On the Recovery of Stratospheric Ozone

S. Godin-Beekmann[1], A. Pazmiño[1], S. Khaykin[1], I. Petropavloskikh[2], D. Hubert[3], J.C. Lambert[3], T. Portafaix[4]

1. LATMOS/IPSL, UVSQ, CNRS, France
2. ESRL, NOAA, USA
3. BIRA – IASB, Belgium
4. LACy, U. Réunion, CNRS, France

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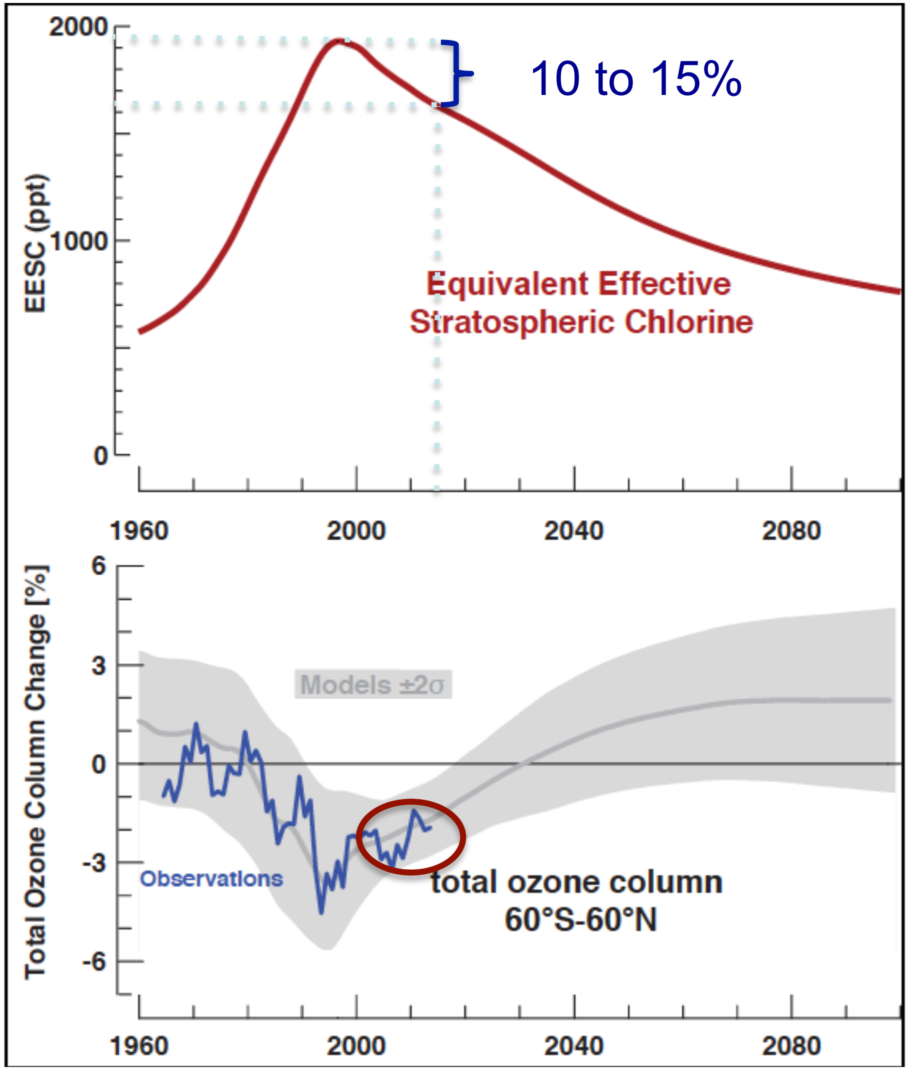
2014 Ozone Assessment



ODS:

10 – 15 % decrease from respective maximum

Polar regions: maximum reached in ~2000; 10% decrease by 2012

Midlatitudes: maximum reached in mid-nineties; 15% decrease by 2012

Ozone:

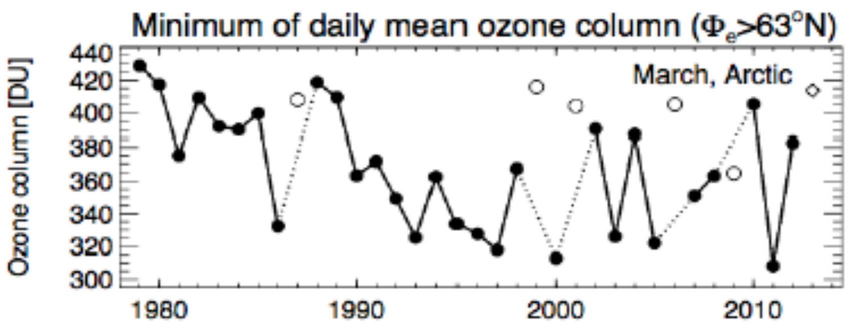
Hints of an increase.

Is it recovery?

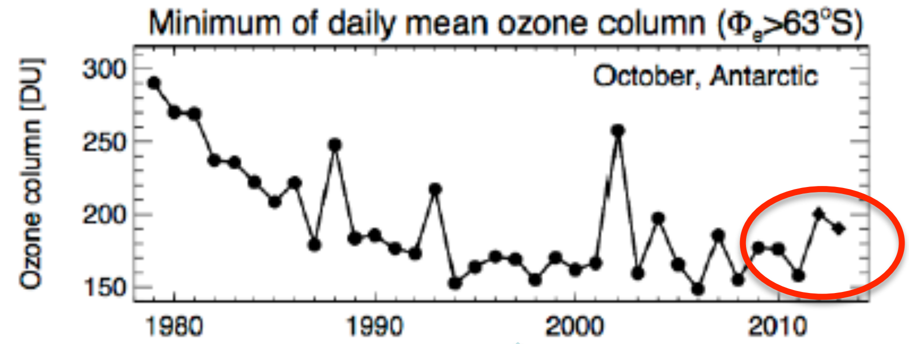
ADM: Figure 1-5

POLAR OZONE TRENDS

WMO Ozone Assessment 2014



Arctic



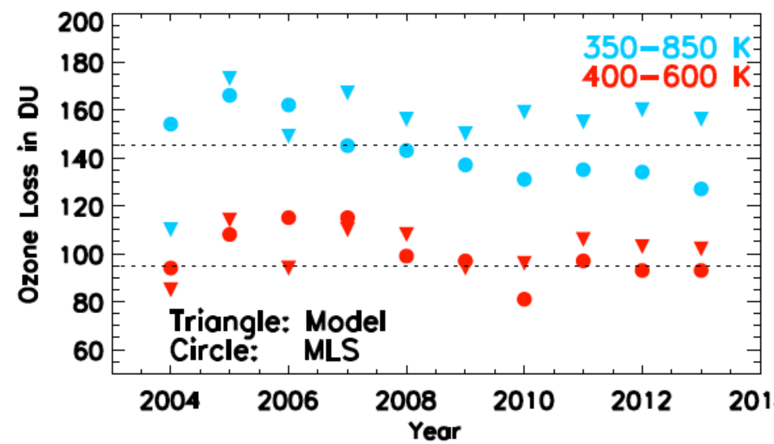
Recovery?

Antarctic

Recent Antarctic ozone holes:

- In 2010, 2012 and 2013, larger ozone columns during winter and spring
- Occurrence of minor SSWs in the course of the winter -> reduced VPSCs
- 2011 winter more similar to winters in the 2000s

Retrieved Antarctic ozone loss



Kuttipurath et al., acpd,2015

Recent polar ozone trend studies

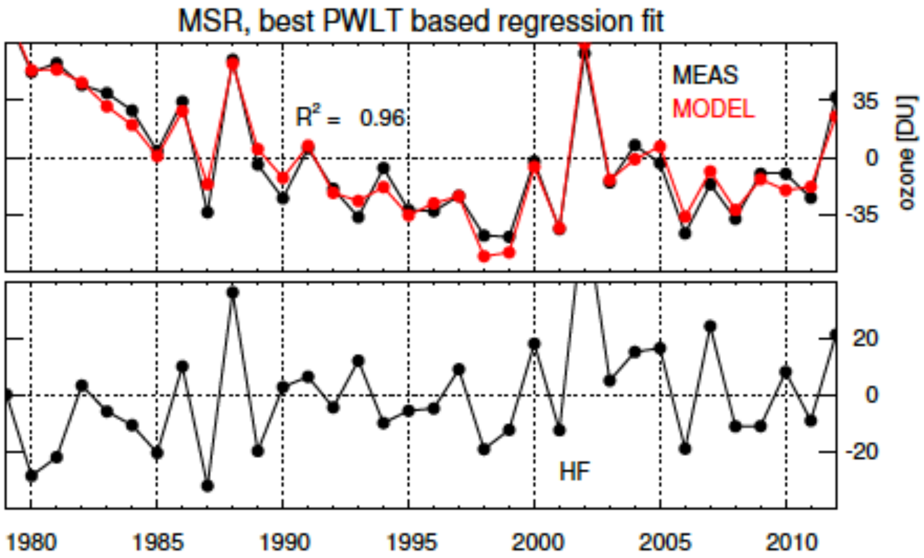
Multivariate regression studies of Antarctic springtime total ozone

- Salby et al. (2011, 2012) and Kuttipurath et al. (2013) used different regression models to analyse springtime total ozone (up to 2010).
- Significate increases (~10 to 15 DU) of TO3 over 10 years but limited discussions of residuals and uncertainties.

Tracing the second stage of ozone in the Antarctic ozone hole

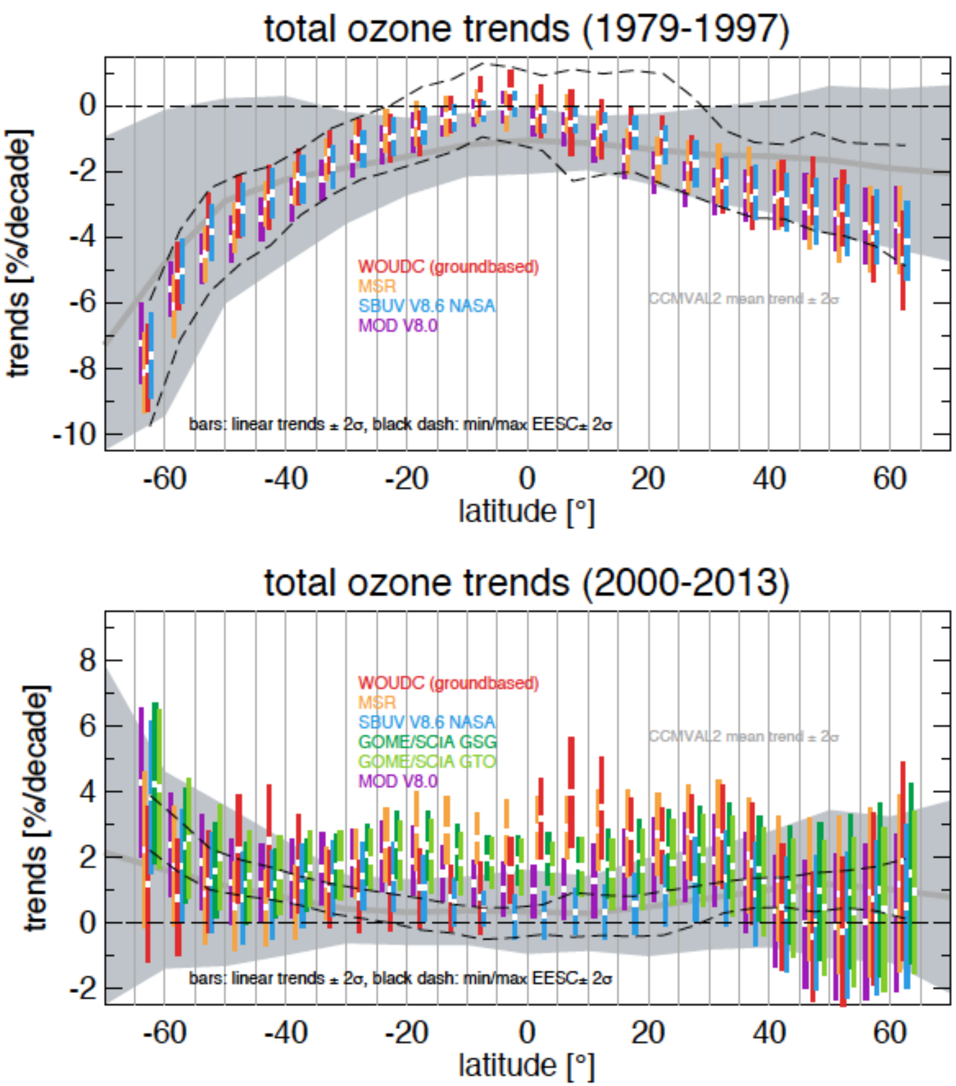
de Laat, et al., ACP 2015

- Ensemble of regressions using similar regression model
- 30-60% of regressions result in statistically significant positive trends
- « Uncertainties do not yet support formal identification of Antarctic ozone hole recovery »



MID-LATITUDE AND TROPICAL OZONE TRENDS

WMO Ozone Assessment 2014



Chapter 2 Fig. 2-4

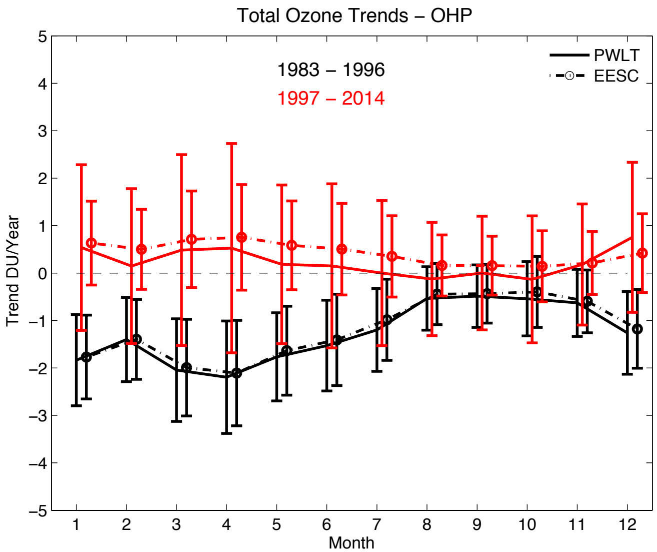
- Multiple linear regressions using QBO, ENSO, Solar cycle and aerosols as proxies for short term variability
- Linear trends before 1997 and after 2000
- After 2000, positive trends of 1 to 2%/decade with similar 2 sigma uncertainty
- Poleward of 40°N, post-2000 trends not significant.
- Causes of positive trends in the tropics unclear

Clear attribution of total ozone increases to declining ODSs not yet possible

Ozone trends at stations

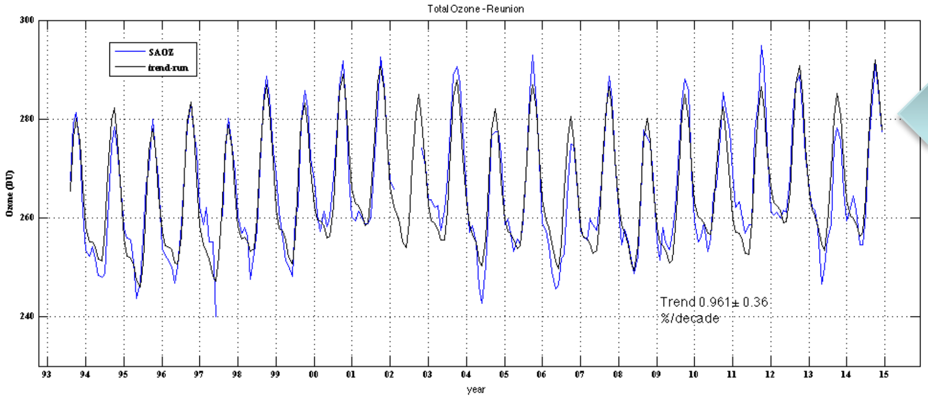
OHP total ozone: SAOZ and Dobson
44°N, 6°E

- Multiple linear regression using QBO, Solar Cycle, Heat flux, NAO, aerosols, PWLT and EESC trends
- Mean annual total ozone PWL Trend : 0.23 ± 0.52 DU/yr



Extension of Nair et al. 2013

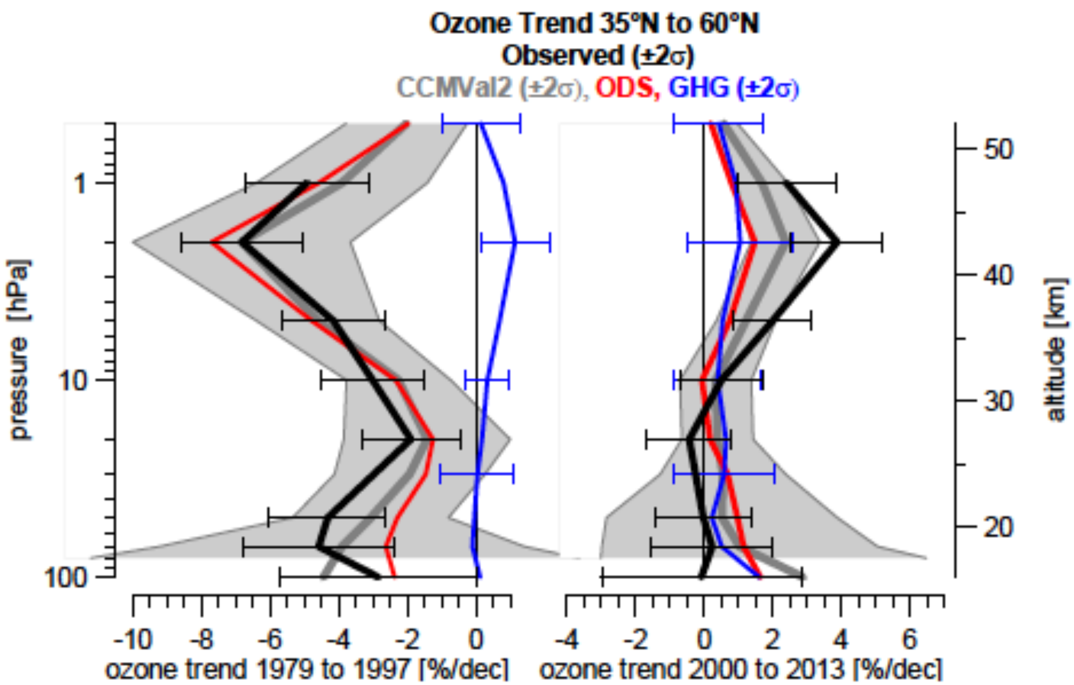
La Réunion Island: SAOZ total ozone
21°S, 55°E



- Multiple linear regression using ENSO, QBO, Solar Cycle, trend
- Trend: 0.96 ± 0.8 %/decade

Ozone profile trends

WMO 2014 Ozone Assessment



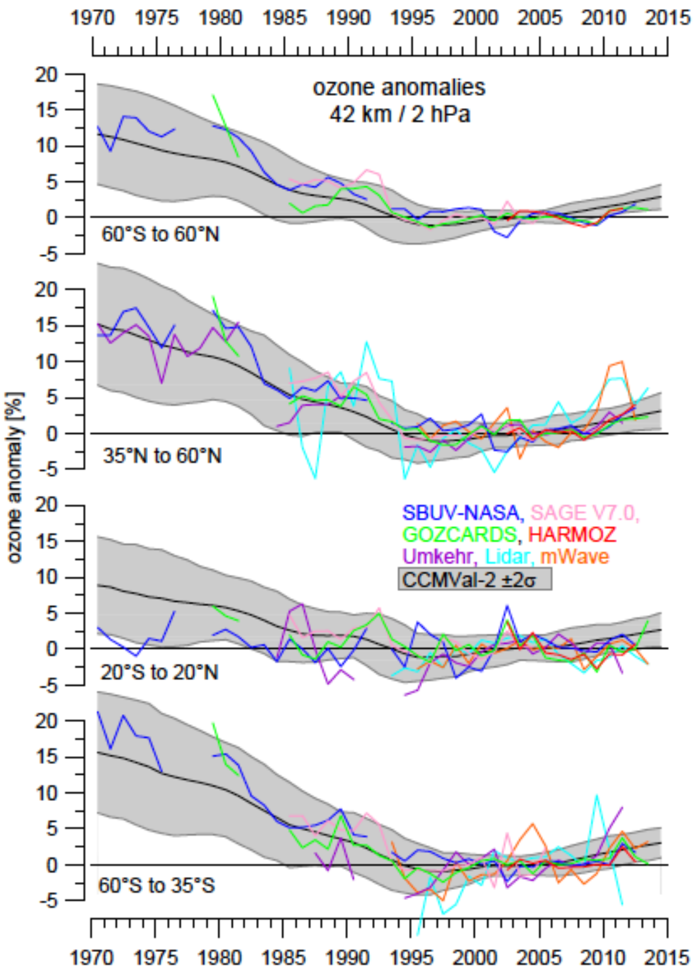
ADM Figure 3-2

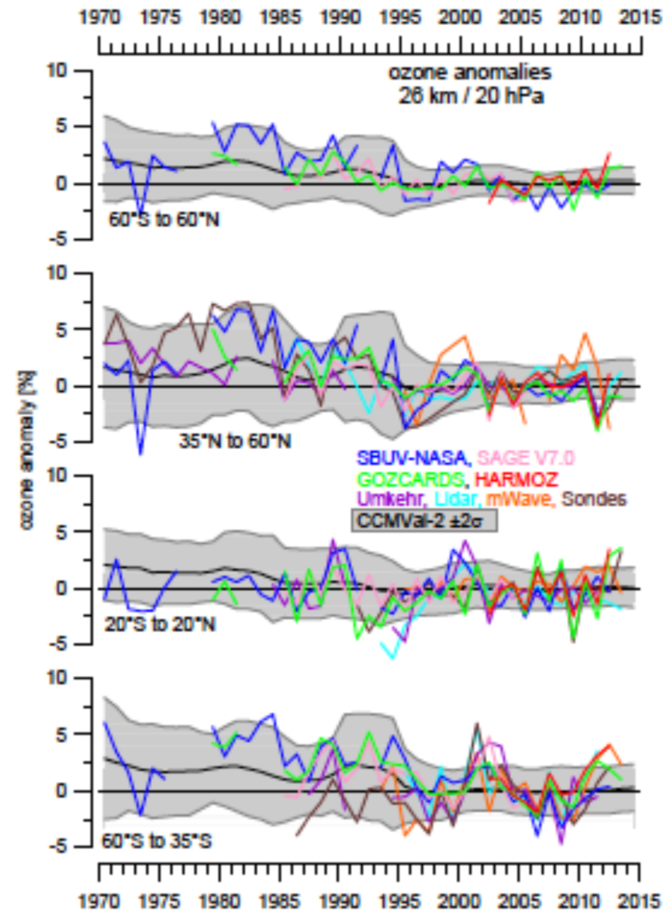
Executive summary:

"Measurements show a statistically significant increase in upper stratospheric ozone (35–45 km altitude) in middle latitudes and the tropics since around 2000. ... ozone has increased by 2.5–5% per decade over the 2000 to 2013 period".

Long-term records

WMO 2014 – Chapter 2





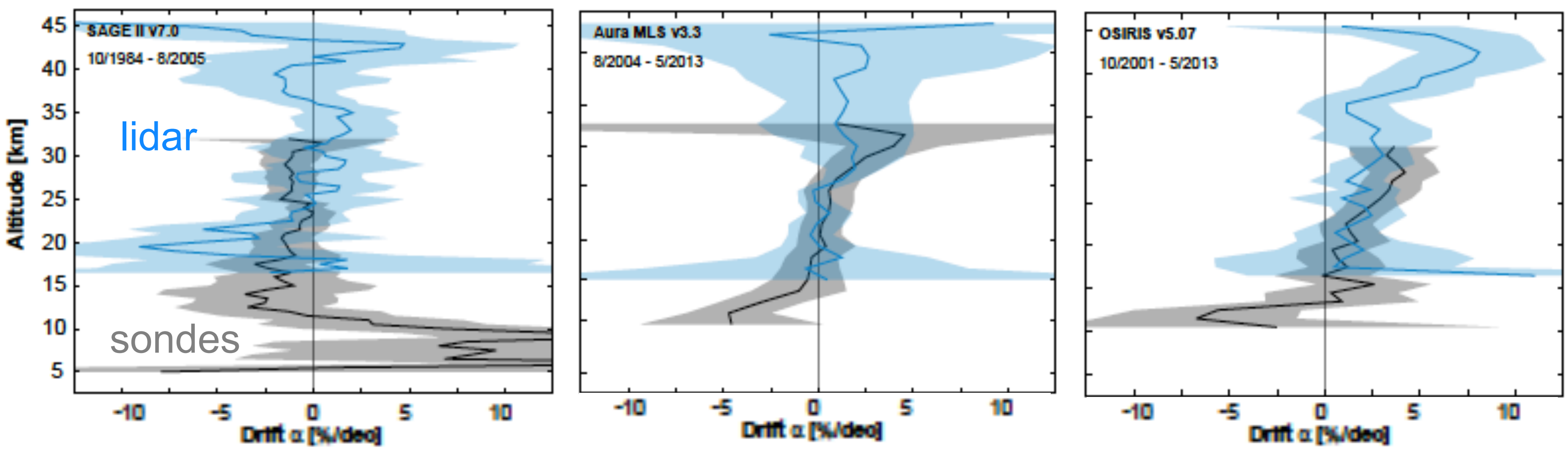
SI2N initiative: Past changes in the vertical distribution of ozone

Instrumental drifts

Ground-based assessment of the bias and long-term stability of fourteen limb and occultation ozone profile data records

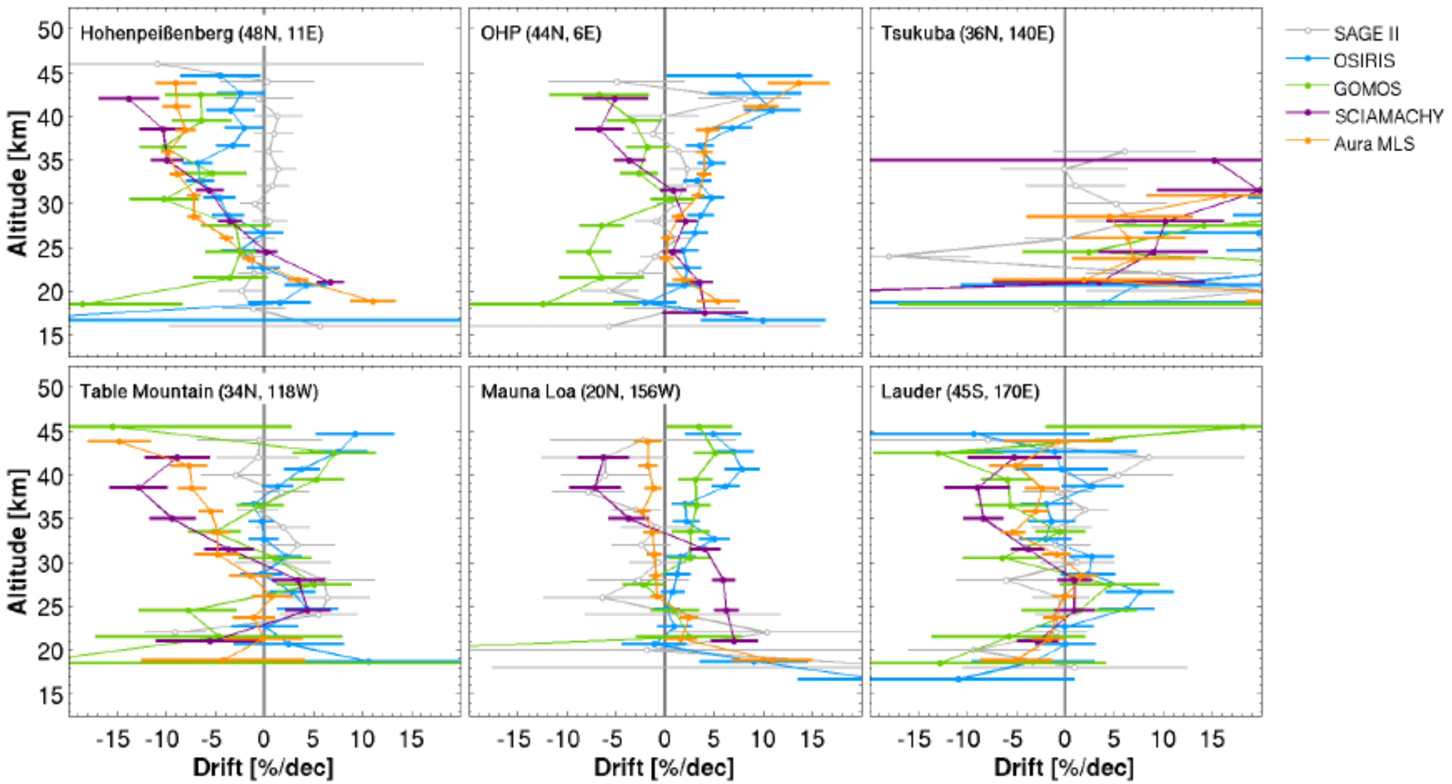
D. Hubert[1], J.-C. Lambert[1], T. Verhoelst[1], J. Granville[1], A. Keppens[1], J.-L. Baray[2], U. Cortesi[3], D. A. Degenstein[4], L. Froidevaux[5], S. Godin-Beekmann[6], K. W. Hoppel[7], E. Kyrölä[8], T. Leblanc[9], G. Lichtenberg[10], C. T. McElroy[11], D. Murtagh[12], H. Nakane[13,14], J. M. Russell III[15], J. Salvador[16], H. G. J. Smit[17], K. Stebel[18], W. Steinbrecht[19], K. B. Strawbridge[20], R. Stübi[21], D. P. J. Swart[22], G. Taha[23,24], A. M. Thompson[24], J. Urban[12,†], J. A. E. van Gijsel[25], P. von der Gathen[26], K. A. Walker[27,28], E. Wolfram[16], and J. M. Zawodny[29]

Average drifts of satellite records relative to entire sonde or lidar networks



- Good agreement between ozone sondes and lidar based drifts
- Some satellite records show significant drifts

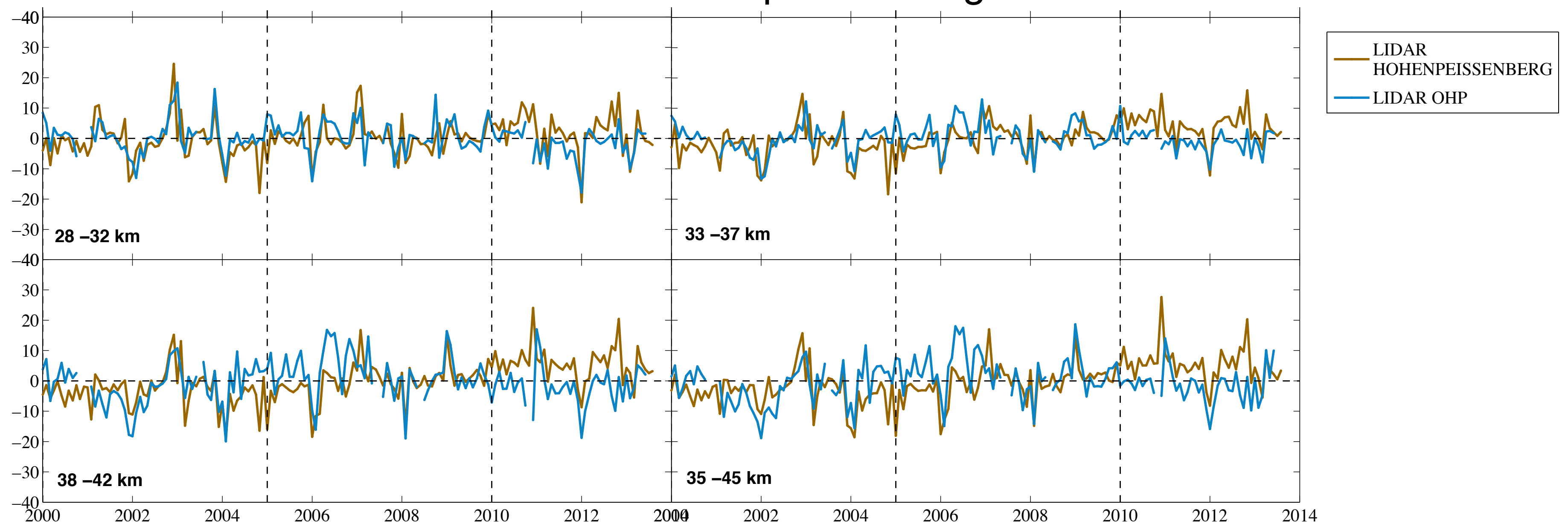
Satellite drifts wrt lidars



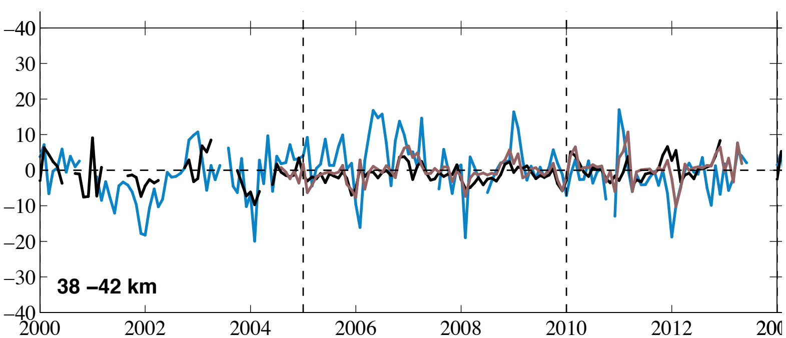
- Few ozone lidars
- Differences between nearby stations

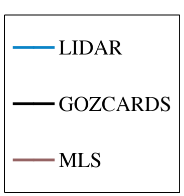
Ozone anomalies comparison

OHP vs Hohenpeissenberg



OHP





Trends from the various records

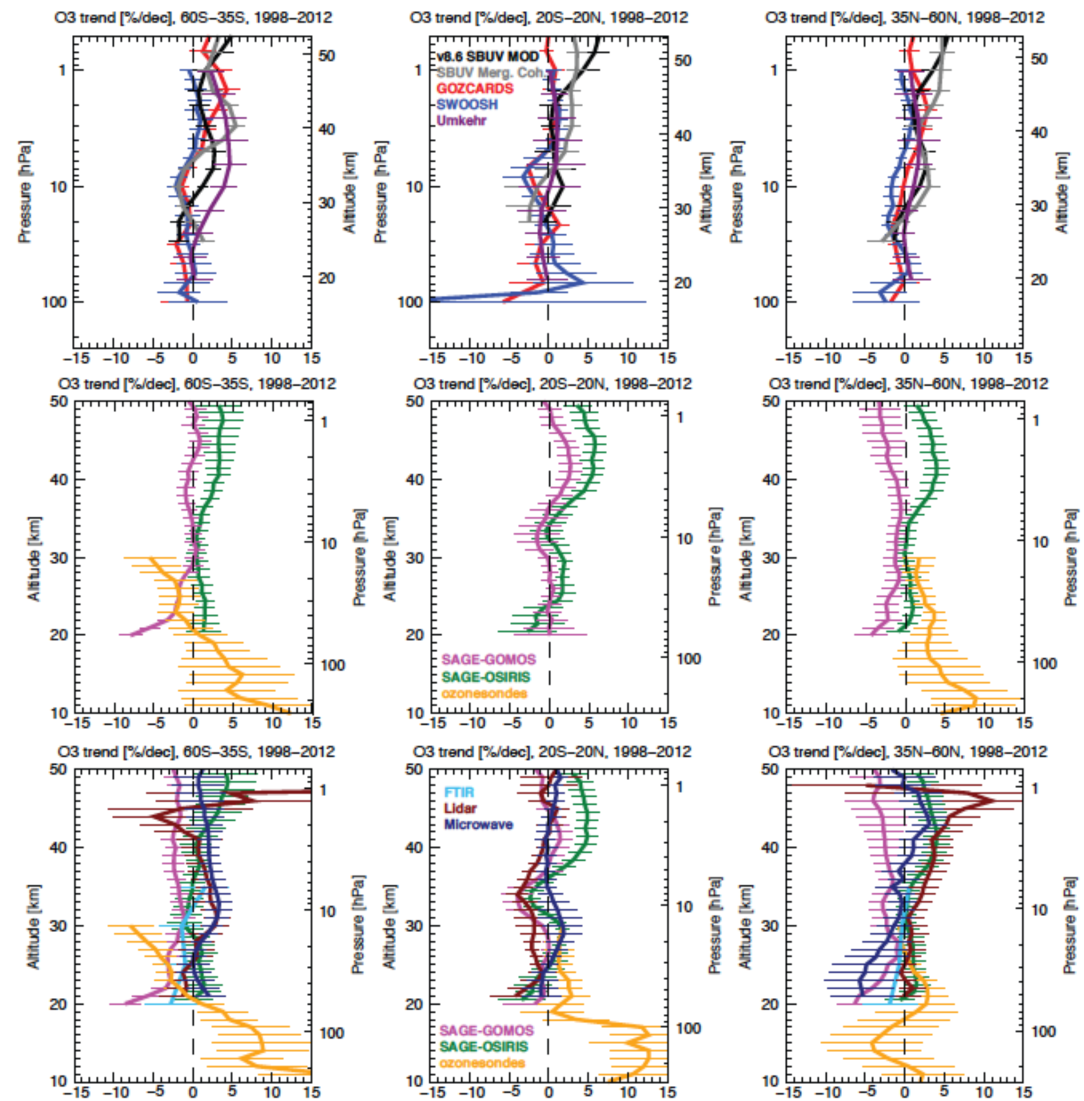
Past changes in the vertical distribution of ozone, Part III:

Analysis and interpretation of trends

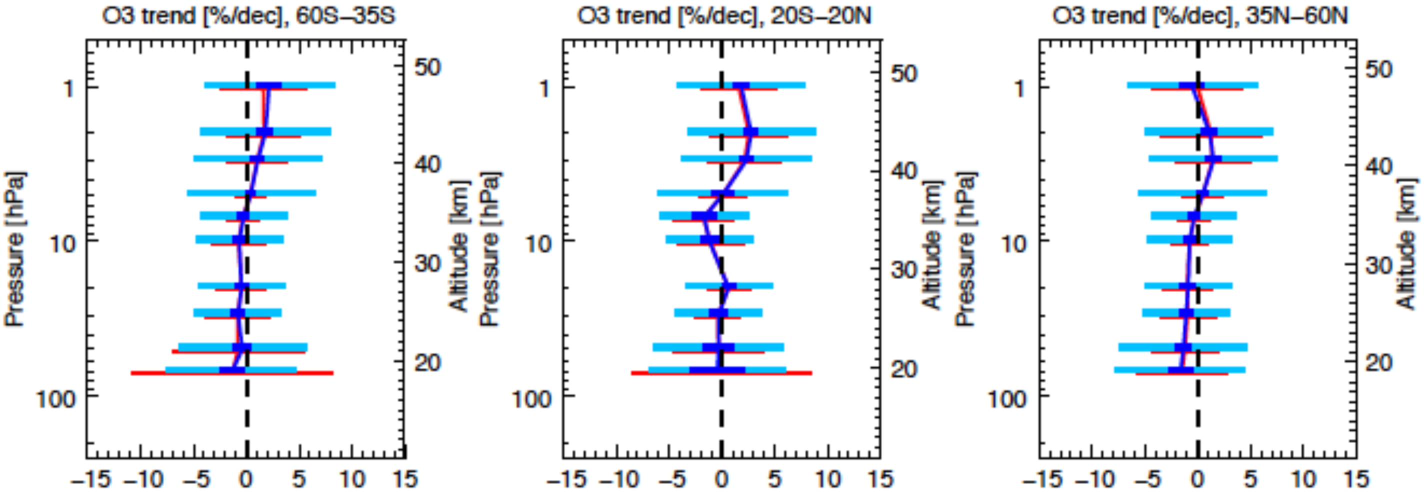
Harris et al., ACPD, 2015

Trend model:
Seasonnal variation,
QBO, ENSO, Solar cycle,
stratospheric aerosols

Post 1998 trends



Post-1998 average trends



Harris et al., ACPD, 2015

Dark blue: Trends from various records considered independent: weighted average and standard error

Light blue : Add a drift uncertainty of 4 to 6%/decade to the previous estimates based on drift analysis study (Hubert et al., 2015)

Red: different estimates combined into a single distribution; 2 sigma error bars computed from the distribution

Results different from trend results in WMO 2014:

- Different records included in the average
- Different treatment of uncertainties
- Trend uncertainties dominated by drift uncertainties

Conclusions

- Early detection of ozone recovery due to ODS decreases easiest in Antarctic spring (total ozone) or higher stratosphere due to lower variability
- Antarctic total ozone: larger meteorogical variability in the latest years -> Detection of recovery delayed
- Higher stratosphere:
    - Several satellite records with different vertical resolution and different drifts wrt ground-based records
    - Ground-based records limited in number and geographical coverage; can show some momentaneous problems
- Expected trends small: ~3 %/decade: needs some more time to detect unambiguous ozone increase due to ODS decrease in the various regions and also continuous monitoring of ozone vertical distribution

Thank you !