Variability features of the ozone column and surface UV irradiance observed over Svalbard.

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Abstract

We present some specific features of the variability in the ozone column and solar UV irradiance that were revealed by the analysis of the observations performed from 2008 to 2014 at Ny-Ålesund by the narrow-band filter radiometer UV-RAD (Petkov et al., 2006). The instrument measurers the surface global solar UV irradiance at 7 channels picked at 300, 306, 310, 315, 325, 338 and 364 nm, each having a bandwidth of about 1 nm. A procedure that allows the reconstruction of the solar UV spectrum within 290 – 400 nm band was developed while the ozone column is determined using the method proposed by Stamnes et al. (1991). UV-RAD was calibrated by comparing it with a similar instrument and the calibration constants were corrected during the Quality Assurance in the Arctic (QAARC) intercomparison campaign carried out in May-June 2009 at Ny-Ålesund. During the campaign the instrument showed nearly 5% discrepancy with respect to the reference spectrophotometer at wavelengths longer than 310 nm, which discrepancy increases until 9% moving towards 300 nm (Gröbner et al., 2010). The behaviour of the UV irradiance observed within the period under study is represented in Fig. 1(a) by the daily erythemal dose D_E, which is a parameter that smooths the diurnal changes and gives an idea about the variations in UV over the daylight period of the year. Figure 1(b) shows the corresponding time patterns of the retrieved daily means of the

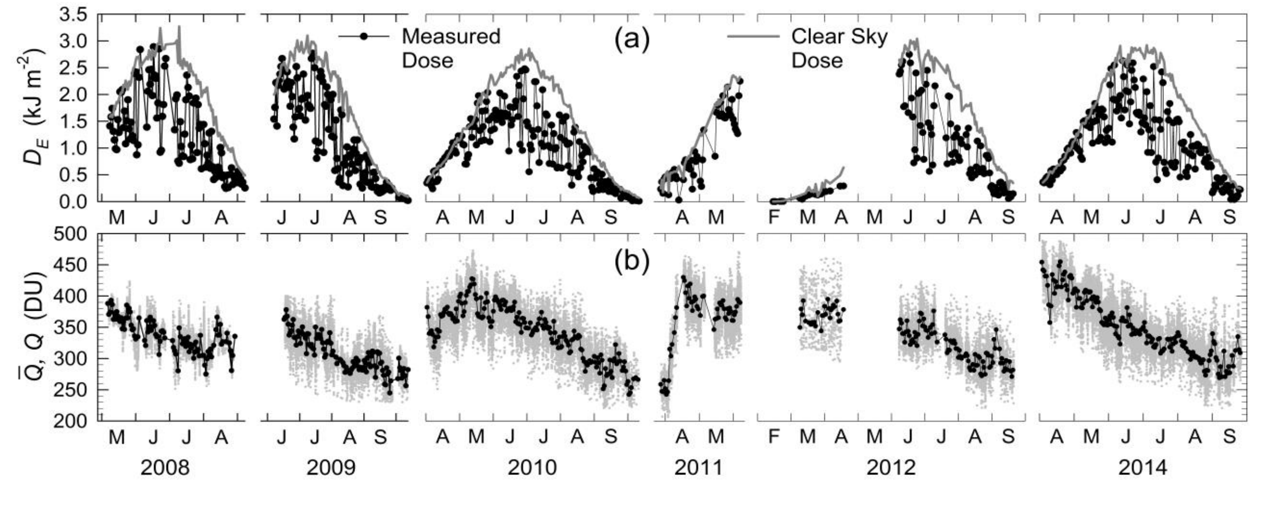

Figure 1: *Time patterns of the daily erythemal dose D_E (a) and ozone column (b) registered during the period under study at Ny-Ålesund. The values of D_E obtained from the measurements are given together with the time patterns of the corresponding clear-sky values that have been simulated through the TUV radiative transfer model. The panel (b) exhibits the daily mean ozone column $\bar{Q}$ (black circles with black curve) together with the 5-minute time resolution measurements Q (grey circles).*

ozone column $\bar{Q}$ together with the values Q obtained with 5-minute resolution. It is seen that, except for the seasonal variations, both dose D_E and ozone $\bar{Q}$ are subjects of large day-to-day fluctuations, which could be attributed to the intensive dynamical processes causing variations in the atmospheric transparency and a frequent change of the air masses characterised by different ozone content. The grey curves in Fig. 1(a) are computed by the Tropospheric Ultraviolet-Visible (TUV) radiative transfer model (Madronich and Flocke, 1997) and provide an approximation of the clear sky values, since they were calculated for free of clouds atmosphere. It is seen that for the most of the days, the measured doses D_E are much lower than the corresponding clear sky values that assumes predominantly cloudy sky conditions during the considered period. Figure 1(a) indicates that the day-to-day variations in UV irradiance observed in June – July, are stronger than those registered in the rest of the period. For these two months, the amplitude of the daily erythemal dose reaches a value of more than 2.0 kJ m^{-2} that is about 67% of the observed yearly variations, which are about 3 kJ m^{-2}.

The polar summer gives the opportunity to register the solar irradiance 24 h per day during several months that provides comparatively long continuous time series as regards for the short- (diurnal) and medium-term (monthly) variations. To exclude the hypothesis about the artificial nature of the large amplitudes registered in the short-term ozone column variations, which can be due to the measurement or methodological errors, they were related to the corresponding variations in the solar UV radiation and such a comparison showed a strong relationship between these two parameters (Petkov et al., 2012). The short-period oscillations were studied using the methods developed for the analysis of non-linear dynamical systems that revealed a complex chaotic interaction among the ozone column and five other atmospheric factors. This approach leads to the conclusion that the short-term variations can be predicted for 10–20 h if a long history is available (Petkov et al., 2015).

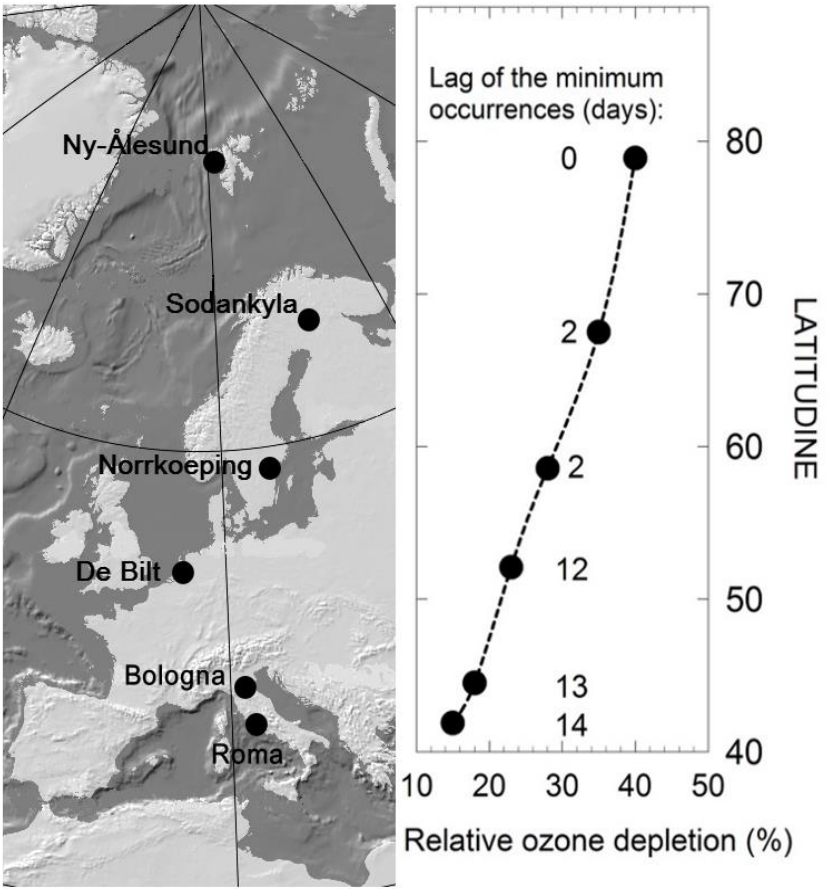

Figure 2: The deepest relative ozone depletion during April 2011, observed over Europe as a result of the corresponding Arctic event. The left panel indicates the stations where the ozone reduction (given on the right) was observed. The lag of the minimum occurrence for each of the stations is given in the right panel.

The effect of a sporadic phenomenon, such as the ozone depletion event, occurred over Arctic in the spring of 2011 (see Fig 1b), which can be considered an impulse perturbation of the medium-term ozone variations, on the mid-latitude ozone column and surface solar UV irradiance has been studied by analysing the data collected from surface stations (Petkov et al., 2014). Figure 2 exhibits the maximum relative ozone decrease observed at 6 stations located at latitudes from about 80°N to nearly 40°N, which decrease was evaluated with respect to the corresponding mean value determined for the same period of the last years. It is seen that the ozone column depletion at the northernmost station was about 40%, gradually decreasing toward mid-latitudes where it reached a value of about 15%. The lowest ozone amounts at the stations showed in Fig. 2 were registered with a delay relative to Ny-Ålesund as indicated in the right panel. Such a lag confirms the hypothesis that the ozone depletion over the mid latitude observed in April 2011 was not a causal phenomenon but it was a sequence of the Arctic event.

The seasonal variations in the ozone column over the north polar region is governed to high extent by the Brewer–Dobson circulation (Brewer, 1949; Dobson, 1956) that transports air masses from the tropics toward polar areas. In this context, the propagation of the 2011 ozone depletion event, or the propagation of a deep perturbation in medium-term ozone variations in Arctic to lower latitudes reveals a feedback and, hence, a complex interaction between the mid-latitude and polar air masses driving the medium-term ozone variations.

The model simulations showed that the increase of the midday erythemal dose at mid-latitudes in April 2011 was slightly higher than the corresponding increase at the polar regions despite that the ozone depletion at lower latitudes was smaller, which can be accounted for the sharp increase of the solar elevation at mid-latitudes in the spring with respect to the Arctic. On the other hand, the results indicate that the biosystems in Arctic were subjects of about 4 times higher UV stress than those at mid-latitudes.

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