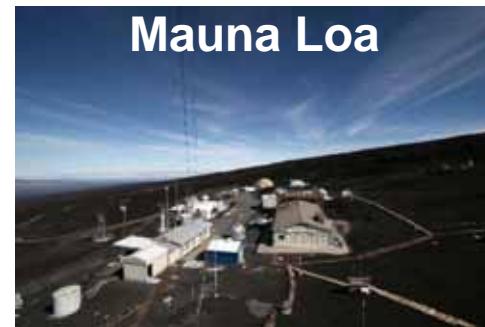


Tropospheric ozone trends at Mauna Loa Observatory tied to decadal climate variability: Implications for HTAP2

Meiyun Lin

Coauthors: L. W. Horowitz (NOAA/GFDL), S. J. Oltmans (NOAA/ESRL),
A. M. Fiore (Columbia/LDEO), S. Fan (NOAA/GFDL)

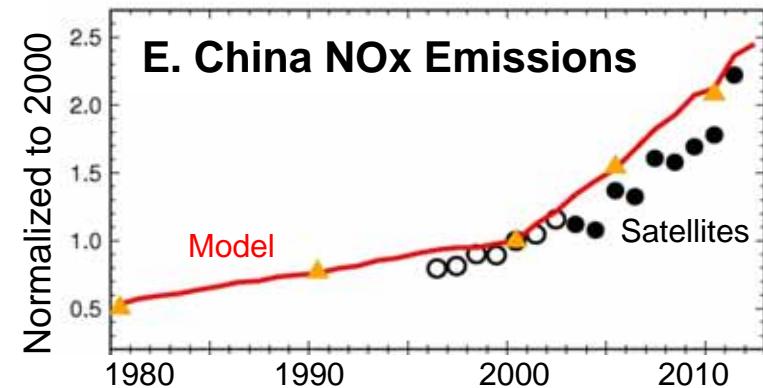
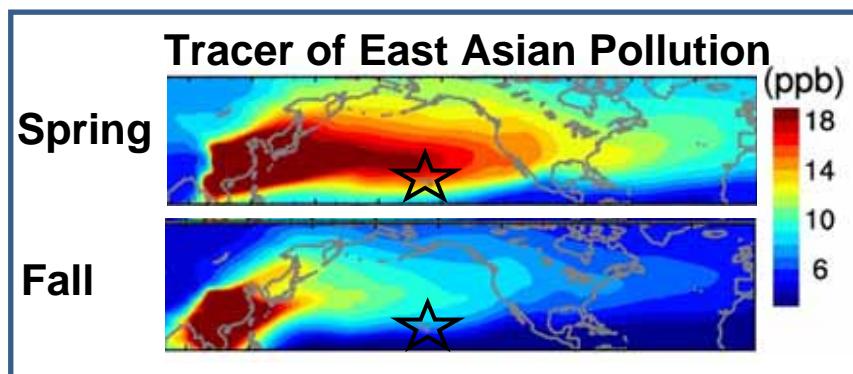
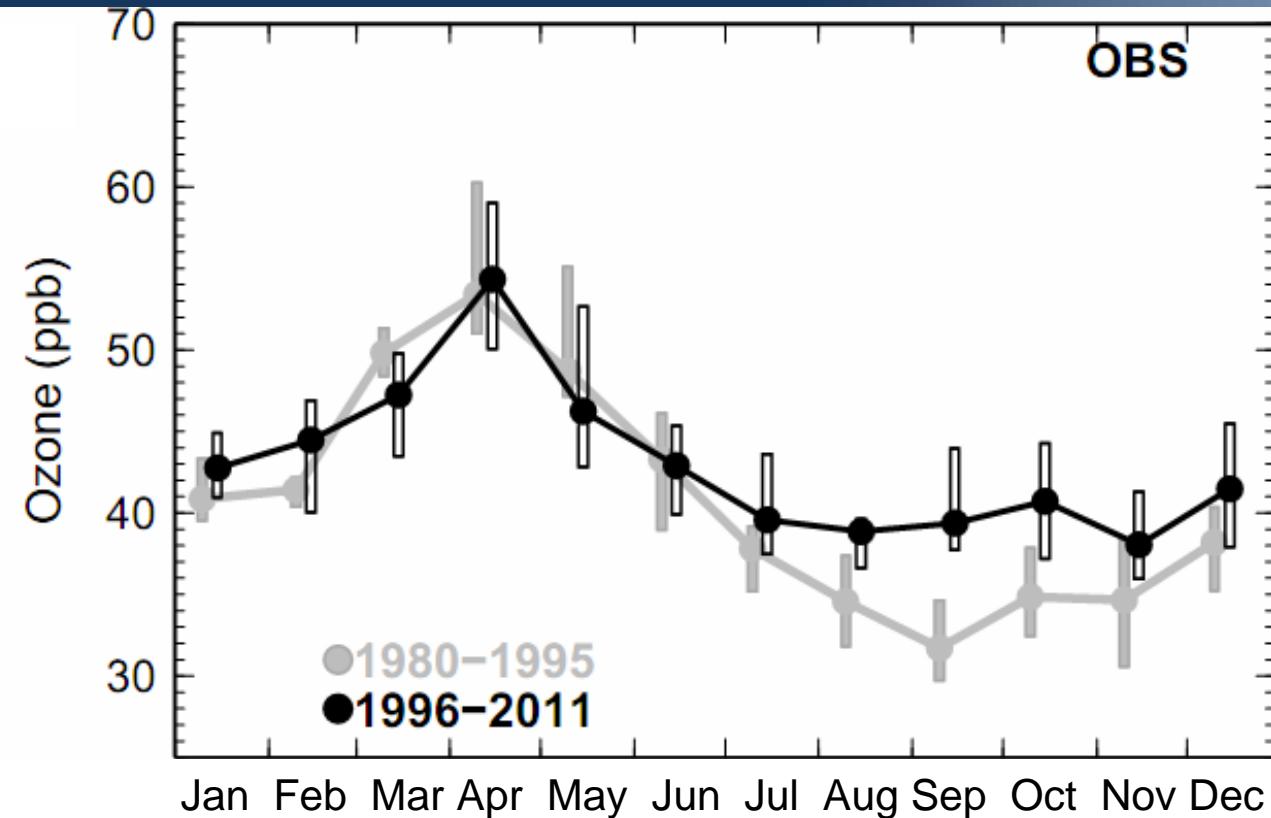
Acknowledgements: Hiram “Chip” Levy II and Isaac Held



(Photo: www.forrestmims.org)

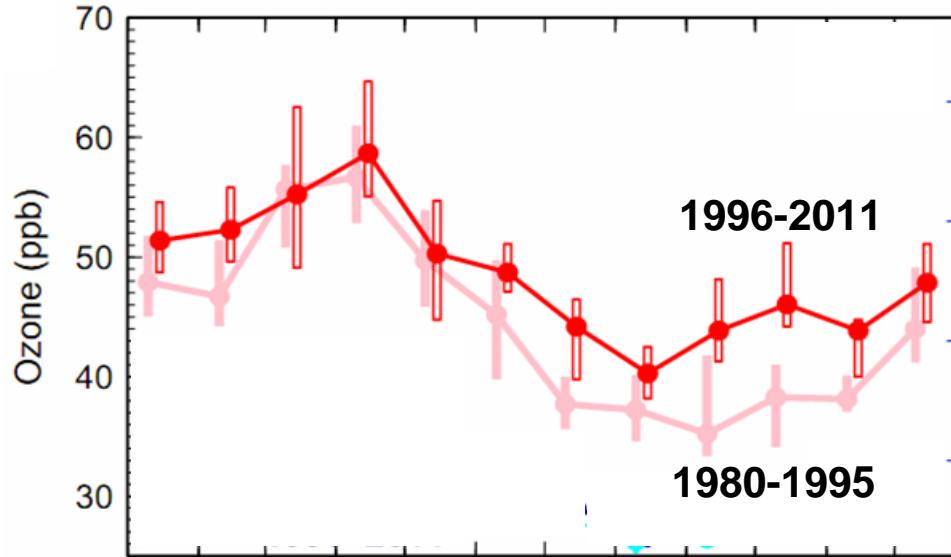


The puzzle: Mauna Loa ozone increases in autumn but shows little change in spring

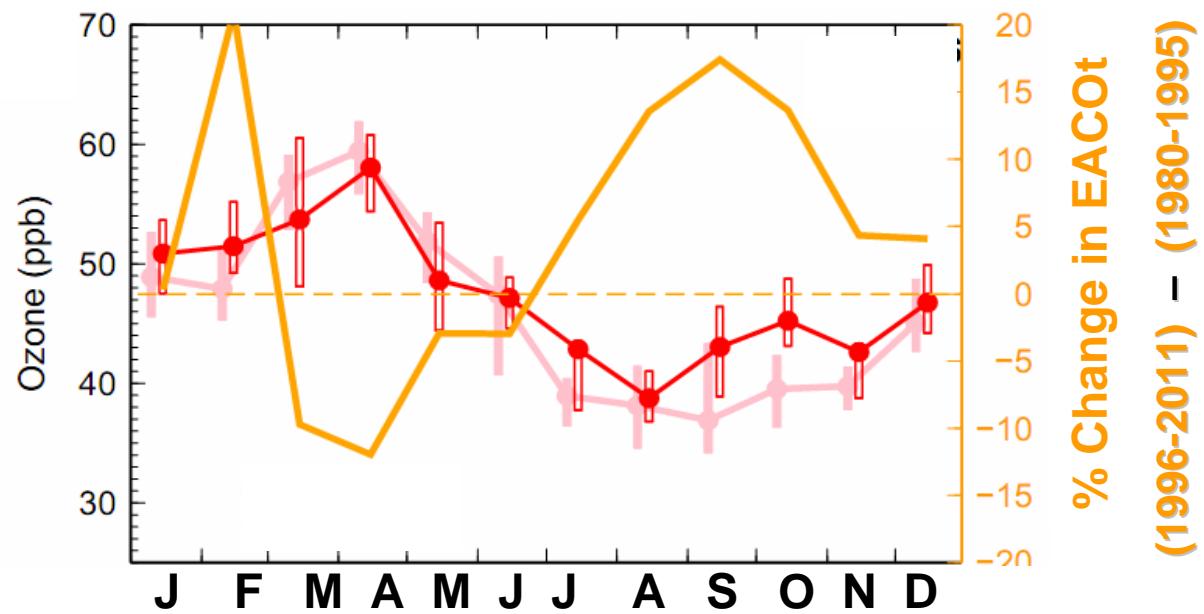


GFDL model indicates influence from circulation shifts that modulate Asian pollution reaching Hawaii

BASE
(Model w/ varying emissions)

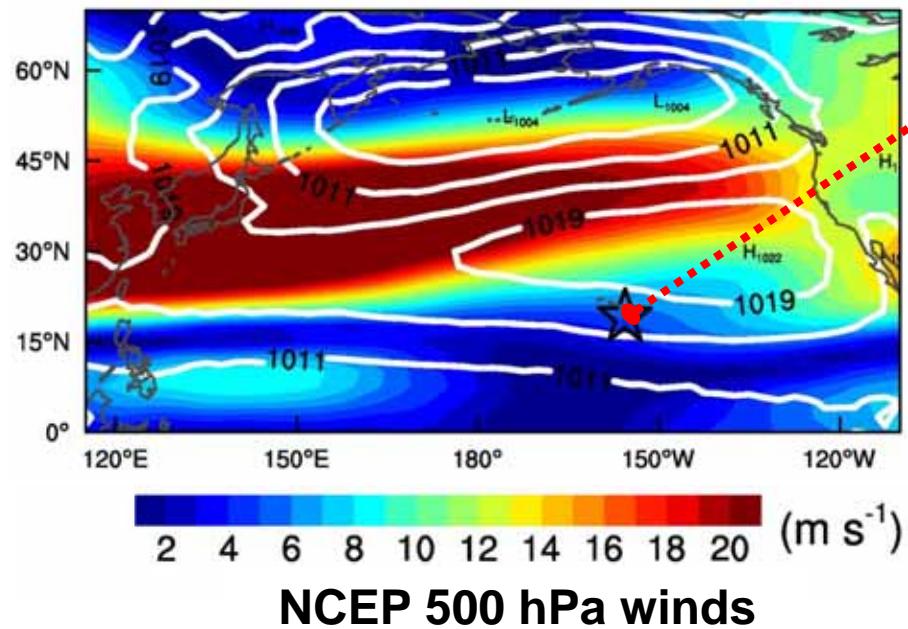


FIXEMIS
(Model w/ constant emissions)



% Change in EACO_t
(1996-2011) – (1980-1995)

A climate perspective ...

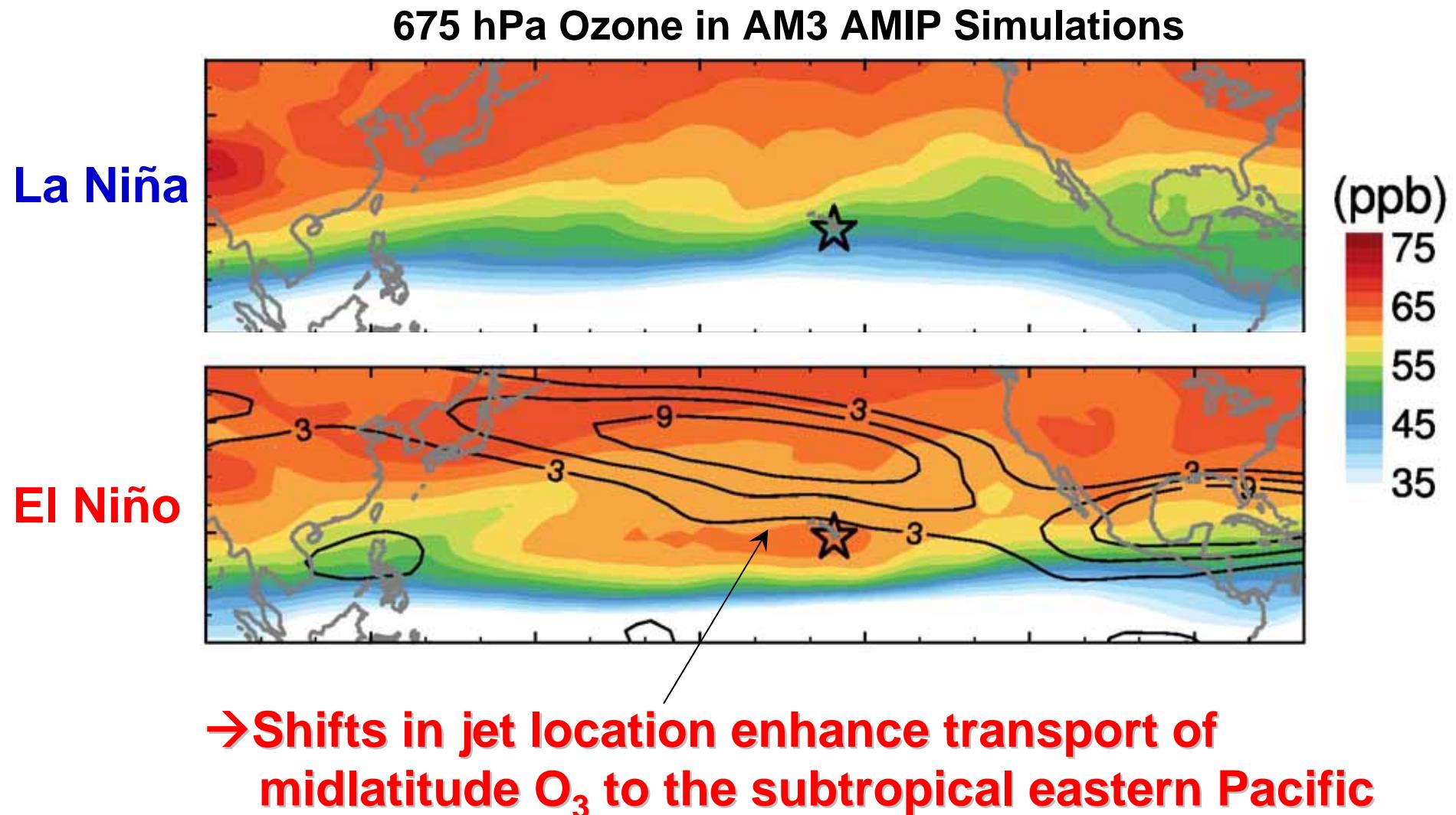


Boreal Spring:

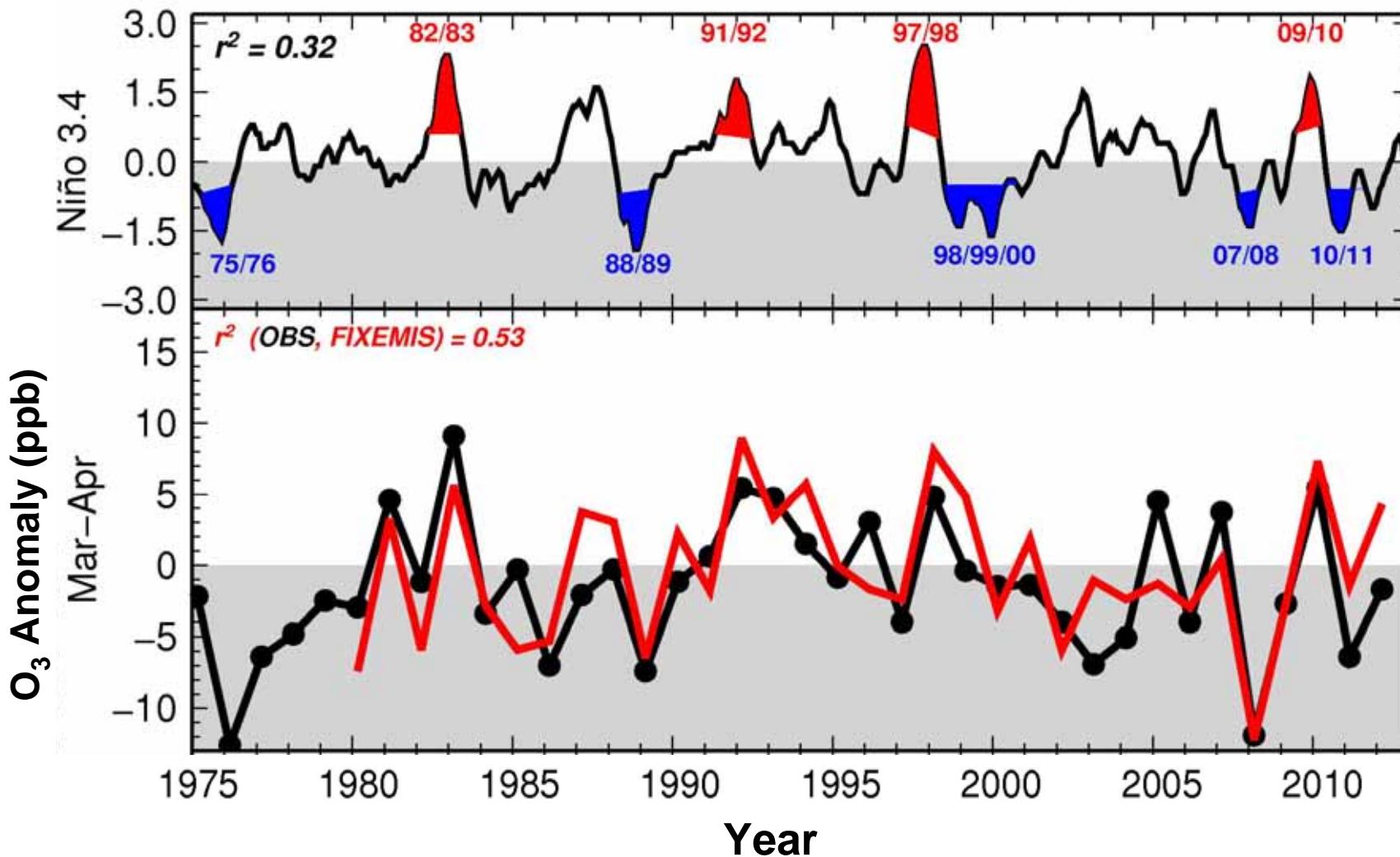
- Sensitive to the subtropical jet location
- ENSO
- Pacific Decadal Oscillation (PDO)
- The Hadley circulation



Weakening airflow from Asia in SPRING tied to recent La-Niña-like decadal cooling in the eastern equatorial Pacific

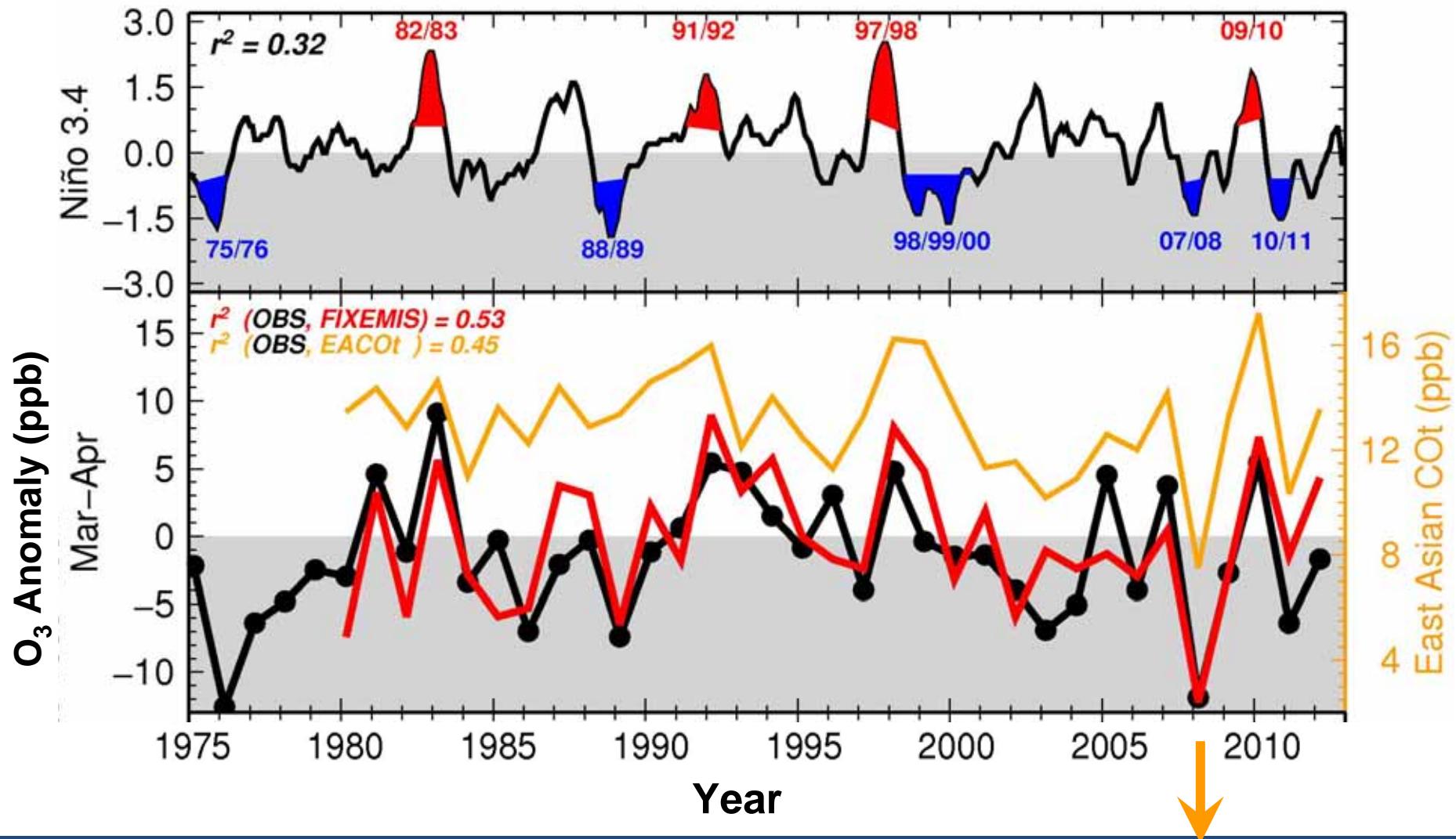


Weakening airflow from Asia in SPRING tied to recent La-Niña-like decadal cooling in the eastern equatorial Pacific



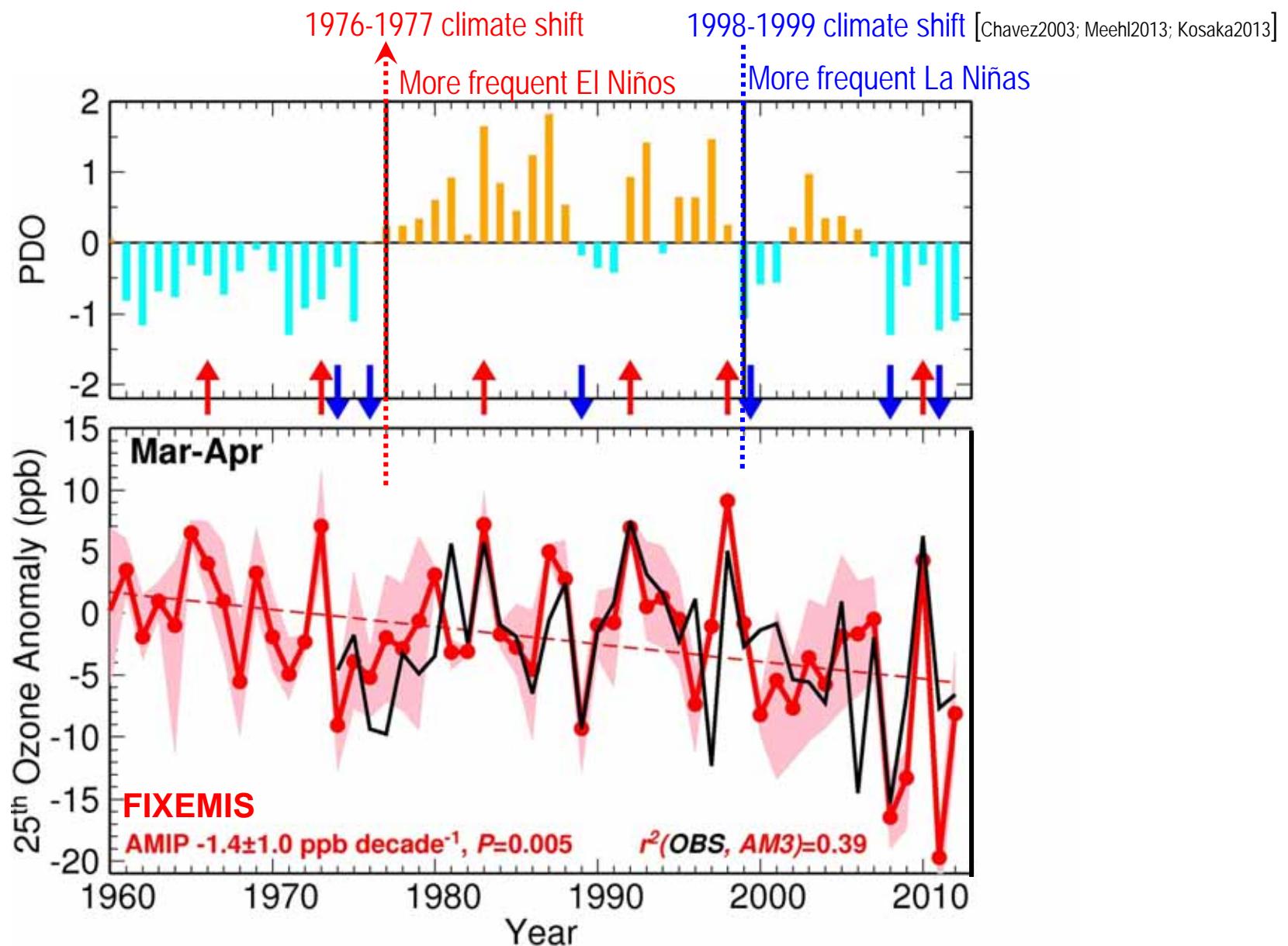
Mauna Loa ozone correlates with the Niño index

Weakening airflow from Asia in SPRING tied to recent La-Niña-like decadal cooling in the eastern equatorial Pacific

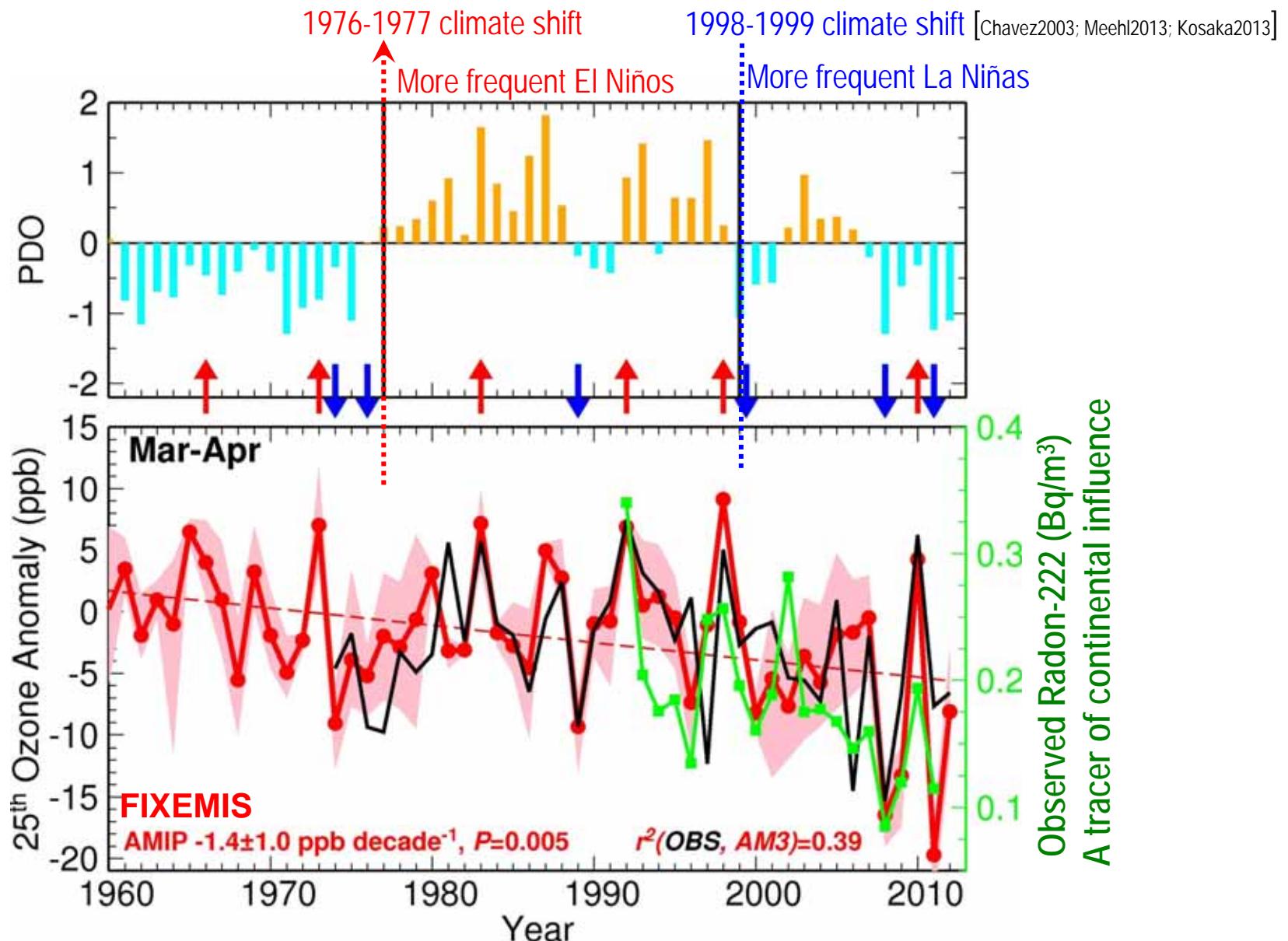


Weakening airflow from Asia during La Niña events

Weakening airflow from Asia in SPRING tied to recent La-Niña-like decadal cooling in the eastern equatorial Pacific

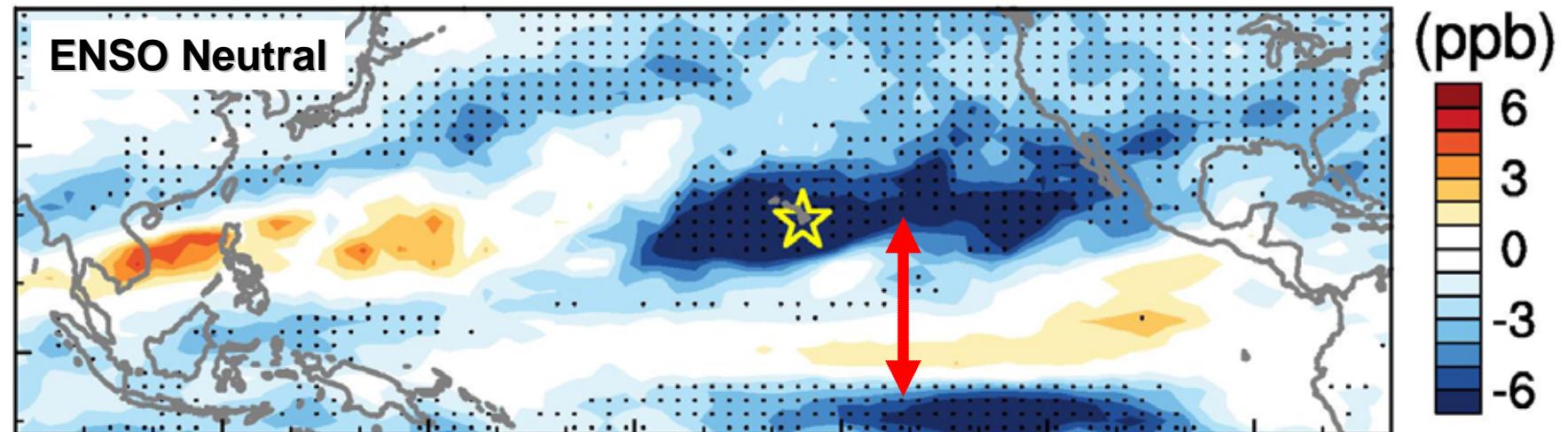


Weakening airflow from Asia in SPRING tied to recent La-Niña-like decadal cooling in the eastern equatorial Pacific



Weakening airflow from Asia in SPRING: The tropical expansion plays a role?

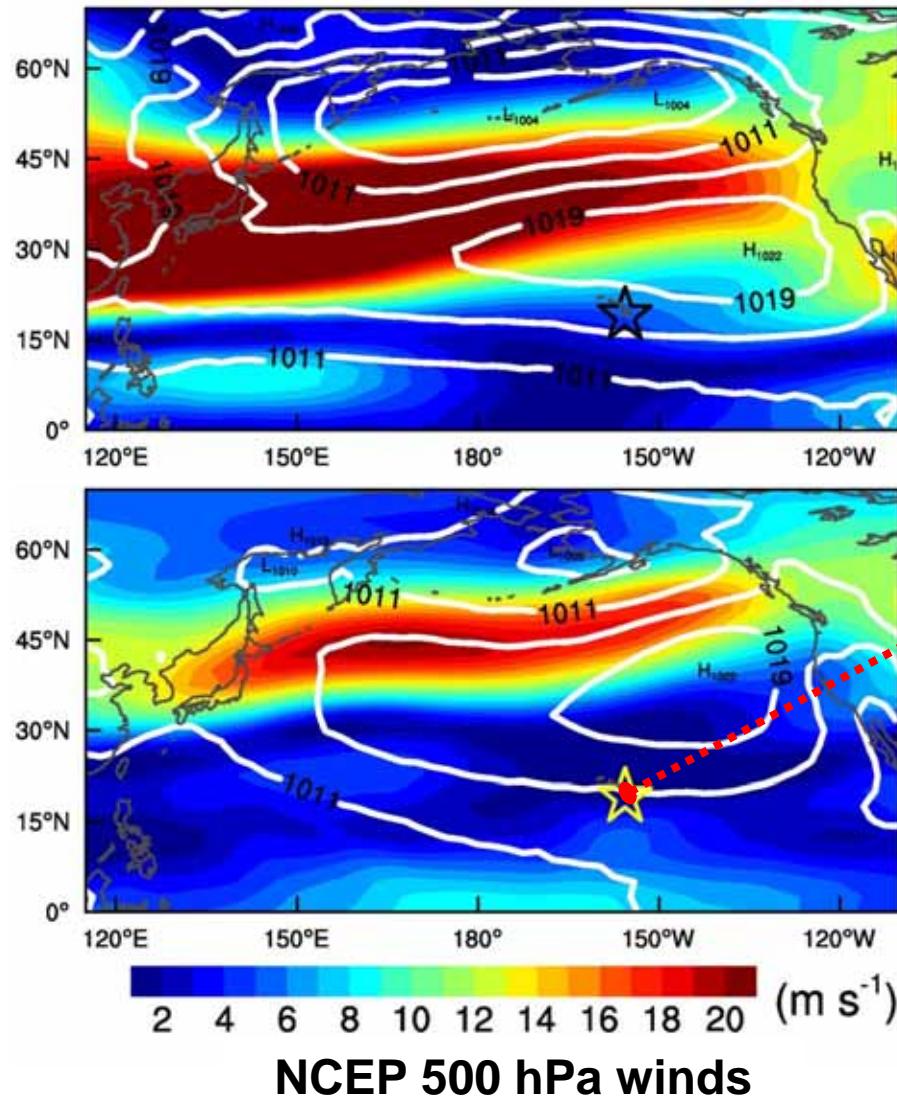
Changes in 25th % of daily 675hPa O₃ (2000-2012 minus 1960-1975)



- **Consistent with the observed widening of the tropical belt since 1960s**
[Seidel et al 2008; Lu et al. 2009; Allen et al., 2012]
- **Some diagnostic methods indicate weaker or insignificant widening trends**
[Davis et al., 2012]



Circulation Regimes In FALL



Boreal Spring:

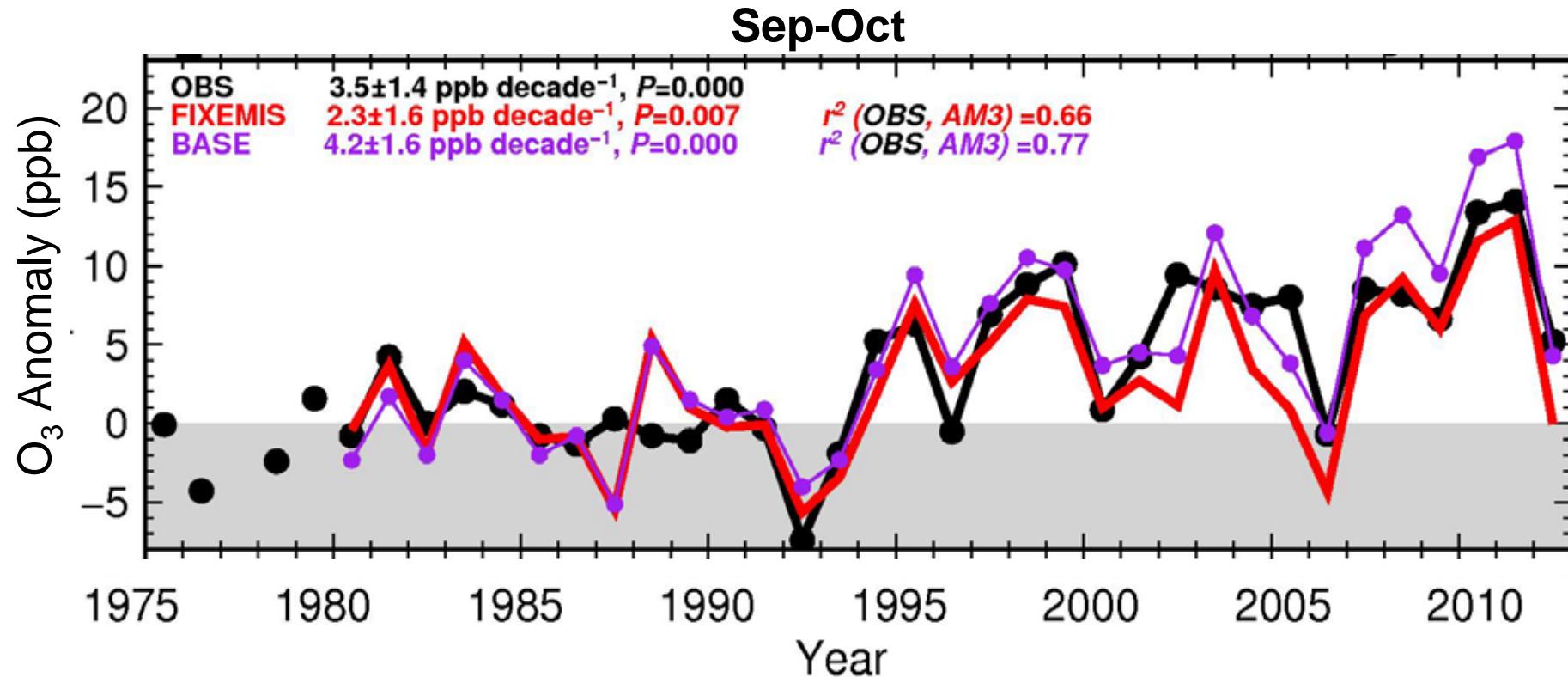
Sensitive to the subtropical jet location
→ ENSO
→ Pacific Decadal Oscillation (PDO)
→ The Hadley circulation

Boreal Fall:

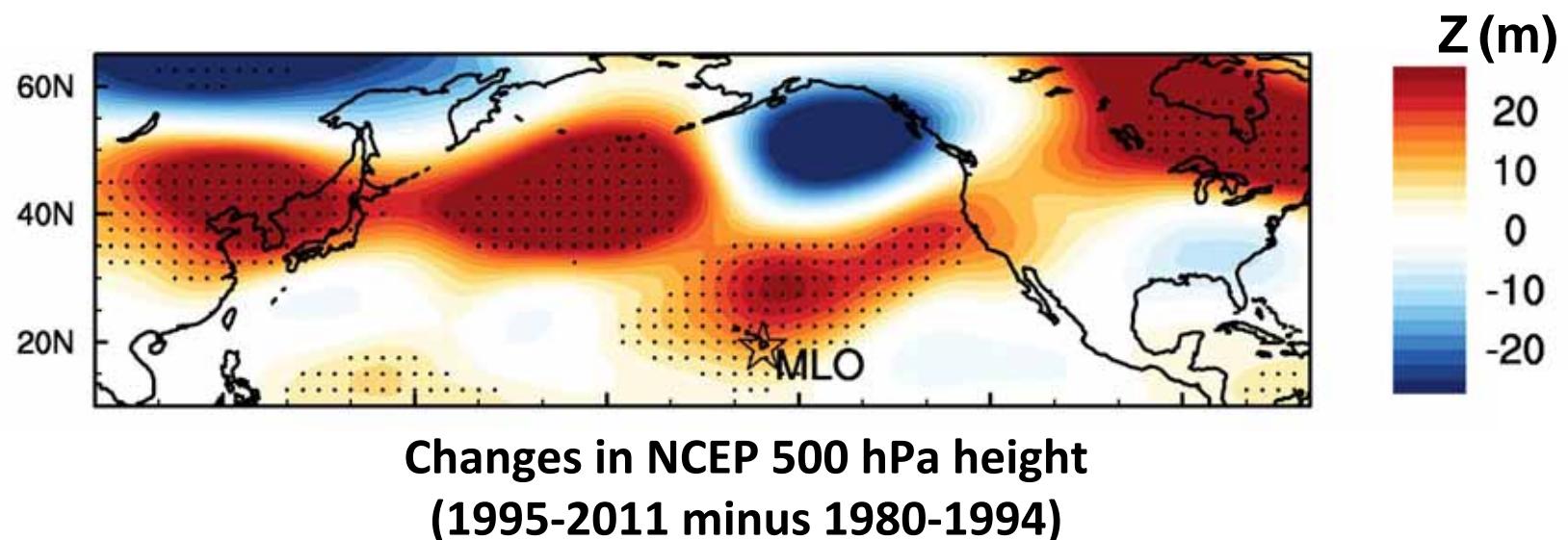
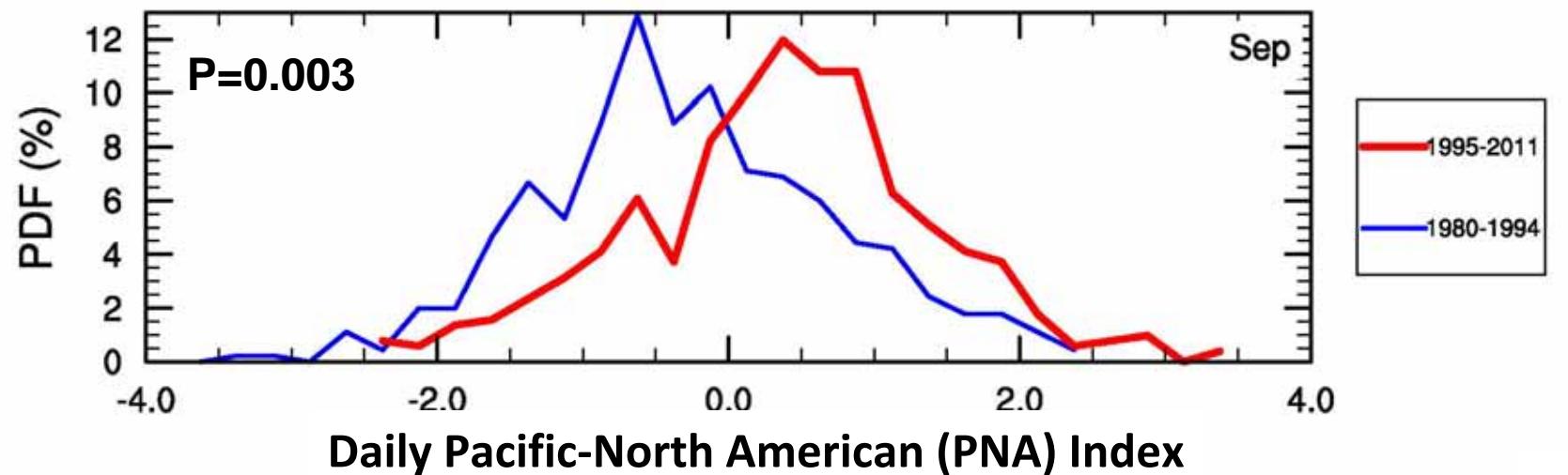
Deep in the tropical belt
→ Isentropic subsidence of midlatitude
pollution to MLO
→ Pressure dipoles related to the
Pacific North-American (PNA)
teleconnection pattern



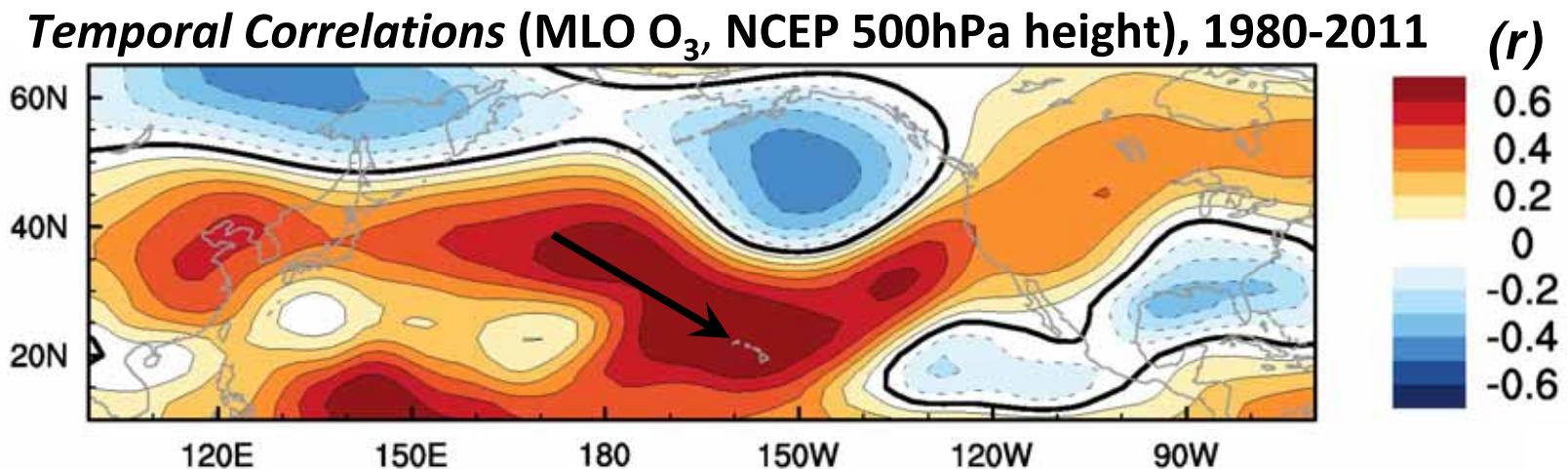
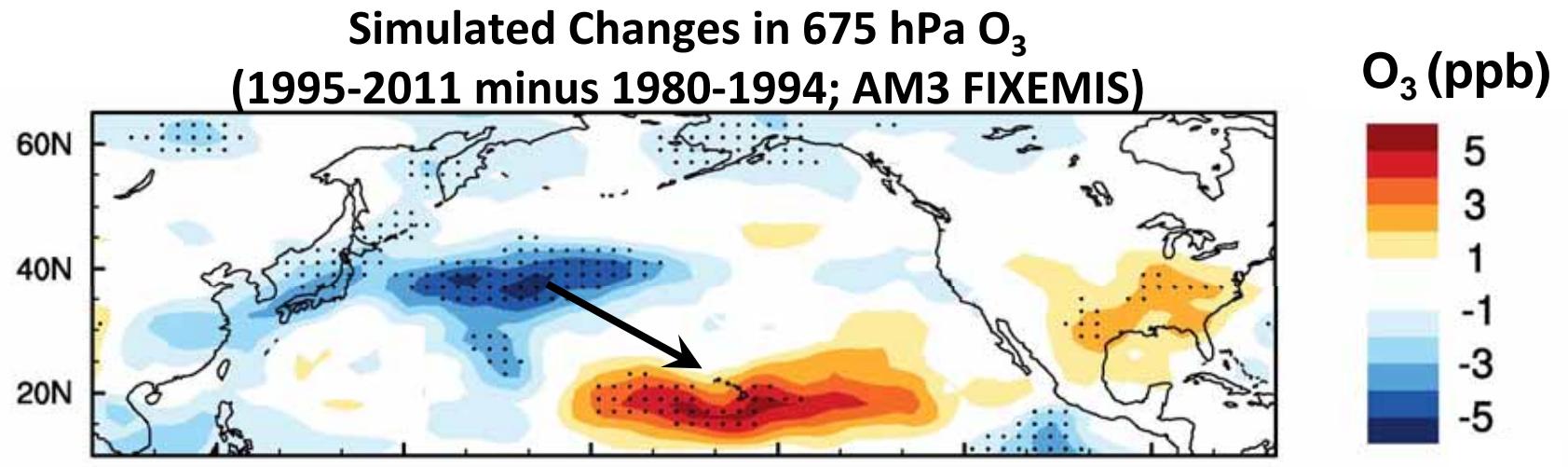
The meteorological shift near 1995 plays a key role in the observed ozone increase in FALL



Increasing ozone at MLO in FALL tied to a shift in the PNA towards more frequent positive modes since mid-1990s



Increasing ozone at MLO in FALL tied to a shift in the PNA towards more frequent positive modes since mid-1990s

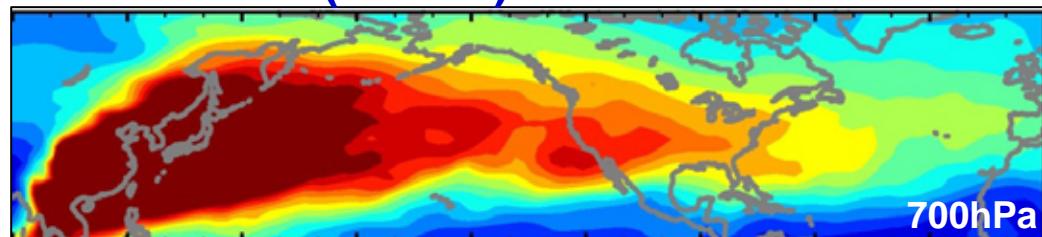


The positive PNA pattern facilitates isentropic subsidence of midlatitude pollution towards Hawaii.

So what? Decadal climate shifts modulate tropospheric ozone trends!

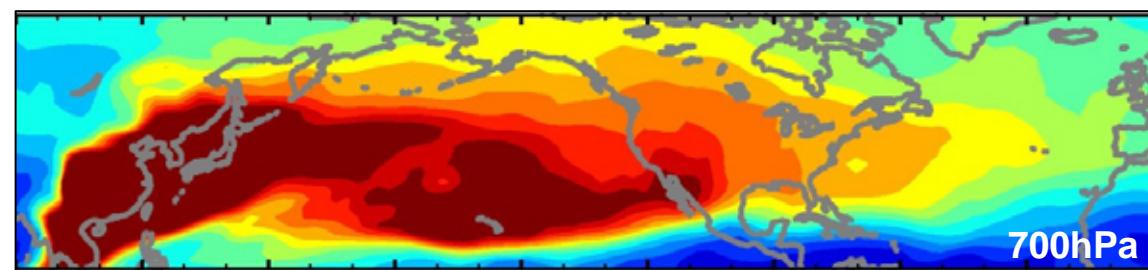
- Changes in tropospheric O₃ observed at other NH remote sites may be similarly influenced by shifts in circulation regimes.
- Interannual to decadal climate variability must be considered ...
 - When attributing observed O₃ changes to trends in precursor emissions
 - When applying the S/R relationships from the 2008-2010 HTAP experiments

2008 La Niña (EACOt)

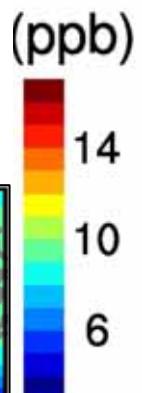


700hPa

2010 El Niño (EACOt)



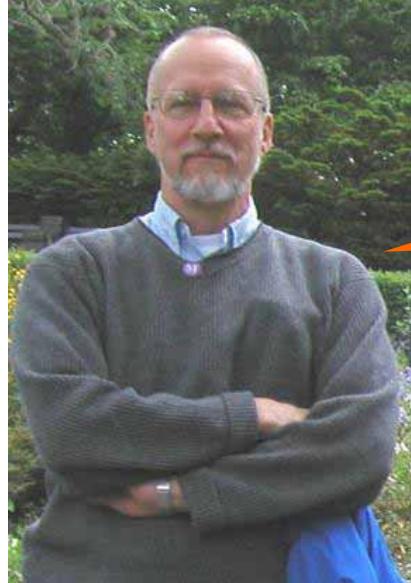
700hPa



(ppb)

Bonus Slides

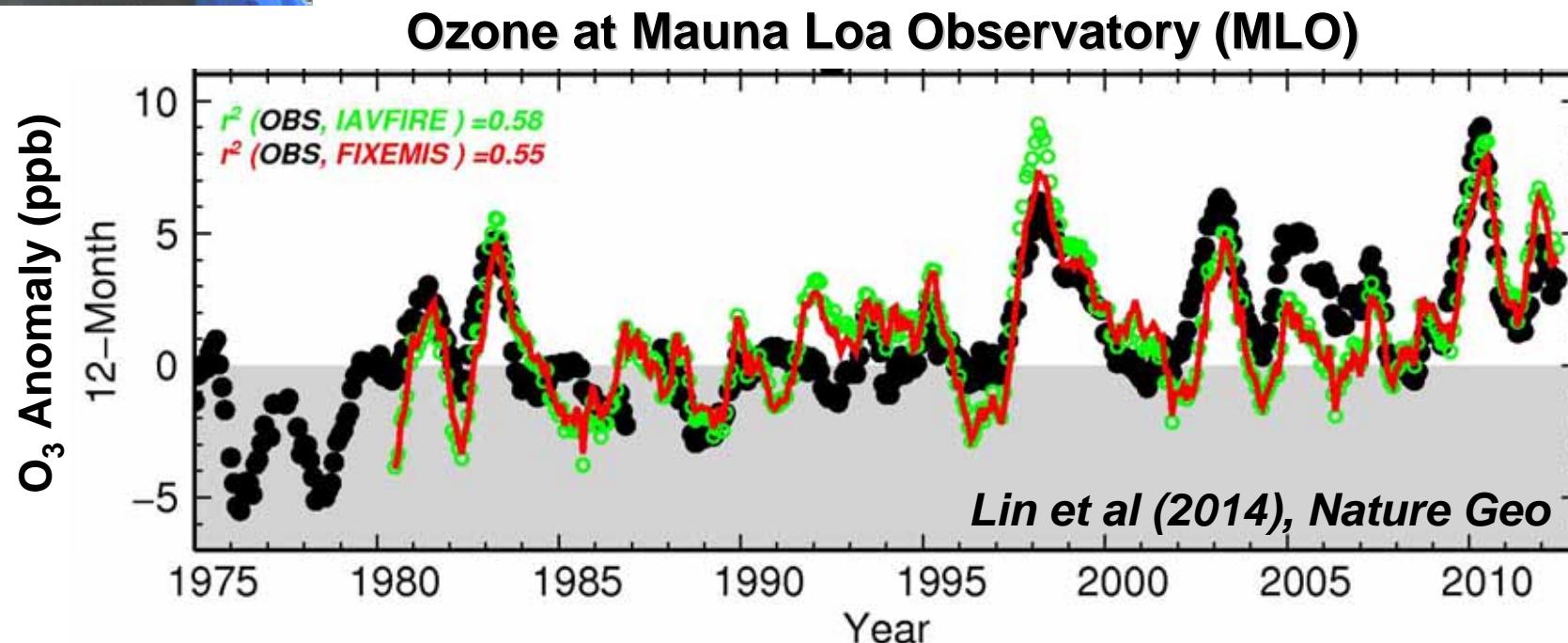




We need 30+ years of data
for seeing an ozone trend!

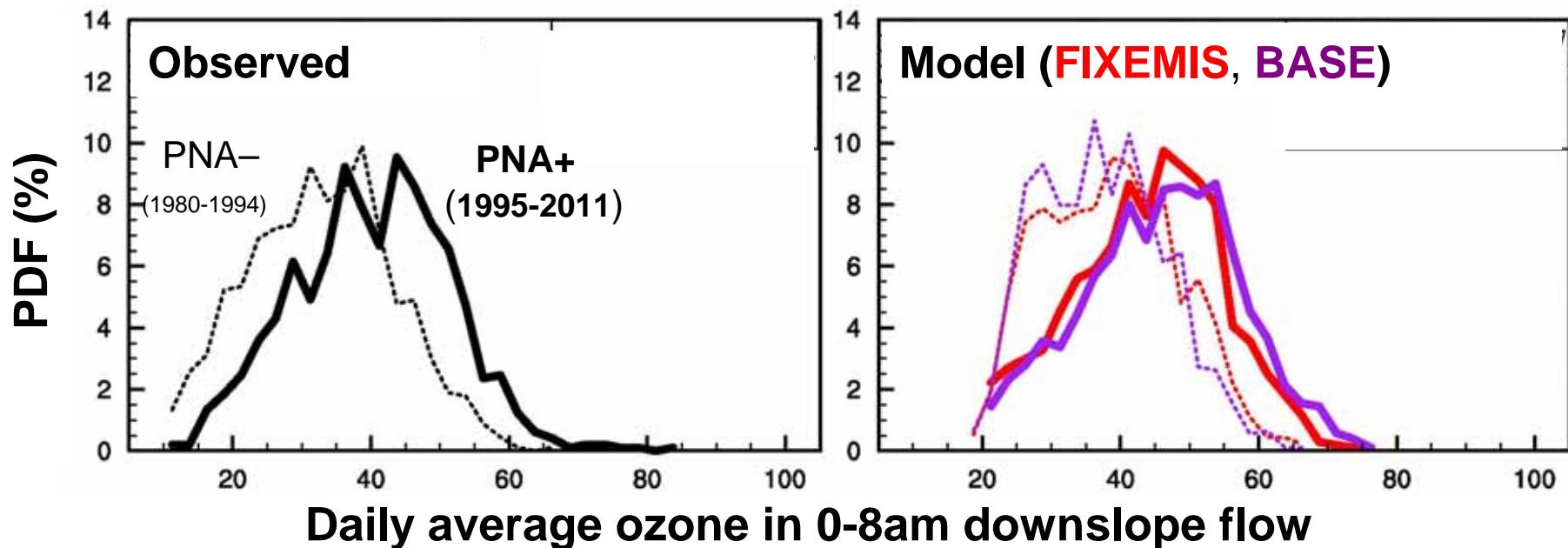
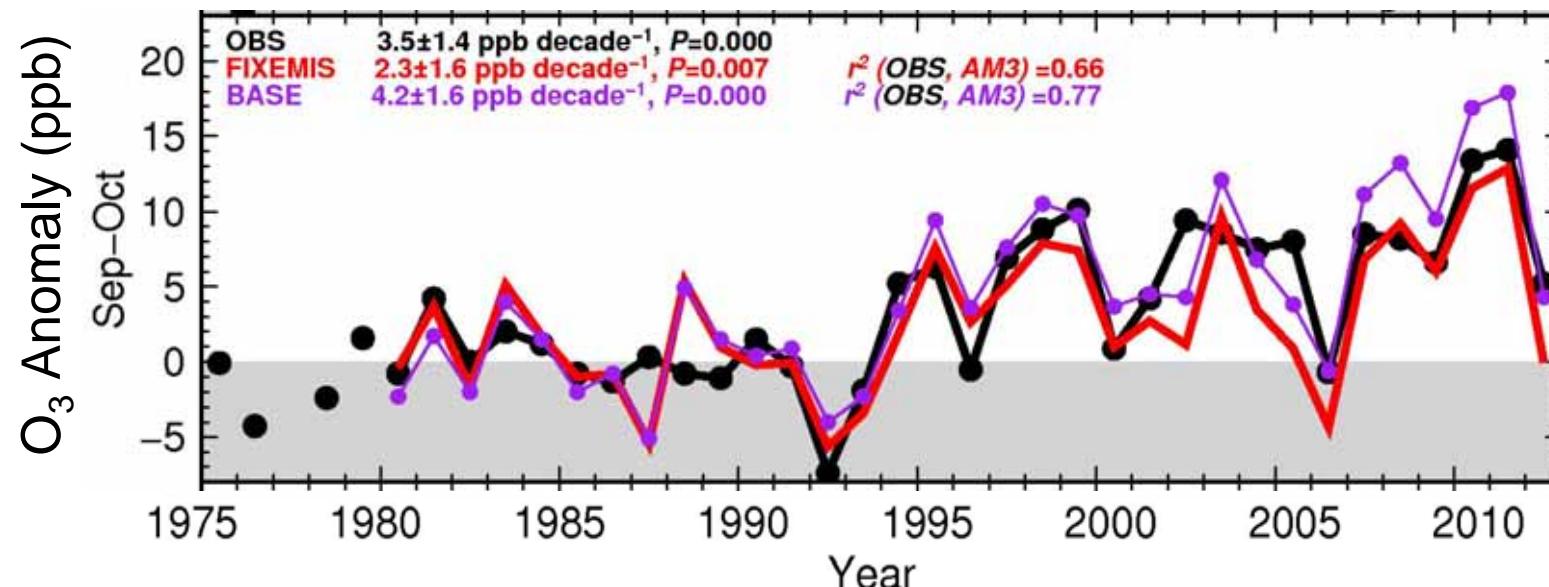
Changes in ozone ($t=22$ d) at a remote location can reflect:

- Trends in hemispheric precursor emissions
- Variability in large-scale circulation patterns



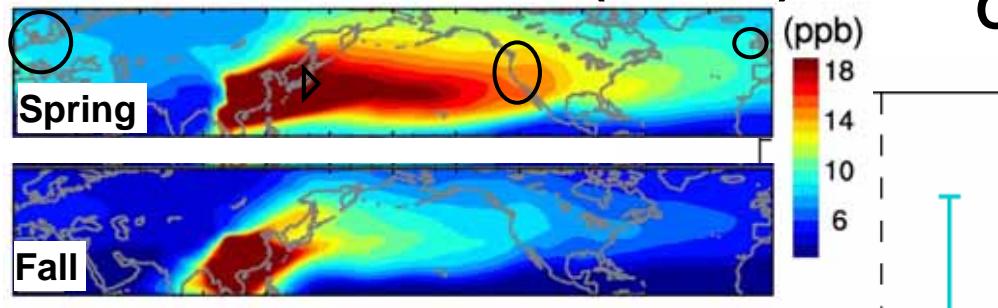
- GFDL AM3 with fixed emissions (nudged) captures observed O_3 changes
- Negligible influence from El Niño-related wildfires in equatorial Asia

The meteorological shift near 1995 plays a key role in the observed ozone increase in FALL

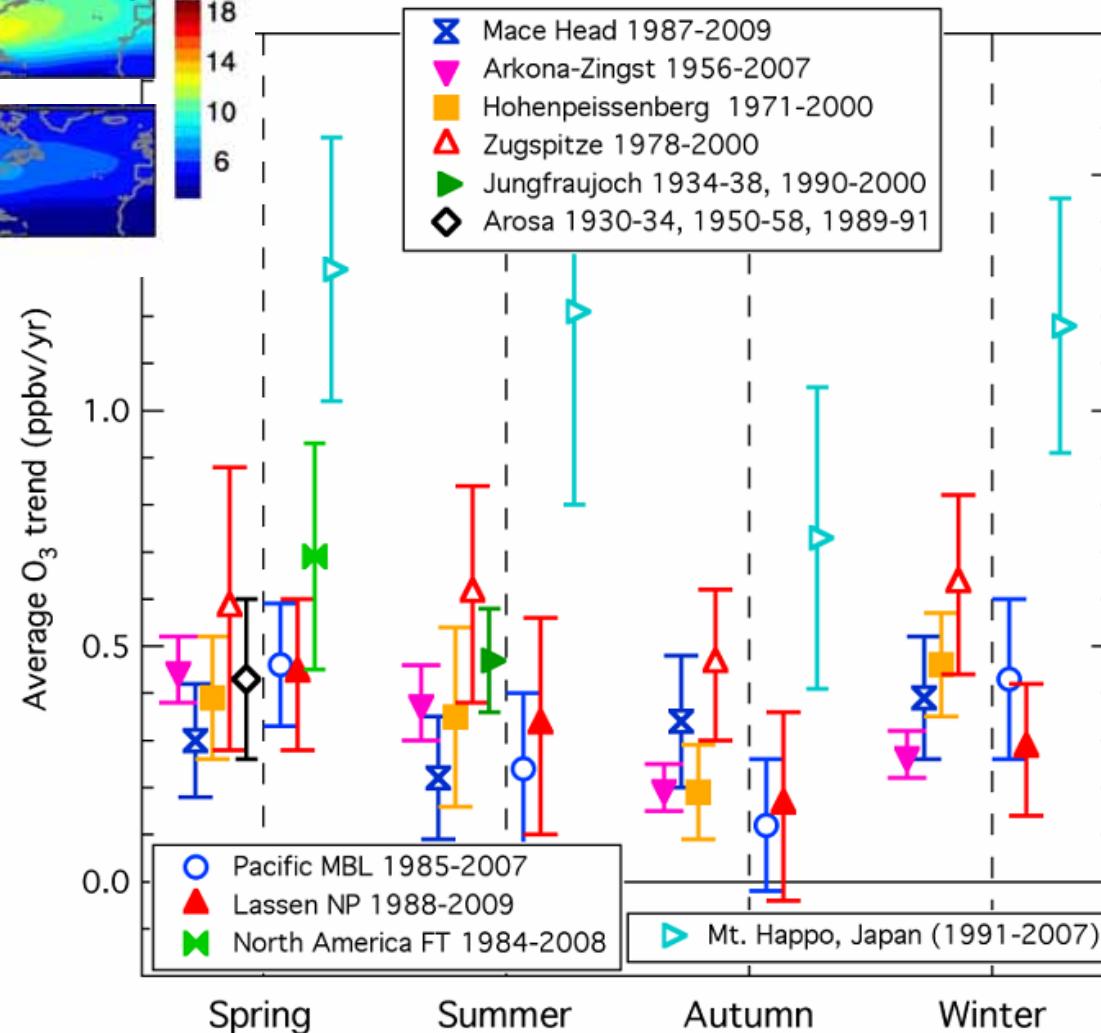


Rising northern midlatitude baseline O₃ highest in spring when hemispheric pollution transport is greatest

Model East Asian COt (EACOt)



Observed ozone trends [Parrish et al., 2012]



NO_x emissions from Eastern China almost tripled from 1980s to 2000s

