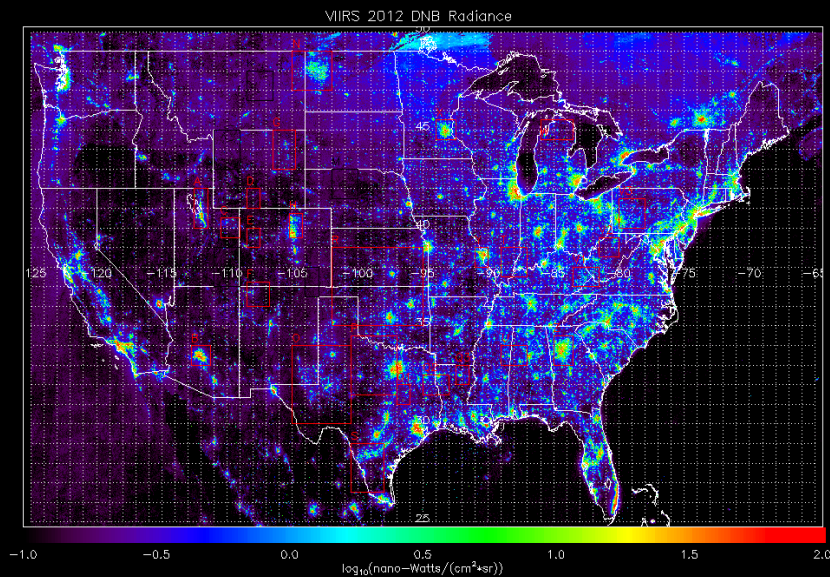
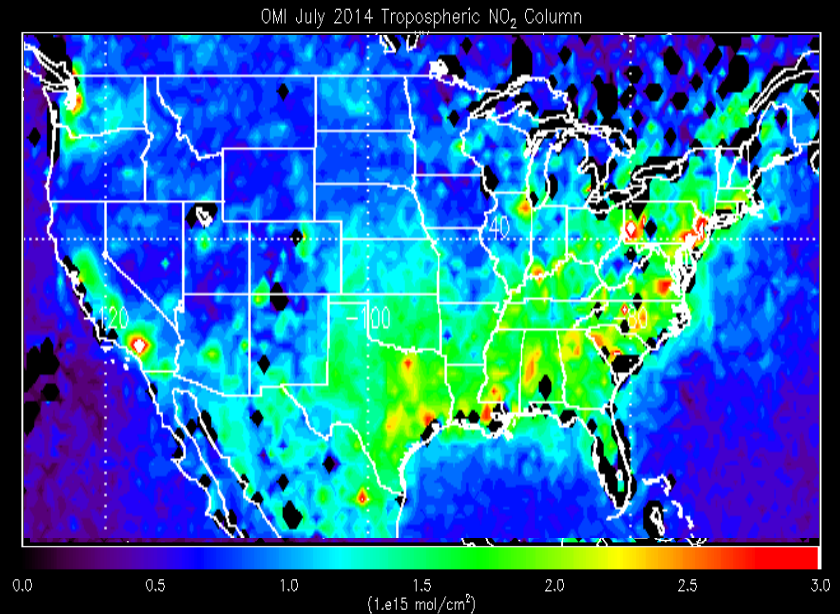


High resolution OMI NO₂ retrievals for urban scale AQ monitoring using VIIRS day-night-band radiances

Application to Wisconsin DNR/LADCO Lake Breeze Study Brad Pierce NOAA/NESDIS

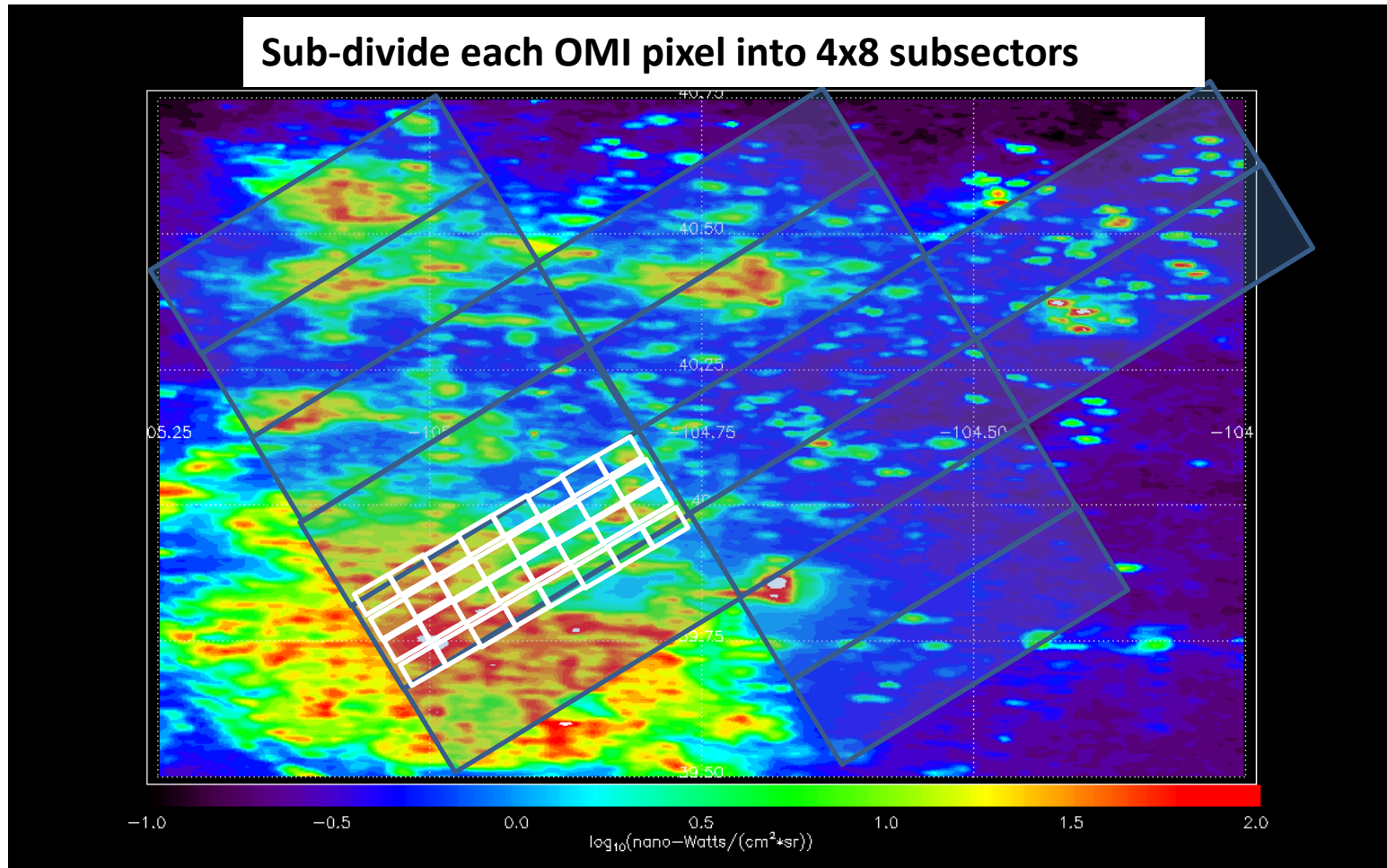


VIIRS DNB cloud free composite from NOAA National Geophysical Data Center



OMI July 2014 cloud free composite from NASA Aura Satellite

Using VIIRS Day Night Band (DNB) radiances to add sub-pixel (~4x4km) variability to native (13x24km) OMI NO2 retrieval

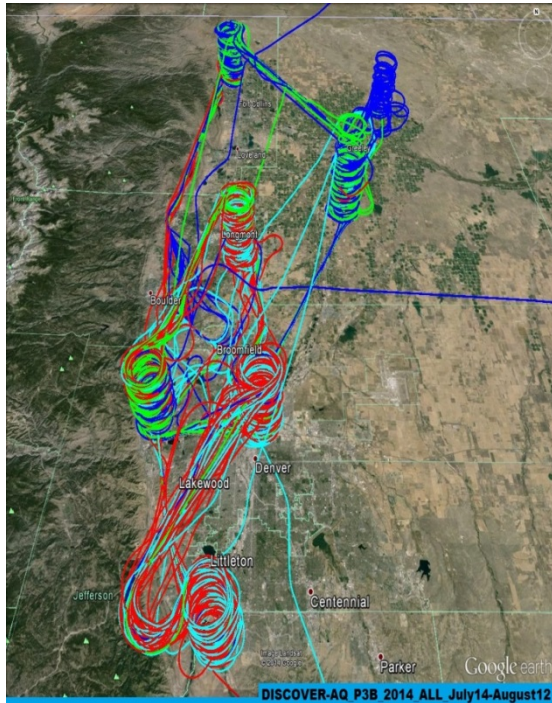


Denver, CO VIIRS Day Night Band (DNB) nighttime lights

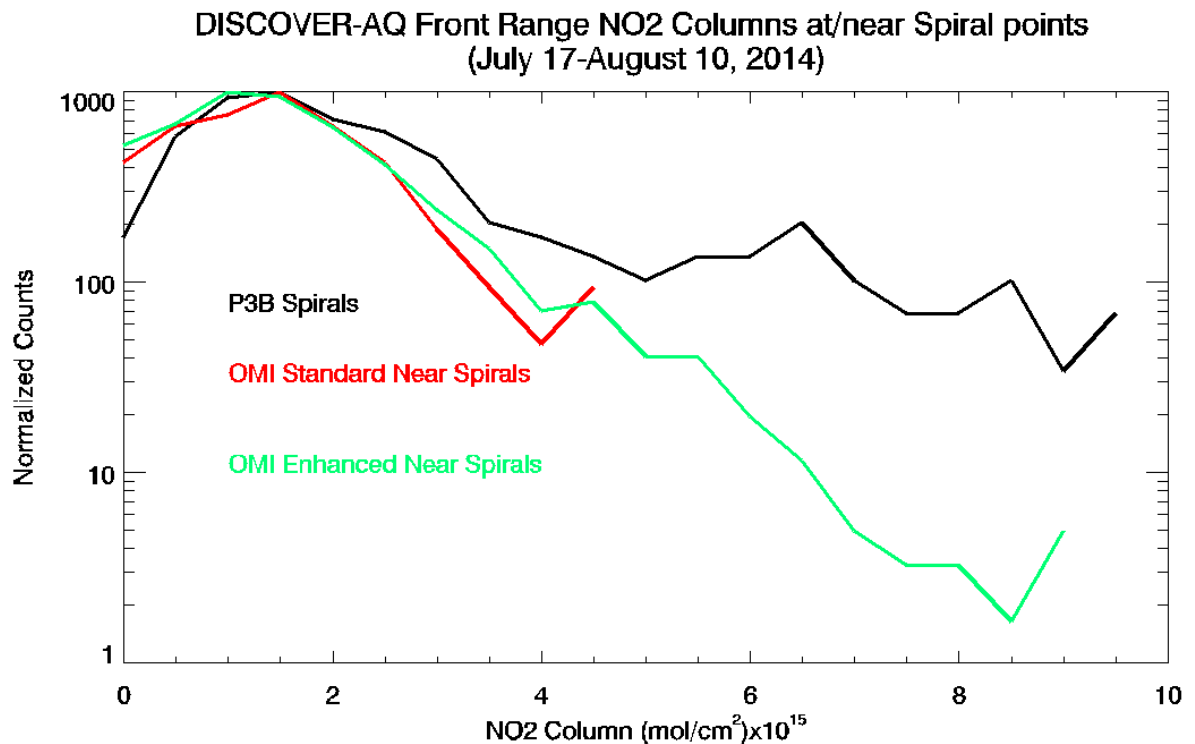
Validation for Denver, CO

July-August 2014 FRAPPE/DISCOVER-AQ

Integration of airborne insitu NO₂ profiles collected during DISCOVER-AQ over the depth of the profile provide column NO₂ measurements for validating the OMI Standard, and OMI Enhanced NO₂ retrievals.

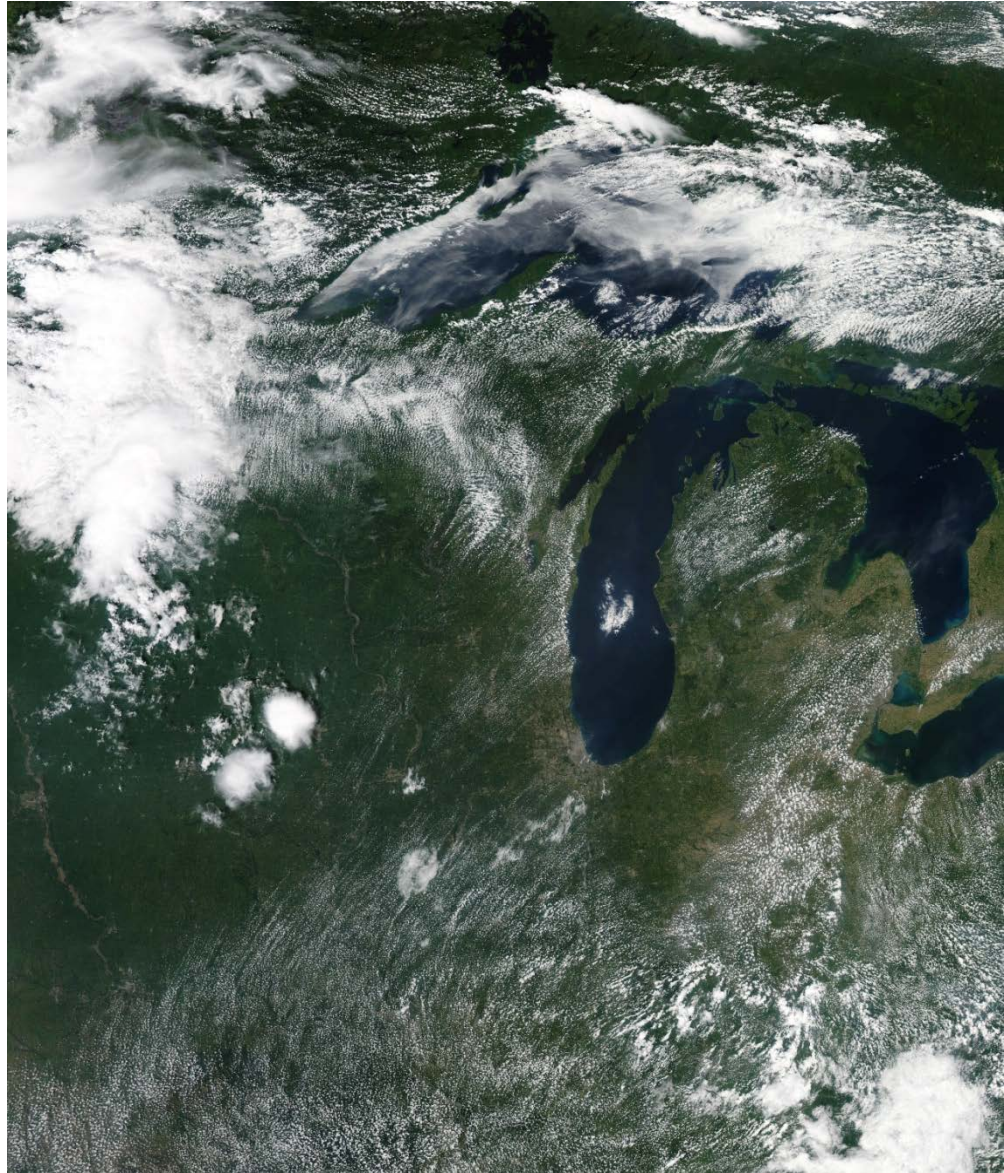


Map of DISCOVER-AQ flights



Histograms of the airborne NO₂ columns (black) show a long tail towards higher values from profiles over the Denver metropolitan area which is better captured by the OMI Enhanced retrieval (green) than the OMI Standard retrieval (red)

MODIS Image July 17, 2011



From Mike Majewski, WDNR

MODIS Image July 17, 2011



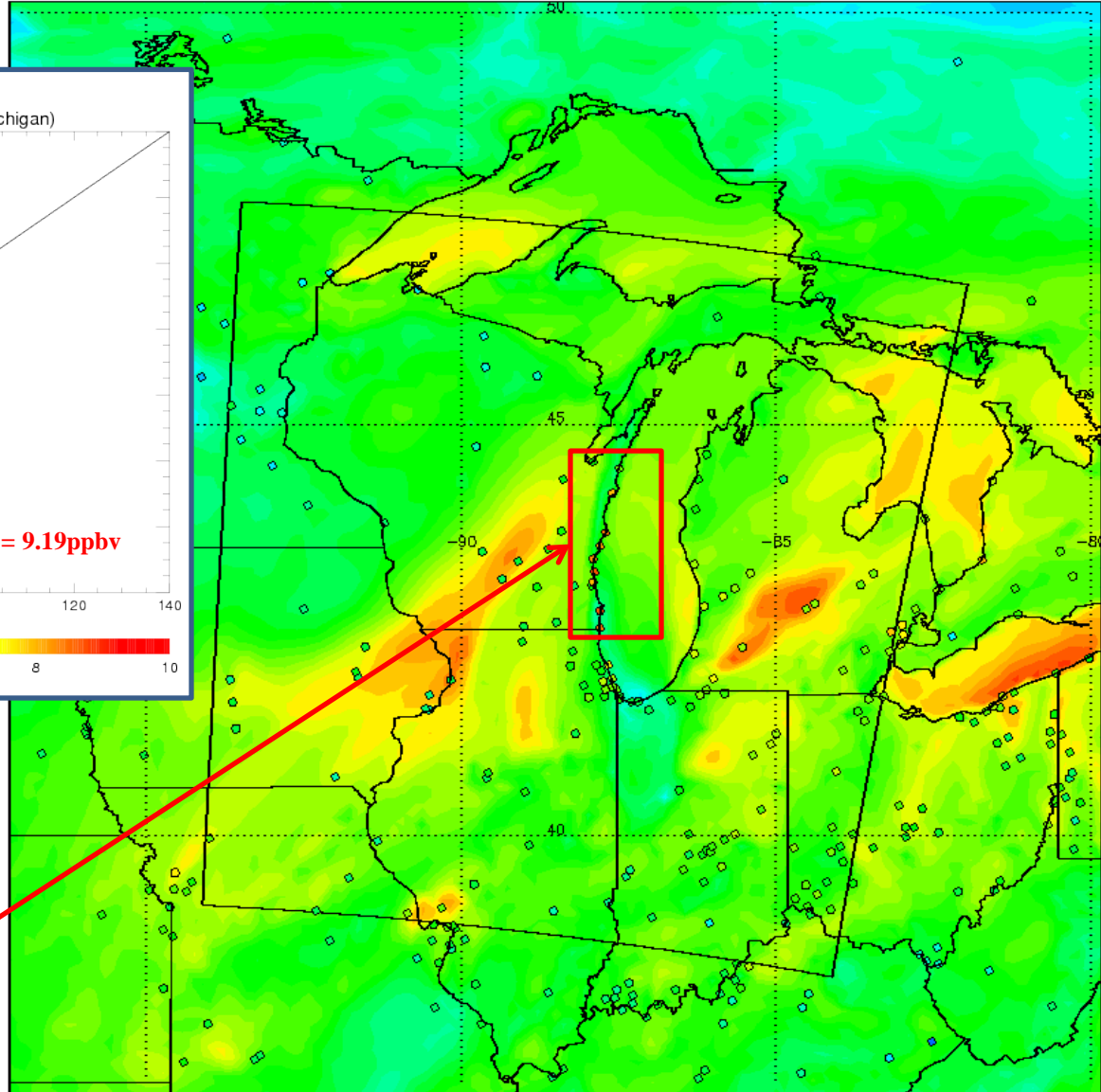
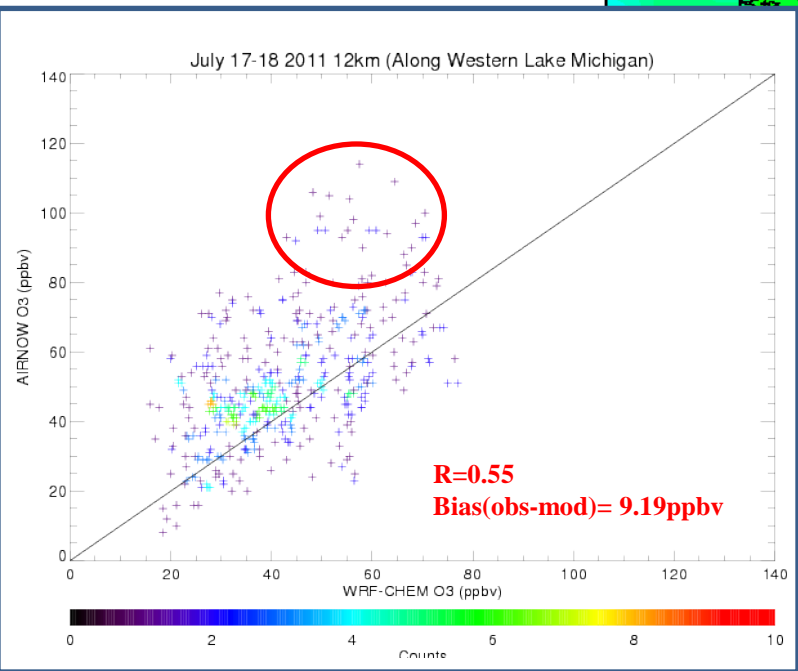
Lake Breeze
Front

Prevailing winds

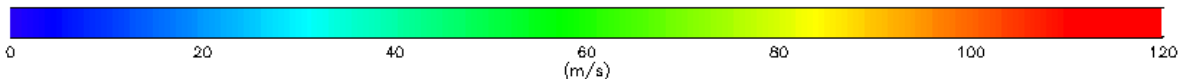
From Mike Majewski, WDNR

12km WRF-CHEM Surface O3 22Z (5:00pm Central) July 17, 2011

WRF-CHEM 12km Surface O3 RAQMS LBC valid 2011-07-17_22:00:00

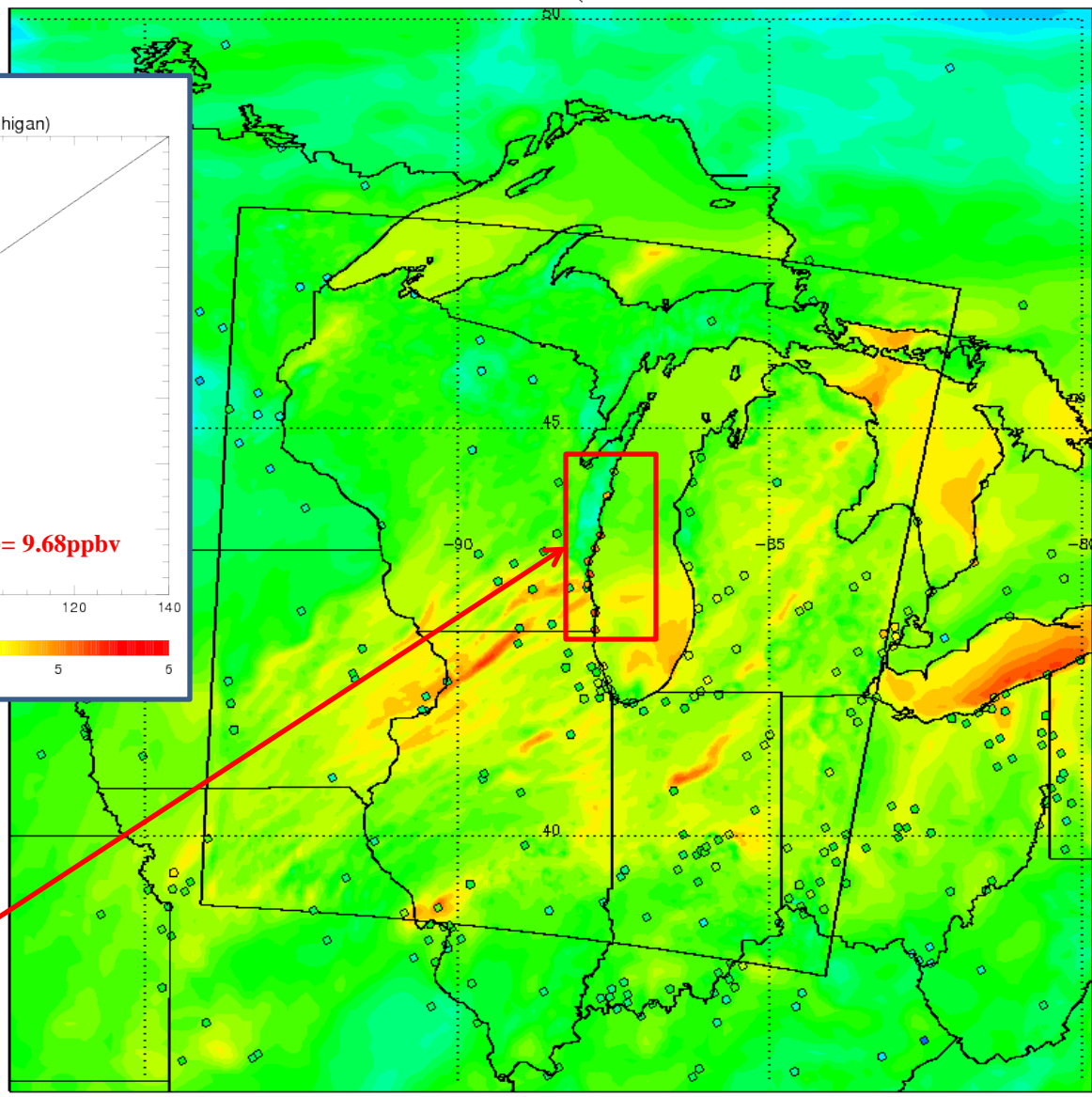
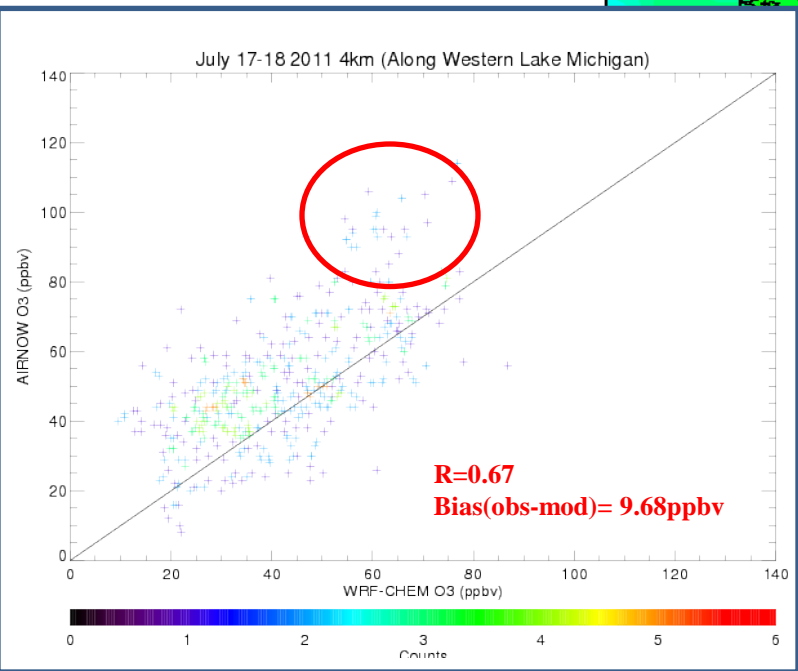


12km run significantly under predicts surface ozone along Western Shore of Lake Michigan – Shows minimum ozone along coast where highest ozone is observed

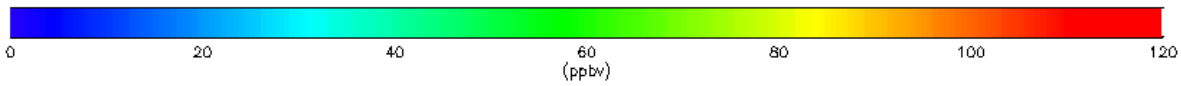


4km WRF-CHEM Surface O3 22Z (5:00pm Central) July 17, 2011

WRF-CHEM 12km and 4km Surface O3 RAQMS LBC valid 2011-07-17_22:00:00

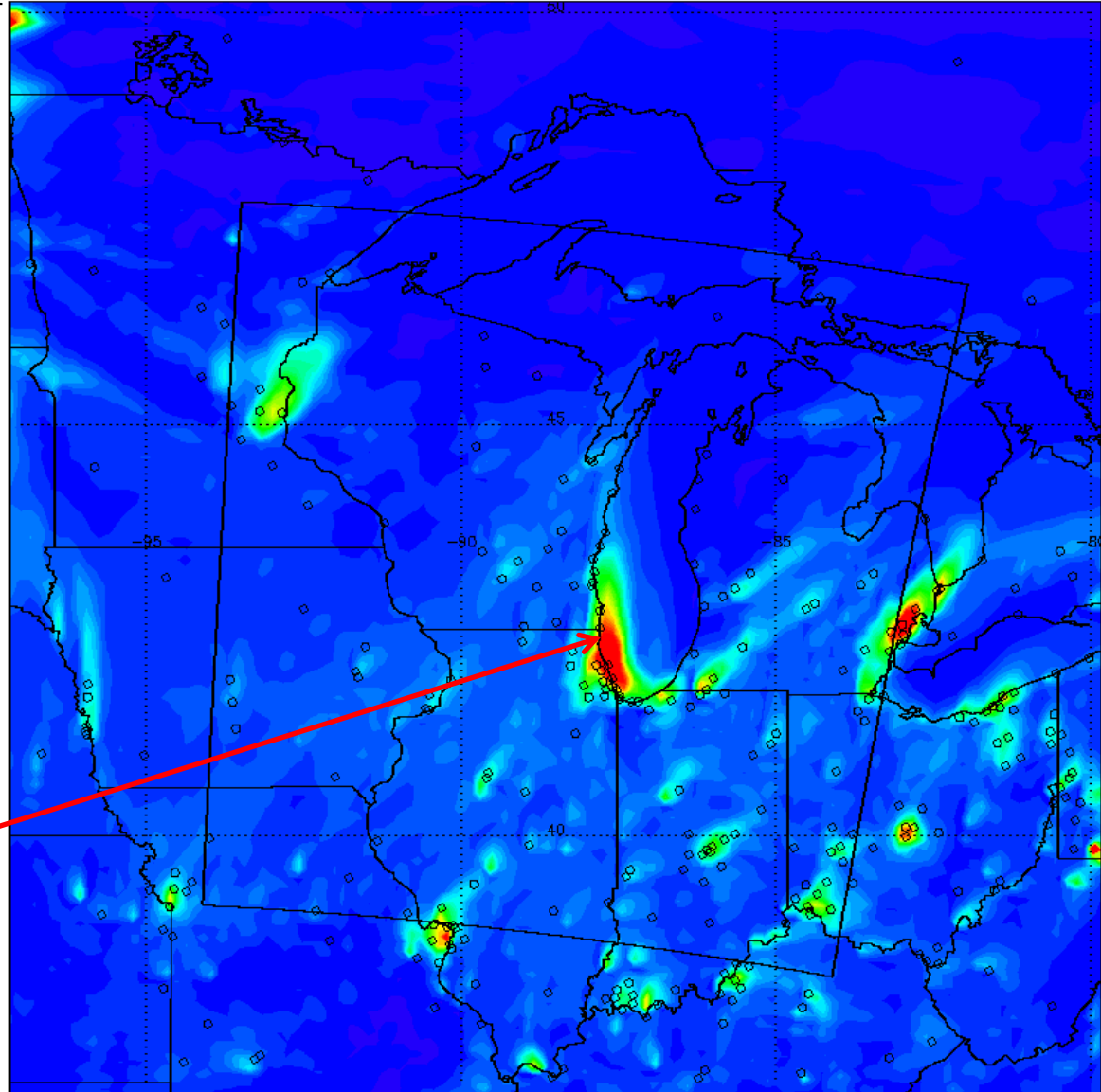


4km also significantly under predicts surface ozone along Western Shore of Lake Michigan – Captures SE Wisconsin better but shows lower minimum in ozone North of Milwaukee

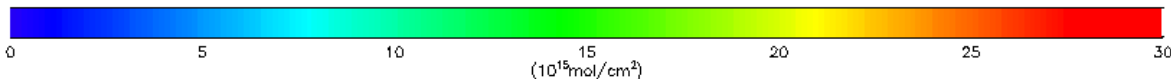


12km WRF-CHEM Tropospheric NO2 Column 22Z (5:00pm Central) July 17, 2011

WRF-CHEM 12km Tropospheric NO2 Column RAQMS LBC valid 2011-07-17_22:00:00



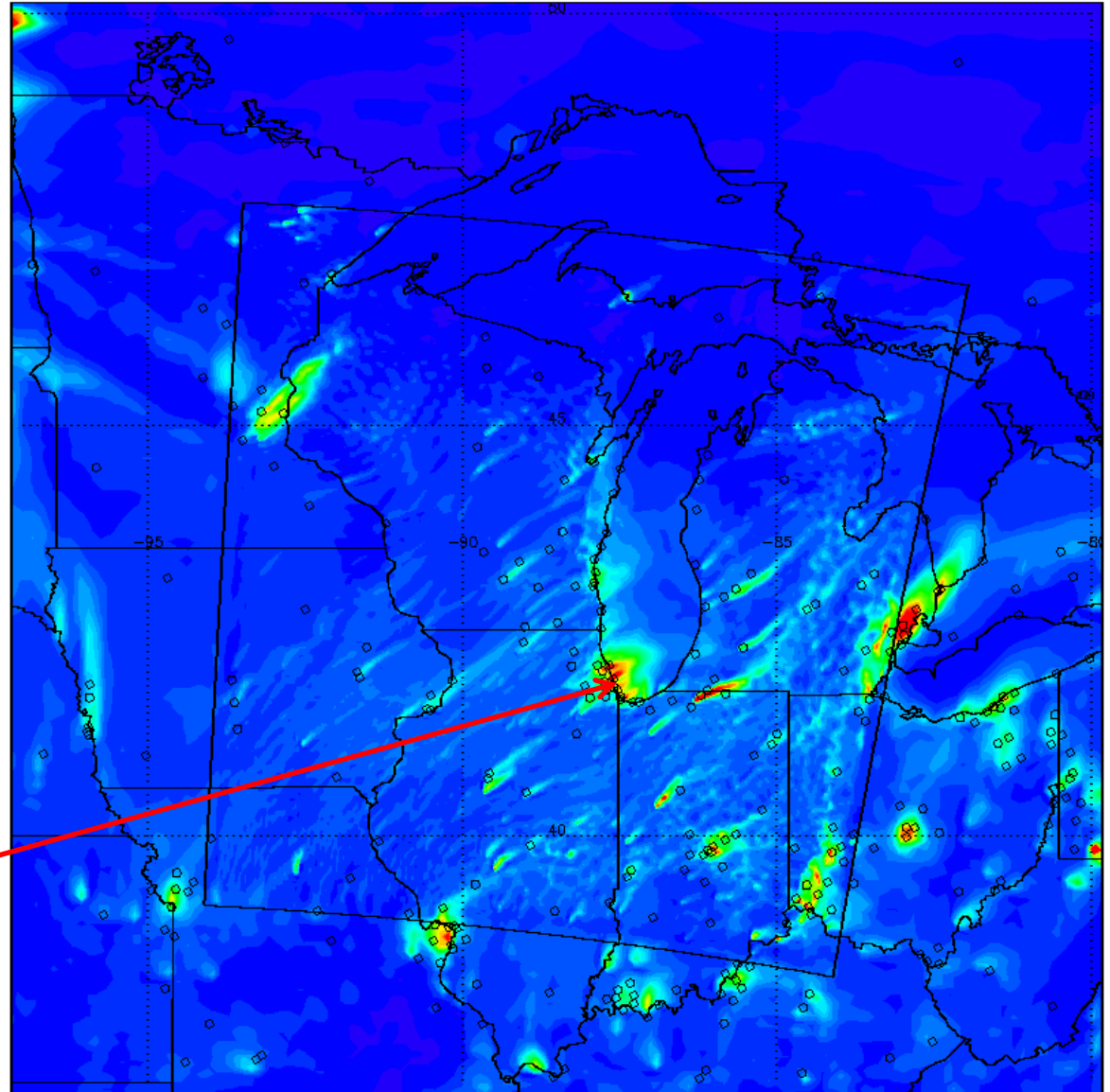
12km Tropospheric NO2 column shows values in excess of $30 \times 10^{15} \text{ mol/cm}^2$ North of Chicago



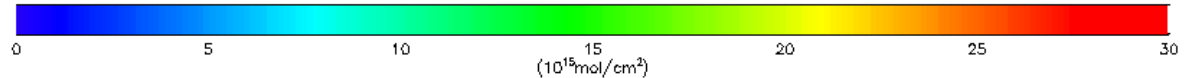
4km WRF-CHEM Tropospheric NO2 Column 22Z (5:00pm Central)

July 17, 2011

WRF-CHEM 12km and 4km Tropospheric NO2 Column RAQMS LBC valid 2011-07-17_22:00:00



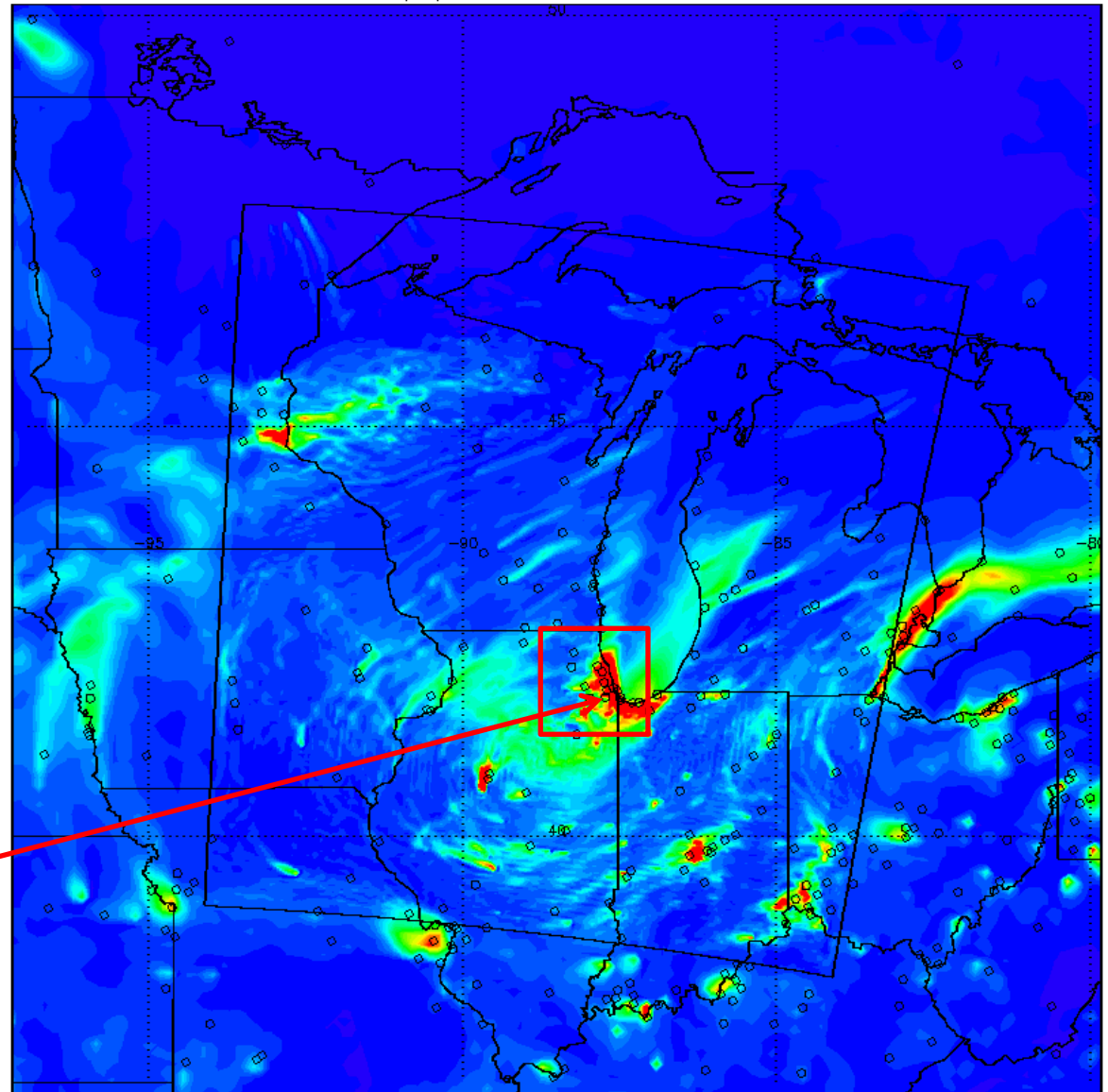
4km Tropospheric NO2 column shows values in excess of 25×10^{15} mol/cm² only immediately offshore of Chicago



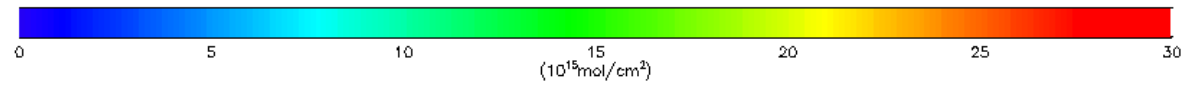
**Comparisons between near nadir OMI Standard
and
Spatially Enhanced NO₂ column retrievals
and
4km WRF-CHEM NO₂ columns**

4km WRF-CHEM Tropospheric NO₂ Column 18Z (1:00pm Central 07/05, 2011)

WRF-CHEM 12km and 4km Tropospheric NO₂ Column RAQMS LBC valid 2011-07-05_18:00:00



4km Tropospheric NO₂ column shows values in excess of 30×10^{15} mol/cm² over Chicago, IL and Gary, IN

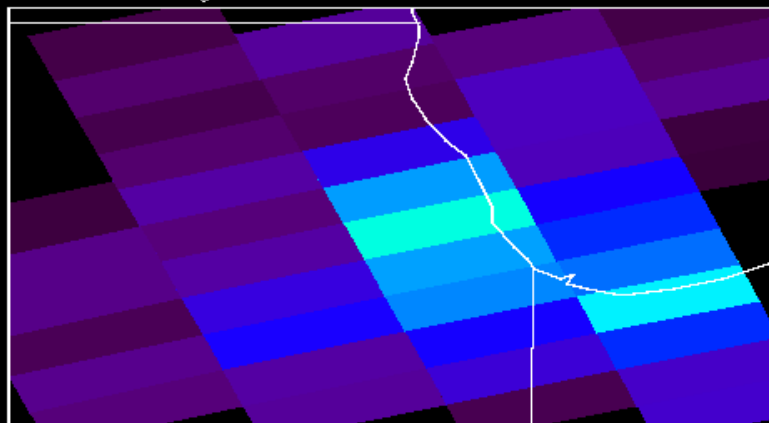


Chicago OMI Standard and Enhanced NO2 Columns

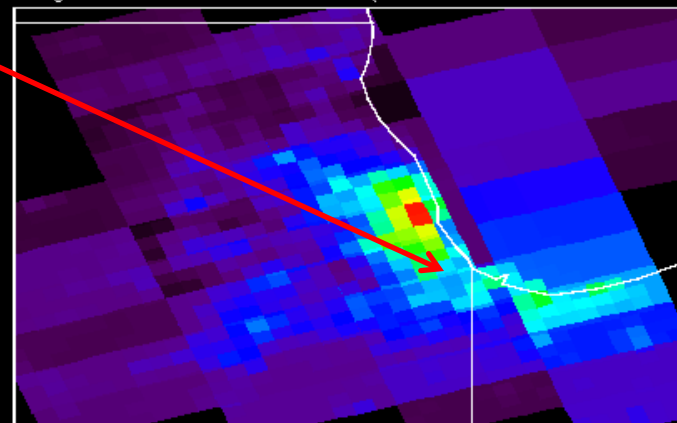
17:47Z July 05, 2011

OMI Enhanced Tropospheric NO2 column shows values in $15\text{-}30 \times 10^{15}$ mol/cm² over Chicago

Chicago OMI Standard NO2 L2-OMNO2

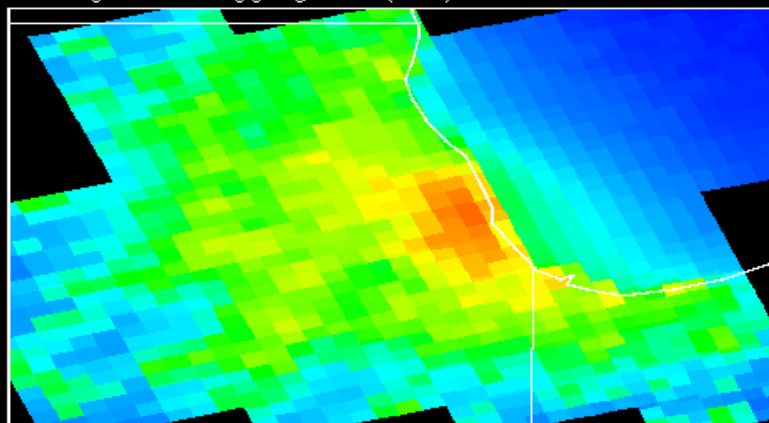


Chicago OMI Standard NO2 (VIIRS DNB Enhancement)



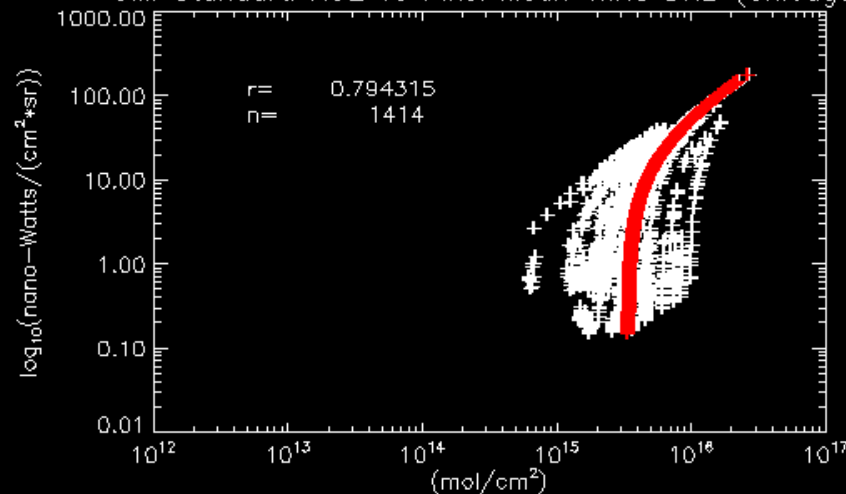
0 5 10 15 20 25 30 (mol/cm²) $\times 10^{15}$

Chicago VIIRS Aggregated (4x8) DNB within OMI Pixel



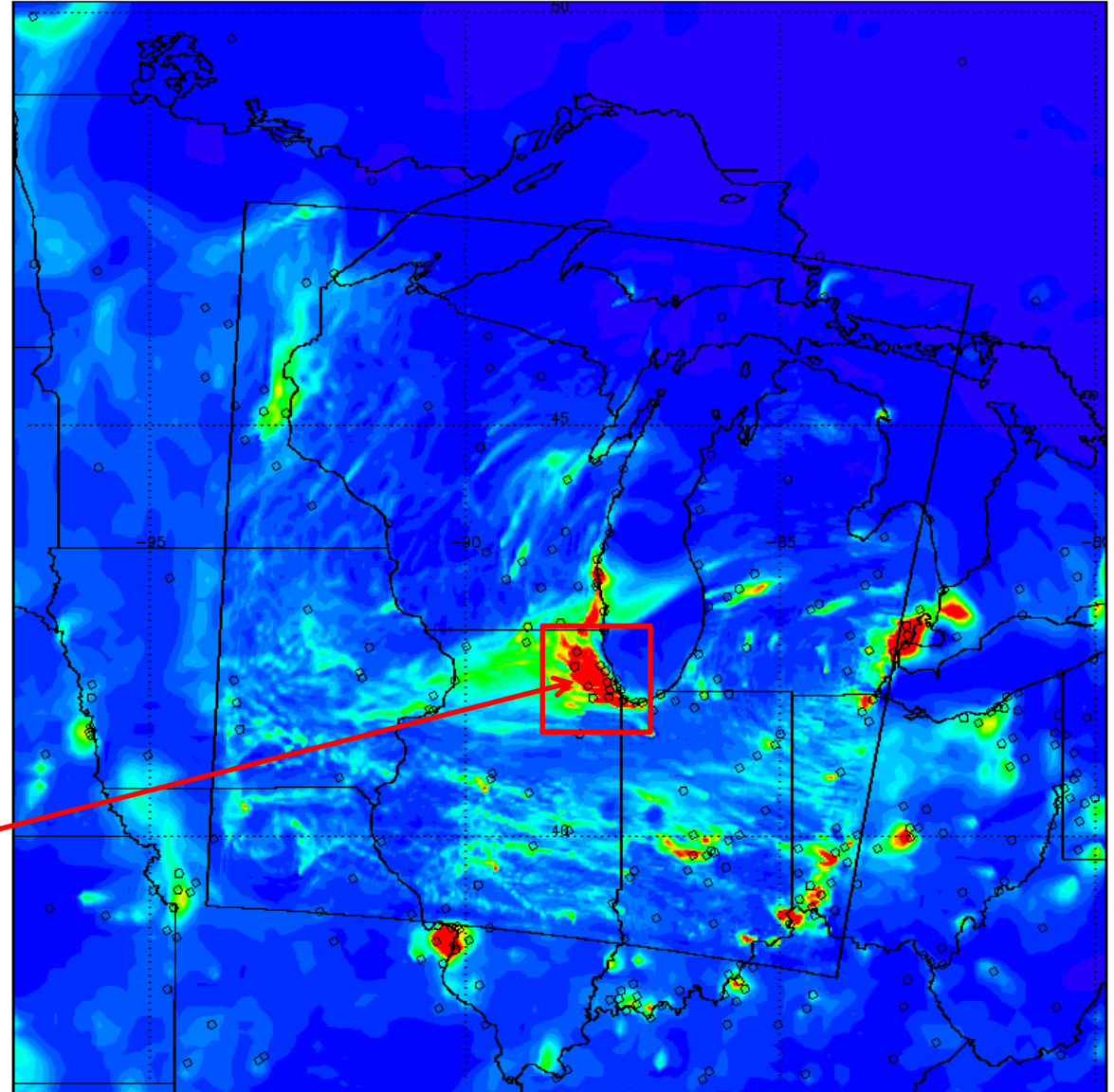
-2 -1 0 1 2 3 $\log_{10}(\text{nano-Watts}/(\text{cm}^2 \cdot \text{sr}))$

OMI Standard NO2 vs Pixel Mean VIIRS DNB (Chicago)

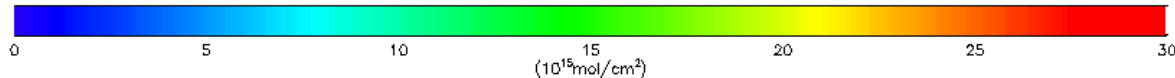


4km WRF-CHEM Tropospheric NO₂ Column 18Z (1:00pm Central 07/30, 2011)

WRF-CHEM 12km and 4km Tropospheric NO₂ Column RAQMS LBC valid 2011-07-30_18:00:00



4km Tropospheric NO₂ column shows values in excess of 30×10^{15} mol/cm² over Chicago

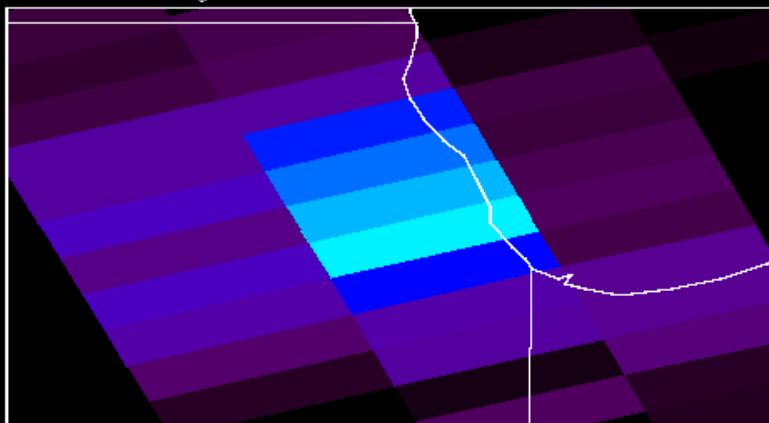


Chicago OMI Standard and Enhanced NO2 Columns

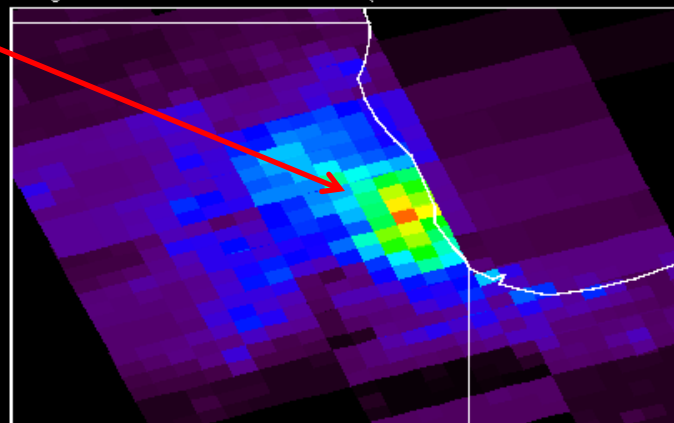
17:39Z July 30, 2011

OMI Enhanced Tropospheric NO2 column shows values in $15\text{-}25 \times 10^{15}$ mol/cm² over Chicago

Chicago OMI Standard NO2 L2-OMNO2

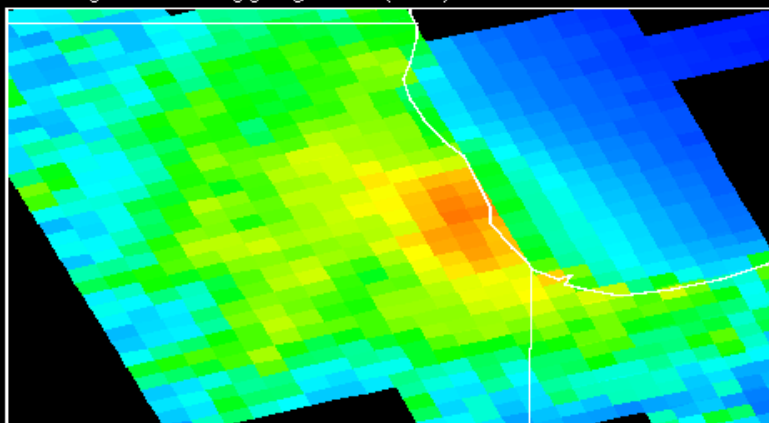


Chicago OMI Standard NO2 (VIIRS DNB Enhancement)



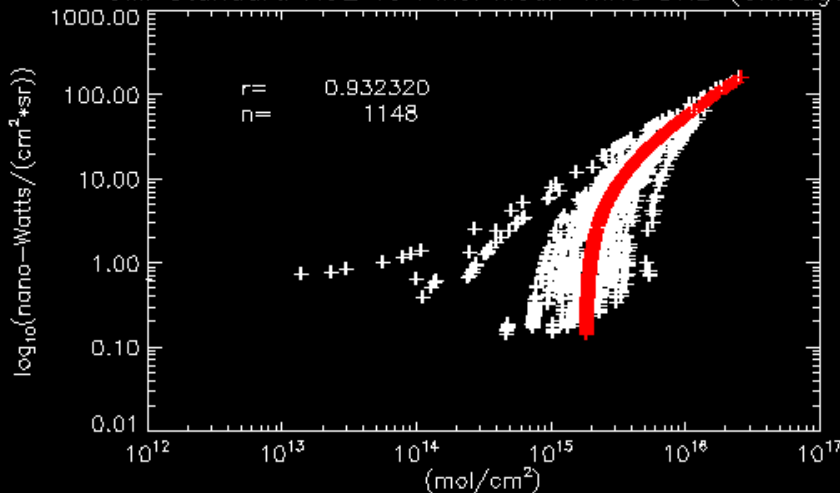
0 5 10 15 20 25 30 (mol/cm²) × 10¹⁵

Chicago VIIRS Aggregated (4x8) DNB within OMI Pixel

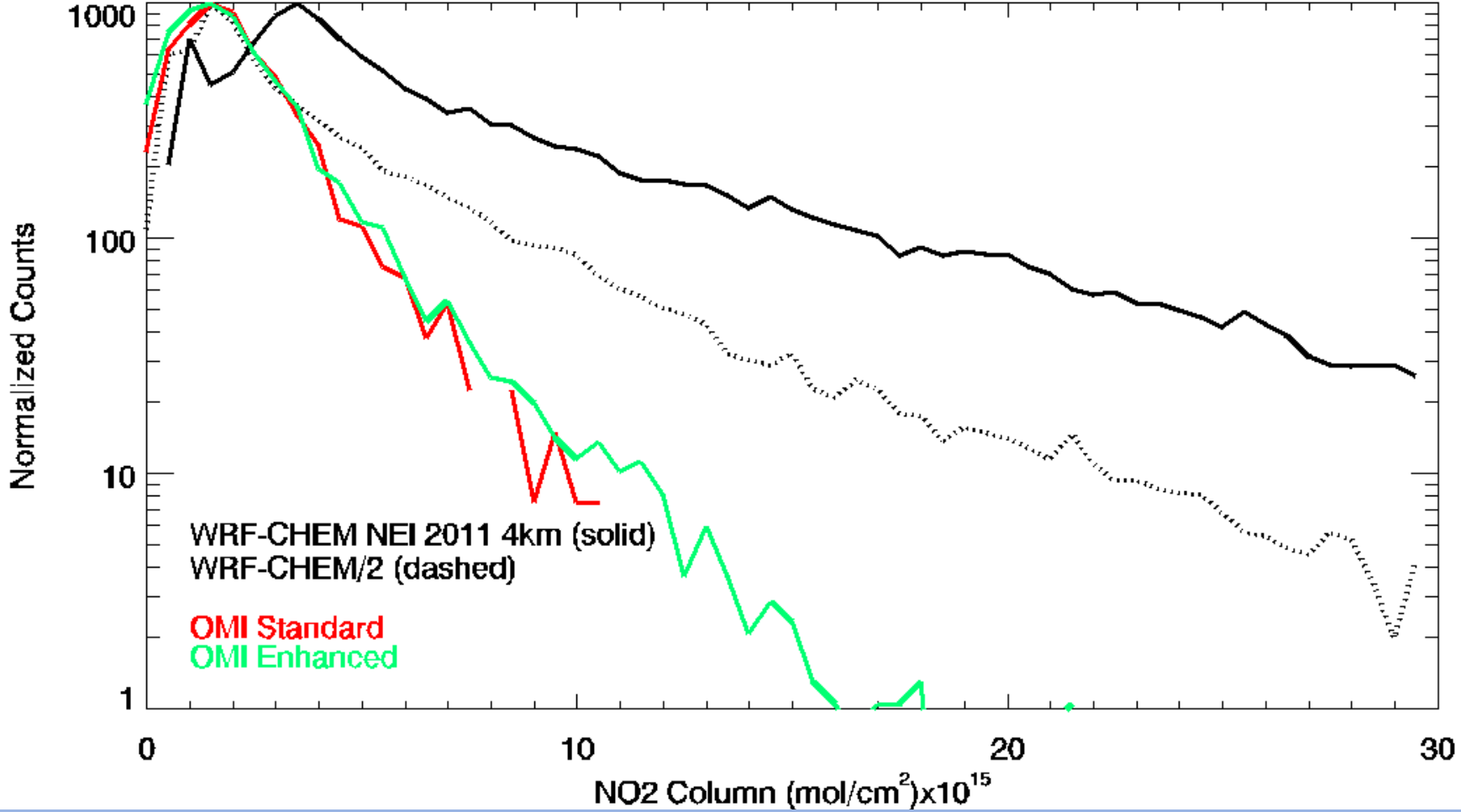


-2 -1 0 1 2 3 log₁₀(nano-Watts/(cm²*sr))

OMI Standard NO2 vs Pixel Mean VIIRS DNB (Chicago)



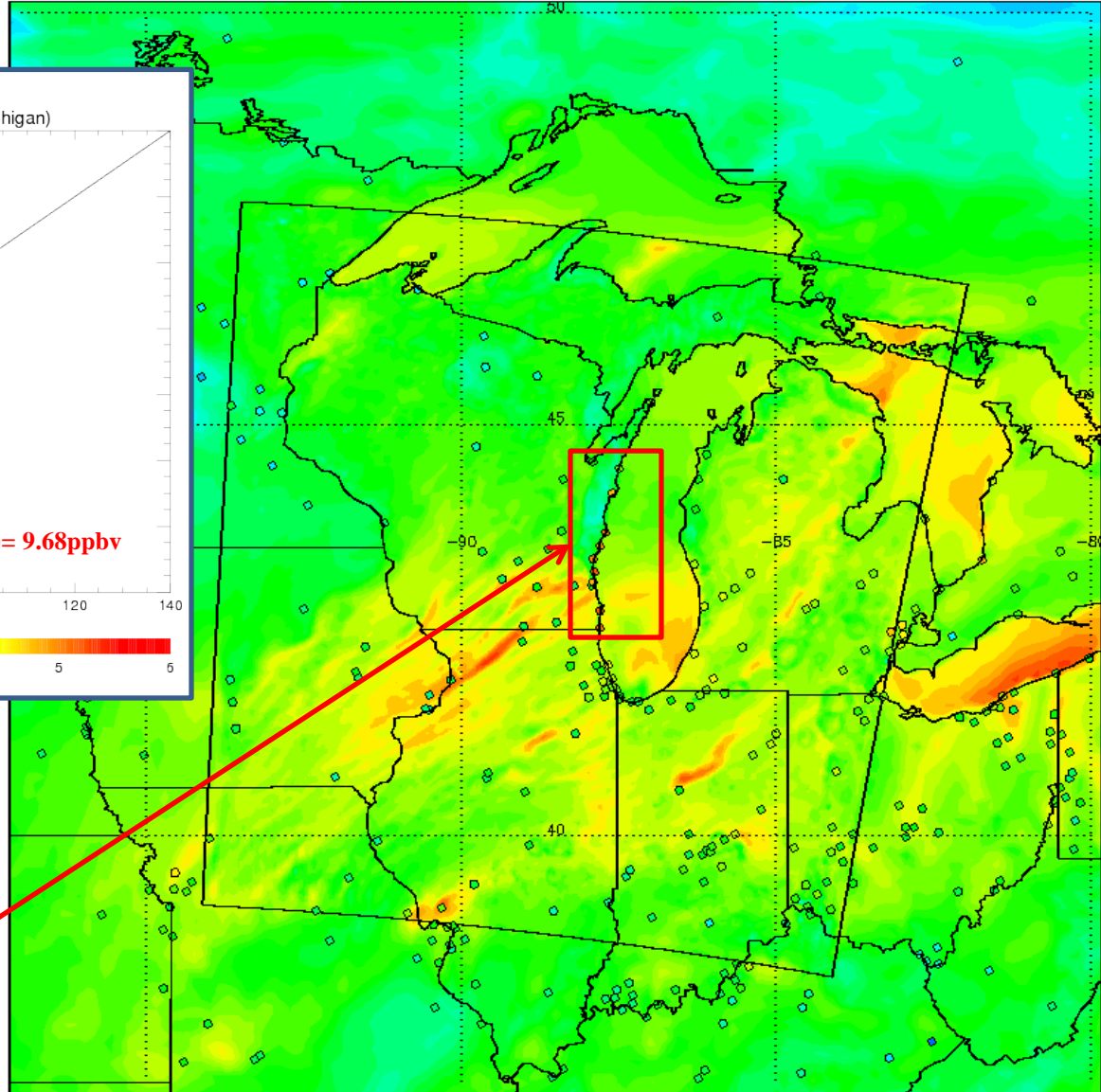
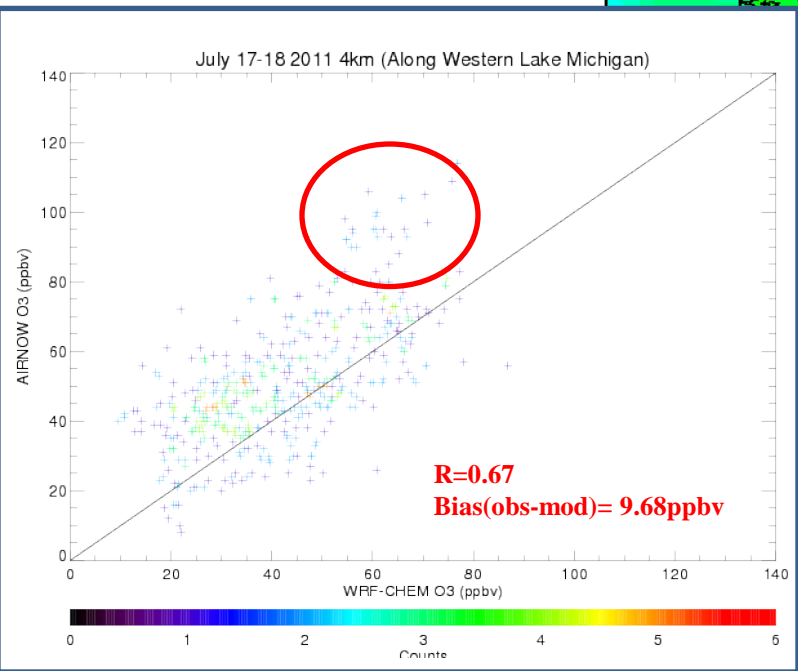
NO2 Columns Chicago July, 2011



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 Surface O3 22Z (5:00pm Central) July 17, 2011

WRF-CHEM 12km and 4km Surface O3 RAQMS LBC valid 2011-07-17_22:00:00

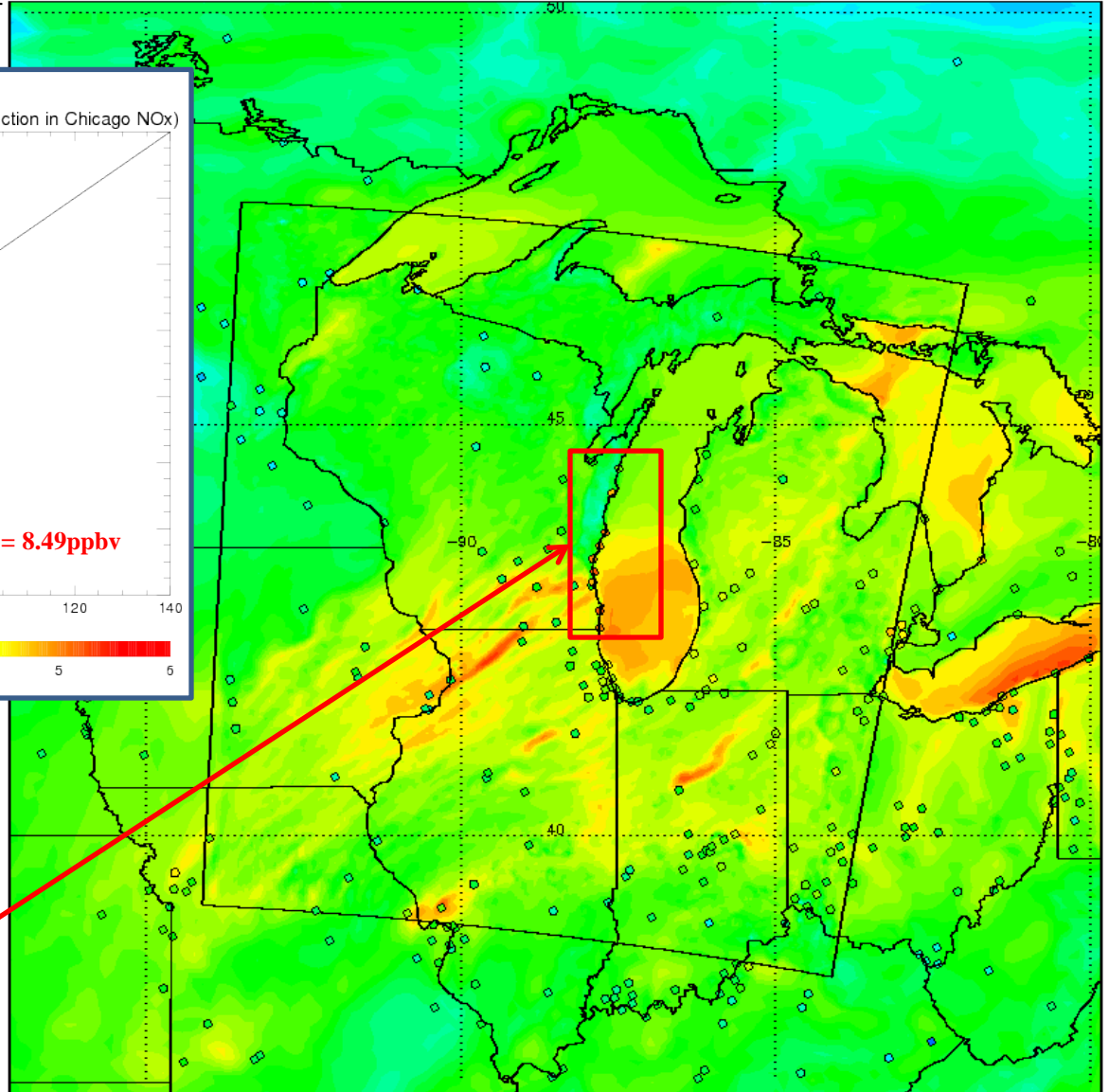
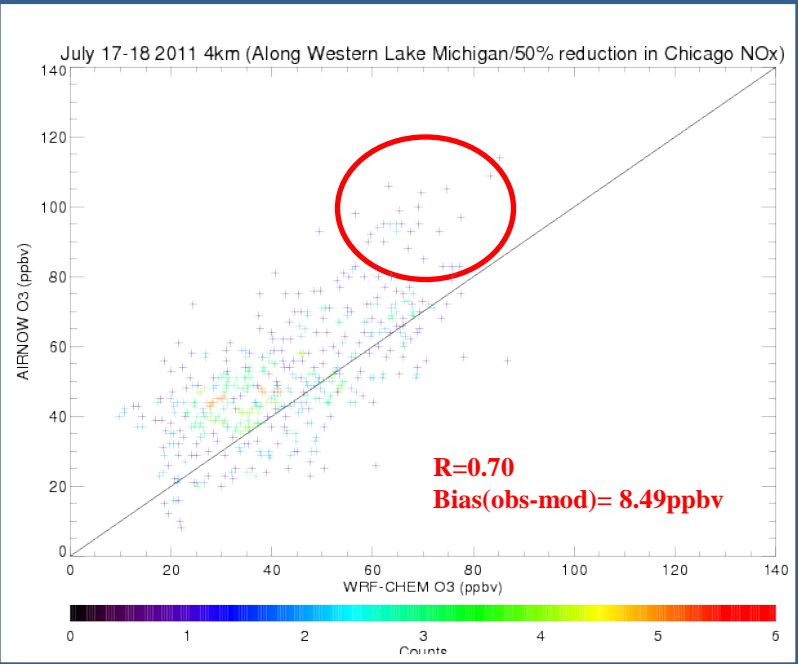


4km with NEI 2011 Standard NO emissions significantly under predicts surface ozone along Western Shore of Lake Michigan

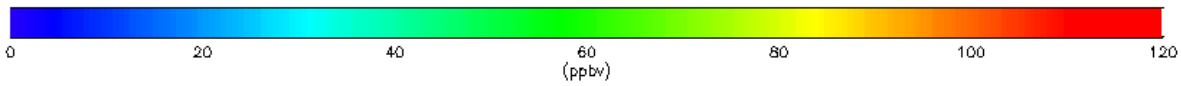


4km reduced Chicago NO WRF-CHEM Surface O3 22Z (5:00pm Central) July 17, 2011

WRF-CHEM 12km and 4km Surface O3 RAQMS LBC valid 2011-07-17_22:00:00



4km with reduced Chicago NO emissions shows higher O3 over Southern Lake Michigan but still shows low minimum in ozone along coast North of Milwaukee



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

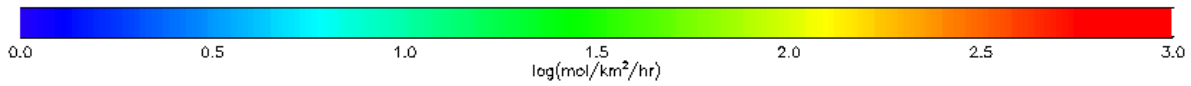
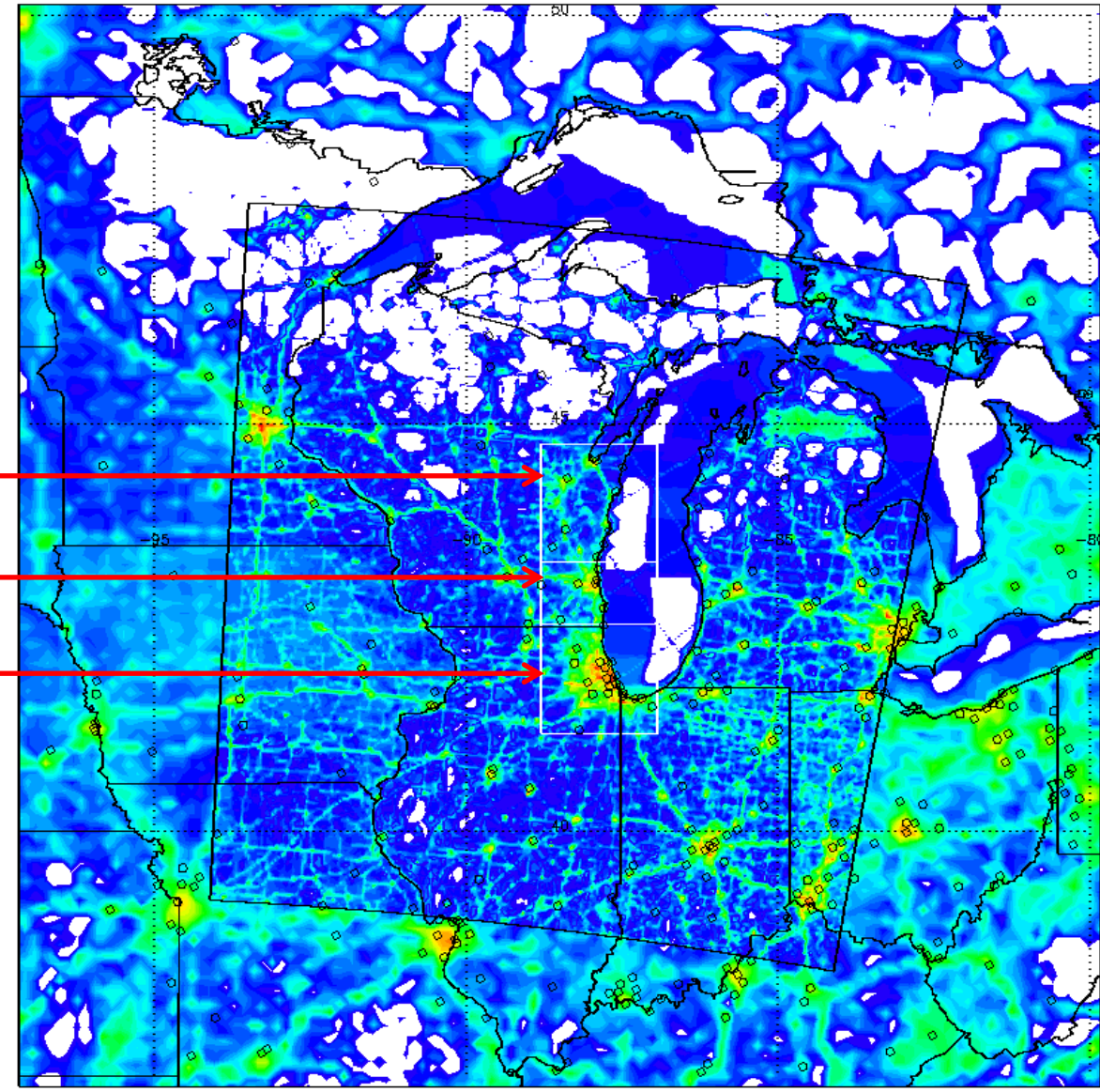
WRF-CHEM 12km and 4km Surface NO Emissions RAQMS LBC valid 2011-07-17_22:00:00

Green Bay (GB) domain

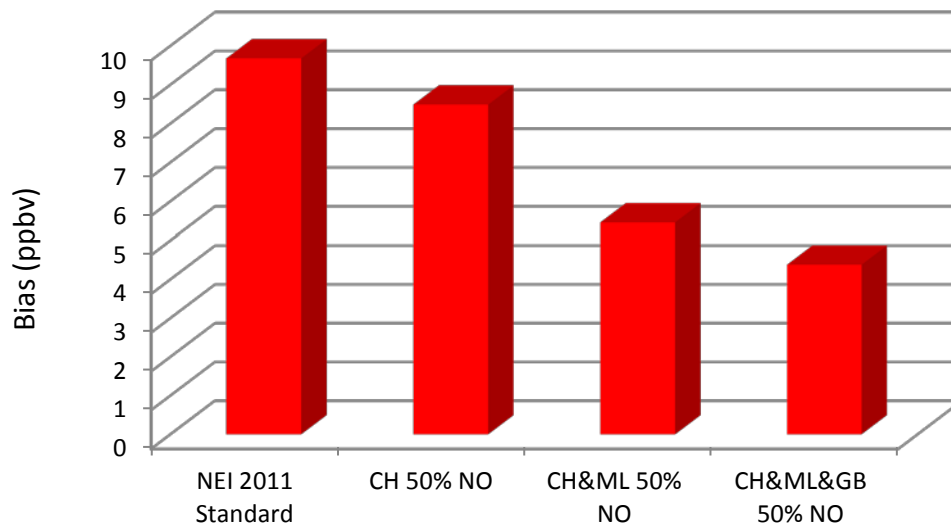
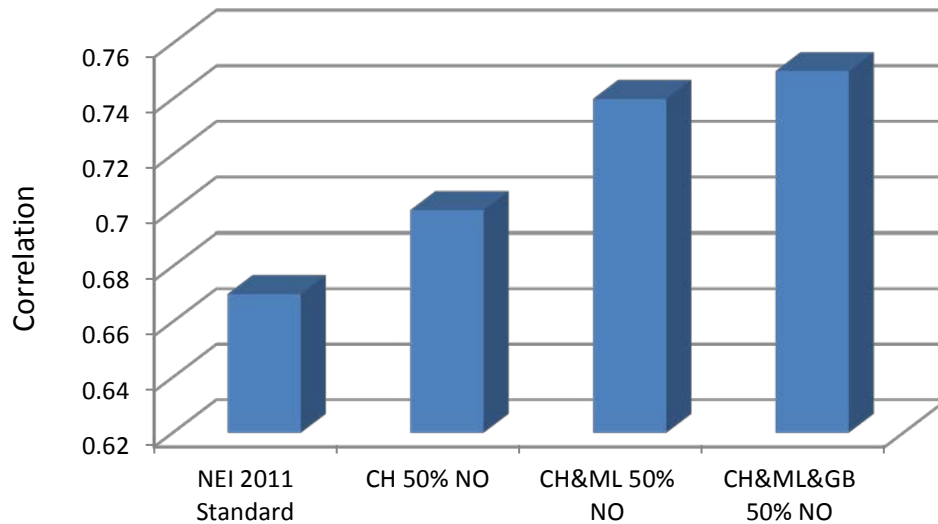
Milwaukee (ML) domain

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



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 biases during the July 17, 2011 ozone episode.

Conclusions:

➤ The utility of using the OMI spatially enhanced NO₂ retrieval to understand urban NO₂ distributions is demonstrated by looking at the impact of NEI 2011 NO emissions on modeled ozone enhancements associated with lake breeze circulations along the western shore of Lake Michigan

- High NO₂ emissions in the Chicago area lead to excessive ozone titration within a lake breeze driven plume of high NO₂ column for both 12 and 4 km standard NEI 2011 simulations
- Comparisons between OMI Standard and Spatially Enhanced NO₂ column retrievals and 4km WRF-CHEM NO₂ columns over Chicago during July 2011 shows that the WRF-CHEM NO₂ columns are high by a factor of 2
- Sensitivity experiments show that reductions in Chicago NO emissions by 50% lead to higher surface ozone over Southern Lake Michigan but little improvement in surface ozone predictions North of Milwaukee
- Sensitivity experiments including reductions in Chicago, Milwaukee, and Green Bay NO emissions show overall improvement in the correlation with AIRNow and reductions in the biases along western Lake Michigan but are still not able to capture the high surface ozone observed North of Milwaukee on July 17, 2011.

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OBSERVING OUR FUTURE



Ozone



Nitrogen dioxide



Sulfur dioxide



Formaldehyde



Surface UV-B



Aerosols



Carbon Monoxide



Methane



Bromine oxide



Glyoxal



Water vapor



Clouds



TROPOMI
TROPOspheric Monitoring Instrument

SCIENCE WEBSITE

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The TROPOspheric Monitoring Instrument (TROPOMI) is a European satellite instrument to be launched in 2016 for a mission of seven years. TROPOMI will measure ozone (O₃), nitrogen dioxide (NO₂), formaldehyde (HCHO), Sulphur dioxide (SO₂) and aerosols. In addition a NIR channel and a SWIR-module are added for enhanced cloud detection, aerosol height distribution and detection of carbon monoxide (CO) and methane (CH₄) at a high spatial resolution of 7x7 km²

<http://www.tropomi.eu/>