Attribution of the Californian Fire Emissions to the Surface Pollutant Levels in Sweden

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Abstract In early September 2020, California experienced a combination of meteorological conditions leading to an "explosive fire growth" period. According to the estimates from ECMWF, the carbon levels from forest fires over California and Oregon peaked on the 16th of September. The amount of burned forest gave a distinct signal of the emitted pollutants that could be traced across the Atlantic reaching Europe within a few days, whilst undergoing chemical transformations. During the same period, Sweden experienced high hourly concentrations of PM10 in some air quality stations with values exceeding 150 $\mu g \cdot m^{-3}$. To understand the role of the contributing sources to these concentrations, a study was designed using the in-house chemical transport model MATCH. Two domains of simulations were set, one over the Northern Hemisphere and the other over Europe, both forced by the IFS-ECMWF meteorology. The European domain was defined according to the one used on the Copernicus Atmospheric Monitoring Service regional (CAMS regional) daily production. To trace the particulate matter from the fires transported from outside the domain a MATCH hemispheric run was set. The hemispheric run was restricted to cover PM fire emissions (from GFAS) and added to the boundaries of the European domain. This way the transported particulate matter from the fires occurring elsewhere to the boundaries of the European domain are uniquely tagged making it possible to follow their transport over Europe and to account for their contribution to the measured concentrations. The MATCH model results show a signal of the transported aerosol emitted by the fires over California when compared to the CALIPSO satellite data, in the free troposphere. Still it remains to conclude on the in-situ measurements.

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1 Introduction

During the month of September 2020, several outliers in the PM10 measurements were detected over the Scandinavian countries, with concentrations higher than 150 $\mu g \cdot m^{-3}$ in least at three different locations on different days, between the 11th and the 19th of September. Given the emissions and chemical boundaries used for operational purposes, MATCH did not reproduce this elevated PM10 levels at high latitudes. However, this period coincides with the arrival of the air masses transported from North American subcontinent carrying the plumes of the fires occurred in California, as it was well monitored by the CAMS-Copernicus service (URL 1).

In order to attribute the high-altitude long-range transport of pollutants from across the Atlantic to near surface elevated concentrations at the Scandinavian in situ stations, one should consider the vertical exchange of air masses between the lower stratosphere and lower troposphere. One such example is the ozone transport which is mainly explained by different processes associated with low pressure systems and cut-off lows (Johnson & Viezee, 1981; Davies & Schuepbach, 1994). Several studies and review papers associate the folding of these weather systems with ozone concentration measured at surface, both in mountains as in other air quality stations (as examples: Monks, 2000; Elbern et al., 1998; San José et al., 2005, and recently Akritidis et al., 2018). However, physical processes also affect the distribution of other components in the free troposphere. Birmili et al. (2010) and the references therein suggested that the main mechanism by which the North American polluted air masses influence the air quality measurements over Europe is by lifting and long-range transport via warm conveyor belts. A statistical analysis of the aerosol vertical distribution from Calipso passes over Sweden indicated the presence of the aerosols in the free troposphere, above 3 km during the winter half of the year (Thomas et al., 2013). It was also observed that weather conditions such as north westerly winds and an enhanced positive phase of north Atlantic oscillation favour the long-range transatlantic transport of pollutants into the Nordic countries (Thomas & Devasthale, 2014).

In the light of the aforementioned studies, in this study, we investigate the attribution of the different processes that led to the observed elevated surface PM10 concentrations over the Scandinavian countries. We hypothesize that these high surface concentrations are as a result of the long-range transport of pollutants from the explosive fires in California that emitted the pollutants to high altitudes and a subsidence to the surface over the northern part of Europe via a deep fold that occurred during that time.

2 Methods

The preferred tool used is the chemistry transport model MATCH (Langner et al., 1998; Robertson et al., 1999), which is part of the ensemble of the Copernicus

CAMS regional services (URL 2 and URL 3), where it is validated both inside the consortium of models but also independently through other CAMS services and other model applications (Plu et al., 2021).

To look into the sources and mechanisms responsible for the high PM10 concentrations mentioned in the introductory part, the MATCH runs were perform using two domains: The European domain and a North Hemispheric one. The European domain has the same horizontal and vertical extension to the one used for the daily Copernicus Atmospheric Monitoring Service regional (CAMS regional) daily production; the chemical boundary conditions imposed are taken from the CAMS global archive, and the emissions treated according to their sources: the anthropogenic are defined by CAMS-REG-AP version 3.1, monoterpene, sesquiterpene and isoprene are calculated on-line, and the fire pollutant fluxes are given by the hourly Global Fire Assimilation System—GFAS product; The hemispheric run was restricted to cover PM fire emissions (from GFAS) represented as fine and coarse mode and added to the boundaries of the European domain as tagged species to enable distinct contribution to the measured concentrations; The period of simulation spans the interval between the 5th and 19th of September 2020, in order to assure a proper spin-up of the MATCH model.

3 Results

Hourly real time preliminary data of the PM10 surface measurements showed very high values in different days during the first three weeks of the September 2020, at least. The high concentrations values where measured over station in central and southern Sweden always during the morning (between 7 and 10 UTC), ranging from 153 up to 546 $\mu g \cdot m^{-3}$. However, the MATCH model was not able reproduce the measured peak concentrations, they were in fact one order of magnitude lower.

To understand if the MATCH model could reproduce the signal of the dynamic process behind the long-range transport, the simulated PM10 concentrations were qualitatively compared with the aerosol subtype classification applied to the measured data (URL 4) on the sensor on board of the CALIPSO satellite. As an example, we present the results for September 17th. The MATCH results' cross sections with hourly mean results of PM10 concentration, and the species tagged to follow the fire particulate matter (CAL_PM) entering from the boundaries through the simulation of the MATCH hemispheric run were plotted (Fig. 2) over the CALIPSO track under the red box depicted in Fig. 1.

In spite of the very low concentrations, the CAL_PM cross section helps to understand that there are possible two regions influencing the PM10 concentration fields, the fires occurring in the E and SE part of Europe, which are transported at lower altitudes, and the transport of the fires occurring over North America that travels at higher altitudes. The vertical transport to lower altitudes is achieved in regions where the vertical wind is downwards, which is consistent with the weather system over

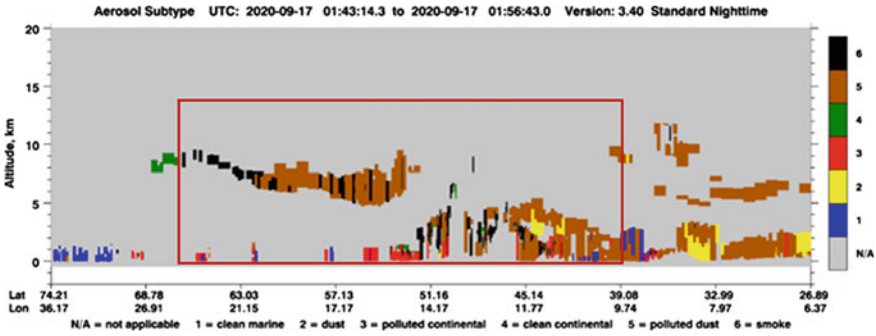

Fig. 1 Aerosol subtype classified over the track of lidar sensor on board CALIPSO (URL 4) passing near Sweden in the 17th of September 2020 (the red box represents the area the cross section of the MATCH model results in Fig. 2)

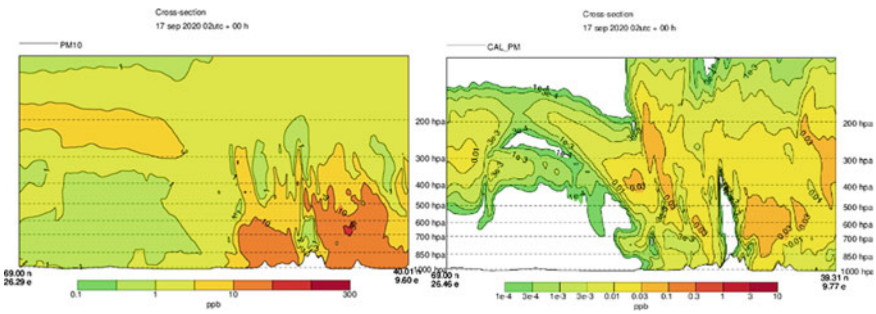

Fig. 2 Cross-sections of the PM10 and tagged specie (CAL_PM) of the fires entering and transported through the European MATCH domain

the region, a low-pressure system over Eastern Finland and a high-pressure located in the coast of Norway.

4 Final Remarks

Tagging species in limited area air quality models is a valuable tool when the processes leading to high concentration over are complex and need accountability to explain how surface concentrations can be attained. The work shows that the dynamical processes can be reproduced, however more effort is needed to accurately simulate the observed concentrations.

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URL 2: https://atmosphere.copernicus.eu/sites/default/files/2018-02/CAMS50_factsheet_201610_v2.pdf

URL 3: https://regional.atmosphere.copernicus.eu/index.php?category=ensemble&subensemble=hourly_ensemble&date=LAST&calculation-model=ENSEMBLE&species=o3&level=SFC&offset=000

URL 4: https://www-calipso.larc.nasa.gov/products/lidar/browse_images/