CH4 and CO2 Profiles derived from SCIAMACHY Solar Occultation Measurements with Onion Peeling DOAS

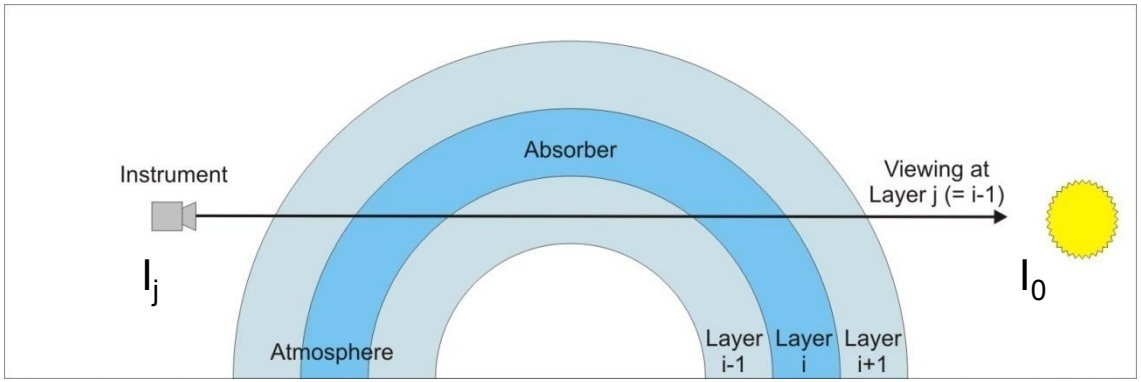
S. Noël, K. Bramstedt, A. Rozanov, P. Liebing, M. Reuter, H. Bovensmann, J. P. Burrows

IFE/IUP, University of Bremen, Germany

Universität Bremen

Stefan.Noel@iup.physik.uni-bremen.de

Onion Peeling DOAS



- Atmosphere is divided into horizontal layers
- For each layer, a weighting function DOAS fit is performed
- Retrieval starts at top layer and then propagates downwards, taking into account the results of the upper layers
- After the retrieval, several corrections are performed (vertical smoothing, non-linearity/saturation corrections)
- VMRs derived from retrieved number densities using p, T from ECMWF

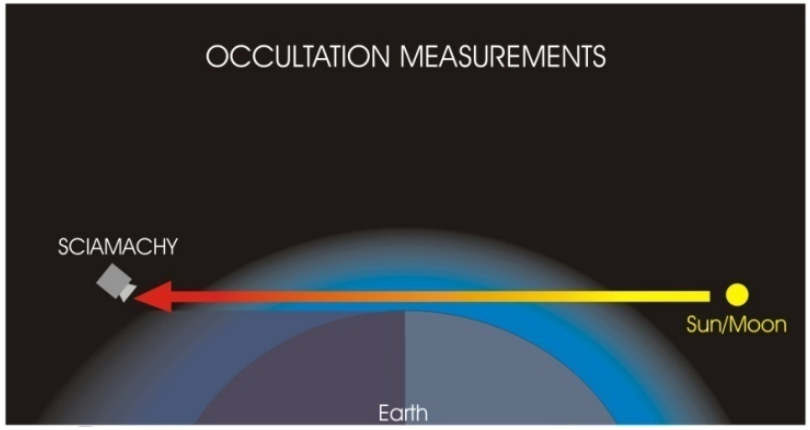
Basic Formula

$$\ln\left(\frac{I_j}{I_0}\right) = P_j + \ln\left(\frac{I_{j,\mathrm{ref}}}{I_{0,\mathrm{ref}}}\right) + \sum_k \sum_i \alpha_{ij,k}\ a_{i,k}$$

- I_j / I_0 = measured transmission for TH j
- $I_{j,ref}$ / $I_{0,ref}$ = reference transmission for TH j (from RTM)
- Index i = layer altitudes
- Index k = absorber
- $\alpha_{ij,k}$ = relative weighting functions for absorber k, layer i, TH j
- $a_{i,k}$ = relative change of absorber k in layer i (only a_j fitted in TH j)
- Additionally fitted: Polynomial P_j, spectral calibration

Application to SCIAMACHY

- Fit interval: 1559 -1671 nm
- Absorbers:
  - CH_4, CO_2 (fitted)
  - T, p (from ECMWF)
- Retrieval altitude grid:
  0 – 50 km, 1 km steps

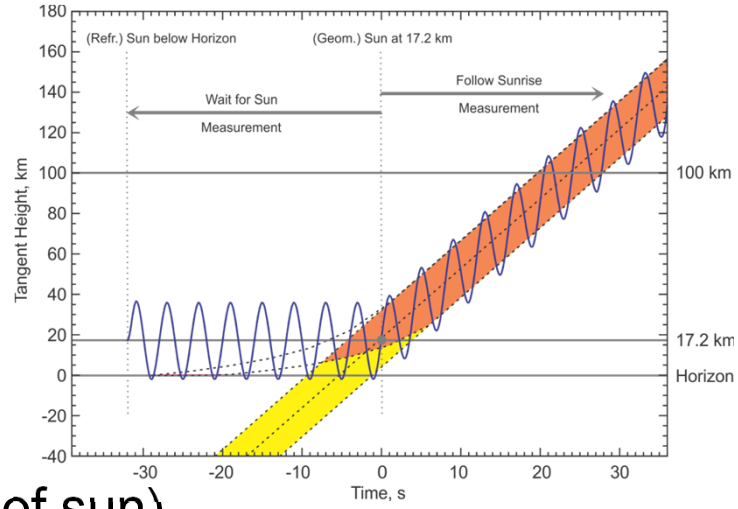


- Use only selected subset of SCIAMACHY solar occultation data
- SCIAMACHY spectra are interpolated to retrieval grid before retrieval (required by method)

- Previous product version: V3.3.6 (Noël et al., AMT, 2011):
  - Only reasonable results for CH_4
  - Restricted to 20 – 40 km

Main Changes

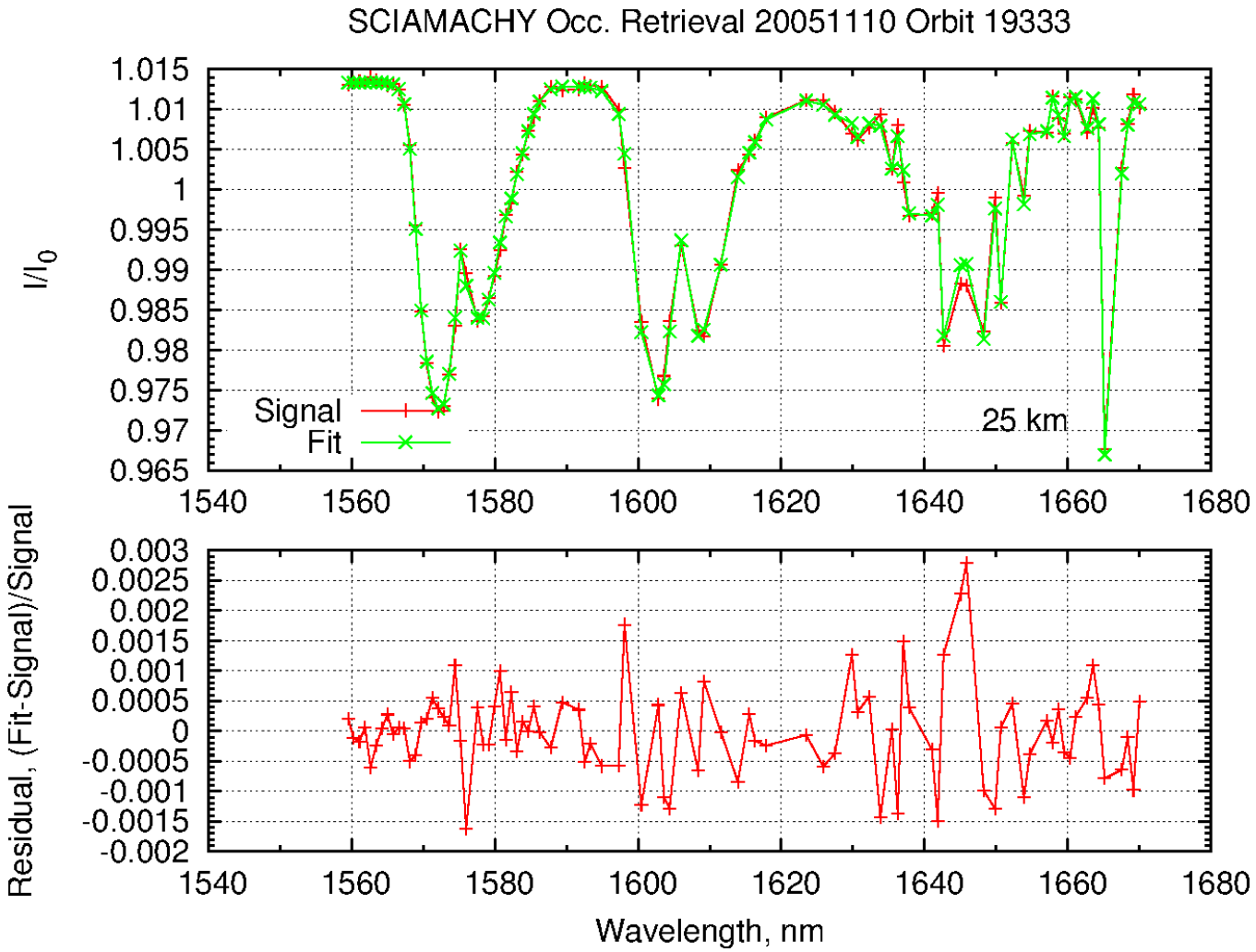
- Use improved pointing information (Bramstedt et al., 2012)
- Optimised selection procedure for readouts (take data with highest transmissions, both up & downscan); especially important at lower altitudes (refraction)
- Include FOV integration (4.1 km) in RTM data calculation (IFOV + scan + motion of sun)
- Additional a-posteriori corrections (esp. change of CH_4 & CO_2 as function of p, T)
- Improved error calculation



- Current product version 4.2.1:
  - Improved performance at altitudes below 20 km
  - CO_2 (originally secondary product) now also reasonable

Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

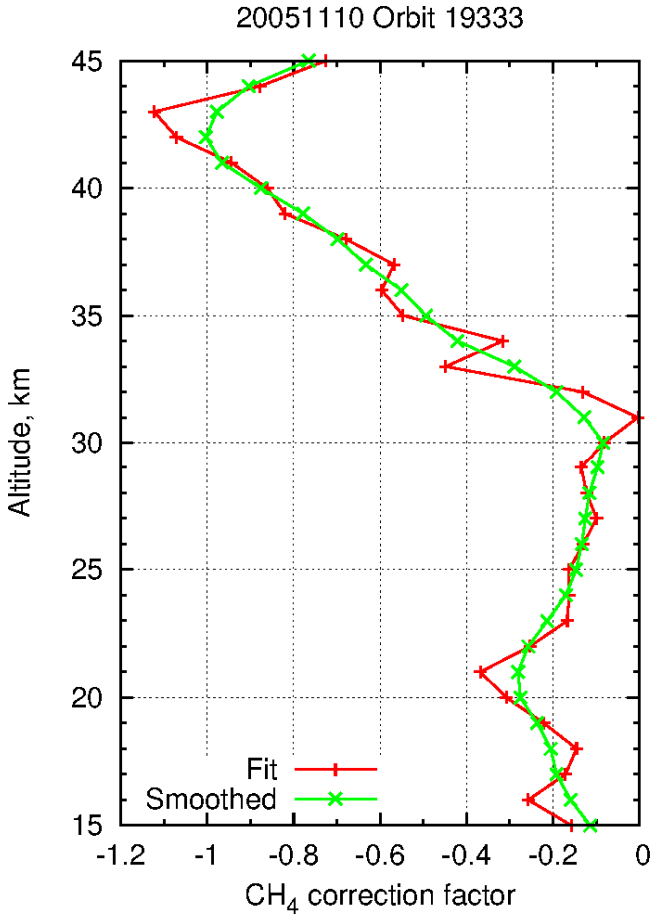
Example Fit (25 km)

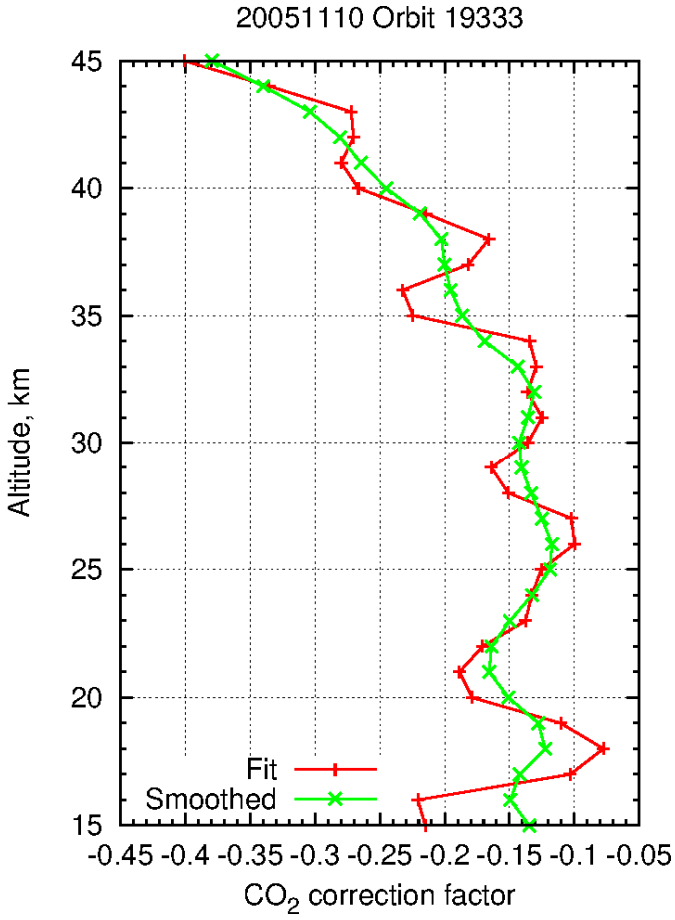


Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

Vertical Smoothing

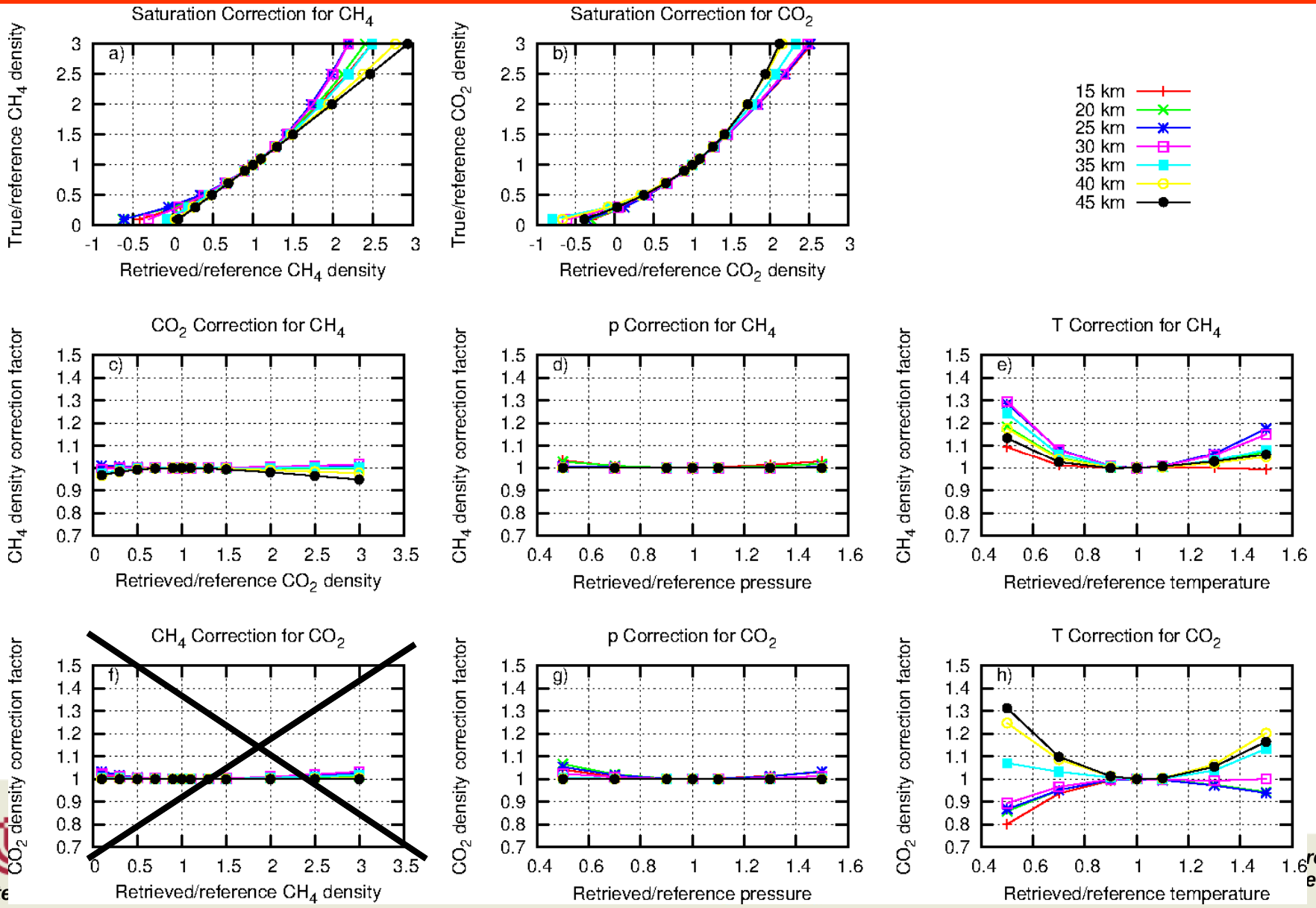
- Smoothing with 4.1 km boxcar
- Reduces artificial oscillations with altitude introduced by onion peeling method
- Remaining oscillations (CO_2)?



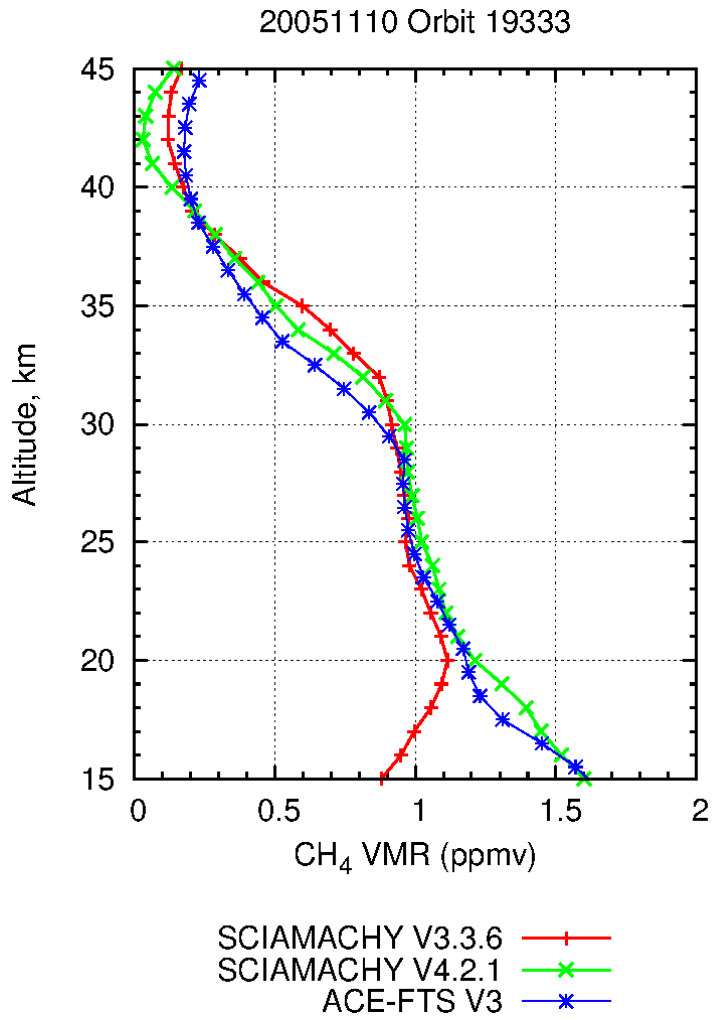


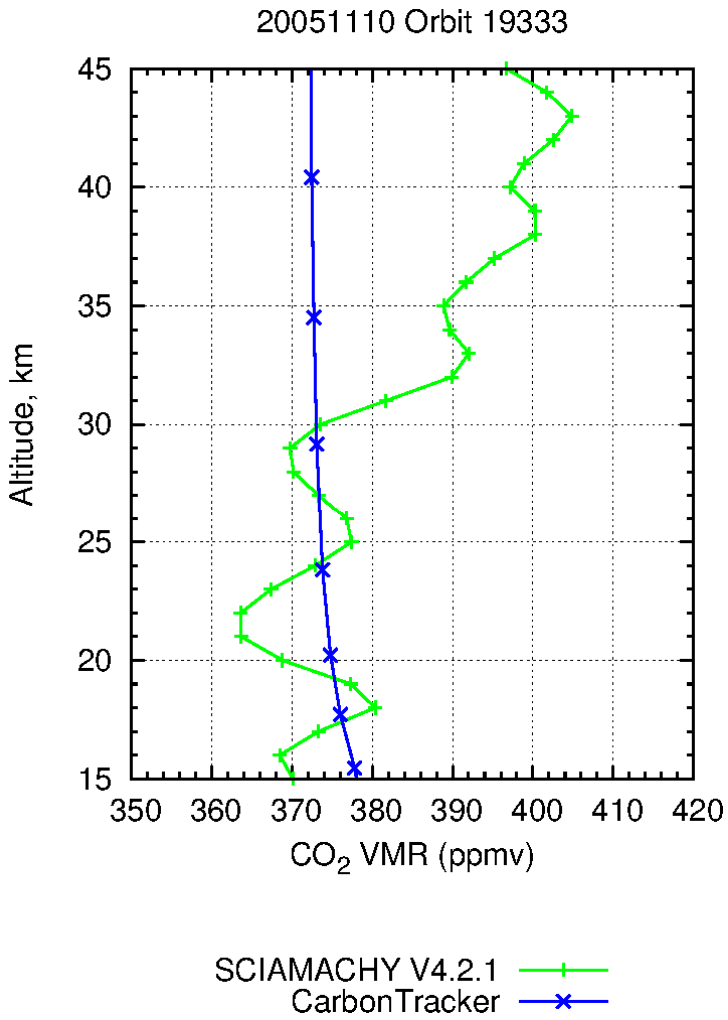
Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

Further Corrections (Non-Linearities)



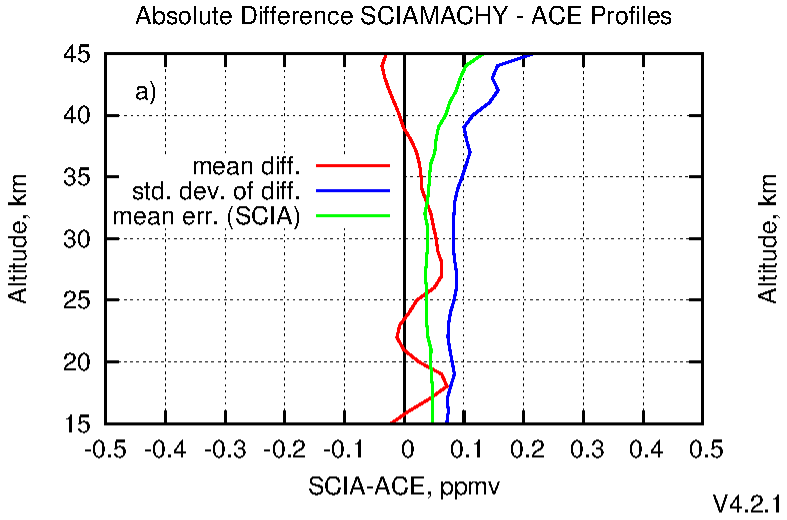
Example Results

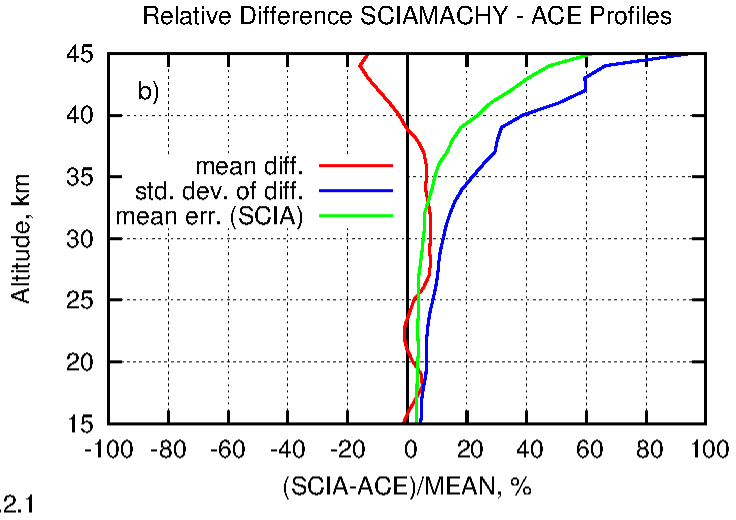


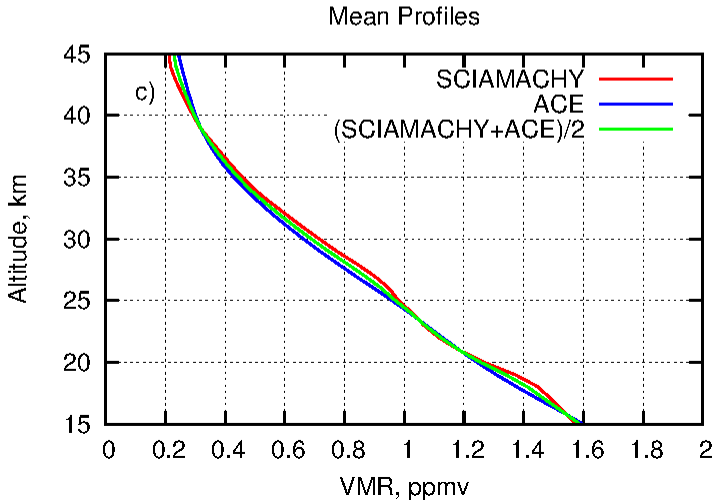


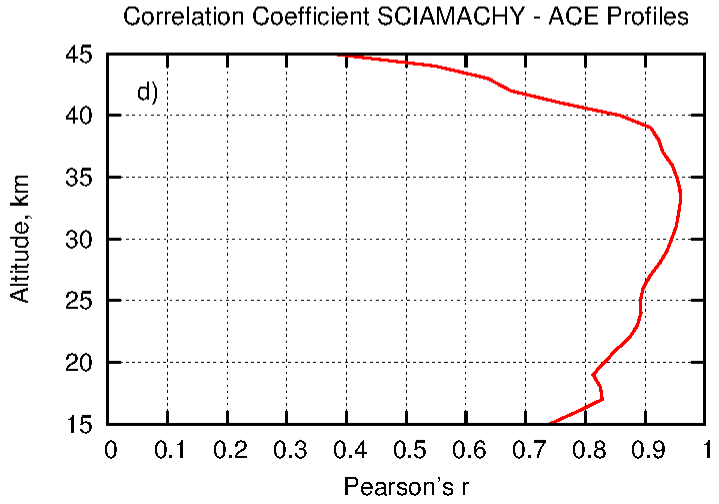
Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

CH_4 Comparison (ACE V3)





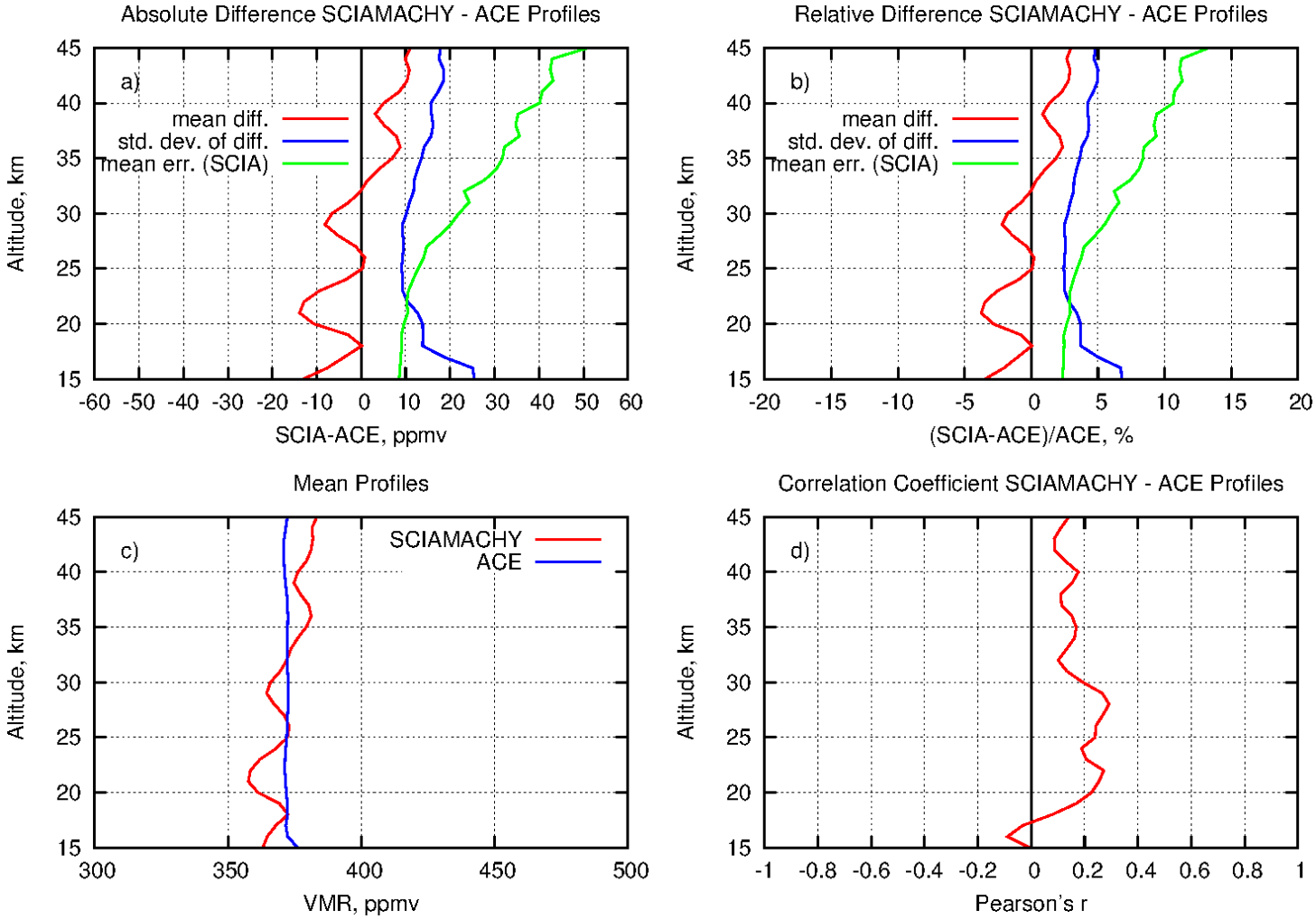




About 920 collocations between 2004 and Oct 2010 (sunset data, 500 km max. distance)

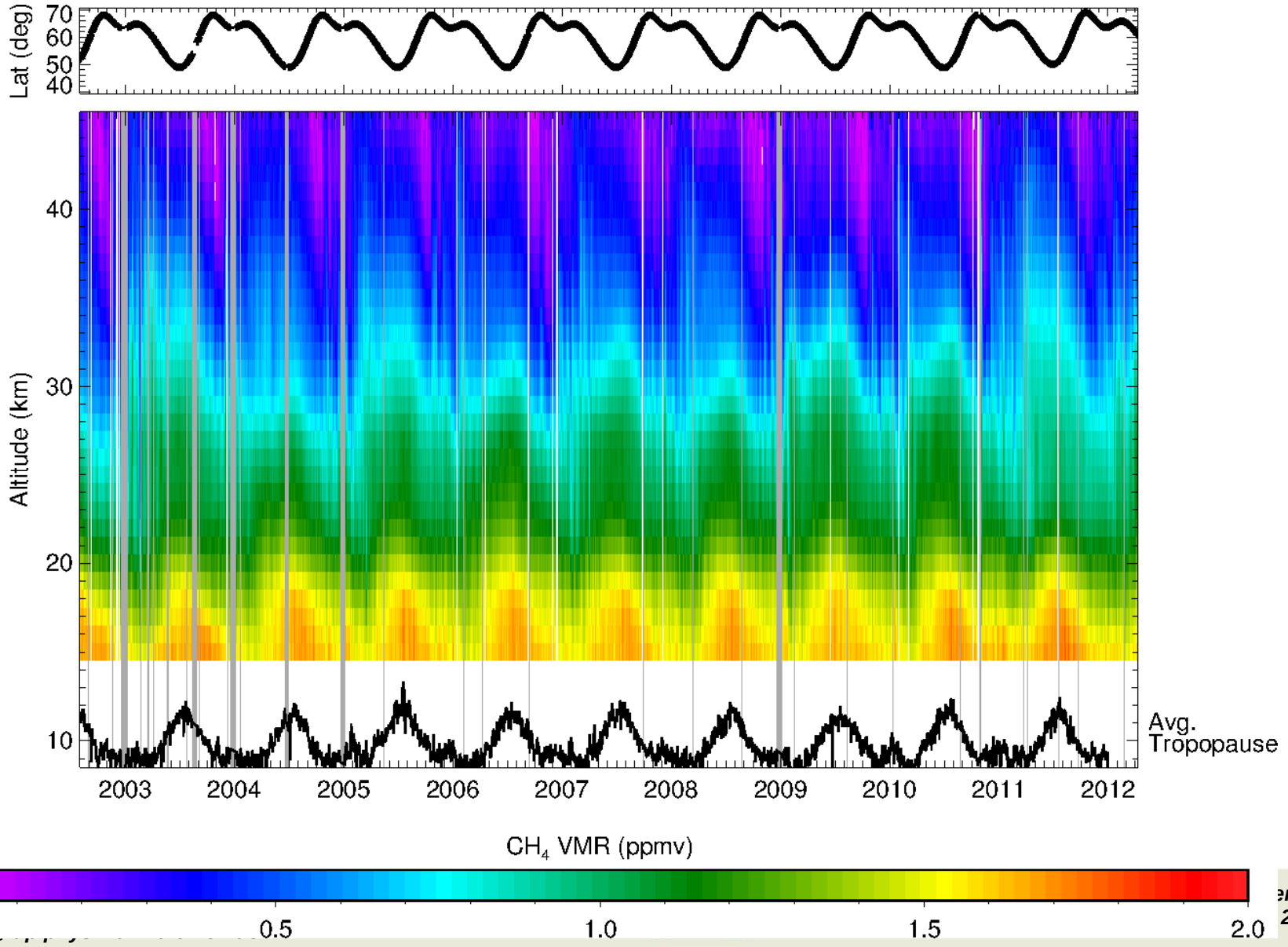
Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

CO_2 Comparison (CT2011)

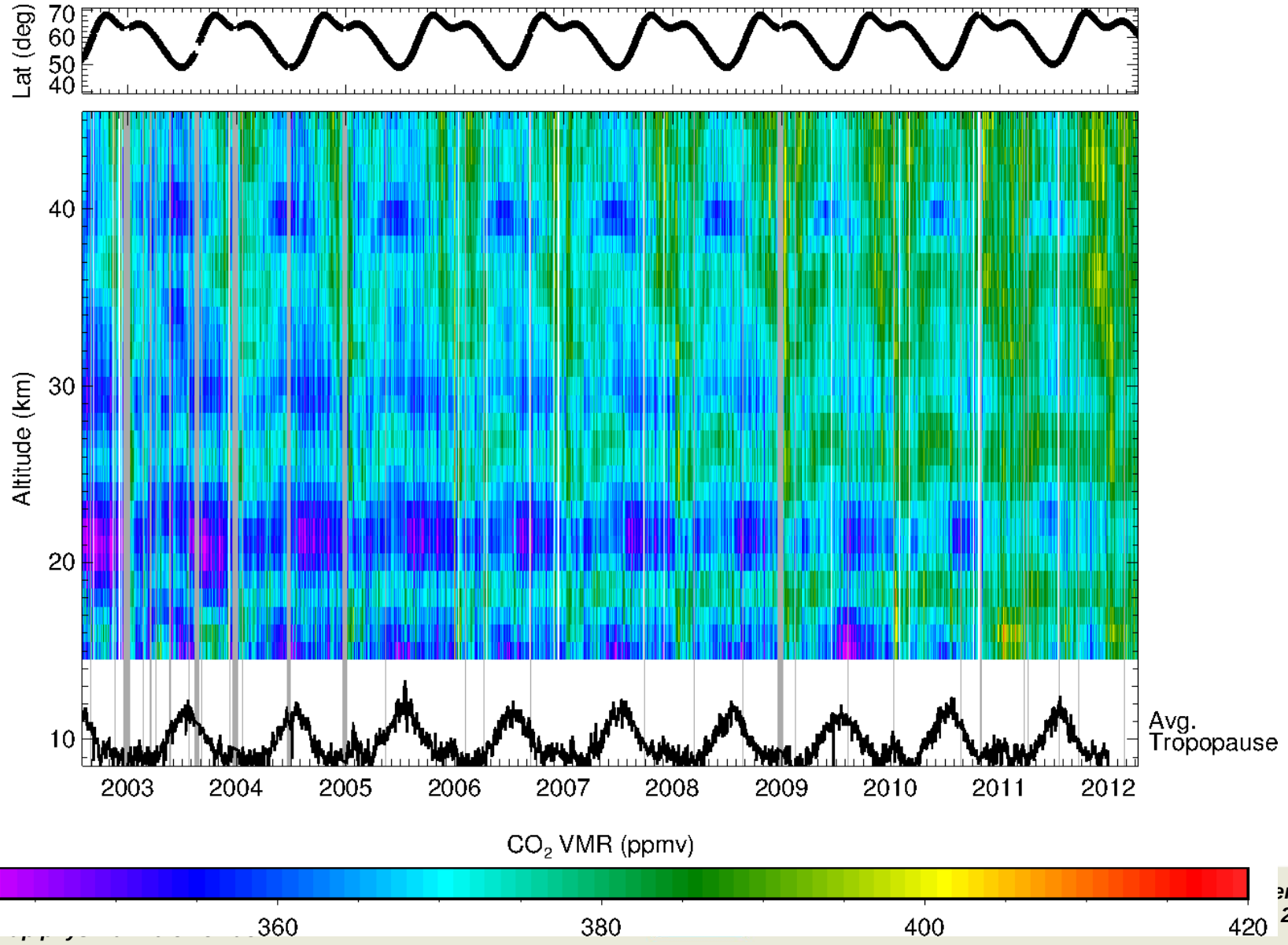


Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

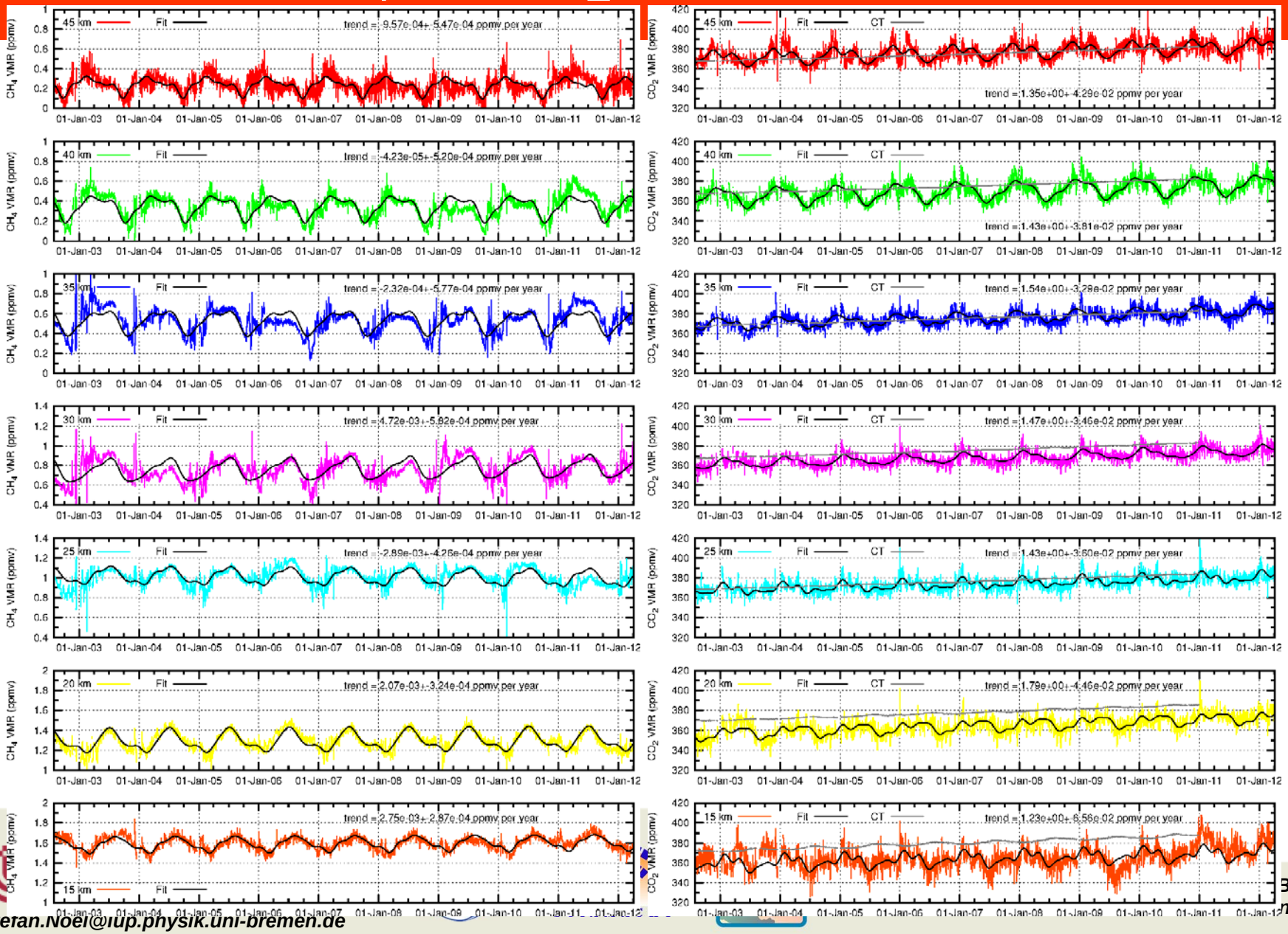
CH_4 Daily Means



CO_2 Daily Means

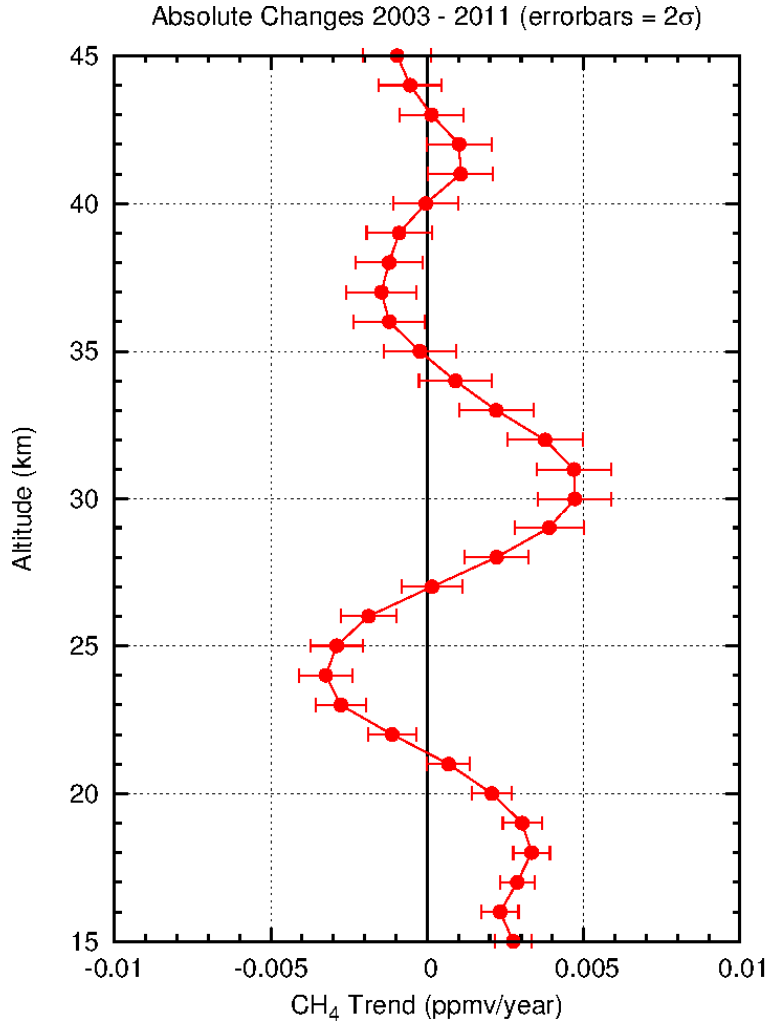


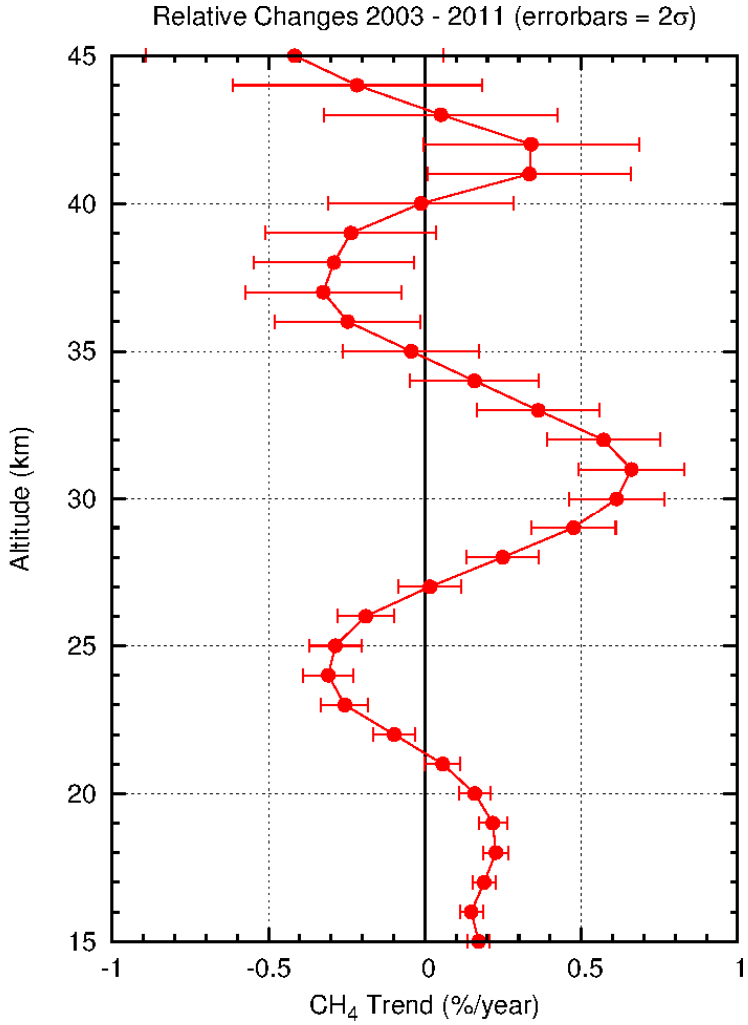
CH_4 & CO_2 Altitude Plots



Steran.Noel@iup.physik.uni-bremen.de

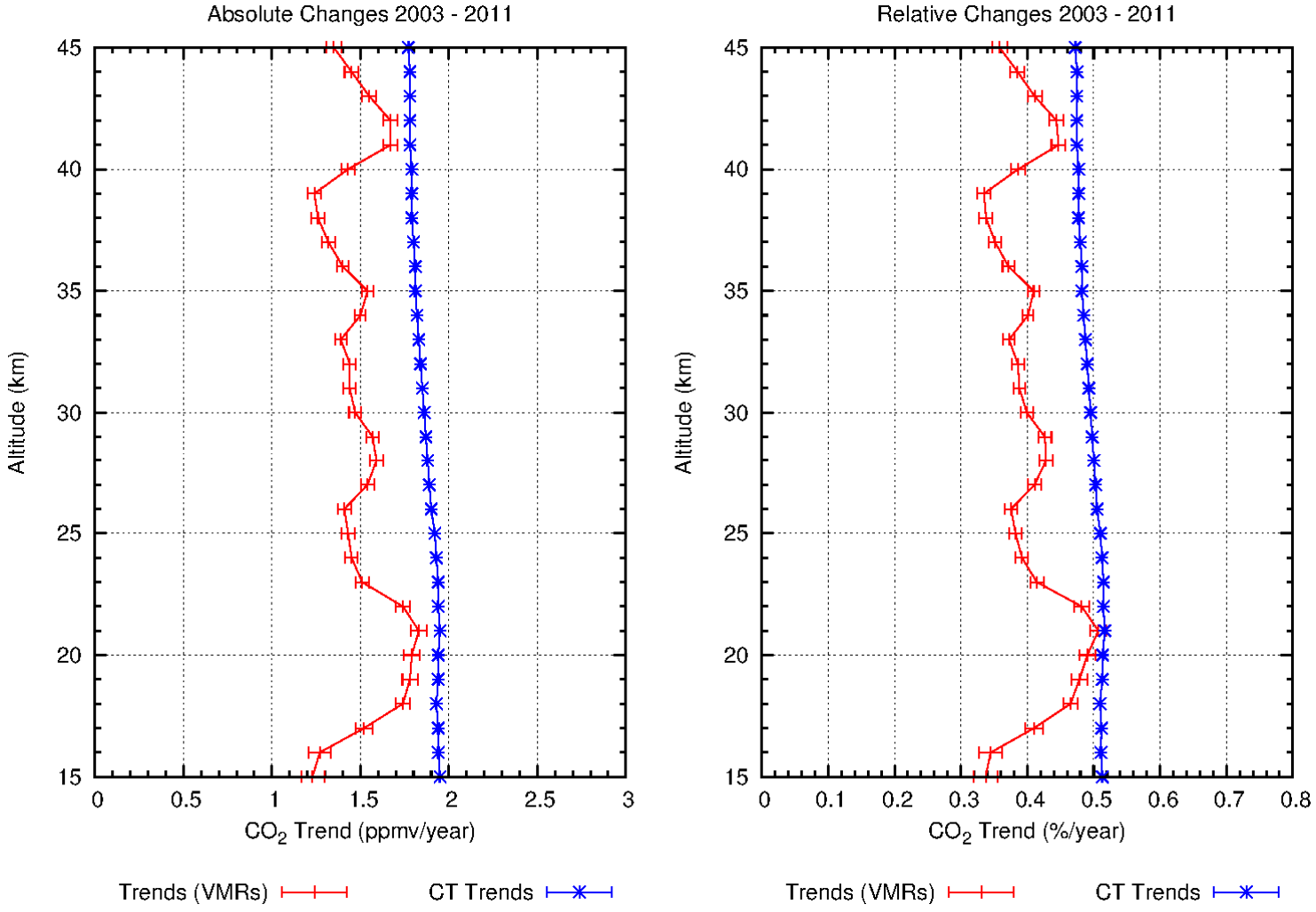
Preliminary CH_4 Trends





Universität Bremen
Stefan.Noel@iup.physik.uni-bremen.de

Preliminary CO_2 Trends



Universität Bremen

Stefan.Noel@iup.physik.uni-bremen.de

Summary

- Improved version 4.2.1 of ONPD CO_2 and CH_4 products available
- Complete SCIAMACHY time series (August 2002 to April 2012) has been processed
- Reasonable results between about 15 and 45 km
- First validation indicates accuracy of about 5% (compared to ACE-FTS and CarbonTracker)
- Main issues: Seasonal variations and vertical oscillations (specifically CO_2): Retrieval artefact?
- Possible way forward: Normalisation to SCIAMACHY O_2:
  - Data products will be more independent from ECMWF
  - Systematic errors might cancel
  - Investigations ongoing

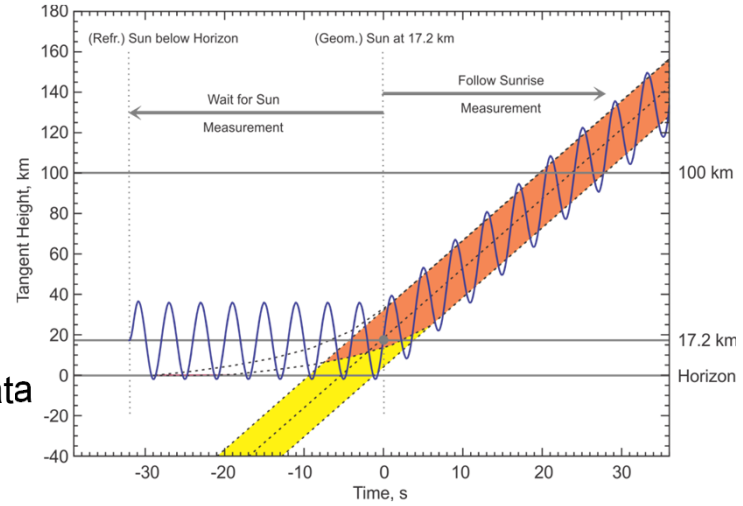
Acknowledgements

- SCIAMACHY is a national contribution to the ESA ENVISAT project, funded by Germany, The Netherlands, and Belgium. SCIAMACHY data have been provided by ESA.
- The Atmospheric Chemistry Experiment (ACE), also known as SCISAT, is a Canadian-led mission mainly supported by the Canadian Space Agency and the Natural Sciences and Engineering Research Council of Canada.
- CarbonTracker 2011 results provided by NOAA ESRL, Boulder, Colorado, USA from the website at http://carbontracker.noaa.gov.
- We thank the European Centre for Medium RangeWeather Forecasts (ECMWF) for providing us with analysed meteorological fields.
- We thank Geoffrey Toon of the NASA Jet Propulsion Laboratory for providing the empirical solar line list used in this work.
- This work has been funded by DLR Space Agency (Germany), the ESA GHG-cci and by the University of Bremen.

THANK YOU FOR YOUR ATTENTION!

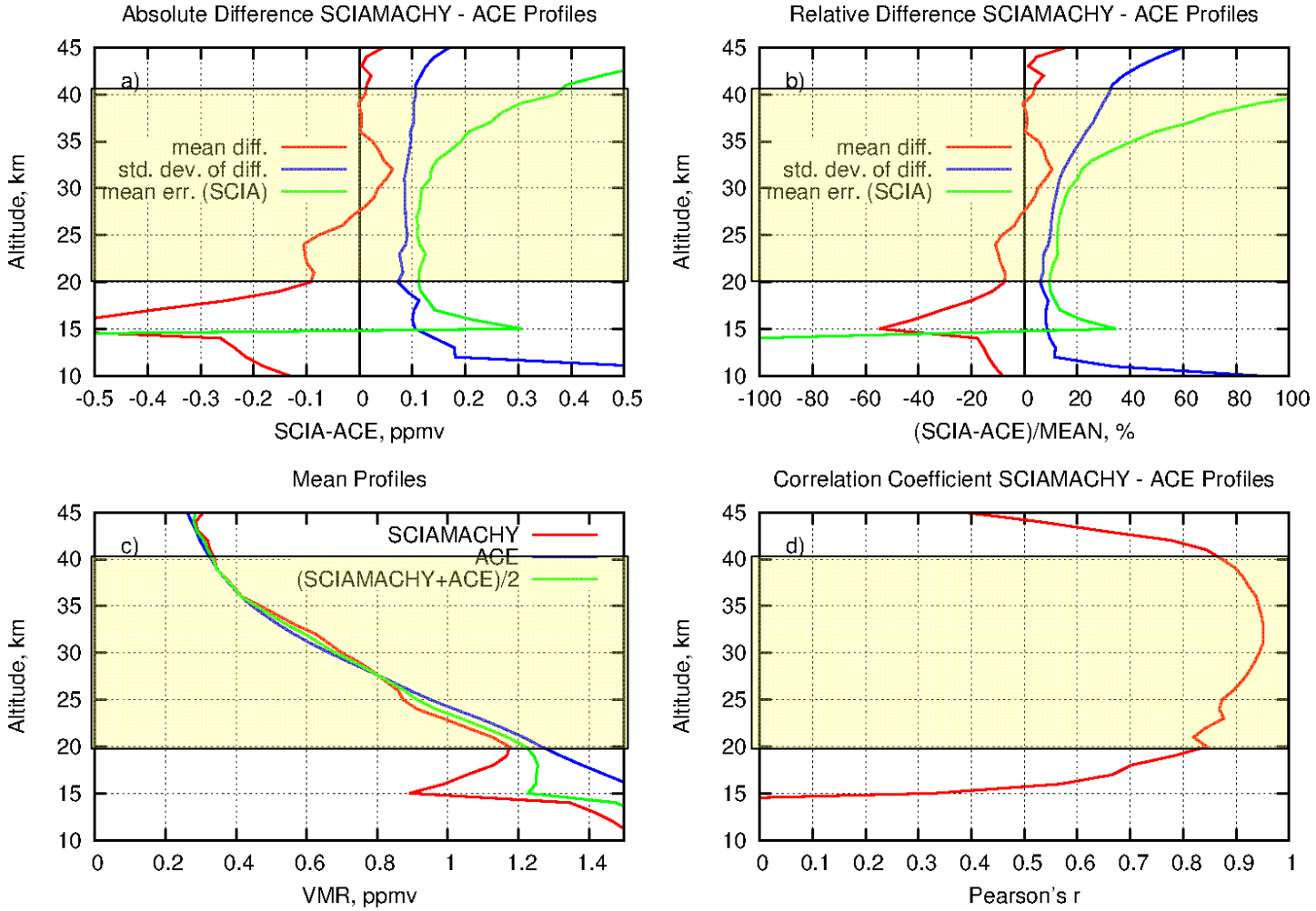
Main Changes

- Measurement data:
  - Use improved pointing information (Bramstedt et al., 2012)
  - Optimised selection procedure (take data with highest transmissions, both up & downscan)
    -> better for lower altitudes (refracted sun)



- RTM data base:
  - Include FOV integration (4.1 km) -> vert. smoothed RTM data
  - Include stratospheric background aerosol
- Retrieval program:
  - Include altitudes below tangent height in sum (because of refraction)
  - No fit of p, T withinCH_4 retrieval; use ECMWF Interim data instead
  - Shift & squeeze for correction of wavelength calibration
- A-posteriori corrections:
  - New error correction
  - Additional p, T corrections (change of CH_4 & CO_2 as function of p, T)
- Current product version 4.2.1:
  - includes CH_4 and CO_2

Results V 3.3.6



Universität Bremen

Stefan.Noel@iup.physik.uni-bremen.de

Error correction

- Retrieved error is too high because errors of higher altitudes are not considered
- Can be corrected afterwards, but introduces additional oscillations in error as function of altitude
- Better: Use altitude independent scaling factor of 0.66
- Same factor for CO_2, CH_4