Note: Reviewer's comments are in italics. Changes to manuscript text are in blue.

Reply to reviewers:

"Glaciological characteristics in the Dome Fuji region and new assessment for 1.5Ma old ice"

Reviewer #3

This manuscript provides a new glaciological information (ice thickness, bedrock, topography, GHF, basal condition etc.) of the Dome Fuji area on the base on airborne radar surveys conducted during the 2014/15 and 2016/17 Antarctic season. An accurate geophysical survey is prerequisite for any paleoclimatic ice core site selection. The important effort to provide new geophysical survey in a remotest area of East Antarctica must be supported.

While the main result is of interest this manuscript suffers of some flaws: it is not clear the use of previous radar survey (Soviet, Japan and bedmap2 compilation) in the new map; the grid cell of 500 m is unsustainable and useless with a survey spacing from 5 to 10 km and relative interpolation of tens km; the information about internal layering depth and age respect to Dome Fuij ice core are not reported anywhere; the description of subglacial lakes detection is very limited and the thickness of melting/no melting threshold is not reported, and it is a crucial point for GHF; as reported by Fisher et al., 2013 it is very important not only find undisturbed ice of 1.5 Myr but also that the ice between 1.2 and 1.5 myr must be enough thick to detect the 40 kyr cycle, a map of the deepest datable isochrones (from DF) is a crucial point to analyse and report.

We have rewritten several sections of the manuscript, including adding more information on survey spacing, interpolation scheme and lake detection. We have also changed our main result to a 1km map although we retain the 500m resolution in the area around Dome Fuji, where data are more dense.

The inclusion of previous surveys have been made clearer with the addition of a figure (2A) showing all radarlines that are included in the gridded thickness map. However, it is beyond the scope of this study to produce a map of isochrones depth or conduct internal layering analysis beyond the continuity index method.

The observations and methods section new starts with the following paragraph:

"The new topography relies primarily on datasets from two field campaigns, conducted during the Antarctic seasons 2014/15 and 2016/17 (Fig. 1 green and blue lines, respectively). In both cases the radar instrument was mounted on AWI's Basler BT-67 aircraft. The data from the 2014/15 season were collected as part of the GEA (Geodynamic Evolution of East Antarctica) project, a collaboration between AWI and the Federal Institute for Gesosciences and Natural Resources, Germany (Ruppel et al., 2018). In that earlier survey, close to 40,000 km of radarlines were conducted but here we include only the 10 flights that directly intersect our area of interest corresponding to 12,000 km. The spacing between the radarlines is 10 km for the grid and the mean data-collection spacing along the flight direction is approximately 5 m although it varies with aircraft speed which is influenced by wind speed and direction. The 7-fold stacked thereby get a spacing of approximately 35 m. The more recent survey is part of the Oldest Ice Reconnaissance (OIR) project, a contribution to BE-OI. During this field campaign, measurements were conducted from a temporary camp (located at 79S, 30E) 290 km from the Dome Fuji station. A total of 19,000 km of radar data were collected in 26 radarlines. The spacing between the OIR radarlines is 10 km with the exception of the radarlines southeast of Dome Fuji that were flown with a 15 km spacing, and the lines acquired while leaving or approaching the OIR camp where the distance between radarlines is much smaller. The mean data-collection spacing along the flight direction was also approximately 5 m leading to the same spacing on the 7-fold stacked data as the GEA data, i.e., 35 m, The radar data in both campaigns were collected using AWI's EMR (Electromagnetic Reflection) system (Nixdorf et al., 1999) with a constant distance to the ice surface. Radar waves were emitted with a centre frequency of 150 MHz and an amplitude of 1.6 kW as a 600 ns long pulse aiming to return a clear signal from the ice/bedrock interface as well as capturing information on the englacial properties of the ice. The system rectifies the returned energy and applies a logarithmic amplification."

And the section on uncertainties now reads:

"2.2 Results and Uncertainties

The resulting ice thickness is displayed in Fig. 2A and in the following we refer to this dataset as the OIR (ice thickness) data although it is based on data from several surveys (cf. the radarlines shown in Fig. 2A). The denser data coverage from the GEA and OIR surveys reveals a landscape with ice thicknesses varying between 2000 m and 4000 m with an average ice thickness of 3021 m. Immediately south of the Dome Fuji is an area with shallow ice thicknesses while the ice further to the south and to the southeast and is significantly thicker. A complex terrain with a patchwork of thick and thin ice has now become visible north and west of Dome Fuji. Since the surface topography in this part of Antarctica is relatively flat, ice thicknesses are good indicators of bed topography, thus thick ice indicates valleys while shallower ice indicates mountains or highlands. The OIR dataset shows a system of valleys surrounded by high plateaus.

The difference between the OIR and the Bedmap2 datasets is shown in Fig. 2C. The largest differences appear to the west of Dome Fuji between 30˚W and 35˚W, and 77˚S. In the immediate vicinity of the station, differences are smaller due to the high-resolution data from Japanese ground-based surveys that were included in the Bedmap2 and the OIR compilations. The difference between the new ice thickness map and Bedmap2 is upwards of 800 m in some areas, with a mean difference of 20 m, a mean absolute difference of 136 m, and a standard deviation of 177 m. This difference is undoubtedly due to the geolocation uncertainty of the Soviet data included in Bedmap2.

We examine the uncertainties of our result by comparing the gridded ice thickness map with point measurements from the individual radarlines, and through crossover analysis of the radarlines. In the latter analysis, we consider all points within 50 m of each other to be crossover points following Fretwell et al. (2013). For the GEA-OIR radarlines, 2453 points were found to be crossover points. The mean difference in ice thickness between the radarlines is -13 m with a standard deviation of 79m. For 18% of the crossover points the difference exceeded 100 m. We ascribe this difference to geometrical effects of flightline orientation since we observe that radarlines intersecting each other at oblique angles have a larger thickness difference than those that are almost parallel.

Turning to the gridded ice thickness map, the mean difference between the GEA-OIR point measurements along the radarlines and the gridded map and is 1.5 m (cf. Fig. 3), indicating that the gridded ice thickness is slightly underestimating the ice thickness on this spatial scale. The standard deviation is 117 m. The mean difference between the gridded ice thickness and the individual data points from the older German survey is -11 m and the standard deviation is 162 m. For the Japanese surveys the mean difference and standard deviation is -16 m and 187 m, respectively. The overall high value for the standard deviation is an inevitable result of the smoothing introduced by the kriging interpolation scheme. Indeed, the negative mean difference between the high-resolution ground-based survey data and the gridded map indicates that the gridded data tend to overestimate the ice thickness in some areas, most likely because subglacial valleys are made broader by the kriging. This is a direct result of the smoothing introduced by the kriging scheme. This is also evident from the standard deviation in the grid points calculated by the kriging scheme (Fig. 2D). The standard deviation lies typically between 110-120 m close to the data points and increases with distance. Towards the margin of data coverage area the values exceed 200 m. We note that 110–120 m is still smaller than the difference between the OIR data and Bedmap2.

The decision to exclude the Soviet data was partly based on results from a crossover analysis. Comparison between the Soviet radarlines and the OIR and GEA surveys shows that only slightly more than 100 points is within 50m of each other. For these points, the mean difference in ice thickness between the points is -5 m with a standard deviation of 193 m. This larger standard deviation is likely due the poorly resolved bed rock and the large navigational uncertainty in the Soviet radarlines. Considerable differences were also found between Soviet data and ground-based JARE surveys (Fujita, pers. comm., 2016)

We performed a similar crossover analysis of the surface elevation measured in the GEA-OIR surveys. Here, we find a mean difference of less than 1 m with a standard deviation of 2.5 m. Thus, the uncertainties in the surface reflection measurements are negligible compared to uncertainties in the bed picking. Based on this we assign an average uncertainty of 150~m to the OIR ice thickness although we note that uncertainties increase with distance from data point are likely larger along the edge of the survey grid."

In detail:

Fig 1

WGS84 is not a map projection, is a geodetic spatial reference system

The figure caption has been changed to

The Dome Fuji region in East Antarctica (the left-hand figure is a polar stereographic projection with standard…

All figure: add elevation contour line, change West with East, Are data plotted only OIR (fig 2 and 5) or GEA-OIR?

Surface elevation contours have been added to figures 1 and 2, and West has been changed to East in all figures. Fig. 2 has been updated to show all data. The caption of Fig. 5 (now 5B) states "Continuity index of the internal layers in the OIR data."

Page 3 Line 29-30 *the elevation change is negligible information, remove.*

We have rewritten part of the paragraph mentioning the elevation change, however, we would like to keep this for the sake of clarity re. uncertainties.

Page 3 Line 29-33 *If the Soviet data are not useful due to the position uncertainty why use bedmap2 based on this data? The new grid must be constructed using only the AWI and Japan data, and BEDMAP2 must be used outside the new survey area.*

That is what we have done. With the additional Fig.2A this should be clearer.

Paragraph 2.2 *The paragraph must be clarify and analysed only the cross point of radar profile and not the gridded data.*

This section has been rewritten. We use the crossover analysis between radar profiles and the gridded data to examine the uncertainties and smoothing introduced by the kriging scheme. Thus, we believe there is value in doing this analysis.

Page 4 line 8 *"parallel" or "perpendicular"?*

Parallel

Page 4 Line 16-19 *what is the meaning of "points qualified"? The difference in ice thickness and standard deviation between Soviet and AWI does not appear so large respect to the comparison of GPS position survey of GEA-OIR and AWI-Japan. Please clarify the point and the uncertain in geographic position of Soviet profile.*

The section on uncertainties has been rewritten and it should be clearer that, for example, the standard deviation of the GEA-OIR data compared to the gridded data is 117m while it is 193m for the Soviet data.

The specific sentence re. "points qualified" has been changed to:

"The decision to exclude the Soviet data was partly based on results from a crossover analysis. Comparison between the Soviet radarlines and the OIR and GEA surveys shows that only slightly more than 100 points is within 50m of each other. For these points, the mean difference in ice thickness between the points is -5 m with a standard deviation of 193 m. This larger standard deviation is likely due the poorly resolved bed rock and the large navigational uncertainty in the Soviet radarlines. Considerable differences were also found between Soviet data and ground-based JARE surveys (Fujita, pers. comm., 2016)"

Figure 2 *Add the radar profile, why use only OIR profile, instead OIR e GEA? East instead of West*

Figure 2 has been updated to show better which datasets are included in final data product. A separate figure has been added showing a radargram with lakes and continuity index.

Figure 3 *Elevation contour, yellow line New Thickness is very far from radar profile (25 km?), is it the gridded area?*

The caption has been changed to:

"…Blue dots show lake locations identified from the radar data, the extent of the gridded OIR thickness map is outlined with a yellow line,.."

Page 9 Line 2 *Dome Fuji area is about 1000 km from the coast, and it is not "the most easily accessible region", but the closer to the Dome Fuji Station.*

The sentence has been changed to

"The most promising is also the most easily accessible region from the existing Dome Fuji station:…"

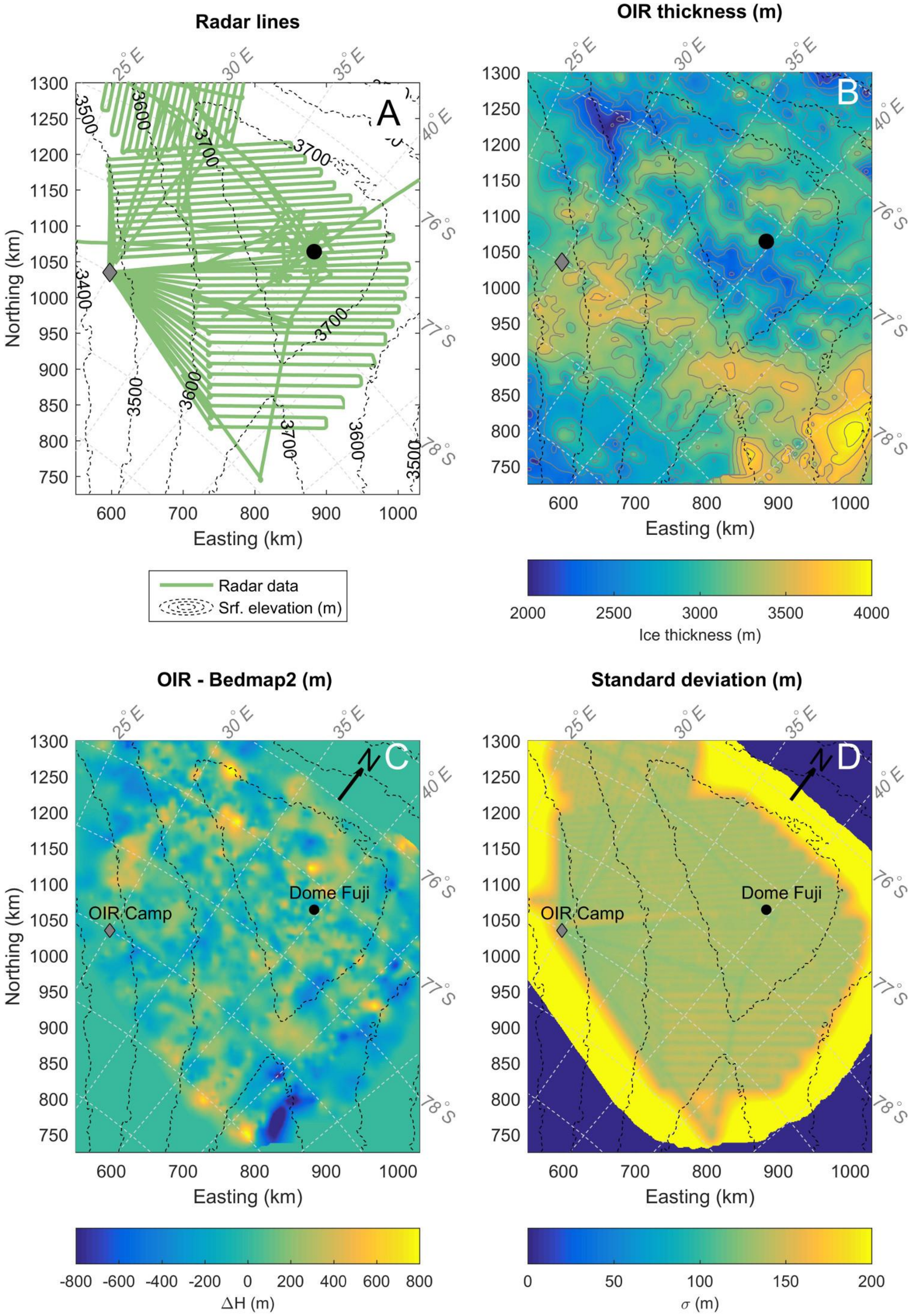
Fig 6 Add elevation contour line and radar line used, it is not clear (cf Fujita et al., 2012) explain.

The figure has been changed to include model results from the area. The figure now includes surface contours and the caption reads:

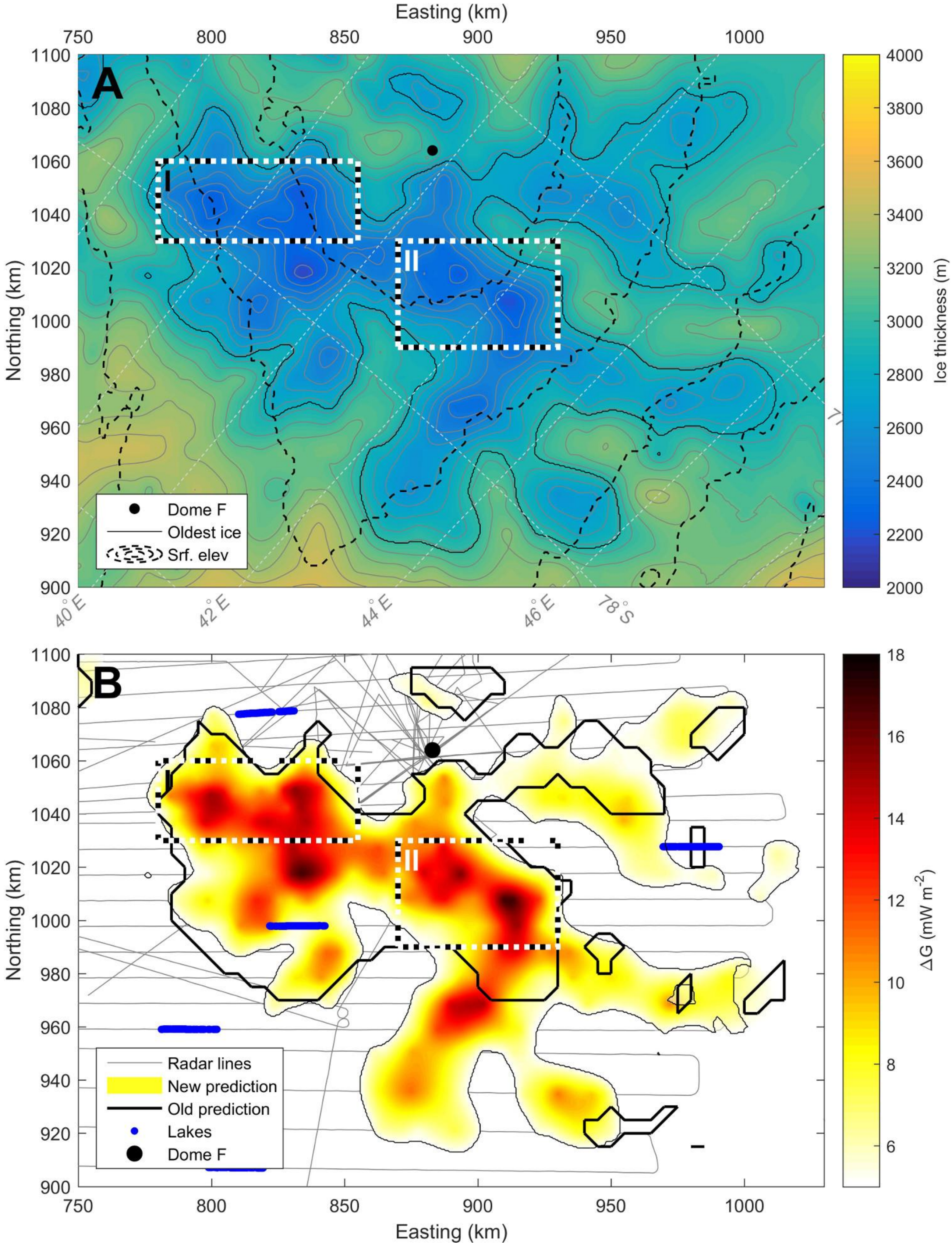
"(A) Ice thickness in the area close to Dome Fuji station in 500 m resolution and (B) Updated predictions of possible Oldest Ice locations (colours) on a 500 m resolution grid compared to the prediction of Van

Liefferinge and Pattyn (2013) outlined in black. The colour scale show the values of ΔG, semi-transparent colours show areas with a threshold horizontal ice-flow velocity of <2m/a, fully saturated colours show areas where the threshold is <1m/a. Blue dots show lake locations identified from the radar data. The white/black boxes indicate the two most favourable Oldest Ice spots according to our analysis.”

New figure 2


Radar lines
OIR thickness (m)
A
B
Northing (km)
Easting (km)
Radar data
Srf. elevation (m)
Ice thickness (m)
OIR - Bedmap2 (m)
Standard deviation (m)
C
D
OIR Camp
Dome Fuji
ΔH (m)
σ (m)

New figure 6



Easting (km)
750
800
850
900
950
1000
1100
1080
1060
1040
1020
1000
980
960
940
920
900
Northing (km)
A
I
II
Dome F
Oldest ice
Srf. elev
40°E
42°E
44°E
46°E
78°S
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
Ice thickness (m)
B
Radar lines
New prediction
Old prediction
Lakes
Dome F
18
16
14
12
10
8
6
ΔG (mW m^{-2})