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Excess Air in Noble Gas Data Sets: Systematics and Paleoclimatic Significance

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Groundwater noble gas temperature (NGT) studies have consistently observed excess air (EA), i.e., concentrations of dissolved atmospheric gases exceeding solubility equilibrium. Laboratory and field studies have shown that EA originates from entrapped soil air that dissolves under pressure. Several studies have interpreted variations of EA in terms of changing water tables, related to changes in precipitation and recharge. Here we present results from a comprehensive review of EA observations in records extending back to the late glacial and assess the applicability of EA as a hydroclimatic proxy. This global evaluation is based on the compilation of noble gas data sets used by Seltzer et al. (2021) [1] to aggregate glacial-interglacial temperature change estimates based on NGTs.

We focus on the size of the EA component expressed by DNe, the relative excess of Ne above solubility equilibrium. This quantity is a robust measure of the amount of dissolved EA that only weakly depends on the estimated NGT, and hence, on the different models for EA formation and elemental composition. We looked for systematic relationships between DNe and groundwater age as well as climatic proxies such as NGTs and stable isotopes. Over all available studies, covering a wide climatic range indicated by NGTs between 0 and 35 °C, the relationship between DNe and NGT shows a pattern of increasing size and variability of DNe with increasing temperature, reaching a maximum at about 25°C. If the data are subdivided according to climate zones, the semi-arid areas show the highest values of DNe along with their largest spread.

On the level of individual studies, the data sets from warm climates with strong seasonality of recharge exhibit the most intriguing patterns in EA. The dominant temporal trend in semi-arid areas is a decrease of DNe from the late glacial into the Holocene, although some records also exhibit peaks that have been linked to periods of wetter climate. Two semi-arid data sets exhibit a statistically significant negative correlation between DNe and NGT. In contrast, data sets from monsoon-dominated areas tend towards a positive correlation between DNe and NGT.

[1] Seltzer et al., 2021. Nature 593: 228–232.