Key drivers of Western U.S. surface O_3 variability during 1980-2050: From extreme transport events to background trends

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Acknowledgements:

NOAA: L.W. Horowitz, O.R. Cooper, A.O. Langford, S. J. Oltmans

Others: A.M. Fiore and H. Rieder (Columbia), D. Tarasick (Environment Canada)
Mae Gustin and Rebekka Fine (Univ of Nevada)

Geophysical Fluid Dynamics Laboratory

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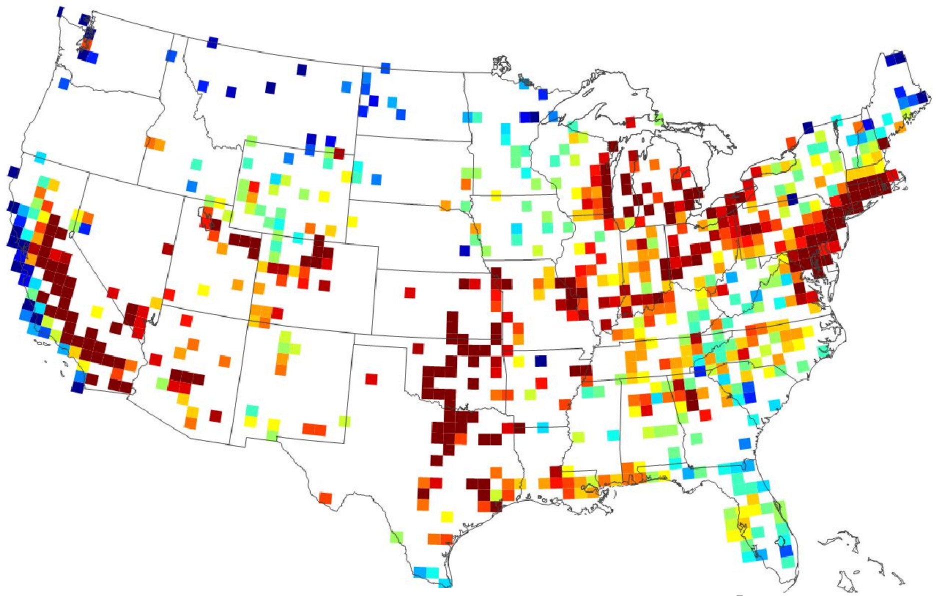
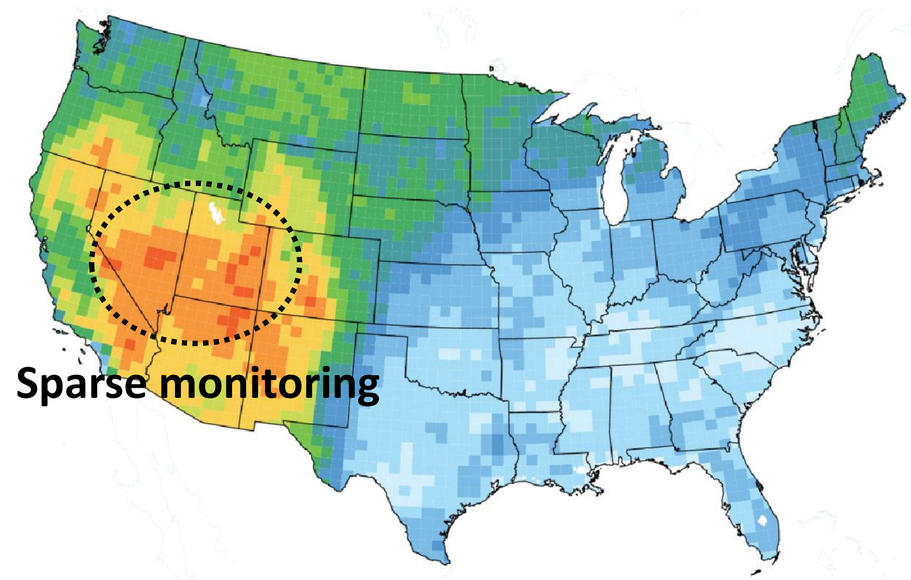
Major challenges for Western U.S. air quality managements



Annual 4th Hi MDA8 O_3

(2011-2013 AQS)



Mean background, Apr-Jun

(NA anthrop emis off in GFDL-AM3 model)

MAJOR CHALLENGES:

- **-Frequency of stratospheric intrusions in spring** [e.g. *Langford et al*., 2009; *Lin et al*., 2012b]
- **-Rising Asian emissions and global CH_4** [e.g. *Jacob et al*. 1999; *Cooper et al*. 2010; Fiore et al. 2012]
- **-More frequent wildfires in summer** [e.g. *Westerling et al*. 2006; *Pfister et al*. 2008; *Jaffe 2011*]
- **-High winter O_3 pollution in an oil and natural gas basin** [e.g. *Edwards et al*. 2014]

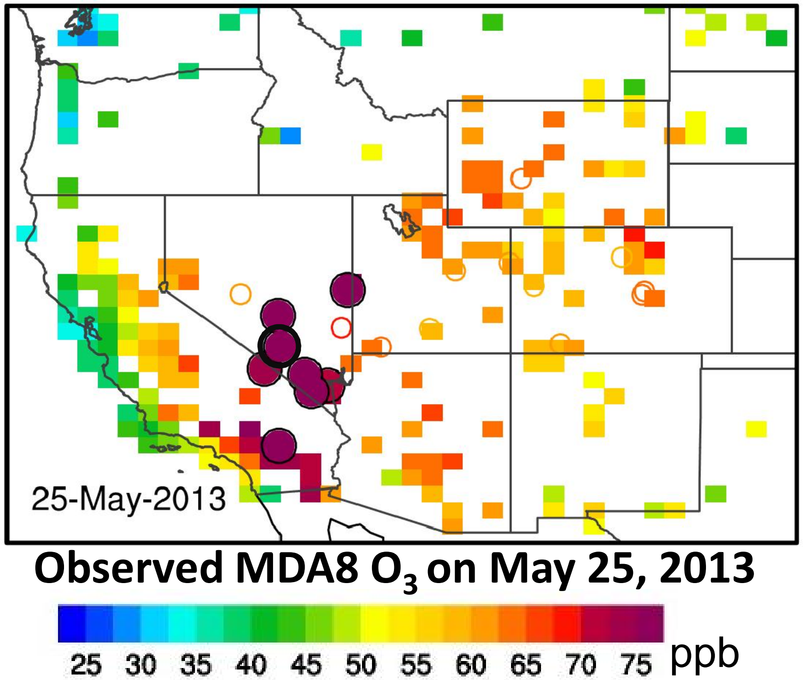
NEED PROCESS-LEVEL UNDERSTANDING ON DAILY TO MULTI-DECADAL TIME SCALES

Stratospheric intrusions push observed surface ozone in S. Nevada above the 75 ppbv NAAQS threshold

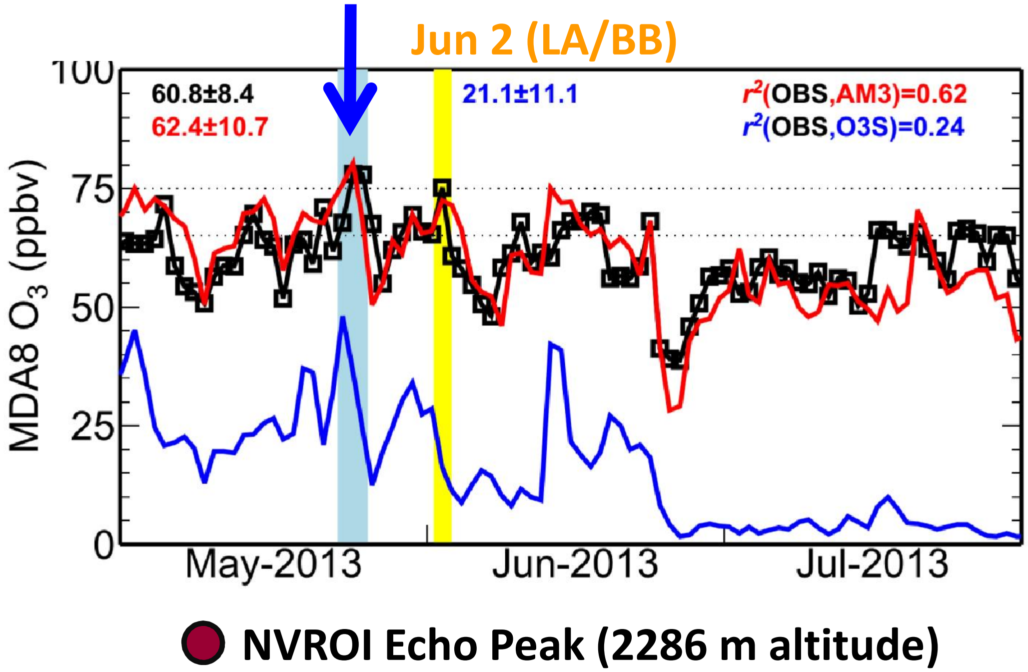
New Measurements:

-Nevada Rural Ozone Initiative (NVROI), July 2011-present (M. Gustin & R. Fine)

-Las Vegas Ozone Study, May-June 2013 (A.O. Langford)

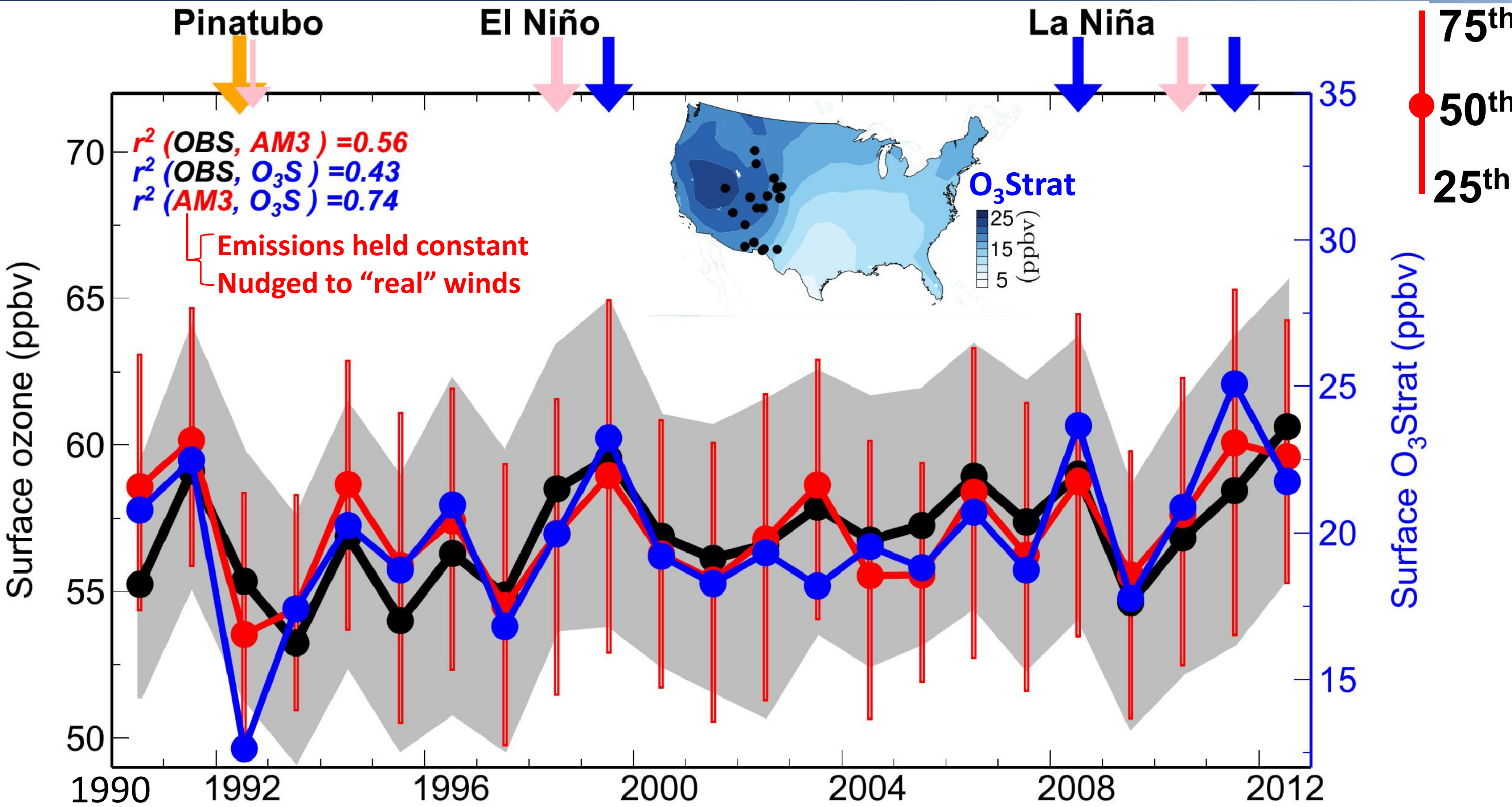


Observed MDA8 O_3 on May 25, 2013



- **Consistent with modeling results from Lin et al (JGR, 2012b)**
- **How do such events vary from year to year and what controls its variability?**

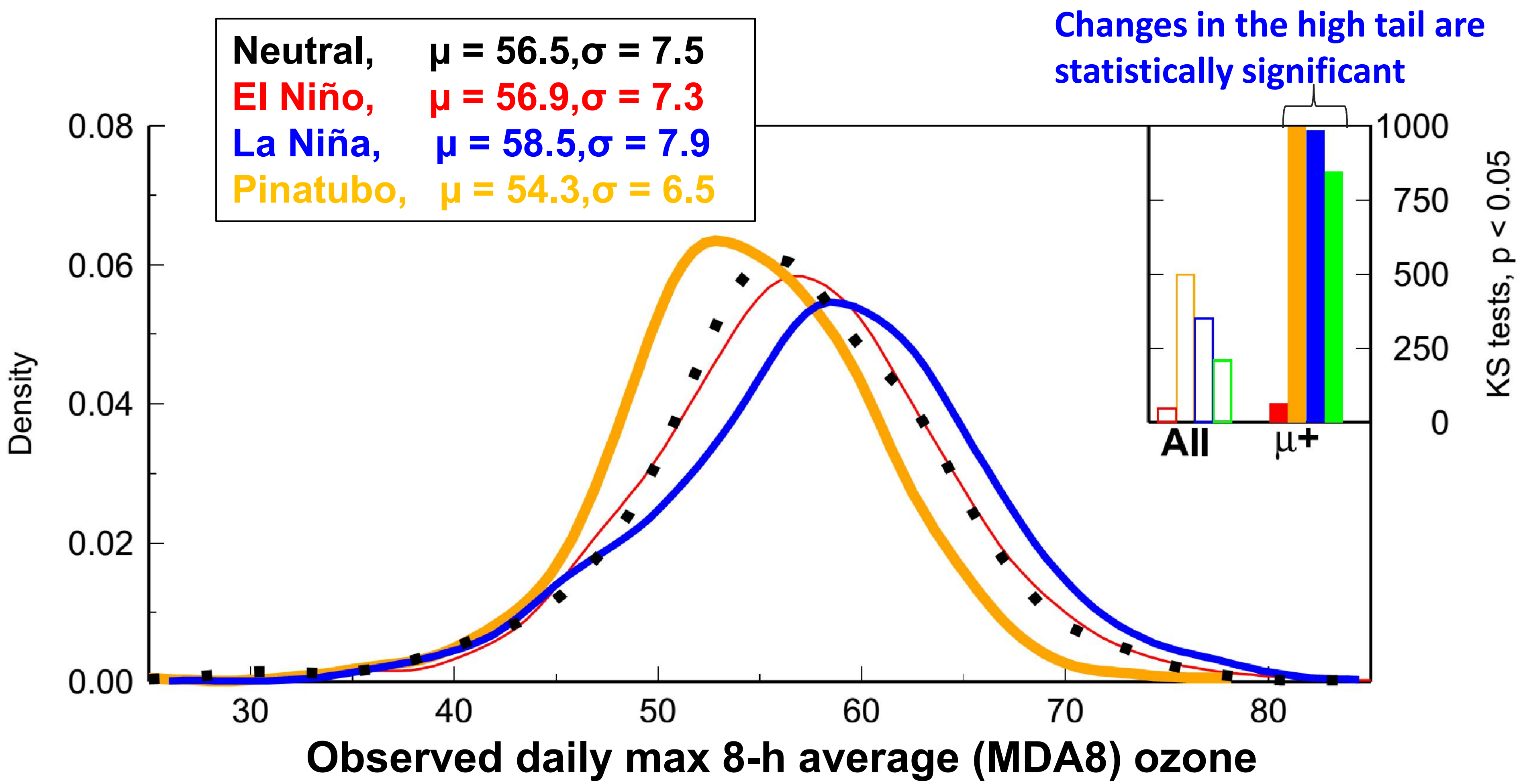
Strong stratospheric influence on year-to-year variability of high-elevation Western U.S. surface O_3 during April-May



- In contrast, the influences from wildfire emissions and Asian pollution are minimal (See paper)
- Large IAV may complicate the attribution of observed O_3 trends in short records (See also *Lin et al.*; Nature Geosci, 2014a)

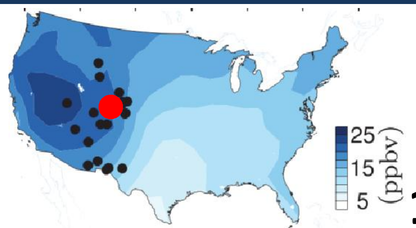
Lin M.Y. et al (in review, 2014b)

The high tail of the observed daily surface O_3 distribution over Western U.S. increases during La Niña springs



- **See my talk** A51Q-07 **on Friday (9:30am, Moscone West 3006) for explanations on the physical mechanisms**

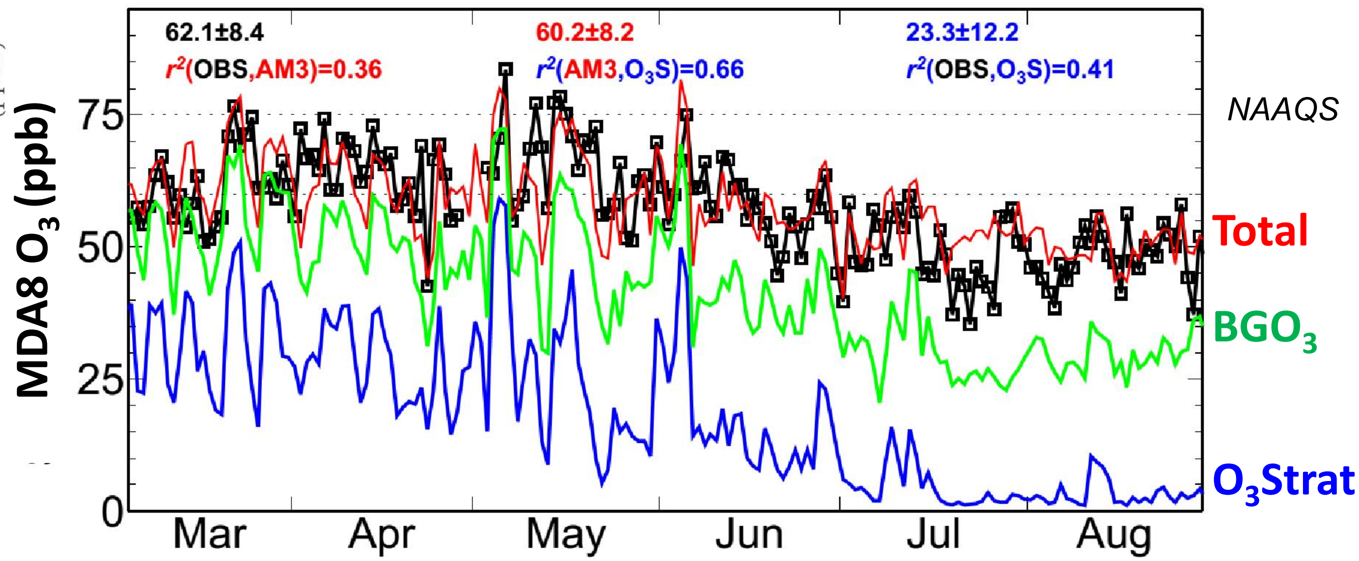
Following La Niña conditions, deep STT may occur with sufficient frequency as to confound NAAQS attainment



Gothic in the Colorado Rocky Mtn (2.9 km altitude)

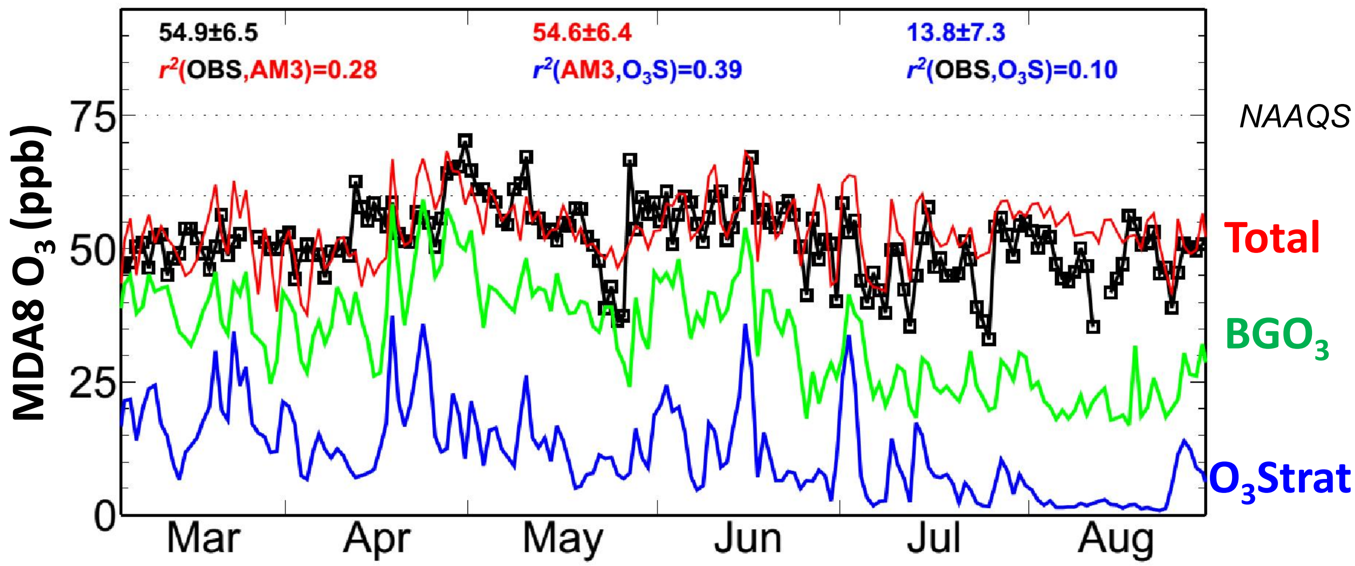
1999 (La Niña)

- Frequent deep STT events



1992 (Pinatubo)

- Weaker events, lower mean values



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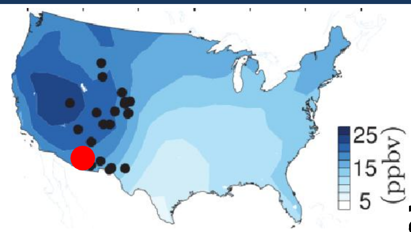
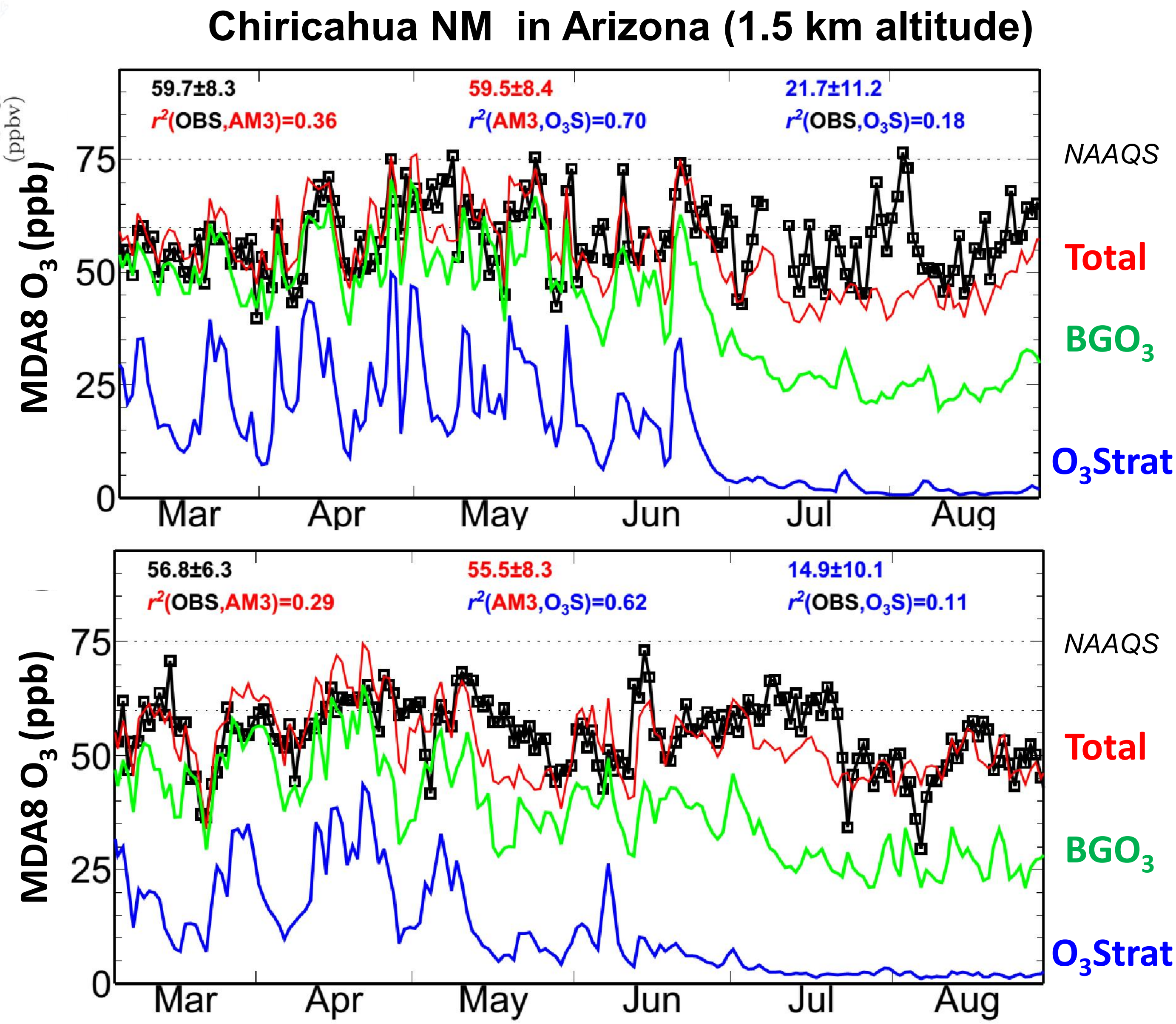


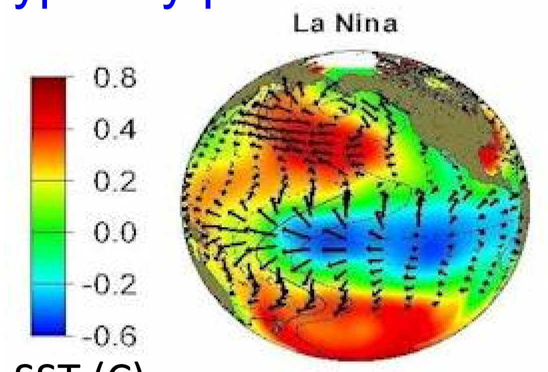
2011 (La Niña)

2007 (Neutral)

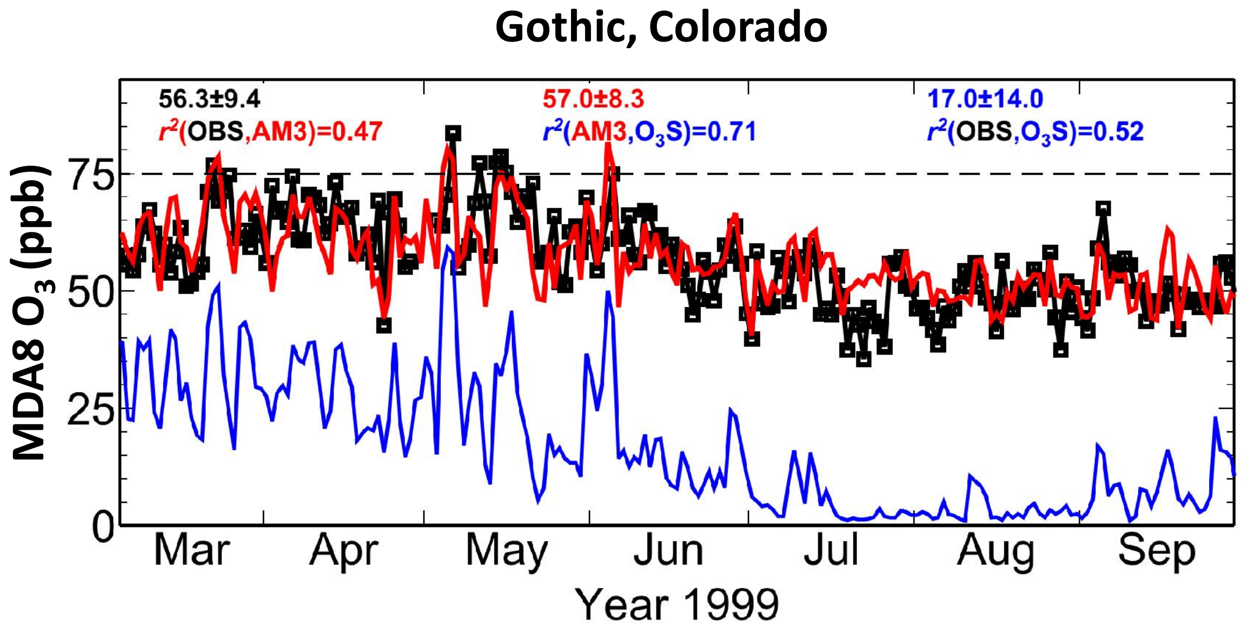


Developing seasonal predictions with a few months of lead time to aid Western U.S. AQ planning?

Tropical SST cooling typically peaks in **winter**



More frequent stratospheric intrusions expected in **the following spring** over WUS?

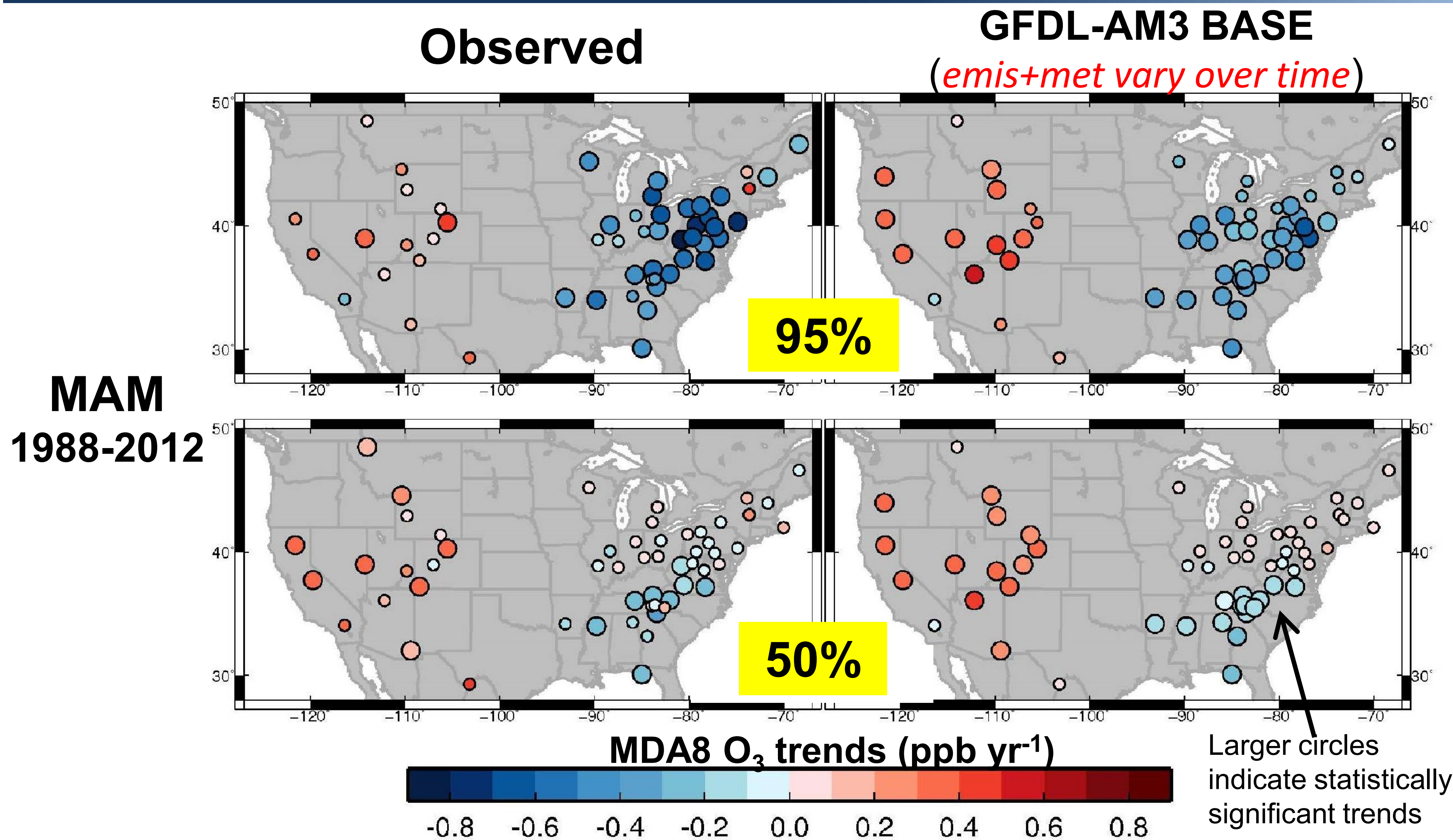


The time lag could allow regional preparations, e.g.

- **Conducting daily forecasts for public health alerts**
- **Deploying targeted measurements aimed at identifying "exceptional events"**

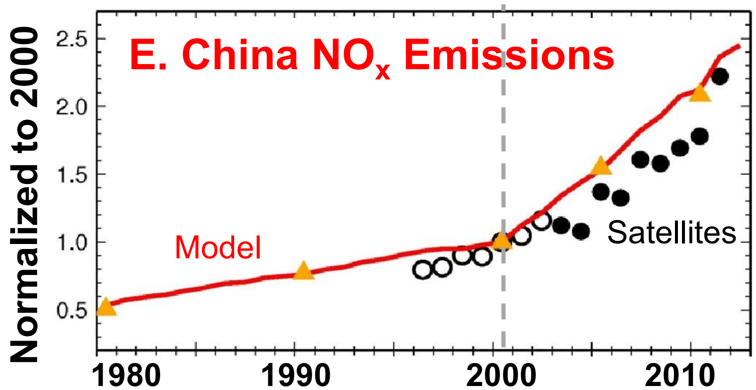
Lin M.Y. et al (in review, 2014b)

Long-term U.S. surface ozone trends:
Did regional NO_x reductions work?

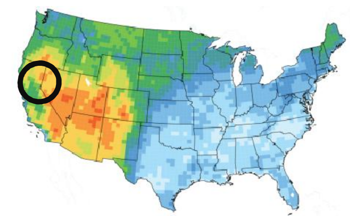


The model is nudged to “real” winds, sampled at site elevation and filtered to remove local influence -- more representative of observed conditions at remote WUS sites

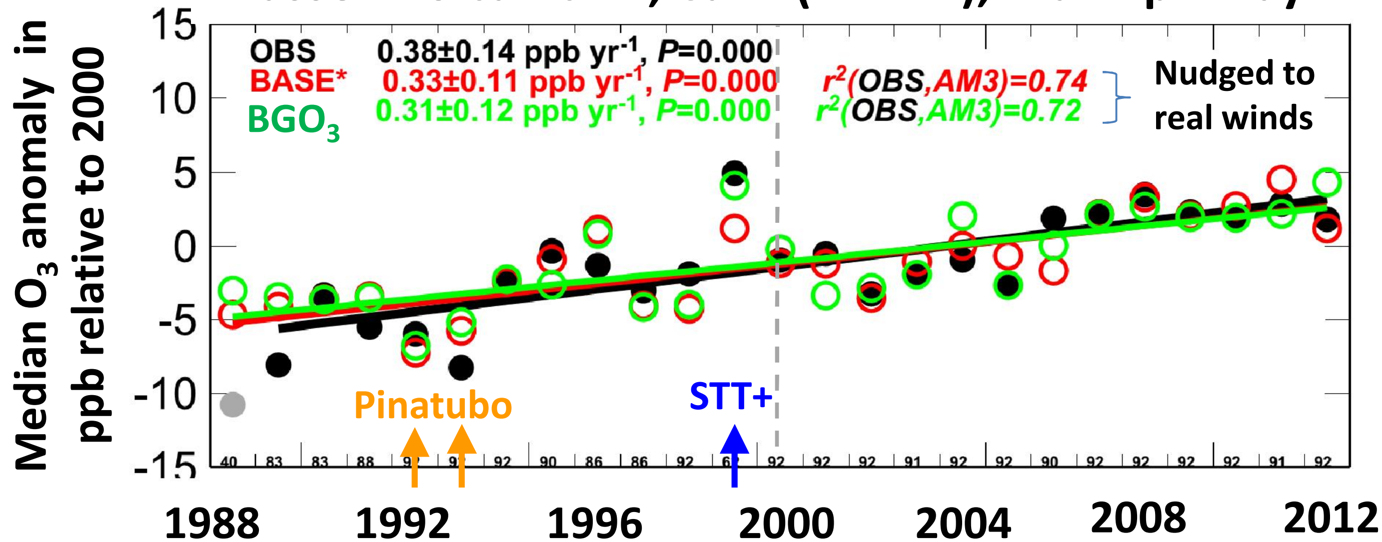
Must consider variability in atmospheric circulation when interpreting observed changes in baseline O_3



Larger growth of Asian emissions in the 2000s, but weaker rate of O_3 changes observed at Lassen as compared to the 1990s

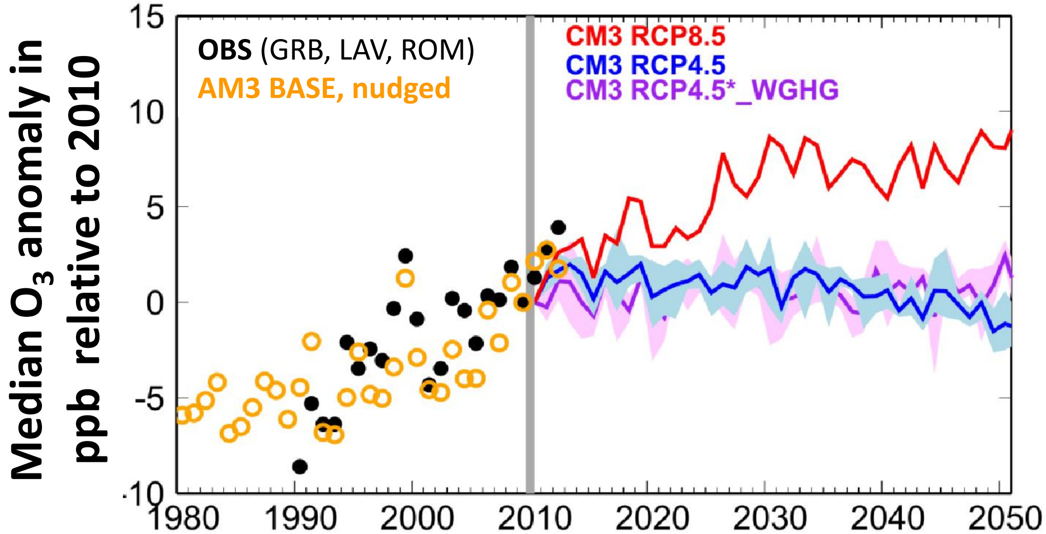


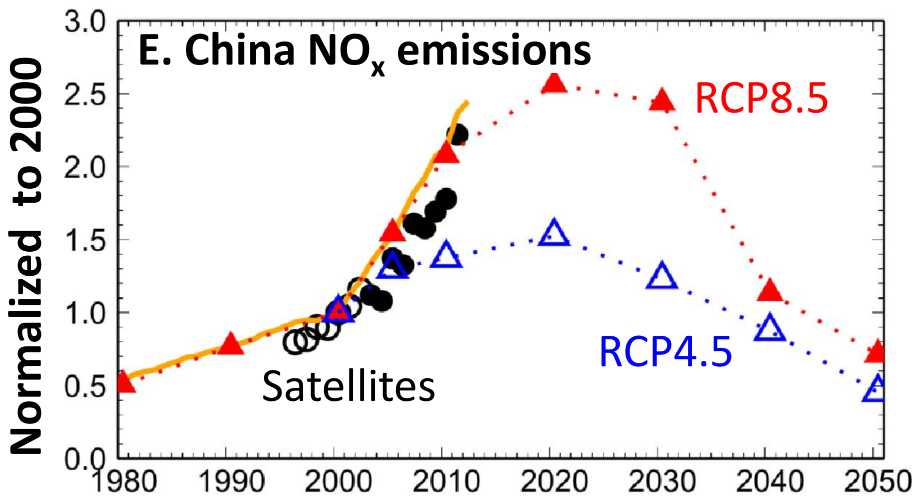
Lassen Volcanic NP, Calif. (1.7 km), Mar-Apr-May

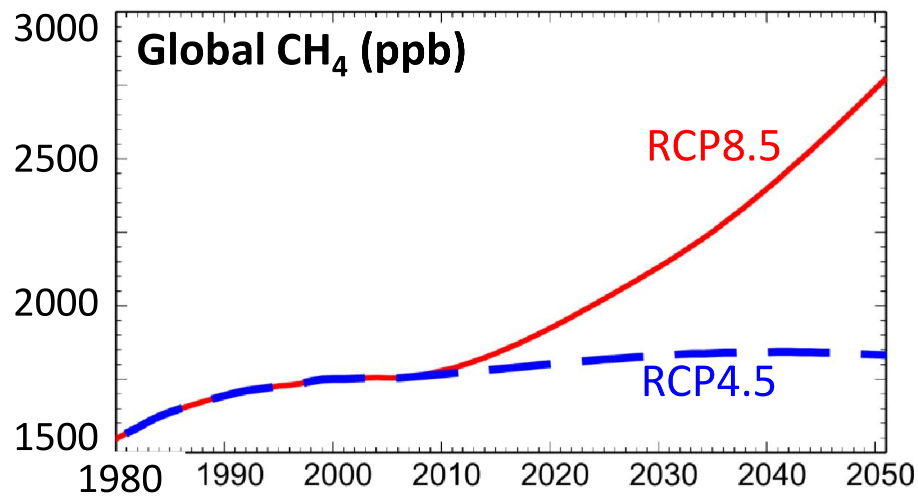


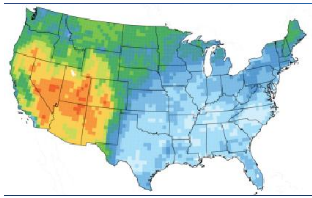
- **Weaker variability in the 2000s attributed to changes in background rather than in N.A. pollution**

Projections of near-term changes in WUS lower trop. ozone in spring (March-April-May)







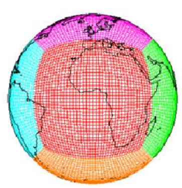


Summarizing drivers of WUS O_3 variability

- The frequency of deep STT affects year-to-year variability in springtime high-O_3 events
  → Linked to La Niña in the previous winter
  → Potential for seasonal forecast

- Rising Asian emissions and global CH_4 are likely the major drivers of long-term changes in mean baseline ozone, **but ….**

- Ozone measurements contain signatures of circulation variability:
  → Short records may complicate the attribution of trends
  → Must ensure an apple-to-apple comparison btw model and obs



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Additional slides for Q & A

The GFDL AM3 Model Hindcasts for 1978- 2012

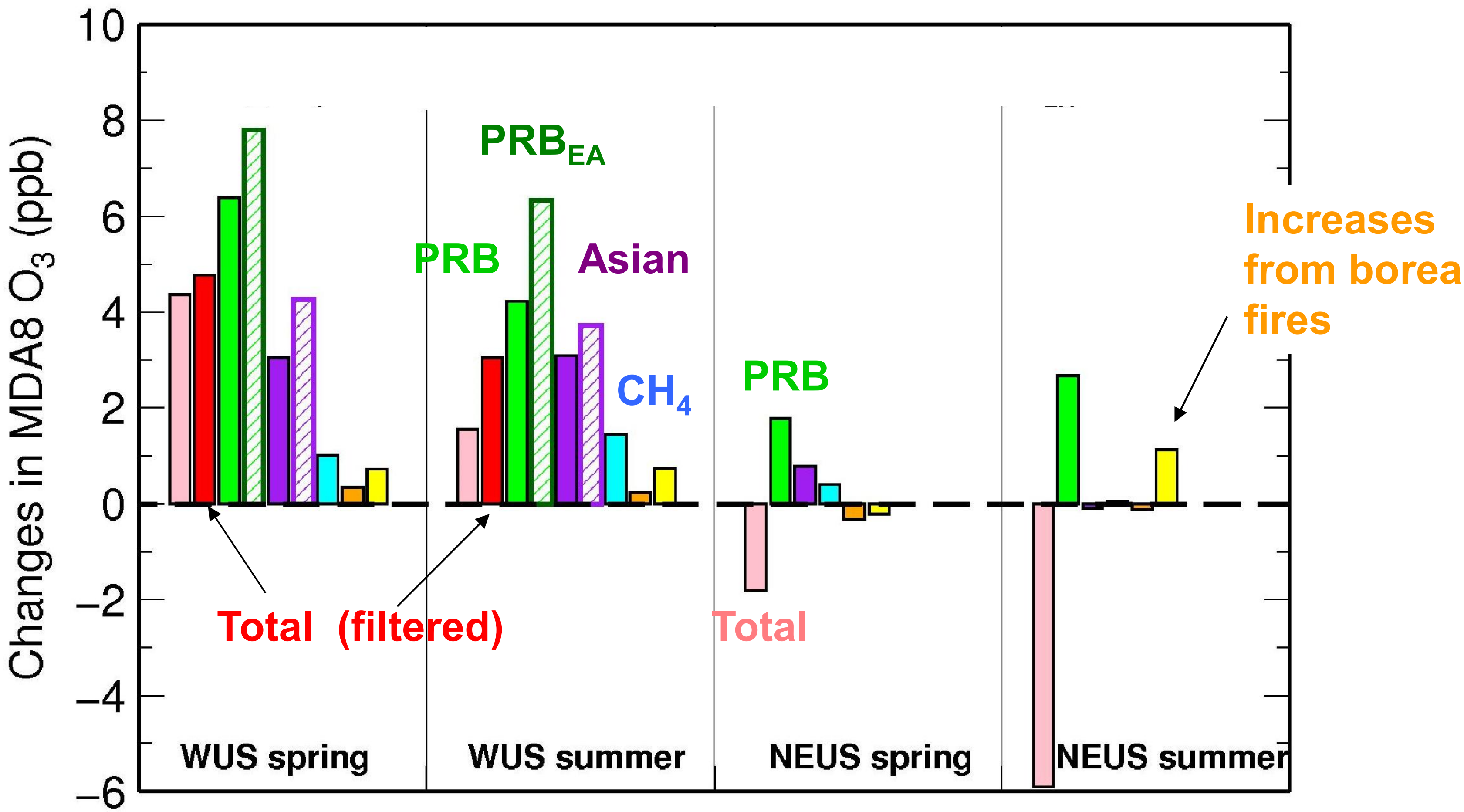
Experiment	Meteorology	Forcings (radiation)	CH_4 (chemistry)	Aerosol and O_3 precursors	Fire emissions
BASE	Nudged to NCEP U&V	Historical	Historical	Historical and RCP 8.5 beyond 2005	Historical
PRB	as BASE	Historical	Historical	Shut off over NA; as BASE elsewhere	Historical
FIXEMIS	as BASE	Historical	2000	Fixed	Fixed
IAVFIRE	as BASE	Historical	2000	Fixed	Historical
IAVASIA	as BASE	Historical	1980	Varying in Asia only	Fixed
IAV_CH_4Chem	as BASE	Historical	Historical	Fixed	Fixed

Model setup similar to *Lin et al*. [2012a, b], but at 2ºx2º resolution

Designed to isolate the role of changes in ***meteorology*****,** ***background*****,** ***STE*****,** ***wildfires*****,** ***methane****, and* ***Asian*** *vs.* ***North American*** *anthropogenic emissions*

Summarizing drivers of U.S. ozone trends In the historical period (1980-2012)

GFDL AM3 (2003-2012 minus 1981-1990)

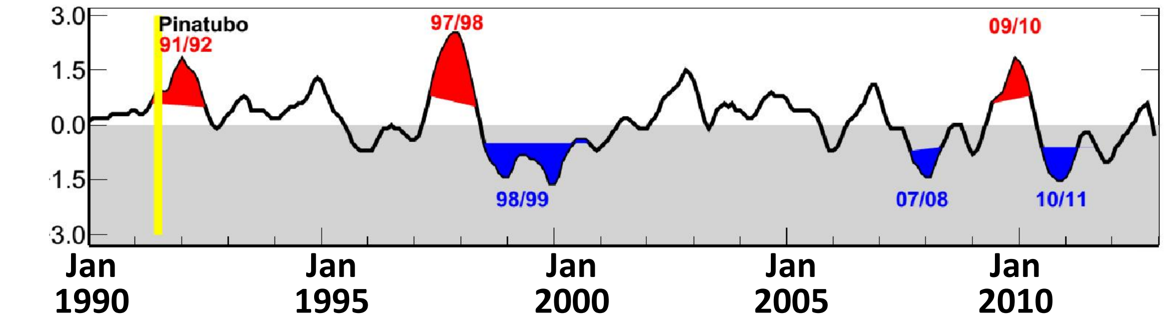


Increases in total ozone over WUS despite reductions in local emissions

Rising Asian emissions contribute ~50% of total background increases

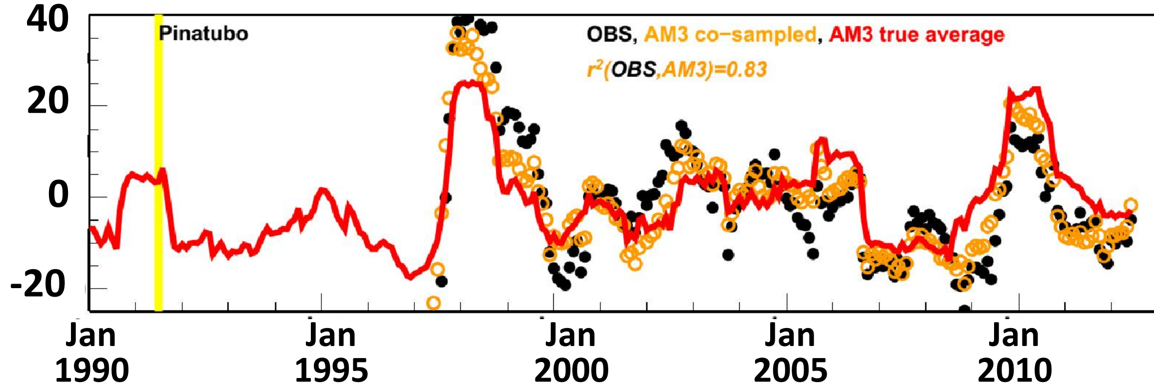
Western US surface O_3 variability correlates poorly with O_3 burdens in the UTLS but strongly with that in the Free Trop

Niño 3.4 Index



12-mon running mean UTLS O_3 anomaly (%)

r^2(UTLS, Surface) = 0.07



Trinidad

Apr-May mean FreeTrop & Surface O_3 anomaly (ppb)

r^2(FreeTrop, Surface) =0.74