



just a few proxy records to represent a well-sampled NH average temperature, land-based temperature proxies to reconstruct marine temperatures, and precipitation-sensitive proxies to reconstruct past temperatures might all result in reconstructions that are insufficiently “red” (see the figure caption), that is, lacking in variance at longer time scales.

The message of the study by von Storch *et al.* is that existing reconstructions of the NH temperature of recent centuries may systematically underestimate the true centennial variability of climate. The factor of 2 or more suggested by their study is uncertain because the extent of the problem may depend on the shape of the real climate spectrum. Of course, we do not know the true shape of the spectrum of NH temperature for recent millennia. Nor do we know whether the 1000-year climate simulation used by von Storch *et al.* is closer to the real world than any of the various proxy-based reconstructions. Other model simulations of the climate of the past 1000 years (5) may be less “red,” implying that the underestimation of long-term climate change could be less pronounced.

If the true natural variability of NH temperature is indeed greater than is currently accepted, the extent to which recent warming can be viewed as “unusual” would need to be reassessed. Systematic errors in existing climate reconstructions will also complicate the evaluation of climate model simulations of past variability. Achieving consistency between our knowledge of past climate and model simulations of that climate is crucial for building confidence in our ability to simulate future climate.

Incompatible colors of climate variability. (A) A variance spectrum expresses the amount of variance in a time series that occurs at different frequencies or time scales. A white spectrum has equal variance at all time scales, whereas a red spectrum has greater variance at longer time scales than at shorter time scales. A typical temperature record has a “red” variance spectrum. (B) Pseudo-proxies constructed by adding white noise to a simulated temperature record have variance that is increased equally at all time scales, reducing the “redness” of the spectrum (the ratio of long-time scale to short-time scale variance). (C) Regression-based calibration approaches scale the pseudo-proxy records by constant multipliers, leaving their redness unchanged (and thus still lower than the redness of the actual temperature spectrum). (D) It is not possible, therefore, for any linearly scaled proxy record to match the actual temperature spectrum at all time scales, and the fit tends to be optimized to the time scales represented in the calibration period (typically the last 100 years or less, and dominated by annual to decadal variability), resulting in a deficiency in variance at longer time scales.

The most important ramification of the report of von Storch *et al.* (1) is that greater long-term climate variability is likely to imply greater sensitivity of climate to radiative forcings such as greenhouse gases. Improved climate reconstructions, further model

simulations, and a methodology that takes account of all sources of error are needed to determine whether the widely cited range of a 1.5 to 4.5 K increase in average global temperature for a doubling in CO₂ (6) is compatible with evidence from the past. It is already clear, however, that

greater past climate variations imply greater future climate change.

References and Notes

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PLANT BIOLOGY

A Plant ABC Transporter Takes the Lotus Seat

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When plants moved from water to land 450 million years ago, they needed to develop a sealed surface to protect themselves against water loss in the “dry” air environment. To solve this problem, plants invented an epicuticular wax layer that covers the entire surface of the plant that is exposed to air. This protective wax cuticle also serves a multitude of other functions. Its elaborate micro- and nanostructure prevents water and other particles from sticking to the surface of leaves, keeping them clean and so enhancing their ability to trap light for photosynthesis. Adhering water droplets and other particles are washed away in a self-cleaning

process called the lotus effect (1). The wax layer also filters out damaging ultraviolet rays, prevents volatile chemicals and pollutants from sticking to leaves and stems, and protects plants against attack by microbes and herbivores.

The plant cuticle is composed of a mixture of cutins and polysaccharides, an intracuticular wax layer, and an epicuticular surface layer of wax crystals (see the figure). The wax layer is formed from wax precursor molecules—very long chain fatty acids (VLCFAs) and their derivatives—that are synthesized by plant epidermal cells. But how is such an elaborate structure constructed on the surface of plants? How do the highly hydrophobic wax precursor molecules get to the construction site outside of the plant cell? And what were the evolutionary steps that led to this innovation? On page 702 of this issue, Pighin *et al.* (2) provide crucial in-

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