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25-years Svalbard data record reveals change in long-range transport of sulphur agents to the warming Arctic

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BACKGROUND

Sulphur dioxide (SO_2) is a strong acidifying agent emitted via combustion of fossil fuel and various industrial processes. Atmospheric aerosols containing sulphate (SO_4^{2-}), an oxidation product of SO_2, scatter sunlight and have negative radiative forcing. Since SO_2 is moderately soluble gas and SO_4^{2-}-particles are hydrophilic, efficiency of their removal through wet deposition depends on temperature and water content in the air masses (Fig.1). At the Zeppelin station in Svalbard (Fig. 2) the highest concentration of sulphur agents were measured in winter and spring when the long-range transport of pollution from mid-latitudes to the High Arctic is the most pronounced due to lack of sunlight during polar night, low air temperature and humidity.

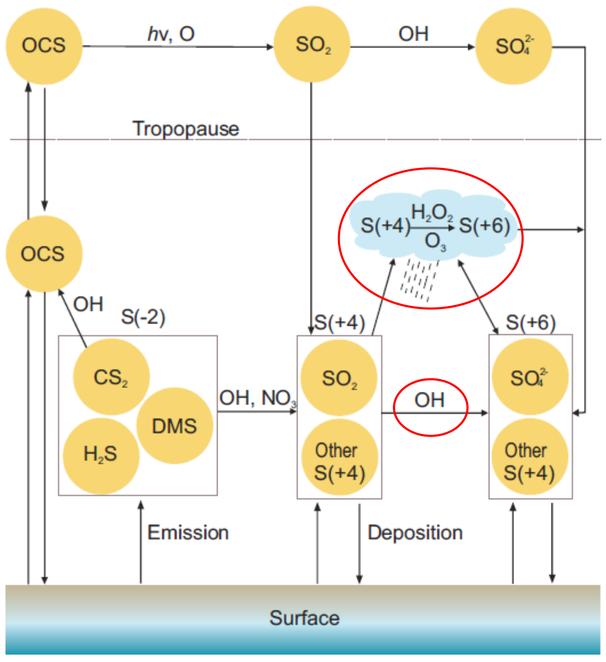
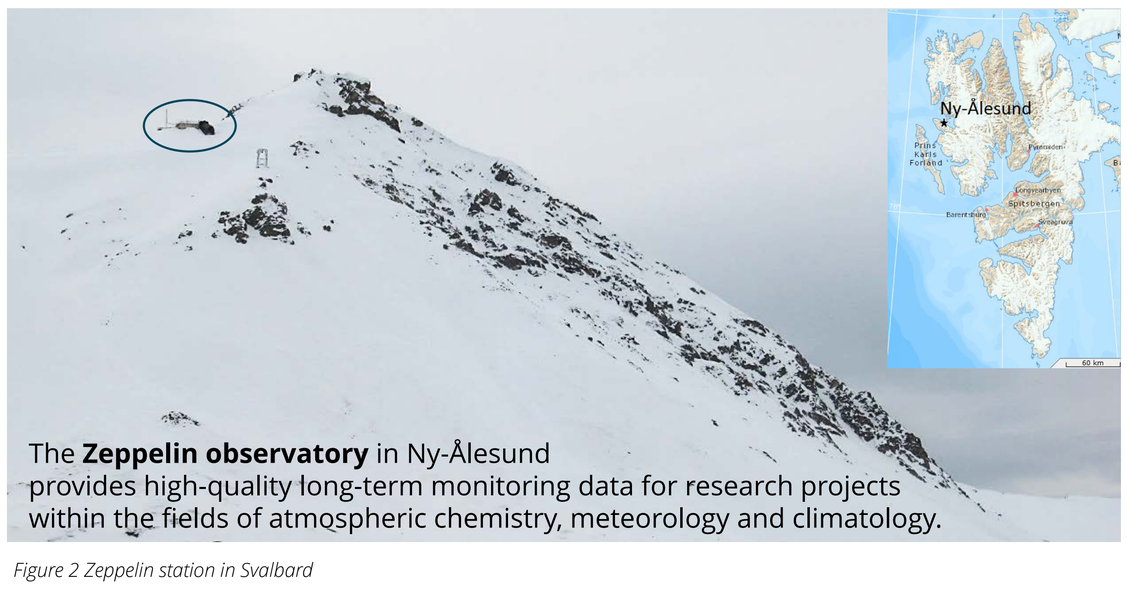


Figure 1 Physical and chemical processes affecting atmospheric lifetime of sulphur agents (modified Figure 3.1 from AMAP, 2006. AMAP Assessment Report: Acidifying Pollutants, Arctic Haze, and Acidification in the Arctic, Oslo, Norway)



The **Zeppelin observatory** in Ny-Ålesund provides high-quality long-term monitoring data for research projects within the fields of atmospheric chemistry, meteorology and climatology.

Figure 2 Zeppelin station in Svalbard

Current study investigates the 25-years seasonal trend in the concentration of SO_2 and non-sea salt SO_4^{2-} and compares observed changes with the evolution in emission of sulphur agents in primary source regions of anthropogenic aerosols and alteration in characteristics of air masses transporting pollutants to Svalbard.

METHODOLOGY

Daily concentration of sulphur dioxide (SO_2) and non-sea salt sulphate (XSO_4^{2-}) collected on filter samples at the Zeppelin station (Fig.3) have been analysed along with the data from NOAA HYSPLIT air trajectories and ECMWF ERA-Interim reanalysis. The reanalysis data had 6-hours temporal and 0.75°x0.75° spatial resolution, respectively, and were available for the whole period of measurements from January 1993 to December 2017. Four 240-hours backward air trajectories per day (starting at 00, 06, 12 and 18 UTC) have been modelled for the same period except for four months (December and January 2012 and January and February 2014) when the data needed for trajectory modelling were not available. In addition to this, monthly SO_2 data from the CEDS global emission inventory with 0.5°x0.5° spatial resolution for the period from 1993-2014 have been utilized to investigate the contribution from different sources to the air pollution transported to Svalbard and assess the change in emission amount during this period.

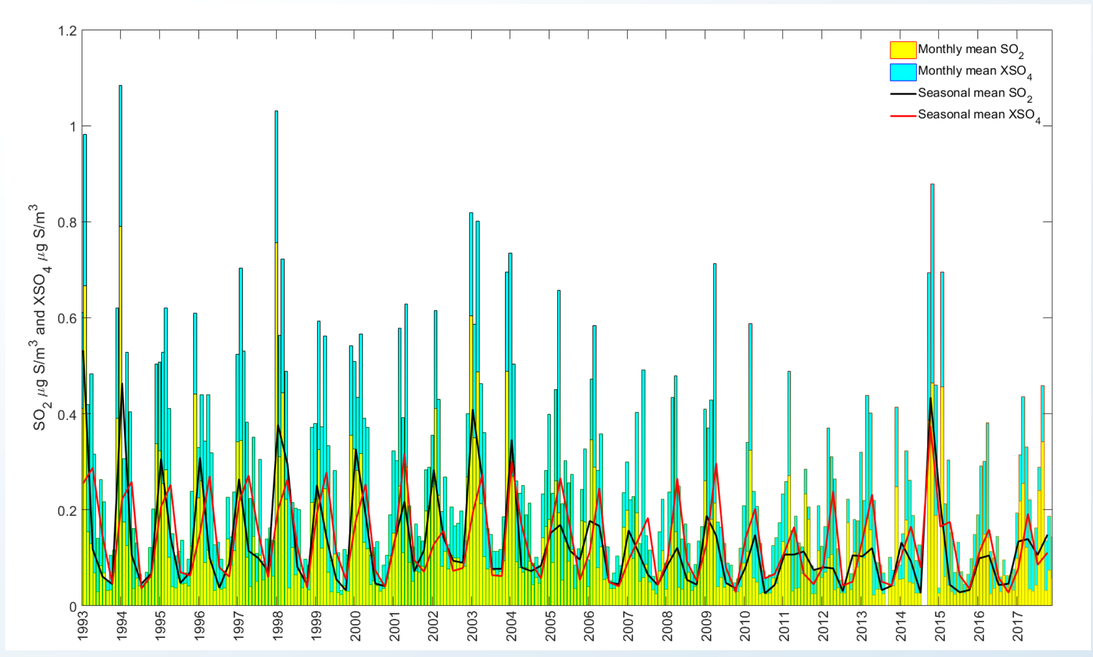


Figure 1 Monthly and seasonal mean concentrations of SO_2 and XSO_4^{2-} measured at the Zeppelin station

RESULTS

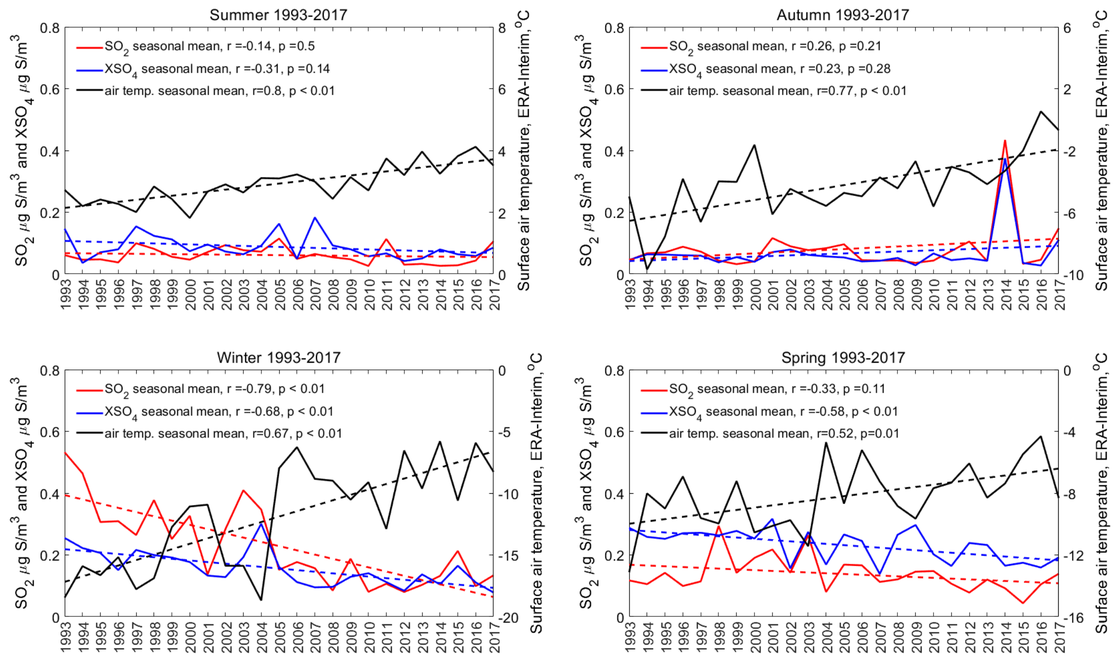


Figure 4 Seasonal timeseries of SO_2 and XSO_4^{2-} concentration measured at the Zeppelin station and air temperature in the ERA-Interim reanalysis data

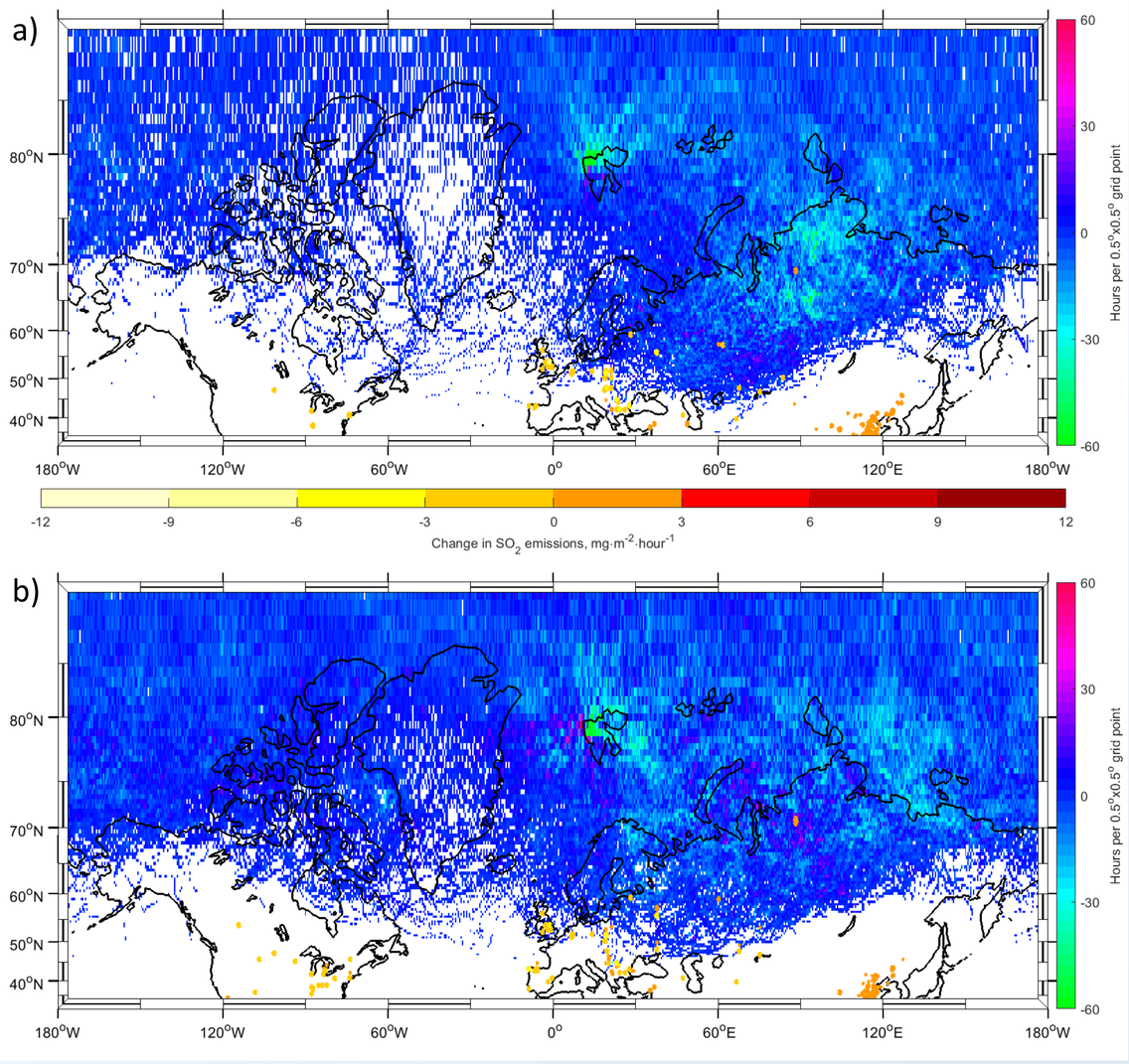


Figure 5 Difference between 2005-2014 and 1993-2004 periods in time spent over each grid point for the trajectories modelled for the days with SO_2+XSO_4 concentration above monthly mean at the Zeppelin station in winters (a) and springs (b). The scale under the Figure 5a) shows change in total SO_2 emissions from 8 sectors (agriculture; energy; industry; transportation; residential, commercial and other; solvents production and application; waste; international shipping).

CONCLUSIONS

Concentrations of SO_2 and XSO_4 measured in winter and spring at the Zeppelin station have significant moderate negative correlation with daily air temperature and specific humidity ($p<0.001$). The Wilcoxon rank sum test results show that air arriving from the source regions, impacting the concentrations at the Zeppelin station the most, is warmer and more humid, and therefore some of air pollutants could have been removed through wet deposition and aerosol processing within the clouds. The modelled precipitation along trajectories increased significantly for winters and springs 2005-2014 in comparison with the previous decade. Median temperature and specific humidity have also significantly increased along winter trajectories for the same period.

FUTURE WORK

- Sensitivity analysis and testing of the different trajectories lengths and grid sizes for source detection procedure
- Comparison of CEDS with other emission inventories such as EDGAR v4.3.2
- Extension of the study to other compounds such as black carbon, ammonia and NO_x
- Trajectory analysis for the summer and autumn seasons

ACKNOWLEDGEMENTS

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