NASA Air Quality Applied Sciences Team:

Investigating processes affecting Western U.S. air quality

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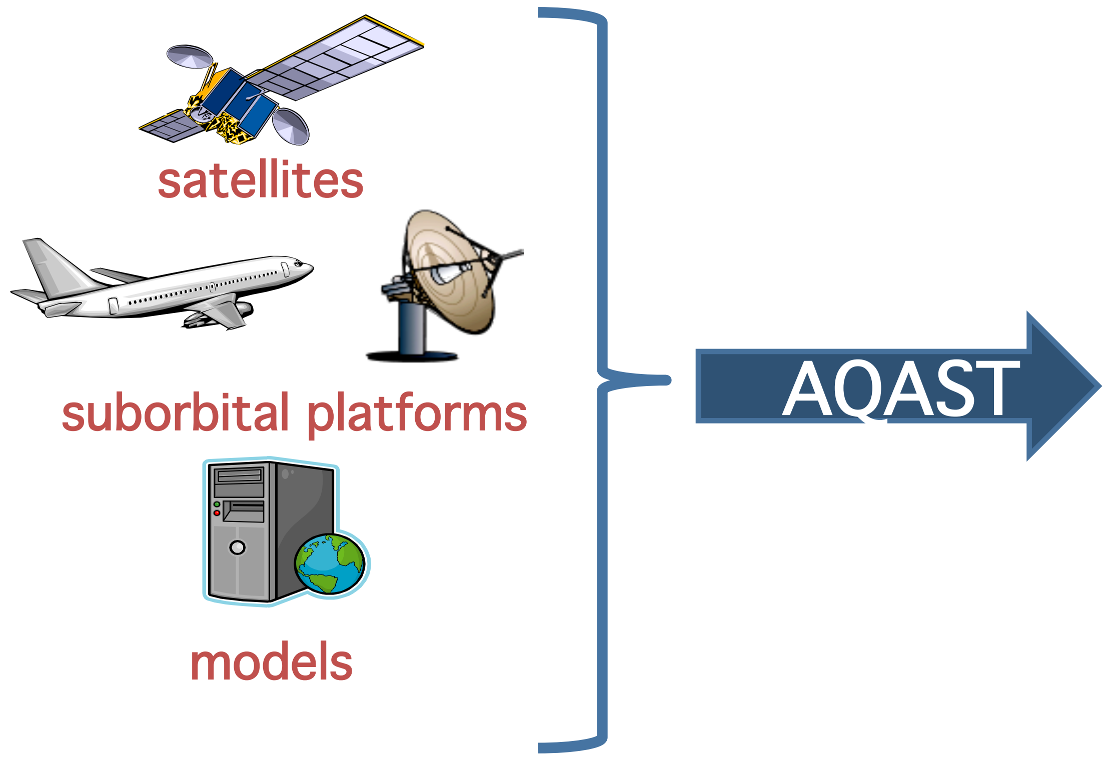
Acknowledgments. Olivia Clifton (CU/LDEO), Gus Correa (CU/LDEO), Larry Horowitz (GFDL), Daniel Jacob (Harvard), Meiyun Lin (Princeton), Vaishali Naik (GFDL), Jacob Oberman (U WI), Lin Zhang (Peking University)

Western Air Quality Modeling Workshop
Boulder, CO, July 11, 2013

NASA Air Quality Applied Sciences Team

Earth Science Serving Air Quality Management Needs



Pollution monitoring
Exposure assessment
AQ forecasting
Source attribution
Quantifying emissions
Natural & foreign influences
AQ processes
Climate-AQ interactions

NASA Air Quality Applied Sciences Team

Earth Science Serving Air Quality Management Needs

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AQAST member directory

Gregory Carmichael
University of Iowa

Regional-scale air quality modeling, air quality forecasting, boundary air pollution, short-lived climate pollutants, assimilation.

Daniel Cohan
Rice University
cohan@rice.edu

Regional photochemical modeling; ozone and particulate response to emission control strategies; uncertainty analysis; OMI NO2 satellite data; inverse modeling of emissions; satellite observations of vegetation; SIP attainment plan development; air quality trends analysis.

Russell Dickerson
University of Maryland
russ@atmos.umd.edu

Surface and aircraft measurements of trace gases (O3, NOx, NOy, SO2, CO, VOCs, etc.) as well as aerosol chemical and optical properties. Chemical transport modeling; satellite observations of NO2, SO2 and aerosols; nitrogen cycling and deposition; chemistry/meteorology interactions.

Bryan Duncan
NASA GSFC
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NASA satellite data, including NO2 and HCHO for air quality applications; long-range transport of pollution; general chemistry associated with air quality; NASA aircraft data; global methane modeling.

David Edwards
NCAR
edwards@ucar.edu

Satellite remote sensing of atmospheric composition methodology, instrumentation and retrieval techniques. Pollutant spatial distributions and temporal variations with an emphasis on biomass burning and wildfires. Observation System Experiments (OSEs) to evaluate the relative contribution of measurements in constraining AQ analyses and forecasts, and Observation System Simulation Experiments (OSSEs) to quantify the impact of future observations.

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Global chemical transport and chemistry-climate modeling; air quality and climate; sources of background ozone; intercontinental pollution; trends and variability in methane and ozone.

Jack Fishman
Saint Louis University

Impact of air pollution on agricultural productivity; Education-Public Outreach coordinator for AQAST – PI for the St. Louis

On AQAST website (google AQAST), click on "members" for list of 19 members and areas of expertise

What makes AQAST unique?

All AQAST projects connect Earth Science and air quality management:

- active **partnerships with air quality managers** with deliverables/outcomes
- **self-organizing** to respond **quickly** to demands
- **flexibility** in how it allocates its resources
- **INVESTIGATOR PROJECTS (IPs)**: members adjust work plans each year to meet evolving AQ needs
- **"TIGER TEAM" PROJECTS (TTs):** multi-member efforts to address emerging, pressing problems requiring coordinated activity

www.aqast.org: click on "projects" for brief descriptions + link to pdf describing each project

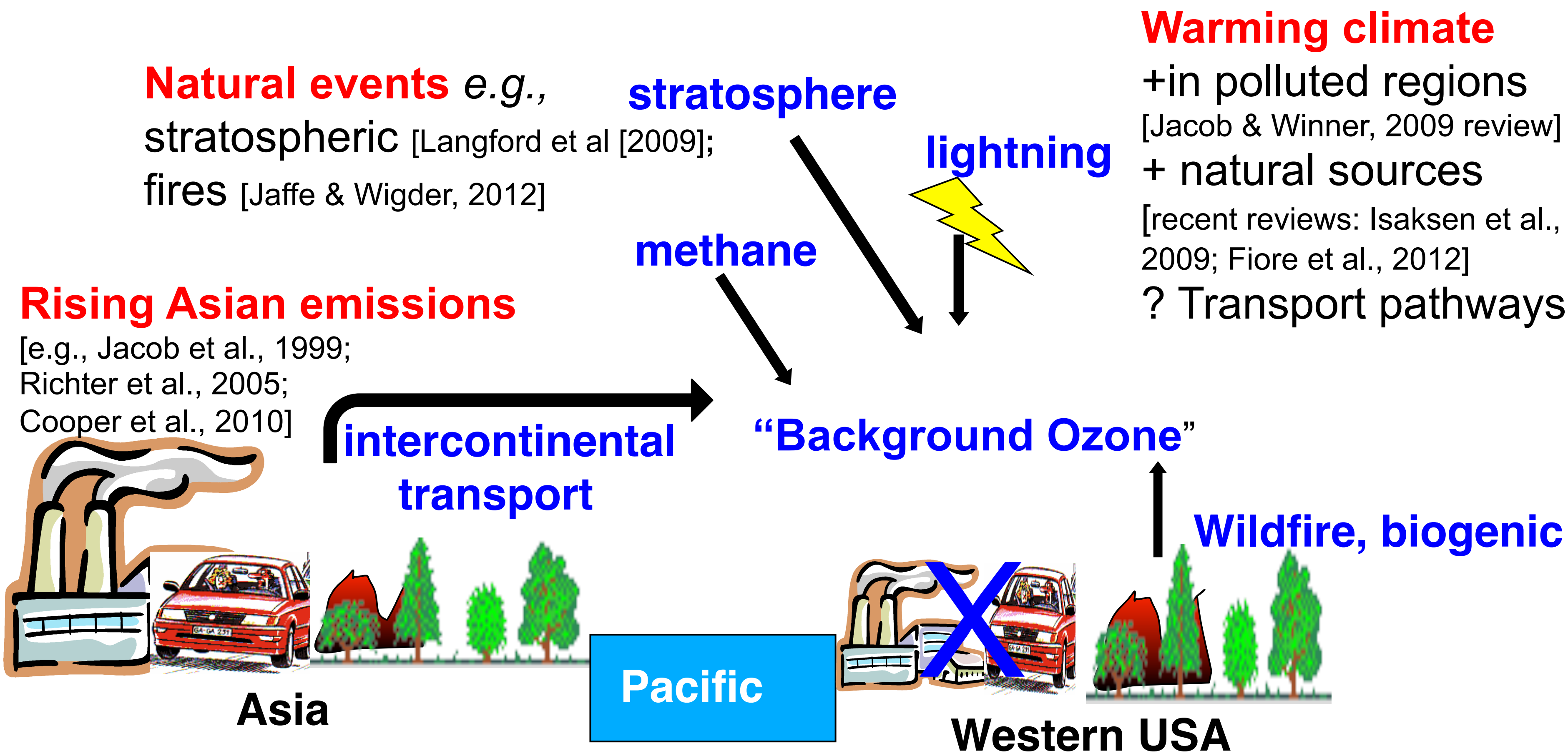
Tiger Team proposals currently under development (Y3, review in Sept) include:

- Web-enabled AQ management tools
- AQ reanalysis
- Ensemble based AQ forecasting
- Emissions & Processes for AQ models
- Source attribution for high-O_3 events over EUS
- Quantifying oil & gas emissions
- Satellite-derived NO_x emissions and trends

NASA

AQAST
NASA AIR QUALITY APPLIED SCIENCES TEAM

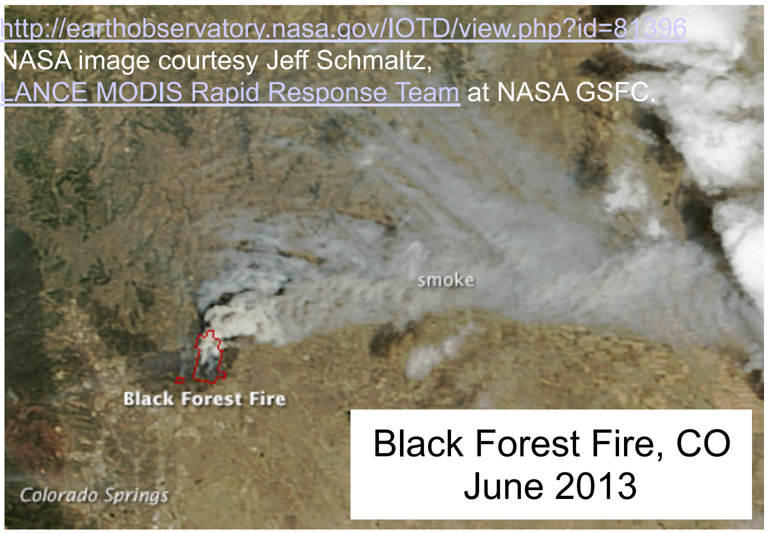
Some challenges for WUS O_3 air quality management



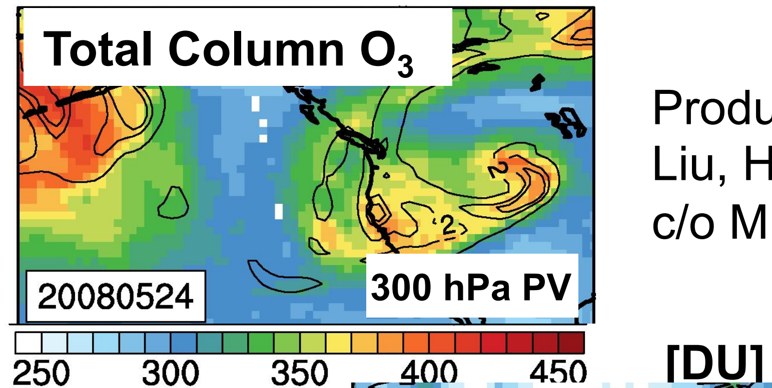
Need process-level understanding on daily to multi-decadal time scales

Satellite products indicate potential for contributions from transported "background"

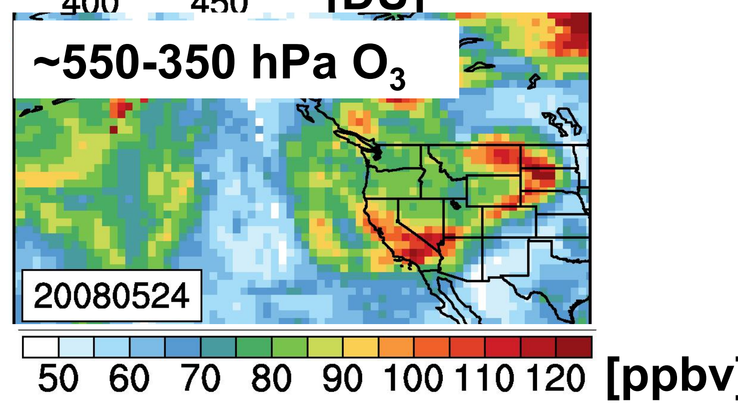
Fires: MODIS



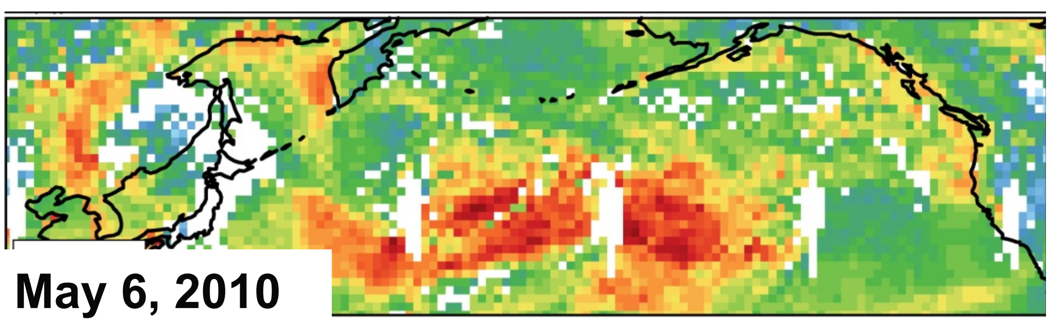
Stratospheric intrusions: OMI



Products from X. Liu, Harvard c/o M. Lin



Intercontinental transport: AIRS CO



(Lin et al., 2012a)

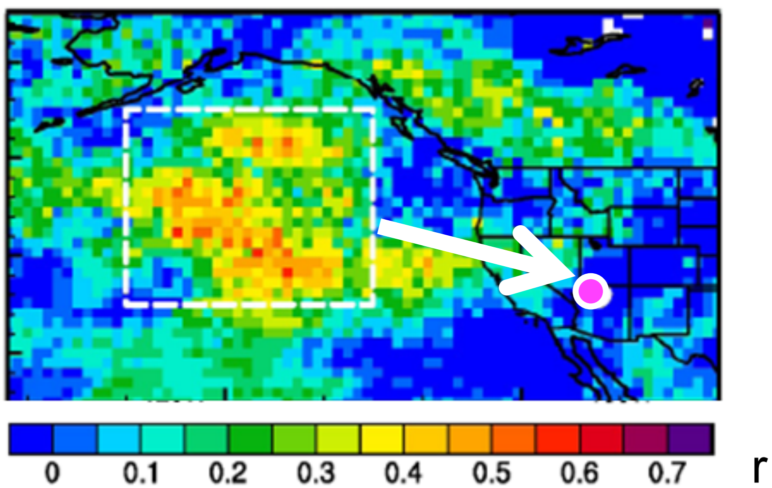
→ Identify exceptional events

→ Estimates of individual background components (with models)

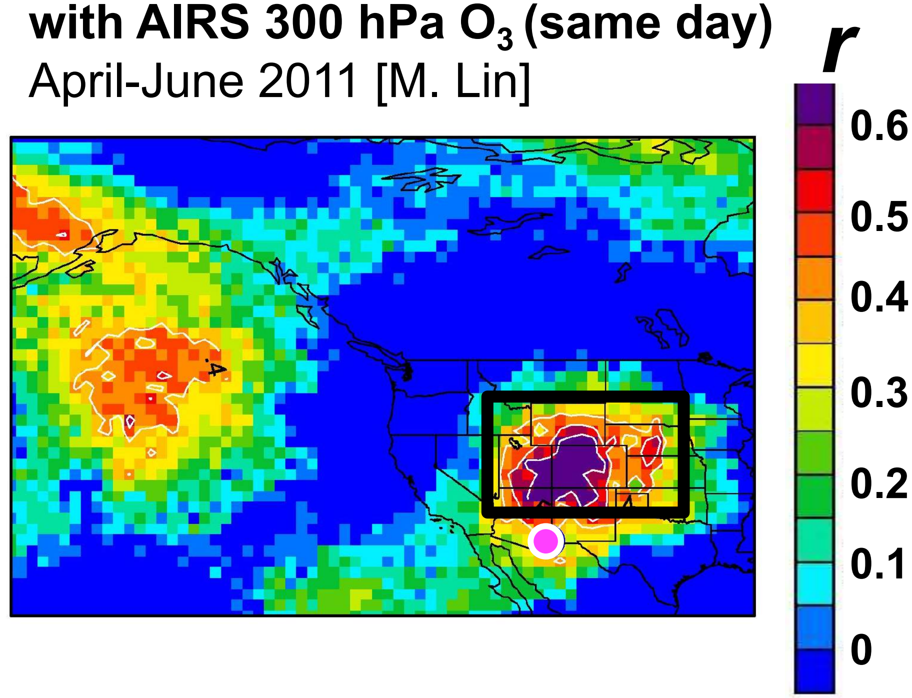
Developing space-based indicators of daily variability associated with Asian pollution and STT events

Correlation coefficients of AM3 daily Asian or Stratospheric O_3 sampled at a selected CASTNet site with AIRS products at each 1ºx1º grid

AM3 Asian O_3 at Grand Canyon NP with AIRS CO columns 2 days prior
May-June, 2010 [Lin et al., 2012a]



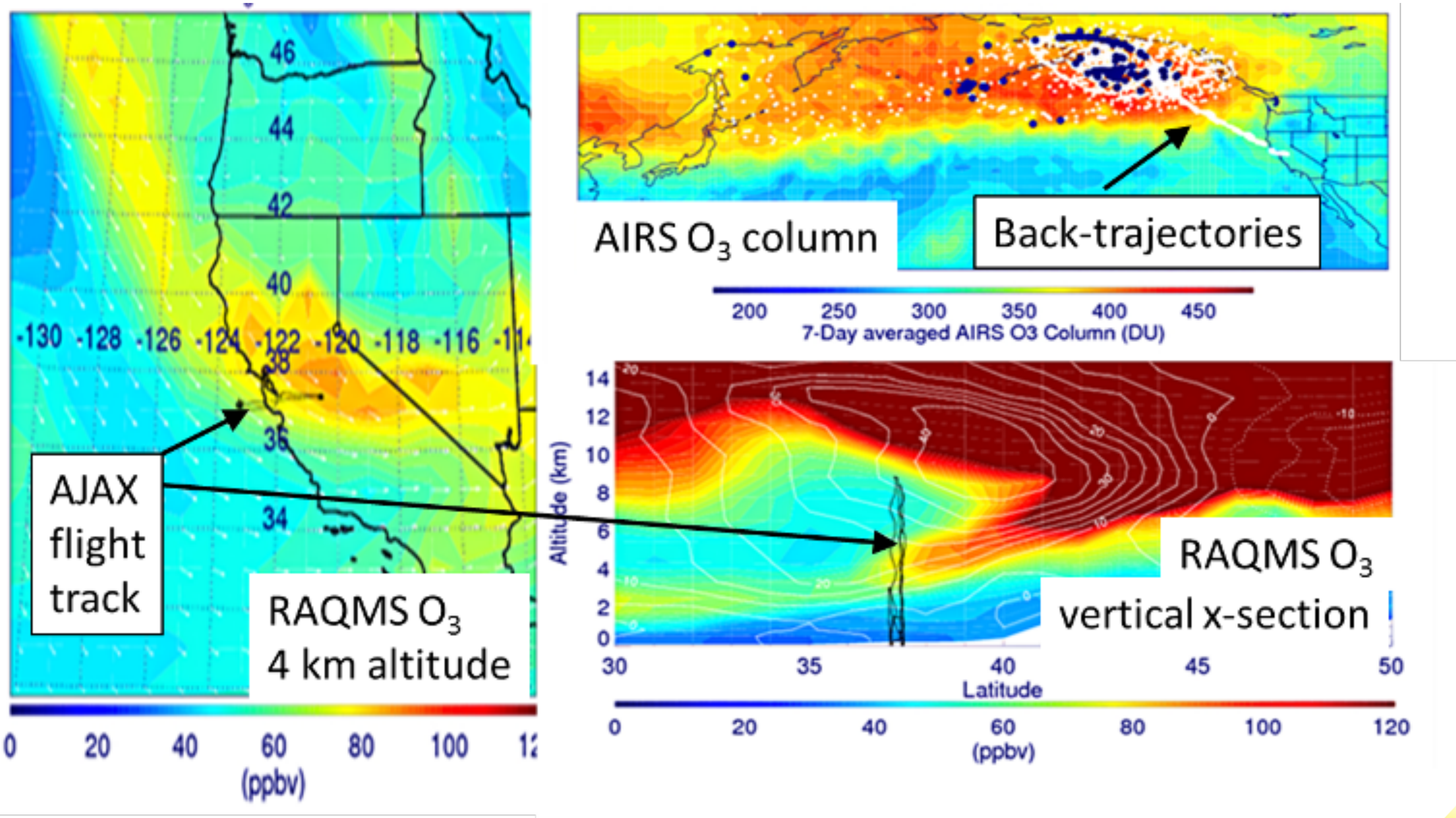
AM3 O3S at Chiricahua, NM with AIRS 300 hPa O_3 (same day)
April-June 2011 [M. Lin]



→ Site-specific "source" regions for characterizing exceptional events
→ Ongoing analysis to extend over decades
→ Advanced warning of Asian/STT impacts?
--e.g., trajectory-based tools from Brad Pierce and colleagues

AQAST Highlight: Wyoming Exceptional Event Demonstration

Wyoming DEQ/AQD used AQAST resources to issue an exceptional event demonstration package for an ozone exceedance at Thunder Basin, June 6, 2012



R.B. Pierce et al.

AQAST progress towards an OMI AQ management toolkit

1. Easily obtain useful data in familiar formats

Custom OMI NO_2 “Level 3” products on any grid in netCDF with WHIPS (*Holloway*)

Annual NO_2 shapefiles - OMI & CMAQ on CMAQ grids (*AQAST Tiger Team*)

Google Earth

2. Find easy-to-use guidance & example scripts for understanding OMI products and comparing to simulated troposphere & PBL concentrations

One-stop user portal (*Holloway & AQAST Tiger Team*)

OMI NO_2 & SO_2 guidance, field campaign example case studies (*Spak* & *AQAST Tiger Team*)

3. Obtain OMI observational operators for assimilation & emissions inversion in CMAQ

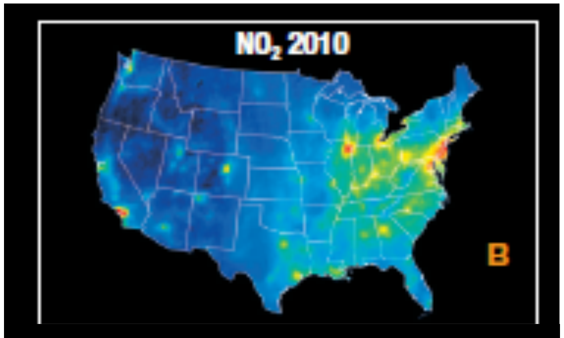
•NO_2 in GEOS-Chem ➔ CMAQ (*Henze*, Pye)

•SO_2 in STEM ➔ CMAQ (*Spak*, Kim)

•O_3 in STEM ➔ CMAQ (Huang, *Carmichael*, Kim)

AQAST PIs: Carmichael, Spak

Communications and outreach

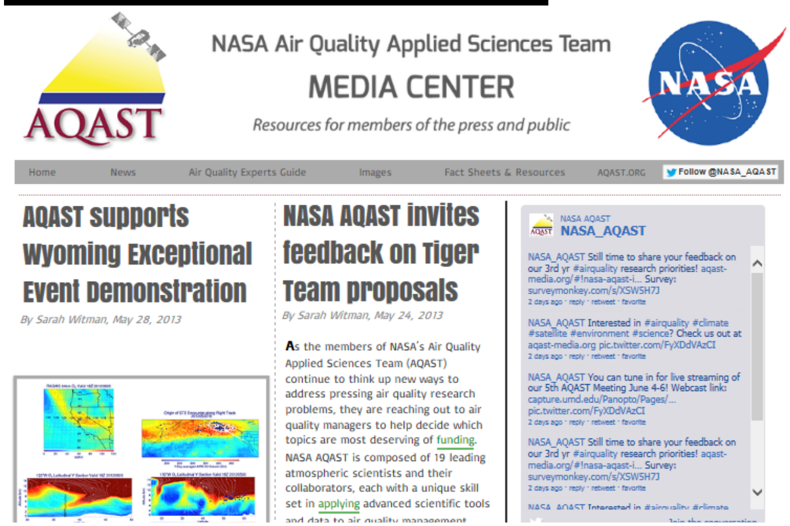


NO_2 trends lenticular

PI: Duncan

St. Louis ozone garden

PI: Fishman



Tiger Team activity: Key factors contributing to differences in model estimates for O_3 "background"

<u>Problem</u>: Poorly quantified errors in background distributions complicate NAAQS-setting and interpreting SIP attainment simulations

To date, EPA N. American Background estimates provided by one model.

<u>Approach</u>:

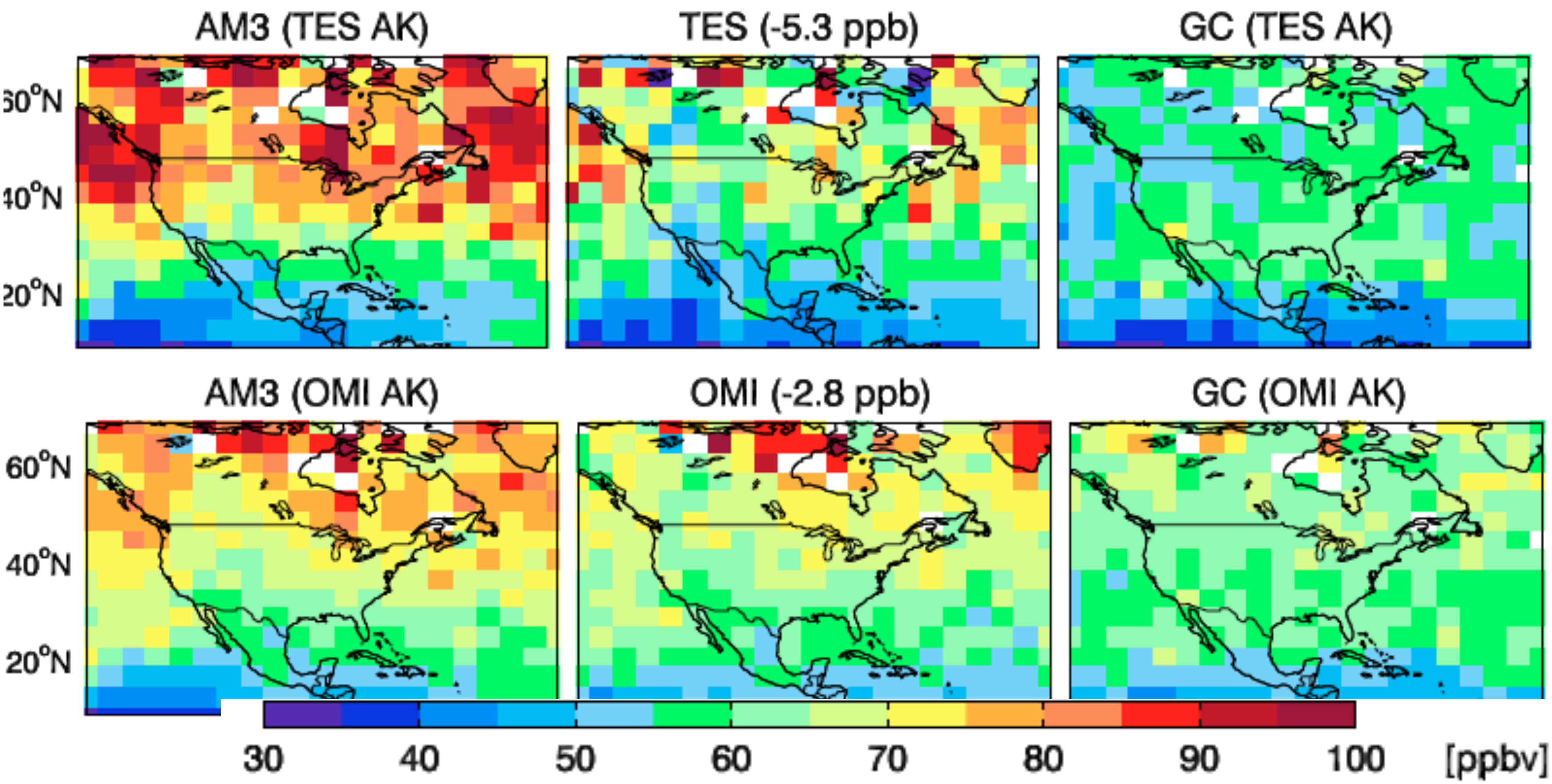
1) Compare GFDL AM3 and GEOS-Chem NAB (Mar-Aug 2006)
2) Process-oriented analysis of factors contributing to model differences

YEAR 2006	GEOS-Chem	GFDL AM3
Resolution	½°x⅔° (and 2°x2.5°)	~2°x2°
Meteorology	Offline (GEOS-5)	Coupled, nudged to NCEP U and V
Strat. O_3 & STE	Parameterized (Linoz)	Full strat. chem & dynamics
Isoprene nitrate chemistry	18% yield … recycling	… NO_x recycling (obs … al, 2007)
Lightning NO_x	tied to mo… clouds, sc… climat; higher NO_x at N. mid-lat	…ective clouds
Emissions	NEI 2005 + 2006 fires (emitted at surface)	ACCMIP historical + RCP4.5 (2005, 2010); vert. dist. climatological fires

ALL DIFFERENT!

Constraints on springtime background O_3 from mid-tropospheric satellite (OMI, TES) products (2006)

Bias vs sondes subtracted from retrievals as in Zhang et al., ACP, 2010

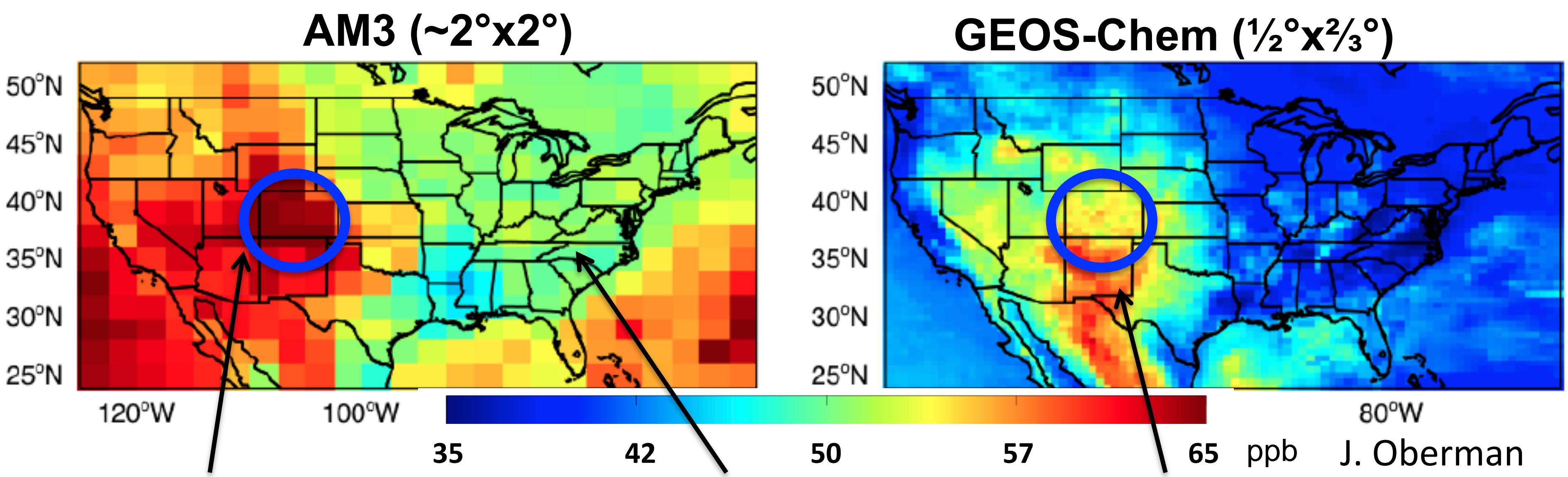


L. Zhang, Harvard

→AM3 generally high; GEOS-Chem low
→Implies that the models bracket the true background
→Probe role of specific processes

Estimates of North American background in 2 models
(simulations with N. American anth. emissions set to zero)

Fourth-highest North American background MDA8 O_3
in model surface layer between Mar 1 and Aug 31, 2006



Higher background:
More exchange with surface?
Larger stratospheric influence?

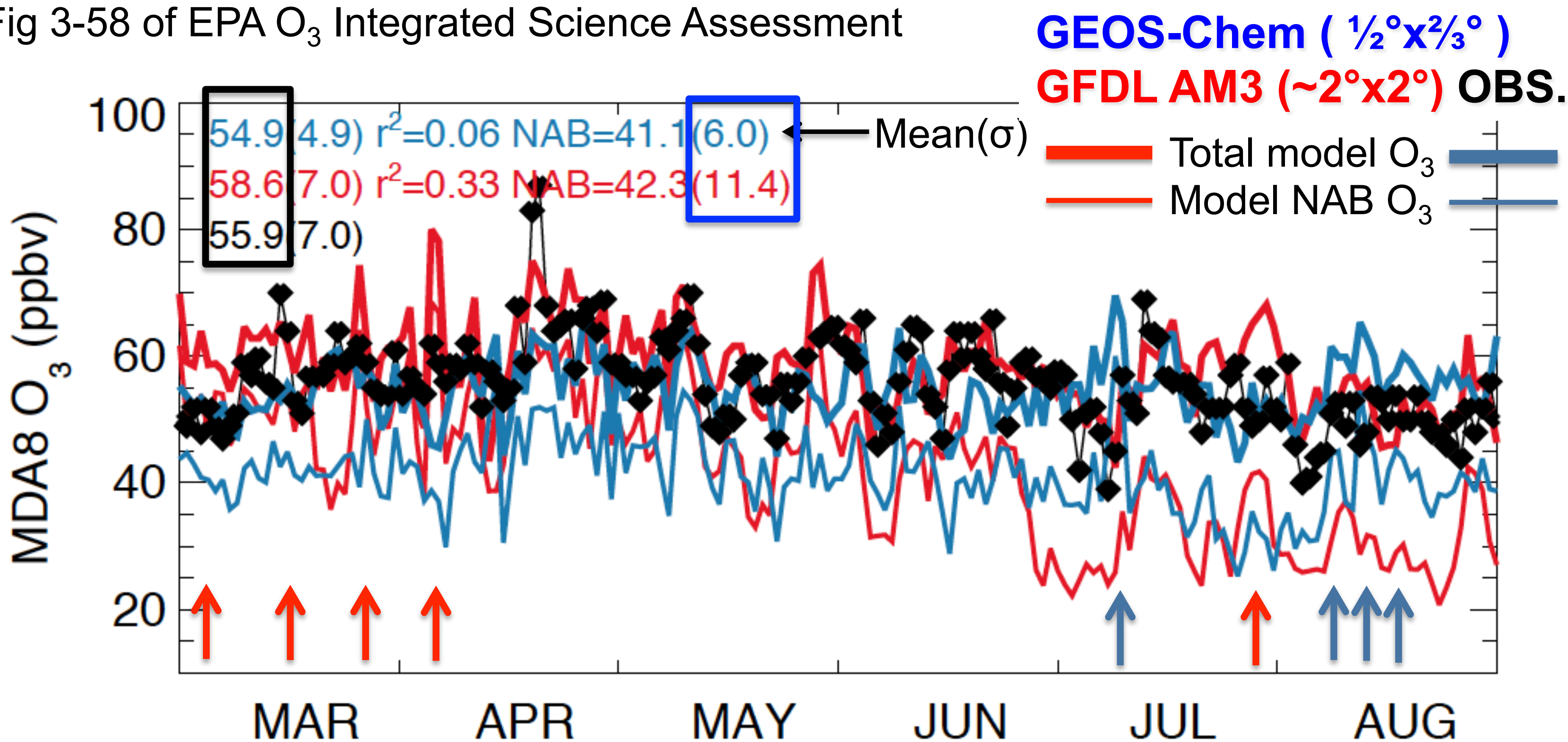
High AM3 bias in EUS; caution on N. Amer. Background here!

Excessive lightning NO_x in summer

→ Models robustly agree N. American background is higher at altitude in WUS
→ Multi-model enables error estimates, in context of observational constraints

Models differ in day-to-day and seasonal variability of North American background: Gothic, CO (107W, 39N, 2.9 km)

Fig 3-58 of EPA O_3 Integrated Science Assessment



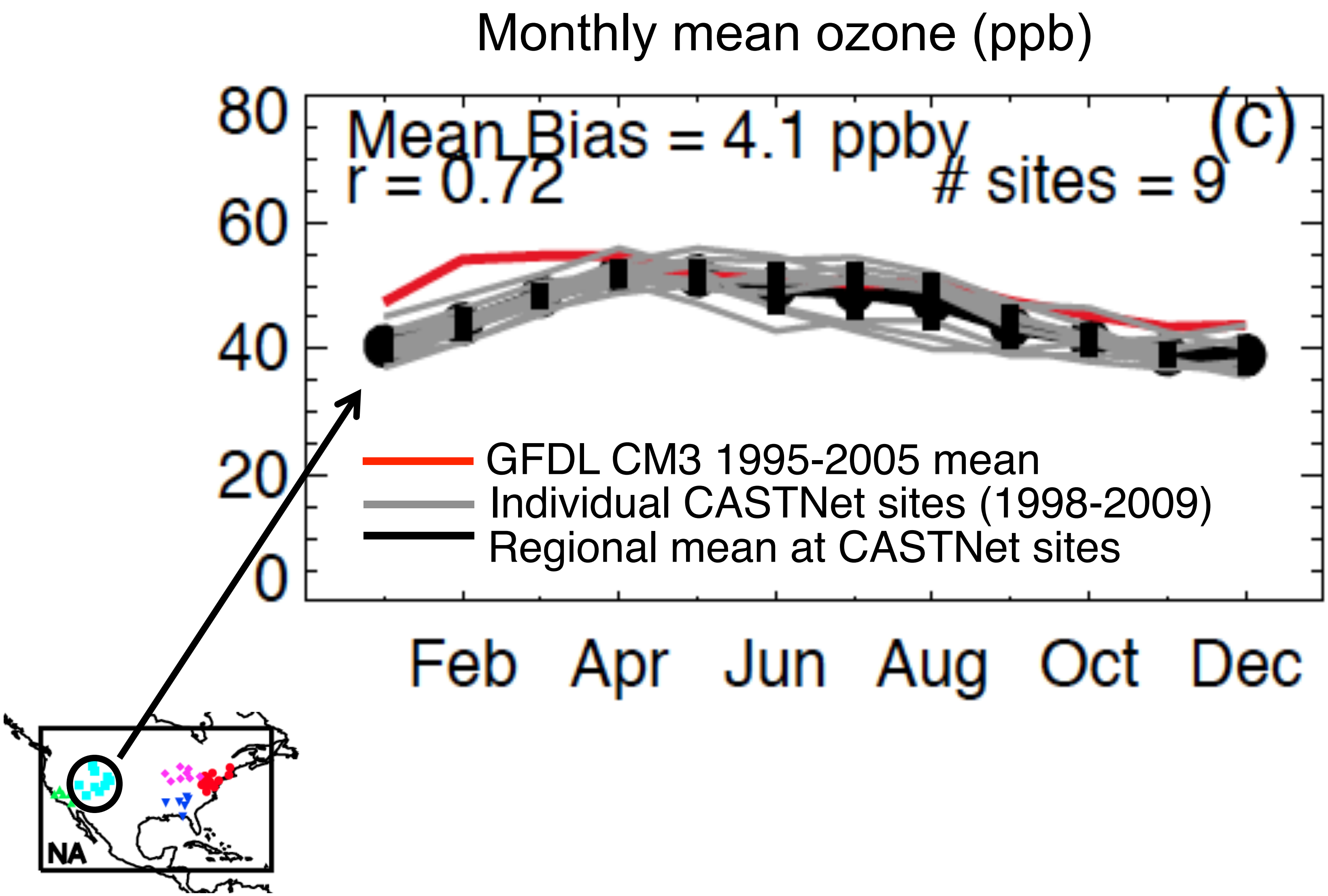
→ Models bracket OBS; similar mean N. American background (NAB)

→ GC NAB variability (σ) ~2x smaller than in AM3

→ AM3 NAB > GC NAB in MAM; reverses in JJA (lightning)

→ Impact of model biases on 4th highest NAB (AM3 in March; GC in August)

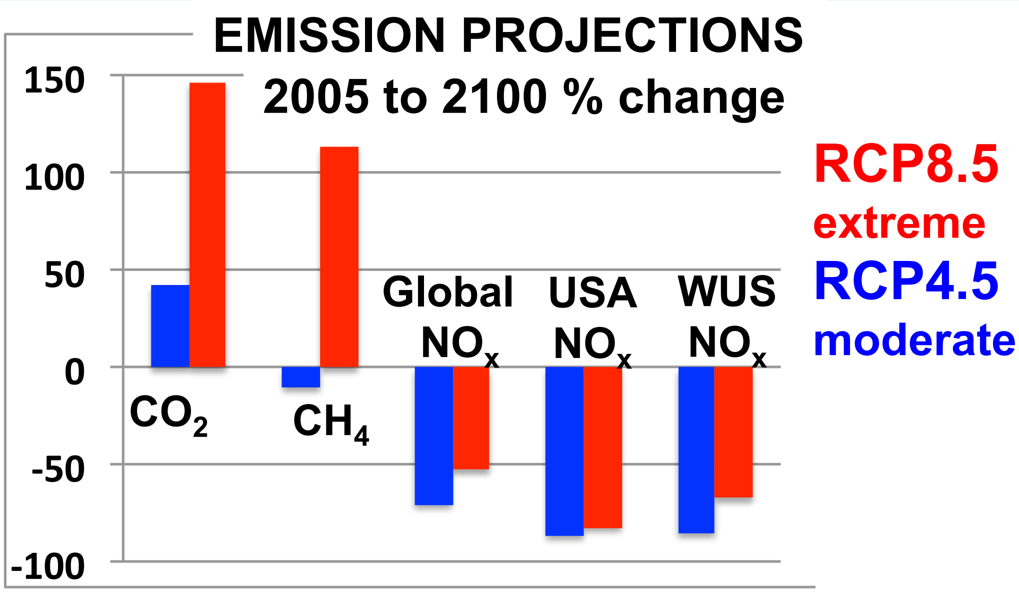
GFDL CM3 chemistry-climate model roughly captures decadal mean seasonal cycle over the Mountainous West

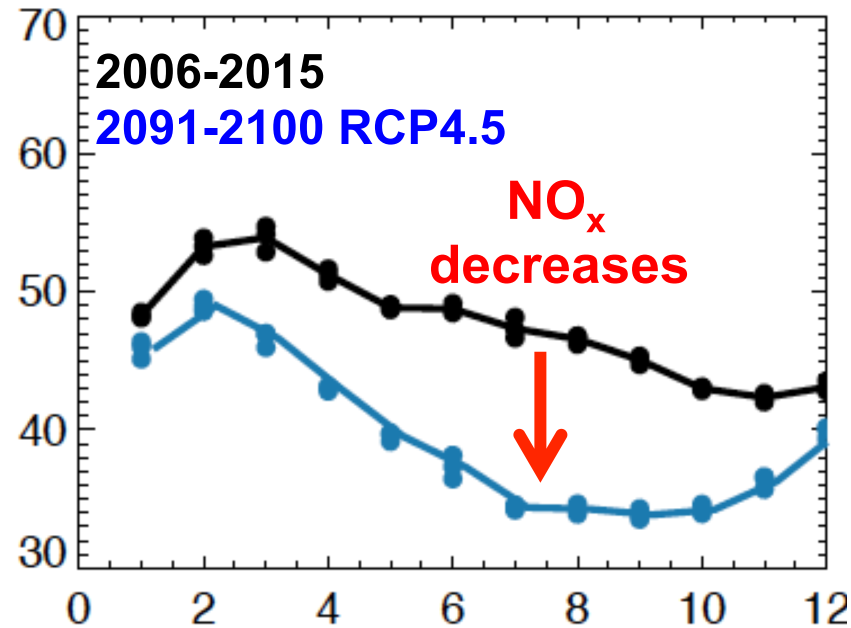


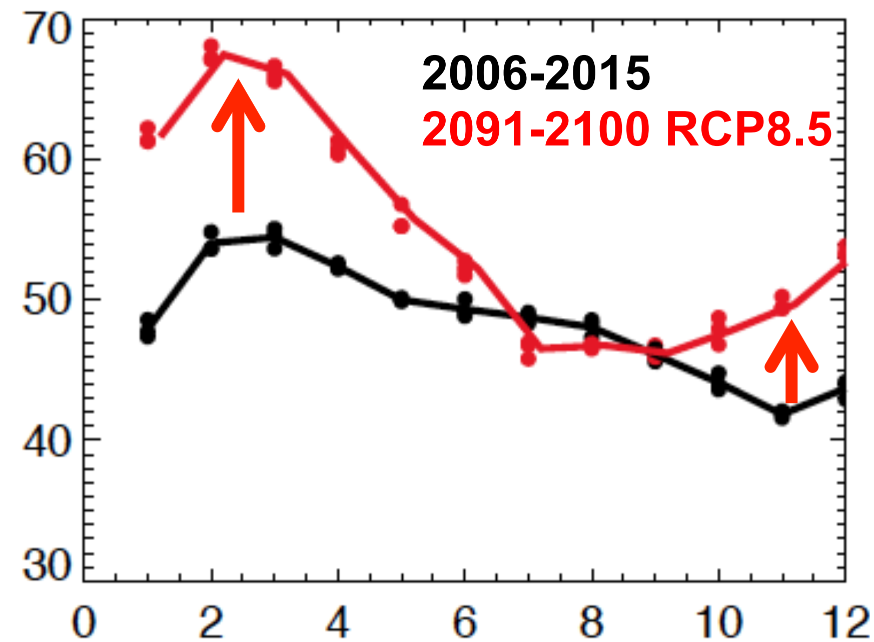
O. Clifton

Mtn. West (36-46N, 105-115W) surface O_3 21st C Projections

Transient simulations (climate + emissions) with GFDL CM3 model







→ NO_x reductions decrease O_3 in all months under RCP4.5

→ Higher O_3 in RCP8.5 in cooler months despite NO_x decreases

WHY?

O. Clifton

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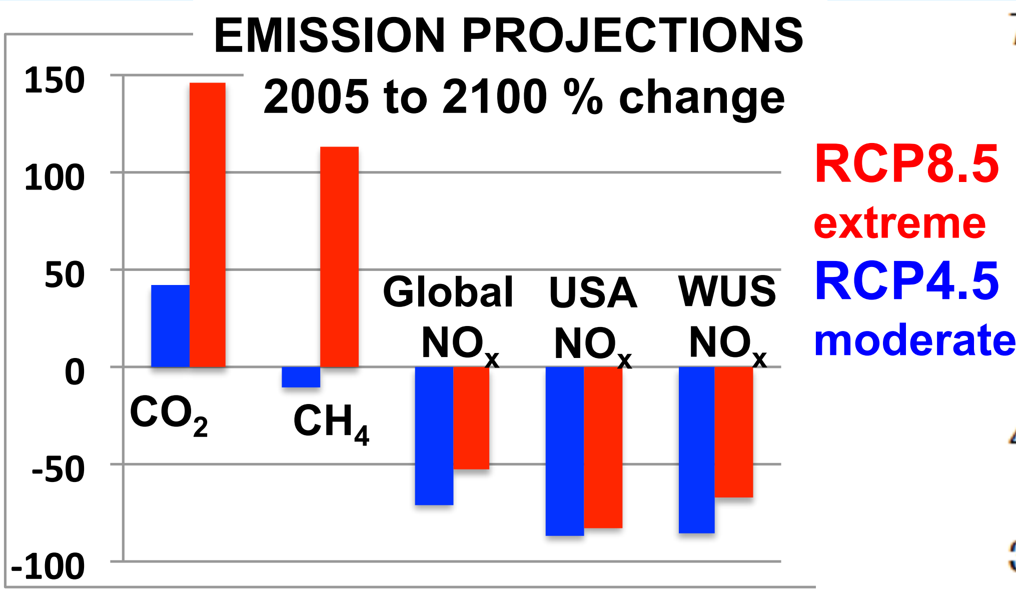
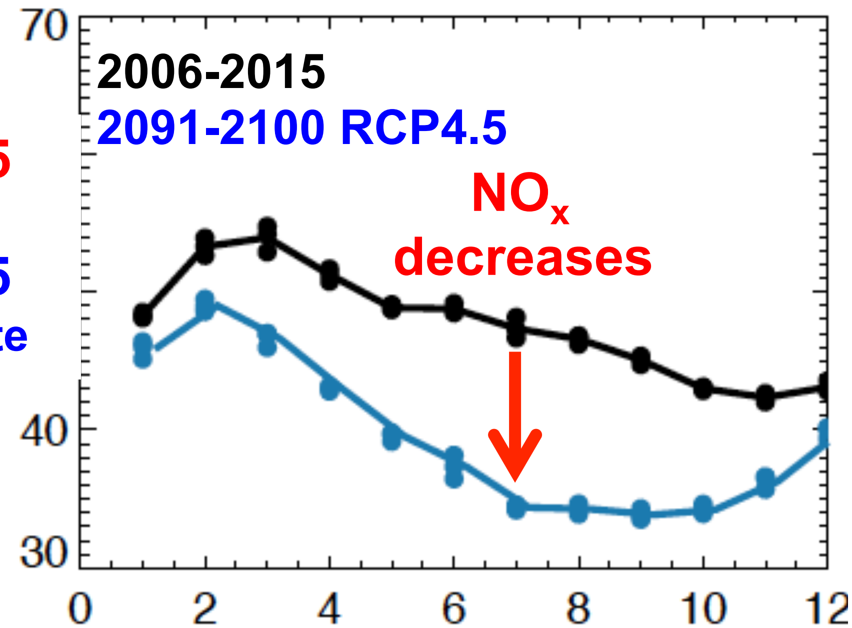
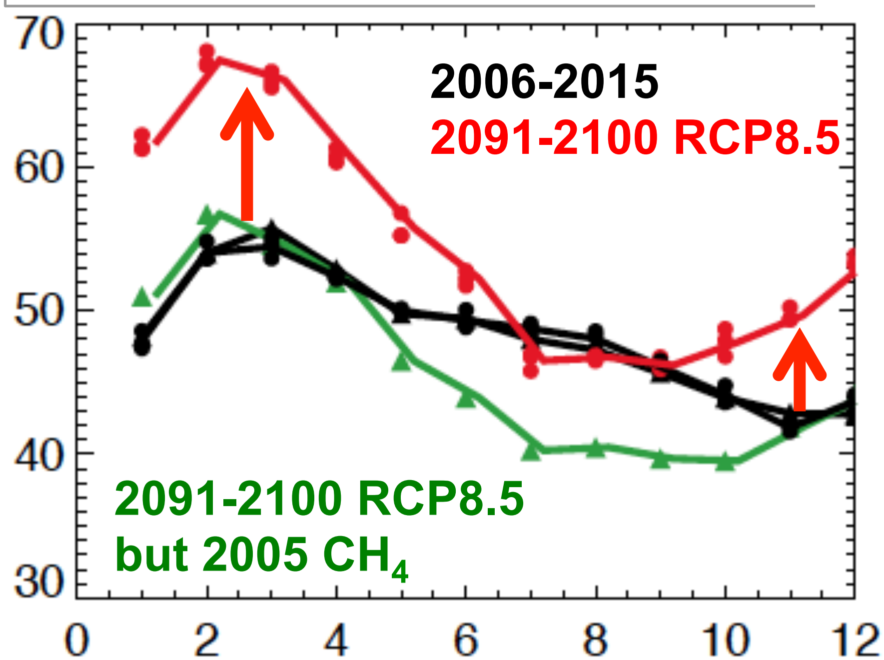
Transient simulations (climate + emissions) with GFDL CM3 model



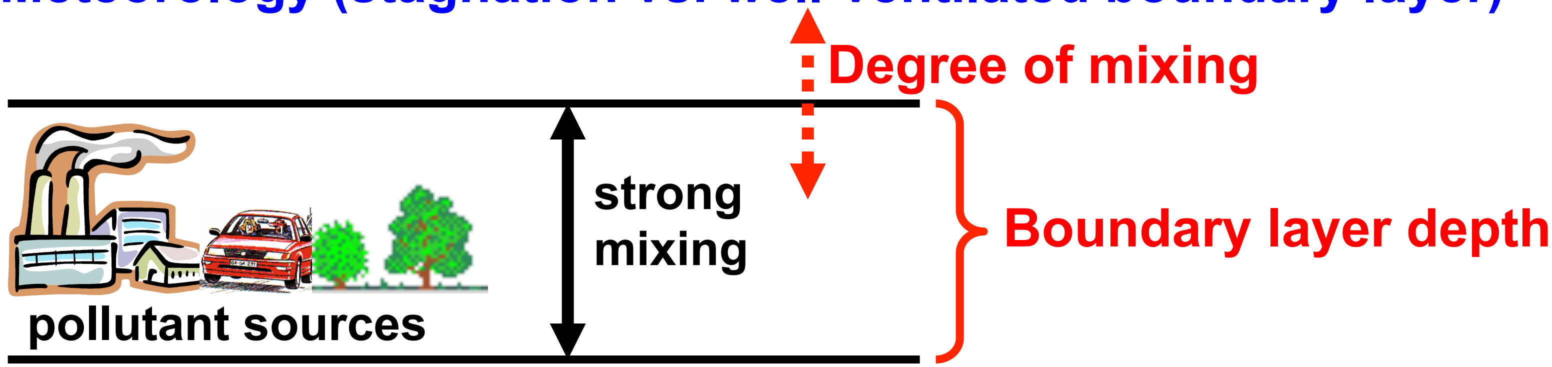




- → NO_x reductions decrease O_3 in all months under RCP4.5
- → Higher O_3 in RCP8.5 in cooler months despite NO_x decreases
- → More-than-doubling of global CH_4 offsets NO_x-driven decreases
- → Shifting balance of regional-vs-global sources

How does climate affect air quality?

(1) Meteorology (stagnation vs. well-ventilated boundary layer)



(2) Feedbacks from Emissions, Deposition, Chemistry

Not included in results on previous slide

CONSIDERATIONS FOR FUTURE SCENARIOS

→ Land-use change influences emissions from the biosphere

- Driving datasets for biogenic VOC, NO_x, CH_4, fires, deposition?

→ Regional climate responses not robust across modeling systems

- Not just climate change: how does climate variability influence air pollution?

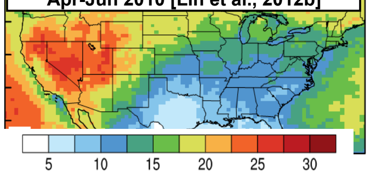
Insights into processes affecting Western U.S. Air Quality from integrated analyses (models, satellite, *in situ* data)

NASA Air Quality Applied Science Team: www.aqast.org

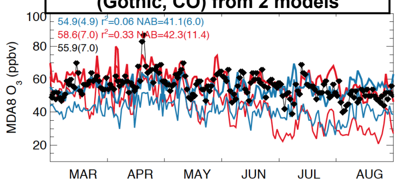
Earth Science Resources → AQ management needs

AQAST members want to hear from you!

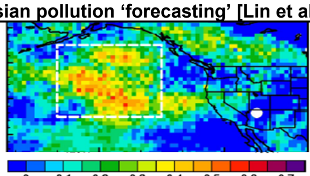
AM3 model stratospheric O3 (ppb): Apr-Jun 2010 [Lin et al., 2012b]



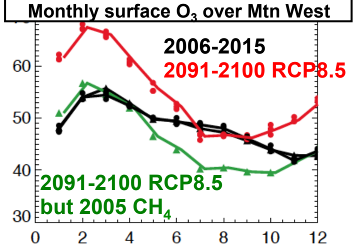
Estimates of N Amer. Background (Gothic, CO) from 2 models



Asian pollution 'forecasting' [Lin et al., 2012a]



Monthly surface O_3 over Mtn West



Addressing WUS background O_3:

-- quantifying components: Asian, strat, fires

-- harness strengths of multiple models + obs.

- error characterization for AQ metrics (MDA8, W126)
- contribute to SIP modeling (BCs, input datasets)

-- developing tools for exceptional event analysis

- simple correlations to chemical data assimilation

-- impacts from global change in 21st C

- shifting balance of local vs. transported O_3 (methane)

-- climate change, variability and predictability

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