Experimental determination of the Atmospheric heating Rate due to light absorbing aerosol in remote high Altitude sites (EXARA)

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Keywords: Light Absorbing Aerosol; heating rate

1. Project description

Atmospheric warming is a global phenomenon, but the surface temperature increase is affecting particularly some remote areas, such as Arctic (England et al., 2021) and mountain regions, with important consequences for the ecosystems and the hydrologic cycles. Indeed, available observations suggest that some mountain regions (including Alps) are experiencing seasonal warming rates that are greater than the global land average (Rangwala and Miller, 2012). Therefore, investigating climate change and its causes in these areas is crucial.

In particular, light absorbing aerosol (LAA), i.e. Black/Brown Carbon and Dust, absorbs solar radiation and warms the mid-troposphere, which in turn increases the rate of spring snowmelt and leads to enhanced warming of the atmosphere-land system. Moreover, LAA can affect cloud formation, properties and microstructure and thus also affect the formation of precipitation.

Therefore, the main objective of this project is to determine the atmospheric heating rate (HR) due to LAA at the Jungfraujoch (JFJ) remote high altitude site. The HR can be computed (for the first time in the free troposphere) in a fully experimental way by means of an innovative method (Ferrero, 2018), obtained by cumulatively taking into account LAA absorption coefficients and incident radiation (direct, diffuse and reflected) across the entire solar spectrum.

This experimental HR methodology has already been applied at the surface in both urban (especially in Milano) and remote areas (Arctic Ocean during three summer campaigns from mid-latitudes to North Pole and tropical North Atlantic Ocean during the EUREC4A campaign). So LAA HR values in different remote areas of the globe (latitudinal and altitude remote sites) can be compared in the coming months. Moreover, HR was measured last summer at the JFJ, in Payerne and in Milano at the same time, allowing to compare also HR data from urban/plain and remote high altitude sites in the same period.

HR may be also related to cloud fraction and cloud type and it will be apportioned on the basis of species and sources. In particular, we will improve the apportionment, including also dust in addition to BC and BrC. Indeed, transport of dust from lower latitudes can have an important role in the LAA HR at higher altitudes. For this purpose, the JFJ facility is an ideal site, because it is characterized by important dust events ((Brunner et al., 2021) detected 26 Saharan dust events at the JFJ from February to December 2020), whose optical properties are already continuously determined. Dust is less studied as a LAA species than black carbon, but its role can be important in remote areas where there is low BC concentration (few emission sources), but intrusions of Saharan dust. It may become even more important in the future due to desertification and the retreat of glaciers.

The JFJ research station was already equipped with instrumentation for the determination of LAA concentrations and absorption coefficients and aerosol size distribution. Two radiometers (Figure 1), required for HR calculation, were added in the period from May 2023 to January 2024: an SPN1 Sunshine Pyranometer (by Delta T) for total and diffuse solar radiation values and a RoX (by JB Hyperspectral Devices) for continuous hyperspectral measurements of incoming and reflected radiance from UV to IR region. The RoX was equipped also with a moving shadow band in order to infer also the diffuse component (and the direct one by subtraction). Both instruments provided data at 1 minute temporal resolution.

Figure 1. SPN1 pyranometer (on the left in the background) and RoX system, equipped with a moving shadowband (on the right in the foreground).

The first preliminary results of LAA HR from April 28 to July 5 (daily averages) are shown in Figure 2. Global radiation daily averages were quite constant in that period. Therefore, the HR trend has mainly followed that of the LAA concentrations (whose variations were thus the main driver of HR values). The average HR in that period was 0.035 ± 4*10-4 K/day. This value is not particularly low: it is about an order of magnitude less than the summer average values found in Milano, but it is an order of magnitude higher than those found in the Arctic (Losi et al., 2023).

The forthcoming analysis will allow to better understand whether these rather high HR values (given the measurement site) were mainly due to combustion products or dust transport, and provide the complete time series from May to January.

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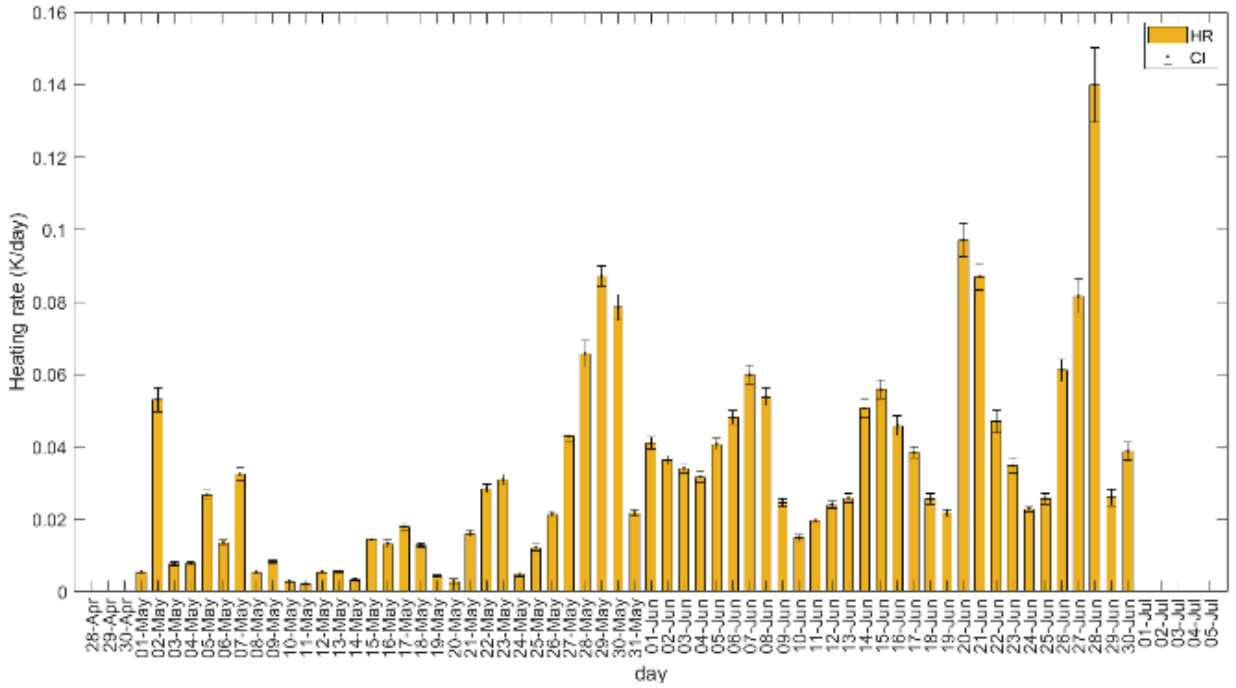

Figure 2. HR daily averages at the JFJ from April 28 to July 5, 2023.