Use of IASI as an Inter-Calibration Reference

Tim Hewison

With thanks to:

Marianne König, Johannes Müller, Lars Fiedler (EUMETSAT),
Bob Iacovazzi, Likun Wang (NOAA),
Denis Blumstein (CNES),
Dave Tobin (CIMSS), and many more…

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- Introduction to GSICS
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- Meteosat-IASI Inter-Calibration
  - Meteosat-HIRS inter-comparison
- Meteosat Ice Contamination Model

- HIRS-IASI Inter-Calibration

- AIRS-IASI inter-comparison

- Conclusions

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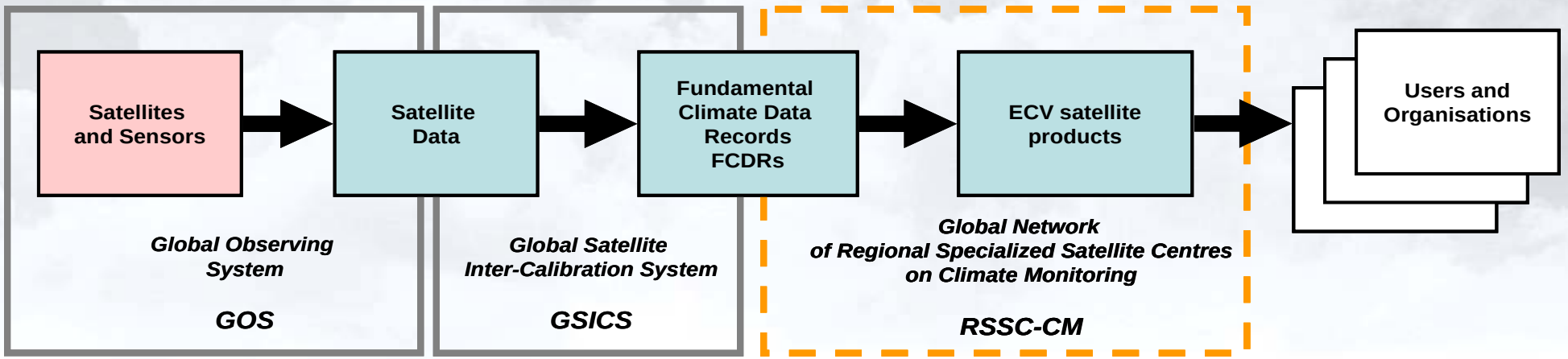
Global Space-based Inter-Calibration System

- What is GSICS?
  - Global Space-based Inter-Calibration System
  - Initiative of CGMS and WMO
  - An effort to produce consistent, well-calibrated data from the international constellation of operational satellites
- What are the basic strategies of GSICS?
  - Make pre-launch instrument tests traceable to SI standards
  - Improve on-orbit calibration by integrated cal/val system
    - Initially by LEO-GEO Inter-satellite/inter-sensor calibration
- This will allow us to:
  - Better specify future instruments
  - Improve consistency between instruments' observations
  - Produce less bias in Level 1 and 2 products
  - Retrospectively re-calibrate archive data using this

GSICS Interface to R/SSC-CM

Regional Specialised Satellite Centers on Climate Monitoring (R/SSC-CM) Network will be:

- Based on activities of existing initiatives (GOS, GCOS and GSICS)
- Build upon existing operational infrastructures
- Serve users and other organisations
  (e.g. WMO Regional Climate Centres RCC, National Weather Services)
- => The way toward operational production of ECVs



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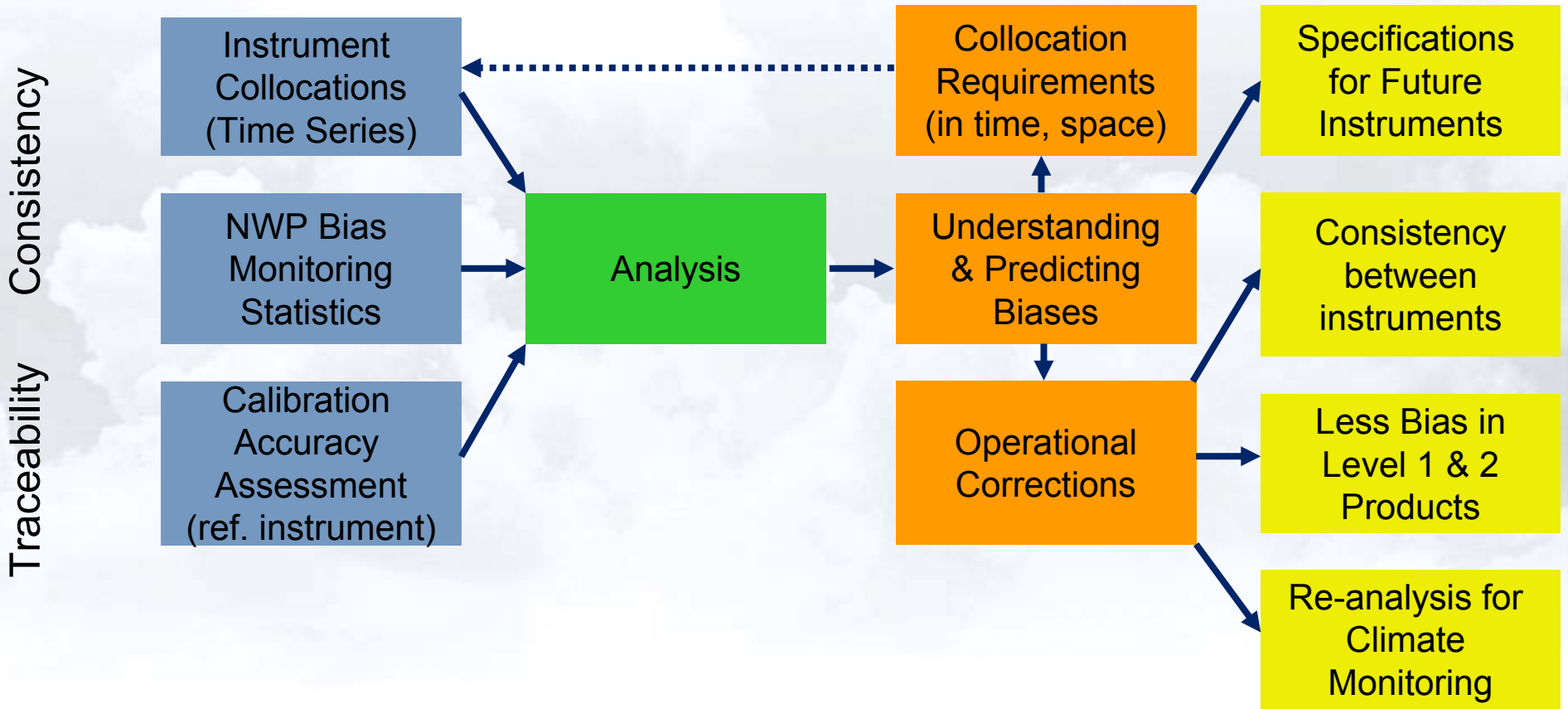
Inter-calibration Strategy

Principles Methodology Results Benefits



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Use of IASI as a Reference

Meteosat Geostationary Imager

+

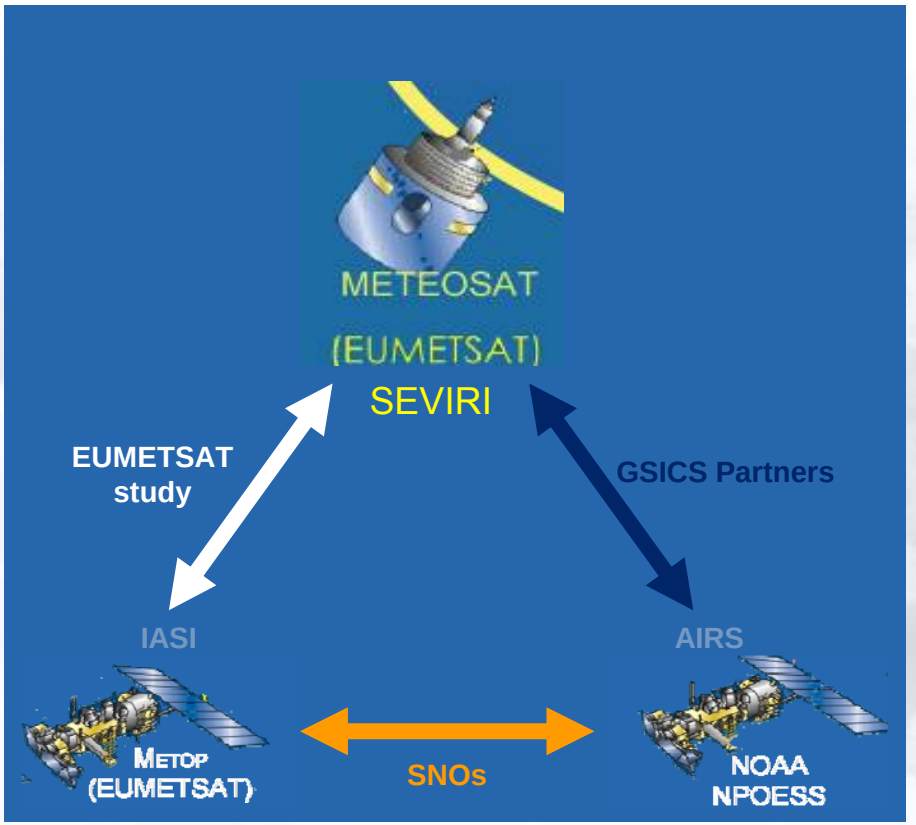
Infrared Atmospheric Sounding Interferometer, IASI, on Metop polar-orbiting satellite

Benefits of IASI as reference:

- Well-characterised
- Carefully controlled calibration
- Built-in linearity controls
- No spectral gaps
- On same platform as HIRS/4

Can cross-check with AIRS:

- Simultaneous Nadir Overpasses: SNOs
- Inter-calibrating Meteosat-AIRS



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Data Processing Chain

1. Collocation
   - Finding observations coincident in space and time
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   - To allow direct comparison
   - Spatial averaging
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3. Filtering
   - Selecting scenes of interest
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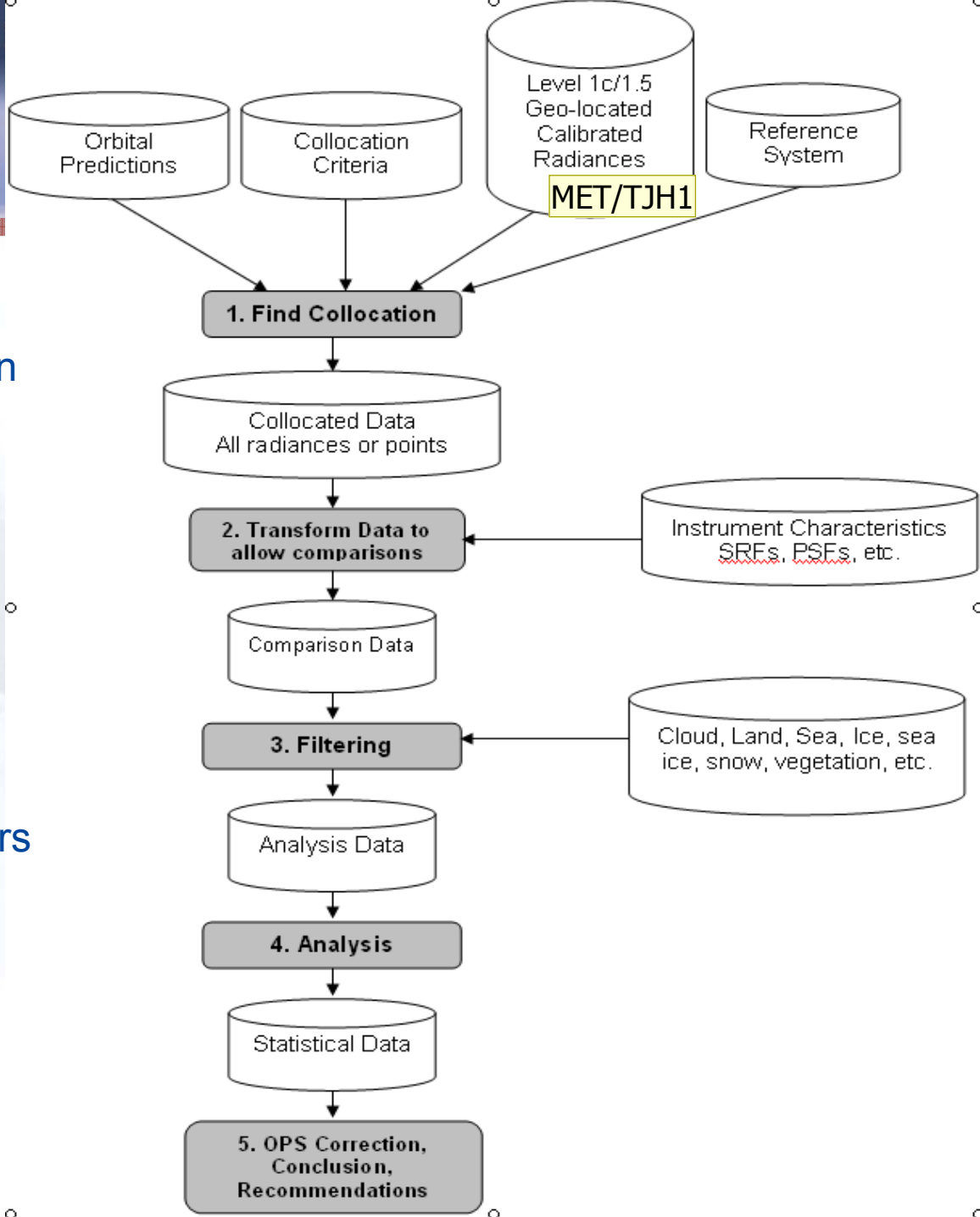
4. Analysis
   - Comparing observations
   - Calculating biases and errors
5. Developing corrections



MET/TJH1 New Radiance Defintion!

Tim Hewison, 8/26/2008

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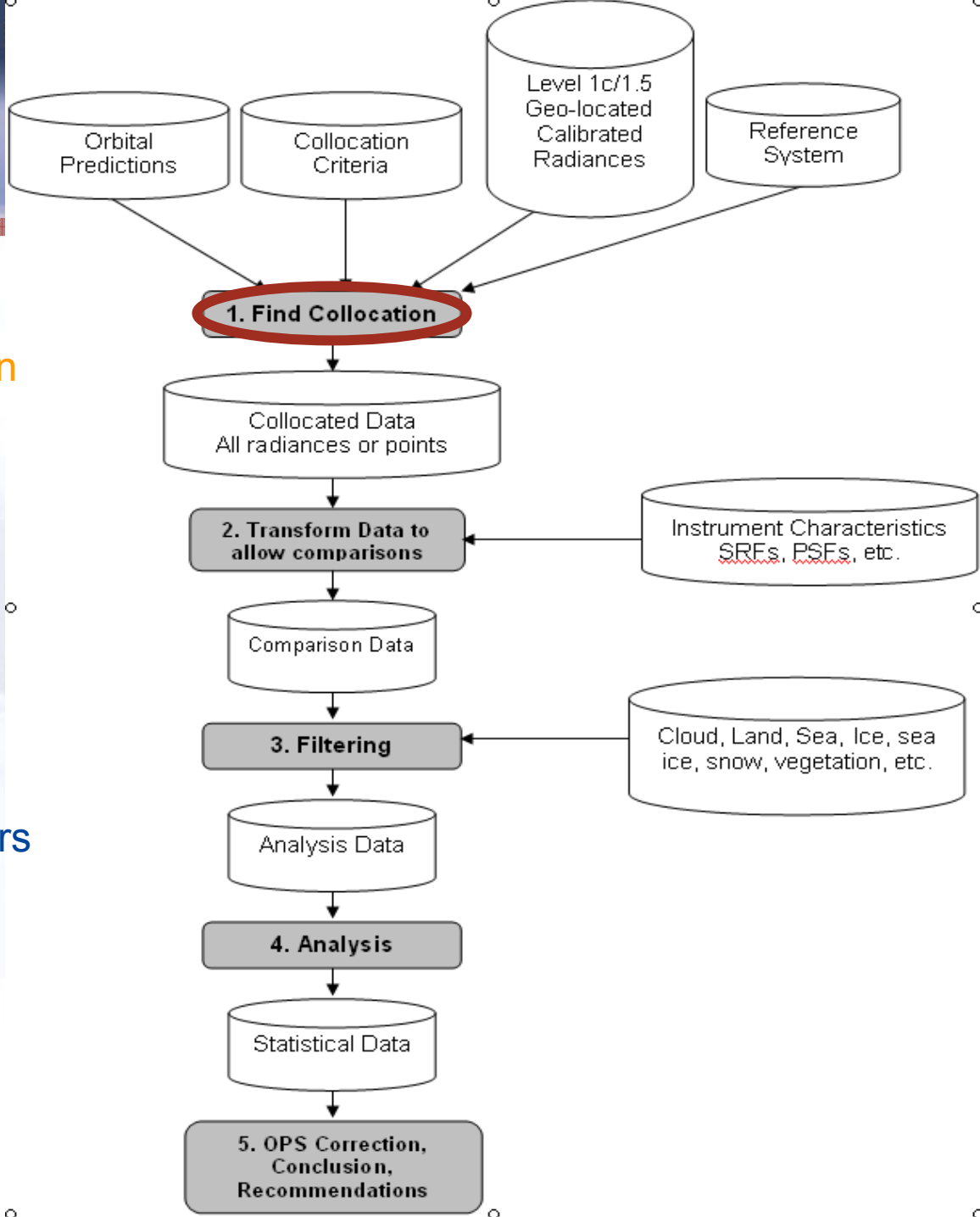


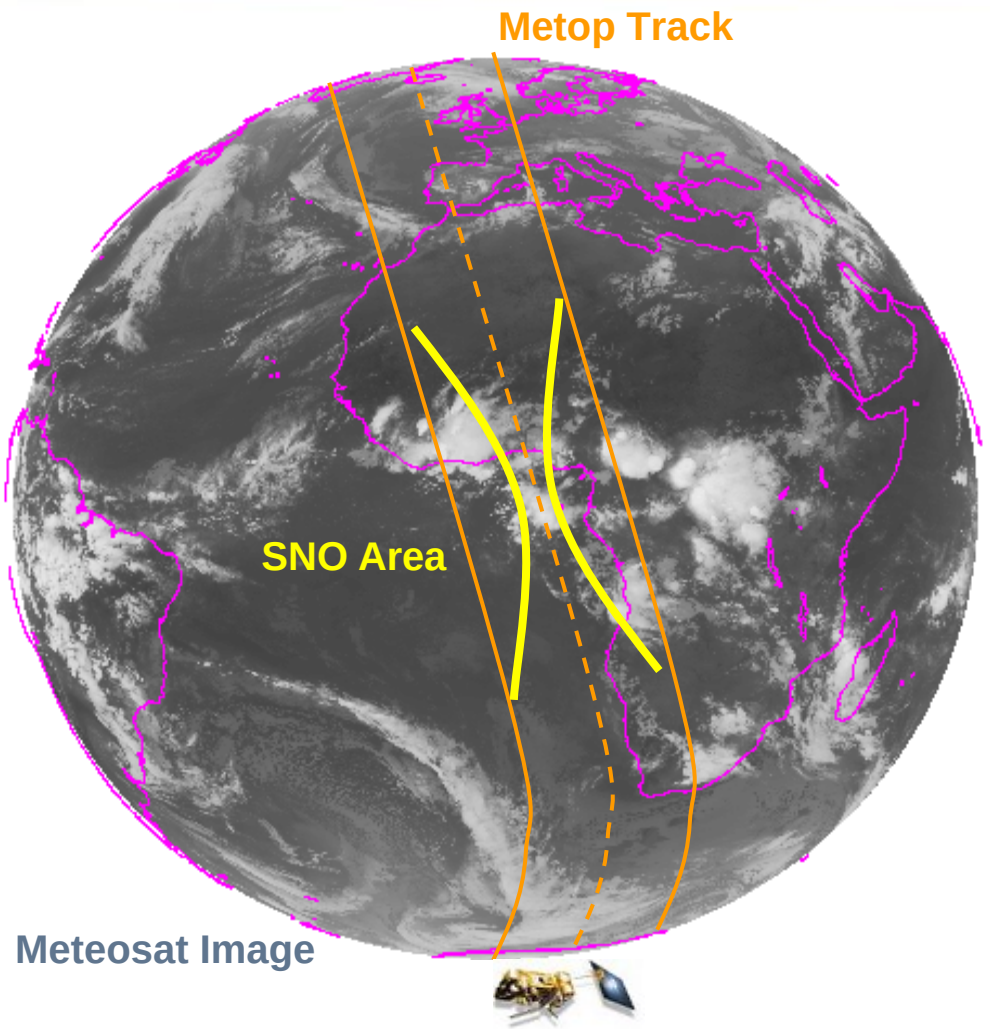
Collocation Criteria

Simultaneous near-Nadir Overpasses

of Meteosat and Metop

- Only night-time data
- $\Delta Lat < 30°$, $\Delta Lon < 30°$ of SSP
- $\Delta t < 15$ mins (=scan period)
- $|\theta| < 15°$ (Incidence angle)
- $\Delta\theta < 2°$ (Incidence angle diff.)
- 5x5 MSG pixels / IASI iFoV

Restricts collocations to Tropics
~1 orbit/day
~200 good collocations



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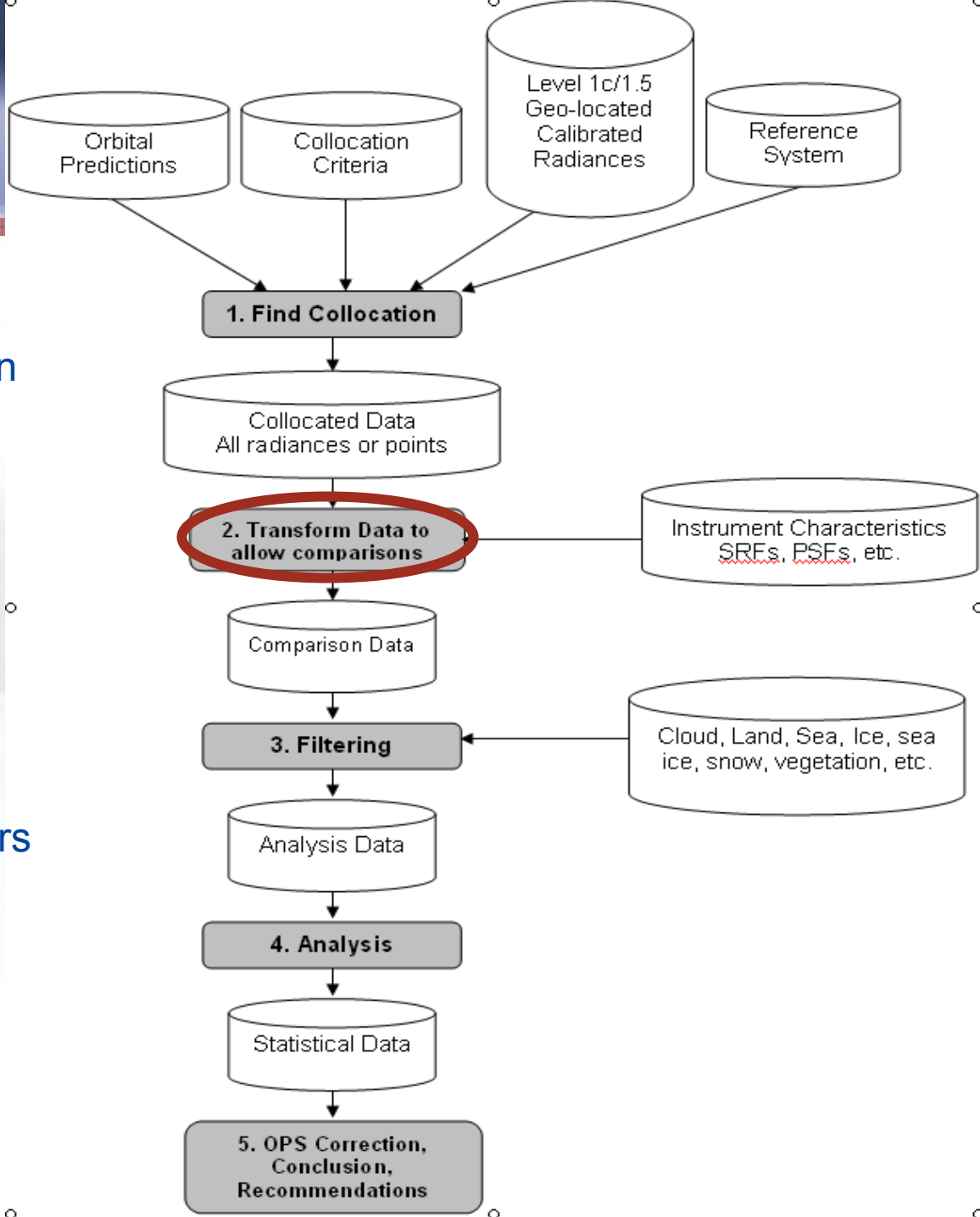
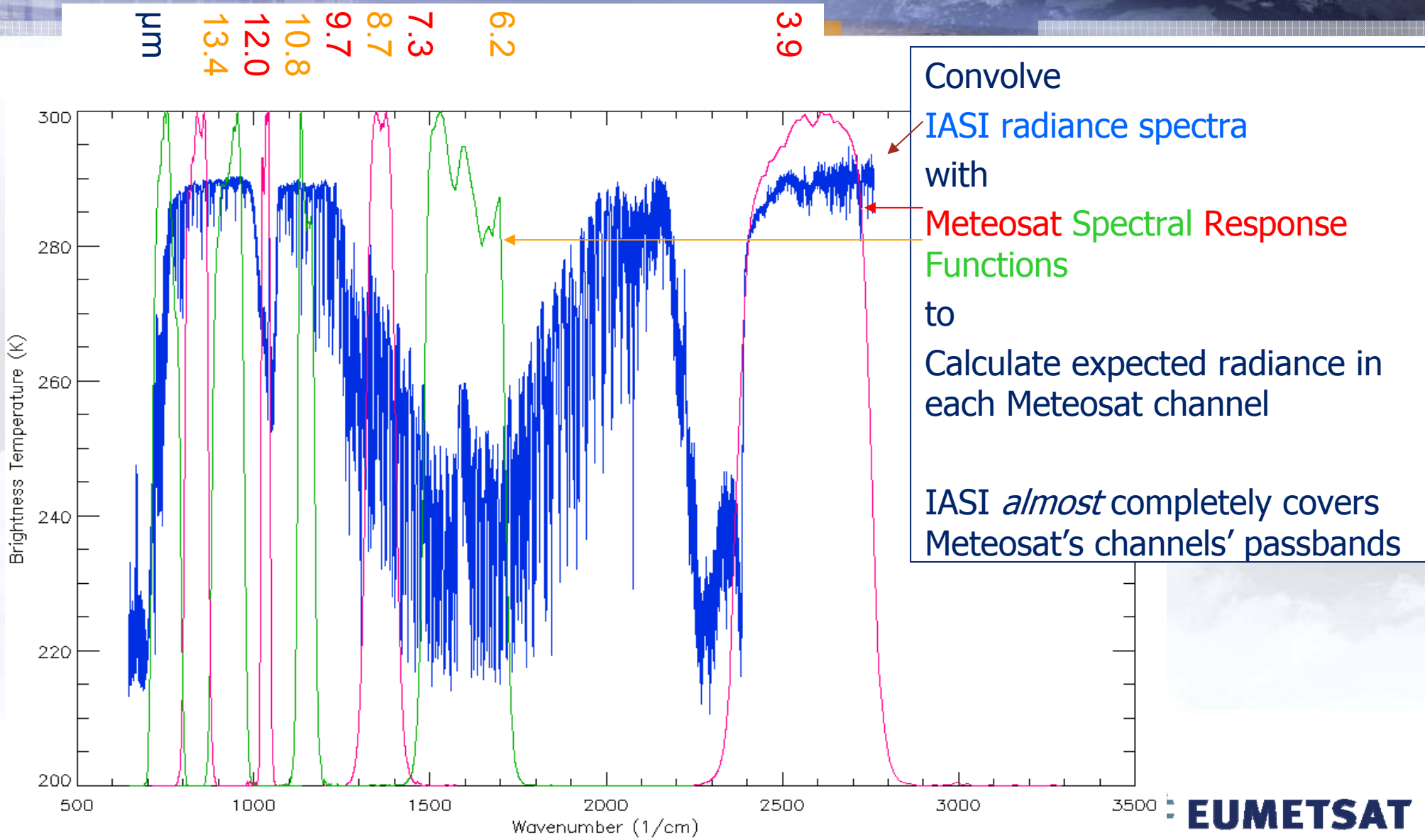


Spectral Convolution



Convolve

IASI radiance spectra

with

Meteosat Spectral Response Functions

to

Calculate expected radiance in each Meteosat channel

IASI *almost* completely covers Meteosat's channels' passbands

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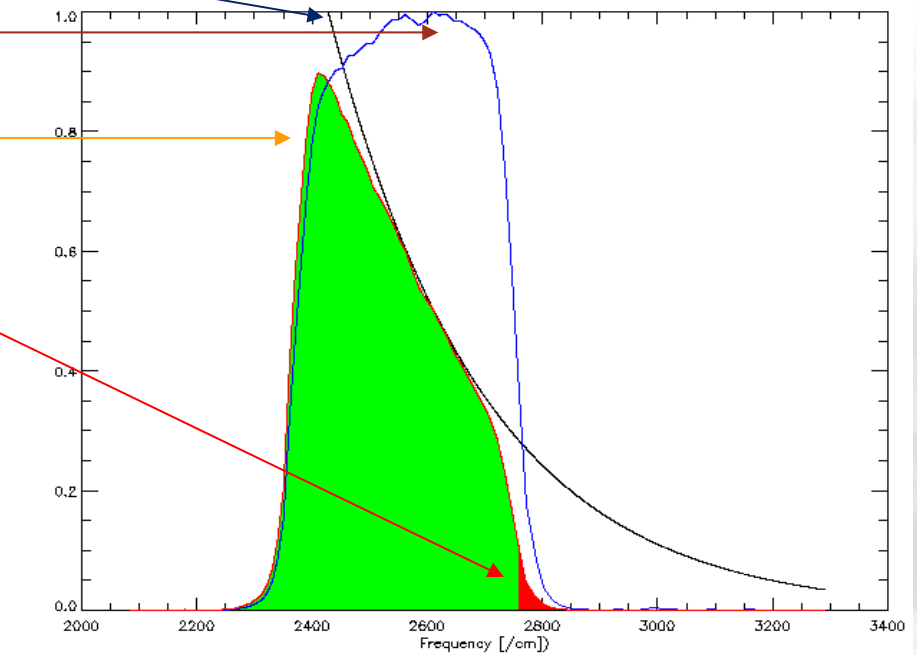
Missing Energy in MSG 3.9 µm channel

Black-body Planck function at 290K
convolved with
Spectral Response Function of MSG
Integrate to calculate
Total Radiance
Missing energy not seen by IASI in the
Small fraction beyond 2760cm^{-1}
Convert to Brightness Temperatures



Result:

IASI under-estimates MSG 3.9µm radiance by 1.33% of scene radiance, or ~0.17K at 290K (Scene-dependent)

Not accounted for in analysis

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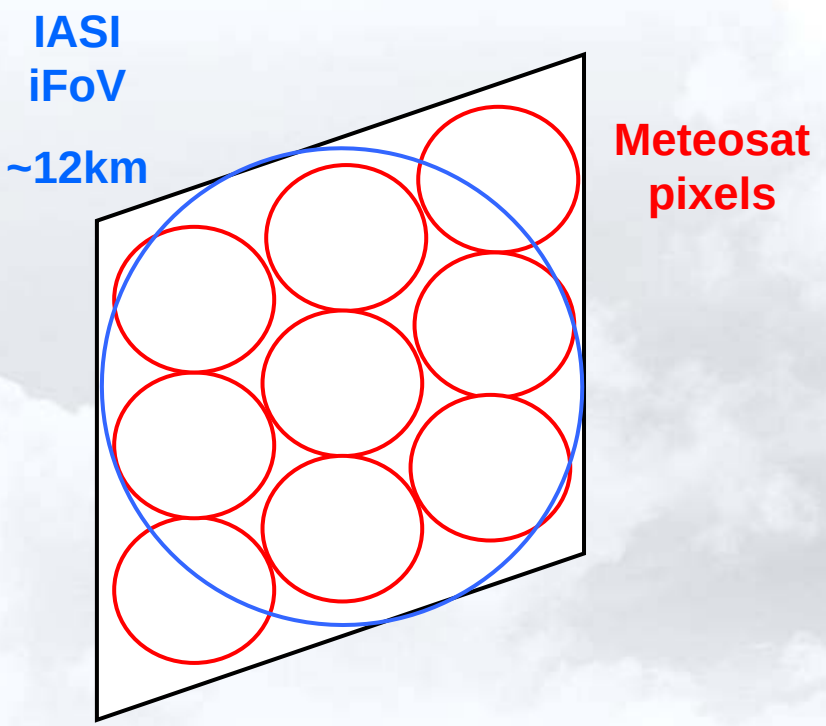
Spatial Averaging

Average Meteosat pixels within each IASI iFoV

Estimate uncertainty due to spatial variability as Standard Deviation of Meteosat pixels

Use in weighted regression



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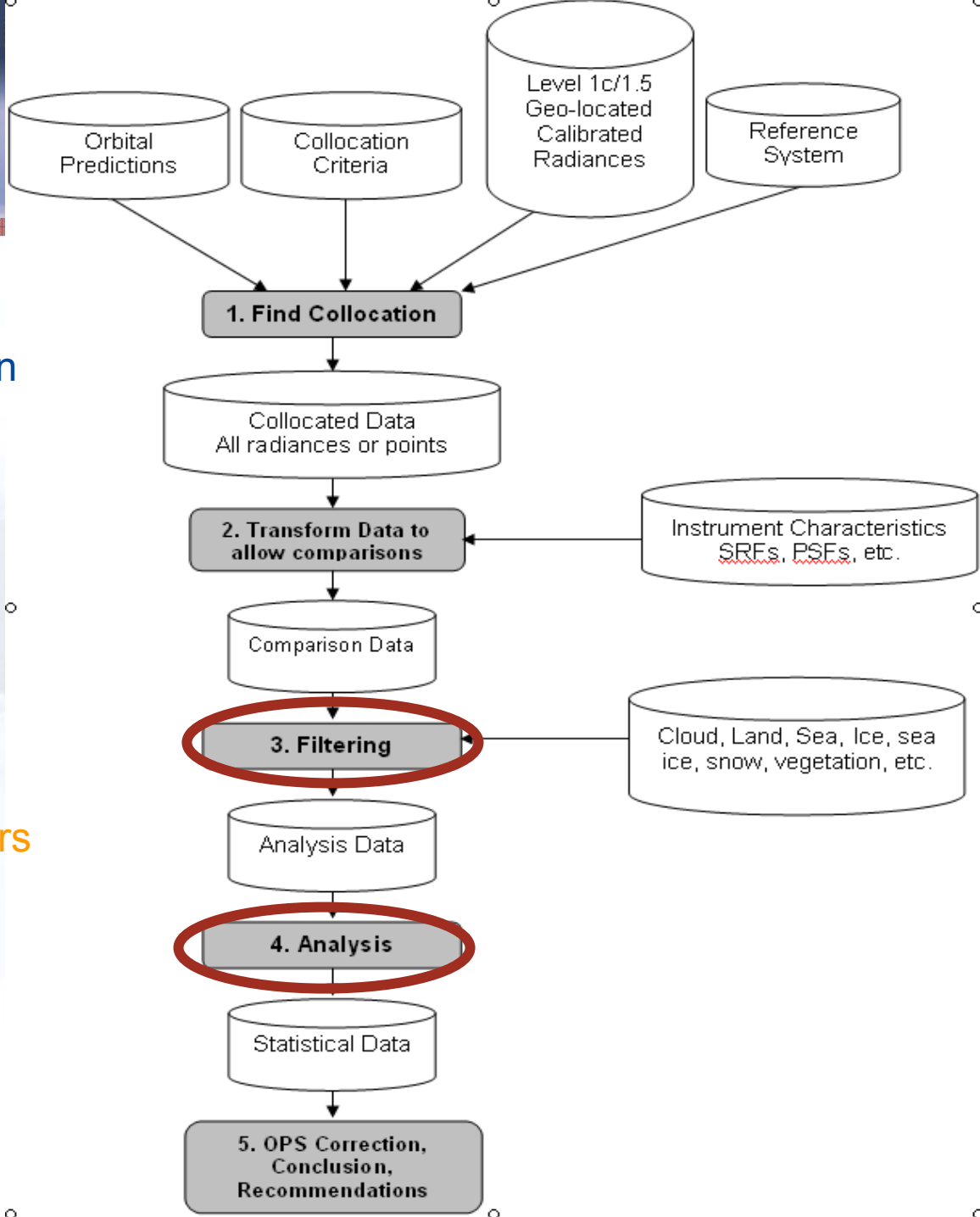
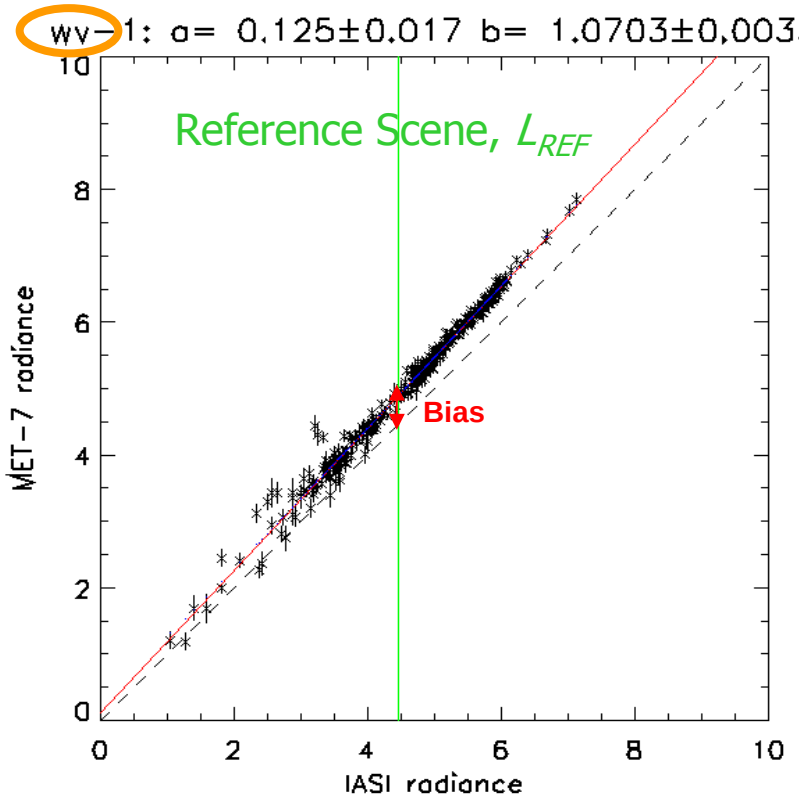
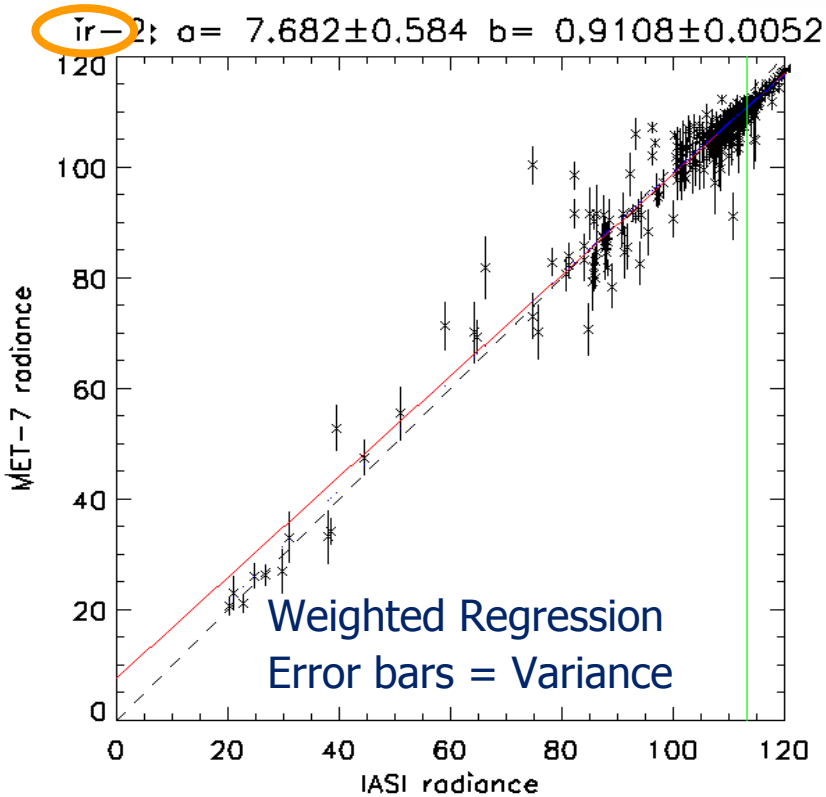


Regression

Offset ≠ 0 Slope ≠ 1 => Difference is scene-dependent





Reference Scene
defined as modal value
(typical clear sky radiance)

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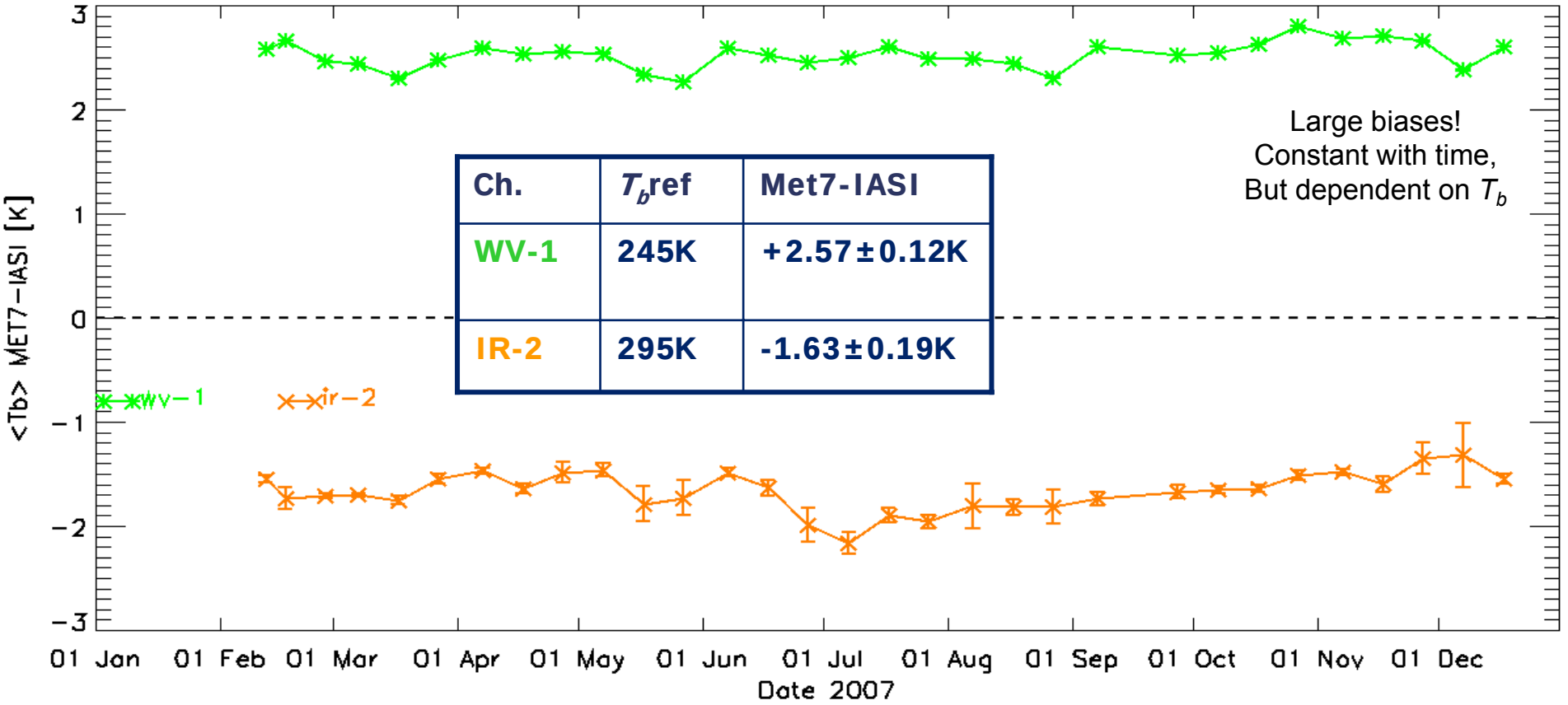
MVIRI on Meteosat-7 – IASI on Metop-A



Time series of brightness temperature differences between Met7-IASI for typical clear-sky radiances: Each Met7 infrared channel is shown in a different color, with different symbols, following the legend. Error bars represent statistical uncertainty on each mean bias (may be very small).

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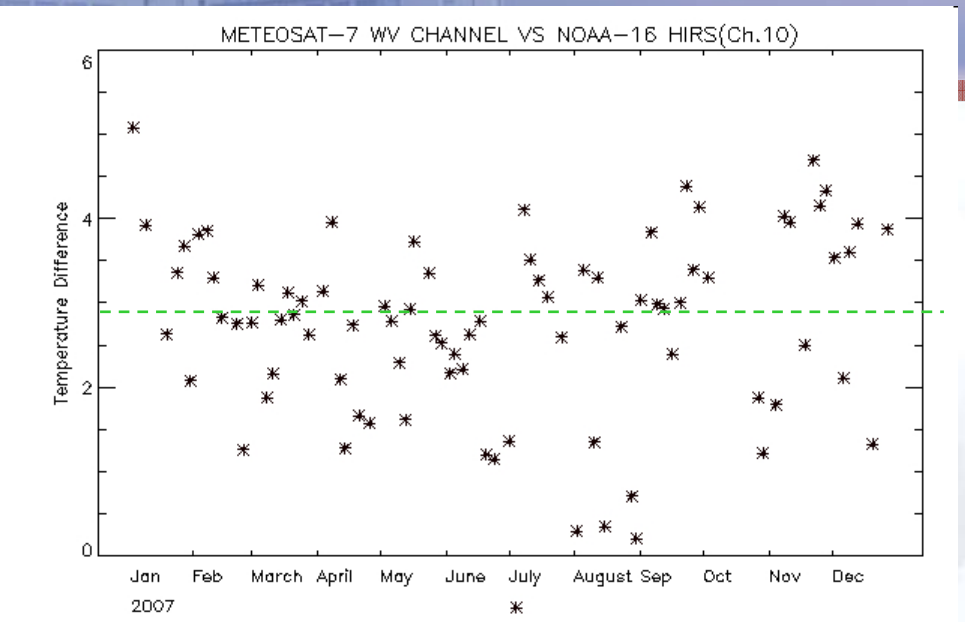
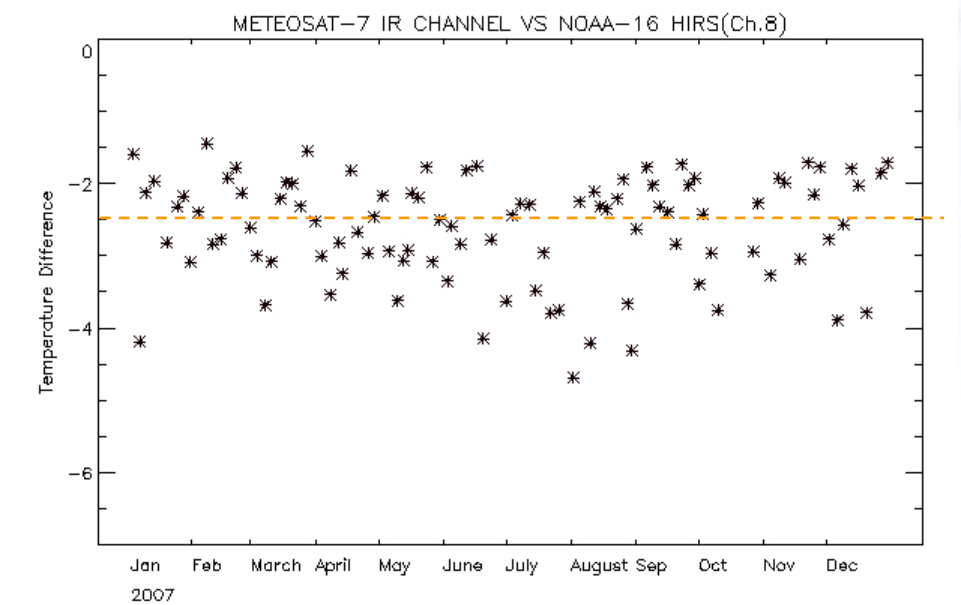
Meteosat-7 – HIRS Inter-Comparisons





- Comparisons of Met-7 – HIRS
  - –Processed operationally at EUMETSAT
  - –used to check Met-7 calibration
- Needs to account for different SRFs
  - –Increases uncertainty

- Noisy, but stable
- WV: +2.8 ± 1.0 K
- IR : -2.5 ± 0.6 K

- Biases similar to Met-7 – IASI
- Variances much larger

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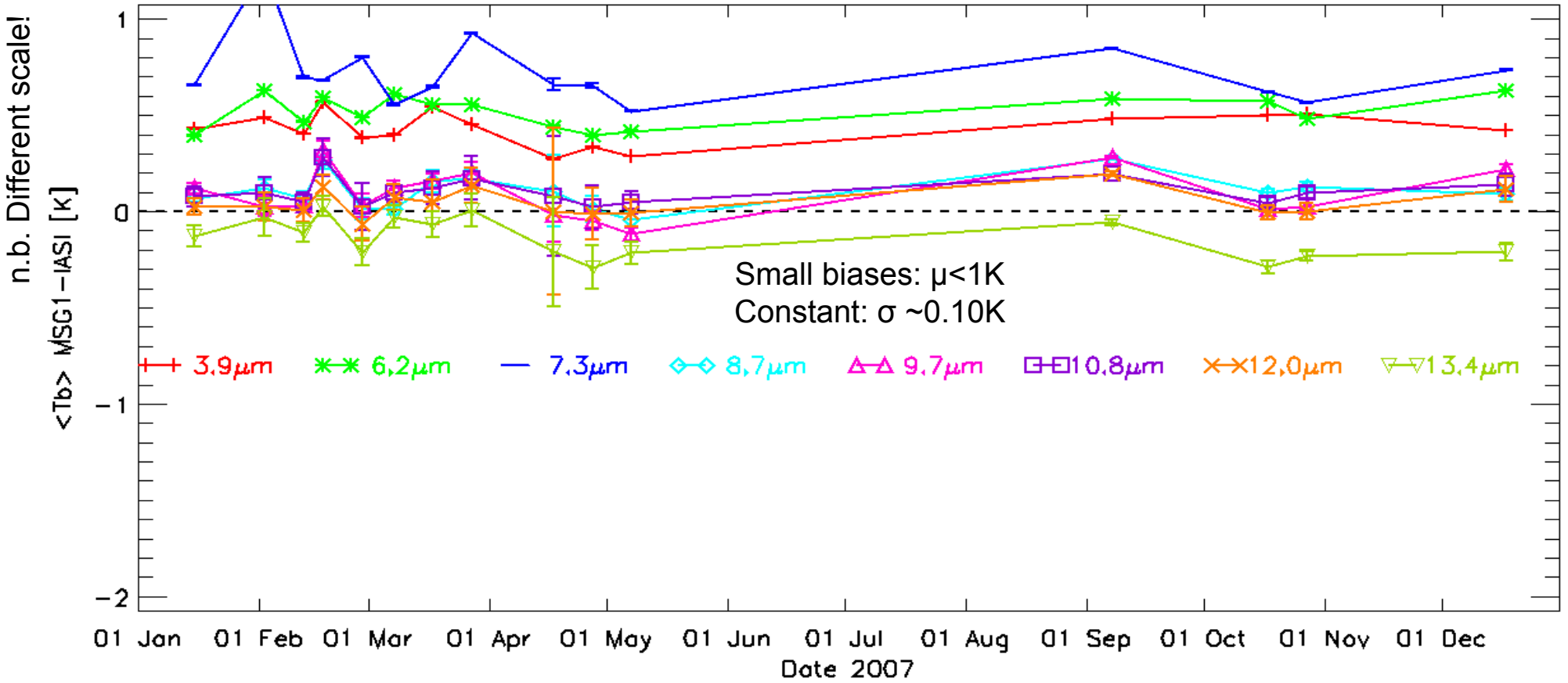
SEVIRI on Meteosat-8 – IASI on Metop-A



Time series of brightness temperature differences between MSG1-IASI for typical clear-sky radiances. Each MSG infrared channel is shown in a different color, with different symbols, following the legend. Error bars represent statistical uncertainty on each mean bias (may be very small).

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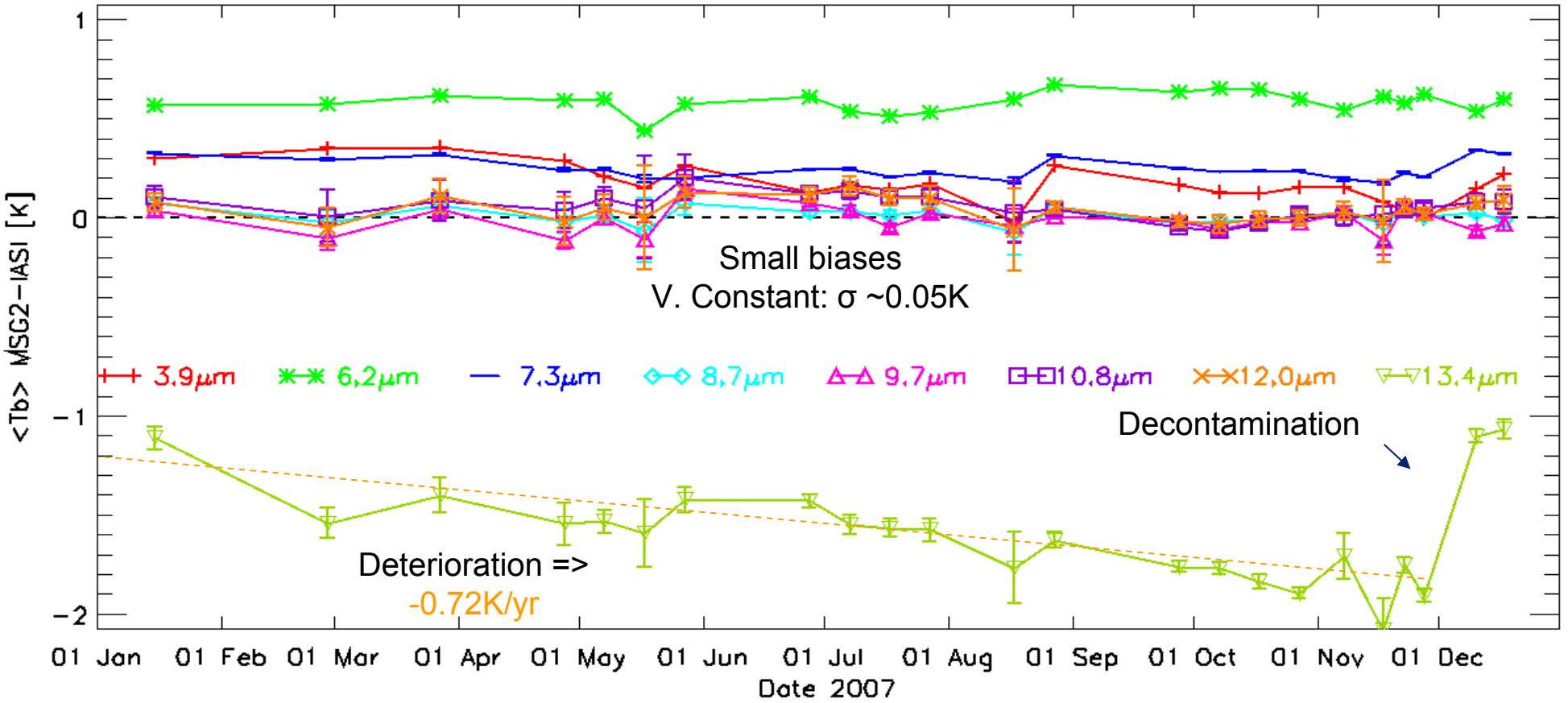
SEVIRI on Meteosat-9 – IASI on Metop-A



Time series of brightness temperature differences between MSG2-IASI for typical clear-sky radiances. Each MSG infrared channel is shown in a different color, with different symbols, following the legend. Error bars represent statistical uncertainty on each mean bias (may be very small).

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Summary of Meteosat-IASI during 2007
(using original IMPF radiance definition)

Channel (μm)		3.9	6.2	7.3	8.7	9.7	10.8	12.0	13.4
Ref Scene T_{bref} (K)		290	240	260	290	270	290	290	270
Meteosat-7	Mean Bias (K)		**+2.57**				**-1.63**		
	Std. Dev. (K)		0.12				0.19		
Meteosat-8	Mean Bias (K)	**0.46**	**0.56**	**0.77**	**0.22**	0.19	**0.16**	0.13	-0.13
	Std. Dev. (K)	0.09	0.08	0.18	0.09	0.14	0.07	0.07	0.16
Meteosat-9	Mean Bias (K)	0.17	**0.61**	**0.25**	0.02	0.00	0.03	0.05	**-1.63**
	Std. Dev. (K)	0.10	0.05	0.04	0.04	0.07	0.06	0.06	0.26

Brightness Temperatures, T_b, for Reference Scenes and Mean Difference between Meteosat and IASI during 2007.

Statistically significant (at >95% level) biases highlighted in **bold**.

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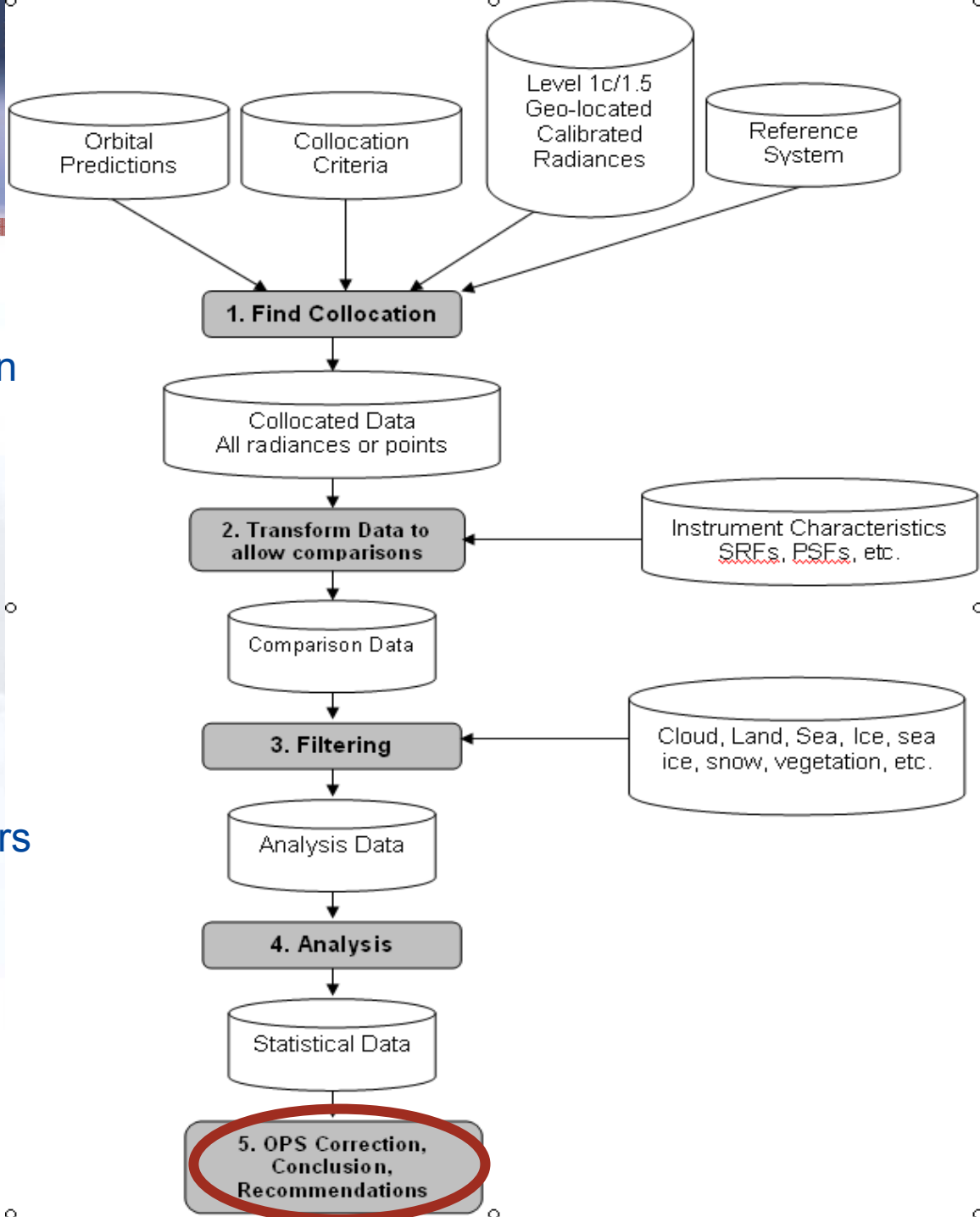

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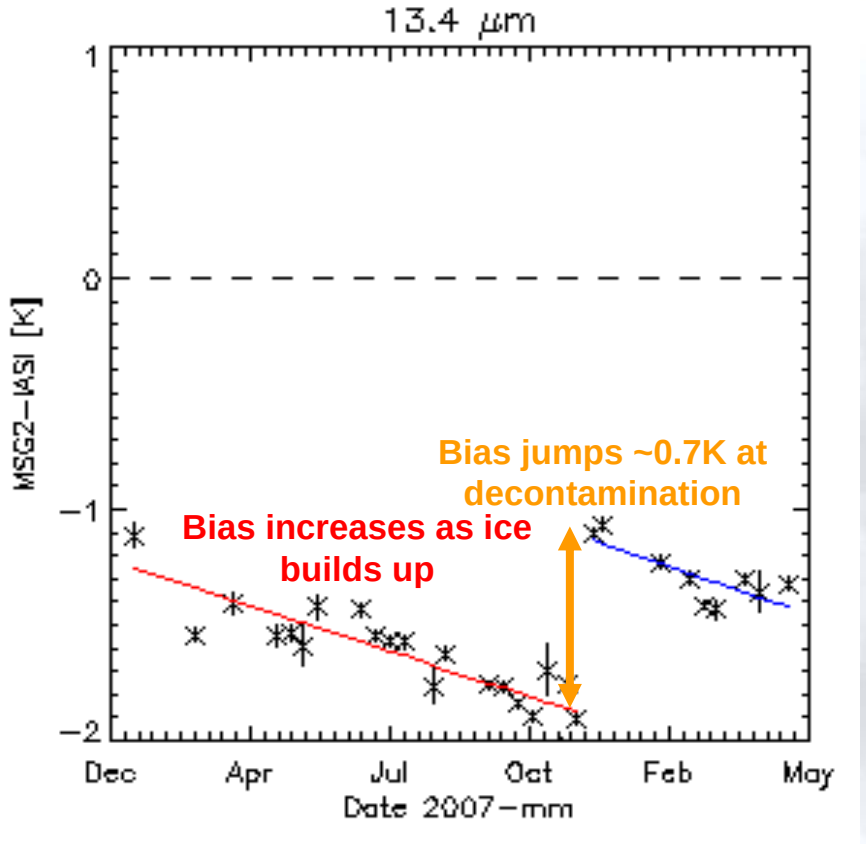
Ice Contamination of Meteosat IR13.4

- Inter-calibration of MSG-IASI showed bias in 13.4µm channel, increasing by ~1K/yr
- Recovers after decontamination
- Theory: Due to Ice on optics



Time series of relative bias (Meteosat-9 – IASI) Lines show fits to data before and after decontamination

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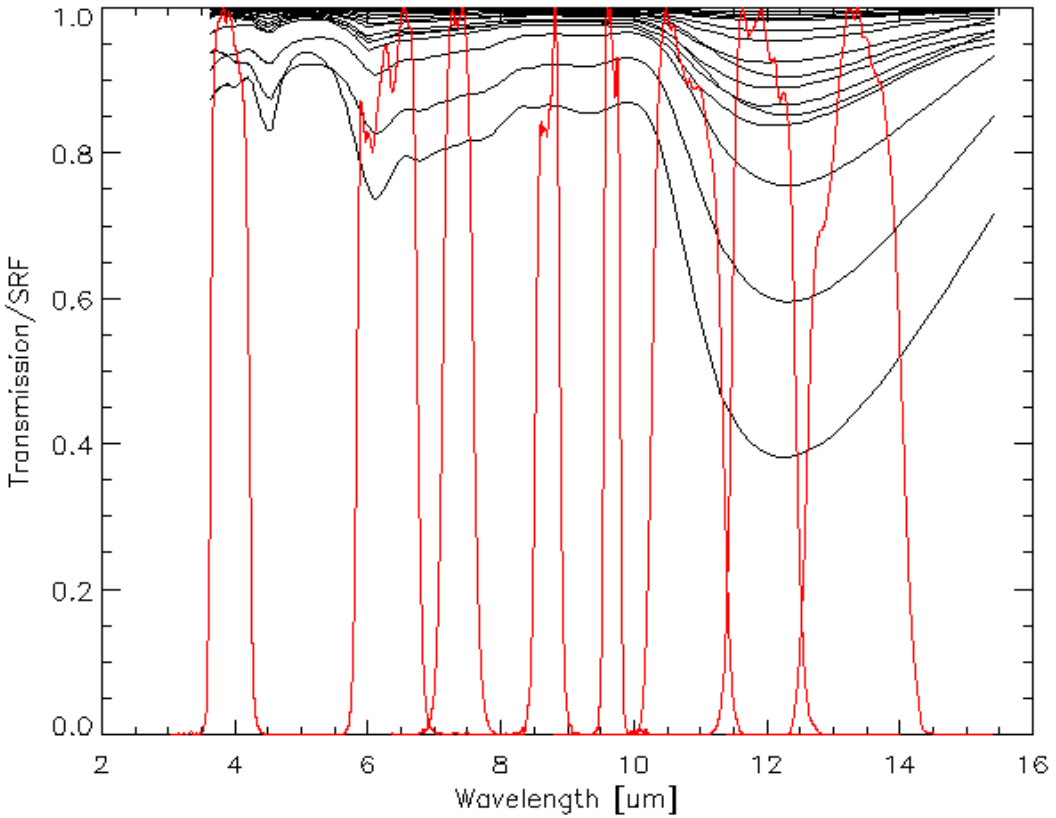
Ice Contamination of Meteosat IR13.4

- Inter-calibration of MSG-IASI showe bias in 13.4µm channel, increasing by ~1K/yr
- Recovers after decontamination
- Theory: Due to Ice on optics
- 2 Models of ice absorption
  - –from CNES & Astrium
- Changes SRF of IR13.4



Transmission spectra of ice layers of different thicknesses (black): 12 - 2000 nm layers.
Spectral Response Functions of Meteosat-9 (red).

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Ice Contamination of Meteosat IR13.4

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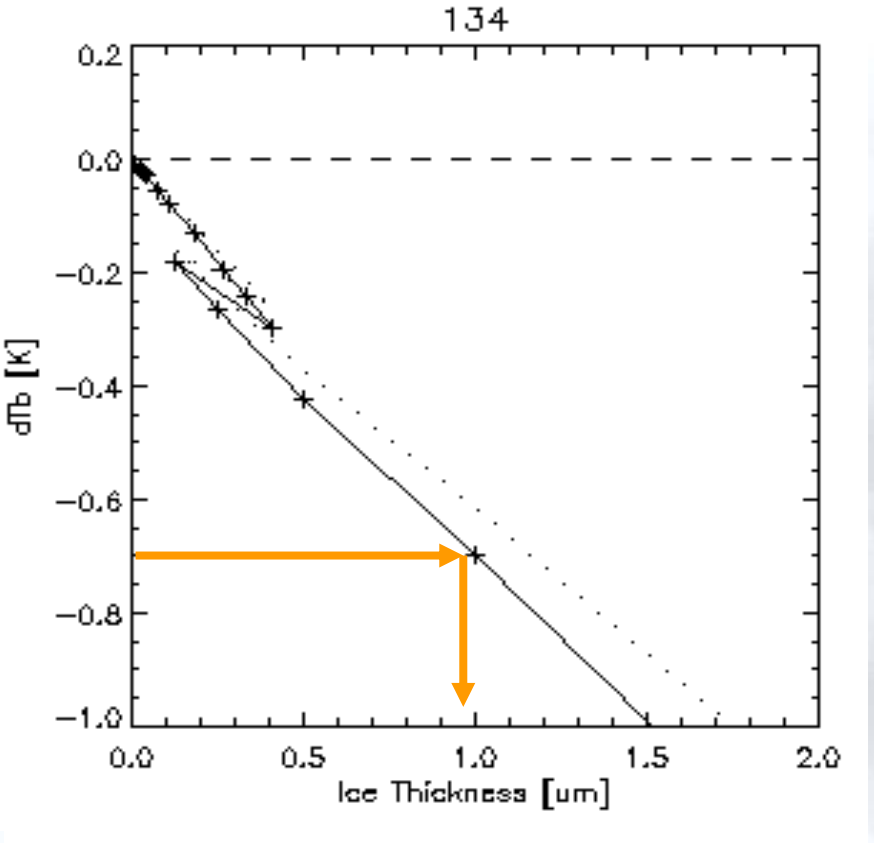
- Recovers after decontamination
- Theory: Due to Ice on optics
- 2 Models of ice absorption
  - –from CNES & Astrium
- Changes SRF of IR13.4
- Introduces bias when not accounted for in calibration
- Can be modelled by ~1µm ice



Brightness temperatures Bias modelled by modifying Meteosat-9's SRF by the absorption of different thicknesses of ice.

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HIRS-IASI Inter-Calibration

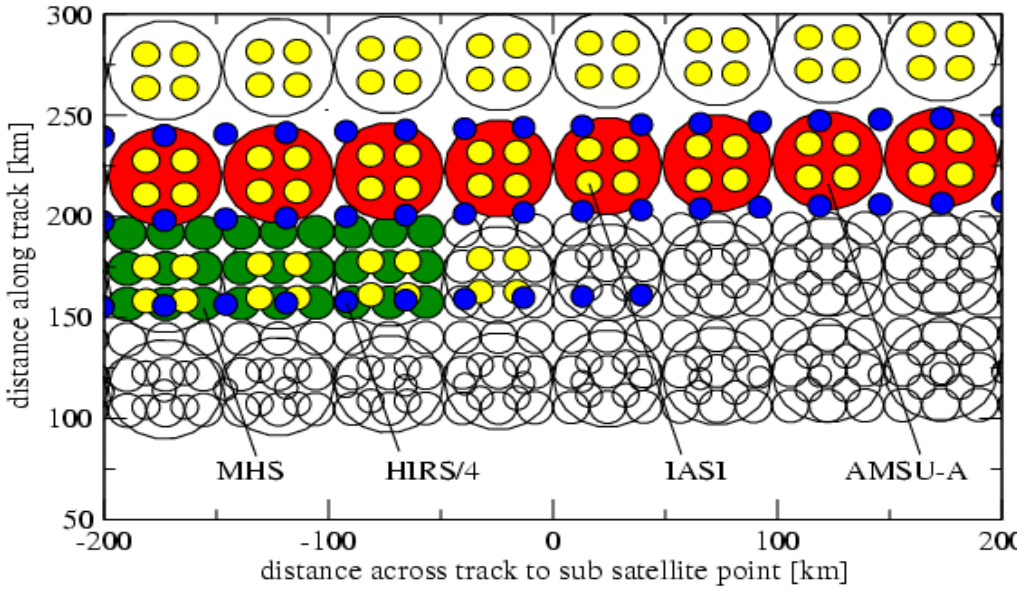
- HIRS = *High-resolution* Infrared Radiation Sounder
- Operated on polar-orbiting satellites since 1970s
  - Importance for Climate-monitoring applications
  - Potential reference for inter-calibration of older GEO radiometers
- Can inter-calibrate with IASI
  - Similar method to Meteosat
- HIRS/4 – IASI both operate on Metop-A
  - *Easy* collocations
  - Over full global range of conditions
  - Allow detailed break-down of statistics

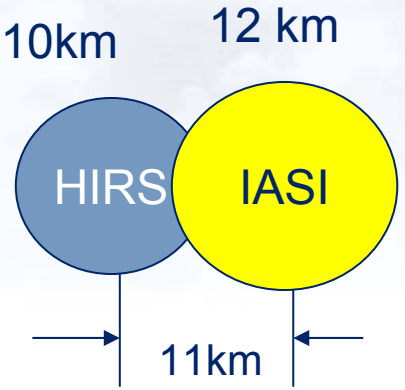
Collocating under-sampled scan patterns

- GEO-LEO spatial collocation:
  - –All GEO pixels within LEO FoV
- LEO-LEO SNO spatial collocation:
  - –Resample microwave
    e.g. Iacovazzi *et al.* [2007]

But on Metop-A:

- HIRS & IASI are under-sampled
  - –Should not interpolate
  - –Take ‘overlapping’ pixels
    [Fiedler (EUMETSAT)]
    [Wang *et al.*, 2008]
  - –Or average 4 IASI iFoVs





Define overlapped HIRS-IASI pixels at nadir whose distance are less that (12+10)/2=11 km

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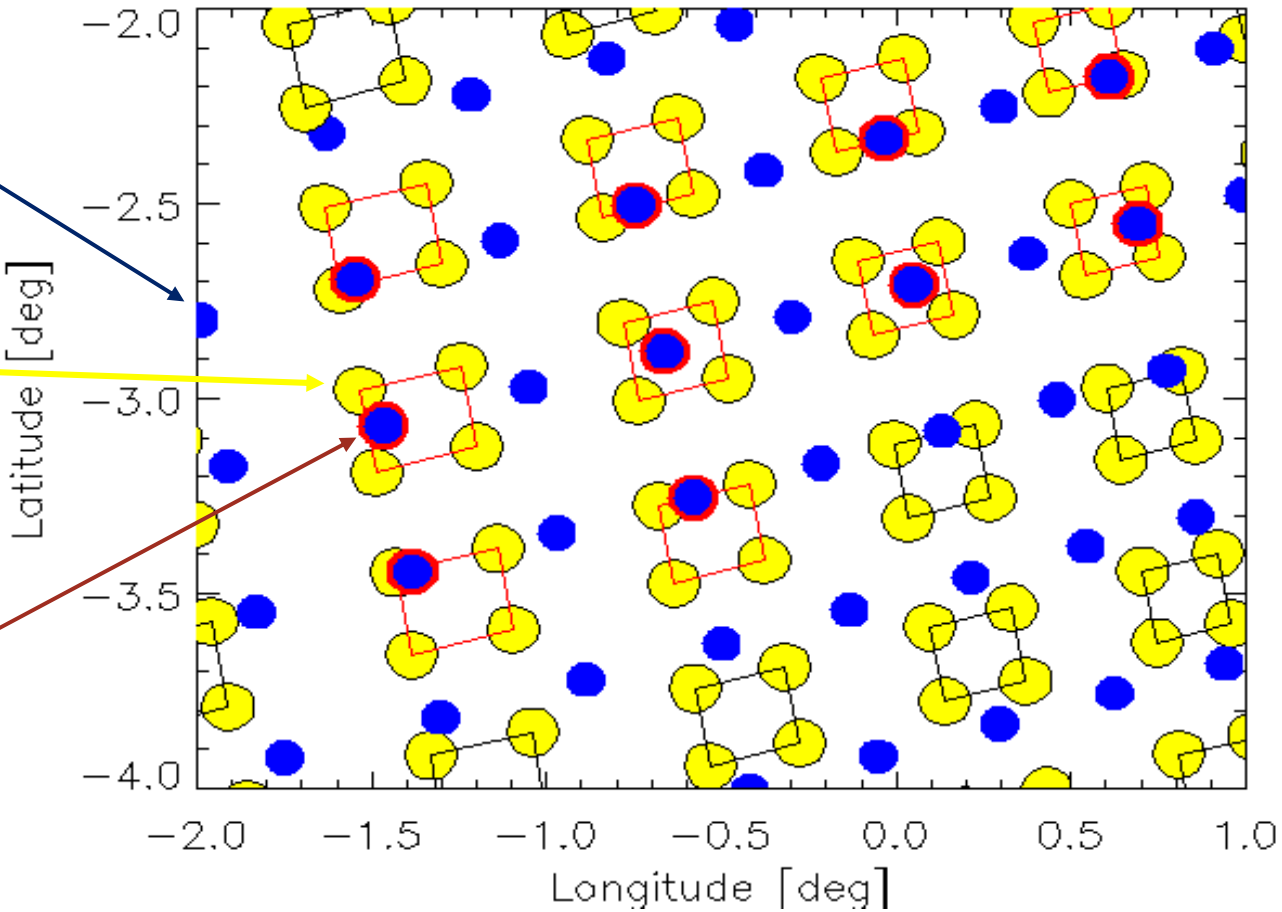
HIRS-IASI collocations + environment

- HIRS pixels
- Ø =10km @ nadir
- Δx=26km @ nadir
- Δy~43km @ nadir

- IASI pixels
- Box of 4 IASI iFoVs (Define environment)

- Collocated HIRS pixels within IASI iFoV box



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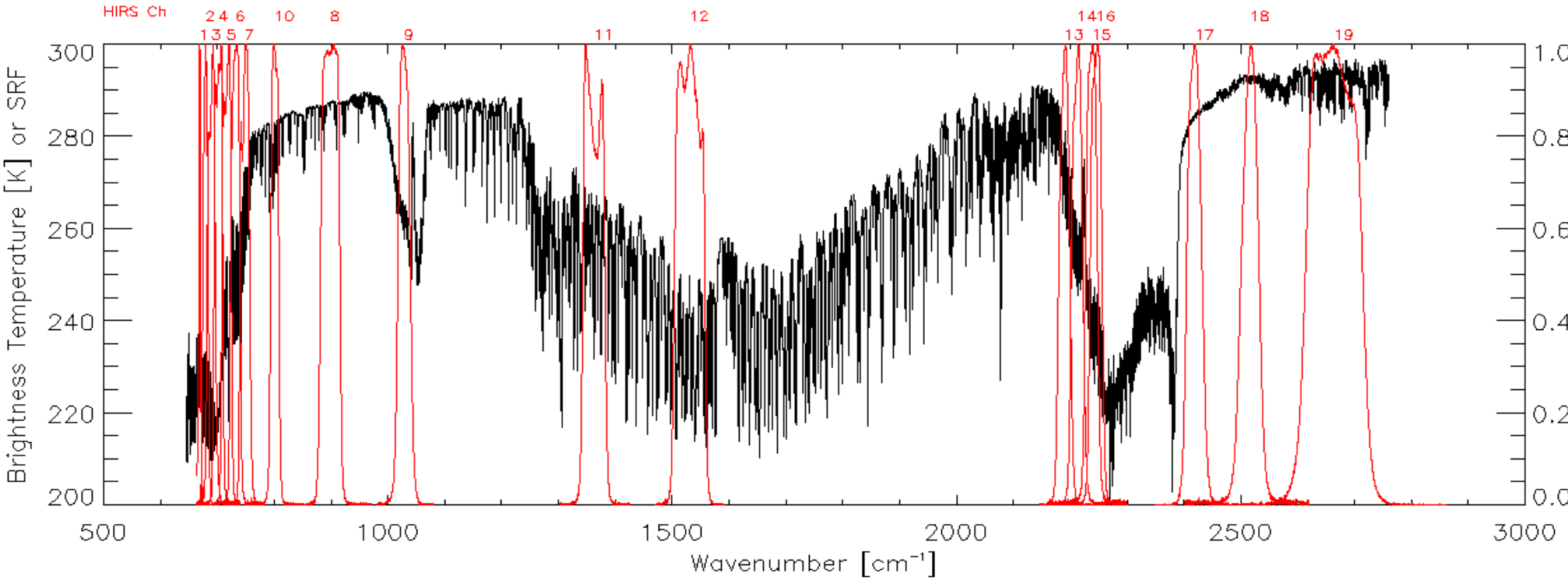
IASI T_b Spectrum + HIRS SRFs



IASI *Tb* Spectrum
HIRS SRFs

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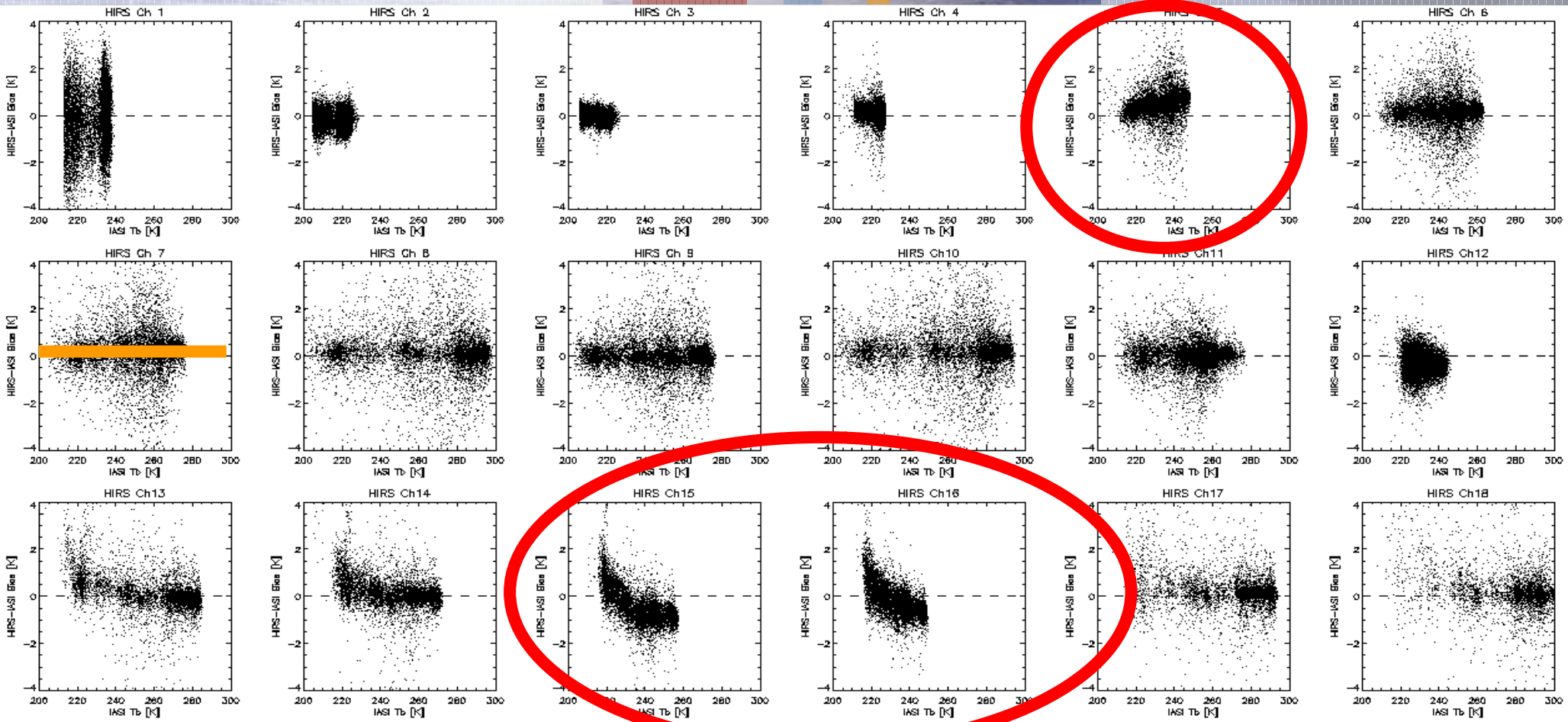
HIRS-IASI Brightness Temp. Bias [K]



Most channels unbiased

Bias depends on brightness temp.

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HIRS-IASI Bias at T_{bref}

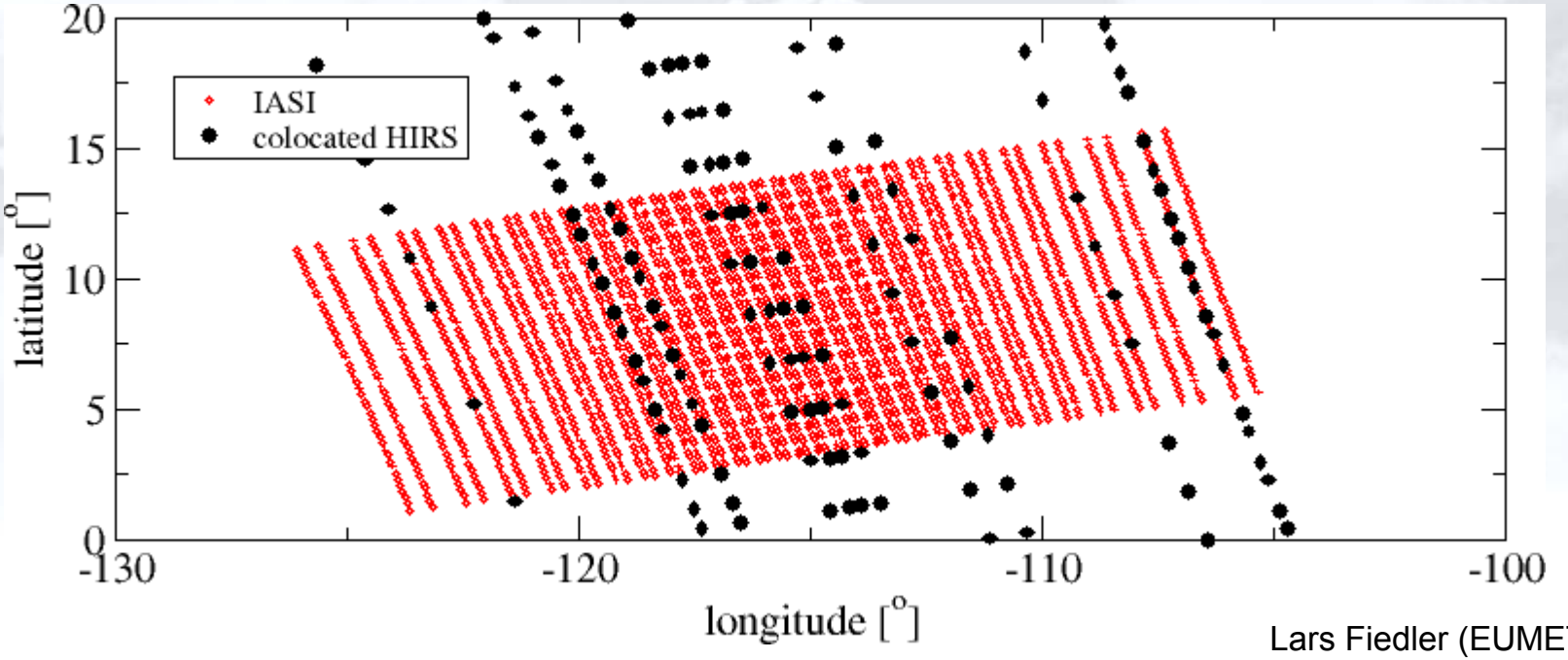
- Relative biases of HIRS-IASI
  - for two Metop orbits
- 1-σ uncertainty ~0.01 K
- Largest biases in bold
  - Channels with low T_{bref}
- All biases < 1 K
- In second case (~1 yr later):
  - first 2 channels changed
  - others very constant
  - RMS difference = 0.03 K

- Processed operationally
  - at EUMETSAT since June 2008
  - See Lars Fiedler

HIRS Channel	Reference Scene, T_{bref} [K]	HIRS-IASI bias at T_{bref} [K]	
		2007-04-27 19:38	2008-05-07 20:56
1	230	-0.35	-0.06
2	220	-0.22	-0.06
3	215	-0.03	-0.04
4	225	0.12	0.04
5	240	**0.60**	**0.61**
6	255	0.22	0.18
7	265	0.20	0.23
8	285	0.08	0.10
9	260	0.00	-0.01
10	280	0.18	0.21
11	260	0.02	0.01
12	235	-0.25	-0.32
13	275	-0.03	-0.06
14	260	0.04	0.02
15	250	**-0.80**	**-0.76**
16	240	**-0.46**	**-0.45**
17	280	0.11	0.13
18	285	0.09	0.11
19	290	0.02	-0.02

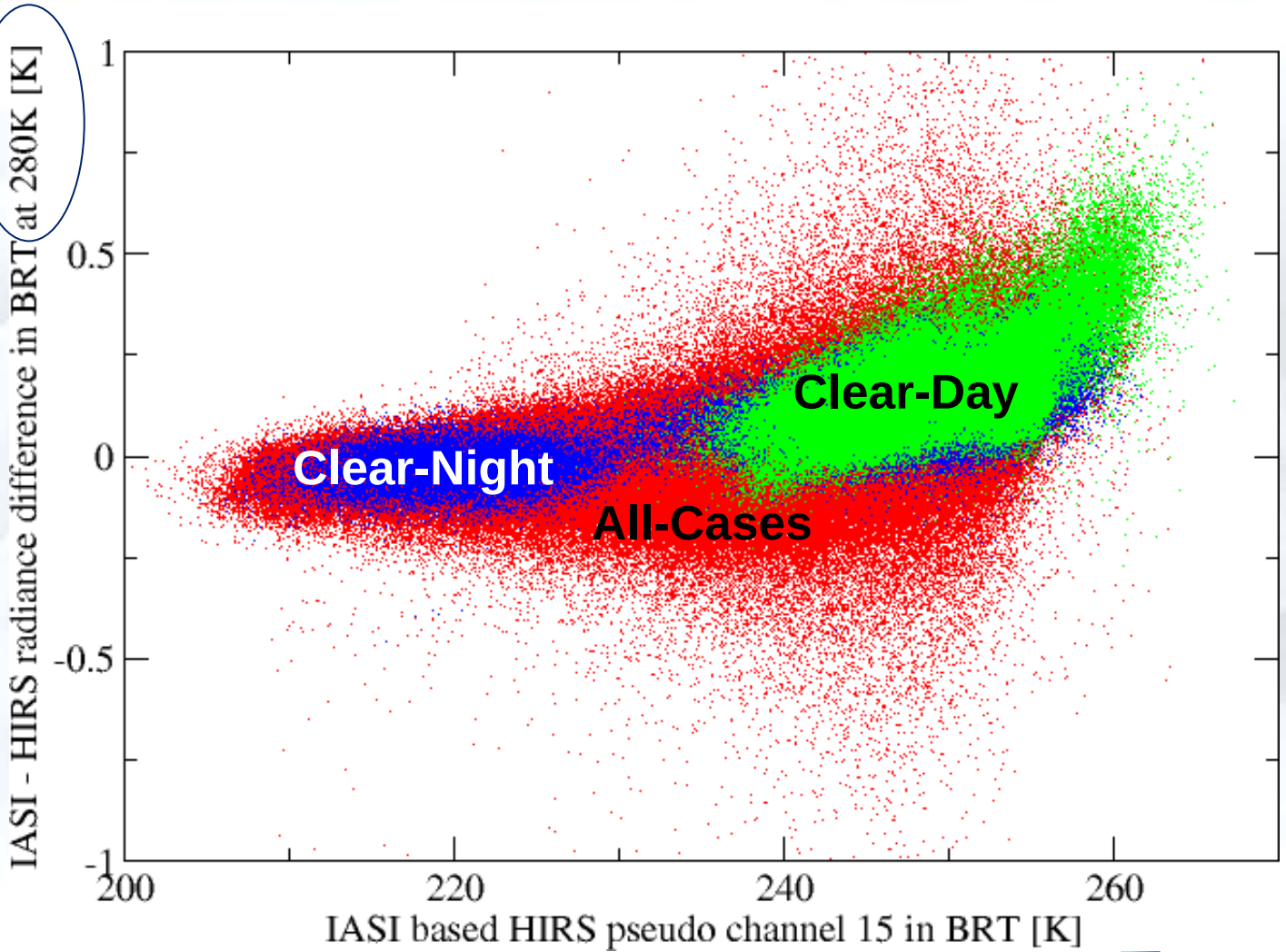
IASI – HIRS for radiance monitoring at EUMETSAT

- IASI and HIRS co-location criteria is 3 km distance
- All situations (land, sea, day, night, etc.) are collected
- Maximum of 10 IASI-HIRS co-locations per IASI scan line
- IASI versus HIRS monitoring started end of May 2008
- About 1 million collocations have been recorded

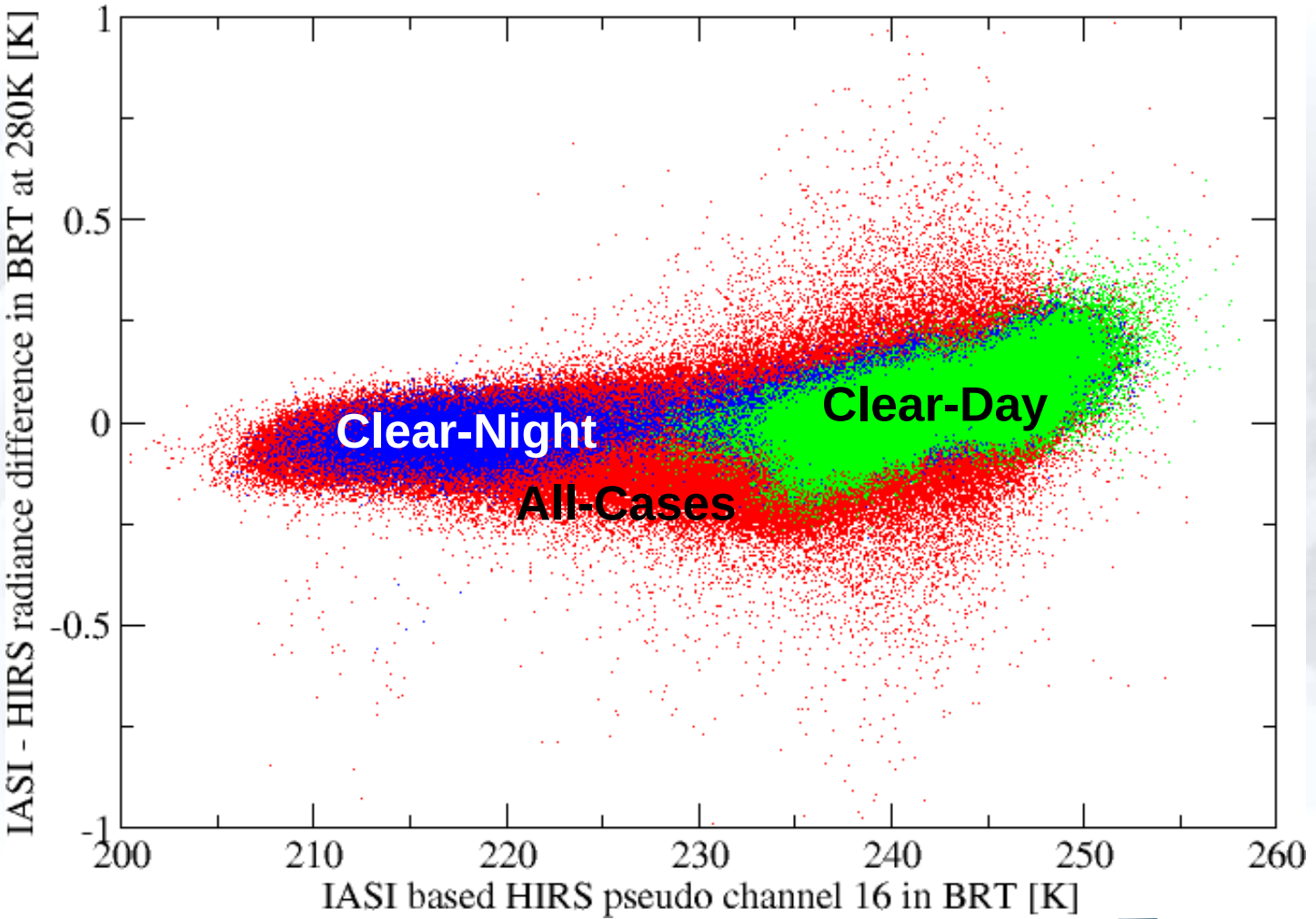


Bias IASI – HIRS Scene temperature dependency Channel 15

n.b. Scale reversed!

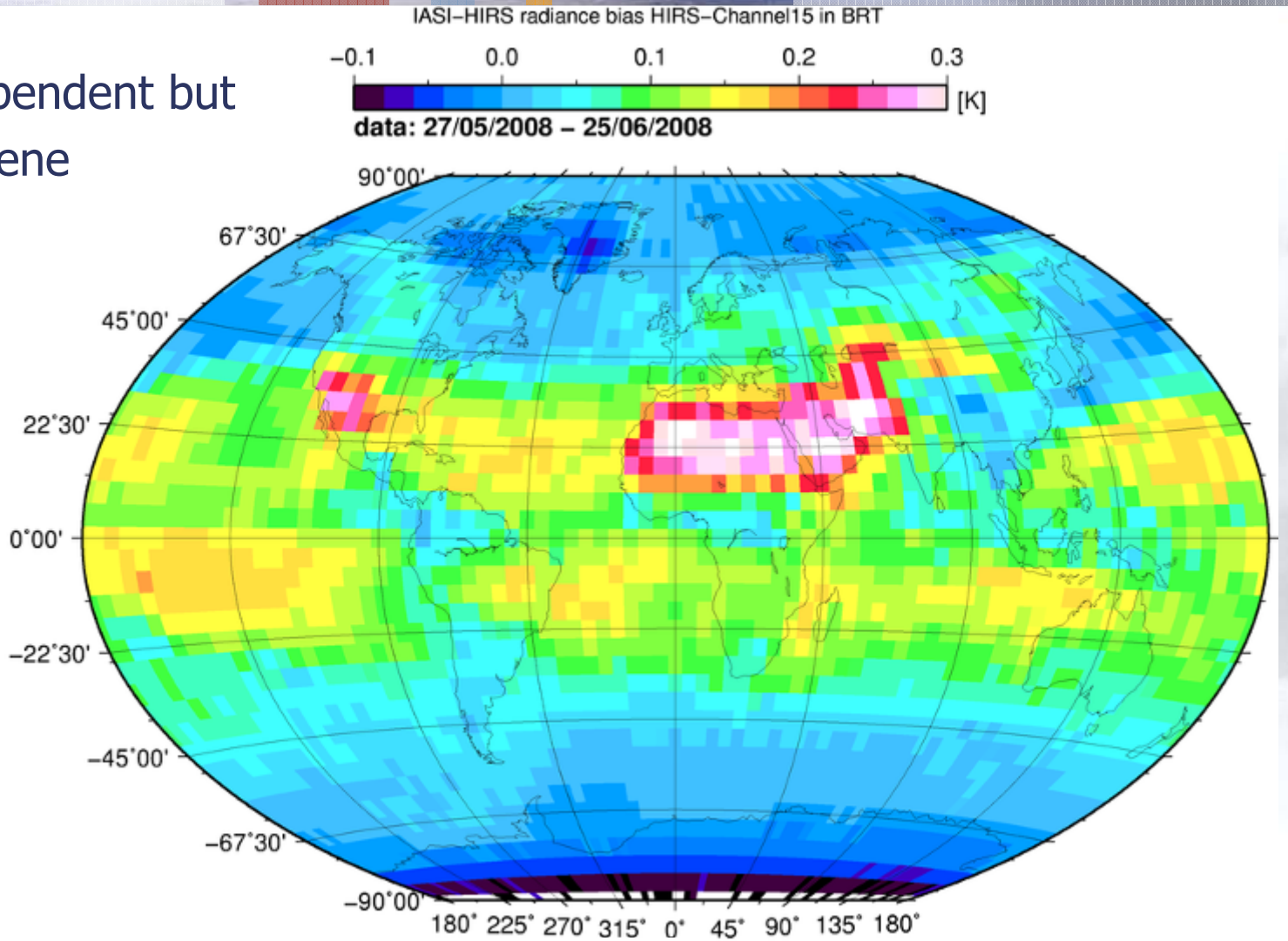


Bias IASI – HIRS Scene temperature dependency Channel 16



IASI - HIRS geo distribution of bias ch15

- Bias is not orbit dependent but
- Bias depends on scene temperature



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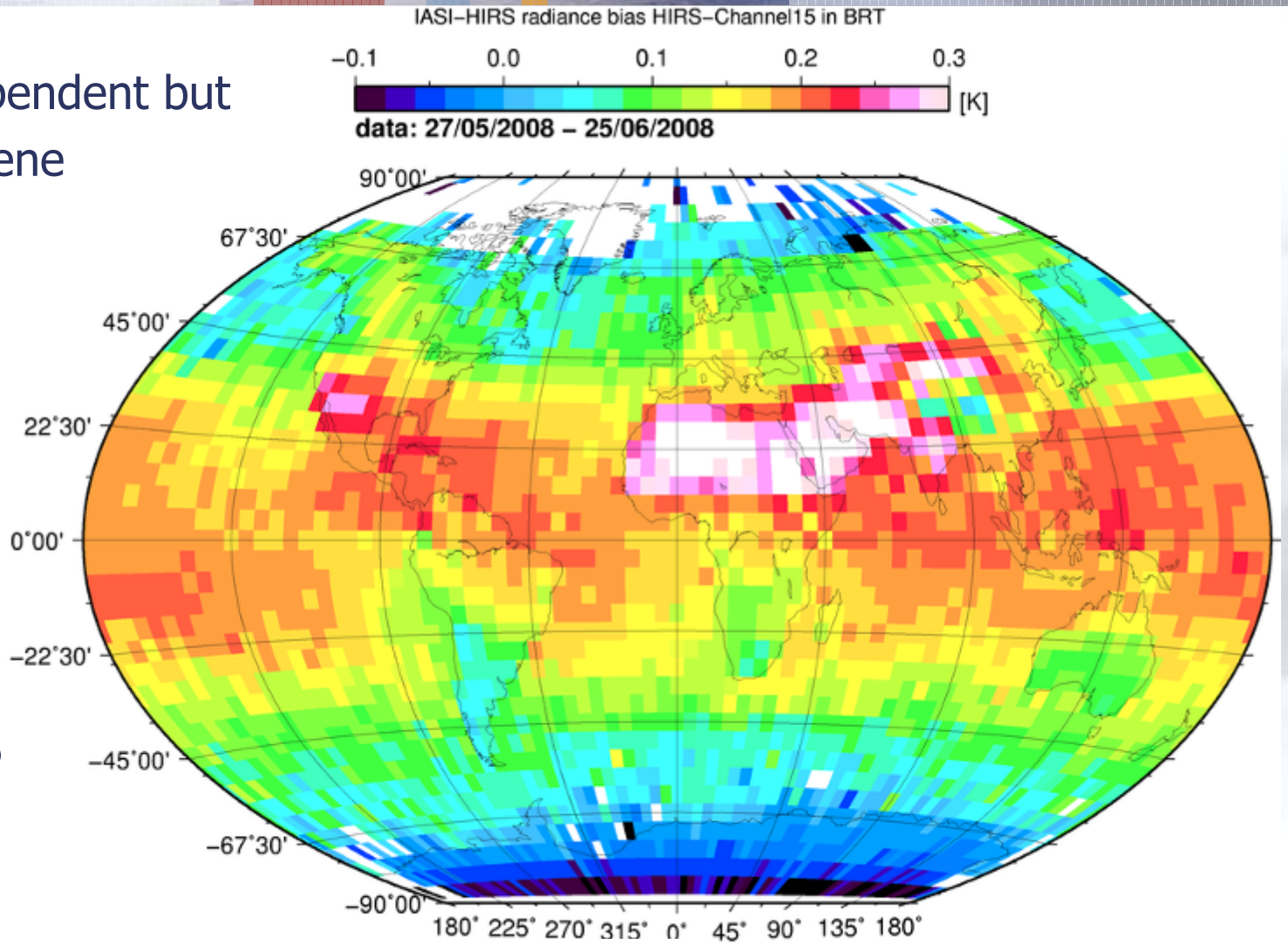
IASI - HIRS geo distribution of bias ch15 clear sky

- Bias is not orbit dependent but
- Bias depends on scene temperature

- with similar effects on channel 16



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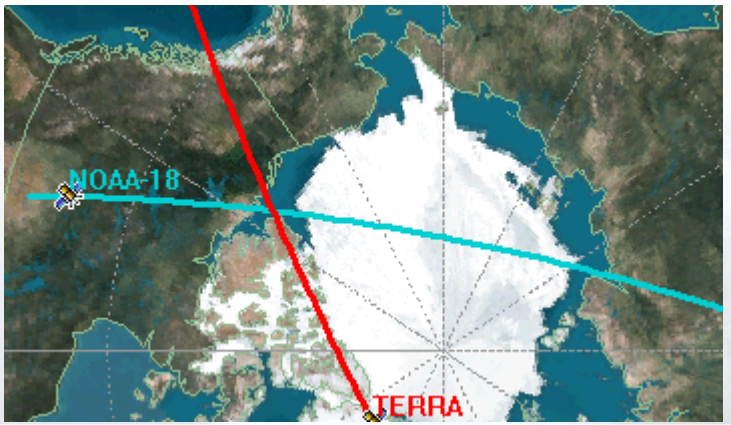
- AIRS-IASI inter-comparison

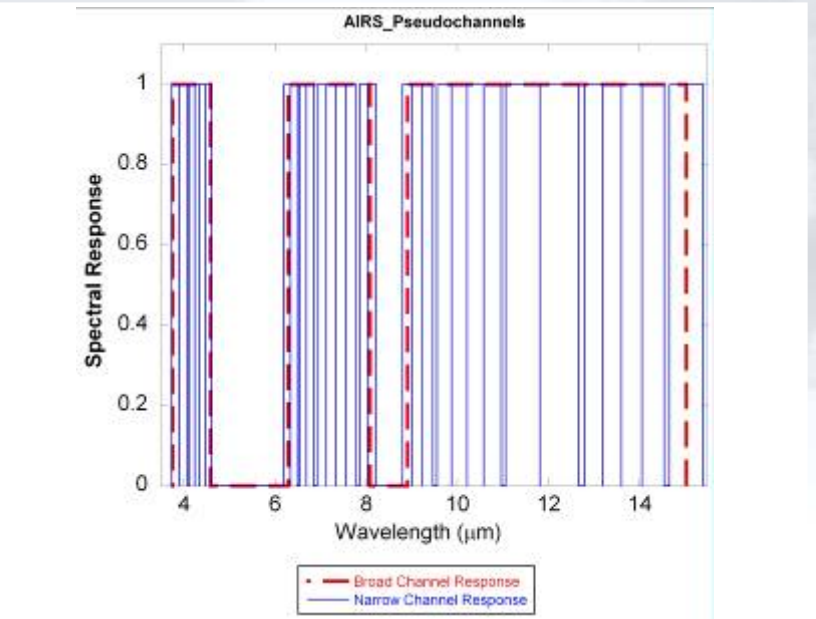
- Conclusions

Simultaneous Nadir Overpass (SNO) Method

- Allow direct comparison of instruments on 2 polar-orbiting satellites
- Only in polar regions for sun-sync satellites
  - near North & South poles
- Every few days

- Integrate AIRS & IASI radiance spectra
- Compare 33 boxcar *pseudochannels*





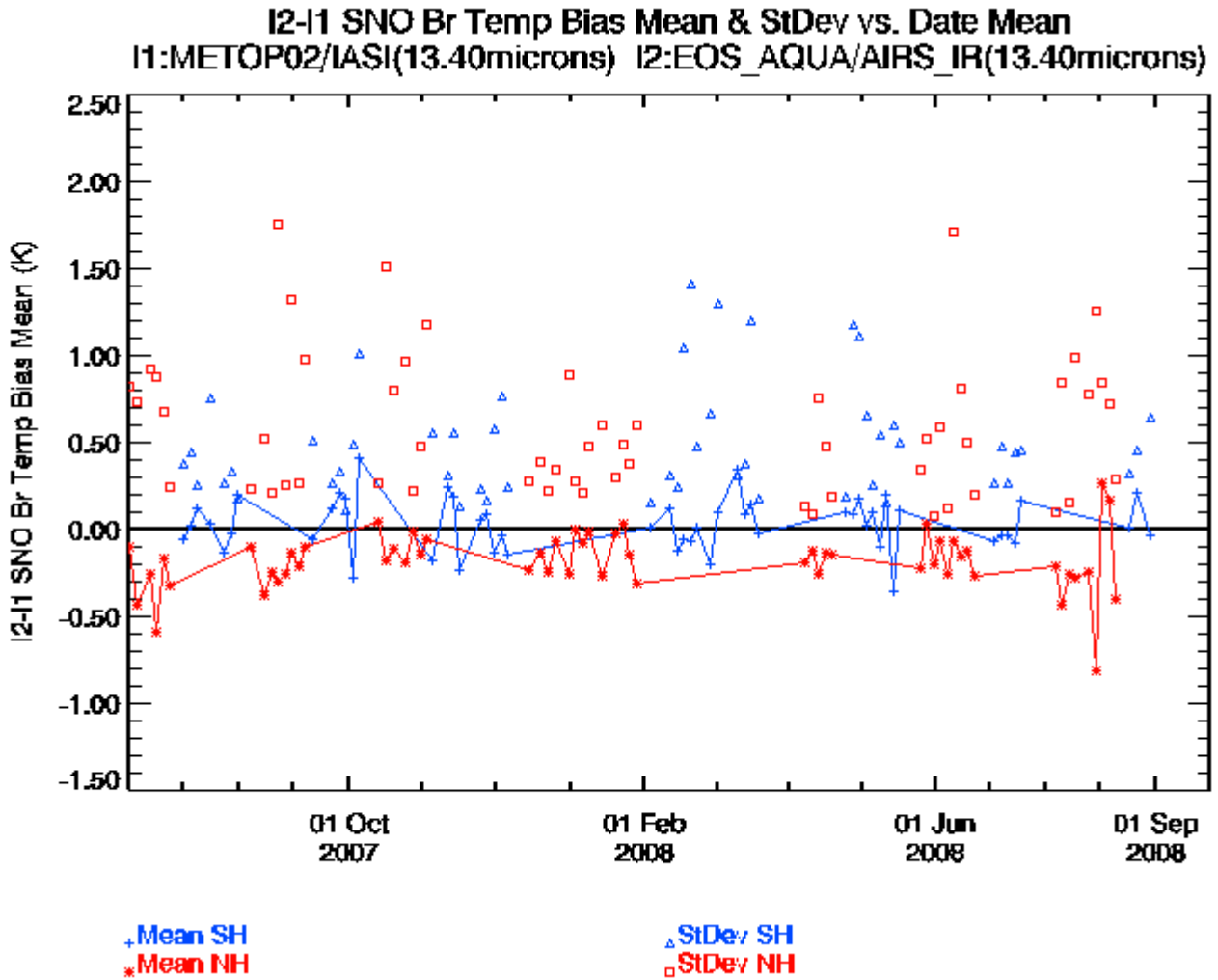
Courtesy of Bob Iacovazzi (NOAA)

AIRS-IASI by SNO – Results for 13.4 µm

- Plot of Brightness Temperature difference
- AIRS-IASI 13.4 µm pseudochannel

- Small biases <1K
- Stable over >1yr
  - Can calc mean of all
- For all channels >4.5µm
- Biases depend on radiance

- Ongoing work - See also
  - Denis Blumstein (CNES),
  - Dave Tobin (CIMSS)

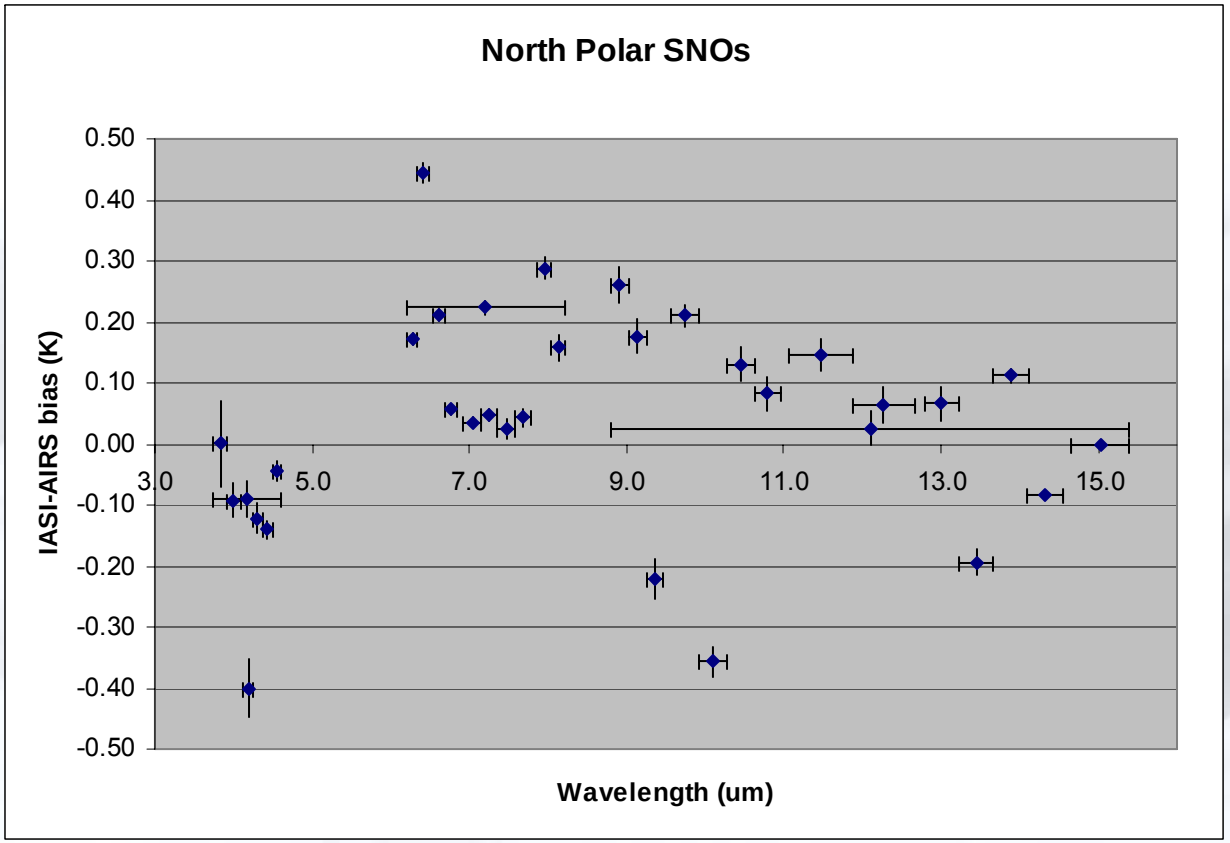


Data from GSICS website

EUMETSAT

Analysis of IASI-AIRS North Polar SNOs

- Plot of Mean IASI-AIRS Brightness Temperature differences
  - from 58 SNOs
  - July 2007 to Sept 2008
  - in 33 pseudo channels
- Stable over >1yr
  - No significant trends
- Small differences <0.5K
- r.m.s. difference =0.18K
- No mean difference
  - 0.04K and not significant
- Ongoing work
  - see Bob Iacovazzi (NOAA)



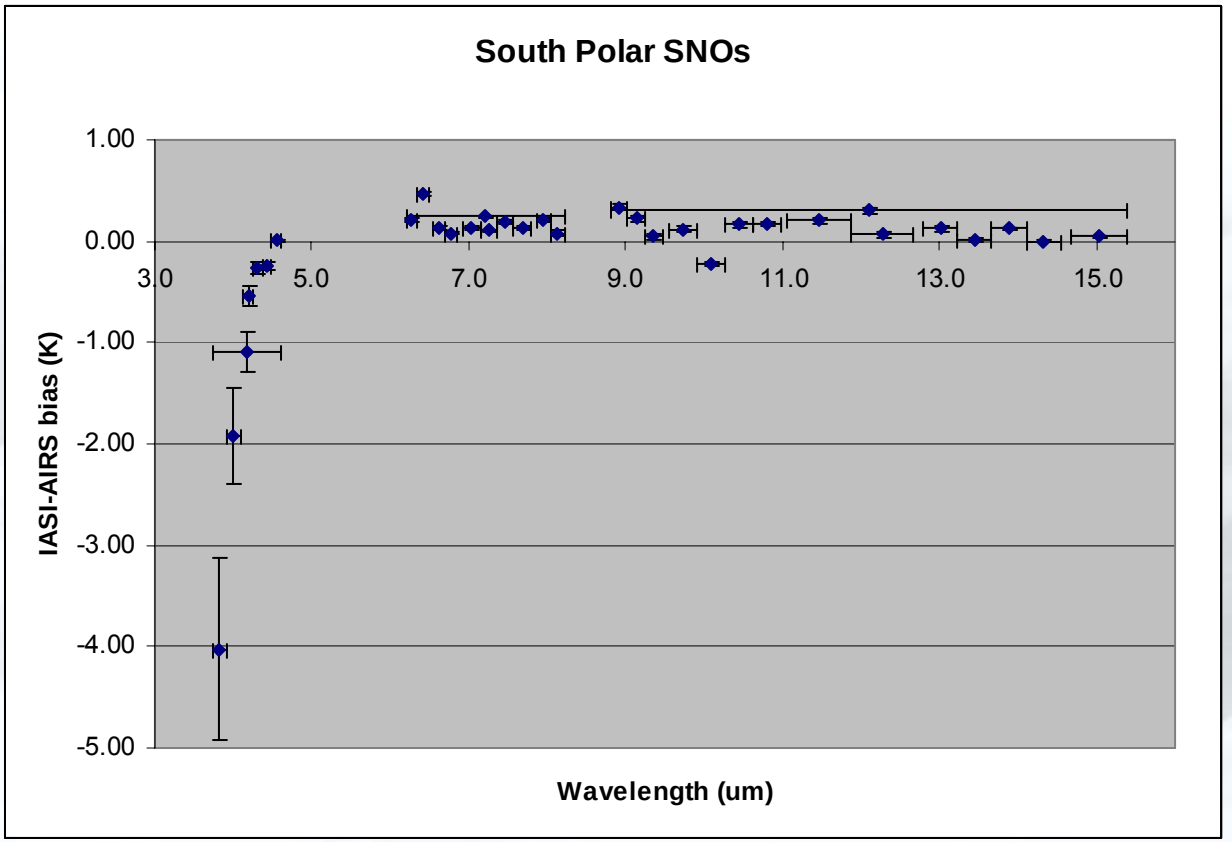
Plot of mean IASI-AIRS Brightness Temperature differences.
Y-error bars show standard error of the mean.
X-error bars show the full spectral range of each pseudo channel.

Data from GSICS website

EUMETSAT

Analysis of IASI-AIRS South Polar SNOs

- Plot of Mean IASI-AIRS Brightness Temperature differences
  - from 53 SNOs
  - July 2007 to Sept 2008
  - in 33 pseudo channels
- Stable over >1yr
  - No significant trends
- For >4.2µm *channels* :
  - Small differences <0.5K
  - r.m.s. difference =0.18K
- Large differences at ≤4.2µm
  - Due to IASI problems at low radiances scenes
- Other SNOs are available:
  - Denis Blumstein (CNES),
  - Dave Tobin (CIMSS)



Plot of mean IASI-AIRS Brightness Temperature differences.
Y-error bars show standard error of the mean.
X-error bars show the full spectral range of each pseudo channel.

Data from GSICS website

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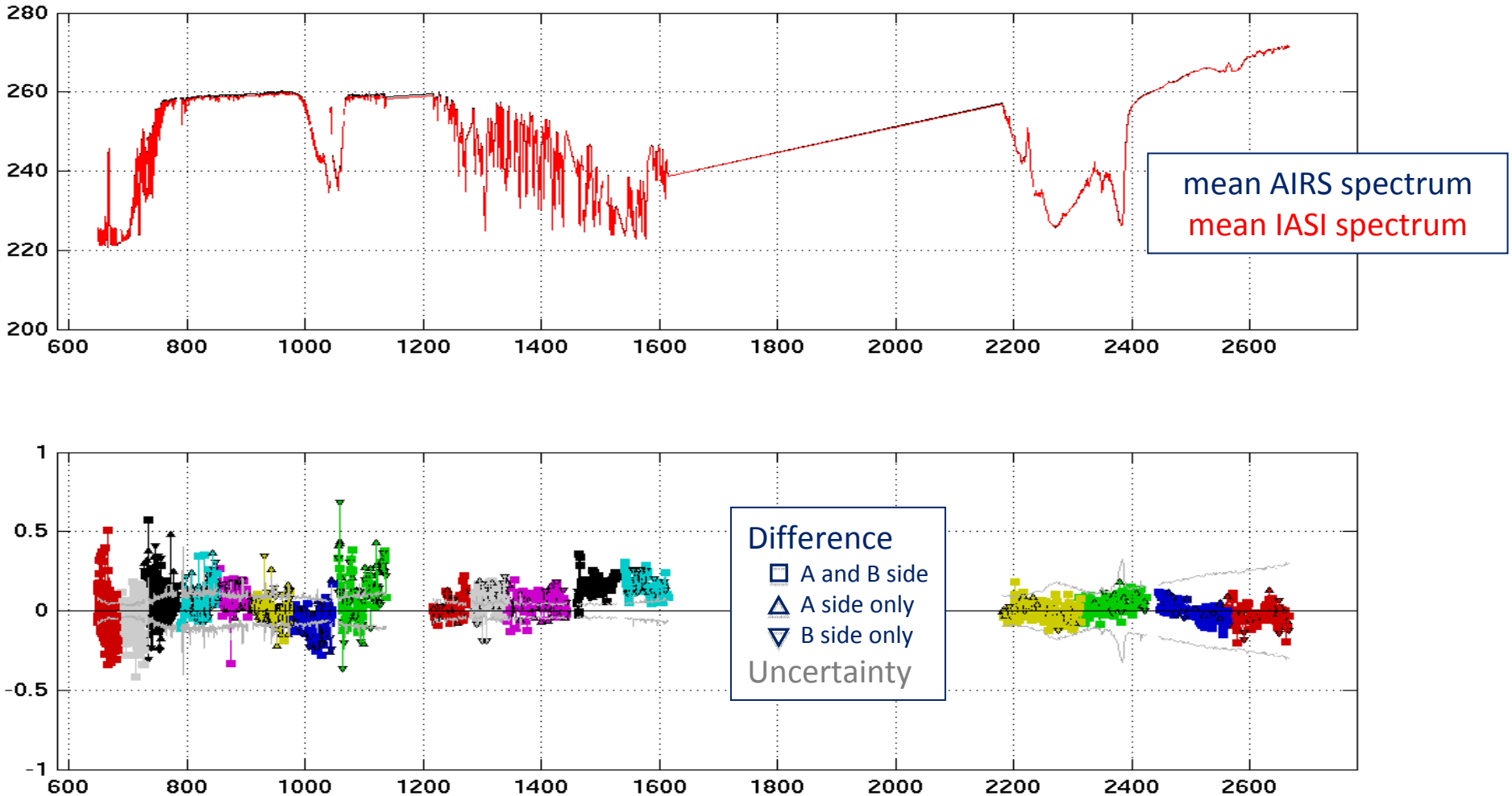
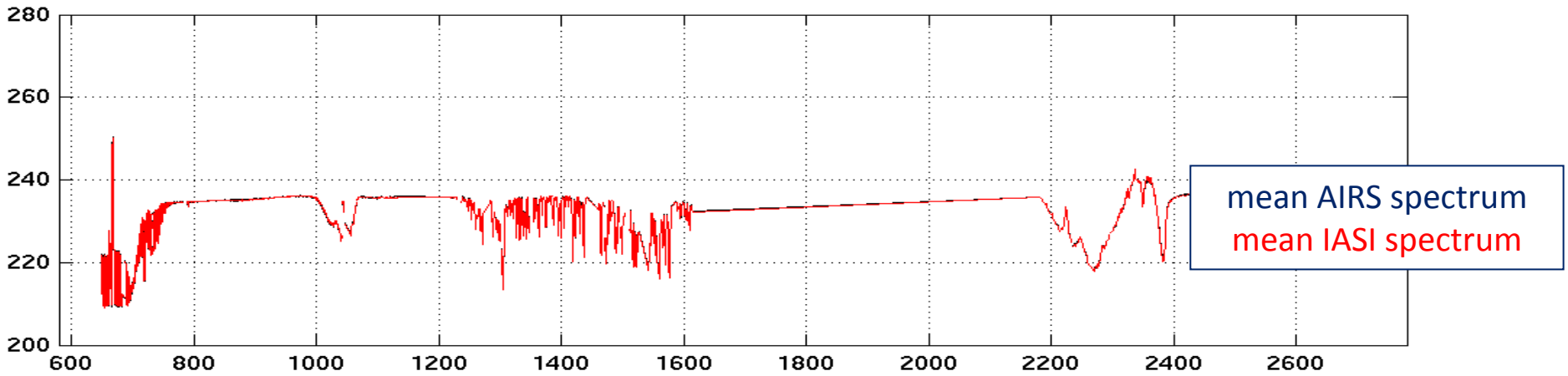
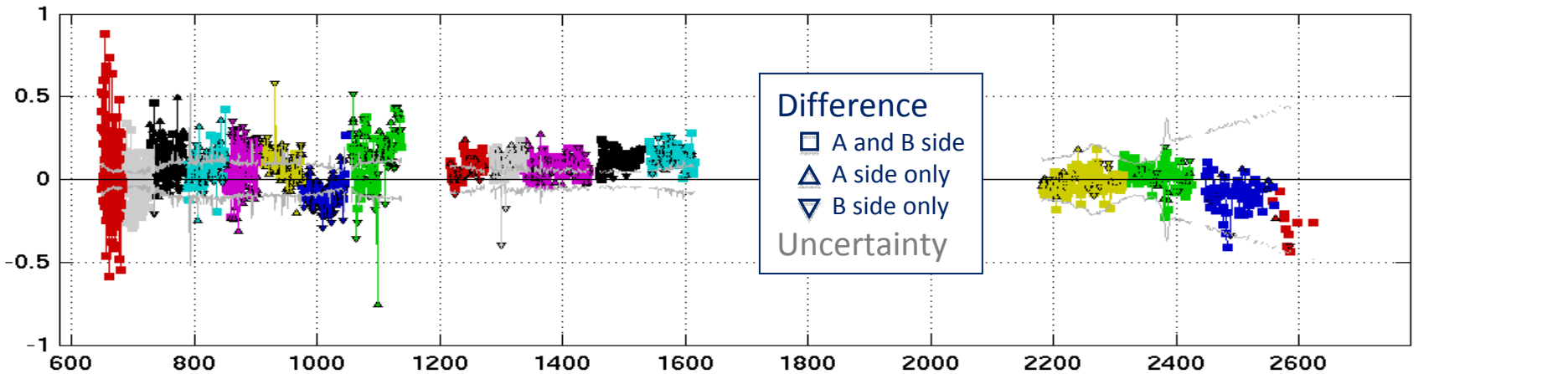
Northern SNO's from Dave Tobin



Southern SNO's from Dave Tobin



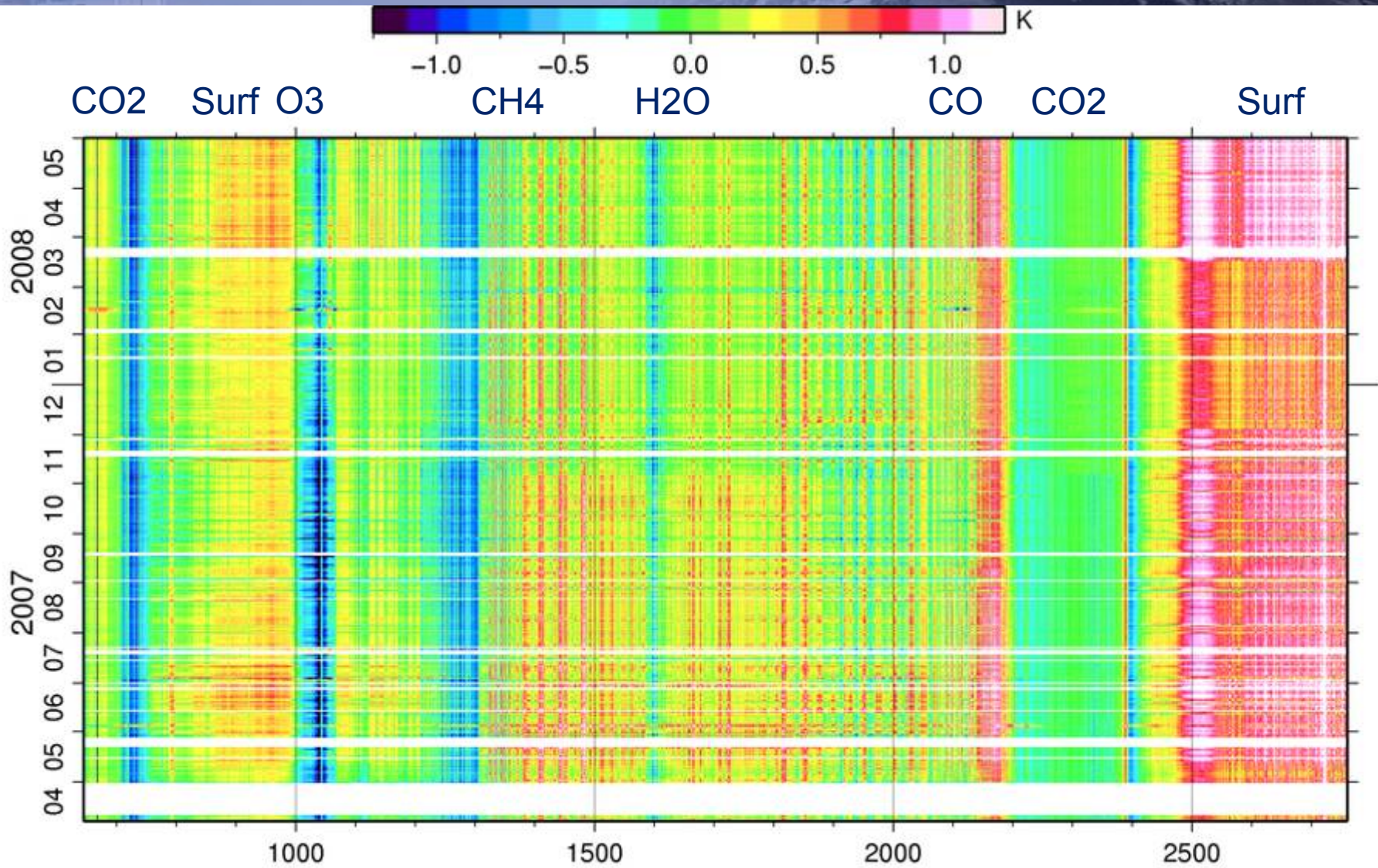


ECMWF bias monitoring for AIRS & IASI

Channel (µm)	<AIRS-FG> (K)	< IASI-FG> (K)
14.98	**-3.3**	**<-2**
14.33	-0.3	-0.1
14.03	-0.3	0.0
10.90	-0.6	-0.1
9.622	+0.1	**-1.6**
8.840	-0.3	-0.5
7.513	-0.1	-0.1
7.130	+0.8	-0.2
6.426	**>+2**	+0.1
4.426	+0.9	+0.6
4.186	**+1.5**	+0.4
4.175	-0.5	-0.5
4.013	**+1.1**	+0.6

- Jan 2008
- Tropics, Clear Skies over Sea
- Day and night
  - –But different orbits!
  - –May not be comparable
- Mean OBS-FG estimated
  - –Same AIRS-IASI channels
- Significant biases (>95%) in **bold**:
  - – 4 channels for AIRS
  - – 2 channels for IASI
- Processed operationally
  - –at EUMETSAT since June 2008
  - –See Lars Fiedler

RM: Daily average of radiance bias in brightness temperature at 280K



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Conclusions

- Inter-calibration of IR channels with IASI
  - Can be used to monitor relative biases
  - With a repeatability of <0.20 K for Meteosat-7,
    ~0.10 K for Meteosat-8,
    ~0.05 K for Meteosat-9,
    ~0.03 K for HIRS/4
  - Detect day-to-day changes, or monthly trends
  - Develop and validate correction algorithms
  - Near real time and archive applications
- Small, steady differences between AIRS-IASI (<0.5K)
- Example of application of GSICS
  - Global Space-based Inter-Calibration System

Thank you

Questions and Answers