Assessment and assimilation of observations of the hyperspectral IR sounder IKFS-2 on board the Russian Meteor-M N2 satellite

Saint-Sauveur, QC, Canada, 4 Nov 2019
Outline

• Russian Earth Observation Satellites Program in a nutshell
• A brief introduction of the IKFS-2 hyperspectral infrared Fourier spectrometer
• Pre-processing of IKFS-2 data
• Assessment of accuracy of IKFS-2 data. Comparison with the accuracy of IASI data
• Selection of channels
• Assimilation of IKFS-2 data in 3D-Var data assimilation system.
## Russian Earth Observation Satellites Program
(Federal Space Program for 2005-2015 and 2016-2025)

<table>
<thead>
<tr>
<th>System</th>
<th>Launches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geostationary meteorological system</strong></td>
<td><img src="image" alt="Timeline" /></td>
</tr>
<tr>
<td><strong>HEO satellite system «Arctica»</strong></td>
<td><img src="image" alt="Timeline" /></td>
</tr>
<tr>
<td><strong>Polar-orbiting meteorological system</strong></td>
<td><img src="image" alt="Timeline" /></td>
</tr>
<tr>
<td><strong>R&amp;D environmental satellites</strong></td>
<td><img src="image" alt="Timeline" /></td>
</tr>
<tr>
<td><strong>Space weather satellites</strong></td>
<td><img src="image" alt="Timeline" /></td>
</tr>
</tbody>
</table>

### Geostationary meteorological system
- **ELECTRO-L №1 (14.5°W)**: launched on January 20, 2011
- **ELECTRO-L №3 (165.8°E)**
- **ELECTRO-L №4 (14.5°W)**
- **ELECTRO-L №5**: launched on December 11, 2015

### HEO satellite system «Arctica»
- **ARCTICA-M №1**: launched on
- **ARCTICA-M №2**: launched on
- **ARCTICA-M №3**: launched on
- **ARCTICA-M №4**: launched on
- **ARCTICA-M №5**: launched on

### Polar-orbiting meteorological system
- **METEOR-M №1**: launched on September 17, 2009
- **METEOR-M №2**: launched on July 8, 2014 - lost at launch on November 28, 2017
- **METEOR-M №2-3**: launched on July 5, 2019
- **METEOR-M №2-4**: launched on

### R&D environmental satellites
- **KANOPUS-V №1**: launched on July 22, 2012
- **KANOPUS-V №3,4**: launched on February 1, 2018
- **KANOPUS-V №5,6**: launched on December 27, 2018

### Space weather satellites
- **RESURS-P №1**: launched on June 25, 2013
- **RESURS-P №2**: launched on December 26, 2014
- **RESURS-P №3**: launched on March 13, 2016
- **RESURS-P №4**: launched on
- **RESURS-P №5**: launched on
- **RESURS-PM №1**: launched on
- **RESURS-PM №2**: launched on
- **RESURS-PM №3**: launched on

### Other satellites
- **IONOSPHERE-M №1,2**: launched on
- **IONOSPHERE-M №3,4**: launched on
Meteor-M polar orbiting satellites

- Both morning and afternoon orbits

**Payload includes:**

1. Microwave imager/sounder MTVZA-GY (29 channels)
2. Hyper-spectral infrared sounder IKFS-2 (2670 channels)
### IKFS-2 Fourier spectrometer

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral range</strong></td>
<td>5-15 µm (660 – 2000 cm⁻¹)</td>
</tr>
<tr>
<td>Spectral resolution (non-apodized)</td>
<td>0.4 cm⁻¹</td>
</tr>
<tr>
<td>Radiometric calibration error (λ = 11...12 µm, T = 280...300 K)</td>
<td>&lt; 0.5 K</td>
</tr>
<tr>
<td>Radiometric noise NESR, [W m⁻² sr⁻¹ (cm⁻¹)⁻¹]</td>
<td>3.5·10⁻⁴ for λ = 6 µm</td>
</tr>
<tr>
<td></td>
<td>1.5·10⁻⁴ for λ = 13 µm</td>
</tr>
<tr>
<td></td>
<td>4.5·10⁻⁴ for λ = 15 µm</td>
</tr>
<tr>
<td>Instantaneous field of view (IFOV)</td>
<td>40 mrad</td>
</tr>
<tr>
<td>IFOV diameter at sub-satellite point</td>
<td>30 km</td>
</tr>
<tr>
<td>Swath width</td>
<td>1000...2500 km</td>
</tr>
<tr>
<td>Spatial sampling</td>
<td>60...110 km</td>
</tr>
<tr>
<td>IFG period (sweep + reverse time)</td>
<td>0.6 s</td>
</tr>
<tr>
<td>Data rate</td>
<td>580 kb/s</td>
</tr>
<tr>
<td>Mass</td>
<td>50 kg</td>
</tr>
<tr>
<td>Power consumption</td>
<td>50 W</td>
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</table>
Daily coverage of IKFS-2 data provided by METEOR-M № 2
Pre-processing of IKFS-2 data

- We consider spectral range 680-750 cm\(^{-1}\)
- Clear-sky observations only, both land and sea
- Radiative transfer model RTTOV v.12
- Bias correction: following Harris and Kelly (2001); cyclic updates of coefficients of linear correction with a 3-4 days memory.
- Rejection of too high channels (whose Jacobian has a significant part above the model’s top)
- Rejection of cloud-contaminated observations: following McNally and Watts (2003)
- Quality control: background check at the moment
IKFS-2 Jacobians (680-750 cm$^{-1}$ range)
Accuracy of IKFS-2 data. Comparison against IASI data.

- RTTOV was applied to NCEP GFS fields (0.5 deg. resolution, up to 10 hPa)
- IASI data were treated in the same way as IKFS-2 data (with the averaging over 4 IFOVs to get the comparable horizontal resolution with IKFS-2)
IKFS-minus-background statistics, K

Cloud filtered obs IKFS

Wavenumber (cm\(^{-1}\))
Cloud filtered obs IASI IFOV averaged

Wavenumber (cm⁻¹)
Channel selection

**Principle:** Select channels having the sharpest and most dissimilar Jacobians

Compute the *similarity matrix* whose entries are \( S(m,n) = \text{corr}(J(m), J(n)) \)

**Algorithm:**

1. Select the sharpest channel \( k \).
2. Remove channels \( n \) for which \( \text{corr}(J(k), J(n)) > 1 - \alpha \), where \( \alpha \sim 0.01 \sim 0.05 \).
3. Repeat steps 1—2 with channels not selected or removed from the list until there are no channels left.
Similarity matrix: 140 channels
Similarity matrix: 14 channels

IKFS-2 inter-channel similarity matrix
Assimilation of IKFS-2 data: setup

IKFS-2 observations were implemented into the 3D-VAR data assimilation system of HMC of Russia. Experiment length – 7 days, April 2019.

- Forecast model – SL-AV (Semi-Lagrangian model developed in HMC of Russia). Model top level – 5hPa.
- No other MW or IR radiances were assimilated
- Thinning – 200 km

We considered 3 configurations:

1. No IR observations assimilated
2. IKFS-2 observations assimilated with simple channels selection. We assimilate every third channel (~40 channels total)
3. IKFS observations assimilated using the similarity matrix. The selection of channels is independent at each point (~14 channels per pixel)
Assimilation of IKFS-2 data

Tmre. SH, 72 h forecast RMSE
Conclusions

- IKFS-2 is a hyper-spectral IR sounder on board Russian Meteor-M-series satellites
- IKFS-2 observations have in temperature sensitive channels (in the spectral range 680—750 cm\(^{-1}\)) a similar quality as compared with IASI data
- Assimilation of IKFS-2 observations into the 3D-Var based data assimilation scheme of the Hydrometcentre of Russia improves forecasts in the Southern Hemisphere. The effect in the Northern Hemisphere if neutral

References
