

Report on the content of the dissertation

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(name of the member of the committee)

Shaposhnikov Dmitry Sergeevich

(name of the candidate for the degree)

Numerical Simulation of the Hydrological Cycle of Mars

(Title of the dissertation, degree, speciality)

candidate of physical and mathematical sciences

01.03.04 – Planetary Research

Date of the defense: 18.12.2019

The evaluation of the dissertation in accordance with the Regulations on the award of scientific degrees of candidates and doctors of sciences at MIPT (hereinafter – Regulations):

1. Relevance of the topic of the dissertation:

Thesis of D.S. Shaposhnikov is dedicated to modeling of the hydrological cycle in the Martian atmosphere using various dust scenarios. Atmospheric modeling is an actively developing area of modern scientific research of Mars. Water vapor plays an important role in the climate of the planet due to its influence through radiation-active clouds. Currently, there are only a few models that can accurately reproduce the annual behavior of water vapor and only one that simulates the planet's upper atmosphere in 3D. An indisputable influence on the water cycle of the planet's cycle is the behavior of dust acting as condensation nuclei for water ice. Accurate reproduction of water vapor behavior, in turn, is important for future space missions such as ExoMars / TGO. Thus, the research topic is relevant.

2. Scientific novelty of the results:

Thesis D.S. Shaposhnikov presents the following new results. For the first time, three-dimensional modeling was carried out using a bimodal dust distribution scheme based on SPICAM experimental data. The effect of dust scenario on the annual distribution of water vapor and ice is shown. The simulation area was expanded into the thermosphere of the planet up to 160 km considering the photodissociation of water vapor. The mechanism of water vapor transfer to the upper atmosphere is modeled and explained. The errors of the widespread implementation of the nucleation / growth scheme of a part and its dependence on time are shown. Methods for dealing with instability are proposed.

3. Theoretical and practical importance of the dissertation:

The thesis results can be used to theoretically substantiate the landing site and flight paths of future and current aircraft, aimed at studying the climate of the planet, which is an important task. It is also possible to apply the obtained model and conclusions of the dissertation to develop future models of the long-term evolution of climate, including the mechanisms of terraforming.

4. Completeness of publication of the main results of the dissertation in peer-reviewed scientific journals in accordance with the requirements of the Regulations:

The main results of the work were reported at 18 conferences, 9 of which are international, and presented in 6 publications, 3 of which are published in refereed journals included in Web of Science and Scopus and recommended by Higher Attestation Commission, 3 — in conference proceedings. The certificate of state registration of computer program №2019611779 was obtained by D.S. Shaposhnikov. The requirements of the Regulation are met.

5. Questions and remarks (according to part 4.13 of the Regulations, the candidate addresses the questions and remarks formulated below during the defense):
The disadvantages of this work include an extremely primitive scheme of chemical reactions in the upper atmosphere of the planet. It is known that modern one-dimensional atmospheric models take into account hundreds of chemical reactions, which include water vapor, among others. Only photodissociation is specified in the model. Does it somehow affect the distribution of water vapor in the upper atmosphere in the model? The second important point relates to the fact that the dust in the model is predefined and cannot move. How does this affect the accuracy of model predictions? Can dust be a tracer? Nevertheless, these remarks are advisory in nature and do not reduce the value of the work as a whole.
6. General evaluation of the dissertation (excluding the introductory part):
The new actual scientific results were obtained during the dissertation research. I believe that the topic of the dissertation is of both scientific and practical interest, it corresponds to the basic directions of research in priority areas of science.

The topic of the dissertation corresponds to the specialization 01.03.04 - Planetary Research. The dissertation is in accordance with the Regulations on the award of scientific degrees of candidates and doctors of sciences at MIPT.

Date 25.11.2019

Signature *Zasova* / Liudmila Veniaminovna Zasova
full name

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Ученый сектор *Савоский А.М.*

