

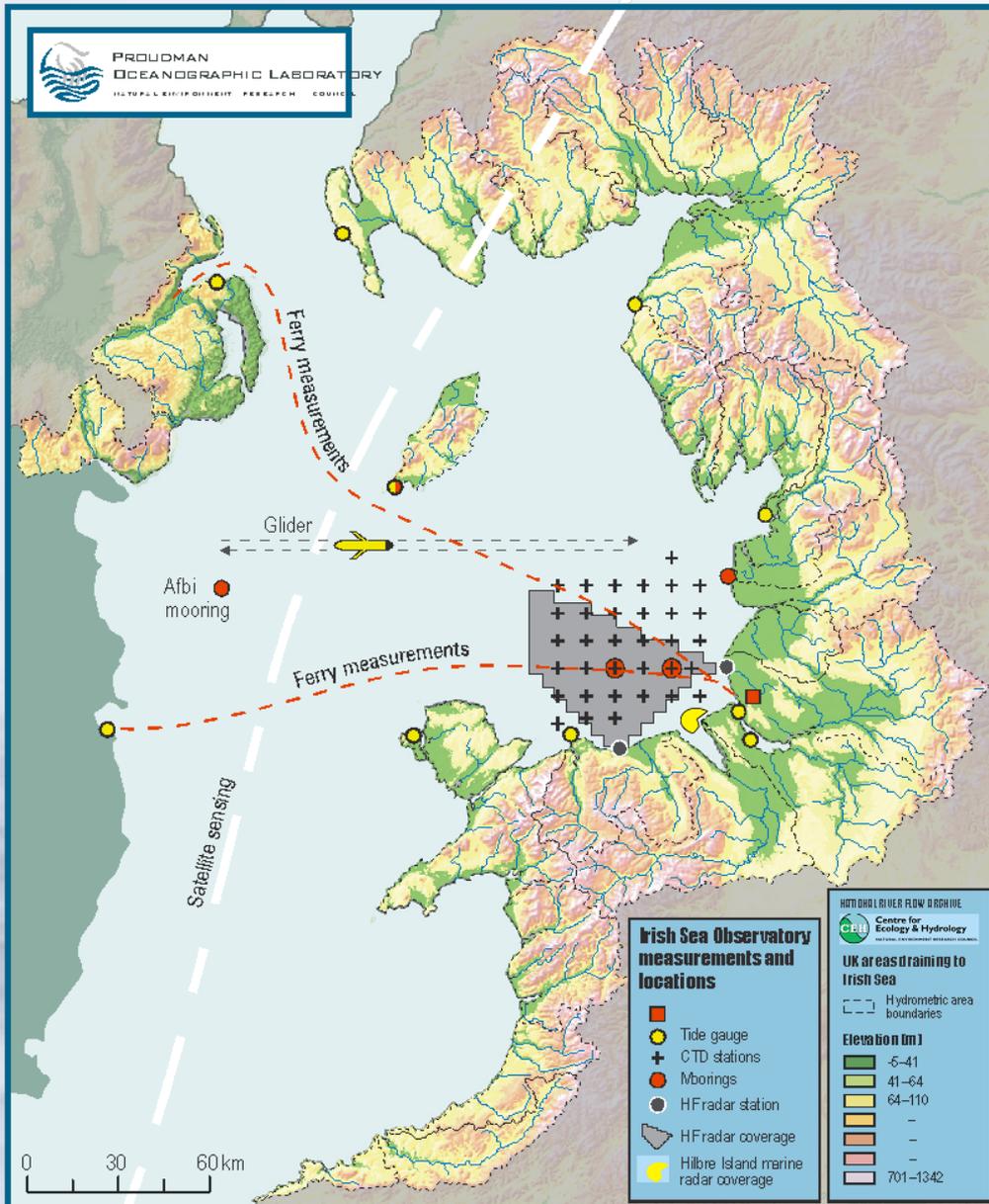
6 years of HF radar measurements in Liverpool Bay

John Howarth

Background
Data quality
Waves
Currents



Integrated measurements



Measurements to test models

Variety of space and time scales

Real time

Multi-disciplinary

Long time series

In situ time series
Sites A and B

Spatial survey

HF Radar

Ferry

Satellite (weekly composite)

Glider

Issues

Frequency permission

Sites (two)

Boresight (phased array)

Separation of sites

Power

Telephone

Interference

Radio – diurnal variation

Frequency shift

Shipping

Wind farms

Sampling regime

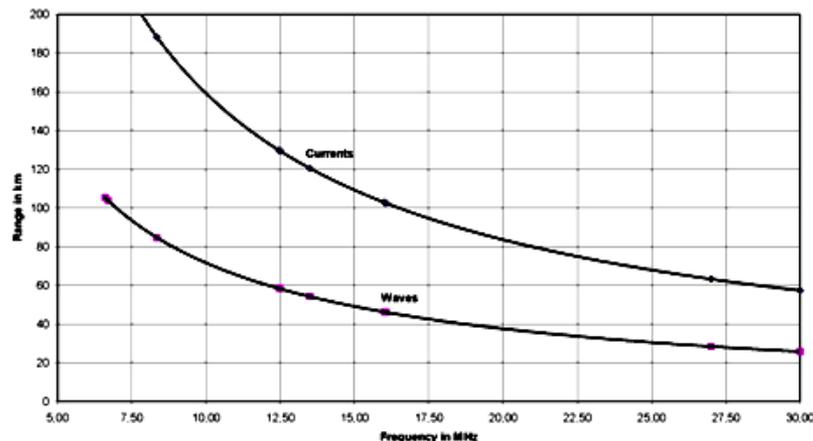
Currents, waves

FMcw Radar "WERA"

5. Limiting Factors of Bandwidth and Center Frequency

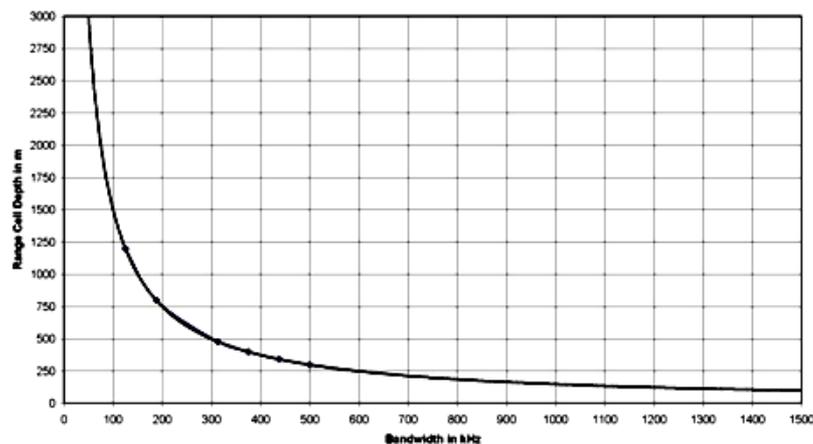
The center frequency is chosen mainly to guarantee the required operating range. Low frequencies give longer ranges.

Typical WERA Ranges versus Frequency



The sweep bandwidth affects the range resolution of the system. A wider bandwidth results in a higher spatial resolution.

Range Cell versus Bandwidth



Frequency / bandwidth

Frequency 5 – 30 MHz

Range (up to 200 km)

High / low cut-off (for waves)

Accuracy for currents

Bandwidth / resolution

Down to 250 m

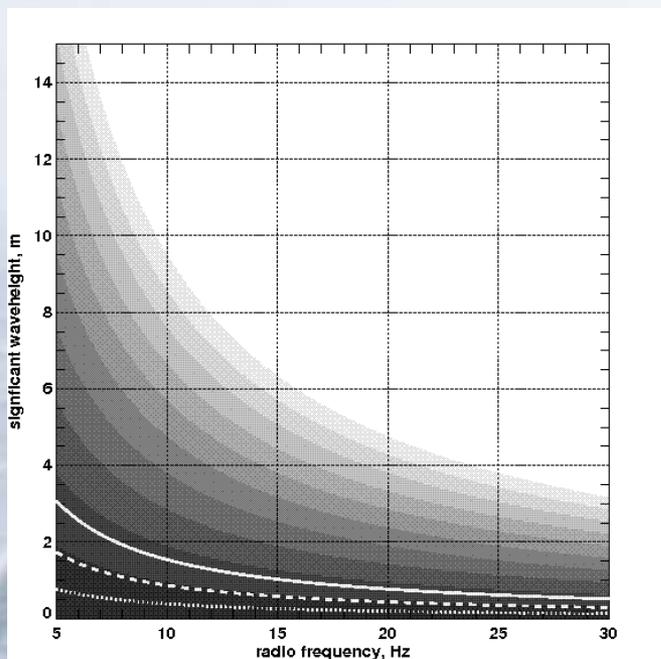


Figure 2. Contoured perturbation parameter.

Lucy Wyatt



Formby Point (12.5MHz)

Transmit / receive de-coupled

Boresight

Exposed beach at low water

Sand accretion

Public access

Receive array distant from cabin

Llanddulas (13.4 MHz)

Close to sea

Fenced off

Cabin close to receive array

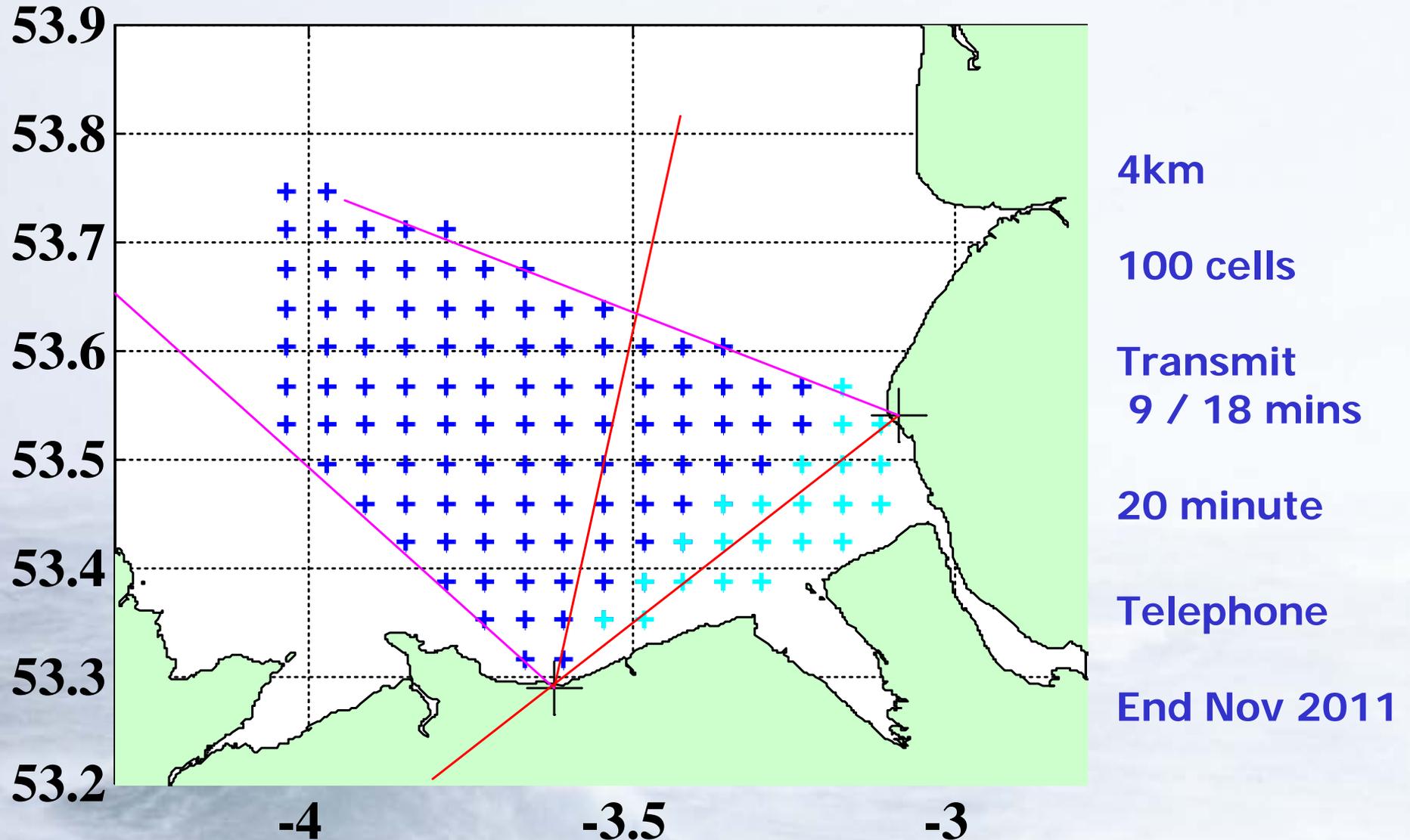
Transmit / receive coupled

Road / rail

Time limited permit?



August 2005 – July 2011



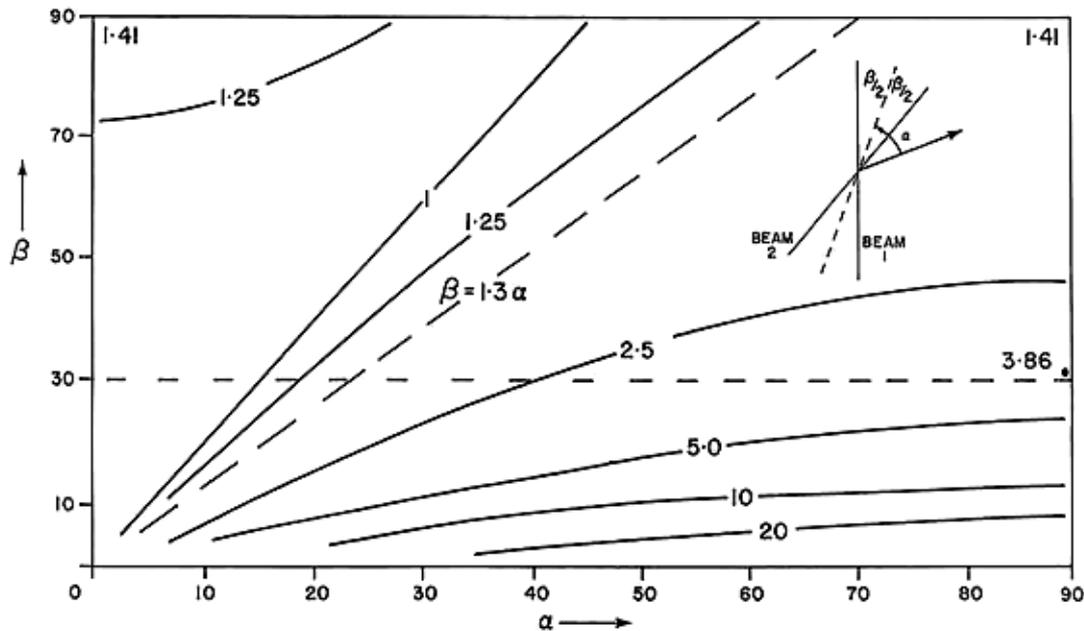
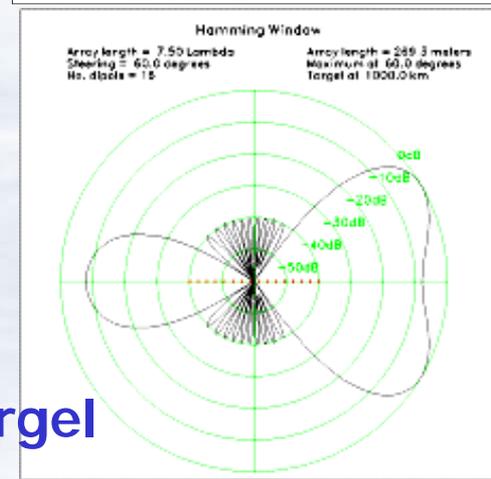
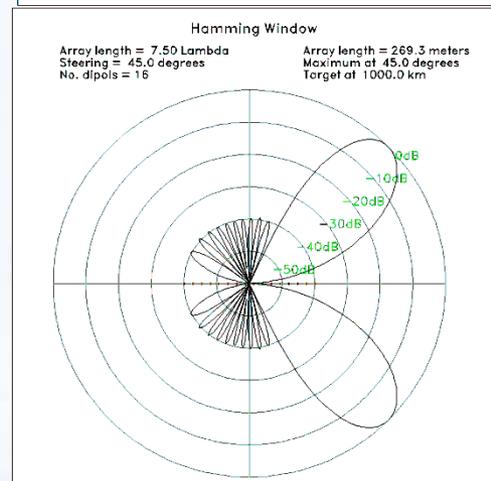
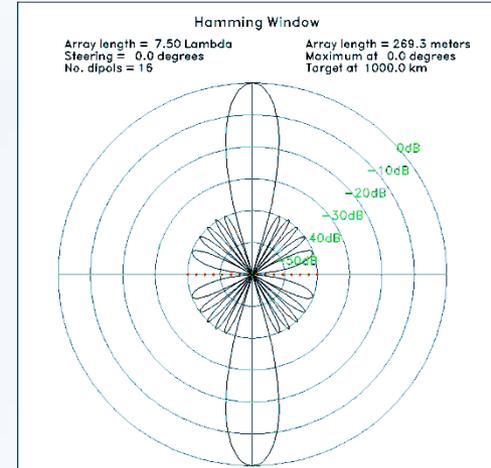


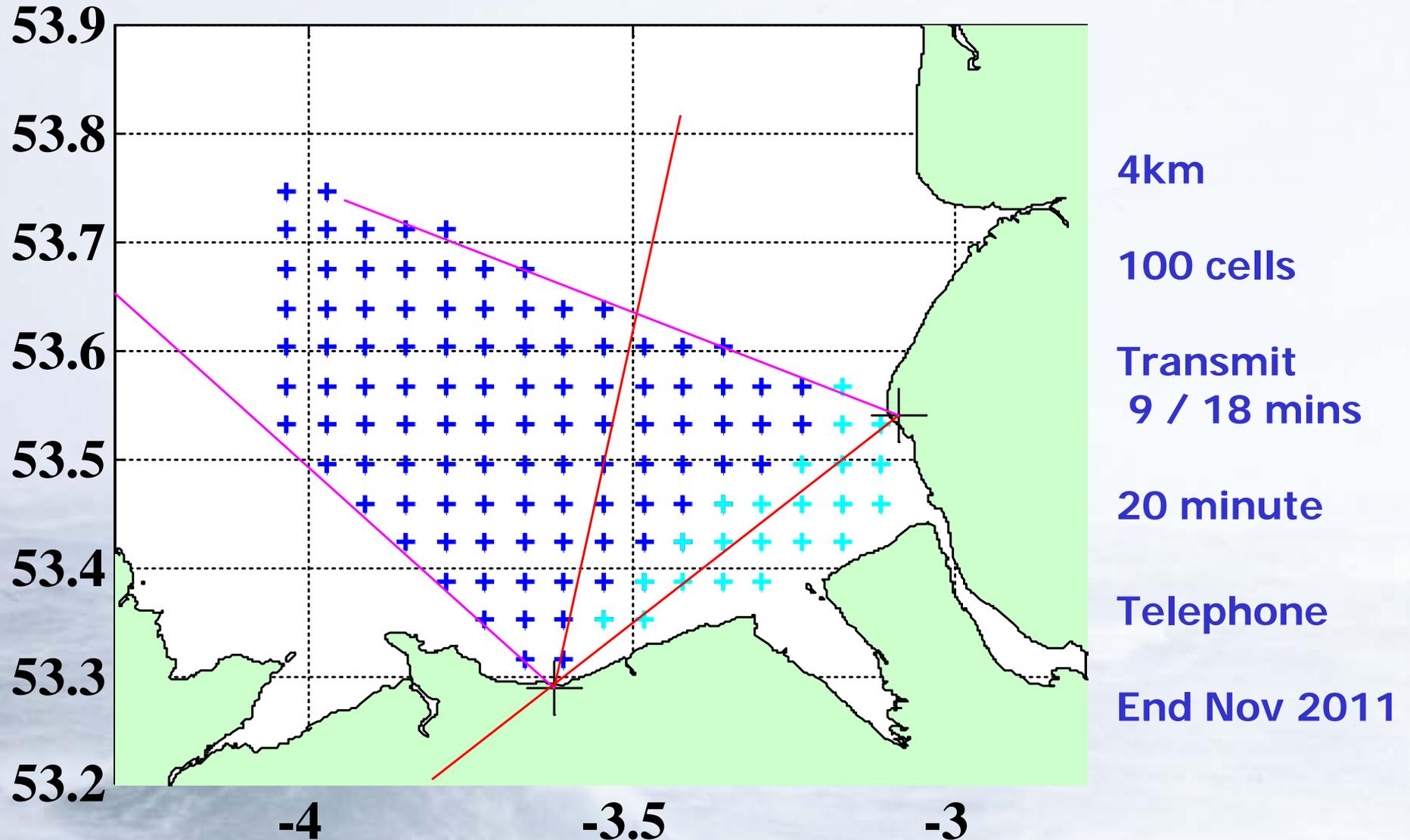
FIG.3. Amplification factor of standard error as a function of α and β (PRANDLE, 1990a). α angle between the bisector of the two beams and the current vector direction, β angle between the two beams.

GDOP, David Prandle

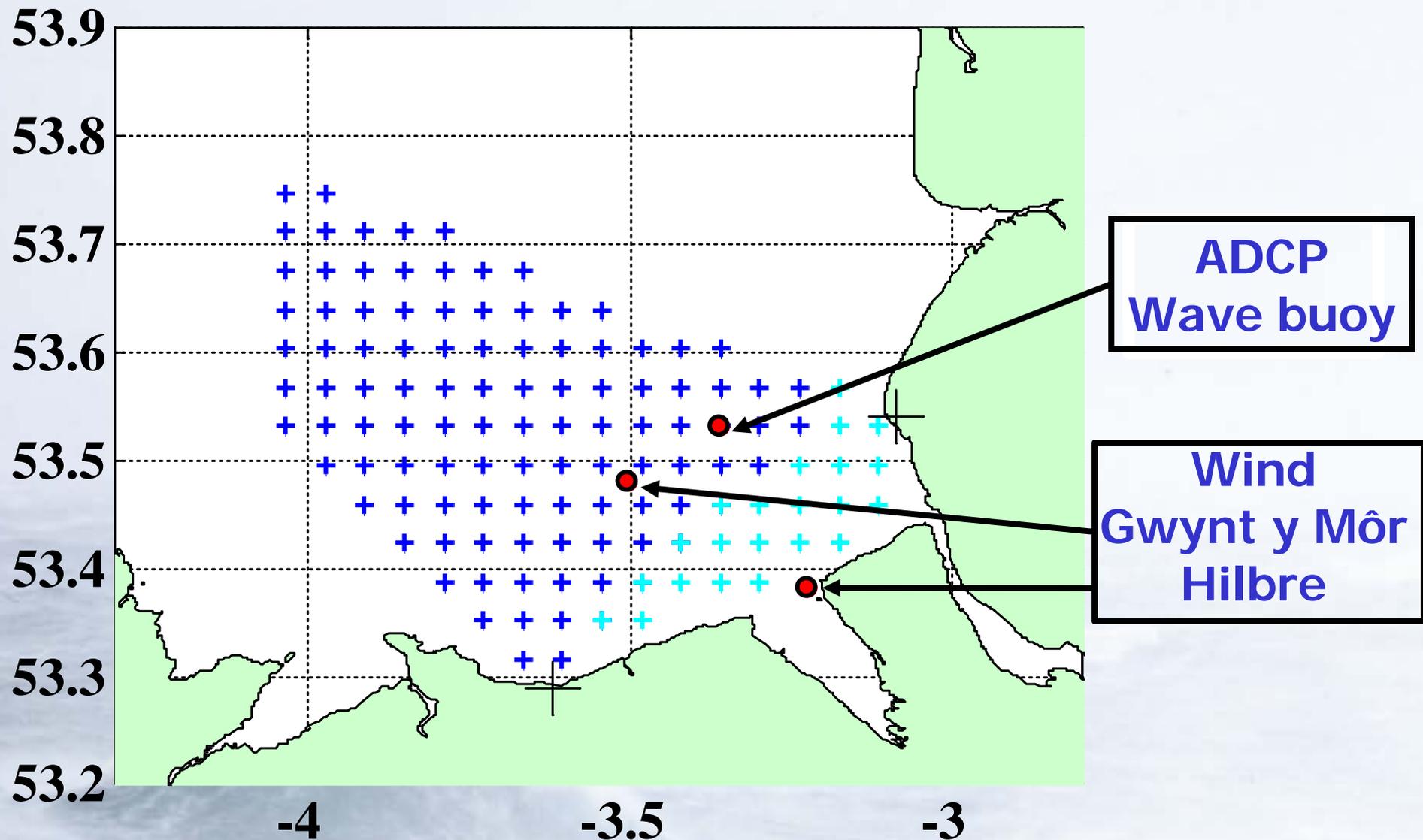


Klaus-Werner Gurgel

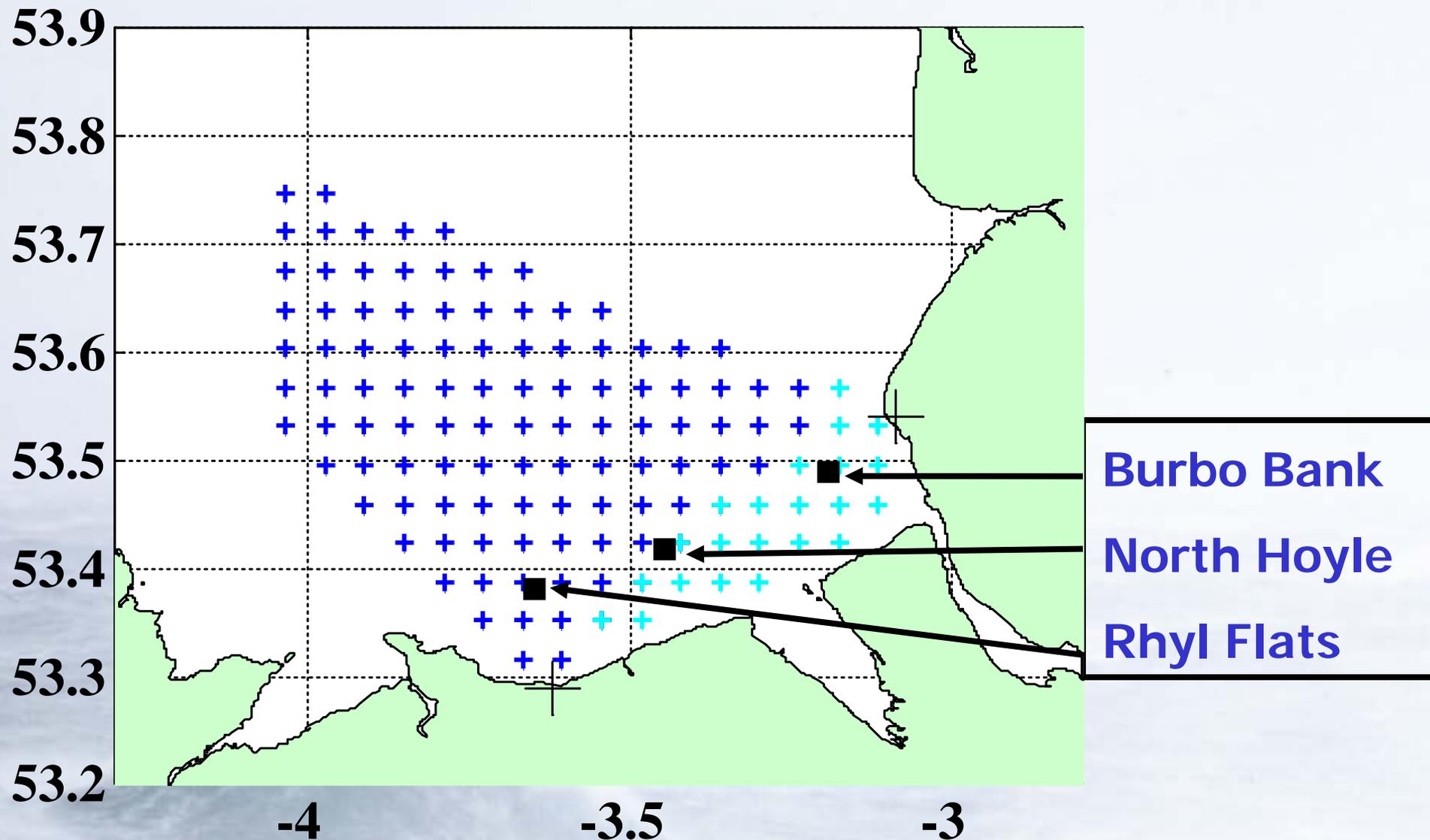
August 2005 – July 2011



Other measurements



Wind farms

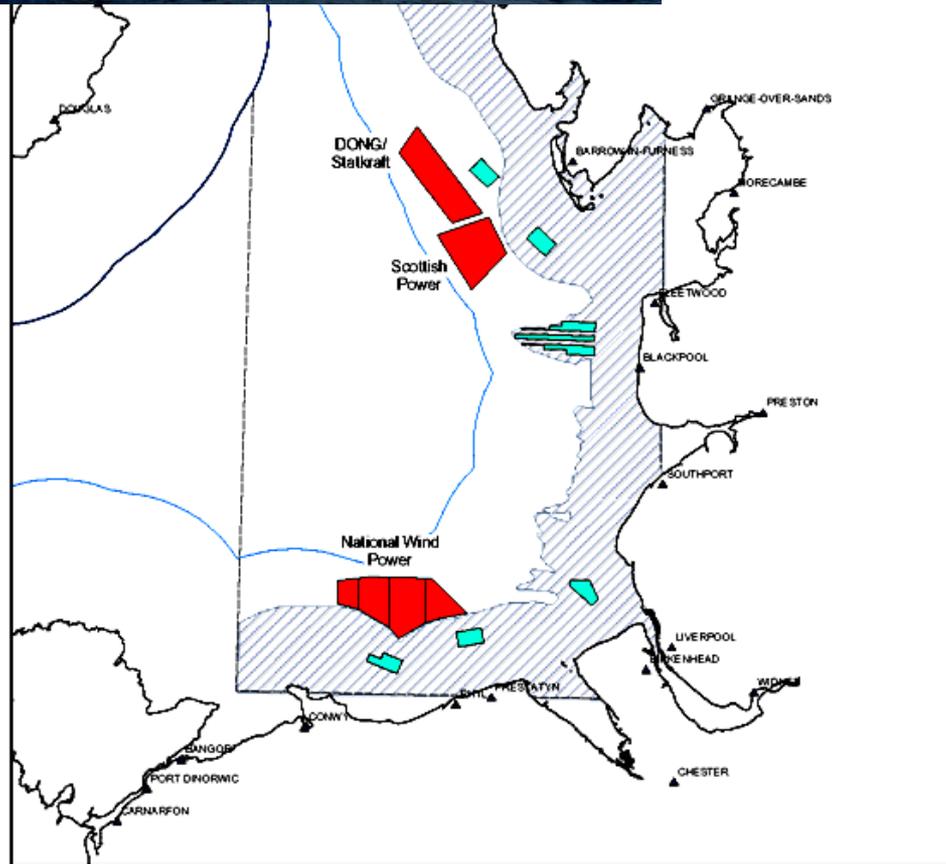




THE CROWN ESTATE

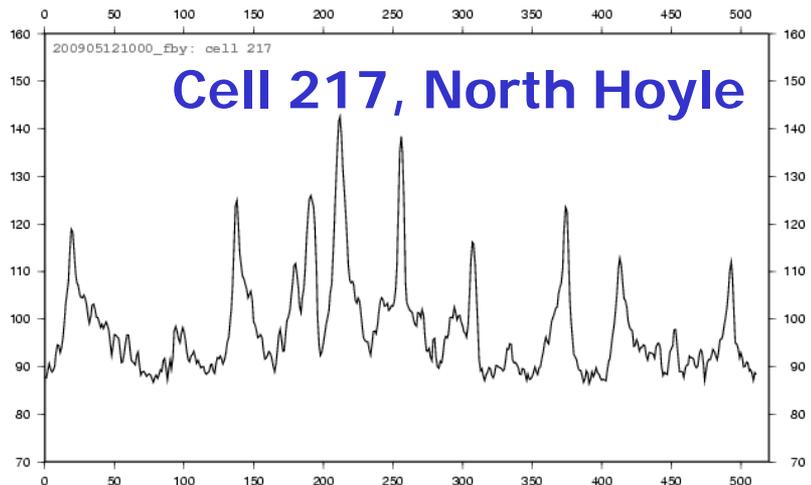
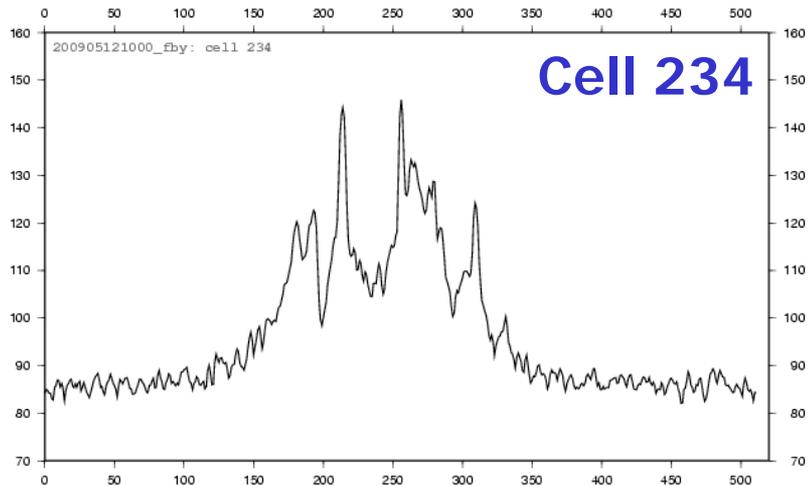
Round 2 Wind Farm Sites

- Round 2 Wind Farm S
- Round 1 Wind Farm S
- DTI Exclusion Zone
- DTI SEA
- International Waters
- 12 mile limit



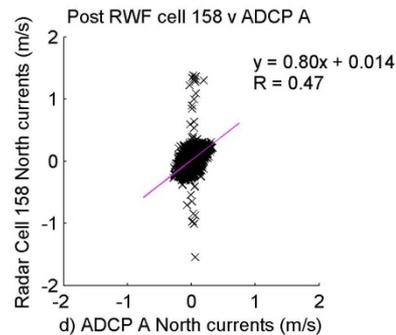
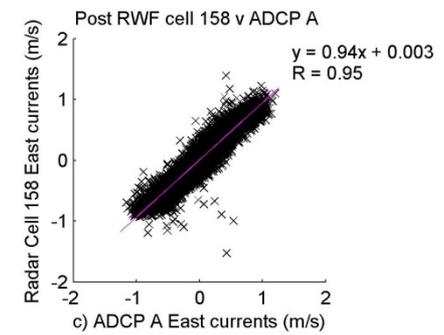
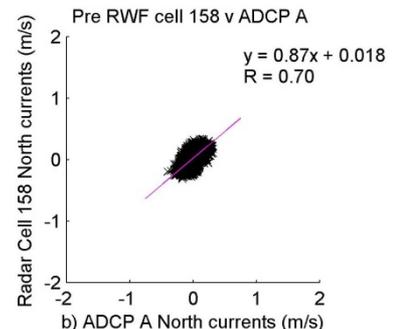
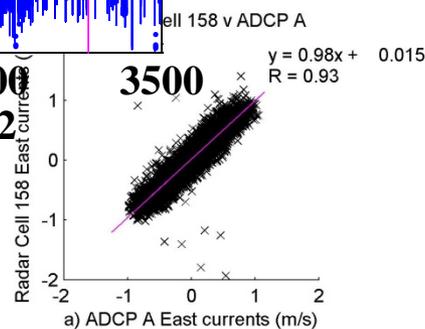
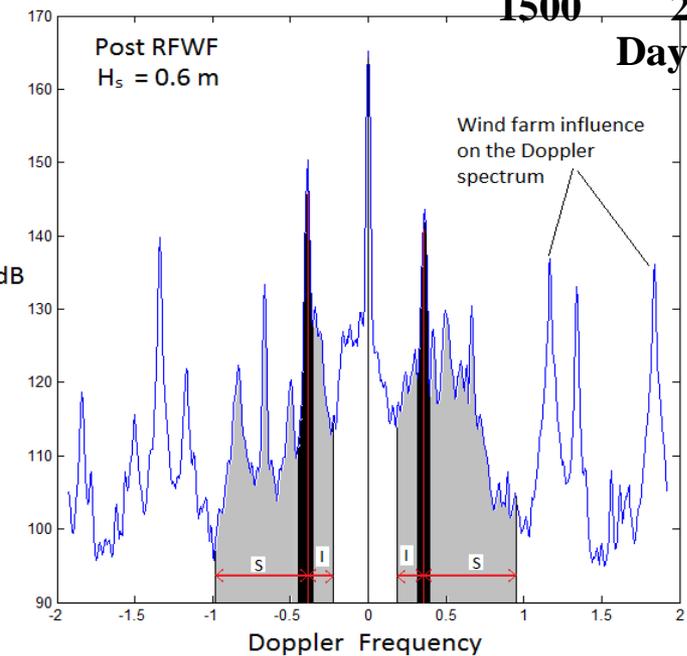
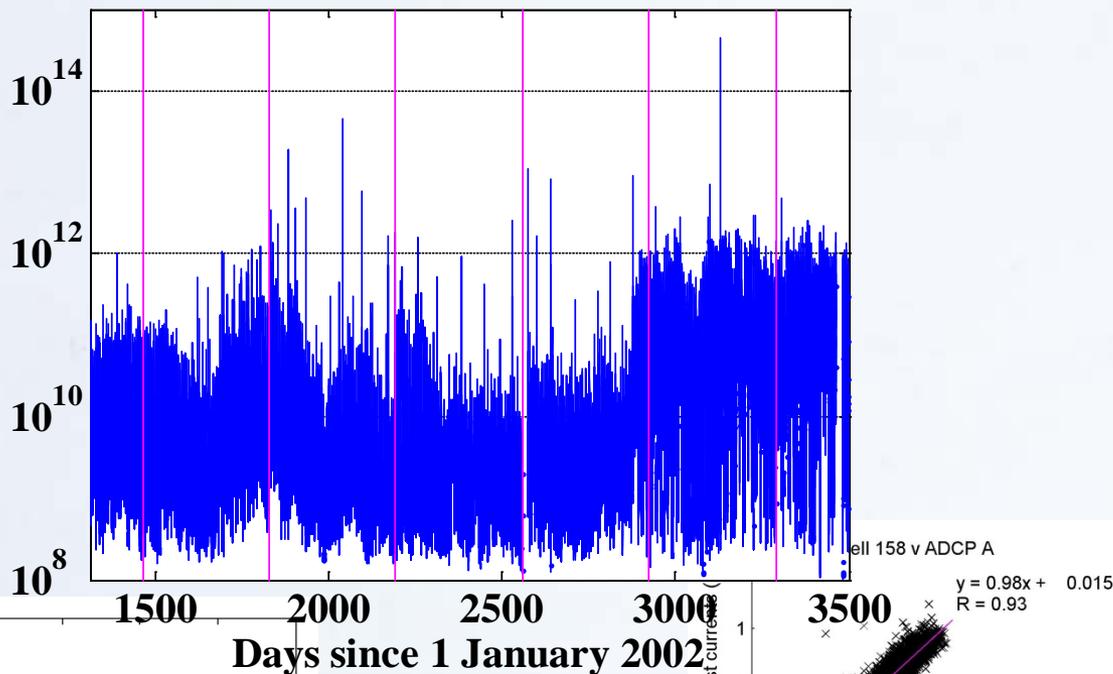
Wind farms

Formby



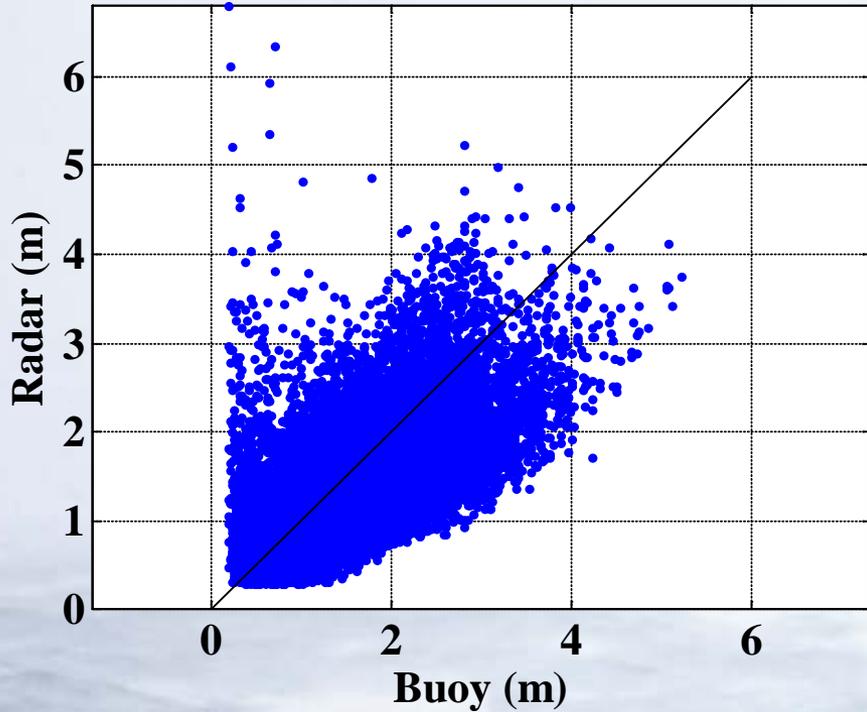
Effect of wind farms

Noise



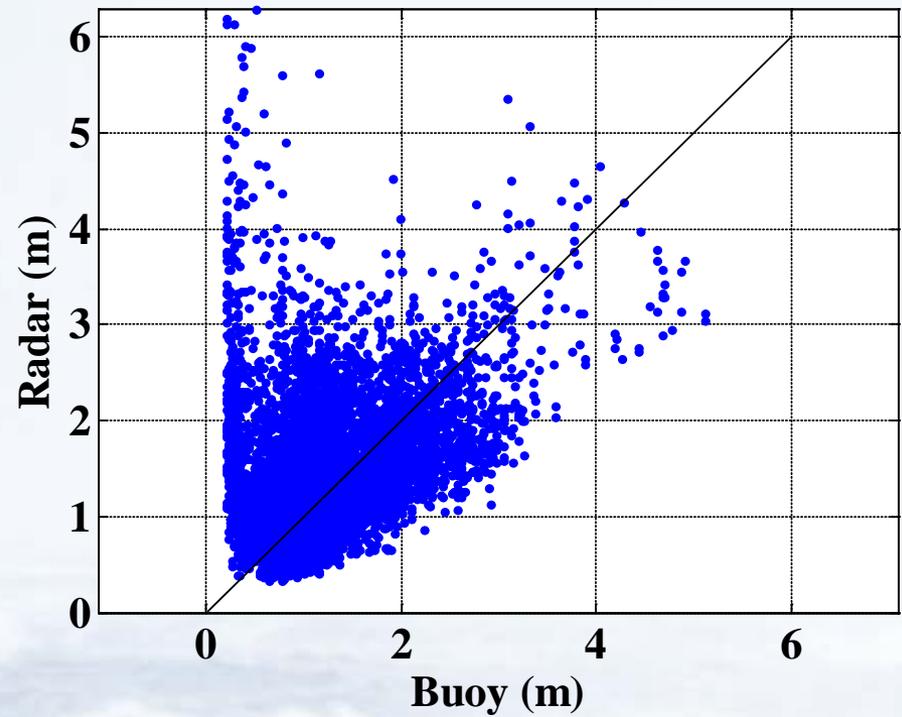
Waves

Before



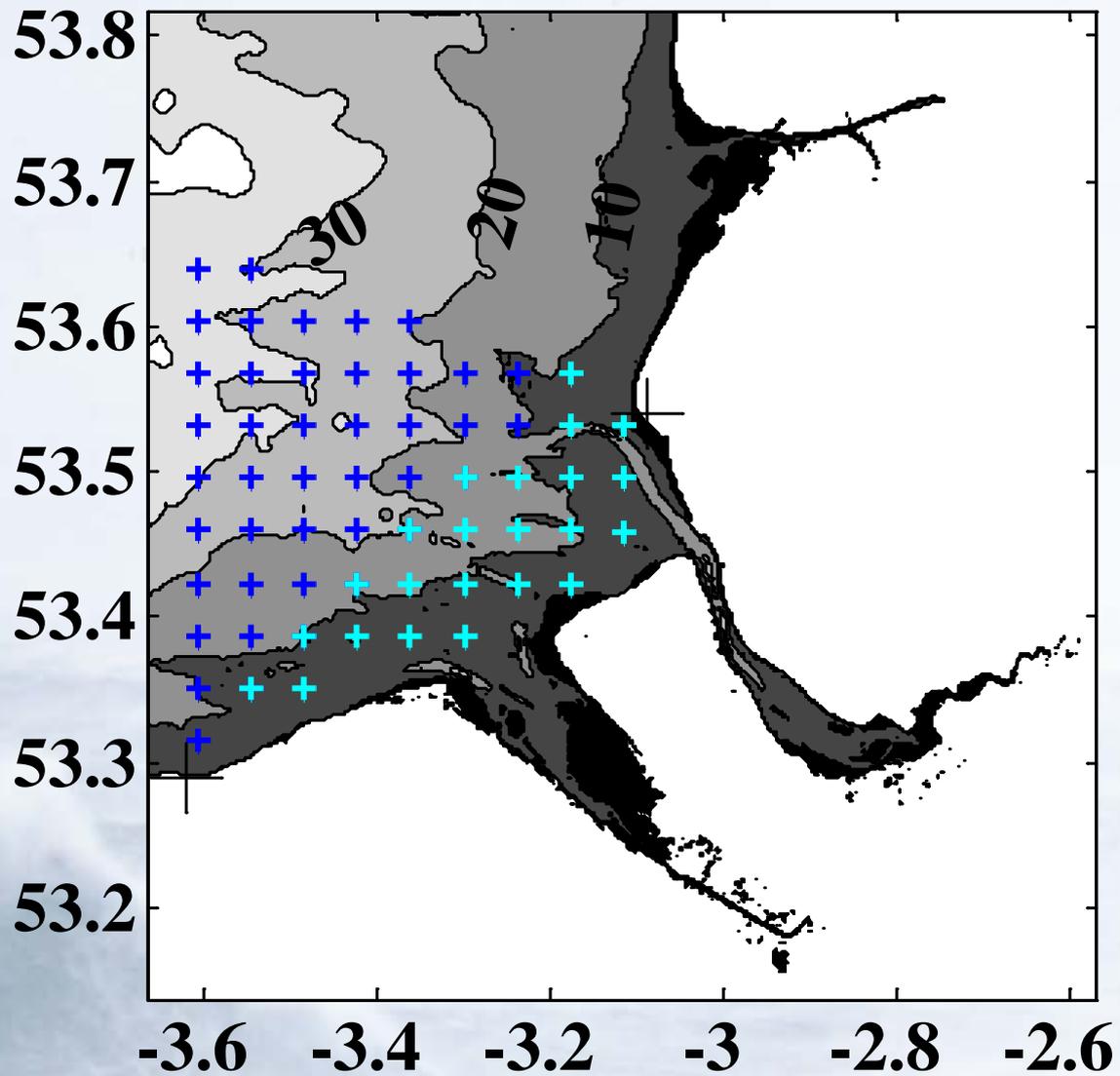
Correlation = 0.66
Number = 32%

After



Correlation = 0.29
Number = 14%

Water depths



Operational failures / maintenance

Computer hard disc
 Buried power amplifier overheating
 twice
 Cables – rodents, repair,
 tracked vehicle
 UPS

 Modems
 Unpaid telephone bill

 Sand accretion (cable)
 Dumping of soil
 Replace coils

Neptune Radar	Last Year	Overall
Formby Real Time	98%	95%
Formby Archive	92%	95%
Llanddulas Real Time	82%	88%
Llanddulas Archive	97%	96%
Dual Real Time	81%	84%
Dual Archive	89%	91%



Quality checks

Signal to noise

Separation of Bragg peaks

Range (for currents preferably on tidal residual)

Rate of change

Radar observing local wind sea

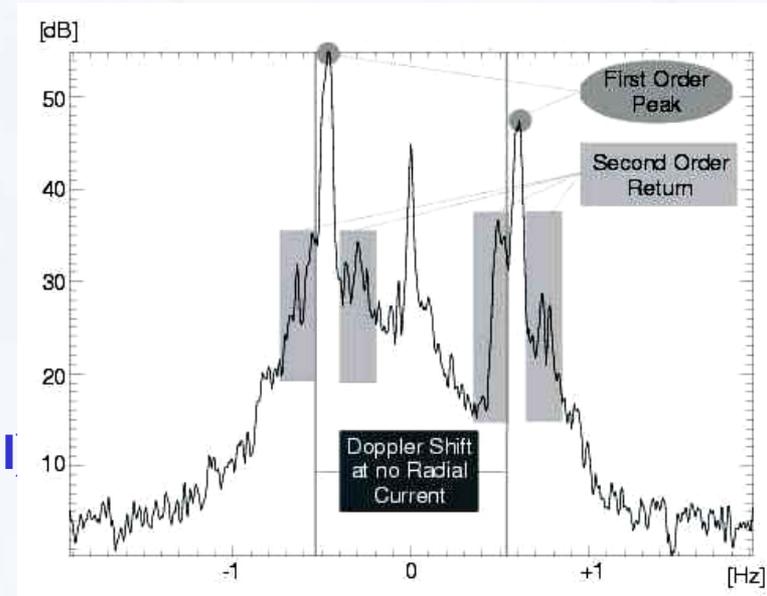
$H_s > 0.08 \times \text{vel. of light} / (2 \pi \text{ frequency}) (=0.3 \text{ m})$

Wave steepness $2 \pi H_s / (g T_z^2) < 1/13$

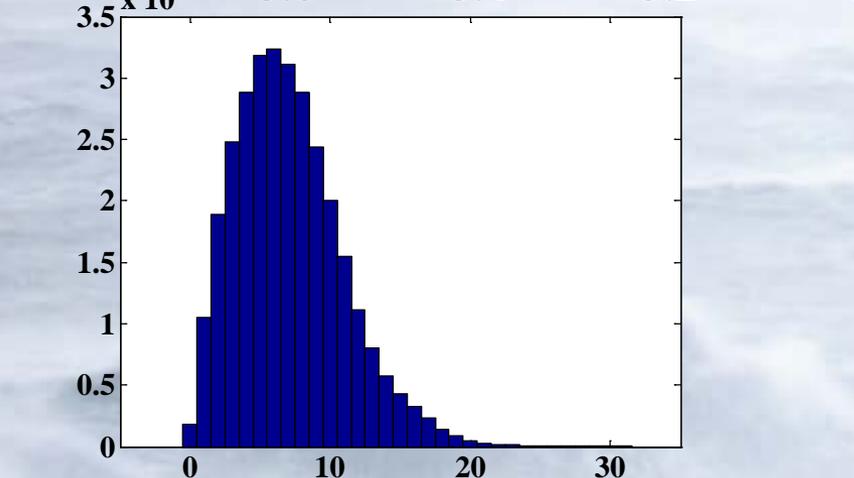
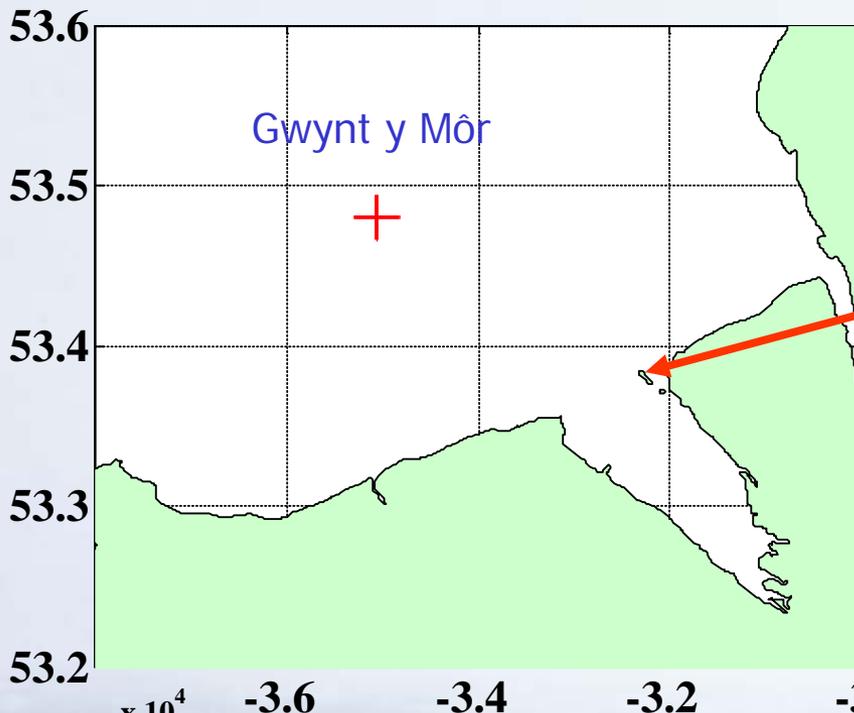
Inversion residual < threshold

Baseline: median difference:

-0.001, -0.001, 0.008. -0.005, 0.001, -0.005 m s^{-1}



Hilbre Island



Hilbre Island weather station

Instrument heights ($\pm 0.02\text{m}$) above Ordnance Datum Newlyn (ODN)

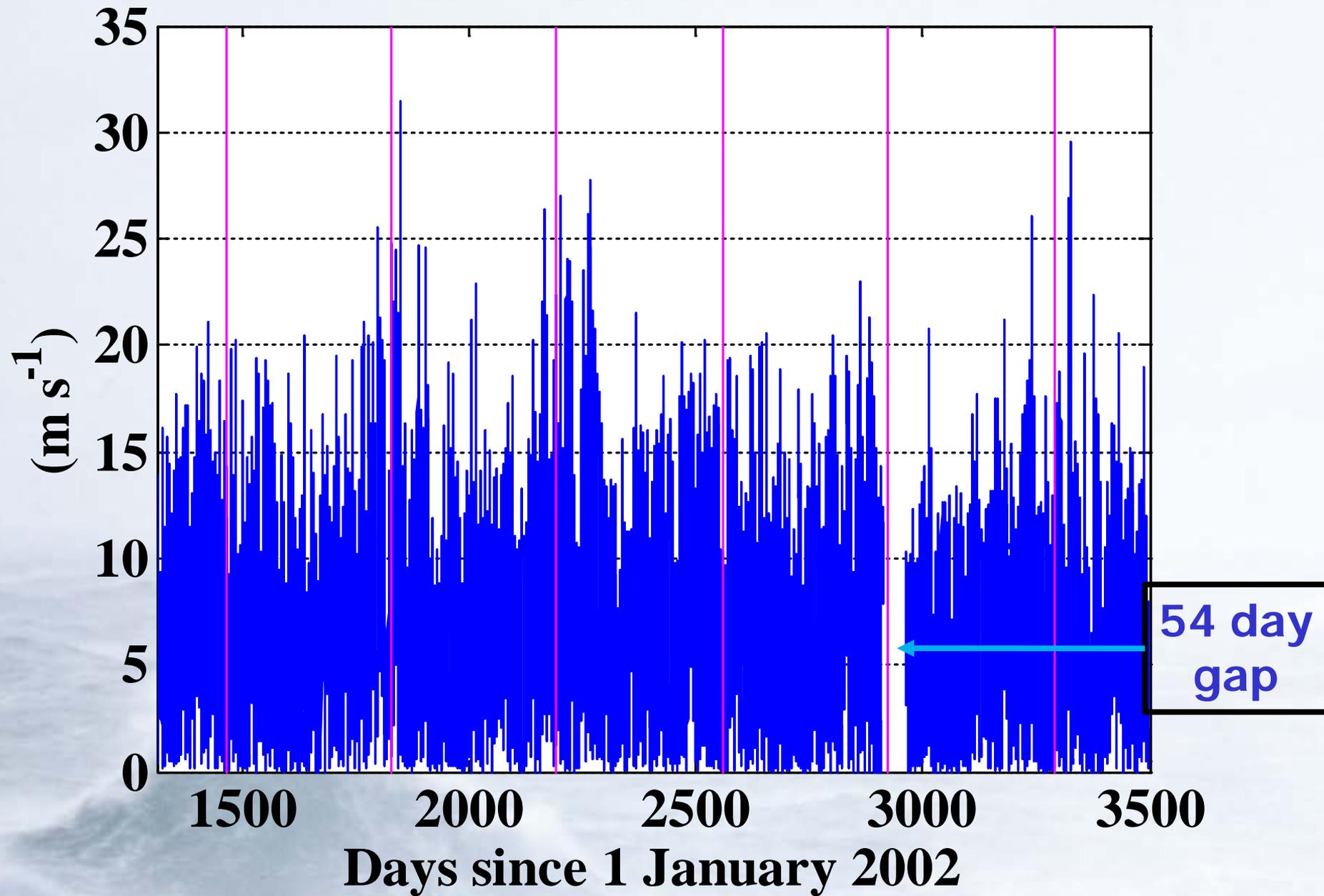
The photograph shows a tall, lattice-structured metal tower on a grassy hill overlooking the sea. Various instruments are mounted at different heights. A red arrow points from the map to the tower. A white arrow points to a benchmark in the foreground. The following table lists the instrument heights:

Instrument	Height (m)
base of tower	17.36
top of ledge	16.75
benchmark	16.49
platform	23.40
pressure sensor (inside logger box)	24.73
extension beam	26.36
temperature/relative humidity, solar, PAR	26.55
anemometer, rain gauge	26.92
x-band radar, webcam	26.92

Other height markers on the tower: 6.04m, 1.60m, 2.07m.

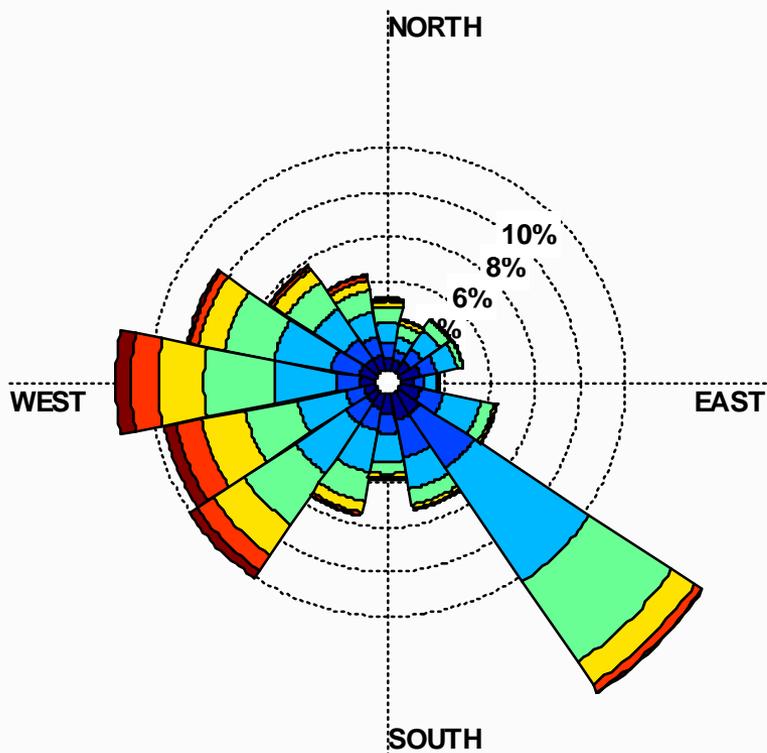
SJ 1842 8801
 53°22.956'N 3°13.680'W WGS84

Hilbre Island winds

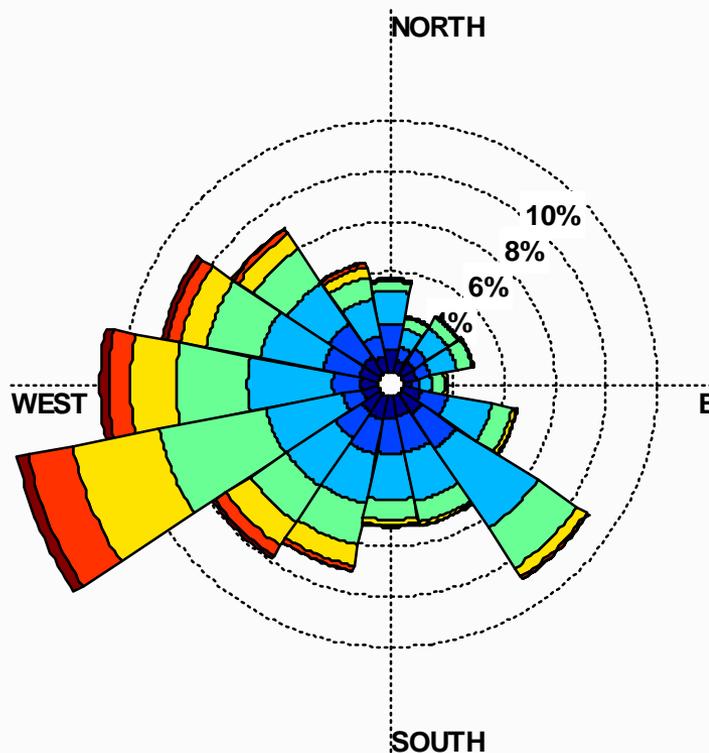


Winds: April 05 – April 08

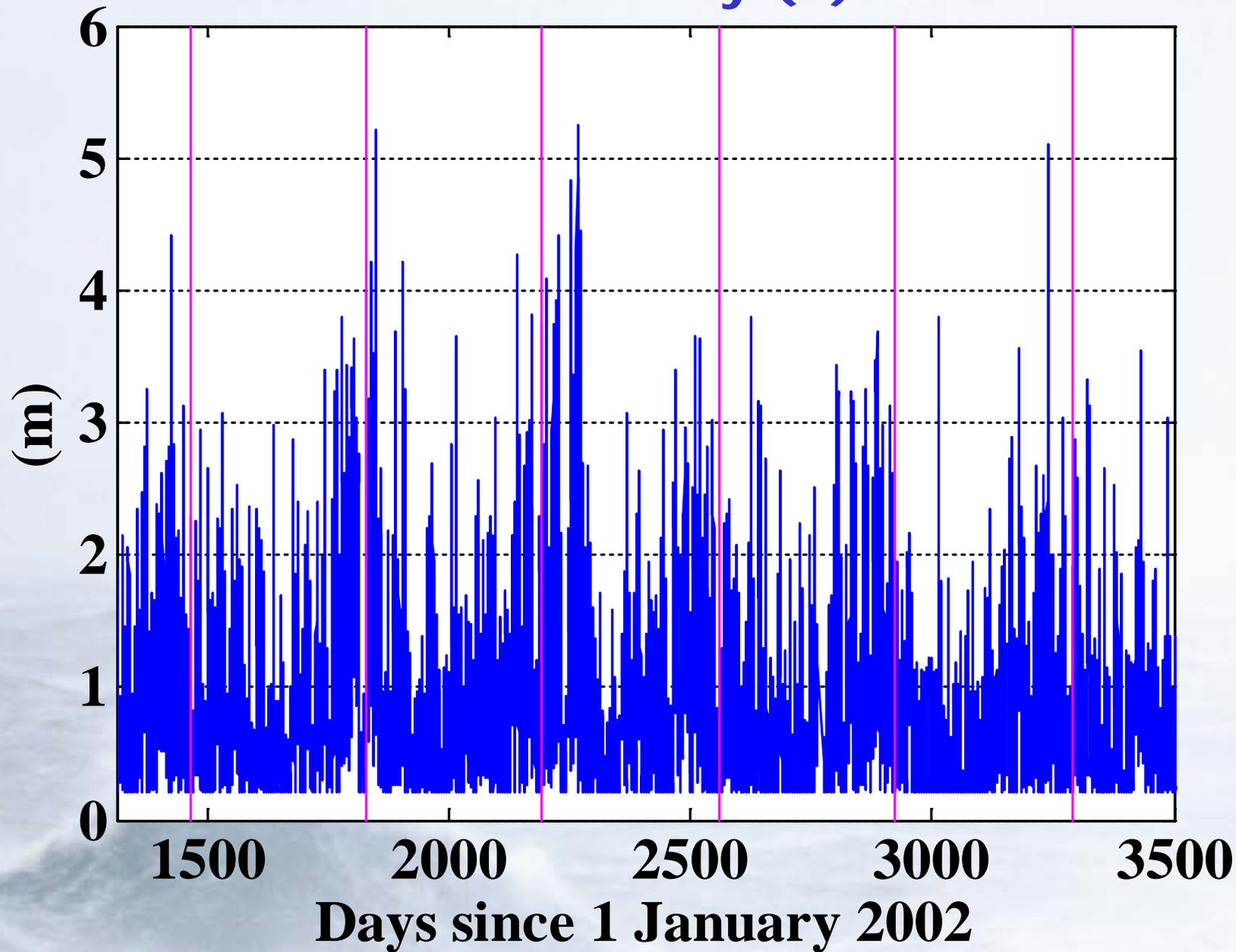
Hilbre



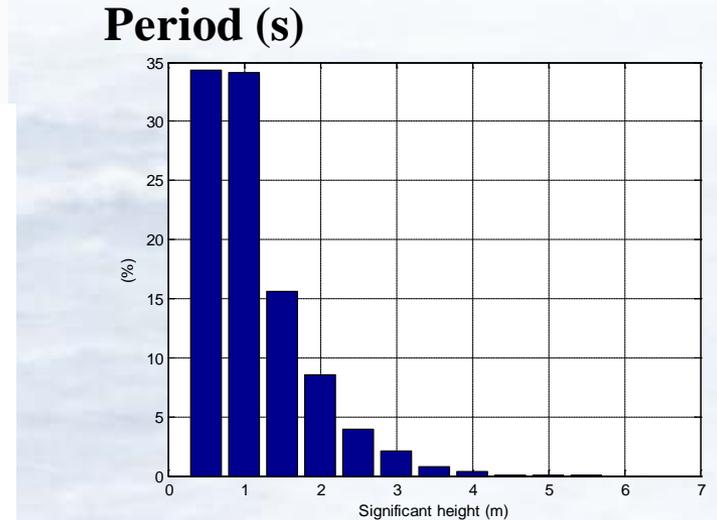
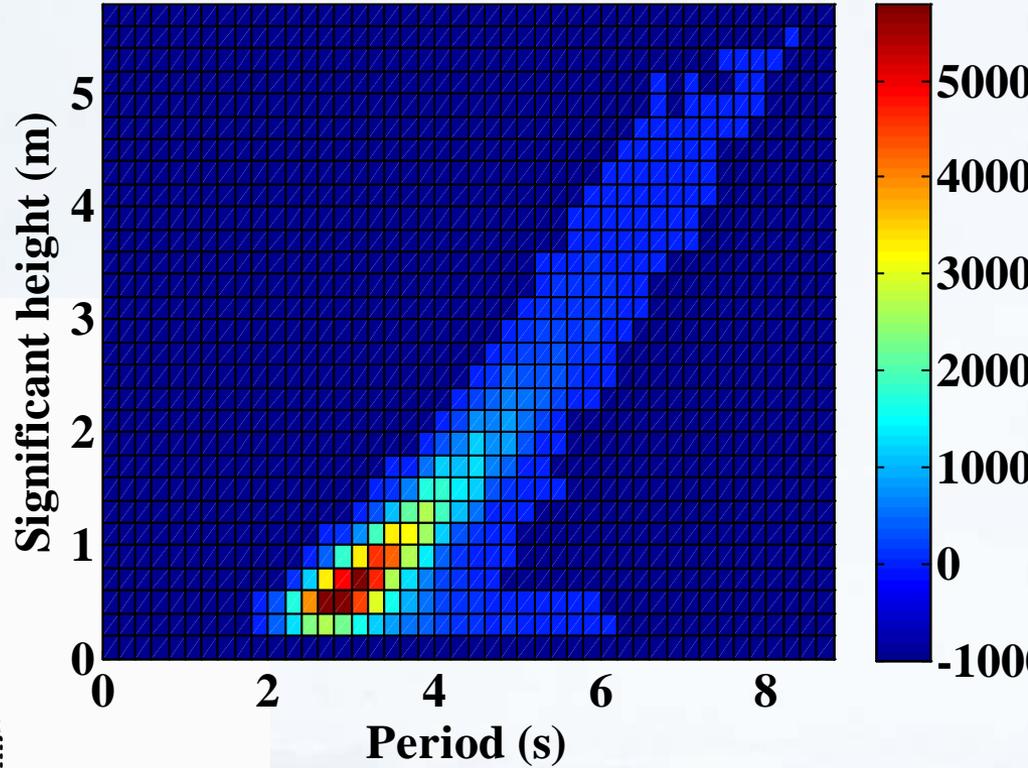
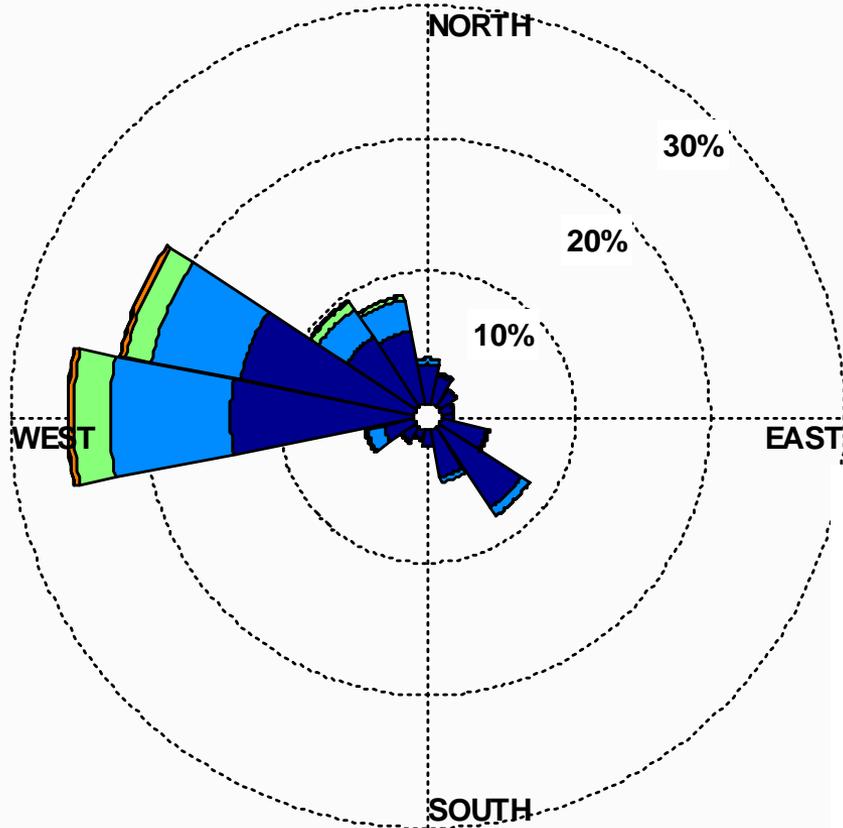
Gwynt y Môr



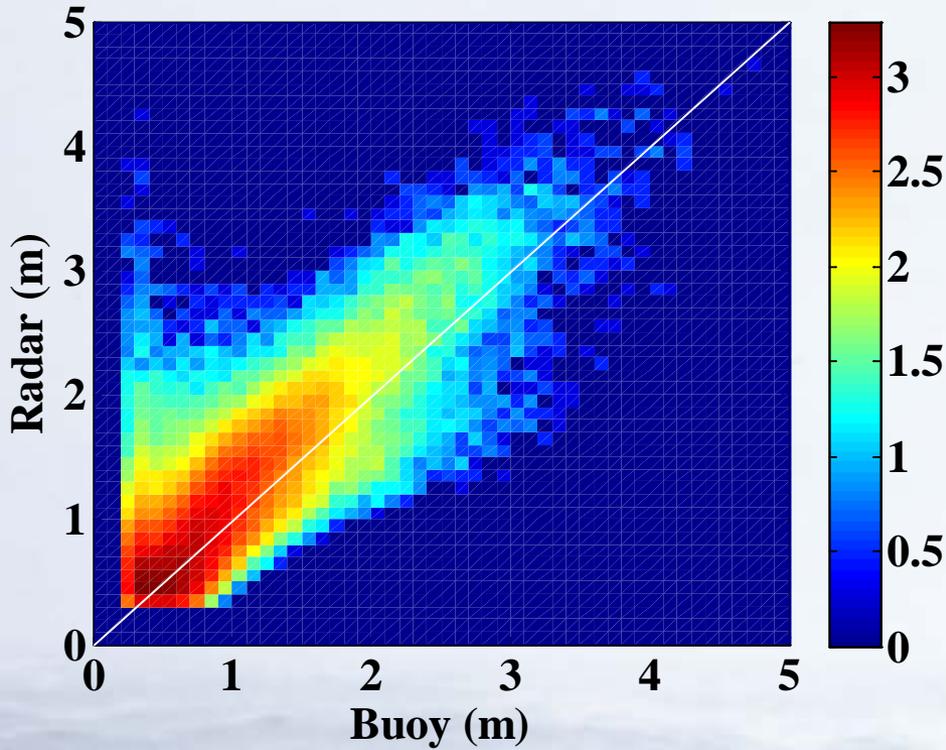
Wave Buoy (1)



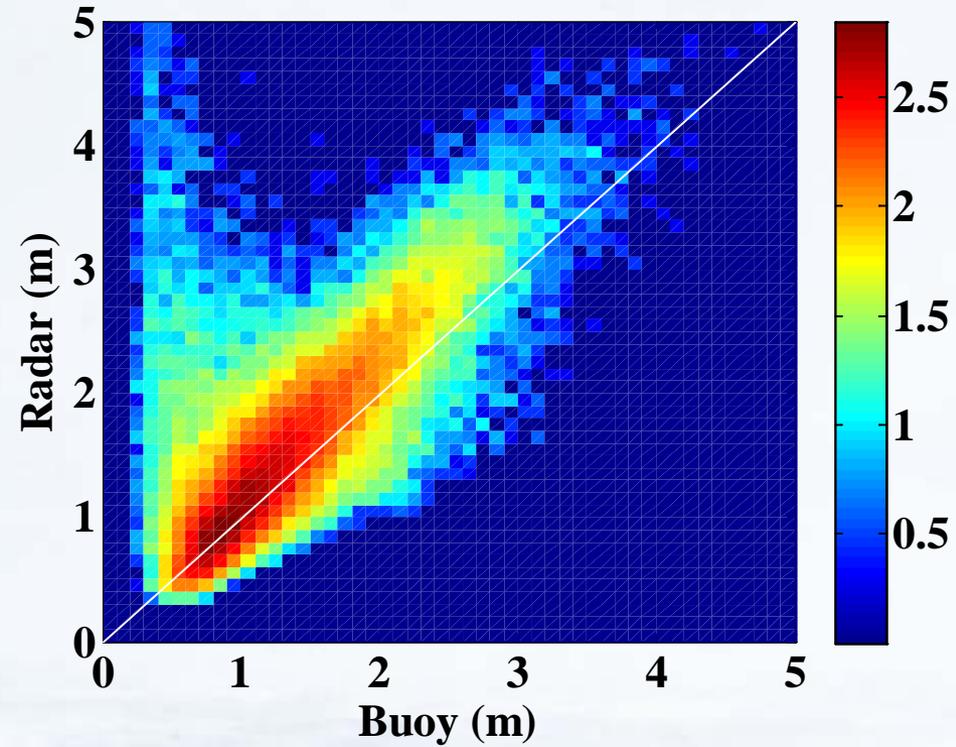
Wave buoy (2)



Significant wave height (Aug 2005 – July 2011)

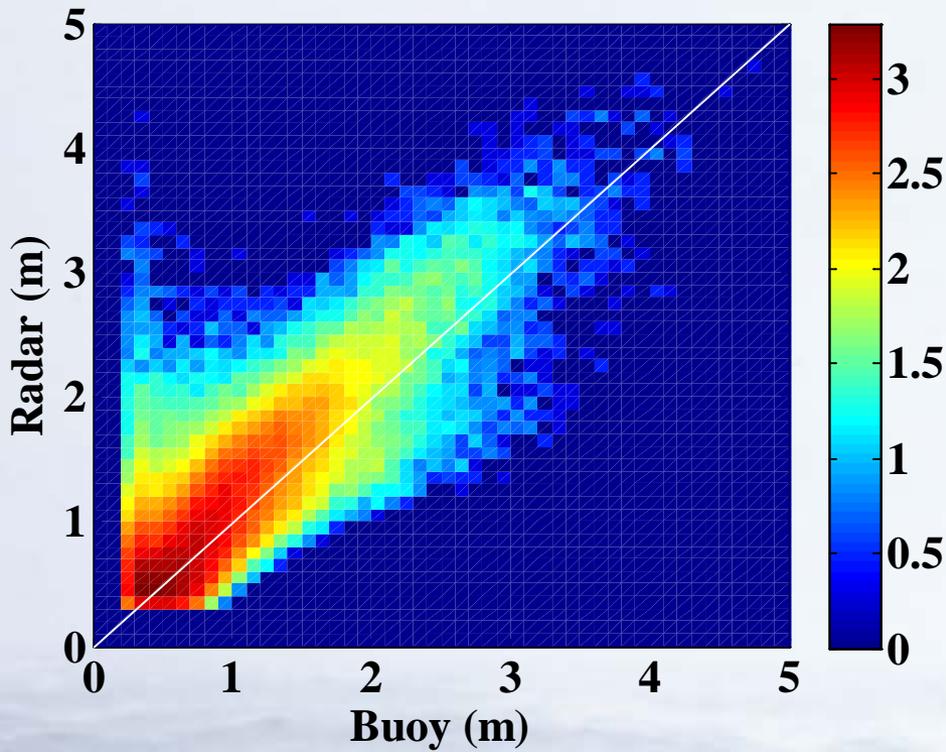


Single radar, Formby
 $r=0.81$; $n=65\%$

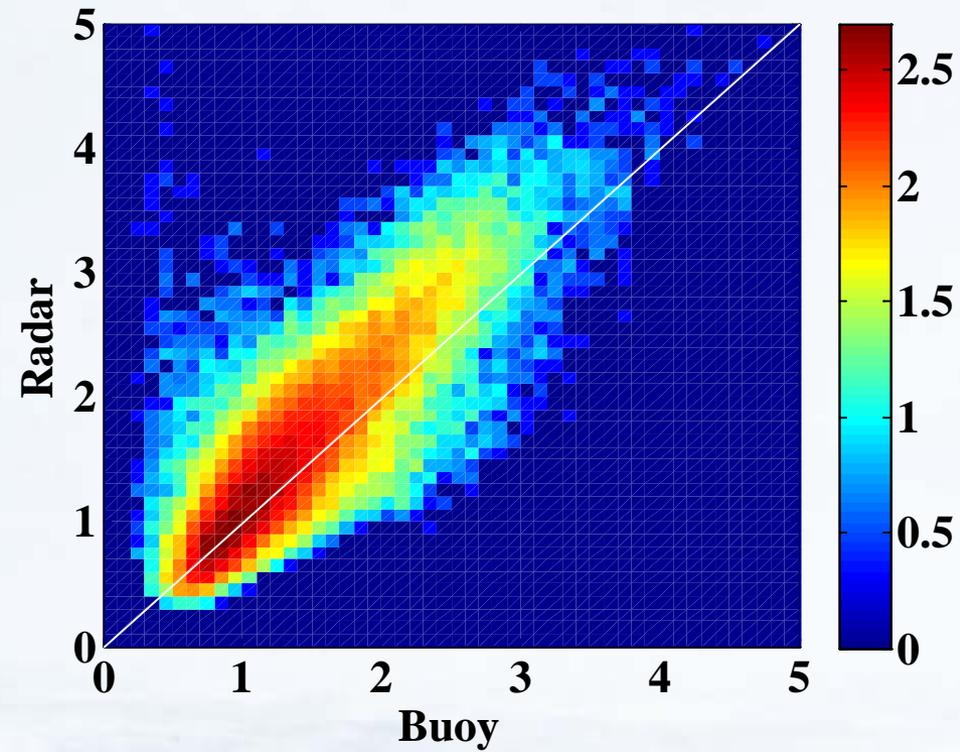


Dual radar
 $r=0.66$; $n=33\%$

Significant wave height (Aug 2005 – Dec 2010)



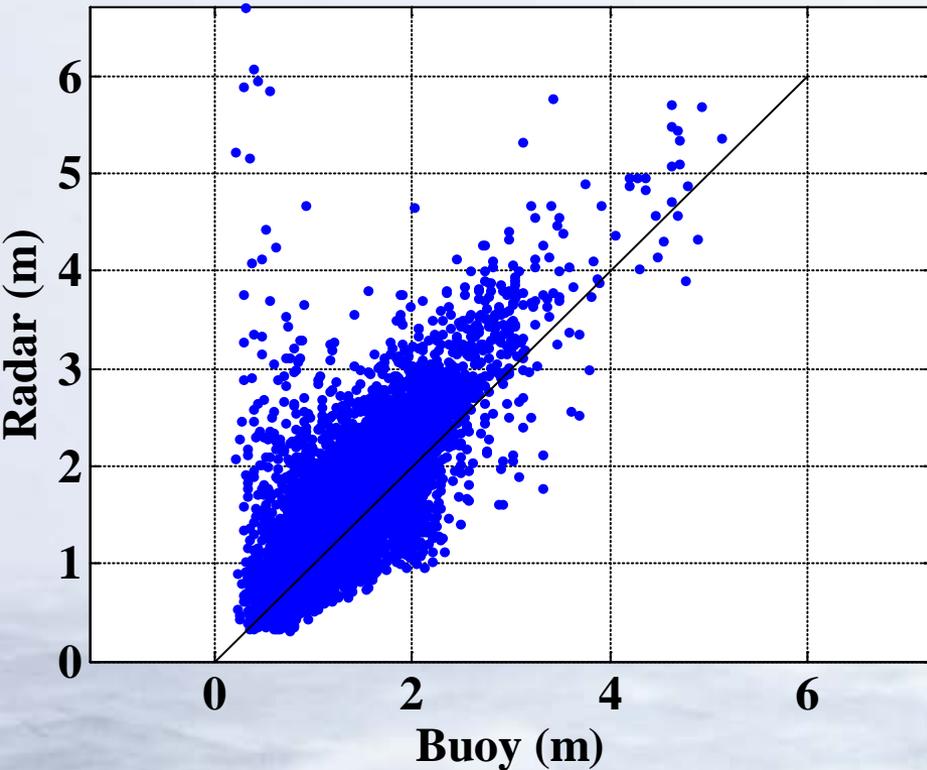
Single radar, Formby
 $r=0.81$; $n=65\%$



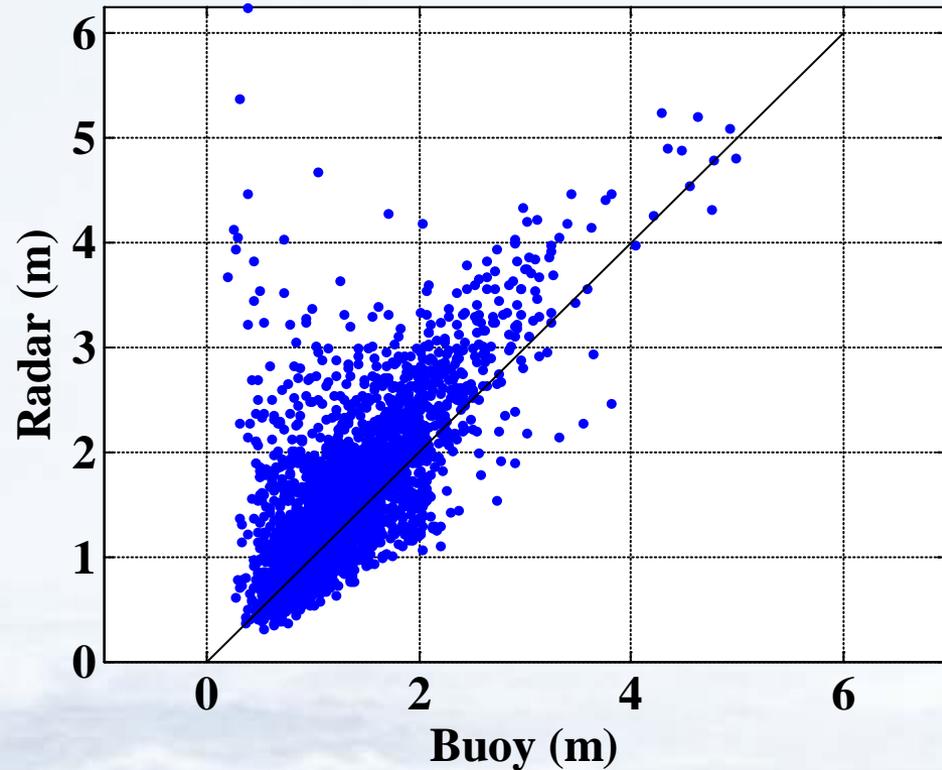
Dual radar
Inversion threshold 0.3
 $r=0.80$; $n=29\%$
(Julio Figueroa)

Sample duration

10 min every 20 min



20 min every hour



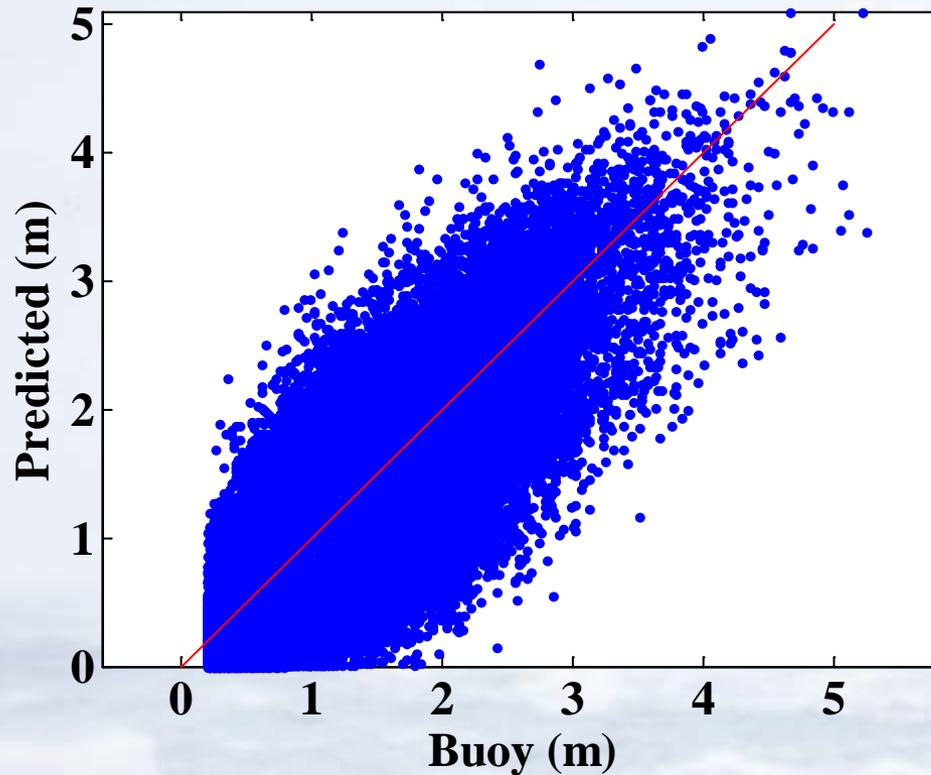
20 min: $r=0.72$; $n=27\%$:

10 min: $r=0.76$; $n=26\%$

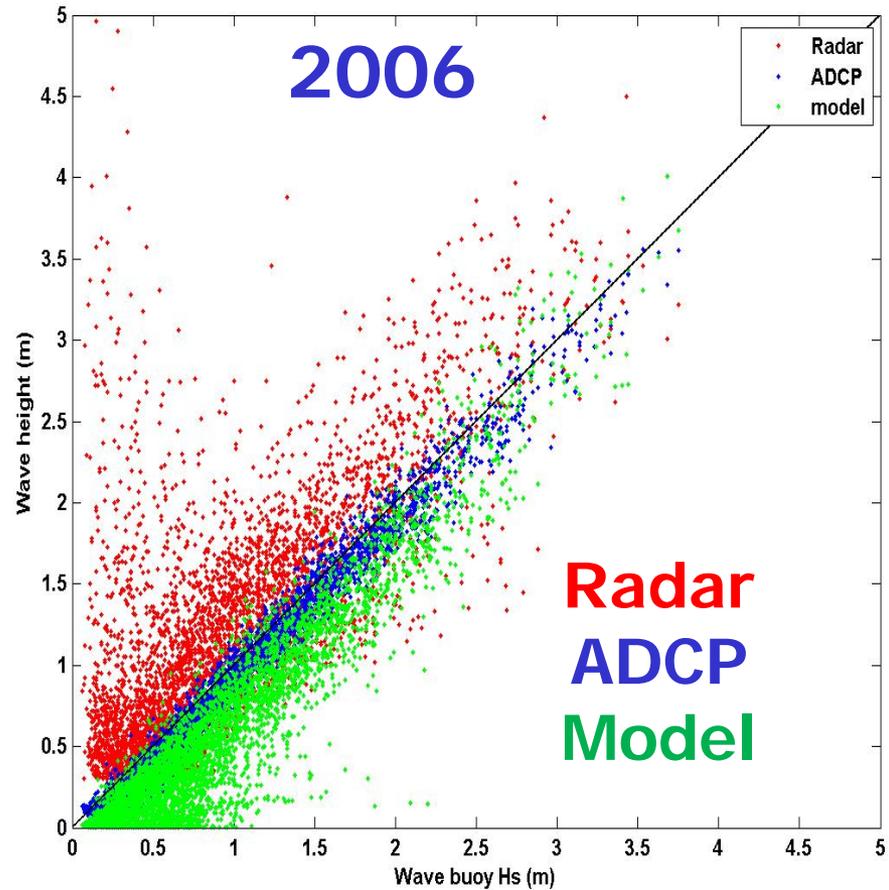
18 Nov 2009 to 30 Dec 2010

Inversion residual 0.3

Simple wave prediction formula

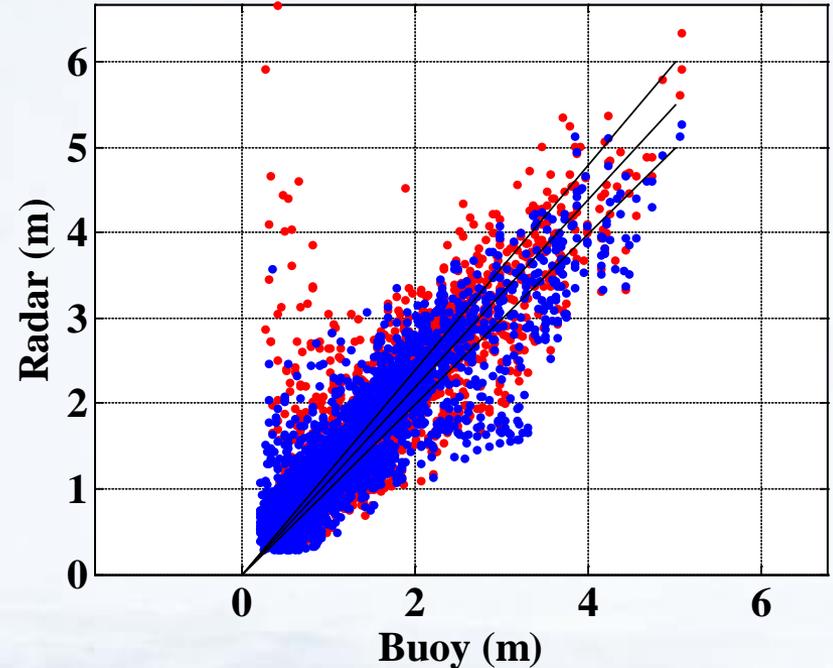
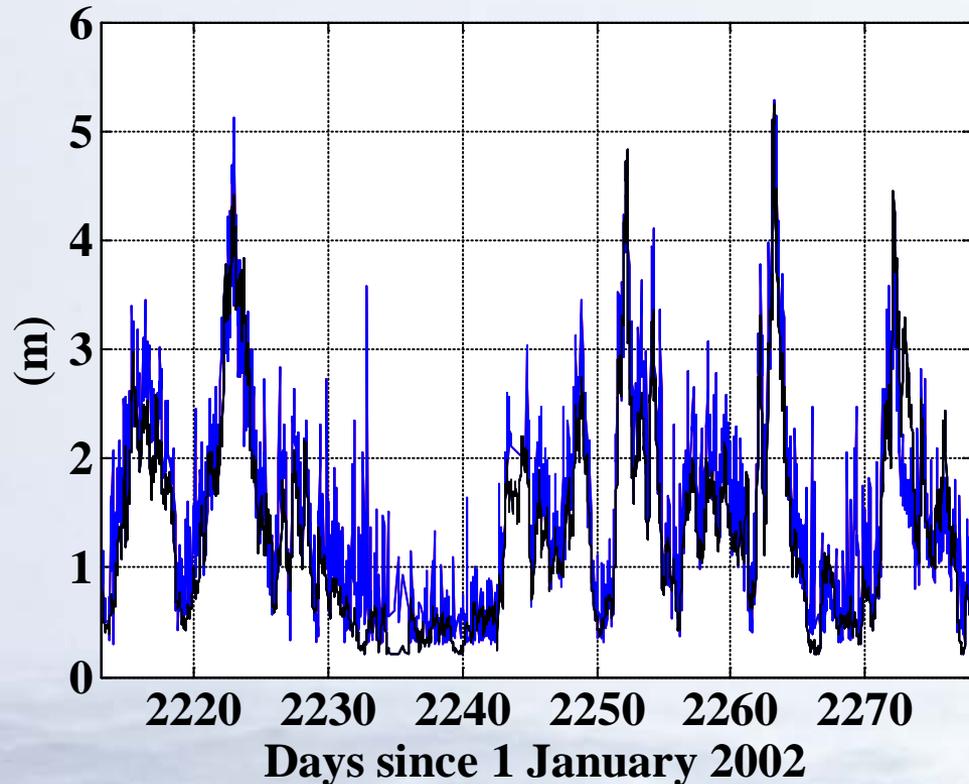


	r	Mean difference (m)
Hilbre	0.84	0.09
Gwynt y Môr	0.89	-0.03



	Bias (m)	Rms error (m)	Correlation
Hf radar	0.25	0.57	0.63
ADCP	-0.09	0.12	0.99
Model	-0.31	0.38	0.93

Stormy period (21 January – 26 March 2008)



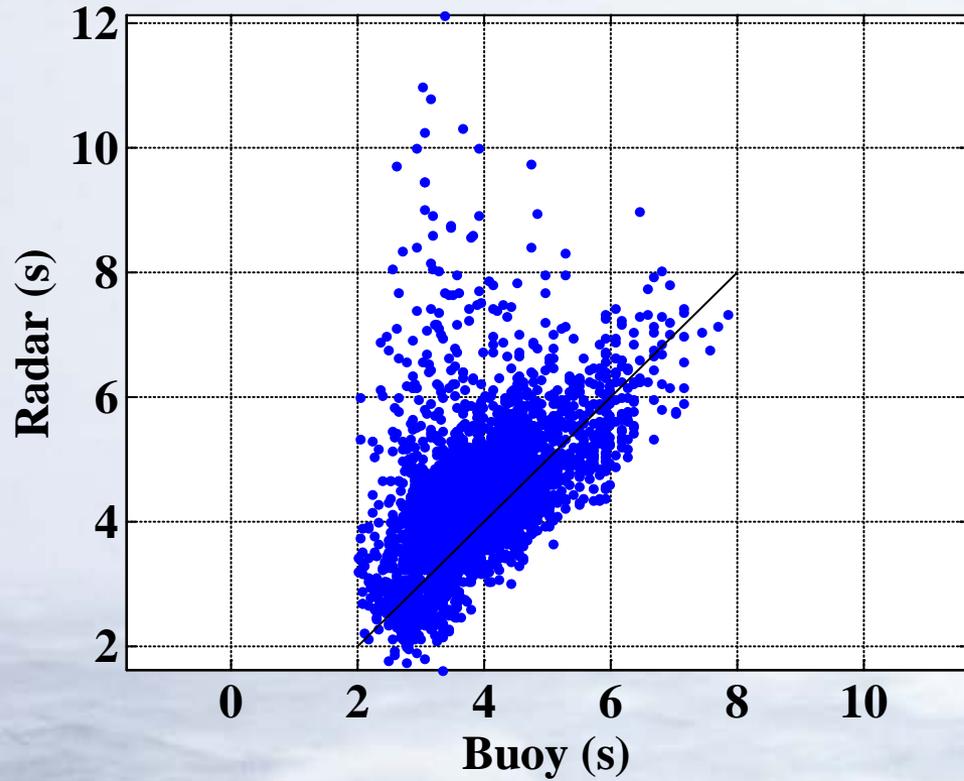
Single **0.89**

Dual **0.81**

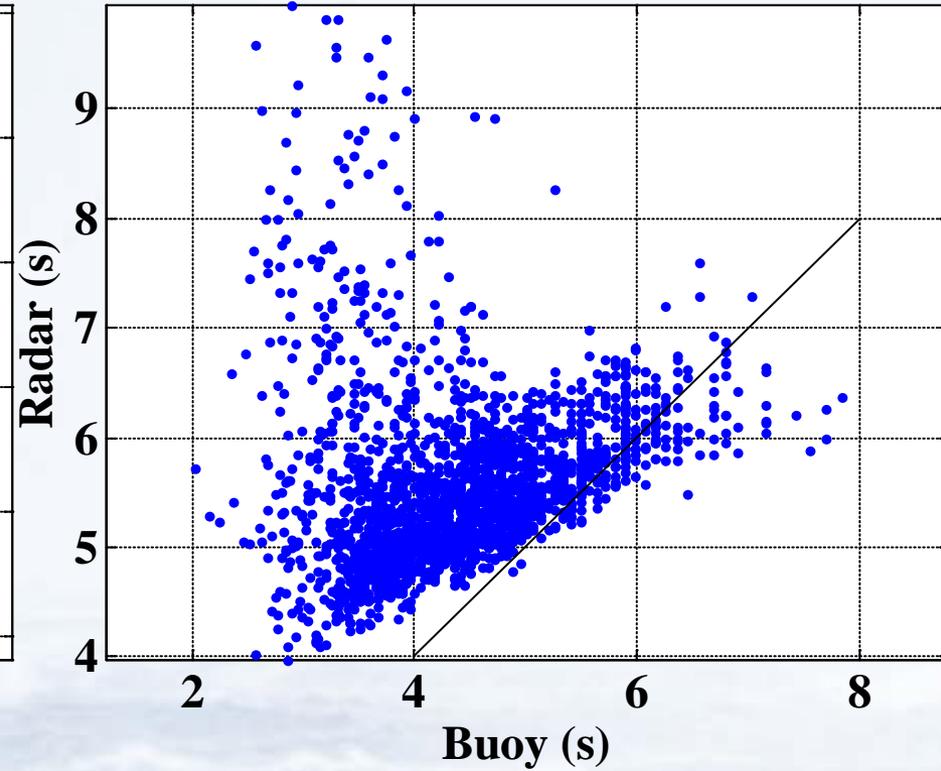
First three storms from west, fourth from North

1:1, 1:1.1, 1:1.2 slopes indicated

Period

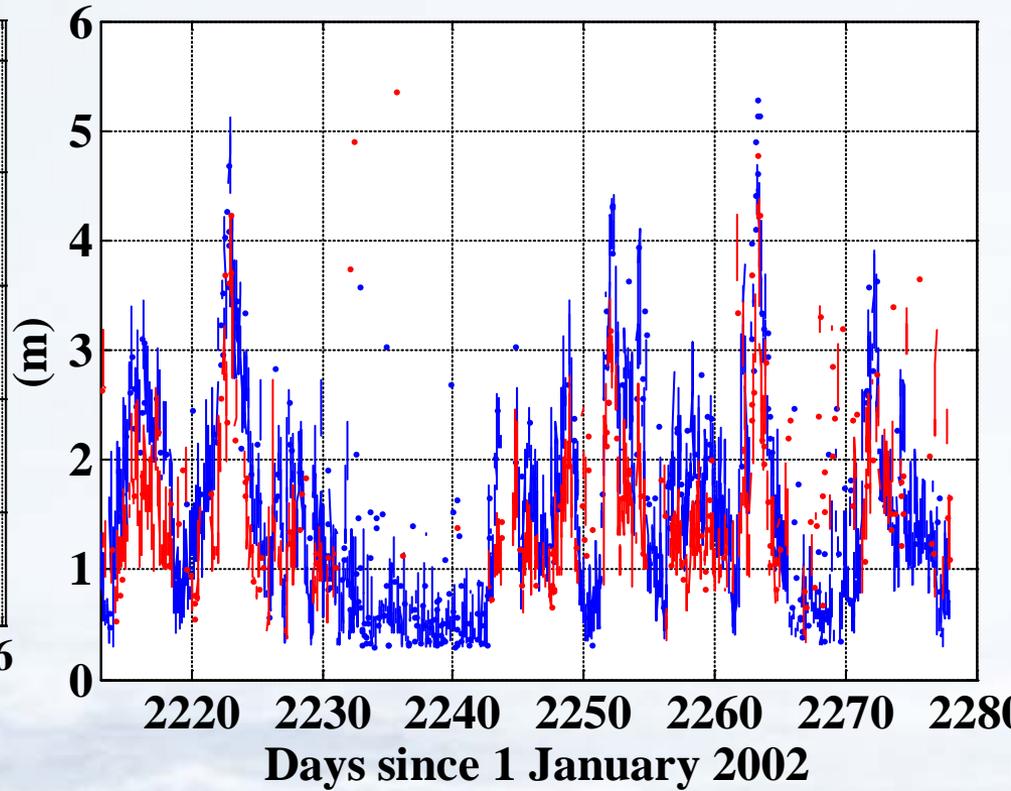
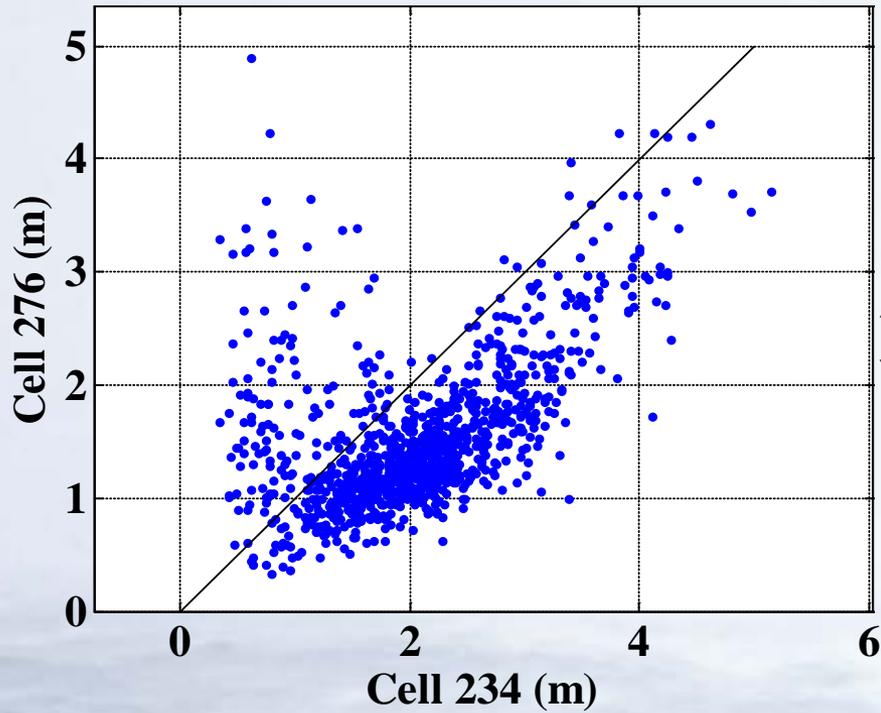


Single
 $R=0.53$



Dual
 $r=0.19$

Shallowing water

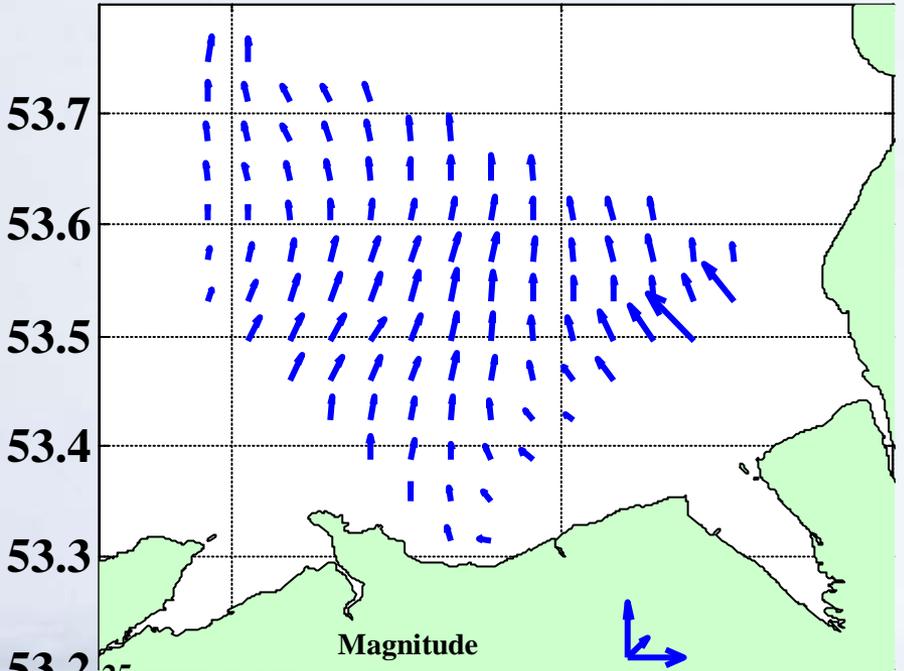


Cell 234

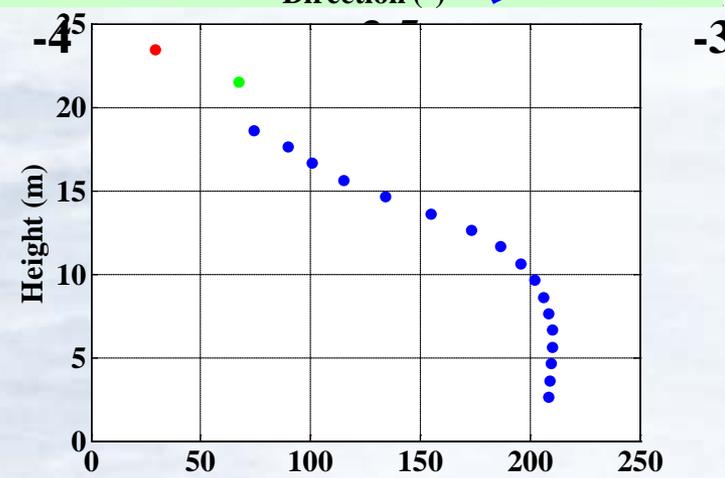
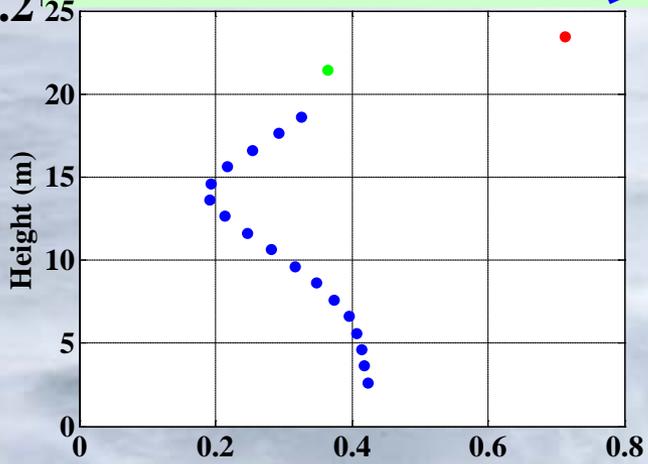
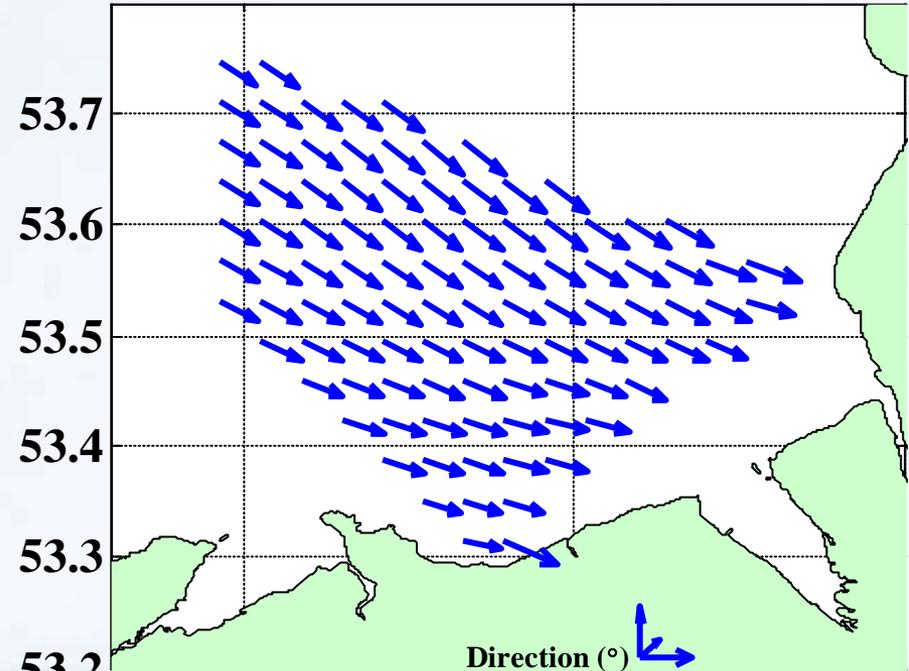
Cell 276

Correlation between wind and residual current

Offset



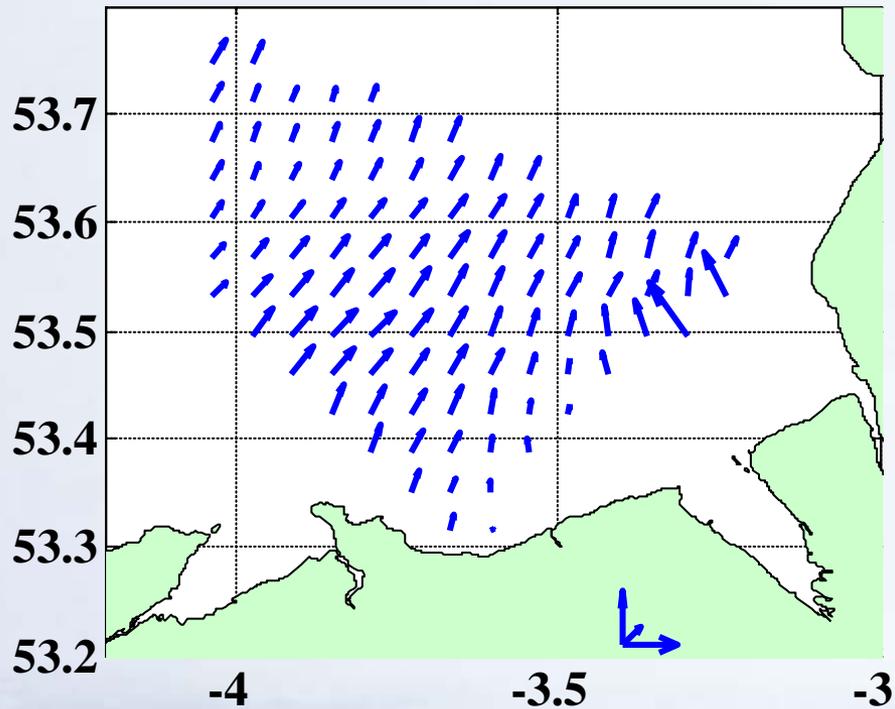
Slope



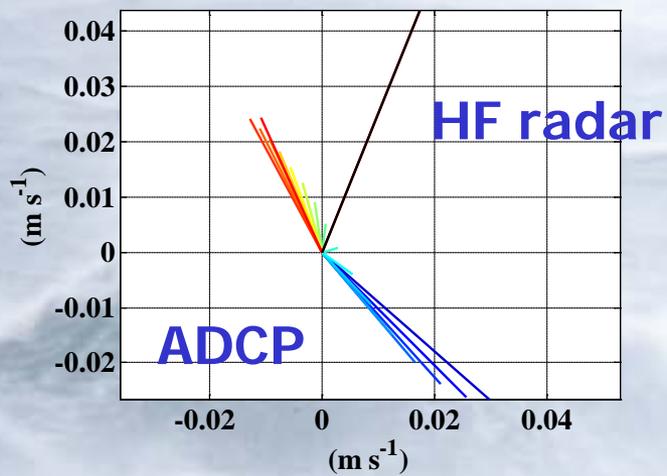
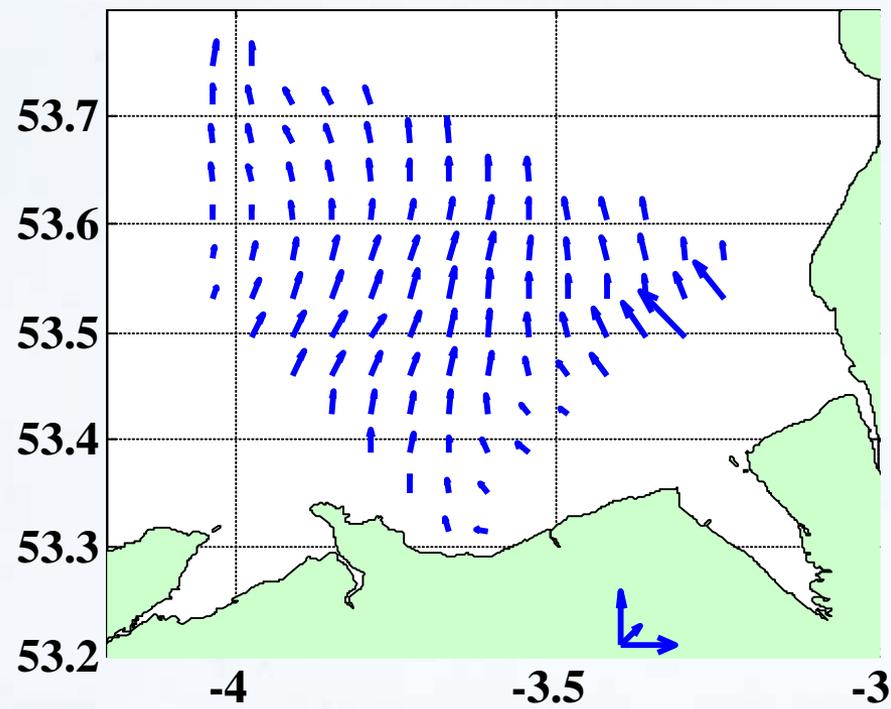
Mean wind
factor
0.009, 29°

Mean current

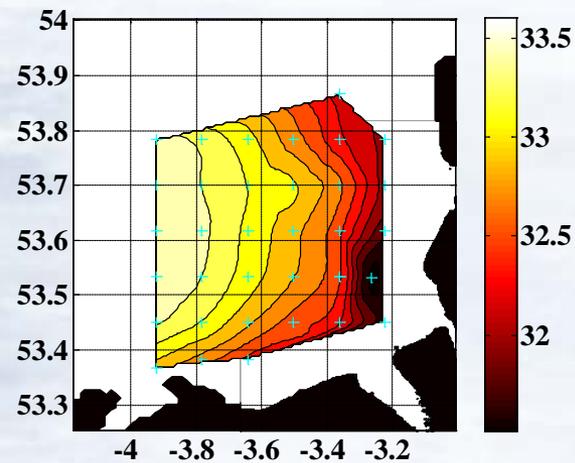
Z_0



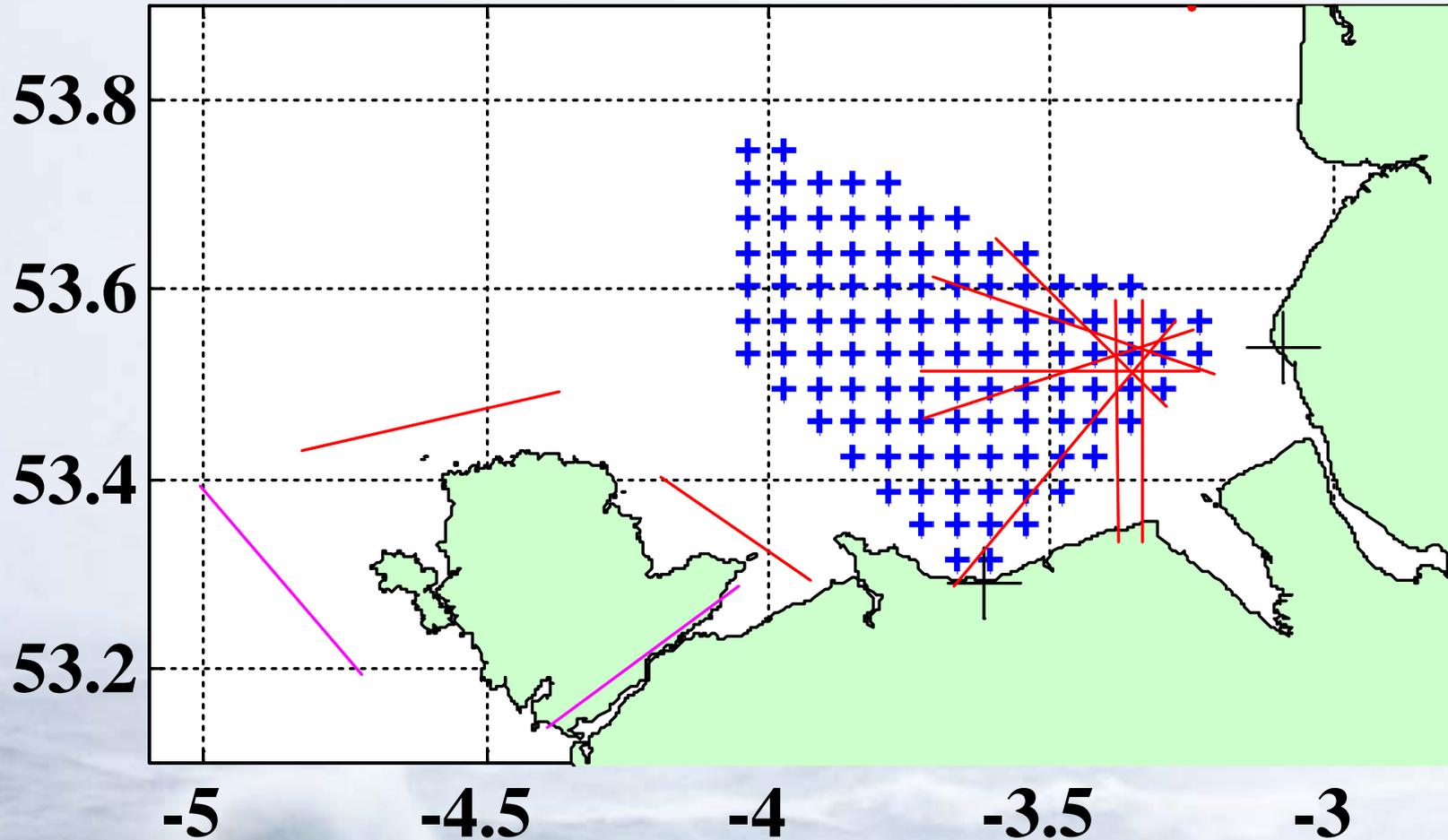
Offset



Near bed salinity



Wavemill



Spring tides - ebb
01:30 26 October
02:15 27 October

Summary

Operation in a continental shelf sea

Running for 6 years - reliable

Min wave height for wave measurement (1 m)

Max wave height no problem

Non optimal deployment

Single v. dual radar

Radar wave heights over-predicted

Period

Surface currents (average over 1m) include Stokes drift

Tides, wind forced, mean

August 2005 – November 2011