**A TEMPERATURE DISTRIBUTION MODEL IN THE LUNAR SOIL AT THE POLAR REGIONS.**
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**Introduction:** The diurnal temperature fluctuations in the lunar soil in the equatorial region completely attenuate at a depth of about 80 cm, where a constant temperature of about -21°C is observed [1, Ref. there in]. In the Moon Polar Regions, the Sun shines tangentially and, depending on the relief, the degree of illumination can vary from its complete absence to 80% [2], and the temperature on the surface from 273 to 27 K [3]. Estimating the temperature distribution in the lunar soil in the Polar Regions is one of the urgent tasks at the present stage of lunar exploration and is necessary, among other things, for the development and creation of scientific equipment and various lunar soil sampling and drilling devices.

**Equatorial Region:** In the equatorial region, the daily temperature variation on the surface from the minimum (night) to the maximum (day) reaches 300 degrees. The lunar soil thermophysical properties, the diurnal variation and distribution of temperature in the lunar soil were measured in the area of the Hadley Rille in Mare Imbrium and in the Taurus Littrow in Mare Serenitatis at Apollo 15 and Apollo 17 landing sites of [4, 5]. It was found that daily temperature fluctuations in the lunar soil in the equatorial region completely attenuate at a depth down to 80 cm, while annual temperature fluctuations can be traced to a depth of 2 m or more (Fig. 1).

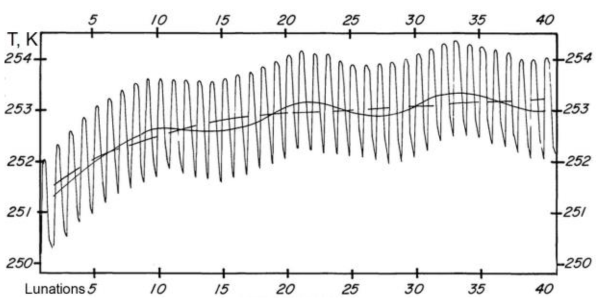


**Fig. 1**. Daily temperature variation (y) at a depth of 45 cm during 38 lunations (lunar days) (x) according to [6]. The smoothed solid line reflects annual temperature fluctuations minus daily variations with a resolution of ±0.015 K. The dashed line after subtracting annual temperature variations reflects the transition to an equilibrium state disturbed by the activity of astronauts on the surface.

Thus, the average temperature established at depth is known, as well as daily and annual temperature fluctuations depending on depth, and the periodic dependence of the heat wave on time, i.e. function T(z, t), where z is depth, t is time. To calculate a thermal wave in the lunar soil, boundary conditions and thermophysical properties of an inhomogeneous solid body (lunar soil) are required [1, Ref. there in]: thermal conductivity,

$$K_e(T) = (1,66\times10^{-2}z^{3/5}) + (8,4\times10^{-11}T^3,$$

heat capacity,

$$c=-23.173+2.1270T+1.5009\times10^{-2}T^2-7.3699\times10^{-5}T^3+9.6552\times10^{-8}T^4,$$

density,

$$\rho=1.92(z+12.2)/(z+18).$$

The boundary conditions for the nonlinear one-dimensional heat equation are determined by the step function of the surface heating temperature from 80 to 380 K (Fig. 2). Since the thermal conductivity of the upper loose soil layer with a thickness of about 3-5 cm is almost an order of magnitude less than the underlying layer [1, Ref. there in], then to simplify the problem, the conditional surface is set at a depth of z=5 cm. The next boundary condition in the form of a fixed temperature is set at a conditionally large depth, since annual temperature fluctuations at a depth of 2 m become negligible [6]. Thermal waves decay exponentially (Fig. 2). At a depth of z ~ 30 cm, a clear asymptotic line of the average temperature value is already visible, around which oscillations occur. The straight horizontal line indicates the establishment of an equilibrium constant temperature in the lunar soil. An upward slope would indicate heating, and a downward slope would indicate cooling.

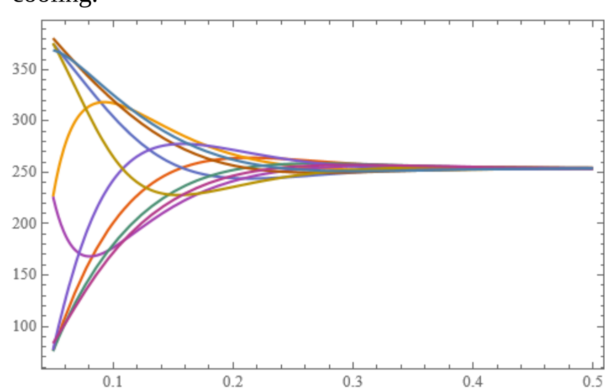


**Fig. 2**. Model of the daily course of temperature distribution in the lunar soil (x) of the equatorial region depending on the temperature on the surface (y) with

superimposed fluctuations in the region of all possible values.

The T(z) model, taking into account the known thermophysical properties of the lunar soil and depending on the specified conditions on the surface (duration of day and night, average day and night temperatures on the surface), allows solving the inverse problem to determine the steady-state equilibrium temperature in the lunar soil at depth. For example, according to this model, the calculated constant temperature in the equatorial region at a depth of 45 cm is estimated at 254 K with a fluctuation of 1 K, which is in good agreement with the measured data [6] (Fig. 1).

**Polar Region:** According to a comparative analysis of several sites at the South Pole, the most preferable site for accommodating a lunar scientific station [7] is site #2, a flat hill on the rim of the Shackleton crater (Fig. 3), where the degree of illumination reaches 80%, i.e. the lunar day lasts 80%, and the night 20% [2]. In the summer season, the average temperature is 165 K, the maximum is 255 K, and the minimum is 90 K (Fig. 4) [3]. Given these conditions on the surface, the calculated constant temperature at a depth of 45 cm in the lunar soil is 230 K. In the winter season, the average temperature is 130 K, the maximum is 240 K, and the minimum is 80 K (Fig. 4). Given these conditions on the surface, the calculated constant temperature at a depth of 45 cm in the lunar soil is 210 K (Fig. 5).

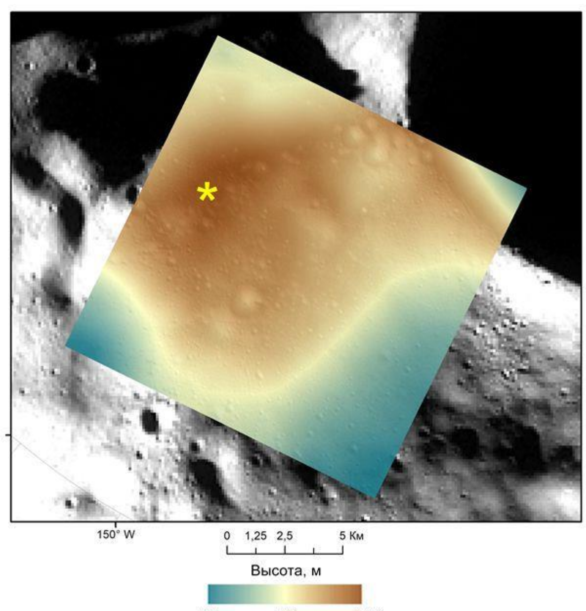


**Fig. 3**. Digital elevation models of sites #2 by data on LRO spacecraft (NASA) [7]. The asterisk shows the location of the temperature estimate in the lunar soil.

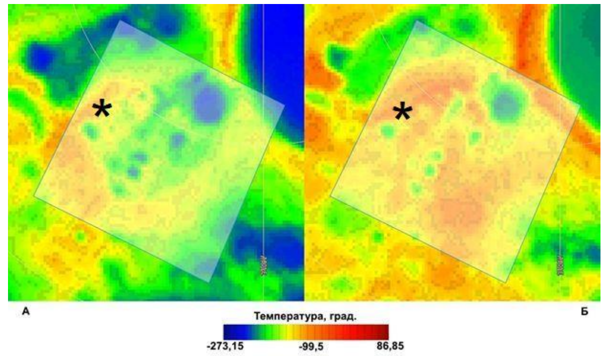


**Fig. 4**. Average winter (left) and summer (right) temperatures at site #2 [4]. The asterisk shows the location of the temperature estimate in the lunar soil.

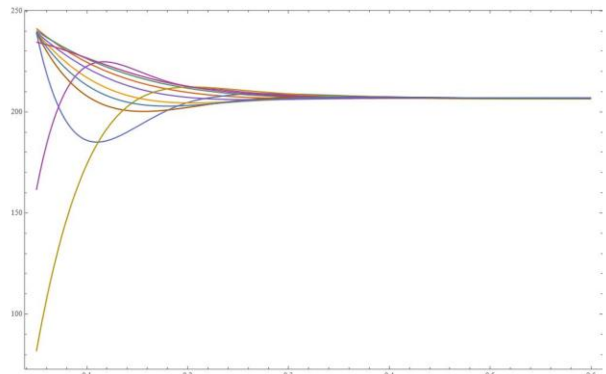


**Fig. 5**. Model of the daily course of temperature distribution in the lunar soil (x) at site #2 in the winter season (Fig. 4) depending on the temperature on the surface (y) with superimposed fluctuations in the region of all possible values.

**Summary:** The T(z) model, depending on the given conditions on the surface (duration of day and night, average day and night temperatures on the surface), allows solving the inverse problem for determining the steady-state equilibrium temperature in the lunar soil at depth. The estimated constant equilibrium temperature in the lunar soil at a depth of about 45 cm on a hill near the Shackleton crater with a degree of illumination of about 80% in the Summer season is about 230 K, and in the Winter season it drops to 210 K, which is 40 degrees lower than in the equatorial areas where there is no change of seasons.

**References:** [1] Slyuta E. N. et al., (2021) *Sol. Sys. Res*. 55(5), 446–466. [2] Mazarico E. et al. (2011) *Icarus* 211, 1066-1081. [3] Williams et al. (2019) *LPSC L* Abstract #2852. [4] Langseth M. G.et al. (1972) In: Apollo 15. Preliminary Science Report. NASA. Washington, D.C., 11-1 – 11-23. [5] Langseth M. G.et al. et al. (1973) In: Apollo 17. Preliminary Science Report. NASA. Washington, D.C., 9-1 – 9-24. [6] Langseth et al. (1976) *Proc. LPSC VII*, 3143-3171. [7] Slyuta E. N. et al., (2023) *LPSC LIV* Abstract #1092.