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ON THE CURRENT STATE AND PROSPECTS OF SPACE WEATHER MONITORING IN RUSSIA

Federal service on hydrometeorology and environmental monitoring (ROSHYDROMET)
Russia

AOMSUC-10 - Melbourne, Australia - 5 December 2019
What is the space weather?

- **Space weather** – is the complex of geophysical phenomena on the Sun, in the interplanetary and near-Earth space, magnetosphere, ionosphere and upper atmosphere (solar flashes, magnetic storms, ionosphere disturbances, cosmic rays) influencing the functioning of technical equipment and systems (navigation, radio communication, electric power industry, on-board equipment of aircrafts and spacecrafts etc.) and having biomedical effects for human
ENHANCEMENT OF SOLAR ACTIVITY

Number of solar spots

23 solar cycle

24 solar cycle

We are here

smootherd monthly values --> monthly values
Changing of the magnetic pole position

Changing of the auroral area

CHANGE OF RUSSIA TERRITORY SUBJECT TO MAGNETIC FIELD DISTURBANCES
GROUND BASED NETWORK OF SPACE WEATHER MONITORING FACILITIES

- Solar Telescope
- High-orbit radio tomography
- Low-orbit radio tomography
- Riometer
- Magnetometer
- Ion sounder
RUSSIAN SATELLITE GROUPING FOR SPACE WEATHER MONITORING

- operational (4)
- perspective to 2025 (17)
RUSSIAN OPERATIONAL SPACECRAFTS WITH HELIOGEOPHYSICAL PAYLOAD

METEOR-M № 1, 2, 2-2 (near circular sun-synchronous orbit, $H_{\text{orb}} = 820$ km)

**Heliogeophysical instrument complex GGAK-M**

1. Multi-channel spectrometer of corpuscular radiation MSGI-MKA
2. Spectrometer of solar cosmic rays SKL-M
3. Detector of galactic cosmic rays GALS-M
4. Short-wave solar radiation measurement device IKOR-M
5. Radio-frequency mass-spectrometer RIMS-M

*Global monitoring of heliogeophysical parameters for:*
- control and forecasting of radiation environment in near-earth space and geomagnetic field
- control and forecasting of the state of ionosphere and radio wave propagation conditions
- diagnostic and control of magnetosphere and upper atmosphere
RUSSIAN OPERATIONAL SPACECRAFTS WITH HELIOGEOPHYSICAL PAYLOAD

ELEKTRO-L № 2 (geostationary orbit, $H_{orb} = 36000$ km, staying point $76^\circ E$)

Heliogeophysical instrument complex GGAK-E

1. Spectrometer of corpuscular radiation SKIF-6
2. Spectrometer of solar cosmic rays SKL-E
3. Detector of galactic cosmic rays GALS-E
4. Solar constant measurement device ISP-2M
5. Ultra-violet solar radiation measurement device VUSS-E
6. X-ray solar radiation measurement device DIR-E
7. Magnetometer instrument FM-E

*Global monitoring of heliogeophysical parameters for:*
- control and forecasting of flash activity of the Sun
- control of radiation environment in near-earth space
- diagnostic and control of geomagnetic field
1. **The unified corpuscular radiation spectrometer SKIF-VE** for low-energy electrons and protons differential energy spectra measurement in energy range 0.05...20.0 keV and alpha-particles ~9.0...50.0 MeV

2. **Galactic cosmic rays detector GALS-VE** for measuring of galactic cosmic rays proton flux density with energy higher than 600 MeV;

3. **Magnetometer instrument FM-VE** for measuring of three components of the magnetic induction vector in the range ±65 mT

4. **Electronic interface device BND-VE** for recording, storage, preliminary processing and preparation for transmission of heliogeophysical data from all GGAK-VE instruments.

- **HEO «ARKTIKA» system** will consist of two satellites for high-latitude frequent observation.
- The platforms are actively stabilized over 3 axes.
- The design life time is 5 years.
- The satellites exploit the highly elliptical «Molniya»-type orbit.

**Orbit parameters:**
- apogee height ($\alpha$) ~ 40000 km;
- perigee height ($\pi$) ~ 1000 km;
- inclination (i) ~ 63°;
- circulation period ~ 12 hours

**Mutual orbit arrangement:**
coincidence of ascending node of SC №1 orbit and descending node of SC №2 orbit
Space system "IONOZOND"

- "IONOSFERA" subsystem:
  4 satellites - 2 satellites in 2 circular sun-synchronous orbits of 600-900 km altitude, to be launched in 2023-2024

- "ZOND" subsystem:
  1 satellite "ZOND" in near-circular sun-synchronous near-terminator orbit, altitude at equator 600-650 km, period 98 min, inclination 97°, to be launched after 2025
The payload of “IONOSFERA” will include:
- ion sounder operating in the range 0,1-20 MHz;
- plasma spectrometer;
- ozonometer;
- low-frequency wave complex;
- TEC meter;
- spectrometer of plasma and high-energy radiation;
- galactic cosmic rays spectrometer;
- gamma-spectrometer;

The payload of “ZOND” will include:
- FM-G – magnetometer for measurement of magnetic field vector with dynamic range: ±4 to ±65556 nT and resolution ±1 nT;
- SUF – Spectrometer for measuring UV radiation from the Sun in the range 50-130 nm;
- STEK – Telescope-coronagraph to measure solar UV and VIS radiation;
- Galactic gamma-ray spectrometer;
- SRF – X-ray photometer for monitoring soft solar X-radiation for the range 10-100 keV.
- SOLIST – X-ray and UV telescope to measure solar radiation in the X-ray and UV fields;
- RIMS-A – Radio-frequency mass spectrometer;
Global map of charged particles flow (electrons with energy more than 0.7 MeV and protons with energy more than 15 MeV) at the METEOR-M №2 orbit altitude for January 2016
SKL-E sensor of ELEKTRO-L №1 data for 07 March 2012 - 16 March 2012.
Solar proton event recorded on 7 March 2012.

Energy range, MeV

<table>
<thead>
<tr>
<th>Energy range</th>
<th>Ee</th>
<th>Ep</th>
</tr>
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<tbody>
<tr>
<td>ch 1</td>
<td>≥0.2</td>
<td>≥3.5</td>
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<tr>
<td>ch 6</td>
<td>13.7-23</td>
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<td>ch 7</td>
<td>23-42</td>
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<td>ch 8</td>
<td>42-112</td>
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<tr>
<td>ch 10</td>
<td>≥1</td>
<td>≥15</td>
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</table>
Magnetic storm recorded on 16 March 2016 by magnetometer FM-E of ELEKTRO-L №2 and GOES spacecraft.
Operation of GALS-E detector of ELEKRO-L №2 spacecraft in quiet heliogeophysical conditions
RATAN 600: daily multi-wave radio scanning of the Sun with active regions flare productivity estimation
INFORMATION PRODUCTS OF HELIOGEOPHYSICAL MONITORING (GROUND SEGMENT)

High-orbit radio tomography – the use of global navigation satellite systems

GLONASS

3-D reconstruction of ionosphere electron concentration spatial distribution

GPS
Specialized information products of tomographic network

Critical frequency of f0F2 layer

Scintillation index

Equivalent ionosphere thickness

TEC

TEC hourly change

Latitude (longitude) – altitude sections
INFORMATION PRODUCTS OF HELIOGEOPHYSICAL MONITORING (GROUND SEGMENT)

State of geomagnetic field at ground stations

- Barentsburg
- Murmansk
- Amderma
- Tiksi
- Moscow
- Novosibirsk
- St-Petersburg
- Petropavlovsk-Kamchatsky
In 2017 International civil aviation organization (ICAO) has initiated Meteorological Service for International Air Navigation (Annex 3: Amendment 78) prescriptive to provide Space weather advisory messages.

In 2018 Applied Geophysics Institute (AGI) of Roshydromet has passed the audit of ICAO as regional provider of space weather information for civil aviation. The space weather center organized on the basis of AGI has started operation as regional center of space weather.

In July 2018 the Russian-Chines Consortium was established between Roshydromet and CMA. Now the Consortium is attaining to become a global center of space weather.
RUSSIAN SPACE WEATHER CENTER TO SUPPORT INTERNATIONAL AIR NAVIGATION
Space weather advisory messages

<table>
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<tr>
<th>SWX ADVISORY</th>
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<tbody>
<tr>
<td>DTG:</td>
<td>20170419/0300Z</td>
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<tr>
<td>SWXC:</td>
<td>(tbd)</td>
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<tr>
<td>SWX EFFECT:</td>
<td>RADIATION MOD</td>
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<tr>
<td>ADVISORY NR:</td>
<td>2017/2</td>
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<tr>
<td>FCST SWX:</td>
<td>20170419/0300Z HNH HSH E18000-W18000 ABV FL370</td>
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<tr>
<td>FCST SWX + 6 HR:</td>
<td>20170419/0900Z HNH HSH E18000-W18000 ABV FL370</td>
</tr>
<tr>
<td>FCST SWX + 12 HR:</td>
<td>20170419/1500Z HNH HSH E18000-W18000 ABV FL370</td>
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<tr>
<td>FCST SWX + 18 HR:</td>
<td>20170419/2100Z NO SWX EXP</td>
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<tr>
<td>FCST SWX + 24 HR:</td>
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<td>RMK:</td>
<td>RADIATION AT AIRCRAFT ALTITUDES ELEVATED BY SMALL ENHANCEMENT JUST ABOVE PRESCRIBED THRESHOLD. DURATION TO BE SHORT-LIVED. SEE <a href="http://WWW.SPACEWEATHERPROVIDER.COM">WWW.SPACEWEATHERPROVIDER.COM</a>.</td>
</tr>
<tr>
<td>NXT ADVISORY:</td>
<td>NO FURTHER ADVISORIES</td>
</tr>
</tbody>
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Dissemination of space weather information

AFS ICAO

SADIS / WIFS (Backup)

ROC/IROG London

RTH Exeter

AMHS

ROC/IROG Toulouse

RTH Toulouse

AMHS

ROC/IROG Vienna

RTH Prague

AMHS

AFTN

AMHS in the future

AFTN

260 Russian AMOs (28 MWOs)
Aerodrome meteorological offices
Meteorological watch offices

Corporate network of Roshydromet «MECOM»

INTERNET

National OPMET Centers (NOCs)

NOC Belarus
NOC Ukraine
NOC Moldova
NOC Armenia
NOC Georgia
NOC Azerbaijan
NOC Kazakhstan
NOC Uzbekistan
NOC Turkmenistan
NOC Tajikistan
NOC Kyrgyzstan

AMHS in the future

AMHS

ATC (air traffic control units)

BRIEFING (crew members)

2016 - 2023

MSS / FSS

RUSSIAN SPACE WEATHER CENTER
TO SUPPORT INTERNATIONAL AIR NAVIGATION

Roshydromet

National OPMET Center (ROC in the future)

Bank of OPMET Data
INSTITUTE OF APPLIED GEOPHYSICS «IAG»

MSS/FSS

GISC
Audit report 26-27.03.2013

FTP «RUSAVIAMET»

RMDCN Contract with Interoute Communication Ltd № 33/16 23.03.2016

The Order of Roshydromet № 206 20.10.2003

RUSSIAN SPACE WEATHER CENTER
TO SUPPORT INTERNATIONAL AIR NAVIGATION

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THANK YOU!