The isotopic composition of rainfall on a subtropical mountainous island

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1.Introduction

Stable water isotopes—$^1H^2HO$, $H_2{}^{18}O$, and $H_2{}^{16}O$—are **useful tools** that have been employed in the study of a wide variety of processes in the Earth's system.

In Hawaiʻi, water isotopes have been used in the study of paleoclimate or to estimate recharge times of the islands' aquifers.

Most collections were **limited in time**, they were done at **low frequency** (e.g., 3 months), or when meteorological data were **scarcer** than today. As a result, data interpretation can be **challenging**.

Here, we introduce a **new network** of sites on the island of Oʻahu, in the Hawaiian Archipelago, where data has been collected for the last two years at a quasi-weekly frequency.

The data collection is still ongoing and new sites on other islands are being deployed. The goal is to establish **a long-term multi-site dataset** comprising **rainfall** and **water vapor** isotope data.

2. Methods

The network consists of five sites that form a transect with a NE/SW orientation (Fig. 1), roughly the same followed by the trade-wind flow over the island.

Data was collected using Palmex Rain Samplers RS1 (Waikīkī, HIG, Lyon Arboretum) and RS2 (Maunawili), and with a 1-L separatory funnel (Kailua).

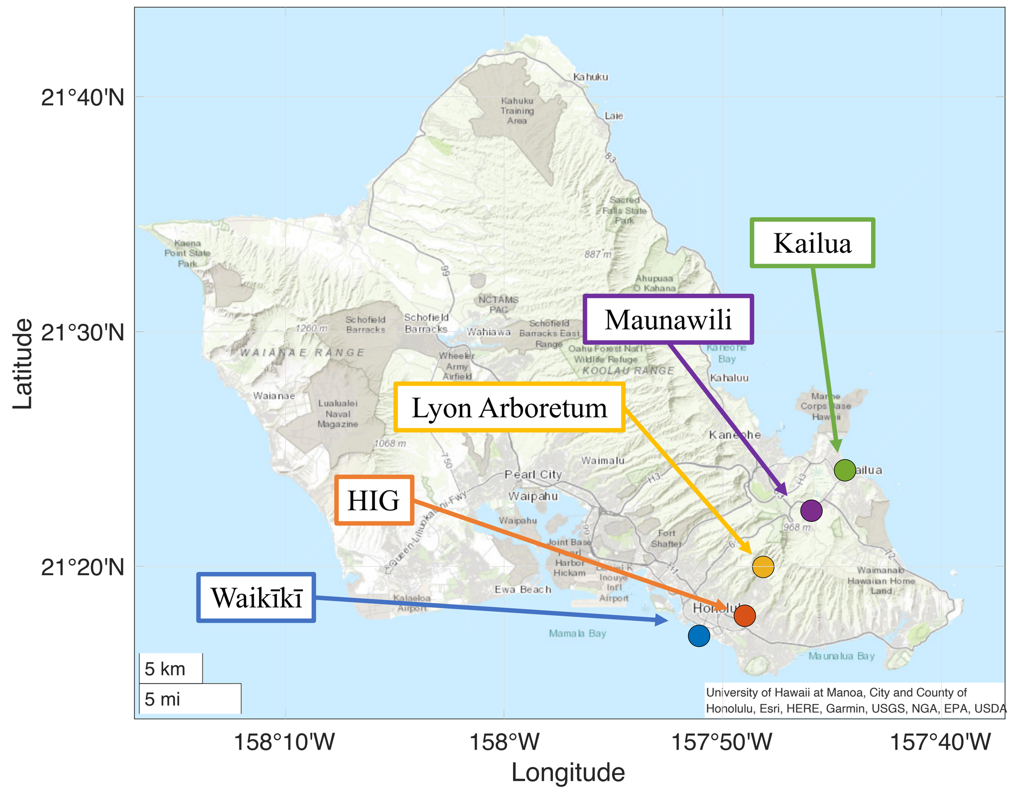

Fig. 1: Topographic map of Oʻahu with the five sites marked by colored circles

3. The isotopic composition of rainfall

Rainfall rates are similar for all the sites (Fig. 2), except for Lyon Arboretum, where orographic effects lead to significantly higher values.

As expected, rain rates are higher during the wet season (October-March).

Highest rain rates are due to subtropical storms known as Kona lows. Significant wet-season rain is also due to cold fronts and occasional thunderstorms.

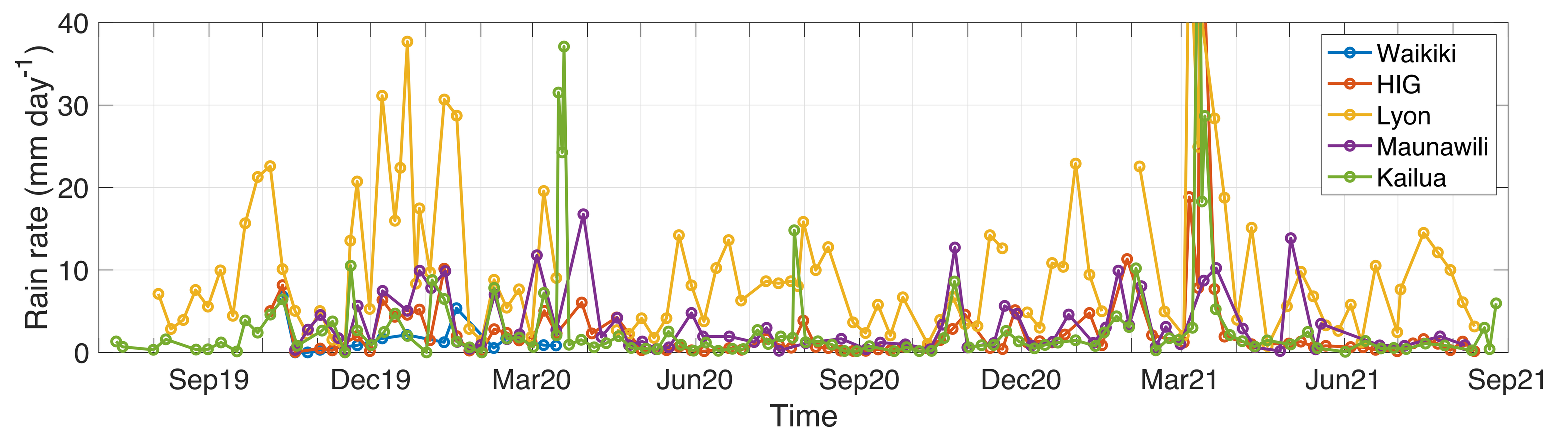

Fig. 2: Time series of rain rates for the five sites, determined as the total accumulated rain for each collection period divided by the time since the previous collection.

Trade-wind showers represent the main source of rainfall on the island (Fig. 3), and they are responsible for some of the highest $\delta^{18}O$ and δ^2H abundances.

The wet season is characterized by greater synoptic variability than the dry season, and, therefore, greater variability of isotopic abundances.

The lowest values of $\delta^{18}O$ and δ^2H are generated by Kona lows.

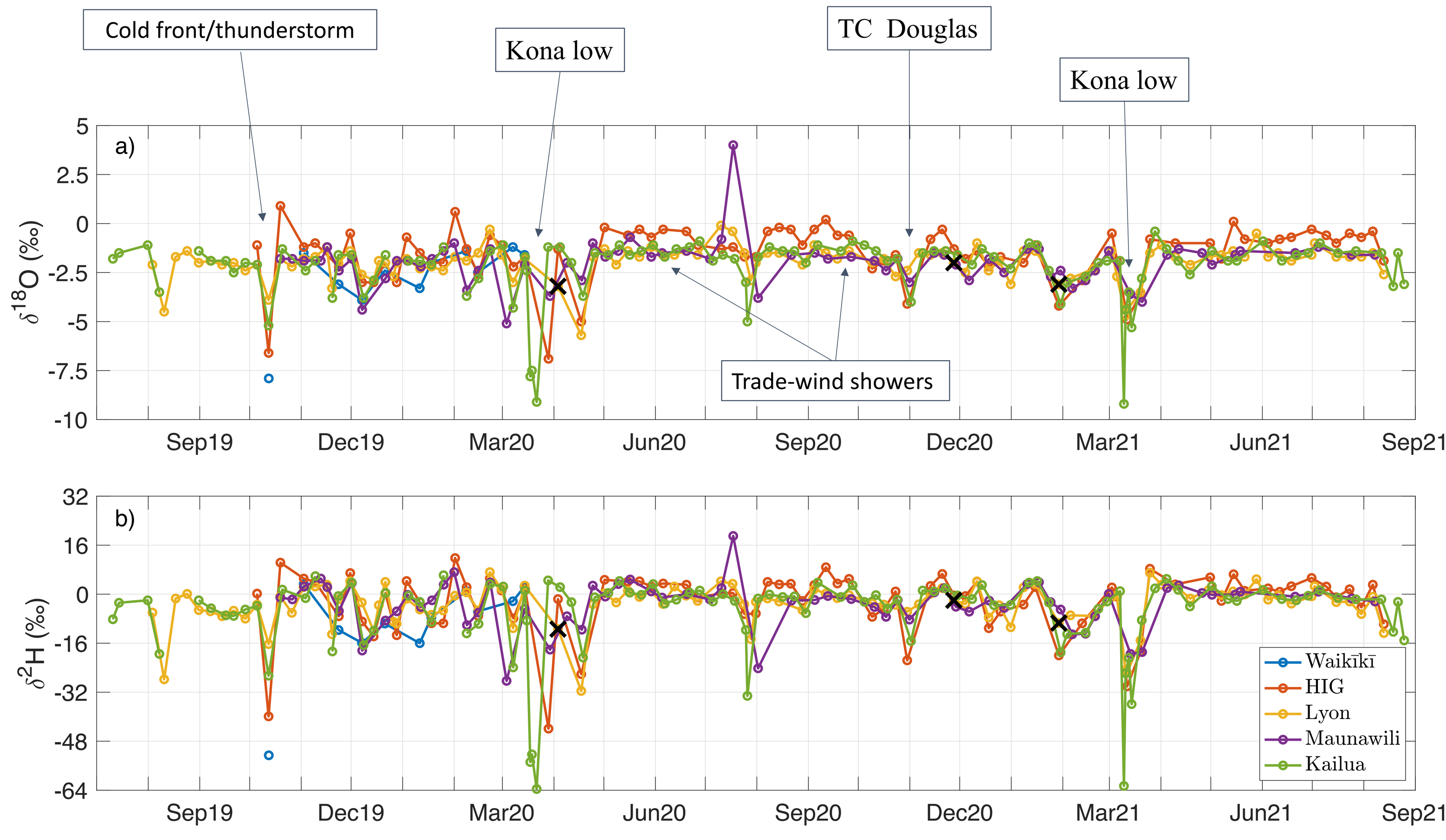

Fig. 3: Time series of $\delta^{18}O$ (a) and δ^2H (b) values for the five sites: Kailua (green); Maunawili (purple); Lyon Arboretum (yellow); HIG (orange); Waikīkī (blue). Black crosses represent data collected when the sampler had overflown.

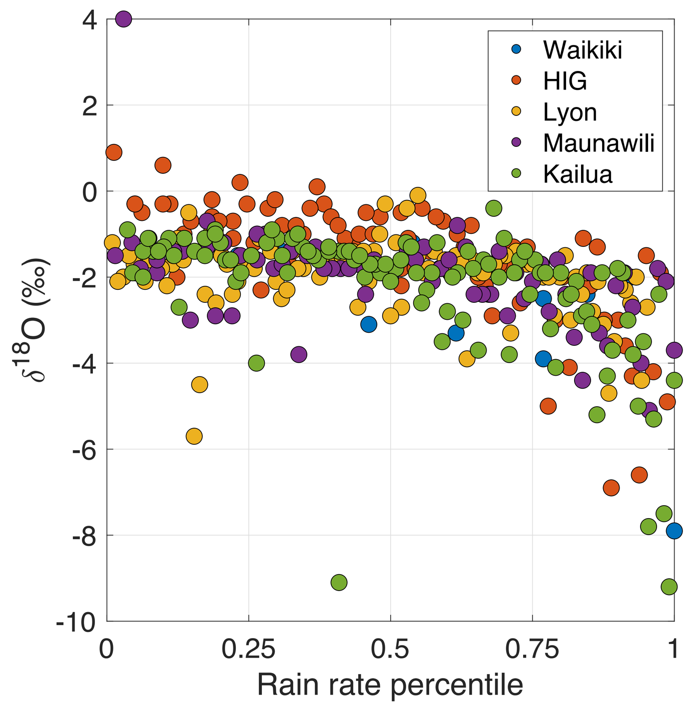

Fig. 4: $\delta^{18}O$ values as a function of rain rate percentile for each site shown for the entire collection period.

The site at HIG records isotopic abundances that are significantly higher than at other locations, particularly during the dry season, between April and September (Fig. 4) .

Comparing relative humidity at HIG and at the nearby site of Lyon Arboretum reveals a strong gradient (Fig. 5), with conditions being much drier at the former site.

This suggests high rain evaporation rates as precipitating systems move across the island, which could explain the higher $\delta^{18}O$ and δ^2H recorded at HIG.

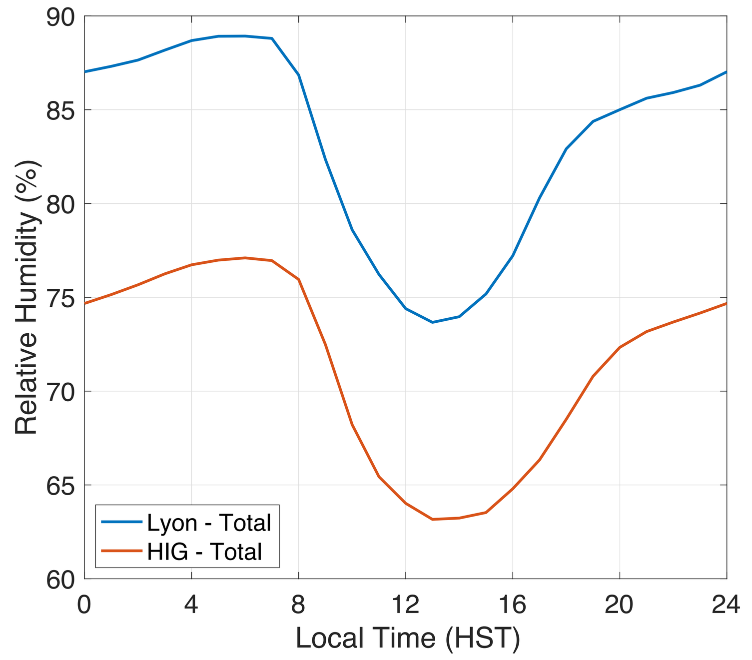

Fig. 5: Average diurnal cycles of relative humidity at Lyon Arboretum (blue), and at HIG (red).

4. The deuterium excess

Deuterium excess shows seasonal variations (Fig. 6), with lower values during the dry season.

Could be due to seasonal changes of thermodynamic variables, or different origin of air masses contributing to precipitation

Deuterium excess values at HIG site significantly lower than at the other sites, consistent with the hypothesis of increased rain evaporation (see Panel 3).

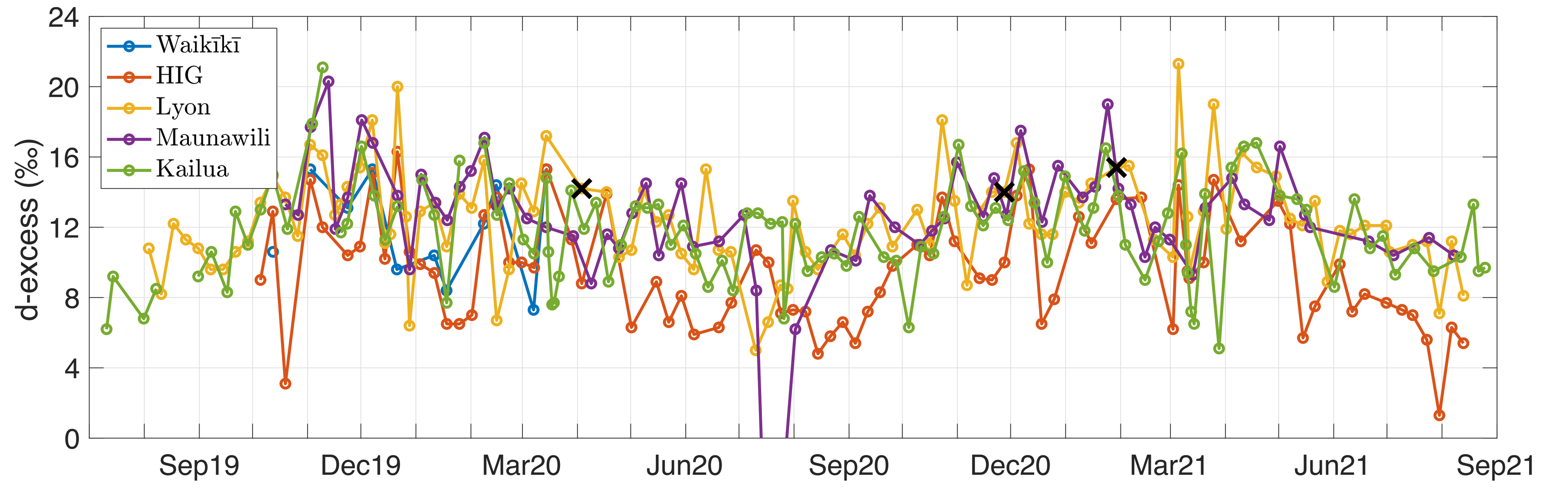

Fig. 6: Time series of deuterium excess for each site during the entire collection period, from July 2019 to August 2021. Black crosses represent data collected when the sampler had overflown.

Trajectory Analysis

A Lagrangian trajectory model (HYSPLIT) was used to diagnose the origin of air masses during the wet and the dry season.

For each day, 27 trajectories are initialized on Oʻahu and traced back 5 days.

Differences in trajectory densities reveal significant differences in the air mass origin (Fig. 7).

Dry-season air parcels originate mostly over the Easter Pacific, where deuterium excess values are lower.

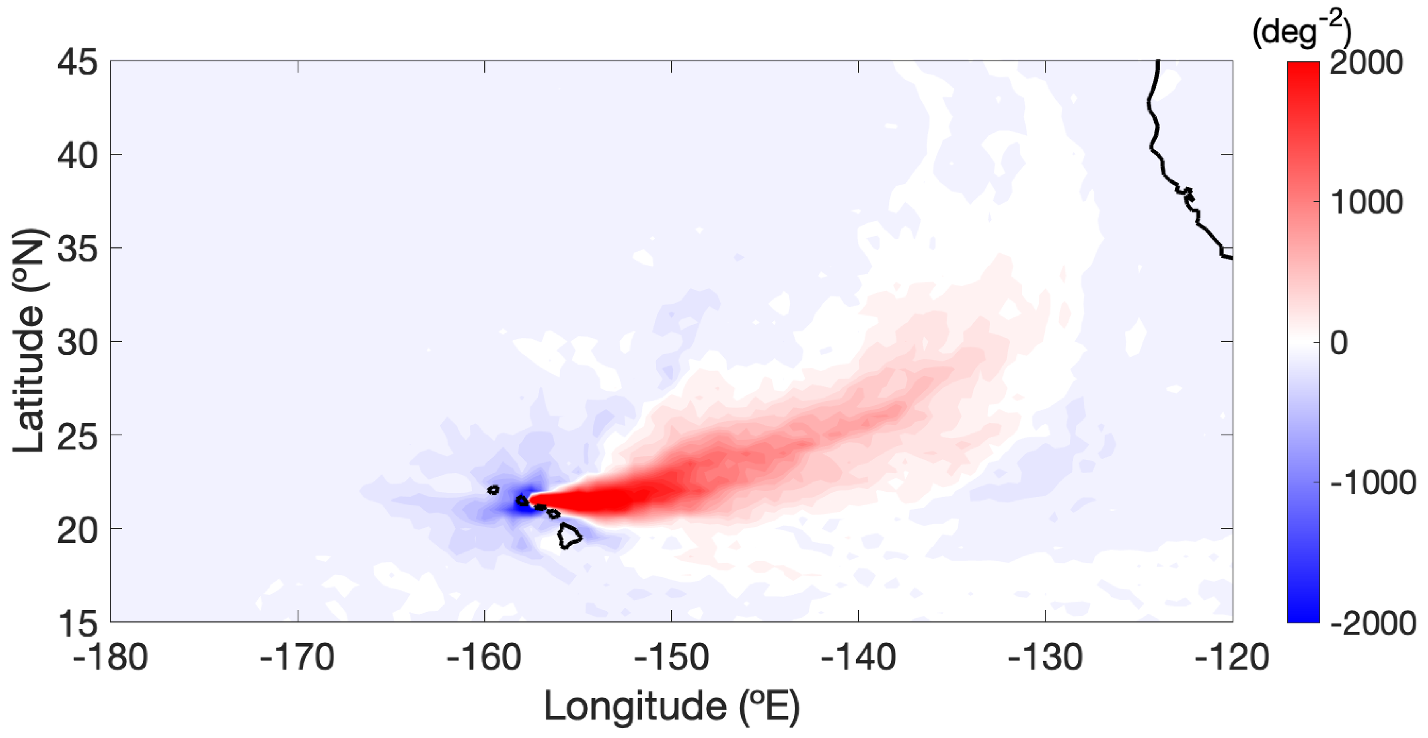

Fig. 7: Differences in trajectory densities obtained using HYSPLIT between dry- and wet-season months

5. Conclusions

- A **new network** of sites to collect rainfall isotopes was established on Oʻahu, Hawaiʻi at a higher frequency than was done in the past.
- **Kona lows** produce the **lowest abundances**, trade-wind showers the highest.
- Significant differences of $\delta^{18}O$ and δ^2H across the sites due to the **complex microclimate** on the island.
- **Season variations of deuterium excess** values were observed, and they were attributed to differences in the **origin of air parcels** contributing to rain.

6. Bibliography

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