Recent Tropospheric Ozone Changes – A Pattern Dominated by Slow or No Growth

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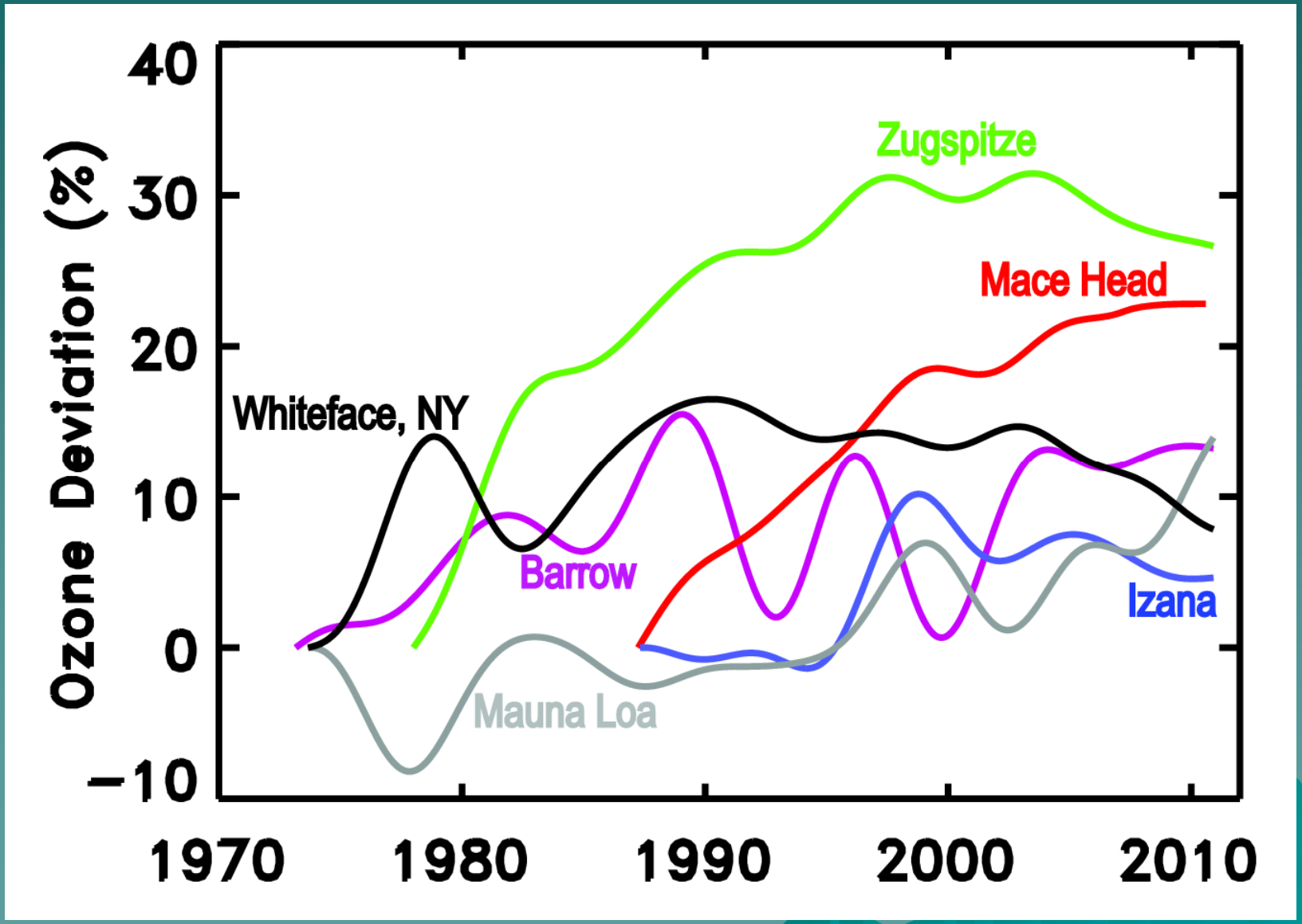
What is this talk about?

- **What are results from the available data from four decades (~1971-2010) of observations for the longest records?**
- **Increasing number of locations that have more than 25 years of observations (surface and ozonesondes).**
- **What are the implications from this record of observations?**
  - Are the records consistent in regions with multiple records?
  - At what geographic scale can conclusions about trends be drawn (global, hemispheric, regional)?
  - Are changes related to precursor emissions, transport variability, even climate change?
  - Has the pattern of change been changing with time?

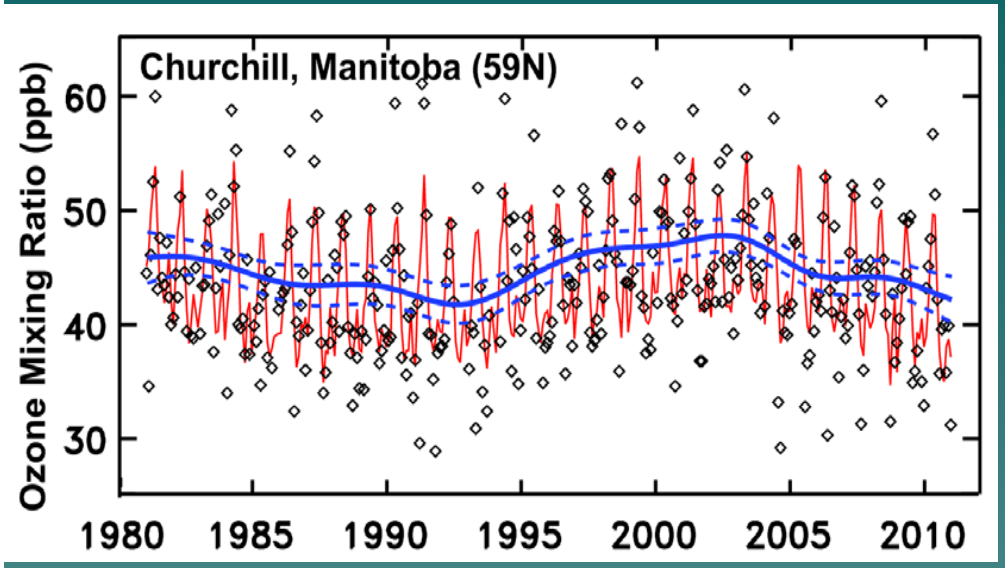
Trends at selected N.H. surface ozone sites

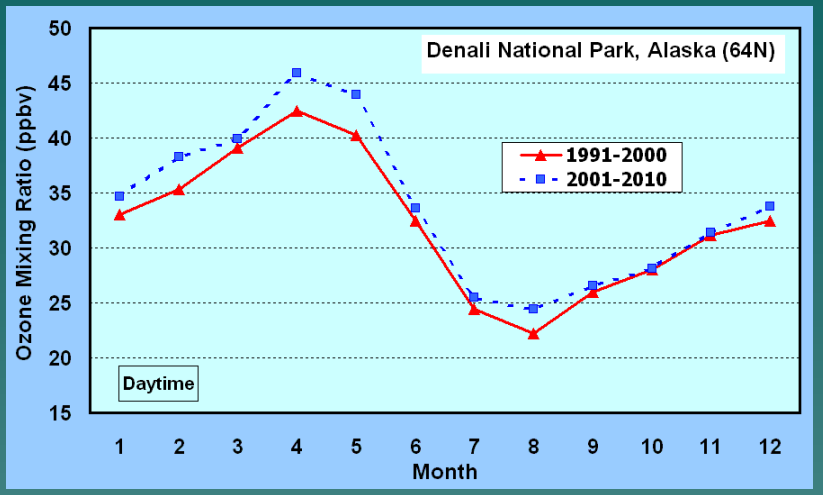


Data available for investigating longer-term changes in tropospheric ozone

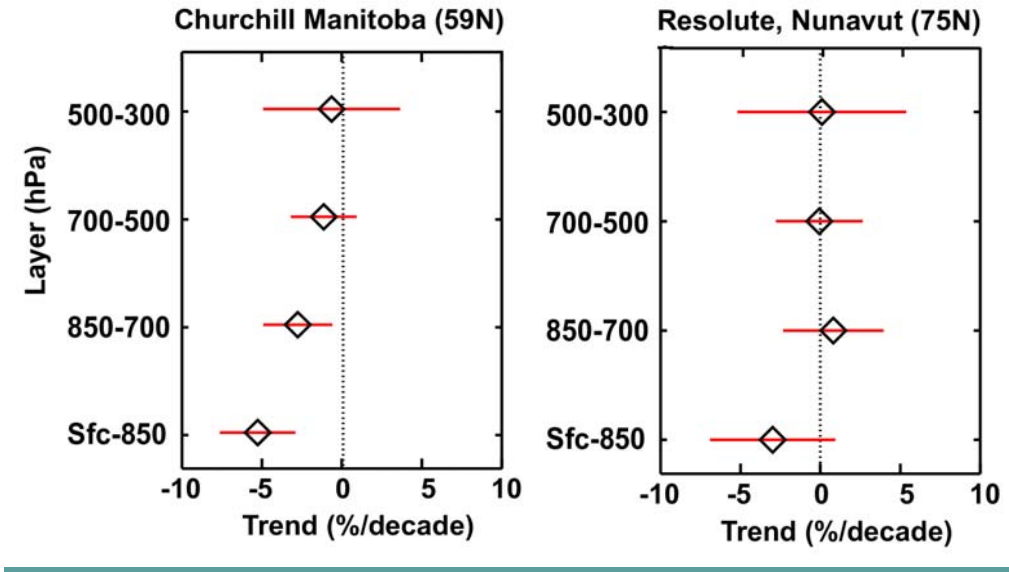
- Ozone vertical profile measurements from ozonesondes with the earliest records going back to the late 1960s.
- Surface ozone observations with the oldest continuing records beginning in the mid 1970s.
- Particular interest in records that are representative of broad geographic regions.
- Looking for sites or altitude regions where local effects are minimized (have made some compromises to include several long records).
- Look at changes by region (northern mid latitudes, high northern latitudes, southern hemisphere)
- Consider two interesting cases in the NH tropics (Hawaii) and the high Arctic (Barrow, Alaska)

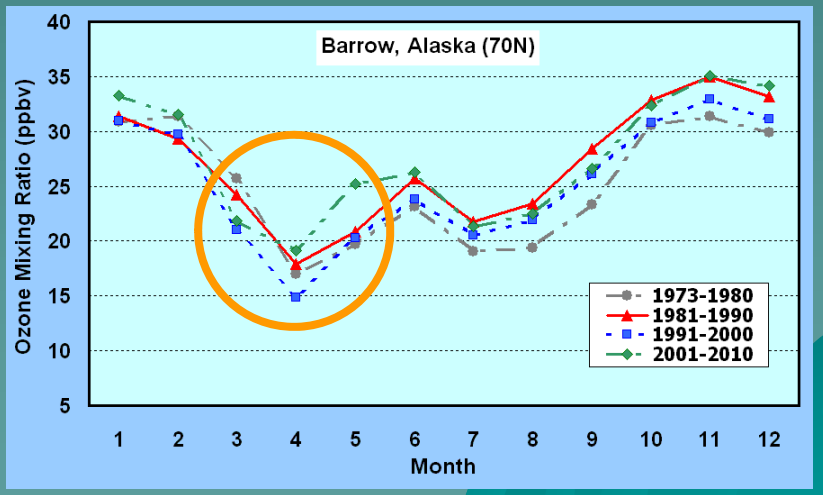
High Latitude North America





Result: Spring change may be related To biomass burning in Eurasia.

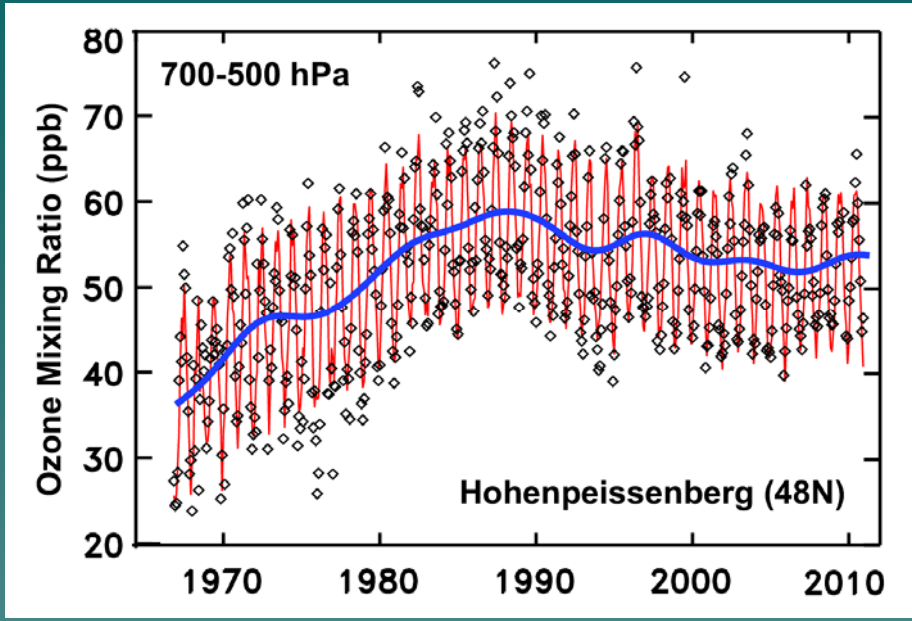


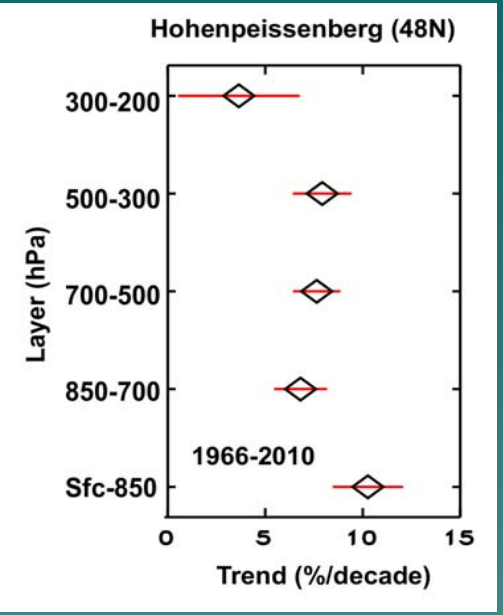


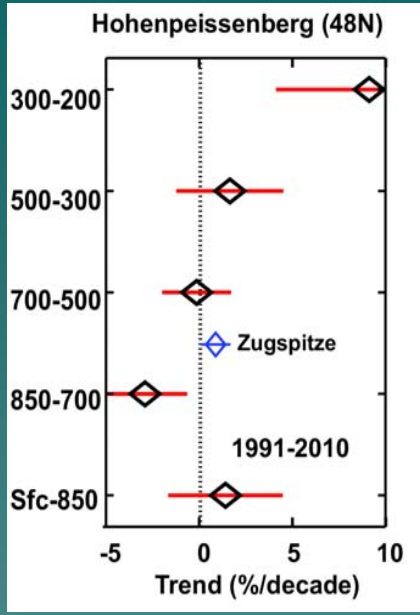
Result: Canadian ozonesonde stations show only small changes over 30 years.

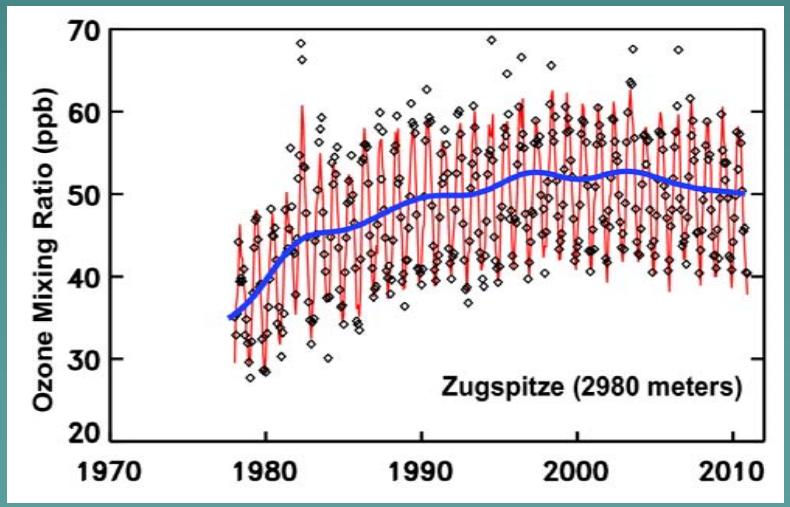
Result: Is there an indication of a change in spring related to climate?

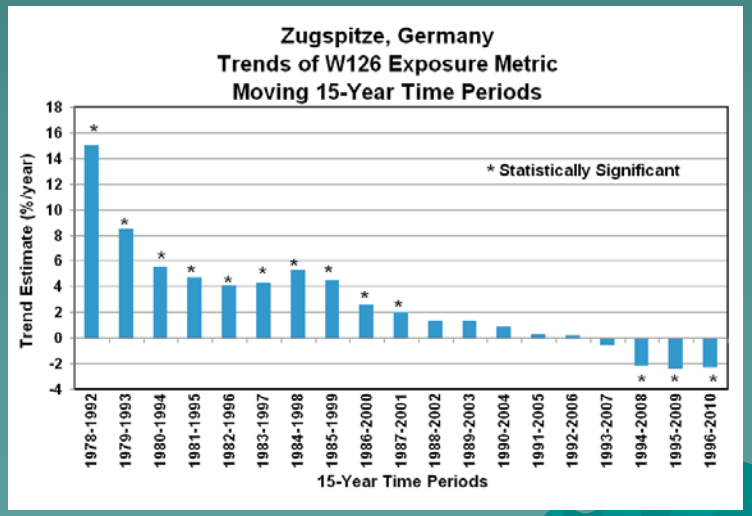
Trends in Western Europe







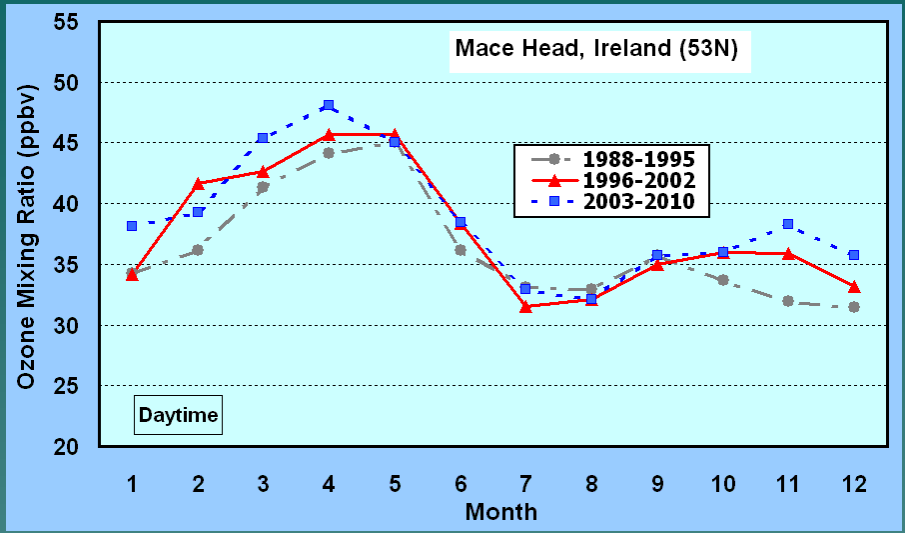


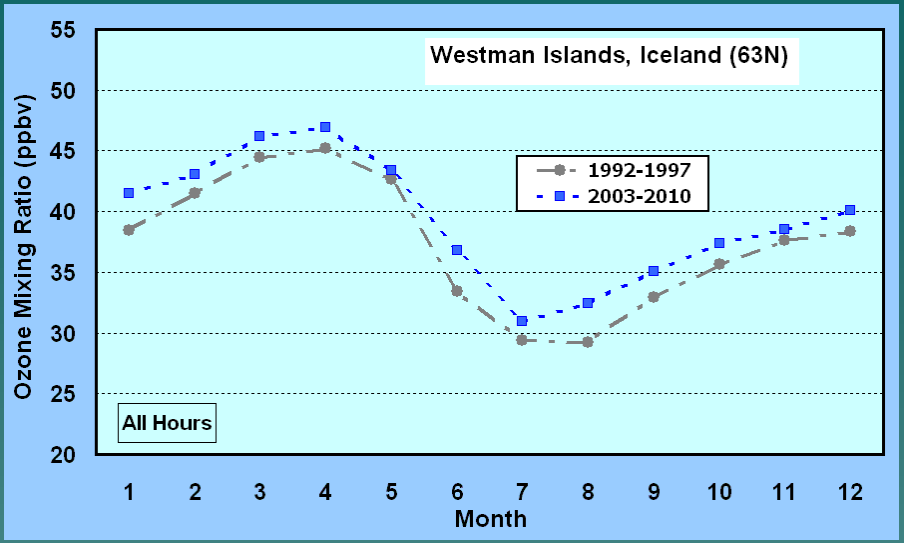


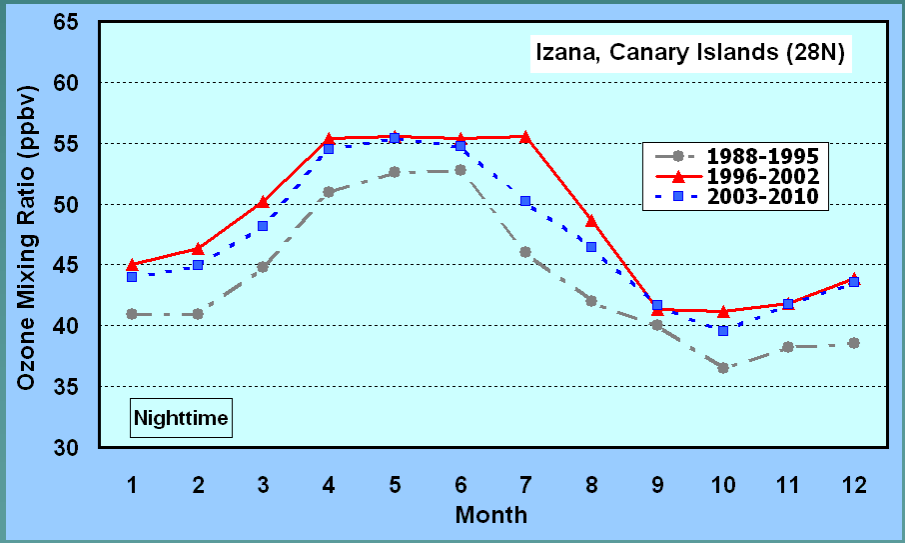
Result: Most locations in W. Europe show decreases in the past 10-15 years

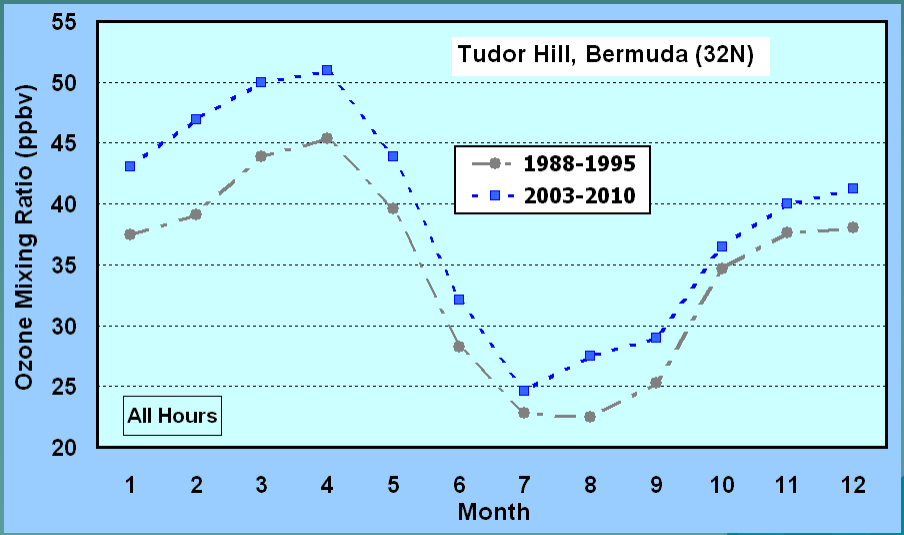
Thorough discussion of the changes In Europe in J. Logan et al., JGR, In press.

Changes Over the North Atlantic



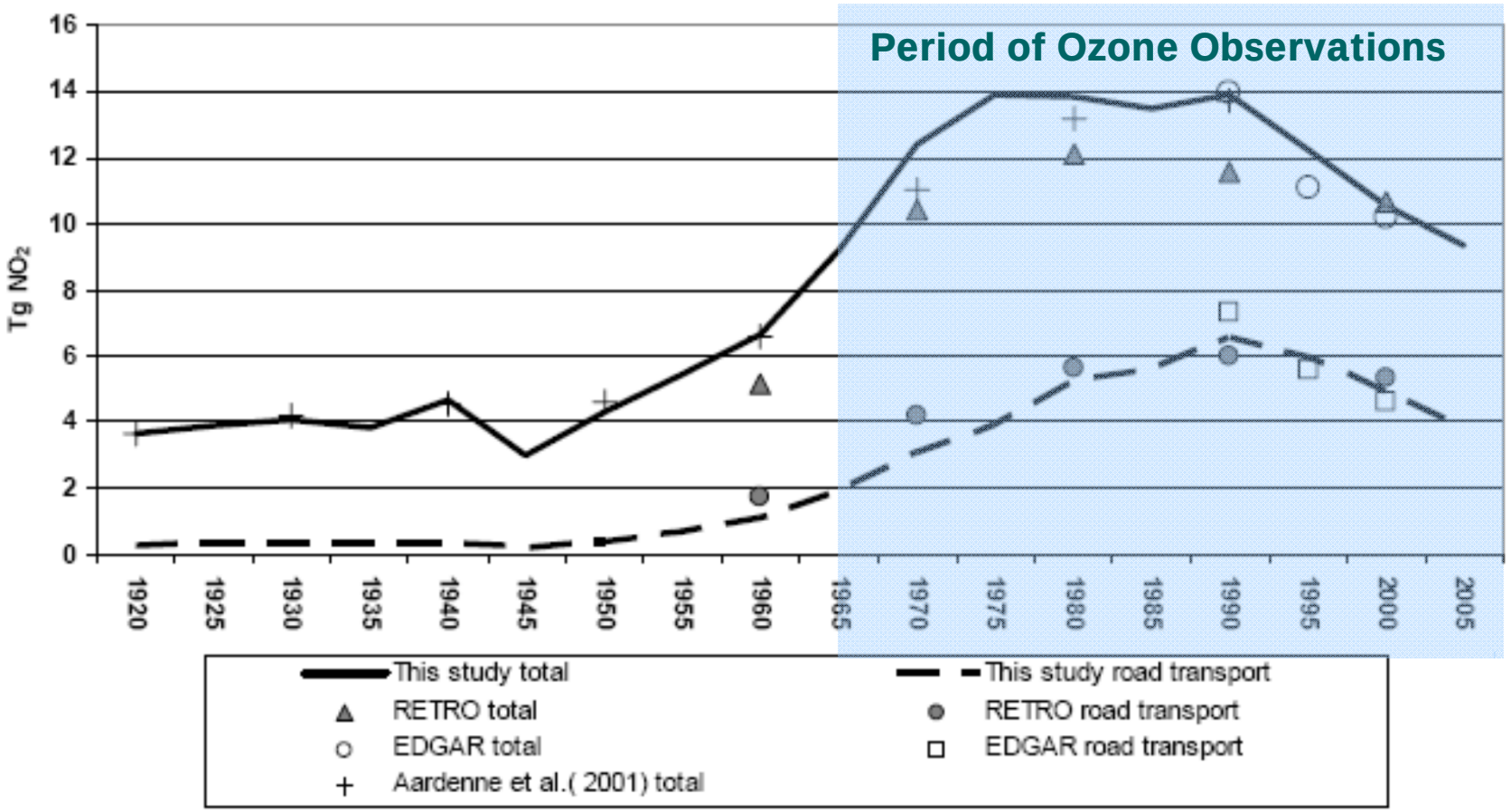






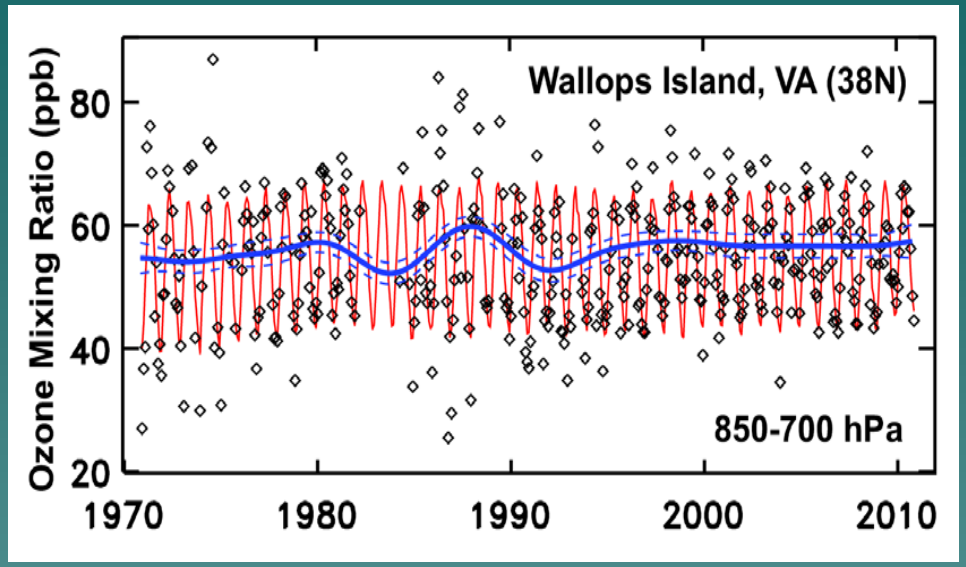
Result: Earlier increase has been followed by a leveling off in the most recent period.

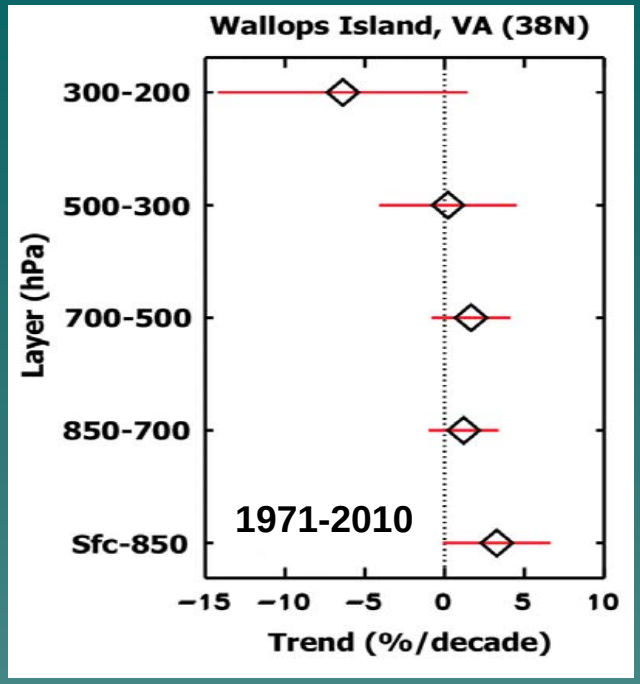
Historical European NO_X Emissions



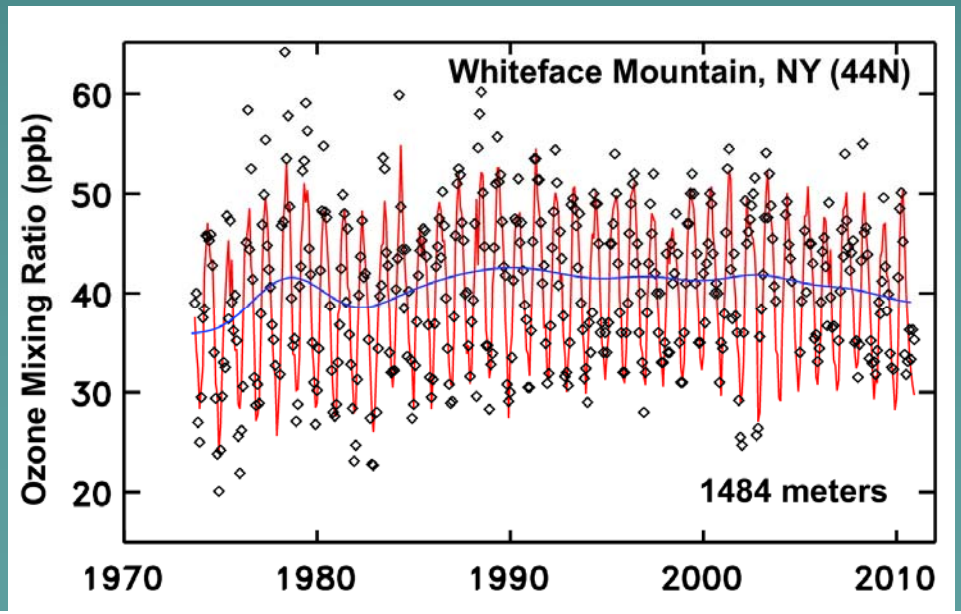
Vestreng, V., Ntziachristos, L., Semb, A., Reis, S., Isaksen, I. S. A., and Tarrasón, L.: Evolution of NOx emissions in Europe with focus on road transport control measures, Atmos. Chem. Phys. Discuss., 8, 10697-10747, 2008.

Changes in the Eastern United States

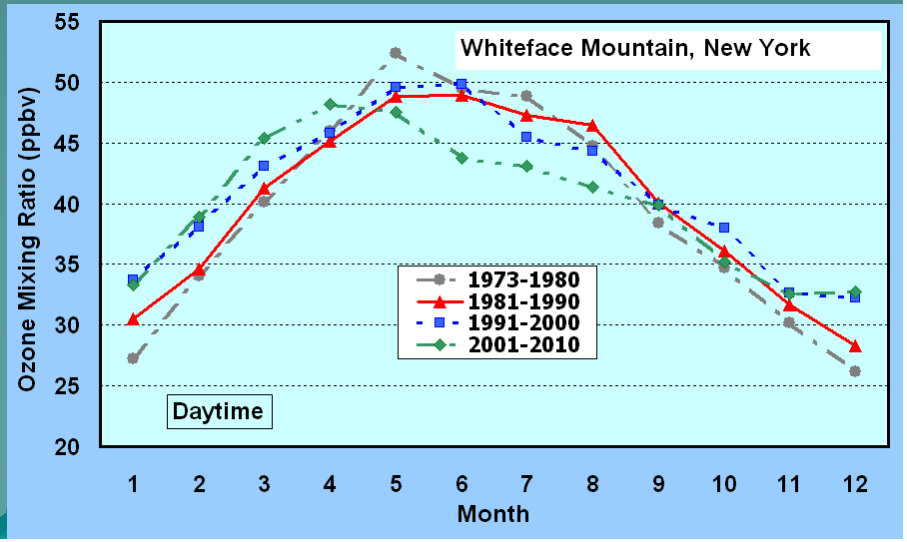




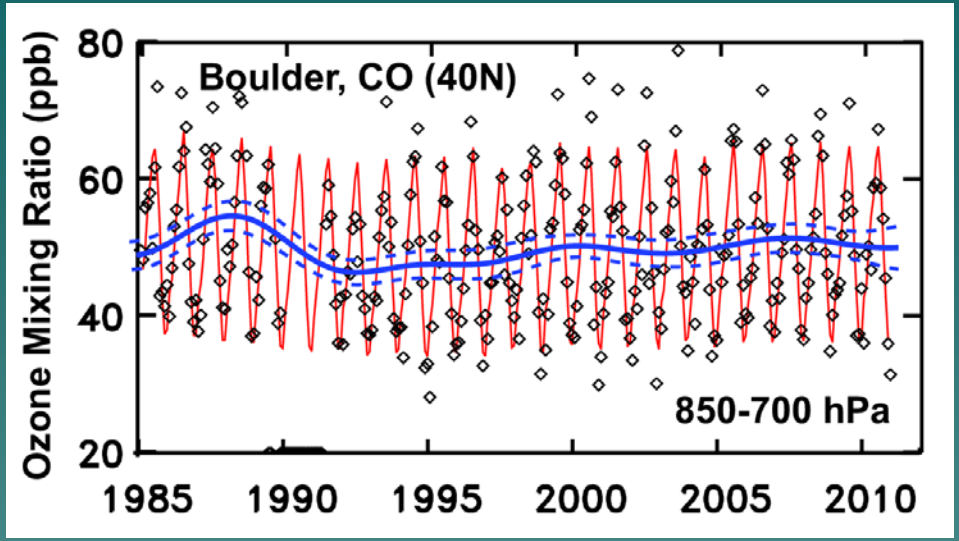
Trends with altitude at Wallops Island, Virginia

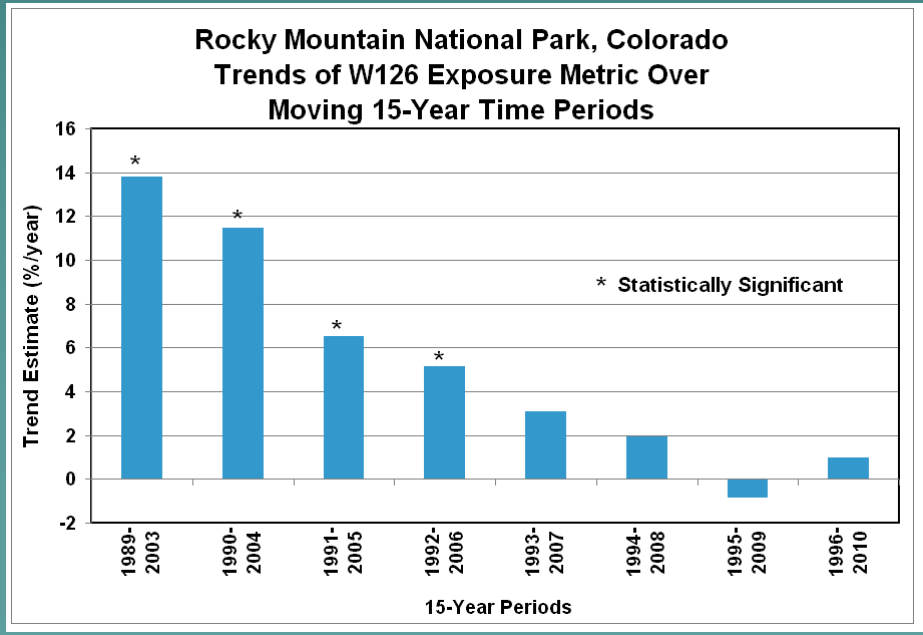


Whiteface 10-year average seasonal variation

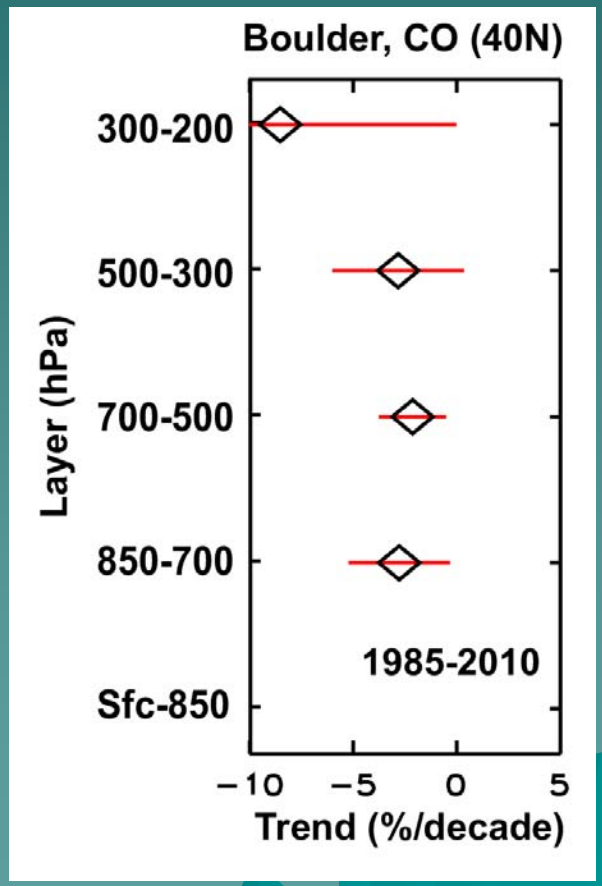


Changes in Western North America

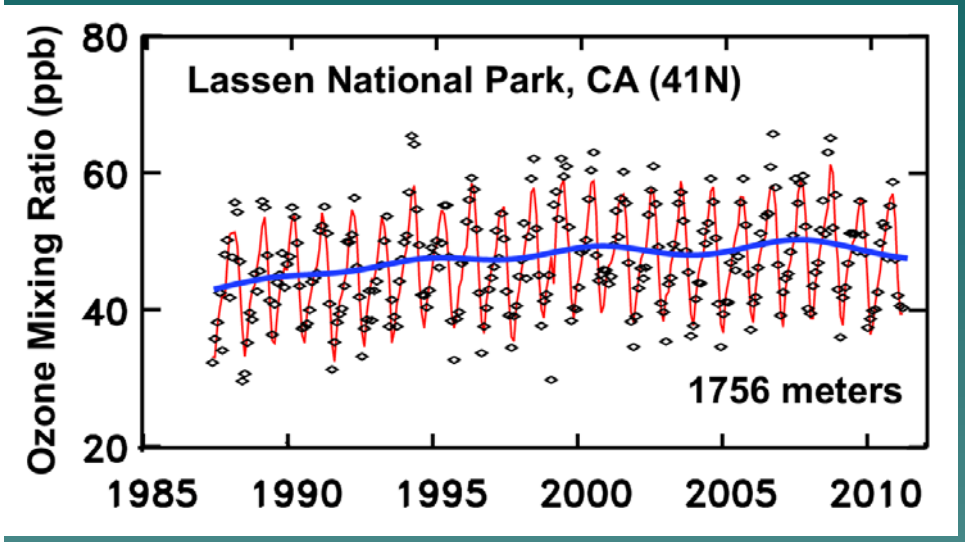


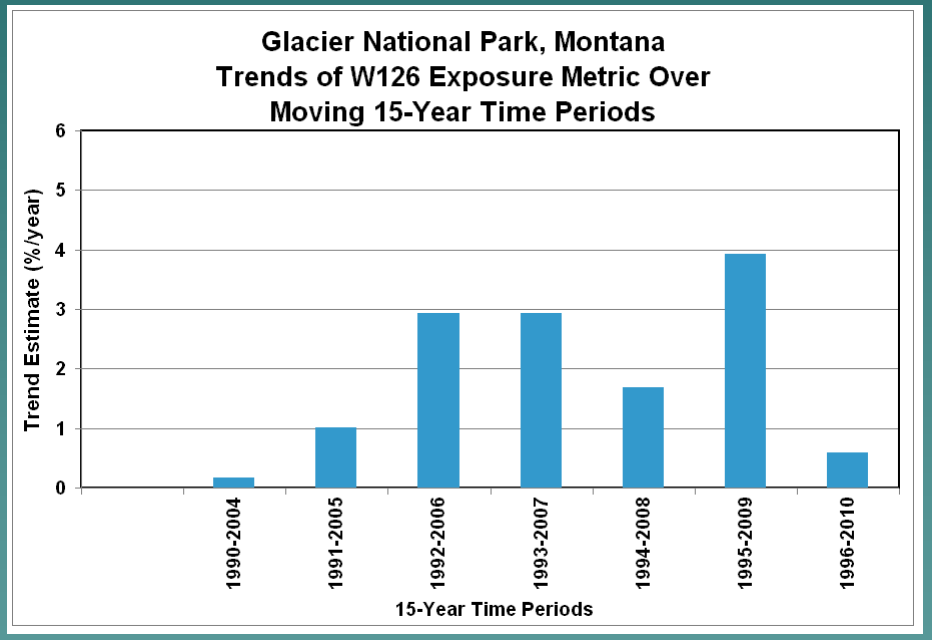


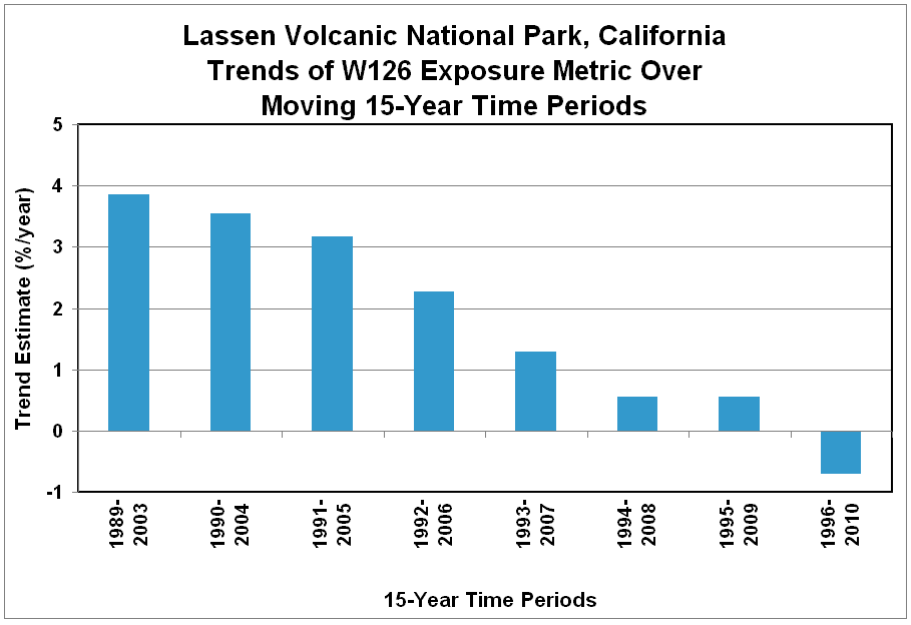
Trends with altitude at Boulder, Colorado



Changes in Western North America

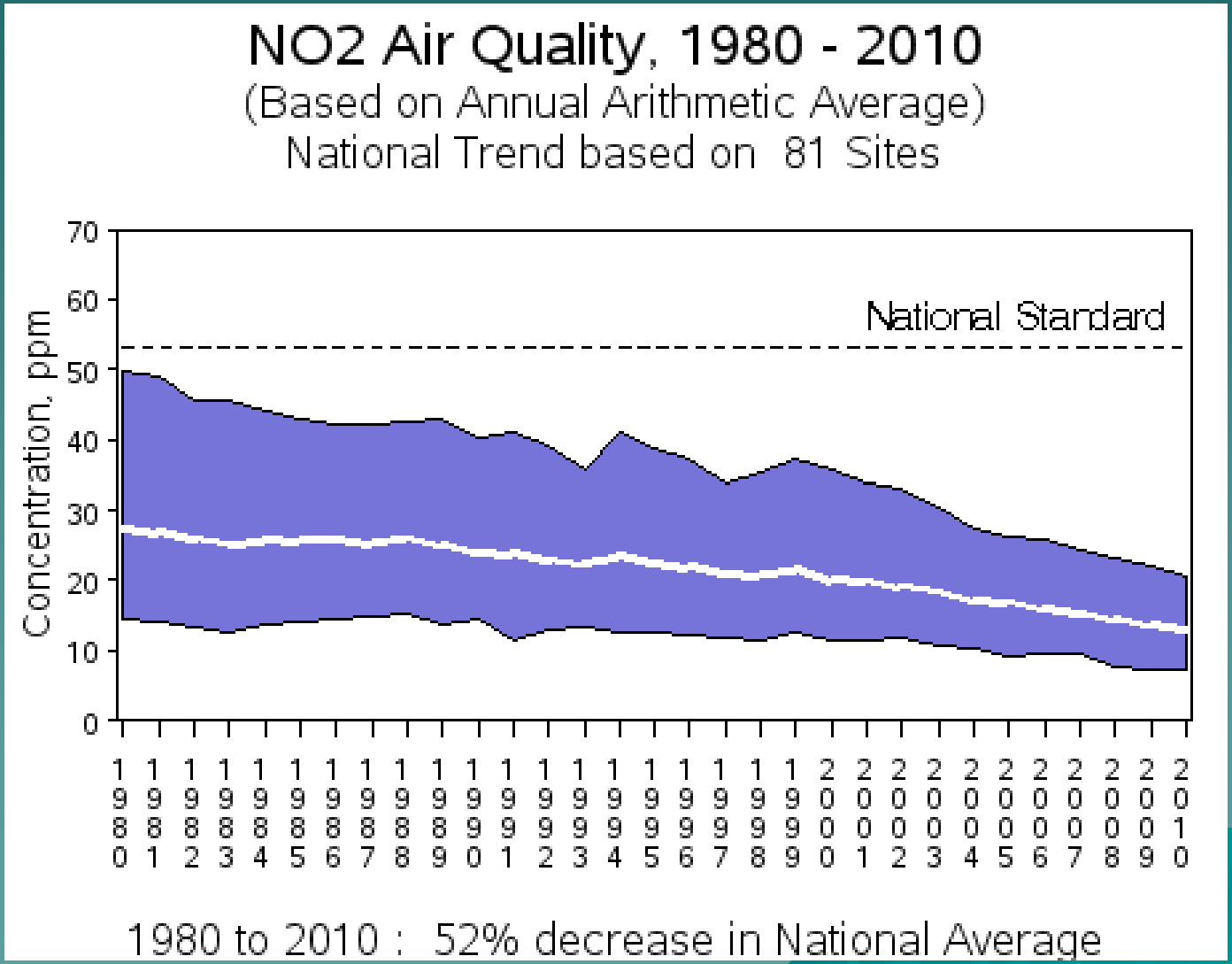




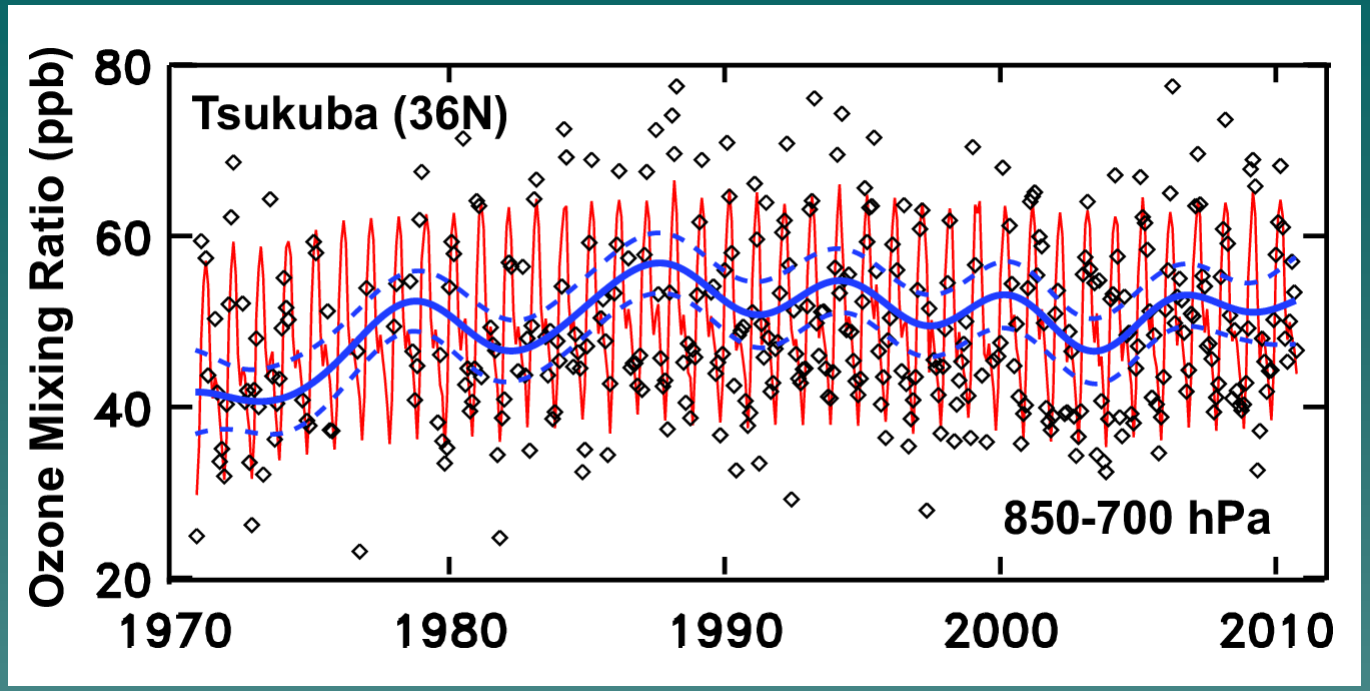


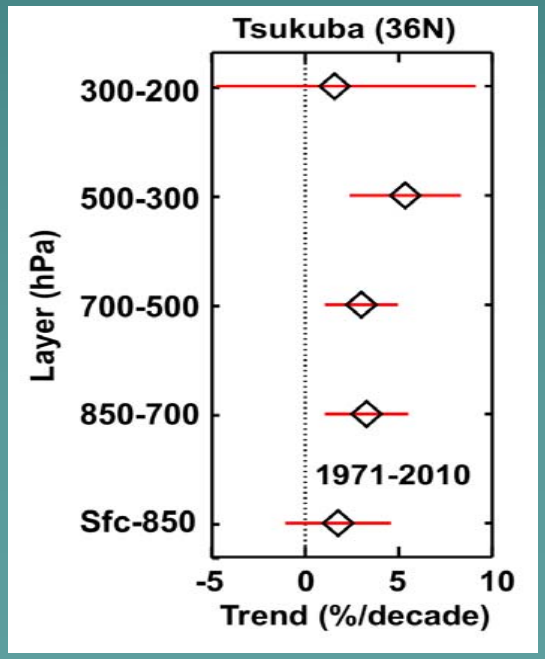
Result: Weak upward trends have leveled off.

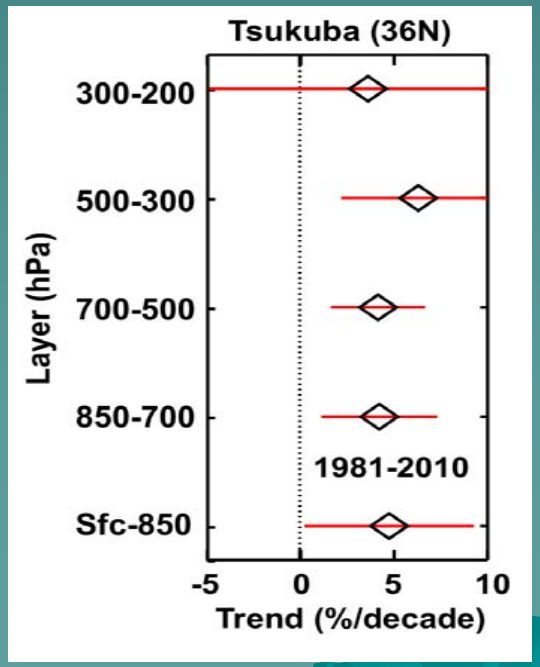
U.S. NO_2 Changes (U.S. EPA)

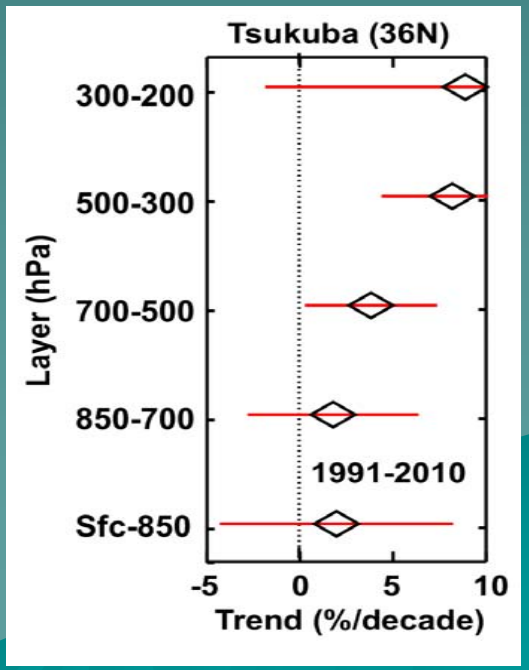


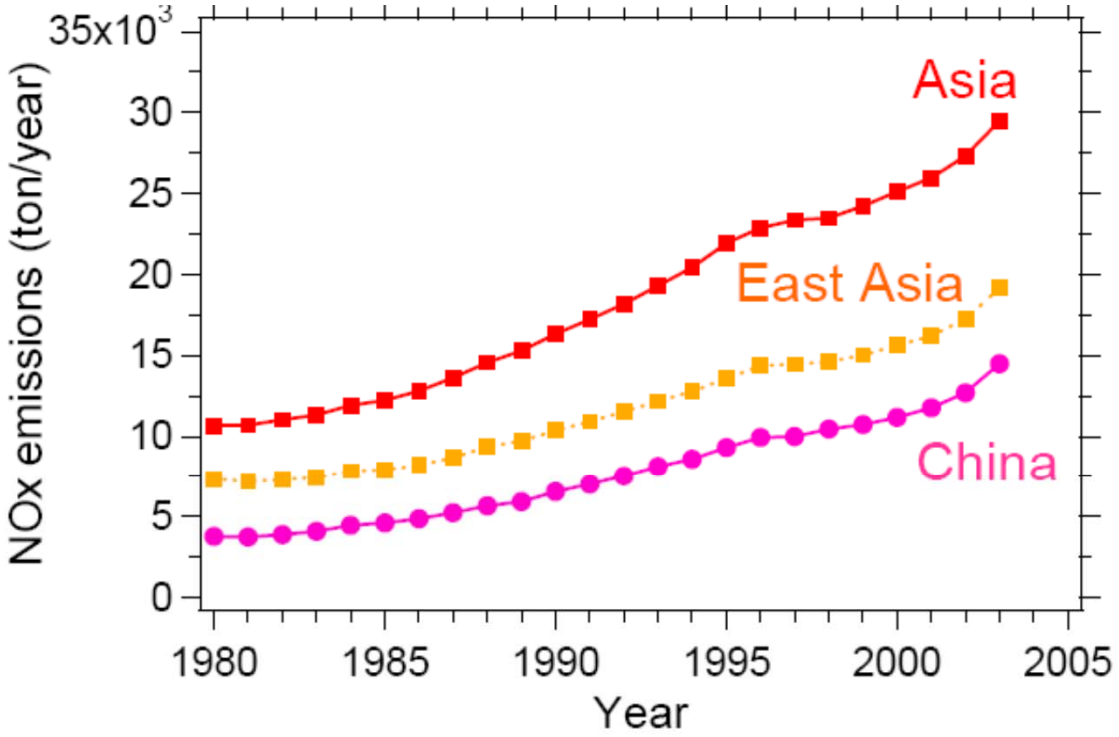
Japan Ozonesonde 850-700 hPa









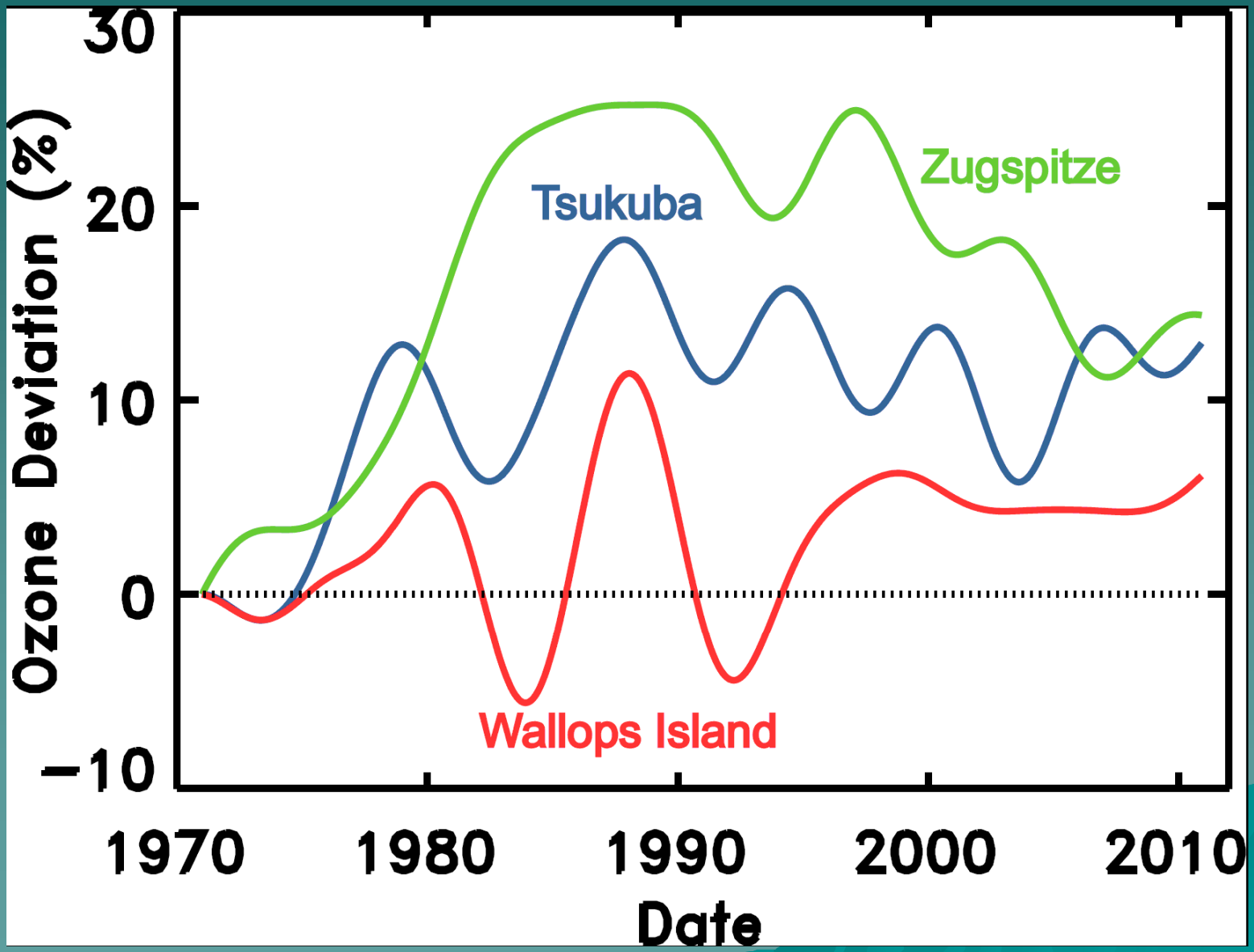


- Chinese emissions dominate ~75% of East Asia, ~50% of Asia
- Mainly from power plants (LPS) and transport sectors
- Rapid increase in recent years

From H. Tanimoto http://www.htap.org/01_2007/presentations/Thursday%20afternoon/Tanimoto-2007%20tfhtap%20tanimoto_MODIFIED.pdf

Result: Some recent NOx emission inventories suggest that emission rates may be slowing. Ozonesondes in Japan have not shown any substantial increases In the lower troposphere in the past decade.

Trends of Ozonesonde Data (1971-2010) at 3 Stations With Long Records (N.America, Europe, Japan)



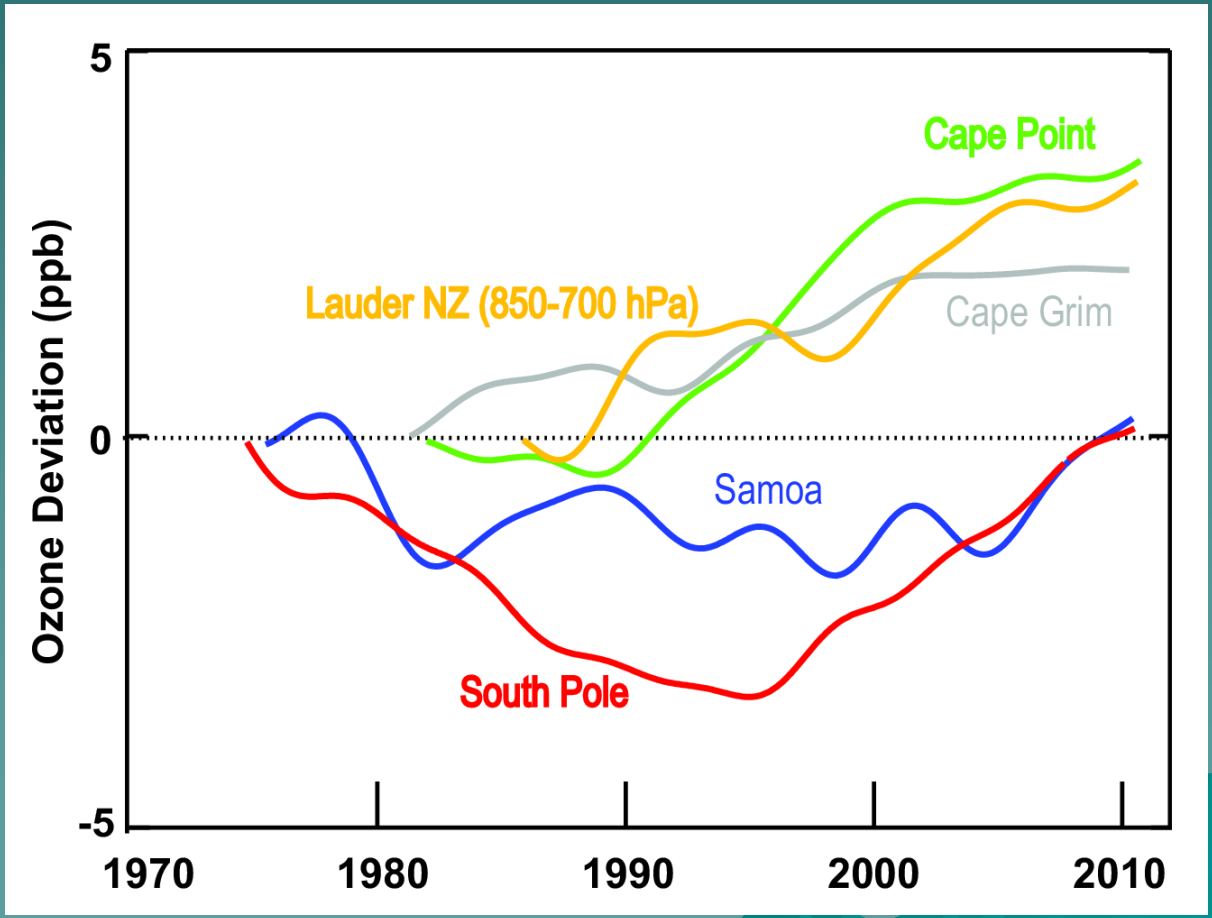
Changes at mid latitudes of the N.H.

- Western Europe – Hohenpeissenberg ozonesondes and Zugspitze surface ozone (high altitude Alpine site)
- North Atlantic - Mace Head, Izana, Bermuda, Iceland surface ozone
- North America – Eastern U.S. (Wallops Island ozonesondes, Whiteface Mountain surface);

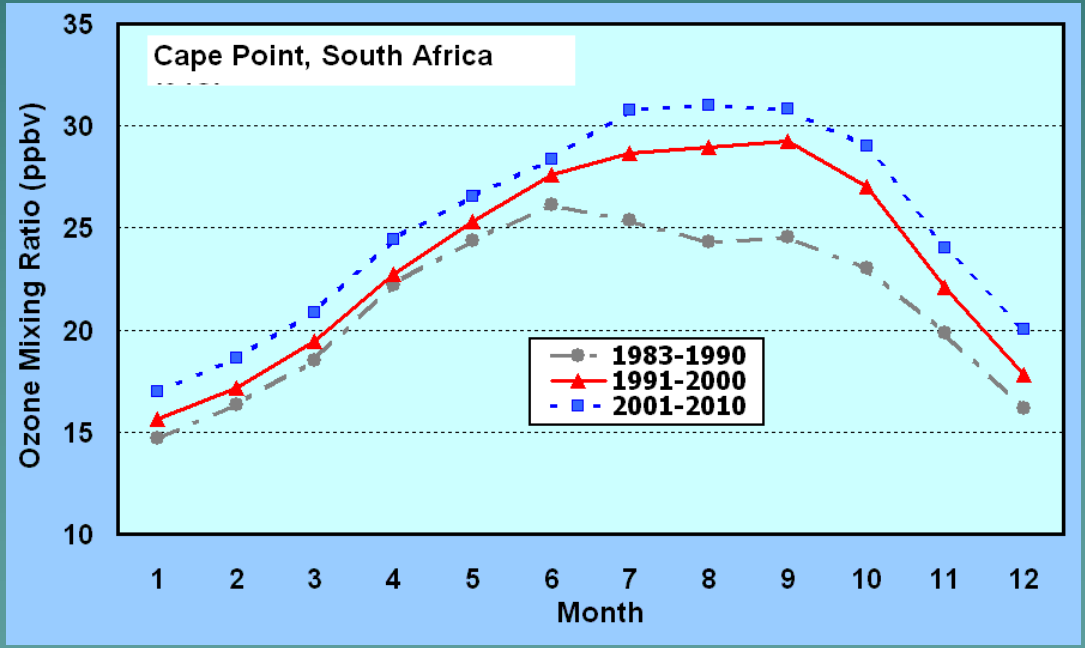
  Western U.S. (Boulder CO ozonesondes; Glacier National Park, Lassen Volcanoes NP, Rocky Moutain NP, Glacier NP surface)
- Japan – Tsukuba and Sapporo ozonesondes

- ALL THESE REGIONS INDICATE NO SUBSTANIAL INCREASE AND SOME SHOW MODEST DECLINES IN THE MOS RECENT 10-15 YEAR PERIOD.

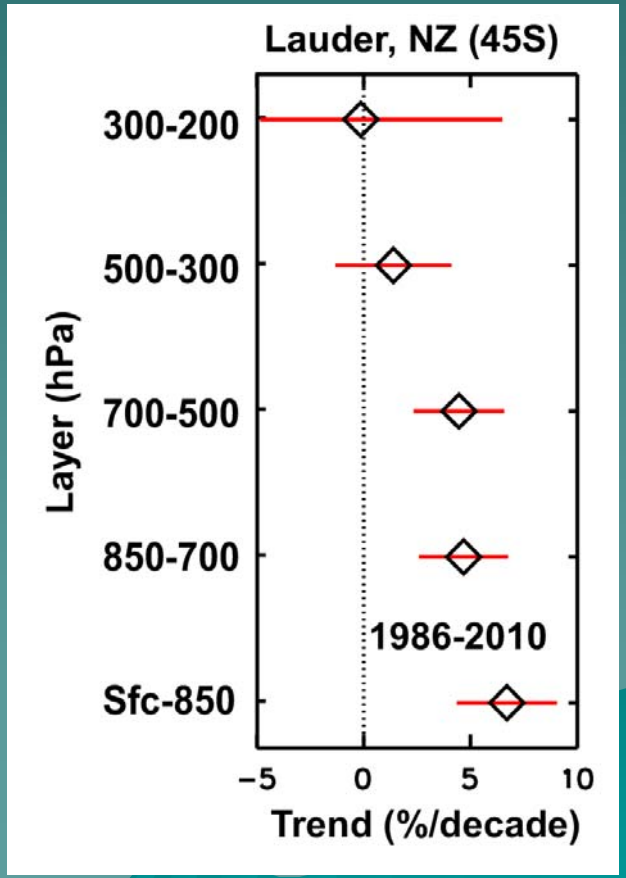
Trends of S.H. surface and Lauder 850-700 hPa ozonesonde data



Seasonal variation of surface ozone at Cape Point



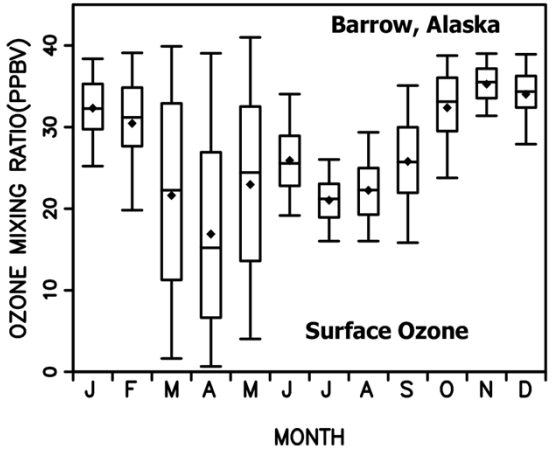
Lauder Trend with altitude



Changes in the Southern Hemisphere

- There have been significant increases at mid latitudes of the southern hemisphere.
- There may be a slowdown of the increases in the most recent decade.
- In the S.H. tropics and polar regions the changes have been small.
- Understanding of changes is minimal.
- The observational network in the S.H. is not adequate to demonstrate the overall pattern of change.

Spring Change in the High Arctic (Barrow)



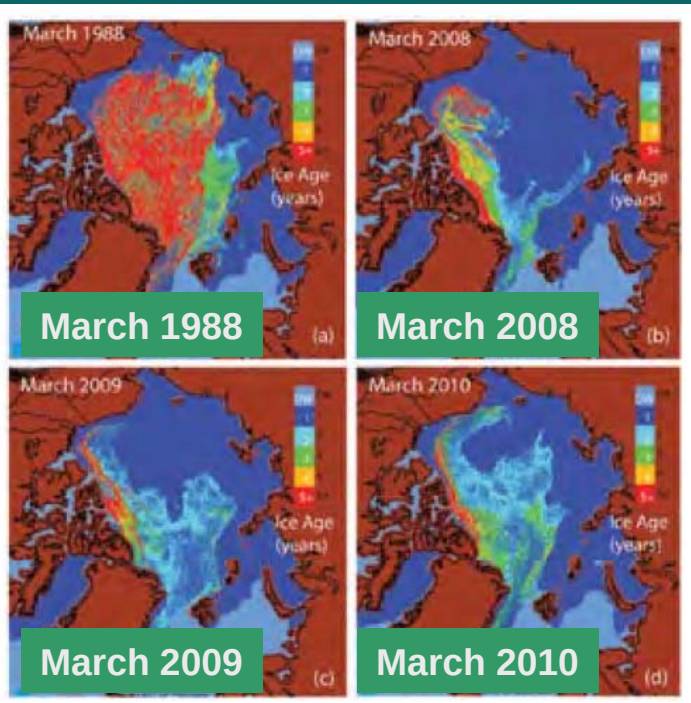
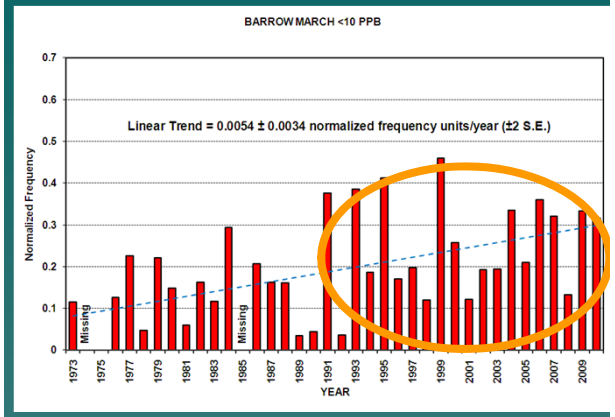
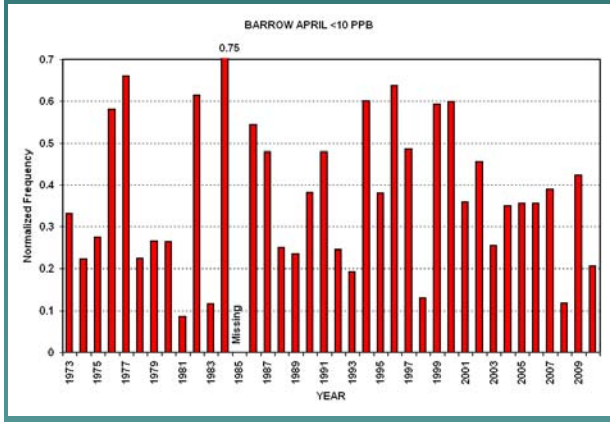
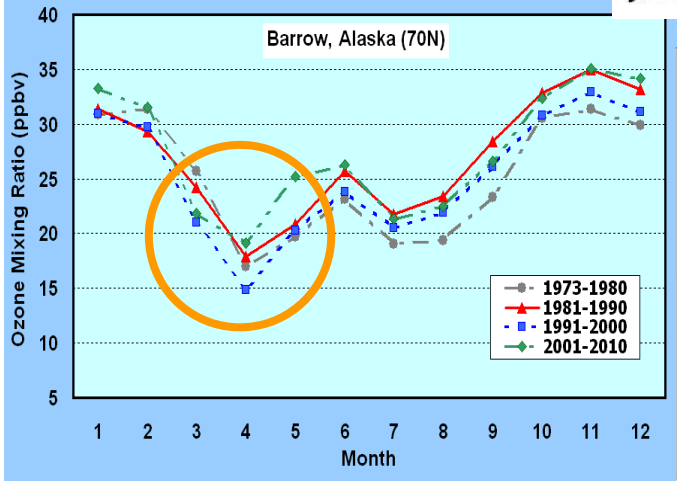
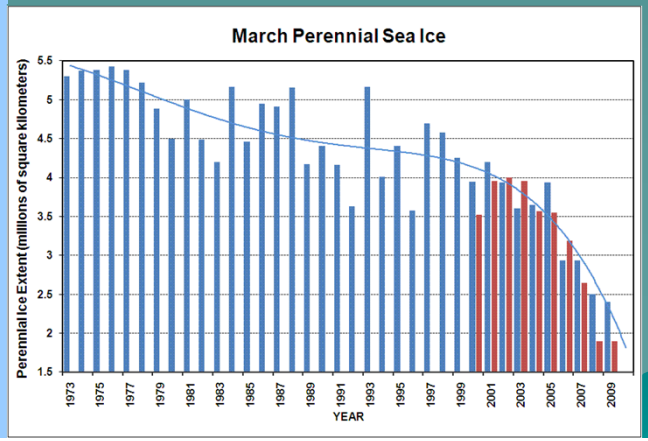


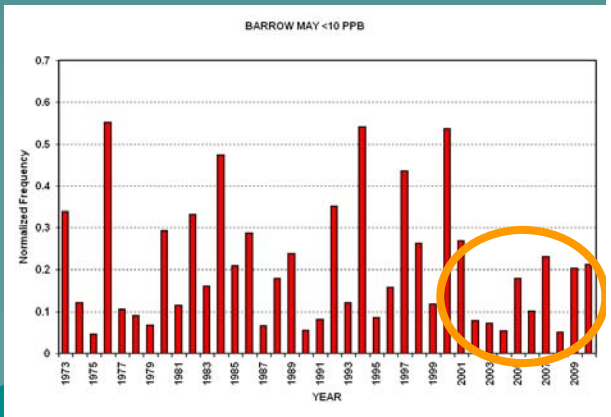
FIG. 5.12. Sea ice age in the first week of March, derived by tracking the drift of parcels of ice floes with satellite data, illustrates the substantial loss of old ice in the Arctic Basin in recent years compared to the late 1980s. (a) 1988, (b) 2008, (c) 2009, and (d) 2010. (Figure courtesy of National Snow and Ice Data Center, J. Maslanik and C. Fowler.)

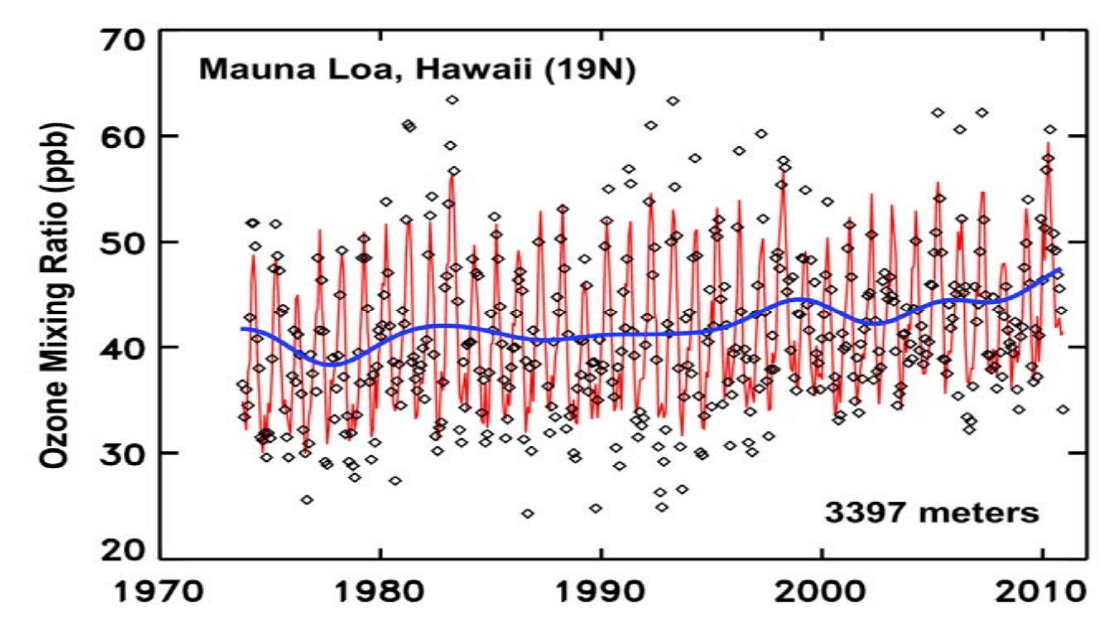




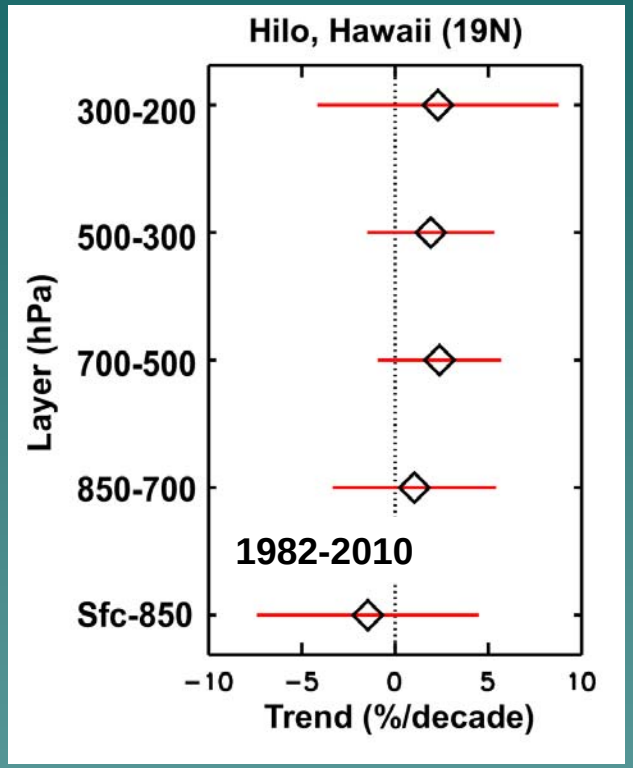




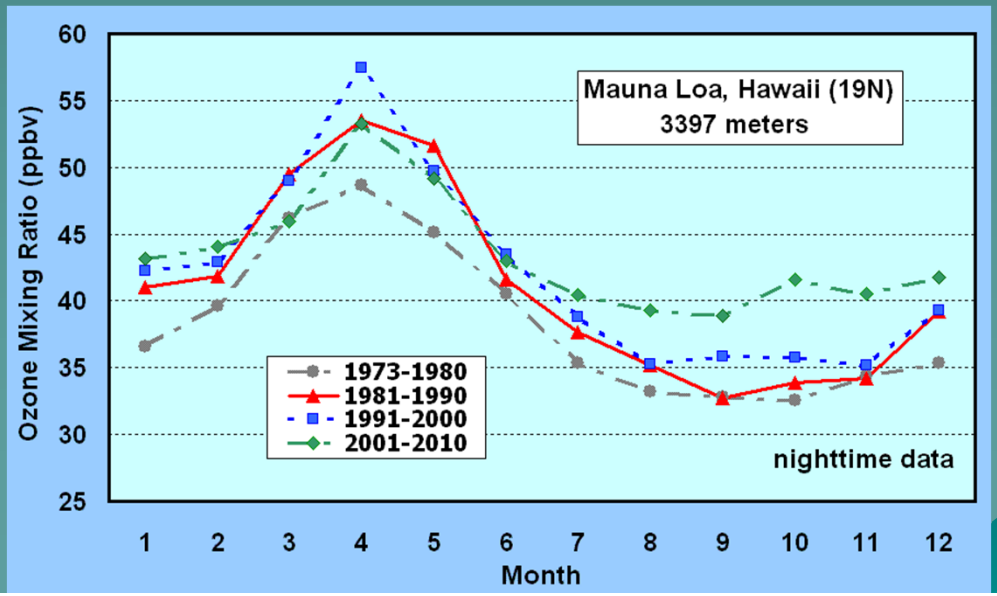




Trends with altitude at Hilo, Hawaii

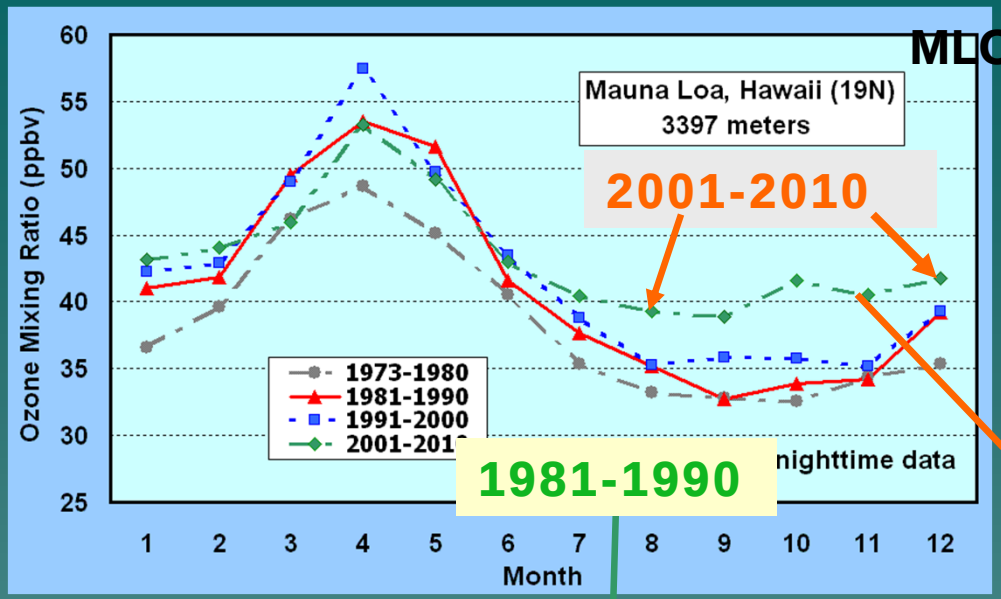


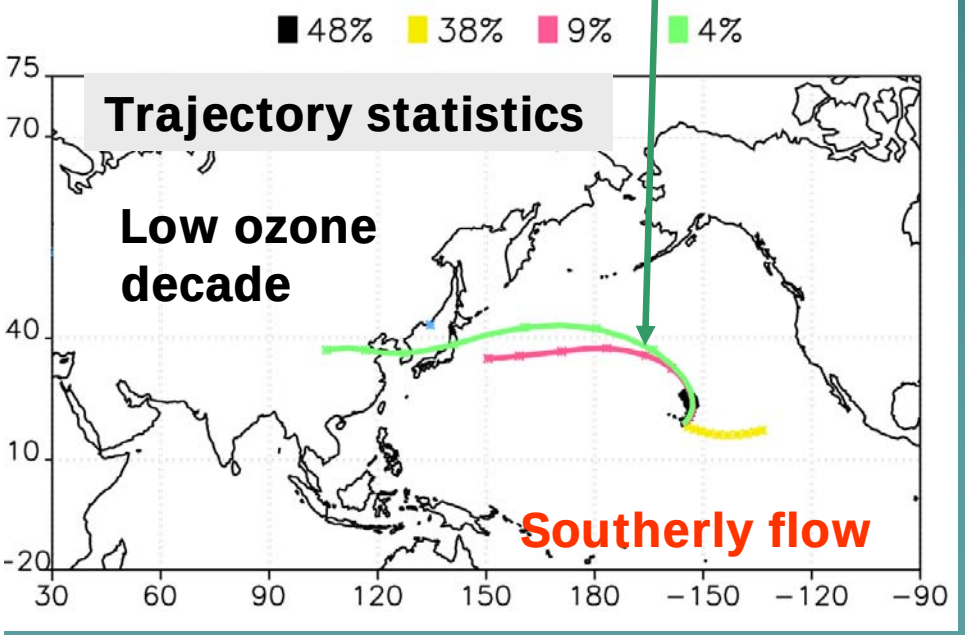
Mauna Loa Hawaii
10-year average seasonal variation

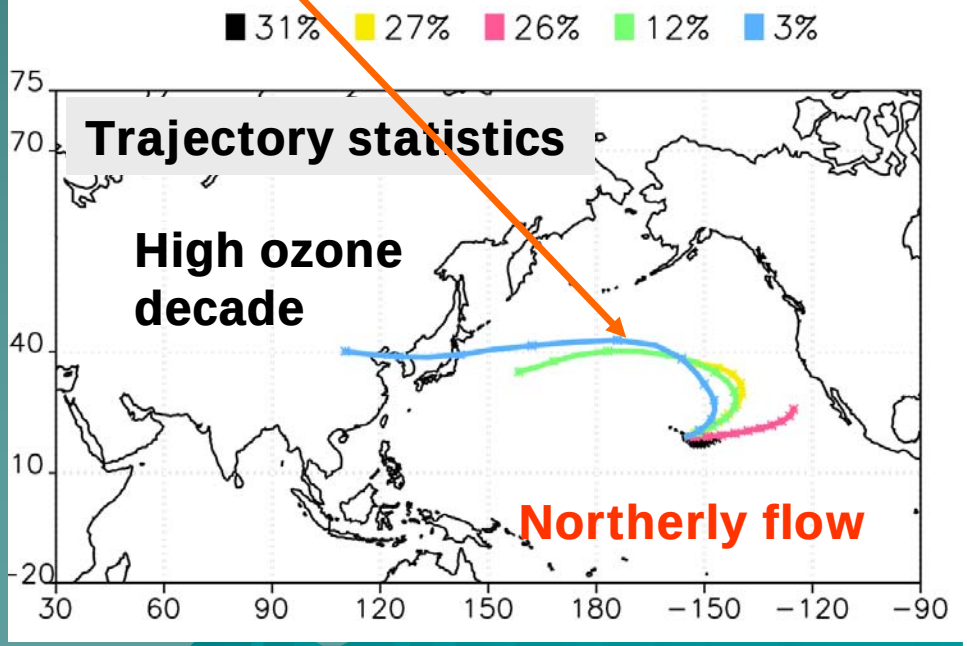


Decadal air flow patterns to Hawaii influence ozone.

- Northerly flow: high ozone (2001-2010)
- Southerly flow: low ozone (1981-1990)







Conclusions

- In the N.H. there is a somewhat different pattern of long-term changes between N. America, Europe, and Japan.
- Over N. America earlier increases (primarily before 1990) have become small to moderate declines.
- Western Europe saw the largest increases prior to 1990 but a significant decrease in growth rates (and in some cases declines) over the past 15 years over continental Europe.
- In Japan increases were primarily prior to the mid 1980s, but with recent increases in Okinawa.
- In Hawaii (N. Pacific tropics) increases

Conclusions (continued)

- The tropical south Pacific (Samoa) has not shown significant changes in tropospheric ozone.
- In the S.H. mid latitudes, at Cape Point, Cape Grim, and Lauder ozone has increased significantly.
- At South Pole earlier declines have reversed so that overall there has been almost no change.

Some possible implications of recent (30-year) observed changes

- The relationship between emission changes and longer term hemispheric and global tropospheric ozone changes is not adequately understood.
- The climate forcing of tropospheric ozone changes over the recent past is and in the future is still very uncertain.
- It will be difficult to assess the climate forcing reductions that can be gained by reducing tropospheric ozone with the current network of observations.