SUMMER IS COMING SOON ON SATURN'S MOON TITAN. A.P. Vidmachenko[1] and O.F. Steklov[2], [1]National University of Life and Environmental Sciences of Ukraine, Str. Heroyiv Oborony, 12, Kyiv, 03041, Ukraine, avidmachenko@gmail.com; [2]Main Astronomical Observatory of National Academy of Sciences of Ukraine, Ak. Zabolotnogo Str., 27, Kyiv, 03143, Ukraine

Introduction: On the planets of the Solar System with a significant inclination of the plane of the equator to the plane of their orbits, during the time of rotation around the Sun, there are significant differences in the arrival of solar energy to different latitude zones. For example, the inclination of Saturn's equator to the plane of its orbit is B≈26°44' with a period of rotation around the Sun of 29.46 years. Therefore, this planet was the object on which we began to study seasonal changes in its atmosphere back in 1977. Our calculations [11] showed that Saturn passes the perihelion of its orbit in the summer epoch for the southern hemisphere; in aphelion – we have summer for the northern hemisphere. And due to the eccentricity of the orbit e≈0.056, the southern hemisphere of Saturn receives 25% more energy from the Sun than the northern one. The rings additionally block the access of sunlight to Saturn's clouds, enhancing seasonal contrasts [11]. Similar changes in atmospheric irradiation affect the physical characteristics of clouds, fog above them, and the vertical structure of the troposphere [16]. Therefore, they are associated with seasonal changes [1] inflow of solar energy.

Saturn's satellite Titan, with a diameter of 5152 km, is the second largest in the Solar System [13] after Jupiter's satellite Ganymede [15]. Titan orbits at an average distance of 1221870 km from the planet. The period of its rotation in the orbit of 15.945 Earth days, is synchronized with the rotation around the planet. The plane of the satellite's orbit almost coincides with the plane of Saturn's rings. Therefore, it is illuminated by the Sun in the same way as Saturn itself. This means that in 29.46 Earth years, Titan alternately leans towards the Sun by the northern and southern polar regions. This also leads to changes in the inflow of solar energy to the northern and southern hemispheres of the satellite.

Titan's atmosphere consists of 95% nitrogen with admixtures of methane and small amounts of other gases. Its powerful atmosphere creates a pressure near the surface of almost 1.5 bar [9]. The temperature on the surface of the satellite is 94 K, which is the condensation temperature of nitrogen.

The first radar studies from space vehicles and observations in the infrared (IR) region of the spectrum with the Hubble telescope, Keck's telescopes and with the Very Large Telescope – indicated the possibility of the existence on the surface of Titan of seas, lakes and swamps of liquid nitrogen, islands of frozen water and methane, and also silicates on a "dry" surface. At the same time, methane rains were also recorded. These facts made it possible to put forward proposals for comparing the water cycle on Earth with the processes on Titan. We drew attention [15] to the possibility of seasonal changes in Titan's powerful atmosphere [19]. These changes should cause periodic restructuring and variations of physical characteristics in the northern and southern hemispheres of the satellite [21], similar to the existing seasonal changes in the atmosphere of Saturn [6], Jupiter [2, 8], Mars [14] or Earth [3-5].

Features of clouds on Titan. Observations from Earth also showed that the vast majority of changes in visible clouds on Titan occurred within a period of 20-25 years. After all, it is during this time that the polar regions of one of the hemispheres are illuminated by sunlight. And the polar regions of the opposite hemisphere at the same time are in the polar night. And there, the activity of the processes, is almost completely stopped for 4-7 years. At the end of this period, the activity of processes in the atmosphere resumes for the next similar period already in the opposite hemisphere.

Observational data on the vertical structure of the satellite's atmosphere were obtained during the descent of the "Huygens" module. The structure of denser clouds turned out to be similar to terrestrial cumulus formations [10]. Only the sizes of methane droplets on Titan were almost two orders of magnitude larger than terrestrial water droplets. Therefore, at the same level of humidity, the droplets in the clouds on Titan were located at a greater distance from each other, and had a lower density. The obtained observational data showed that huge masses of warm gases at an altitude of about 7 km moved from the southern hemisphere to the northern polar region; there – they went down and turned back. The results of a computer simulation of global atmospheric circulation, and measurements in the IR range showed that the integrated temperature gradually decreased when moving from south to north. In 2006, it was winter there [2]. And the southern hemisphere at the same time was tilted towards the Sun.

During the descent of the "Huygens" probe, it was recorded that at an altitude of 6-7 km, and then at an altitude of 0.7 km above the surface, the wind changed its direction twice to the opposite. It is believed that these two height values in Titan's atmosphere [7] indicate a circulation process known as the Hadley cell that circulated between the poles. It was the main way of heat transfer in the atmosphere. Therefore, it was 10 K warmer in the south of Titan than at the equator. Such a southern summer continued until 2010. After that, Titan began to tilt on its orbit so, that already its northern hemisphere began to be heated more and more by the Sun. Due to very slow Titan's rotation, the system of air flows on the satellite is significantly different from what is registered on Earth [14]. This fact makes it possible to study a climate system significantly different from Earth in a comparative aspect.

Characteristics of seasonal changes. In Titan's atmosphere in the winter northern hemisphere, clouds of ethane snow were also observed. It is believed that it is the condensation of ethane in the polar regions of Titan during the polar winter that can explain the practical absence of liquid reservoirs almost to tropical latitudes. Near the "Huygens" landing site, even near Titan's equator, the riverbeds were not filled with liquid. That is, they could be as seasonal channels that are filled only during the period of the year when precipitation falls. Whereas at the time of the probe landing, there was a dry season [20]. It took almost 2 years after the landing of "Huygens" before the seasonal hypothesis received direct confirmation about of the end of winter in the northern polar region by radar studies from "Cassini".

The main chemical component of the atmosphere on Titan and Earth is the same: it is nitrogen. The role of rocky rocks on Titan is assigned to water ice [14, 15], and the role of terrestrial water is performed by liquid methane with additives. The long period of rotation of Saturn around the Sun, and the change of seasons caused by this fact, well explains the fact that during the operation of "Cassini" in 2008-2017, there were heavy rains in the northern hemisphere. Therefore, it was there that the appearance of a large number of hydrocarbon lakes was registered, which covered a sixth of this area [23]. And in the southern hemisphere, almost all reservoirs dried up in those days.

After that, radar observations of the region around the South Pole began. This made it possible to reveal significant differences between the northern and southern polar regions of Titan. Beyond the winter southern polar circle, it was possible to find a large number of dry depressions, which were similar in shape to craters [17, 18], to northern lakes [12], to a basin from under a dry sea with a system of rivers and canals [22].

Conclusions. The main reason for the sharp contrast in the landscapes around the opposite poles of Titan is most likely the differences in natural conditions between the winter and summer seasons [3] in these regions.

It can be predicted that at the equinox in 2024-2025, the southern hemisphere of Titan will have the end of winter, and the northern hemisphere - the end of summer. At these moments, the existing contours of lakes and seas undergo radically opposite changes. After all, the gradual heating of the southern polar region will lead to the rise of evaporated methane there, the formation of thick clouds and the fall of methane rains, which will fill the previously dry southern lowlands. And around the North Pole, almost all the liquid will freeze, and only the remains of the largest sea and several small lakes will remain there.

Therefore, it would be very appropriate to conduct patrol observations in the IR range with large telescopes in 2023-2030 in order to test this hypothesis regarding seasonal changes on Titan. This would open up new opportunities for comparative studies of the seasonal dynamics of changes in the sufficiently powerful atmospheres of Titan and our planet Earth.

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