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Heating rate and energy gradient from the tropics to the North Pole

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Absorbing aerosol species, such as Black (BC) and Brown (BrC) Carbon, are able to warm the atmosphere. The role of aerosols is one of the least clear aspects in the so called “Arctic Amplification” (AA) and up to now this was mostly modelled [1,2]. For this reason, we took part in four scientific cruises (AREX, Arctic-Expedition, summer 2018, 2019, 2021 and EUREC4A, 2020) in the North Atlantic, eastward and south-eastward of Barbados, aiming at the determination of the aerosol chemical composition and properties from the Tropics to the North Pole.

The Heating Rate (HR) was experimentally determined at 1 minute time-resolution along different latitudes by means of an innovative methodology [3], obtained by cumulatively taking into account the aerosol optical properties, i.e. the absorption coefficients (measured by AE33 Aethalometer) and incident radiation (direct, diffuse and reflected) across the entire solar spectrum. The HR computed along AREX and in Milan (in the same period) were used to determine the energy gradient, due to the LAA induced heat storage at mid-latitudes, which contributes to AA through the atmospheric heat transport northward.

Moreover, aerosol chemical composition was achieved by means of sampling via high volume sampler (ECHO-PUF Tecora) and analysis via ion chromatography, TCA08 for Total Carbon content, Aethalometer AE33 (for BC), ICP-OES for elements.

A clear latitudinal behaviour in Black Carbon concentrations, with the highest values at low latitudes (e.g. average BC concentration in Gdansk up to 1507±75 ng/m^3) and a progressive decrease moving northwards and away from the big Arctic settlements (Black Carbon concentrations within the 81st parallel: 5±1 ng/m^3).

According to the latitudinal behaviour of BC concentrations and solar radiation (decreases towards the north while the diffuse component increases), HR decreases noticeably towards the Arctic: e.g.

higher in the harbor of Gdansk (0.290±0.010 K/day) followed by the Baltic Sea (0.04±0.01 K/day), the Norvegian Sea (0.010±0.010 K/day) and finally with the lowest values in the pure Arctic Ocean (0.003±0.001 K/day). Accordingly, the energy density added to the system by the aerosol, a positive forcing that differs by 2 orders of magnitude between mid-latitudes and North Pole was found: 347.3 ± 11.8 J/m^3 (Milan), 244.8 ± 12.2 J/m^3 (Gdansk) and 2.6 ± 0.2 J/m^3 (80°N). These results highlight the presence of a great energy gradient between mid-latitudes and Arctic that can trigger a heat transport towards the Arctic. Moreover this was strengthen by the HR value for EUREC4A in Barbados that was 0.175±0.003 K/day. Finally, preliminary results from Antarctica collected onboard the Italian RV Laura Bassi cruising the Southern Ocean and the Ross Sea will be shown.

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