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Oxygen isotope anomaly observed in water vapor from Alert, Canada and the implication for the stratosphere

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In order to characterize the anomalous oxygen isotope signature in stratospheric water predicted by model studies, twenty-five ground-level water vapor samples were collected in 2002-2005 at Alert (82º30'N), Canada, where there is relatively strong downward transport of stratospheric air to the polar troposphere predicted by Brewer-Dobson circulation, and were analyzed for δ^{17}O and δ^{18}O compositions. Twenty-seven Chicago local precipitation samples collected in 2003-2005 were analyzed as a reference because the relatively large evaporative moisture source should erase any possible oxygen isotope anomaly from the stratosphere. A mass-dependent fractionation coefficient for meteoric waters, $\lambda_{MDF}(H_2O)$ = 0.5292 $\pm$ 0.0030, was determined from measurement of Chicago local precipitation. This λ value is equal to 0.529$\pm$0.001 for liquid-vapor equilibrium found by Barkan and Luz (2005). An oxygen isotopic anomaly of Δ^{17}O = 0.076 $\pm$ 0.016 ‰ was found in water vapor samples from Alert relative to Chicago local precipitation. This positive signature can be explained by the transfer of the positive oxygen isotopic anomaly from ozone to water in the stratosphere (Lyons, 2003; Zahn, 2006), and the subsequent mixing of this anomalous stratospheric water with tropospheric water at high latitudes where downward transport is strong and the water vapor mixing ratio is low. A steady-state air mass flux box-model was developed and Δ^{17}O in stratospheric water was calculated to be 17$\pm$22‰ when taking the downward air flux at maximum of 1.2 $\times$ 10^{-2} kg m^{-2} s^{-1} measured by Karpechko et al. (2007), although conventional theoretical flux value would bring the stratospheric water anomaly much higher. This estimate is consistent with predictions by Lyons (2003) and Zahn (2006) and is not inconsistent with Franz and Röckmann (2005) observation since Δ^{17}O was predicted to be small in the lowermost stratosphere. Alert snow samples of recent years were collected and are now being analyzed by A. Landais in France. In this study, we also found that Chicago local precipitation has a Δ^{17}O=0.070‰ relative to non-natural VSMOW. Miller (2008) emphasized the offset of VSMOW from natural water fractionation line as well.

Landais et al. (2008a) found ^{17}O-excess values from 20 to 40 ppm from glaciation to deglaciation in Vostok ice core and an average ^{17}O-excess of 45 ppm for Antarctic surface snow. Landais et al. (2008b, 2011) estimated the maximum stratospheric input to be 6 ppm based on the downward water vapor flux by Karpechko et al. (2007), the lowermost stratospheric water ^{17}O-excess from Franz and Röckmann (2005), and the precipitation rate at Dome C region. However, this estimate took the downward water vapor flux to be averaged over the globe. In the Brewer-Dobson circulation, downward air flow takes place mainly at the poles; this brings the maximum stratospheric input to about 30 ppm, significant comparing to the ^{17}O-excess in Vostok ice and Antarctic surface snow. Miller (2008) suggested stratospheric water as a component for surface snow at Dome C. Luz and Barkan (2011) found an average 37 ppm ^{17}O-excess in meteoric water samples relative to VSMOW, similar to our finding but they explained it by evaporation.

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