High Resolution Air Quality Forecasting systems for India and the United States

Rajesh Kumar\textsuperscript{1}, Gabriele Pfister\textsuperscript{1}, Sachin Ghude\textsuperscript{2}
\textsuperscript{1}National Center for Atmospheric Research, Boulder, CO, USA
\textsuperscript{2}Indian Institute for Tropical Meteorology, Pune, India

11 Sep 2019


This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.
Government of India (Ministry of Earth Sciences and Ministry of Environment, Forest, and Climate Change) has taken several initiatives to address the growing problem of air pollution in India.

- Air Quality Monitoring Network
- Air Quality Forecasting System
- Information Dissemination System
- Graded Response Action Plan (GRAP)
## Delhi Air Quality Forecasting System - Configuration

![Air Quality Map]

Model domain covers northern Indian subcontinent at 10 km resolution.

<table>
<thead>
<tr>
<th>Atmospheric process</th>
<th>Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud microphysics</td>
<td>Thompson microphysics</td>
</tr>
<tr>
<td>Short- and Long-wave radiation</td>
<td>RRTMG (Iacono et al., 2008)</td>
</tr>
<tr>
<td>Surface Layer</td>
<td>Monin-Obukhov (Janjic Eta) Scheme (Janjic, 1996, 2002)</td>
</tr>
<tr>
<td>Land surface model</td>
<td>Unified Noah land-surface model (Tewari et al., 2004)</td>
</tr>
<tr>
<td>Planetary boundary layer</td>
<td>BouLac TKE ((Bougeault and Lacarrere, 1989)</td>
</tr>
<tr>
<td>Cumulus</td>
<td>Grell-Freitas ensemble scheme (Grell &amp; Freitas, 2014)</td>
</tr>
<tr>
<td>Gas phase chemistry</td>
<td>MOZART (Emmons et al., 2010)</td>
</tr>
<tr>
<td>Aerosol processes</td>
<td>GOCART (Chin et al., 2000)</td>
</tr>
</tbody>
</table>
Delhi Air Quality Forecasting System - Workflow

- GFS met IC/BC
- NRT fire emissions
- WACCM chem BC
- Anthropogenic emissions
- Previous day forecast

Other Input Datasets

- Background IC
- MODIS NRT AOD
- GSI DA system

WRF-Chem air quality forecasting system

- Met and chem BC
- Corrected (Aerosol) IC

72 hour air quality forecast
Improvements in PM$_{2.5}$ Forecasts (US Embassy, Delhi)

- Large improvements (up to 200 µg/m$^3$) in surface PM$_{2.5}$ forecasts are observed during all the three forecast days in both 2016 and 2017.
- PM$_{2.5}$ levels peaked about a week earlier in 2016 compared to 2017. This was found to be related to difference in wind speed between the two years.
- Similar improvements are seen in comparison with CPCB observations.
AOD assimilation improves weather forecasts!

Punjab

Haryana

Delhi

2017

1st day

2nd day

3rd day

Temperature (°C)


Obs
WRF-Chem (BKG)
WRF-Chem (ASIM)

Obs
WRF-Chem (BKG)
WRF-Chem (ASIM)

Obs
WRF-Chem (BKG)
WRF-Chem (ASIM)
Operational Air Quality Forecast - Example
Forecasting Crop-residue burning influence in Delhi
Verification of operational PM$_{2.5}$ forecasts

Delhi pollution: Ban on trucks, construction extended till Monday
Air Quality Forecasting System for the CONUS

Objectives

- Provide forecast support for FIREX-AQ Summer 2019
- Provide forecast and hindcast products to the research community on an ongoing basis (e.g. TOLNET team)
- Offer regular air quality predictions for Stakeholders, the Public and anyone interested.
- Evaluate performance of WRF-Chem in near-real time and test new developments
- Extend the current global ACOM prediction capability
- Provide long-term model output for use in research projects including health studies

Disclaimer: This is a research product and not intended for official guidance. For the operational U.S. air quality forecast please visit https://airnow.gov/. For information on air quality health effects and U.S. standards please visit https://www.epa.gov/environmental-topics/air-topics.
CONUS Air Quality Forecasting System - Workflow

GFS met IC/BC → WRF-Chem air quality forecasting system → 48 hour air quality forecast
NRT fire emissions → Meteorological and Chemical IC and BC
WACCM chem BC → Previous day forecast
Anthropogenic emissions → Other Input Datasets
Dissemination of the CONUS AQ forecasts

NCAR ACOM website

https://www2.acom.ucar.edu/acresp/forecasts-and-near-real-time-nrt-products
Dissemination of the CONUS AQ forecasts

CONUS, Colorado, Front Range

Surface, 3km, 5km, 8km

More Information:

WRF-Chem and WRF Configuration and Specifics. Evaluation and additional visualization.
Dissemination of the CONUS AQ forecasts

CO Tracers: keep track of CO and subjected to the same physical and chemical processing in the atmosphere as the standard model CO but do not affect the standard model physics or chemistry.

Tracers for:
- Anthropogenic and biomass burning emission sources located inside the domain
- Photochemical production of CO
- Background CO flowing into the domain
Dissemination of the CONUS AQ forecasts

Inert Tracers: based on CO emissions from four different sources. For each source, a decaying and a non-decaying tracer is used → lifetime estimate.

- **2D_Fire**: Fire emissions in CONUS are emitted at surface
- **3D_Fire**: Fire emissions in CONUS are distributed vertically through WRF-Chem plumerise code
- **Anthro Tracer**: Anthropogenic emissions from CONUS
- **LBC Tracer**: Inflow of CO emitted by fires outside the CONUS from the domain boundaries
Near Real Time Evaluation of the CONUS AQ forecasts

Surface Observations are typically available a few hours past real-time
Evaluation and Additional Visualization

**AverageStatistics**: Observed and Modeled timeseries for entire domain average, individual EPA regions, all Colorado, Colorado Front Range & spatial statistics

**HourlyMaps**: Hourly maps of observed and modeled surface ozone & PM2.5

**KMZ**: kmz files for 2D fire tracer

**TOLNET**: curtain plots for various parameters at 5 TOLNET sites (with Bo Wang, UHA)
Evaluation and Additional Visualization

<table>
<thead>
<tr>
<th>Name</th>
<th>Modified</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>AverageStatistics/</td>
<td>2019-08-08 07:11:09</td>
<td>4KB</td>
</tr>
<tr>
<td>HourlyMaps/</td>
<td>2019-08-08 07:11:59</td>
<td>4KB</td>
</tr>
<tr>
<td>KMZ/</td>
<td>2019-07-23 07:11:51</td>
<td>8KB</td>
</tr>
<tr>
<td>TOLNet/</td>
<td>2019-08-08 06:10:01</td>
<td>40KB</td>
</tr>
</tbody>
</table>
Custom made plots for FIREX-AQ

https://www.acom.ucar.edu/firex-aq/flight.shtml
Ongoing and Next Steps

- Make monthly evaluation statistics public
  - Day-1 and Day-2 forecast and observed surface ozone and PM2.5 timeseries for each region
  - Spatial & temporal statistics for Day-1 and Day-2 forecasts for each region

- Evaluation with TOLNET data and create dedicated website

- Publication on forecast setup and operational evaluation

- Full evaluation with FIREX-AQ

Feedback and collaborations welcome
Summary

• Improvement in aerosol initialization via assimilation of MODIS AOD significantly improved both PM$_{2.5}$ and surface temperature forecasts during the crop-residue burning season.

• Air quality forecasting system in Delhi went operational in Oct 2018 and has been found to enhance the air quality decision-making activity.

• The CONUS air quality forecasting system started in Jun 2019 and aims to assist field campaigns, research community, facilitate routine evaluation of WRF-Chem performance, and provide additional piece of information to decision-makers.

Thank You!