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Surface ozone changes in Switzerland and relation to emission changes and climatic factors

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Ozone is formed in ambient air by photochemical reactions from its precursors (Volatile Organic Compounds (VOCs), carbon monoxide (CO) and nitrogen oxides (NOx: NO + NO2)). Anthropogenic ozone precursor emissions in Switzerland decreased significantly since the early 1990s (more than 50% for NMVOCs and around 50% for NOx) because of strengthening of air pollution legislation (e.g. successful introduction of catalytic converters in gasoline driven vehicles). In order to check the response of ambient air pollution concentration on emission changes we used data of the Swiss air pollution monitoring network NABEL which provides continuous high quality air pollutant measurements at 16 stations in Switzerland (sampling mainly planetary boundary layer (PBL) air except at the high alpine observatory Jungfraujoch, 3 640 m. asl.). However, according to NABEL ozone peaking values decreased only slightly in the Swiss planetary boundary layer. In order to (at least partially) remove the effect of meteorological variability from long-term changes in air pollutant concentrations we used Generalized Additive Models (GAM). In a first step meteorological quantities explaining most of variability of ozone and precursor concentrations were determined by a forward selection routine, showing that meteorological variability can be described (at most sites) by 60-80% by 5 explanatory variables. When removing meteorological variability and studying the ten highest daily maximum concentrations (MTDM) we found decreases at rural and prealpine sites. They are (qualitatively) expected from the emission changes, however, the decrease in MTDM values (1990-2009) was quantitatively rather small (0.3-0.4 ppb/year), much less than predicted by the EMEP Unified Chemical Transport Model (ground level ozone concentrations from 1995-2005 was modeled on a 50*50km grid taking into account the ozone precursor decrease in all European countries yielding for receptor points in Switzerland values around -1.20 ppb/year). Ozone at the high alpine site considerably increased during the 1990s and therefore increasing ozone mixing ratios in the air advected from the Atlantic to Europe possibly partially compensated the expected decrease in ozone maxima in the Swiss planetary boundary layer. Besides changes in ozone precursor emissions and intercontinental transport the following factors are expected to influence ozone in the (Swiss) PBL in future: (i) The largest (positive) ozone anomaly was found in 2003 when an outstanding heat wave over Europe prevented mixing of ozone of the planetary boundary layer with the free tropospheric air for many weeks. Because of climate change such type of extreme weather conditions are expected to occur rather regularly by the end of this century; (ii) climate change also might increase the downward flux of ozone from the stratosphere.