Optical and Chemical Properties of Wildfire Aerosol Plumes in the Free Troposphere

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Motivation

Pedrógão Grande Fire, Portugal, June 2017, Image Source: Paolo Cunho / EPA

Wildfires...

...are becoming more frequent and are considered a strong positive climate feedback

...destroy land, lives and ecosystems.

...produce primary particulate matter (PM) and gaseous aerosol precursors.

Wildfire emissions in the free troposphere...

...can be transported over long distances.

...undergo chemical aging.

...influence the earth's energy budget.[1]

Aim

A better characterization od optical, microphiliscal and chemical properties of wildfire plumes transported to the Jungfraujoch Hilgh Altitude Reasearch Station (3571 m.a.s.l.).

Measurements

Measurement Site: Jungfraujoch (Switzerland, Europe), 3571 m.a.s.l.

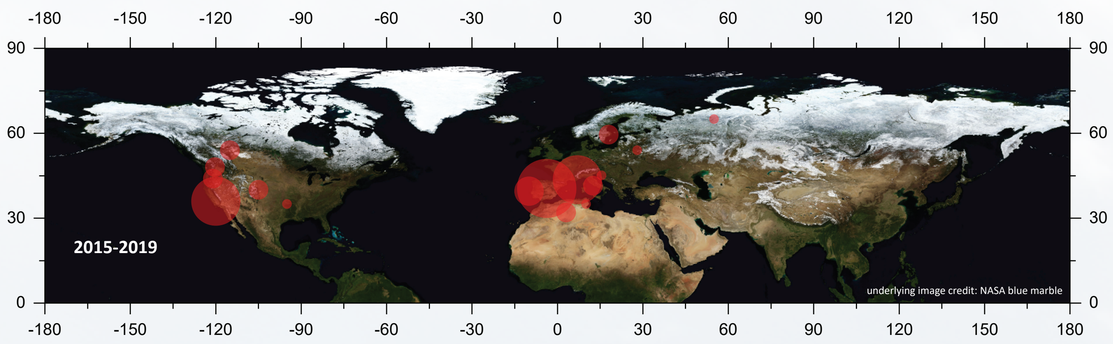
Dataset 1: 2015 - 2019

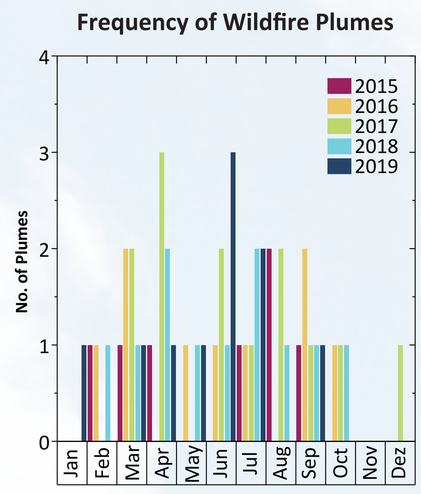
Dataset 2: 08/2012- 09/2013

Property	Parameter	Instrument
Optical coefficients	Scattering (b_{sp}) and Backscattering (b_{sp}) at 450, 550, 700 nm	Nephelometer TSI 3563
	Light absorption (b_{ap}) at 370, 470, 520, 590, 660, 880, 950 nm	Aethalometer AE-33
Particle size distributions	Fine: 16 – 600 nm (el. mobility diameter)	SMPS (PSI)
	Coarse: 0.3 – 18 µm (optical diameter)	OPS FIDAS
Chemical composition*	Organics, Nitrate, Sulphate, Ammonium	Aerodyne TOF-ACSM
Inorganic gases	CO_2, CO, CH_4	PICARRO CRD (IR abs)
	NO, NO_2, NO_x	Eco Physics CLD
	NO_y	Eco Physics CLD
	Rn-222	2-filter α scintillation counter
Halogenated Gases and VOCs	CH_3Cl, Benzene, Toluene	Medusa Cold Trap – GC-MS

*only available for dataset 2

Most Wildfire Plumes Detected at Jungfraujoch Originate From Europe and North America





- 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)

- 6-10 wildfire plumes per year
- In comparison to SDEs (400-600 h/yr) plume occurrence is lower and less frequent
- 2017 most significant year with fires in Southern France (March/April), Portugal (June) Canada (September) and Spain (October)

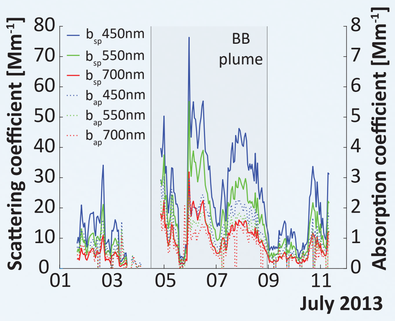
- 4 wilfire plumes with chemical information in 2012/13

Most Prominent Plume in 2012/13: Quebec Fires

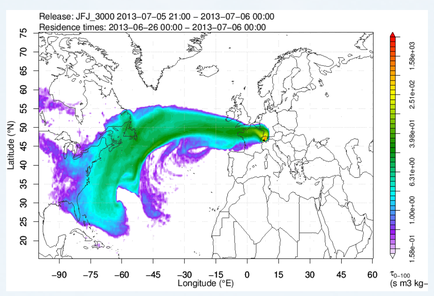
Quebec Fires, 22.06.-08.07

Image: https://earthobservatory.nasa.gov/images/81622/fires-in-quebec

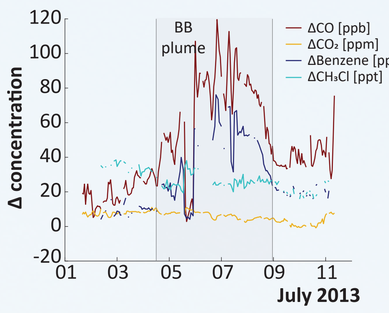
Light Scattering and Absorption



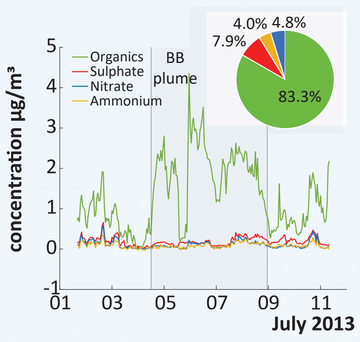
Back Trajectory Analysis



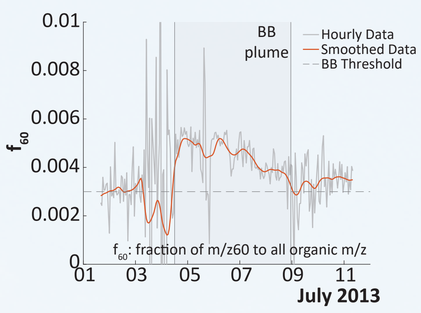
Enhancements in CO, CO_2 and VOC Concentrations



Non-Refractory PM1



Biomass Burning Aerosol Tracer f_{60}

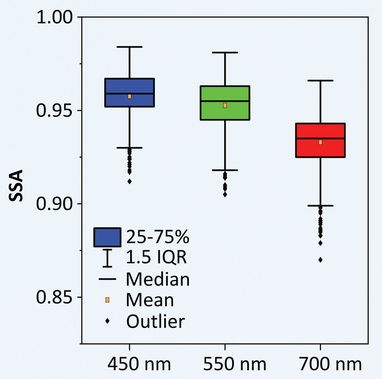


- Enhanced levels of CO, benzene and organic particulate matter
- Despite long range transport slightly enhanced levels and increased signal-to-noise ratios of fragments f_{60} and f_{73} derived from levoglucosan-like species (known tracers for biomass burning[2]) in this plume (not in all other plumes)

Well-Defined Physical Aerosol Porperties

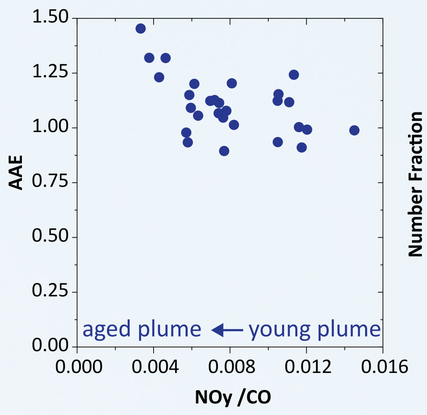
Optical properties

e.g. Single scattering albedo, relevant for radiation balance

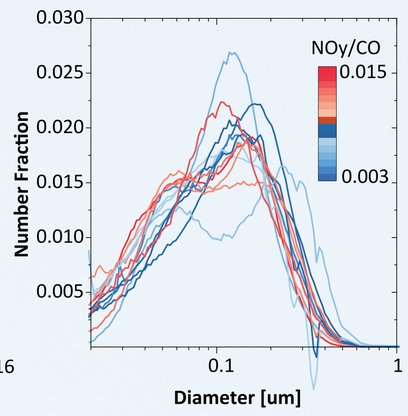


Change of properties with plume age

Spectral absorption



Particle Size Distribution



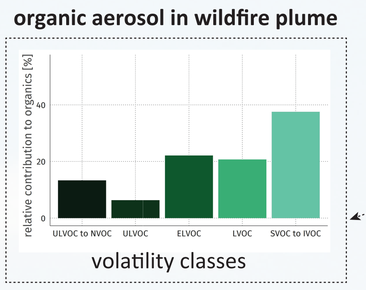
- Plume processing during medium to long-range transport leads to quite well-defined aerosol properties
- Spectral absorption is enhanced with plume age
- Single scattering albedo and particle size distributions exhibit small changes with plume age

Conclusions

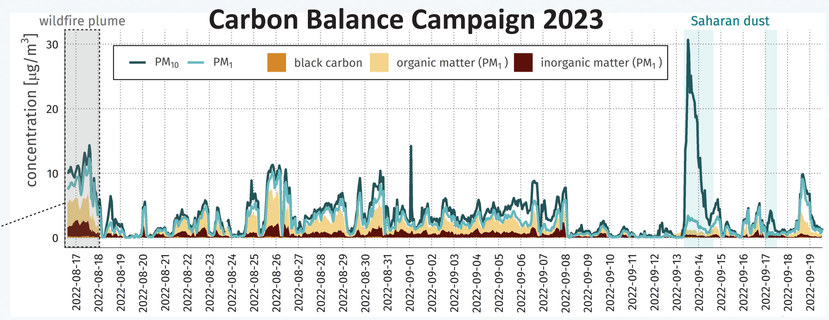
- Wildfire emissions are transported to Jungfraujoch frequently (5-10 plumes per year)
- Optical properties and size distributions are well-defined
- Chemical composition is dominated by organics

What's Next?

organic aerosol in wildfire plume



Carbon Balance Campaign 2023



- In-depth chemical characterization (aerosol volatility & comprehensive VOC information) of wildfire plume detected during the Carbon Balance Campaign 2023
- For statistical analysis on chemical composition data, a larger dataset is needed (chemical composition is measured continuously since December 2021)
- Future analyses may investigate transport dependent chemical composition

References:

1. Val Martin, M., Honrath, R. E., Owen, R. C., Pfister, G., Fialho, P., and Barata, F., (2006), J. Geophys. Res. Atmos., 111, 456- 462.
2. Milic, A., Mallet, M. D., Cravigan, L. T., Alroe, J., Ristovski, Z. D., Selleck, P., Lawson, S. J., Ward, J., Desservettaz, M. J., Paton-Walsh, C., Williams, L. R., Keywood, M. D., and Miljevic, B. (2017). Atmos. Chem. and Phys., 17(6), 3945–3961.

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Jungfraujoch near-realtime data: