Long-term sulphur observations in the Norwegian Arctic

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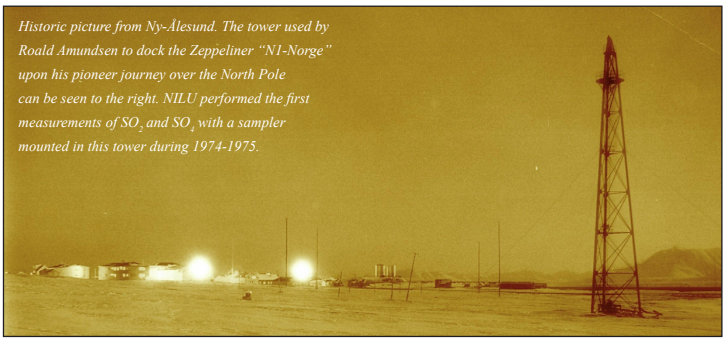


Historic picture from Ny-Ålesund. The tower used by Roald Amundsen to dock the Zeppeliner "N1-Norge" upon his pioneer journey over the North Pole can be seen to the right. NILU performed the first measurements of SO_2 and SO_4 with a sampler mounted in this tower during 1974-1975.

Introduction

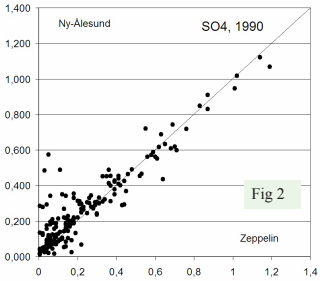
Continuous measurements of sulphur compounds in the Norwegian Arctic were initiated in the late 1970ies and included analysis of SO_2 and SO_4 at the sites Bear Island (74 °26'N, 19°01'E, 20 masl.) and Ny-Ålesund (Spitzbergen) (78 °55'N, 11°55'E, 10 masl.). In 1989, the Mt. Zeppelin observatory was established (78 °54'N, 11°54'E, 474 masl.), and after one year of parallel observations between the new site and measurements in Ny-Ålesund, the Ny-Ålesund and Bear Island sites were discontinued. As the Bear Island site was the only site for which data was reported to the European Monitoring and Evaluation Programme (EMEP), data series from Ny-Ålesund until 1990 have so far only been available as monthly means in historic data reports. Recently, the original repository of chemical analysis results at the chemistry laboratory of NILU was revisited to provide the data previously not being available. This poster presents for the first time this unique dataset with observations during a period of about 26 years for which measurements were made using comparable methodology.

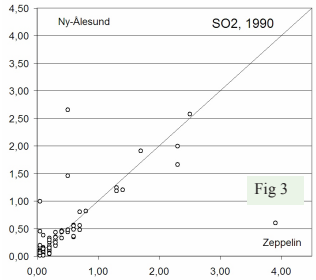
Consistent measurement methodology

A three-stage filterpack system is used for sampling main air components. The first filter is a Teflon filter (Zefluor) for collection of aerosols, the second is a Whatman 40 filter impregnated with KOH to collect acid gasses (SO_2 and HNO_3), and the last is a Whatman 40 filter impregnated with oxalic acid to collect NH_3. The water extract of the aerosol filter, hydrogen-peroxide extraction of the acid impregnated filter and HNO_3 extract of oxalic acid impregnated filter are all analysed for main ions by ion chromatography. Measurements of nitrogen species were initiated in 1984, but are not presented here.

Combining the Ny-Ålesund/Zeppelin time series

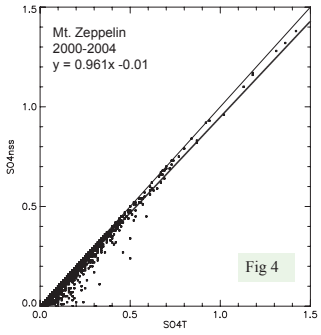
The establishment of the Zeppelin observatory in November 1989 enabled observations at a location less affected by local activities than the previous location in Ny-Ålesund (e.g. a coal fired power generator in Ny-Ålesund was expected to have some influence on the observations). Further, the contribution of sea-salt to ambient SO_4 is reduced due to the difference in elevation (about 450 meters). To quantify the differences between the two sites, measurements were run in parallel for a period of 14 months (fig. 2 and 3).

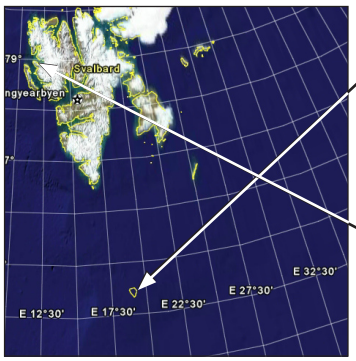




The sea-salt contribution to ambient sulphate

As described above, the practice related to sea salt corrections was not consistent over the observation period. This hampers the evaluation of trends in the time series. The data indicate that the contribution to ambient concentrations is in the order of 3-10 percent. Further, due to the large reductions seen in anthropogenic SO_4, the relative contribution from sea-salt in the 1970-1980-ies would definitively have been even lower.





Bear Island

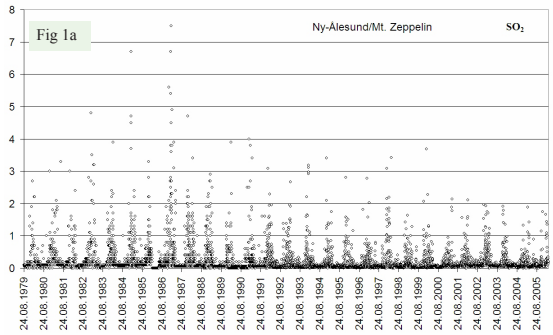
Measurements of SO_4 in aerosols at Bear Island were initiated on 1 October 1977 while SO_2 measurements started 1 January 1978. Daily observations are available until 1 January 1989. From 1 January 1989 until 31 July 1989 samples were taken as 2-3 day integrated samples, after which the measurements were discontinued.

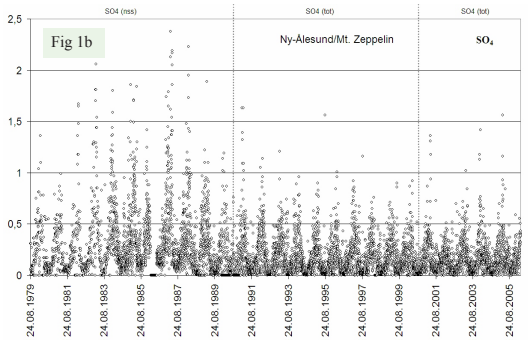
Ny-Ålesund

Measurements were initiated on 24 August 1979, irregular but continuous sampling (2-3 day integrated samples) until 31 December 1983 when daily sampling was initiated. Sulphate data was corrected for the sea-salt contribution. With the exception of the year 1990, sea-salt concentrations were however not stored, and total sulphate values can unfortunately not be reconstructed (see note below about sea-salt contribution). Two extreme values were removed from the original data series (13 July-15 July 1980 of 5,8/2,8; 4 August 1997 of 3,33/2,8 µg SO_4/SO_2 (as S) respectively). Measurements were discontinued on 1 January 1991.

Mt. Zeppelin

Measurements were initiated in November 1988, but with incomplete sampling until 1 January 1991 (due to technical problems, samples could be taken only every second day). No corrections made for sea-salt contribution until 1 January 2000. From 2000, data are available for total sulphate, non sea-salt as well as for Mg and Na allowing calculation of sea salt contributions.





Main findings

- Long-term observations are fundamental for understanding long-term changes in atmospheric composition. The dataset presented here offers additional insight into the trends of air pollution in the European Arctic. Figure 1a-1b presents the individual data points for Ny-Ålesund/Mt. Zeppelin during 1979-2005.
- Significant downward trends are seen both for SO_4 and SO_2 due to reduced anthropogenic emissions in Europe and Eurasia.
- Most of the reductions occur from the end of the 1980ies resembling well the trends in emissions in Eastern Europe.
- When comparing the seasonal variation during 1980-1988 with 2000-2004 (fig. 5) reductions are in the order of 60-70% during winter and 30-50% during summer.
- Concentration levels at Bear Island are, with respect to the lower percentiles of the frequency distribution, quite similar to what is observed at Ny-Ålesund, but for the higher percentiles, levels are significantly higher (fig. 6). This is likely due to a combination of more frequent transport episodes and shorter transport time from the source regions in Europe.
- The data here provided for Ny-Ålesund extends the series of daily data back to 1 January 1984. Further extension of the data series backwards in time needs to rely on data with longer integration times, making the statistics of episodic events more difficult to interpret. Still, consistent trends in monthly, seasonal and annual means can be derived from data going back to 1979.
- Downward trends are evident for all percentiles of the frequency distribution. The lower percentiles of SO_2 and SO_4 during summer, and of SO_2 during winter indicate that levels are slightly higher during the last 5 years compared to the mid- to late 1990ies. It is however not obvious if this trend is significant, and to which extent meteorological variability influence the trend. One hypothesis is that warmer summers and increased wild fires in the boreal regions may be of importence.