Exceptional aerosol load observed in the arctic during summer 2019

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Ny-Alesund Atmosphere Flagship online seminar
10 April 2025 09:00 CEST

Universidad de Valladolid

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Consiglio Nazionale delle Ricerche

AWI

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Data & Projects

NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research

Re-evaluation and Homogenization of Aerosol Optical Depth Observations in Svalbard (ReHearsol)

RCN Project No: 311250/E40 - ReHearsol Final Report

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https://nilu.brage.unit.no/nilu-xmlui/handle/11250/3012843

SESS Report 2022

SIOS Svalbard Integrated Arctic Earth Observing System

Published January 23, 2023 | Version v1

Report Open

Long-term observations of aerosol optical depth and their relation to in-situ aerosol properties in the Svalbard region (LOAD-RIS)

Hansen, Georg[1]; Kouremeti, Natalia[2]; Gilardoni, Stefania[3]; Stebel, Kerstin[1]; Evangeliou, Nikolaos[1]; Ritter, Christoph[4]; Zielinski, Tymon[5]; Herrero, Sara[6]; Kazadzis, Stelios[2]; Mateos, David[6]; Mazzola, Mauro[3]; Pakszys, Paulina[5]; Eleftheriadis, Konstantinos[7]

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This is chapter 2 of the State of Environmental Science in Svalbard (SESS) report 2022.

Aerosols are an important constituent of the atmosphere both influencing the climate system and contributing to increasing pollution of the Arctic. At the same time, their adequate monitoring is a big challenge, as instruments on the ground only can sample aerosols in the lowermost atmosphere. For this reason, these measurements are complemented with observations of aerosol optical depth (AOD) which quantify the total amount of aerosols throughout the atmosphere from the attenuation of direct sunlight (and moonlight). This procedure requires extremely careful instrument calibration and removal of cloud contaminated data. In Svalbard, such measurements have been performed by several research groups with different instruments, mostly in Ny-Ålesund and in Hornsund, but also on research vessels offshore. In the framework of the SSF Strategic Grant project ReHearsol, all AOD data from the Svalbard region since 2002 have been collected and made available to the SIOS research community. They indicate that number and intensity of Arctic haze episodes occurring in late winter and spring have decreased consistently and significantly in the last 20 years, while pollution events in summer/early autumn, caused by boreal biomass burning, are on the rise, though not as consistently. Comparison between in-situ measurements at Gruvebadet Atmosphere Laboratory in Ny-Ålesund and AOD measurements indicate that most (more than 65%) of the episodes with high aerosol load are not captured by surface measurements. This finding does not change when one includes in-situ measurements at Zeppelin Observatory (475 m a.s.l.). Studying extensive high-AOD episodes such as those in summer 2019 requires a multi-tool approach including in-situ and remote-sensing measurements combined with model tools.

https://doi.org/10.5281/zenodo.7376140

The main goal of the ReHearsol project was to collect, inter-compare and quality-assure all observations of aerosol optical depth and black carbon in Svalbard and make them available to the SIOS (and wider scientific) community.

Long-term observations of aerosol optical depth and their relation to in-situ aerosol properties in the Svalbard region (LOAD-RIS)

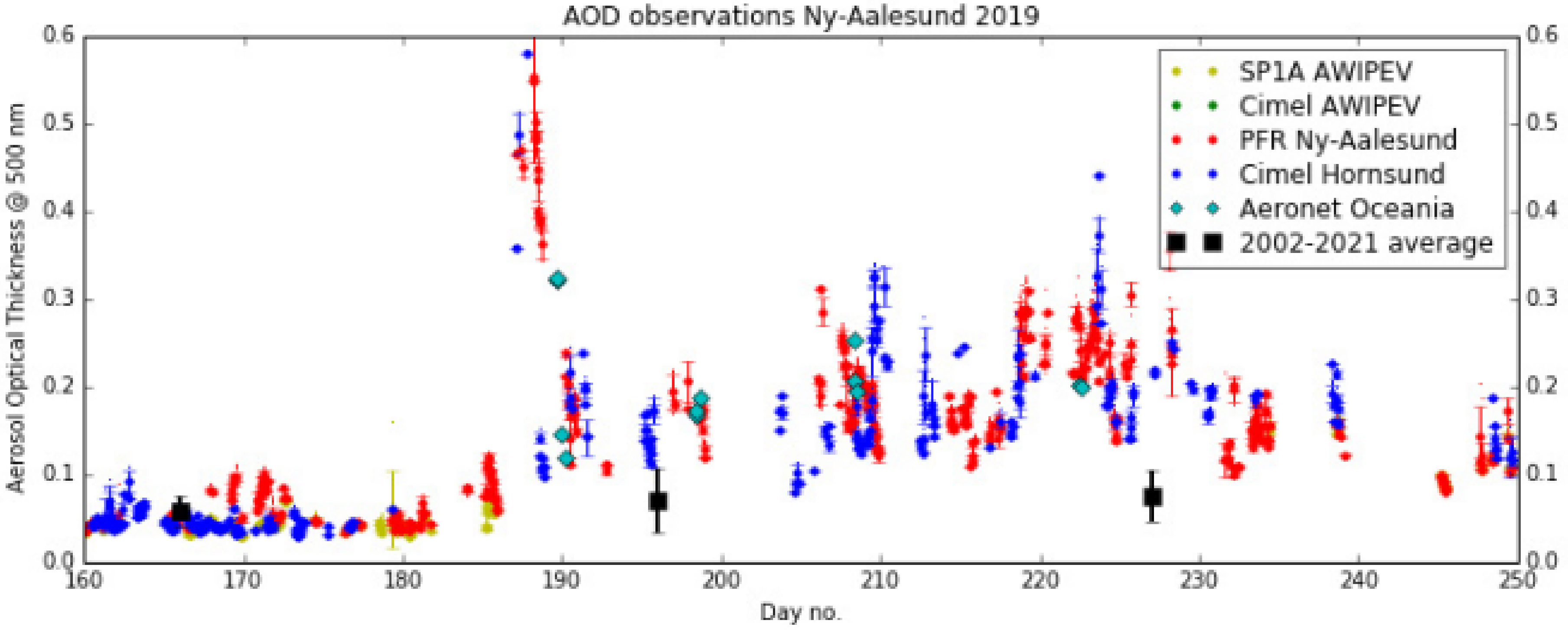
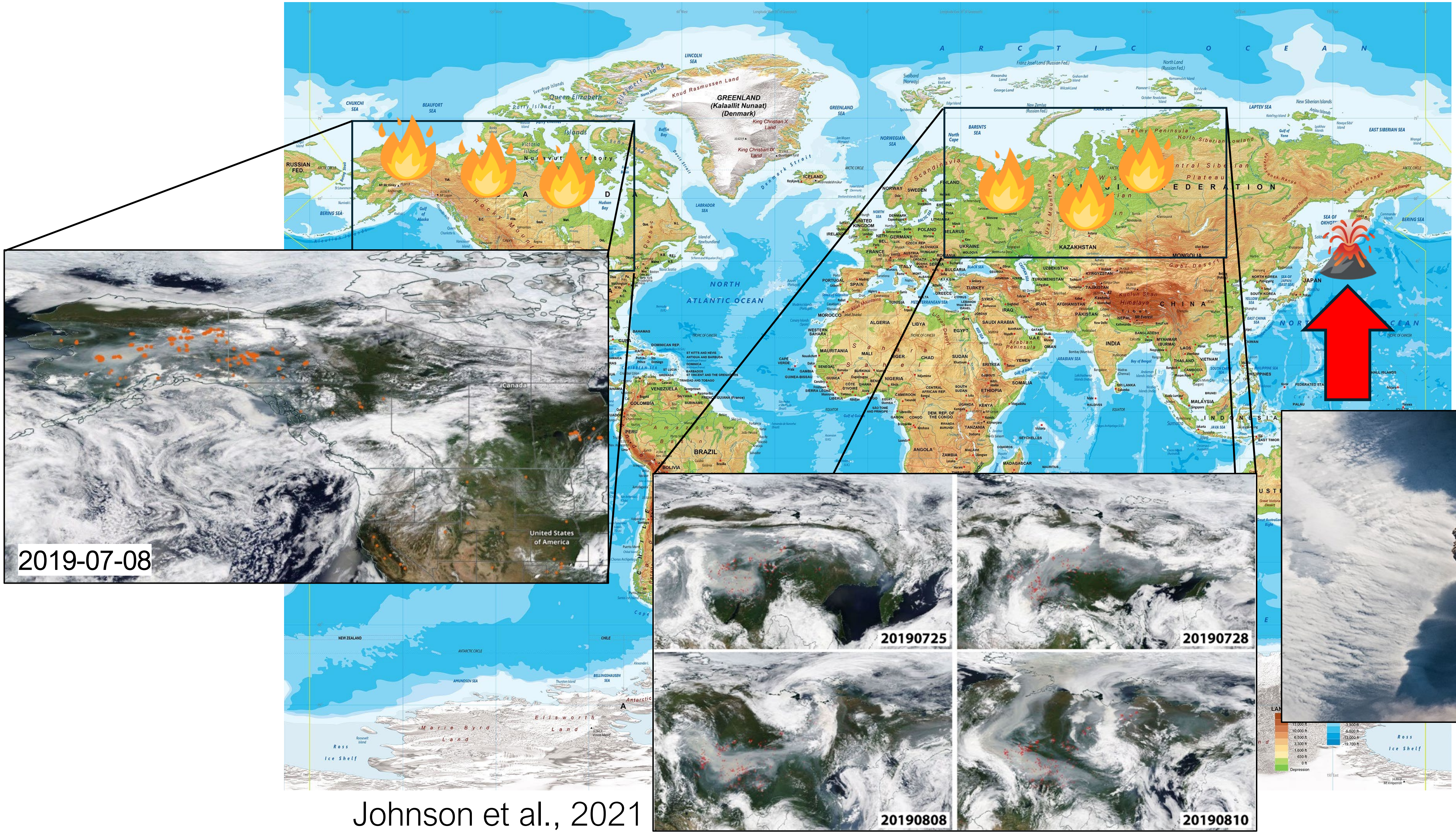


Figure 6: AOD measurements (hourly means with standard deviation of single measurements) performed in and around Svalbard in summer 2019 (9 June–6 September), with data from Ny-Ålesund, Hornsund and *R/V Oceania* (in the Fram Strait). Long-term monthly means of PFR measurements in Ny-Ålesund are shown as black squares with error bars. No CIMEL measurements were made in Ny-Ålesund in this time interval of 2019.

2019 events

Raikoke volcanic eruption
Wildfires in North America
Wildfires in Siberia



Johnson et al., 2021

June 22, 2019,

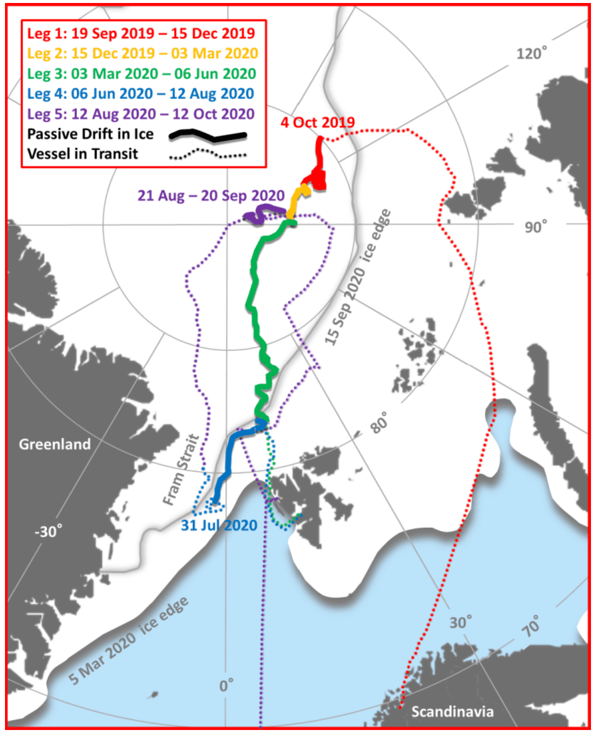
Credits: NASA

MOSAiC

International Arctic Drift Expedition

Multidisciplinary drifting Observatory for the Study of Arctic Climate expedition

September 2019 - October 2020



Ohneiser et al., 2021

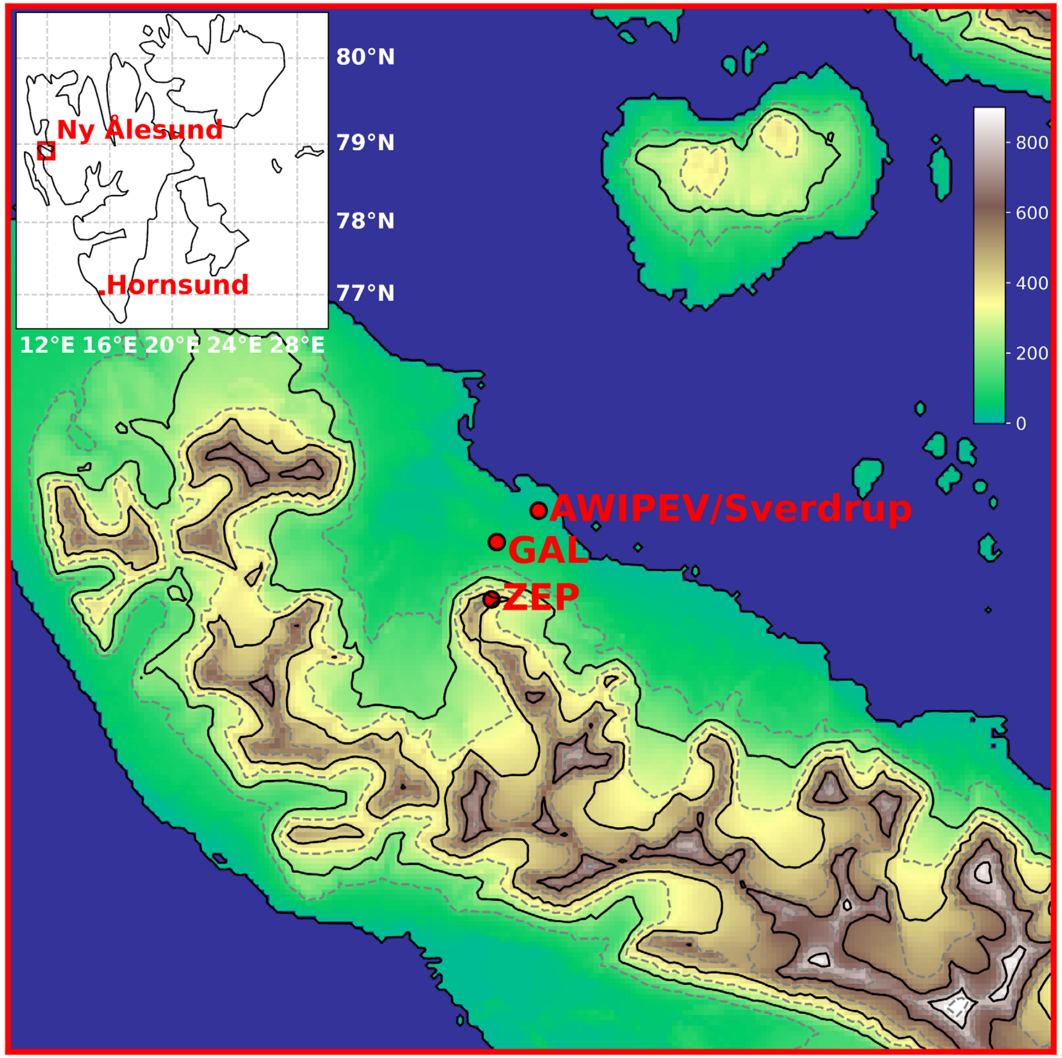
Expected to find a thin aerosol layer AOD (500 nm) 0.005-0.01

- Continuous 10 km deep aerosol layer AOD ~ 0.1 in the UTLS from September 2019 to April 2020
- The Raikoke aerosol fraction was estimated to always be lower than 15 %.
- Clear sign of wildfire smoke dominating aerosol type.

Conclusion: <u>the origin of this aerosol remains unclear</u>

Stations & Instrumentation

Site	Coordinates	Instruments	Product
AWIPEV	78.92° N 11.92° E 7 m a.s.l.	SP1A	AOD 550 nm
		KARL	Backscatter profiles at 355, 532 and 1064 nm
		Radiometers	Direct solar radiation
		CMP22 Pyranometer	Upward and downward solar radiation (200 to 3600 nm)
		CGR4 and Eppley PIR pyrgeometers	Upward and downward thermal radiation (4.5 to 42 μm)
Sverdrup	78.92° N 11.93° E 10 m a.s.l.	PFR	AOD 550 nm
GAL	78.92° N 11.89° E 20 m a.s.l.	PSAP	aerosol absorption coefficient
		SMPS, APS	aerosol absorption coefficient, aerosol particle number size distribution
ZEP	78.91° N 11.89° E 474 m a.s.l.	SP1A	AOD 500 nm
		AE-31	Aerosol absorption coefficient
Hornsund	77.00° N 15.54° E 12.5 m a.s.l.	CE-318T	AOD at 550 nm, volume size distribution and single scattering albedo at 440, 675, 870 and 1020 nm
R/V OCEANIA	67-85° N 20° W-20° E 0 m a.s.l.	Microtops II	AOD 500 nm
CALIPSO	< 50 km from Ny-Ålesund	CALIOP	Extiction 532 nm

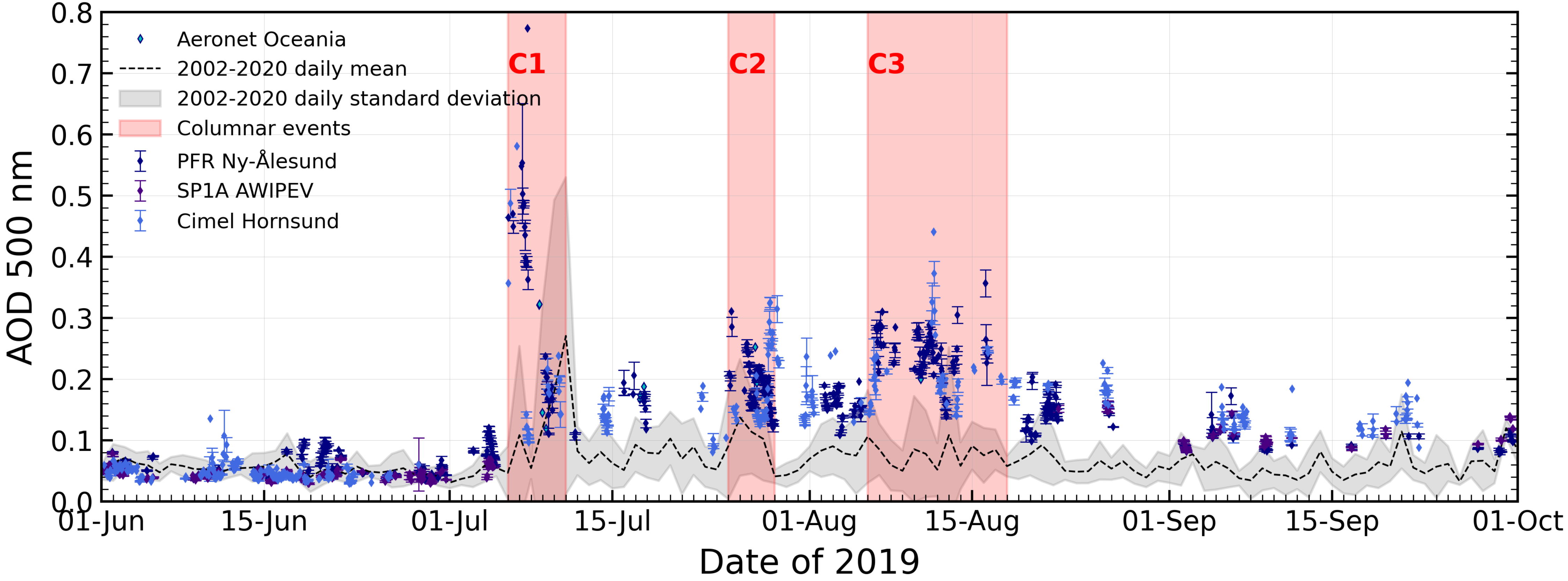


created using the dataset by Moholdt at el. (2019)
doi:10.21334/NPOLAR.2019.675565F7

Methodogy

1. **Sun-photometer** (columnar analysis)
2. **In situ** (Surface analysis)
3. **Lidar** (onboard satellite & ground-based) (Vertical profiling)
4. **Dispersion model** (Origin identification)
5. **Radiative impact** (overall effect)

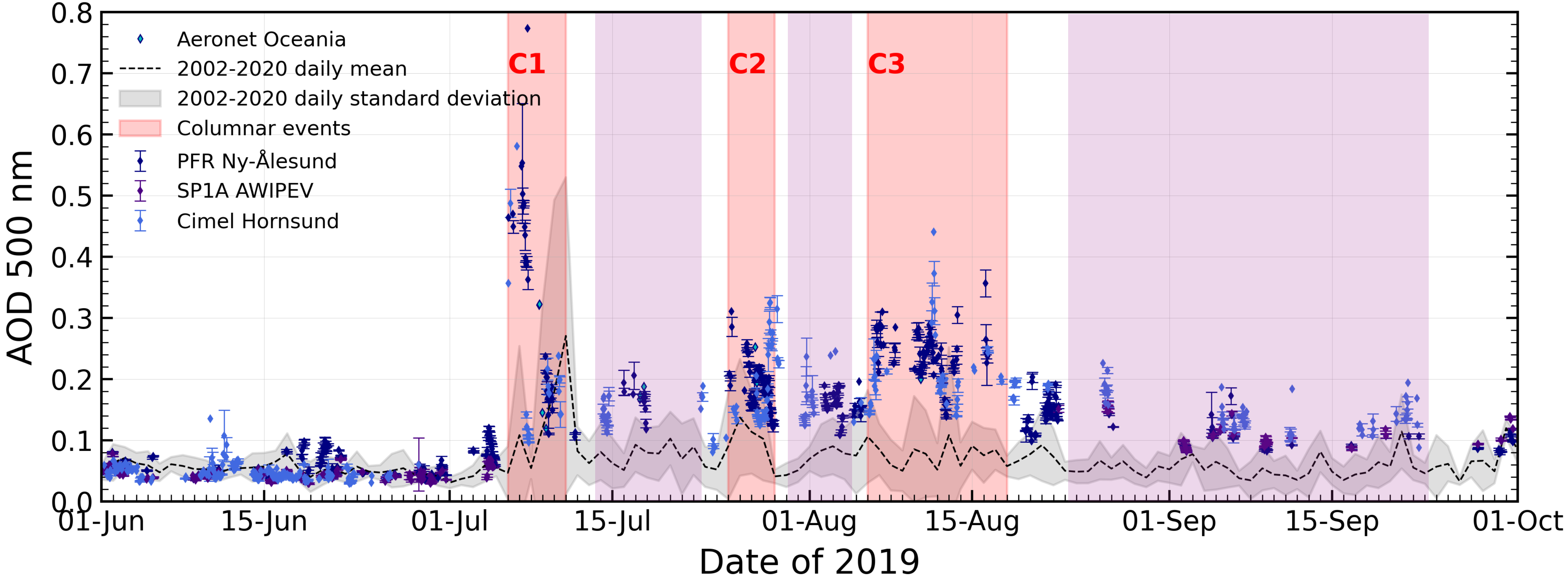
Remote sensing - Sun photometer



COLUMNAR EVENT FLAG AOD at 500 nm > summer average plus 3 times the standard deviation

- **C1 6-10 July**
- **C2 25-28 July**
- **C3 6-17 August**

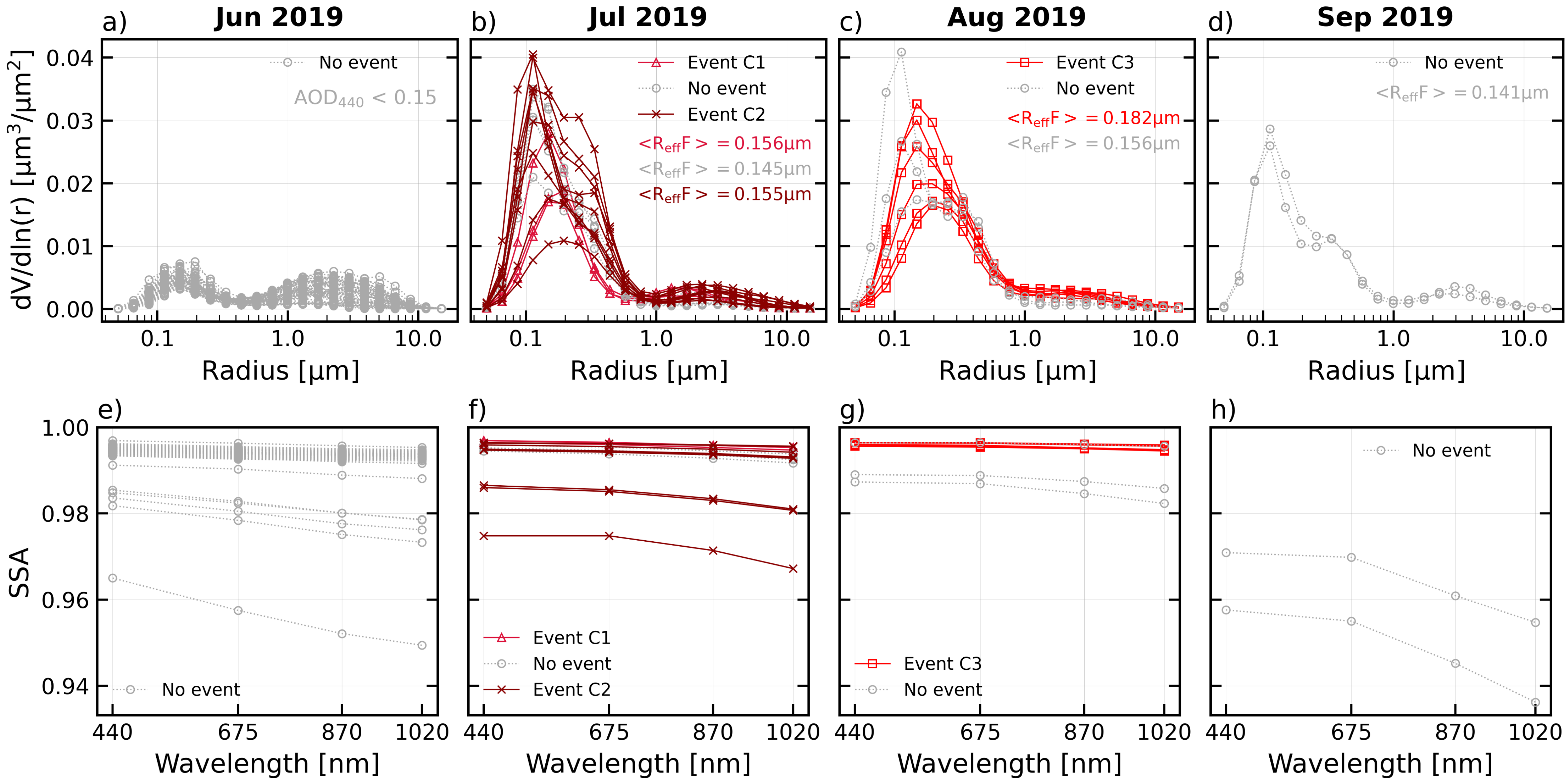
Remote sensing - Sun photometer



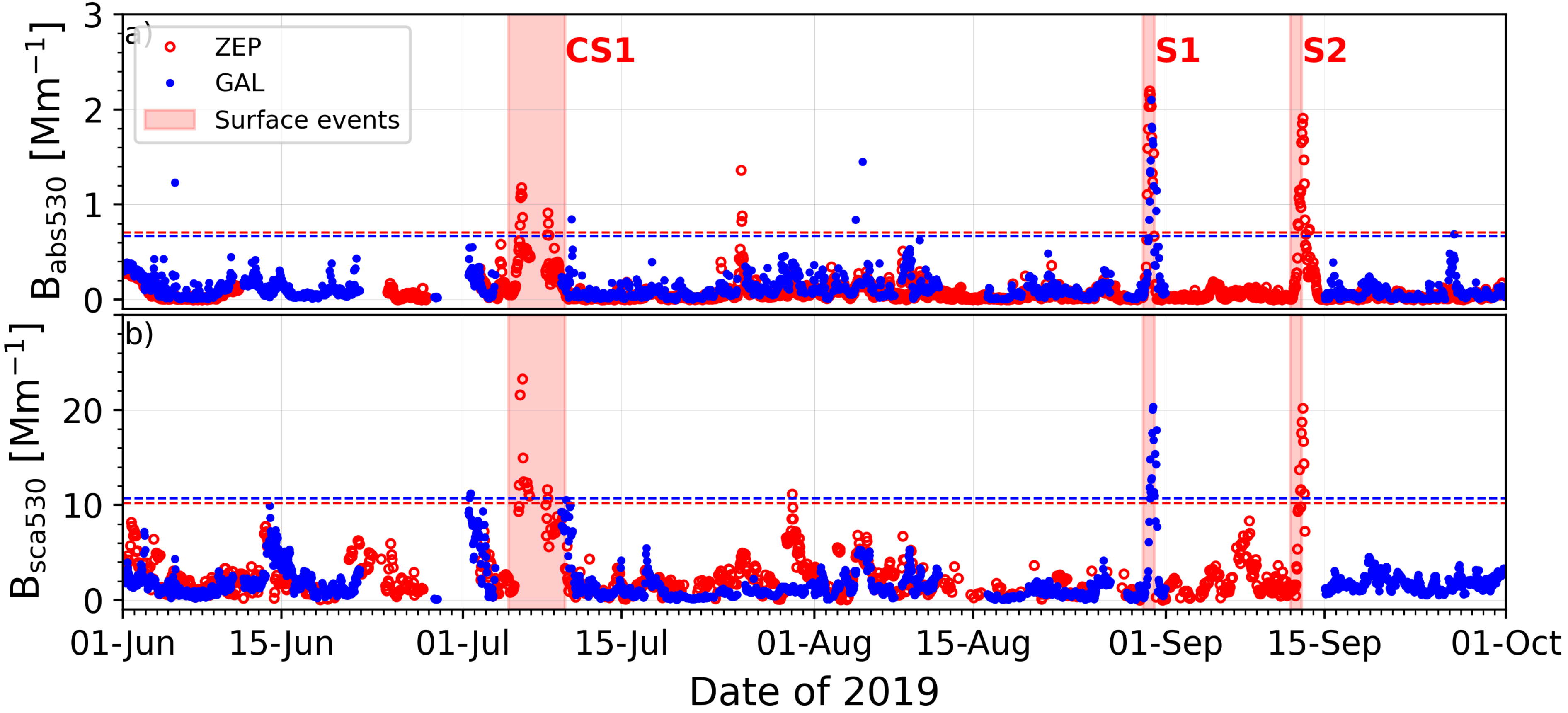
COLUMNAR EVENT FLAG AOD at 500 nm > summer average plus 3 times the standard deviation

- **C1 6-10 July**
- **C2 25-28 July**
- **C3 6-17 August**

Remote sensing – Inversion properties



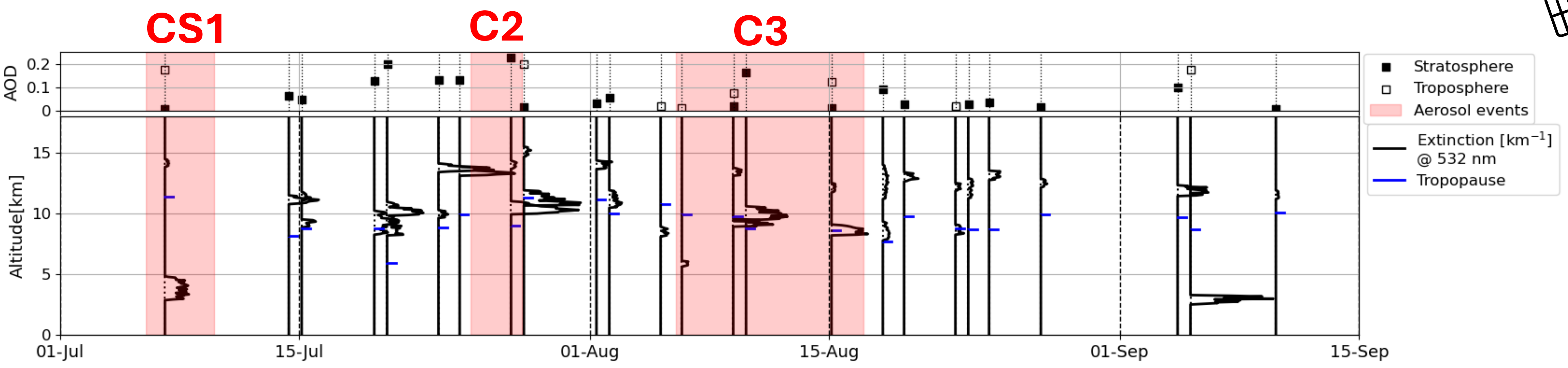
In-situ surface observations



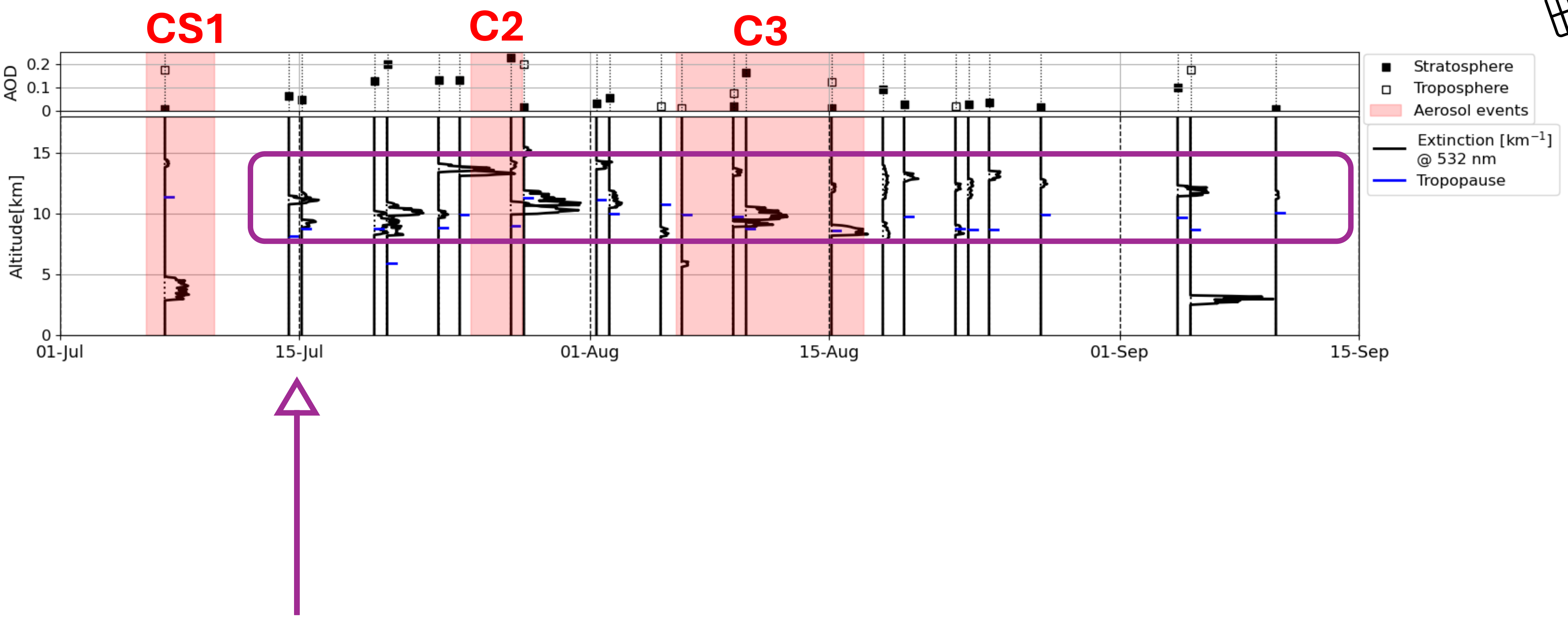
SURFACE EVENT FLAG the logarithm of both Babs530 and Bsca530 2018-2020 summer average + two times the standard deviation (horizontal lines in Figure)

- **C1⇨CS1 5-9 July**
- **S1 30 August**
- **S2 12 September**

CALIOP observations – nearest profile to Ny-Ålesund (in 50 km)

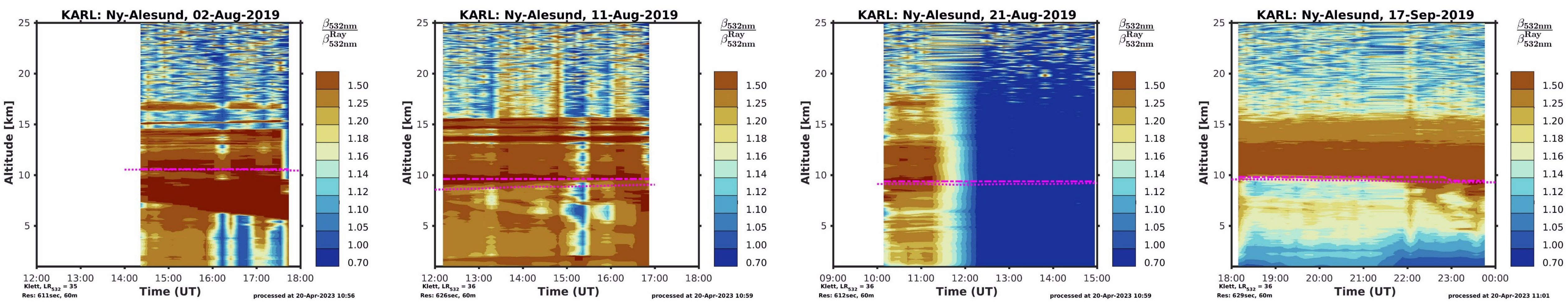


CALIOP observations – nearest profile to Ny-Ålesund (in 50 km)



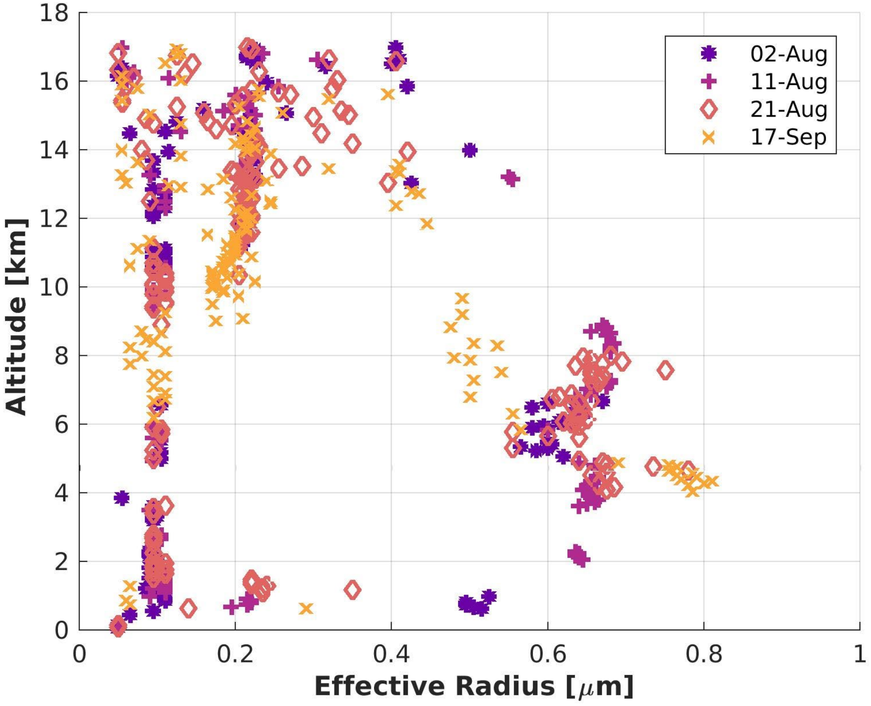
Intense stratospheric layers from ~ 15th july

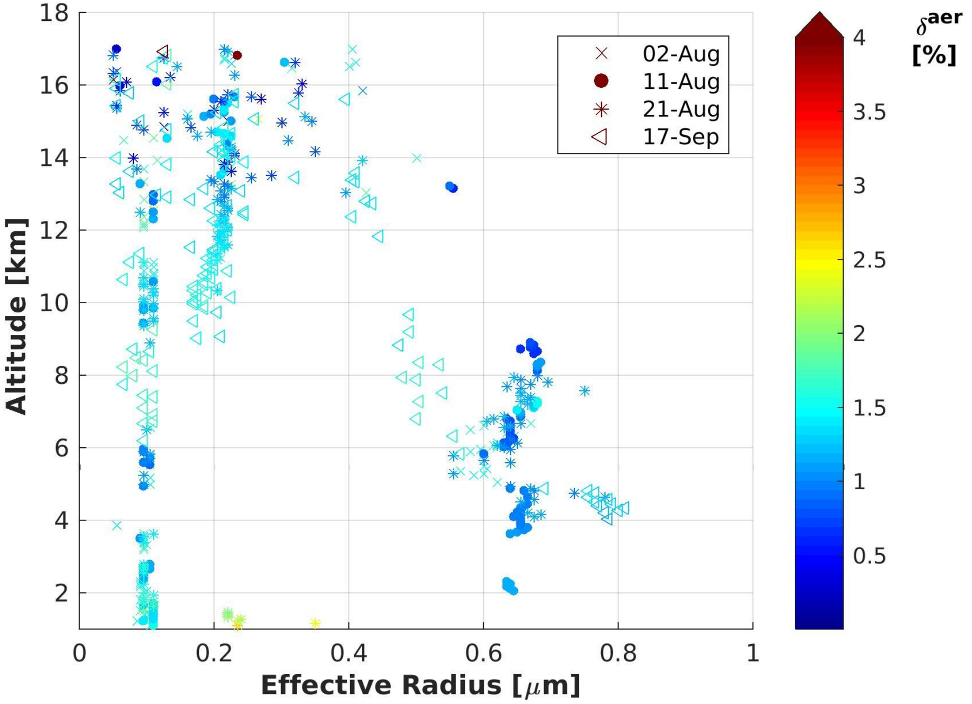
KARL in Ny-Ålesund (AWIPEV)



- The increased backscatter profile of CALIOP correlates in altitude with a **temporally stable layer just above the tropopause.**
- **The lower stratosphere** (up to around 16~km a.g.l.) has in all cases several **thin aerosol layers** with a comparably **strong backscatter coefficient**.

KARL in Ny-Ålesund (AWIPEV): Vertically resolved effective radius





- The **background aerosol** is for all days and the entire troposphere **at around 0.1**µm.
- The **pronounced layers** reveal aerosols from **0.5 to 0.8** µm.
- The results for **Augus**t are **very similar**, while the effective radius for the observation on **17th Septembe**r are about **0.2** µm **smaller** in the altitude range between 7 and 9~km a.g.l. than during August.
- For all four days δaer <3%, indicating **spherical particles.**
- Effective radii are very **similar to the** one **seen by the sun-pho**tometer, especially for the observations in August. The background aerosol has an effective radius of about 0.1 to 0.2 µm.

FLEXPART https://atmo-access.nilu.no/ZEPP_lidar.py

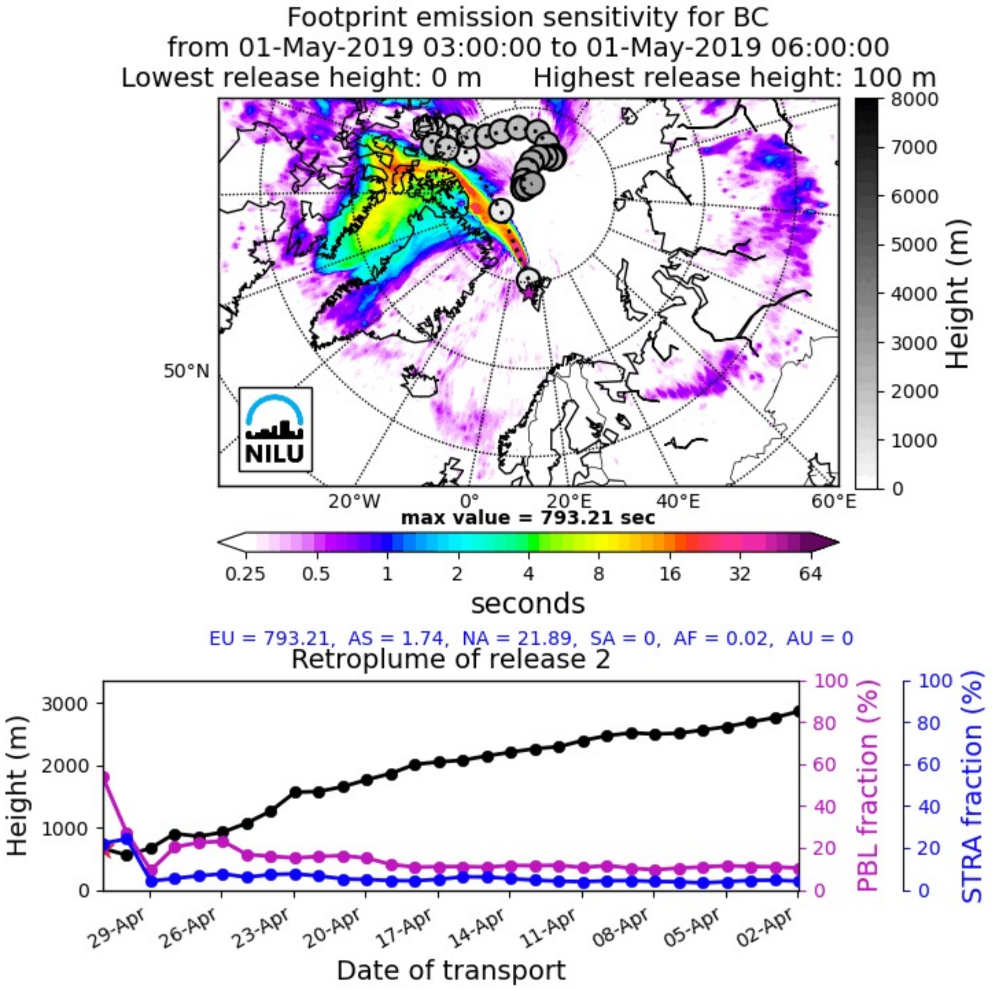
Thanks Nikolaos Evangeliou and Sabine Eckhardt

NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research

FLEXPART products for BC measurements

For support and more information please submit a request here: https://flexpart-request.nilu.no/support

OUT_201905 | 0 | Aerosol | Footprint | regional | FIRST | -10 | PREV | NEXT | +10 | LAST | VIEW PLOT | NETCDF | 2/248
SUBMIT



Developed by N. Evangeliou (ne@nilu.no) and S. Eckhardt (sec@nilu.no) (NILU) under ATMO-ACCESS, EU grant agreement No 101008004

Biomass burning emissions: Copernicus Global Fire Assimilated System (CAMS GFAS)(Kaise et al., 2012)

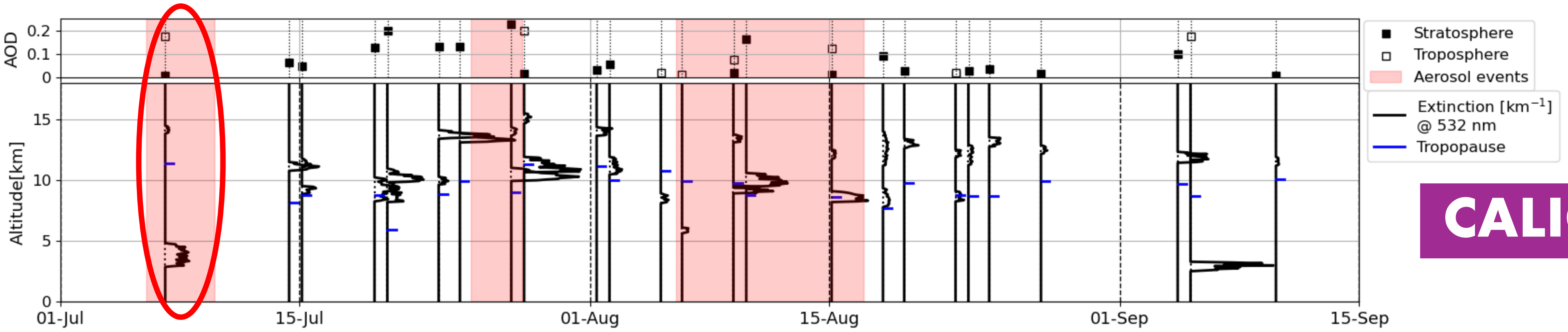
Anthropogenic emissions: v6b of the ECLIPSE (Evaluating the CLimate and Air Quality ImPacts of ShortlivEd Pollutants) emission inventory (Klimont et al., 2017)

Vertically resolved backward trajectories

Altitudes: 0, 100, 500, 4000, 6000 and 10000 m.

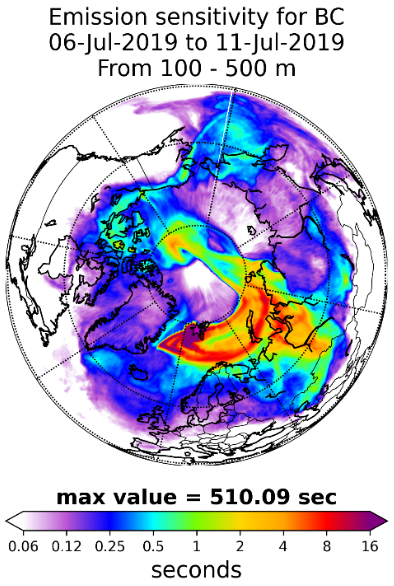
Products:

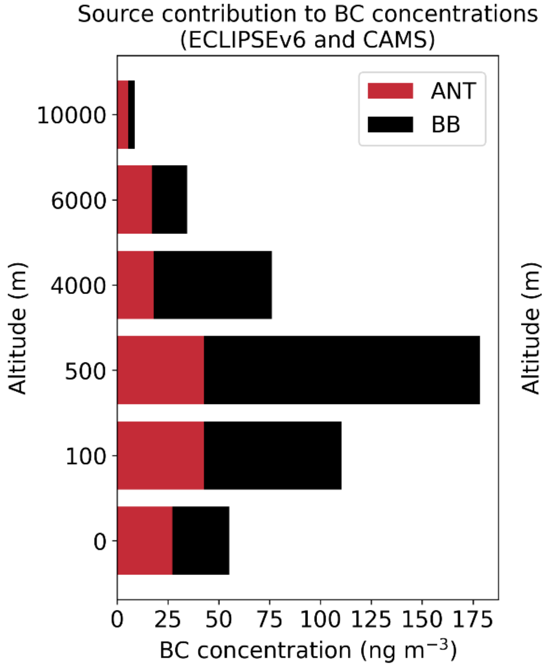
- Footprint: Footprint emissions sensitivity showing the probability of any release occurring in any grid-cell to reach the receptor (station) for 30 days particle tracking. Black carbon.
- Continental contribution: EUROPE, RUSSIA, NORTH AMERICA...
- Source contribution.
- Age contribution.

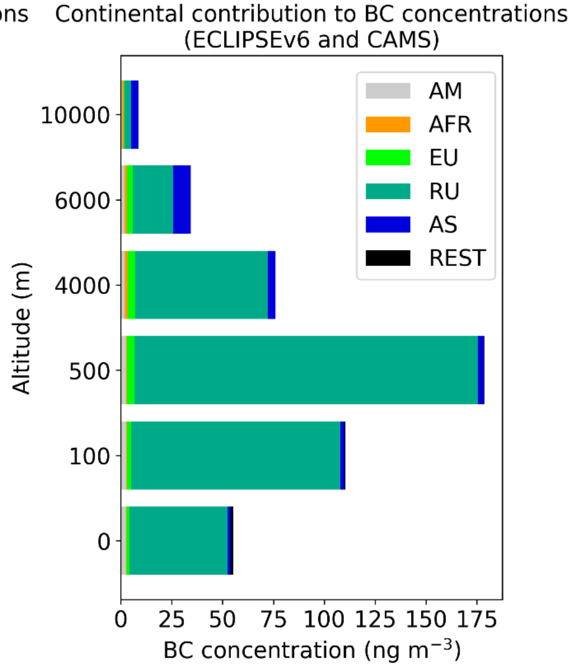


CALIOP

CS1 (4000 m): 5-9th Jul BB aerosol, russian WF







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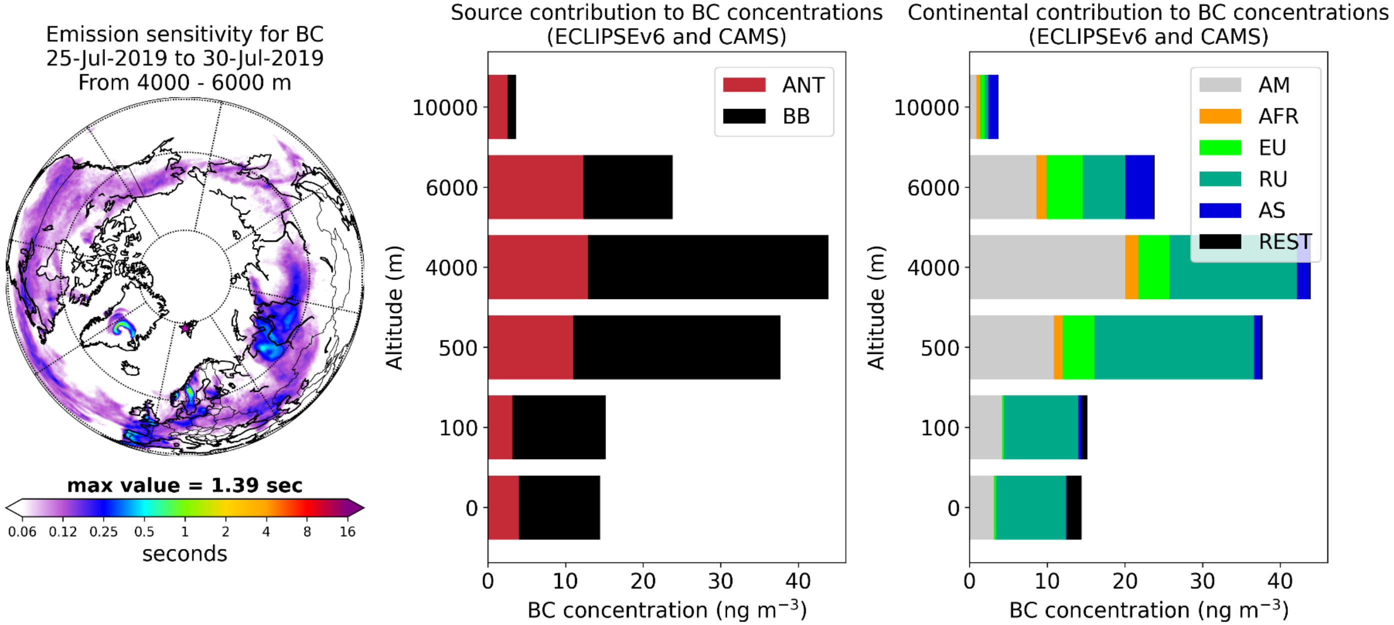
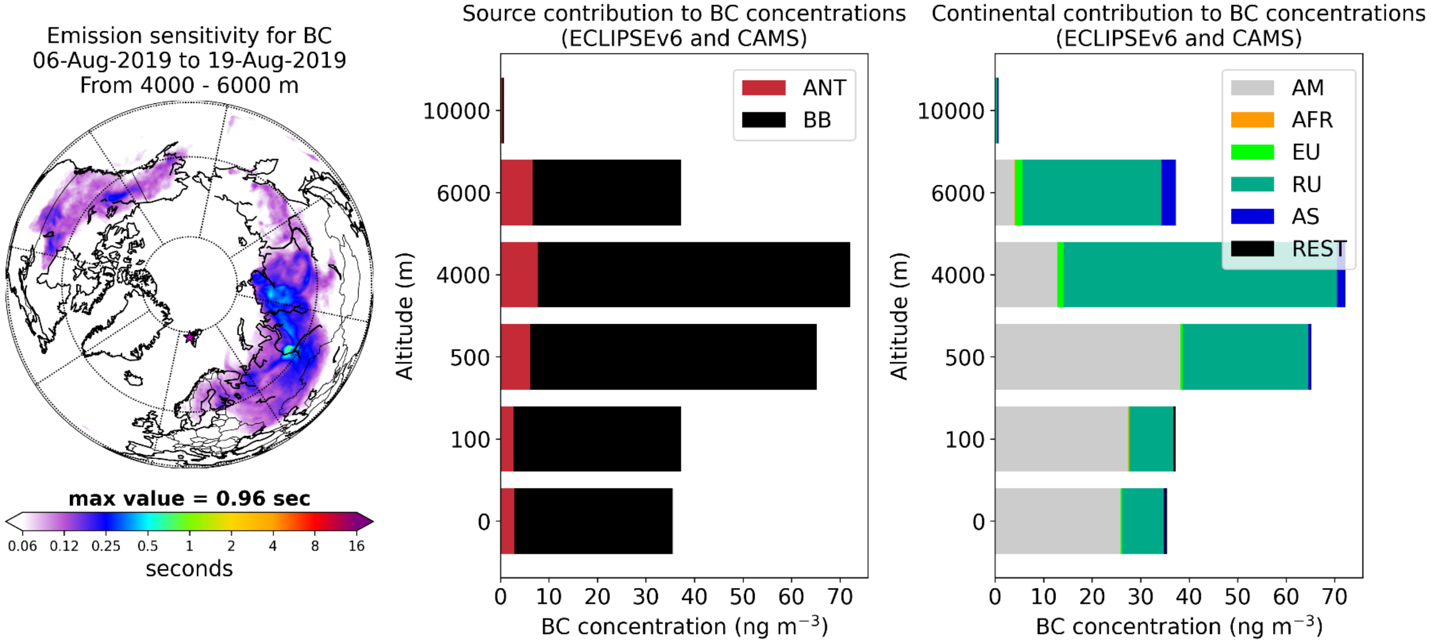
C2 (6000 m): 25 -28th July WF from North America



C3 (4000 m): 6-17th Aug WF from Russia mainly but also from North America



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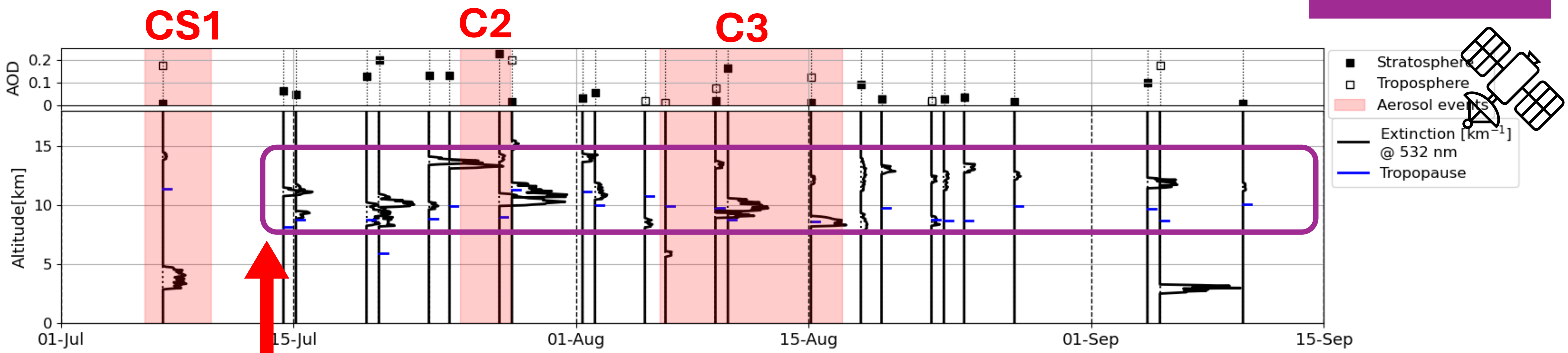
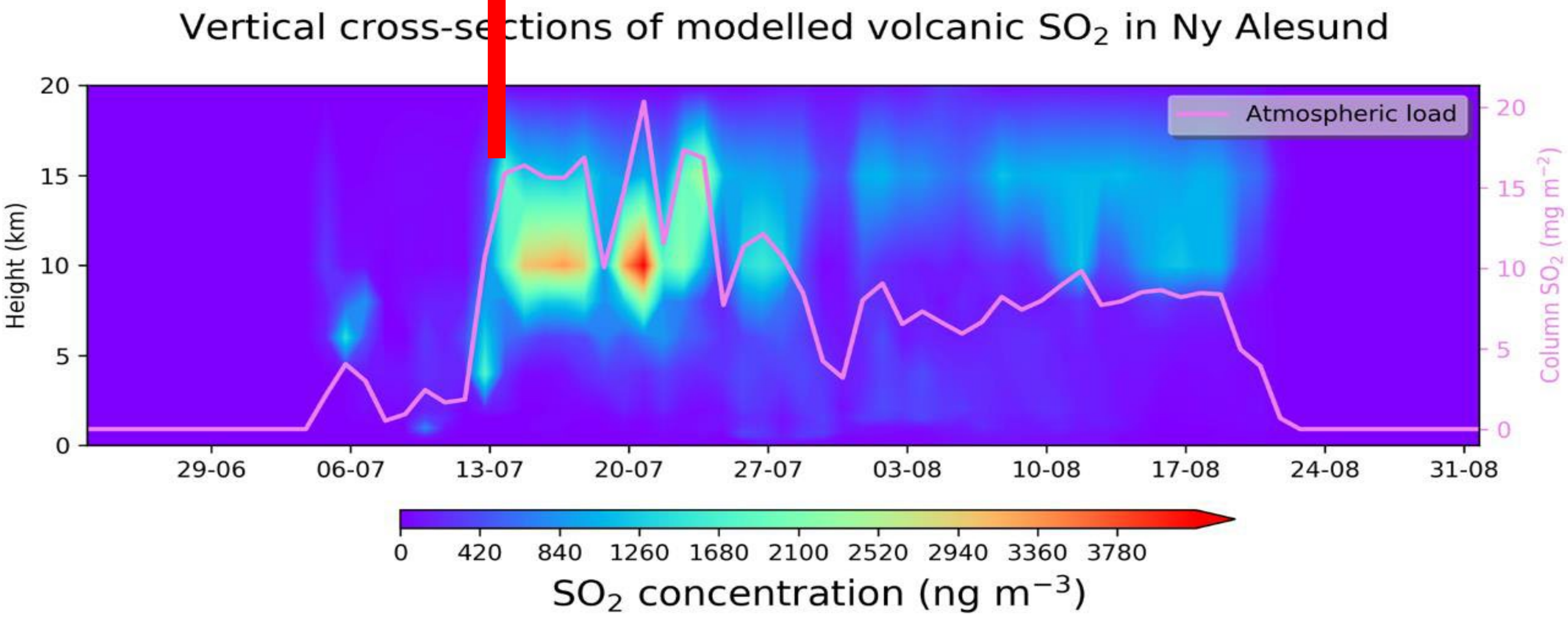
Middle episode: simulations using new inventory for the volcanic SO2 emissions

CALIOP





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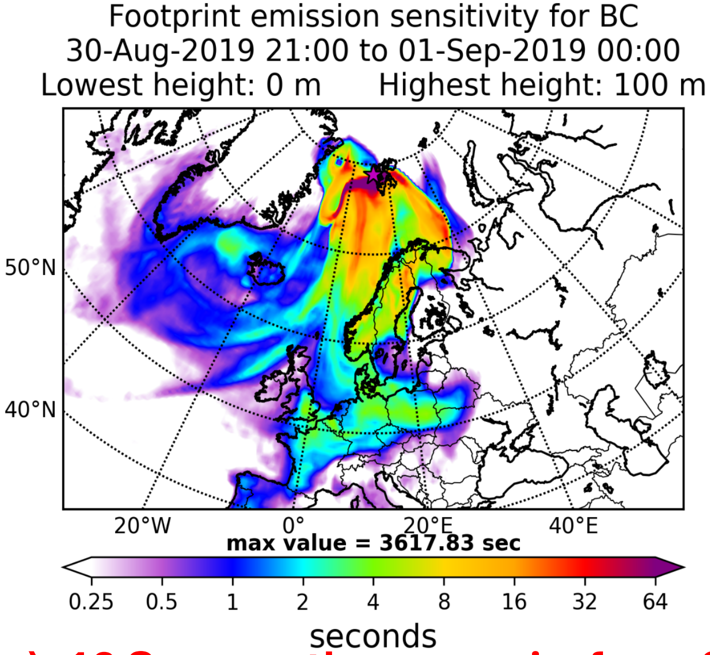
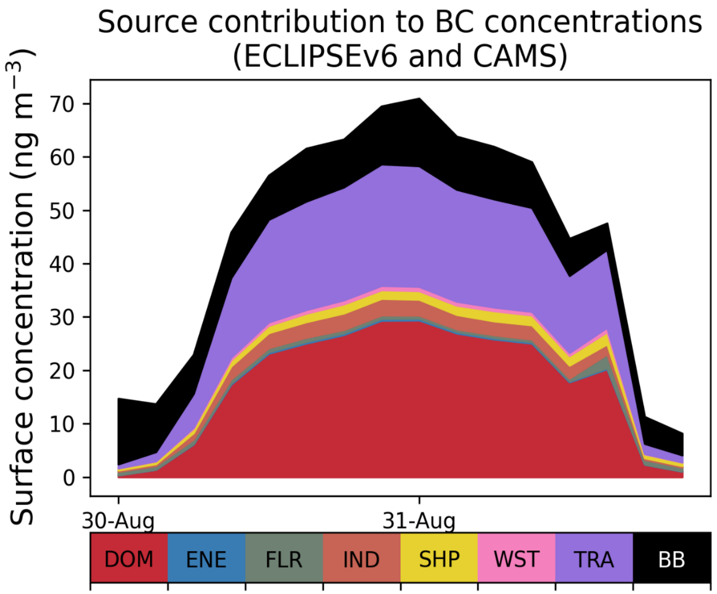
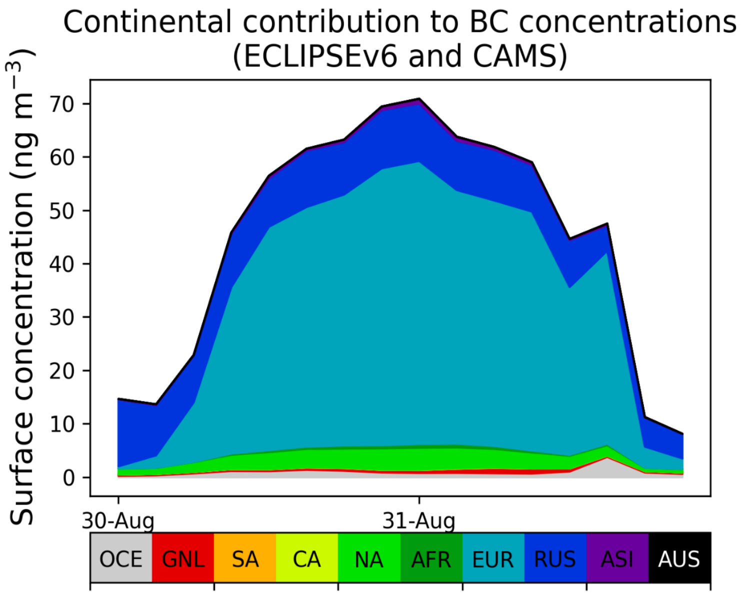
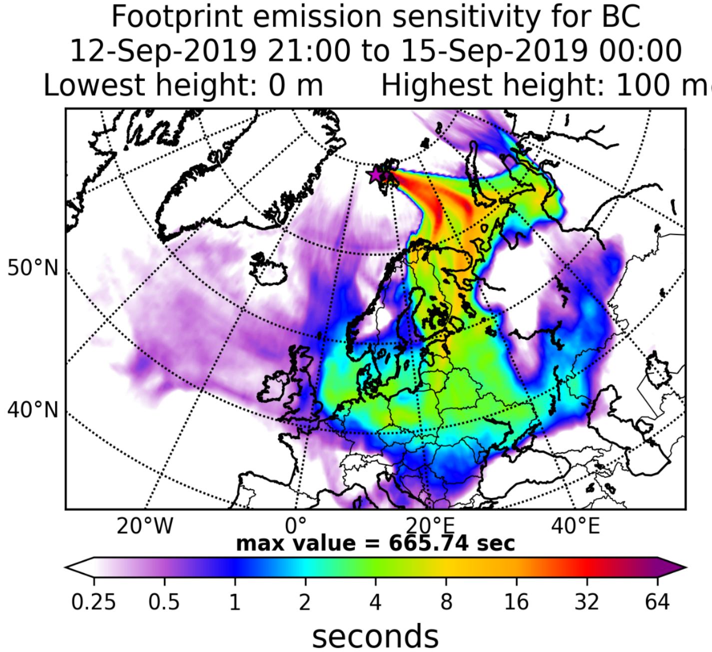
S1 (0 m): 30 Aug – anthropogenic from Finland

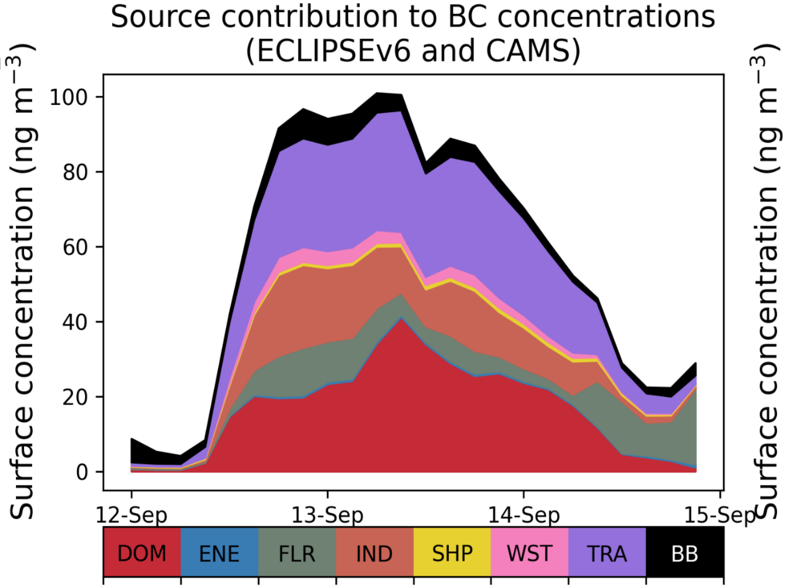


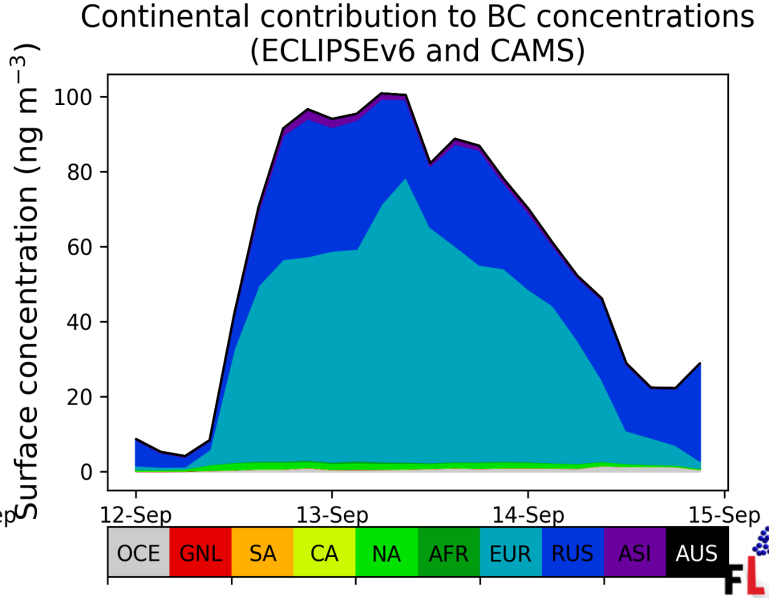




S2 (0m): 12 Sep – anthropogenic from Scandinavia







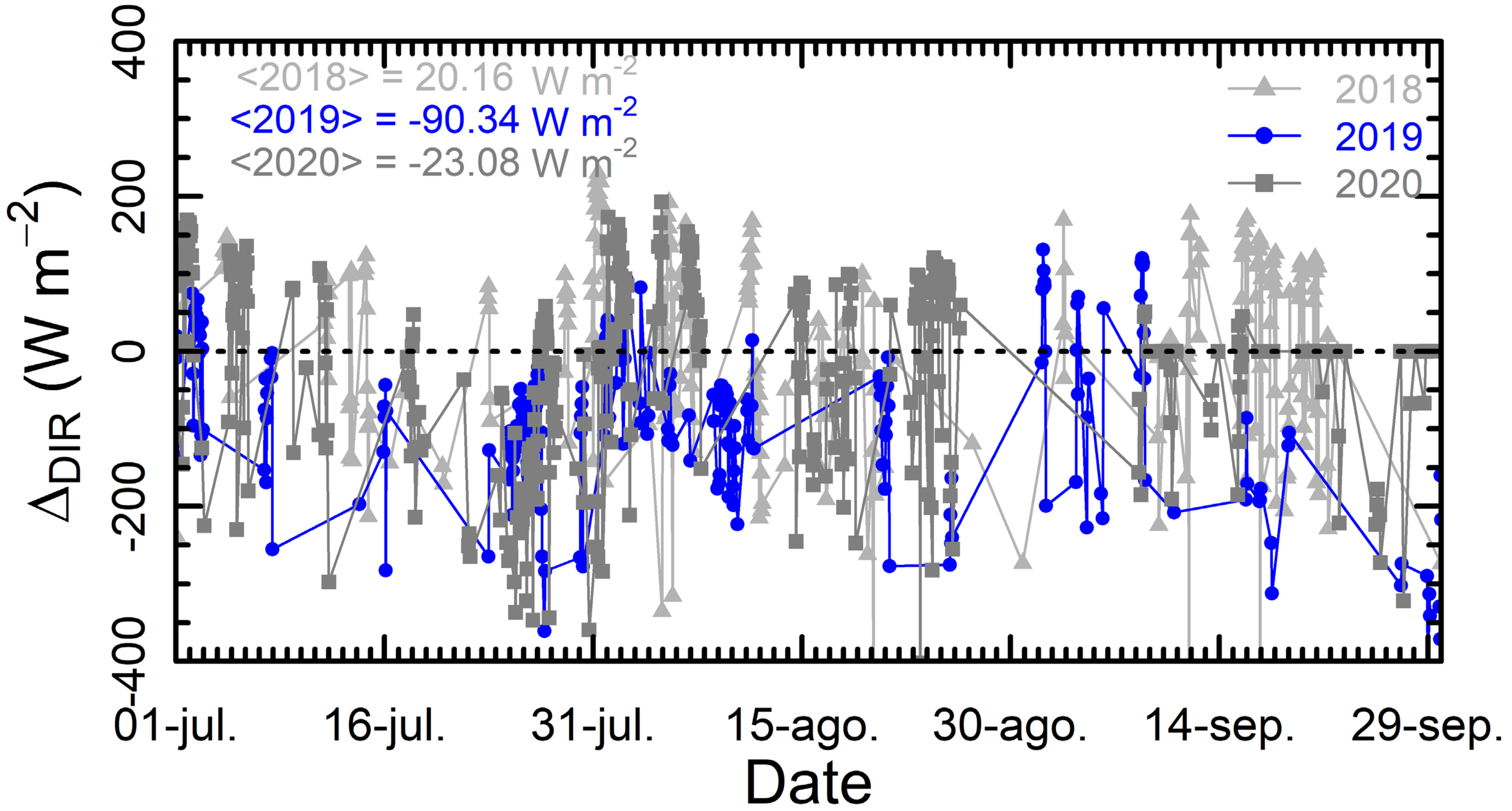
FLEXPART

Impact of aerosol on direct radiation

$$\Delta_{DIRy} = I_{DIRy} - I_{DIR(2006-2020)}$$

For years (y): 2018, 2019, 2020. *

*The diffuse ratio (Long et al., 1995) is used to reduce the influence of clouds on the results ($Diff\ R = \frac{I_{diff}}{I_{DIR} + I_{diff}}$)
Only data with hourly DifR < 0.25 have been used



Thanks for your time!

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