Quantifying lake hydrological and isotopic responses to climate change: A coupled hydrologic-isotopic mass balance model applied to two Australian maar lakes

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QUANTIFYING LAKE HYDROLOGICAL AND ISOTOPIC RESPONSES TO CLIMATE CHANGE: A COUPLED HYDROLOGIC-ISOTOPIC MASS BALANCE MODEL APPLIED TO TWO AUSTRALIAN MAAR LAKES

LAKE HYDROLOGIC-ISOTOPIC MODELLING

ABSTRACT

A hydrologic-isotopic mass balance model was developed and applied to Lakes Bullen Merri and Gnotuk in the Newer Volcanic Province, Australia to investigate the influence of basin morphometry upon a lake's hydrological and isotopic response to climate change. Model calibrations were successful from 1965 to 2001, however no calibration simulated an extreme lake level change from 1889 to 2006. This is interpreted to reflect that catchment flow to the lake is not proportional to catchment area, suggesting an additional influence from groundwater, and demonstrating the need for long-term lake monitoring documenting a range of lake conditions. The model broadly captures change in lake $\delta^{18}O$ and δD, based upon a sparse monitoring dataset. Both observed and modeled values indicate opposing trends in $\delta^{18}O$ and δD, which implies lake water re-equilibration to past climate change. Experiments were carried out to explore the influence of lake morphology on both the timing and extent of isotopic responses to changes in hydroclimate. Following a shift in precipitation, lake water isotope ratios underwent transient excursions opposite in sign to the precipitation change, before returning to an equilibrium value. Lakes with shallower basin slopes resulted in more rapid excursions with a lower magnitude. Lakes with longer residence times had longer and more subdued excursions. Applying a 1400 year hypothetical climate with both El Nino Southern Oscillation (ENSO) type cycles and hydroclimate shifts to the Gnotuk basin suggested that on the shallow slopes at lower lake levels, the seasonal isotopic cycle would obscure both ENSO cycles and hydroclimate shifts, while at higher lake levels and steeper basin slopes, the excursions following hydroclimate change may became identifiable. These results demonstrate that lake isotopic studies should target records that capture isotopic composition over several years, or during specific times of the year, so as to minimise the seasonal isotopic cycle.

KEYWORDS

CHIMBLE, Model, Isotopes, Hydrology, Lakes, Victoria, Australia, Palaeoclimate

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