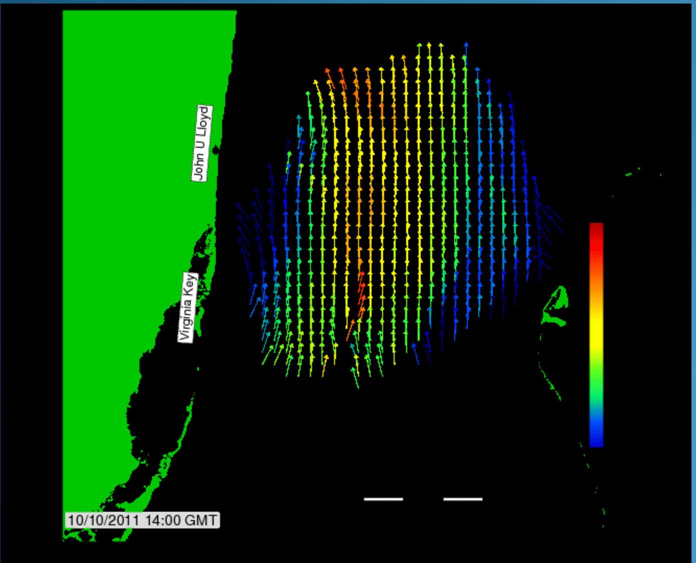
HF Radar Wave Measurements in a High Surface Current Environment

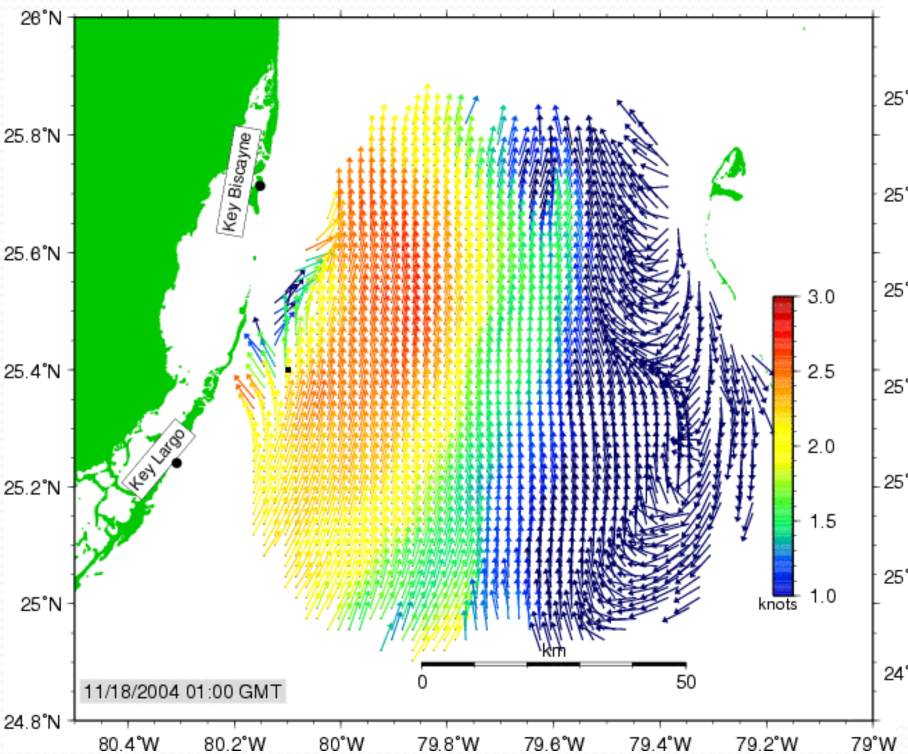
Brian K. Haus

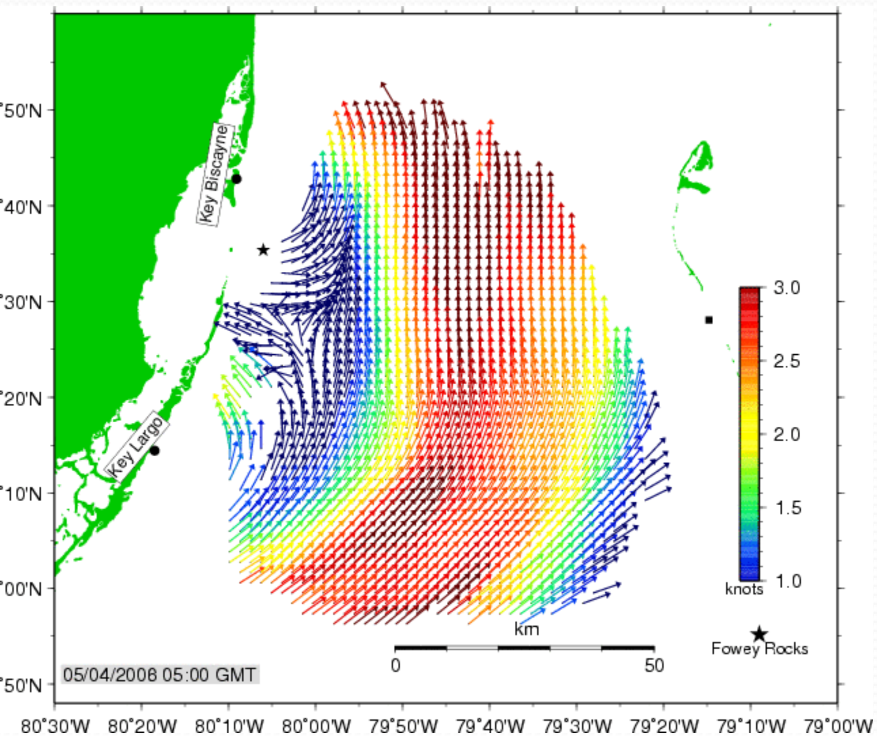
Nick Shay, Jorge Martinez, Mei Wang



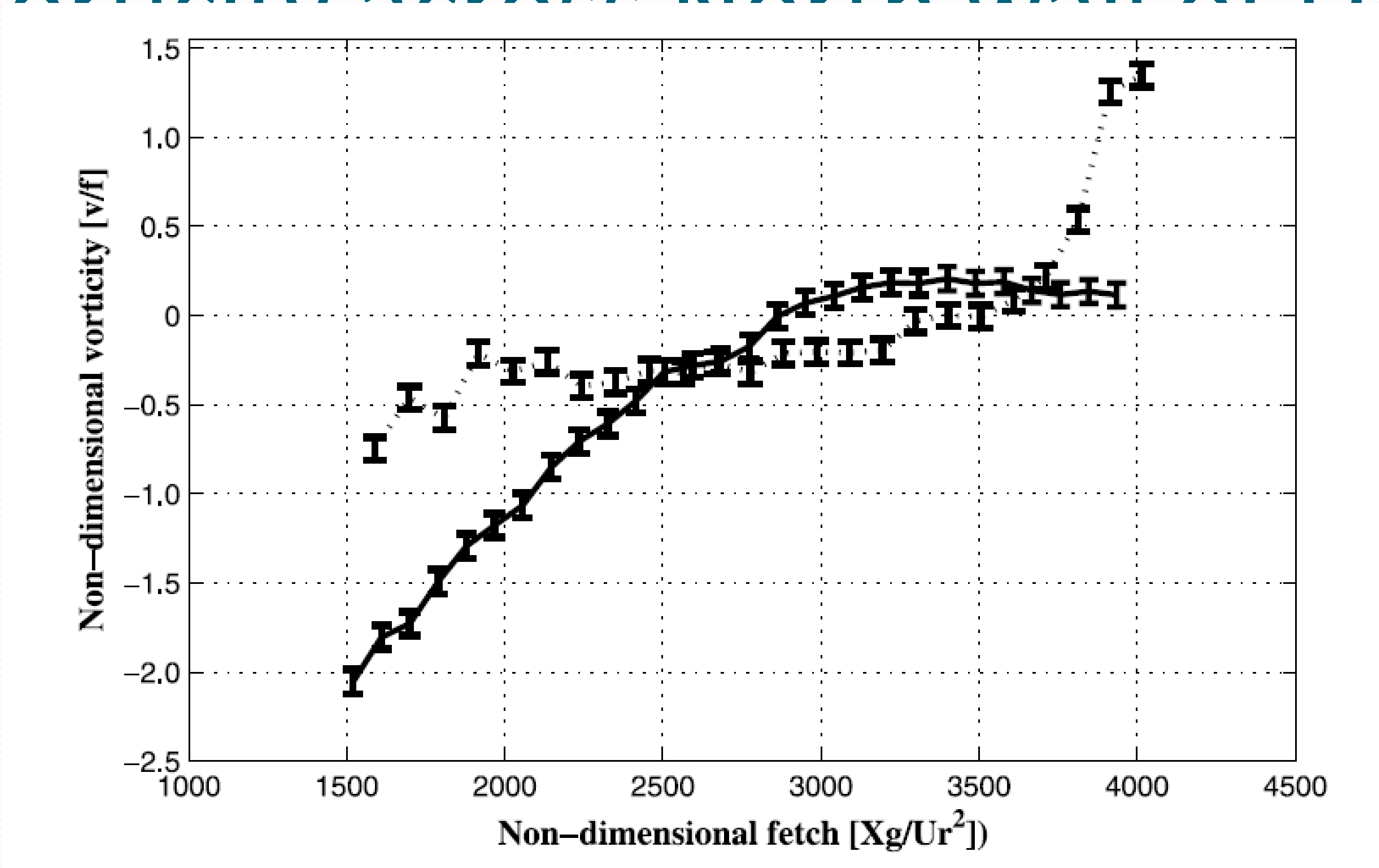
Should it matter?

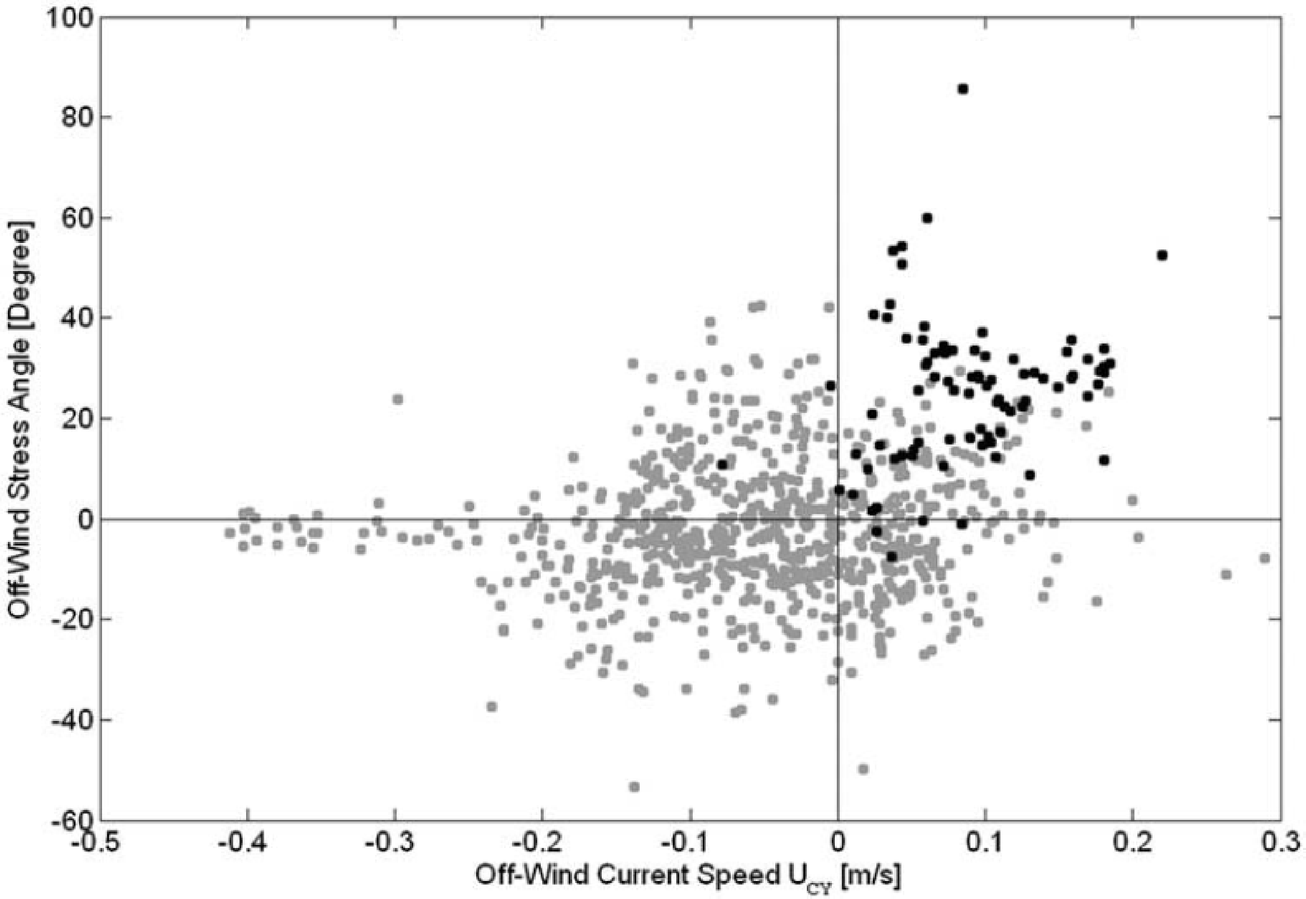
- Radars measure currents, cant we correct for any deficiences? Yes but .....
- Possible sources of errors
  - Current shear → multiple 1^{st} order peaks
    - Issue for both waves and currents
      - Nadai (2006)
  - Current shear → sidelobes
- Wave direction not necessarily in Wind direction.


26°N
25.8°N
25.6°N
25.4°N
25.2°N
25°N
24.8°N
80.4°W
80.2°W
80°W
79.8°W
79.6°W
79.4°W
79.2°W
79°W
Key Biscayne
Key Largo
3.0
2.5
2.0
1.5
1.0
knots
km
0
50
11/18/2004 01:00 GMT


25°50'N
25°40'N
25°30'N
25°20'N
25°10'N
25°00'N
24°50'N
80°30'W
80°20'W
80°10'W
80°00'W
79°50'W
79°40'W
79°30'W
79°20'W
79°10'W
79°00'W
Key Biscayne
Key Largo
3.0
2.5
2.0
1.5
1.0
knots
km
0
50
Fowey Rocks
05/04/2006 05:00 GMT

Vorticity across North wall of FC

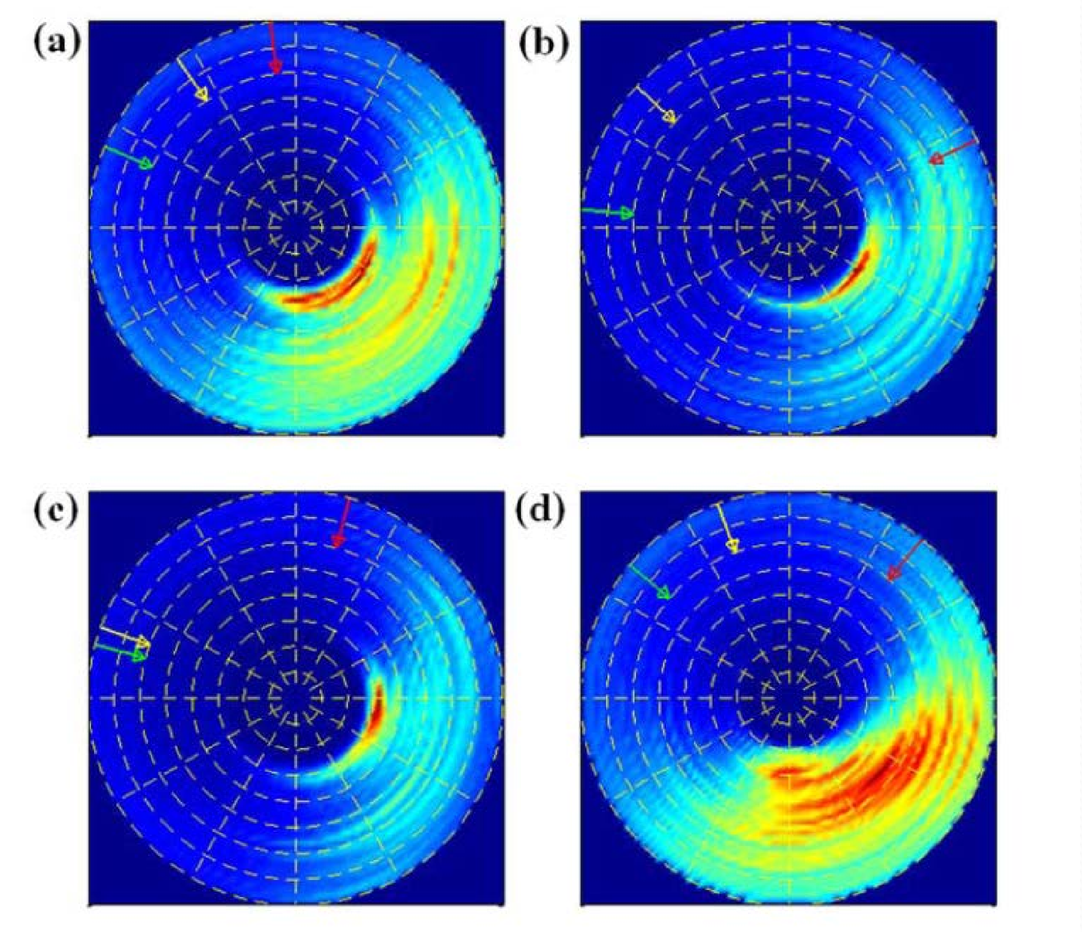




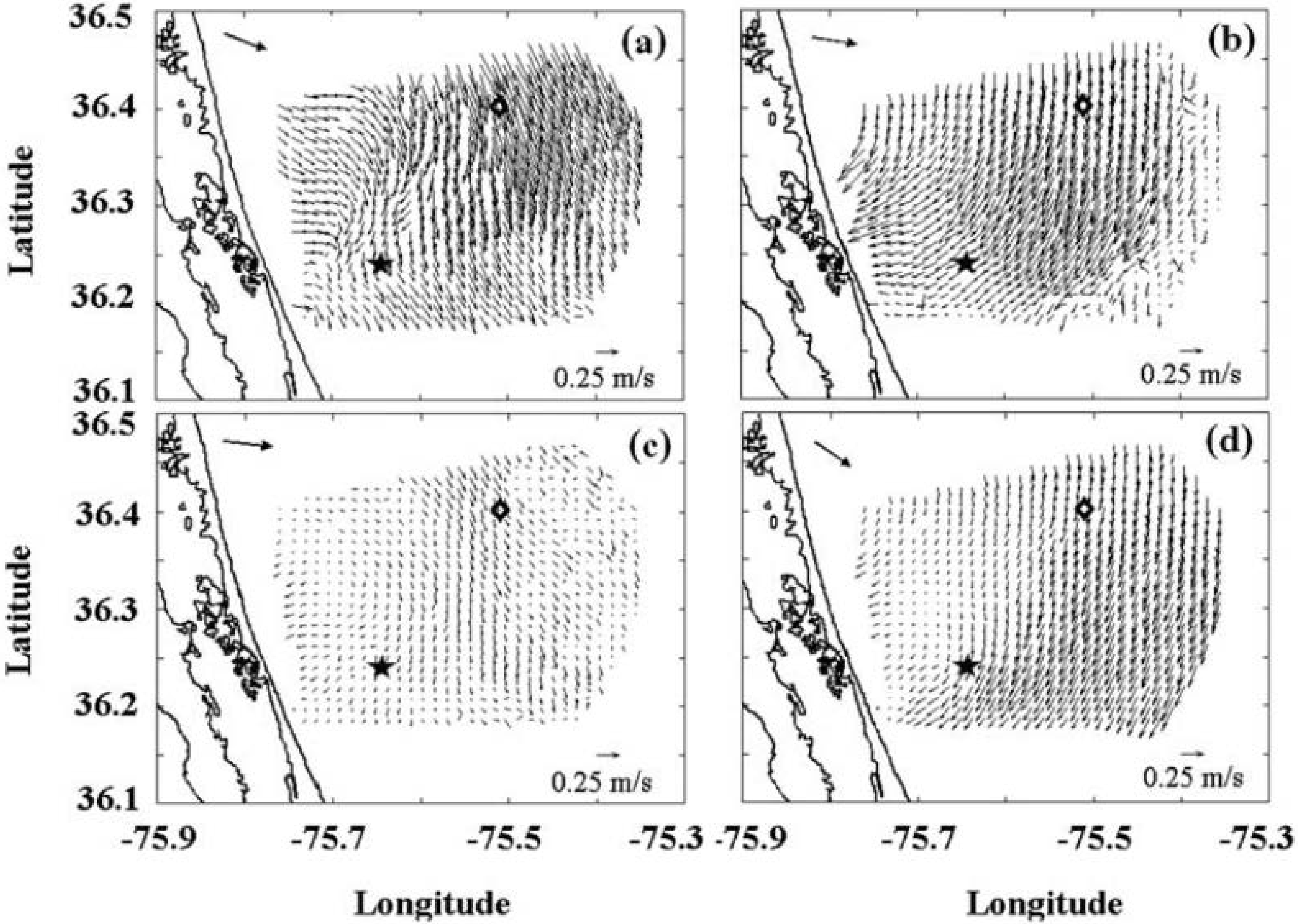
Buoy data from Showex 1999, Zhang et al. (2009)

Wave refraction by sheared currents

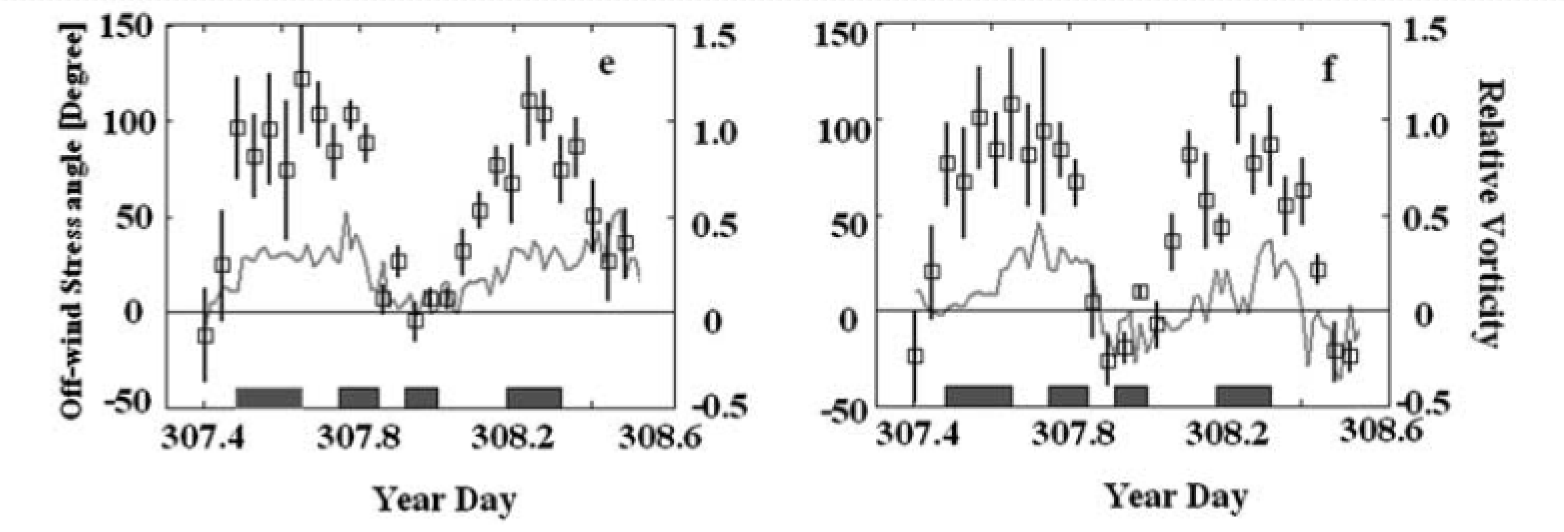
- Short waves most strongly impacted by current shear
- However short waves have smallest relaxation times.



Green- wind direction, yellow – wind stress, red – current direction



OSCR current vector maps for the four time periods identified in Figure 6 (a for A, etc). The two ASIS buoys Bravo (star) and Yankee (diamond) located in the scanning domain of OSCR are indicated. The arrows at the upper-left corners indicate the average wind direction. The velocity scale in the lower right refers to the current vector.



Off-wind Stress angle [Degree]
150
100
50
0
-50
1.5
1.0
0.5
0
-0.5
e
307.4
307.8
308.2
308.6
Year Day
150
100
50
0
-50
1.5
1.0
0.5
0
-0.5
f
Relative Vorticity
307.4
307.8
308.2
308.6
Year Day

S

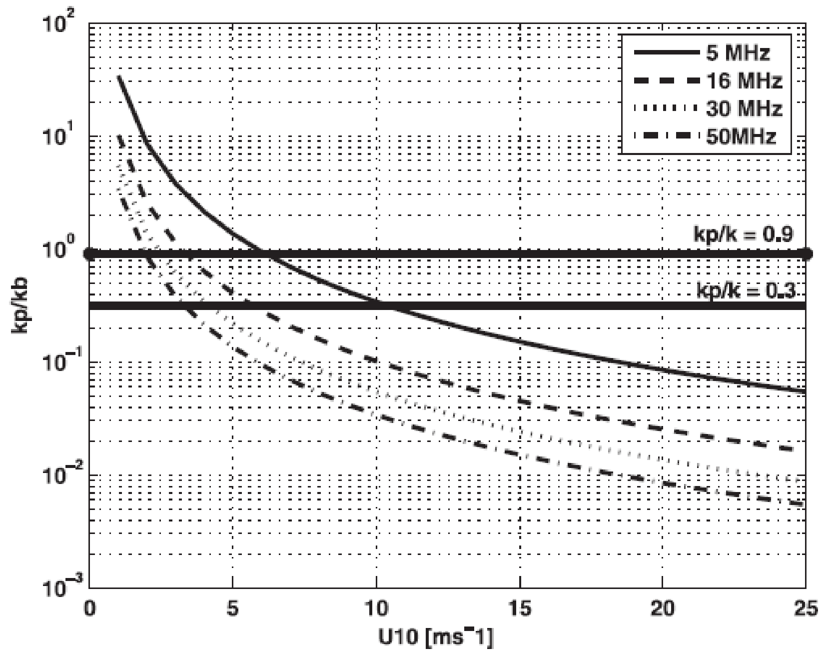
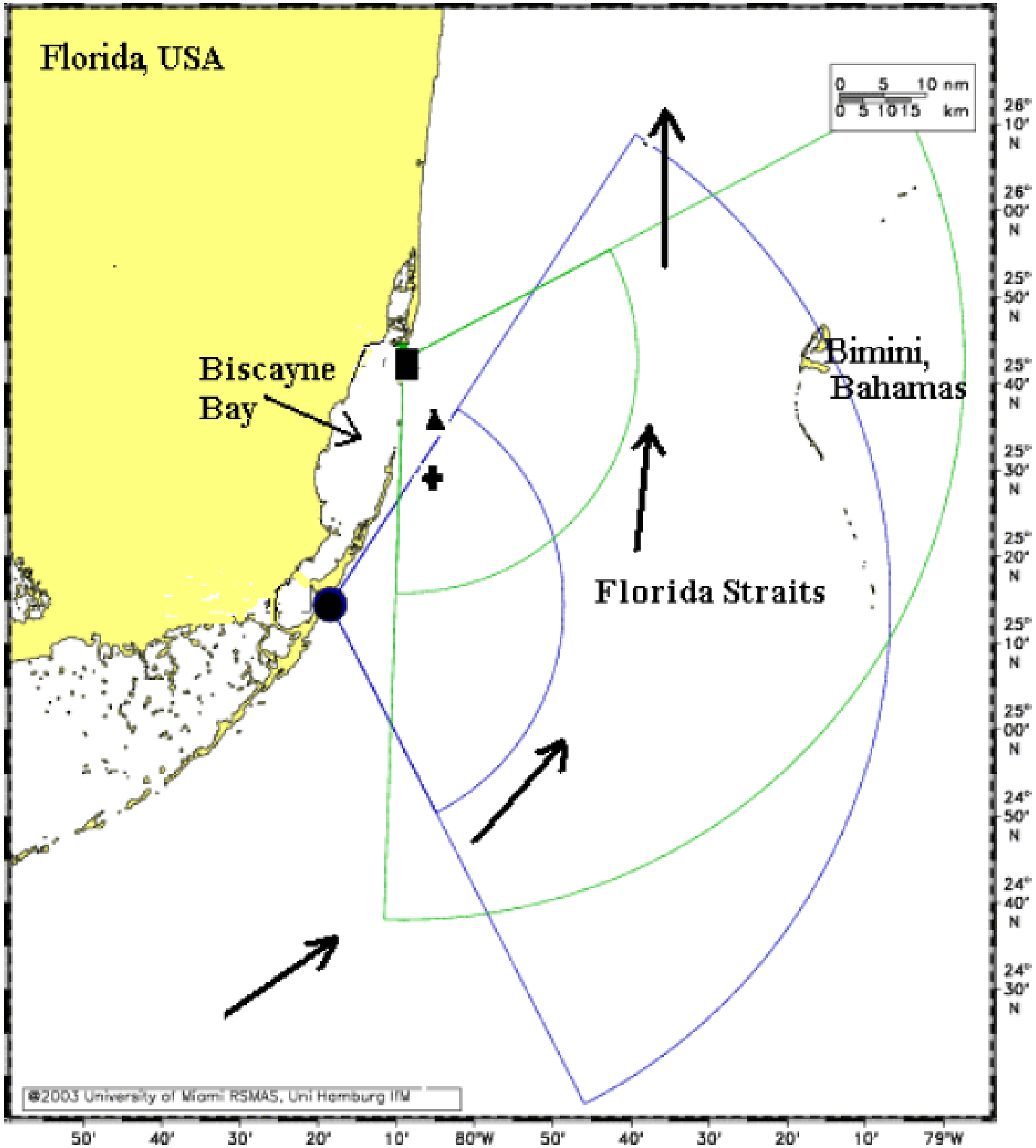


FIG. 2. Wind speed dependence of the ratio of the Bragg scattering wavenumber at various HF and VHF frequencies to the wavenumber of the spectral peak as calculated from Donelan and Pierson (1987). Wavenumbers of inflection points ($k_p/k = 0.3, 0.9$) in the Donelan et al. (1985) directional spreading function are shown.

Datasets:

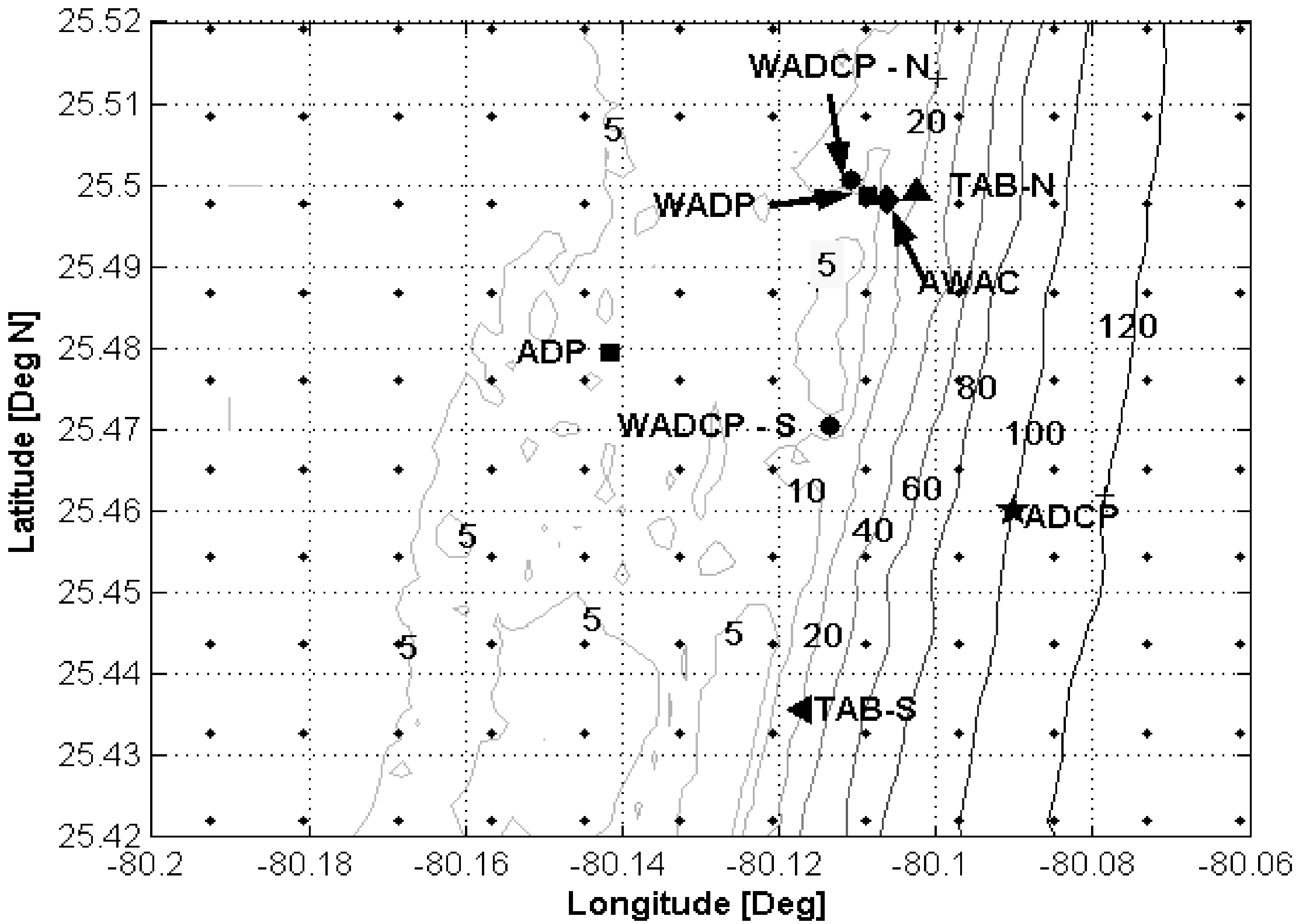
- Mini-waves Experiment
- Other Datasets

University of Miami WERA system	
Operating frequency	16.045 MHz
Peak transmitted power	30 W
Bragg wavelength	9.35 m
Nominal measurement depth	0.8 m
Operating range	80–120 km
Range resolution	1.2 km
Integration time	5 min
Azimuthal resolution (3-dB down)	2°
Accuracy of radial current component	0.02 m s^{-1}

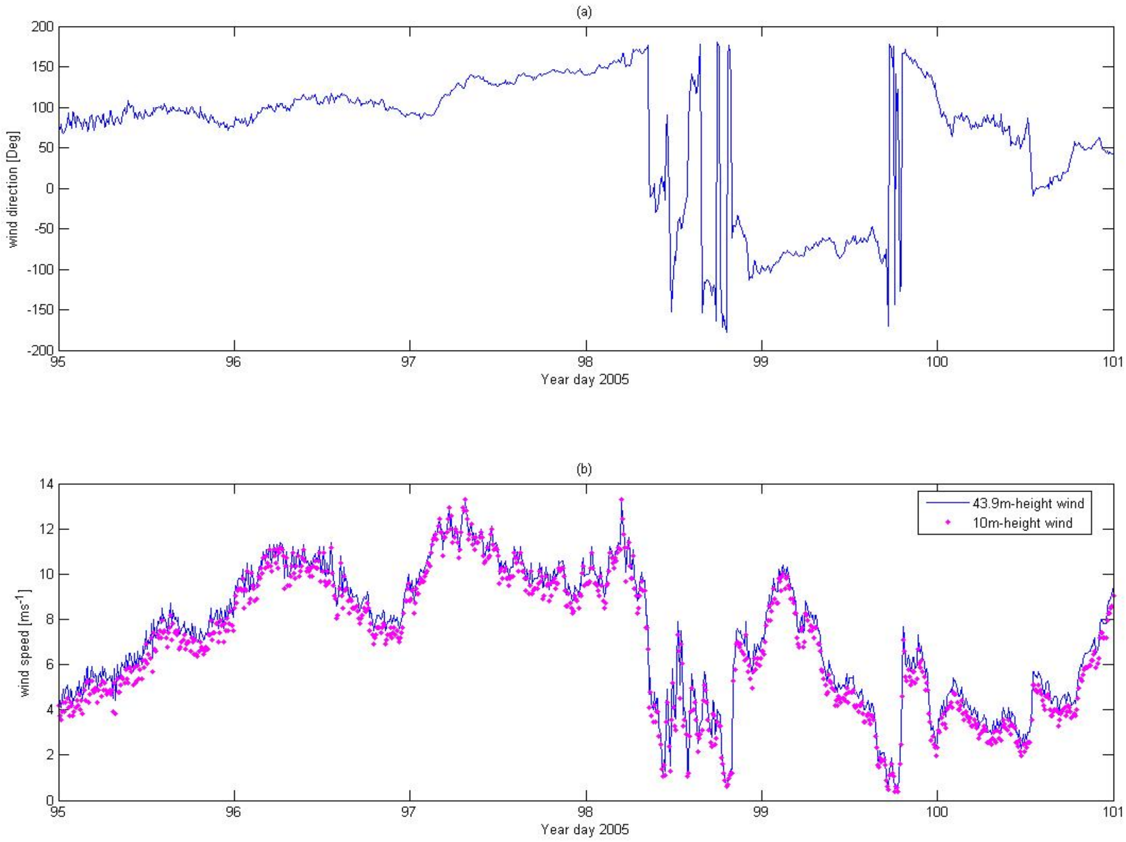


WERA characteristics:

Frequency~16.045 MHz
Bragg wavelength~9.35 m
Range cell resolution~1.2 km
Range for current~80-120 km
Range for wave~40-60 km
Integration time~5 minutes
Azimuthal resolution~2º



Expanded view of in-situ measurement locations
during Mini-Waves Cal-Val experiment



YD 95-YD 98
$4ms^{-1}$—$14ms^{-1}$

FWFY1 CMAN station observed winds at height of 43.9 m above MWL from April 5th to 10th, 2005

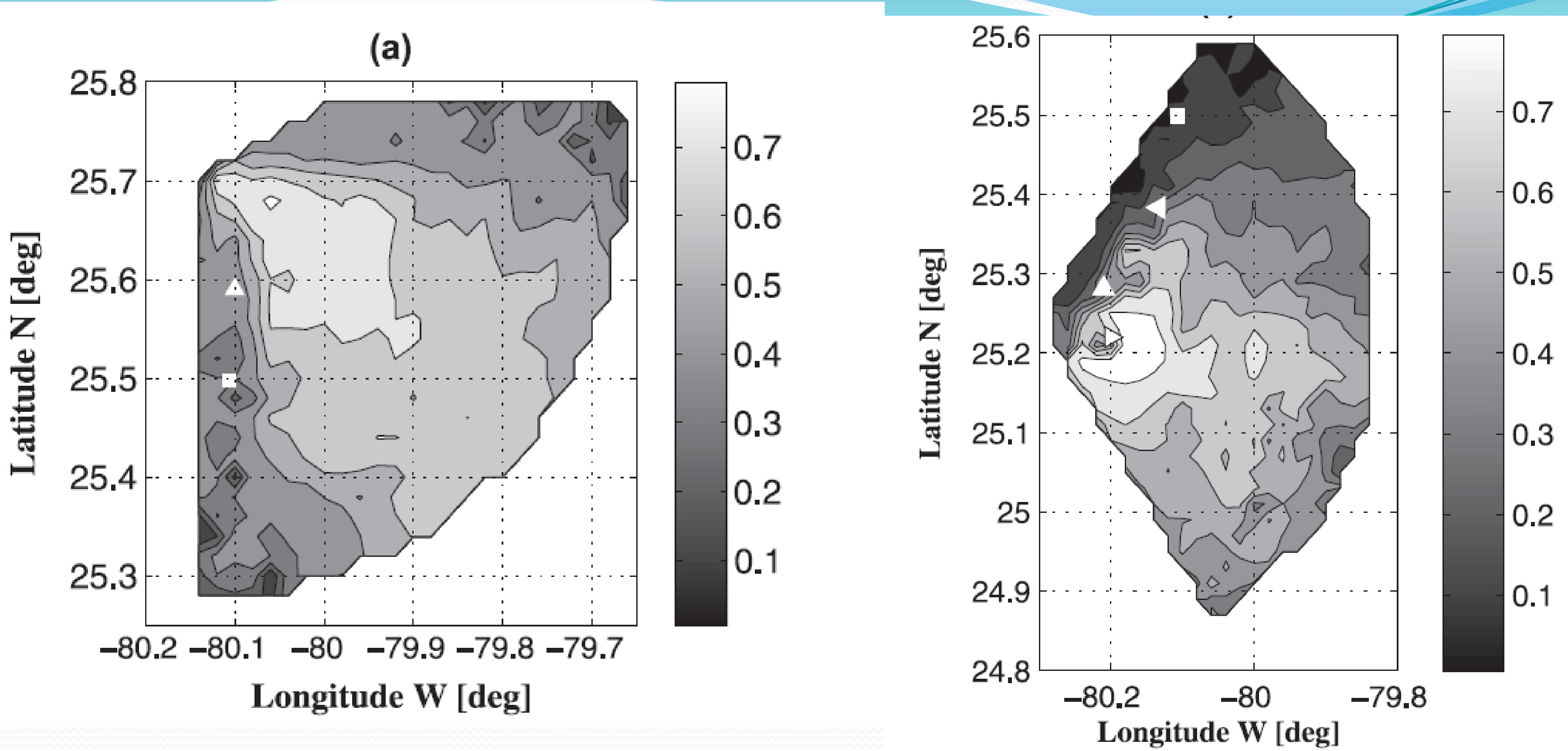
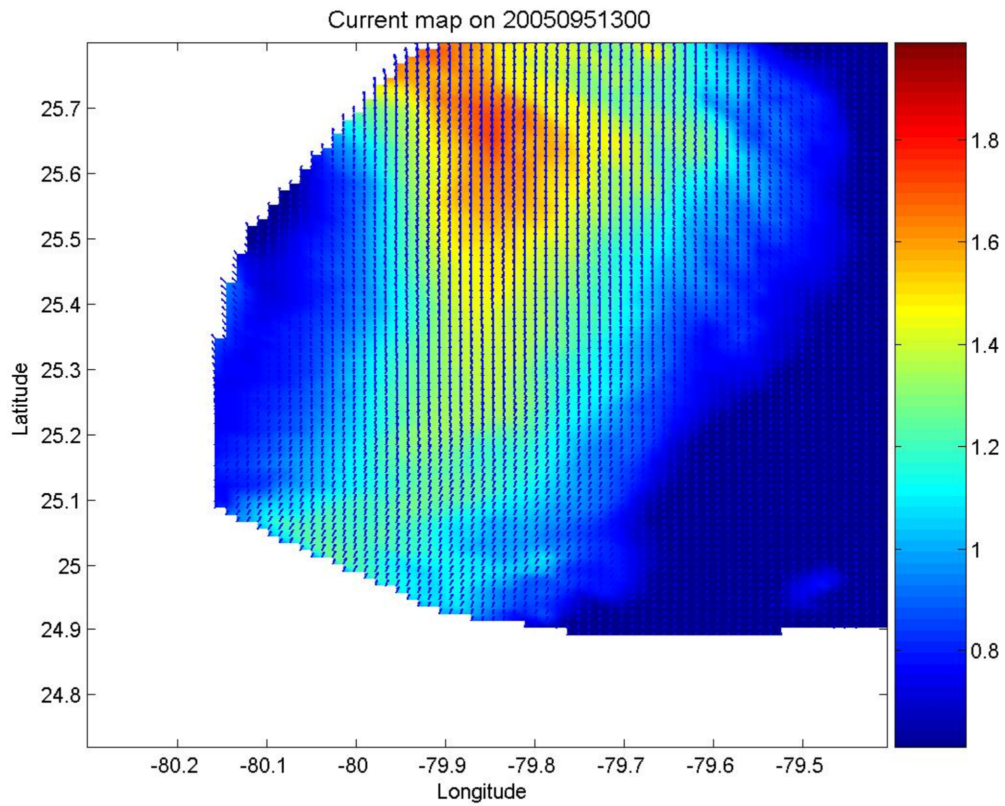


FIG. 5. Linear correlation coefficient for wave height extracted from single-site observations from each individual WERA cell and WADP from YD 79 to 100 2005. Grayscale indicates correlation coefficient. The position of WADP within each radar measurement domain is marked (white ■). (a) CDN to WADP correlation coefficients. The location of the Fowey Rocks CMAN station is marked (white ▲). (b) NKL to WADP correlation coefficients. The location of Turtle Reef (white ▲), Ajax reef (white ◀), and Carysfort Reef Light (white ▶) are marked.

TABLE 2. Linear correlation coefficients for H_s between all available platforms obtained during the validation period (YD 100–145). "WERA-CDN" and "WERA-NKL" were obtained using the cell that was best correlated with Sontek during calibration (YD 75–99). "WERA-both" is the average of the two single-site results.

	TAB-N	TAB-S	SNTK	RDI-N	RDI-S	WERA-NKL	WERA-CDN	WERA-Both
TAB-N	1							
TAB-S	0.97	1						
SNTK	0.93	0.93	1					
RDI-N	0.95	0.94	0.93	1				
RDI-S	0.95	0.95	0.92	0.95	1			
WERA-NKL	0.80	0.81	0.83	0.80	0.80	1		
WERA-CDN	0.71	0.70	0.72	0.71	0.70	0.59	1	
WERA-Both	0.85	0.85	0.86	0.85	0.84	0.91	0.87	1

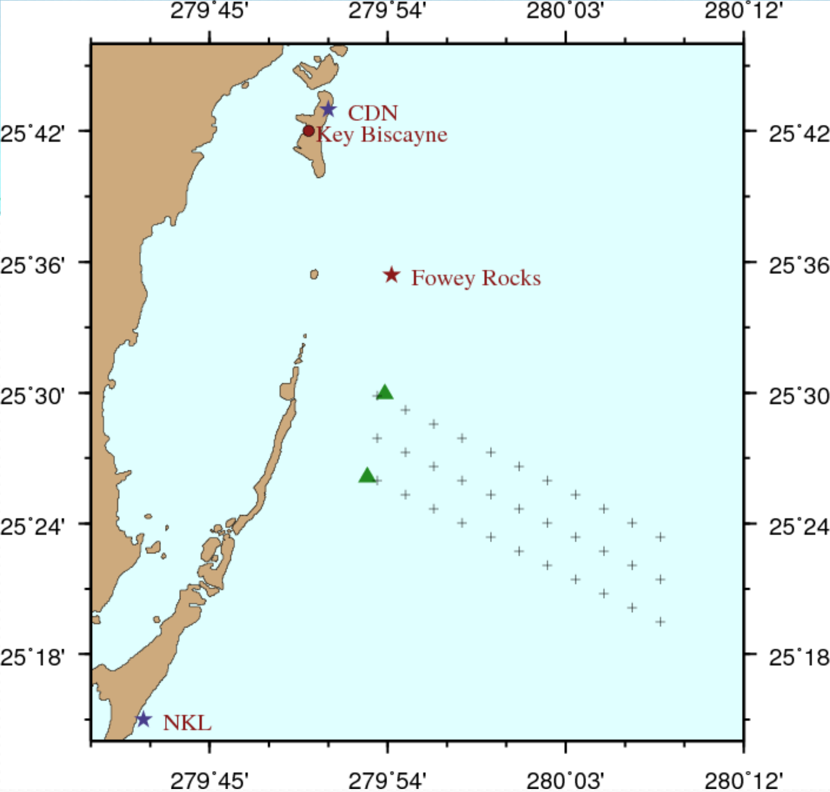
SWAN model: Initial tests



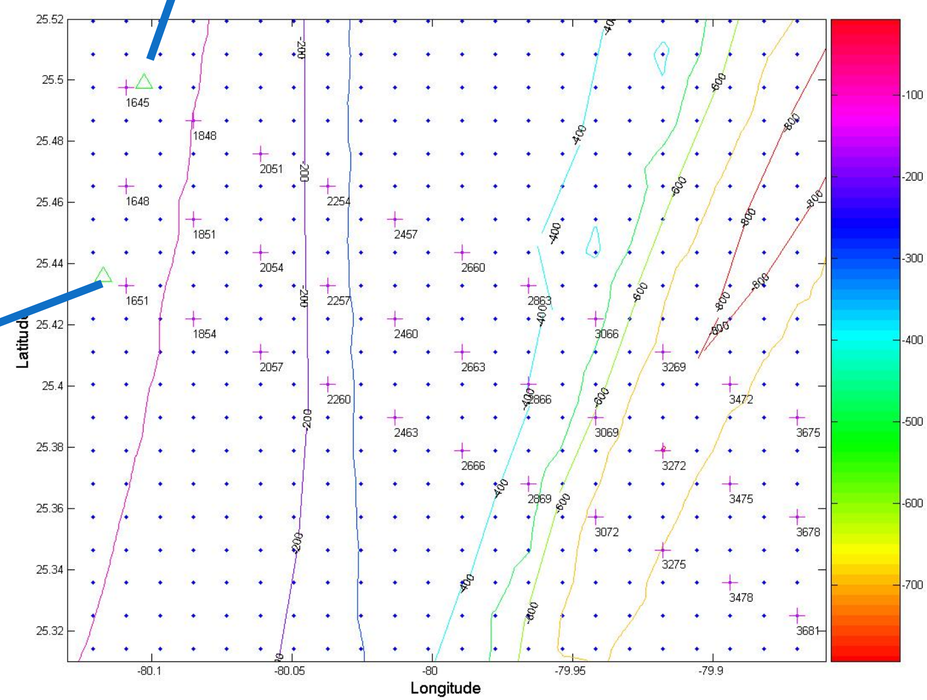
Current map obtained by WERA on 1300 GMT, April 5th, 2005

SWAN setup:

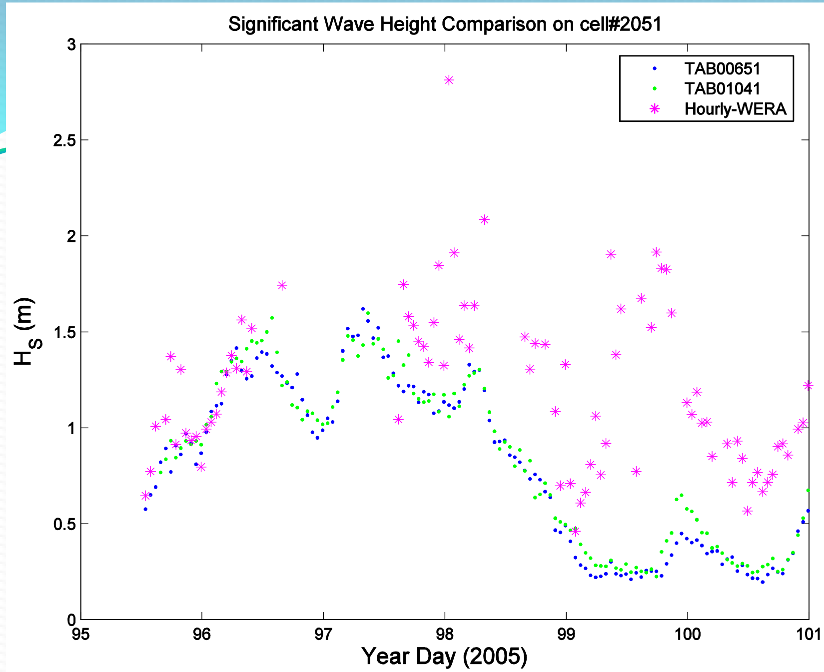
-use hourly-averaged wind field (FWFY1) as initial wind forcing;
-use a uniform wind field;
-use current field from WERA as an input;
-spatial resolution:
longitude ~ 3.66 km
latitude ~ 4.86 km;
-frequency resolution ~ 0.01 Hz;
-azimuthal resolution ~ 10 degree

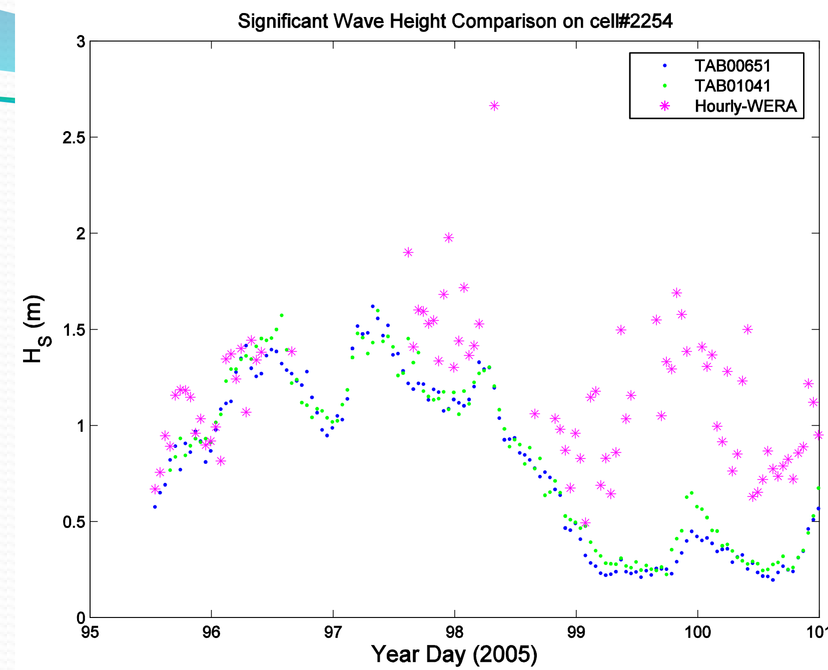


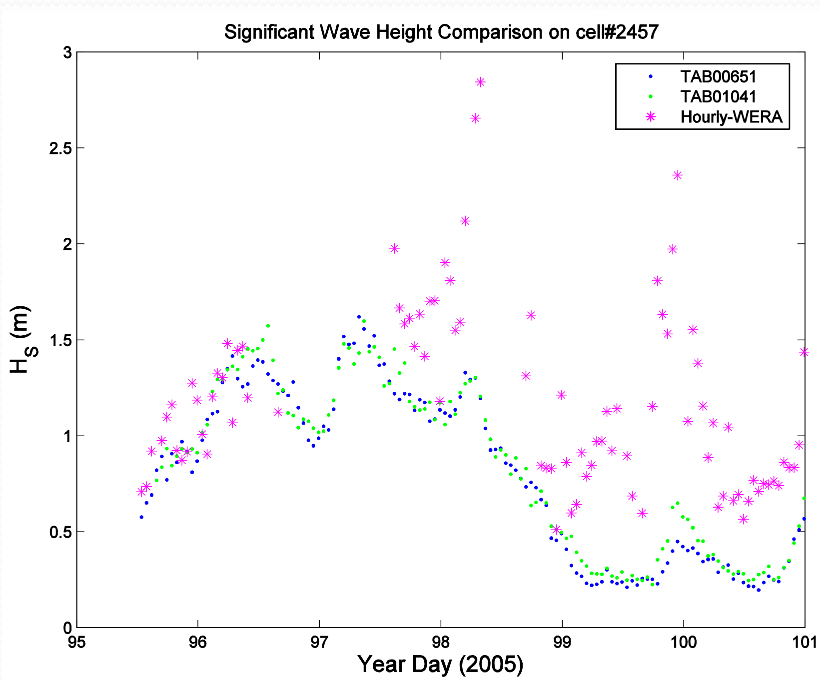
TAB01041—TAB-N

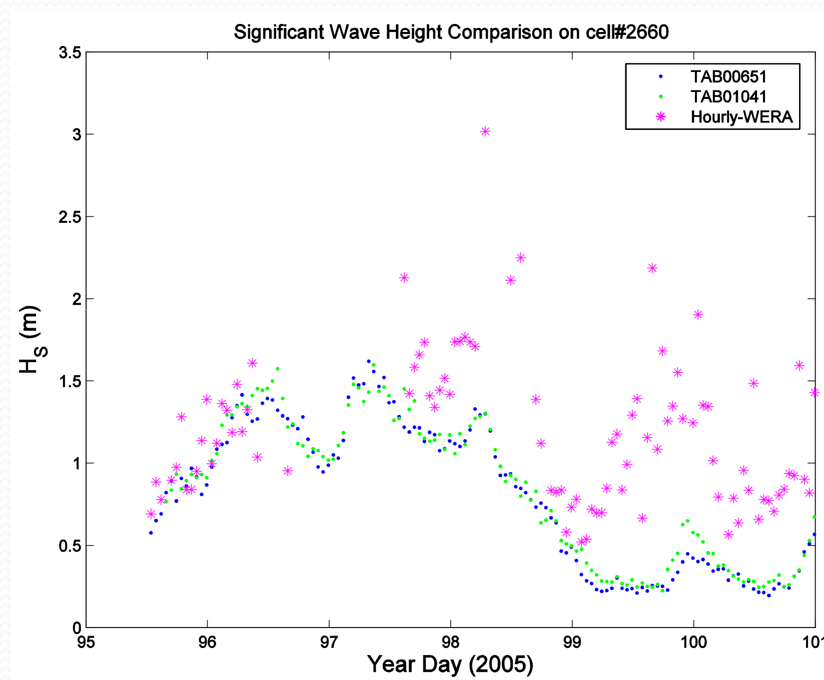


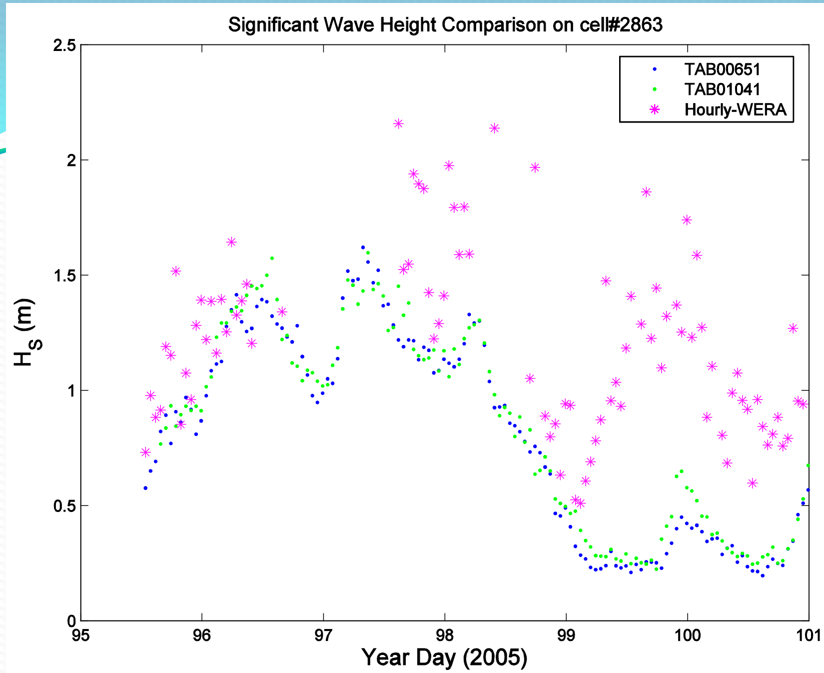
TAB00651—TAB-S

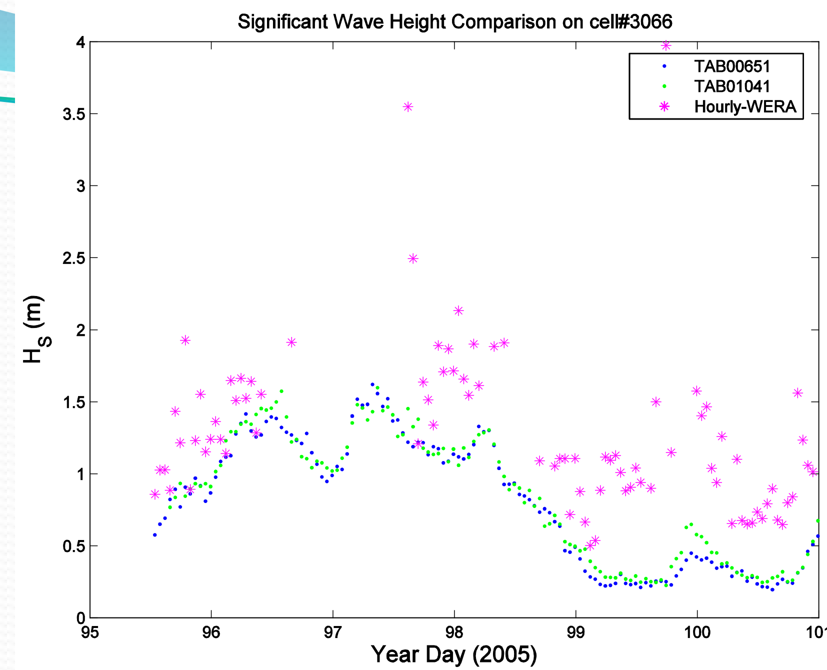

Significant Wave Height Comparison on cell#2051
TAB00651
TAB01041
Hourly-WERA
H_S (m)
0
0.5
1
1.5
2
2.5
3
95
96
97
98
99
100
101
Year Day (2005)

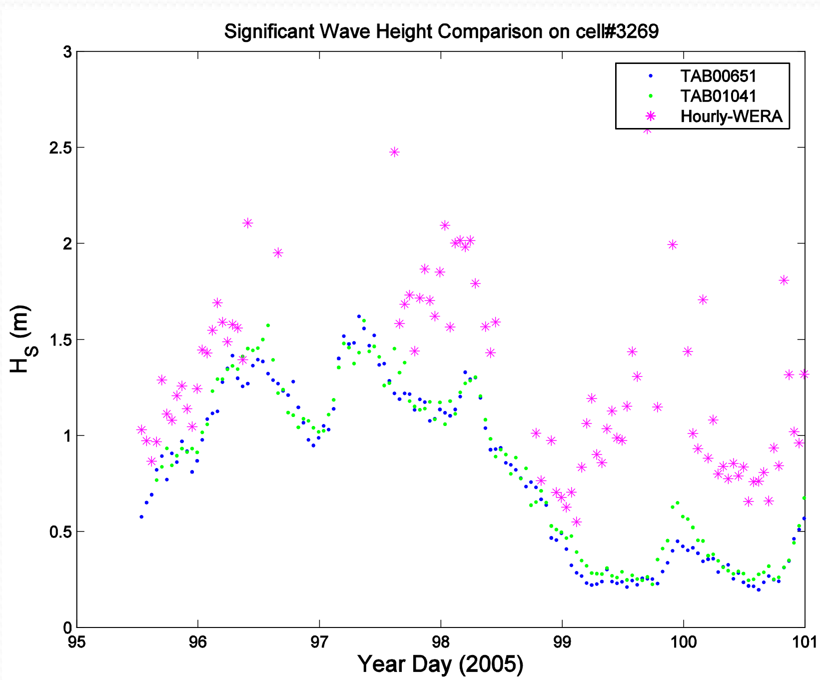

Significant Wave Height Comparison on cell#2254
TAB00651
TAB01041
Hourly-WERA
H_S (m)
0
0.5
1
1.5
2
2.5
3
95
96
97
98
99
100
101
Year Day (2005)

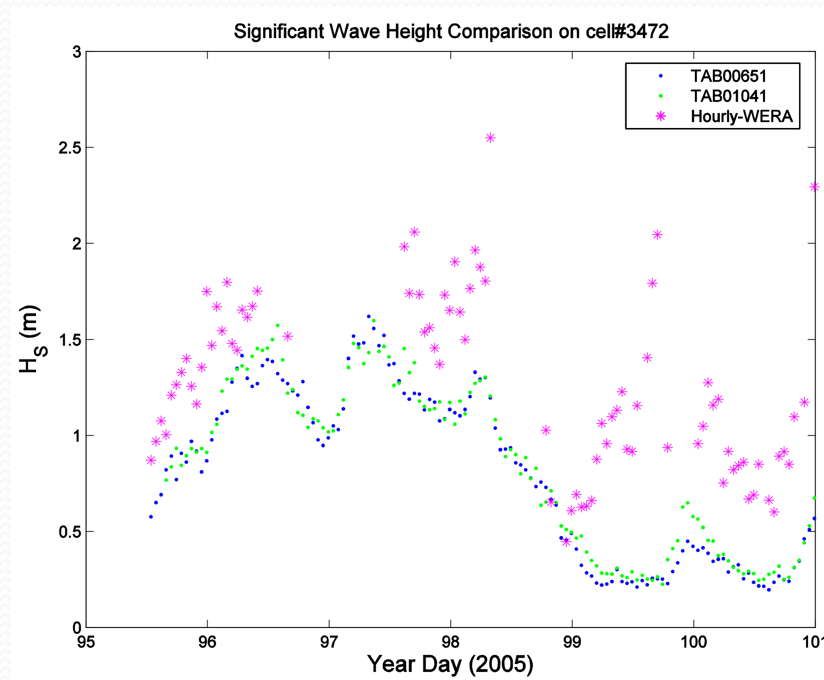

Significant Wave Height Comparison on cell#2457
TAB00651
TAB01041
Hourly-WERA
H_S (m)
0
0.5
1
1.5
2
2.5
3
95
96
97
98
99
100
101
Year Day (2005)

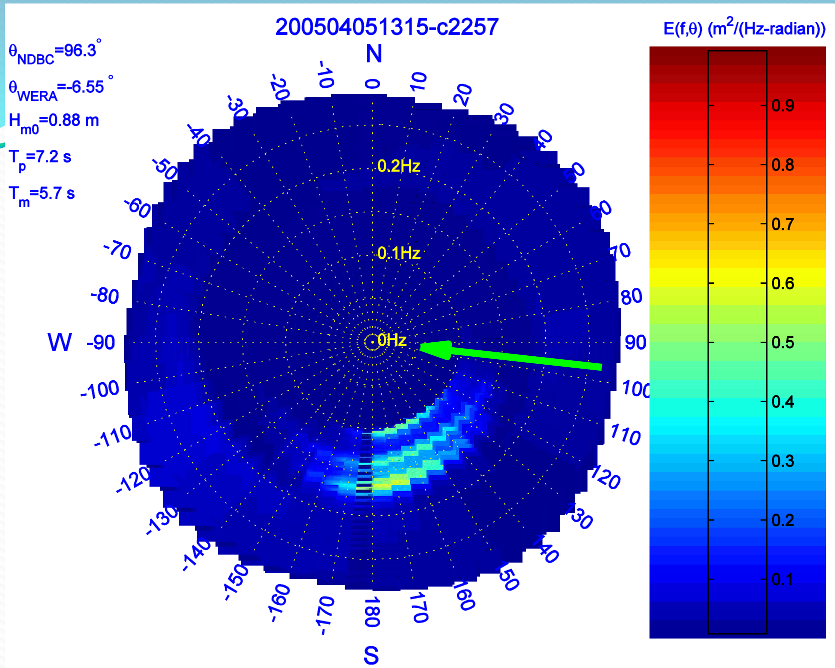

Significant Wave Height Comparison on cell#2660
TAB00651
TAB01041
Hourly-WERA
H_S (m)
0
0.5
1
1.5
2
2.5
3
3.5
95
96
97
98
99
100
101
Year Day (2005)

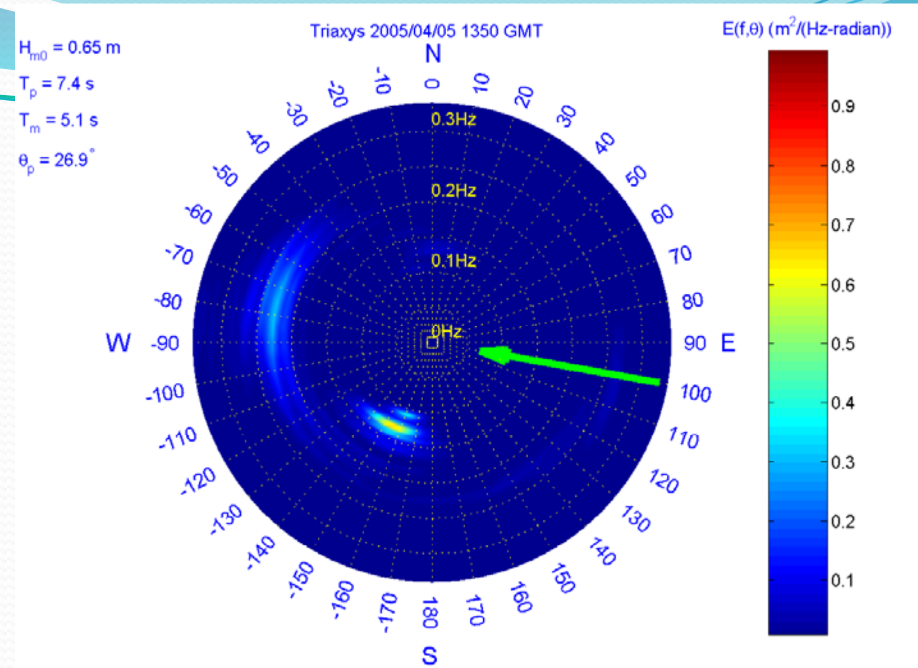

Significant Wave Height Comparison on cell#2863
TAB00651
TAB01041
Hourly-WERA
H_S (m)
Year Day (2005)

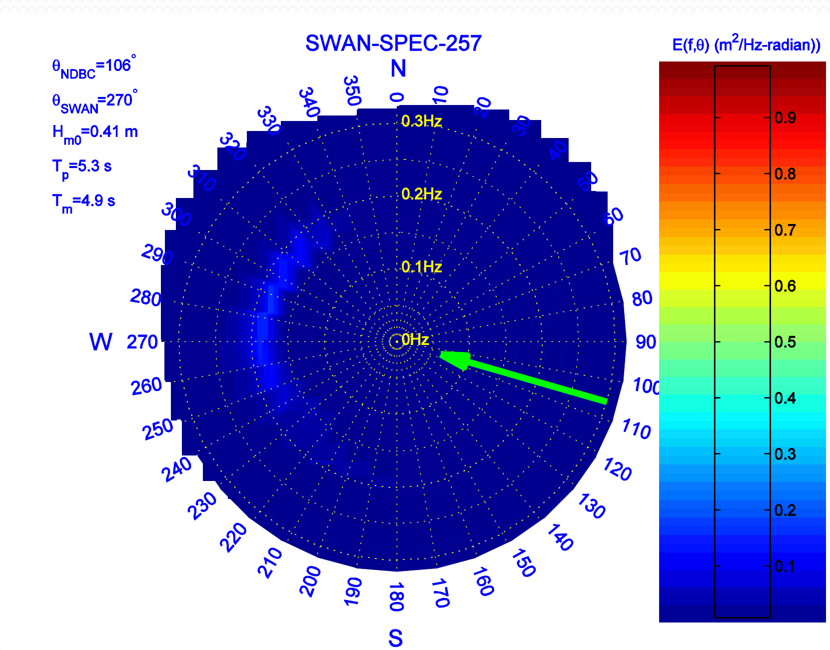

Significant Wave Height Comparison on cell#3066
TAB00651
TAB01041
Hourly-WERA
H_S (m)
Year Day (2005)


Significant Wave Height Comparison on cell#3269
TAB00651
TAB01041
Hourly-WERA
H_S (m)
Year Day (2005)

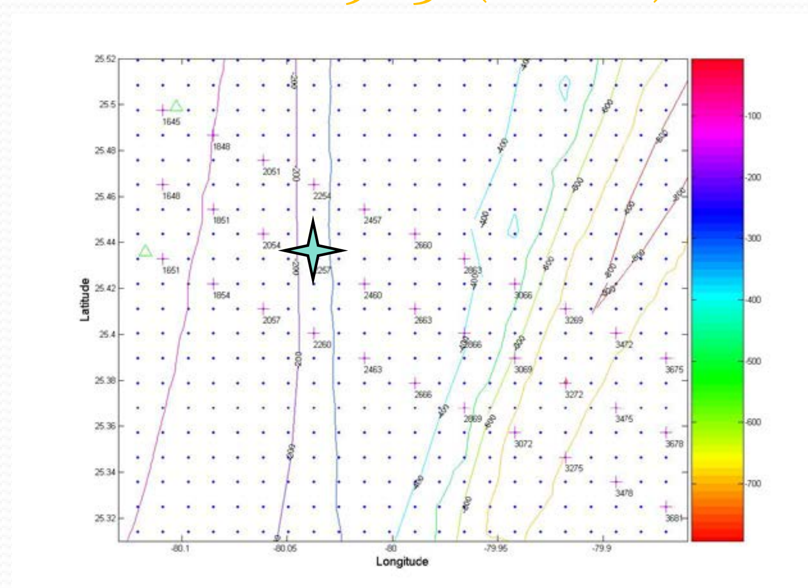

Significant Wave Height Comparison on cell#3472
TAB00651
TAB01041
Hourly-WERA
H_S (m)
Year Day (2005)

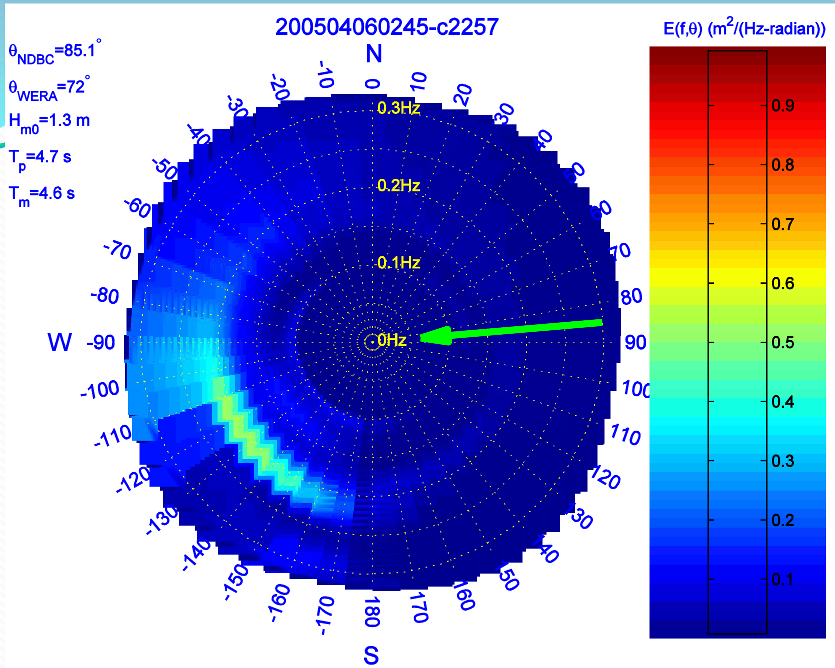


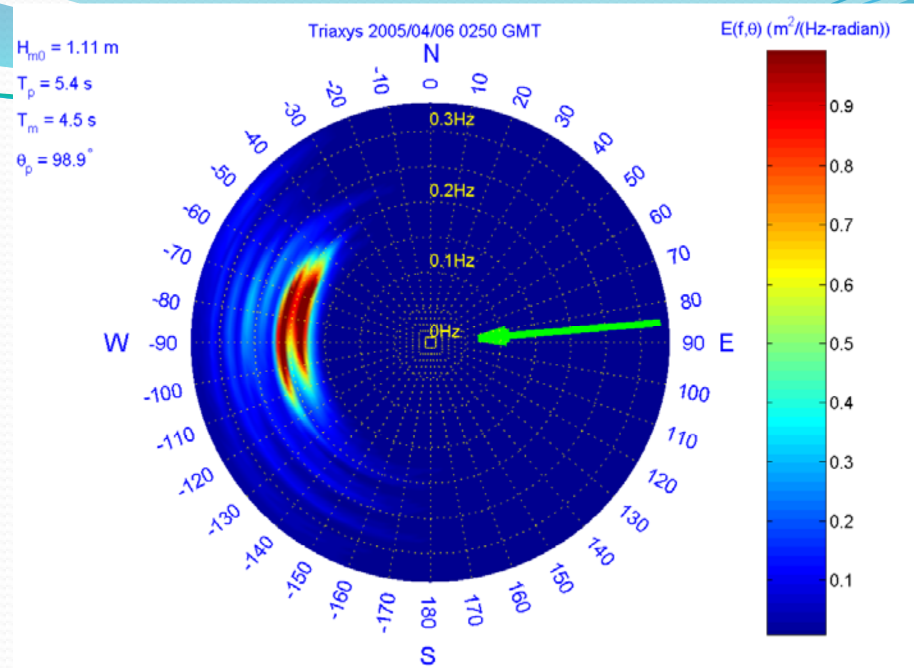


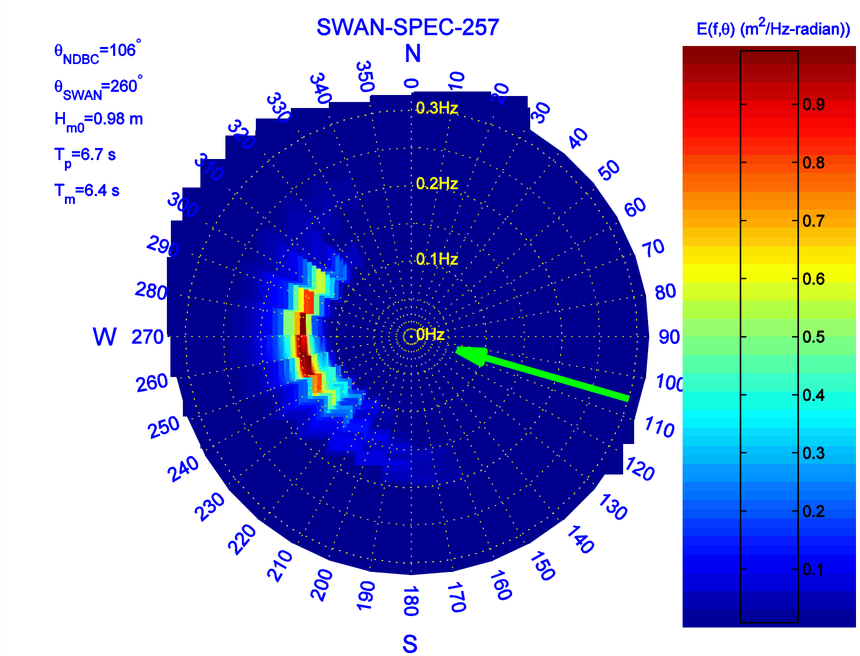


Wind direction ~ 96.3º (FWFY1)

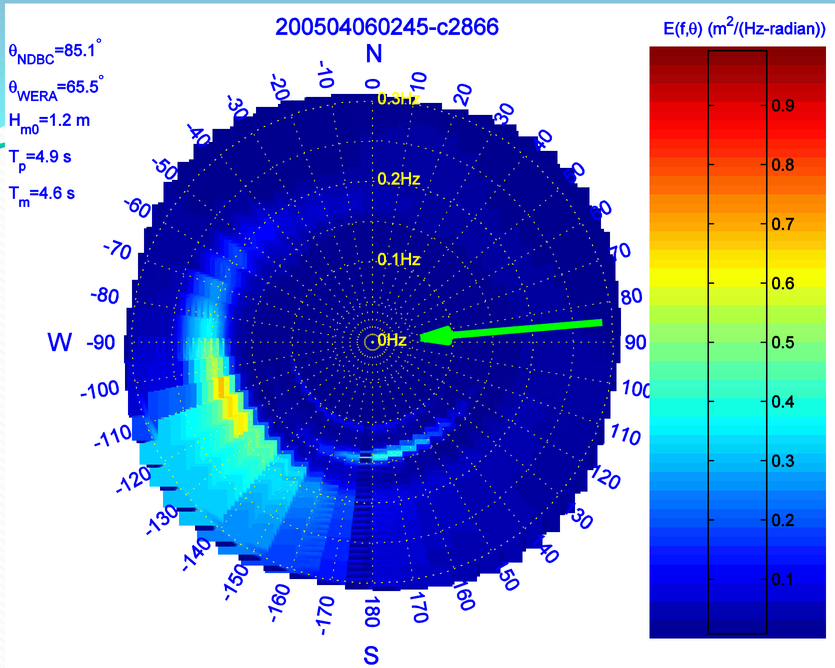


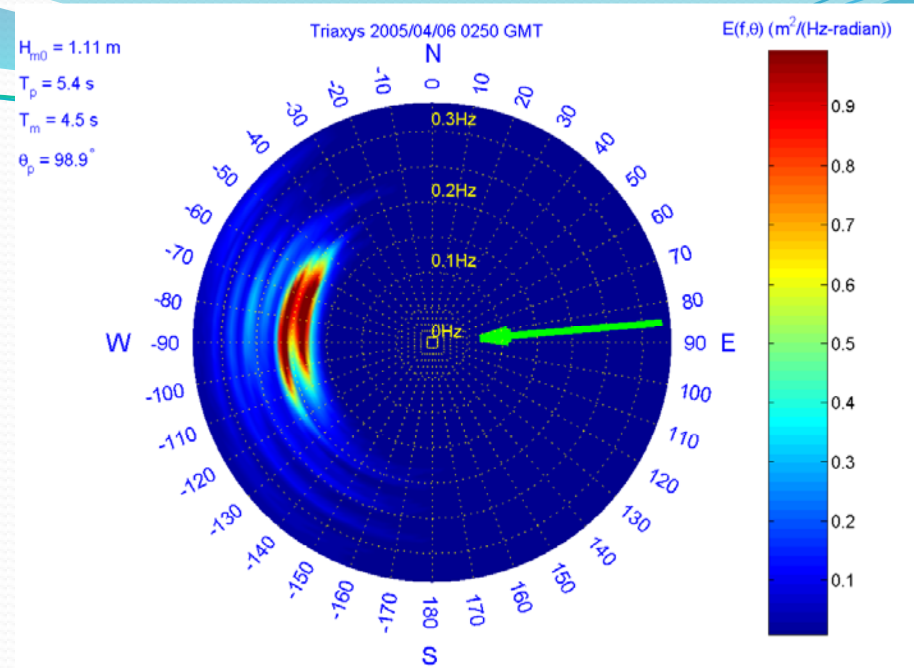


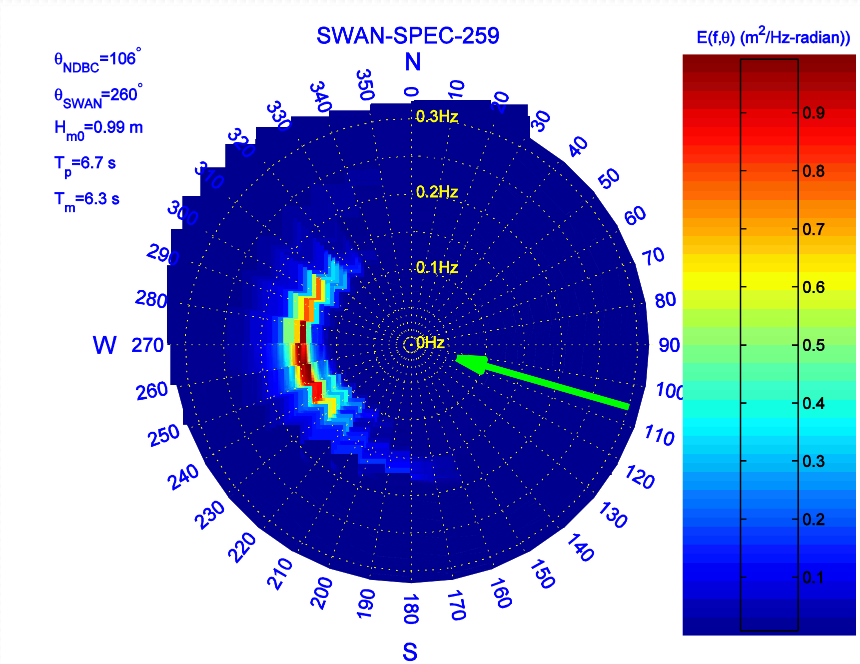




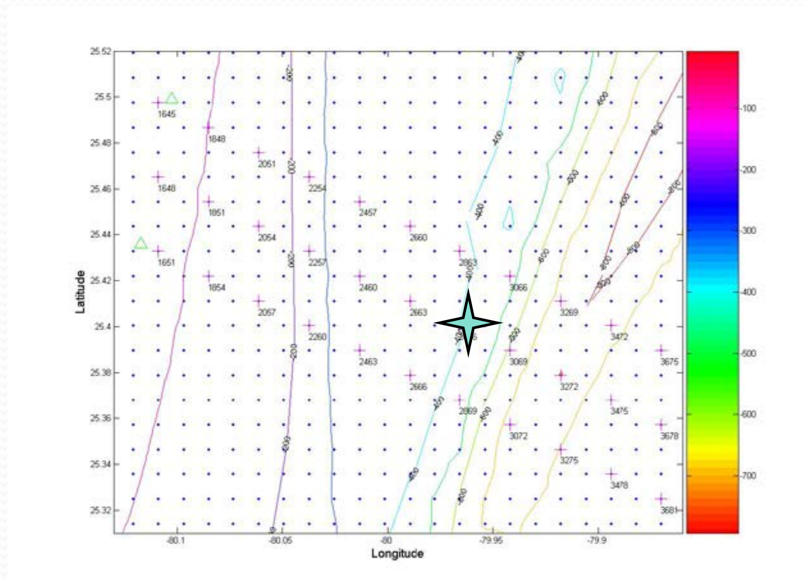
Wind direction ~ 85.1° (FWFY1)

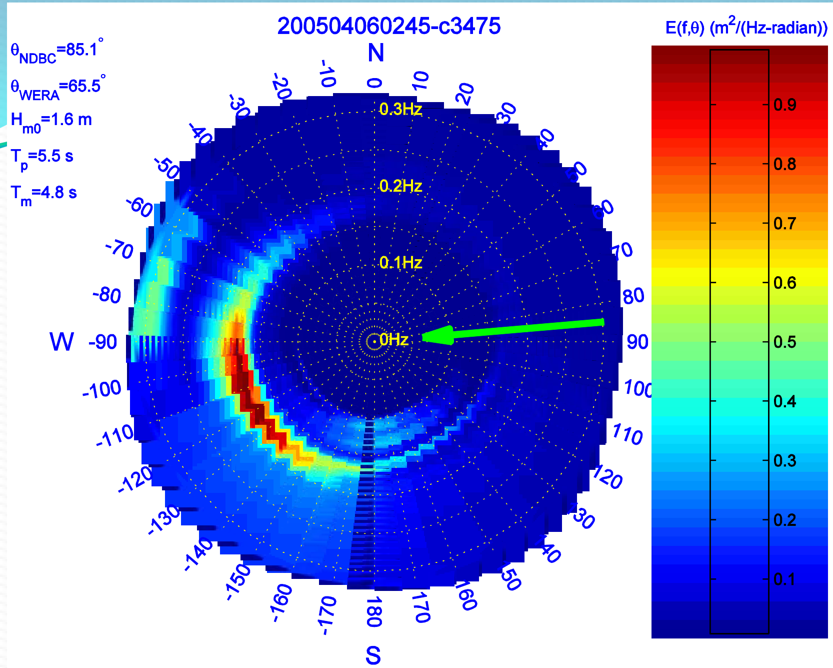


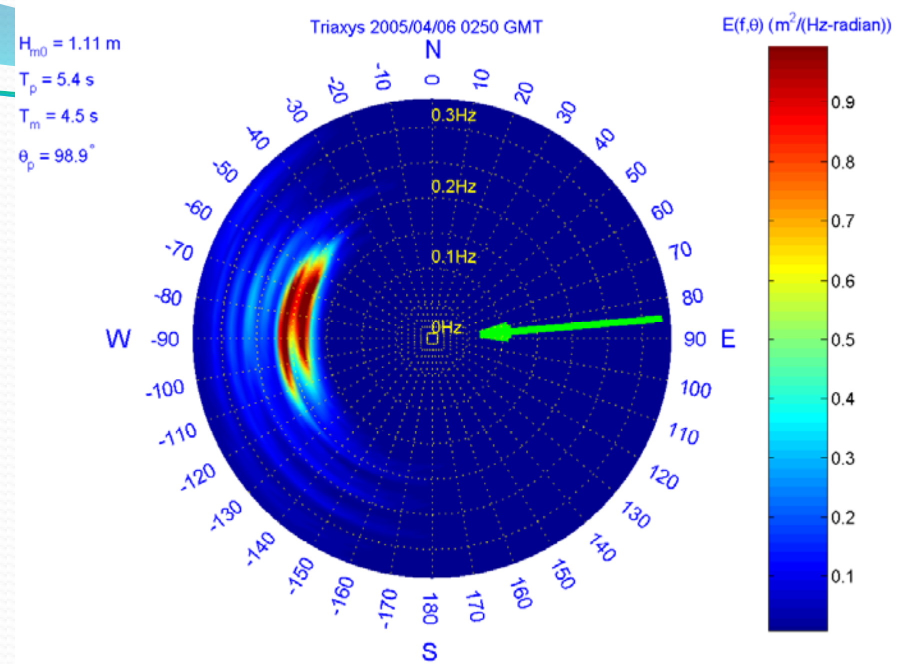


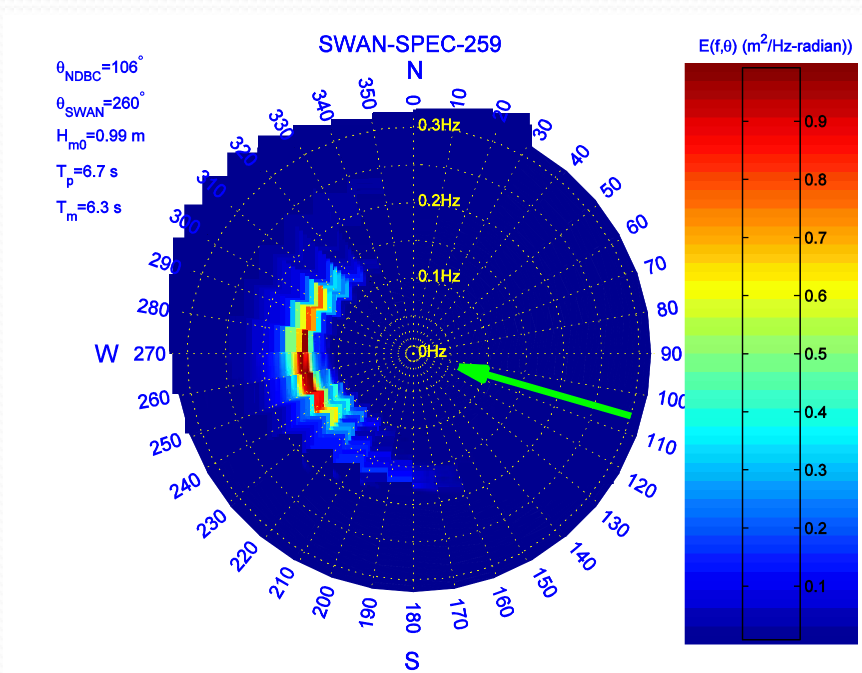


Wind direction ~ 85.1° (FWFY1)

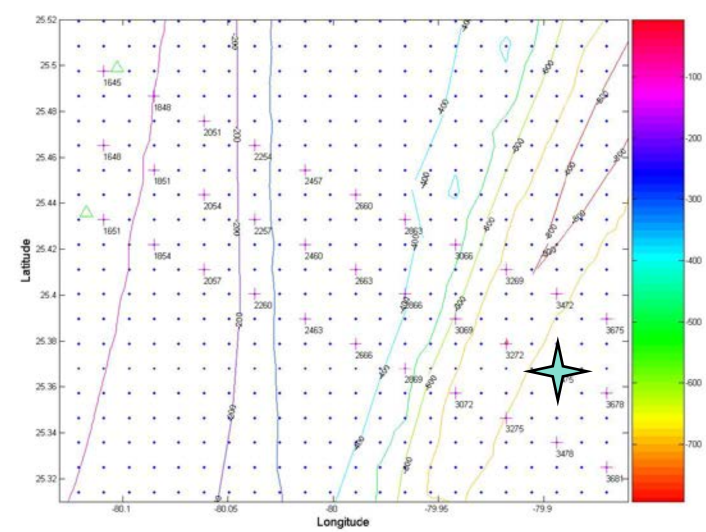




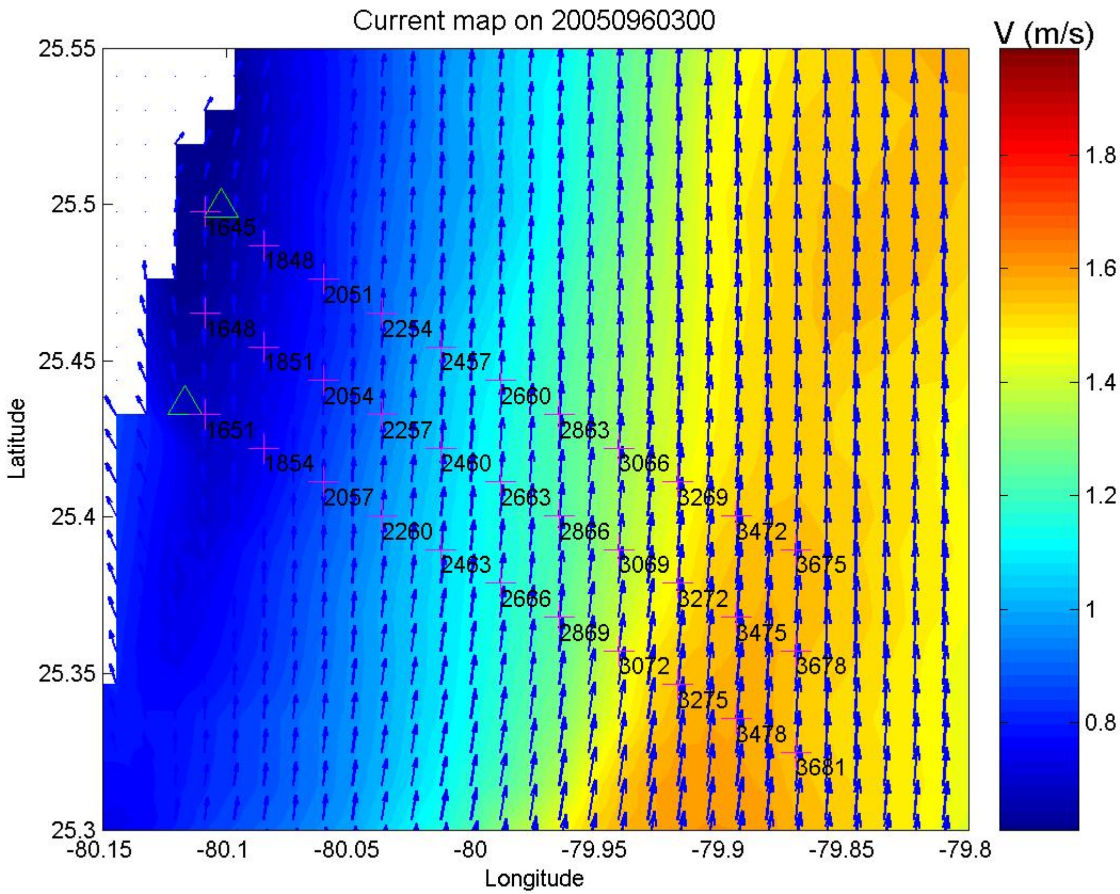




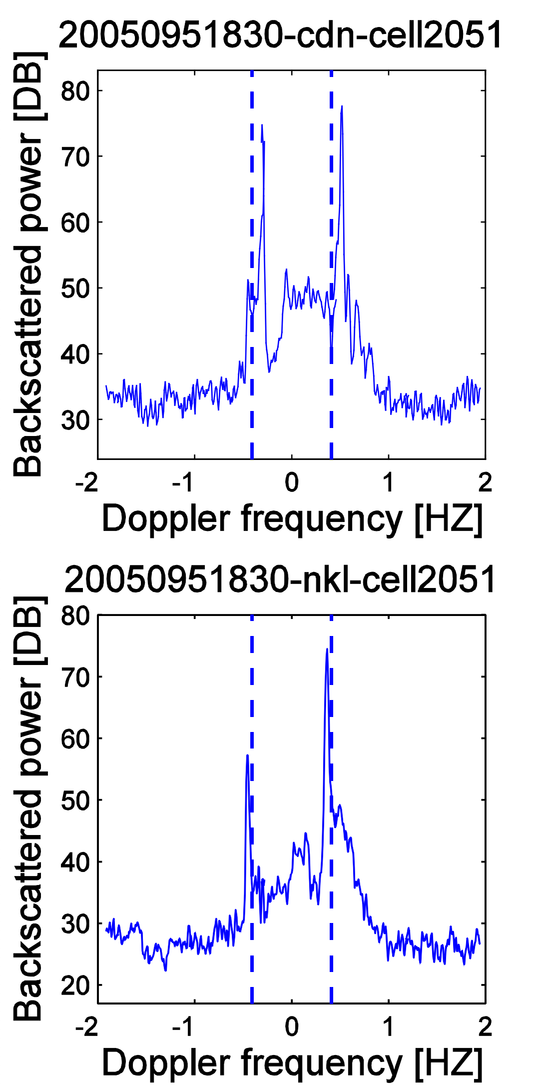
Wind direction ~ 85.1° (FWFY1)



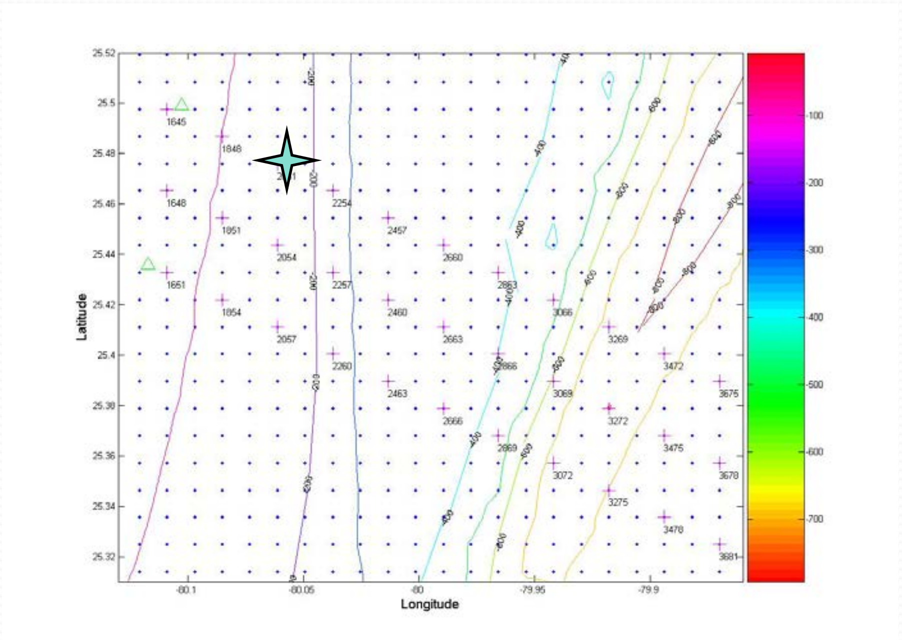
Spatial Variability of Horizontal Current

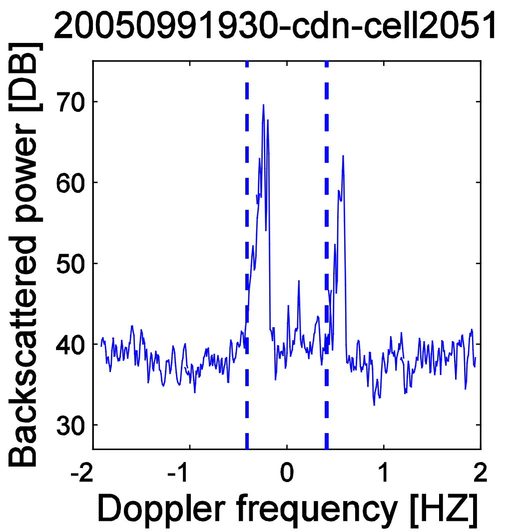


Current shear effects or Sidelobes

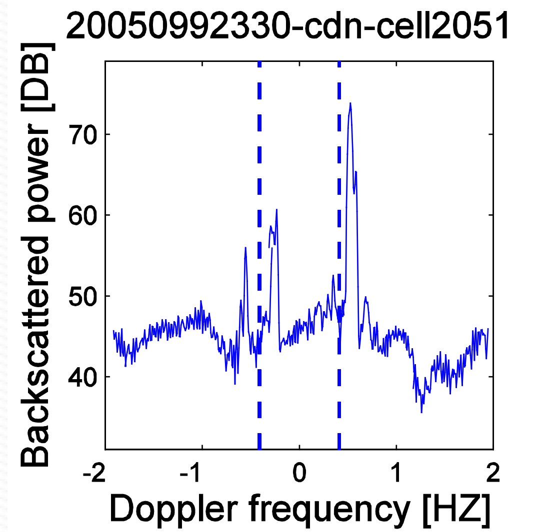


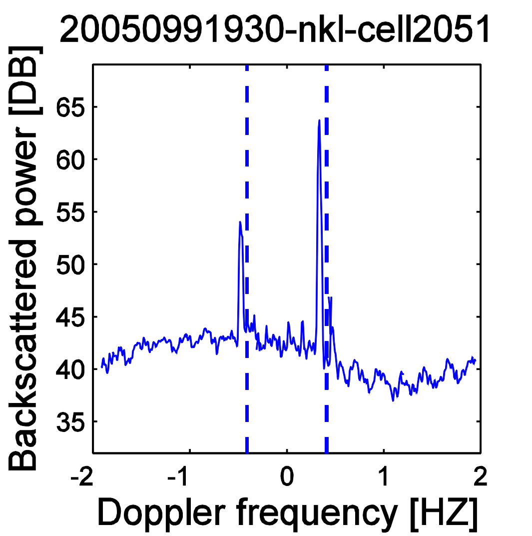
Hs observation :
0.91 m from TAB01041;
0.84 m from TAB 00651;
0.91 m from WERA # 2051



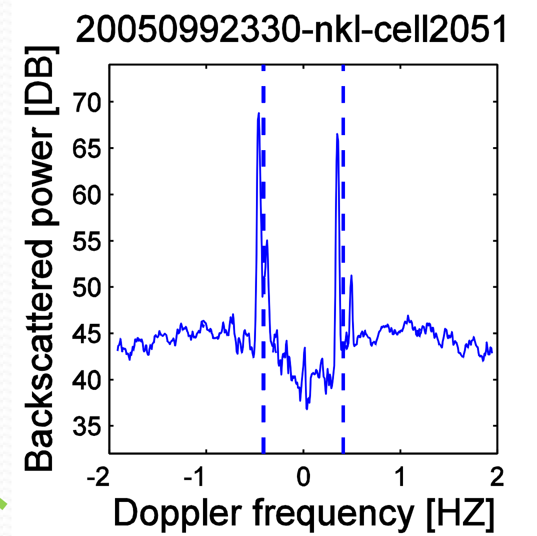


Hs observation:
0.41 m from TAB 01041
0.29 m from TAB 00651;
1.83 m from WERA;





Hs observation:
0.67 m from TAB 01041;
0.57 m from TAB 00651;
1.22 m from WERA;



Summary:

- Showex Data showed disparate effects of Current shear on waves.
- The agreement between WERA waves and buoys is inconsisten.
- There are some possible reasons for this disagreement:

  (1), radar antenna side-lobe contamination during low sea-states, which causes higher significant wave height estimation and spurious wave system in the directional wave spectrum.

  (2), spatial variability of current shear can cause the deviation of the wave propagation direction from the wind blowing direction.

  (3) sub-optimal spacing

Some procedures to improve data quality:

- Sampling method has been changed from 5-minute interval (1024 samples) to 10-minute interval (2048 samples) since 2006; --- improved spectral noise suppression
- Suppress RFI effect on WERA observations.
- Additional In-situ measurements
- Improved location for wave measurements.

(see Uriah Gravois poster for more in-depth, Radar –SWAN intercomparison)