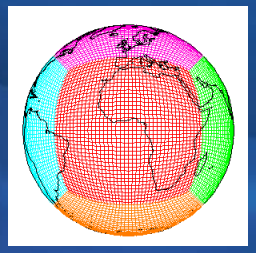
Presented at CARB/UC Davis MET-MAQ conference

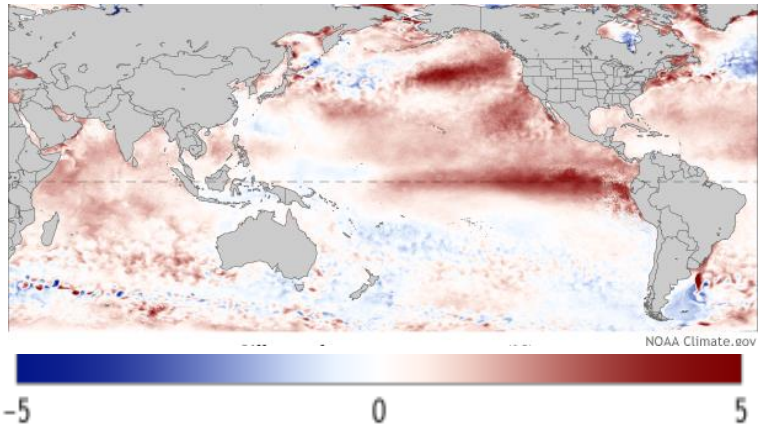
Detecting changes in US background O_3 means and extremes amidst climate variability

MEIYUN LIN
(PRINCETON/NOAA GFDL)



GFDL-AM3

SST anomalies (August 2015)

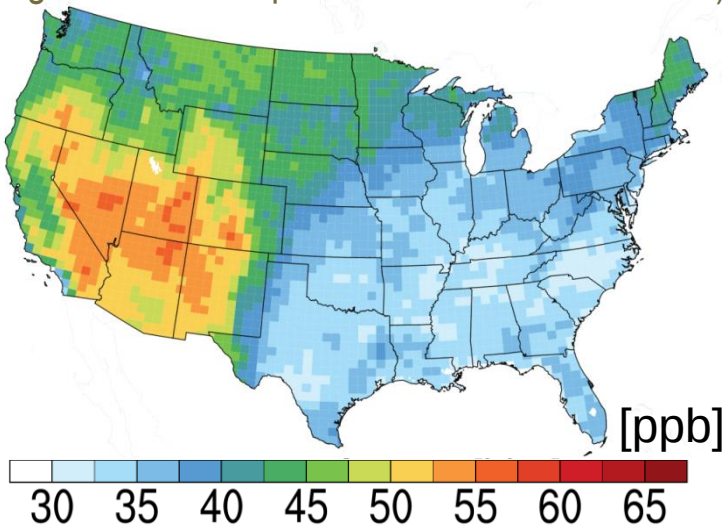


NOAA: >90% chance that El Niño will continue through winter 2015-16

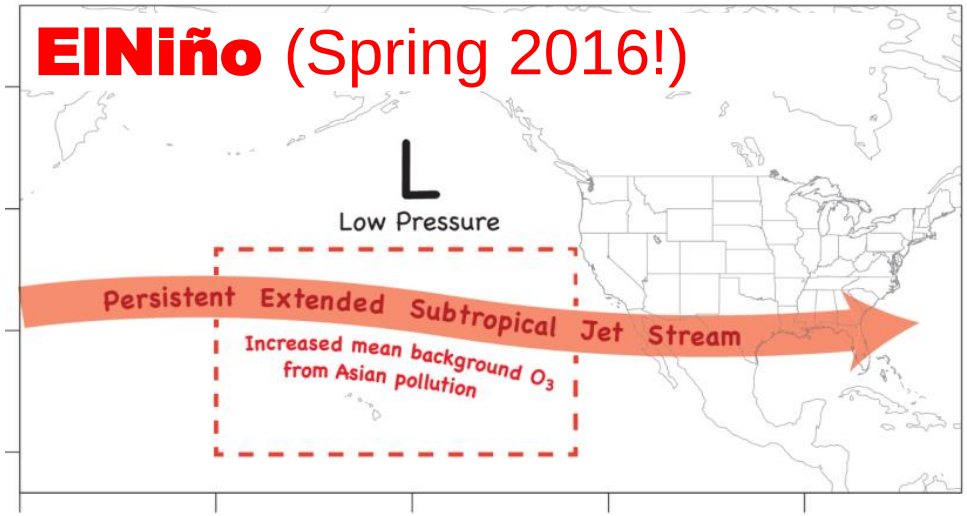
?

Mean surface background O_3, Apr-Jun

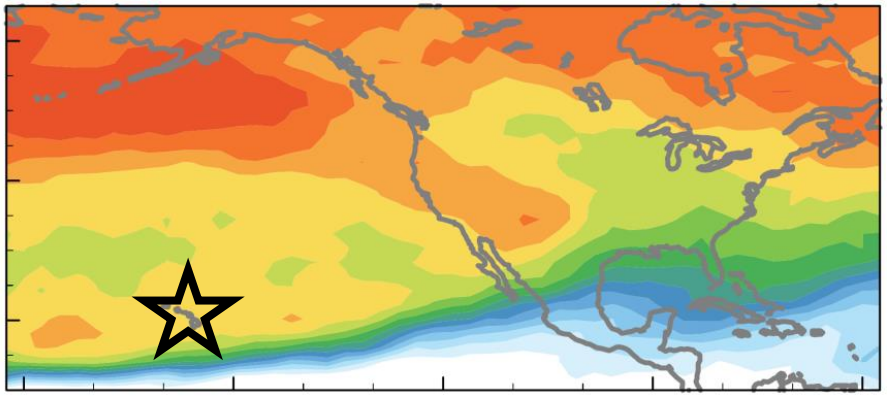
(zeroing out US anthrop. emissions in ~50 km AM3)

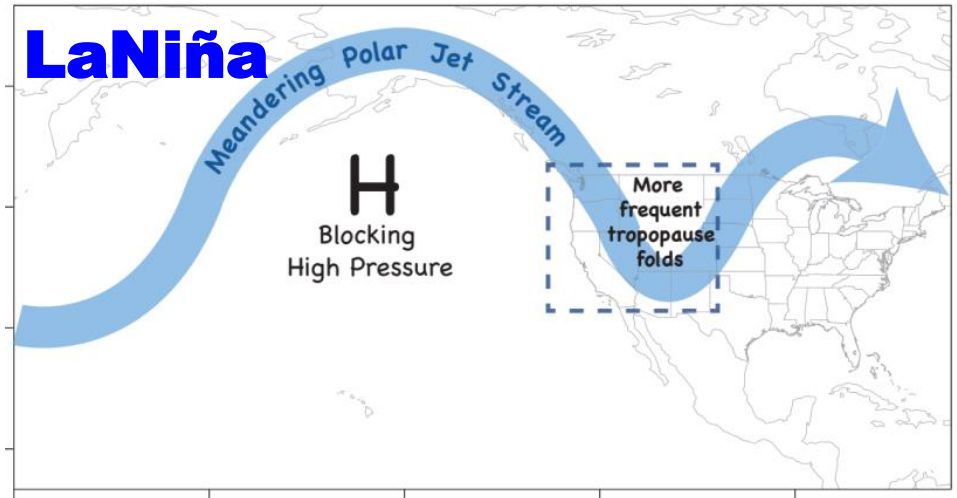


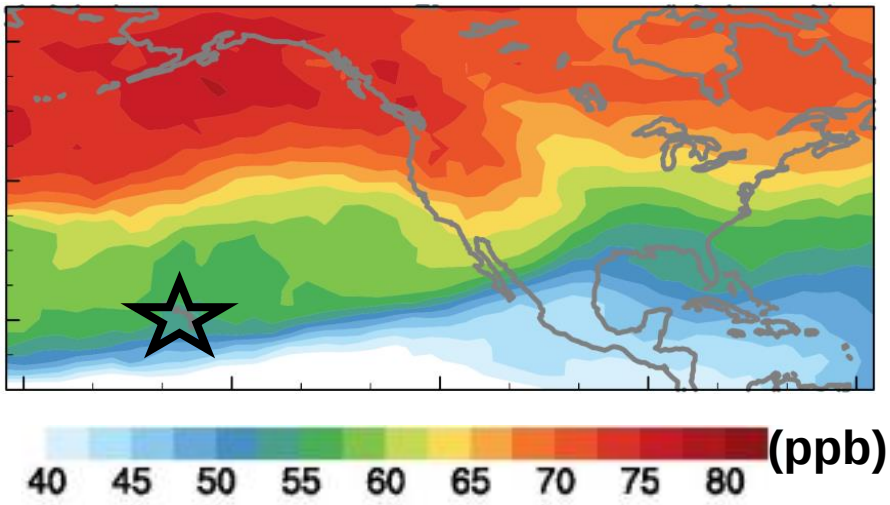
Towards a predictive understanding



Mean background O_3 (500hPa, Apr-May)



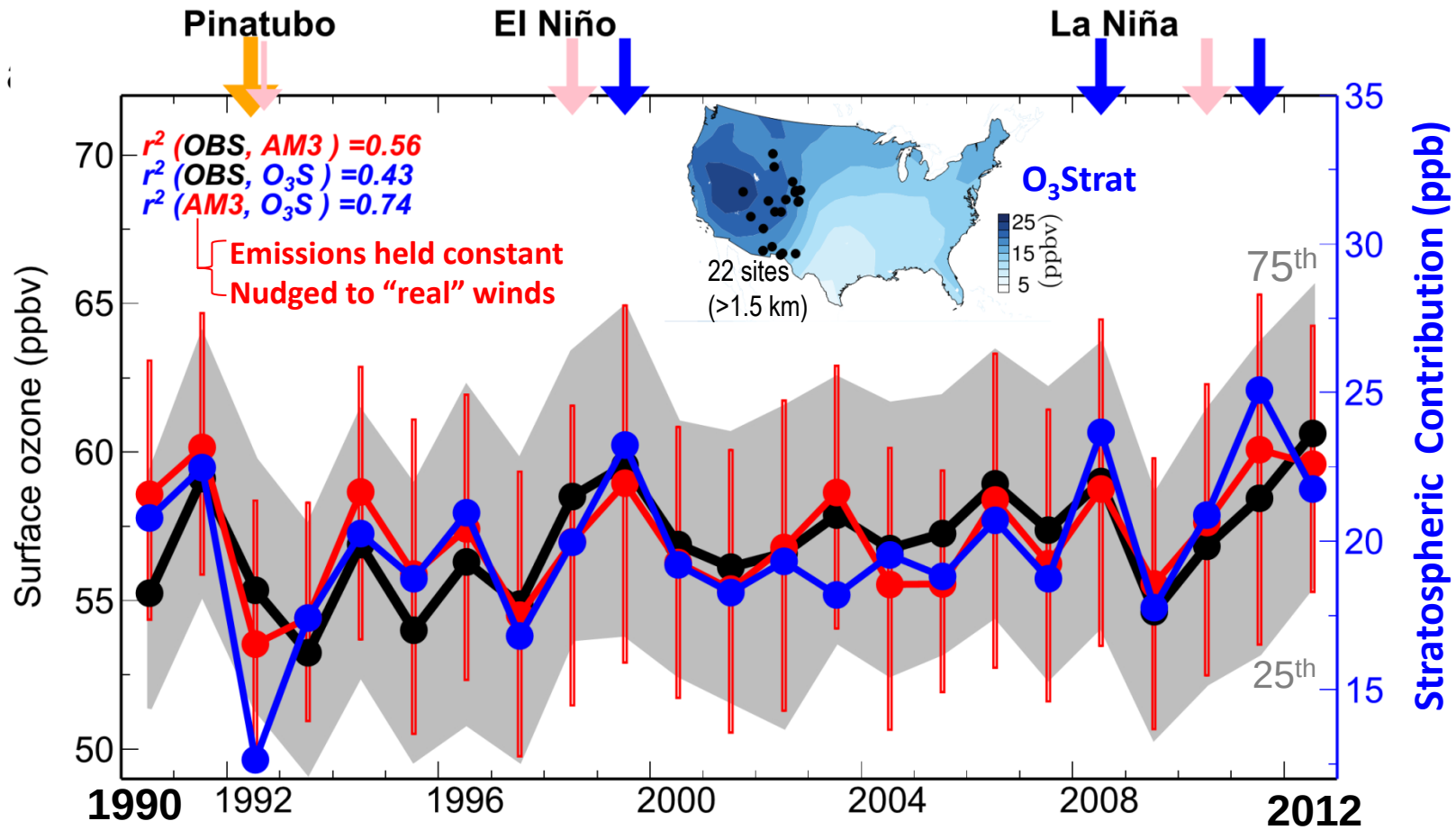




|Niño3.4|>1.0; winter + spring (more O_3)

Meiyun Lin et al (Nature GeoSci., 2014; Nature Commun. 2015)

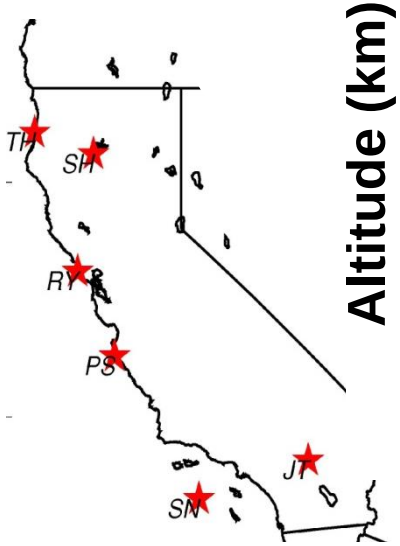
La Niña modulates WUS surface O_3 via deep stratospheric intrusions

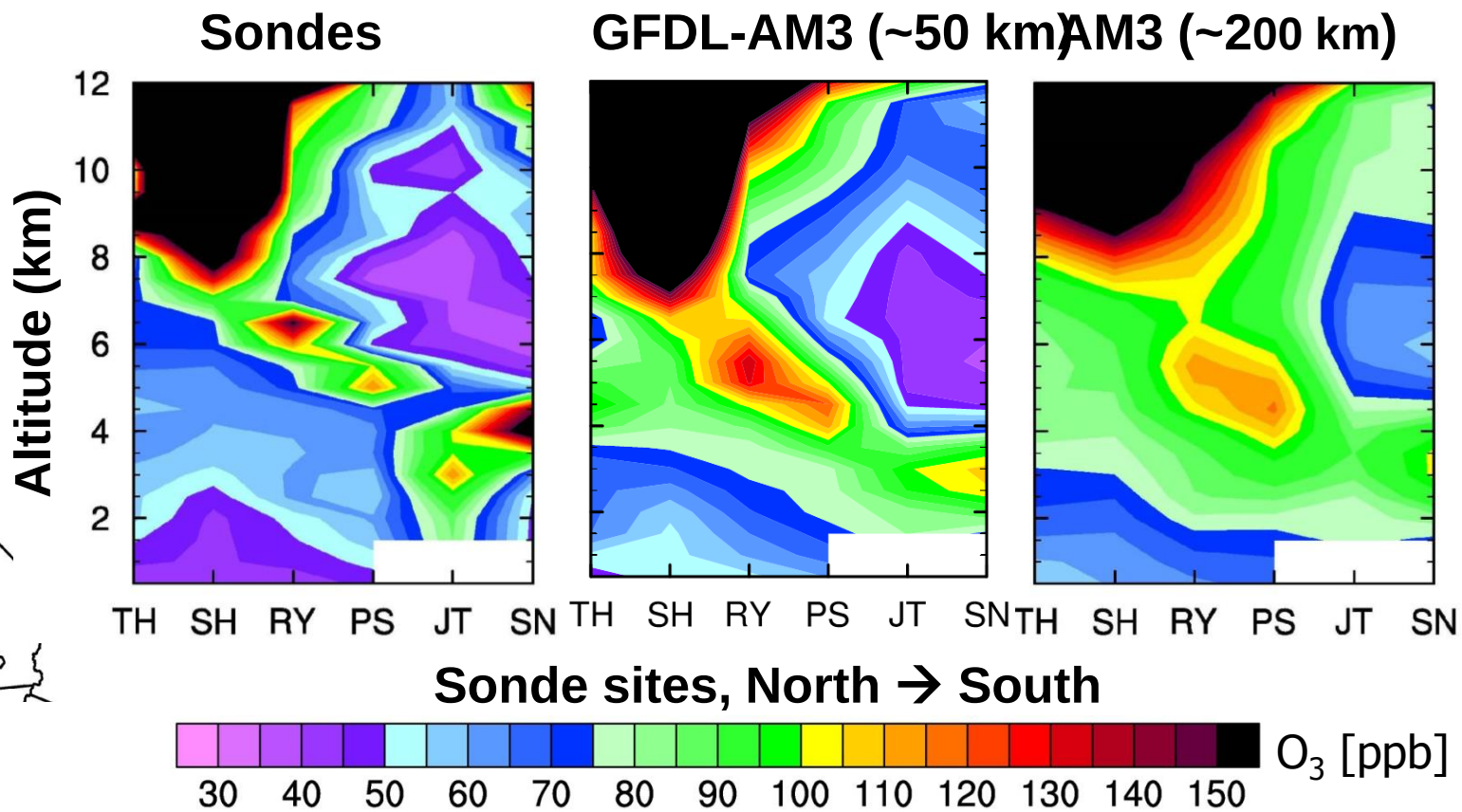


April-May (deeper mixing depths than in winter)

- **Strong stratospheric influence on interannual variability**

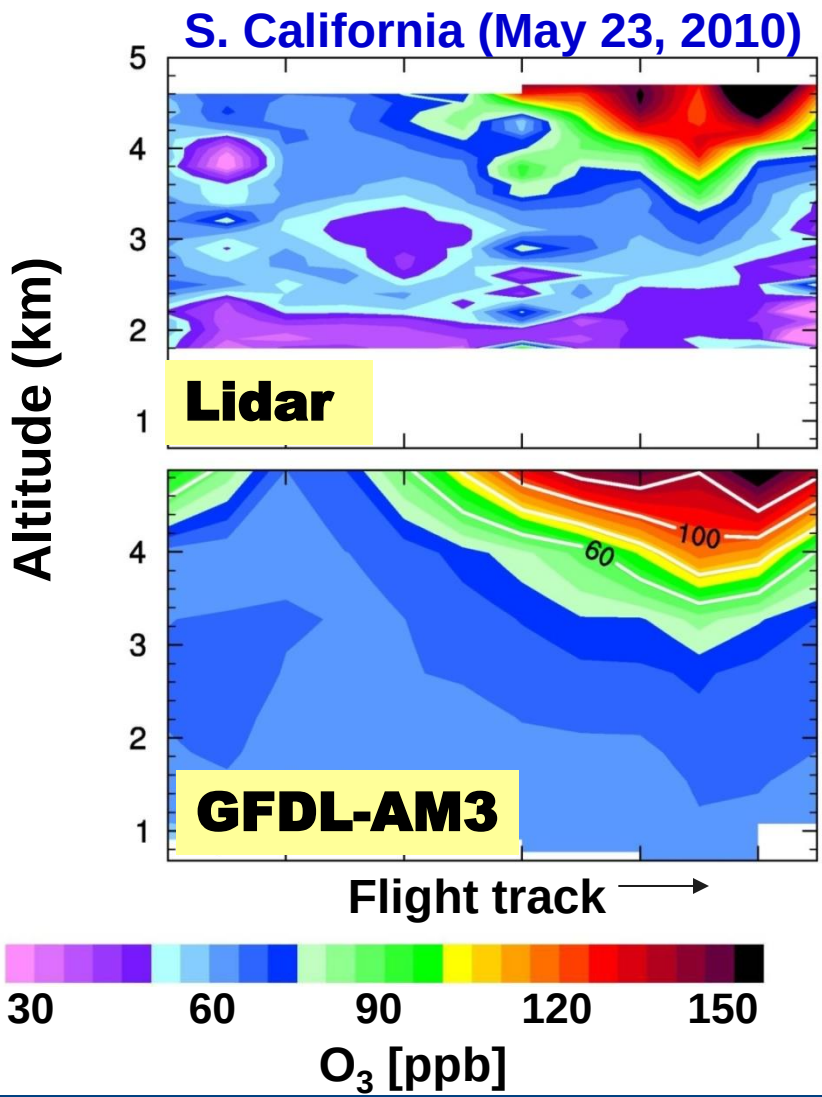
Deep stratospheric O_3 intrusions over California
(May 28, 2010 example)

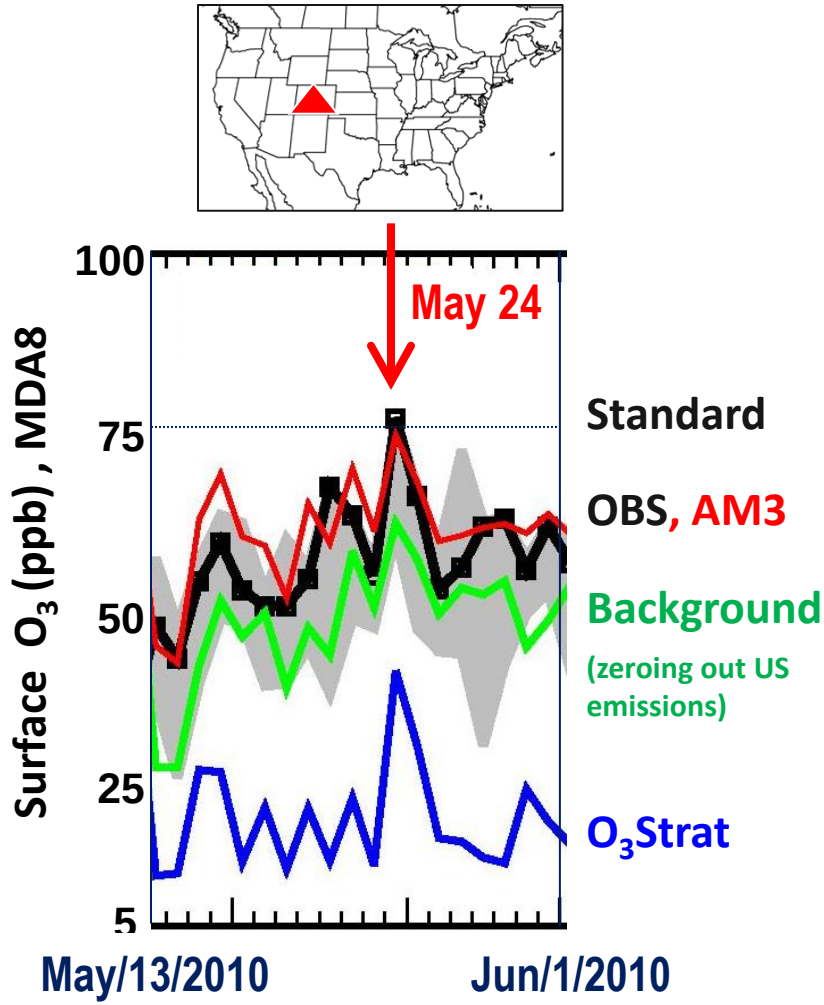




- Push surface O_3 above 75 ppbv at EPA monitors on May 29

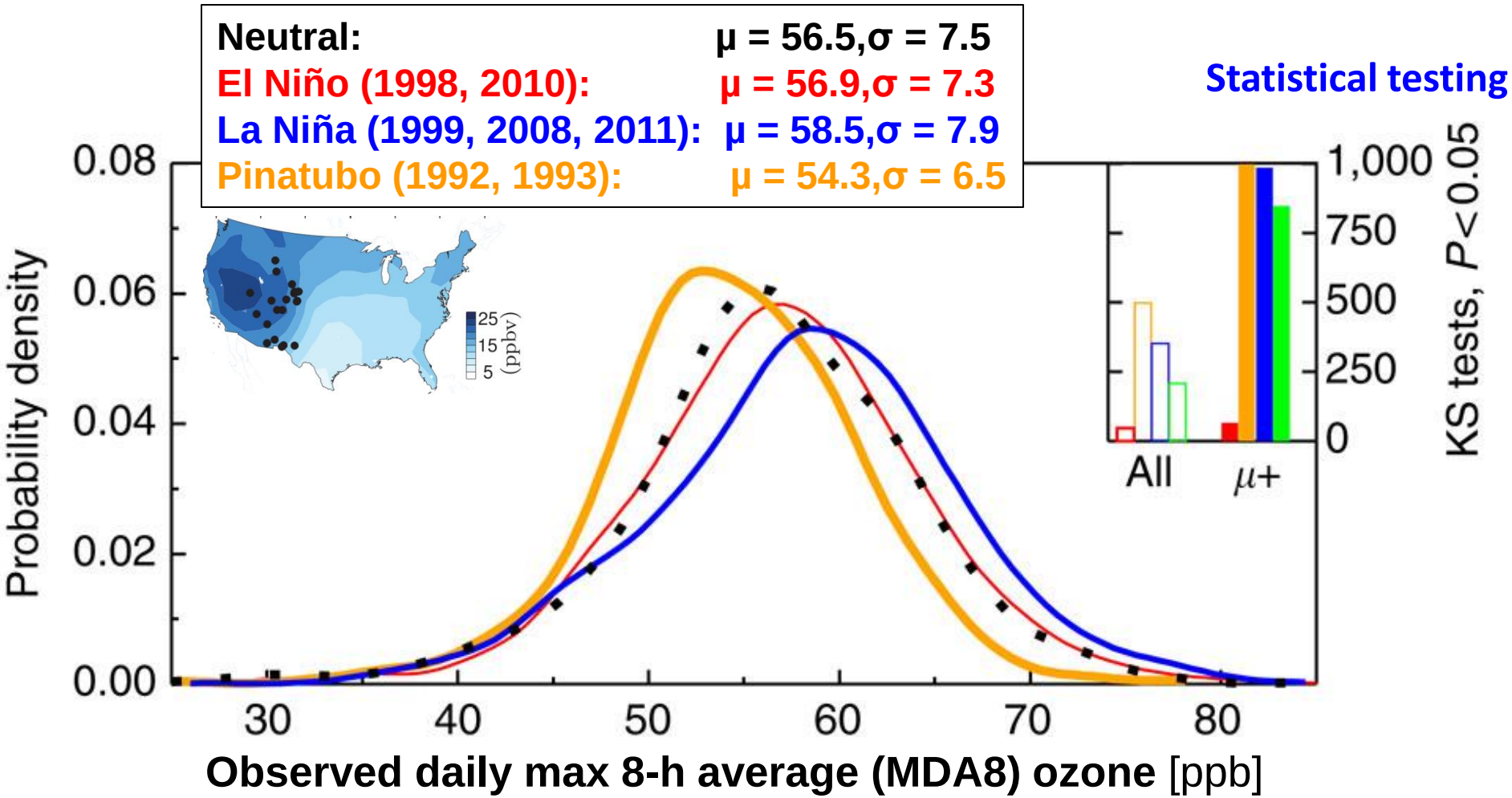
GFDL-AM3 captures a deep intrusion event observed by an ozone lidar





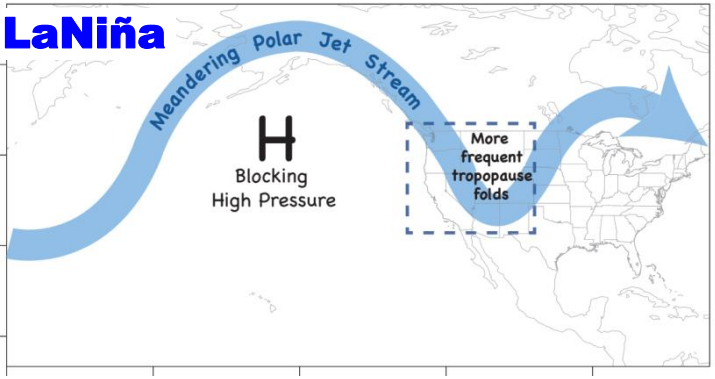
Meiyun Lin et al (JGR, 2012b): *Springtime high surface ozone events over WUS …*

The high tail of observed surface O_3 distribution increases during La Niña springs

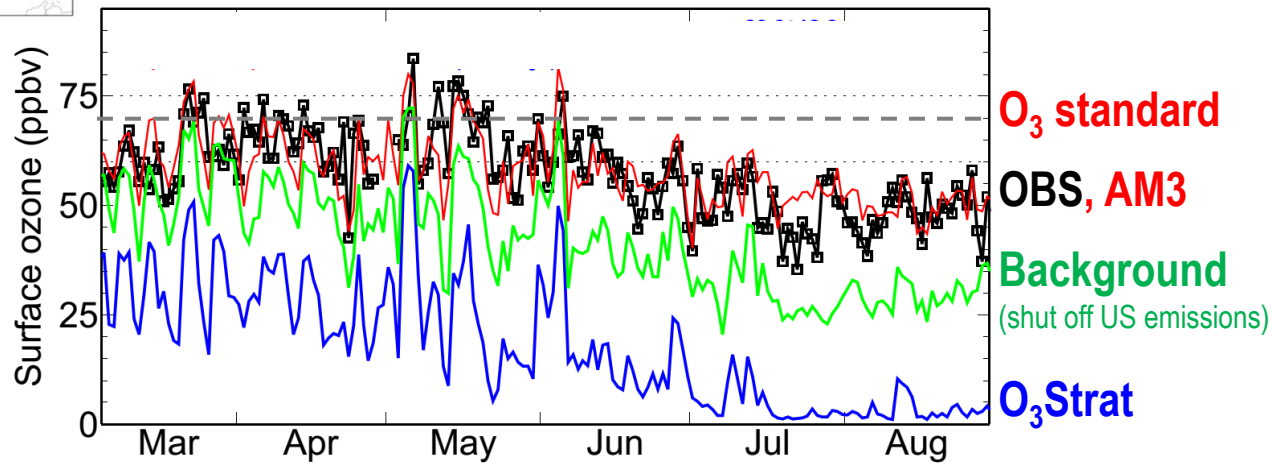


→ Similar distributions in GFDL-AM3 stratospheric ozone tracer

Developing ozone seasonal forecasts to aid western US air quality planning



Following a La Niña winter, more frequent deep stratospheric intrusions expected over WUS during spring



Gothic in Colorado Rocky Mtn (1999)

REGIONAL PREPARATIONS:

- **Deploy targeted measurements aimed at identifying "exceptional events"**
- **Conduct daily forecast for public health alerts**

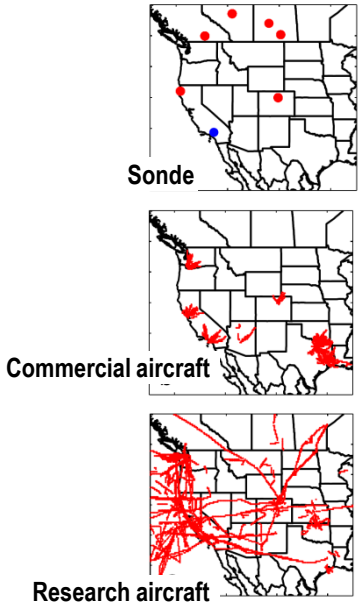
Meiyun Lin et al. (Nature Communications, 2015)

nature Vol 463|21 January 2010|doi:10.1038/nature08708

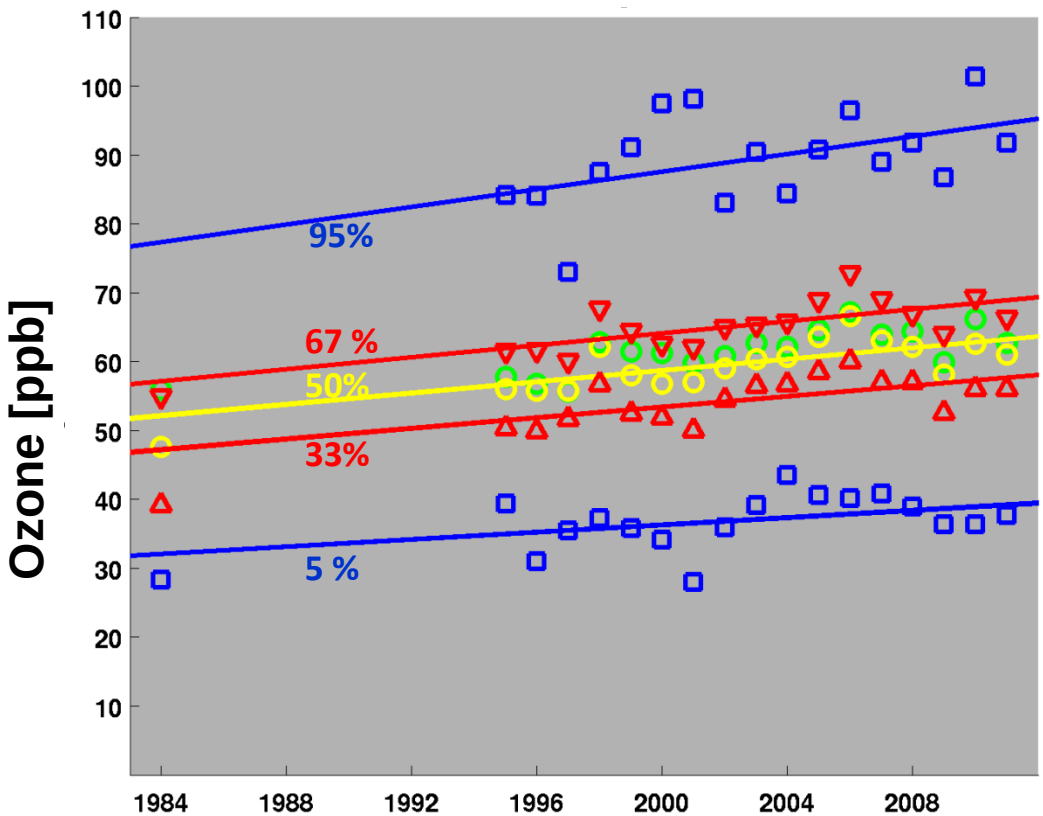
LETTERS

Increasing springtime ozone mixing ratios in the free troposphere over western North America

O. R. Cooper[1,2], D. D. Parrish[2], A. Stohl[3], M. Trainer[2], P. Nédélec[4], V. Thouret[4], J. P. Cammas[4], S. J. Oltmans[2], B. J. Johnson[2], D. Tarasick[5], T. Leblanc[6], I. S. McDermid[6], D. Jaffe[7], R. Gao[2], J. Stith[8], T. Ryerson[2], K. Aikin[1,2], T. Campos[9], A. Weinheimer[9] & M. A. Avery[10]



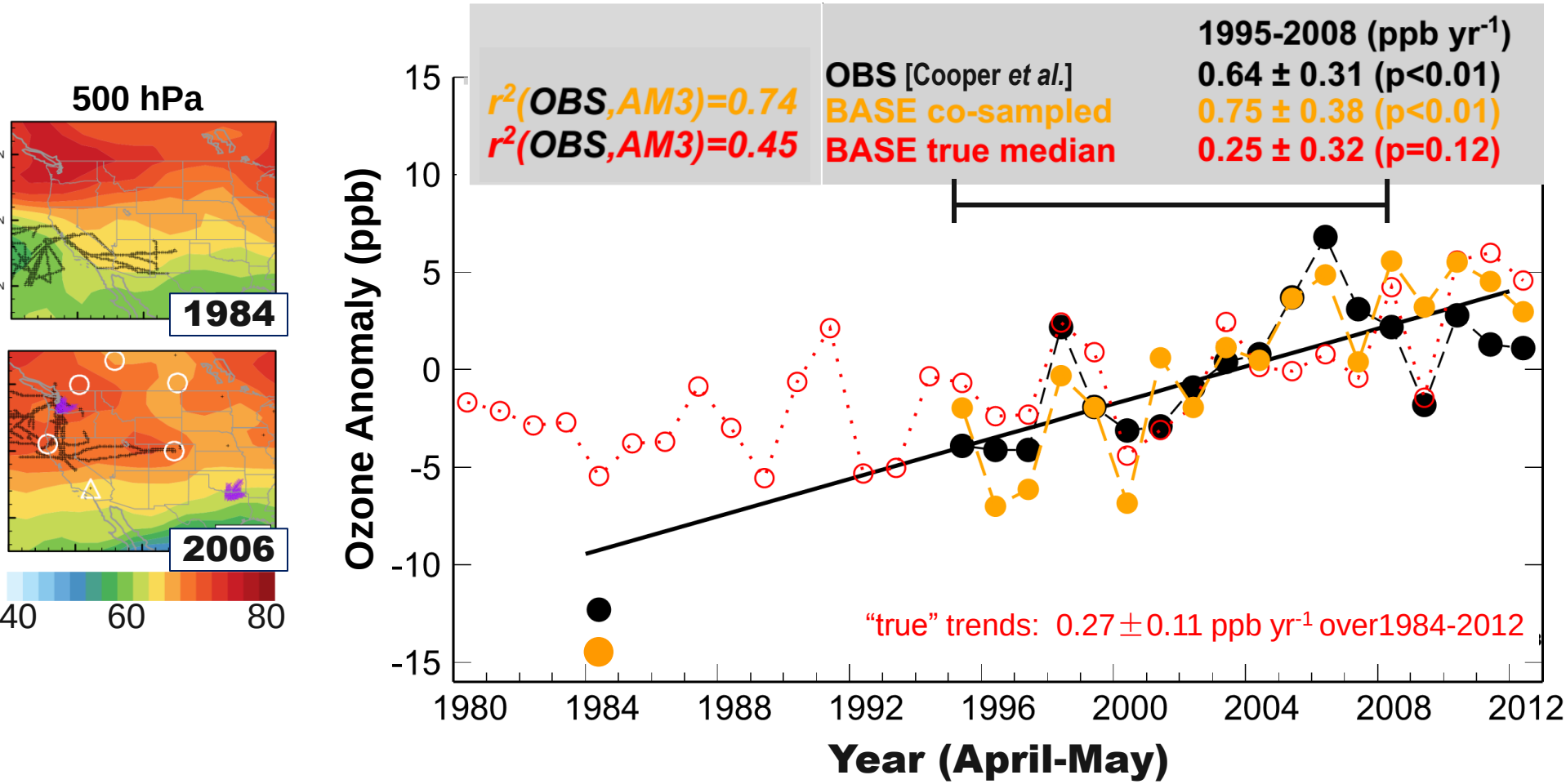
3-8 km altitude



increase by ~20 ppbv;
attributed to rising Asian emissions

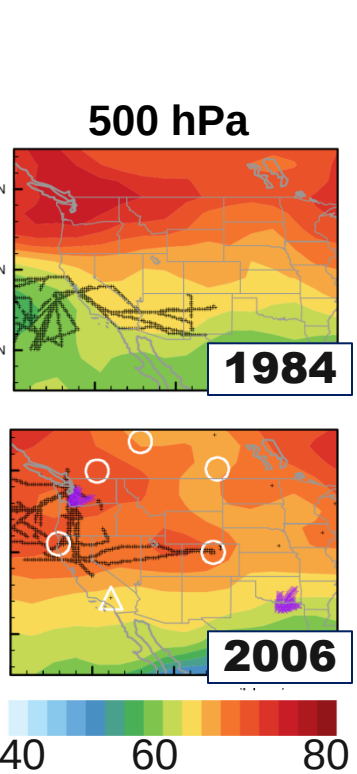
Lamarque *et al.* [2010];
Parrish *et al.* [2014]:
Free-running CCMs capture only <50% of observed O_3 trends

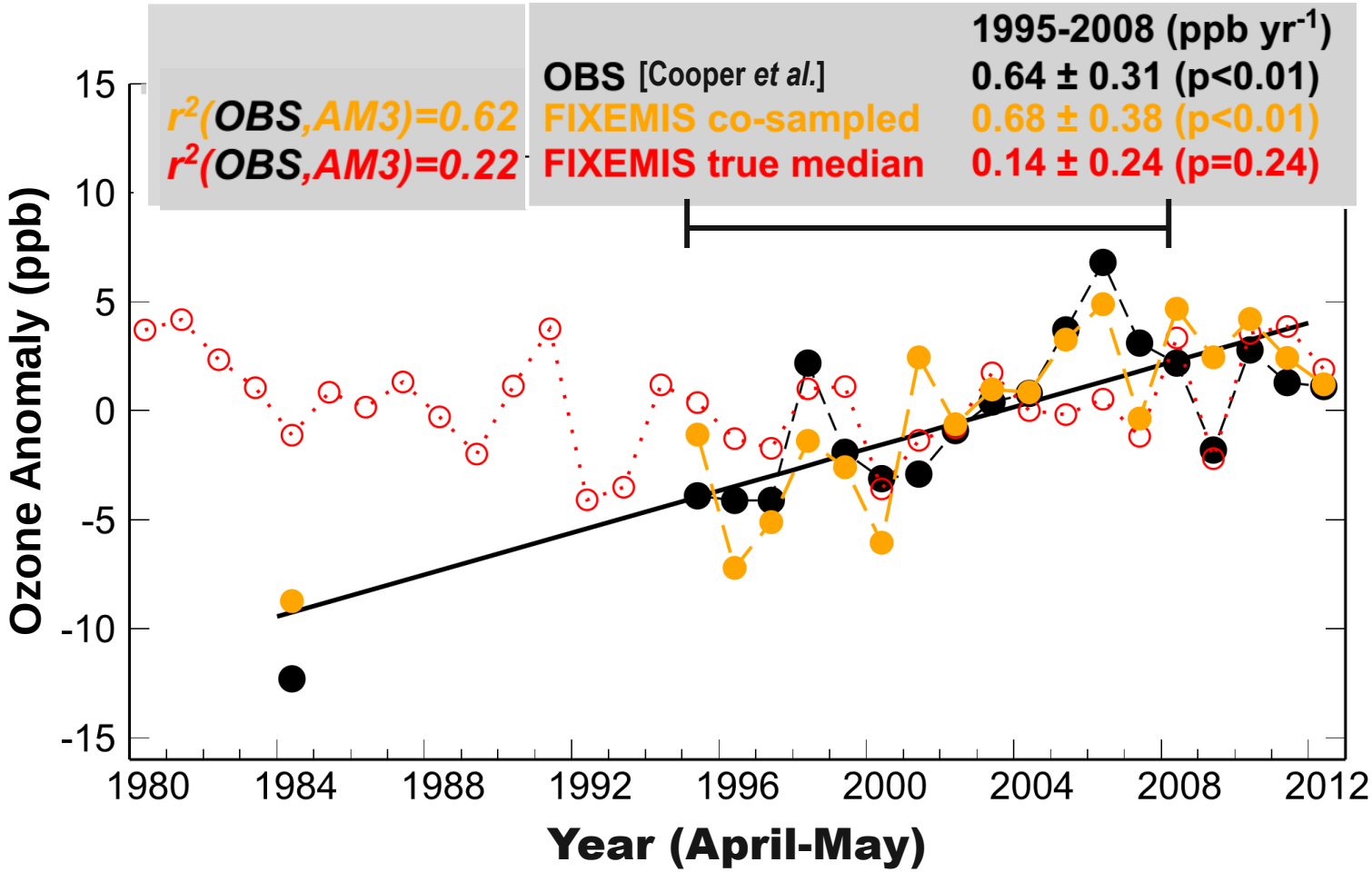
Interpreting representativeness of observation records with GFDL-AM3 hindcast simulations (nudged)



Lin, Meiyun; LW, Horowitz, OR Cooper, et al [GRL, 2015]

Even with constant emissions, AM3 co-sampled reproduces much of observed O_3 variability and trends





→ **Need to improve the current observation network**

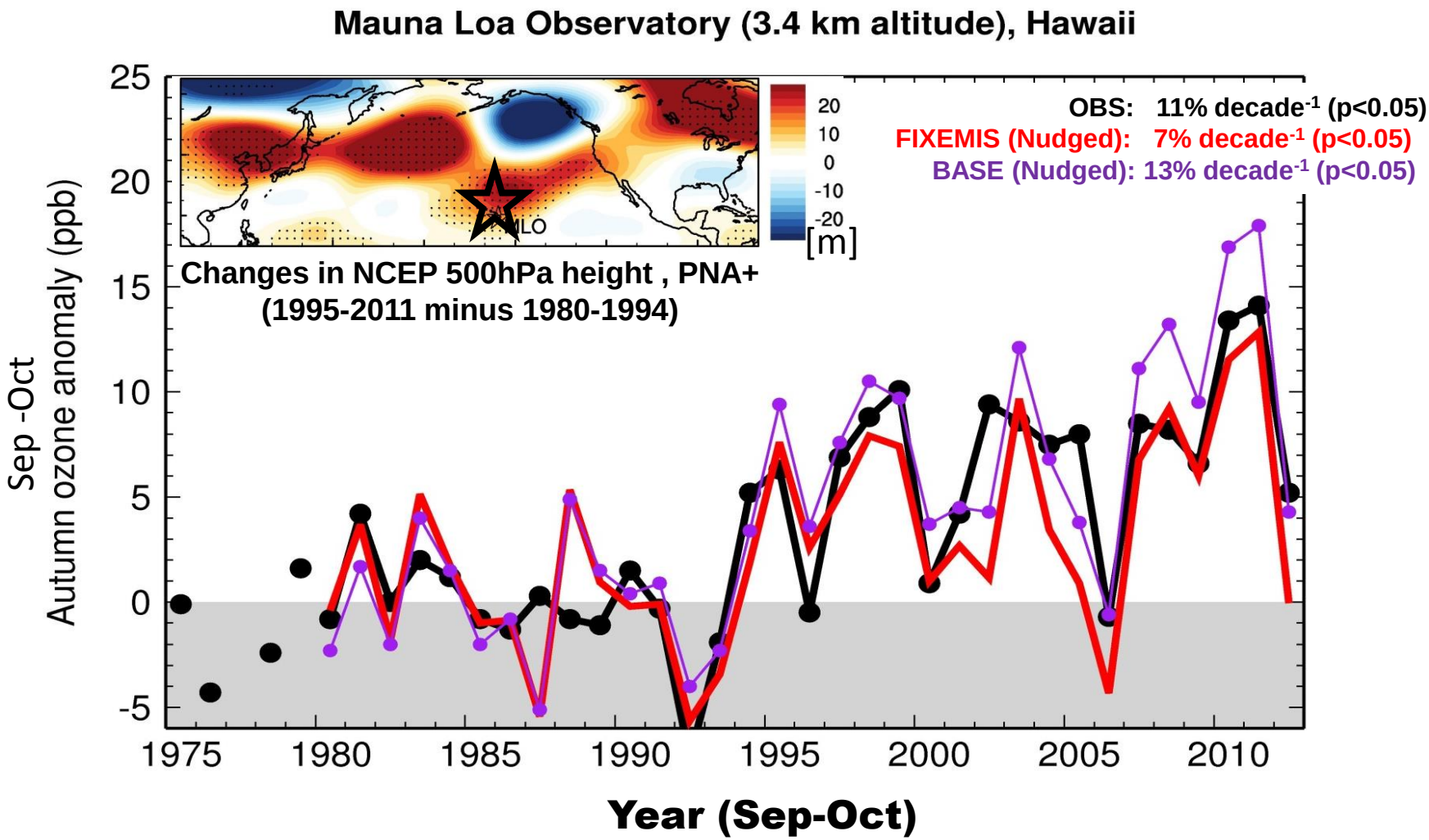
→ **Large met variability & sparse in-situ sampling complicate O_3 trend estimates**

Lin, Meiyun; LW, Horowitz, OR Cooper, et al [GRL, 2015]

nature geoscience

Tropospheric ozone trends at Mauna Loa Observatory tied to decadal climate variability

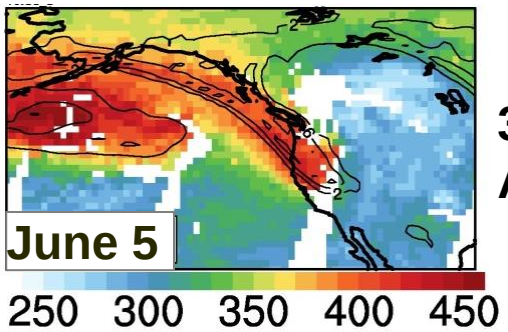
By Meiyun Lin, Larry Horowitz, Samuel Oltmans, Arlene Fiore, and Songmiao Fan (2014)



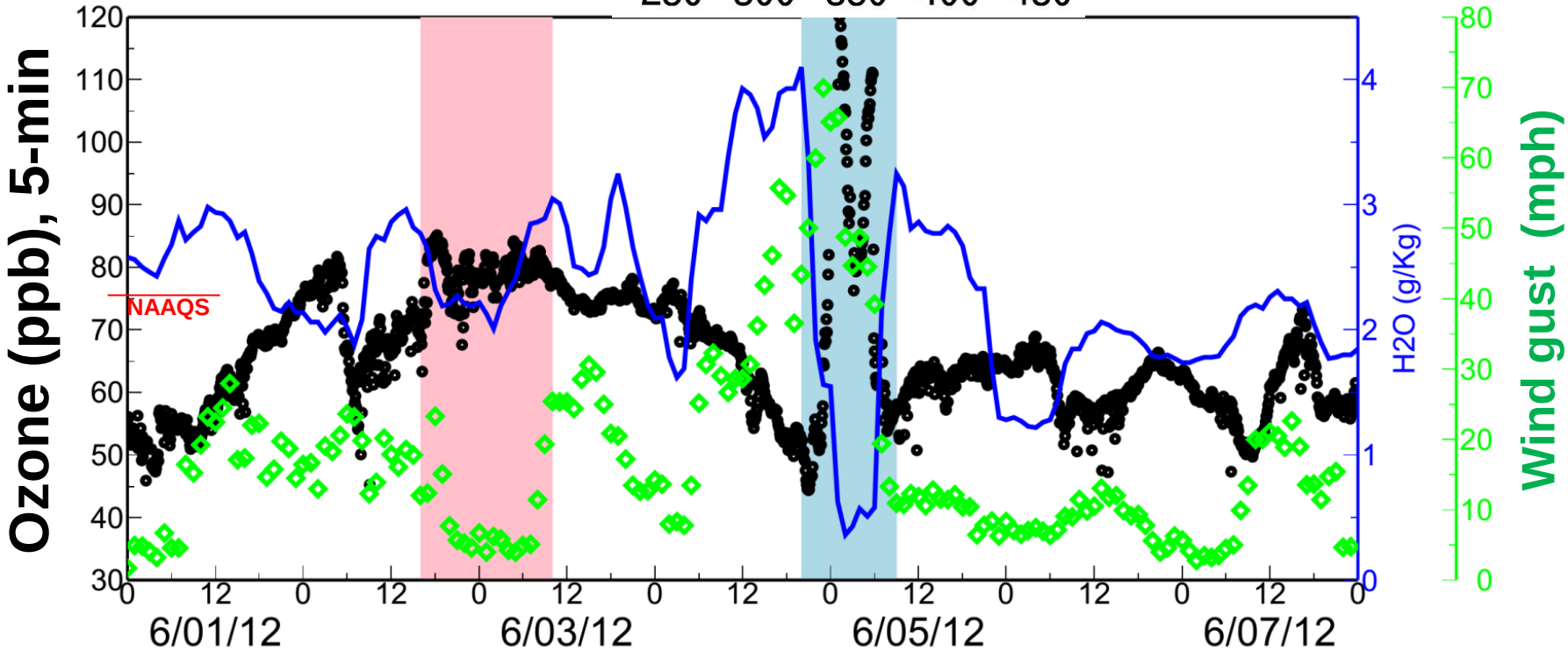
→ **Must consider internal "climate noise" when interpreting baseline O_3 changes!**

Additional Slides for Discussions

Observed evidence of surface high-O_3 events from regional pollution vs stratospheric intrusions



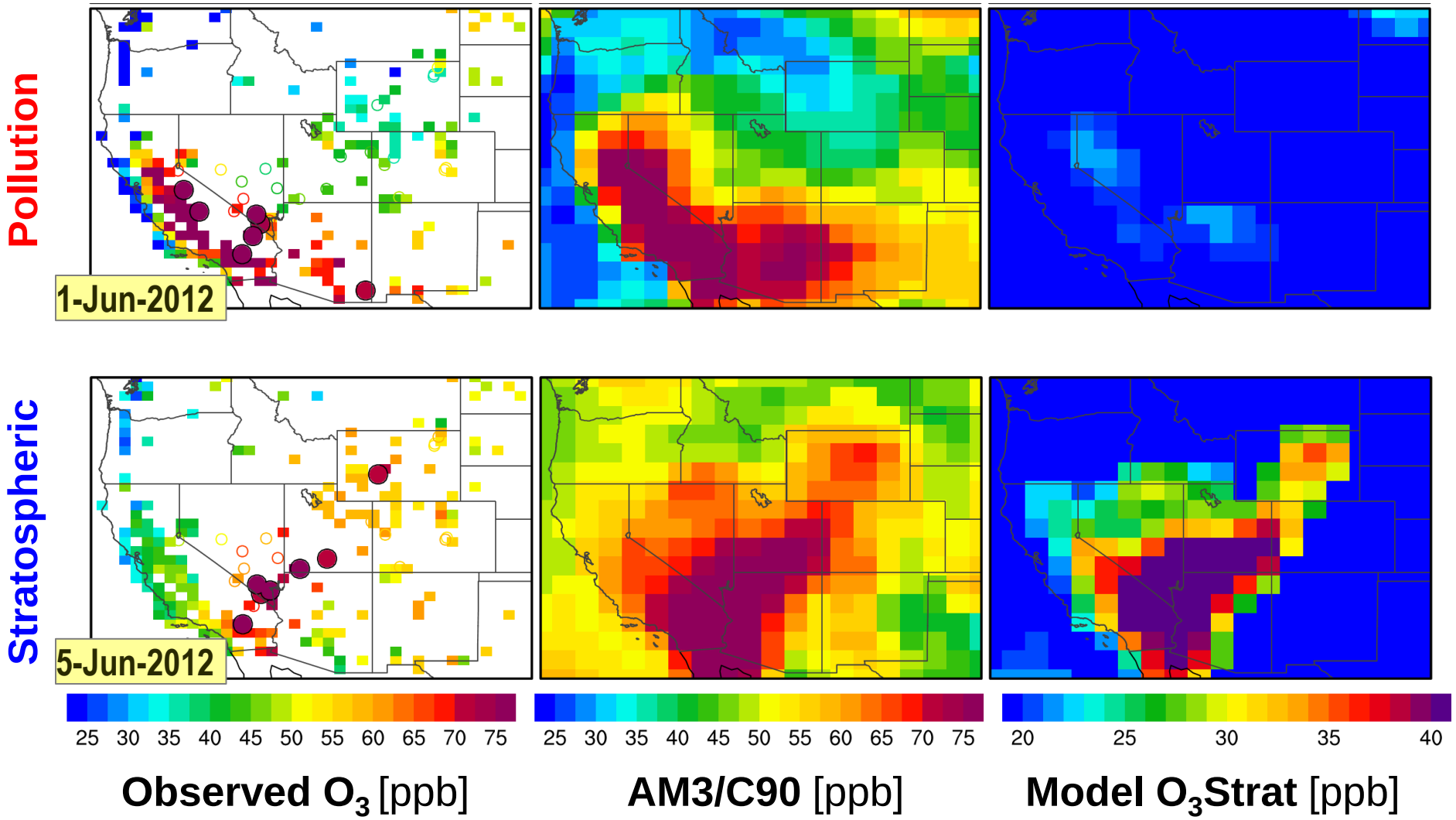
300hPa PV with AIRS Total O_3 [DU]



Spring Mtn Youth Camp, Nevada (2.6 km altitude)

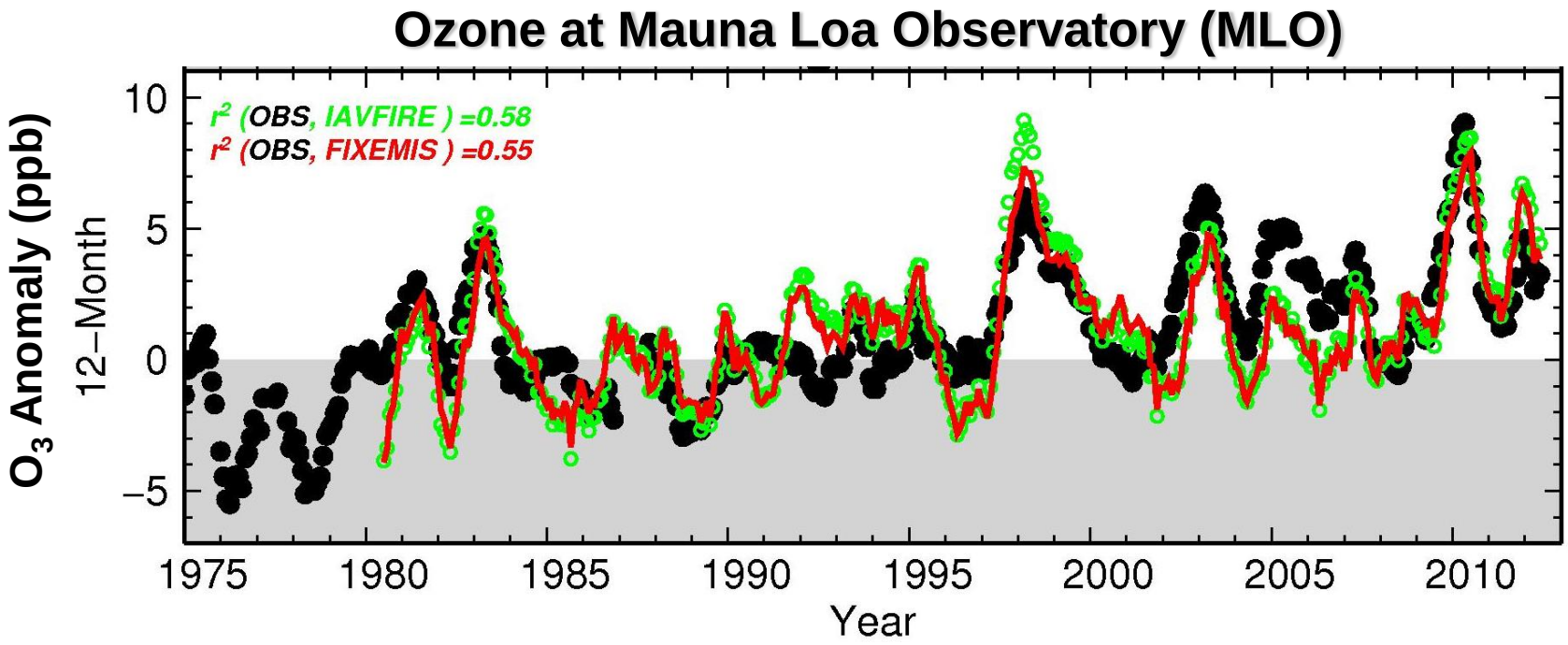
- *Ozone data (Zheng Li, Nevada Clark County)*
- *Meteorological data (NOAA Desert Research Institute)*

Simulated surface high-O_3 events from regional pollution vs stratospheric intrusions



Stratospheric ozone tracer (O_3Strat) as described in Lin MY et al (JGR, 2012b)

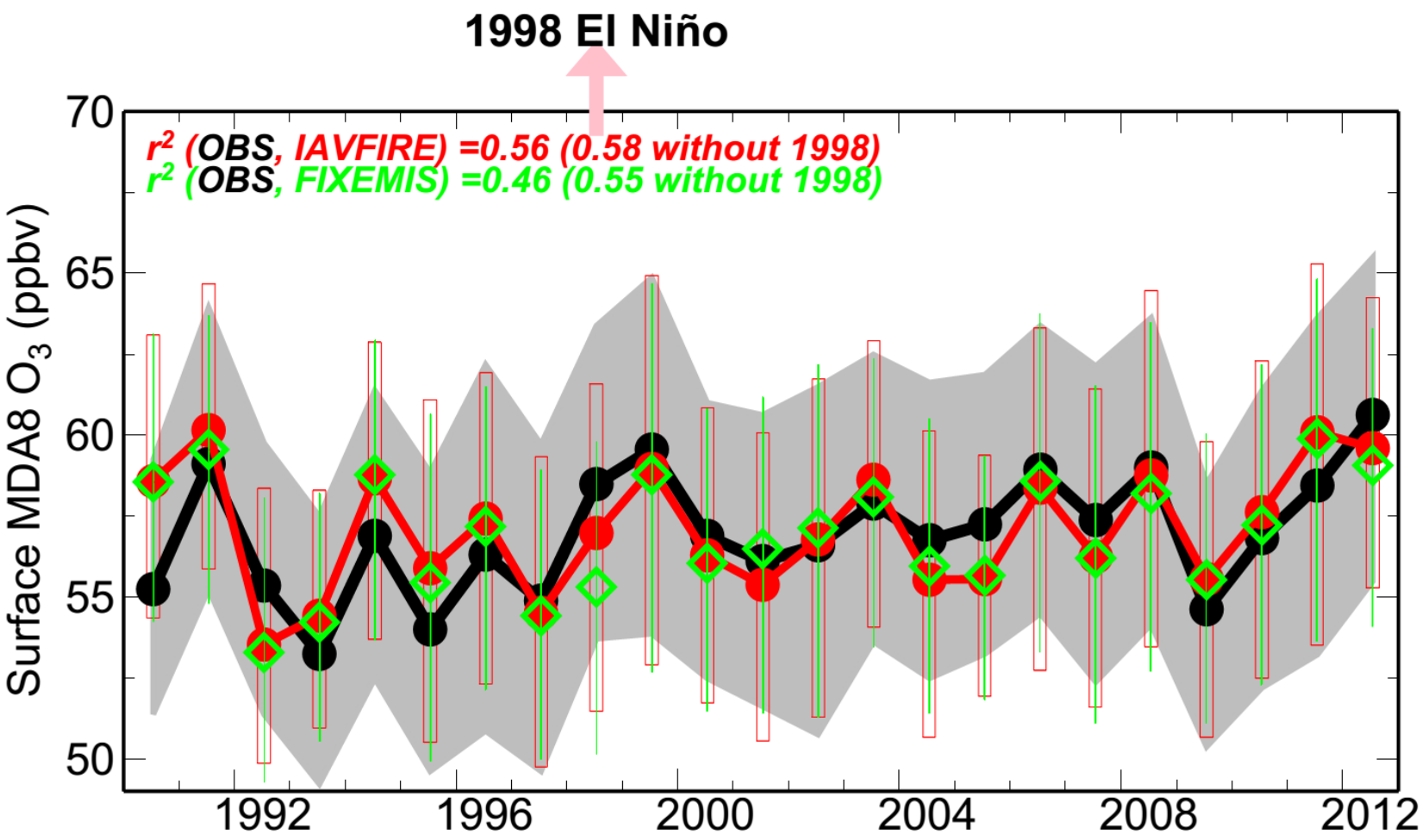
Minor influence from wildfire emissions



- GFDL AM3 with fixed emissions (nudged) captures observed O_3 changes
- Negligible influence from El Niño-related wildfires in equatorial Asia

Lin M.Y. et al (Nature GeoSci., 2014)

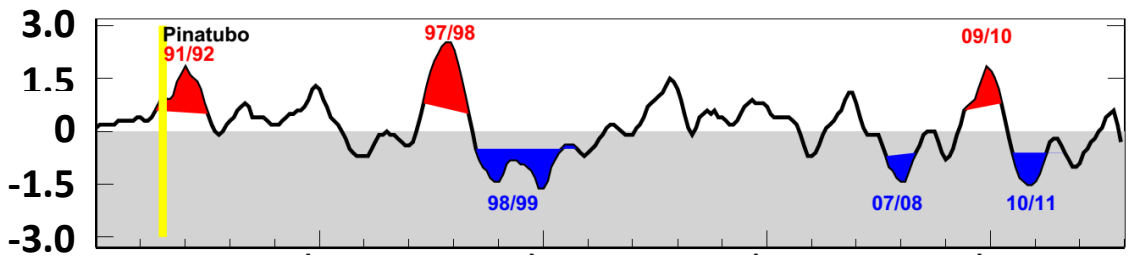
Minor influence from wildfire emissions



Meiyun Lin et al (Nature Communications, 2015)

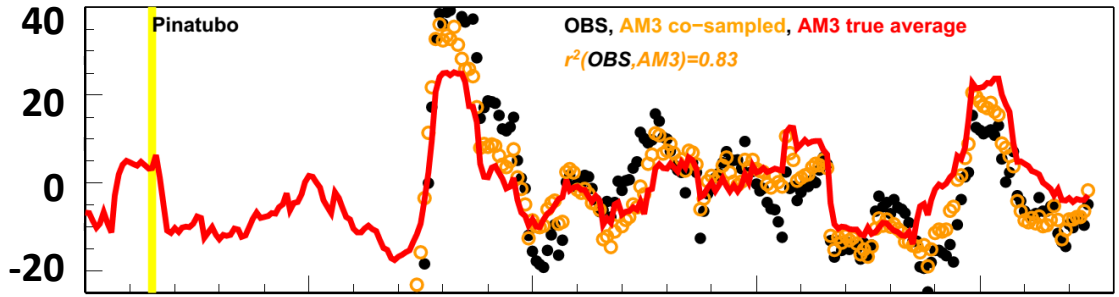
Western US surface O_3 variability correlates poorly with O_3 burdens in the UTLS but strongly with that in the Free Trop

Niño 3.4 Index



12-mon running mean 250-150hPa O_3 anomaly (%)

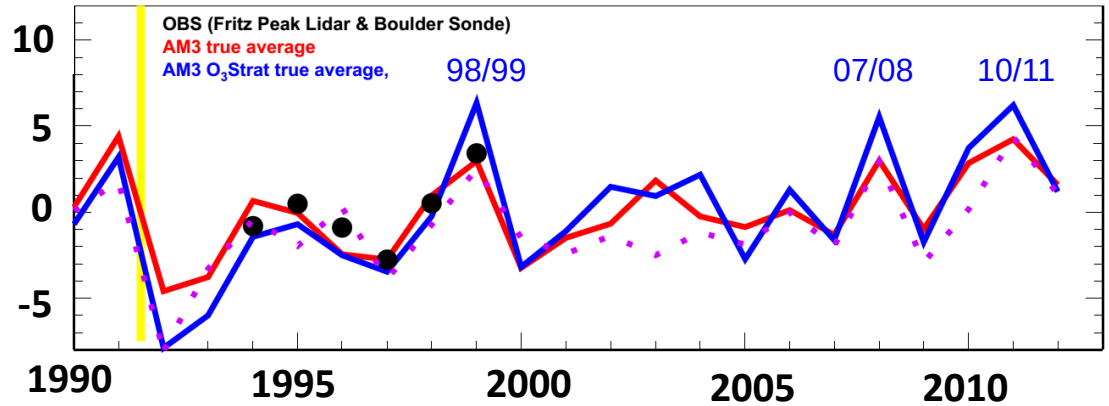
r^2(UTLS, Surface) = 0.07



Trinidad

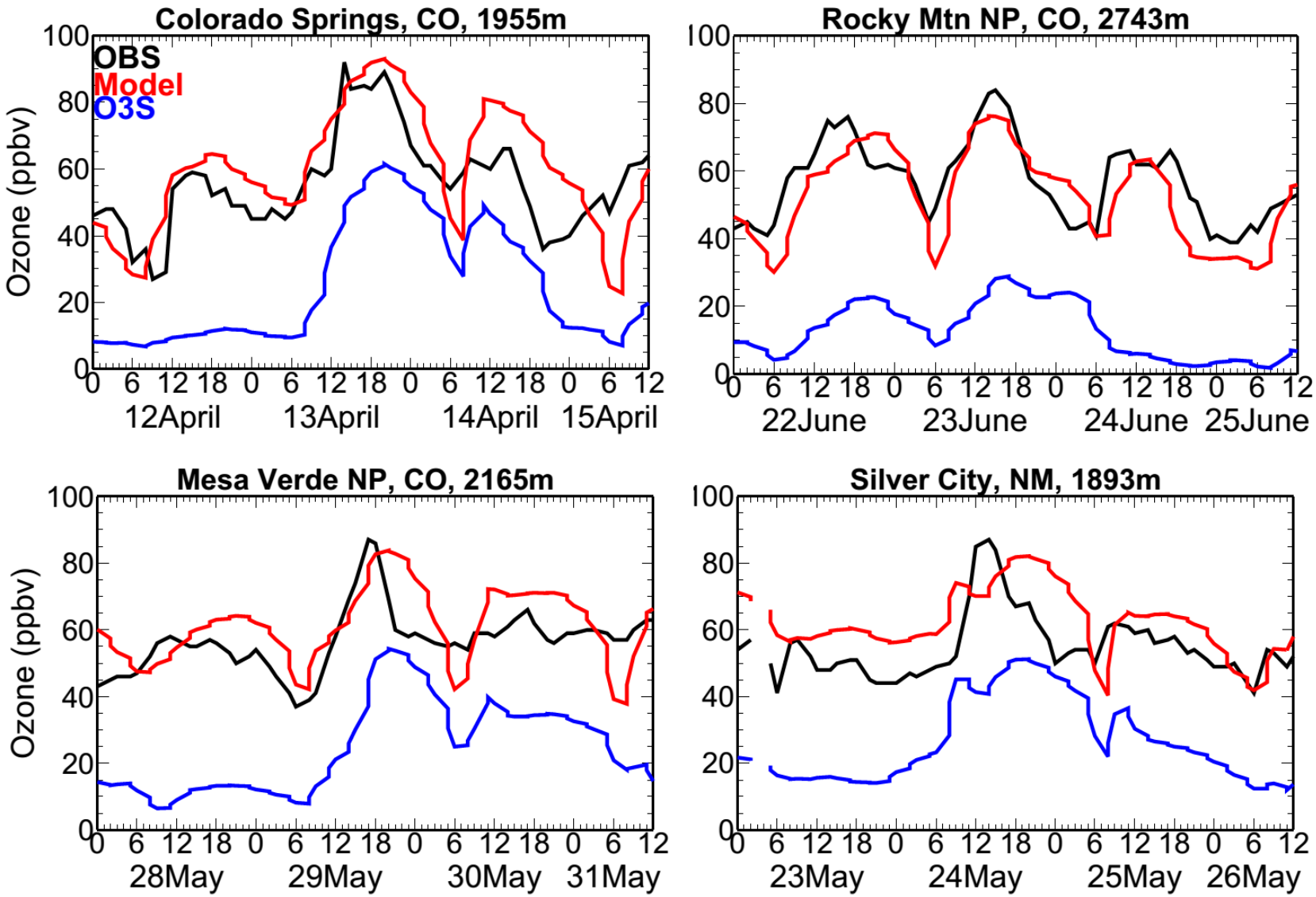
Apr-May mean FreeTrop & Surface O_3 anomaly (ppb)

r^2(FreeTrop, Surface) =0.74



- Langford1999 noted **positive correlations** btw FreeTrop and UTLS O_3 observed at Fritz Peak **during 1994-1998** (without La Niña years)**:** AM3 captures the observed relationship (r^2=0.69) for this short record but indicates **little correlation** (r^2=0.18) **for the entire 1990-2012 period.**

Diurnal variations



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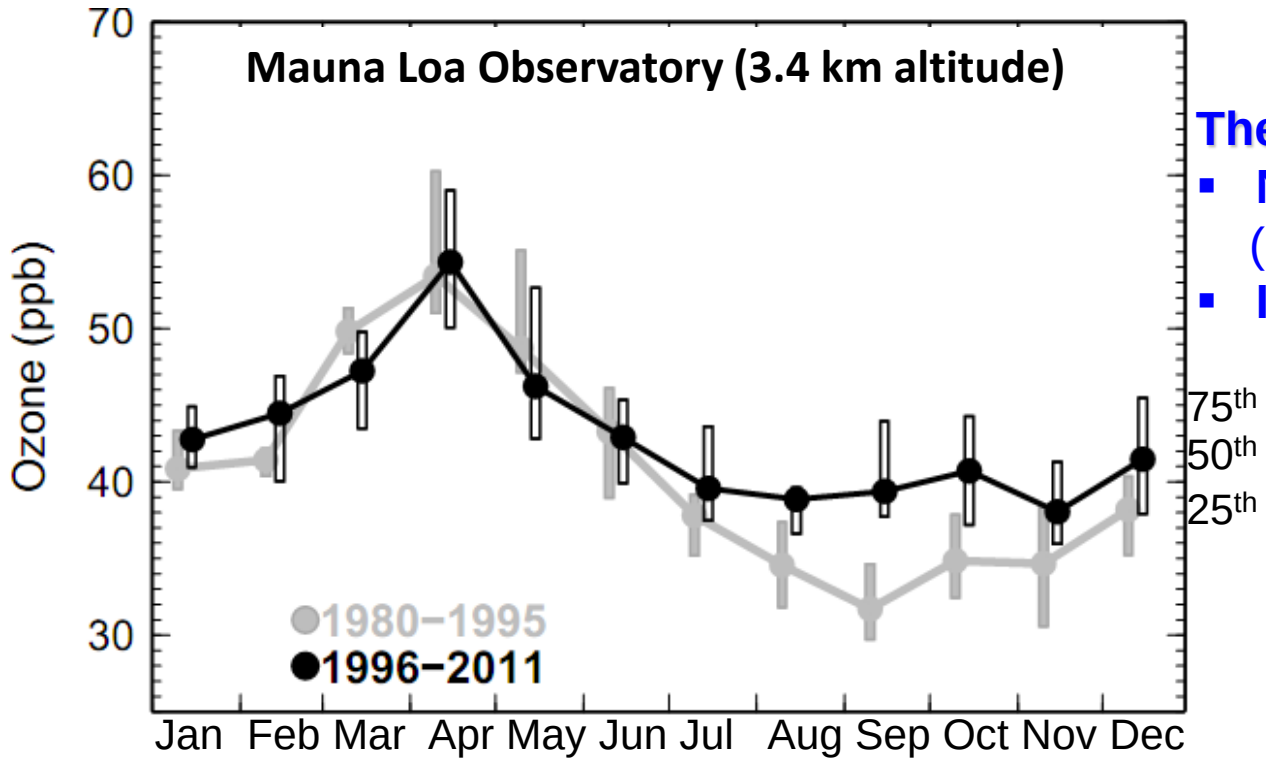
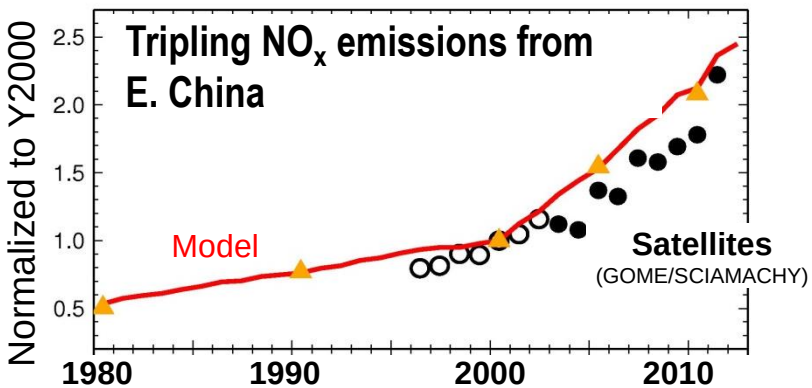
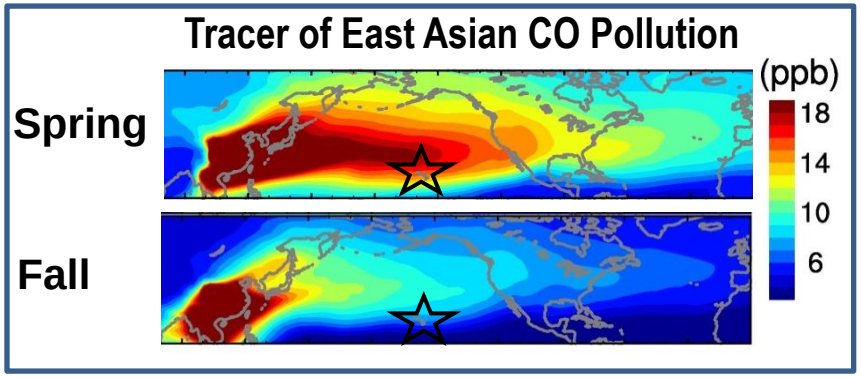


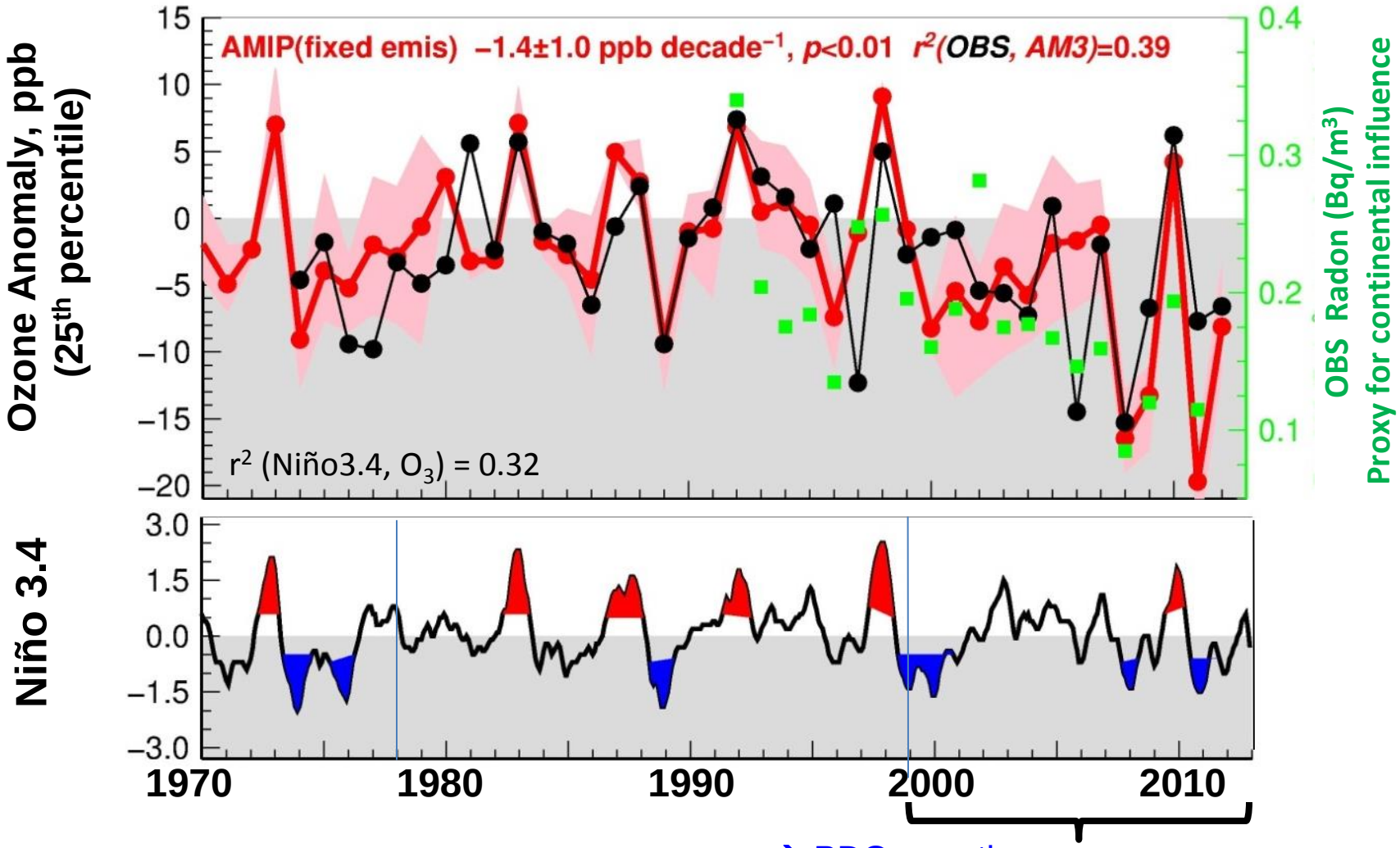
The puzzle:

- **No trend in spring** (*decrease in 25th*)
- **Increase in fall**





Springtime ozone variability at Mauna Loa tied to ENSO (interannual) and PDO (decadal)



→ PDO negative [Chavez2003; Meehl2013; Kosaka2013]
→ Expansion of Hadley Cell [Seidel & Fu et al., 2008]
→ Poleward shift of subtropical jet [Allen et al., 2014]
→ Offsetting rising O_3 from Asian emissions

Lin M.Y. et al (Nature GeoSci., 2014)