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Estimating background ozone, and its specific components, over the western United States to support NAAQS-setting, implementation, and attainment planning

Meiyun Lin

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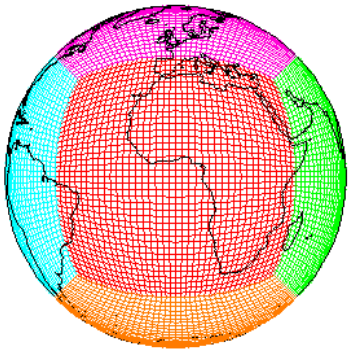
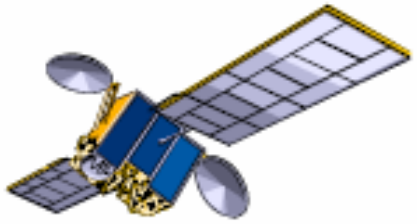
Project collaborators: **Owen Cooper** and **Samuel Oltmans** (NOAA ESRL), **Hiram Levy II** and **Vaishali Naik** (NOAA GFDL)



GFDL AM3



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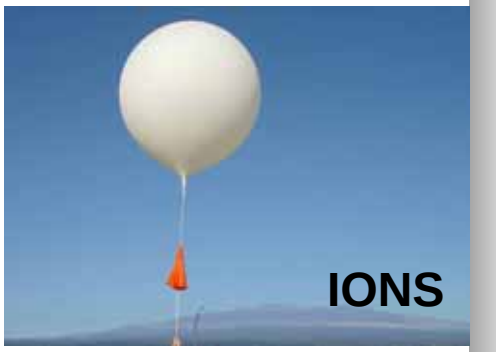

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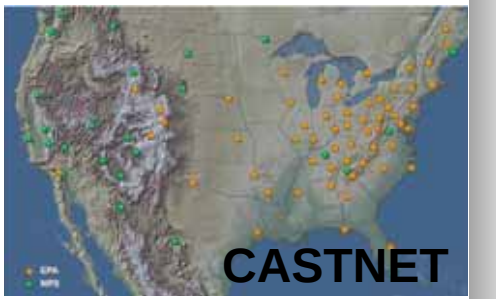


CASTNET

Understanding variability and long-term changes of North American background O_3 (NAB)

- Improve process understanding of regional variability in NAB on multiple spatial (25 to 200 km horizontal) scales

→ **Global high-res (~50km) simulation during CalNex 2010**

- Scope potential for space-based daily-to-yearly indicators for specific components of NAB, including

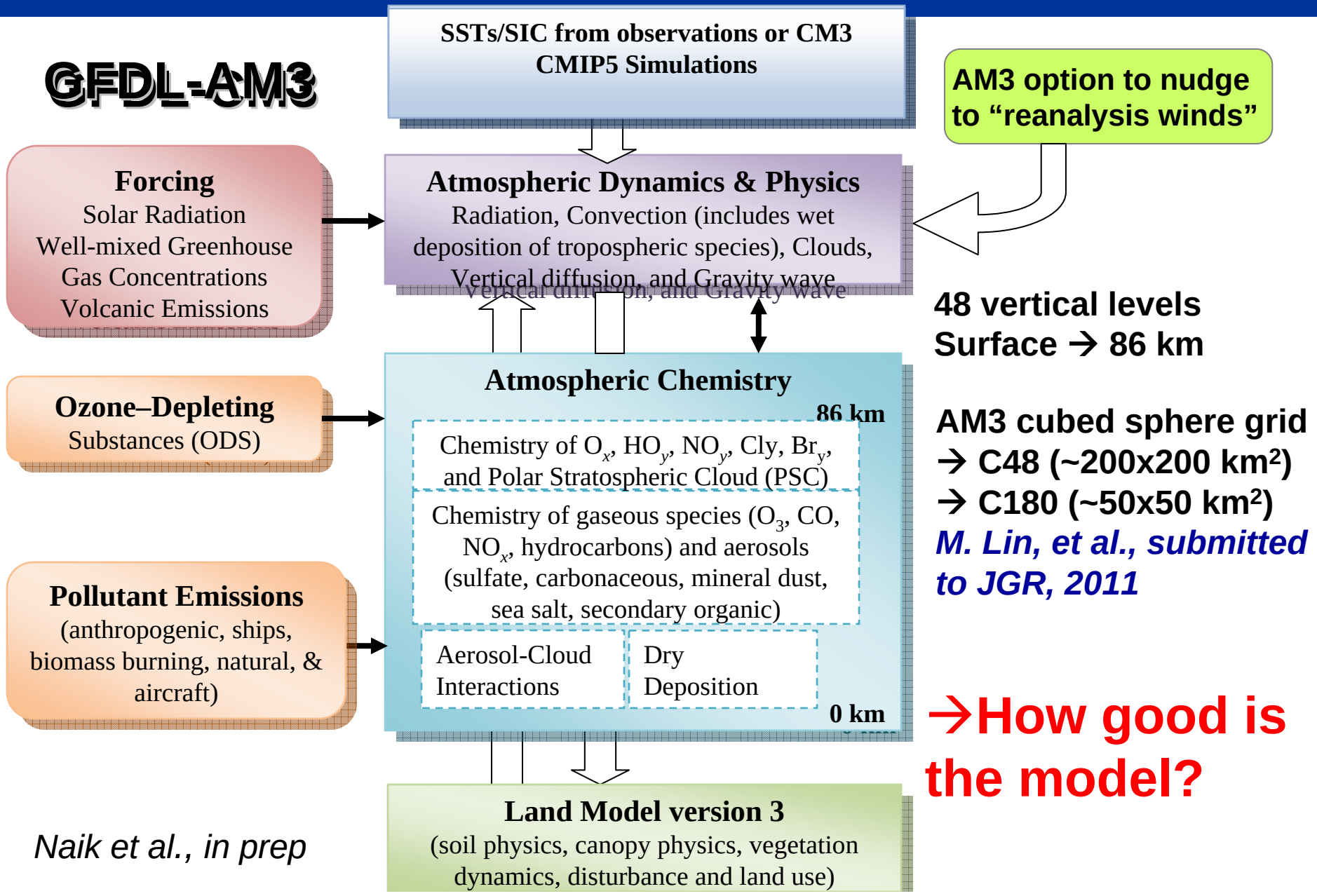
Stratospheric intrusions: AIRS, MLS, OMI/MLS, TOMS, OMPS?
Intercontinental transport: **AIRS**, OMI/MLS
Fires: AIRS, MOPITT, OMI
Natural emissions: OMI

- Investigate how NAB (+components) responds to climate variability, long-term changes and evolving global precursor emissions

→ **Historical AM3 simulations with "real winds" (1970-2010)**
→ **Climate-mode CM3/AM3 simulations (1860-2100):**
Historical + IPCC/AR5 RCPs

The new GFDL CM3/AM3 chemistry-climate model

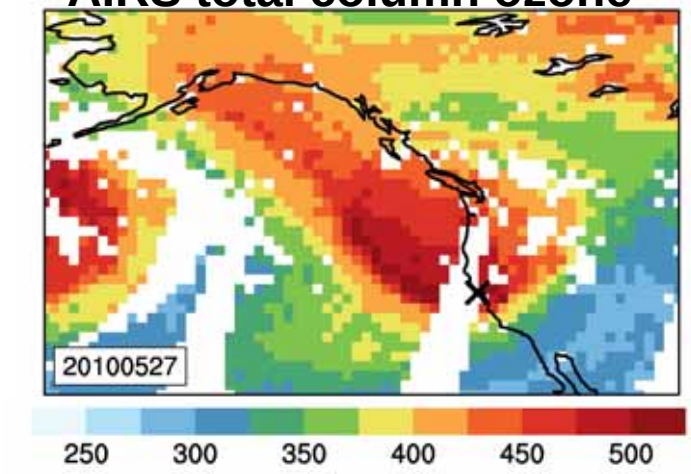
Donner et al., Golaz et al., Griffies et al., J. Climate, 2011



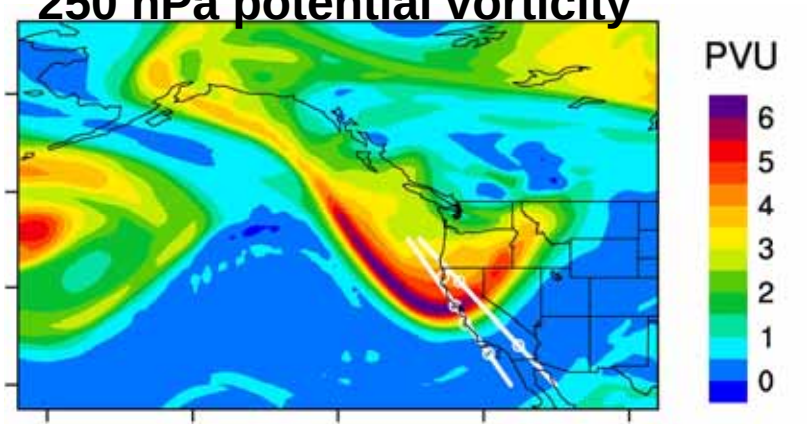
Diagnosing stratospheric ozone intrusions: Verify dynamical consistencies in independent datasets

Satellite observations | **May 27, 2010** | **AM3/C180 simulations**

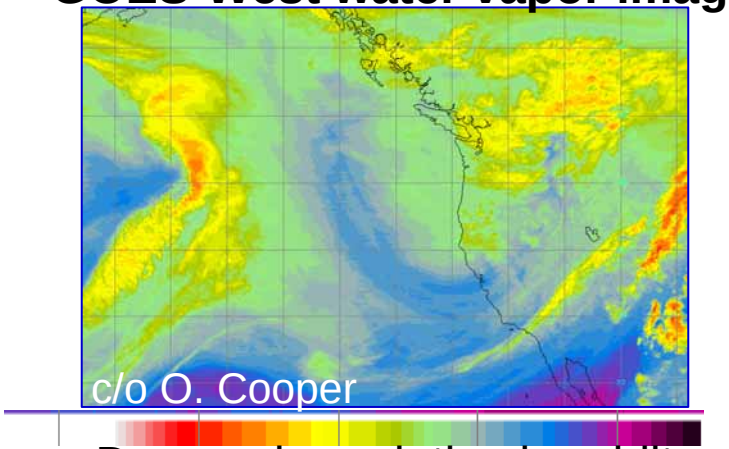
AIRS total column ozone



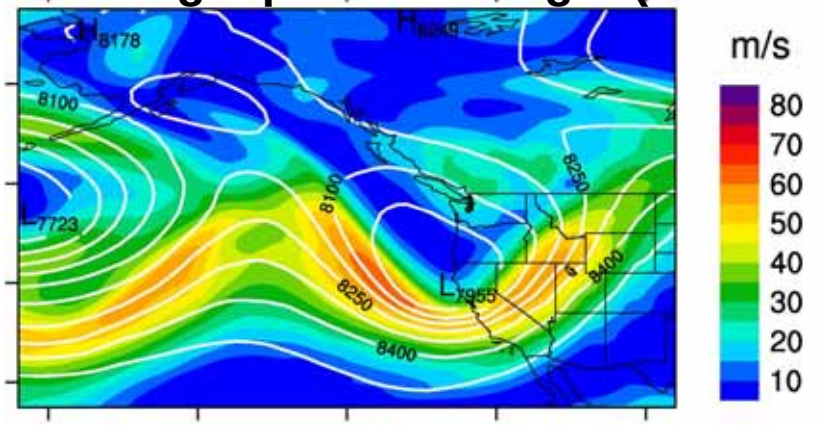
250 hPa potential vorticity



GOES-West water vapor image



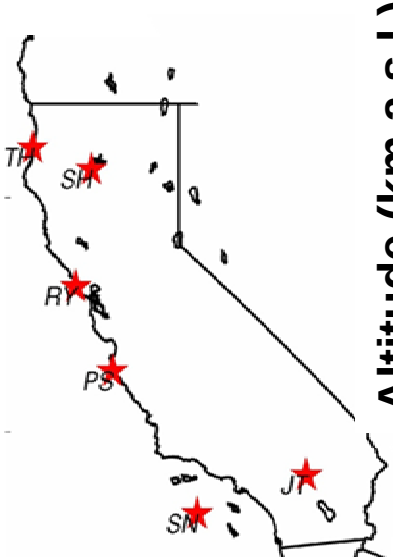
250 hPa jet (color)
350 hPa geopotential height (contour)



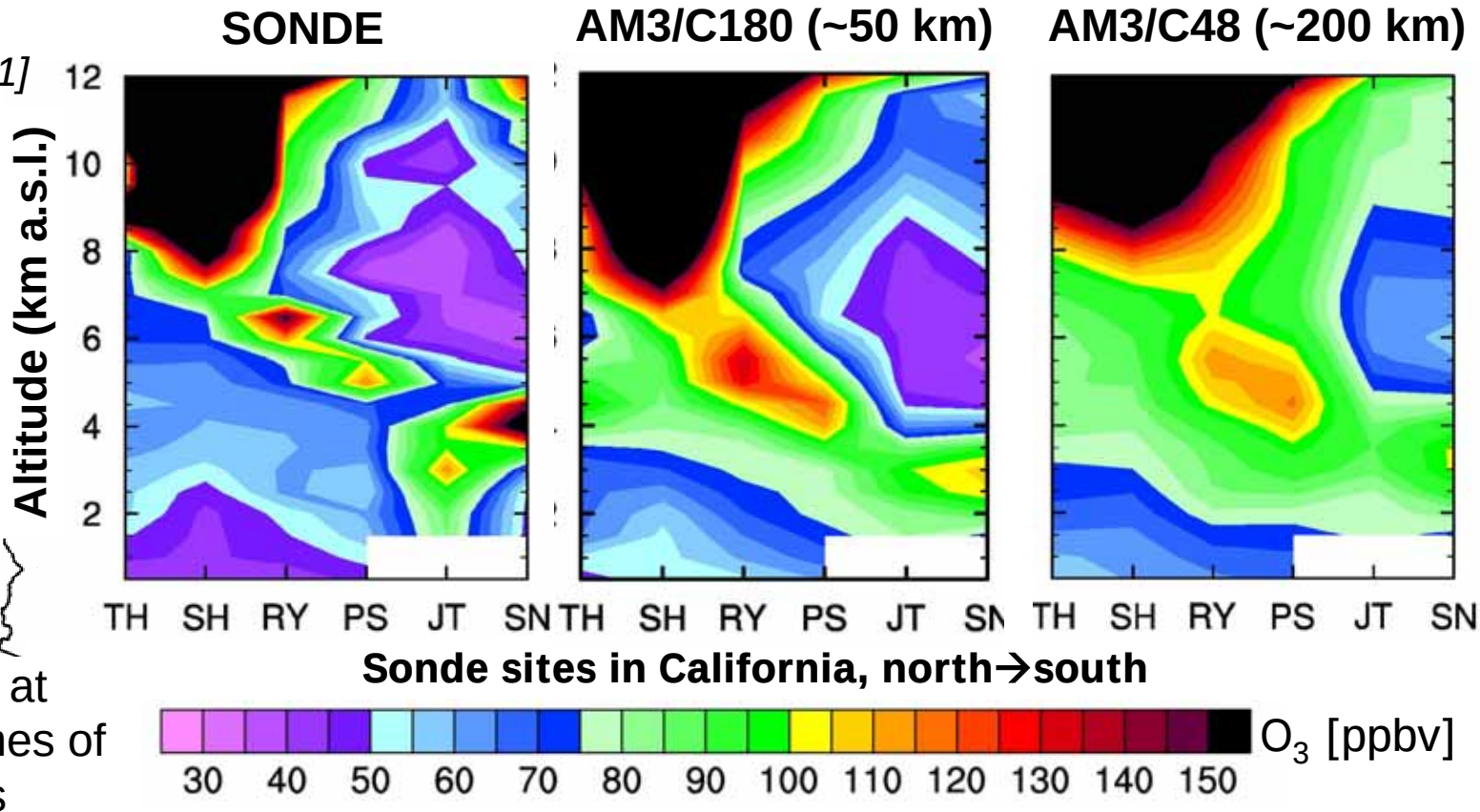
→ Only deep (<3 km a.s.l.) intrusions are likely to influence surface O_3

Subsidence of stratospheric ozone to the lower troposphere of southern California (May 28, 2010)

Sonde data c/o Cooper et al. [2011]



model sampled at location and times of sonde launches



- **High O_3 mixing ratios (90-150 ppbv) just 2-4 km above populated LA**
- **AM3/C180 better captures vertical structure**
- **AM3/C48 reproduces the large-scale view**

M. Lin et al., in prep.

Trans-Pacific transport of Asian pollution plumes to WUS often coincides with ozone injected from stratosphere

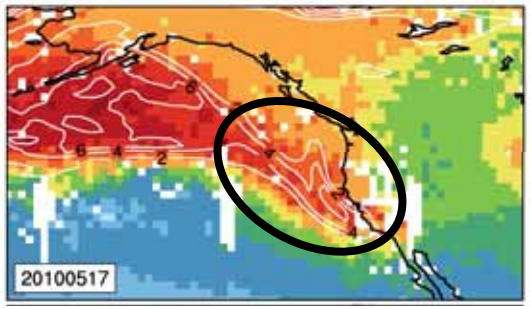
AIRS total O_3 columns

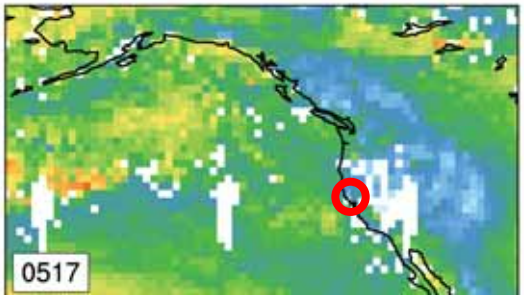
Contours: 300hPa PV

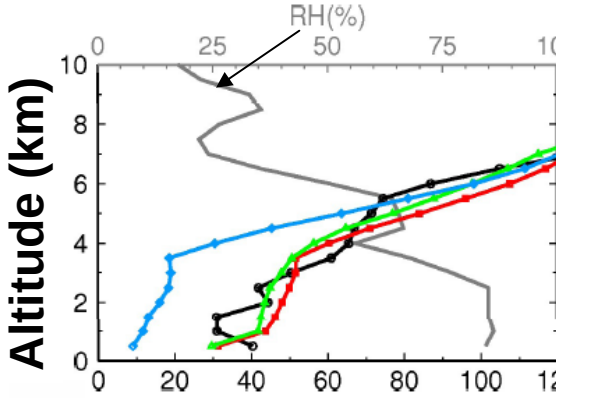
AIRS CO columns

Point Reyes Sonde, CA

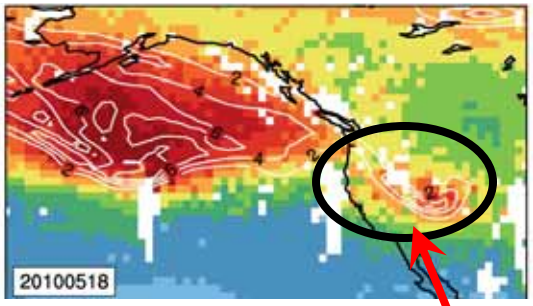
May 17

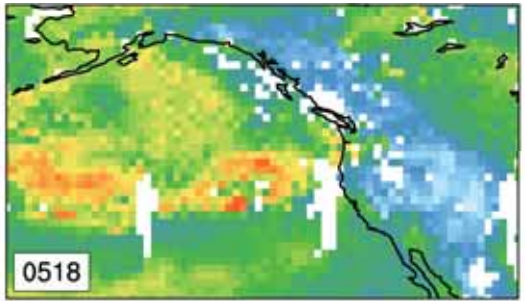


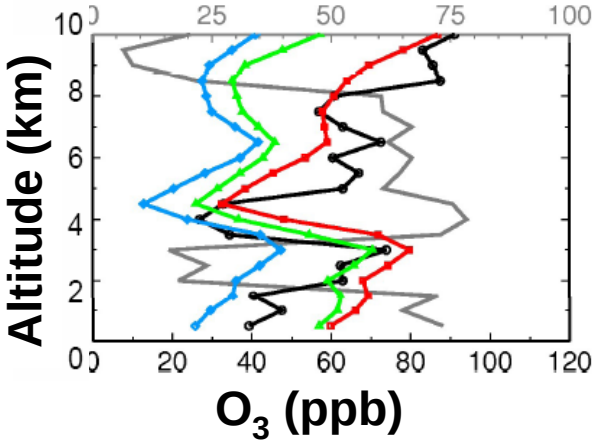




May 18







[Dobson Unit]

250 300 350 400 450 500

[10^{18} molecules cm^{-2}]

1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2

Advanced warning of stratospheric impacts on surface O_3?

→ **Imply satellite-based O_3/CO correlations should be interpreted with caution**

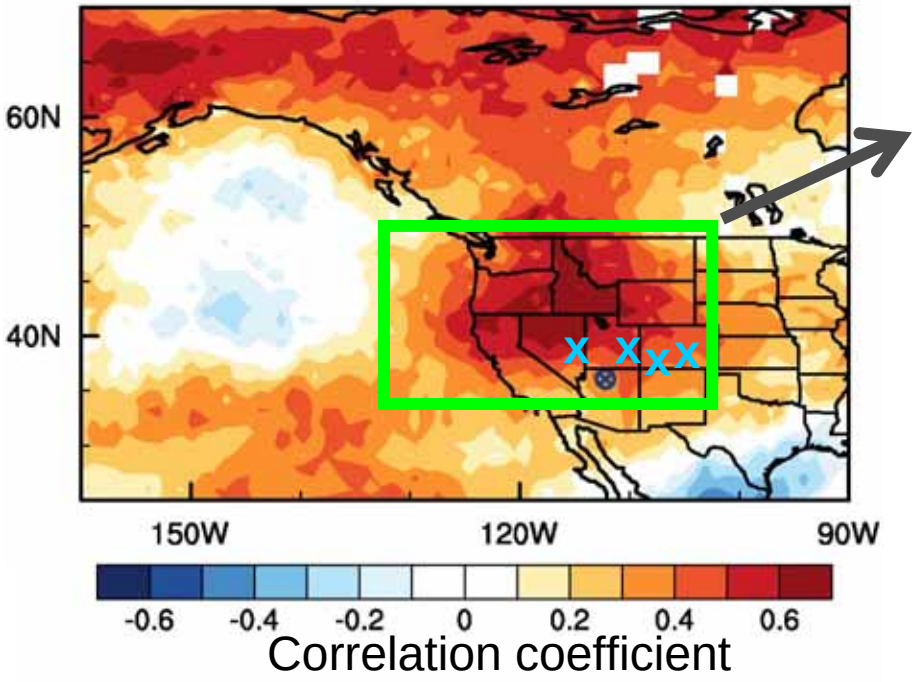
O_3/CO ↑ ✗→ Anthrop. Influence on O_3

OBS	**AM3**
zeroEA	**O_3-strat**

M. Lin et al., submitted to JGR

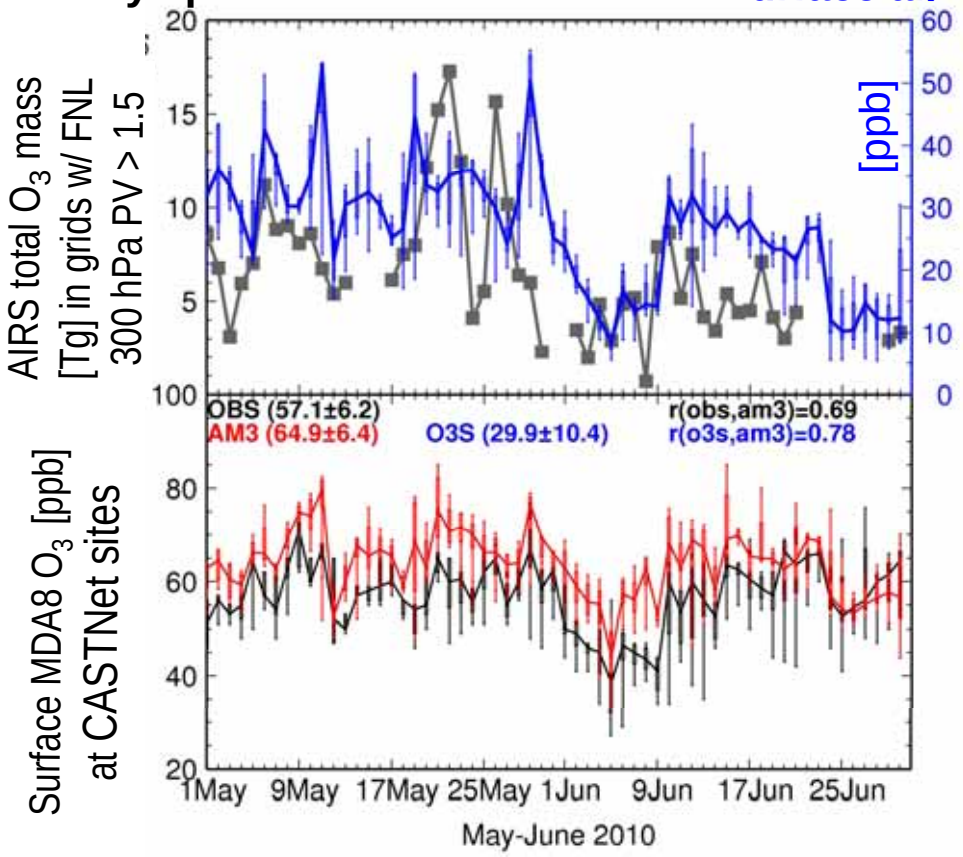
Potential for developing space-based "indicators" for day-to-day variability in *stratospheric influence* on surface O_3?

Correlation of strat. enhancement at Grand Canyon NP in AM3 with AIRS total O_3 on the previous day



AIRS peaked 1-2 days prior

O_3-strat in surface air



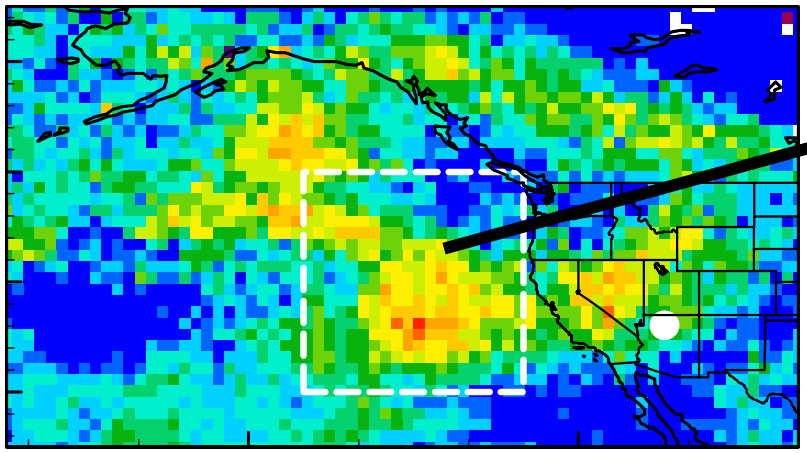
Potential AQ applications:

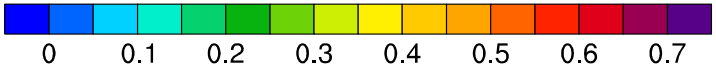
1) **Early warning indicator**
2) **Screening of exceptional events**

- **AM3 has positive surface O_3 bias, but**
- **Reproduces the variability, suggesting stratospheric intrusions are the key driver**

Potential for developing space-based "indicators" for day-to-day variability in Asian influence at WUS sites?

Correlation of strat. enhancement at Grand Canyon NP in AM3 with AIRS CO observations on the previous day

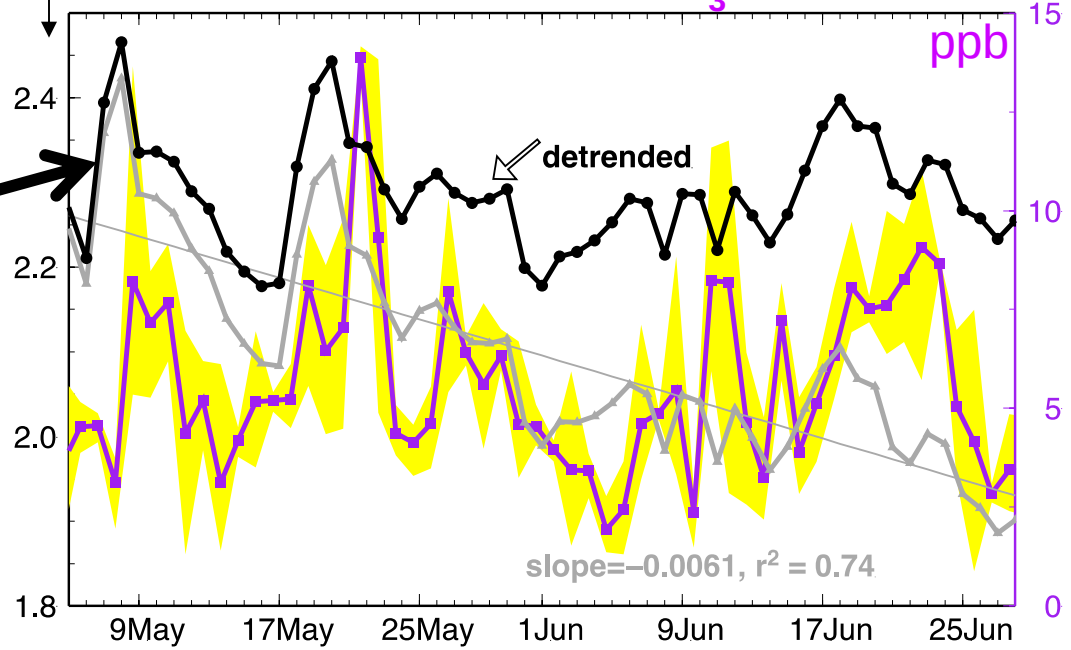




Correlation coefficient

AIRS CO (10^{18} molec cm^{-2}) averaged over NE Pacific

AM3 Asian O_3 at 3 WUS sites



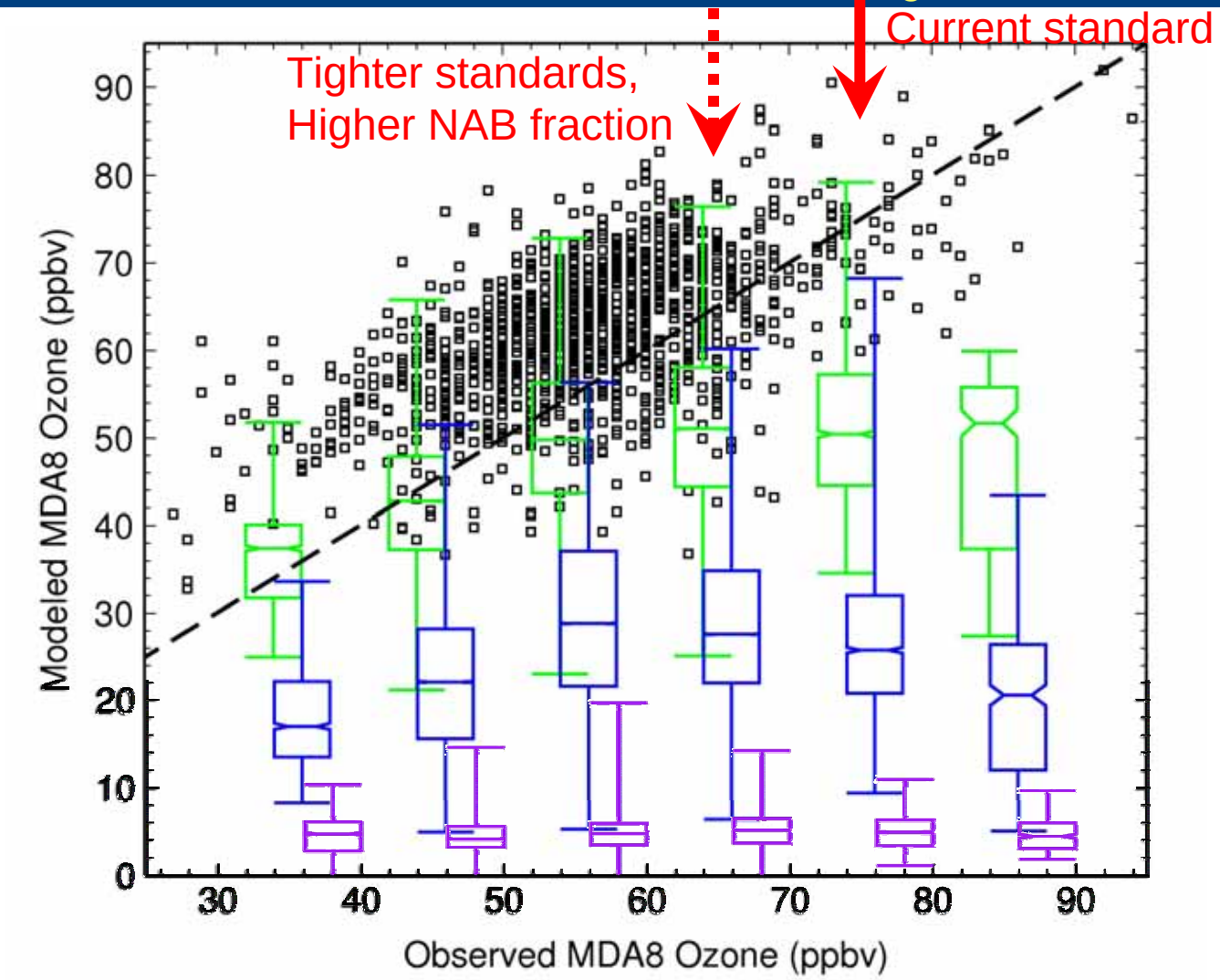
May–June 2010

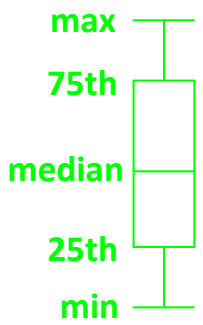
For details, please see M. Lin et al., submitted to JGR

→ **Qualitatively promising… but short data set**

→ **Need further test for a quantitative relationship and extending to other years?**

Summarizing results for the U.S. Mountain West (Apr-Jun 2010): Model NAB statistics vs. observed O_3 at 14 CASTNet sites





NAB distribution binned by observed values (every 10 ppb)

O_3-Strat (*upper limit*)

O_3-Asian

- **AM3 model captures some observed high-O_3 events (>70ppb)**
- **NAB (including stratospheric and Asian components) is largest in the 50-80 ppb range of observed total O_3 →May confound attaining tighter standards**

Discussion and ongoing work

- **Stratospheric and Asian components enhance U.S. "background" levels, contributing to high-O_3 events in the Western U.S. (high-altitude) in spring and early summer**

  → Implications for attaining more stringent standards

  → Insights from integrated analysis of several obs platforms w/ models

  → Consistent view from ~200x200 km^2 vs ~50x50 km^2 (spatially refined)

- **Utility of satellite observed total O_3 and CO column to diagnose these exceptional events (appreciate feedback)**

  → Extending to other years and regions (e.g., eastern US, SEMAQS…)

  → Further test w/ IONS 2004, IONS 2006, DISCOVER AQ (collaboration?)

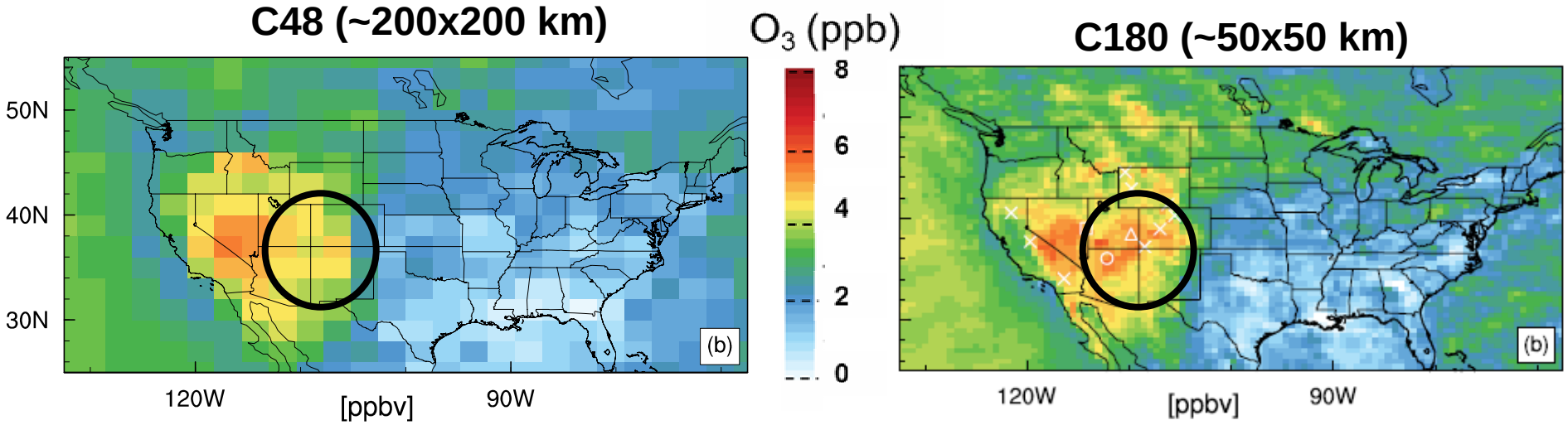
  → Satellite retrieved UT/LS ozone vertical profiles (AIRS, MLS, OMPS?) + tropopause folding events (GOES-WEST…)

- **Analysis of long-term satellite and in-situ obs with model may reveal key connections between climate and air quality**

Extra slides

Mean Asian impacts on U.S. surface O_3 in spring: high-resolution model spatially refines estimates

Daily max 8-hr average O_3 in surface air, May-June 2010 average



Diagnosed as difference between pairs of simulations:
Base – Zero Asian anthrop. emissions

(Anthrop. emissions: *Lamarque et al*., 2010; U.S. NEI 2005; Asian 2006 [*Zhang et al*., 2009] but scaled to 2010 for Chinese NO_x & NMVOC)

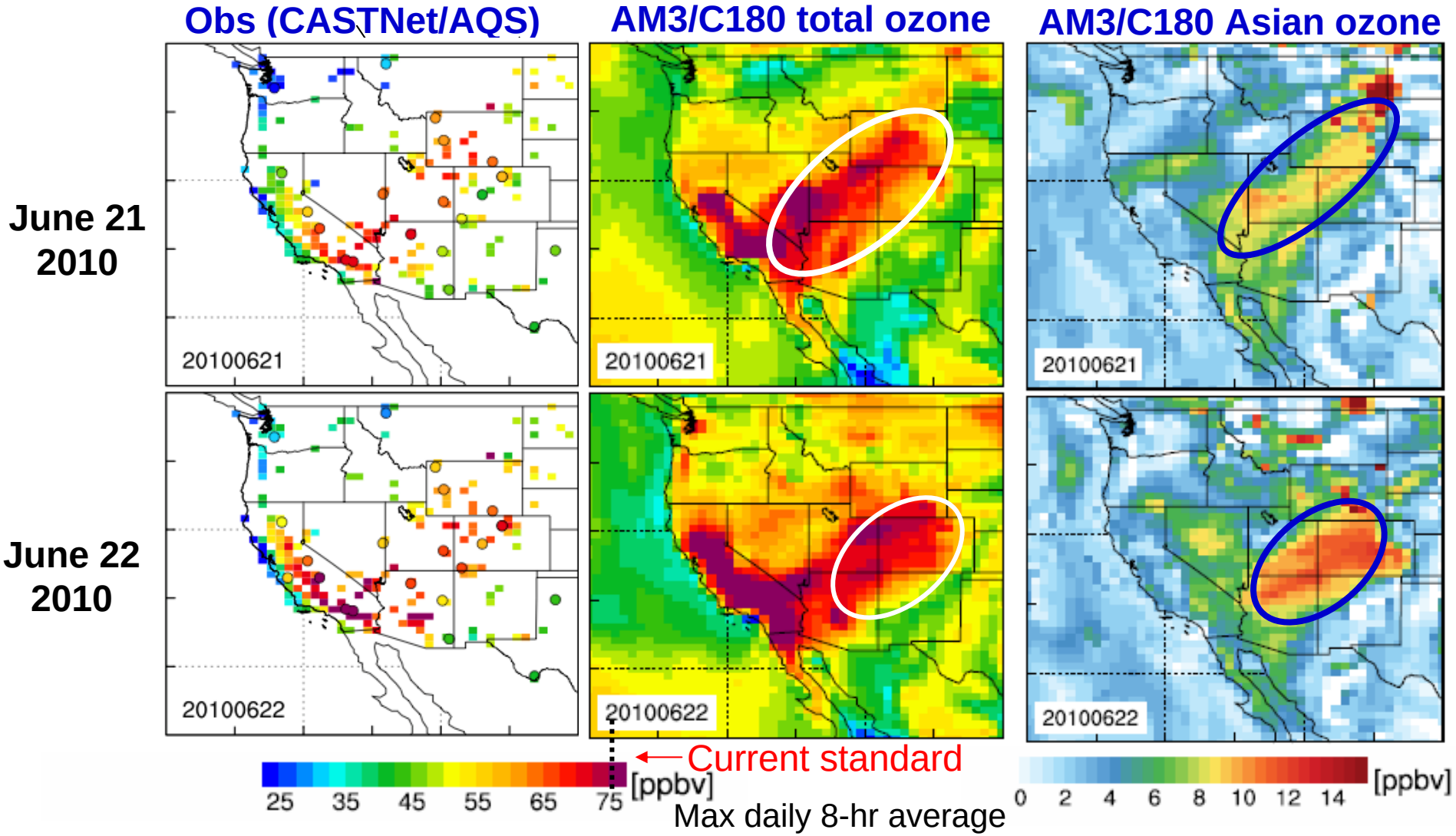
→ **Maximum in the western U.S. (4-7 ppb)**

→ **Large-scale conclusions independent of resolution, though high-res spatially refines estimates:1-2 ppbv (~20% in total) higher over SWUS**

How much does Asian pollution contribute to surface high-O_3 events?

M. Lin et al., submitted to JGR

Asian pollution contribution to high surface O_3 events



→ **Asian influence may confound attaining tighter standards in WUS**

M. Lin et al., submitted to JGR