Spatial characteristics of accumulation patterns derived from combined data sets on Amundsenisen plateau, Antarctica

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Aim of study

The studies underlying this work were carried out within the European Project for Ice Coring in Antarctica (EPICA), but is likewise a contribution to the International Trans-Antarctic Scientific Expedition programme (ITASE). We aim at estimating the spatial representativity of accumulation rates derived from ice-penetrating radar surveys (IPR) and findings from point measurements, done by firn and ice core studies. Usually, surface mass balance calculations are done by stake readings, snow-pit samples and shallow firn cores. These measurements yield parameters to model the spatial variability of the Antarctic surface mass balance, as well as its variations over the last few decades. Working with this information only is problematic, however, as it is uncertain how these irregularly and sparsely collected data are able to represent general climatic trends of precipitation and wind drift patterns for larger areas. Over recent years, the traditional methods have been supplemented by high frequency IPR studies to improve the understanding of spatial accumulation patterns. This method is capable of imaging the physical structure of the upper hundreds of metres of the ice column in meter resolution. On the Antarctic inland plateau, this provides a means to derive information about local surface mass balance over the last hundred to thousand years. The two-dimensional limitations of IPR surveys might be overcome by combination with radar data, derived by satellite remote sensing. This requires the interpretation of backscattering signatures in connection to known accumulation patterns.

Area under investigation

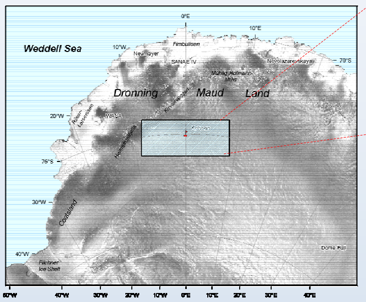
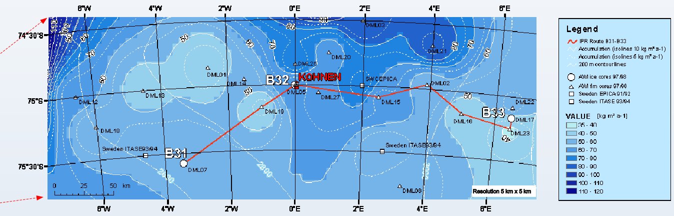


Fig. 1a. Map of Dronning Maud Land



Projection Polar stereographic, WGS84, standard parallel 71

Figure 1b. Map of accumulation distribution

Method for spatial interpolation: Inverse Distance Weighted (IDW), (Power 3.0, 20 Neighbors)

Software: ArcInfo within ArcGIS 8.3 software package by ESRI

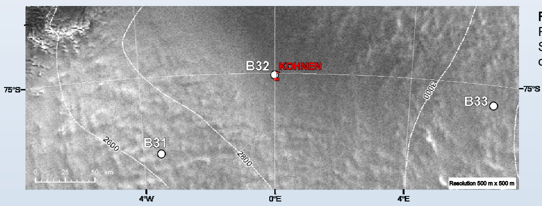


Fig. 1c. RADARSAT SAR picture of study area

The interpolatetd map shows the general trend of decreasing accumulation rates from the coastal area towards the interior of the ice sheet. In the East as well as in the West of the studied area spots with accumulation rates less than 45 kg m^{-2} a^{-1} are found. In the middle, mainly eastwards of point DML05, along the ice divide, the accumulation rates vary between 45 and 65 kg m^{-2} a^{-1}. Towards the North the accumulation rates increase to values around 90 kg m^{-2} a^{-1} (DML03).

Radar derived surface mass balance

Ice-penetrating radar was used along a continuous profile over a distance of 320 km, passing several irn and ice core drilling sites, to map variations in snow-layer thickness within the upper 100 m of the ice sheet (see red line in Fig.1b).

The depths of selected internal reflection horizons (IRH) and the cumulative mass of the overlaying ice column are calculated from dielectric profiling data of ice cores. The local surface mass balance is determined as temporal average, covering a time span of almost two centuries.

Technical equipment:

radar system:	RAMAC radar set (Malå Geoscience, Sweden), mono-pulse bistatic, 200 & 250 MHz antennae
data processing:	AGC, filter, 8 stacks
post-processing:	Paradigm Geophysical FOCUS version 4.2 software

Depth-density profiles

Dielectric profiling of the firn and ice cores provides profiles of the wave speed-depth and the density-depth distribution (Wilhelms, 2000; Eisen and others, 2002). Wave speeds are used to convert radar data from travel time to depth, integration of density profiles yield the distribution of cumulative mass with depth. The smoothed dielectric profiles of all three ice cores within our study area (B31 - B33) are much alike (Fig. 3). We therefore assumed a homogeneous depth-density distribution within the area of interest and used the data from B32, located between B31 and B33, for the whole radar profile.

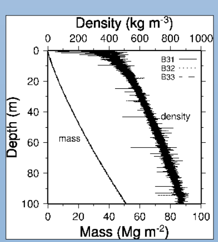
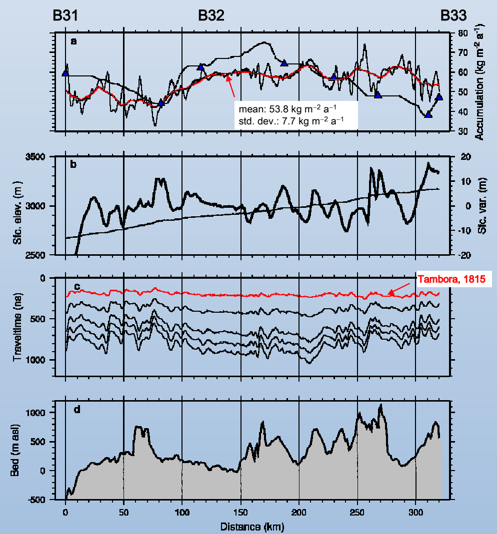


Figure 3. Depth profiles of density and cumulative mass of the ice cores B31, B32, B33, derived from dielectric profiling.

Depth-age profile

Datings of IRHs are obtained by transferring the ice core ages to the respective depth of the IRH at each drilling location. The ice cores are dated by annual layer counting of multi-parameter chemical records combined with identification of volcanic horizons (Sommer and others, 2000).

Radar data vs. point measurements



Figures 2 a-d.

a) Surface mass balance profiles based on IPR (thin line), its 50 km running mean (red line), and IDW interpolation (dashed line); location and spot values of firn cores are symbolized as triangles (see also Fig.1b).

b) Surface topography and difference of local height in metres from the 50 km running mean of elevation (RAMP Digital Elevation Model version 2.0, Liu and others, 2001).

c) Depth distribution of selected internal reflection horizons (IRH); variations are in the order of 100–500 ns (10 to 50 m) over short distances. The uppermost horizon is recorded at a depth of 20 m on average and linked to the Tambora volcanic eruption in 1815.

d) Bedrock topography (Steinhage and others ,1999)

The continuous surface mass balance profile, calculated from the uppermost IRH, is identical to findings from most of the passed firn and ice core samples (Fig. 2a). Between the single core locations, the IPR results show strong variations in layer thickness, thus revealing a rather complex accumulation pattern. In many parts of the survey profile, e.g. between DML07 and DML19, an increase in mass balance occurs at surface depressions, while a lower accumulation rate can be observed were the elevation reaches peaks.

Compared to the IPR profile line, accumulation rates interpolated from point measurements lead to alternating over- and underestimations of surface mass balances. However, a general trend of changes can be approximated on a regional scale. Along our IPR route the interpolated profile is in phase with the 50 km running mean of the IPR derived accumulation data (Fig. 2a), reaching a higher amplitude, however.

Annual mass balance vs. sigma0-measurements

Annual surface mass balance rate is put against remotely sensed sigma0 measurements from the spaceborne RADARSAT - SAR instrument. This radar system operates at C-band (5.3 GHz) with HH polarisation.

At first, up to the ice core drilling site B32 at kilometre 150 a clear contrary course of the two curves can be observed (marked blue). Sigma0-values fall, where the accumulation rate is rising. In the second part, however, a switch to a rather positive correlation takes place, indicated by the yellow connection lines.

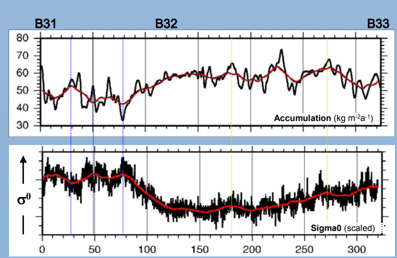


Fig. 4. Comparison of radar derived annual mass balance vs. remotely sensed sigma0-measurements

Conclusion

The accumulation variation can be derived from IPR radar surveys, providing detailed information on surface mass balance rates along continuous linear profiles.

The results indicate a complex accumulation pattern superimposed on a general low surface mass balance, which is related to small-scale surface undulations caused by bedrock relief.

A possible link between accumulation rates and backscattering characteristics of the show surface will be object to further studies.

References

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