Comparison of solar UV irradiance and total ozone column observed at two contrasting Antarctic sites

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Introduction

Understanding the distribution of solar ultraviolet (UV) irradiance observed in high latitudes of the Southern Hemisphere is important for variety of effects and feedbacks in the marine and terrestrial ecosystems. Seasonal increase of the UV irradiance caused by a decrease of the stratospheric ozone is a specific feature of solar radiation in Antarctica. Apart from ozone, the UV irradiance is strongly affected by various environmental factors such as cloudiness, surface reflectivity (albedo), and aerosol loadings (Petkov et al., 2016).

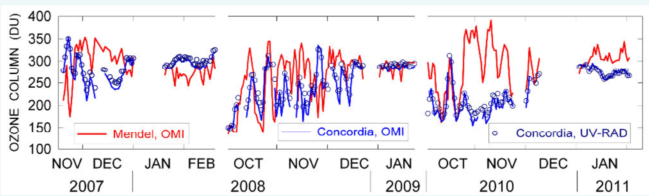
In this contribution, the features of solar radiation and total ozone observed at two contrasting Antarctic sites located in the coastal zone and highly-elevated interior plateau were analysed with the aims of examining the role of the environmental factors, impacting irradiance variability during the daylight part of the year.

Johann Gregor Mendel Station

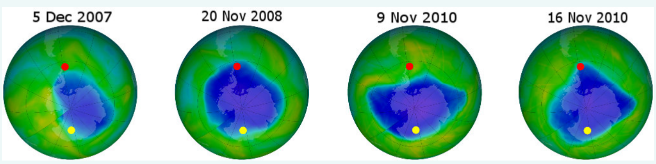
- James Ross Island (63°48'S, 57°53'W)
- Altitude: 7 m a. s. l.
- Mean Albedo: 62% (OMI level 2G)
- Mean Cloud Cover: 63% (based on AIRS L3 cloud retrievals)

Dome Concordia Station

- Antarctic Plateau (75°06'S, 123°21'E)
- Altitude: 3233 m a. s. l.
- Mean Albedo: 94% (OMI level 2G)
- Mean Cloud Cover: 4% (based on AIRS L3 cloud retrievals)



Ozone column variations at Mendel and Concordia stations determined by the satellite-based OMI instrument (NASA GSFC, ftp://jwocky.gsfc.nasa.gov/pub/omi/data/overpass/) and the ground-based UV-RAD radiometer.

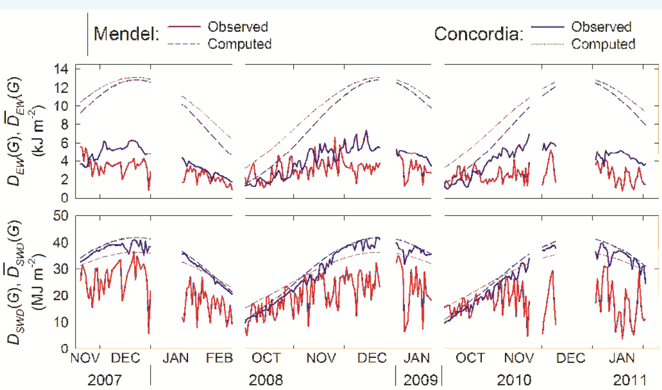


Daily ozone column distribution with the area of the ozone depletion (blue) over the Southern Hemisphere provided by the GSFC, NASA (http://ozonewatch.gsfc.nasa.gov). Locations of the both stations are shown by red (Mendel) and yellow (Concordia) circles.

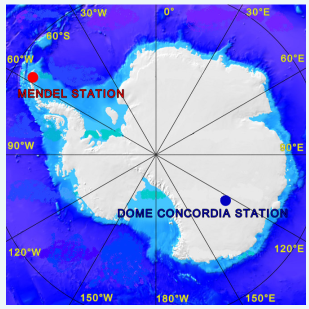
Data and Methods

Erythemally weighted (EW) irradiance and total ozone column at Mendel Station were acquired from the UV-Biometer 501A measurements and OMI data retrievals (Láska et al., 2011), while the narrowband filter radiometer UV-RAD, providing EW and ozone column (Vitale et al., 2011), and OMI data were used at Concordia. The transmittance characteristics of the atmosphere at both sites were quantified using a short-wave downwelling (SWD) solar irradiance measured by CM11 (Mendel) and CM22 (Concordia) pyranometers.

The Tropospheric Ultraviolet-Visible (TUV) radiative transfer model (Madronich and Flocke, 1997) was used for estimation of clear sky irradiance and for extracting the effects of individual environmental factors (Petkov et al., 2016).

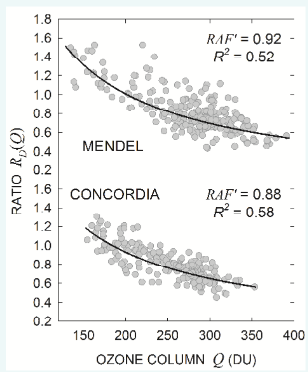


Variation of daily doses of the erythemally weighted $D_{EW}(G)$ and short-wave downwelling $D_{SWD}(G)$ irradiances observed at both stations in 2007–2011. Time patterns of the corresponding modelled TUV values $\overline{D}_{EW}(G)$ and $\overline{D}_{SWD}(G)$ that are considered a realistic representation of the seasonal variations are exhibited by dashed curves. The doses $D_{EW}(G)$ were evaluated for the minimum ozone column registered to be 135 DU at Mendel and 150 DU at Concordia in the period 2007–2011.



Johann Gregor Mendel station at the northern coast of James Ross Island, Antarctic Peninsula. Credit: Masaryk University.

Concordia station, Antarctic Plateau. Credit: NASA / Michael Studinger.



Scatterplots of the ratio of $D_{EW}(G)$ and $D_{SWD}(G)$ irradiances ($R_D(Q)$) versus the mean daily ozone column Q for the considered stations. The grey circles present the measured values, while the black curves indicate the best fits made through power functions, analogously to the radiation amplification factor (RAF'). Parameter RAF is used to quantify sensitivity of the UV irradiance to the variations in the ozone column (Madronich, 1993).

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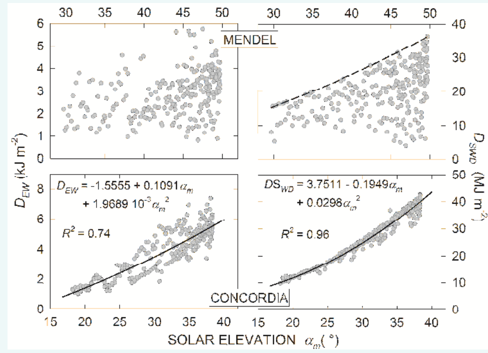

Scatterplots of daily doses of the erythemally weighted $D_{EW}(G)$ and short-wave downwelling $D_{SWD}(G)$ irradiances on the solar elevation α_m at both stations. The grey circles show the measured values, while the best fit polynoms with the coefficients of determination R^2, approximating the dependences at Concordia Station (lower panels). The black dashed curve (upper right panel) indicates the dependence of the modelled seasonal variations $\overline{D}_{SWD}(G)$ on α_m at Mendel station.

Effect of the environmental factors (%)		
Station	Cloud cover, aerosols, albedo	Ozone column (concerns only)
Mendel	25 (20–35) (*EW*) 29 (0–50) (*SWD*)	46 (31–56)
Concordia	5 (0–10) (only clouds)	46 (31–56)

Results and Summary

- Solar irradiance at Mendel Station was strongly affected by the changes in the cloud cover and albedo that cause a decrease in *EW* component between 20–35%, and from 0–50% in *SWD* component.
- Albedo at Mendel Station ranged between 12% in summer (January) and 96% in the late winter (August). In contrast, the permanent snow-covered surface at Concordia Station was characterised by a high albedo varying from 88% to 100% during the year.
- Contributions of the environmental factors at Mendel were slightly lower than the seasonal *SWD* variations evaluated to be about 71%.
- Changes in the cloudiness at Concordia Station produced only a 5% reduction of the solar irradiance, whilst the seasonal oscillations of 94% turn out to be the predominant mode.
- Variations in the ozone column caused an average decrease of about 46% in *EW* irradiance with respect to the value found in the case of minimum ozone content at each of the stations.
- Ozone variation over both stations was closely related to the ozone depletion area and the instability of polar vortex occurring in November and December each year.
- Ratio between *EW* and *SWD* spectral components can be used to achieve a realistic assessment of the radiation amplification factor (*RAF*) that quantifies the relationship between the atmospheric ozone and the surface UV irradiance.

References

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