The role of dynamics in determining tropospheric ozone variability and trends

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Background O$_3$ over the Pacific and Western N. America varies in space and time

Western U.S.
- Sensitive to polar frontal jet
- Prone to deep strat. intrusions
- Highly variable on synoptic timescales

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., 2014a]

→ Need process-level understanding on daily to multi-decadal timescales
→ Must consider climate variability for attribution of observed trends
The puzzle: Mauna Loa ozone increases in autumn but shows little change in spring

Mauna Loa Observatory (3.4 km altitude)

Lin M.Y. et al (Nature Geo, 2014)
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”
Increasing ozone at Mauna Loa in **FALL** tied to a shift in circulation patterns since the mid-1990s

**Mauna Loa Observatory (3.4 km altitude), Hawaii**

- **OBS**: 11% decade\(^{-1}\) (p<0.05)
- **FIXEMIS**: 7% decade\(^{-1}\) (p<0.05)
- **BASE**: 13% decade\(^{-1}\) (p<0.05)


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

ENSO and mid-tropospheric O$_3$ over Pacific N.A. in **SPRING**

**Median background O$_3$ at 500hPa**

*Lin M.Y. et al (2014b, in revision)*
Following El Niño conditions, stronger airflow from Asia towards Hawaii in **SPRING**

Decreasing ozone at Mauna Loa in SPRING tied to recent La-Niña-like decadal cooling + tropical expansion

$\text{LaNiña-like decadal cooling}$

[Chavez2003; Meehl2013; Kosaka2013]

$\text{Observed Radon-222 (Bq/m}^3\text{)}$

A tracer of continental influence

$\text{ElNiño}$

$\text{ENSO Neutral conditions}$


$\text{AMIP (fixed emissions)}$

$-1.4\pm1.0 \text{ ppb decade}^-1$, $P=0.005$

$\text{OBS, AM3}=0.39$

$675\text{hPa 25}^{\text{th}} \text{percentile O}_3 \text{ changes}$

$\text{for ENSO Neutral conditions}$

$\text{(2000-2012 minus 1960-1975)}$

Following La Niña conditions, more frequent tropopause folds over Western N.A. in spring.

Variance in daily $O_3$Strat at 500hPa

Lin M.Y. et al (2014b, in revision)
Strong stratospheric influence on year-to-year variability of Western U.S. surface O$_3$ during spring

Lin M.Y. et al (2014b, in revision)
The high tail of the observed daily surface $O_3$ distribution over Western U.S. increases during La Niña springs.

Neutral, $\mu = 56.5, \sigma = 7.5$
El Niño, $\mu = 56.9, \sigma = 7.3$
La Niña, $\mu = 58.5, \sigma = 7.9$
Pinatubo, $\mu = 54.3, \sigma = 6.5$

Changes in the high tail are statistically significant.
Role of dynamical variability on free tropospheric ozone over Western U.S. during spring

Western U.S. (32-50N, 128-104W, 3-8 km altitude)

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

• Long-term ozone measurements contain signatures of interannual to decadal climate variability.

• Shifts in atmospheric circulation patterns should be considered when interpreting observed trends in tropospheric ozone levels.

• Sparse sampling and short records may complicate the unambiguous attribution of observed trends.

• An apple-to-apple comparison must be ensured when interpreting bias between models and observations.

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Additional slides for Q & A
Changes in lower stratospheric ozone

- UT/LS $O_3$ is observed to increase following El Niño conditions (see also Langford et al., 1998; Bronnimann et al., 2004; Manzini, 2009; Randel et al., 2009)
- Little change in UT/LS $O_3$ during La Niña despite increased $O_3S$ in surface air