Case study comparisons of UK macro-tidal regime wave and current interaction: mesoscale model versus coastal buoy data

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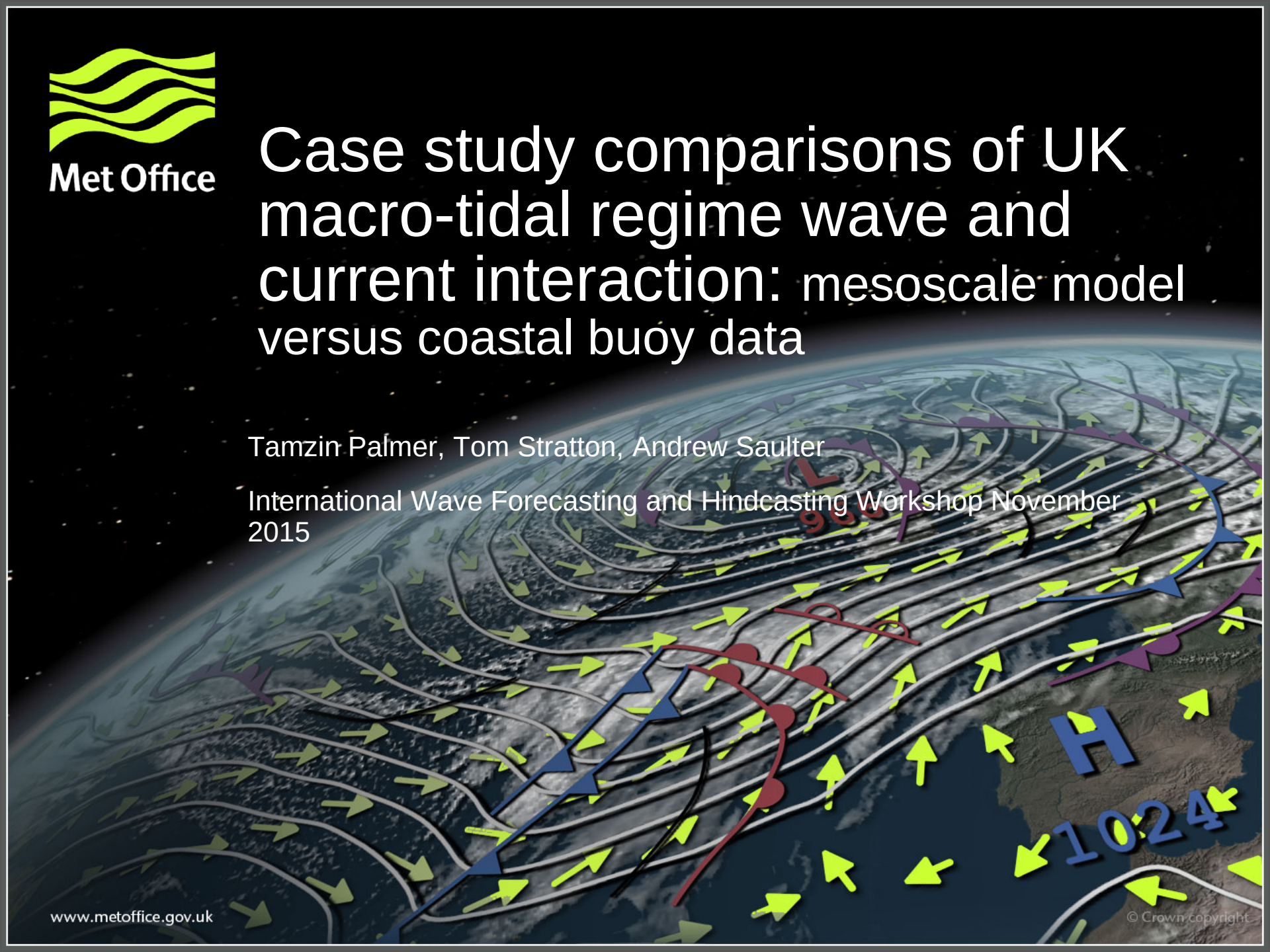
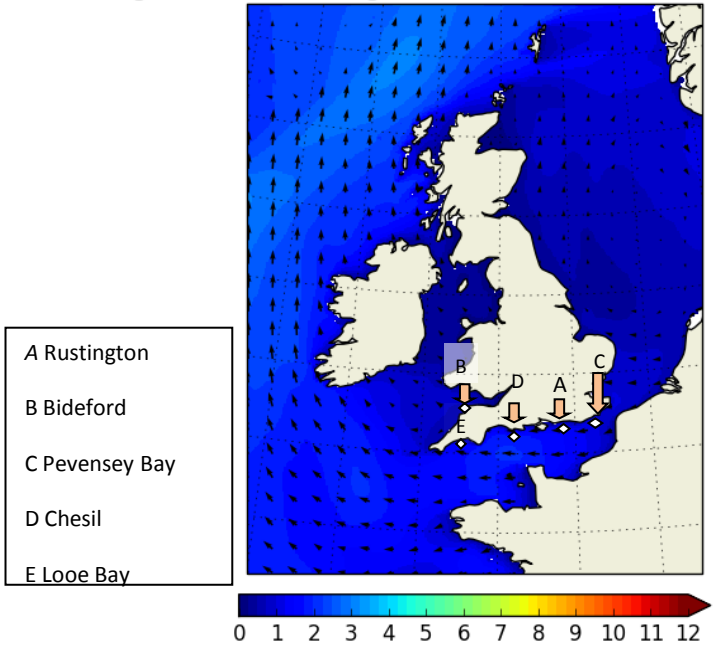


Overview

- Coastal Wave Modelling around the UK coast.
- Wave model set-up
- Wave current interactions at the locations chosen for this study.
- Wavelet analysis of the wave time-series.
- Cross correlation of the wavelet analysis with the Sea Surface Height (SSH).
- Case studies carried out at two different coastal locations

Coastal Wave Modelling in the UK

Significant wave height (m) at T+000 [28/09/2015 00:00]



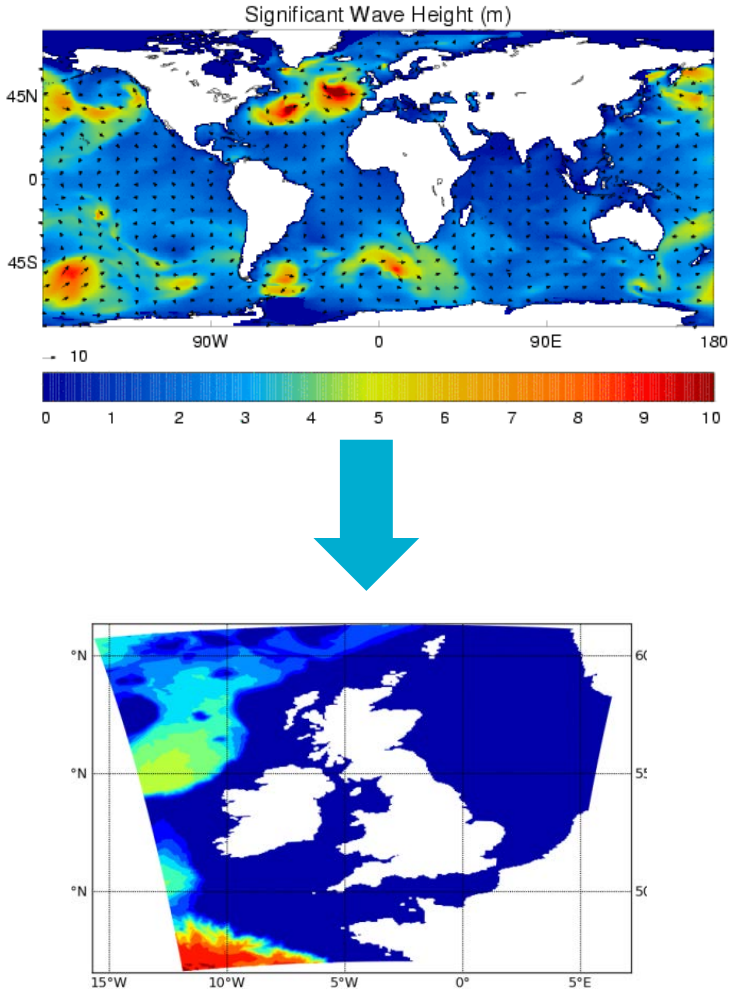
- Around the UK coast there are a number of locations where the tidal range is several metres.

- Current speeds can be in excess of 2m/s.

- Two areas of interest in this study: the English Channel near the Isle of Wight and Bideford near the Bristol Channel.

- The tidal range of the Bristol Channel can be up to 14m, current speed can be over 2.5m/s.

Wave Model Set-Up



- WAVEWATCH III (3.14) has been used by the Met Office for all operational outputs since 2008.

- WAM 4 Physics (Bidlot et al.,2007a, Ardhuin et al., 2010) for wave growth and dissipation.

- 2nd order advection scheme (Li 2008).

- Global Model 35km, wind forcing from MetOffice UM analysis fields (25km).

- UK 4km wave model, boundary conditions from global model, wind forcing from UM analysis fields (25km).

- Rotated grid.

- Current fields from Atlantic Margin Model (AMM 7km).

Wave – Current Effects in the Study Area

•Changes in water depth and ambient currents due to tides are known to alter the wave field through a number of processes

• Modulations in the Hs, mean period (Tz) and directional spread have been observed in a number of coastal locations.

• In an opposing current blocking may occur if the speed of the current approaches or exceeds the group speed if the waves. Dissipation of wave energy due to break is also likely to occur

•Currents may also affect the local generation of waves. The speed and direction of a current may alter the effective fetch or the relative effect of the wind speed on the waves.

•Current induced refraction.

Atlantic Margin Model (AMM7)

• Coupled hydrodynamic-ecosystems model, nested into the Met Office global Forecast Ocean Assimilation Model (FOAM) configuration.

•FOAM AMM system run daily and produces 3D analyses and 6 day forecasts of ocean currents, traces and several biogeochemical and optical quantities.

• AMM hydrodynamics are taken from NEMO (Nucleus for European Modelling of the Ocean). This is a community ocean modelling framework.

•Surface forcing is taken from the Met Office NWP model: heat, moisture, wind speed and surface pressure.

•Tidal forcing on the open boundary is via a Flather radiation boundary condition (Flather 1976) and through the inclusion of an equilibrium tide.

Wave Model Validation

- The UK 4km Model configuration was run as a hindcast for 2012.

- A control run was carried out using UM analysis wind data as the only forcing field.

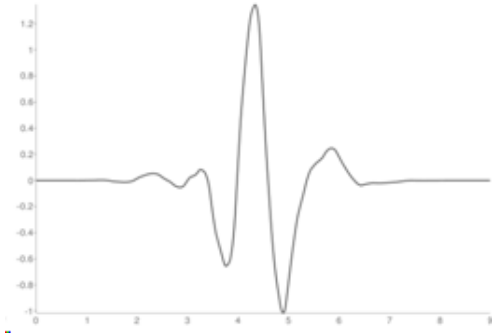
- The model was also run with an additional surface current input field from the AMM7 model.

- The model runs were validated against offshore and coastal in-situ data.

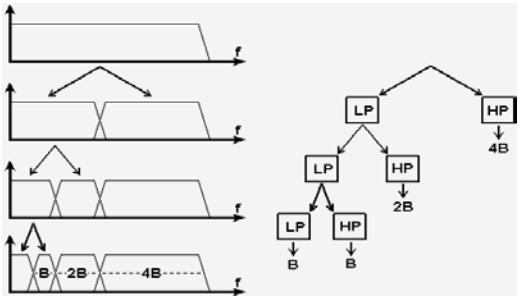
- Offshore validation against in-situ for the two models was very similar with little or no difference in the RMSE.

- The models were also validated against the Channel Coastal Observatory (CCO) wave buoys.

Multi-level Discrete Wavelet Analysis



'Sym 5' symlet



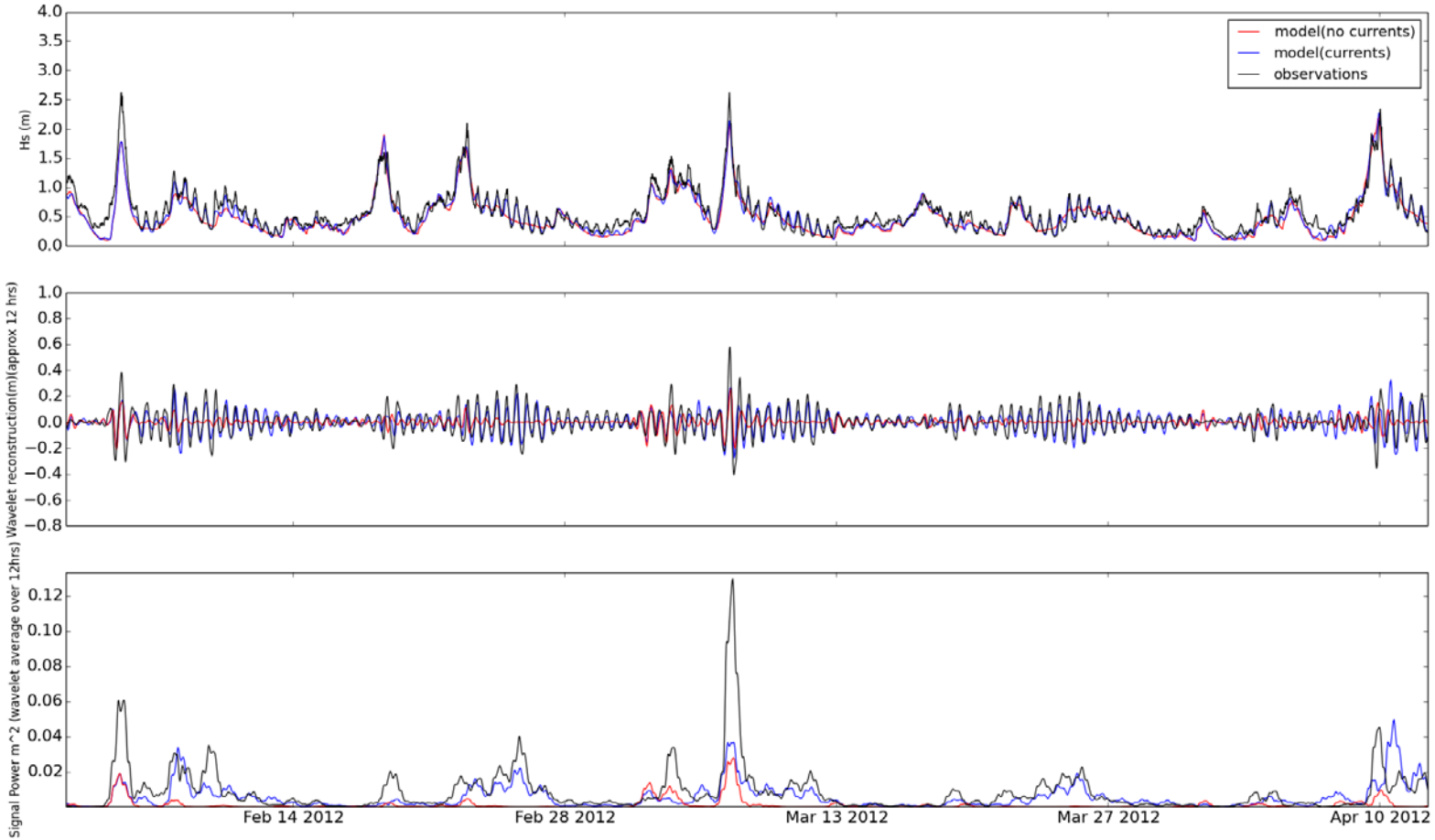
•To identify periods of strong modulation due to tidal effects as far as possible, a discrete wavelet analysis was carried out on the wave model time series for each wave buoy location.

•The central frequency of the wavelet was also chosen to allow an approximate frequency as close to the semi-diurnal (M2) tidal signal as possible

•A ‘Sym 5’ symlet (see left top) had an approximate 12 hour period at the 2nd dilation level for the hourly model data and the 3rd level for the half hourly buoy data.

$$Fa = \frac{Fc}{s \times \Delta}$$

Where Fa is approximate frequency, Fc is the central frequency of the wavelet , $s = 2^n$ and Δ is the sample width of the data set.


model(no currents)
model(currents)
observations
Hs (m)
Wavelet reconstruction(m)(approx 12 hrs)
Signal Power m^2 (wavelet average over 12hrs)
Feb 14 2012
Feb 28 2012
Mar 13 2012
Mar 27 2012
Apr 10 2012

Cross Correlation with Sea Surface Height

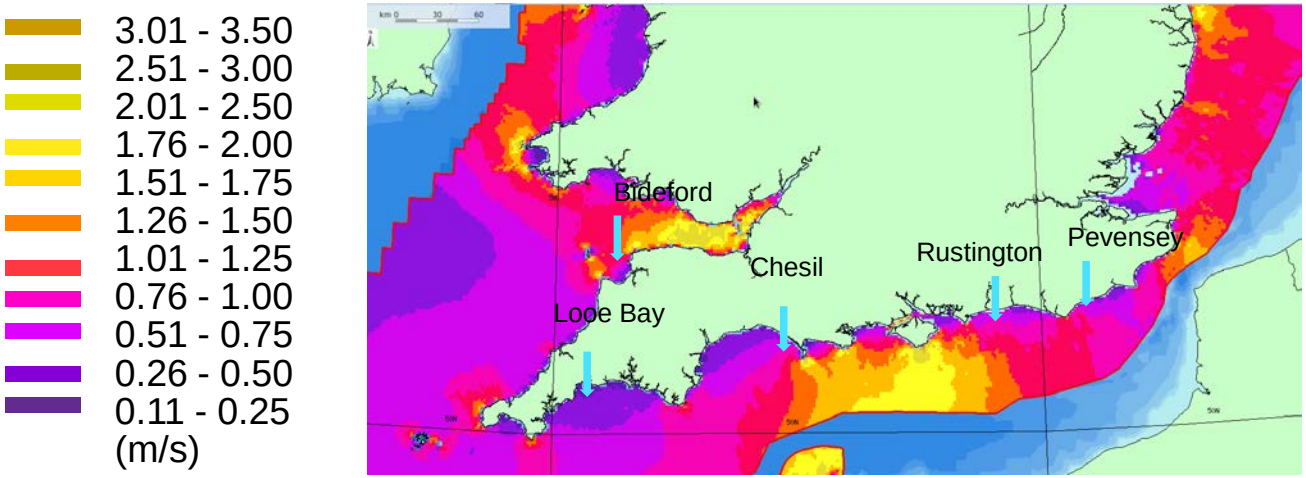
Location	Wave parameter	Pearson Correlation Coefficient (Obs, Model, Model – no currents)	Lag behind SSH (Obs, Model, Model – no currents)
Rustington	**Hs**	**0.637, 0.623 , 0.005**	**12, 12 , 12**
	Tz	**0.645, 0.559 , 0.113**	**0, 0, 4**
Bideford	**Hs**	**0.706, 0.501 , 0.014**	**8, 9 ,10**
	Tz	**0.666, 0.266, 0.146**	**6, 5, 1**
Looe Bay	**Hs**	**0.066, 0.060 , 0.024**	**5, 9, 6**
	Tz	**0.389, 0.256, 0.109**	**5, 2, 4**
Pevensey	**Hs**	**0.373, 0.341, 0.062**	**0, 0, 5**
	Tz	**0.449, 0.514, 0.101**	**1, 0, 4**
Chesil	**Hs**	**0.519, 0.170, 0.098**	**3, 3, 4**
	Tz	**0.580, 0.188, 0.056**	**3, 6, 9**

Met Office

- Strongest correlation with SSH near regions of fastest currents.

- Rustington is immediately down wave of the current gradient and the strongest current related modulations are observed here.

- The effects of the currents are still observed to a lesser extent at Pevensey.

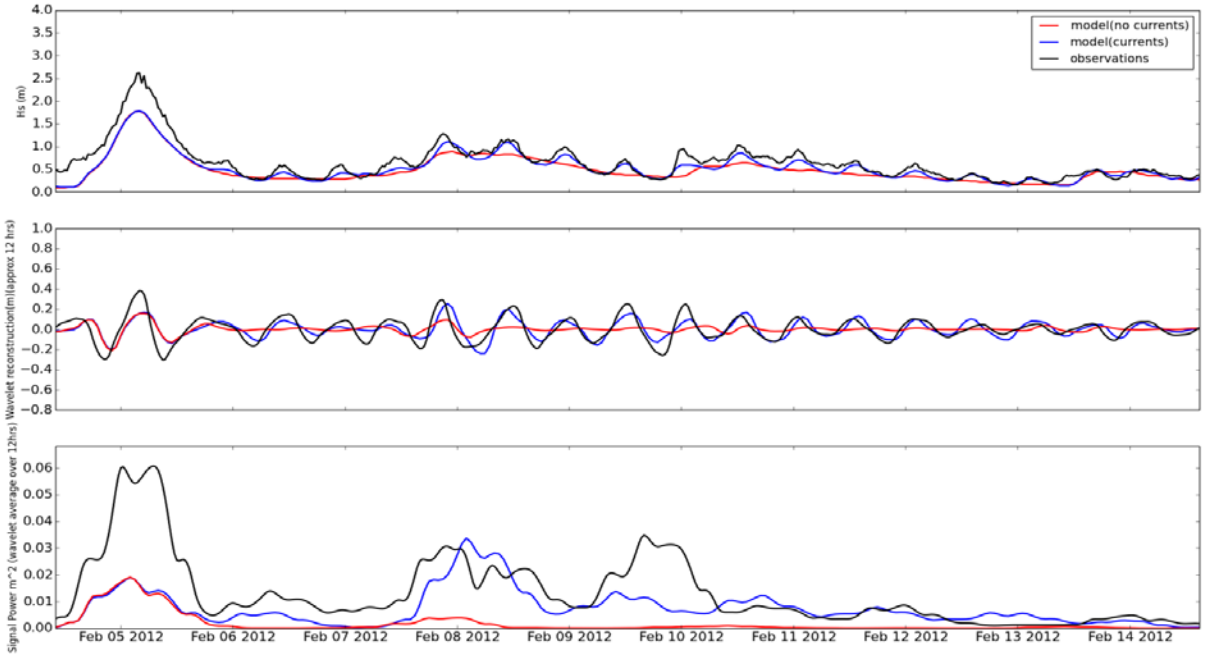


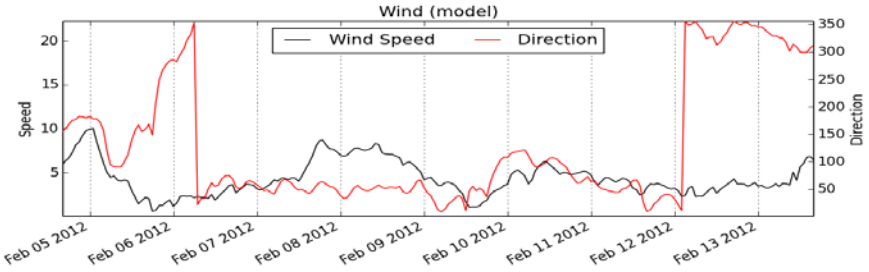
Taken from Atlas of UK Marine Renewable Energy Resources. 2008. ABPmer. (. 29 October 2015) http://www.renewables-atlas.info/

Case Studies: Rustington

RMSE control 0.18m.

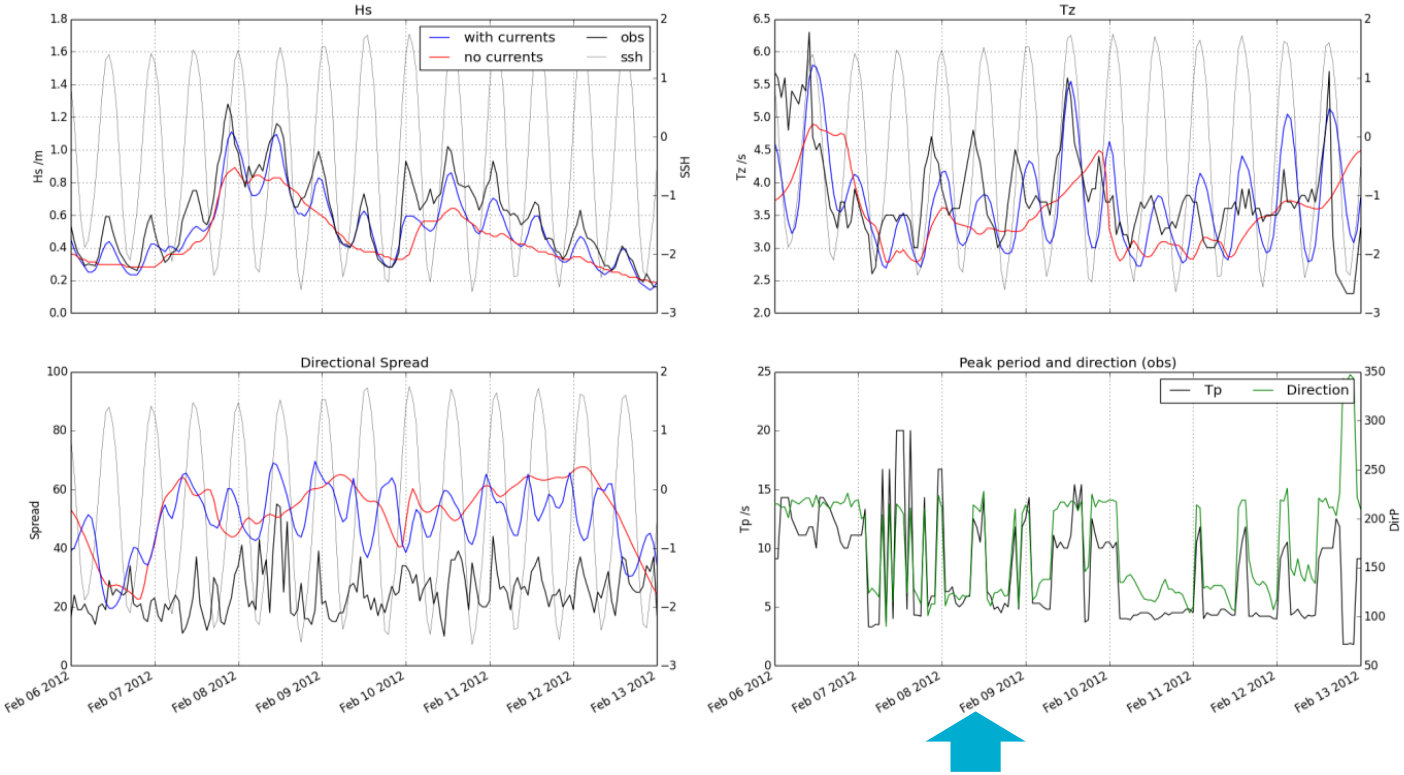
RMSE currents added 0.15m





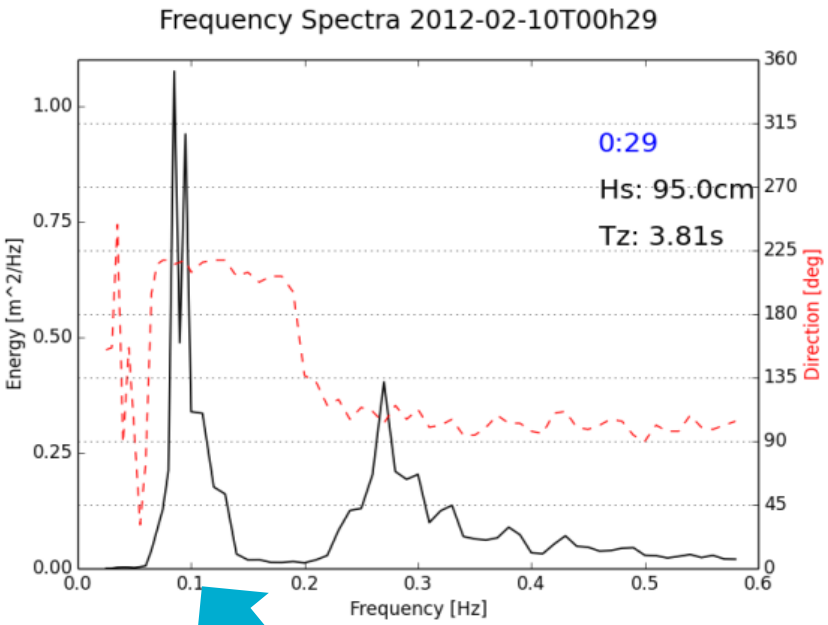
Case Studies:Rustington

6th – 13th February 2012

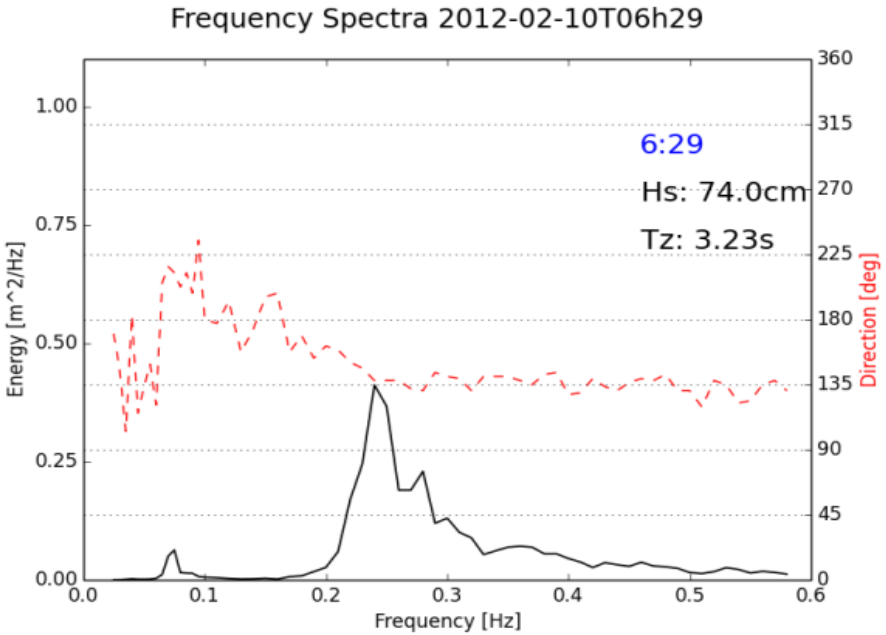


Rapid large changes in the observed peak frequency and peak direction suggest a bimodal wave spectrum

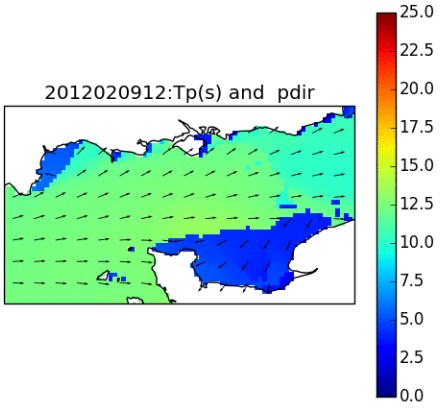
Observed Frequency Spectra: Rustington

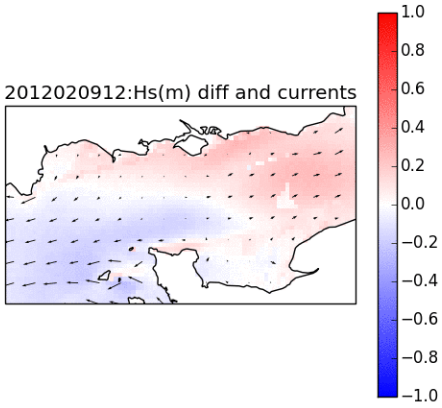


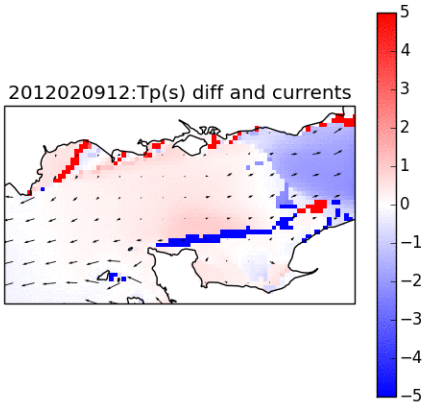
Swell energy at high tide.

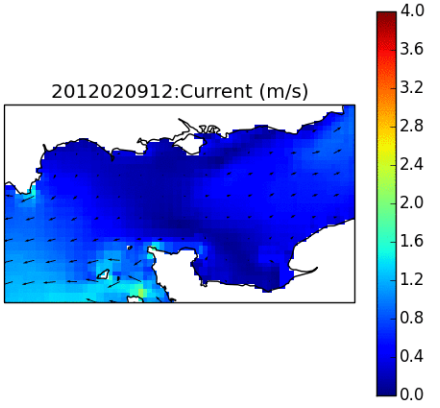


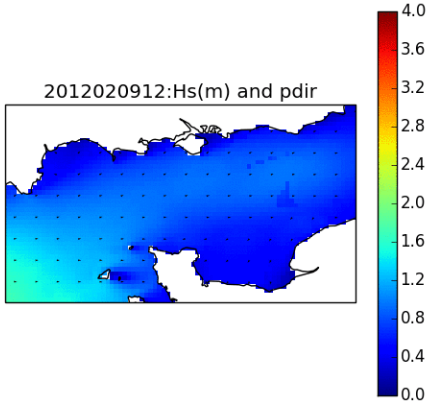
Low tide

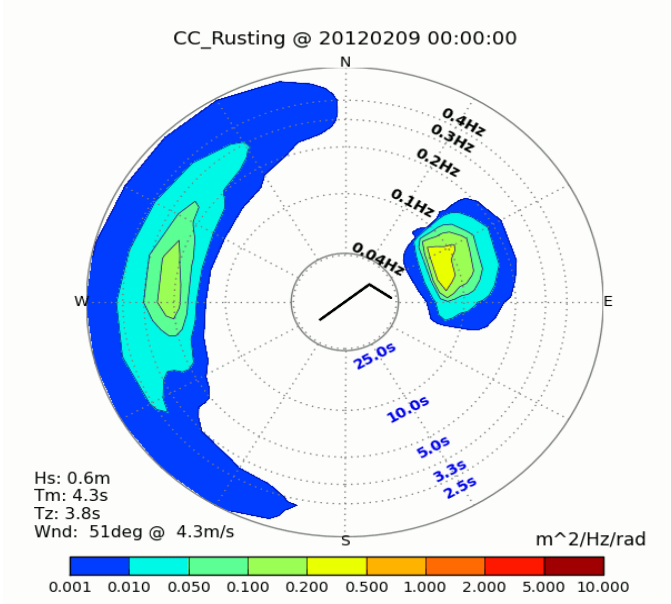

2012020912:Tp(s) and pdir
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0


2012020912:Hs(m) diff and currents
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0

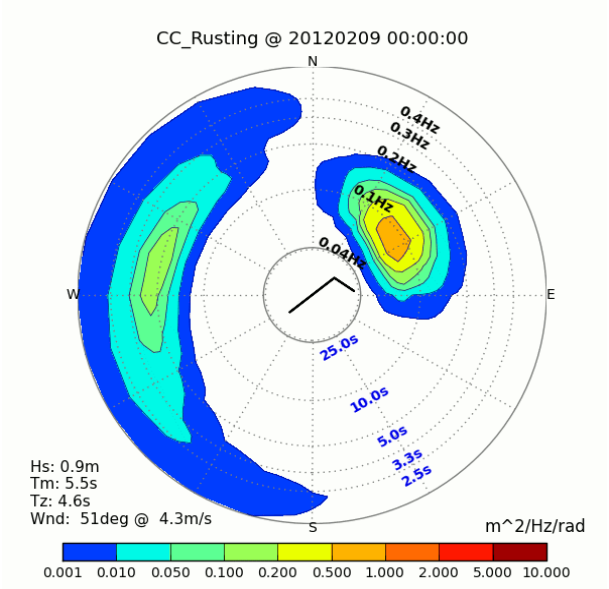

2012020912:Tp(s) diff and currents
5
4
3
2
1
0
−1
−2
−3
−4
−5


2012020912:Current (m/s)
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0

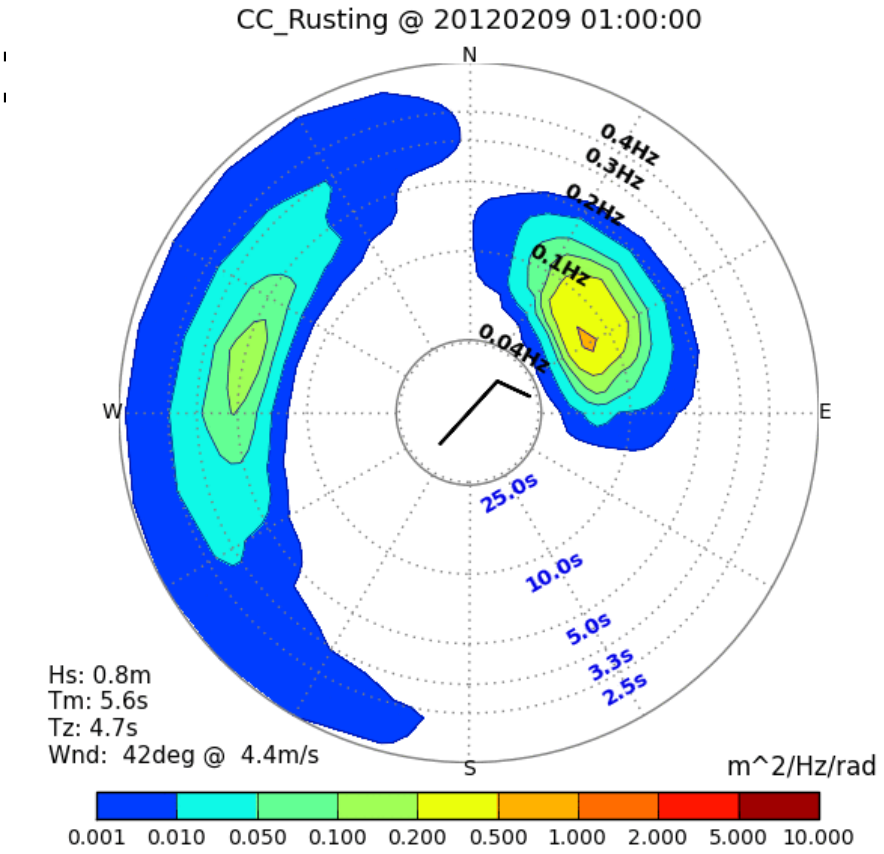

2012020912:Hs(m) and pdir
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0



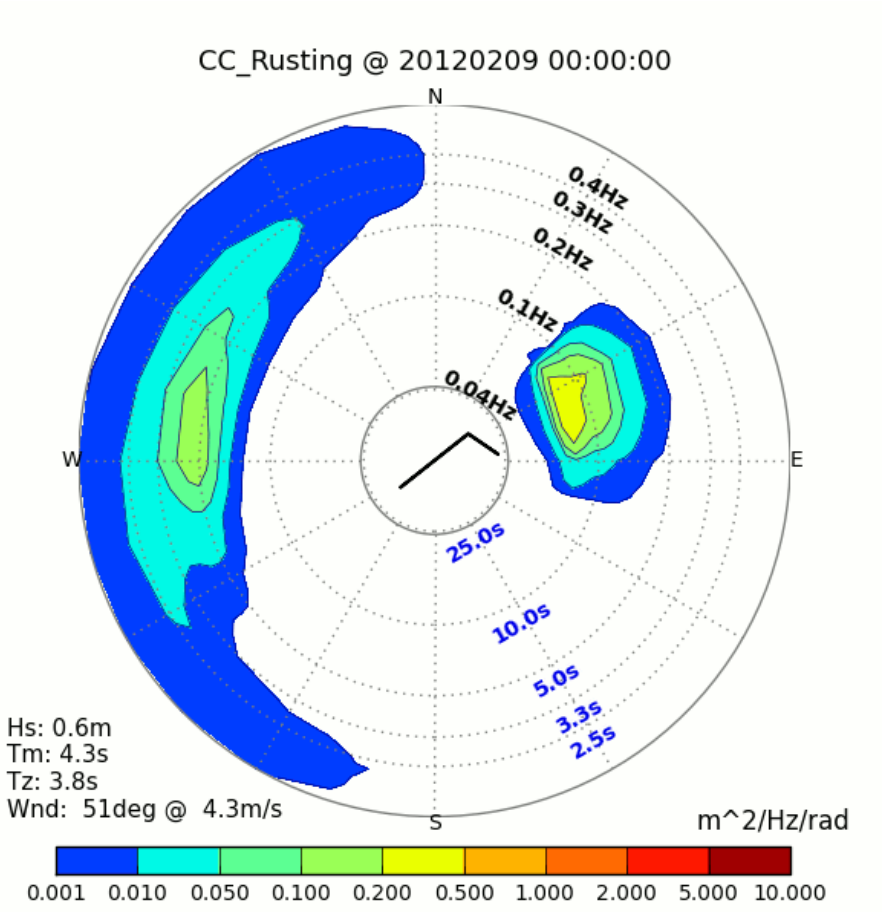
Control



Currents



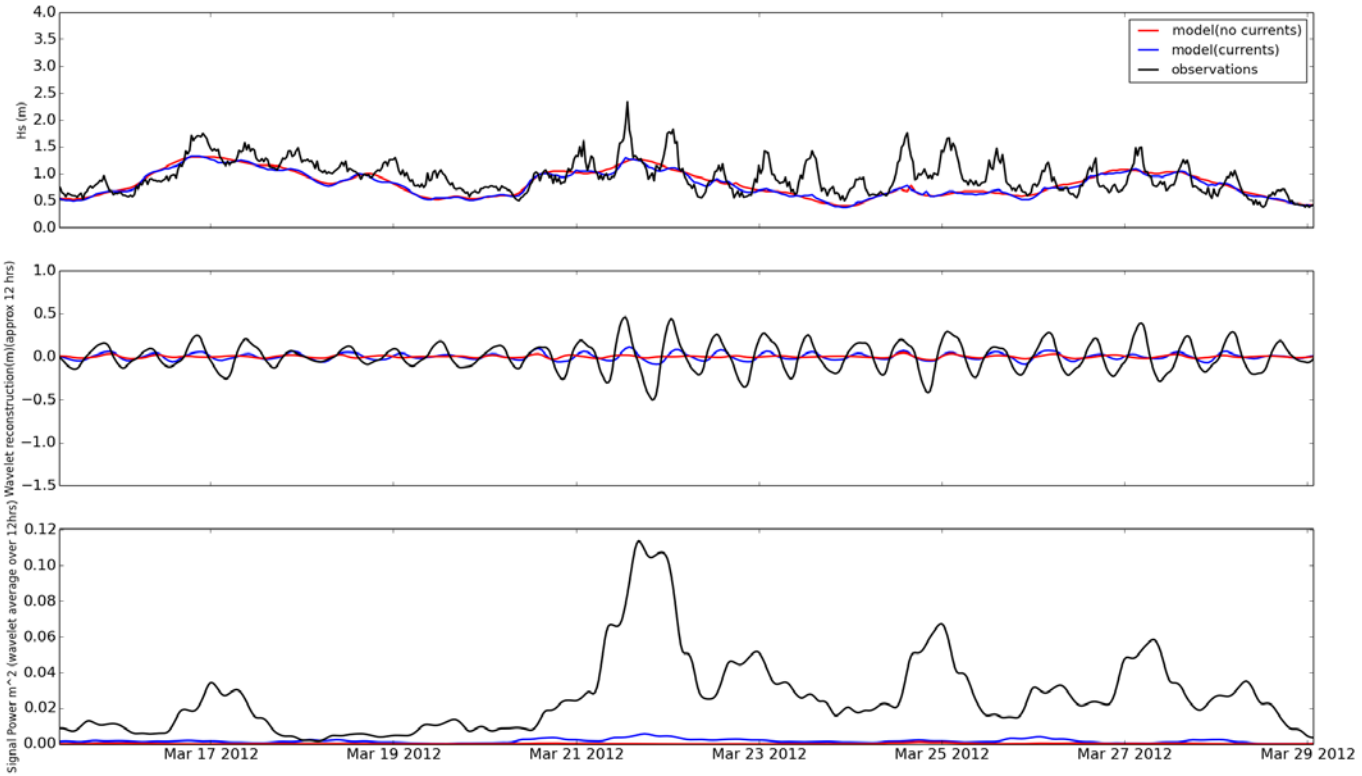
With currents.


CC_Rusting @ 20120209 00:00:00
N
W
E
S
0.4Hz
0.3Hz
0.2Hz
0.1Hz
0.04Hz
25.0s
10.0s
5.0s
3.3s
2.5s
Hs: 0.6m
Tm: 4.3s
Tz: 3.8s
Wnd: 51deg @ 4.3m/s
m^2/Hz/rad
0.001 0.010 0.050 0.100 0.200 0.500 1.000 2.000 5.000 10.000

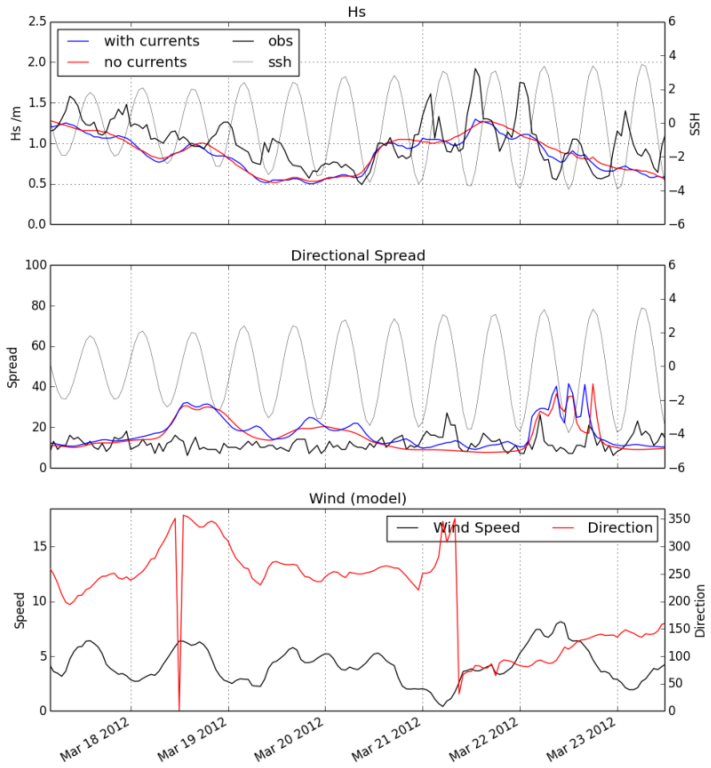
Control run.

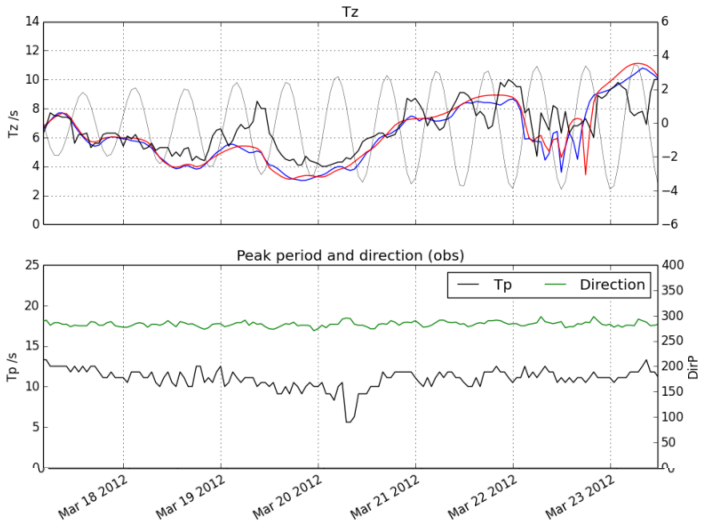
Case Studies: Bideford

21st-22nd March 2012.

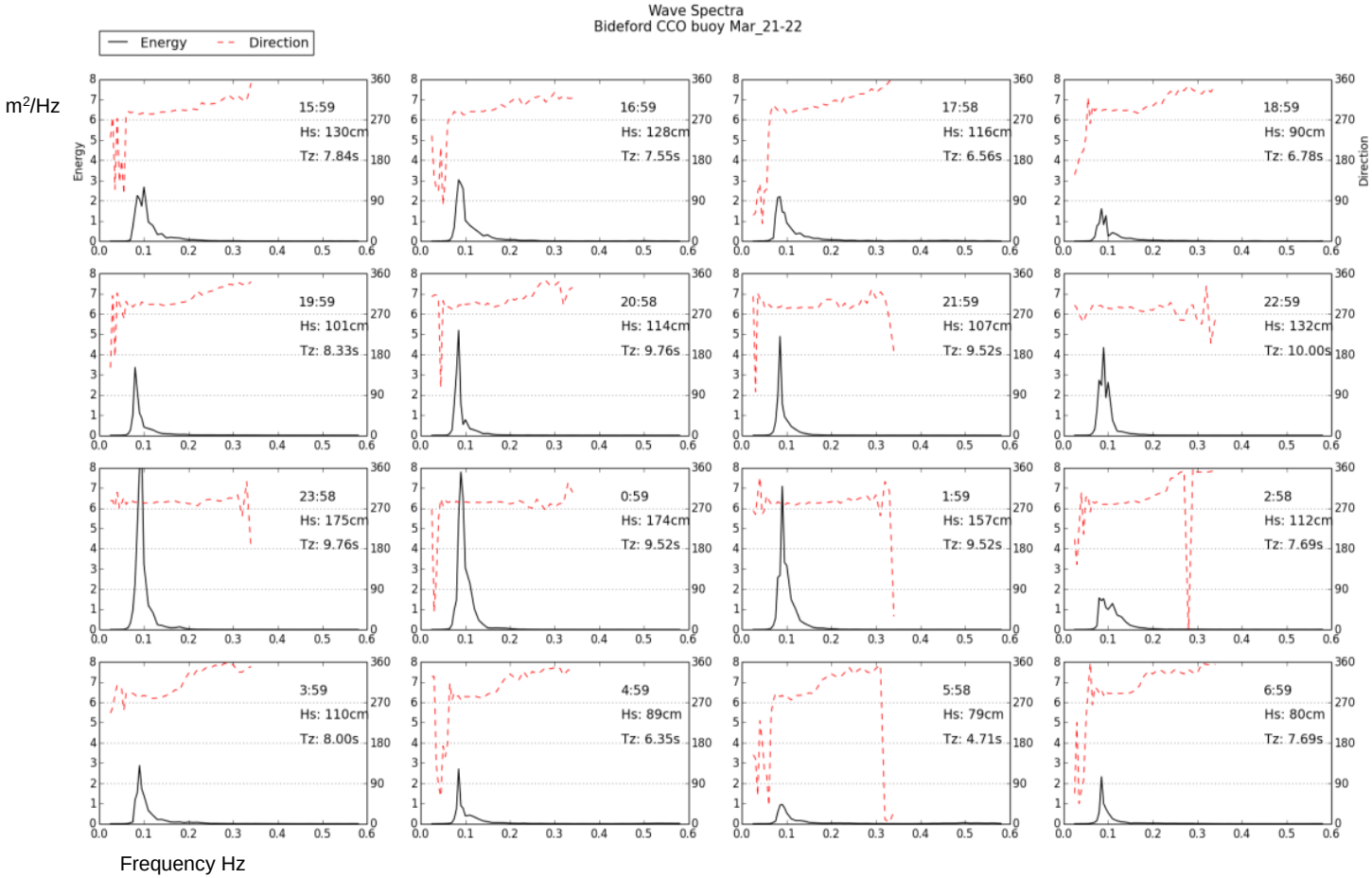


Case Studies: Bideford





Observed Frequency Spectra: Bideford



Low tide:
00:00

High tide:
06:00

Summary and Conclusions

• A discrete wavelet analysis has been used to successfully to identify suitable case studies case studies for the validation of wave-current interaction in a one way coupled model.

• Comparison of the cross correlation between the wavelet high pass filter (12 hour period) with processes such as the SSH is a useful way to investigate processes at different locations.

•This may also be a useful way to validate the model over longer time periods.

•Investigating periods where current processes dominate has shown an improvement in the wave model performance when a current field is added to the wave model.

Met Office

Thank you for listening.