Accumulation rates from 38 ka and 161 ka radio-echo sounding horizons in East Antarctica

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Introduction

The surface mass balance (SMB), used for the spin up of ice sheet models, has great influence on the models' results. On the East Antarctic Ice Sheet (EAIS) the accumulation is (nearly) the only component of the SMB. Even though, the coverage with information on SMB is still sparse. Paleo-accumulation rates can be derived from ice cores or radio-echo sounding (RES) data, the latter having the advantage of spatial coverage. To retrieve accumulation rates from isochronous RES horizons, independent assessment of the horizons' ages and the thinning of the original layer by flow divergence is necessary.

We use two RES horizons, that are dated at deep drill sites, and trace them continuously across great parts of the EAIS. To account for the strain thinning by ice flow, we use the Parallel Ice Sheet Model (PISM). Our result is a large scale spatial distribution of accumulation rates for two time intervals.

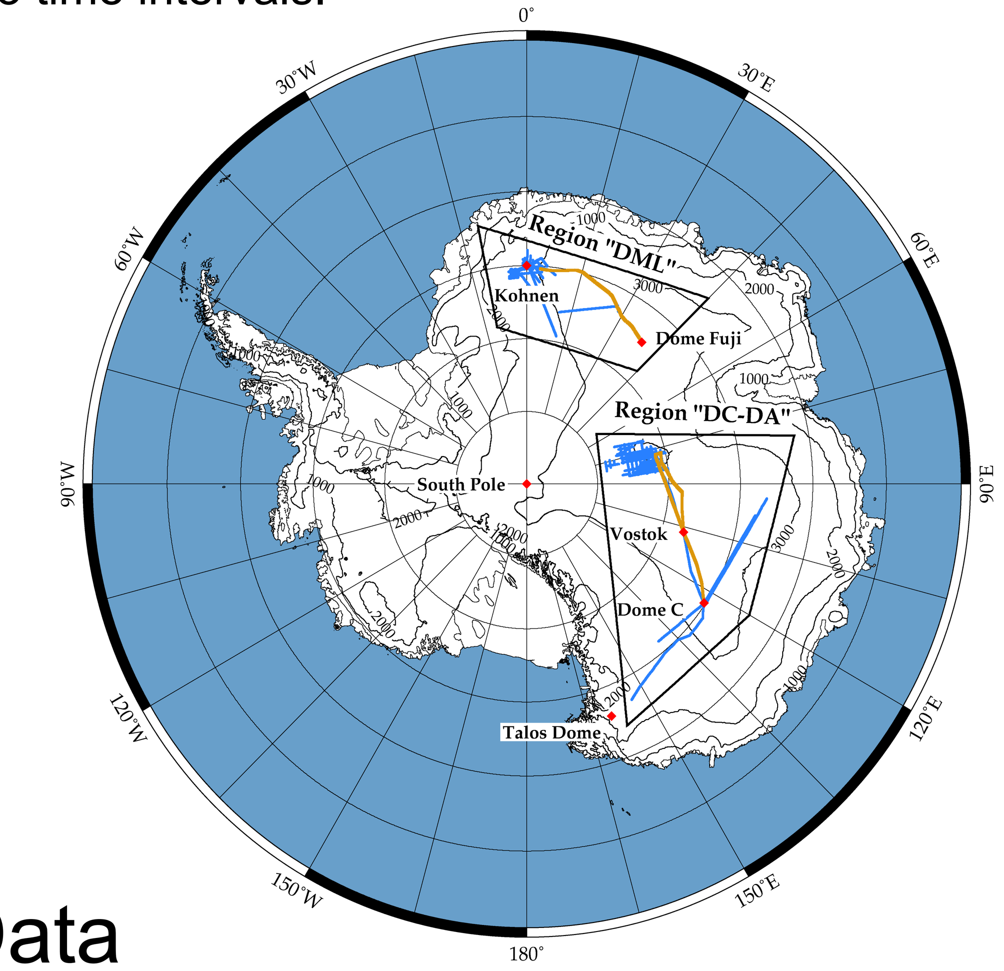

Figure 1: Overview of the deep drill sites (red diamonds) and RES profiles (blue and yellow lines) in East Antarctica, separated in regions DC-DA and DML. Results for the yellow profiles are shown in Fig. 2.

Data

RES data of the Alfred Wegener Institute

- Center frequency: 150 MHz
- Toggle mode with pulse lengths of 60 ns and 600 ns
- Vertical resolution of about 5 and 50 m in ice
- Ten-fold stack to trace distance of about 75 m

of the Antarctica's Gamburtsev Province Project (AGAP)

- Center frequency: 150 MHz
- Bandwidths: 15 to 20 MHz
- Vertical resolution of about 6.5 to 8.5 m in ice
- Ten-fold stack to trace distance of about 15 m

Horizon data

- Two horizons, traced continuously along the RES profiles shown in Fig. 1
- Horizons with ages 38.2 ka and 73.8 ka in the DML region
- Horizons with ages 38.2 ka and 161.1 ka in the DC-DA region

Model data

- PISM 0.6 with 10 km horizontal resolution
- Spin up as in Weikusat et al. (2017) (RACMO 2.3 accumulation rate and surface skin temperature, Shapiro & Ritzwoller heat flux), but with freely evolving geometry

Method

- Accumulated mass above and between RES horizons, calculated with ice-core densities (see Fig. 2, middle panels)
- Gradient field of PISM velocities gives the horizontal divergence values, the negative sum of which equals the vertical divergence
- Extraction of depth curves of the horizontal divergence values at every RES profile point, using bilinear interpolation
- Numerical integration of divergence curves from surface to respective depths of horizons
- Adding this to the respective accumulated mass of each horizon and division by ages gives the mean accumulation rates (Fig. 2, bottom panels, and Fig. 5)
- Calculation of stream lines, using PISM velocities, to assess the tenability of neglecting the particle paths (Fig. 4)
- Extracting spatial variation in present-day accumulation rate along stream lines (Fig. 3, bottom)

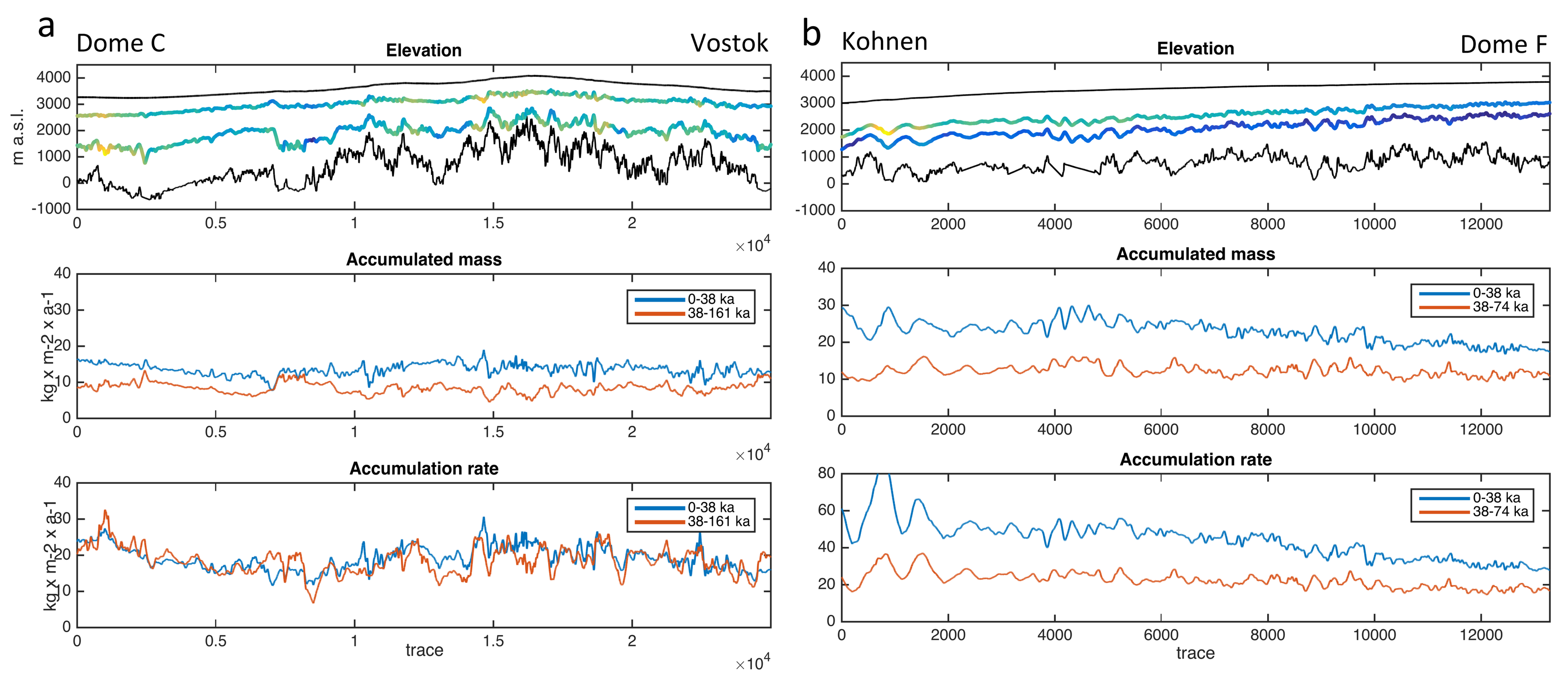

Figure 2: Example profiles for the DC-DA (a) and DML (b) regions to illustrate our method. The profiles are marked yellow in Fig. 1. Top panels: Elevation of the traced RES horizons. Middle panels: Accumulated mass per year. Bottom panels: Mean accumulation rates for the two time intervals.

Results

In Fig. 3 (top panel) we compare our results for the DML profile with those of Huybrechts et al. (2009). They use a more complex model to additionally account for upstream deposition of snow and possible accumulation variations along the stream lines. There is a good fit of the large-scale pattern of our accumulation rates for both time intervals. This reassures us to use our method also for the DC-DA region.

Deviations occur mainly where the accumulation rates vary strongly on a small scale. In order to assess where our approach might be too simplistic, we calculate stream lines (Fig. 4) and the variation of accumulation rates along those stream lines (Fig.3, bottom).

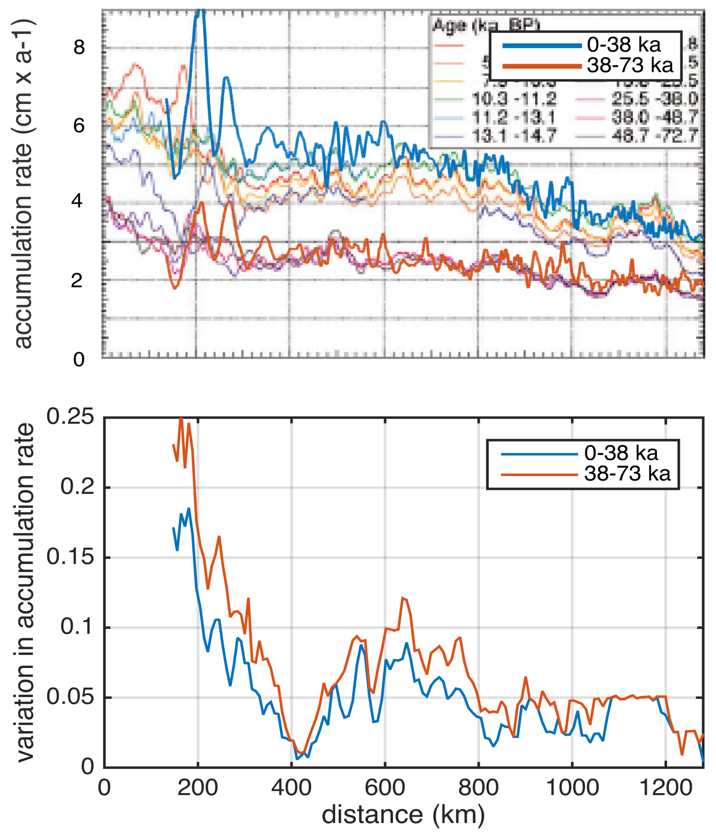

Figure 3: Our accumulation rates for the DML profile plotted over the results from Huybrechts et al. (2009) (top). Bottom panel: variation in present-day accumulation rates along the stream lines.

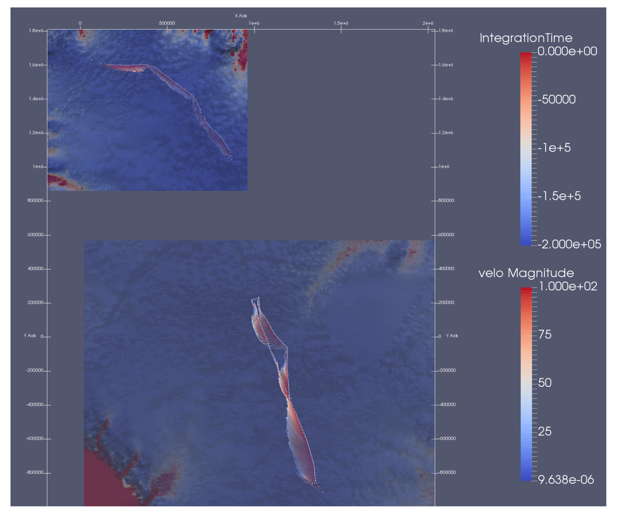

Figure 4: Stream lines with seed points on the example profiles' older horizon, calculated with PISM velocities.

Figure 5 shows the spatial distribution of mean accumulation rates for the intervals of 0-38.2 ka and 38.2-161.1 ka in the DC-DA region and of 0-38.2 ka and 38.2-73.8 ka in the DML region. There is a general trend towards higher accumulation rates in the younger time interval compared to the older one, and towards lower accumulation rates further inland.

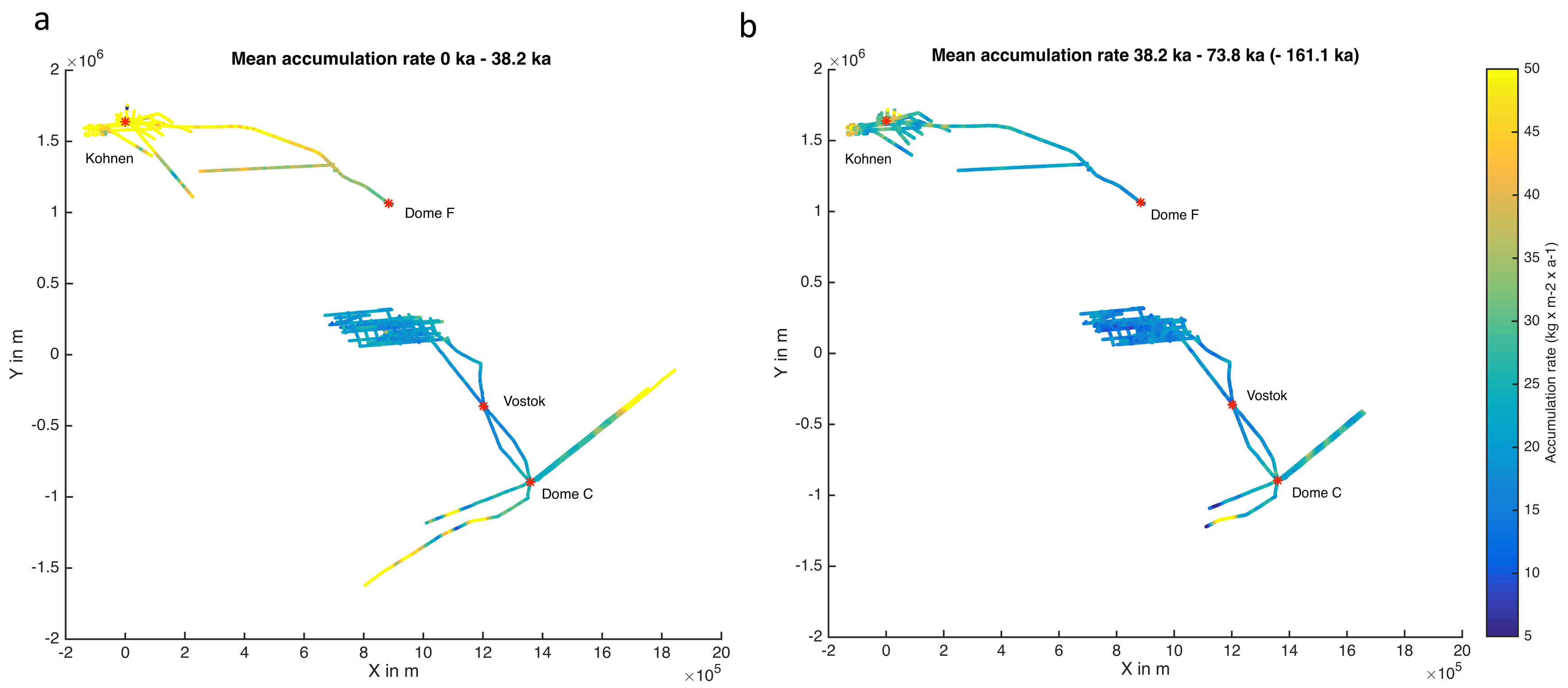

Figure 5: Spatial distribution of accumulation rates for all profiles for the 0 – 38.2 ka period (a) and the 38.2 – 73.8/161.1 ka period (b).

Figure 6: Sections of the radargrams for the example DC-DA (left panel) and DML (right panel) profiles with traced horizons.

References
Huybrechts P., Rybak O., Steinhage D. & Pattyn F. (2009) Past and present accumulation rate reconstruction along the Dome Fuji—Kohnen radio-echo sounding profile, Dronning Maud Land, East Antarctica, Annals of glaciology, International Glaciological Society, 50, 112-120
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