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Influence of altitude on ozone levels and variability in the lower troposphere: a ground-based study for western Europe over the period 2001–2004

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Abstract. The PAES (French acronym for synoptic scale atmospheric pollution) network focuses on the chemical composition (ozone, CO, $NO_{x/y}$ and aerosols) of the lower troposphere (0–3000 m). Its high-altitude surface stations located in different mountainous areas in France complete the low-altitude rural MERA stations (the French contribution to the european program EMEP, European Monitoring and Evaluation Program). They are representative of pollution at the scale of the French territory because they are away from any major source of pollution.

This study deals with ozone observations between 2001 and 2004 at 11 stations from PAES and MERA, in addition to 16 elevated stations located in mountainous areas of Switzerland, Germany, Austria, Italy and Spain. The set of stations covers a range of altitudes between 115 and 3550 m. The comparison between recent ozone mixing ratios to those of the last decade at Pic du Midi (2877 m), as well as trends calculated over 14-year data series at three high-altitude sites in the Alps (Jungfraujoch, Sonnblick and Zugspitze) reveal that ozone is still increasing but at a slower rate than in the 1980s and 1990s.

The 2001–2004 mean levels of ozone from surface stations capture the ozone stratification revealed by climatological profiles from the airborne observation system MOZAIC (Measurement of OZone and water vapour by Airbus In-service airCraft) and from ozone soundings above Payerne (Switzerland). In particular all data evidence a clear transition at about 1000–1200 m a.s.l. between a sharp gradient below (of the order of +30 ppb/km) and a gentler gradient (+3 ppb/km) above. The same altitude (1200 m) is also found to be a threshold regarding how well the ozone levels at the surface stations agree with the free-tropospheric reference (MOZAIC or soundings). Below the departure can be as large as 40%, but suddenly drops within 15% above. For stations above 2000 m, the departure is even less than 8%. Ozone variability also reveals a clear transition between boundary-layer and free-tropospheric regimes around 1000 m a.s.l. Below, diurnal photochemistry accounts for about the third of the variability in summer, but less than 20% above – and at all levels in winter – where ozone variability is mostly due to day-to-day changes (linked to weather conditions or synoptic transport). In summary, the altitude range 1000–1200 m clearly turns out in our study to be an upper

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limit below which specific surface effects dominate the ozone content.

Monthly-mean ozone mixing-ratios show at all levels a minimum in winter and the classical summer broad maximum in spring and summer – which is actually the superposition of the tropospheric spring maximum (April–May) and regional pollution episodes linked to persistent anticyclonic conditions that may occur from June to September. To complement this classical result it is shown that summer maxima are associated with considerably more variability than the spring maximum. This ensemble of findings support the relevance of mountain station networks such as PAES for the long-term observation of free-tropospheric ozone over Europe.

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