The response of stratospheric ozone and dynamics to changes in atmospheric oxygen

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Photolysis of molecular oxygen (O\(_2\)) maintains the stratospheric ozone layer, protecting living organisms on Earth by absorbing harmful ultraviolet radiation. The atmospheric oxygen level has not always been constant, and has been held responsible for species extinctions via a thinning of the ozone layer in the past. On paleo-climate timescales, it ranged between 10 and 35% depending on the level of photosynthetic activity of plants and oceans. Previous estimates, however, showed highly uncertain ozone (O\(_3\)) responses to atmospheric O\(_2\) changes, including monotonic positive or negative correlations, or displaying a maximum in O\(_3\) column around a certain oxygen level. Motivated by these discrepancies we reviewed how the ozone layer responds to atmospheric oxygen changes by means of a state-of-the-art chemistry-climate model (CCM). We used the CCM SOCOL-AERv2 to assess the ozone layer sensitivity to past and potential future concentrations of atmospheric oxygen varying from 5 to 40 %. Our findings are at odds with previous studies: we find that the current mixing ratio of O\(_2\), 21 %, indeed maximizes the O\(_3\) layer thickness and, thus, represents an optimal state for life on Earth. In the model, any alteration in atmospheric oxygen would result globally in less total column ozone and, therefore, more UV reaching the troposphere. Total ozone column in low-latitude regions is less sensitive to the changes, because of the “self-healing” effect, i.e. more UV entering lower levels, where O\(_2\) photolyzes, can partly compensate the O\(_3\) lack higher up. Mid- and high-latitudes, however, are characterized by ±20 DU ozone hemispheric redistributions even for small (±5 %) variations in O\(_2\) content. Additional regional patterns result from the hemispheric asymmetry of meridional transport pathways via the Brewer-Dobson circulation (BDC). We will discuss the different ozone responses resulting from changes in the BDC. These effects are further modulated by the influence of ozone on stratospheric temperatures and thus on the BDC. Lower O\(_2\) cases result in a deceleration of the BDC. This renders the relation between ozone and molecular oxygen changes non-linear on both global and regional scales.