ARTICLE

Check for updates

https://doi.org/10.1038/s41467-022-28210-1 OPEN

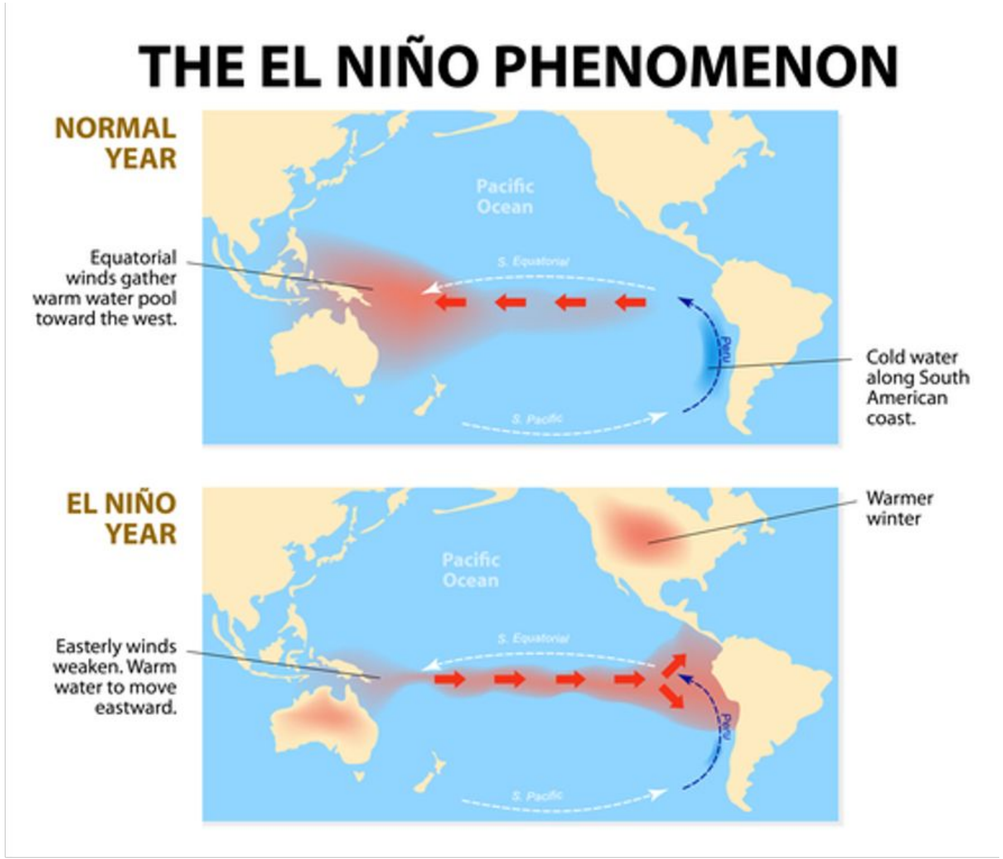
A re-appraisal of the ENSO response to volcanism with paleoclimate data assimilation

Volcanism and ENSO

A Re-appraisal with Paleoclimate Data Assimilation

Feng Zhu (NCAR), Julien Emile-Geay (USC), Kevin J. Anchukaitis (U. Arizona), Gregory J. Hakim (UW), Andrew Wittenberg (GFDL), Mariano Morales (CONICET) , Matthew Toohey (U. Saskatchewan), Jonathan King (U. Arizona)

The ENSO response to volcanism?



Models suggest El Niño-like response in year following eruptions:
e.g. Mann et al. (2005); Emile-Geay et al. (2008); Ohba et al. (2013); Stevenson et al. (2016), McGregor et al. (2020)

Tree-ring based studies

Most tree-ring based observational studies support a strong linkage. For instance, Li et al. (2013) [Li13]

LETTERS

PUBLISHED ONLINE: 2 JULY 2013 | DOI: 10.1038/NCLIMATE1936

nature climate change

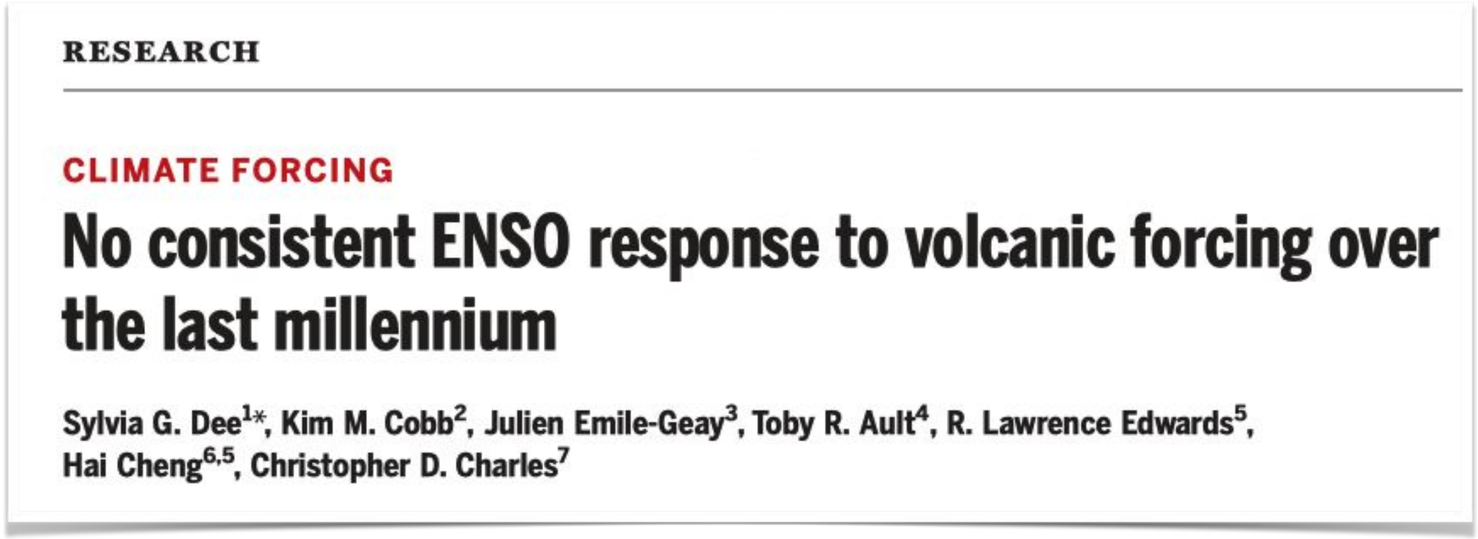
El Niño modulations over the past seven centuries

Jinbao Li[1,2*], Shang-Ping Xie[2,3,4], Edward R. Cook[5], Mariano S. Morales[6], Duncan A. Christie[7,8], Nathaniel C. Johnson[2], Fahu Chen[9], Rosanne D'Arrigo[5], Anthony M. Fowler[10], Xiaohua Gou[9] and Keyan Fang[9]

"… our reconstruction reveals a robust ENSO response to large tropical eruptions …"

Coral based studies

However, a recent coral-based observational study Dee et al. (2020) [D20] suggests a much weaker – if not inexistent – linkage between volcanoes and ENSO.



RESEARCH

CLIMATE FORCING

No consistent ENSO response to volcanic forcing over the last millennium

Sylvia G. Dee[1]*, Kim M. Cobb[2], Julien Emile-Geay[3], Toby R. Ault[4], R. Lawrence Edwards[5], Hai Cheng[6,5], Christopher D. Charles[7]

“Superposed epoch analysis reveals a weak tendency for an El Niño–like response in the year after an eruption, but this response is not statistically significant, nor does it appear after the outsized 1257 Samalas eruption.”

How should we understand the seemingly divergent conclusions?

Contradictions between **trees** and **corals**?

LETTERS
PUBLISHED ONLINE: 2 JULY 2013 | DOI: 10.1038/NCLIMATE1936
nature climate change

El Niño modulations over the past seven centuries

Jinbao Li[1,2]*, Shang-Ping Xie[2,3,4], Edward R. Cook[5], Mariano S. Morales[6], Duncan A. Christie[7,8], Nathaniel C. Johnson[2], Fahu Chen[9], Rosanne D'Arrigo[5], Anthony M. Fowler[10], Xiaohua Gou[9] and Keyan Fang[9]

RESEARCH

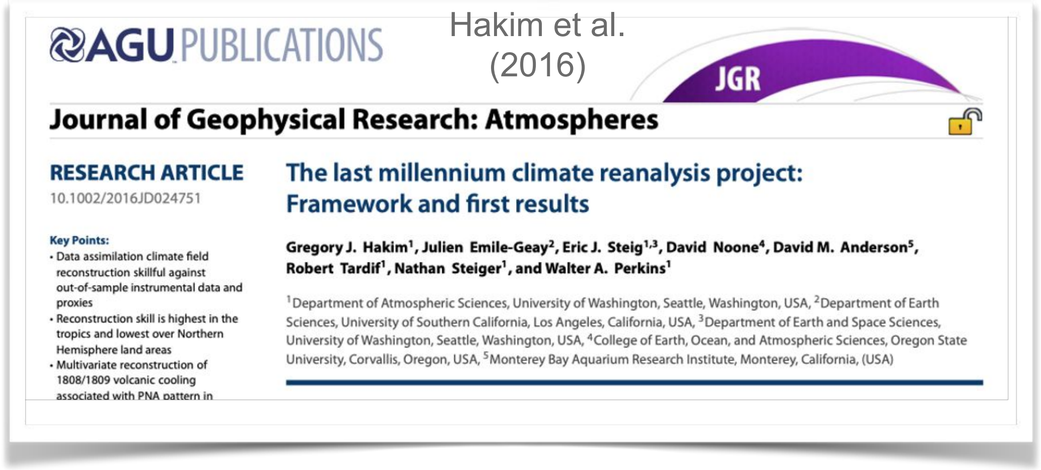
CLIMATE FORCING

No consistent ENSO response to volcanic forcing over the last millennium

Sylvia G. Dee[1]*, Kim M. Cobb[2], Julien Emile-Geay[3], Toby R. Ault[4], R. Lawrence Edwards[5], Hai Cheng[6,5], Christopher D. Charles[7]

The LMR PDA framework

LMR: Last Millennium Reanalysis



AGU PUBLICATIONS

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2016JD024751

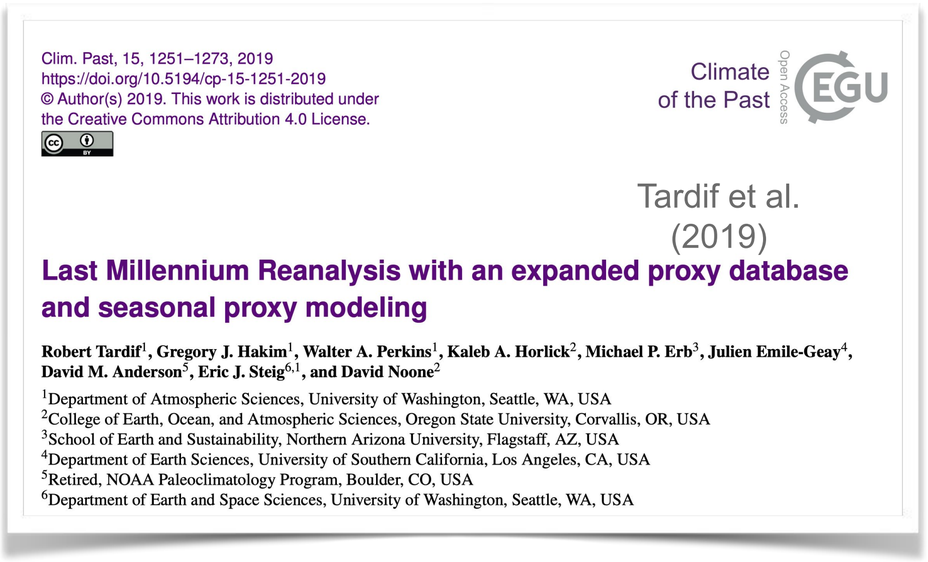
Key Points:
- Data assimilation climate field reconstruction skillful against out-of-sample instrumental data and proxies
- Reconstruction skill is highest in the tropics and lowest over Northern Hemisphere land areas
- Multivariate reconstruction of 1808/1809 volcanic cooling associated with PNA pattern in

The last millennium climate reanalysis project: Framework and first results

Gregory J. Hakim[1], Julien Emile-Geay[2], Eric J. Steig[1,3], David Noone[4], David M. Anderson[5], Robert Tardif[1], Nathan Steiger[1], and Walter A. Perkins[1]

[1]Department of Atmospheric Sciences, University of Washington, Seattle, Washington, USA, [2]Department of Earth Sciences, University of Southern California, Los Angeles, California, USA, [3]Department of Earth and Space Sciences, University of Washington, Seattle, Washington, USA, [4]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA, [5]Monterey Bay Aquarium Research Institute, Monterey, California, (USA)

Hakim et al. (2016)



Clim. Past, 15, 1251–1273, 2019
https://doi.org/10.5194/cp-15-1251-2019
© Author(s) 2019. This work is distributed under the Creative Commons Attribution 4.0 License.

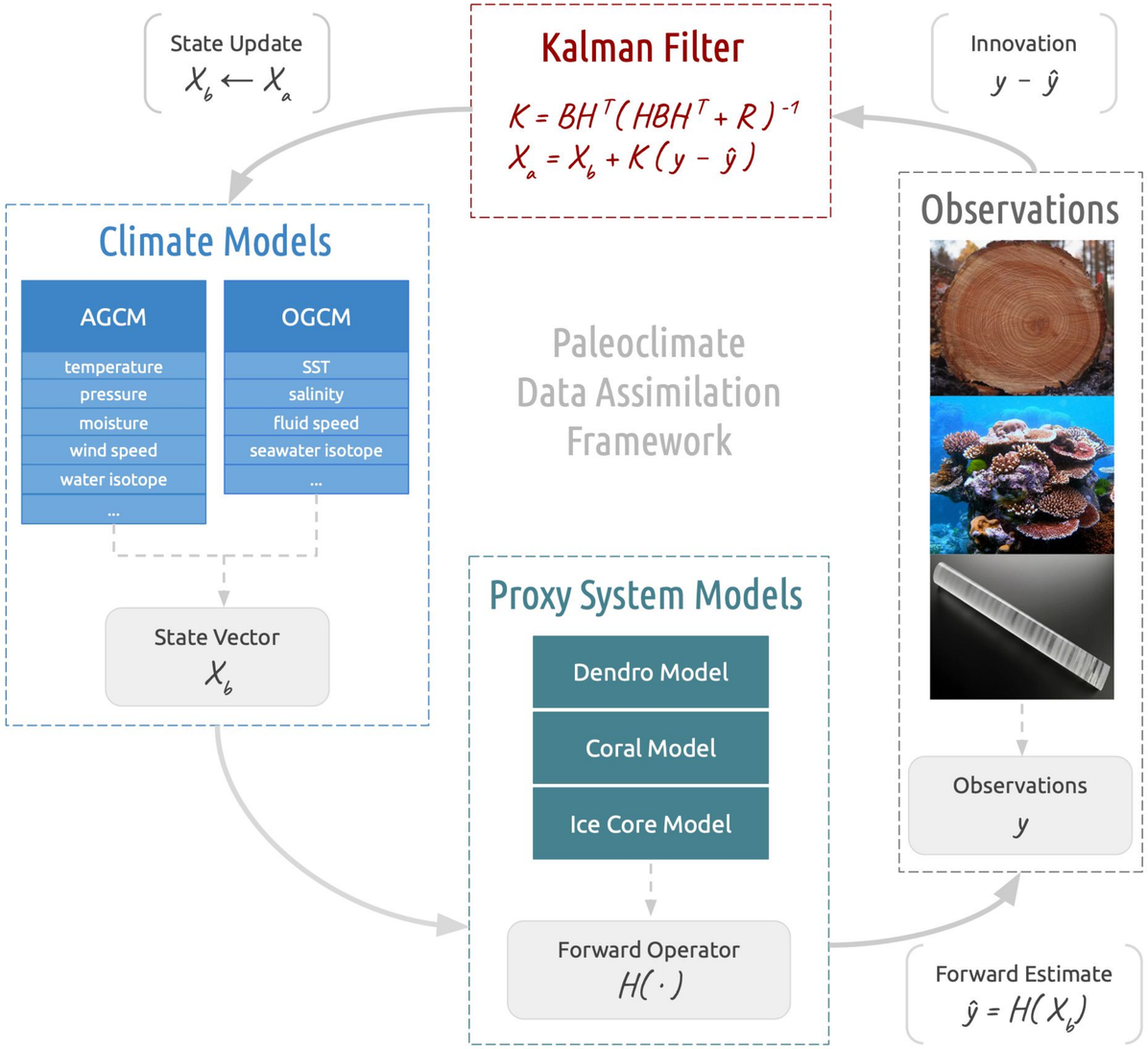
Climate of the Past — Open Access — EGU

Last Millennium Reanalysis with an expanded proxy database and seasonal proxy modeling

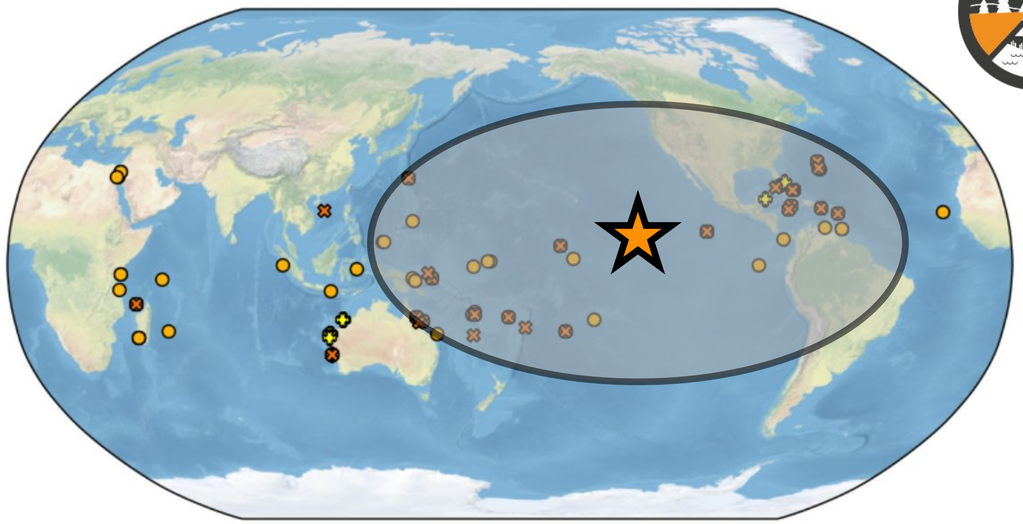
Robert Tardif[1], Gregory J. Hakim[1], Walter A. Perkins[1], Kaleb A. Horlick[2], Michael P. Erb[3], Julien Emile-Geay[4], David M. Anderson[5], Eric J. Steig[6,1], and David Noone[2]

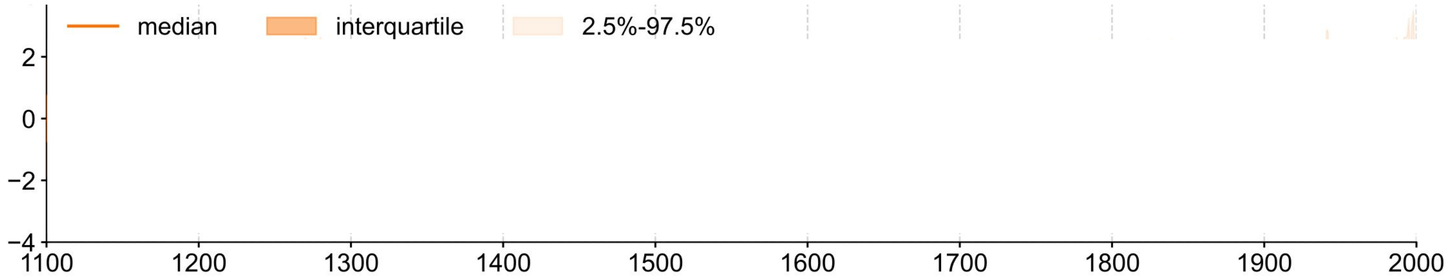
[1]Department of Atmospheric Sciences, University of Washington, Seattle, WA, USA
[2]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA
[3]School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ, USA
[4]Department of Earth Sciences, University of Southern California, Los Angeles, CA, USA
[5]Retired, NOAA Paleoclimatology Program, Boulder, CO, USA
[6]Department of Earth and Space Sciences, University of Washington, Seattle, WA, USA

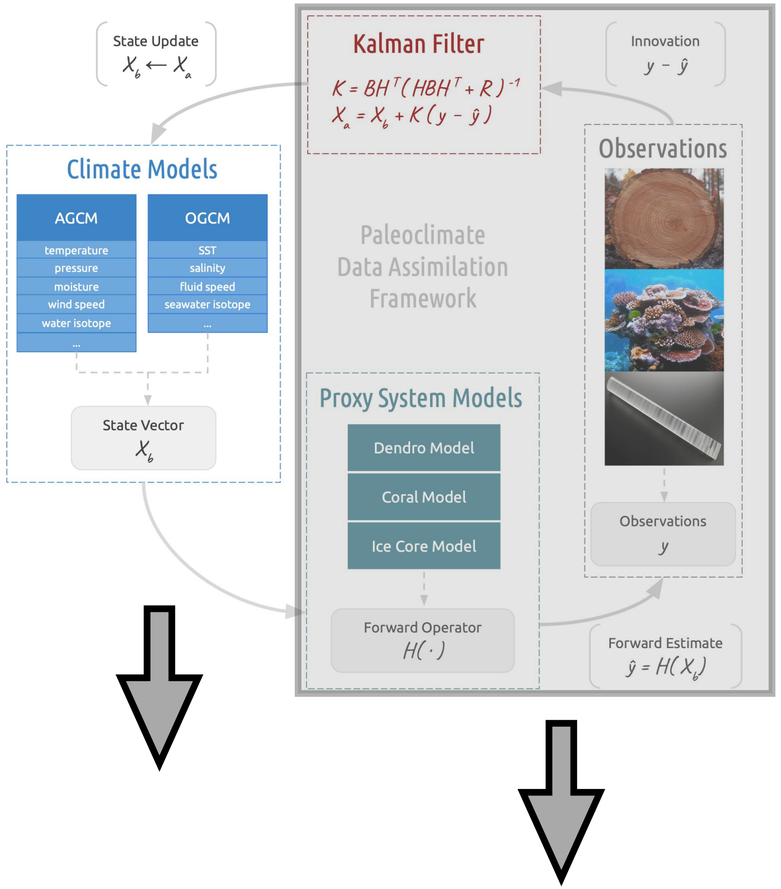
Tardif et al. (2019)



The LMR PDA framework

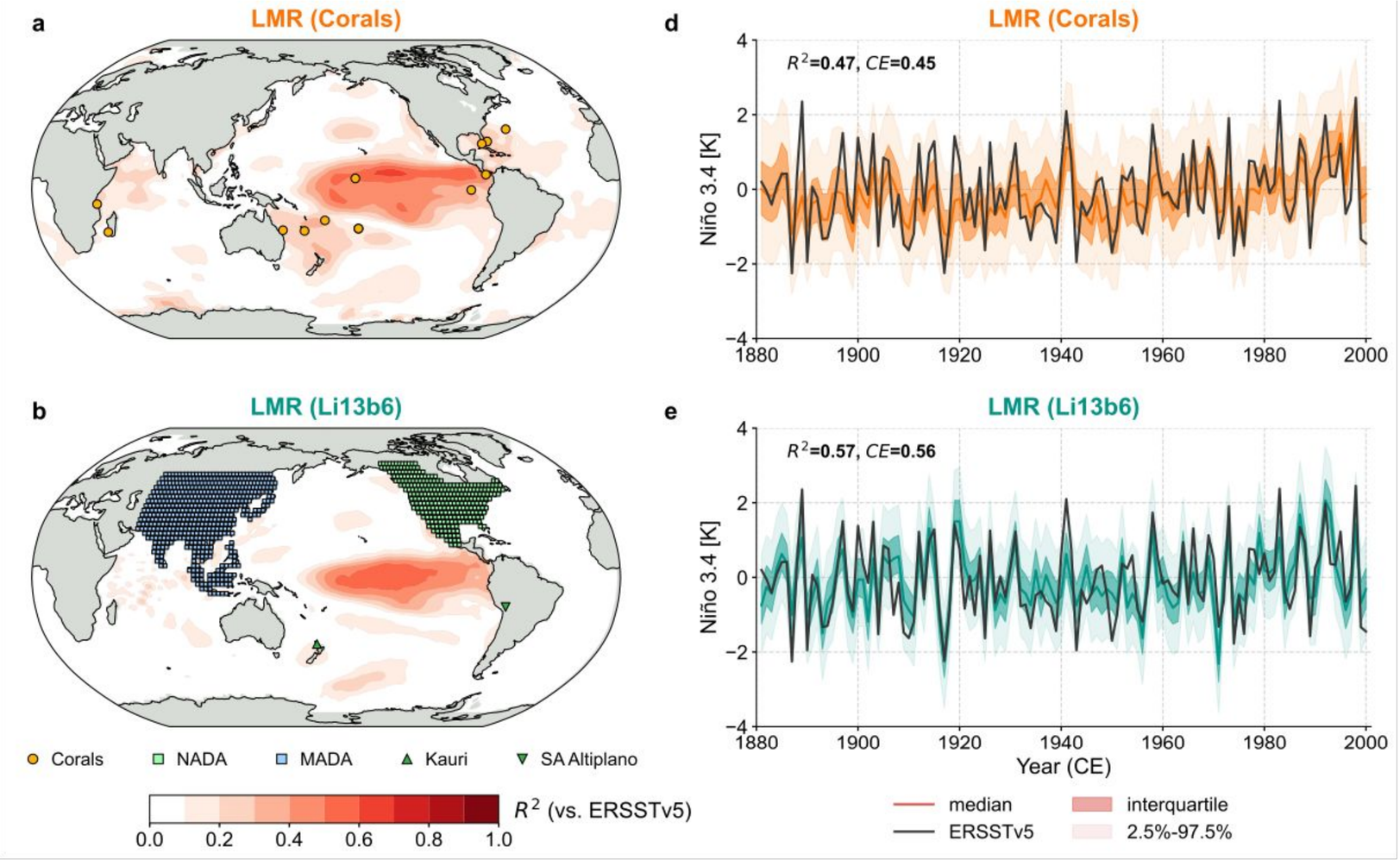






The temporal variability comes purely from the proxies.

Contradictions between trees and corals?



Corals only

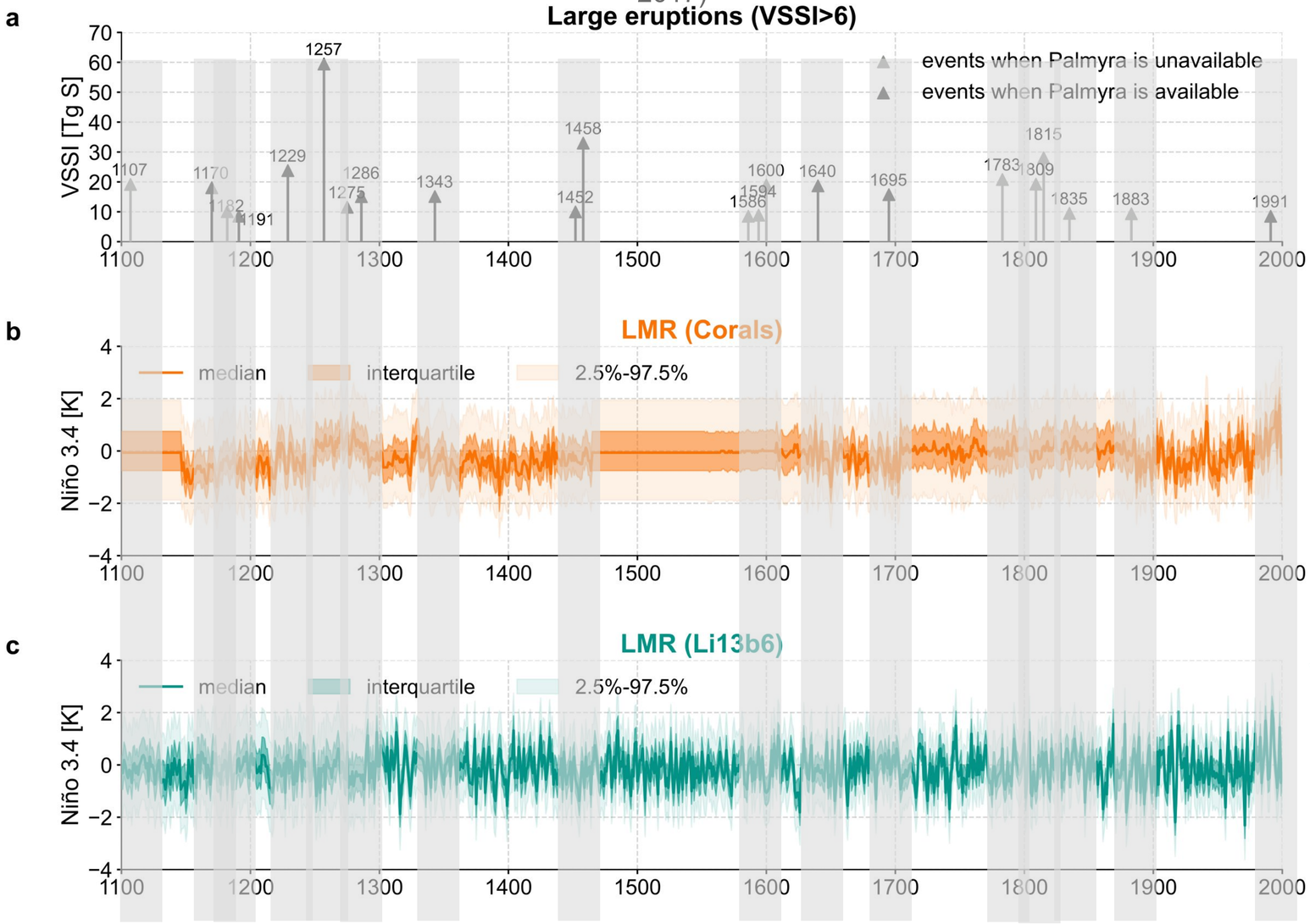
- Ocean 2k [Tierney et al. 2015]
- Latest Palmyra [D20]

Trees only

- best 6/7 predictors [Li13]
  - PC1&2 of NADA [Cook et al. 2004] and MADA [Cook et al. 2010]
  - Kauri composite [Wahl et al. 2014]
  - South American Altiplano composite [Morales et al. 2012]

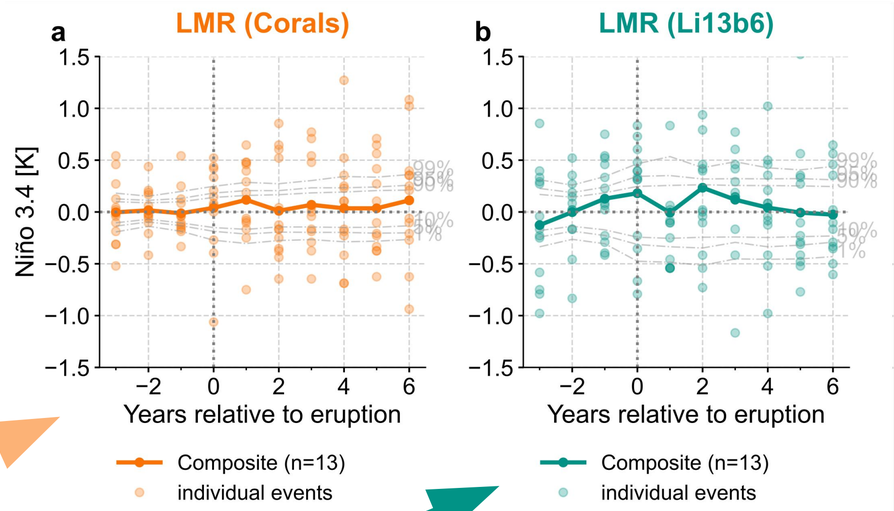
Contradictions between trees and corals?

eVolv2k v3 (Toohey & Sigl, 2017)



Superposed Epoch Analysis (SEA)

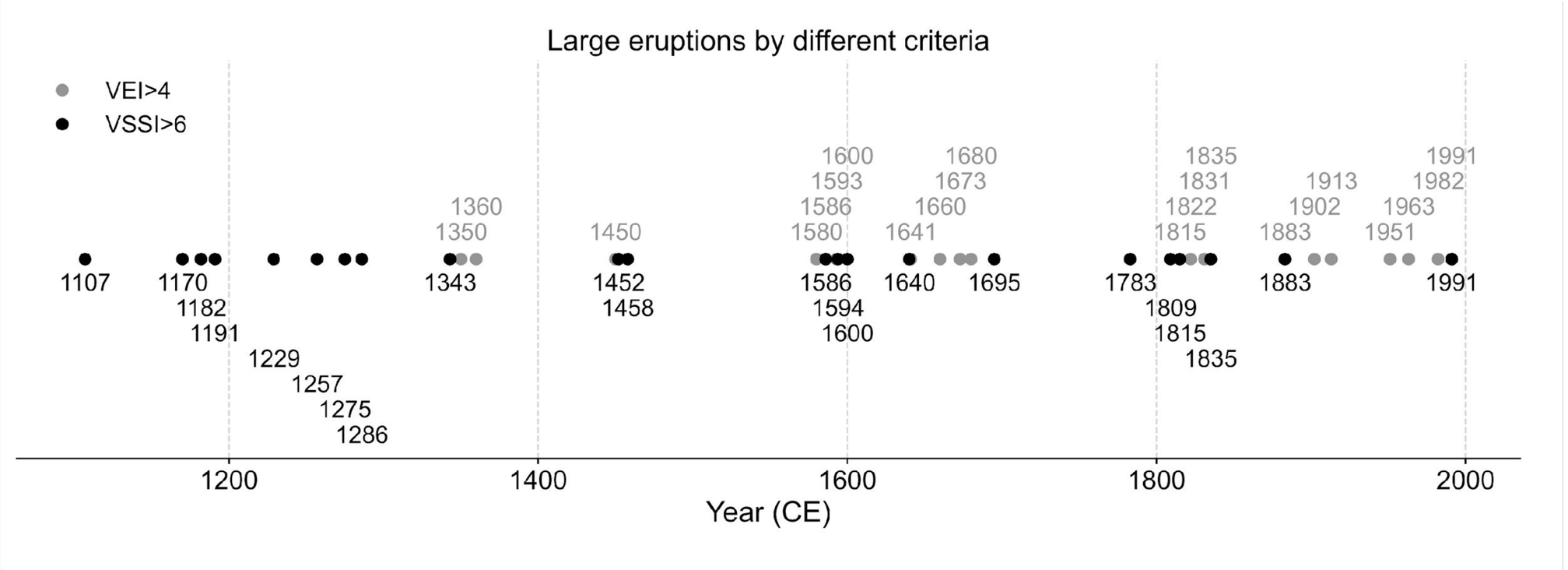
UQ: double bootstrap as in *Rao et al. (2019)*



A consistent <u>insignificant</u> El Niño response to large eruptions in both reconstructions.

The difference in proxy type does not lead to the different conclusions.

Different criteria for event selection

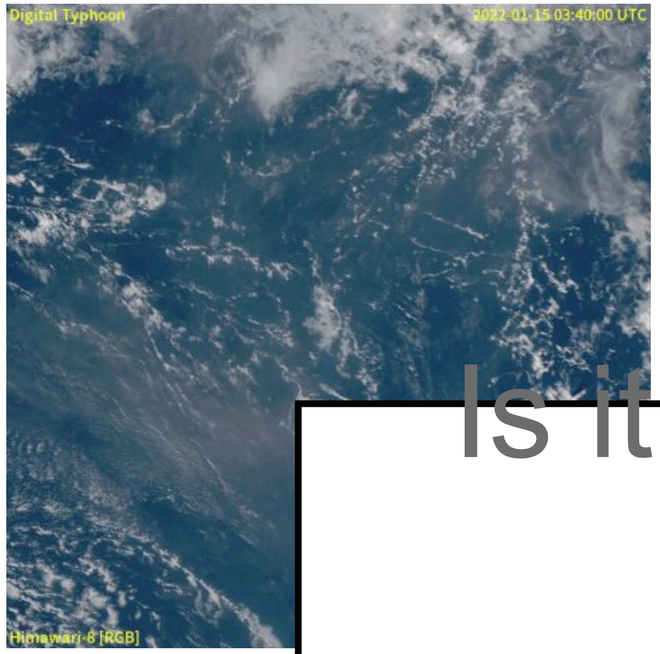


[Li13] **VEI** (Volcanic Explosivity Index): measures **the volume of the erupted tephra**

[D20] **VSSI** (volcanic stratospheric sulfur injection):

measures **the mass of the sulfur injected to the stratosphere**, which directly affects the amount of shortwave radiation that enters the climate system

Tonga-Hunga Ha’apai eruption on 1/15/2022



https://en.wikipedia.org/wiki/2
Ha‘apai_erupti

Contents lists available at ScienceDirect

KeAi
CHINESE ROOTS
GLOBAL IMPACT

Earthquake Research Advances

journal homepage: www.keaipublishing.com/en/journals/earthquake-research-advances

Under the surface: Pressure-induced planetary-scale waves, volcanic lightning, and gaseous clouds caused by the submarine eruption of Hunga Tonga-Hunga Ha'apai volcano

Check for updates

Is it the different criteria that leads to the different conclusions ?

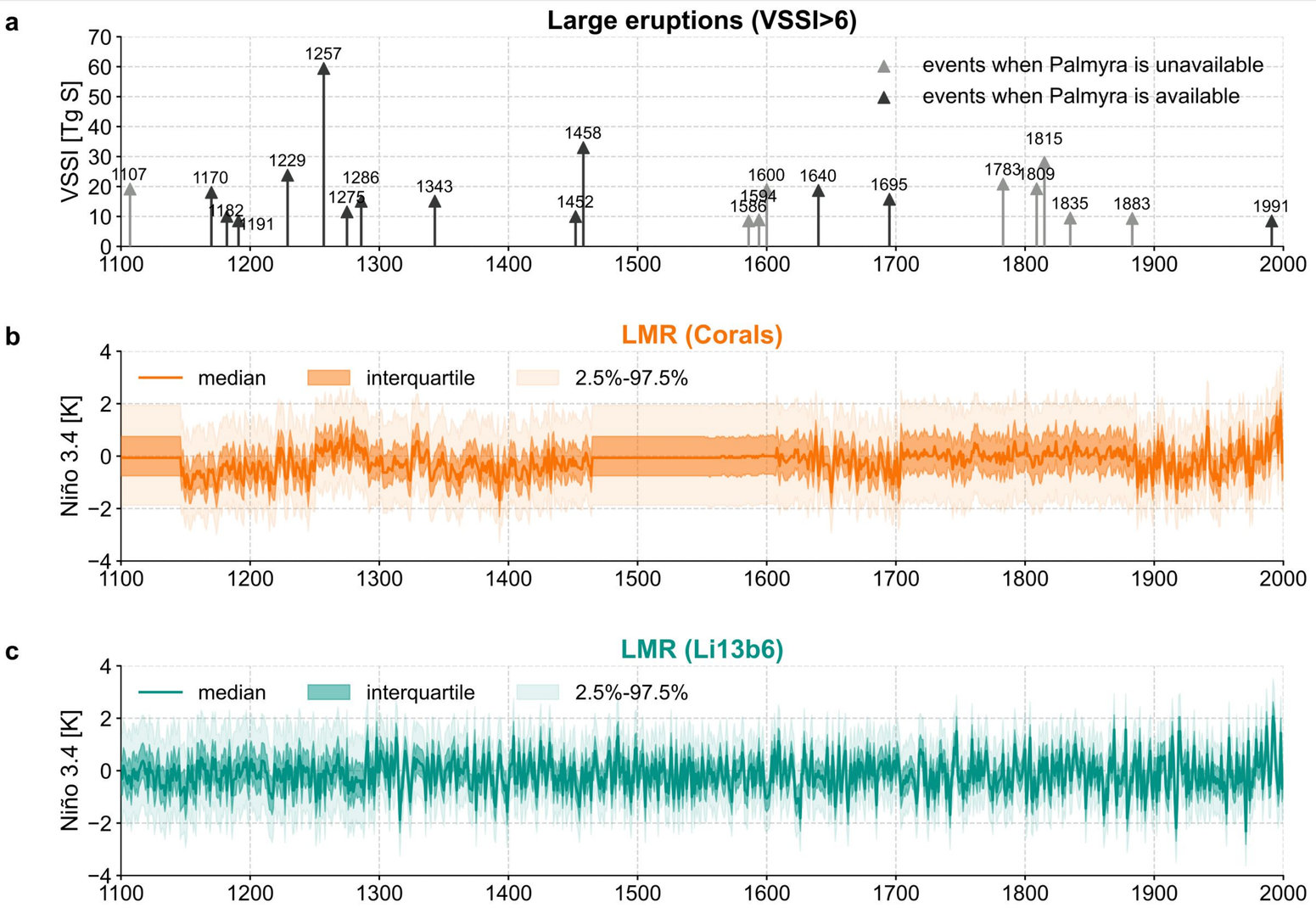
from a Historical Perspective*

Meng ZUO[1], Tianjun ZHOU*[1,2], Wenmin MAN[1], Xiaolong CHEN[1], Jian LIU[3], Fei LIU[4], and Chaochao GAO[5]

“the current eruption of the HTHH volcano is not strong enough to overwhelm the global warming tendency or to have significant impacts on the global climate.”

VEI bears a less direct relation to climate forcing

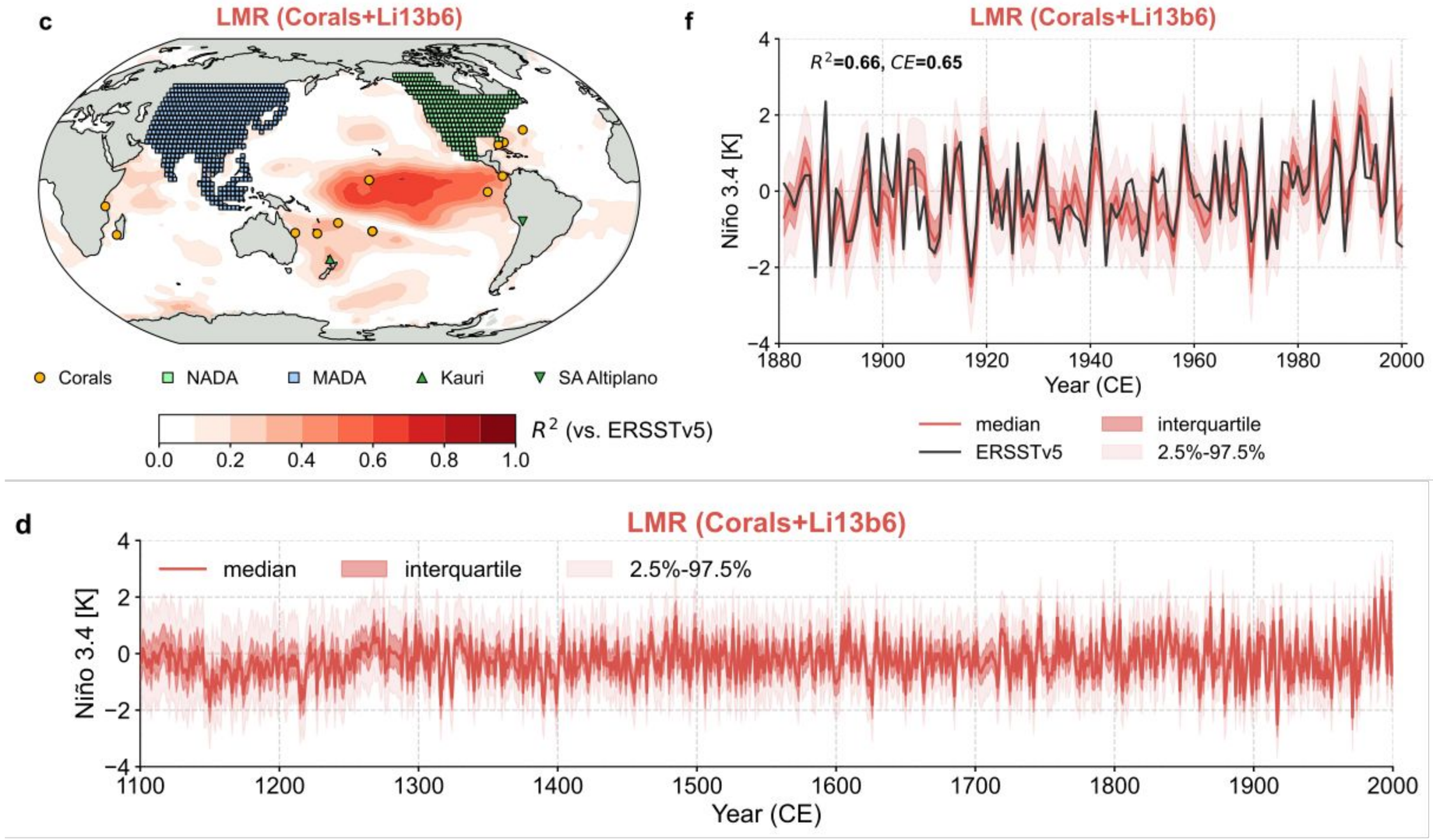
Pros & cons of each proxy type



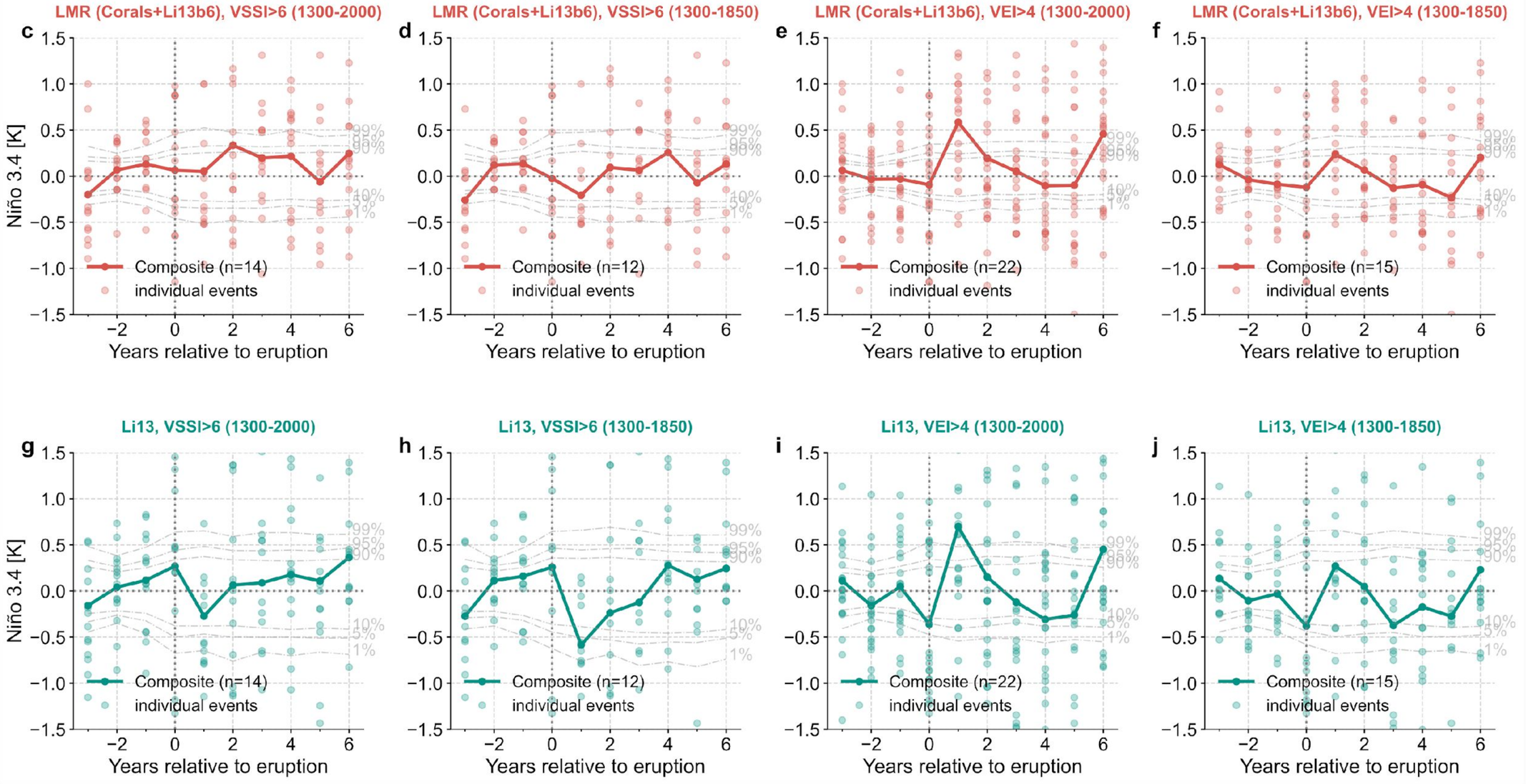
	Distance to target	Continuity
Corals	close	discontinuous
Trees	far away	continuous

PDA offers the opportunity to fuse different proxies and yield the optimal estimate.

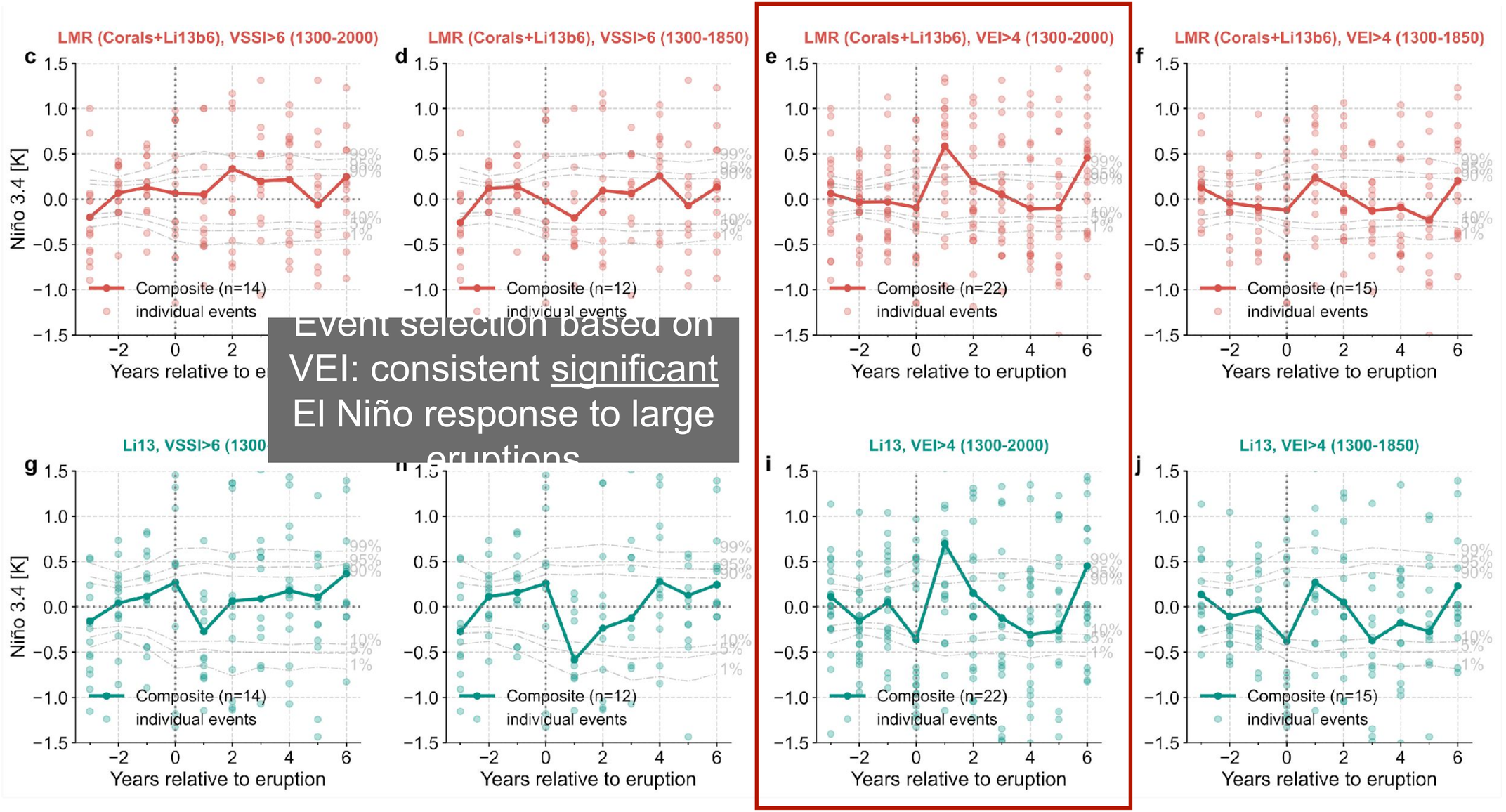
The “best” reconstruction fusing both trees & corals



Superposed Epoch Analysis (SEA)

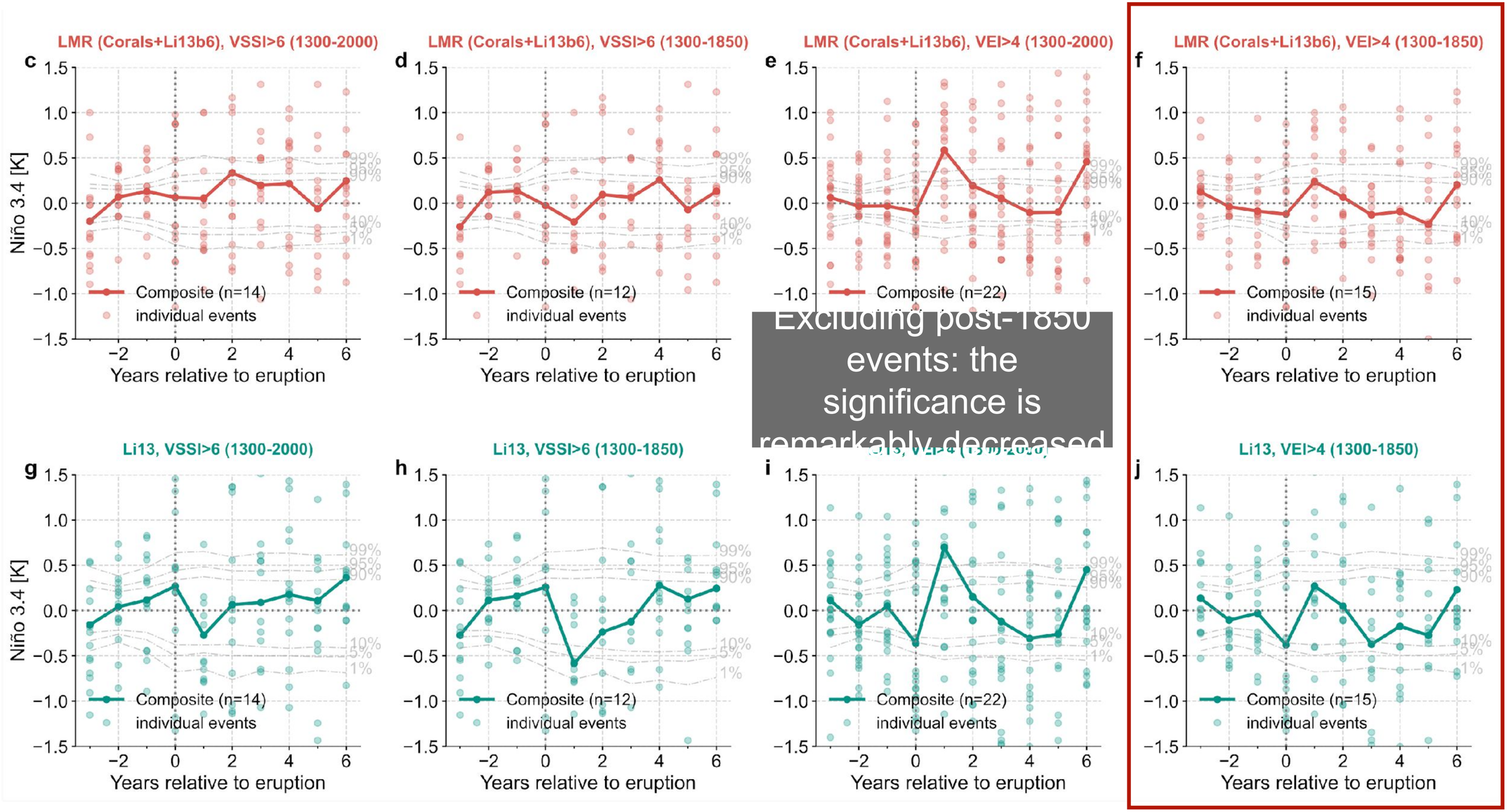


Superposed Epoch Analysis (SEA)



Event selection based on VEI: consistent significant El Niño response to large eruptions

Superposed Epoch Analysis (SEA)



Coincidence ?

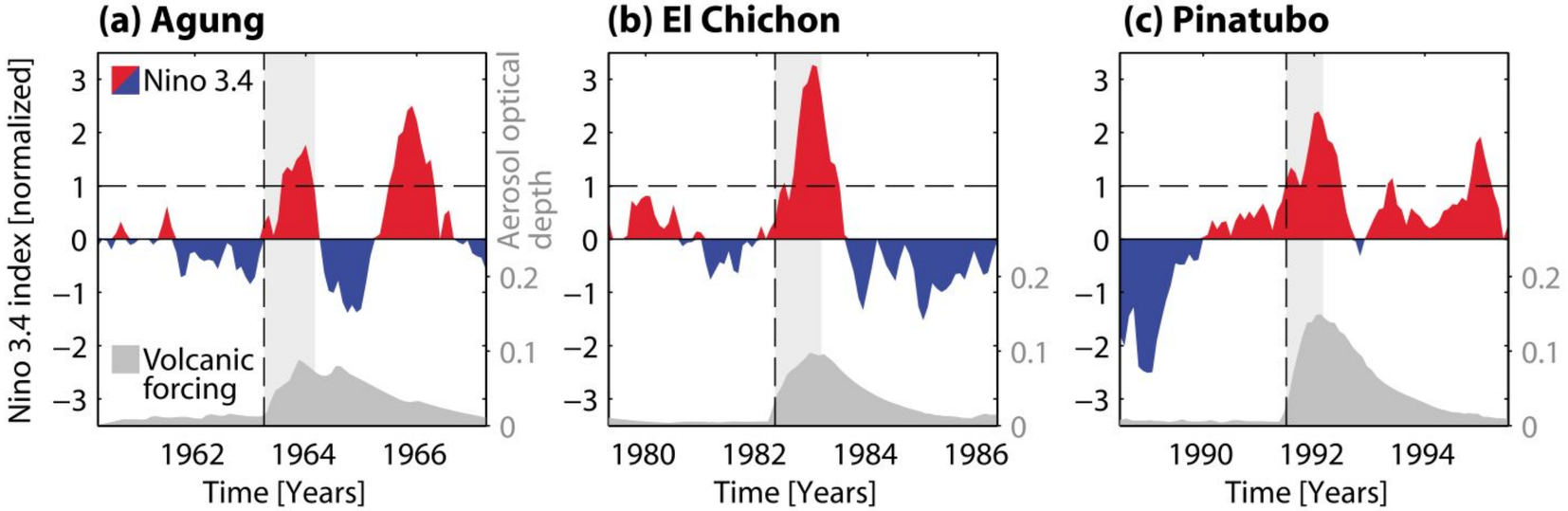
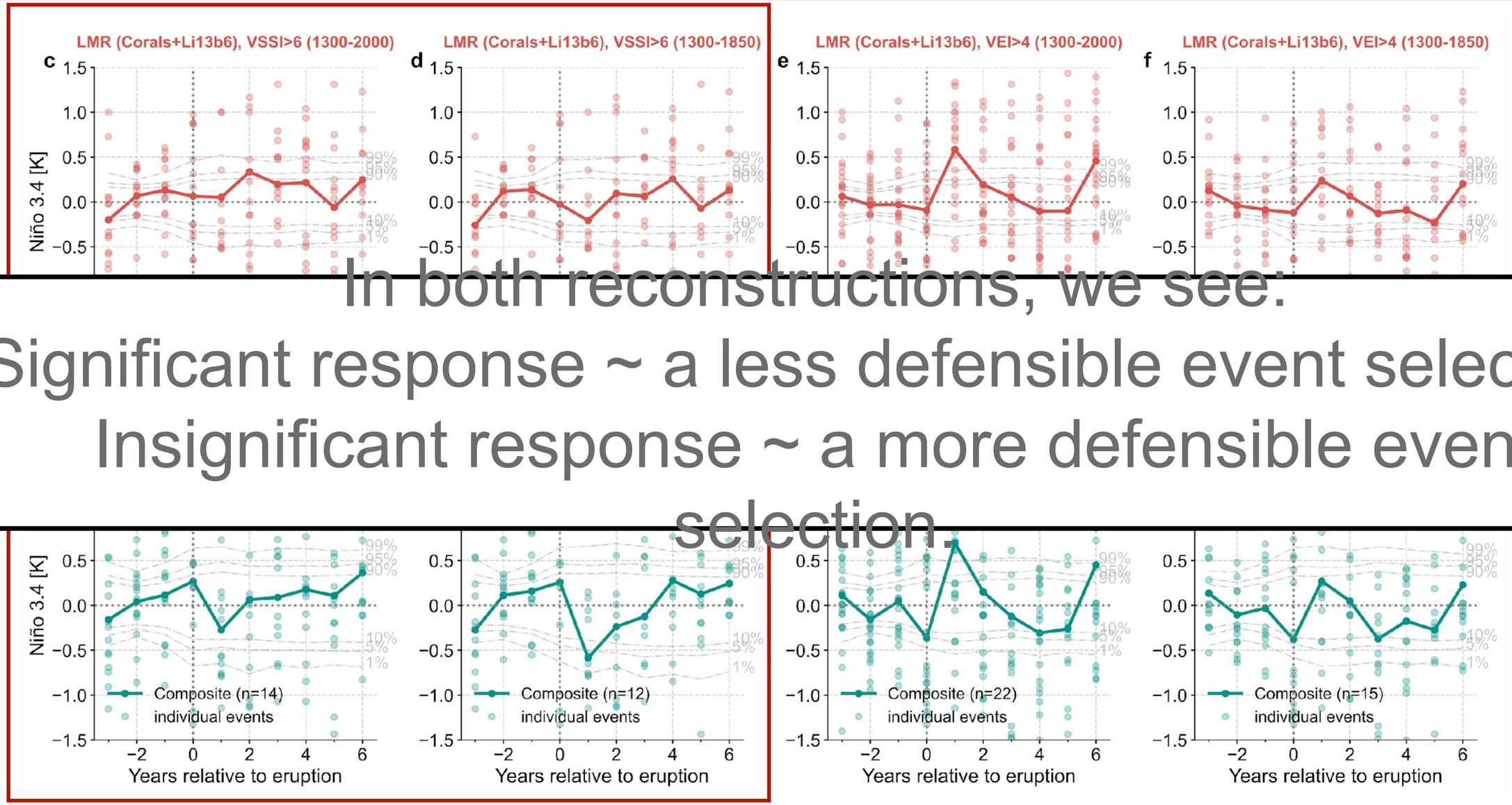


Figure 1. Coincidence of volcanic eruptions with El Niño events. Observed Nino3.4 sea surface temperature anomaly index (http://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino34.long.anom.data; units of standard deviations) and aerosol optical depth [*Sato et al.*, 1993] during the eruptions of (a) Agung, (b) El Chichon, and (c) Pinatubo. Light gray shading indicates the interval between the eruption start date and February of the following year. Horizontal dashed line indicates the El Niño selection criterion (1 standard deviation of the Nino3.4 index).

[Lehner et al. 2016]

Superposed Epoch Analysis (SEA)

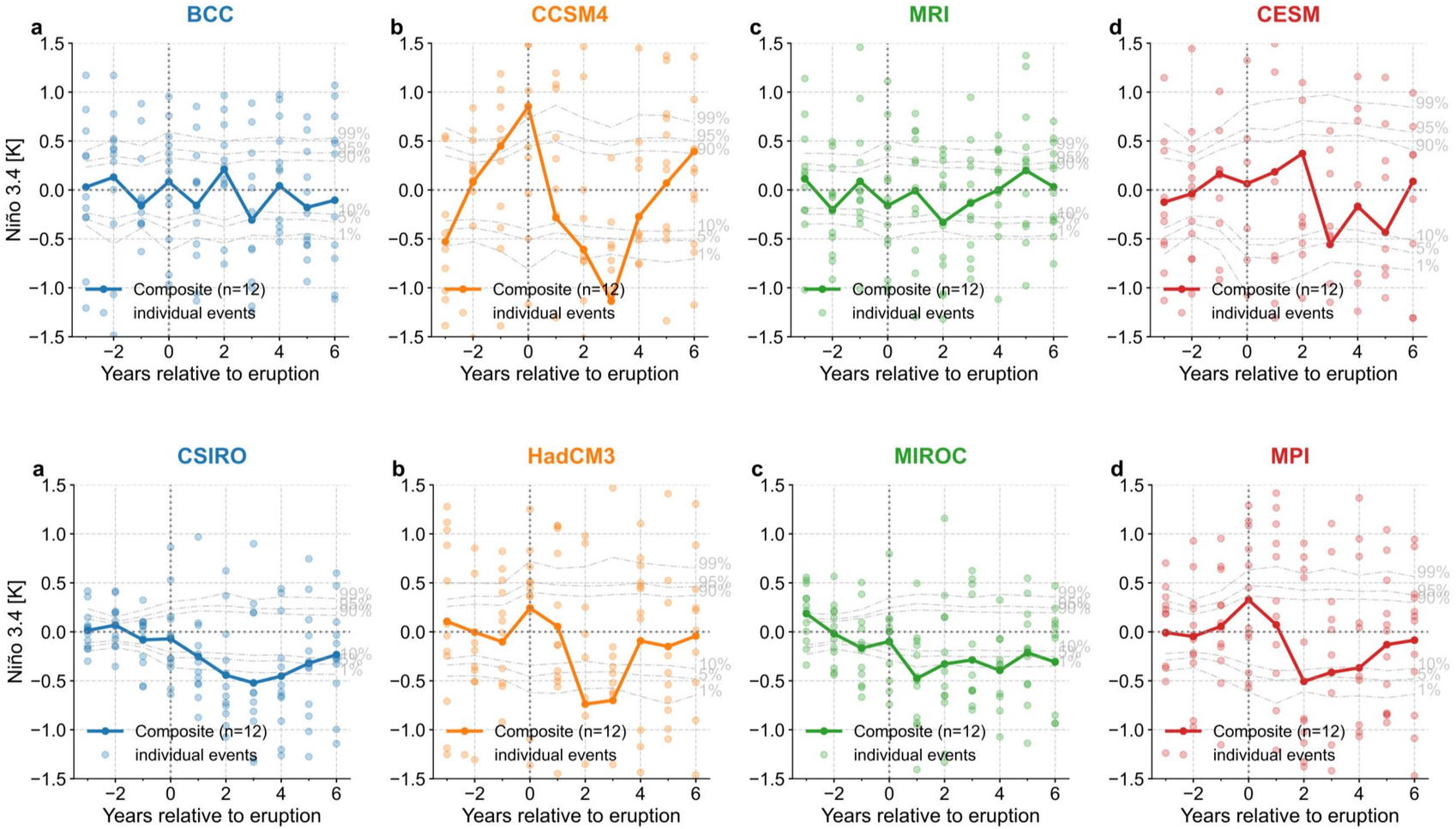


In both reconstructions, we see:

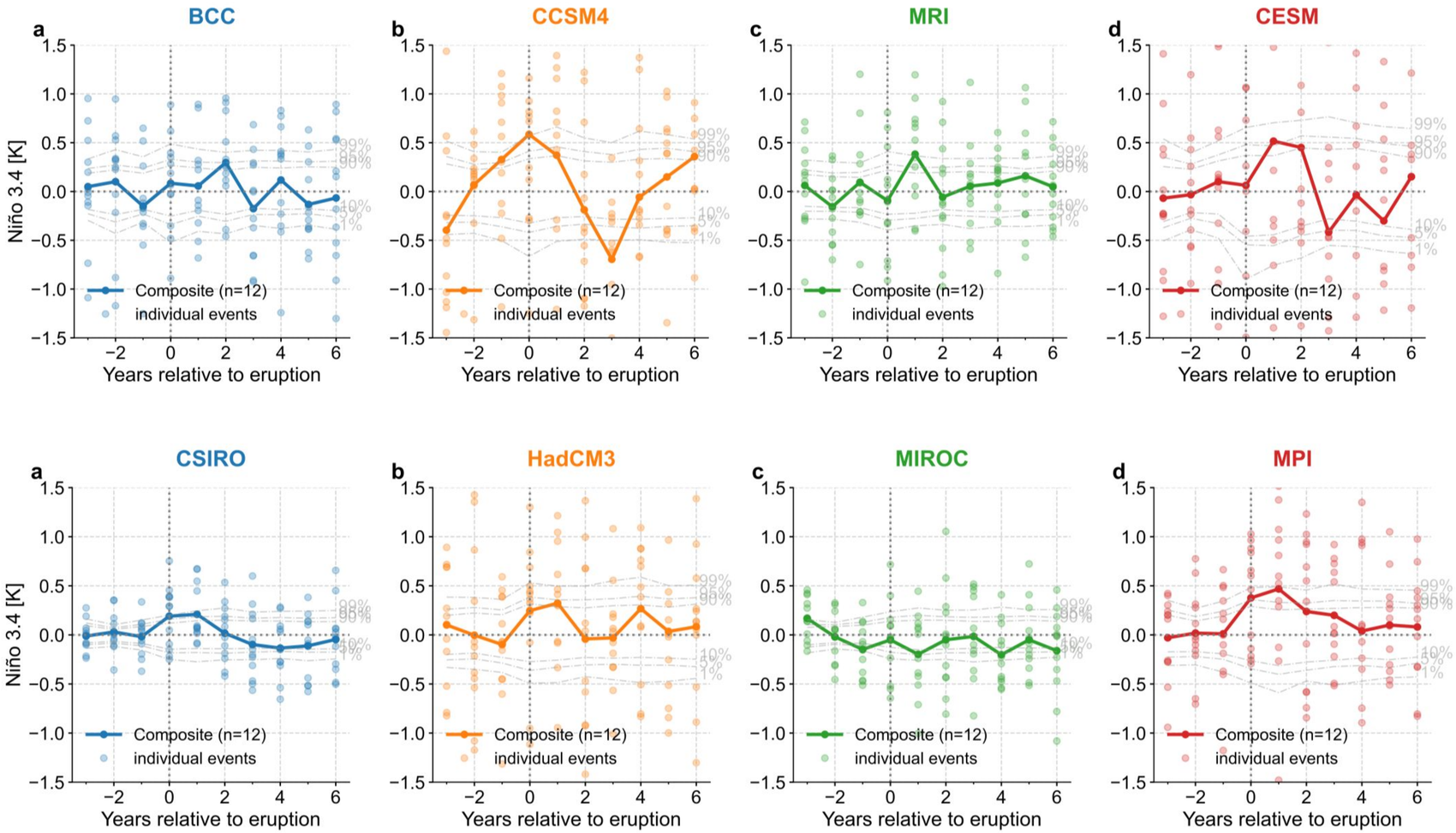
Significant response ~ a less defensible event selection;

Insignificant response ~ a more defensible event selection.

Climate model simulations – SST



Climate model simulations – Relative SST (RSST)



RSST highlights the impact of volcanism on ENSO relative to the tropical mean cooling (Khodri, et al., 2017).

Conclusions & Discussion

- **Paleoclimate data assimilation** enables the **comparison and optimized fusion of different proxy records** within a consistent dynamical framework.
- We see **no real contradiction between trees and corals**, and **the event selection** is more consequential. We **still lack convincing observational evidence** of the significant ENSO response.
- Absence of evidence is not evidence of absence. **Recent modeling studies (e.g., Predybaylo et al., 2017; 2020) suggest that multiple factors can affect the ENSO response to volcanism**: location, intensity, season, preconditioning of the ENSO state.
- **We need longer proxy records; last millennium is not enough**: given **the large number of DoF**, a correspondingly **large sample size** is needed to isolate a consistent signal.
- **We need more proxy sites to enable the RSST based analysis** on the reconstructions.

Feng Zhu, Julien Emile-Geay, Kevin J. Anchukaitis, Gregory J. Hakim, Andrew Wittenberg, Mariano Morales, Matthew Toohey, and Johnathan M. King, 2022: A re-appraisal of the ENSO response to volcanism with paleoclimate data assimilation. ***Nature Communications***. doi:10.1038/s41467-022-28210-1.

Thank you!

fengzhu@ucar.edu