Results from the Zugspitze Ozone Records

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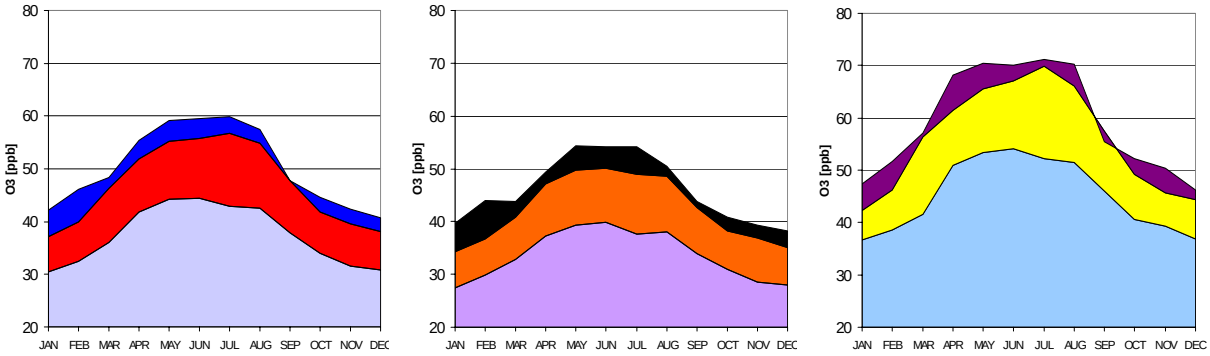
In situ ozone measurements have been performed at the Zugspitze mountain site in the German Alps (2962 m a.s.l., 47°N, 11°E) since 1978. Within the European research programs VOTALP and TOR-2, the O_3 data, in combination with other parameters, have been analyzed statistically over different time scales. This was aimed at a classification of O_3 concentrations with respect to different types of air mass, focusing on stratospheric influence and background levels of O_3. Based on data from 1990-1998, the O_3 influx at 3000 m via directly detected stratospheric events was estimated to be 4 ppb on an annual average. The relative contribution amounted to about 5–6% during the summer half-year and about 12% during winter. Similarly, the relative contributions of other specific conditions (e.g., polluted and unpolluted air) to the actual O_3 concentration were estimated.

O_3 trends were determined separately for the individual months of the year and over different parts of the timeseries using monthly statistical parameters, in particular a set of percentiles. The shapes of the seasonal cycles and the related average growth rates have shown that the recent overall O_3 increase at Zugspitze has been driven by the contribution of the winter months, indicating changes in atmospheric conditions over the observation period. The area plots below visualize the shift of the major increase from summer to winter. Moreover, between 1983 and 1991 the increase for the summer months was mainly related to the higher O_3 concentrations. In contrast, for 1992-1998 the highest growth rates are observed for winter (January/February) and are most pronounced in the lower concentrations. Taken together with an observed positive trend of ^7Be at Zugspitze, an increase in the contribution of upper tropospheric air and/or stratospheric influence seems probable.

Long-term O_3 trends as reflected by seasonal cycles



Seasonal cycles for the alpine site Zugspitze, 2962 m, 47°N, 11°E. The three different areas in each of the plots show the contributions to the present O_3 levels as related to three averaging intervals (using nighttime values, 00-05 CET). Interval I1: 1978-1980 (base series, O_3 values shown in lowest area of each plot), I2: 1983–1991 (middle), I3: 1992-1998 (contribution shown in top area of each plot). Statistical parameters: Monthly means in left plot, 25th percentiles (P25) in the middle, and 90th percentiles (P90) in the right plot. For each month, the width of the upper band reflects the temporal changes in the contributions to the ozone increase during the periods 1983-1991 and 1992-1998.