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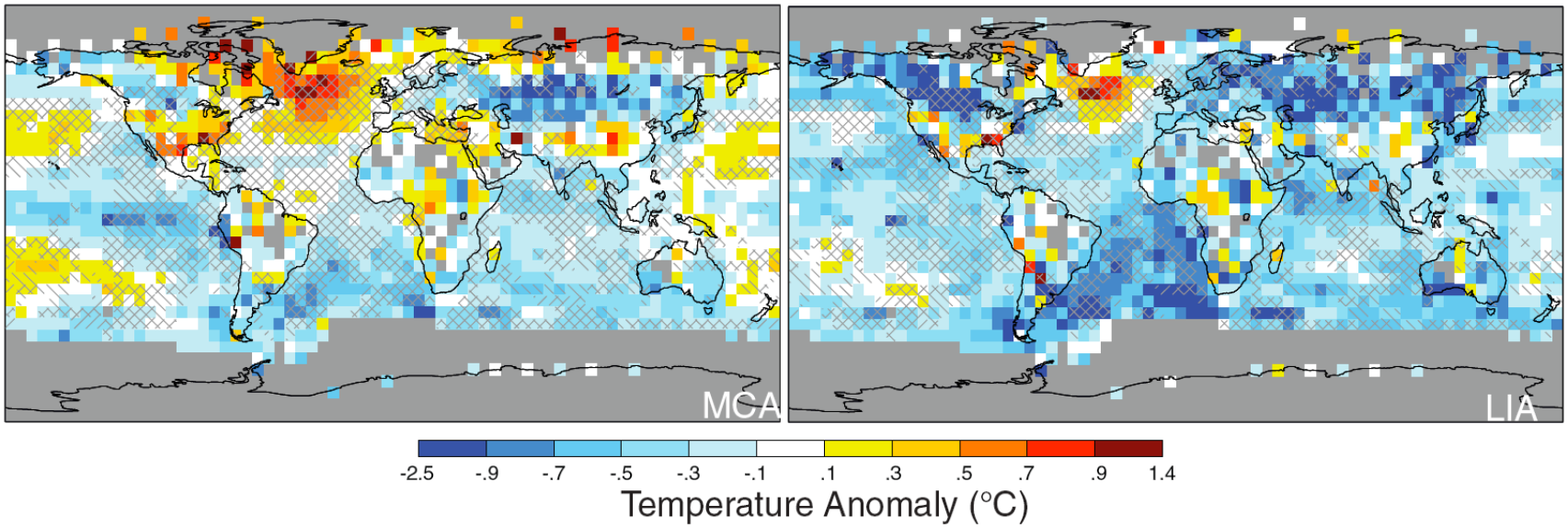
High-Resolution Climate Field Reconstructions for Multidecadal Dynamic Analysis: *Prospects and Challenges*

Jason E. Smerdon

GloDecH Meeting – Wednesday, March 9th, 2011

Lamont-Doherty Earth Observatory of Columbia University

Spatiotemporal Reconstructions, Dynamic Inferences, and Model Validation



Mann et al., Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly, *Science*, 326, 2009.

Secular ENSO Behavior

AMO Variability and Consequences

Volcanism and Monsoons

MCA and LIA Dynamics and Causes

Drought Variability, Forcing and Impacts

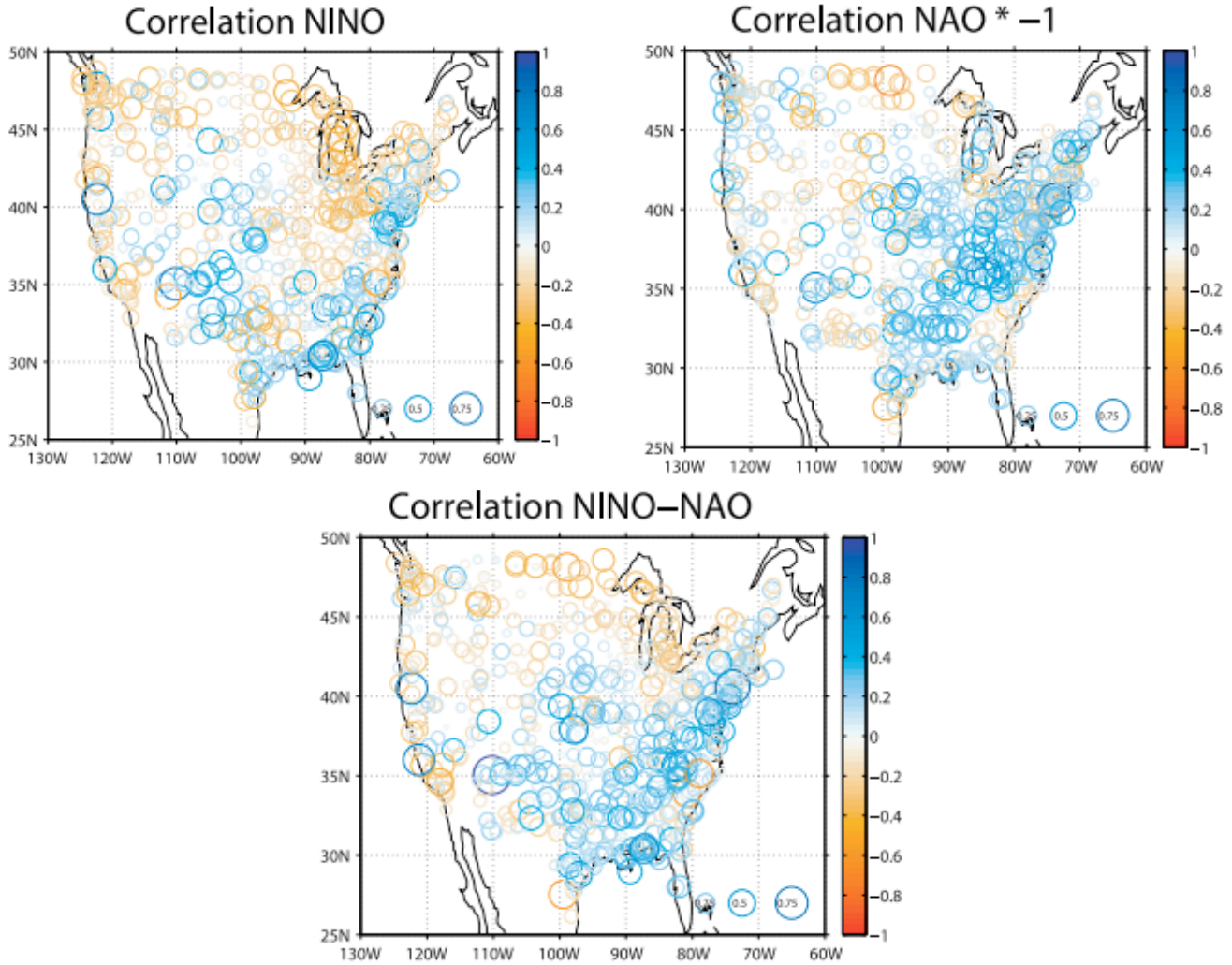
Extremes

Global and Regional Climate Sensitivity

Characterize Decadal/Multidecadal Var.

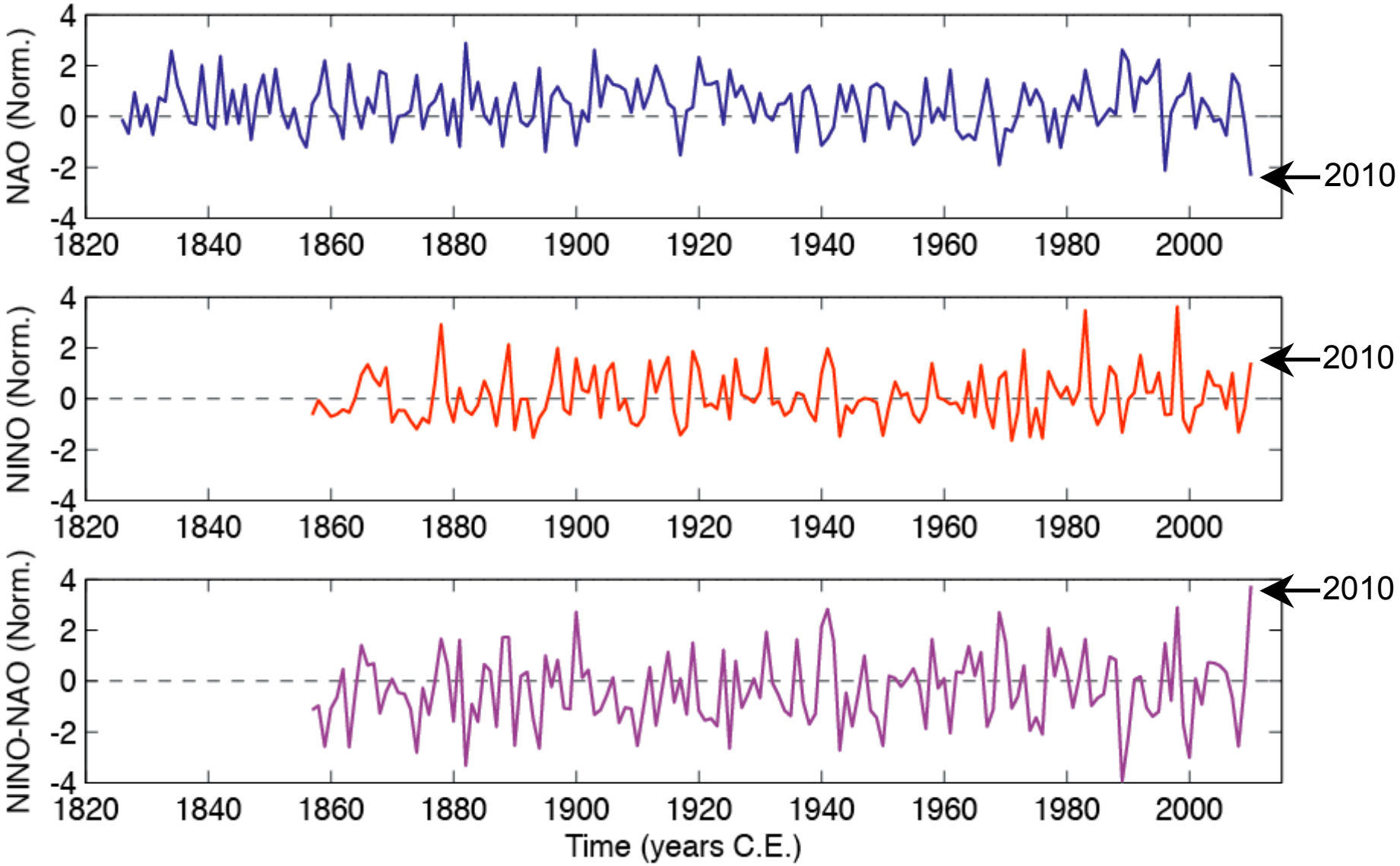
NAO, El Nino and N. Am. Winters

Dec-Mar 1950-99 Snowfall Anomalies (inches/season)

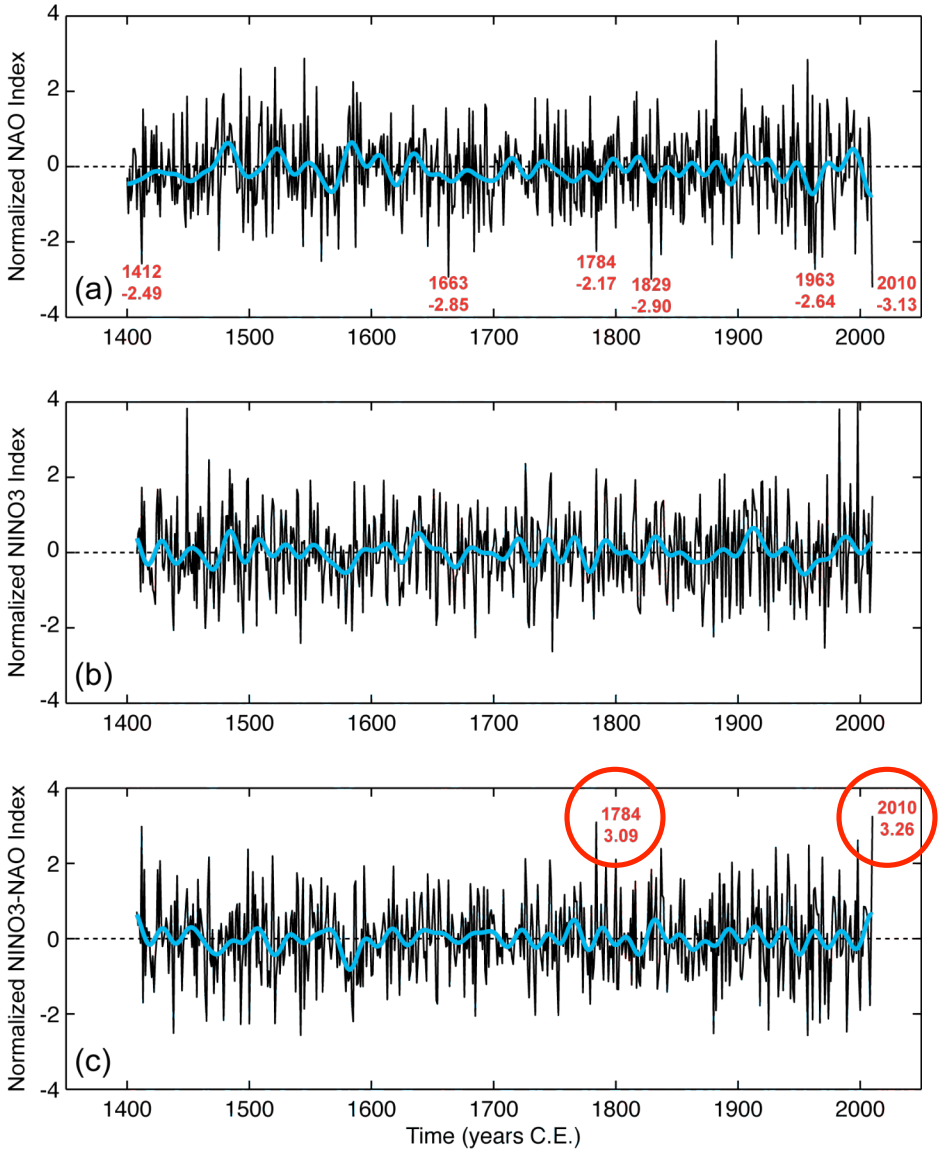


Seager, R., Y. Kushnir, J. Nakamura, M. Ting, and N. Naik (2010), Northern Hemisphere winter snow anomalies: ENSO, NAO and the winter of 2009/10, Geophys. Res. Lett., 37, L14703, doi:10.1029/2010GL043830

Modern NINO3 and NAO Indices



Paleo-Modern NAO and NINO3 Indices



Cook, E. (2000), Niño-3 SST reconstruction, ITRDB, *NOAA Paleoclimatology*, CO.

Cook, E., R. D'Arrigo and M. E. Mann (2002), A well-verified, multi-proxy reconstruction of the winter NAO index since AD 1400, *J. Clim.*15, 1754-1764.

D'Arrigo, R, R. Seager, J.E. Smerdon, A. LeGrande, and E.R. Cook (2011), The anomalous winter of 1783-84: Was the Laki eruption or an analog of the 2009-10 winter to blame?, *Geophys. Res. Lett.*, in press.

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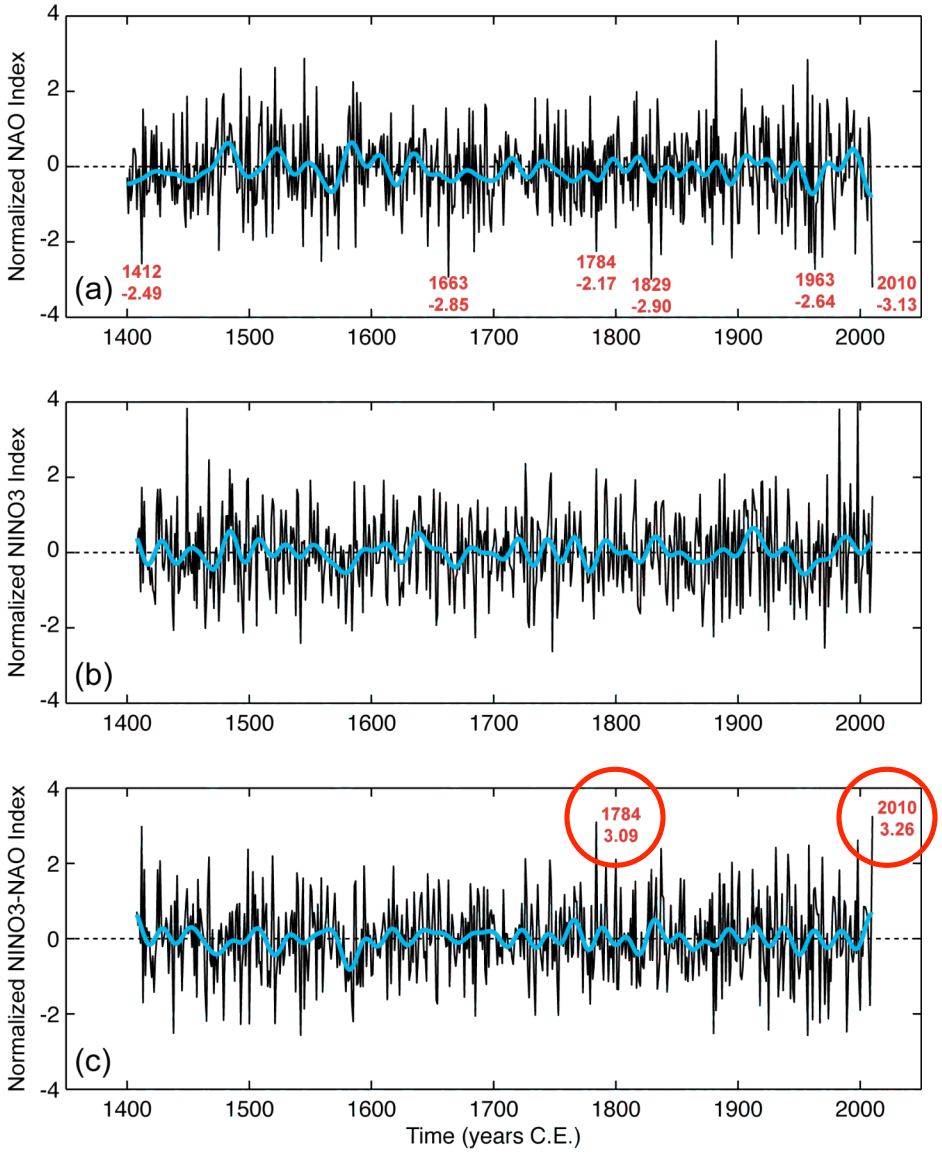
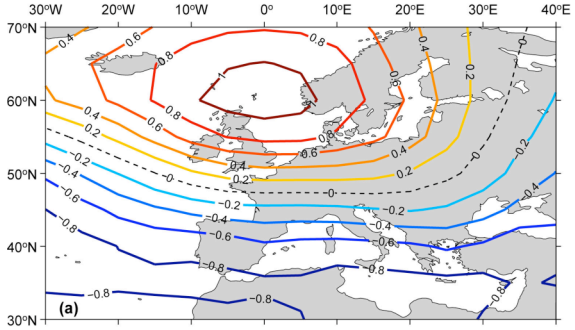
Field Reconstructions for 1783–4 C.E.





SLP DJF 1783–4

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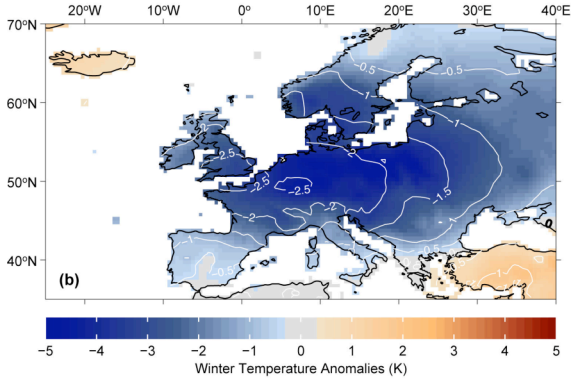

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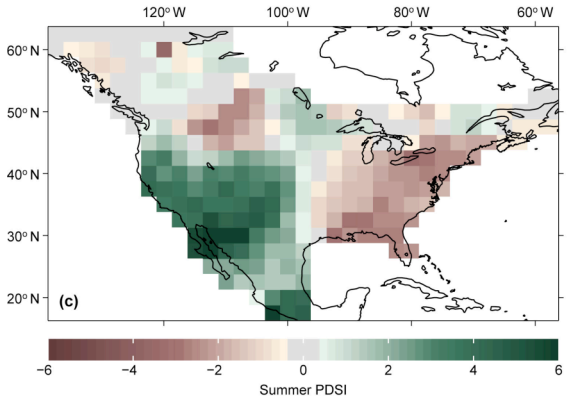

PDSI JJA 1784

Cook, E.R., et al. 2008. North American Summer PDSI Reconstructions, Version 2a. IGBP PAGES/World Data Center for Paleoclimatology

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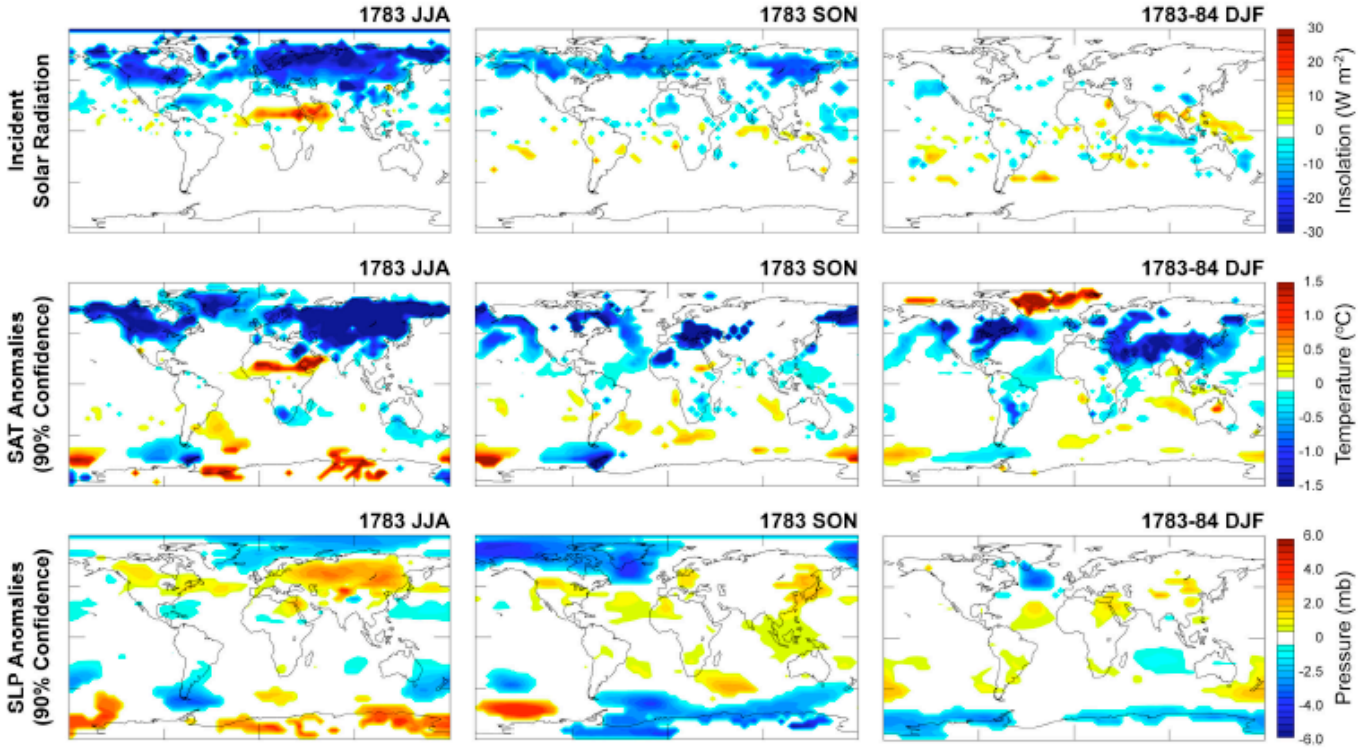
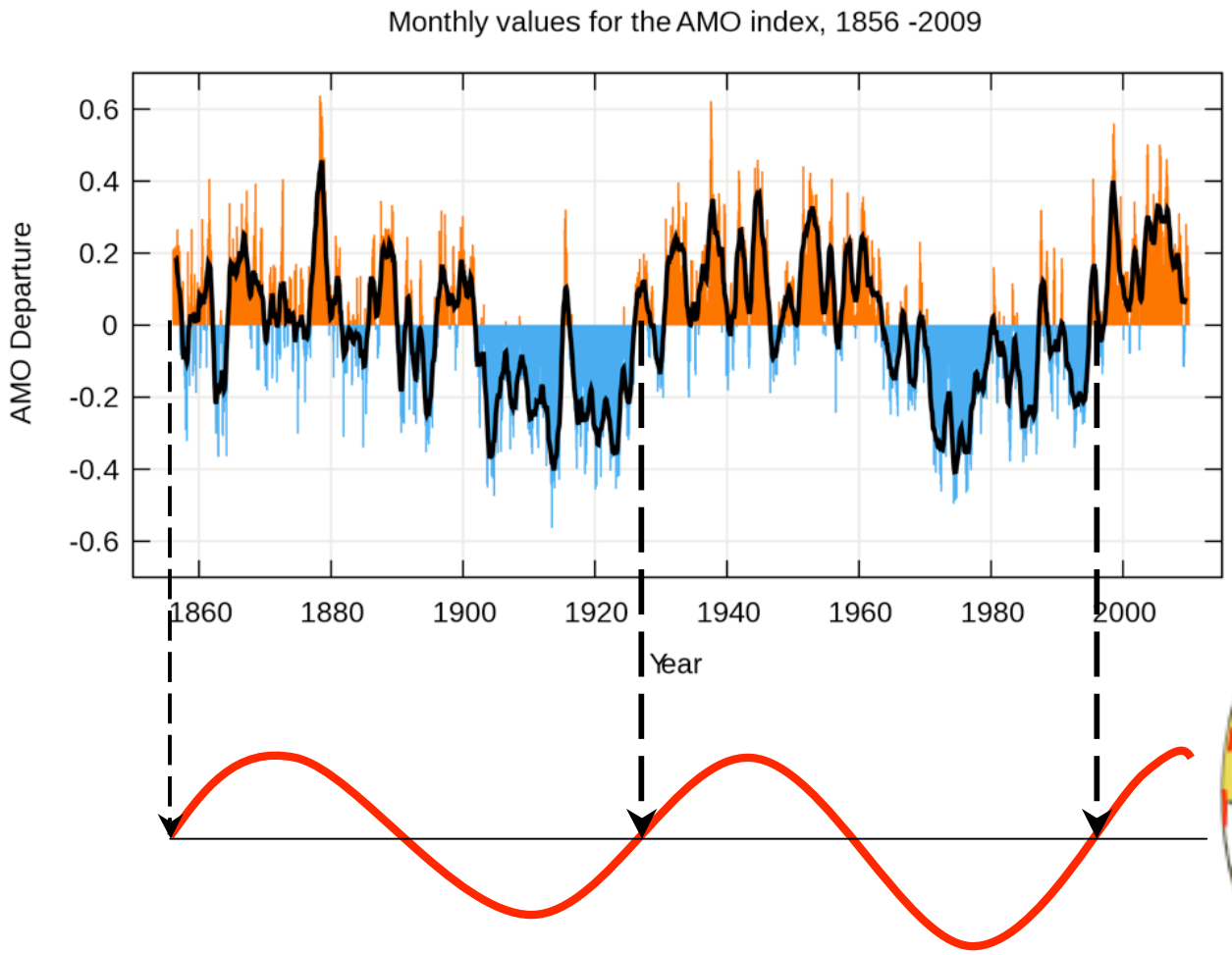
Laki Eruption and the 1783–4 Winter



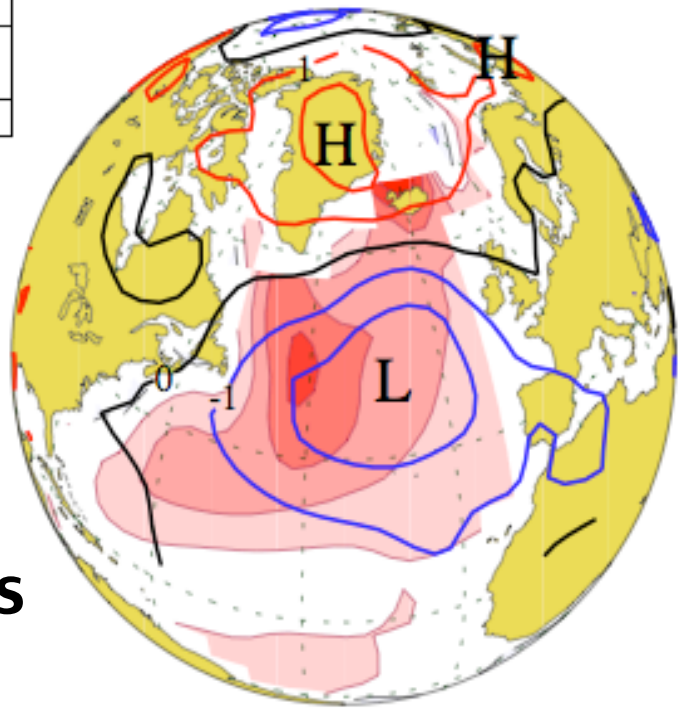
Benjamin Franklin (Paris, 1784): *"…when the effect of the sun's rays to heat the earth in these northern regions should have been greater, there existed a constant fog over all Europe, and a great part of North America…hence perhaps the winter of 1783-4 was more severe than any that had happened for many years…The cause of this universal fog is not yet ascertained…whether it was the vast quantity of smoke, long continuing, to issue during the summer from Hekla in Iceland, and that other volcano which arose out of the sea near that island…is yet uncertain."*

D'Arrigo, R, R. Seager, J.E. Smerdon, A. LeGrande, and E.R. Cook (2011), The anomalous winter of 1783-84: Was the Laki eruption or an analog of the 2009-10 winter to blame?, *Geophys. Res. Lett.*, in press.

Atlantic Multidecadal Oscillation

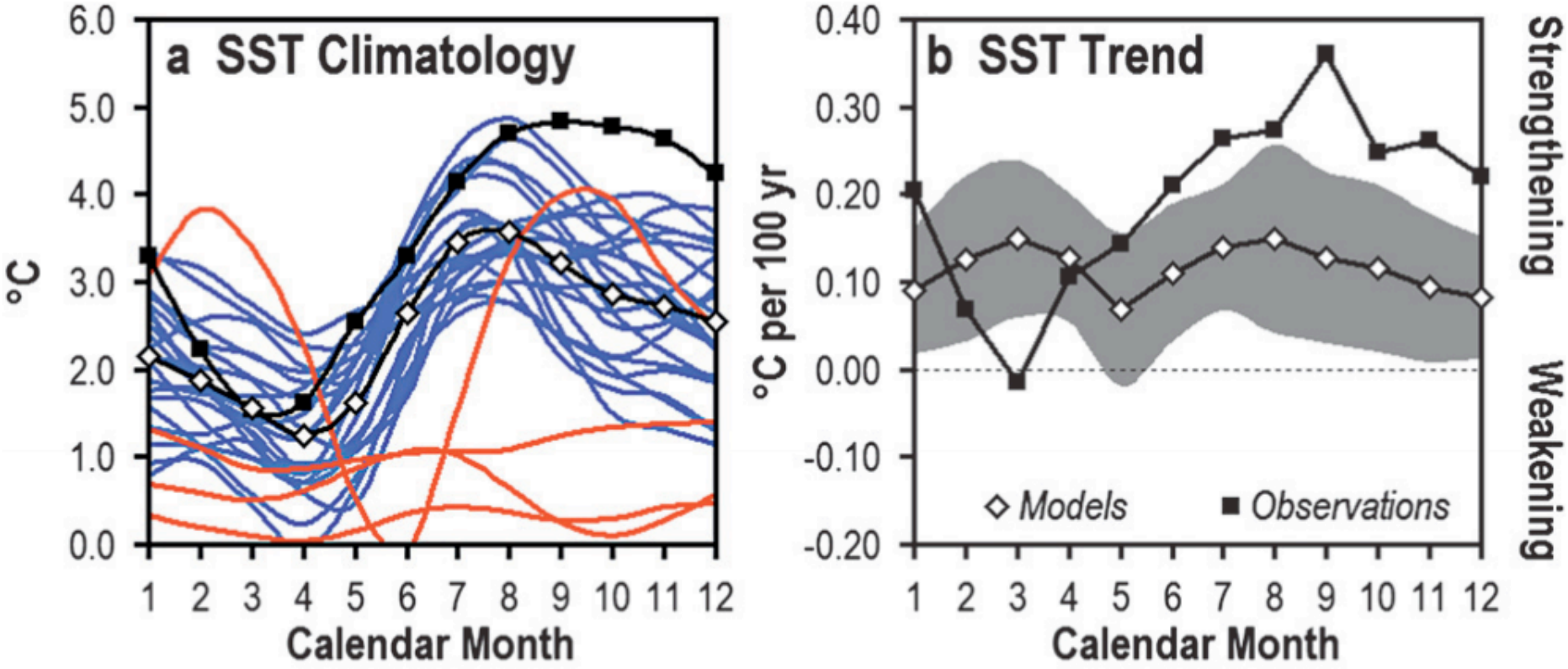


SST and SLP



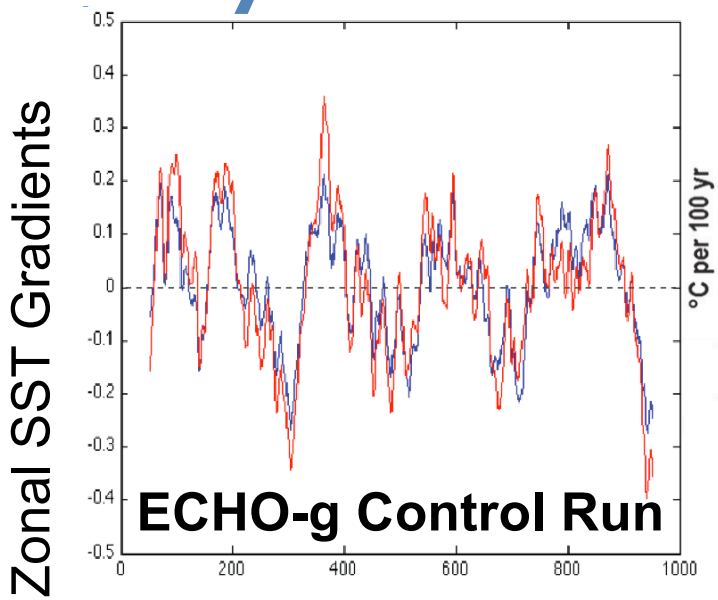
AMO Oscillatory Period ~ 60–70 years

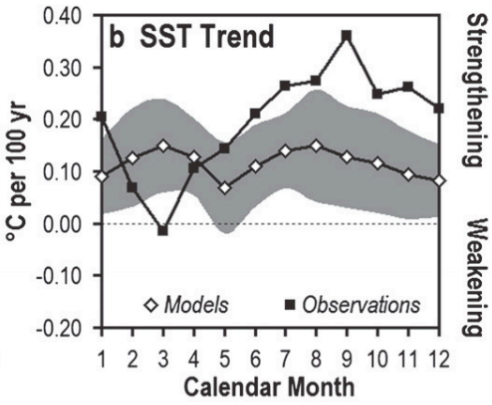
The Secular Behavior of ENSO

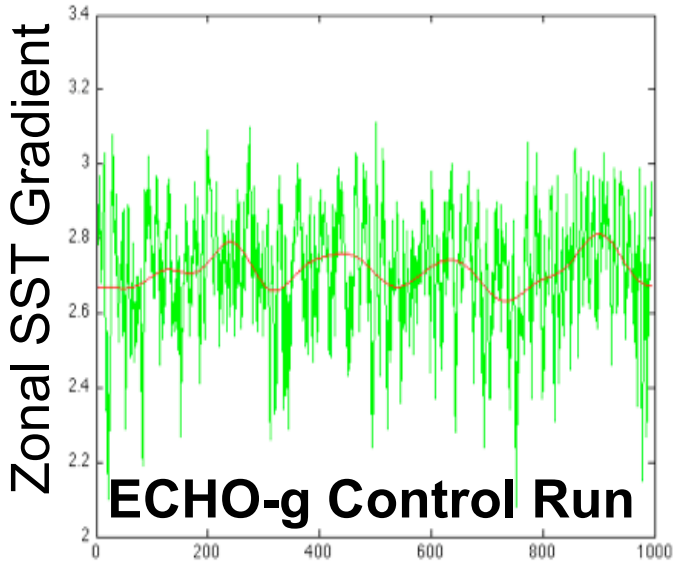


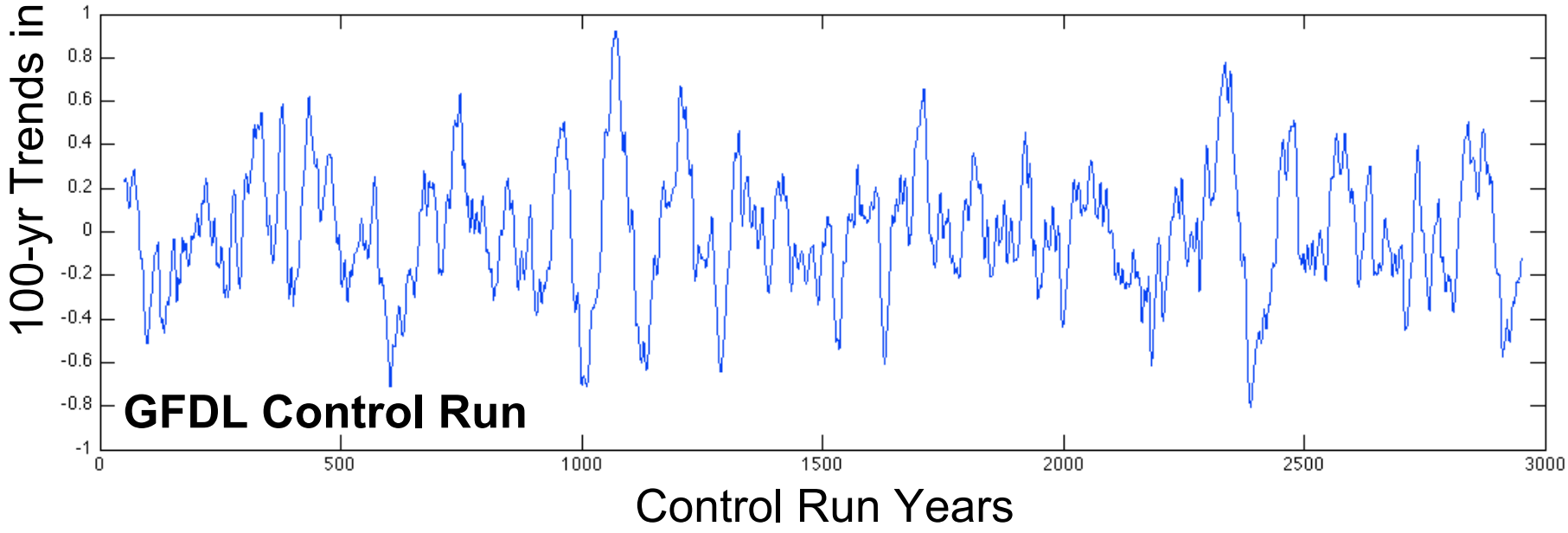
Karnauskas, K.B, R. Seager, A. Kaplan, Y. Kushnir, and M.A. Cane, Observed Strengthening of the Zonal Sea Surface Temperature Gradient across the Equatorial Pacific Ocean, *J. Clim.*, 22, 4316-4321.

100-yr Trends in Zonal SST Gradients

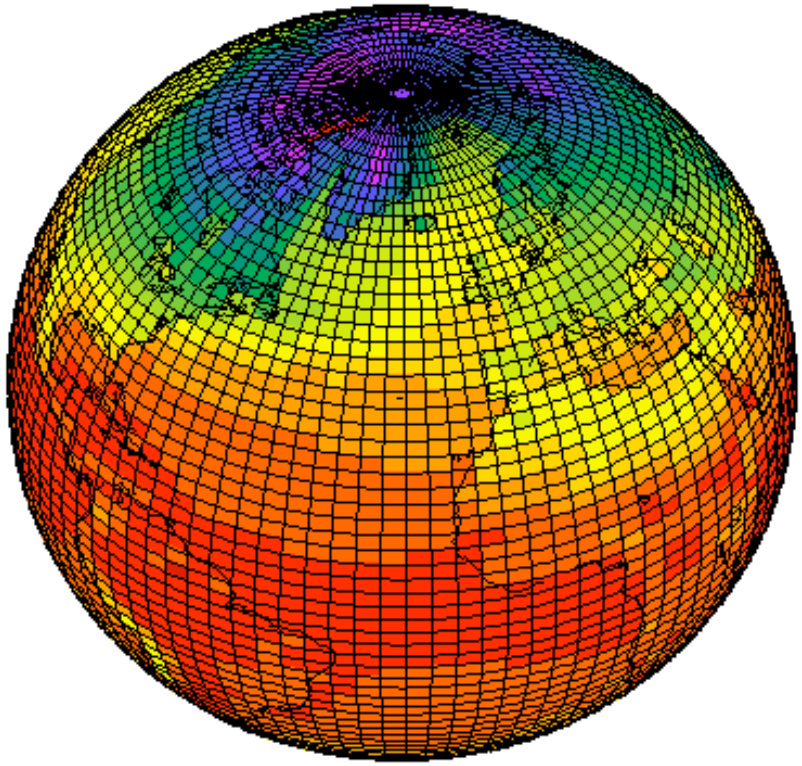


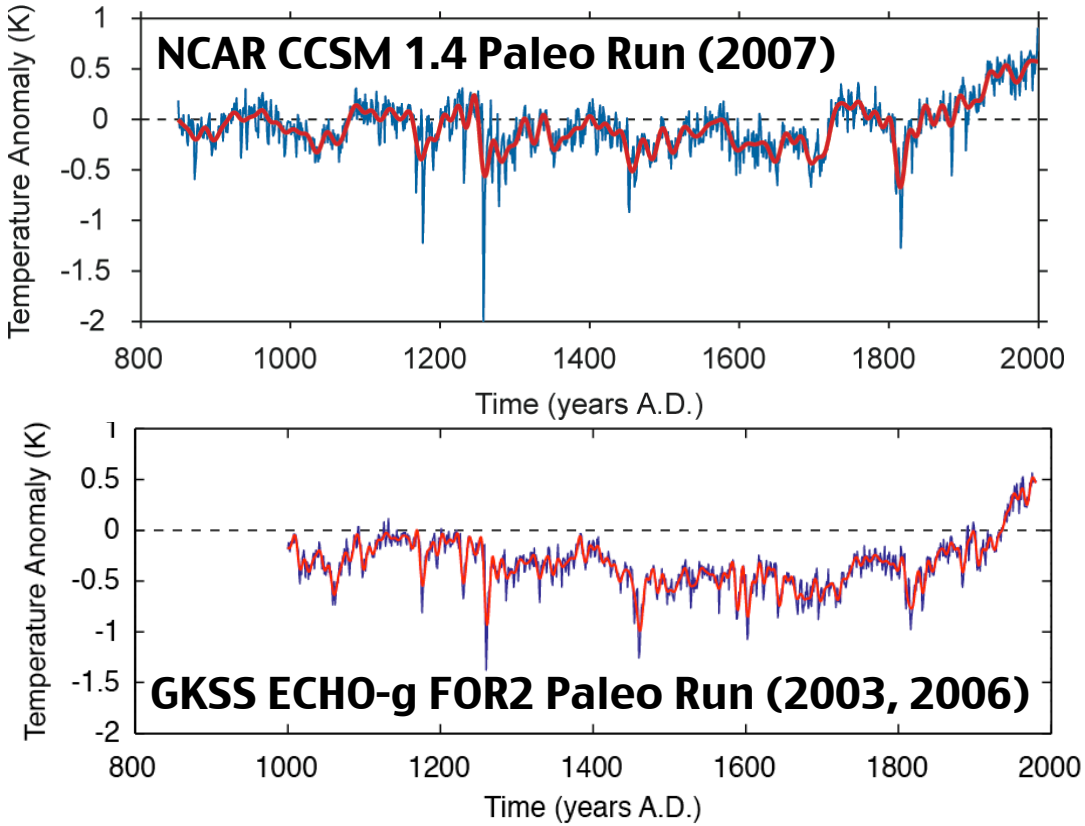






Millennial Climate Model Simulations





Coupled Model Intercomparison Project Phase 5 (CMIP5)

21 Modeling Groups Performing "Long-Term Experiments"

10 Groups Performing (multiple) Last Millennium Experiments

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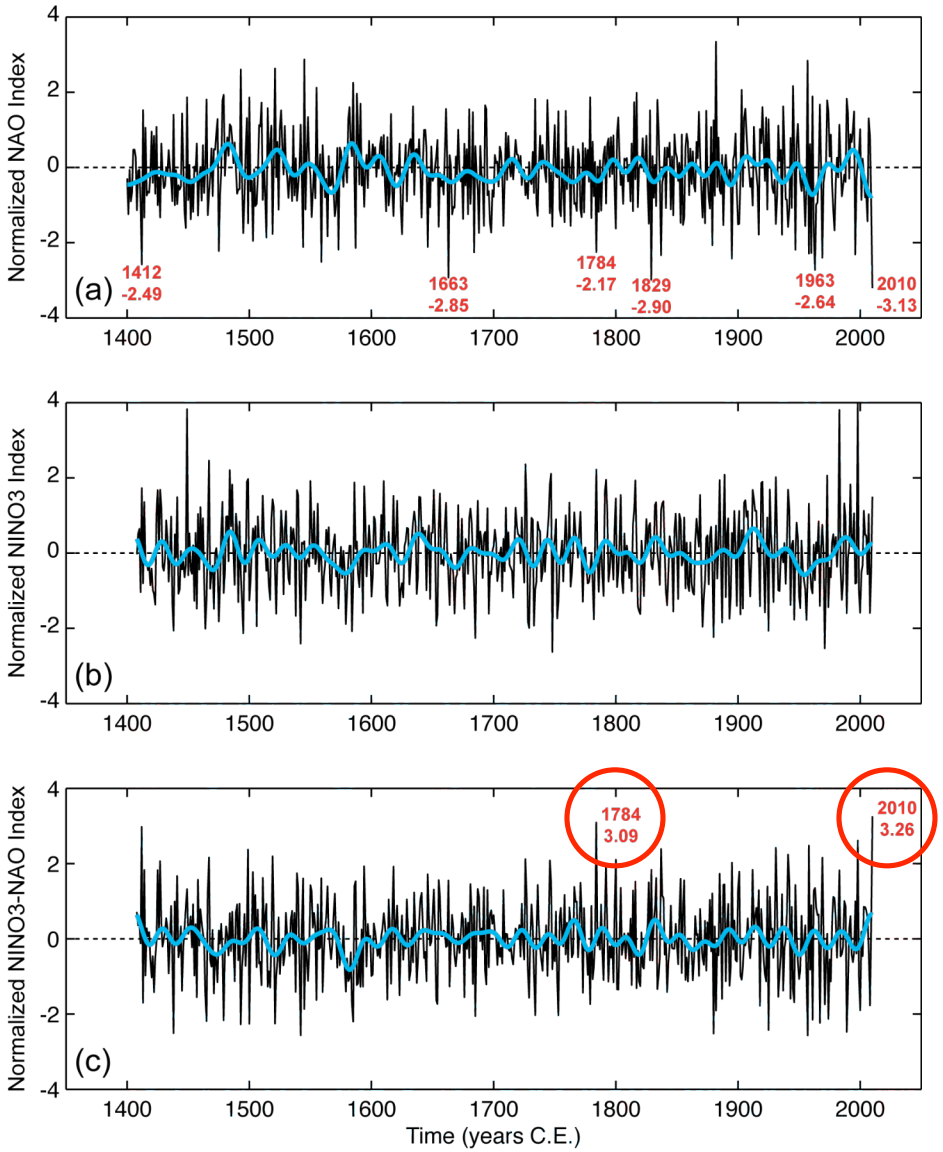

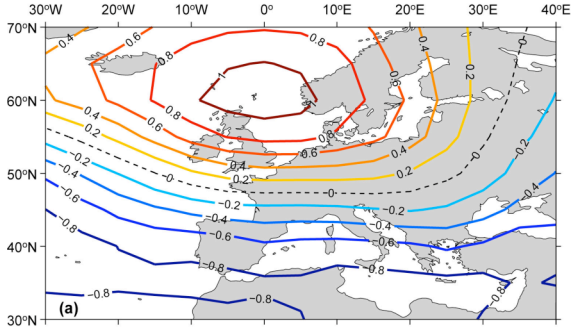

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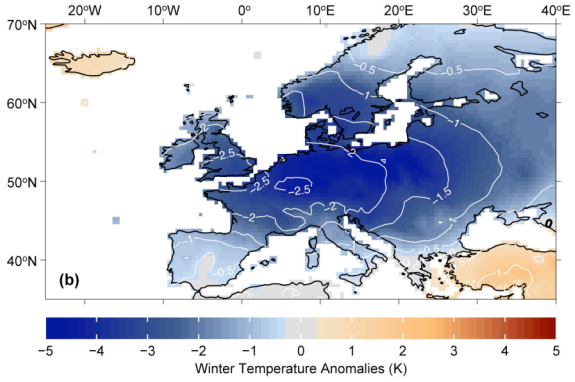

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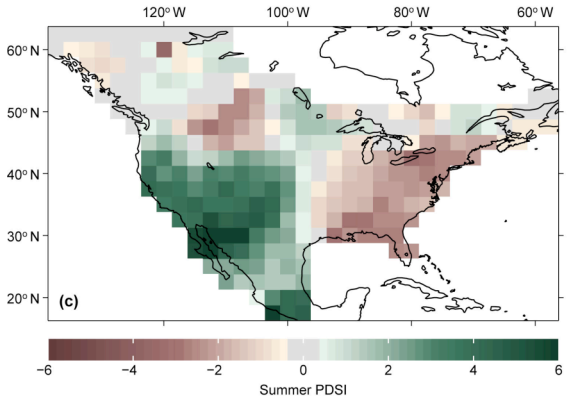

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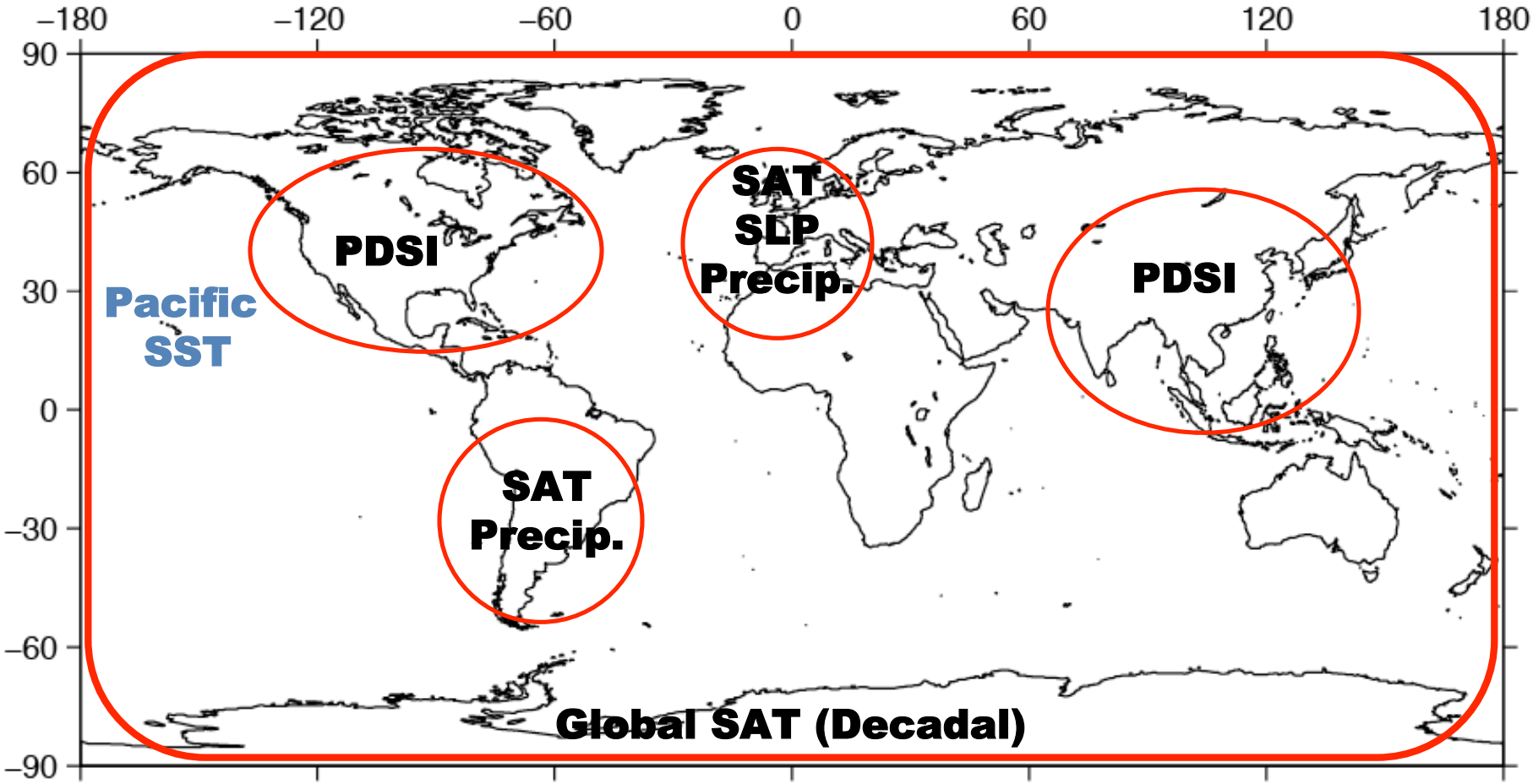
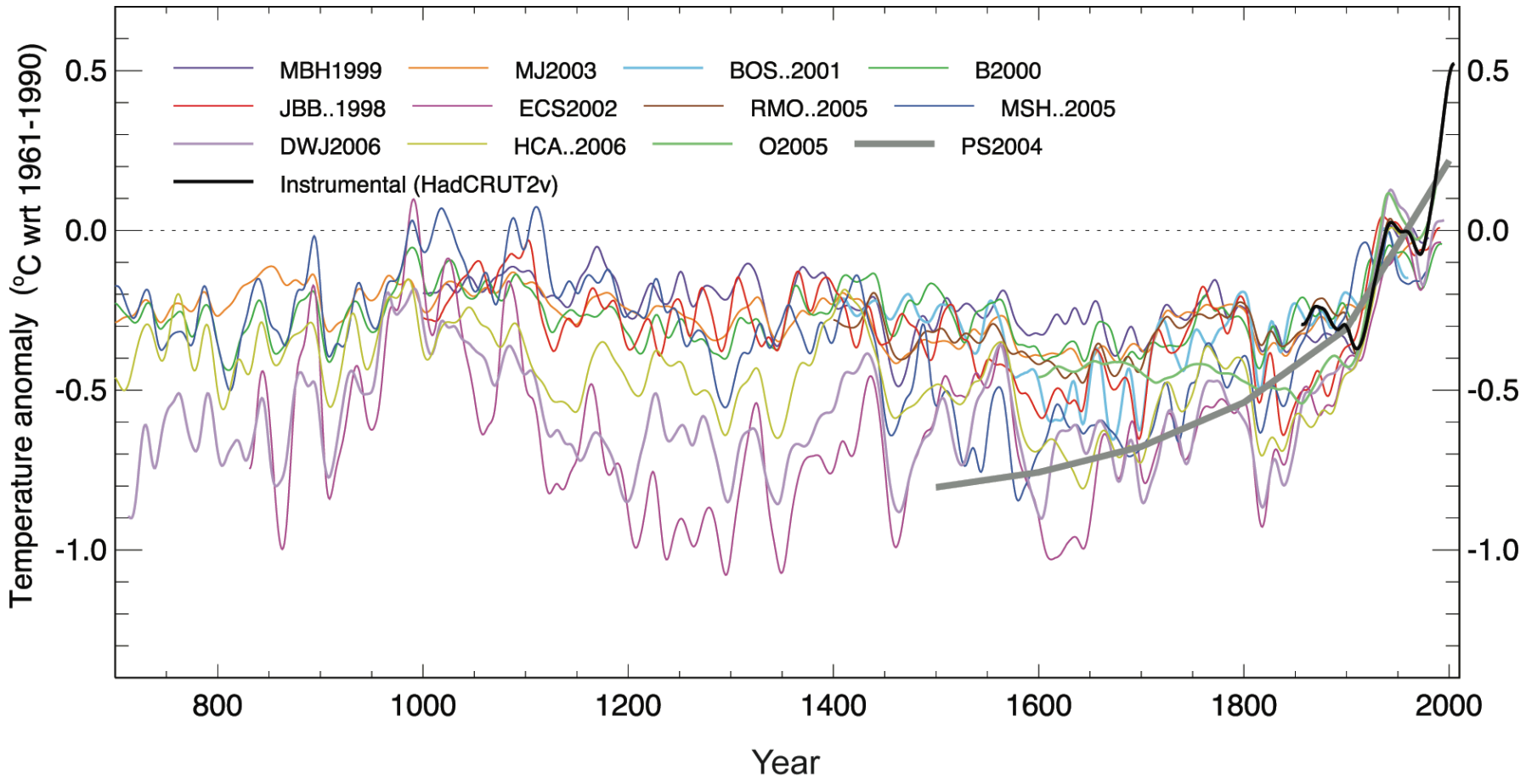
Available CFRs for the Common Era



Which Ones Are CFRs?



IPCC, AR4, 2007.

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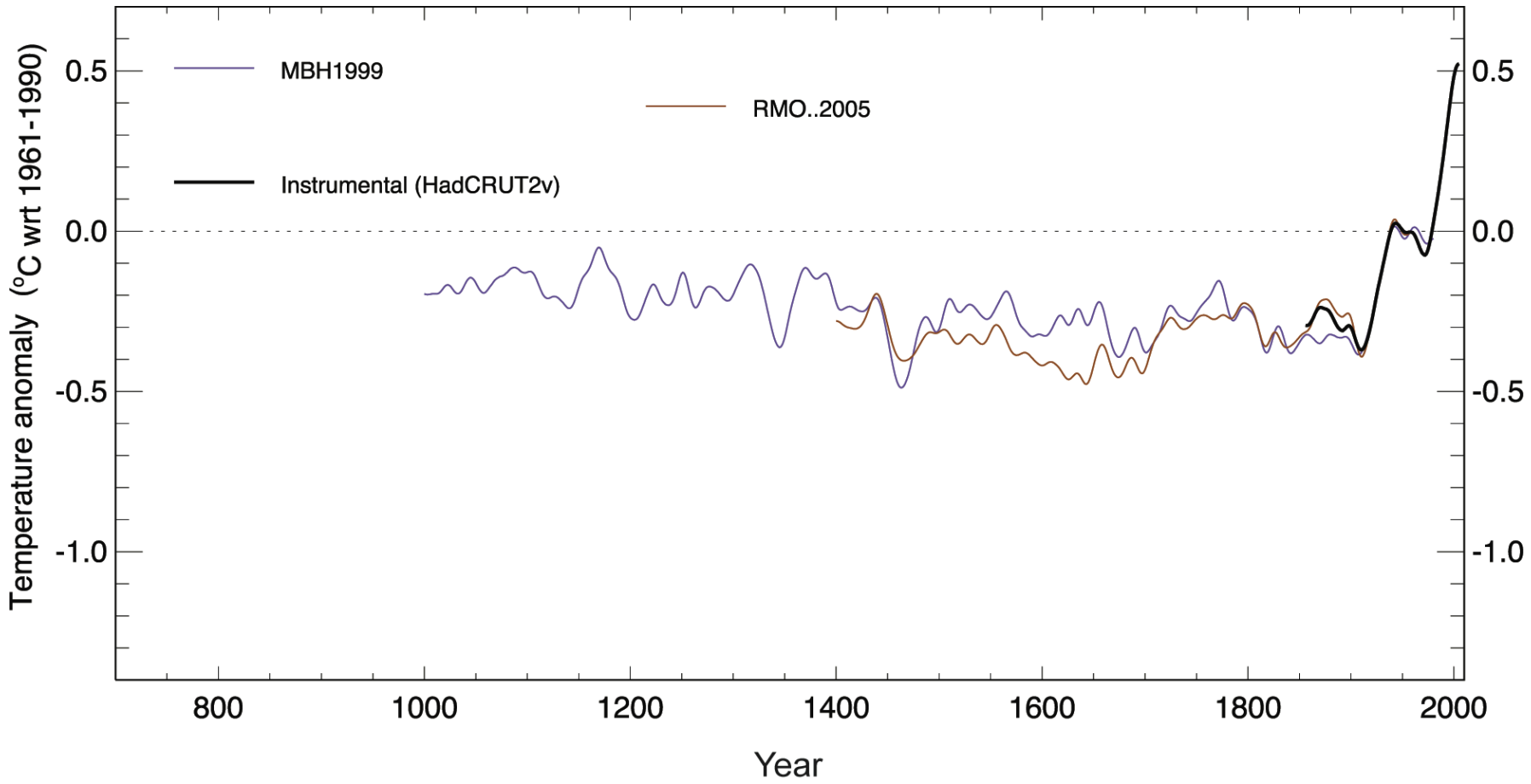

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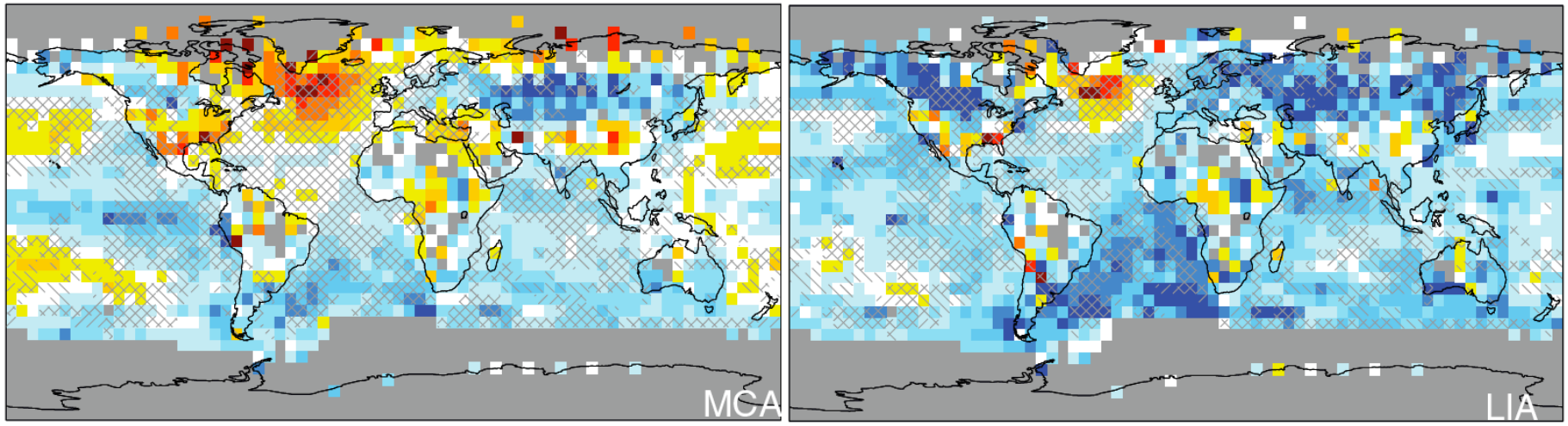
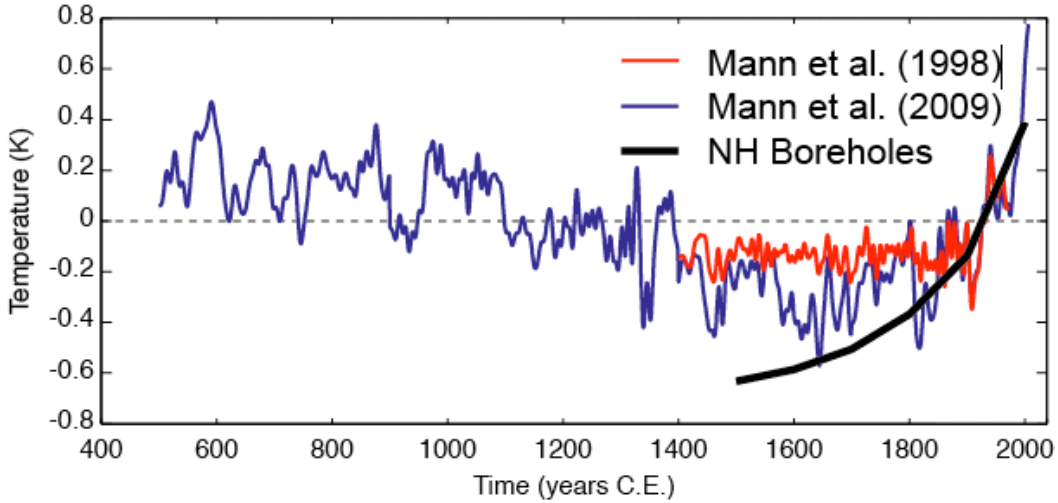
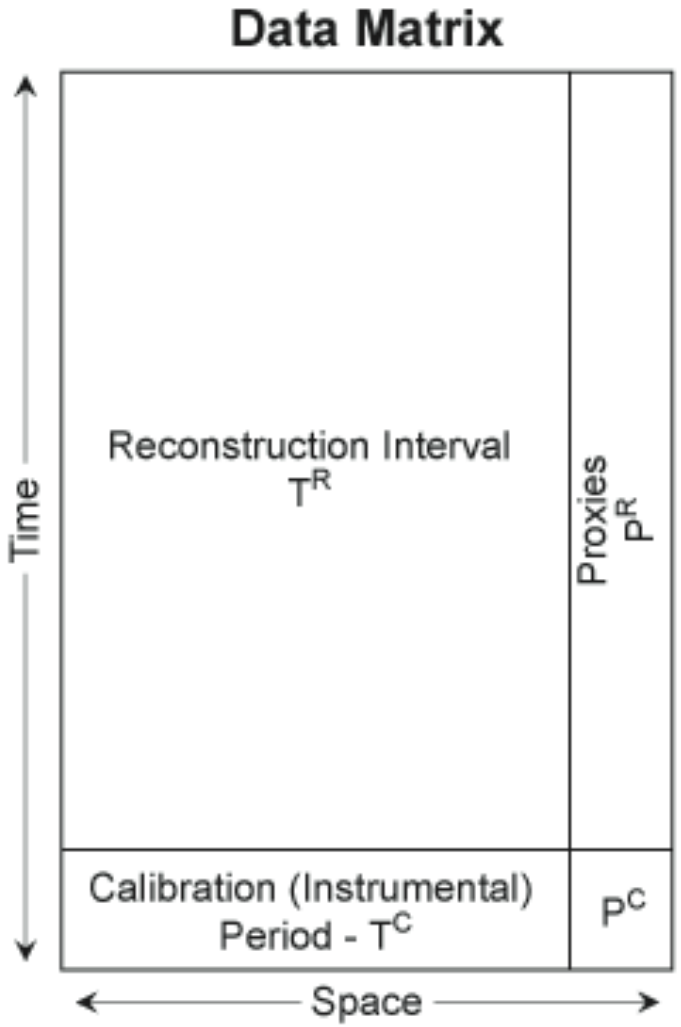
Mann et al., *Science*, 2009





Mann et al., Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly, *Science*, 326, 2009.

Most Reconstruction Approaches: Multivariate Linear Regression

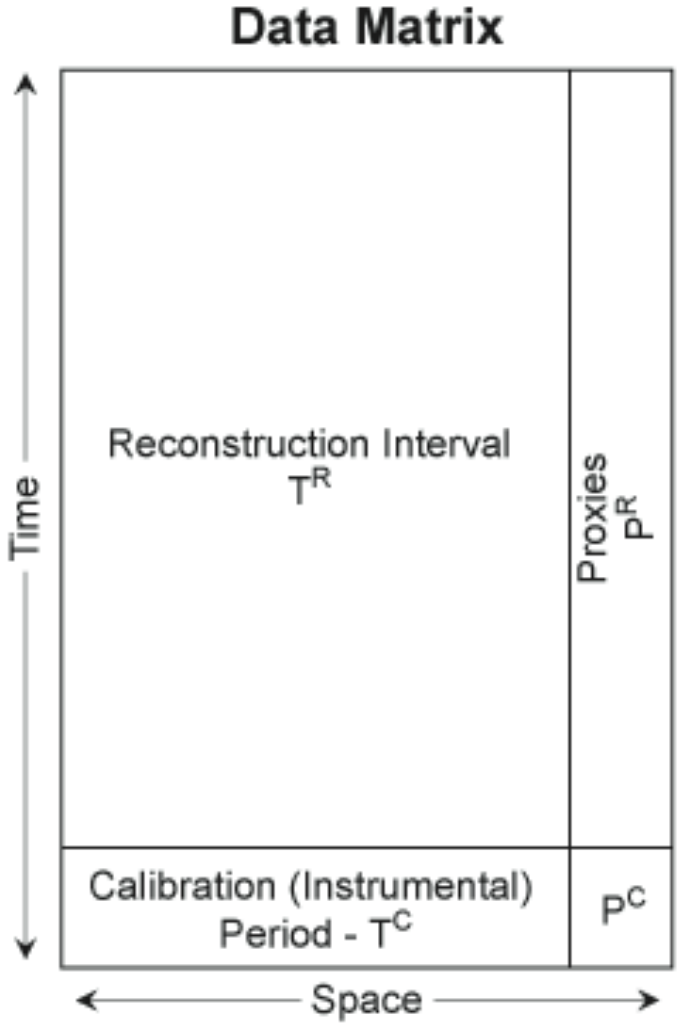


$$\textit{Calibration} \rightarrow \mathbf{T^C = BP^C + \varepsilon}$$

$$\textit{Reconstruction} \rightarrow \mathbf{T^R = BP^R}$$

T = Temperature Field
P = Proxies
C → Calibration Interval
R → Reconstruction Interval

Global CFRs: Reduced Space Regression Approaches

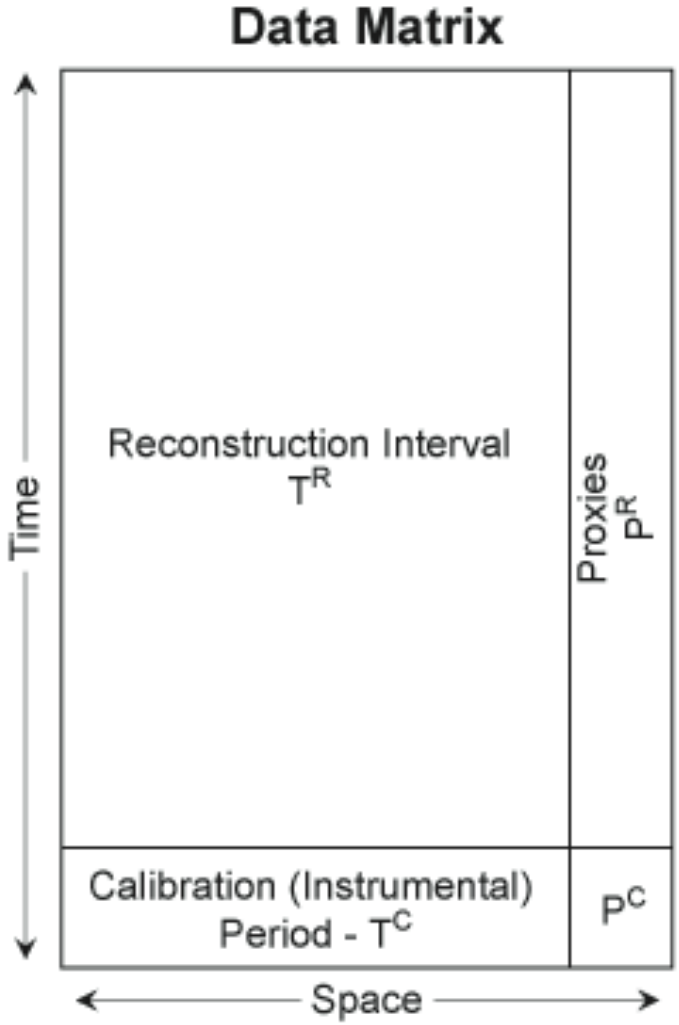


Ordinary Least Squares Estimator:

$$\mathbf{B} = (\mathbf{T}\mathbf{P}^T)(\mathbf{P}\mathbf{P}^T)^{-1}$$

BUT, estimation of the B matrix works best when the system is overdetermined, that is, when the time dimension *n* is much larger than the spatial dimension *m*, because the covariances are more reliably estimated.

Global CFRs: Reduced Space Regression Approaches



Ordinary Least Squares Estimator:

$$\mathbf{B} = (\mathbf{T}\mathbf{P}^T)(\mathbf{P}\mathbf{P}^T)^{-1}$$

Three Principal Choices

Reduced Space Representation of T and P :

$$\mathbf{T} = \mathbf{U}_t^r \boldsymbol{\Sigma}_t^r \mathbf{V}_t^{r\,T}$$

$$\mathbf{P} = \mathbf{U}_p^r \boldsymbol{\Sigma}_p^r \mathbf{V}_p^{r\,T}$$

Regularization of B :

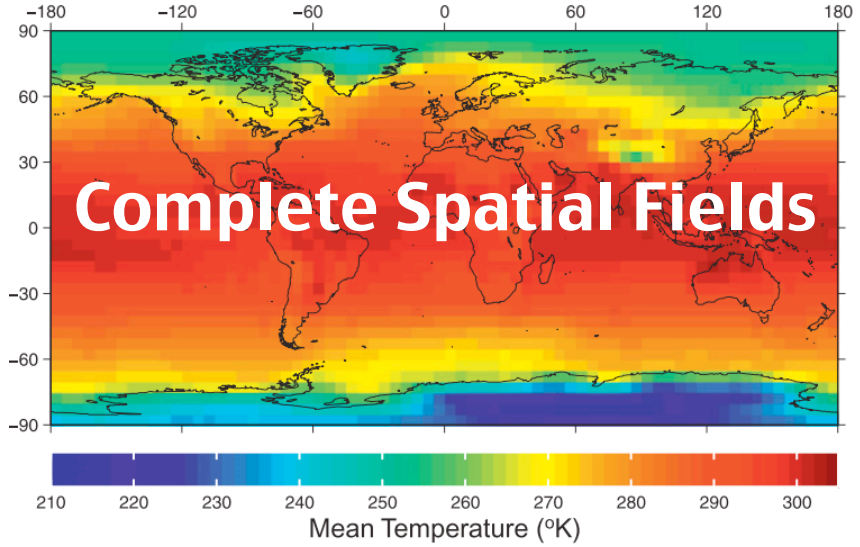
$$\mathbf{B} = \mathbf{U}_t^r \boldsymbol{\Sigma}_t^r \mathbf{V}_t^{r\,T} \mathbf{V}_p^r \boldsymbol{\Sigma}_p^{r\,-1} \mathbf{U}_p^{r\,T}$$

Important (Potentially Violated) Assumptions

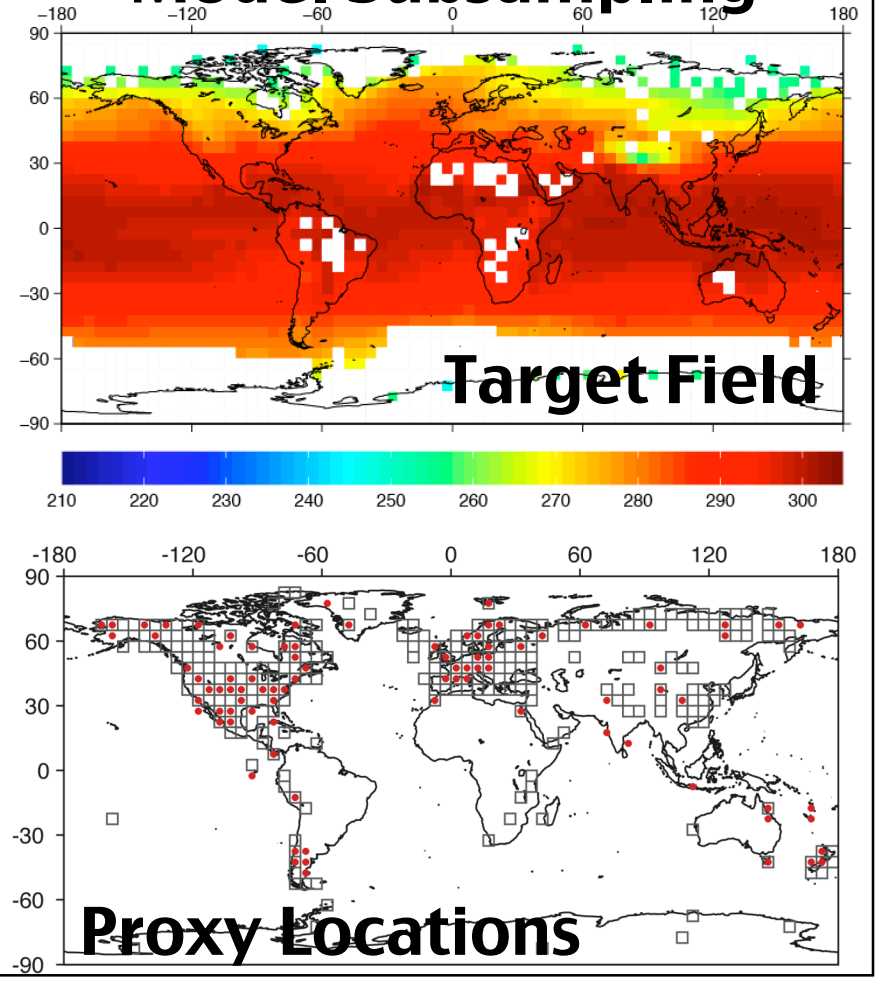
- Proxy-Climate Connection is linear, stationary and univariate
- Target patterns are stationary and well-represented in the calibration interval
- Missing values are missing at random
- Climate teleconnections justify non-local connections between proxies and the target field

Employing Millennial GCM Simulations for Synthetic CFR Experiments

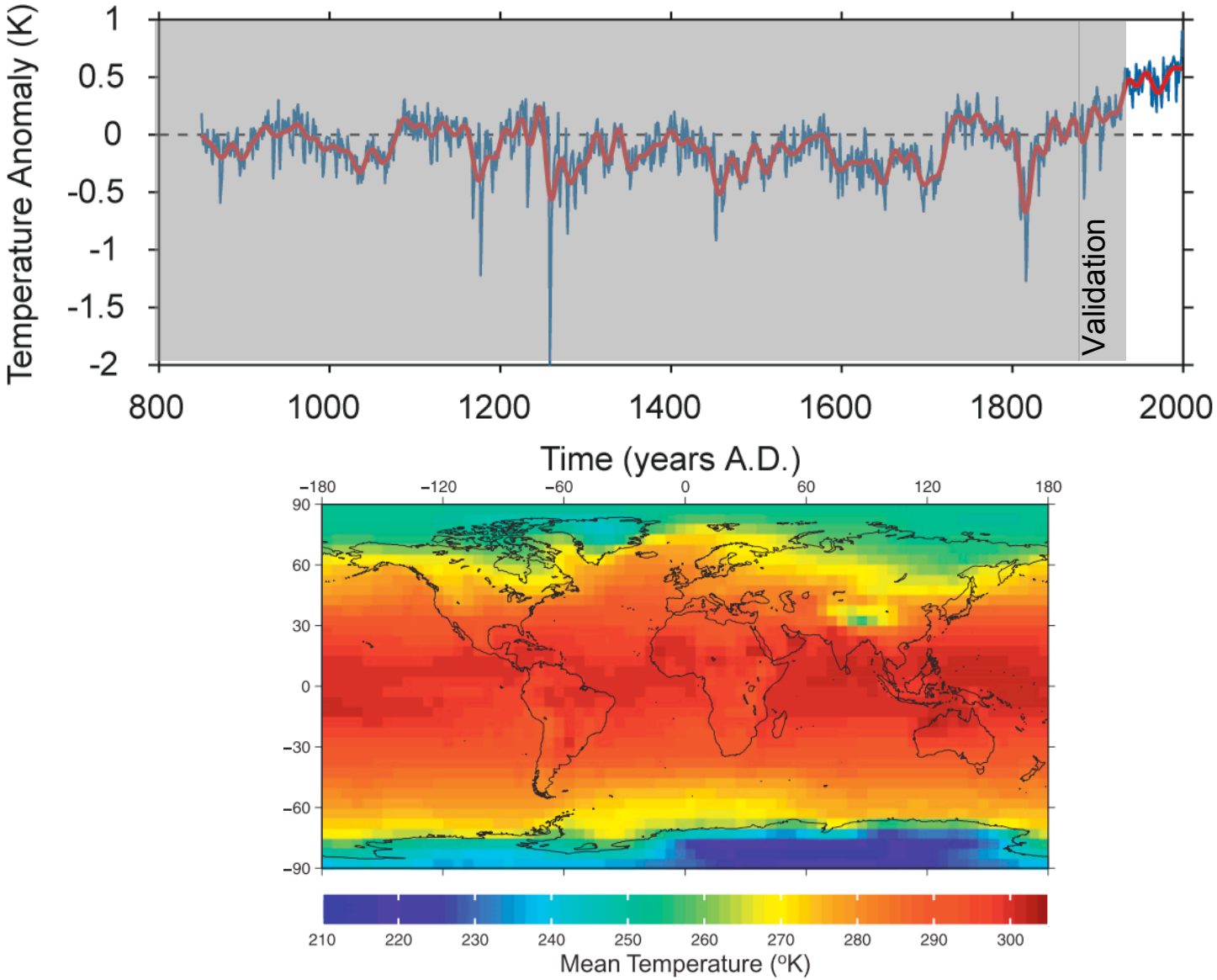
Model Data



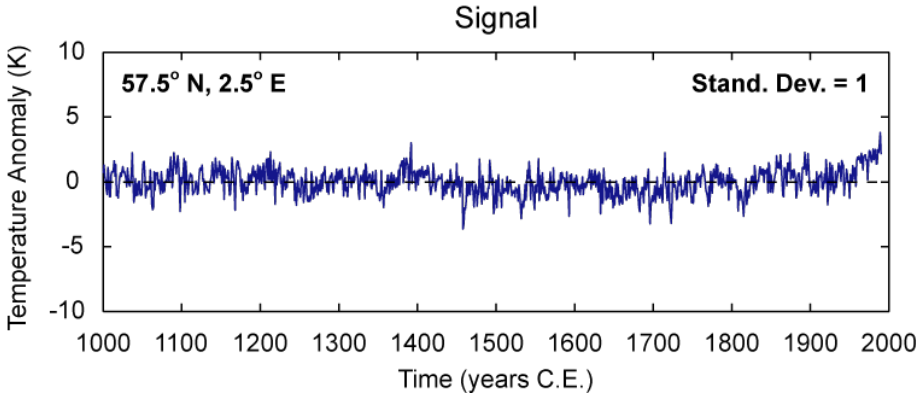
Model Subsampling

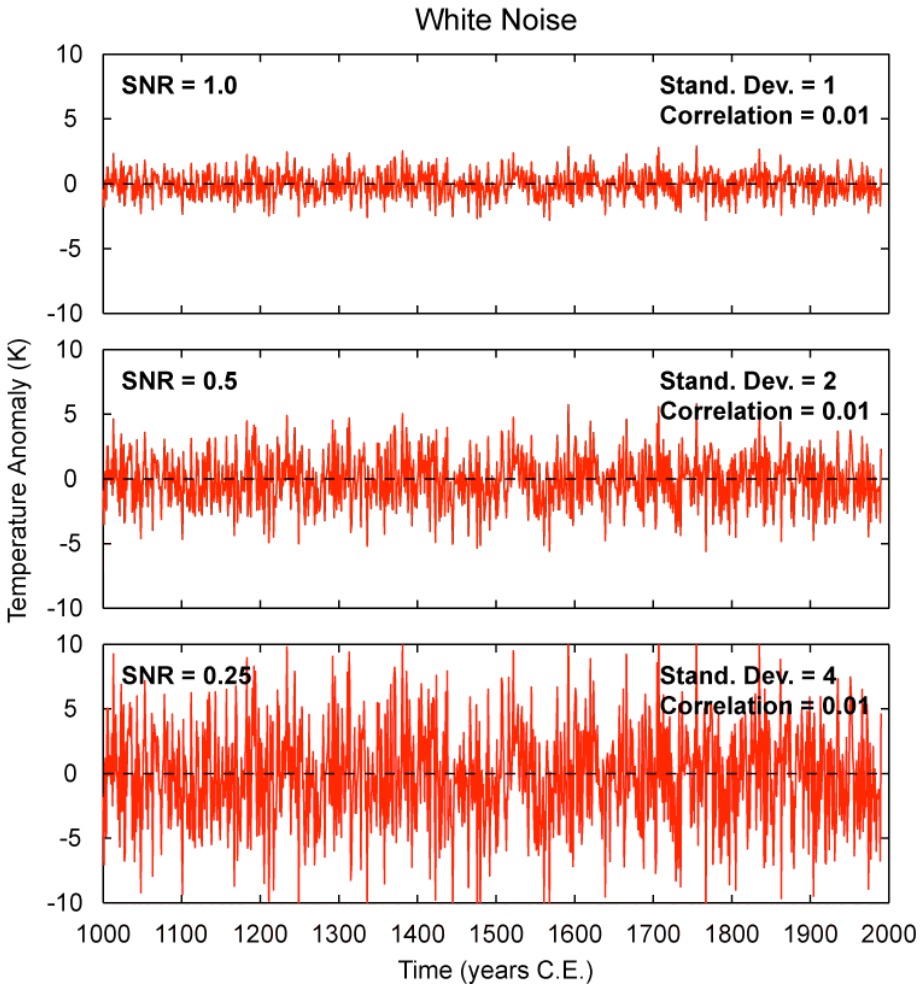


Pseudoproxy Validation



Making Pseudoproxies





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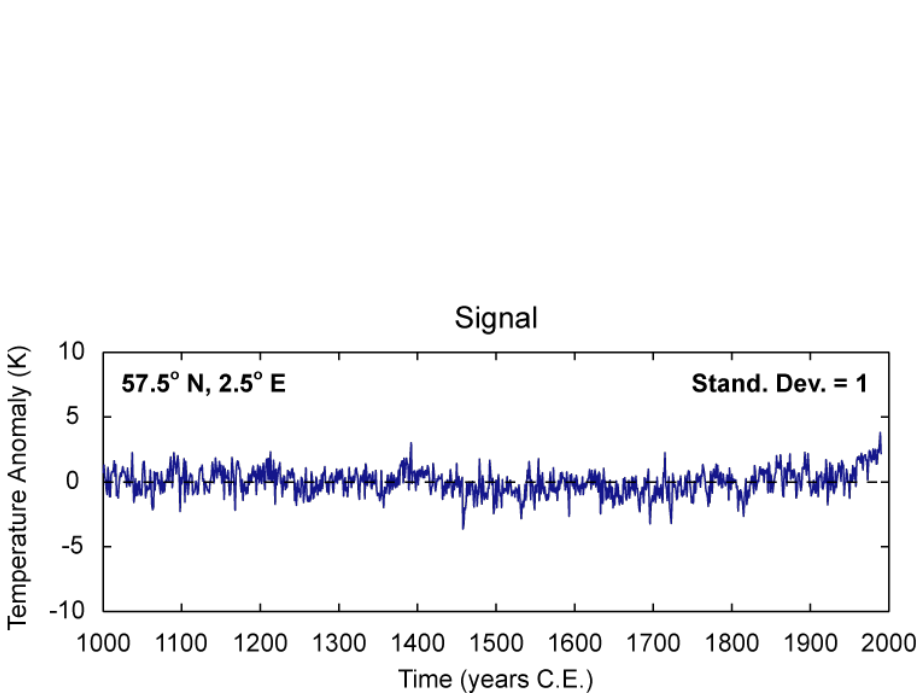
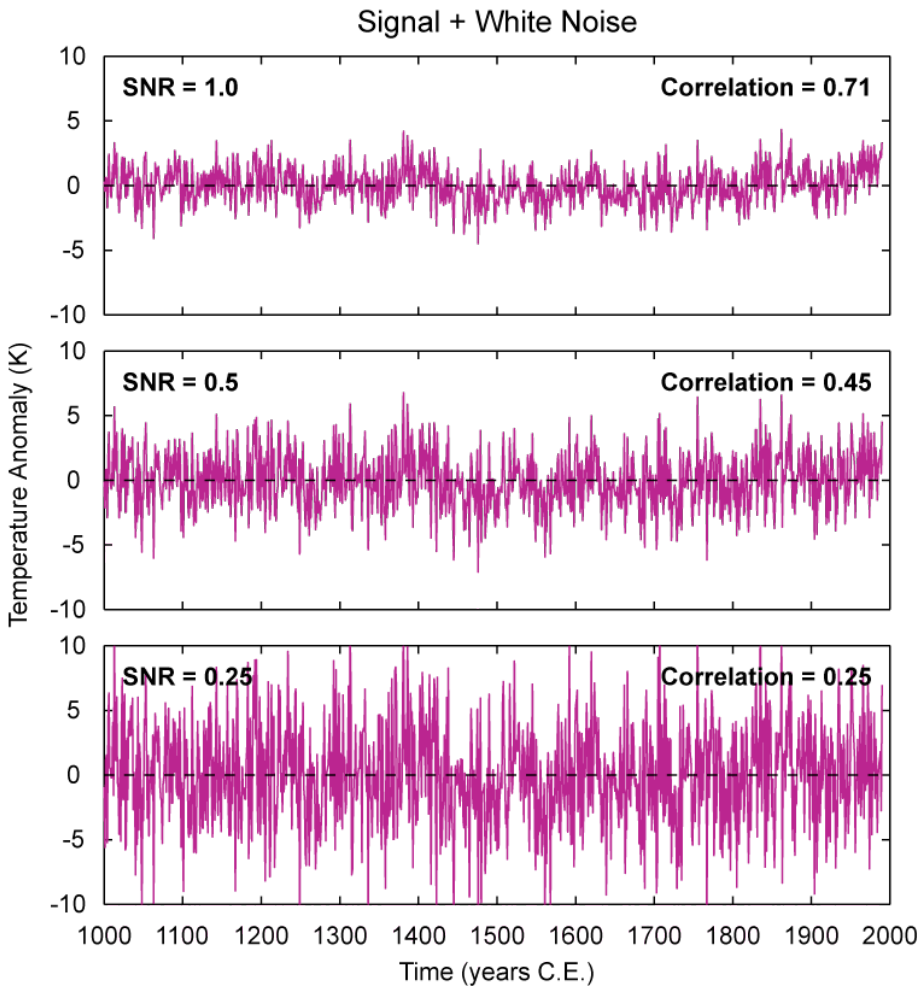
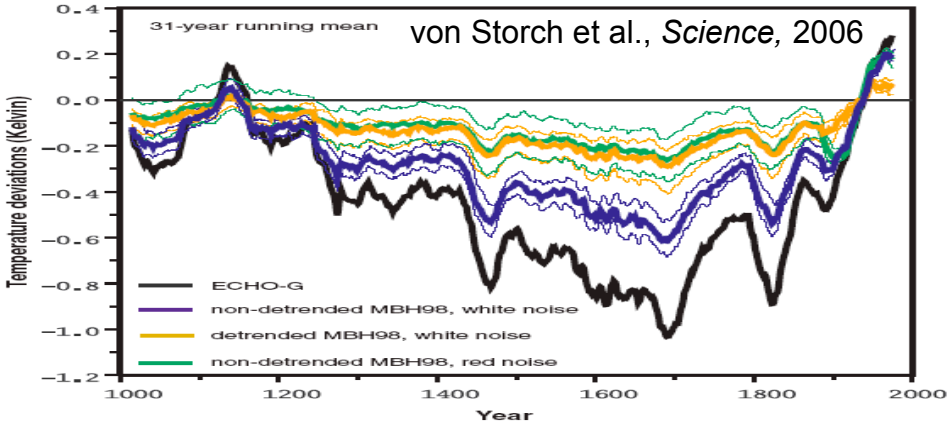




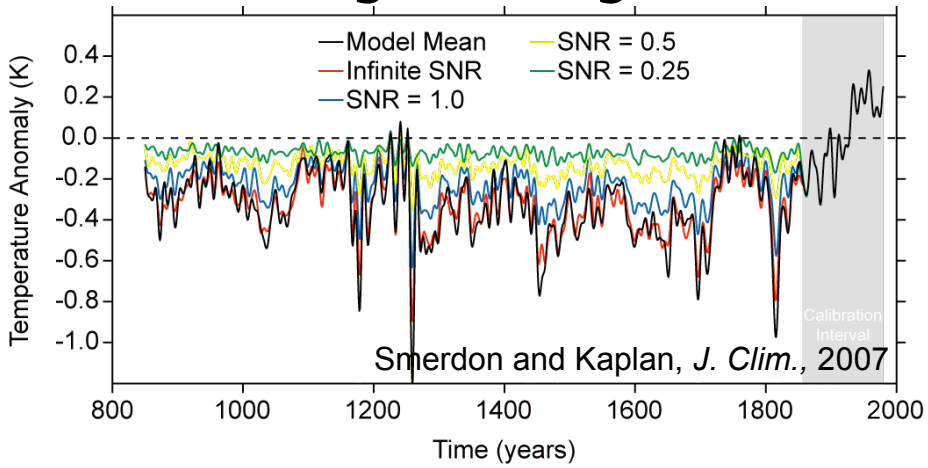

http://www.autismspot.com/tags/Spot-Content-Tags/lab-mouse

NH Mean Performance

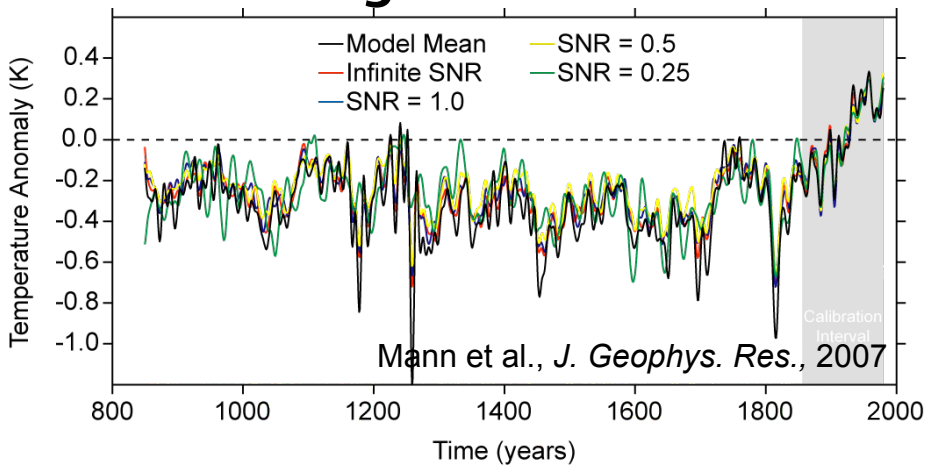
MBH98 Method



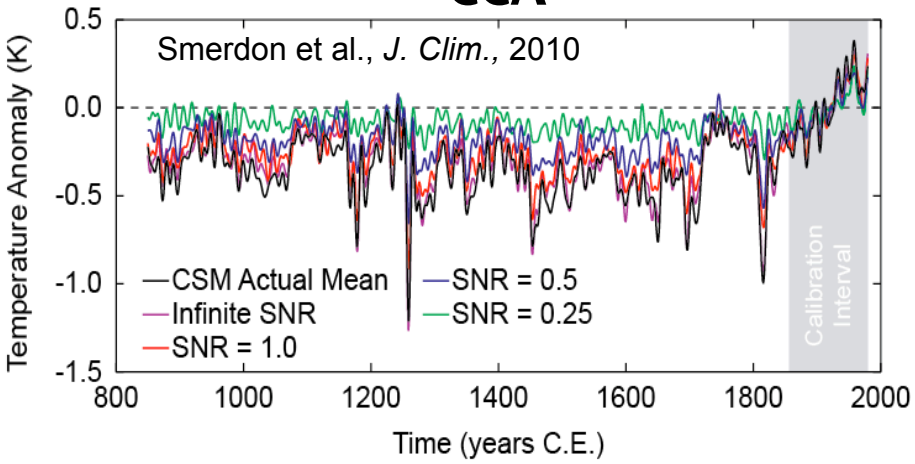
RegEM - Ridge



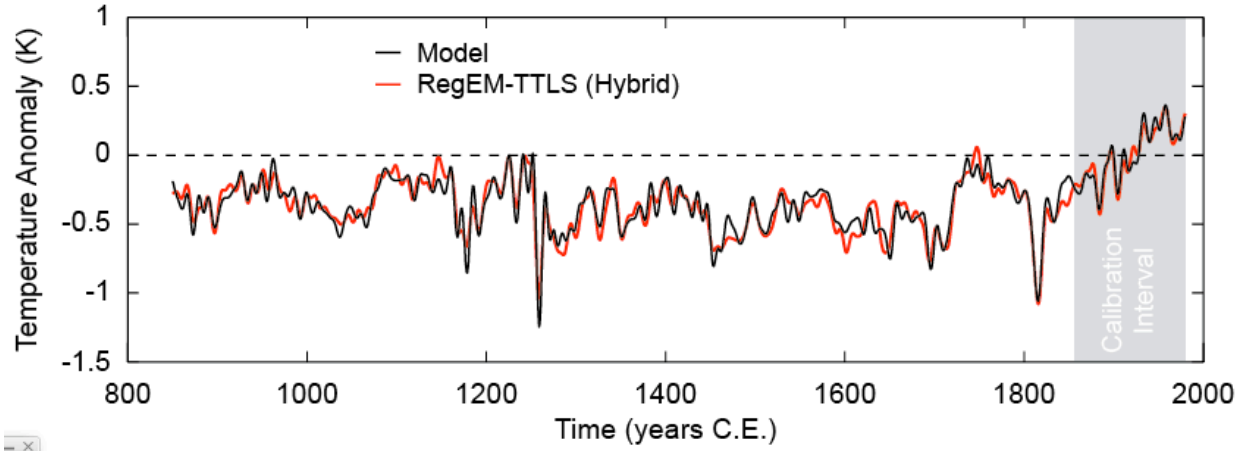
RegEM - TTLS

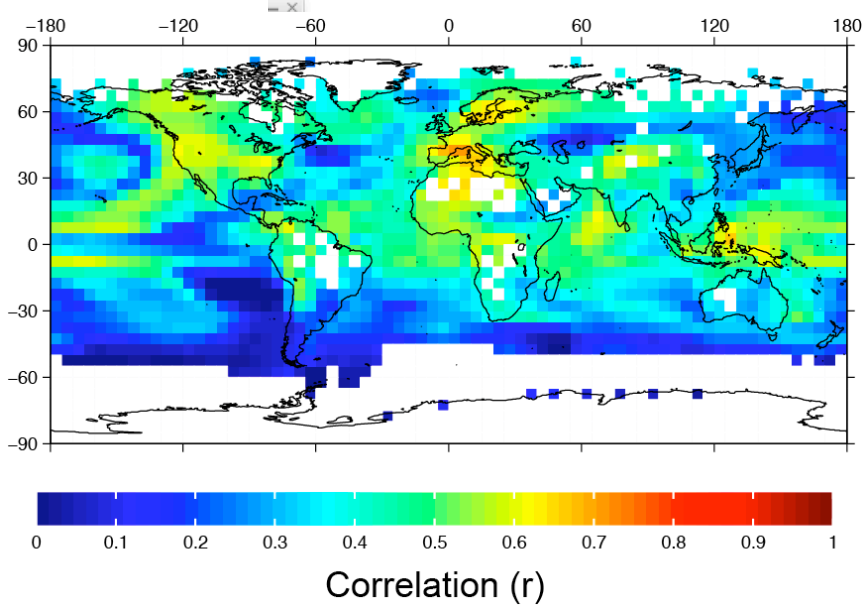


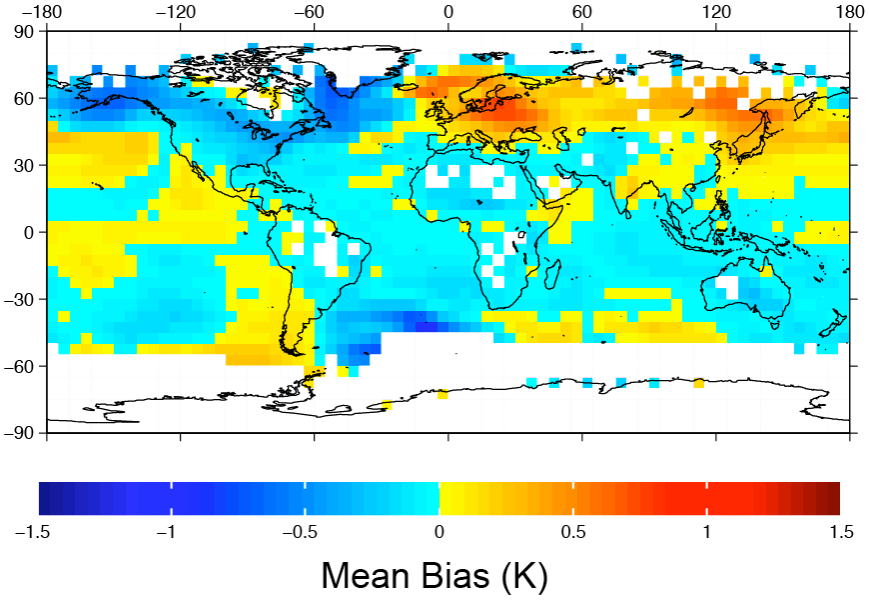
CCA



Global or Hemispheric Mean Evaluations of CFRs are not Enough

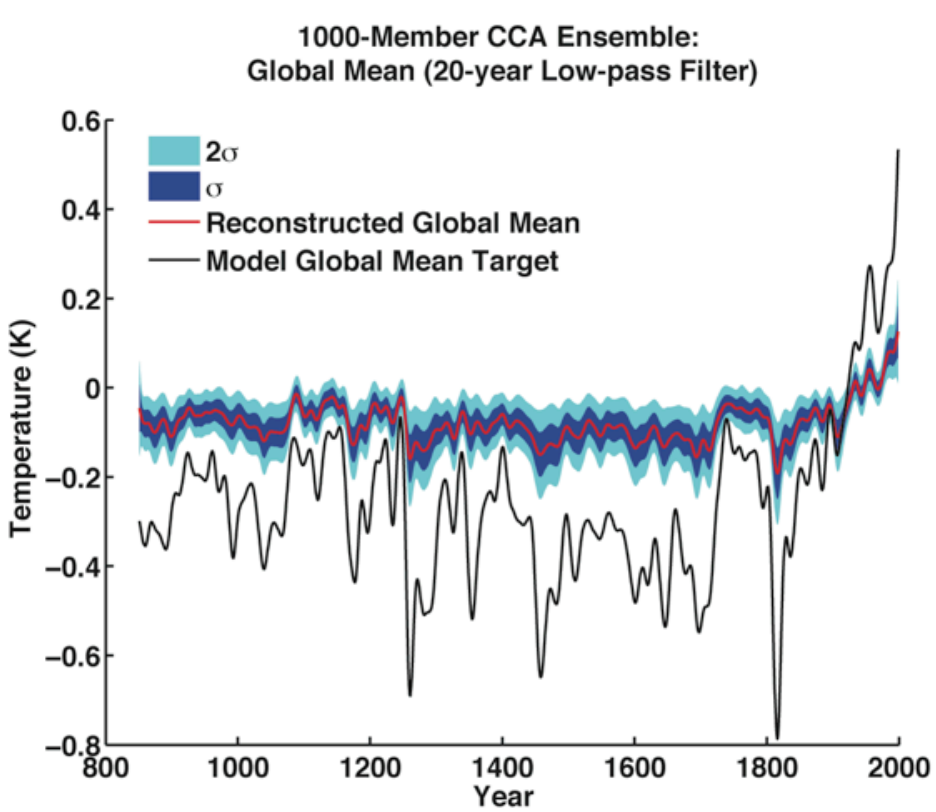


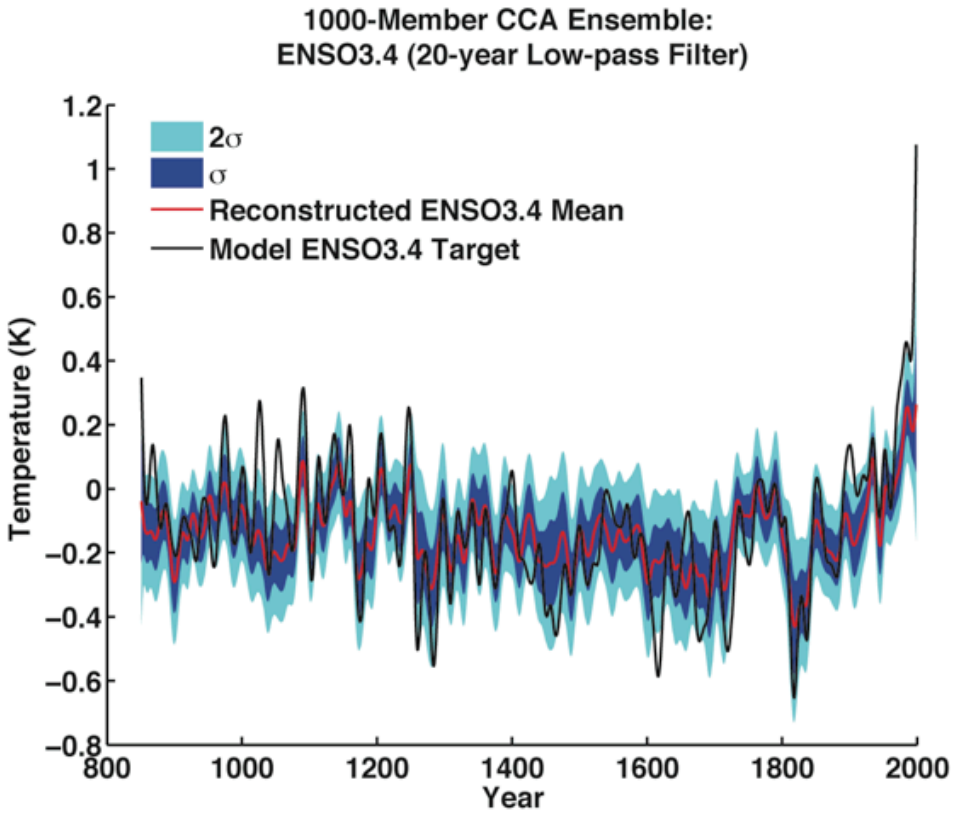




Smerdon et al., Spatial Performance of Four Climate Field Reconstruction Methods Targeting the Common Era, *GRL*, in review.

Another Way of Looking at It: Global Mean vs. ENSO3.4

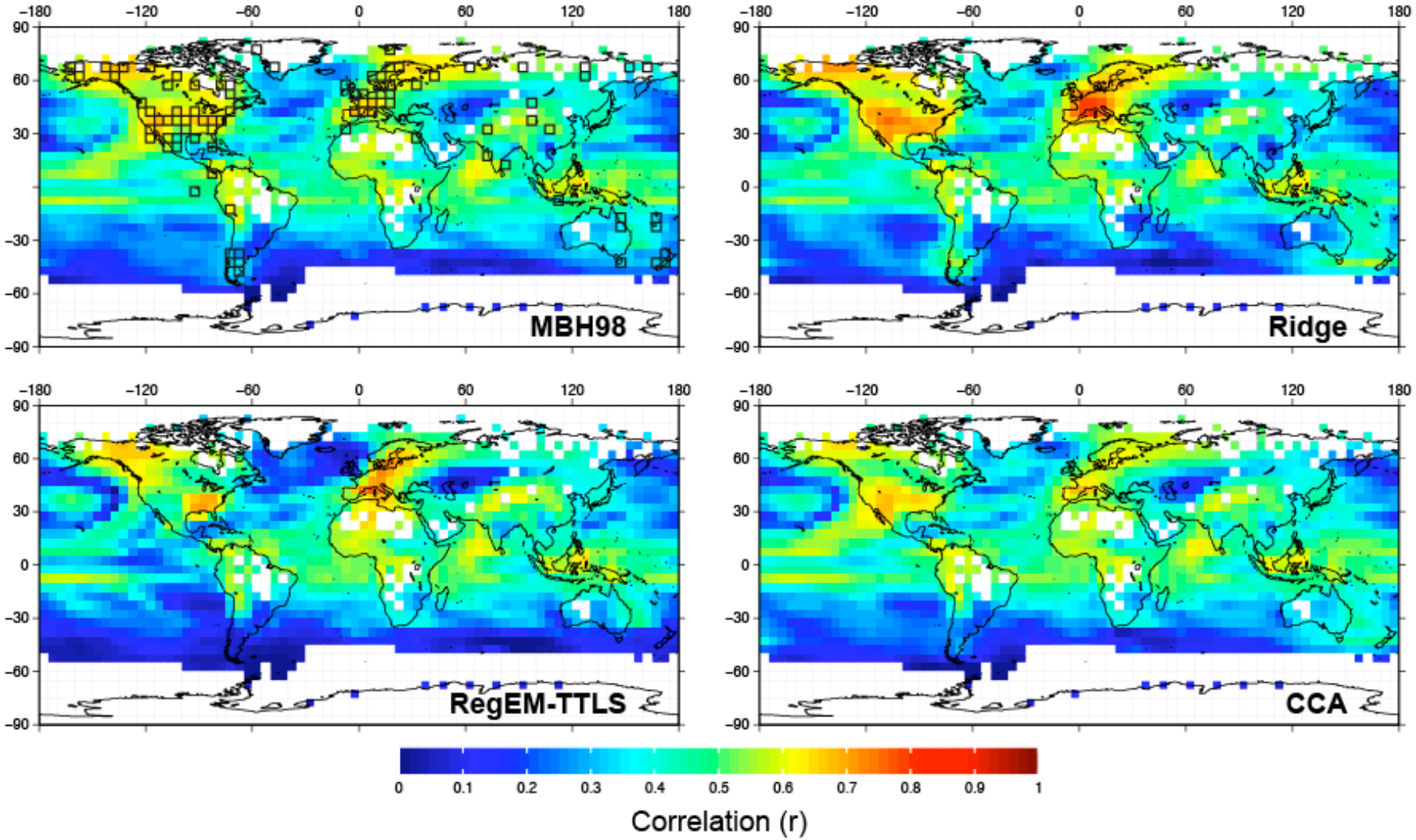




Amrhein, D. E., J. E. Smerdon and, A. Kaplan, 2010: A pseudoproxy ensemble study of climate field reconstructions for the Common Era using CCA. *Climate Dynamics*, in prep.

Grid-Point Correlations

Pseudoproxy SNR: 0.5

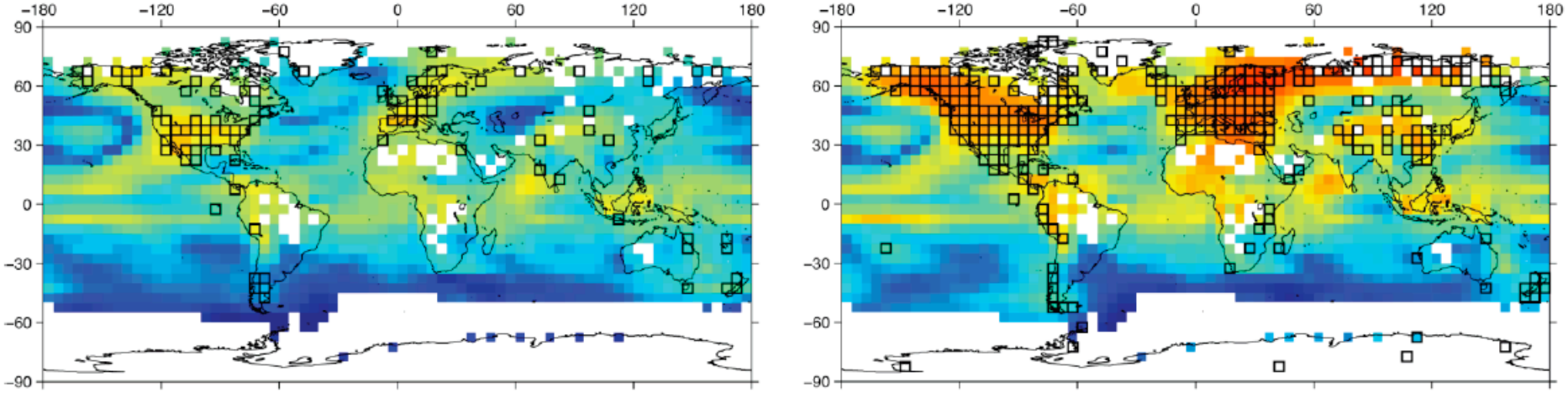


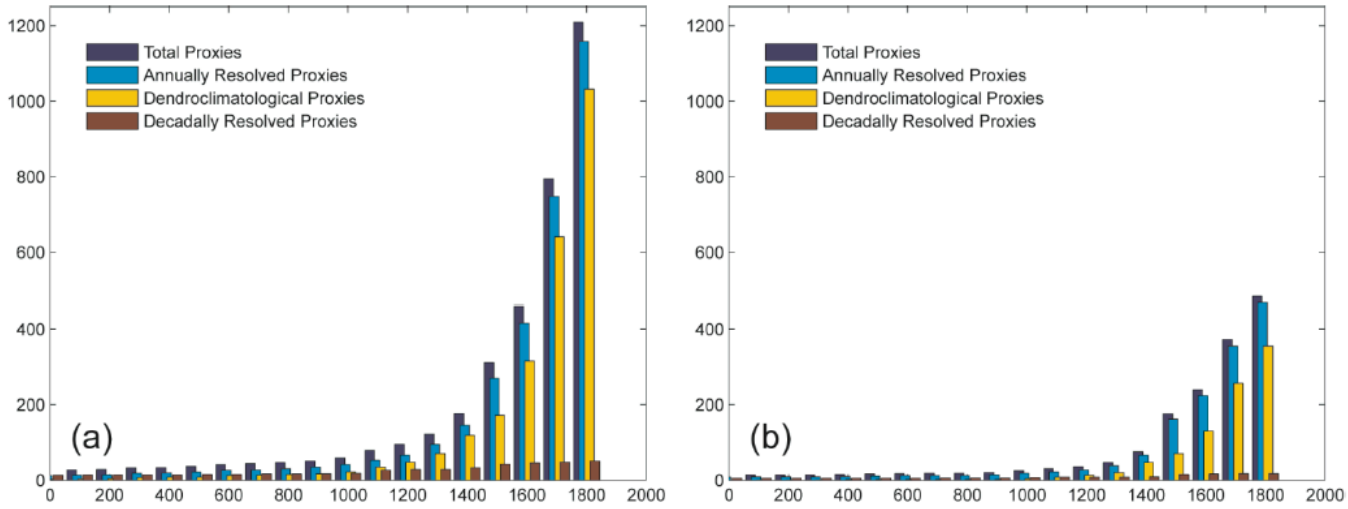
Smerdon et al., Spatial Performance of Four Climate Field Reconstruction Methods Targeting the Common Era, *GRL*, in review.

Impact of Network Sampling

Mann et al. (1998) Network

Mann et al. (2008) Network





Smerdon, J.E., A. Kaplan, E. Zorita, J.F. Gonzalez-Rouco, and M.N. Evans, Spatial Performance of Four Climate Field Reconstruction Methods Targeting the Common Era, *GRL*, in review.

Lamont-Doherty Earth Observatory
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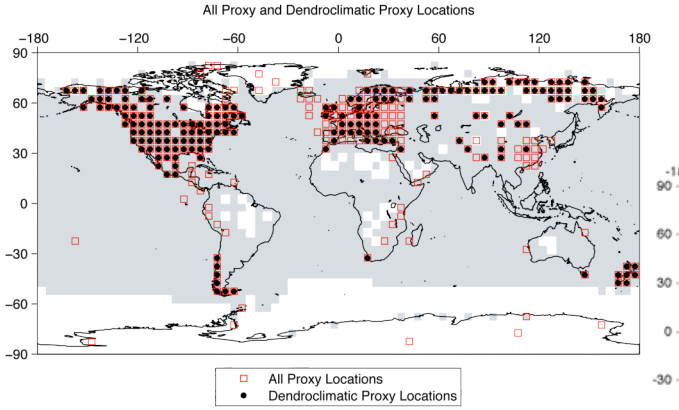
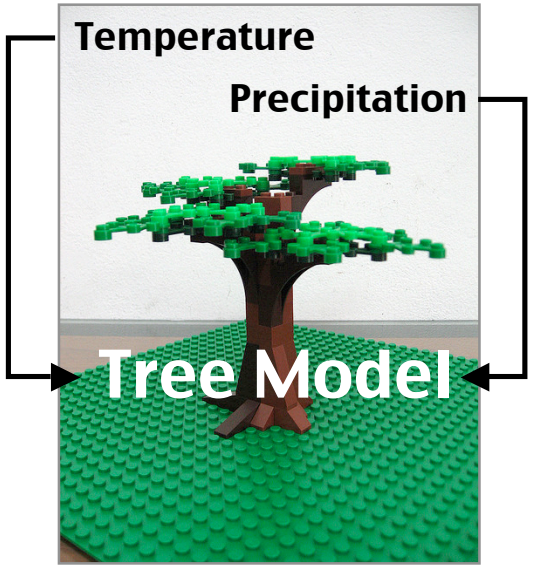
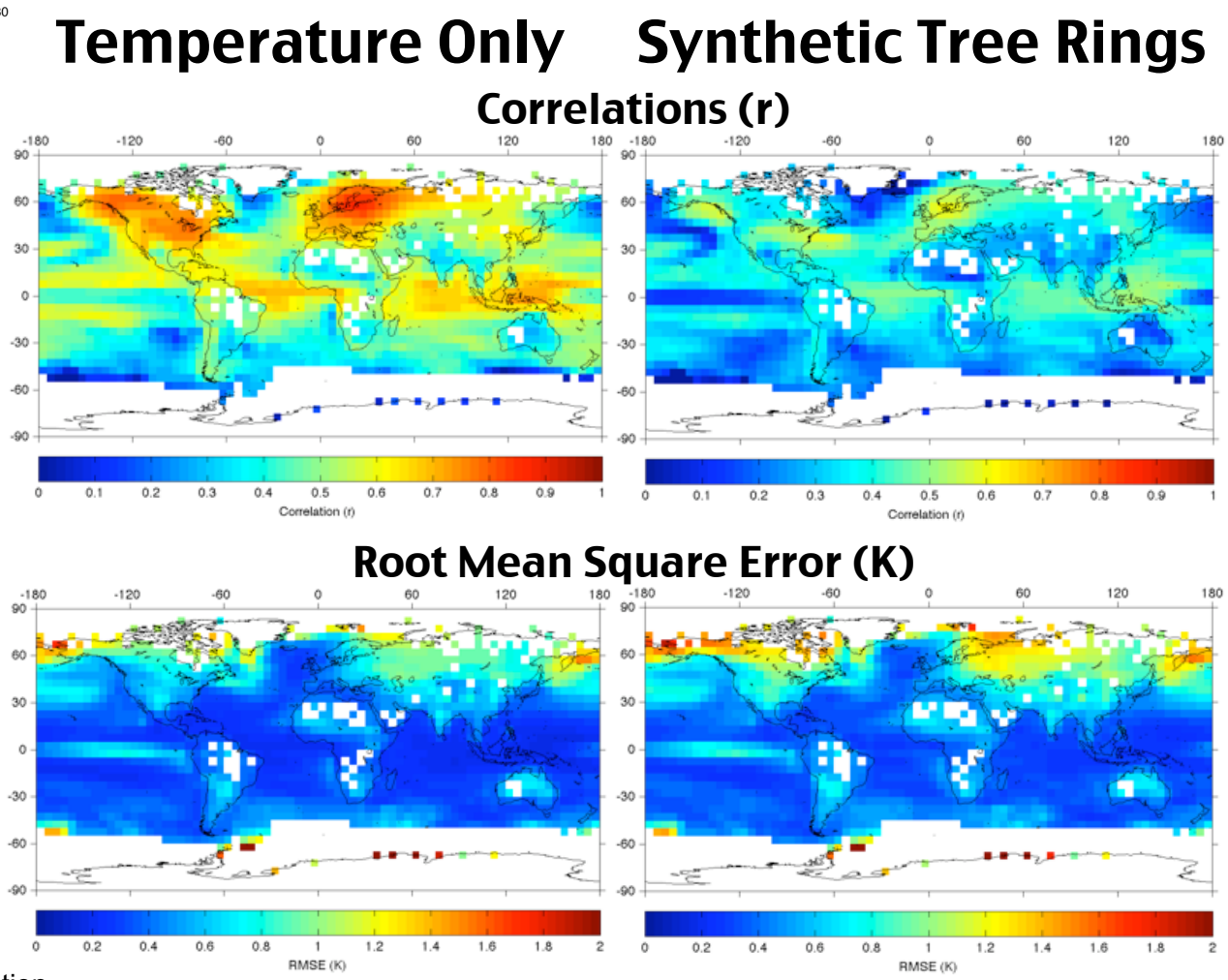
Synthetic Tree-Ring Experiments





Tolwinski-Ward, S.E., et al., An efficient forward model of the climate controls on interannual variation in tree-ring width, Climate Dynamics, doi:10.1007/s00382-010-0945-5, (2010).



Smerdon et al., Impact of tree-ring simulated pseudoproxies on reconstruction skill in climate field reconstructions, in prep.

CFRs and the Future

Work with what we've got

- Uncertainties, uncertainties, uncertainties…
- Expanded proxy networks
- Constrained CFRs targeting high skill regions
- Continued methodological testing

Work toward what we've not

- Process-based characterization of climate-proxy connections
- Local calibrations and error constraints
- Bayesian formulations
- Other climate variables (multivariate target fields)