7.4. Ushuaia, Argentina

The ozone hole in the austral fall of 2000 was very unusual. Already in early August an exceptionally large area of very low stratospheric temperatures was noted over Antarctica, which set the state for the earlier than usual development of the annual Austral Spring ozone hole. After a particularly rapid growth during August, the ozone hole reached the largest size on record with an extent of close to 30 million km^2 on September 9. In early October, it was also the deepest with ozone losses exceeding 50% within most of the area of the ozone hole when compared to the pre-ozone-hole conditions. The hole in 2000 grew three weeks earlier than in 1999 and reached its peak one week earlier than in 1999. Its edge was located above southern South America several times in September and October, leading to record UV levels at Ushuaia, as will be shown below. After October 20, 2000, the ozone hole begun a very rapid, sustained decreased in size, closing between November 20 and 25. This was the earliest break-up since 1991 and took place almost a month earlier than in 1998 and 1999.[1]

The ozone hole of 2001 showed a similar pattern than that observed during the late 1990s. It reached an area of 25 million km^2 in mid-September. The largest ozone mass deficit[2] was 54 Mt, which is smaller than the record deficit of 57 Mt observed in 2000. Both values are higher than those typical for the 1990s. Like in 2000, the outskirts of the ozone hole passed several times over Ushuaia, leading to significant increases in UV radiation. The 2001 ozone hole remained large until late November. As it kept a circular shape centered over the South Pole, its influence for Ushuaia was small after October 27.

Figure 7.4.1 shows total column ozone over Ushuaia as measured by TOMS. On September 9 and October 7, 12, and 18, ozone values dropped below 200 DU when the edge of the ozone hole was located above Ushuaia. The value observed on October 12 was 140.4 DU, which is the lowest value of the 22-year time series of TOMS ozone observations at Ushuaia. After October 28, ozone values are significantly higher than the average calculated from the 1990s, indicating the early break-up of the polar vortex in 2000.

In 2001, ozone dropped below 220 DU on October 15 and 21 (220 DU is the ozone column that is usually used to define the edge of the ozone hole). On both days, ozone depleted air masses were moving over Ushuaia. Note that ozone values in November 2001 are higher than average values from the 1990s, like it was observed in 2000.

The low ozone values in October 2000 lead to record high UV levels. Figure 7.4.2 shows noon-time (i.e. 17:00 UT) irradiance of the 298.51 - 303.03 nm integral. Noon-time values on October 7, 12, and 18 are 7.4, 11.0, and 8.6 $\mu W/cm^2$, respectively. As UV levels are also controlled by cloud cover, the highest UV values do not necessary occur during solar noon. This was the case on October 18 when 11.5 $\mu W/cm^2$ were observed on 16:15 UT, exceeding the noon-time value by a factor of 1.34. This is the highest 298.51 - 303.03 nm integral value measured by the instrument in Ushuaia since its start of operation in 1988. Note that noon-time measurements of the integral on October 16 are 0.047 $\mu W/cm^2$ only. This value is 245 times smaller than the record reading from two days later. The great difference is mostly the consequence of differences in cloud attenuation between the two days rather than ozone column. This demonstrates both the large natural variability in UV radiation and the great influence of factors other than ozone on the UV climate.

Figure 7.4.3 contrast noon-time erythemal irradiance measured in 2000 and 2001 with the values observed in the 1990s. Erythemal UV levels on October 7, 12, and 18 and 2000 were 21.0, 25.8, and 20.8 $\mu W/cm^2$, respectively. The maximum values observed on these days were 22.4, 25.9, and 26.6 $\mu W/cm^2$, respectively. These values correspond to UV Indices of 9.0, 10.4, and 10.6. These Indices well exceed typical summer levels for Ushuaia of 8, which are observed during December and January, when the sun is about 15°

[1] The summary of the year 2000 ozone hole was compiled from Pablo O. Canziani, "The Evolution of the Antarctic zone hole in 2000", http://www.aero.jussieu.fr/~sparc/News16/16_Canziani.html, and the WMO Antarctic ozone bulletins, http://www.wmo.ch/web/arep/00/

[2] The ozone mass deficit is defined as the mass of ozone destroyed in the Antarctic ozone hole region compared to the pre-ozone hole norms. It is expressed in millions of tons (Mt).

higher in the sky than in mid-October. For comparison, the UV-Index in San Diego is typically 10 during the summer, and never exceeds 12.

As can be expected, the effect of ozone depletion can also be seen in daily doses. Figure 7.4.4 shows that DNA-weighted daily dose observed in October 2000 significantly exceeded levels that are typical for this part of the year. The highest October dose (i.e. 0.124 kJ/m^2) was observed on October 12, 2000, the day with the lowest ozone column on record. This value is close to the largest DNA-weighted daily doses on record, measured on November 26, 1996 (0.130 kJ/m^2) and December 8, 1998 (0.134 kJ/m^2). Note that daily doses in November 2000 and 2001 were below the average calculated from the 1991-1999 data.

Erythemal daily doses (Figure 7.4.5) are less affected by ozone variations than DNA-weighted daily doses. This explains the difference seen in Figures 7.4.4 and 7.4.5. Specifically, the relatively high values observed in October 2000 are surpassed by higher summer values observed in previous years. Yet the high value observed on October 12, 2000 is outstanding and may had a significant impact on both citizens of Ushuaia and native wildlife, which may not be well adapted to high UV levels early in the spring.

In Figure 7.4.6, daily doses in the 400-600 nm range are shown. Since radiation in the visible is not affected by atmospheric ozone concentrations, Volume 10 measurements agree well with measurements from previous years. Note that there is a large day-to-day variability, caused by rapid changes in cloudiness.

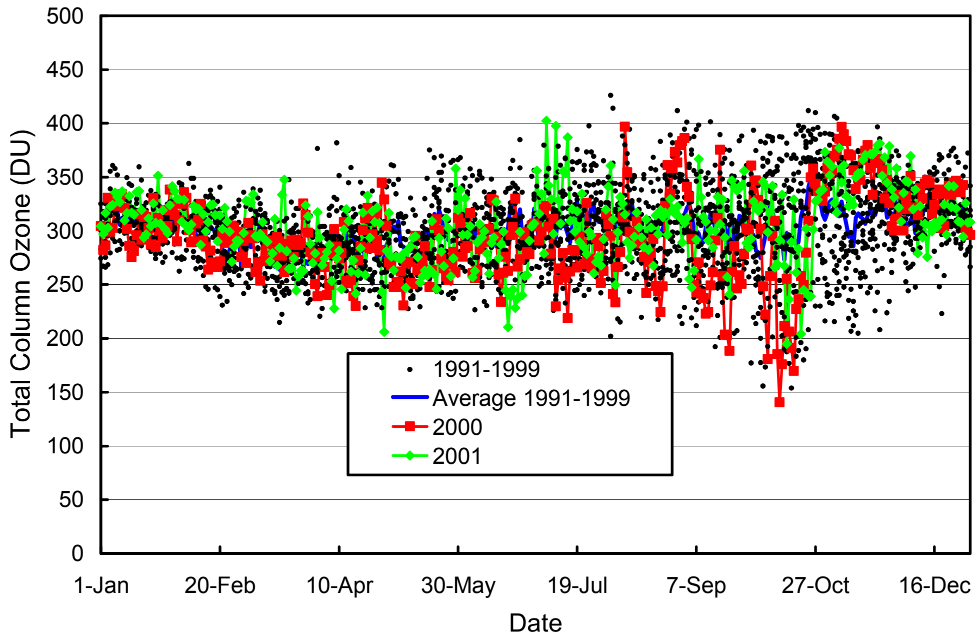

Figure 7.4.1. *Total column ozone in Ushuaia. TOMS/Earth Probe measurements from 2000 and 2001 are contrasted with ozone data from the years 1991-1999 recorded by TOMS /Nimbus-7(1991-1993),TOMS/ Meteor-3 (1993-1994), NOAA/TOVS (1995-1996), and TOMS/Earth Probe (1997-1999) satellites.*

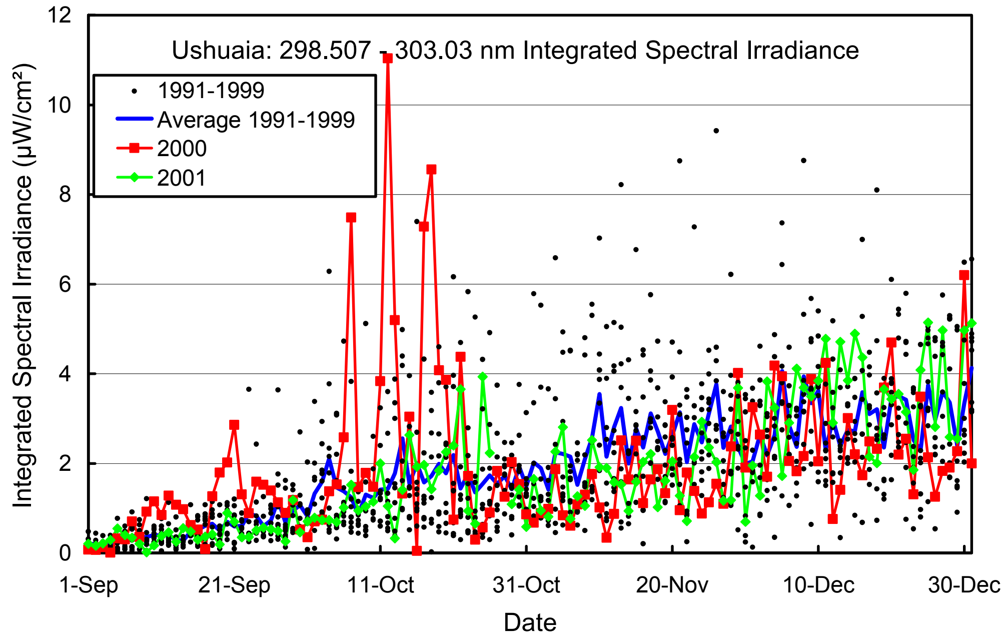

Figure 7.4.2. *Noontime integrated spectral UV irradiance (298.51 - 303.03 nm) at Ushuaia. Measurements from 2000 (squares) and 2001 (diamonds) are contrasted with individual data points and the average of measurements taken between 1991 and 1999.*

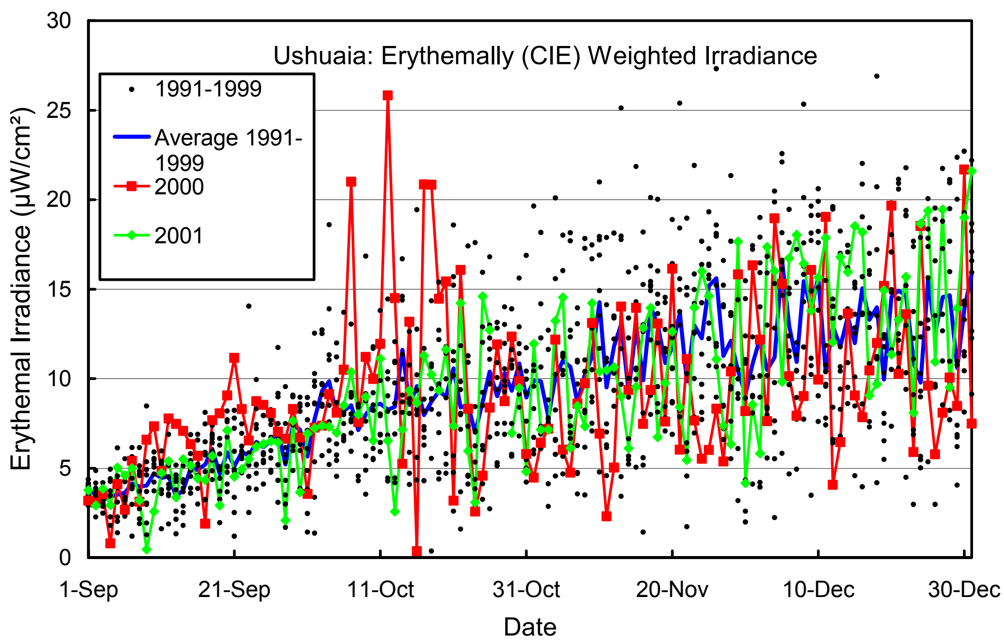

Figure 7.4.3. *Erythemally (CIE) weighted irradiance at Ushuaia. Measurements from 2000 (squares) and 2001 (diamonds) are contrasted with individual data points and the average of measurements taken between 1991 and 1999.*

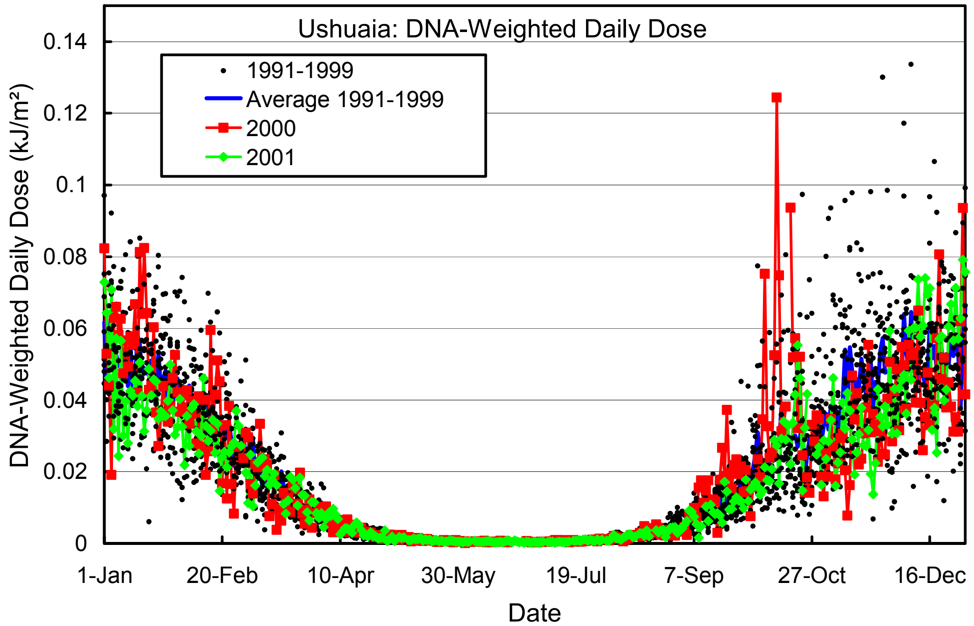

Figure 7.4.4. *Daily DNA-weighted dose for Ushuaia. Measurements from 2000 (squares) and 2001 (diamonds) are contrasted with individual data points and the average of measurements taken between 1991 and 1999.*

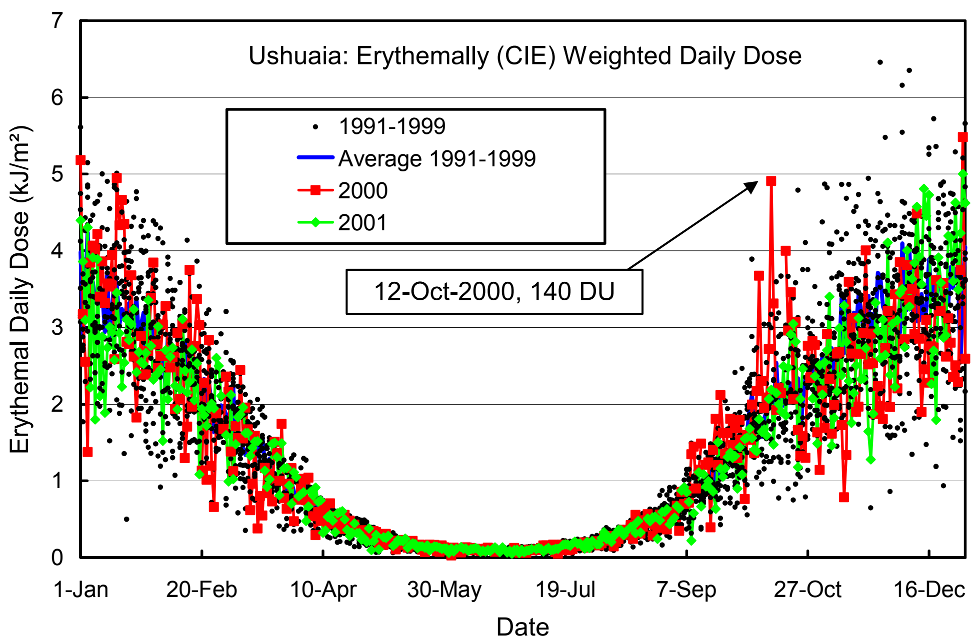

Figure 7.4.5. *Daily erythemal dose for Ushuaia. Measurements from 2000 (squares) and 2001 (diamonds) are contrasted with individual data points and the average of measurements taken between 1991 and 1999.*

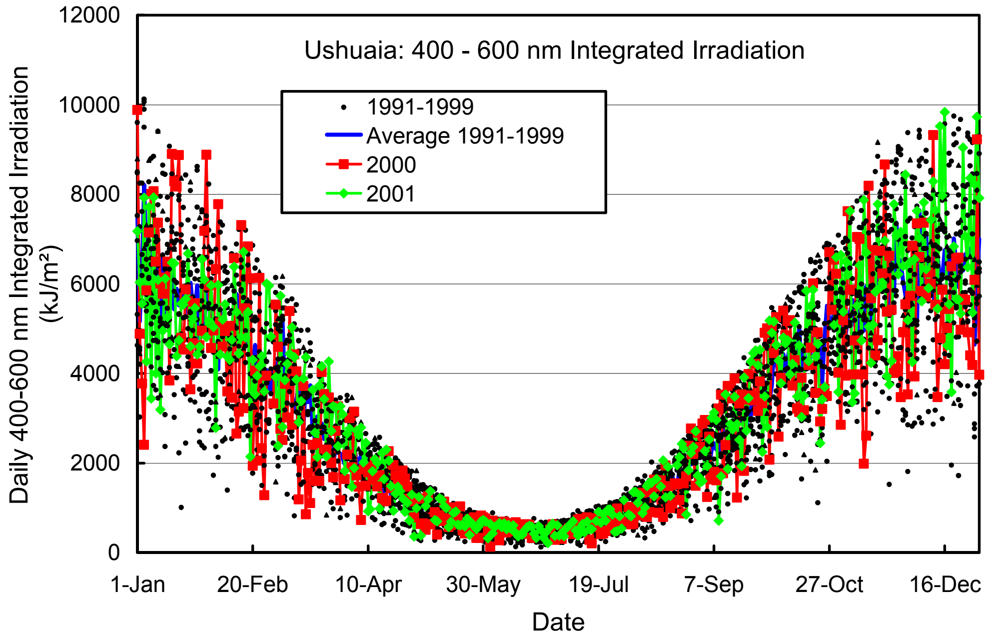

Figure 7.4.6. *Daily irradiation of the 400-600 nm band for Ushuaia. Measurements from 2000 (squares) and 2001 (diamonds) are contrasted with individual data points and the average of measurements taken between 1991 and 1999.*