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Laboratory of Atmospheric Chemistry

Occurrence and Radiative Properties of Long-Range Transported Wildfire Aerosol Measured at the Jungfraujoch

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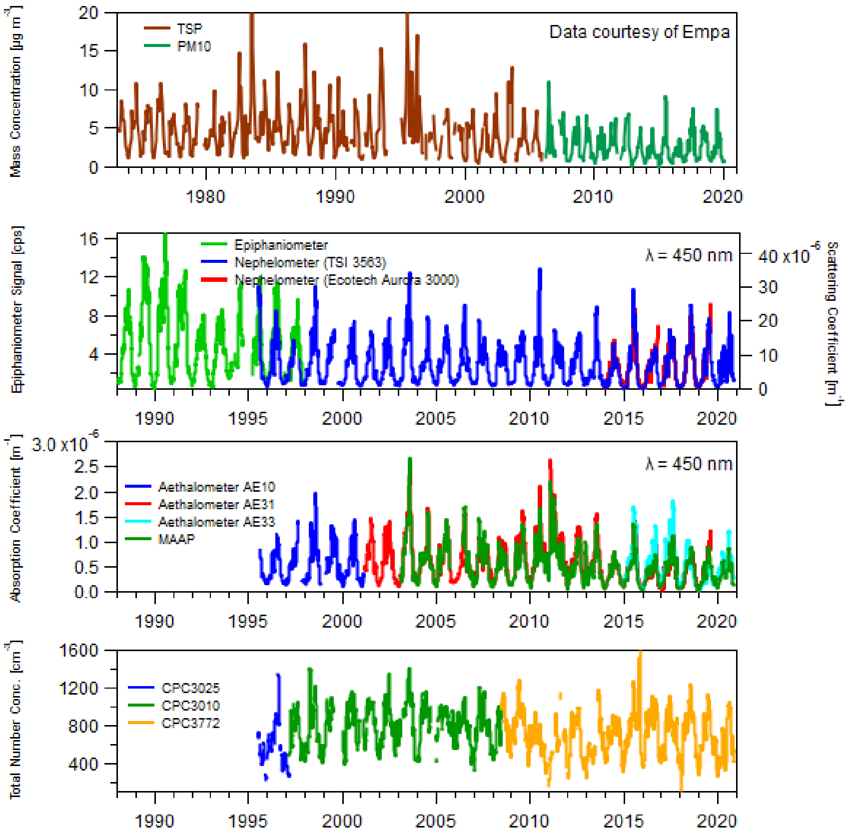
24th ETH-Conference on Combustion Generated Nanoparticles – Cyber Space – 22 Juni 2021

25+ Years of Continuous Aerosol Observations on the Jungfraujoch

JFJ




credit: JF Bahnen

- One of the longest continuous records within Europe
- Trends and climate relevant aerosol properties have been the key focus of our monitoring program
- Transport from the polluted planetary boundary layer (PBL) during the summer months drives the annual oscillation

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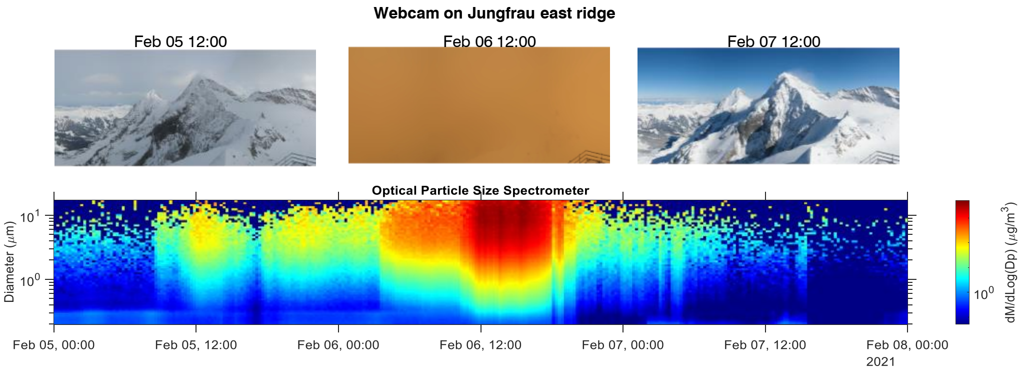
Known Long- Range Transported Aerosols at JFJ

LABORATORY OF ATMOSPHERIC CHEMISTRY

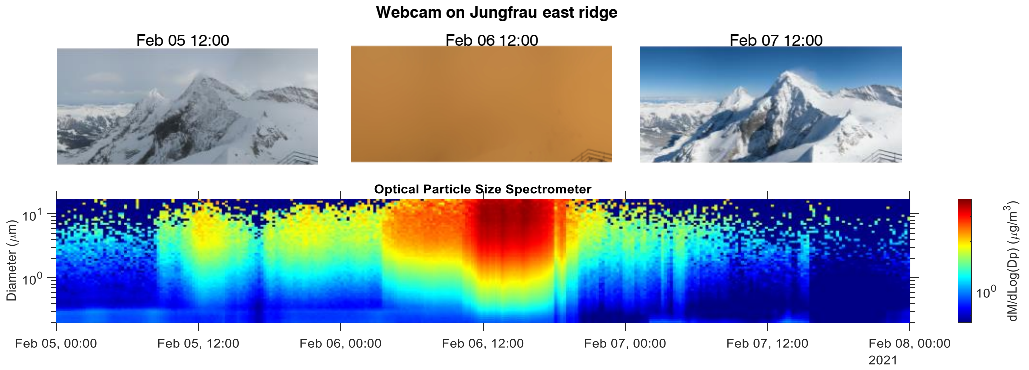
SDE

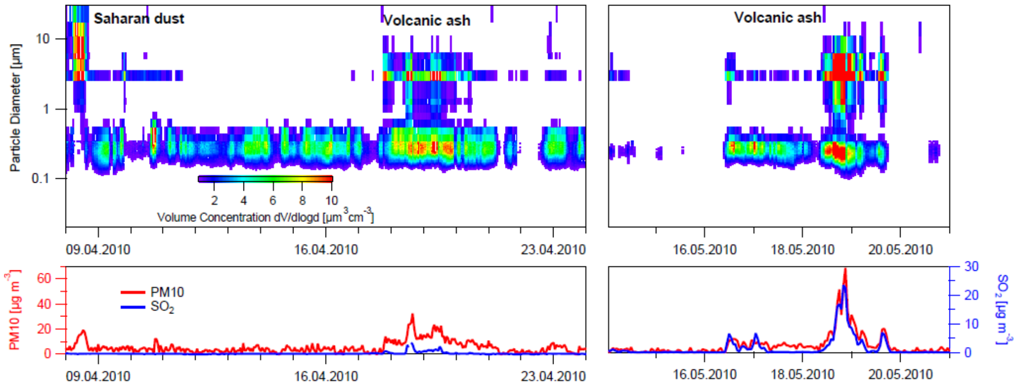


- Saharan Dust (e.g. Feb.6, 2021)
  - 20 to 50 events per year
  - Contribute to ~25 to 30% of total PM mass
  - Very distinct coarse mode and optical characteristics

Schwikowski, M., et al., Atmos. Environ. 32: 4001–4010, (1998)
Collaud Coen, M., et al., Atmos. Chem. Phys., 4, 2465-2480, (2004)

Known Long- Range Transported Aerosols at JFJ





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- Volcanic Ash (e.g. Eyjafjallajökull 2011)
  - 2 to 3 events per decade
  - Distinct bi –modal distribution with significant sulfate mass in the accumulation mode

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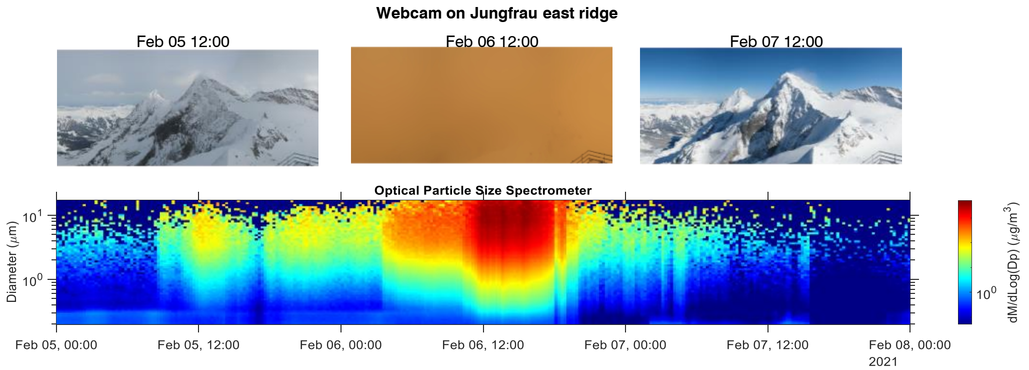
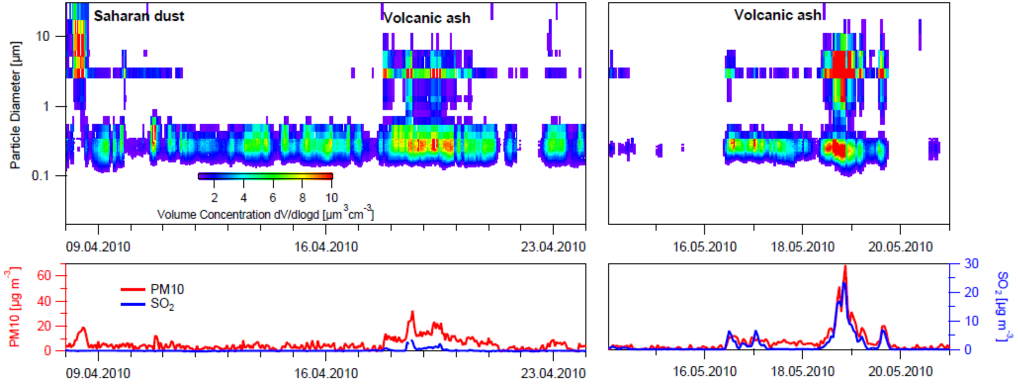
Known Long- Range Transported Aerosols at JFJ





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What about Wildfires?

Motivation and Objectives

- Large-scale forest fires are making headlines (*e.g.* 2017 Portugal, 2018 Sweden, 2019 Indonesia, Australia, Siberia, 2020 California)
- In boreal regions they are a symptom of the earth's warming and their frequency is increasing
- A fraction of fire emissions are injected into the free troposphere where they can be transported over long distances

A large pyrocumulus cloud above the Carr fire in California, 2018 (Getty Images)

Objectives:

1) Develop a data screening procedure to identify forest fire plumes in Jungfraujoch *in-situ* data
2) Report plume frequency of occurrence and durations
3) Provide climate relevant optical and microphysical plume properties

Data Screening

2015 – 2019 period evaluated for the following hourly datasets:

Property	Instrument
b_{sp}, b_{bsp}	TSI 3536Nephelometer
b_{ap}	Magee AE-33 Aethalometer
PSD (fine)	SMPS (PSI)
PSD (coarse)	TSI 3330 OPS
CO_2, CO, CH_4	NDIR
NO, NO_2, NO_y	CLD
VOCs	GC-MS

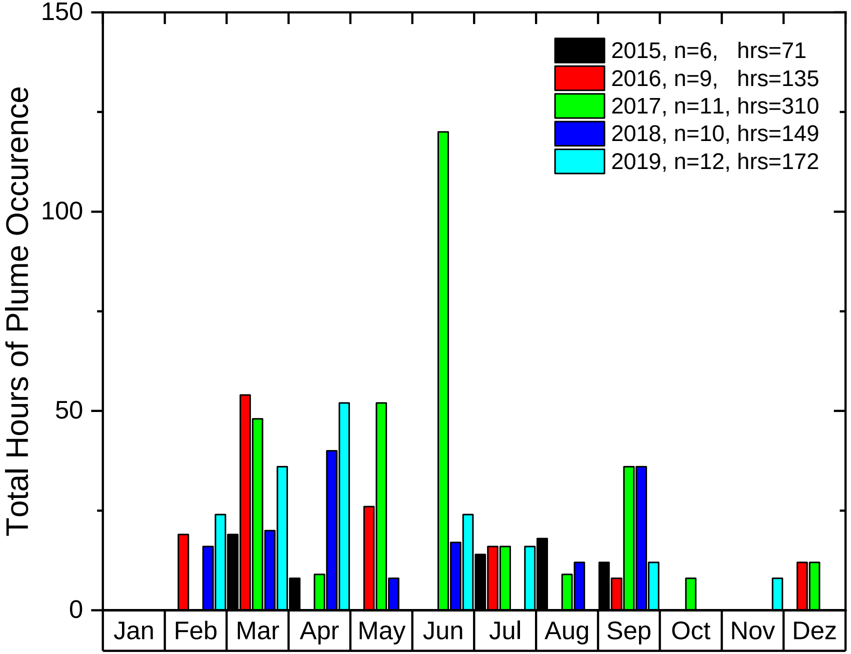
Data Screening:

1. $b_{ap} > 0.3\ Mm^{-1}$ (λ =550nm) → avoid LOD
2. $\alpha_{SSA} > 0.035$ → reject SDEs[1]
3. $\alpha_{ap470\_520} > \alpha_{ap470\_950}$ → short λ enhanced b_{ap}
   wbf_470 and 950 > 0.5 [2]
4. $CO/CO_2 > 2.4\text{x}10^{-4}$ → Only major plumes
5. $NO_y/CO < 7.5\text{x}10^{-3}$ → Avoid local influence [3]

- Plume was considered when these criteria prevailed ≥ 8 hrs.
- Empa's FLEXPART browser[4] used to identify source sensitivities and regions

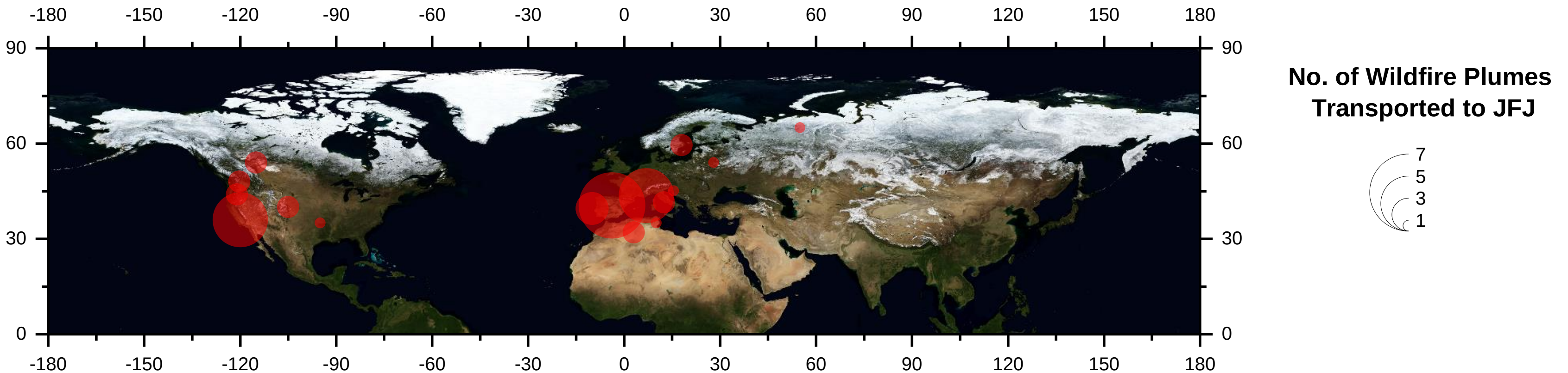
(1) Collaud Coen, M., et al., Atmos. Chem. Phys., 4, 2465-2480, (2004)
(3) Zellweger, C., et al., Atmos. Chem. Phys., 3, 779–796, (2003)
(2) Sandradewi, J., et al., Atmos. Environ., 42, 101–112, (2008)
(4) https://lagrange.empa.ch/FLEXPART_browser/

Wildfire Plume Occurence and Frequency



- In comparison to SDEs (400-600 hrs. yr^{-1}) plume occurrence is lower and also less frequent
- 2017 most significant year with fires in Southern France (March/ April), Portugal (June) Canada (September) and Spain (October)

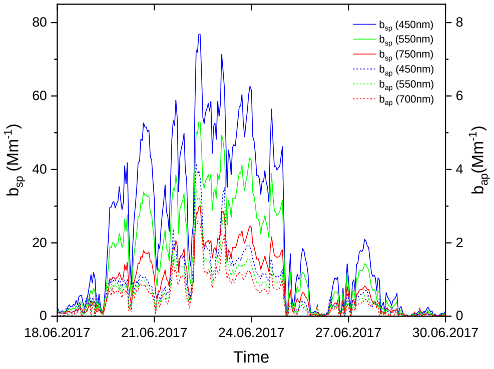
Wildfire Plume Origins

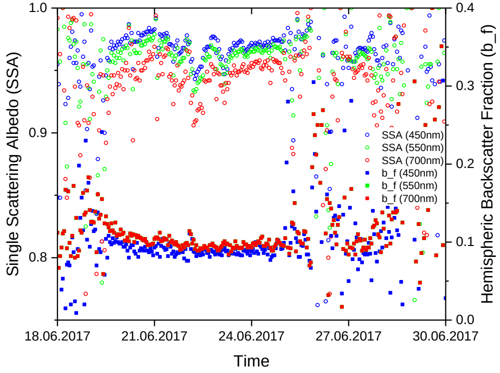


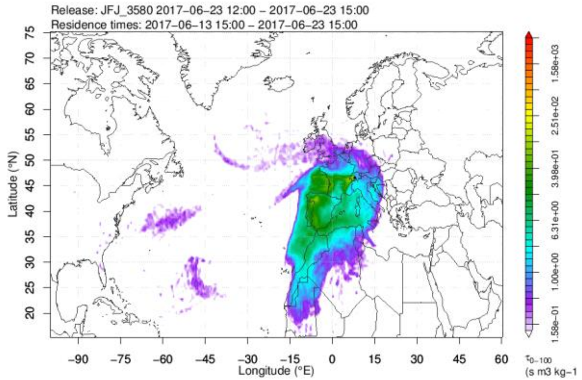
Underlying image credit: NASA blue marble

- Back trajectory analysis identified source regions with reported fires for 37/49 plumes
- Source regions: Europe (19), North America (14), North Africa (3), Asiatic Russia (1)

Pedrógão Grande Plume Example

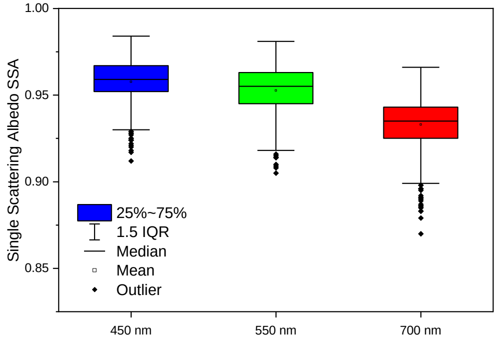


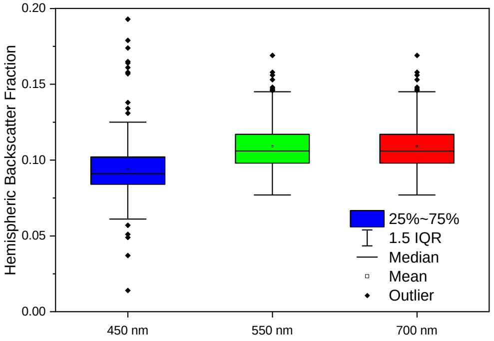


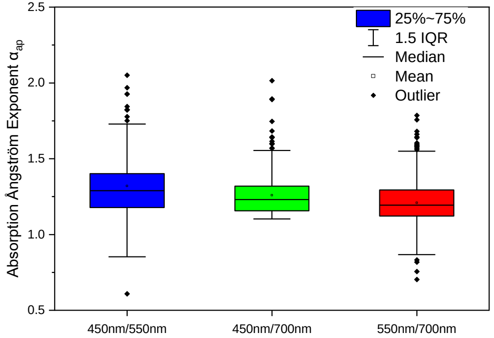


- Scattering and absorption levels reach values of a city outflow
- Single scattering albedo and backscatter fraction remain fairly constant during event indicative of an atmospheric processing

Relevant Plume Properties







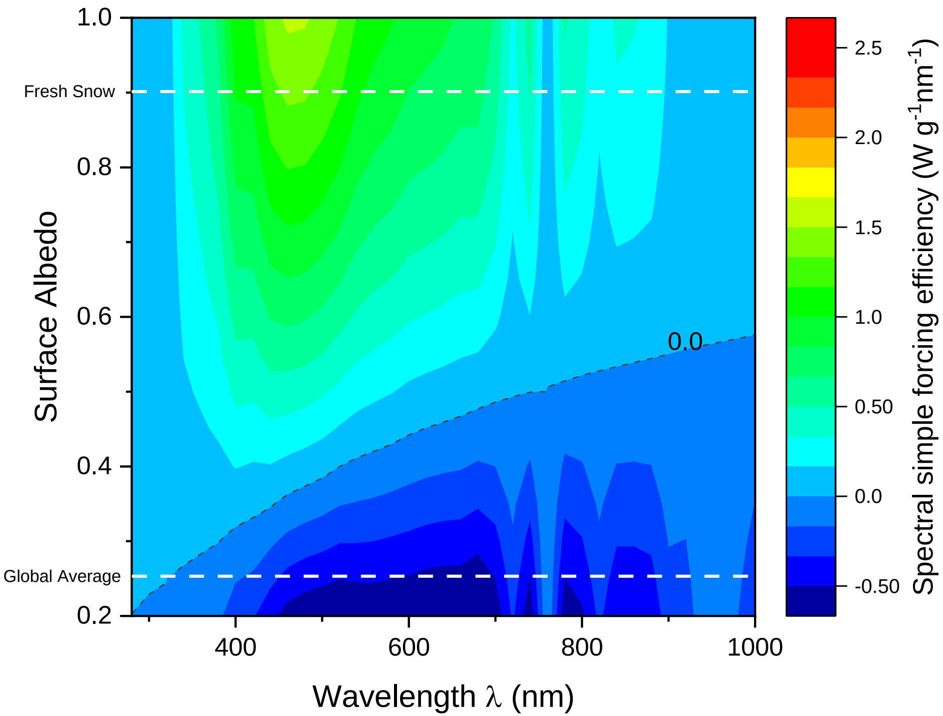
Size Distribution Statistics	
Accum. Mode CMD(µm)	0.189 ± 0.04
Coarse Mode CMD(µm)	1.2 ± 0.4
GSD	1.75 ± 0.18

- No drastic variations, indicative of the atmospheric processing of these plumes[(1)]
- Size distribution statistics in line with aircraft observations of other plumes;[(2)] however, we do not observe an additional Aitken mode

(1) e.g. Liu, S., et al., Geophys. Res. Lett., 41,742–748 (2014)
(2) e.g. Petzold, A., et al., Atmos. Chem. Phys., 7, 5105–5127, (2007)

Radiative Impact

- On a global average (surface albedo ≈ 0.26) these plumes exhibit a negative radiative forcing in the atmospheric column
- However, over clouds or fresh snow (surface albedo ≈ 0.9), the forcing is positive
- The increased UV-Vis forcing might have implications for the actinic flux and photochemistry in the atmospheric column below the plume



Conclusions and Outlook

- Wildfire plumes occur frequently at the Jungfraujoch (6-12 plumes/ avg. 167 hrs. yr^{-1})
- The plumes have fairly low variations in optical properties and size distributions indicative of atmospheric processing/ transport
- The plumes exhibit on average a negative radiative forcing. However, effects on the actinic flux and photochemistry in the underlying column might be relevant

Next steps:

- Analysis of cloud droplet activation properties
- Analysis of plume age influence
- Permanent installation of an aerosol chemical speciation monitor will allow to look for biomass burning markers (starting this year)

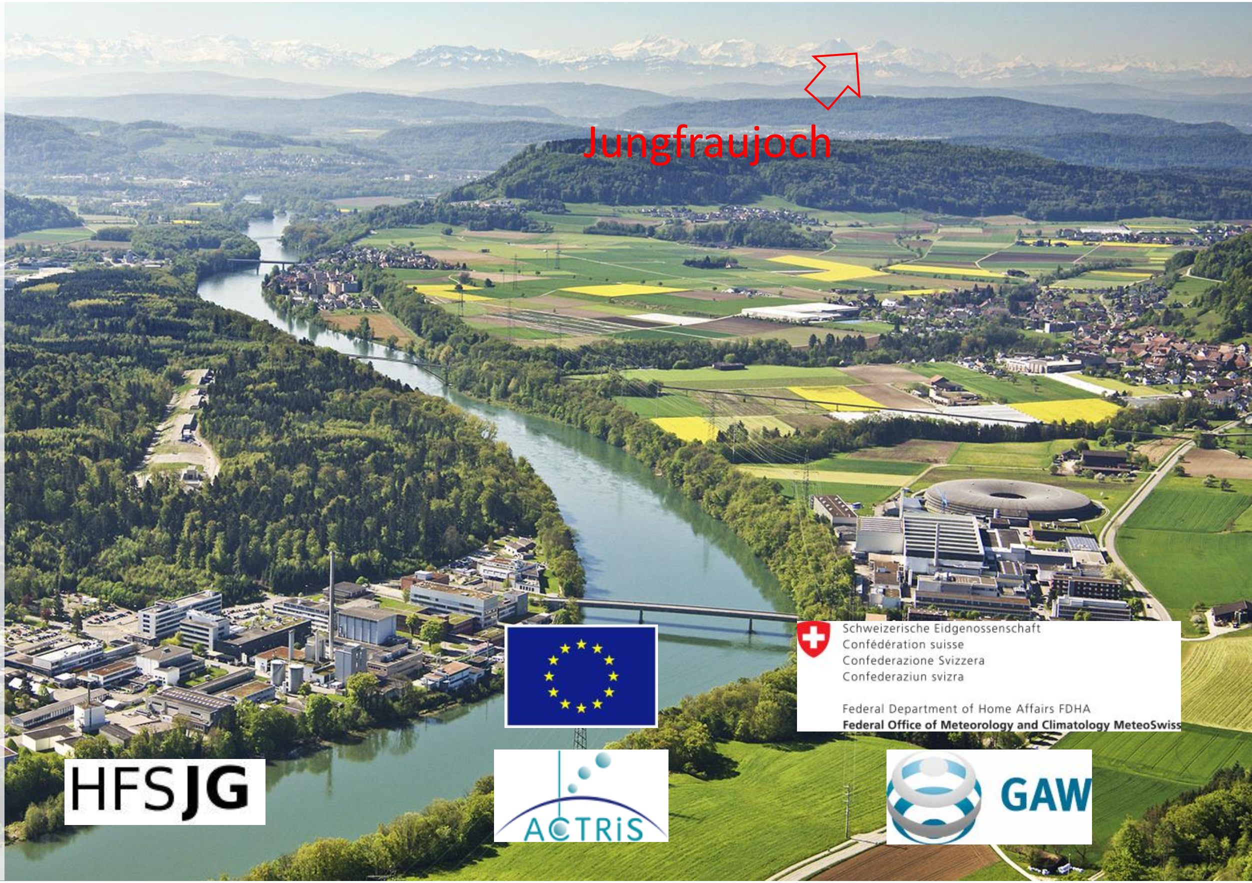
Acknowledgements

Funding:

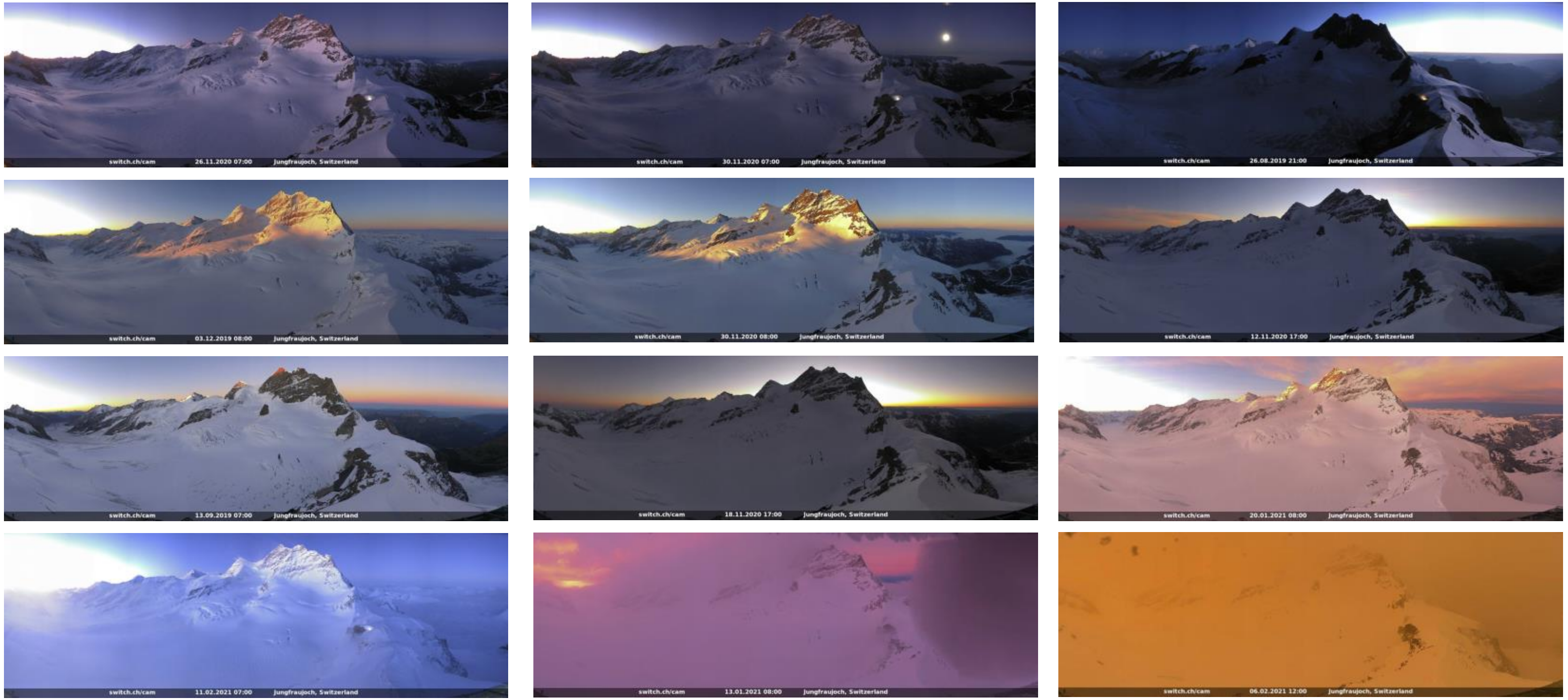
- International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat
- MeteoSwiss Global Atmosphere Watch program
- European Union's Horizon 2020 research and innovation program under grant agreement No 654109 (ACTRIS2)
- the Swiss National Air Pollution Monitoring Network (NABEL) NABEL is operated by Empa in collaboration with the Swiss Federal Office for the Environment (FOEN)

My thanks go to:

- Günther Wehrle and Pascal Schneider (PSI LAC Engineering Team)
- Cyril Brunner, Zamin Kanji, Ulrike Lohmann IAC ETH
- Alejandro Keller and Ernest Weingartner FHNW



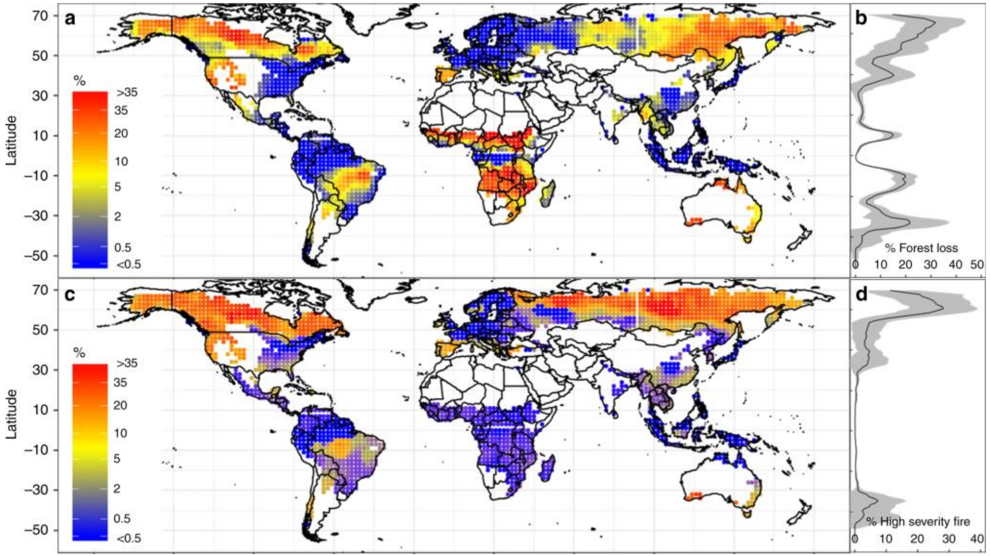
THANK YOU FOR YOUR ATTENTION!



https://www.psi.ch/de/lac/projects/last-72h-of-aerosol-data-from-jungfraujoch

email: benjamin.brem@psi.ch phone: +41 56 310 24 65

Appendix: Fire induced forest loss 2003 -2014



Percent of mean annual fire-induced forest loss and fire severity between 2003 and 2014
Liu, Z., et al., Nat. Commun. 10, 214 (2019)

Appendix Modeling of Radiative Impact

Simple Forcing Efficiency (*SFE*) calculates added energy (W) at the top of the atmosphere per mass (g) of aerosol (*Bond and Bergstrom,* 2006)

$$SFE \approx -\frac{S_0}{4}\tau_{\mathrm{Atm}}^2(1-F_{\mathrm{C}})\left[2\left(1-a_{\mathrm{S}}\right)^2 \beta MSC - 4a_{\mathrm{S}}MAC\right]$$

- S = Solar irradiance (W m^{-2})
- τ_{Atm} = Atmospheric transmission
- F_c = Cloud fraction
- a_s = Surface albedo
- β = plume backscatter fraction
- *MSC* = plume mass scattering cross-section (m^2 g^{-1})
- *MAC* = plume mass absorption cross-section (m^2 g^{-1})

} Calculated from Plume Properties