Inter-calibration of Meteosat IR measurements using HIRS data

R. Roebeling[1], J. Schulz[1], T. Hewison[1], B. Theodore[1,2]
[1] EUMETSAT, Eumetsat-Allee 1, 64295 Darmstadt, Germany
[2] MOLTEK, United Kingdom

Introduction

The detection of climate change and analysis of climate variability at inter-annual scales requires well calibrated observations and long-term homogeneity of time series of data. Observations from EUMETSAT's series of Meteosat First and Second Generation geostationary satellites spans a period from 1982 to today for the zero degree longitude sub-satellite position and from 1997 over the Indian Ocean providing data for climate analysis at multi-decadal scale. However, to turn this series into a Fundamental Climate Data Record, heterogeneities in the time series, introduced due to successive radiometers having different spectral responses and due to changes in calibration methodology over time, need to be resolved.

This poster presents the methodology and first results of an effort to inter-calibrate the complete time series of the Meteosat First and Second Generation radiometers MVIRI and SEVIRI IR channels (6.3 and 11.8 μm) to HIRS observations. In particular the uncertainties due the necessary spectral conversion among the instruments has been studied. HIRS has been chosen because it provides a long series and similar channels. The final method to be used will follow the methodology used to inter-calibrate the SEVIRI instrument with IASI as already demonstrated within the GSICS initiative. The activity is performed in the frame of EUMETSAT's Climate Data Record generation activities and will be introduced to GSICS.

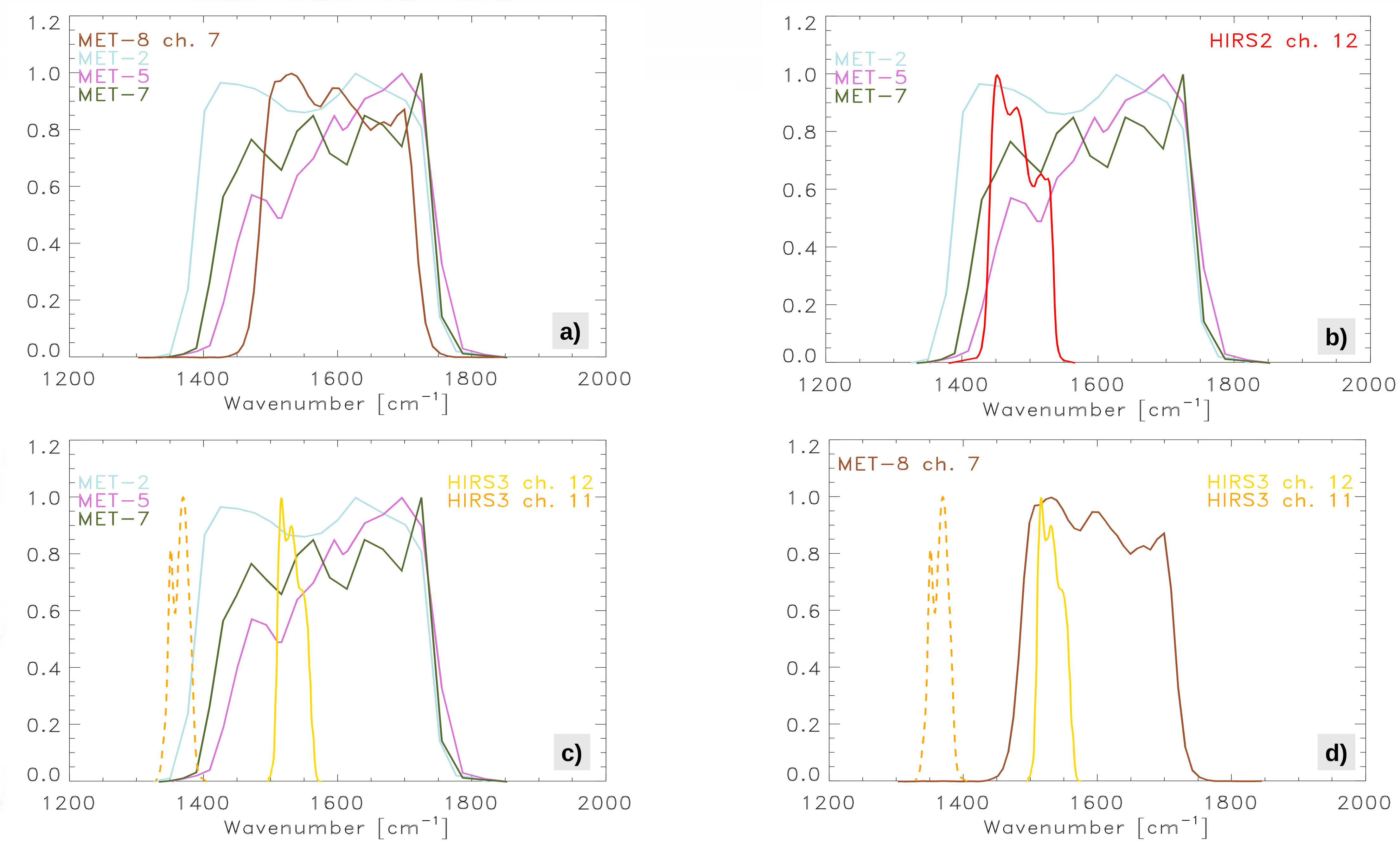


*Fig: Spectral response functions (SRF) for the water vapour channel of Meteosat MVIRI vs. SEVIRI **(a)**, MVIRI vs. HIRS/2 channel 12 **(b)**, MVIRI vs. HIRS/3 Channel 11 and 12 **(c)** and SEVIRI vs. HIRS/3 channel 11 and 12 **(d)**. The Meteosat SRFs differ from satellite to satellite, in particular, the SEVIRI SRF is narrower than any of the MVIRI ones. The HIRS instrument series consists of three different instruments where a big change in spectral position and width was introduced with the launch of the HIRS/3 instrument. An inter-calibration method for both series needs to convert radiances to one reference channel.*

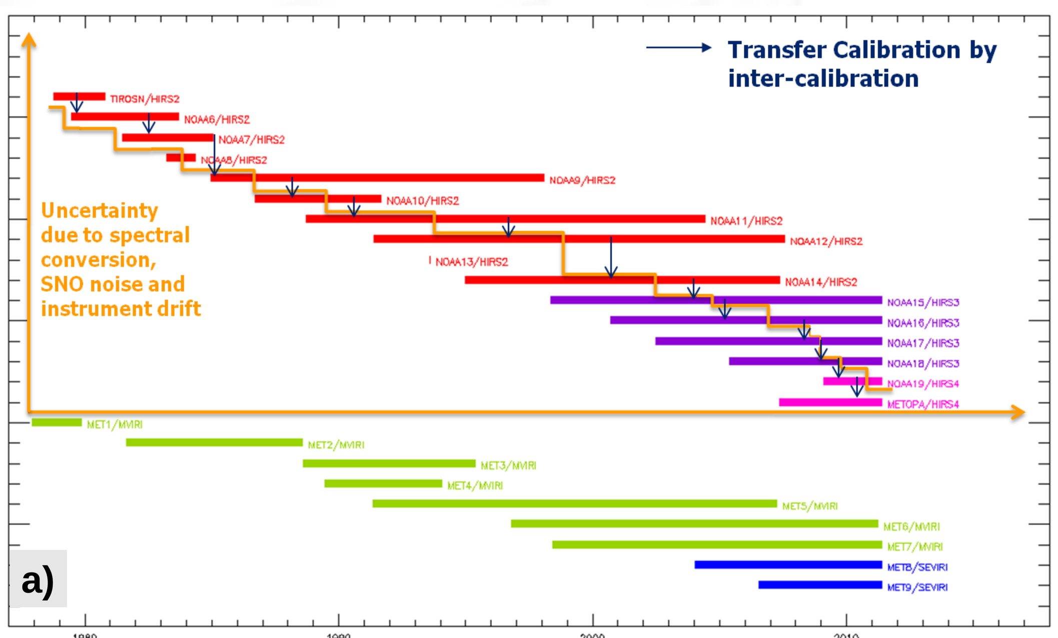


Fig: Examples illustrating the increase of uncertainty with time due to transferring calibrations,

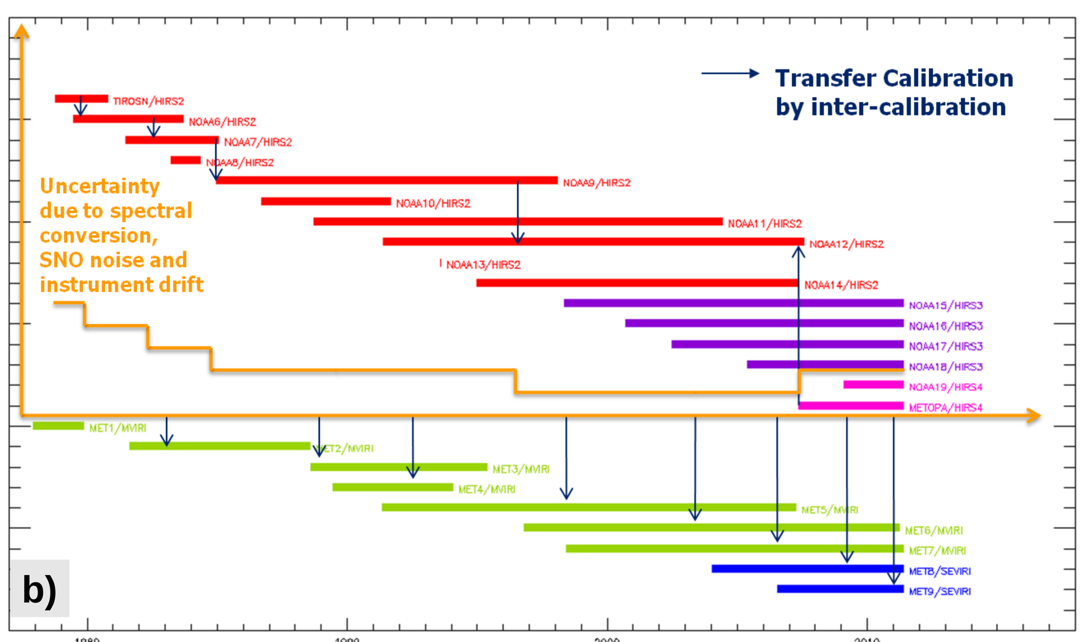


Fig: Examples illustrating the "traditional" re-calibration procedure by transferring the reference calibration to the monitored instruments.

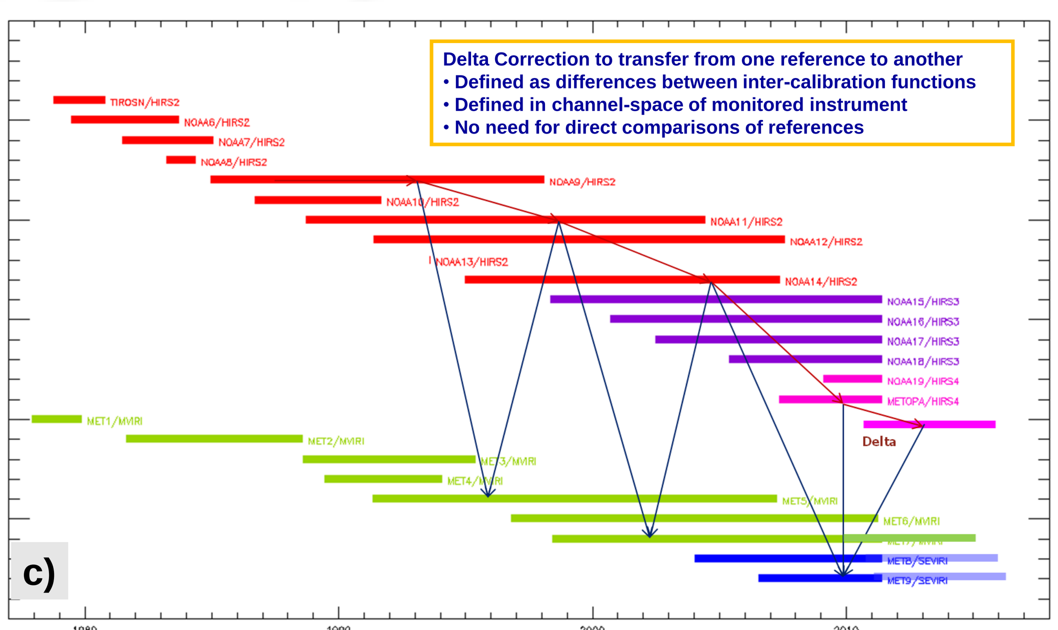
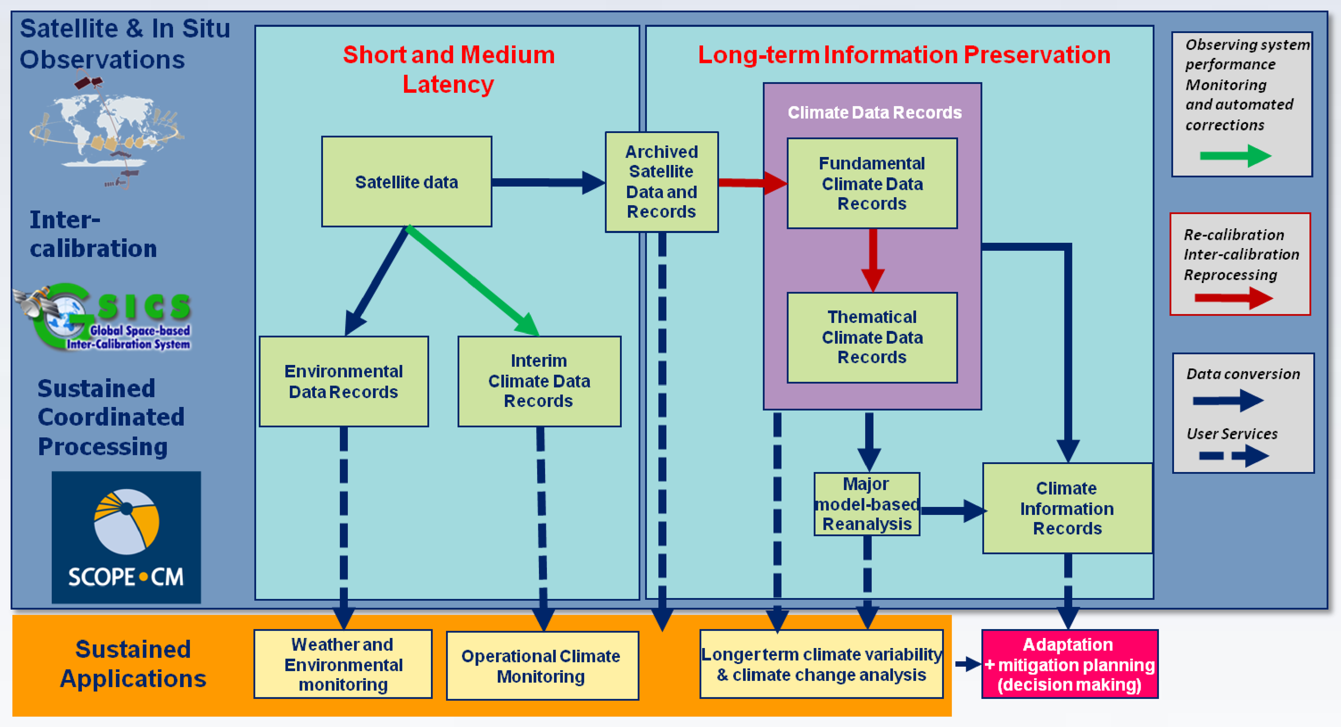


Fig: Schematic representation of the "Zipper" approach using double differences to transfer the calibrations.

Sustained Climate Information Flow



Spectral Conversion Functions

- Need a function to convert radiances measured with 1 channel (SRF) to look like another
- Cannot investigate all combinations of variables
- Use RMSD of fitted T_b as metric to select optimum combination from reduced set
- Then evaluate for full set of channels

OR

- Optimise each variable in turn
- For reduced set of instr./channels

Variable	Range	Full set	Reduced Set
Monitored Instrument	Met2-9 NOAAn/HIRS Total	8 12 20	2 4 6
Reference Instrument	Meteosats NOAAn/HIRS Total	8 12 20	0 3: HIRS/2-4 3
Channels	Meteosats NOAAn/HIRS Total	2/8 19 21/27	2: WV&IR 2: 8 & 12 2
Validation Set	ECMWF, ROABs, IASI obs	3	1
Latitude Range	±30°, ±45°, ±60°, ±90°	4	2
Order of fit	Linear/quadratic	2	2
Channels fit	Single/Multiple	2	2
Cloud	Clear, 700mb, 100mb, cloudy, all	5	2
Angles	Nadir, 60°, both	3	1

Channels	Fit	Latitude	Cloud	Zenith Angles	WV Tb RMSD [K]	IR Tb RMSD [K]
Single	Linear	±90°	All	0°, 60°	2.18	0.60
Multiple	Linear	±90°	All	0°, 60°	1.19	0.046
Multiple	**Quadratic**	**±90°**	**All**	**0°, 60°**	**0.74**	**0.034**
Multiple	Quadratic	±60°	All	0°, 60°	0.62	0.034
Multiple	Quadratic	±45°	All	0°, 60°	0.56	0.034
Multiple	Quadratic	±90°	Clear only	0°, 60°	0.76	0.040
Multiple	Quadratic	±90°	No high cloud	0°, 60°	0.78	0.035
Multiple	Quadratic	±60°	Cloudy only	0°, 60°	0.65	0.017
Multiple	Quadratic	±90°	All	0° only	0.77	0.029

Fig: Fit much improved using multiple channels & quadratic form, but not much by limiting range – So keep it general: global, all sky, all angles!

	HIRS/2 NOAA6-14	HIRS/3 NOAA15-17	HIRS/4 NOAA18-MetopB	MVIRI Meteosat 1-3	MVIRI Meteosat 4-7	SEVIRI Meteosat 8-11
HIRS/2 NOAA6-14	0.04	1.03	1.07	0.07	0.16	0.41
HIRS/3 NOAA15-17	0.78	0.05	0.06	X	0.67	0.51
HIRS/4 NOAA18-MetopB	0.84	0.06	0.03	X	0.74	0.57

Fig: Uncertainties due to spectral conversion using multiple channels for each class of instrument for the water vapour channel. The left column is the reference instrument. Numbers represent the mean RMSD T_b [K].

Discussion

The uncertainty of inter-calibration of Meteosat instruments vs. HIRS has three major components **(1)** due to spectral conversion, **(2)** due to noise of the pixel collocations and **(3)** due to instrument drift. All of those need to be characterised to have a final uncertainty estimate for the homogenised time series. The plots on the left show schematically different ways how to transfer the calibration among the instruments. **Plot a)** shows a transfer from HIRS to HIRS. The uncertainty due to the spectral conversion increases with each step. Taking into account that individual satellites overlap more than one other satellite one can also use less spectral conversions with some larger uncertainty steps as illustrated in **Plot b).** The inter-calibrated series of HIRS could then be used as reference for each Meteosat instrument. Another way of doing it is using double differences employing one Meteosat and two HIRS at a time to find out the difference between the HIRS instruments or two Meteosats and one HIRS to find differences between the Meteosats, as illustrated in **Plot c).** The reference instrument needs to be stable over the used time period. Starting with the Metop-A satellite we can use the IASI instrument as the standard for the whole series of HIRS and Meteosat instruments.

The top right table gives the mean RMSD as brightness temperature [K] for all spectral conversion among the different types of Meteosat and HIRS instruments using a quadratic fit with multiple HIRS channels. Lowest RMSDs are always found for the same instrument class. Among different instruments the HIRS/2 – MVIRI combination gives the lowest uncertainties whereas conversions from HIRS/2 to HIRS/3 (1.03K) and HIRS/4 (1.07) show highest uncertainty. Uncertainties for transfers from HIRS to MVIRI and SEVIRI are small for the old instruments but reach values of 0.74K for HIRS/4-MVIRI (Met 4-7) and 0.57K from HIRS/4 to SEVIRI.

Contact: rob.roebeling@eumetsat.int or joerg.schulz@eumetsat.int

EUMETSAT