Development & Validation of Hindcast-Driven Nearshore Wave Information

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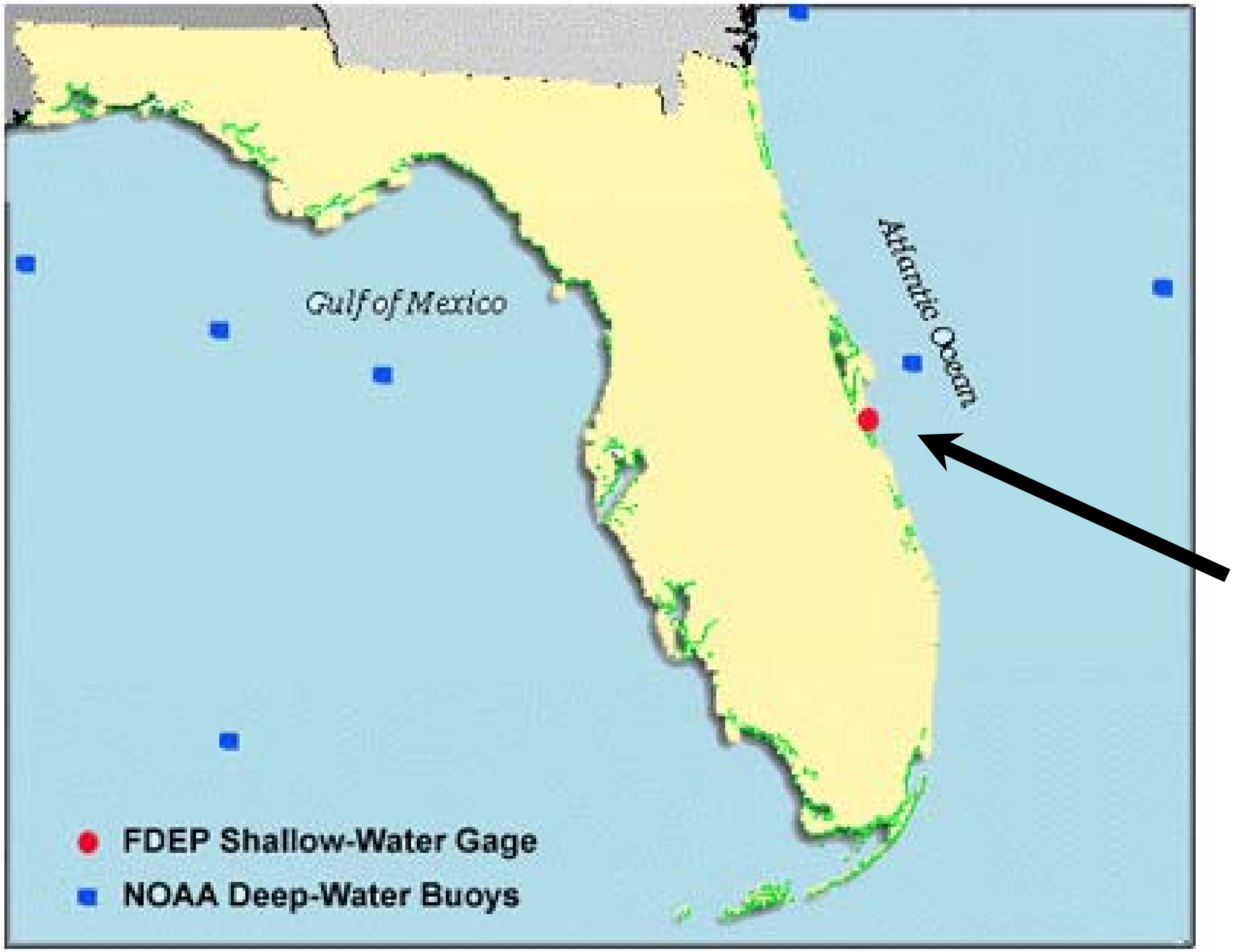
Surfbreak Engineering Sciences, Inc.

Thanks to: FDEP Bureau of Beaches & Coastal Systems
US Army Corps ERDC

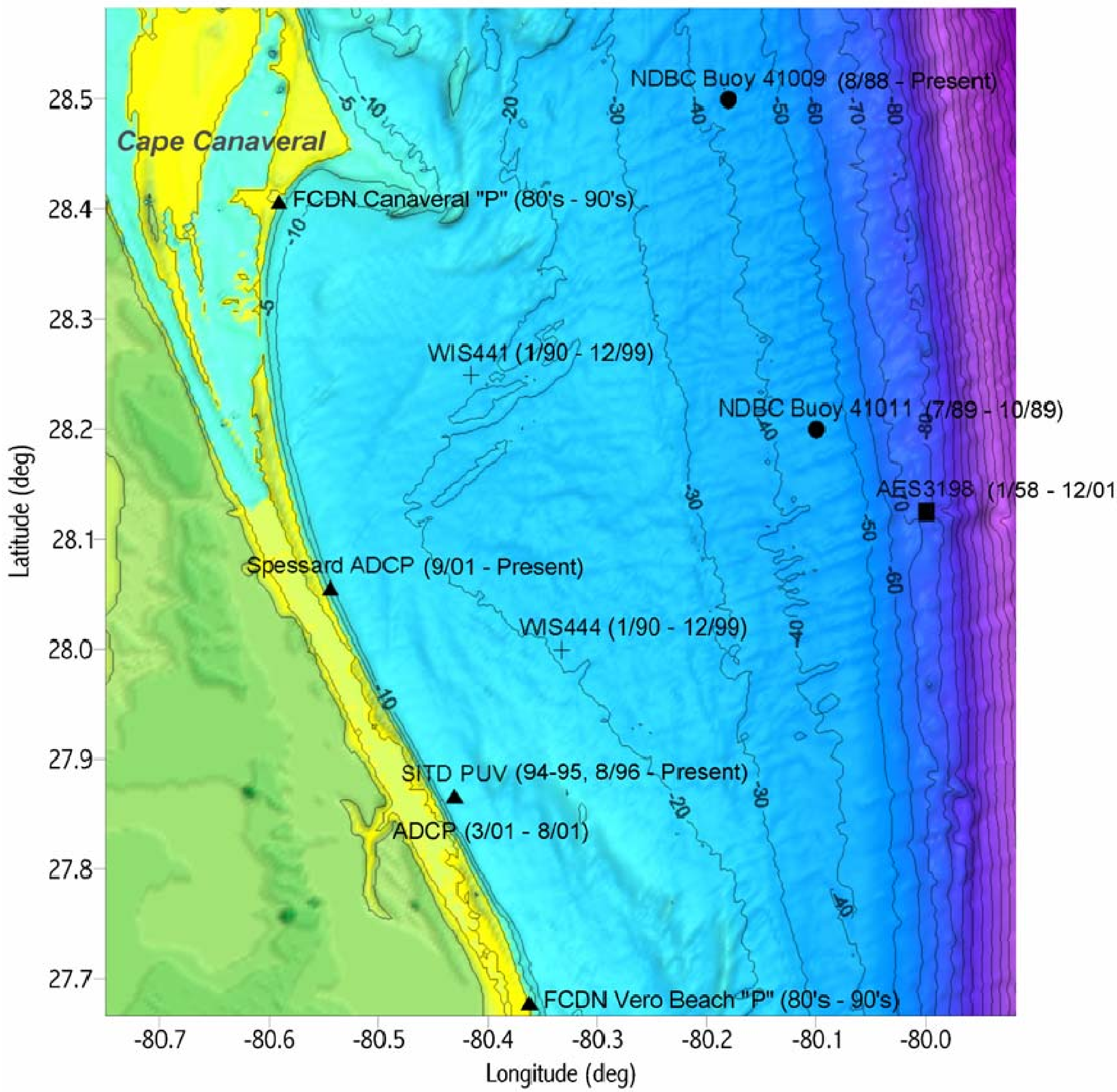


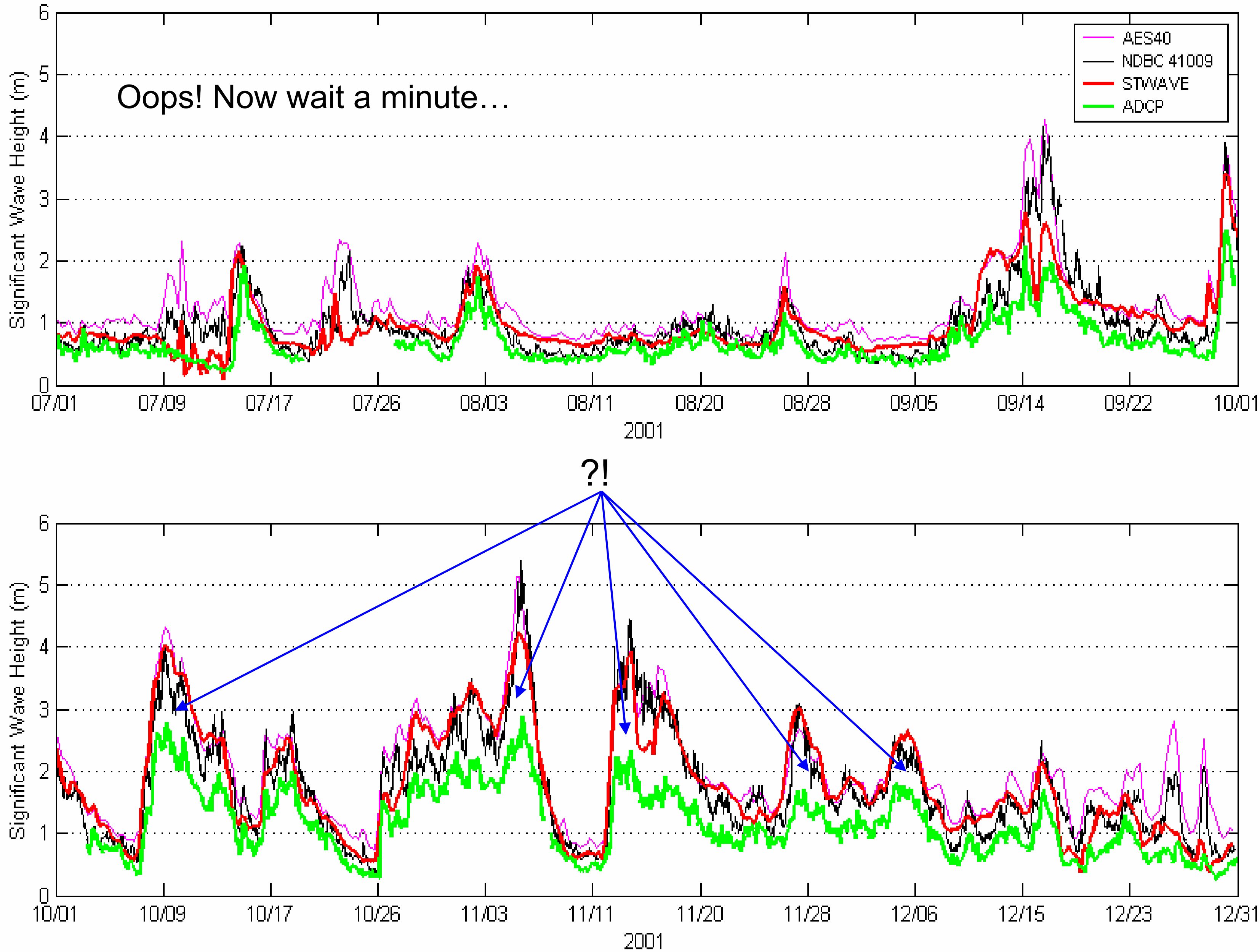
Gulf of Mexico
Atlantic Ocean
FDEP Shallow-Water Gage
NOAA Deep-Water Buoys

Objective: Create long-term nearshore wave climate by transforming AES-50 deepwater hindcast information to shallow water using STWAVE.

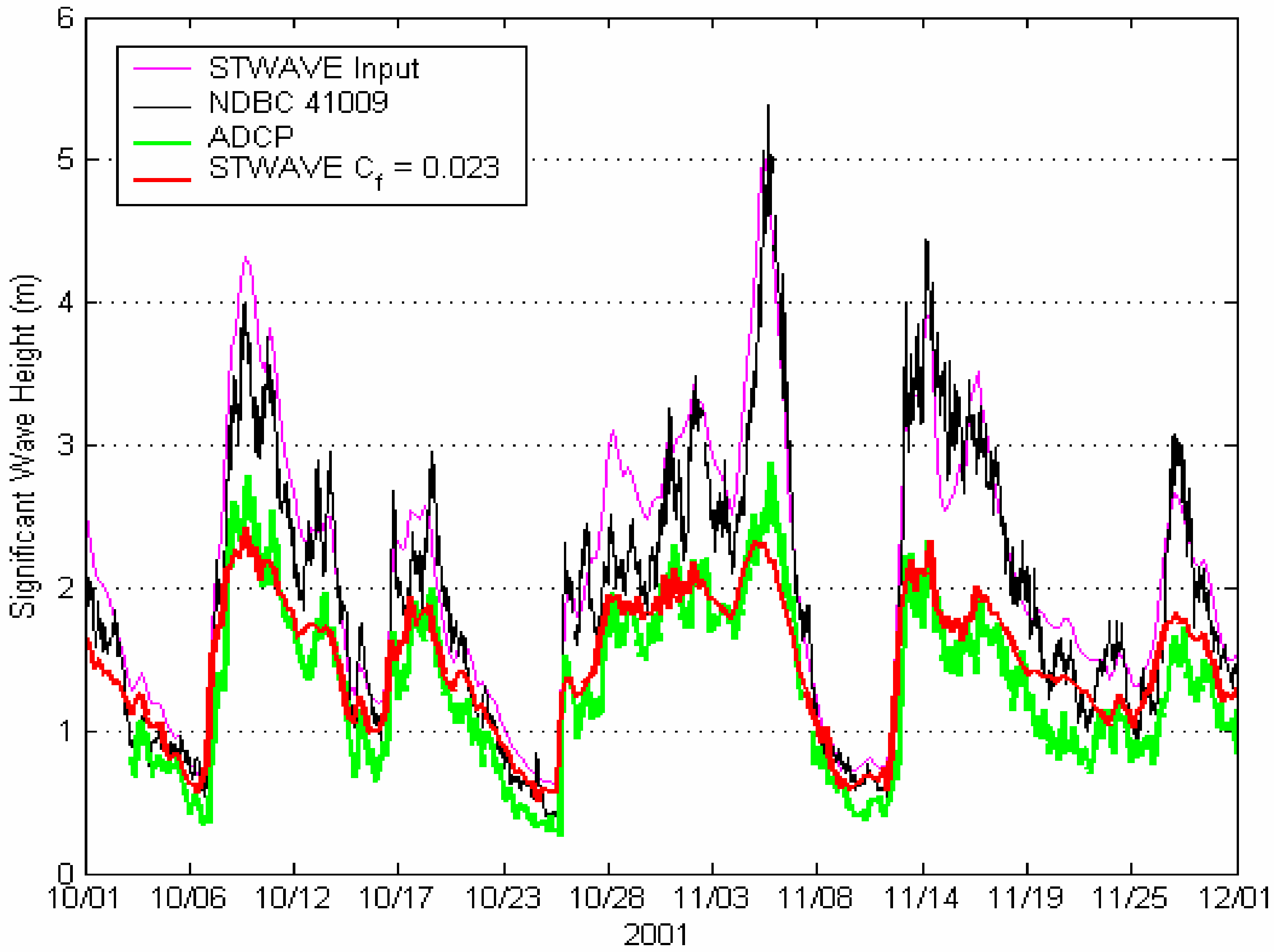
However: directional spectra must first be reconstituted from archived parameters.

Validate: using available shallow water measurements.




Oops! Now wait a minute…
?!
AES40
NDBC 41009
STWAVE
ADCP
Significant Wave Height (m)
0
1
2
3
4
5
6
07/01
07/09
07/17
07/26
08/03
08/11
08/20
08/28
09/05
09/14
09/22
10/01
2001
10/01
10/09
10/17
10/26
11/03
11/11
11/20
11/28
12/06
12/15
12/23
12/31
2001

Bottom friction added to STWAVE



How to select C_f?

- Don't want C_f to be a 'tuning knob' for shortcomings in physics in either the deepwater or the transformation models (e.g. whitecapping, air-sea & wave-wave interactions).

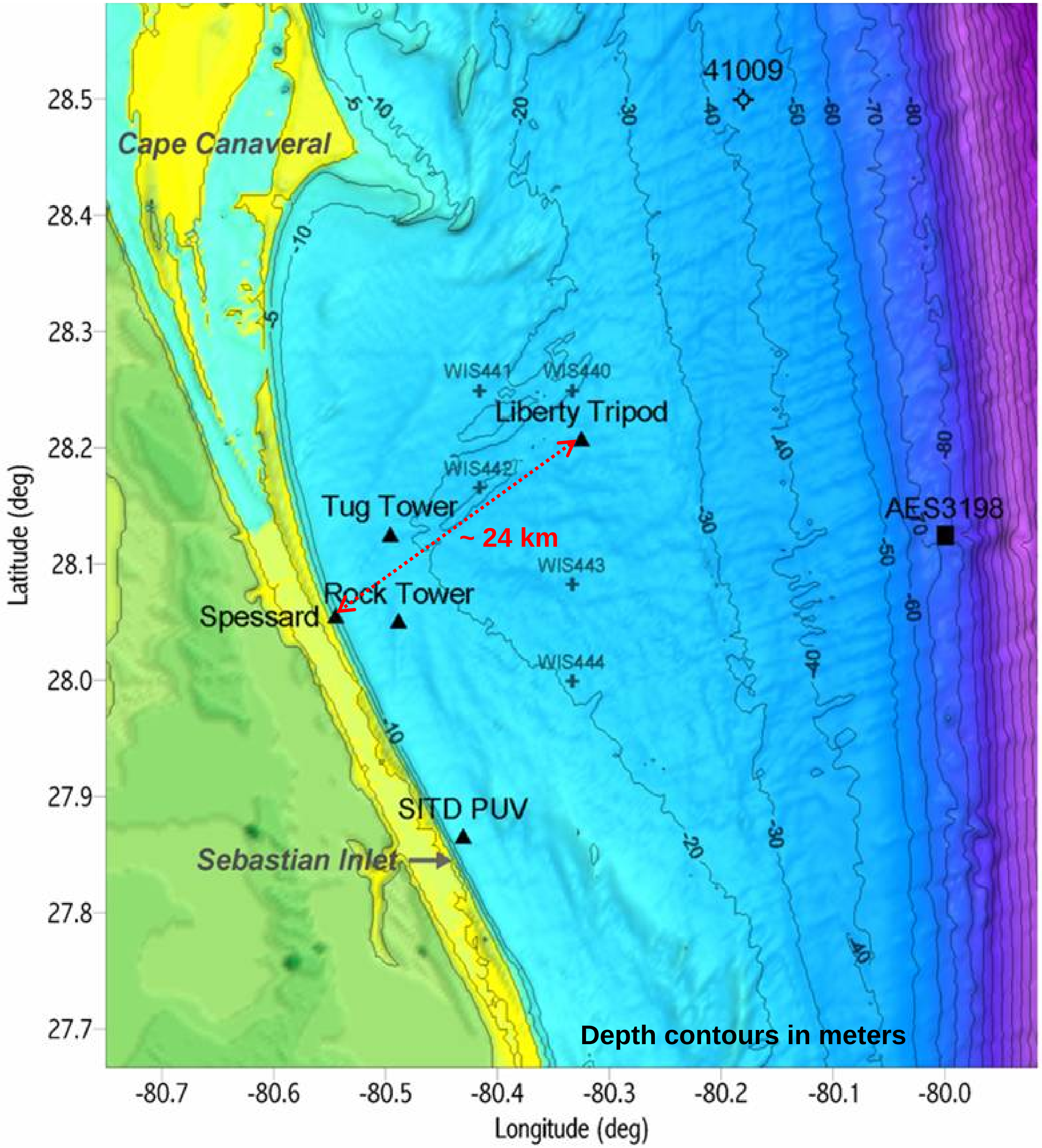
- Don't want selection of C_f to be convoluted by other processes (e.g. opposing winds).

Motivation for the Canaveral Cross-Shelf Experiment

1) Collect high-resolution directional spectra in as great a depth as possible, to use as <u>direct</u> input for STWAVE^{+} friction-calibration against Spessard ADCP.

2) Study the evolution of the directional spectrum as waves cross the shelf.

3) Mount all ADCP's at nominally the same distance below msl, so that an apples-to-apples comparison could be made between the spectra measured at different water depths.

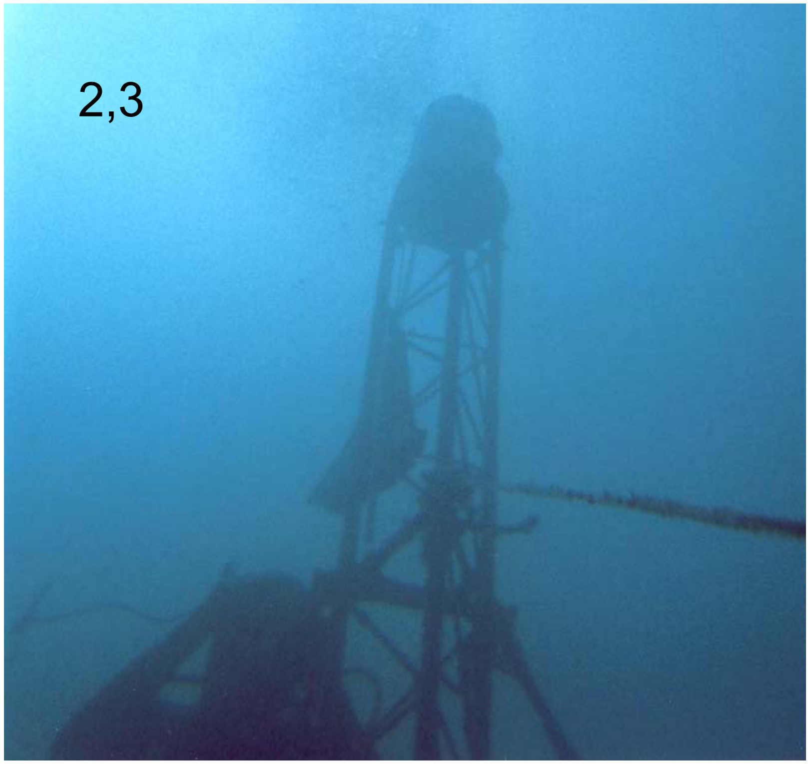

Cape Canaveral
41009
WIS441
WIS440
Liberty Tripod
WIS442
Tug Tower
~ 24 km
WIS443
Rock Tower
Spessard
WIS444
AES3198
SITD PUV
Sebastian Inlet
Depth contours in meters
Latitude (deg)
Longitude (deg)
28.5
28.4
28.3
28.2
28.1
28.0
27.9
27.8
27.7
-80.7
-80.6
-80.5
-80.4
-80.3
-80.2
-80.1
-80.0

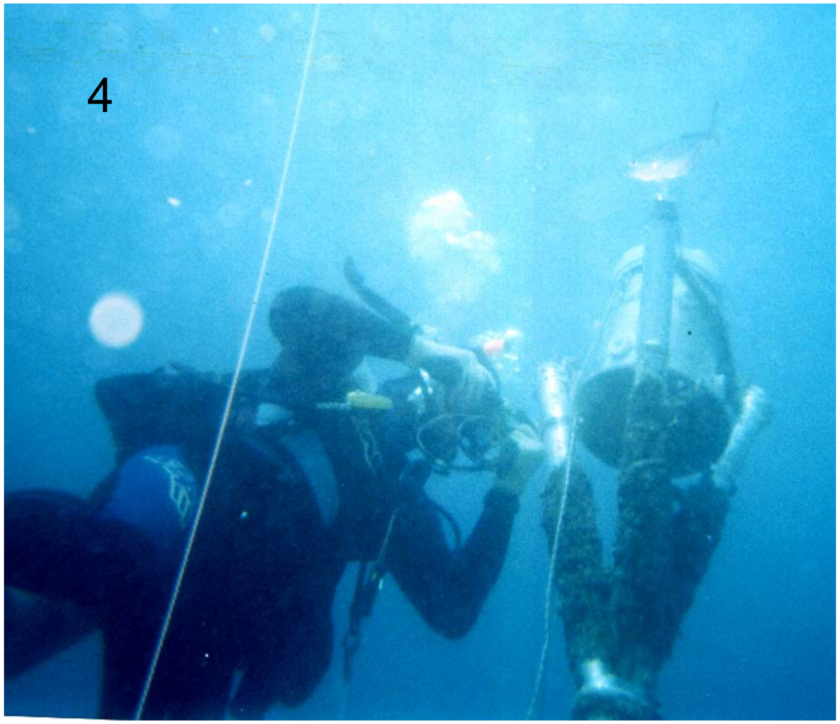
1)Spessard Spud (8.5 m depth)

2)Rock Tower (17.7 m depth)

3)Tug Tower (19.2 m depth)

4)Liberty Tripod (22.0 m depth)

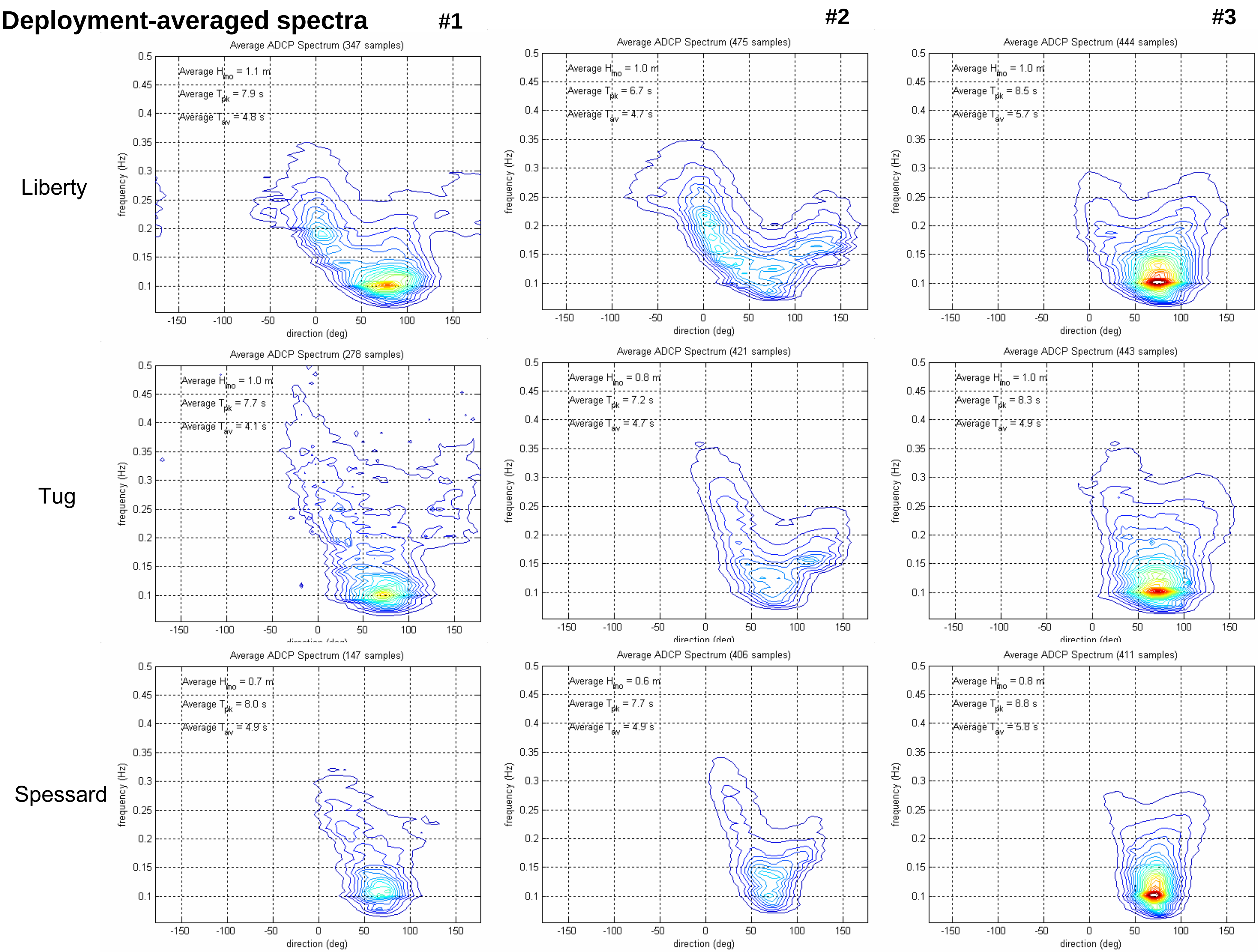




Canaveral Cross-Shelf Experiment

- Four 1200 kHz ADCP instruments deployed:
- Deployed and retrieved gauges 3 times - approx. 90 days of measurements.
- Collected simultaneous directional wave spectra (20-min. records, bi-hourly) and current profiles.
- Wind measurements from NDBC 41009 and Spessard station.

Deployment-averaged spectra



Bottom friction calibration procedure

1. Screen the data using dissipation indicator threshold (0.01 m^2/s).

2. Omit times with opposing winds.

3. Window the Liberty directional spectra to fit STWAVE+ half-plane (-20^o to 160^o).

4. Use the selected Liberty spectra to drive STWAVE+ with 3 different friction factors (0.0, 0.05, 0.10), and archive results at Spessard.

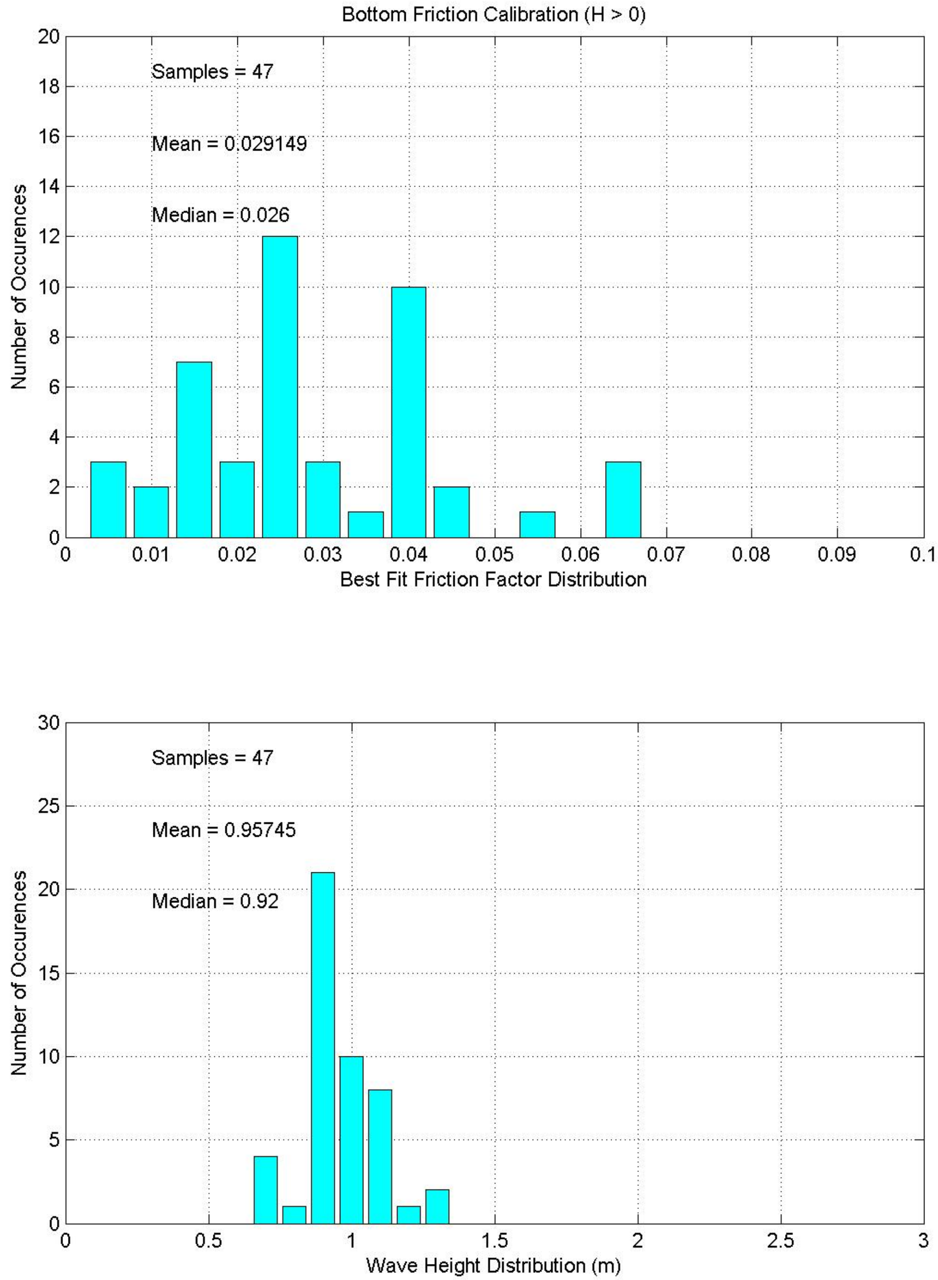
5. For each STWAVE+ run, fit a parabola to the modeled $H_{mo}(C_f)$ at Spessard, and use the measured H_{mo} to compute a 'best-fit' factor.

Bottom friction dissipation indicator:

$$\varepsilon_F = \frac{\frac{\sqrt{2}}{3} \pi^2 f_p^3 H_{mo}^3}{\sinh^3 k_p h}$$

47 out of ~1200 Liberty/Spessard-pairs used to calibrate.

$C_f \sim 0.026$



Reconstitution of Directional Spectra from AES Parameters

<u>7 Parameters used:</u>

Sea

1) energy, 2) peak period, 3) mean direction

Swell

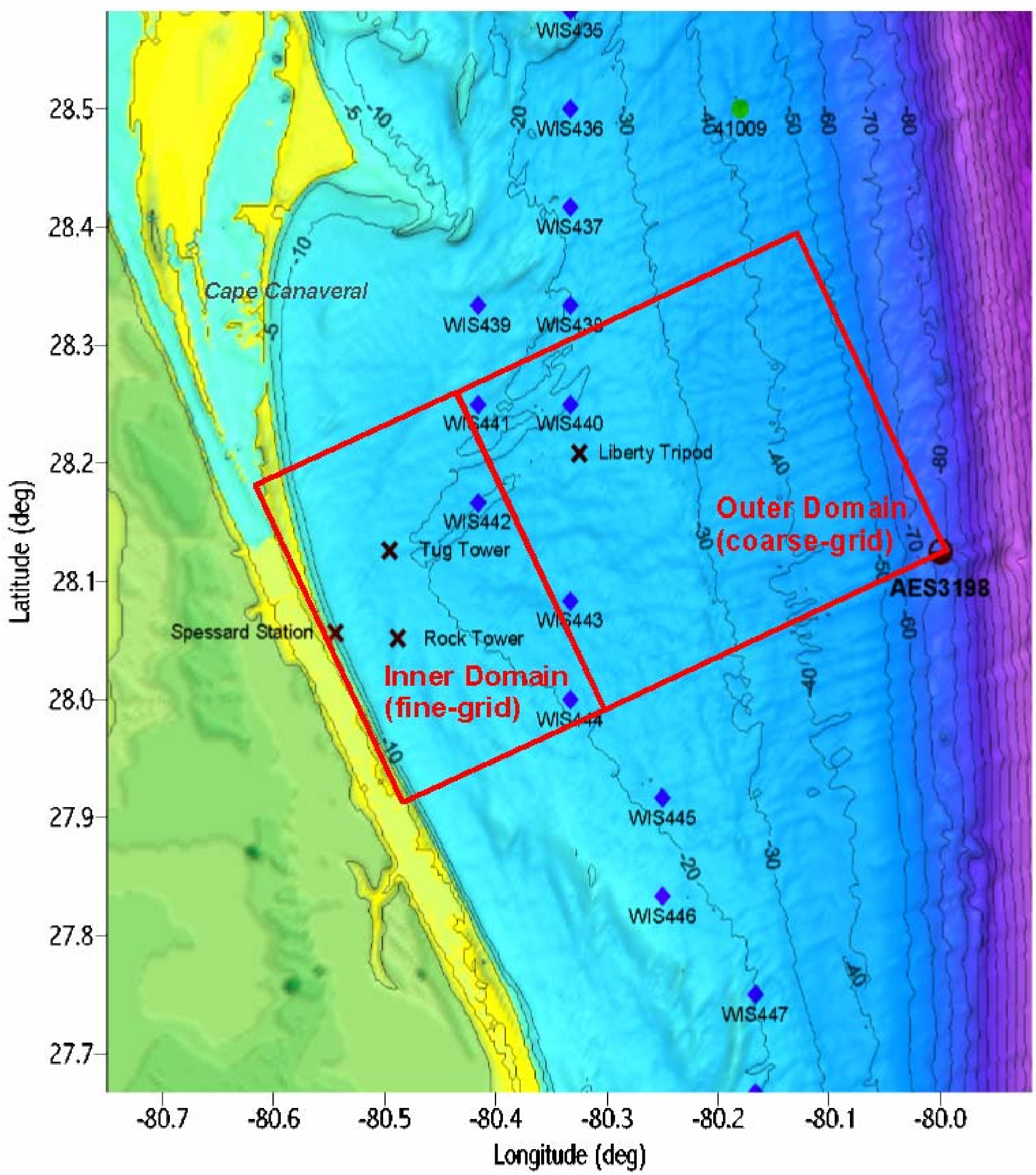
4) energy, 5) peak period, 6) mean direction

7) directional spreading coefficient of total spectrum

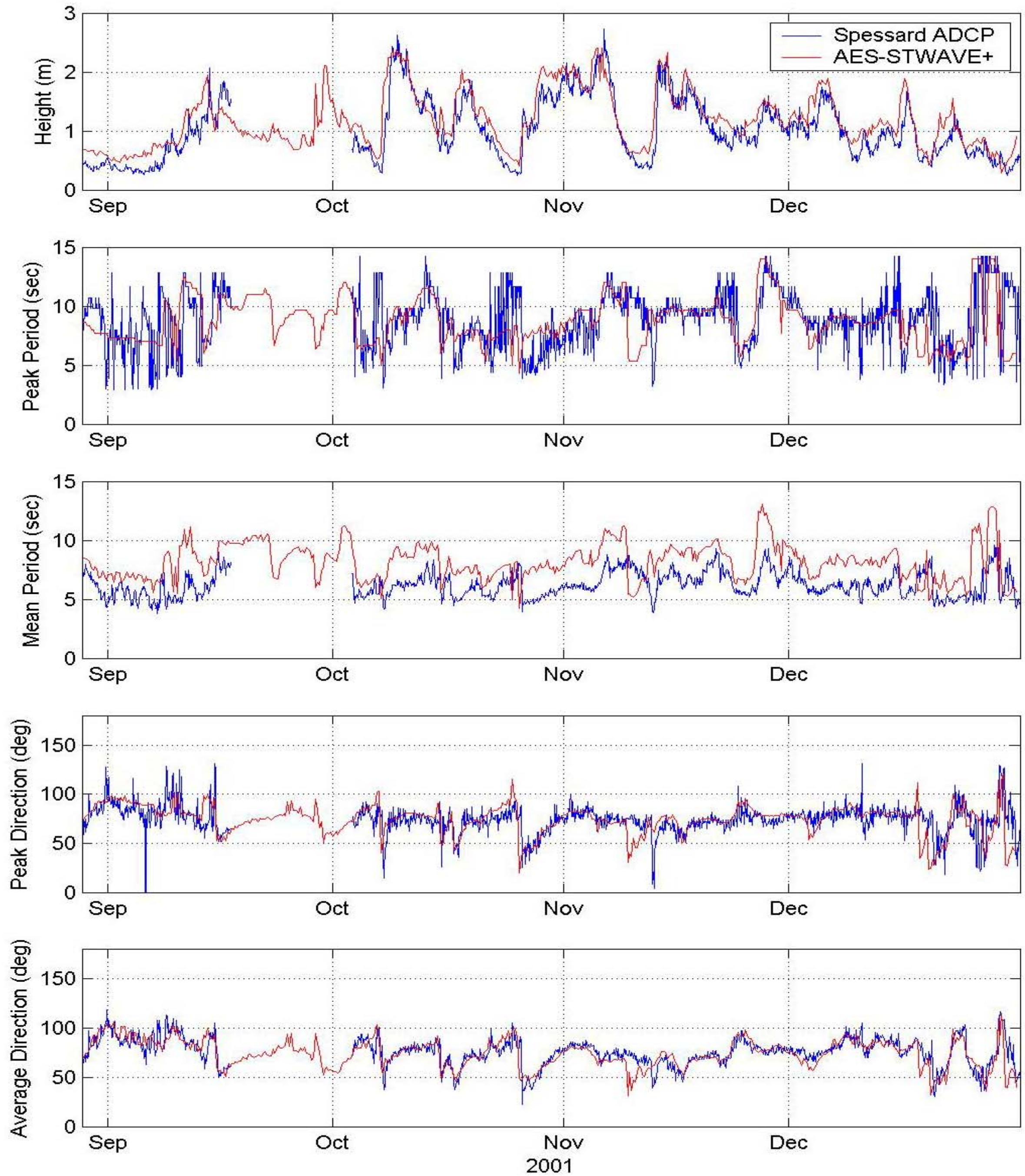
JONSWAP for frequency (γ=3.3)

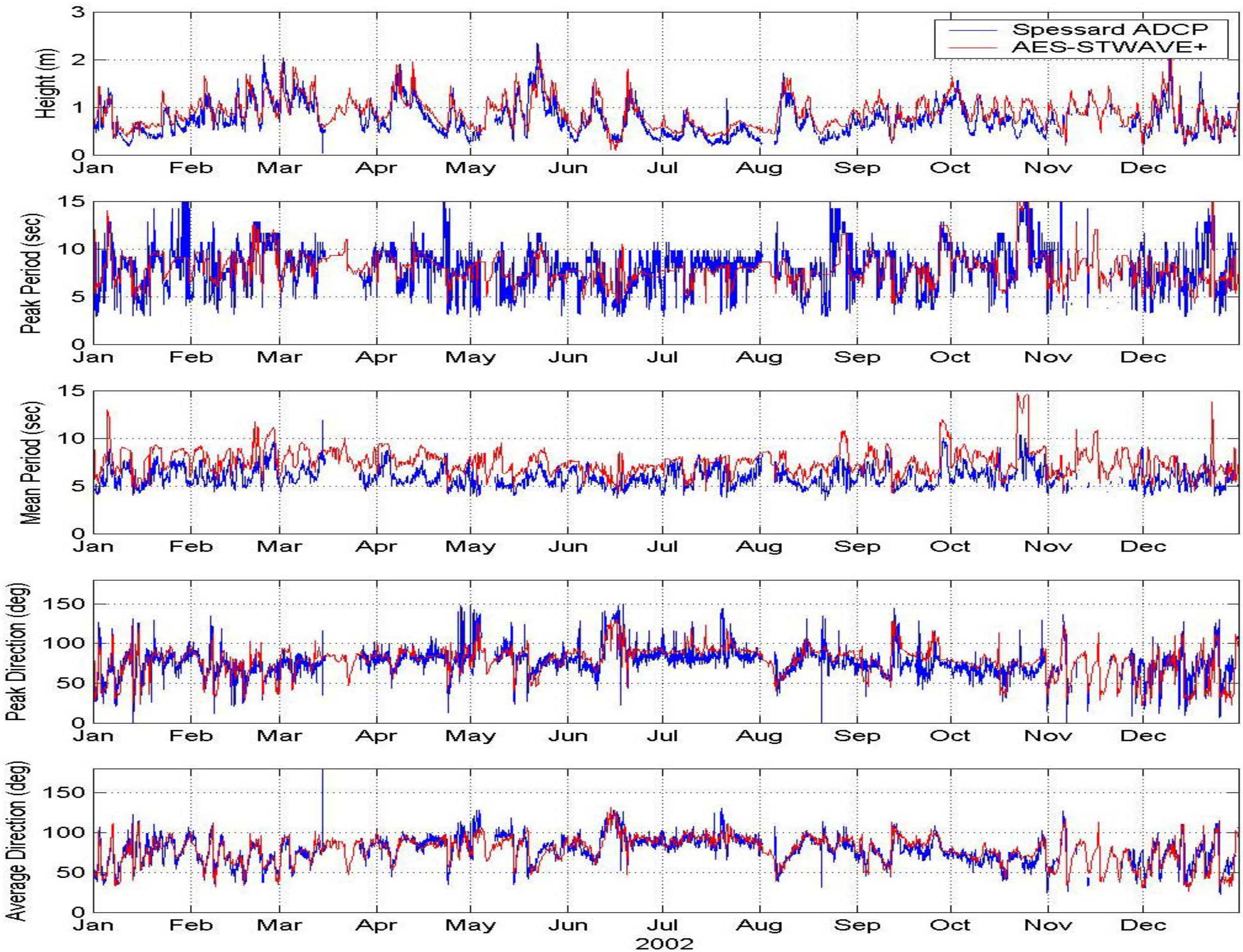
Mitsuyazu for directional spread

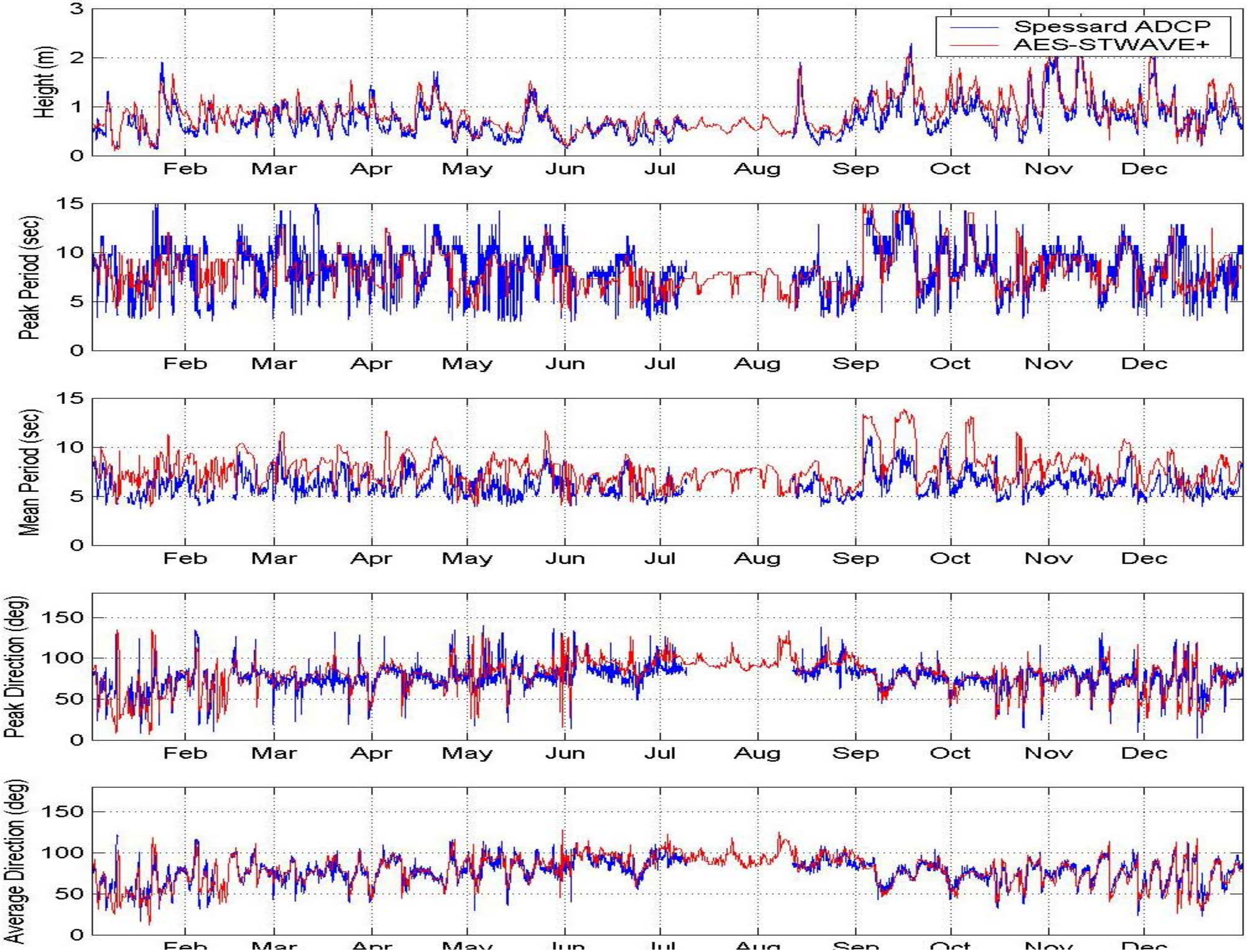
Apply $C_f = 0.026$ everywhere in the model domain.



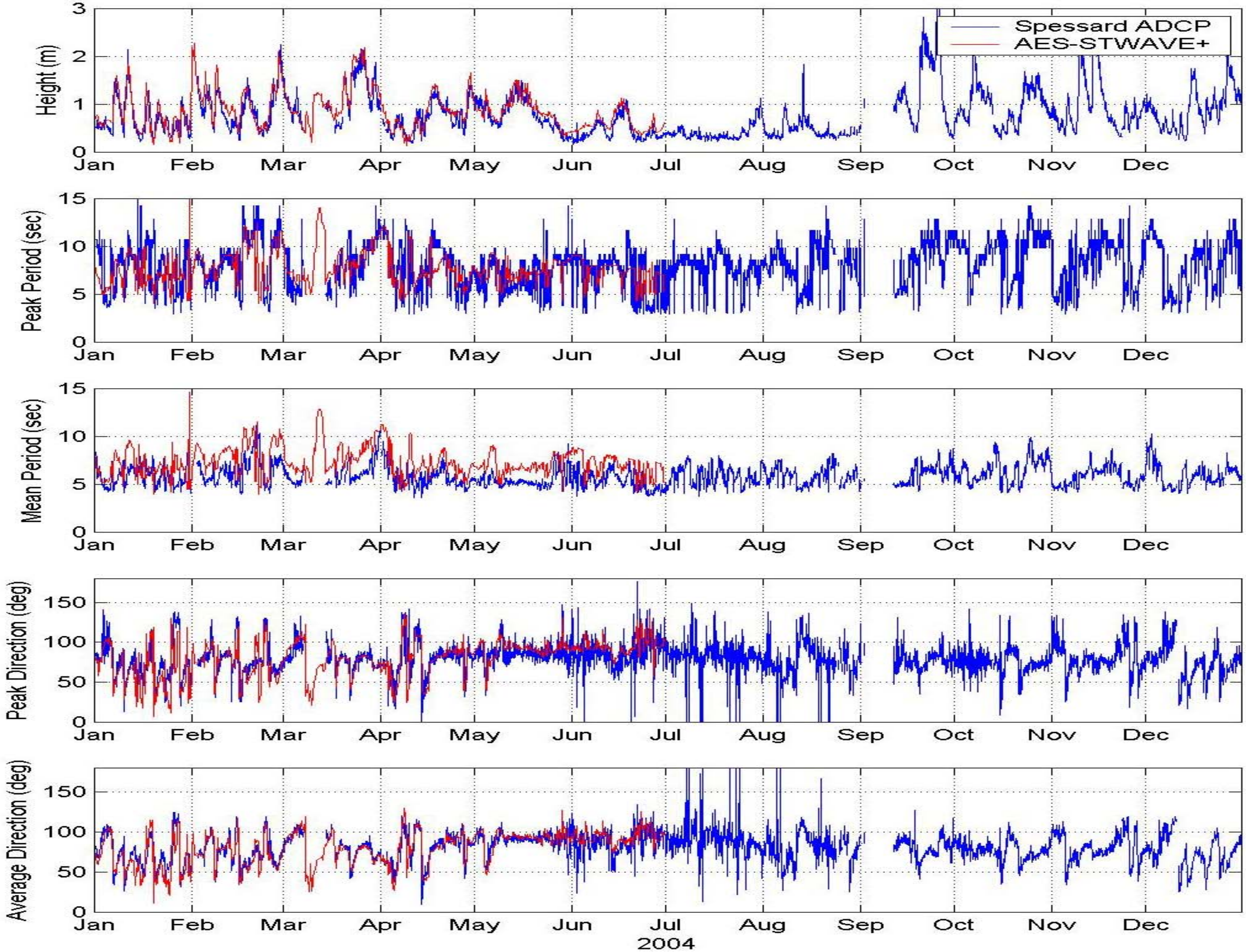
AES/STWAVE+ modeling results: August 28, 2001 – June 30, 2004



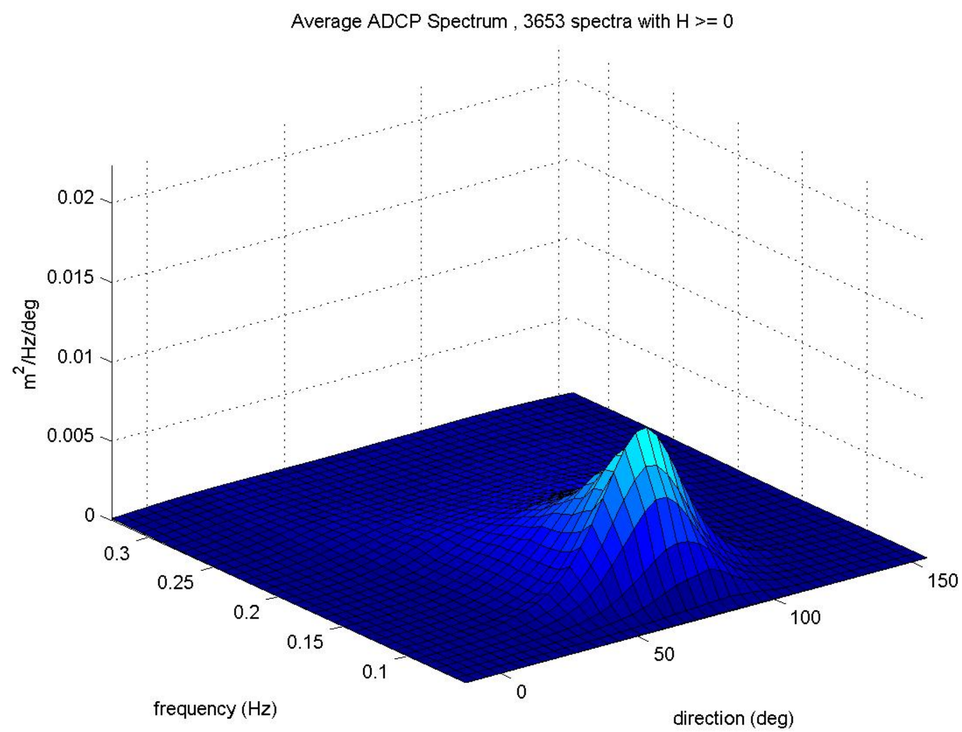

Spessard ADCP
AES-STWAVE+
Height (m)
Peak Period (sec)
Mean Period (sec)
Peak Direction (deg)
Average Direction (deg)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2002



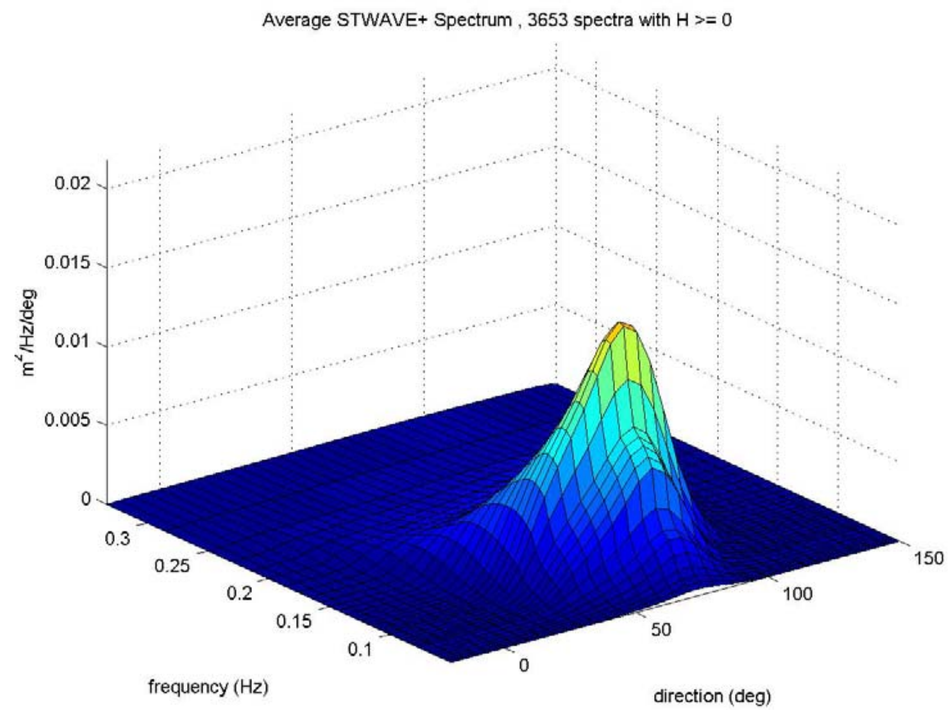
Spessard ADCP
AES-STWAVE+
Height (m)
Peak Period (sec)
Mean Period (sec)
Peak Direction (deg)
Average Direction (deg)
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Spessard ADCP
AES-STWAVE+
Height (m)
Peak Period (sec)
Mean Period (sec)
Peak Direction (deg)
Average Direction (deg)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2004

Average spectra at Spessard

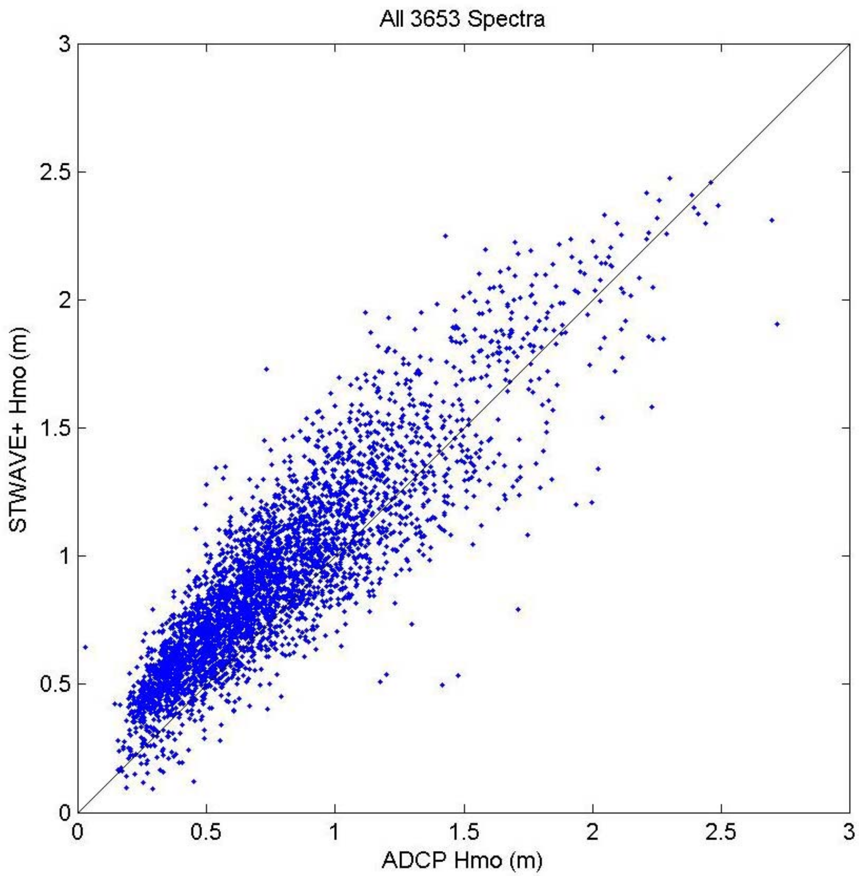


Measured

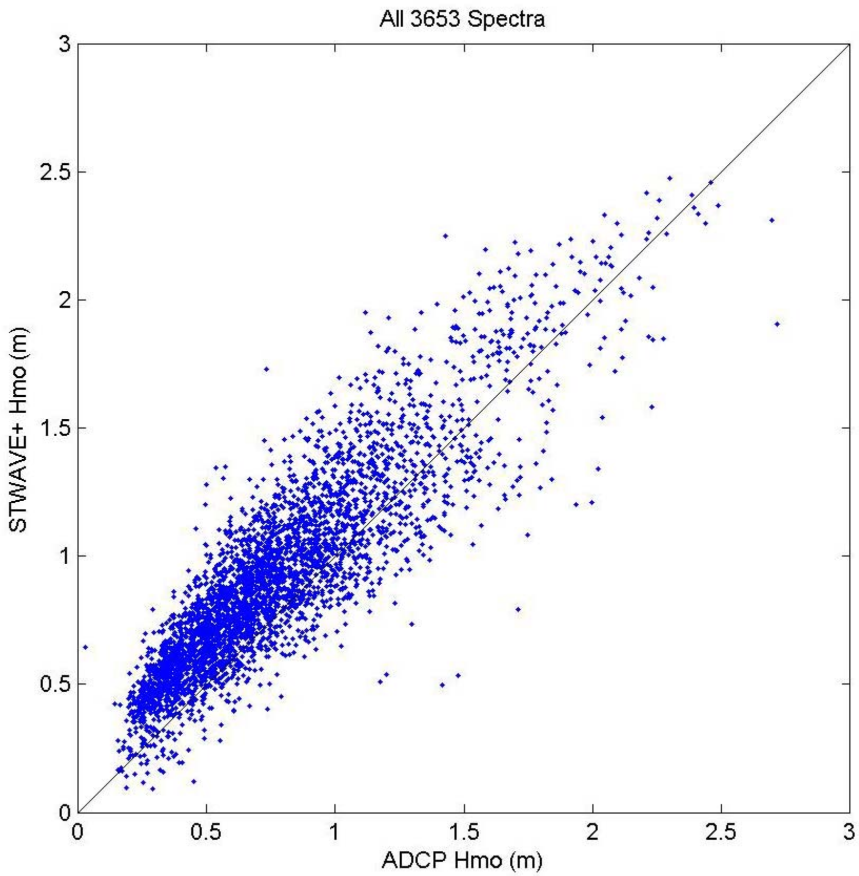


Modeled

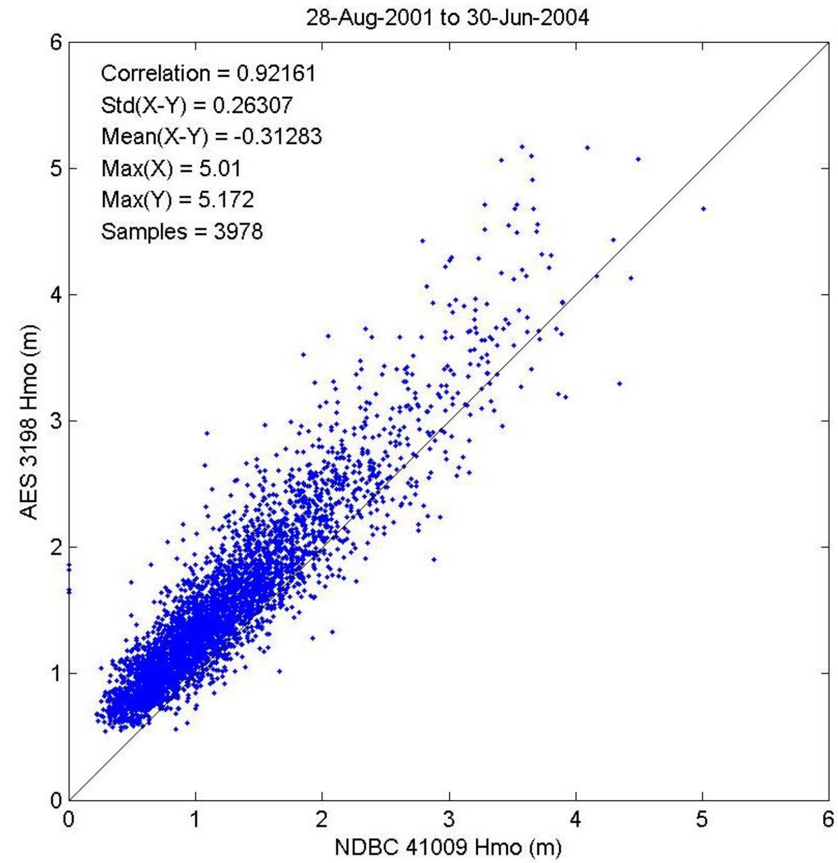
Model vs. Spessard Meas.



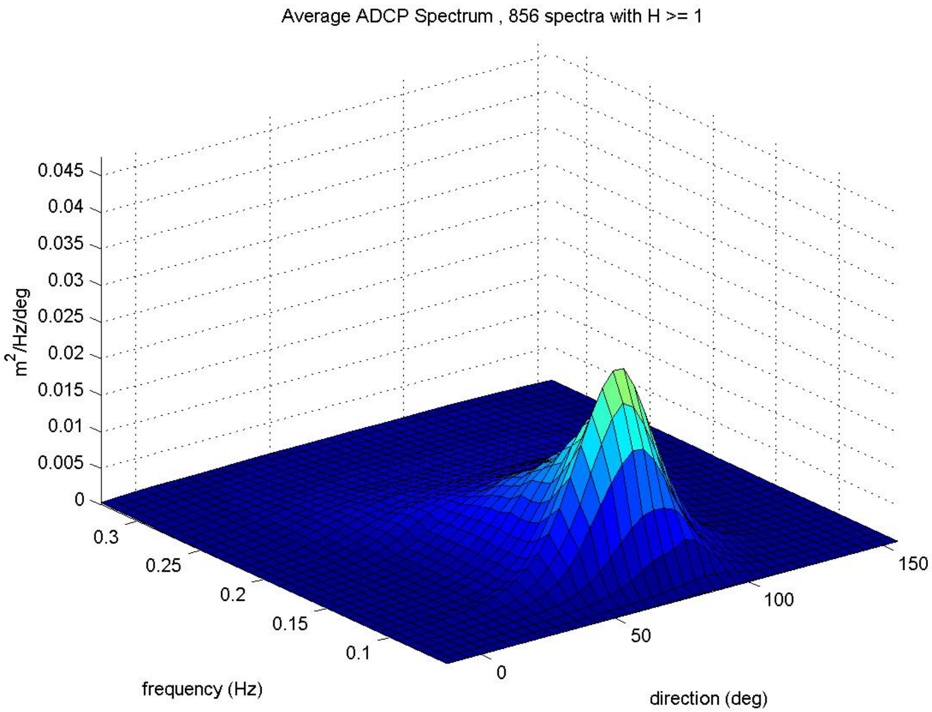
Model vs. Spessard Meas.



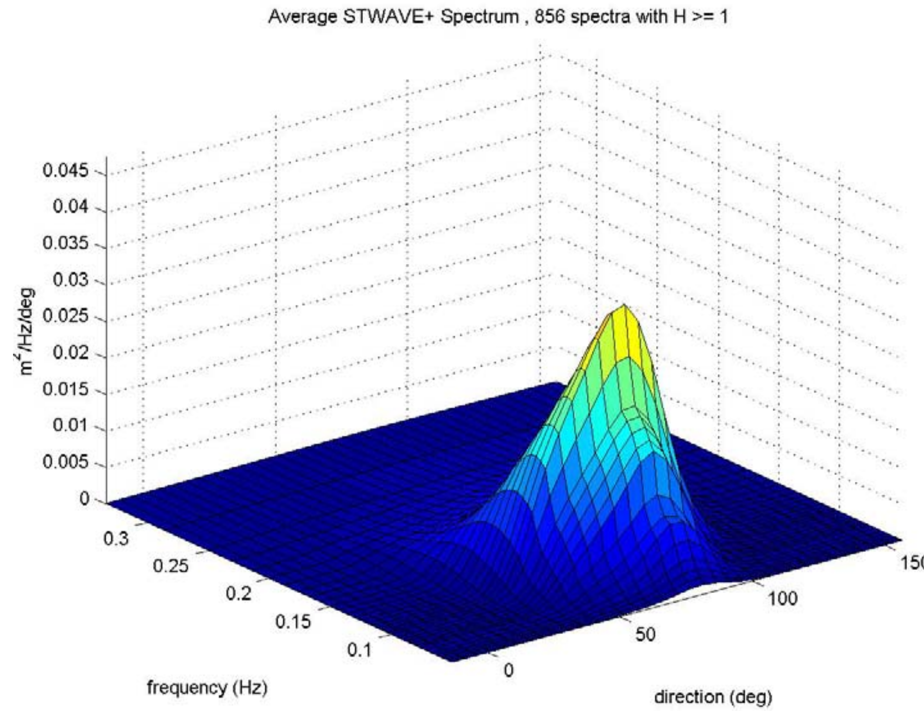
AES vs. Buoy 41009



Average spectra at Spessard, $H_{mo} \geq 1m$

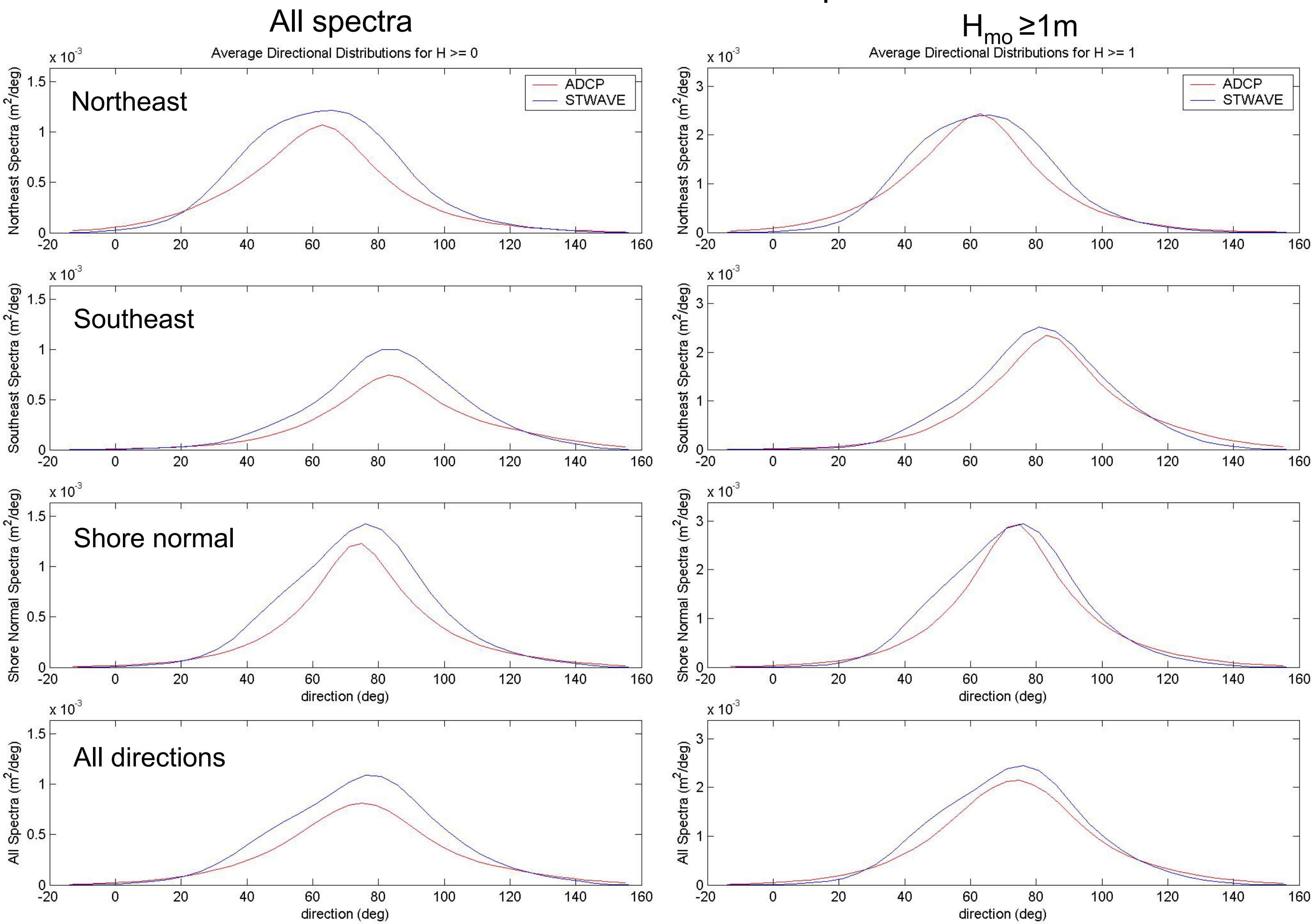


Measured



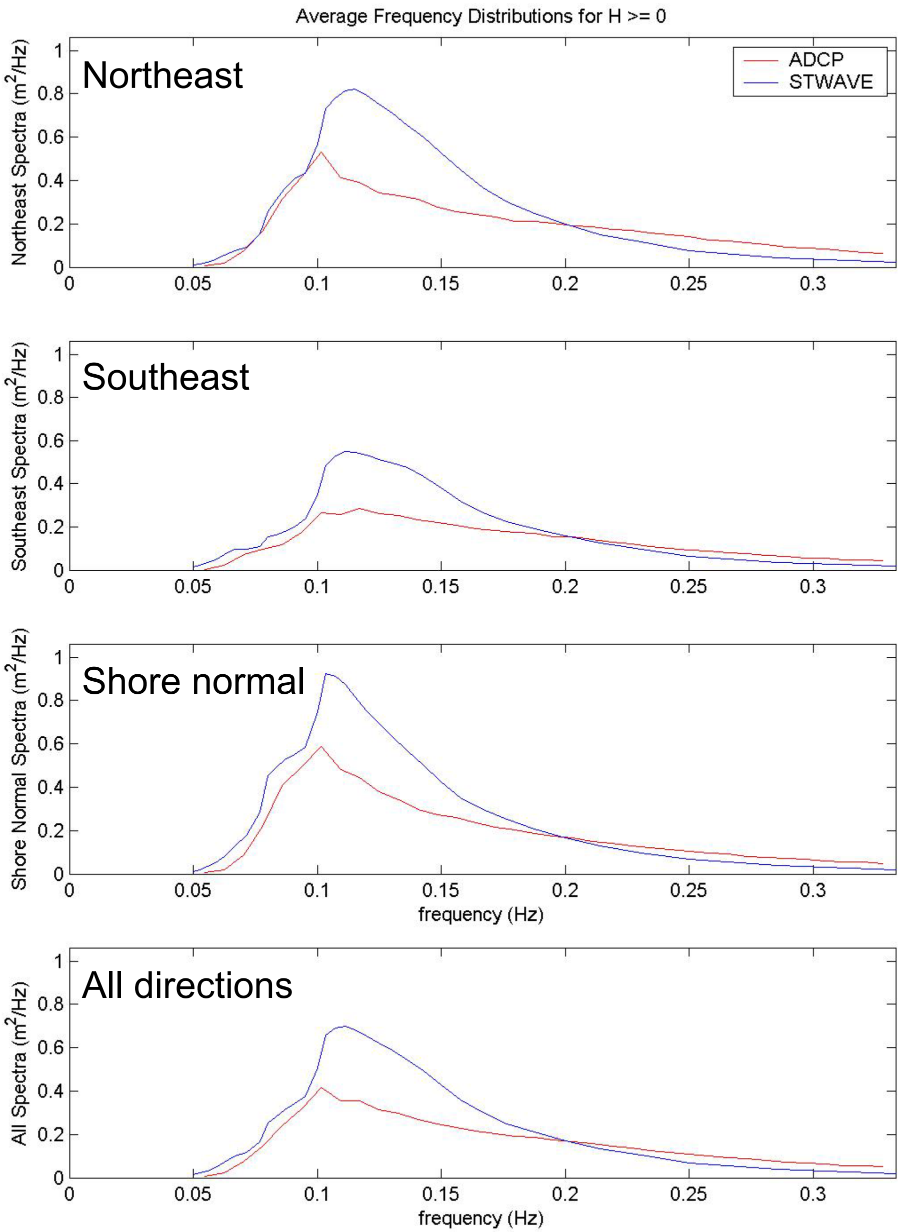
Modeled

Directional Distributions at Spessard

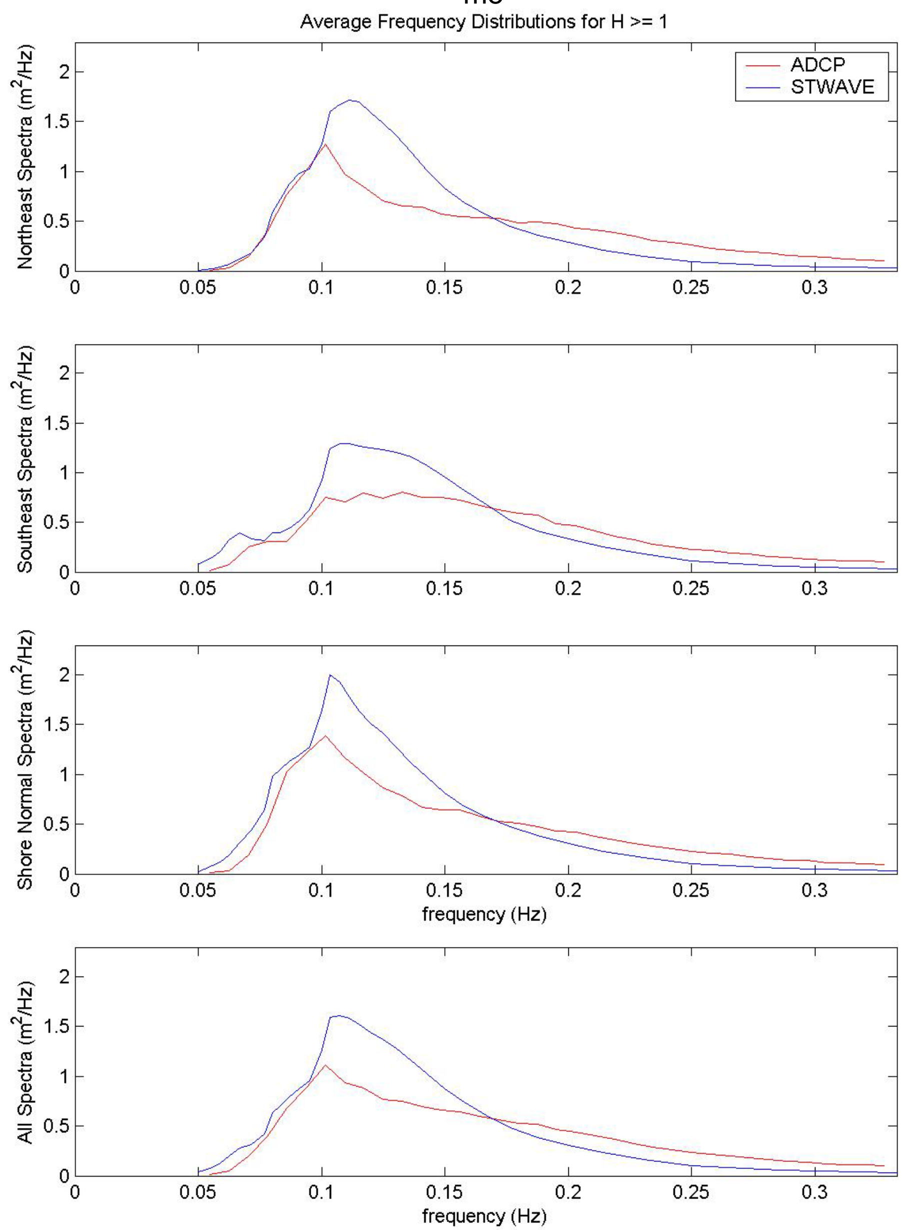


Frequency Distributions at Spessard

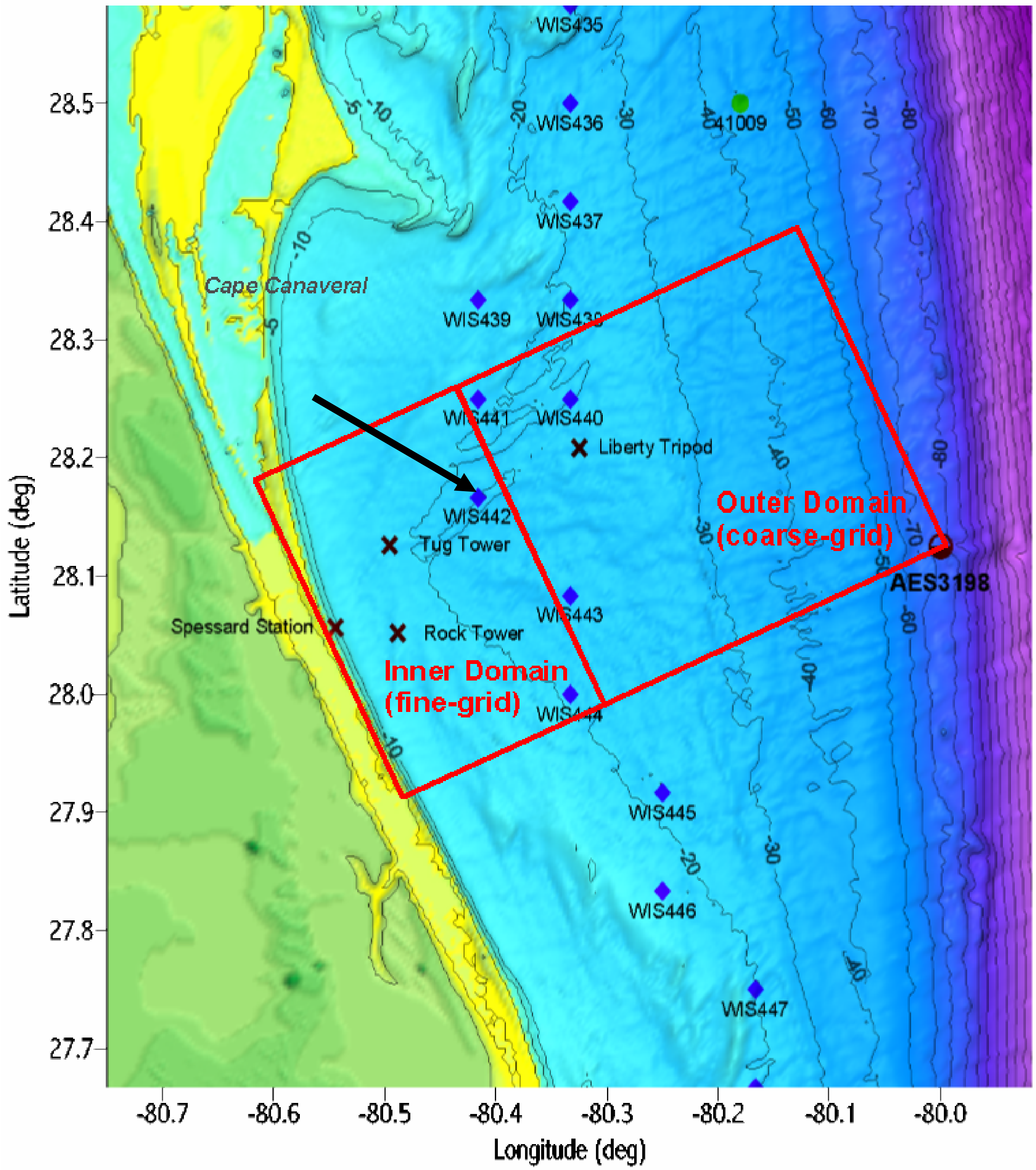
All spectra

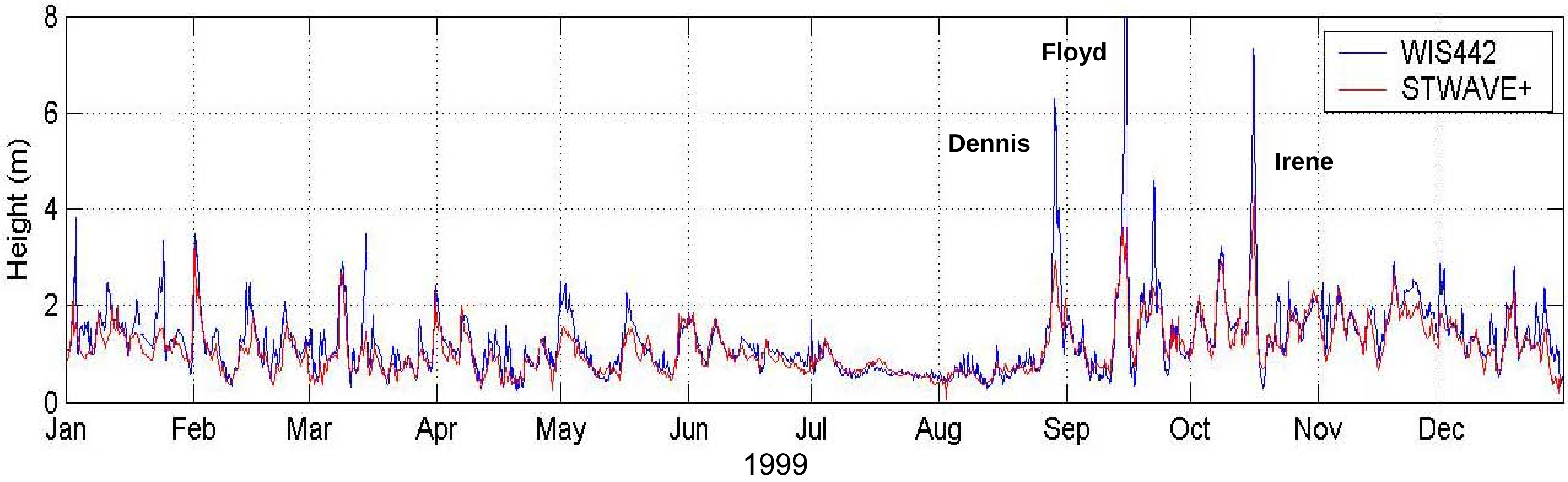


$H_{mo} \geq 1m$

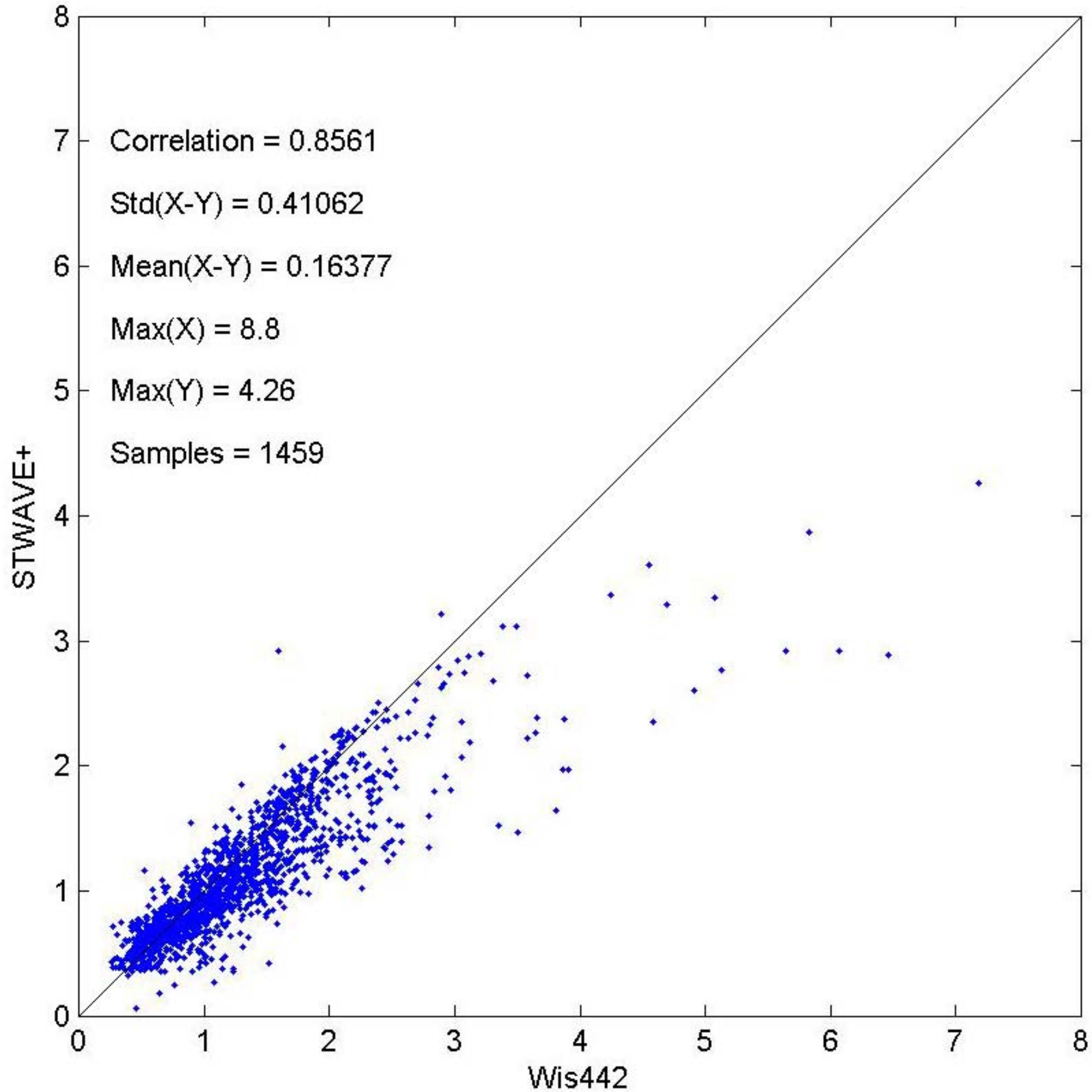


AES/STWAVE+ vs. WIS





Height (m)
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1999
Dennis
Floyd
Irene
WIS442
STWAVE+


Correlation = 0.8561
Std(X-Y) = 0.41062
Mean(X-Y) = 0.16377
Max(X) = 8.8
Max(Y) = 4.26
Samples = 1459
STWAVE+
Wis442
0
1
2
3
4
5
6
7
8

Conclusions/Recommendations/Issues

•Paired wave gauges to address bottom friction – <u>local calibration</u>.

•Reconstitution method: Directional distribution looks OK, frequency distribution needs work. (Hindcast archived as 2D spectra would be nice…)

•Deepwater hindcast overpredicts during low energy – what to do?

•Don't archive deepwater hindcast results in shallow water.

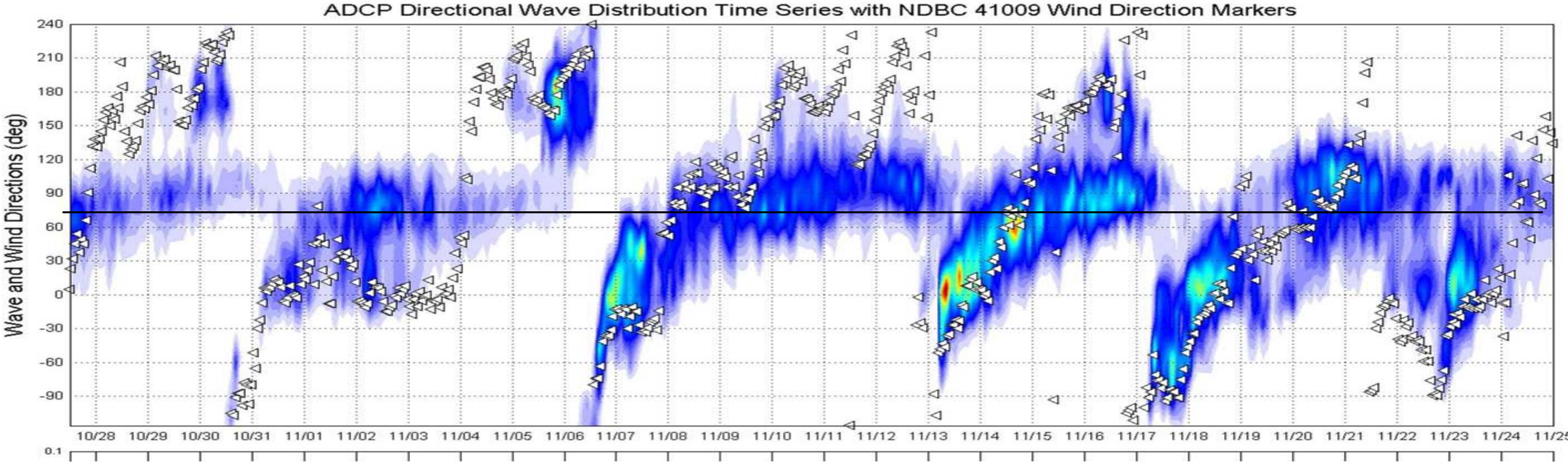
•Measurements are critical to improved, believable hindcast modeling – how to get higher directional resolution in deeper water?

Thank you!

Data from Liberty Tripod

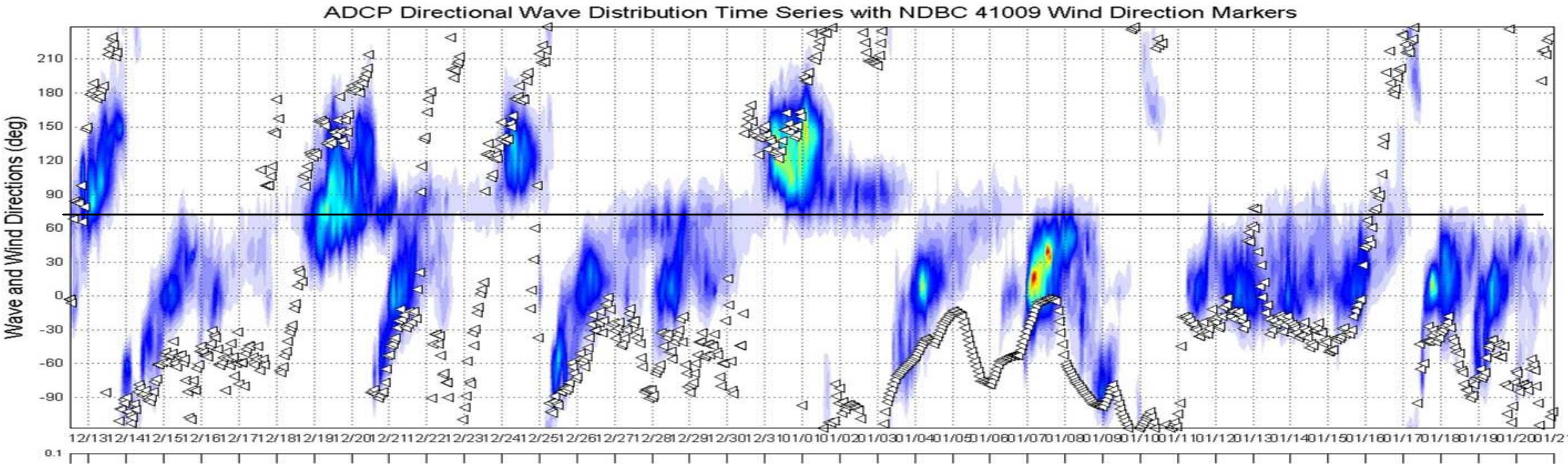
#1

10/27-11/25



#2

12/12-1/21



#3

2/26-4/4

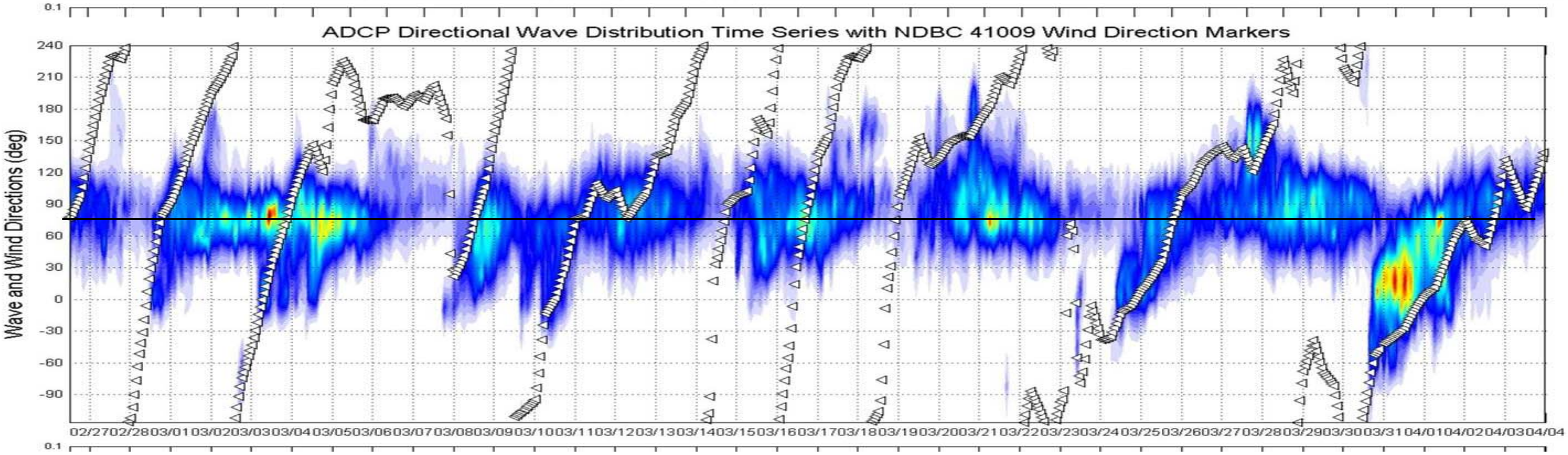
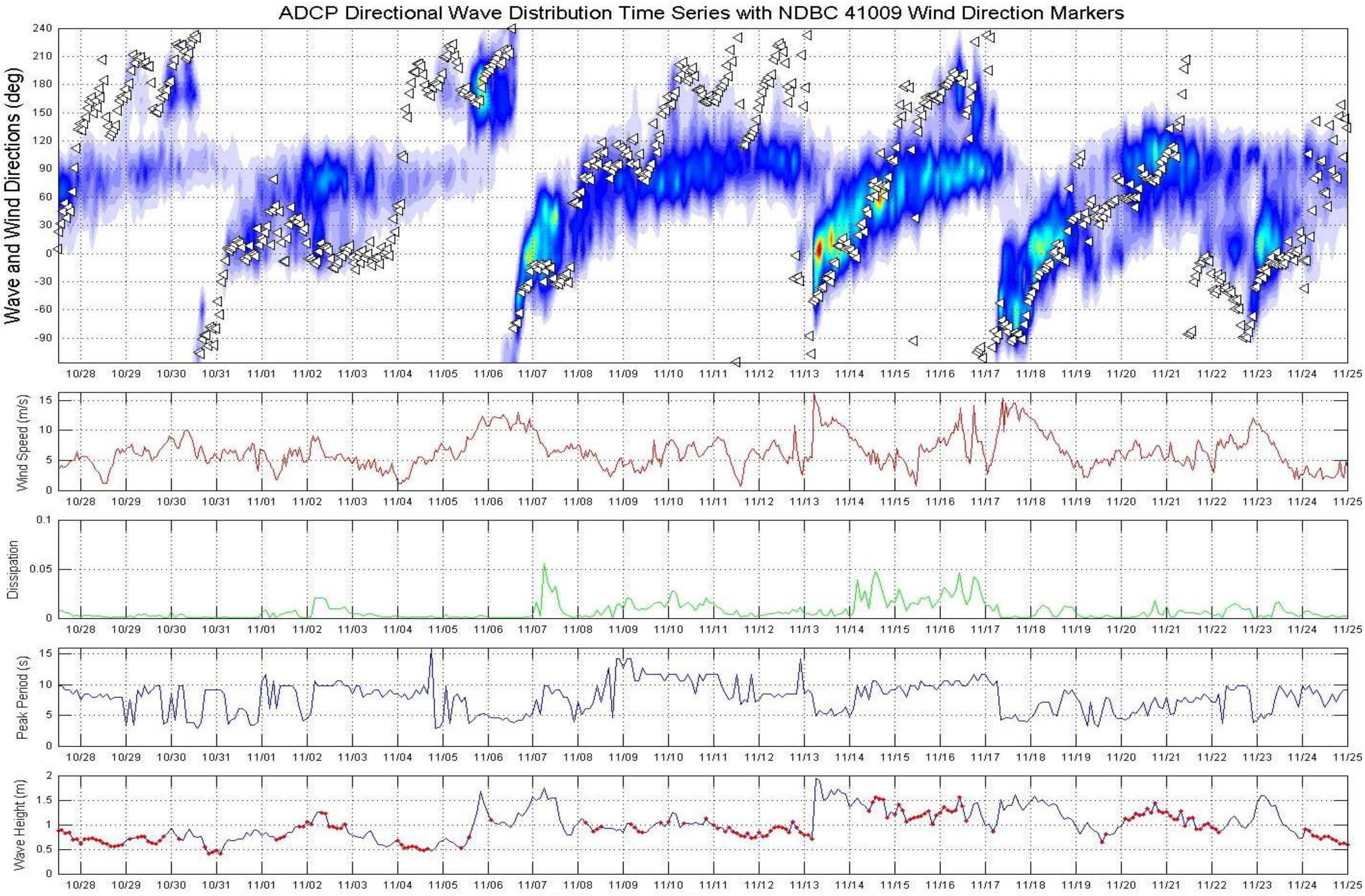
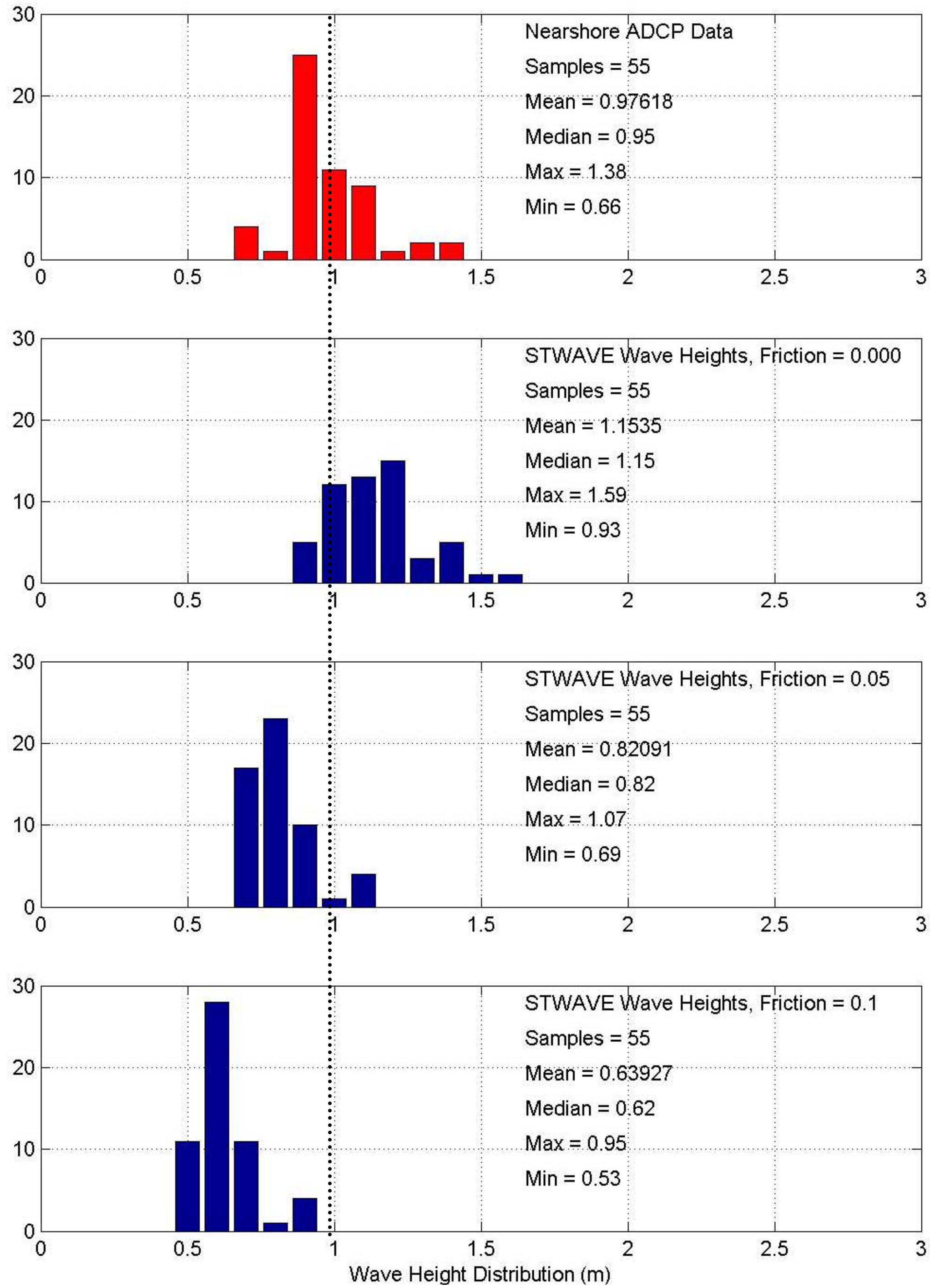
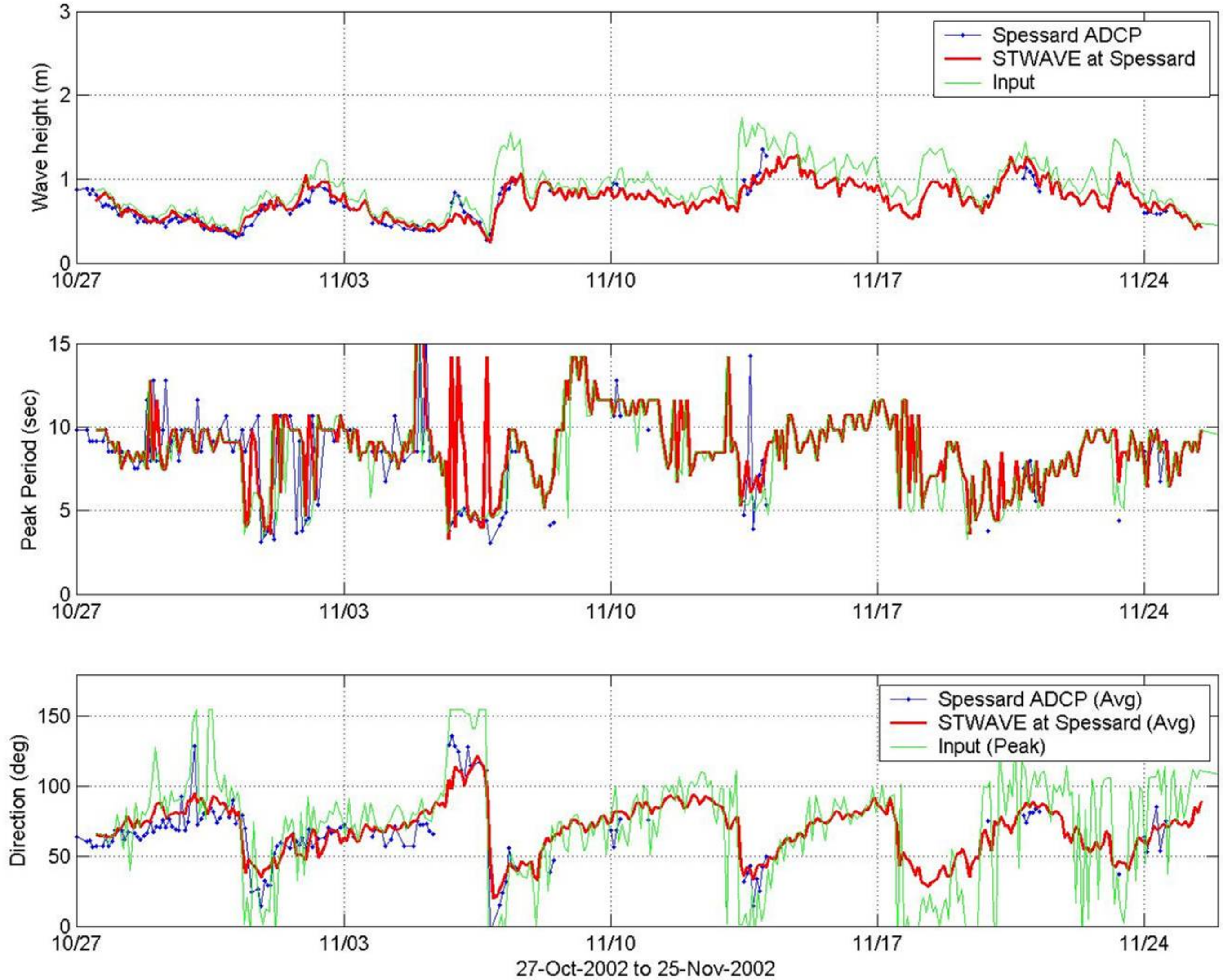


Table 1 – Range in Friction Factor (C_f) for Various Natural Bed Types

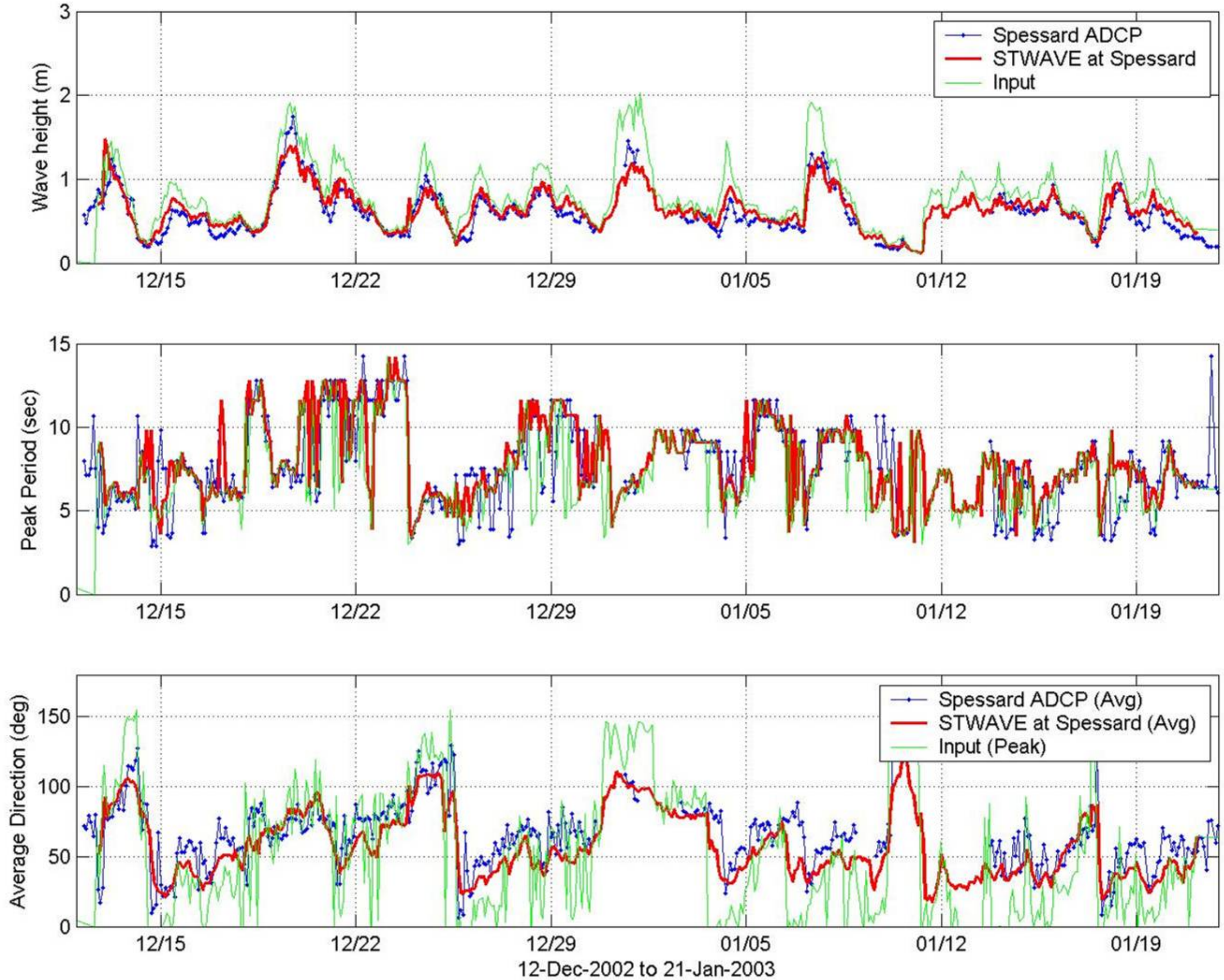
Bed Composition	Friction Factor Range (Typical)	Reference
Flat sand	0.0025 – 0.05 (0.005)	Kamphuis, 1975
Rippled sand	0.003 – 0.25 (0.10)	Nielsen, 1992
Reef	0.05 – 0.25 (0.15)	Gerritsen, 1980


ADCP Directional Wave Distribution Time Series with NDBC 41009 Wind Direction Markers
Wave and Wind Directions (deg)
Wind Speed (m/s)
Dissipation
Peak Period (s)
Wave Height (m)
10/28 10/29 10/30 10/31 11/01 11/02 11/03 11/04 11/05 11/06 11/07 11/08 11/09 11/10 11/11 11/12 11/13 11/14 11/15 11/16 11/17 11/18 11/19 11/20 11/21 11/22 11/23 11/24 11/25

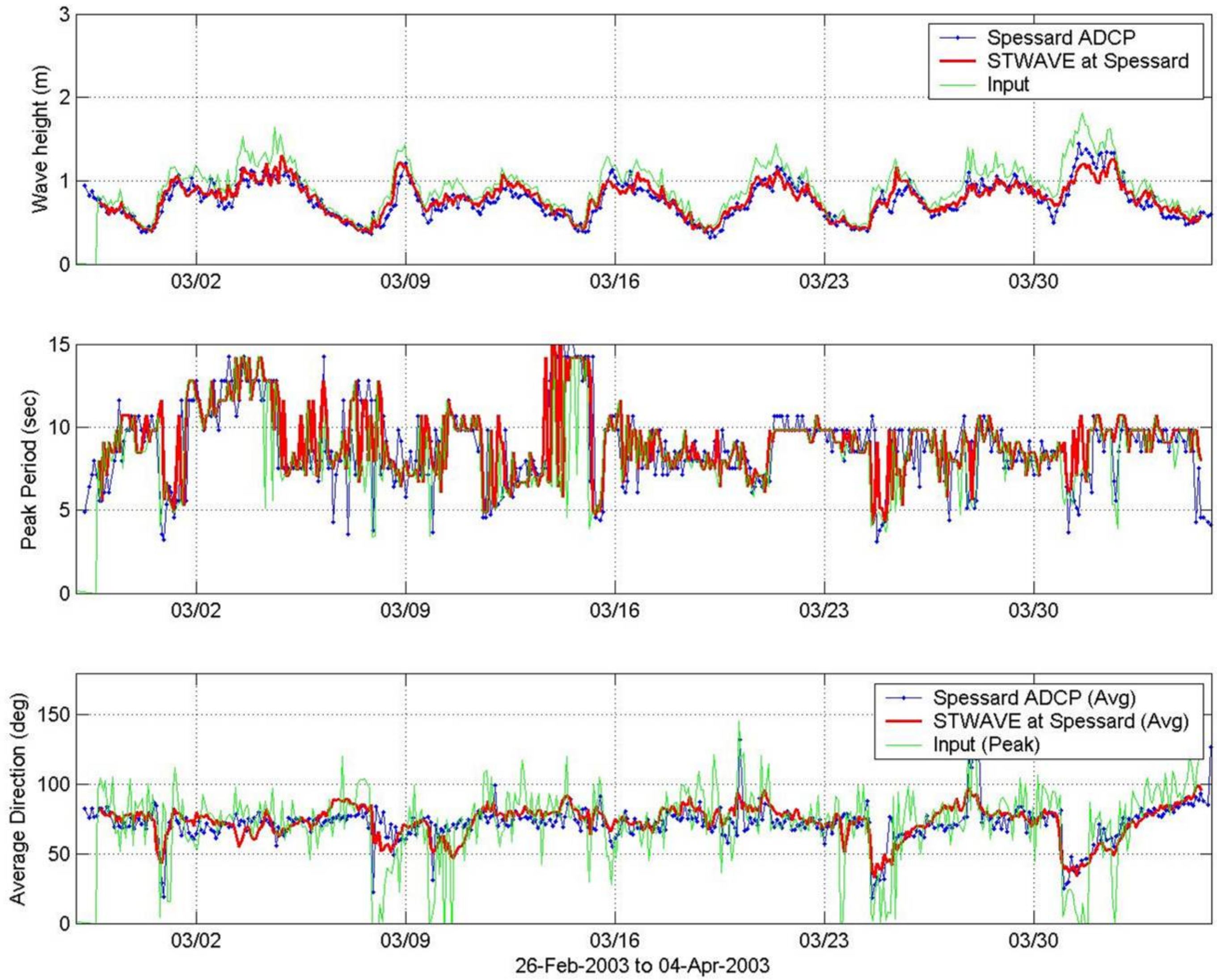

Nearshore ADCP Data
Samples = 55
Mean = 0.97618
Median = 0.95
Max = 1.38
Min = 0.66
STWAVE Wave Heights, Friction = 0.000
Samples = 55
Mean = 1.1535
Median = 1.15
Max = 1.59
Min = 0.93
STWAVE Wave Heights, Friction = 0.05
Samples = 55
Mean = 0.82091
Median = 0.82
Max = 1.07
Min = 0.69
STWAVE Wave Heights, Friction = 0.1
Samples = 55
Mean = 0.63927
Median = 0.62
Max = 0.95
Min = 0.53
Wave Height Distribution (m)



Spessard ADCP
STWAVE at Spessard
Input
Wave height (m)
Peak Period (sec)
Spessard ADCP (Avg)
STWAVE at Spessard (Avg)
Input (Peak)
Direction (deg)
10/27
11/03
11/10
11/17
11/24
27-Oct-2002 to 25-Nov-2002



Spessard ADCP
STWAVE at Spessard
Input
Wave height (m)
3
2
1
0
12/15
12/22
12/29
01/05
01/12
01/19
Peak Period (sec)
15
10
5
0
12/15
12/22
12/29
01/05
01/12
01/19
Spessard ADCP (Avg)
STWAVE at Spessard (Avg)
Input (Peak)
Average Direction (deg)
150
100
50
0
12/15
12/22
12/29
01/05
01/12
01/19
12-Dec-2002 to 21-Jan-2003


Spessard ADCP
STWAVE at Spessard
Input
Wave height (m)
Peak Period (sec)
Spessard ADCP (Avg)
STWAVE at Spessard (Avg)
Input (Peak)
Average Direction (deg)
03/02
03/09
03/16
03/23
03/30
26-Feb-2003 to 04-Apr-2003