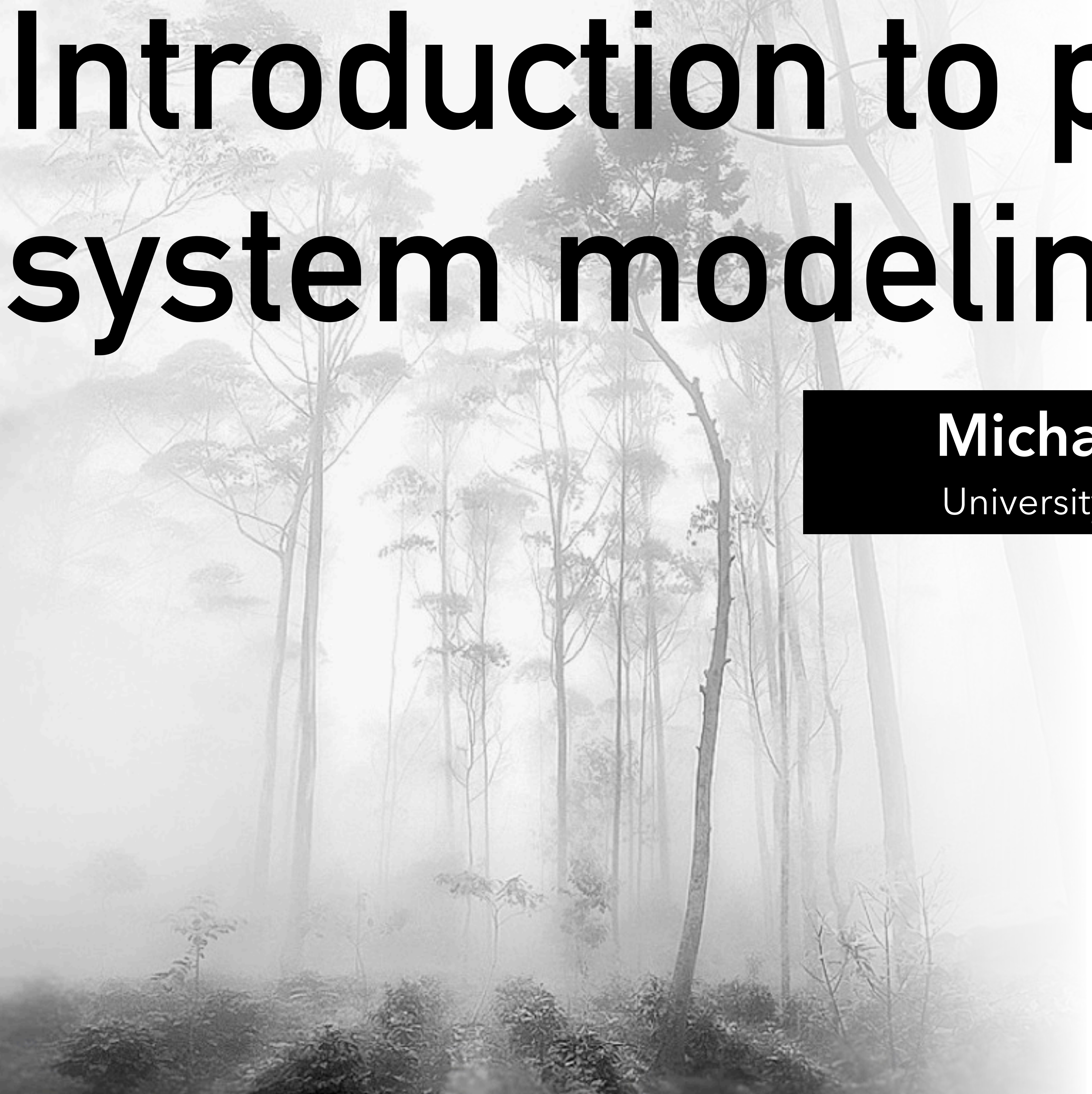
Introduction to proxy system modeling



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Invited review

Applications of proxy system modeling in high resolution paleoclimatology☆

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A R T I C L E I N F O

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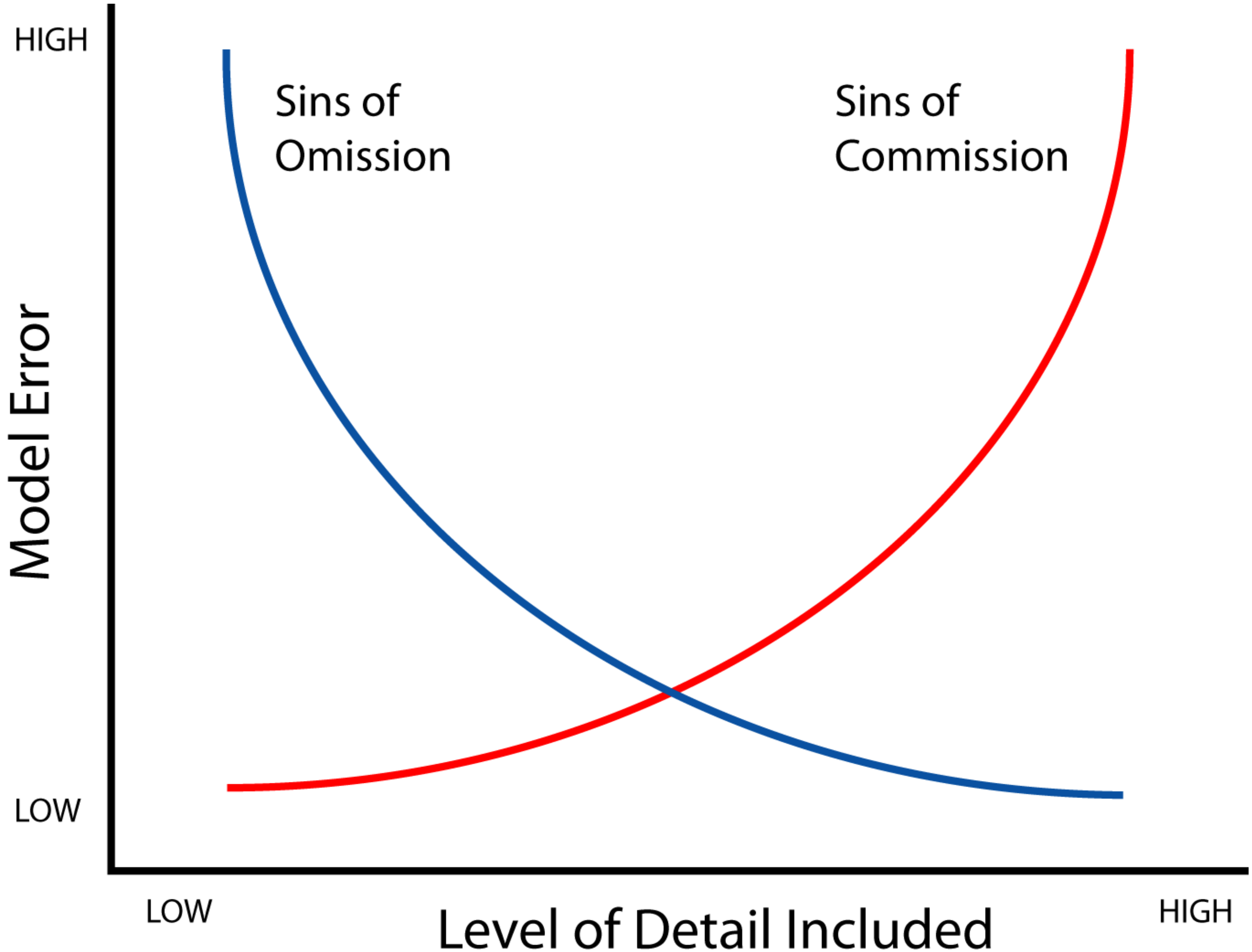
A B S T R A C T

A proxy system model may be defined as the complete set of forward and mechanistic processes by which the response of a sensor to environmental forcing is recorded and subsequently observed in a material archive. Proxy system modeling complements and sharpens signal interpretations based solely on statistical analyses and transformations; provides the basis for observing network optimization, hypothesis testing, and data-model comparisons for uncertainty estimation; and may be incorporated as weak but mechanistically-plausible constraints into paleoclimatic reconstruction algorithms. Following a review illustrating these applications, we recommend future research pathways, including development of intermediate proxy system models for important sensors, archives, and observations; linking proxy system models to climate system models; hypothesis development and evaluation; more realistic multi-archive, multi-observation network design; examination of proxy system behavior under extreme conditions; and generalized modeling of the total uncertainty in paleoclimate reconstructions derived from paleo-observations.

‘The best material model of a cat is another, or preferably the same, cat.’

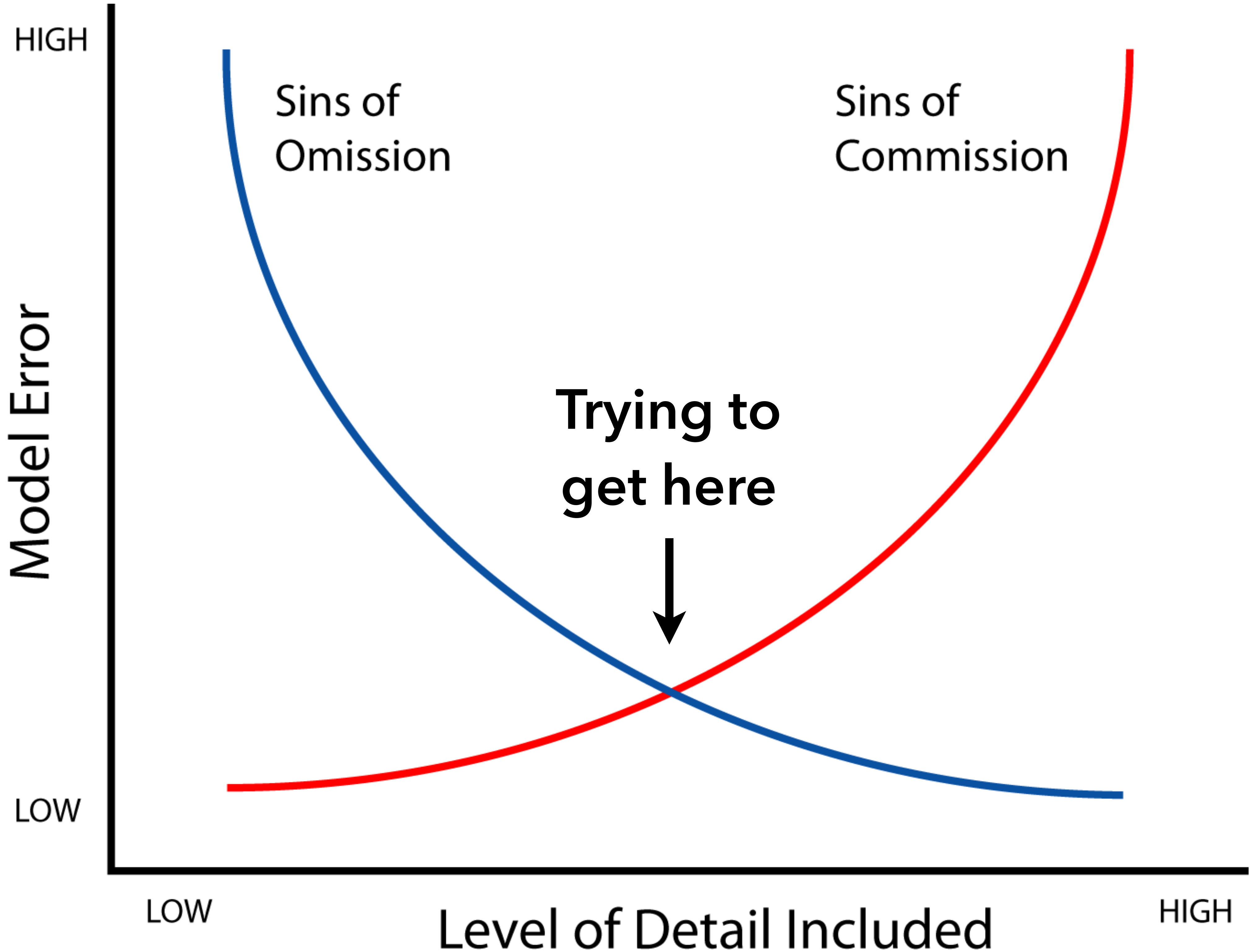
Arturo Rosenblueth and Norbert Wiener

Under- vs. Over-specified Models



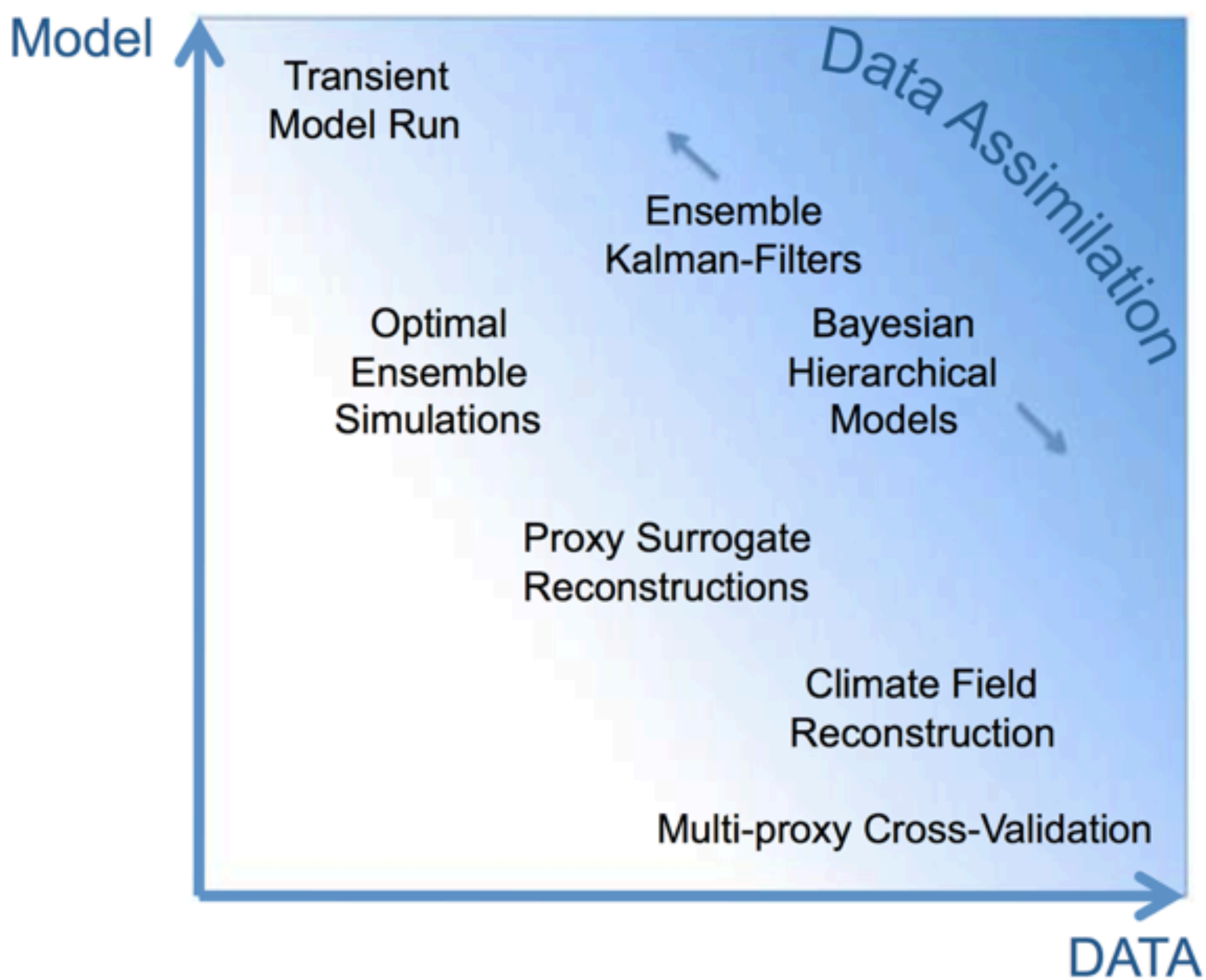
after Dean Urban, Duke University

Under- vs. Over-specified Models

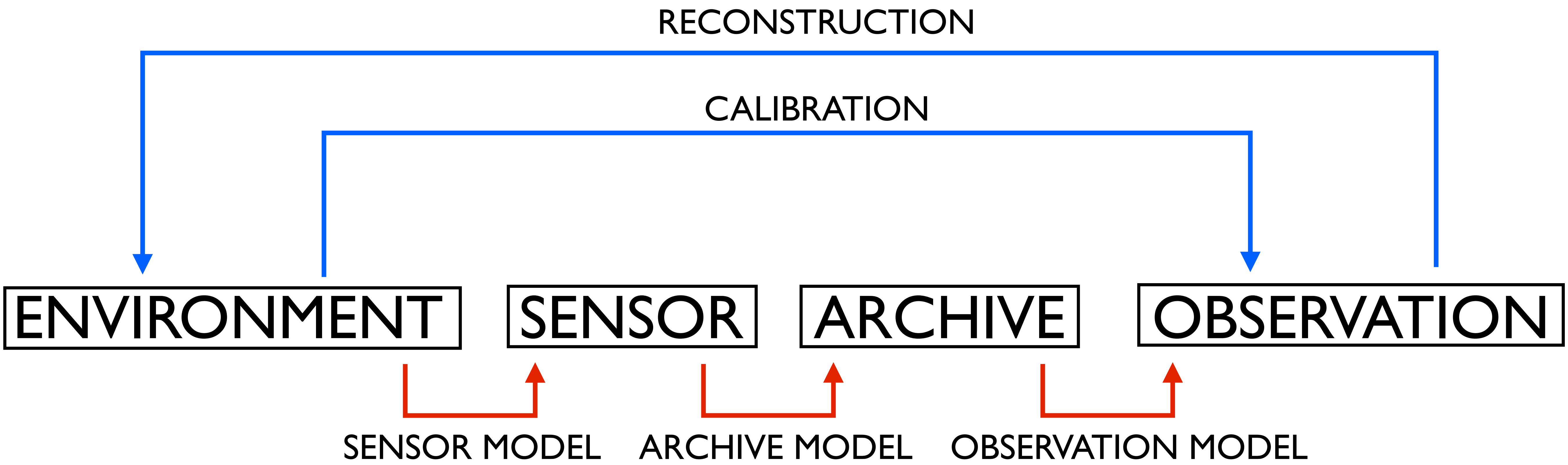


after Dean Urban, Duke University

‘A good forward model requires not only a good understanding of the key **processes** that are responsible for generating the signal (proxy climate record) in the archive, but it also needs appropriate sources of estimates for the **parameters** and a reasonable understanding of various levels of **uncertainties** related to the raw proxy data.’

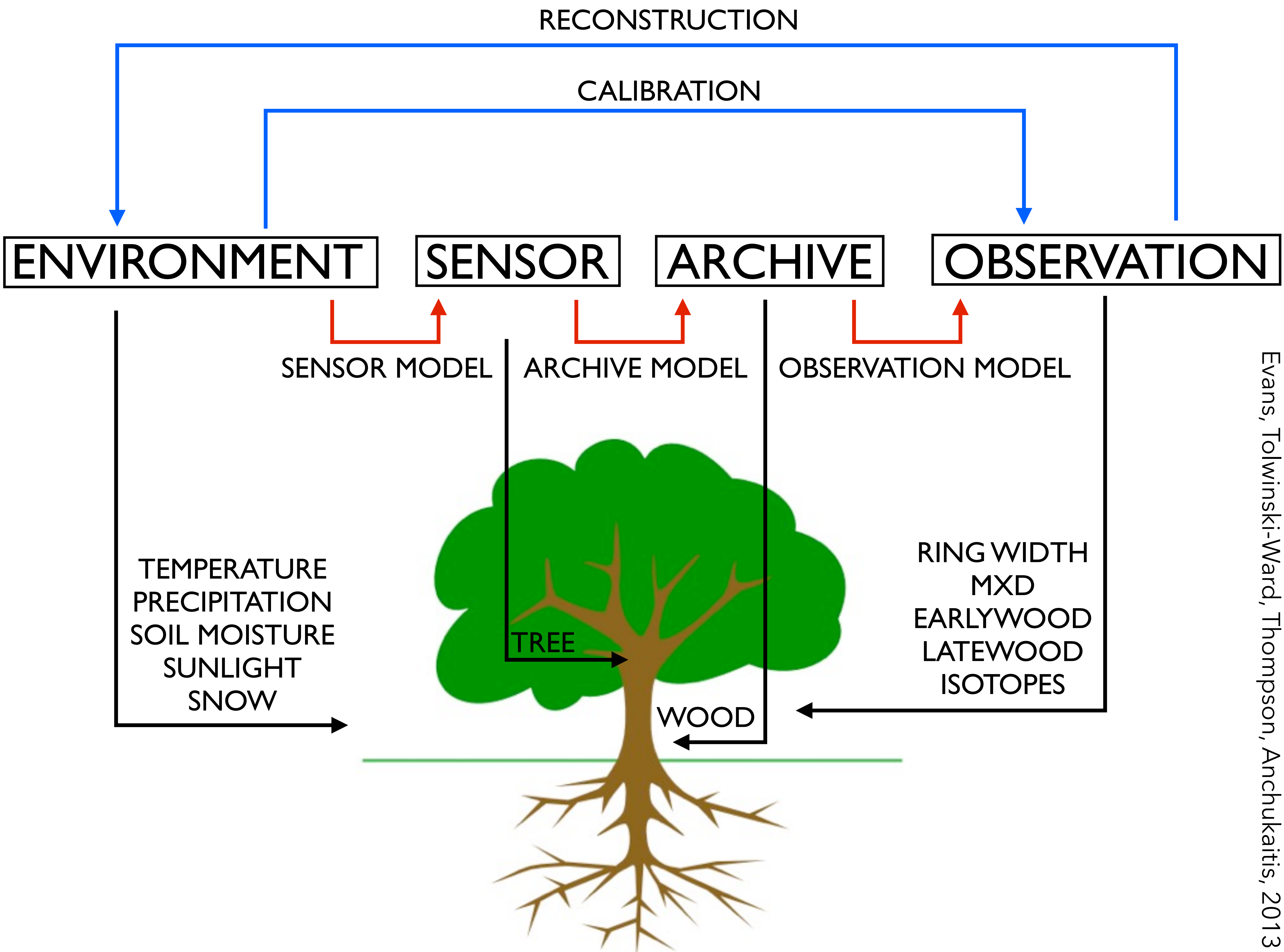


Hughes and Ammann 2009



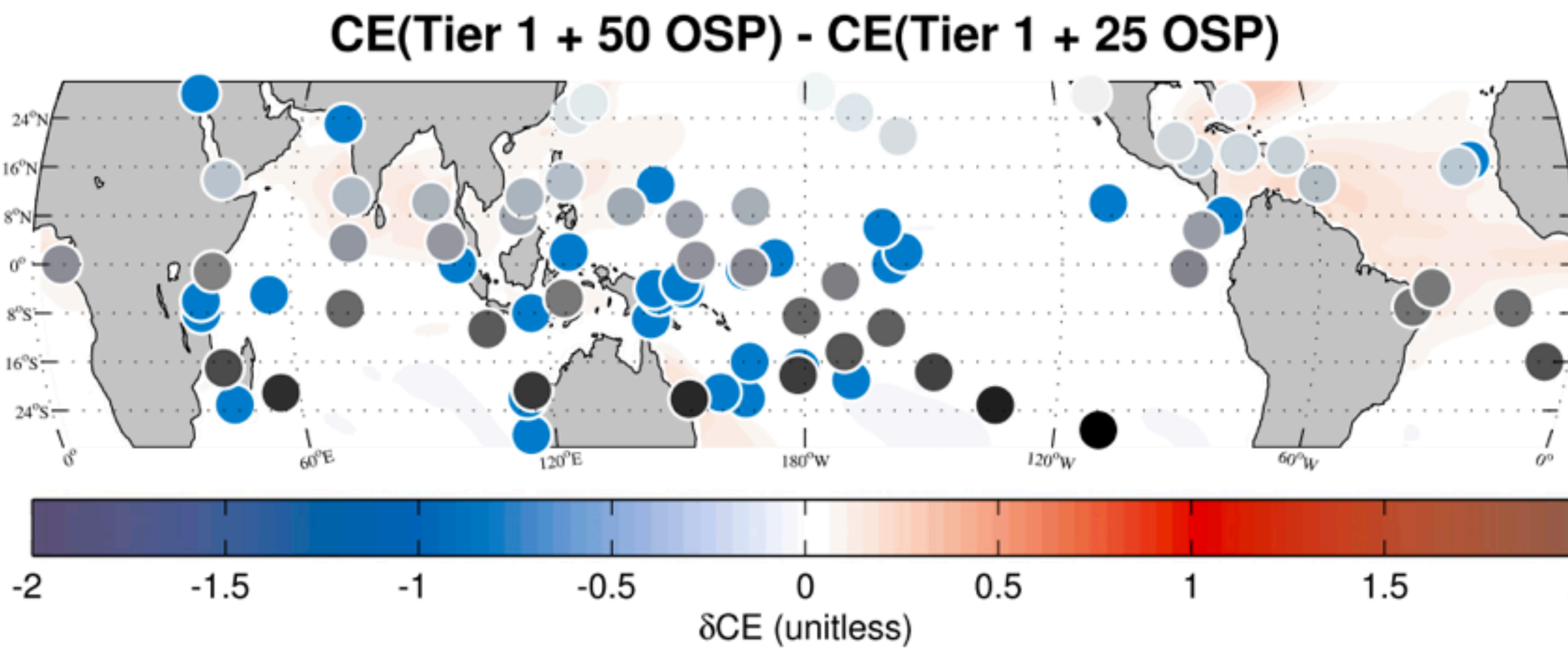
based on SUPRAnet (UK) Working Group

Evans, Tolwinski-Ward, Thompson, Anchukaitis, 2013


RECONSTRUCTION
CALIBRATION
ENVIRONMENT
SENSOR
ARCHIVE
OBSERVATION
SENSOR MODEL
ARCHIVE MODEL
OBSERVATION MODEL
TEMPERATURE
PRECIPITATION
SOIL MOISTURE
SUNLIGHT
SNOW
TREE
WOOD
RING WIDTH
MXD
EARLYWOOD
LATEWOOD
ISOTOPES
Evans, Tolwinski-Ward, Thompson, Anchukaitis, 2013

Application: Observational network design

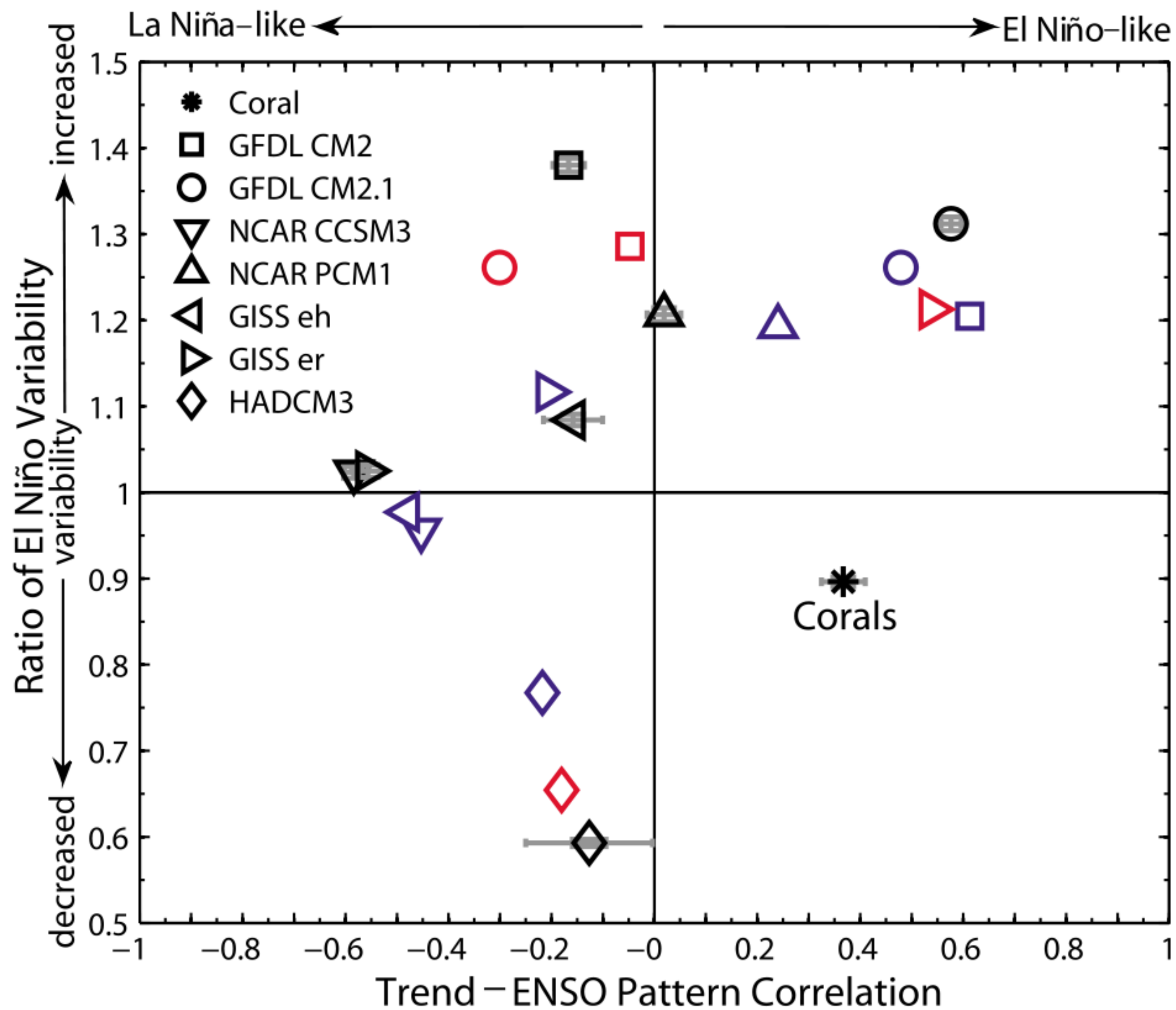
$$\delta^{18}O_{coral} = f(T, S)$$



Comboul et al (2015), using Thompson et al (2011); Other examples: Bradley (1996), Evans et al (1998), Evans (2007)

Application: model/data comparison

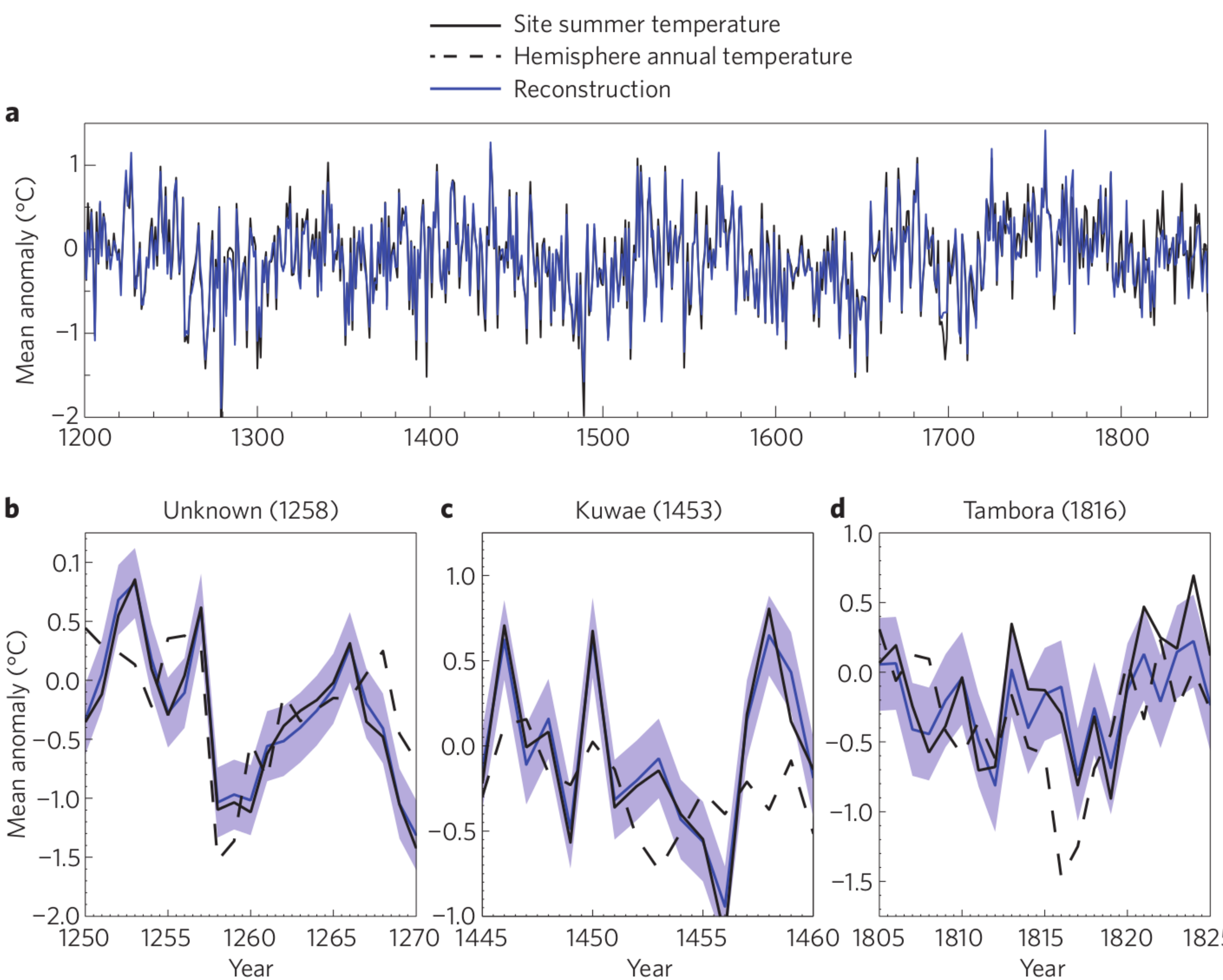
$$\delta^{18}O_{coral} = f(T, S)$$



Thompson et al, 2011, 2012, 2013 after Brown et al (2008) and Meehl et al (2007)

Application: model/data comparison

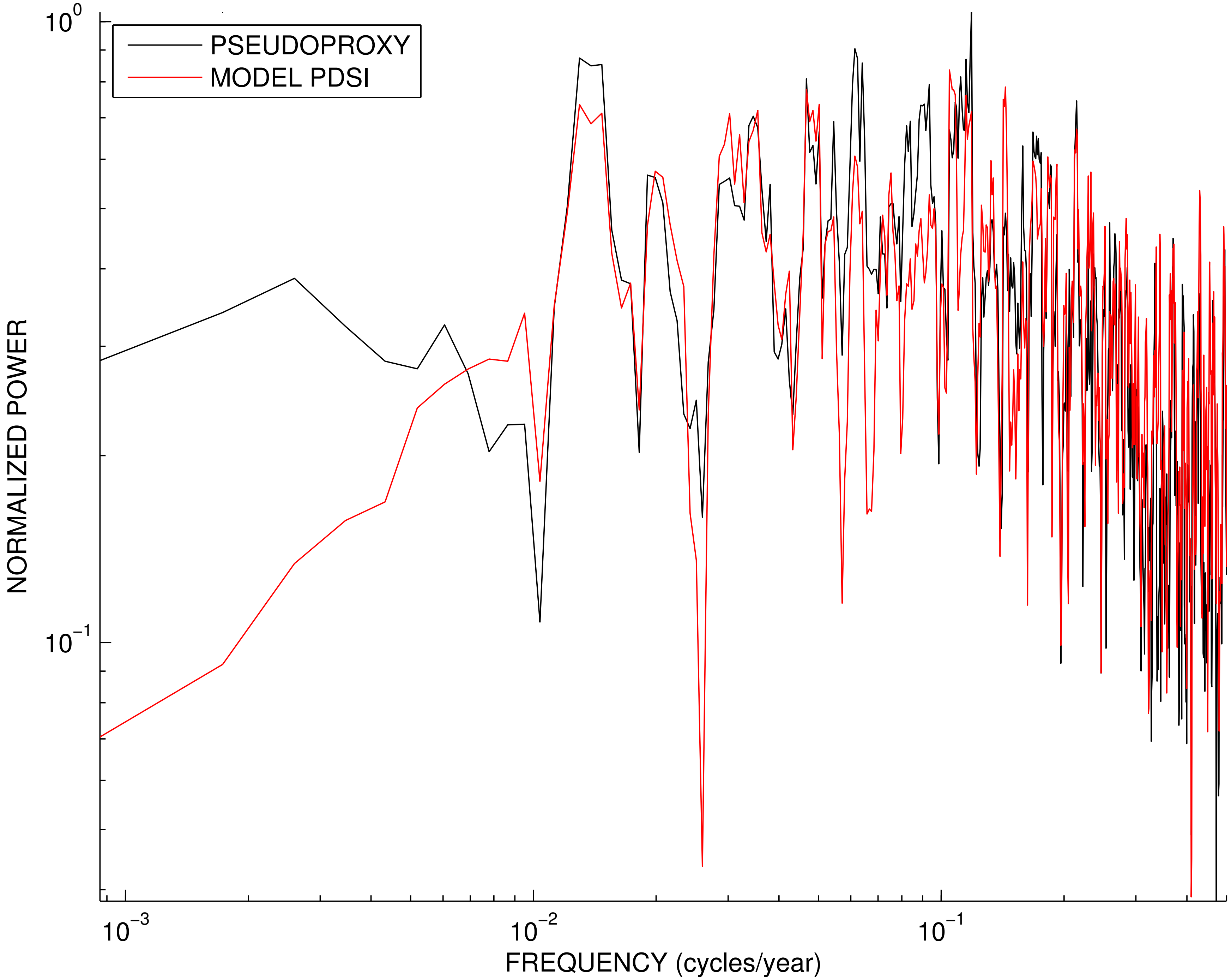
$$TRW = f(T, P, \phi)$$



Anchukaitis et al. 2012

Application: model/data comparison

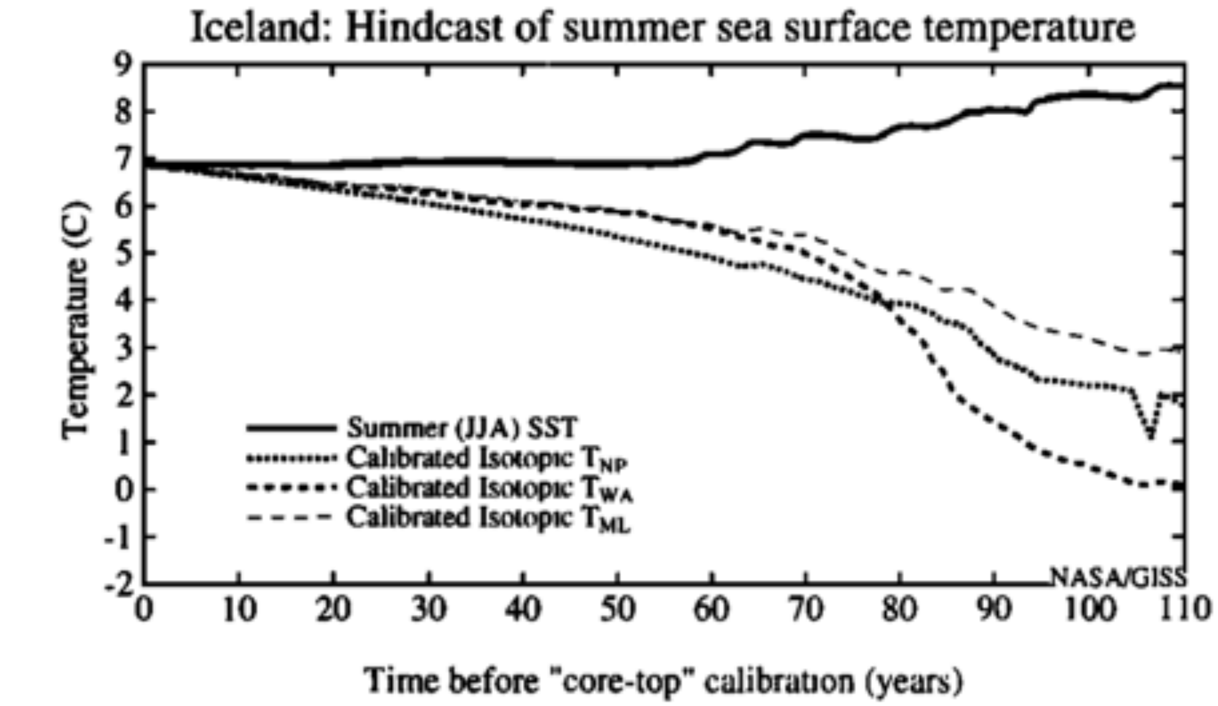
$$TRW = f(T, P, \phi)$$

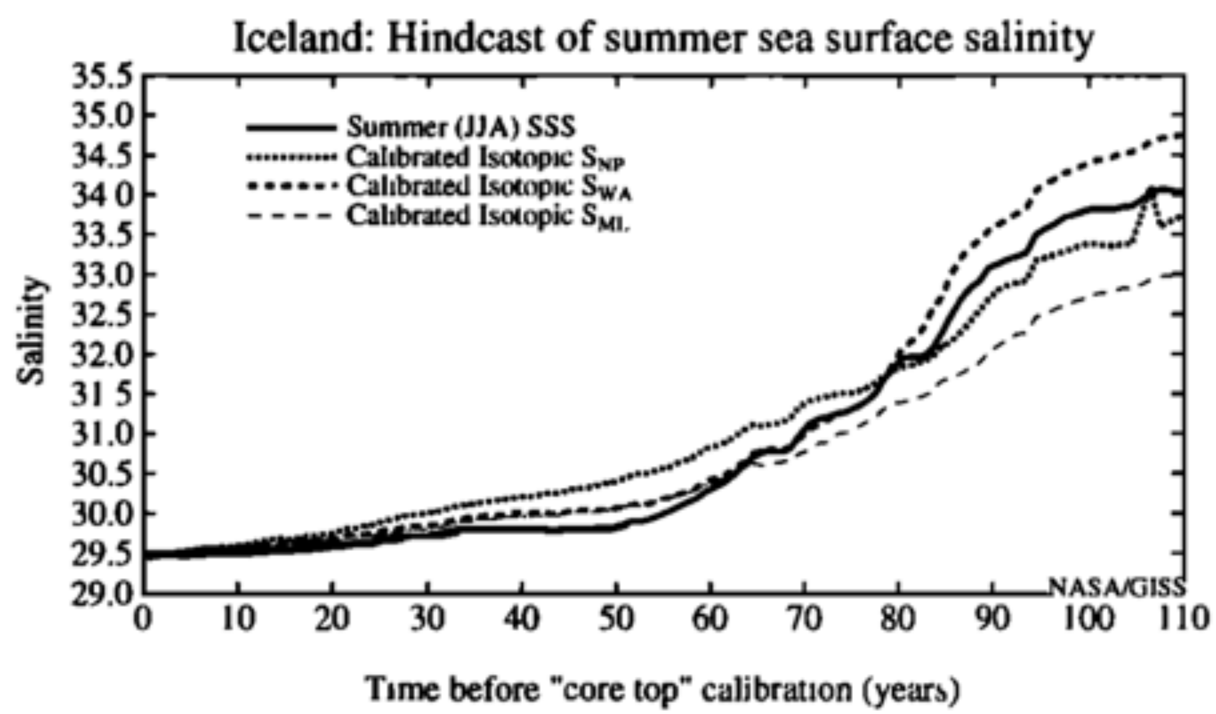


Anchukaitis et al. in preparation

Application: paleoclimate inference & interpretation

$$\delta^{18}O_{foraminifera} = f(T, S, \delta^{18}O_{sw})$$

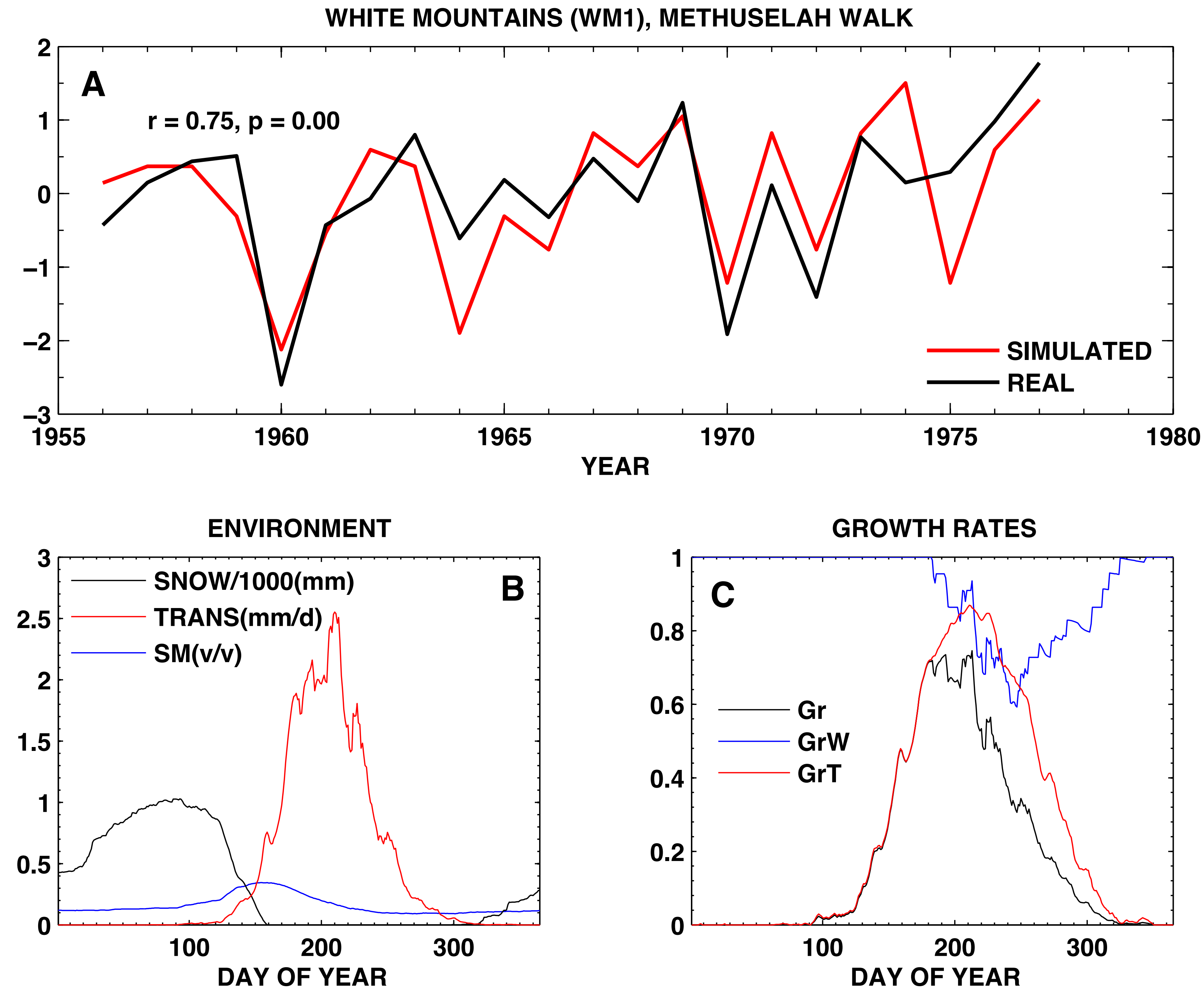




Schmidt 1999

Application: paleoclimate inference & interpretation

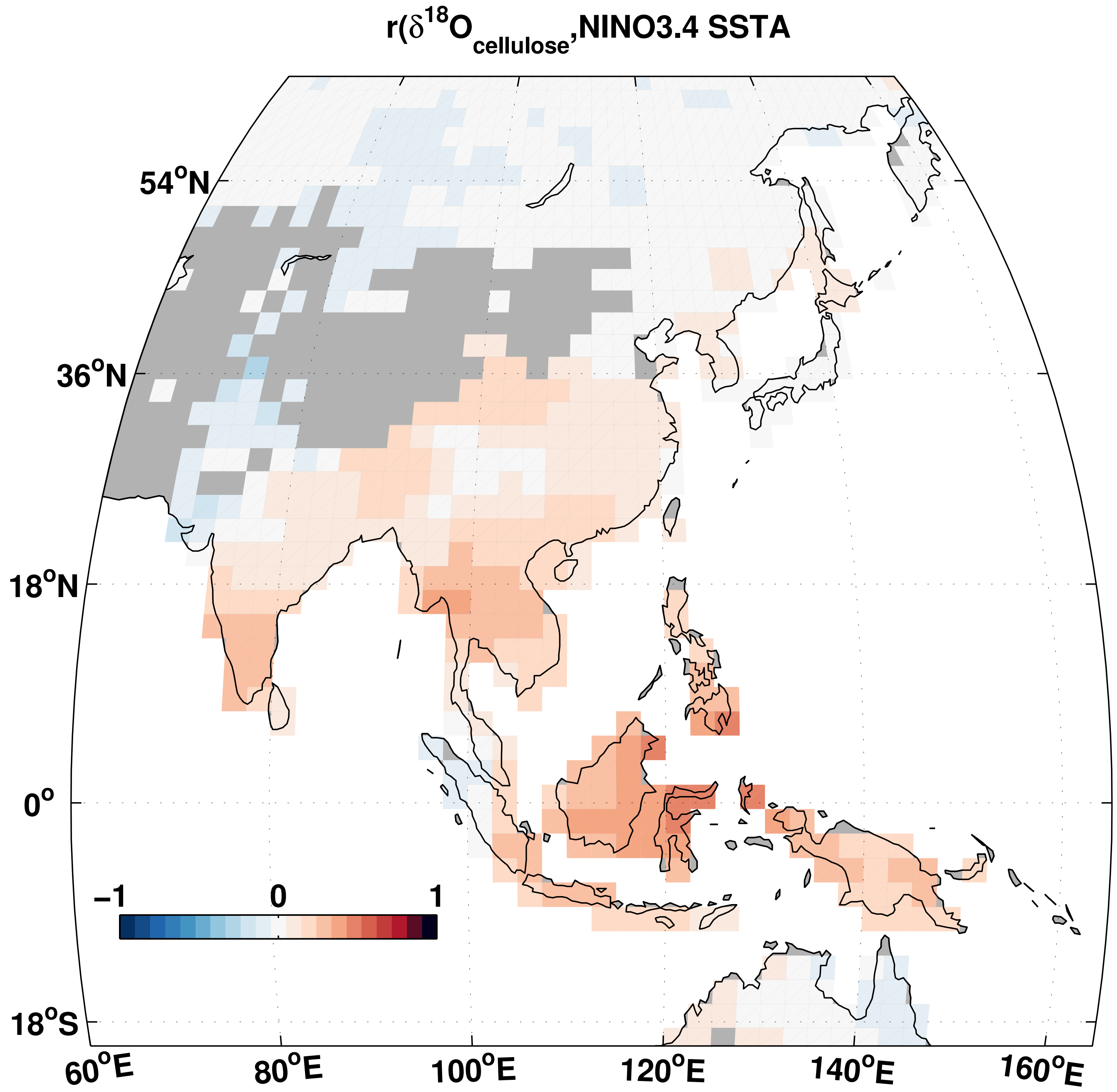
$$TRW = f(T, P, \phi)$$



Anchukaitis, Evans, Hughes

Application: paleoclimate inference & interpretation

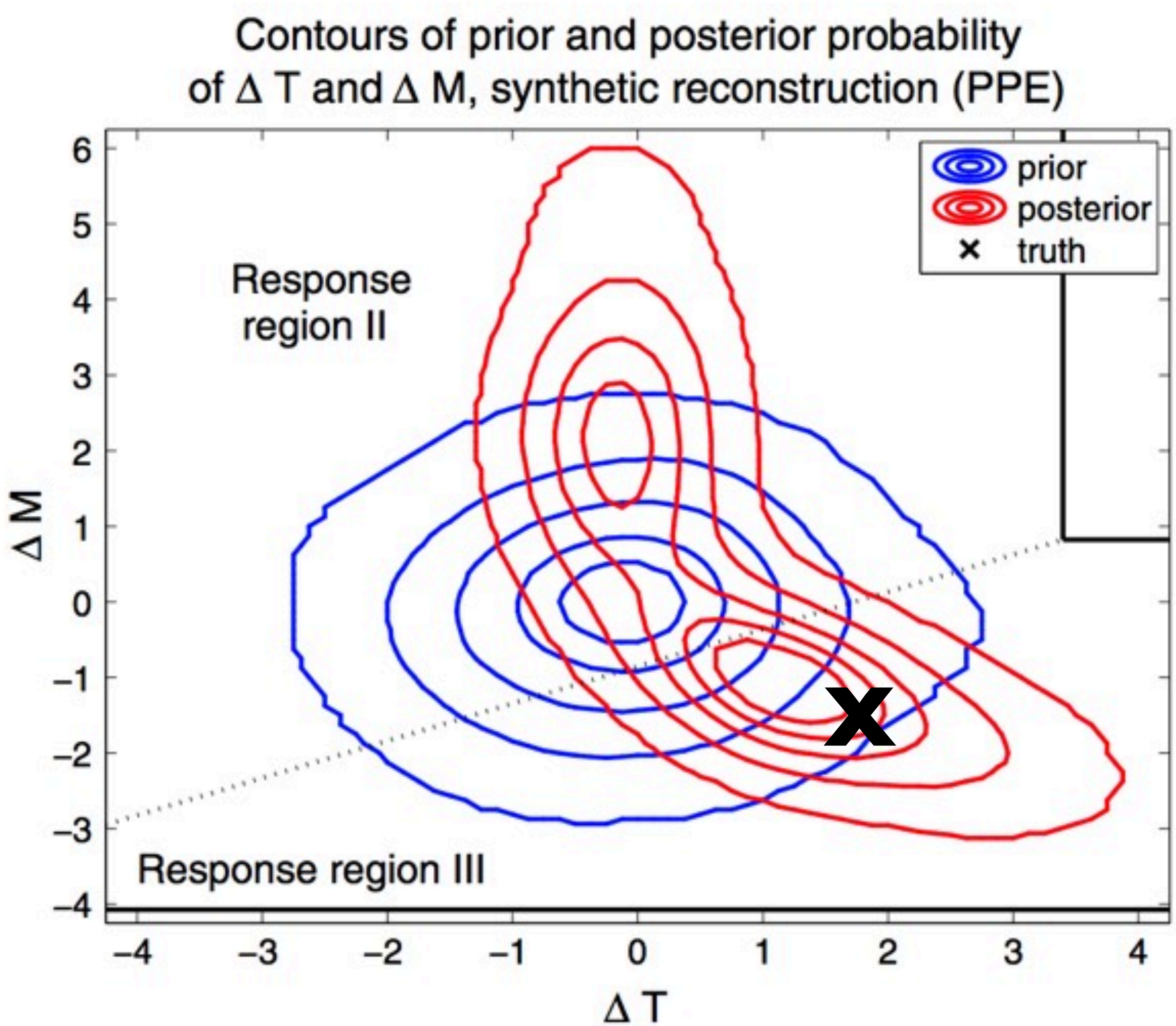
$$\delta^{18}O_{cellulose} = f(T, \delta^{18}O_{rain}, \delta^{18}O_{vapor}, \%RH)$$



Anchukaitis and LeGrande

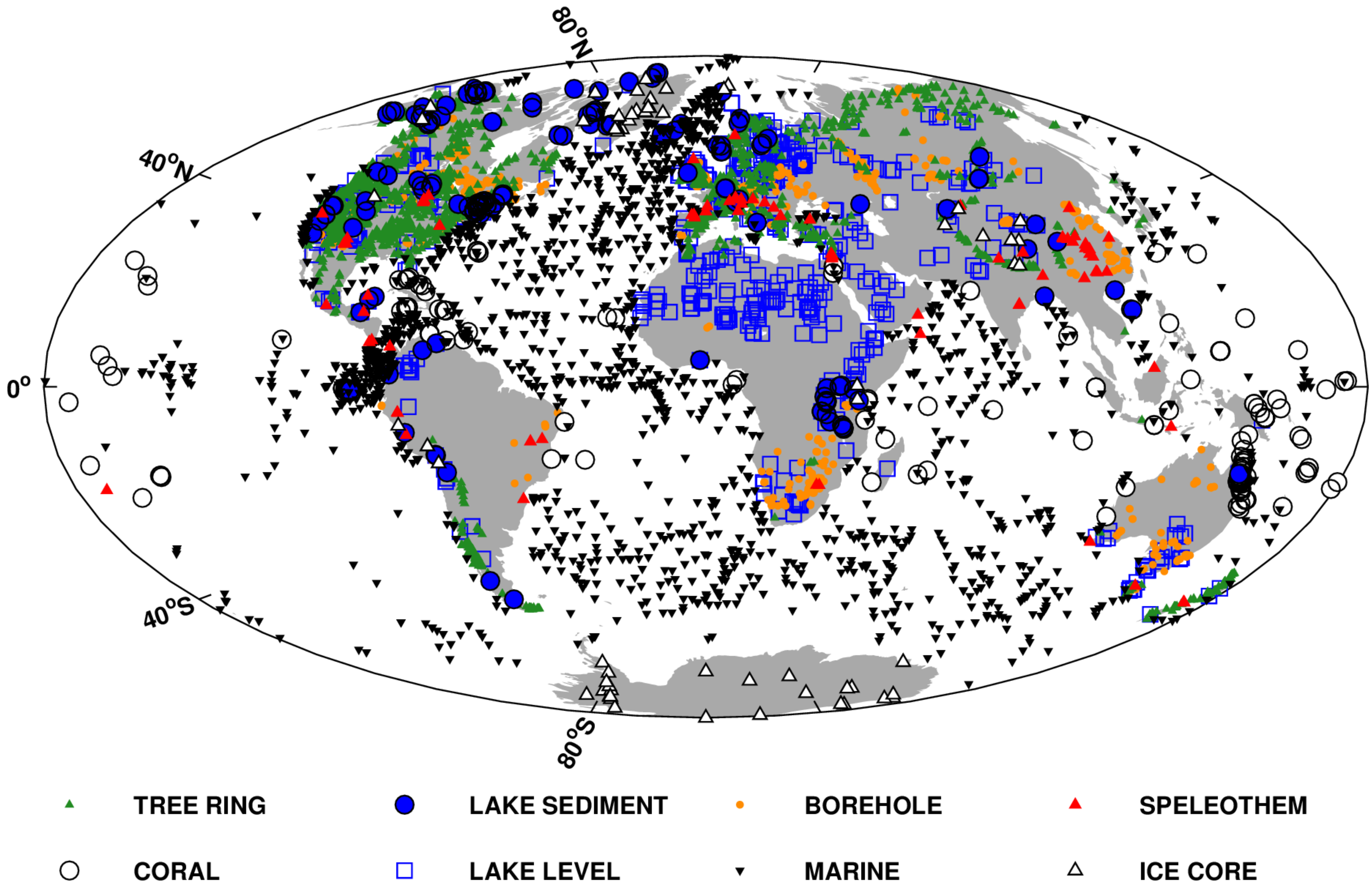
Application: paleoclimate reconstruction constraint

$$TRW = f(T, P, \phi)$$



Tolwinski-Ward et al. 2014

Future work: more proxy systems models!



Proxy systems may be multivariate, nonlinear, spectral climate filters.

Use of "intermediate-class" proxy system models permits:

Paleo-observational network design/hypothesis testing.

Subtle interpretation of the environmental response.

Robust intercomparison of paleodata and climate model output.

Scientifically-defensible weak constraints for paleoreconstructions.

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