Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI August 2010 to October 2010

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Chapter 1

Forewords

Outputs from different fully 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 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.
Chapter 2

Data

Before using observations for verification, care has to be taken to process the data to remove any erroneous observations. Moreover, extra care has to be taken 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, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI are used whenever available. Some sub-areas might only have some of the participants and when all locations are considered, the limited models are left out. The other participants are left blank in the plots below.
References


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Chapter 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, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI are used.

This report was generated automatically, which explains its very generic appearance.
3.1 Comparison for all buoys

Figure 3.1: Buoy locations
Figure 3.2: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common all buoys.
Figure 3.3: Forecast root mean square error (RMSE) and linear correlation coefficient at common all buoys.
Comparison of analysed ECMWF wave height with averaged buoy data. fc from 0 and 12Z.

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

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

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

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

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

Figure 3.4: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Comparison of analysed MSC wave height with averaged buoy data. f.c from 0 and 12Z.

Comparison of forecast(t=48) MSC wave height with averaged buoy data. f.c from 0 and 12Z.

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

Comparison of forecast(t=48) NCEP wave height with averaged buoy data. f.c from 0 and 12Z.

Comparison of analysed MeteoFrance wave height with averaged buoy data. f.c from 0 and 12Z.

Comparison of forecast(t=48) MeteoFrance wave height with averaged buoy data. f.c from 0 and 12Z.

(a) t+0

(b) t+48

Figure 3.5: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Comparison of analysed DWD wave height with averaged buoy data. fc from 0 and 12Z.

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

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

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

(a) t+0

(b) t+48

Figure 3.6: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Comparison of analysed JMA wave height with averaged buoy data. fc from 0 and 12Z.

Comparison of forecast(t=0) JMA wave height with averaged buoy data. fc from 0 and 12Z.

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

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

Comparison of forecast(t=0) KMA wave height with averaged buoy data. fc from 0 and 12Z.

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

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

Comparison of forecast(t=0) PRTOs wave height with averaged buoy data. fc from 0 and 12Z.

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

Figure 3.7: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Comparison of forecast(t=t+48) ECMWF wind speed with height corrected averaged buoy data. fc from 0 and 12Z.

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

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

Figure 3.8: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.
Comparison of forecast (t=t+48) METFR wind speed with height corrected averaged buoy data. fc from 0 and 12Z.

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

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

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

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

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

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

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

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

Figure 3.10: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.
Figure 3.11: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.
Figure 3.12: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.
Comparison of forecast(t=t+48) METFR peak period with averaged buoy data. fc from 0 and 12Z.

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

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

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

Figure 3.13: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.
Comparison of analysed BoM peak period with averaged buoy data. fc from 0 and 12Z.

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

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

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

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

Figure 3.14: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.
Comparison of forecast ($t=48$) PRTOS peak period with averaged buoy data. fc from 0 and 12Z.

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

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

Figure 3.15: Scatter diagrams for peak period at step 0 and 48 for the displayed centres at all buoys.
3.2 Comparison for Hawaiian buoys

Figure 3.16: 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.
Figure 3.17: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Hawaiian buoys.
Figure 3.18: Forecast root mean square error (RMSE) and linear correlation coefficient at common Hawaiian buoys.
3.3 Comparison for North East Pacific buoys

Figure 3.19: 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 3.20: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North East Pacific buoys.
Figure 3.21: Forecast root mean square error (RMSE) and linear correlation coefficient at common North East Pacific buoys.
### 3.4 Comparison for North West Atlantic buoys

#### Number of common observations for North West Atlantic buoys (NWATL) from 201008 to 201010 (wind, Hs, Tp)

<table>
<thead>
<tr>
<th>Number</th>
<th>Buoy Identifier</th>
<th>Coordinates</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41001</td>
<td>170 170 US East Coast, E Hatteras</td>
<td>0 170 170 US North East Coast, Jeffrey's Ledge, M(scripps 160)</td>
</tr>
<tr>
<td>2</td>
<td>41004</td>
<td>170 170 US South-East Coast, Edisto</td>
<td>0 170 169 US South East Coast, Cape Henry (scripps 147)</td>
</tr>
<tr>
<td>3</td>
<td>41010</td>
<td>170 170 US East Florida, Cape Canaveral East</td>
<td>170 170 Nova Scotia, East Scotia slope</td>
</tr>
<tr>
<td>4</td>
<td>44005</td>
<td>170 170 US North East Coast, Gulf of Maine</td>
<td>165 165 165 Nova Scotia, SW Grand Bank</td>
</tr>
<tr>
<td>5</td>
<td>44008</td>
<td>170 170 US North-East Coast, Nantucket</td>
<td>170 170 Newfoundland, Bancpier</td>
</tr>
<tr>
<td>6</td>
<td>44009</td>
<td>170 165 165 US North-East Coast, Nantucket</td>
<td>164 164 164 Nova Scotia, SW Grand Bank</td>
</tr>
<tr>
<td>7</td>
<td>44011</td>
<td>3 3 3 US North-East Coast, Georges Bank</td>
<td>3 3 3 Nova Scotia, Laurentian Fan</td>
</tr>
<tr>
<td>8</td>
<td>44025</td>
<td>0 170 170 US East Coast, Virginia Beach</td>
<td>170 170 Nova Scotia, La Have Bank</td>
</tr>
<tr>
<td>9</td>
<td>44026</td>
<td>170 169 169 US North East Coast, Long Island</td>
<td>169 169 169 Newfoundland, Nickerson Bank</td>
</tr>
<tr>
<td>10</td>
<td>44037</td>
<td>169 169 169 US North East Coast, GMOOS M0102 Jordan Basin</td>
<td>12 12 12 Newfoundland, NE Bugeo Bank</td>
</tr>
</tbody>
</table>

**Figure 3.22:** 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 3.23: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North West Atlantic buoys.
Figure 3.24: Forecast root mean square error (RMSE) and linear correlation coefficient at common North West Atlantic buoys.
3.5 Comparison for Gulf of Mexico buoys

Figure 3.25: 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 3.26: 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.
Figure 3.27: Forecast root mean square error (RMSE) and linear correlation coefficient at common Gulf of Mexico buoys.
3.6 Comparison for Caribbean Sea buoys

Figure 3.28: 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 3.29: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Caribbean Sea buoys.
Figure 3.30: Forecast root mean square error (RMSE) and linear correlation coefficient at common Caribbean Sea buoys.
3.7 Comparison for North East Atlantic buoys

Figure 3.31: 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 3.32: 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.
Figure 3.33: Forecast root mean square error (RMSE) and linear correlation coefficient at common North East Atlantic buoys.
3.8 Comparison for North Sea platforms

Number of common observations for North Sea platforms (NSEA) from 201008 to 201010 (wind, Hs, Tp)

<table>
<thead>
<tr>
<th></th>
<th>Buoy Identifier</th>
<th>Number of Common Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62111</td>
<td>59 59 0 North Sea (Ivanhoe, shell UK)</td>
</tr>
<tr>
<td>2</td>
<td>62118</td>
<td>46 59 0 North Sea (Nelson A, Shell UK)</td>
</tr>
<tr>
<td>3</td>
<td>62117</td>
<td>37 37 0 North Sea (Buchan A, Talisman)</td>
</tr>
<tr>
<td>4</td>
<td>62115</td>
<td>63 61 0 North Sea (Forties, BP UK)</td>
</tr>
<tr>
<td>5</td>
<td>62119</td>
<td>58 58 0 North Sea (Shearwater, Shell UK)</td>
</tr>
<tr>
<td>6</td>
<td>62128</td>
<td>46 45 0 North Sea (Brae West, Marathon UK)</td>
</tr>
<tr>
<td>7</td>
<td>62123</td>
<td>58 58 0 North Sea (Gannet, Shell UK)</td>
</tr>
<tr>
<td>8</td>
<td>62142</td>
<td>68 61 0 North Sea (Leman AD1, Shell UK)</td>
</tr>
<tr>
<td>9</td>
<td>62143</td>
<td>73 64 0 North Sea (Everest, BP UK)</td>
</tr>
<tr>
<td>10</td>
<td>62145</td>
<td>65 64 0 North Sea (Sann PaPa, Shell UK)</td>
</tr>
<tr>
<td>11</td>
<td>62152</td>
<td>0 156 0 North Sea (Elgin, TotalFinaElf)</td>
</tr>
</tbody>
</table>

Figure 3.34: 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.
Figure 3.35: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common North Sea platforms.
Figure 3.36: Forecast root mean square error (RMSE) and linear correlation coefficient at common North Sea platforms.
3.9 Comparison for Southern North Sea buoys

<table>
<thead>
<tr>
<th>Buoy</th>
<th>Wind</th>
<th>Hs</th>
<th>Tp</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSH02</td>
<td>179</td>
<td>0</td>
<td>180</td>
</tr>
<tr>
<td>BSH03</td>
<td>181</td>
<td>0</td>
<td>182</td>
</tr>
<tr>
<td>BSH04</td>
<td>181</td>
<td>0</td>
<td>182</td>
</tr>
</tbody>
</table>

Figure 3.37: 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.
Figure 3.38: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Southern North Sea buoys.
Figure 3.39: Forecast root mean square error (RMSE) and linear correlation coefficient at common Southern North Sea buoys.
3.10 Comparison for Icelandic platforms and Norwegian platforms

Figure 3.40: 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 3.41: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Icelandic platforms and Norwegian platforms.
Figure 3.42: Forecast root mean square error (RMSE) and linear correlation coefficient at common Icelandic platforms and Norwegian platforms.
3.11 Comparison for Barents Sea buoys

Figure 3.43: 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 3.44: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Barents Sea buoys.
Figure 3.45: Forecast root mean square error (RMSE) and linear correlation coefficient at common Barents Sea buoys.
3.12 Comparison for Baltic Sea buoys

Figure 3.46: 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.
Figure 3.47: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Baltic Sea buoys.
Figure 3.48: Forecast root mean square error (RMSE) and linear correlation coefficient at common Baltic Sea buoys.
### 3.13 Comparison for English Channel and Irish Sea

**Figure 3.49:** 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.
Figure 3.50: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common English Channel and Irish Sea.
Figure 3.51: Forecast root mean square error (RMSE) and linear correlation coefficient at common English Channel and Irish Sea.
3.14 Comparison for Western Mediterranean Sea buoys

Number of common observations for Western Mediterranean Sea buoys (WMED) from 201008 to 201010 (wind, Hs, Tp)

<table>
<thead>
<tr>
<th>Buoy ID</th>
<th>Number of collocations</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>61002</td>
<td>140 139 0</td>
<td>Gulf of Lion</td>
</tr>
<tr>
<td>61196</td>
<td>9 130 0</td>
<td>Begur (Spain)</td>
</tr>
<tr>
<td>61198</td>
<td>103 132 0</td>
<td>Cabo Gata (Spain)</td>
</tr>
<tr>
<td>61280</td>
<td>124 73 0</td>
<td>Tarragona (Spain)</td>
</tr>
<tr>
<td>61417</td>
<td>132 119 0</td>
<td>Cabo de Palos (Spain)</td>
</tr>
</tbody>
</table>

Figure 3.52: 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.
Figure 3.53: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Western Mediterranean Sea buoys.
Figure 3.54: Forecast root mean square error (RMSE) and linear correlation coefficient at common Western Mediterranean Sea buoys.
3.15 Comparison for Korean buoys

<table>
<thead>
<tr>
<th>Number</th>
<th>ID</th>
<th>Observations</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22102</td>
<td>165 81 82</td>
<td>Chil-Bal-Do Yellow Sea, South Korea</td>
</tr>
<tr>
<td>2</td>
<td>22103</td>
<td>170 167 167</td>
<td>Geo-Mun-Do, Korean Strait, South Korea</td>
</tr>
<tr>
<td>3</td>
<td>22105</td>
<td>36 33 33</td>
<td>Dong-Hae, Eastern Sea, South Korea</td>
</tr>
<tr>
<td>4</td>
<td>22107</td>
<td>170 170 0</td>
<td>Jeju, Korean Strait, South Korea</td>
</tr>
</tbody>
</table>

Figure 3.55: 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 3.56: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations) and bias (model-buoy) at common Korean buoys.
Figure 3.57: Forecast root mean square error (RMSE) and linear correlation coefficient at common Korean buoys.
3.16 Comparison for Australian South East Coast buoys

Figure 3.58: 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.
Figure 3.59: 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.
Figure 3.60: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South East Coast buoys.
### 3.17 Comparison for Australian South West facing Coast buoys

<table>
<thead>
<tr>
<th>Buoy Identifier</th>
<th>Number of Collocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>55026</td>
<td>0 121 121 Strahan</td>
</tr>
<tr>
<td>55040</td>
<td>0 172 172 Cape Du Couedic</td>
</tr>
<tr>
<td>56004</td>
<td>0 154 154 Jurien</td>
</tr>
<tr>
<td>56005</td>
<td>0 158 158 Rottnest Island</td>
</tr>
<tr>
<td>56010</td>
<td>0 46 46 Esperance</td>
</tr>
<tr>
<td>56011</td>
<td>0 152 152 Albany</td>
</tr>
</tbody>
</table>

**Figure 3.61:** 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.
Figure 3.62: 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.
Figure 3.63: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South West facing Coast buoys.
3.18 Comparison for Australian North West Coast buoys

Number of common observations for Australian North West Coast buoys (ANWC) from 201008 to 201010 (wind, Hs, Tp)

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Number of Common Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>56012</td>
<td>0 150 150 Exmouth</td>
</tr>
</tbody>
</table>

Figure 3.64: 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 3.65: 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.
Figure 3.66: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian North West Coast buoys.