Mapping the Bølling-Allerød transition in the Greenland Ice Sheet using radio-echo sounding data

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Introduction

Radio-echo sounding (RES) data contain information about the dielectric properties of ice sheets, often manifested as internal layers (Fig. 1a). **The layers can be valuable tool for reconstructing the past of an ice sheet** because those layers that are caused by variations in impurity content and acidity are considered to be isochrones. Thus, the stratigraphy of the layers provides information on the past mass-balance rate and ice flow dynamics.

Here we present one of the first attempts at **mapping the internal stratigraphy of the Greenland ice sheet** specifically focusing on the climate transition at the end of the last glacial period 14,700 b2k (according to the GICC05 timescale (Rasmussen and others, 2006)).

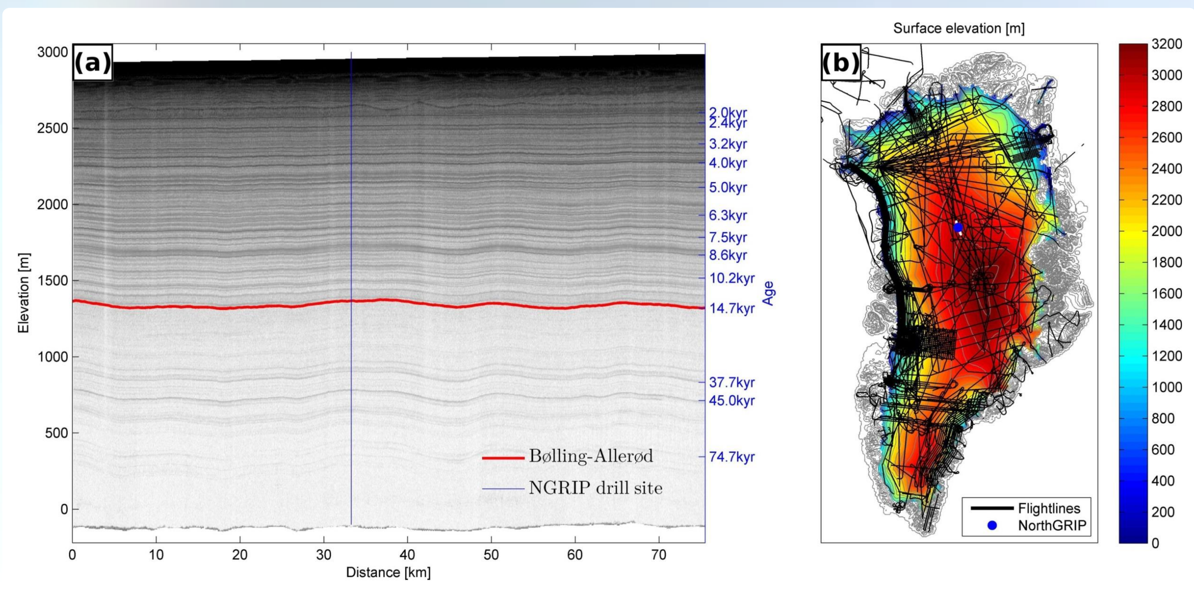

Fig. 1. (a) Example of a radargram (Z-scope) from central Greenland. The upper part has an overall higher background reflectivity than the deeper part. The Bølling–Allerød transition is indicated with a red line and it corresponds to a change in the radargram from higher to lower background reflectivity. The age–depth scale is based on the NorthGRIP ice core (NorthGRIP Members, 2004).
(b) Radar acquisition lines over Greenland as black lines overlain on surface elevation (Bamber et al.,, 2001). The location of the radargram in (a) is marked with a thick, white line, and the NorthGRIP drill site with a blue dot.

Data

The Center for Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas has conducted surveys of the Greenland ice sheet since 1993 (Fig. 1b, see also Gogineni et al., 2001). Comparisons with ice-core records obtained at the ice divide allow for dating of the internal layering in the RES data. The data presented here was acquired between 1993 and 2012.

Results

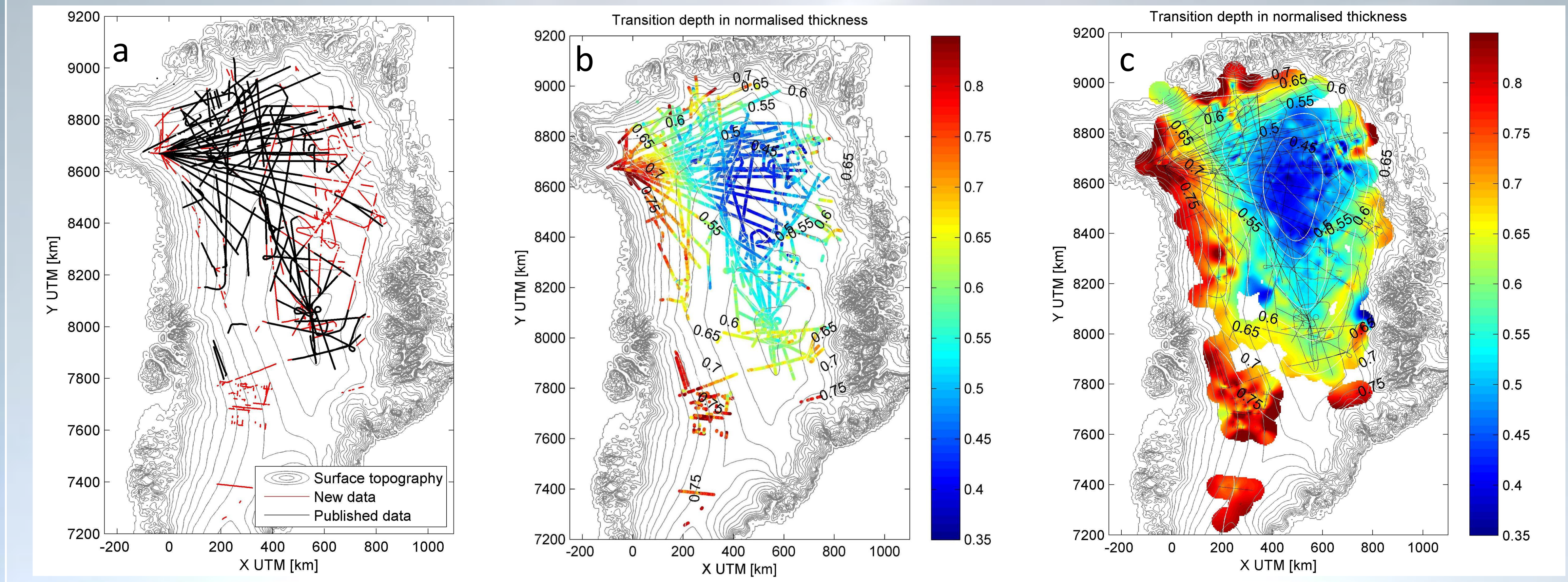

Fig. 2. Surface topography in thin grey lines (Bamber et al., 2001). (a) The location of the radar flightlines processed in this study. (b) The normalised depth of the B-A transition. (c) A gridded map of the normalised depth of the transition in colours with radar flightlines as black lines. White contours outline the transition depth from 0.4 to 0.75 with intervals of 0.05. All data points >50km from a flight-line have been masked out.

The B-A transition was identified and traced in over 450 flightlines (Fig. 2a). To correct for variations in ice thickness the depth of the transition is shown in normalised thickness (where the ice surface = 0). The depth of **the transition varies from 0.24 to 0.98 with a mean value of 0.56** (e.g. Fig. 2b). The maximum depth is found at the margins while the transition is closest to the surface in northern Greenland east of the ice divide (Fig. 2b, 2c).

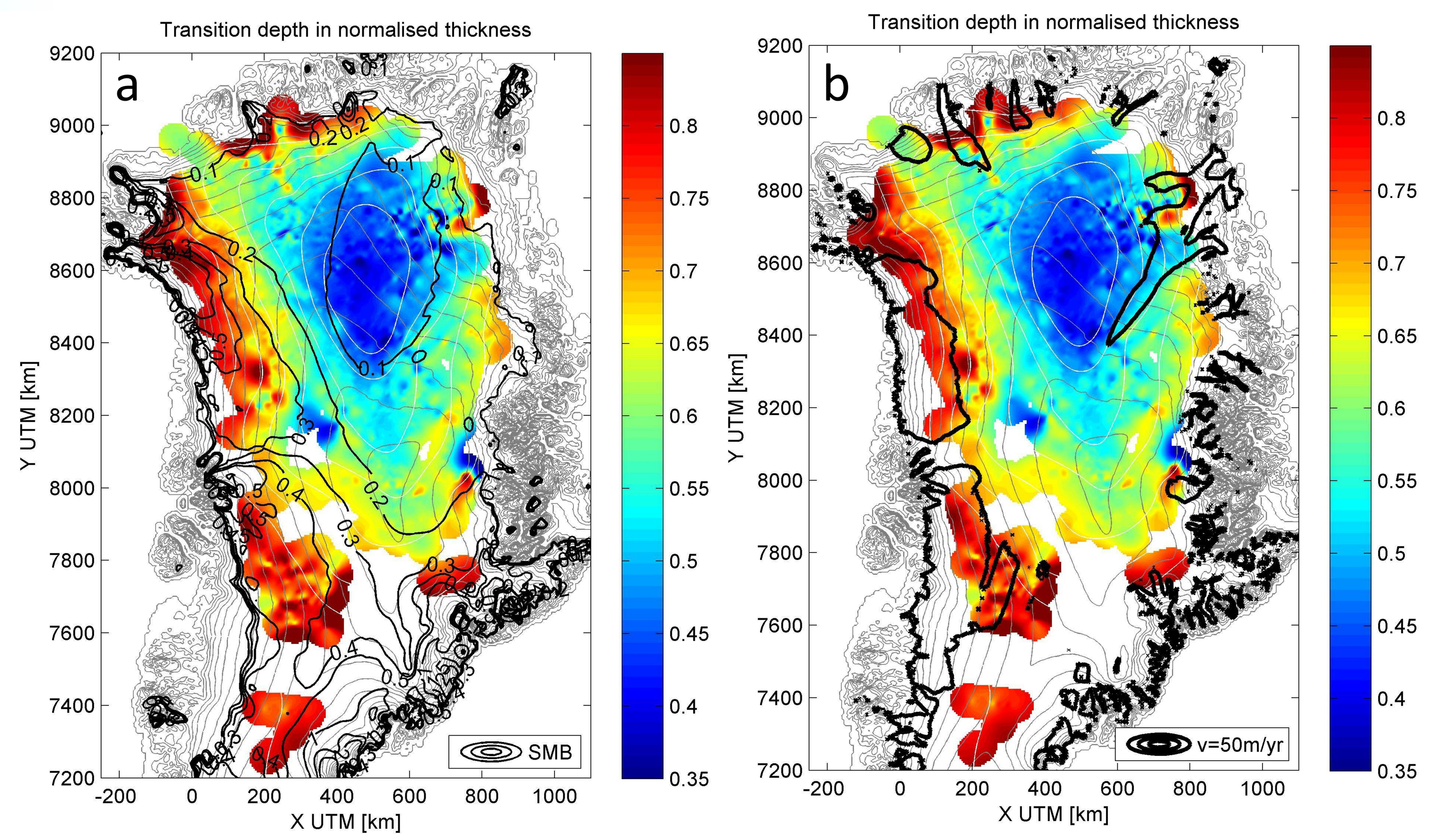

Fig. 3. Normalised depth of the transition. White contours outline the transition depth from 0.4 to 0.75 with intervals of 0.05. All data points >50km from a flight-line have been masked out. (a) Black contours show the surface mass balance (Ettema and others, 2009). (b) The 50m/yr surface velocity contour from Joughin et al., (2010) is shown as a thick black line.

To the first order, the surface mass balance controls the depth of an internal layer. Comparison between current surface mass balance and the transition depth (Fig. 3a) show a clear correlation, indicating that that **the large-scale accumulation pattern has not undergone substantial changes since the onset of the Holocene.** Indications of basal melting can be seen in several flightelines, while further drawdown of the transition can be observed in areas of fast ice flow (Fig. 3b), for example close to the large “Northeast Greenland Ice Stream”.

Use of the data

It is the aim of this study to provide data input for modelling studies of the Greenland Ice Sheet. The dataset may be incorporated in ice flow models to answer questions related to large scale dynamics of the ice sheet such as the extent of the ice during the last glacial, or to investigate the spatial and temporal scales of ice flow in more localised regions.

Methods

Inspired by Mudelsee et al., (2000) we fit the RES data to a 2D version of a ramp function :

$$x(t) = \begin{cases} x_1 & \text{for } t \le t_1 \\ x_1+(t-t_1)(x_2-x_1)/(t_2-t_1) & \text{for } t_1 \le t \le t_2 \\ x_2 & \text{for } t \ge t_2 \end{cases} \quad (1)$$

making use of the fact that Holocene ice has a higher background reflectivity than glacial ice. This change in background reflectivity corresponds to the Bølling–Allerød transition (see Karlsson et al., (2013) for a detailed description of the method).

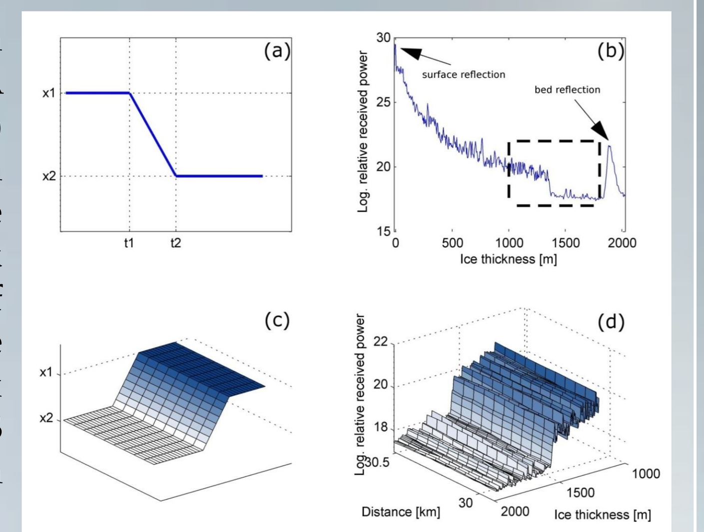

Fig. 3. (a) Illustration of a ramp function (Eqn (1)). (b) A RES data record (A-scope) with the transition between interglacial and glacial ice marked with a dashed, black box. (c) The 2-D version of Eqn (1). (d) Zoom-in on the area in the dashed, black box from (b) and all the RES records 250m horizontally on each side of it.

Get the published data here:

www.iceandclimate.nbi.ku.dk/data

Please cite: Karlsson et al., (2013), Tracing the depth of the Holocene ice in North Greenland from radio-echo sounding data, *Annals of Glaciology* 54(64), p. 44-50.
For unpublished data please email N. B. Karlsson.

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