New approaches to constructing age models: OxCal4

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Introduction

When looking at past changes in the climate and their impact on the environment, timing is all-important. This is not so much because we want to know exactly when something happened but because we want to know how fast and in what order the changes occurred. For this reason, very well dated records, such as ice-cores, play a major role in our understanding of past climate. For most environmental records we need to make use of less precise dating methods, such as radiocarbon or Uranium series, sometimes in conjunction with relative dating information from varves or deposition-rate models. In order to improve overall dating precision, assumptions are also sometimes made about the synchronous nature of climate change—assumptions that can result in circular reasoning when we come to interpret the results.

Age models with uncertainties

It is an unfortunate fact that once we put together a lot of information from different sources, we introduce considerable uncertainties in our age estimates. This is particularly true in the case of radiocarbon dating, where the calibration process results in complex probability distributions that are frequently multimodal. In order to get back to something that is easier to deal with, simple best-fit age models are often applied. However, while this approach may be useful for putting a record roughly onto an absolute timescale, it is not good enough if we wish to compare the timing of events between records with good accuracy and precision. To do so, we need ways of estimating our uncertainties in age at all points in the records and to recover as much relative date information as possible.

For these reasons there has been increasing interest in methods for combining information from different sources. For over a decade now, such approaches have been used in archeological studies where we frequently have relative date information and increasingly these methods are being used in other disciplines (Buck and Millard, 2004). This is in part due to the widespread availability of software such as OxCal (Bronk Ramsey, 1995), BCal (Buck et al., 1999) and DateLab (Jones and Nicholls, 2002) for performing such analyses. In recent years, such methods have also been applied to deposition models, particularly for peat (see for example Blaauw and Christen, 2005). At the 19th international radiocarbon conference held in Oxford in April 2006 (http://c14.arch.ox.ac.uk/conference.html) there were several papers presented on developments in age-depth modeling, including the new age-depth models included in the OxCal program.

Deposition models in OxCal

Version 4

OxCal is a computer program for analysis of chronological information. It is freely available for online use or for download to PC or Mac from http://c14.arch.ox.ac.uk/oxcal.html. Although it is most often used for the straightforward calibration of radiocarbon dates, it can also be used to build chronological models of various kinds, using a range of different dating techniques. Previous versions of the program enabled the stratigraphic order of samples to be constrained within a sequence, and also catered for the special case of known age gaps when ‘wiggle-matching’ radiocarbon-dated tree-ring sequences to the calibration curve.

The new version of the program caters for a much wider range of deposition models. These models were first discussed at the INTIMATE workshop in Iceland in September 2005 (Bronk Ramsey, in press). They range from the loose constraint that dates must be in a particular order (called the Sequence model) to the rigid assumption that the deposition is assumed to be uniform in nature with a constant rate (called the U_Sequence model). Both of these models have been implemented before in several software packages. However, the true situation usually lies between these extremes and a model that allows for random fluctuations in deposition (called the P_Sequence model) is also included and should be appropriate in a much wider range of situations. In many cases, where there are large-scale exposures or multiple cores, the degree of fluctuation in deposition rate can be independently assessed, in other cases this needs to be assessed from the nature of the sediments, or from the dating information itself.

Figure 1 shows one such simple age-depth model and Figure 2 shows the effect of the model on our estimate for the age of one particular sample in the series. The main advantage of using such mod-
21st century suck-in or smear: Testing the timing of events between archives

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Introduction
Proxy-archives are frequently compared with other data in order to imply teleconnections between regions. Well-known examples of widely recorded past climate events are the last glacial-interglacial transition, the “8.2 kyr event”, and the “Little Ice Age”. Although we do not question the existence of these events, reported synchronicity between archives could have been caused by age-modeling errors, mistaken interpretations of proxy data, or even by “wishful-thinking”. Archives could have been tuned to other archives, age-models selected subjectively, non-responsive sites neglected, or suggestive lines drawn connecting events between archives. It is this potentially dangerous practice of sucking-in or smearing of events that we will discuss here. Let’s start with a short review of the usual steps to date and compare non-annual archives:

1) Single archives are dated by, for example, radiocarbon at several depths.
2) These dated levels, with their often considerable chronological uncertainties, are reduced to point estimates (e.g. the midpoints of the calibrated ranges for 14C dates).
3) A single curve is drawn through these points (e.g. linear interpolation, regres-