



PI Brad Pierce (NOAA/NESDIS)

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2017 NASA Health and Air Quality Applications Program Review, September 12-13, 2017, Reno, NV

- 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) 3dimensional 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 Rean	alysis in sup	port Air Q	uality Appl	ications					
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.

Applications Readiness Level (ARL)

Milestone below COMPLETED? Approved, Operational Deployment & Use in Decision-Making (Sustained Use)	ARL 9
Sustained use of application system in decision-making context	ANLI
ALL three milestones below COMPLETED? Application Completed & Qualified (Functionality Proven)	ARL 8
Finalized application system tested, proven operational, and shown to operate as expected within user's environment	
Application qualified and approved by user for use in decision-making activity	
User documentation and training completed	
BOTH milestones below COMPLETED? Application Prototype in Partner's Decision-Making (Functionality Demonstrated)	ARL 7
Prototype application system integrated into end-user's operational environment	
Prototype application functionality tested & demonstrated in decision-making activity	
BOTH milestones below COMPLETED? Demonstration in Relevant Environment (Potential Demonstrated)	ARL 6
Prototype application system beta-tested in a simulated operational environment	~
Projected improvements in performance of decision-making activity demonstrated in simulated operational environment	
BOTH milestones below COMPLETED? Validation in Relevant Environment (Potential Determined)	ARL 5
Application components integrated into a functioning prototype application system with realistic supporting elements	\sim
□ The application system's potential to improve the decision-making activity determined and articulated (e.g., projected impacts on cost, functionality, delivery time, etc.)	
BOTH milestones below COMPLETED? Initial Integration & Verification (Prototype)	ARL 4
Components of eventual application system brought together and technical integration issues worked out	\sim
Organizational challenges and human process issues identified and managed	
ALL three milestones below COMPLETED? Proof of Application Concept (Viability Established)	ARL 3
Components of application tested and validated independently	-
Detailed characterization of user decision-making process completed (e.g., pre- application baseline performance, mechanisms, and limitations)	
Convincing case for the viability of the application concept made	
ALL three milestones below COMPLETED? Application Concept (invention)	ARL 2
Application components formulated and created	
Decision-making activity to be enhanced by the application identified	
Plans to better characterize the decision-making activity developed	
Milestones below completed, or in progress? Basic Research (Baseline Ideas)	ARL 1
Ideas for how specific research results could enhance decision-making developed	\sim
Research results and relevant algorithms documented	

Integration into Partner's System

Development, Testing, & Validation

Discovery & Feasibility

PHASE I

PHASE II

PHASE III

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

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

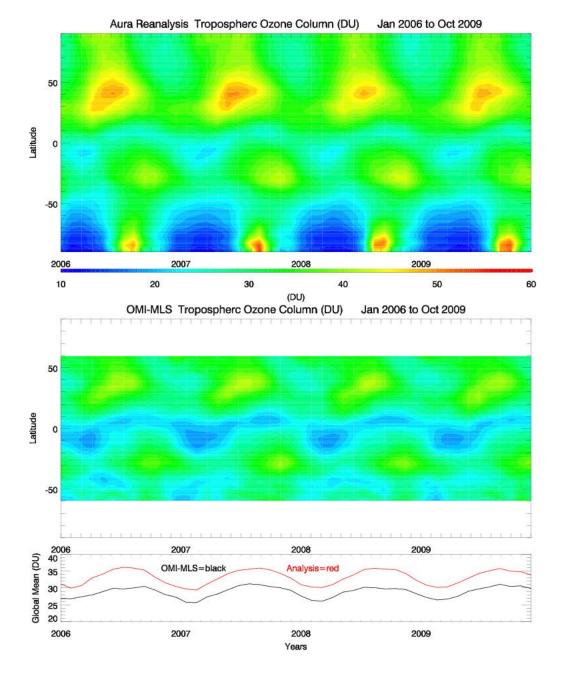
<u>Reached ARL 5</u> (Validation in Relevant Environment) upon completion of 2010 RAQMS/GSI analysis (December 2016)

<u>Currently at ARL 6</u> (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 1year no-cost extension with delivery of RAQMS Aura Reanalysis to DAAC.

- 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

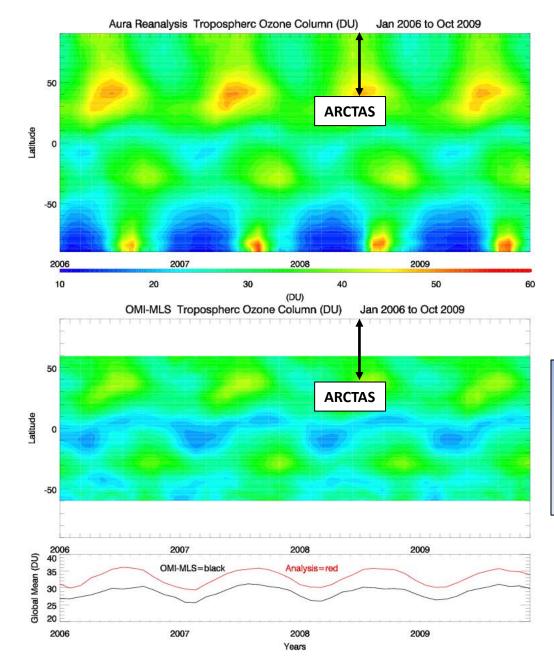
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Analyzed Tropospheric Ozone Column (TOC) vs OMI-MLS Tropospheric Ozone Residuals (TOR)

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.



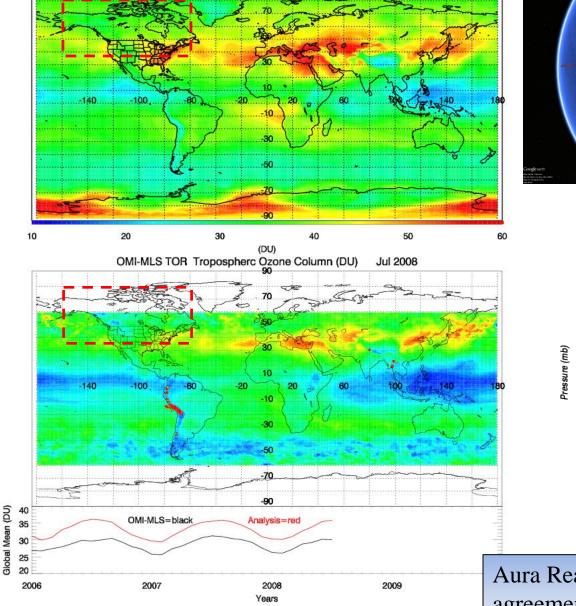


Airborne measurements from NASA ARCTAS field campaign are used to verify Northern Hemisphere Aura Reanalysis TOC during July 2008

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

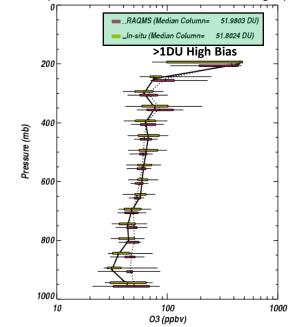
Aura Reanalysis Tropospherc Ozone Column (DU) Jul 2008



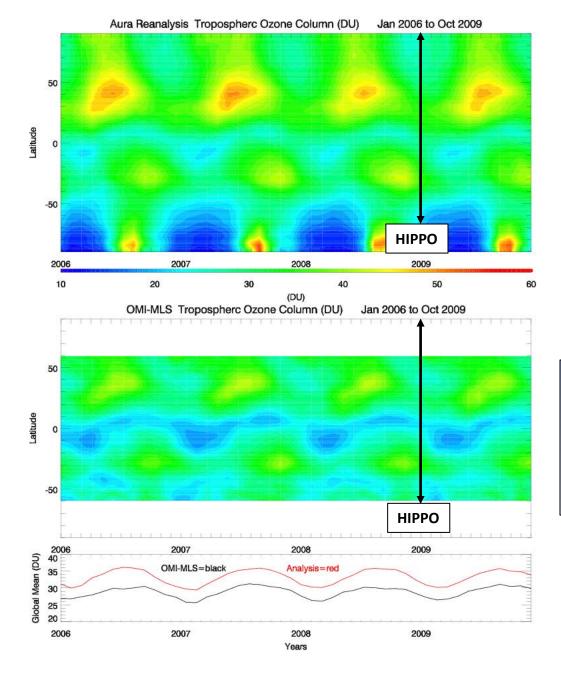
ARCTAS Flight Tracks July 2008



RAQMS //DC8 Insitu O3 (Avery) (06/26-07/13 2008 Cold Lake ARCTAS DC8 Flights)



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

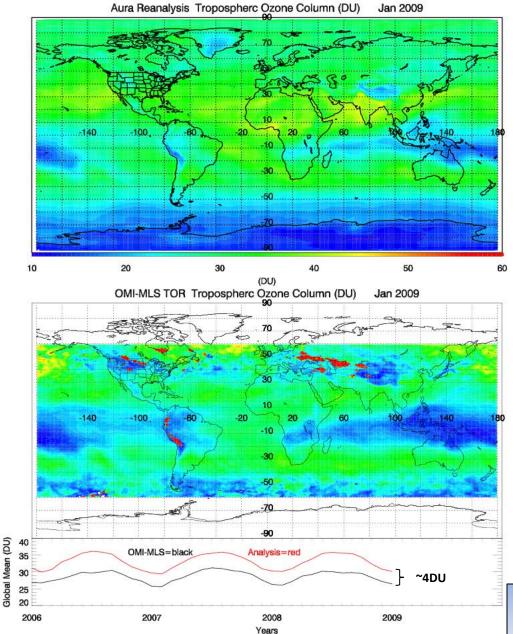




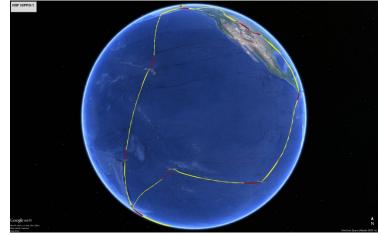
Airborne measurements from NSF HIPPO-I field campaign are used to verify Aura Reanalysis TOC over the Pacific Ocean during January 2009

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.

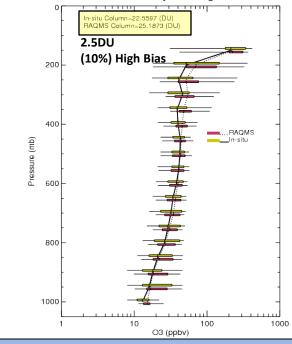
HIPPO-1 January 2009 O3 Verification



HIPPO Flight Tracks January 2009



RAQMS/HIPPO-1 Insitu O3 (Spackman) (Aura Reanalysis) All January 2009 Flights



Aura Reanalysis shows 10% high bias relative to airborne column

HIPPO-1 January 2009 O3 Verification

Northern Hemisphere

200

400

600

800

1000

(a)

latitude

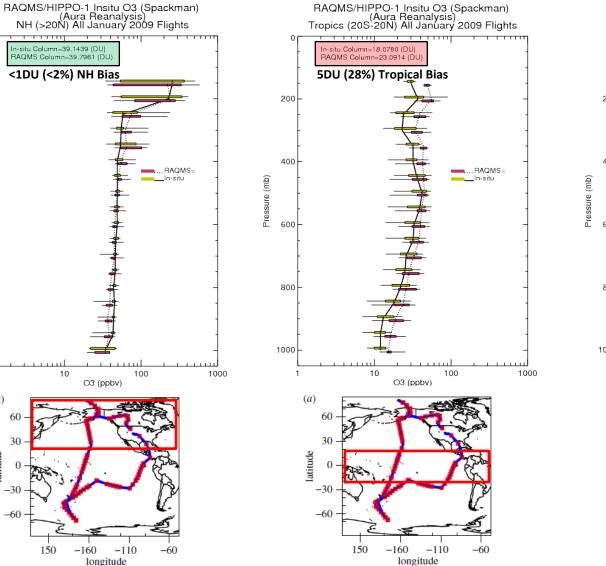
60

30

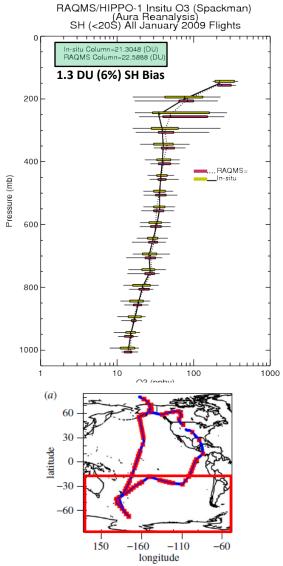
-30

-60

Pressure (mb)



Southern Hemisphere



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

Tropics

HIPPO-1 January 2009 CO Verification

-60 -40

1.0

1.0

-80

-140 -120 -100

0.5

0.5

-160

0.0

0.0

(Aura Reanalysis V1) 90 80 70 60

> 20 10

-10 -20 -30 -40 -50 -60 -70

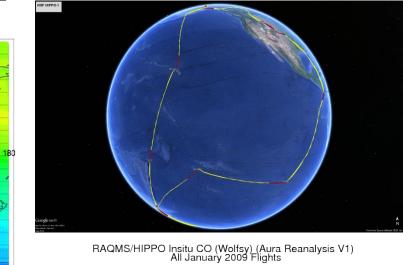
-80

1.5

60 80

-20

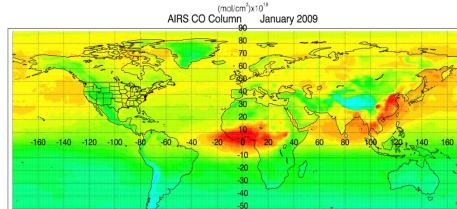
HIPPO Flight Tracks January 2009





3.0

160



-60

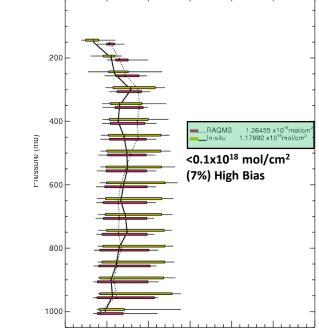
70 -80 -90

1.5

(mol/cm²)x10¹⁸

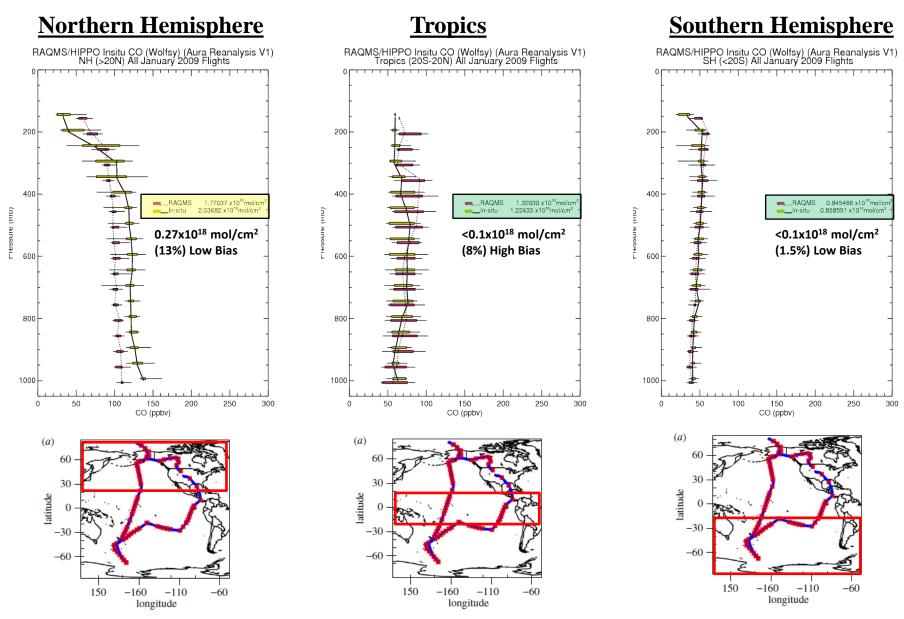
2.0

2.5



Aura Reanalysis shows slight high global bias relative to airborne column

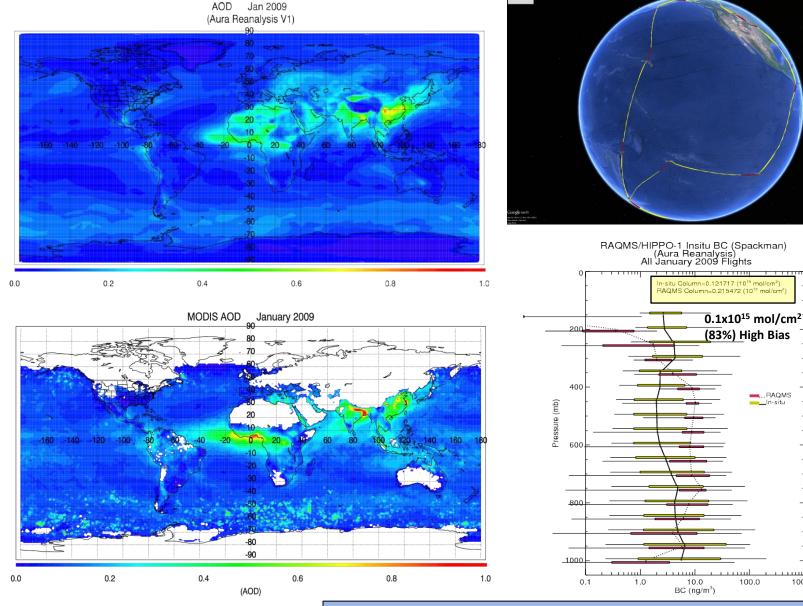
HIPPO-1 January 2009 O3 Verification



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

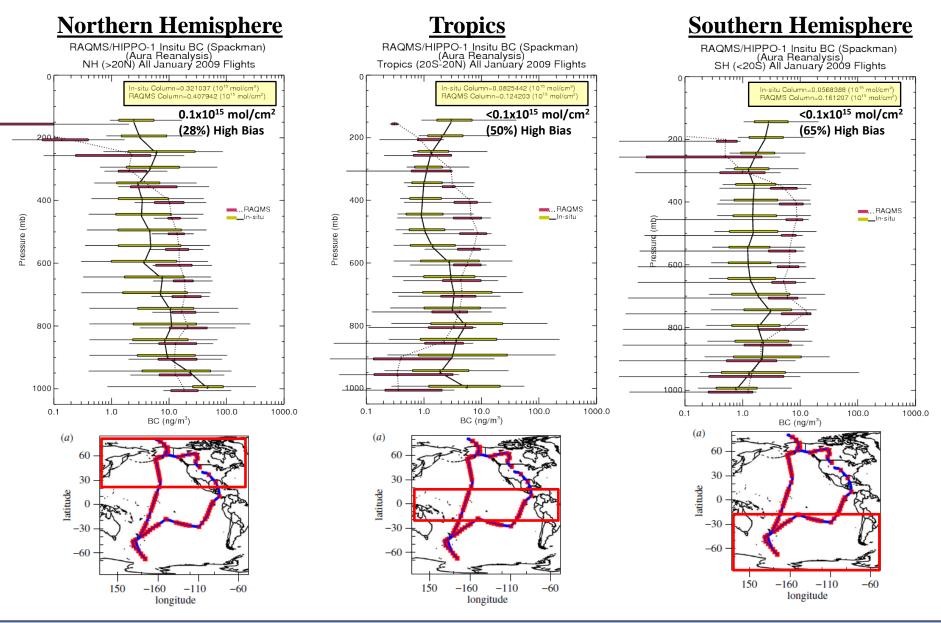


Aura Reanalysis high bias relative to airborne column under low black carbon aerosol loadings

1 1 1 1 1 1

1000.0

HIPPO-1 January 2009 BC Verification



Mid tropospheric BC overestimates of 2-5x dominate overall high biases in BC column relative

HIPPO-1 January 2009 Verification Summary

Species	NH (>20N)	Tropics	SH (<20S)	All Pacific	
03	2% High Bias	28% High Bias	6% High Bias	10% High Bias	
со	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)

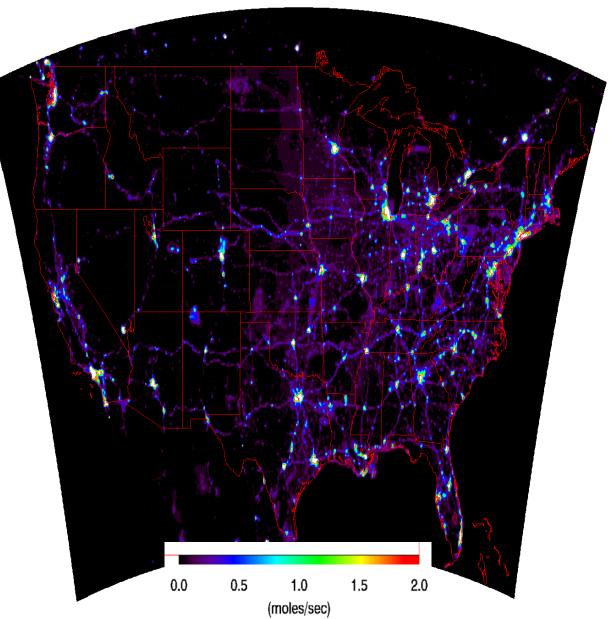
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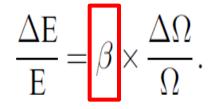
Offline adjustment of area and point NO_x emissions based on OMI Tropospheric NO2 column analysis increments

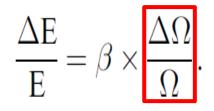
(NO₂ lifetime too short to use assimilation to constrain tropospheric column amounts)

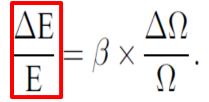
July 2011 average area emissions (NEI)



- 1) Calculate monthly mean NO₂ Jacobian (β) from a 15% NO_X emission reduction perturbation experiment following *Lamsal et al.* 2011
- 2) Calculate monthly mean NO₂ analysis increment using CMAQ/GSI OMI NO₂ assimilation
 - a. Lightning NOx sensitive background errors (to correct LNOx bias)
 - b. NEI 2011 NOx sensitive background errors (to correct NEI emissions)
- 3) Adjust 2011 NEI NO_x emissions using Jacobian and analysis increment





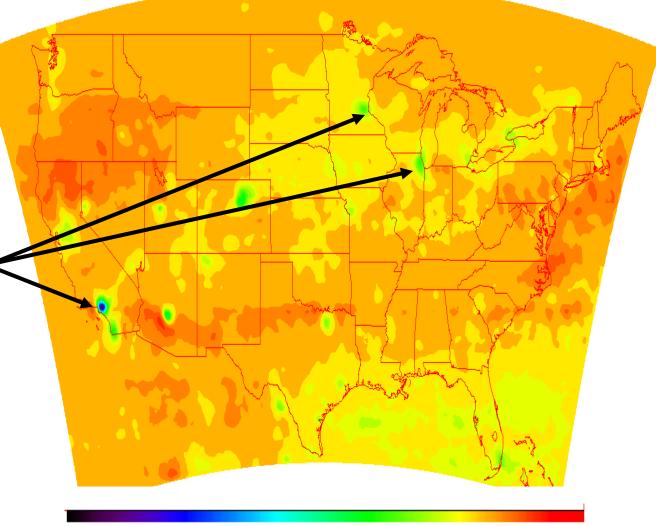


Lamsal, L. N., et al. (2011), Application of satellite observations for timely updates to global anthropogenic NOx emission inventories, Geophys. Res. Lett., 38, L05810, doi:10.1029/2010GL046476.

July 2011 analysis increment

Analysis increment adjusts NO2 columns downward in urban areas

(with adjusted lightning NO_X emissions)



-0.5

0.0

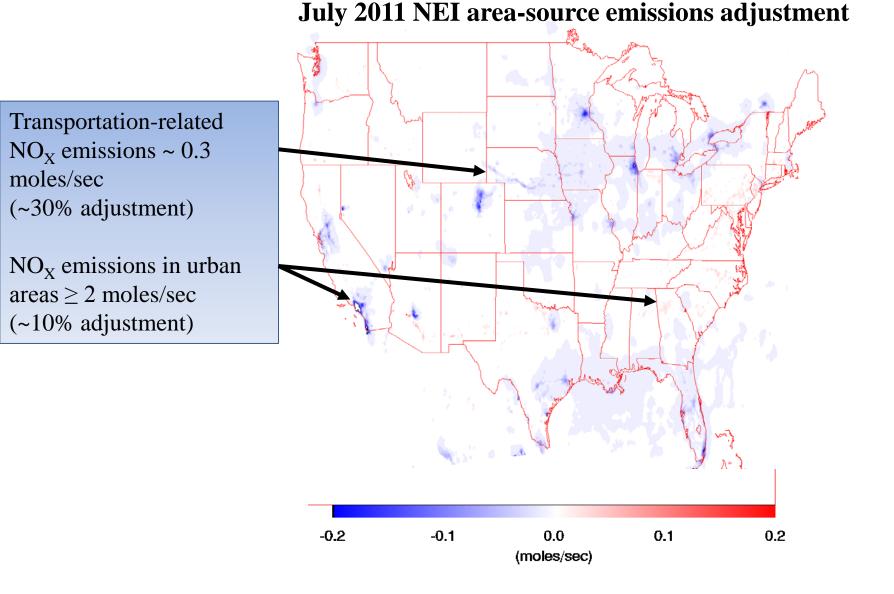
0.5

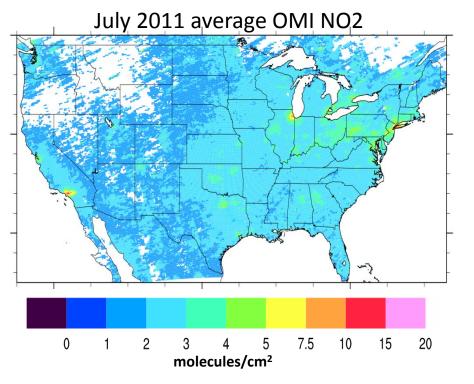
-1.5

-2.0

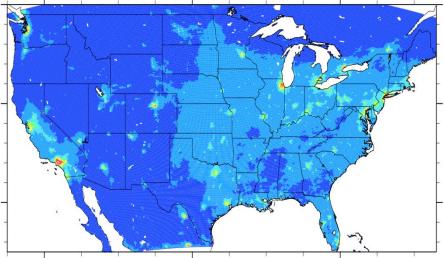
-1.0

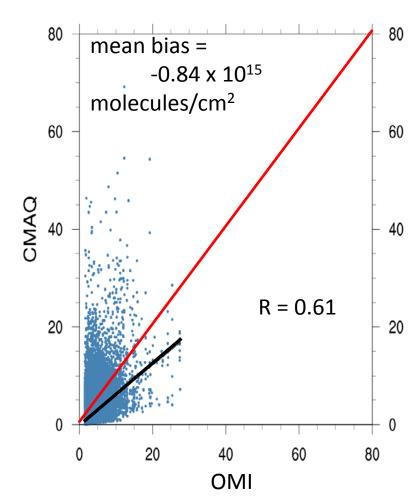
(1e15 mol/cm²)

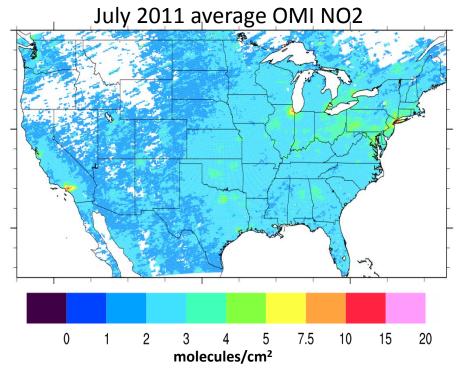




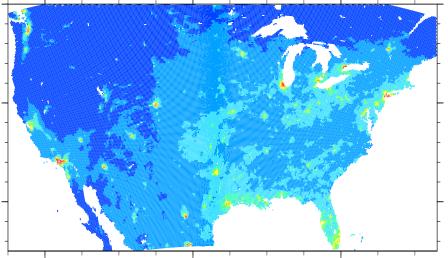
July 2011 average CMAQ (original emissions)



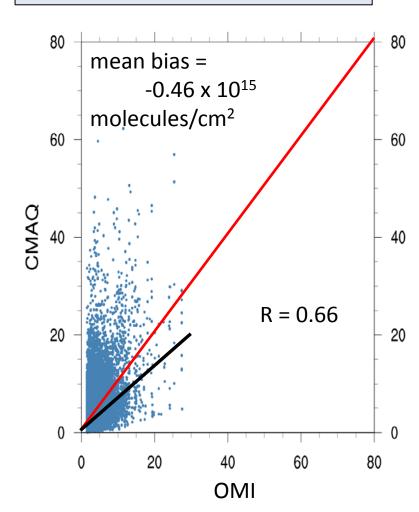




July 2011 average CMAQ (adjusted emissions)



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

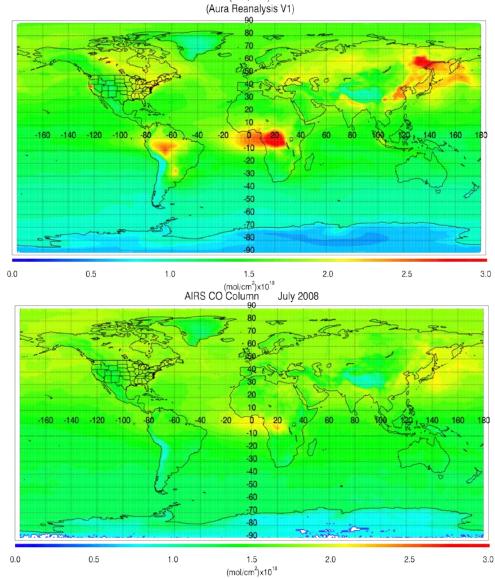
Application to Decision Making

- 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

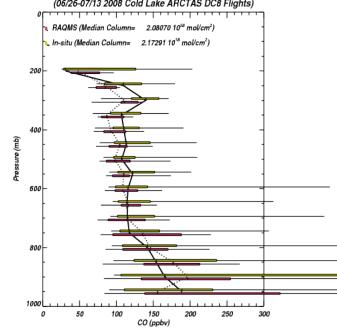
All ARCTAS Cold Lake, AB DC8 Flights

CO Column (mol/cm²) Jul 2008 (Aura Beanalysis V1)



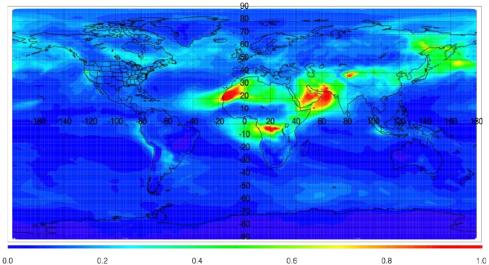


RAQMS /DC8 Insitu CO (Sachse) (06/26-07/13 2008 Cold Lake ARCTAS DC8 Flights)



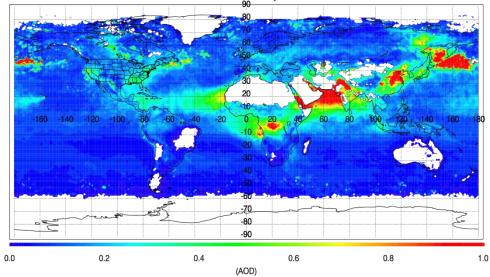
All ARCTAS Cold Lake, AB DC8 Flights

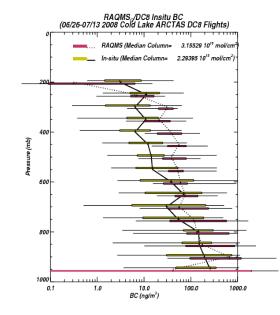
AOD Jul 2008 (Aura Reanalysis V1) 90





MODIS AOD July 2008



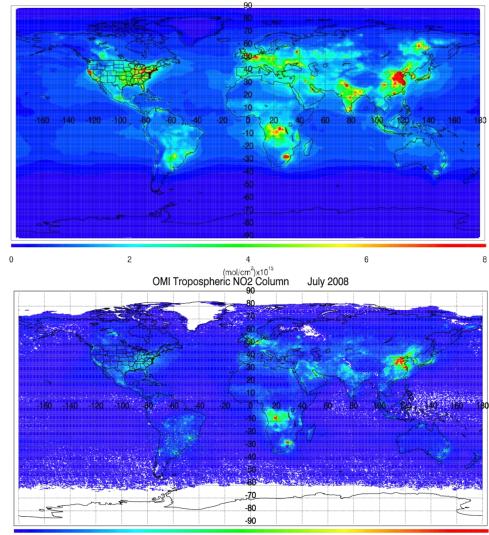


All ARCTAS Cold Lake, AB DC8 Flights

2

0

Tropospheric Column NO2 (1e15 mol/cm²) Jul 2008 (Aura Reanalysis V1) 90



4

(mol/cm²)x10¹⁵

6



RAQMS_G/Insitu NO2 (Cohen)

