Data assimilation using oxygen isotope ratios of proxies aimed at the last millennium climate reconstruction

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Background and Summary

Climate reconstruction is a key to know the long-term climate change. It enables us to quantitatively evaluate the relationship between climate change and human society. This study tries to reconstruct annual variations of climate variables over the last millennium by data assimilation using oxygen isotope ratios of proxies. The experiments incorporating speleothem records (Comas-Bru et al., 2020) and its proxy model (Comas-Bru et al., 2019) were conducted, and decline in surface air temperature after volcanic eruption was reproduced. Changes in other variables are also shown here.

Materials and methods

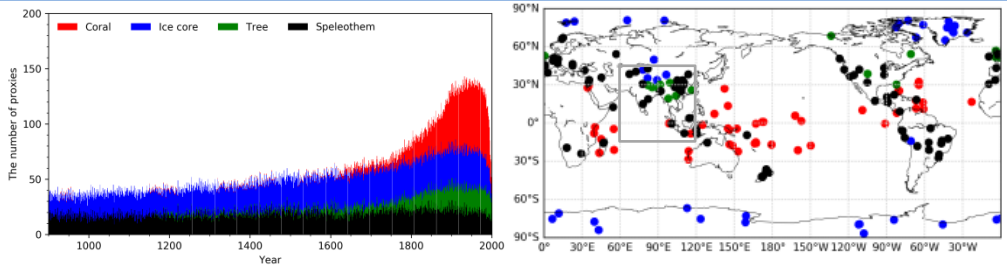


Figure 1. Spatiotemporal distribution of proxies from 901 to 2000.
(red) Coral (blue) Ice core (green) Tree-ring (black) Speleothem

Model

> The isotopes-incorporated global spectral model (IsoGSM; Yoshimura et al., 2008)
> Proxy models (Roden et al., 2000; Liu et al., 2014; Comas-Bru et al., 2019) for $\delta^{18}O$ of each proxy

Proxy

$\delta^{18}O$ of corals, ice cores, tree-ring cellulose, and speleothem (National Oceanic and Atmospheric Administration, NOAA; The 2k Network of the International Geosphere-Biosphere Programme Past Global Changes, PAGES 2k, 2013; The Speleothem Isotope Synthesis and Analyses (SISAL) database version 2, Comas-Bru et al., 2020)

Data assimilation

Serial Ensemble Square Root Filter (Bhend et al., 2012; Steiger et al., 2014; Okazaki and Yoshimura, 2017)

$$\mathbf{X_a} = \mathbf{X_b} + \mathbf{K}[\mathbf{y} - H(\mathbf{X_b})]$$

Results

(blue) CIT (red) CITS (black) 20CR

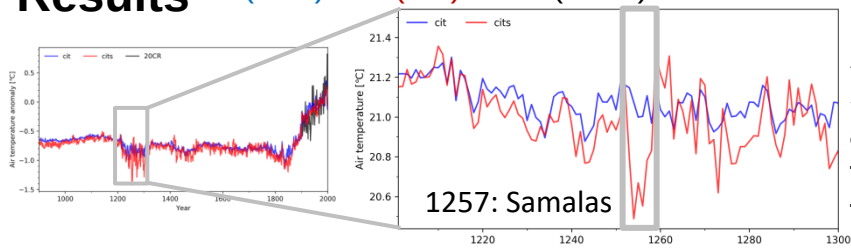
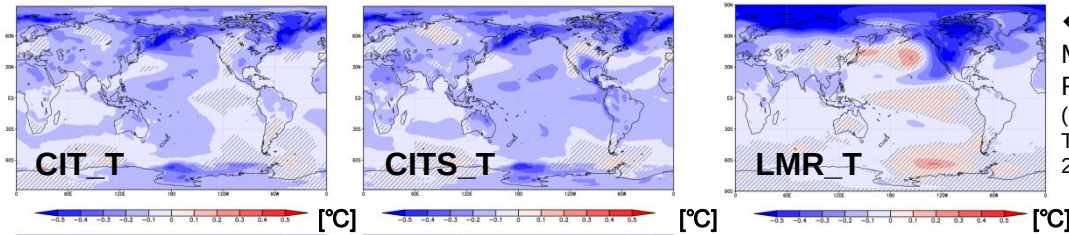


Figure 2.
Annual variations of surface air temperature anomaly in Asia from 901 to 2000 (left) , from 1201 to 1300 (right).

Table 1. Root mean square difference and correlation coefficient of global surface air temperature in the 20th century between this study and 20CR.

	vs 20CR (Compo et al., 2011)			
	Global		Asia	
	RMSD	r	RMSD	r
CIT	0.20	0.86	0.24	0.54
CITS	0.19	0.84	0.21	0.66



← The Last Millennium Reanalysis (LMR, Tardif et al., 2019)

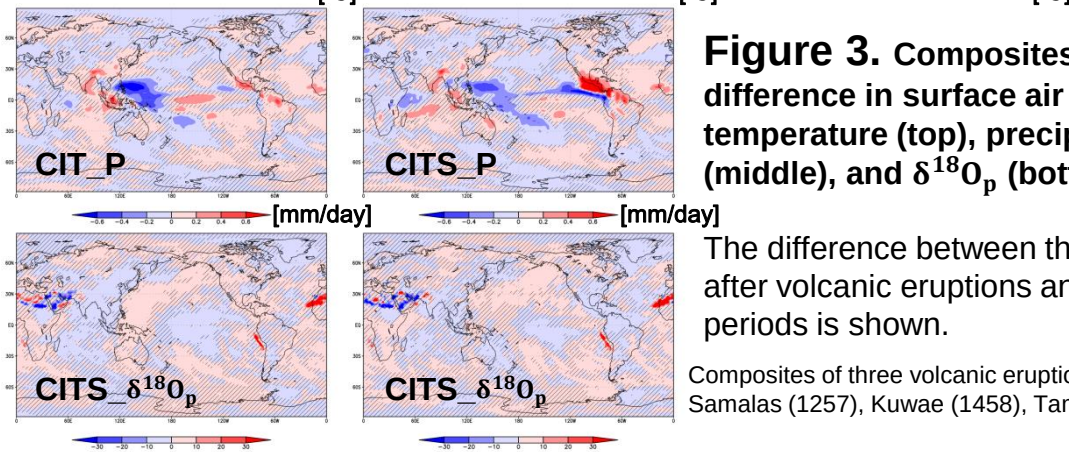


Figure 3. Composites of difference in surface air temperature (top), precipitation (middle), and $\delta^{18}O_p$ (bottom).

The difference between the periods after volcanic eruptions and other periods is shown.

Composites of three volcanic eruptions: Samalas (1257), Kuwae (1458), Tambora (1815)