DISCOVER-AQ and FRAPPÉ Forecast Activities

Compiled from input from different groups
The Air Pollution Control Division (APCD) of the Colorado Department of Public Health & Environment (CDPHE) Will Provide O3 Forecast Support

• 4 meteorologists at the APCD will continue to issue statewide and Front Range forecasts for O3 and other pollutants 7 days a week.

• These will include a 9 AM MDT update, a 24-36 hour forecast by 3 PM MDT, and a multi-day outlook (crafted specifically for FRAPPE and DISCOVER-AQ.)

• Meteorologist will also issue advisories for blowing dust, wildland fire smoke, stratospheric O3 intrusions, and any air quality event in Colorado.

• Forecasts are based on several synoptic and mesoscale meteorological models, a variety of satellite products, observations, in-house regression tools, and more than 7 decades of combined staff Colorado air quality forecasting experience. RAP HRRR best tool for 15-hour convection outlook.

• Forecasts and advisories are currently disseminated on our web pages and via listserves, AIRNow, local media, and hotlines. We can arrange for project-specific methods of distribution. A large number of wildfires will absorb much of our time.

Patrick Reddy/Gordon Pierce
DISCOVER-AQ Forecast Briefings

Meteorology

Forecast maps – NWS surface and NAM upper air; today and the next 3 days

NAM/MOS time series – Denver and Ft. Collins; today and next 3 days; T, TD, WS, WD, RH, POP, Sky cover

BUFKIT – NAM – time series of cloud amount by altitude, precip, and PBLH – next 3 days

PBLH from NOAA/ARL WRF-ARW

Wind fields at several sigma levels from NOAA/ARL WRF-ARW

Cloud forecast maps – NAM, GFS, Canadian, GEOS-5

NWS forecaster comments/advice

Fly/no-fly recommendations

Ken Pickering
Air Quality

Air quality yesterday – surface station $O_3$ observations

Air quality forecast maps – NOAA/ARL CMAQ products – $O_3$, $NO_2$, HCHO today and tomorrow

Ozone forecasts from State agency – today, tomorrow, beyond?

Air quality yesterday – surface station $PM_{2.5}$ observations

AERONET and MODIS AOD – yesterday

Air quality forecast maps – NOAA/ARL CMAQ product – surface $PM_{2.5}$

Air quality forecast maps and time series – GEOS-5 aerosol extinction, AOD, mass concentrations by aerosol type

$PM_{2.5}$ forecasts from State agency – today, tomorrow, beyond?
Forecast Schedule

8 - 10 AM  Review meteorological and air quality model products
10 - 11 AM  Consult with NWS forecaster and CDPHE air quality forecaster
11 AM – 1 PM  Prepare/finalize briefing
1 PM  Conduct briefing
NAQFC-forecasting support: Initialized at 00 UTC with 60 hours forecast duration

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<th>WRF-ARW</th>
<th>Both North America (12 km) &amp; CONUS (4 km)</th>
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<td>Map projection &amp; grid</td>
<td>Lambert Conformal &amp; Arakawa C staggering</td>
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<td>Vert. co-ordinate</td>
<td>42 σ-p unevenly spaced levels</td>
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<td>advection</td>
<td>RK3 (Skamarock and Weisman (2008))</td>
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<td>SW &amp; LW radiation</td>
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<td>Betts-Miller-Janjic Mass adjustment</td>
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<th>CMAQ4.7.1</th>
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<td>Gas chemistry</td>
<td>Cb05 with 156 reactions</td>
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<td>Aerosol chemistry</td>
<td>Aero5 with updated evaporation enthalpy</td>
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<td>Anthropogenic emission</td>
<td>2005NEI as base year, mobile projected using AQS*, area and off-road used CSPR^, point source uses 2012 CEM data</td>
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<td>Biogenic emission</td>
<td>BEIS-3.14</td>
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<td>Lateral BC</td>
<td>RAQM (B. Pierce)</td>
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Forecast: 12 km nested to 4 km

CMAQ4.7.1:
- Both CONUS (12 km) & DISCOVER-AQ/FRAPPE (4 km)
- Lambert Conformal & Arakawa C staggering
- 42 σ-p unevenly spaced levels
- Cb05 with 156 reactions
- Aero5 with updated evaporation enthalpy
- 2005NEI as base year, mobile projected using AQS*, area and off-road used CSPR^, point source uses 2012 CEM data
- BEIS-3.14
- RAQM (B. Pierce)

Air Resources Laboratory/NOAA: DISCOVER-AQ/FRAPPÉ preparation meeting, April 3 2014, Boulder

Ken Pickering
NOAA Experimental CMAQ Forecast for Today from 06Z (1 AM CDT)

3 PM

NOAA Experimental CMAQ Forecast for Today from 06Z (1 AM CDT)

5 PM

NOAA Experimental CMAQ Forecast for Today from 06Z (1 AM CDT)
Conroe profile well forecast

CMAQ missed elevated O₃ layer

O₃ maximum to NNW of Houston well forecast
Global 5-day chemical forecasts customized for each campaign
- O3, aerosols, CO, CO₂, SO₂
- Resolution: Nominally 25 km

Driven by real-time biomass emissions from MODIS

Assimilated aerosols interacts with circulation through radiation

http://gmao.gsfc.nasa.gov/forecasts/

Ken Pickering
# GEOS-5 Atmospheric Data Assimilation System

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<tr>
<th>Feature</th>
<th>Description</th>
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<tr>
<td><strong>Model</strong></td>
<td>GEOS-5 Earth Modeling System, with GOCART coupled to radiation parameterization</td>
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<td><strong>Fire Emissions</strong></td>
<td>QFED: Daily, NRT, MODIS FRP based</td>
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<tr>
<td><strong>Met Data Assim</strong></td>
<td>Full NWP observing system (uses GSI)</td>
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<tr>
<td><strong>Aerosol Data Assim</strong></td>
<td>Local Displacement Ensembles (LDE) MODIS reflectances (Aqua &amp; Terra) AERONET Calibrated AOD’s (Neural Net) Stringent cloud screening</td>
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<tr>
<td><strong>Forecasts</strong></td>
<td>5 day forecasts twice daily: 0Z an 12Z</td>
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<tr>
<td><strong>Resolution</strong></td>
<td>nominally 25 km, 72 layers, top ~85 km</td>
</tr>
<tr>
<td><strong>Aerosol Species</strong></td>
<td>Dust, sea-salt, sulfates, organic &amp; black carbon</td>
</tr>
<tr>
<td><strong>Carbon Species</strong></td>
<td>CO$_2$, CO with several tagged tracers</td>
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</table>
QFED: Quick Fire Emission Dataset

- Near real time estimates based on MODIS Fire Radiative Power (AQUA/TERRA)
- Current focus on MODIS
- Through Joint Center for Satellite Data Assimilation (JCSDA) collaborating with NOAA/STAR on the inclusion of data from
  - Geostationary
  - VIRS
- Plume Rise model (Freitas et al.)
  - Driven by GEOS-5 meteorology
  - Under tuning/validation

QFED relies on LANCE MODIS Level 2 Fire Data

Ken Pickering
GEOS-5 aerosol forecast from 00 UT 14 Sept.

GEOS-5 global model at 0.25 deg. resolution; GOCART aerosols, CO, SO$_2$; includes assimilation of MODIS AOD

Run by Arlindo da Silva at NASA/GSFC
High AOD associated with agricultural fire plumes from Mississippi Valley. Back door cold front pushed smoke over Houston. No real impact seen in surface PM2.5.
Simulations of DISCOVER-AQ/FRAPPE period with CMAQ and WRF-Chem:

36, 12, 4 km resolution domains (perhaps 1.3-km if necessary)
Use best available emission inventories

Evaluate WRF meteorology using:
  Surface stations, sondes, tethered balloon, wind profilers, aircraft
Evaluate chemistry and emissions through comparisons with
  P-3B and C-130 in-situ data, surface in-situ data,
  Pandora and AERONET remote sensing data

Evaluate model column vs. surface correlations against those from observations

Evaluate spatial and temporal variability in model vs. that in observations

Ken Pickering
FRAPPÉ Forecast Briefings

Jointly with DISCOVER-AQ

Additional Met & Chemistry Products

Short-term forecasts for aircraft and mobile vans

Decisions on Flight Day and Flight Pattern for C-130
  • up to 3-5 days out
  • Special events (LRT, fires, ...), transport/flow patterns, emission flight conditions,....
FRAPPÉ Forecast Products

Satellite Products
• FINN near-realtime fire emissions (based on MODIS fire counts) (NCAR/ACD)
• MOPITT CO (within 1 day of overpass) (NCAR/ACD)
• IASI CO (~ 4-day delay) (NCAR/ACD)

Met Forecasts
• WRF with assimilation (NCAR-RAL)
  3DVar (no radar DA, 3h UC/12h fcst/1km)
  3DVar (with radar DA, 1h UC/12h fcst)
  4DVar (with radar DA, 3h UC/12h fcst)
  RTFDDA (with radar DA, 3h UC/24h fcst)

Chemical/Tracer Forecasts
• MOZART-4 global, 5-day forecast (NCAR)
  • Full chemistry at 1.9°x2.5° (possibly assimilation of CO)
  • Tracer forecasts at 0.5°x0.5° (CO, isoprene-like, ....)
• RAQMS (NOAA/NESDIS)
  • Global 1x1 degree on-line chemical and aerosol assimilation and forecasting system
  • Assimilation of MODIS AOD, MLS stratospheric O₃ profiles and OMI total O₃
• WRF-Chem (NOAA/ESRL)
  • WRF-Chem on RAPid refresh (RAP) 13km domain; 48 hour forecast
• WRF-Chem Tracers (NCAR/ACD) - added to RTFDDA
• FLEXPART (NCAR/ACD): Forward trajectories for defined sources
Global Modeling, Fire Emissions and Satellite Support for FRAPPÉ

Louisa Emmons, Christine Wiedinmyer, & MOPITT team
Fire Emissions

Fire INventory from NCAR (FINN)

- Daily fire emissions of trace gases and particles
- FINN is run in real-time based on MODIS Rapid Response fire counts
  [http://www.acd.ucar.edu/acresp/forecast/fire-emissions.shtml](http://www.acd.ucar.edu/acresp/forecast/fire-emissions.shtml)
- Plots and data files available for forecasts and hindcasts

Additional fire products will be compiled:
NASA QFED
NOAA HMS
...
MOZART-4 driven by GEOS-5

Full chemistry at 1.9°x2.5°

http://www.acd.ucar.edu/acresp/forecast/

5-day forecasts, hourly output, currently operational
MOZART-4 Tracers

Forecasts of tracers only at 0.5° horizontal resol.

- Isoprene-like tracer based on MEGAN isoprene emissions
- Anthropogenic NOx tracer from individual cities and/or regions
- Fire CO tracer for various regions
- Others?
- Similar to forecasts for DC3 ([http://www.acd.ucar.edu/acresp/dc3/](http://www.acd.ucar.edu/acresp/dc3/)), will be run specifically for FRAPPE
Chemistry Satellite Observations

- MOPITT CO – available within a day of overpass
- IASI CO – about 4-day delay, global coverage 2x/day
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Real-time Air Quality Modeling System (RAQMS)

- Global 1x1 degree on-line chemical and aerosol assimilation and forecasting system
- Assimilation of MODIS aerosol optical depth, MLS stratospheric ozone profiles and OMI cloud cleared total column ozone
- MODIS fire detection and Ecosystem/Severity dependent fire emissions
- Real-time verification using US EPA AIRNow surface ozone and PM2.5 measurements

Currently used to initialize real-time 8km WRF-CHEM forecast (GOCART aerosol mechanism, [http://raqms.ssec.wisc.edu/](http://raqms.ssec.wisc.edu/)) and 13km RAP-chem forecast (RACM chemical and MOSAIC aerosol mechanisms, [http://ruc.noaa.gov/wrf/WG11_RT/](http://ruc.noaa.gov/wrf/WG11_RT/))
Forecasting weather and air quality with RAP-Chem

- RAP-Chem = WRF-Chem on RAPid refresh (RAP) domain
- Dx=13km, RAP is operational at NCEP with hourly forecast cycle (meteorology only)
- Experimental RAP-Chem:
  - Includes gas-phase chemistry (O3), aerosols (modal approach), Secondary Organic Aerosols (SOA, Volatility Basis Set approach)
  - Includes also wildfires, volcanic ash (if major eruption within North American Grid), dust, sea salt
  - Aerosol interaction with radiation (microphysics interactions may also be included)
  - Chemical boundary conditions from RAQMS or MACC – still to be decided
  - NEI 2011 emissions
  - Produce AQ forecasts and work towards improving weather forecasts
  - 48-hr forecasts
  - Currently on display: O3 (various levels), Nox, CO, HCHO, PM25, OA, Precipitation. Three cross-sections. More possible.
Basic domains, additional Colorado zoom would be possible

Full RAP domain

Example of CONUS zoomed domain

Ozone mixing ratio (ppbv)

Georg Grell
STEP - Short Term Explicit Prediction
Summary of DA/NWP systems

Outside systems:
- NSSL (3DVar with radar DA, 1h UC*/12h fcst)
- GSD/FAB (LAPS with radar DA, 1h UC/12h fcst)
- UK MetOffice (UM-WRF, 6h UC/36h fcst)

Note:
- Each organization will run their own system
- No extra resource required from NCAR

NCAR systems:
- WRF 3DVar (no radar DA, 3h UC/12h fcst/1km)
- WRF 3DVar (with radar DA, 1h UC/12h fcst)
- WRF 4DVar (with radar DA, 3h UC/12h fcst)
- RTFDDA (with radar DA, 3h UC/24h fcst)

* UC – Update Cycle

Jenny Sun/David Gochis
Project Timeline

Feb
- Finalize domains and configurations of each subsystem

Mar
- System Installation

Apr
- Pre-operational testing of each subsystem
  - Yellowstone:
    - Account
    - Dedicated cores
    - Disk space
    - Data transfer

May
- Initial version of web display

June
- Finalize web display

July
- Data transfer and display of outside systems

Aug
- Finish real-time data flow for all obs.
- STEP hydromet 2014 (7 July – 15 August)

Jenny Sun/David Gochis
Suggested Tracers:

- Anthropogenic tracer (NOx like) (area, non-road, point sources)
- Mobile tracer (NOx like)
- Oil & Gas tracer (ethane like)
- Agricultural tracer (emission info needed)

WRF-Chem Tracers
Add to 3km STEP Forecast
Inert with specified lifetime
Lagrangian particle dispersion products with FLEXPART

- trajectories from ground stations / aircraft paths
- forward and backward in time
- based on GFS (global) and WRF (regional) model forecasts / analysis
- can be convolved with emissions

Christoph Knote/Rajesh Kumar
Satellite NO$_2$ Columns: May-Sep. 2010
Morning Orbit

Si-Wan Kim, NOAA/ Andreas Richter, U. of Bremen
Satellite NO₂ Columns: May-Sep. 2010
Afternoon Orbit

Si-Wan Kim, NOAA/ Andreas Richter, U. of Bremen
SCIAMACHY NO$_2$ Columns: May-Sep. 2010
Dots: Oil and Gas Wells

Si-Wan Kim, Gabrielle Petron, Gregory Frost, NOAA