Climate and lower atmosphere studies

Observations of ozone and cloud properties from NSF ultraviolet-monitor measurements at Palmer Station, Antarctica

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The National Science Foundation (NSF) scanning spectroradiometer at Palmer Station provides hourly ground-based measurements of solar ultraviolet irradiance. In addition to defining the ultraviolet radiation environment of the region, these measurements allow the derivation of the column density of atmospheric ozone above the station nearly every daylight hour. This hourly time resolution, not generally available from other methods of monitoring antarctic ozone abundances, enables the detection of large and rapid changes in total column ozone and ultraviolet surface irradiance associated with the dynamics of the polar vortex. Column ozone abundance is derived from a ratio of measured irradiances at 300 and 313.5 nanometers by means of a theoretical calculation of this ratio as a function of total ozone amount and solar zenith angle (Lubin and Frederick 1990). Noontime ozone abundances over Palmer Station obtained from this method agree with those obtained by the Total Ozone Mapping Spectrometer (TOMS) instrument aboard the Nimbus 7 satellite to within 10 percent throughout the austral spring of 1988. The breakup of the 1988 polar vortex occurred within a 24-hour period beginning in mid-afternoon on 15 November. Over the Antarctic Peninsula, the 1989 ozone depletion was slightly greater than that of 1988, the minimum noontime ozone abundances over Palmer Station as measured by the ultraviolet monitor being 194 and 166 Dobson units for 14 October 1988 and 14 October 1989, respectively. The 1989 ozone depletion, however, ended by 5 November over the Antarctic Peninsula, 10 days earlier than the 1988 event.

A likely excursion of the polar vortex over Palmer Station during the 1989 ozone depletion is shown in figure 1. The horizontal coordinate on this figure gives the Greenwich hour,

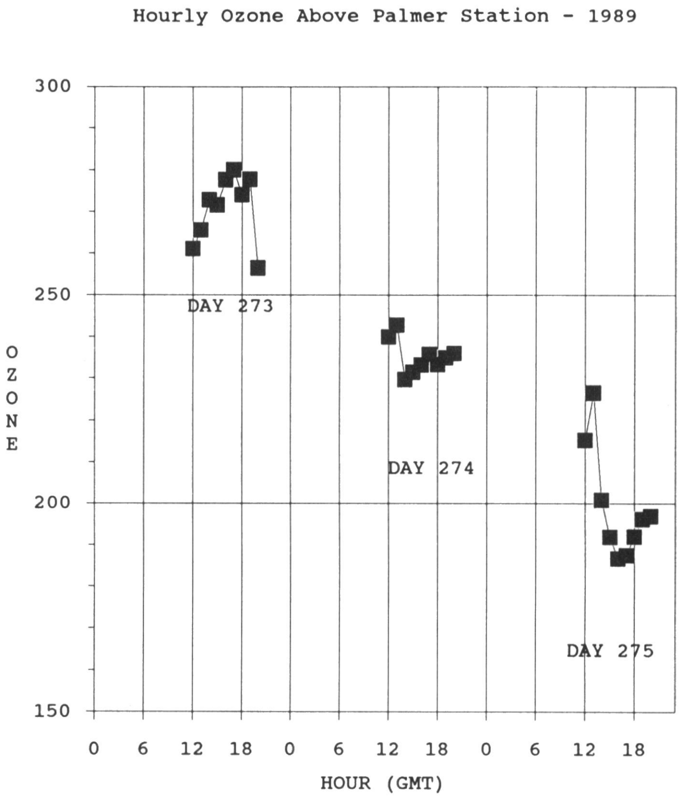

Figure 1. Time history of hourly total column ozone during daylight hours over Palmer Station for the period 30 September (day 273) to 2 October 1989 (day 275), obtained from the NSF scanning spectroradiometer. Ozone abundance is given in Dobson units. (GMT denotes Greenwich mean time.)

and at Palmer Station, solar noon (minimum solar zenith angle) occurs at 16:00 Greenwich mean time. The ozone abundance drops by nearly 100 Dobson units during this 3-day period between 30 September and 2 October 1989 (days 273–275). The most dramatic part of this ozone decrease, a 45-Dobson-unit drop, occurs within 3 hours during the late morning of 2 October (day 275). The hourly surface irradiances at 300 nanometers for days 273–275 appear in figure 2. In response to the decreasing ozone abundance over Palmer Station over this 3-day period, the irradiances on day 274 are typically twice as large as those on day 273, and the irradiances on day 275 are typically three times as large as those on day 274.

In conjunction with a daily record of sky conditions and radiative transfer modeling, the ultraviolet-monitor measurements permit a quantitative understanding of the role of cloud cover in regulating ultraviolet radiation levels at the antarctic Earth surface. The transmission properties of cloud types over the Antarctic Peninsula can be quantified by taking the ratios

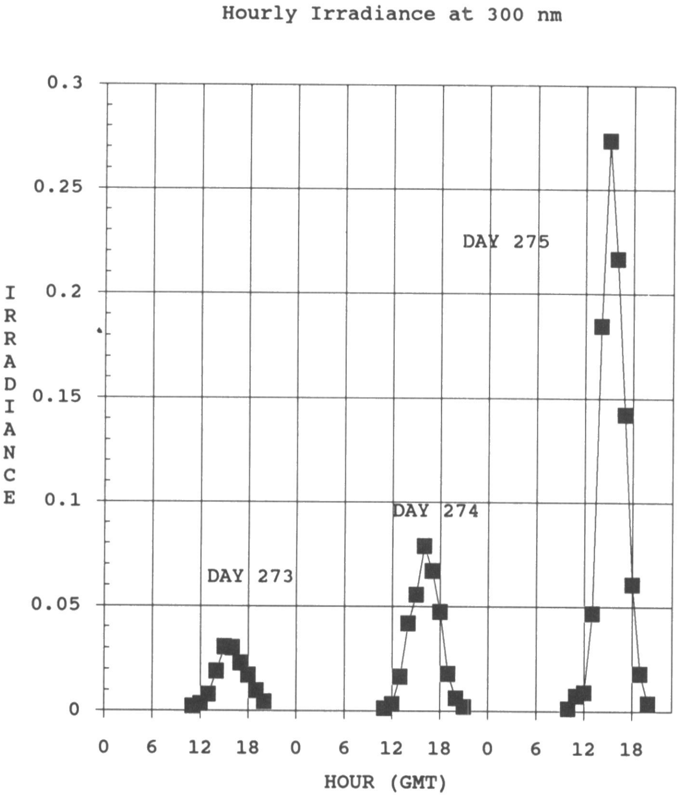

Figure 2. Time history of hourly surface irradiance at 300 nanometers measured at Palmer Station by the NSF scanning spectroradiometer for the time period 30 September (day 273) to 2 October 1989 (day 275). Irradiance is given in microwatts per square centimeter per nanometer. (GMT denotes Greenwich mean time.)

R of ultraviolet-A (UV-A) irradiances measured under them to UV-A irradiances calculated for clear skies and the same solar zenith angle. For this procedure, we use irradiances in the spectral interval 342.5–347.5 nanometers, where ozone absorption is negligible, to avoid a great deal of uncertainty due to ozone. Cloud scattering is essentially wavelength-independent over the entire ultraviolet, and these results can be applied to the UV-B (280–320 nanometers).

Basic optical properties of the various cloud types observed over Palmer Station during spring, 1988, are shown in the table. Shown is the mean cloud transmission $<R>$, the equivalent plane-parallel cloud optical depth γ (from a two-stream calculation), and the number N of observations of each cloud type. The optical depth γ is not shown for partially cloudy skies, because a plane parallel calculation is strictly not meaningful in these cases. While the mean optical depth for overcast skies was 15, overcast layers with optical depths as large as 70 were occasionally observed. Under the average overcast sky in the region, ultraviolet irradiance at all wavelengths is slightly greater than half of the value for clear skies. Under the thickest overcast layers, ultraviolet irradiance at all wavelengths is roughly 20 percent what it would be if the sky were clear. In a seasonally averaged sense, cloudiness has no effect on the percentage enhancement in UV-B surface irradiance which results from the springtime ozone depletion. However, when considering timescales of hours to several days (comparable to the lifetimes or doubling times of organisms at the base of the antarctic marine food web), cloud cover can be discussed in terms of its ability to attenuate the solar irradiance, in some cases giving a surface UV-B level comparable to that found under an unperturbed ozone column and clear skies (Lubin and Frederick in press). Depending on the amount of ozone depletion and the type of cloud cover, there will always be a wavelength below which surface-radiation levels are excessive during spring.

Cloud climatology for Palmer Station during spring, based on NSF scanning spectroradiometer measurements, two-stream radiative transfer calculations, and a written record of 700 weather observations compiled between 16 September and 21 December 1988. The number of observations, the mean cloud transmission, and the mean optical depth are listed for each sky condition. The last five entries refer to partial cloudiness.

Sky condition	N	<R>	>
All overcast skies	441	0.541	15
Storm clouds with high winds	27	0.492	19
Sky obscured due to snowfall	97	0.512	17
All overcast, bases lower than 2,000 feet	129	0.503	18
All overcast, bases 2,000–3,000 feet	158	0.574	13
All overcast, bases above 3,000 feet	40	0.626	10
All overcast with solar disk visible through	29	0.772	4
Less than 1/10 sky coverage	14	0.987	—
1/10–3/10 sky coverage	60	0.966	—
4/10–6/10 sky coverage	74	0.905	—
7/10–8/10 sky coverage	48	0.748	—
Broken all overcast (9/10 or more coverage)	63	0.713	—

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References

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