

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.



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



DISCOVER-AQ Forecast Briefing



Air Quality

Air quality yesterday – surface station O₃ observations

**Air quality forecast maps – NOAA/ARL CMAQ products – O₃, NO₂, 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

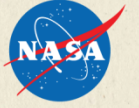
Air quality forecast maps – NOAA/ARL CMAQ product – surface PM_{2.5}

**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



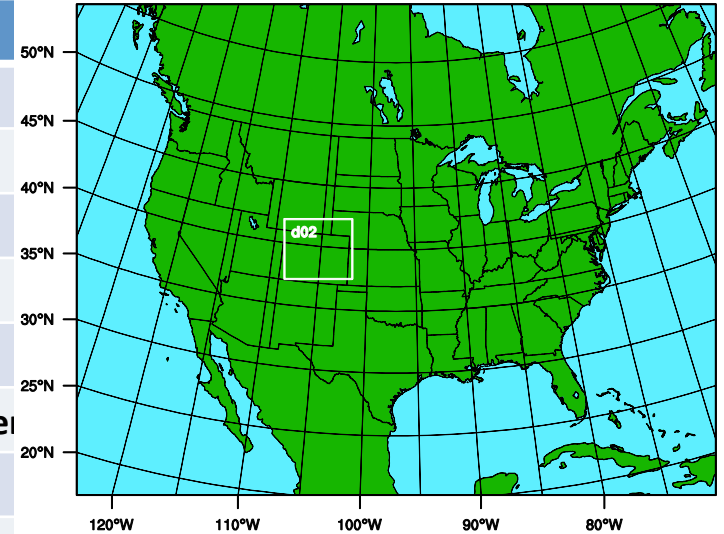
- | | |
|---------------------|---|
| 8 - 10 AM | Review meteorological and air quality model products |
| 10 - 11 AM | Consult with NWS forecaster and CDPHE air quality forecaster |
| 11 AM – 1 PM | Prepare/finalize briefing |
| 1 PM | Conduct briefing |



NAQFC-orecasting support: Initialized at 00 UTC with 60 hours forecast duration

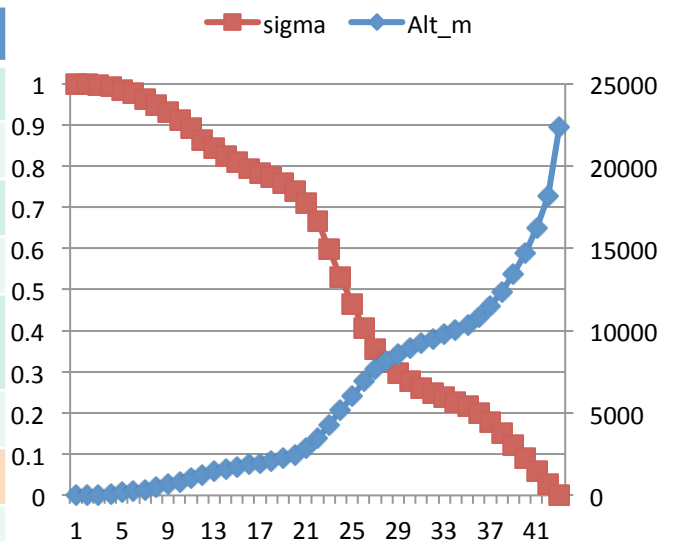


WRF-ARW	Both North America (12 km) & CONUS (4 km)
Map projection & grid	Lambert Conformal & Arakawa C staggering
Vert. co-ordinate	42 σ-p unevenly spaced levels
advection	RK3 (Skamarock and Weisman (2008))
SW & LW radiation	RRTMG (Iacono et al. 2008))
PBL Physics	Mellor-Yamada-Janjic (MYJ) level 2.5 closure
Surface layer scheme	Monin-Obukhov Similarity with viscous sub-layer
Land Surface Model	NCEP Noah
Cloud Microphysics	Thompson et al. (2008)
Cloud convective mixing	Betts-Miller-Janjic Mass adjustment



Forecast: 12 km nested to 4 km

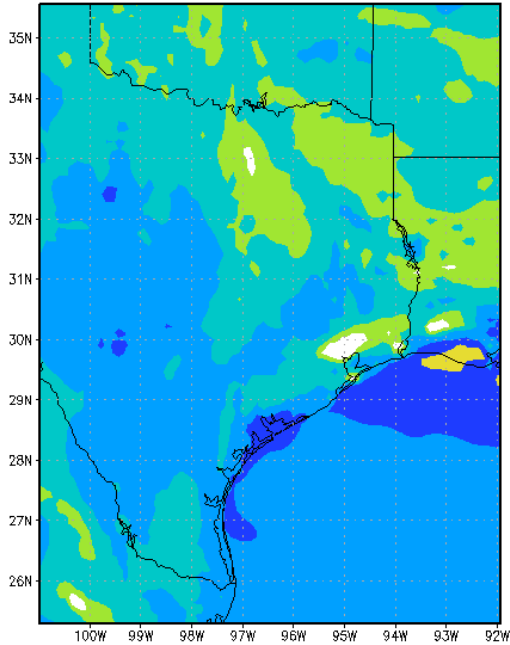
CMAQ4.7.1	Both CONUS(12 km) & DISCOVER-AQ/FRAPPE (4 km)
Map projection & grid	Lambert Conformal & Arakawa C staggering
Vert. co-ordinate	42 σ-p unevenly spaced levels
Gas chemistry	Cb05 with 156 reactions
Aerosol chemistry	Aero5 with updated evaporation enthalpy
Anthropogenic emission	2005NEI as base year, mobile projected using AQS*, area and off-road used CSPR^, point source uses 2012 CEM data
	WRAP oil and gas emissions data
Biogenic emission	BEIS-3.14
Lateral BC	RAQM (B. Pierce)



42 vertical layers

03 [ppb] at 1013 [hPa] Valid 14Z SEP 26 2013

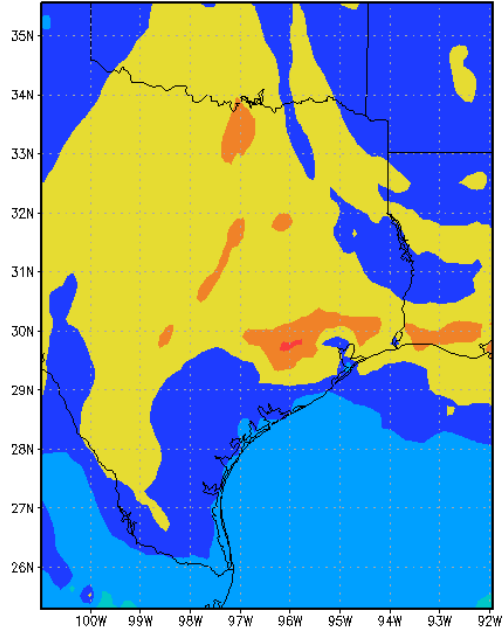
9 AM



03 [ppb] at 1013 [hPa] Valid 17Z SEP 26 2013

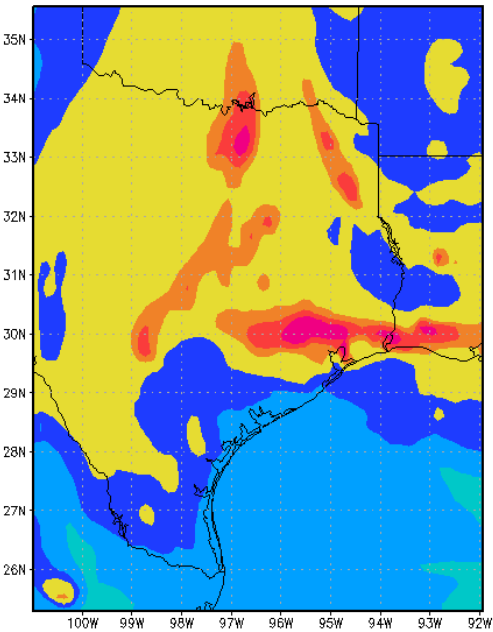
12 PM

Forecast from
06Z SEP 25



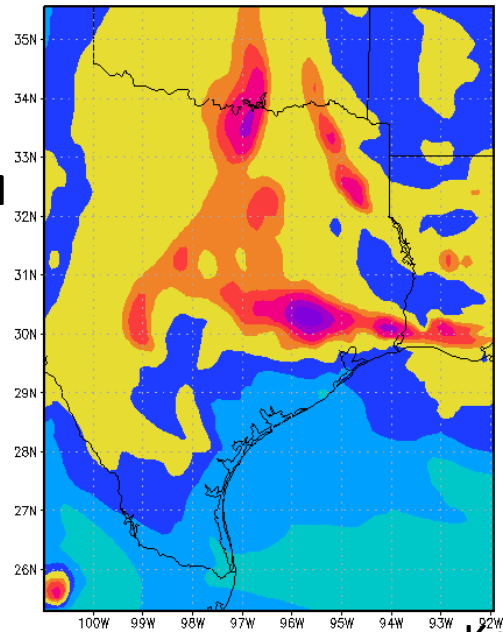
03 [ppb] at 1013 [hPa] Valid 19Z SEP 26 2013

2 PM

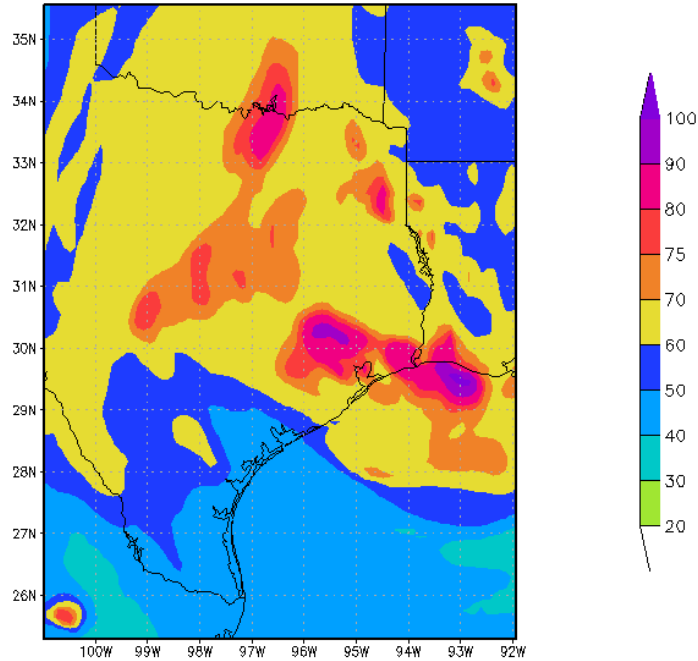


03 [ppb] at 1013 [hPa] Valid 22Z SEP 26 2013

5 PM




O3 [ppb] at 1013 [hPa] Valid 20Z SEP 26 2013



GRADS: COLA/IGES

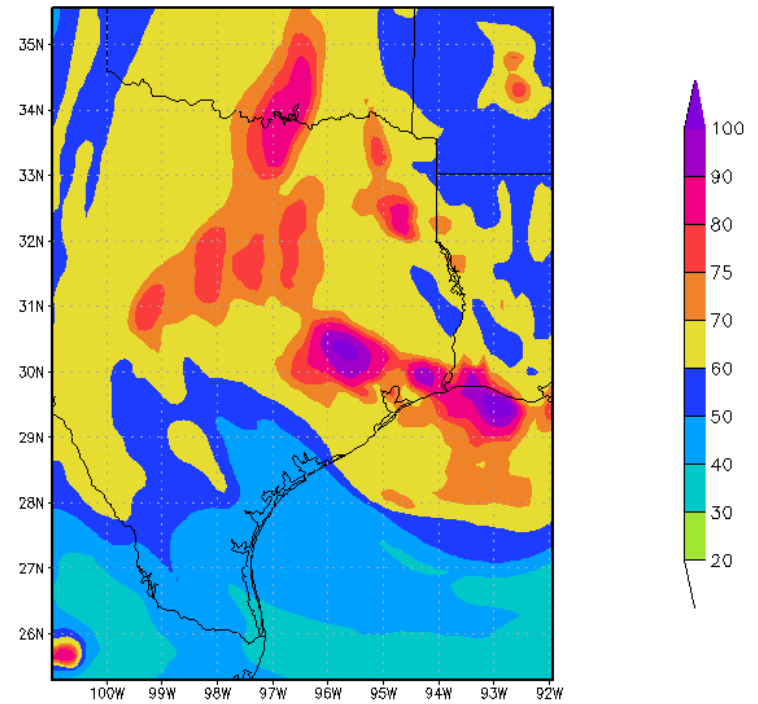
3 PM



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

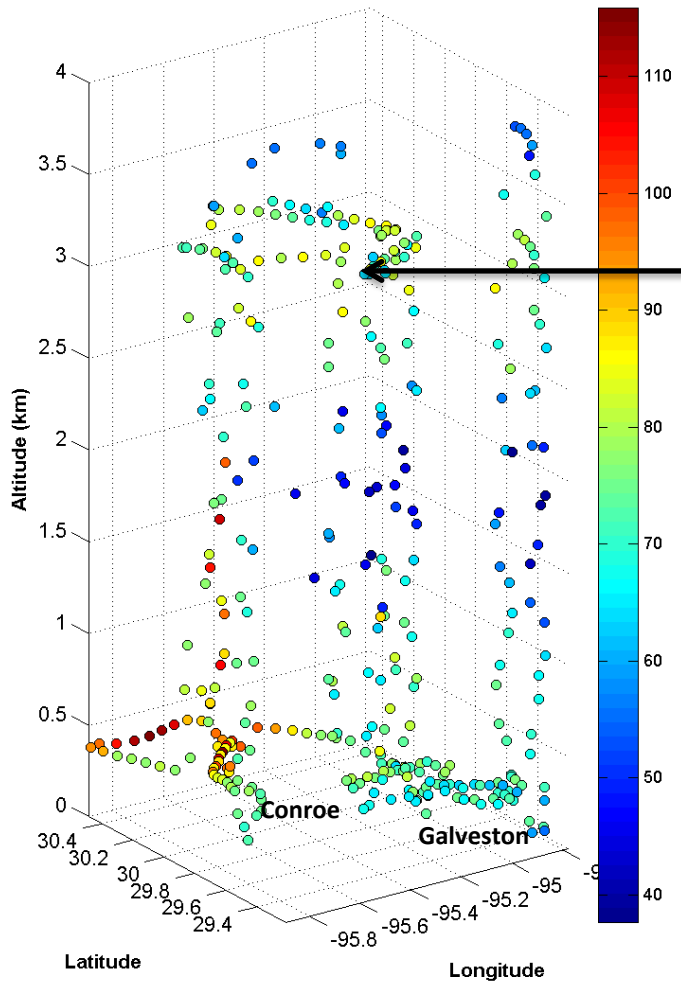
5 PM

O3 [ppb] at 1013 [hPa] Valid 22Z SEP 26 2013

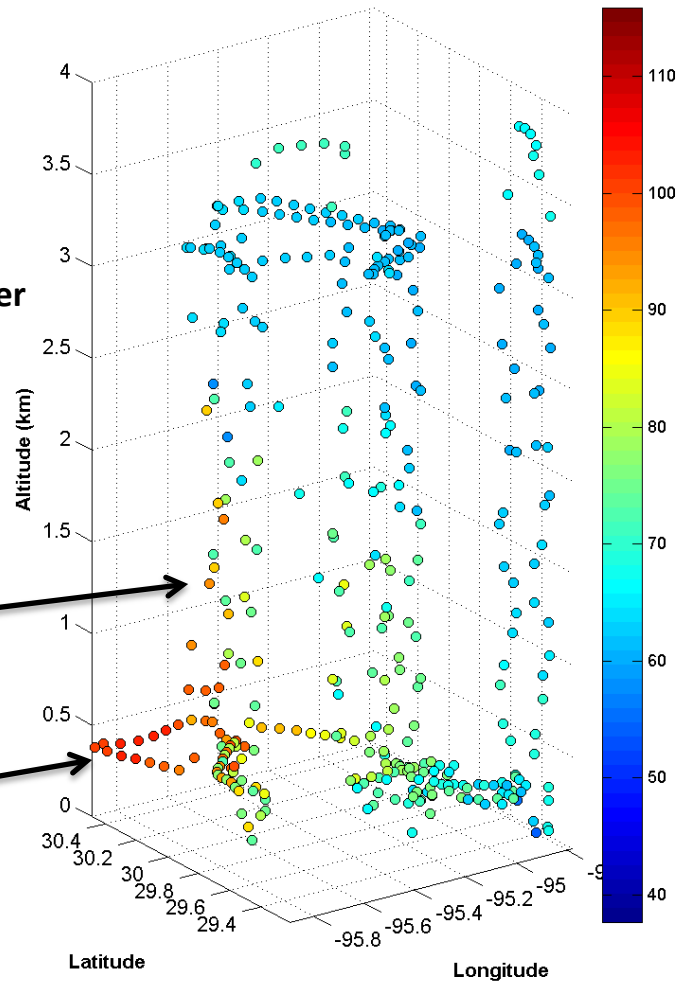


GRADS: COLA/IGES

In situ Flight Track
O₃ MixingRatio (ppbV) for mrg60
DISCOVER-AQ Flight on 09/26/13



CMAQ Flight Track
O₃ MixingRatio (ppbV) for mrg60
DISCOVER-AQ Flight on 09/26/13



CMAQ missed elevated O₃ layer

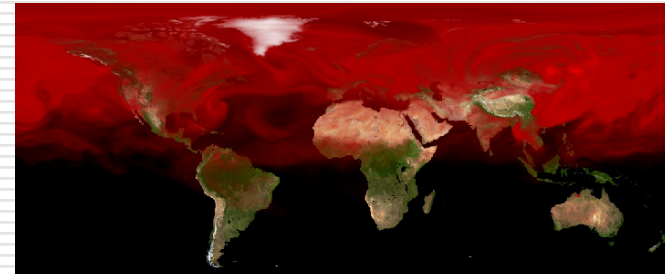
Conroe profile well forecast

O₃ maximum to NNW of Houston well forecast

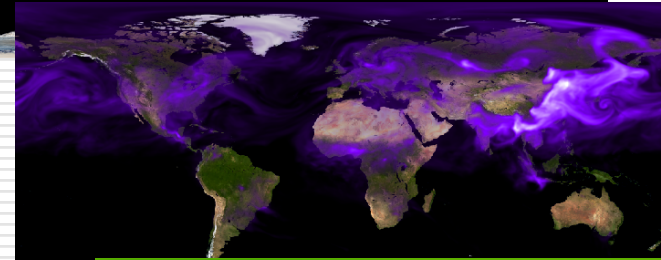
GEOS-5 Forecasting Support

DISCOVER-AQ

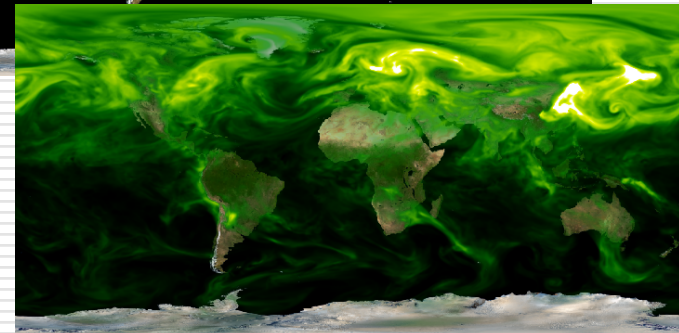
- ❑ Global 5-day chemical forecasts customized for each campaign
 - O₃, aerosols, CO, CO₂, SO₂
 - Resolution: **Nominally 25 km**
- ❑ Driven by real-time biomass emissions from MODIS
- ❑ Assimilated aerosols interacts with circulation through radiation



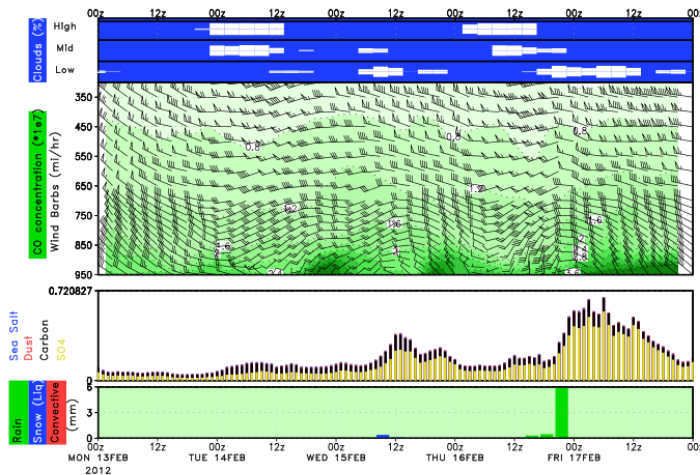
CO



Smoke

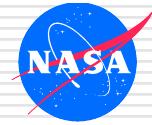


SO₄



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

GEOS-5 Atmospheric Data Assimilation System



Feature	Description
Model	GEOS-5 Earth Modeling System, with GOCART coupled to radiation parameterization
Fire Emissions	QFED: Daily, NRT, MODIS FRP based
Met Data Assim	Full NWP observing system (uses GSI)
Aerosol Data Assimilation	Local Displacement Ensembles (LDE) MODIS reflectances (Aqua & Terra) AERONET Calibrated AOD's (Neural Net) Stringent cloud screening
Forecasts	5 day forecasts twice daily: 0Z an 12Z
Resolution	nominally 25 km, 72 layers, top ~85 km
Aerosol Species	Dust, sea-salt, sulfates, organic & black carbon
Carbon Species	CO ₂ , CO with several tagged tracers

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 Sattelite Data Assimilation (JCSDA) collabotating 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

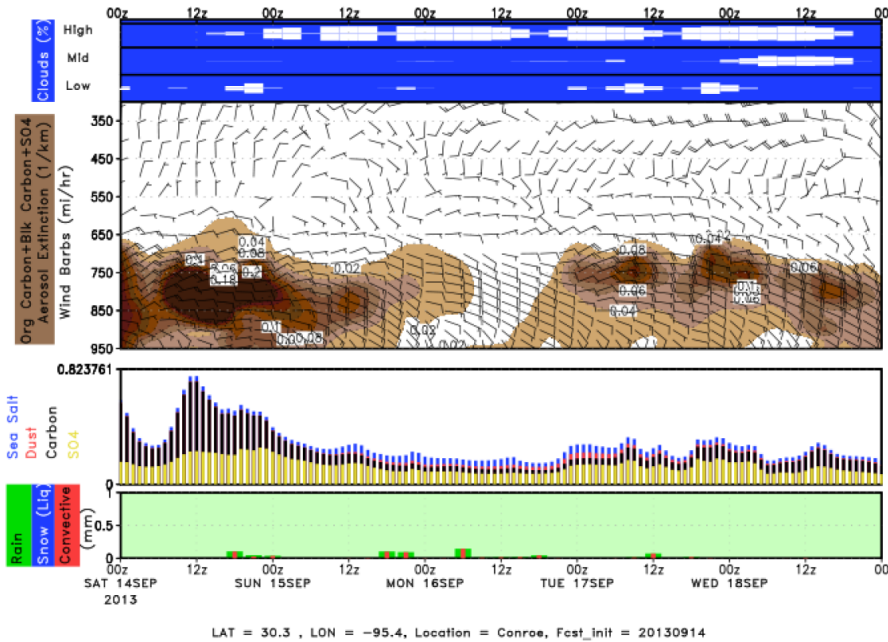


GEOS-5 aerosol forecast from 00 UT 14 Sept.

GEOS-5 global model at 0.25 deg. resolution; GOCART aerosols, CO, SO₂; includes assimilation of MODIS AOD

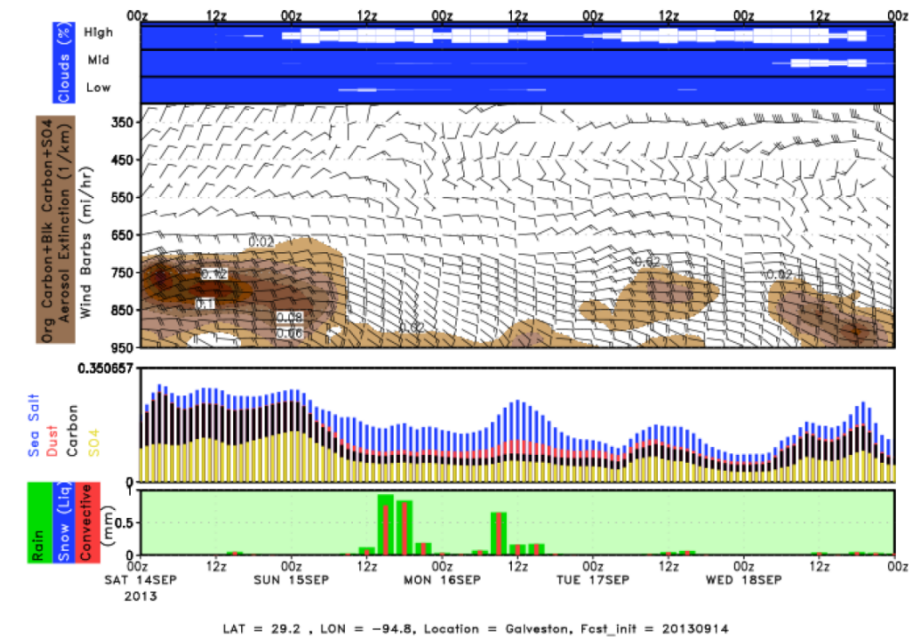
Run by Arlindo da Silva at NASA/GSFC

CONROE



LAT = 30.3 , LON = -95.4, Location = Conroe, Fcst_init = 20130914

GALVESTON



LAT = 29.2 , LON = -94.8, Location = Galveston, Fcst_init = 20130914



Cloud cover

Extinction

AOD

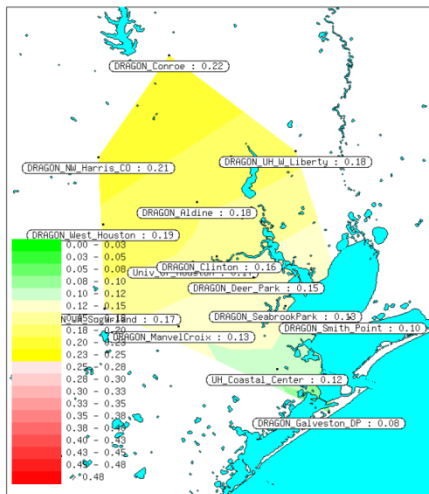
Ken Pickering

DRAGON : September 12th (Thursday) at Level 1.5

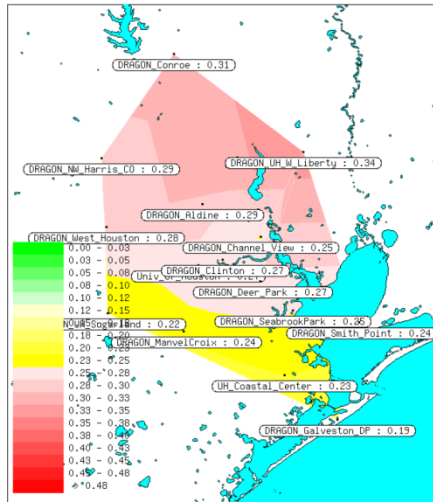
DRAGON : September 13th (Friday) at Level 1.5

DRAGON : September 14th (Saturday) at Level 1.5

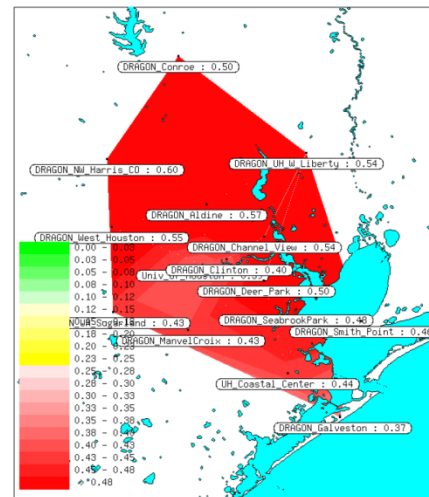
0.08-0.22



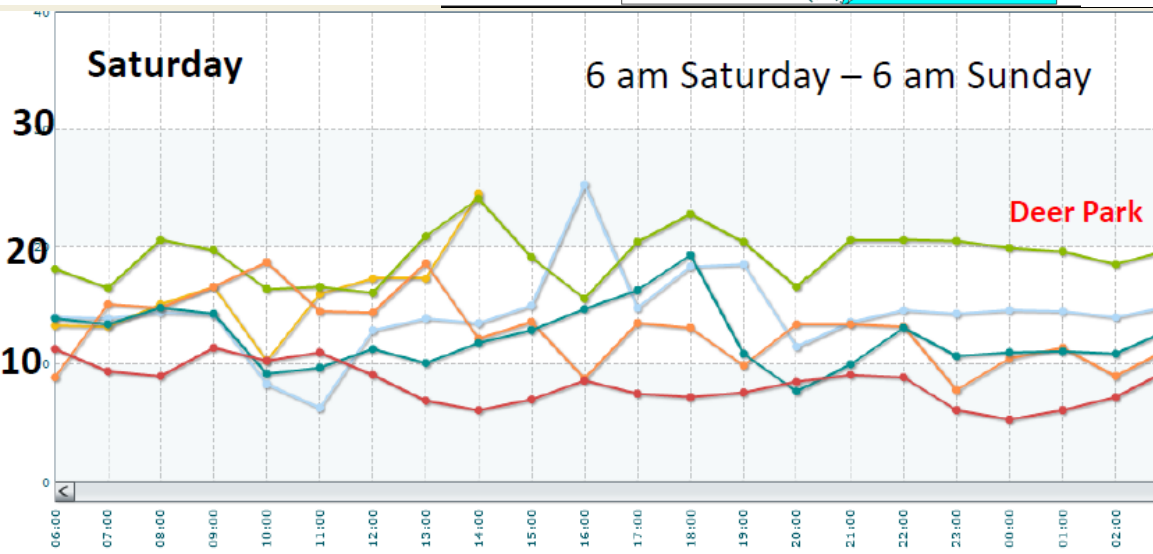
0.19-0.34



0.37-0.60



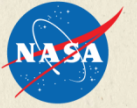
Hourly PM2.5 (µg/m³)



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.

- Houston Aldine C8/PM2.5-88502 - 88502/1 Hr/3
- Houston Deer Park C35/PM2.5-88502 - 88502/1 Hr/3
- Conroe Relocated C78/PM2.5-88502 - 88502/1 Hr/3
- Clinton C403/PM2.5-88502 - 88502/1 Hr/3
- Seabrook Friendship Park C45/PM2.5-88502 - 88502/1 Hr/3
- Galveston Airport C1034/PM2.5-88502 - 88502/1 Hr/3



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**

FRAPPÉ



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,....

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

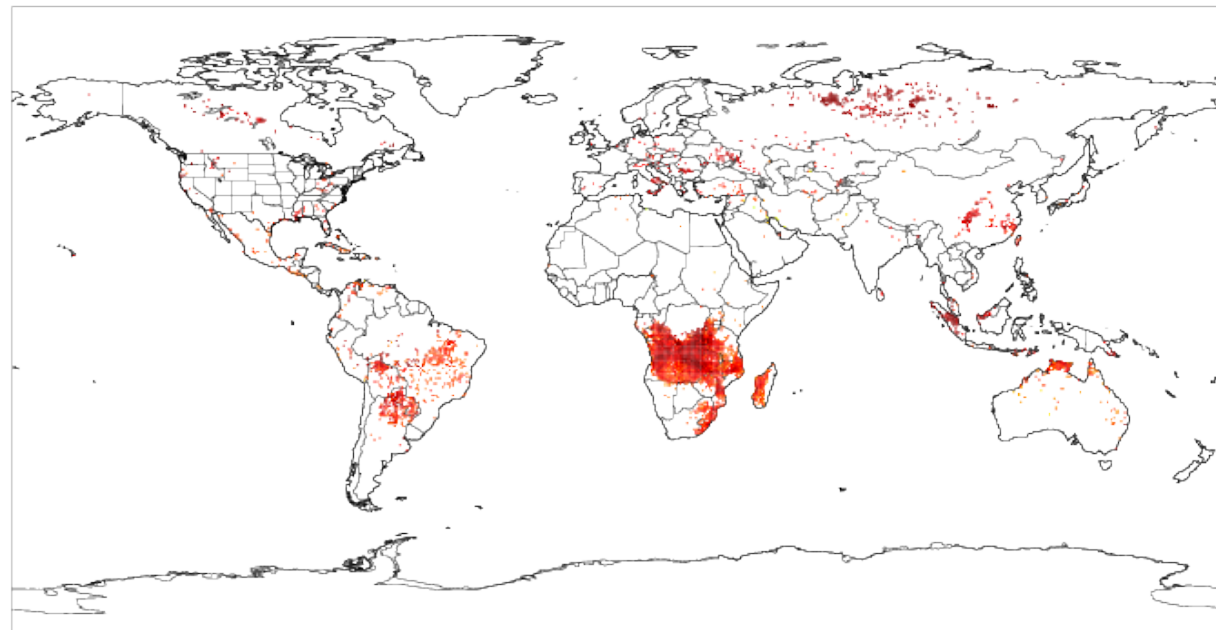
Louisa Emmons, Christine Wiedinmyer, &
MOPITT team

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>
- Plots and data files available for forecasts and hindcasts

FINN CO fire emissions 2013-07-26



Additional fire products
will be compiled:

NASA QFED

NOAA HMS

...

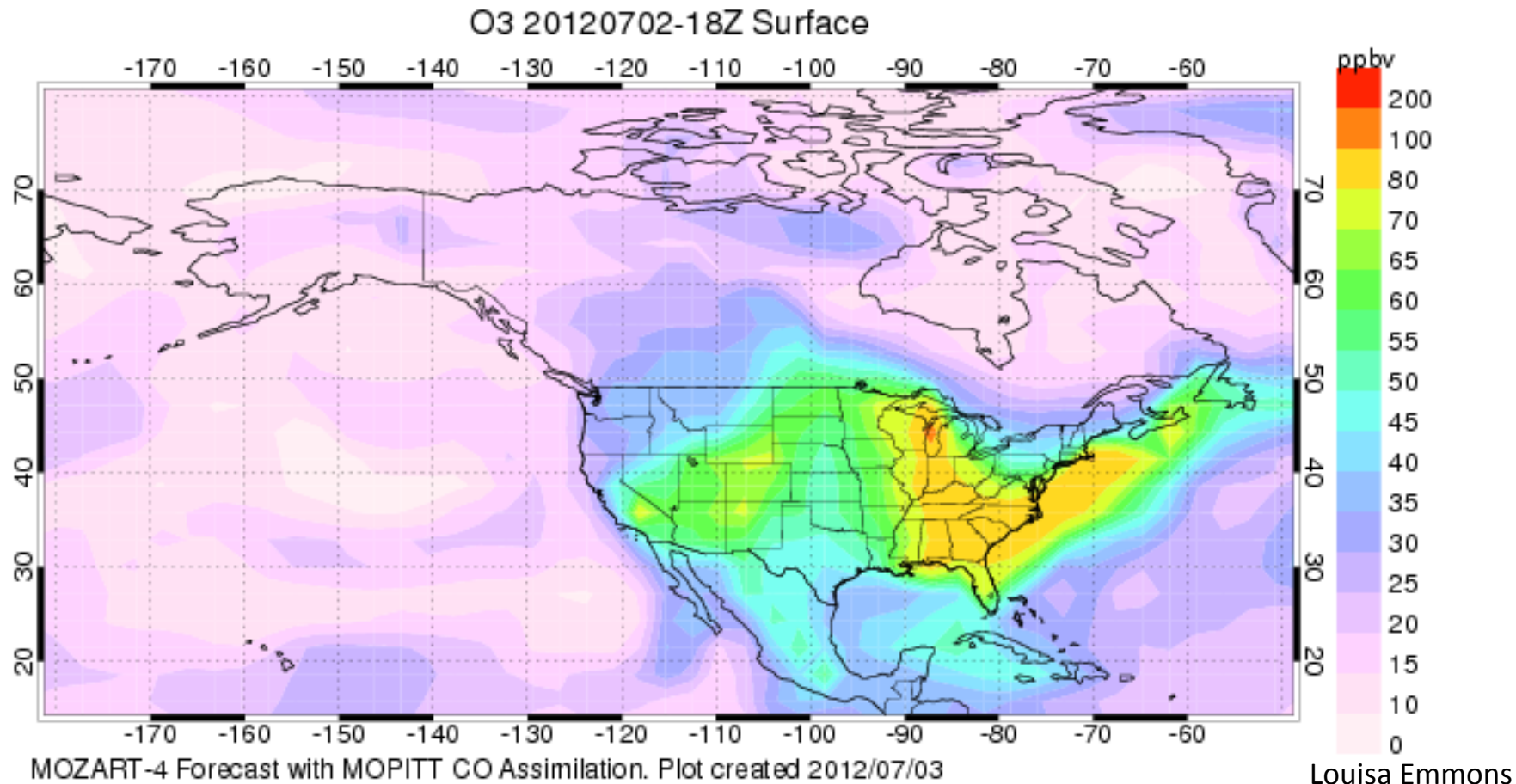
molecules/cm²/s
0.e+00 1.e+09 1.e+10 2.e+10 5.e+10 1.e+11 2.e+11 5.e+11 1.e+12 2.e+12 5.e+12 1.e+13

MOZART-4 driven by GEOS-5

Full chemistry at $1.9^\circ \times 2.5^\circ$

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

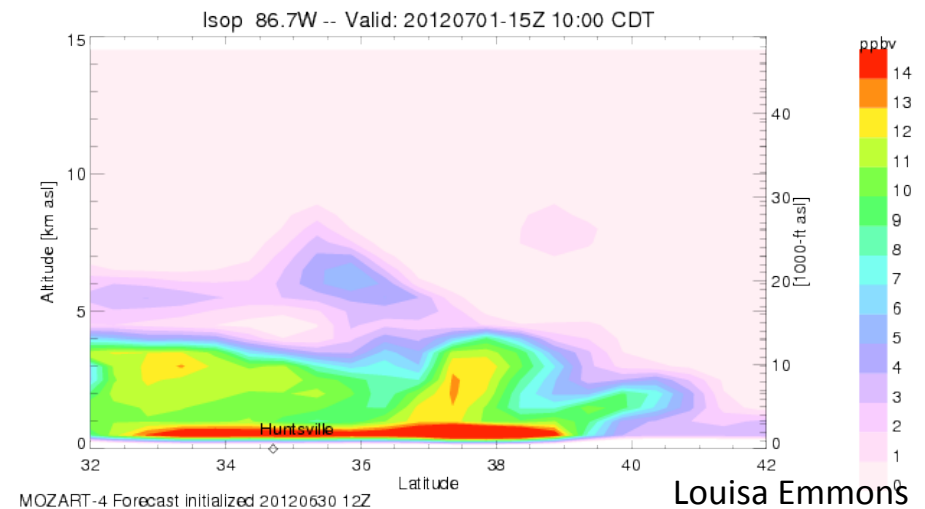
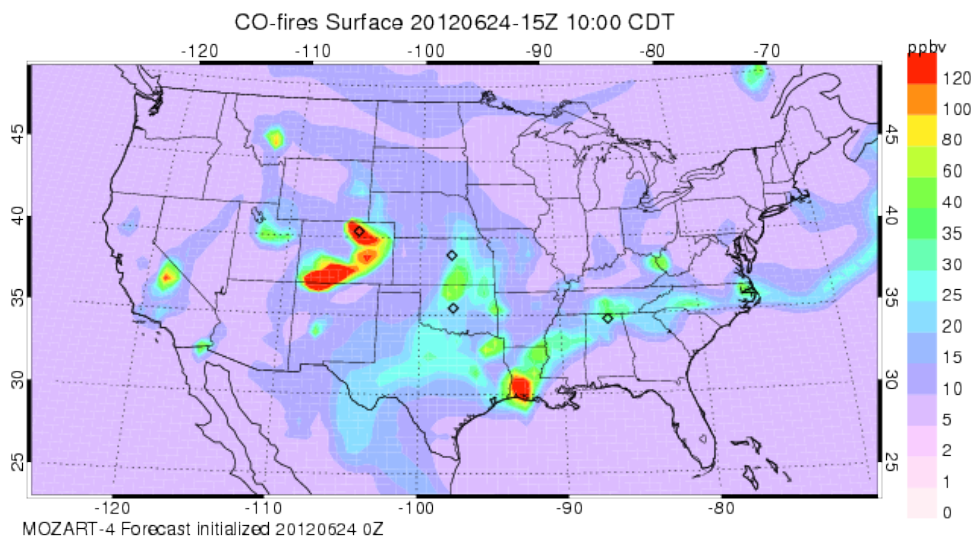
5-day forecasts, hourly output, currently operational



MOZART-4 Tracers

Forecasts of tracers only at 0.5° horizontal resol.

- Isoprene-like tracer based on MEGAN isoprene emissions
- Anthropogenic NO_x 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/>), will be run specifically for FRAPPE



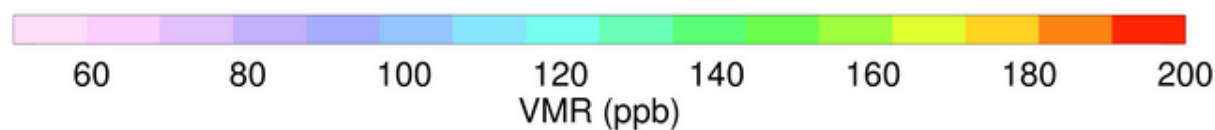
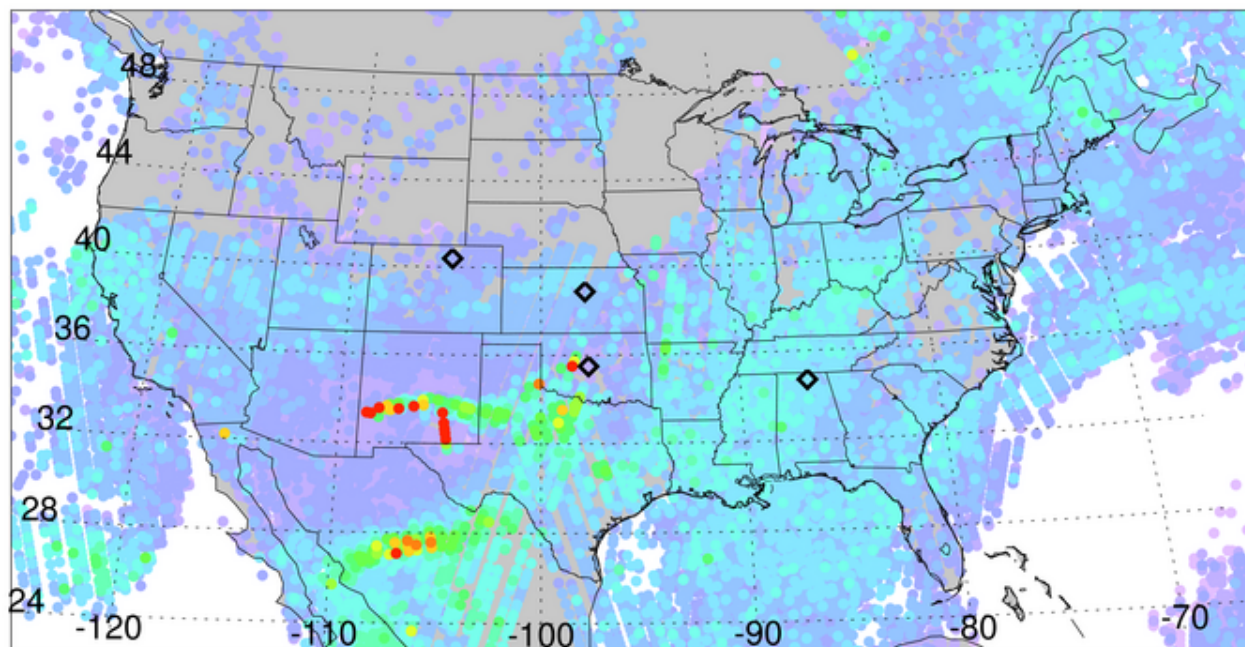
Chemistry Satellite Observations

- MOPITT CO – available within a day of overpass
- IASI CO – about 4-day delay, global coverage 2x/day

NCAR/FORLI

IASI CO Total Column Effective VMR

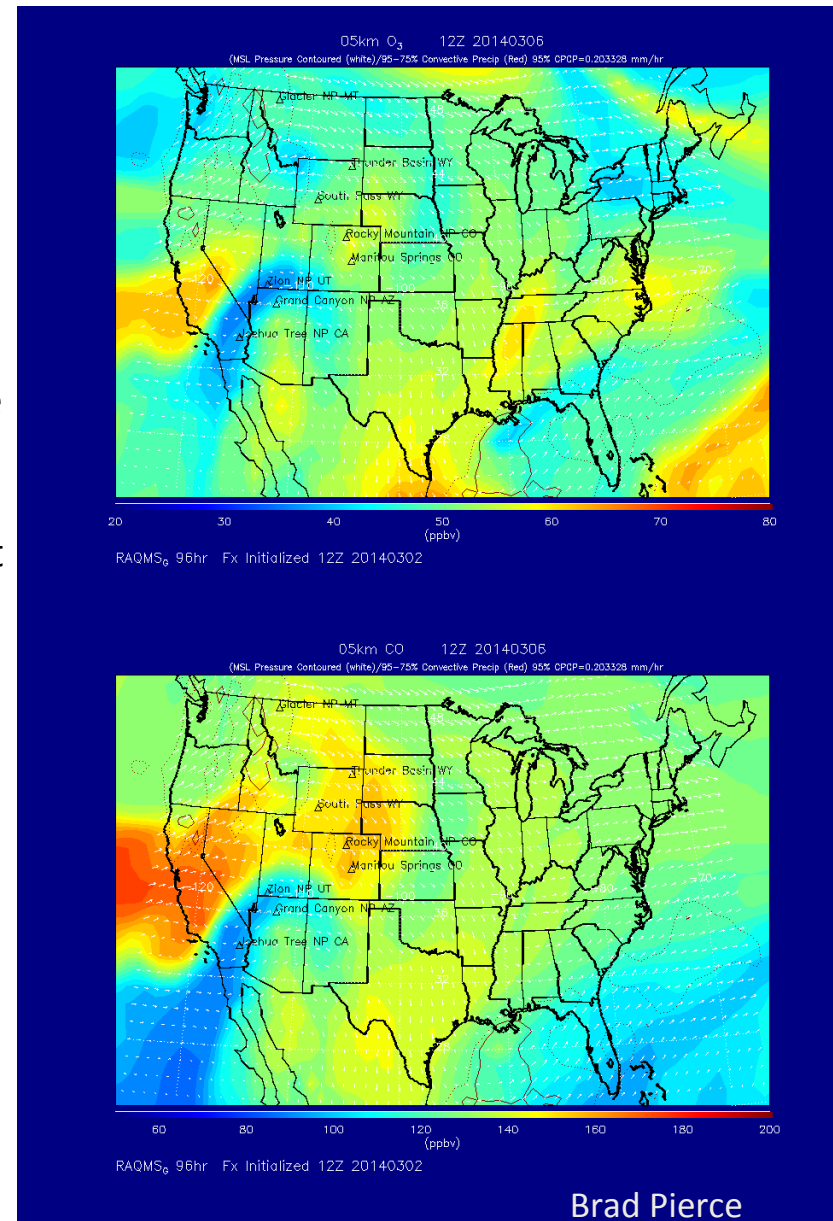
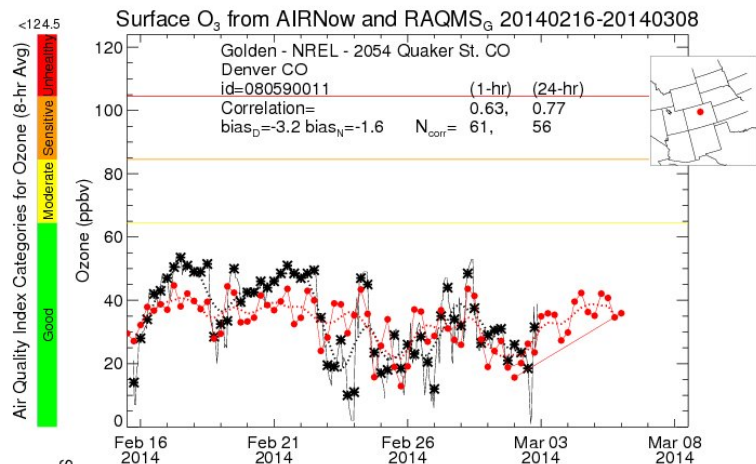
24 May 2012



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/>) and 13km RAP-chem forecast (RACM chemical and MOSAIC aerosol mechanisms, http://ruc.noaa.gov/wrf/WG11_RT/)



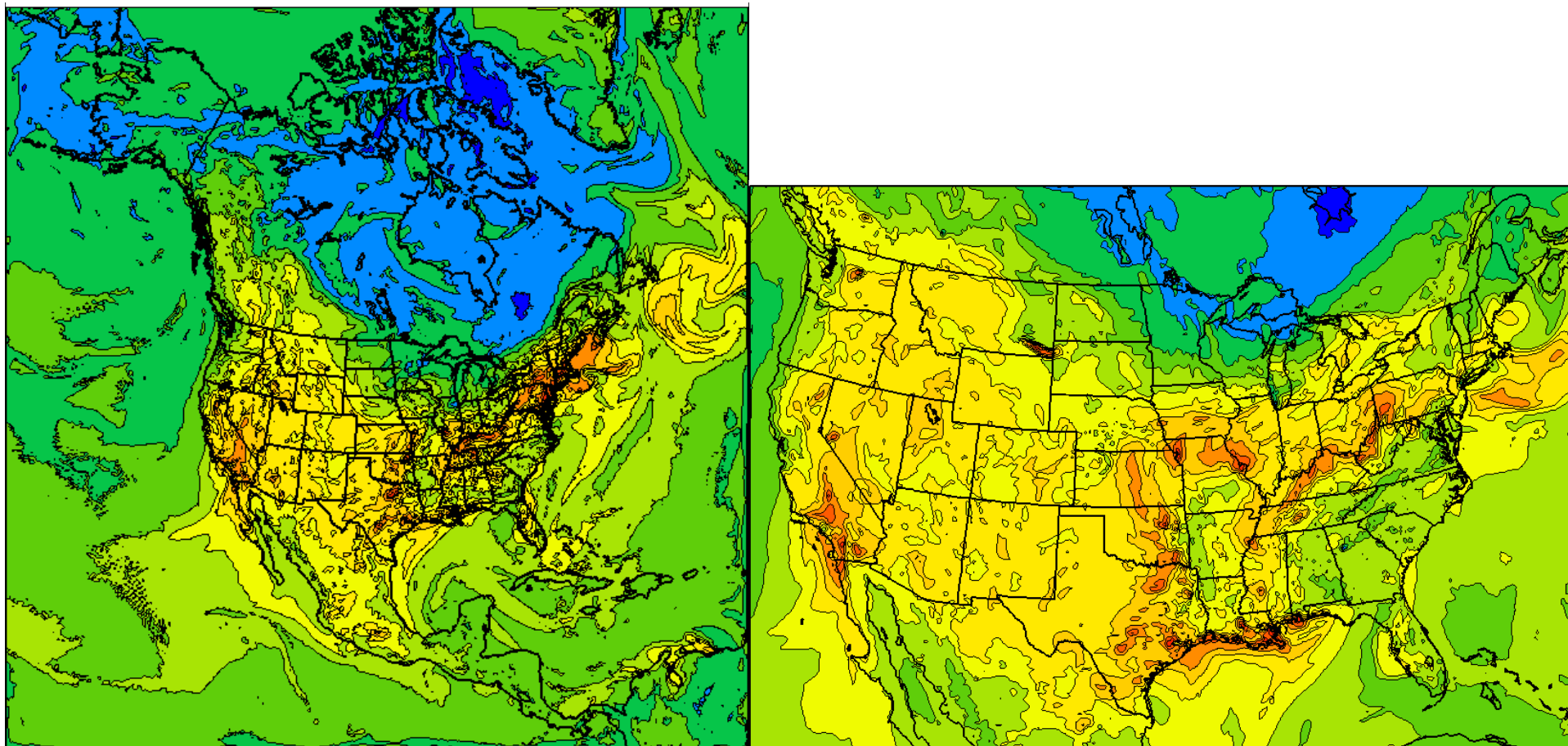
Forecasting weather and air quality with RAP-Chem

- 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, PM_{2.5}, OA, Precipitation. Three cross-sections. More possible.
- Currently displayed on the WEB: full domain and zoomed in CONUS domain (http://ruc.noaa.gov/wrf/WG11_RT/). 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

NCAR/RAL

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:

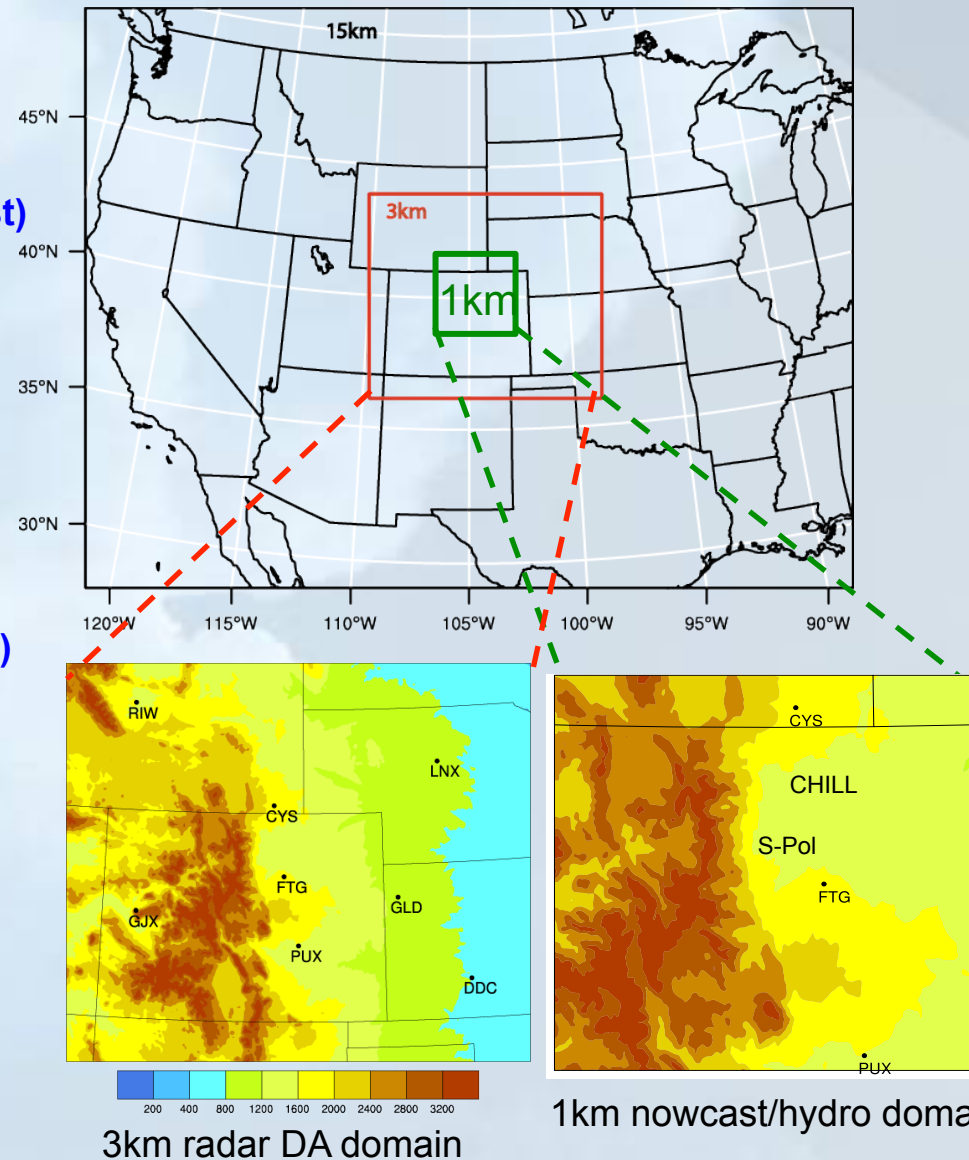
- Each organization will run their own system
- No extra resource required from NCAR

NCAR systems:

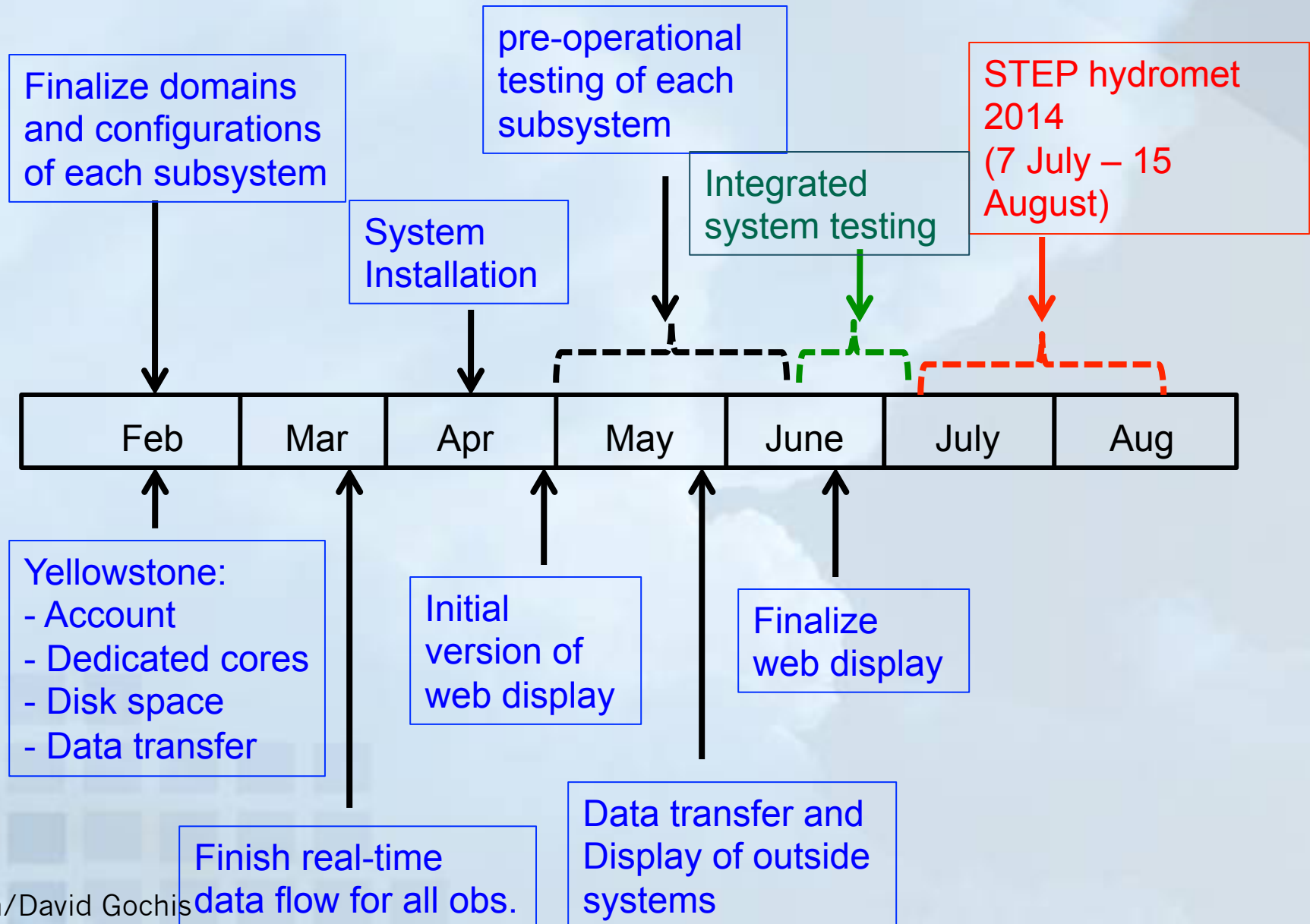
- WRF 3DVar (no radar DA, 3h UC/12h fcst/1km)
- WRF 3DVar (with radar DA, 1h UC/12h fcst)
- WRF 4DVar (with radar DA, 3h UC/12h fcst)
- RTFDDA (with radar DA, 3h UC/24h fcst)

* UC – Update Cycle

Nested WRF domain

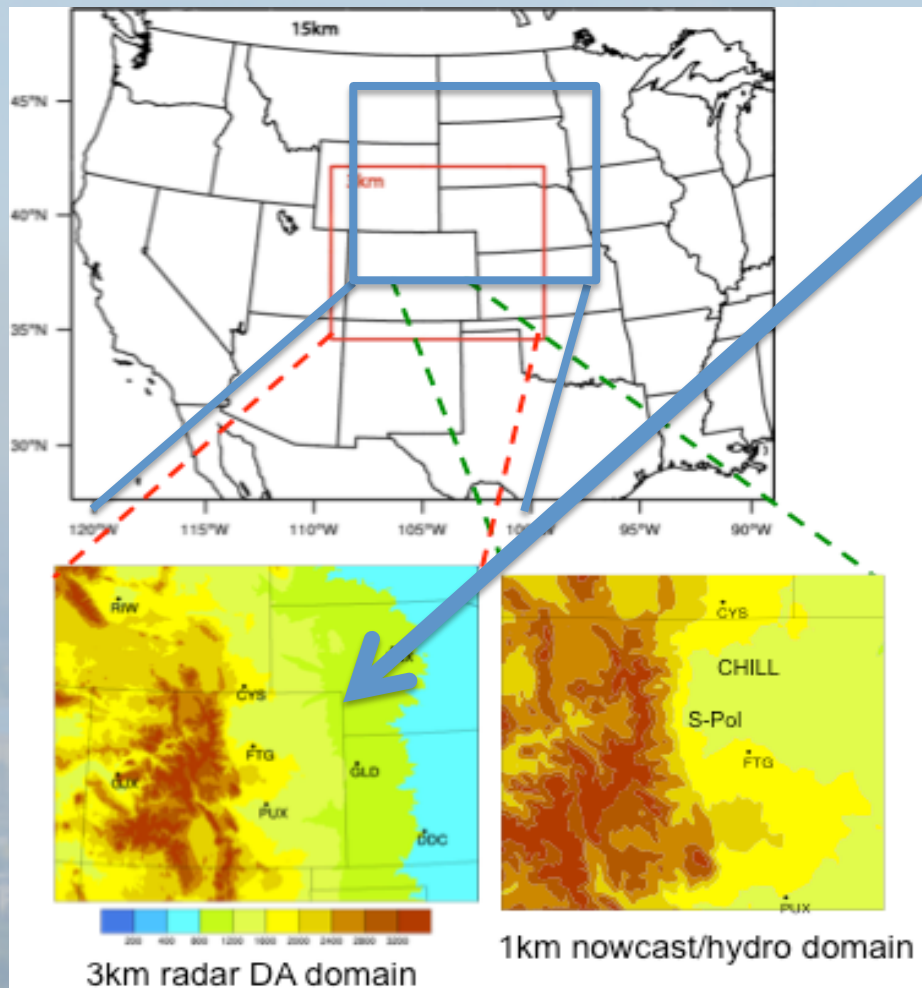


Project Timeline



Suggested Tracers:

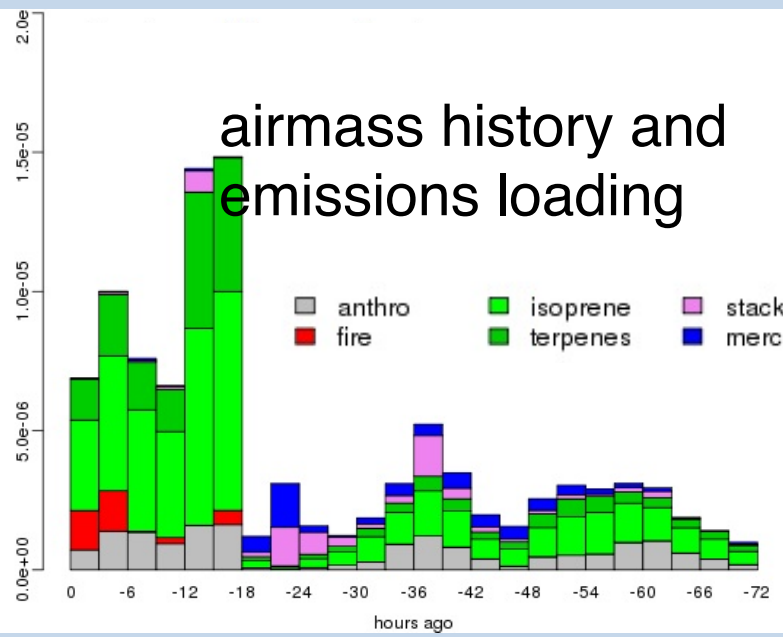
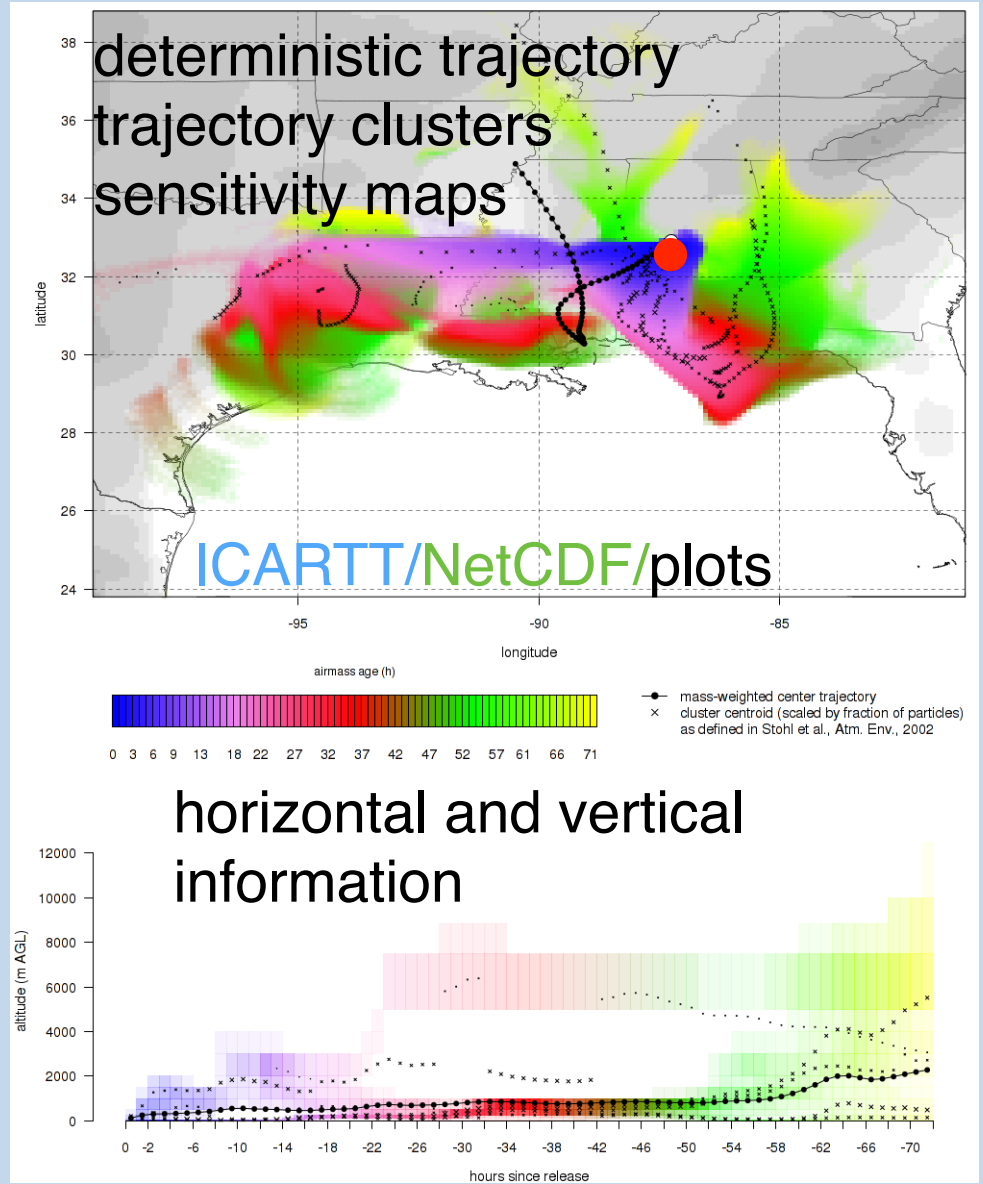
- Anthropogenic tracer (NO_x like)
(area, non-road, point sources)
- Mobile tracer (NO_x like)
- Oil & Gas tracer (ethane like)
- Agricultural tracer (*emission info needed*)

**WRF-Chem Tracers**

Add to 3km STEP Forecast
Inert with specified lifetime

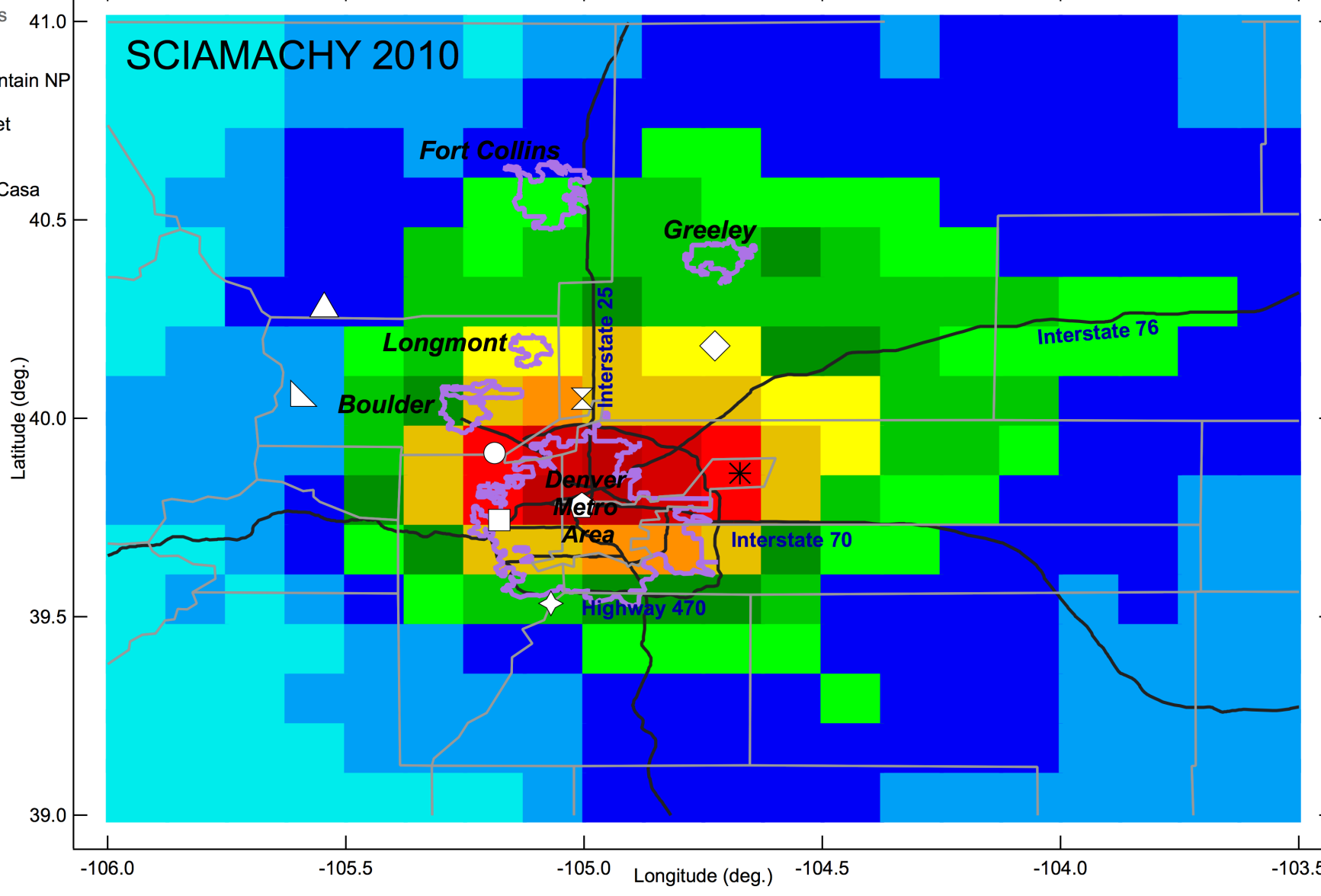
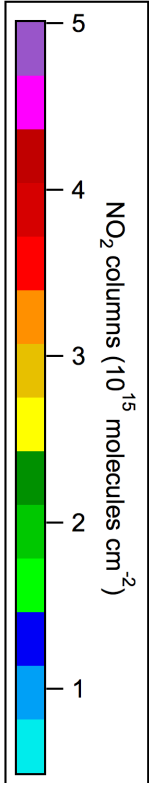
Lagrangian particle dispersion products with FLEXPART

- 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

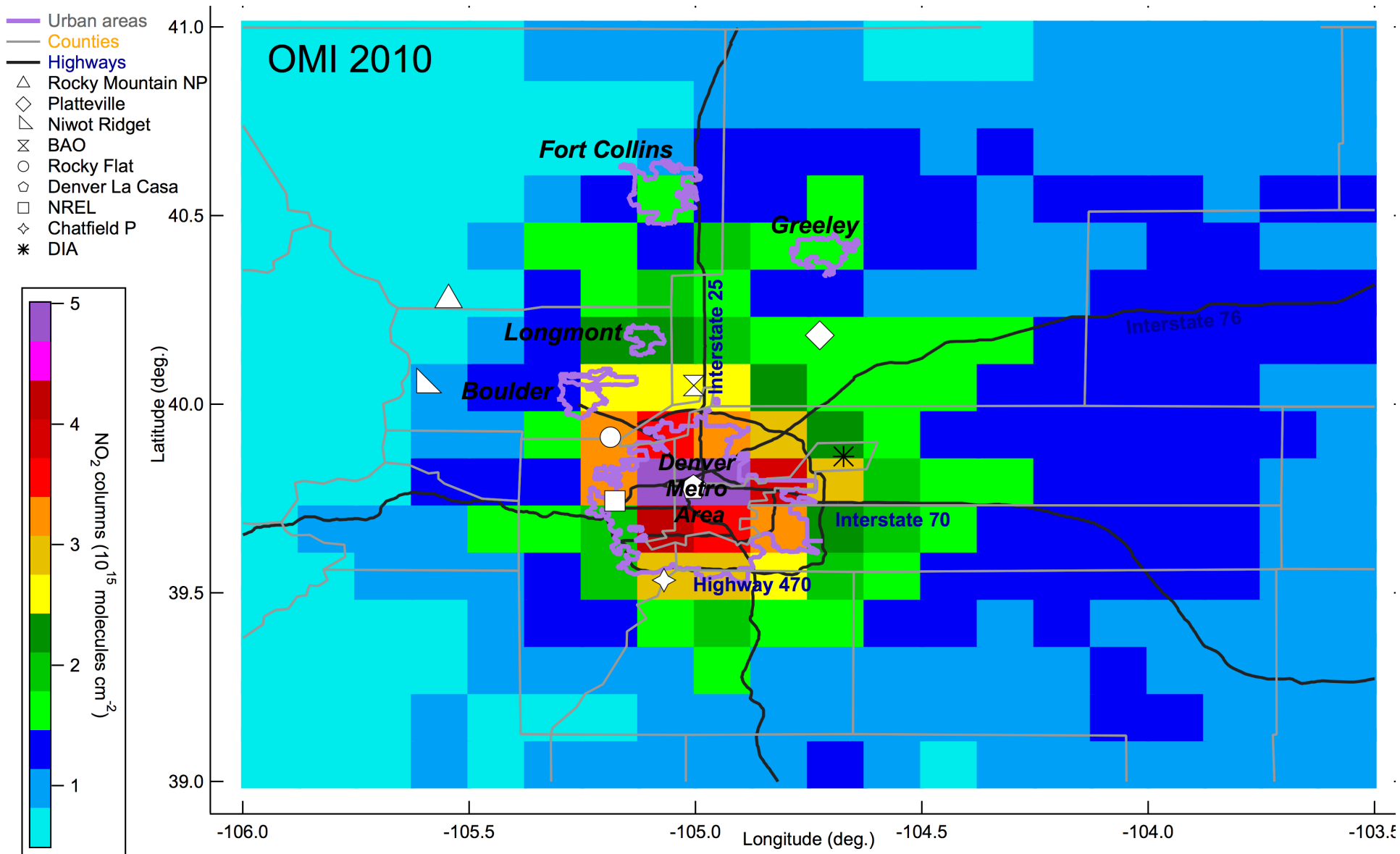


Satellite NO₂ Columns: May-Sep. 2010 Morning Orbit

- Urban areas
- Counties
- Highways
- Rocky Mountain NP
- Platteville
- Niwot Ridget
- BAO
- Rocky Flat
- Denver La Casa
- NREL
- Chatfield P
- DIA

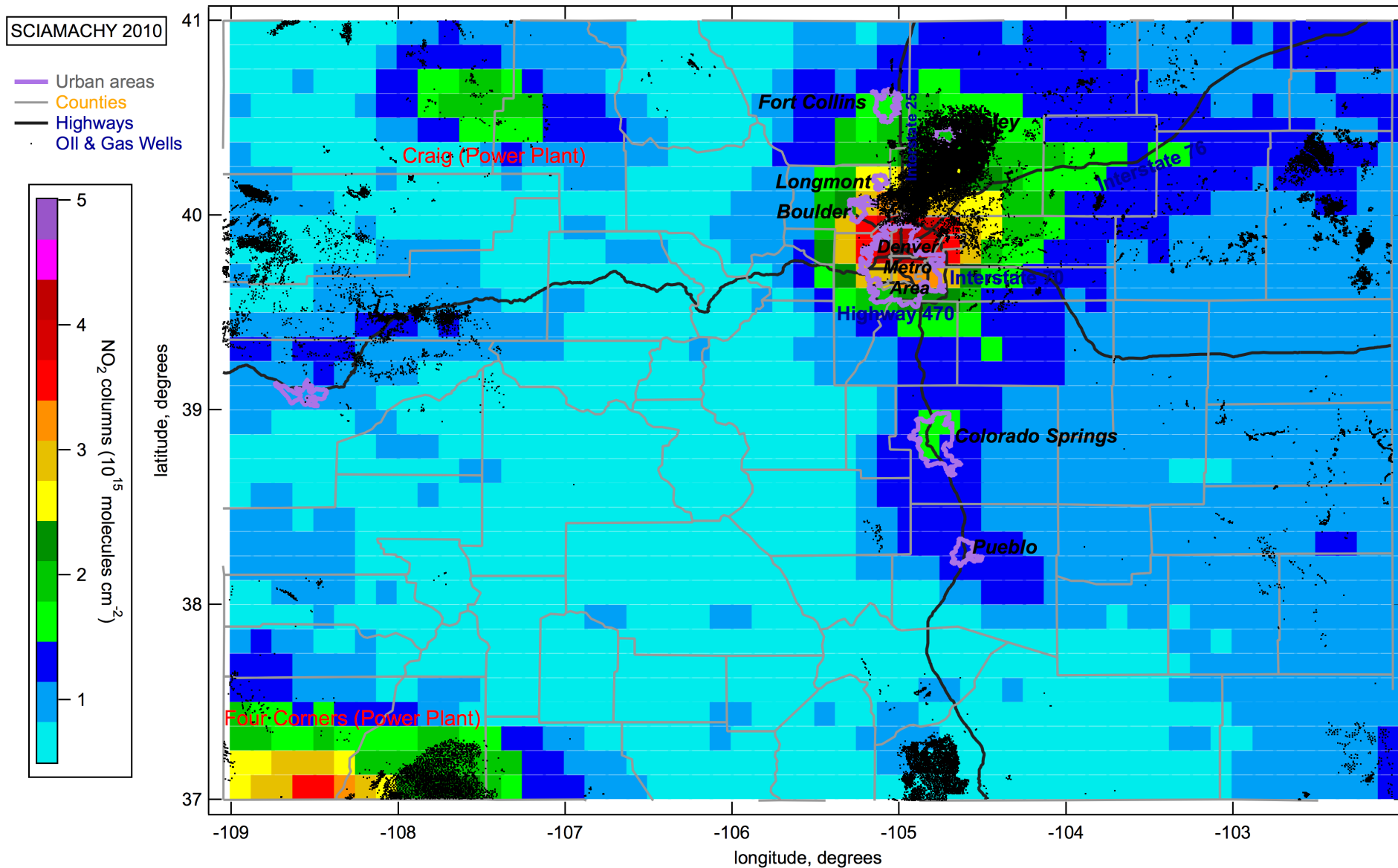


Satellite NO₂ Columns: May-Sep. 2010 Afternoon Orbit



SCIAMACHY NO₂ Columns: May-Sep. 2010

Dots: Oil and Gas Wells



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