A satellite view on wildfire plume aerosols in northern high latitudes in 2023

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Background

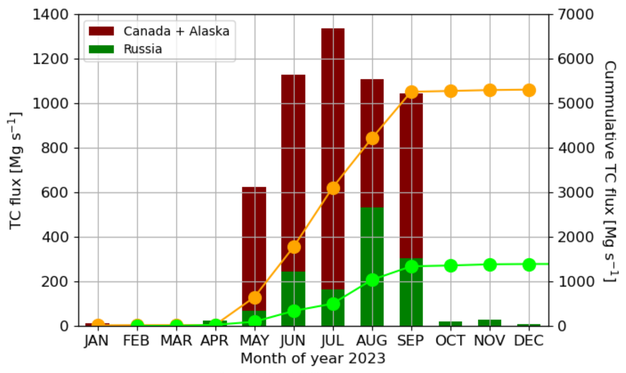
In a changing climate, northern high latitudes are becoming increasingly vulnerable to extreme wildfire activity. During summer, aerosol from fires, e.g. in forested regions and peatlands, frequently influences the Arctic.

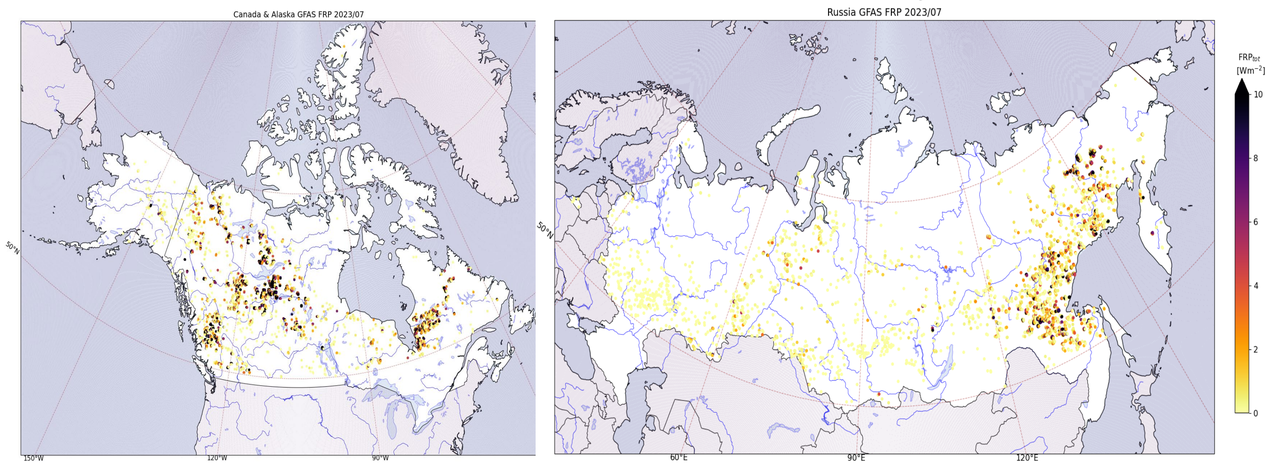
The goal is to study the aerosol characterisation in the proximity of active fires in northern latitudes using data from multiple satellite instruments and retrievals.

The 2023 fire season in northern latitudes

2023 was a year with record-breaking wildfire activity. Most prominent were the Canadian wildfires with carbon emissions being the highest in the last twenty years. Also, in Russia/Siberia large areas were burning in 2023 with smoke reaching as far north as to the North pole.

The total Carbon flux for 2023 is shown in the Figure to the right. In the Figure below, total MODIS based Fire Radiative Powe (FRP) density is shown, illustrating the areas with active fires in July 2023 (prepared using data from GFAS v. 1.2).





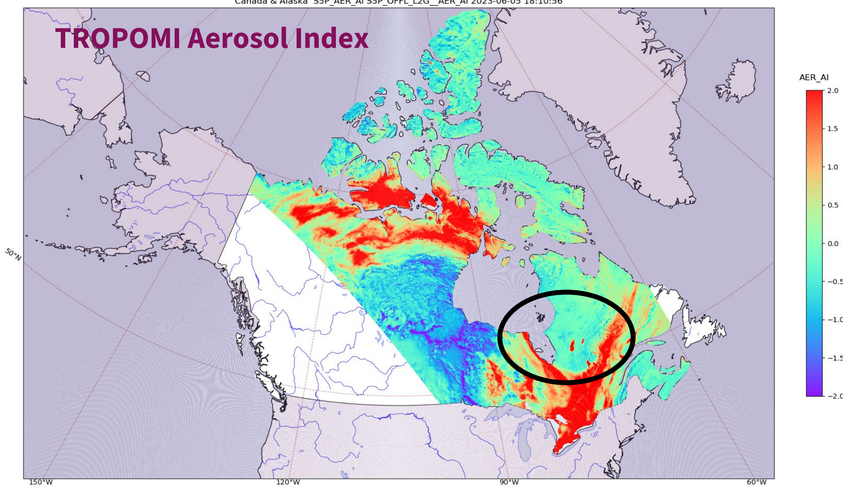
Fire cluster and plume detection

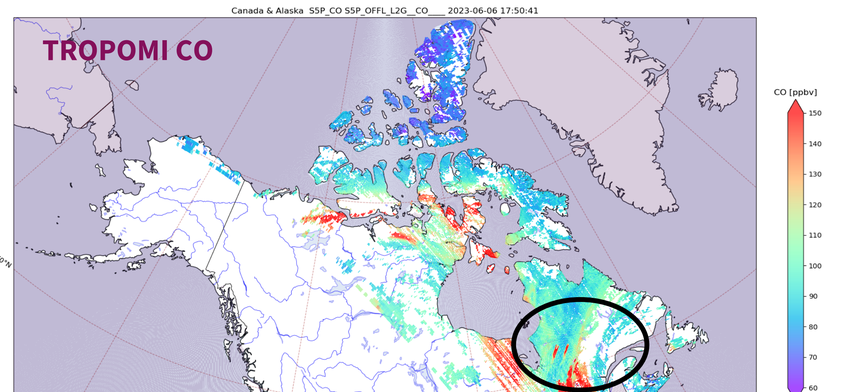
The location and intensity of active fires were determined using clusters of FRP observations from VIIRS (provided by the Fire Information for Resource Management System (FIRMS)) [not shown here].

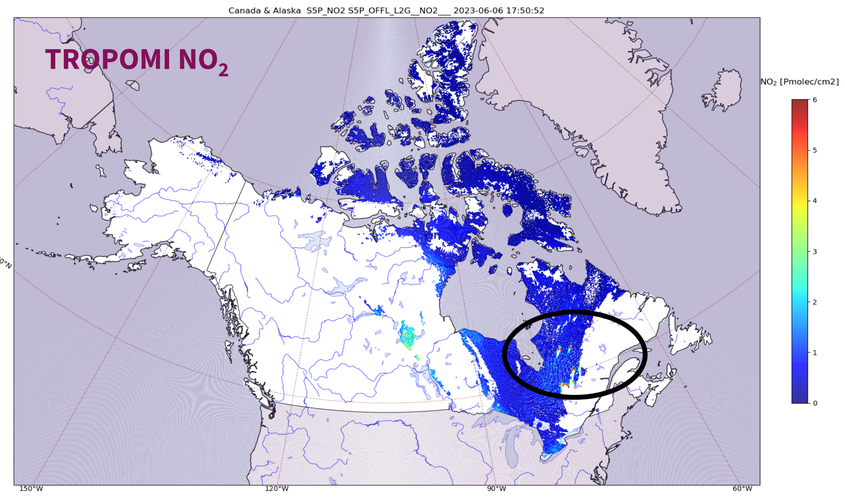
We use TROPOMI L2 data, which were re-gridded into a L2G grid (0.025° x 0.025°).

The Figures on the right show the TROPOMI aerosol Index, CO and NO_2. Two persistent fire plumes were observed 6th of June 2023 in Quebec, eastern Canada.

Medium and large fires can be identified by a positive TROPOMI aerosol index (AI > 1) “absorbing aerosol mask”, in combination with a CO and NO_2 plume detection algorithm, which provides the outline of the smoke plumes in the vicinity of active fires.







For the plume identification, following approaches can be used.

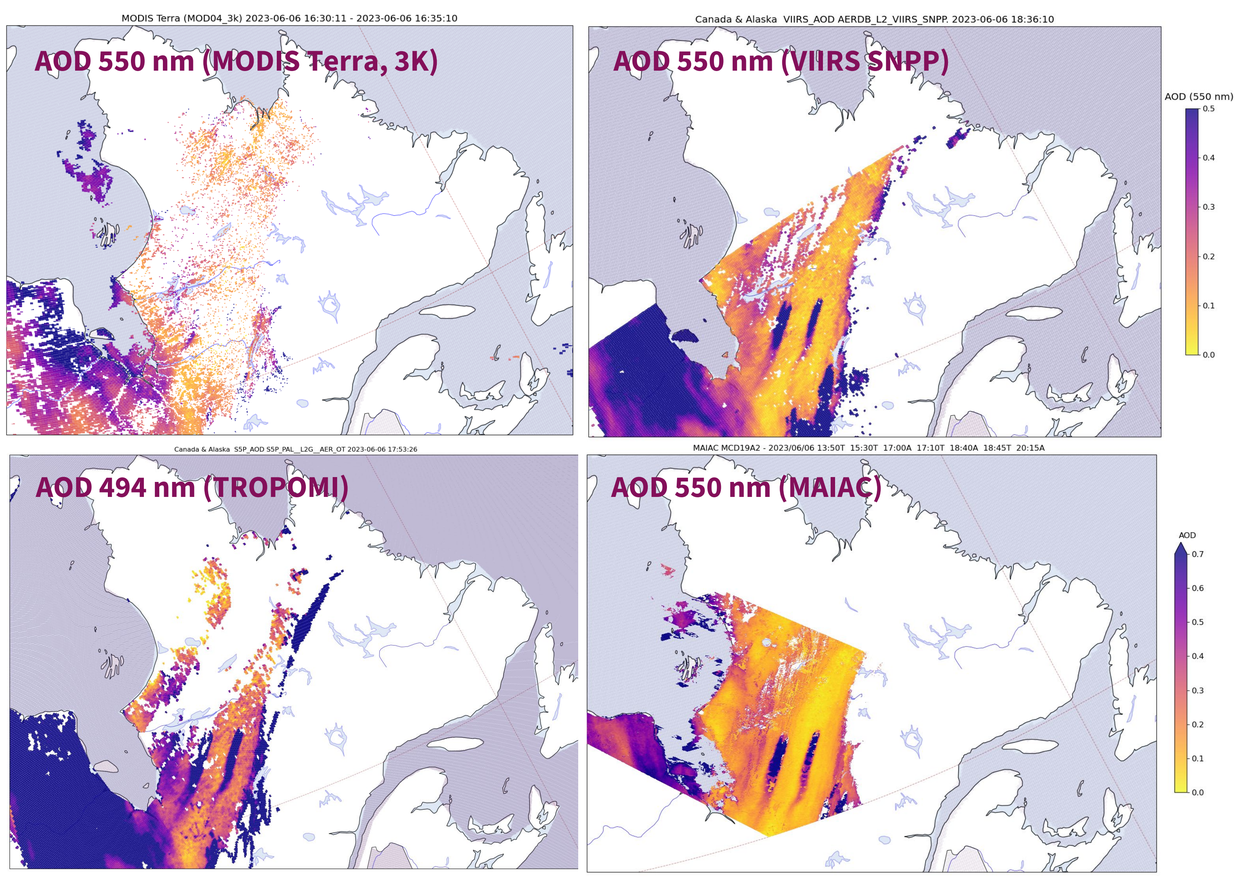
Dataset	QA flag	Fire plume detection
VIIRS FRP		FRP cluster
TROPOMI AI	0.8	>1
TROPOMI CO	0.5	Otsu threshold
TROPOMI NO_2	1 (0.5)	Plume detection/segmentation (adapting the approach developed by Kuhlmann et al. (2019)

Satellite aerosol characterization (AOD and beyond)

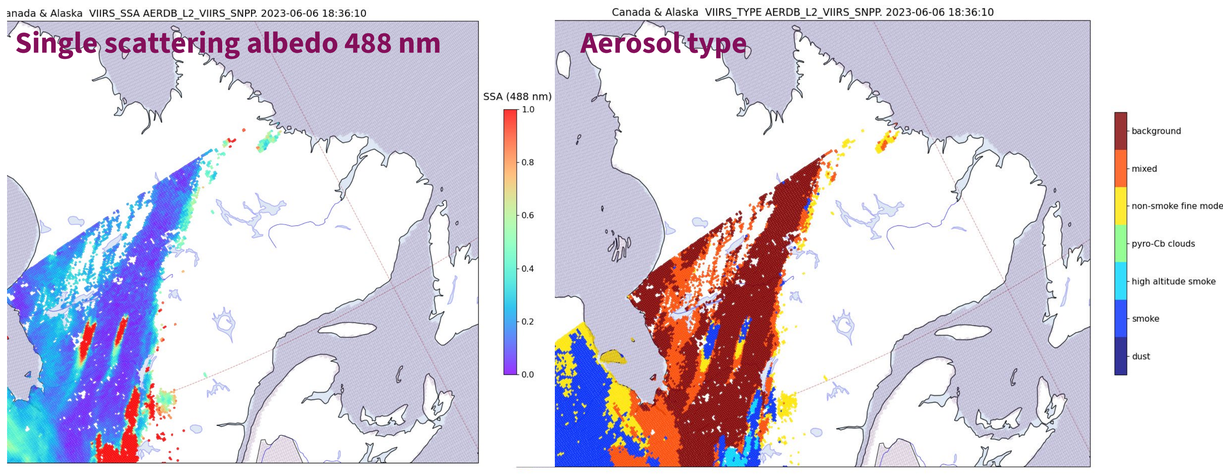
There are numerous ESA/NASA satellite instruments and retrievals providing multi-wavelength AOD and related aerosol parameters. Not all are suitable for this work though, mainly due to more stringent “cloud” filtering (e.g., MODIS onboard Aqua and Terra, L2 (10 km) and 3K (3 km)).

The Figure below shows examples of the smoke AOD from four different retrievals. Upper left: AOD at 550 nm from MODIS Terra (3km); upper right: Deep blue (DB) AOD at 550 nm from VIIRS on SNPP; lower left AOD at 494 nm from TROPOMI PAL (with qua = 100); lower right: AOD at 550 nm from MAIAC (MODIS, 1 km).

Note, for the plume identification, a relaxed quality filter is used, while for the quantitative analysis a more stringent filtering seems more appropriate.



Finally, an example of two additional aerosol products from VIIRS SNPP are shown in the Figure below.



Status and next steps

The fire and aerosol plume detection/segmentation and a qualitative comparison of numerous satellite products have been set up. The next steps will be:

- Process all 2023 datasets and compare with each other
- Calculate any dependence between FRP, NO_2/CO trace gas ratios, land-cover and peat occurrence
- Compare the fire aerosol characteristics in various regions (Canada, Siberia)
- Compare with background aerosol characteristics in the Arctic (e.g. from AERONET)

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