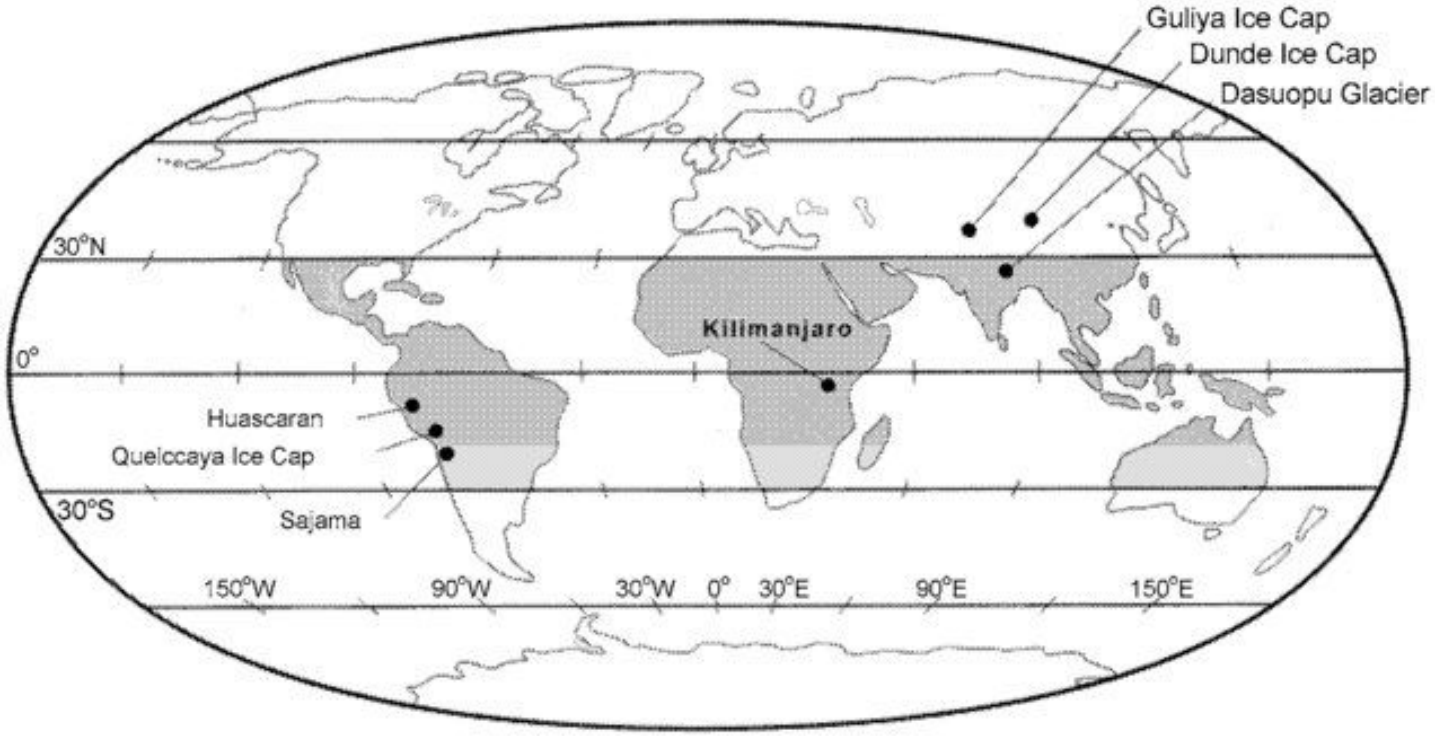
Tropical Glaciers

Map of all tropical glaciers



Gray area = 70% Global population
20% Global agricultural production
80% Global births

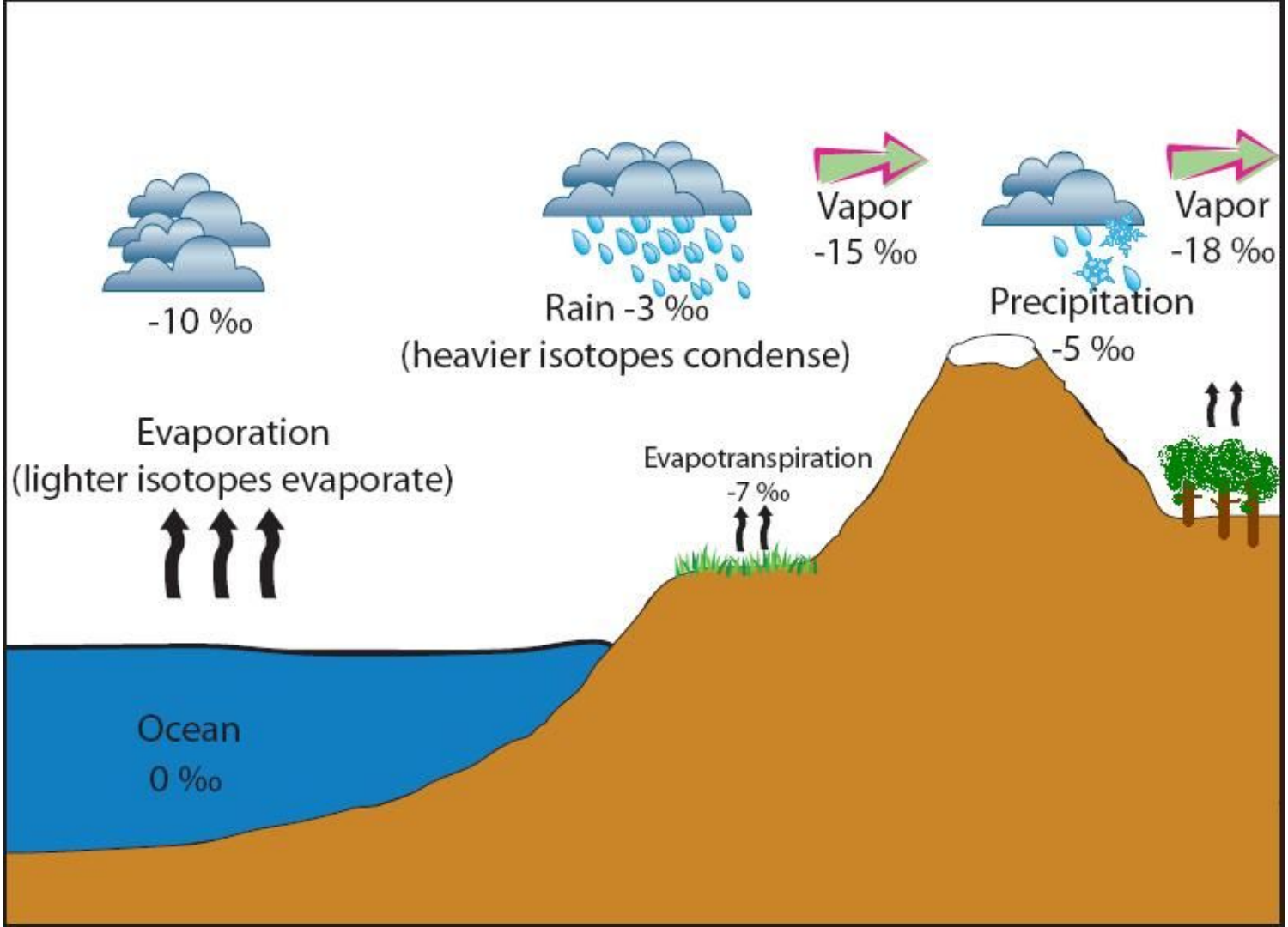
Thompson et al. (2003)

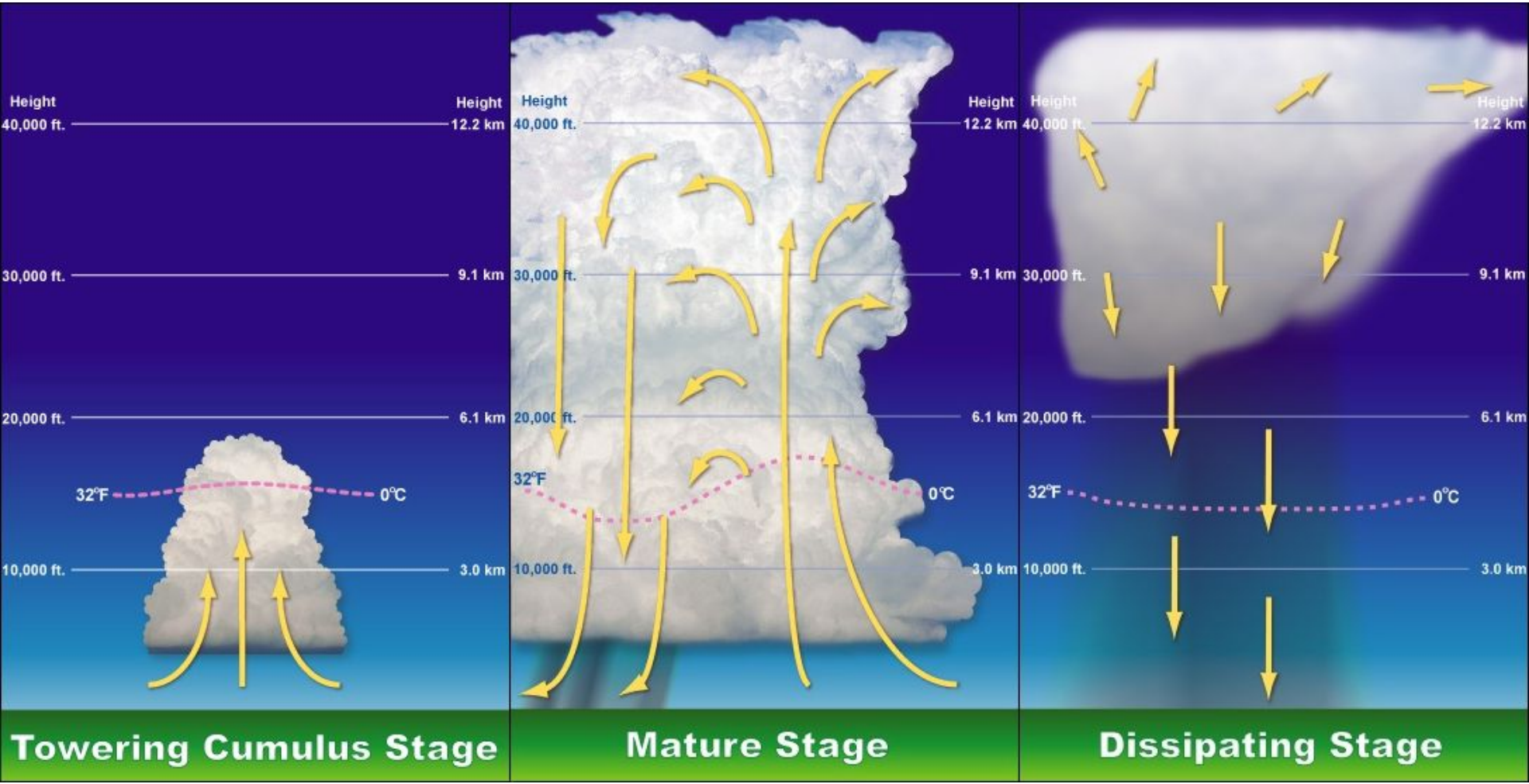
Intro

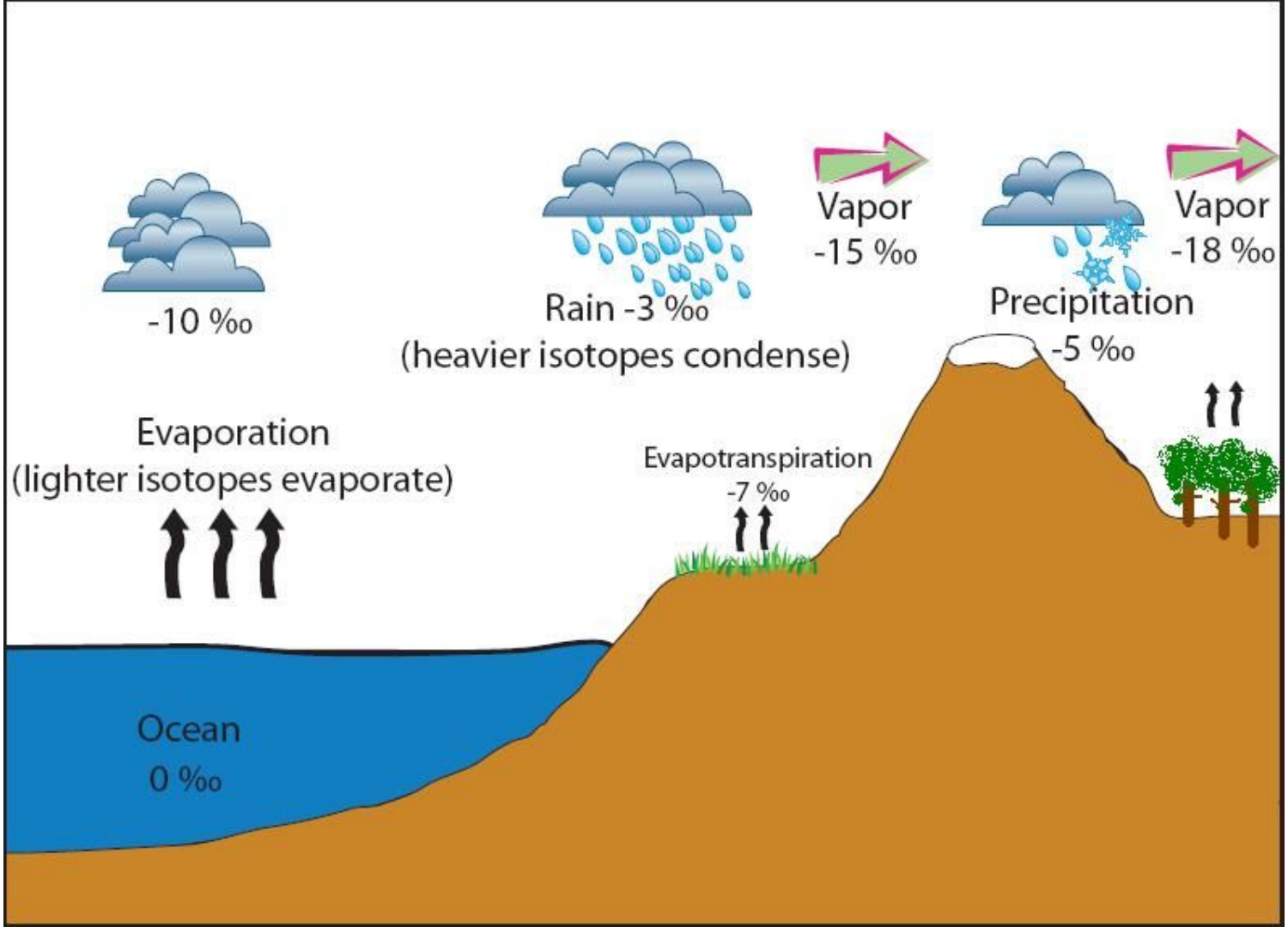
Why do we care about tropical glaciers

- Primary source for global moisture and heat
- 70% of world's population lives there
- Close to a major source region of the global water cycle (Thompson, 1990,2000)
- Few historical climate records beyond the modern era for the tropics
- Rapidly disappearing records, with limited time to extract/utilize them

Tropical isotopes as temperature proxies?


-10 ‰
Rain -3 ‰
(heavier isotopes condense)
Vapor
-15 ‰
Precipitation
-5 ‰
Vapor
-18 ‰
Evaporation
(lighter isotopes evaporate)
Evapotranspiration
-7 ‰
Ocean
0 ‰


Height
Height
40,000 ft.
12.2 km
30,000 ft.
9.1 km
20,000 ft.
6.1 km
32°F
0°C
10,000 ft.
3.0 km
Towering Cumulus Stage
Height
Height
40,000 ft.
12.2 km
30,000 ft.
9.1 km
20,000 ft.
6.1 km
32°F
0°C
10,000 ft.
3.0 km
Mature Stage
Height
Height
40,000 ft.
12.2 km
30,000 ft.
9.1 km
20,000 ft.
6.1 km
32°F
0°C
10,000 ft.
3.0 km
Dissipating Stage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A good temperature proxy?

- Thompson et al. (2003) show high correlations between isotopes and temperature
  - Links changes in convection (and thus isotopic changes) to tropospheric temperature gradients
- Others (e.g. Vimeux et al., 2009) argue that temperature-isotope relationships are tenuous
  - Claim isotopes better correlate with the amount of precipitation
  - Argue no observational/modeling evidence for the importance of tropospheric temperature gradients on isotope values

Can we use tropical isotopes to infer temperature?

Short answer: it depends

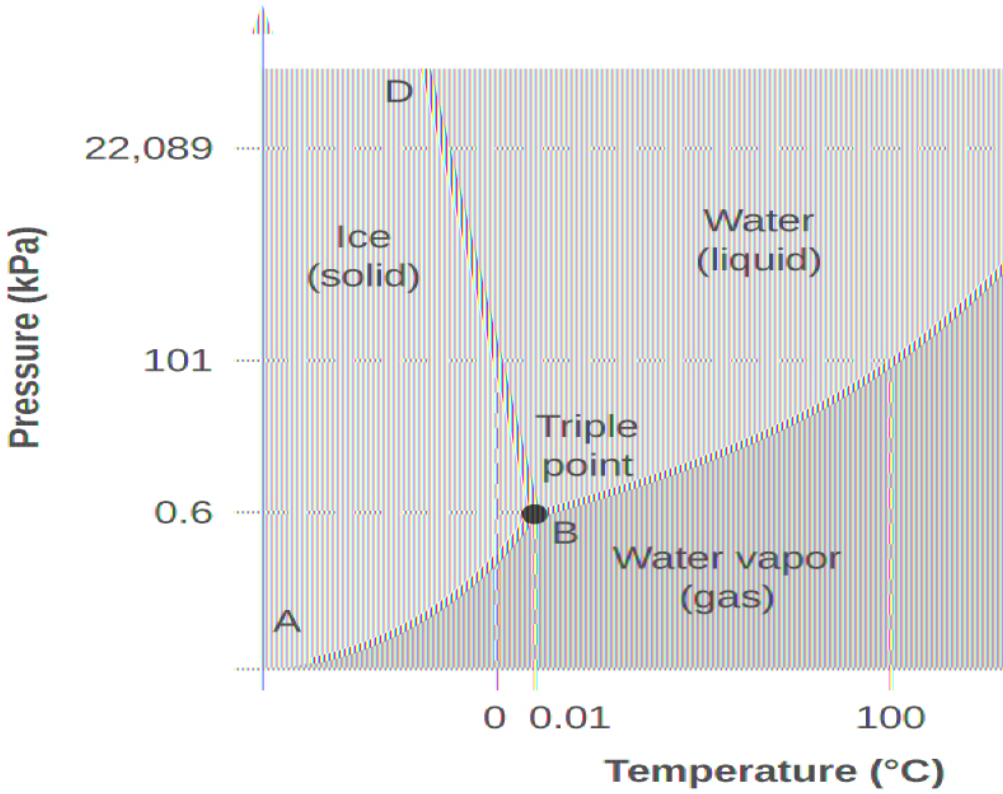
- Some areas show good correlations between the two; others not so much
- More research is needed to understand the controls on isotopic fractionation in the tropics

Take-home message: Isotopes can still be useful in the tropics (for temperature and other reconstructions), but interpretations are more ambiguous than in polar regions

Effects of sublimation

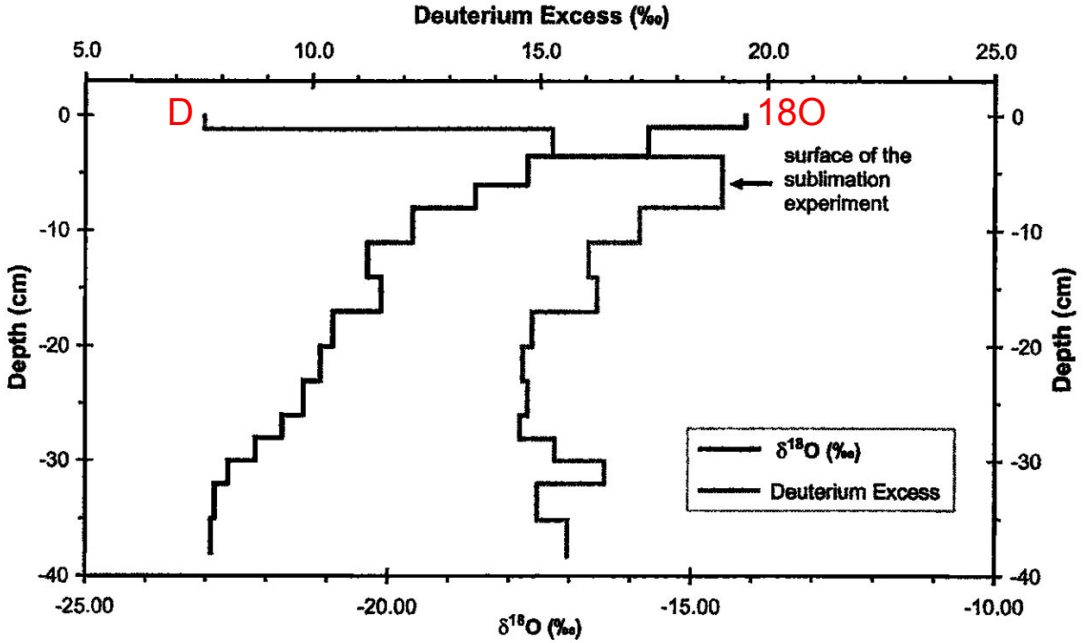
Sublimation

- Transition directly from solid to gas phase
- Often dominates the ablation process on cold, high-altitude tropical glaciers Andes (Stichler, 2011)
- As high as 3 mm per day (Vuille, 1996)
- **How does sublimation effect stable water isotopes records in tropical glaciers?**



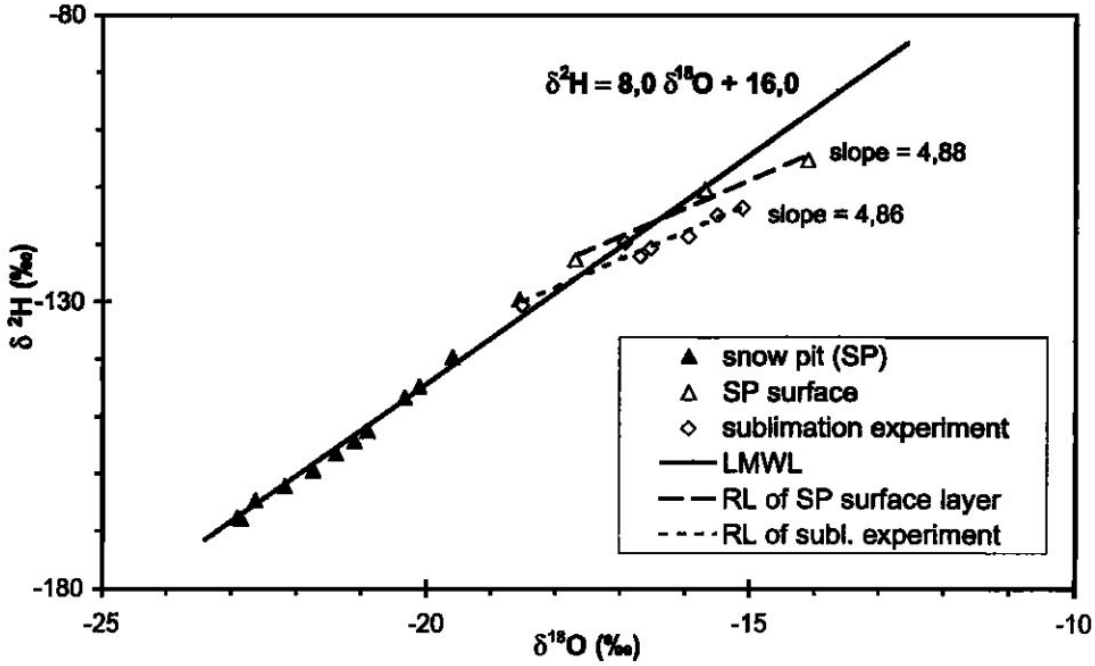
Sublimation Experiment

- Snow pit (38 cm deep) sampled every 1-3 cm
- Sampled surface (morning and evening)
- Repeated for 3.5 days
- Sharp decrease in delta O18 near the surface
- Sharp increase in Deuterium Excess near the surface



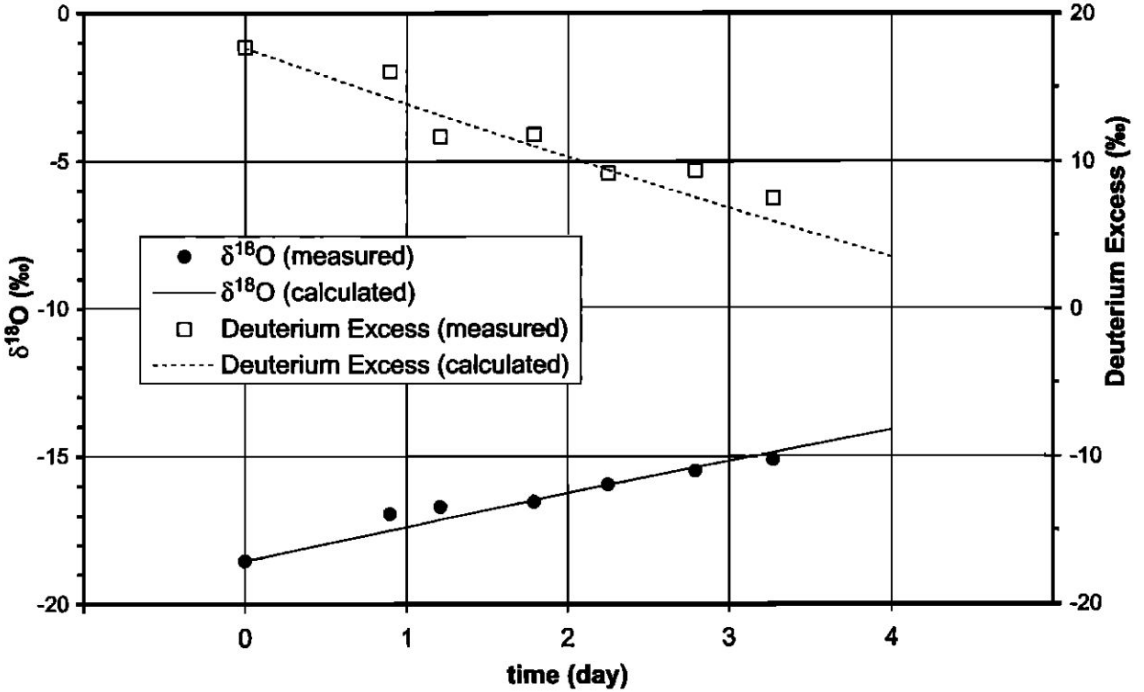
Sublimation

- Compared samples with Local Meteoric Water Line (LMWL)
- Pit samples plotted close to LMWL
- Pit top 7 cm of pit had slope of 4.88; surface samples had slope of 4.86
- Deviations in slope are characteristic of sublimation processes (Stichler, 2011)



Sublimation

- Sublimation is driven by difference in temp. of air and snow
- Sublimation is strongest during the daytime
- Decreases in Deuterium excess greatest during day (reflecting kinetic isotope effect)
- Low night temp results in a condensation front; prevents penetration into deep layers



Sublimation Conclusions

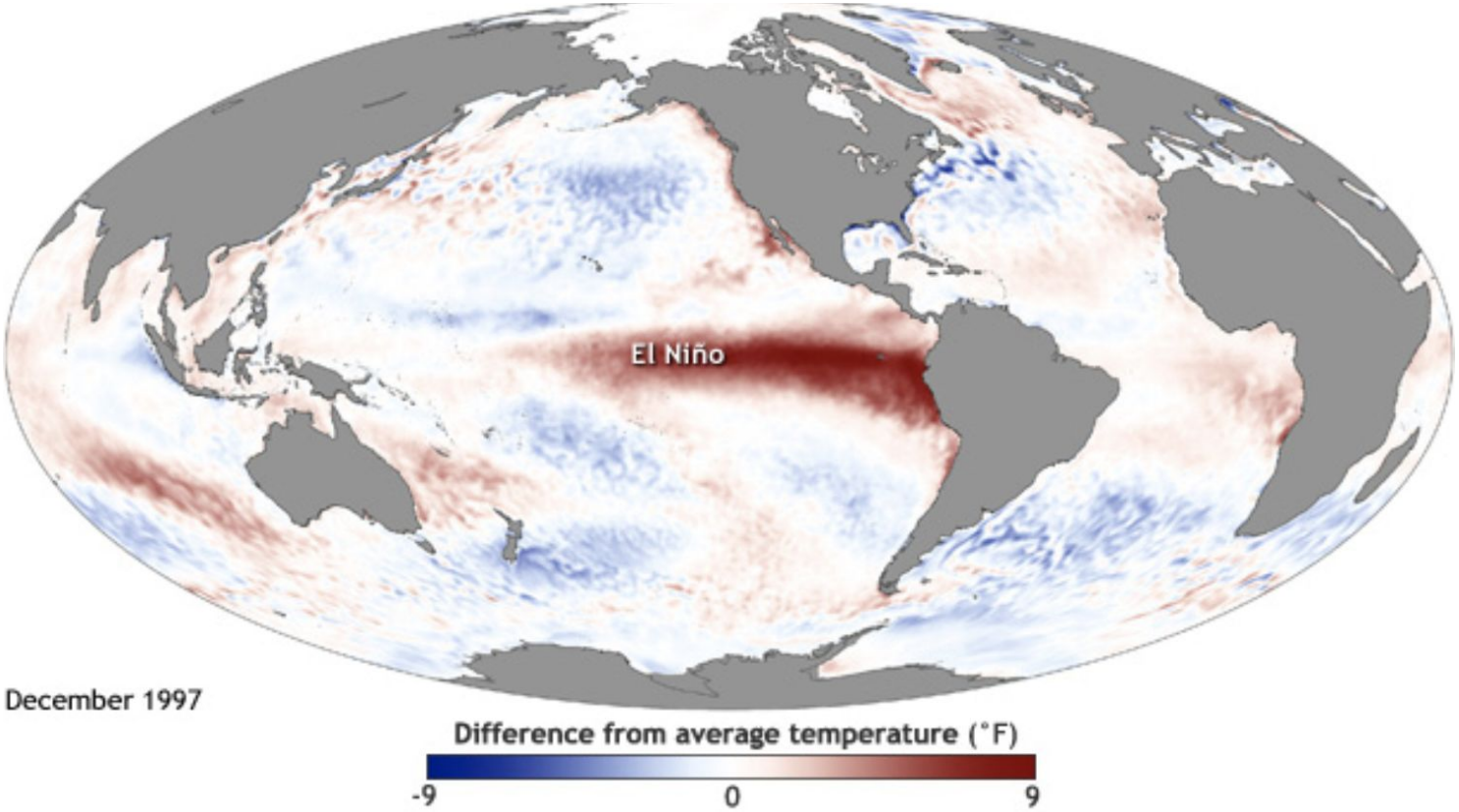
Sublimation at the surface of snow cover…

- Only reaches depth of 5-10 cm.
- Condensation blocks penetration of enriched isotopes into deep layers.
- Must consider mass loss, which may remove enriched layer entirely.
- May be preserved by new snow cover.

Reconstructing ENSO

El Nino Southern Oscillation (ENSO)

El Niño: A warming of the ocean surface, or above-average sea surface temperatures (SST)

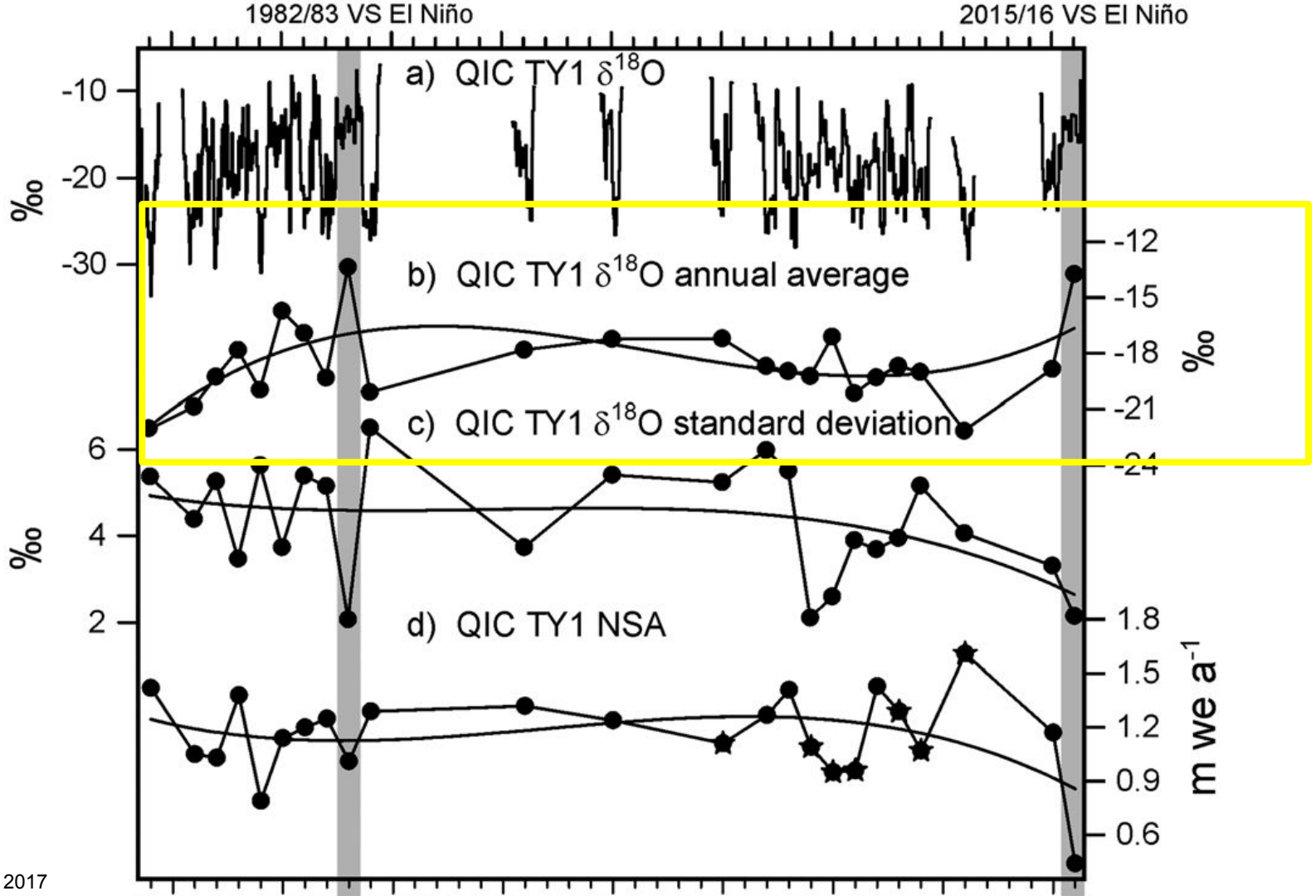


https://www.weather.gov/mhx/ensowhat

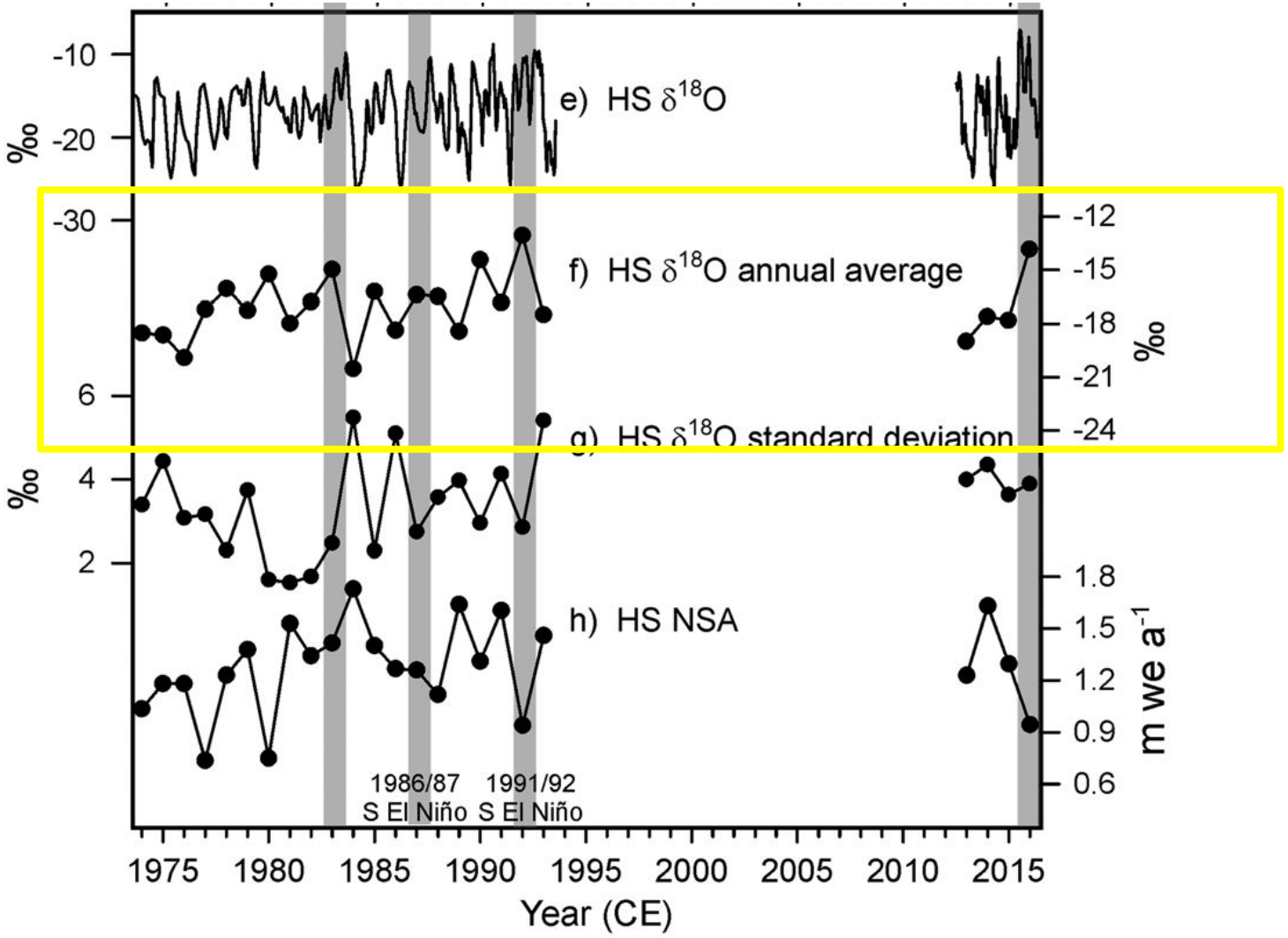
Increased ablation due to factors relating to El Niño

- High air temp (rain > snow)
- Sporadic snowfall (cannot maintain high albedo)
- Low wind speeds (limits transfer of energy from melting to sublimation)
- Reduced cloud cover (increases incoming short-wave radiation)

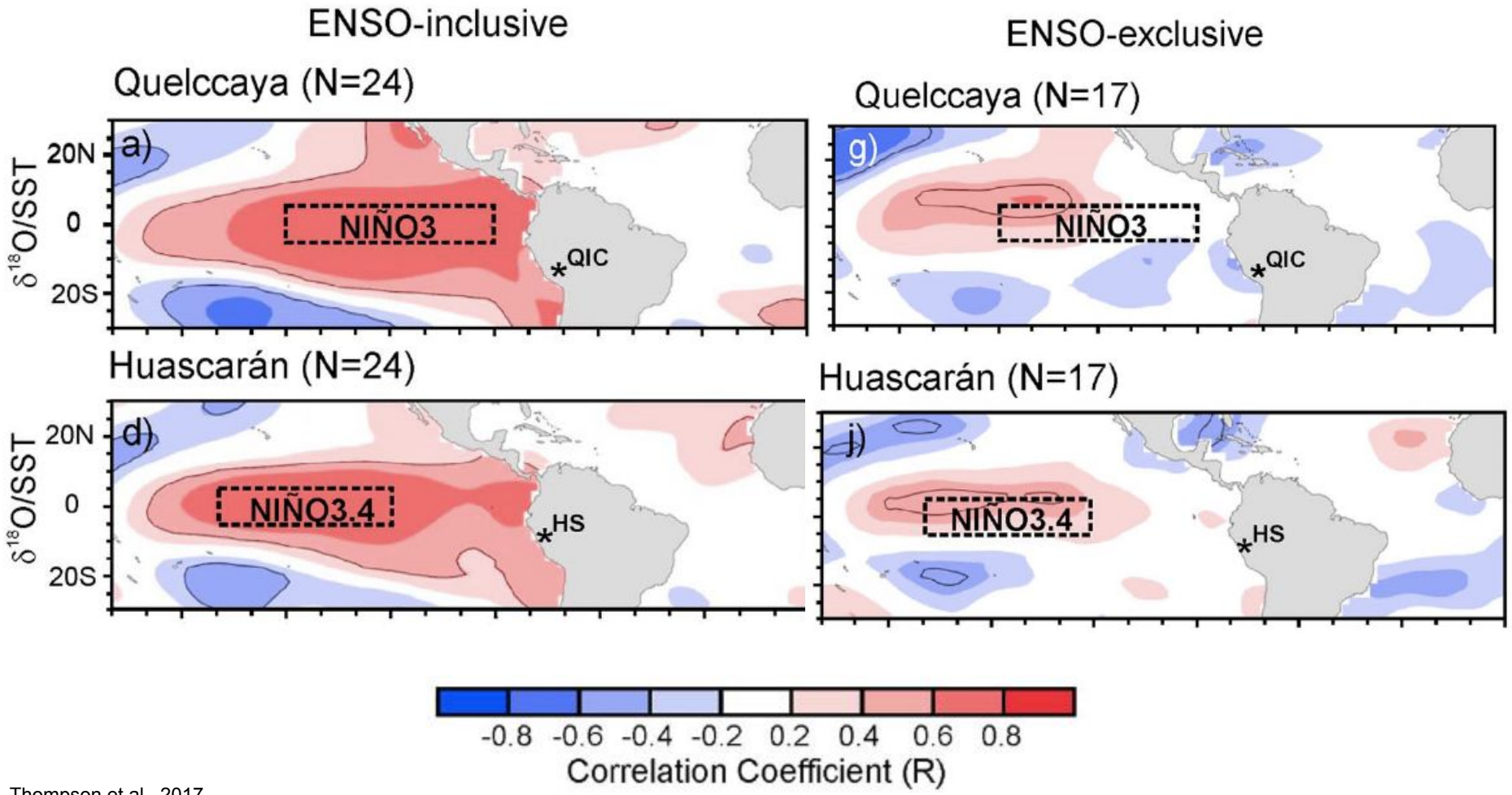
Francou et al., 2004, figure Thompson et al., 2017



Thompson et al., 2017

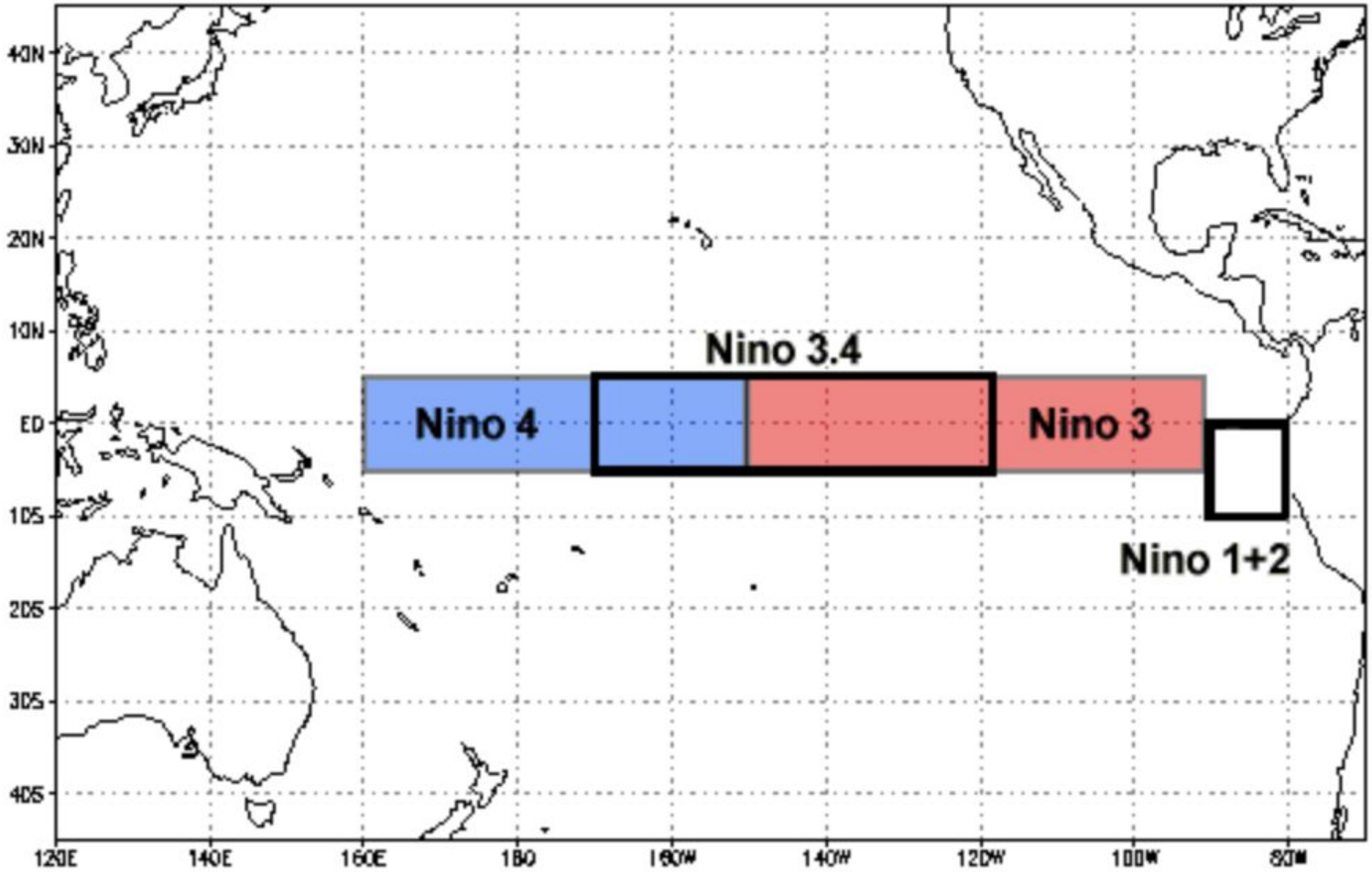


Thompson et al., 2017

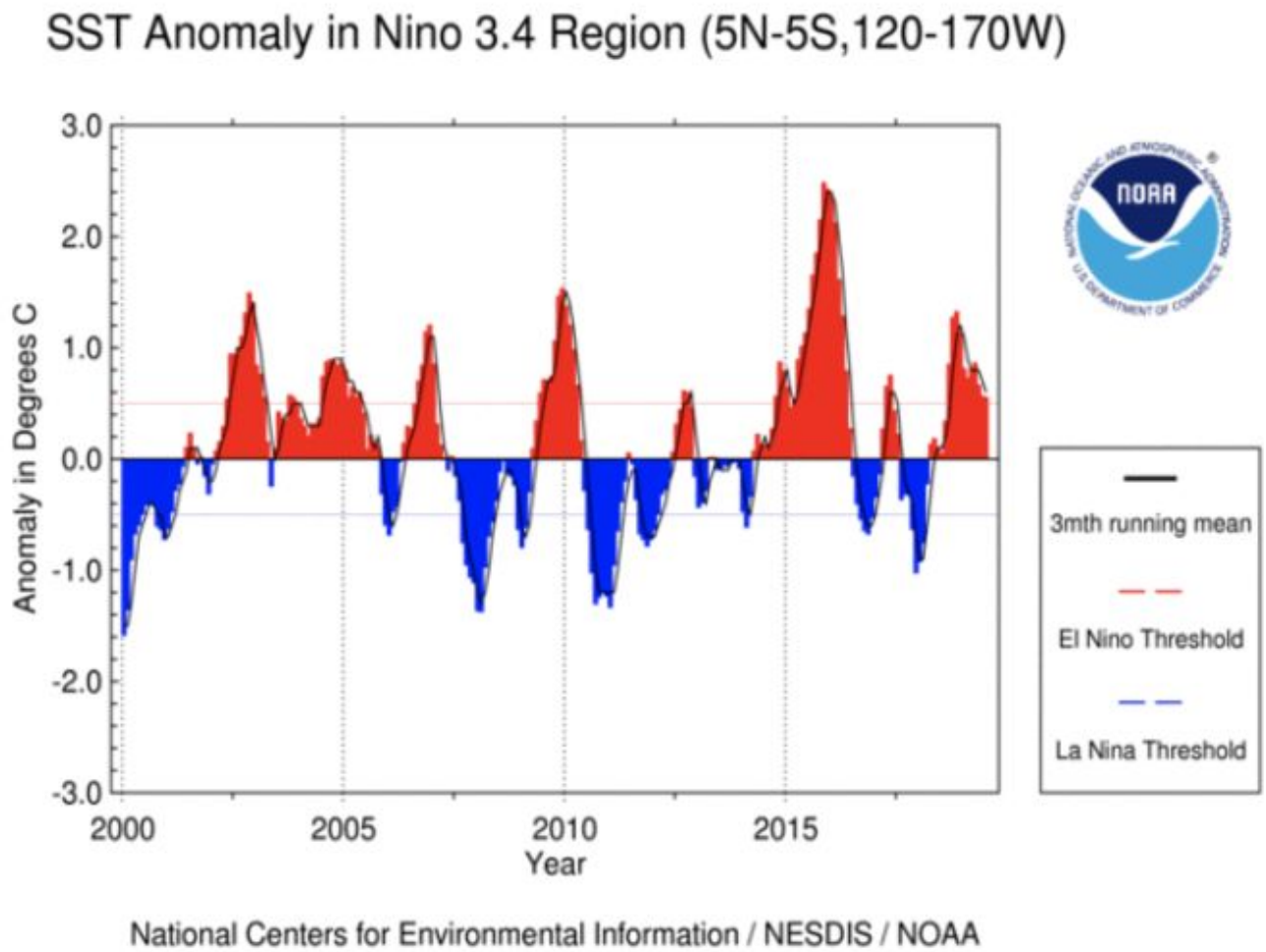


Thompson et al., 2017

Niño Regions



https://www.ncdc.noaa.gov/teleconnections/enso/indicators/sst/



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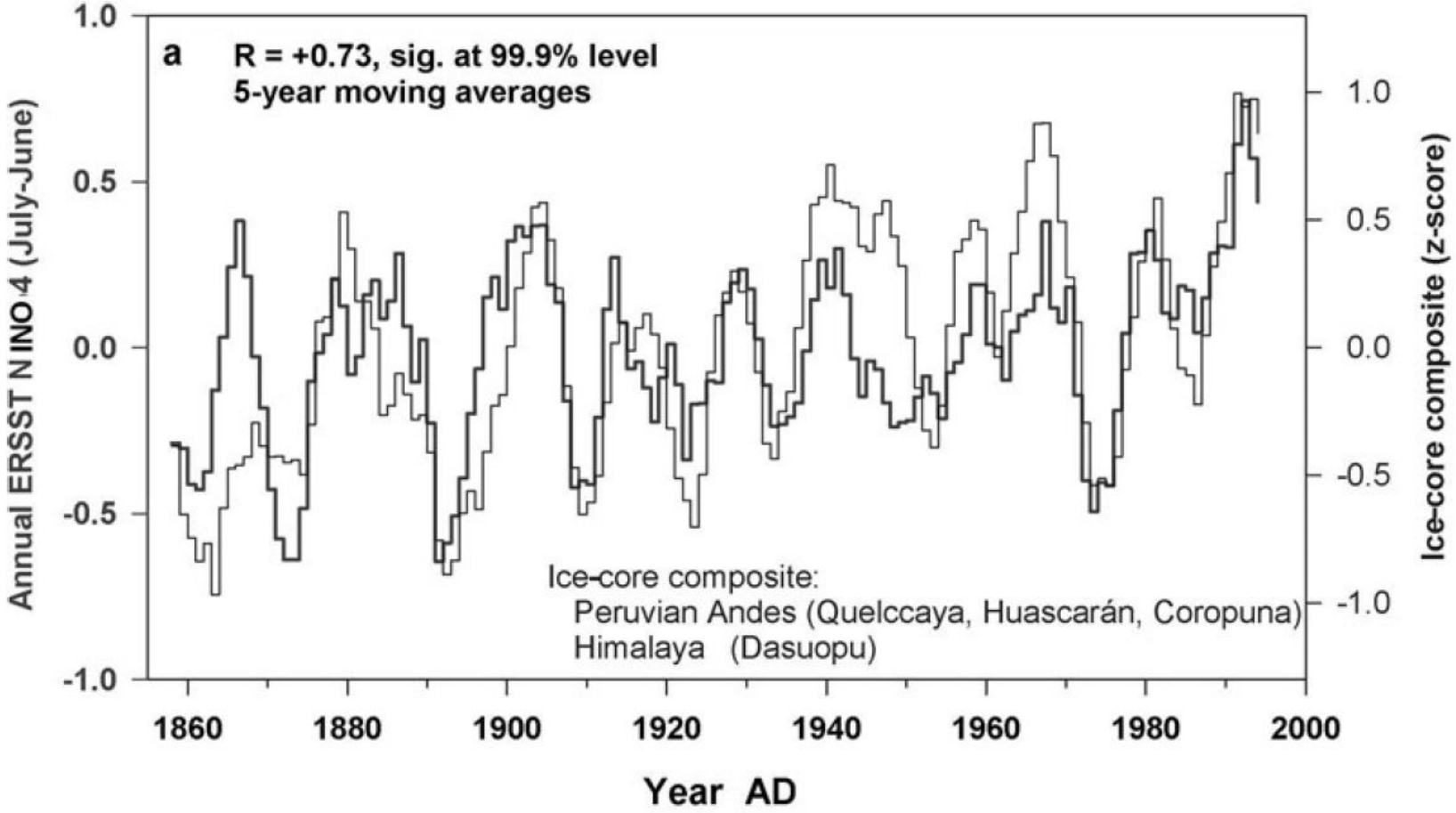
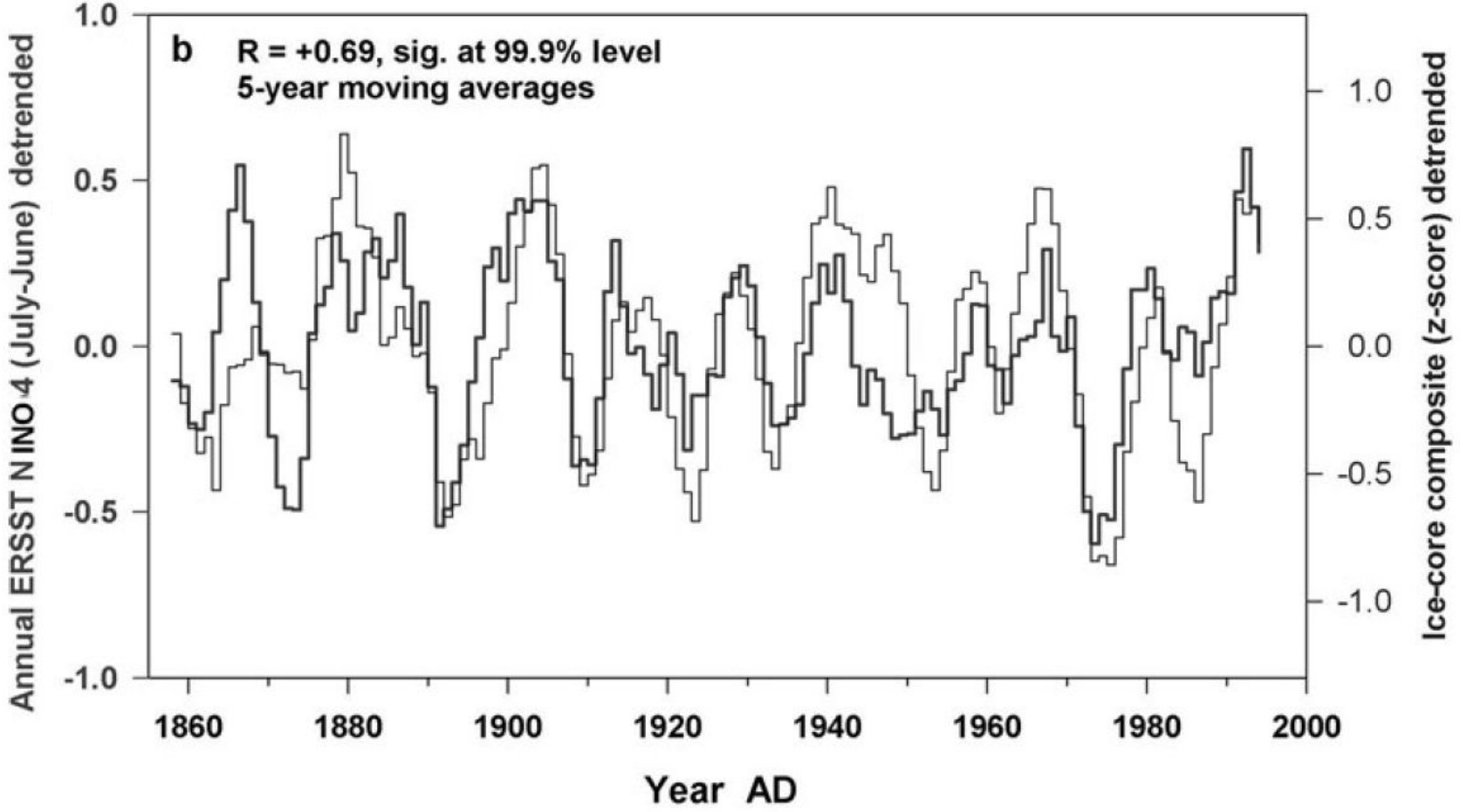


Thompson et al., 2011



Thompson et al., 2011

How is isotopic record interpreted?

- del18O enrichment during El Nino
- Correlation between SSTs and del18O

Tropical records reveal:

- ENSO pattern thru time
- Movement of tropical freezing height (closely related to SSTs)

References:

Francou, B., M. Vuille, V. Favier, and B. Ca´ceres, 2004, New evidence for an ENSO impact on low-latitude glaciers: Antizana 15, Andes of Ecuador, 0280S: Journal of Geophysical Research, v., 109, D18106, doi:10.1029/2003JD004484.

Thompson, L. G., Mosley-Thompson, E., Davis, M.E., and Brecher, H.H., 2011, Tropical Glaciers, Recorders and Indicators of Climate Change, Are Disappearing Globally: *Annals of Glaciology*, v. 52 (59), p. 23–34., doi:10.3189/172756411799096231.

Thompson, L.G., Davis, M., Mosley-Thompson, E., Beaudon, E., Porter, S., Kutuzov, S., Lin, P., Mikhalenko, V. and Mountain, K., 2017, Impacts of Recent Warming and the 2015/2016 El Niño on Tropical Peruvian Ice Fields: Journal of Geophysical Research: Atmospheres, v. 122(23), p.12,688-12,701.

Conclusion

Take away points…

- Tropical Isotopes as Temperature Proxies:
  -
- Sublimation:
  - Can alter stable water isotope composition, but only near the surface
- Reconstructing ENSO:
  -

References

Brennan, C.E., Weaver, A.J., Eby, M. and Meissner, K.J., 2012. Modelling oxygen isotopes in the University of Victoria Earth System Climate Model for pre-industrial and Last Glacial Maximum conditions. *Atmosphere-Ocean*, *50*(4), pp.447-465.

Francou, B., M. Vuille, V. Favier, and B. Ca´ceres, 2004, New evidence for an ENSO impact on low-latitude glaciers: Antizana 15, Andes of Ecuador, 0280S: Journal of Geophysical Research, v., 109, D18106, doi:10.1029/2003JD004484.

Stichler, W., et al. "Influence of sublimation on stable isotope records recovered from high‐altitude glaciers in the tropical Andes." *Journal of Geophysical Research: Atmospheres* 106.D19 (2001): 22613-22620.

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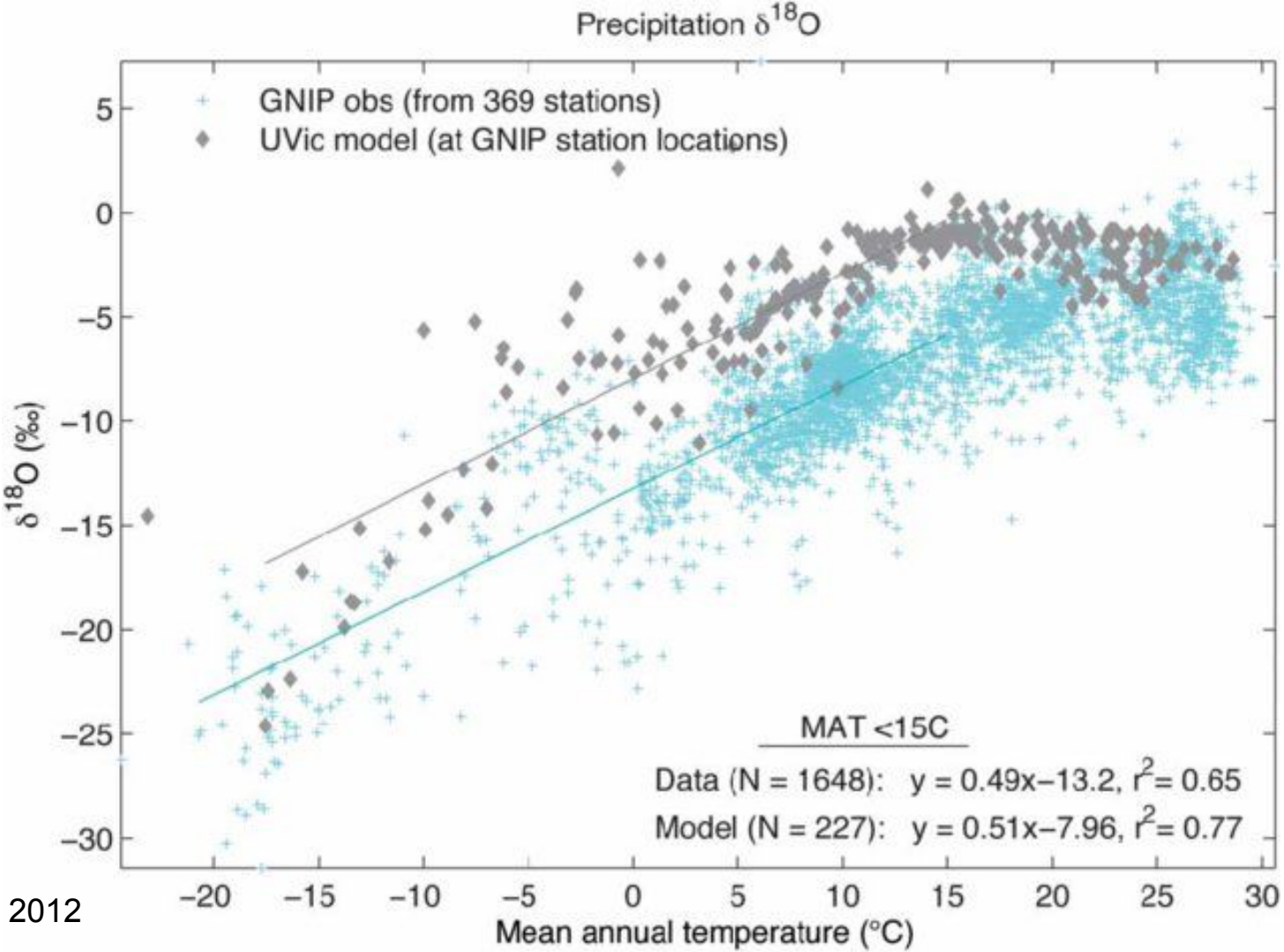
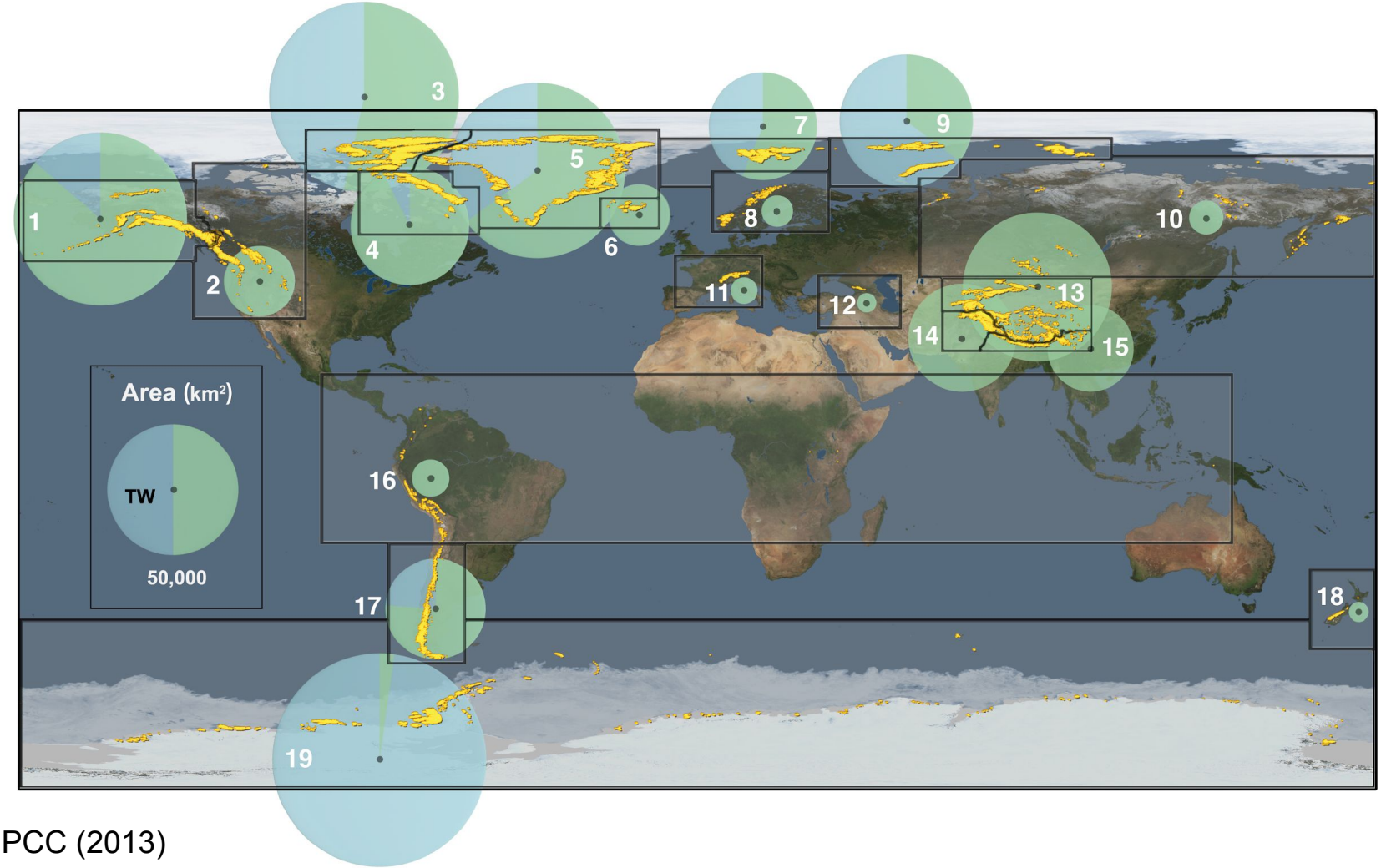
Extra figures



Brennan, 2012



IPCC (2013)