MODELLING THE SURFACE OF THE ANTARCTIC ICE SHEET FOR SATELLITE RADAR ALTIMETER STUDIES

(Abstract)

by

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Remote sensing from space offers unique future opportunities for studying the cryosphere, particularly large ice sheets in polar regions. Of specific importance to glaciology is high-accuracy surface-elevation information, especially if gathered over an entire ice sheet during a very short period of time. Radar altimeters flown aboard GEOS-C and SEASAT satellites have yielded reconnaissance data of this sort for southern Greenland and Antarctica north of 72°S, although their altimeters were optimized for operations over the oceans. During the next decade there will be several additional opportunities to gather altimetry over ice sheets (ERS-1 and possibly RADARSAT) and instrument design should take account of the surface properties of ice sheets and the lessons learned from SEASAT.

The principal problems encountered with radar altimeter tracking systems over ice relate to the inability of the onboard signal processor to identify and position the leading edge of the returned radar pulse accurately within a filter bank, and hence to "track" the ice surface. This difficulty is due to pulse-shape modification and rapid range changes resulting from severe surface roughness of ice sheets and the presence of ice cliffs and other discontinuities such as mountains and nunataks which break the ice surface. Tracker design thus requires the use of an ice-surface model which incorporates as many realistic elements as possible.

As part of a research study for the European Space Agency by a consortium of European laboratories, we have developed an ice-sheet model based principally upon a data set of measured surface topography from airborne radar altimeter missions over Antarctica. The model recognizes three scales of surface roughness.

(1). Ice-sheet geometry (10^2 km)

At the largest scale, four elements of importance are considered. A quasi-parabolic expression is used to account for the *regional surface* due to ice rheology. *Ice streams*, however, are common within the outermost 400 to 500 km and are represented by a concave-upward sinusoidal modification with amplitude increasing down the flow line. A fringing, low-gradient *ice shelf* has been incorporated, terminated by *ice cliffs* of 50 m vertical height.

(2). Dynamic topography (10^1 km)

This intermediate scale of surface roughness is related to the memory effect of the ice-sheet surface to subglacial irregularities. Based upon the airborne data set, three typical surface-terrain types have been distinguished and superimposed as a continuum upon the regional geometry. Type 1, characteristic of inland ice-sheet areas close to ice divides, is relatively smooth (elevation deviations <± 5 m, root mean square (RMS) of elevations <1.0 m, local gradients <0.5%, long (20 to 50 km) wavelengths dominate). Type 2, terrain of intermediate roughness, is typical of more than half the Antarctic ice sheet between the central regions and a 400 km-deep coastal belt (elevation deviations <± 8 m, RMS of elevations 4 to 5 m, local gradients <1.5% with wavelengths of 20 km). Type 3 is rough ice surface, found in steep coastal regions inland of mountainous terrain and at the heads of ice streams (elevation deviations up to ± 30 m, RMS of elevations 10 m, local gradients up to 3%, 10 km wavelengths dominate).

(3). Transient surface features (10^{-1} km)

The small-roughness scale is superimposed on both the geometrical and dynamic scales and comprises such forms as snow waves, ripples, dunes, and ridges. Data are very limited but some information is available from literature searches and study of aerial photographs. Transient features have been modelled as a random field of tent-shaped "mounds" with wavelengths of 6 and 30 km, and variable amplitude of a few metres.

The model is not intended as an exact representation of the Antarctic ice sheet but rather as a synthetic surface incorporating typical characteristics based upon recent and extensive measurements for use in testing radar altimeter tracker systems. The model is available on magnetic tape and may be obtained, at minimal cost, from the above address.

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