Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, MSC, NCEP, MeteoFrance, DWD, BoM, JMA, KMA, Puerto del Estado
August 2009 to October 2009

Jean-Raymond Bidlot, European Centre for Medium-range Weather Forecasts, jean.bidlot@ecmwf.int

December 18, 2009
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 $\pm 2$ 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, JMA, KMA, Puerto del Estado 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


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, JMA, KMA, Puerto del Estado 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.
Figure 3.4: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Figure 3.5: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Figure 3.6: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Figure 3.7: Scatter diagrams for wave height at step 0 and 48 for the displayed centres at all buoys.
Figure 3.8: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.
Figure 3.9: Scatter diagrams for wind speed at step 0 and 48 for the displayed centres at all buoys.
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.
Figure 3.13: 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.
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

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.

<table>
<thead>
<tr>
<th>Buoy Identifier</th>
<th>Model Locations</th>
<th>Number of Collocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US South East Coast, Edisto</td>
<td>4/4/97 7/14 7/14 7/4 US North East Coast, Jordan Basin</td>
</tr>
<tr>
<td>3</td>
<td>US East Coast, Casco Bay offshore</td>
<td>7/18/93 9/6 9/6 9/6 Newfoundland, SW Grand Bank</td>
</tr>
<tr>
<td>4</td>
<td>US North East Coast, Gulf of Maine</td>
<td>1/1/92 3/1/92 3/1/92 3/1/92 Newfoundland, Labrador</td>
</tr>
<tr>
<td>5</td>
<td>US North East Coast, Newfoundland</td>
<td>9/1/92 9/1/92 9/1/92 9/1/92 Newfoundland, Tail Of The Bank</td>
</tr>
<tr>
<td>6</td>
<td>US North East Coast, Delaware Bay</td>
<td>9/1/92 9/1/92 9/1/92 Nova Scotia, Laurentian Bank</td>
</tr>
<tr>
<td>7</td>
<td>US North East Coast, Georges Bank</td>
<td>4/4/97 9/6 9/6 9/6 Nova Scotia, La Have Bank</td>
</tr>
<tr>
<td>8</td>
<td>US East Coast, Virginia Beach</td>
<td>3/1/92 7/1/92 7/1/92 Newfoundland, Newfoundland Bank</td>
</tr>
<tr>
<td>9</td>
<td>US North East Coast, Long Island</td>
<td>4/4/97 9/6 9/6 9/6 Newfoundland, NE Edgeo Bank</td>
</tr>
</tbody>
</table>
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

**Number of common observations for Gulf of Mexico buoys** (Gulf from 200908 to 200910 (Wind, Hs,Tp))

<table>
<thead>
<tr>
<th>Buoy Identifier</th>
<th>Collocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63001 T14 T171 Mid Gulf of Mexico</td>
</tr>
<tr>
<td>2</td>
<td>63002 0 174 170 Western Gulf of Mexico</td>
</tr>
<tr>
<td>3</td>
<td>63003 173 151 East Gulf of Mexico</td>
</tr>
<tr>
<td>4</td>
<td>63019 172 199 196 Gulf of Mexico Corpus Christi</td>
</tr>
</tbody>
</table>

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

![Buoy locations](image)

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Buoy Id</th>
<th>Lat</th>
<th>Lon</th>
<th>Platform</th>
<th>Number of Collocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62111</td>
<td>69°</td>
<td>0°</td>
<td>North Sea (Hellesylt)</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>62116</td>
<td>174°</td>
<td>0°</td>
<td>North Sea (Hellesylt)</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>62117</td>
<td>174°</td>
<td>0°</td>
<td>North Sea (Buchan A)</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>62119</td>
<td>173°</td>
<td>0°</td>
<td>North Sea (???)</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>62120</td>
<td>91°</td>
<td>0°</td>
<td>North Sea (???)</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>62131</td>
<td>171°</td>
<td>0°</td>
<td>North Sea (Gannan)</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>62142</td>
<td>171°</td>
<td>0°</td>
<td>North Sea (Leman A)</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>62143</td>
<td>161°</td>
<td>0°</td>
<td>North Sea (???)</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>62145</td>
<td>171°</td>
<td>0°</td>
<td>North Sea (Steen Piping)</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>62146</td>
<td>69°</td>
<td>0°</td>
<td>North Sea (???)</td>
<td>10</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

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 buoys and Norwegian platforms

<table>
<thead>
<tr>
<th>Buoy Identifier</th>
<th>Norwegian Sea (Number)</th>
<th>Icelandic Platform (Number)</th>
<th>Number of collocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFPR</td>
<td>122 136</td>
<td>N Norwegian Sea (Milne)</td>
<td>0</td>
</tr>
<tr>
<td>LFIF</td>
<td>118 125</td>
<td>N Norwegian Sea (Bjorn)</td>
<td>0</td>
</tr>
<tr>
<td>LFNN</td>
<td>116 137</td>
<td>N Norwegian Sea (Helgum)</td>
<td>0</td>
</tr>
<tr>
<td>LFNB</td>
<td>119 133</td>
<td>N Norwegian Sea (Thrall)</td>
<td>0</td>
</tr>
<tr>
<td>LFIF</td>
<td>118 125</td>
<td>N Norwegian Sea (Bjorn)</td>
<td>0</td>
</tr>
<tr>
<td>LFNN</td>
<td>116 137</td>
<td>N Norwegian Sea (Helgum)</td>
<td>0</td>
</tr>
<tr>
<td>LFNB</td>
<td>119 133</td>
<td>N Norwegian Sea (Thrall)</td>
<td>0</td>
</tr>
<tr>
<td>LFIF</td>
<td>118 125</td>
<td>N Norwegian Sea (Bjorn)</td>
<td>0</td>
</tr>
<tr>
<td>LFNN</td>
<td>116 137</td>
<td>N Norwegian Sea (Helgum)</td>
<td>0</td>
</tr>
<tr>
<td>LFNB</td>
<td>119 133</td>
<td>N Norwegian Sea (Thrall)</td>
<td>0</td>
</tr>
</tbody>
</table>

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 buoys and Norwegian platforms.
Figure 3.42: Forecast root mean square error (RMSE) and linear correlation coefficient at common Icelandic buoys and Norwegian platforms.
3.11 Comparison for Baltic 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 Baltic Sea buoys.
Figure 3.45: Forecast root mean square error (RMSE) and linear correlation coefficient at common Baltic Sea buoys.
3.12 Comparison for English Channel and Irish Sea

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 English Channel and Irish Sea.
Figure 3.48: Forecast root mean square error (RMSE) and linear correlation coefficient at common English Channel and Irish Sea.
3.13 Comparison for Western Mediterranean Sea buoys

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 Western Mediterranean Sea buoys.
Figure 3.51: Forecast root mean square error (RMSE) and linear correlation coefficient at common Western Mediterranean Sea buoys.
3.14 Comparison for Brazilian buoys

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 Brazilian buoys.
Figure 3.54: Forecast root mean square error (RMSE) and linear correlation coefficient at common Brazilian buoys.
3.15 Comparison for South African platform

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 South African platform.
Figure 3.57: Forecast root mean square error (RMSE) and linear correlation coefficient at common South African platform.
3.16 Comparison for Tropical Eastern Pacific 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 Tropical Eastern Pacific buoys.
Figure 3.60: Forecast root mean square error (RMSE) and linear correlation coefficient at common Tropical Eastern Pacific buoys.
3.17 Comparison for Korean buoys

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 Korean buoys.
Figure 3.63: Forecast root mean square error (RMSE) and linear correlation coefficient at common Korean buoys.
3.18 Comparison for Australian South East Coast buoys

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 South East Coast buoys.
Figure 3.66: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South East Coast buoys.
3.19 Comparison for Australian South West facing Coast buoys

Figure 3.67: 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 3.68: 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 3.69: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian South West facing Coast buoys.
3.20 Comparison for Australian North West Coast buoys

Figure 3.70: 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 3.71: 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 3.72: Forecast root mean square error (RMSE) and linear correlation coefficient at common Australian North West Coast buoys.