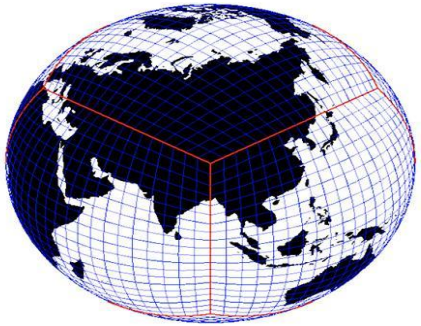
CESM Workshop 2024: Paleoclimate session



Simulating Ice Core $\delta^{18}O$ Evolution and its Implications for the Holocene Temperature Conundrum

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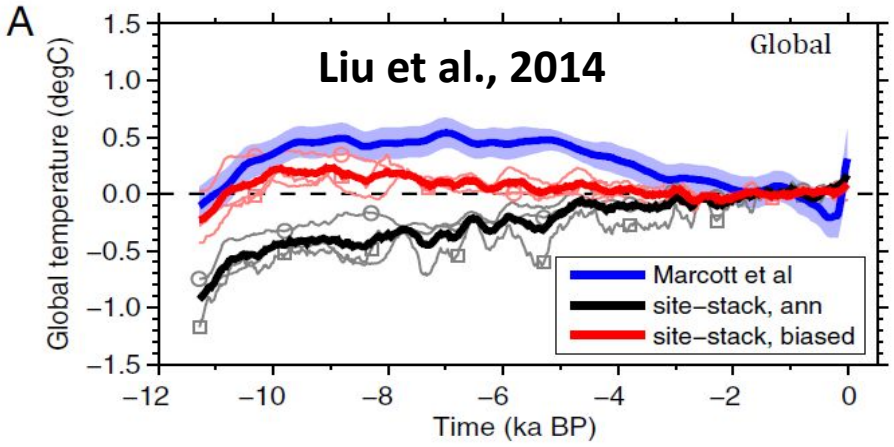
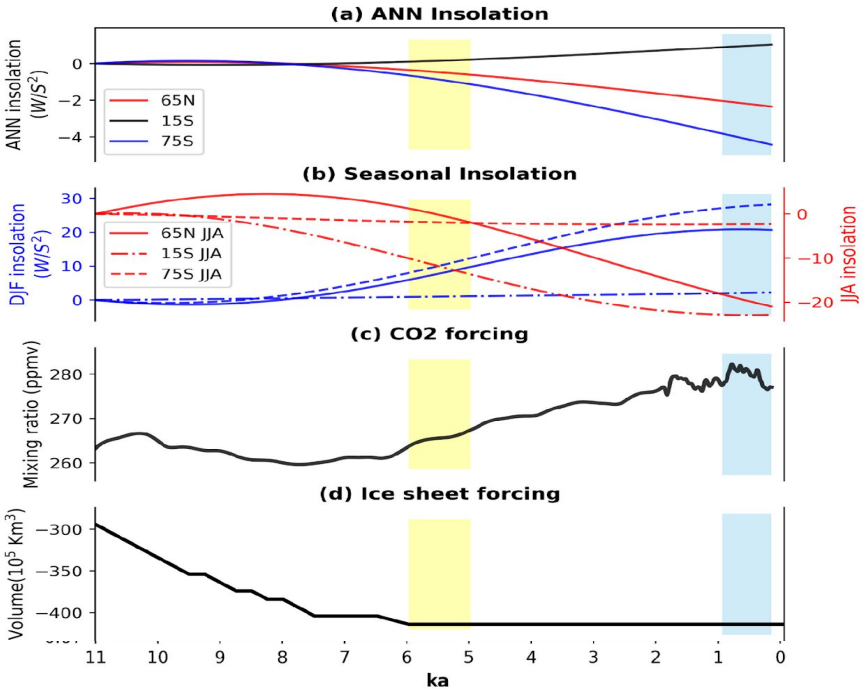
- **Background: The Holocene Temperature Conundrum**

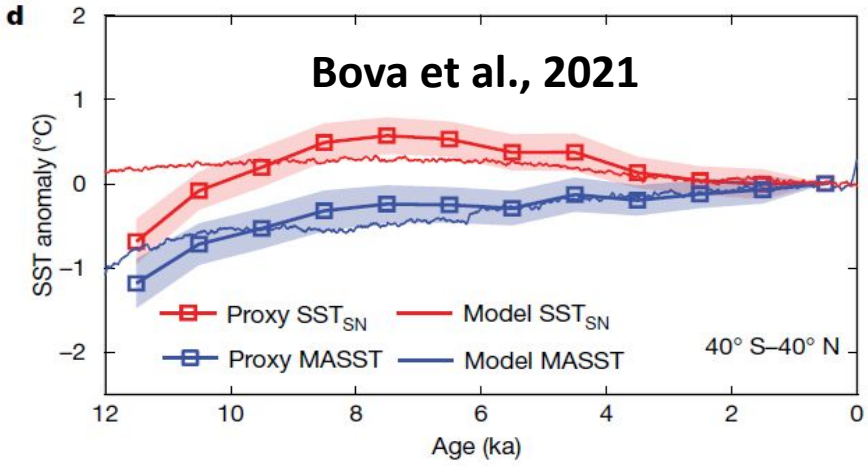




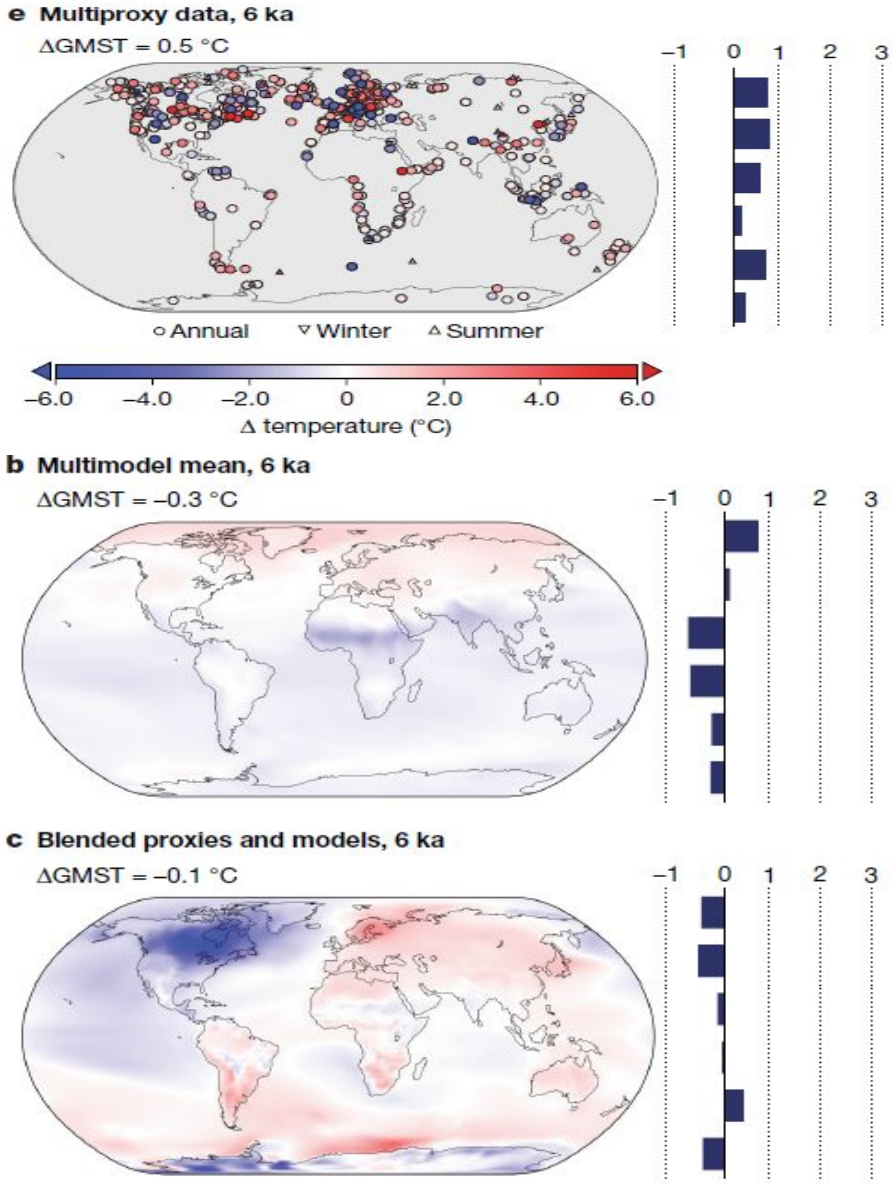
Sources of uncertainties:

- Seasonal bias in the proxy data
- Model deficiencies

Removing seasonal effect



Mostly marine-based proxies!



Kaufman and Broadman, 2023

Recently, a large variety of available evidence (Temp12k dataset), support for a relatively mild global thermal maximum during the mid-Holocene.

- **Unresolved**: Holocene temperature change on land regions and forcing mechanisms?

- **Direct model-data comparison approach**:

Ice core $\delta^{18}O$ records from Greenland (temperature signal), Antarctic (temperature signal), and tropical mountains (?)

&

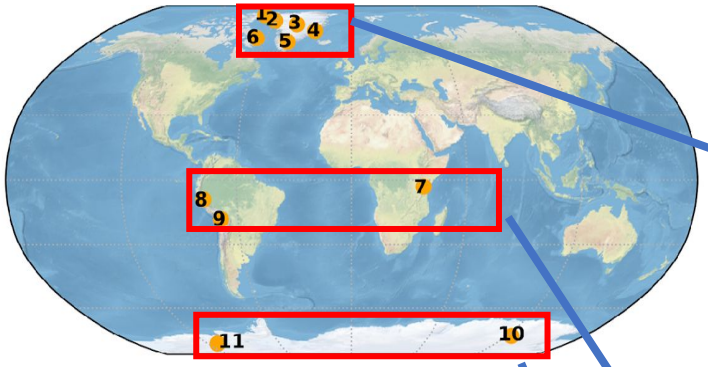
Transient simulations during the Holocene using an isotope-enabled climate model (iCESM): iTRACE

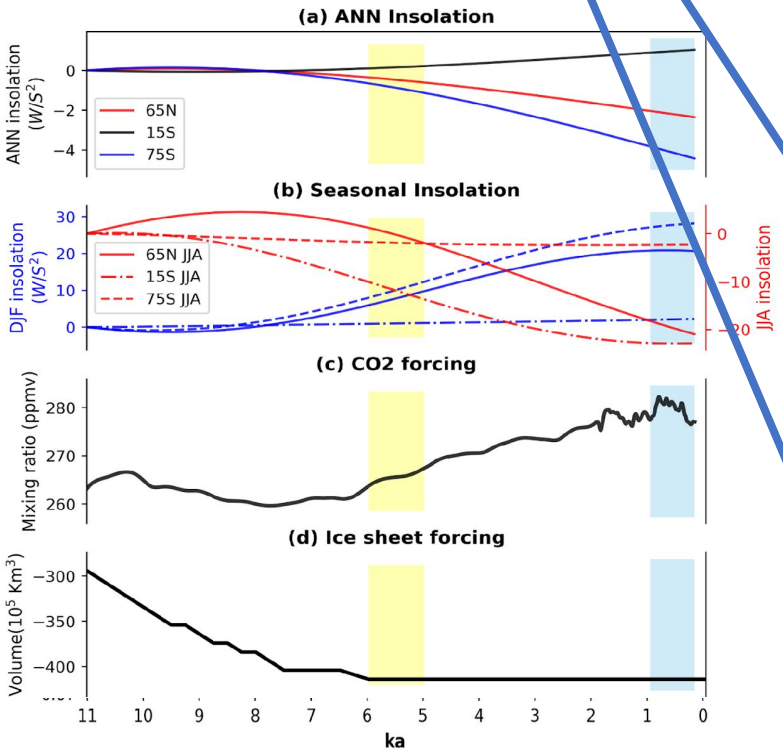
Advantage of this approach:

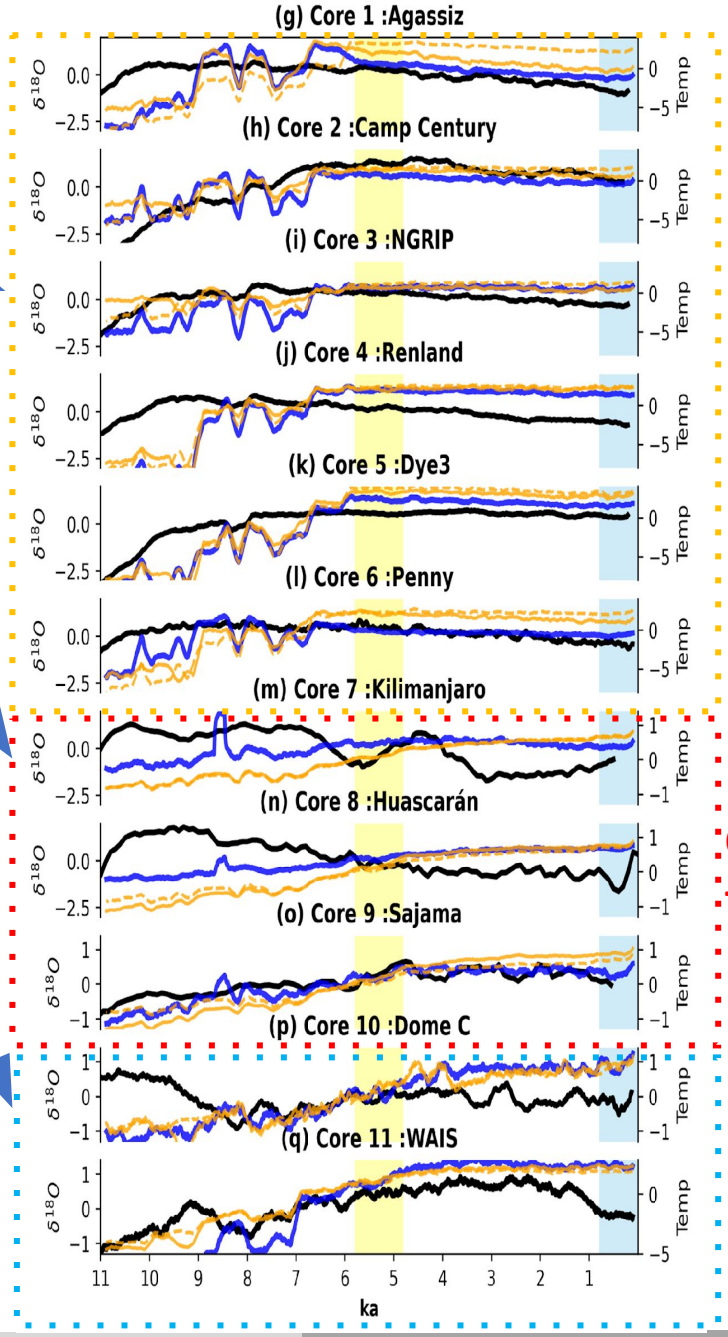
- Alleviating the biases in the temperature reconstruction associated with seasonality and other bio-geochemical factors.
- No need to reconstruct temperature (less errors)
- Better evaluate model performance

- **Direct model-data comparison**

(model: $\delta^{18}O$ weighted by precipitation)

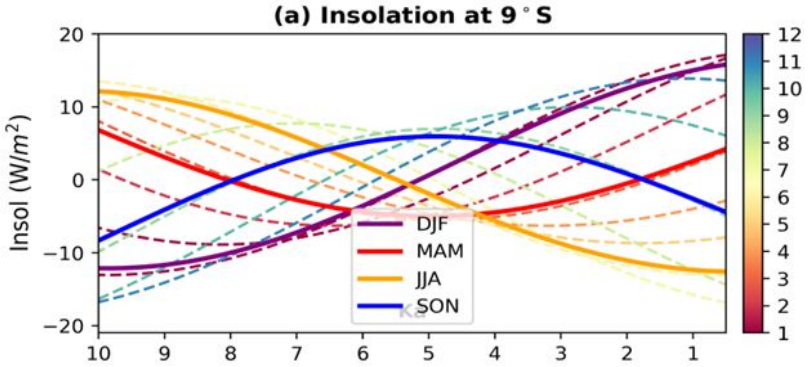


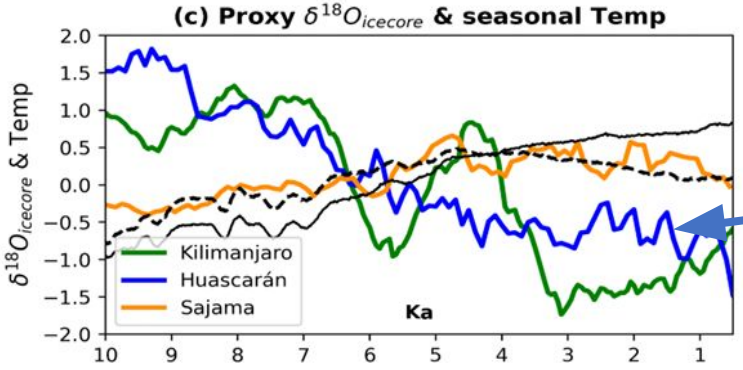


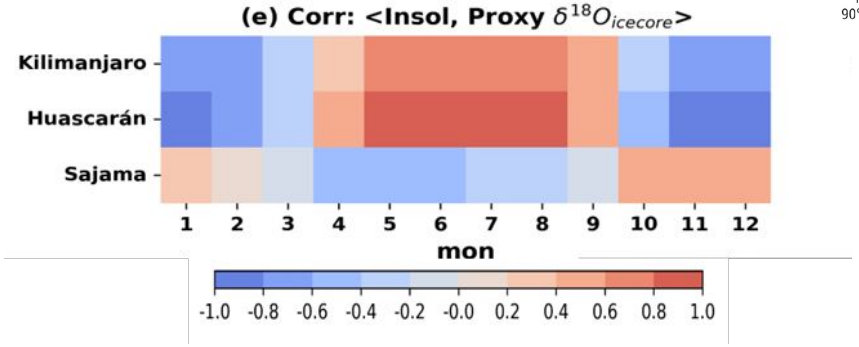


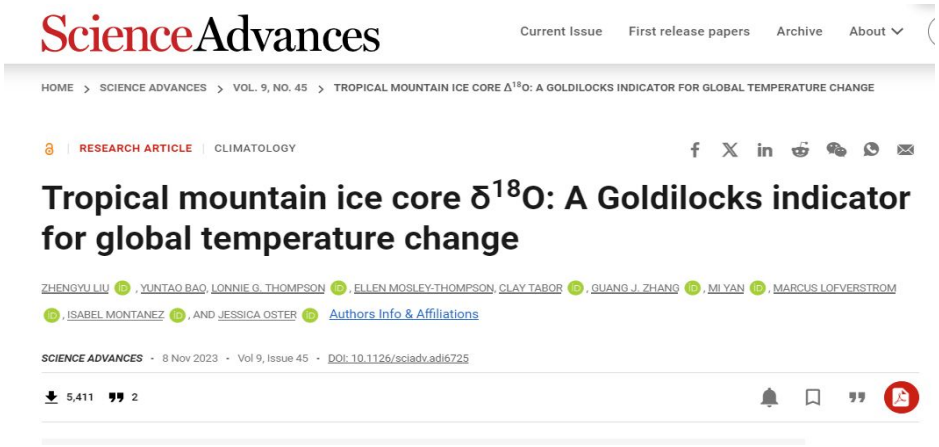
Contrasting trend!

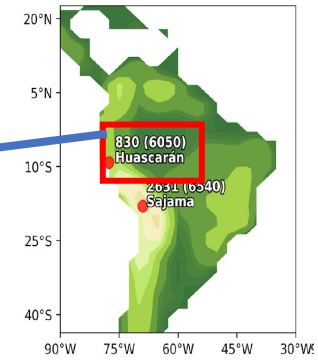
- **The most challenging part: Tropical mountain**

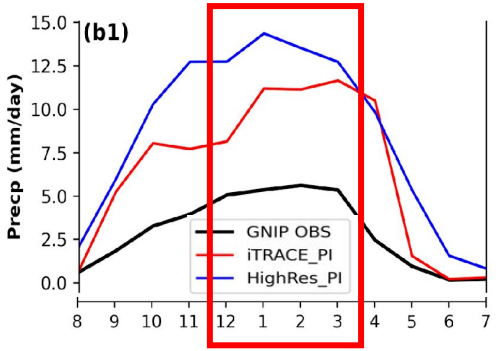










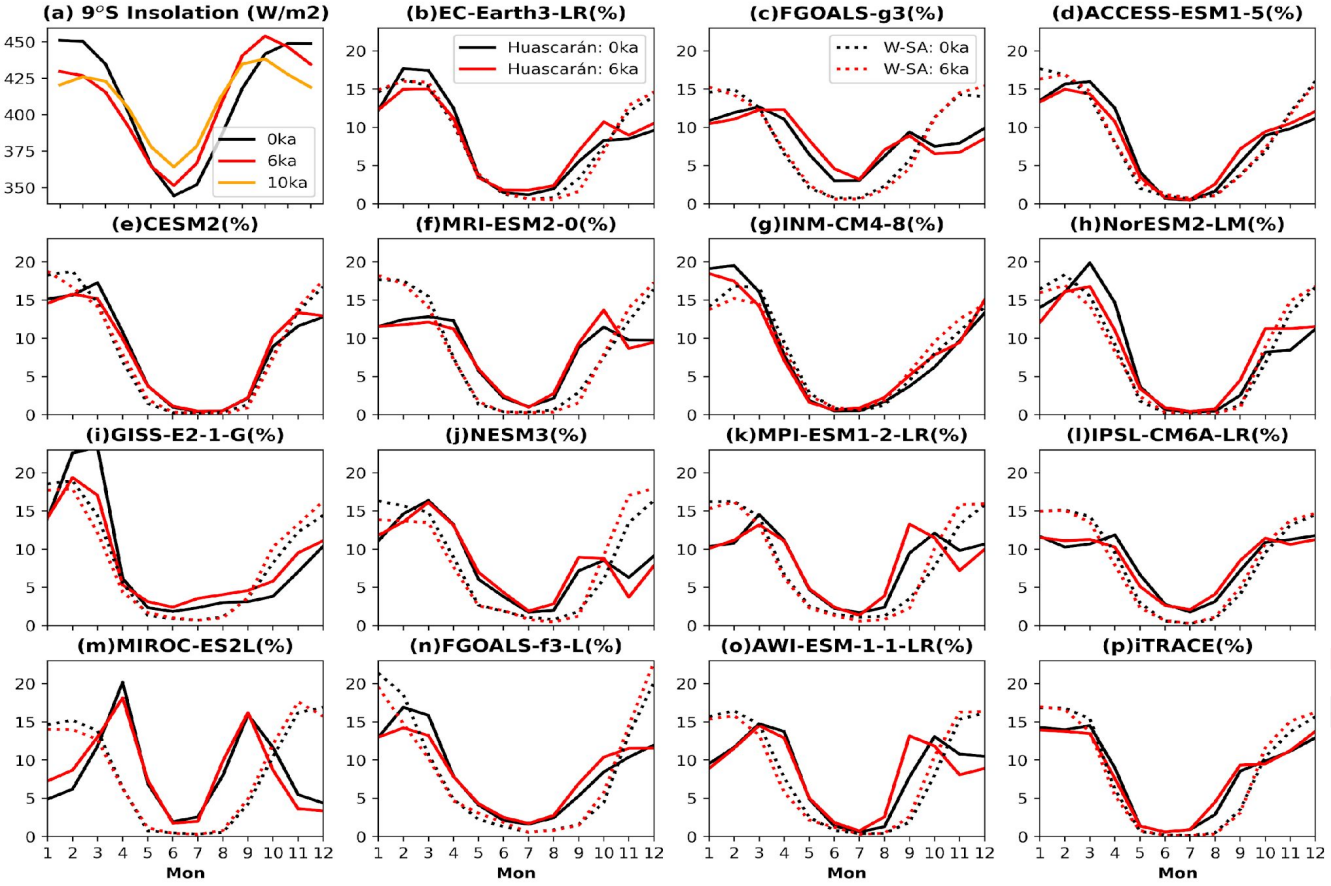


Challenging questions:

- Forcing mechanisms on tropical mountain ice core $\delta^{18}O$?
- Interpretations of ice core $\delta^{18}O$ during the Holocene?

Interpretations of ice core $\delta^{18}O$ during the Holocene? Wet season temp signal?

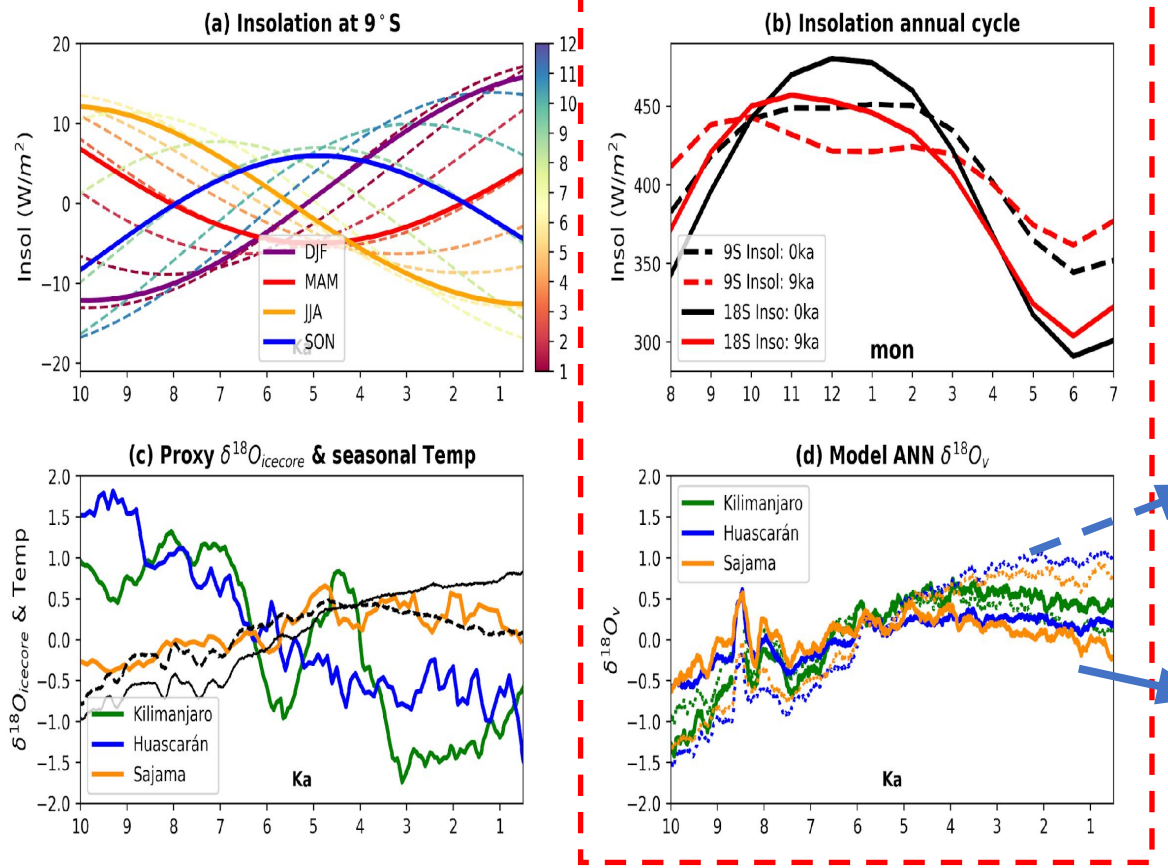
- **If** tropical mountain ice core $\delta^{18}O$ represents in-situ temperature during the wet season, we should expect a large shift in precipitation seasonality.



red: mid-Holocene
black: PI

- However, there seems no obvious seasonality change in precipitation based on the PMIP4 multi-model. **Wet season temperature only may not enough to explain ice core $\delta^{18}O$ change!**

Interpretations of ice core $\delta^{18}O$ during the Holocene? Dry season temp signal?



Dashed (only for wet seasons for precipitation events): annual mean $\delta^{18}Ov$ weighted by precipitation.

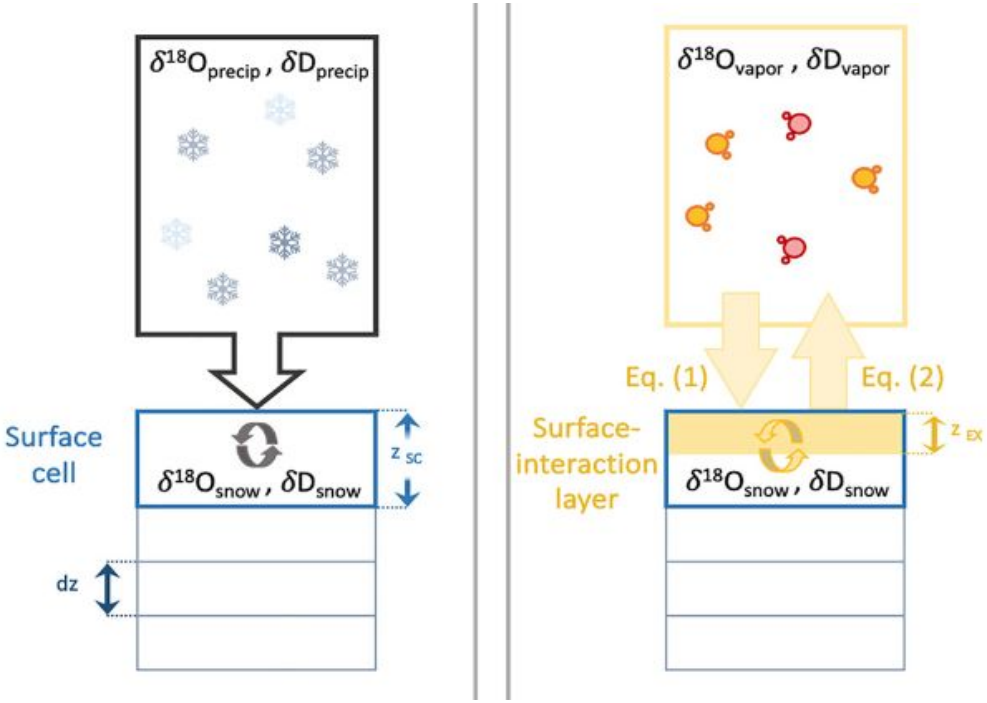
Solid (both dry and wet seasons): arithmetic annual mean $\delta^{18}Ov$. (closer to observation!)

- **If** tropical mountain ice core $\delta^{18}O$ represents in-situ temperature, climate signals during dry seasons (JJA and SON) and precipitation intermissions may also be important in determining $\delta^{18}Ov$ and $\delta^{18}O_{icecore}$ values.

Hypothesis: Interpretations of ice core $\delta^{18}O$ during the Holocene?

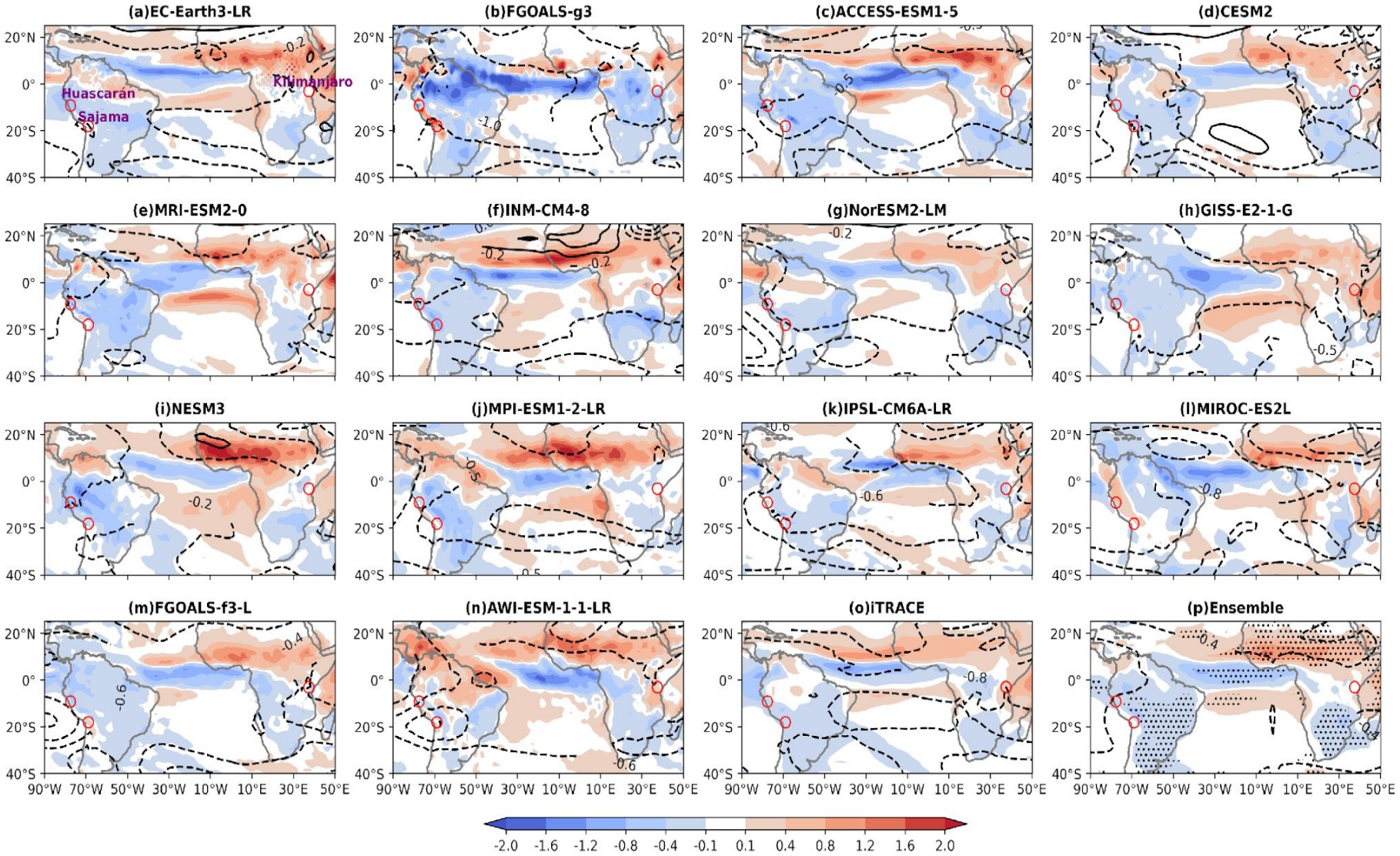
H1: temperature effect: $\delta^{18}O_{icecore}$ represents for temperatures during both wet and dry seasons. During dry seasons, vapor-snow exchange may be important in altering $\delta^{18}O_{icecore}$.

H2: amount effect: $\delta^{18}O_{icecore}$ represents for in-situ precipitation or upstream moisture conditions.



Wahl et al., 2022; Dietrich et al., 2023

PMIP4 model response: midHolocene – PI



Shading: precipitation; Contours: Temperature

Open questions:

- **Unable estimate the Holocene temperature change in tropical mountain regions?** We cannot validate whether the tropical mountain $\delta^{18}O_{icecore}$ represents temperature or precipitation/moisture conditions throughout the Holocene.
- **Possible climate model deficiencies?**

Model resolutions and tropical precipitation bias (double ITCZ bias);

Poleward energy transport bias;

Missing physical processes: e.g., post-condensation processes in ice cores.