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Metrological issues in producing gridded temperature data sets

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Quantitative evidence that global temperature is rising is provided by three data sets, produced independently, of monthly global average temperature at a resolution of several hundred kilometres. Less well known is how climate is changing on a relatively short time scale in different regions on the surface of the globe, a vital concern because of the effect of local temperature extremes on health, transport, energy consumption, etc., as evidenced by recent international disasters.

It was agreed at the WMO's Third World Climate Conference in September 2009 on the need "to strengthen production, availability, delivery and application of science-based climate prediction and services". In February 2010 the Commission on Climatology of the WMO endorsed a UK Met Office proposal to produce land surface temperature data sets on a three-dimensional grid (latitude, longitude and time) [1]. These data sets would have a spatial resolution of a few kilometres and a temporal resolution of one day or less.

The UK Met Office hosted an international workshop in September 2010 to initiate consideration of this challenging task. It was recognized that metrologists have a key role to play in constructing these gridded data sets (GDSs). A large part of metrology today necessarily concerns measurement data processing, including statistical analysis, uncertainty evaluation and numerical analysis, and related measurement modelling. This paper considers metrological issues in producing GDSs, concentrating on traceability, measurement uncertainty, and the interpolation schemes used.

Traceability of measurement is an essential consideration in producing credible data sets. Lack of traceability to internationally agreed standards, in this case the international temperature scale of 1990 (ITS-90) [2], would undermine confidence in the background data, allow for legitimate scepticism and weaken arguments with legislators. The assignment of measurement uncertainties to raw temperature data should be carried out by following internationally agreed best practice [3]. An interpolation scheme used for producing GDSs can be regarded as an input-output model. The quantities for which the raw data are estimates are inputs, and quantities for which the required grid values are to be best estimates are outputs. Uncertainties and correlations associated with a GDS can be obtained by propagating the input uncertainties (those associated with the raw data) through this model [3]. There would be further traceability considerations arising from the manner in which the GDS was formed.

Metrologists would also be able to contribute to a GDS and its use regarding quality issues, definition of measurands, determination of temperature trends, and the influence of statistical correlation.

Concerning quality, it should be ensured that both raw and interpolated temperature data are obtained by means that are recorded in detail (that is, transparent and reproducible) and validated [4]. Also relevant is the topic of homogenization, which is concerned with detecting inhomogeneities in the raw data and making adjustments to create a homogenized data set. Appropriate definition of the measurand, the quantity intended to be measured, is essential. The (ultimate) measurand would be a carefully constructed function of temperature such as the average temperature over a prescribed region (say, between pairs of latitudes and longitudes) at a specified date and time. A time series of best estimates of such measurands would be used to discern temperature trends in that region and their statistical significance, taking full account of uncertainties and correlation.

In addressing the issues associated with environmental data, a multidisciplinary approach is required to which the metrology community has much to offer: measurement traceability, uncertainty evaluation, modelling (including approximation, regression and interpolation, and the comparison of candidate models), numerical analysis, statistics, and software testing (benchmarking).