From Dust to Wildfire Smoke: Influence of Extreme Events on Aerosol Properties on Jungfraujoch

Benjamin T. Brem[1], Leïla Simon[1], Rob L. Modini[1], Martine Collaud Coen[2], Claudia Mohr[1] and Martin Gysel-Beer[1]

[1]PSI Center for Energy and Environmental Sciences, Villigen PSI
[2]Federal Office of Meteorology and Climatology, MeteoSwiss

Contact: benjamin.brem@psi.ch

Poster #1

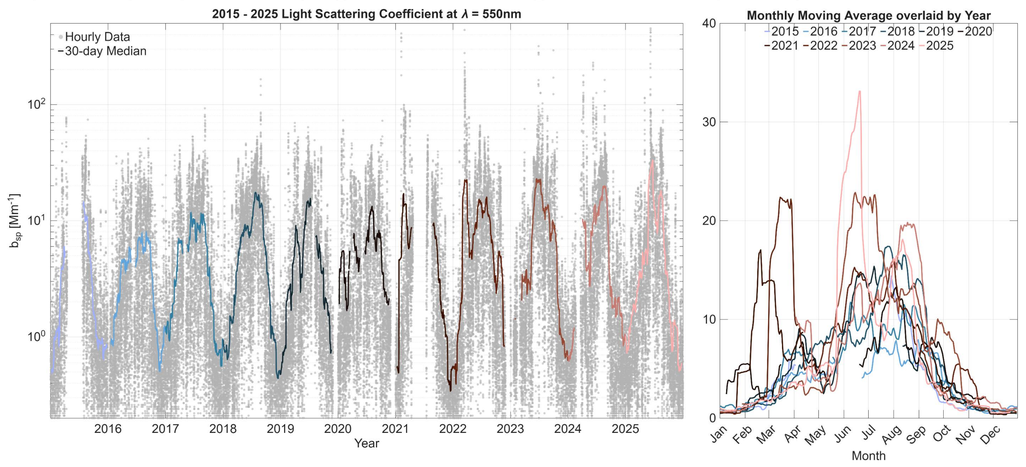
Measurement program

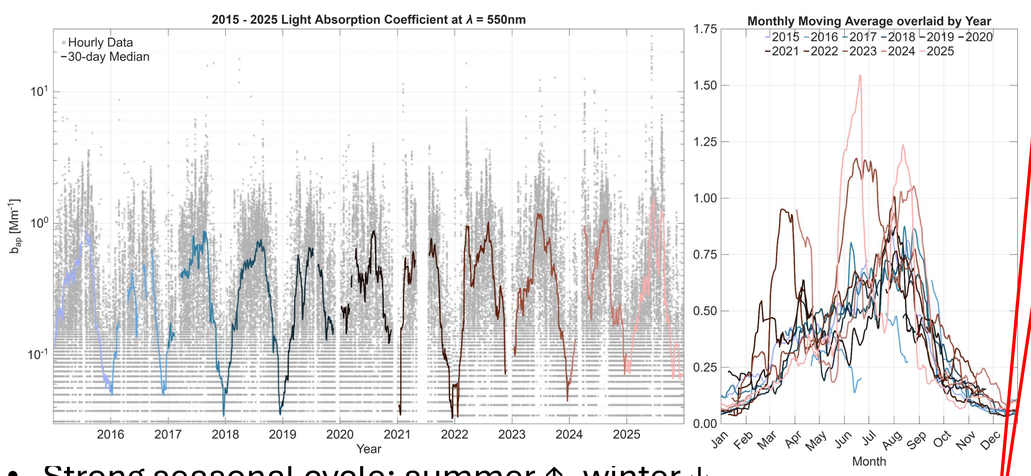
Parameter	Method or instrument	Resolution	Operator	Start JFJ
Particulate Mass (PM)				
PM2.5, PM10	Optical (previously: Betagauge)	1 min	Empa	2007
PM10	HiVol; gravimetric	daily	Empa	2006*
Optical coefficients:				
Absorption (7 wavelengths)	Aethalometers	1 min	PSI	2001**
Scattering (3 wavelengths)	Nephelometers	5 min	PSI	1995
Number concentrations				
Particulate number (PN)	Cond. particle counter (CPC)	1 min	PSI	1995
Cloud Condensation Nuclei (CCN)	CCN counter	60 min	PSI	2008***
Ice Nucleating Particles (INP)	INP counter	10 min	ETH	2019
Size distributions:				
2.5 – 40 nm	NAIS	3 min	Helsinki	2020
10 – 800 nm	Mobility Particle Sizer (MPSS)	5 min	PSI	2009
0.6 – 20 µm	Aerodyn. Particle Sizer (APS)	1 min	PSI	2008
Chemistry:				
PM10: Cl^-, NO_3^-, SO_4^{2-}	Ion chromatography	daily	Empa	2006
PM1 & TSP: major inorganic ions	Ion chromatography	24h in 6d	PSI	2001***
PM1: Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Organics	Aerosol Mass Spectrometry	4 min	PSI	2021
Equivalent Black Carbon (eBC)	Aethalometer	1 min	PSI	2003

*TSP Measurements started in 1973, ** 1 wavelength measurements started in 1995, *** discontinued

Seasonal cycles and year-to-year variability

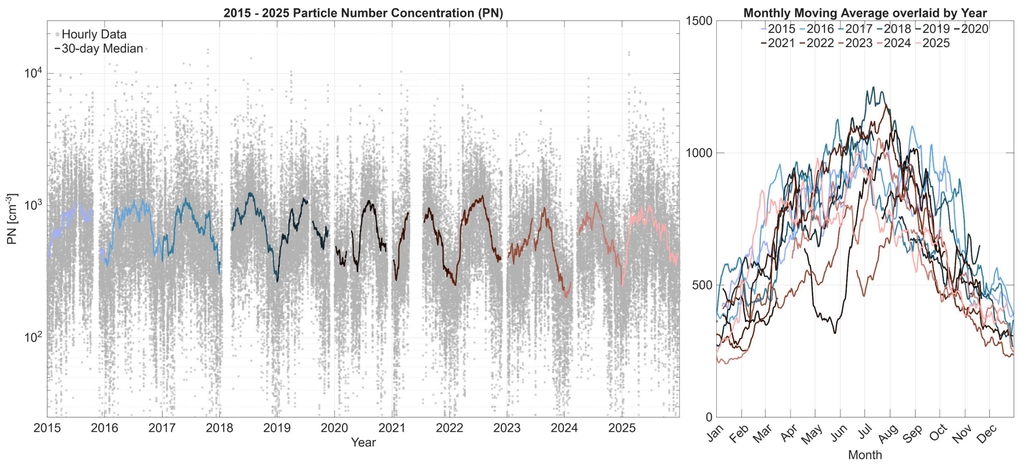
Optical properties (Light Scattering and Absorption):





- Strong seasonal cycle: summer ↑, winter ↓
- Year-to-year variability driven by meteorology and sources
- Major spikes from extreme Saharan dust events (2021, 2022)
- Large wildfire plumes (2023, 2025) caused strong anomalies

Particulate Number (PN) concentration:

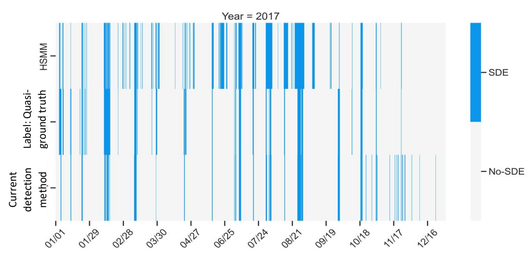


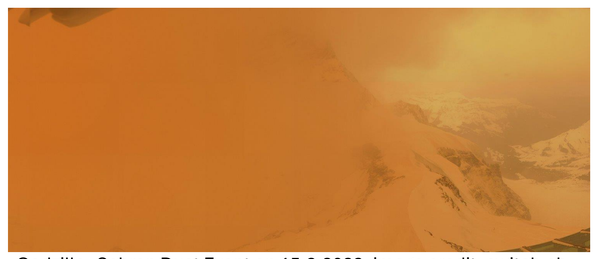
- Saharan dust and wildfire intrusions barely affect number concentrations (impact mainly in coarse/ accumulation modes)
- Noticeable dip during COVID-19 lockdown (Apr–Jun 2020); causes remain uncertain

Saharan Dust

See Martine Collaud Coen's poster #4 for detection and climatology!

- Feb. 2021 and Mar. 2022 events had unprecedented intensity
- Hidden Markov Models (HMMs) have been tested as part of an MSc. Thesis at ETHZ (Andrew Zehr) → potential to classify also non-dust events

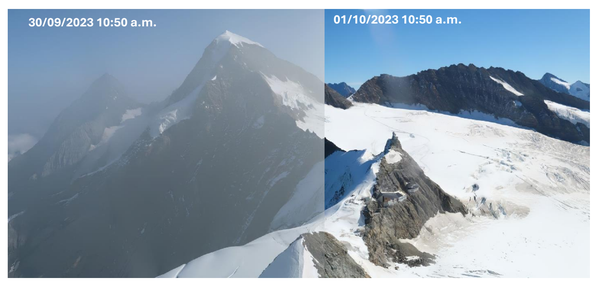




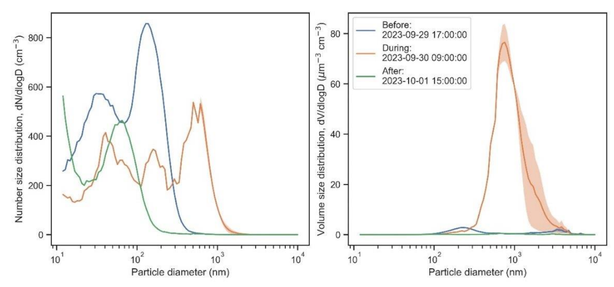
«Godzilla» Sahran Dust Event on 15.3.2022, image credit: switch.ch

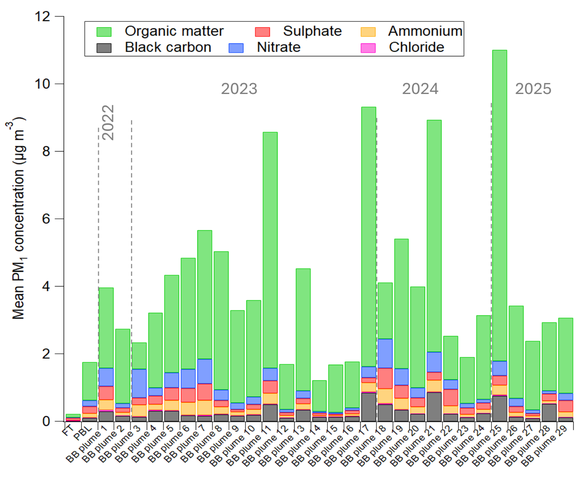
Wildfire Smoke

- Wildfire plumes (notably in 2023 and 2025) have markedly affected aerosol optical properties
- Some plumes have distinct size distribution, which result in unique spectral features that can erroneously trigger Saharan Dust alerts (Masoom et. al, 2025, egusphere-2025-2755)
- Positive Matrix Factorization (PMF) on organic aerosol matrix obtained by the Time of Flight- Aerosol Chemical Speciation Monitor (ToF-ACSM) allowed the detection 29 fire plumes (2022 -2025)
- Most fires have originated from North America in this period
- Near real-time PMF using a constrained BBOA factor could potentially be used for an air quality alert in the future



Quebec fire, Sept. 2023, image credit: Jungfraubahnen Roundshot





Conclusions

- Extreme Saharan dust intrusions (2021, 2022) and wildfire plumes (2023, 2025) strongly affected aerosol optical properties in the last decade, while particle number concentrations stayed largely stable because coarse and accumulation-mode particles contribute little to total counts.
- Jungfraujoch aerosol observations provide key constraints for radiative transfer studies, satellite retrieval validation, and climate and transport model evaluation. They are especially valuable for assessing extreme events against the low, seasonally stable free-tropospheric background, particularly during winter month

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