Using measurements and model simulations to understand the cause of the seasonal variation in the oxygen isotopic composition of precipitation along the western US coast

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This study seeks to find the primary influence on the seasonal cycle in the oxygen isotopic composition of precipitation ($\delta^{18}O_p$) along the west coast of the U.S. Archived precipitation samples were gathered from nine stations from the NADP's National Trends Network. The water samples were isotopically analyzed for $^{18}O/^{16}O$ and D/H composition using a Picarro ring down spectrometer. The weekly measurements of $\delta^{18}O_p$ were used to calculate long-term monthly means for each station. These data are combined with results from previous studies [*IAEA/WMO*, 2006; *Vachon et al.*, 2010; *Berkelhammer et al.*, 2012], and mean seasonal $\delta^{18}O_p$ cycles are presented for 16 stations along the western U.S. coast. The results document high $\delta^{18}O_p$ values in the summer and a drop in $\delta^{18}O_p$ during the winter season. The Isotope-incorporated Global Spectral Model (IsoGSM), nudged to reanalysis wind fields, also simulates this wintertime drop in $\delta^{18}O_p$ along the west coast of the U.S. However, it is not clear from the standard simulation alone what atmospheric variable(s) are responsible for the seasonal cycle in $\delta^{18}O_p$, and deciphering what controls this isotopic cycle has important implications for paleoclimate studies that seek to use isotope tracers to reconstruct past climate variability. We have investigated what factors give rise to the seasonal drop in $\delta^{18}O_p$ in the model by performing a suite of IsoGSM simulations in which individual oxygen isotope fractionation processes were turned off. These simulations reveal that the primary control on the seasonal variations is equilibrium oxygen isotopic fractionation that occurs during vapor condensation. There is almost no influence of the temperature dependence of equilibrium fractionation on the seasonal $\delta^{18}O$ cycle for both ocean evaporation and vapor condensation. Additional experiments (including water tagging simulations) were performed to better understand why Rayleigh distillation causes the seasonal variation in $\delta^{18}O_p$. The tagging simulations reveal that vertical oxygen isotope gradients and variations in condensation height are primarily responsible for the seasonal cycle in $\delta^{18}O_p$. The seasonal change in condensation height results from changes in the polar jet and subsequent changes in divergence and vertical velocities, which affects the uplift of moisture. These findings suggest that $\delta^{18}O_p$ in the western U.S. is a tracer of condensation height on seasonal timescales. The strong influence of condensation height on $\delta^{18}O_p$ complicates efforts to use climate proxy records (such as the $\delta^{18}O$ value of tree cellulose) that do not resolve the seasonal cycle since seasonality is likely not static.

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