Calibration/validation studies for advanced infrared sounder IRFS-2 on "Meteor-M" №2

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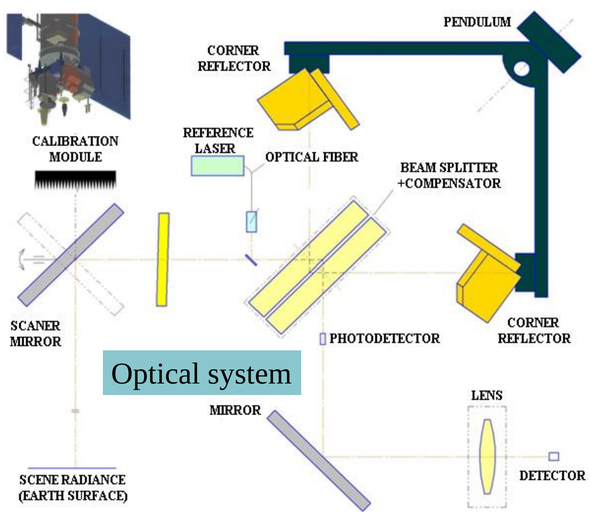
Abstract. Among other payload of "Meteor-M" №2 satellite (launched July, 8th, 2014) the hyperspectral infrared sounder IRFS-2 is considered to be one of the key instruments for operational meteorology. IRFS-2 is a Fourier-transform spectrometer, measuring the IR radiance spectra (2701 channels in the range 667–2000 cm^{-1} or 5.0–15.0 μm). Spatial resolution is about 35 km in sub-satellite point. Ground based processing of IRFS-2 raw measurements (interferograms) provides level 1c data, i.e. calibrated apodized radiances spectra with resolution ~0.4-0.7 cm^{-1}. Evaluation of the spectral resolution together with spectral and radiometric calibration accuracy was performed through inter-comparison with line-by-line radiative transfer model simulations for scenes with clear-sky conditions over sea. Radiometric calibration reliability of IRFS-2 level 1c data was evaluated by comparing collocated SEVIRI/Meteosat-10 measurements and IRFS-2 level 1c data. In these inter-comparison studies the IRFS-2 radiances spectra were integrated over the spectral response functions of SEVIRI channels 7-10. Along with this, the inter-comparison of IRFS-2 spectra with Metop IASI-A, -B data has been performed.

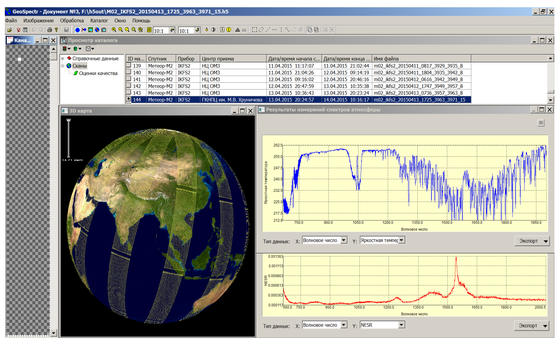
Instrument design, specs & status

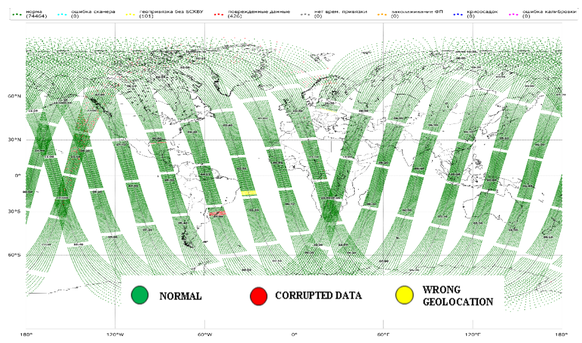


Parameter	Units	Value
Spectral range: wavelength wave number	μm cm^{-1}	5-15 2000-665
Reference channel wavelength	μm	1.06
Maximum optical path difference (OPD)	mm	17
Angular size of FOV	mrad	40 x 40
Spatial resolution (at sub-satellite point)	km	35
Swath width	km	1000-2500
Duration of the interferogram measurement	s	0.5
Dynamic range		2^{16}
Mass	kg	45-50
Power	W	50

Spectral range, cm^{-1}	Absorption band	Application
665 to 780	CO_2	Temperature profile
790 to 980	Atmospheric window	Surface parameters (T_s, ε_ν), cloud properties
1000 to 1070	O_3	Ozone sounding
1080 to 1150	Atmospheric window	T_s, ε_ν,; cloud properties
1210 to 1650	H_2O, N_2O, CH_4	Moisture profile, CH_4, N_2O, column amounts

GeoSpectr – preprocessing software (geolocation, radiometric calibration, metadata registration, serialization). Output: SDR, level 1C, HDF5 format
Screenshot (left) and Data quality quicklook (right)

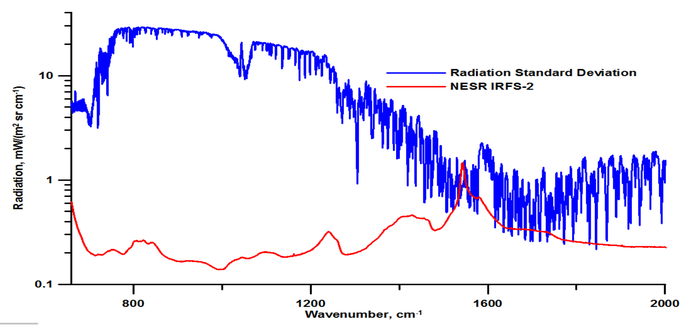




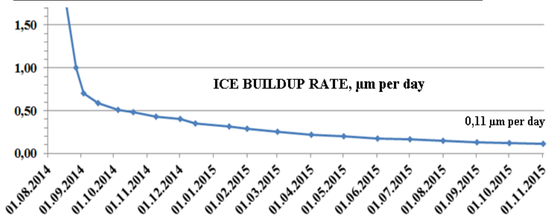
Radiance NESR thresholds

Wave length, μm	Wave number, cm-1	NESR orbit number 1175	NESR orbit number 3963	NESR Specification
15	667	$4.4 \cdot 10^{-4}$	$4.0 \cdot 10^{-4}$	$< 4.5 \cdot 10^{-4}$
13	769	$1.8 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$< 1.5 \cdot 10^{-4}$
6	1667	$3.8 \cdot 10^{-4}$	$3.2 \cdot 10^{-4}$	$< 3.5 \cdot 10^{-4}$

Spectral radiance st.dev and NESR. 2015 Feb.05–Apr.04



Contamination due to the buildup of ice

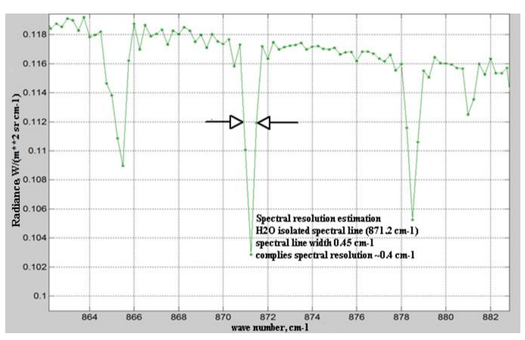


Cyclogram of IRFS-2 functioning for bandwidth 1000 km

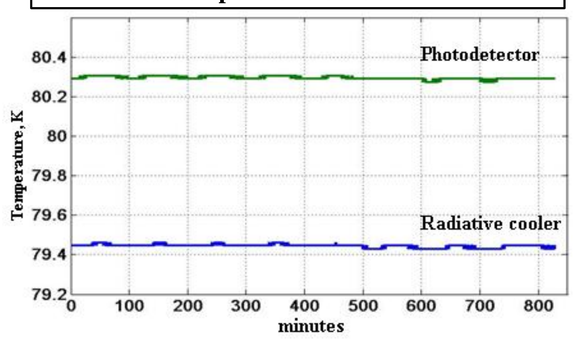
Number of pixels in one scan line – 15;calibration period - 60 scan lines; ice decontamination - two times a month.

IRFS data is not available to direct readout users. Data dumps are now being received in SRC Planeta twice per day. There is also a mode when data is dumped on every orbit.

Assessment of spectral resolution



Photodetector and radiative cooler temperature behavior

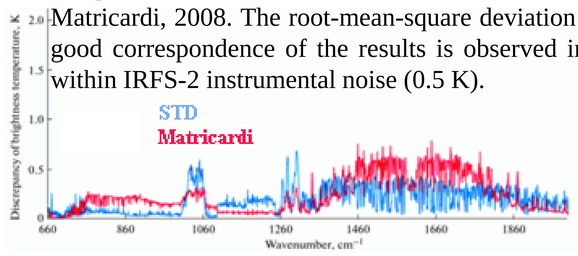


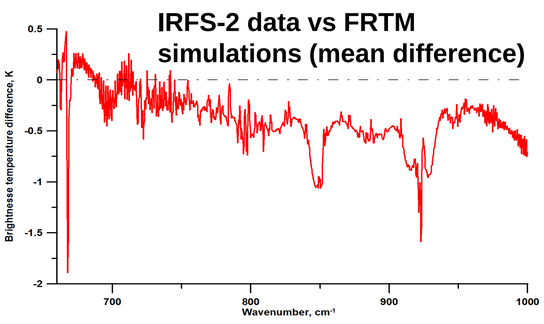
Cal/val studies for IRFS-2 data

Evaluation of radiometric and spectral calibration accuracy as well as spectral resolution was performed through inter-comparison with radiative transfer model simulations using LBLRTM and specially developed FRTM/IRFS-2

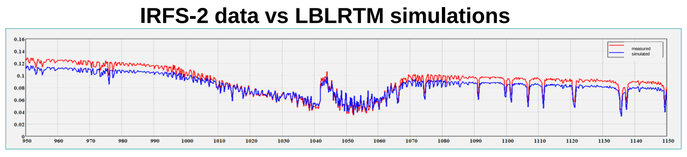
Fast Radiative Transfer Model FRTM/IRFS

FRTM RTTOV - 11 was used as a basis for FRTM/IRFS-2 development. The FRTM/IRFS consists of a set of regressions for each IRFS-2 channel with profile dependent predictors similar to those of RTTOV-11. It provides a significant (30- to 200-fold) acceleration compared with the LBLRTM. For the validation and estimation of the accuracy a comparison was performed between the spectra, calculated using the FRTM/IRFS and LBLRTM in the entire operational spectral range of IRFS-2 instrument (660–2000 cm–1). The results are presented for the independent set (STD) of the standard models WCP-112,1986, and for the training set of atmospheric models of Matricardi, 2008. The root-mean-square deviation mainly does not exceed 0.3 K and is always less than 0.75 K. A good correspondence of the results is observed in the CO_2 absorption band (660–750 cm^{-1}). These values falls within IRFS-2 instrumental noise (0.5 K).

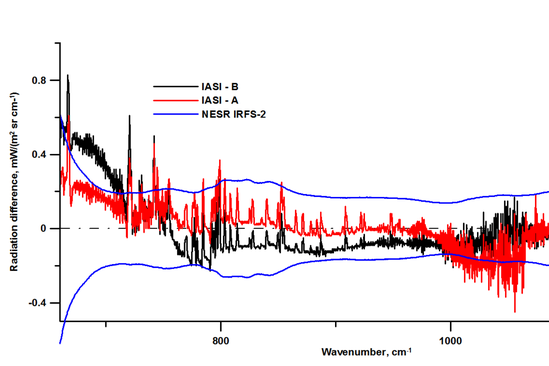


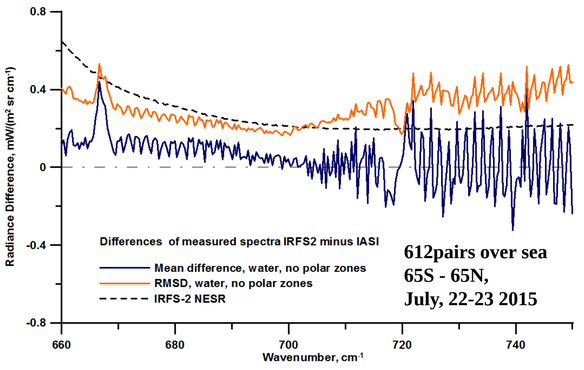


IRFS-2 data vs LBLRTM simulations

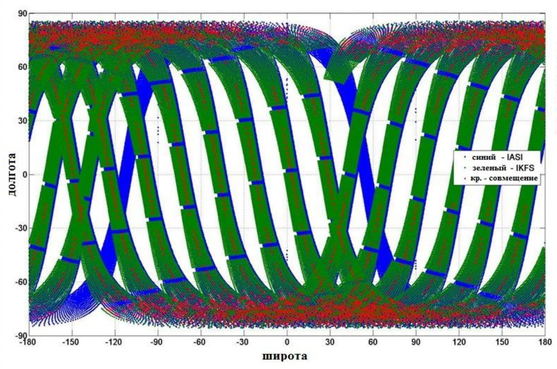


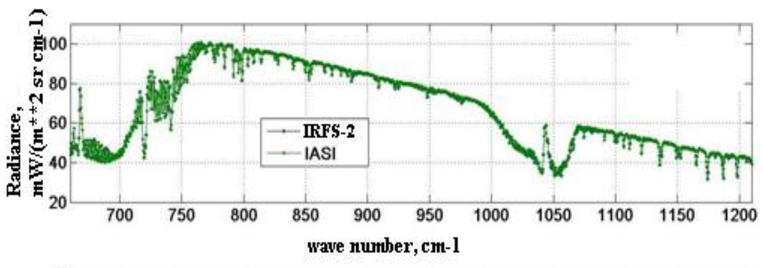
Statistical comparison of IRFS-2 data with IASI-A and IASI-B (presented by Polyakov A., SPB SU)

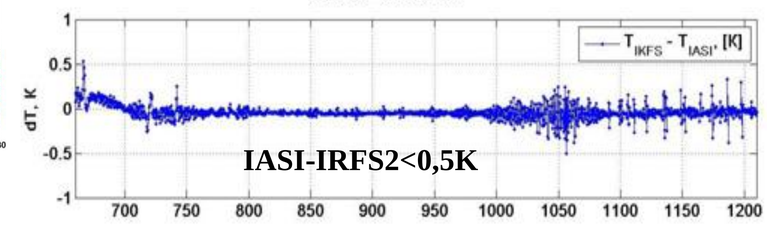




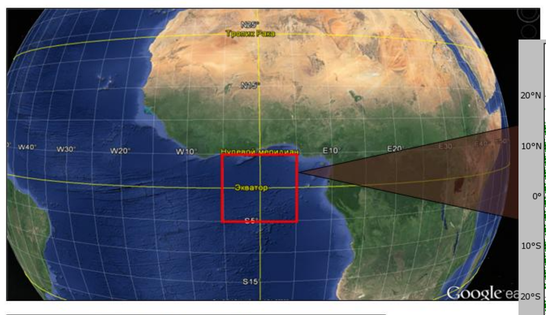
612pairs over sea
65S - 65N,
July, 22-23 2015

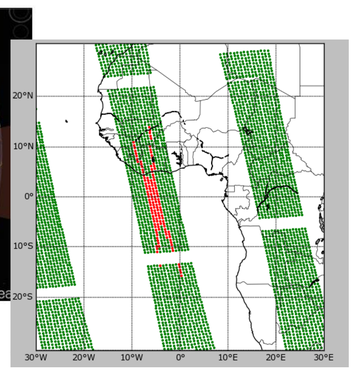


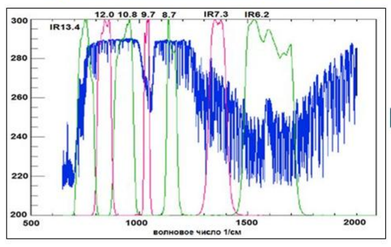




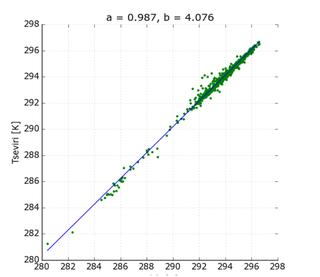
Inter-calibration IRFS-2 vs SEVIRI/Meteosat

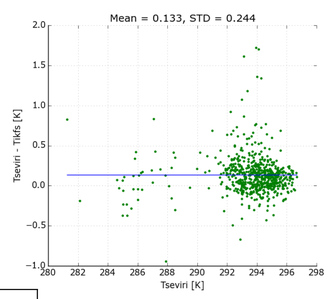






The radiance spectrum, measured by IRFS-2, is convolved with Spectral Response Function of SEVIRI channel (7.3, 8.7, 9.7, 10.8, 12.0, 13.4 μm)





SEVIRI channel	7.3 μm	8.7 μm	9.7 μm	10.8 μm	12 μm	13.4 μm
Spectral range, μm	7.0 - 7.7	8.5 - 9.0	9.5 - 9.8	10.2 - 11.5	11.4 - 12.6	12.5 - 14.2
Spectral range, cm^{-1}	1300 - 1420	1116-1180	1015-1145	873-985	795 - 879	705-798
Bias SEVIRI-IRFS, K	0.17	-0.05	0.17	0.13	0.14	-0.9
St.Dev SEVIRI-IKFS, K	0.2	0.2	0.2	0.2	0.2	0.2

References

Golovin, Yu., Zavelevich, F. ,Nikulin, et al., 2014. A. Spaceborne infrared Fourier-transform spectrometers for temperature and humidity sounding of the Earth's atmosphere. Izvestiya, Atmospheric and Oceanic Physics. No. 9, 1004–1015.

Uspensky, A.B., Rublev, A.N., Rusin, E.V., and Pyatkin, V.P., 2014. A fast radiative transfer model for the Meteor-M satellite-based hyperspectral IR sounders, Izvestiya, Atmospheric and Oceanic Physics. No. 9, 968–977.

E. Rusin, V. Pyatkin, A. Kozlov, A. Rublev, et al. Fast Radiative Transfer Model for hyperspectral Meteor-M data simulation. GSICS Quarterly: Fall Issue 2015, Vol. 9, No. 3, 2015, doi: 10.7289/V54J0C3R

Conclusions

The IRFS-2 instrument status and data quality have been comprehensively tracked by Instrument Performance Monitoring Group (SRC Planeta & Keldysh Center).

The IRFS-2 instrument proved to be fully functional. The performance characteristics (spectral and radiometric calibration, instrumental noise) proved to be in full accordance with design specifications; the radiance products can be used for remote atmospheric sounding applications.

It is planned to complete the development of Instrument Performance Monitoring System and to implement it operationally in SRC Planeta.

IASI 2016