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

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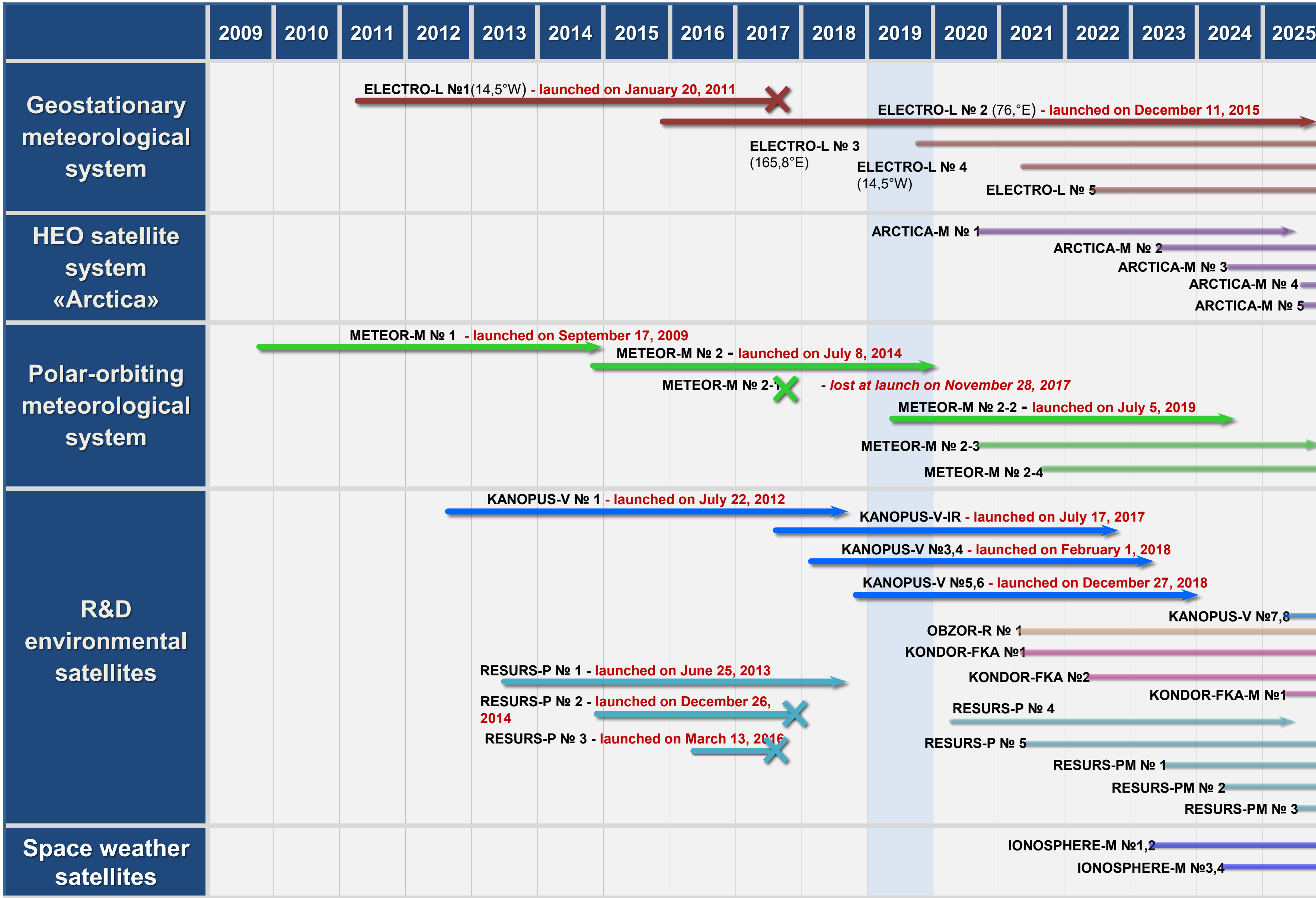
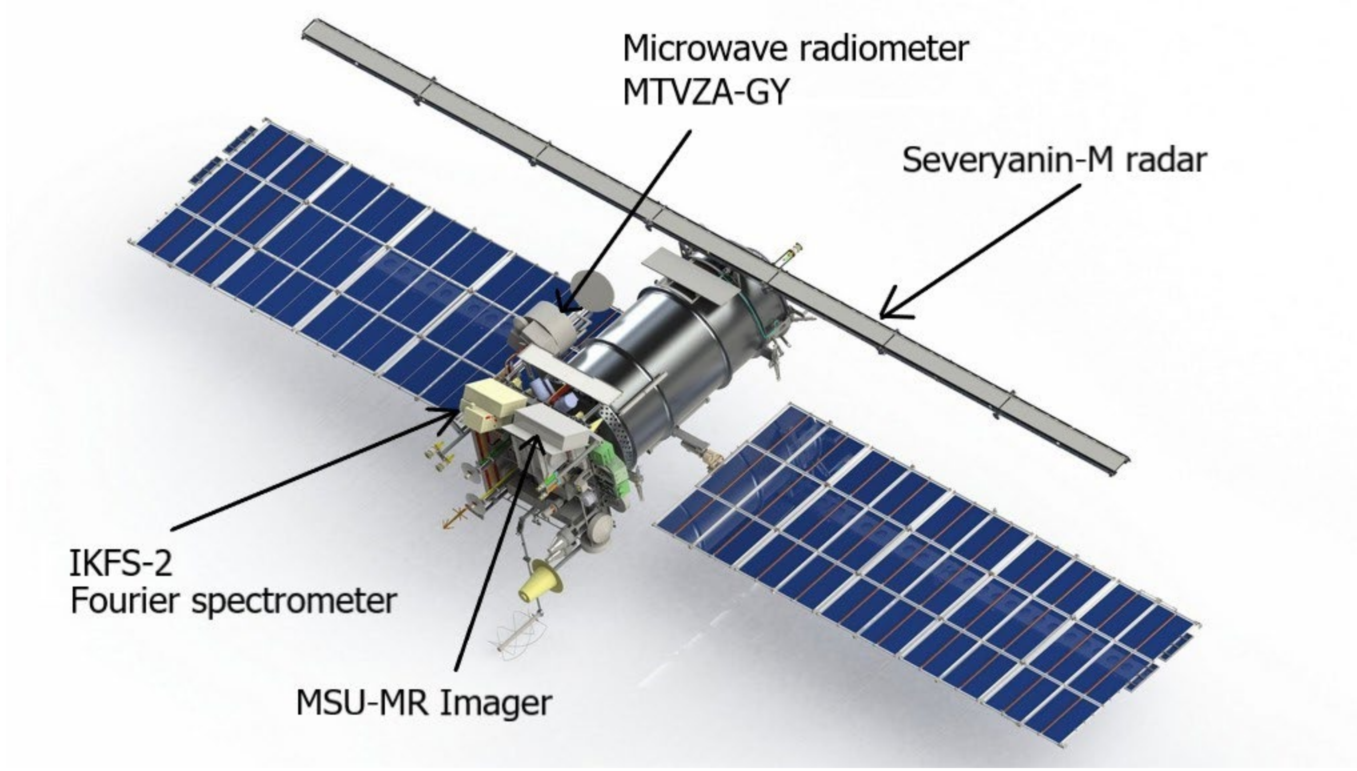
Outline

- 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)



Meteor-M polar orbiting satellites

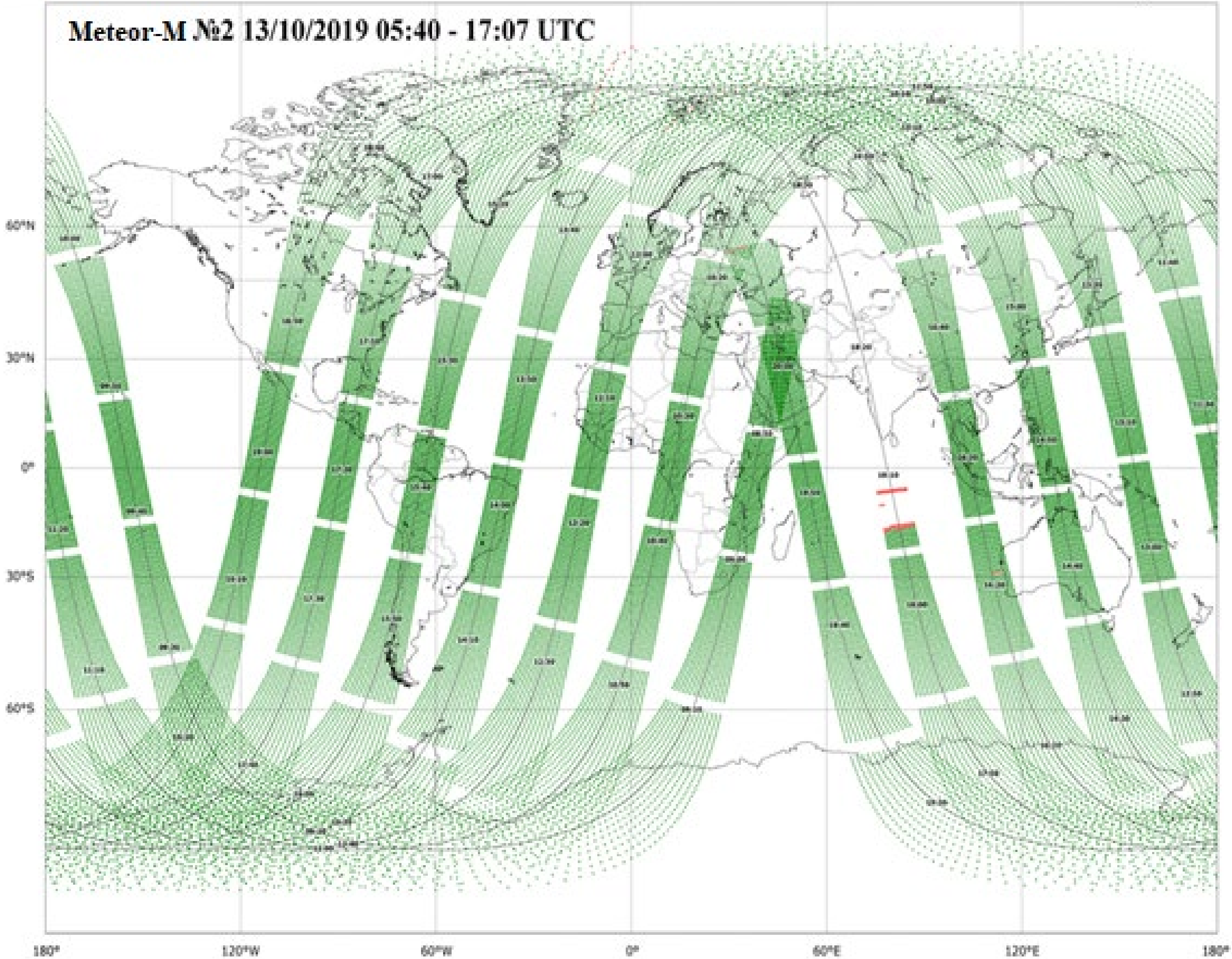


- Two active satellites: Meteor-M N2 launched in 2014, N2-2 launched in 2019.
- Both morning and afternoon orbits
- **Payload includes**:
  1. Microwave imager/sounder MTVZA-GY (29 channels)
  2. Hyper-spectral infrared sounder IKFS-2 (2670 channels)

IKFS-2 Fourier spectrometer

Spectral range	5-15 μm (660 – 2000 cm^{-1})
Spectral resolution (non-apodized)	0.4 cm^{-1}
Radiometric calibration error (λ = 11…12 μm, T = 280…300 K)	< 0.5 K
Radiometric noise NESR, [$W\ m^{-2}\ sr^{-1}\ (cm^{-1})^{-1}$]	$3.5 \cdot 10^{-4}$ for λ = 6 μm $1.5 \cdot 10^{-4}$ for λ = 13 μm $4.5 \cdot 10^{-4}$ for λ = 15 μm
Instantaneous field of view (IFOV)	40 mrad
IFOV diameter at sub-satellite point	30 km
Swath width	1000…2500 km
Spatial sampling	60…110 km
IFG period (sweep + reverse time)	0.6 s
Data rate	580 kb/s
Mass	50 kg
Power consumption	50 W

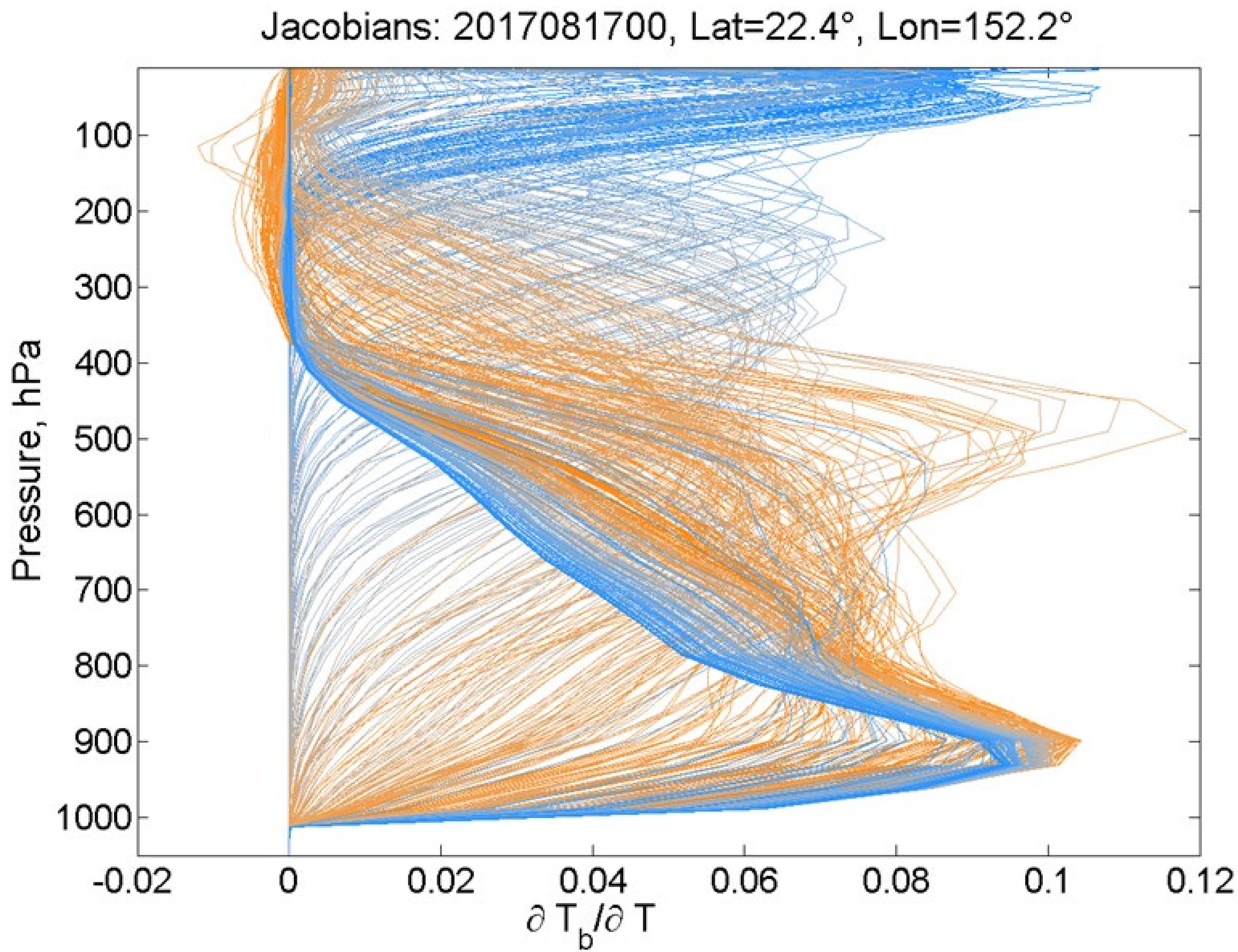
Daily coverage of IKFS-2 data provided by METEOR-M № 2



Pre-processing of IKFS-2 data

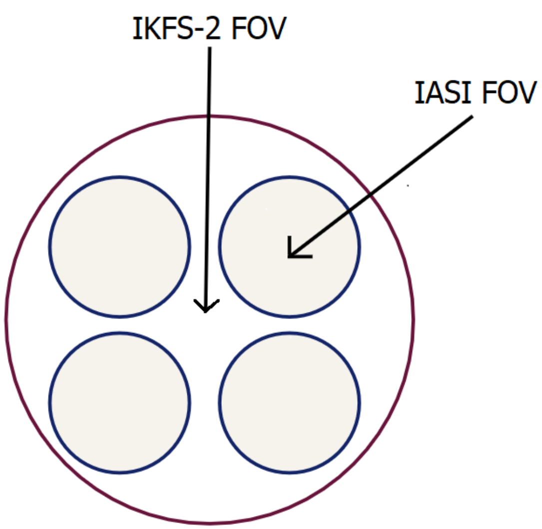
- We consider spectral range 680-750 cm^{-1}
- Clear-sky observations only, both land and sea
- Radiative transfer model RTTOV v.12
- Bias correction: following Harris and Kelly (2001); cyclic updates of coeffitients of linear correction with a 3-4 days memory.
- Rejection of too high channels (whose 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)

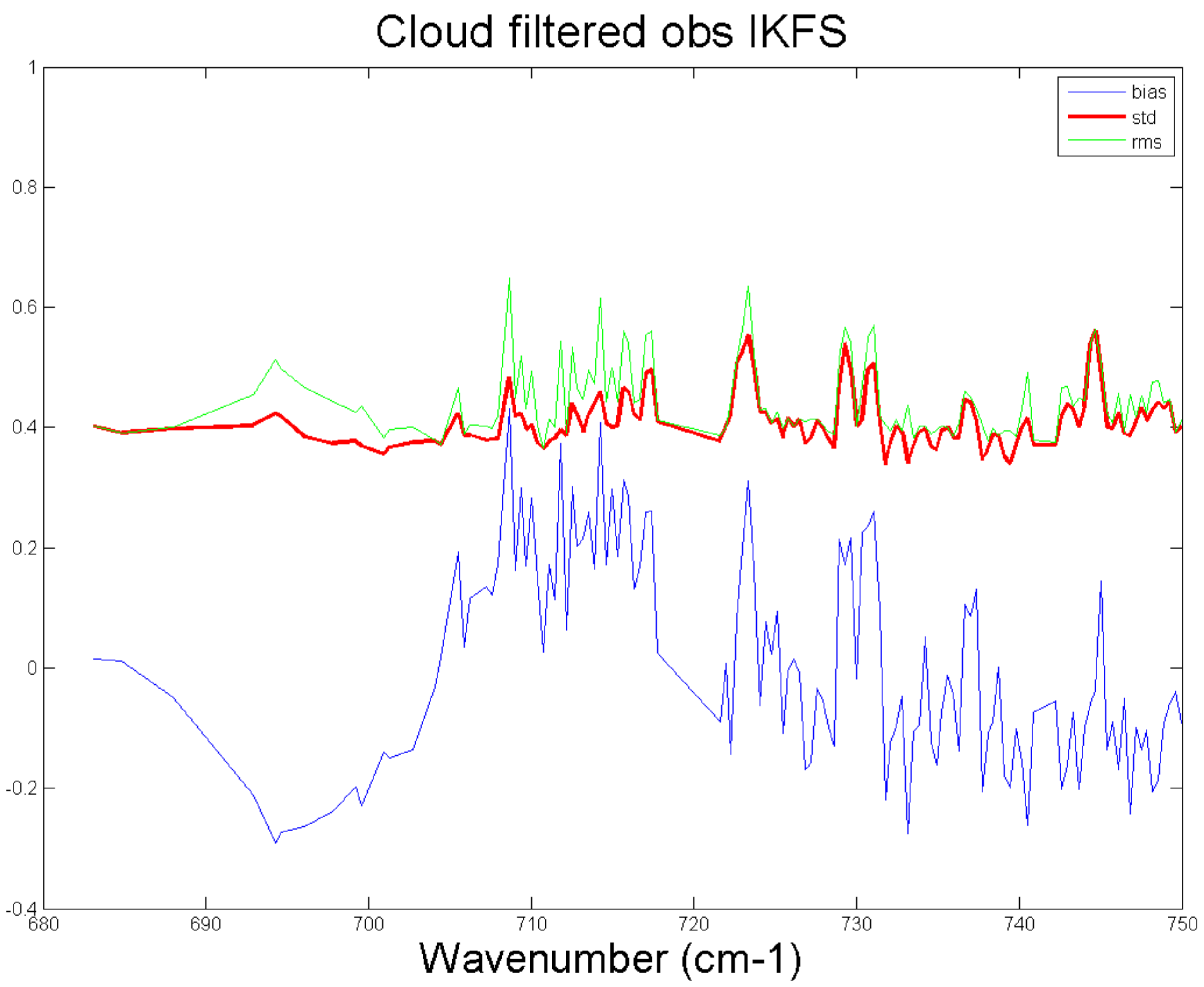


Accuracy of IKFS-2 data. Comparison against IASI data.

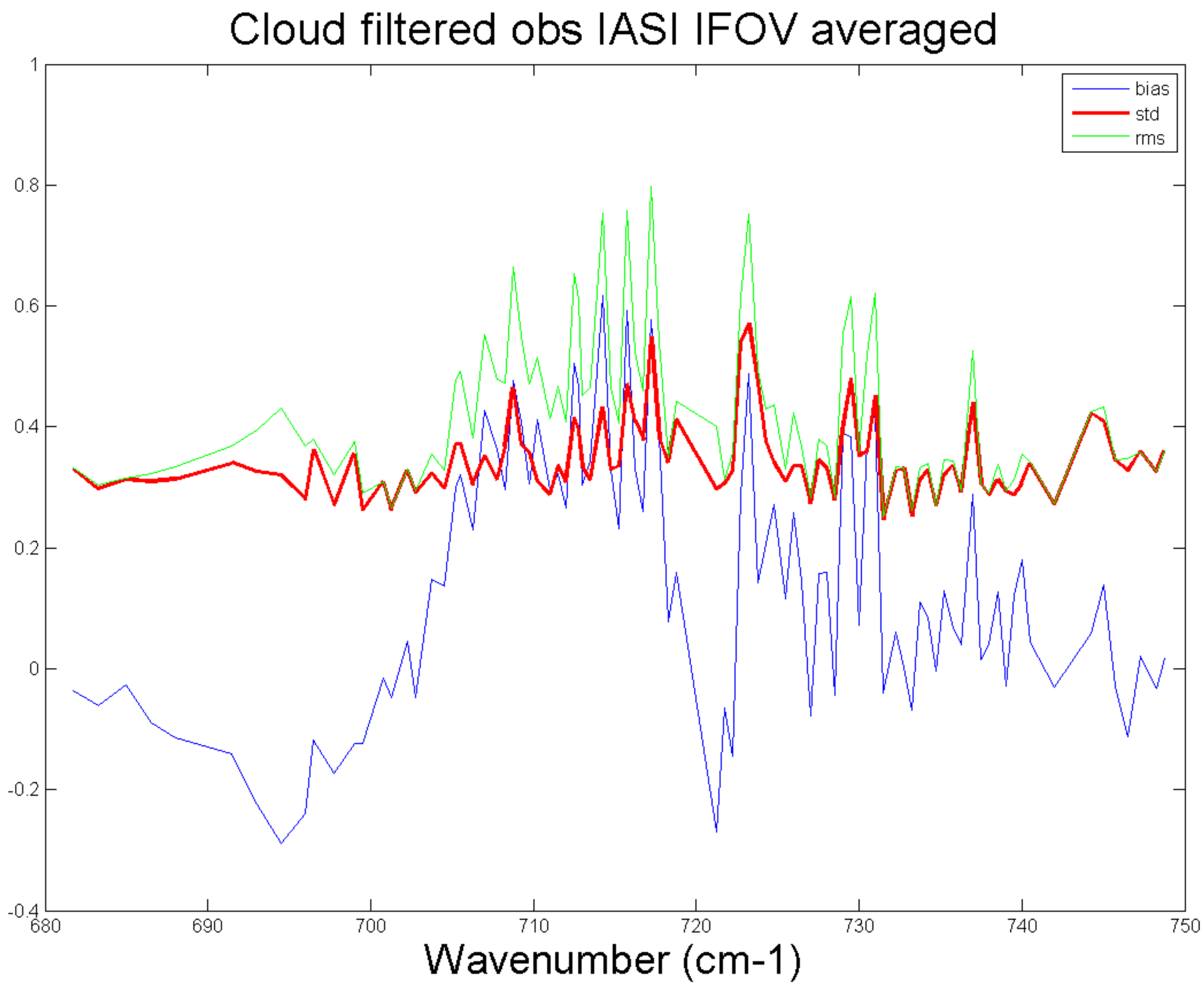
- RTTOV was applied to NCEP GFS fields (0.5 deg. resolution, up to 10 hPa)
- IASI data were treated in the same way as IKFS-2 data (with the averaging over 4 IFOVs to get the comparable horizontal resolution with IKFS-2)



IKFS-minus-background statistics, K



Metop-A IASI Obs-minus-FG statistics, K



Channel selection

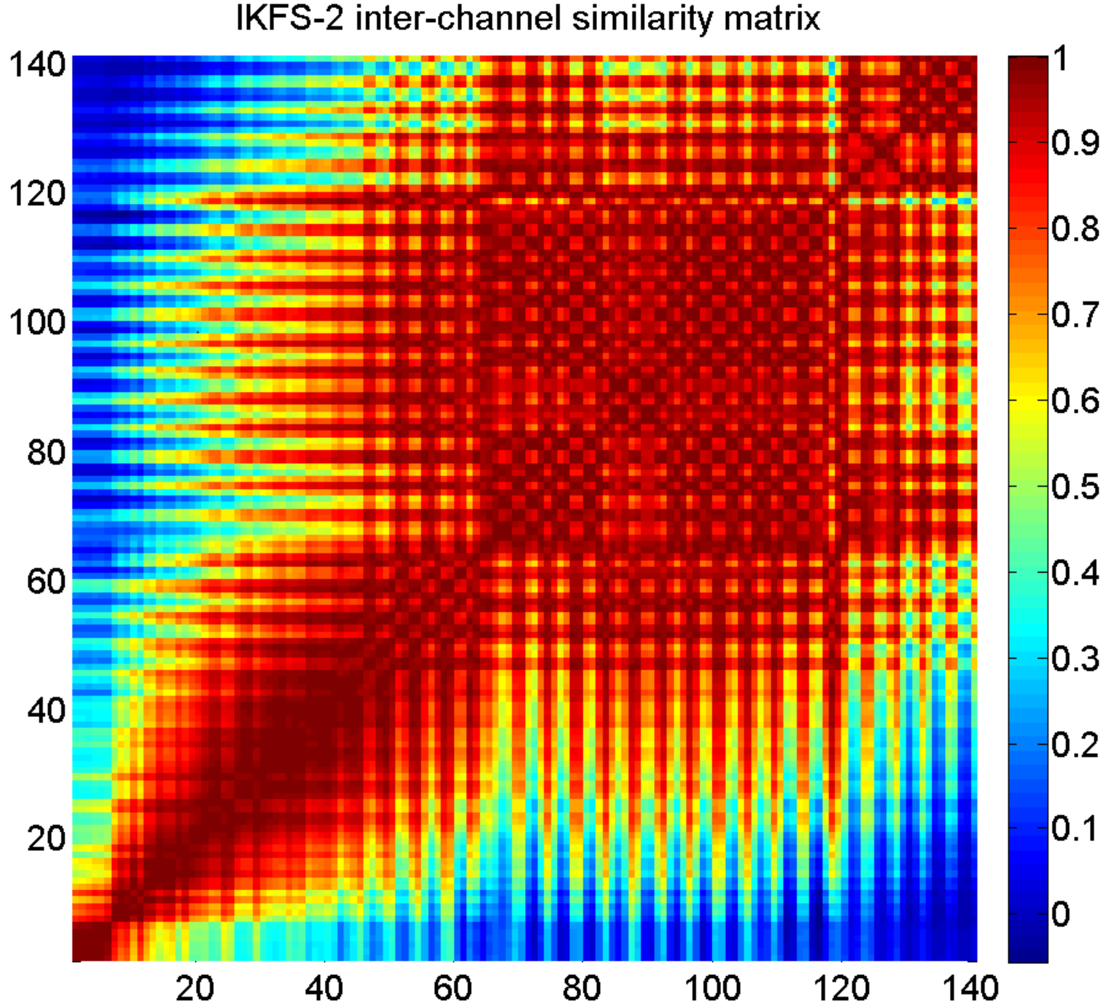
Principle: Select channels having the sharpest and most dissimilar Jacobians

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

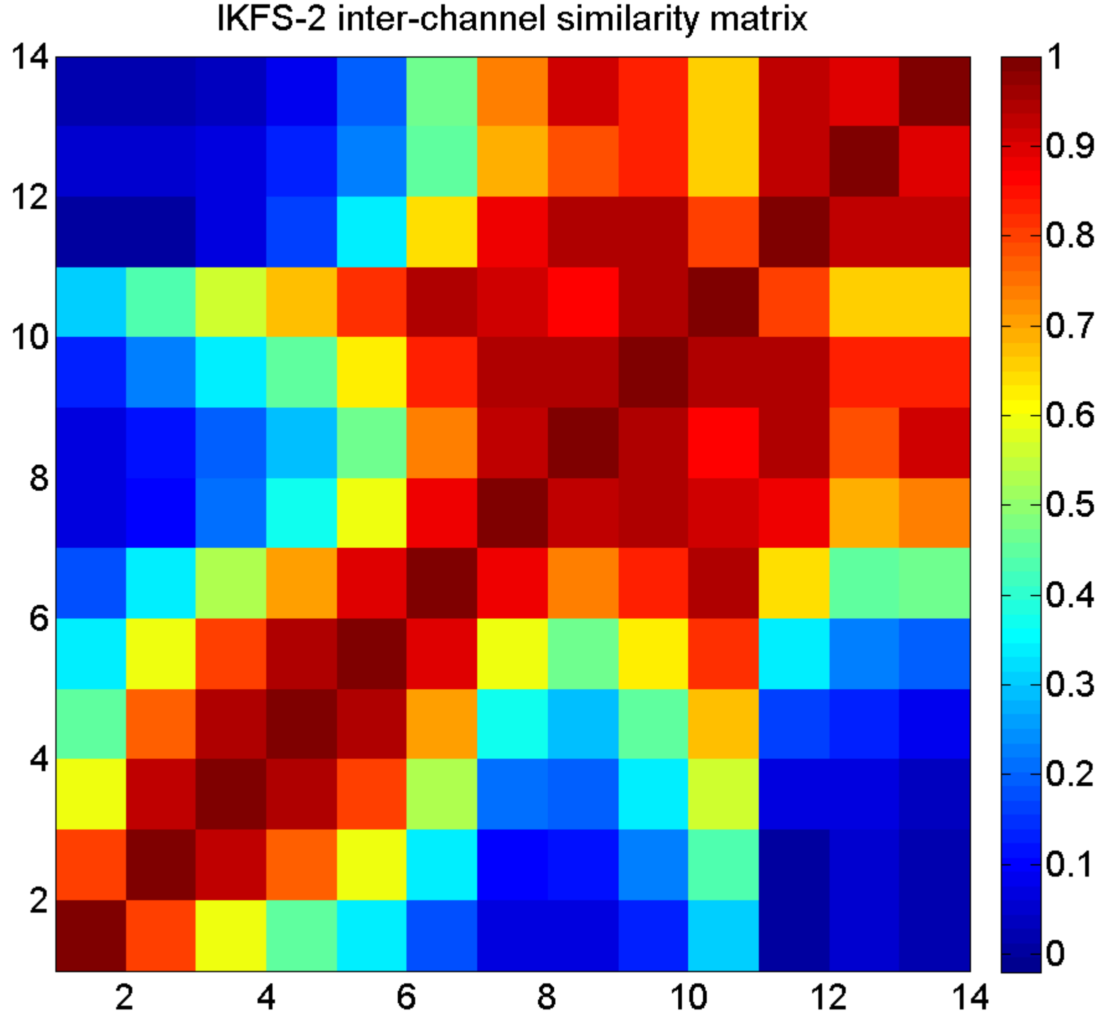
Algorithm:

1. Select the sharpest channel k.
2. Remove channels n for which corr (J(k),J(n))>1-α, where α~0.01 – 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



Assimilation of IKFS-2 data: setup

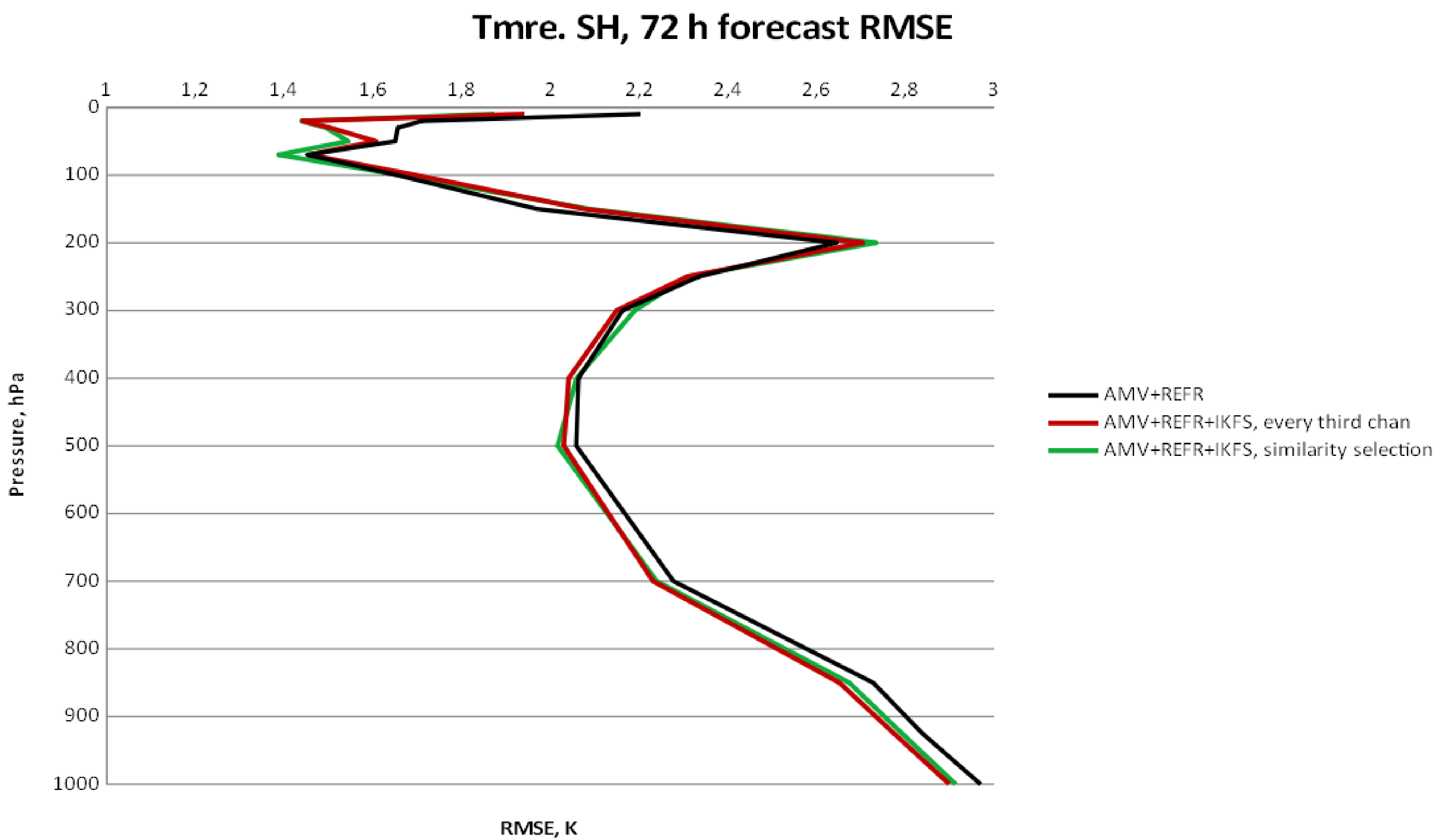
IKFS-2 observations were implemented into the 3D-VAR data assimilation system of HMC of Russia. Experiment length – 7 days, April 2019.

- 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



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

About IKFS-2: Timofeyev, Y.M., Uspensky, A.B., Zavelevich, F.S., Polyakov, A.V., Virolainen, Y.A., Rublev, A.N., Kukharsky, A.V., Kiseleva, J.V., Kozlov, D.A., Kozlov, I.A. and Nikulin, A.G., 2019. Hyperspectral infrared atmospheric sounder IKFS-2 on "Meteor-M" No. 2–Four years in orbit. Journal of Quantitative Spectroscopy and Radiative Transfer, p.106579.

About MTVZA-GY: D.Gayfulin, M.Tsyrulnikov, A.Uspensky. Assessment and Adaptive Correction of Observations in Atmospheric Sounding Channels of the Satellite Microwave Radiometer MTVZA-GY. Pure and Applied Geophysics, 2018, view-only link to the published article: https://rdcu.be/YLSw