ATAL's inter-annual variability derived from Satellite Observations

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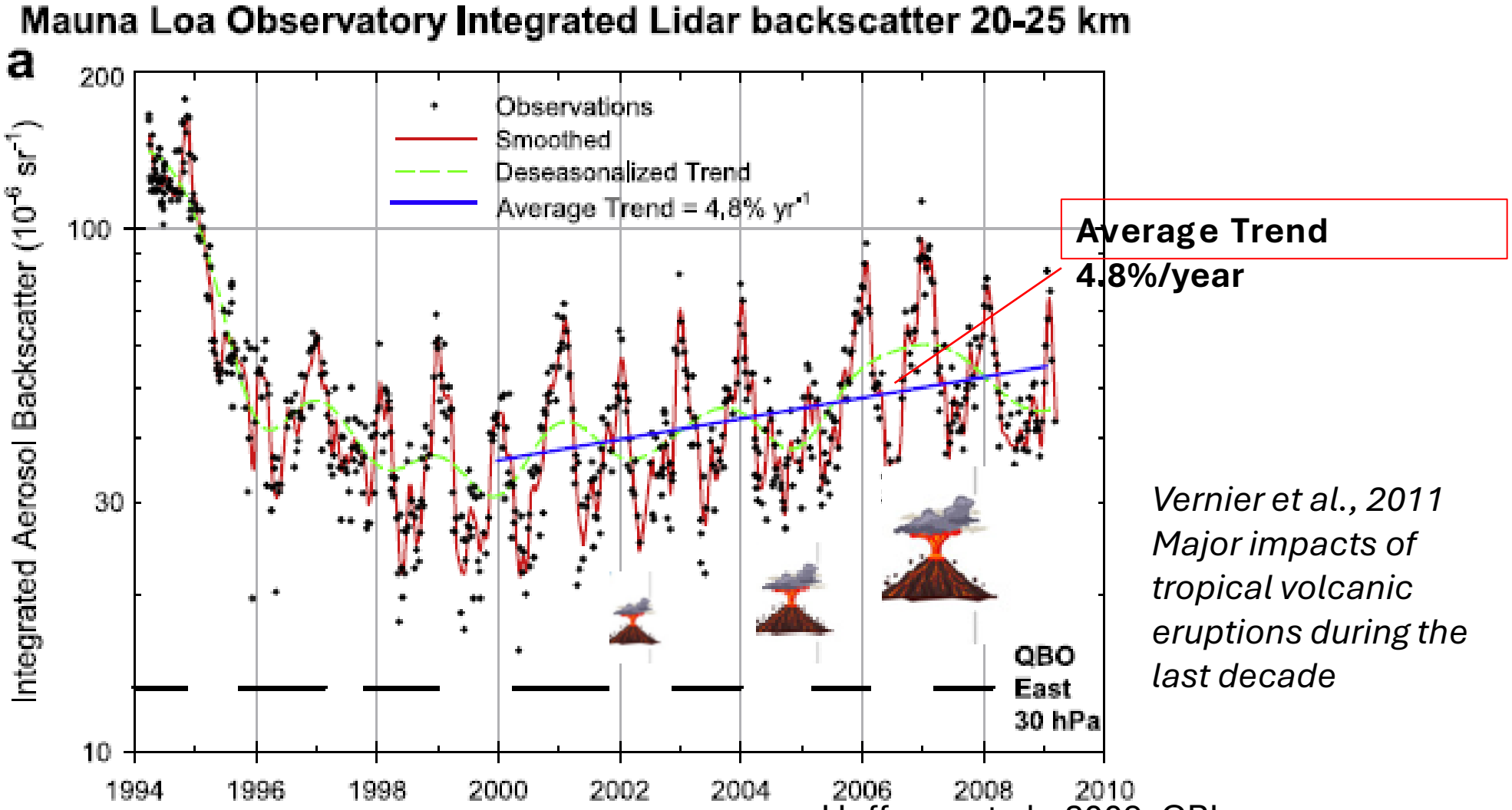
ATAL: Asian Tropopause Aerosol Layer
AMA: Asian Monsoon Anticyclone

6 June 2024, Pune, STIPMEX

Outline

1) Science background about the ATAL
2) Reconsidering trend analysis from Kloss et al. (2024)
3) A deeper look at ATAL in 2003
4) ATAL during the SAGE III/ISS and CALIPSO era
5) Absolute necessity to remove years influenced years by volcanic eruptions and wildfires to study the ATAL
6) Updated SAGE and CALIPSO combined analysis

Increase of background stratospheric aerosol loadings observed at Mauna Loa Observatory



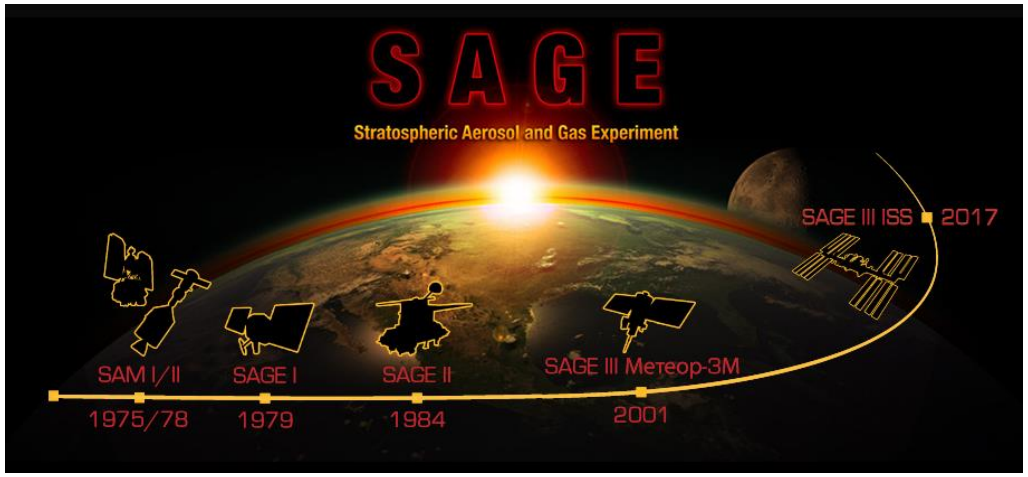
Vernier et al., 2011
Major impacts of tropical volcanic eruptions during the last decade

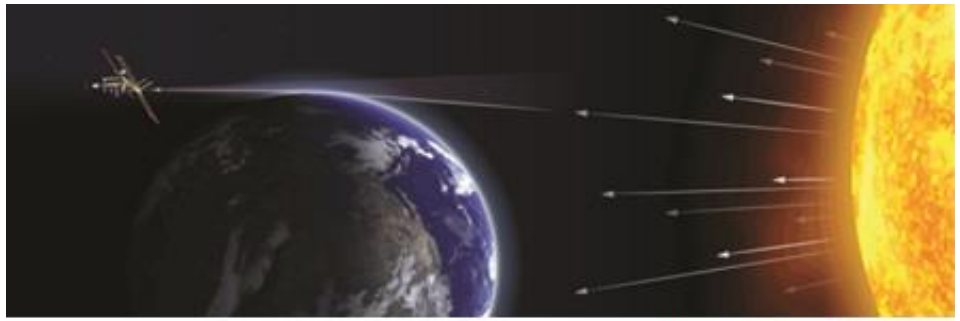
Hoffman et al., 2009, GRL

"Increase in anthropogenic sulfur gas emissions in the troposphere, it appears that a large increase in coal burning since 2002, mainly in China"

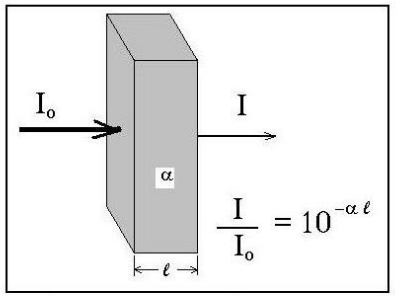
Satellite Observations

SAGE



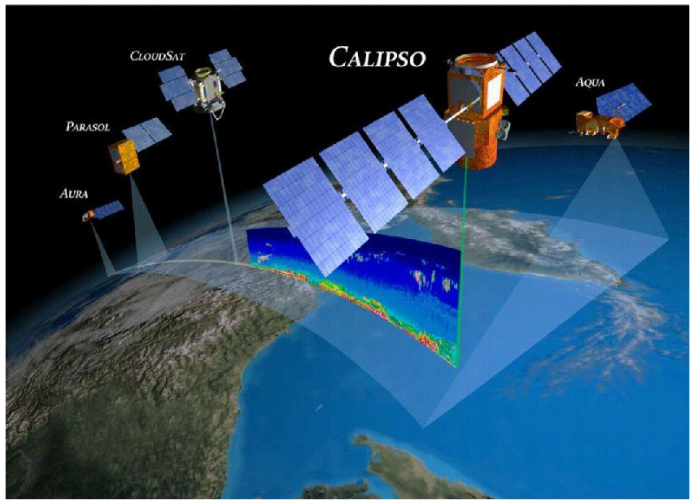


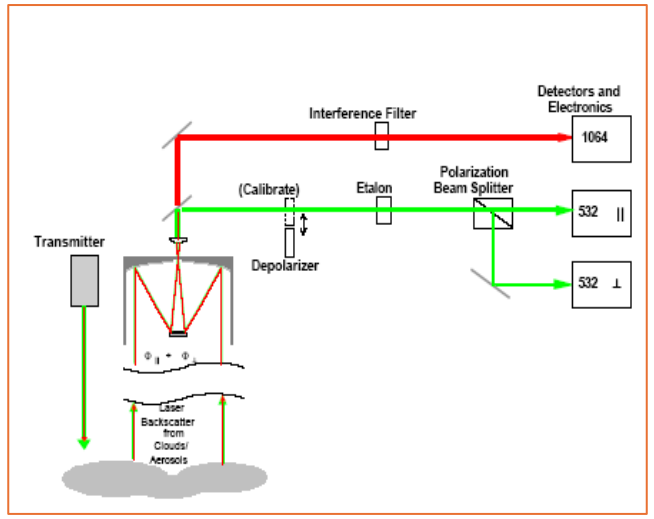
Solar Occultation



The Beer Lambert Law

CALIPSO





- Scattering Ratio

~ Particle mixing ratio

$$SR = \frac{b_{(\wedge+//)532}}{b_m}$$

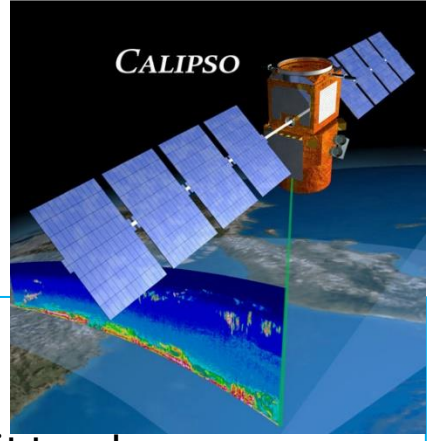
- Depolarization

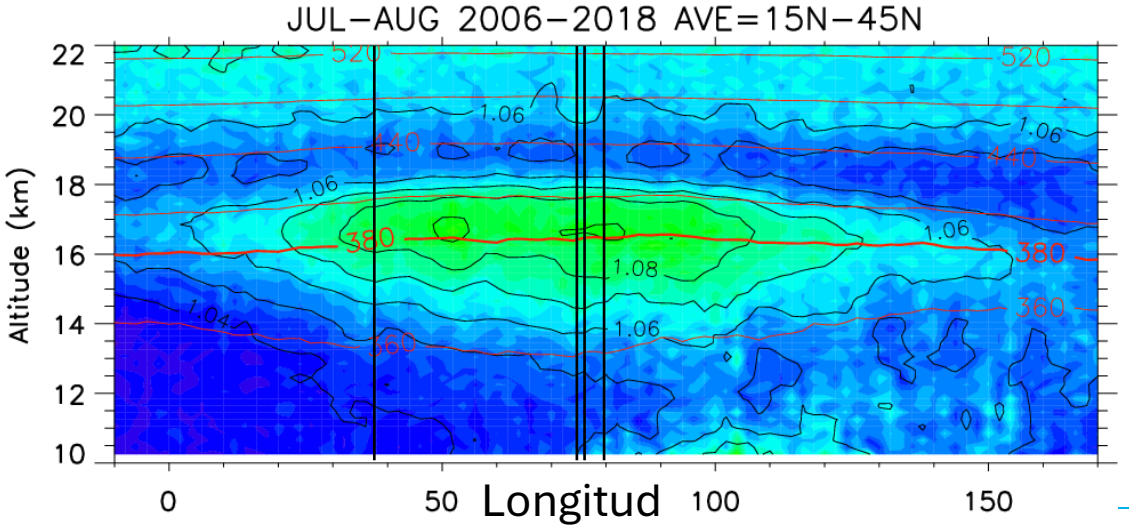
$$\P = \frac{b_{(\wedge)532}}{b_{(//)532}}$$

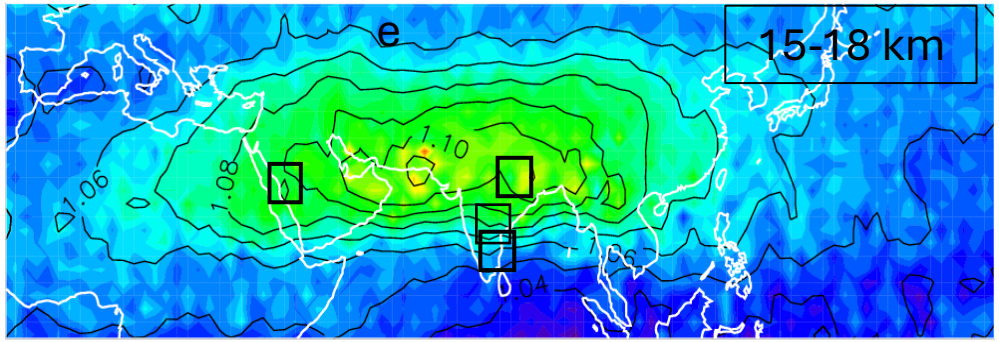
~ particle shape

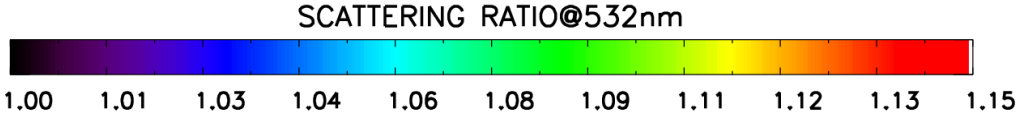
- CALIPSO nadir view : 80 - 180m resolution in the UTLS
- Operation: 2006-2023

Summer Asian Monsoon influence on UTLS aerosols: The Asian Tropopause Aerosol Layer





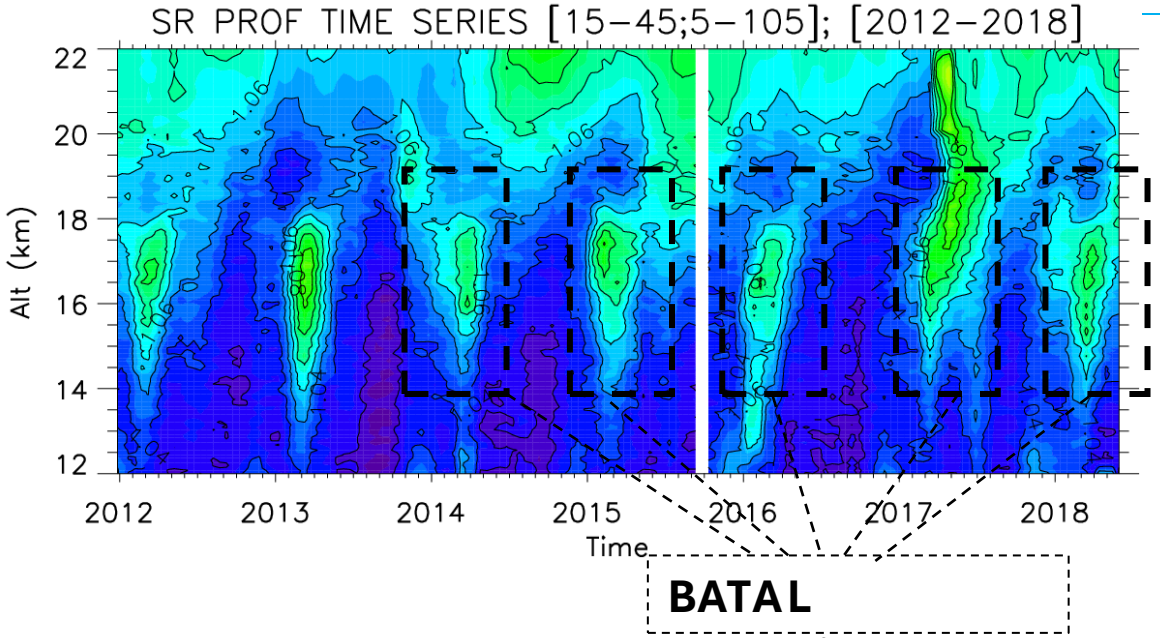




Vernier et al., 2018, BAMS

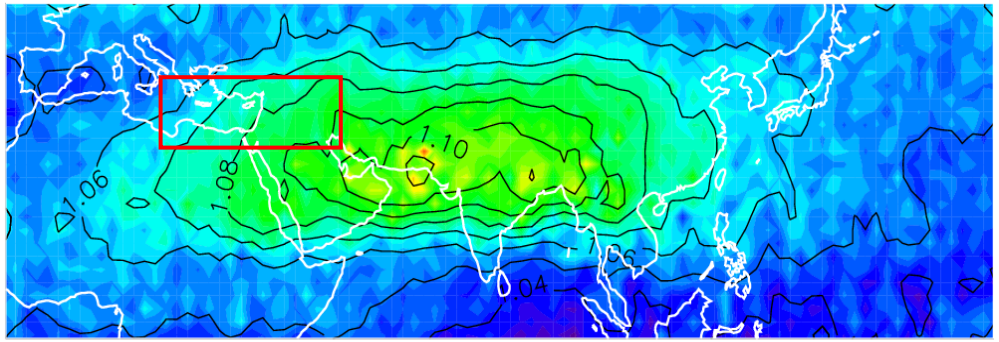
Retrieval Algorithm:

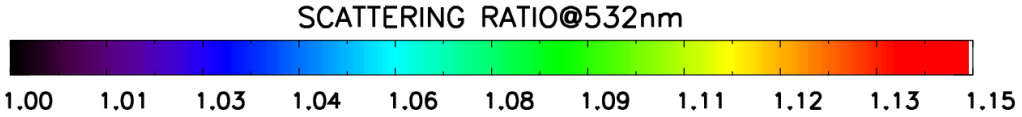
- Data averaged every 1 degree along each orbit track
- Corrected for molecular scattering and ozone absorption
- Scattering Ratio : SR=$\frac{\beta mol+\beta aero}{\beta mol}$; δ=$\frac{\beta perp}{\beta parallel}$
- Cloud removed when δ>5%
- Volcanic years excluded : 2006 (Soufiere Hills) 2009 (Sarychev) ,2011 (Nabro)

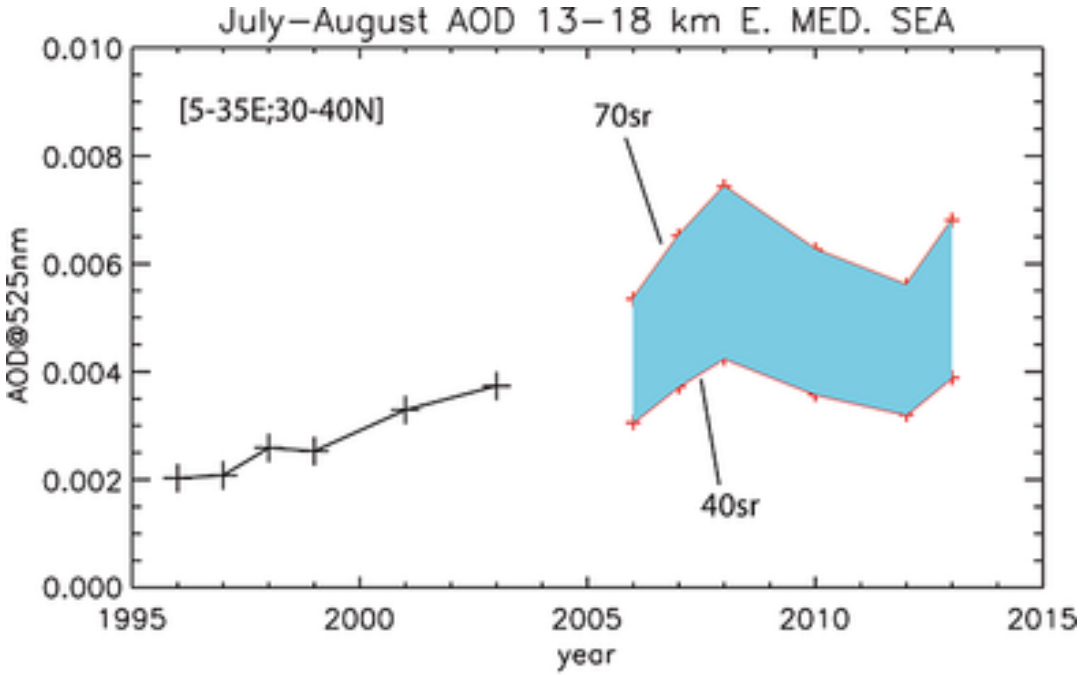


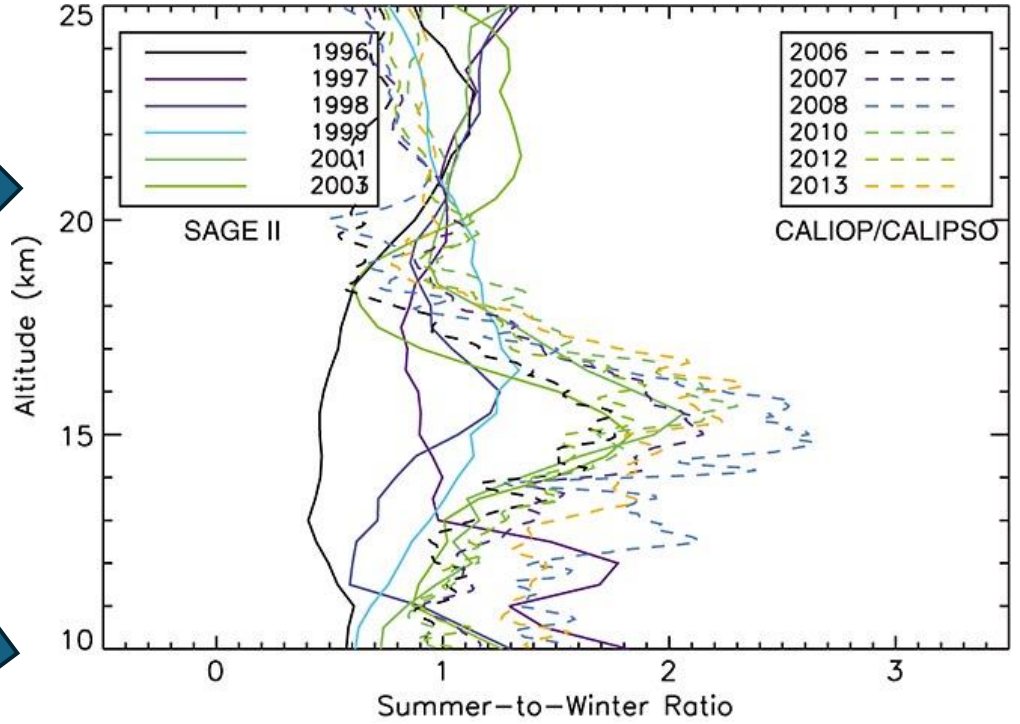
Trends analysis since the late 90's

30-40N; 5-45 E









Extinction Ratio@525nm

- Selected region where influence of clouds is minimal (E. Med Sea, Red box)
- Summer-to-Winter anomaly reveals relative increase in aerosol loadings
- Similar results for extended ATAL region

Vernier et al., 2015, JGR

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2023JD039784

Reconsidering the Existence of a Trend in the Asian Tropopause Aerosol Layer (ATAL) From 1979 to 2017

Key Points:

- Early space-borne observations (SAGE instruments) cannot be used for ATAL

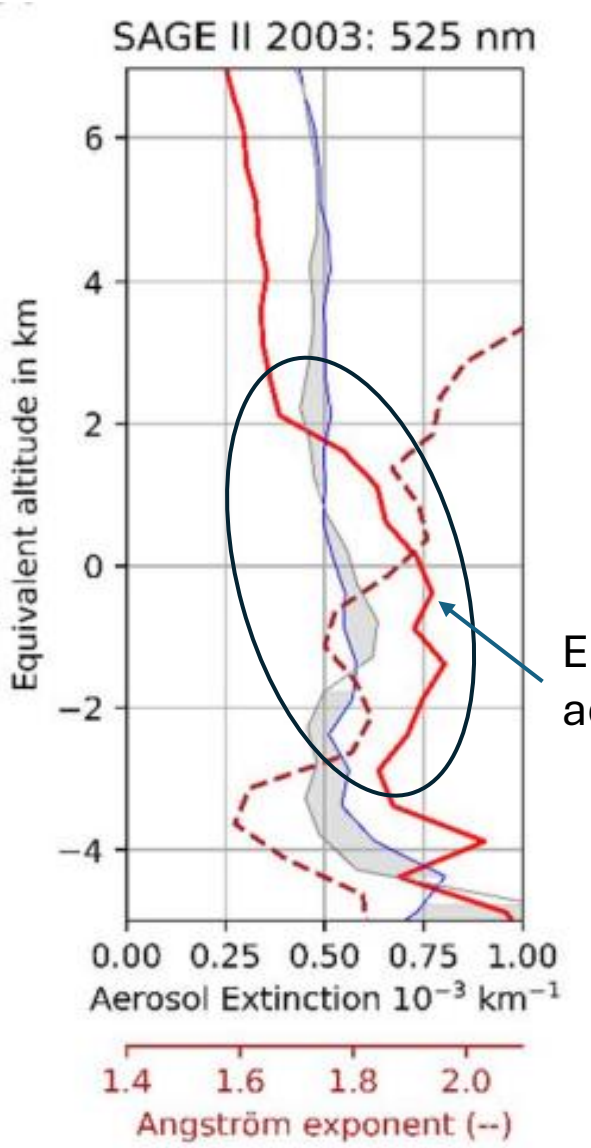
Corinna Kloss[1,2], Adriana Bossolasco[1,3], Larry Thomason[4], Bernard Legras[5], Gwenaël Berthet[1], Fabrice Jégou[1], Suvarna Fadnavis[6], and Pasquale Sellitto[7,8]

- Recent paper from Kloss et al. (2024) challenging those findings :

“ We find that seasonal averaged solar occultation aerosol measurements (past and present) can neither be used to exclude the existence of the ATAL”
In other words : SAGE is not fully suited to study the ATAL

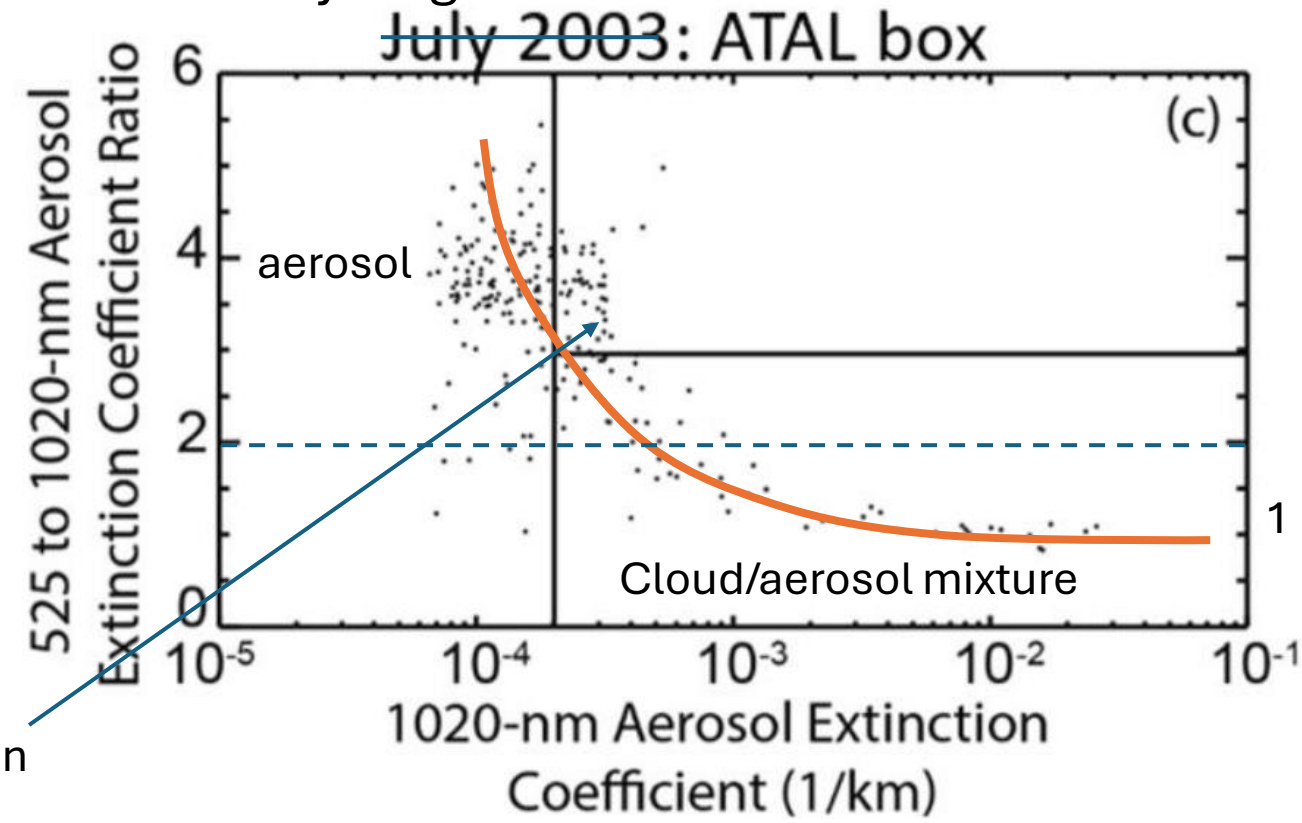
➔Thomason and Vernier (2013) and Vernier et al. (2015) used SAGE II data to shows the existence so will revisit this apparent contradiction
➔Kloss et al. (2017) used SAGE III/ISS to show the existence of the ATAL so will investigate another apparent contradiction

An ATAL feature is visible in July-August 2003 in Kloss et al. (2024)



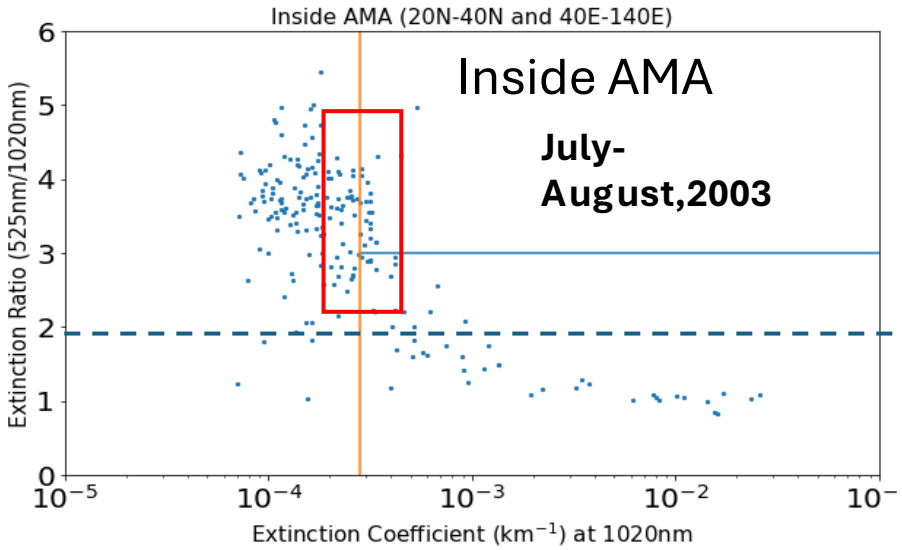
Enhancement of aerosol extinction

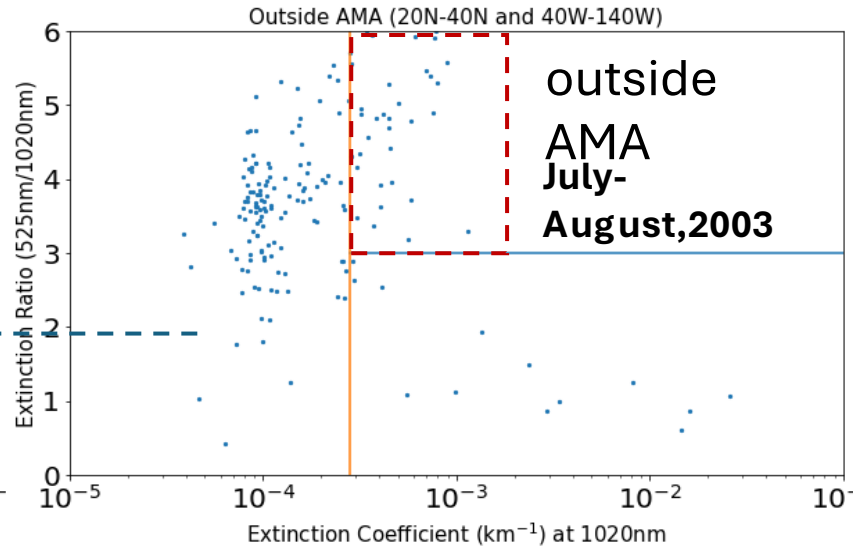
July-August 2003

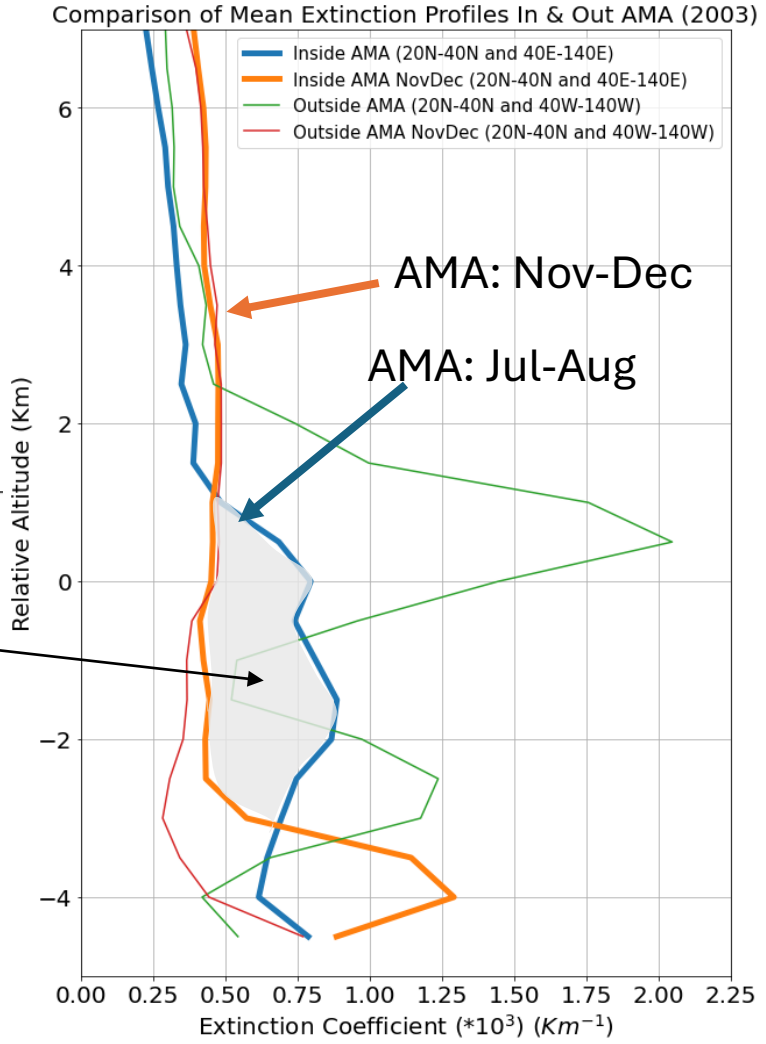


- Separation between cloud and aerosol layers
- Enhanced extinction with high ECR signature of aerosol layers
- Argument used in K24 : another feature is also visible in 2003 outside the AMA region

Comparison of the region inside and outside of the AMA box, July-August 2003



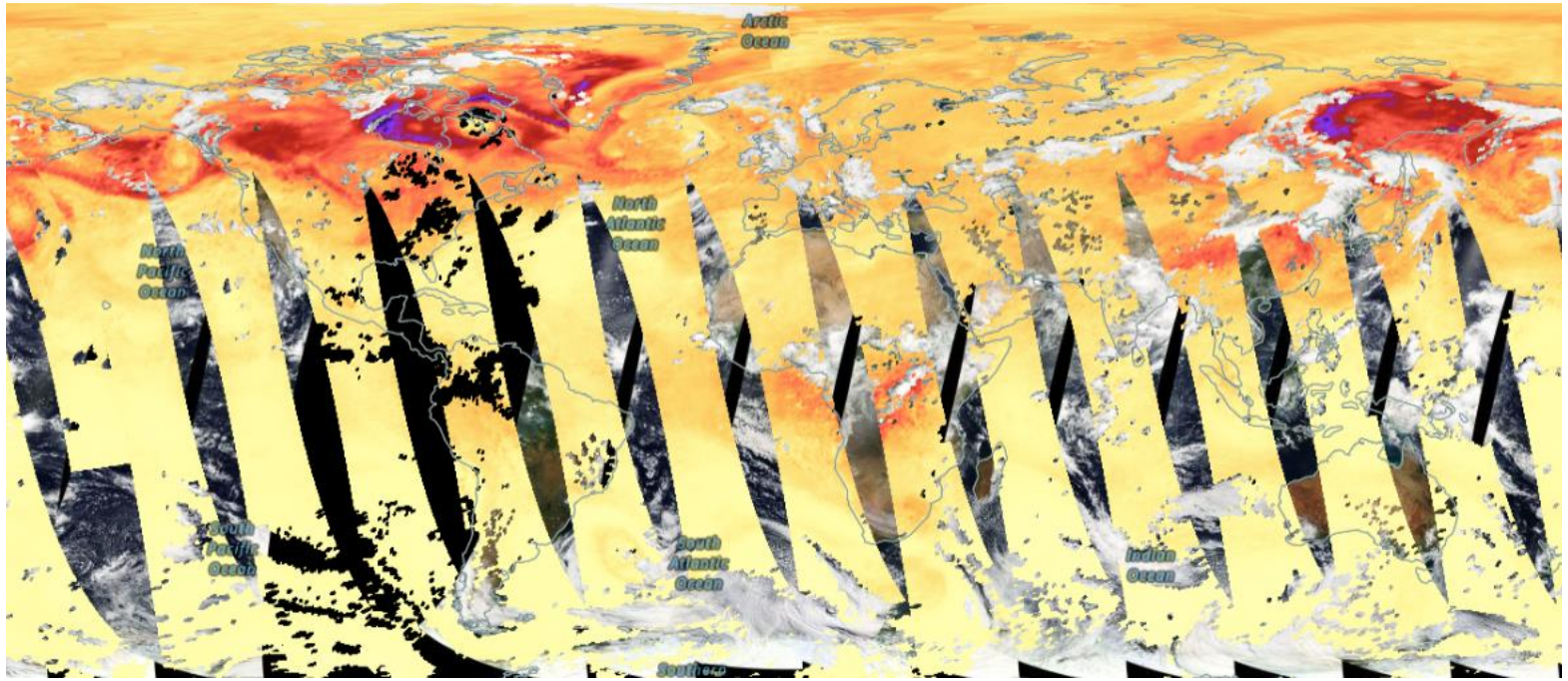


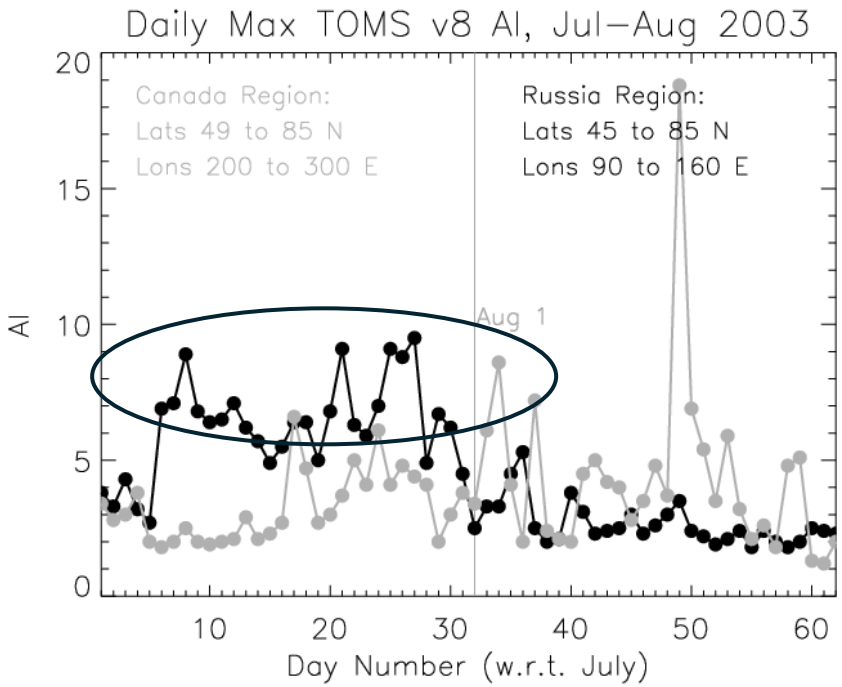


- ATAL feature is visible (tropopause relative altitude between **– *3*** km and ***1*** km).
- Double peak above and below the tropopause outside the AMA region (shape different than ATAL).
- Comparison of two different region to draw similarities may not be applicable here. AMA is a confined region generally limited from the outside transport.
- Outside AMA points (dashed box) are more spread out with higher extinction ratio and values.
- Investigation of the origin of these higher extinction is needed.

Likely influence of wildfires in 2003

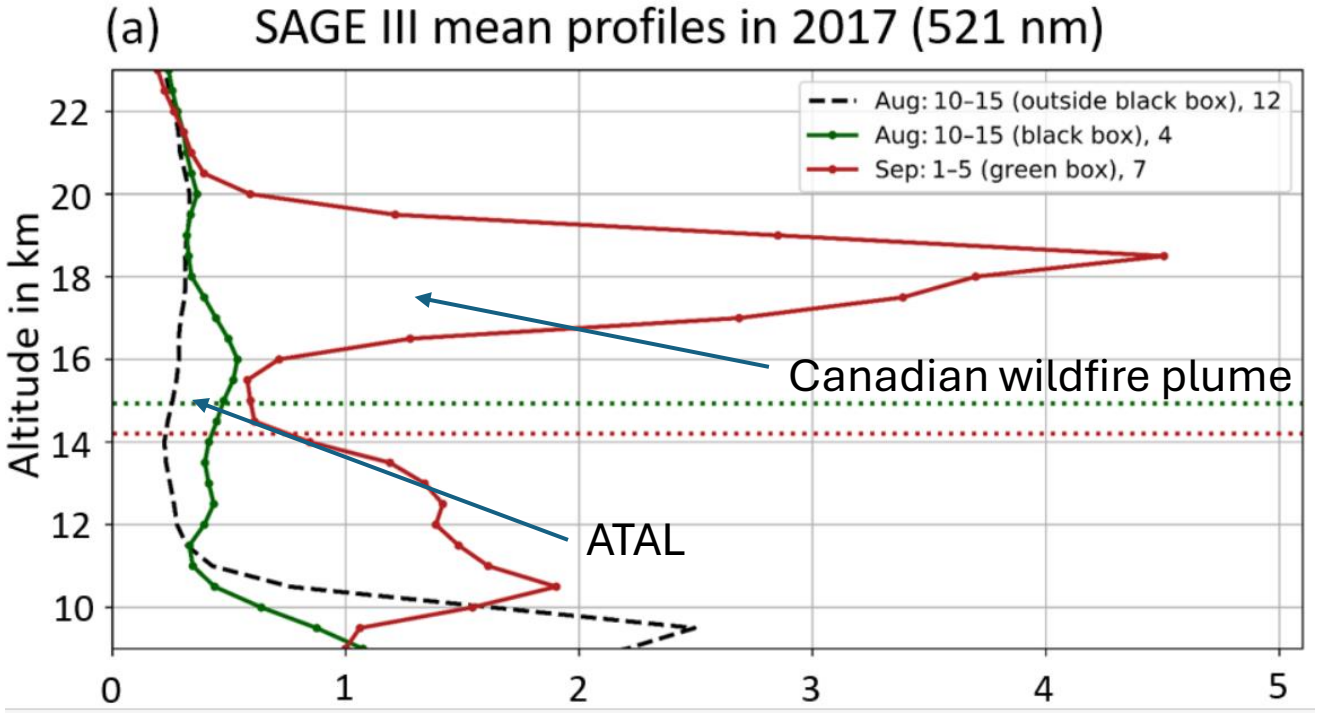
AIRS/CO 31 July 2003 500 hPa

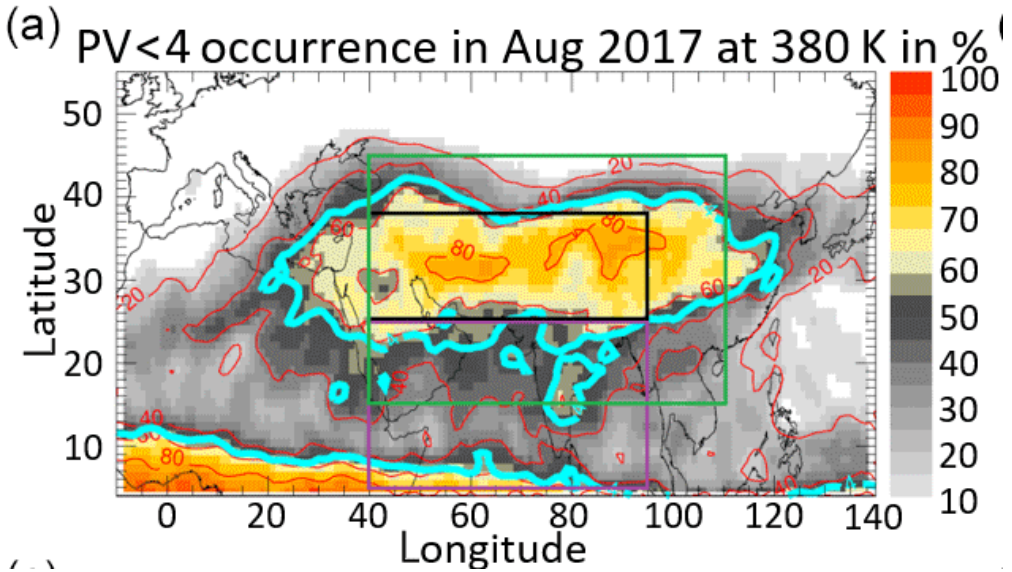




- Multiple Wildfires in Russia and Canada in July 2003
- TOMS Daily Max of AI suggests the presence of smoke throughout July 2003 from Russia
- CO from AIRS confirm the large-scale influence of those fires
- Still need to find which PyroCbs took place

SAGE III/ISS detection of the ATAL

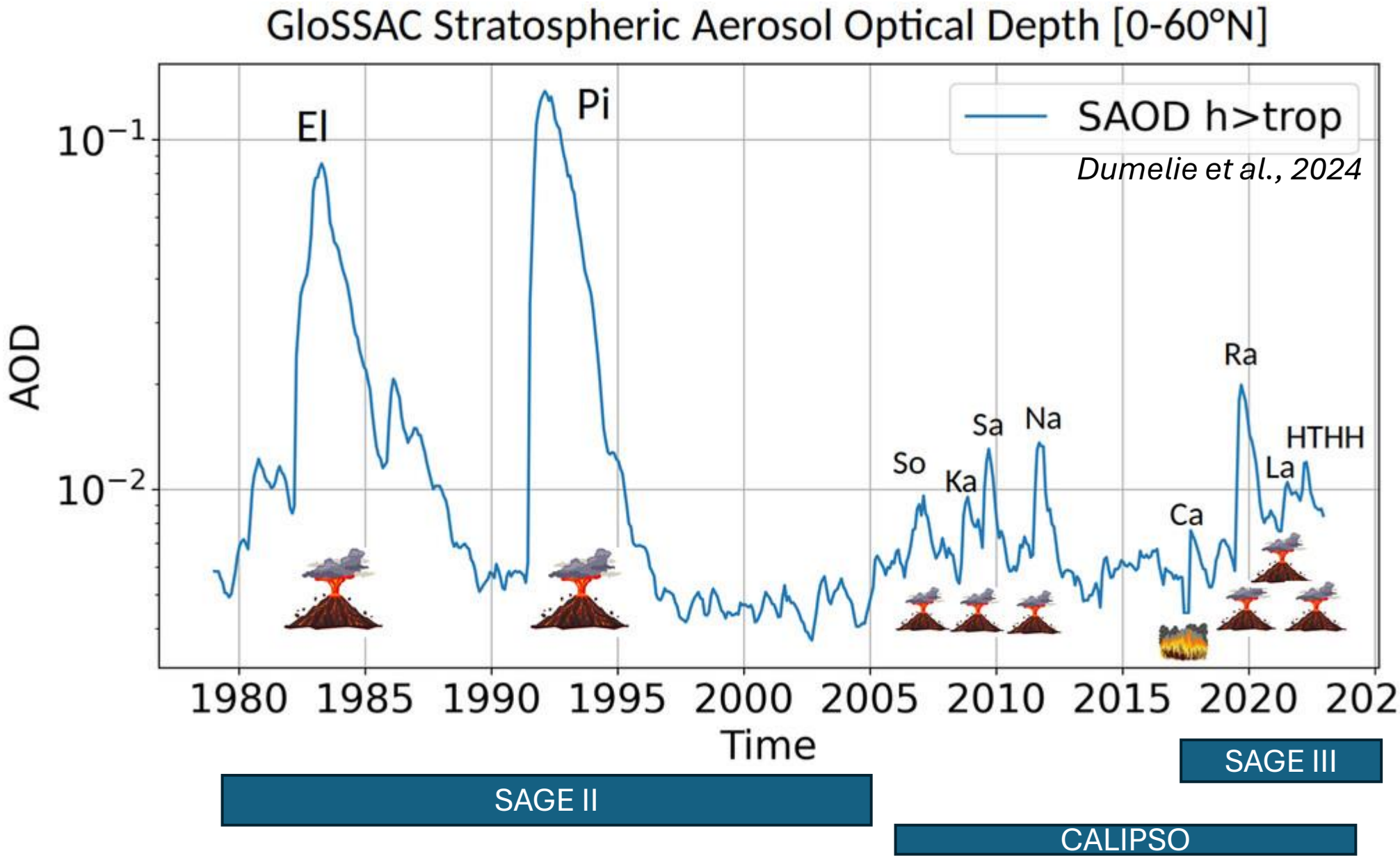




Kloss et al., 2017

- Kloss et al. 2017 shows the presence of the ATAL using SAGE III/ISS before arrival of Canadian wildfires
- Kloss et al. 2024 indicate that the ATAL can be visible on SAGE III/ISS on multiple-day basis (5-day in this case) but not on a seasonal-basis

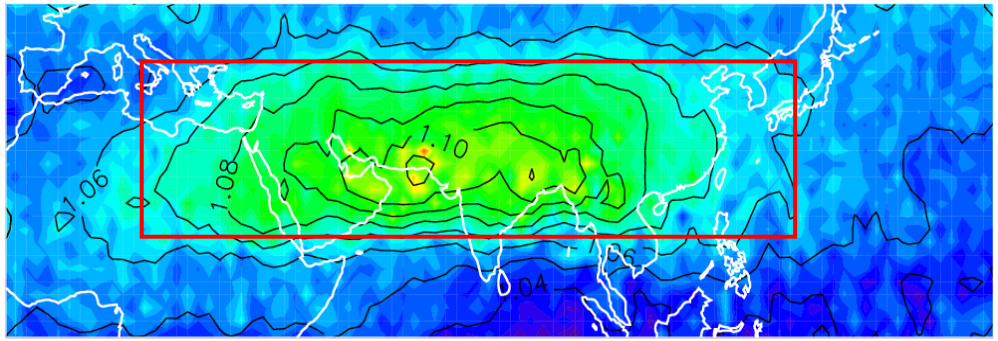
UTLS aerosol variability is complex

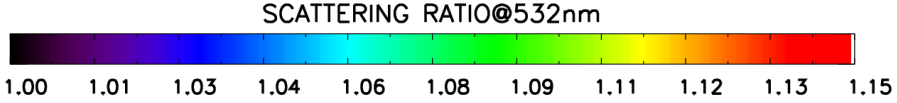


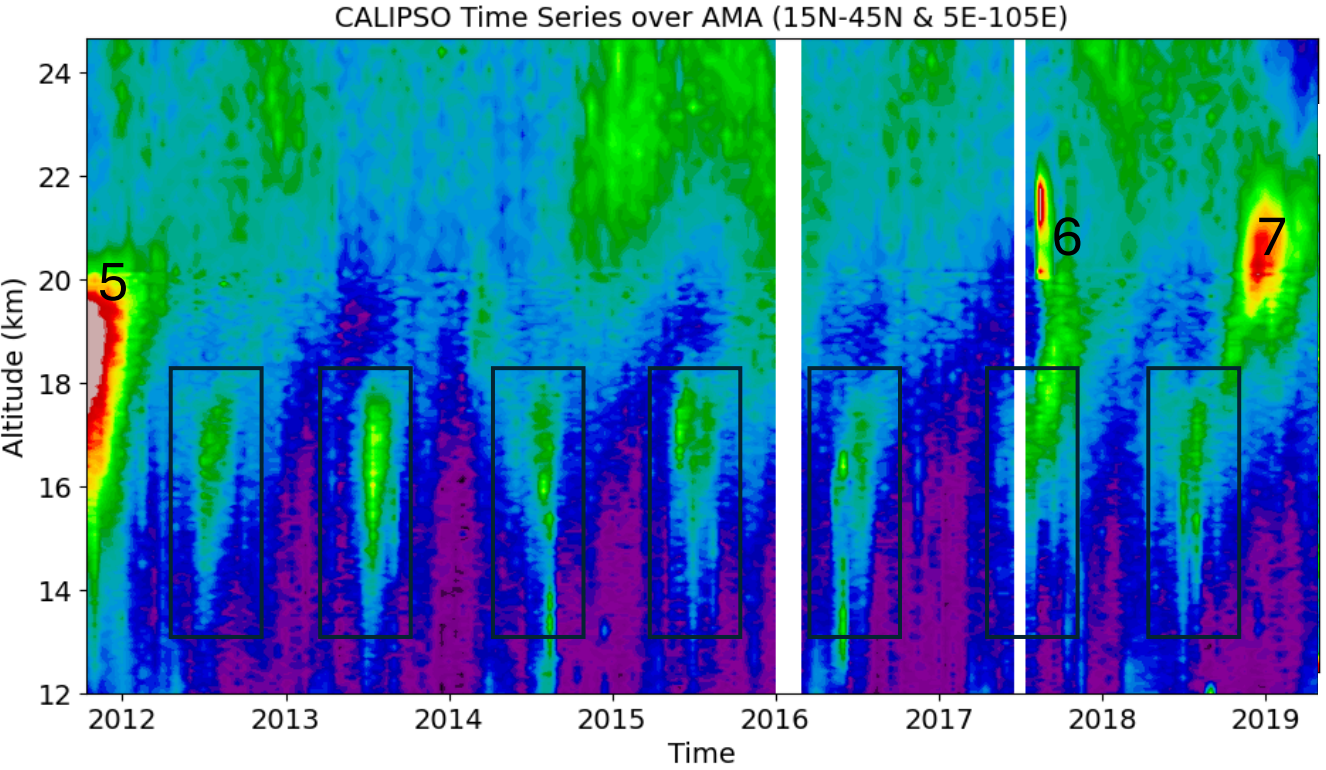
El: El Chinchon
Pi: Mt Pinatubo
So: Soufiere Hills
Ka: Kasatochi
Sa: Sarychev
Na: Nabro
Ca: Canadian WF
La: La Soufiere
HTHH: Hunga Tonga

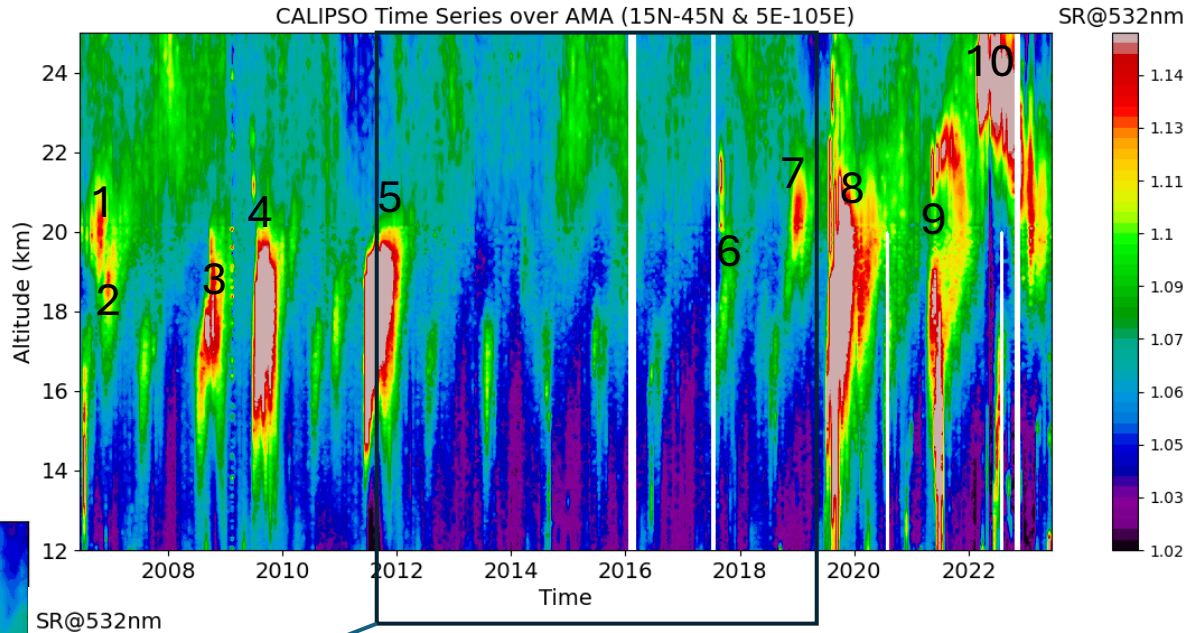
CALIPSO observations of UTLS aerosol

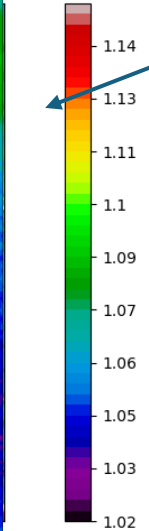
AMA box : 15N45N; 5E-105E







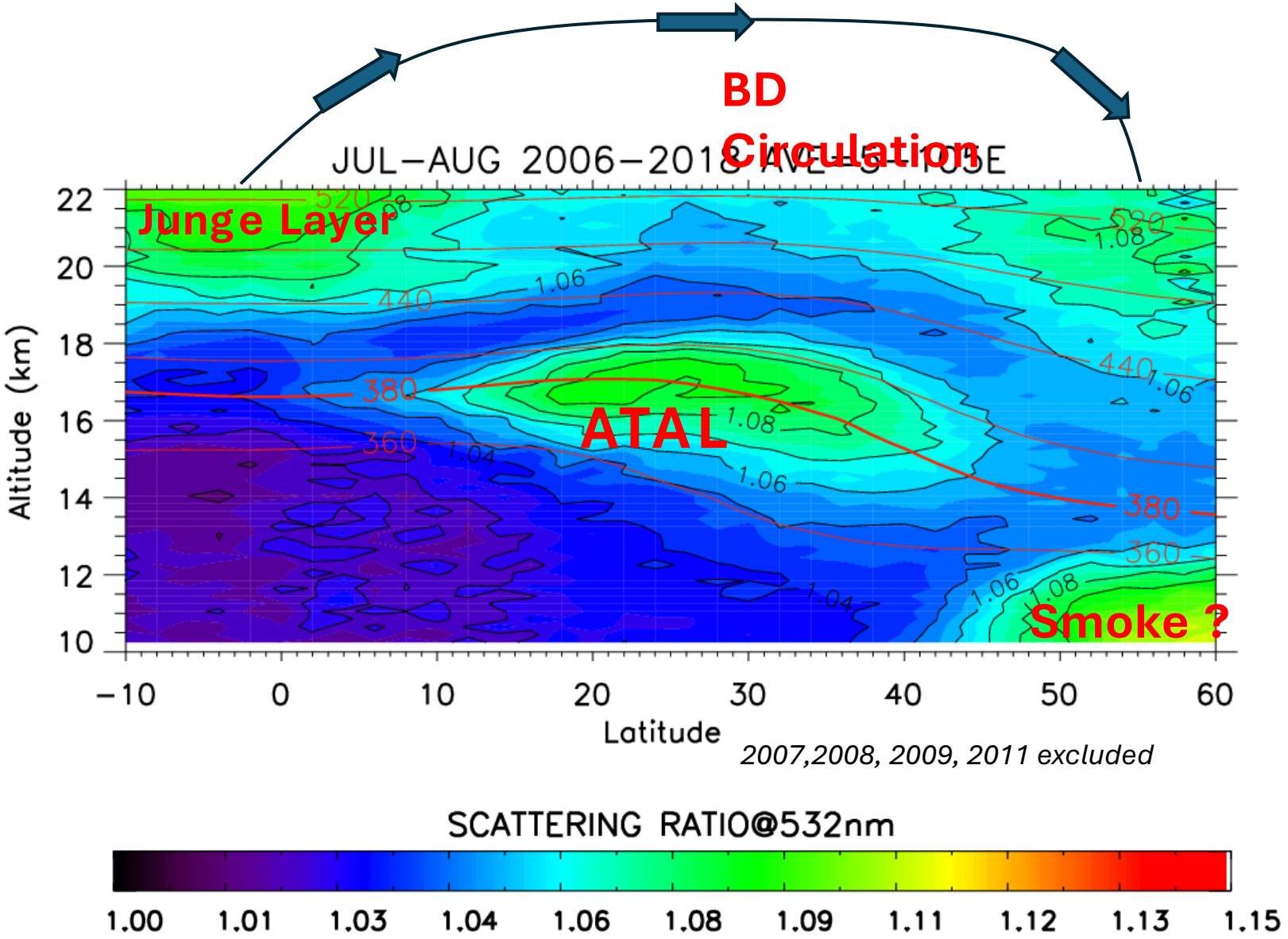




- Aerosol variability within
- 2006-2023 was perturbed by multiple events
- 2012-2019 period ideal to study the ATAL
- 2018-2022: highly perturbed

1. Soufiere Hills, 05/06
2. Tavurvur, 10/06
3. Kasatochi, 08/08
4. Sarychev, 06/09
5. Nabro, 06/11
6. Canada/WF, 06/17
7. Ambae, 07/18
8. Raikoke, 06/19
9. La Soufriere, 04/21
10. HTHH, 01/22

ATAL's among others stratospheric features

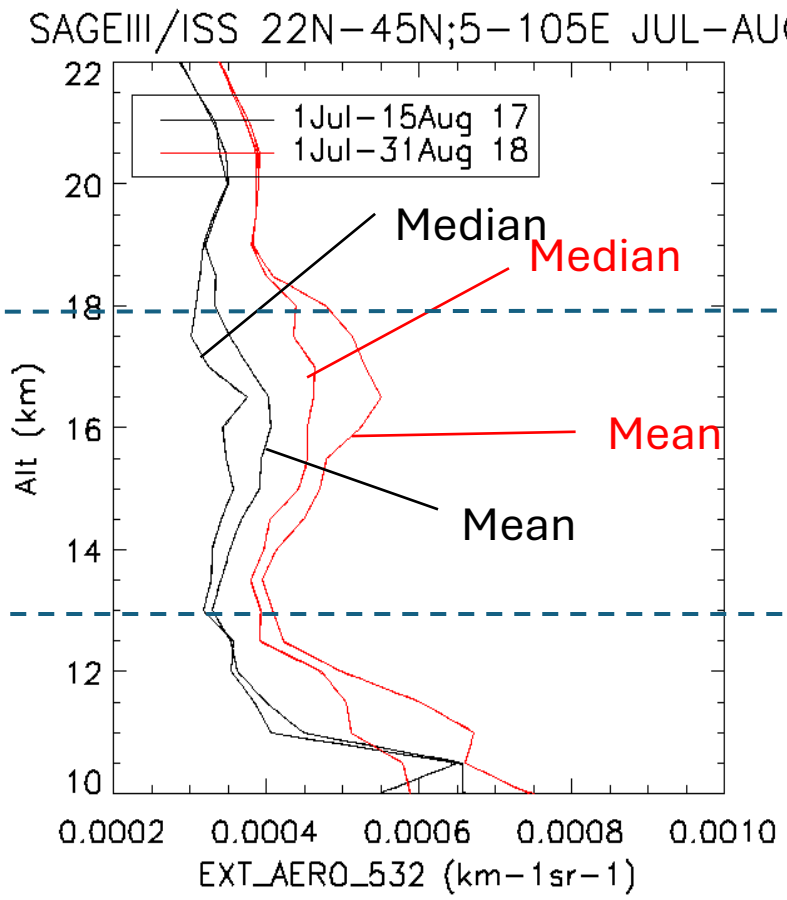


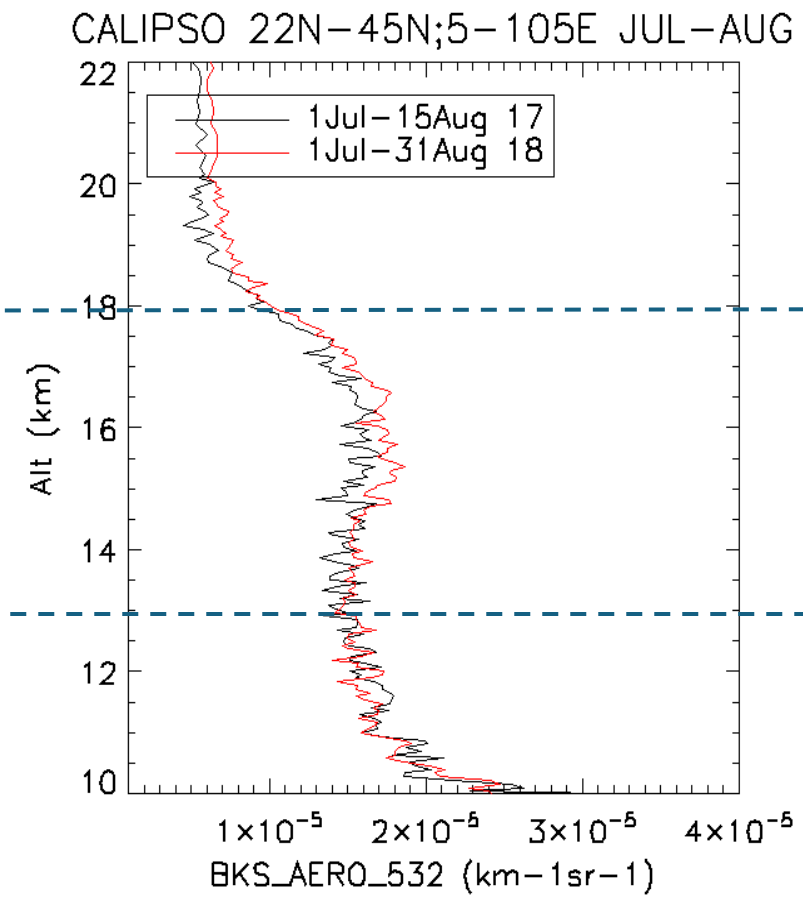
2007,2008, 2009, 2011 excluded

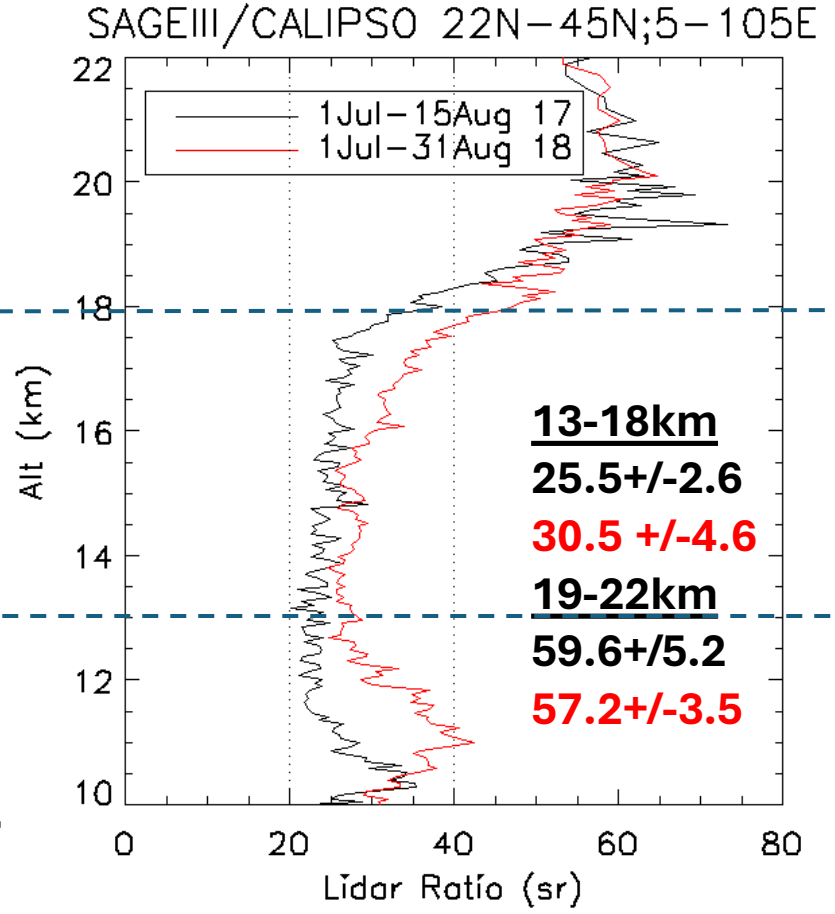
- Evidence for the existence of the ATAL outside periods affected by volcanic eruptions/wildfire
- Other features also visible

June Layer, Smoke, BD Circulation

Comparison between SAGE III/ISS and CALIPSO

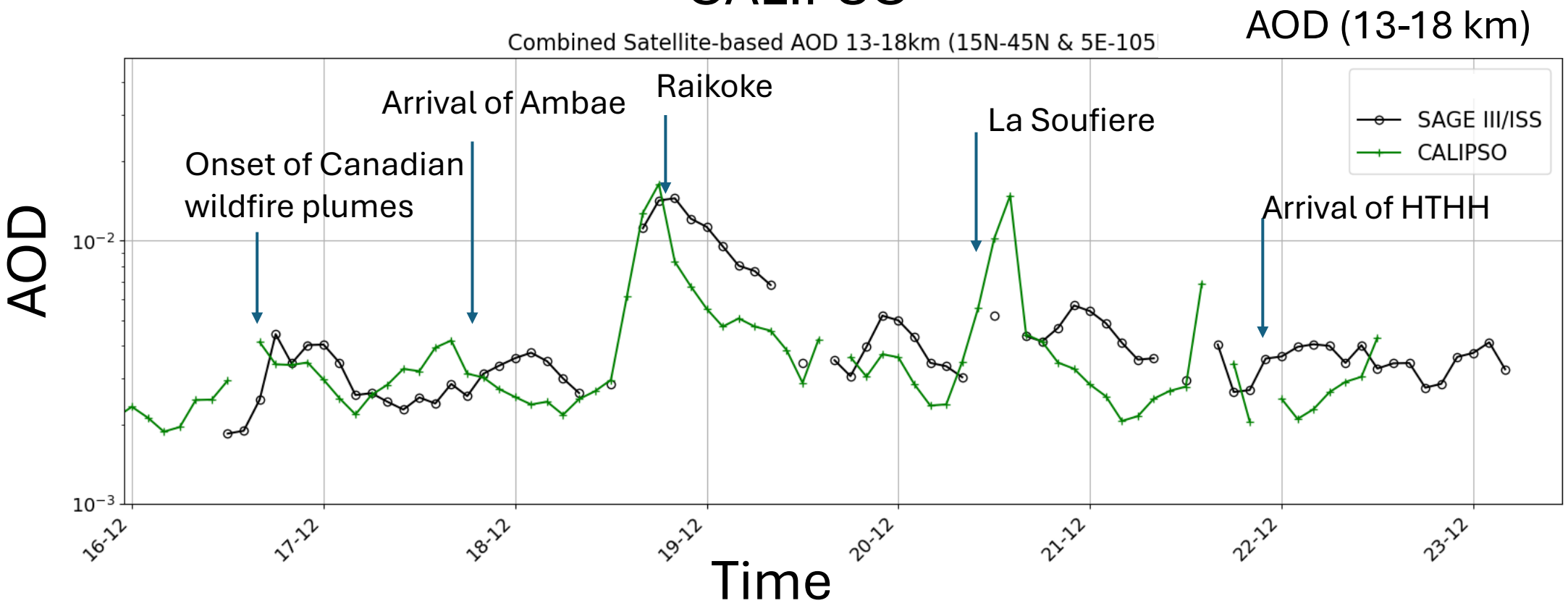






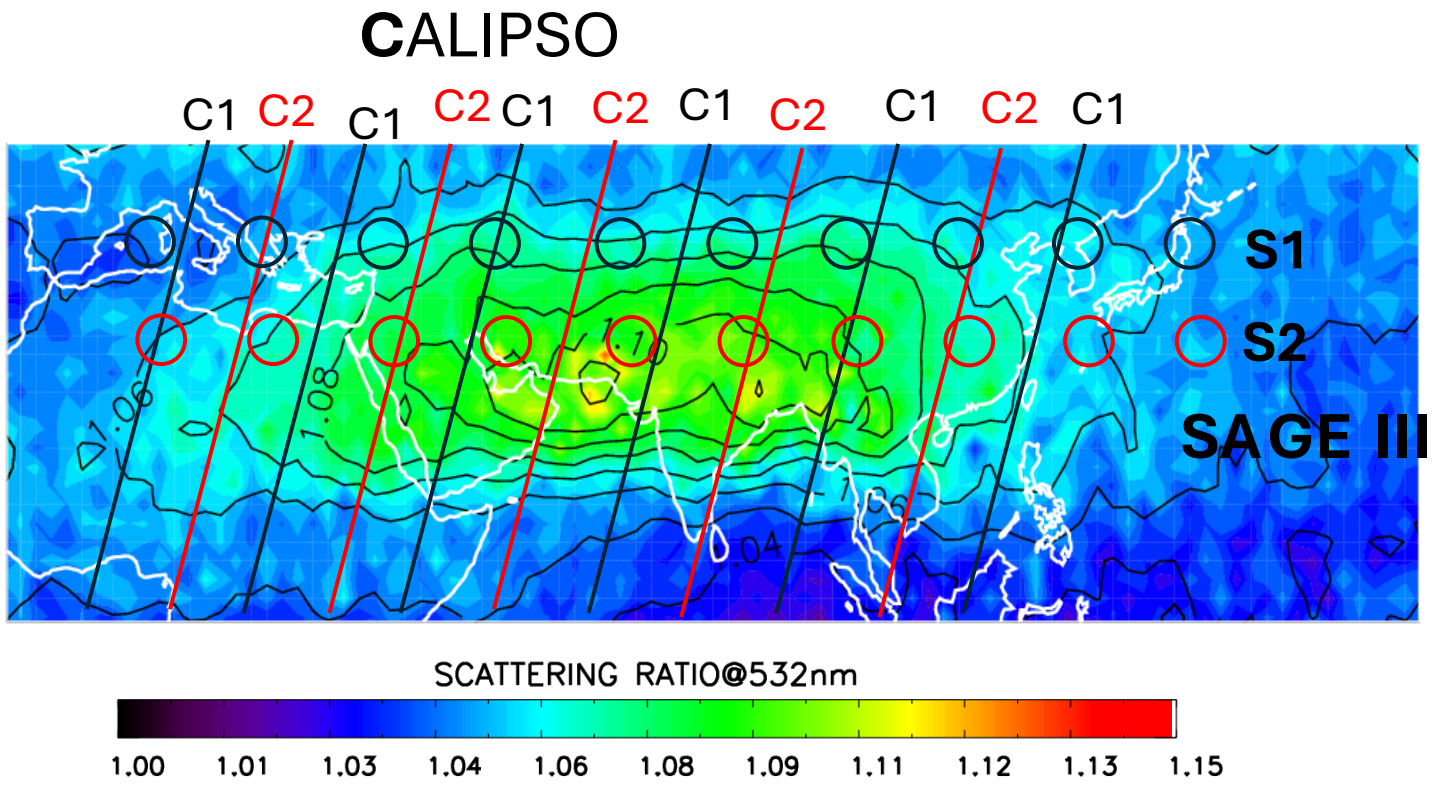
- Similar profile shapes between CALIPSO and SAGE III/ISS
- Lidar Ratio (SAGE/CALIPSO) between 13-18 km inconsistent with what we would expect for aerosols

Perturbed regime makes the comparison more challenging mostly due to sampling difference between SAGE III and CALIPSO



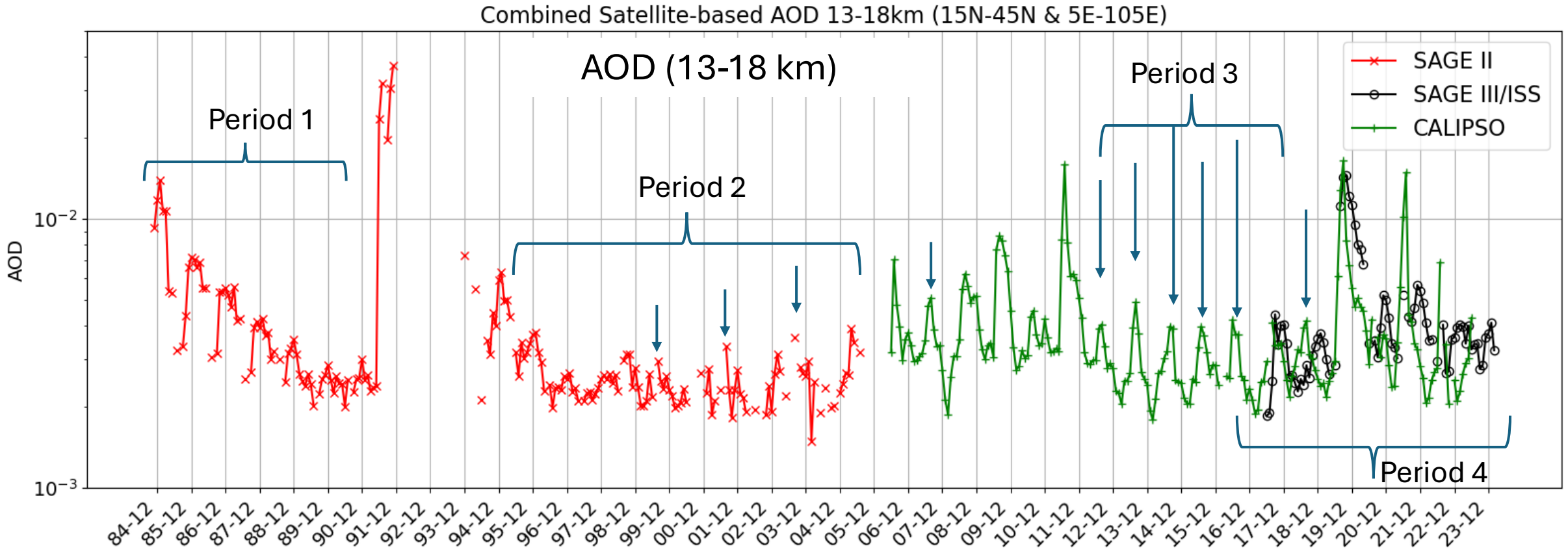
- Multiple events affected UTLS aerosols between 2017-2023
- Possible reasons for discrepancy (Cloud screening, Lidar ratio, Sampling)

Sampling difference between SAGE III/ISS and CALIPSO



- CALIPSO orbit track provide regular obs. Grid ~16 days
- SAGE III/ISS occultation moves across latitudes each D

Combined Satellite-based gives a more complex picture than initial analysis



- Period 1: AOD relaxing from El Chinchon: aerosol max winter (strato air, more efficient cleansing of larger aerosols)
- Period 2: for selected years August largest AOD (1999, 2001, 2003)
- Period 3: Ideal period to study the ATAL
- Period 4: comparison between SAGE III and CALIPSO challenged by multiple events

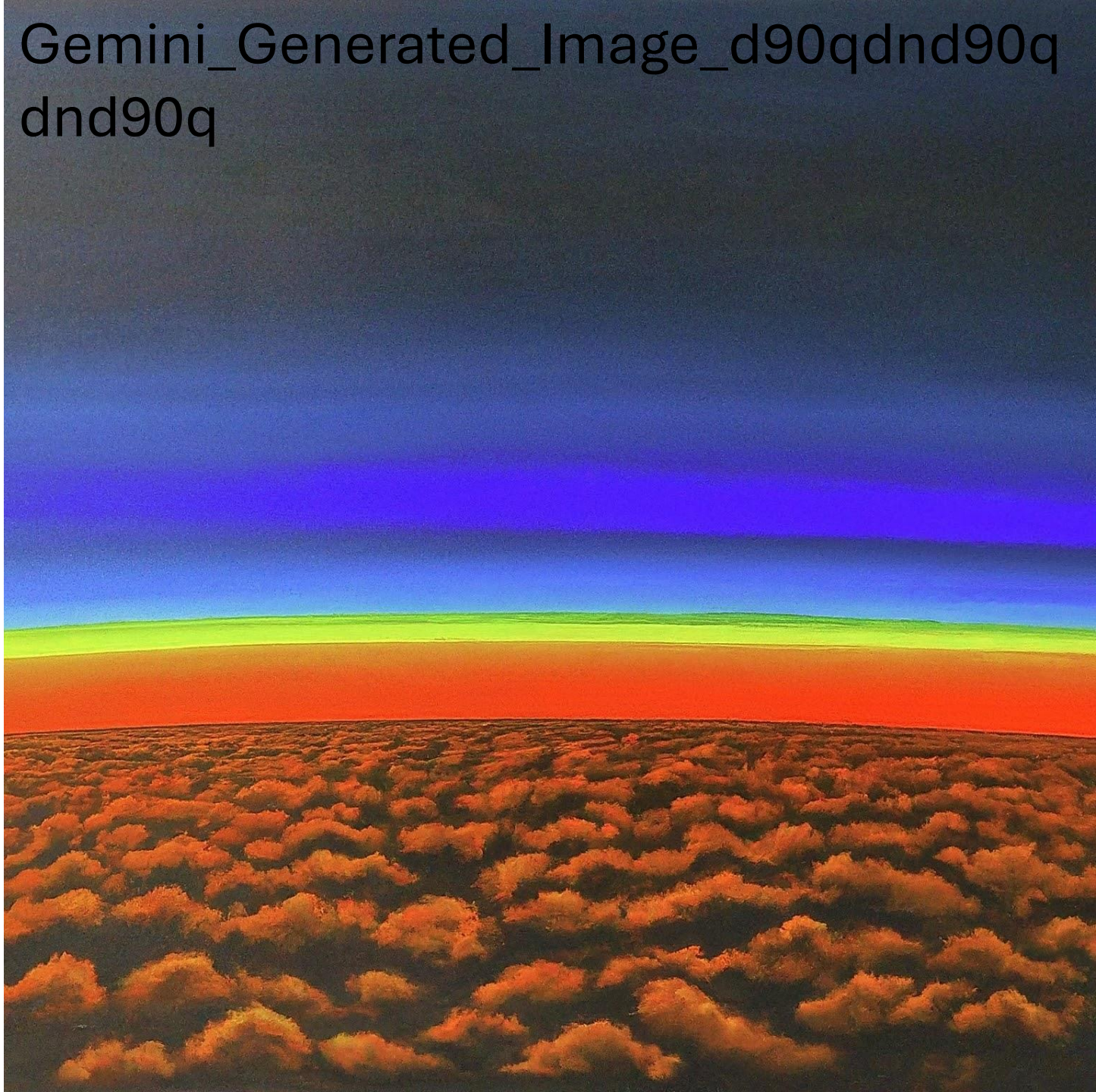
Conclusions

- Removing years affected by volcanic eruptions/wildfires is critical to study the ATAL
- SAGE II/SAGE III observations can be used to study the ATAL but careful screenings is required
- Comparison between SAGE III/ISS and CALIPSO during 2017-2018 remains challenging due to multiple events entering AMA
- Long-term analysis between 1995-2024 still under investigation to remove years affected by volcanic eruptions/wildfires

Thank You !

AI about the ATAL

Me: Please, create a painting about the Asian Tropopause Aerosol Layer
Gemini: Sure, here is a painting about the Asian Tropopause Aerosol Layer:



2017 and 2018 with SAGE III/ISS and CALIPSO
- Derive Lidar Ratio
- Trend discussion
- Wildfires and Volcanic eruptions should be excluded while looking at inter-annual variability
- Rubel :

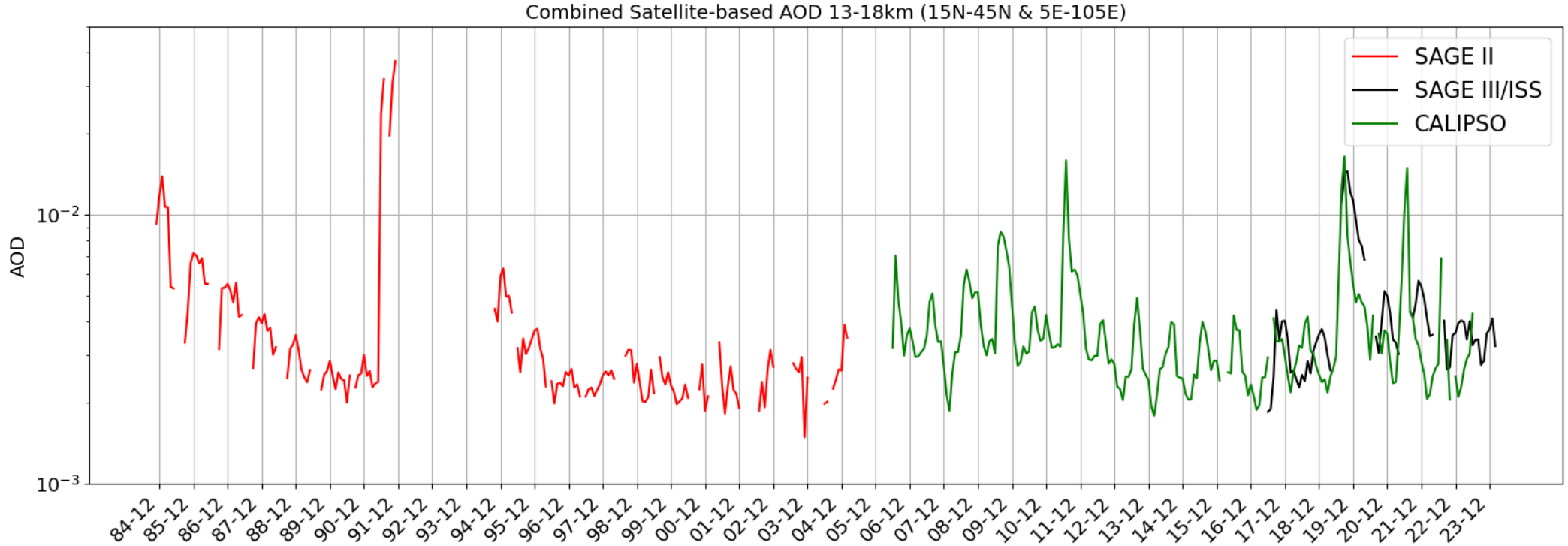
Extinction profiles cloud-cleared with SER2 averaged between 5-105E and 15-45N at 525 (SAGE II) and 520 nm (SAGE III/ISS)

Redo Figure cloud-clearing 5-105E instead 15-105

Trend analysis

- Exclude periods affected by volcanic activities

Extra Slides


Combined Satellite-based AOD 13-18km (15N-45N & 5E-105E)
AOD
10^{-2}
10^{-3}
SAGE II
SAGE III/ISS
CALIPSO
84-12
85-12
86-12
87-12
88-12
89-12
90-12
91-12
92-12
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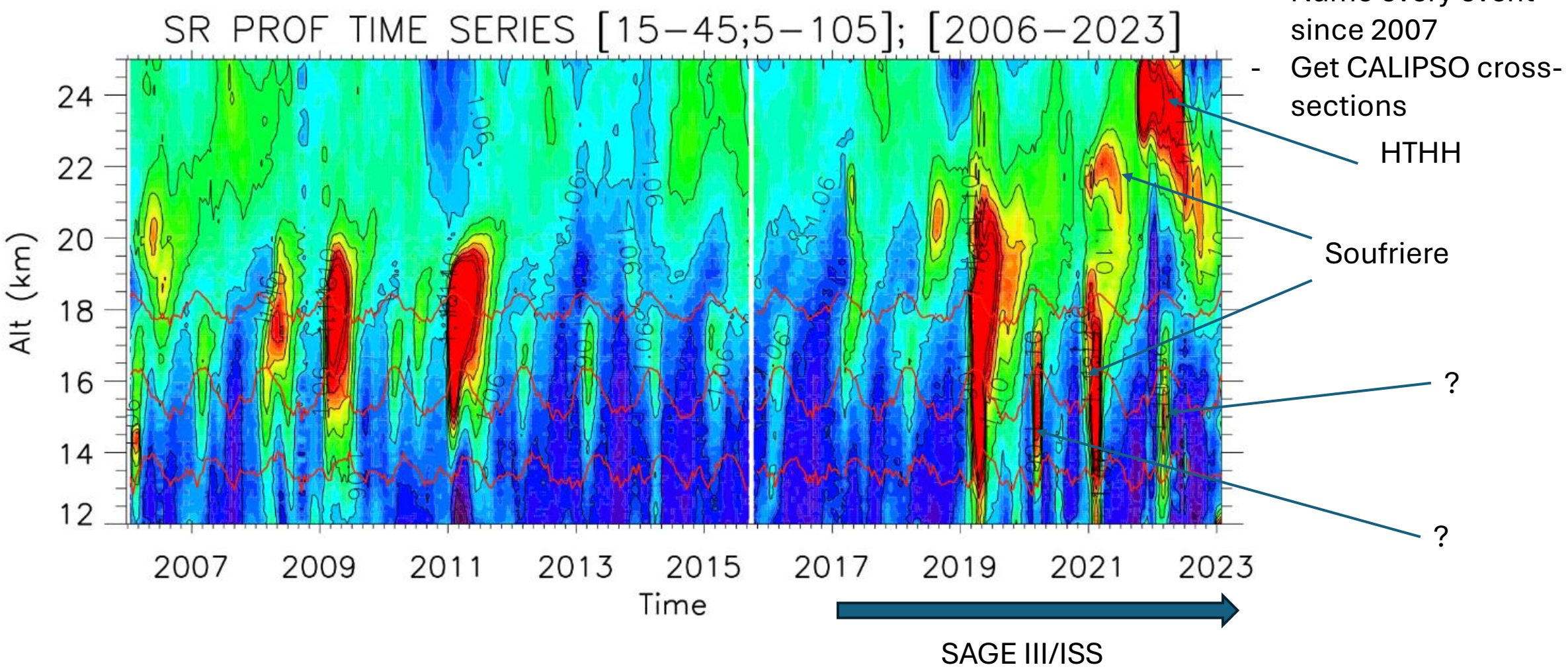
SAGE III/ISS and CALIPSO detection of the ATAL



- Name every event since 2007
- Get CALIPSO cross-sections

HTHH

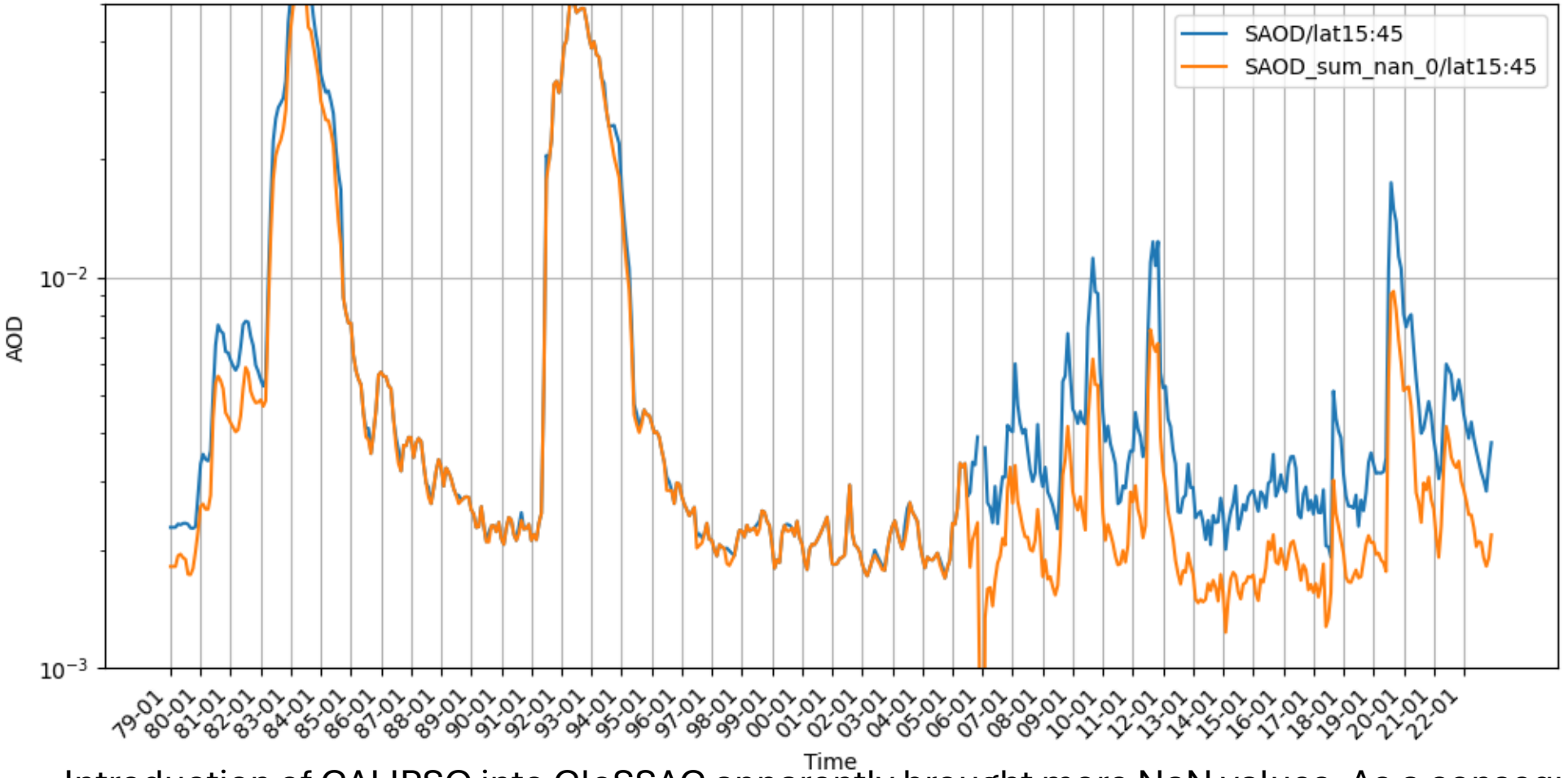
Soufriere

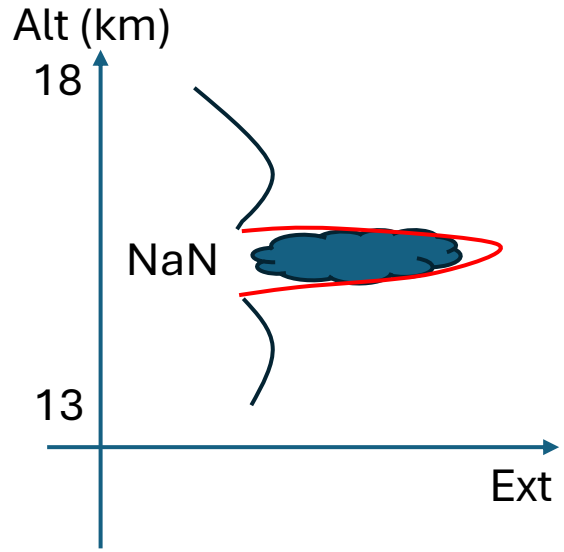
?

?

How to treat NaN (0 versus dot not consider a profile)

GloSSAC V2.1

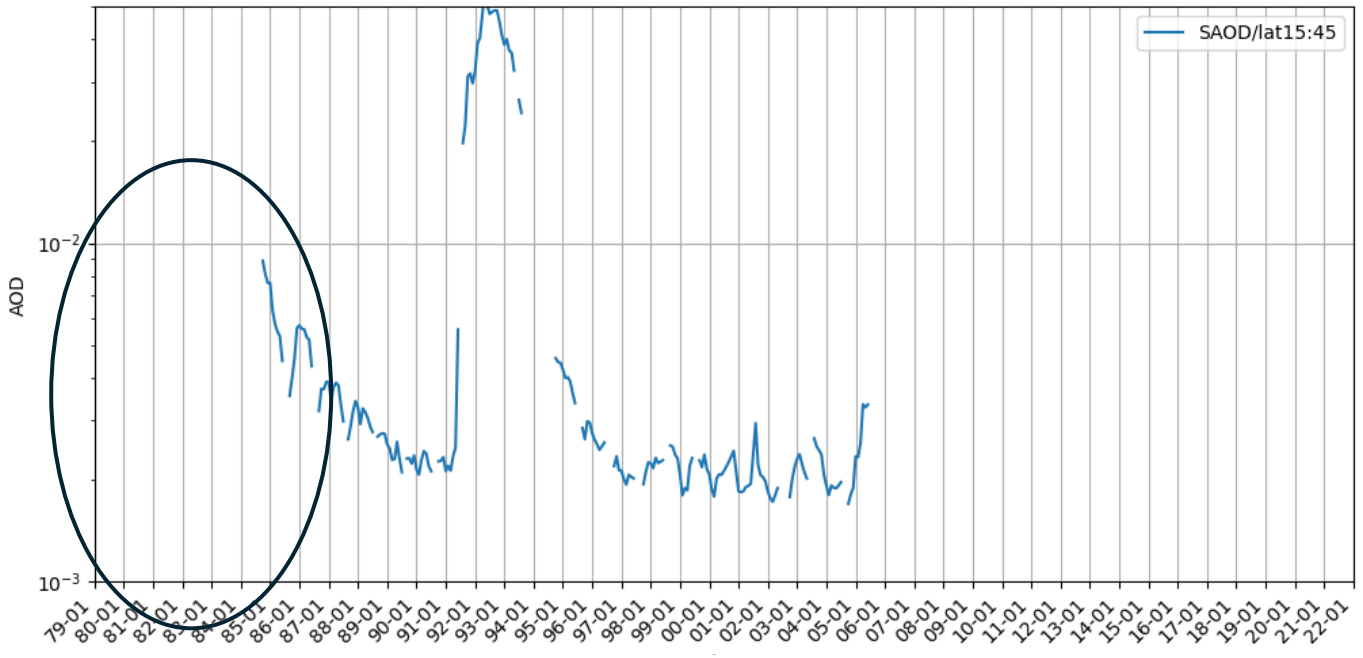




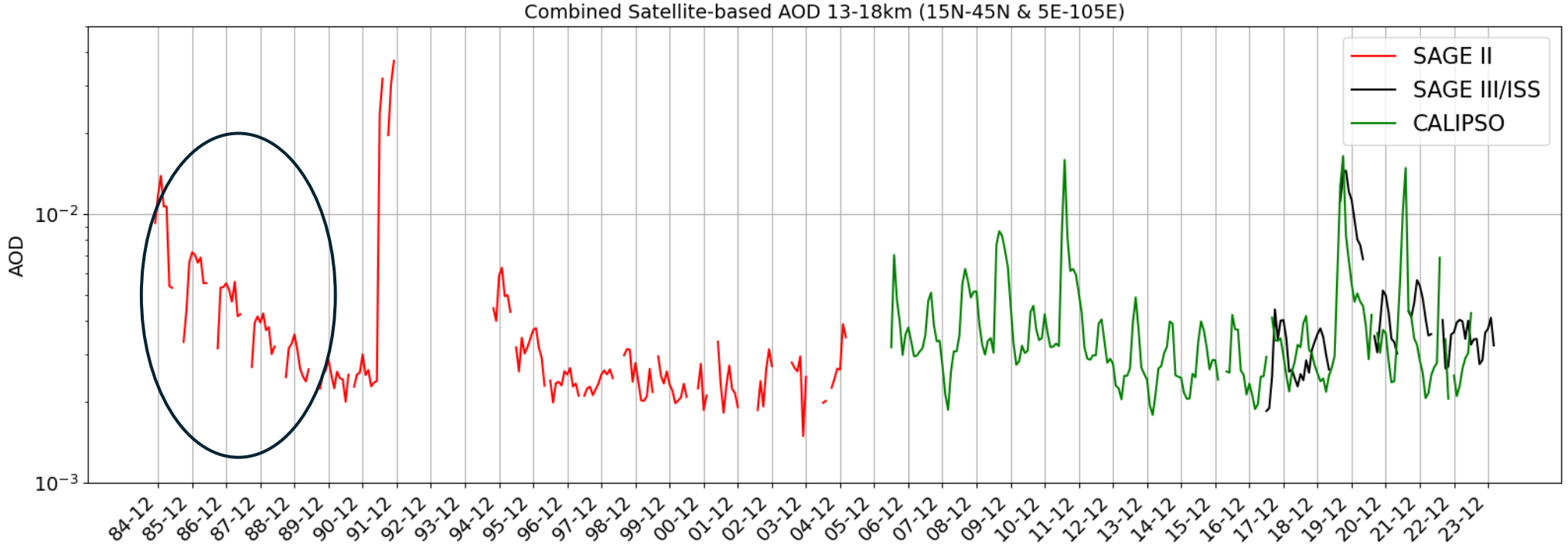
- NaN treated as 0 (np.nansum) in python
- If NaN profile excluded

- Introduction of CALIPSO into GloSSAC apparently brought more NaN values. As a consequence, treating NaN as zeros with np.nansum lead to underestimate the mean AOD

GloSSAC by treating with np.mean and not np.nanmean

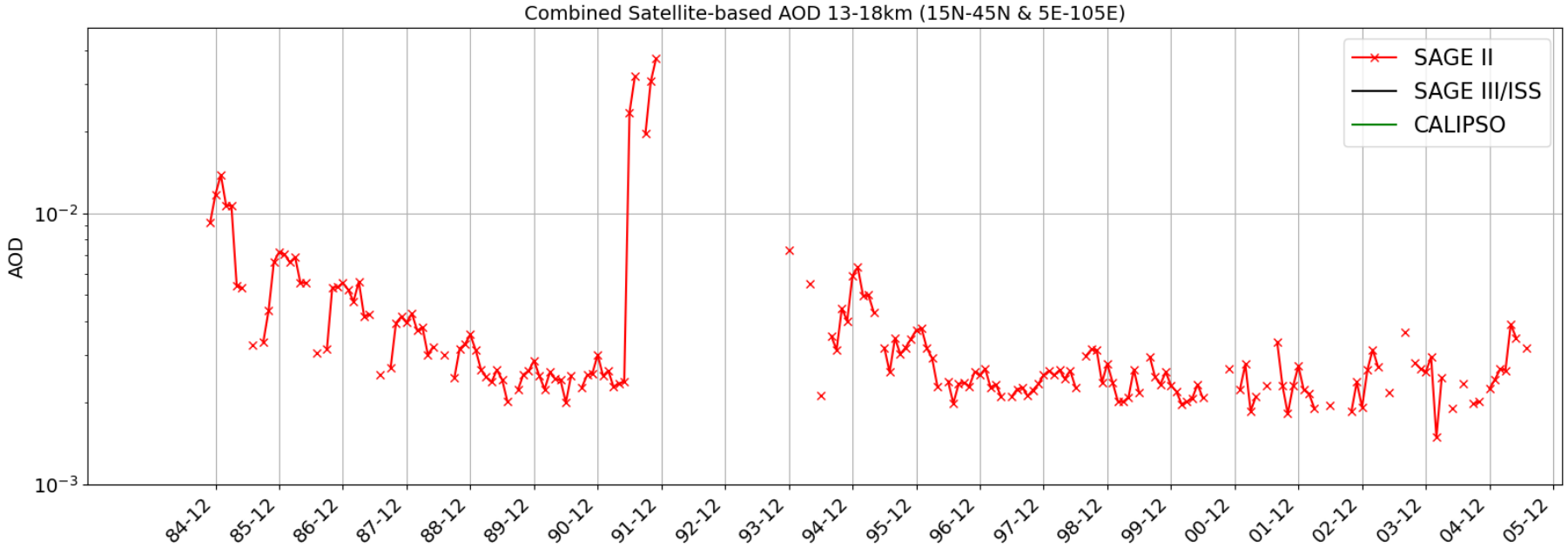


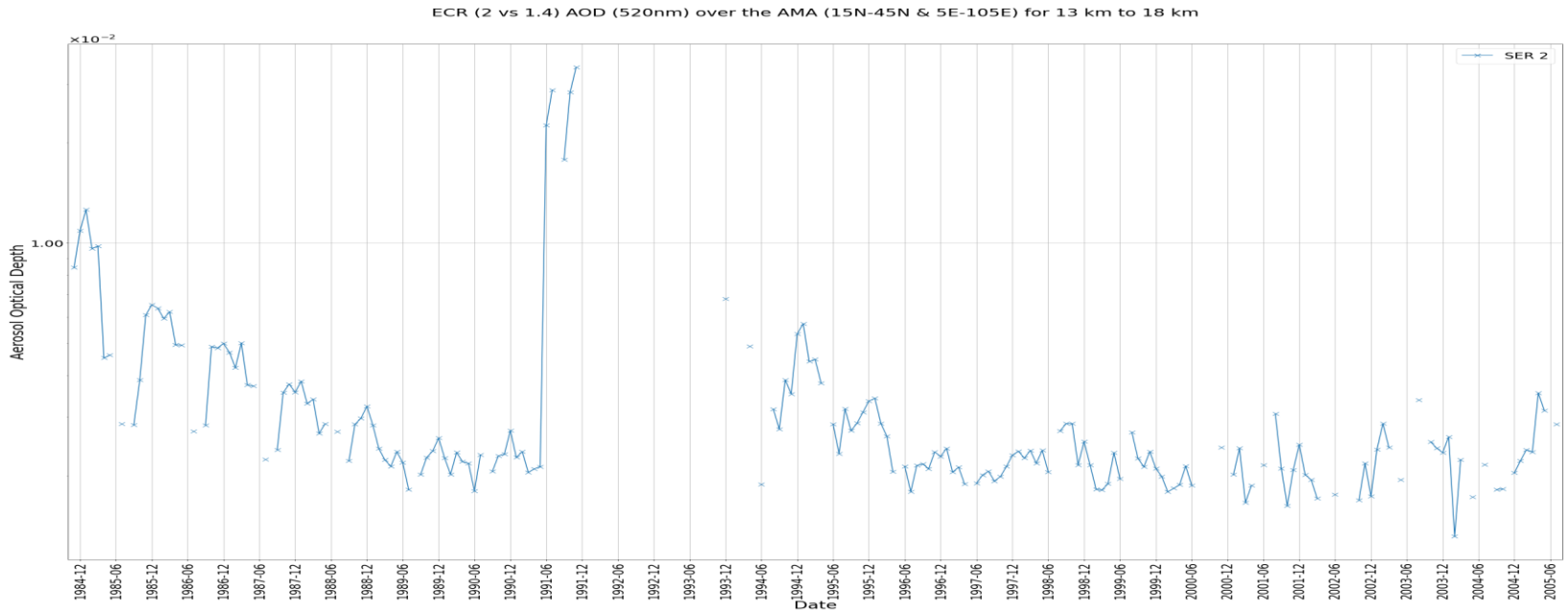
Our analysis aod values only if no nan are present

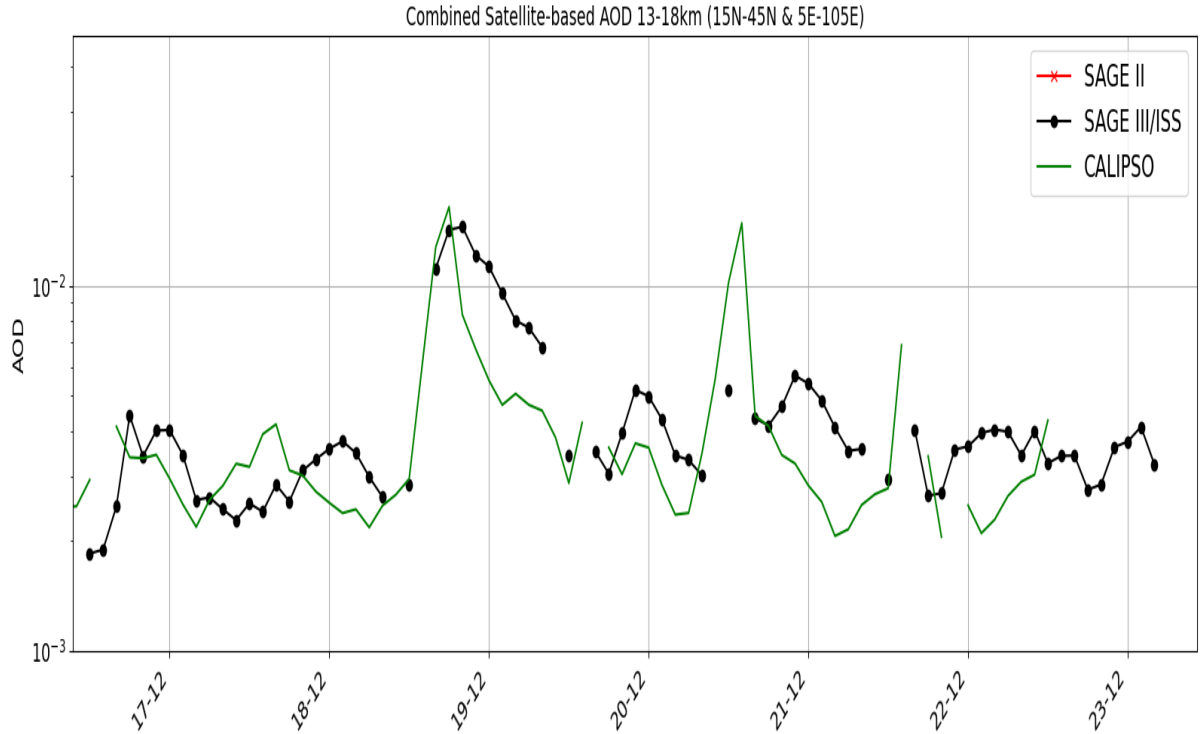


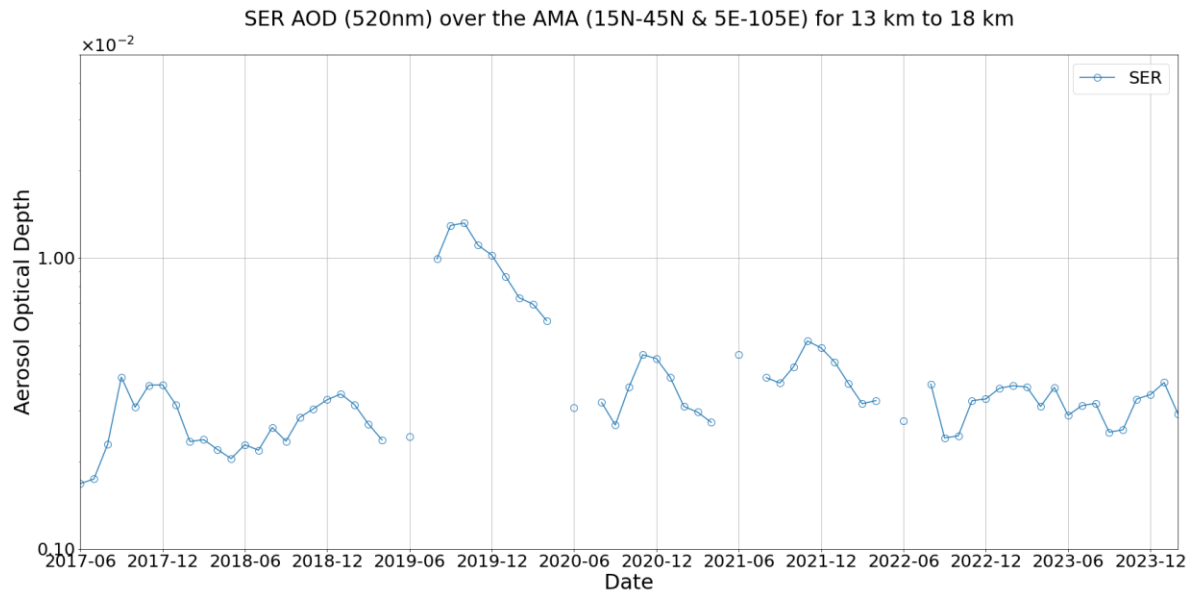
11:00 to 11:25 Tea/Coffee break/Day 2 Tuesday 4 June		
Rapporteur: Dr. Satheesh Chandran		
11:25 to 11:45 Lead oral	Dr. Jean-Paul, Vernier, NASA, LaRC, USA	ATAL's inter-annual variability derived from satellite observations and airborne measurements

15+5min


Combined Satellite-based AOD 13-18km (15N-45N & 5E-105E)
SAGE II
SAGE III/ISS
CALIPSO
AOD
10^{-2}
10^{-3}
84-12
85-12
86-12
87-12
88-12
89-12
90-12
91-12
92-12
93-12
94-12
95-12
96-12
97-12
98-12
99-12
00-12
01-12
02-12
03-12
04-12
05-12


ECR (2 vs 1.4) AOD (520nm) over the AMA (15N-45N & 5E-105E) for 13 km to 18 km
×10⁻²
SER 2
Aerosol Optical Depth
1.00
Date


Combined Satellite-based AOD 13-18km (15N-45N & 5E-105E)
SAGE II
SAGE III/ISS
CALIPSO
AOD
10^{-2}
10^{-3}
17-12
18-12
19-12
20-12
21-12
22-12
23-12


SER AOD (520nm) over the AMA (15N-45N & 5E-105E) for 13 km to 18 km
$\times 10^{-2}$
SER
Aerosol Optical Depth
1.00
0.10
2017-06
2017-12
2018-06
2018-12
2019-06
2019-12
2020-06
2020-12
2021-06
2021-12
2022-06
2022-12
2023-06
2023-12
Date