Inferring global-scale spatio-temporal $\delta^{18}O_P$ patterns from local datasets

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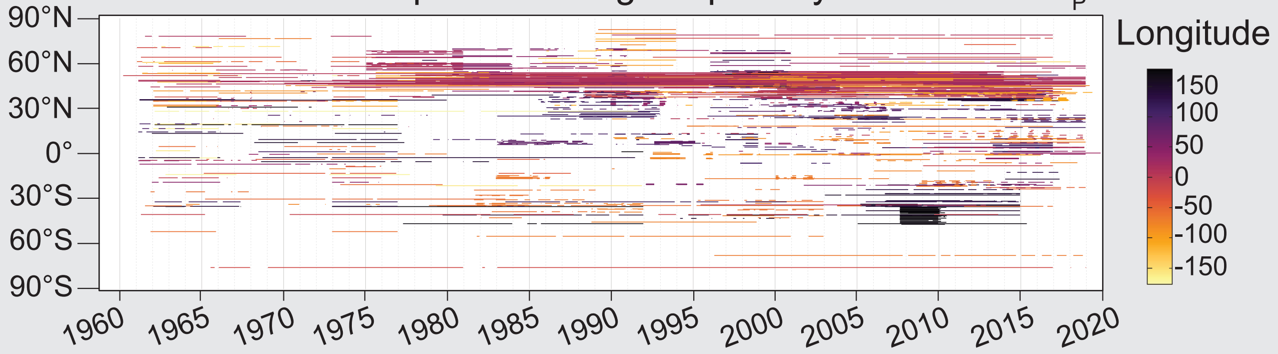
Background & Aims

The abundance of publicly-available precipitation $\delta^{18}O$ ($\delta^{18}O_P$) data allows analysis of **global-scale $\delta^{18}O_P$ patterns**. Most such meta-analyses focus on static **spatial** $\delta^{18}O_P$ patterns.

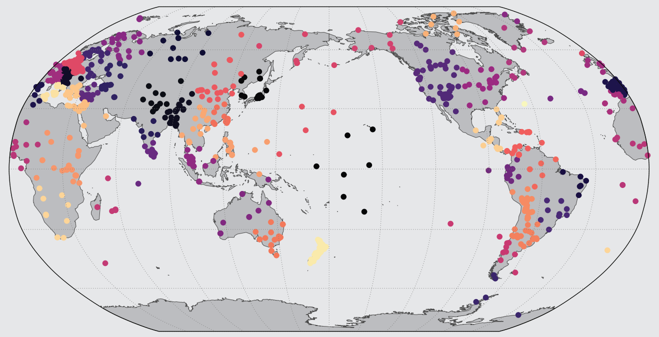
Characterising global-scale $\delta^{18}O_P$ variability **through time** is more difficult. $\delta^{18}O_P$ data availability is spatially & temporally irregular, as shown on the plot below which summarises the temporal coverage of publicly-available $\delta^{18}O_P$ station data.



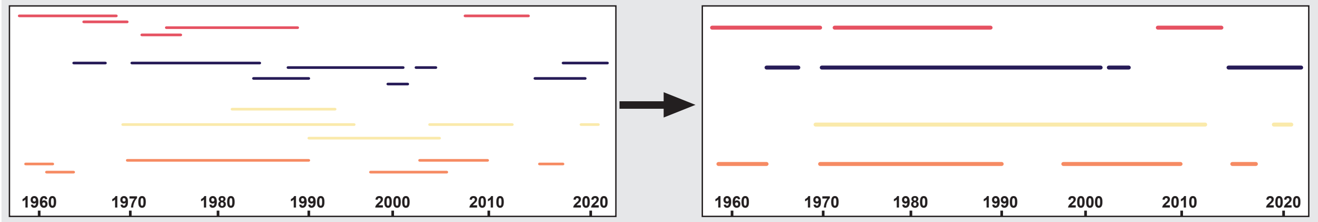
Here we aim to **characterise both the spatial *and* temporal variability in global $\delta^{18}O_P$**, using data from GNIP and the Water Isotopes Database.

Methods

We grouped $\delta^{18}O_P$ stations into **clusters** based on **geographic & climatic parameters.** The map to the right shows $\delta^{18}O_P$ stations coloured according to their assigned cluster (52 clusters total).



We used a novel 'dynamic compositing' method to combine all records in each cluster into a single timeseries, without spurious jumps in mean or variance.



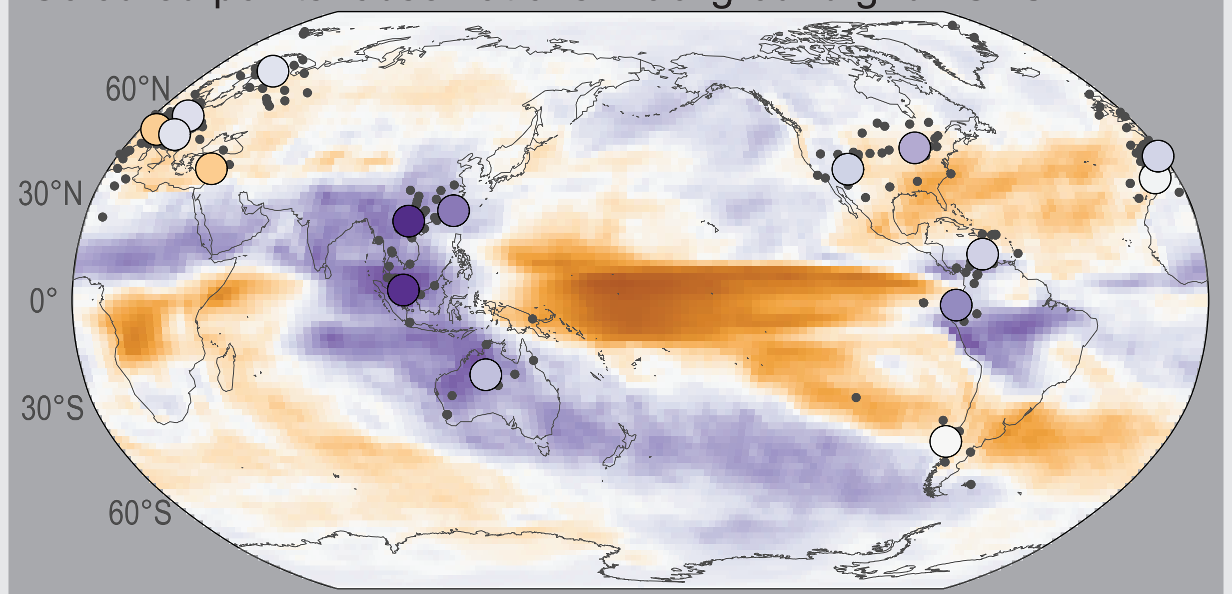
From those 52 clusters we kept only the **16 regional $\delta^{18}O_P$ composites** with **>80 % temporal coverage from 1982 to 2015.**

We found the common gradient underlying these regional $\delta^{18}O_P$ composites (**global $\delta^{18}O_P$ PC1 & EOF1**, at annual resolution), and did the same on simulations from the **isotope-enabled CESM** for comparison.

We then compared the global $\delta^{18}O_P$ PC1 with globally-relevant climate indices.

Results

Global $\delta^{18}O_P$ EOF1 (1982-2015)
Coloured points: observations. Background grid: iCESM iLME.



Orange: positive loading on PC1. Purple: negative loading on PC1.

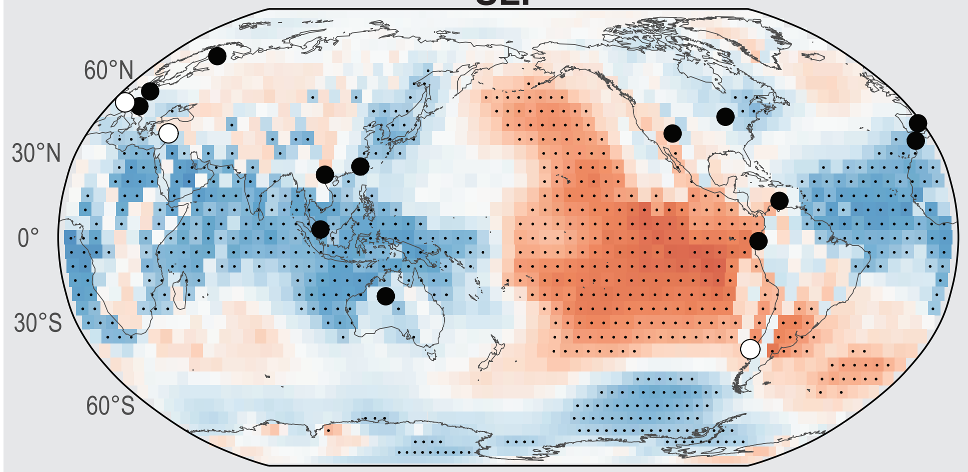
Purple & orange **points** on the map to the left show the loading of regional $\delta^{18}O_P$ composites on the global $\delta^{18}O_P$ PC1 i.e. as PC1 increases, $\delta^{18}O_P$ at purple-coloured sites decreases & $\delta^{18}O_P$ at orange-coloured sites increases.

Small grey circles show the individual sites comprising the regional $\delta^{18}O_P$ composites.

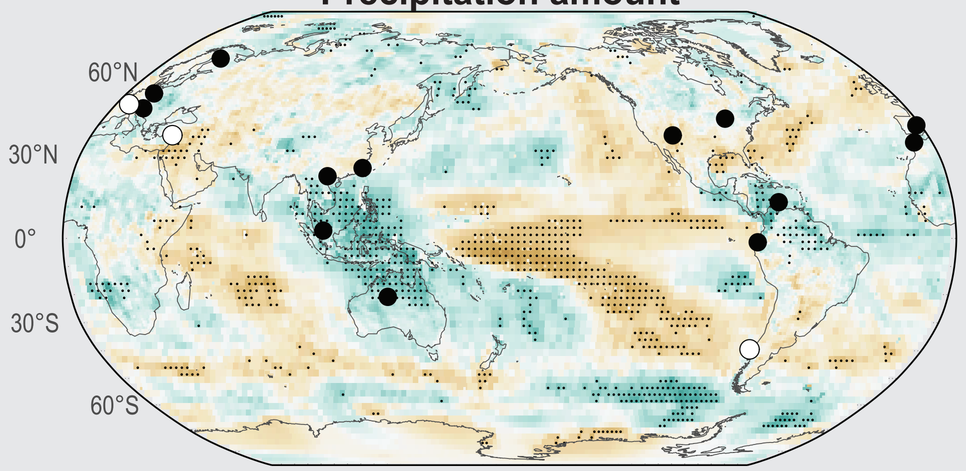
The **background grid** shows $\delta^{18}O_P$ EOF1 from the isotope-enabled CESM.

The three maps below show the **correlation of global $\delta^{18}O_P$ PC1 with climatic variables** (sea level pressure, precipitation, and near-surface winds).

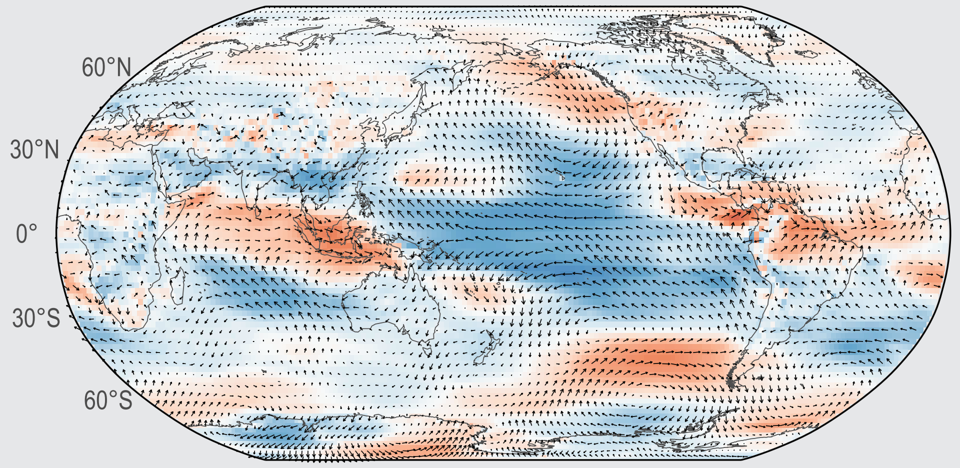
SLP

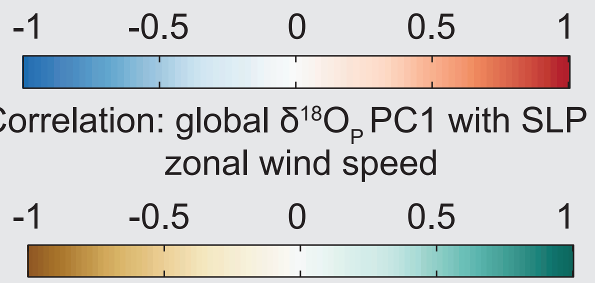


Precipitation amount



850 hPa winds





Correlation: global $\delta^{18}O_P$ PC1 with SLP & zonal wind speed

Correlation: global $\delta^{18}O_P$ PC1 with precipitation

Stippling denotes a significant correlation (accounting for false discovery rate)

Discussion

The table below shows the **correlation** of global $\delta^{18}O_P$ PC1 with globally-relevant climatic indices

Tropical Pacific atmospheric variability	**PWC (ΔSLP)** **0.74***	SOI 0.70*	
Tropical Pacific oceanic variability	Niño 3.4 -0.58*	EMI -0.44*	
Variability outside the tropical Pacific	PMM -0.33	SAM 0.24	DMI -0.03

PWC = Pacific Walker Circulation (as defined by trans-Pacific SLP gradient), SOI = Southern Oscillation Index, EMI = ENSO-Modoki Index, PMM = Pacific Meridional Mode, SAM = Southern Annular Mode, DMI = Dipole Mode Index. Asterisk denotes significant correlation.

Global $\delta^{18}O_P$ PC1 is most strongly correlated with the strength of the **Pacific Walker Circulation.**

We see **similar isotope-climate relationships in observations & the iCESM**, suggesting both that iCESM accurately models $\delta^{18}O_P$ patterns, & that our 16 regional $\delta^{18}O_P$ composites capture a **realistic approximation of spatio-temporal changes in *global* $\delta^{18}O_P$.**

Our methodology could also be used to synthesise regional-scale $\delta^{18}O_P$ variability from local $\delta^{18}O_P$ data, or to analyse $\delta^{18}O_P$ variability in different time periods.

For all the details, see our recent paper (open access):
https://tinyurl.com/falster2021

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