Wind Forecasting using HARMONIE with Bayes Model Averaging for Fine-Tuning

Martin Peters(1), Alastair McKinstry(1), Enda O’Brien(1), Adam Ralph(1), Michael Sheehy(2)

(1) Irish Centre for High-End Computing, NUI Galway, Ireland (www.ichec.ie)
(2) GaelForce Wind Energy, Tralee Co. Kerry, Ireland (www.gaelforceenergy.com)

Introduction
At least two distinct elements are required to make accurate wind-speed forecasts for wind farms:
1. Deterministic output from a weather forecast model, interpolated to the wind-farm site;
2. Some probabilistic or statistical post-processing to correct local biases, or systematic errors in the model.

Here, we take gridder wind forecasts from the operational HARMONIE mesoscale weather forecast model (2.5km resolution), and interpolate them to the precise (3-dimensional) location of the met-mast of a wind farm in southwest Ireland. Forecasts are post-processed using Bayes Model Averaging (BMA) to remove systematic local bias, and to provide forecasts in a calibrated probabilistic format.

The main metric used here to evaluate the forecasts is “Mean Absolute Error” (MAE), in units of m s⁻¹.

Data
Observations: Recorded winds from the wind farm met mast were available for the month of November 2010, and for all of 2012 (with some gaps), at 10-minute intervals.

HARMONIE Forecasts:
• A small ensemble of three different variants of HARMONIE were run for 24 hours, starting at 002 every day during November 2012, to provide forecasts for that month (see Table 1 for details).
• During 2012, output was saved continuously from the operational HARMONIE forecasts run by Met Éireann at 6-hour intervals, and evaluated against the wind-farm observations.
• A 30-day suite of high-resolution (1 km grid) HARMONIE forecasts was also run during Nov.-Dec. 2012. These forecasts were run at 12-hour intervals, and each one was run out to 24 hours.

Model Domain, Wind-Farm Location

Bayesian Model Averaging (BMA)
BMA is a weighted average of the forecasts in an ensemble. The model weights are estimated from a “training set” of recent data (e.g., a 20 or 25-day moving window).

Results from Operational Forecasts
Operational HARMONIE Forecasts were collected during 2012 and compared with recorded wind-speeds at turbine height at the wind farm.

Since a new forecast run was started every 6 hours, even short 24-hour forecasts meant that each wind observation could be used to validate 4 separate forecasts. In fact 4 continuous forecast time-series were constructed, from 24-hour forecasts started at 002, 062, 122 and 182, resp. each day. This constituted a small 4-member “ensemble” for the purposes of BMA analysis. Each ensemble member had lead times between 0 and 23 hours to the validating observation, and so over long times, each member should be statistically equivalent to each other.

Another way to construct an “ensemble” is, for each observation time, to let the first member be the forecast with the shortest lead time (i.e., 0 to 5 hours), the 2nd member be the forecast with lead times of 6-11 hours, the 3rd member the forecast with lead times of 12-17 hours, and the 4th member the forecast with lead times of 18-23 hours. These ensemble members are not equivalent: the member with the shortest lead-time would normally be expected to make the most accurate forecasts.

This is not necessarily the case, however, as shown in Table 2. The first 6 hours of each forecast is typically a period of adjustment to new initial conditions, and generates generally large MAEs when validated against observations.

Table 2. MAE for Jan.-Mar. 2012 from ensemble constructed from 4 forecasts, each with different lead times. Also shown is BMA forecast (after 20 days training during Jan. 2012).

<table>
<thead>
<tr>
<th>Lead Time (hrs)</th>
<th>MAE (m s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>1.80</td>
</tr>
<tr>
<td>6-11</td>
<td>1.71</td>
</tr>
<tr>
<td>12-17</td>
<td>1.78</td>
</tr>
<tr>
<td>18-23</td>
<td>1.79</td>
</tr>
<tr>
<td>BMA Forecast</td>
<td>1.55</td>
</tr>
</tbody>
</table>

Conclusions
Operational HARMONIE forecasts generate MAEs of approximately 1.7 - 2.0 m s⁻¹ when interpolated to the location and height of a wind-farm met-mast. Statistical post-processing (e.g., with BMA) can reduce this to approximately 1.5 - 1.6 m s⁻¹, for an improvement of about 15% on average. These MAEs do not degrade significantly as forecast lead-time increases, at least out to 24 hours. Indeed, the most accurate forecasts are typically not those with the shortest lead times (0-5 hrs), but rather have 6-11 hr lead times. A higher-resolution forecast model, which had slightly better skill-scores than the current operational model when validated against standard observing stations, nevertheless had a slightly higher MAE of 1.84 m s⁻¹ for the wind farm over 30 days of 2012—though that was without the benefit of BMA post-processing.

Acknowledgements
We are grateful for financial support for this work from Irish EPA grant no. CCR-09-FS-5-2. We also thank Met Éireann and GaelForce Green Energy for use of their data.