EARTH SYSTEM RESEARCH LABORATORY

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Non-CO_2 Climate Gases: *Assessing and Understanding Tropospheric Ozone Changes*

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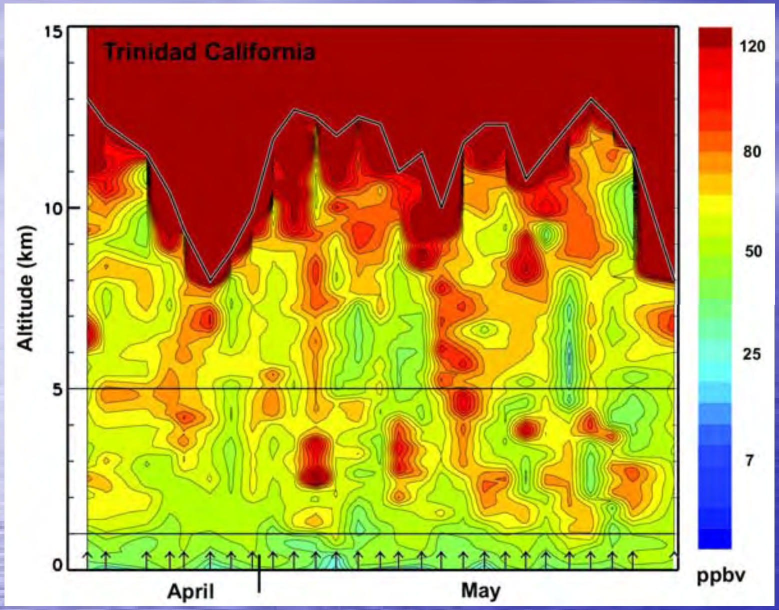
What are the issues with tropospheric ozone?

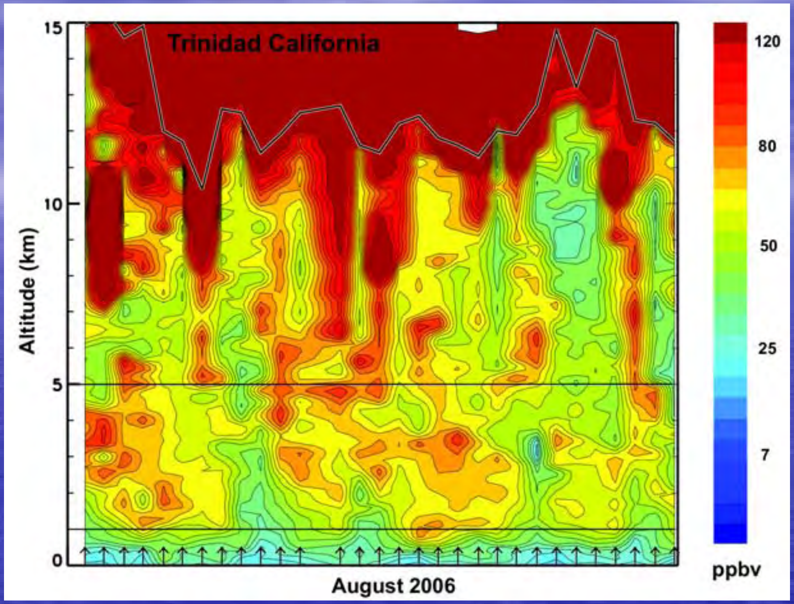
- **Large variability in space and time** require a comprehensive measurement strategy.
- **Multiple sources** makes isolating human impacts complex.
- The influence of **varied sources at different altitudes** requires knowledge of the vertical profile.
- **The impacts** (climate forcing, air quality, oxidizing capacity) of changes in tropospheric ozone **are also altitude dependent**.
- Representative **longer-term measurements are limited** – satellites are beginning to play a role.

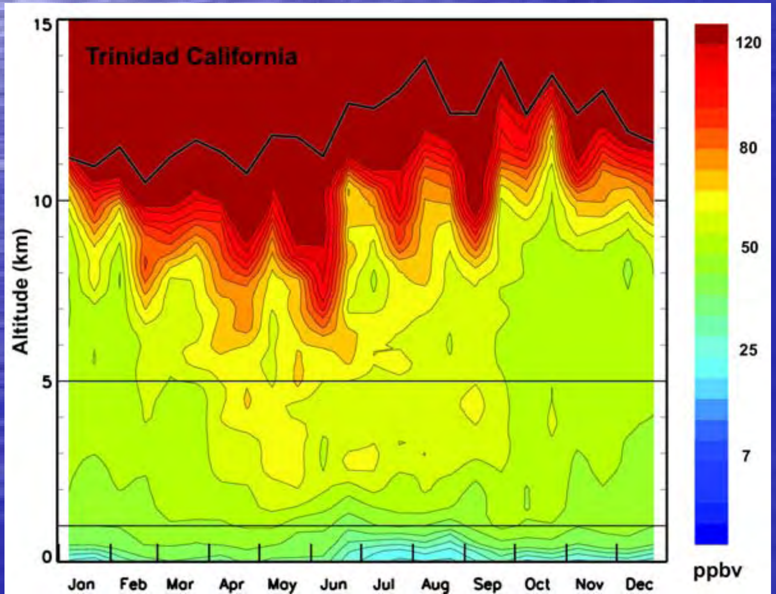
How is ESRL addressing these issues?

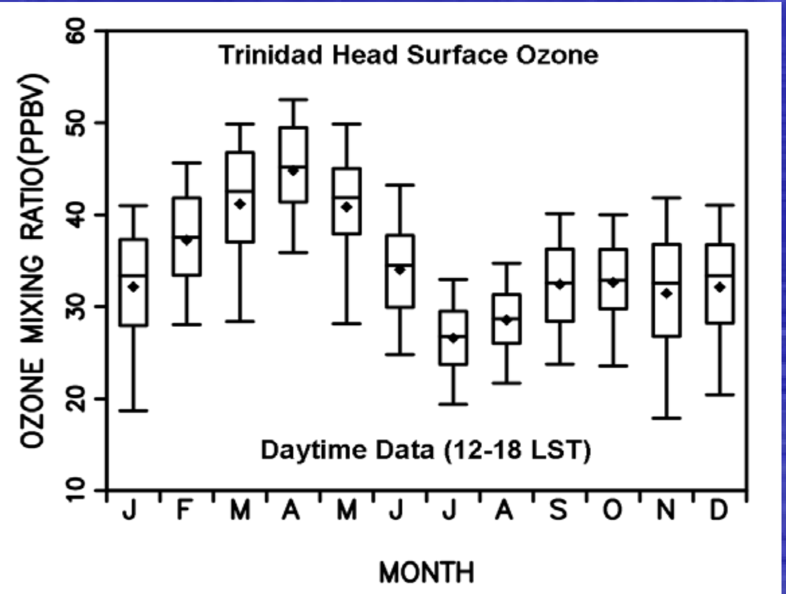
- Extensive network of **ongoing ozone profile and surface ozone measurements**.
- Comprehensive **process studies of ozone formation, chemical transformation, and long-range transport with aircraft, ship, and surface based measurements** – a focus of the Air Quality and Chemical Transformation and Long-Range Transport themes
- Extensive **validation of satellite profiles** from ozonesonde (e.g. SHADOZ, IONS) and aircraft.
- The **longer-term observations and process studies involve broad collaboration** with U.S. and international partners.

Ozone profiles and surface ozone at Trinidad Head, California illustrating the variability in time and altitude

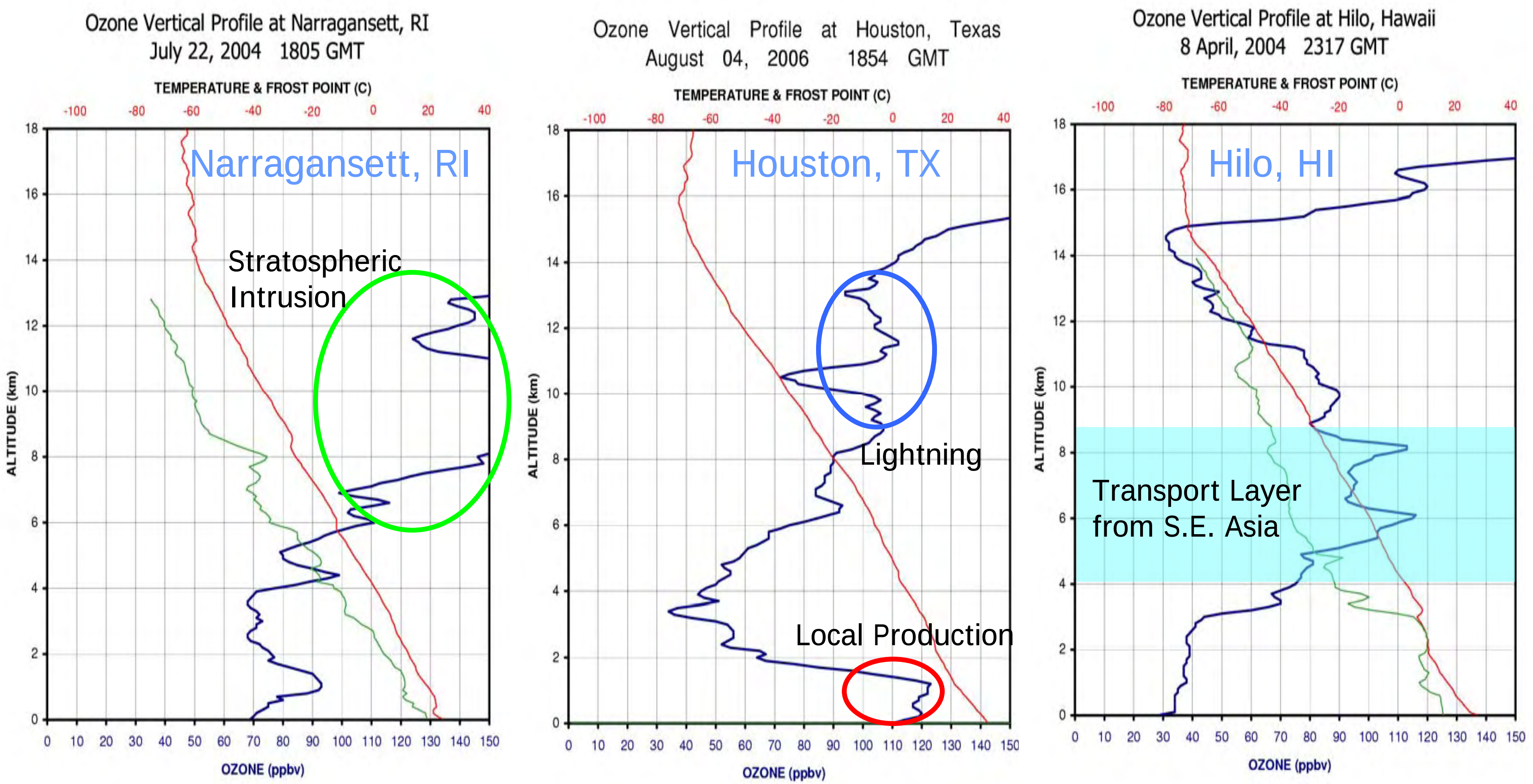








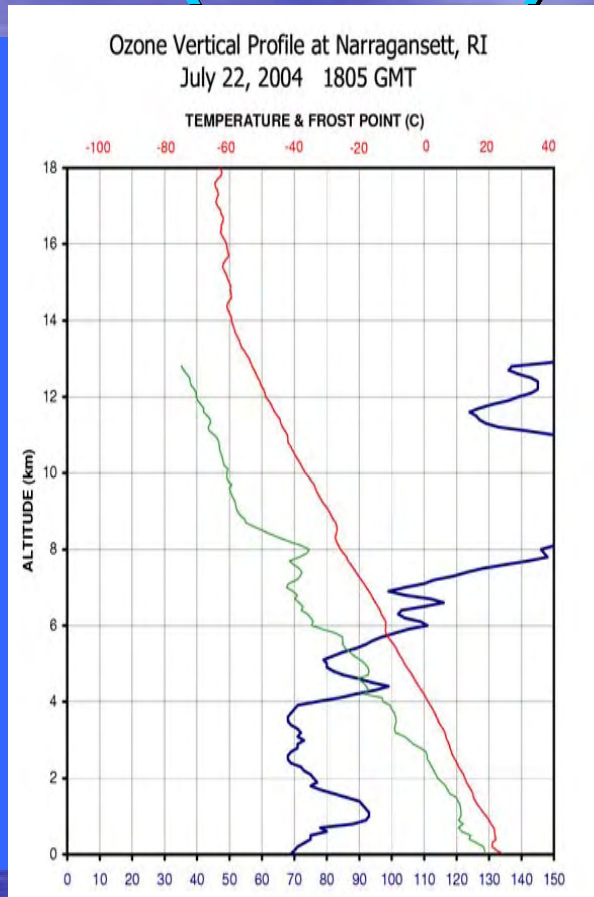
Sources (local and regional production, long-range transport, lightning, injection from the stratosphere)

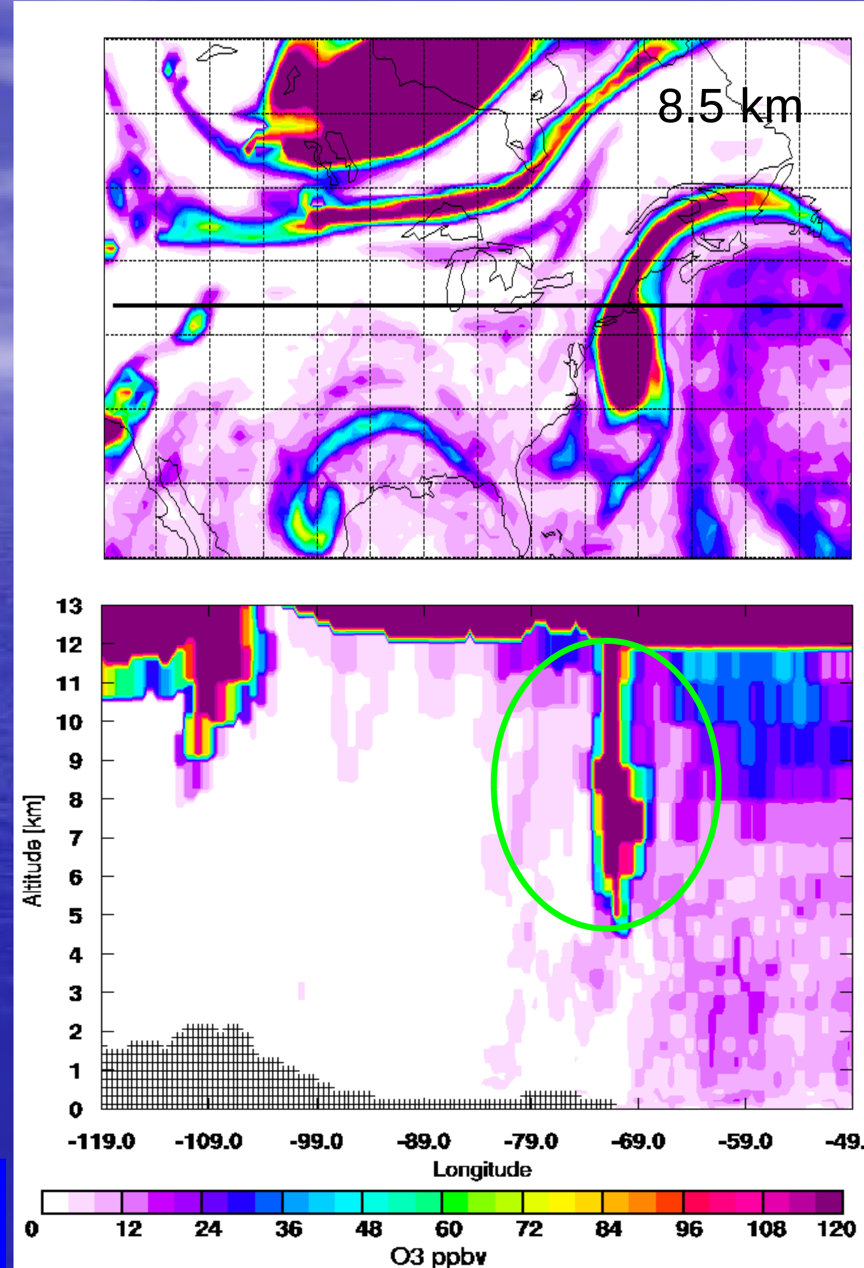


Local and regional photochemical ozone production and long-range transport are major topics of two other theme presentations (AQ and LTCT).

Stratospheric Ozone Tracer at 8.5 km on July 22, 2004 (IONS 04)

Stratospheric ozone tracer comes from the FLEXPART model developed by Andres Stohl. It is a Lagrangian, quantitative particle dispersion model that includes full turbulence and convection parameterizations.



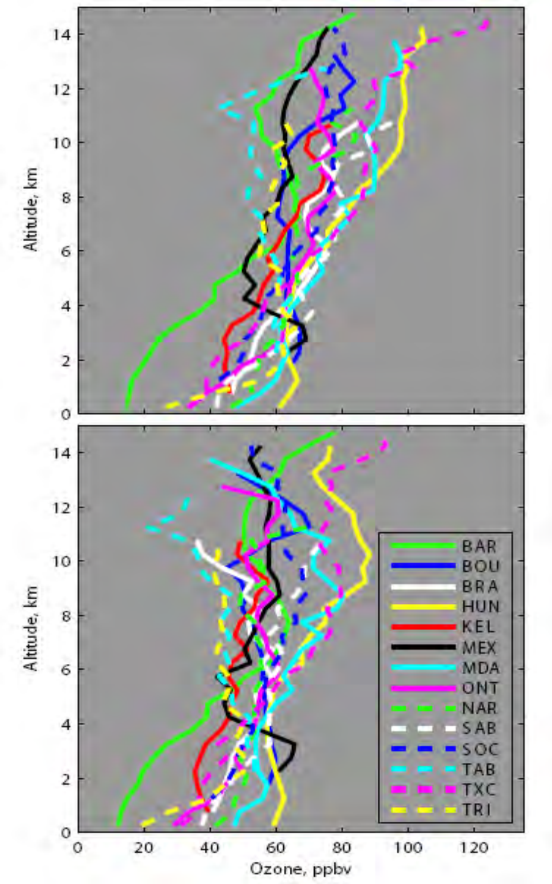


IMPORTANCE: Although not an anthropogenic source, climate change could influence input from the stratosphere. It is also an important test of model performance.

FLEXPART analysis by Owen Cooper

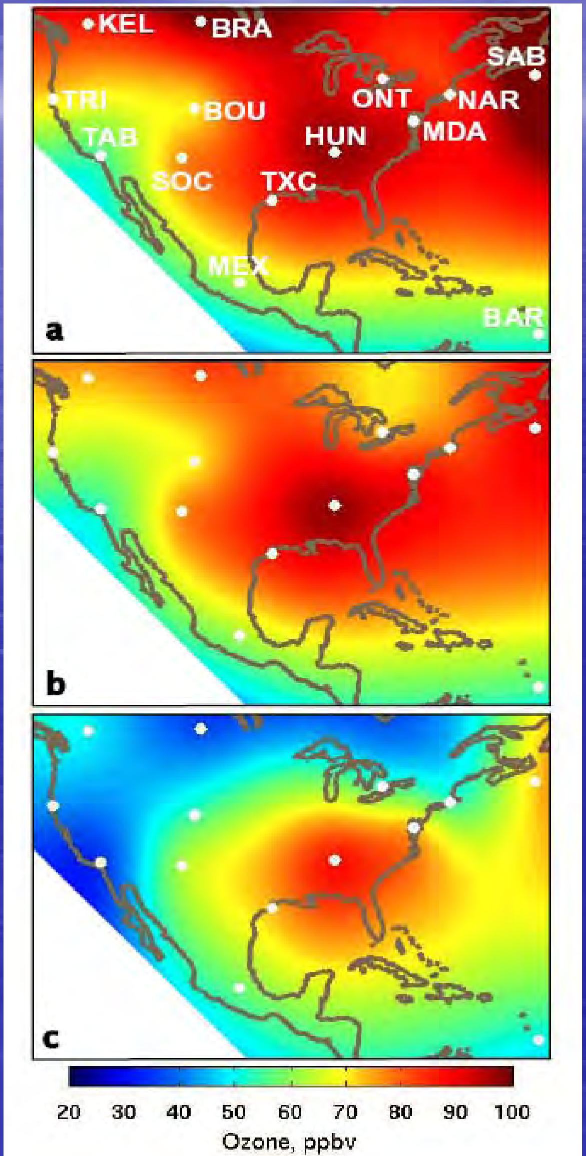
Influence of lightning on upper trop. O_3 over N. America

Average tropospheric ozone profile (top) and with stratospheric ozone removed at IONS 06 sites in Aug. 2006



Cooper et al. (2007), *J. Geophys. Res.*

Contours of ozone mixing ratio at 10-11 km



Modeling study predicted summer upper trop. ozone maximum over central U.S.

Li, Q., et al. (2005), *J. Geophys. Res., 110*, D10301, doi:10.1029/2004JD005039.

Analysis of IONS 04 sonde data suggested that this maximum could have a significant contribution from lightning generated NO_X.

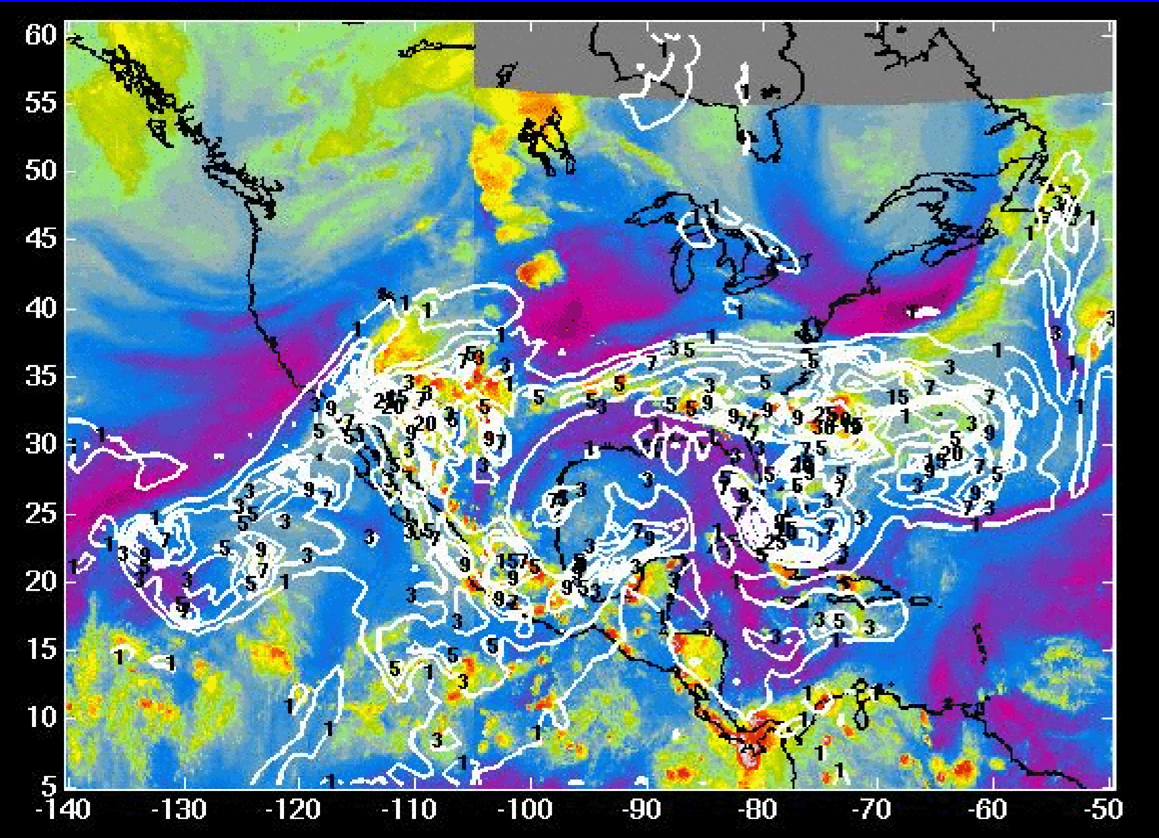
Cooper, O., et al. (2006), *J. Geophys. Res., 111*, doi:10.1029/2006JD007306.

IONS 06 strengthened the connection with lightning, showed the strength and persistence of the maximum, Strong year to year variation.

Cooper O., et al. (2007), *J. Geophys. Res., 112*, D23304, doi:10.1029/2007JD008710.

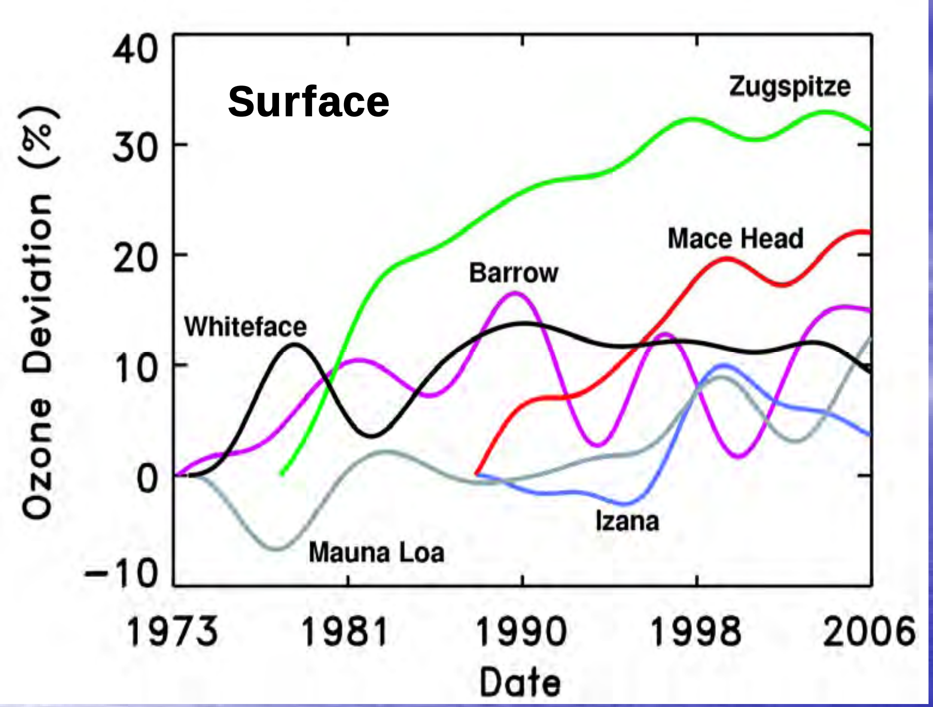
00 UTC, Aug. 12, 2006

Lightning NO_X tracer for FLEXPART superimposed on GOES upper troposphere water vapor image.



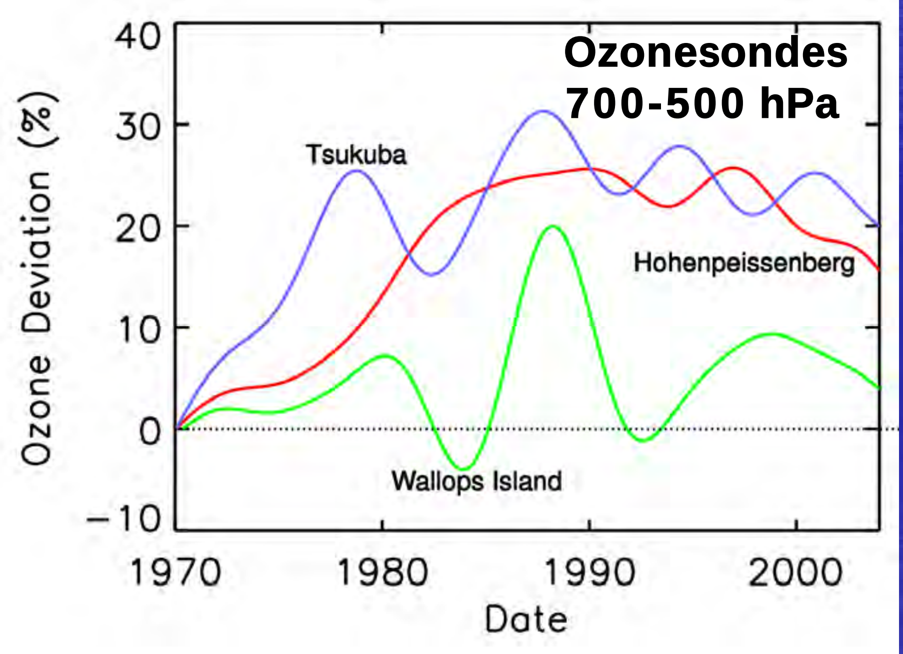
IMPACT: Persistence of the anti-cyclone and connection with convection suggest that upper troposphere ozone in this region could be influenced by and impact climate.

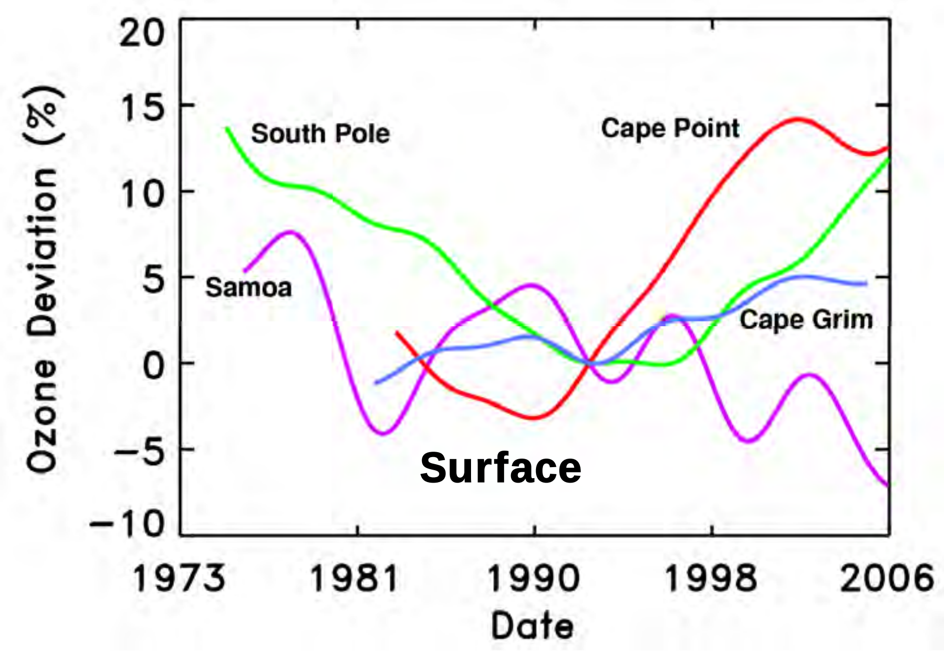
Trends from longer-term surface ozone and ozonesonde measurement stations in the N.H. and S.H.



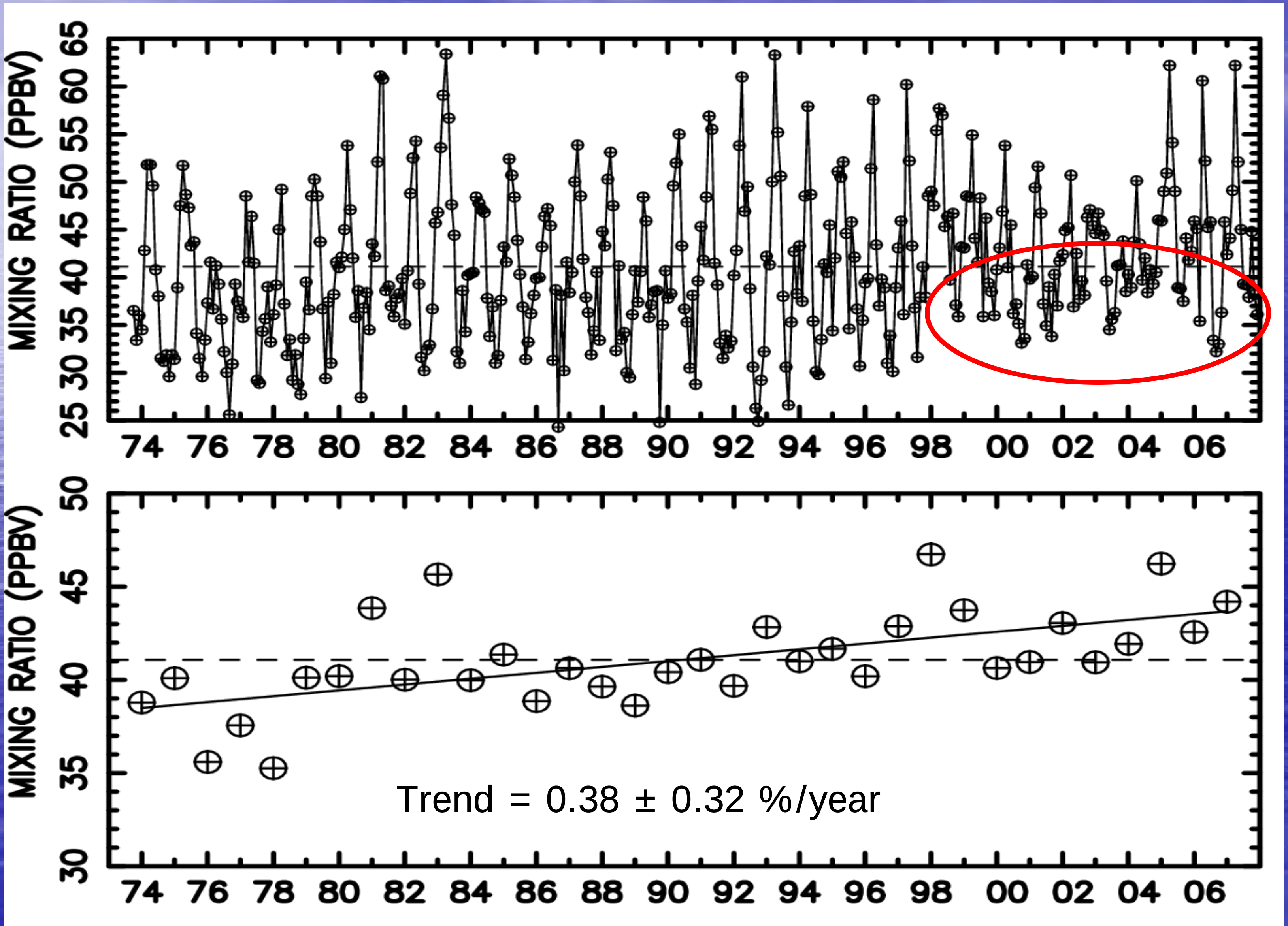
Oltmans et al. (2006) *Atmos. Environ*.

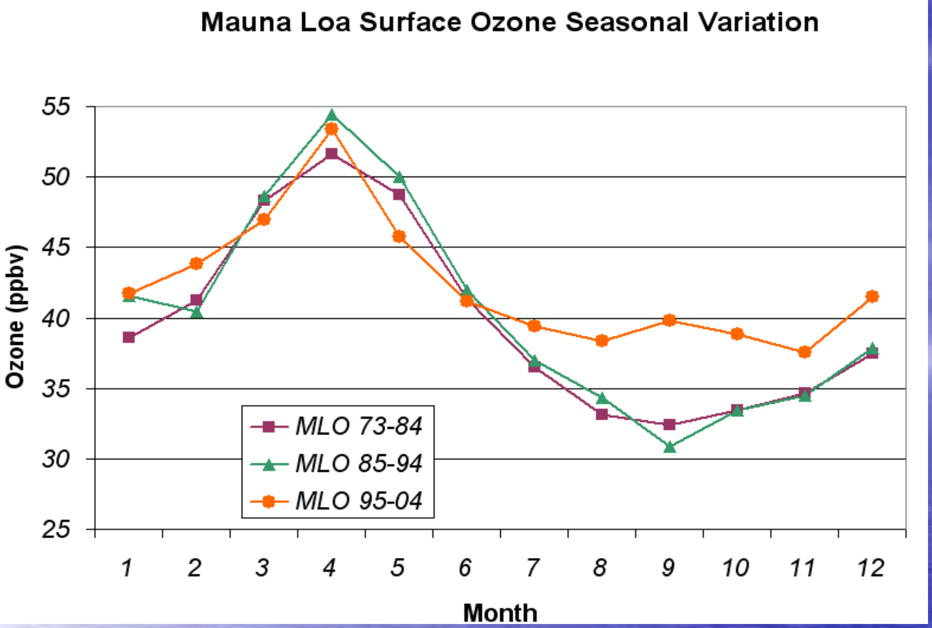
SIGNIFICANCE: Analysis of these “regionally representative” longer-term records provide a primary source of observational information on tropospheric ozone changes.





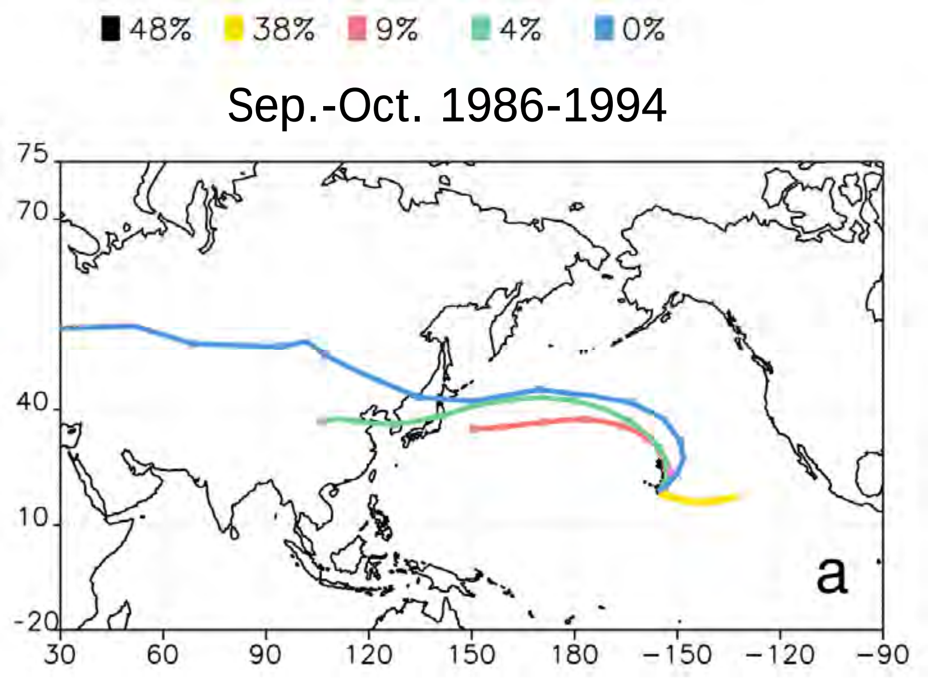
Mauna Loa nighttime (downslope) surface O3 monthly means and annual means. Circled data shows persistent increase in seasonal minimum (autumn) amounts in recent years.

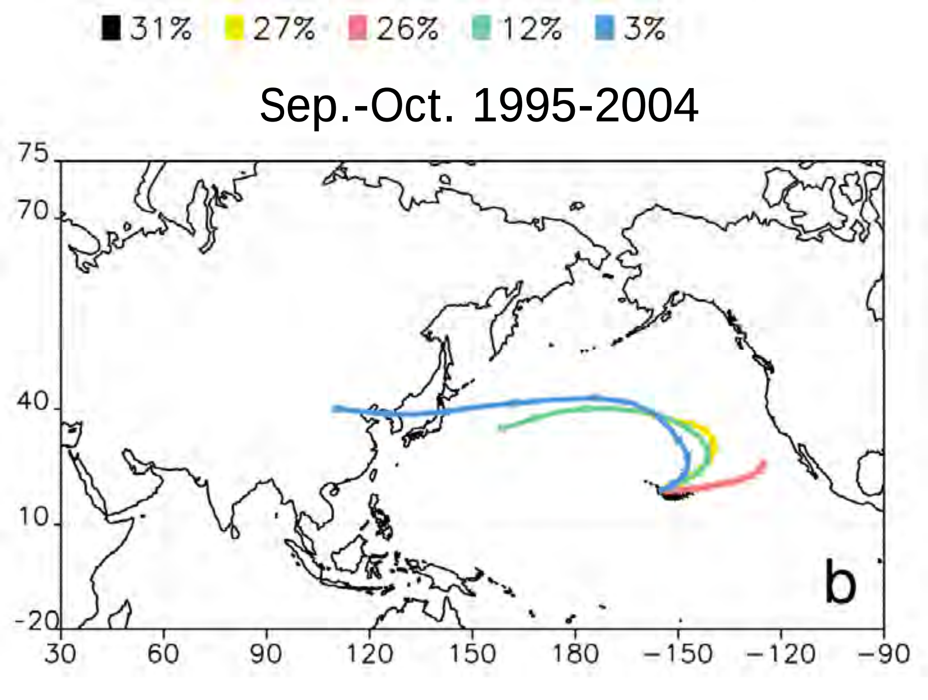




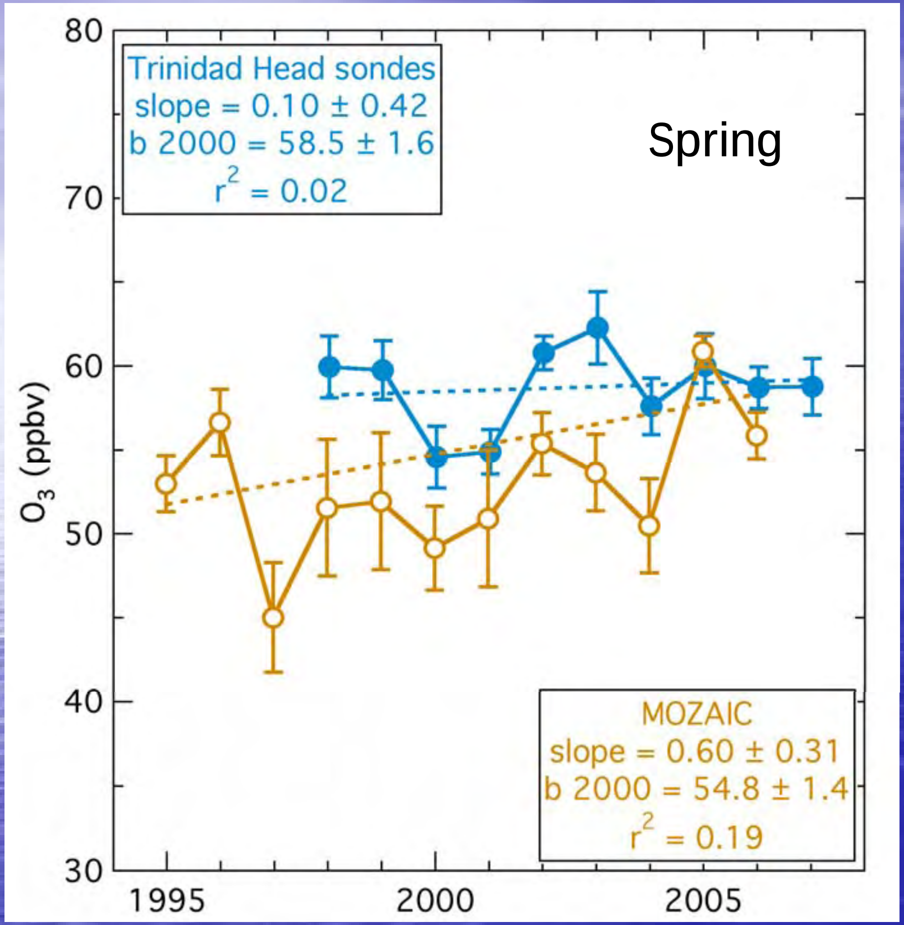
Contrasting flow patterns to Hawaii for the two time periods in September and October when significant changes have taken place.

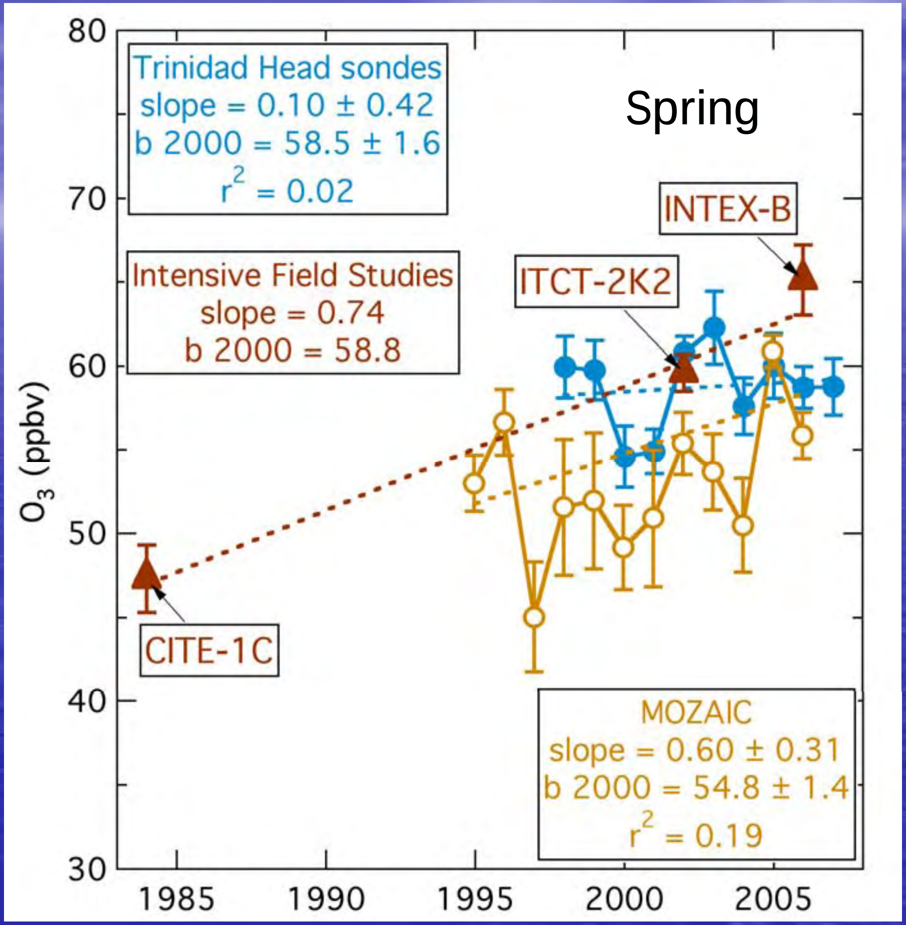
Emphasizes the importance of transport in ozone changes





Comparison of west coast aircraft (MOZAIC and campaign) profiles and Trinidad Head ozonesonde profiles.

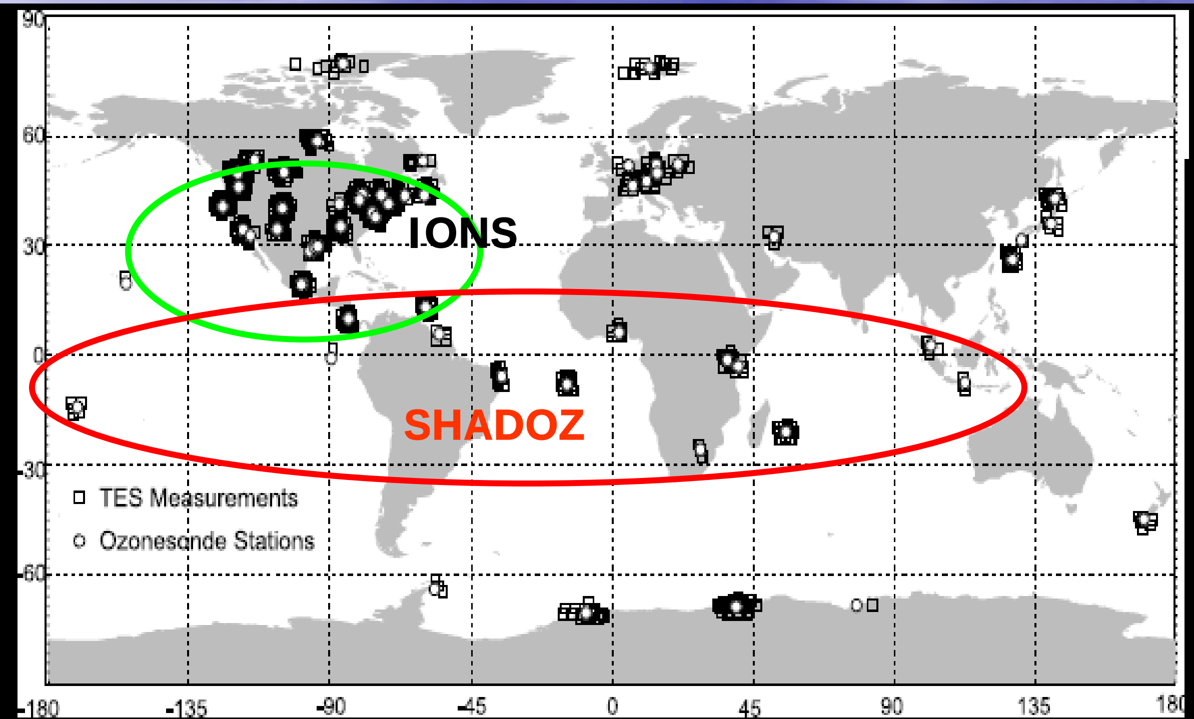




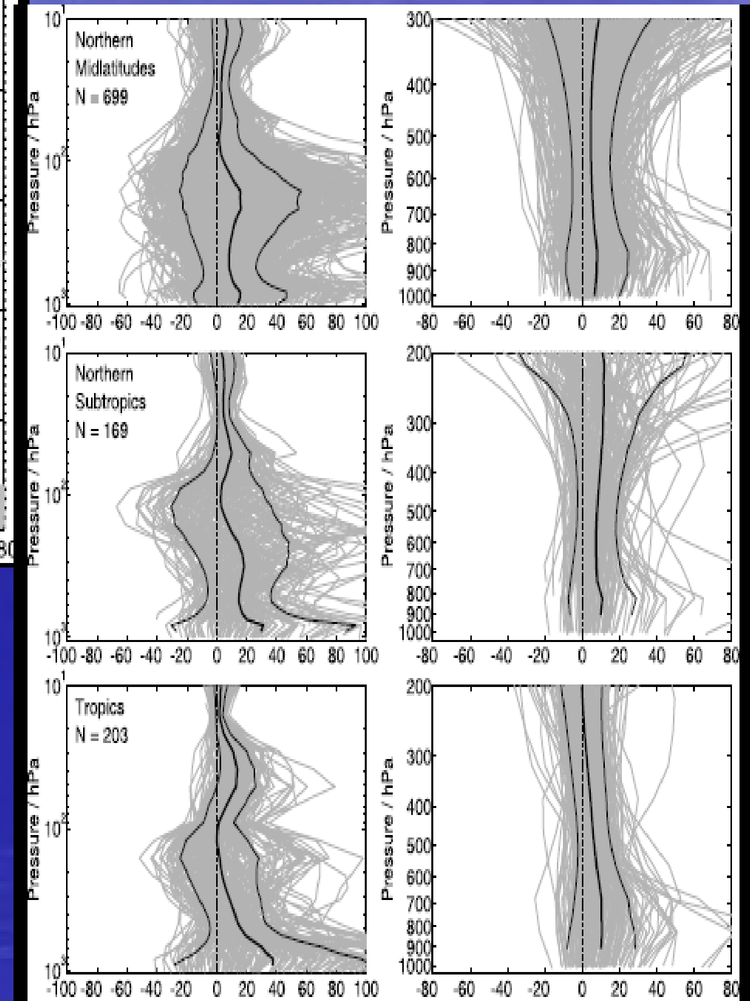
Parrish et al. (2008) in preparation

Analysis of different data sets (ozonesondes vs. aircraft, different time periods) suggest that current data leave open the question of how well west coast U.S. tropospheric ozone changes are known – a strong incentive to continue monitoring and conduct intensive field studies.

Validation of satellite tropospheric ozone profiles



Nassar et al. (2008), *J. Geophys. Res.*, in press



NOAA/ESRL has partnered with NASA, Met. Service of Canada and a number of others to develop “strategic” ozonesonde networks that have played a major role in satellite trop. ozone validation (TES, AIRS, OMI).

Summary

- **Long-term tropospheric ozone changes** on a global basis **are not well determined** from observations.
- **A variety of processes can contribute to** both the geographic distribution and vertical structure of **longer-term changes**.
- **Continuing measurements** of representative tropospheric ozone time series **and studies of processes** responsible for longer-term changes **are essential for understanding** the role of tropospheric ozone as a greenhouse gas (and other roles as well).