Neural Network Prediction of Pollutant Emissions from Open Burning of Crop residues and Application to Air Quality Forecasts in Southern China

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1st Regional GEOS-Chem Asia Meeting

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Open burning of crop residues is human-modulated interaction between air quality and meteorology

\[
\Delta = C_{\text{b}} - C_{\text{N}_2\text{O}} - C_{\text{H}_2\text{O}}
\]

The contribution of biomass burning to mean PM2.5 mass concentrations is 10%~50%.

Shenzhen observations (Aerosol Mass Spectrometry, He et al. 2011)

Modified CMAQ (Li, Fu* et al., 2013)
Question 1: How do we use the BPNNs to obtain the daily-variable biomass burning emissions?

**Output**

**BPNN models**

\[ E_{m,n,d}(x, y) = \frac{\text{FINN}_n E_{m,n}(x, y)}{\text{FC}_n} \cdot \left[ \frac{\text{FC}_{n,d}}{\text{FC}_n} \right] \]

- **m**\(^{th}\) specie
- **n**\(^{th}\) box
- **d**\(^{th}\) day in January

**Scale factors**

**MODIS fire observations**

**FINN (Fire Inventory)**

**3° longitude × 2° latitude**

\[ E_{m,n,d}(x, y) \]

**Back-propagation neural network**

**NCEP reanalysis**


**MODIS fire counts** (2003-2012)

**Predicted fire counts**

**Training data**

- JAN (2003-2012)

**Validation data**


**Scale factors**

- MODIS fire observations

**FINN (Fire Inventory)**

**BPNN models**

\[ E_{m,n,d}(x, y) = \frac{\text{FINN}_n E_{m,n}(x, y)}{\text{FC}_n} \cdot \left[ \frac{\text{FC}_{n,d}}{\text{FC}_n} \right] \]

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**BPNN models**

\[ E_{m,n,d}(x, y) = \frac{\text{FINN}_n E_{m,n}(x, y)}{\text{FC}_n} \cdot \left[ \frac{\text{FC}_{n,d}}{\text{FC}_n} \right] \]
Question 2: What are the impacts of daily crop residue burning emissions on air quality?

The nested domain in our WRF-Chem simulations

<table>
<thead>
<tr>
<th>Case</th>
<th>FINN_2014</th>
<th>BPNN_2014</th>
<th>FINN_MEAN</th>
<th>NO_BB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model version</td>
<td>WRF-Chem v3.6.1</td>
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<tr>
<td>Simulated period</td>
<td>2014.01.01 00:00 – 2014.01.31 00:00 (UTC)</td>
<td></td>
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</tbody>
</table>
The interannual change and daily variability of fire counts can be forecasted by BPNN ensembles.

- MODIS-observed fire counts
- Forecasted fire counts using the BPNN ensembles
- Climatological January mean fire counts from MODIS
- MODIS-observed daily fire counts from 2003 to 2012

<table>
<thead>
<tr>
<th></th>
<th>OBS MEAN</th>
<th>BPNN MEAN</th>
<th>R</th>
<th>RMSE</th>
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</thead>
<tbody>
<tr>
<td>2013</td>
<td>13</td>
<td>46</td>
<td>0.60</td>
<td>40.0</td>
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<tr>
<td>2014</td>
<td>100</td>
<td>89</td>
<td>0.77</td>
<td>68.6</td>
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<tr>
<td>2015</td>
<td>37</td>
<td>56</td>
<td>0.80</td>
<td>33.3</td>
</tr>
</tbody>
</table>

**Interannual variation**  **Day-to-day variability**
BPNNs reproduced the temporal variability of PM$_{2.5}$ emission rates from biomass burning.

The time series of PM$_{2.5}$ emission rates in January given by FINN (FINN_2014), forecasted by our BPNN ensembles (BPNN_2014) and climatological January mean FINN (FINN_MEAN).
The daily-variable emissions lead to improvements in the forecasts of PM$_{2.5}$ concentrations of observations in 23 sites and simulations from (a) “BPNN_2014” case and (b) “FINN_MEAN” case during Jan 4$^{th}$ to 30$^{th}$, 2014.

Time-average PM$_{2.5}$ concentrations of observations in 23 sites and simulations from (a) “BPNN_2014” case and (b) “FINN_MEAN” case during Jan 4$^{th}$ to 30$^{th}$, 2014.
Open burning of crop residue is a human-modulated interaction between air quality and meteorology.

We used BPNN models to forecast the daily variable emissions of open crop residues burning with an accuracy over 70%.

Our forecasted daily-variable emissions led to improvements in the forecasts of PM$_{2.5}$ concentrations in Southern China.