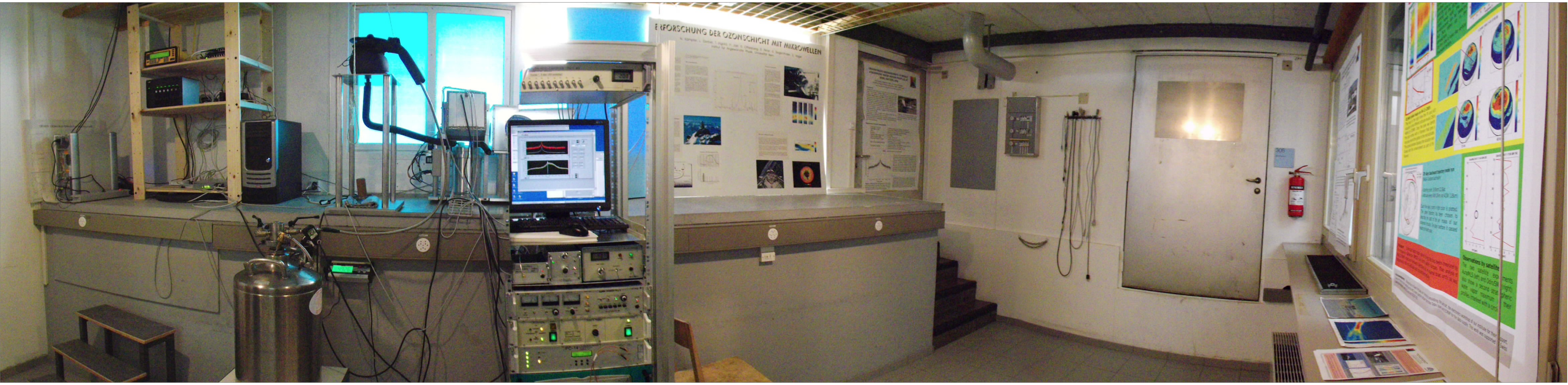
Harmonisation and trend analysis of the 20 years time series of stratospheric ozone profiles observed by the GROMOS microwave radiometer at Bern



Lorena Moreira[1], K. Hocke[1], E. Eckert[2], T. von Clarmann[2], and N. Kämpfer[1]
[1]Institute of Applied Physics, University of Bern, Switzerland
[2]Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Karlsruhe, Germany

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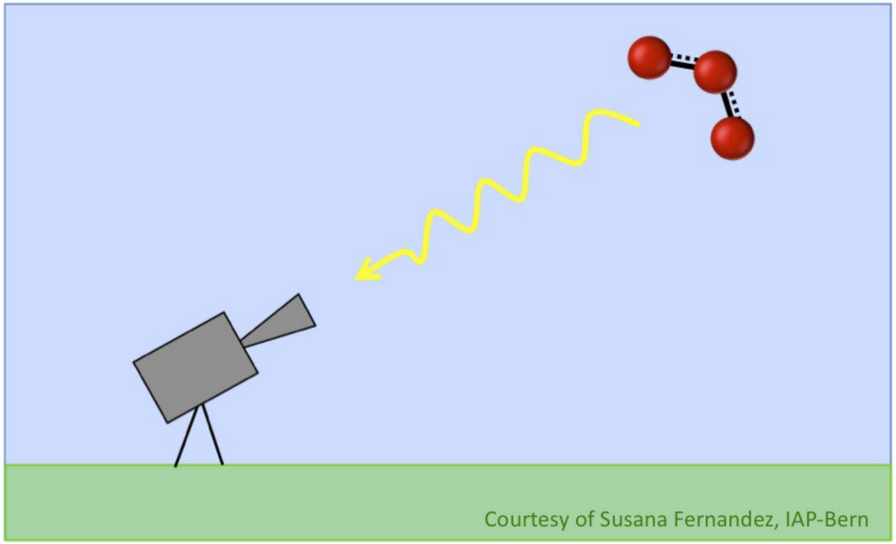
Outline

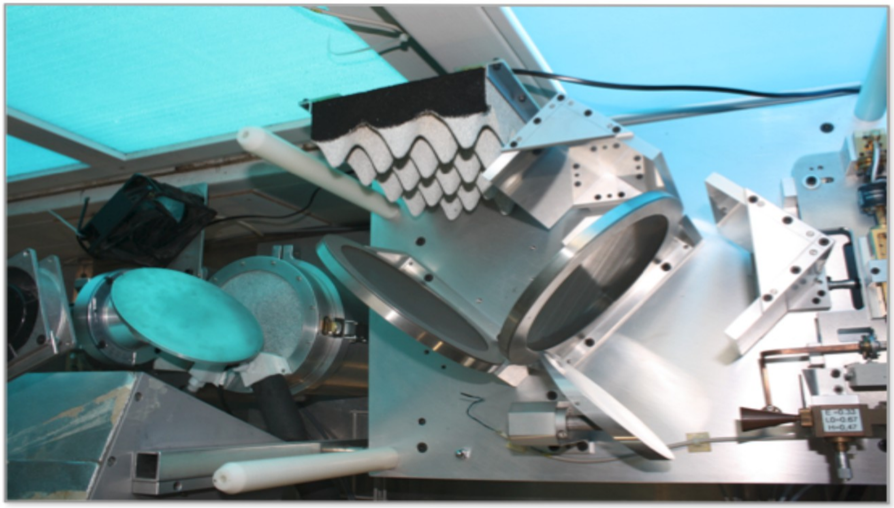
- The microwave ozone radiometer GROMOS
- Harmonisation method
- Trend estimation
- Conclusions

GROMOS

(GROund-based Millimeter wave Ozone Spectrometer)

- Triple switched 142.175 GHz total power radiometer
- Operational since 1994
- Located at Bern, Switzerland (45.95°, 7.44°, 577m)
- Spectrometer upgrade in July 2009
- Day + night time. Nearly all weather
- Pressure broadened rotational transition line of O_3
- Vertical O_3 profile retrieval by the ARTS/Qpack + OEM





Comparison between FB and FFTS

	N° Channels	Bandwidth	Frequency resolution	Time resolution	Measurement period
Filter Bench (**FB**)	45	1.2 GHz	From 200kHz at the line centre to 100MHz at the line winds	1 h	November 1994 to September 2011
Fast-Fourier Transform Spectrometer (**FFTS**)	32768	1 GHz	30.5 kHz	30 min	Since July 2009 till present

2 years of overlapping measurements

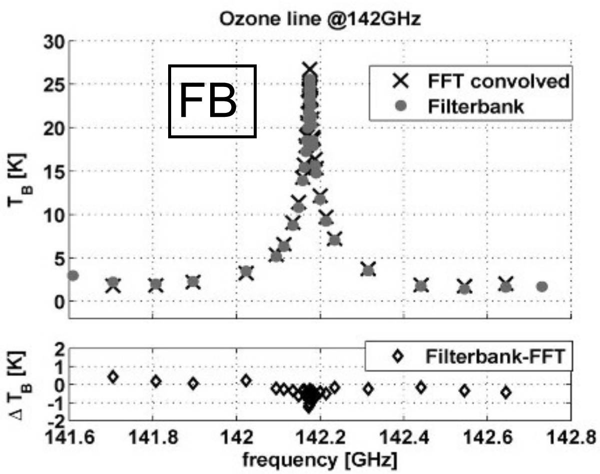


Fig. 9. Measurement of the O_3 line at 142 GHz at Bern, Switzerland, with Filterbank and FFT spectrometer. FFT spectrometer channels are convolved with the filter characteristic of the Filterbank for comparison. The elevation angle of the instrument is 40 °C.

Müller et al., IEEE TGRS, 2009

Advantages of FFT Spectrometer:

- High frequency resolution
- Broad bandwidth
- Stability
- High accuracy

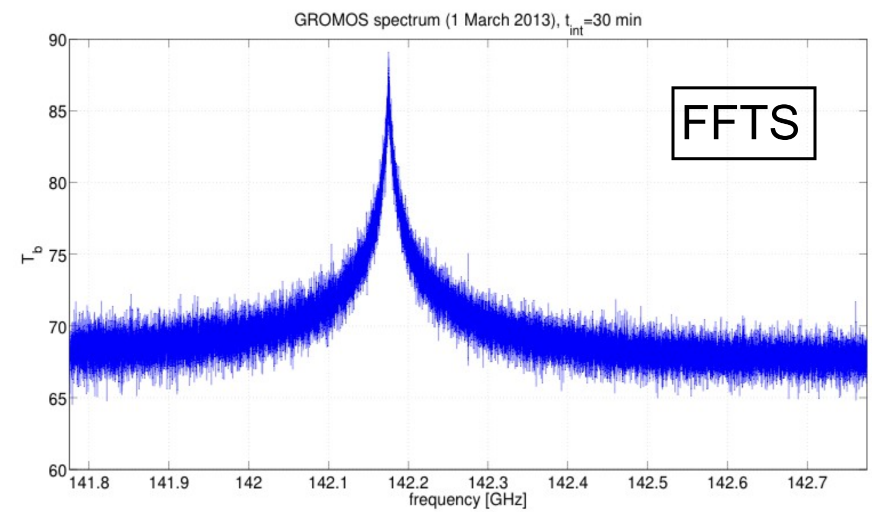
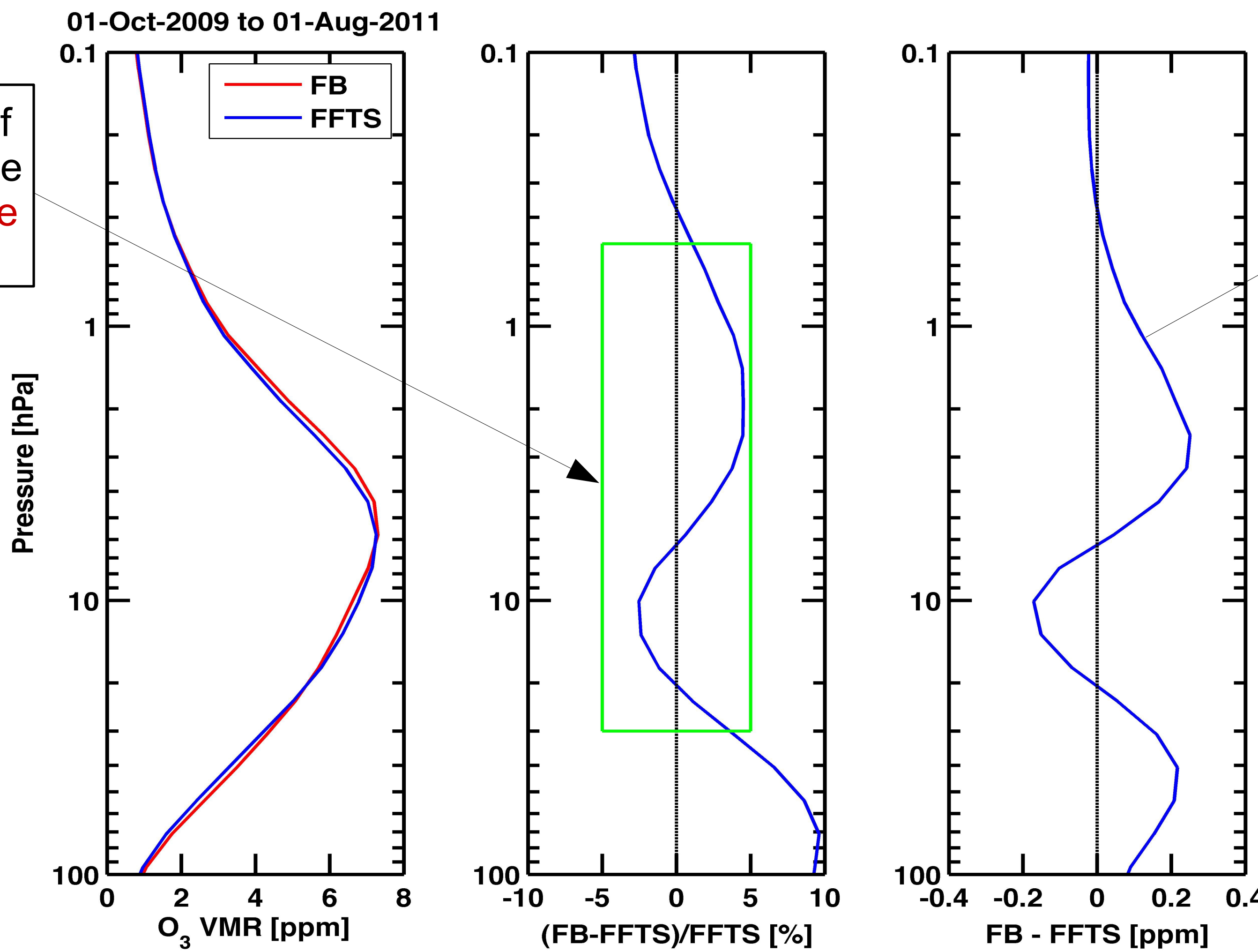


Figure 2.4: Ozone spectrum at 142 GHz recorded by the Aqiris FFT spectrometer of GROMOS.

Courtesy of Simone Studer

Harmonisation process

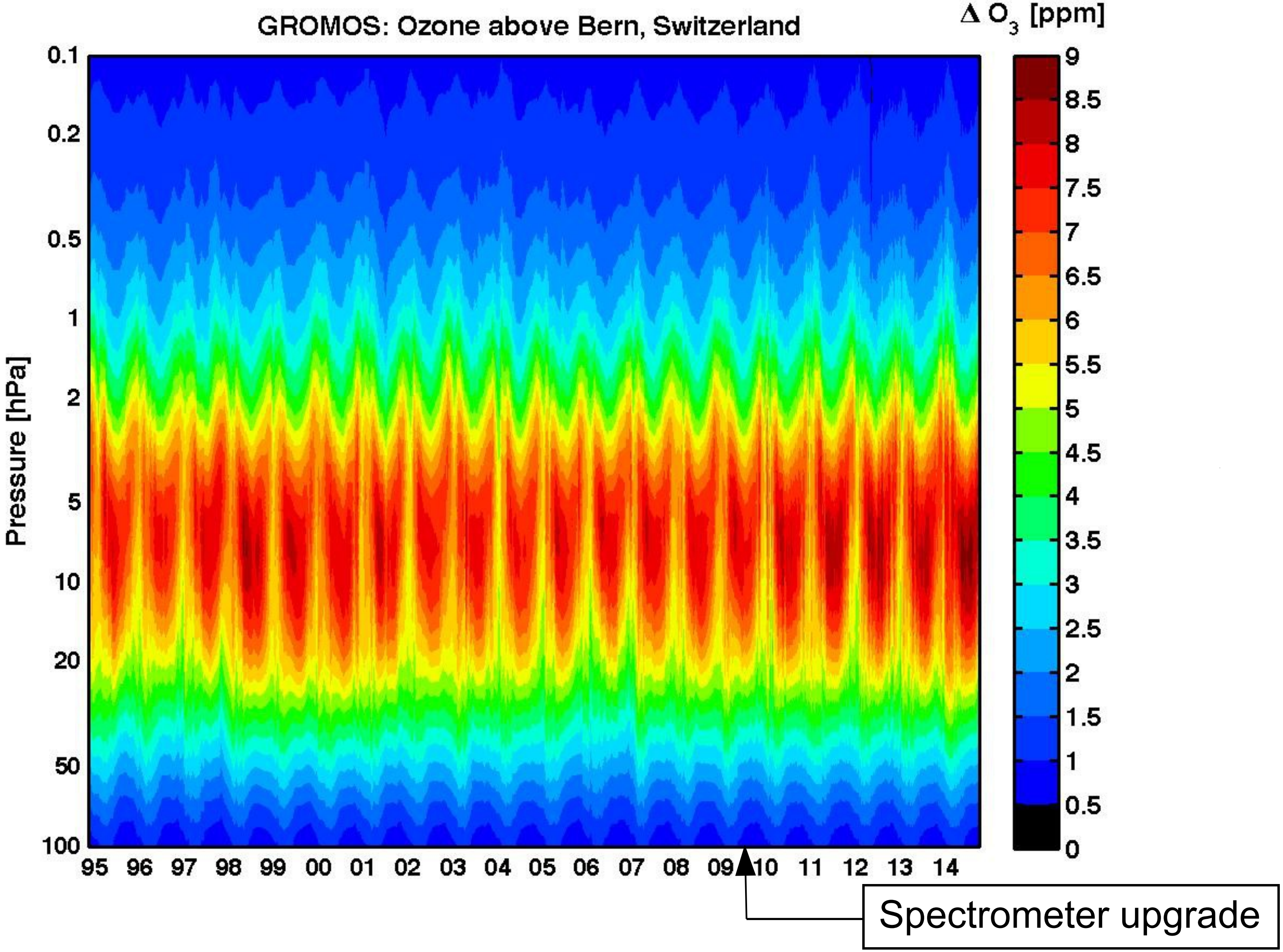
FFTS and FB of GROMOS agree within 5% above 20 hPa



Mean bias profile: FB - FFTS

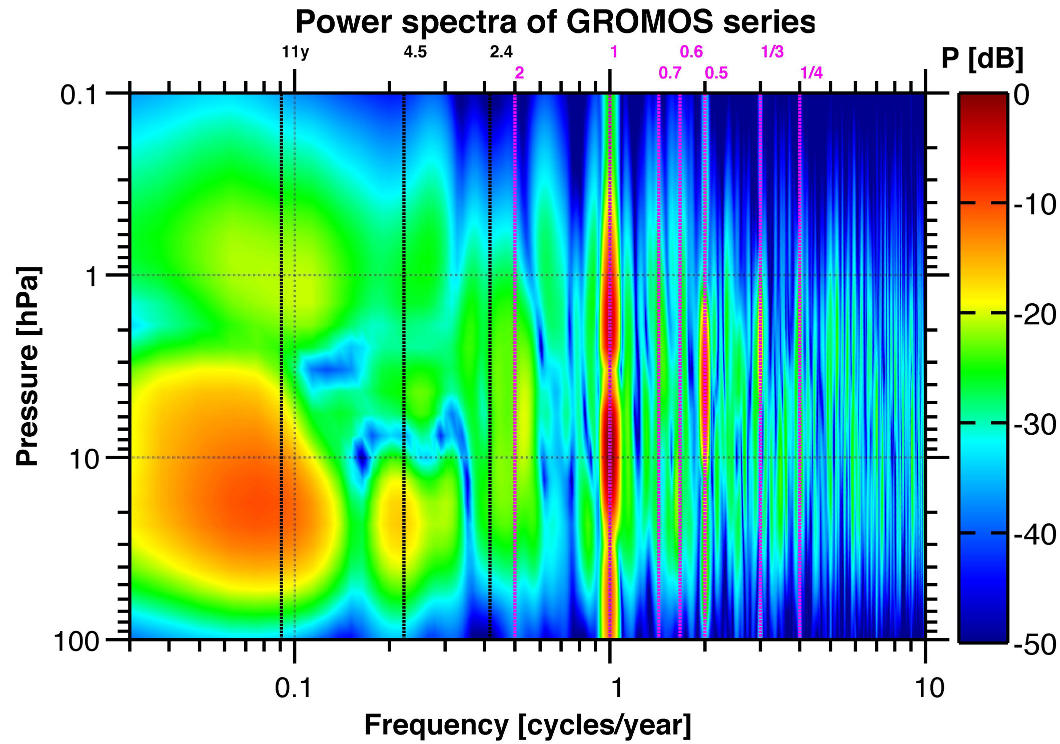
Correction of Filter bench

Harmonised time series



KIT-trend estimation method

- Multilinear parametric trend model (von Clarmann, ACP, 2010)
- Linear trend estimation by using Optimal Estimation Method and cost function



Solar cycle

$$\hat{y}(t) = a + b \cdot t + c_1 \cdot qbo_1(t) + d_1 \cdot qbo_2(t) + e \cdot F10.7(t) + f \cdot MEI(t) + \sum_{n=2}^{m} \left(c_n \cdot \sin\left(\frac{2\pi \cdot t}{l_n}\right) + d_n \cdot \cos\left(\frac{2\pi \cdot t}{l_n}\right)\right)$$

ENSO

QBO

Power spectra of GROMOS ozone series to select the fitting frequencies of annual and semi-annual oscillation and the overtones with periods of 3, 4, 7.2, 8.4 and 24 months

Estimation of uncertainty

Inputs required by KIT-trend estimation program:

- Ozone **monthly mean profiles**
- **σ** of the monthly mean profiles

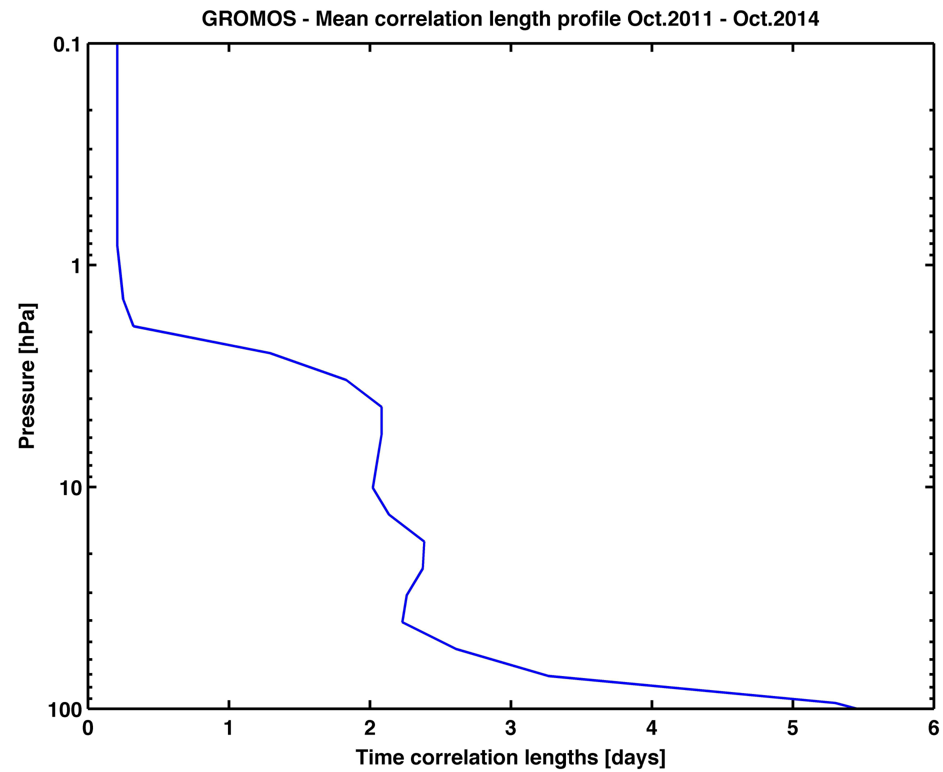
Effect of autocorrelation

$$\sigma = \frac{\sigma}{\sqrt{n}}$$

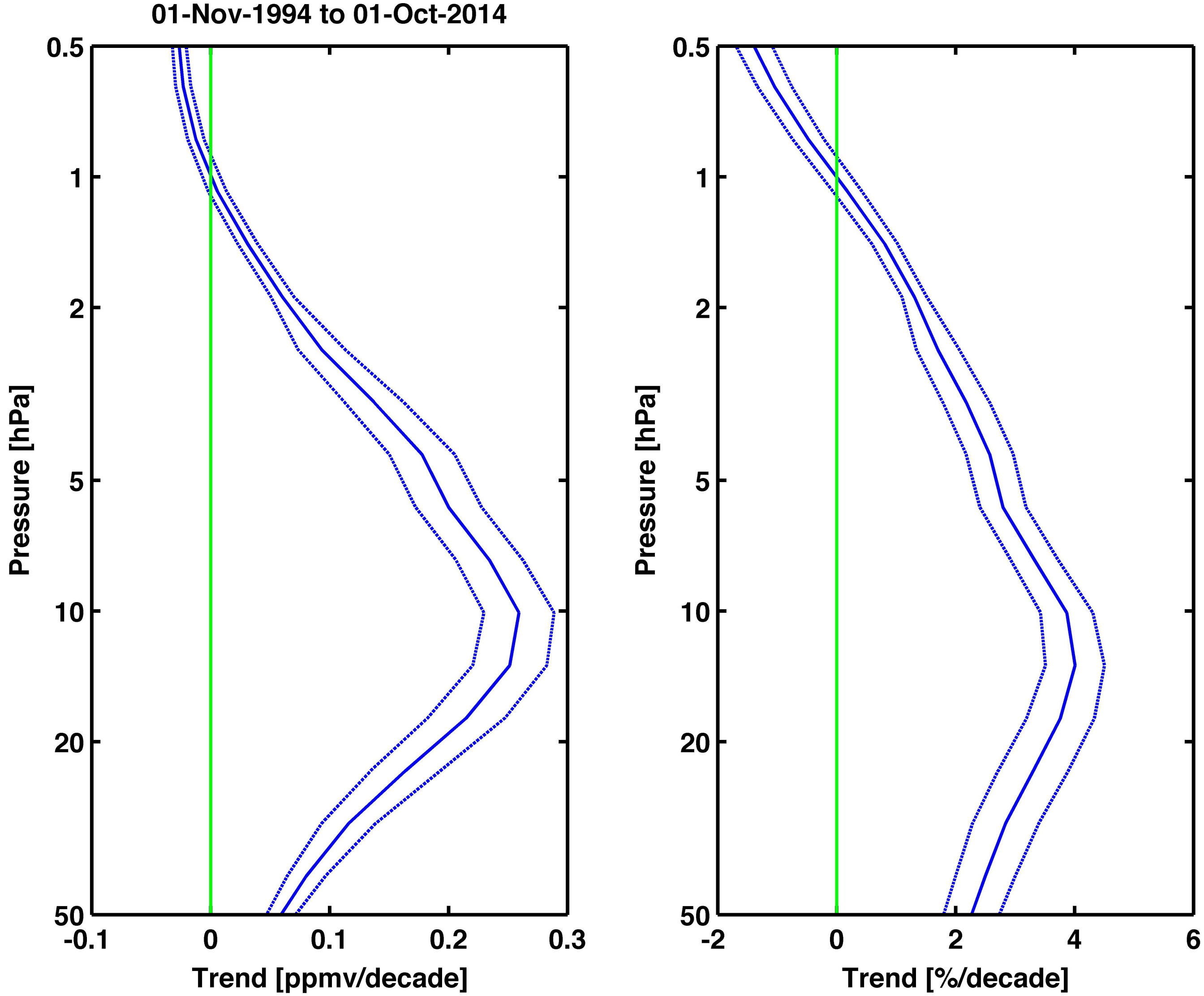
$$\sigma_m = \frac{\sigma}{\sqrt{\frac{n}{nc}}}$$

Number of independent values per month

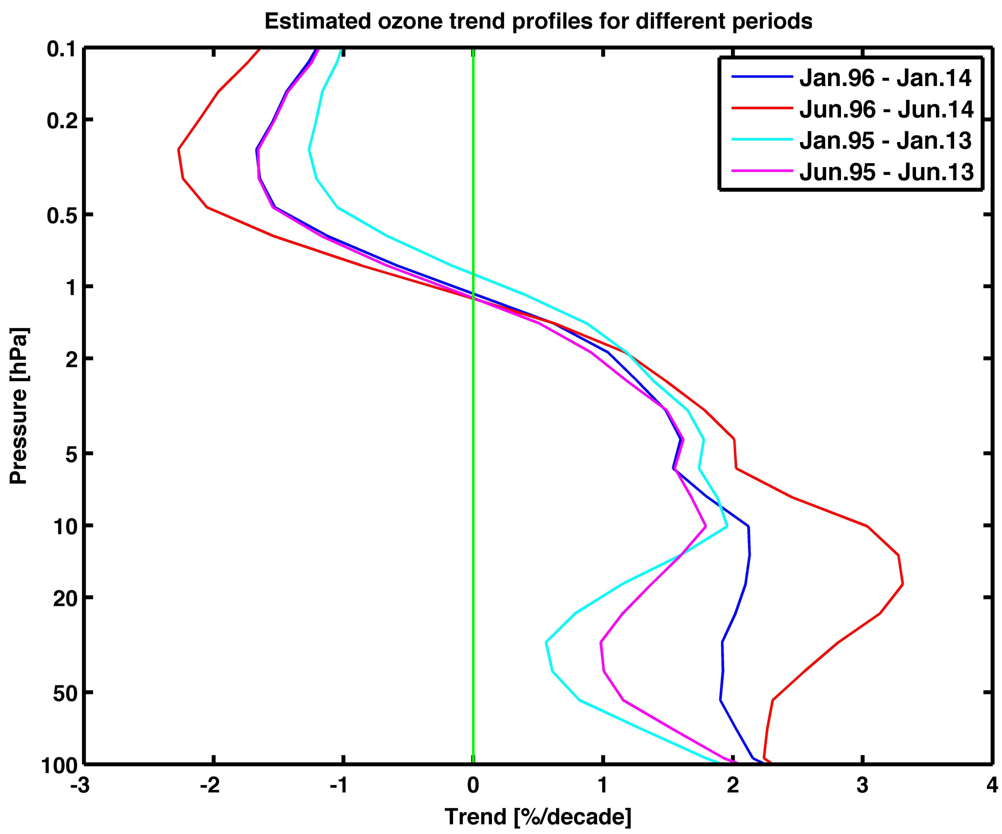
n_c is the mean correlation length profile of the autocorrelated values within 95% of confidence level



Estimated O_3 trend



Outlook



- Include retrieval error in the trend estimation
- Influence of time interval on the trend estimation

Conclusions

- FFT spectrometer provides more stability and accuracy
- FB agrees within 5% with FFTS
- Harmonisation is done by taking FFTS as benchmark
- Ozone trends from 1% to 4% per decade are observed at 30km
- Ozone trend above Switzerland is in agreement with northern mid-latitudes trend estimations (Steinbrecht *et al.*, 2009, Nair *et al.*, 2013, ...)

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Thanks for your attention!