**P-2**

**331783**

# AEROSOL PARTICLE SIZE DISTRIBUTION AND EXTINCTION COEFFICIENTS FROM SCIAMACHY LIMB MEASUREMENTS


**Elizaveta Malinina**[1] (malininaep@iup.physik.uni-bremen.de), **Alexei Rozanov**[1], **Landon Rieger**[2], **Vladimir Rozanov**[1], **Adam Bourassa**[2], **Doug Degenstein**[2], **Heinrich Bovensmann**[1], **John P. Burrows**[1]

[1] Institute of Environmental Physics, University of Bremen, Bremen, Germany

[2] University of Saskatchewan, Saskatoon, Canada


## DATA AND INSTRUMENT

- SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric Chartography) onboard Envisat (limb data used).
- Operation time (August 2002—April 2012).
- Wavelength interval: 214—2386 nm.
- Spectral resolution: 0.22—1.48 nm.
- For aerosol particle size distribution retrieval $\alpha_{750/1530}$ 7 spectral intervals were used: $\lambda_1$=750±2nm, $\lambda_2$=807±2nm, $\lambda_3$=870±2nm, $\lambda_4$=1090±2nm, $\lambda_5$=1235±20nm, $\lambda_6$=1300±6nm, $\lambda_7$=1530±30nm.

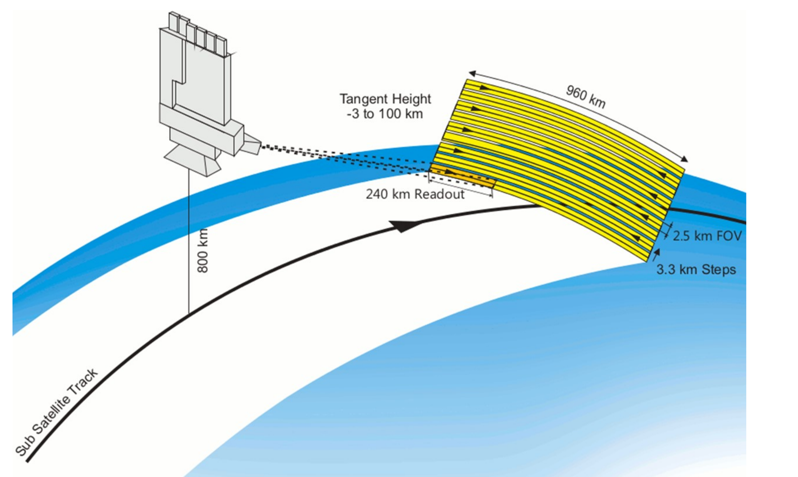


*Fig. 1. SCIAMACHY limb operation mode.*

## RETRIEVED PARAMETERS ERRORS

- Stratospheric aerosols are assumed to have unimodal log-normal particle size distribution described by

$$\frac{dn}{dr} = \frac{N}{\sqrt{2\pi}\ln(\sigma)r}\exp\left(\frac{(\ln(r_g)-\ln(r))^2}{2\ln^2(\sigma)}\right)$$

where N is particle number density, $r_g$ is median radius, and σ is distribution width parameter.

- Our retrieval algorithm allows to retrieve $R_{mod}=r_g/\exp(\ln^2\sigma)$ and σ. Fixed background N profile from ECSTRA model was used for the whole retrieval process. More details in Malinina et al., 2018.
- Absolute distribution width (w) is recalculated from the retrieved values as follows

$$w = \sqrt{r_g^2\exp(\ln^2(\sigma))(\exp(\ln^2(\sigma))-1)}$$

- Errors were assessed through synthetic retrievals. Five different scenarios were simulated with 100 independent noise sequences.

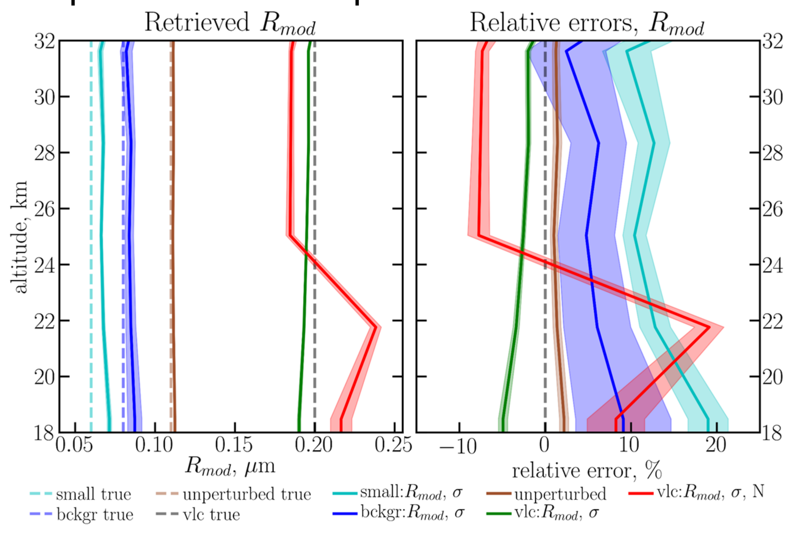


*Fig. 2. $R_{mod}$ profiles and their relative errors for a typical tropical observation geometry. Shaded areas show ±1 standard deviation.*

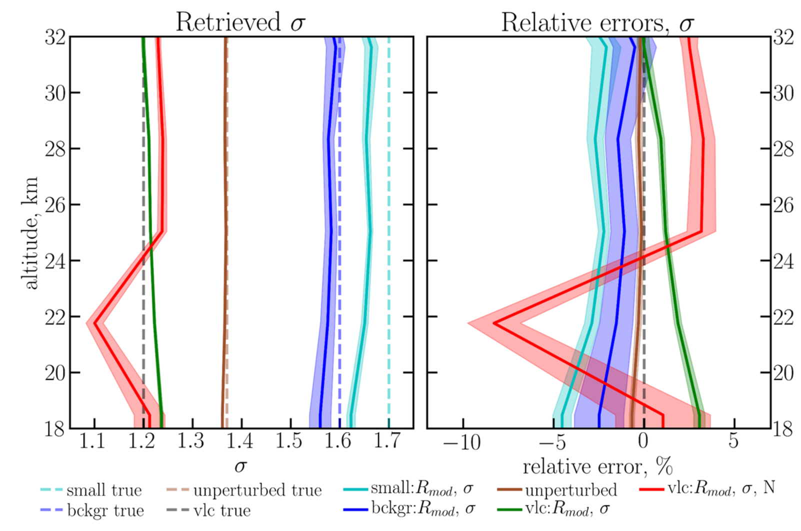


*Fig. 3. σ profiles and their relative errors for a typical tropical observation geometry. Shaded areas show ±1 standard deviation.*

## OBTAINED PARAMETERS ERRORS

- From the retrieved $R_{mod}$ and σ aerosol extinction coefficient at any desirable wavelength λ can be obtained as follows: $Ext_\lambda=\beta_{aer}(\lambda,R_{mod},\sigma)N$, where $\beta_{aer}$ is aerosol extinction cross section. In the end product $Ext_{525}$, $Ext_{750}$, $Ext_{1020}$, $Ext_{1530}$ were calculated.
- Angstrom exponents were calculated $\alpha_{\lambda1/\lambda2}=-\ln(Ext_{\lambda1}/Ext_{\lambda2})/\ln(\lambda_1/\lambda_2)$. In the end product $\alpha_{525/1020}$, $\alpha_{750/1530}$ were obtained.

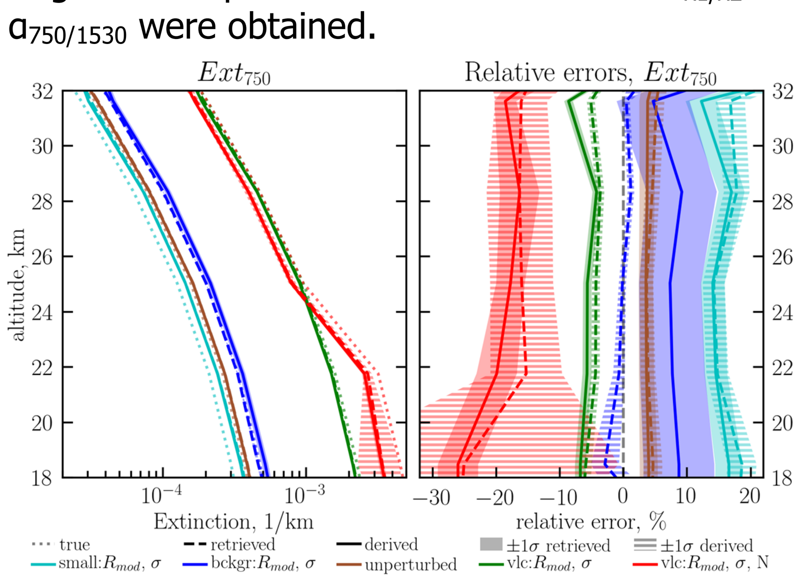


*Fig. 4. Recalculated and retrieved $Ext_{750}$ profiles and their relative errors for a typical tropical observation geometry. Shaded areas show ±1 standard deviation.*

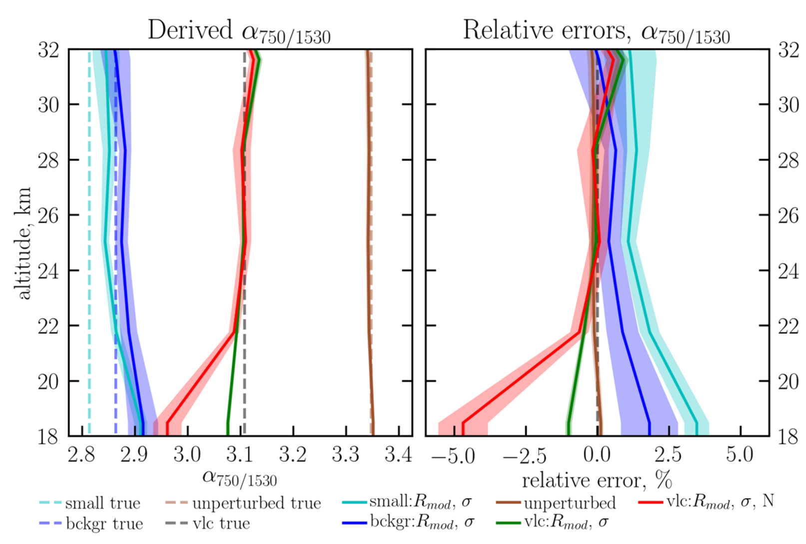


*Fig. 5. Derived $\alpha_{750/1530}$ profiles and their relative errors for a typical tropical observation geometry. Shaded areas show ±1 standard deviation.*

## RETRIEVED TIME SERIES

- $R_{mod}$ and σ were retrieved for the whole SCIAMACHY observation period. From this data w was recalculated. For the retrieval just completely cloud free profiles were used (9727 profiles).
- To evaluate the overall state of the atmosphere monthly zonal (20°N - 20°S) anomalies (deseasonalized time series) were used.
- After tropical volcanic eruptions (Manam, Tavurvur, Nabro) there is increase in $R_{mod}$. In contrary w can increase (Tavurvur), decrease (Nabro) or not change (Manam) after different eruptions.
- For both parameters QBO signatures were observed at the high altitudes (28-32 km).

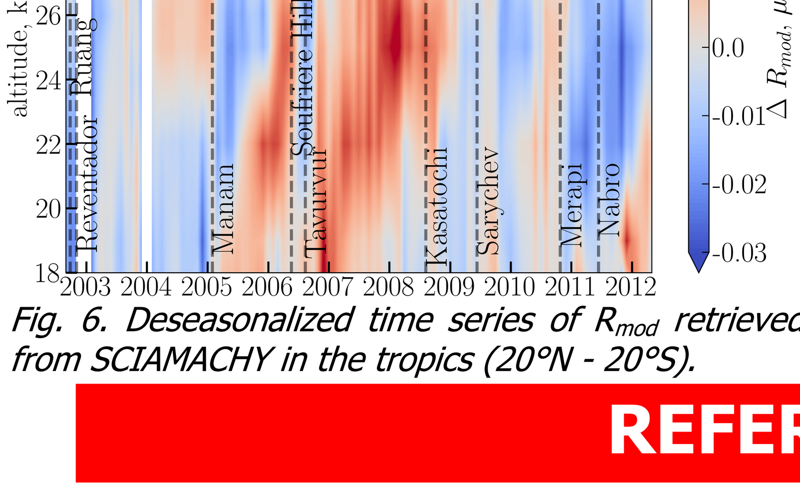


*Fig. 6. Deseasonalized time series of $R_{mod}$ retrieved from SCIAMACHY in the tropics (20°N - 20°S).*

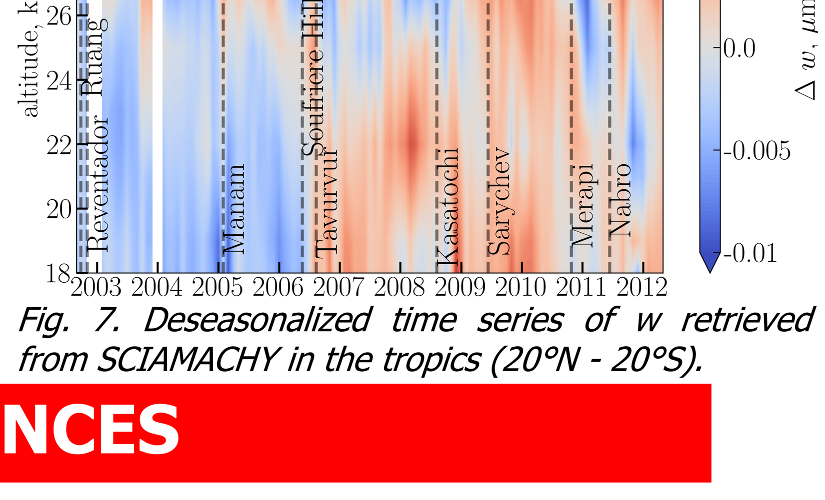


*Fig. 7. Deseasonalized time series of w retrieved from SCIAMACHY in the tropics (20°N - 20°S).*

## COMPARISON WITH SAGE II

- SAGE II was a key instrument providing stratospheric aerosol measurements in solar occultation technique from 1984 till 2005.
- For SCIAMACHY and SAGE II overlap period there were just 57 collocated profiles found (±5° latitude, ±20° longitude, ±24 hours). Such parameters as effective radius $r_{eff}=r_g\exp(2.5\ln^2(\sigma))$, as well as $Ext_{525}$, $Ext_{1020}$ and $Ext_{750}$ were compared. $Ext_{750}$ from SCIAMACHY was calculated using the $Ext_\lambda$ formula ($Ext_{750}$ (PSD)) and converted with Angstrom exponent from $Ext_{525}$ and $Ext_{1020}$ ($Ext_{750}$ ($\alpha_{525/1020}$)).
- Most likely all the differences between the instruments are coming from the different sensitivity (ΔI) of instruments to the small particles.

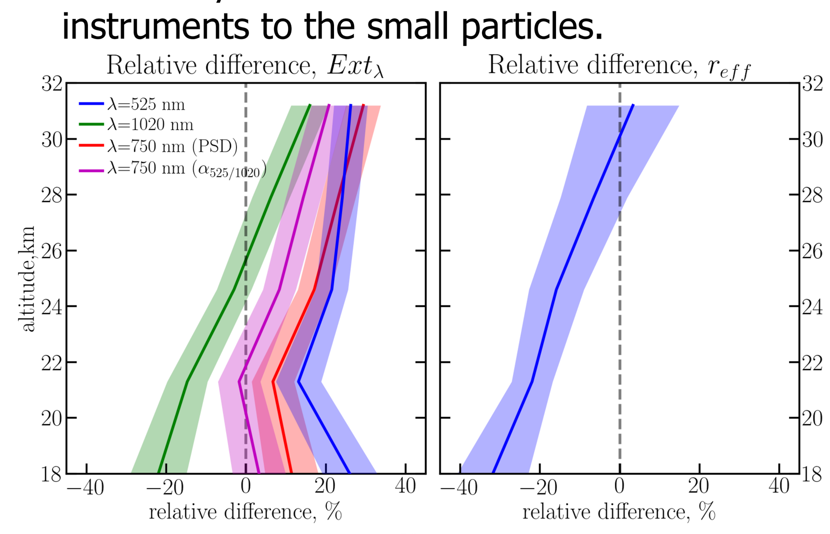


*Fig. 8. Mean relative difference ((SCIAMACHY-SAGE II)/SAGE II) of $Ext_{525}$, $Ext_{750}$ (PSD), $Ext_{750}$ ($\alpha_{525/1020}$), $Ext_{1020}$ (left panel) and $r_{eff}$ (right panel).*

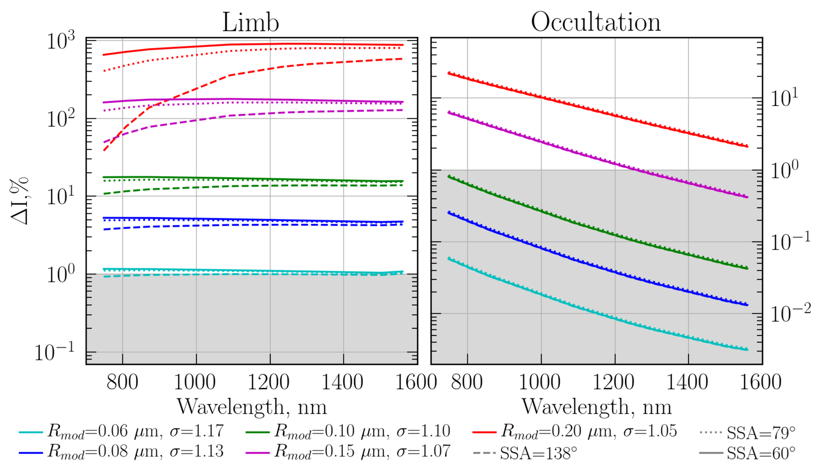


*Fig. 9. Relative sensitivity (ΔI) for limb and occultation measurements modelled for different particle size distributions.*

## ANGSTRÖM EXPONENTS COMPARISON

- Obtained from SCIAMACHY Angström exponents ($\alpha_{525/1020}$) were compared to ones from SAGE II.
- $\alpha_{750/1530}$ were compared to another limb viewing instrument OSIRIS, which operates since 2001 and has similar technical specifications. The same colocation criteria as for SAGE II were used (4603 prof).

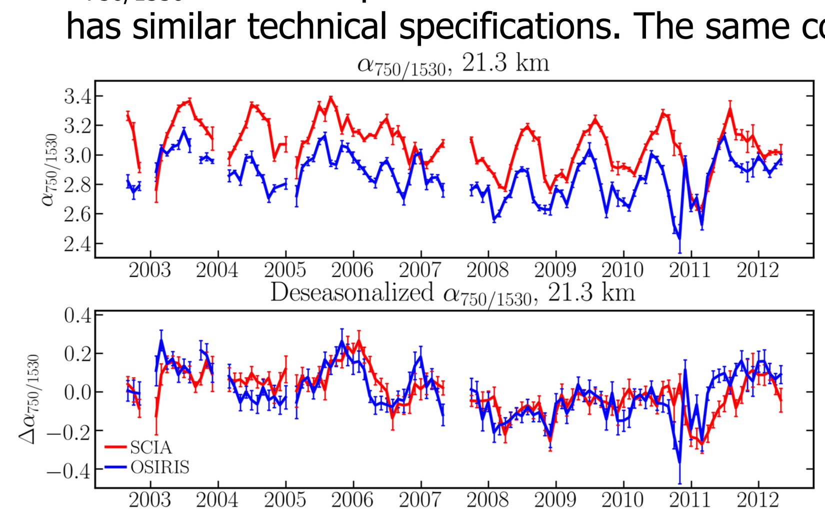


*Fig. 10. Monthly zonal mean (upper panel) and anomalies (lower panel) of $\alpha_{750/1530}$ from collocated SCIAMACHY and OSIRIS measurements.*

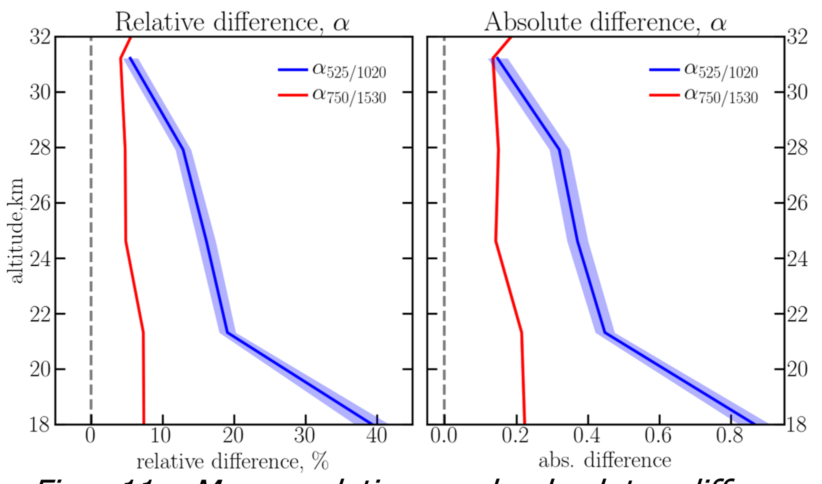


*Fig. 11. Mean relative and absolute difference between SCIAMACHY and OSIRIS ($\alpha_{750/1530}$) and SCIAMACHY and SAGE II ($\alpha_{525/1020}$).*

## ANGSTRÖM EXPONENT TIME SERIES

- Angström exponents were calculated for the whole SCIAMACHY time series.
- The behavior of $\alpha_{750/1530}$ anomalies reminds qualitatively the behavior of w anomalies.
- However, the dependency of $\alpha_{750/1530}$ on $R_{mod}$ and w is quite complicated and non-linear, and both $R_{mod}$ and w contribute to the changes in $\alpha_{750/1530}$.

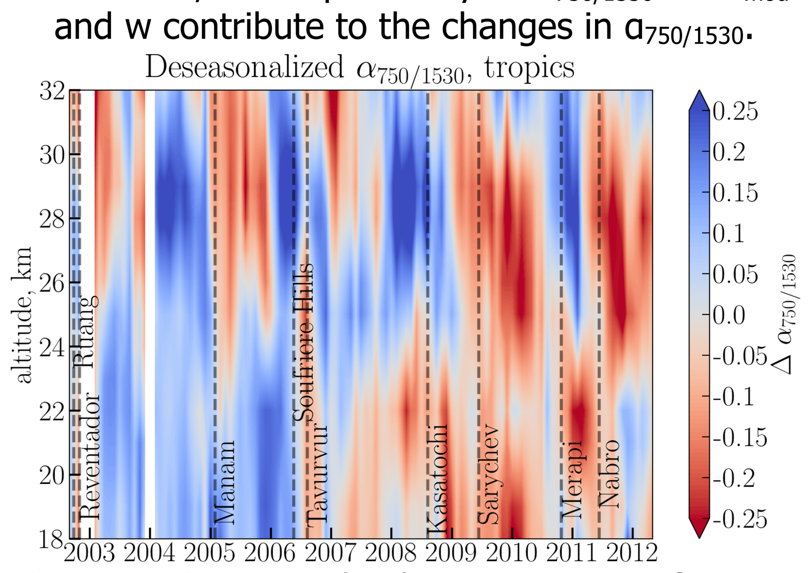


*Fig. 12. Deseasonalized time series of $\alpha_{750/1530}$ obtained from SCIAMACHY in the tropics (20°N-20°S).*

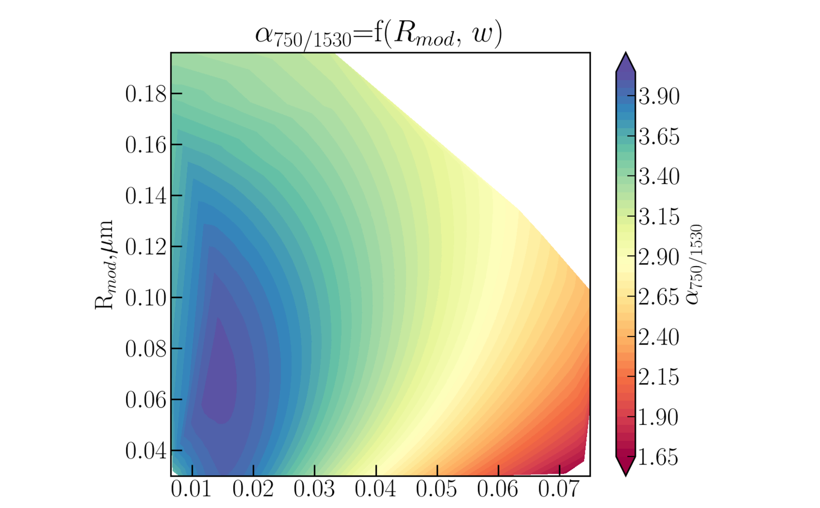


*Fig. 13. Dependency of $\alpha_{750/1530}$ on $R_{mod}$ and w based on SCIAMACHY limb measurements .*

## OUTLOOK

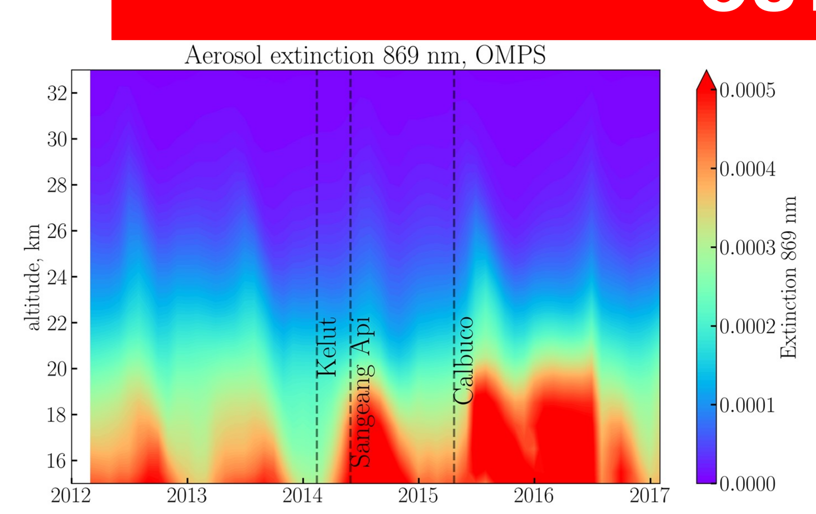


*Fig. 14. Monthly zonal mean (20°N - 20°S) $Ext_{869}$ retrieved from OMPS–LP measurements.*

- Aerosol extinction coefficient $Ext_{869}$ was retrieved using OMPS-LP data (2012—now). Cloud contaminated and cloud free profiles from central slit in all latitude bads were used.
- This particular wavelength was chosen, as it lays outside of absorbtion lines.
- There is increase of $Ext_{869}$ in tropics after Kelut and Calbuco eruptions. The „tail" of the Nabro eruption in 2011 is also well pronounced.
- In the future merging of SCIAMACHY and OMPS aerosol extinction coefficients will be possible.

## CONCLUSIONS

- Aerosol particle size distribution parameters ($R_{mod}$ and σ) were retrieved for the tropical region (20°N - 20°S) from SCHIMACHY limb measurents in the 2002–2012 period. From these parameters w, $Ext_{525}$, $Ext_{750}$, $Ext_{1020}$, $Ext_{1530}$, $\alpha_{525/1020}$ and $\alpha_{750/1530}$ were recalculated.
- According to synthetic data $R_{mod}$ is retrieved with the relative error of about 20%, while for σ the errors are less than 10%.
- Recalculated from particle size distribution product $Ext_{750}$ has about ±25% error, and $\alpha_{750/1530}$ is retrieved with about 5% accuracy. For $Ext_{525}$, $Ext_{1020}$, $Ext_{1530}$ and $\alpha_{525/1020}$ the errors are comparable.
- It was shown, that after volcanic eruptions $R_{mod}$ increases, while w can increase, decrease or remain unchanged.
- Comparison of $r_{eff}$ from SCIAMCHY and SAGE II showed 30% changes for the lower altitudes reaching 0% at 30 km. For aerosol extinction coefficients the diffrences are also altitude dependent and vary from –20 to 30%. Most likely the differences are caused by different sensitivity of limb and occulation instruments to the small particles.
- Comparison of $\alpha_{750/1530}$ from SCIAMACHY and OSIRIS showed about 7% difference. Although there is about 0.2 bias between the instruments, they show similar patterns on the time series.
- $\alpha_{750/1530}$ obtained from SCIAMACHY measurements showed similar temporal behavior as w.
- The dependency of $\alpha_{750/1530}$ on $R_{mod}$ and w is non-linear, and both $R_{mod}$ and w contribute to the changes in $\alpha_{750/1530}$.
- $Ext_{869}$ was retrieved from OMPS-LP measurements. There is an increase of the $Ext_{869}$ in the tropics after Calbuco, Kelut and Nabro eruptions.

## REFERENCES


1. Damadeo, R. P., Zawodny, J. M., Thomason, L. W., and Iyer, N.: SAGE version 7.0 algorithm: application to SAGE II, Atmos. Meas. Tech., 6, 3539-3561, https://doi.org/10.5194/amt-6-3539-2013, 2013.
2. Gottwald, M. and Bovensmann, H.: SCIAMACHY - Exploring the Changing Earth's Atmosphere, Springer, Dordrecht, doi:10.1007/978-90- 481-9896-2, 2011.
3. Malinina, E., Rozanov, A., Rozanov, V., Liebing, P., Bovensmann, H., and Burrows, J. P.: Aerosol particle size distribution in the stratosphere retrieved from SCIAMACHY limb measurements, https://doi.org/10.5194/amt-2017-388, accepted to Atmos. Meas. Tech. , 2017.
4. Rieger, L. A., Bourassa, A. E., and Degenstein, D. A.: Stratospheric aerosol particle size information in Odin-OSIRIS limb scatter spectra, Atmos. Meas. Tech., 7, 507-522, https://doi.org/10.5194/amt-7-507-2014, 2014.


Universität Bremen

University of Saskatchewan