Influence of seasonal mesoscale and microscale meteorological conditions in Svalbard on results of monitoring of long-range transported pollution

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/ BACKGROUND

The Zeppelin Observatory is an atmospheric monitoring station located on the north-west coast of Spitzbergen island, in the Svalbard archipelago. The station provides background air composition, meteorological and climatological data for numerous research projects. The observatory is located on a mountain ridge in a region with complex topography that affects local atmospheric circulation processes.

Figure 1 Zeppelin station above the fog (photo: Margrete N. S. Keyser / Svalbard Science Forum)

Seasonal change in the position of the Arctic front plays key role in long-range transport of atmospheric pollutants to the site (Fig. 2a):

- in autumn, winter and spring, long-range transported pollution prevails;
- in summer, the ship traffic intensifies and becomes a significant local source of pollution in Ny-Ålesund, a small settlement near the station.

Research question:

How the seasonal data collected at the Zeppelin observatory and Ny-Ålesund station (Fig. 2b), a temporarily station in the settlement, is affected by:

1) micrometeorological conditions
2) mesoscale dynamics
3) local air pollution?

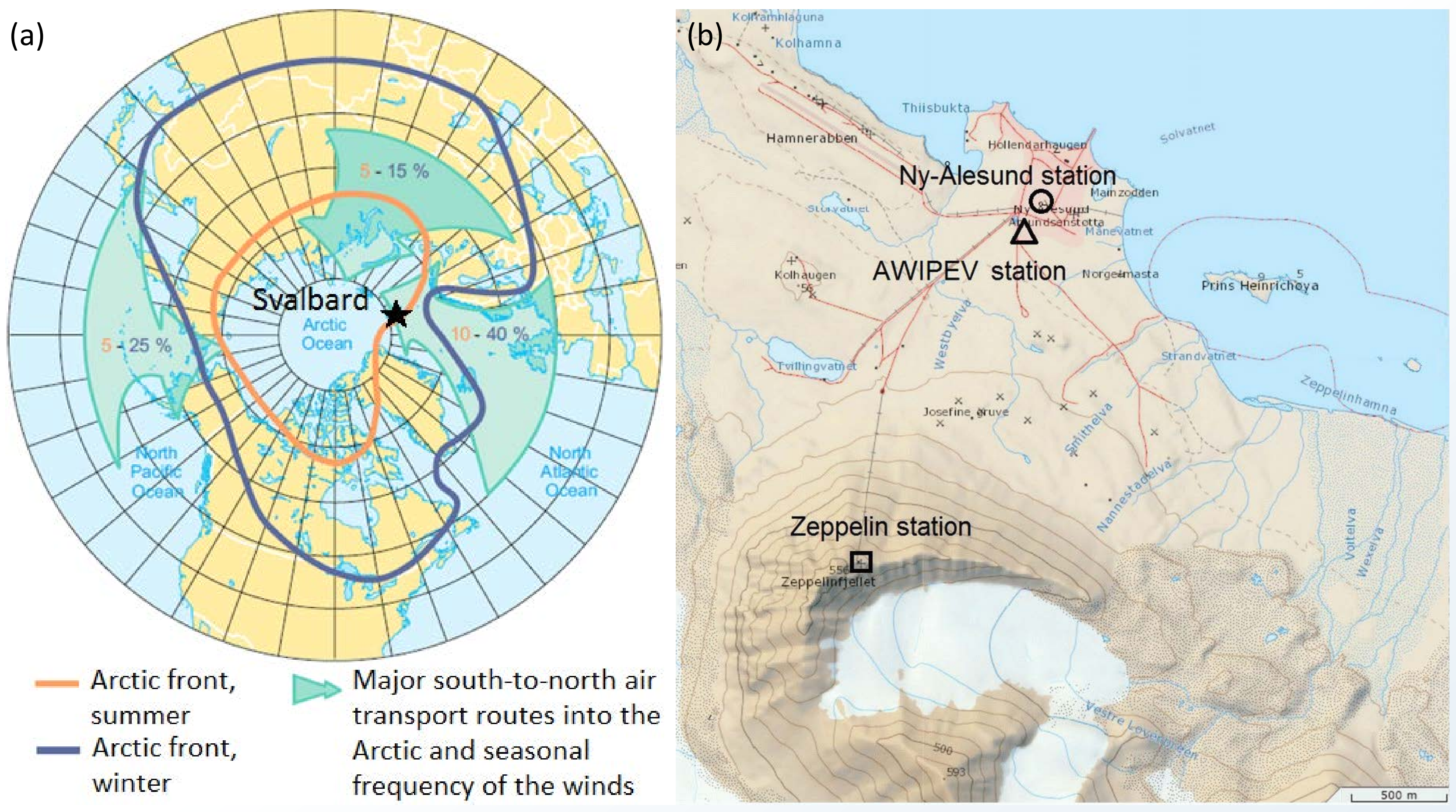


Figure 2 a) Location of Svalbard (black star) (modified Figure 3.4 from AMAP, 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme, Oslo, Norway); b) map of Ny-Ålesund, indicating the locations of the measurement stations.

/ METHODOLOGY

Study area and materials

Daily filter measurements of sulphur dioxide (SO_2) and non-sea salt sulphate (XSO_4^{2-}) and meteorological data from Ny-Ålesund and Zeppelin station have been analysed along with the data from radiosonde soundings from AWIPEV station (Fig. 2b) and ERA-Interim reanalysis data set produced by the European Centre for Medium-Range Weather Forecasts.

Data analysis

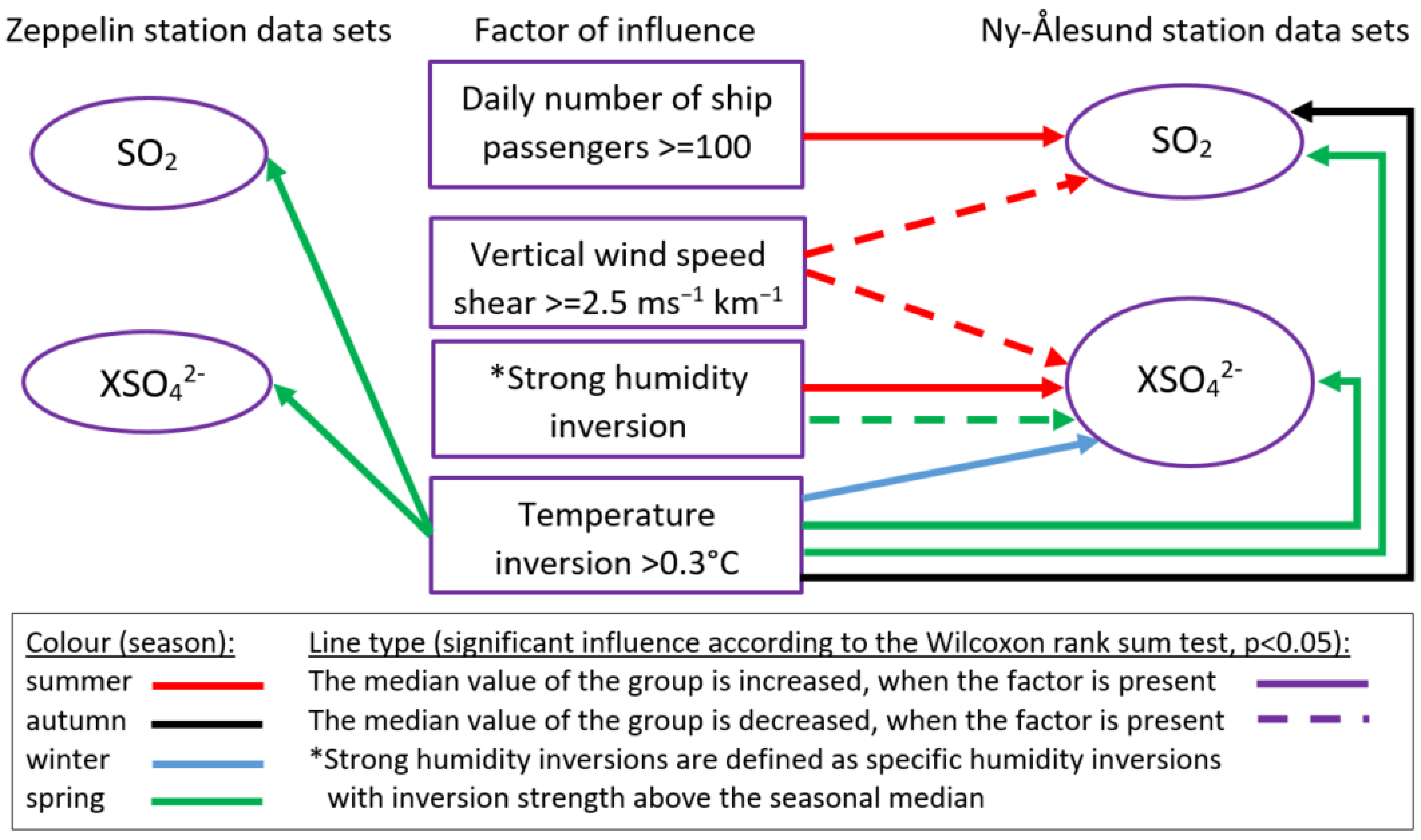
The SO_2 and XSO_4^{2-} daily data sets from the Ny-Ålesund and the Zeppelin stations were grouped seasonally, and each seasonal data set was divided into two samples according to the absence or presence of the factor of interest: directional and wind speed shear, temperature inversion and/or humidity inversion, and local summertime pollution from ships. The Wilcoxon rank sum test has been applied to check if there is a statistically significant difference between the two samples. If p<0.05, the factor on the basis of which the data were grouped is recognized as being important.

In addition to this, the height of the mixed layer h_{con} in the lowest atmosphere has been calculated using summer radiosonde profiles. h_{con} affects the possibility of local pollution from ships emissions reaching the Zeppelin observatory.

/ RESULTS

The correlation of daily SO_2 and XSO_4^{2-} data sets from the Ny-Ålesund station and the Zeppelin mountain station has a large seasonal variation.

Summer: SO_2 data sets: r=0.06, p=0.50; XSO_4^{2-} data sets: r=0.27, p=0.003
Autumn: SO_2 data sets: r=0.43, p<0.001; XSO_4^{2-} data sets: r=0.64, p<0.001
Winter: SO_2 data sets: r=0.98, p<0.001; XSO_4^{2-} data sets: r=0.63, p<0.001
Spring: SO_2 data sets: r=0.50, p<0.001; XSO_4^{2-} data sets: r=0.68, p<0.001



Zeppelin station data sets

Factor of influence

Ny-Ålesund station data sets

SO_2

XSO_4^{2-}

Daily number of ship passengers >=100

Vertical wind speed shear >=2.5 ms^{-1} km^{-1}

*Strong humidity inversion

Temperature inversion >0.3°C

SO_2

XSO_4^{2-}

Colour (season):
summer 🟥
autumn ⬛
winter 🟦
spring 🟩

Line type (significant influence according to the Wilcoxon rank sum test, p<0.05):
The median value of the group is increased, when the factor is present ———
The median value of the group is decreased, when the factor is present – – ·
*Strong humidity inversions are defined as specific humidity inversions with inversion strength above the seasonal median

Figure 3 Diagram of the statistically significant factors of influence based on the results of the Wilcoxon rank sum test (p < 0.05)

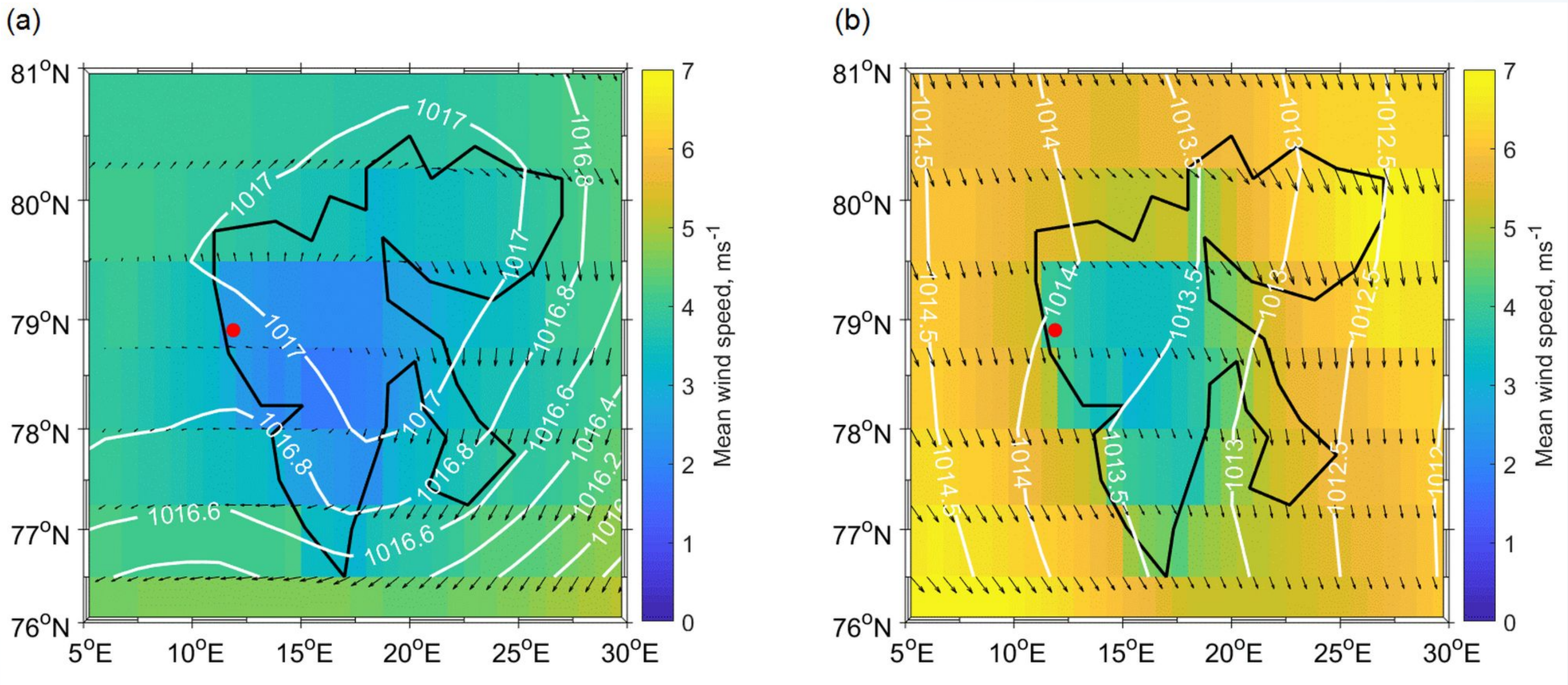


Figure 4 Summer mean wind speed in m·s^{-1} (colour scale), wind direction (black arrows with the length relative to the wind speed) and mean sea-level pressure in mbar (white lines) in the Svalbard area (black outline) and Ny-Ålesund (red dot), obtained from surface ERA-Interim data: (a) for days with strong humidity inversion; (b) for days with normal or no humidity inversion.

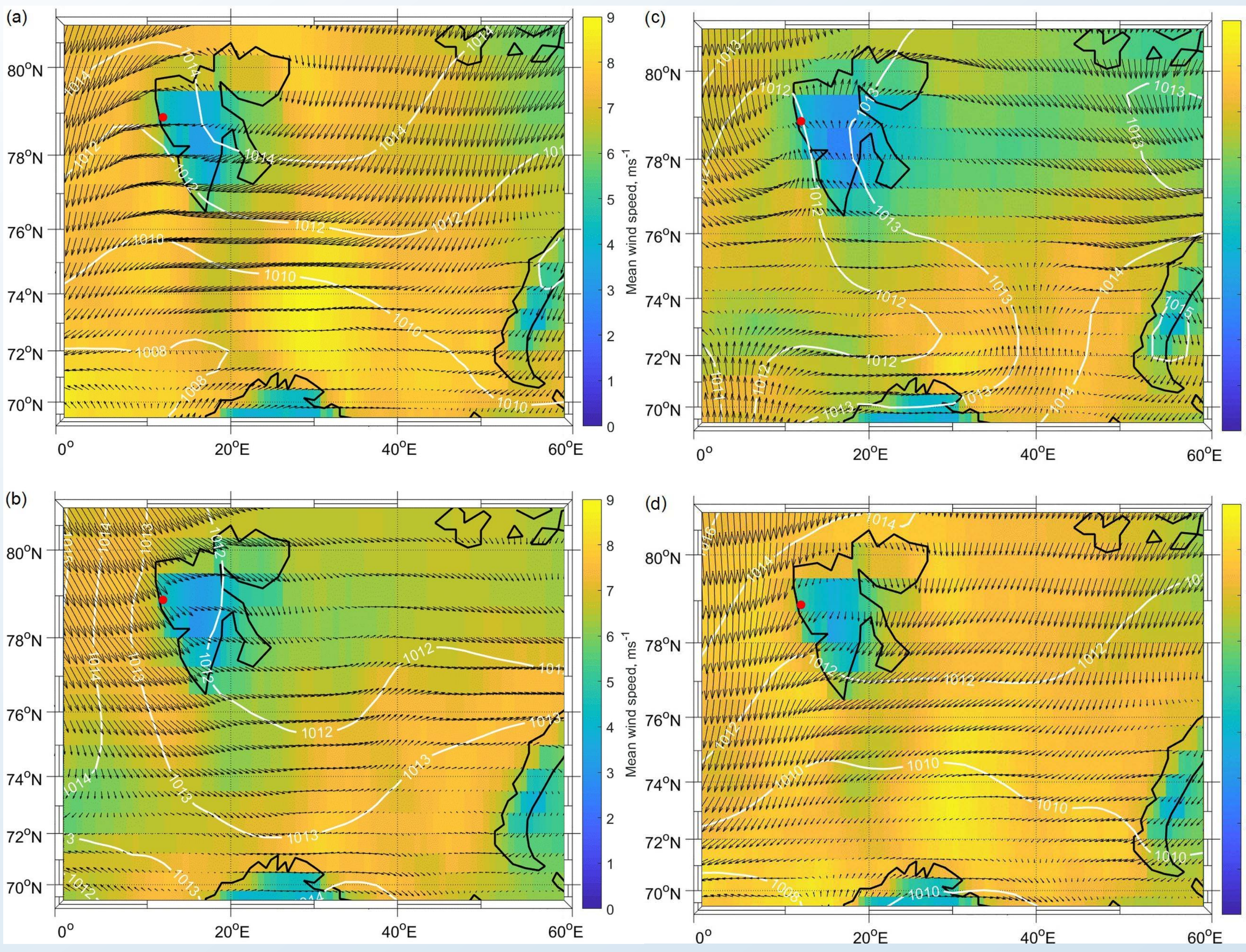


Figure 5 Spring mean wind speed in m·s^{-1}, wind direction and mean sea-level pressure in mbar in the Greenland and Barents seas, obtained from surface ERA-Interim data: (a) for days with temperature inversion; (b) for days without temperature inversion; c) for days with strong humidity inversion; d) for days with normal or no humidity inversion

/ CONCLUSIONS

There is no significant correlation between the SO_2 data sets from the two stations in the summer, while it is very strong in the winter. The values of Pearson correlation coefficient in autumn and spring are intermediate to moderate. The correlation between the XSO_4^{2-} data sets is significant for all seasons, but it is the lowest for the summer data. The correlation of the data varies due to the influence of different micrometeorological phenomena and local pollution. Modelling of these environmental factors is still challenging, and it needs to be considered when one compares modelling results with measurements taken at different heights in the area with complex topography.