Aura Chemical Reanalysis in support Air Quality Applications

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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 NOx emissions on US air quality during the Aura period.
  3. Provide global 3 dimensional O3, CH4, N2O 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.

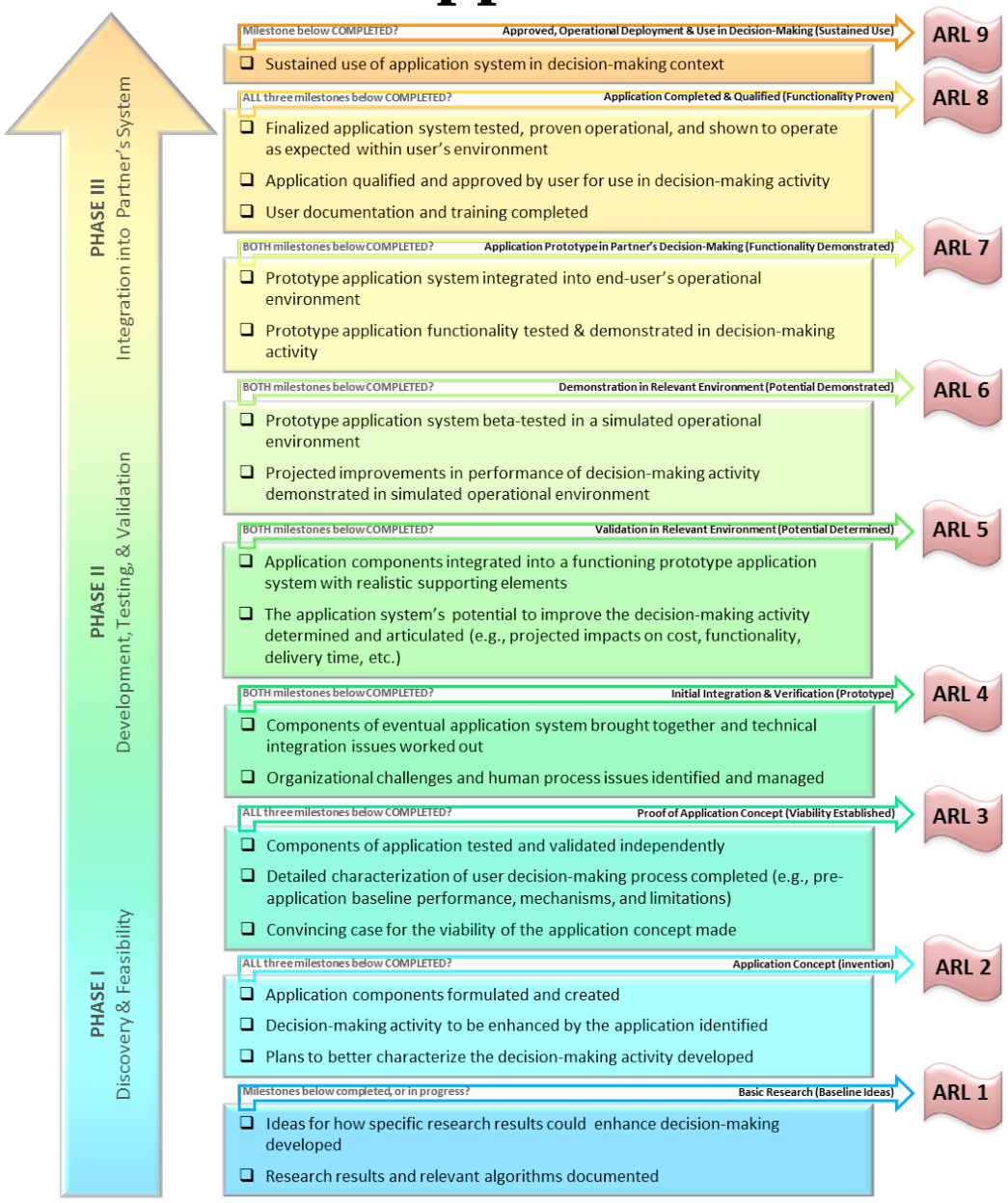
Budget

As of May 23, 2017					PY16				
PI/POC	Institution	Category	Portfolio	WBS	Budget	Obligated	Unobligated	Costed	Uncosted
Pierce, Brad				Total	$153,028	$153,028	$0	$103,878	$49,150
Aura Chemical Reanalysis in support Air Quality Applications									
NOAA/NESDIS/STAR		389018.02.09.01.60			$153,028	$153,028	$0	$103,878	$49,150
					PY15				
					Budget	Obligated	Unobligated	Costed	Uncosted
Pierce, Brad				Total	$149,579	$149,579	$0	$144,677	$4,902
Aura Chemical Reanalysis in support Air Quality Applications									
NOAA/NESDIS/STAR		389018.02.09.01.60			$149,579	$149,579	$0	$144,677	$4,902

- FY16 funds (final year, $153,028) were received by NESDIS/STAR on July 19, 2016 due to delays in MOU approval by NOAA legal.
- CIMSS received FY16 funding from NESDIS/STAR on Sept, 15, 2016.
- NESDIS/STAR has requested a 1 year no-cost extension to complete the Aura Reanalysis project, which is currently scheduled to close on Sept 30, 2017.

Aura Chemical Reanalysis in support Air Quality Applications

Applications Readiness Level (ARL)



Started at ARL 3 (Proof of Application Concept) with real-time RAQMS Data assimilation

Reached ARL 4 (Initial Integration and Verification) upon successfully completing the RAQMS/GSI Data Denial experiments (September, 2016)

Reached ARL 5 (Validation in Relevant Environment) upon completion of 2010 RAQMS/GSI analysis (December 2016)

Currently at ARL 6 (Demonstration in Relevant Environment) based on finalizing 2006-2016 emissions constraints, MLS, OMI, AIRS, and MODIS assimilation procedures, and successful completion of the first four years of Aura Reanalysis.

Will reach ARL 7 by the end of requested 1-year no-cost extension with delivery of RAQMS Aura Reanalysis to DAAC.

Aura Chemical Reanalysis in support Air Quality Applications

- Results and Milestones (Year 3)
  - Completed first 4 years (2006-2009) of the 10 year Aura Reanalysis
  - Conducted verification studies to assess the fidelity of the Aura Reanalysis through comparisons with airborne insitu measurements collected during NASA, NOAA and NSF field campaigns
  - Completed CMAQ/GSI NOx emission adjustment experiments using offline CMAQ/GSI OMI NO2 assimilation constraints

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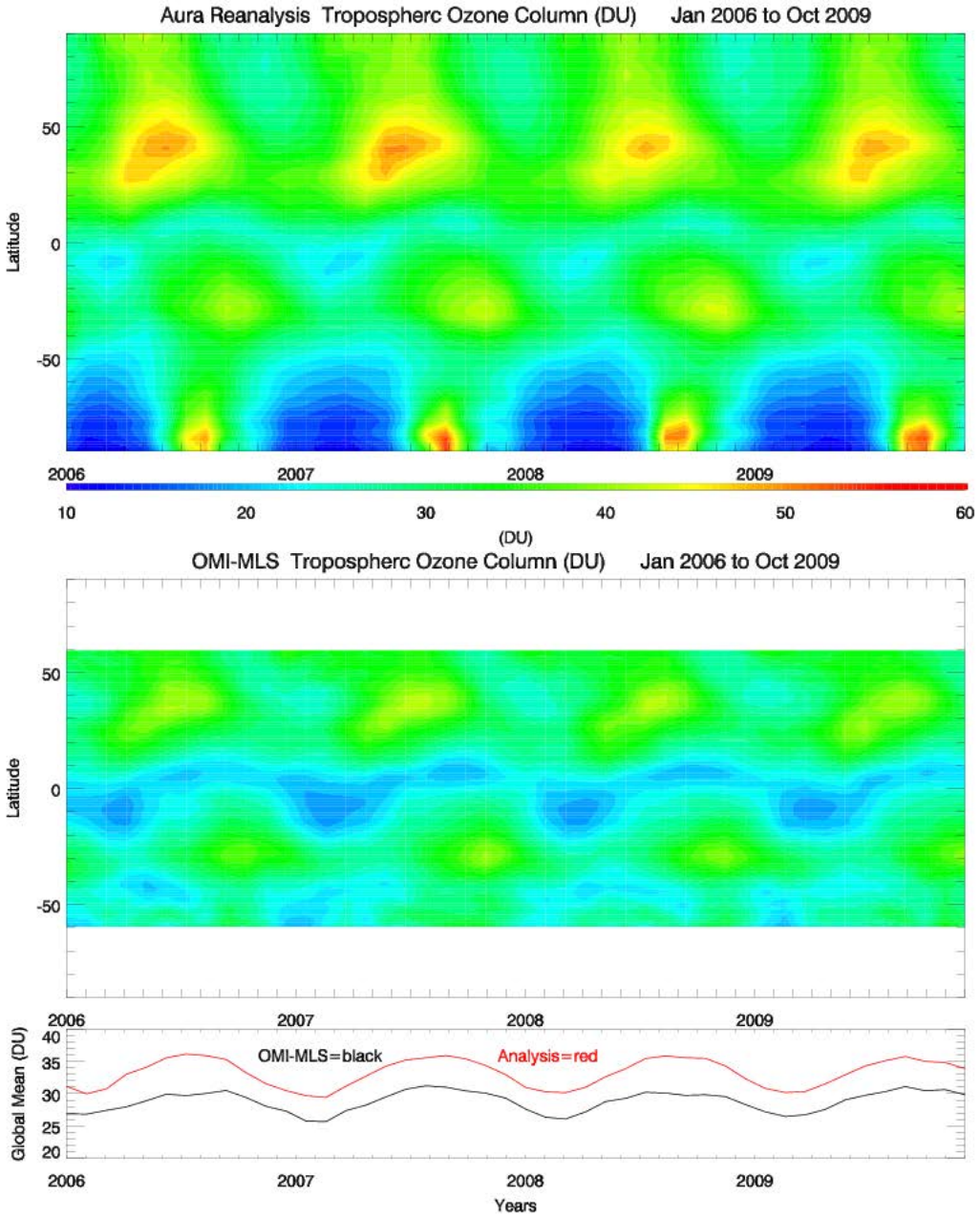
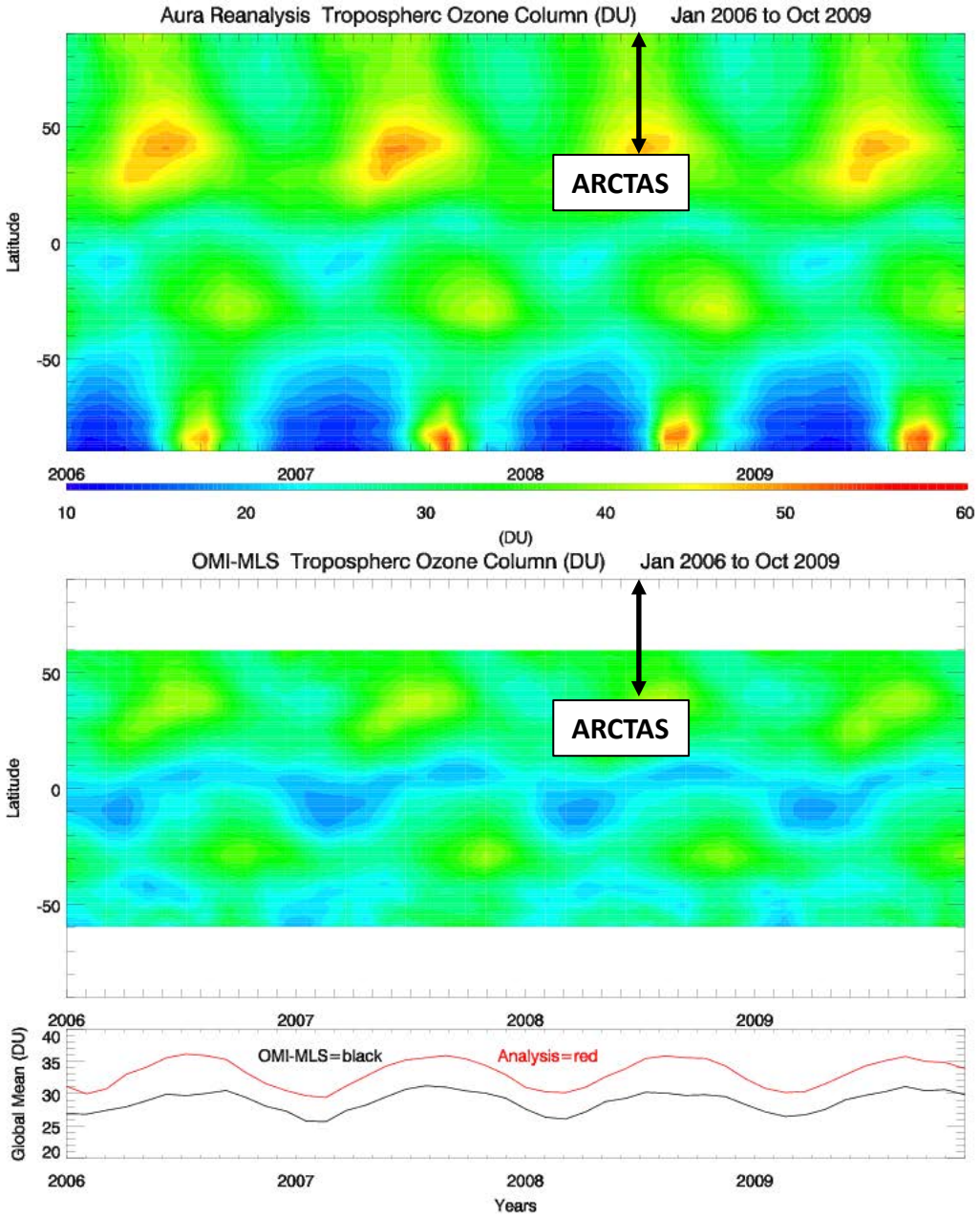
Analyzed Tropospheric Ozone Column (TOC) vs OMI-MLS Tropospheric Ozone Residuals (TOR)



Aura Reanalysis captures seasonal variation but shows a systematic high bias relative to the OMI-MLS TOR

Ziemke, et al. (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, J. Geophys. Res., 111, D19303, doi:10.1029/2006JD007089.

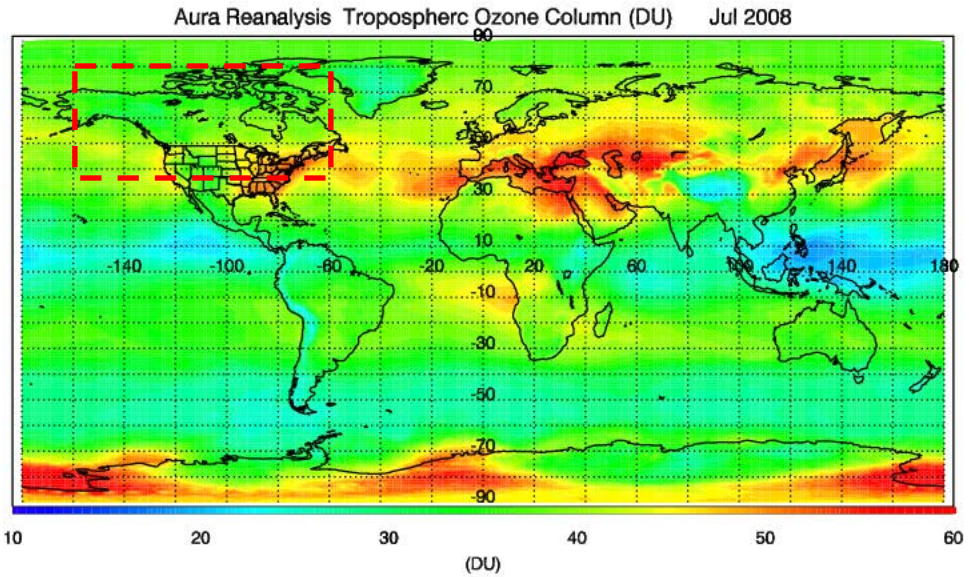


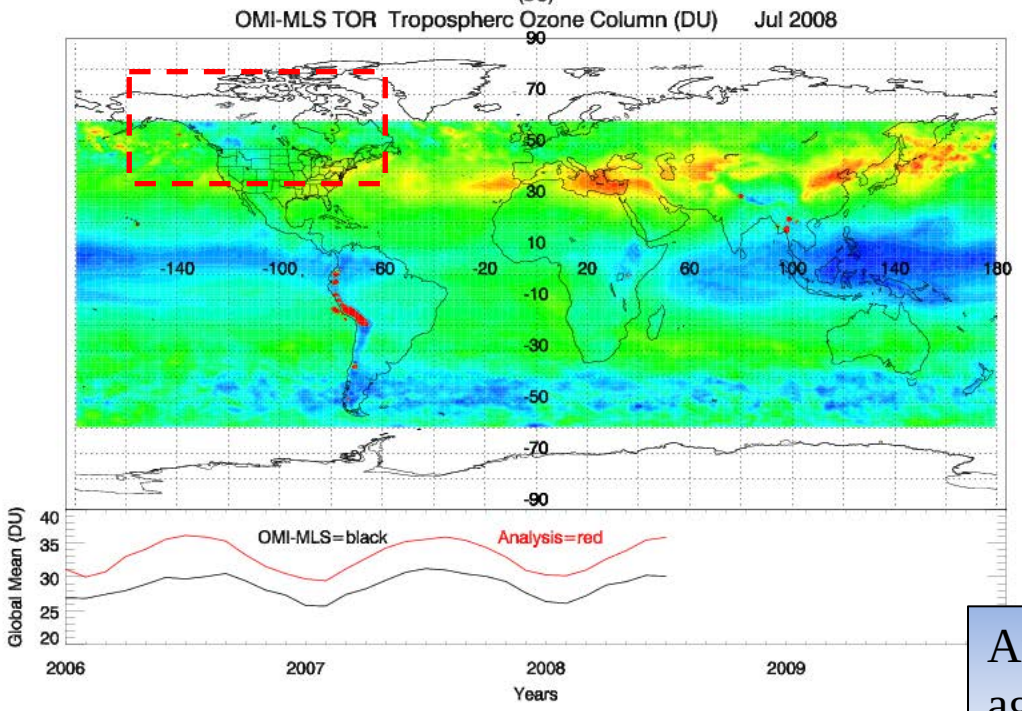
Airborne measurements from NASA ARCTAS field campaign are used to verify Northern Hemisphere Aura Reanalysis TOC during July 2008

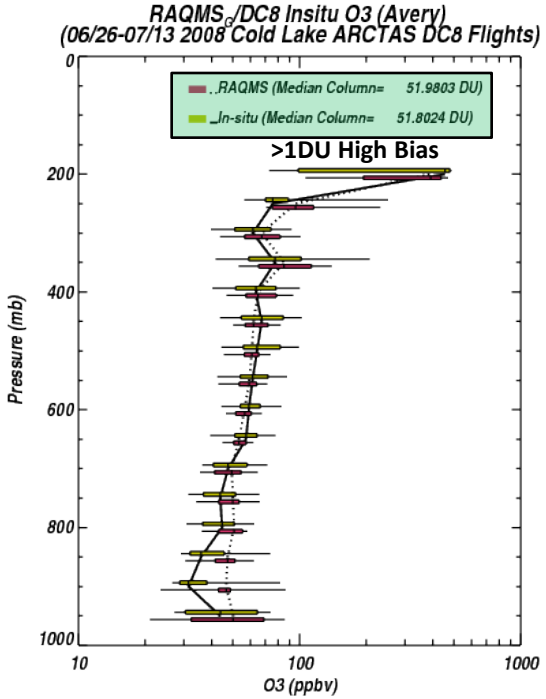
Ziemke, et al. (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, J. Geophys. Res., 111, D19303, doi:10.1029/2006JD007089.

NASA ARCTAS Cold Lake, AB Phase

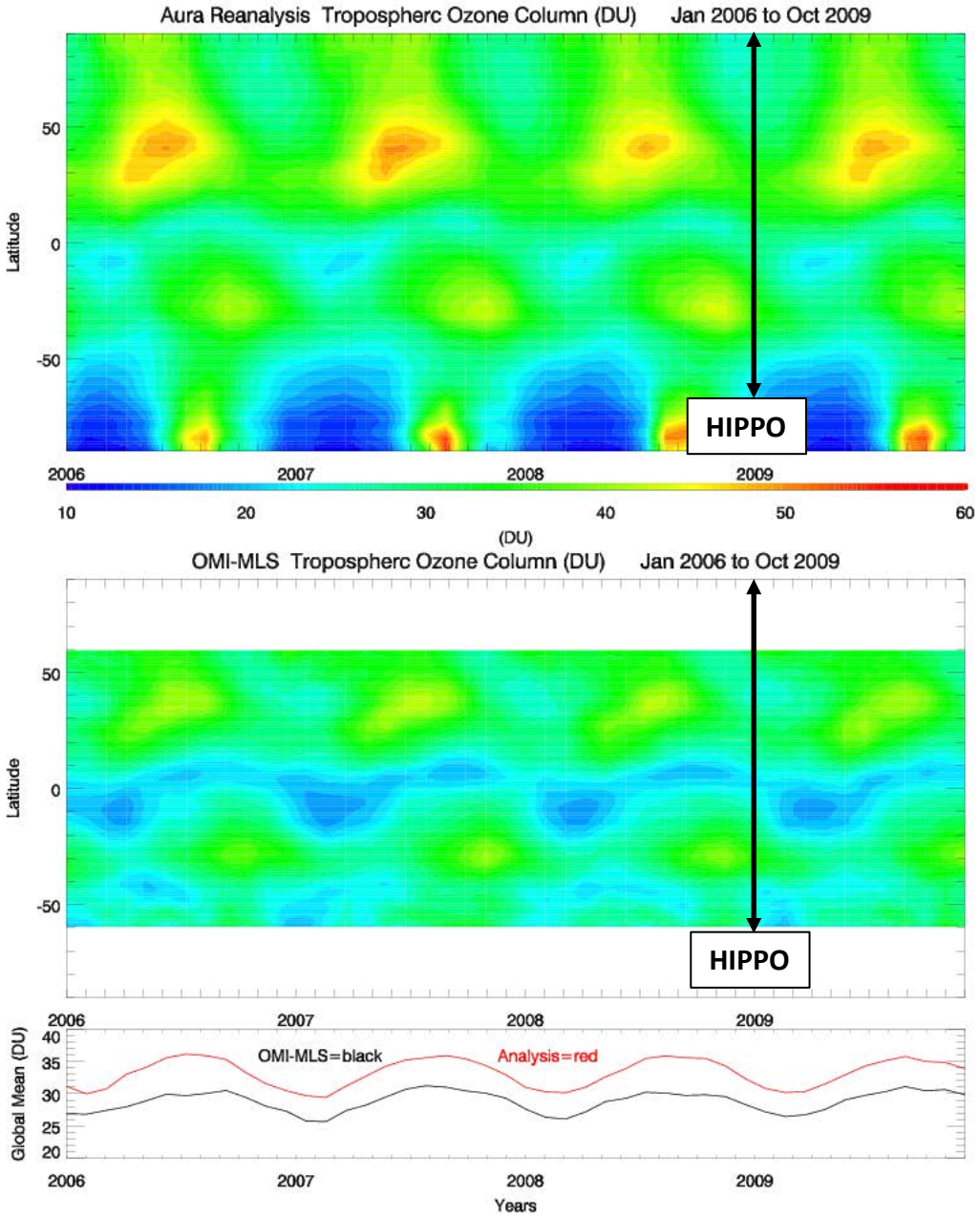
ARCTAS Flight Tracks July 2008







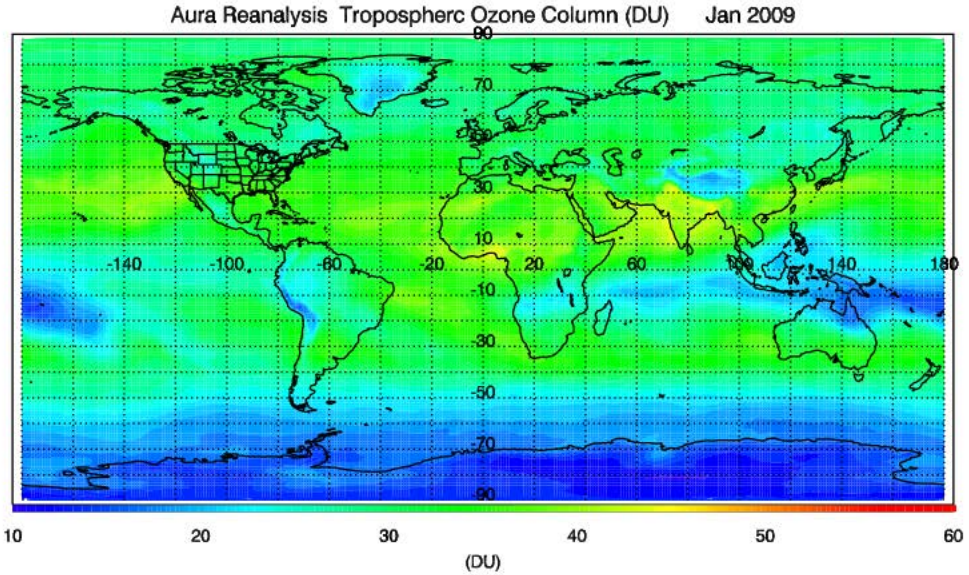
Aura Reanalysis shows excellent (<1%) agreement with airborne column

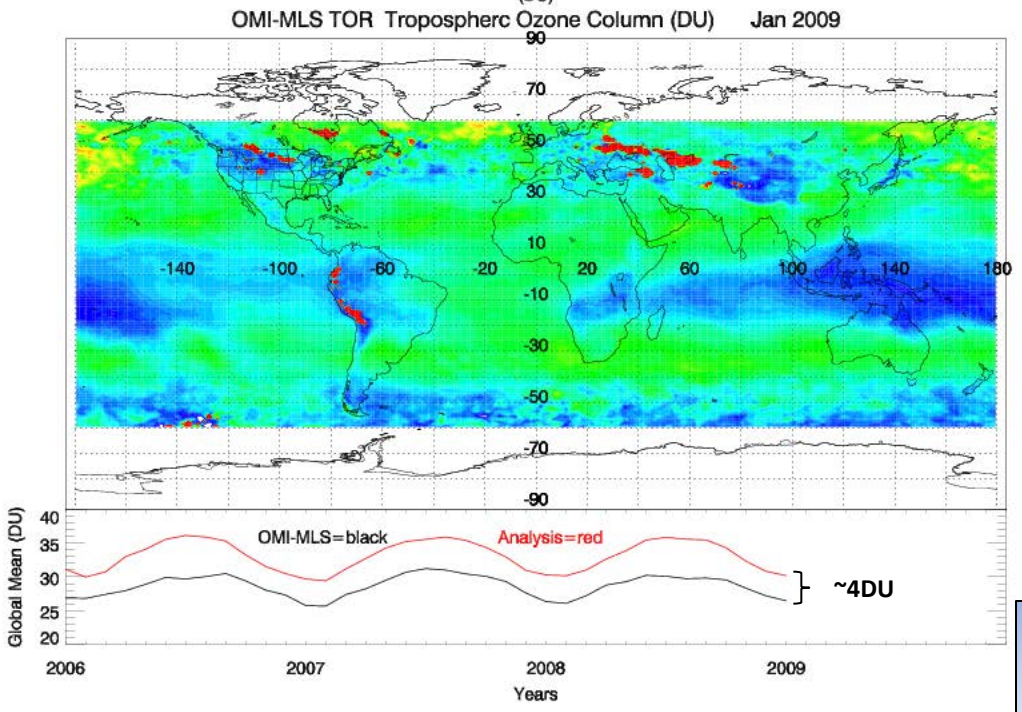


Airborne measurements from NSF HIPPO-I field campaign are used to verify Aura Reanalysis TOC over the Pacific Ocean during January 2009

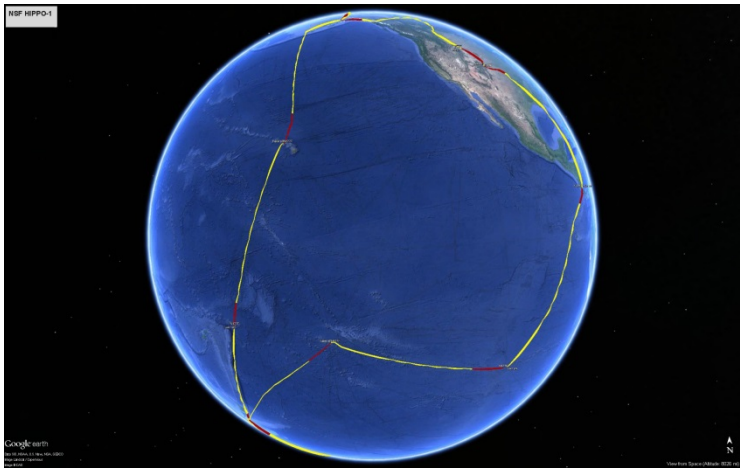
Ziemke, et al. (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, J. Geophys. Res., 111, D19303, doi:10.1029/2006JD007089.

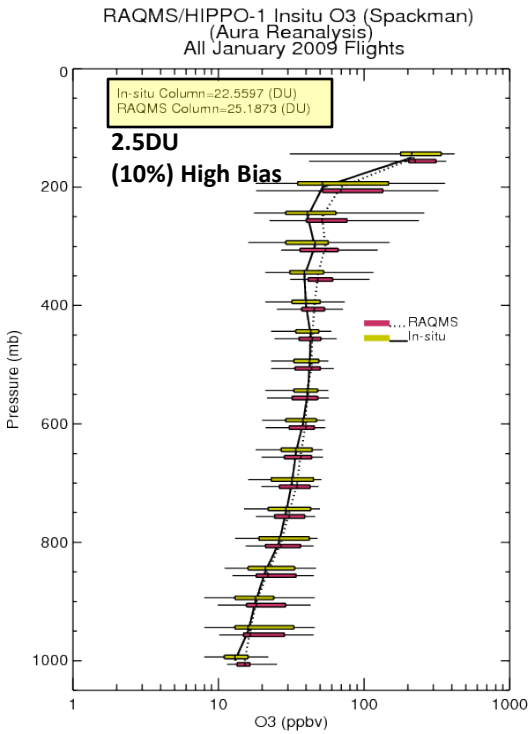
HIPPO-1 January 2009 O3 Verification





HIPPO Flight Tracks January 2009

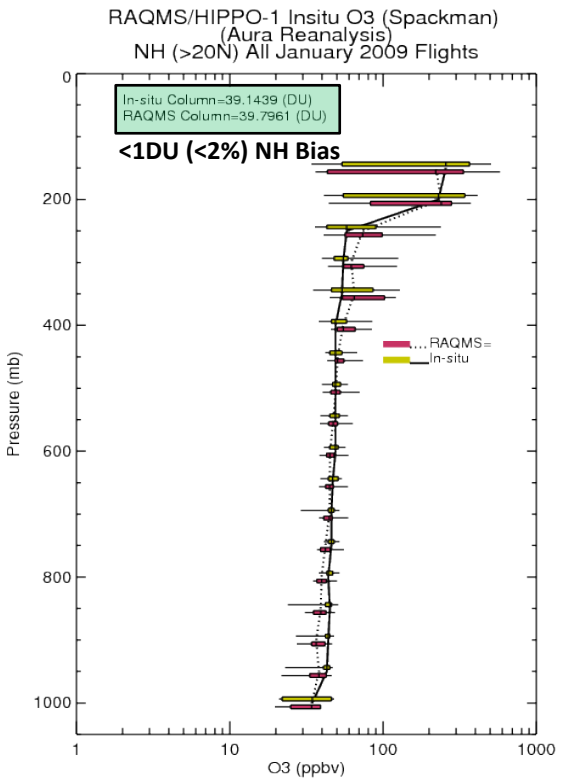


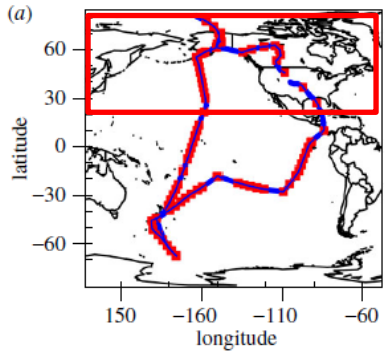


Aura Reanalysis shows 10% high bias relative to airborne column

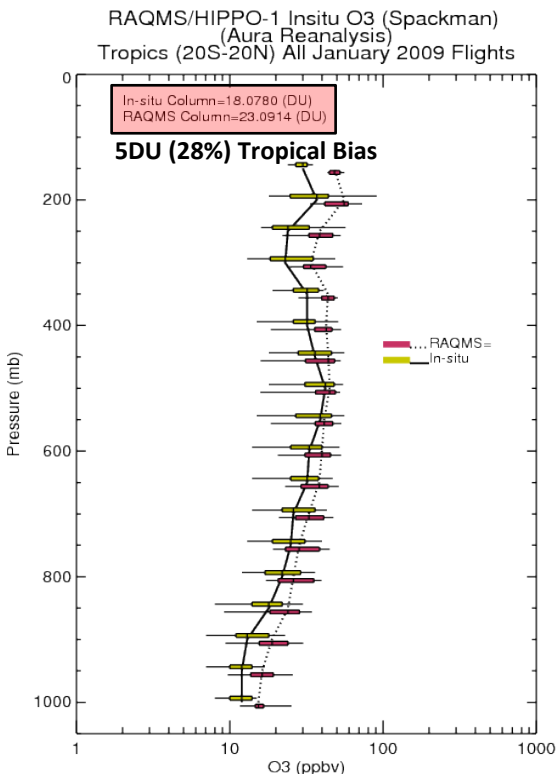
HIPPO-1 January 2009 O3 Verification

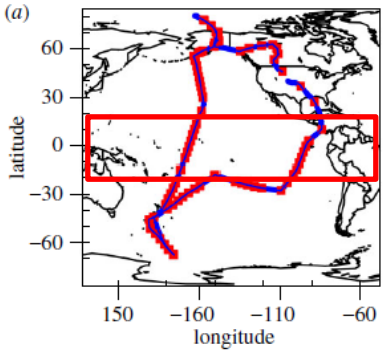
Northern Hemisphere



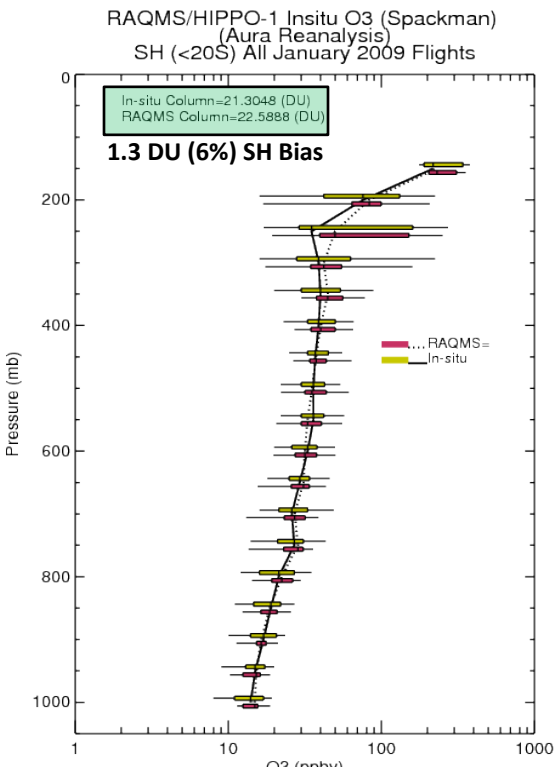


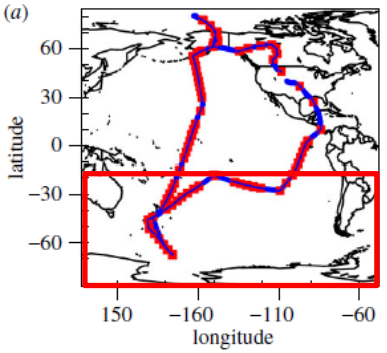
Tropics





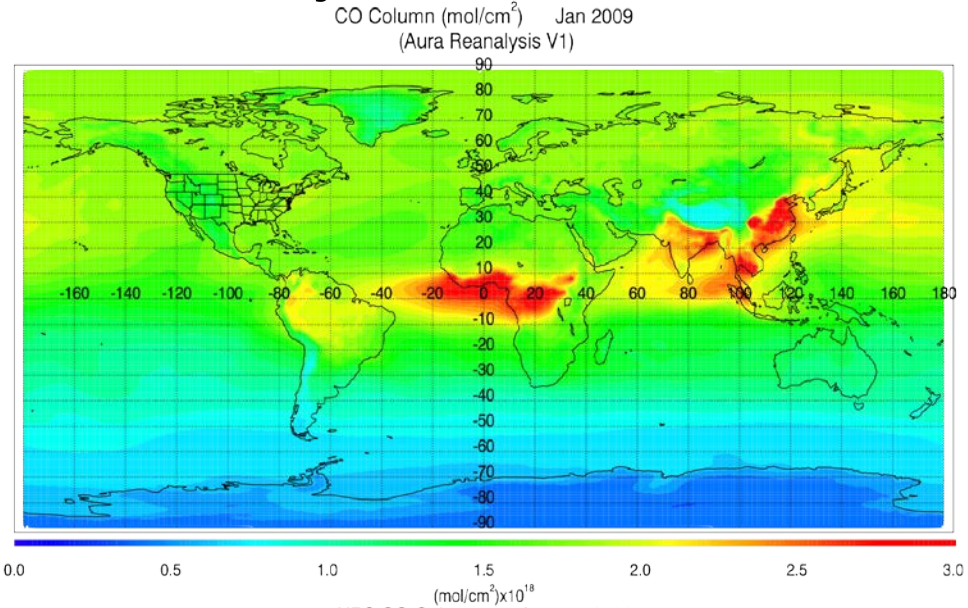
Southern Hemisphere

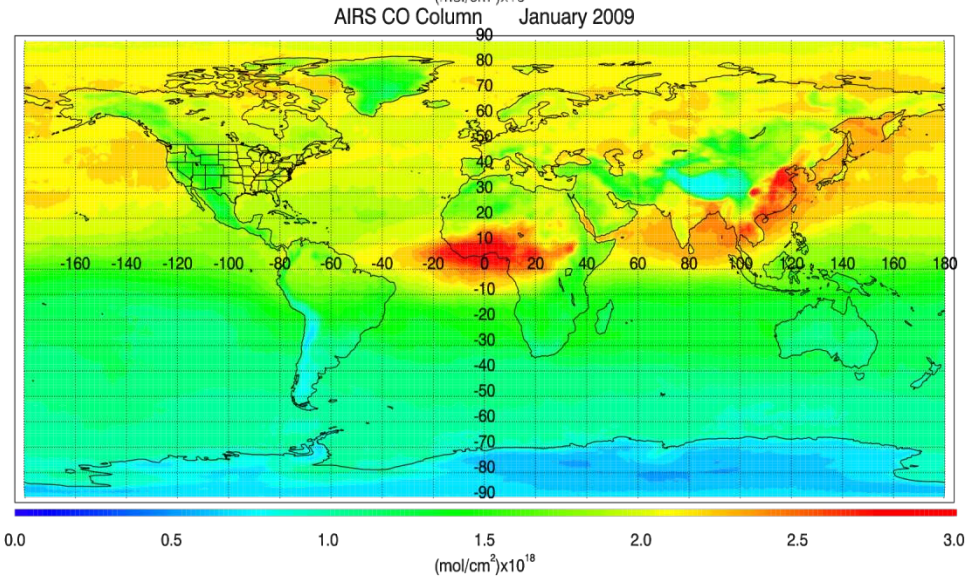




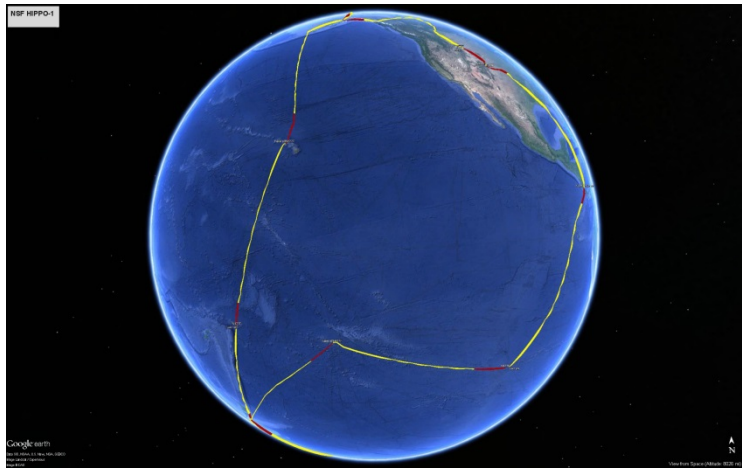
Tropical Pacific region (20N-20S) dominates the 10% high bias in Tropospheric ozone column

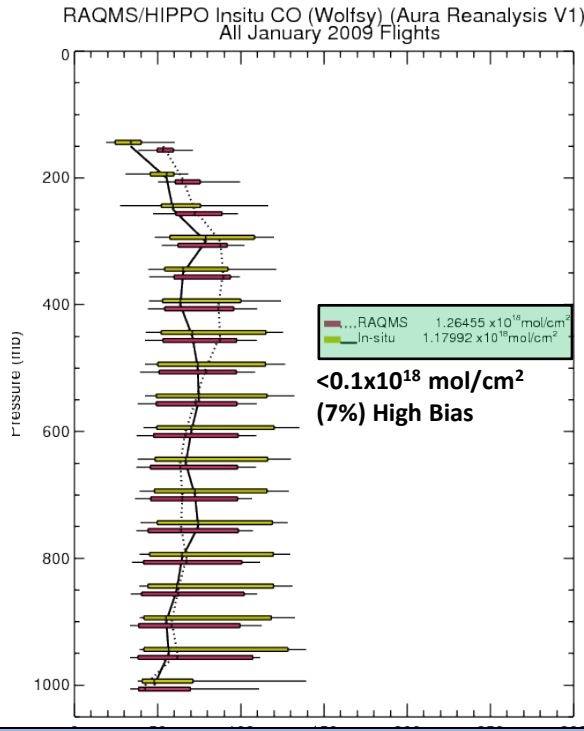
HIPPO-1 January 2009 CO Verification





HIPPO Flight Tracks January 2009

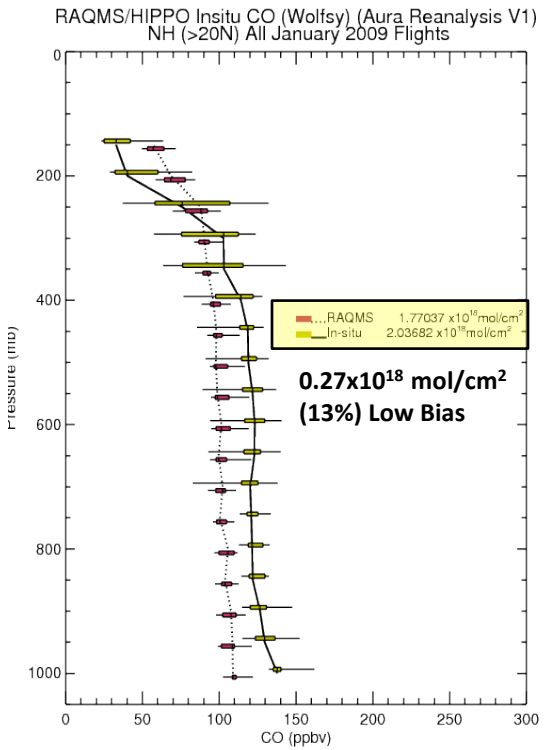




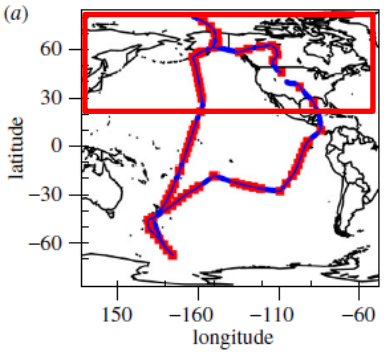
Aura Reanalysis shows slight high global bias relative to airborne column

HIPPO-1 January 2009 O3 Verification

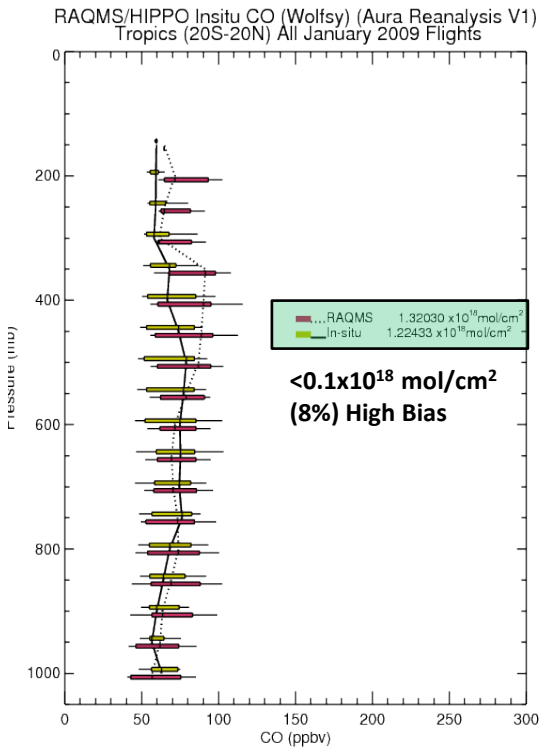
Northern Hemisphere



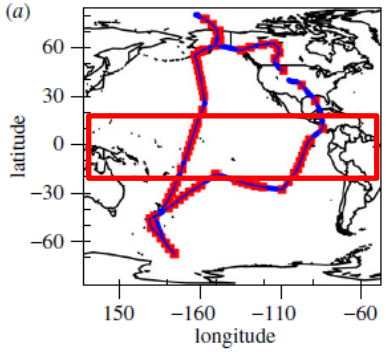
0.27x10^{18} mol/cm^2 (13%) Low Bias



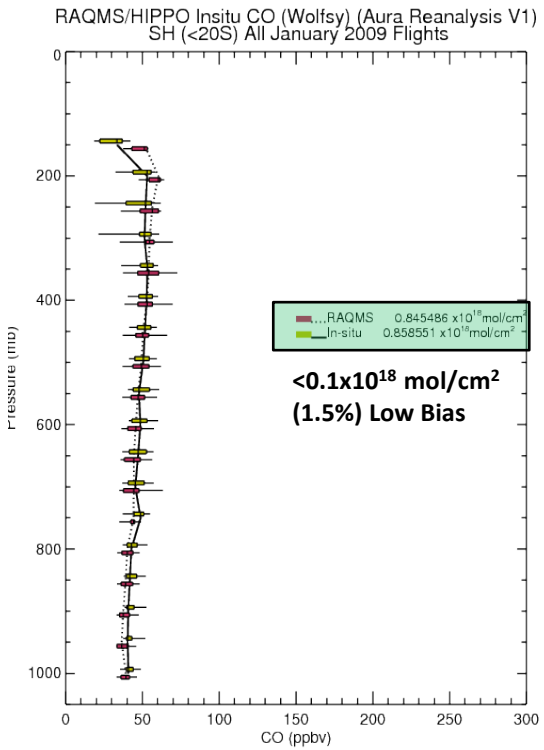
Tropics



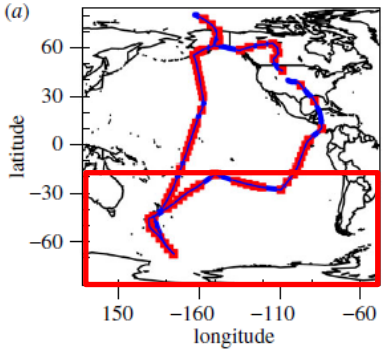
<0.1x10^{18} mol/cm^2 (8%) High Bias



Southern Hemisphere

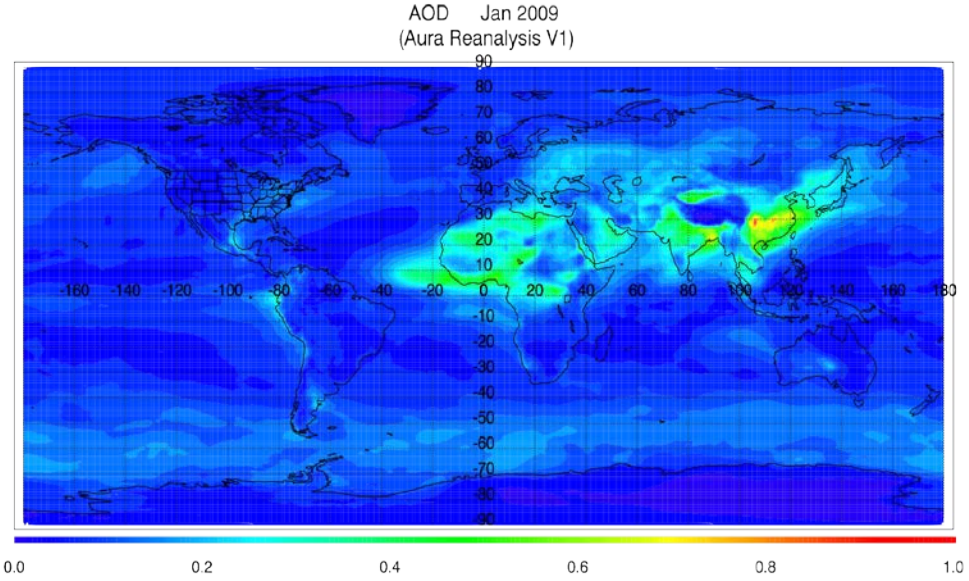


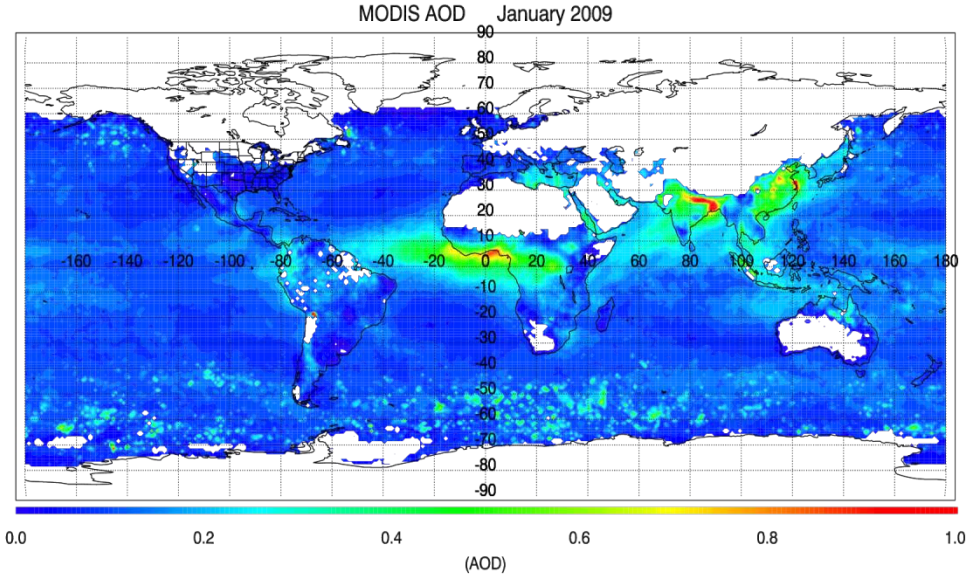
<0.1x10^{18} mol/cm^2 (1.5%) Low Bias



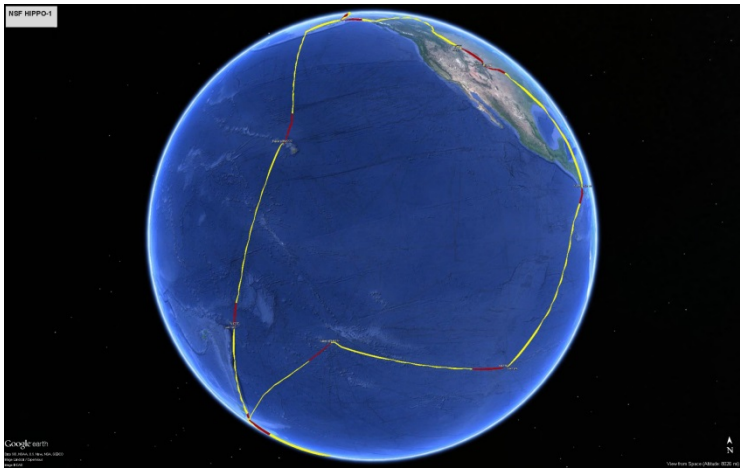
Northern Hemisphere (>20N) has 13% low bias in CO column relative to airborne measurements

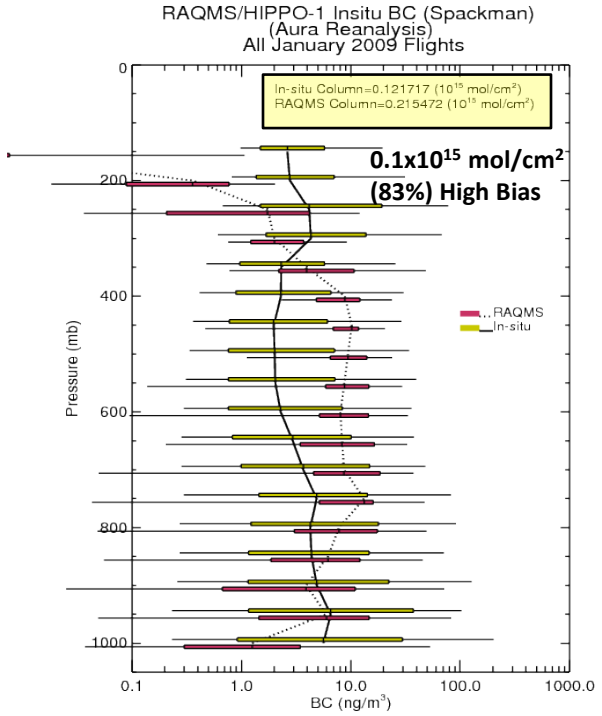
HIPPO-1 January 2009 BC Verification





HIPPO Flight Tracks January 2009

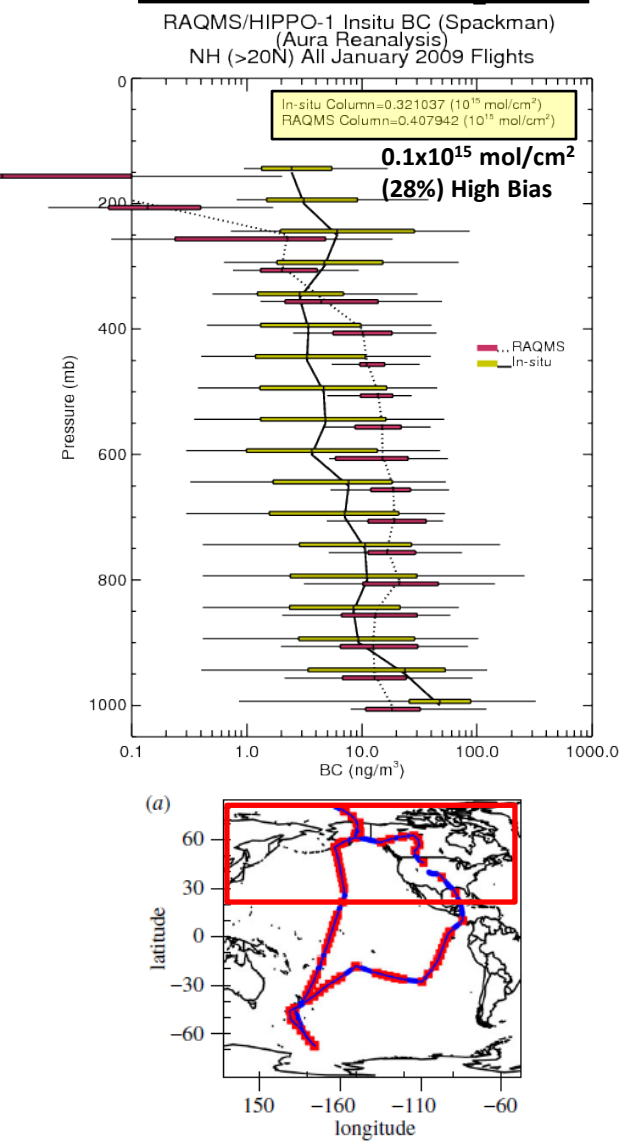




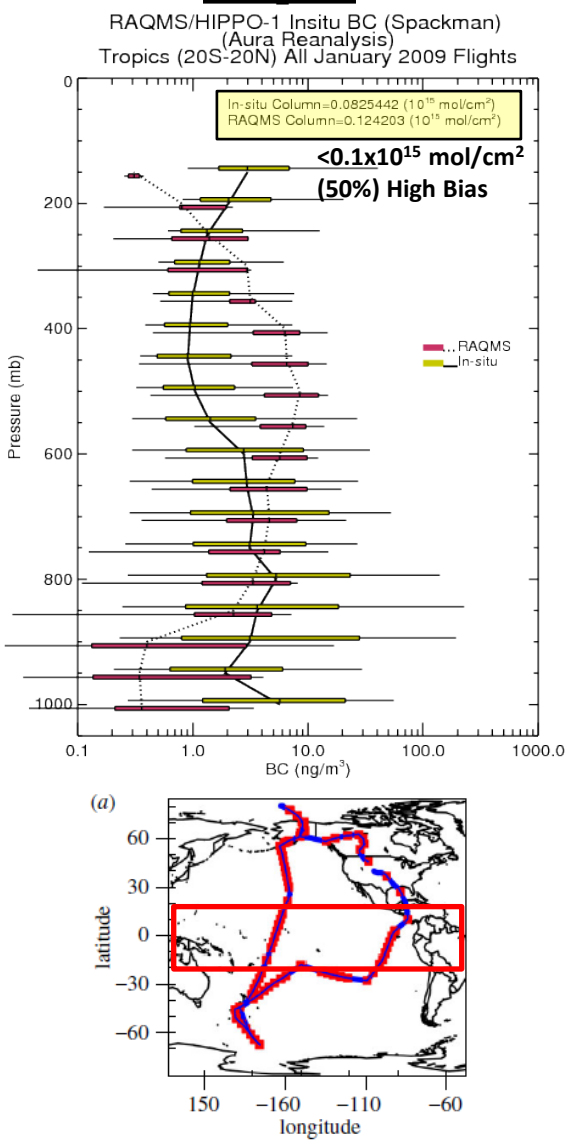
Aura Reanalysis high bias relative to airborne column under low black carbon aerosol loadings

HIPPO-1 January 2009 BC Verification

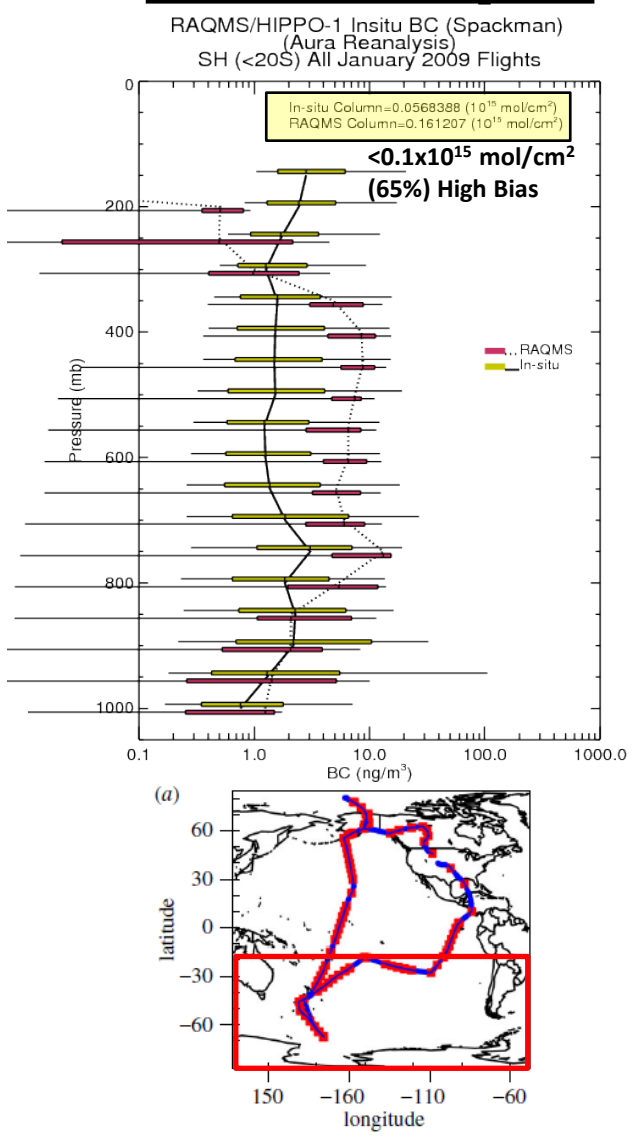
Northern Hemisphere



Tropics



Southern Hemisphere



Mid tropospheric BC overestimates of 2-5x dominate overall high biases in BC column relative to airborne measurements under low aerosol loadings

HIPPO-1 January 2009 Verification Summary

Species	NH (>20N)	Tropics	SH (<20S)	All Pacific
O3	2% High Bias	28% High Bias	6% High Bias	10% High Bias
CO	13% Low Bias	8% High Bias	1.5% Low Bias	7% High Bias
BC	28% High Bias	50% High Bias	65% High Bias	83% High Bias*

*AEROCOM models overestimate the BC concentrations in remote regions by a factor of five on average (Schwarz et al. 2010)

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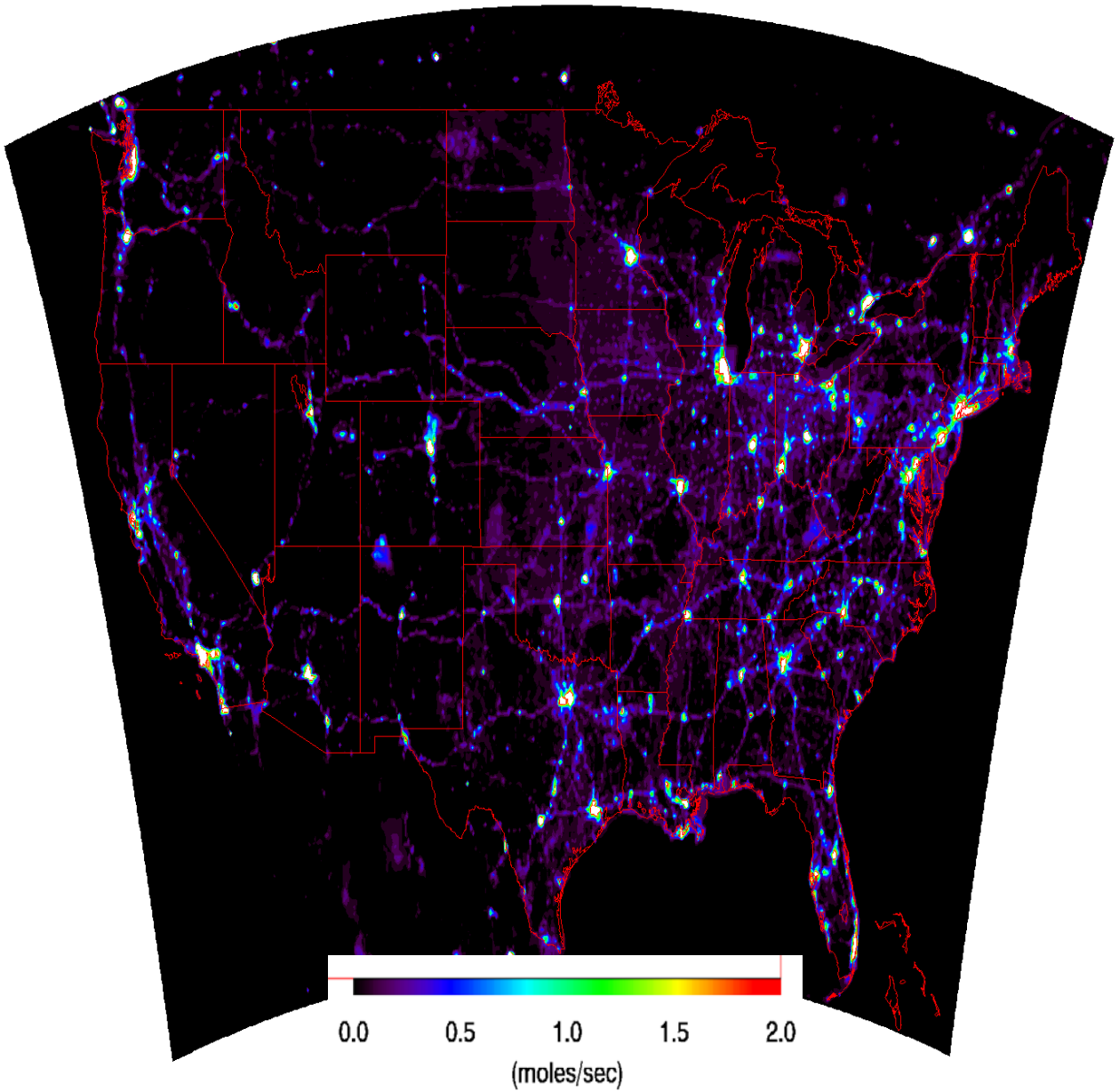
CMAQ/GSI NOx emission adjustment experiments

Offline adjustment of area and point NO_x emissions based on OMI Tropospheric NO2 column analysis increments

(NO_2 lifetime too short to use assimilation to constrain tropospheric column amounts)

July 2011 average area emissions (NEI)



CMAQ/GSI NOx emission adjustment experiments

1) Calculate monthly mean NO_2 Jacobian (β) from a 15% NO_X emission reduction perturbation experiment following *Lamsal et al.* 2011

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

2) Calculate monthly mean NO_2 analysis increment using CMAQ/GSI OMI NO_2 assimilation
   a. Lightning NOx sensitive background errors (to correct LNOx bias)
   b. NEI 2011 NOx sensitive background errors (to correct NEI emissions)

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

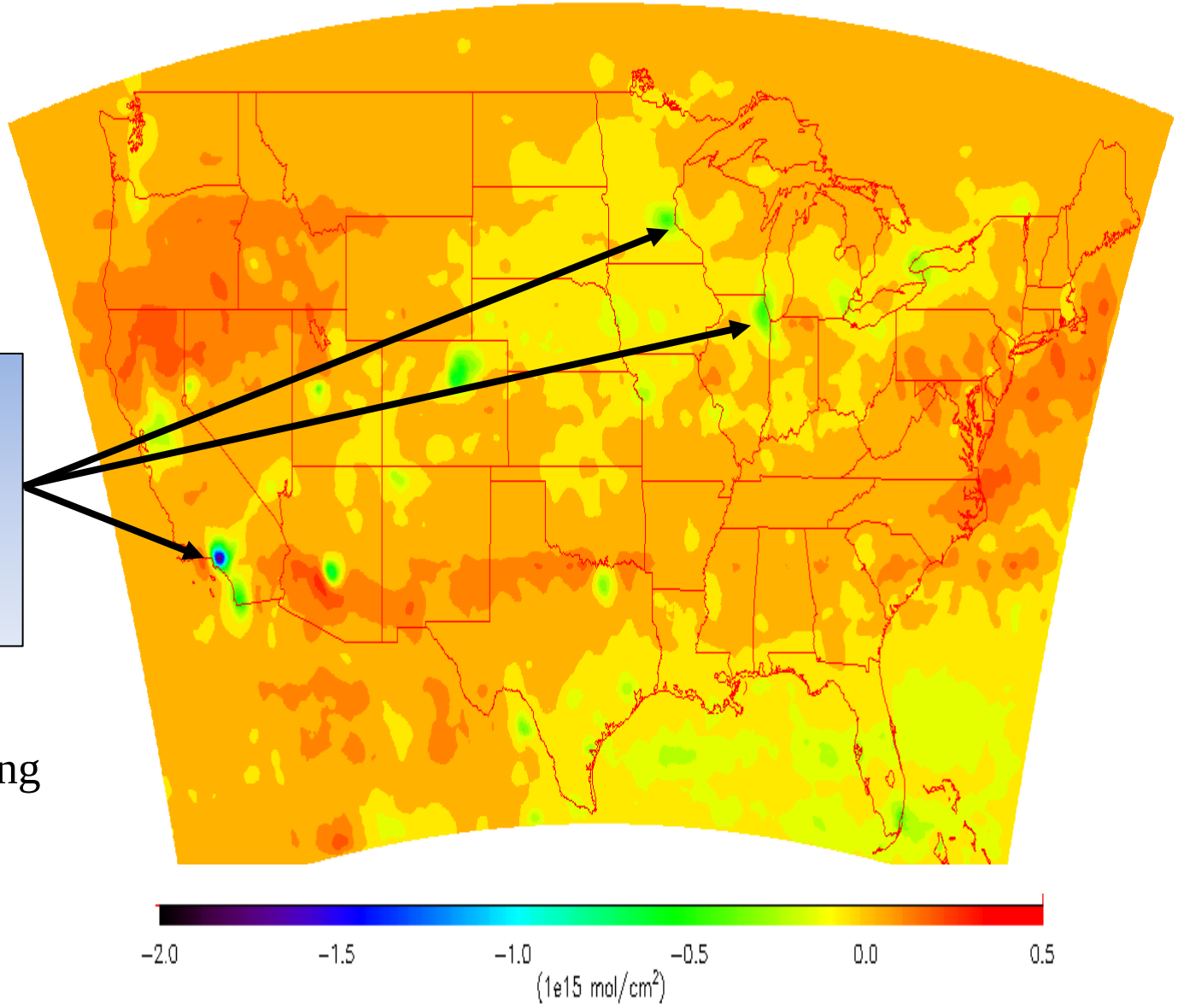
3) Adjust 2011 NEI NO_x emissions using Jacobian and analysis increment

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

Lamsal, L. N., et al. (2011), Application of satellite observations for timely updates to global anthropogenic NOx emission inventories, Geophys. Res. Lett., 38, L05810, doi:10.1029/2010GL046476.

CMAQ/GSI NOx emission adjustment experiments

July 2011 analysis increment



Analysis increment adjusts NO2 columns downward in urban areas

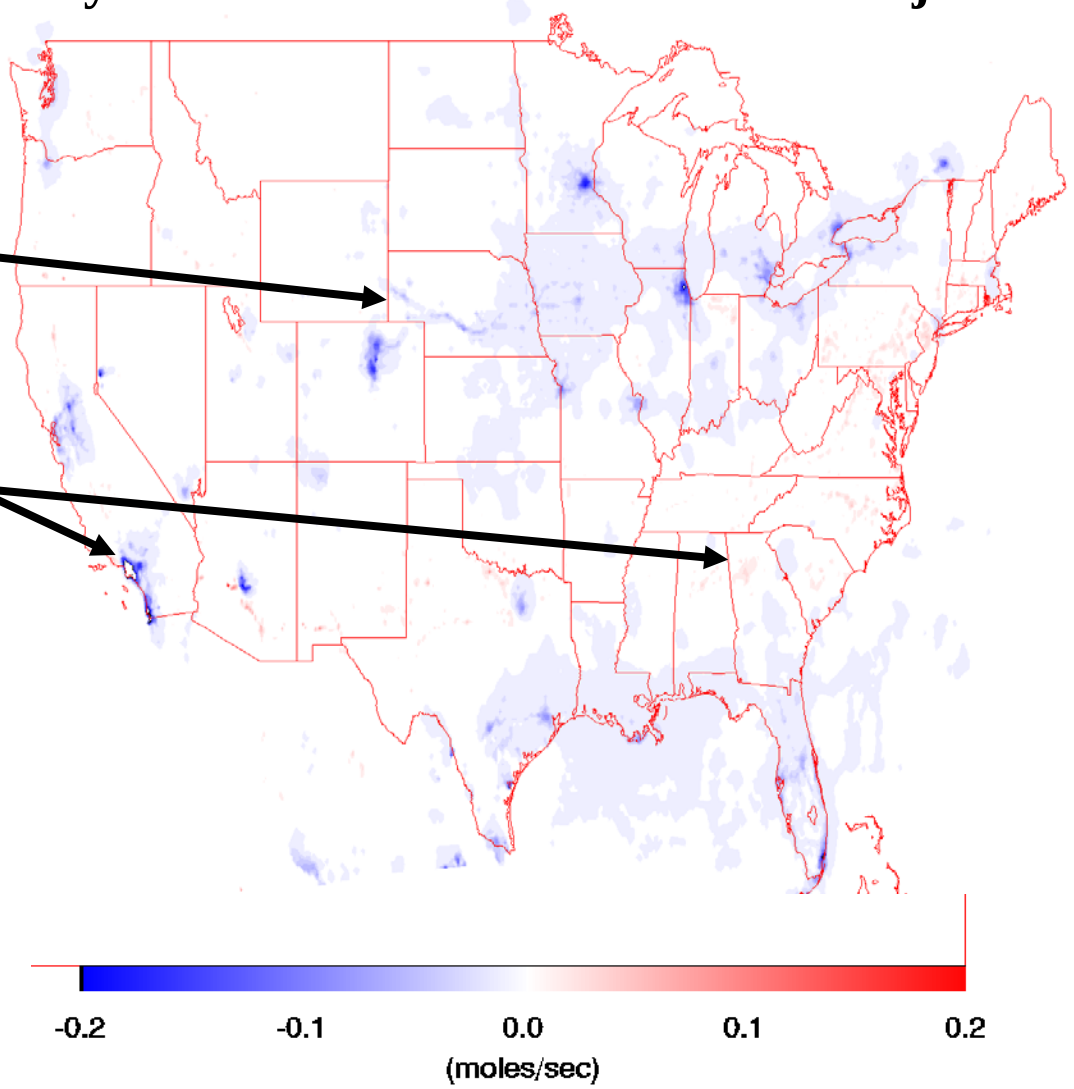
(with adjusted lightning NO_X emissions)

CMAQ/GSI NOx emission adjustment experiments

Transportation-related NO_X emissions ~ 0.3 moles/sec (~30% adjustment)

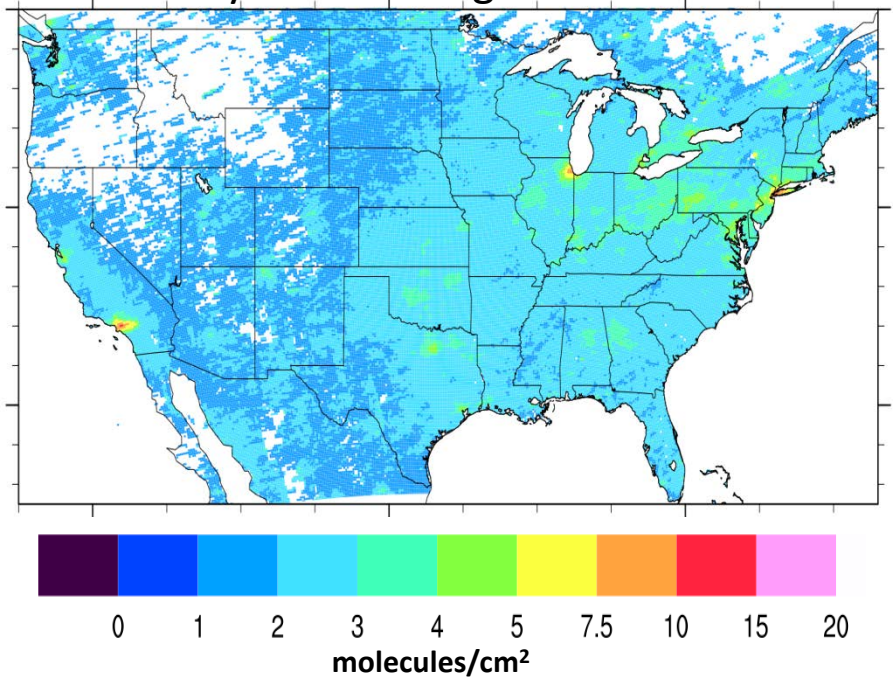
NO_X emissions in urban areas ≥ 2 moles/sec (~10% adjustment)

July 2011 NEI area-source emissions adjustment

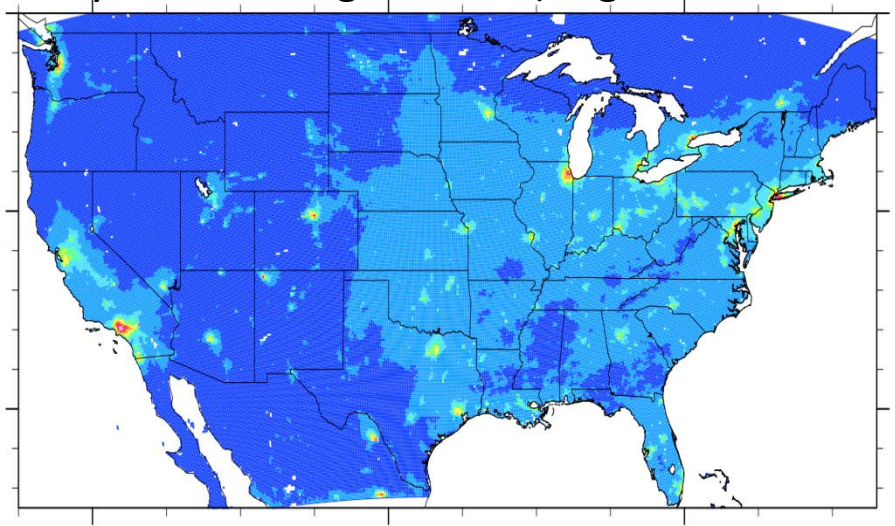


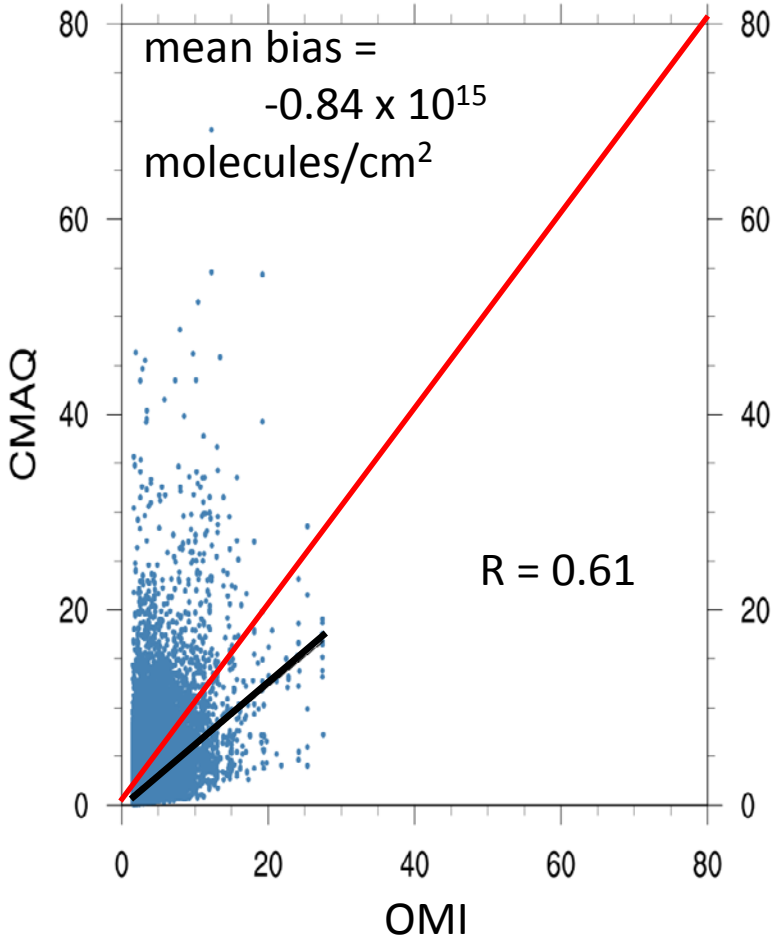
CMAQ/GSI NOx emission adjustment experiments

July 2011 average OMI NO2



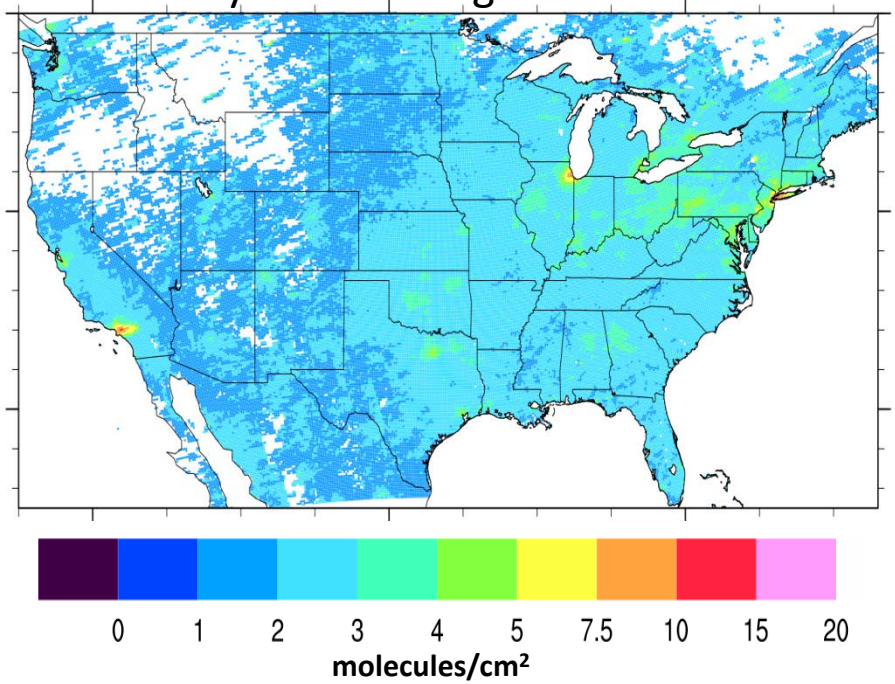
July 2011 average CMAQ (original emissions)



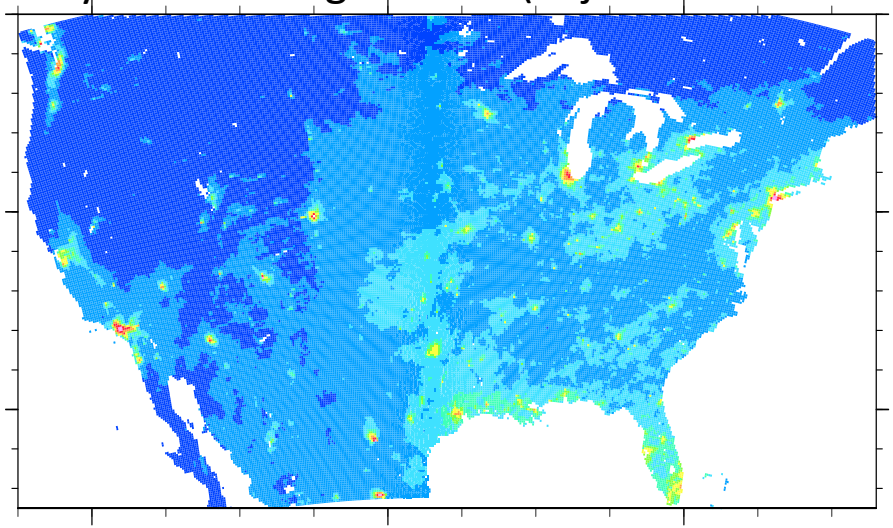


CMAQ/GSI NOx emission adjustment experiments

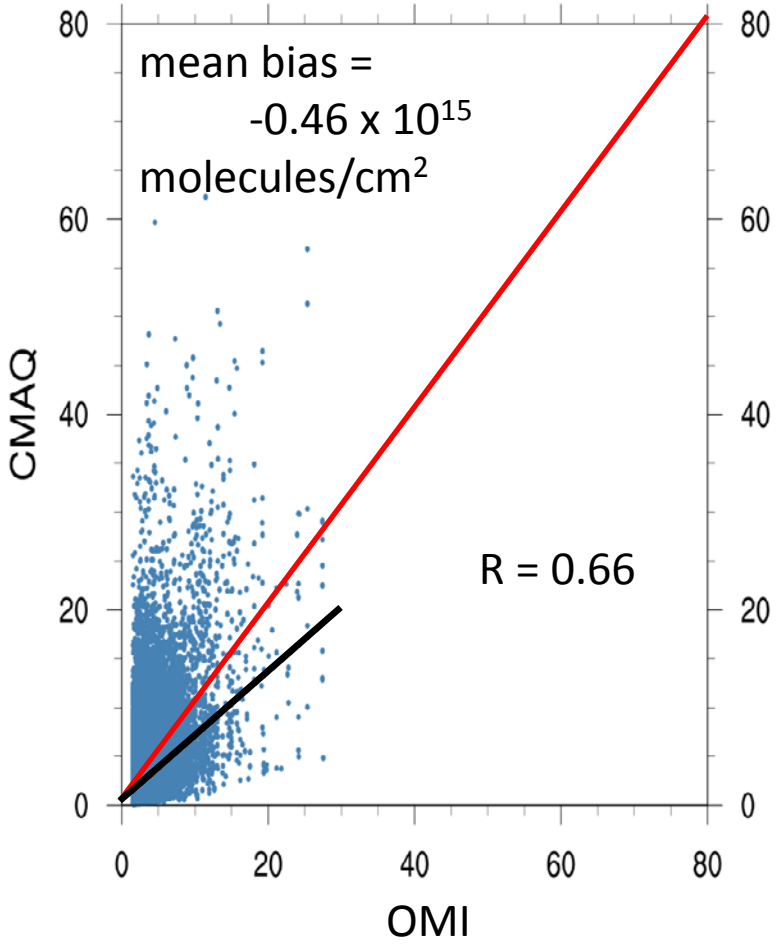
July 2011 average OMI NO2



July 2011 average CMAQ (adjusted emissions)



CMAQ simulation with adjusted Lighting and NEI Emissions shows reduced low biases and increased correlations with OMI



Aura Chemical Reanalysis in support Air Quality Applications

Ongoing activities

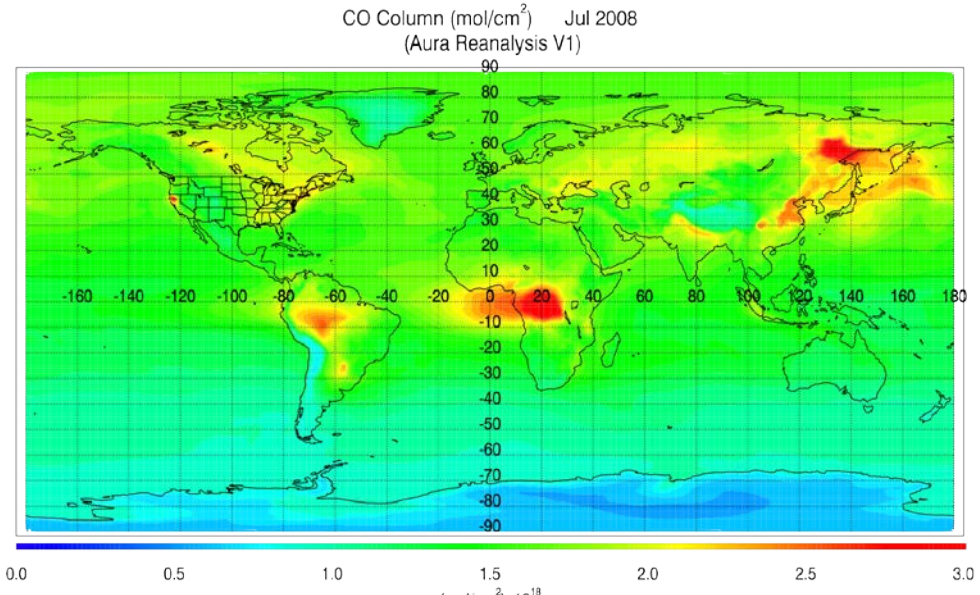
- PI and Co-I are members of Aerosol and Atmospheric Composition Task Force for development of NOAA's Next Generation Global Prediction System (NGGPS)
  - Funded by NOAA Research Transition Acceleration Program (RTAP) for implementation of reduced troposphere/stratosphere chemistry algorithms into NGGPS.
  - Aura Reanalysis will provide climatological regressions for NGGPS N2O and CH4 and ClOx and BrOx catalyzed stratospheric ozone loss
- PI is Co-Lead (with Daniel Tong, GMU) of a multi-agency (NOAA, EPA, CDC) HAQAST Tiger Team for improved NEI NOx emissions based on CMAQ/GSI/OMI NO2 DA activities
  - OMI based emissions adjustment approaches will be demonstrated within the NOAA NWS National Air Quality Forecasting Capability (NAQFC) and EPA/CDC fusion applications

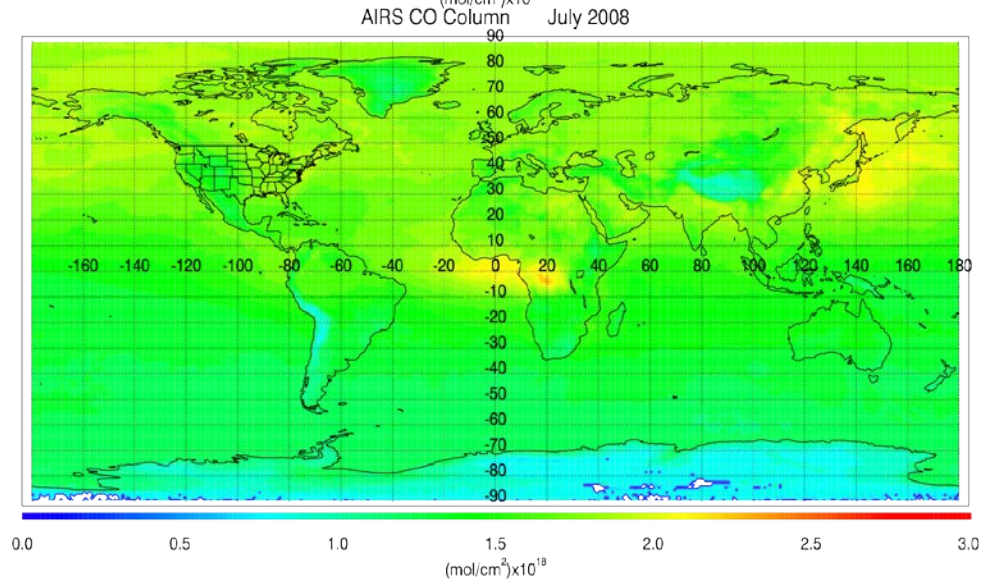
Application to Decision Making

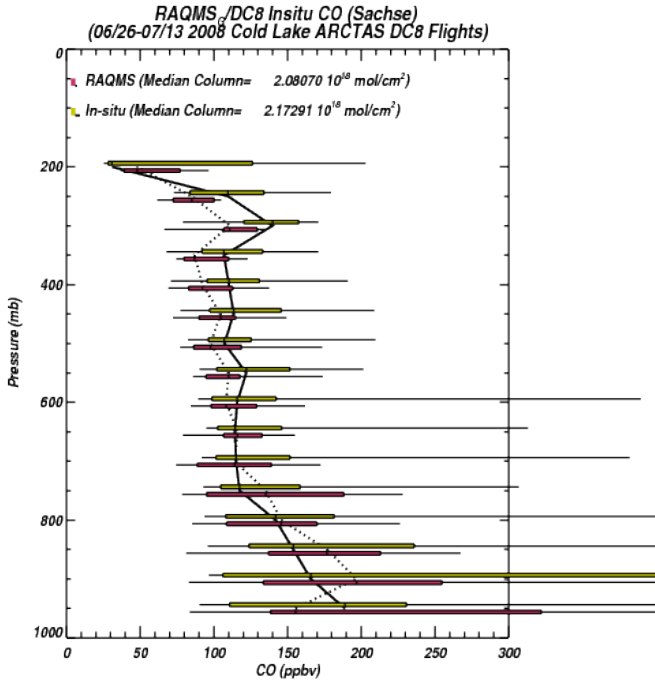
- The RAQMS Aura Reanalysis is the first complete global chemical and aerosol reanalysis that has been attempted within the US.
- It follows the path lead by the European Monitoring Atmospheric Composition and Climate - Interim Implementation (MACC-II) project within the Copernicus Atmosphere Monitoring Service that is now operational at ECMWF.
- The RAQMS Aura Reanalysis will provide comprehensive chemical and aerosol analyses for assessing global air quality and for providing lateral boundary conditions for regional air quality management such as State Implementation Planning (SIP) activites.

Extra Slides

All ARCTAS Cold Lake, AB DC8 Flights







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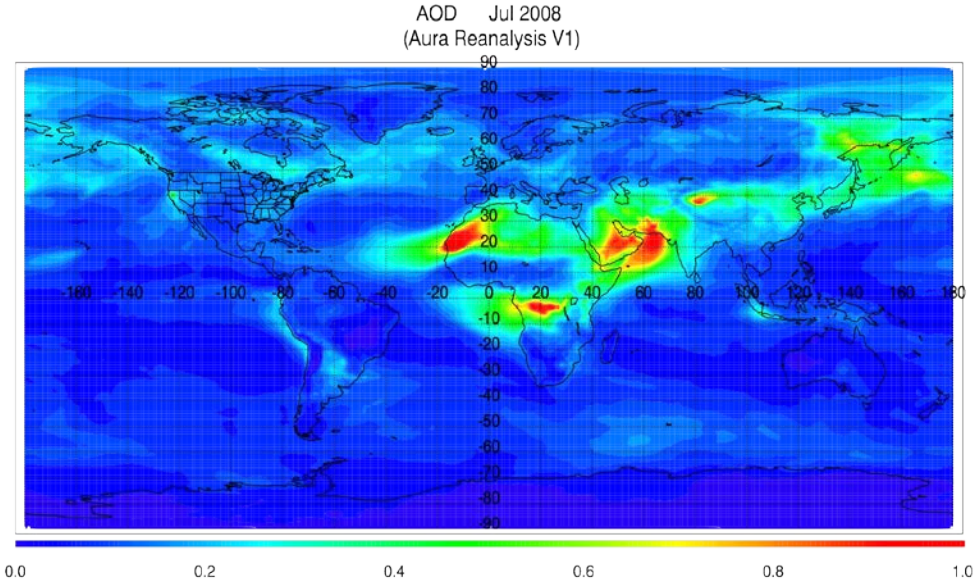

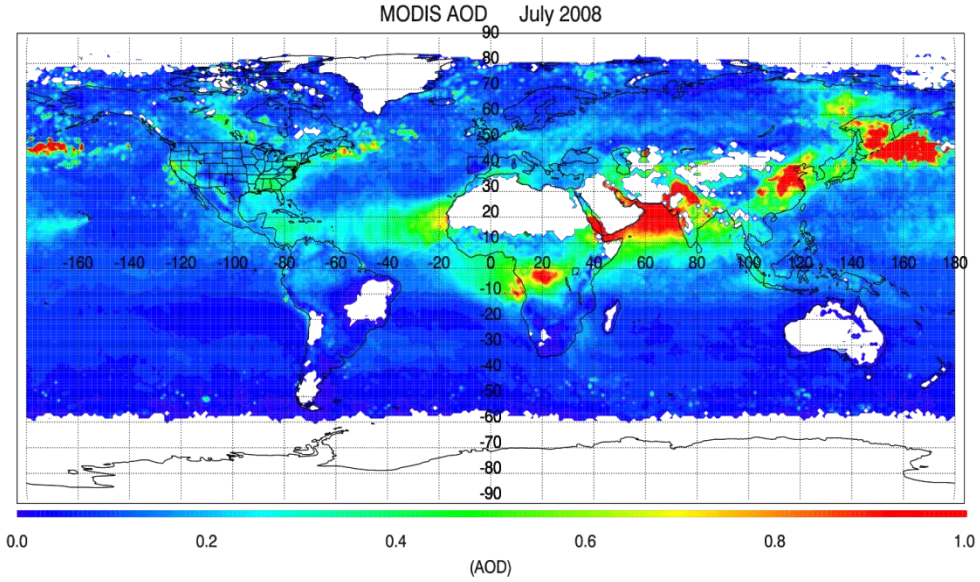

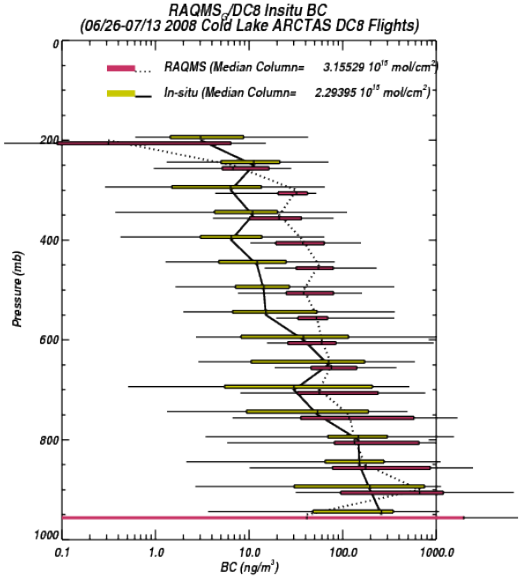

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