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

Rajesh Kumar[1], Gabriele Pfister[1], Sachin Ghude[2]

[1]National Center for Atmospheric Research, Boulder, CO, USA

[2]Indian Institute for Tropical Meteorology, Pune, India

11 Sep 2019

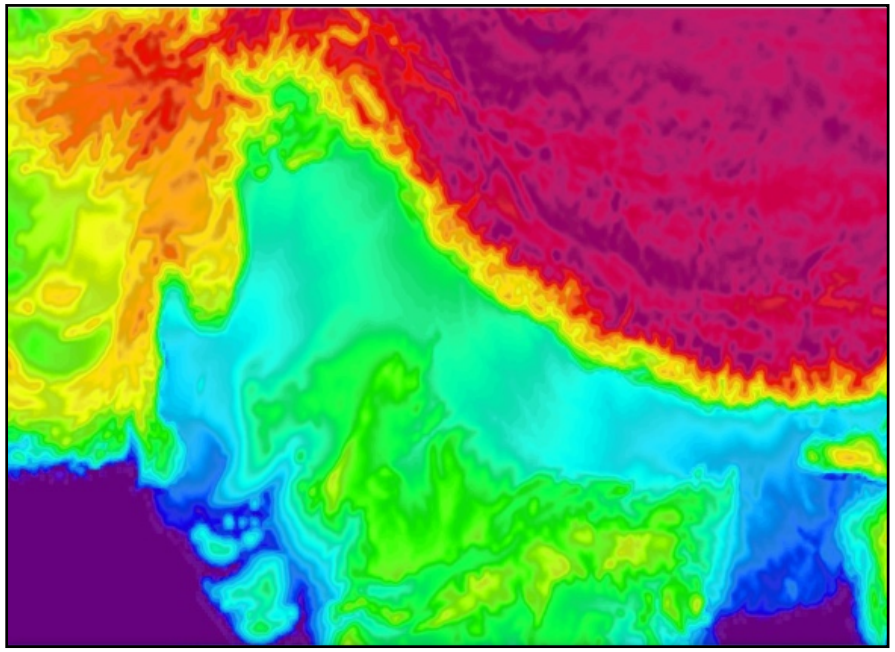
Carl Drews, Garth D'Attilo, Shawn Honomichl, Chinmay Jena, Sreyashi Debnath, Stefano Alessandrini, Santosh Kulkarni, Prakash Pithani, D.M. Chate, V.K. Soni, Siddhartha Singh, Ravi S. Nanjundiah, M. Rajeevan

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)**

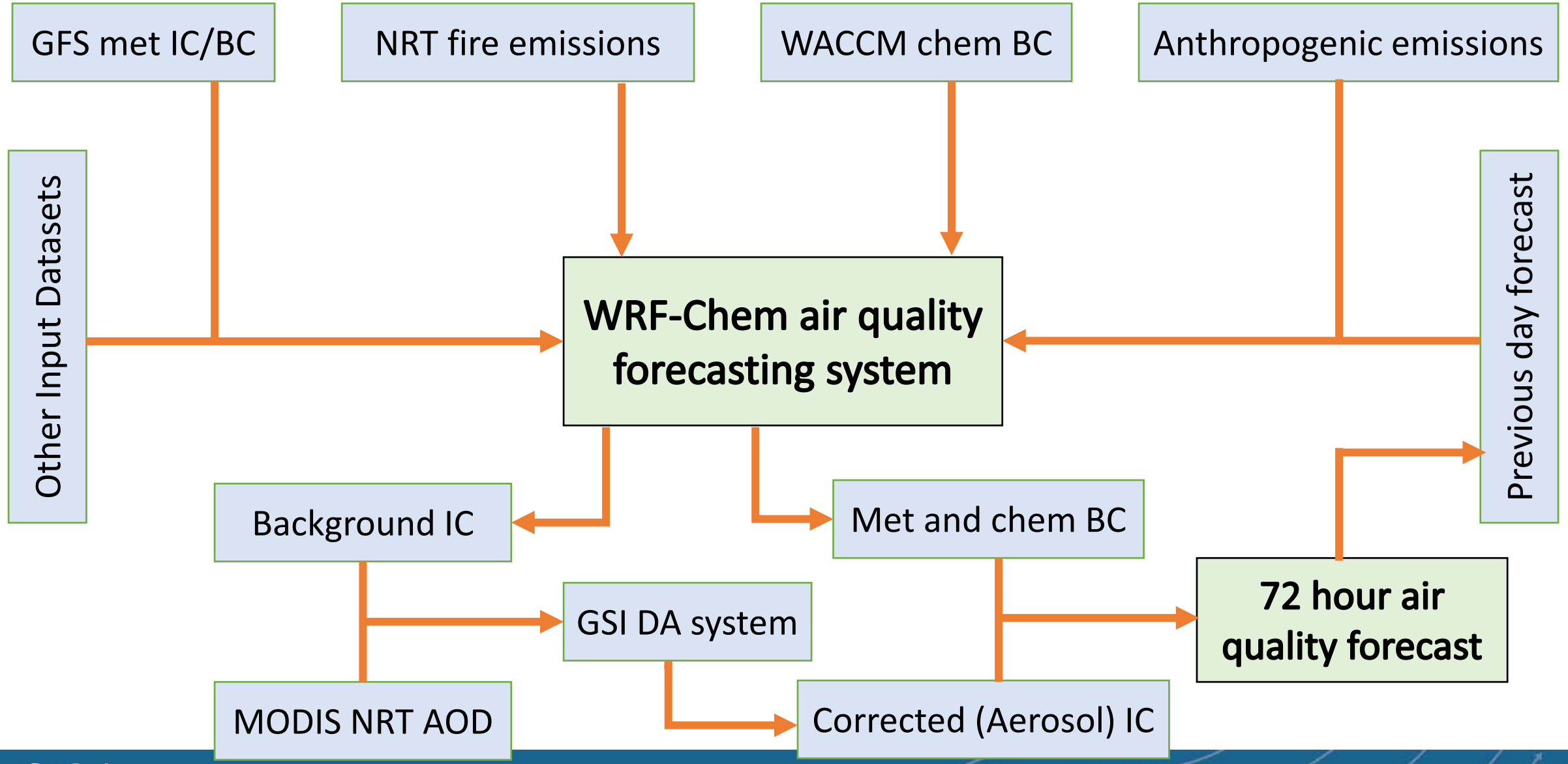
Delhi Air Quality Forecasting System - Configuration



Model domain covers northern Indian subcontinent at 10 km resolution.

Atmospheric process	Schemes
Cloud microphysics	Thompson microphysics
Short- and Long-wave radiation	RRTMG (Iacono et al., 2008)
Surface Layer	Monin-Obukhov (Janjic Eta) Scheme (Janjic, 1996, 2002)
Land surface model	Unified Noah land-surface model (Tewari et al., 2004)
Planetary boundary layer	BouLac TKE ((Bougeault and Lacarrere, 1989)
Cumulus	Grell-Freitas ensemble scheme (Grell & Freitas, 2014)
Gas phase chemistry	MOZART (Emmons et al., 2010)
Aerosol processes	GOCART (Chin et al., 2000)

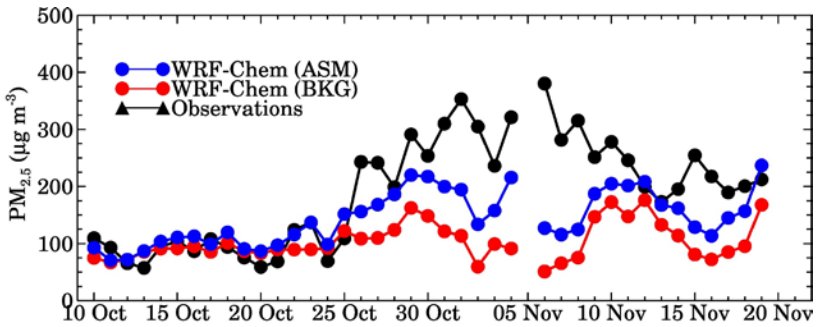
Delhi Air Quality Forecasting System - Workflow

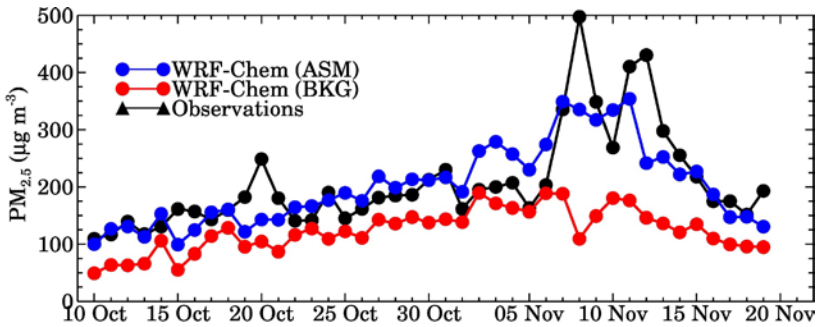


Improvements in $PM_{2.5}$ Forecasts (US Embassy, Delhi)

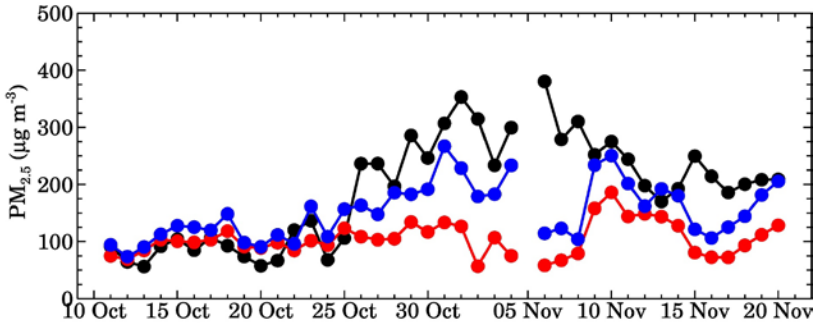
2016 2017

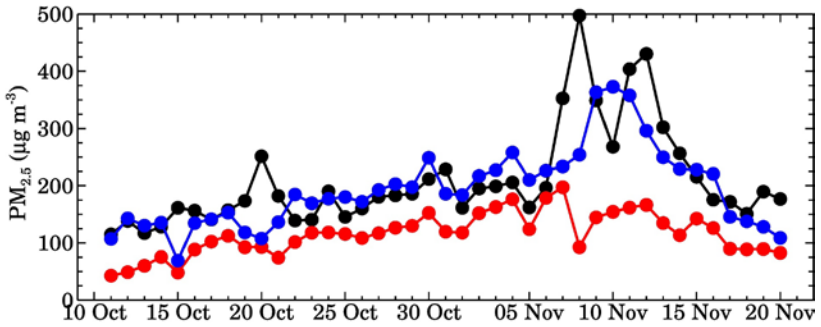
1st day



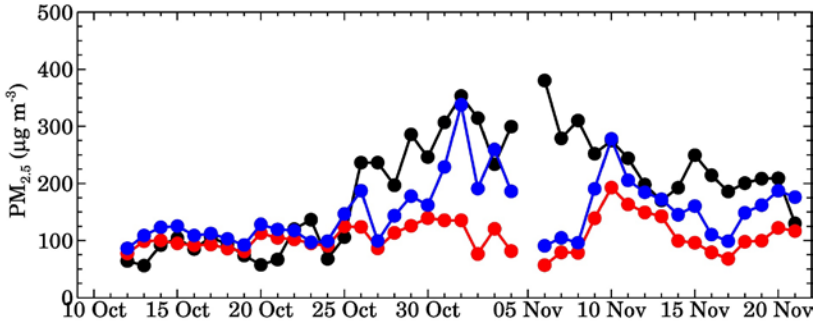


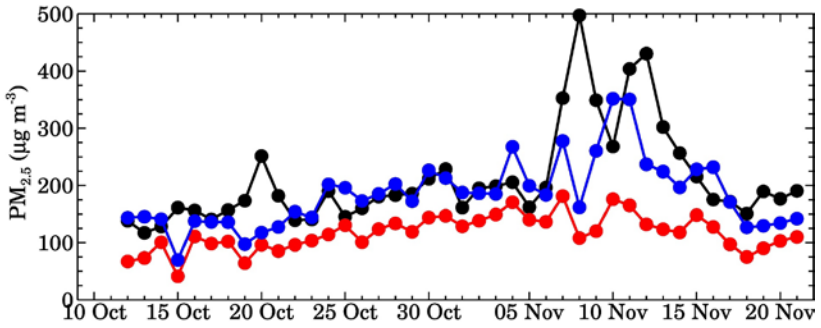
2nd day





3rd day





- 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.

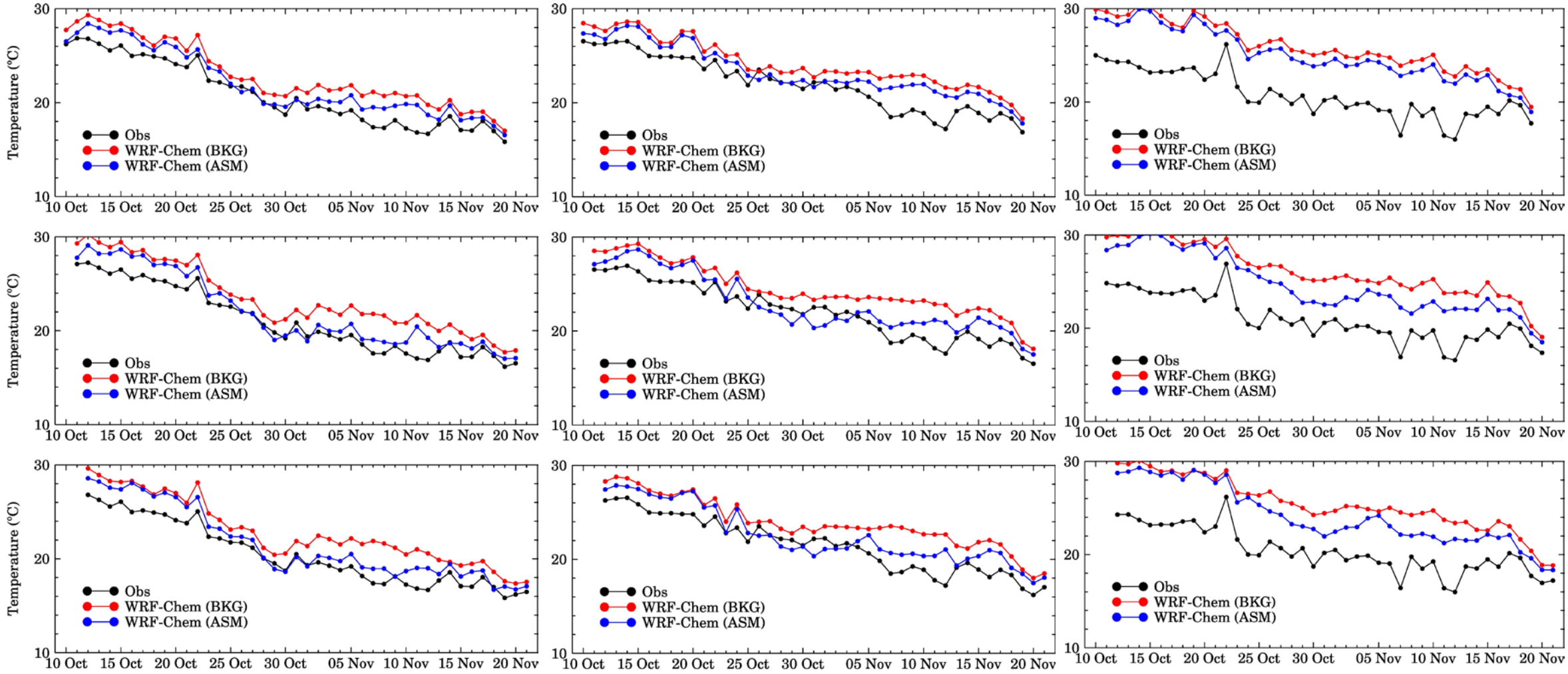
AOD assimilation improves weather forecasts!

Punjab Haryana Delhi 2017

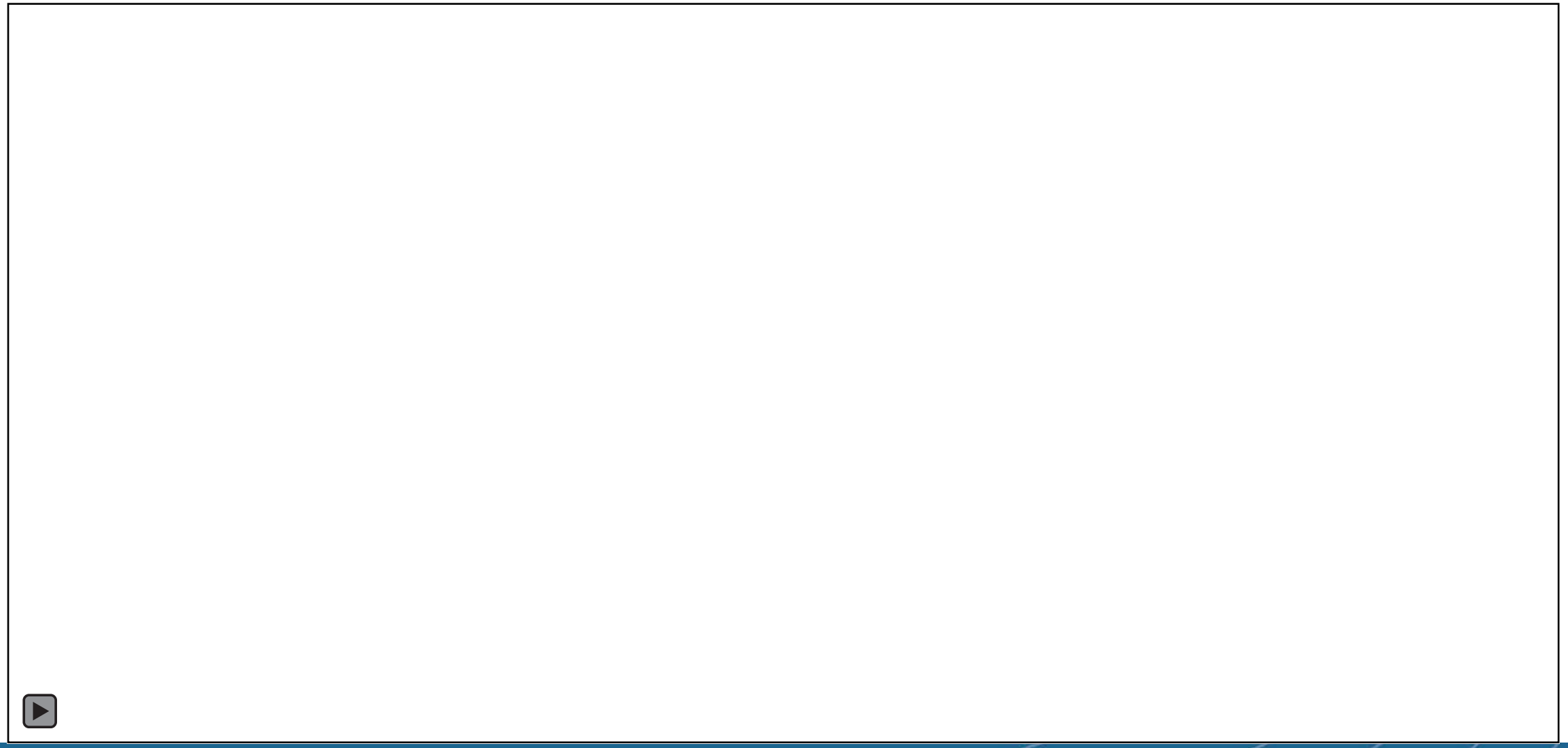
1st day

2nd day

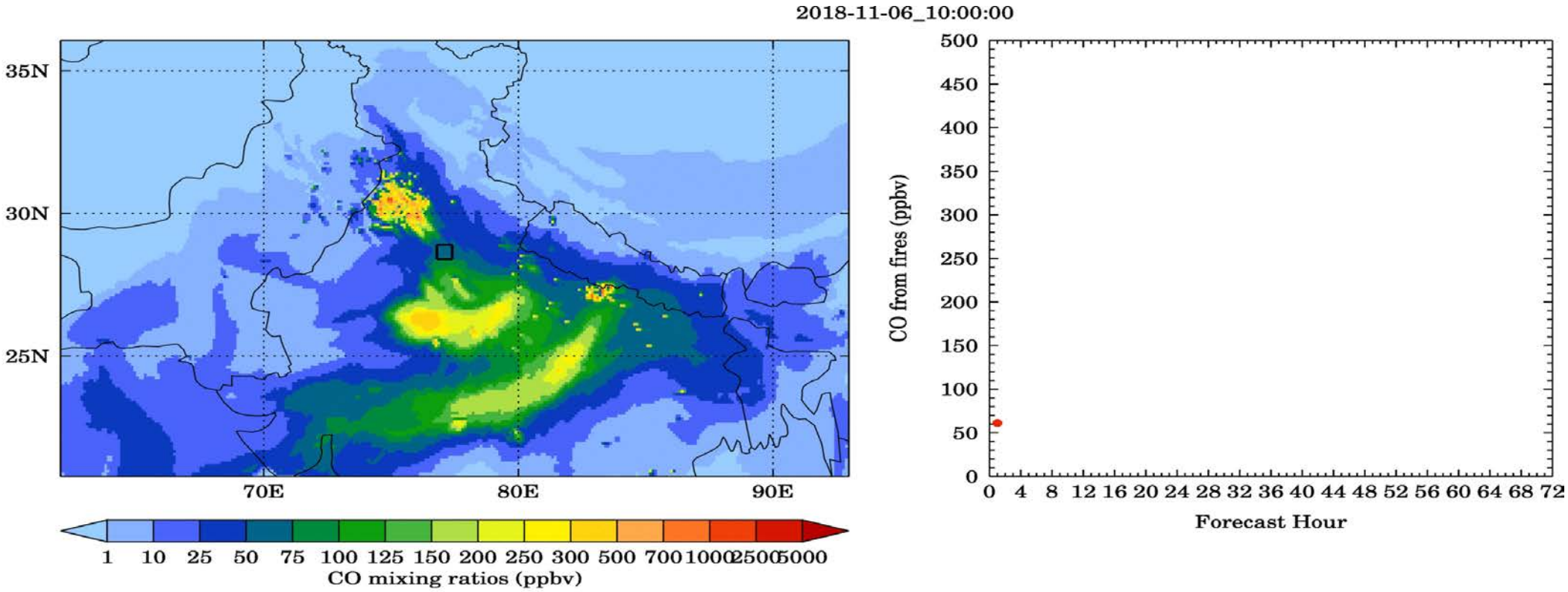
3rd day



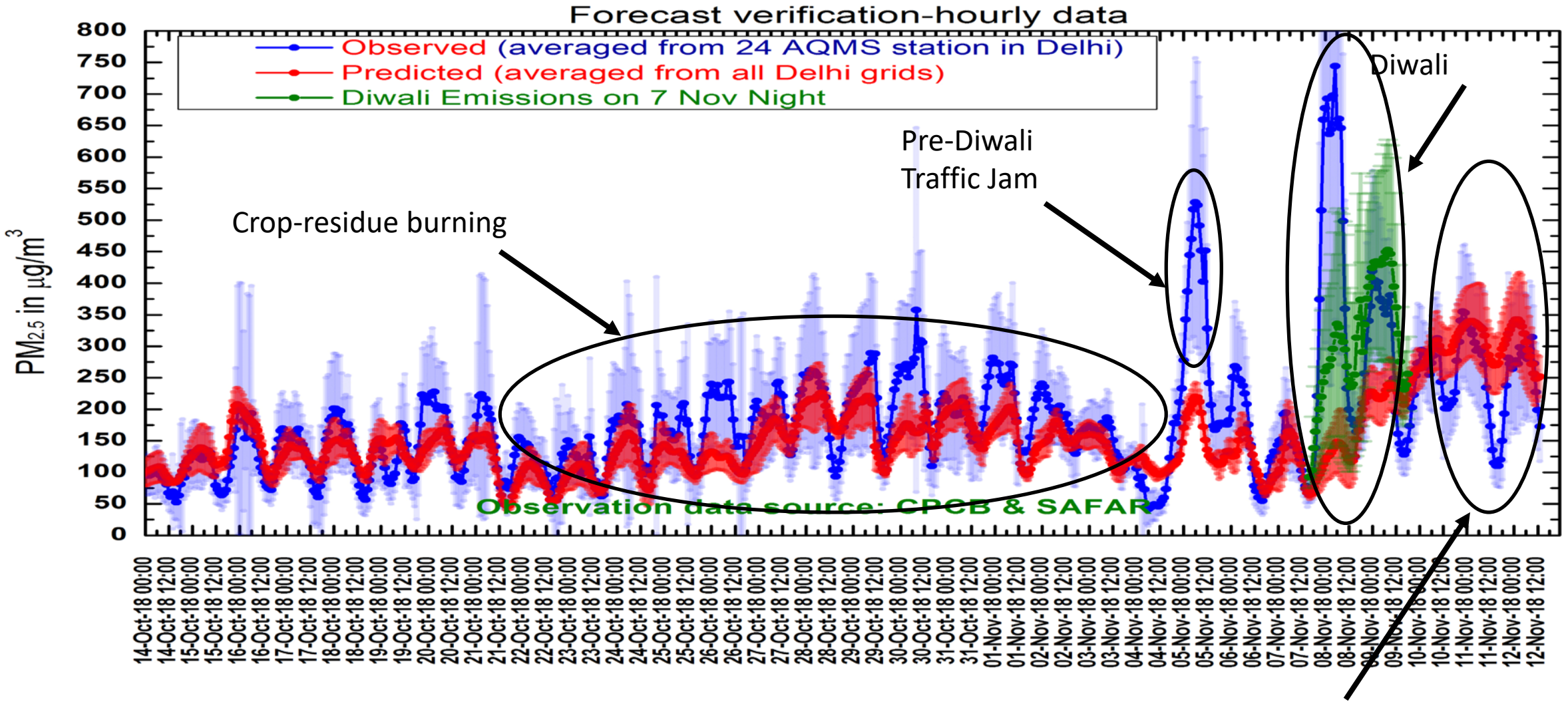
Operational Air Quality Forecast - Example



Forecasting Crop-residue burning influence in Delhi



Verification of operational $PM_{2.5}$ forecasts



THE TIMES OF INDIA

Delhi pollution: Ban on trucks, construction extended till Monday

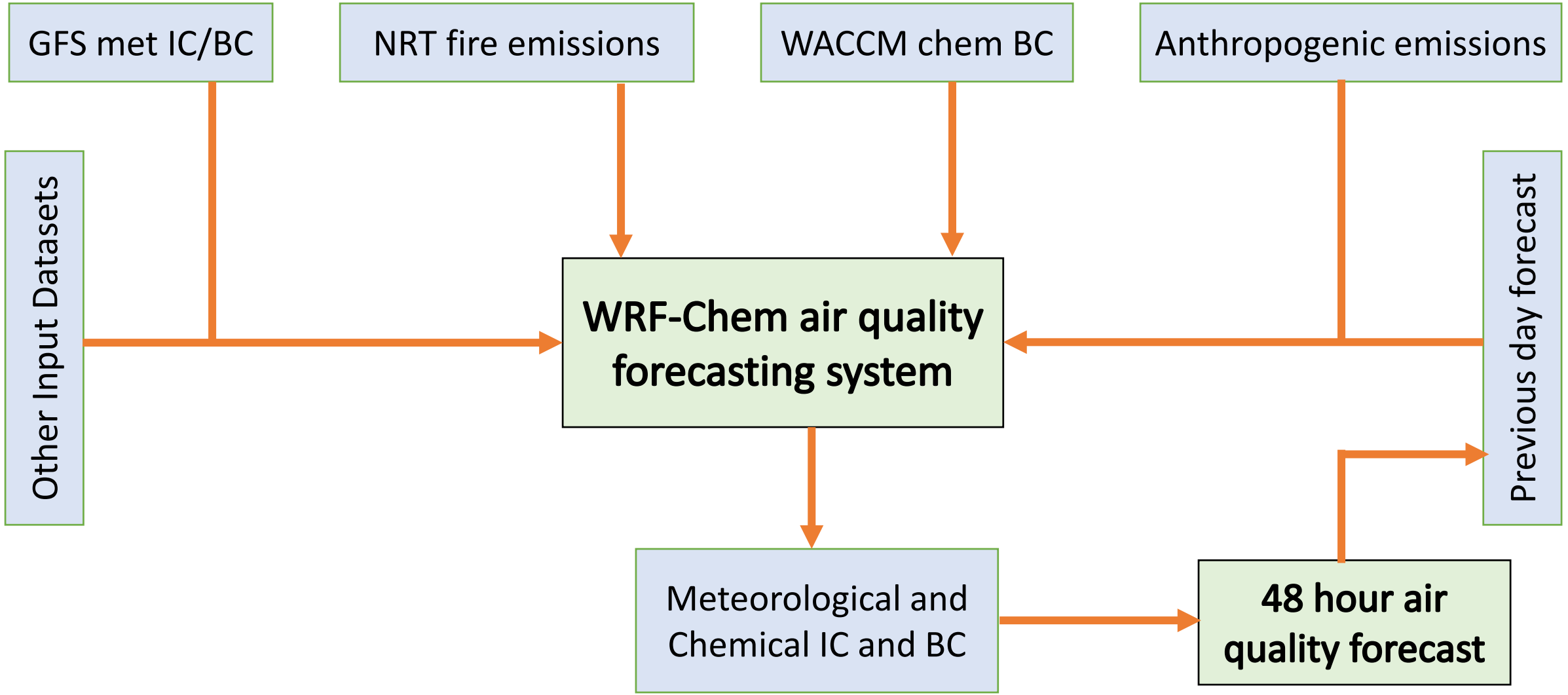
Air Quality Forecasting System for the CONUS

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

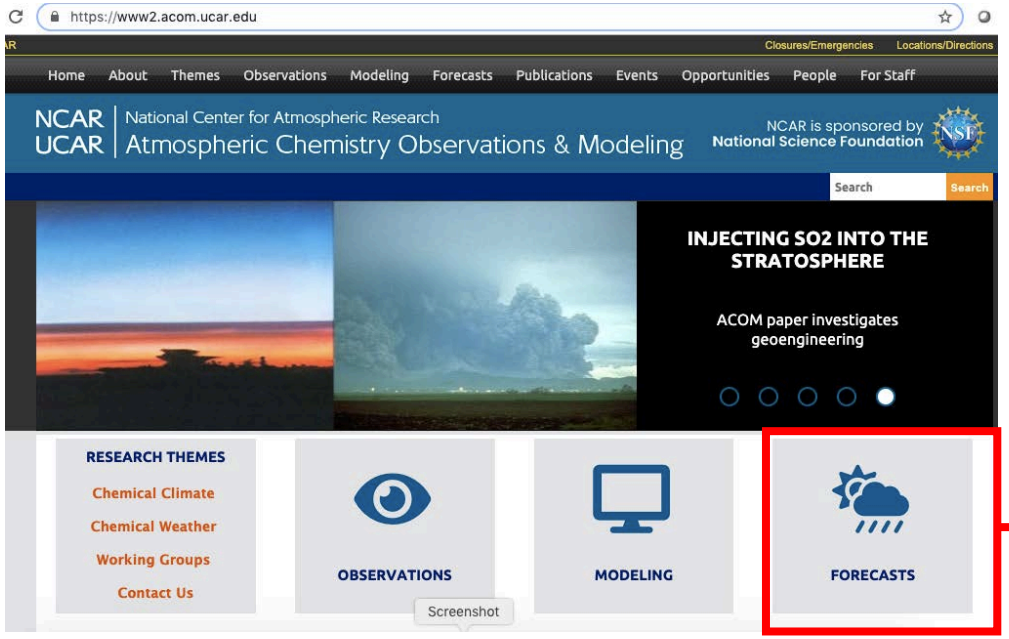
*Disclaimer: This is a research product and not intended for official guidance. For the operational U.S. air quality forecast please visit **https://airnow.gov/**. For information on air quality health effects and U.S. standards please visit **https://www.epa.gov/environmental-topics/air-topics**.*

CONUS Air Quality Forecasting System - Workflow



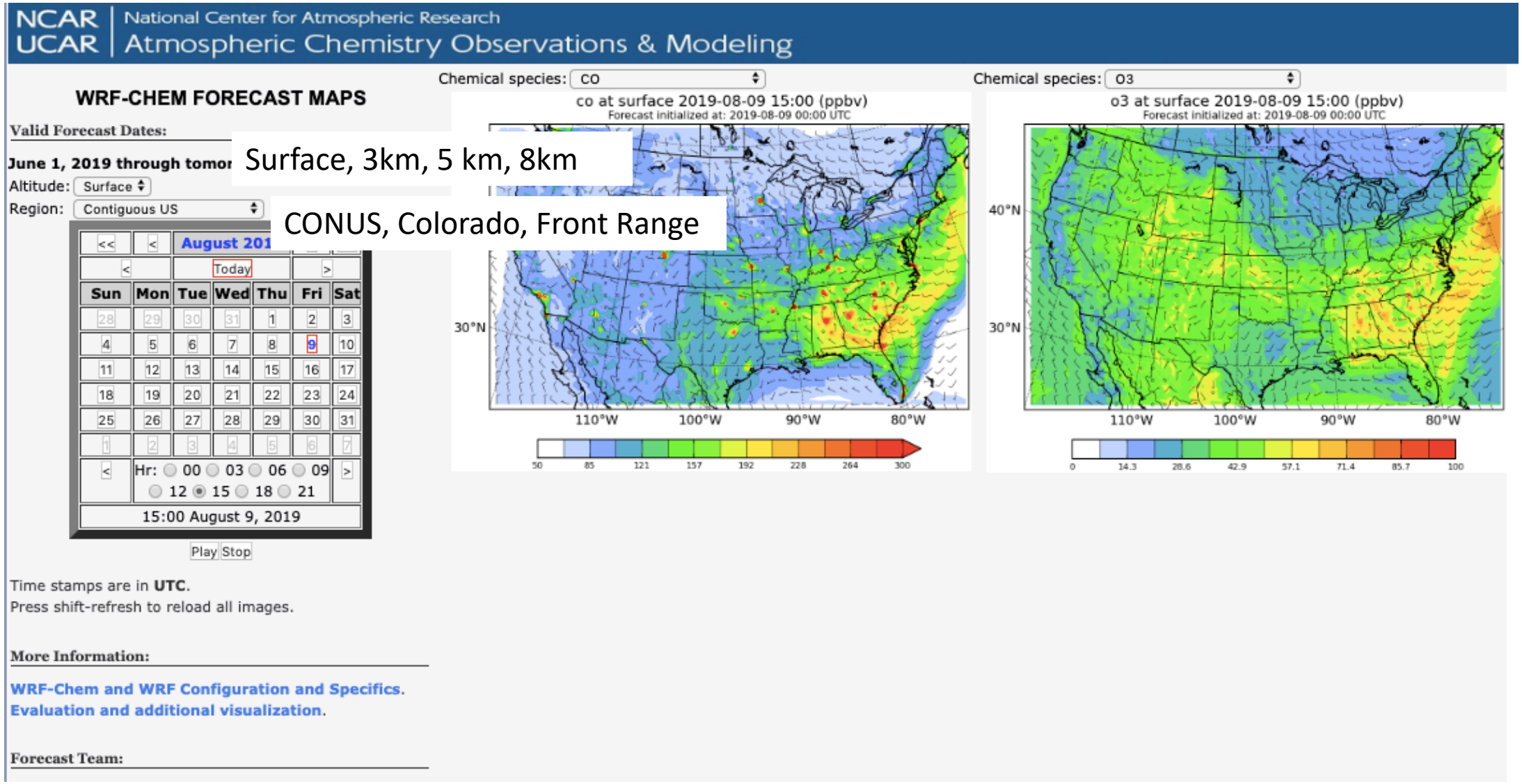
Dissemination of the CONUS AQ forecasts

NCAR ACOM website

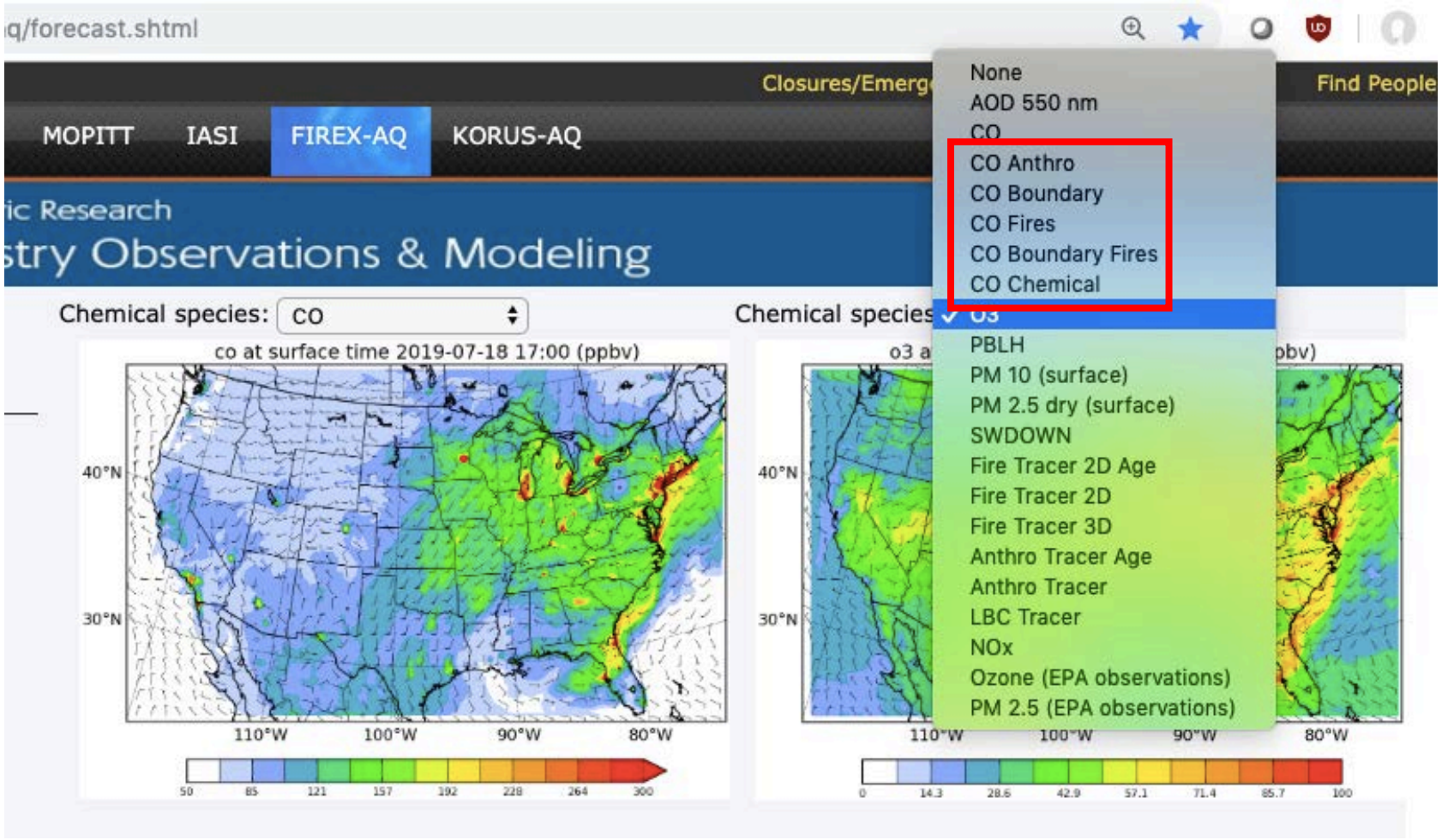


https://www2.acom.ucar.edu/acresp/forecasts-and-near-real-time-nrt-products

Dissemination of the CONUS AQ forecasts



Dissemination of the CONUS AQ forecasts

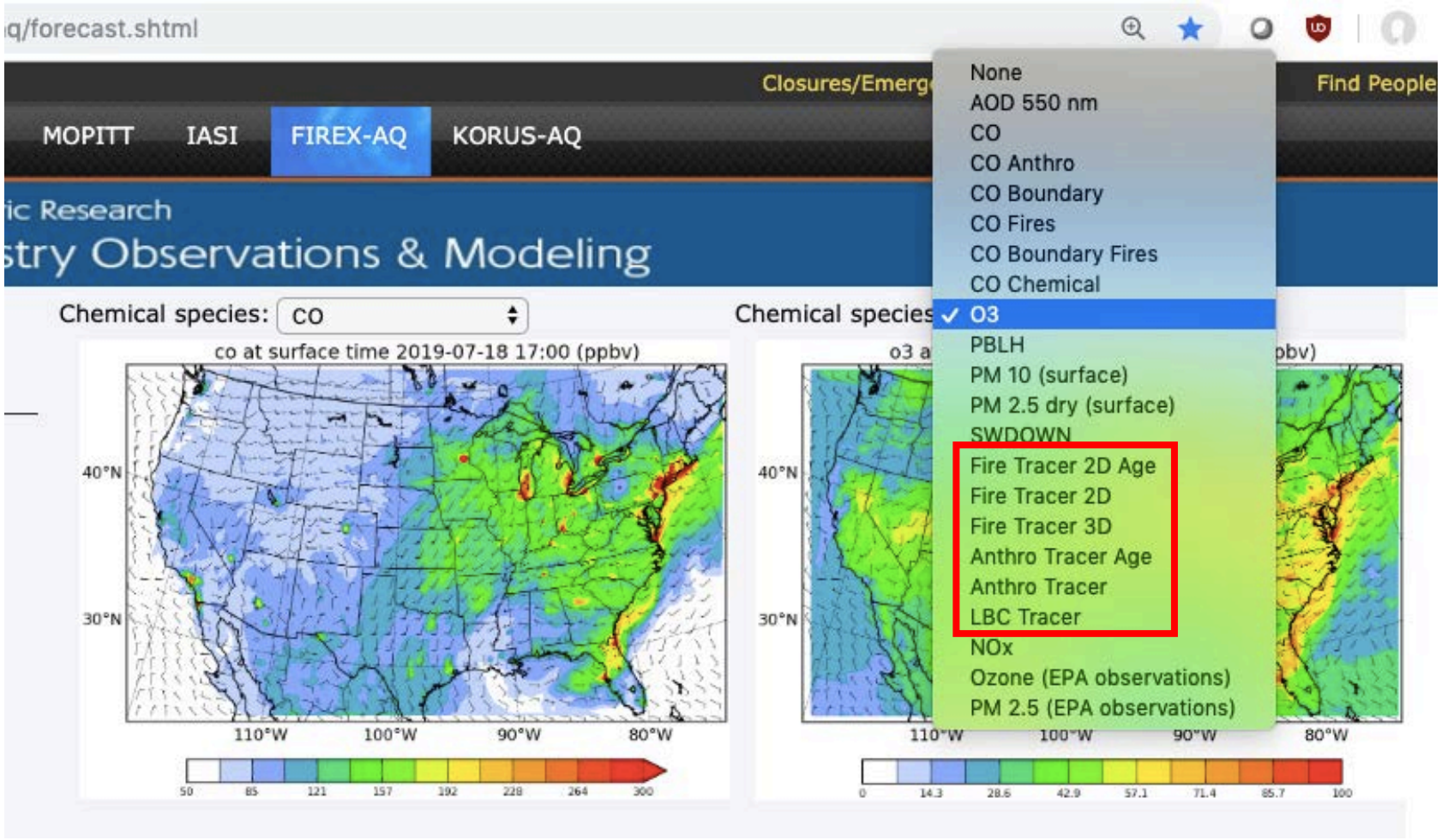


CO Tracers: keep track of CO and subjected to the same physical and chemical processing in the atmosphere as the standard model CO but do not affect the standard model physics or chemistry.

Tracers for:

- Anthropogenic and biomass burning emission sources located inside the domain
- Photochemical production of CO
- Background CO flowing into the domain

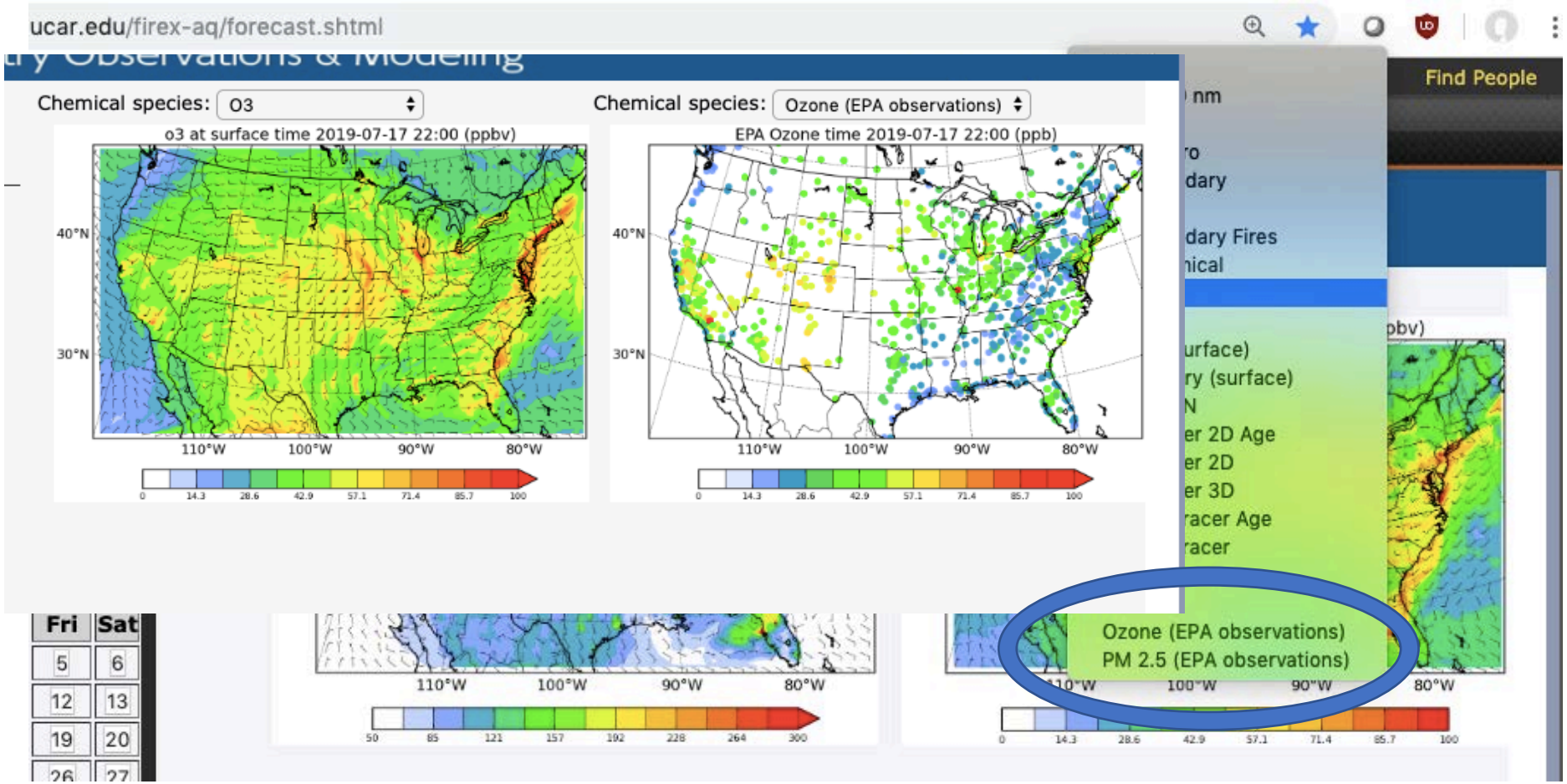
Dissemination of the CONUS AQ forecasts



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

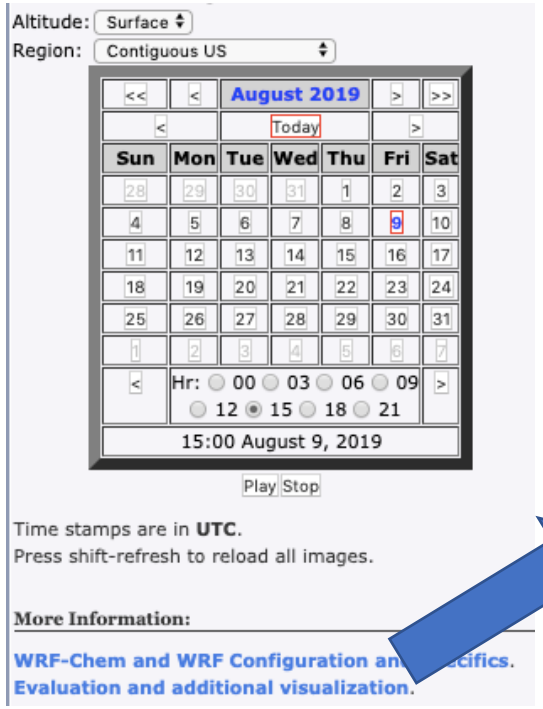
- 2D_Fire : Fire emissions in CONUS are emitted at surface
- 3D_Fire: Fire emissions in CONUS are distributed vertically through WRF-Chem plumerise code
- Anthro Tracer: Anthropogenic emissions from CONUS
- LBC Tracer: Inflow of CO emitted by fires outside the CONUS from the domain boundaries

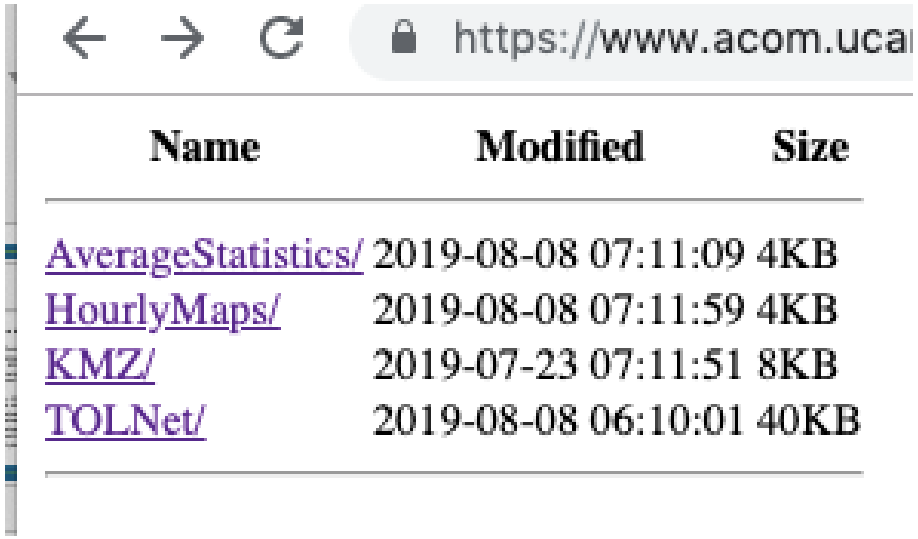
Near Real Time Evaluation of the CONUS AQ forecasts



Surface Observations are typically available a few hours past real-time

Evaluation and Additional Visualization





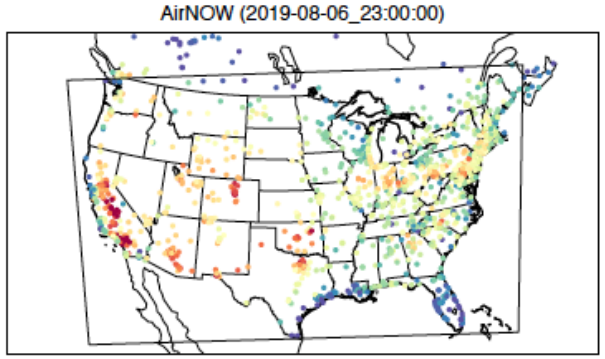
AverageStatictics: Observed and Modeled timeseries for entire domain average, individual EPA regions, all Colorado, Colorado Front Range & spatial statistics

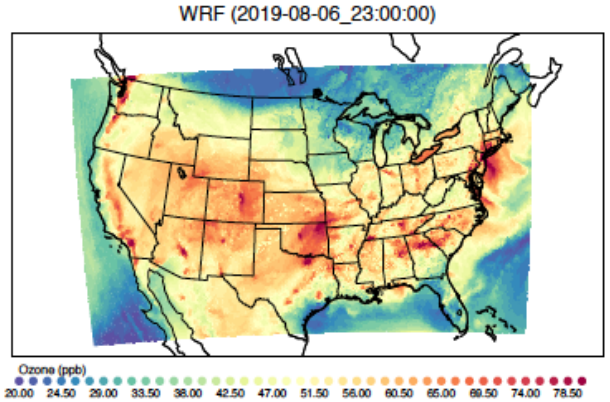
HourlyMaps: Hourly maps of observed and modeled surface ozone & PM2.5

KMZ: kmz files for 2D fire tracer

TOLNET: curtain plots for various parameters at 5 TOLNET sites (with Bo Wang, UHA)

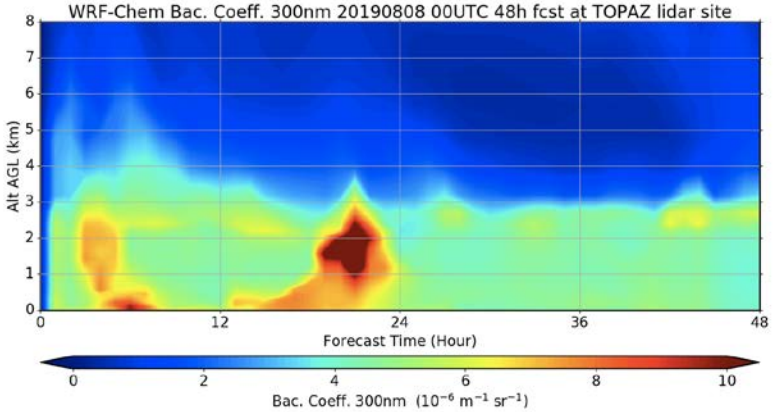
Evaluation and Additional Visualization

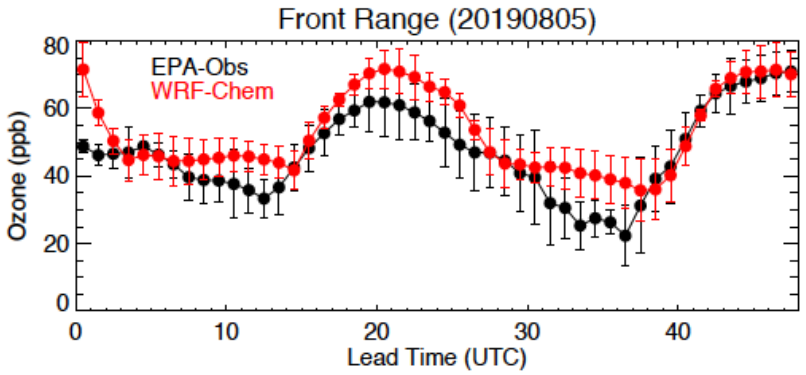


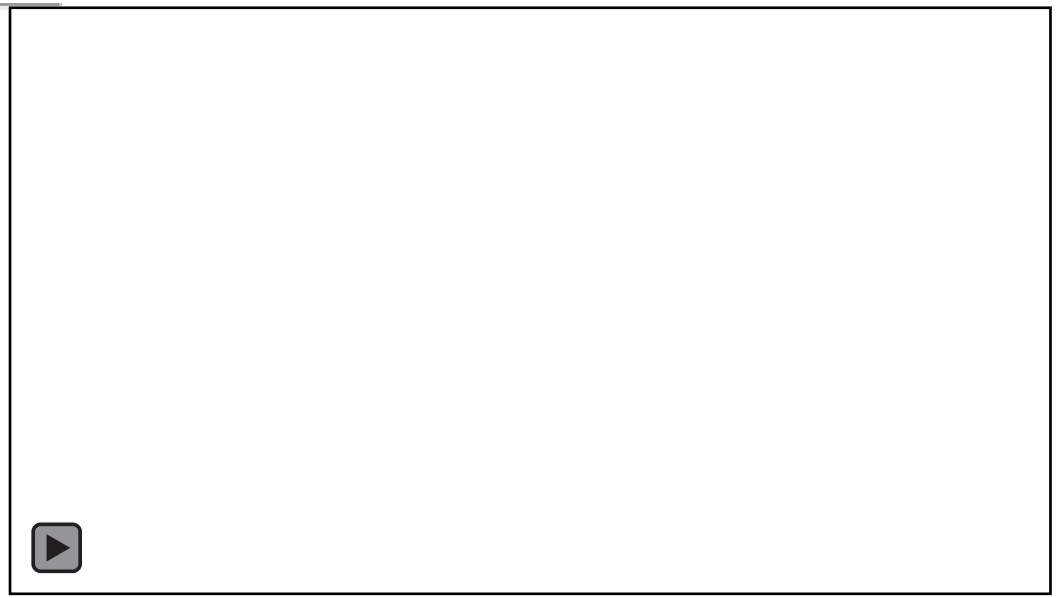


https://www.acom.ucar

Name	Modified	Size
AverageStatistics/	2019-08-08 07:11:09	4KB
HourlyMaps/	2019-08-08 07:11:59	4KB
KMZ/	2019-07-23 07:11:51	8KB
TOLNet/	2019-08-08 06:10:01	40KB

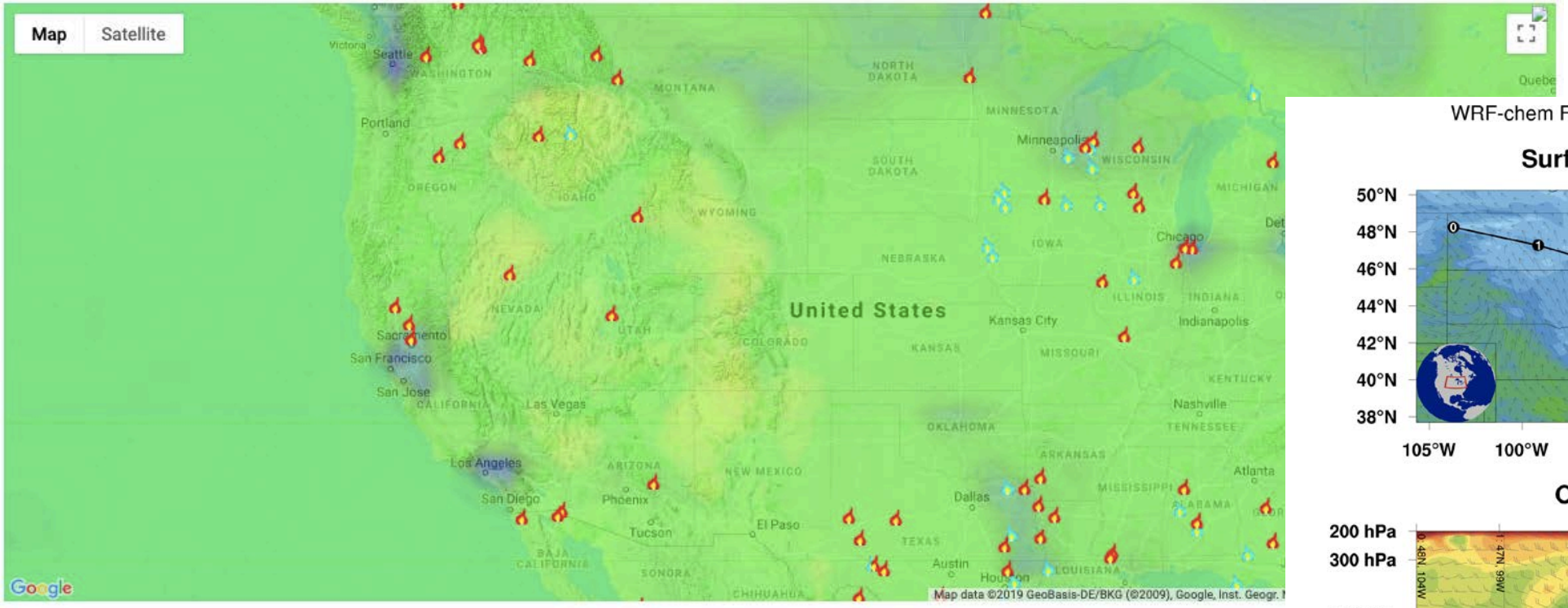






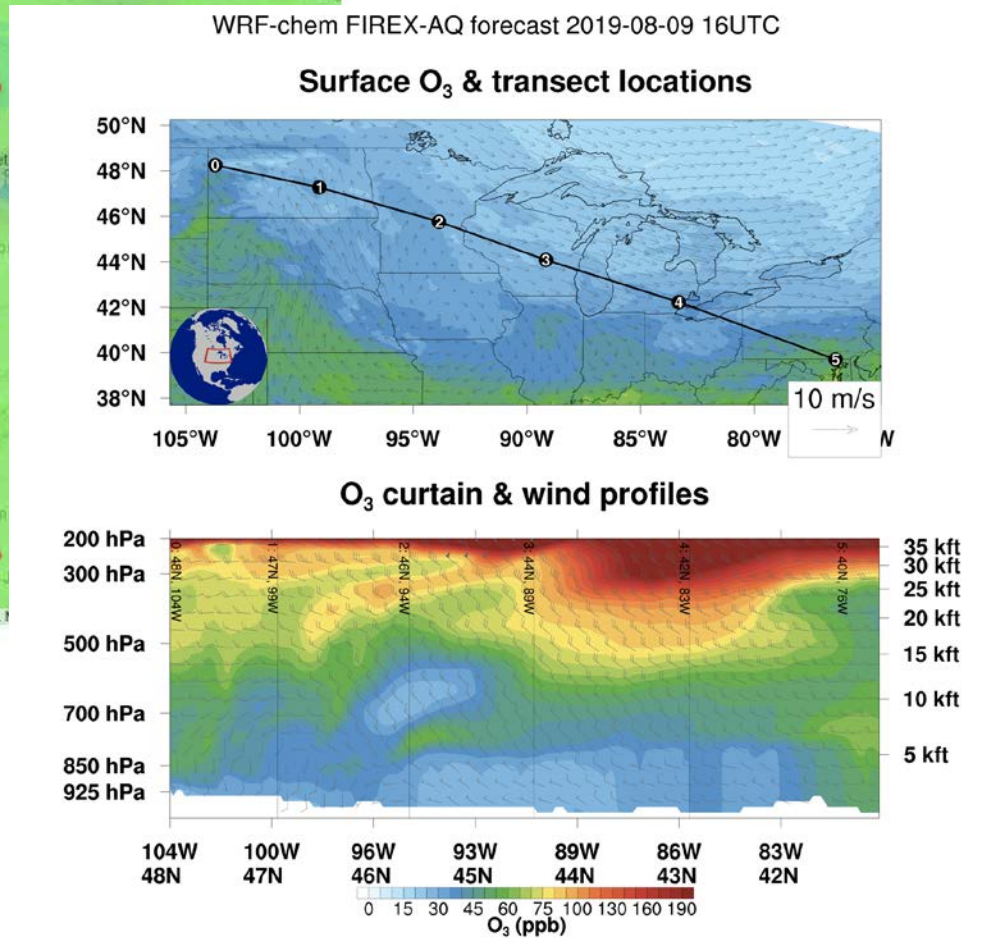
Custom made plots for FIREX-AQ

https://www.acom.ucar.edu/firex-aq/flight.shtml



Click on the map to accumulate points along the flight path. Plot Clear plot
Points (latitude, longitude, height in 1k feet):

Forecast date (yyyymmdd): 20190809 and hour (hh): 16 UTC
Show: fires. **Show chemical:** Ozone
This is an **experimental** display using WRF-Chem. What am I looking at?



Enter way points or click on map

Ongoing and Next Steps

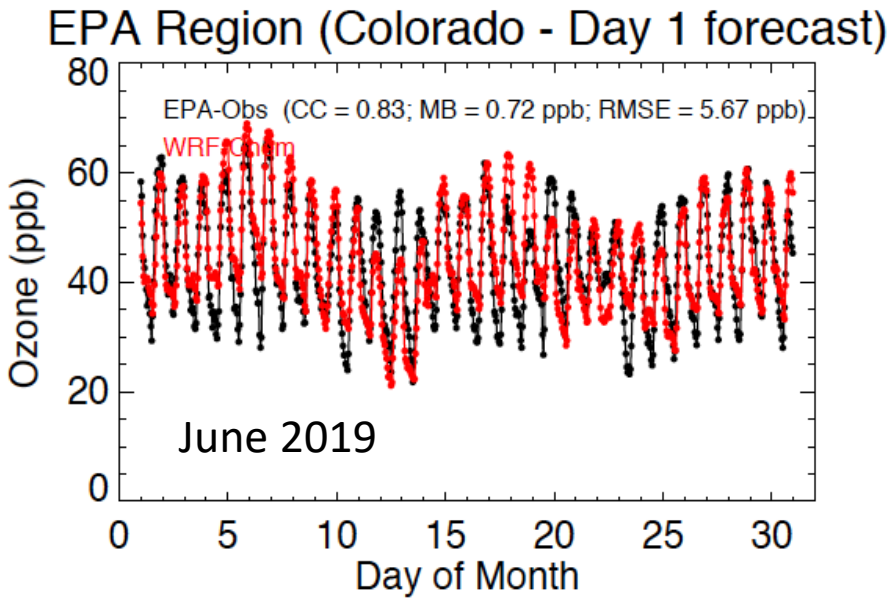
- Make monthly evaluation statistics public
  - Day-1 and Day-2 forecast and observed surface ozone and PM2.5 timeseries for each region
  - Spatial & temporal statistics for Day-1 and Day-2 forecasts for each region

- 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 !