

Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, DWD, BoM, and SHOM June 2008 to August 2008

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0.1 Forewords

Outputs from different operational forecasting centres are compared to buoy and platform data as broadcasted to the meteorological community via the Global Telecommunication System (GTS). On a monthly basis, data are gathered informally from operational weather services with an interest in wave forecasting (Bidlot and Holt, 2006). The different data sets are subsequently merged and made available to all participating partners for further evaluation. In this document, examples, in graphical and tabular forms, are shown. These results have been processed at ECMWF and should serve as an example to the kind of information that could be obtained from such comparison. No statement of quality, nor reasons why the different systems are performing differently will be given.

0.2 Data

Before using observations for verification, care has to be taken to process the data to remove any erroneous observations and also in order to match the scale of both model and observations. This scale matching is achieved by averaging the hourly data in ± 2 hour time windows centered on the four major synoptic times corresponding to the normal model output times. The original quality control and averaging procedure was discussed in Bidlot *et al.* (2002). It was extended to include platform data as described in Sætra and Bidlot (2004). Note that in this paper we refer to these data as buoy data since most of them are from moored buoys, except if stated otherwise.

The intercomparison relies on the exchange of model output at buoy locations. An agreed upon list of locations is used where observations are known to be available. Because buoy networks are changing with time, as witnessed by a rapid increase in the number of buoys available via the GTS since the mid-nineties, updates to the list have been necessary. Not all participating centres have been able to update their list however. Other participants are only running limited area model(s) or do produce the parameter(s) that can be compared to the buoy data. Because of the limited number of buoys, a fair comparison between the different systems can only be achieved if the same number of buoys and the same number of buoy-model collocations are used.

In this document, data that are common to ECMWF, MetOffice, FNMOC, DWD, BoM, and SHOM are used. The other participants are left blank in the plots below.

References

- Bidlot J.-R., D. J. Holmes, P. A. Wittmann, R. Lalbeharry, H. S. Chen, 2002: Intercomparison of the performance of operational ocean wave forecasting systems with buoy data. *Wea. Forecasting*, **17**, 287-310.
- Bidlot J.-R. and M.W. Holt, 2006: Verification of operational global and regional wave forecasting systems against measurements from moored buoys. *JCOMM Technical Report*, **30**. WMO/TD-No. 1333.
- Sætra, Ø. and J.-R. Bidlot, 2004: On the potential benefit of using probabilistic forecast for waves and marine winds based on the ECMWF ensemble prediction system. *Wea. Forecasting*, **19**, 673-689.

0.3 Results

In the remaining pages, some of the results of the comparison with buoys are presented for all common buoys and for common buoys within a sub-area as displayed by the corresponding maps. Summary forecast scores are shown first, followed by density scatter diagrams with associated statistics for each subarea. Only common data to ECMWF, MetOffice, FNMOC, DWD, BoM, and SHOM are used.

0.3.1 Comparison for all buoys

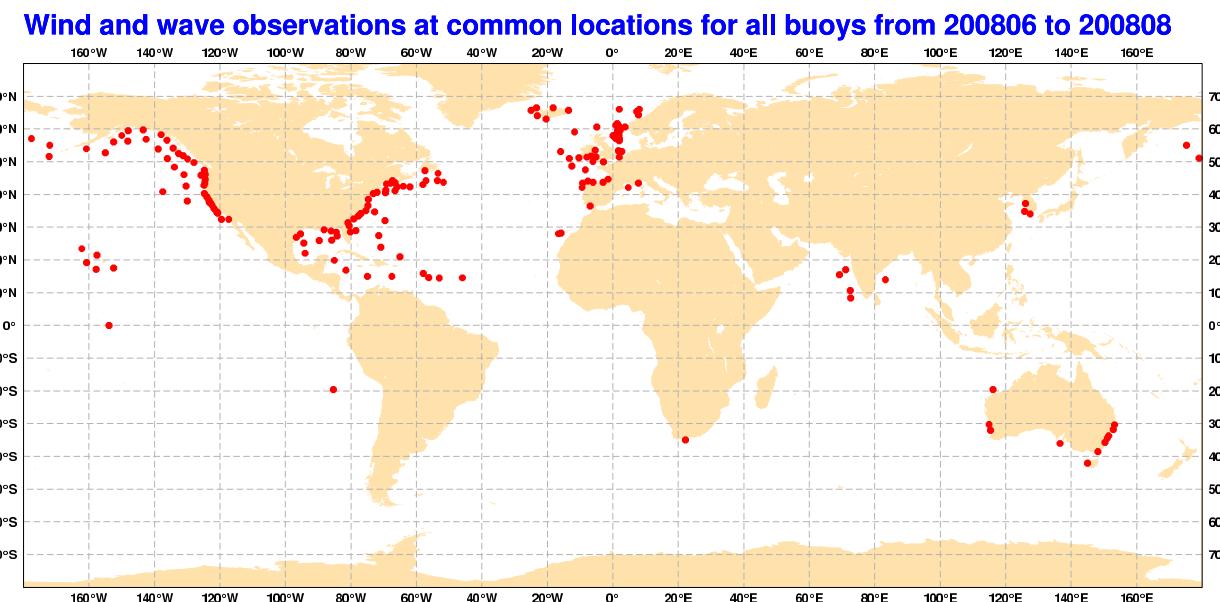
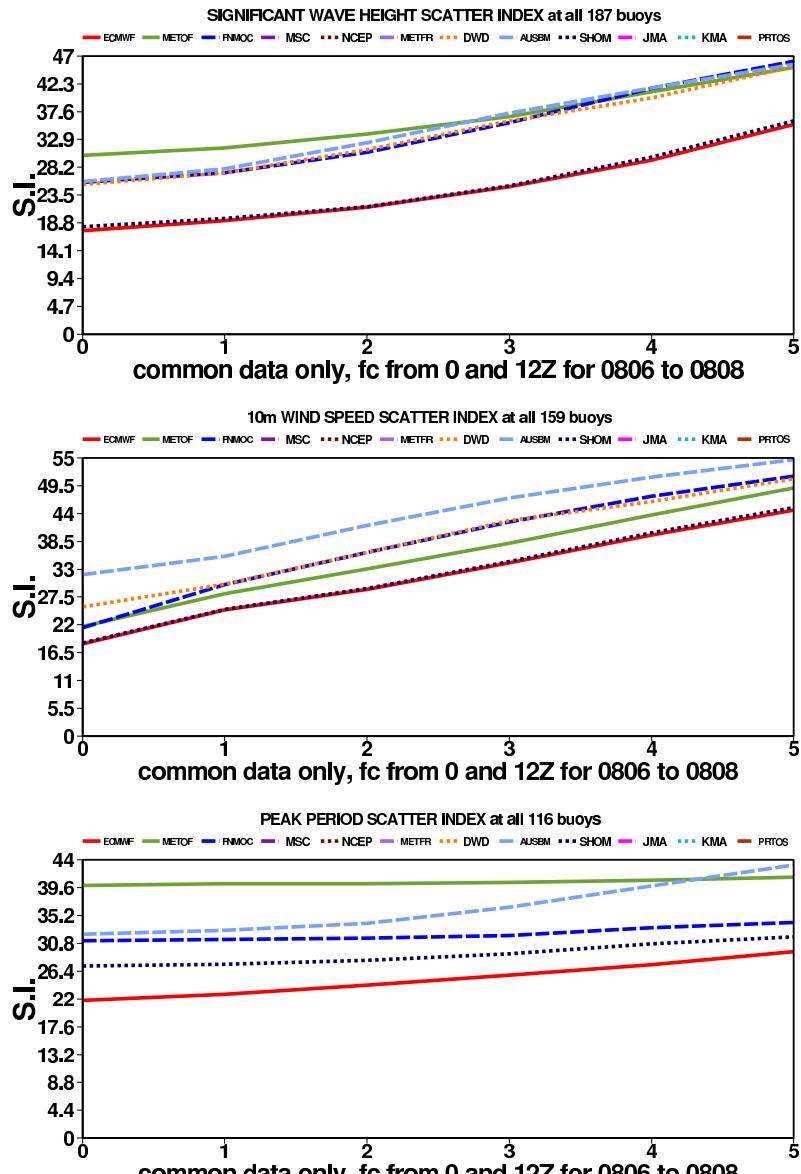
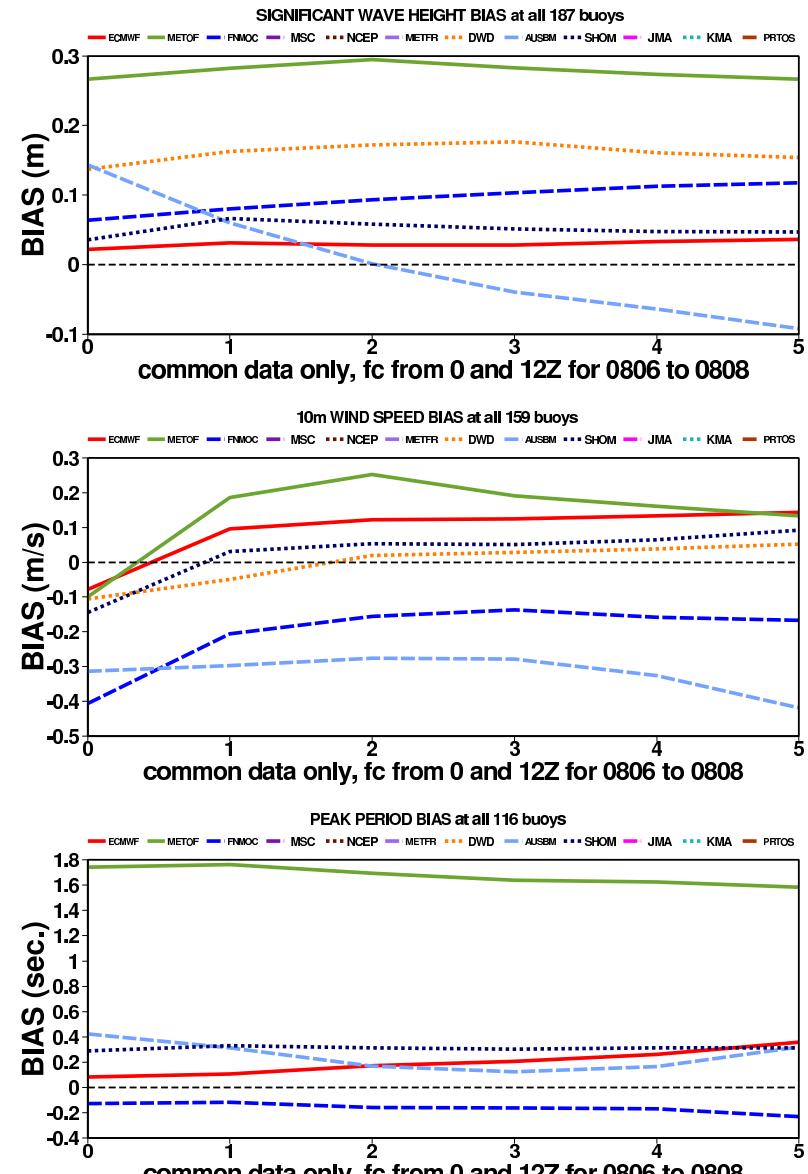


Figure 1: Buoy locations

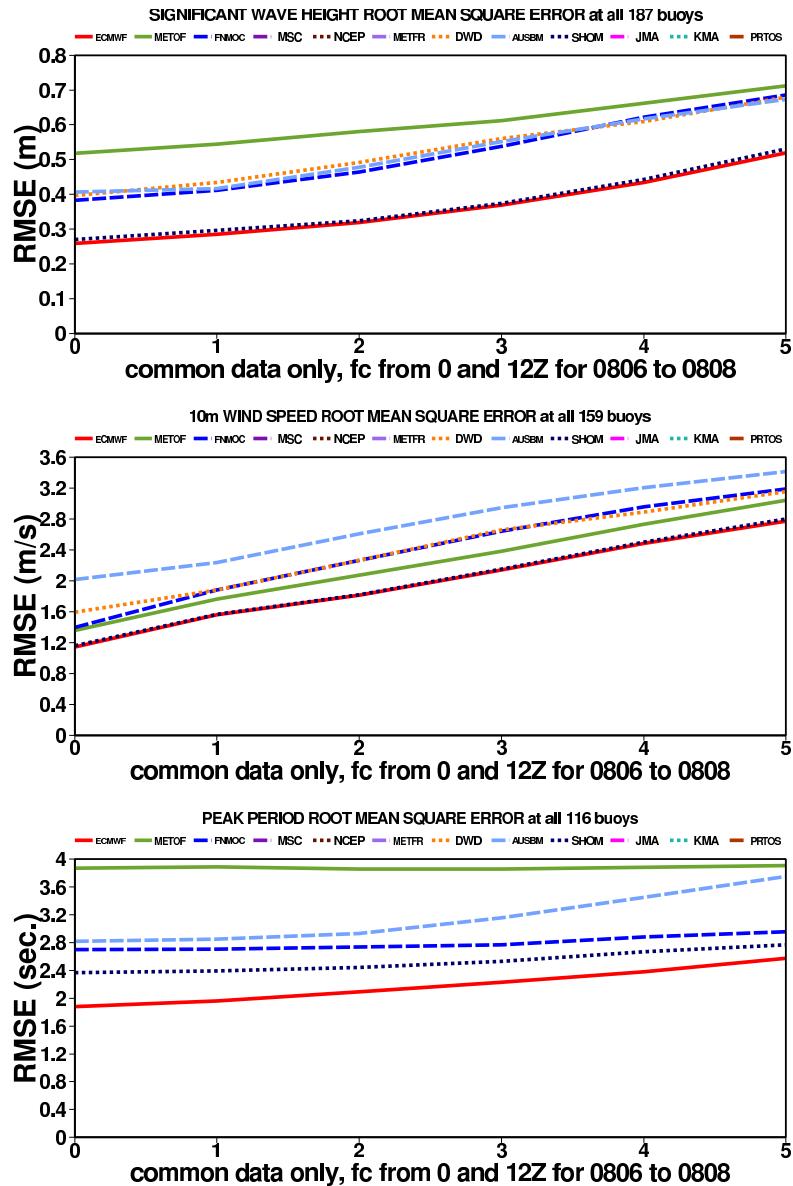


(a) Scatter Index (%)

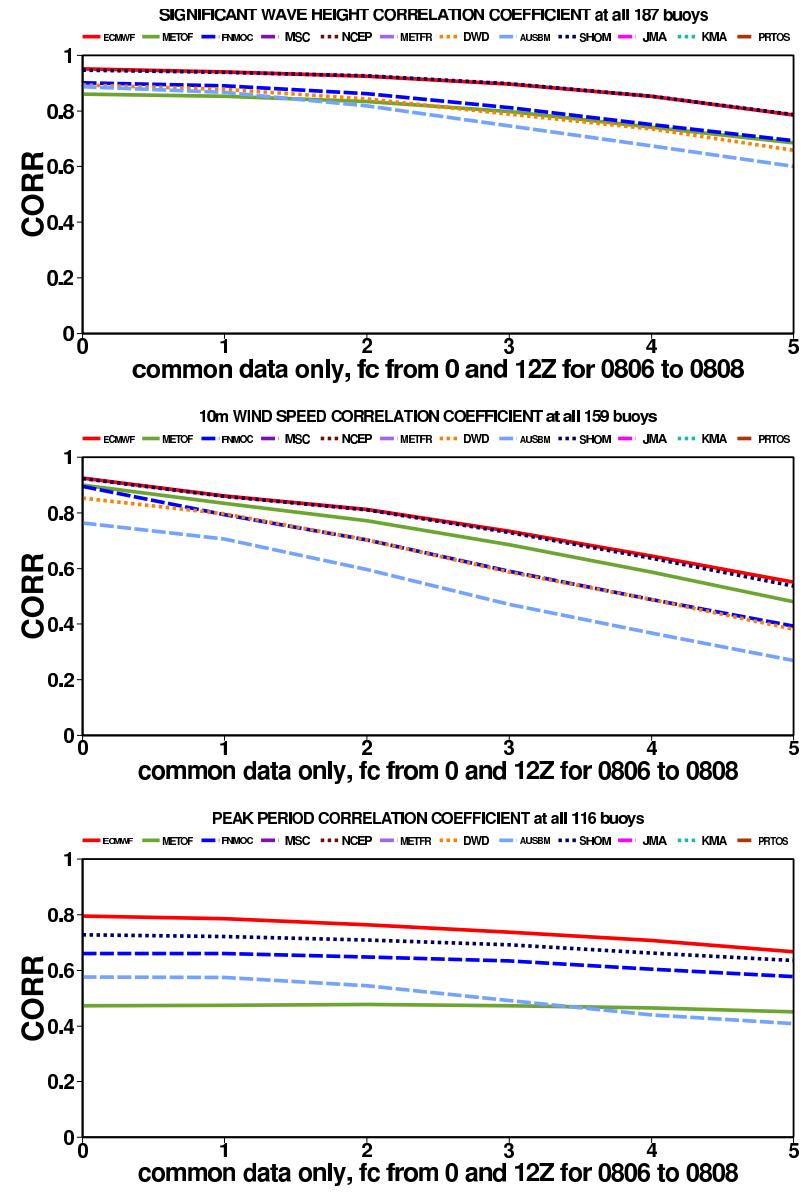


(b) Bias (model-buoy)

Figure 2: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common all buoys.



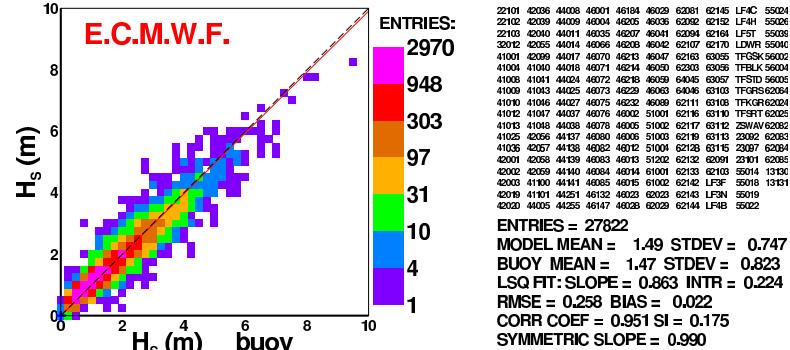
(a) R.M.S.E.



(b) Correlation Coefficient

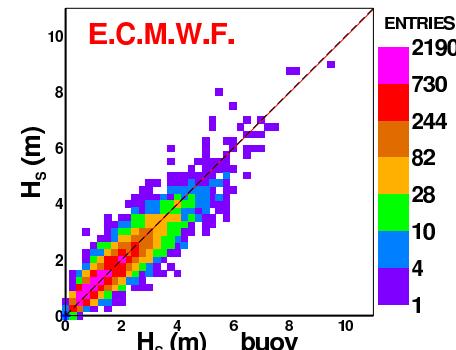
Figure 3: Forecast root mean square error (RMSE) and linear correlation coefficient at common all buoys.

all buoys 0806 to 0808

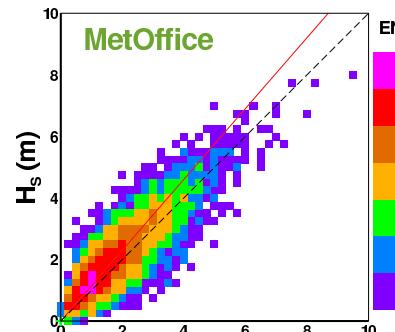


Comparison of analysed ECMWF wave height with averaged buoy data. fc from 0 and 12Z.

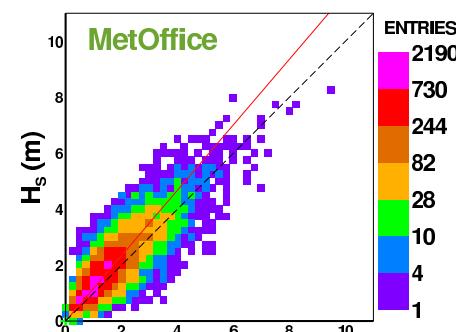
all buoys 0806 to 0808



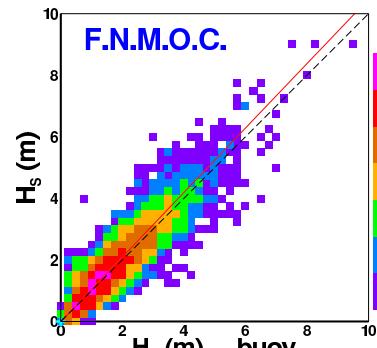
Comparison of forecast(t-t+48) ECMWF wave height with averaged buoy data. fc from 0 and 12Z.



Comparison of analysed NCEP wave height with averaged buoy data. fc from 0 and 12Z.

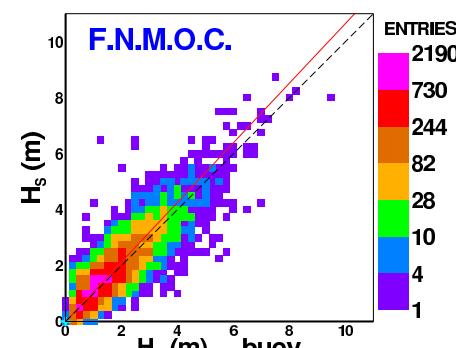


Comparison of forecast(t-t+48) NCEP wave height with averaged buoy data. fc from 0 and 12Z.



Comparison of analysed FNMOc wave height with averaged buoy data. fc from 0 and 12Z.

(a) t+0

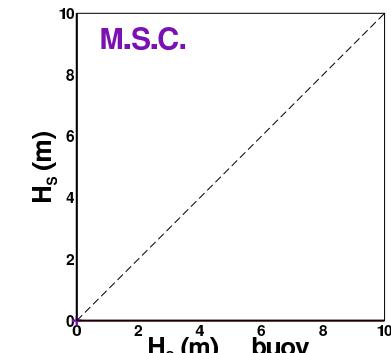


Comparison of forecast(t-t+48) FNMOc wave height with averaged buoy data. fc from 0 and 12Z.

(b) t+48

Figure 4: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

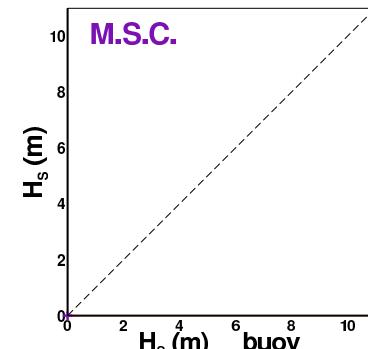


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BUOY MEAN = 0.00 STDEV = 0.000
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RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

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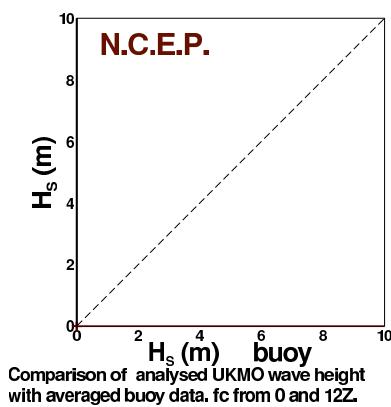
all buoys 0806 to 0808



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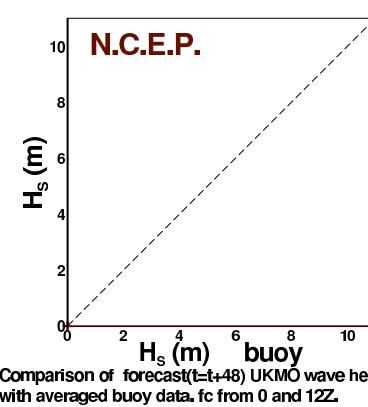
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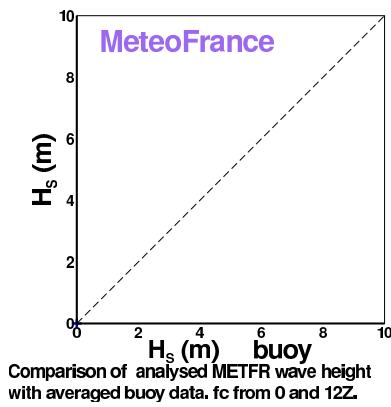
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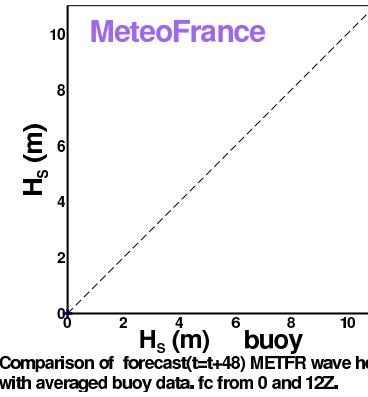
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RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

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ENTRIES = 0
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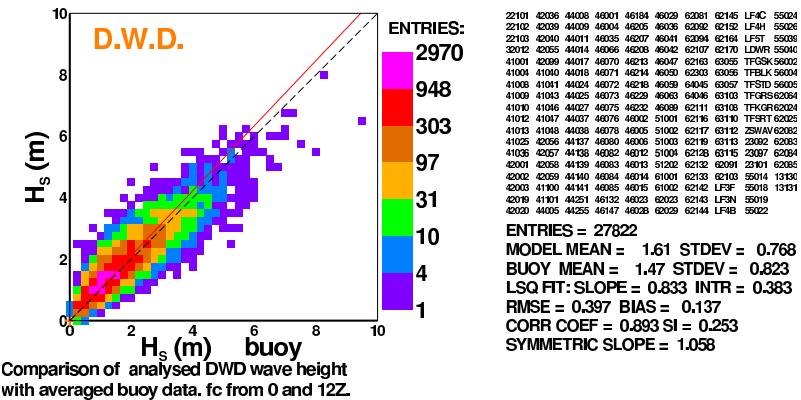
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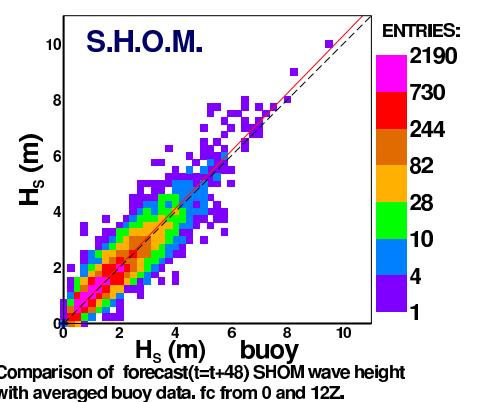
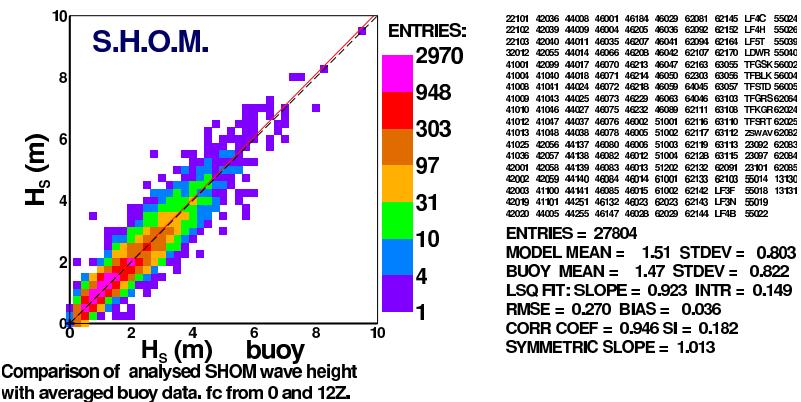
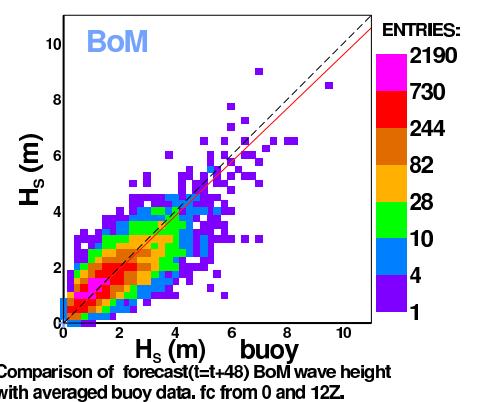
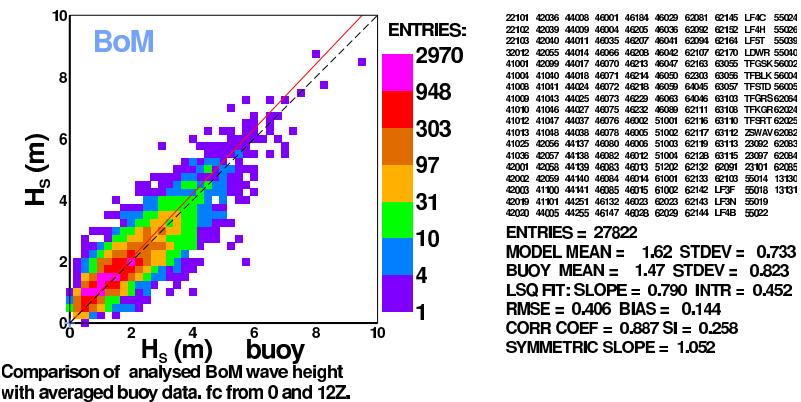
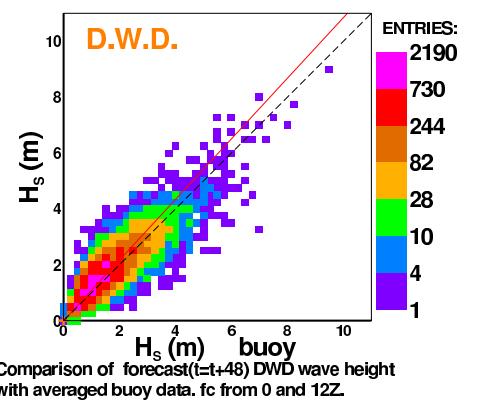
(b) $t+48$

Figure 5: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808



all buoys 0806 to 0808

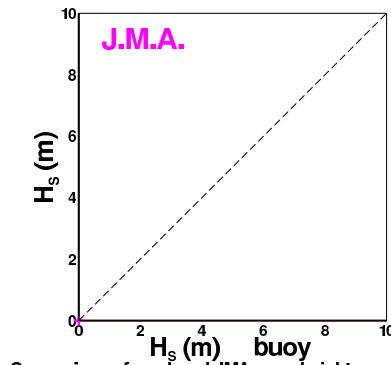


(a) t+0

(b) t+48

Figure 6: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

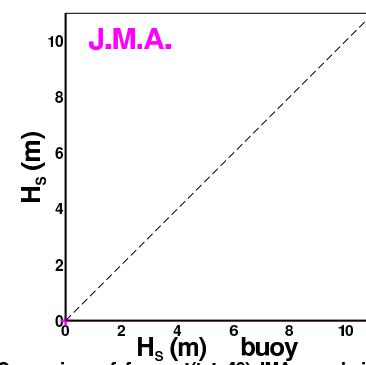


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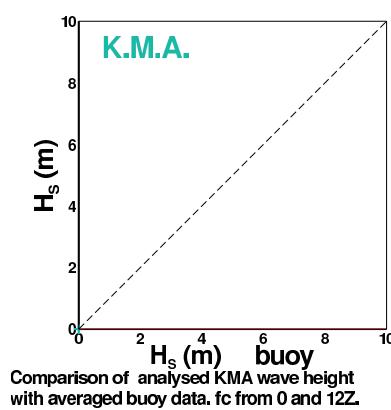
all buoys 0806 to 0808



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CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

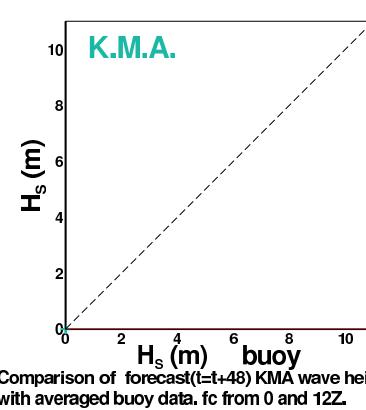
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RMSE = 0.000 BIAS = 0.000
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SYMMETRIC SLOPE = 0.000

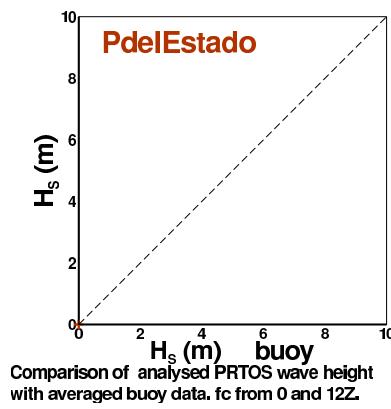
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RMSE = 0.000 BIAS = 0.000
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SYMMETRIC SLOPE = 0.000

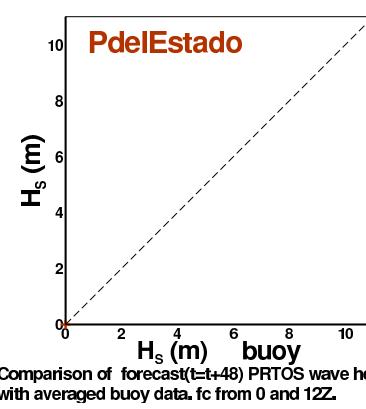
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RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

```



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ENTRIES = 0
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BUOY MEAN = 0.00 STDEV = 0.000
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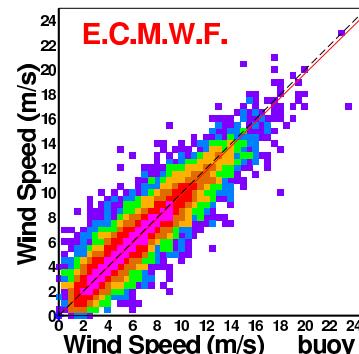
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(a) $t=0$

(b) $t=48$

Figure 7: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.

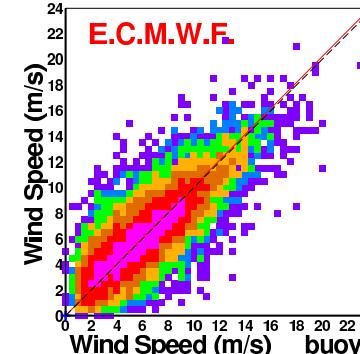
all buoys 0806 to 0808



Comparison of analysed ECMWF wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

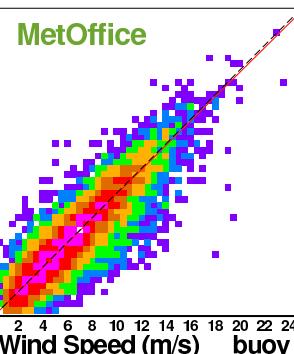
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BUOY MEAN = 6.23 STDEV = 2.982
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RMSE = 1.142 BIAS = -0.077
CORR COEF = 0.925 SI = 0.183
SYMMETRIC SLOPE = 0.984

all buoys 0806 to 0808



Comparison of forecast(t=48) ECMWF wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

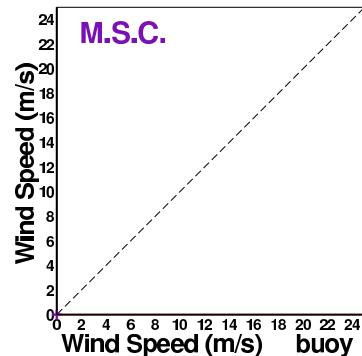
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42010 41109 44159 46140 46056 62110 63103 23101
ENTRIES = 240
MODEL MEAN = 6.35 STDEV = 2.903
BUOY MEAN = 6.23 STDEV = 2.999
LSQ FIT: SLOPE = 0.787 INTR = 1.450
RMSE = 1.812 BIAS = 0.122
CORR COEF = 0.813 SI = 0.290
SYMMETRIC SLOPE = 1.010



Comparison of analysed NCEP wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

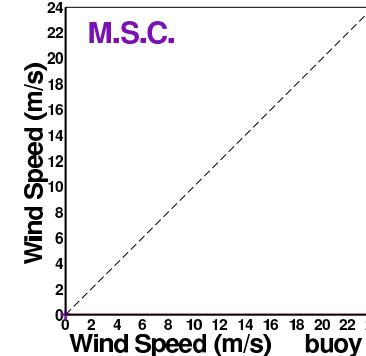
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all buoys 0806 to 0808

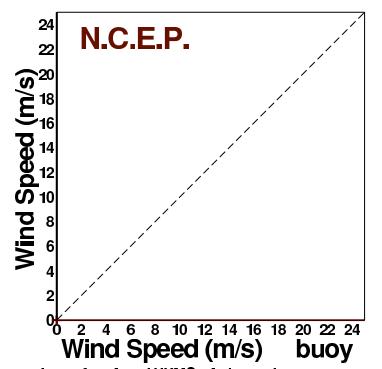


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RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

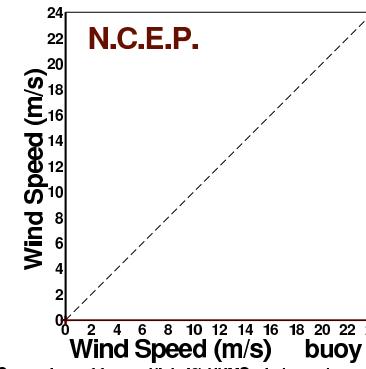
all buoys 0806 to 0808



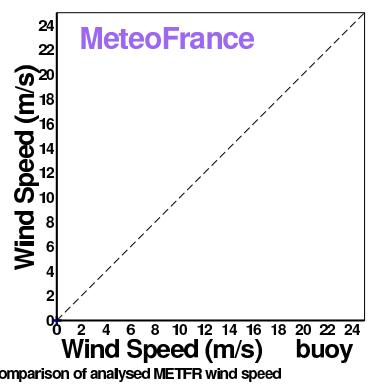
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SYMMETRIC SLOPE = 0.000



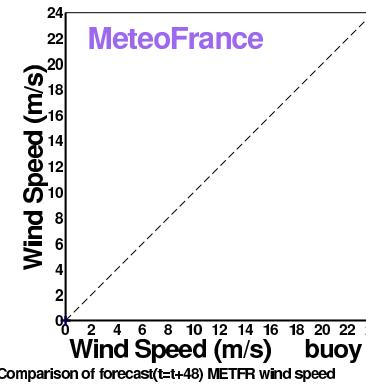
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BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



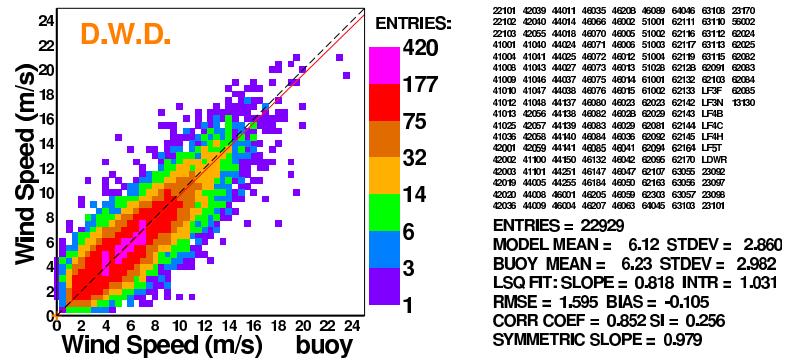
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MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

(a) t+0

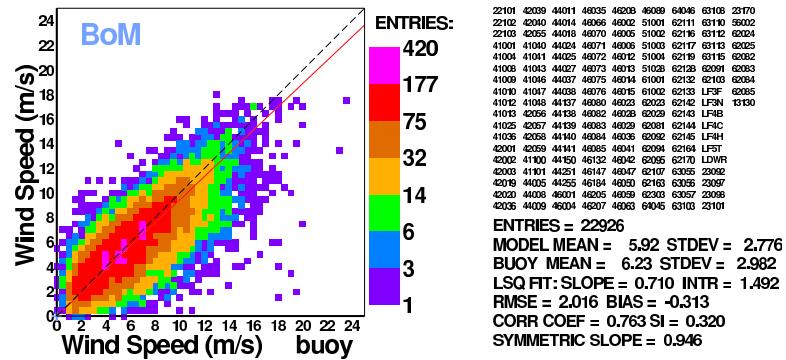
(b) t+48

Figure 9: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.

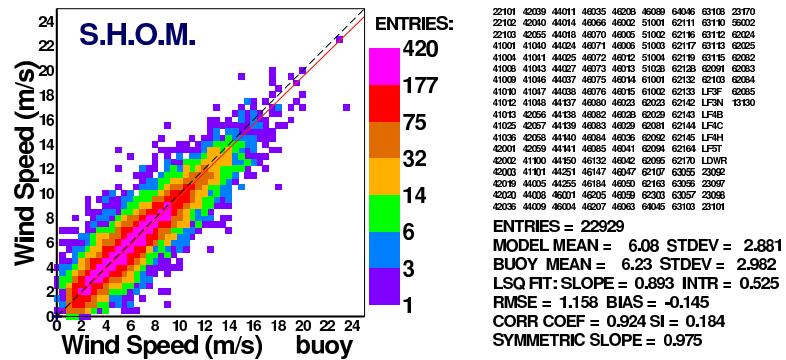
all buoys 0806 to 0808



Comparison of analysed DWD wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.



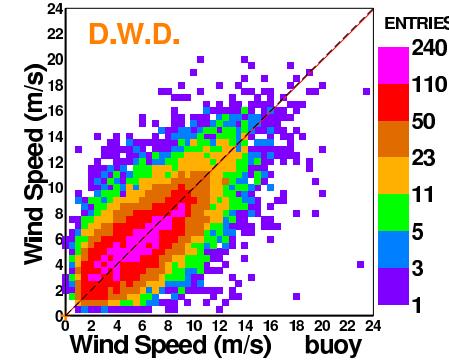
Comparison of analysed BoM wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.



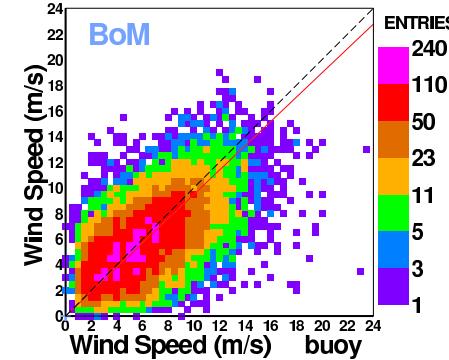
Comparison of analysed SHOM wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

(a) t+0

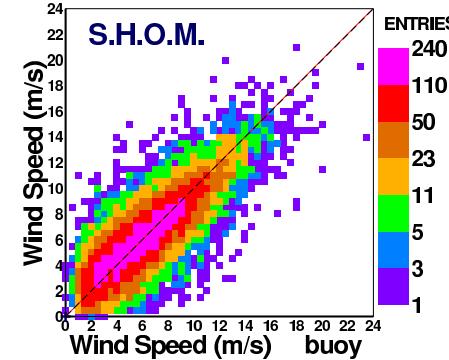
all buoys 0806 to 0808



Comparison of forecast(t=t+48) DWD wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.



Comparison of forecast(t=t+48) BoM wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

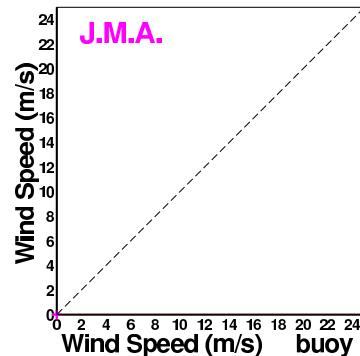


Comparison of forecast(t=t+48) SHOM wind speed
with height corrected averaged buoy data. fc from 0 and 12Z.

(b) t+48

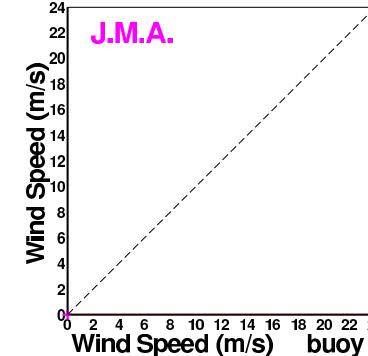
Figure 10: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

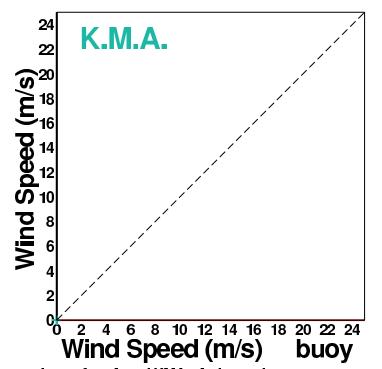


ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

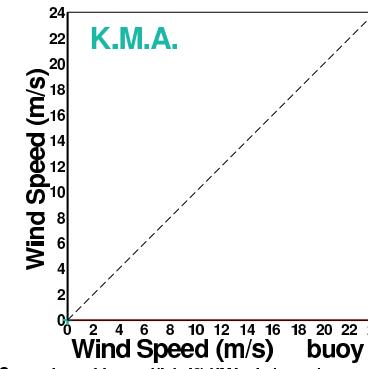
all buoys 0806 to 0808



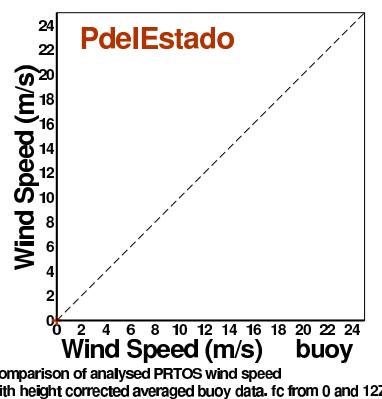
ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



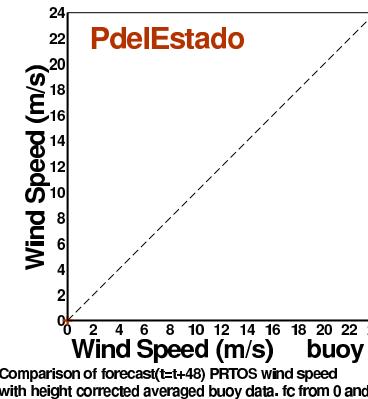
ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000



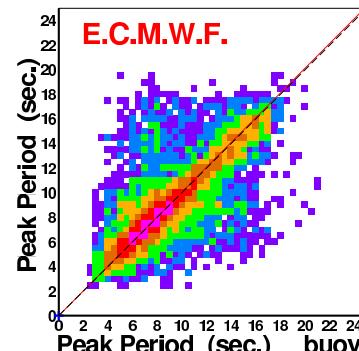
ENTRIES = 0
MODEL MEAN = 0.00 STDEV = 0.000
BUOY MEAN = 0.00 STDEV = 0.000
LSQ FIT: SLOPE = 0.000 INTR = 0.000
RMSE = 0.000 BIAS = 0.000
CORR COEF = 0.000 SI = 0.000
SYMMETRIC SLOPE = 0.000

(a) t+0

(b) t+48

Figure 11: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

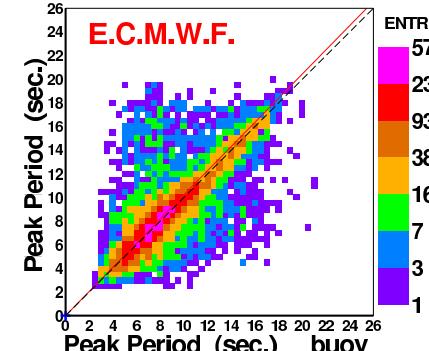


Comparison of analysed ECMWF peak period with averaged buoy data. fc from 0 and 12Z.

ENTRIES: 660
22101 42036 44011 46066 46213 46047 56004
22102 42039 44014 46070 46214 46059 56005
33012 42035 44018 46072 46218 46059
41001 41010 44025 46075 46002 51001
41003 41011 44027 46078 46005 51002
41009 41014 44027 46080 46003 51003
41019 41016 44137 46082 46012 51004
41021 41017 44137 46084 46013 51002
41023 42036 44109 46084 46014 55014
41025 42036 44110 46085 46015 55015
41033 42057 44111 46132 46023 55019
42001 42058 44251 46147 46028 55022
42002 42059 44252 46164 46029 55024
42003 42058 46001 46285 46036 55025
42017 44018 46007 46287 46041 55039
42120 44039 46035 46203 46042 55040

ENTRIES = 18205
MODEL MEAN = 8.72 STDEV = 2.904
BUOY MEAN = 8.64 STDEV = 2.965
LSQ FIT: SLOPE = 0.779 INTR = 1.994
RMSE = 1.881 BIAS = 0.083
CORR COEF = 0.795 SI = 0.218
SYMMETRIC SLOPE = 1.006

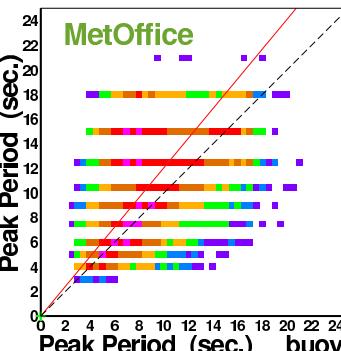
all buoys 0806 to 0808



Comparison of forecast(t=+48) ECMWF peak period with averaged buoy data. fc from 0 and 12Z.

ENTRIES: 570
22101 42036 44011 46066 46213 46047 56004
22102 42039 44014 46070 46214 46059 56005
33012 42035 44018 46072 46218 46059
41001 41010 44025 46075 46002 51001
41003 41011 44027 46078 46005 51002
41009 41014 44027 46080 46003 51003
41019 41013 44037 46083 46006 51003
41016 41016 44137 46082 46012 51004
41015 41018 44138 46083 46013 51004
41025 42056 44140 46085 46015 55016
41036 42057 44141 46132 46023 55019
42001 42058 44251 46147 46028 55022
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42003 42058 46001 46285 46036 55025
42017 44018 46007 46287 46041 55039
42120 44039 46035 46203 46042 55040

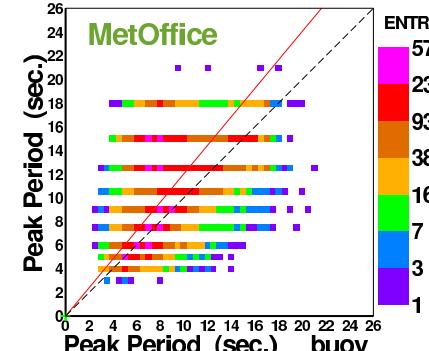
ENTRIES = 16461
MODEL MEAN = 8.79 STDEV = 3.100
BUOY MEAN = 8.62 STDEV = 2.964
LSQ FIT: SLOPE = 0.799 INTR = 1.902
RMSE = 2.094 BIAS = 0.171
CORR COEF = 0.764 SI = 0.242
SYMMETRIC SLOPE = 1.023



Comparison of analysed NCEP peak period with averaged buoy data. fc from 0 and 12Z.

ENTRIES: 660
22101 42036 44011 46066 46213 46047 56004
22102 42039 44014 46070 46214 46059 56005
33012 42035 44018 46072 46218 46059
41001 41009 44024 46073 46232 46059
41003 41013 44027 46078 46005 51003
41009 41016 44027 46080 46003 51002
41012 41017 44138 46083 46013 51002
41013 41018 44139 46084 46014 55014
41025 42056 44140 46085 46015 55016
42003 44005 46001 46205 46035 55025
42019 44008 46004 46207 46041 55039
42020 44009 46035 46203 46042 55040

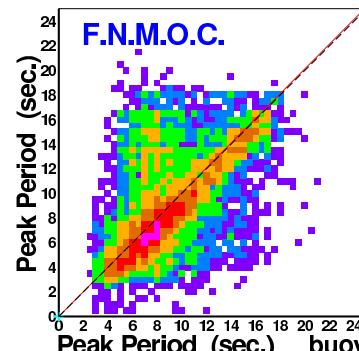
ENTRIES = 18205
MODEL MEAN = 10.38 STDEV = 3.659
BUOY MEAN = 8.64 STDEV = 2.965
LSQ FIT: SLOPE = 0.583 INTR = 5.343
RMSE = 3.868 BIAS = 1.742
CORR COEF = 0.473 SI = 0.400
SYMMETRIC SLOPE = 1.205



Comparison of forecast(t=+48) MetOffice peak period with averaged buoy data. fc from 0 and 12Z.

ENTRIES: 570
22101 42036 44011 46066 46213 46047 56004
22102 42039 44014 46070 46214 46059 56005
33012 42035 44018 46072 46218 46059
41001 41009 44024 46073 46232 46059
41003 41013 44027 46078 46005 51003
41009 41016 44027 46080 46003 51002
41012 41017 44138 46083 46013 51002
41013 41018 44139 46084 46014 55014
41025 42056 44140 46085 46015 55016
42003 44005 46001 46205 46035 55025
42019 44008 46004 46207 46041 55039
42020 44009 46035 46203 46042 55040

ENTRIES = 16461
MODEL MEAN = 10.32 STDEV = 3.705
BUOY MEAN = 8.62 STDEV = 2.964
LSQ FIT: SLOPE = 0.598 INTR = 5.164
RMSE = 3.858 BIAS = 1.695
CORR COEF = 0.478 SI = 0.402
SYMMETRIC SLOPE = 1.202

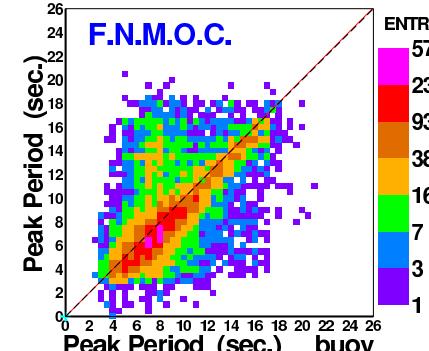


Comparison of analysed FNMO.C peak period with averaged buoy data. fc from 0 and 12Z.

(a) t+0

ENTRIES: 660
22101 42036 44011 46066 46213 46047 56004
22102 42039 44014 46070 46214 46059 56005
33012 42035 44018 46072 46218 46059
41001 41009 44024 46073 46232 46059
41003 41013 44027 46078 46005 51003
41009 41016 44027 46080 46003 51002
41019 41017 44137 46089 46012 51002
41021 41018 44138 46090 46013 51001
41015 41016 44139 46091 46014 55014
41023 42057 44140 46092 46015 55016
42003 44007 46001 46207 46035 55025
42019 44008 46003 46207 46041 55039
42020 44009 46035 46203 46042 55040

ENTRIES = 18200
MODEL MEAN = 8.51 STDEV = 3.474
BUOY MEAN = 8.64 STDEV = 2.964
LSQ FIT: SLOPE = 0.774 INTR = 1.828
RMSE = 2.697 BIAS = -0.127
CORR COEF = 0.660 SI = 0.312
SYMMETRIC SLOPE = 1.007

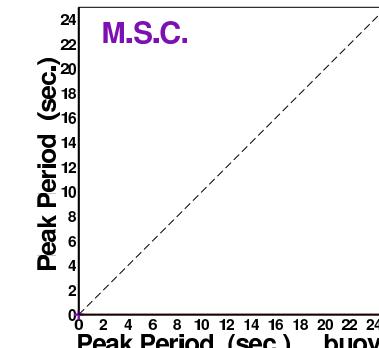


Comparison of forecast(t=+48) FNMO.C peak period with averaged buoy data. fc from 0 and 12Z.

(b) t+48

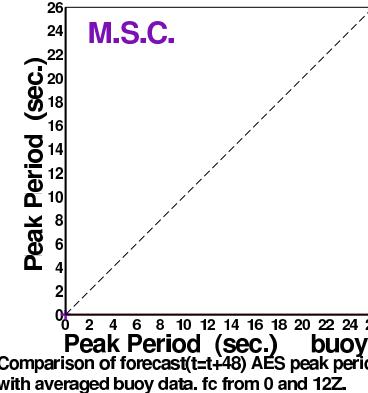
Figure 12: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

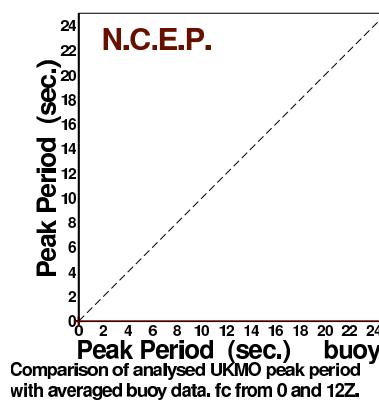


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 BUOY MEAN = 0.00 STDEV = 0.000
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 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000

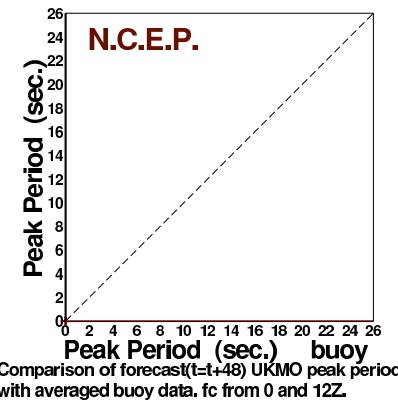
all buoys 0806 to 0808



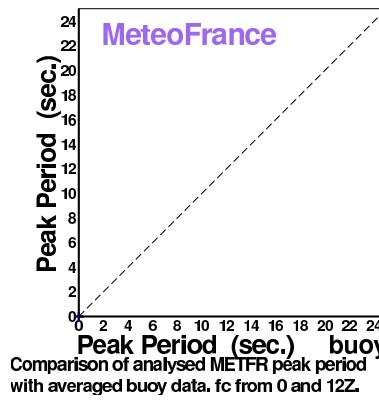
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 BUOY MEAN = 0.00 STDEV = 0.000
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 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



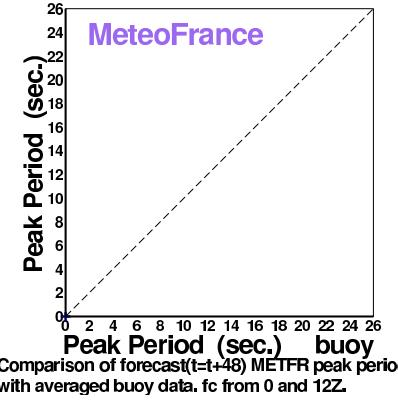
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 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



ENTRIES = 0
 MODEL MEAN = 0.00 STDEV = 0.000
 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



ENTRIES = 0
 MODEL MEAN = 0.00 STDEV = 0.000
 BUOY MEAN = 0.00 STDEV = 0.000
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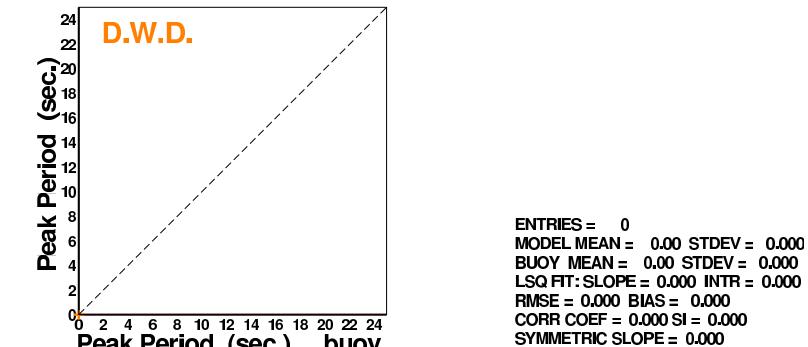
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(a) $t+0$

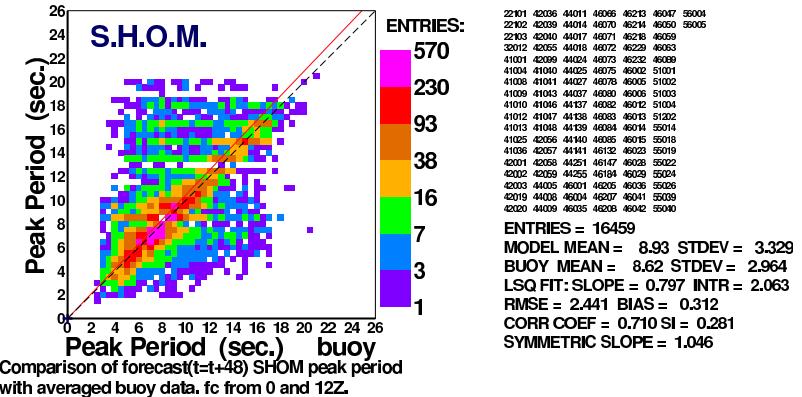
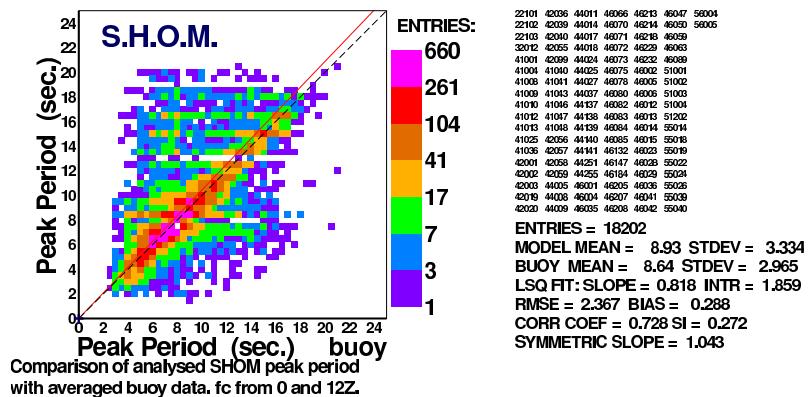
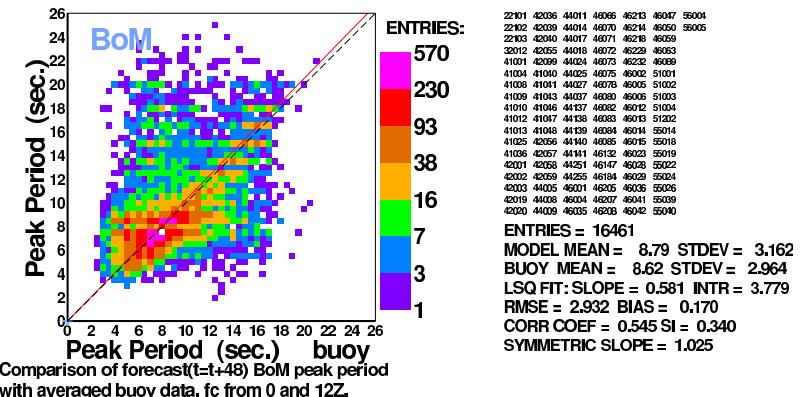
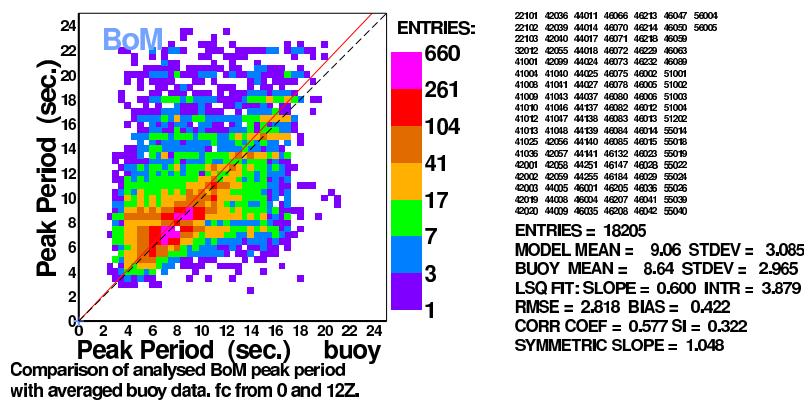
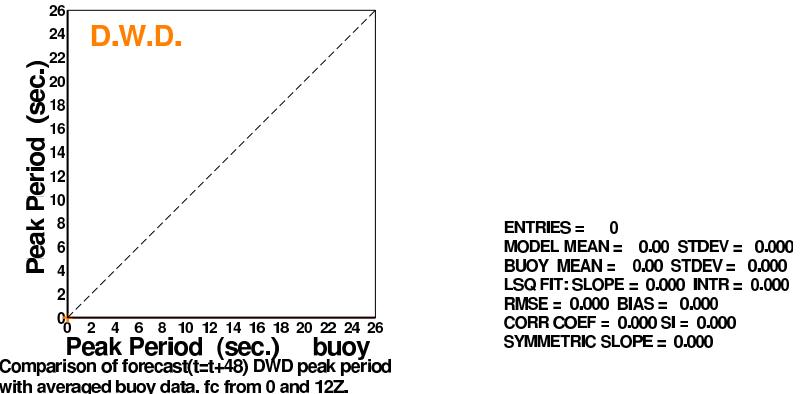
(b) $t+48$

Figure 13: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808



all buoys 0806 to 0808

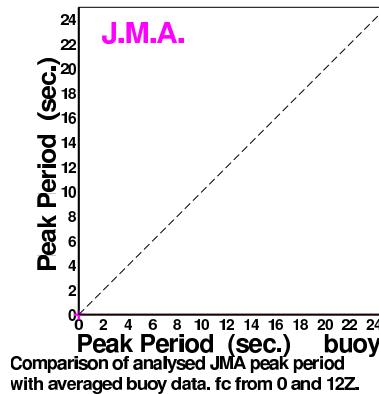


(a) t+0

(b) t+48

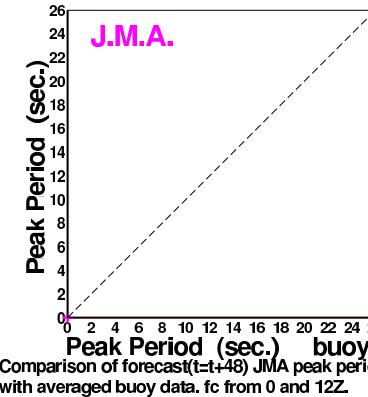
Figure 14: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.

all buoys 0806 to 0808

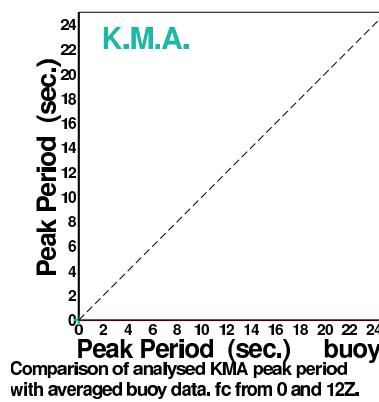


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 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
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 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000

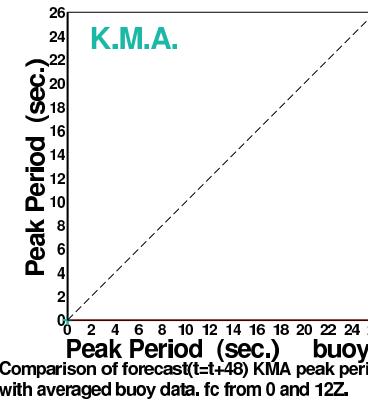
all buoys 0806 to 0808



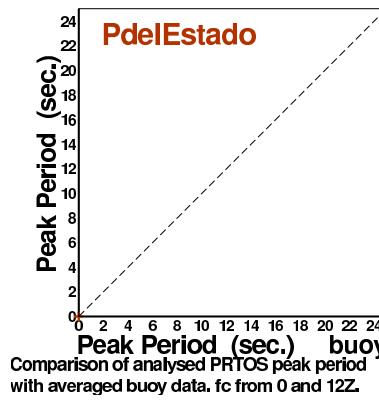
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 BUOY MEAN = 0.00 STDEV = 0.000
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 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



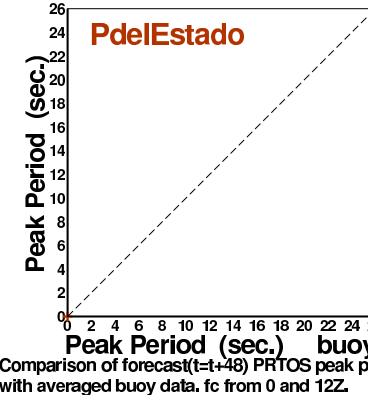
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 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



ENTRIES = 0
 MODEL MEAN = 0.00 STDEV = 0.000
 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



ENTRIES = 0
 MODEL MEAN = 0.00 STDEV = 0.000
 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000



ENTRIES = 0
 MODEL MEAN = 0.00 STDEV = 0.000
 BUOY MEAN = 0.00 STDEV = 0.000
 LSQ FIT: SLOPE = 0.000 INTR = 0.000
 RMSE = 0.000 BIAS = 0.000
 CORR COEF = 0.000 SI = 0.000
 SYMMETRIC SLOPE = 0.000

(a) t+0

(b) t+48

Figure 15: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.

0.3.2 Comparison for Hawaiian buoys

Number of common observations for Hawaiian buoys (HW) from 200806 to 200808 (wind, Hs, Tp)

1	51001	182	182	182	Hawaii North West	4	51004	15	15	15	Hawaii South East
2	51002	181	181	181	Hawaii South West	5	51028	181	0	0	Christmas Island DWA
3	51003	182	182	182	Hawaii West	6	51202	0	179	179	Hawaii Mokapu Point (scripps 098)

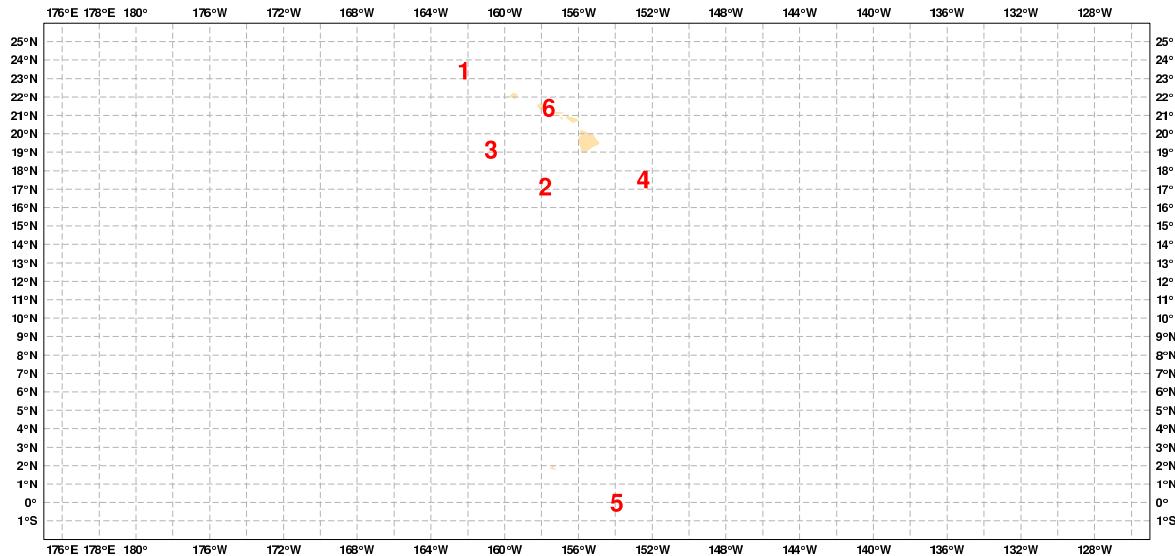
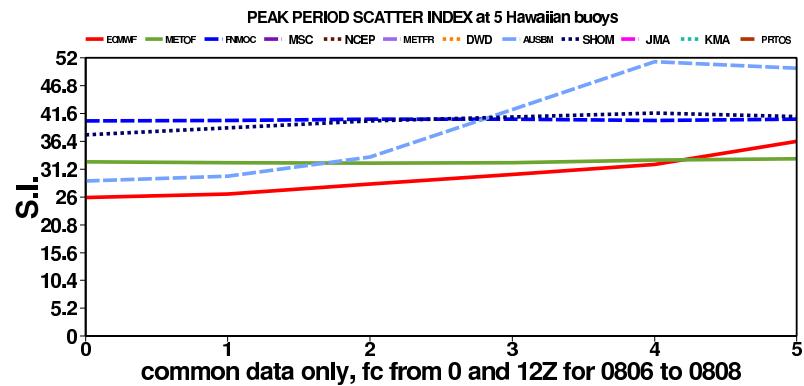
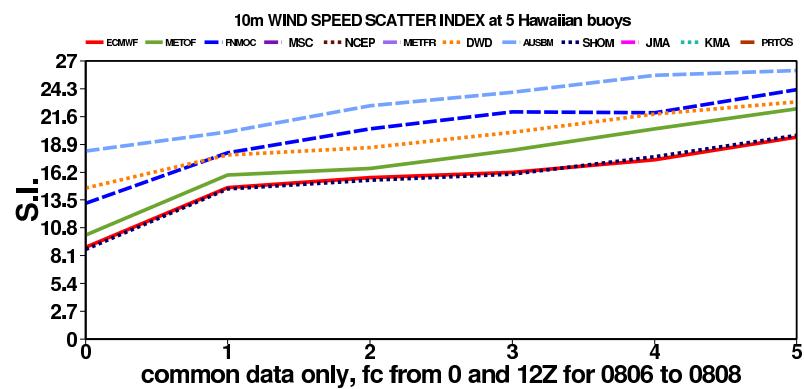
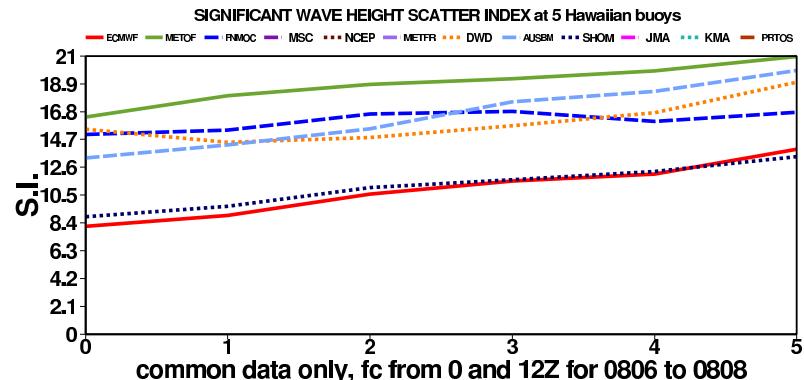
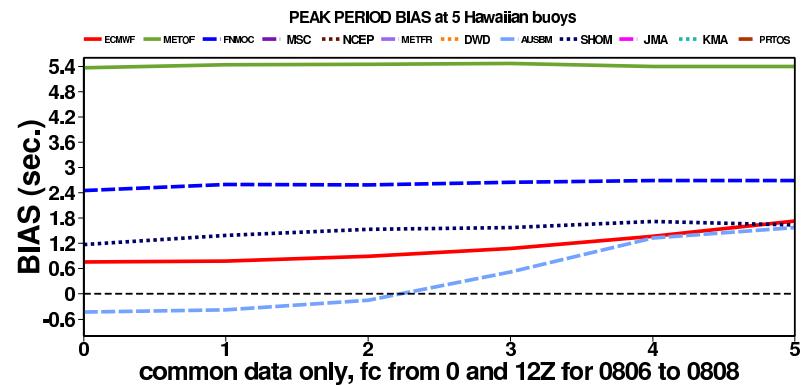
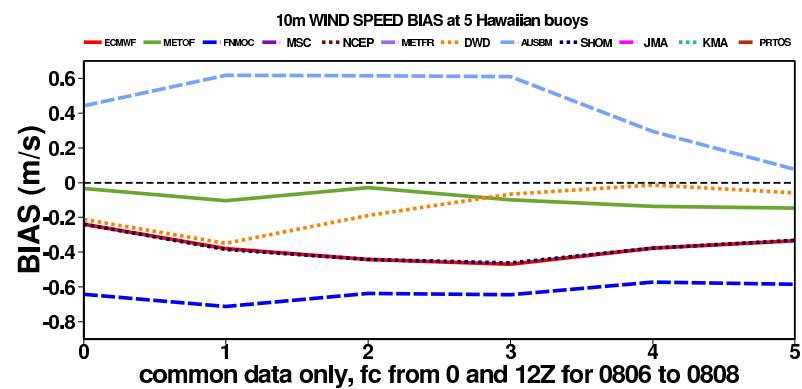
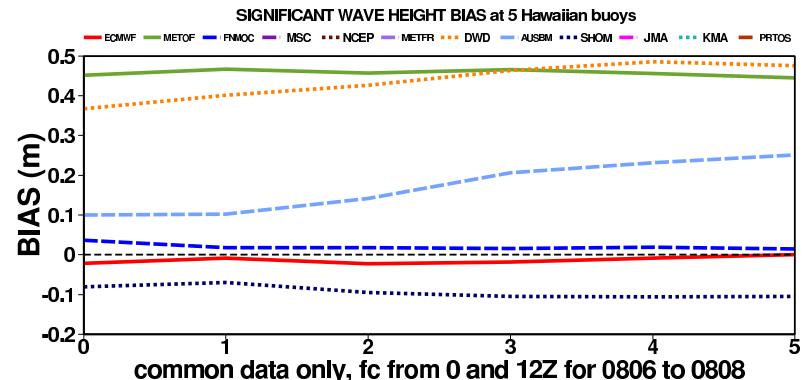


Figure 16: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

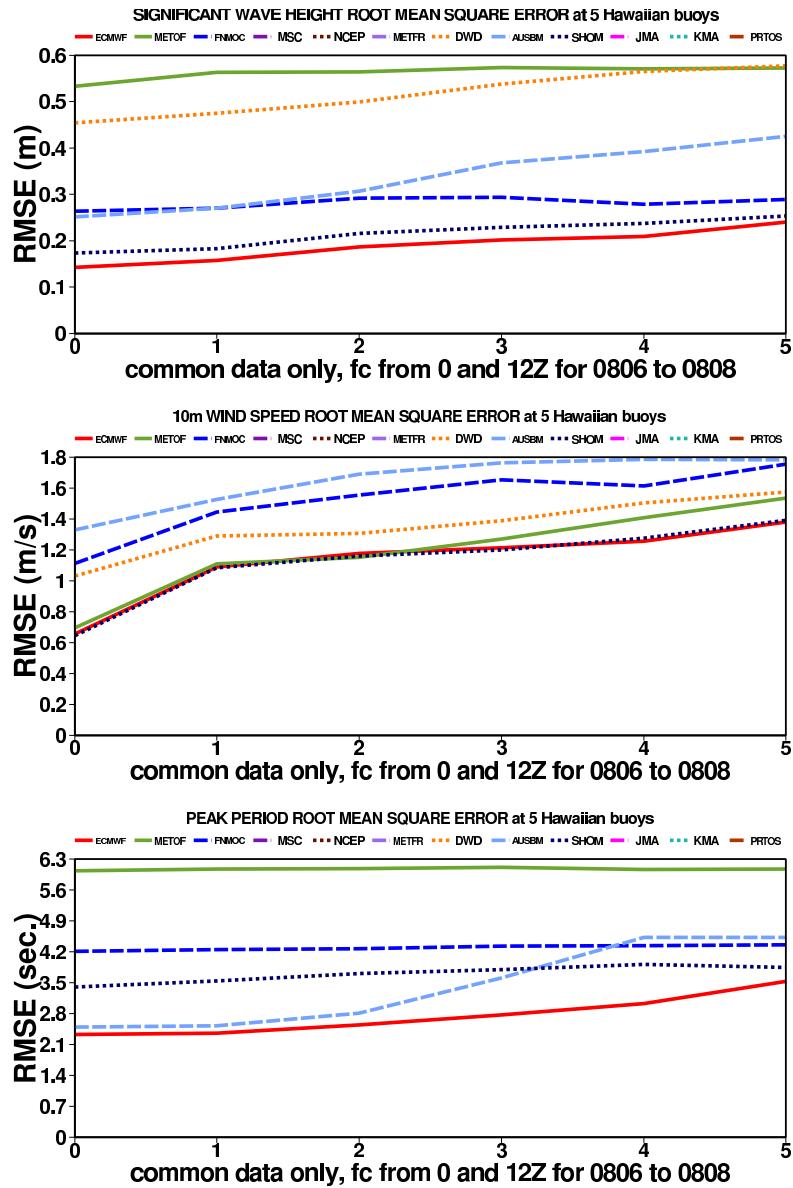


(a) Scatter Index (%)

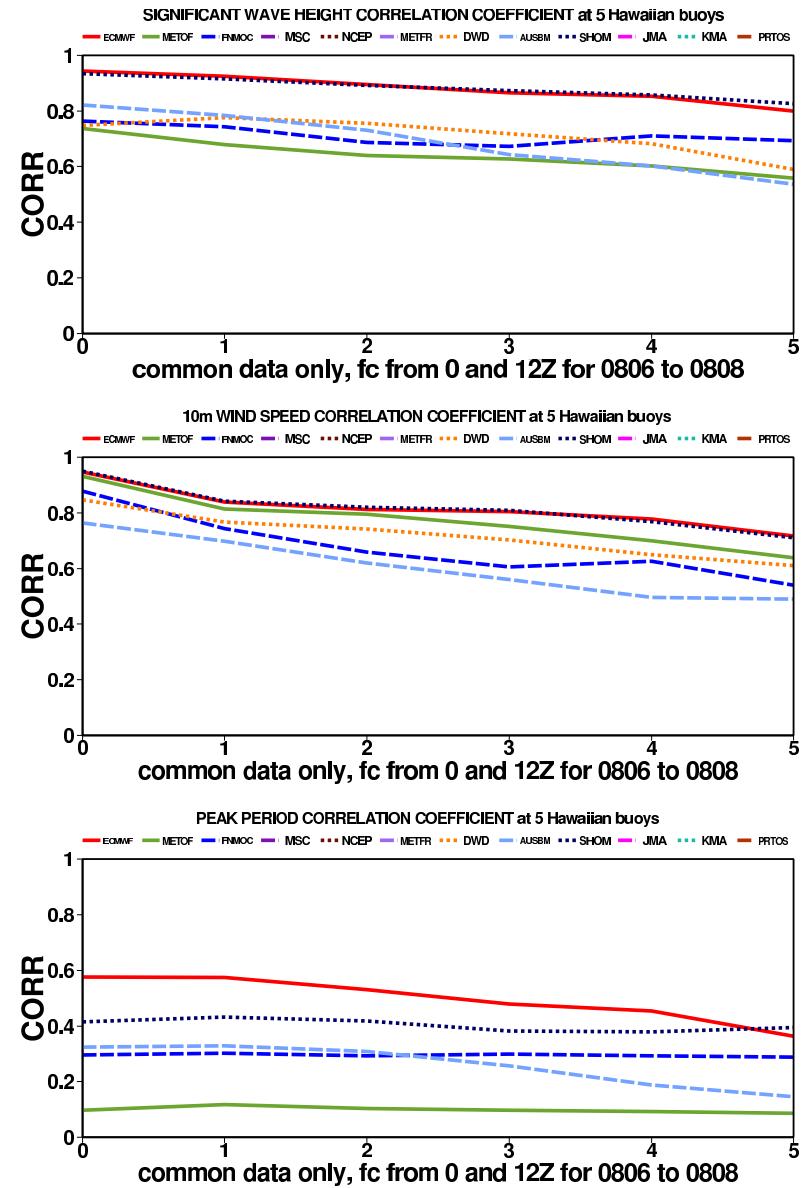


(b) Bias (model-buoy)

Figure 17: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Hawaiian buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 18: Forecast root mean square error (RMSE) and linear correlation coefficient at common Hawaiian buoys.

0.3.3 Comparison for North Pacific buoys

Number of common observations for North Pacific buoys (NPC) from 200806 to 200808 (wind, Hs,Tp)

1	46001	182	182	182	Gulf of Alaska	12	46080	65	67	67	Gulf of Alaska, Kennedy Entrance
2	46004	181	181	181	Canada West Coast, Middle Nomad	13	46082	55	56	56	Gulf of Alaska, Cape Suckling
3	46035	182	181	181	Bering Sea	14	46083	148	182	182	Gulf of Alaska, Fairweather Grounds
4	46066	182	181	182	Gulf of Alaska, S Aleutians	15	46084	181	182	182	Gulf of Alaska, Cape Edgecumbe
5	46070	181	173	173	Southwest Bering Sea	16	46085	178	180	179	Central Gulf of Alaska
6	46071	165	165	165	North Pacific, Western Aleutians	17	46132	182	182	182	Canada West Coast, South Brooks
7	46072	13	182	182	North Pacific, Central Aleutians	18	46147	182	182	182	Canada West Coast, South Moresby
8	46073	182	177	177	Southeast Bering Sea	19	46184	182	182	181	Canada West Coast, North Nomad
9	46075	60	180	180	North Pacific, Shumagin Islands	20	46205	182	182	182	Canada West Coast, W. Dixon Entrance
10	46076	143	144	0	Gulf of Alaska, Cape Clear	21	46207	182	182	182	Canada West Coast, East Dellwood
11	46078	0	178	177	Gulf of Alaska, Albatross Banks	22	46208	182	182	182	Canada West Coast, West Moresby

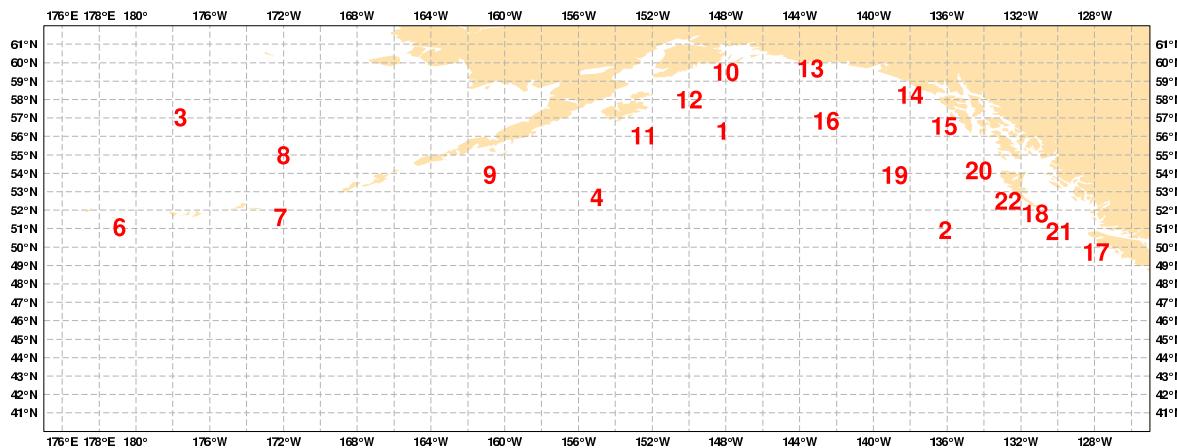


Figure 19: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

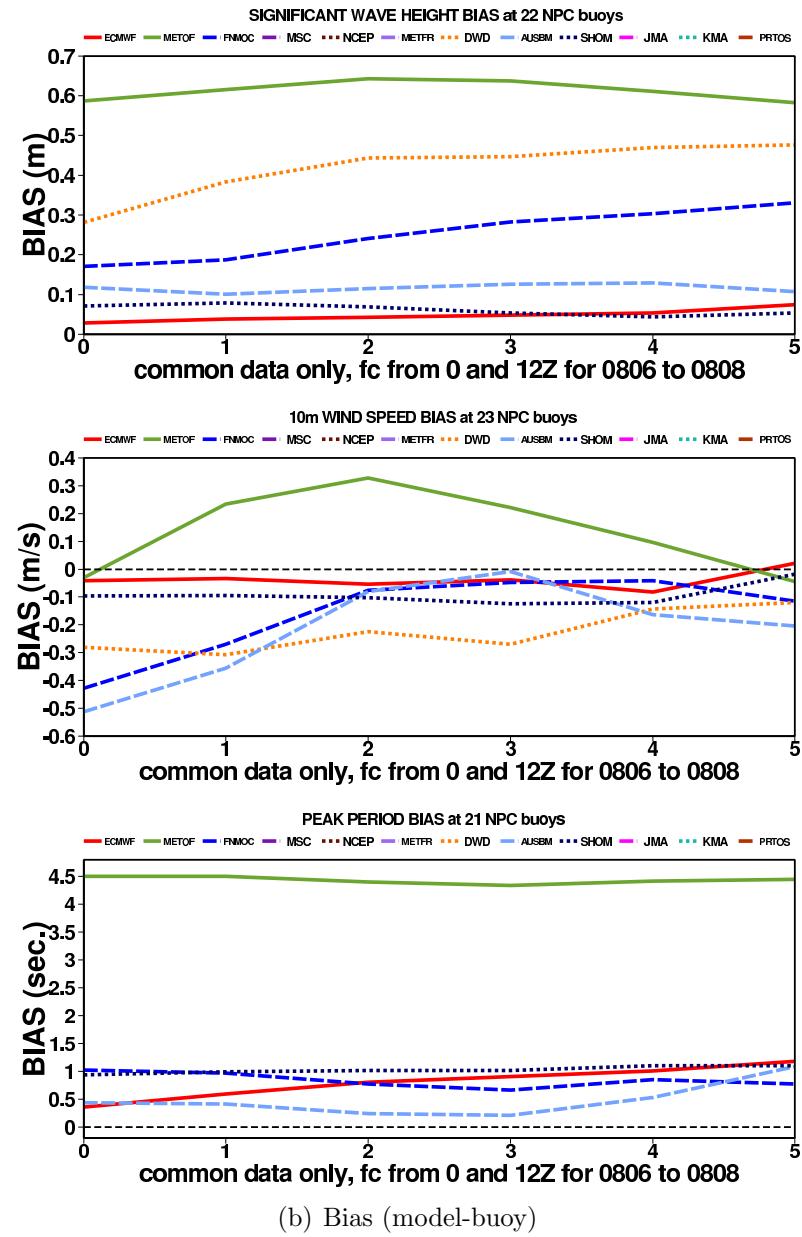
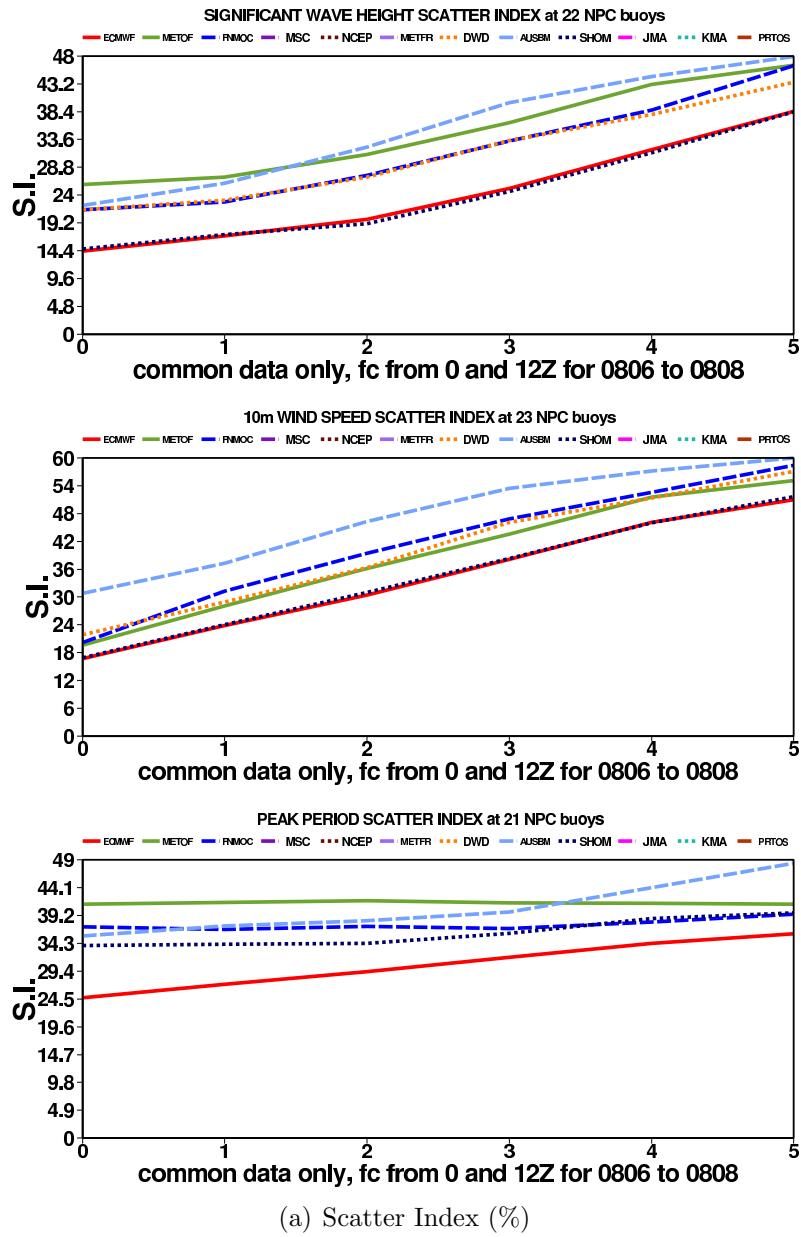
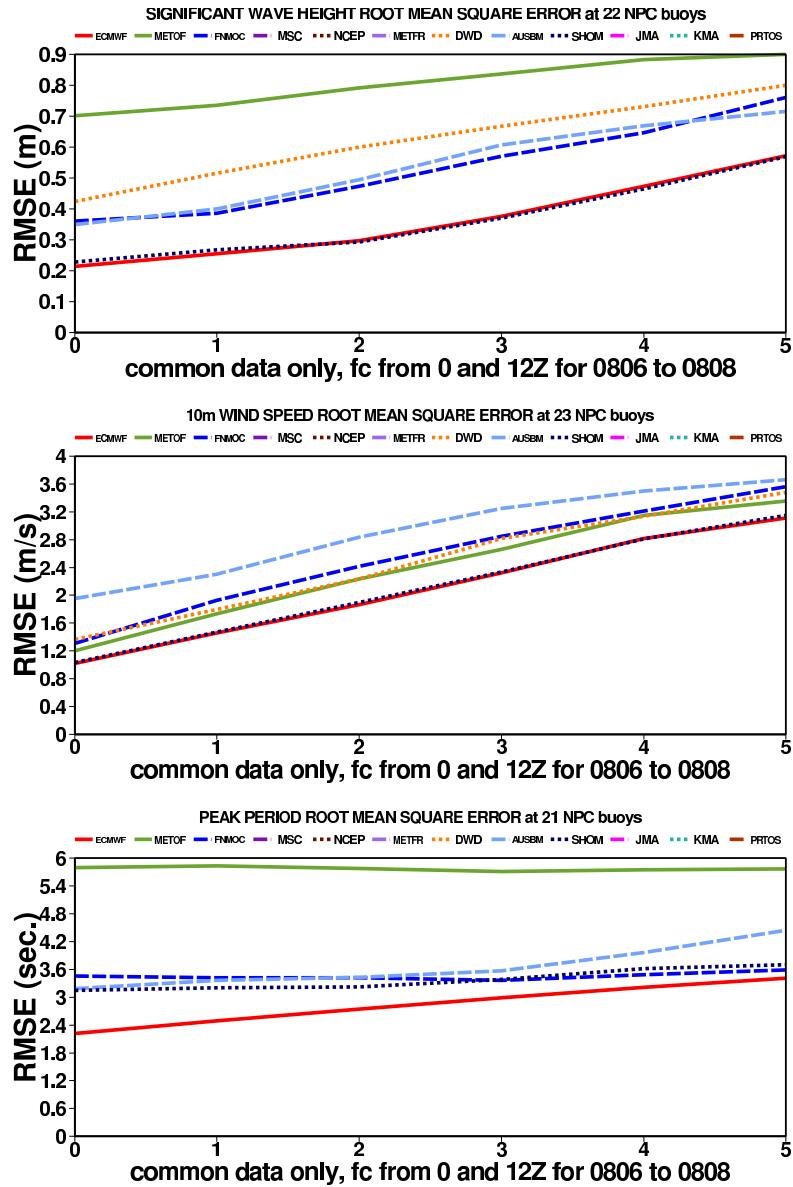
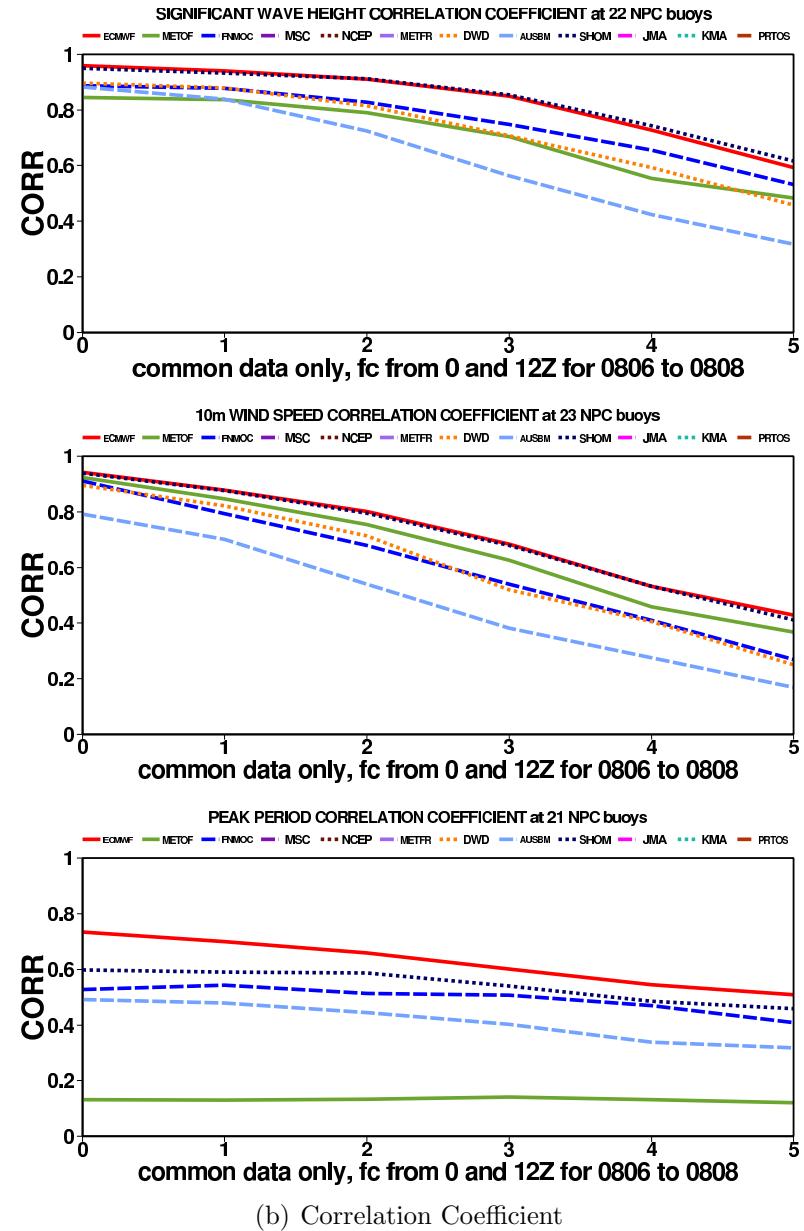


Figure 20: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North Pacific buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 21: Forecast root mean square error (RMSE) and linear correlation coefficient at common North Pacific buoys .

0.3.4 Comparison for US West Coast buoys

Number of common observations for US West Coast buoys (USWC) from 200806 to 200808 (wind, Hs, Tp)

1	46002	134	135	135	US West Coast, Oregon	13	46042	182	146	145	US South-West Coast, Monterey
2	46005	132	132	132	US North-West Coast, W Astoria	14	46047	182	182	182	US South-West Coast, Tanner Banks
3	46006	17	17	17	US West Coast, SW Astoria	15	46050	182	182	182	US West Coast, Yaquina Bay
4	46012	170	170	170	US South-West Coast, Half Moon Bay	16	46059	182	182	182	US West Coast, California
5	46013	182	182	182	US South-West Coast, Bodega	17	46063	182	182	182	US West Coast, Pt Conception
6	46014	182	182	181	US South-West Coast, Point Arena	18	46089	128	128	128	US West Coast, Tillamook, OR
7	46015	120	116	116	US West Coast, Port Orford	19	46213	0	182	182	US South-West Coast, Cape Mendocino (scripps 094)
8	46023	182	182	182	US South-West Coast, Point Arguello	20	46214	0	176	176	US South-West Coast, Point Reyes (scripps 029)
9	46028	182	180	180	US South-West Coast, Cape St Martin	21	46218	0	182	182	US South-West Coast, Harvest (scripps 071)
10	46029	182	182	182	US West Coast, Columbia River Bar	22	46229	0	182	182	US West Coast, Coos Bay (scripps 126)
11	46036	181	182	181	Canada West Coast, South Nomad	23	46232	0	182	181	US South West Coast, Coronado Islands MX (scripps 133)
12	46041	168	182	182	US North-West Coast, Cape Elisabeth						

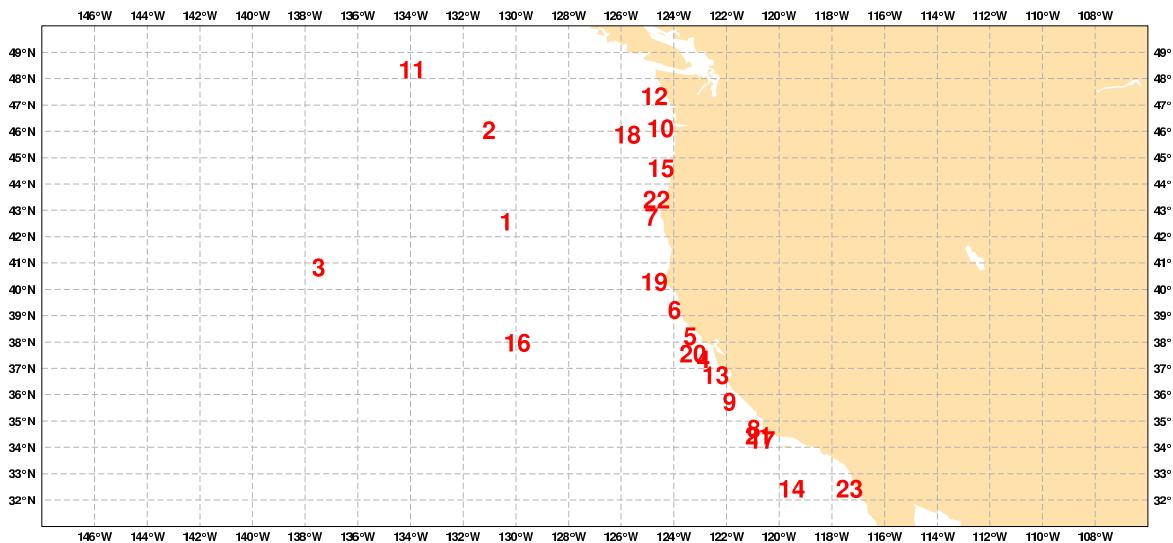


Figure 22: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

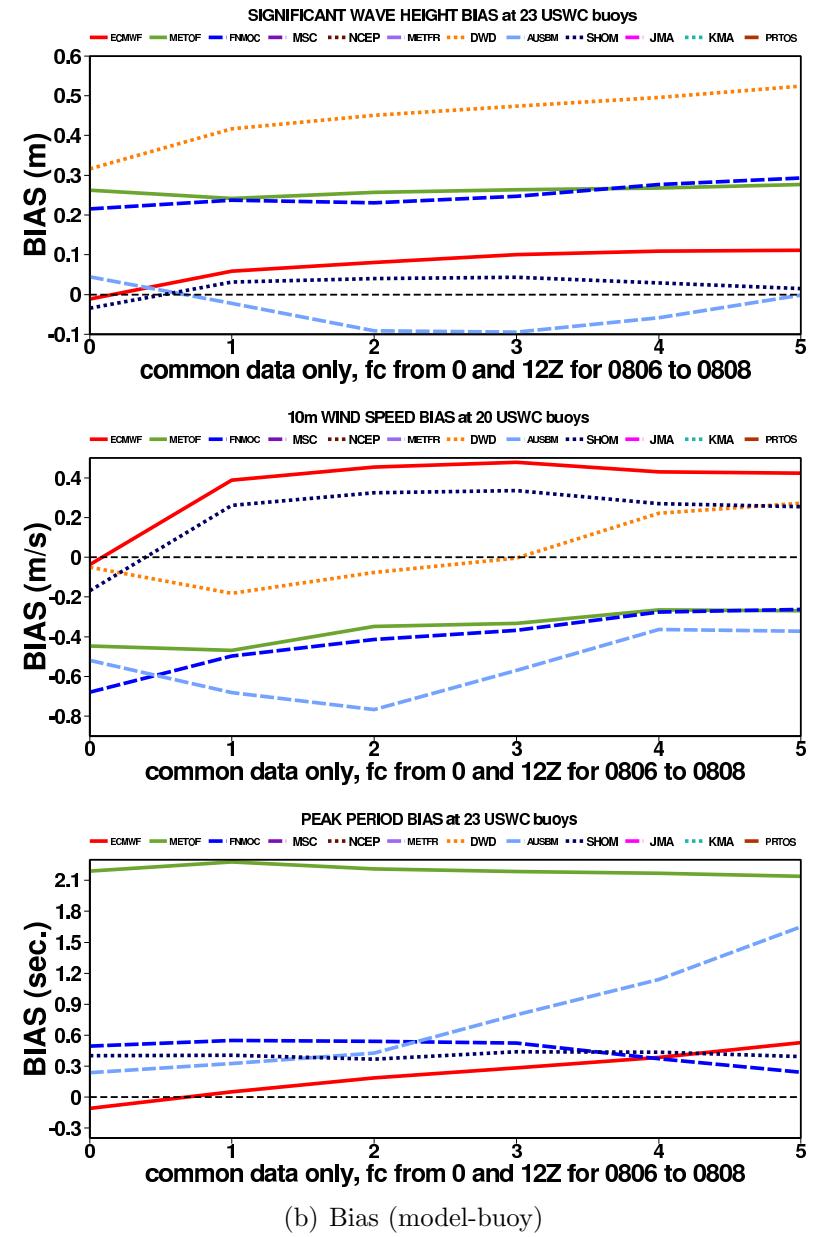
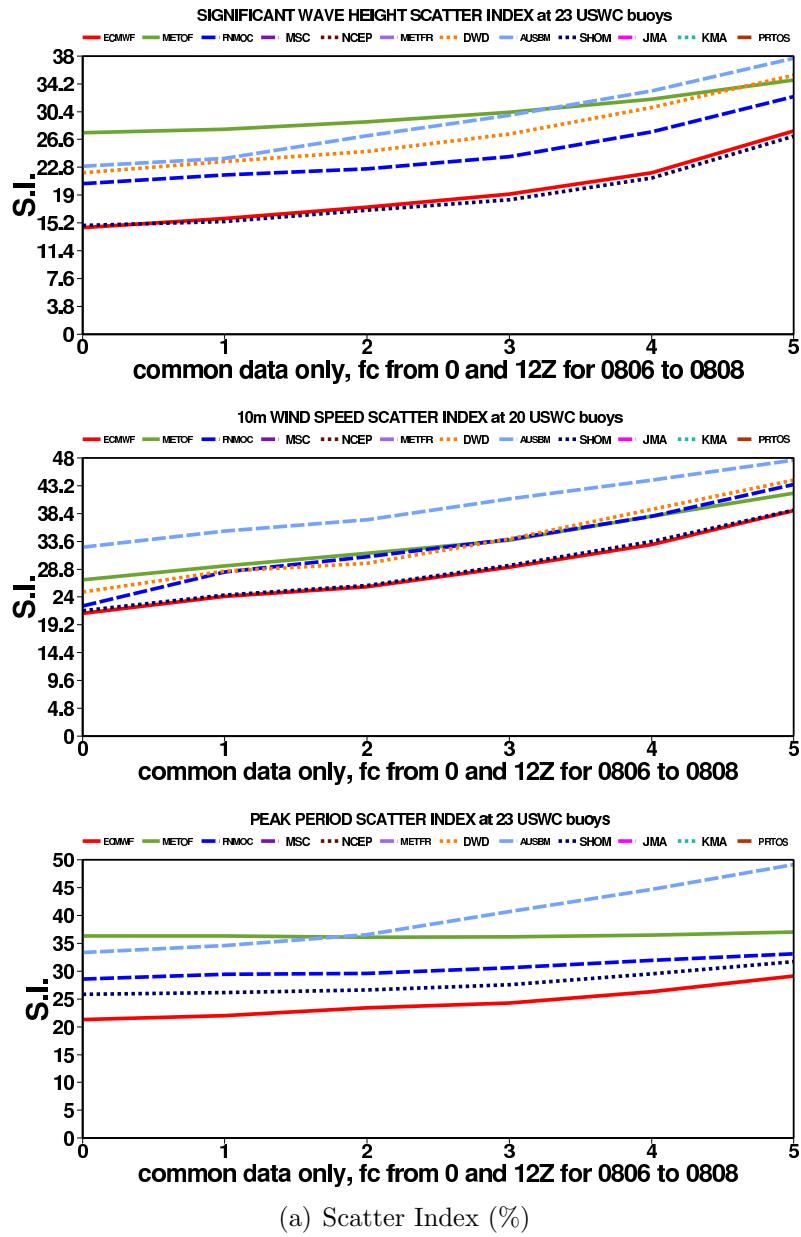
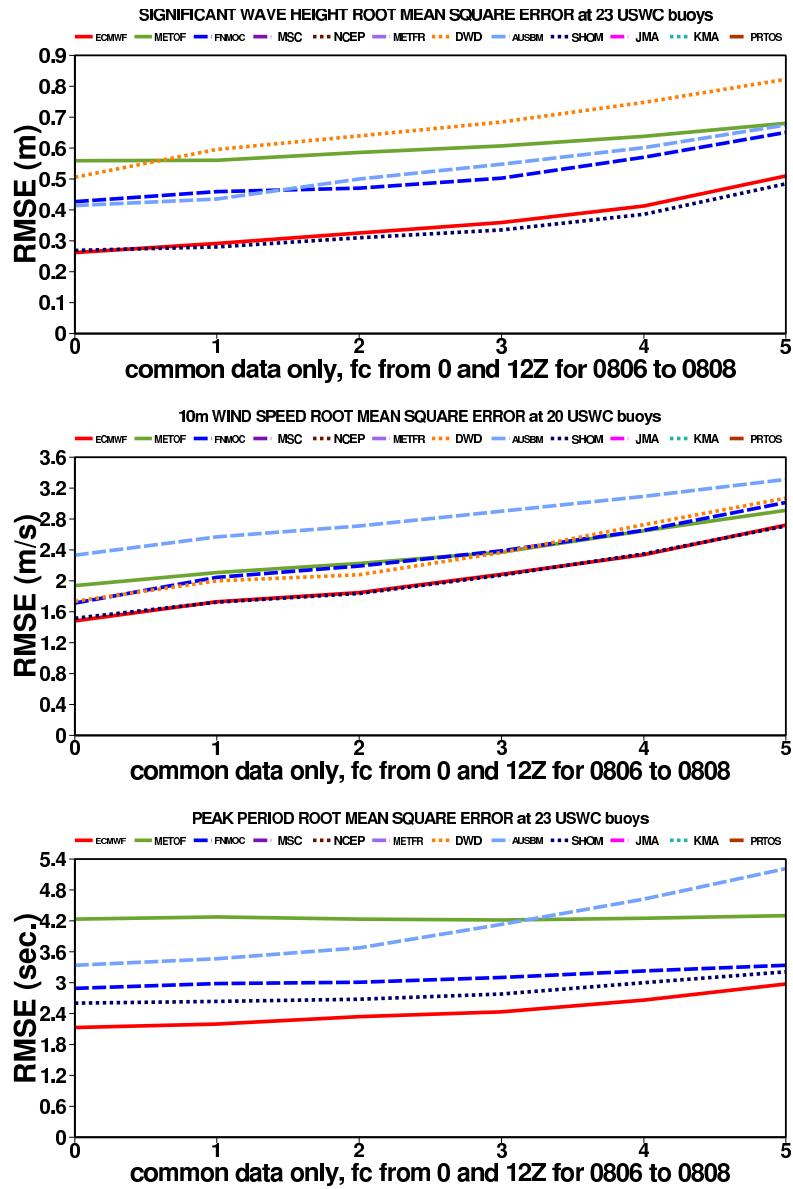
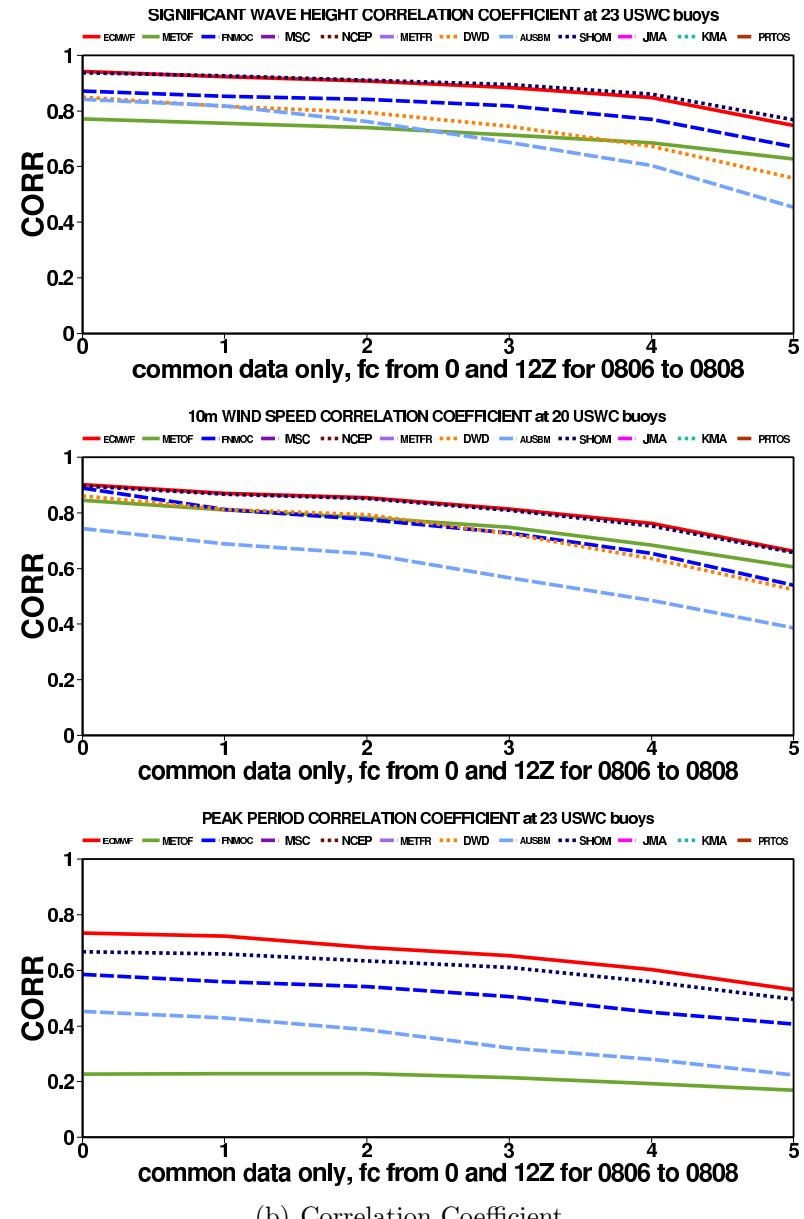


Figure 23: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common US West Coast buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 24: Forecast root mean square error (RMSE) and linear correlation coefficient at common US West Coast buoys .

0.3.5 Comparison for US East Coast buoys

Number of common observations for US East Coast buoys (USEC) from 200806 to 200808 (wind, Hs,Tp)

1	41001	82	82	82	US East Coast, E Hatteras	12	44006	182	182	182	US North-East Coast, Nantucket
2	41004	177	177	177	US South-East Coast, Edisto	13	44009	181	182	182	US North-East Coast, Delaware bay
3	41008	180	180	180	US South-East Coast, Grays reef	14	44011	179	180	180	US North-East Coast, Georges Bank
4	41009	91	126	126	US East Florida , Cape Canaveral	15	44014	120	120	120	US East Coast, Virginia Beach
5	41010	182	182	182	US East Florida , Cape Canaveral East	16	44017	0	182	182	US North-East Coast, Momauk Point
6	41012	181	155	155	US East Florida , St Augustine	17	44018	180	182	182	US North-East Coast, SE Cape Cod
7	41013	182	182	182	US South-East Coast , Frying Pan Shoals	18	44024	181	181	181	US North East Coast, Northeast Channel
8	41025	182	171	171	US East Coast, Diamond Shoals (Red Buoy)	19	44025	182	182	182	US North East Coast, Long Island
9	41036	182	182	182	US East Coast, Onslow Bay offshore	20	44027	182	182	177	US North East Coast, Jonesport
10	41048	182	179	179	W Bermuda	21	44037	181	182	181	US North East Coast, Jordan Basin
11	44005	76	76	76	US North East Coast, Gulf of Maine	22	44038	182	182	0	US North East Coast, Scotian Shelf

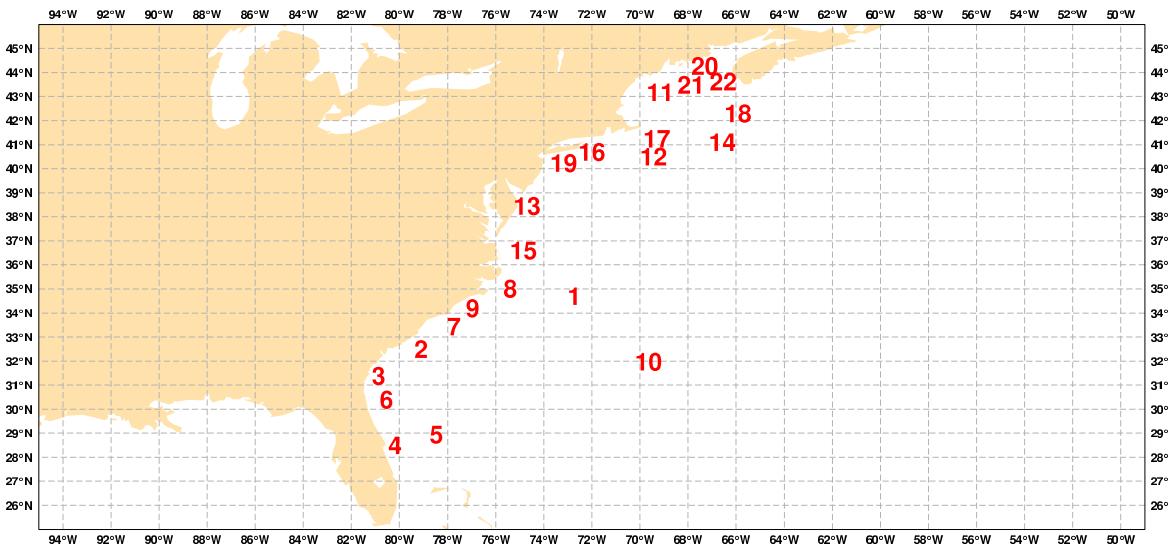


Figure 25: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

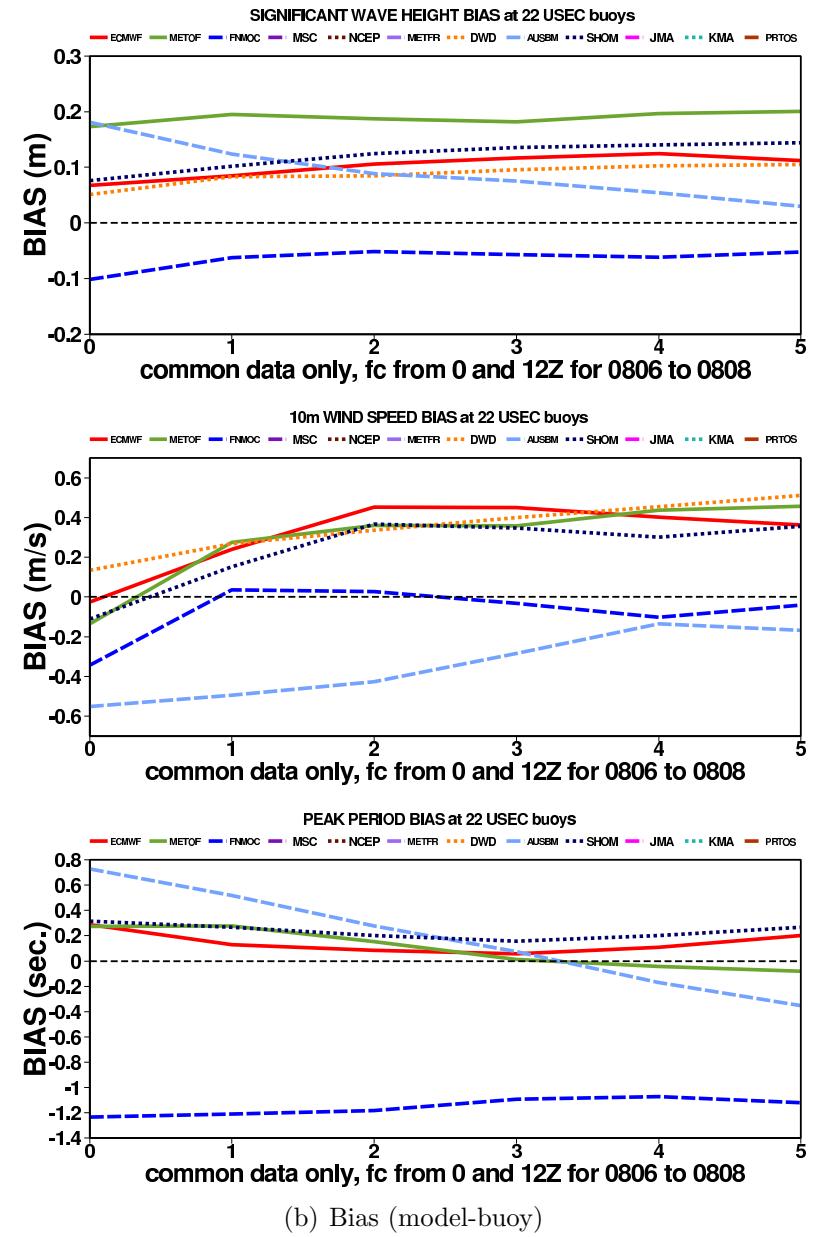
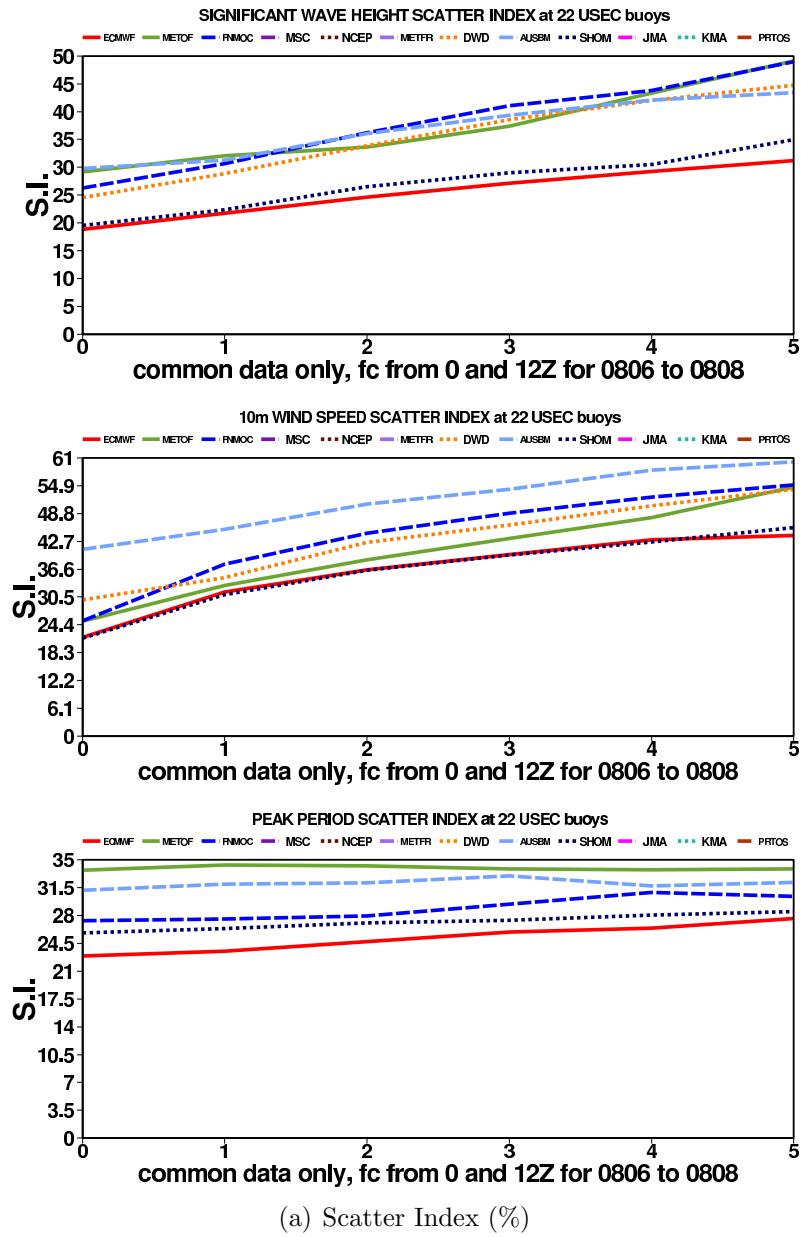
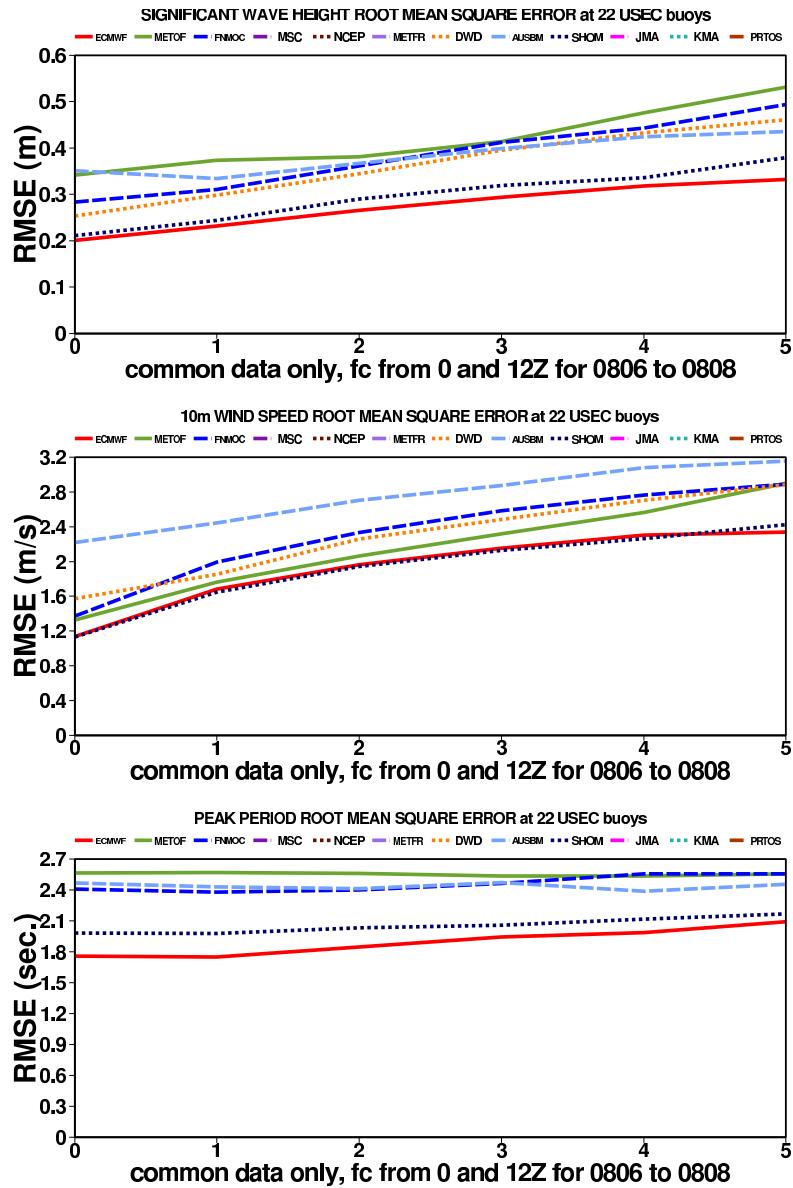
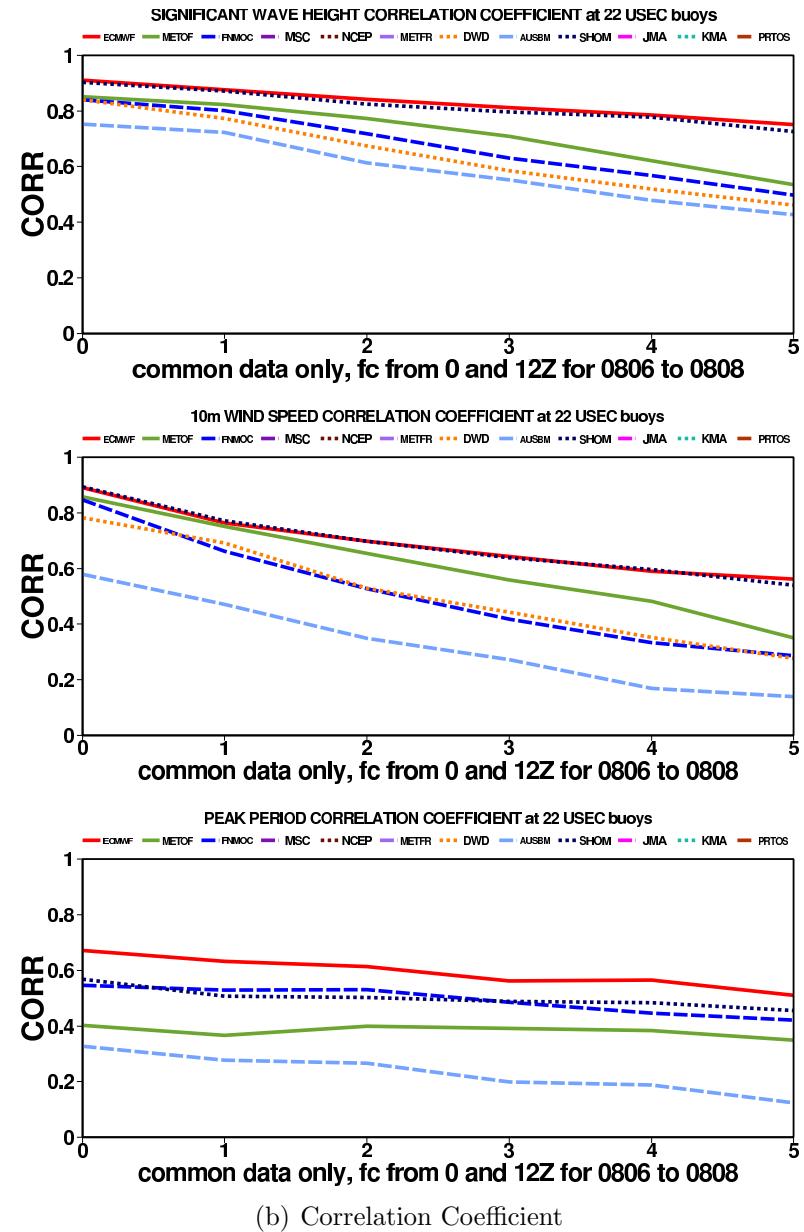


Figure 26: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common US East Coast buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 27: Forecast root mean square error (RMSE) and linear correlation coefficient at common US East Coast buoys .

0.3.6 Comparison for Gulf of Mexico buoys

Number of common observations for Gulf of Mexico buoys (GM) from 200806 to 200808 (wind, Hs, Tp)

1	42001	182	181	174	Mid Gulf of Mexico	6	42036	181	182	165	Gulf of Mexico W Tampa
2	42002	182	178	171	Western Gulf of Mexico	7	42039	181	181	173	Gulf of Mexico Pensacola S
3	42003	180	180	178	East Gulf of Mexico	8	42040	181	182	173	Gulf of Mexico Mobile S
4	42019	182	182	181	Gulf of Mexico Lanelle	9	42055	181	181	178	Bay of Campeche
5	42020	182	182	179	Gulf of Mexico Corpus Christi	10	42099	0	180	173	Gulf Mexico, St Peterburg (scripps 144)

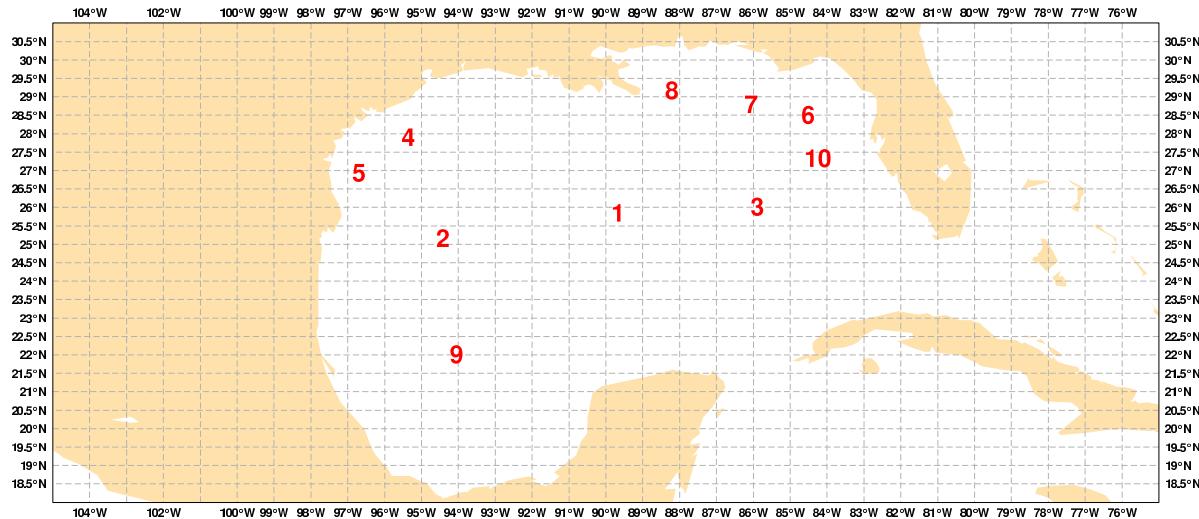


Figure 28: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

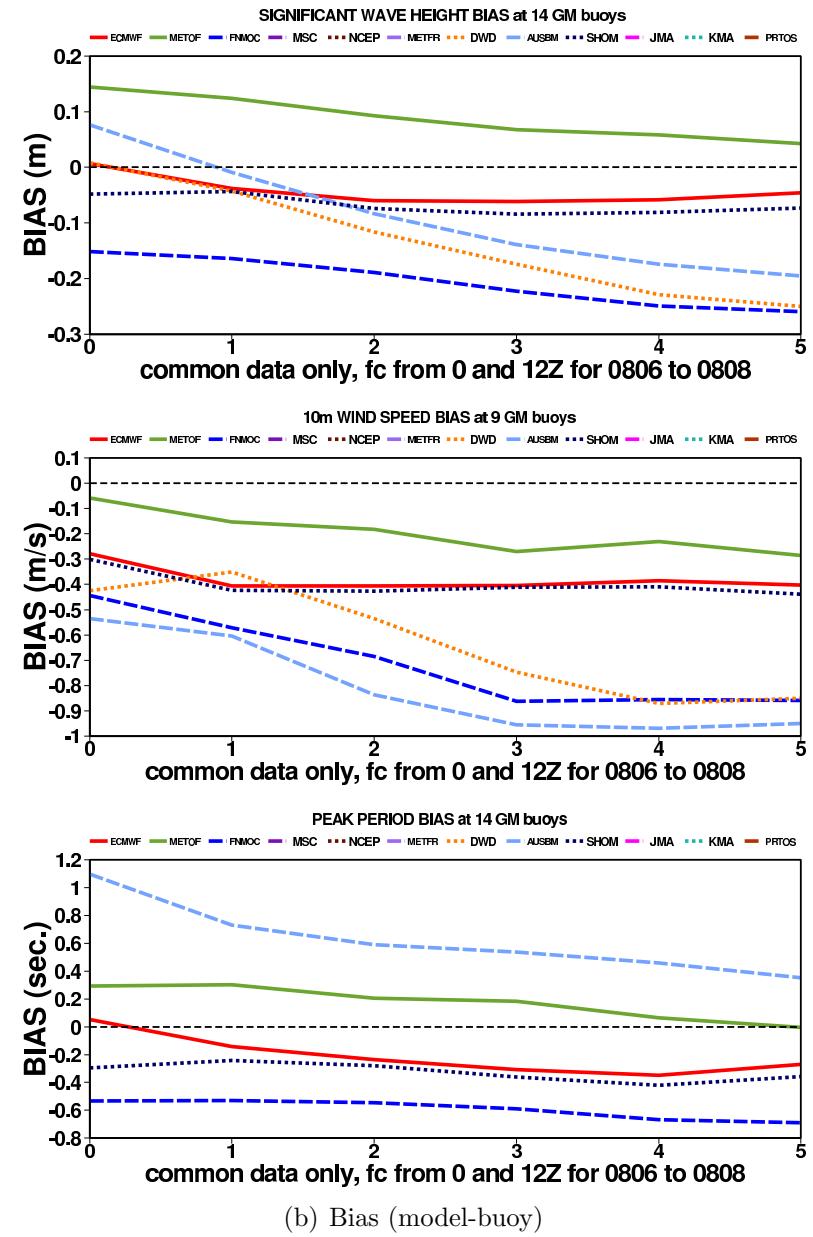
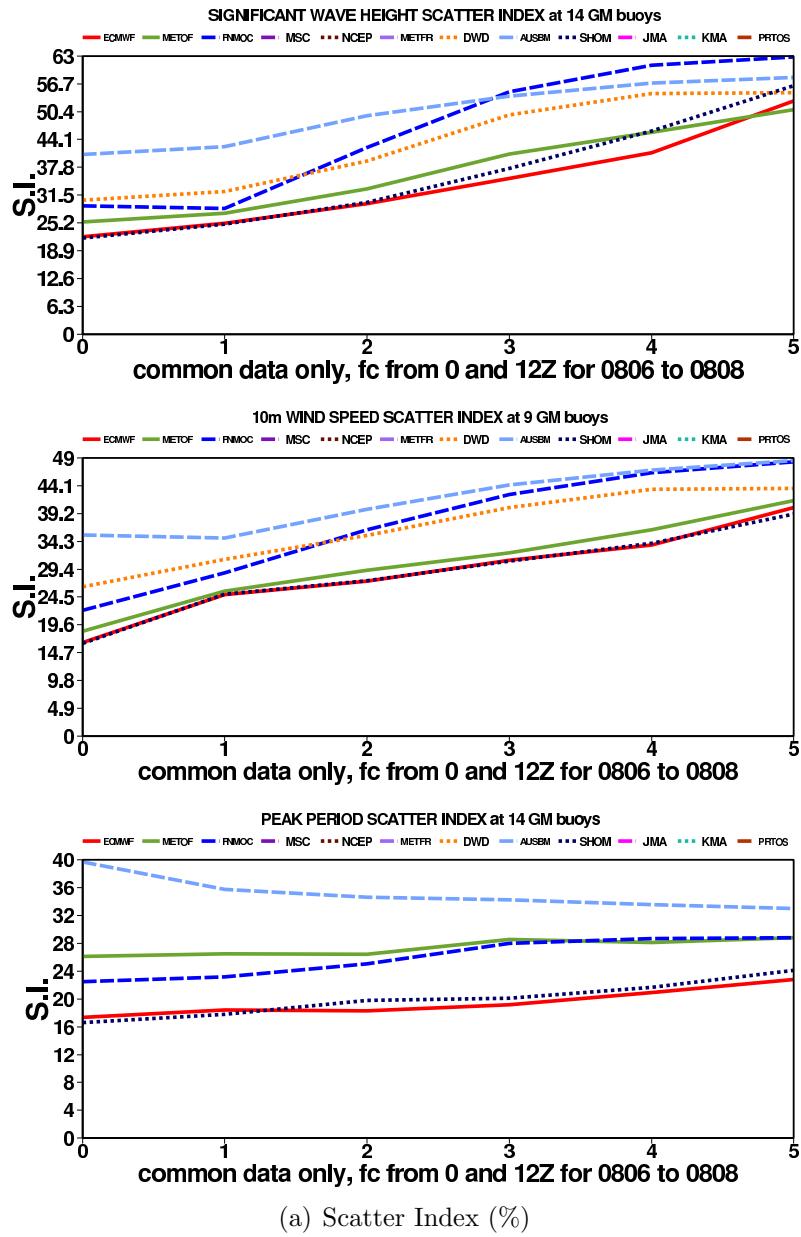
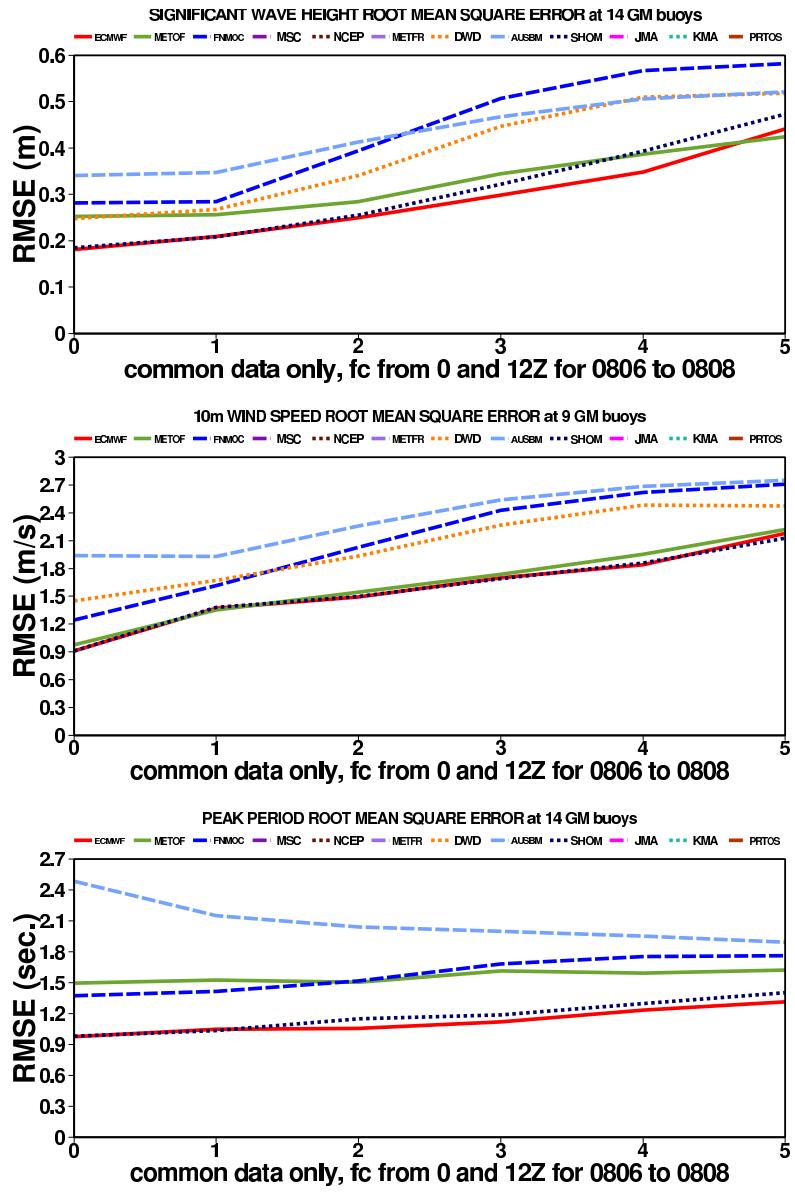
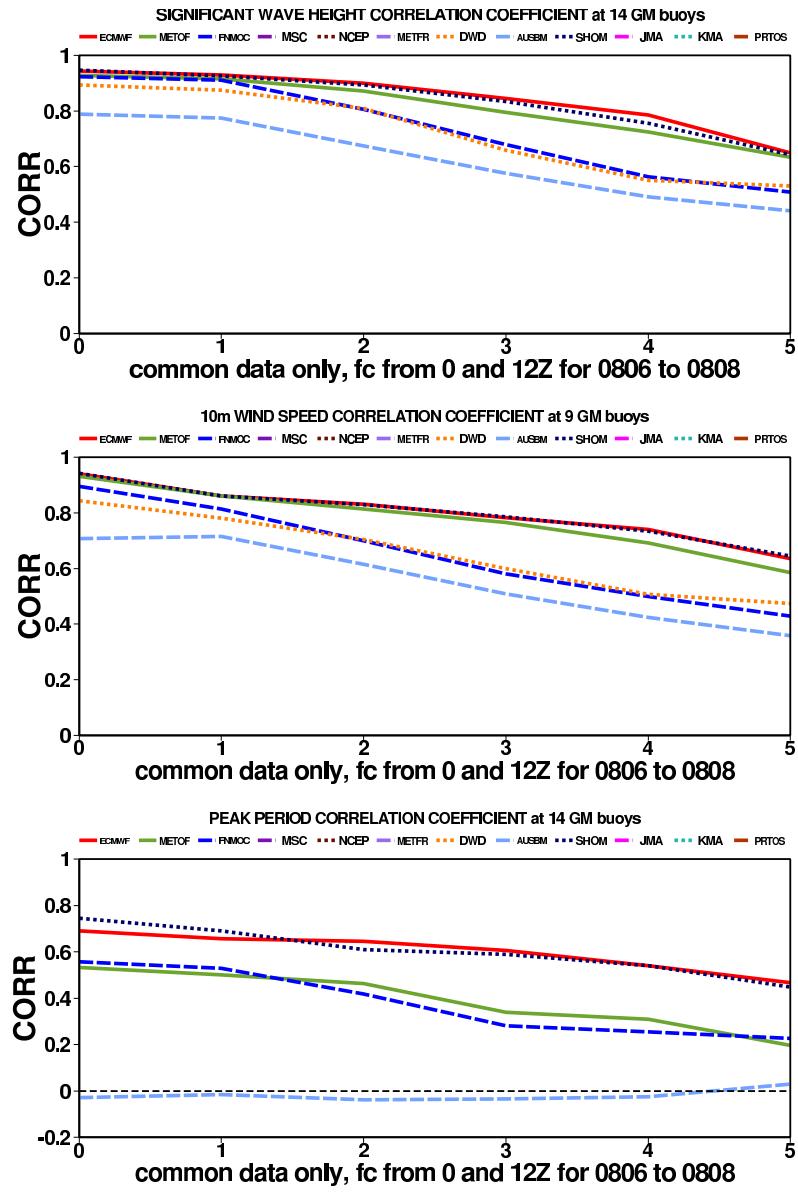


Figure 29: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Gulf of Mexico buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 30: Forecast root mean square error (RMSE) and linear correlation coefficient at common Gulf of Mexico buoys .

0.3.7 Comparison for Canadian East Coast buoys

Number of common observations for Canadian East Coast buoys (CANEC) from 200806 to 200808 (wind, Hs,Tp)

1	44137	104	180	180	Nova Scotia, East Scotia slope	5	44141	24	177	176	Nova Scotia, Laurentian Fan
2	44138	182	182	182	Newfoundland, SW Grand Bank	6	44150	182	0	0	Nova Scotia, La Have Bank
3	44139	181	180	181	Newfoundland, Banquerau	7	44251	153	153	153	Newfoundland, Nickerson Bank
4	44140	167	17	17	Newfoundland, Tail Of The Bank	8	44255	180	175	175	Newfoundland, NE Bugeo Bank

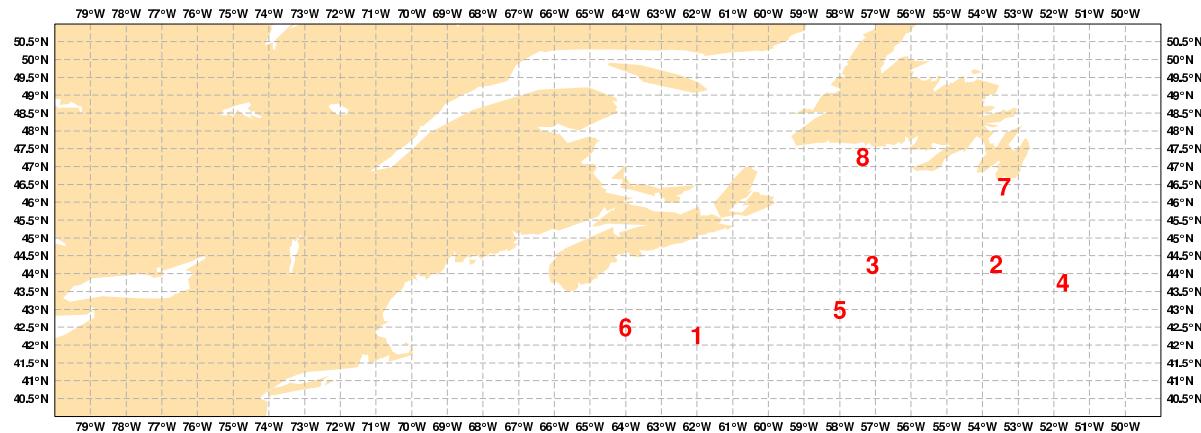


Figure 31: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

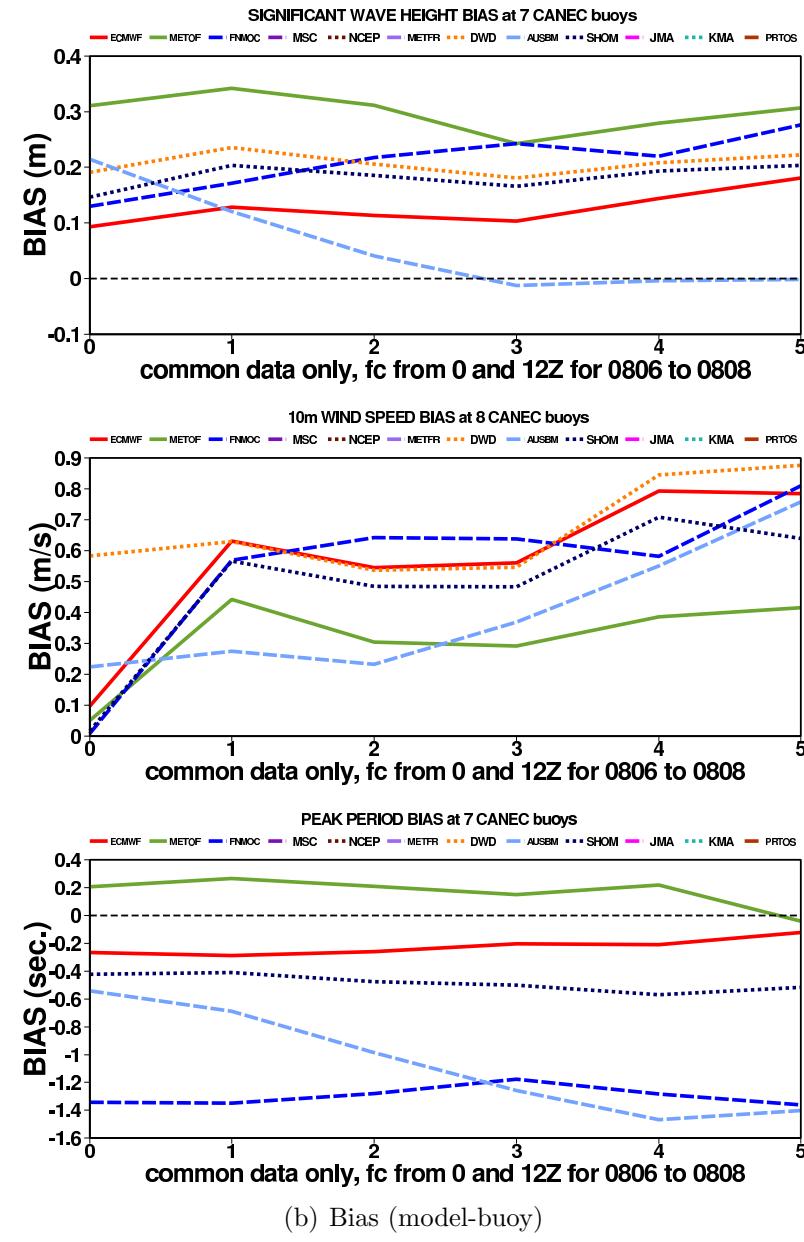
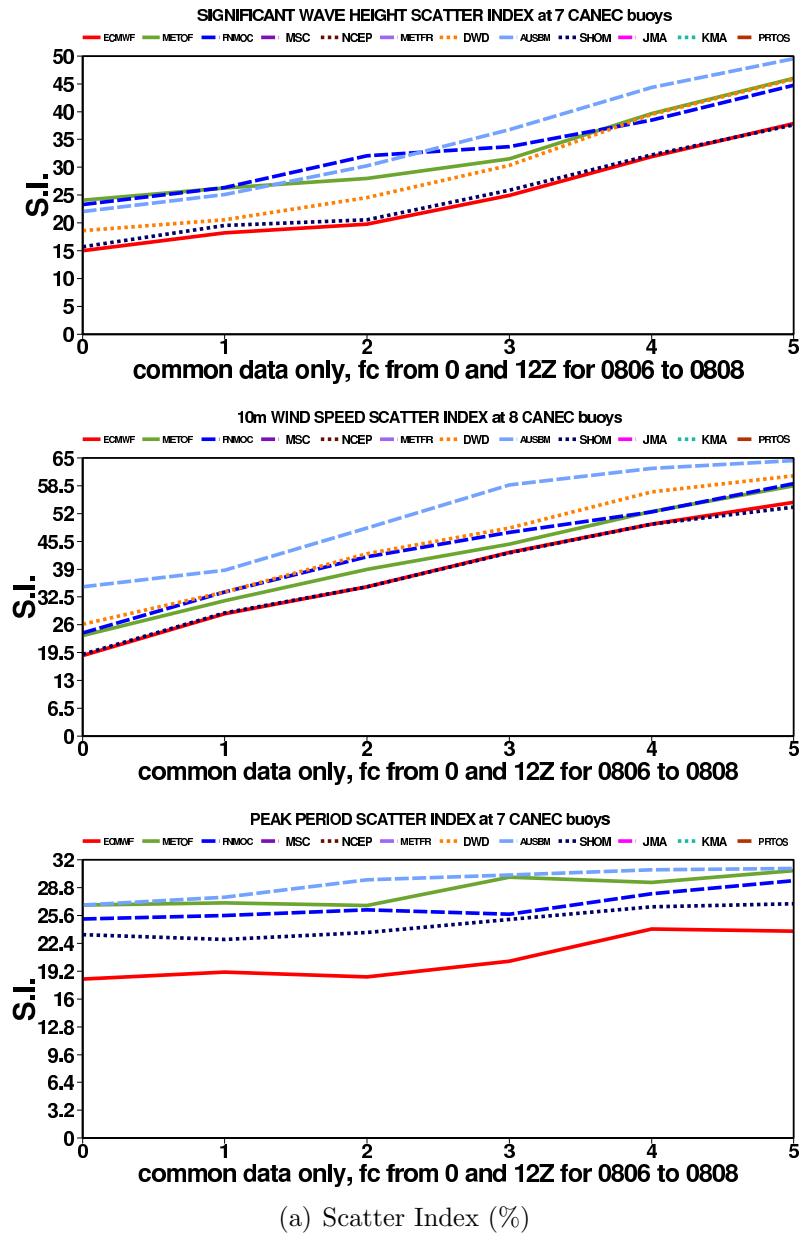
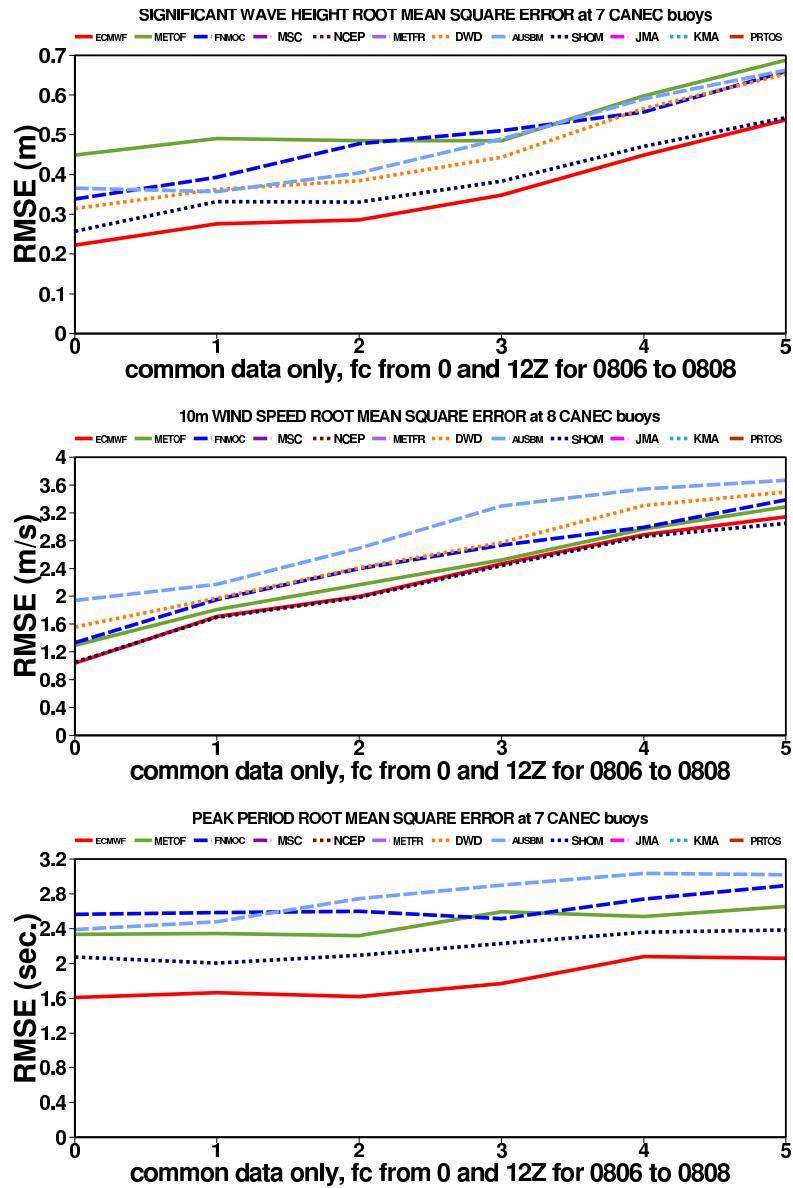
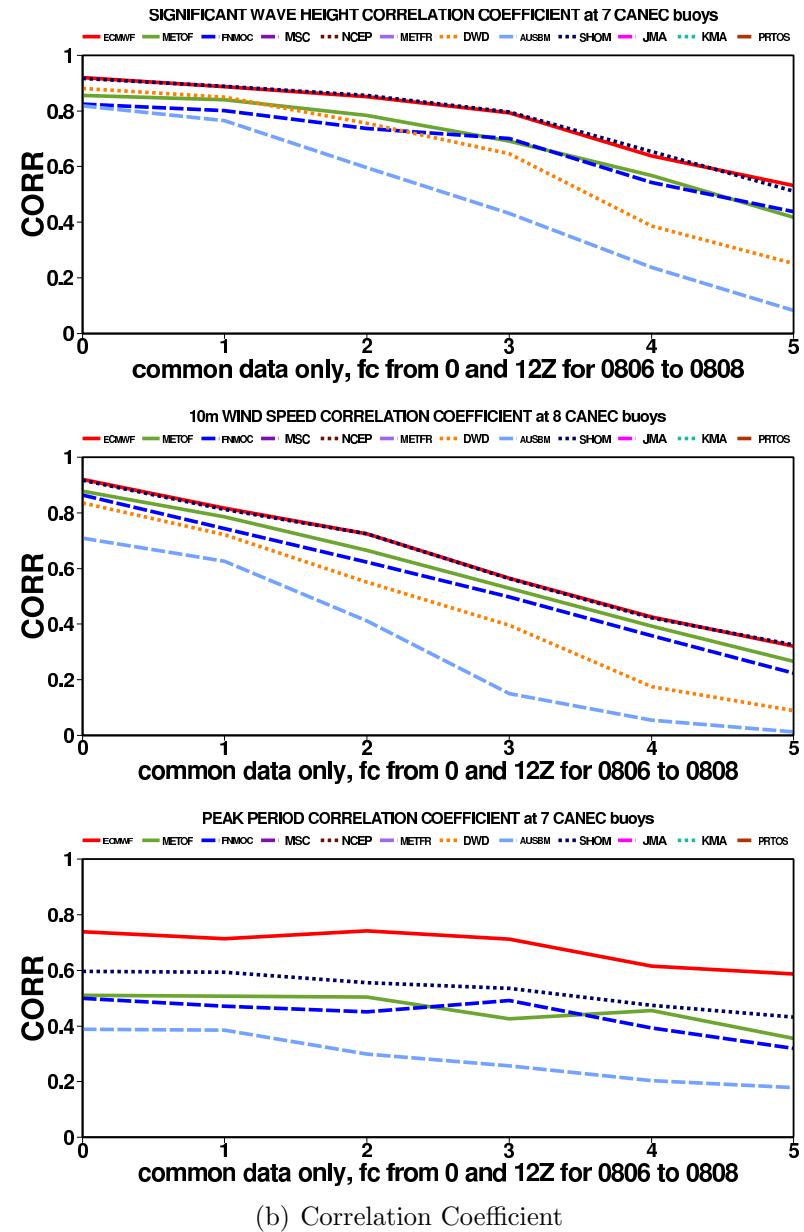


Figure 32: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Canadian East Coast buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 33: Forecast root mean square error (RMSE) and linear correlation coefficient at common Canadian East Coast buoys .

0.3.8 Comparison for Caribbean Sea buoys

Number of common observations for Caribbean Sea buoys (CRB) from 200806 to 200808 (wind, Hs,Tp)

1	41040	182	182	182	Tropical Atlantic, West Atlantic	7	41101	181	181	0	French West Indies (Antilles 2)
2	41041	182	181	180	Tropical Atlantic, Middle Atlantic	8	42056	181	181	182	Yucatan Basin
3	41043	177	177	177	South Western Atlantic	9	42057	182	182	182	Western Caribbean
4	41046	180	179	180	E Bahamas	10	42058	181	180	180	Central Caribbean
5	41047	181	180	181	NE Bahamas	11	42059	181	181	181	Eastern Caribbean
6	41100	179	182	0	French West Indies (Antilles 1)						

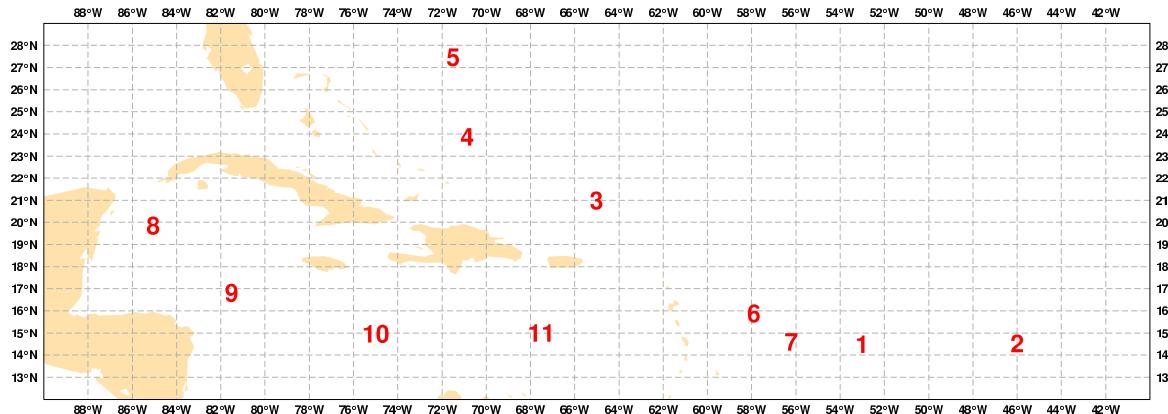
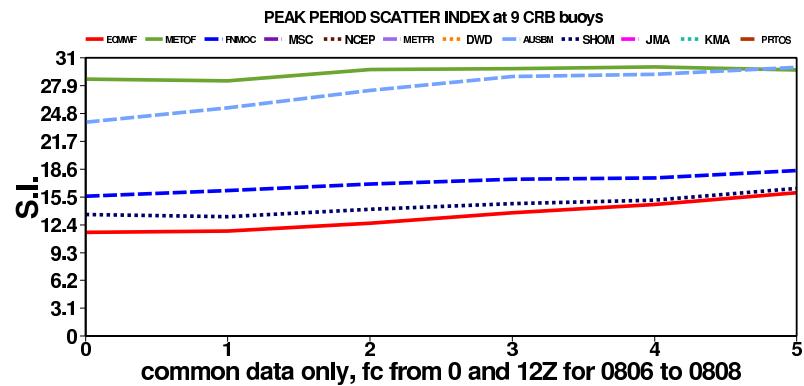
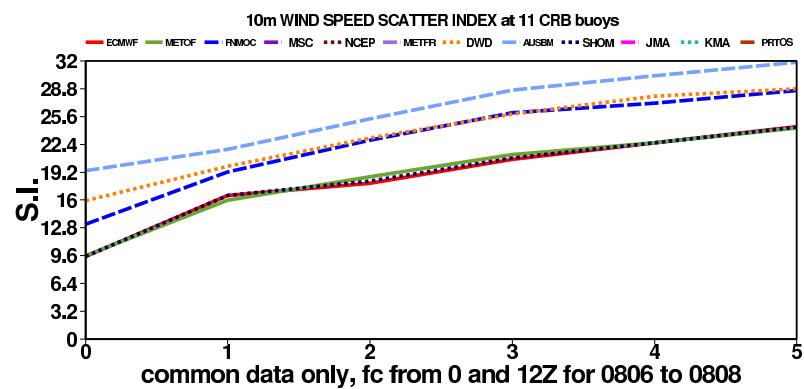
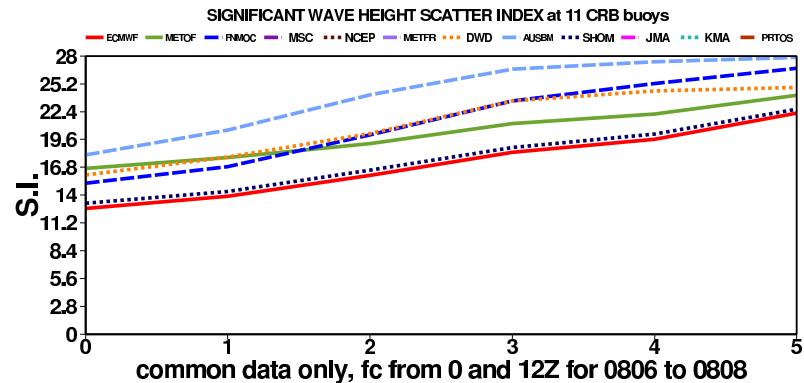
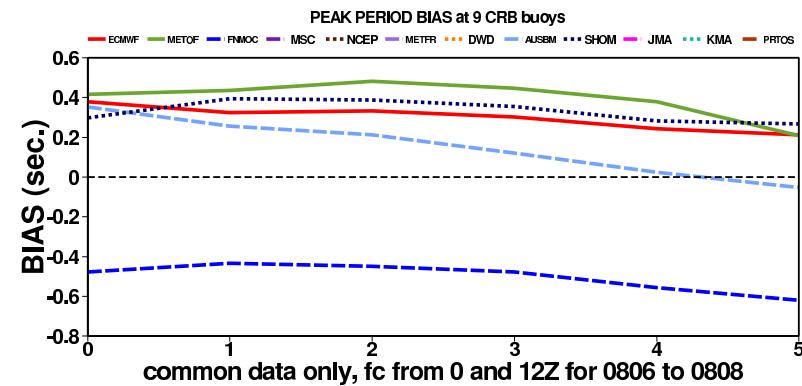
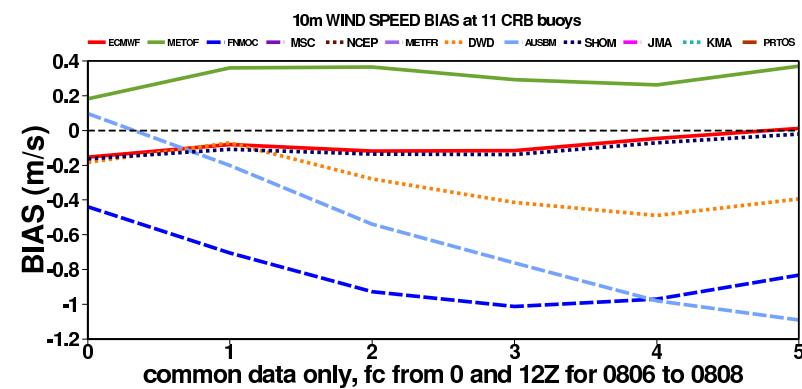
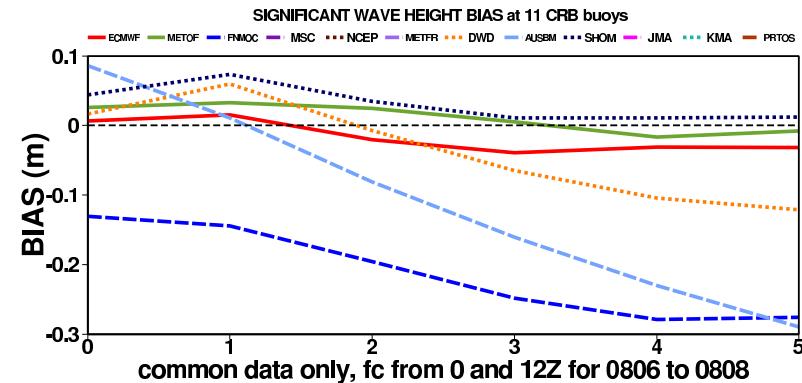


Figure 34: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

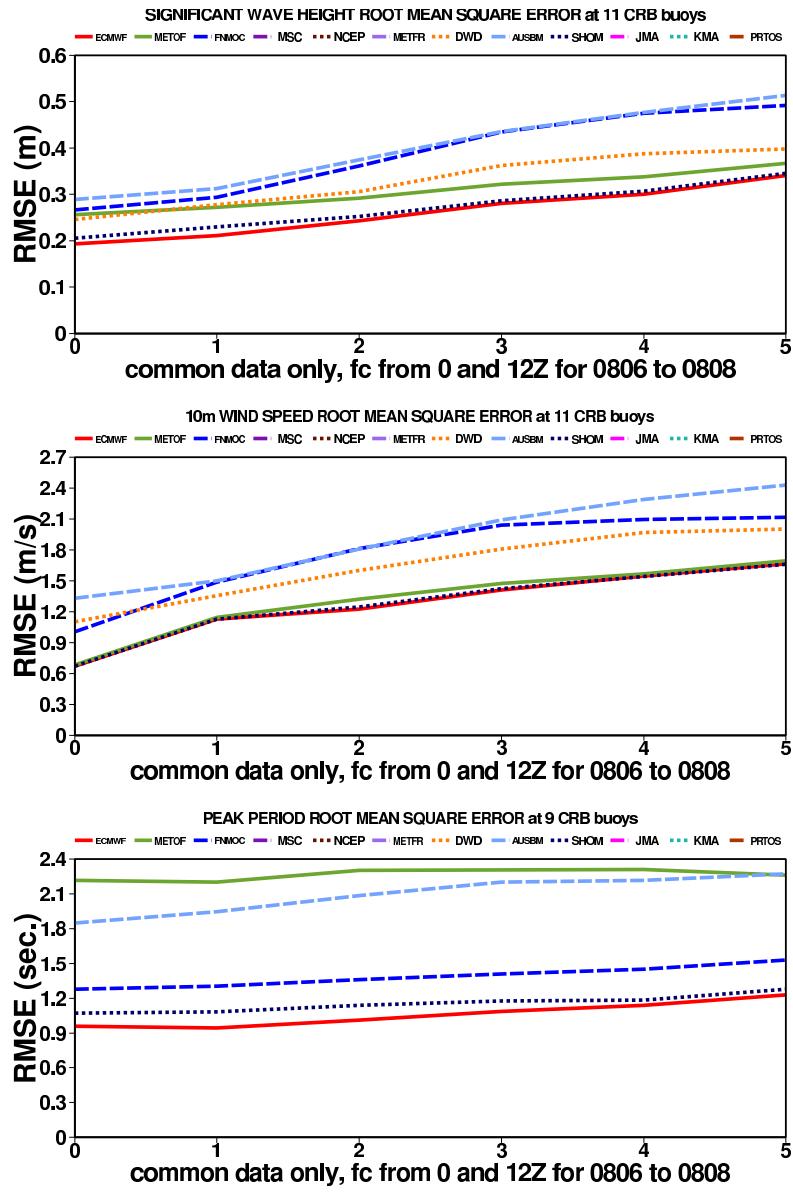


(a) Scatter Index (%)

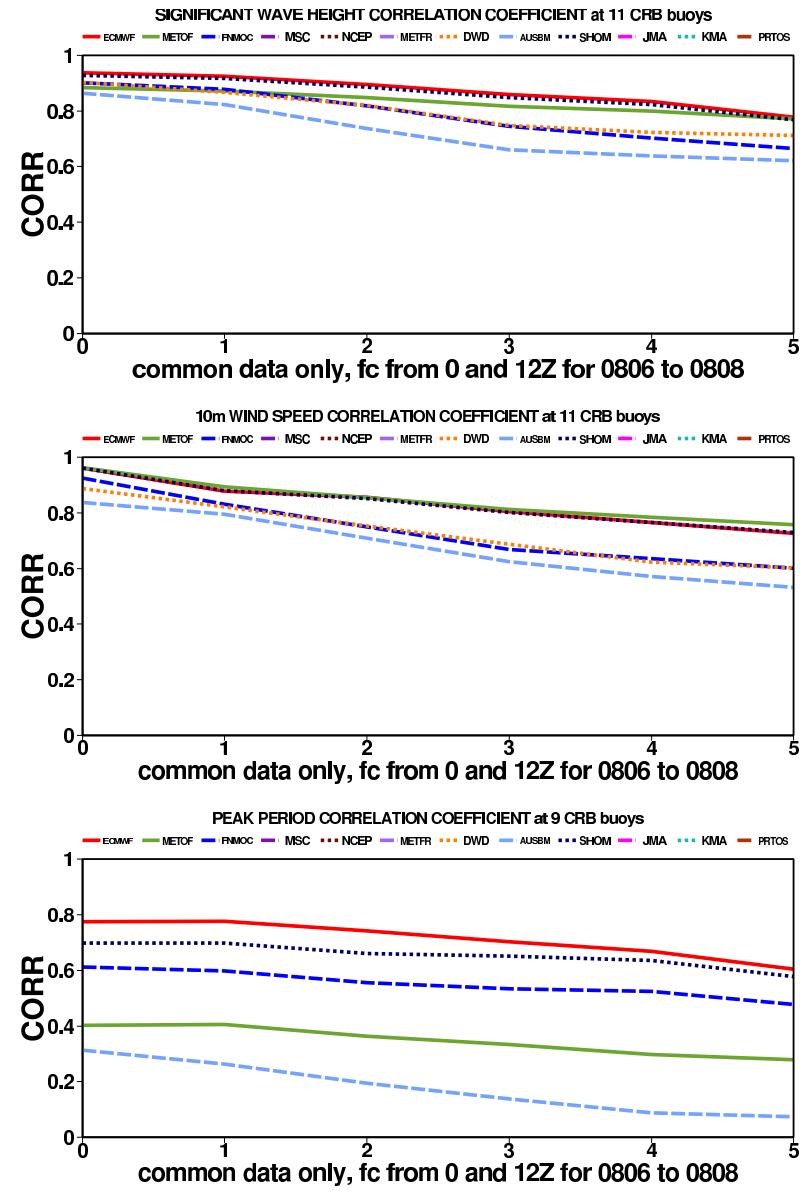


(b) Bias (model-buoy)

Figure 35: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Caribbean Sea buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 36: Forecast root mean square error (RMSE) and linear correlation coefficient at common Caribbean Sea buoys.

0.3.9 Comparison for North East Atlantic buoys

Number of common observations for North East Atlantic buoys (NEATL) from 200806 to 200808 (wind, Hs,Tp)

1	62023	162	163	0	South Ireland, Marathon rig	10	62085	147	168	0	Cadiz (Spain)
2	62024	99	100	0	Bilbao (Spain)	11	62092	8	182	0	South West Ireland (M3), Mizen Head
3	62025	166	169	0	Cabo de Penas (Spain)	12	62094	181	181	0	South Ireland (M5), South East
4	62029	177	181	0	UK Celtic Sea shelf break (K1)	13	62095	122	0	0	West Ireland (M6), West Coast
5	62064	0	95	0	SHOM (Cape Ferret)	14	62107	180	180	0	Isle of Scilly (7 stones)
6	62081	182	182	0	UK East Atlantic (K2)	15	62163	133	182	0	UK Celtic Sea shelf break (Brittany)
7	62082	155	155	0	Estaca de Bares (Spain)	16	62303	179	180	0	Bristol Channel (Pembroke buoy)
8	62083	169	169	0	Villano-Sisargas (Spain)	17	64045	81	178	0	UK North-East Atlantic (K5)
9	62084	167	167	0	Silleiro Spain)	18	64046	173	165	0	UK North-East Atlantic (K7)

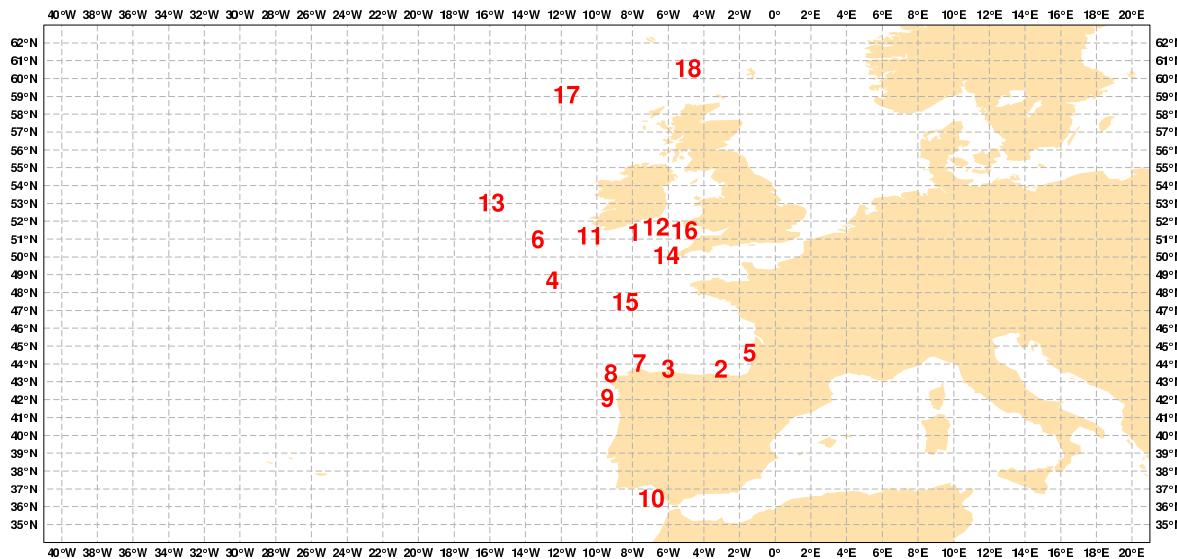
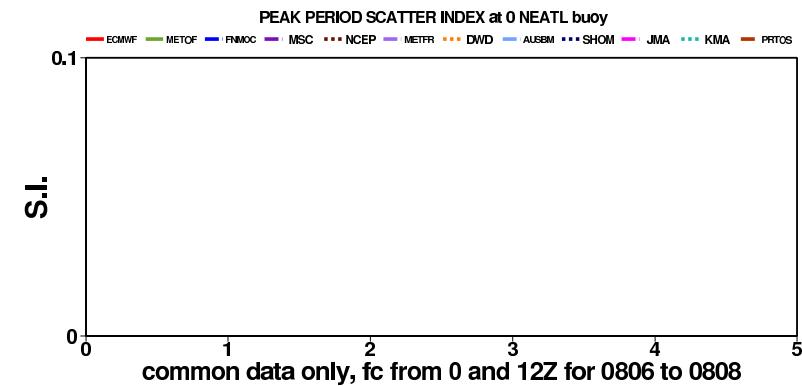
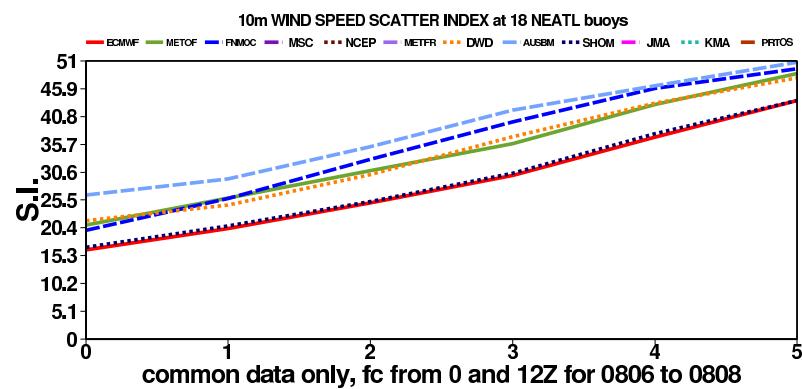
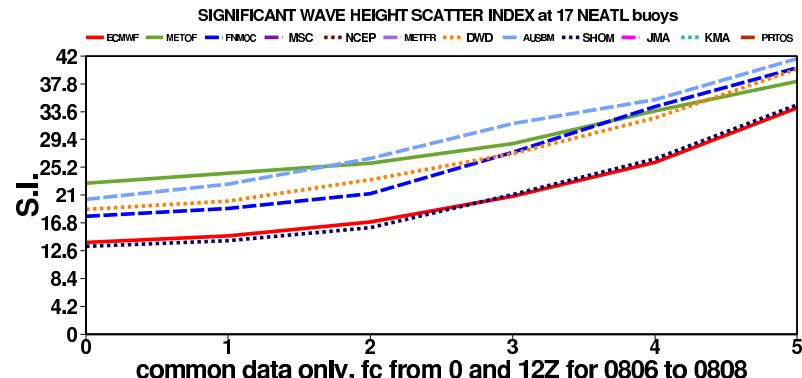
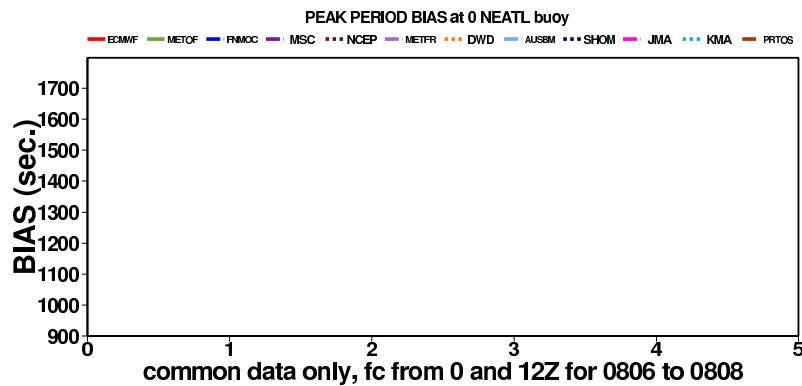
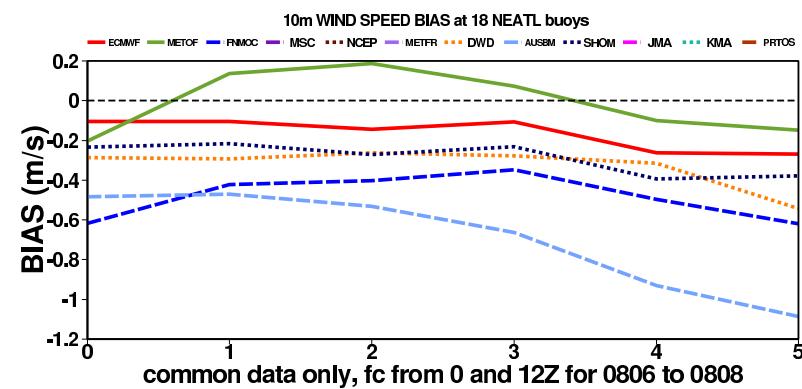
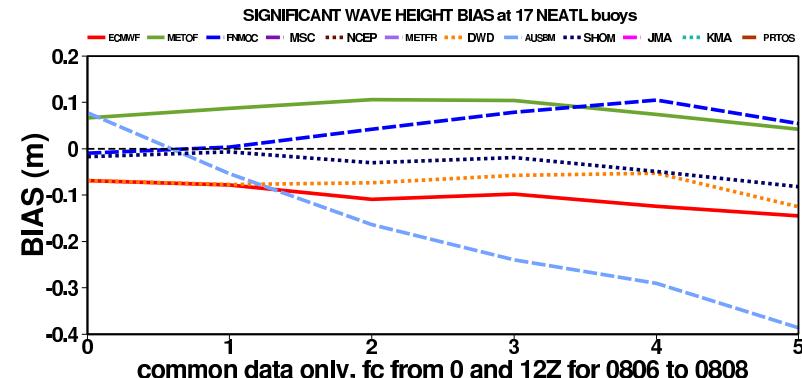


Figure 37: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

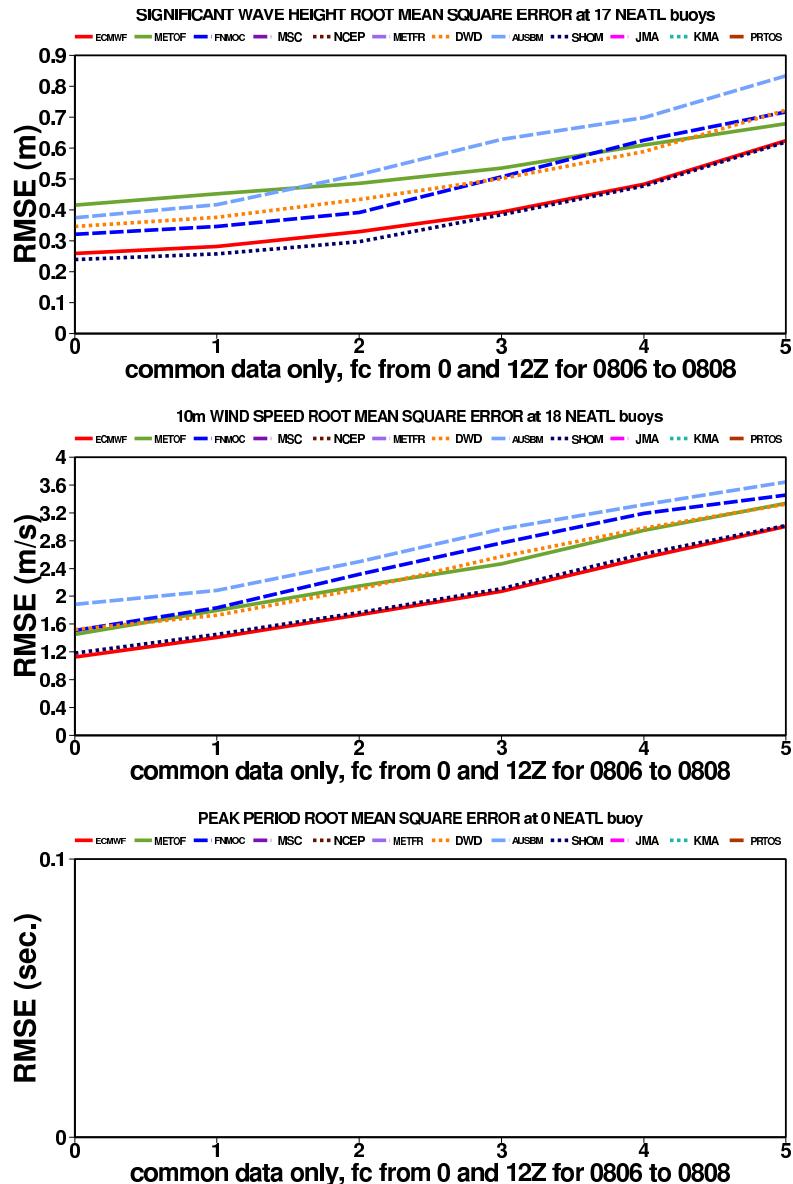


(a) Scatter Index (%)

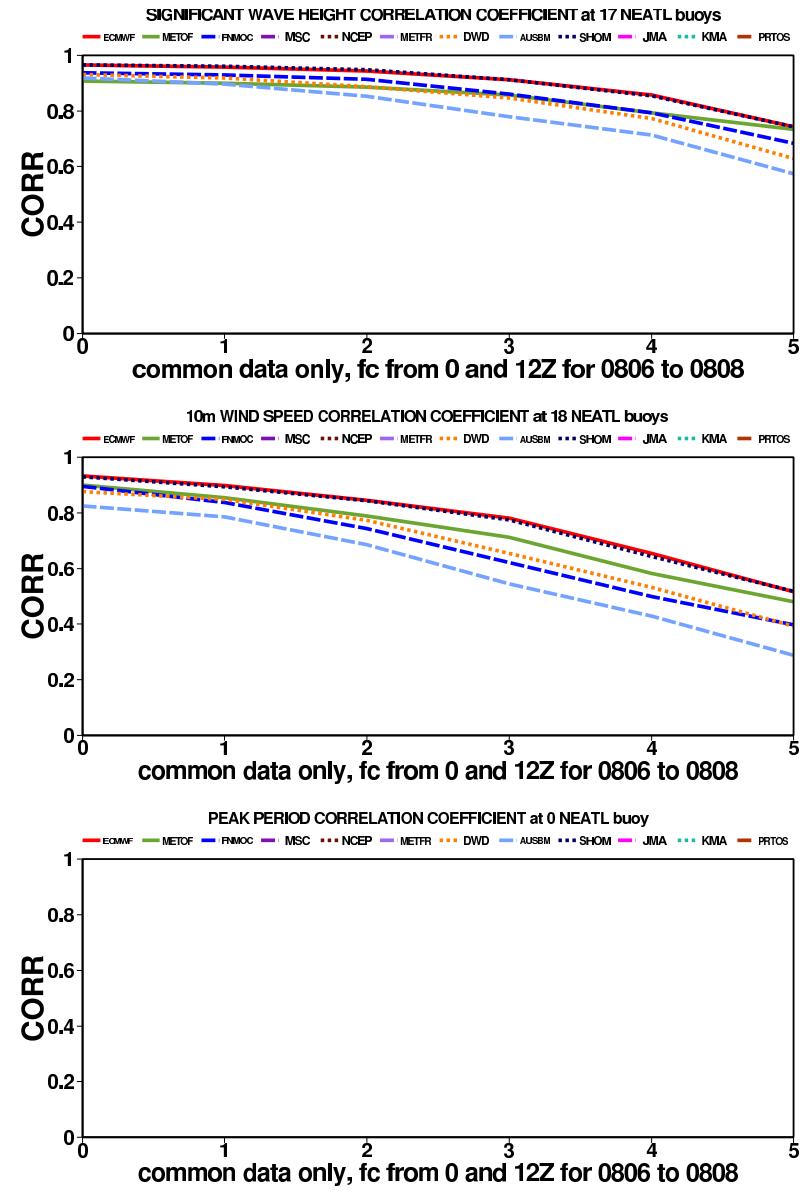


(b) Bias (model-buoy)

Figure 38: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North East Atlantic buoys .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 39: Forecast root mean square error (RMSE) and linear correlation coefficient at common North East Atlantic buoys .

0.3.10 Comparison for North Sea platforms

Number of common observations for North Sea (NSEA) from 200806 to 200808 (wind, Hs, Tp)

1	62111	180	180	0	North Sea (Ivanhoe)	13	62164	64	126	0	North Sea (Anasuria)
2	62116	156	178	0	North Sea (Nelson)	14	62170	164	161	0	Channel (F3 light vessel)
3	62117	46	64	0	North Sea (???????)	15	63055	37	136	0	North Sea shelf break (?????????)
4	62119	132	130	0	North Sea (???????)	16	63056	129	11	0	North Sea shelf break (?????????)
5	62128	125	123	0	North Sea (???????)	17	63057	6	6	0	North Sea shelf break (?????????)
6	62132	34	34	0	North Sea (Auk A)	18	63103	179	179	0	S Norwegian Sea (North Cormorant)
7	62133	179	179	0	North Sea (Gannet)	19	63108	179	179	0	S Norwegian Sea (North Alwyn)
8	62142	180	180	0	North Sea (Leman)	20	63110	89	91	0	North Sea shelf break (???????)
9	62143	177	177	0	North Sea (???????)	21	63112	175	176	0	North Sea shelf break (?????????)
10	62144	160	154	0	North Sea (Clipper)	22	63113	57	57	0	North Sea shelf break
11	62145	180	170	0	North Sea (Sean P)	23	63115	177	177	0	North Sea shelf break (???????)
12	62152	0	178	0	North Sea (???????)						

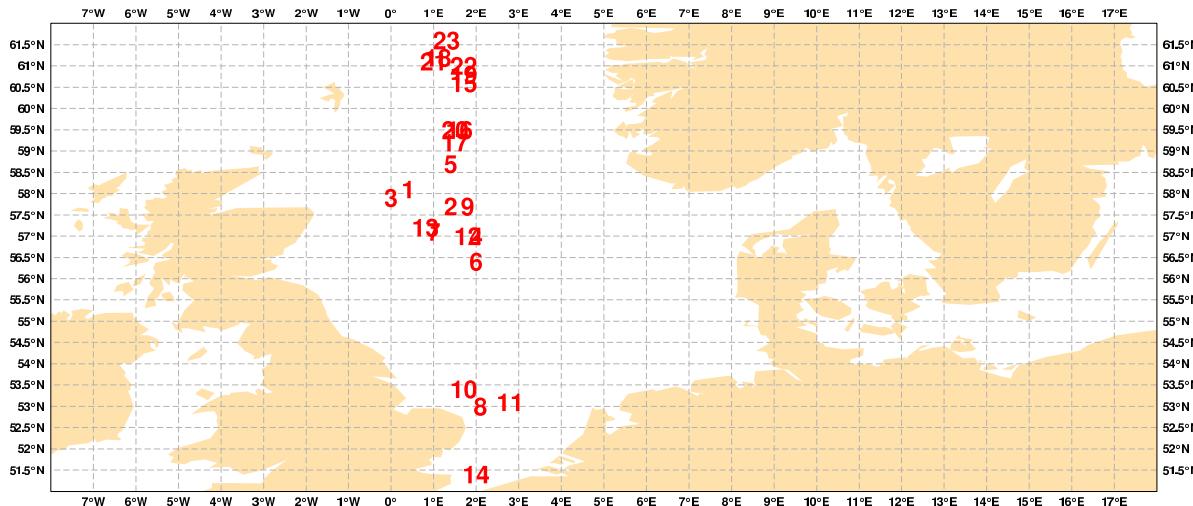


Figure 40: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

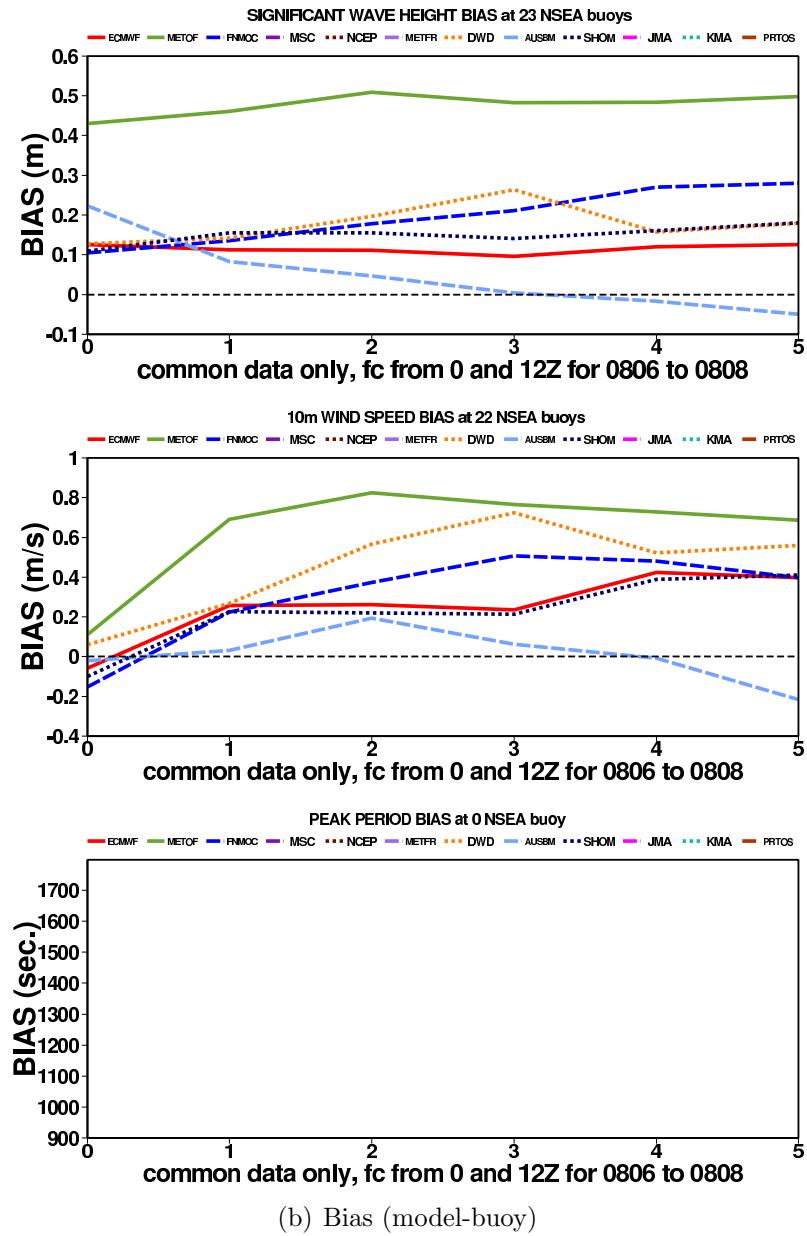
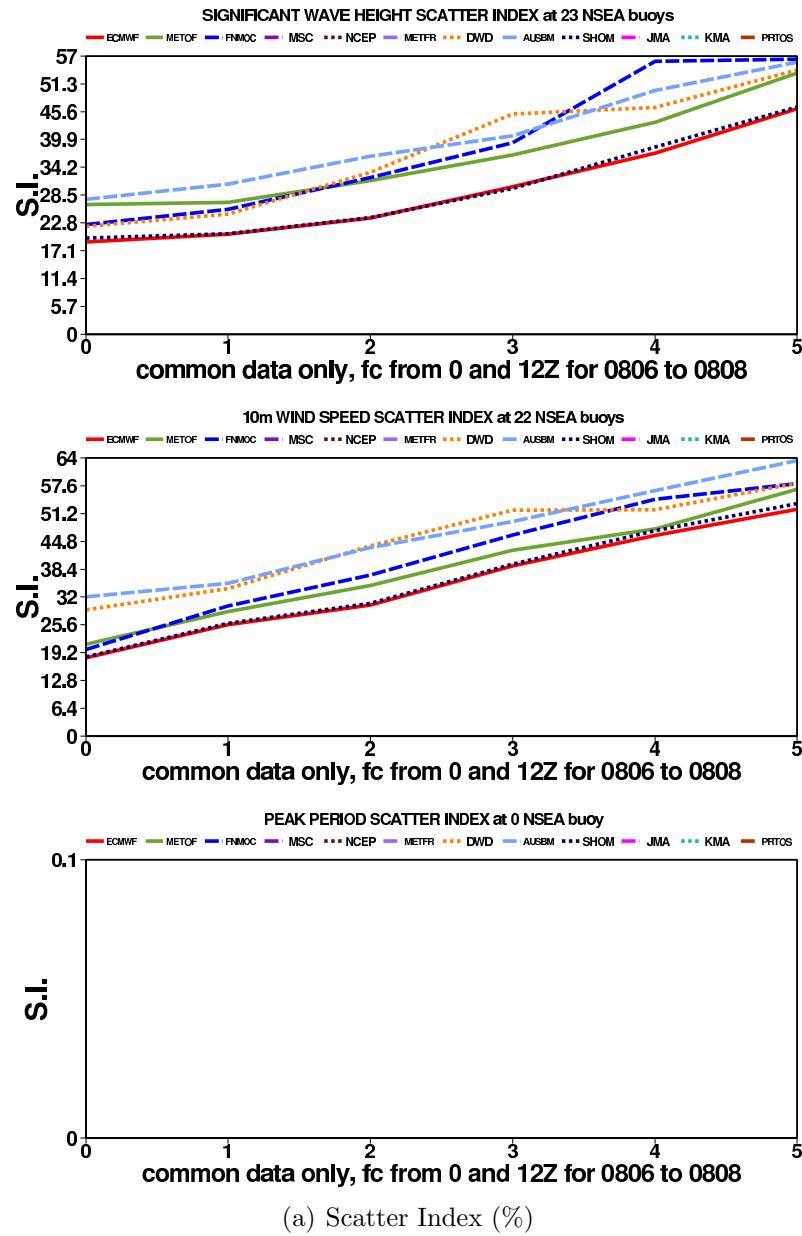
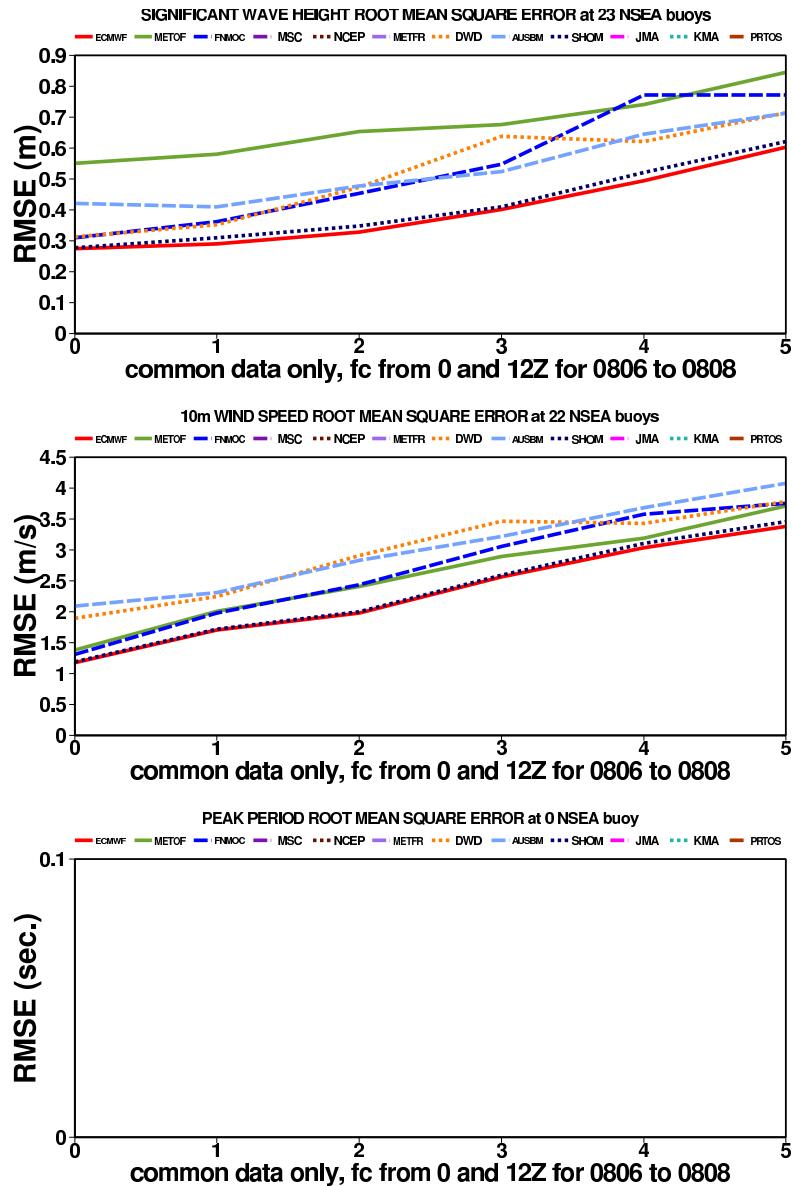
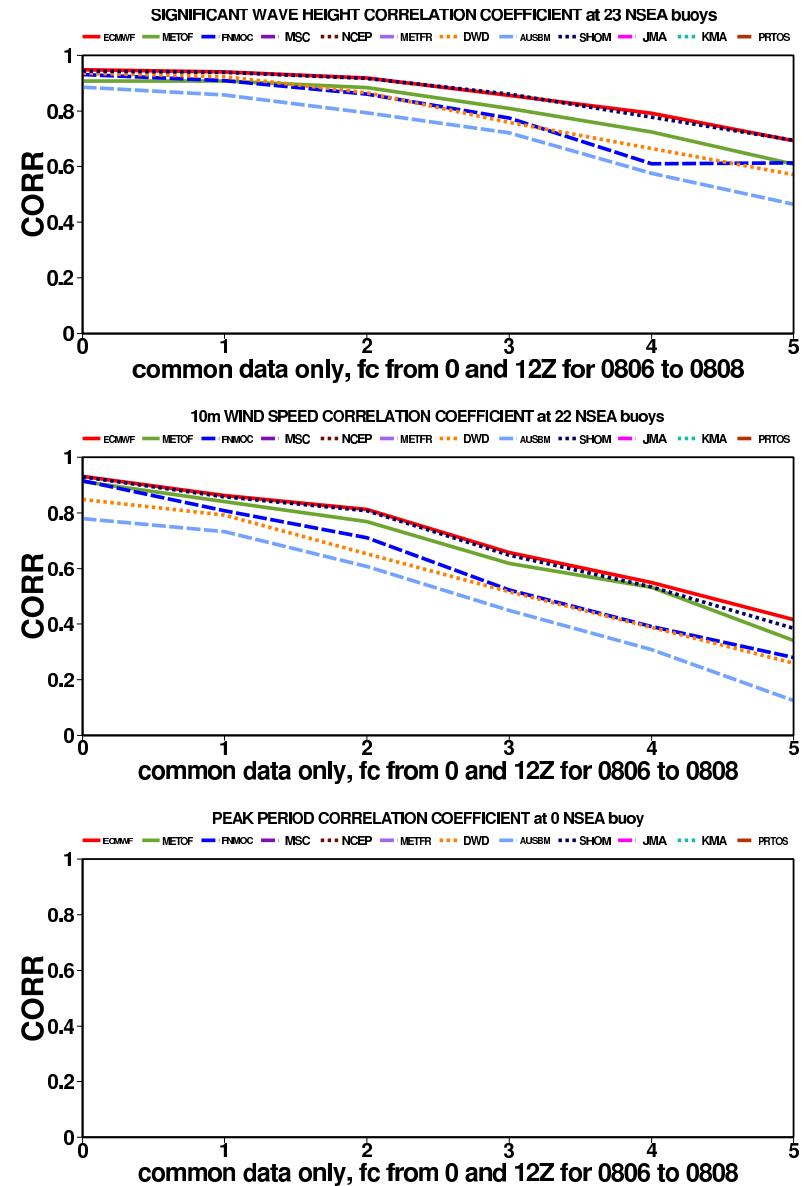


Figure 41: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North Sea platforms.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 42: Forecast root mean square error (RMSE) and linear correlation coefficient at common North Sea platforms.

0.3.11 Comparison for Icelandic buoys and Norwegian platforms

Number of common observations for Iceland and Norway (NRDIC) from 200806 to 200808 (wind, Hs,Tp)

1	LDWR	178	178	0	N Norwegian Sea (Mjøke)	8	TFBLK	0	156	0	West Iceland (Blaeksnes)
2	LF3F	158	96	0	N Norwegian Sea (Draugen)	9	TFGRS	0	151	0	North Iceland (Grimseyjarsund)
3	LF3N	179	169	0	N Norwegian Sea (Heldrun)	10	TFGSK	0	152	0	West Iceland (Gardskagi)
4	LF4B	176	93	0	S Norwegian Sea (Troll A)	11	TFKGR	0	114	0	East Iceland (Kogur)
5	LF4C	169	108	0	North Sea (Steipner)	12	TFSRRT	0	132	0	South Iceland (Sursey)
6	LF4H	182	182	0	S Norwegian Sea (Helmsdal)	13	TFSTD	0	165	0	North West Iceland (Straumnes)
7	LF5T	127	55	0	N Norwegian Sea (Norne)						

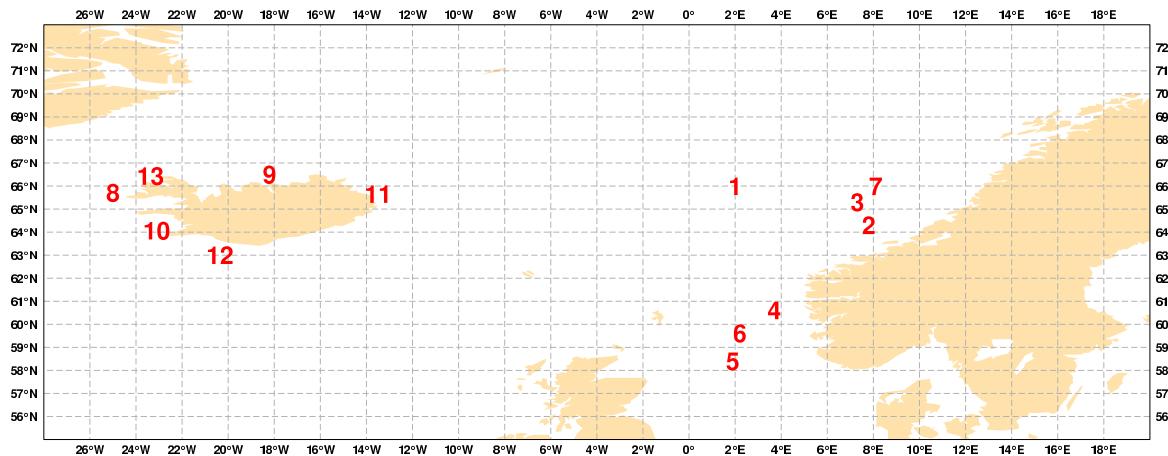


Figure 43: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

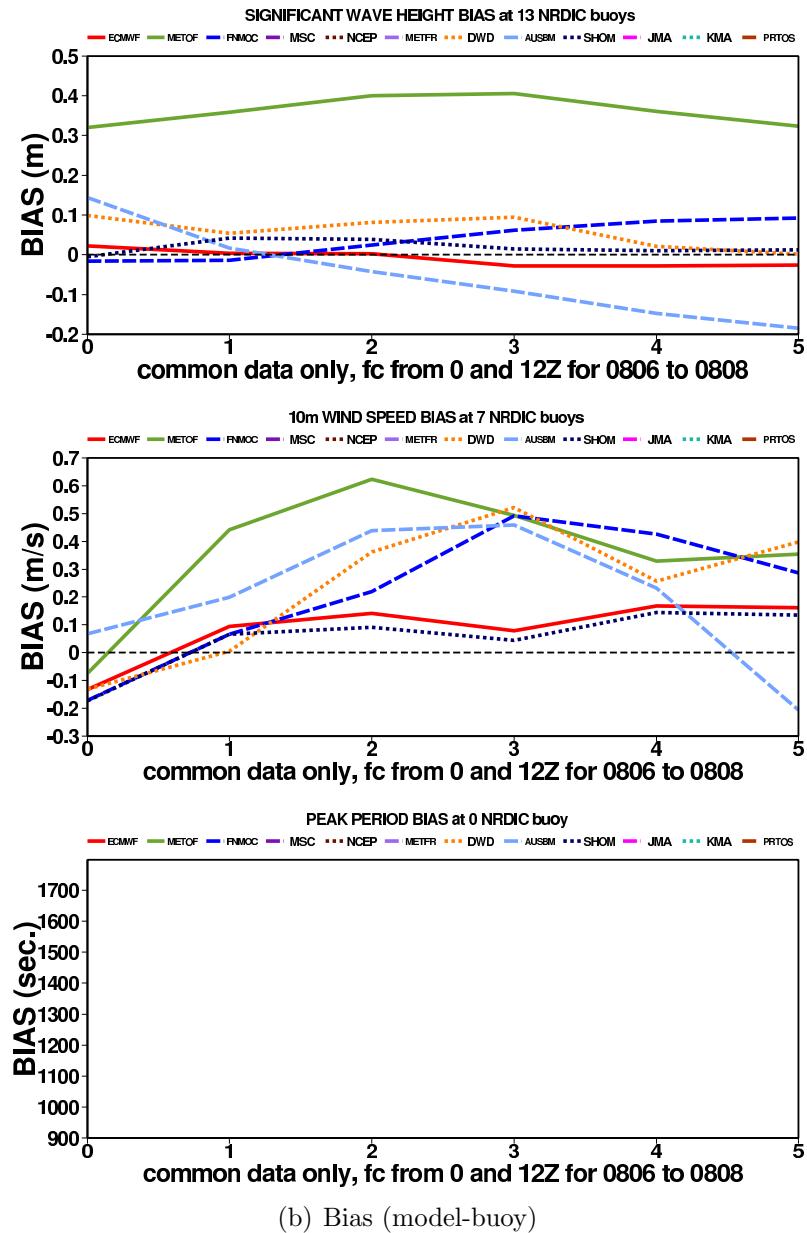
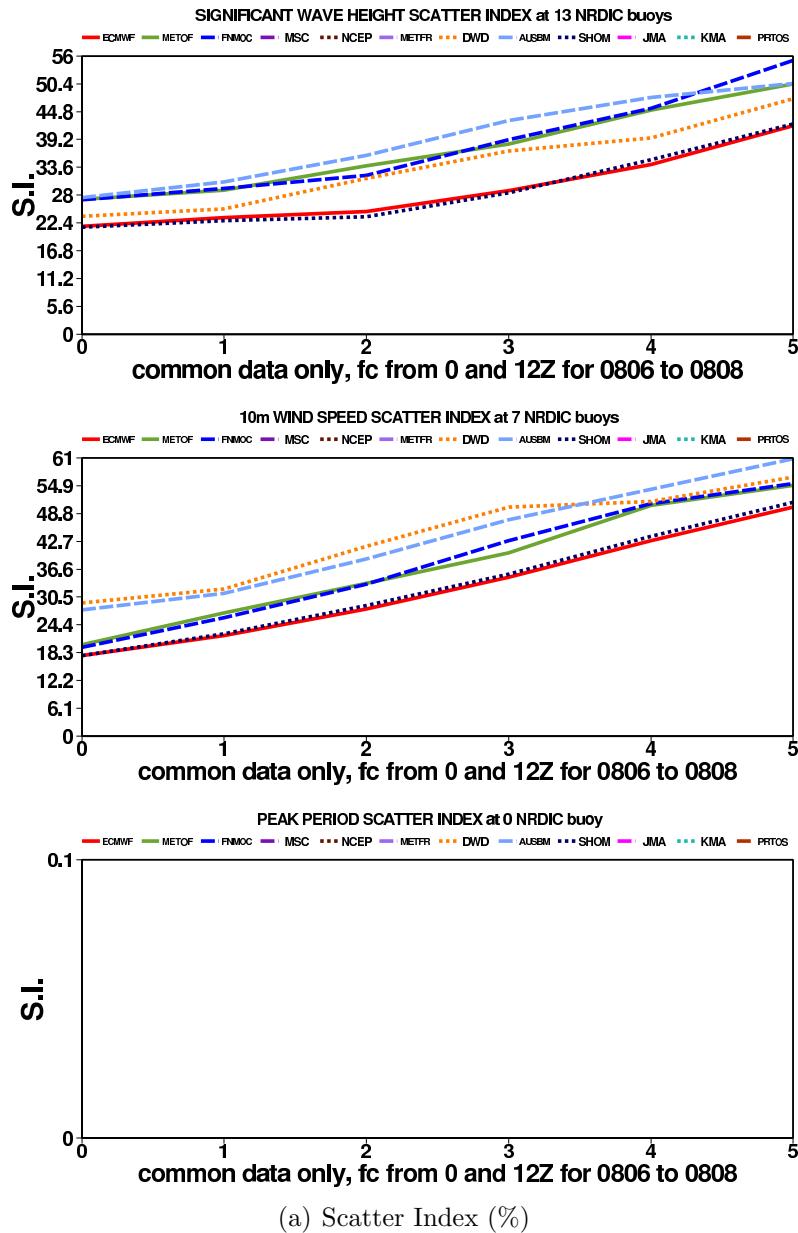
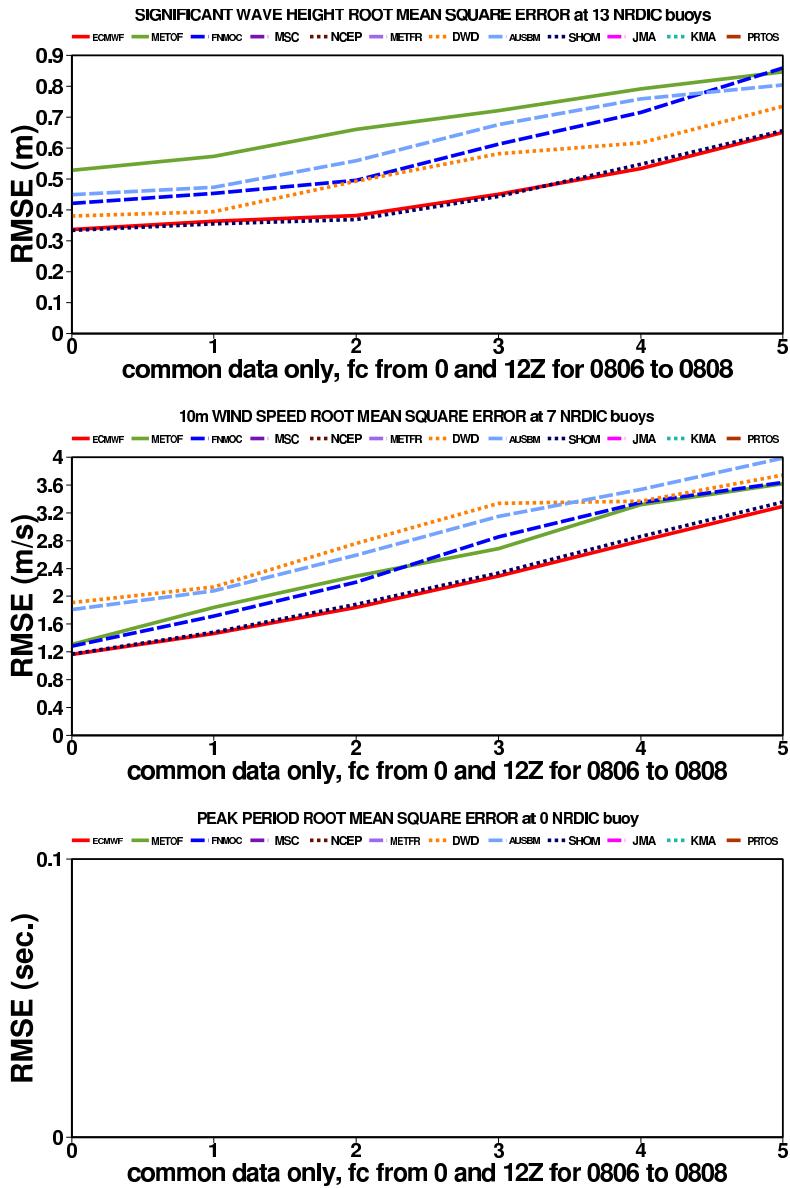
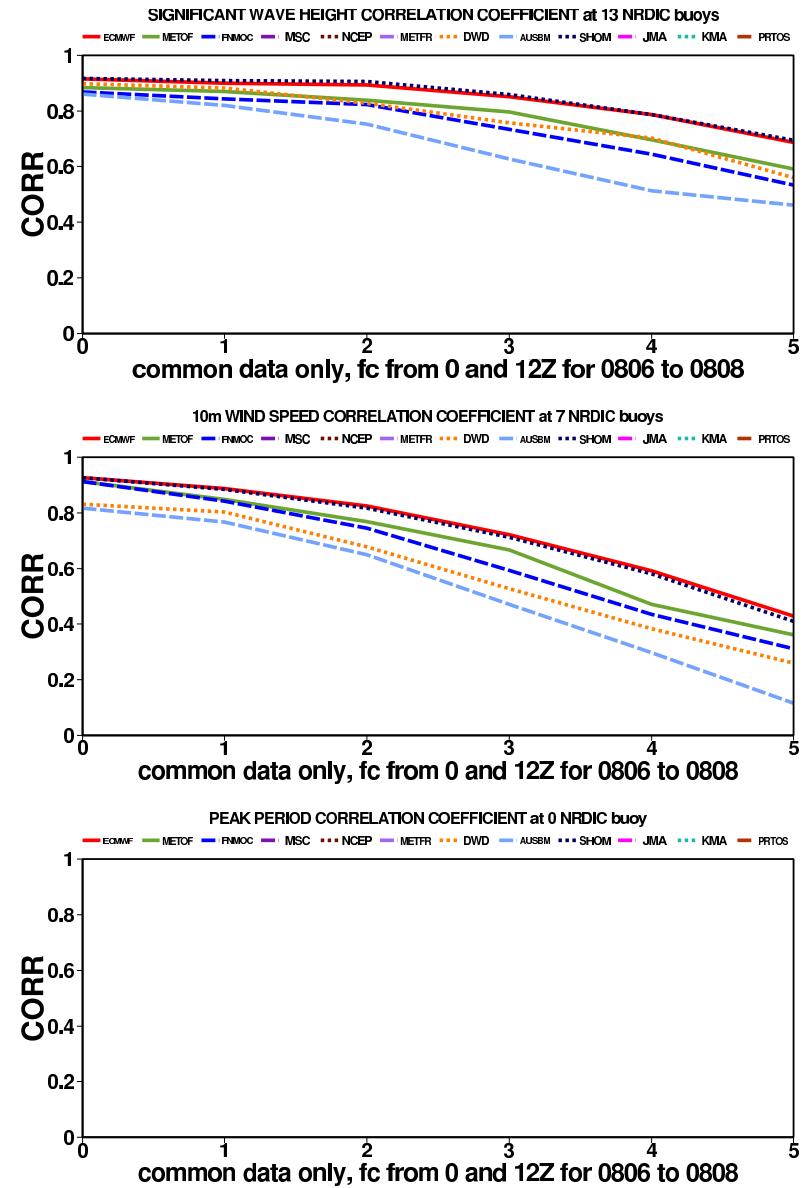


Figure 44: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Icelandic buoys and Norwegian platforms .



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 45: Forecast root mean square error (RMSE) and linear correlation coefficient at common Icelandic buoys and Norwegian platforms .

0.3.12 Comparison for South African platform

Number of common observations for South Africa (SA) from 200806 to 200808 (wind, Hs,Tp)

1	ZSWAV	0	178	0	SA Agulhas Bank
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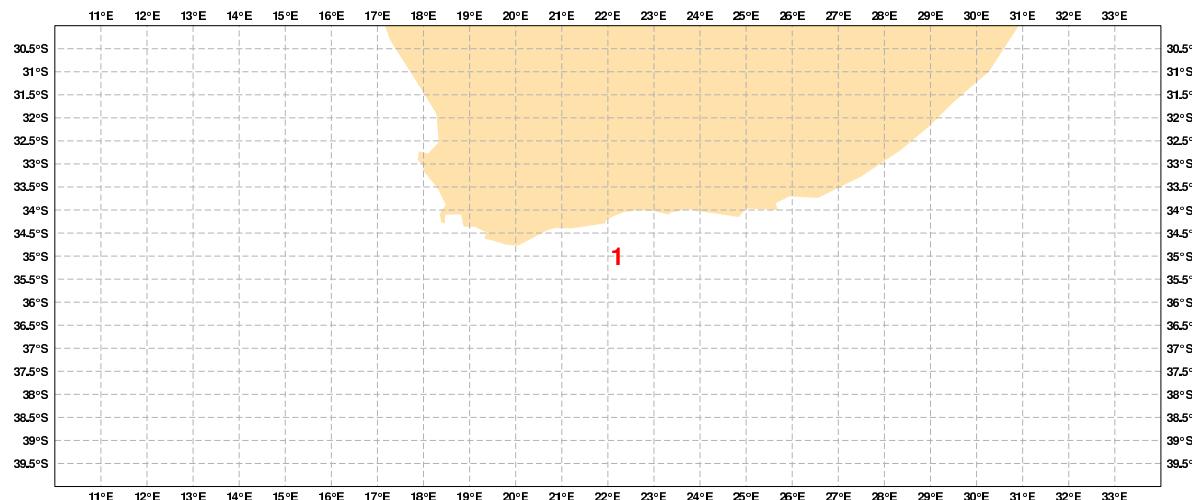
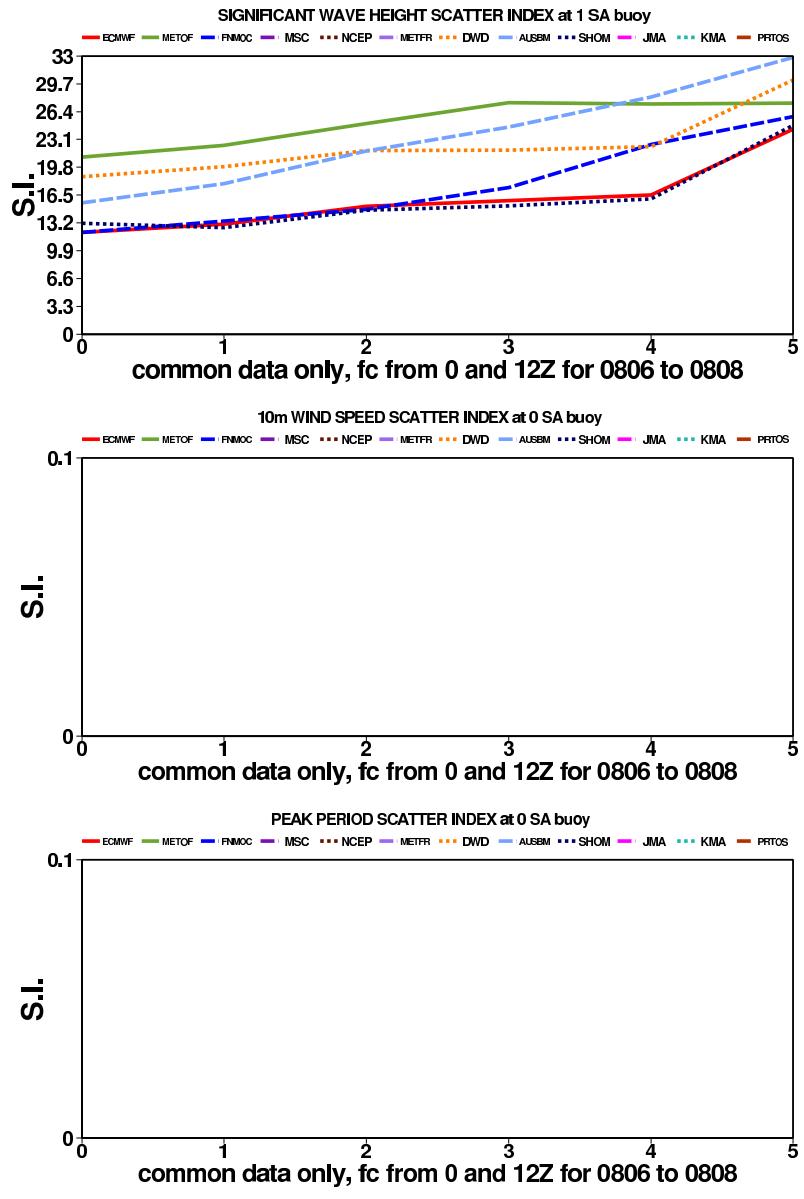
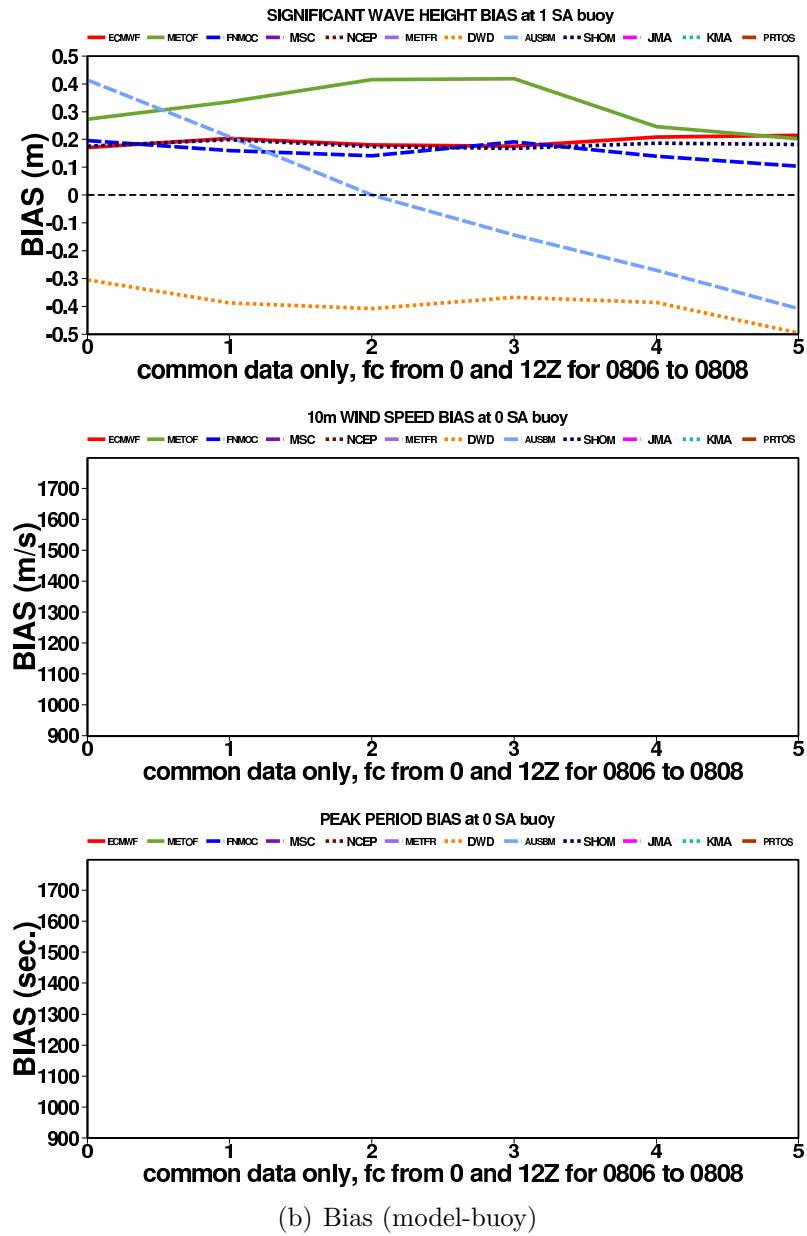


Figure 46: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

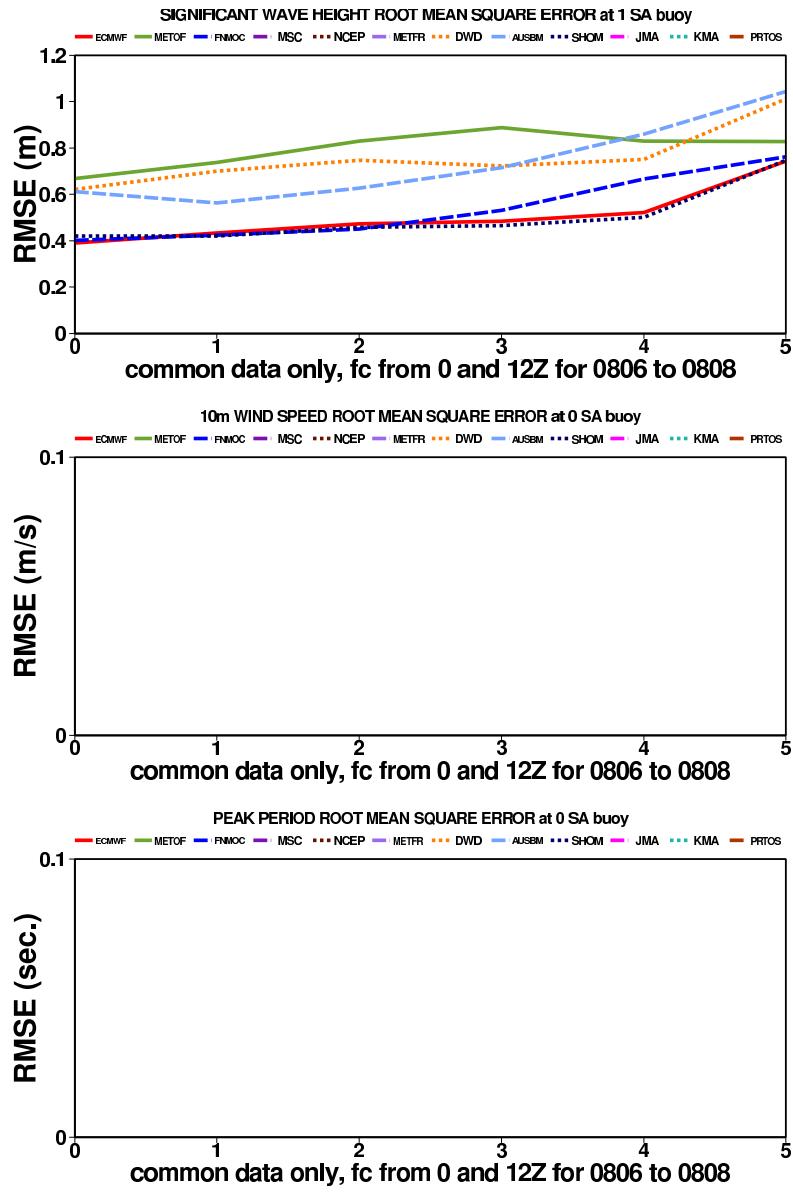


(a) Scatter Index (%)

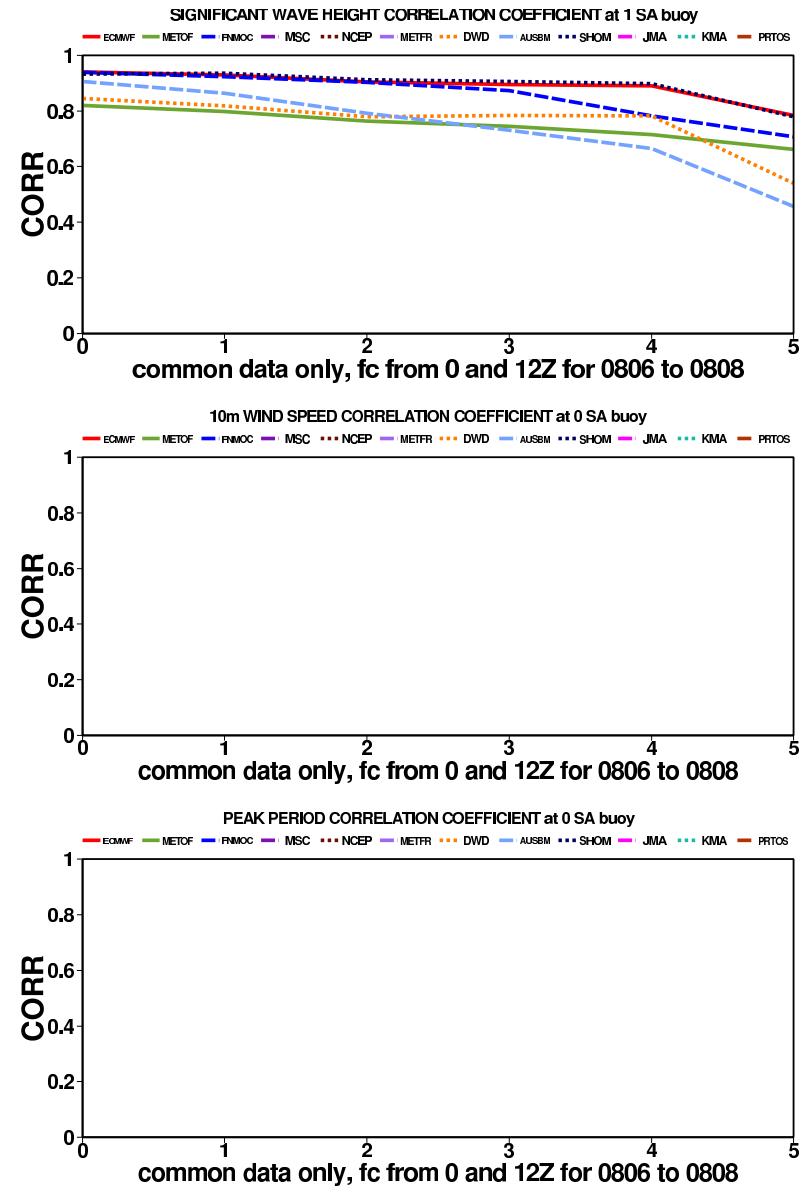


(b) Bias (model-buoy)

Figure 47: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common South African platform.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 48: Forecast root mean square error (RMSE) and linear correlation coefficient at common South African platform.

0.3.13 Comparison for Indian buoys

Number of common observations for India (INDIA) from 200806 to 200808 (wind, Hs,Tp)

1	23092	73	74	0	Arabian Sea	4	23101	22	17	0	Bay of Bengal
2	23097	4	4	0	Arabian Sea	5	23170	26	0	0	Arabian Sea
3	23098	13	0	0	Arabian Sea						

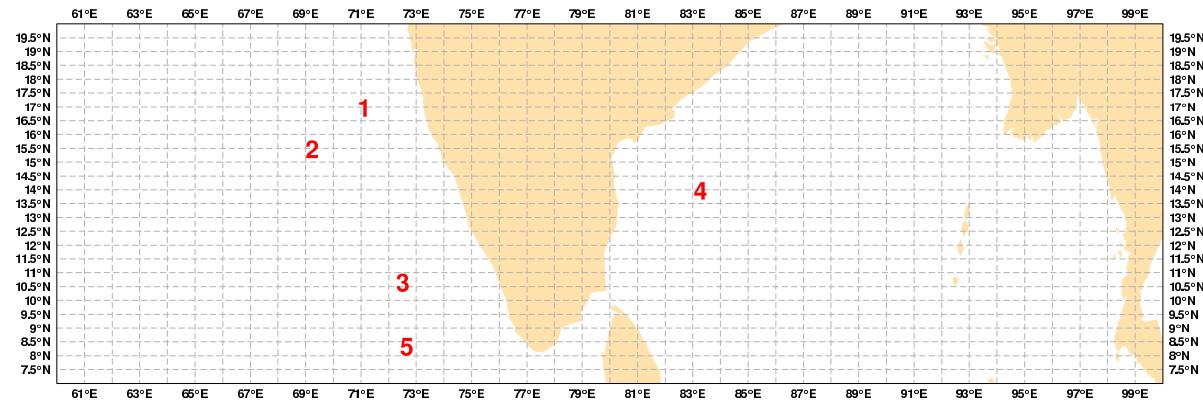
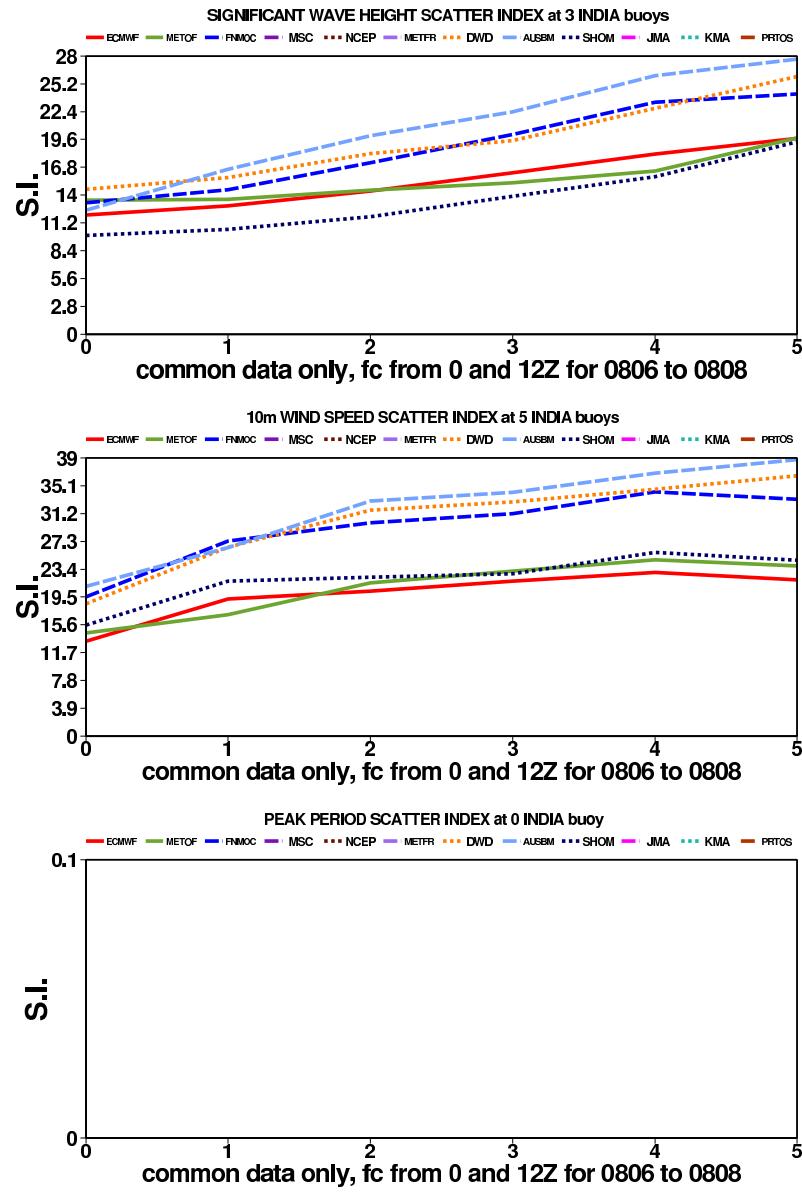
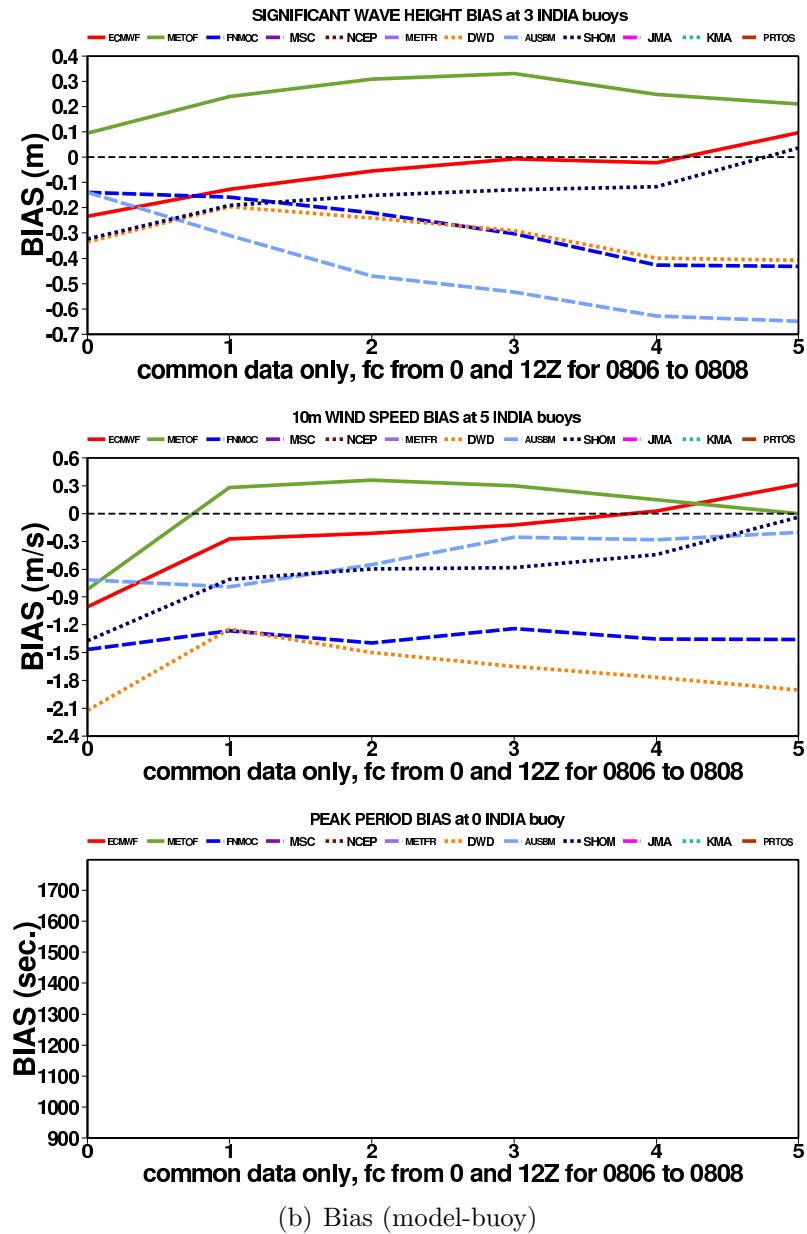


Figure 49: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

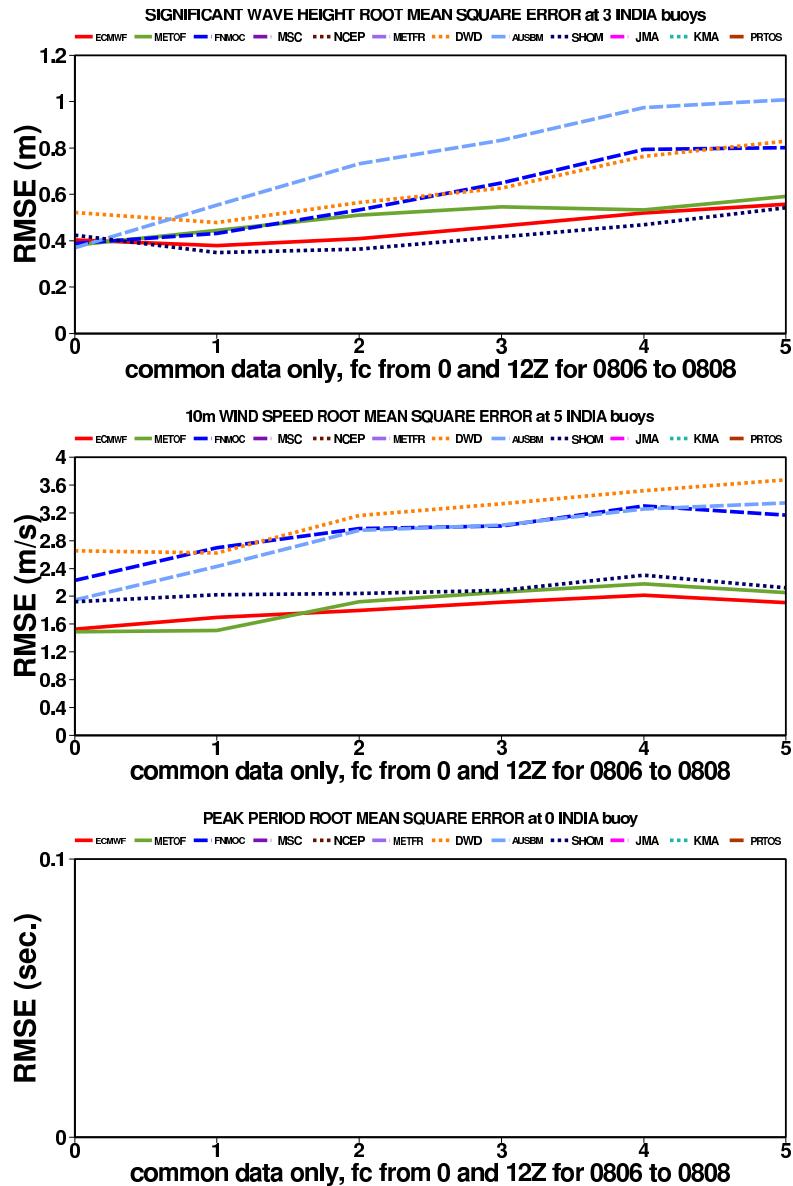


(a) Scatter Index (%)

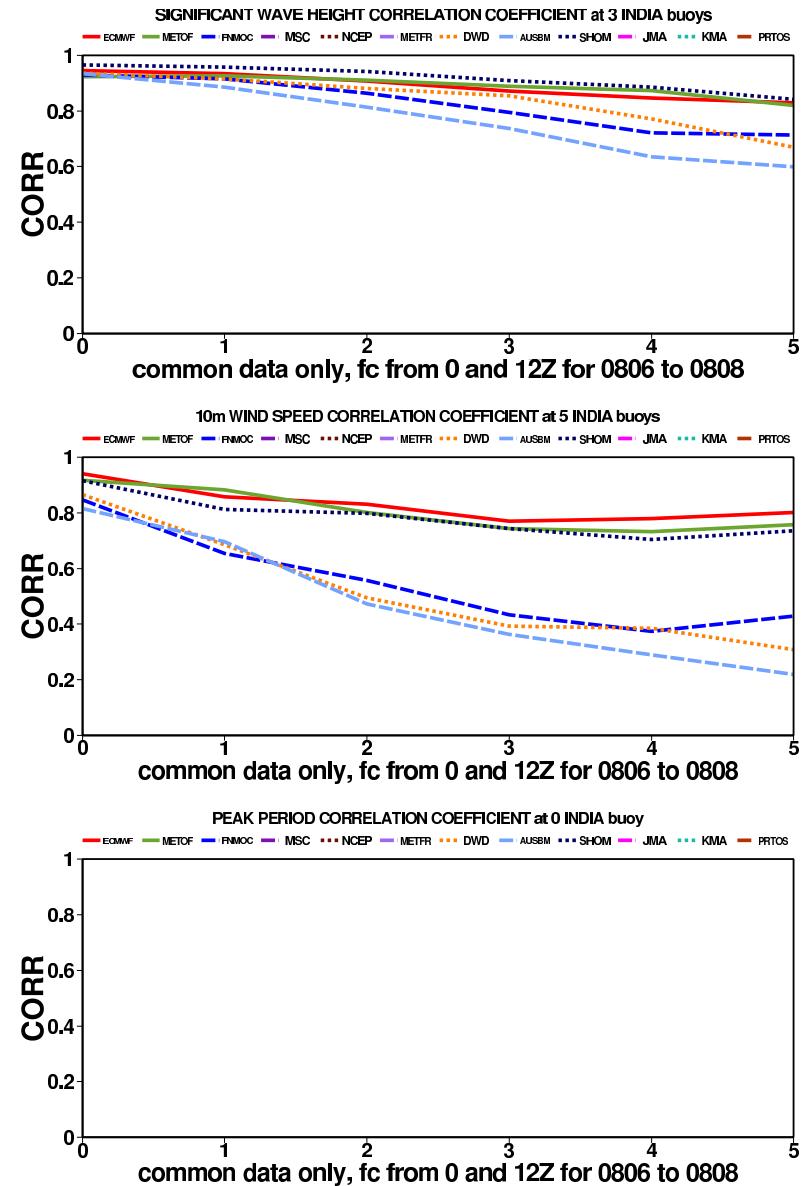


(b) Bias (model-buoy)

Figure 50: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Indian buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 51: Forecast root mean square error (RMSE) and linear correlation coefficient at common Indian buoys.

0.3.14 Comparison for Australian South East Coast buoys

Number of common observations for Australian South East Coast (ASEC) from 200806 to 200808 (wind, Hs,Tp)

1	55014	0	150	150	Bateman's Bay	4	55022	0	120	120	Port Kembla
2	55018	0	172	172	Coffs Harbour	5	55024	0	178	178	Sydney
3	55019	0	170	170	Crowdy Head	6	55039	0	182	179	Kingfish B

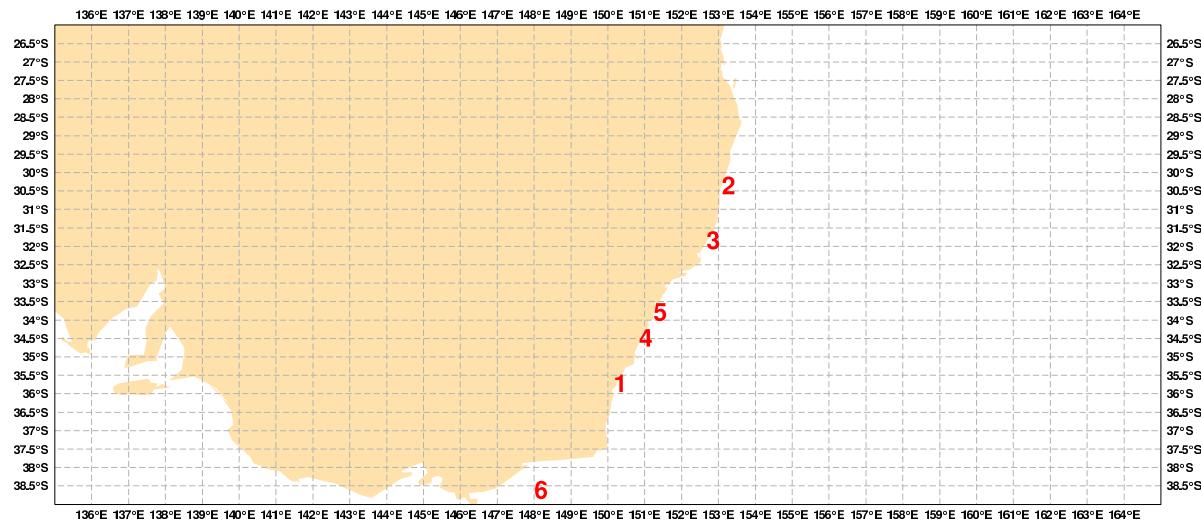
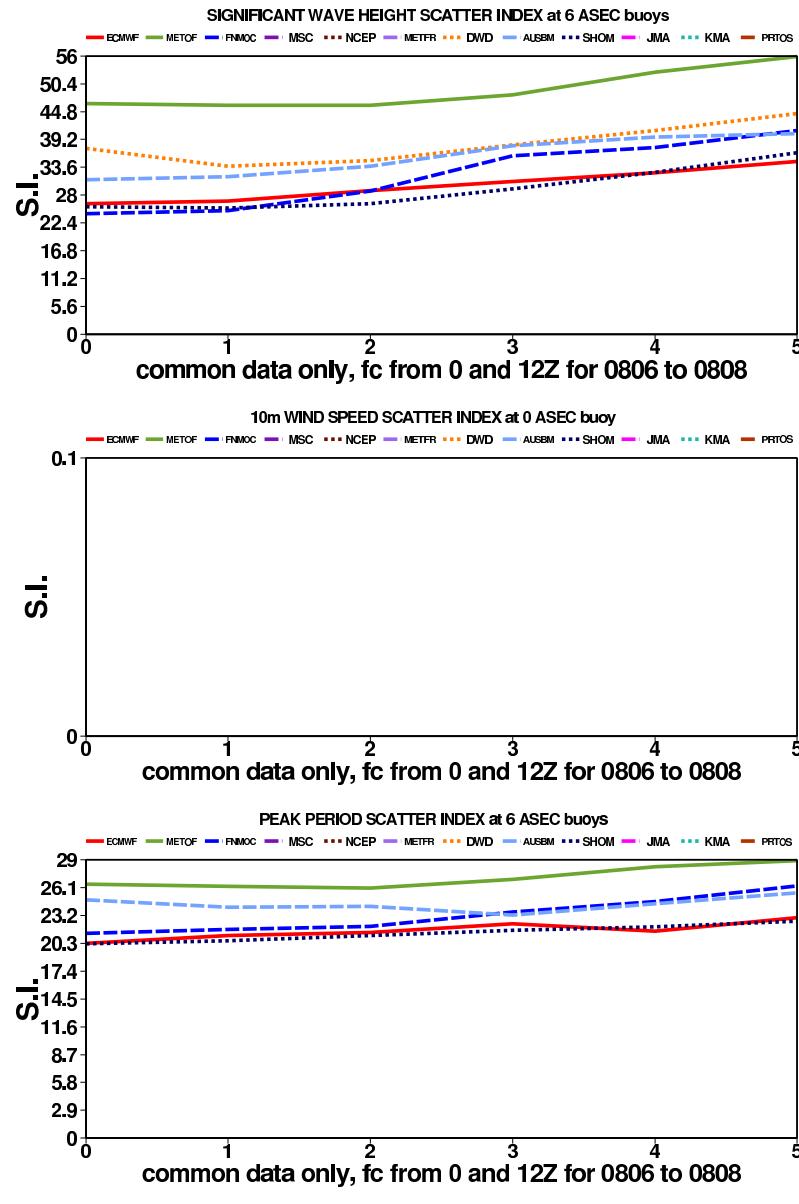
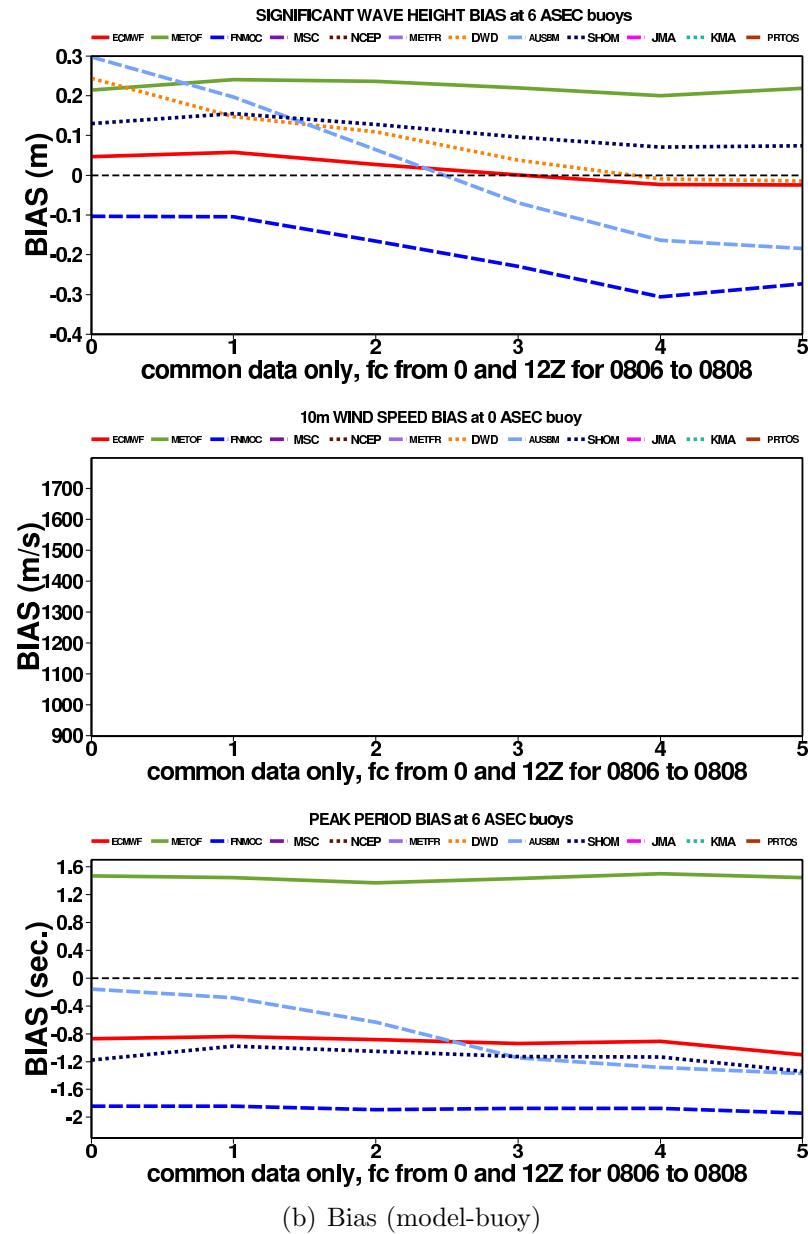


Figure 52: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

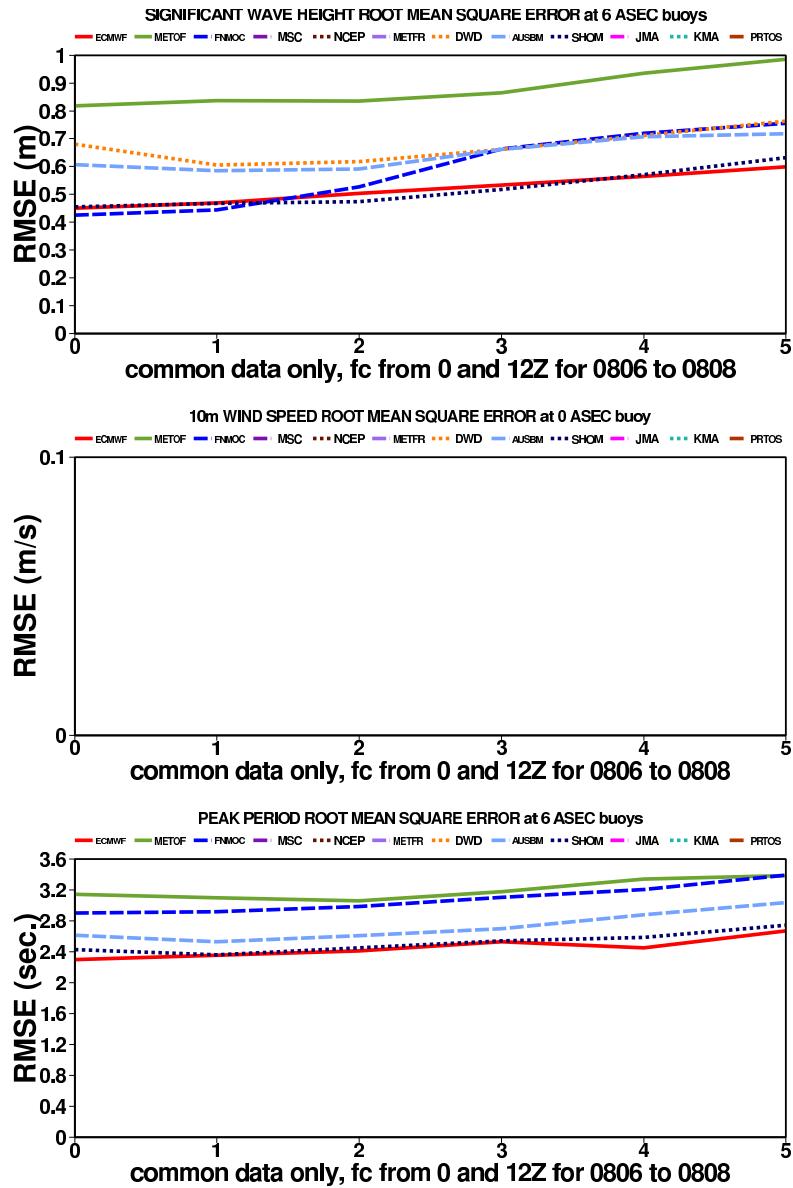


(a) Scatter Index (%)

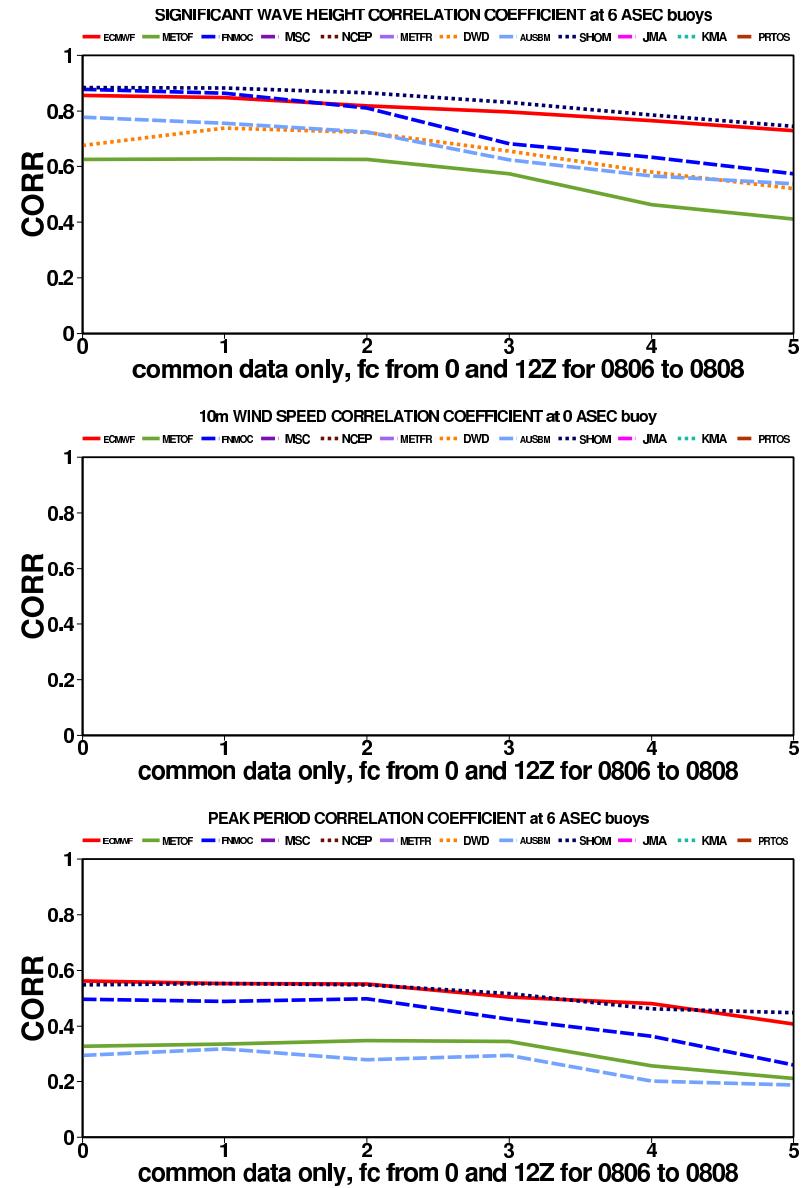


(b) Bias (model-buoy)

Figure 53: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Australian South East Coast buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 54: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South East Coast buoys.

0.3.15 Comparison for Australian Great Barrier Reef buoys

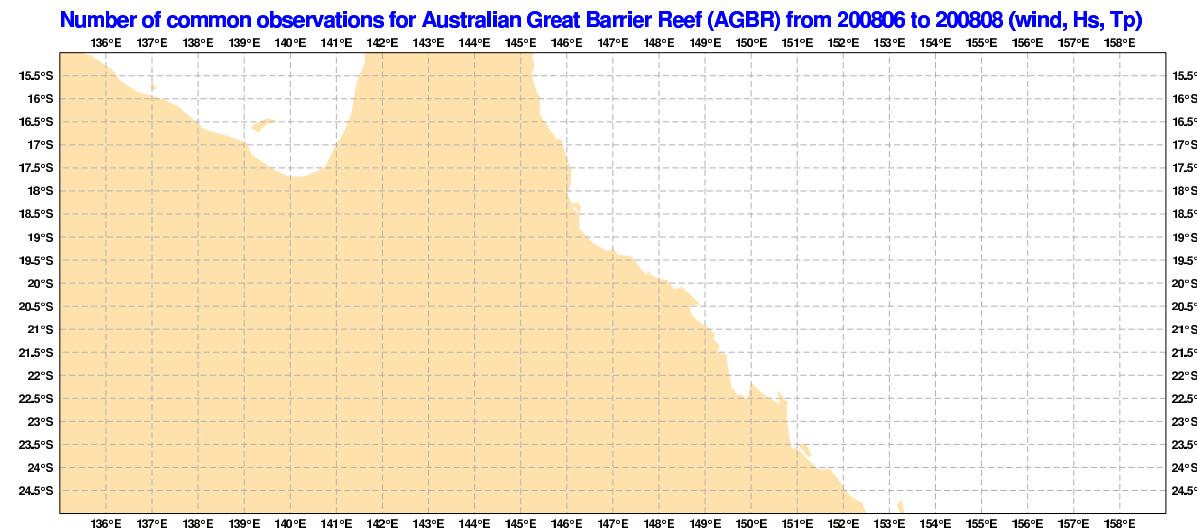


Figure 55: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

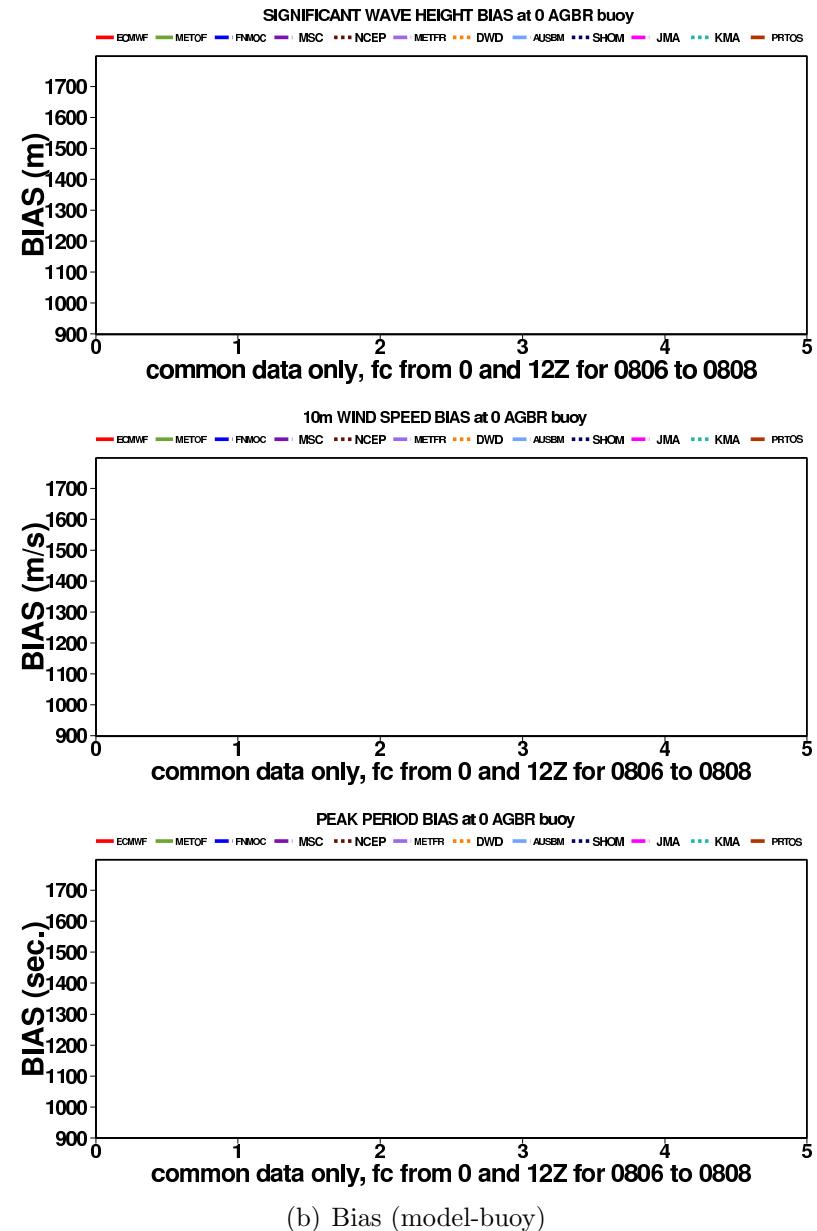
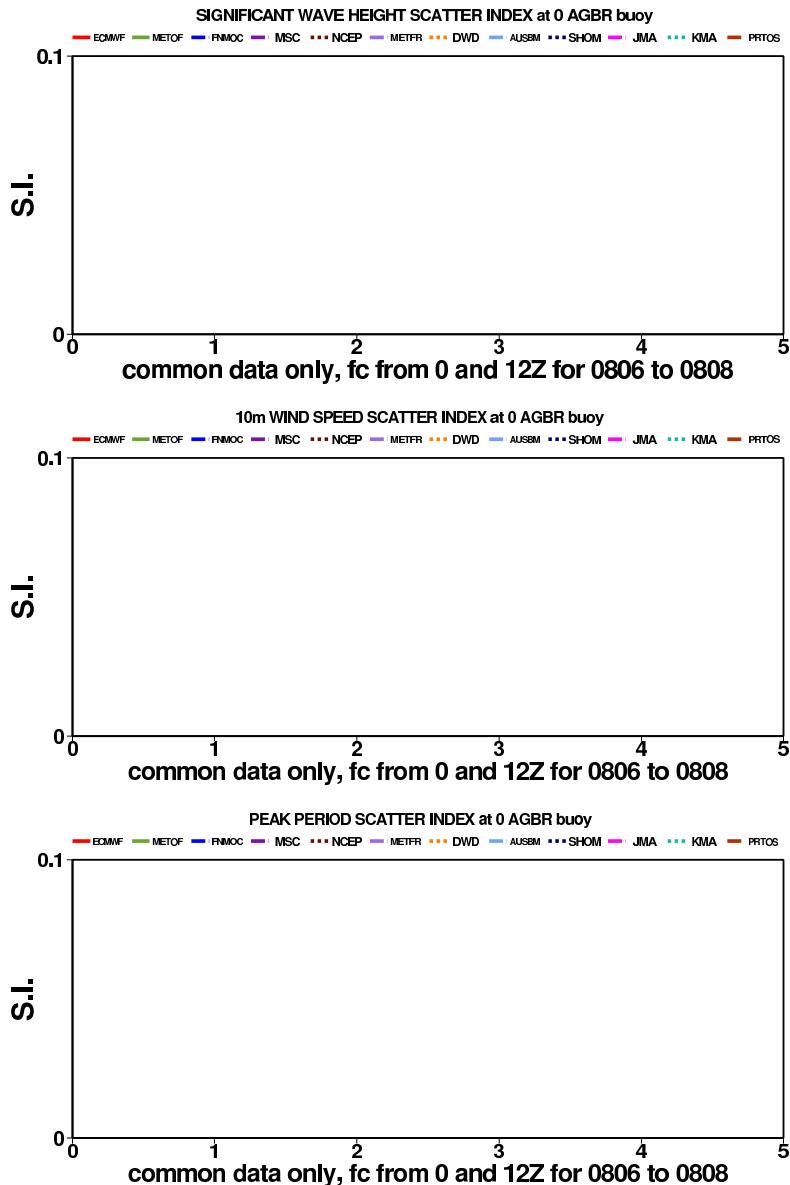


Figure 56: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Australian Great Barrier Reef buoys.

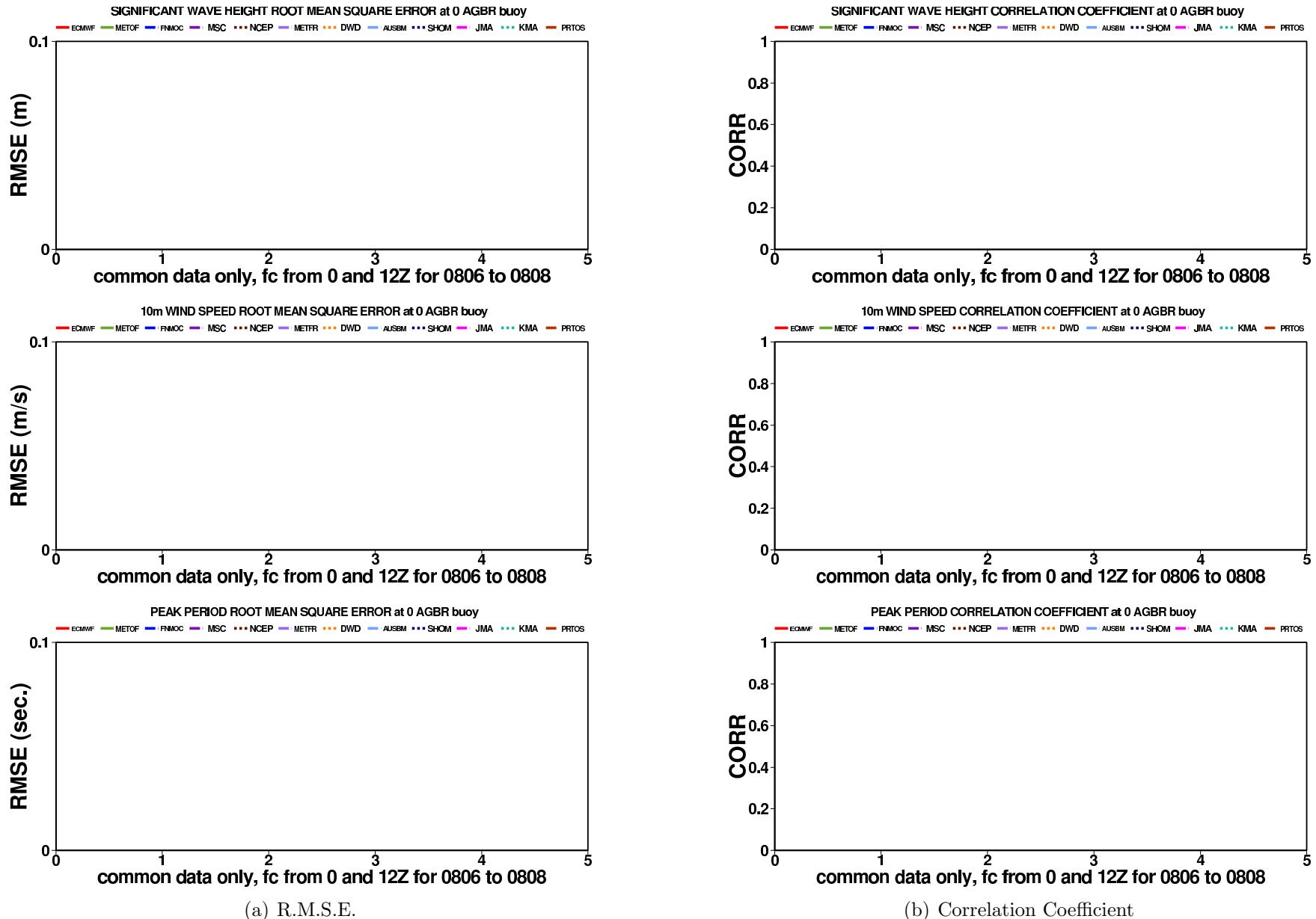


Figure 57: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian Great Barrier Reef buoys.

0.3.16 Comparison for Australian South West facing Coast buoys

Number of common observations for Australian South West facing Coast (ASWC) from 200806 to 200808 (wind, Hs, Tp)

1	55026	0	182	182	Strahan	3	56004	0	177	177	Jurien
2	55040	0	182	182	Cape Du Couedic	4	56005	0	175	175	Rottnest Island

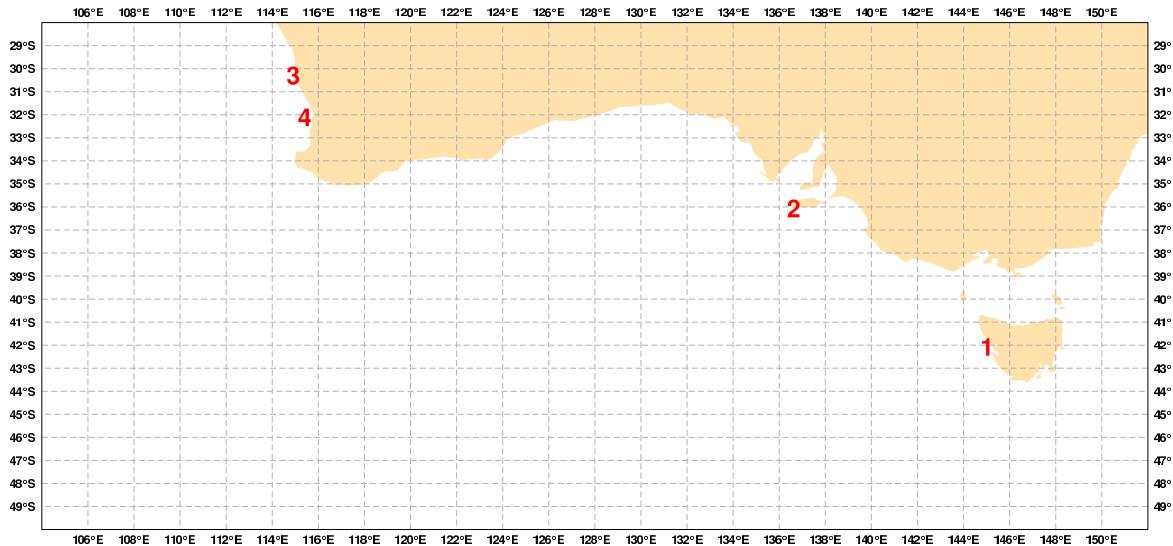
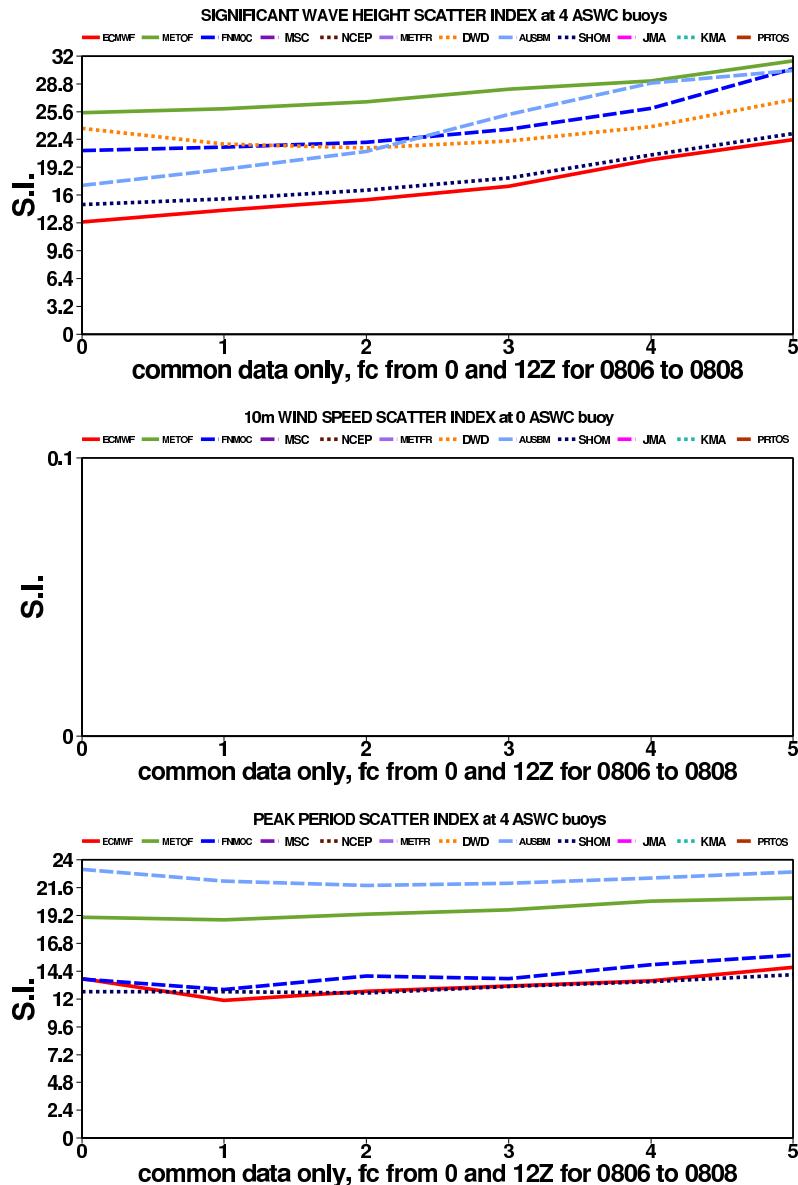
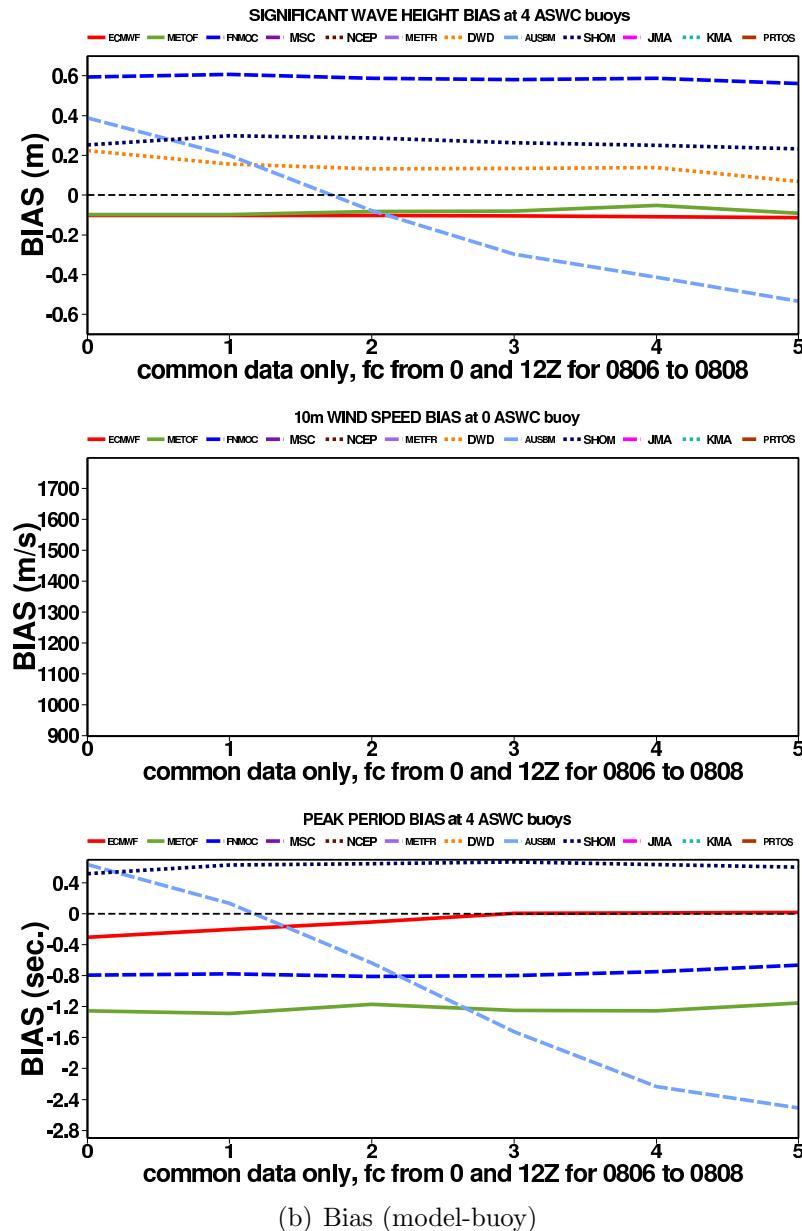


Figure 58: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

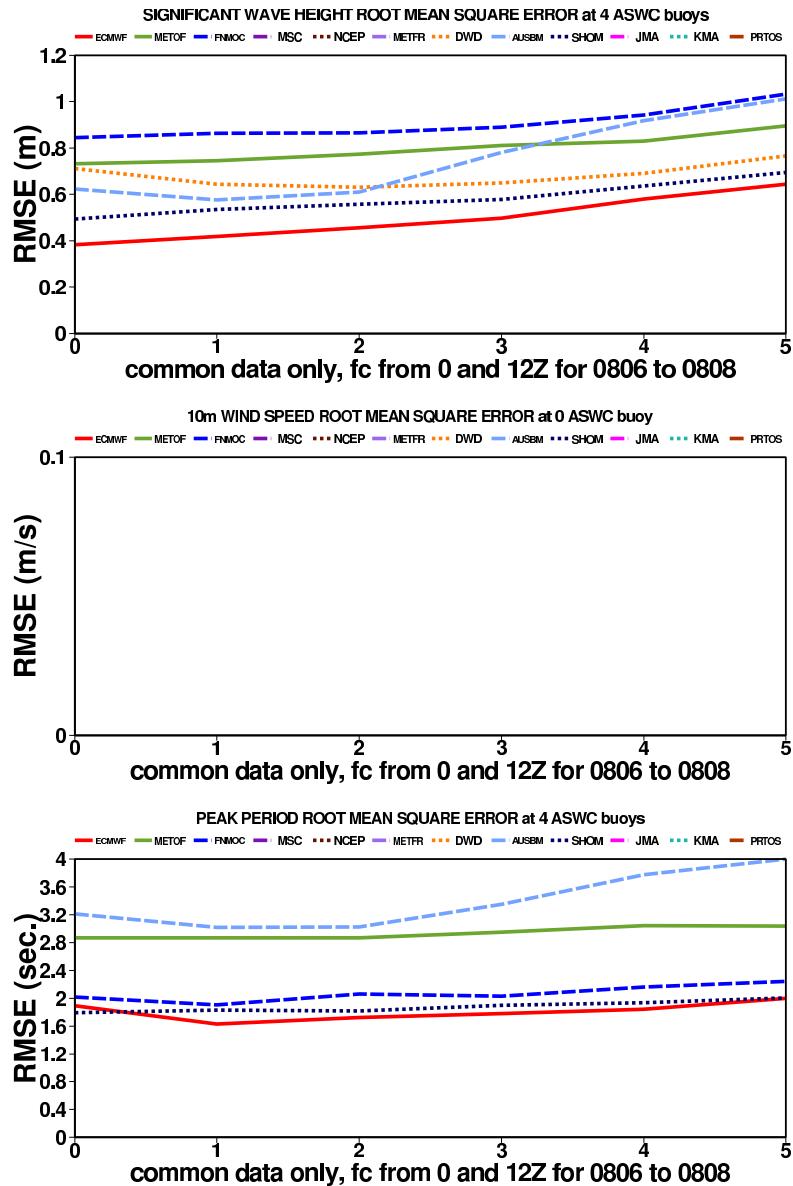


(a) Scatter Index (%)

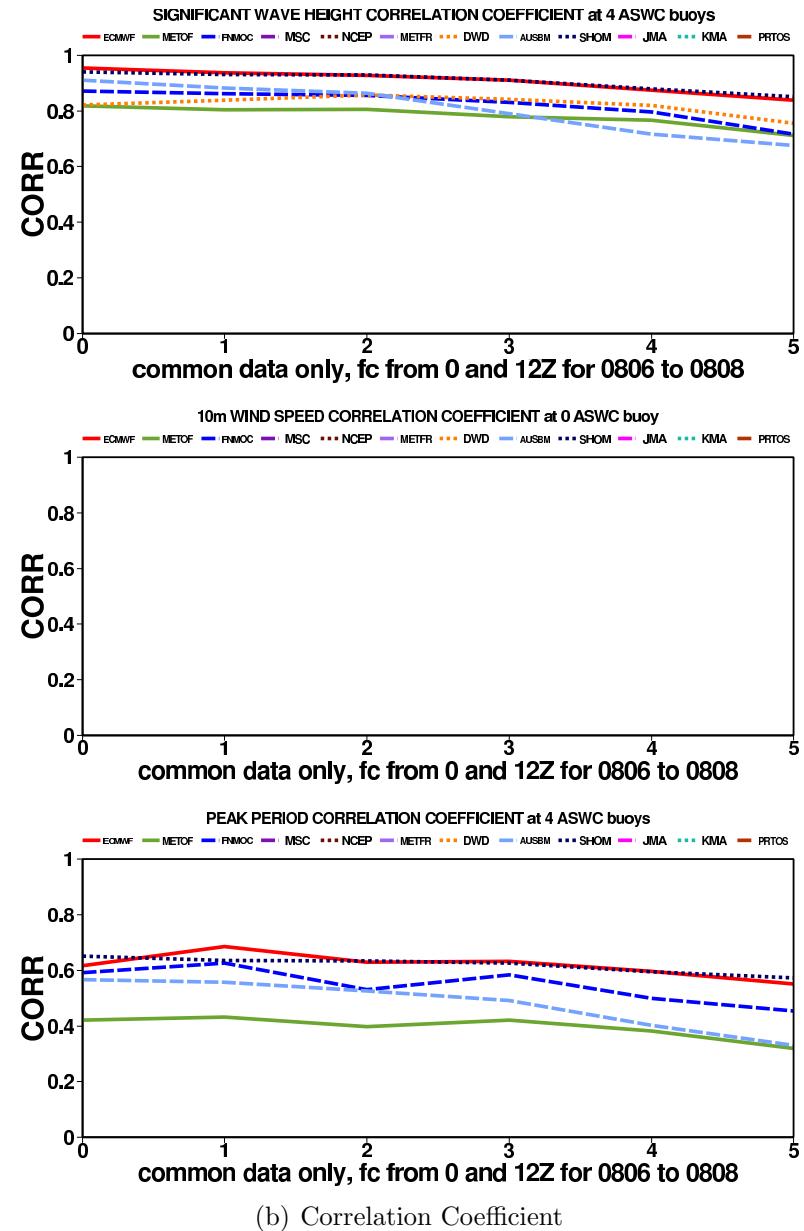


(b) Bias (model-buoy)

Figure 59: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Australian South West facing Coast buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 60: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South West facing Coast buoys.

0.3.17 Comparison for Australian North West Coast buoys

Number of common observations for Australian North West Coast (ANWC) from 200806 to 200808 (wind, Hs,Tp)

1	56002	35	35	0	North Rankin
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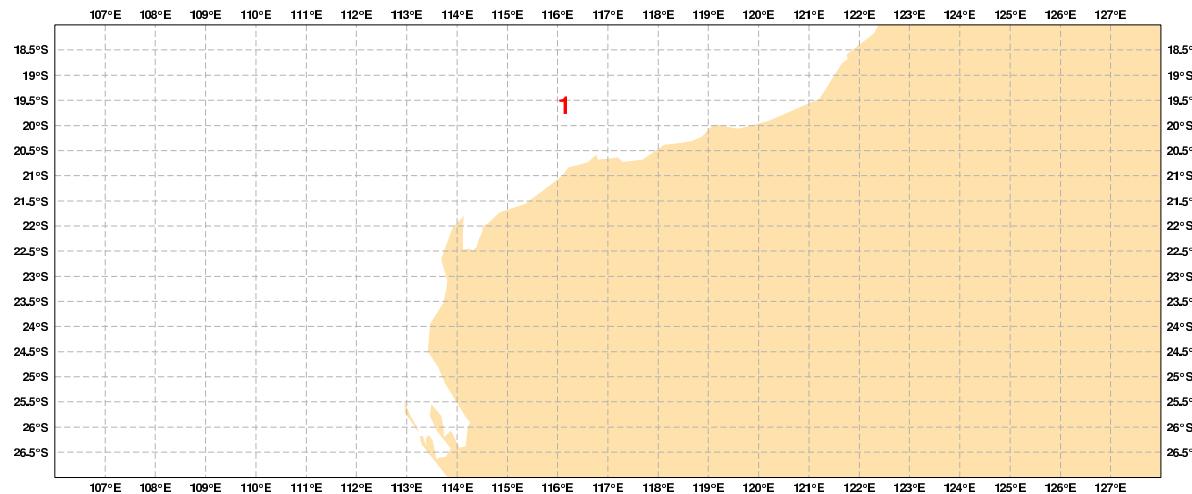
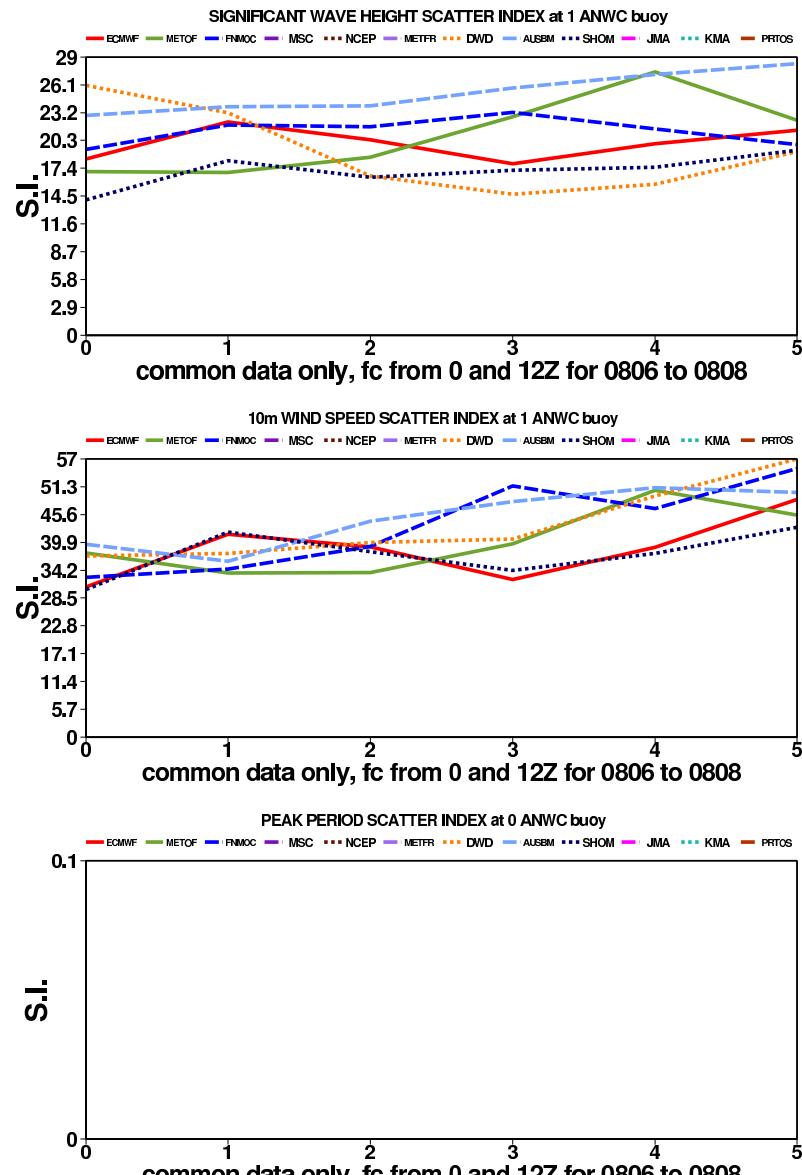
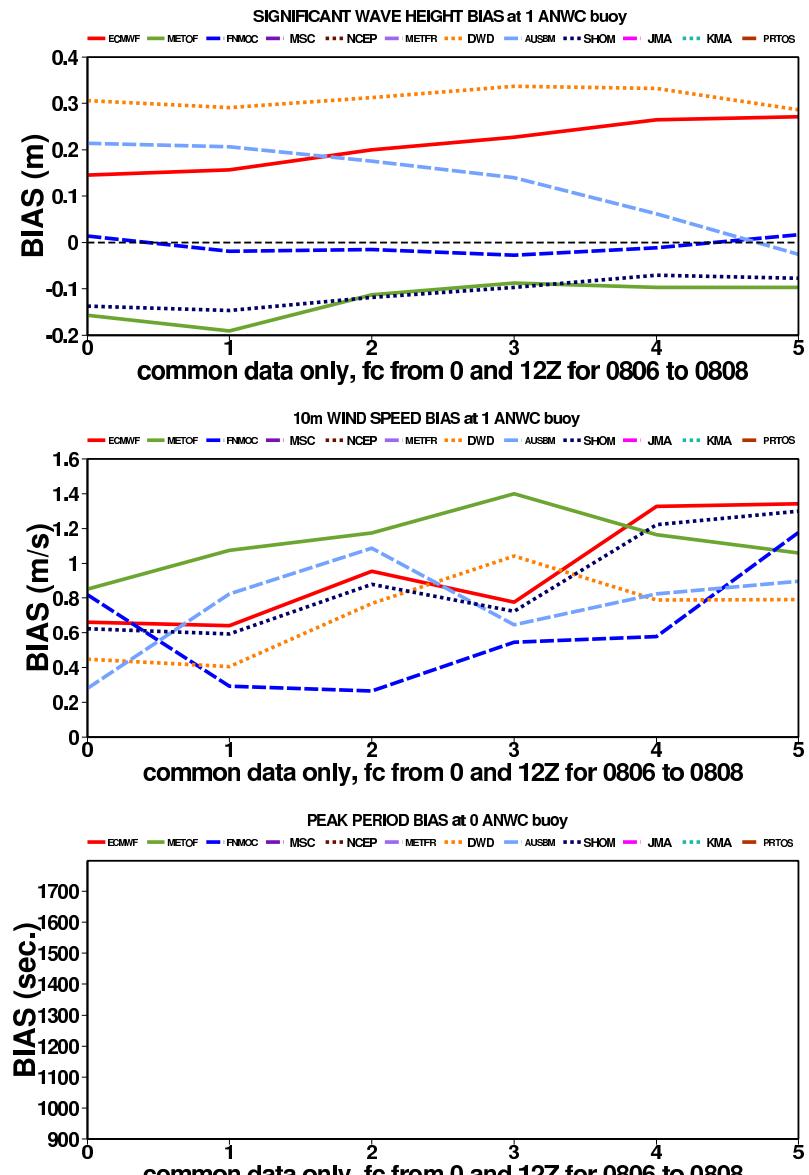


Figure 61: Buoy locations. The numbers in the table following each buoy identifier are the number of collocations between models and buoy wind speed, wave height and peak period.

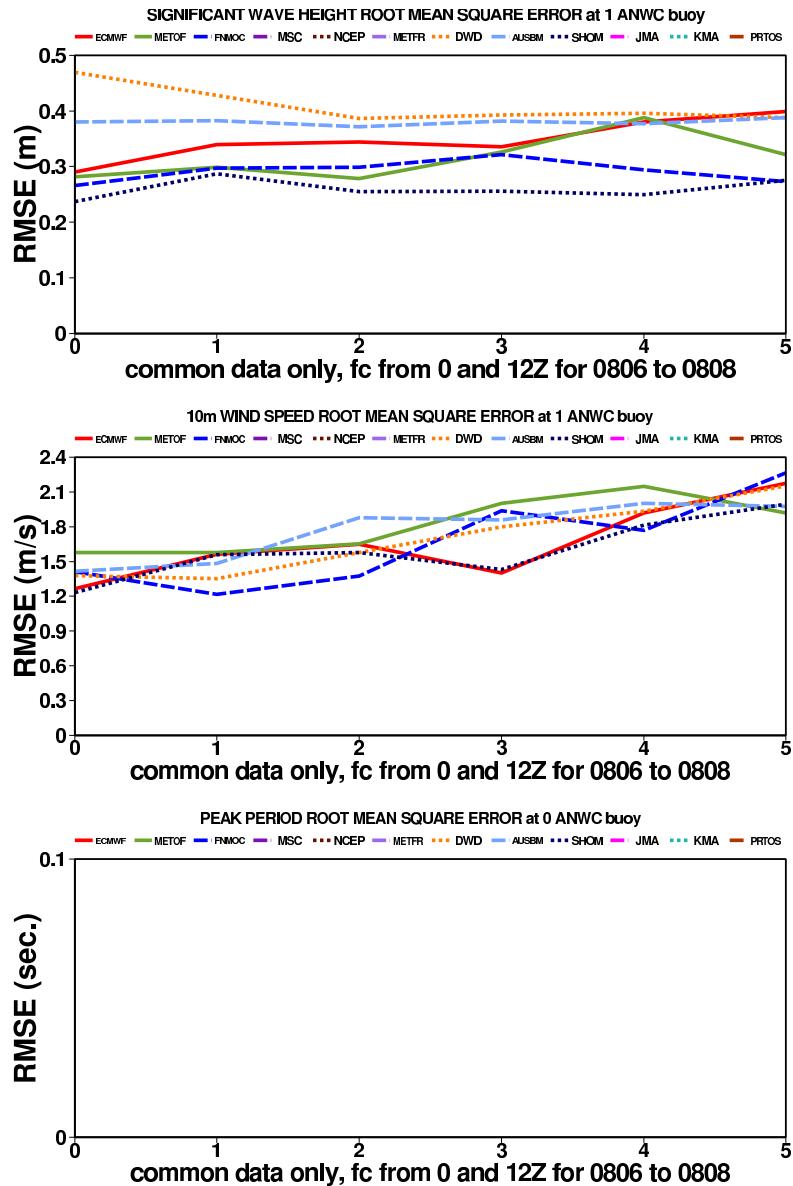


(a) Scatter Index (%)

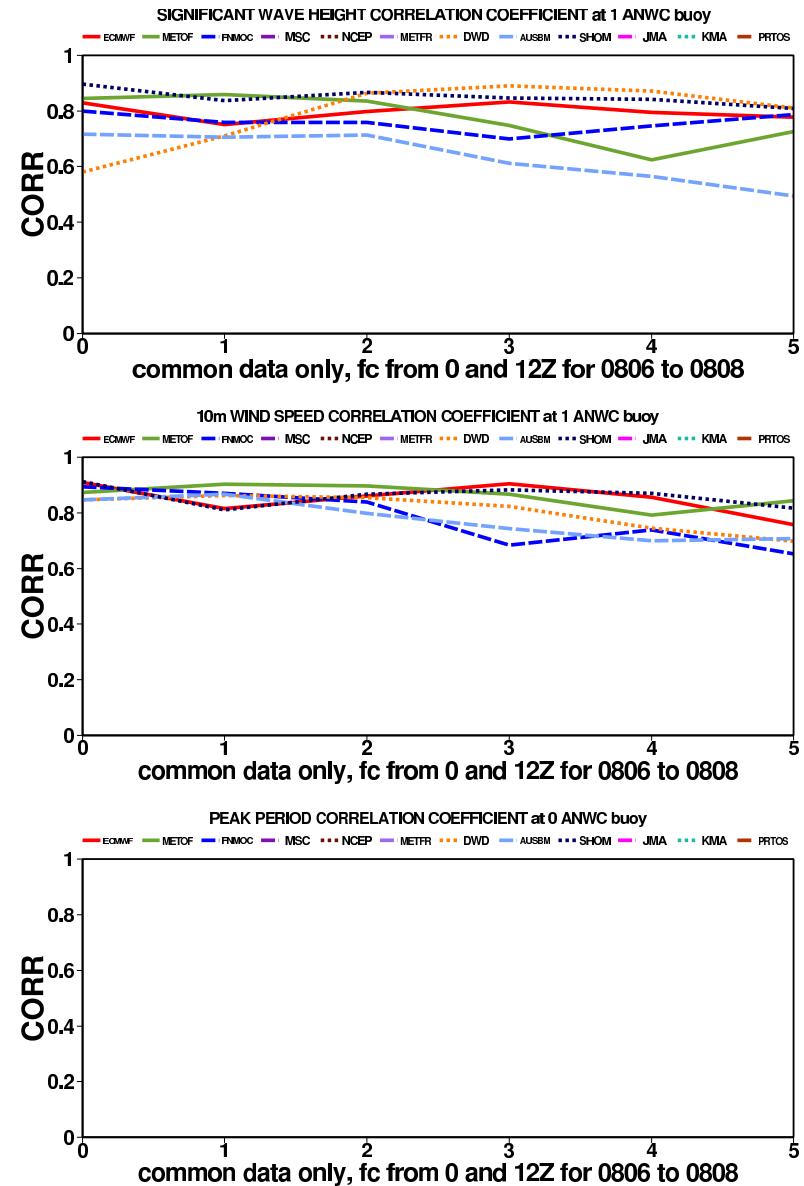


(b) Bias (model-buoy)

Figure 62: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Australian North West Coast buoys.



(a) R.M.S.E.



(b) Correlation Coefficient

Figure 63: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian North West Coast buoys.