Thesis review

Applicant: Shaposhnikov Dmitry Sergeevich

Thesis: "Numerical Simulation of the Hydrological Cycle of Mars"

Scientific specialty: 03.06.01 - "Physics and Astronomy"

The degree for which the thesis is presented: PhD in Physical and Mathematical sciences

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Reviewer

Fadeev Rostislav Yurievich

Academic degree: Phd

Year of awarding the degree and the scientific specialty in which the degree was awarded: 2009, 25.00.29 - "Physics of Atmosphere and Hydrosphere"

Academic title:

Employment: Marchuk Institute of Numerical Mathematics Russian Academy of Sciences

Position: senior researcher

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1. Research relevance

Mars is a terrestrial planet with a rarefied atmosphere but with seasonal changes reminiscent of those on Earth. The current understanding of the Martian atmosphere dynamics and the climate is based on the scarce and short-term data obtained from orbital vehicles equipped with remote sensing instruments. One of the promising ways to fill the gap in our knowledge of the atmosphere of Mars is to develop the numerical atmospheric models.

Evidences for water on the surface of Mars were found due to radar data (2005), the Mars rover Spirit (2007) and the Phoenix lander that directly sampled water ice in the shallow Martian soil (2008). Water and dust play an important role the Martial climate so that development of models including the cloud microphysics and corresponding parameterization seems to be of great importance.

2. Scientific novelty

The author designed the method to study the hydrological cycle in the atmosphere of Mars. To this end a new extension to the MPI-MGCM model and a diagnostic parameterization package were developed.

3. Theoretical and practical significance of the thesis

The importance of the dissertation work is due to consistent consideration of the processes affecting the hydrological cycle on Mars and appropriate parameterizations. All results of numerical modeling were carefully verified by comparison with available measurement data.

4. Completeness of publication of the main results of the thesis in refereed scientific journals

3 papers were published on the subject of the thesis in refereed journals indexed by WoS and Scopus. The main results of the work were reported at 9 international conferences.

5. Questions and comments
    1. The development of parameterizations for global atmospheric circulation model is a time-consuming and complicated process that involves verification and carefully tuned methods. The subgrid scale process parameterizations usually contain a large number of parameters. On the basis of which criteria the dimensionless constants were selected in the proposed parameterizations? For example, no proof for the choice of the exchange coefficient Cd (formula 2.46, page 44) is presented. This parameter substantially affects the flux of water between the Martian surface and its atmosphere.
    2. The dissertation discusses the parameterization of water transport in different phases, including precipitation and sublimation from the surface. Parameterizations are implemented into the MPI-MGCM global model independently tested in other studies. Verification of parameterizations is limited to tests that analyze the quality of hydrological cycle. Water together with dust in the atmosphere of Mars regulates the amount of incoming solar radiation to the surface of the planet, which, in turn, has a significant impact on the large-scale dynamics. This means that the influence of ice droplets as well as of dust particles can be indirectly taken into account in the parameters of the MPI-MGCM model. The work should be extended by analysis of the quality of global circulation, taking into account the feedback from the water content in the atmosphere of Mars (with the prescribed dust distribution).
    3. Dust plays an important role in the Martian hydrological cycle. One of the most important mechanisms of moisture transport in the atmosphere of Mars is water ice condensations on dust nuclei. Can it be that satellite observations on dust distribution in the atmosphere of Mars take into account the dust particles covered by ice? If so, the amount of dust used in numerical experiments seems to be overestimated.
    4. The domain of MPI-MGCM model has been extended up to about 160 km. Usually, the inclusion of the new atmospheric layers into the model is accompanied by the development of new parameterizations to describe specific processes. Has the quality of lower atmosphere dynamics been tested in the frame of the new version of the model using the standard tests?
    5. What time step was used in the numerical experiments in the MPI-MGCM model core?

Despite the above comments, the thesis by Dmitry Shaposhnikov includes important and new scientific results about the hydrological cycle in the atmosphere of Mars. The author of the thesis proved his ability to perform research and to achieve scientific results. I believe that the work is fully consistent with the thesis requirements, and Dmitry Sergeevich Shaposhnikov deserves the degree of candidate of physical and mathematical sciences in the specialty 01.03.04 - Planetary Research.

Date: 30.08.2019

Rostislav Yu. Fadeev

I confirm signature and content,
scientific secretary of the INM RAS scientific council
Phd, Professor

Shutyaev V.P