MEASURING OF VOLUME AND THICKNESSES OF REMNANT MASSIFS OF LAYERED DEPOSITS ON MARS, USING ALTIMETRY DATA AND MATH APPROXIMATION

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In the high northern latitudes of Mars, around the polar cap, the remnant massifs of layered deposits can be found. These massifs could be remnants of polar layered deposits (PLD) of northern polar cup. In our research, we used the MOLA topography data to assess the shape of ice massifs both on the flat surface and within larger impact craters. For the ice deposits in the craters, we used an empirical relationship between the craters depth and diameter, original program for measuring of average elevation and math approximation approach to estimate volume of ice.

Introduction

Around the north polar cup of Mars, ice layered deposits can be found. There is a hypothesis that boundaries of the northern polar cap advanced to the lower latitudes in previous climatic epochs [1, 2]. The last such advance could happen in previous ice age in period 0.4–2.1 Myr ago [3, 4]. In this period, the polar cap could reach ~ 75°N [2] and overlap such regions as Olympia Undae and Scandia Cavi. Currently, around the polar cap we can find residual massifs of the ice layered deposits in a zone between 70–85°N on northern plain and within of impact craters [2]. Study of these features provide important information about evolution of climate and the polar caps on Mars. The remnant ice massifs contain a large volume of water, which is an important resource for the feature human exploration of the planet.

Measuring of ice massifs using altimetry data

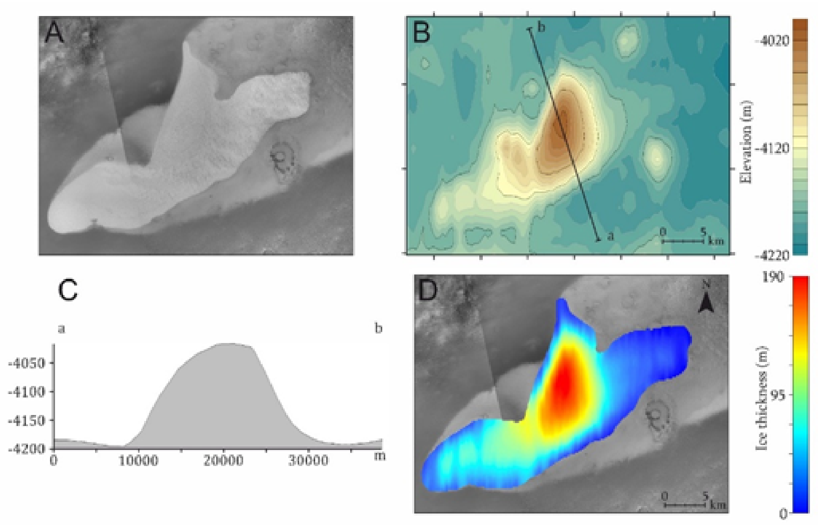

Fig. 1. Analysis of MOLA altimetry data. A–CTX images mosaic of an ice massif at 105°E, 73°40'N; B — elevation map with a topographic profile (C); D — thickness of ice massif.

In our study, we firstly analyzed morphometric parameters of several topographically positive features on the flat surface of the northern plains. Their thicknesses and volumes can be calculated by an elevation difference between their elevation model and the surrounding surface. This approach gives reasonably accurate estimates only for relatively small objects, located on a flat surface (Fig. 1).

The results of the measurements are compared to the radar SHARAD data in Table 1. For each measurement, we have a systematic difference of 50–100 m between the altimetry and SHARAD data. We ascribe it to the lower spatial (3–6 km) and vertical (~15 m) resolution of the SHARAD data. Density of the radar profiles is also relatively low and the profiles can miss the thickest portions of the ice massifs.

Measuring of ice massifs in craters using math approximation

If an ice massif is on a rough surface or inside a crater, determination of the massif thickness and volume is more complicated. In this situation measurements should be done using either the SHARAD data or an empirical dependence between the depth and diameter of craters on Mars [5] and additional math approximation approach.

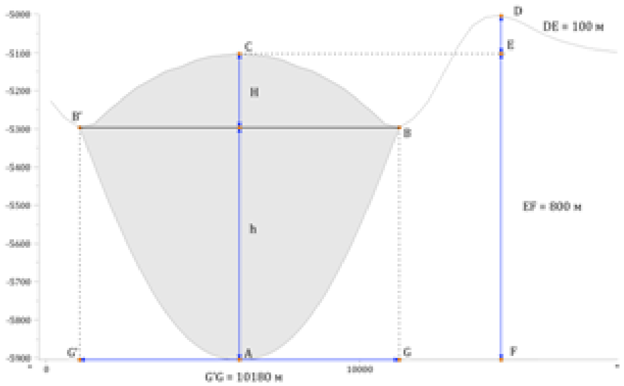

Fig. 2. Measuring of ice massif volume in craters using the empirical model for the shape of the Mars craters and approximation of the ice massif profile by two parabolas.

For ice massifs, located in impact craters, analysis of crater morphology and applying of math approximation, can be alternative approach in calculation of ice volume. According to this model, the characteristic relationship between diameter (D) and depth (d) of the fresher craters is described by the following formula $d=(0.19D)^{0.55}$ [5]:

In order to apply this relationship for estimates of the thickness of the ice massifs in craters, we used an original computer program [6], which calculates an average elevation in a series of concentric zones extending from the center of a crater to three crater radii from the center. The difference between the model depth of a crater [5] and its actual averaged profile gives an estimate of the thickness of an ice massif located within the crater.

The next step was a calculation of volume of ice massif. The maximum possible volume of the ice massifs were estimated under an assumption that craters have bowl-like shape. and positive ice massif on the bottom of it have a "hill" shape, bellow we will make some approximation to calculate volume of ice using math approximation. We assume, that central profile of massif can be sufficiently accurate approximated by two parabolas (B', A, C and B', C, B). Sought-for volume is the volume of axisymmetric body — solid of revolution. Let's locate coordinate axe x throw B' and B points, and axe y throw points A and C. In this approximation, if we know coordinates of points B', A, B and C in axis x and y, equations of parabolas can be calculated. These equations will describe upper and lower part of central profile. Using this approach, volume of ice massif can be described as sum of volumes of two bodies, formed by rotation of arcs of lower and upper parabolas related to vertical axe y.

Table 1. Morphometrical parameters of the ice massifs on the plains and in craters.

№	Locality	Coordinates		Area and Diameter	Volume, km^3	Maximum thicknesses, km	Radar
		Longitude	Latitude				
1a	Plain	95°	74°10’	404.1 km2	41.3	0.35	0.27
1b	Plain	98°	74°30’	1535.5km2	115.5	0.42	0.33
2	Plain	102°	74°30’	18.1 km2	0.9	0.12	-
3	Plain	103°40’	74°40’	4.7 km^2	0.12	0.03	-
4	Plain	105°	73°40’	291.3 km2	27.8	0.17	0.12
5	Plain	107°30’	74°50’	11.5 km2	0.3	0.02	-
5	Plain	110°30’	74°44’	113.4 km2	26.1	0.12	0.09
6	Crater	319°10’	73°14’	16.9 km	32.7	0.8	-
7	Crater	164°30’	72°40’	83.9 km	2169.3	1.48	1.48
8	Crater	240°10’	78°06’	15.8 km	3.3	0.4	-
9	Crater	103°10’	70°11’	37.3 km	3.6	0.1	0.15
10	Crater	159°40’	79°20’	6.3 km	7.4	0.48	-
11	Crater	1°40’	78°	4.5 km	0.1	0.4	-
12	Crater	151°20’	76°23’	4 km	0.5	0.4	-
13	Crater	190°10’	81°	19.5 km	26.2	0.8	-
14	Crater	60°50’	79°08’	24 km	12.2	0.4	0.3
15	Crater	89°10’	77°06’	31.4 km	148.5	1.1	0.38

Results:

MOLA data can be used on the plain surface for measuring of thickness and volume of surface ice massif deposits. Using [5] model, our average profiling of craters and math approximation, volume and thickness of ice massifs in part of crates can be calculated. For others cases, when we have deposition of ice massif in territory with rough relief, or when massif cover huge area, SHARAD data should be used.

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