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FEATURES OF THE COMPOSITION AND STRUCTURE OF THE ATMOSPHERE OF MARS

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Abstract. The structure, composition, and dynamics of the rather thin atmosphere of Mars are considered. Climatic conditions and very extreme temperature changes on the planet's surface are studied. The atmosphere of Mars is an extremely thin gas shell consisting mainly (up to 96%) of carbon dioxide (CO_2). This makes it completely unsuitable for breathing by terrestrial organisms. Water vapor (H_2O) is a variable component with a content of 0.03-0.2%, and it plays a significant role in the formation of clouds and frost. The current composition of the atmosphere of Mars is the result of a long evolution. In modeling, the atmosphere is divided into the lower atmosphere (up to 7 km), where the temperature linearly and quite rapidly decreases with height, and the upper atmosphere (above 7 km), where the temperature also decreases, but with a smaller gradient. Clouds are observed in the Martian atmosphere, which consist mainly of water ice crystals, sometimes of dry ice (CO_2); the atmosphere is constantly filled with small dust particles.

Key words: Mars atmosphere, climatic conditions, clouds.

Introduction.

Let us consider the composition, structure and dynamics of the very thin atmosphere of Mars, as well as the climatic conditions and rather extreme temperature changes on its surface. After all, the atmosphere of Mars is one of the key factors that determines its modern climatic conditions [22, 25] and distinguishes it from the Earth. It is an extremely thin gas shell, which differs significantly in composition, pressure and structure from the Earth's atmosphere.

Composition and structure of the atmosphere.

The main component of the Martian atmosphere [9] is carbon dioxide (CO_2), which makes up 95-96% of its volume. Other significant components are nitrogen (N_2), the share of which is up to 2.7%, and argon (Ar) - up to 1.94%. The oxygen (O_2) content in the atmosphere of Mars is very low, only up to 0.16%. And this makes it absolutely unsuitable for the respiration of terrestrial organisms (Table 1). Carbon monoxide (CO) is also present at a concentration of 0.06-0.08%.

Water vapor (H_2O) is a variable component, its content usually does not exceed 0.03-0.2%, but it plays an important role in the formation of clouds and frost. Among other microcomponents, neon (Ne), krypton (Kr), xenon (Xe), nitric oxide (NO), ozone (O_3) and other gases in trace amounts have been found.

Compared to Earth, the composition of the Martian atmosphere is radically different. The Earth's atmosphere consists mainly of nitrogen (~78%) and oxygen (~21%). Although the absolute amount of CO_2 in the Martian atmosphere is small due to its overall rarefaction (Fig. 1 - 1), the relative concentration of carbon dioxide on Mars is approximately 23 times higher than in the Earth's atmosphere. The current composition of the Martian atmosphere is the result of a long evolution that includes the loss of lighter gases and water into space due to the weak gravitational field and the absence of a global magnetic field [1, 11] to protect against the solar wind, as well as chemical reactions with surface rocks, including the oxidation of iron.

Table 1 – Comparison of the composition of the atmospheres of Mars and Earth [24]

Components	**Mars (%)**	**Earth (%)**
Carbon Dioxide (CO_2)	95.1 - 96.0	~0.04
Nitrogen (N_2)	2.6 - 2.7	~78.08
Argon (Ar)	1.6 - 1.94	~0.93
Oxygen (O_2)	0.13 - 0.16	~20.95
Carbon monoxide (CO)	0.06 - 0.08	Traces
Water vapor (H_2O)	< 0.2 (variable)	< 4 (variable)
Medium pressure	~6.36 mbar	~1013 mbar

This table highlights the fundamental differences between the atmospheres of Mars and Earth that have a decisive influence on their climatic conditions and potential suitability for life [5, 6]. Structurally, the atmosphere of Mars [2] is a very thin shell (Fig. 1 - 2) with an average value of the characteristic height scale of about 11.1 km. However, in model calculations, the atmosphere is often divided into two main layers: the lower atmosphere (up to about 7 km), where the temperature decreases linearly and quite rapidly with height, and the upper atmosphere (above 7 km), where the temperature also decreases linearly, but with a smaller gradient.

The Martian atmosphere contains clouds that consist mainly of water ice crystals (Fig. 1 - 3), and sometimes of dry ice (CO_2). The atmosphere also constantly contains small dust particles that are lifted from the surface by the wind. On 02.05.2025, NASA's “Mars Odyssey” orbiter captured an image of the summit of the Martian volcano Arsia Mons, located above a greenish haze of water ice clouds. At the same time, it was possible to record how the clouds rise along the slopes of the volcano, cool and condense.

Formations of a condensation nature that periodically appear in the atmosphere of Mars are mainly represented by white clouds (Fig. 1 - 3) and fogs (Fig. 1 - 4). If the former were discovered during telescopic observations, then the latter were discovered thanks to data from spacecraft.

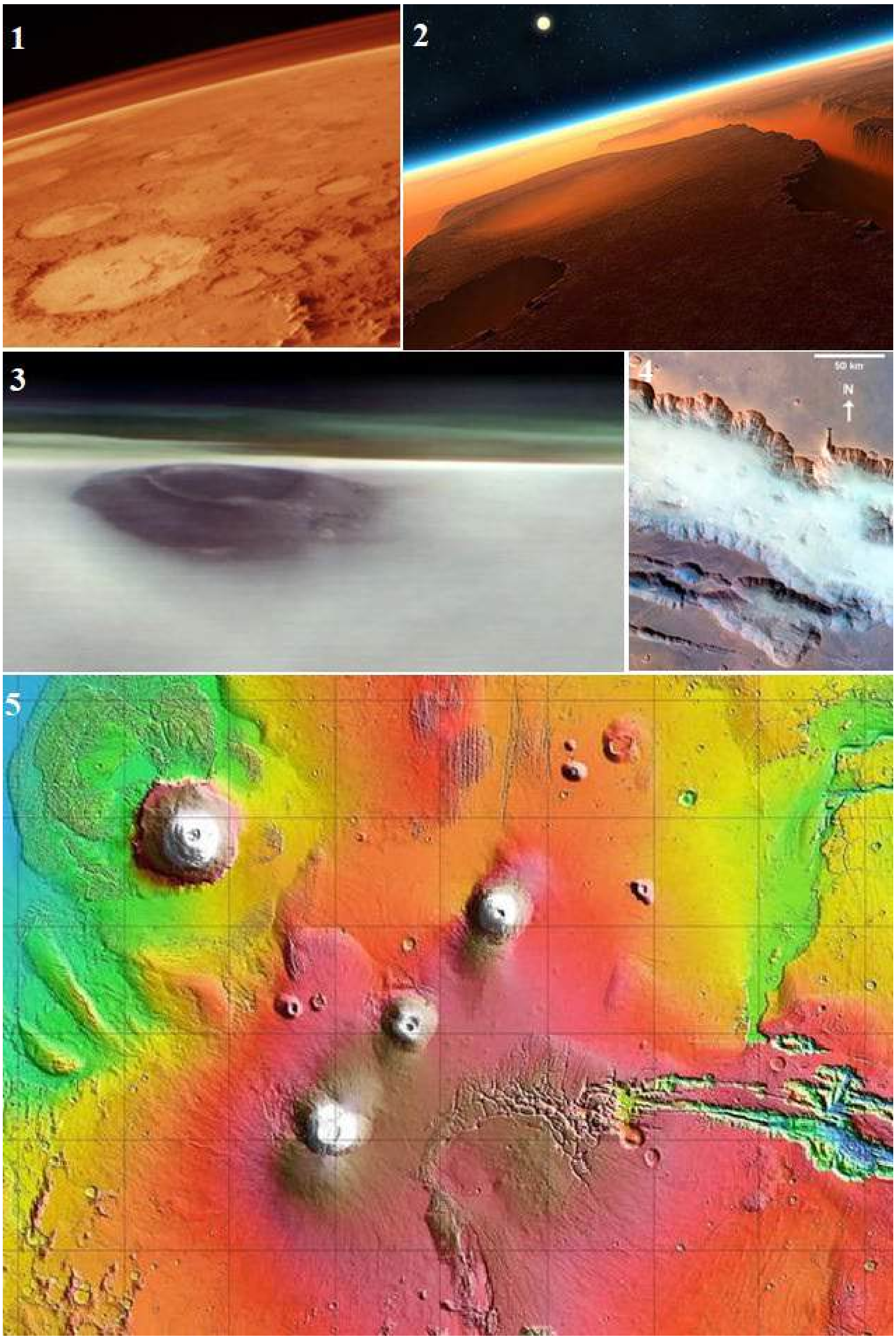

Figure 1. Features of the relief and atmosphere of Mars. 1 – A picture from the "Viking" orbiter shows the thin atmosphere on Mars over the Argyre region (http://photojournal.jpl.nasa.gov/). 2 – A view of the thin atmosphere over the surface of Mars (https://vsviti.com.ua/wp-content/uploads/2016/12/mars_009.jpg). 3 – An image of the summit of the Martian volcano Arsia Mons, visible through a haze of water ice clouds (https://cikavosti.com/wp-content/uploads/2025/06/hqz99coo2taj66tmefdb4u-970-80.jpg.webp). 4 – Image of dense ground fog in the western part of Valles Marineris from "Mars Express" on 25.05.2004 (https://cdn.theatlantic.com/media/mt/science/assets_c/2013/07/Marineris%20fog-thumb-570x738-127871.jpg). 5. Arsia Mons is the southernmost of the three volcanoes that make up the Tharsis Montes volcanic region. The largest volcano in the Solar System, Olympus Mons, is at the top left (https://cikavosti.com/wp-content/uploads/2025/06/600-443-20-06-25-01.jpg).

High-altitude aerosol formations (at altitudes above 20 km) in the atmosphere mainly arise from the condensation of CO_2. The same process is responsible for the formation of near-surface fogs in the polar regions. Most often, clouds and fogs form near the polar caps in winter, when the temperature in the atmosphere drops below the freezing point of carbon dioxide CO_2 (147 K). Clouds beyond the Arctic Circle are usually located quite low above the surface, at altitudes of less than 10 km. And these clouds are quite thin formations of ice CO_2 in winter and H_2O in summer.

Infrared spectra of white clouds at mid- and low latitudes obtained by many spacecraft have confirmed that white cloud formations consist mainly of water ice crystals. Typically, such water clouds form above the Martian surface at altitudes of about 20 km. In the morning, fogs thicken in the valleys (Fig. 1 - 4). Then winds can lift cooled air masses to the plateau, and white clouds could appear over high mountains (Fig. 1 - 3). In winter, the polar cap in the north is also enveloped by a curtain of dust and ice fog. Similar phenomena, but on a somewhat smaller scale, are observed around the southern polar cap. Both polar caps change their size in accordance with the changes of the seasons. It is also noted that many such clouds are formed when air masses rise along the windward slopes of large landforms.

However, it should be noted that there are very few suitable components for cloud formation in the atmosphere. After all, even if all the moisture were deposited on the surface, it would cover it with a layer of less than 0.01 mm. In the cold time of day, fogs often form over some lowlands, as well as on the bottoms of craters. Such fog most often consists of water ice particles. The volcano Arsia Mons is located in the south of the Tharsis Montes highland (Fig. 1 - 5), which consists of three volcanoes; the largest volcano in the Solar System [18-20] – Olympus Mons – is located in the same figure at the top left.

Atmospheric pressure and its variations.

One of the key characteristics of the Martian atmosphere is its extremely low pressure value.

The current atmospheric pressure on the Martian surface varies greatly depending on topography, from only about 30 Pa at the summit of Mount Olympus to over 1155 Pa in the deepest basins, such as the Hellas Plain. The average pressure on the planet's surface is only about 6.36 mbar. or 636 pascals (Pa). This is less than 1% of the average atmospheric pressure at sea level on Earth (about 1013 mbar). This low pressure has important consequences. In particular, it is very close to the triple point pressure of water (about 6.1 mbar) [3]. This indicates that liquid water cannot stably exist on most of the Martian surface under present-day conditions. At temperatures below 0°C, water exists as ice [4, 10, 21], and at temperatures above 0°C, it rapidly boils and evaporates on the Martian surface, i.e. sublimates from ice due to the low pressure.

This feature is a fundamental limitation for the possibility of terrestrial life forms on the modern surface of Mars [23]. Although short-term flows of very salty water, which has a much lower freezing point and a higher boiling point, are still possible under certain conditions on the Martian surface [7, 14-17].

The atmospheric pressure on Mars is not constant. It undergoes significant seasonal [8, 12, 13] fluctuations, varying at the mean surface level from approximately 4.0 to 8.7 mbar. These fluctuations, which can reach 30% of the average value, are caused by a unique process of condensation and sublimation of the main component of the atmosphere – carbon dioxide – at the polar caps. In winter, temperatures at the corresponding pole fall so low that CO_2 freezes, falling out of the atmosphere and forming a seasonal polar cap of dry ice.

This leads to a decrease in the total mass of the atmosphere and a drop in global pressure. In the spring, as the pole warms, the dry ice sublimates, returning CO_2 to the atmosphere and increasing pressure. This large-scale seasonal mass exchange between the atmosphere and the surface, involving a major atmospheric gas, is unique in the solar system and a key factor in Martian climate dynamics. Pressure also varies significantly with altitude, decreasing exponentially with elevation. For example, at the summit of the giant volcano Olympus Mons (Fig. 1 - 5), the pressure is only a small fraction of that in deep depressions such as the Hellas Plain.

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