Chemical and Aerosol Data Assimilation Activities during CalNex

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Demonstration of:

- Real-time assimilation of Microwave Limb Sounder (MLS) stratospheric ozone profiles
- Real-time assimilation of Ozone Monitoring Instrument (OMI) total ozone column
- Real-time incorporation of Moderate Resolution Imaging Spectroradiometer (MODIS) fire detection
CalNex-2010 O₃ sondes – Owen Cooper (NOAA ESRL)

CalNex Ozonesonde

RAQMS NO ASSIM is low biased up to 30% of OzoneSonde
CalNex-2010 O₃ sondes – Owen Cooper (NOAA ESRL)

CalNex OzoneSonde

RAQMS MLS+OMI analysis is within 20% of OzoneSonde
Assimilation of MLS+OMI O3 retrievals results in increased lower-tropospheric O3 (and improved agreement with airborne insitu O3) over Southern California.
RAQMS CalNex AOD Assimilation Procedure

Demonstration of:
• Real-time assimilation of MODIS Aerosol Optical Depth (AOD)
• Real-time incorporation of MODIS based biomass burning emissions

Forward model:
Compute layer/species extinctionbased on tabulated extinction efficiency and hydroscopic growth factors

Inverse model:
Distribute total AOD increment across aerosol dry mass based on layer/species extinction accounting for extinction due to hydroscopic growth

Modulated aerosol mass
Adjusted aerosol mass
First Guess AOD
AOD increment

Ecosystem/Severity Based wildfire emissions
RAQMS Global Met/Aerosol

MODIS Rapid Response Wild fire locations
NOAA GFS Global Met

MODIS AM/PM AOD

Column Assimilation Cycle

Forward model

Inverse model
Comparison with HSRL Lidar Measurements (Primarily LA Basin, Chris Hostetler, NASA LaRC)

RAQMS free tropospheric median aerosol extinction is in very good agreement with HSRL.

Variability is underestimated, particularly for lower values of aerosol extinction.

Largest biases are found within the LA Basin Boundary Layer (below 1000m) were RAQMS median extinction is low.
Comparison with NOAA P3 Insitu Aerosol Measurements (Primarily LA Basin/Central Valley)

- Boundary Layer extinction underestimates arise due to underestimates in local LA sources and neglect of nitrate aerosol in GOCART module.
- Assimilation of MODIS AOD results in overestimates of free tropospheric aerosol dry mass due to uncertainties in hydroscopic growth.

Need to better understand size range of measured insitu dry mass and Extinction measurements.
Assessment of Global 850mb O3 and Aerosol Extinction Forecast Skill

- Anomaly Correlations (AC)
  - Correlation between forecast and analysis
  - May-June mean removed
  - Spectrally truncated to wavenumber 20
  - Averaged from 20N-80N

Anomaly Correl day 5 Z 500mb n hem lat 20–80

![Graph showing correlation over time with useful skill indicated.](http://www.emc.ncep.noaa.gov/gmb/STATS/html/monarch.html)
• 850mb ozone forecasts have useful skill past 3 days (significantly better than water vapor)
• 850mb extinction forecasts do not have useful skill at 1 day
Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (With MLS/OMI/MODIS Assimilation)

- Assimilation of O3 retrievals results in slight improvements in 850mb ozone forecasts
- Assimilation of AOD retrievals results in significant improvement in 850mb extinction forecasts with useful skill at ~1.5 days
Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (No Assimilation)

- Only 850mb SO4 extinction forecasts useful skill past 1 day
- Black and organic carbon (BC+OC) and dust extinctions are both poorly initialized and forecasted
Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (With MODIS Assimilation)

- MODIS AOD assimilation results in small changes in 850mb SO4 extinction forecasts
- MODIS AOD assimilation results in significant improvements in black and organic carbon (BC+OC) and dust forecast skill (dust prediction useful at 2 days)
Sacramento CO May-June 2010 RAQMS 1x1 Degree Re-analysis

May 10-12  May 22-24
Sacramento O3 May-June 2010
RAQMS 1x1 Degree Re-analysis

May 10-12
May 22-24
Sacramento Dust Extinction May-June 2010
RAQMS 1x1 Degree Re-analysis

May 10-12
May 22-24
HSRL aerosol Scattering Ratio
Saturday, May 22, 2010

HSRL data from Chris Hostetler and Rich Ferrare, NASA LaRC
GOES WV 00Z 20100523 (Saturday Afternoon)

RAQMS RDF 5km Dust forecast
GOES WV 00Z 20100523 (Saturday Afternoon)

RAQMS RDF 5km CO forecast
3km RDF CO, O3, Dust, and Vertical Displacement 00Z 20100523 (Saturday Afternoon)

RAQMS RDF 3km CO forecast

3km RDF CO, O3, Dust, and Vertical Displacement 00Z 20100523 (Saturday Afternoon)

RAQMS RDF 3km O3 forecast

RAQMS RDF 3km Dust forecast

RAQMS RDF 3km Descent forecast
Two real-time experimental NAM-CMAQ CB5 runs were conducted by NCEP (Y. Tang) during CalNex.

- one with Fixed lateral boundary conditions (LBC)
- one with RAQMS LBC.

We are conducting NAM-CMAQ post-mission studies focusing on assimilation of GOES Total Column Ozone.

Here we look at the “Baseline” (no assimilation) results.
NAM-CMAQ CalNex Experimental Runs

- Fixed Lateral Boundary Conditions
- RAQMS Lateral Boundary Conditions

RAQMS LBC results in increased surface ozone over Southern California and Inter-mountain West

Inter-mountain West

Central Valley

Southern California
NAM-CMAQ verses AIRNOW May 22-June 30, 2010
Southern California (33N-35N 121W-114W)

**FIXED LBC**

- Mean Bias = -2.14021 (ppbv)
- $R = 0.603405$

**RAQMS LBC**

- Mean Bias = 0.650771 (ppbv)
- $R = 0.596081$

**Bias**

- FIXED LBC: -2.14 ppbv
- RAQMS LBC: 0.65 ppbv

RAQMS LBC increases Southern California surface ozone and reduces bias
NAM-CMAQ verses AIRNOW May 22-June 30, 2010 Central Valley (35N-39N 124W-118W)

**Fixed LBC**

- **Baseline Fix LBC Bias (CMAQ-AIRNOW)**
  - Mean Bias = 2.56452 (ppbv)
  - R = 0.682879

**RaQMS LBC**

- **Baseline RaQMS LBC Bias (CMAQ-AIRNOW)**
  - Mean Bias = 3.35860 (ppbv)
  - R = 0.685325

**Bias**

- **Fixed LBC**: Bias = 2.56 ppbv
- **RaQMS LBC**: Bias = 3.35 ppbv

RaQMS LBC increases Central Valley surface ozone and increases bias
NAM-CMAQ verses AIRNOW May 22-June 30, 2010
Inter-mountain West (35N-45N 115W-105W)

FIXED LBC

RAQMS LBC

Bias = -1.04 ppbv

Bias = 8.36 ppbv

RAQMS LBC increases Inter-mountain surface ozone and increases bias
**CalNex-2010 O$_3$ sondes – Owen Cooper (NOAA ESRL)**

**CalNex Ozone sonde**

**NAM-CMAQ FIXED LBC**

**FIXED LBC NAM-CMAQ experiment significantly underestimates upper tropospheric (<300mb) ozone and free tropospheric (<900mb) variance**
RAQMS LBC NAM-CMAQ experiment overestimates free tropospheric (600-200mb) ozone and boundary layer (>900mb) variance but shows improved agreement in free tropospheric variance
• NAM-CMAQ RAQMS LBC experiment shows more descent of high ozone air than RAQMS 1x1 re-analysis which may lead to overestimates in surface ozone

• Points to the need for improved vertical resolution in NAM-CMAQ upper troposphere/lower stratosphere
• FIXED LBC experiment shows less descent of high ozone air then RAQMS LBC experiment

• FIXED LBC experiment shows less variance then either RAQMS or the RAQMS LBC experiment
Summary:

• Assimilation of global satellite ozone retrievals results in improved agreement with CalNex P3 airborne and ozonesonde ozone measurements and slight improvements in large-scale ozone forecasts

• Assimilation of global aerosol retrievals results in improved agreement with CalNex HSRL airborne aerosol extinction measurements and significant improvements in large-scale dust forecasts
  • Leads to overestimates of insitu aerosol dry mass and extinction
  • Need to understand the contribution from large aerosols to ambient extinction

• Use of real-time RAQMS LBC within experimental CB5 NAM-CMAQ leads to improved agreement with UTLS ozonesonde measurements and improved representation of free tropospheric variance but leads to overestimates in surface ozone over the inter-mountain west
  • Need to increase the vertical resolution of NAM-CMAQ in the UTLS

• Forecasting exceedances under the proposed ozone National Ambient Air Quality Standards (NAAQS) will require improved treatment of free tropospheric ozone within regional AQ forecasting and assessment systems