Past Changes in the Vertical Distribution of Ozone: the SI^2N Activity and Its Outcome

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Trend & merged data set papers to be submitted to ACPD by the end of 2014

What is SI^2N?

- The joint SPARC/IO_3C/IGAC-O_3/NDACC Initiative on Past Trends in the Vertical Distribution of Ozone
- Follow on activity to the SPARC/IOC/GAW Assessment of trends in the vertical distribution of ozone, 1998, (*which addressed the difficulties in deriving consistent global profile ozone trends in the lower stratosphere and disagreement between existing satellite time series*)

SI^{2}N

- Activity started with a workshop in Geneva in Jan 2011…led by Neil Harris and Rich Stolarski.
- It is culminating with publication of > 30 papers in a special issue of Atmospheric Chemistry and Physics (ACP), Atmospheric Measurement Techniques (AMT) and Earth System Science Data (EESD). The link for the complete issue is http://www.atmos-chem-phys.net/special_issue284.html
- This presentation will address points from three of the special issue papers: a measurement overview (Hassler et al., 2014), a paper on merging data sets (Tummon et al, in prep) and a paper on ozone trends (Harris et al., in prep).

SI^2N

Key Goal: Provide measurements that can be used for detection and attribution of stratospheric ozone changes

critical examination of the pattern and time sequence of ozone change

Accurate knowledge of altitude, latitude, and seasonal structure of the ozone variability is required

High quality measurements with well defined uncertainties

SI^2N – working groups

Long-term ozone changes

Long-term satellite records
J. Tamminen, R. Wang
SAGE II reprocessing (1984-2005)
SAGE extensions (1979-81; 2005 on)
SBUV consolidation (1979-now)

Umkehr (Dobson & Brewer)
T. McElroy, I. Petropavlovskikh
Brewer data collection
Retrieval improvement & QA/QC
40 yr record with increasing coverage

Climate variability

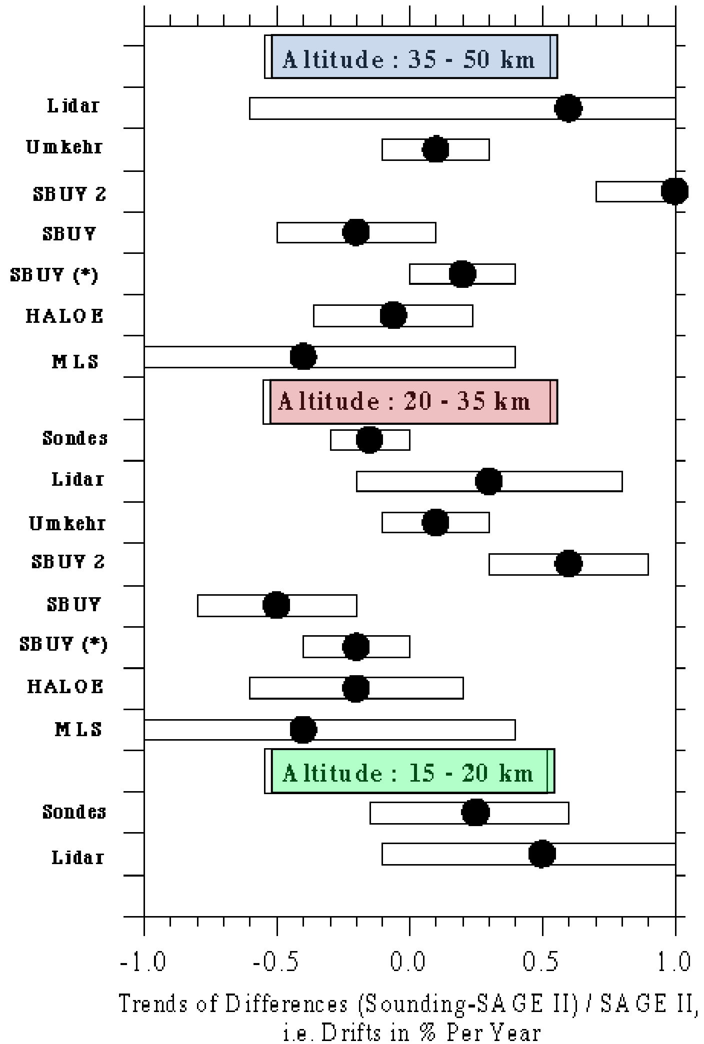
The last decade (satellite)
M. van Roozendael, L. Froidevaux
ODIN, ACE, Envisat, Aura
Existing projects
SPARC Data Initiative

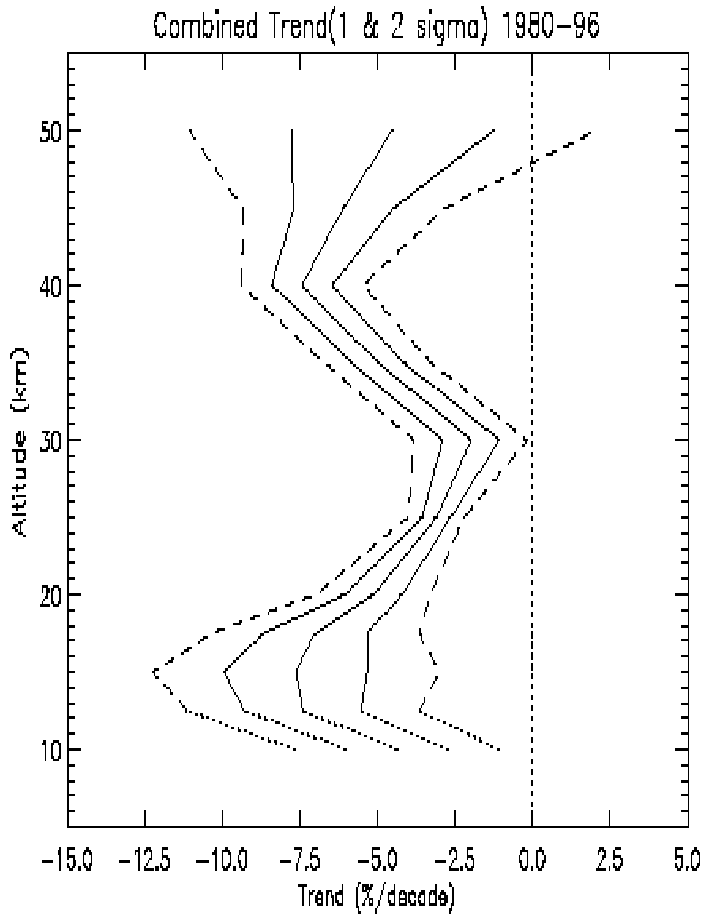
Ground-based systems
NDACC Working groups
Lidar, microwave and FTIR
Internal consistency
Mainly from ~1990 on

Ozonesondes
S. Oltmans, H. Smit
Homogenised data set
Clear documentation
40 yr record with increasing coverage

+ 1 on the issues associated with merging

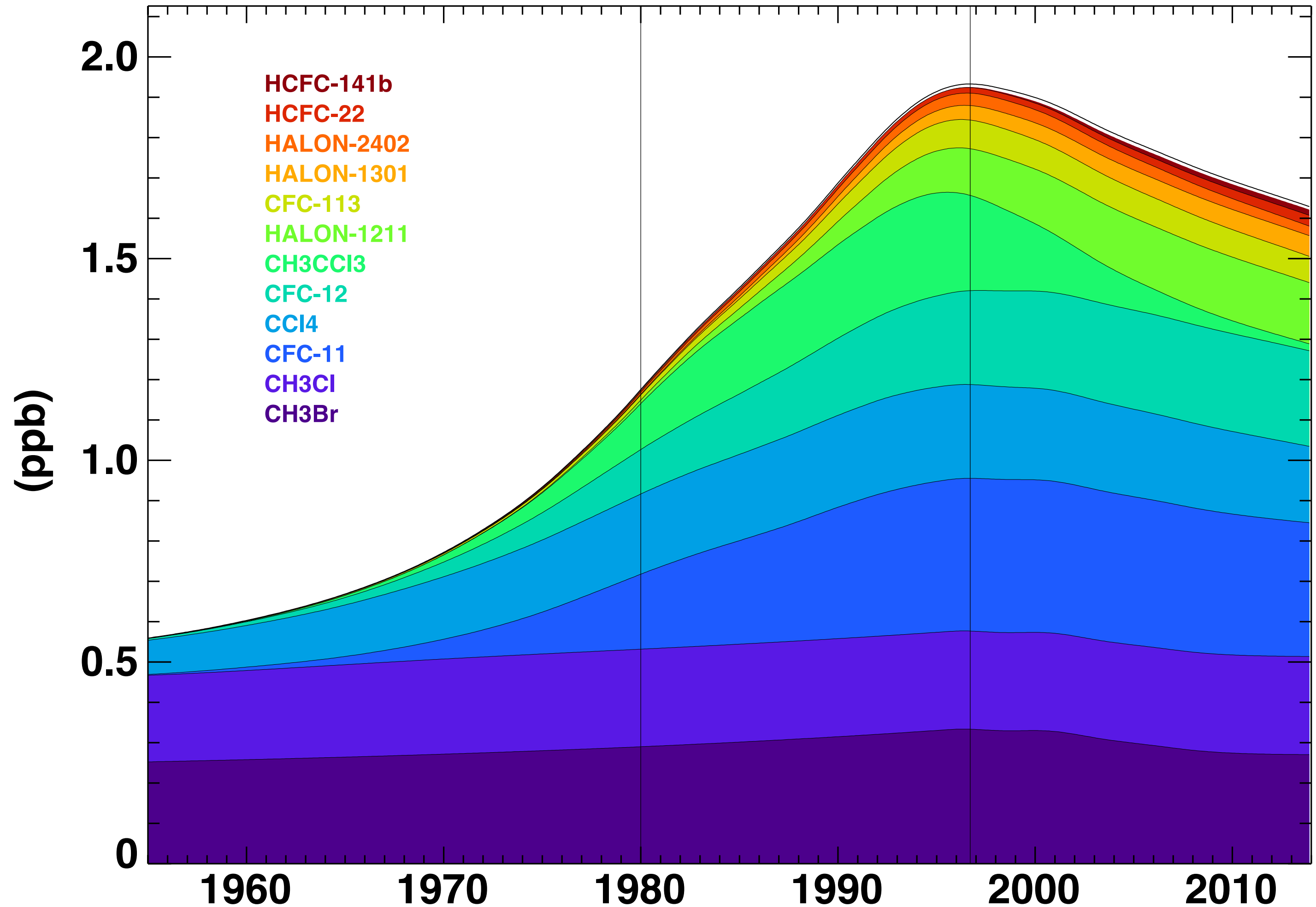
Motivation: What were the conclusions of SPARC, 1998; what do we need to know now?





Combined estimate of the mean trend in vertical distribution of ozone over **northern mid-latitudes** from 1980-1996 (heavy solid line) calculated using the trends derived from SAGE I/II, ozonesondes, SBUV and Umkehr measurements. Uncertainties are shown as 1σ (light solid lines) and 2σ (dashed lines).

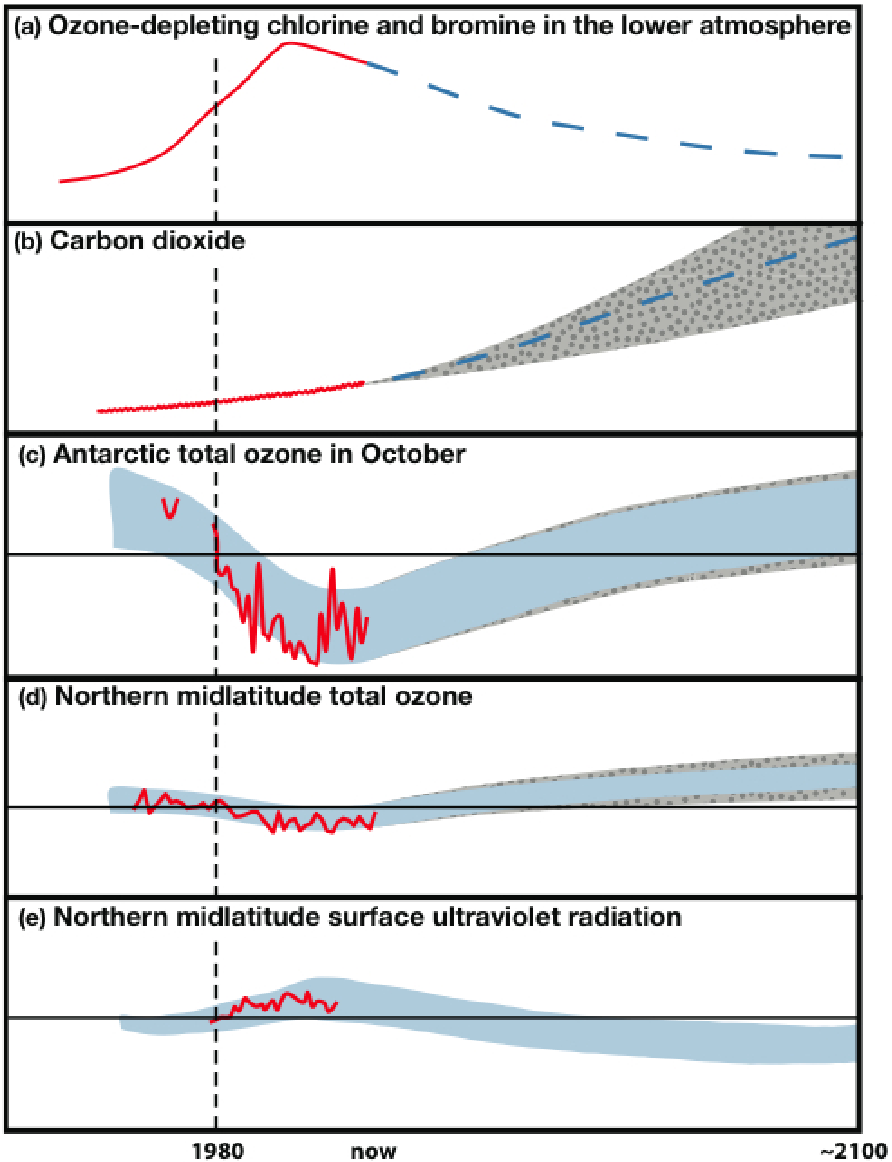
Where are we now?



mid latitude Equivalent Effective Stratospheric Chlorine, from P. Newman

Motivation: Where do we stand now?

How does the ozone profile recover as ODS decrease?



Recent measurements of the vertical ozone distribution did not say much at all about

- ODS recovery
- Effect of climate change

Why?

No consistent global view of ozone profile measurements after 2005

- SAGE (workhorse for 1984-2005) turned off; as was HALOE (1991-2005)
- Many satellites making profile measurements since 2005, but they have not been well enough assessed to know what has been happening to trends in ozone profile

Slide from Neil Harris

SI^{2}N Approach

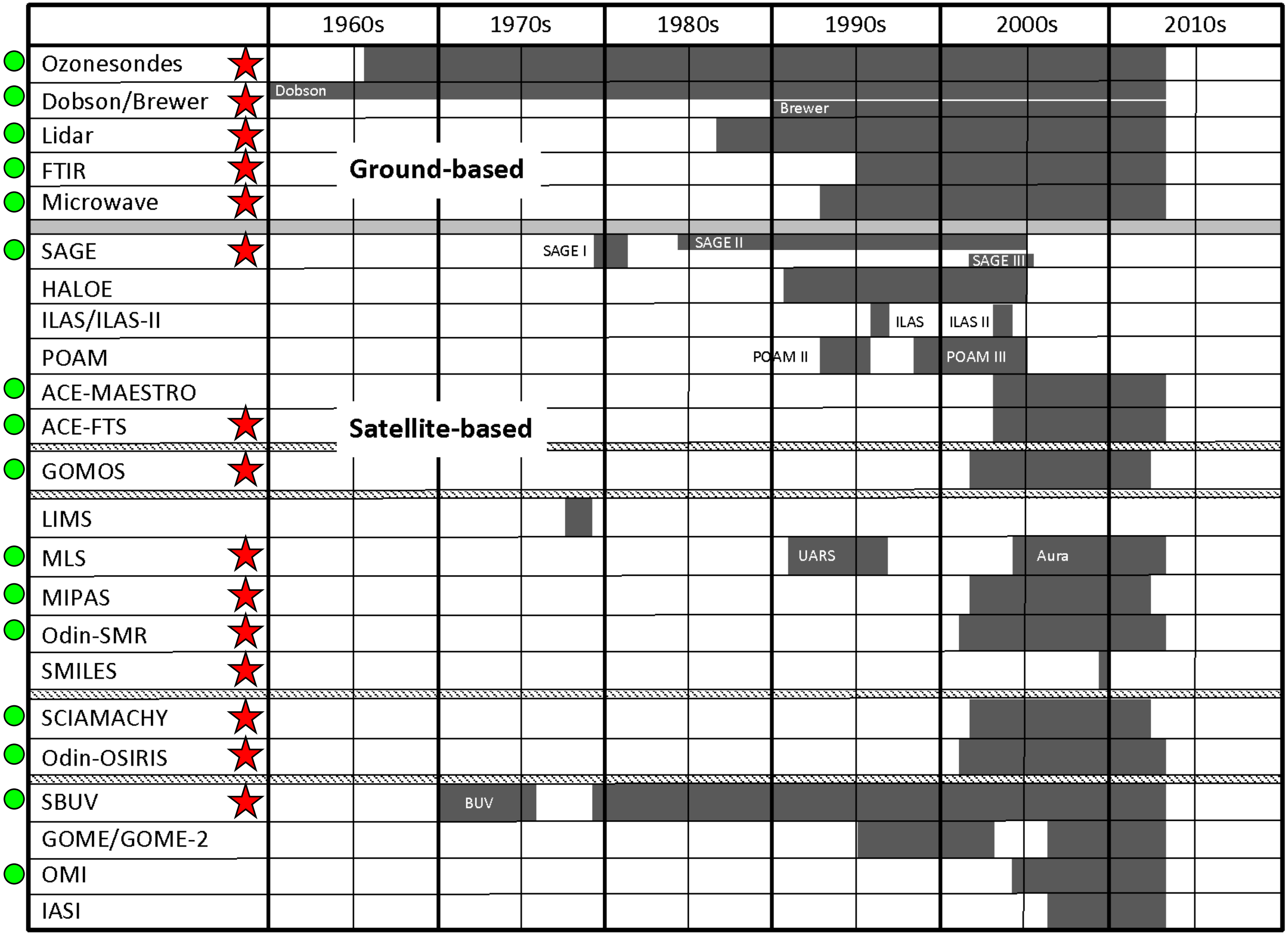
1) Compile and document all ozone profile data in a consistent manner/location
   See Hassler et al., 2014, AMTD (accepted in AMT)

2) Merge data sets where possible to extend periods for which trends can be assessed
   Paper in preparation: Fionna Tummon et al (for ACPD)

3) Analyze trends using both merged and individual instrument data sets.
   Paper in preparation: Neil Harris et al. (for ACPD)

   Note: there is also a measurement validation component, and the lead scientist is Jean-Christopher Lambert. This is not sufficiently mature to discuss here.

SI^{2}N - Measurements



Participated in SI^{2}N   Related publication in the special issue

Hassler et al., 2014 AMT paper; measurements overview

4 tables presented:
1a) Measurement techniques and altitude ranges
1b) Vertical resolution, native vertical grid and native units
1c) Temporal coverage, number of measurements and time of day
1d) Data version, URL, relevant references

Lots of information given…currently on line at AMTD, it is accepted and will hopefully be on AMT soon.

Table 1b. Summary of the vertical resolution, native vertical grid and native ozone units for the five ground-based measurement systems and all described satellite measurement systems.

Name of instrument	Vertical resolution[1]	Representation grid	Native vertical grid[1]	Native ozone units[1]
		Ground-based measurement systems		
Ozonesondes	100–150 m (at ascent rate of 5 $m s^{-1}$ and response time of 20–30 s)	100–200 m	Flight time	Partial ozone pressure in milli Pascal (mPa)
Dobson/Brewer	≈ 10 km	≈ 10 km	Pressure levels	Dobson units (DU)
Lidar	The resolution varies as a function of altitude from 0.5 km below 20 km, 2 km around 30 km to more than 5 km above 45 km.	Depending on the systems: 0.15 or 0.3 km	Altitude levels	Ozone number density (cm^{-3})
FTIR	≈ 8–10 km for the ground ≈ 9 km layer ≈ 8 km for the lower and middle stratospheric layer ≈ 15–20 km for the upper stratospheric layer (≈ 28–45 km)	In NDACC HDF archived files: the retrieval grid contains, depending on the station, about 41 to 47 levels (from ground to 100 km).	Altitude levels	Volume mixing ratio (ppmv) (provided also as partial columns ($mol cm^{-2}$))
Microwave	Typ. 8–10 km, from ≈ 20 to 40 km, then increasing to ≈ 17 km at ≈ 60 km	Varies by instrument. Typ. ≈ 2 km intervals	Pressure levels (grid on which data are provided varies by instrument)	Volume mixing ratio (ppmv)

SI^{2}N - merged data sets (Tummon paper)

- 7 altogether
- 7 different ways of combining different measurements
- Single measurement system: SBUV (2x)
- Two measurement systems: SAGE II and OSIRIS, SAGE II and GOMOS (2x)
- Multiple measurement systems: GOZCARDS, SWOOSH

Figure 1: Temporal coverage

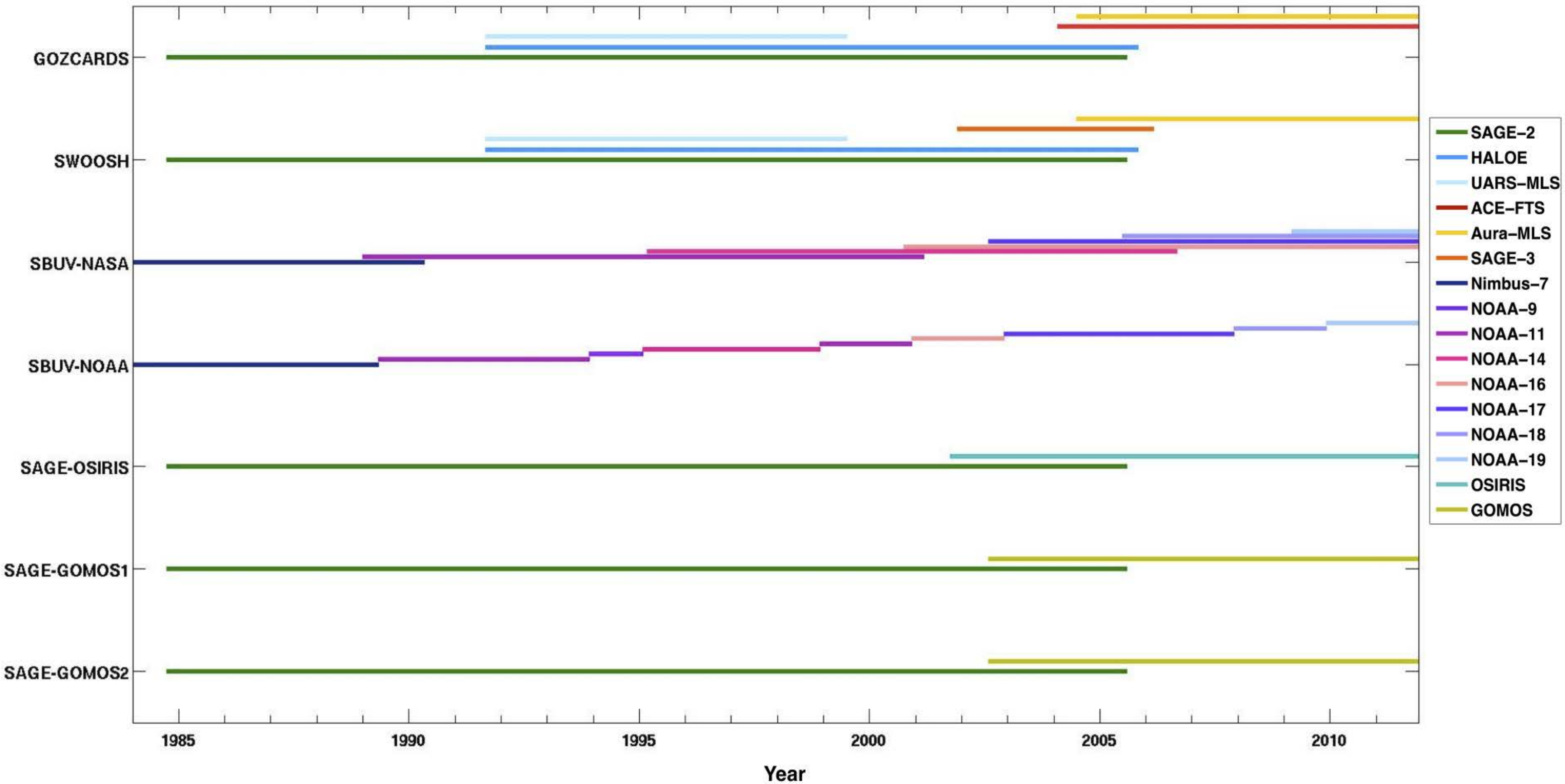
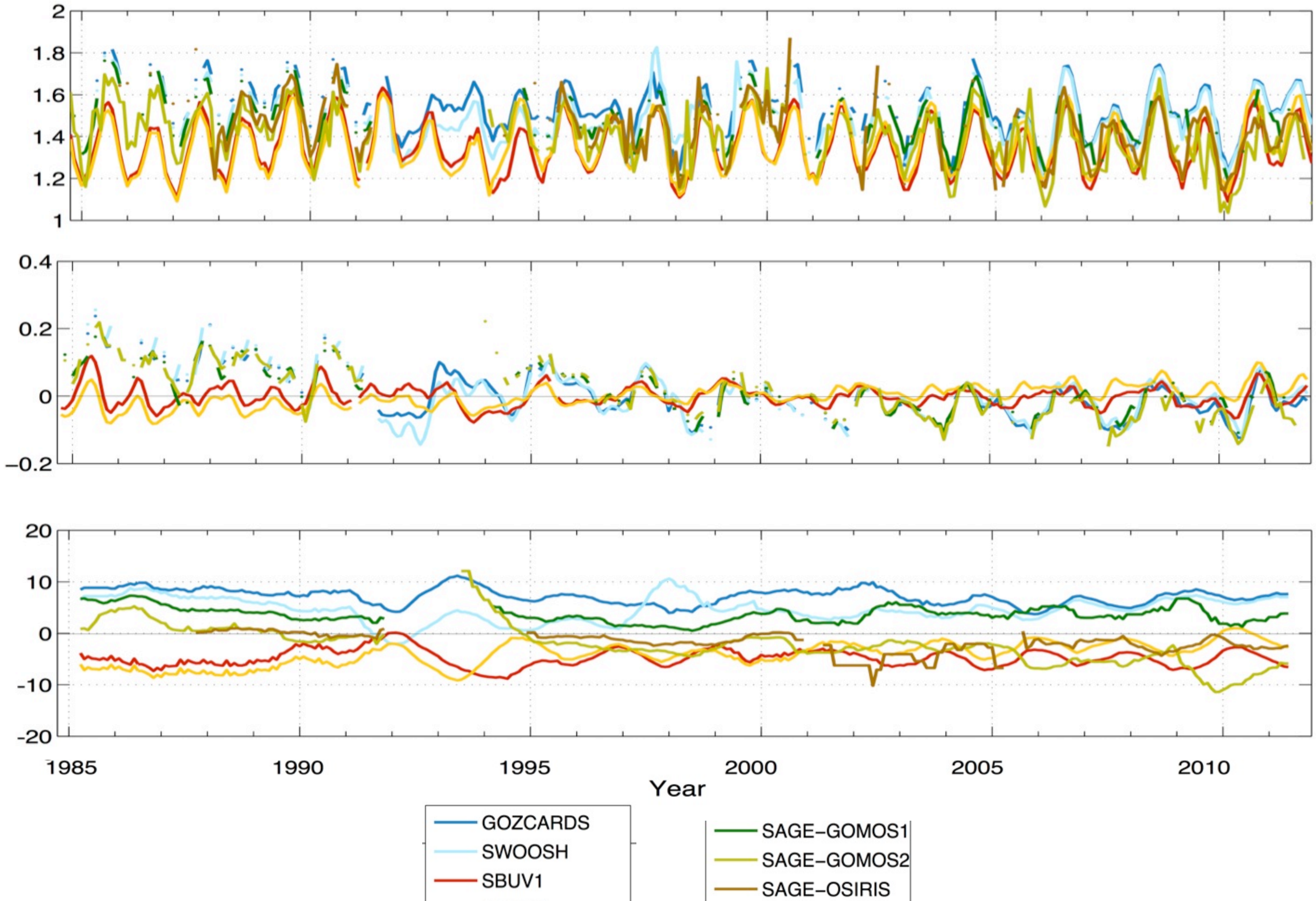


Figure 1: Time coverage of the individual instruments contributing to each of the seven merged data sets over the time period of this study (1984-2011).

Ozone Timeseries & anomalies & % differences, 20N-20S, 50hPa



From Tummon et al.

Figure 4: Annual Cycle

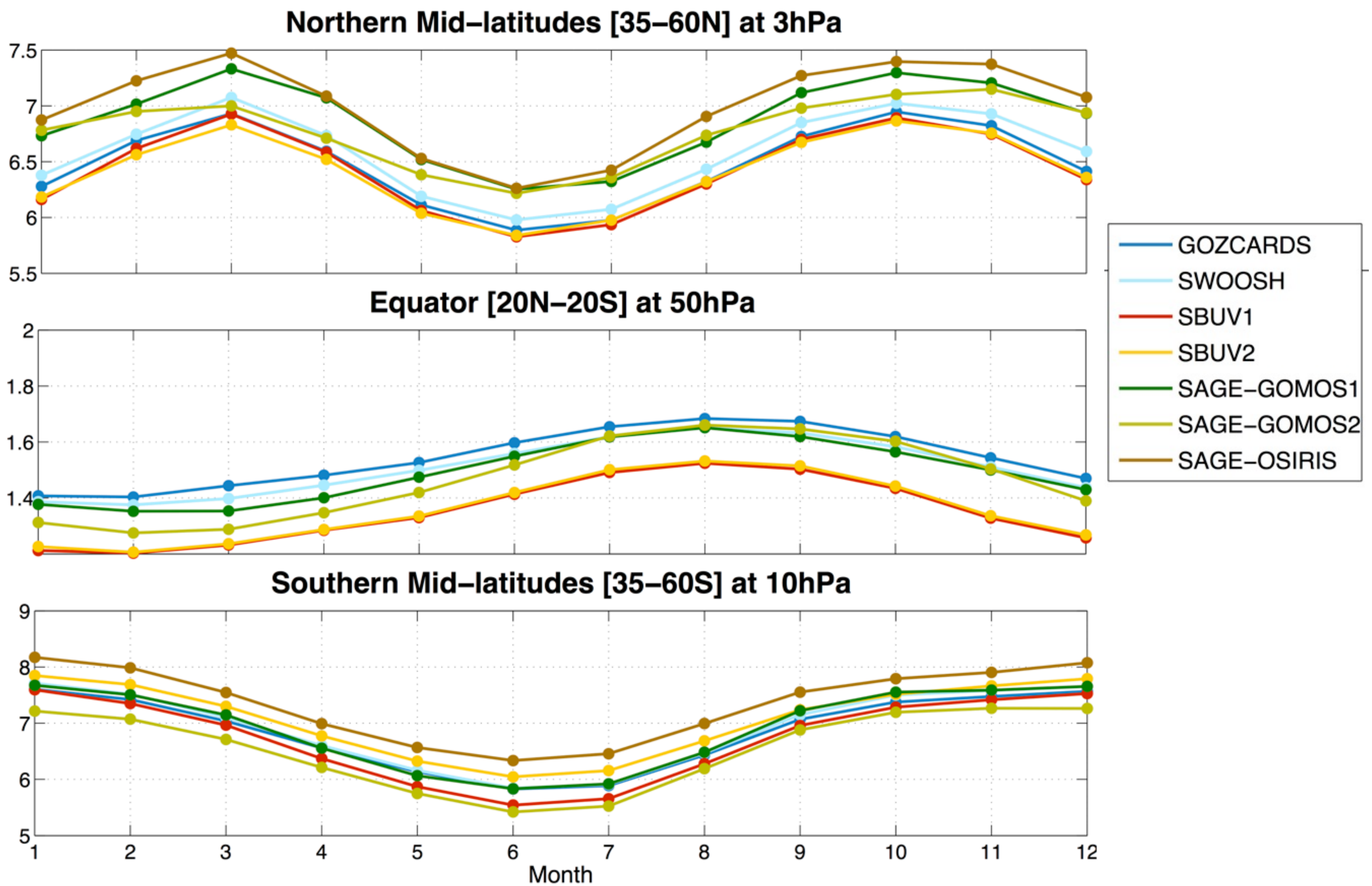


Figure 4: Annual cycle, as described by the multiple linear regression model at (a) the NH upper stratosphere (3hPa/~40km), (b) EQ lower stratosphere (50hPa/~20km), and (c) SH middle stratosphere (10hPa/~30km).

Merging paper conclusions:

Needed because we don't have a long term continuous data set that is global

Differences are smaller than seen on an instrument by instrument study (Tegtmeir et al. 2013)

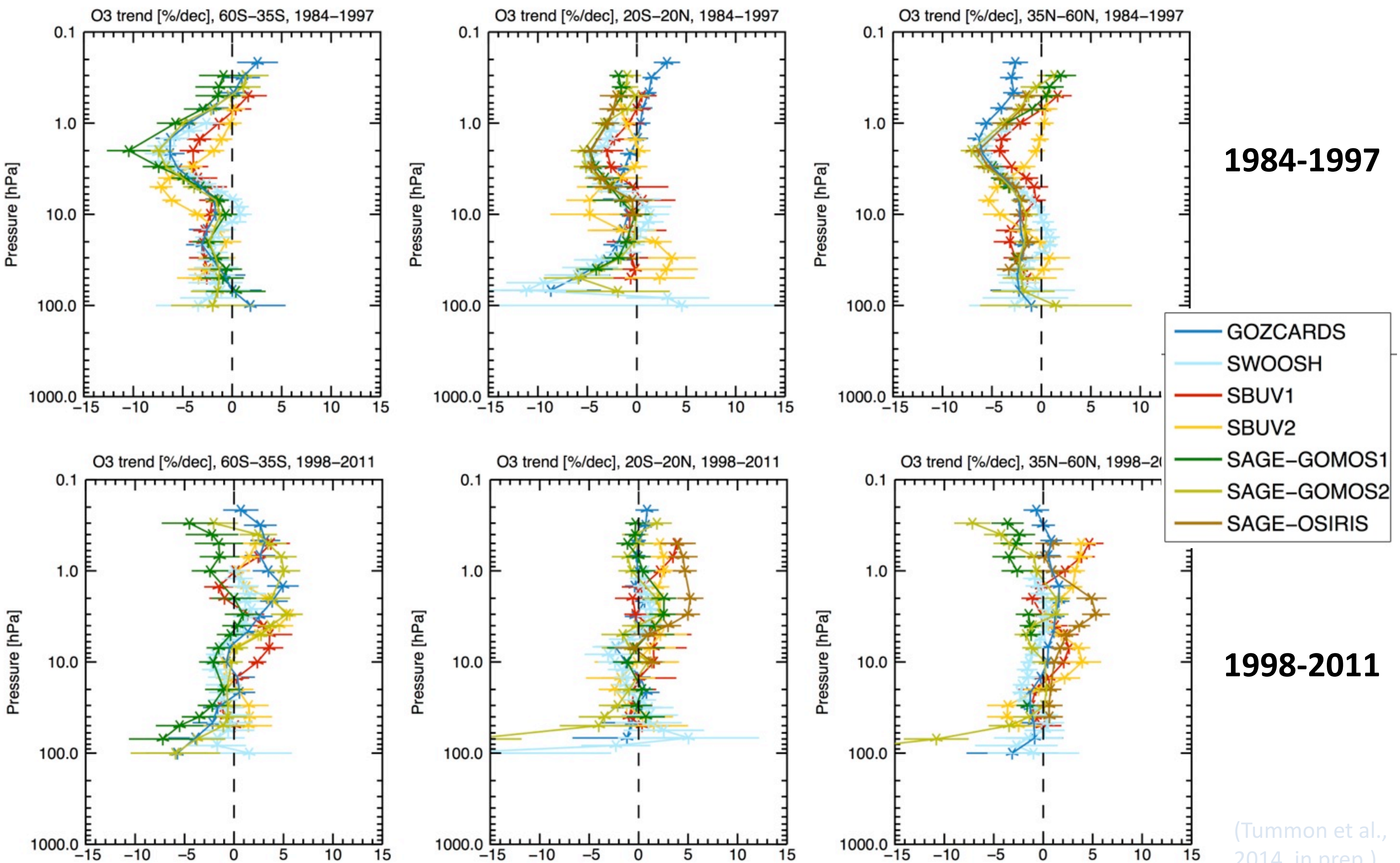
Differences have impacts on calculated trends…particularly where the trend is small.

Trends: estimated via regression

- Piece-wise multiple linear regression
- Two linear trends with an inflection point at the end of 1997
- Monthly means – not deseasonalized before used in the regression
- Basis functions: Offset (annual cycle), 2x trend, 2x QBO (second QBO time series orthogonalized to first), solar cycle, ENSO, volcanic aerosol
- Regression only calculated if at least 50% of input data are available

Harris et al., in prep

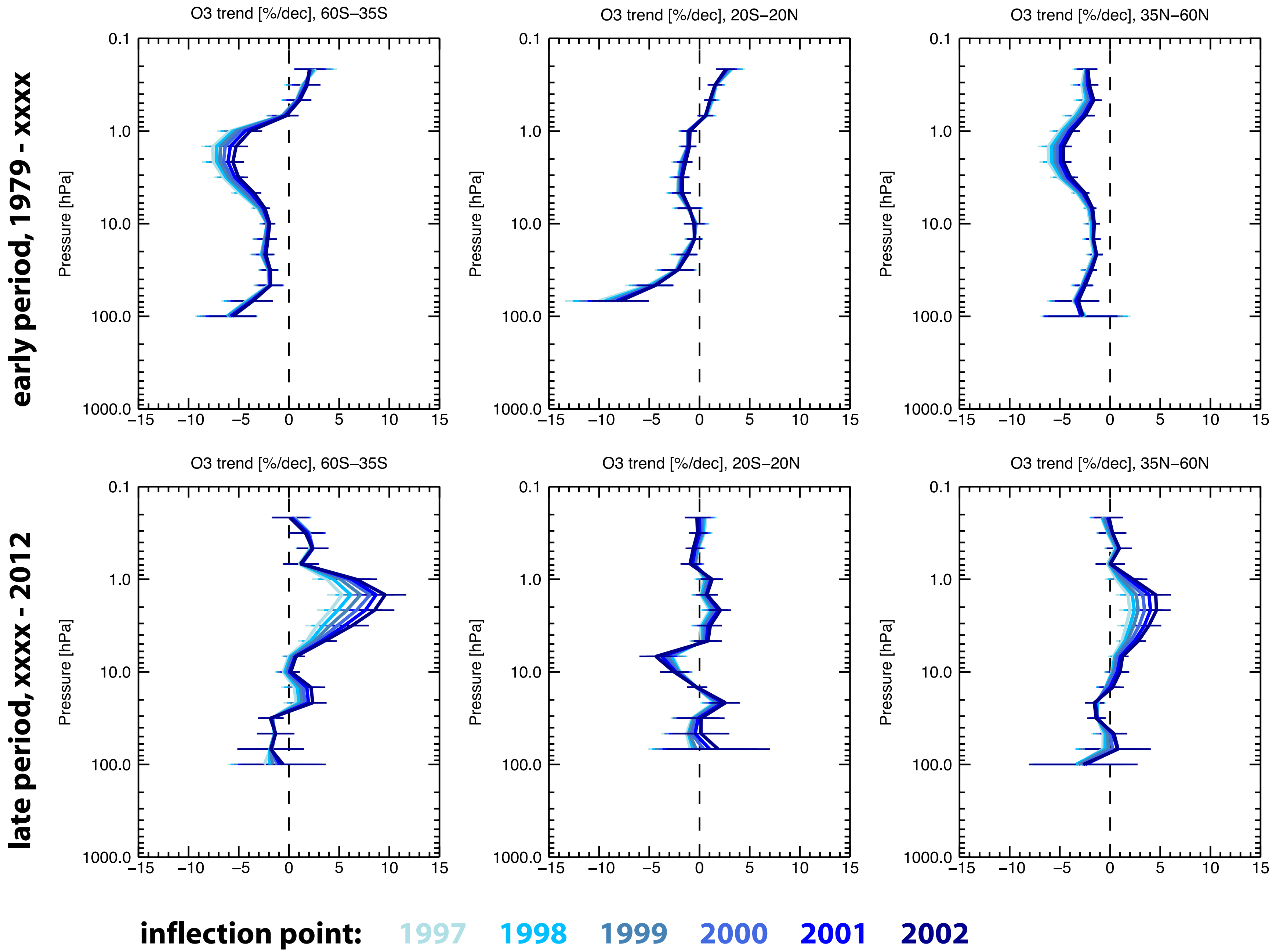
SI^{2}N - merged data sets: trends



(Tummon et al., 2014, in prep.)

Latitude average of annual trends (in %/decade) for 1984-1997 (top row) and for 1998-2011 (bottom row), SH (left), EQ (middle), NH (right).

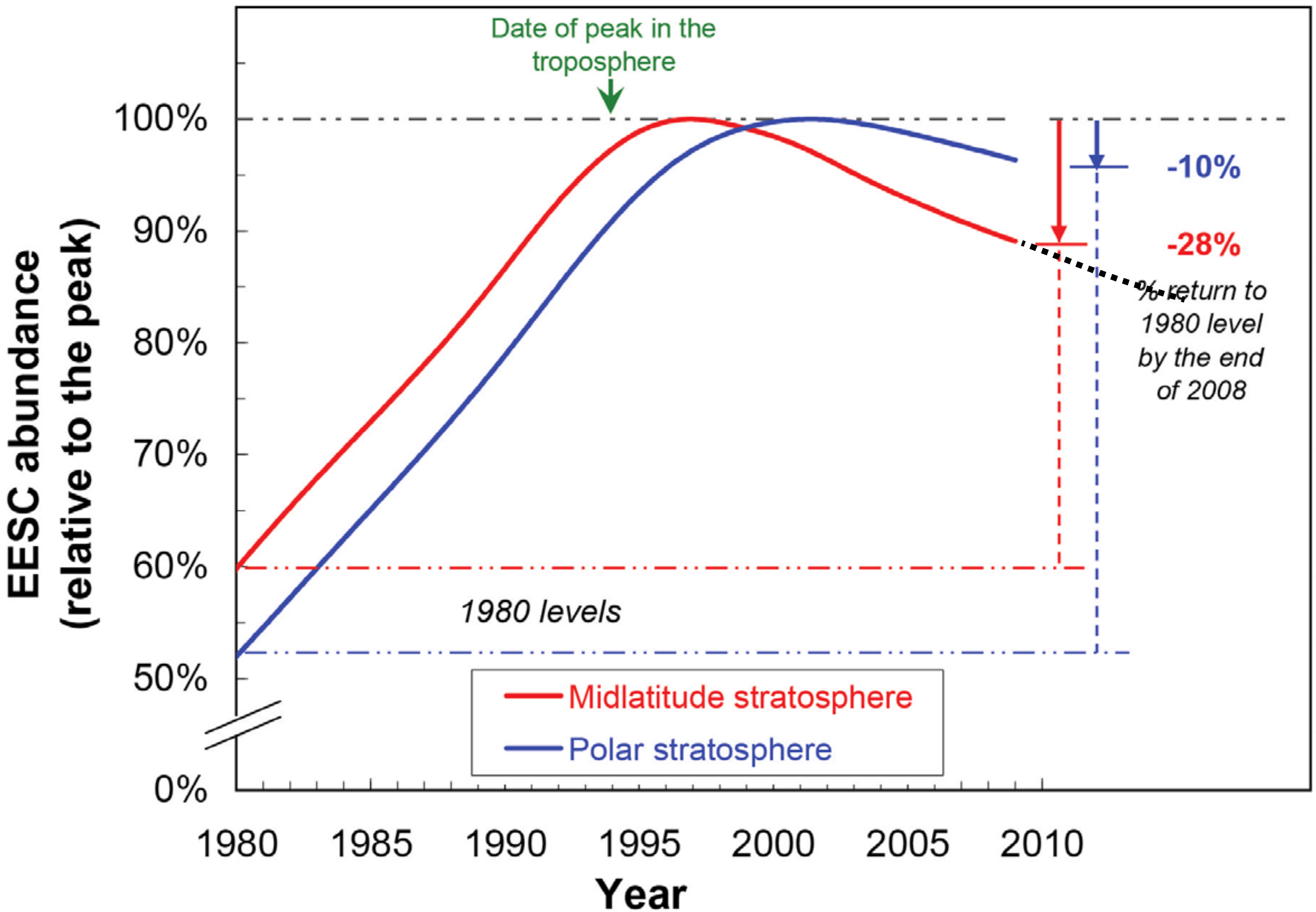
Do endpoints matter? **GOZCARDS, piecewise linear trends**



SI^2N - merged data sets: lessons learned

- Essential for determining trends as we go forward
- Introduces a lot of uncertainties into trend analysis (more work is needed to merge better)
- Should be a point of consideration for planning future observational systems
- Ground-based measurement systems absolutely necessary to validate the merged data sets
- Overall, stratospheric decreases during the early period have shifted to either smaller negative values or to increases. Next step should be comparisons to model predictions for the same time periods.

Thanks for listening!



From Chapter 1 of *Scientific Assessment of Ozone Depletion: 2010* (WMO, 2011).