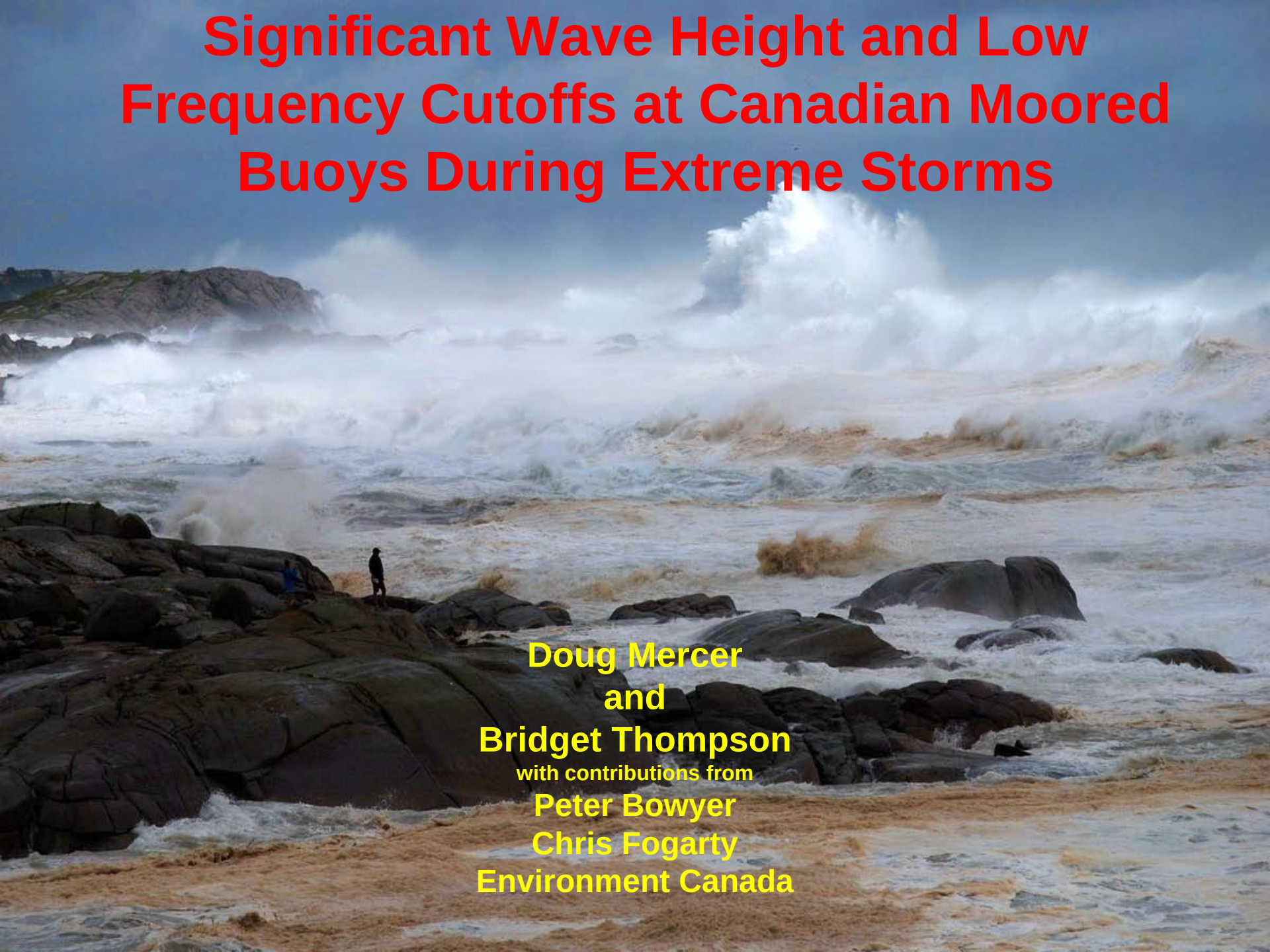
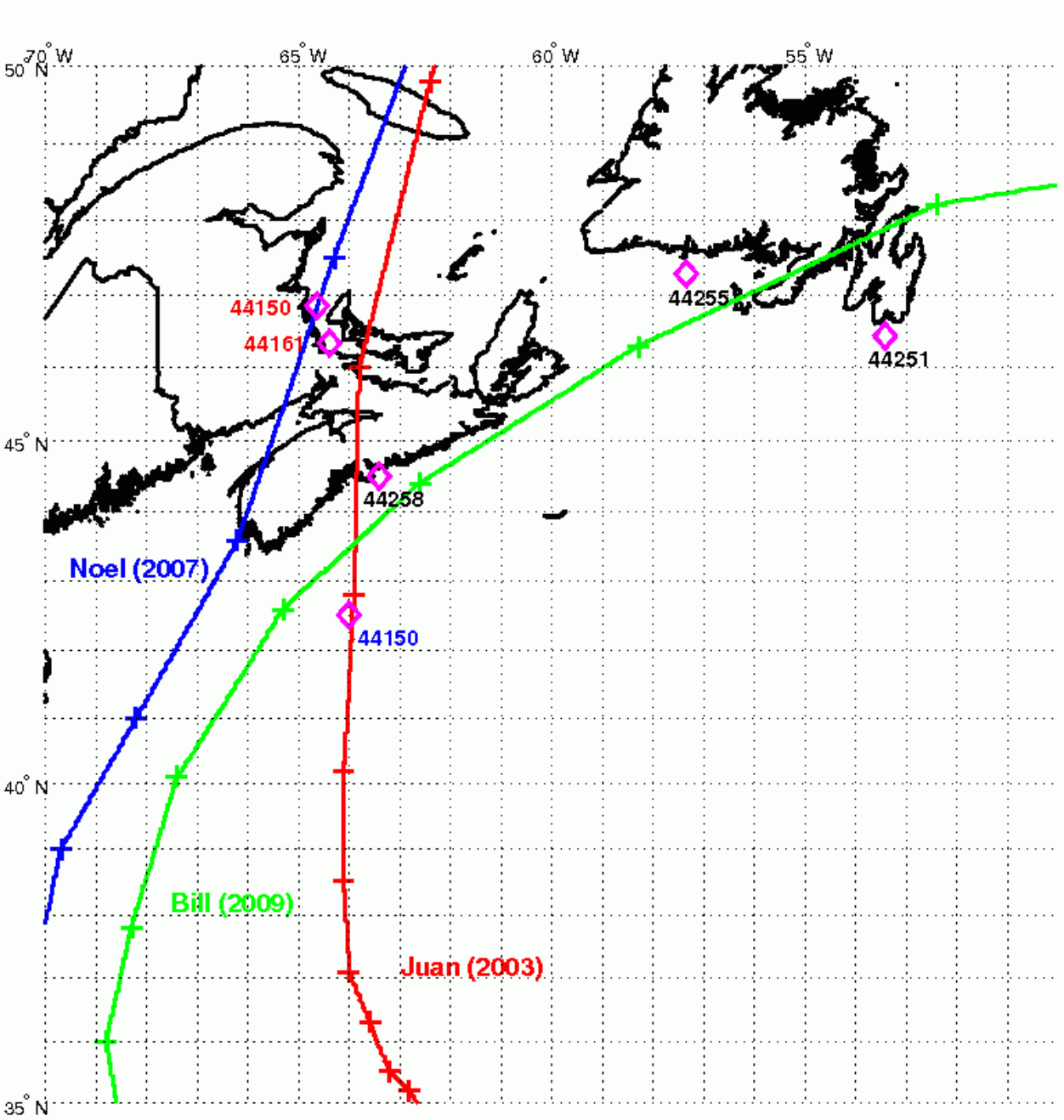
Significant Wave Height and Low Frequency Cutoffs at Canadian Moored Buoys During Extreme Storms



Doug Mercer
and
Bridget Thompson
with contributions from
Peter Bowyer
Chris Fogarty
Environment Canada

Outline

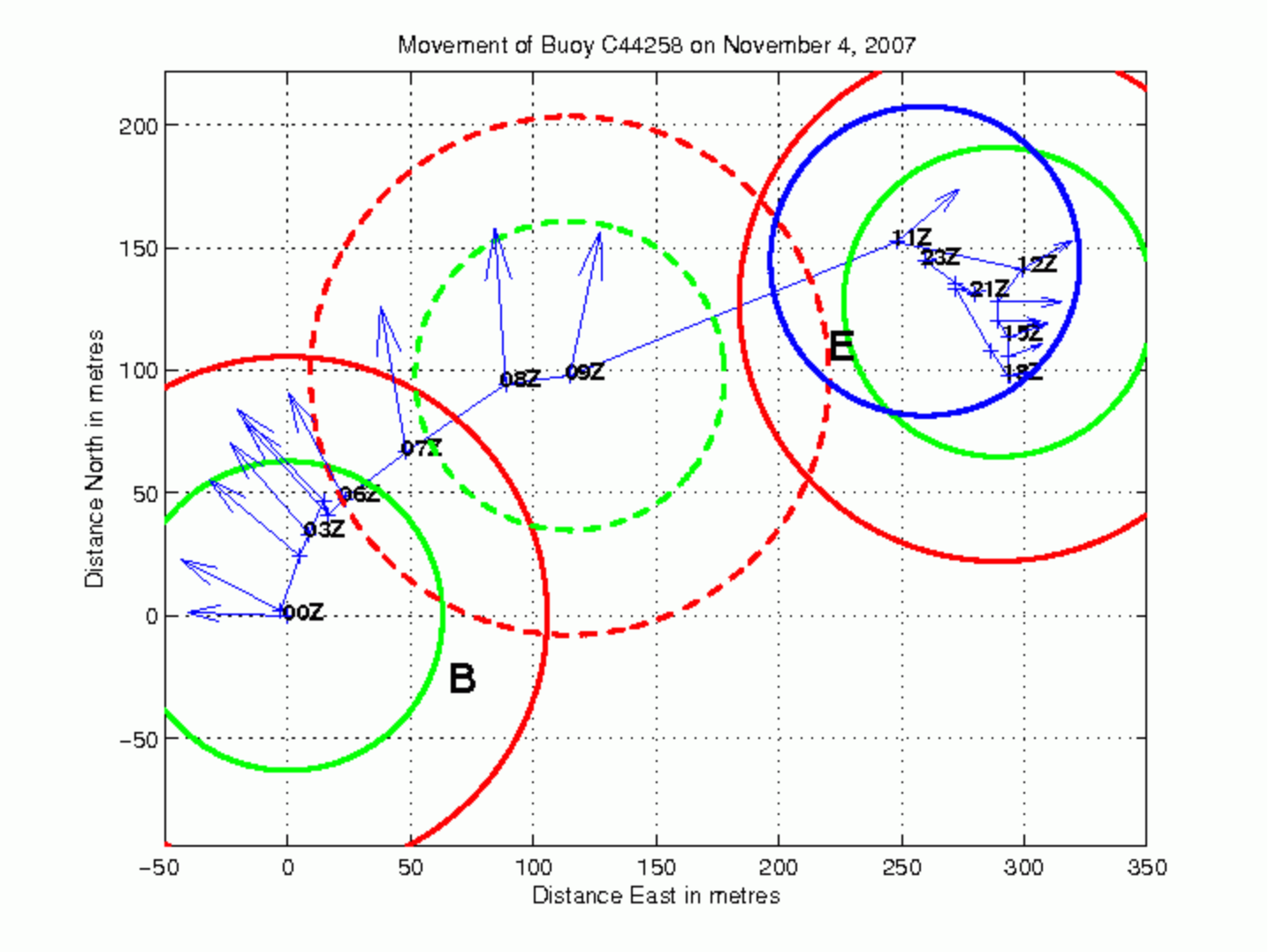
- Background
  - Focus on buoy C44258
  - Focus on effects of
    - Juan (2003): Marginal Cat 2
    - Noel (2007): Post-tropical storm with very large fetch
    - Bill (2009): Cat 1
- Effects of
  - Movement of the Buoy
    - Peak Wave Height
    - Contamination of SWH?
  - Low Frequency Cutoff (LFC)
    - Juan (2003) versus Noel (2007) versus Bill (2009)
  - Other effects
- Lessons Learned


70° W
65° W
60° W
55° W
50° N
45° N
40° N
35° N
44150
44161
44255
44251
44258
Noel (2007)
44150
Bill (2009)
Juan (2003)

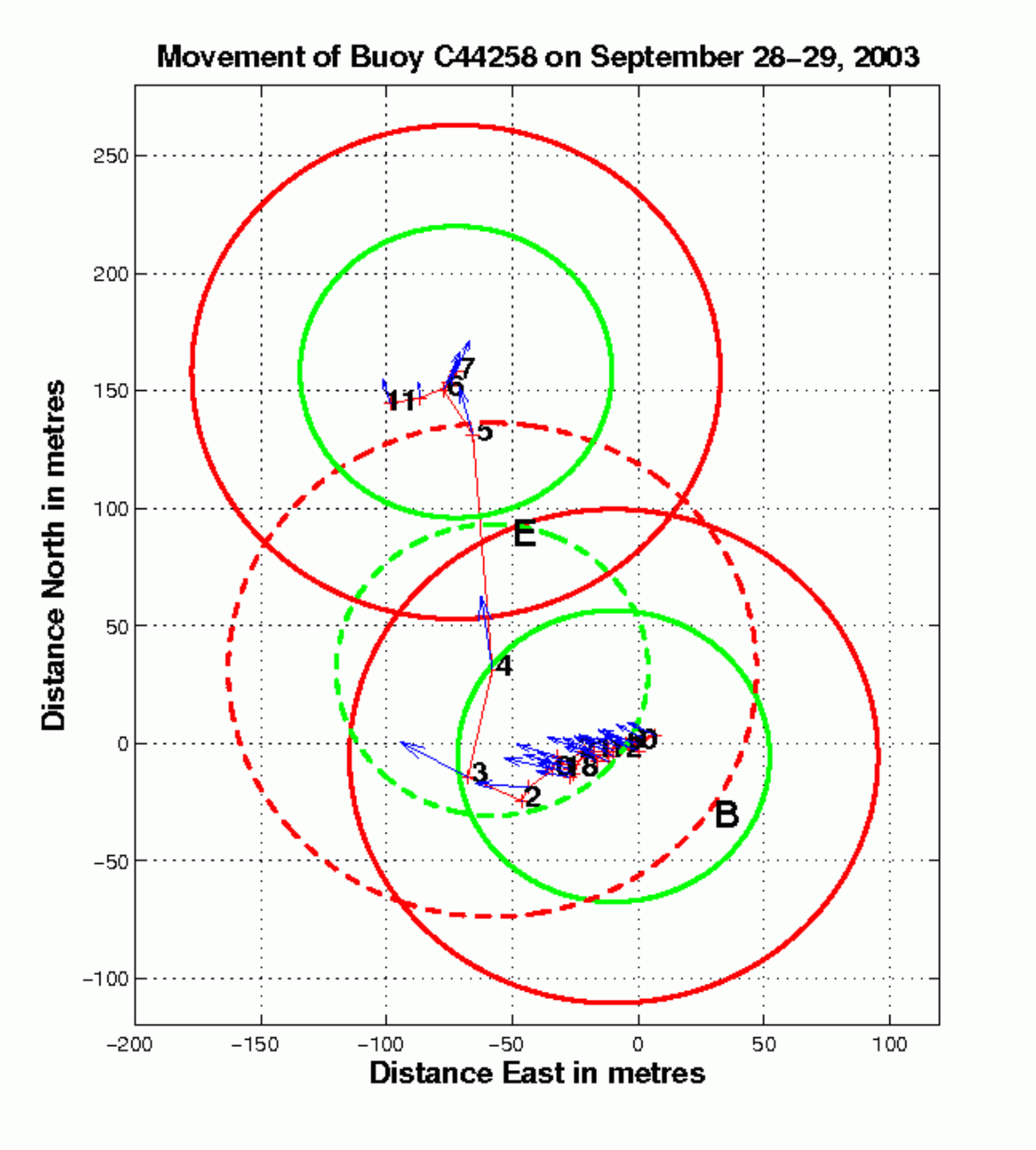
Effect 1: Buoy Movement

- Buoy 44258
- 3 m Discus in 2007 (Noel) to now
  - 58 m depth
  - 120 metre reverse catenary mooring
  - Buoy 1360 kg (3000 lb) with net buoyancy of 8000 lb
  - 8000 lb anchor mooring
  - On-board GPS
- 6 m Nomad in 2003 (Juan)
  - 5200 kg (11440 lb)
  - 120 metre reverse catenary mooring
  - On-board GPS

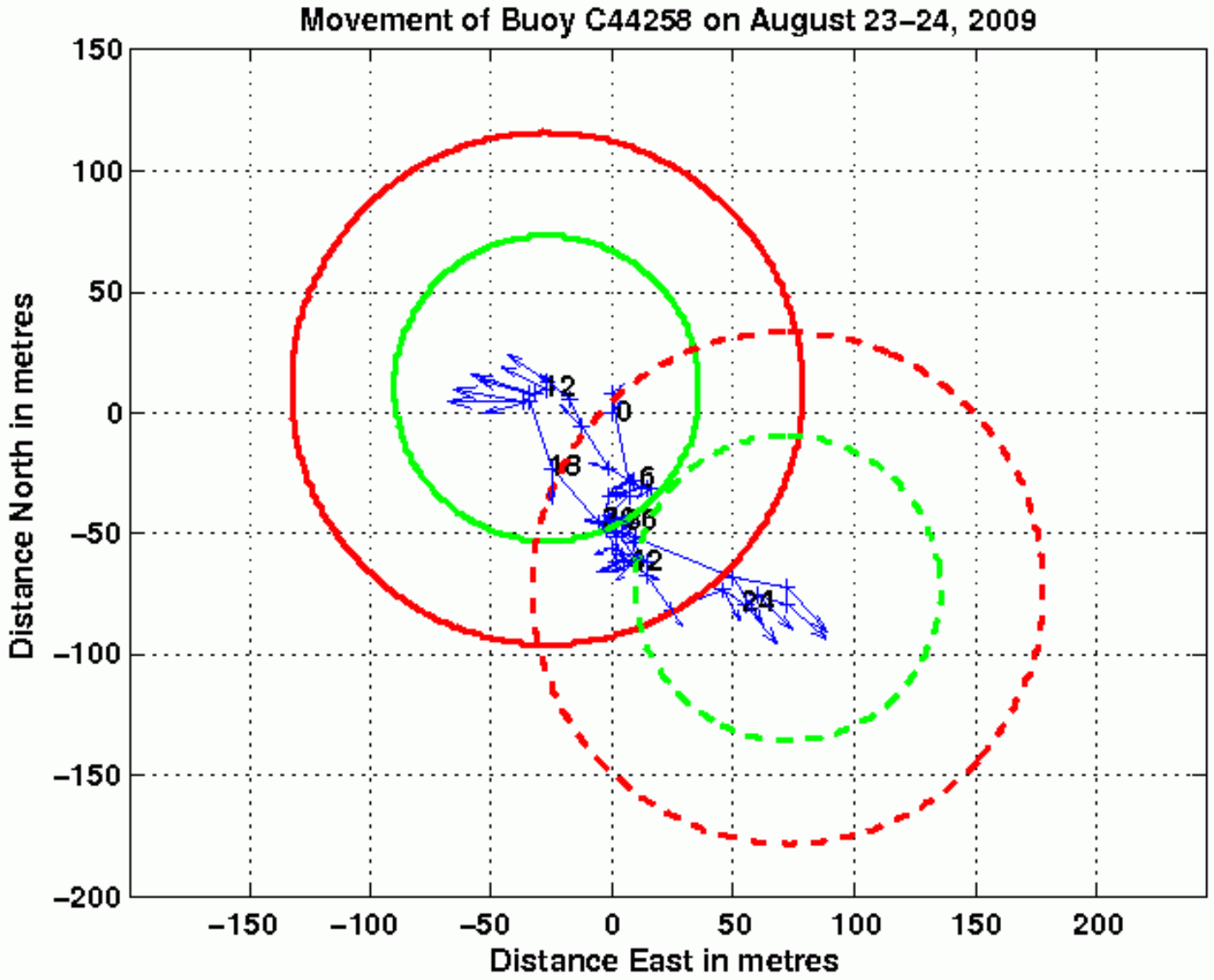
Buoy 44258 Movement due to Noel



Buoy 44258 Motion due to Juan



Buoy 44258 Movement due to Bill



Main Points

- Buoy dragged for Juan and Noel, maybe not for Bill.
- Significant Wave Height (SWH) was suspect during dragging phase.
- Peak wave height extremely suspect during dragging phase (algorithm perfectly designed to catch jerky movement due to the mooring). Plus the acceleration is capped at +/- 15 m.
- Movement was probably mainly due to “peak” waves.

Main Points continued

- Very Important:
  - While we don't know the SWH and peak wave height, we do know they were enough to move the buoy up to hundreds of metres.
  - Checking GPS may be a good idea for extreme events for shallow water buoys.

Effect 2: Low Frequency Cutoff

- **Environment Canada shallow water ODAS buoys have a short wave cutoff for wave spectra**
- Depends on water depth
  - Atlantic
    - B44258 (58 m depth) nothing longer than 15 s band until this fall where it was increased to 32 s
    - B44251 (71 m depth) nothing longer than 17.1 s band
    - All other operational EC buoys in Atlantic waters have 25 s or greater
  - Pacific
    - B46206 (72 m and 18 s)
    - B46183 (65 m and 15 s).
    - All others are 25 s or greater, or are in sheltered waters.

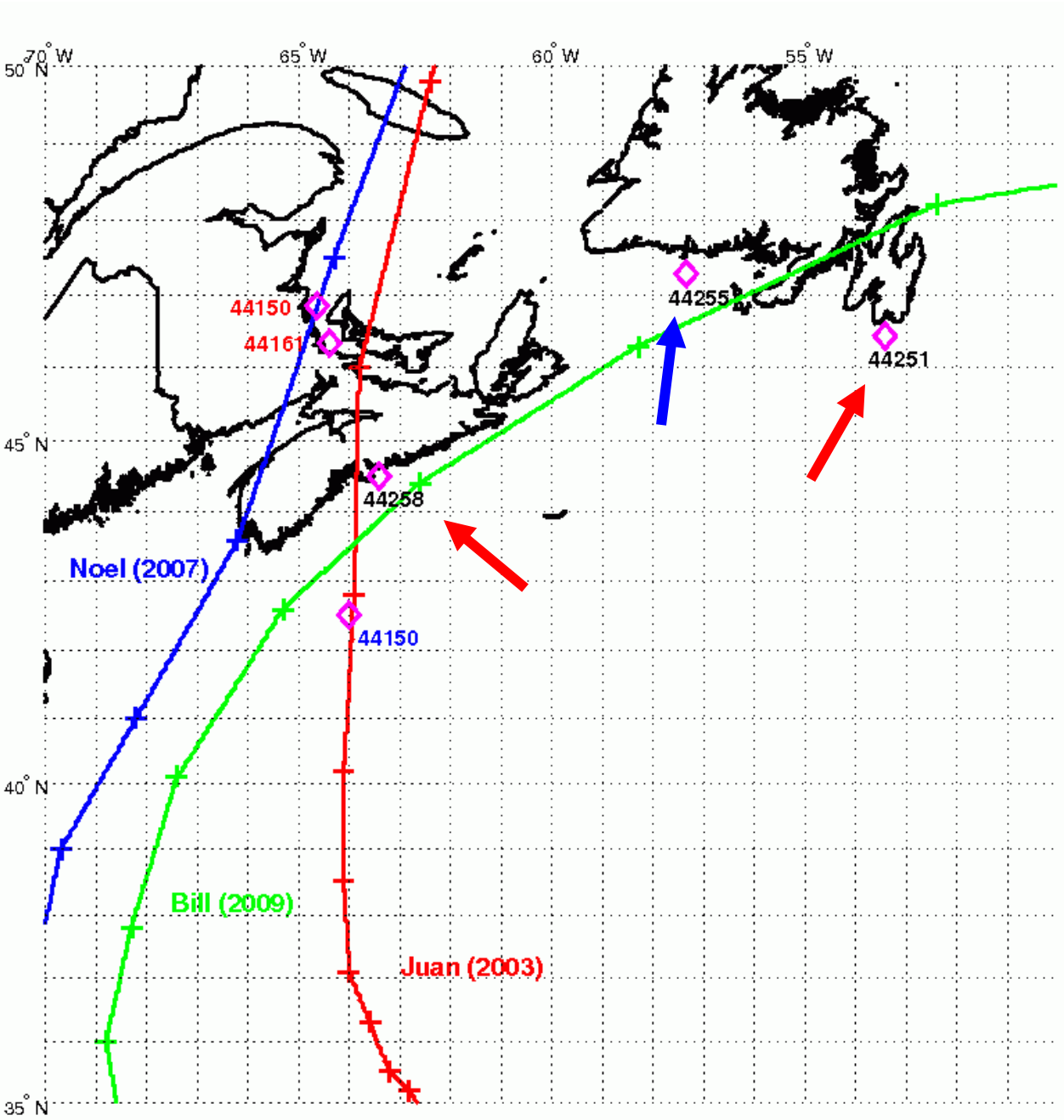
- American Buoys keep all periods up to 30 s regardless of water depth
- Why do they (we) do it?
  - "Contamination of wave estimate from low frequency energy due to mooring-buoy interactions and other effects"
  - Probably valid for restricted waters
- Why is it important?

  -for buoys in shallow water but exposed to open oceans, especially for

  -intense midlatitude storms,

  -Tropical Cyclones and ET transitions

  -long period swell


70° W
65° W
60° W
55° W
50° N
45° N
40° N
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44150
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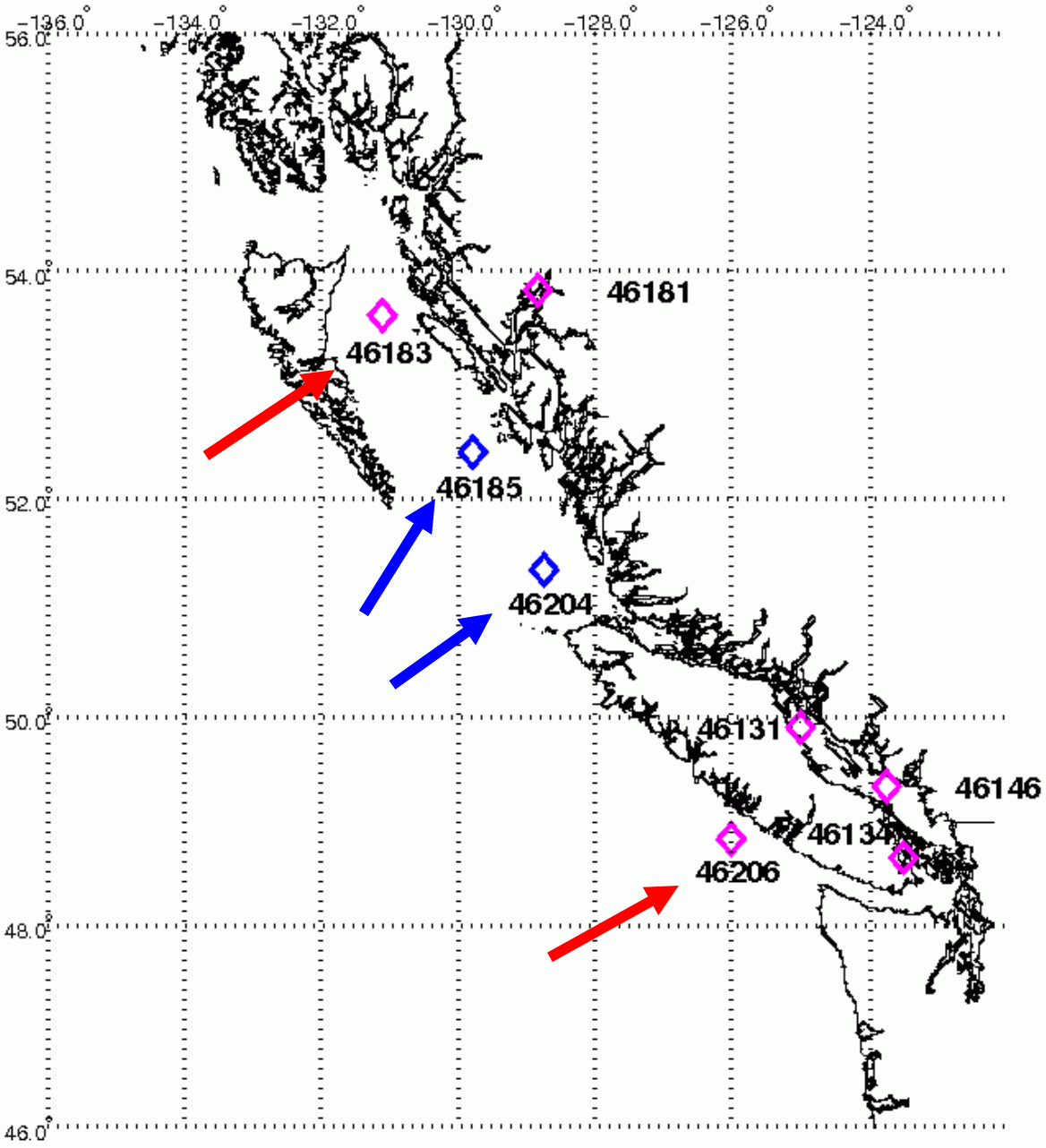
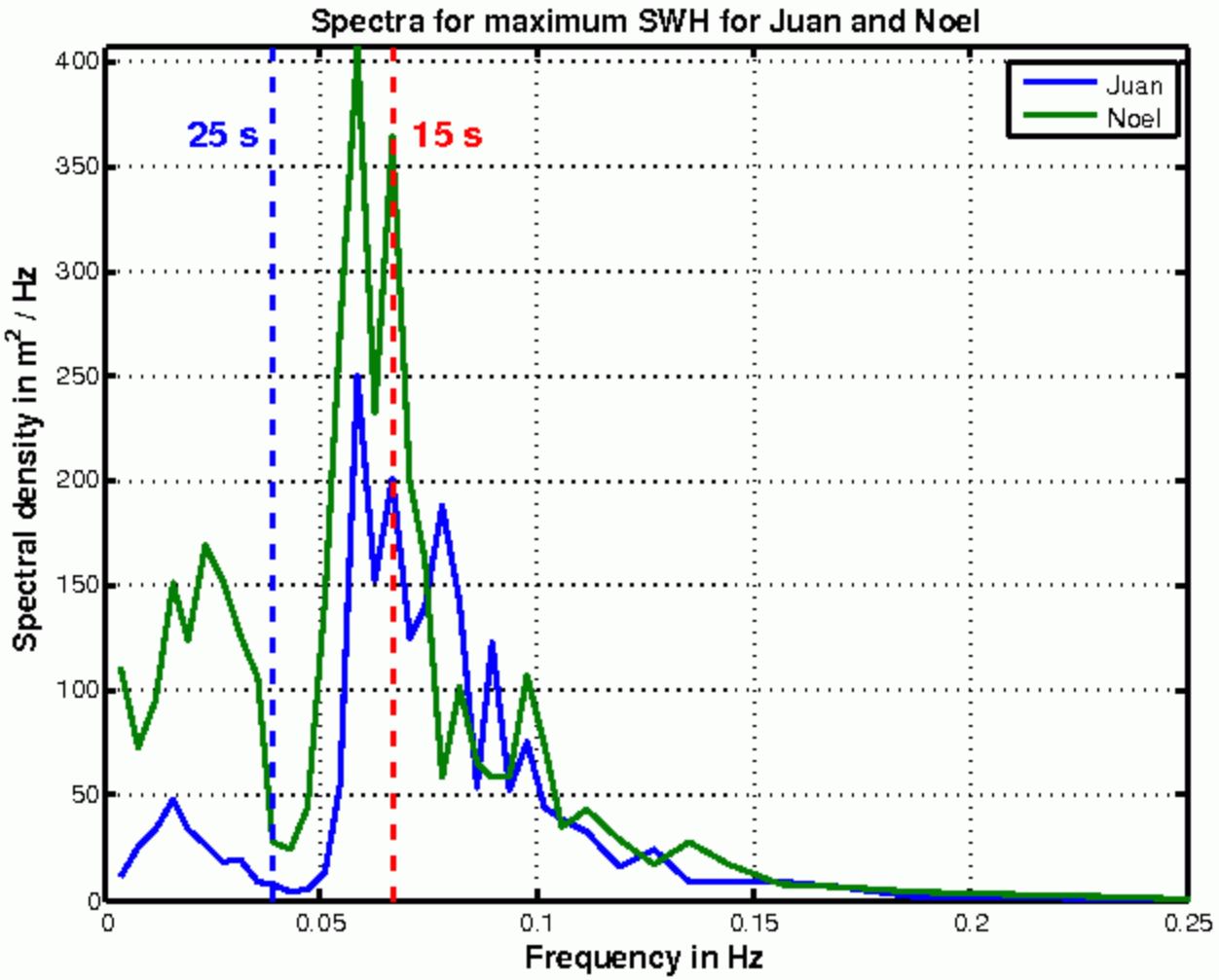
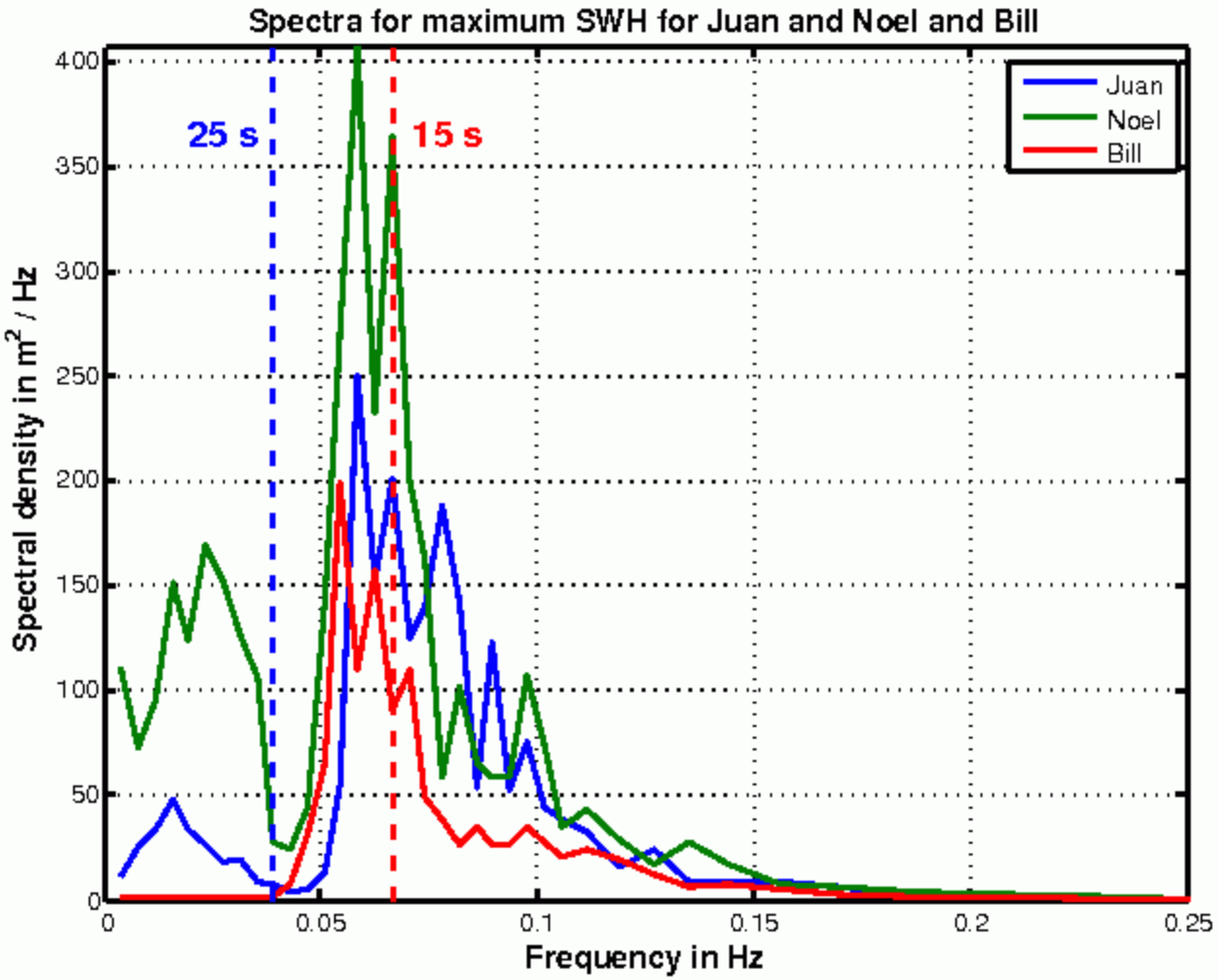
Noel (2007)
Bill (2009)
Juan (2003)

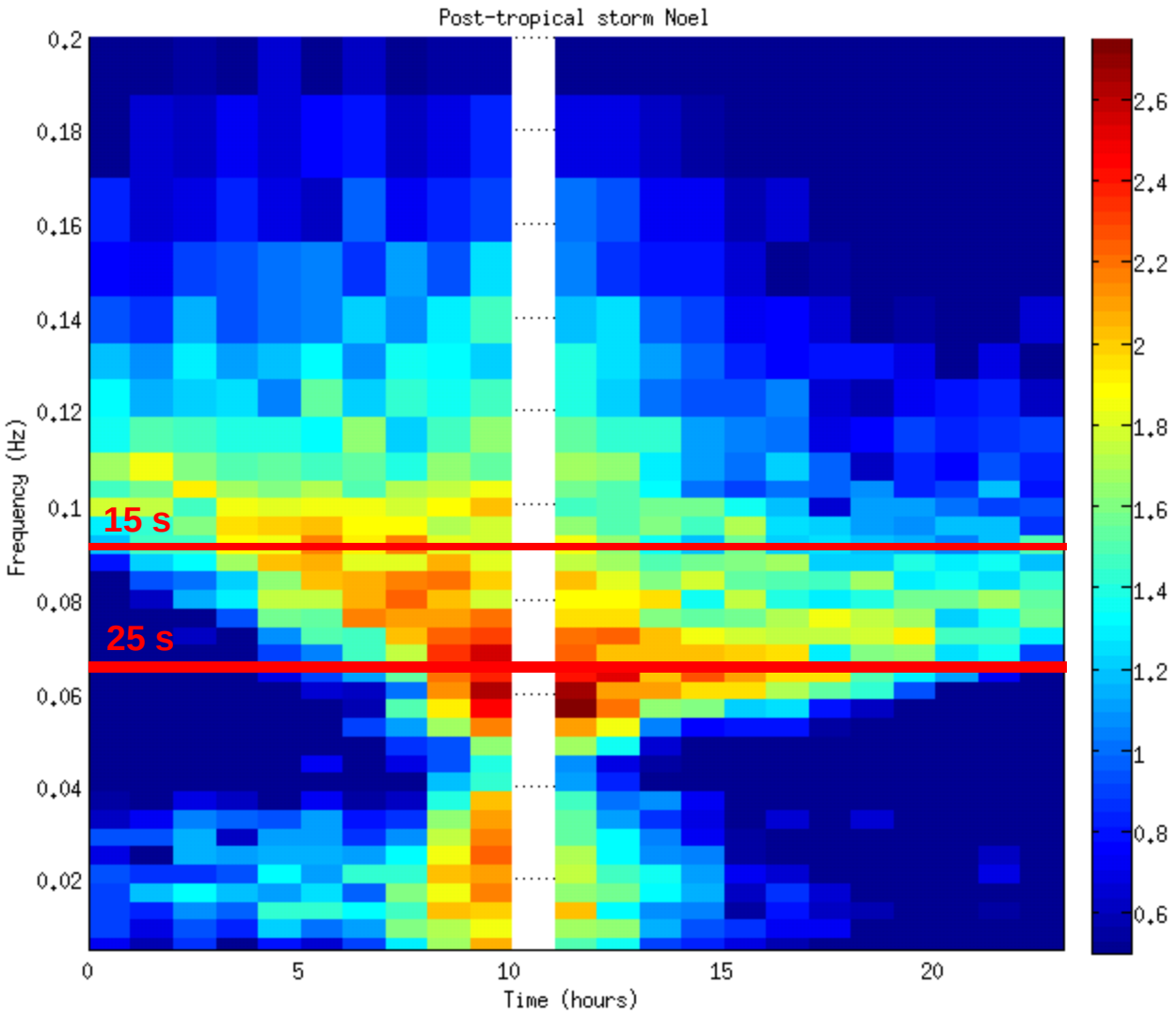

-136.0°
-134.0°
-132.0°
-130.0°
-128.0°
-126.0°
-124.0°
56.0°
54.0°
52.0°
50.0°
48.0°
46.0°
46181
46183
46185
46204
46131
46146
46134
46206

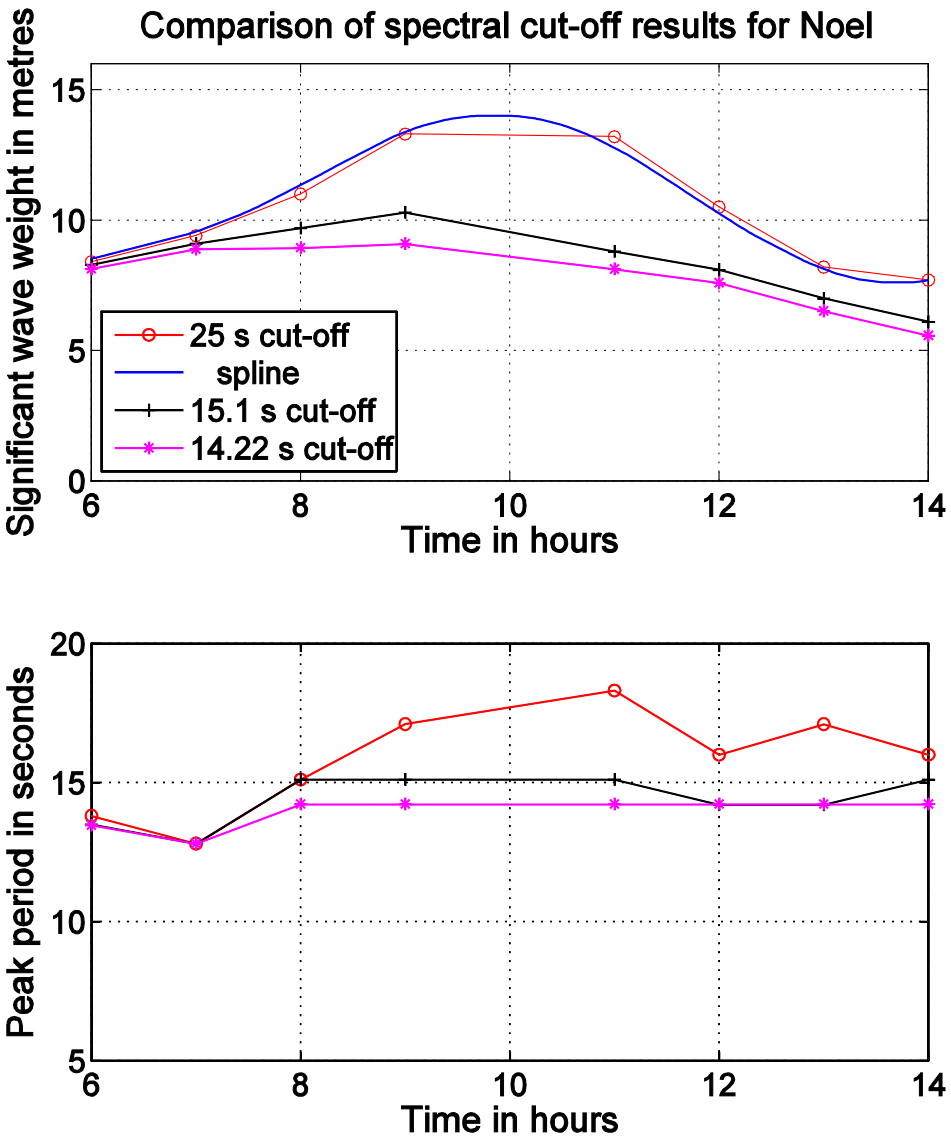
Effect of LFC



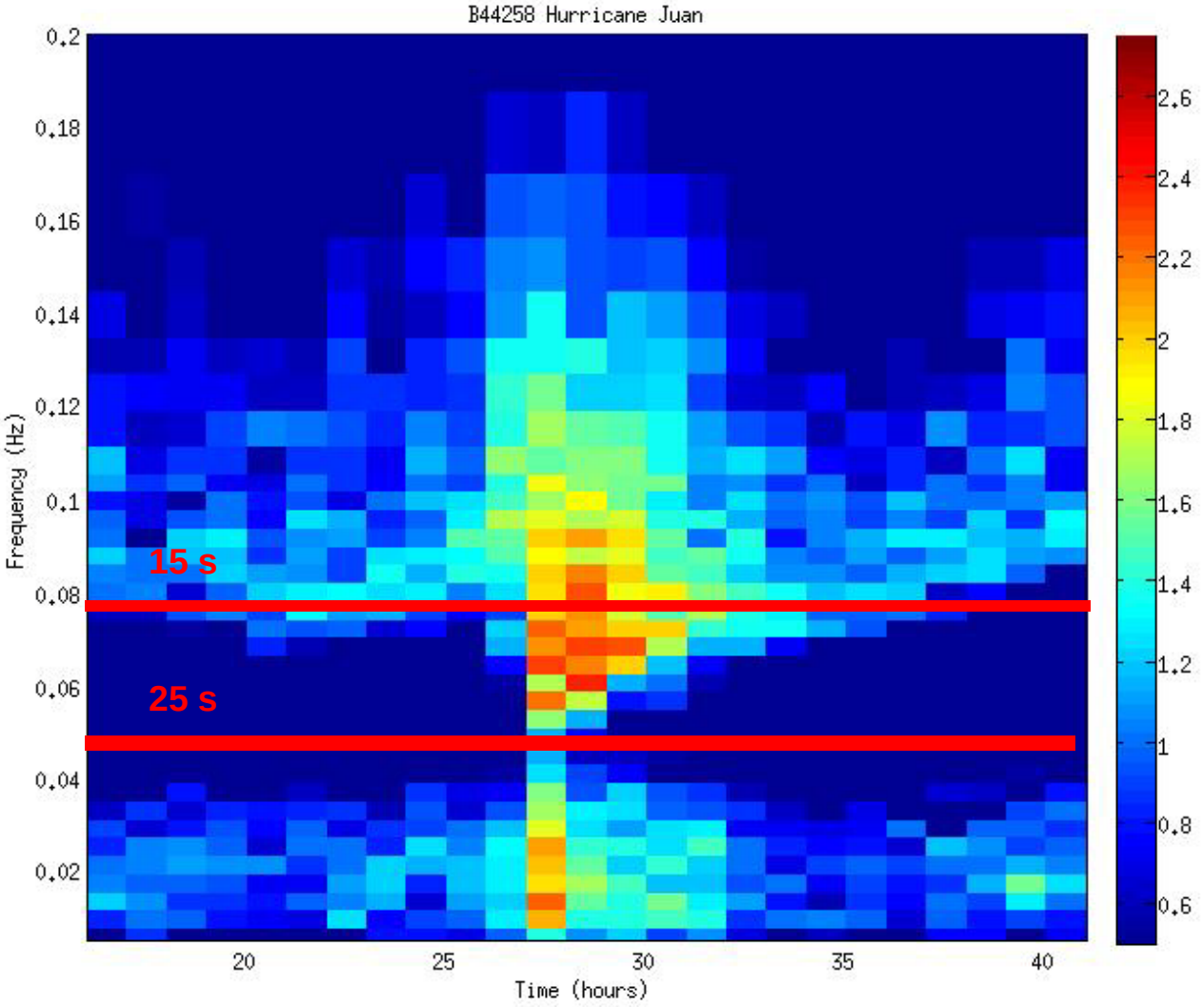

Spectra for maximum SWH for Juan and Noel and Bill
25 s
15 s
Juan
Noel
Bill
Spectral density in m² / Hz
Frequency in Hz
0
50
100
150
200
250
300
350
400
0
0.05
0.1
0.15
0.2
0.25

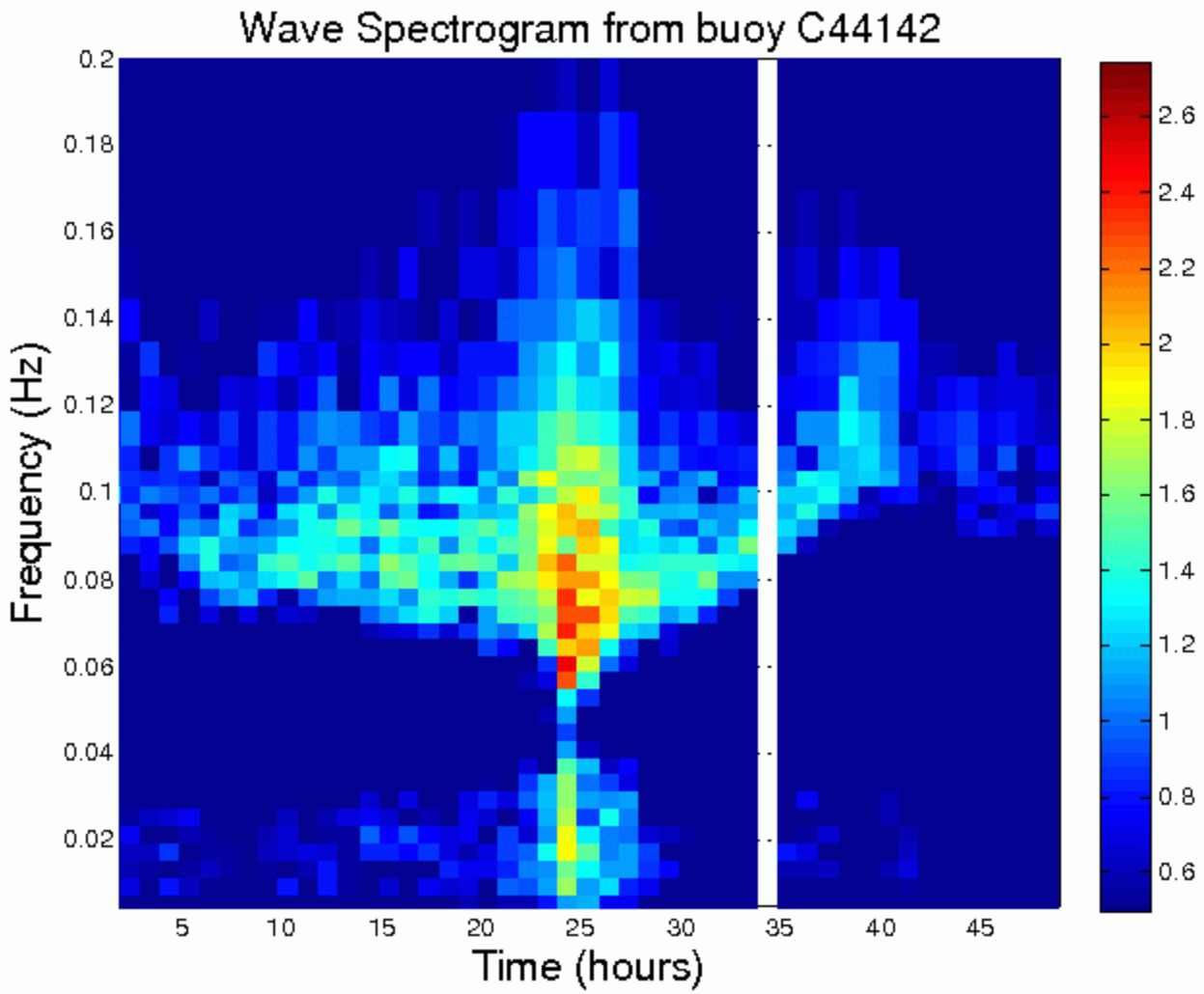
Noel (2007)

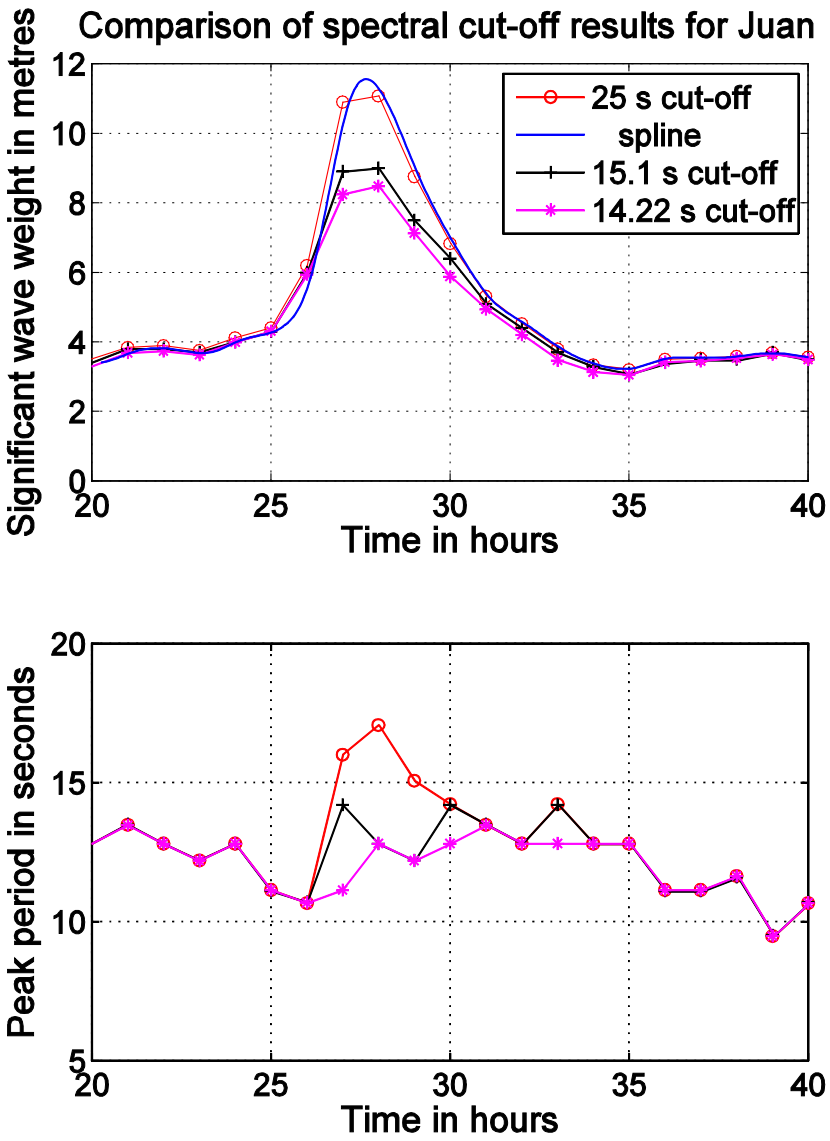

Post-tropical storm Noel
Frequency (Hz)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
15 s
25 s
0
5
10
15
20
Time (hours)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6


Comparison of spectral cut-off results for Noel
Significant wave weight in metres
Time in hours
25 s cut-off
spline
15.1 s cut-off
14.22 s cut-off
Peak period in seconds
Time in hours

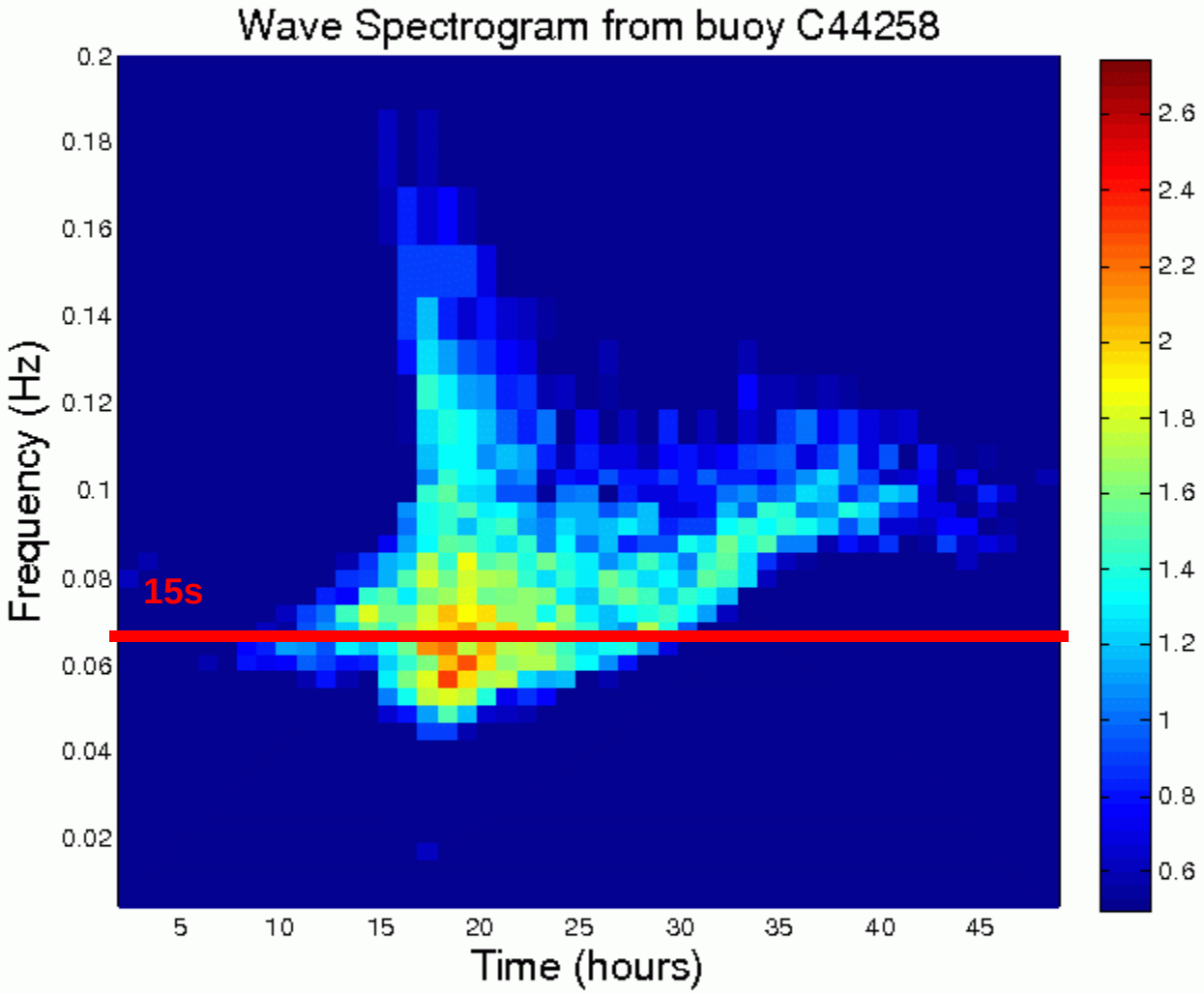
Juan (2003) B44258



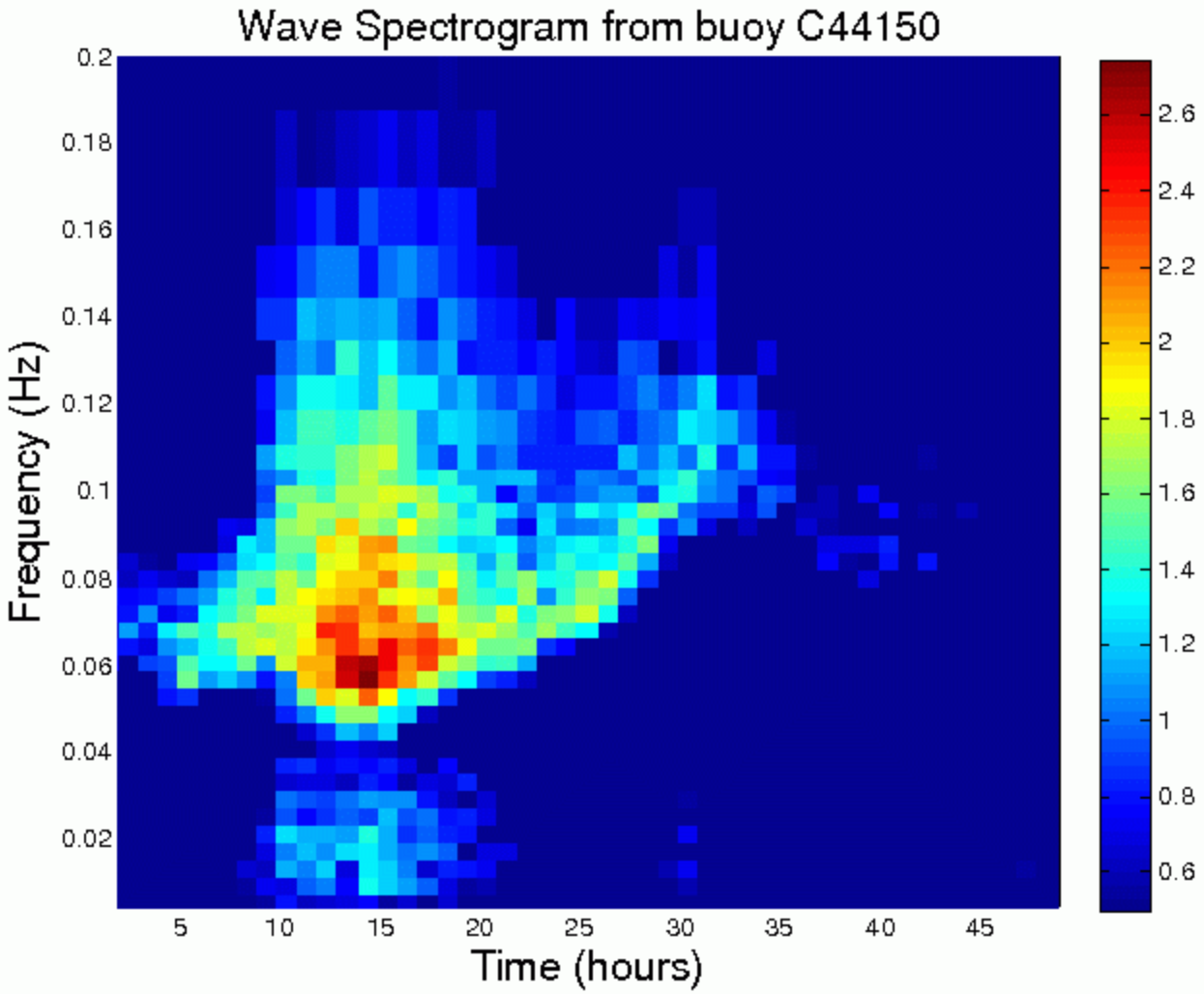

Wave Spectrogram from buoy C44142
Frequency (Hz)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
5
10
15
20
25
30
35
40
45
Time (hours)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6


Comparison of spectral cut-off results for Juan
Significant wave weight in metres
Time in hours
25 s cut-off
spline
15.1 s cut-off
14.22 s cut-off
Peak period in seconds
Time in hours

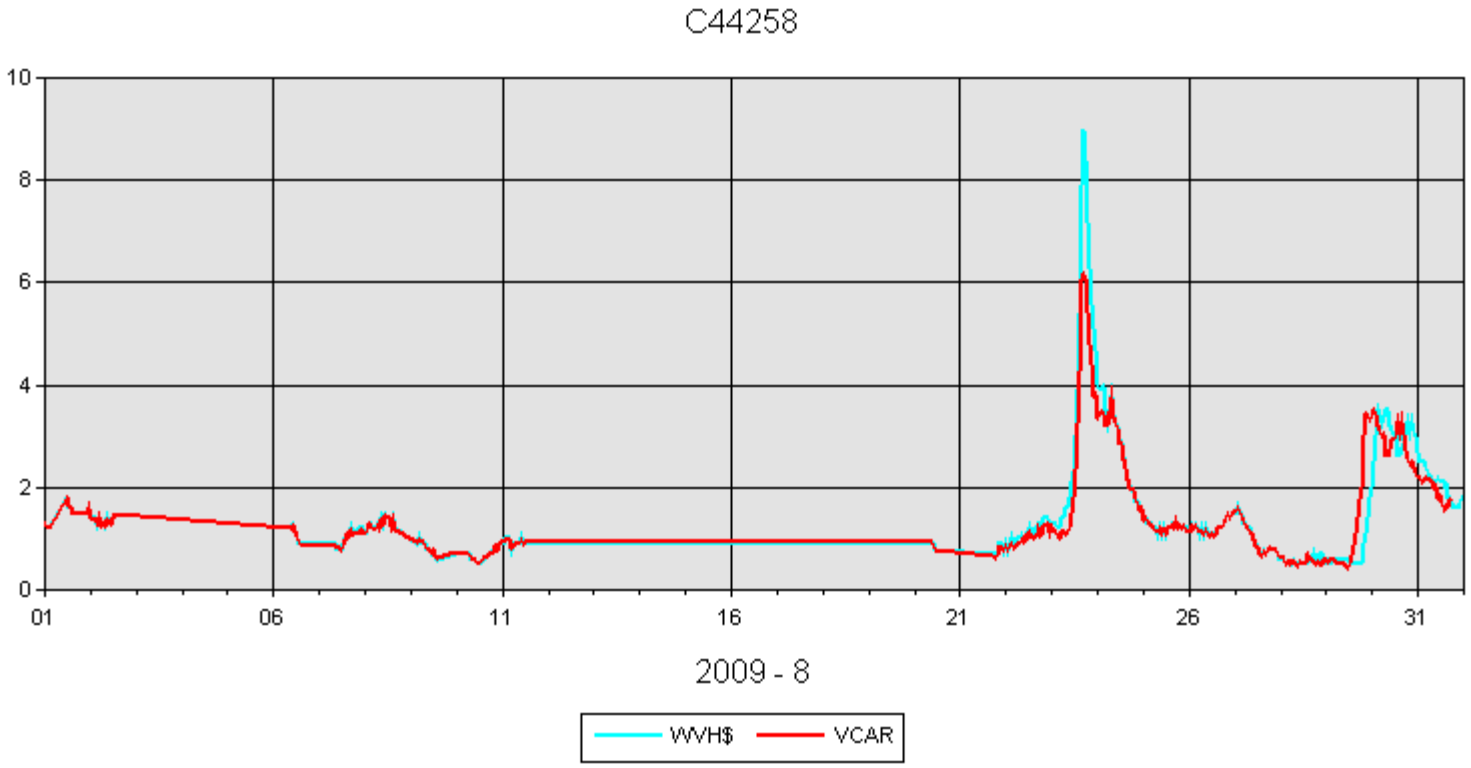
Hurricane Bill (2009)



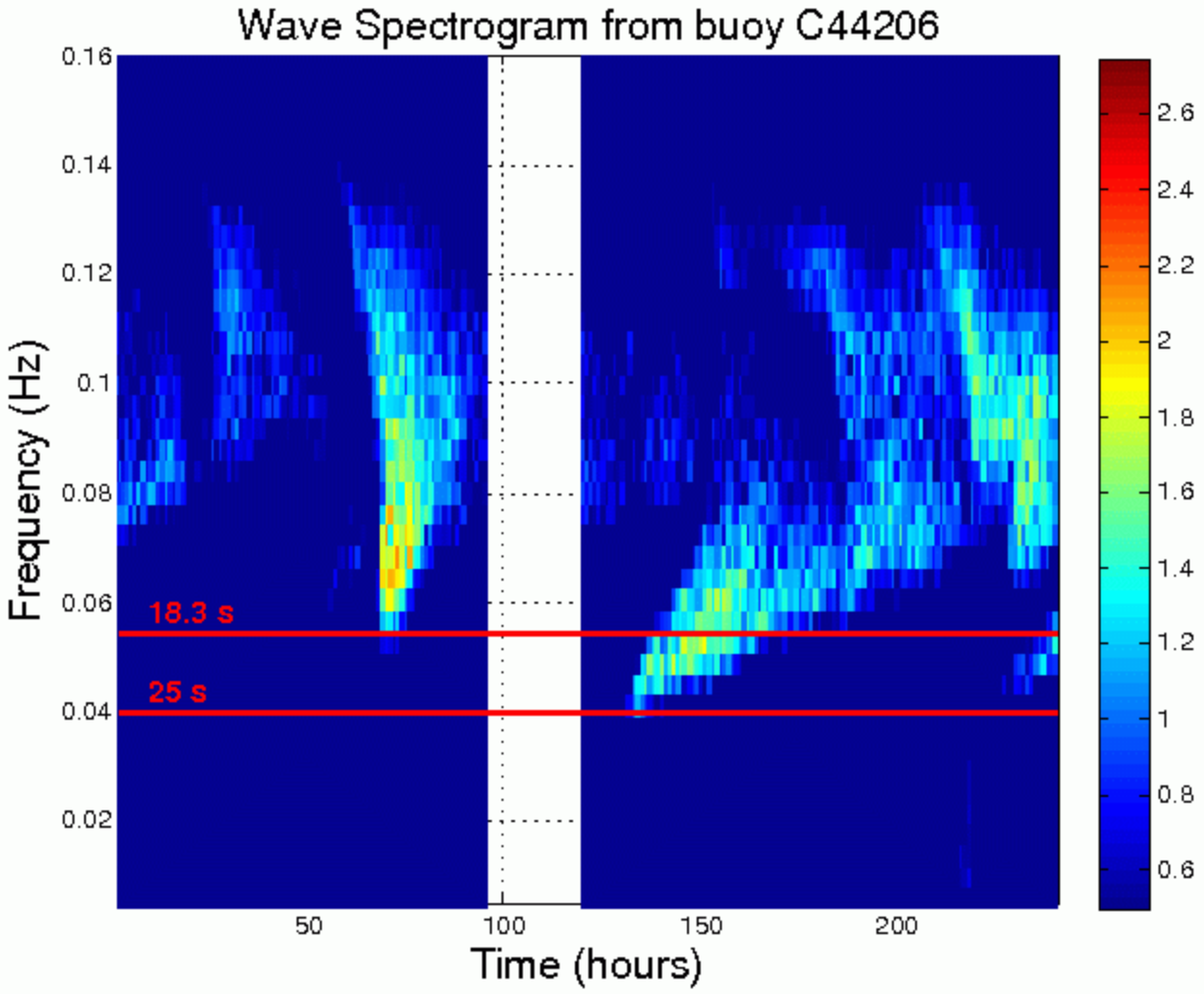
Hurricane Bill (2009)



ISDM (red) versus Buoy Processor (blue) SWH for Hurricane Bill



Long period swell (Pacific)



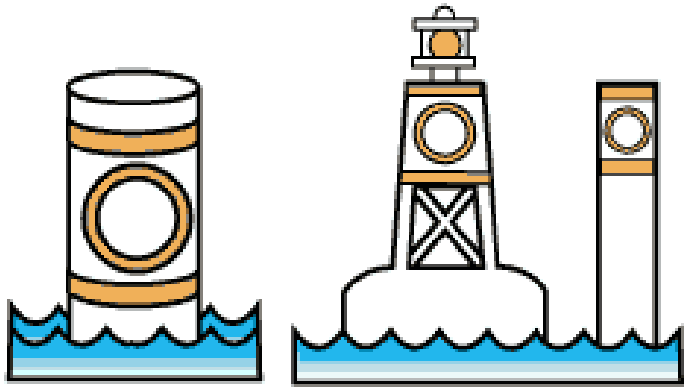
Main Points

- For shallow water buoys exposed to significant oceanic wave energy, LFC should be moved to 25+ s, and for these cases a cut-off at 32 s had minimal contamination from low frequency energy (< 0.5 m for Noel)
- Energy in the low frequency band below 25-30 s periods could indicate buoy-mooring interactions
- In some cases low frequency energy might contaminate SWH calculation

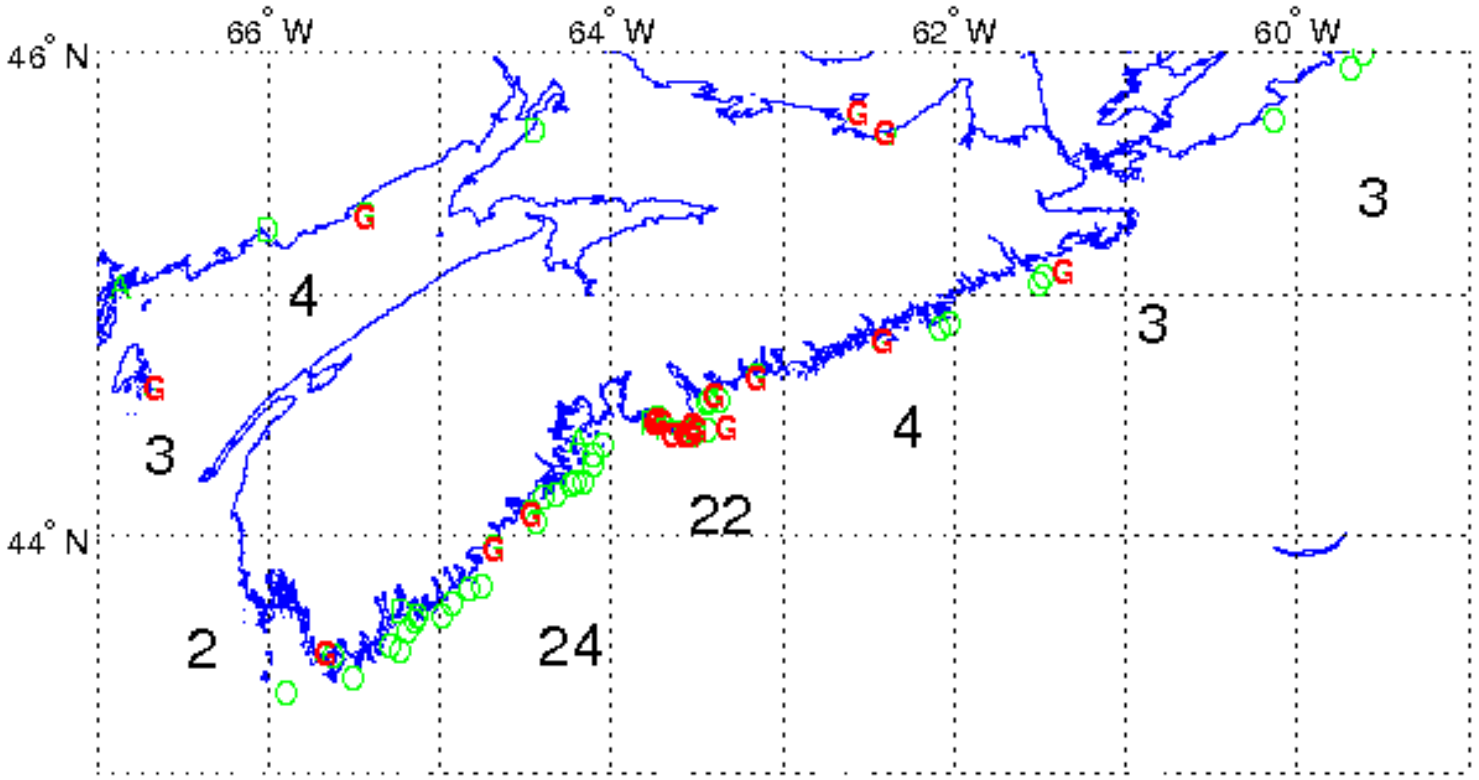
Bill versus Juan versus Noel: comparative coastal effects

- Bill had its largest SWH of 9.0 m with long period waves exceeding 15 s peak periods.
- Juan had its “largest” SWH of 9.0 m with long period waves exceeding 15 s peak periods. (11+ m? corrected)
- Noel “recorded” 10.3 m for the maximum SWH. (13+ m? corrected)
- For Bill, the buoy did not have the old low frequency cutoff, and recorded periods up to 32 s . It may be okay.
- Here is a comparison of the damage done.

Canadian Coast Guard Navigational Buoys

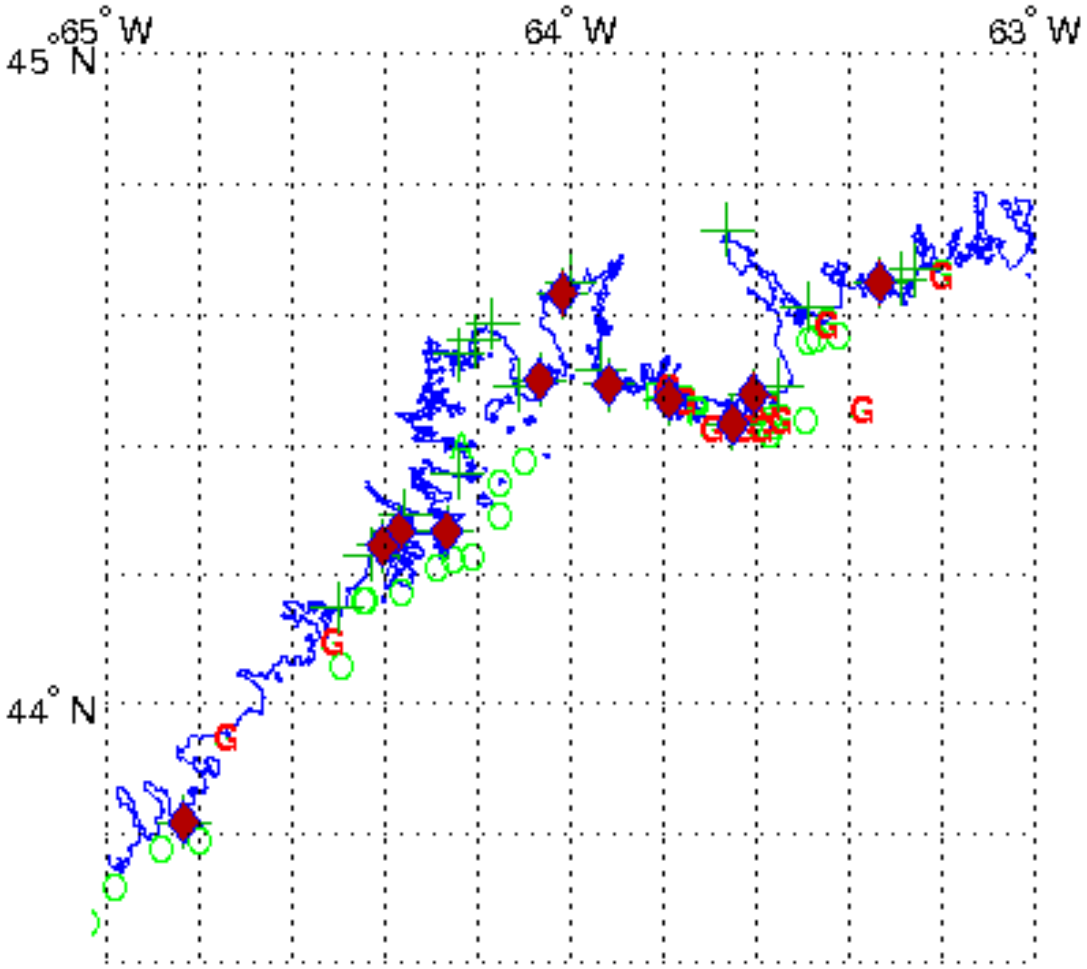


Buoys moved, gone, or damaged by Noel (2007)



Midcoast region buoys moved, gone, or damaged by Noel (2007)

- From Noel (2007), 22
- Juan (2003), about 10-15
- For Bill (2009), 2 had to be moved back



JUST AFTER HURRICANE JUAN (03)


JUST AFTER P.T.NOEL (07)

Just after Bill (09)

Other effects

- Shallow water modification of the spectra (Battjes and Groenendijk (2000))
- American/Canadian bias
  - Relative to NOAA buoys, Canadian buoys 10% less.
- Limits on accelerometer
  - +/- 15 m, should be increased

Lessons Learned

- All buoys
  - If the buoy is dragging its anchor, the peak wave height is not to be trusted, and the significant wave heights may be affected.
  - Shallow water modification of spectra not significant for this buoy for SWH < 16 m.
- Canadian buoys
  - LFC for Canadian shallow water buoys exposed to oceanic waves should be extended.
  - Extreme wave events possibly suspect for 44258, 44251 in Atlantic and 46206, 46183 in Pacific.

Recommendations

- Low frequency cut off should be removed for coastal buoys exposed to long-period waves (done for Buoy 44258)
- When analysing waves from shallow water waves after the fact, we recommend the following
  - Check GPS for undue movement
  - Check the entire spectra
  - Be careful about unduly high peak wave heights
  - Check cut-off period versus real peak period
- Climatology of extreme wave events may be corrupted for this buoy and other shallow water buoys, and should be checked.


The End