

## Quantifying Source Contributions to O<sub>3</sub> and PM<sub>2.5</sub> Pollution Episodes across the Eastern US

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Professor, University of Wisconsin—Madison

Deputy Leader, NASA Air Quality Applied Sciences Team

April 22, 2014





### NASA Air Quality Applied Sciences Team

Earth Science Serving Air Quality Management Needs





### Why is AQAST Unique?

All AQAST projects connect Earth Science and air quality management:

- Pursue science to support air quality management
- Collaborate with partners in air quality management
- Expand relationships through meetings, online tools, newsletters

AQAST has flexibility in how it allocates its resources

- Members can adjust work plans to meet evolving air quality needs
- Multi-member "Tiger Teams" compete for funding to address strategic problems requiring coordinated activity
- AQAST is self-organizing and can respond quickly to demands

AQAST supports two types of projects:

- Investigator Projects core funding to individual members
- Tiger Team Projects collaborations between AQAST members with supplementary funding to address urgent air quality management needs

Quick, collaborative, flexible, responsive to the needs of the AQ community



www.aqast.org & www.aqast-media.org



### **AQAST members**

- Daniel Jacob (leader), Loretta Mickley (Harvard)
- Tracey Holloway (deputy leader), Steve Ackerman (U.
- Wisconsin); Bart Sponseller (Wisconsin DNR)
- Greg Carmichael (U. Iowa)
- Dan Cohan (Rice U.)
- Russ Dickerson (U. Maryland)
- Bryan Duncan, Yasuko Yoshida, Melanie Follette-Cook (NASA/GSFC); Jennifer Olson (NASA/LaRC)
- David Edwards (NCAR)
- Arlene Fiore (Columbia Univ.); Meiyun Lin (Princeton)
- Jack Fishman, Ben de Foy (Saint Louis U.)
- Daven Henze, Jana Milford (U. Colorado)
- Edward Hyer, Jeff Reid, Doug Westphal, Kim Richardson (NRL)
- Pius Lee, Tianfeng Chai (NOAA/NESDIS)
- Yang Liu, Matthew Strickland (Emory U.), Bin Yu (UC Berkeley)
- Richard McNider, Arastoo Biazar (U. Alabama Huntsville)
- Brad Pierce (NOAA/NESDIS)
- **Ted Russell,** Yongtao Hu, Talat Odman (Georgia Tech); Lorraine Remer (NASA/GSFC)
- David Streets (Argonne)
- Jim Szykman (EPA/ORD/NERL)
- Anne Thompson, William Ryan, Suellen Haupt (Penn State U.)

### **Scope of current AQAST projects**



## 2013 Tiger Team Process

- **1. Merit.** Is the work proposed sound, creative, interesting, important?
- **2. Responsiveness.** Does it address a pressing AQ management need?
- **3. Uniqueness.** Does it use Earth Science assets that go beyond standard AQ tools?
- **4. Team.** Will team members effectively work together?

Designing effective SIPs requires knowledge of source contributions to  $O_3$  and PM<sub>2.5</sub> pollution episodes

Observed pollution levels are the summation of in-state, out-of-state, international and natural sources

AQAST can help quantify these components, but how can we be most effective?

- → Build a framework for continued communication with the stakeholders
- → Request priority O<sub>3</sub> and high-PM<sub>2.5</sub> episodes from AQMs (2007-2012)
- $\rightarrow$  First teleconference will be April 28, 1 PM CDT



## **TT** Participants

- Lead PIs: Tracey Holloway (Univ. of Wisconsin) and Arlene Fiore (Columbia/LDEO)
- Other AQAST Scientists: Greg Carmichael (Univ. of IA), Daniel Cohan (Rice Univ.), Bryan Duncan (NASA), Daven Henze (CU-Boulder), Edward Hyer (NRL), Daniel Jacob (Harvard), Russ Dickerson (Univ. of MD), Gabriele Pfister (NCAR)
- AQM Partners: Bart Sponseller [Wisconsin DNR]; Angela Dickens [Wisconsin DNR/LADCO]; Tad Aburn [Maryland Dept. Env.]; Mark Estes [Texas/TCEQ]; Michael Ku [NYSDEC]; other states representatives to serve on Advisory Council; Terry Keating, Kirk Baker [US EPA]... & you?

### We request that each air agency develop a "wish list" of episodes where additional analysis would be helpful. Criteria for selecting episodes:

- Larger scale, regional episodes, generally affecting multiple states (or multiple cities within large states like TX)
- High ozone and/or PM are high.
- Suspected import from out-of-state
- Expectation that that this type of event could occur again
- Could also be large-scale exceptional events due to transported background
- Coming from forest fires or possibly stratospheric intrusions Focus **on 2007 through 2013**, though certain years have specific resources that can be brought to bear, or are of particular policy interest:
- > 2007 is the PM NAAQS base year
- 2010 is a focus year for multi-model project under Task Force on Hemispheric Transport of Air Pollution
- > 2011 EPA NEI year, also DISCOVER-AQ campaign
- 2013 has several field campaigns

### **Deliverables & Expected AQ outcomes**

- 1. Establishment of a stakeholder advisory committee (set priorities) → Build broader engagement between AQAST and state-level AQMs
- 2. For each episode, generate reports with technical details of approach in appendices ("the recipe" for the analysis)
  → New info / approaches to support SIP development
  - $\rightarrow$  New IIIO / approaches to support SIP development  $\rightarrow$  Build capacity by providing case studies for future analy
  - $\rightarrow$  Build capacity by providing case studies for future analyses
- 3. Develop website archive of reports, and links to related AQAST resources, including coordination with RSIG TT activity, other web tools
  → Broader dissemination of approaches & findings
- 4. Online interactive graphics to facilitate exploration of model and satellite data
  - → Developing user-friendly space-based and model products to provide information on contributions from transported pollution



April 25 (Friday): "Wish Lists" Requested

April 28 (Monday): First Telecon

Next Slides: Angela Dickens, WI DNR/LADCO

#### 2007 Ozone Concentrations (>60 ppb)



A. Dickens, WDNR/LADCO

#### 2007 Ozone Concentrations (>60 ppb)



A. Dickens, WDNR/LADCO

## 2007 episode of interest:

- June 10-18 (high concentrations inland through the 15<sup>th</sup>)
- Episode begins with a classic lake breeze
- Middle of the episode has high concentrations far inland from the lake; lower concentrations on the lakeshore
- Minnesota and Michigan also observed the highest ozone concentrations of the year during this episode
- Illinois had high (~90 ppb) concentrations as well.
- During much of this period, there were winds blowing from the east across the state
- high ozone concentrations were observed even in farthest northern monitoring stations.

# What tools and data can support analysis of this episode?

# AQAST resources for source attribution during EUS pollution episodes



satellite instruments

OMI NO2 MOPITT CO MODIS AOD

Transport events

- Inter-state
- Wildfire
- International



suborbital platforms

DISCOVER-AQ (2011; SIP Base year) SEAC4RS/SOAS/SENEX (2013) EPA AQS CASTNet

Size of episode

- Areal extent
- Duration
- Transport

For each episode, organically determine best use of AQAST resources (which team members, tools)



models

CAMx CMAQ GEOS-Chem GFDL AM3 STEM

Source attribution

- Several horizontal resolutions
- Forward/adjoint
- HTAP simulations
- Connect suborbital and space-based information

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Applying Satellite Data to Air Quality Management

FERRIJARY 2014

Can Windows and Other OSs Play in the Same Sandbox?

ctions: Notes From the 1st Clean Fuels d Vehicles Forum in the ASEAN Region

Research conducted by the NASA Air Quality Applied Sciences Team (AQAST) shows that Earth science data are a great potential resource for air quality managers

Witman, S., T. Holloway, and P. Reddy, 2013



**Figure 2:** Ratio of tropospheric formaldehyde (HCHO) to tropospheric nitrogen dioxide (NO<sub>2</sub>) over the Colorado Front Range area, derived from mean GOME2 satellite measurements for July 2007 and 2008. A ratio of above 1.0 may indicate a NO<sub>x</sub>-sensitive ozone production regime. All ratios in this region show ratios are above 1.0. Gridded data from KNMI TEMIS

(http://www.temis.nl/airpollution/no2.html). Figure courtesy of **Patrick Reddy**, from presentation "2009 Ozone Season Review: Briefing to the Colorado Air Quality Control Commission," September 17, 2009

#### Winter Average FNR in 2007 90N 60N The FNR "Recipe" 30N 30S Air Quality Results 60S 🛃 🛨 🕘 sage.wisc.edu/airquality\_ratios/airquality\_scripts.html Ċ 0 🛄 🏢 Technical R...s Workgroup uk-air.defr...INAL\_low.pdf AirData | US...tion Agency Pivot Silverlight Overview http://www....uly2010.pdf Fortran 77 Tutorial Import to Mendeley News 🔻 908 6th Biannual AQAST Meeting (A... nspires.nasaprs.com/external/v... www.ladco.org/about/general/ + . Air Quality Results 180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180 Spring Average FNR in 2007 90N NELSON INSTITUTE Center for 60N Sustainability and the **Global Environment** 30N UNIVERSITY OF WISCONSIN-MADISON 0 About SAGE Contact Us 305 People **NCL Scripts** News & Events Supporting SAGE 60S a. Data Preprocessing Research b. FNR Calculation Education 905 Outreach c. FNR Plotting 180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E Summer Average FNR in 2007 Publications 90N Maps, Data, Models Sage.wisc.edu// For Prospective Students 60N .INAL\_low.pdf AirData / US...tion Agency Air Quality Ratio In the absence of VOC and NOx information, the ratio of formaldehyde to nitrogen dioxide (FNR) can be used as a proxy to determine the reaime (Martin et al.. 2004) over polluted reaions. The tropospheric column of nitrogen dioxide and Updated: 1/11/1 In the absence of VOC and NOx information, the ratio of formaldehyde to nitrogen dioxide (FNR) can be used as a determine the regime (Martin et al., 2004) over polluted regions. The tropospheric column of nitrogen dioxide and formaldehyde can be obtained from satellite measurements. such as OMI. GOME and SCIAMACHY. Martin et al. ( SAGE determine the regime (Martin et al., 2004) over polluted regions. The tropospheric column of nitrogen dioxide and formaldehyde can be obtained from satellite measurements, such as OMI, GOME and SCIAMACHY, Martin et al. (2004) estimated the transition between VOC-limited and NOx-limited regimes occurs when FNR is close to 1.Thus. regions with formaldehyde can be obtained from satellite measurements, such as OMI, GOME and SCIAMACHY. Martin et al. (2004) estimated the transition between VOC-limited and NOx-limited regimes occurs when FNR is close to 1.Thus, regions with FNR > 1 can be approximately classified as NOx-limited reaime, while regions with FNR < 1 can be approximately estimated the transition between VOC-limited and NOx-limited regimes occurs when FNR is close to 1.Thus, region FNR > 1 can be approximately classified as NOx-limited regime, while regions with FNR < 1 can be approximately classified as VOC-limited regime. VINSTITUTE 2. How to calculate FNR? The following instructions describe how to calculate space-based FNR using OMI satellite data http://disc.sci.netc.naca.nov/&ura/data.holdinge/CMI/index.shtml The rollowing instructions describe now to calculate space-based http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/index.shtml Center nonlity and the Sustainability and the 60W 30W 90E 120E 150E WO 90W 0 30E 60E 180 TY OF WISCONSIN-MADISON Fall Average FNR in 2007 a. Data Acquisition Average FNR Result Download OMI NO2 and HCHO gridded data (Level 2G or Level 3) from the following websites: TEMIS: http://www.temis.nl/index.php TEMIS: http://www.temis.nl/index.php An efficient way to download global satellite data in bulk under Mac OS: Just connect to the server of NASA Antipicanties netrinaea anulae a muset wear linder the "Go" tab find and convitte data way want An efficient way to download global satellite data in bulk under Mac OS: Just connect to the serve (ftp://acdisc.gsfc.nasa.gov) as a guest user under the "Go" tab, find and copy the data you want. b. Data pre-processing 2005 The OMI NO<sub>2</sub> products contain NO<sub>2</sub> data: total and troposnhor ting SAGE Read: OMI HCHO http://sage.wisc.edu/airquality\_ratios Wans, Data, Models ospective Students Publications 90E 120E 150E 180

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SAGE Center for Sustainability and the Global Environment

WHIPS

### Wisconsin Horizontal Interpolation Program for Satellites

- Create custom "Level-3" gridded satellite data
- Select grid resolution and projection – easier comparison with regional models
- NO<sub>2</sub> (KNMI & NASA), CO (MOPITT), MODIS AOD



Above: January 2007; 12 km x 12 km NO<sub>2</sub>. Units of 10^15 molecules/cm<sup>2</sup>

Students: Jacob Oberman, Erica Scotty, & Keith Maki

http://www.sage.wisc.edu/download/WHIPS/WHIPS.html





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nload/WHIPS/WHIPS.html

http://www.sag.

## Aligning Satellite & Model Data

### Satellite

Fixed grid



Allows comparison across satellites, from satellite to model, satellite to ground-based measurements, etc.

Jacob Oberman



### 0.25° x 0.25° lat/lon grid



## WHIPS Output Grids

### 12 km x 12 km example grid

Average Tropospheric VCD from 07-01-05 through 07-31-05



# Only available on the single grid specified for that product.

## Flexible in resolution/projection; (Lambert Conic Conformal)

Visualization on this slide was produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

# User-choice for interpolation method













Jacob Oberman



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## Preliminary work from NASA AQAST Tiger Team on Source Attribution for EUS Pollution Episodes

14 13

12

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#### GEOS-Chem model (2°x2.5°), EPA NEI2005

June 10-18, 2007 simulation: large-scale event throughout entire Mississippi Valley

Hourly surface ozone and winds

22Z 14 Jun 2007



 Developed new capability to zero a single state's emissions

 Sensitivity simulations performed with N. American, United States, or Wisconsin precursor emissions individually removed; also natural sources

### Sample estimated contribution of WI emissions to surface O<sub>3</sub>



- Boundary conditions archived for regional scale model
- Currently evaluating the ability of the coarse model to provide rapid firstlook estimates of event source attribution in advance of regionalscale modeling

## Canadian pollution influence on ozone in Northeast US

Mean Canadian/Mexican pollution influences on MDA8 ozone (Jun-Aug 2001)

as determined by a GEOS-Chem simulation with those sources shut off



Mean national influence over US is small (3 ppb) but regional influence can be large

Wang et al. [2009]

### CANADIAN AND MEXICAN POLLUTION INFLUENCE

Jun-Aug 2001 time series at the sites most affected



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### NASA DISCOVER-AQ : Stratospheric Intrusions Influence the Eastern U.S Surface Air during July 2011 (L. Ott, B. Duncan, A. Thompson, NASA)

The NASA GEOS-5 global model's new high resolution (25x25 km<sup>2</sup>) capability allows for the simulation of fine structures associated with stratospheric intrusions. Two dynamic tracers clearly show the influence of an intrusion on the boundary layer on July 27, 2011 in Maryland. Several intrusions were identified during the campaign in July.



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## Contour Plot of Contributions from Gridded BC Emissions to Mortality in NY/PHI Region



- Adjoint simulations performed using CMAQ\_ADJ (Hakami et. al, 2007)
  - CMAQ\_ADJ updated to include aerosol microphysics (Turner, in prep).
  - 11 months of sensitivities calculated (Feb. 2007 Dec. 2007)
- Cost Function (number of mortalities attributed to exposure to BC exposure in NY/PHI region) = 1,923 mortalities in 2007
  - Cost function calculated using concentration response factor from Krewski et. al (2009)
  - Baseline mortality rates obtained from BenMAP

#### Matthew Turner, University of Colorado at Boulder



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### Twitter @NASA\_AQAST

## Thank you!

### www.aqast.org www.aqast-media.org



NASA Air Quality Applied Sciences Team Earth Science Serving Air Quality Management Needs



### Relevance of Canadian pollution for US air quality policy

Number of days per year when MDA8 ozone exceeds 75 or 70 ppb and Canadian pollution influence exceeds 10 ppb



Canadian sources need to be considered in ozone mitigation plans for Northeast

Wang et al. [2009]



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