



# **Aura Chemical Reanalysis in support Air Quality Applications**

**PI Brad Pierce  
(NOAA/NESDIS)**

**Presented by  
Allen Lenzen  
(UW-Madison, SSEC)**



# Aura Chemical Reanalysis in support Air Quality Applications

- Solicitation – ROSES 2013 Aura Science Team
- Project Summary

Utilize the Real-time Air Quality Modeling System (RAQMS) in conjunction with the NOAA Operational Gridpoint Statistical Interpolation (GSI) 3-dimensional variational data assimilation (DA) system to conduct a multi-year global chemical and aerosol reanalysis using NASA Aura and A-Train measurements.

- Project Objectives

1. Provide the air quality community with a multi-year global chemical and aerosol reanalysis using NASA Aura and A-Train measurements.
2. Conduct regional chemical data assimilation experiments to quantify the influences in changes in NO<sub>x</sub> emissions on US air quality during the Aura period.
3. Provide global 3 dimensional O<sub>3</sub>, CH<sub>4</sub>, N<sub>2</sub>O production and loss rates for next generation NOAA global forecast system.
4. Collaborate with International, Federal, State and Local air quality management communities in the utilization of the Aura and A-Train measurements and reanalysis for air quality assessment activities.

# Aura Chemical Reanalysis in support Air Quality Applications

As of July 16, 2015

## Budget – NASA’s Monthly Financial Report

As of July 8, 2015					PY15				
PI/POC	Institution	Category	Portfolio	WBS	Budget	Obligated	Unobligated	Costed	Uncosted
<b>Pierce, Brad</b>				<b>Total</b>	149579	149579	0	0	149579
<b>Aura Chemical Reanalysis in support Air Quality Applications</b>									
NOAA/NESDIS/STAR		389018.02.09.01.60			149,579	149,579	-	-	149,579
					PY14				
					Budget	Obligated	Unobligated	Costed	Uncosted
<b>Pierce, Brad</b>				<b>Total</b>	144,677	144,677	0	123,885	20,792
<b>Aura Chemical Reanalysis in support Air Quality Applications</b>									
NOAA/NESDIS/STAR		389018.02.09.01.60			144,677	144,677	-	123,885	20,792

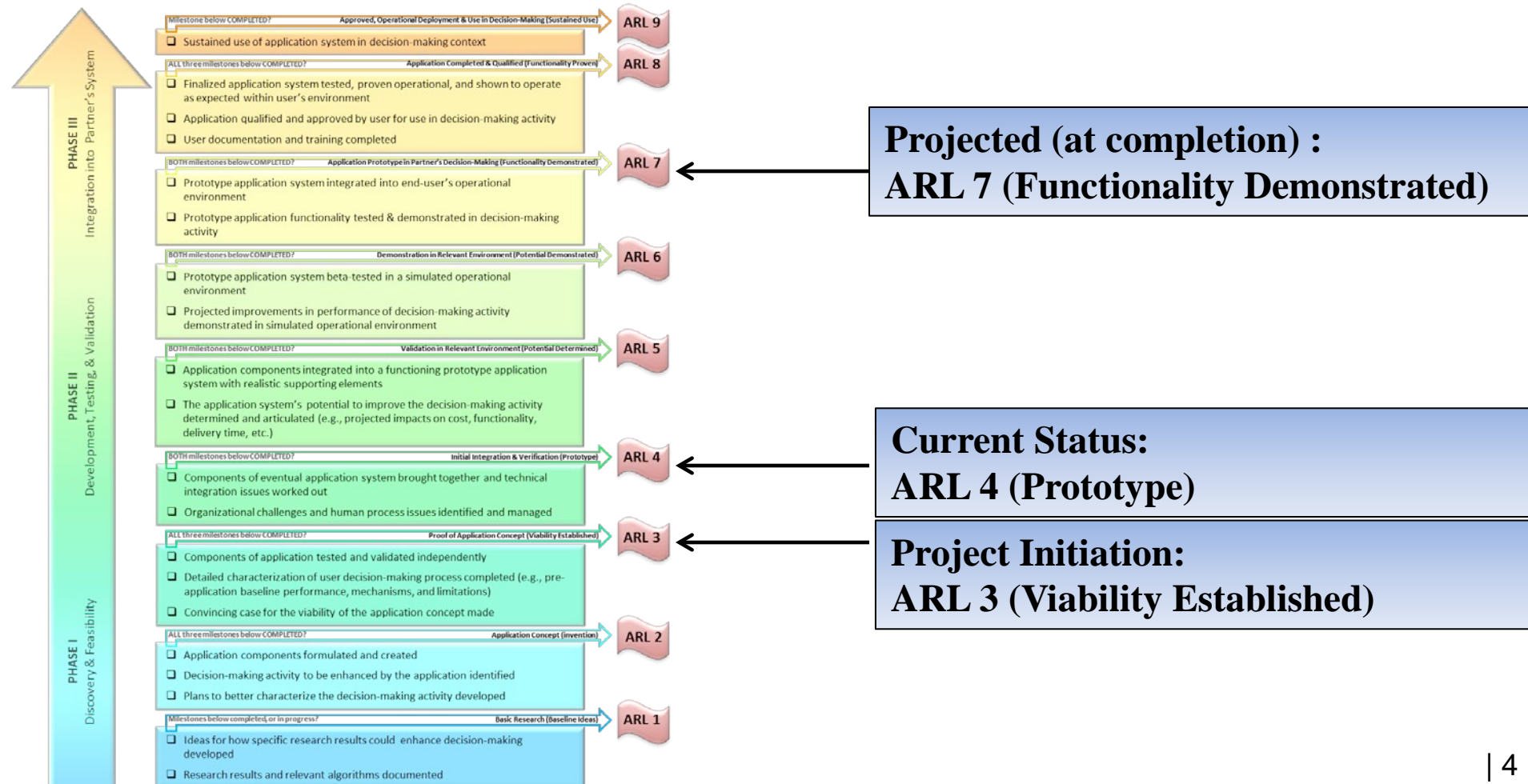
The uncosted FY14 amount due to costing/reporting from multiple entities – Cooperative Institute for Meteorological Satellite Studies (CIMSS), NESDIS Center for Satellite Applications and Research (STAR) Cooperative Research Program (CoRP)

FY15 Funds received by CIMSS on August 19, 2015

# Aura Chemical Reanalysis in support Air Quality Applications

## Applications Readiness Level (ARL)

ARL was not required for this Project at Project Start in July 2014  
Credentials established in eBooks to input deliverables in July 2015  
Retroactively submitted Aug 14, Nov 14, Feb 15, May 15 ARLs



# Aura Chemical Reanalysis in support Air Quality Applications

- Results and Milestones (Year 1)

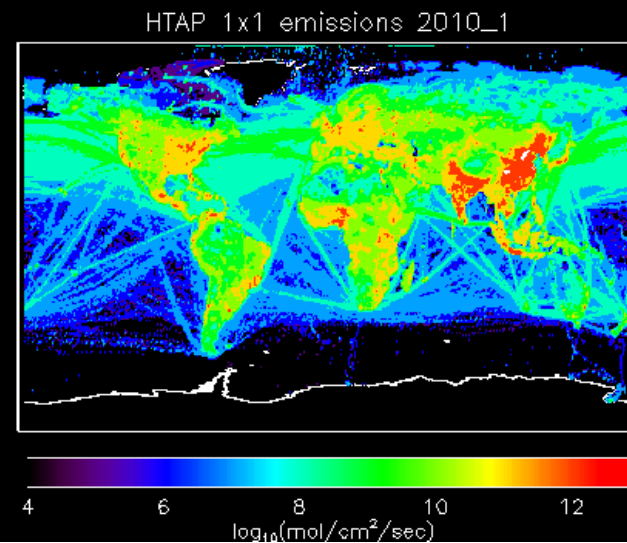
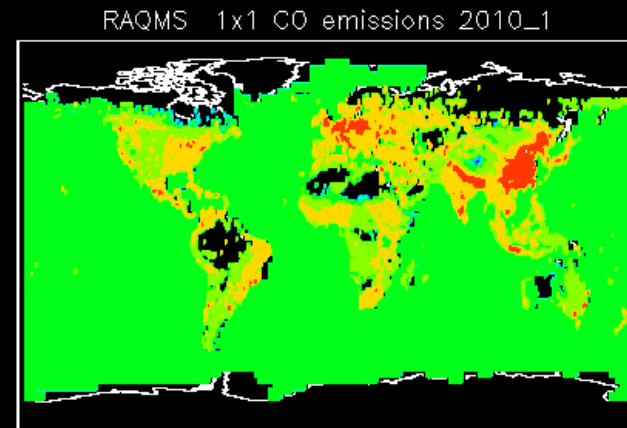
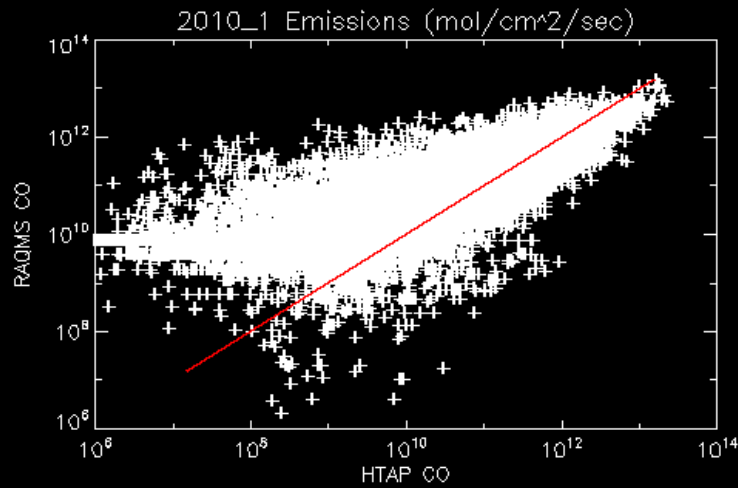
- Global emissions development based on Hemispheric Transport of Air Pollution (HTAP) 0.1x0.1 degree emission inventory
- Participation in HTAP Work Package 3.2 “Inflow processes influencing air quality over western North America” (Lead: Owen R. Cooper, NOAA/ESRL)
- 2010 data denial studies conducted for OMI O3 total column, MLS stratospheric O3 profiles, OMI tropospheric NO2 column retrieval assimilation within coupled RAQMS/GSI Analysis system

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Comparison between the standard RAQMS CO emissions and the EDGAR HTAP\_V2 CO emissions for January 2010.



- RAQMS assumes a uniform oceanic background CO emission to account for unresolved oceanic VOCs which results in an overall high bias in the RAQMS CO emissions at the low end of the global emission distribution.
- EDGAR HTAP\_V2 emissions are higher than RAQMS in SE Asia and India which results in overall low bias in the RAQMS CO emissions at the high end of the global emissions.

# Aura Chemical Reanalysis in support Air Quality Applications

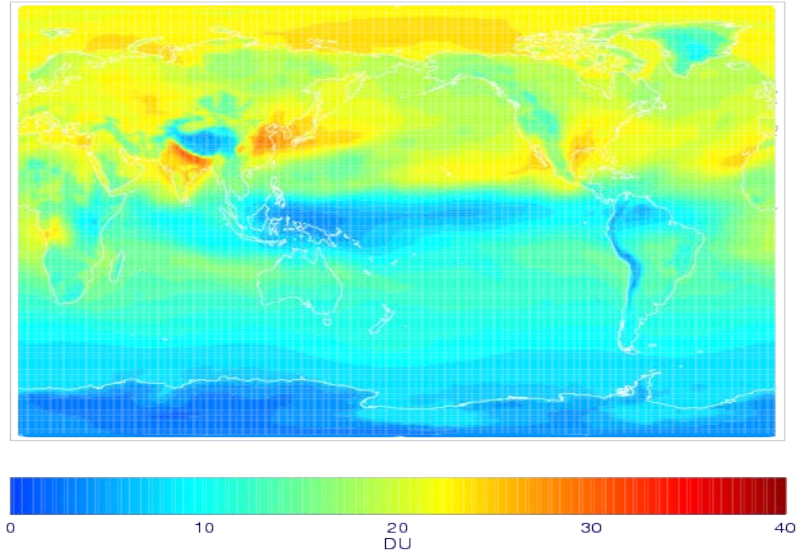
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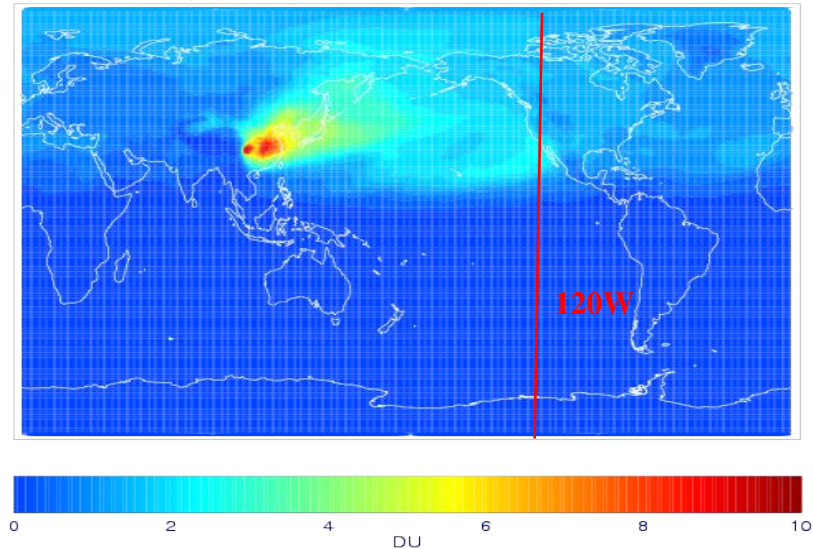


# Impacts of East Asian Emissions – May 2010

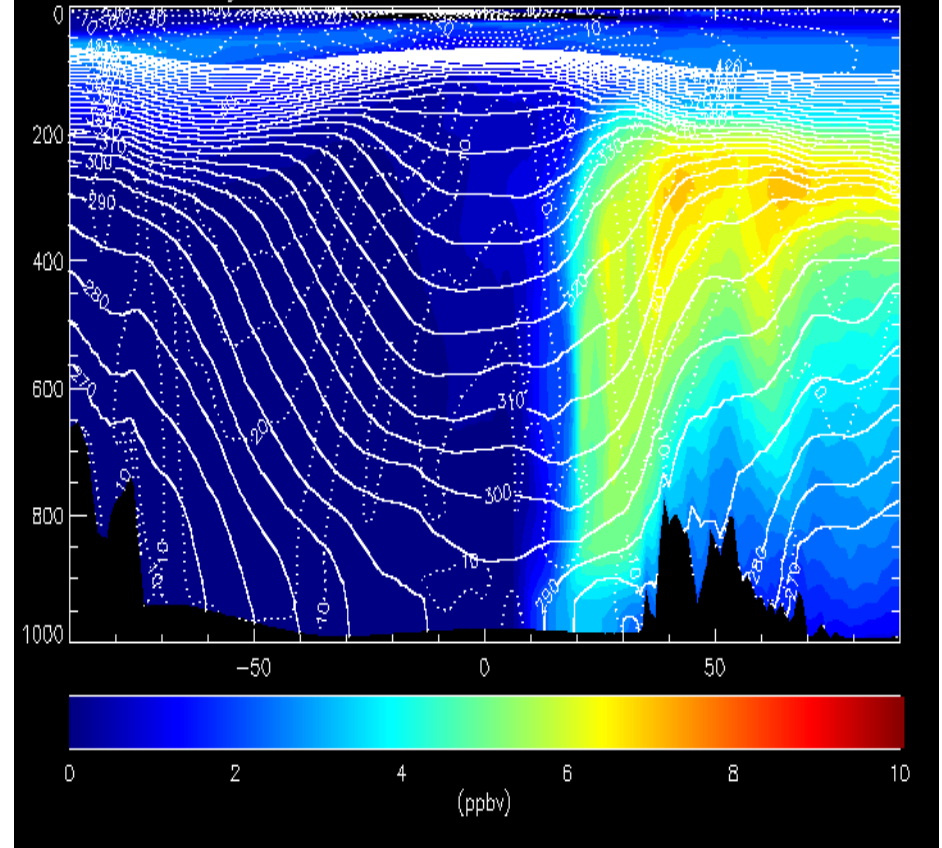
May 2010 RAQMS O3 (400mb-SFC)



May 2010 RAQMS dO3 East Asian Emissions



May 2010 RAQMS dO3 @ 120W East Asian Emissions



**Impact of East Asian ozone production extends into North America with potential US Air Quality impacts**

**The Task Force on Hemispheric Transport of Air Pollution (TF HTAP) is an international scientific cooperative effort to improve the understanding of the intercontinental transport of air pollution across the Northern Hemisphere.**

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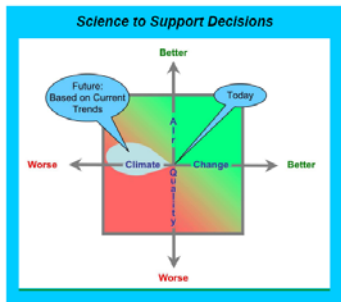
# Aura Chemical Reanalysis in support Air Quality Applications

## CalNex-2010 O<sub>3</sub> sondes – Owen Cooper (NOAA ESRL)

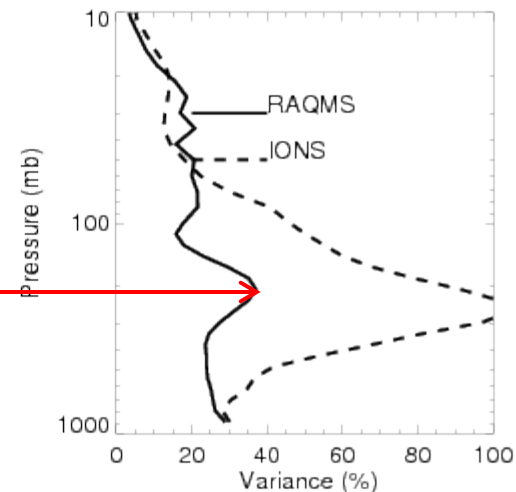
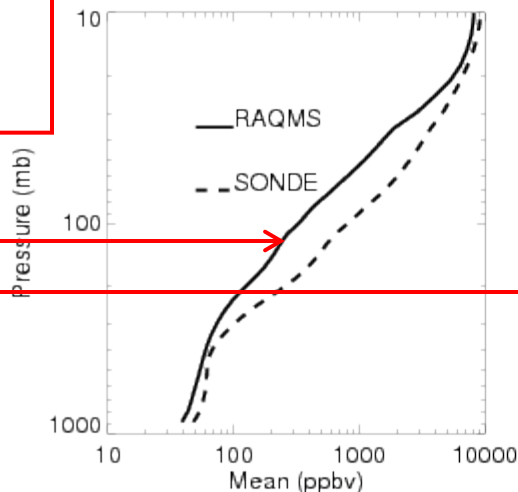
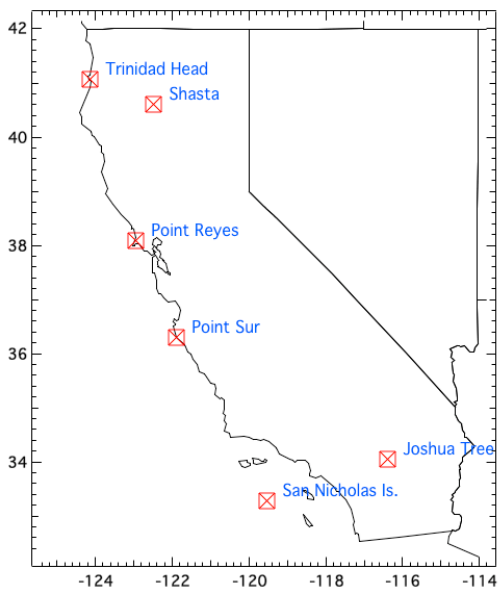
May-June, 2010

CalNex was organized by the California Air Resources Board (CARB) and NOAA to investigate scientific issues at the nexus between air quality and climate change.

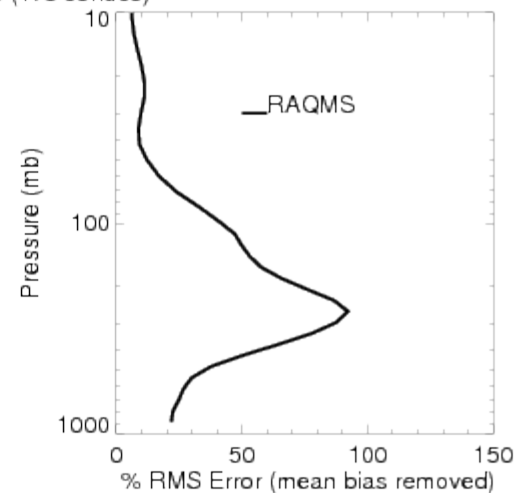
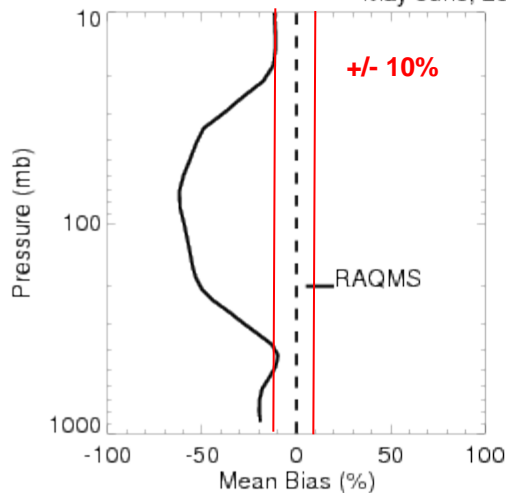
RAQMS baseline (no assimilation) underestimates ozone and ozone variance in the stratosphere and troposphere



Research at the Nexus of Air Quality and Climate Change



CalNex IONS/RAQMS HTAPEMISSION NO ASSIM/Sonde O3  
May-June, 2010 (178 sondes)



CalNex ozonesonde measurements provide an opportunity to assess the impact of MLS and OMI O<sub>3</sub> assimilation on ozone within the Aura Reanalysis along the California coast

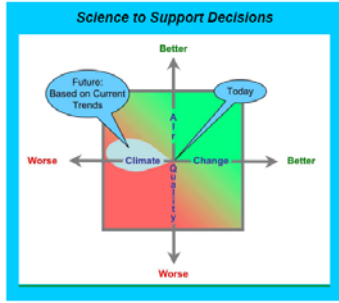
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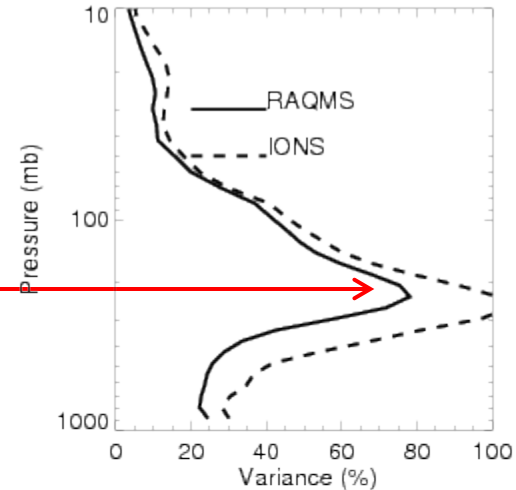
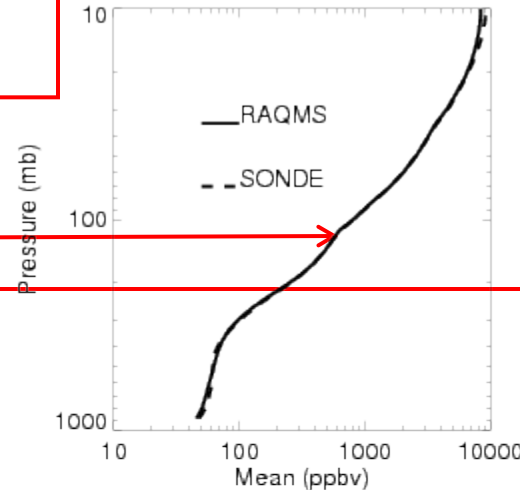
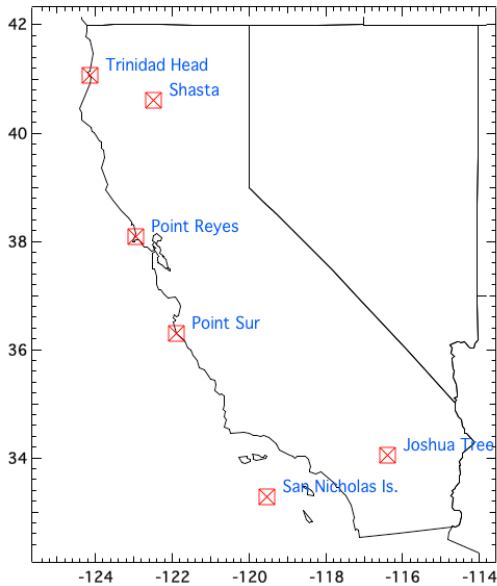
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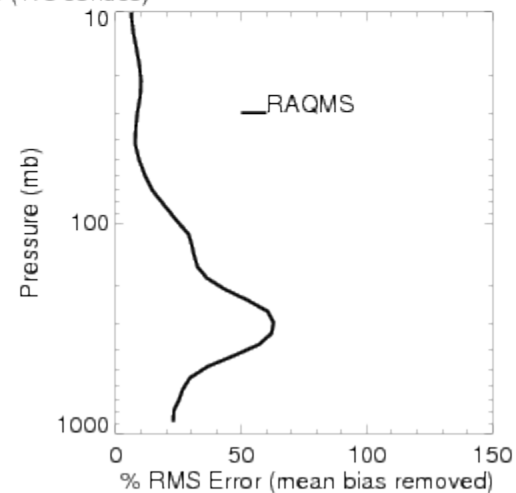
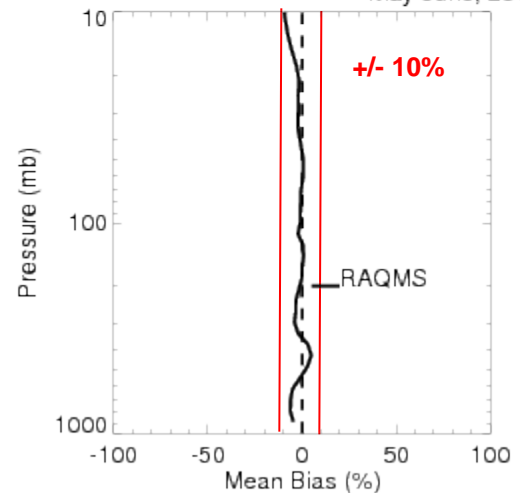
RAQMS Aura Reanalysis improves ozone and ozone variance in the stratosphere and troposphere



Research at the Nexus of Air Quality and Climate Change



CalNex IONS/RAQMS HTAPEMISSION Aura MLS 215mb Reanalysis/S May-June, 2010 (178 sondes)

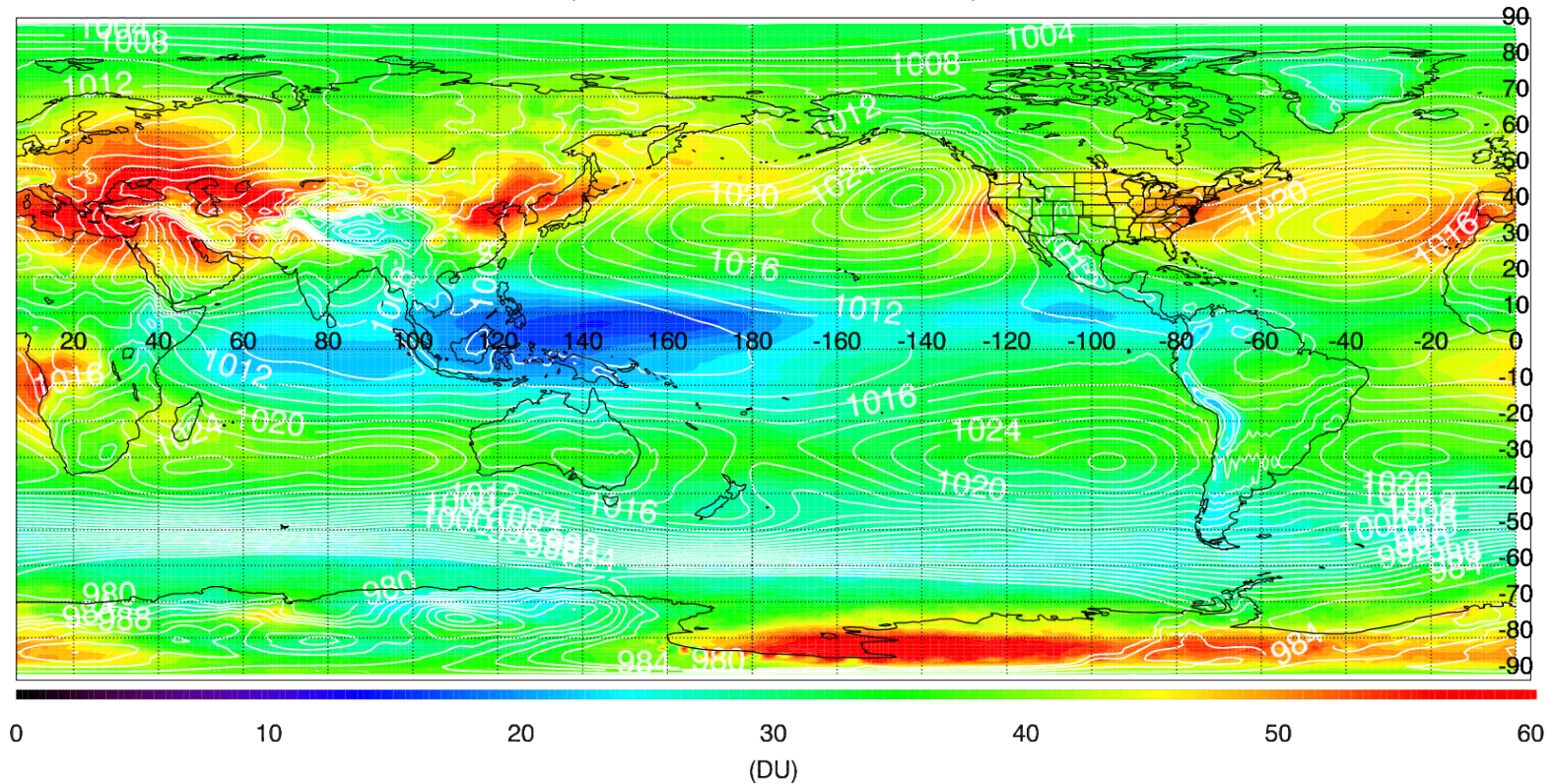


CalNex ozonesonde measurements provide an opportunity to assess the impact of MLS and OMI O<sub>3</sub> assimilation on ozone within the Aura Reanalysis along the California coast

# Aura Chemical Reanalysis in support Air Quality Applications

## July 2010 OMI NO2 Data Assimilation Studies

Tropospheric Ozone Column (DU) July 2010  
(ASSIM.HTAPEMISS.GSINO2)



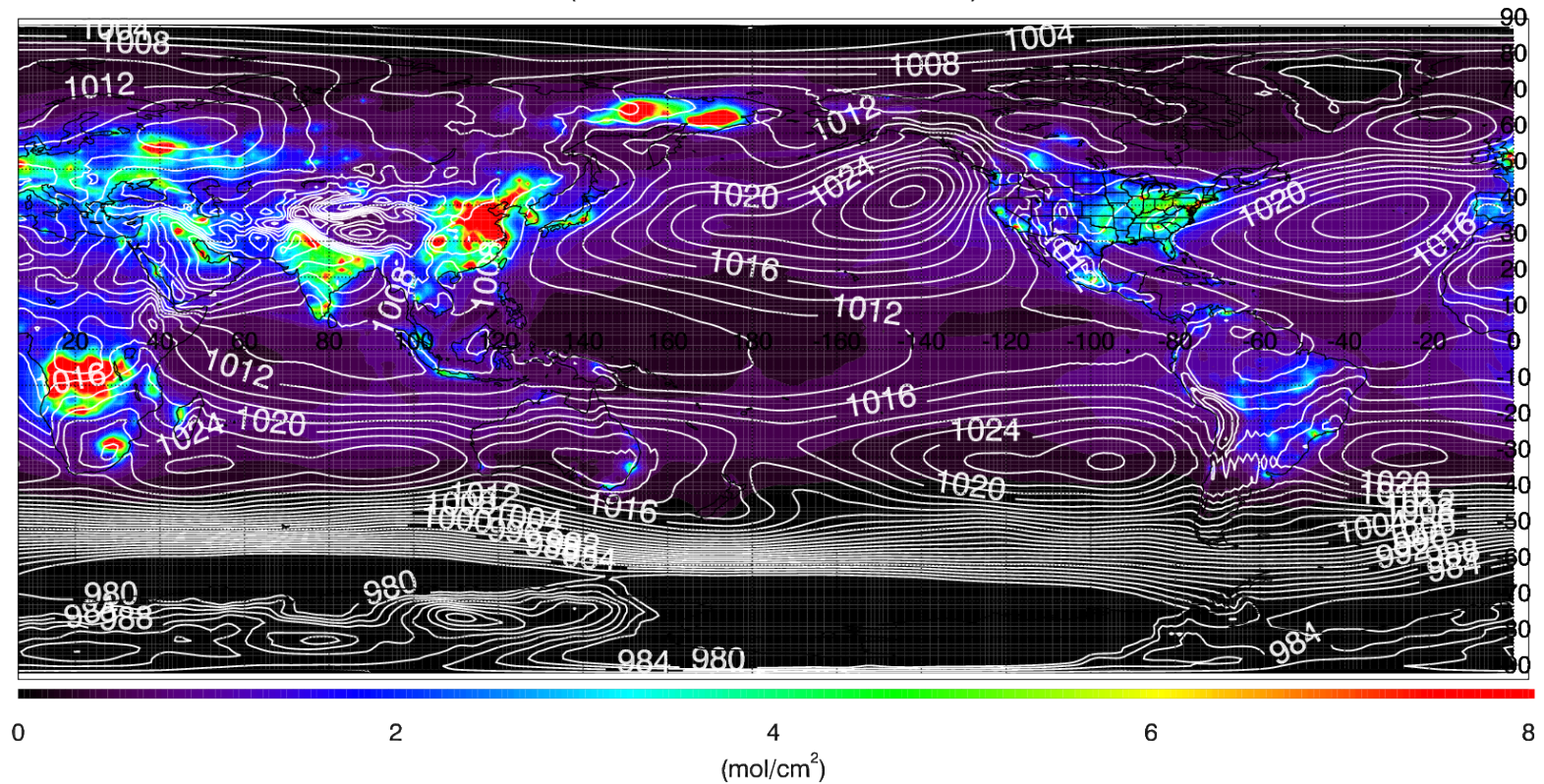
RAQMS Tropospheric Ozone Column: July 2010

High Tropospheric ozone over major urban/industrial and biomass burning regions  
Export of E. Asian and US emissions and accumulation within oceanic high pressure systems

# Aura Chemical Reanalysis in support Air Quality Applications

## July 2010 OMI NO2 Data Assimilation Studies

Tropospheric Column NO<sub>2</sub> (mol/cm<sup>2</sup>) July 2010  
(ASSIM.HTAPEMISS.GSINO2)

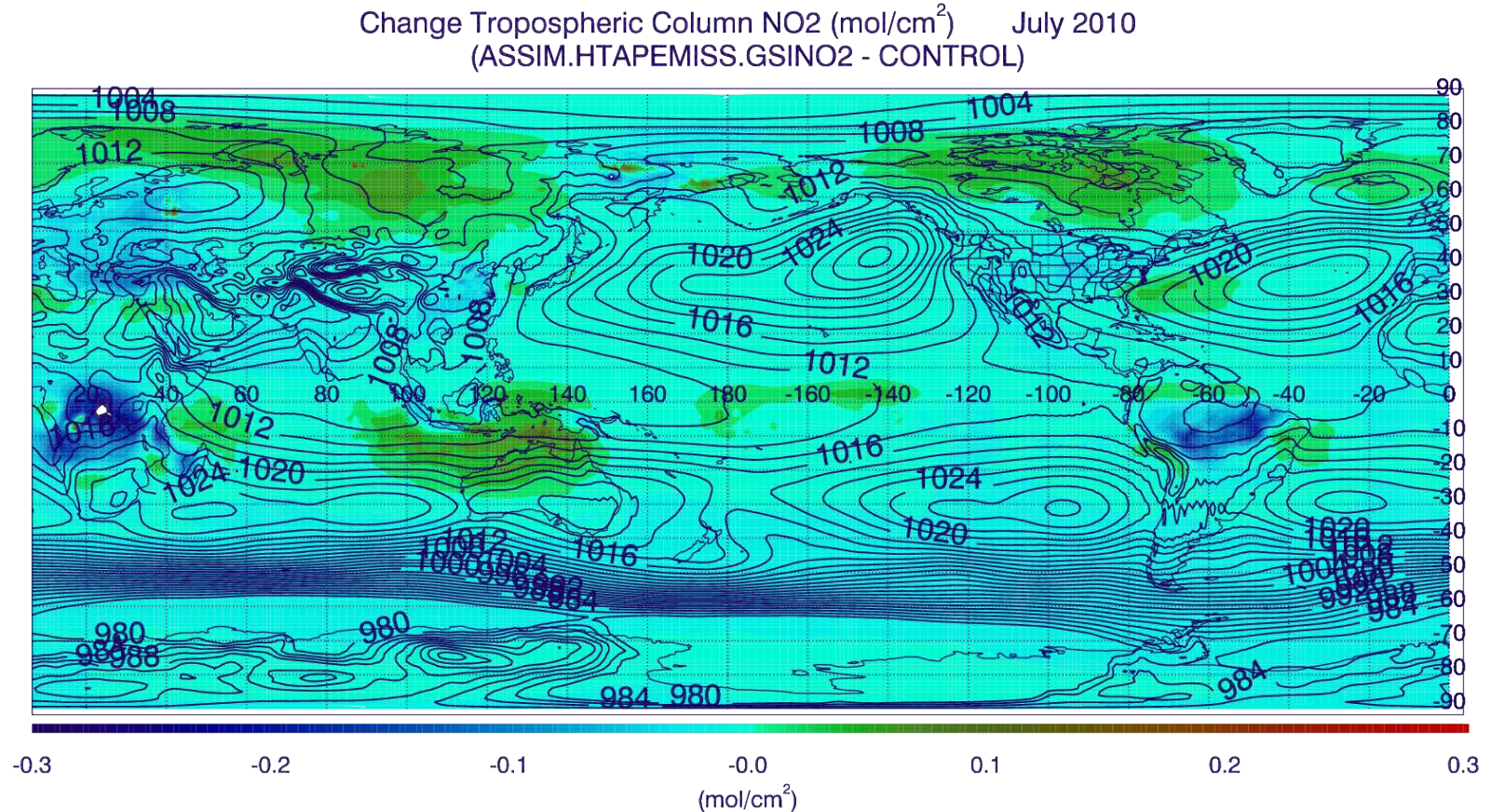


RAQMS Tropospheric NO<sub>2</sub> Column: July 2010

High Tropospheric NO<sub>2</sub> over major urban/industrial and biomass burning regions

# Aura Chemical Reanalysis in support Air Quality Applications

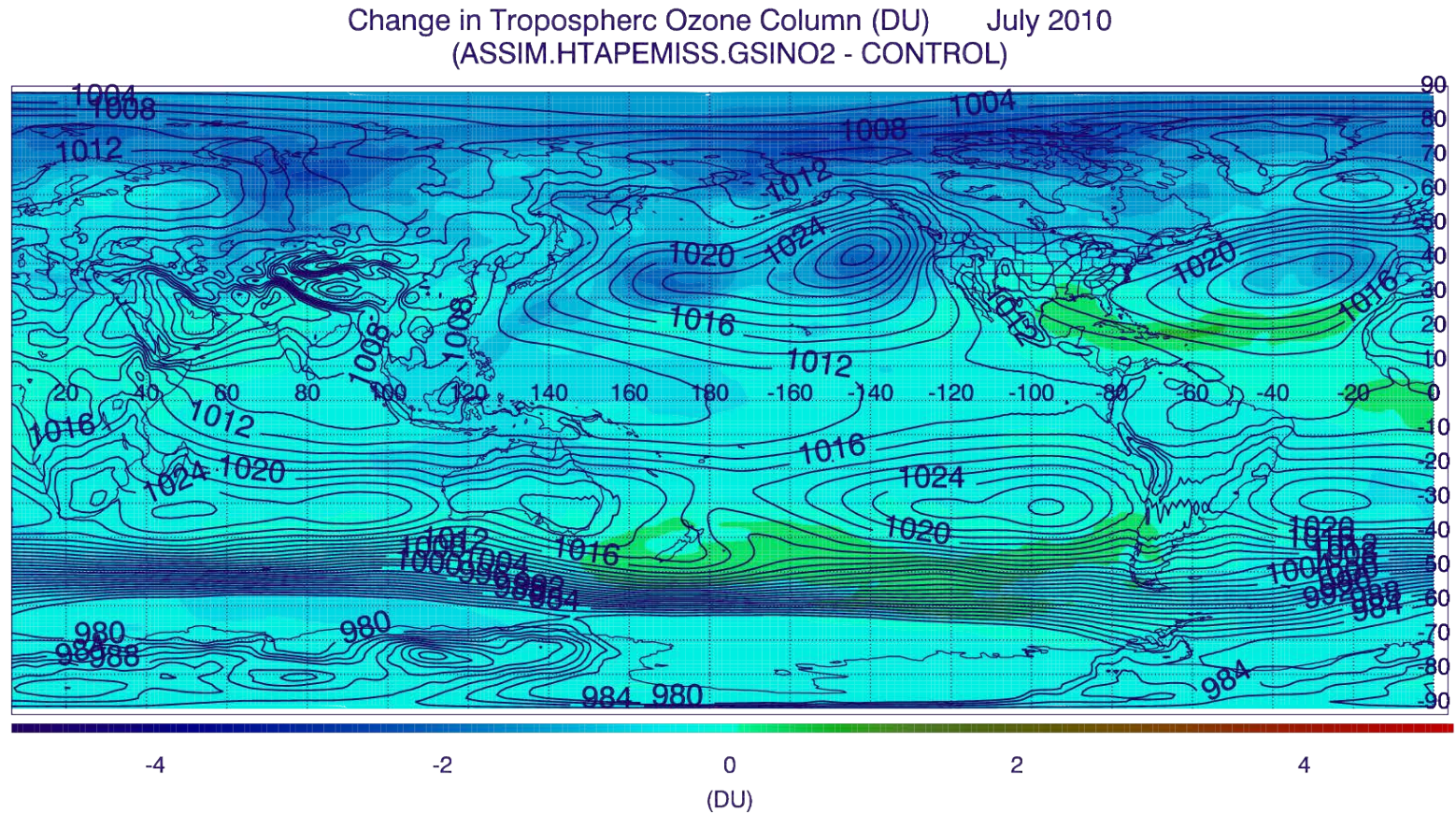
## July 2010 OMI NO2 Data Assimilation Studies



Impact on Tropospheric NO2 Column due to OMI Tropospheric NO2 assimilation : July 2010  
Largest reduction over South Africa and South American Biomass burning regions  
Largest increase over Asia and North America at high latitudes

# Aura Chemical Reanalysis in support Air Quality Applications

## July 2010 OMI NO2 Data Assimilation Studies



Change in Tropospheric Ozone due to Tropospheric NO<sub>2</sub> Column assimilation : July 2010  
Largest reduction is over Arctic and within Oceanic high pressure systems  
Largest increase is over Gulf of Mexico and South of Atlantic High pressure system



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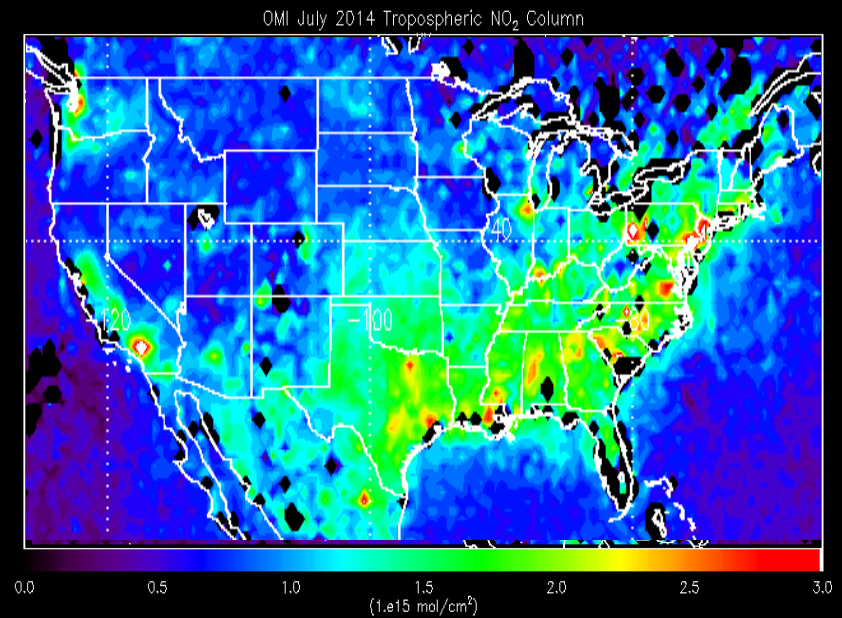
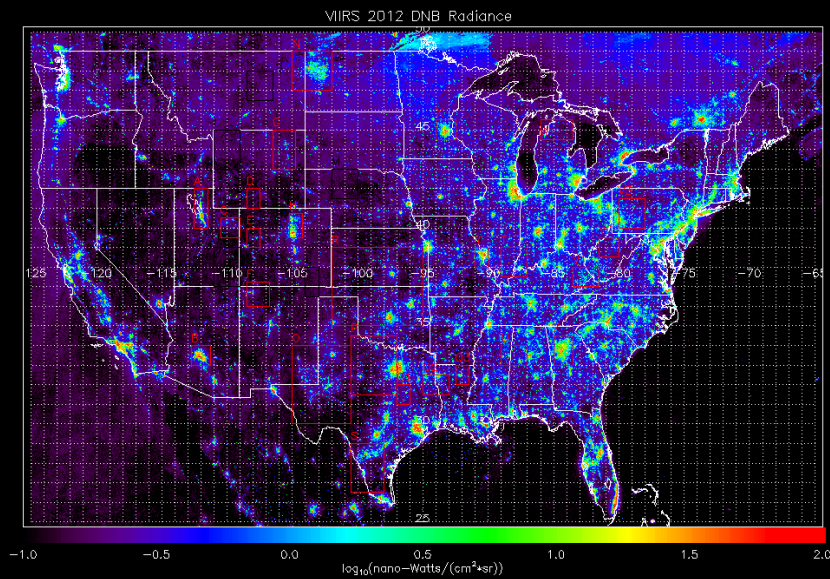
## Ongoing activities

- Collaboration with Wisconsin Department of Natural Resources (WDNR) and Lake Michigan Air Directors Consortium (LADCO) on influence of Chicago NO<sub>2</sub> emissions on ozone exceedances at Sheboygan, WI (exceeded limit for the 2013-15 design value in 2015)
  - Conducted regional and urban WRF-CHEM simulations for July 2011 investigating influence of Chicago, Milwaukee, and Green Bay NO<sub>2</sub> emissions on Sheboygan, WI exceedances
  - Planning 2011 CMAQ OMI NO<sub>2</sub> data assimilation experiments using OMI standard and enhanced spatial resolution NO<sub>2</sub> retrievals
- PI is member of Aerosol and Atmospheric Composition Task Force for development of NOAA's Next Generation Global Prediction System (NGGPS)
  - Planning on FY16 testing of the use of climatological tropospheric ozone production and loss rates generated from RAQMS/GSI Aura Reanalysis within NGGPS Atmospheric Composition forecast

# **Extra Slides**

# High resolution OMI NO<sub>2</sub> retrievals for urban scale AQ monitoring using VIIRS day-night-band radiances

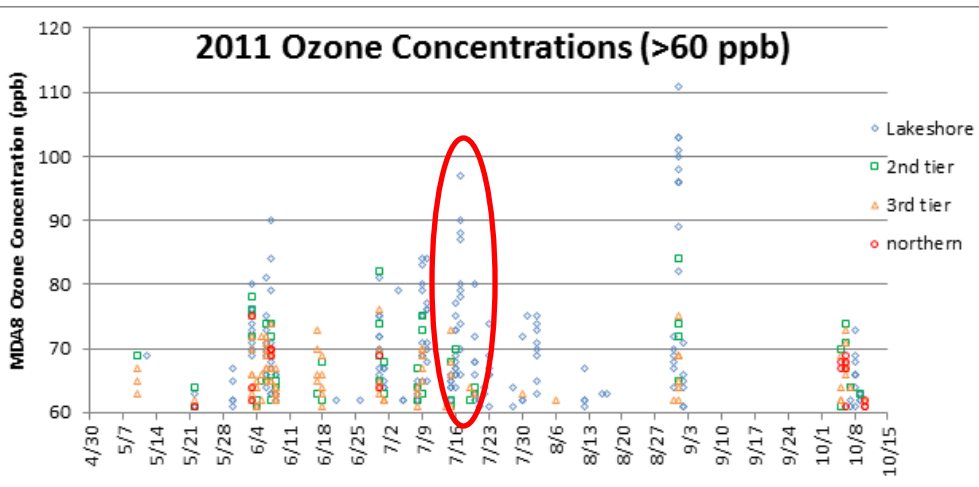
**Objective: Use high resolution VIIRS Day-Night-Band (DNB) radiance composites to redistribute OMI tropospheric NO<sub>2</sub> column retrievals within the OMI pixel and conduct high resolution air quality modeling/DA to assess the impact of urban NO<sub>x</sub> emissions on US Air Quality**



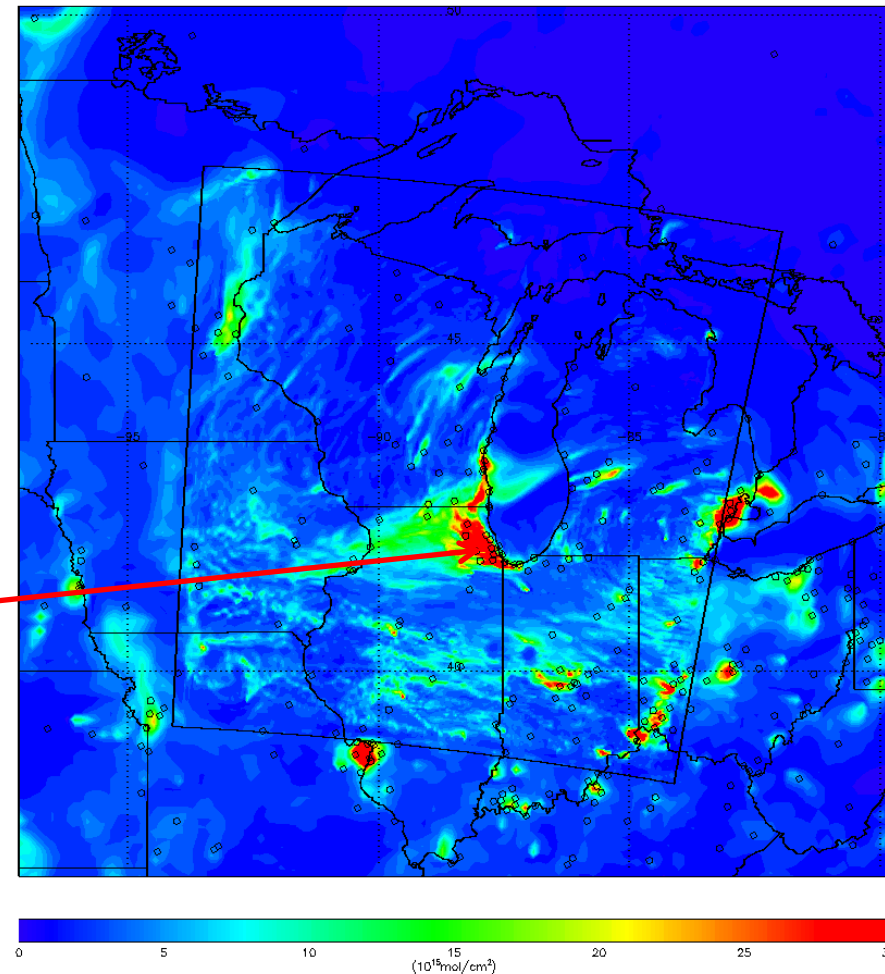
**VIIRS DNB cloud free composite from NOAA National Geophysical Data Center**

# Application to Wisconsin DNR/LADCO Lake Breeze Study (July 2011) With Rob Kaleel (LADCO) and Angie Dickens (WDNR)

## Wisconsin AIRNow surface O3 2011



## 12km/4km WRF-CHEM Tropospheric NO2 Column 18Z 07/30, 2011



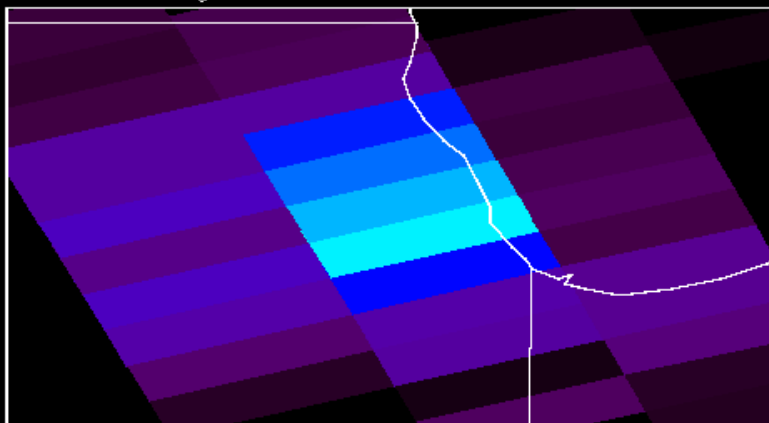
**4km WRF-CHEM  
Tropospheric NO2  
column shows values in  
excess of 30x10<sup>15</sup> mol/cm<sup>2</sup>  
over Chicago**

# Chicago OMI Standard and Enhanced NO2 Columns

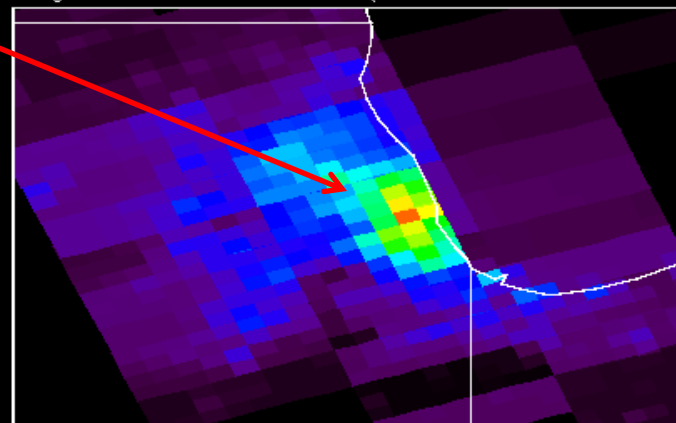
17:39Z July 30, 2011

OMI Enhanced Tropospheric NO2 column shows values in  $15\text{-}25 \times 10^{15}$  mol/cm<sup>2</sup> over Chicago

Chicago OMI Standard NO2 L2-OMNO2

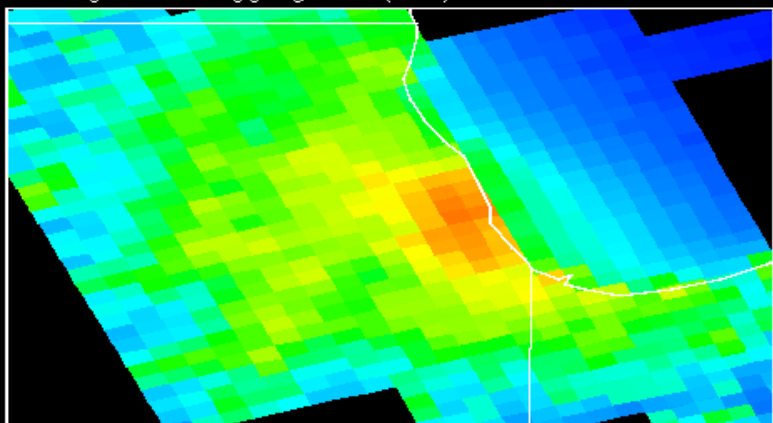


Chicago OMI Standard NO2 (VIIRS DNB Enhancement)



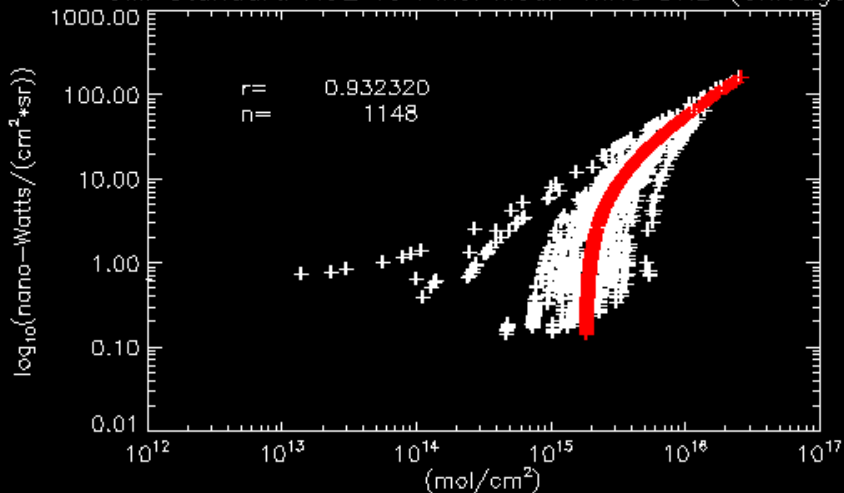
0 5 10 15 20 25 30 (mol/cm<sup>2</sup>) × 10<sup>15</sup>

Chicago VIIRS Aggregated (4x8) DNB within OMI Pixel

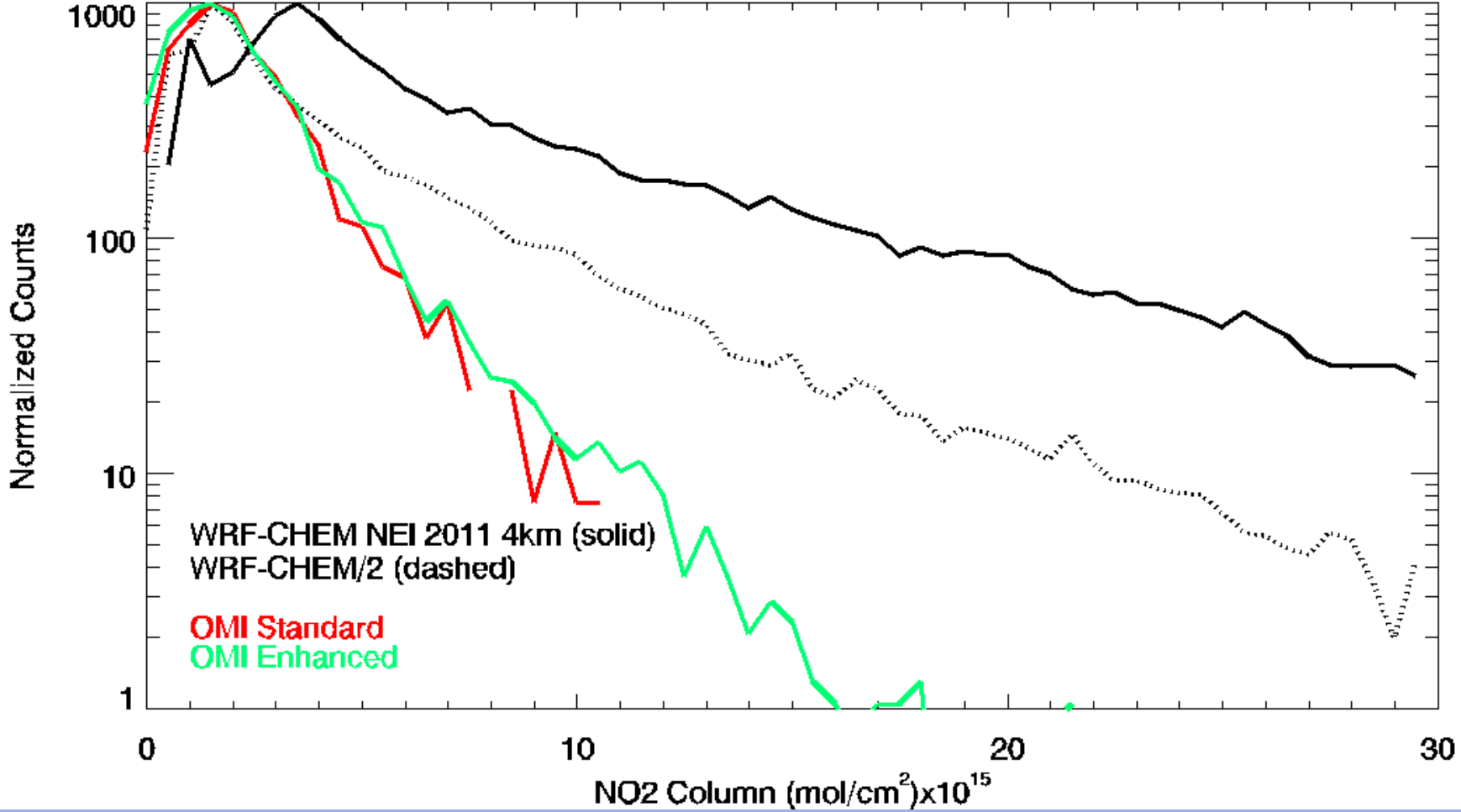


-2 -1 0 1 2 3 log<sub>10</sub>(nano-Watts/(cm<sup>2</sup>\*sr))

OMI Standard NO2 vs Pixel Mean VIIRS DNB (Chicago)



# NO2 Columns Chicago July, 2011



Histograms of the 4km WRF-CHEM NO2 columns (black) show median values that are 2x larger than either the OMI Enhanced retrieval (green) than the OMI Standard retrieval (red)

# 4km WRF-Chem NEI 2011 NO emission O3 sensitivity studies

July, 2011

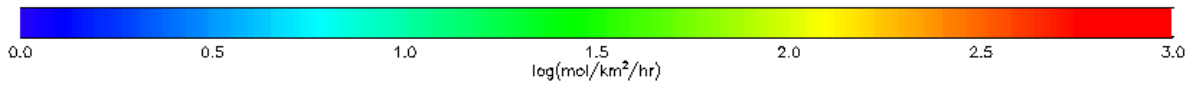
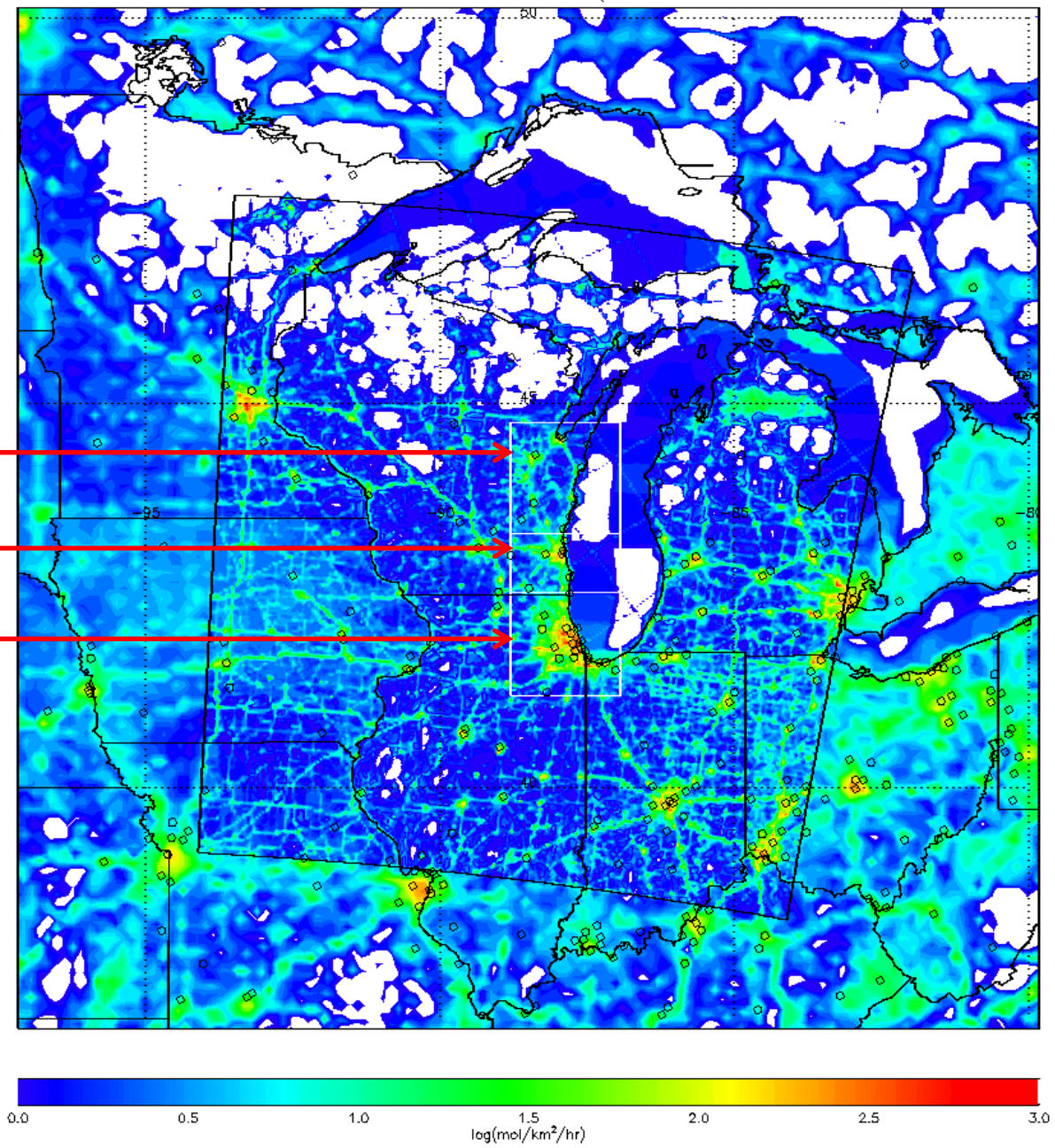
WRF-CHEM 12km and 4km Surface NO Emissions RAQMS LBC valid 2011-07-17\_22:00:00

**Green Bay (GB) domain**

**Milwaukee (ML) domain**

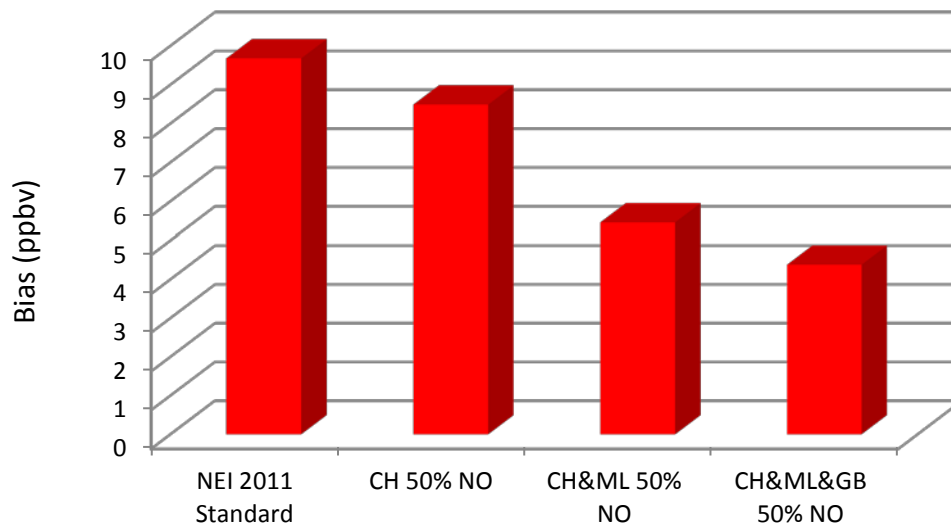
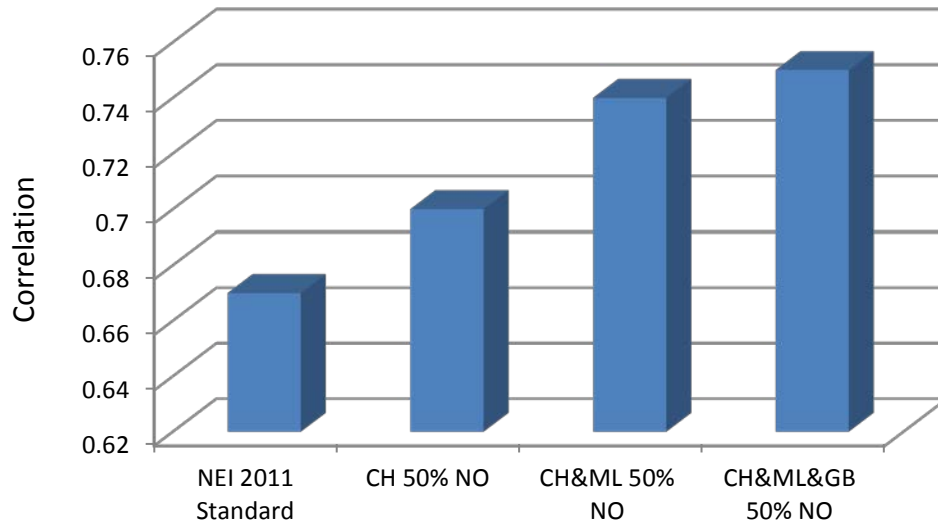
**Chicago (CH) domain**

**Green Bay domain includes mobile sources long Western Lake Michigan and Fox River Valley**



# Summary of 4km WRF-Chem NEI NO emission O3 sensitivity studies for Western Lake Michigan AIRNow sites July 17-18, 2011

## AIRNow vs WRF-CHEM O3



**50% reductions in Chicago (CH), Chicago & Milwaukee (CH&ML), Chicago & Milwaukee & Green Bay (CH&ML&GB) NO emissions show progressive increases in correlations and reductions in surface ozone biases during the July 17-18, 2011 ozone episode.**