

To the editor – Ji *et al.*¹ present a methodology to analyse global (excluding Antarctica) spatiotemporal patterns of temperature change, using mean monthly temperature obtained from the updated Climate Research Unit (CRU) high-resolution gridded climate database^{2,3}. Their analysis fails to take into account several key characteristics of the CRU database, seriously compromising the conclusions regarding the spatiotemporal patterns of global warming during the 20th century.

Climatic data comes from thousands of stations scattered non-randomly across Earth, with much higher densities at mid-latitudes than in the tropics or the Arctic, creating spatial bias. A distance-weighted interpolation from available meteorological stations was implemented to fill spatial gaps in the CRU database²⁻⁴. Land pixels outside a search radius of 1,200 km from the closest meteorological station were given the corresponding CRU 0.5° 1961–90 mean monthly climatology^{4,5}

(Supplementary Figure 1).

In terms of temporal bias, the CRU dataset logically contains many less observations in the early part of its record. This is particularly prevalent in remote tropical and arctic regions, where temperature records abound with long-term climatological averages. Consequently, the temporal autocorrelation of such time-series is artificially high, and the climatic variability they portray for the early decades of the record, meaningless (**Fig. 1**).

Ji *et al.*¹ fail to address these spatial and temporal biases. **Supplementary Figure 3** strongly suggests that the absence of a trend over the first half of the 20th century in many tropical regions can be attributed to the lack of climatic information and the corresponding flattened time-series representing a succession of climatological means. Consequently, early-warming hotspots (between 1900 and 1950 C.E.) – and their delayed-warming counterparts – share the spatial patterns of meteorological station availability: that is, early-warming regions largely coincide with the availability of climatic data. It is of concern that many of the regions with the highest observed lag-1 autocorrelation in Ji *et al.*¹ (**Fig. 6, Supplementary Information**) occur in tropical regions with many repeated values (**Fig. 1**). The frequency decomposition method shown in **Fig. 4, Supplementary**

*Information*¹ for three grid cells in North America would reveal the above-mentioned limitations if applied to many tropical regions.

We believe it very likely that the spatiotemporal temperature patterns described in Ji *et al.*¹ are strongly contaminated by the spatial and temporal heterogeneities of the *CRU database*.

Independently of the high spatiotemporal locality of the statistical procedures used in Ji *et al.*¹, the problem affects the whole analysis, since this consists of a global comparison between all regions (i.e. comparisons between regions with adequate data and regions with poor data are biased) and time periods (i.e. artificially flattened trends in early 20th century will reflect slower warming trends than observed trends in late 20th century).

Reliable results using this approach may be obtained restricting the analysis to periods and areas over which it can be carried on: this can be transparently achieved by removing all points falling outside the search radius for each month (available from the CRU). If the aim is global coverage, the optimal period should not start before the 1950s (see e.g. Burrows *et al.*⁶), although this would compromise the authors' aim to capture long-term trends¹.

References

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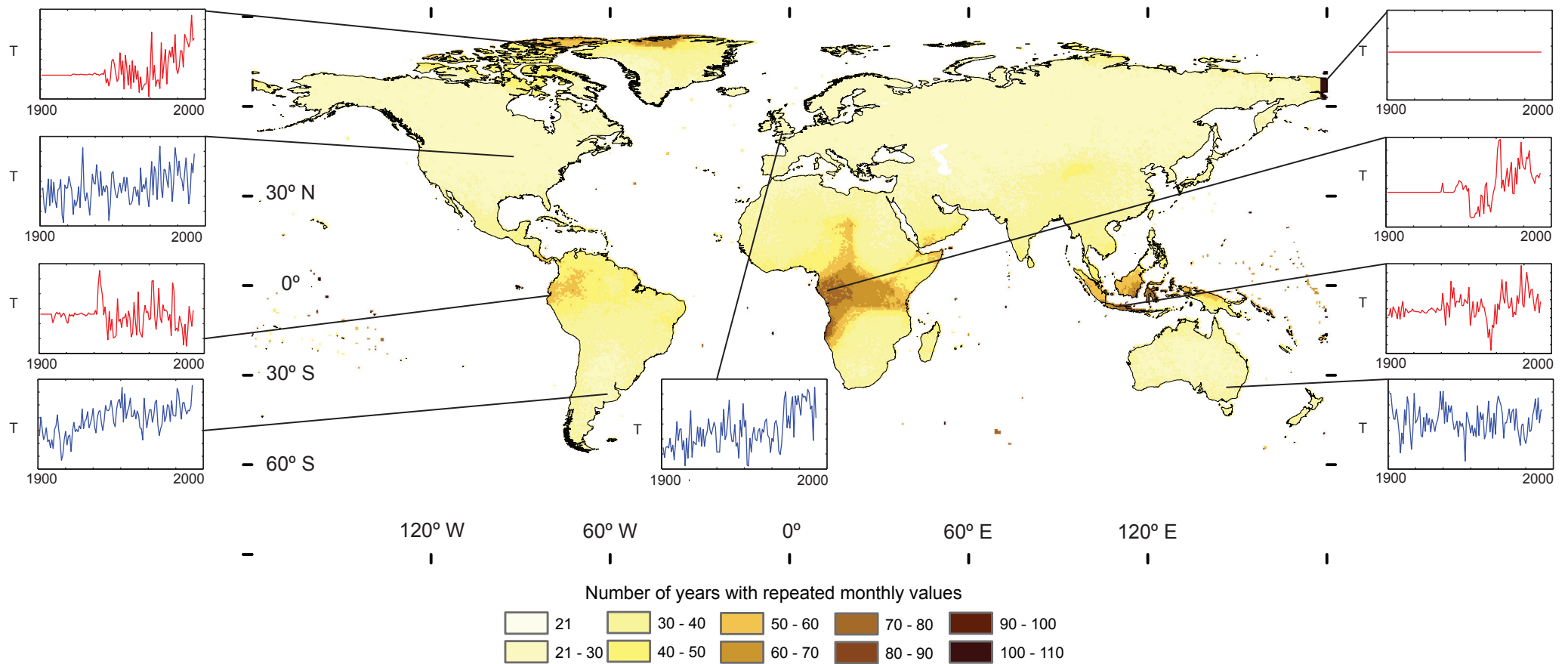
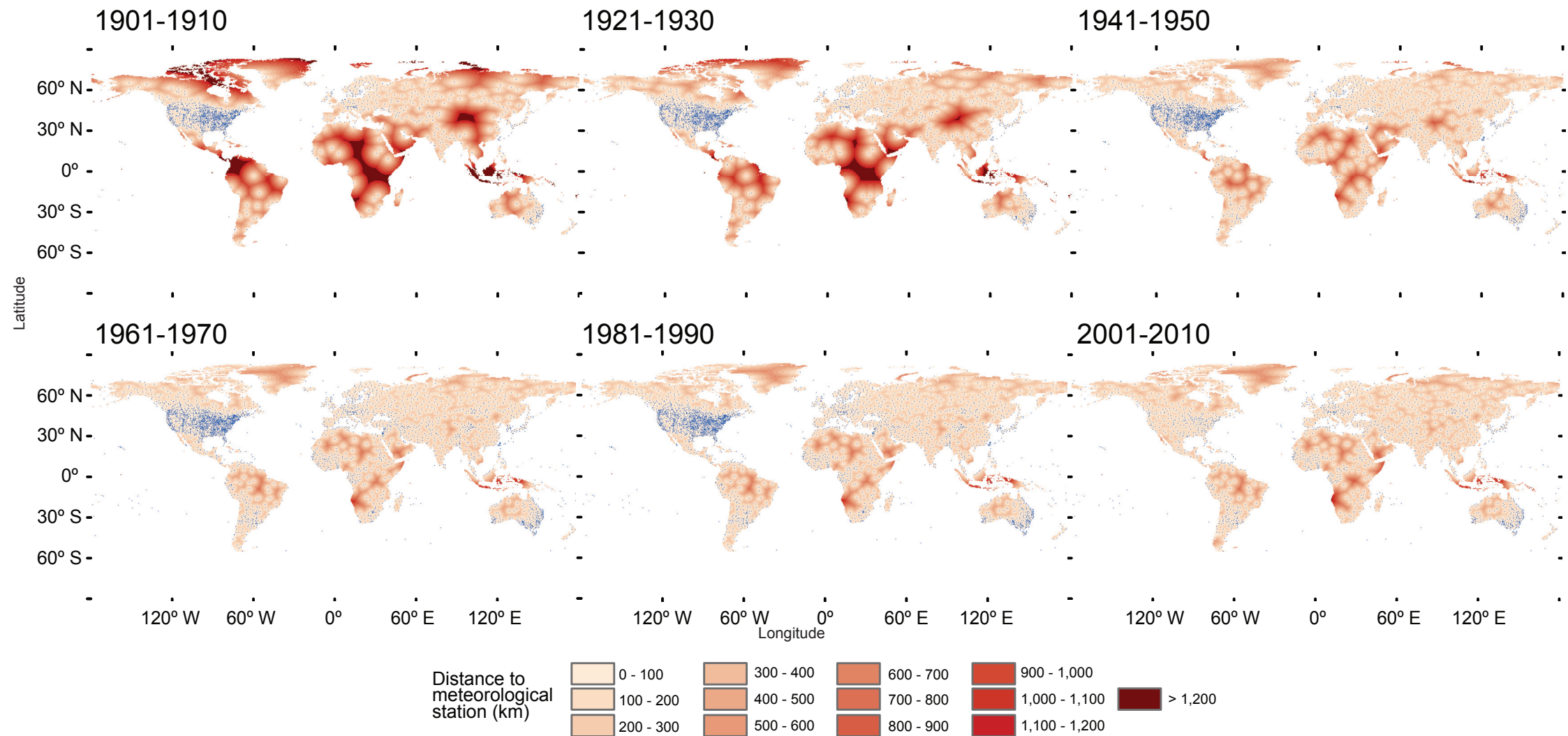
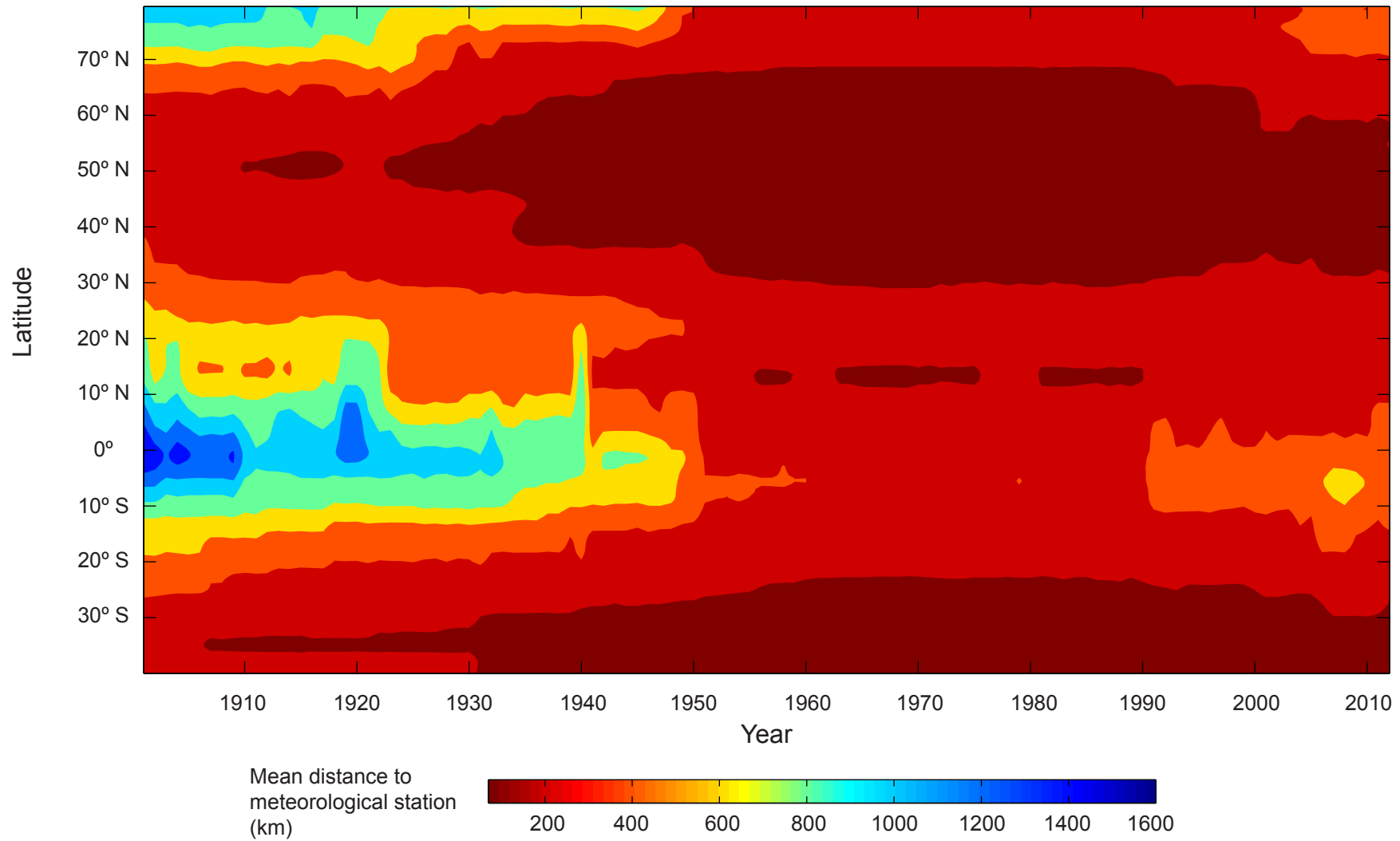


Figure 1. Number years with repeated monthly temperature values per 0.5° land grid cell (e.g. repeated March temperature values over different years; period 1901-2012). Note the large area in which many repeated values are found, strongly suggesting the substitution of missing values with the corresponding CRU 0.5° 1961–90 mean monthly climatology^{4,5}, especially in the initial decades of the 20th century. Inset time-series show the consequences of this on climatic variability for grid cells with good coverage (*in blue*) vs. grid cells with poor coverage (*in red*). The indiscriminate use of all time-series invalidates the frequency approach used in Ji *et al.*¹.



Supplementary Figure 1. Location of meteorological stations used in the production of the *CRU database* per decade (**blue dots**). The distance of every 0.5° land grid cell to the nearest meteorological station is shown as an underlying colour scale (darkest areas denote areas where no contemporary meteorological station data were used). The interpolation methodology can be seen in the spatial structure of the distances. Note the large area in the tropics and the high northern latitudes for which very little or no meteorological data was available during the first decades of the 20th century. This summary figure shows the maximum number of stations available per decade: that is, distances to meteorological stations for individual months/years within each decade might be larger.



Supplementary Figure 2. Temporal evolution of the zonally averaged minimum distance to a meteorological station for every 0.5° land grid cell. A running mean over a 5° band in the meridional direction was applied (as in Fig. 3 in Ji *et al.*¹). Note the similarity with the temporal evolution of warming depicted in Fig. 3 in Ji *et al.*¹.