What are the Sources of Uncertainty in the Tree-Ring Data: How can They be Quantified and Represented?

White paper on tree rings submitted by Keith Briffa and Ed Cook

Essential to recognise and distinguish between

i. Uncertainty in the Tree-Ring Data themselves
ii. Uncertainty in the interpretation of these data

– though they are linked it is *more informative* to *represent them separately*.

Uncertainty in the Tree-Ring Data Themselves

Vital to recognise that there is not necessarily a unique growth influence (or 'signal') underlying "a chronology" but rather a potential mix of ecological forcings and responses at different timescales and levels within trees, forests and regions. This is not semantics – it affects the way the net growth forcing signal is expressed and the extent to which "it" may be maximised by replication and statistical processing and how it will likely vary through time.

i.e. Sample collections may represent varying sample homogeneity and hence different growth-forcing signals. This is at heart of chronology confidence.

Tree-ring research has traditionally traded on absolute dating: this is justified and rests on the rigour of crossdating, effectively at a near inter-annual timescale where the data are often strongly coherent. Even here crossdating power is sometimes associated with intermittent common behaviour (signature events) and there is potential for error with low replication and short overlap – but in general this is not a problem.

At "medium-frequency" timescales [decades to centuries] the expression of common growth variability is probably invariably weaker than for year-to-year changes – yet we commonly use inappropriate measures of this medium-frequency common variability (e.g. running EPS using short-period window) to claim "a chronology is of acceptable statistical quality." Low-frequency tree-ring variance [centuries to millennia] is virtually unresolved in all but a few chronologies worldwide. In many multi-century-length series it is undefined or random! This is because of the statistical standardisation techniques used with the intention of mitigating tree 'age effects' bias in tree-ring and other tree-derived measurement timeseries.

Curve fitting methods suffer from 'segment length curse'. They can also suffer from "end-effect bias" when recent growth forcing signal is increasing (Melvin and Briffa paper in press). This effect is certainly implicated to some extent in the contentious "divergence" issue, i.e. the *apparent* loss of temperature sensitivity *apparently* manifest increasingly over recent decades in various high-latitude locations, like in North America, Northern Europe and Siberia.

Some methods for processing tree-ring data (Regional Curve Standardisation and Age-Band Decomposition) do preserve more medium and long-timescale evidence of growth forcing changes, but they very prone to bias associated with non-homogenous samples and potential end-effect bias (Briffa and Melvin paper in press).

A fundamental problem is that tree-ring data from a site/region can produce very different chronologies according to specific sampling and processing – this is confusing for secondary users and other non-dendroclimatologists.

Uncertainty in the Interpretation of These Data

A major source of such uncertainty is the imposition/selection of a specific climatic parameter against which to 'calibrate' tree-ring chronology or chronologies. Many series have strong seasonal sensitivities, but their characterisation is also variable in time. Climate forcing is often time varying and its expression in different tree-growth parameters subject to complex lag effects. There is a likelihood of regression bias (in regression coefficients) arising with respect to the characteristics of the calibration data, in terms of spectral make up and in terms of any recent anomalous response that might be uncharacteristic of other periods (possible anthropogenic effects). The way in which the climate data have been pre-processed (i.e, homogenized) is also an issue that can profoundly affect interpretations of tree-ring data. This makes it doubly hard to identify and assess the signal(s) in the tree rings because it all may not be the tree rings fault!

There exists very large potential for over-calibration in multiple regressions and in spatial reconstructions, due to numerous chronology predictors (lag variables or networks of chronologies – even when using PC regression techniques). Frequently, the much vaunted 'verification' of tree-ring regression equations is of limited rigour, and tells us virtually nothing about the validity of long-timescale climate estimates or those that represent extrapolations beyond the range of calibrated variability.

Using smoothed data from multiple source regions, it is all too easy to calibrate large-scale (NH) temperature trends, perhaps by chance alone.

Possible ways of Reducing Uncertainties

We need a different mind set as regards sampling: sample numbers an order of magnitude greater than the "commonly perceived" need for 15-20 trees should be targeted, even at a single site level. While this "mega-sampling" approach is highly desirable, its practicality is often limited by the nature of the tree-ring resource being sampled and available project resources.

We should not sample only dominant or co-dominant trees and not sample only the oldest trees.

Regional networks of such well-replicated data should be developed – and if possible from different ecological situations (range of elevations, aspect, substrate type, etc.). We must then undertake greater site characterisation of common growth trends, if necessary subdividing the data for separate processing. If a sample from a given site contains mixed growth forcing signals, even very large sample numbers will not resolve one or other signal series.

We must use chronology production techniques that preserve *common* low-frequency variability. We can apply and adapt these to mitigate biases. Chronologies should be constructed to represent different timescales of underlying growth forcing explicitly and with associated uncertainty expressed for specific areas and time scales. Much greater use and development of bootstrap and Bayesian approaches to uncertainty estimation should be made.

Chronologies should be interpreted on a local/regional geographic scale and the optimal climate data, with expressed uncertainty, used as input to Hemispheric or Global average reconstructions as a subsequent exercise. This is implicit in some spatial reconstruction approaches anyway.

Many chronologies need updating, but existing data sets need additional sampling (especially in 'proven' areas) to improve replication and allow improved standardisation methods to be used and enable longer calibration/verification and to explore responses of tree growth to recent climate trends in many areas of the world (i.e. just as stressed by IPCC AR4 Chapter 6).

Linear regression and issues surrounding them will be covered by other briefing papers.

Data Base/Archiving Needs

The ITRDB is a great resource. It needs to be continually improved to allow easy storage of other than "usual" tree-ring width data. Improved meta data should be sought for all submissions, including tree dimensions and architecture and information on context of measurements (routinely including estimates of missing rings to pith). When standardised indices are archived, precise details of standardisation options should always accompany them. This should include detailed output from the programs used for standardization, such as the ARSTAN program. Only in this way can others replicate how standardized tree-ring chronologies were developed.

However, it is not just the measurement data that should be highlighted in this discussion. As an example the following is a quote from Jonathan Palmer:

Major crisis looming here are the physical samples. We are loosing the trees. Steady can tell you about his efforts in SE-Asia. In NZ, we have 40,000 year old ancient kauri being mined. I reckon it will be exhausted within 10 years. The holocene sites in 5 years. Saw-millers are already starting to buy farms so that they can secure some future supply. We have set-up an archive at a local museum for biscuits of kauri for future research

programs. In other words I have adopted a fire-fighting approach - save as many samples as I can and hope there might be funding to work on them later. Steady has funded me over the last 5 years to collect silver pine (Halocarpus biformis) from the West Cost. We have multi-millennial chronos thanks to that investment - but some sources have been completely destroyed by the land being converted to dairy pastures. The other area is now a kiwi habitat sanctuary so the permit process for further sampling has become much harder. So, data archiving is vital, but I'm first trying to save samples!

Many dendro people, in different parts of the world, could tell similar stories. PAGES highlighted this problem once, but little came of it. The sources of old tree-ring material are disappearing around the world and as old dendrochronologists whither away, their sample collections often disappear with them!