Cal/Val studies for microwave and infrared sounding data from METEOR-M series satellites

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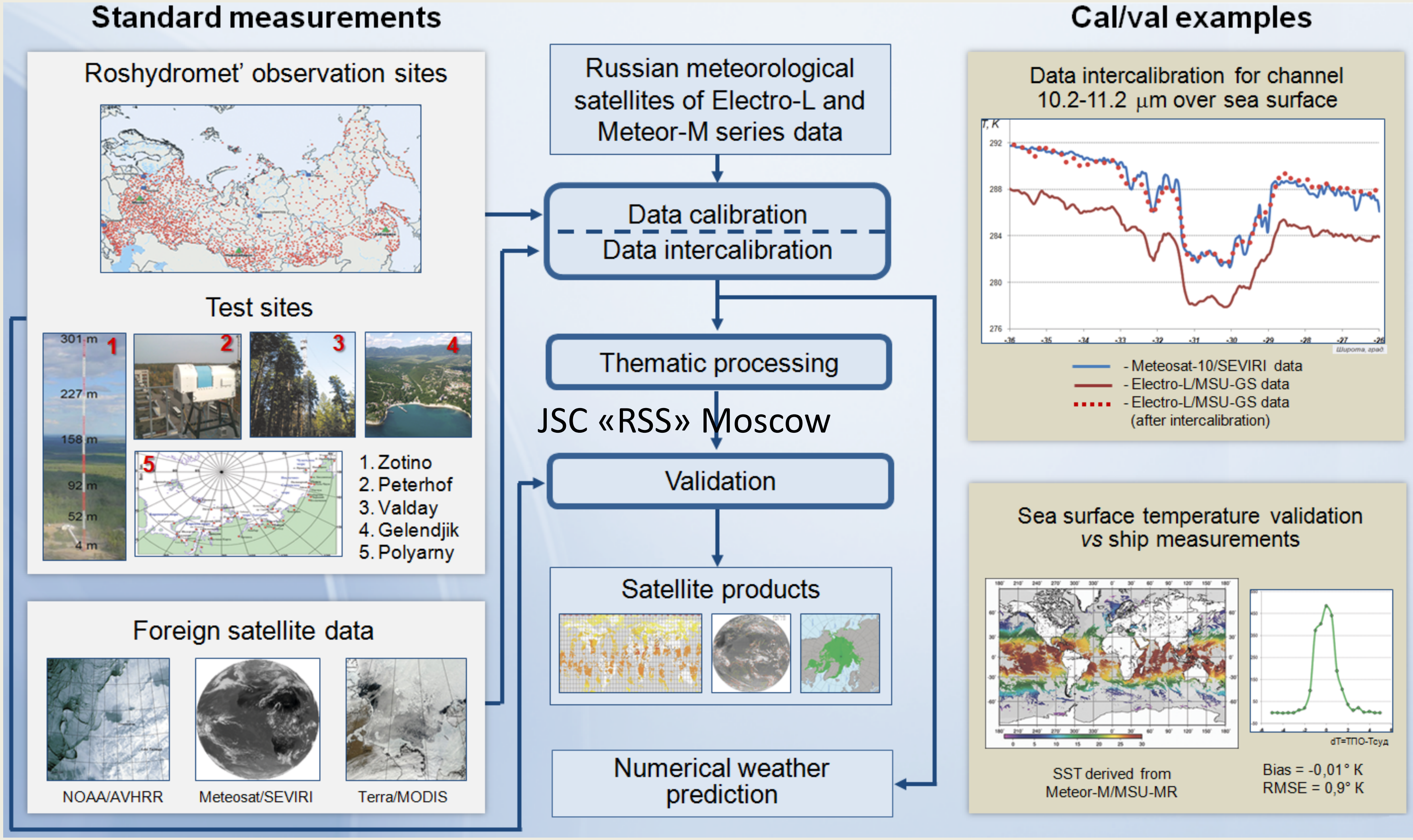
Outline

- CAL/VAL System for Satellite Data and Products
- Post-launch MTVZA-GY data absolute calibration and assessment
- Post-launch IKFS-2 data cross-calibration and assessment
- Validation of MTVZA - and IKFS-based temperature and humidity soundings
- Conclusion
- MTVZA-GY data assimilation trials in Hydrometcenter of Russian Federation

CAL/VAL System for Satellite Data and Products



Meteor-M N2 Basic Instrument Specifications

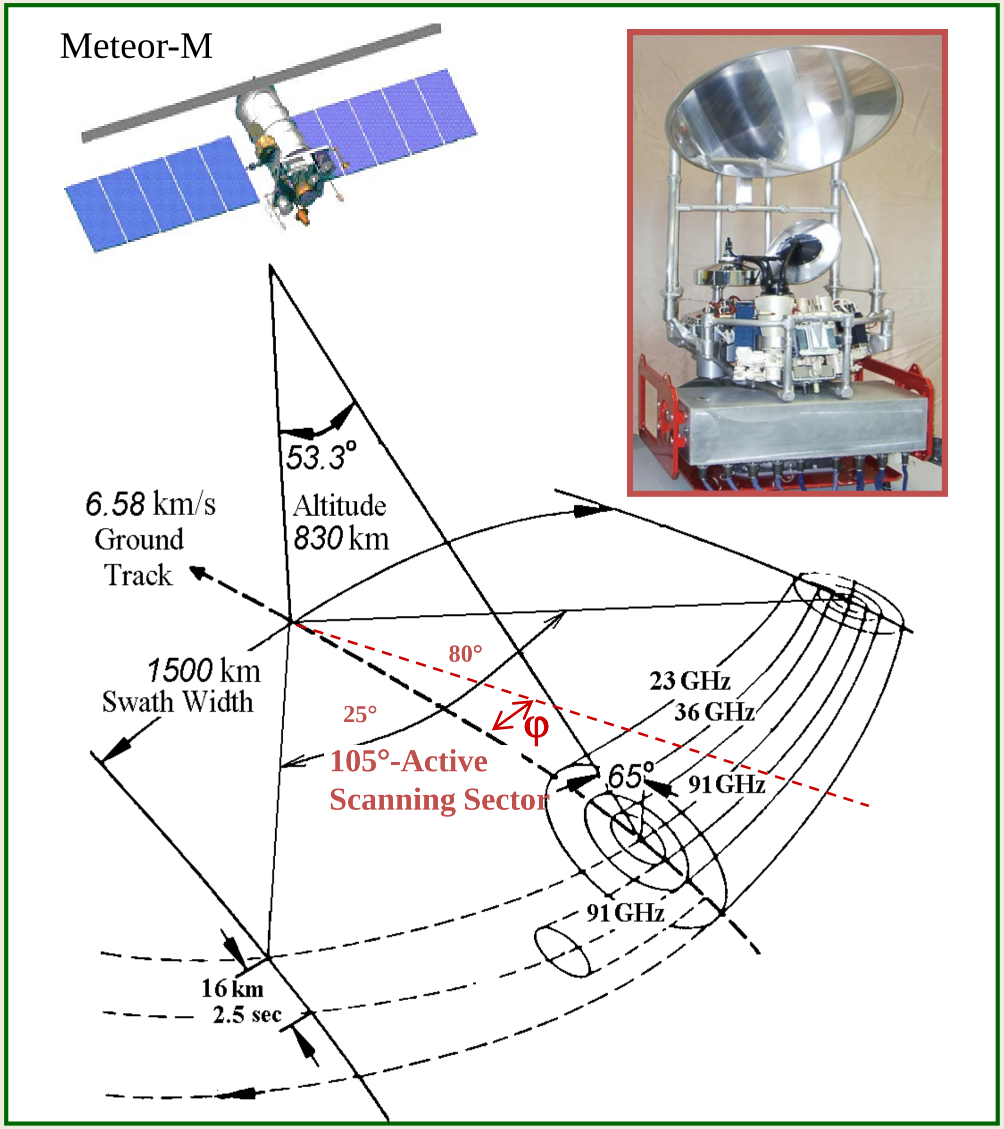
Instrument	Application	Spectral band	Swath-width (km)	Resolutio n (km)
MSU-MR Multi-spectral scanning low resolution radiometer	Global and regional cloud cover mapping, ice and snow cover observation, forest fire monitoring, …	0,5 – 12,5μm (6 channels)	3000	1
IKFS-2 Advanced IR sounder (infrared Fourier-spectrometer)	Atmospheric temperature and humidity profiles	5-15 μm	2000	35
MTVZA-GY Microwave radiometer for sounding atmospheric temperature and humidity	Atmospheric temperature and humidity profiles, atmospheric motion vectors	10,6-183,3 GHz (26 channels)	2600	12 – 75
KMSS Set of multi-spectral imager	Earth surface monitoring for various issues (floods, soils and vegetation state, ice extent)	0,4-0,9 μm (3+3 channels)	450/900	0,05/0,1
"Severyanin-M" Synthetic aperture radar	All-weather Ice cover monitoring	9500-9700 MHz	600	0,5/1
GGAK-M Heliogeophysical suite	Heliogeophysical data			
BRK SSPD Data Collection System	Data retransmission from DCP			

Post-launch MTVZA-GY data absolute calibration and assessment

The microwave radiometer MTVZA-GY on board the Russian polar orbiting meteorological satellite Meteor-M N2 is briefly described. A new post-launch calibration technique is proposed. The technique sequentially assimilates observed minus simulated radiance data in a perpetual 6h cycle in order to estimate up-to-date calibration coefficients. The simulated radiances are computed by the RTTOV radiative transfer model from 6h NCEP forecasts. The calibration coefficients are defined to be functions of zenith and azimuth solar angles. The calibration technique is implemented for atmospheric temperature and humidity sensitive channels.

The comparison was made with simpler and more traditional calibration techniques.

Microwave Imager/Sounder MTVZA-GY



Parameter	Value
Frequencies, GHz	10.6, 18.7, 23.8, 36.5, 52-57, 91, 183.31
Channels	29
Antenna Aperture, cm	65
Spatial Resolution, km	16-198
Sensitivity, K/pixel	0.3-1.7
Calibration Accuracy, K	< 1
Swath Width, km	1800
Conical Scanning Period, s	2.5
Data Rate, Kbit/s	35
Mass, kg	94
Power , W	80

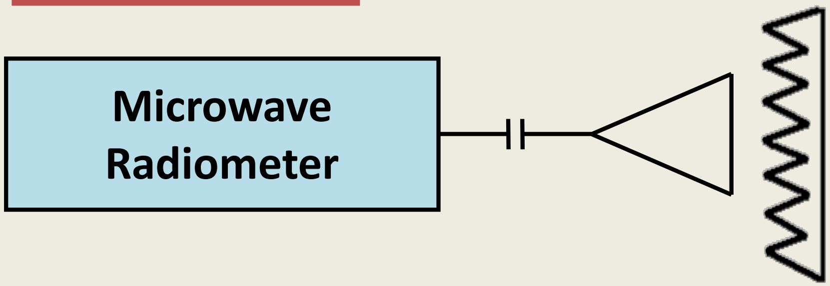
Courtesy I.Cherny, JSC «RSS» Moscow

Channel numbering in MTVZA-GY HDF data sets and RTTOV v11

Channel no in MTVZA-GY data file (HDF)	Channel no in RTTOV coefficient's file	Central frequency and polarisation, GHz	Channel name (atmospheric sounding channels)
1	1	10.6V	
2	2	10.6H	
3	3	18.7V	
4	4	18.7H	
5	5	23.8V	
6	6	23.8H	
7	9	36.7V	
8	10	36.7H	
9	25	91.65V	
10 (unavailable)	26	91.65H	
11	15	52.80V	O1
12	16	53.30V	O2
13	17	53.80V	O3
14	18	54.64V	O4
15	19	55.63V	O5
16	20	57+0.32± 0.1H	O6
17	21	57+0.32± 0.05H	O7
18	22	57+0.32± 0.025H	O8
19	23	57+0.32± 0.01H	O9
20	24	57+0.32± 0.005H	O10
21	29	183.31±1.4	HO3
22	27	183.31±7.0	HO1
23	28	183.31±3.0	HO2
24 (unavailable)	-	-	
25 (unavailable)	-	-	
26	7	31.5V	
27	8	31.5H	
28 (unavailable)	-	-	
29 (unavailable)	-	-	

Onboard calibration (signal to TDR)

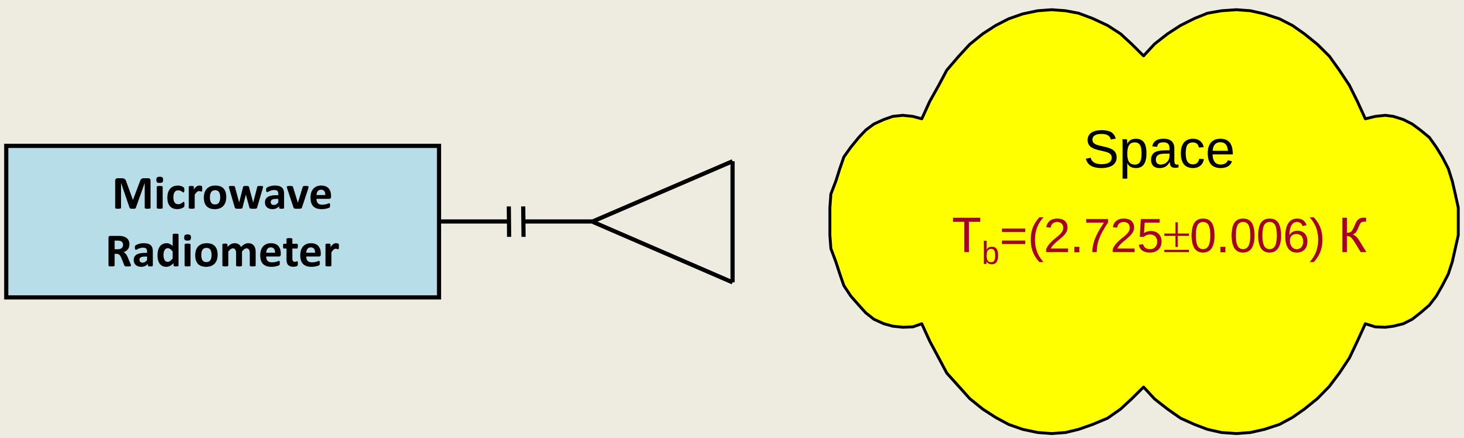
Two-point calibration scheme: warm load and space



$r < 0.0001$ $\delta r = \pm 0.000001$

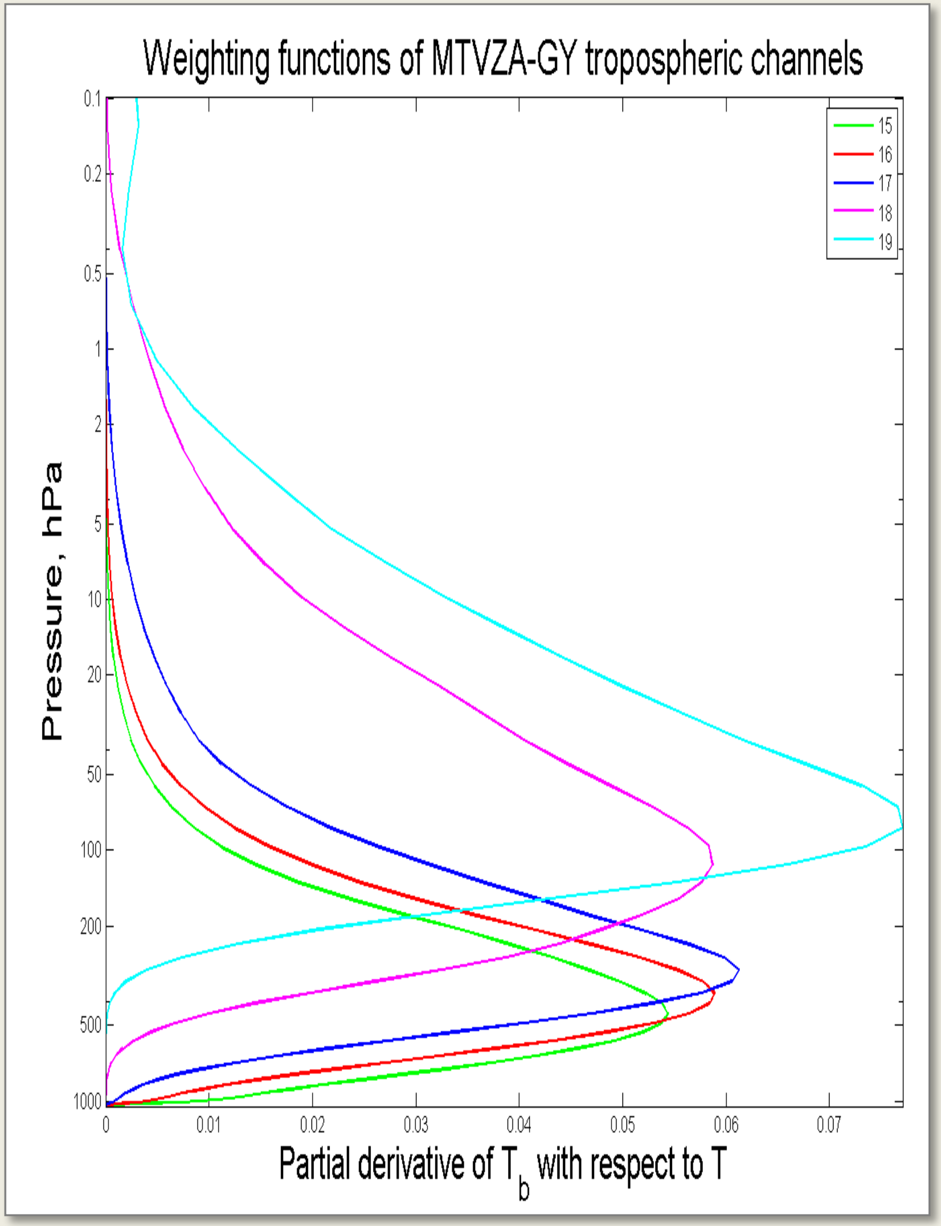
$\varepsilon = 1 - r = 0.9999\ldots$ $T_0 = 300$ K

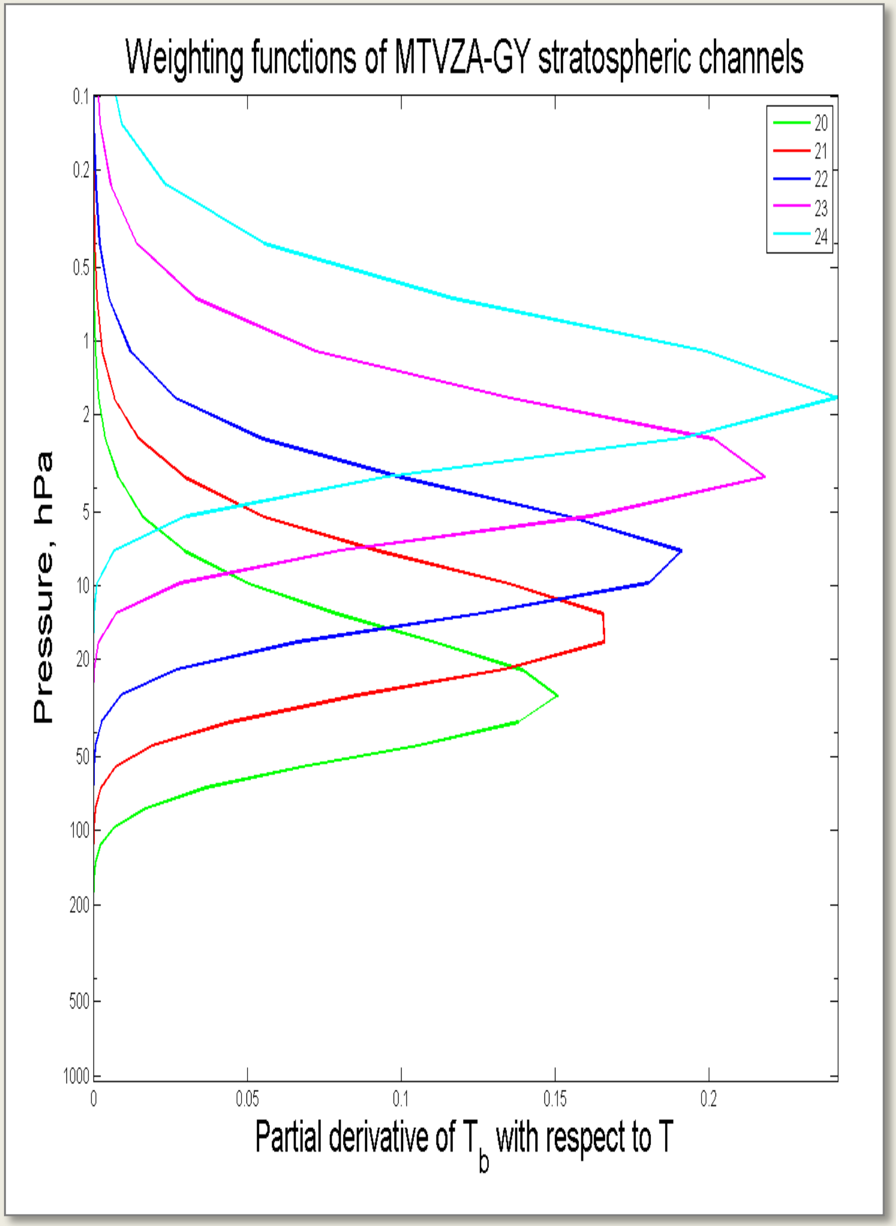
$T_b = \varepsilon T_0$ $\Delta T_b \leq 0.05$ K



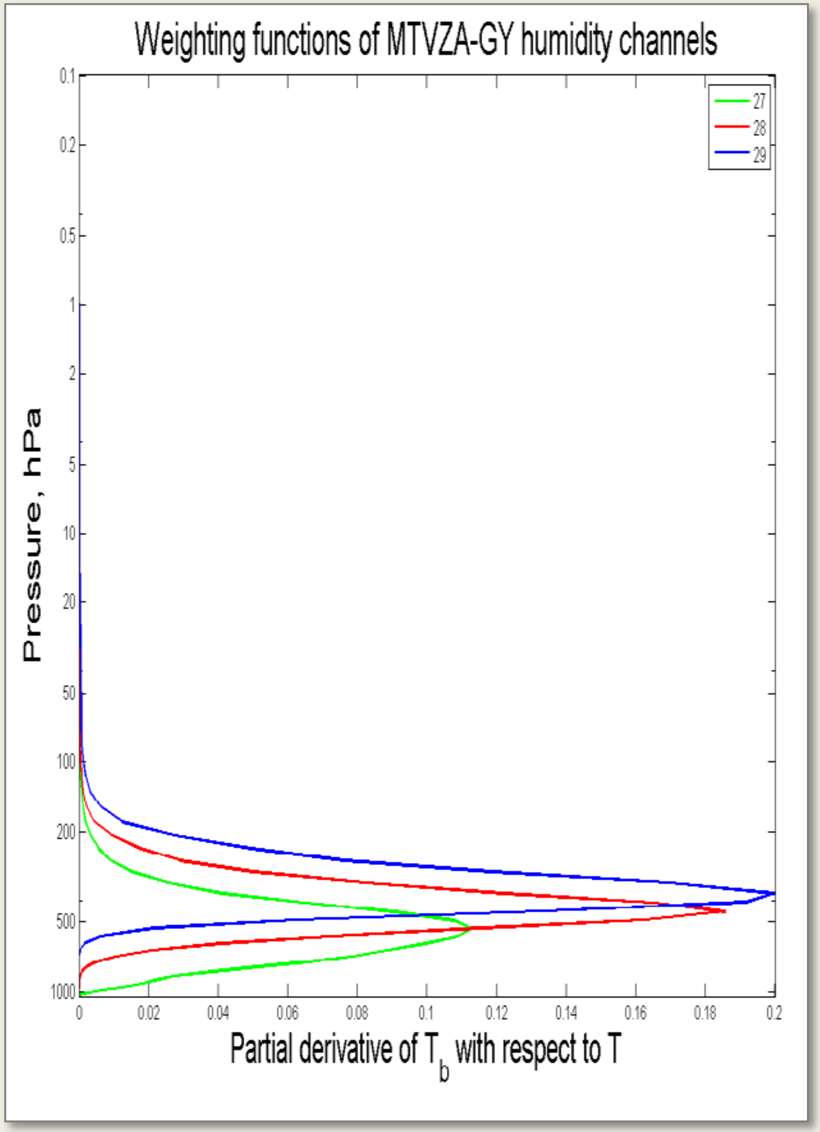
Courtesy I.Cherny, JSC «RSS» Moscow

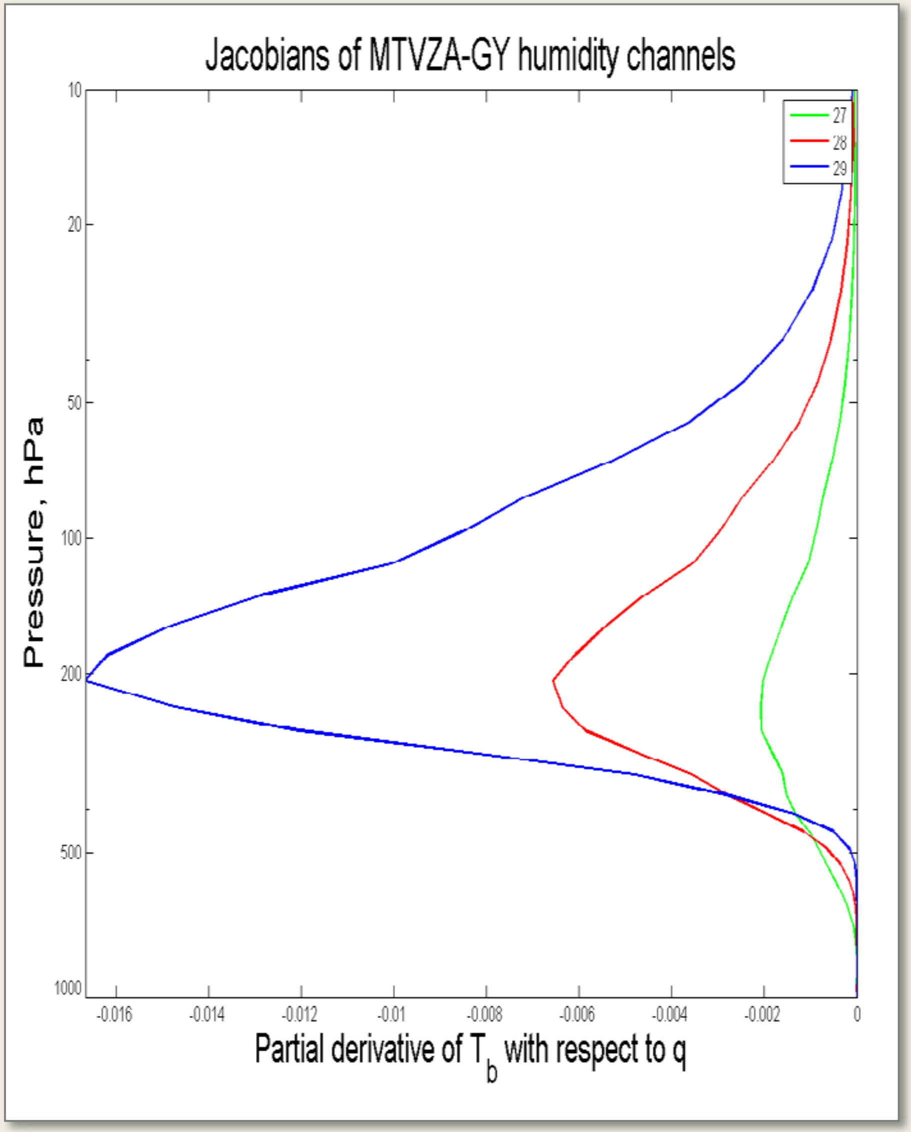
MTVZA-GY temperature channels weighting functions





MTVZA-GY humidity channels weighting functions





Post-launch radiometric calibration and validation of MTVZA-GY atmospheric sounding channels

Post-launch absolute calibration algorithm is based on comparison between observed radiances (antenna brightness temperatures) and RTTOV-simulated radiances (sensor brightness temperatures), and linear regression.

The calibration models (three in total) convert the antenna temperature into the brightness temperature using a regression. The two regression coefficients **a** and **b** are being treated as functions of two arguments: solar zenith angle and solar azimuth angle.

Calibration techniques used for comparison

1) $T_b = aT_a + b$, where **a=const** and **b=const** are the regression coefficients estimated using least squares from a training sample of the observed Ta's and the collocated reference Tb's computed by the RTTOV from 6h GFS NCEP forecast fields (simplest approach);

2) $T_b = a(t)T_a + b(t)$- evolving in time but constant in space coefficients **a**, **b.** This approach uses temporal “on-line" smoothing of the **a** and **b** coefficients for each of the 6-hours time spacing intervals.

3) $T_b = a(\alpha;\zeta)\, T_a + b(\alpha;\zeta)$ - evolving in time and in space coefficients **a**, **b.** α, ζ- solar azimuth and zenith angles (Solar Angle Correction). The fields $a(\alpha;\zeta)$ and $b(\alpha;\zeta)$ are defined on a grid in the **α- ζ** plane. The coefficients are cyclically updated every 6 hours using deviations of the antenna temperatures from the reference as observations.

Training sample compilation and data quality control

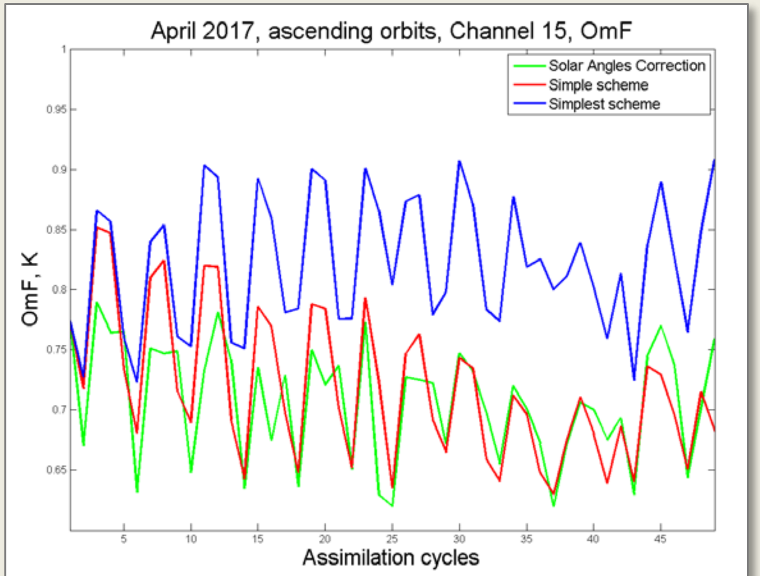
1**. Surface check.** Over land and sea ice, we compute the partial derivative of the observation Tb with respect to the surface temperature Ts (calculated by the RTTOV) in the lower tropospheric temperature channels 15 and 16 and the three humidity channels The observation is rejected if the partial derivative exceeds an empirically selected threshold of 0.1 K.

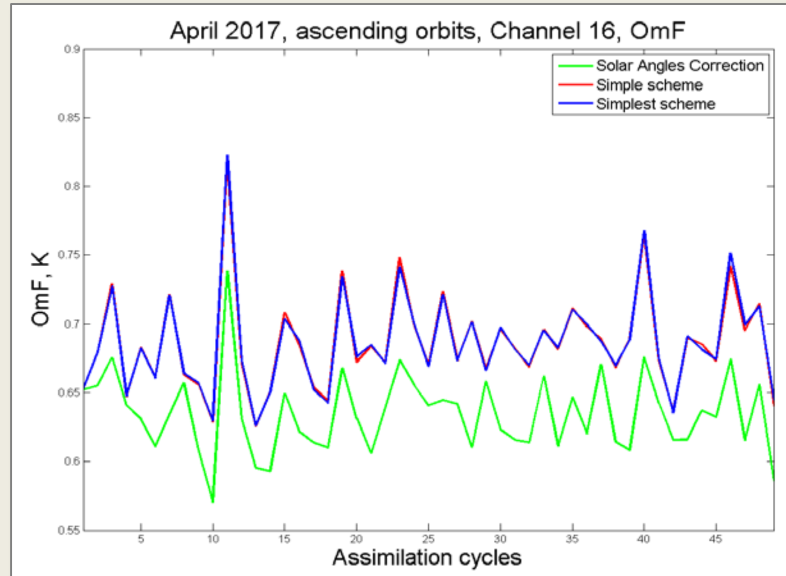
2**. Background check.** An observation is rejected if its departure from the background (computed by applying RTTOV to the background fields) exceeds 3 K.

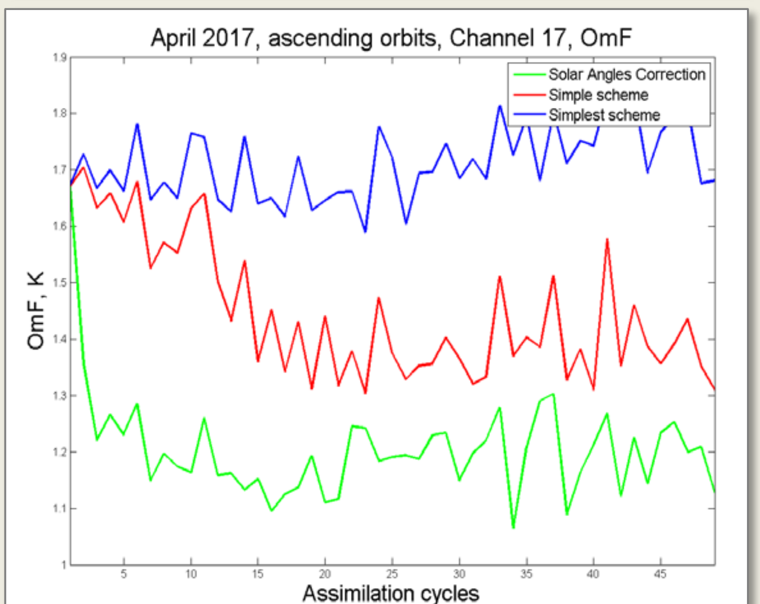
3. **Buddy check.** Neighboring observations that appear to be too different (more than 3K for the temperature channels and more than 4K for the humidity channels) are rejected.

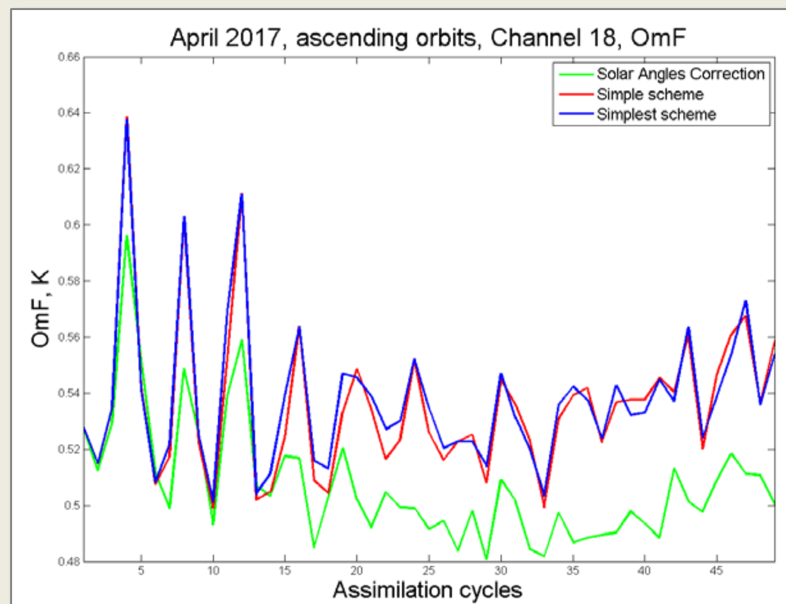
4. **Heavy rain check.** Observations in heavily precipitating cloud areas are rejected if the liquid water path computed from the background is larger than 0.05 kg/m^2.

RMS differences (Obs – First Guess) for 3 proposed calibration schemes, channels 15-18

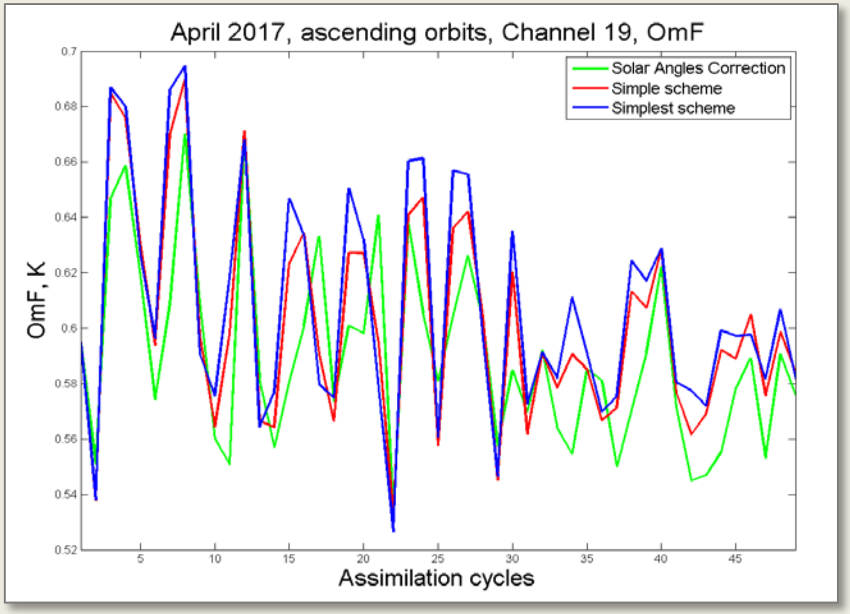


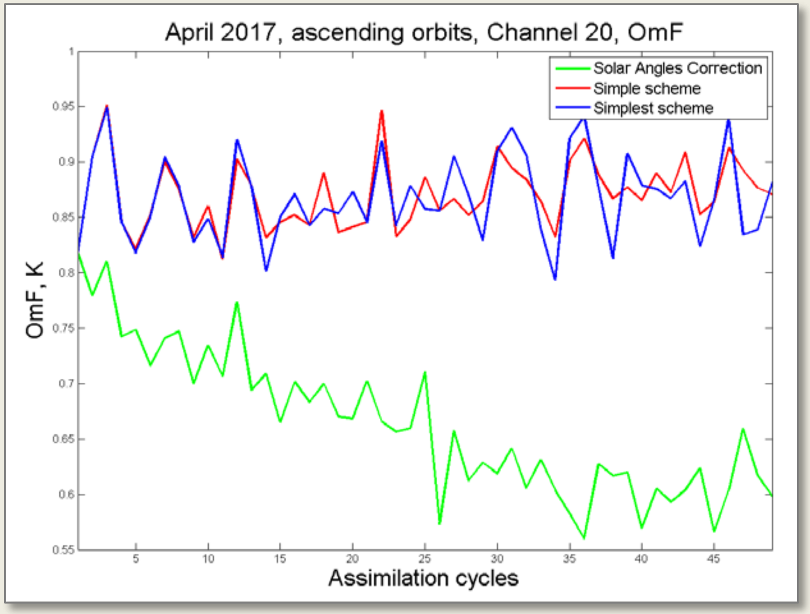


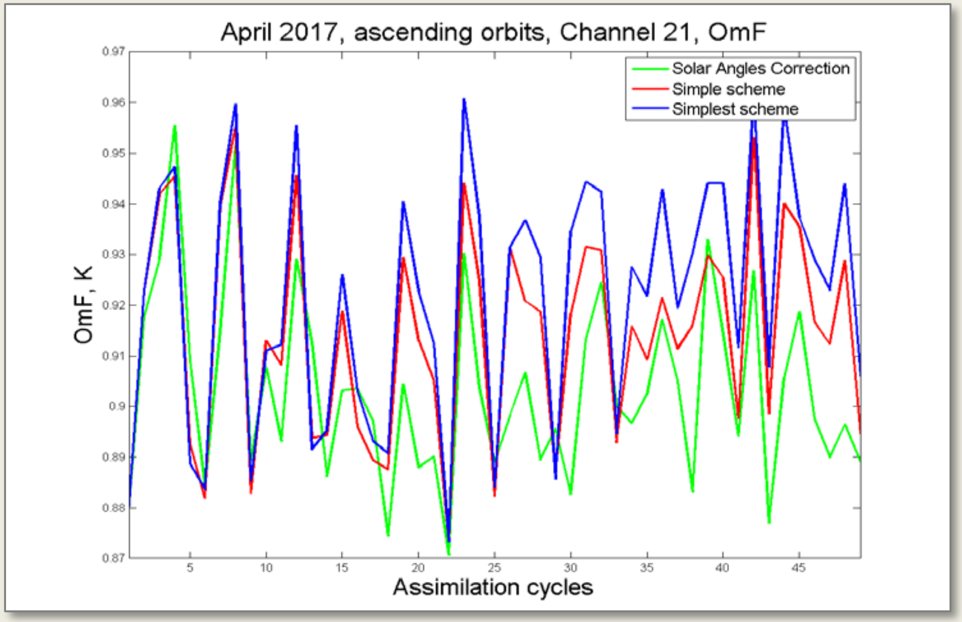




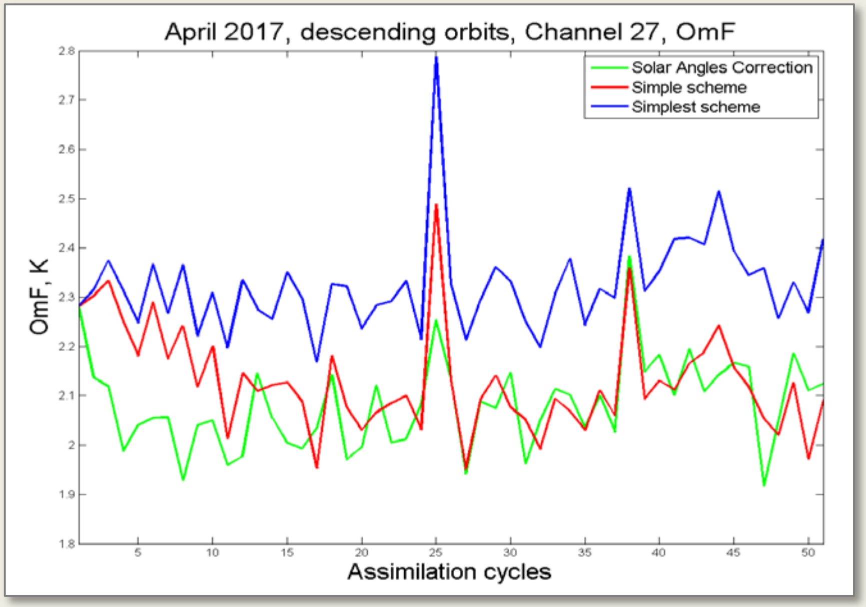
RMS differences (Obs – First Guess) for 3 proposed calibration schemes, channels 19-21

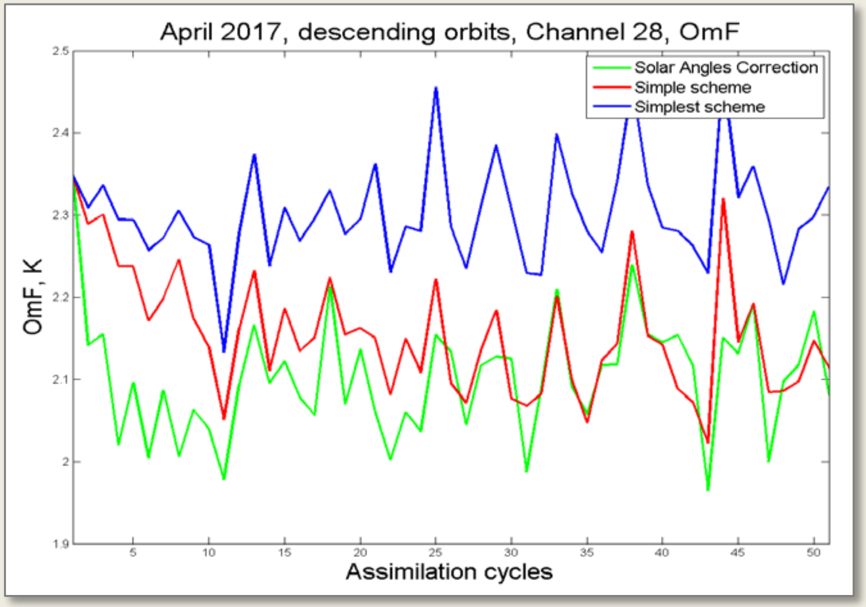


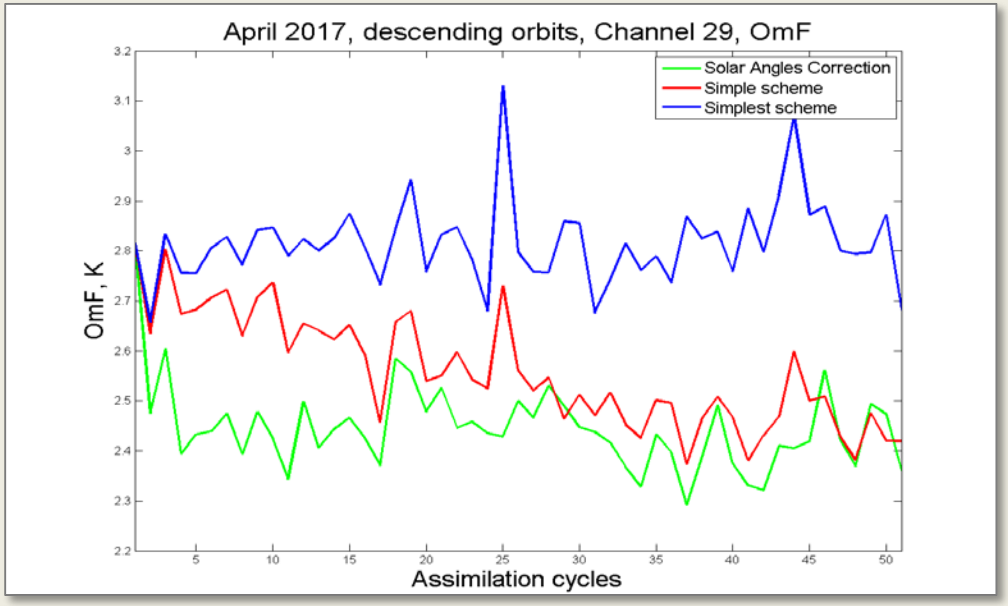




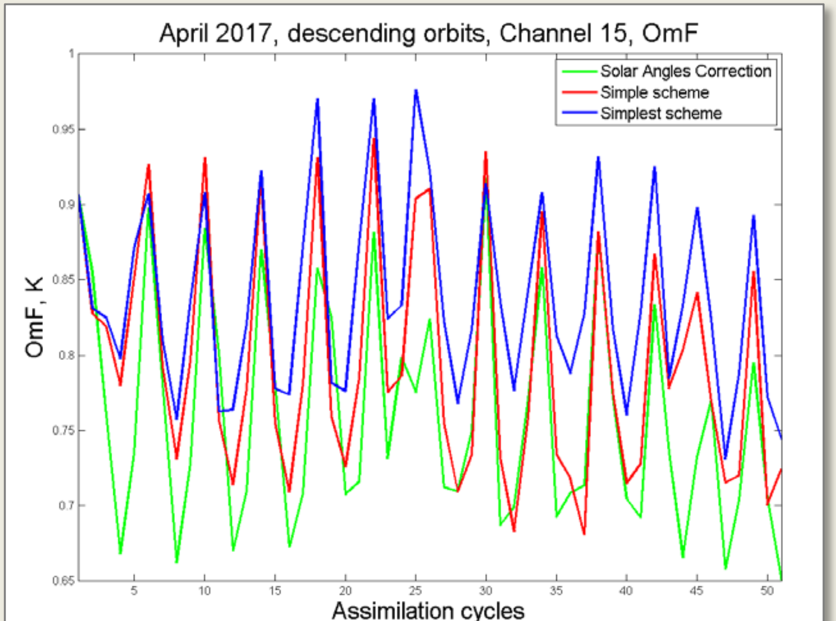
RMS differences (Obs – First Guess) for 3 proposed calibration schemes, channels 27-29

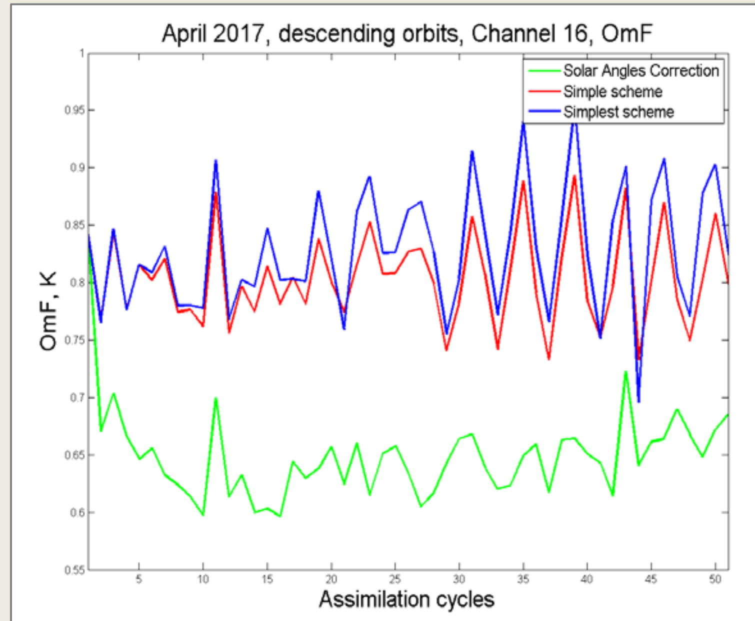


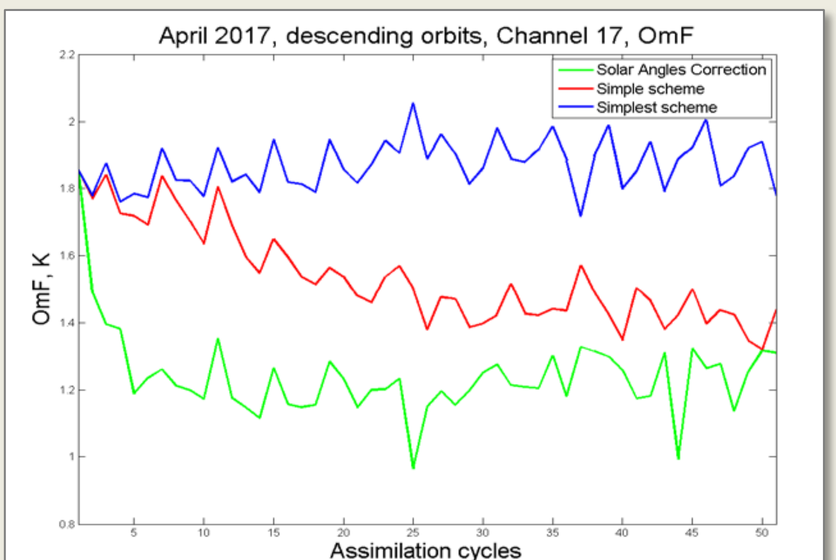


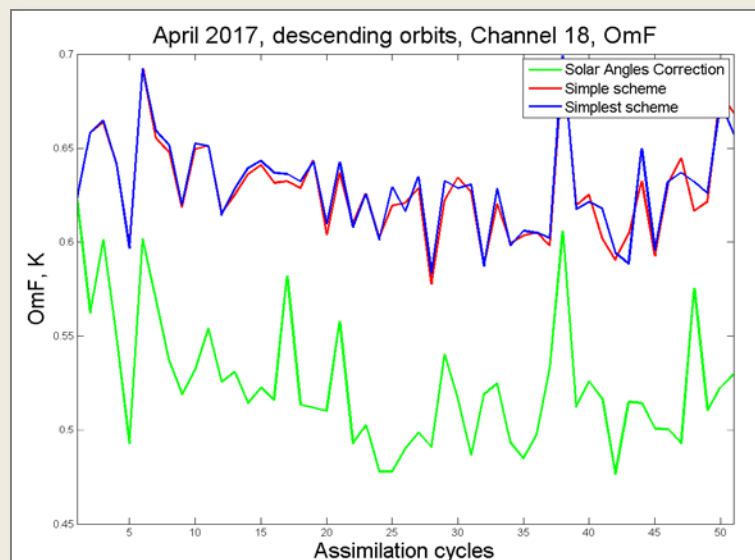


RMS differences (Obs – First Guess) for 3 proposed calibration schemes, channels 15-18









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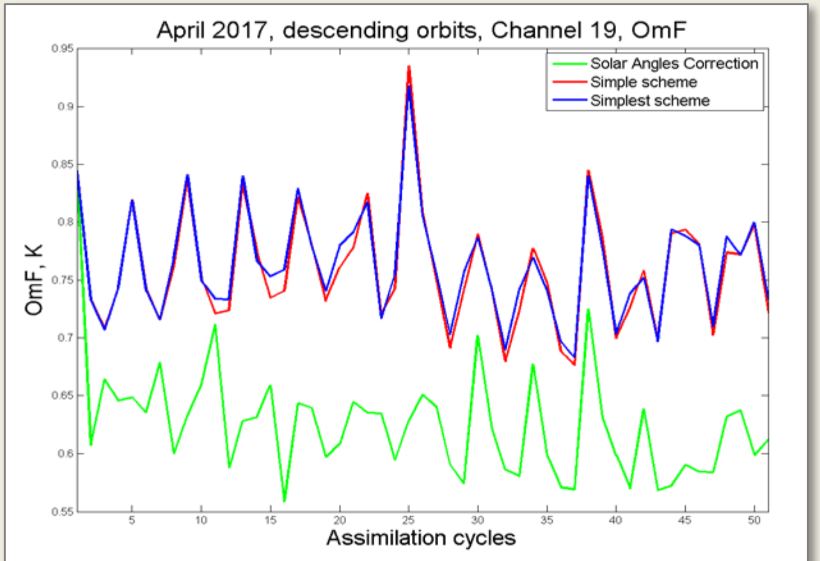
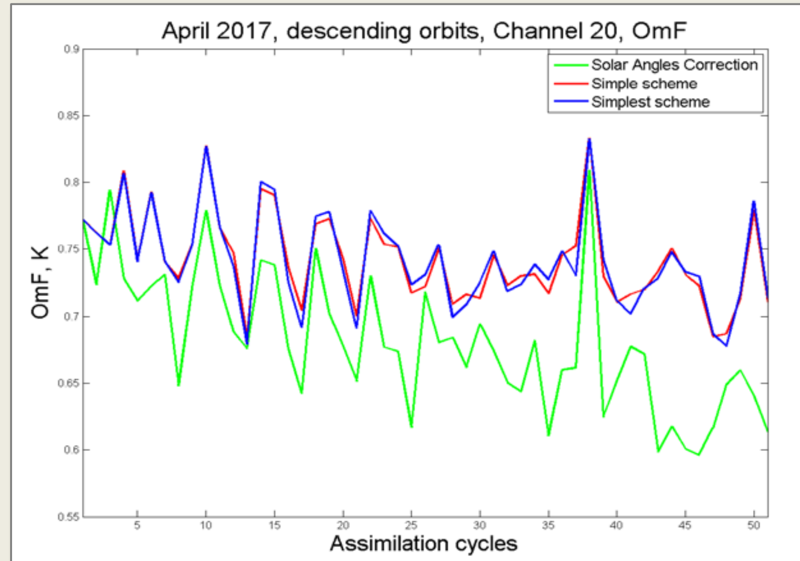
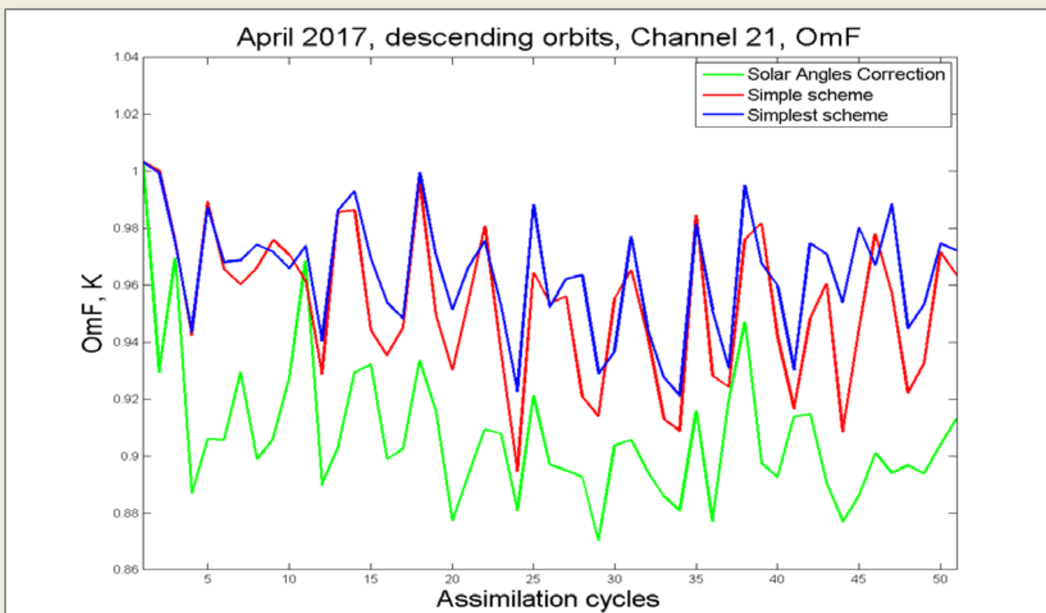
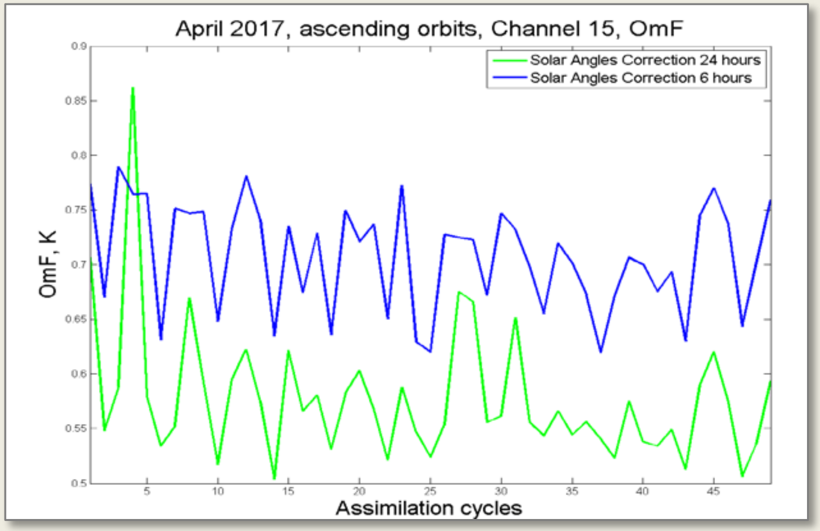
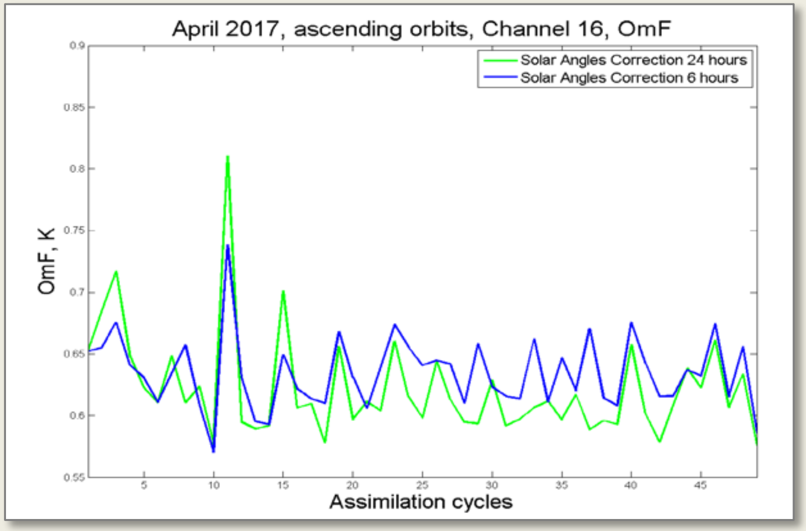


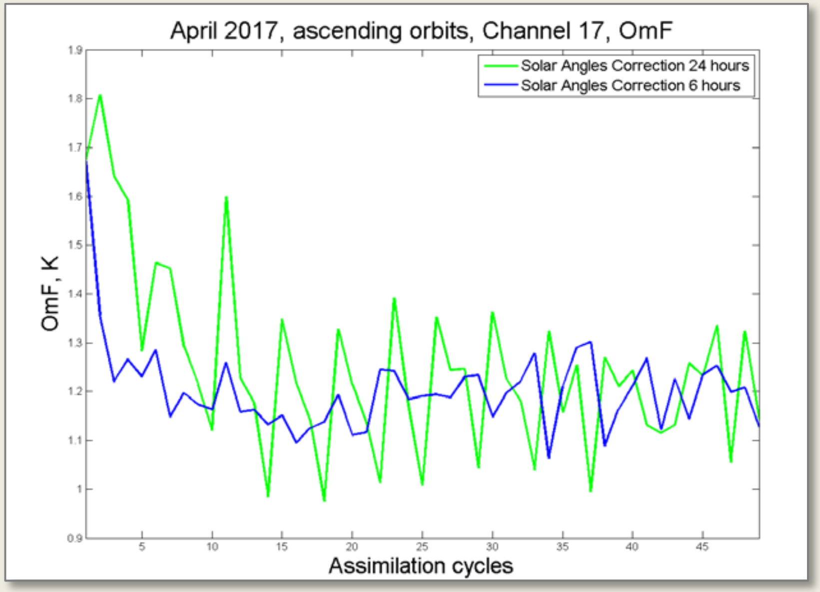


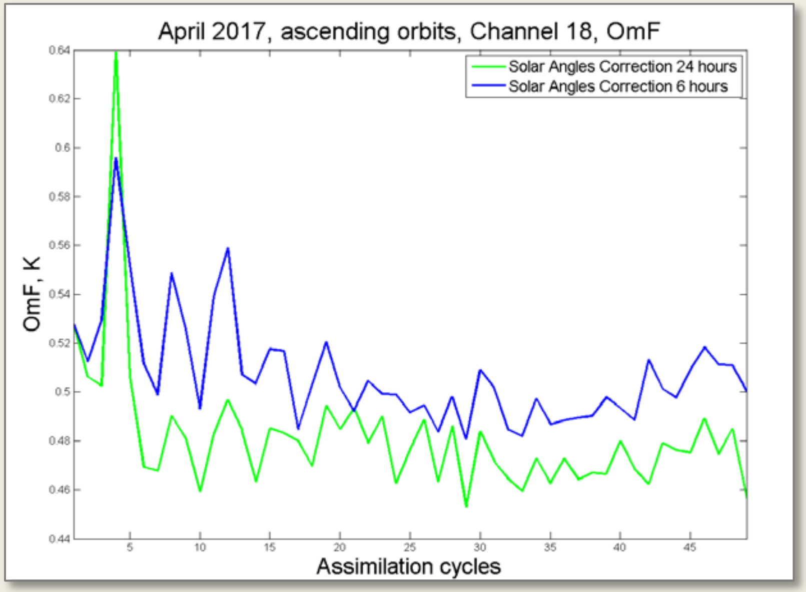


RMS differences (Obs – First Guess) for 6- and 24-hours coefficients' updating, channels 15-18

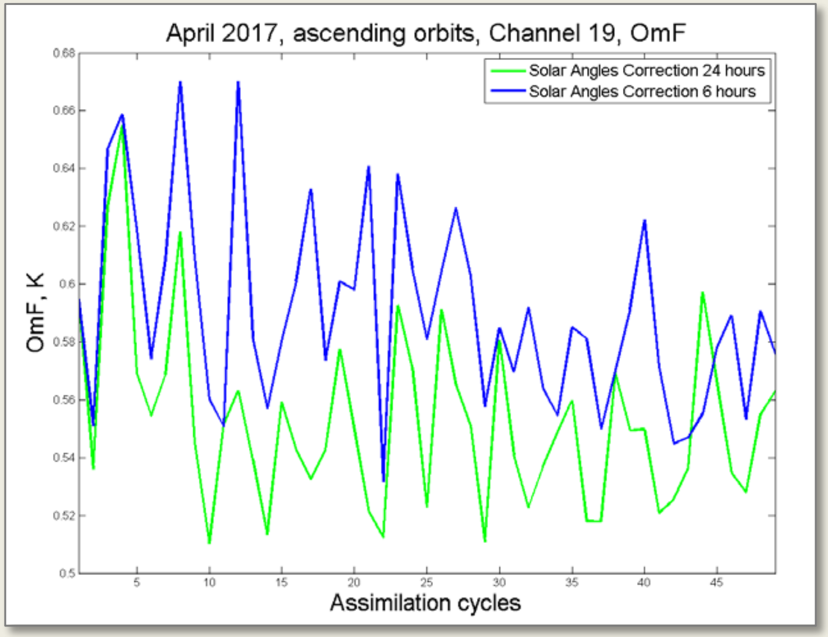


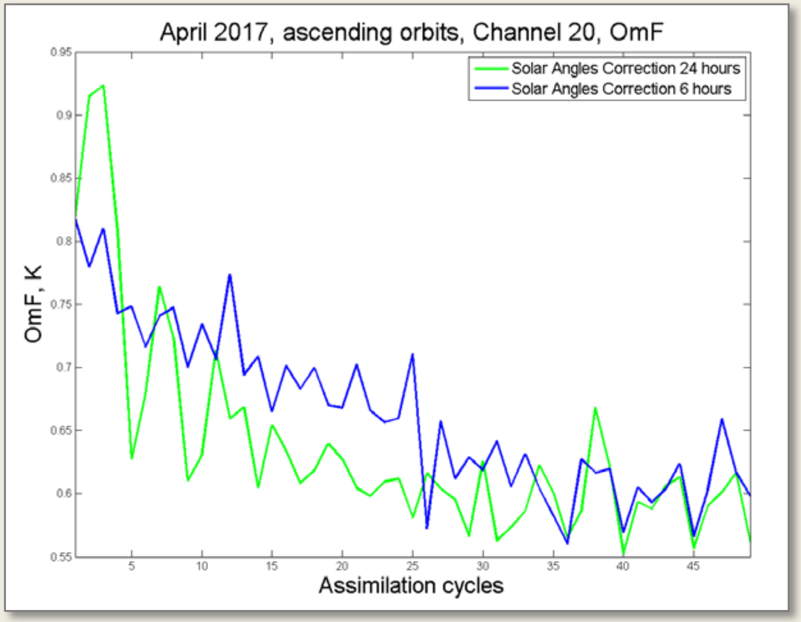


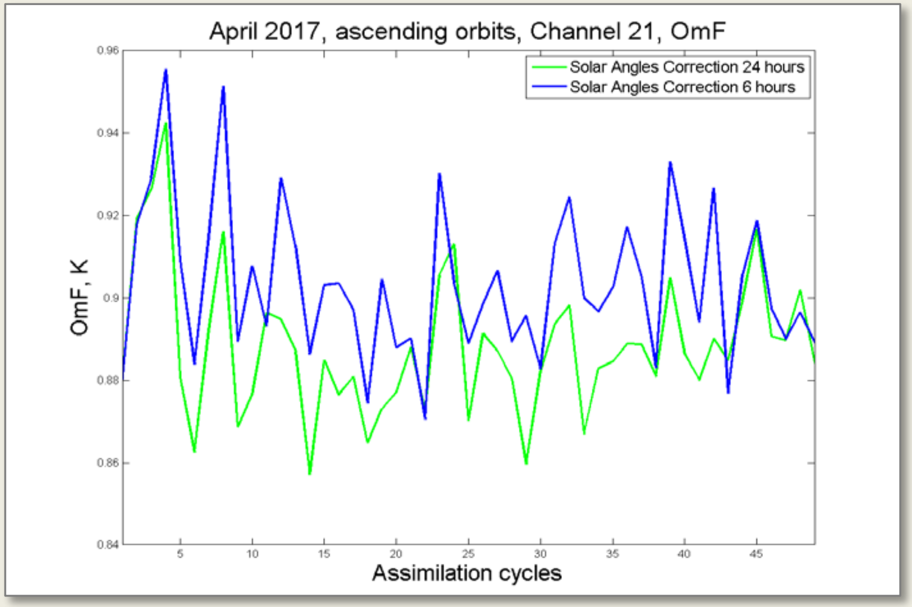




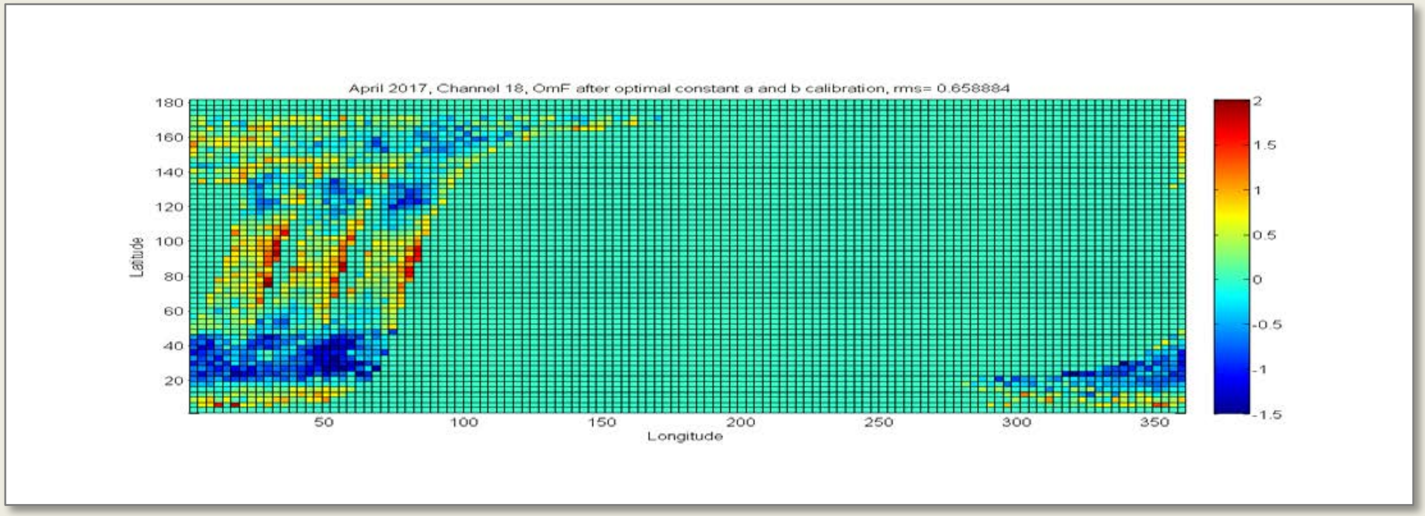
RMS differences (Obs – First Guess) for 6- and 24-hours coefficients' updating, channels 19-21

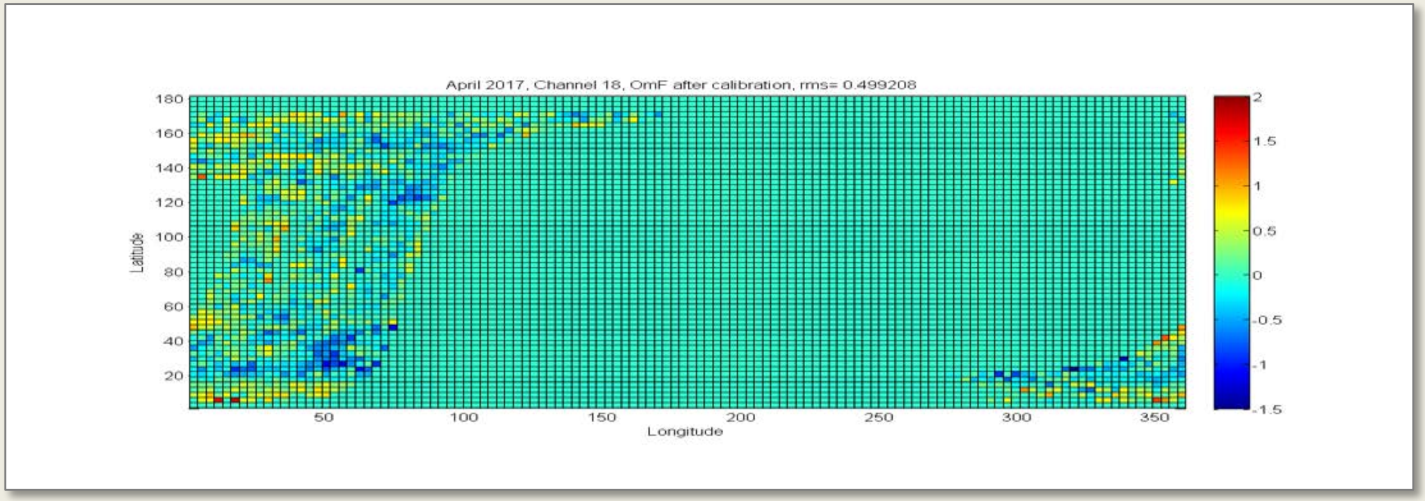




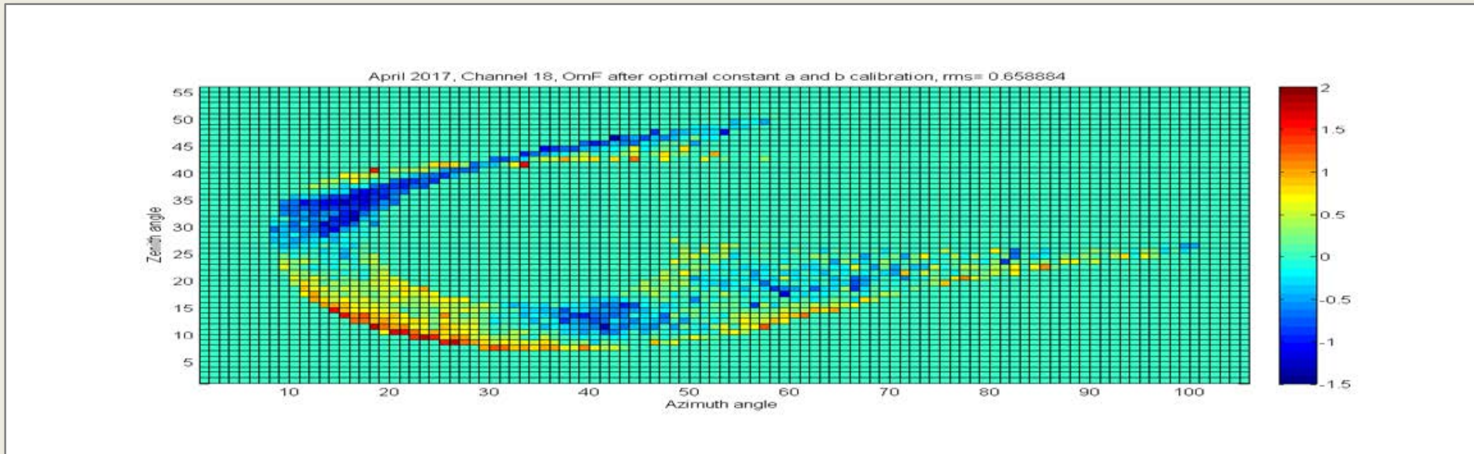


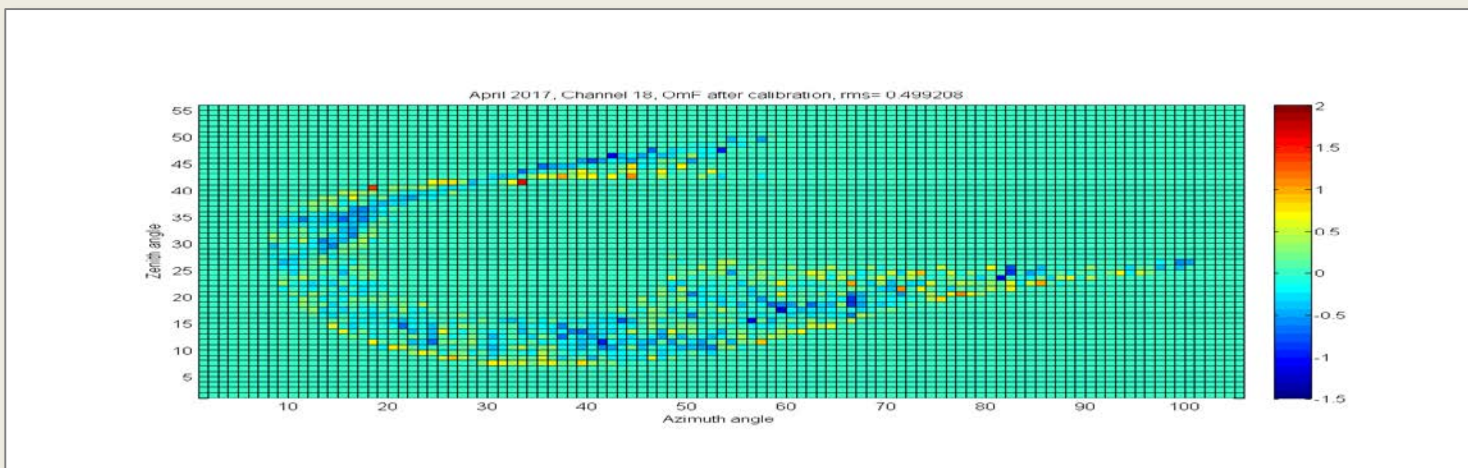
RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd



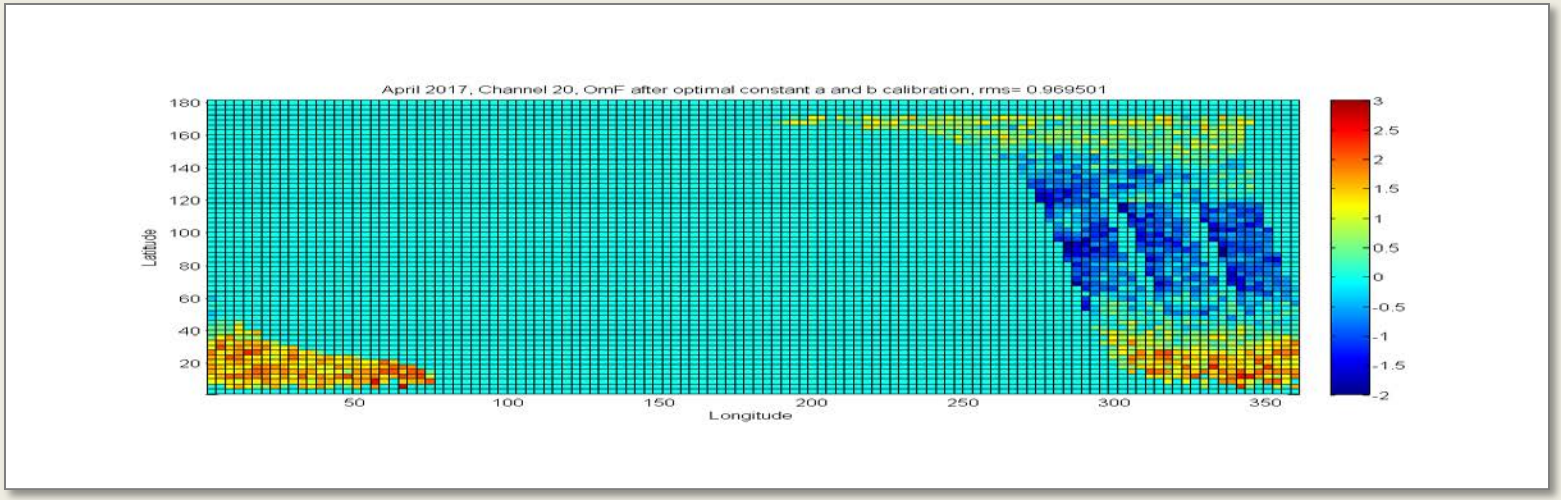


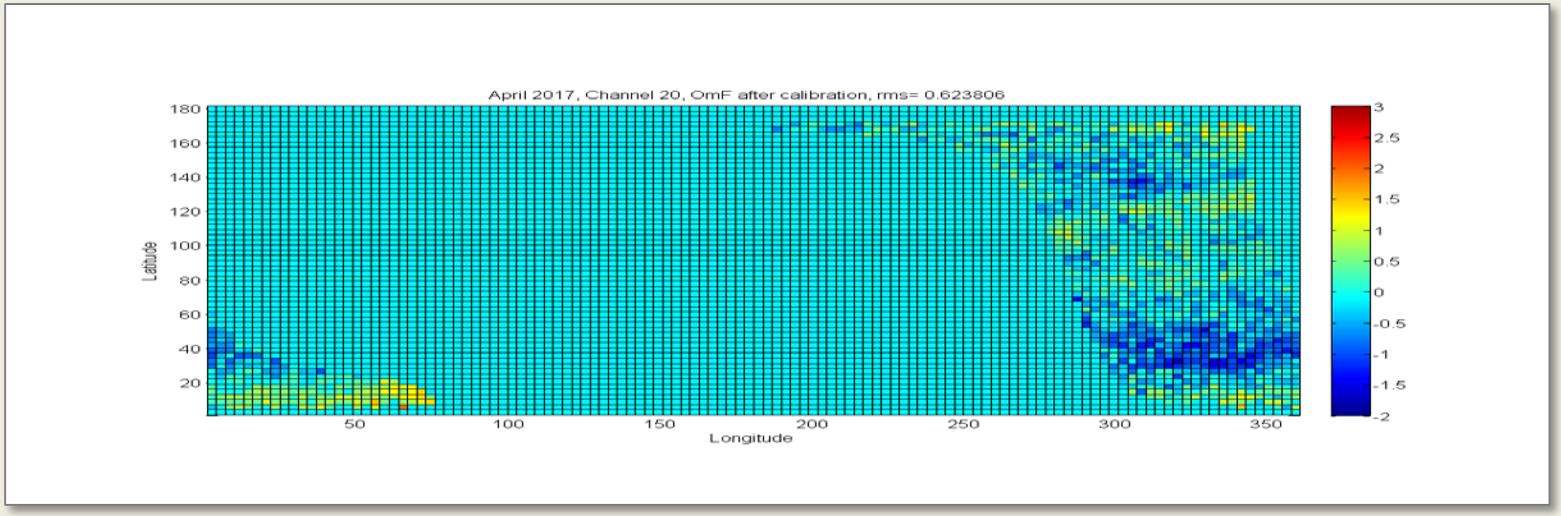
RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd plotted in azimuth-zenith angle plane



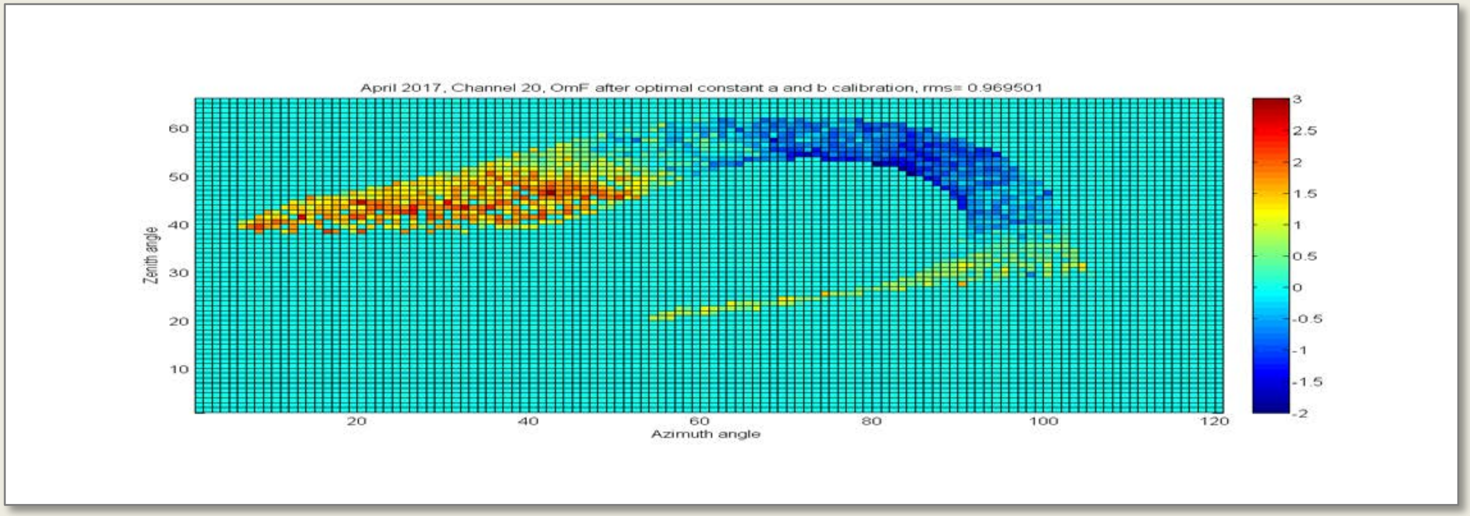


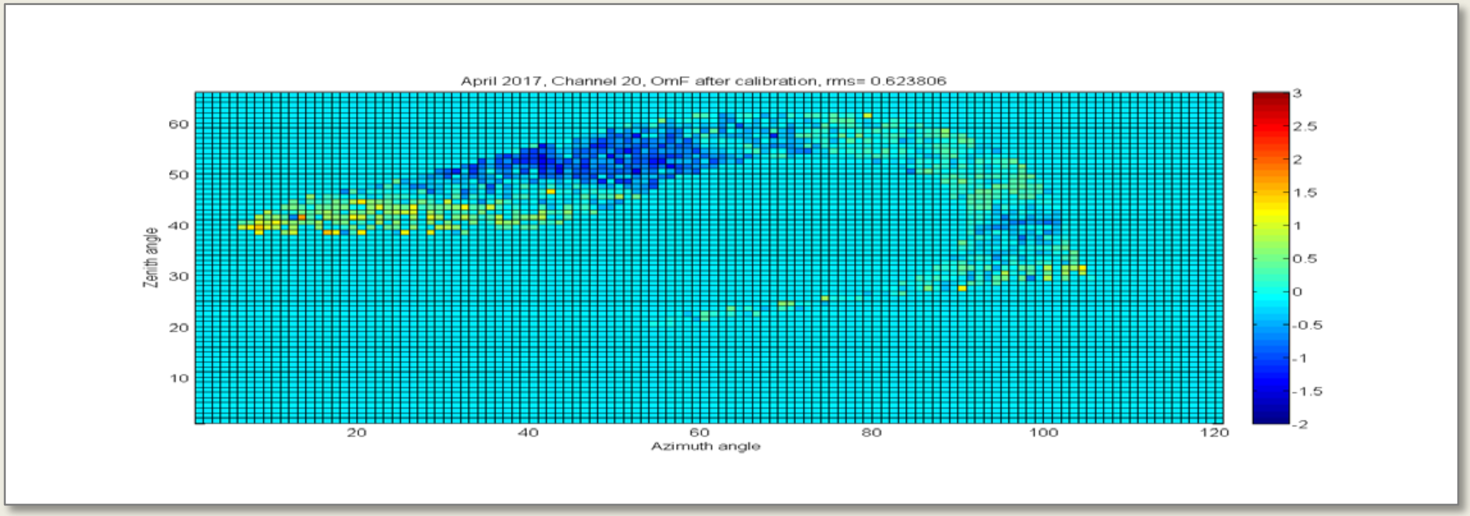
RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd



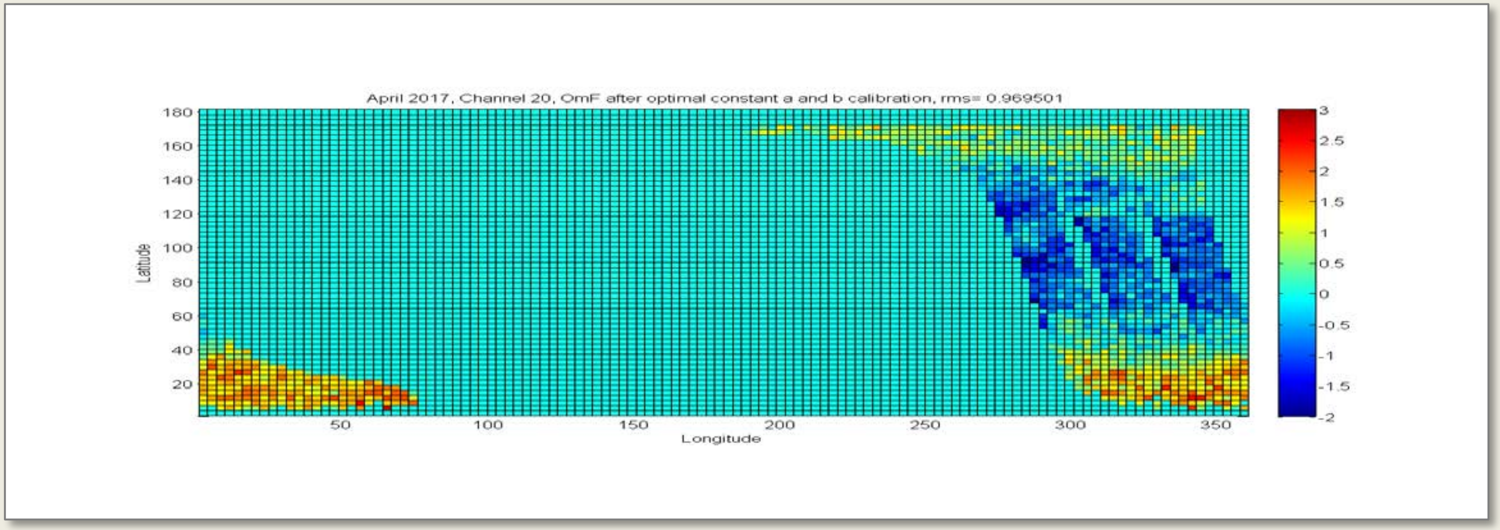


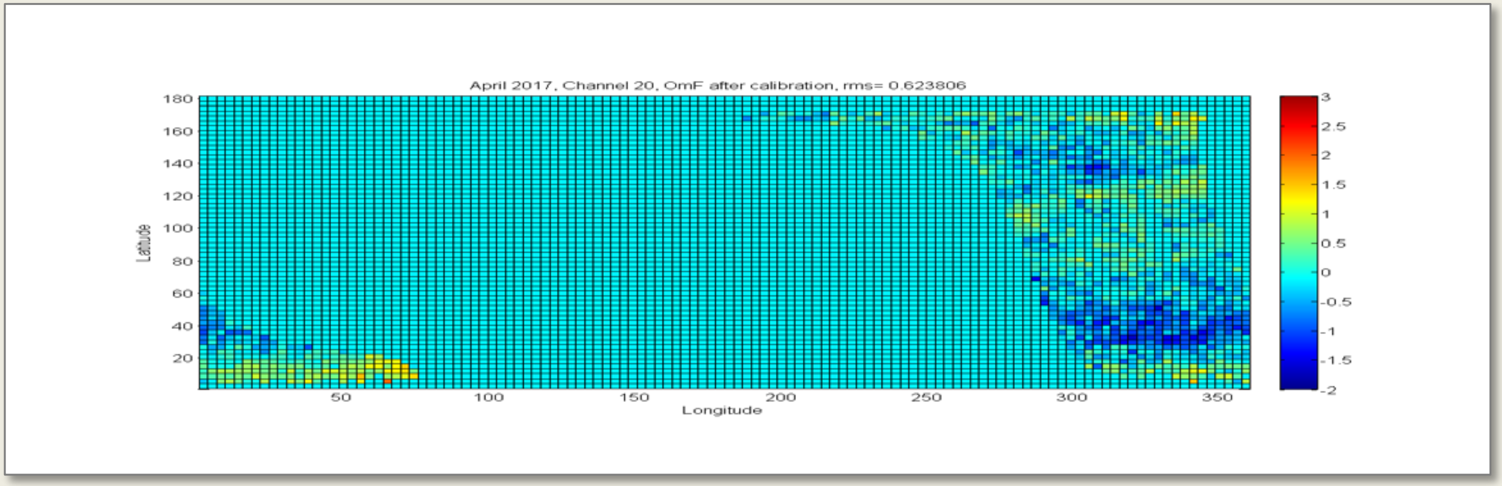
RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd plotted in azimuth-zenith angle plane



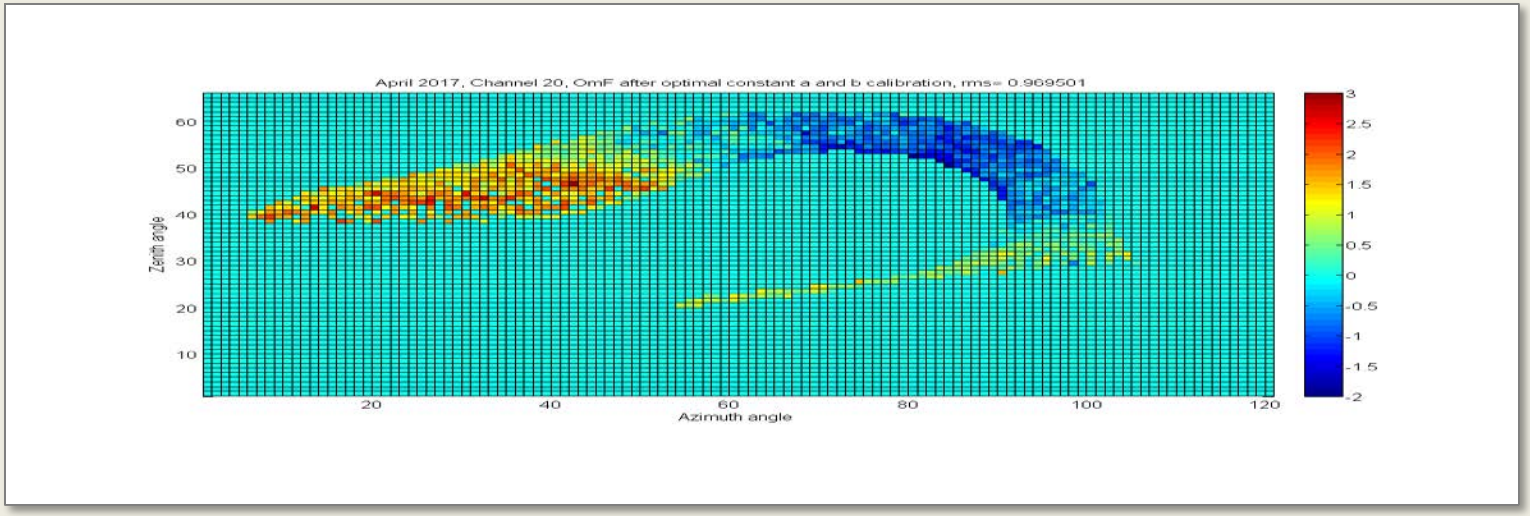


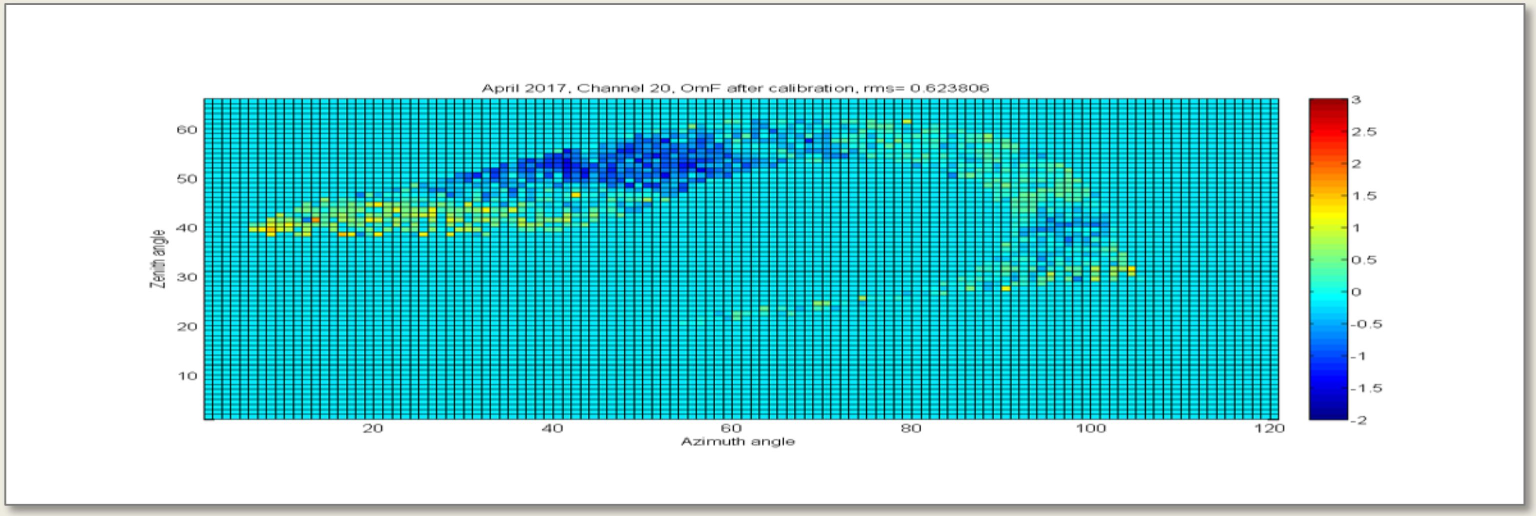
RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd





RMS differences (Obs – First Guess) for two types of calibration scheme, 1st and 3rd plotted in azimuth-zenith angle plane

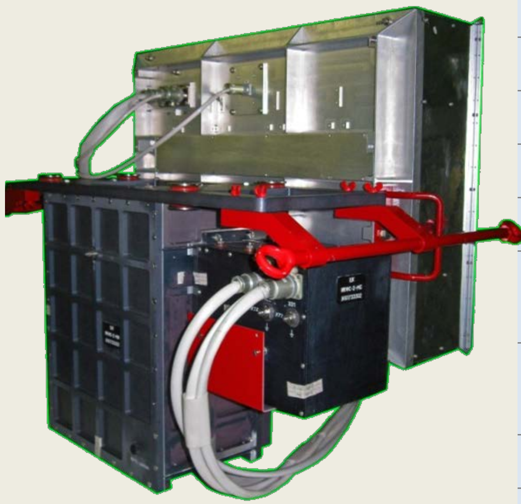




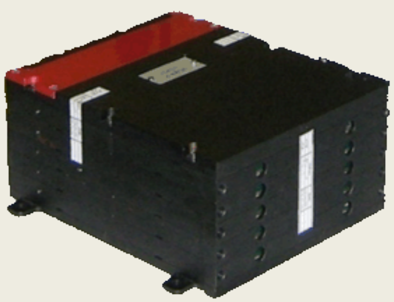
Summary

A new microwave-radiometer calibration technique is proposed. The technique sequentially assimilates observed minus simulated radiance data in every 6h cycle in order to estimate up-to-date calibration coefficients. The calibration coefficients are defined to be functions of the two solar angles. The positive effect of the developed calibration technique is demonstrated. The calibrated observations are shown be significantly more accurate as compared with observations that undergo simpler and more traditional calibration techniques.

Post-launch IKFS-2 data cross-calibration and assessment

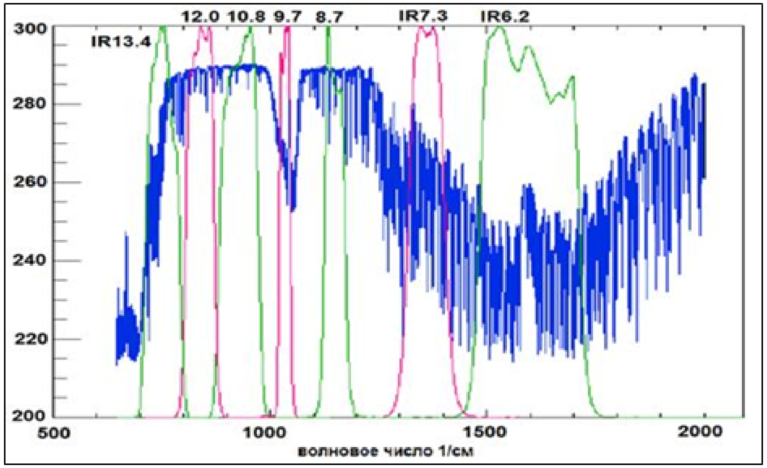


Parameter	*Units*	*Value*
Spectral range: wavelength wave number	μm cm^{-1}	5-15 2000-665
Reference channel wavelength	μm	1.06
Maximum optical path difference (OPD)	mm	17
Angular size of FOV	mrad	40 x 40
Spatial resolution (at sub-satellite point)	km	35
Swath width and spatial sampling	km	2500, 110 2000, 100
Duration of the interferogram measurement	s	0.5
Dynamic range		2^{16}
Mass	kg	45-50
Power	W	50

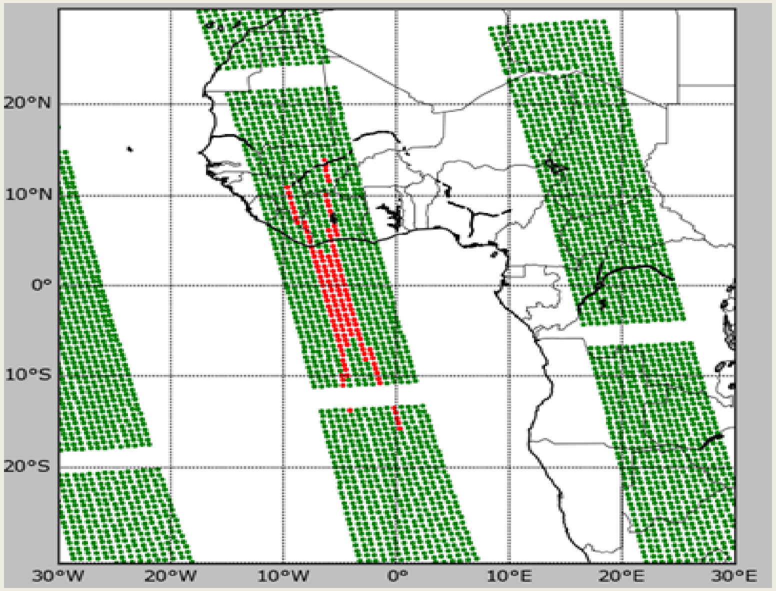


Spectral range	*Absorption band*	*Application*
665 to 780 cm^{-1}	CO_2	Temperature profile
790 to 980 cm^{-1}	Atmospheric window	Surface parameters (T_s, ε_ν), cloud properties
1000 to 1070 cm^{-1}	O_3	Ozone sounding
1080 to 1150 cm^{-1}	Atmospheric window	T_s, ε_ν,; cloud properties
1210 to 1650 cm^{-1}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

IKFS-2 cross-calibration vs Meteosat-10/SEVIRI data



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

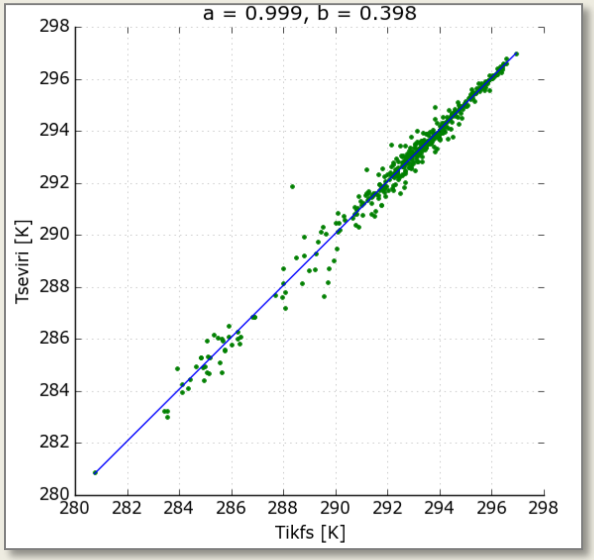


Channel	SEVIRI-IKFS	SEVIRI-IASI
IR13.4	-1± 0.20	-1± 0.1
IR12.0	0.08 ± 0.21	0 ± 0.1
IR10.8	0.09 ± 0.21	0 ± 0.1
IR9.7	0.06 c	0 ± 0.1
IR8.7	-0.10 ± 0.20	0 ± 0.1
WV7.3	0.12 ± 0.21	0 ± 0.2

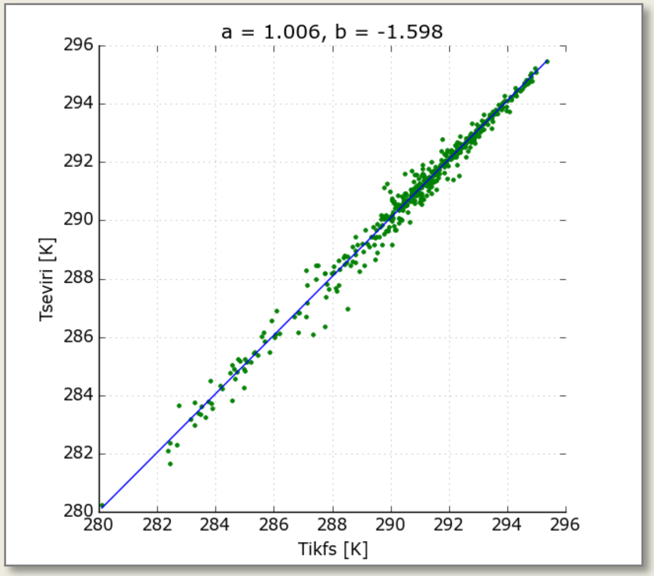
IKFS-2 calibration vs Meteosat-10/SEVIRI data

February – May, 2017

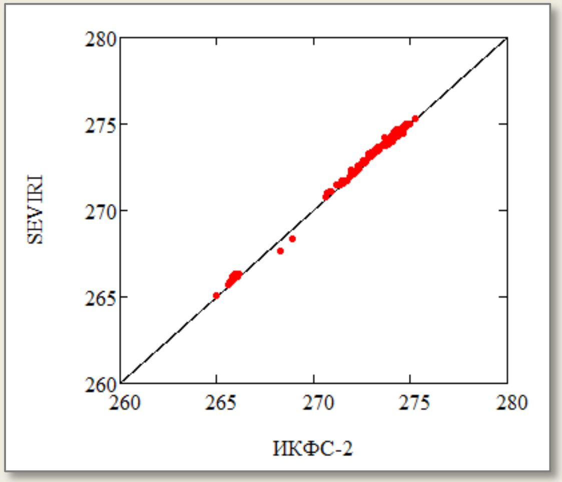
10.8 μm



12.0 μm



9.7 μm



IKFS-2 cross-calibration vs Meteosat-10/SEVIRI data, 2015 and 2017

IKFS-SEVIRI, 2015						
SEVIRI channel	7.3μm	8.7μm	9.7μm	10.8μm	12.0μm	13.4μm
Bias, K	-0.12	0.10	-0.06	-0.1	-0.1	1.0
RMS, K	0.07	0.07	0.07	0.07	0.07	-

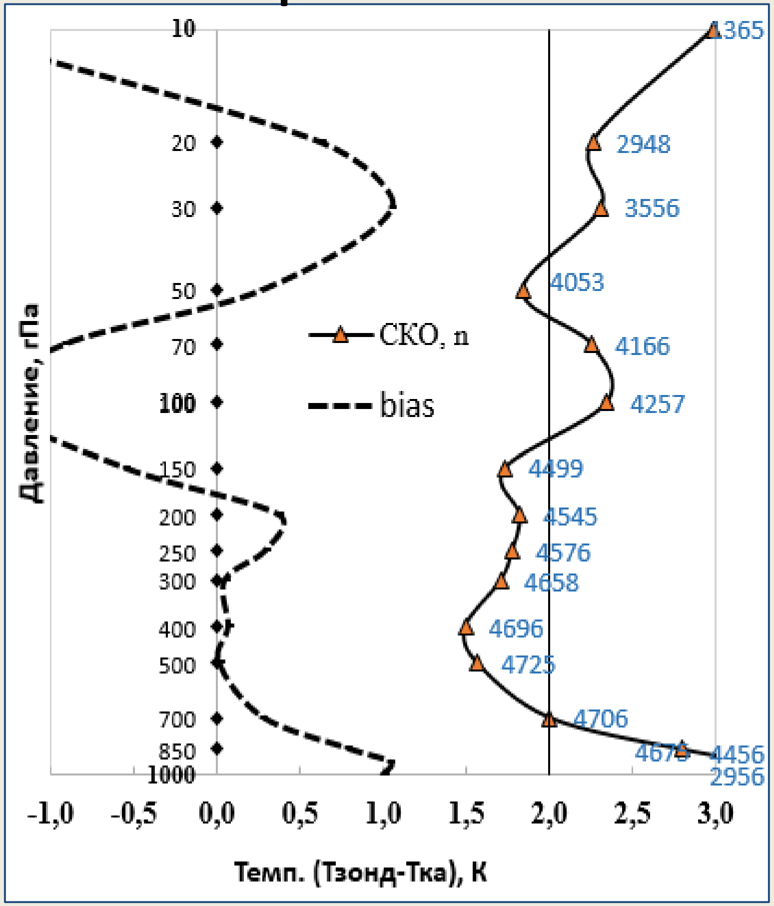
IKFS-SEVIRI, 2017						
SEVIRI channel	7.3μm	8.7μm	9.7μm	10.8μm	12.0μm	13.4μm
Bias, K	-0.10	0.07	-0.2	-0.1	-0.1	1.2
RMS, K	0.01	0.01	0.01	0.01	0.01	0.02

Summary

- The results of IKFS-2 cross-calibration vs Meteosat-10/SEVIRI data for 2015 and 2017 are similar and confirm the stability and high accuracy of IKFS-2 on-board radiometric calibration.
- IKFS-2 instrument performance proved to be stable and is according to specs.

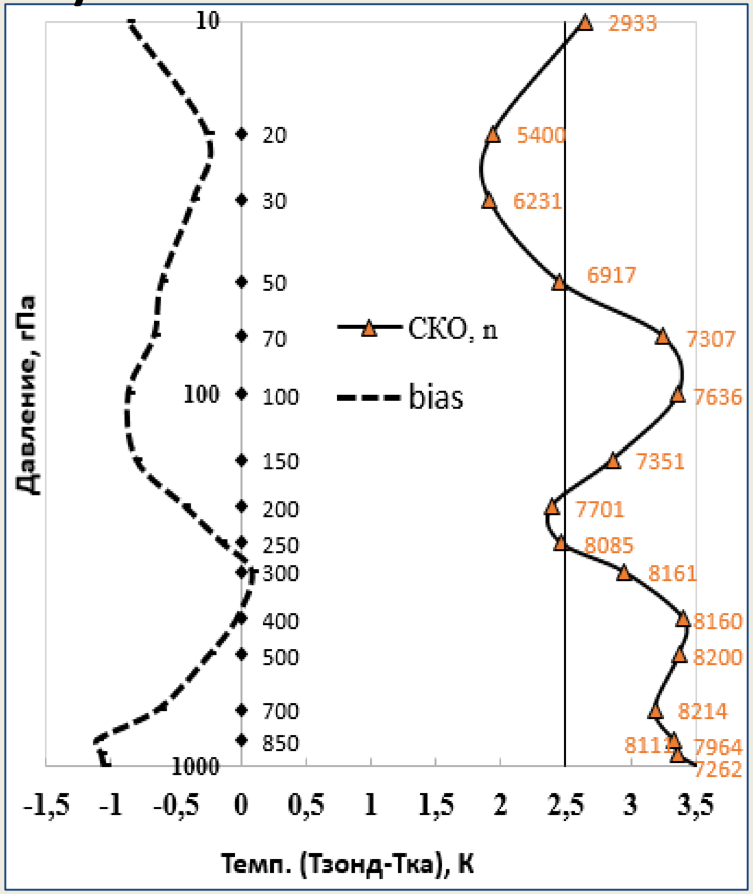
Validation of MTVZA - and IKFS-based temperature and humidity soundings

Temperature and Relative Humidity Profile Error Statistics



IKFS-2

January-November 2017

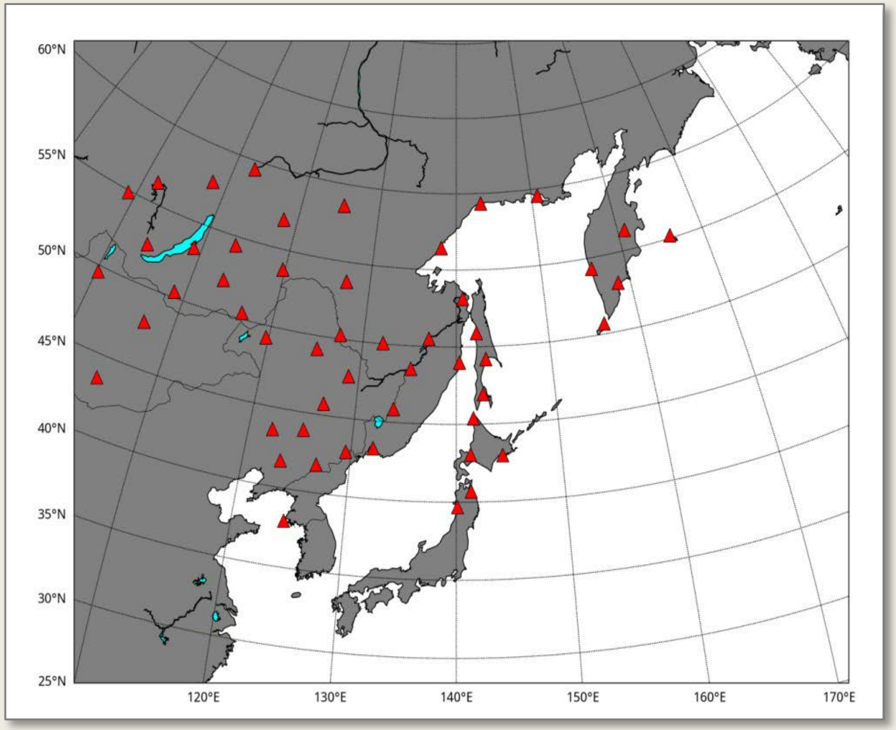


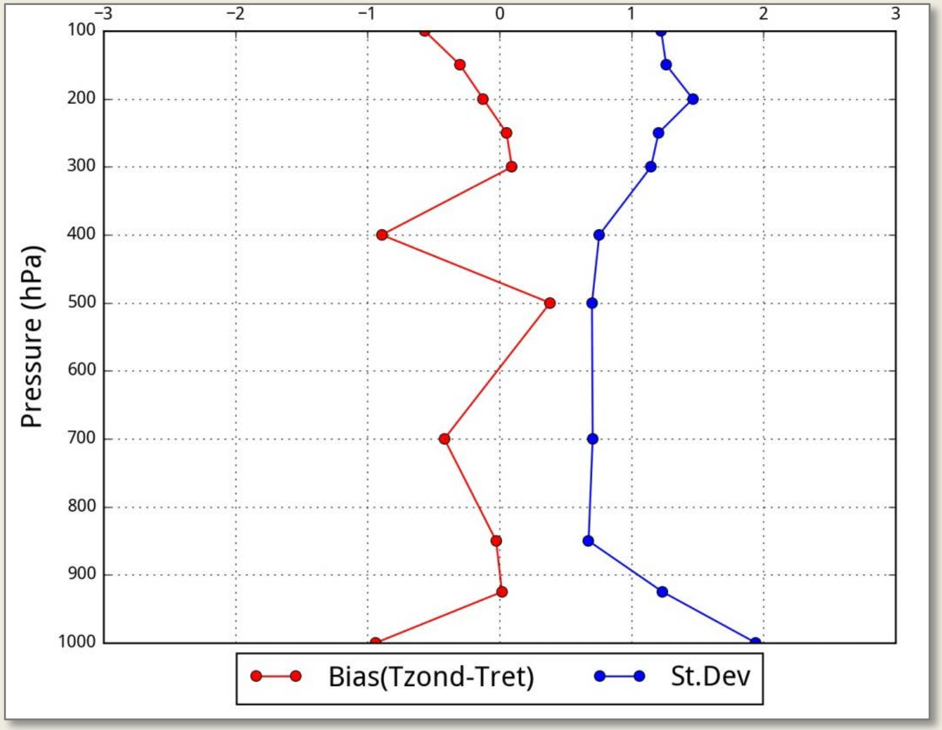
MTVZA-GY

January-August 2017

Temperature Profile Error Statistics
IR sounder IKFS-2, Far-Eastern region

(retrievals vs radiosonde data, March-May 2017)





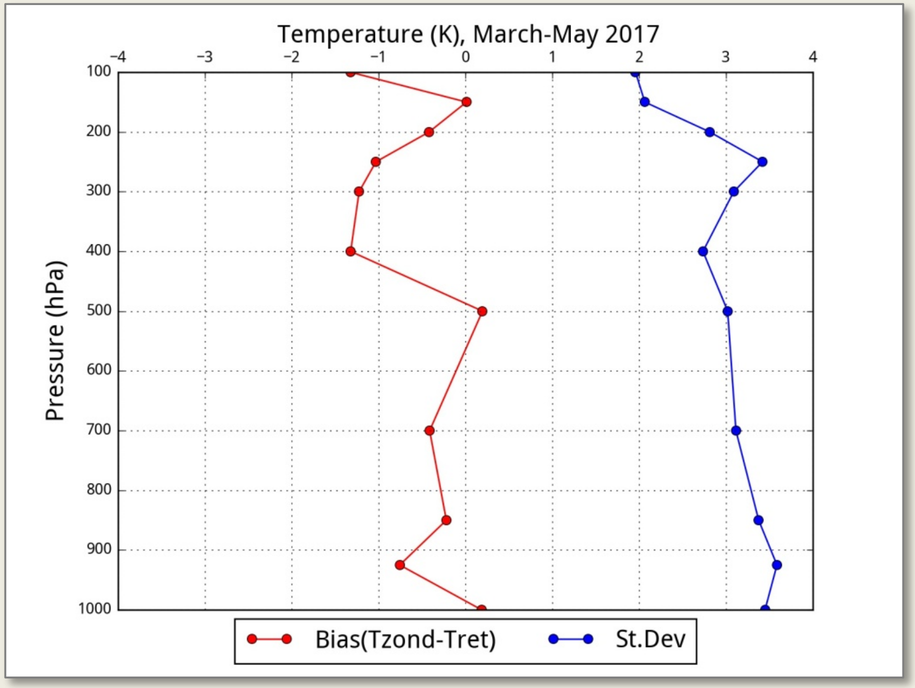
Location of aerological stations

At least 1000 pairs of comparisons

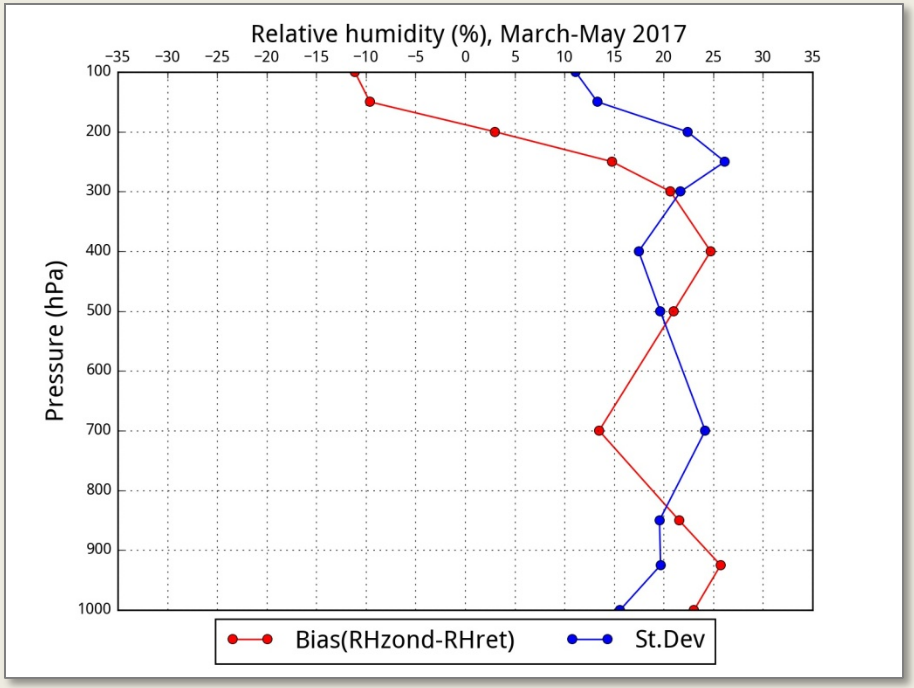
Temperature and Relative Humidity Profile Error Statistics MTVZA-GY sounder, Far-Eastern region

(March-May 2017)

T vs radiosonde data



RH vs radiosonde data

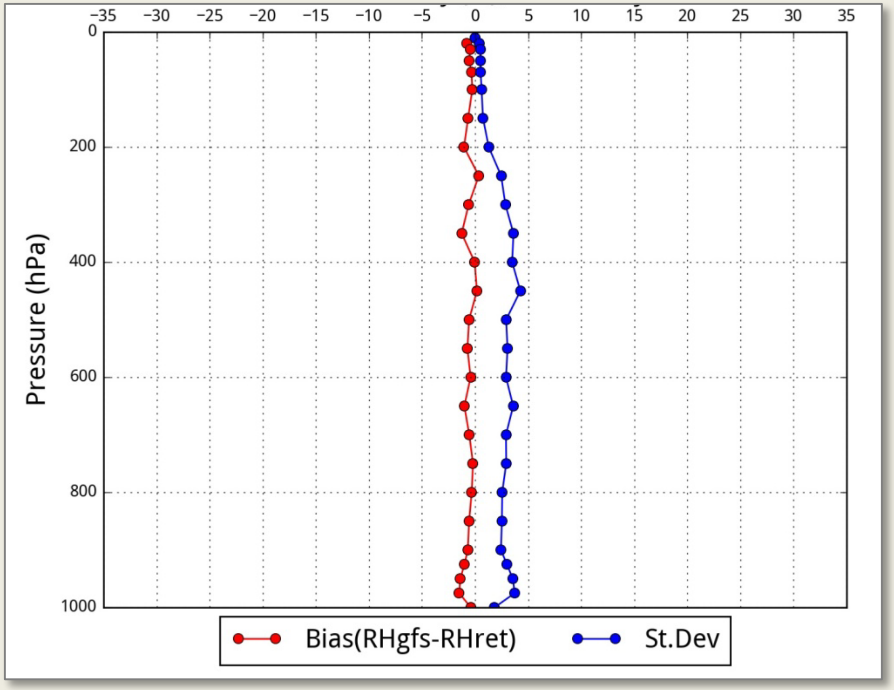


At least 1000 pairs of comparisons

Relative Humidity Profile Error Statistics
IR sounder IKFS-2, Far-Eastern region

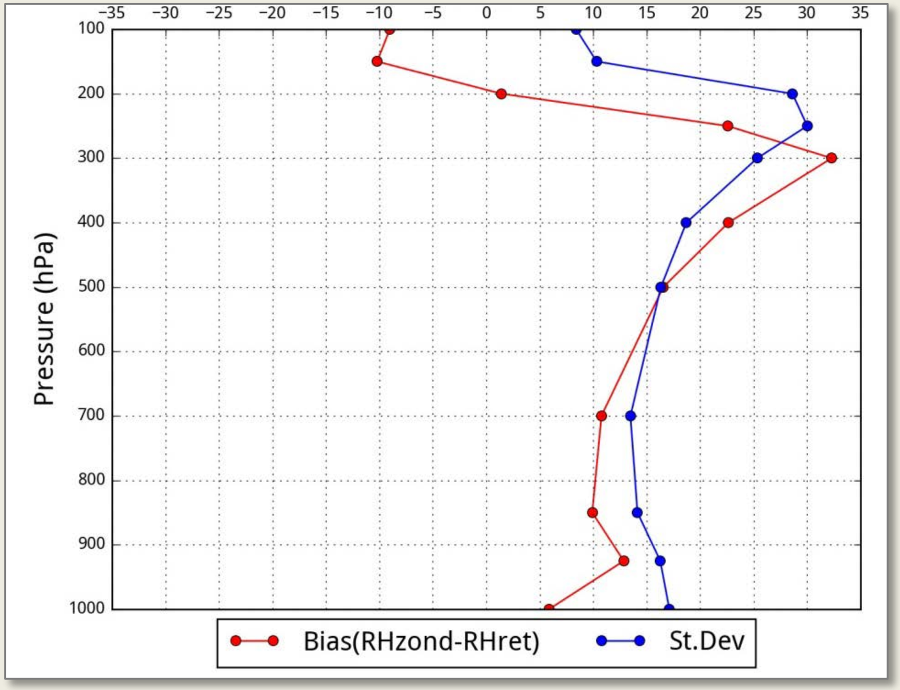
(March-May 2017)

Retrievals vs Global Forecast System data



At least 3000 pairs of comparisons

Retrievals vs radiosonde data



At least 1000 pairs of comparisons

Conclusion

CAL/VAL System for Satellite Data and Products, developed at SRC Planeta, provides on regular basis:

- Post-launch MTVZA-GY data absolute calibration and assessment;
- Post-launch IKFS-2 data cross-calibration and assessment
- Validation of MTVZA - and IKFS-based temperature and humidity soundings

MTVZA-GY data assimilation in Hydrometcenter of Russia

Assimilation of MTVZA-GY data

The MTVZA-GY channels 15-20 were included in the data assimilation system of the Hydrometcenter of Russia. Their impact was measured by the RMS error of 24-72h forecasts started from the assimilated analyses.

The forecasts were run every 12 hours (at 00 and 12 UTC) for two weeks in January 2016. The verification scores were computed against the operational analysis of the Hydrometcenter of Russia.

The following observations were assimilated: *in situ* (near-surface, including ships and buoys, radiosonde, and aircraft observations), AMV (wind observations based on the cloud movement and humidity fields), and GPS radio occultation refractivity profiles (REFR).

The experiments were conducted for the following configurations:

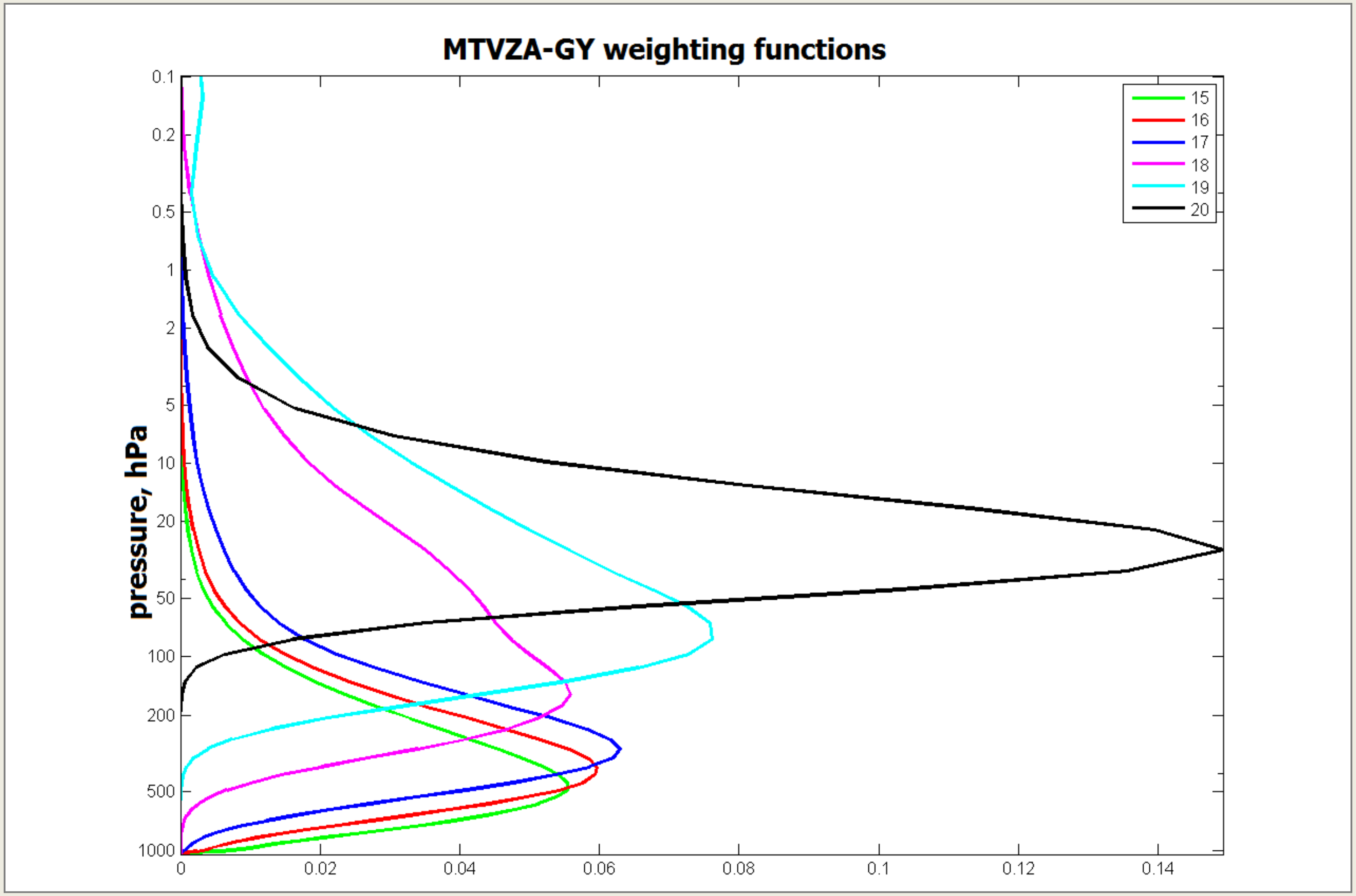
• Without microwave observations.

• Using MTVZA-GY observations without AMSU-A data.

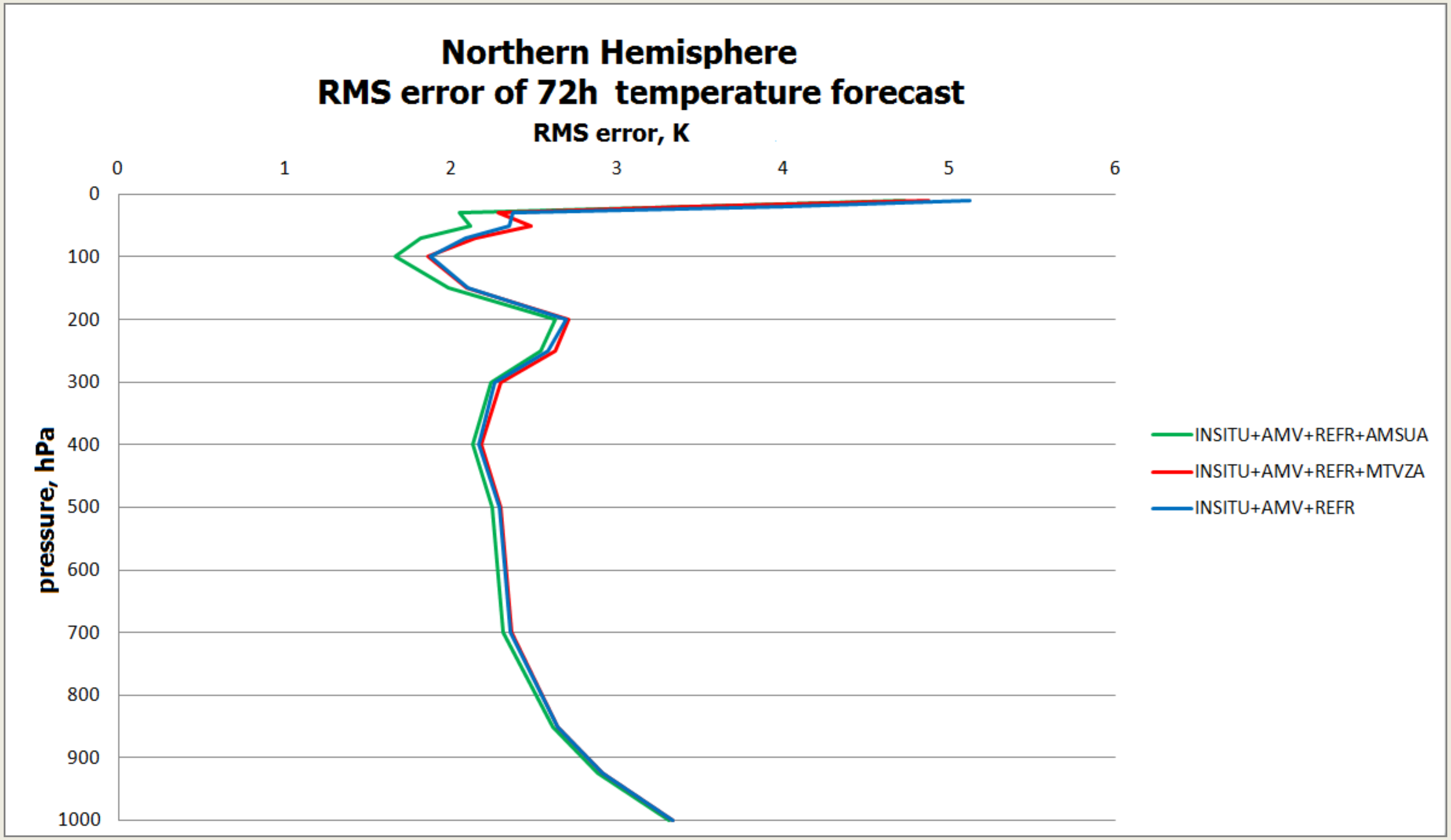
• Using AMSU-A data from Metop-A (whose orbit nearly coincides with the orbit of Meteor-M N2)

•without MTVZA-GY observations.

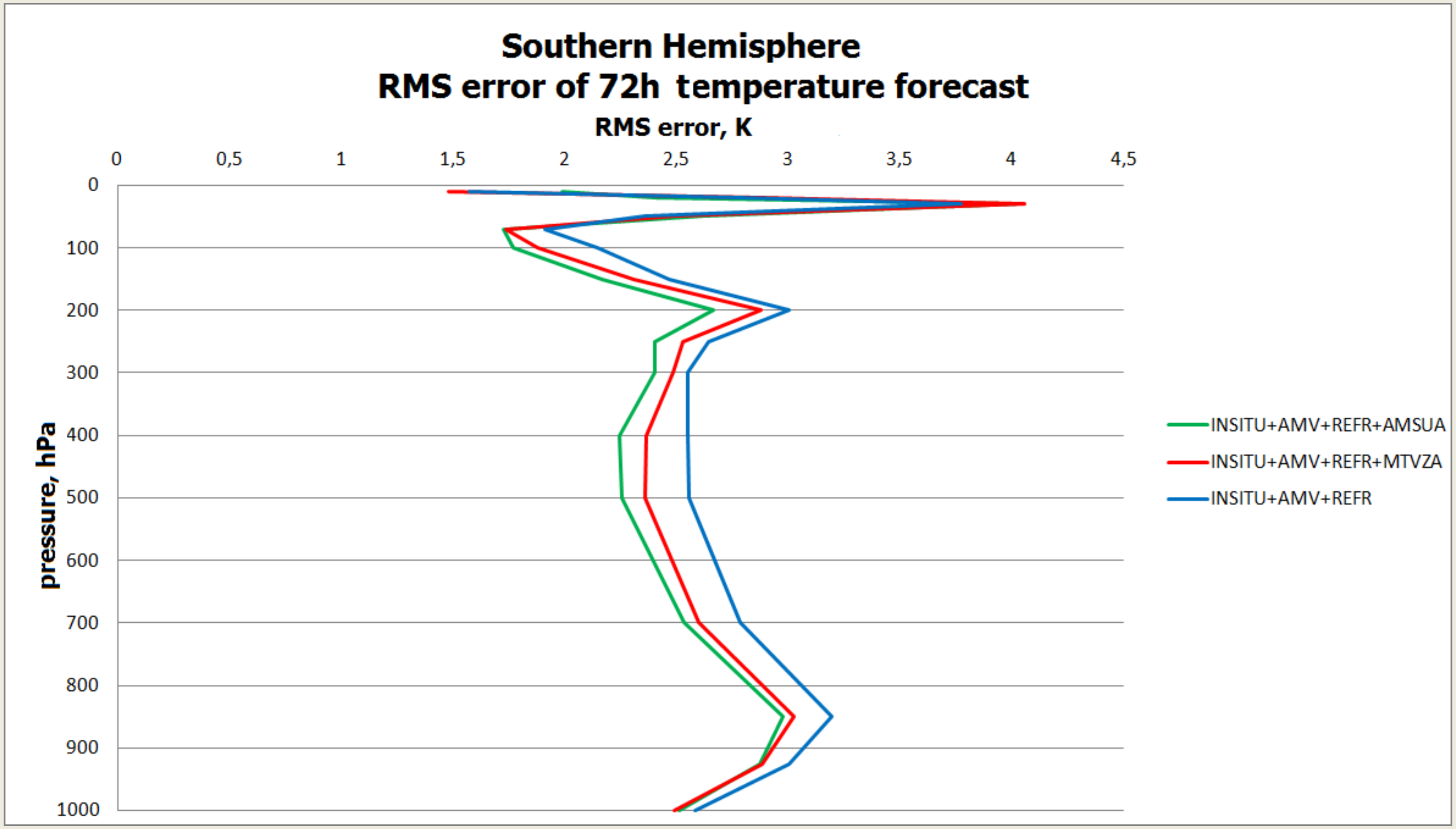
Weighting functions of MTVZA-GY channels



MTVZA impact: Northern Hemisphere



MTVZA impact: Southern Hemisphere



Summary

- Data from the microwave radiometer MTVZA-GY onboard the Russian Meteor-M N2 satellite are examined and found usable for global data assimilation.
- The error of MTVZA-GY observations is 1.5-2 times greater than the error of AMSU-A data in similar channels.
- The impact of MTVZA-GY observations in the global data assimilation system of the Hydrometcenter of Russia is neutral in the Northern Hemisphere and signicantly positive in the Southern Hemisphere.
- The impact of MTVZA-GY data in the presence of AMSU-A observations is neutral in both hemispheres.

References

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Thanks for attention!