A Data-Model Comparison over Europe using a new 2000-yr Summer Temperature Reconstruction from the PAGES 2k Regional Network and Last-Millennium GCM Simulations

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A new reconstruction of European summer (JJA) land temperatures is presented and compared to 37 forced transient simulations of the last millennium from coupled General Circulation Models (CGCMs). The reconstructions are derived from eleven annually resolved tree-ring and documentary records from ten European countries/regions, compiled as part of the Euro_Med working group contribution to the PAGES 2k Regional Network. Records were selected based upon their summer temperature signal, annual resolution, and time-continuous sampling. All tree-ring data were detrended using the Regional Curve Standardization (RCS) method to retain low-frequency variance in the resulting mean chronologies.

A nested Composite-Plus-Scale (CPS) mean temperature reconstruction extending from 138 B.C.E. to 2003 C.E. was derived using nine nests reflecting the availability of predictors back in time. Each nest was calculated using a weighted composite based on the correlation of each proxy with the CRUTEM4v mean European JJA land temperature (35°-70°N, 10°W-40°E). The CPS methodology was implemented using a sliding calibration period, initially extending from 1850-1953 C.E. and incrementing by one year until reaching the final period of 1900-2003 C.E. Within each calibration step, the 50 years excluded from calibration were used for validation. Validation statistics across all reconstruction ensemble members within each nest indicate skillful reconstructions (RE: 0.42-0.64; CE: 0.26-0.54) and are all above the maximum validation statistics achieved in an ensemble of red noise benchmarking experiments.

A gridded (5°x5°) European summer (JJA) temperature reconstruction back to 750 C.E. was derived using Bayesian inference together with a localized stochastic description of the underlying processes. Instrumental data are JJA means from the 5° European land grid cells in the CRUTEM4v dataset. Predictive experiments using the full proxy data were made, resulting in a multivariate distribution of temperature reconstructions from 750-2003 C.E. The mean of this distribution is the optimal estimate of the gridded JJA temperature anomalies and its width provides objective reconstruction uncertainties. The derived reconstruction is compared to withheld instrumental and proxy data to evaluate reconstruction skill on decadal-to-centennial time scales. A comparison between the mean Bayesian and CPS reconstructions indicates remarkable agreement, with a correlation during their period of overlap of 0.95.

In both the Bayesian and CPS reconstructions, warm periods during the 1st, 2nd, and 7th-12th centuries compare to similar warm summer temperatures during the mid 20th century, although the 2003 summer remains the warmest single summer over the duration of the reconstructions. A relative period of cold summer temperatures is also noted from the 14th-19th centuries, consistent with the expected timing of the Little Ice Age. Comparisons between the reconstructions and the 37-member ensemble of millennium-length forced transient simulations from CGCMs, including eleven simulations from the collection of CMIP5/PMIP3 last-millennium experiments, indicate good regional agreement between reconstructions and models. Based on the separation of simulations

into strong or weak scaling of total solar irradiance (TSI) forcing over the last millennium, there is some evidence that there is better agreement with the ensemble using strong TSI as forcing.