Quaternary Science Reviews 63 (2013) 109–127

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

How to evaluate model-derived deglaciation chronologies: a case study using Antarctica

Robert D. Briggs, Lev Tarasov*

Department of Physics and Physical Oceanography, Memorial University of Newfoundland, St. John's, NL A1B 3X7, Canada

ARTICLE INFO

Article history:
Received 30 June 2012
Received in revised form
15 November 2012
Accepted 18 November 2012

Keywords:
Model evaluation
Observational data
Ice-sheet model
Antarctica
Deglaciation
Data model comparison

ABSTRACT

We address the evaluation of model-derived deglaciation chronologies using observational data. The study has been undertaken using the Antarctic ice sheet as the focus, however, the issues addressed and the methods described are applicable to the evaluation of other ice sheet reconstructions. Within this context, we present an initial database of observational data for constraining Antarctic ice sheet deglaciation chronologies (AntICEdat). The database constrains present-day ice sheet configuration, relative sea level, past ice thickness and grounding line retreat and is made available as a spreadsheet. We consider the non-trivial translation of an observation to model-applicable constraint data. Through observational error models and data-weighting we address the main issues that arise from evaluating modelled reconstructions – generated with a glacial systems model that has, like all such models, inherent structural deficiencies – using heterogeneous observational data. The evaluation method uses observational error models to quantify model to observational misfits that also incorporate the measurement uncertainties for each data-point. The data-point misfits are adjusted by data-weighting and combined to generate a score for the model output. As such, different chronologies can be evaluated and compared. We examine the sensitivity of the score to the different data-types and associated weighting using model-derived reconstructions. In addition, suggested reporting requirements are proposed to ensure that maximum value can be extracted from observational data.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Like any numerical model of complex environmental systems, the glacial system models (GSMs) that are used to produce deglaciation chronologies necessarily invoke simplifications in their representation of physical processes (e.g. due to computational restrictions and incomplete understanding). Such chronologies therefore have little meaning without a clear account of uncertainties. Further uncertainties arise in the boundary conditions imposed (such as assumed climate forcings, subglacial topographies,...). By employing adjustable parameters, a modeller can account to a varying (but incomplete) degree for these uncertainties. Each set of model parameters defines a model glacial chronology and therefore is a sample out of a phase-space of possible reconstructions.

Exploration of this phase-space generally requires an ensemble of model runs and subsequent comparison of each run against observations to assess its plausibility. In this article we address the non-trivial question of how to quantitatively evaluate model generated deglaciation chronologies using observational data. Deglaciation chronologies are crucial to aid our understanding of ice sheet dynamics (be it past, present, or future), and global sea level change (e.g. Bentley, 2010; Kopp, 2012). Furthermore, associated uncertainty estimations are essential to ensure that the reconstructions can be interpreted with the appropriate degree of confidence.

A data-constrained large ensemble analysis technique has been employed in reconstructions of Greenland (Tarasov and Peltier, 2003), the North American ice sheet complex (Tarasov and Peltier, 2004), Eurasia (in prep.), and is now being employed in generating Antarctic ice sheet (AIS) reconstructions. This required the compilation of a AIS constraint database and an associated evaluation methodology for assessing each reconstruction against the observations, provoking this article.

Other data-model approaches have been used to evaluate ice sheet reconstructions. For the Greenland ice sheet (GrIS), Simpson et al. (2009) compared model generated configurations against relative sea level (RSL) and past ice extent data. By adjusting the lithosphere, upper and lower mantle thicknesses of the Earth viscosity structure, and the grounding line extent of the ice sheet

* Corresponding author.
E-mail address: lev@mun.ca (L. Tarasov).

0277-3791/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.quascirev.2012.11.021

model they produced different ice sheet configurations. Through assessment of the model to observations misfit they explored the sensitivity ranges of the results.

A recent AIS glaciological modelling study (Whitehouse et al., 2012) with the objective of producing a loading history for a glacial isostatic model, has produced a data constrained-deglaciation chronology with range estimated uncertainties of sea level contributions. They used the community ice sheet model Glimmer (Rutt et al., 2009) at a resolution of 20 km, to generate different AIS configurations at five time-slices (20, 15, 10, 5, 0 ka[1]). The reconstructions were produced by fixing the grounding line extent, defined using marine geophysical and marine geological data-sets, and adjusting the boundary conditions (climate inputs, bed sliding parameters, relative sea level, isostatic behaviour and geothermal heat flux). Each configuration generated was then evaluated using terrestrial constraint data for past ice sheet elevation and 'no-ice' zones. The model to observation misfit was then scored (see Whitehouse et al. (2012) for details) for each configuration. Weighting was applied using inverse distance and a subjective data quality factor.

However, no article to date (to our knowledge) has adequately addressed observational error models, data-weighting issues, and model scoring for glaciological reconstruction. The task of using observations to constrain model output requires both observational and modelling issues to be tackled, as such this article is targeted towards both communities. Although the focus of this study is the AIS, the issues that are addressed and the methods described are applicable to any ice sheet reconstruction.

The structure of the article is as follows: first a brief overview of the development of the constraint database is given, this is followed by a description of the compilation, sorting, and processing of published data so that it can be employed as constraint data for the AIS. The subsequent section presents the deglaciation chronology evaluation process. Next, the issues that are raised in applying the data to glacial reconstructions for the purposes of constraint are discussed. Finally a summary and discussion of future work and outstanding issues is given. To prevent the text becoming unwieldy many abbreviations are used and are listed in Table 1 for ease of reference.

Table 1
Table of abbreviations.

AIS	Antarctic ice sheet
AGGD	Antarctica Glaciological Geological Database
$ALBMAP_{40}$	ALBMAP dataset resampled to 40 km dataset as described in the supporting on-line material
$ALBMAP_5$	ALBMAP dataset at 5 km resolution
AntICEdat	Antarctic ICesheet Evolution database
EAIS	East Antarctic ice sheet
ELEV	Data-type: thickness from elevation markers
EXT	Data-type: ice sheet extent
Et	Total (grounded + floating) ice in EAIS
GLR	Grounding line retreat (variant of EXT)
MSE	Mean squared error
OMC	Open marine conditions (variant of EXT)
PALa	Only paleo data-types (with the baseline inter-data-type-weighting)
PD	Data-type: present-day ice sheet configuration
PDx	Present-day constraints, *x* is a unique identifier for the scheme
PDxPx	Schemes use both present day and paleo-data, *x*'s are unique identifiers
PDxPxSEy	Employs all data [just paleo-data] and sieve y
PxSEy	Employs just paleo-data and sieve y
RISgl	Ross ice shelf grounding line
RSL	Data-type: relative sea level
SE	Squared errors
SOM	Supporting on-line material
ShfAr	Ice shelf area
WAIS	West Antarctic ice sheet
Wf	Floating ice in WAIS
Wg	Grounded ice in WAIS
volg	Grounded ice volume
vol0g	Present day grounded ice volume
vol20g	LGM grounded ice volume
$\Delta\xi$	Equivalent sea level contribution (vol20g−vol0g)

2. Development of a constraint database

The Antarctic ICesheet Evolution database (AntICEdat) presented in this article has been developed to contain sufficient high quality data to provide spatial and temporal coverage (within the limits of the available data) for constraining modelled AIS deglaciation chronologies at continental and regional scales. This initial version is intended as the start of a community database that will evolve in both size and ease of access and update. As such, to ensure that AntICEdat is future-proof and flexible enough to be adopted for other purposes, a survey, summarized below, of existing constraint databases for Antarctica and other Quaternary ice sheets was performed. Their strengths and weaknesses were identified and used to guide the design of AntICEdat.

A comprehensive but unfortunately stale resource is the Antarctica Glaciological Geological Database (AGGD) (Kluiving and van der Wateren, 2001), a collection of geological, geomorphological and glaciological constraints taken from nearly 250 references, the most recent being 2001. The database format is a html website navigable by geographic locale; useful for viewing the data, but does not lend itself to automated processing and manipulation/searching by a user. The database includes all data-points from the original referenced studies including data that is inconsistent or that provides superfluous constraint information. For each site (which generally pertains to a single reference) there is a summary page presenting a table of data and a site description. Bentley and Hodgson (2009) provide an overview of on-shore and off-shore studies, made since 2000, effectively filling in the gap left by the AGGD.

Other resources are more data-type specific. As part of a study to explore the provenance of meltwater pulse 1 A, Bassett et al. (2007) present a textual summary of eight relative sea level (RSL) sites from around Antarctica, all those sites are used in AntICEdat. Following on from work focused in the Antarctic Peninsula by Heroy and Anderson (2007), Livingstone et al. (2012) presented an overview of AIS paleo-ice streams and, as part of that work, they compiled an exhaustive database of marine cores that provide ice extent data. The cores are made available in tabular form and as a spreadsheet.

The deglaciation study published by Whitehouse et al. (2012) presents a well-referenced suite of constraint data of differing types, organized by region and site. As a consequence of the modelling/evaluation methodology they employ, the data has been binned into 5 ka time slices. From this a minimum, maximum, and likely constraint is inferred. Individual data-points in their source form, as required by the evaluation method we present, are not available, nor are the temporal and spatial uncertainties provided.

Of the non-AIS database surveyed, two RSL databases were particularly useful in developing the format for this constraint database. Brooks and Edwards (2006) present a RSL database for Ireland compiled from existing publications, available for download as a spreadsheet. The database contains 206 data-points distributed (unevenly) around 22 regional sites. Because of the discordant nature of the data (as extracted from the source publications), they categorized the data into four groups based on the data quality and its utility. The large ensemble analysis of the North America ice

[1] Within this article ka is defined as 10^3 calendar years before present whereas kyr is a time period of 10^3 yrs.

Download English Version:

https://daneshyari.com/en/article/4736370

Download Persian Version:

https://daneshyari.com/article/4736370

Daneshyari.com