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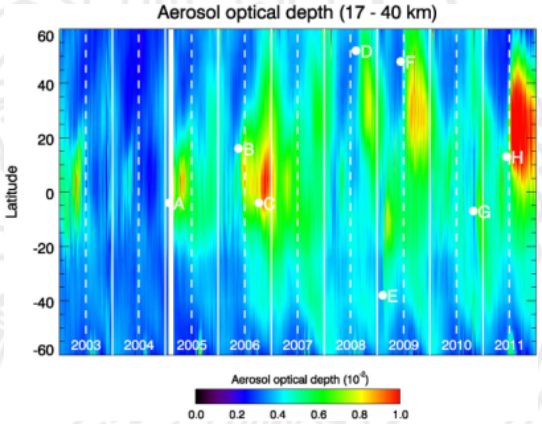
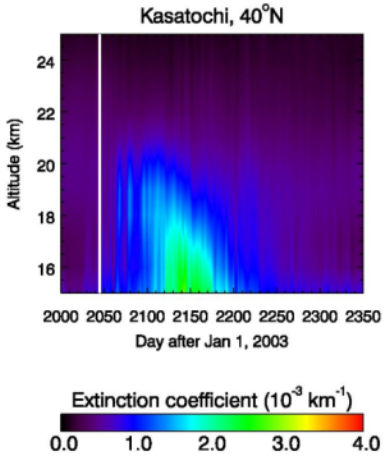
Global morphology of stratospheric aerosols from 2003 – 2011 retrieved from SCIAMACHY limb-scatter observations

Christian von Savigny[1], René Hommel[2], Alexei Rozanov[2],
Jacob Zalach[1] and John Burrows[2]





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Outline

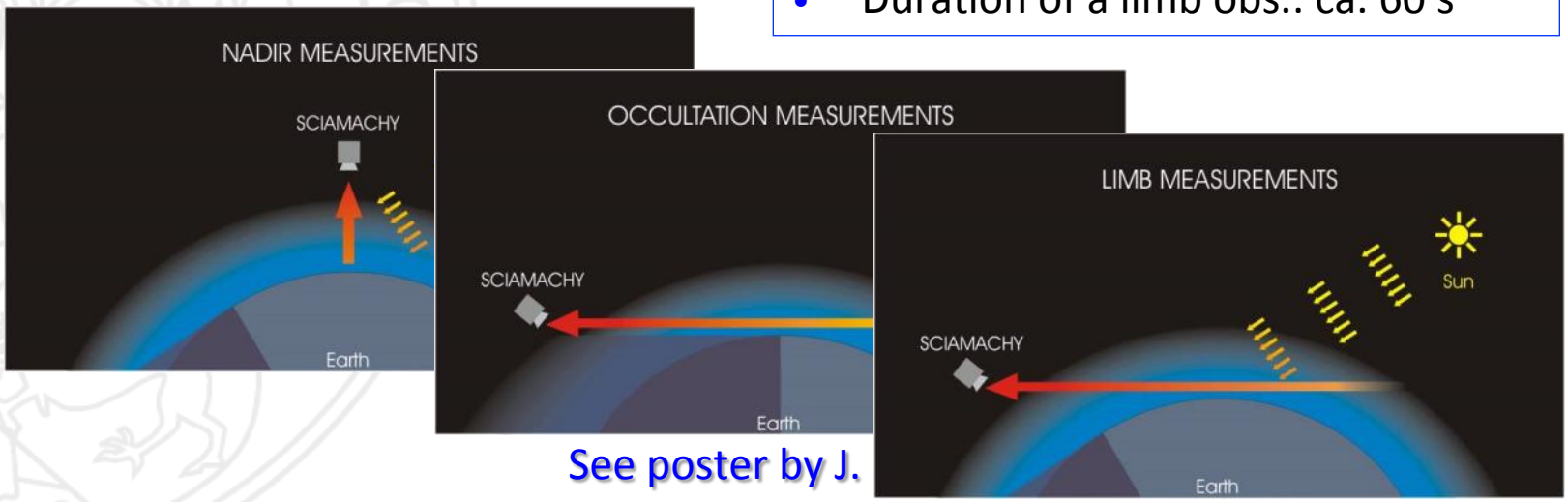
- Stratospheric aerosol profile retrievals from SCIAMACHY limb-scatter observations
- Stratospheric aerosol extinction climatology 2003 – 2011
- Indications for a (solar-driven ?) 27-day cycle in stratospheric aerosol extinction

SCIAMACHY on Envisat (2002 – 2012)

SCIAMACHY = SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (PI: Prof. J. Burrows, IUP Bremen)

Main features:

- UV/Vis/NIR grating spectrometer: 220 - 2380 nm
- Spectral resolution: 0.2 – 1.5 nm
- Observation geometries:



Limb-scatter observations:

- Tangent height range: 0 – 92 km (Eclipse: 73 – 150 km)
- Vertical step size: 3.3 km
- Vertical field of view: 2.8 km
- Duration of a limb obs.: ca. 60 s

See poster by J.

See poster by E. Malinina

ESA‘s Envisat satellite

- Launch: 28. Februar 2002
- Polar, sun-synchronous orbit
- Descending node: 10:00 local solar time
- Altitude: 800 km
- Launch vehicle: Ariane 5
- Envisat hosts 10 scientific instruments
- The *atmospheric chemistry pay-load* consists of:

  - GOMOS (Global Ozone Monitoring by Occultation of Stars)

  - MIPAS (Michelson Interferometer for Passive Atmospheric Sounding)

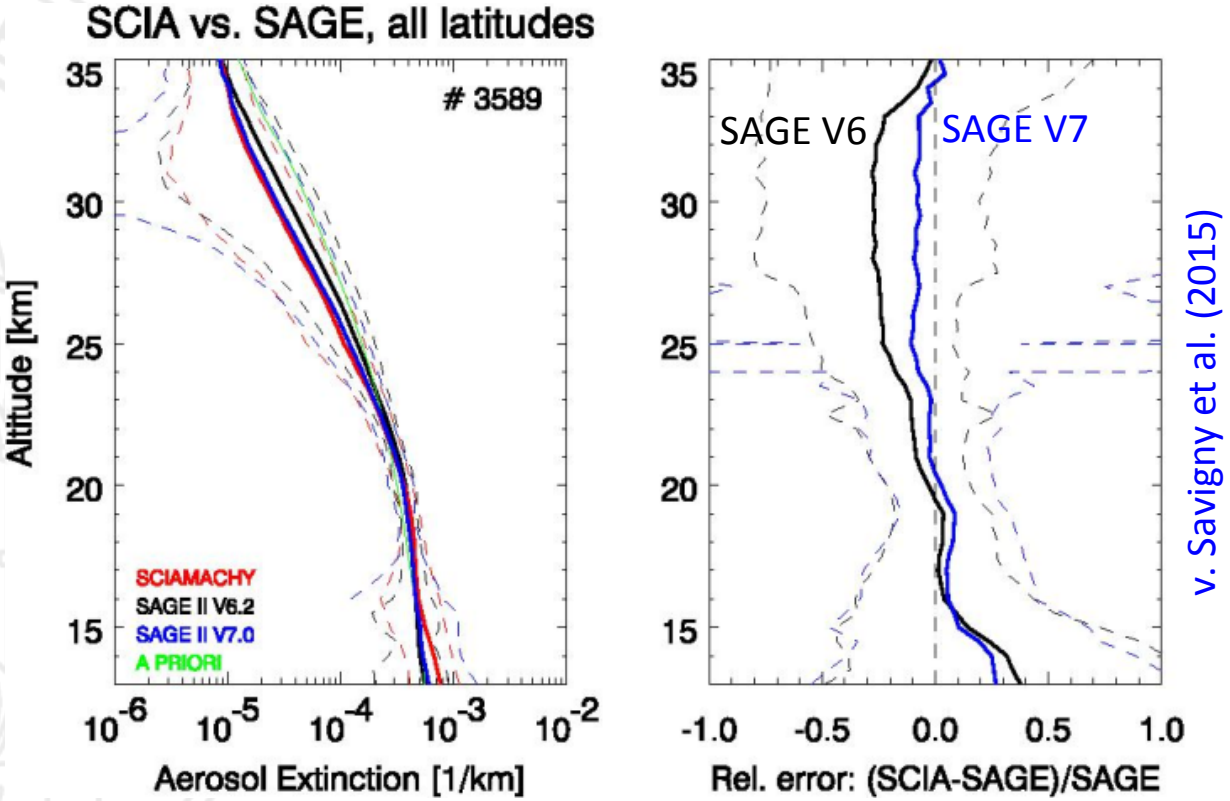
  - SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY)

Aerosol profile retrievals from SCIAMACHY limb-scatter measurements

- Retrieval is based on:
  I. Normalized limb-radiance profiles (w.r.t. 35 km tangent height)
  II. Pairing of normalized limb-radiance profiles at 470 nm and 750 nm
- Inversion performed with iterative Optimal Estimation approach driving the radiative transfer model SCIATRAN
- Data product: Aerosol extinction coefficient profile
  (Note: Angstrom exponent is fixed)
- Current data product version:
  1.1: Mie phase function with log-normal PSD and $r = 0.11\ \mu m$, $\sigma = 1.32$ (Deshler, 2008)

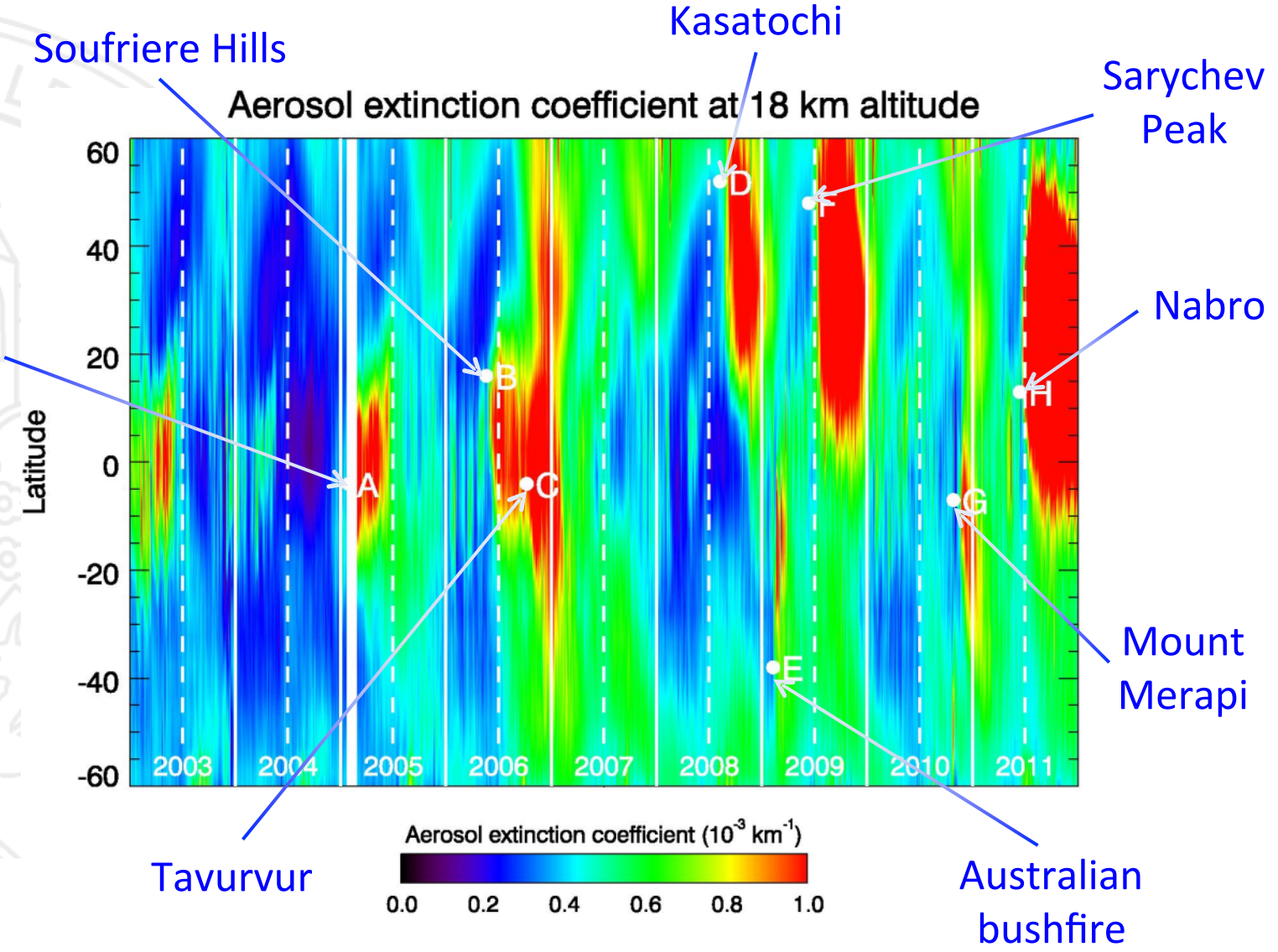
Comparison to SAGE II

SCIA V 1.1 vs. SAGE V6.2 and V7.0

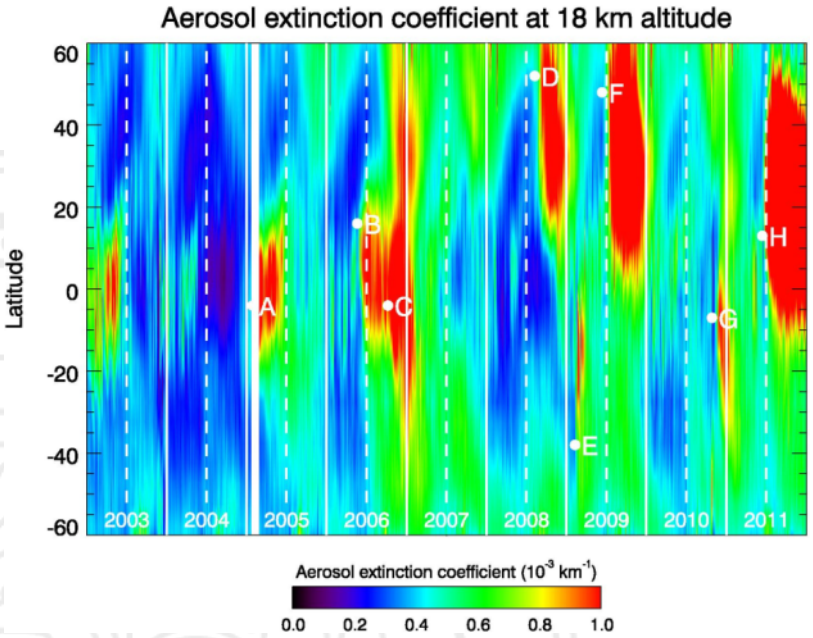


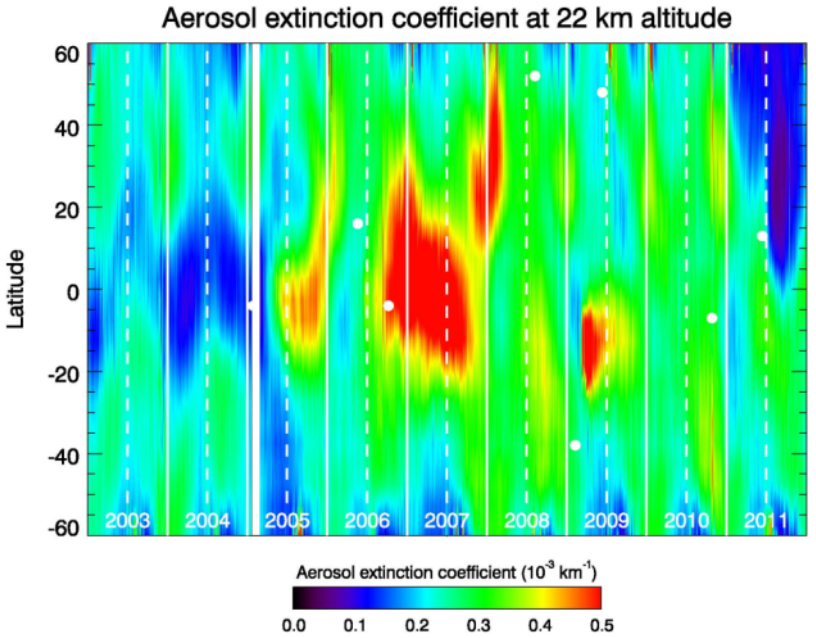
Globally averaged agreement within 15% between SAGE V7.0 and SCIA V 1.1 from 16 to 35 km

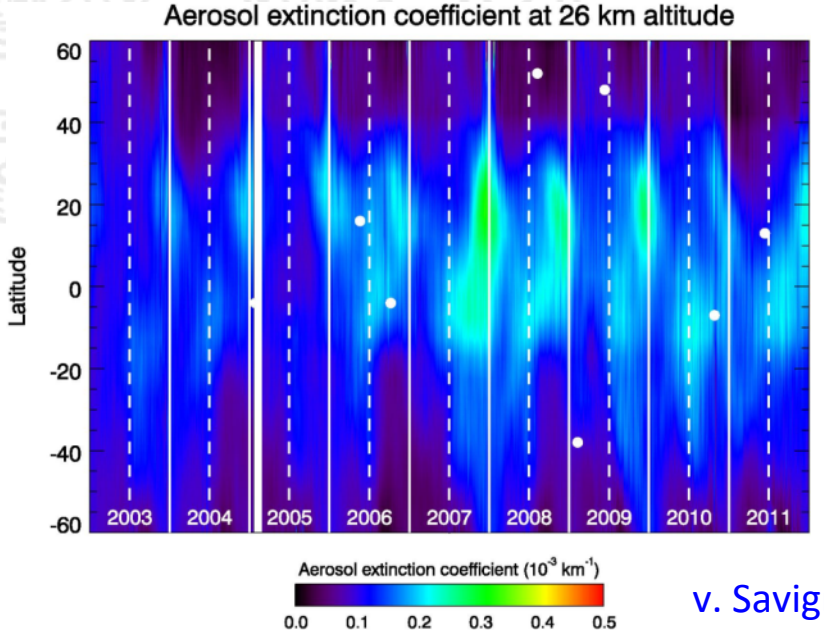
Aerosol extinction coefficient at 18 km altitude (525 nm)

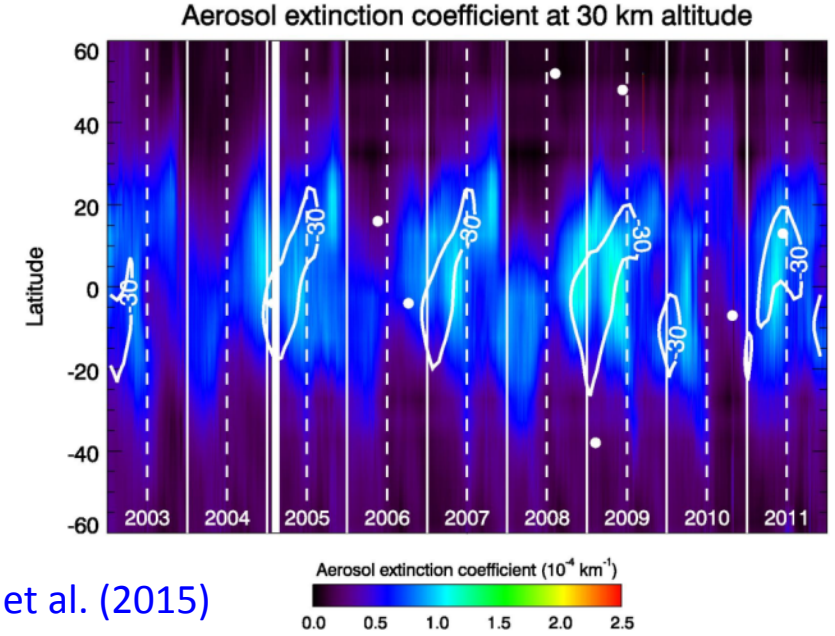


Aerosol extinction coefficient at different altitudes









v. Savigny et al. (2015)

Stratospheric aerosol optical depth (Θ = 380 K – 40 km, 525 nm)

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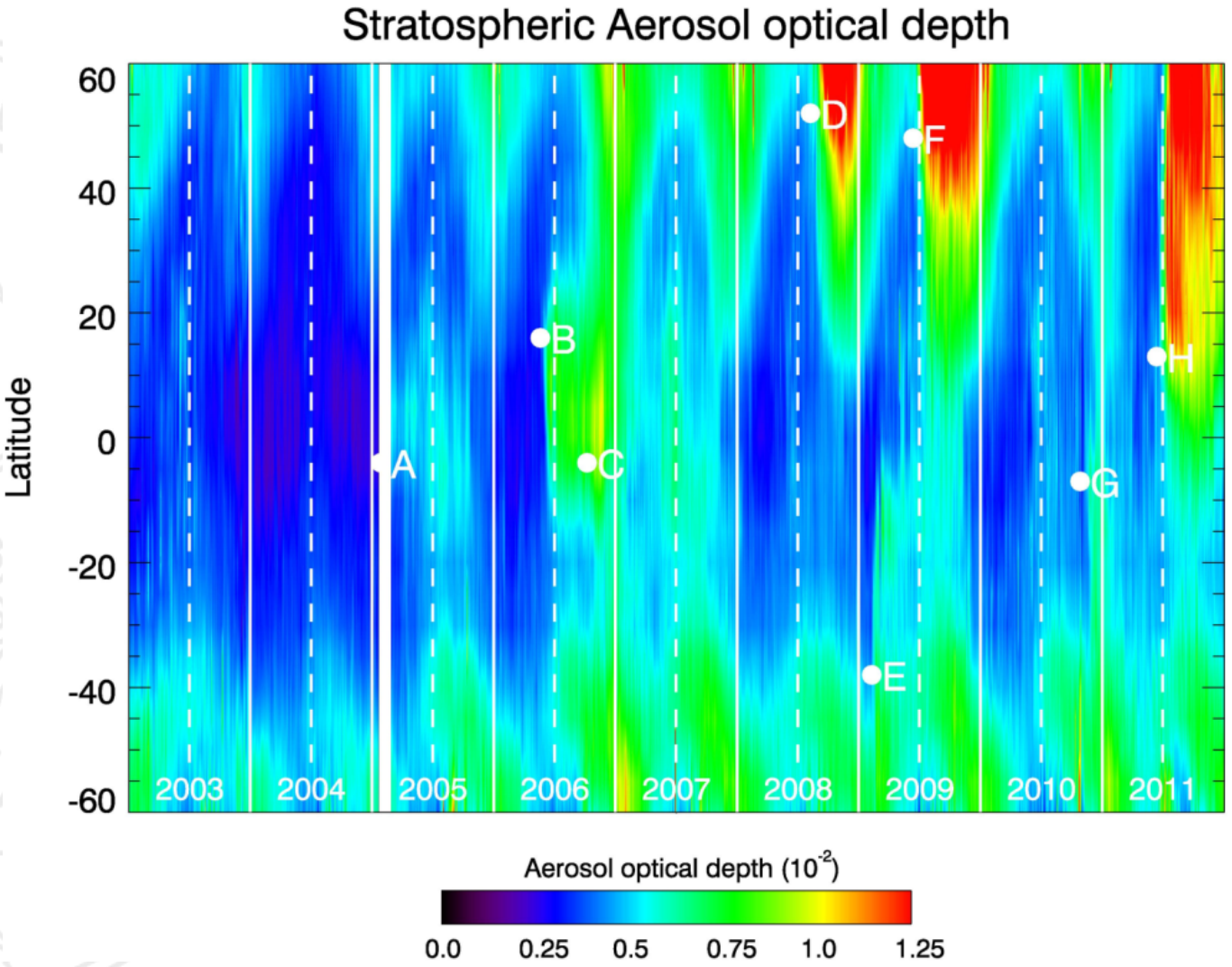

Indications for a 27-day signature in stratospheric aerosol extinction

MgII index and aerosol extinction anomalies

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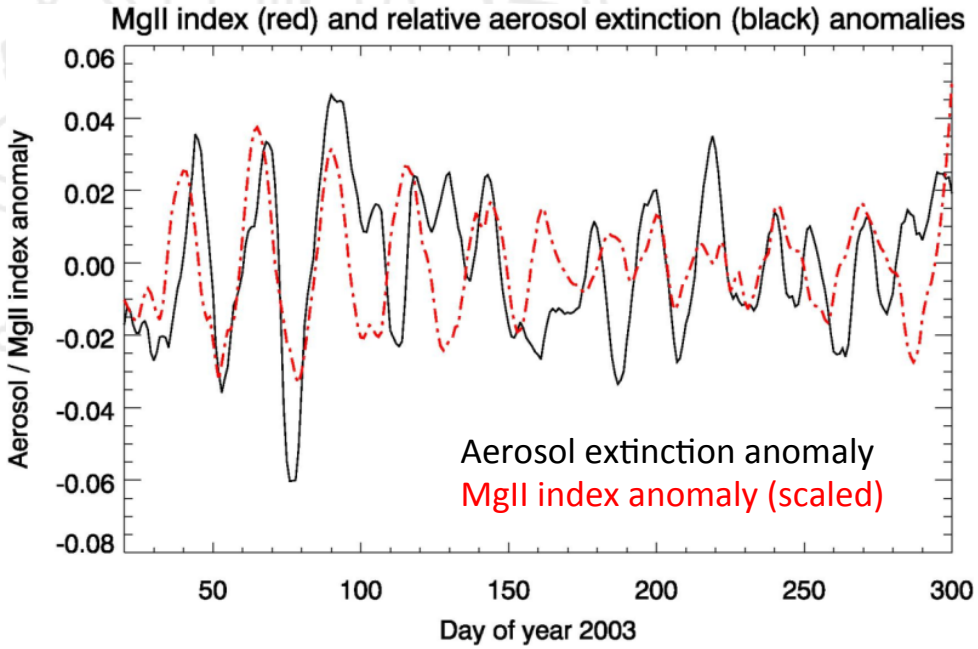
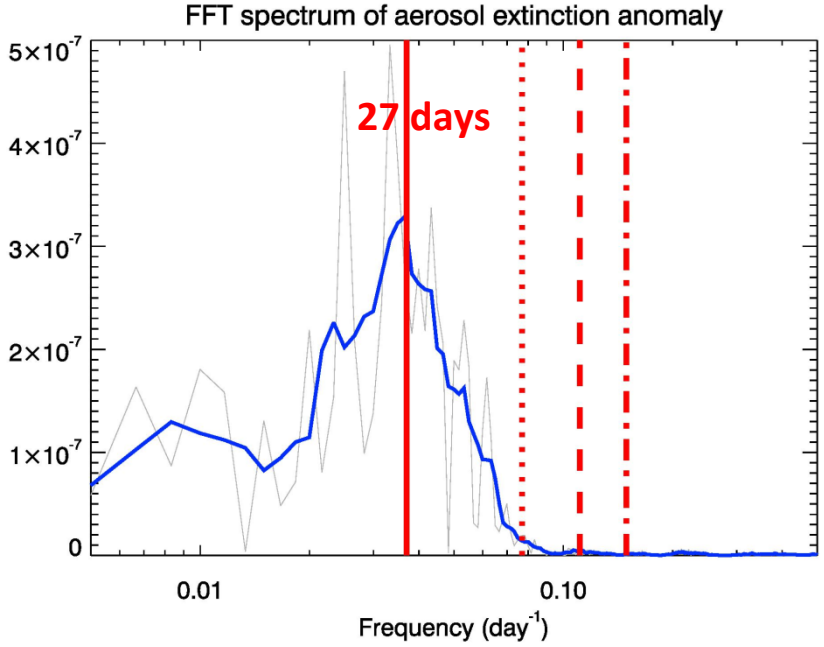
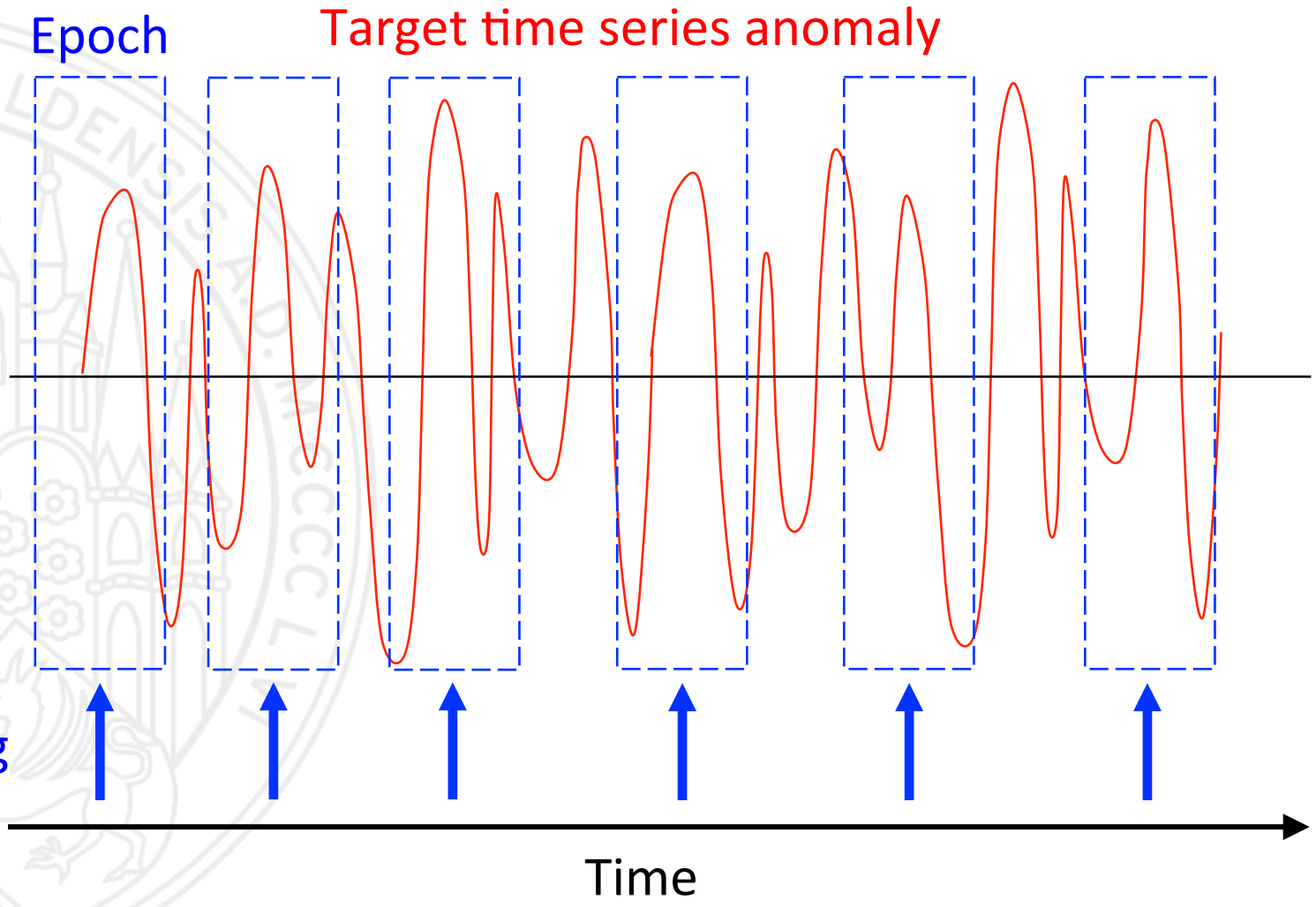
- SCIAMACHY aerosol extinction (version 1.1) data set zonally averaged and meridionally averaged between 20S° and 20°N and the 30 – 35 km altitude range
- Solar proxy: MgII index from SCIAMACHY spectral solar irradiance measurements
- Anomalies determined by removing 35-day running mean and division by time averaged value of extinction



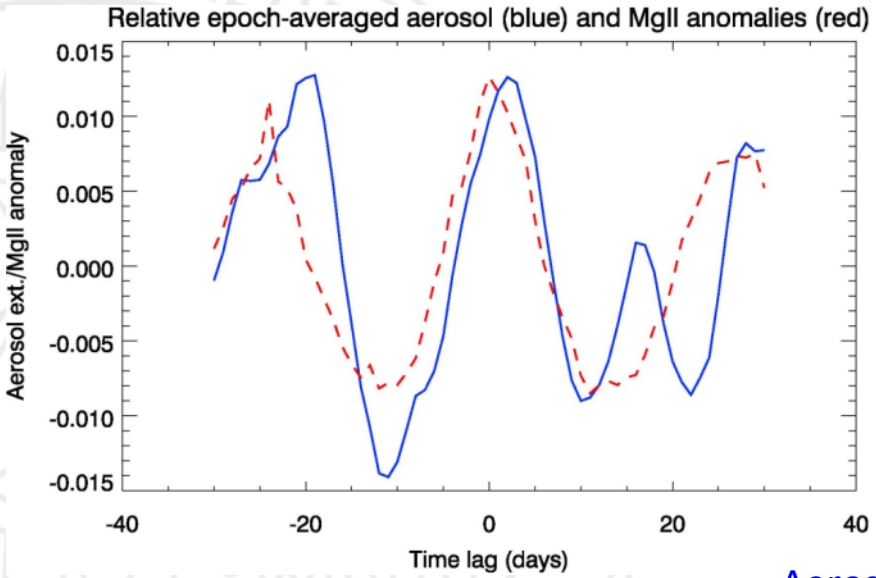


Superposed Epoch Analysis (SEA)

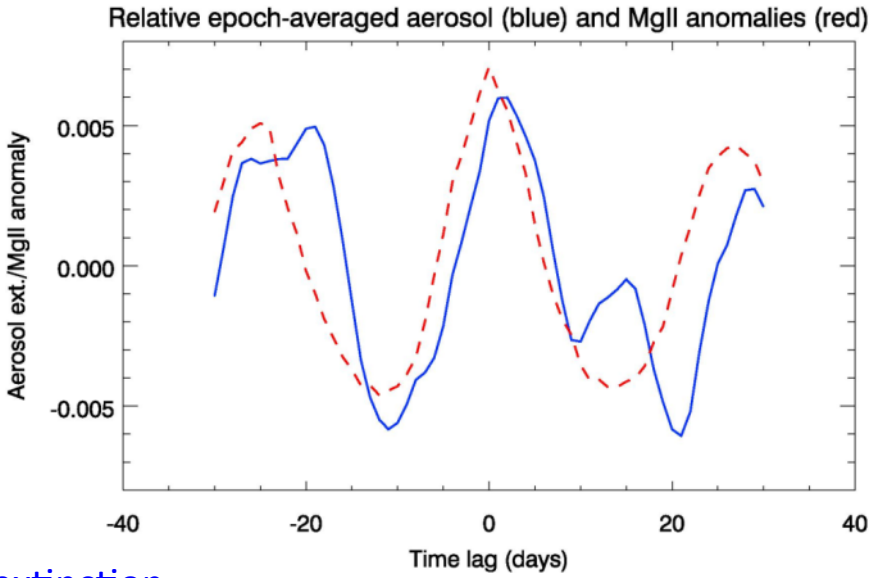


Epoch-averaged MgII and extinction anomalies

2003



2003 – 2011



Aerosol extinction
MgII index (scaled)

- Aerosol extinction and solar activity positively correlated
- Time lag between solar forcing and aerosol response a few days at most
- Relative variations in aerosol extinction with 27-day cycle: ≈ ± 1 %
- Origin of additional peaks unclear

Is the 27-day signature real?

- Is 27-day signature in aerosol extinction spuriously introduced by established 27-day signatures in
  - I. Stratospheric temperature (~ 0.1 K), density or
  - II. Stratospheric O_3 (~ 1 %)

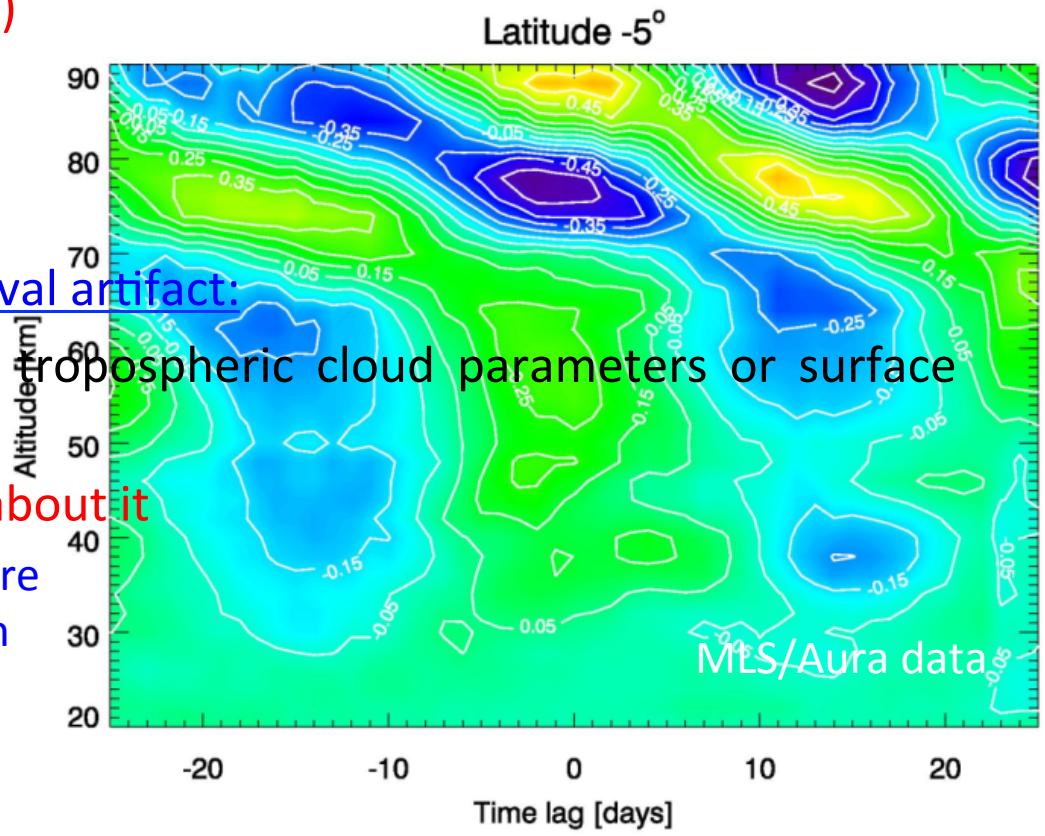
- Answer: No, most likely not

- Other possibilities for a retrieval artifact:

  Solar 27-day cycles in tropospheric cloud parameters or surface albedo?

- But: little or nothing known about it

Epoch-averaged temperature anomalies (K) as a function of time lag and altitude



Possible mechanisms – model studies

- What processes can cause the observed extinction signature:

Atmospheric Process	Degree Of Explaining Signature	Reason
Ambient conditions (T, q)	Very likely	Too weak (amplitude <0.1%)
Evaporation H_2SO_4	Not - too slow	Too slow
Condensation H_2SO_4	Yes	From view of isolated microphysics
Sed[illegible]tion	Unclear	Affecting results when prescribed
Atmospher[illegible]	Not unlikely	Advection (QBO similarity) or Rossby mode

More infos on Poster by René Hommel

- If condensation is the likely reas[illegible]oduce the H_2SO_4:

Process Pathway	Degree Of Explaining Sig[illegible]	Reason
OCS Photolysis (J_{OCS})	very likely	Stron[illegible]t enough)
other Js of S-compounds	Very unlikely	Too weak/s[illegible]
OCS+O(^{1}D) Reaction	Unlikely	Too weak
J_{OCS} Underestimation	+ 5 % SSI → 1 % in H_2SO_4 Vapour + 50 % SSI → 1 % in Extinction always time lag too large	"Bias" in OCS cross section or SSI UV-B/C
SSI Underestimation	With parametrised sedimentation: + 10 % SSI → 3-4 % Signature in H_2SO_4 Vapour + 100 % SSI → 0.7 % Signature in Extinction No sedimentation: + 10% SSI → 1-2 % Signature in Extinction	

“Whole atmosphere (dynamical) response” ?

27-day signatures in outgoing longwave radiation (Takahashi et al., 2010; Huang et al., 2015)

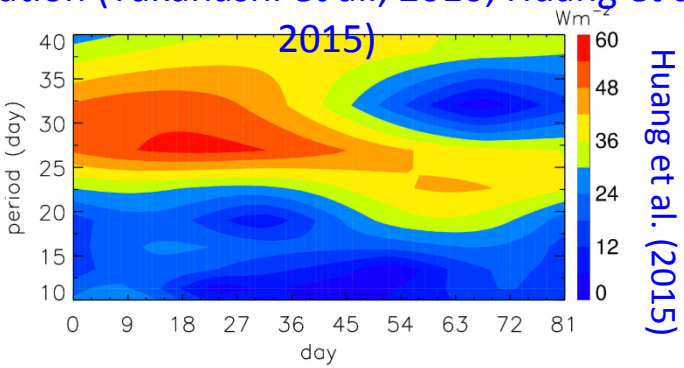
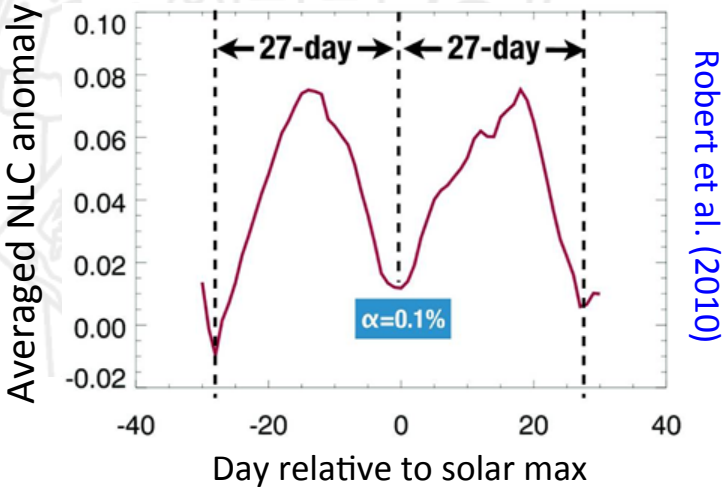


Figure 12. Wavelet spectrum of OLR at 157.5° W (averaged over 5–20° N) from NCEP/NCAR-interpolated OLR data.

27-day signature in Noctilucent clouds



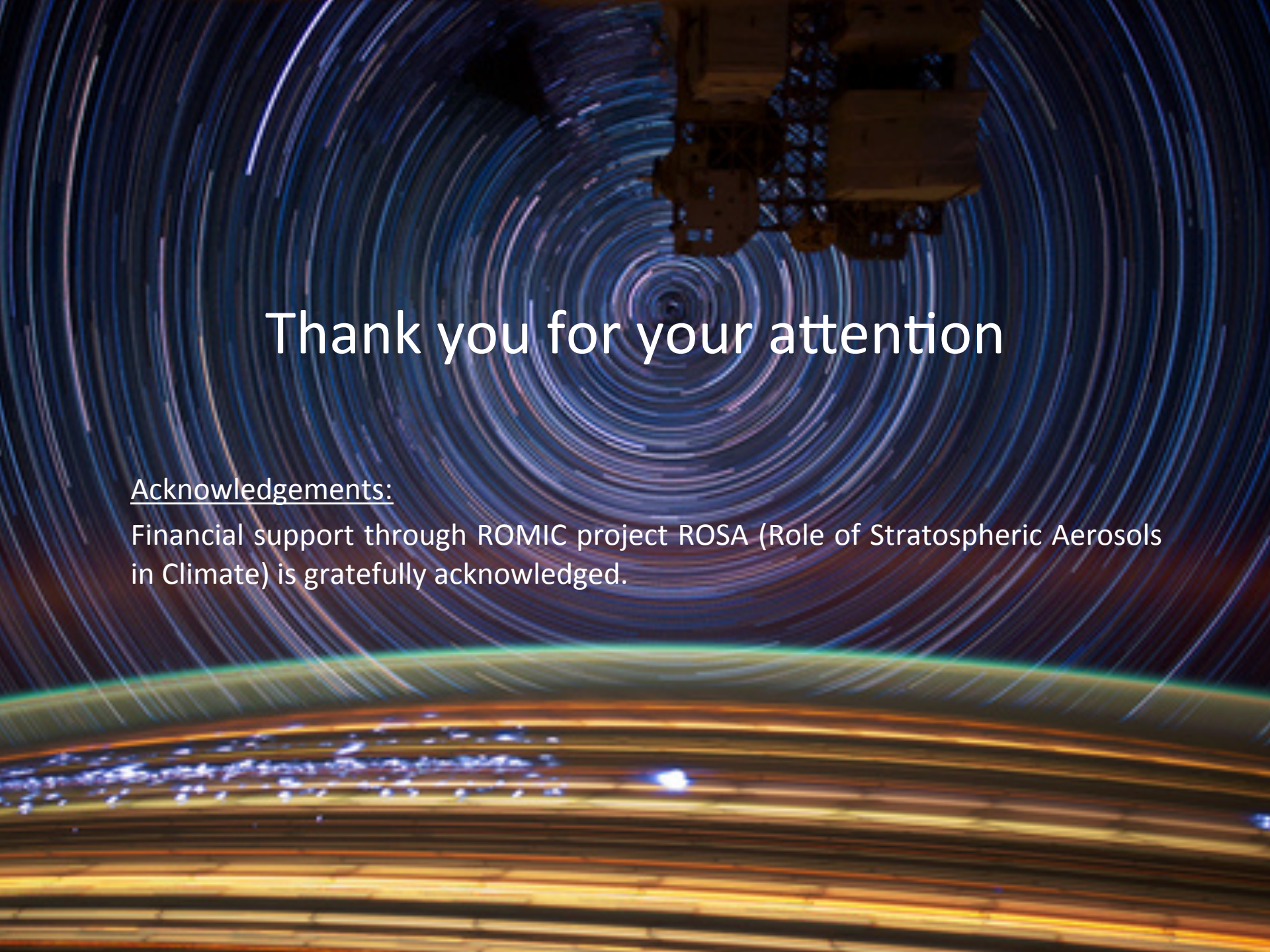
- Rossby (1,4) normal mode (~ 28 days) identified mesopause winds and temperature (Huang et al., 2015)
- 27-day signatures seen in middle atmosphere temperature, even without 27-day solar forcing (Gruzdev et al., 2009)

→ Increasing evidence that atmospheric 27-day signatures are not only due to photochemistry and diabatic heating changes

Summary

- Stratospheric aerosol extinction profiles are retrieved from SCIAMACHY limb-scatter observations (08/2002 – 04/2012)
- Data set available (registration required) at:

  http://www.iup.uni-bremen.de/scia-arc/
- Globally averaged agreement with co-located SAGE II (version 7.0) solar occultation measurements within 15% between 16 and 35 km altitude
- Aerosol extinction and optical depth fields show strong variability associated with volcanic eruptions, seasons and phase of the QBO
- First indications for a (solar-driven?) 27-day signature in stratospheric aerosol extinction

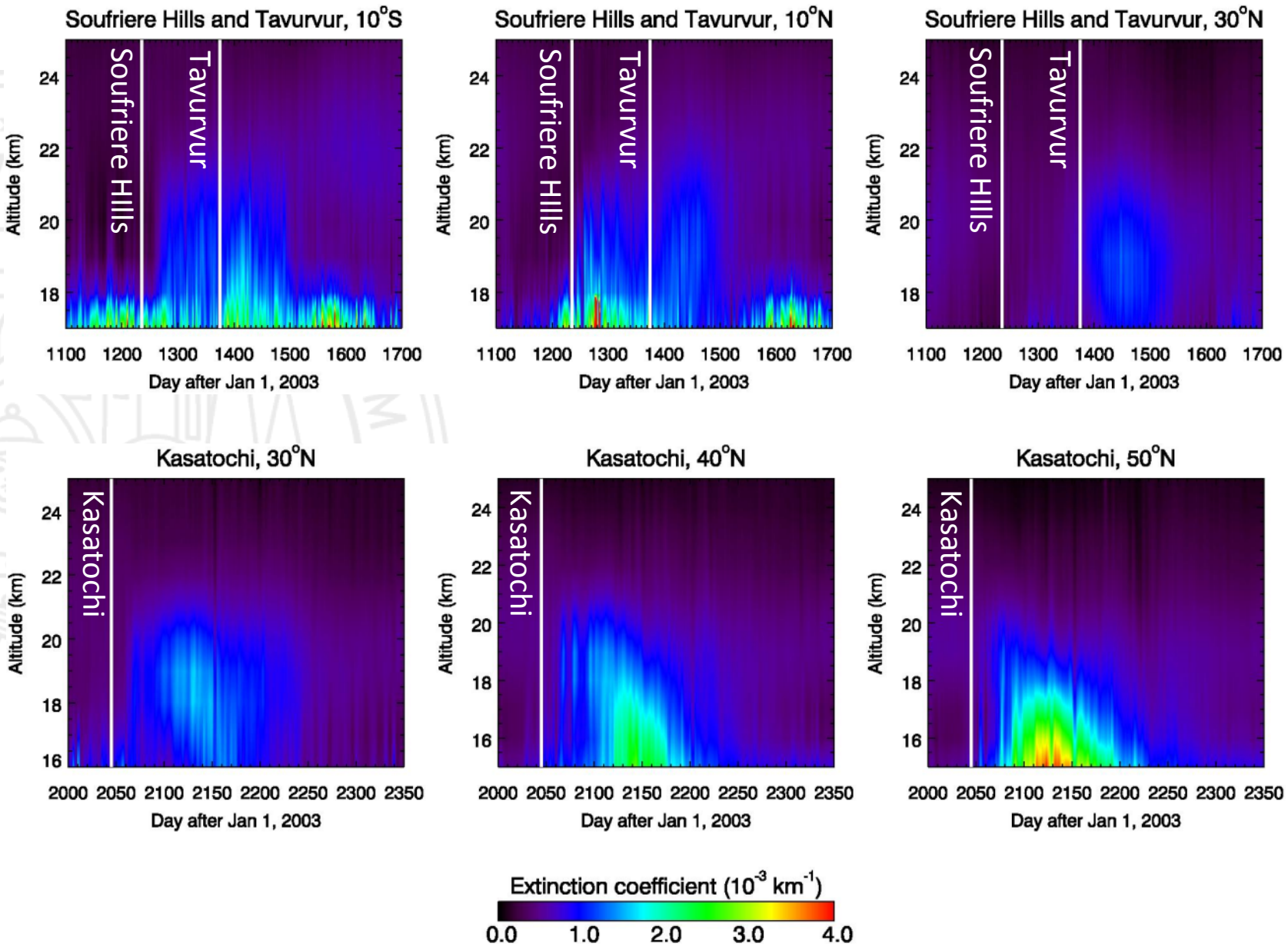


Thank you for your attention

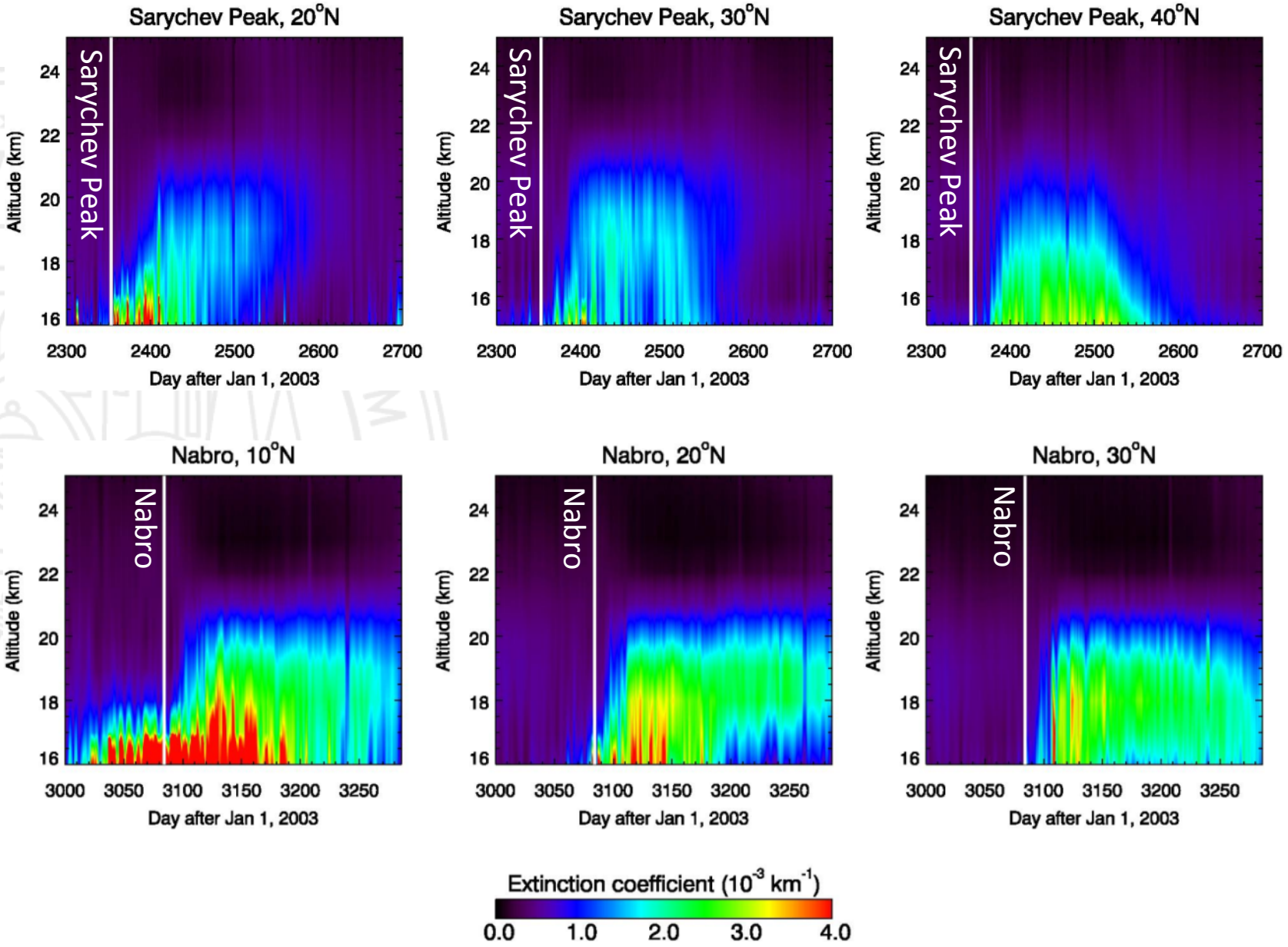
Acknowledgements:

Financial support through ROMIC project ROSA (Role of Stratospheric Aerosols in Climate) is gratefully acknowledged.

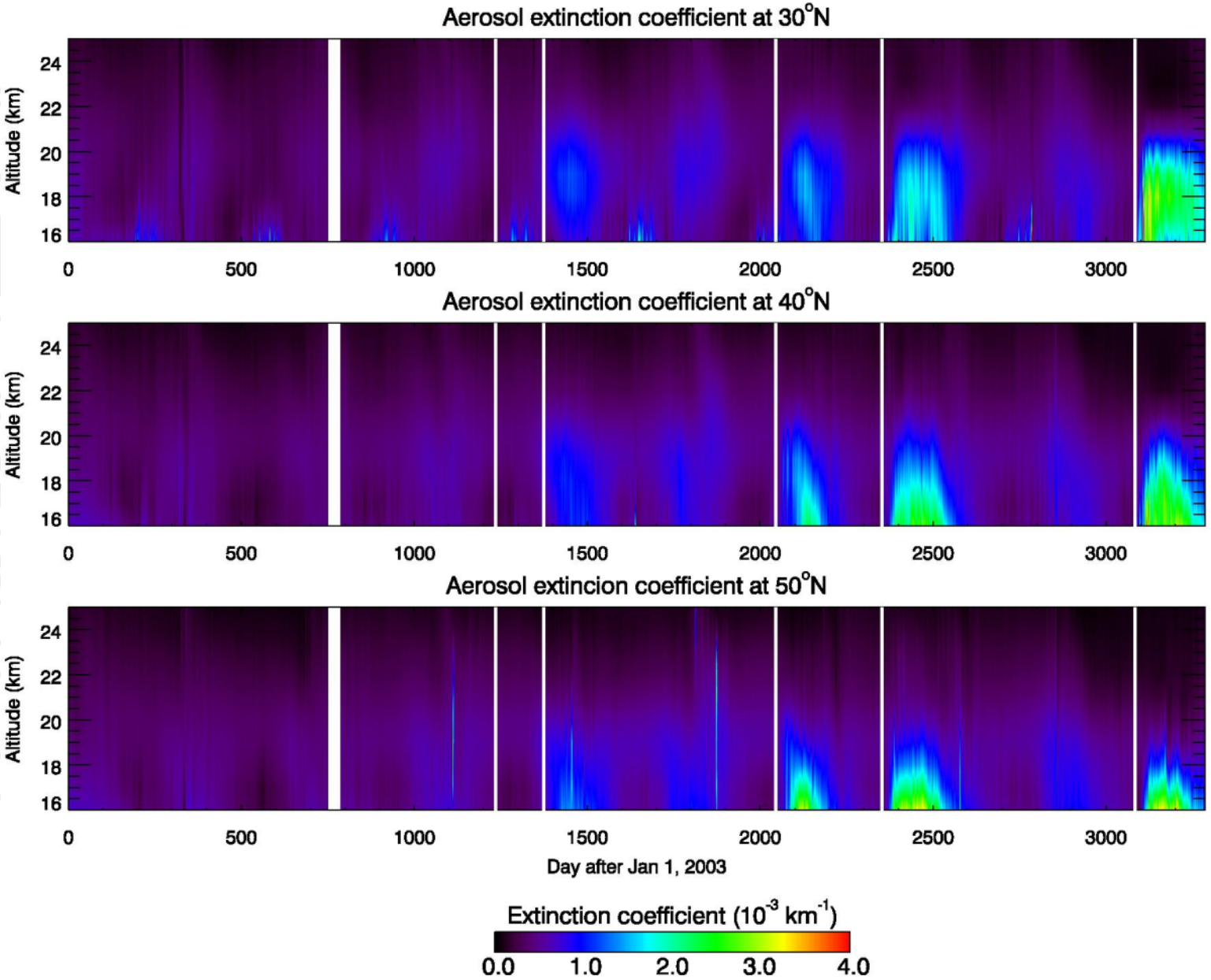
Soufriere Hills, Tavurvur (2006) and Kasatochi (2008)



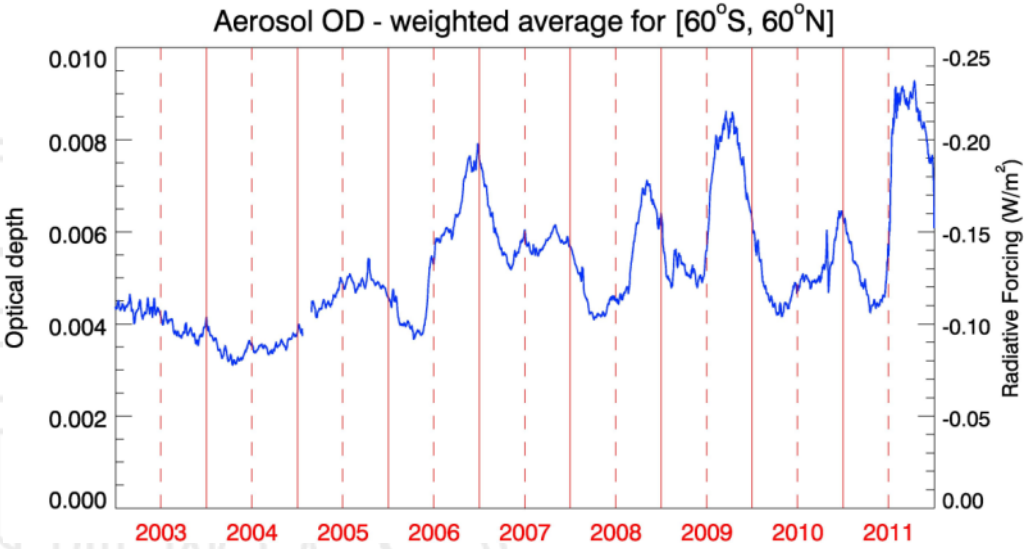
Sarychev Peak (2009) and Nabro (2011) eruptions

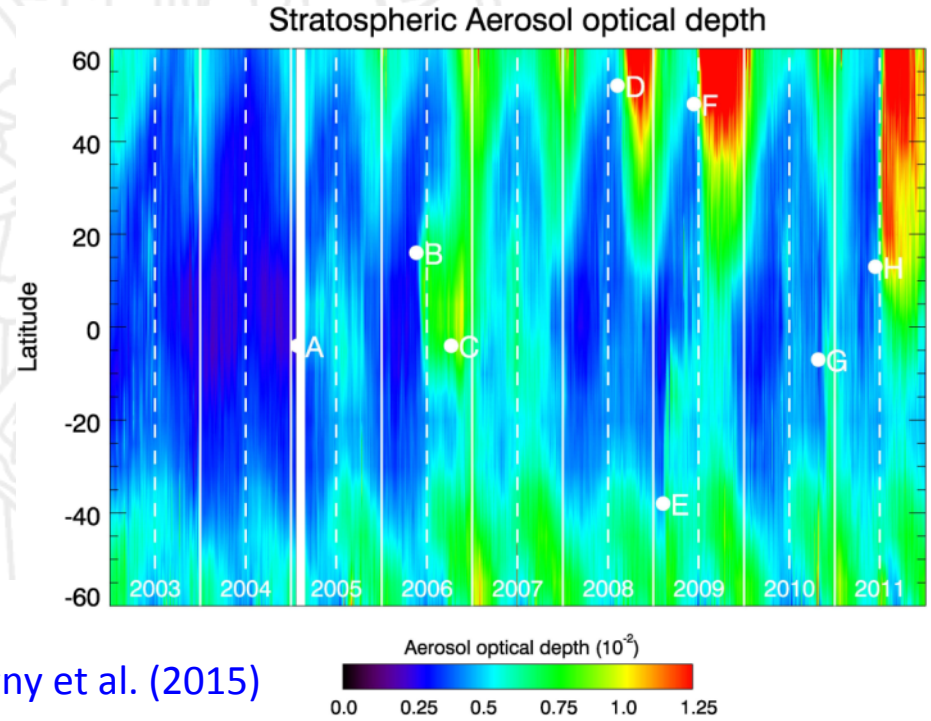


Aerosol extinction time series at 30°, 40° & 50° N



Stratospheric aerosol optical depth (380 K – 40 km) time series





v. Savigny et al. (2015)

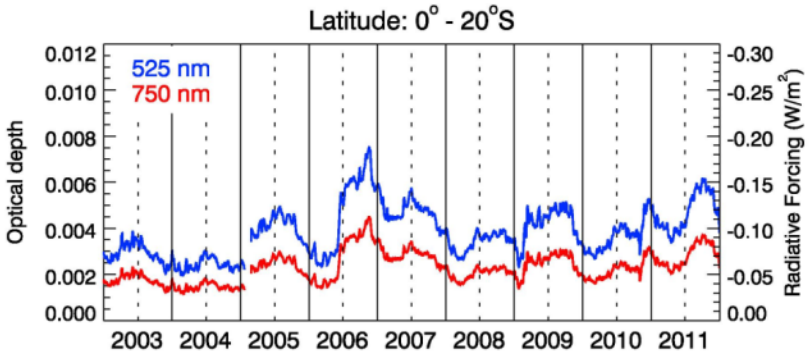
Conversion of OD to radiative forcing (RF):

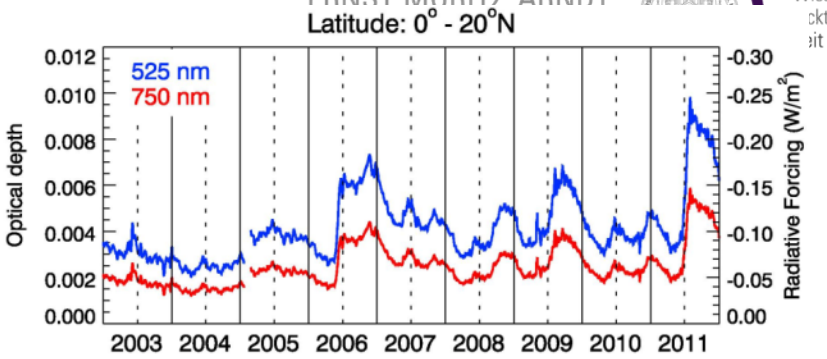
$$RF = -25 \times OD$$

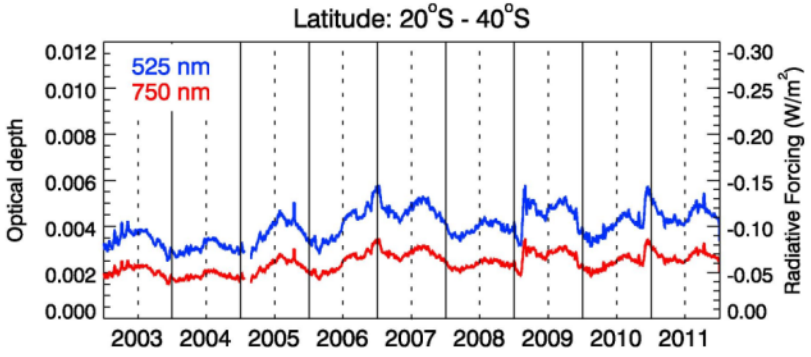
(Hansen et al., Efficacy of climate forcings, JGR, 2005)

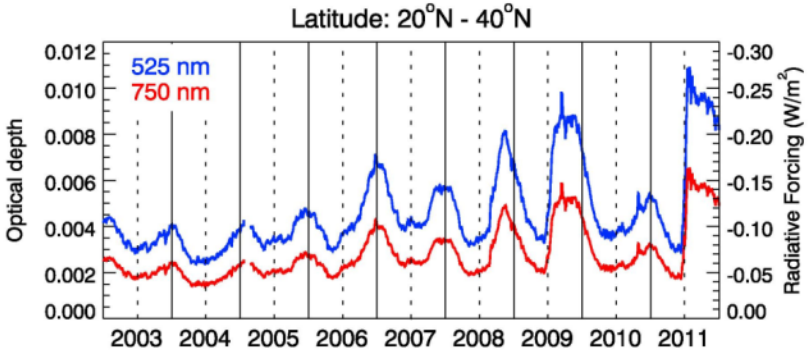
A: Manam, Jan 2005, 4°S
B: Soufriere Hills, May 2006, 16°N
C: Tavurvur, Oct 2006, 4°S
D: Kasatochi, Aug 2008, 52°N
E: Black Saturday, Feb 2009, 38°S
F: Sarychev Peak, Jun 2009, 48°N
G: Mount Merapi, Oct 2010, 7°S
H: Nabro, Jun 2011, 13°N

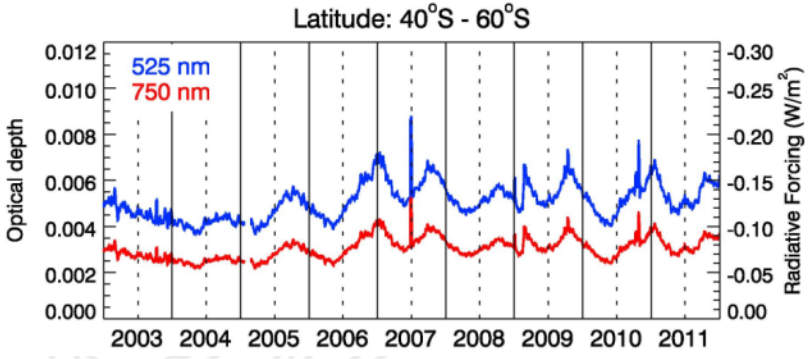
Stratospheric aerosol optical depth time series

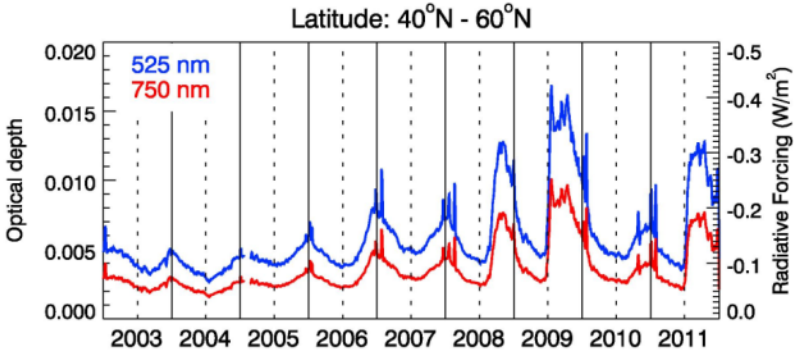








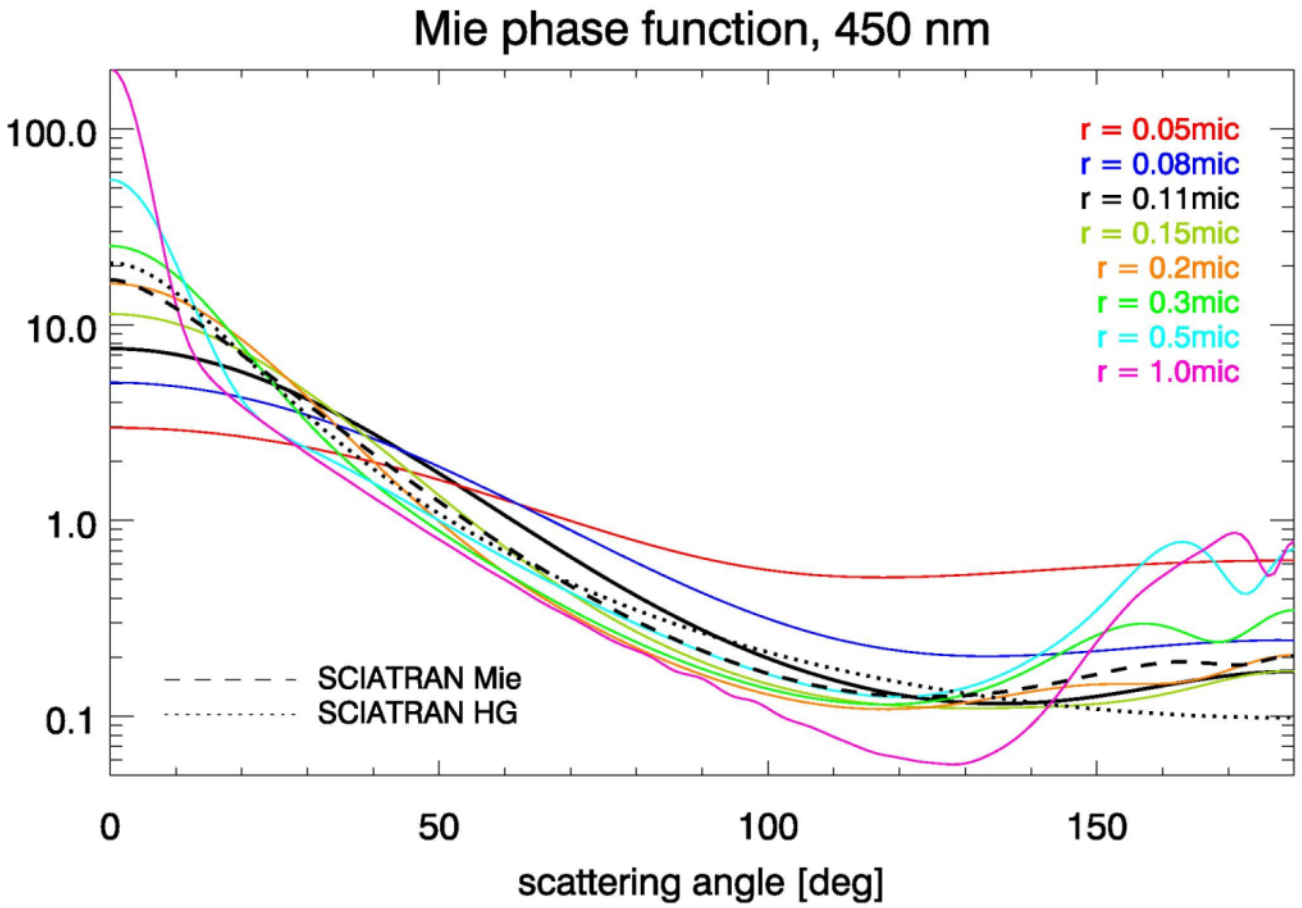




- AOD integrated from Θ = 380 K – 40 km

v. Savigny et al. (2015)

Mie phase functions for stratospheric sulphate aerosols



λ = 450 nm

R = 50 nm … 1000 nm

$\alpha \approx 0.7 \ldots 14$

Limb-Radianz-Spektren (OSIRIS/Odin Messungen)