Analysis of Integrated Forecasts from Different Combinations of NWP Models

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Background

- General lack of numerical models specifically designed and developed to do nowcasting
- Nowcasting is often based on one or several available Numerical Weather Prediction (NWP) models regardless of the spatial resolution for a particular location
  - NWP models originally developed for short to medium weather forecasts with lead times greater than 12 hours
  - Major limitations of using NWP models for nowcasting:
    - coarse spatial resolution
    - spin-up
    - cannot be updated frequently
- A weighting, evaluation, bias correction and integrated system (WEBIS) has been developed at EC to generate integrated weighted forecasts (INTW) from several NWP models for nowcasting (up to 6 hrs)

Integrated Model Generation

Major Steps of INTW Generation

- Data pre-checking - defining the available NWP models and observations
- Extracting the available data for specific variable and location
- Calculating statistics from NWP model data, e.g. MAE, RMSE
- Deriving weights from model variables based on model performance
- Defining and performing dynamic and variational bias correction
- Generating Integrated Model forecasts

Flowchart of Integrated Model Generation

- Check data availability
- Calculate 1st weights (based on model performance)
- Perform bias correction if needed
- Calculate 2nd weights (based on model performance)
- No
- Yes
- Perform bias correction if needed
- Combine weighted and bias corrected forecasts
- Adjusted forecasts

Data Sources Used in This Study

<table>
<thead>
<tr>
<th>Name</th>
<th>Run times</th>
<th>Resolution</th>
<th>Data from</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM Regional (REG)</td>
<td>0, 6, 12, 18 Z</td>
<td>15 km</td>
<td>CMC of EC</td>
</tr>
<tr>
<td>GEM LAM east (LAM)</td>
<td>12 Z</td>
<td>2.5 km</td>
<td>CMC of EC</td>
</tr>
<tr>
<td>GEM LAM west (LAM)</td>
<td>9, 21 Z</td>
<td>2.5 km</td>
<td>CMC of EC</td>
</tr>
<tr>
<td>RUC</td>
<td>every hour</td>
<td>13 km</td>
<td>NOAA/NCEP</td>
</tr>
<tr>
<td>OBS</td>
<td>1 min</td>
<td>point</td>
<td>min</td>
</tr>
</tbody>
</table>

Verification of NWP Models

MAE from 3 NWP models for different variables at CYYZ

<table>
<thead>
<tr>
<th>Variables</th>
<th>REG</th>
<th>LAM</th>
<th>RUC</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>1.7</td>
<td>2.3</td>
<td>1.9</td>
<td>deg C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>10.5</td>
<td>9.0</td>
<td>12.1</td>
<td>%</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>1.6</td>
<td>1.2</td>
<td>1.4</td>
<td>m/s</td>
</tr>
<tr>
<td>Wind Direction</td>
<td>19.3</td>
<td>20.6</td>
<td>23.3</td>
<td>deg</td>
</tr>
<tr>
<td>Wind Gust</td>
<td>2.3</td>
<td>2.4</td>
<td>1.7</td>
<td>m/s</td>
</tr>
</tbody>
</table>

NWP Model with minimum MAE at CYYZ and CYVR

(Winter: 2009.12.01-2010.03.31, Summer: 2010.03.01-2010.08.31)

<table>
<thead>
<tr>
<th>Variables</th>
<th>CYYZ</th>
<th>CYVR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>REG</td>
<td>RUC</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>LAM</td>
<td>LAM</td>
</tr>
<tr>
<td>Wind speed</td>
<td>LAM</td>
<td>RUC</td>
</tr>
<tr>
<td>Wind direction</td>
<td>REG</td>
<td>RUC</td>
</tr>
<tr>
<td>Wind gust</td>
<td>RUC</td>
<td>LAM</td>
</tr>
</tbody>
</table>

Comparison of model performance from all models

<table>
<thead>
<tr>
<th>Site</th>
<th>Season</th>
<th>Temperature</th>
<th>Relative Humidity</th>
<th>Wind Speed</th>
<th>Wind Direction</th>
<th>Wind Gust</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYZZ</td>
<td>winter</td>
<td>RJ / Y</td>
<td>LR / Y</td>
<td>8 / Y</td>
<td>8 / Y</td>
<td>2 / Y</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>RJ / Y</td>
<td>LR / Y</td>
<td>8 / Y</td>
<td>8 / Y</td>
<td>2 / Y</td>
</tr>
<tr>
<td>CYVR</td>
<td>winter</td>
<td>RJ / Y</td>
<td>LR / Y</td>
<td>8 / Y</td>
<td>8 / Y</td>
<td>2 / Y</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>RJ / Y</td>
<td>LR / Y</td>
<td>8 / Y</td>
<td>8 / Y</td>
<td>2 / Y</td>
</tr>
</tbody>
</table>

In the graphs:

- INT_L - INTW based on LAM
- INT_U - INTW based on RUC
- INT_LU - INTW based on LAM and RUC
- INT_LRU - INTW based on LAM, REG and RUC
- INT_R - INTW based on REG
- INT_LR - INTW based on LAM and REG
- INT_RU - INTW based on REG and RUC
- OBS - Observation persistence

Analysis of Model Performance

NWP model performance varies by variable, time and location
- All integrated models have smaller MAE than raw NWP models
- The integrated models based on more than one model have smaller MAE than integrated model based on only one NWP model
- The integrated models based on 2 optimal models lead to the smallest MAE among all models.

For some variables, there are no big differences in MAE among models based on either two optimal NWP models (2 with smaller MAE than 3rd one) or three NWP models
- However, it cannot be predetermined which two models will be the optimal ones when making a real time forecast. Thus it is best to use all available models

Summary

- Integrating multiple forecasts can increase nowcasting accuracy
- Dynamic weighting and variational bias correction are the key methods for the improvement
- High frequency observations and NWP models are critical for deriving integrated forecasts
- Integrated model can provide better forecasts than individual NWP models for the first couple of hours regardless of selected variables and locations
- It is better to use as many NWP models as possible to generate integrated forecasts when NWP model performances are unknown

References

* Huang, L.X, Isaac, G.A, and Sheng, G., 2012: Integrating NWP forecasts and observation data to improve nowcasting accuracy. Weather and Forecasting. 27. 938-953