On the Role of Climate Variability on Tropospheric Ozone

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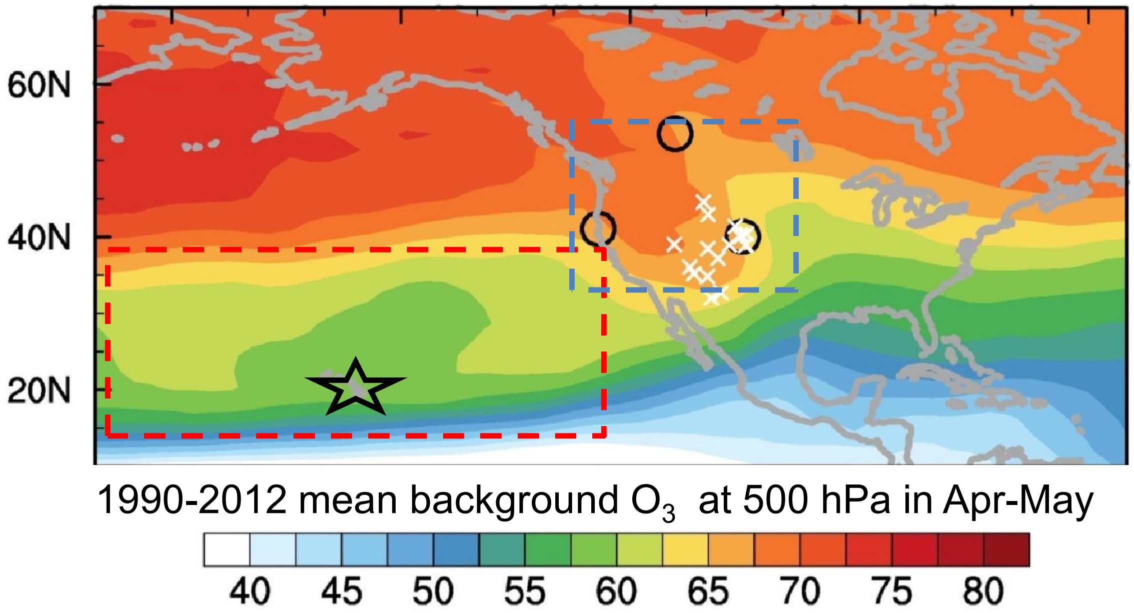
Drivers of trop. O_3 variability over the North Pacific and Western N. America in SPRING



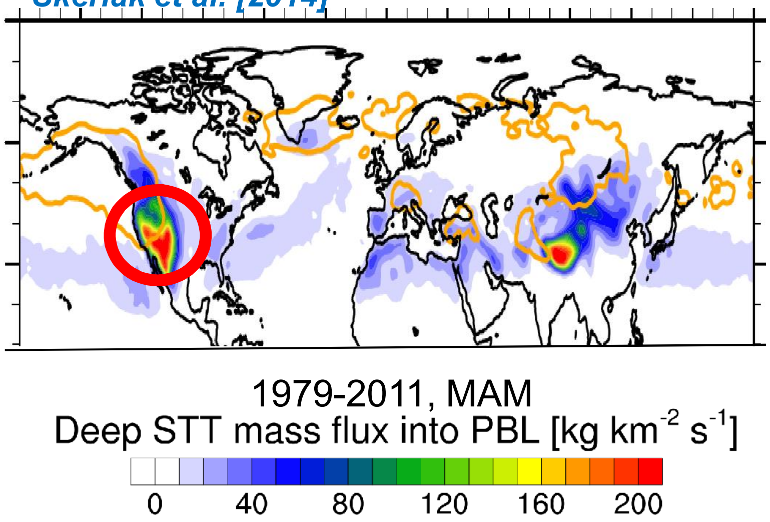
1990-2012 mean background O_3 at 500 hPa in Apr-May

WESTERN U.S.

- Sensitive to the eddy-driven jet
- Highly variable on synoptic time scales
- Prone to deep strat. Intrusions

Langford et al. 2009; Lin et al. 2012ab

Skerlak et al. [2014]



1979-2011, MAM
Deep STT mass flux into PBL [kg km^{-2} s^{-1}]

PACIFIC SUBTROPICAL REGION:

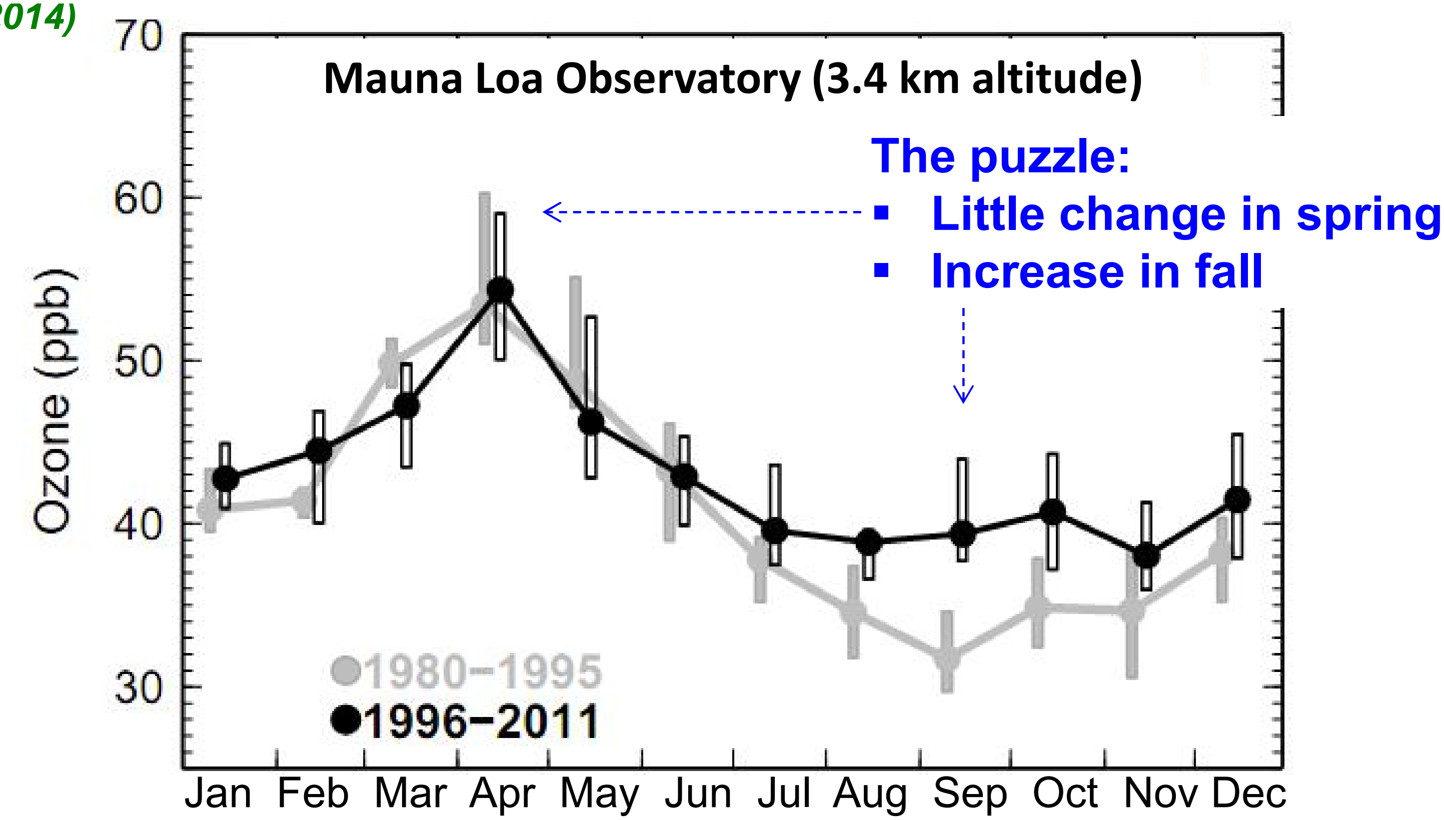
- Sensitive to the subtropical jet location *[Zeng & Pyle 2005; Koumoutsaris et al 2008; Neu et al 2014]*
- Greater Asian than stratospheric influence on variability *[Lin et al., Nature Geosci, 2014a]*

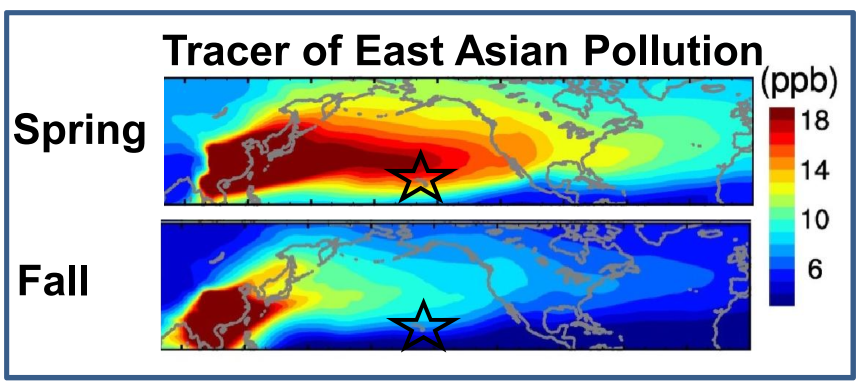
NEED PROCESS-LEVEL UNDERSTANDING ON DAILY TO MULTI-DECADAL TIME SCALES

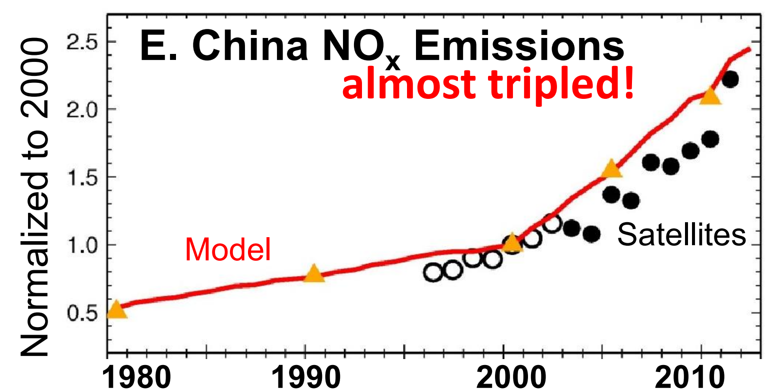
nature geoscience

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

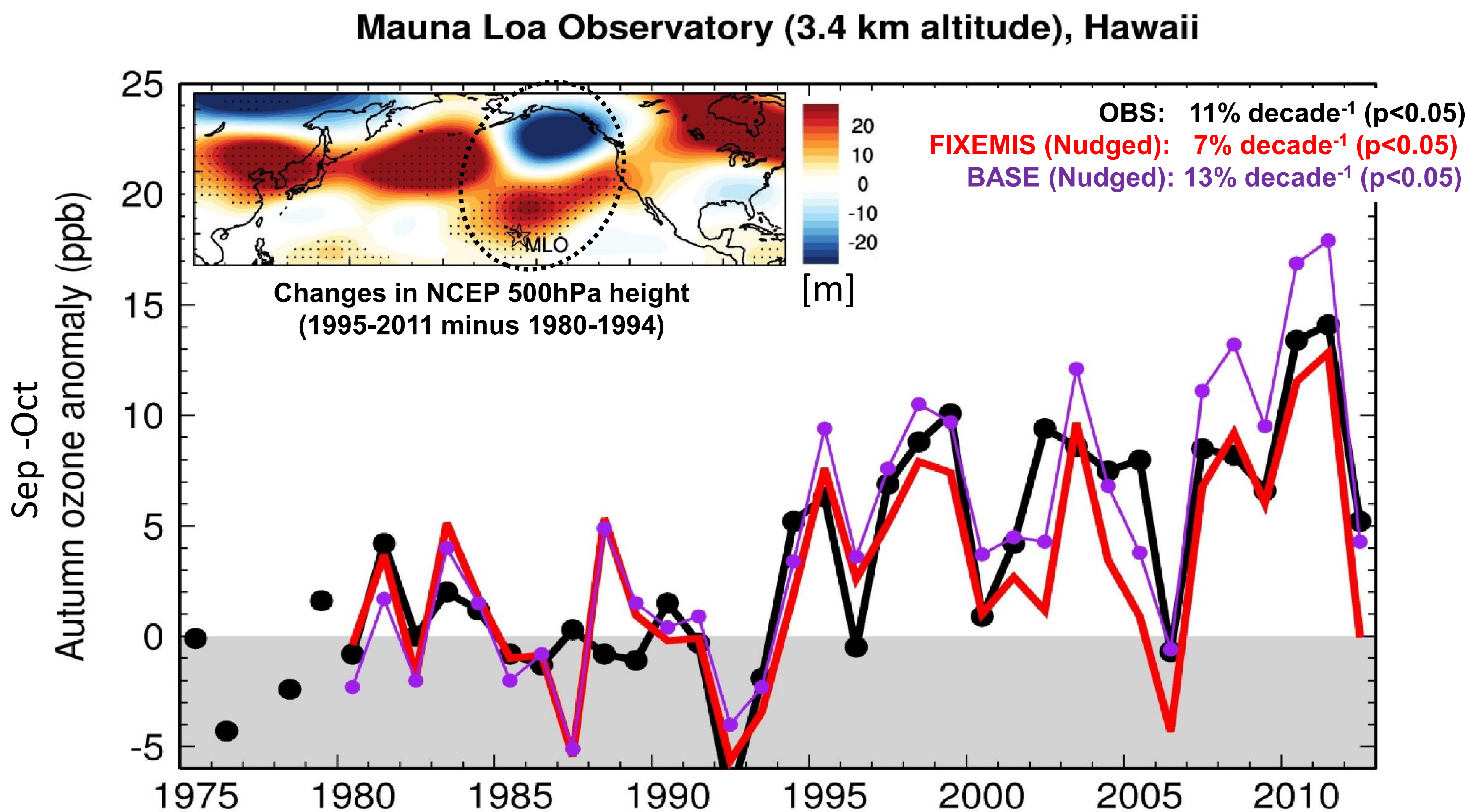
Lin M.Y. et al (2014)





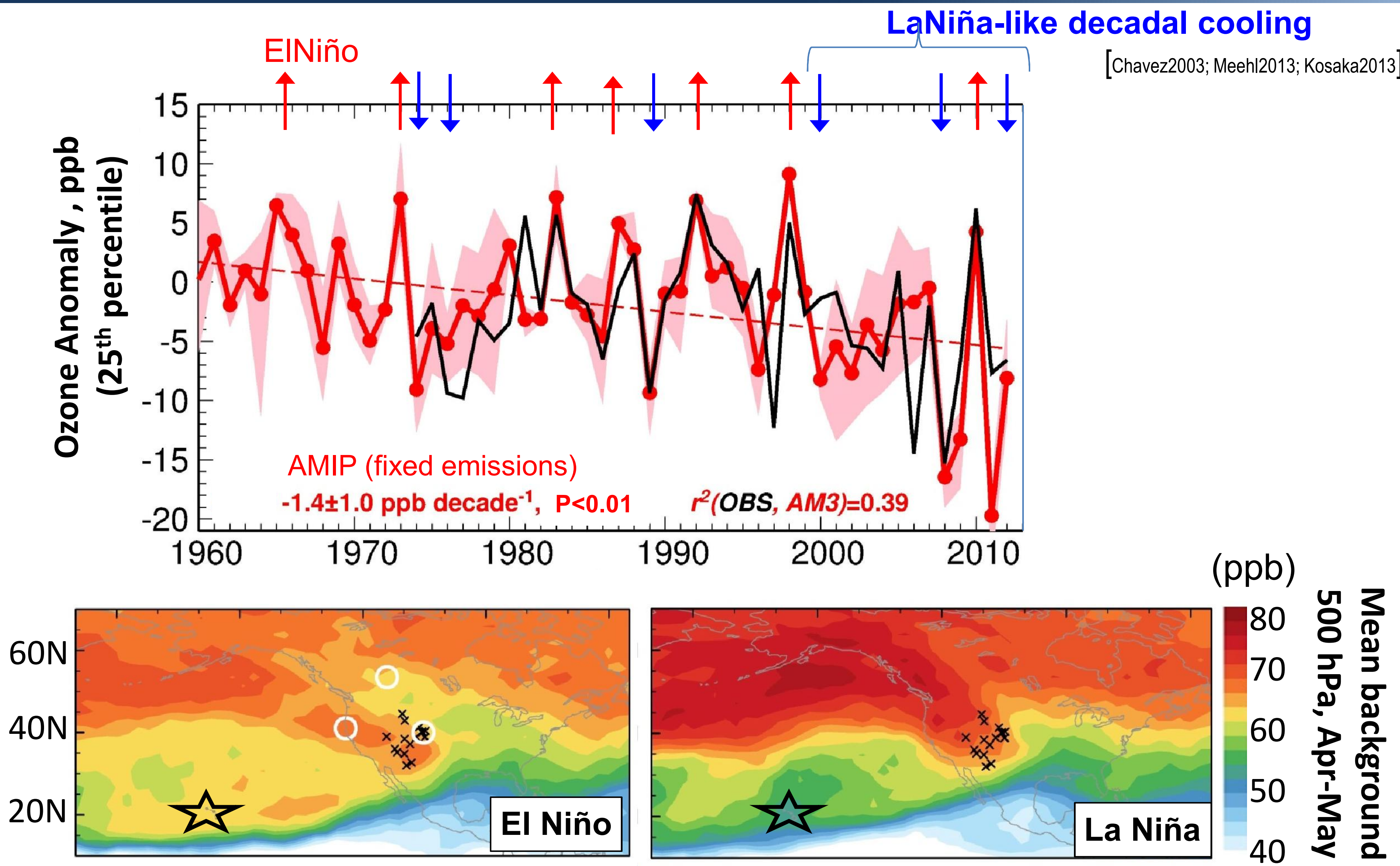


Increasing ozone at Mauna Loa in FALL tied to a shift in circulation patterns since the mid-1990s



Must consider decadal climate variability as well as emission changes for attribution of pollutant trends

Decreasing ozone at Mauna Loa in SPRING tied to recent La-Niña-like decadal cooling + weakening airflow from Asia



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

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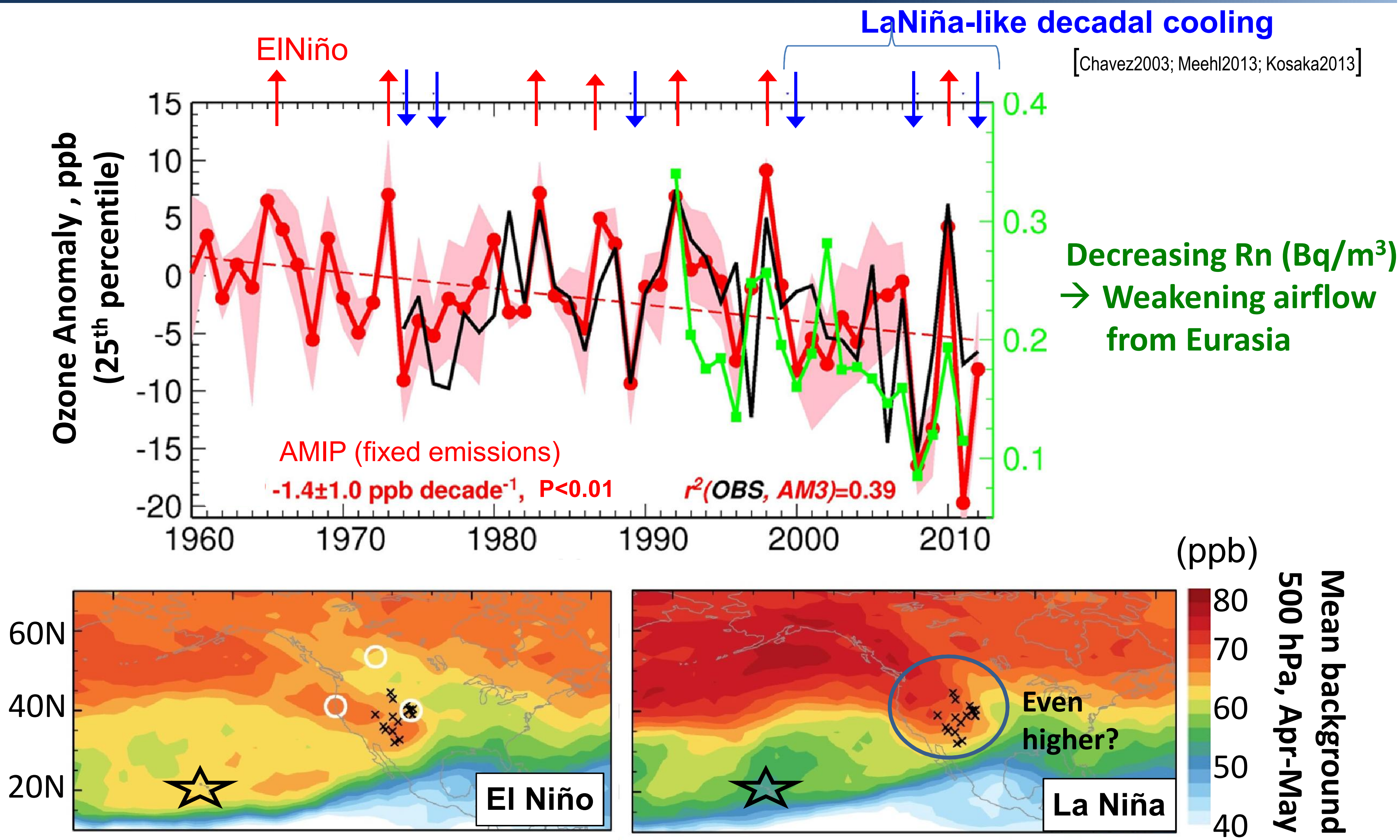
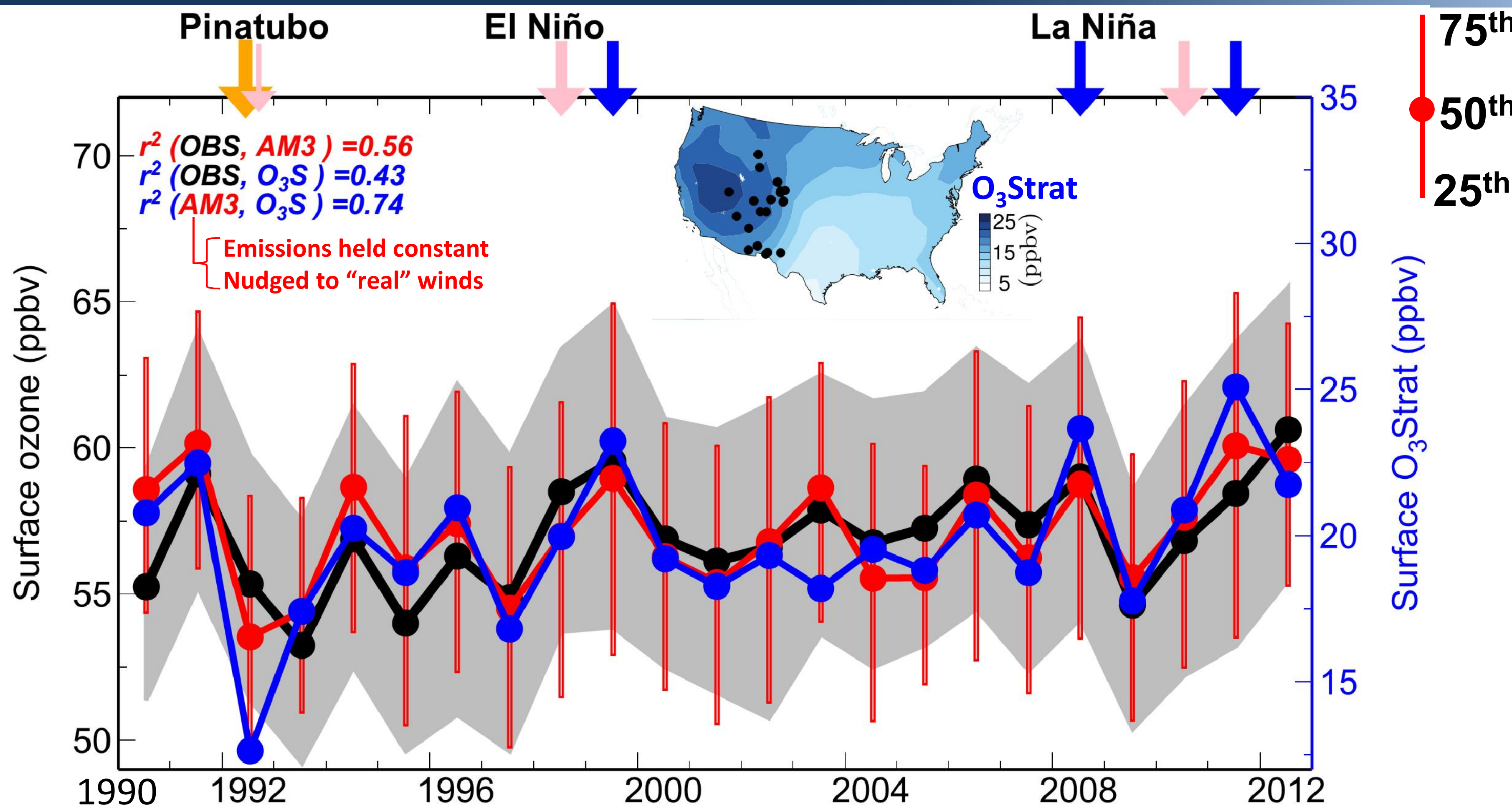


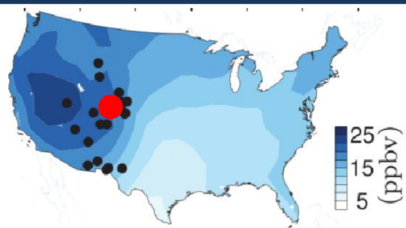
Lin M.Y. et al (Nature GeoSci., 2014)

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



- In contrast, the influence of wildfire emissions and Asian pollution are minimal (see paper)
- Large IAV may complicate the attribution of observed O_3 trends in short records.

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



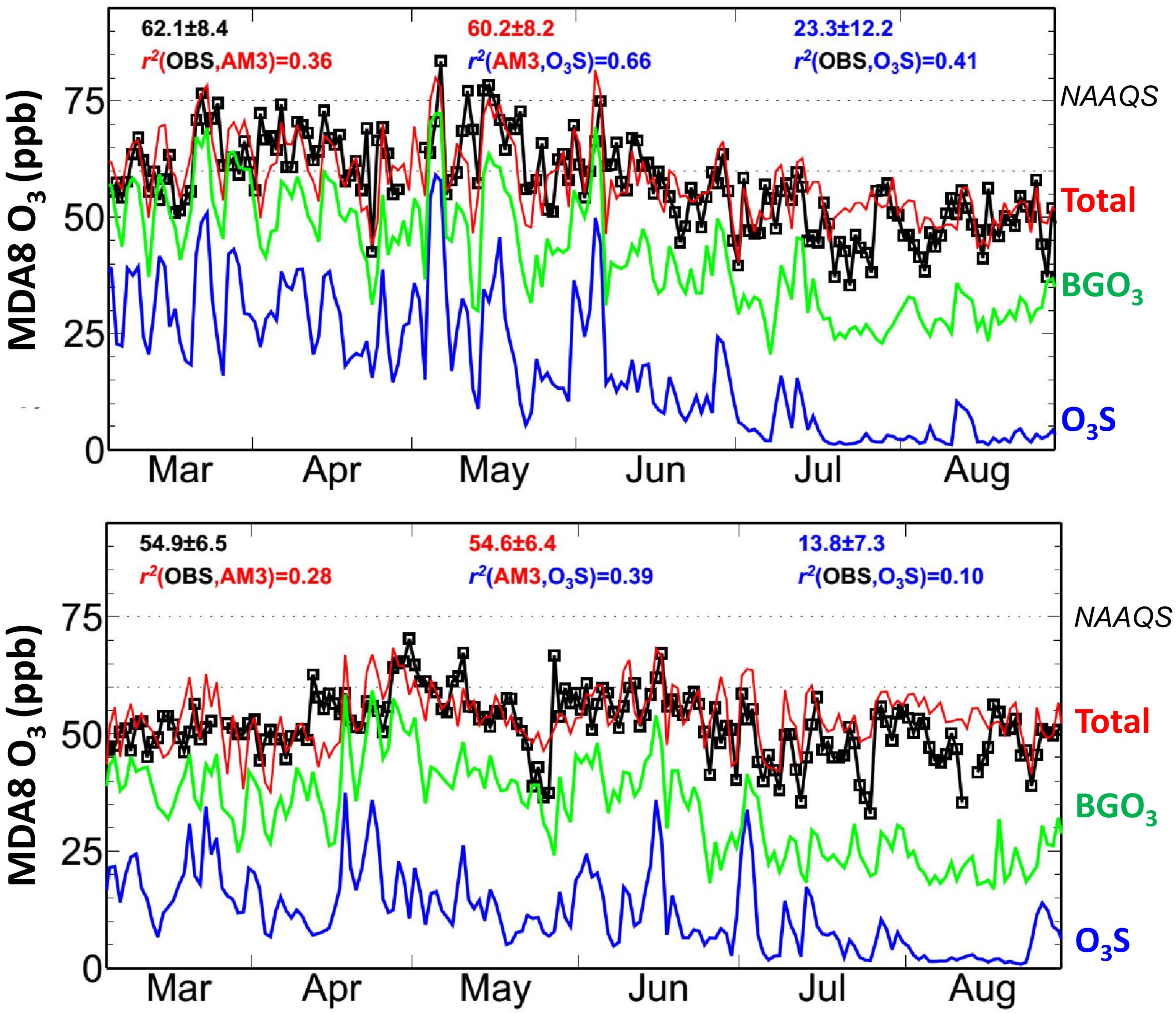
1999 (La Niña)→

- Frequent deep STT events

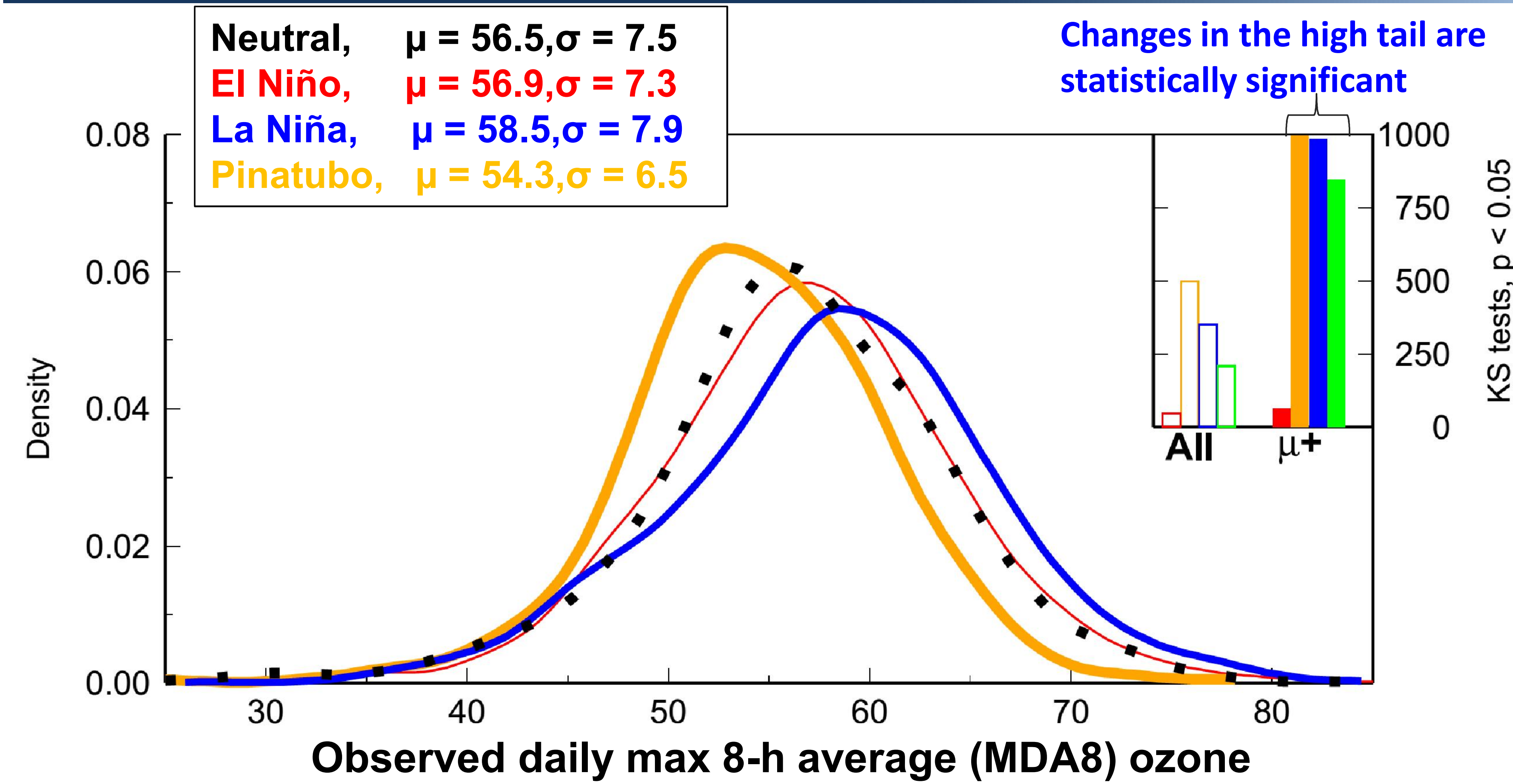
1992 (Pinatubo)→

- Weaker events, lower mean values

Gothic in the Colorado Rocky Mtn (2.9 km altitude)



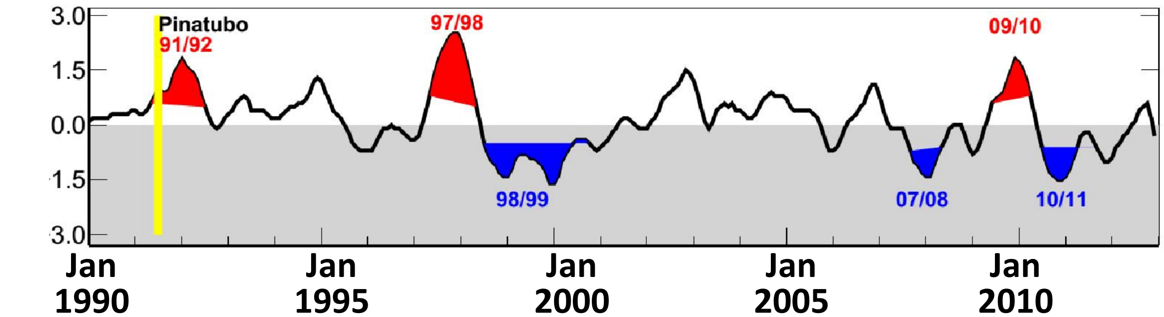
The high tail of the observed daily surface O_3 distribution over Western U.S. increases during La Niña springs



- **Little change in WUS surface O_3 during El Niño despite increased UTLS O_3 burdens reported previously** [e.g. Langford1998; Bronnimann2004; Neu2014].

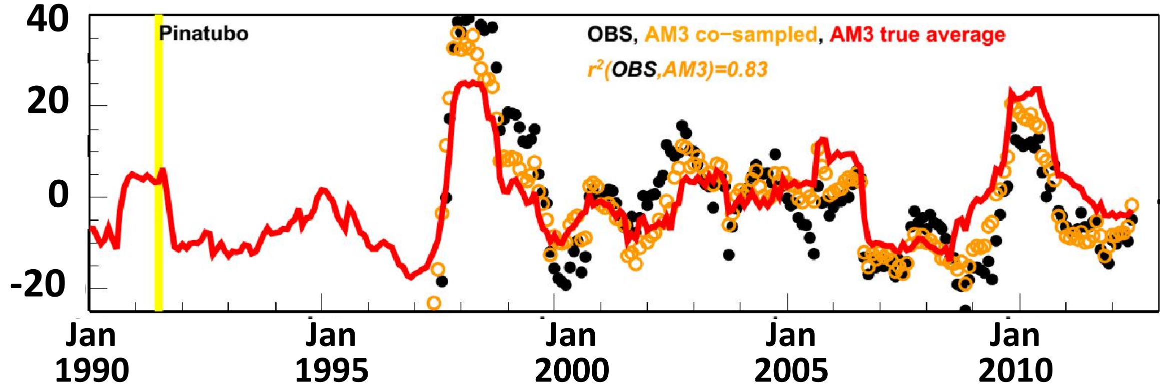
Western US surface O_3 variability correlates poorly with O_3 burdens in the UTLS but strongly with that in the Free Trop

Niño 3.4 Index



12-mon running mean UTLS O_3 anomaly (%)

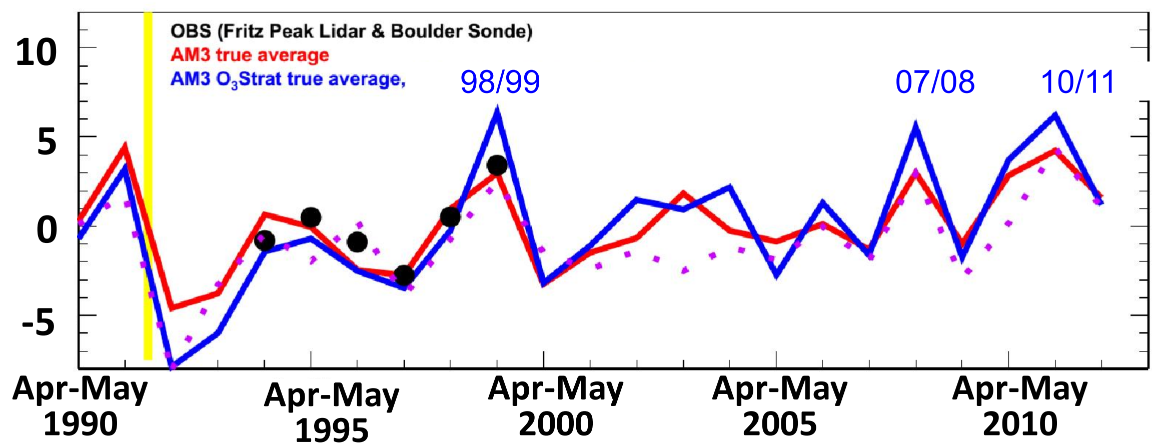
r^2(UTLS, Surface) = 0.07



Trinidad

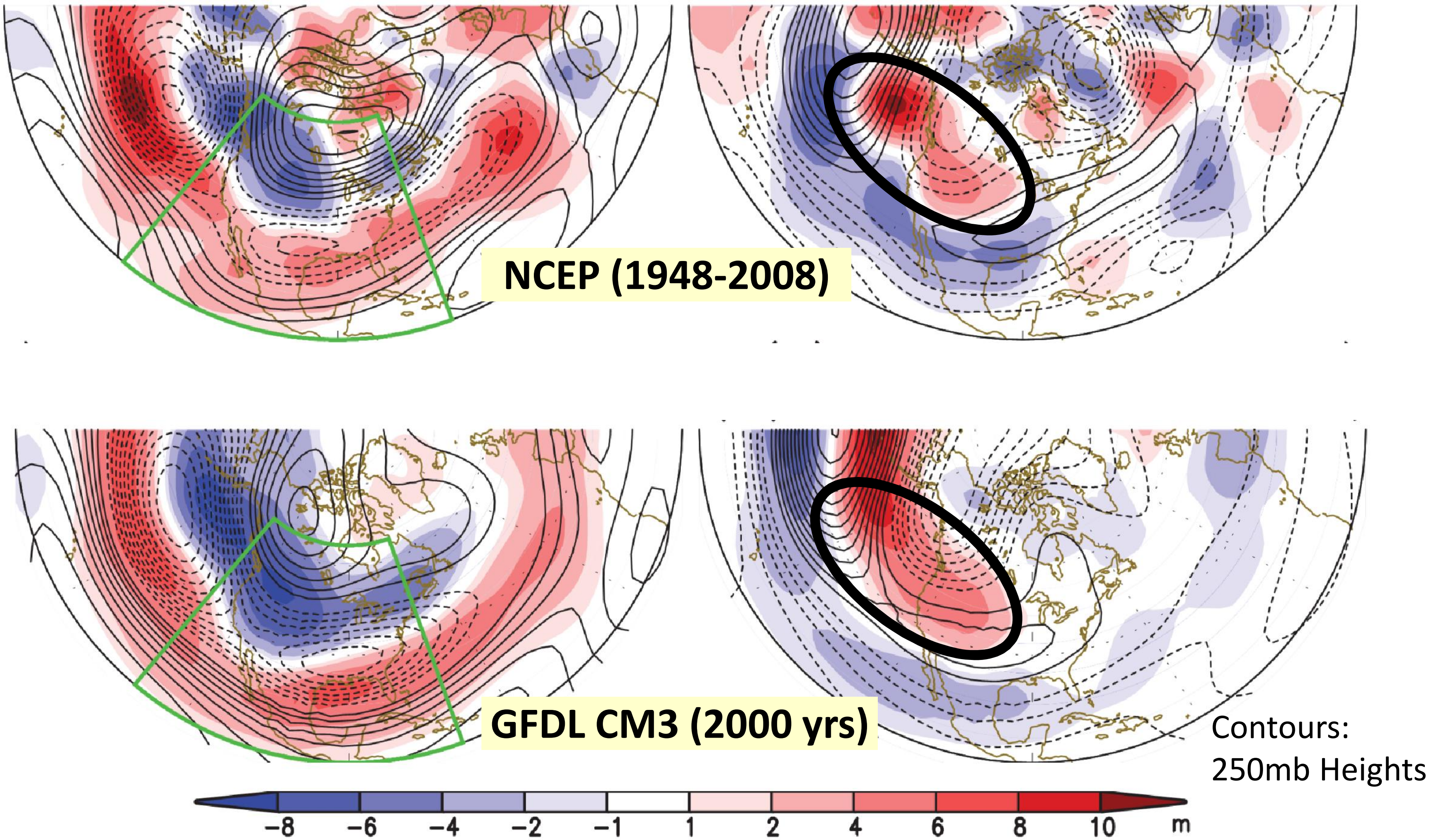
Apr-May mean FreeTrop & Surface O_3 anomaly (ppb)

r^2(FreeTrop, Surface) =0.74



Late winter storm-track shifts towards U.S. Pacific Northwest during La Niña, facilitating deep tropopause folds

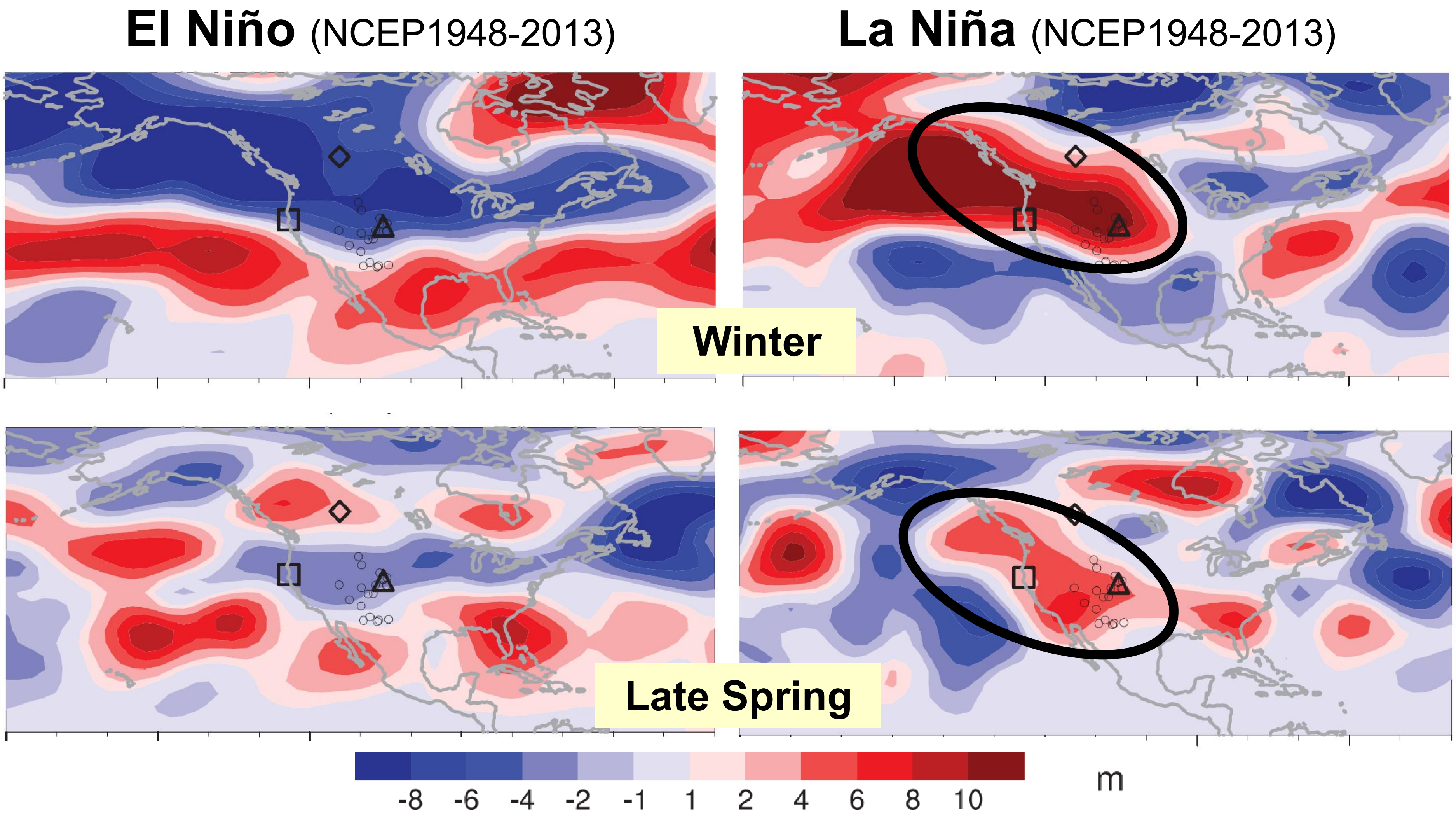
El Niño **La Niña**



Anomalies in rms of 2-10-day bandpassed filtered 500mb heights

- *Figure from Li & Lau (J. Climate, 2012); See also discussions in* Trenberth et al, 1998; Seager2010

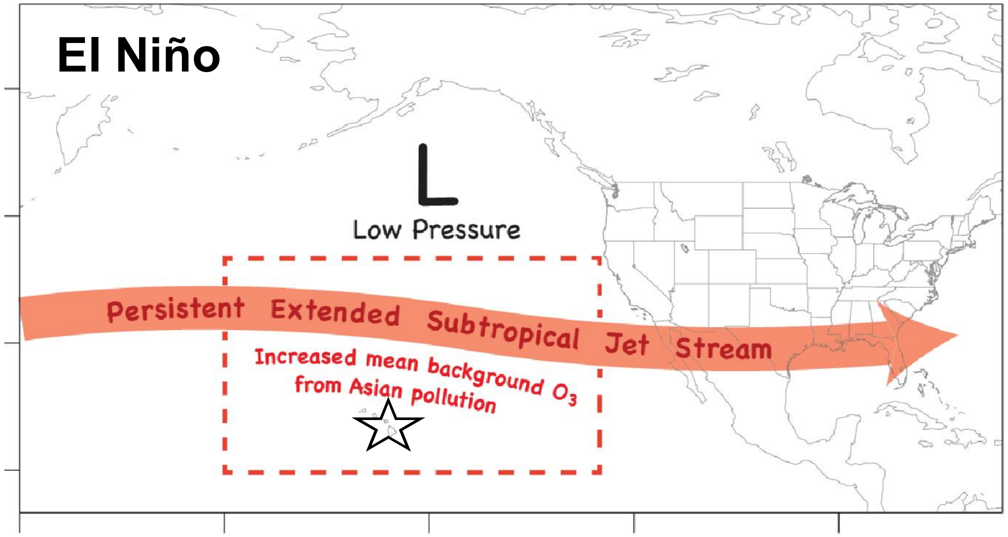
The enhanced storm-track activity over the central western U.S. persists in late spring for strong La Niña episodes

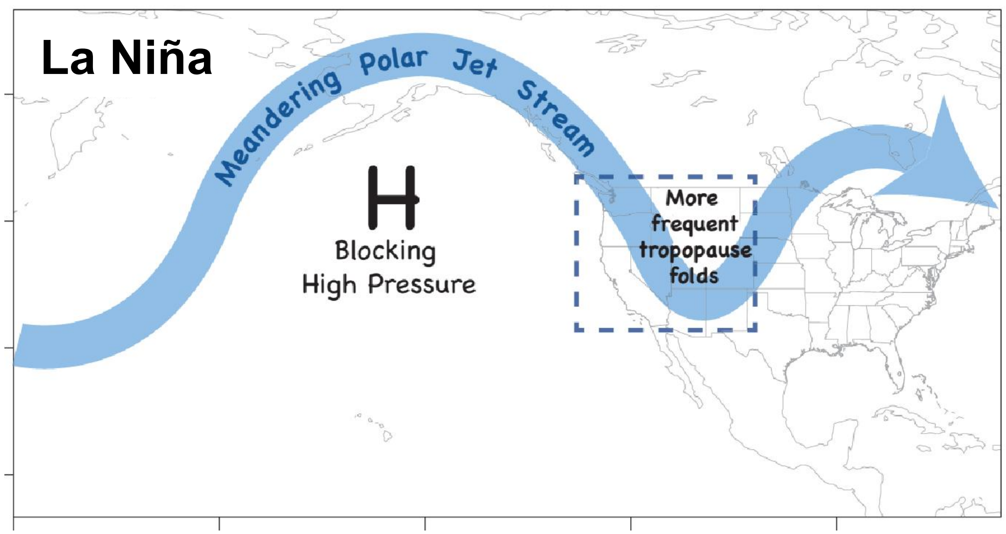


Anomalies in rms of 2-10-day bandpassed filtered 500mb heights

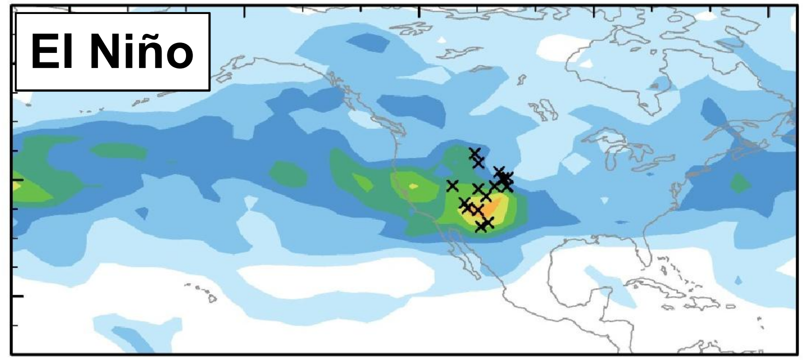
Lin M.Y. et al (in review, 2014b)

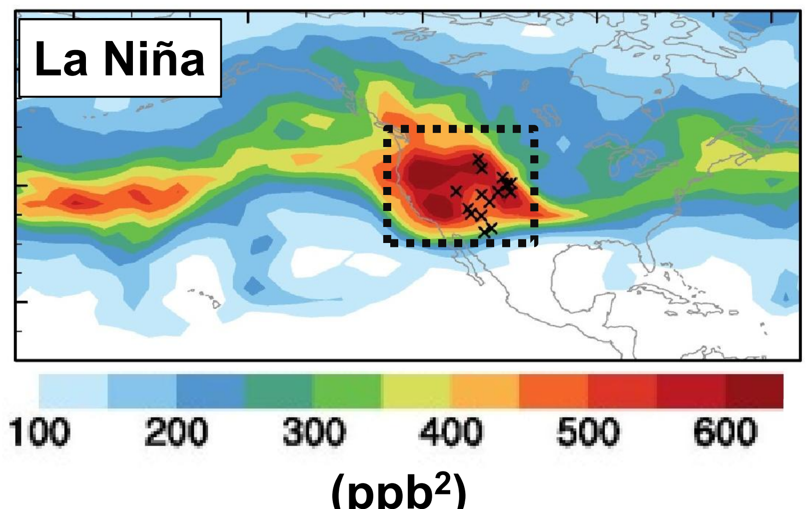
Summarizing sources in daily to interannual variability of lower trop. ozone during spring related to ENSO





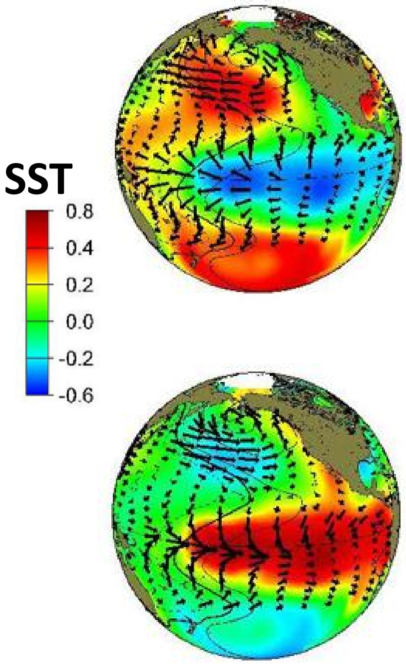
Variance in daily O_3Strat at 500hPa





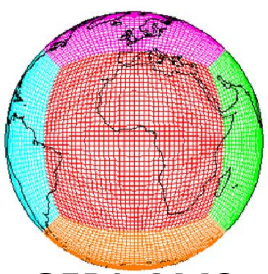
Lin M.Y. et al (Nature GeoSci., 2014a); Lin M.Y. et al (in review, 2014b)

Take-Home Messages



La Niña Winter → **More frequent deep STT events in the following spring over Western US;** ***Potential for seasonal prediction***

El Niño Winter → **Little influence on Western US surface O_3 despite increased UTLS O_3 burdens**



GFDL AM3

Must consider climate variability when interpreting observed trends in tropospheric ozone levels.

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Additional slides for Q & A

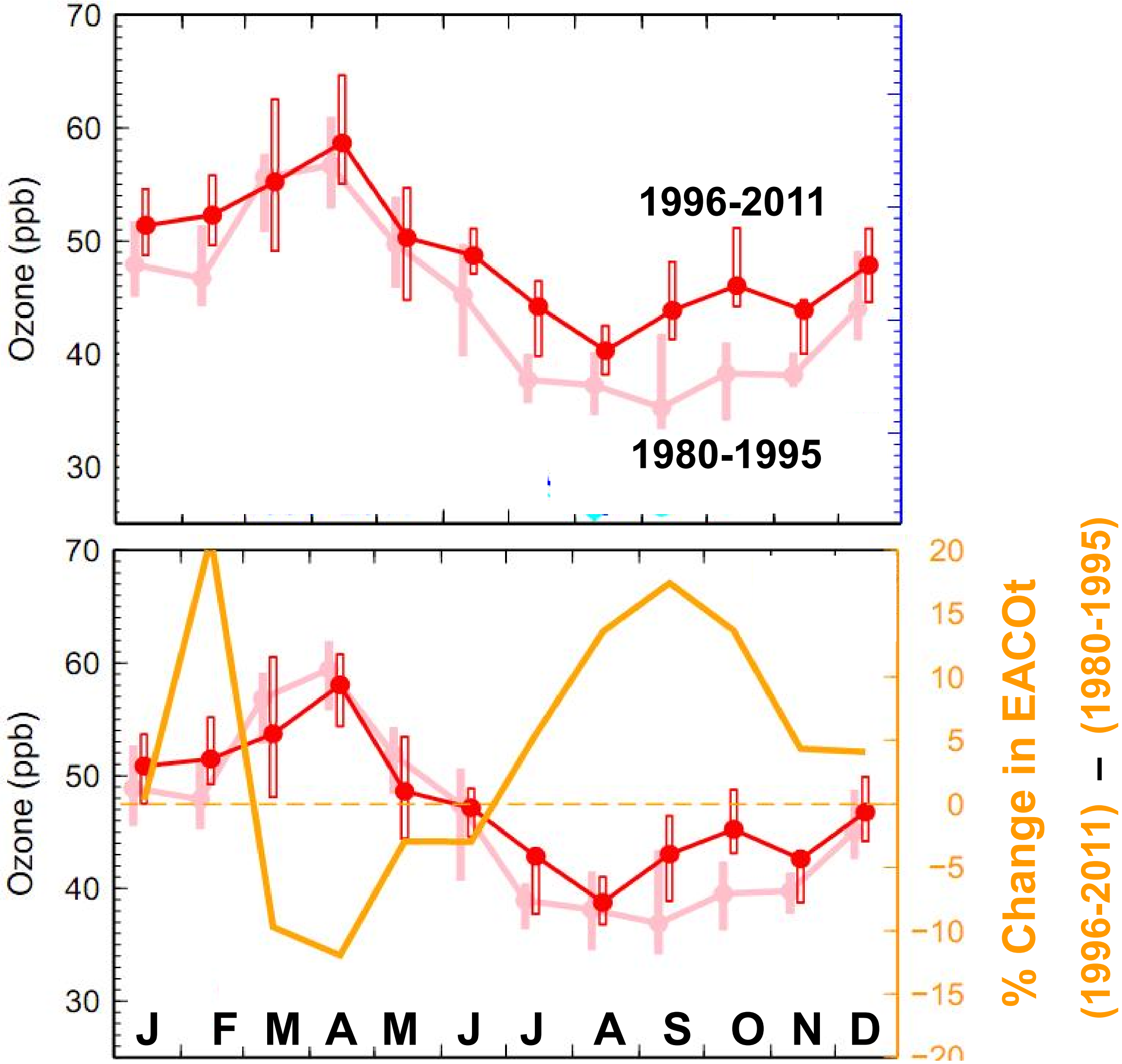
GFDL model indicates influence from circulation shifts that modulate Asian pollution reaching Hawaii

BASE

- Varying emissions
- Nudged to "real winds"

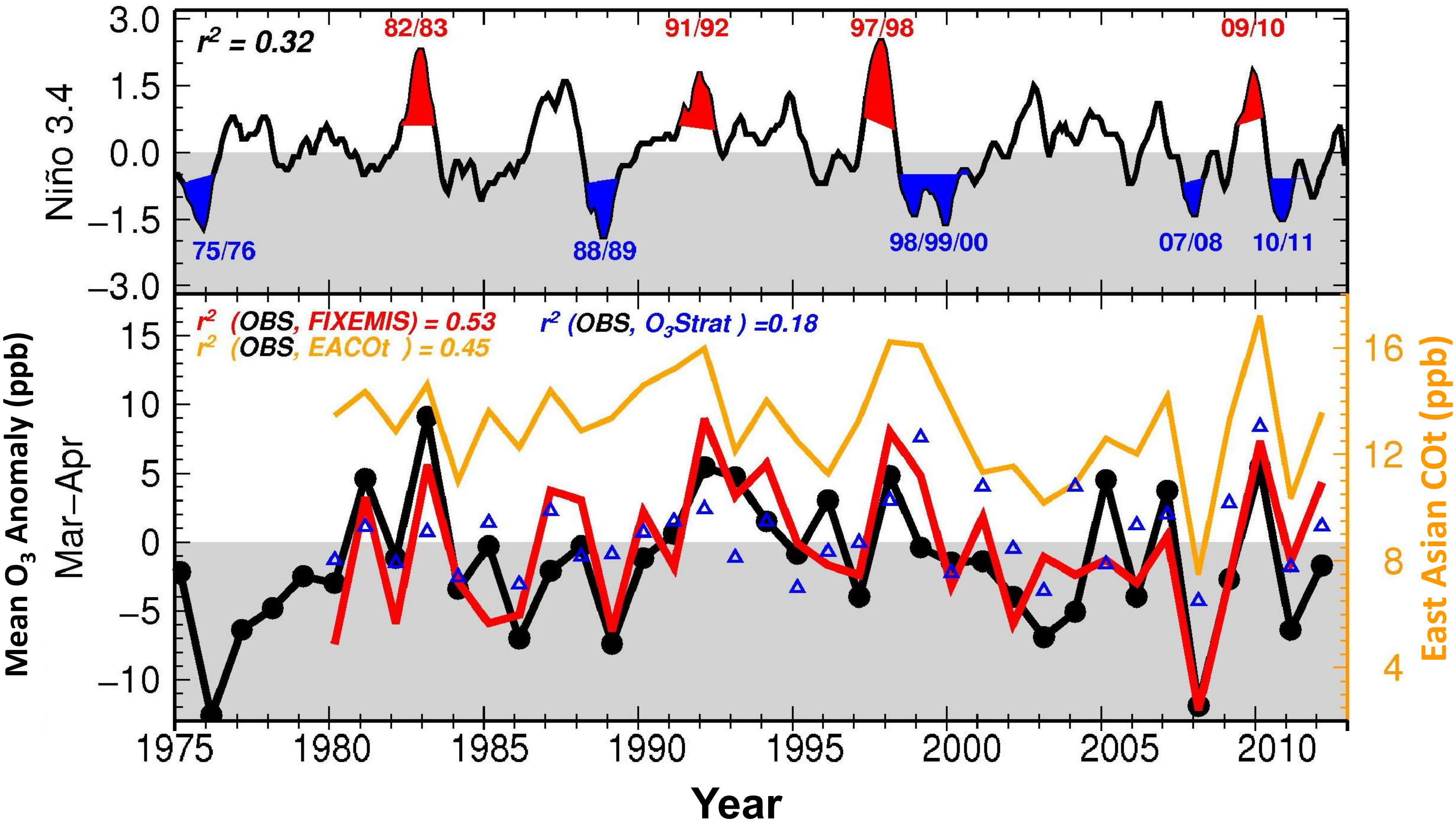
FIXEMIS

- Constant emissions
- Nudged to "real winds"



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

Following El Niño conditions, stronger airflow from Asia towards Hawaii in SPRING

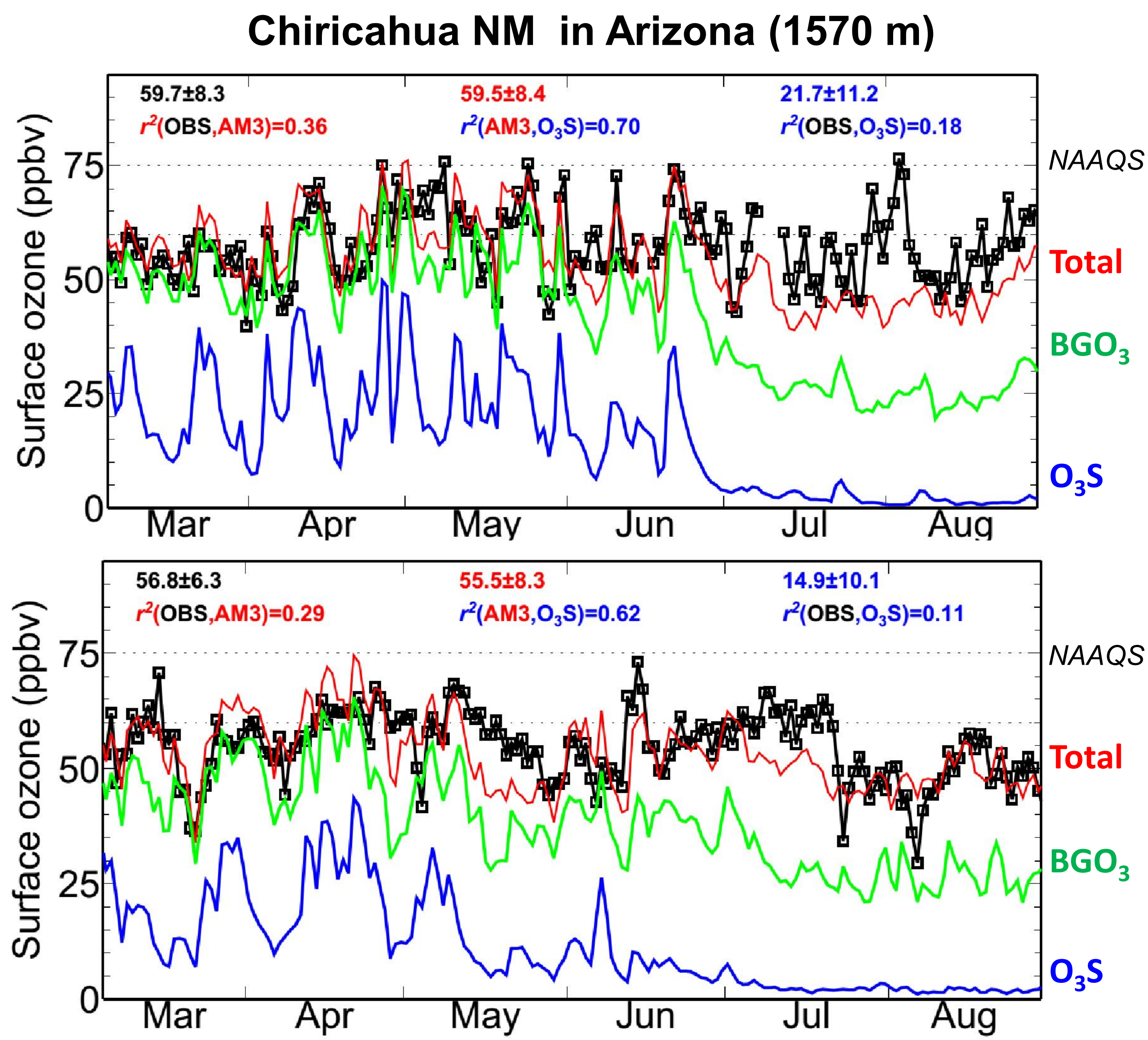


Lin M.Y. et al (Nature GeoSci., 2014)

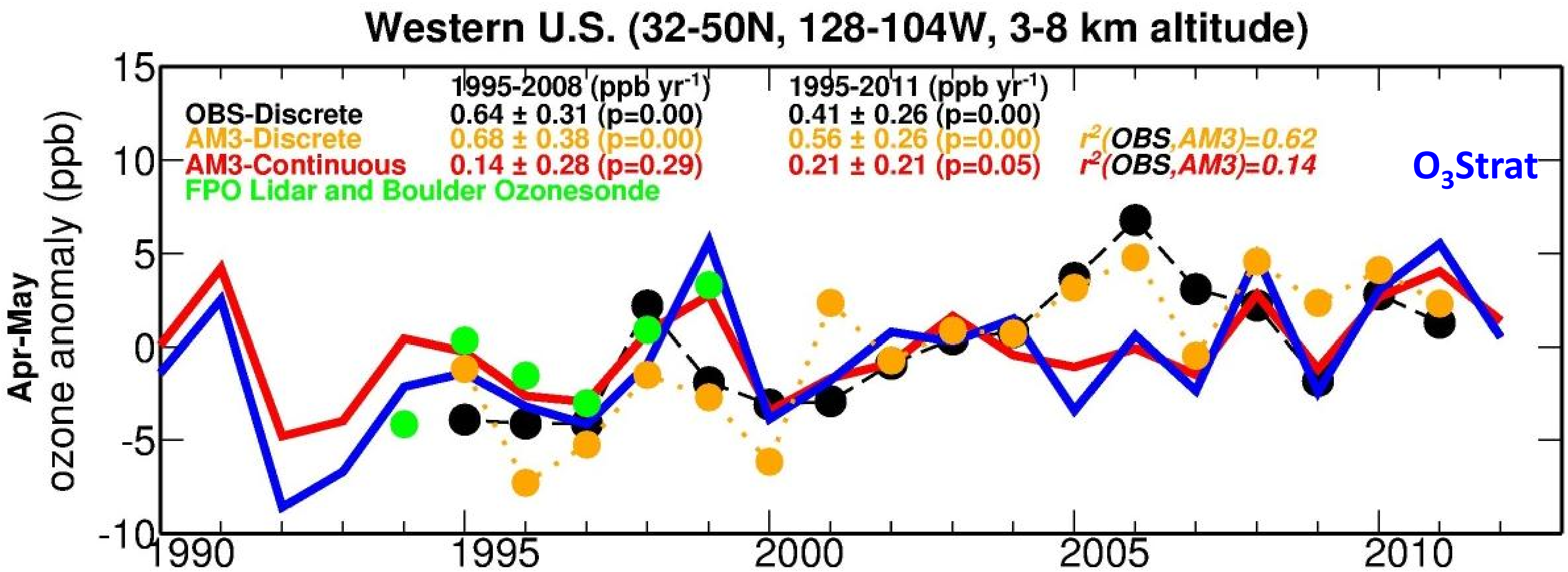
Following La Niña conditions, deep STT may occur with sufficient frequency as to confound NAAQS attainment

2011 (La Niña)

2007 (Neutral)



Role of dynamical variability on free tropospheric ozone over Western U.S. during spring



- **Observations as in Cooper et al. [2010; 2012].**
- **Sparse sampling and short records may complicate the unambiguous attribution of observed trends**

Meiyun Lin et al., in prep