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Planetary fertility during the past 400 ka based on the triple isotope composition of atmospheric oxygen in trapped gases from the Vostok ice core

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The productivity of the biosphere leaves its imprint on the isotopic composition of atmospheric oxygen. Ultimately atmospheric oxygen, through photosynthesis, originates from seawater. Fractionations during the passage from seawater to atmospheric O_2 and during respiration are mass dependent, affecting $\delta^{17}O$ about half as much as $\delta^{18}O$. An "anomalous" (also termed mass independent) fractionation process changes $\delta^{17}O$ about 1.7 times as much as $\delta^{18}O$ during isotope exchange between O_2 and CO_2 in the stratosphere. The relative rates of biological O_2 production and stratospheric processing determine the relationship between $\delta^{17}O$ and $\delta^{18}O$ of O_2 in the atmosphere. Variations of this relationship thus allow us to estimate changes in the rate of mass dependent O_2 production by photosynthesis versus the rate of mass independent O_2-CO_2 exchange in the stratosphere. However, the analysis of the ^{17}O anomaly is complicated because each hydrological and biological process influencing $\delta^{17}O$ and $\delta^{18}O$ fractionates ^{17}O and ^{18}O in slightly different proportions. In this study we present oxygen data covering the last 400 kyr from the Vostok ice core. We reconstruct oxygen productivities from the triple isotope composition of atmospheric oxygen with a box model. Our steady state model for the oxygen cycle takes into account fractionation during photosynthesis and respiration of the land and ocean biosphere as well as fractionation when oxygen passes through the stratosphere. We consider changes of fractionation factors linked to climate variations taking into account the span of estimates of the main factors affecting our calculations. We find that ocean oxygen productivity was likely elevated relative to modern during glacials. However, this increase probably did not fully compensate for a reduction in land ocean productivity resulting in a slight reduction in total oxygen production during glacials.