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## LMSU contribution to PSWS Alert Service

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| **PP** | Restricted to other programme participants (including the Commission Service) | |
| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
| **CO** | Confidential, only for members of the consortium (excluding the Commission Services) | |

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**Abstract:** Data on energetic particle fluxes measured by MKL instrument onboard Coronas-F satellite are collected at Space Monitoring Data Center (SMDC) of Skobeltsyn Institute of Nuclear Physics Lomonosov Moscow State University (LMSU). LMSU data service is connected to VESPA via EPN TAP. Our team has also improved the paraboloid magnetospheric model and has continued working on a generalized magnetospheric model. This model can be calibrated to be used for analysis of the magnetosphere of any solar system planet possessing an intrinsic magnetic field.
Consequently, we aim to develop a generalized approach for description of magnetospheric processes while using a paraboloid of revolution to define the magnetopause shape in all scenarios.

# 1. Access to Coronas-F measurements of charged particle fluxes in the Earth's magnetosphere

## 1.1 Introduction and goals

Data on energetic particle fluxes from Russian satellites have been collected in the Space Monitoring Data Center (SMDC) of Skobeltsyn Institute of Nuclear Physics of Moscow State University (LMSU) in the near real-time mode. Web-portal http://smdc.sinp.msu.ru/ provides operational information on radiation state of the near-Earth space. Currently operational data are coming from space missions ELECTRO-L2, Meteor-M1 and Meteor-M2. High-resolution data on energetic electron fluxes was obtained from recent MSU's missions Vernov and Lomonosov. Measurements from previous Russian Missions: Coronas-F, Coronas-Photon, Meteor- 3M, are also available. Specific tools allow the visual representation of the satellite orbit in 3D space simultaneously with particle fluxes variations. Web-portal http://smdc.sinp.msu.ru/ provides access to the unique data characterizing the radiation conditions in the Earth's magnetosphere in the real-time mode and also to historical data. The main aim of this work is to create at SMDC the prototype of data service that will include ///measurements to VESPA environment through EPN-TAP.

## 1.2 Implementation

## 1.21 Access to data

Data can be accessed by two different ways. The first is direct http access to daily CDF files and the second one is using EPN-TAP protocol with URL http://vespa.sinp.msu.ru/_system_/tap/run/tap by one of the avalable compatible software (TOPCAT for example).

## 1.22 Future development

VESPA data service give the possibility to provide virtual access to the some datasets collected at Space Monitoring Data Center. Two types of data can be collected by EPN-TAP instruments: satellite measurements data and paraboloid model input parameters. The latter will be obtained from data on magnetic field measured during recent planetary missions: Cassini, Juno, Messenger. These data will be accessed through EPN-TAP services to provide "on-the-fly" calculations of the planetary magnetic field model in the framework of Europlanet Research infrastructure.

## 2. Upgrade the paraboloid magnetospheric models of the Solar system planets.

During this reporting period (from January 2017 till September 2018) the Lomonosov Moscow State University team has created the VESPA data gate at Lomonosov Moscow State University and maintains it in an operational condition (see section 1). Our team has also improved the paraboloid magnetospheric model and has continued working on a generalized magnetospheric model. This model can be calibrated to be used for analysis of the magnetosphere of any solar system planet possessing an intrinsic magnetic field. Consequently, we aim to develop a generalized approach for description of magnetospheric processes while using a paraboloid of revolution to define the magnetopause shape in all scenarios. Once successful, we can test the model using spacecraft data from European and US missions (MESSENGER, Cassini, Galileo, Juno); additionally, it may be used to investigate exoplanetary magnetospheres and to interpret the role of magnetic field in planetary atmosphere evolution and potential habitability.

The short list of main achievements for 2017-2018 years is:

**2.1 The combined model of Mercury's magnetosphere**

The combined model (comprised of a numerical hybrid simulation and the empirical paraboloid model) of Mercury's magnetosphere has been constructed. It gives us the possibility to refine the global parameters of magnetosphere using MESSENGER's magnetometer data from each of over 4100 orbits of the spacecraft around Mercury (see Parunakian, D., S. Dyadechkin, I. Alexeev, E. Belenkaya, M. Khodachenko, E. Kallio, and M. Alho (2017), Simulation of Mercury's magnetosheath with a combined hybrid-paraboloid model, J. Geophys. Res. Space Physics, 122, 8310–8326, doi: 10.1002/2017JA024105).

We have performed calculation of the initial magnetospheric magnetic field of Mercury and the boundary conditions for subsequent hybrid modeling and defined the initial parameters of the global magnetospheric current systems in a way that allows us to minimize paraboloid magnetic field deviation along the trajectory of MESSENGER from the experimental data. We have modelled the magnetosheath magnetic field and calculated the portion of the interplanetary magnetic field penetrating the magnetosphere (see Alexeev I., Parunakian, D., Dyadechkin, S. et al. Cosmic Res (2018) 56: 108. https://doi.org/10.1134/S0010952518020028).

**2.2 Optimal parameters of the Jovian magnetodisc**

Juno measurements of the magnetic field during the Perijove 1 pass have allowed us to determine optimal parameters of the magnetodisc using the paraboloid magnetospheric magnetic field model which employs analytic expressions for the magnetospheric current systems. Specifically, within the model we determine the size of the Jovian magnetodisc and the magnetic field strength at its outer edge (Pensionerov et al., 2019,. Ann. Geophys., 37, 101-109, https://doi.org/10.5194/angeo-37-101-2019). We have also researched alternative magnetodisc descriptions, including the 1/r azimuthal current density dependence on the radial distance to the planet and $1/r^2$ dependence.

**2.3 An open and a partially closed models of the Saturn's magnetosphere.**

We have continued our work on the determination of the main features of Saturn's magnetosphere using Cassini magnetic field data. We have compared 2012/2013 Saturn northern spring interval of highly inclined orbits with similar data from late southern summer in 2008, thus providing unique information on the seasonality of the currents that couple momentum between Saturn's ionosphere and magnetosphere. Inferred meridional ionospheric currents in both cases consist of a steady component related to plasma subcorotation, together with the rotating current systems of the northern and southern planetary period oscillations. This can help us to develop a correct model of the field-aligned currents in the magnetosphere (see Bradley, T. J., Cowley, S. W. H., Provan, G., Hunt, G. J., Bunce, E. J., Wharton, S. J., Alexeev, I. I., Belenkaya, E.S., Kalegaev, V.V., Dougherty, M.K. (2018). Field-aligned currents in Saturn's nightside magnetosphere: Subcorotation and planetary period oscillation components during northern spring. Journal of Geophysical Research: Space Physics, 123, 3602–3636, https://doi.org/10.1029/2017JA024885).

We have also considered two magnetospheric magnetic field models for the case of Saturn: an open model in which the interplanetary magnetic field penetrates the magnetosphere, and a partially closed model in which field lines from the ionosphere go to the distant tail and interact with the solar wind at its end. To that end we have used Cassini magnetometer data, images of Saturn's ultraviolet aurora obtained by the Hubble Space Telescop, and the paraboloid model of Saturn's magnetospheric magnetic field. We have concluded that the open model is preferable, which is more obvious for southward interplanetary magnetic field; this result will be used in the generalized paraboloid model for the case of Saturn. Different magnetospheric topologies determine different mapping of the open-closed boundary in the ionosphere, which can be considered as a proxy for the poleward edge of the auroral oval (see Belenkaya, E. S., Cowley, S. W. H., Alexeev, I. I., Kalegaev, V. V., Pensionerov, I. A., Blokhina, M. S., and Parunakian, D. A.: Open and partially closed models of the solar wind interaction with outer planet magnetospheres: the case of Saturn, Ann. Geophys., 35, 1293-1308, https://doi.org/10.5194/angeo-35-1293-2017,
2017).