Satellite Instrument Calibration Issues: Geostationary platforms

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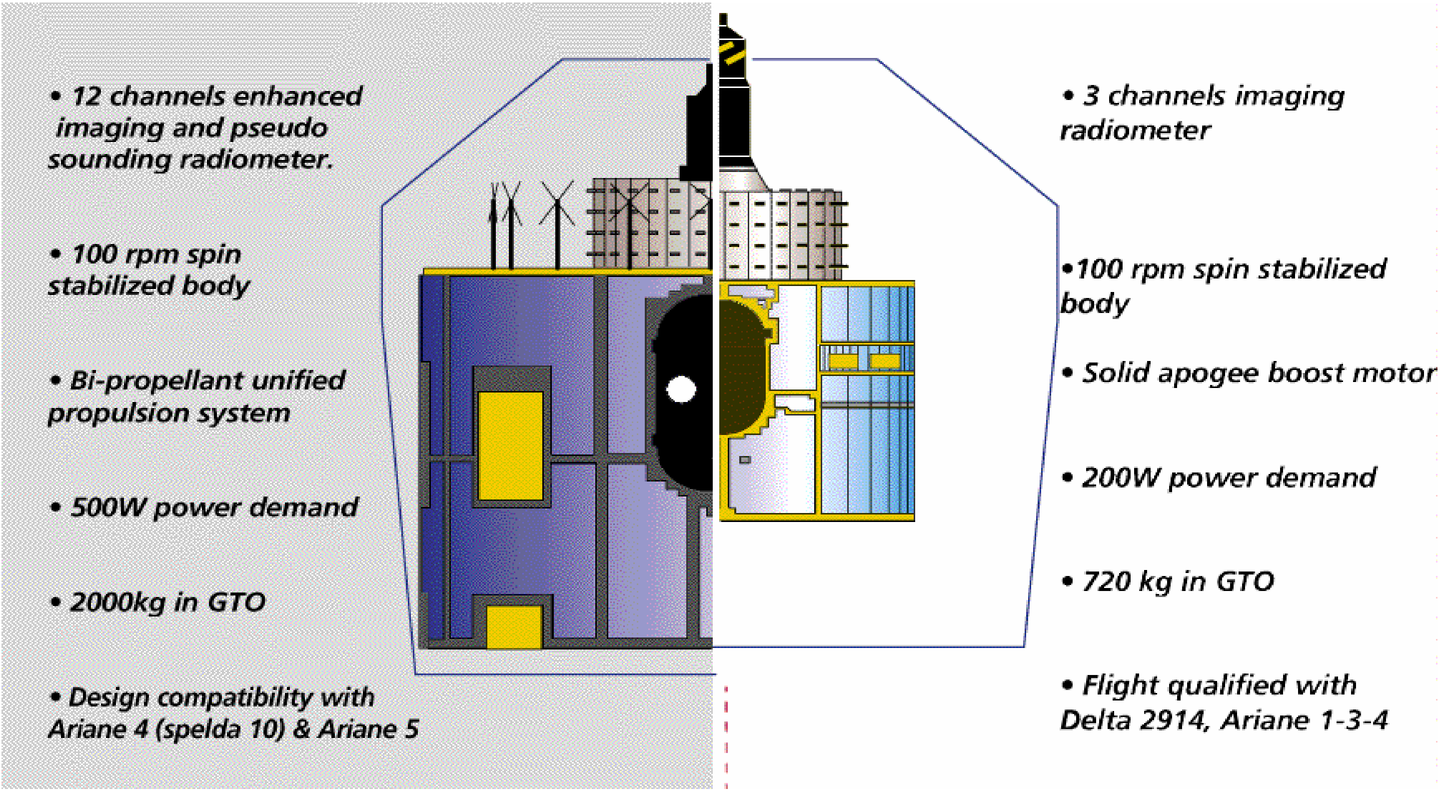
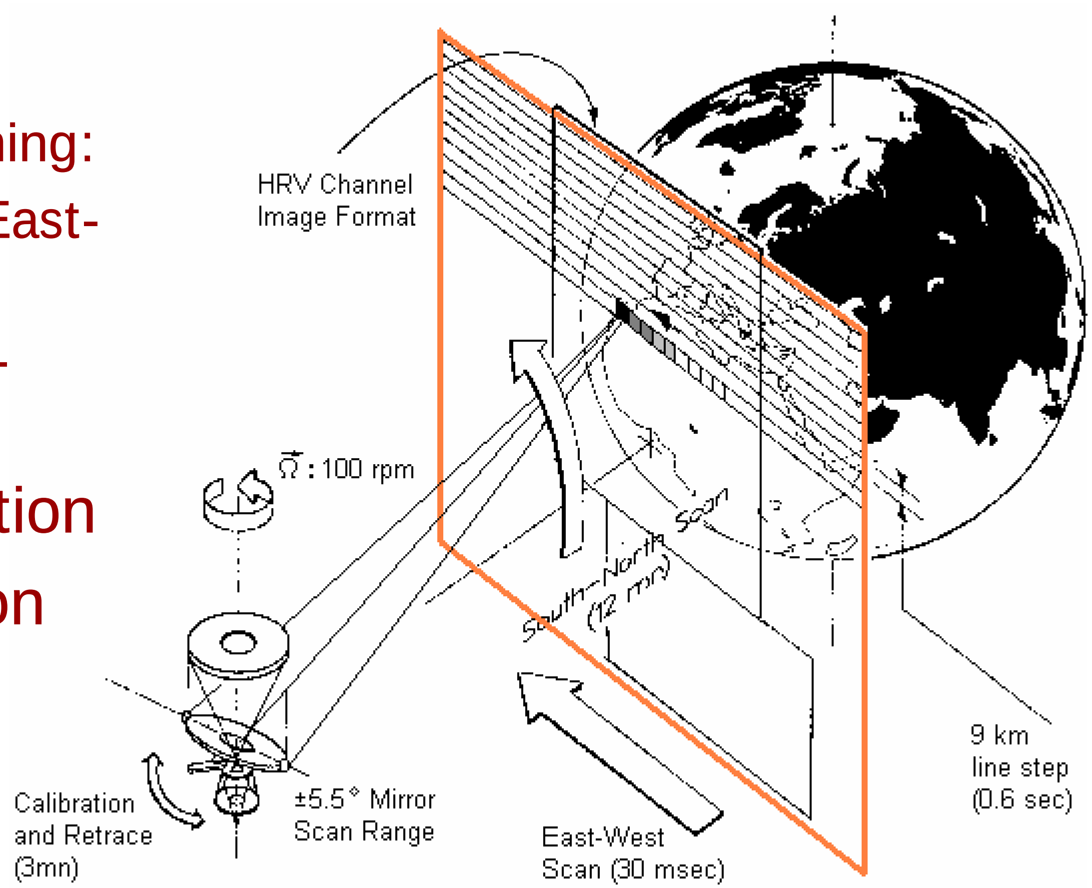
- Introduction to SEVIRI (and MVIRI)
- Blackbody calibration
- Calibration issues and status
- Clear Sky Radiance Product
- Introduction to Atmospheric Motion Vectors
- Reprocessing
- Summary

MSG - MOP/MTP Comparison



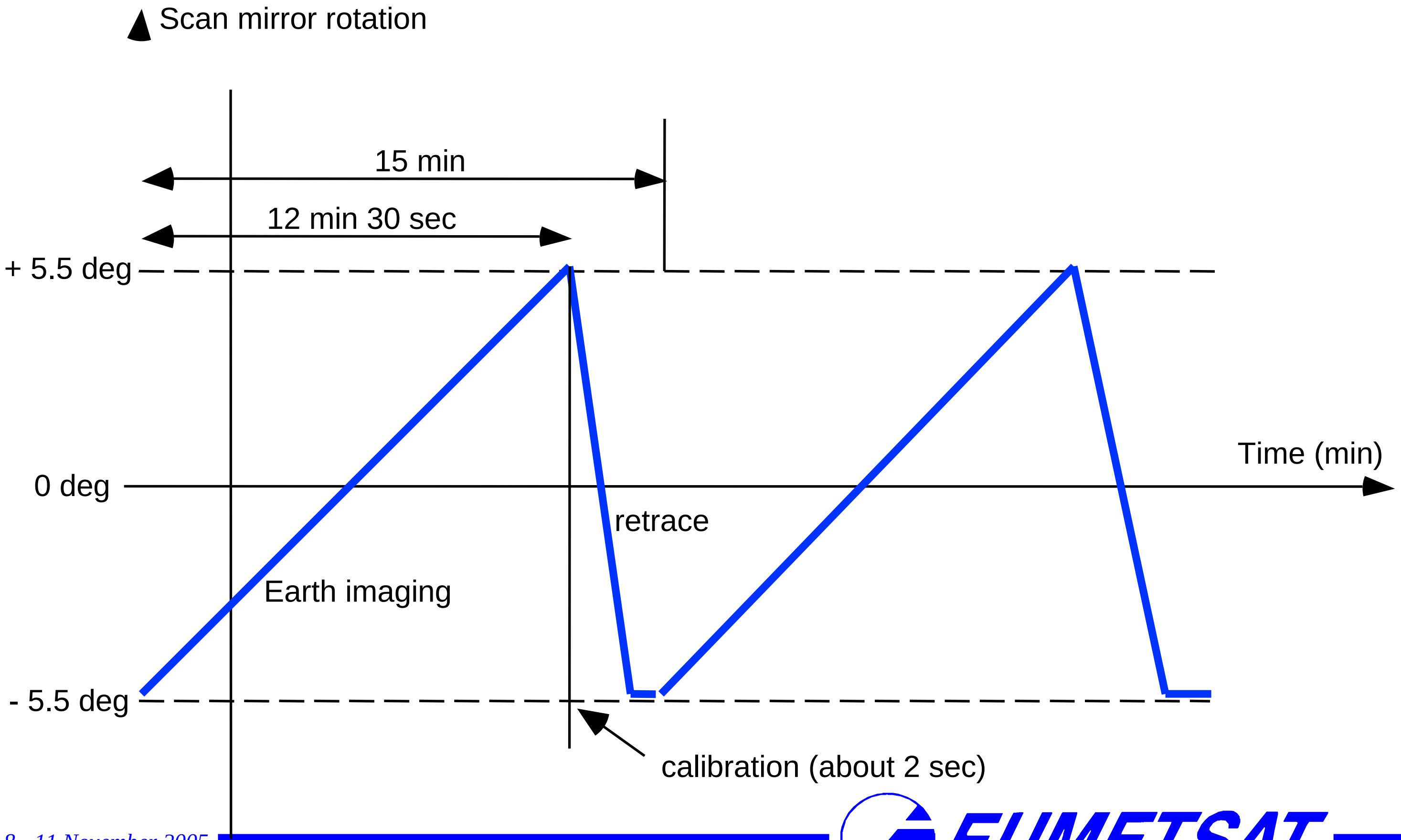
MVIRI/SEVIRI Imaging Principle

– Earth imaging is obtained by bi-dimensional Earth scan combining:
  - satellite spin at 100 rpm for East-West scan
  - scan mirror motion for North-South scan
– SEVIRI scans 3 lines/revolution
– MVIRI scans 1 line/revolution



SEVIRI Imaging Principle

The image repeat cycle is split into the Earth imaging phase (1249 scan lines), the calibration phase (typically 4 lines) and the retrace phase (about 2’30” - profile driven by k-factors to inhibit nutation).



MVIRI vs. SEVIRI

- More frequent full disc imaging (15 min vs. 30 min)
- Faster data transmission
- More wavelengths (12 vs. 3)
- Better sampling distance (normal:3 vs 4.5 km, HRV: 1 vs 2.25 km)
- Note: Normal pixel size similar (4.8 vs. 5 km) (HRV: 1.4 vs. 2.25 km)

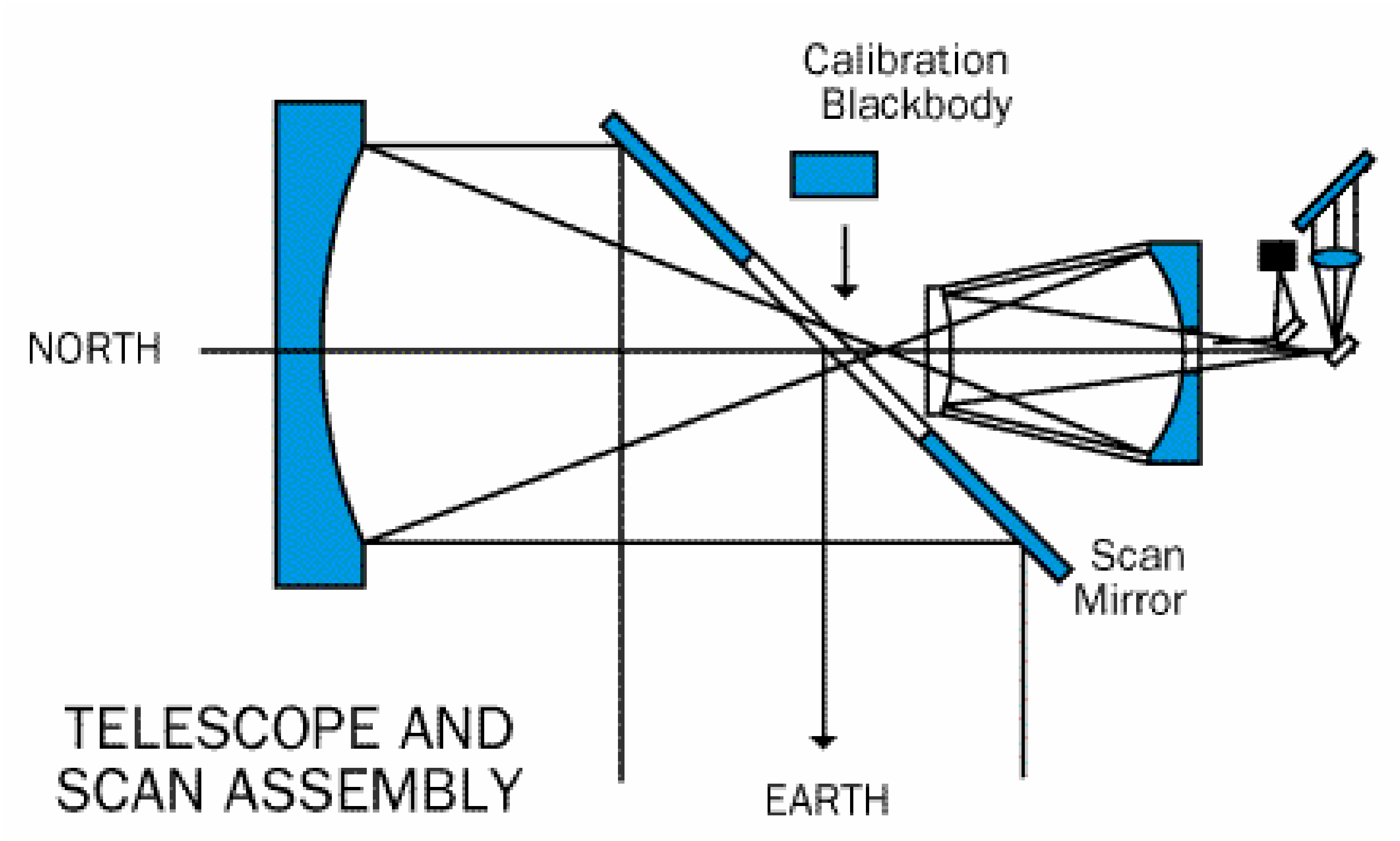
SEVIRI INSTRUMENT

	Channel Spectral Band in µm			Maximum Dynamic range
	λ_{cen}	λ_{min}	λ_{max}	
HRV	**Broadband (silicon response)**			**460 $Wm^{-2}sr^{-1}\mu m^{-1}$**
VIS0.6	**0.635**	**0.56**	**0.71**	**533 $Wm^{-2}sr^{-1}\mu m^{-1}$**
VIS0.8	**0.81**	**0.74**	**0.88**	**357 $Wm^{-2}sr^{-1}\mu m^{-1}$**
NIR1.6	**1.64**	**1.50**	**1.78**	**75 $Wm^{-2}sr^{-1}\mu m^{-1}$**
IR3.9	3.90	3.48	4.36	335 K
WV6.2	6.25	5.35	7.15	300 K
WV7.3	7.35	6.85	7.85	300 K
IR8.7	8.70	8.30	9.10	300 K
IR9.7	9.66	9.38	9.94	310 K
IR10.8	10.80	9.80	11.80	335 K
IR12.0	12.00	11.00	13.00	335 K
IR13.4	13.40	12.40	14.40	300 K

Calibration Status

- Meteosat-8 (MSG-1)
  - Black-body calibration
- Meteosat-7
  - Black-body calibration
- Meteosat-5 (Replaced by Meteosat-7 by end of 2006)
  - Cross-calibration with Meteosat-7 (May 2001)
- Meteosat-6
  - Image normalisation/correction with Meteosat-7 (May 2002)
  - Fixed calibration factor from IPS

SEVIRI Calibration

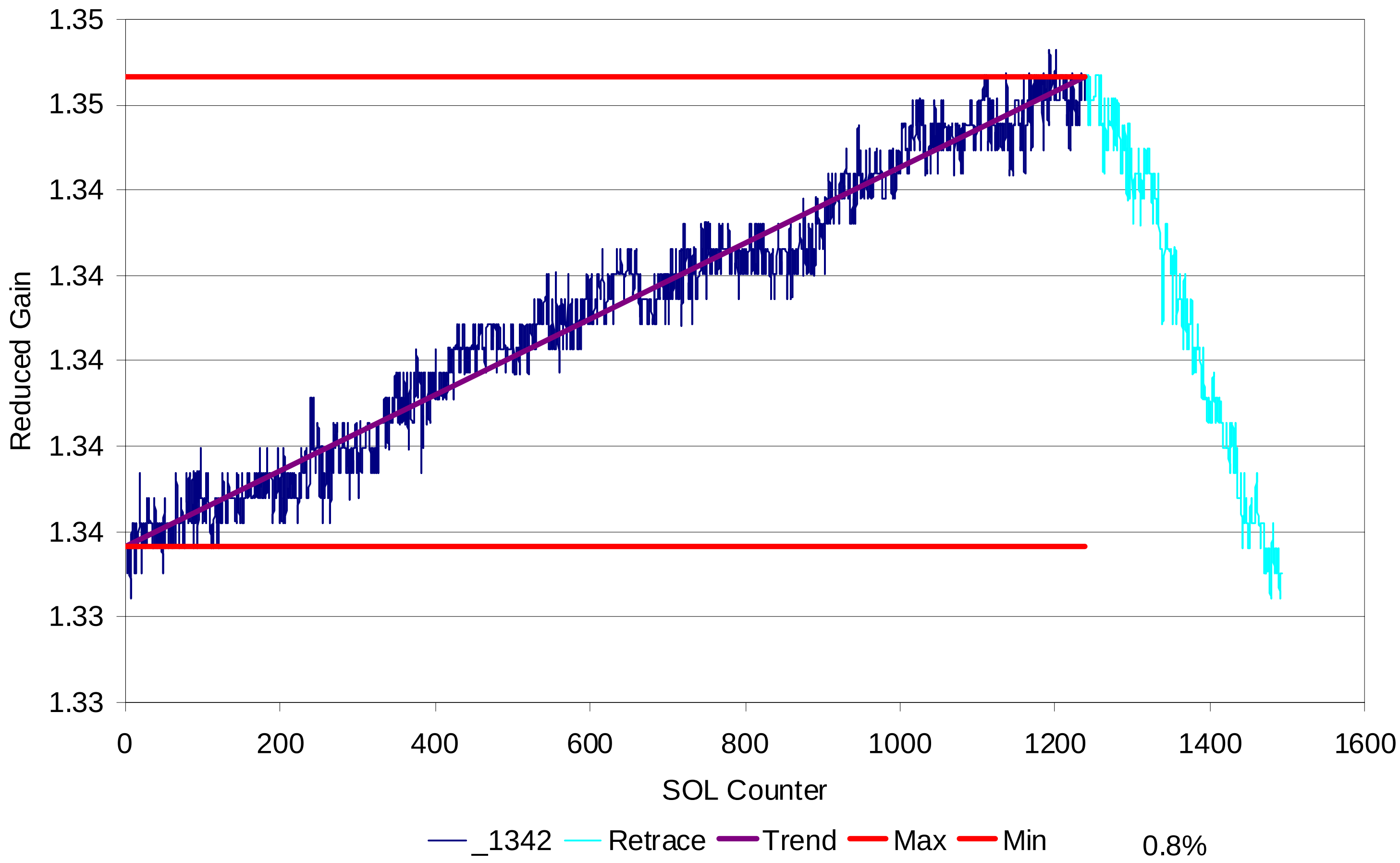


Calibration issues

- The calibration unit is inserted in the optical path between the primary and secondary mirrors
- The effect from the from optics has to be modelled
  - 3 different models available, agree to within 0.1 - 0.5 K.
- Two point approach (cold and warm)
- Non-linear effects are not considered
- 2 - 3 hour oscillation in gain determines calibration frequency
- WV 6.2 micron channel gain setting

Applied corrections

- Scan angle dependency (coating of the mirrors) for each channel



The WV 6.2 micron channel gain setting

- Black body must be in the observable temperature range defined by the gain setting
- Current hot blackbody temperature is 320 K
- WV 6.2 micron observations has therefore to cover roughly a 120 K range (210 - 330 K)
- Free atmosphere observations only to max 290
- Observation data 10 bit -> 8 bit, i.e. loss of sensitivity
- Solution: change gain before and after BB-cal
  - Currently done with MTP
- To be tested during MSG-2 commissioning

Calibration Validation

- Use of different blackbody calibration models
  - Agree to within 0.1 - 0.5 K
- Use of vicarious calibration
  - 7*7 pixel average at f/c grid or observation point
  - Minimum number of pixels = 40
  - Only clear sky over water for f/c
- Cross-calibration with other satellite data

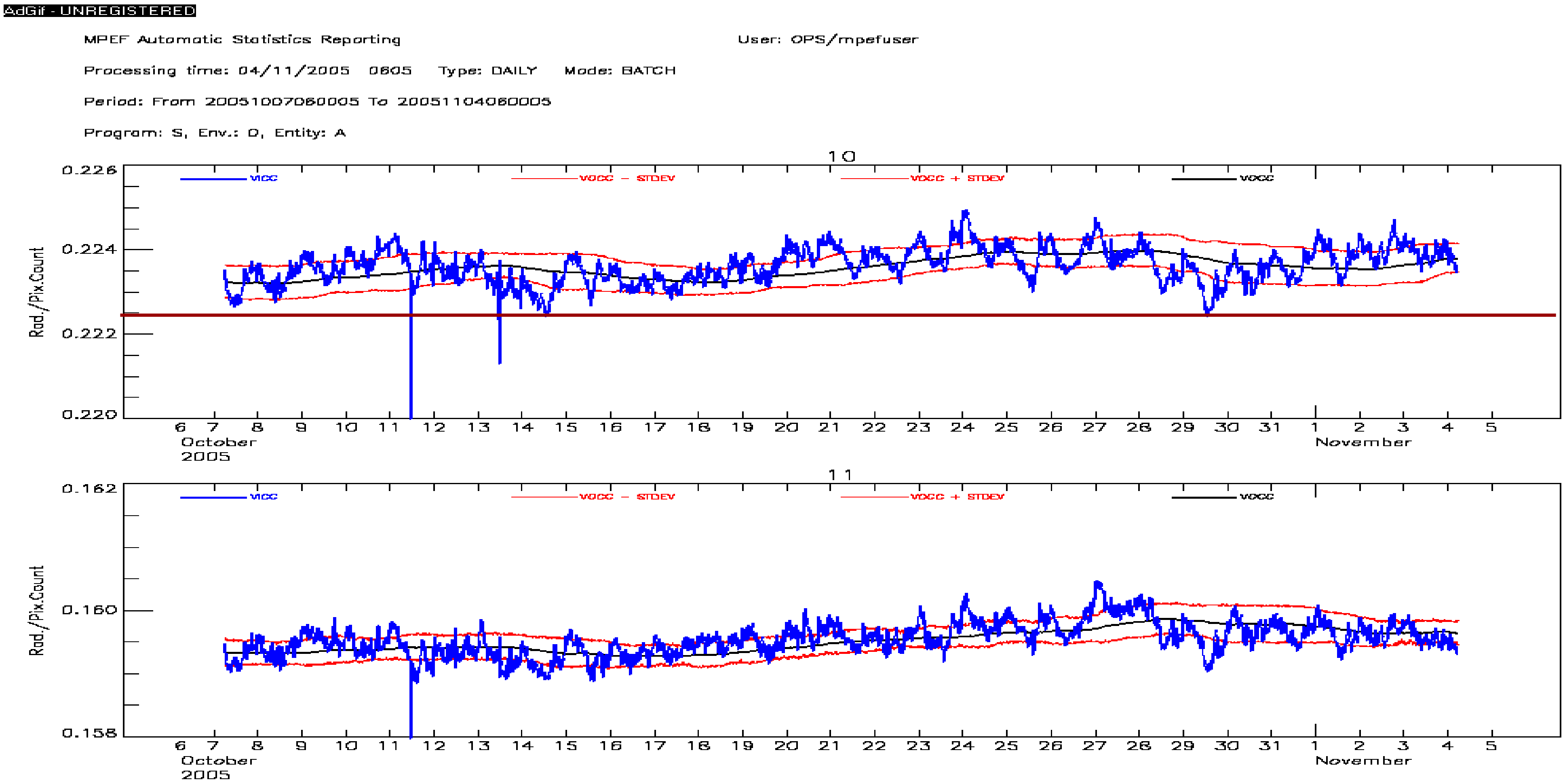
GPRTM

- Course resolution Line-by-line code
  - Monochromatic calculation
- Input
  - Line parameters, surface emissivity
  - Model data, radiosonde
- Output
  - Up and downward radiance for IR channels of SEVIRI at different levels in atmosphere for
    - SCE, AMV, ACT, CAL, TH
- Accuracy 1 - 2 % from comparison to reference calculations (LBL-RTM)

Vicarious calibration results with f/c

12.0 micron: 0.222310 = .5% =.25K

13.4: 0.1576



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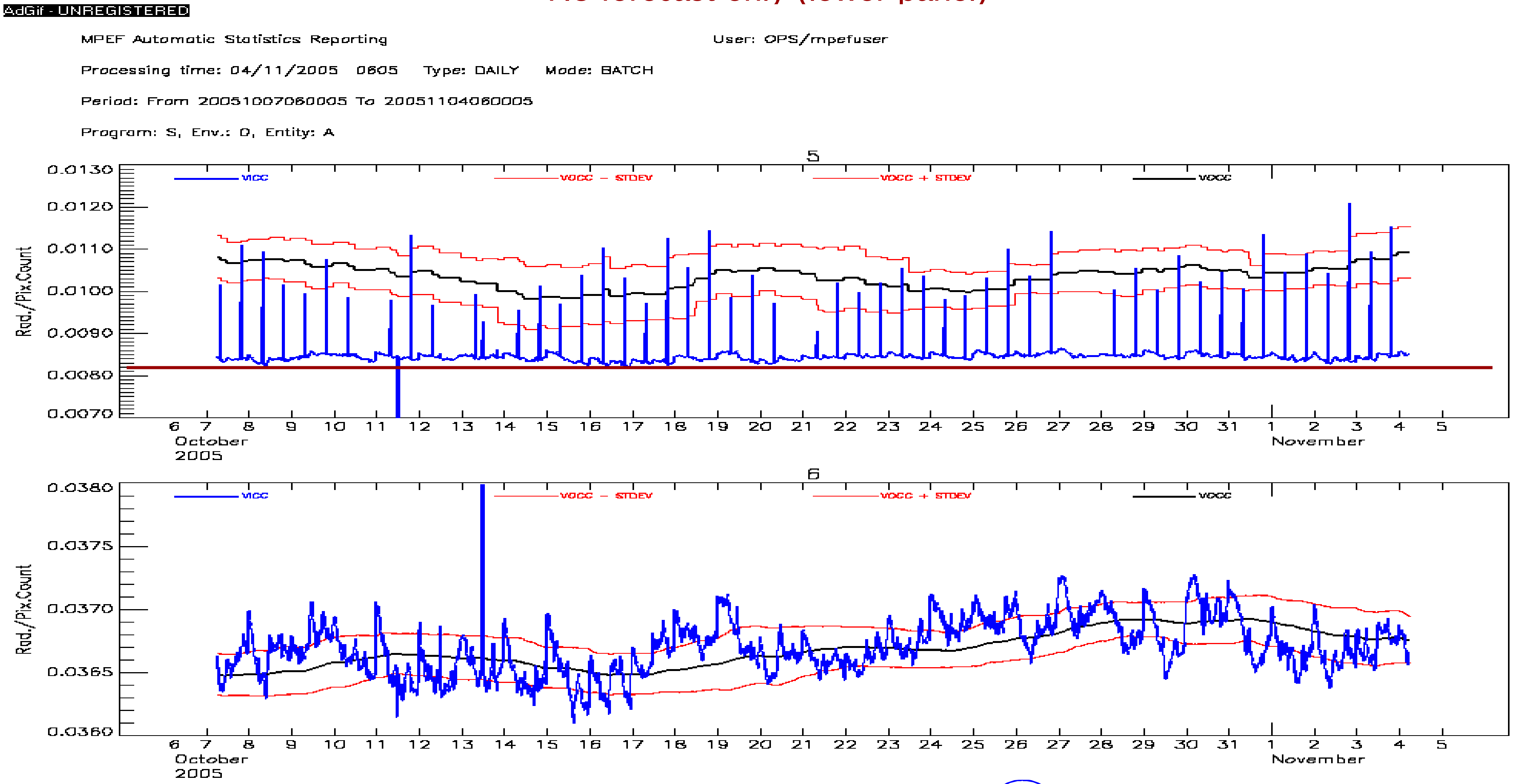
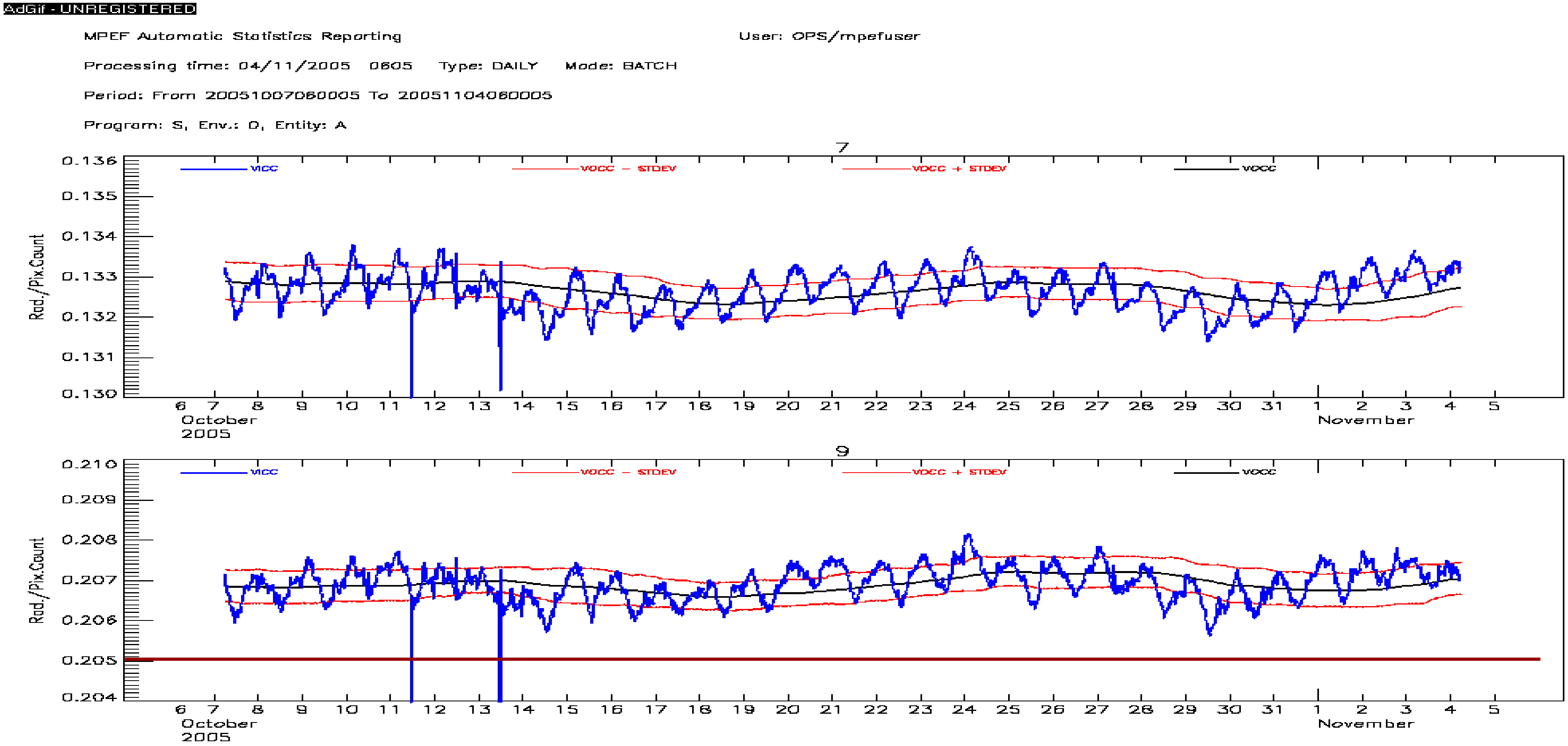
WV Vicarious calibration results

6.2 micron: Blue solid is forecast, Black is radiosonde showing problems
7.3 forecast only (lower panel)



F/c vicarious calibration results
8.7 and 10.8 micron



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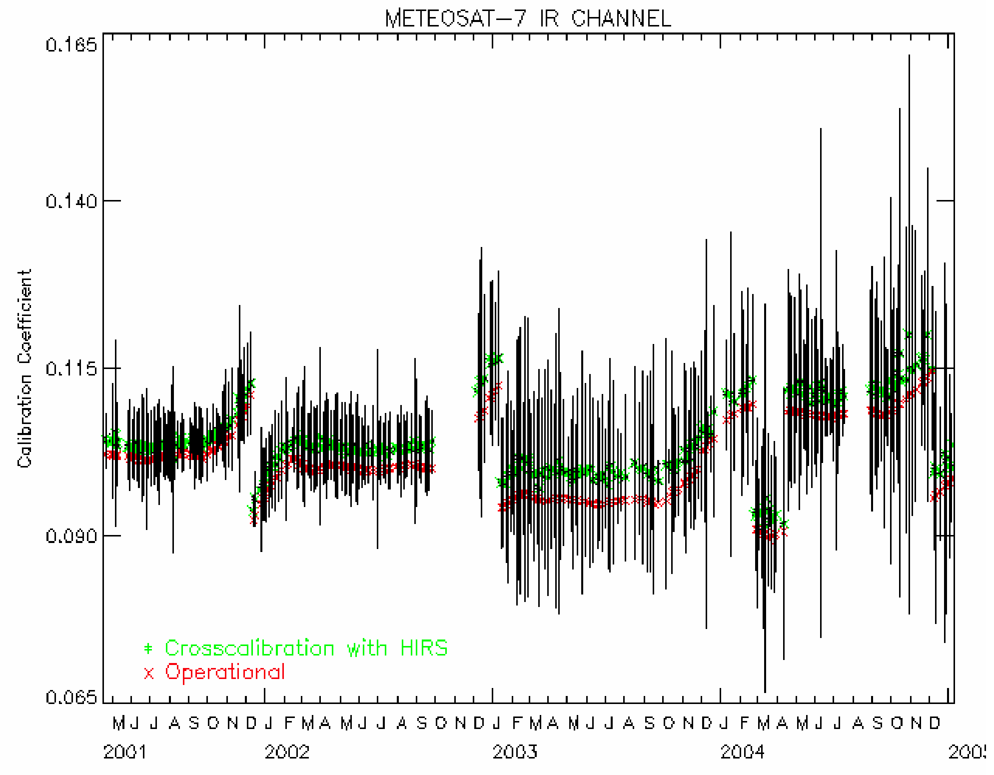
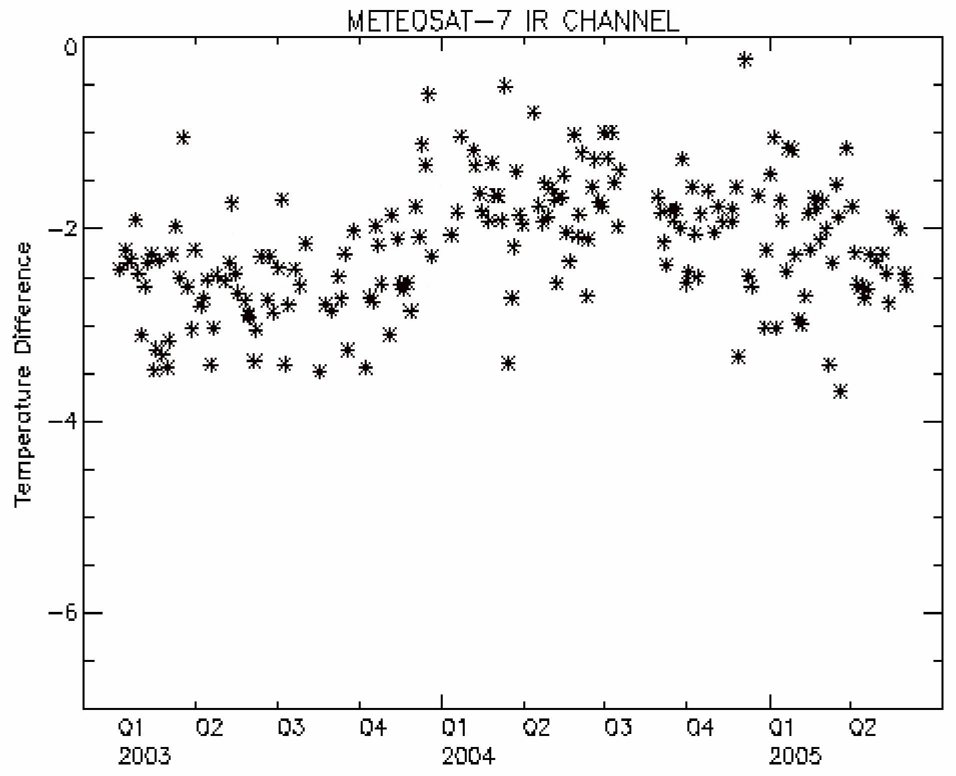
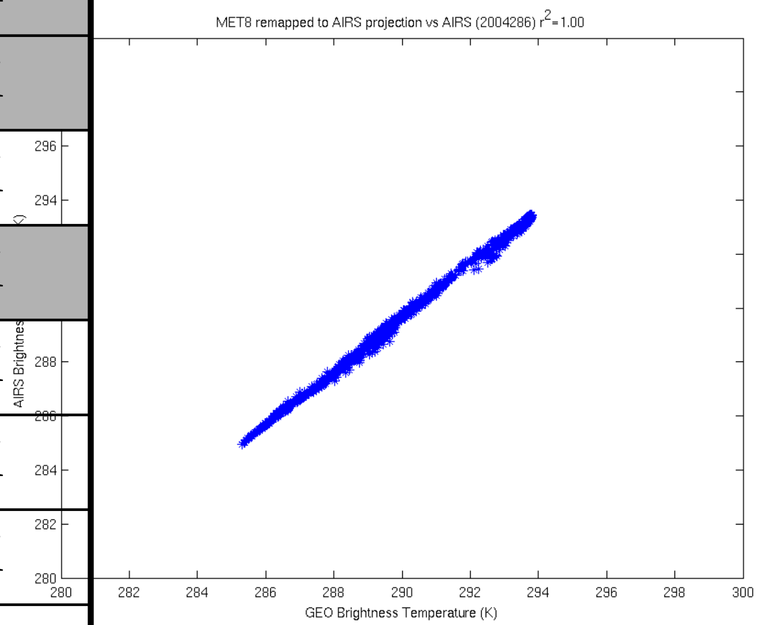
Cross calibration





Vicarious calibration results
With AIRS (Menzel)

Band	n	Mean ΔTbb (MET-8 minus AIRS)	Stand. Dev. (from mean)
4 (4.2 μm)	16	-2.3 K	0.49 K
5 (6.2 μm)	16	-7.0 K	0.16 K
6 (7.3 μm)	16	-0.9 K	0.15 K
7 (8.7 μm)	16	-0.2 K	0.72 K
8 (9.7 μm)	16	-0.3 K	0.10 K
9 (10.8 μm)	16	0.4 K	0.09 K
10 (12.1 μm)	16	0.6 K	0.11 K
11 (13.4 μm)	16	0.1 K	0.28 K

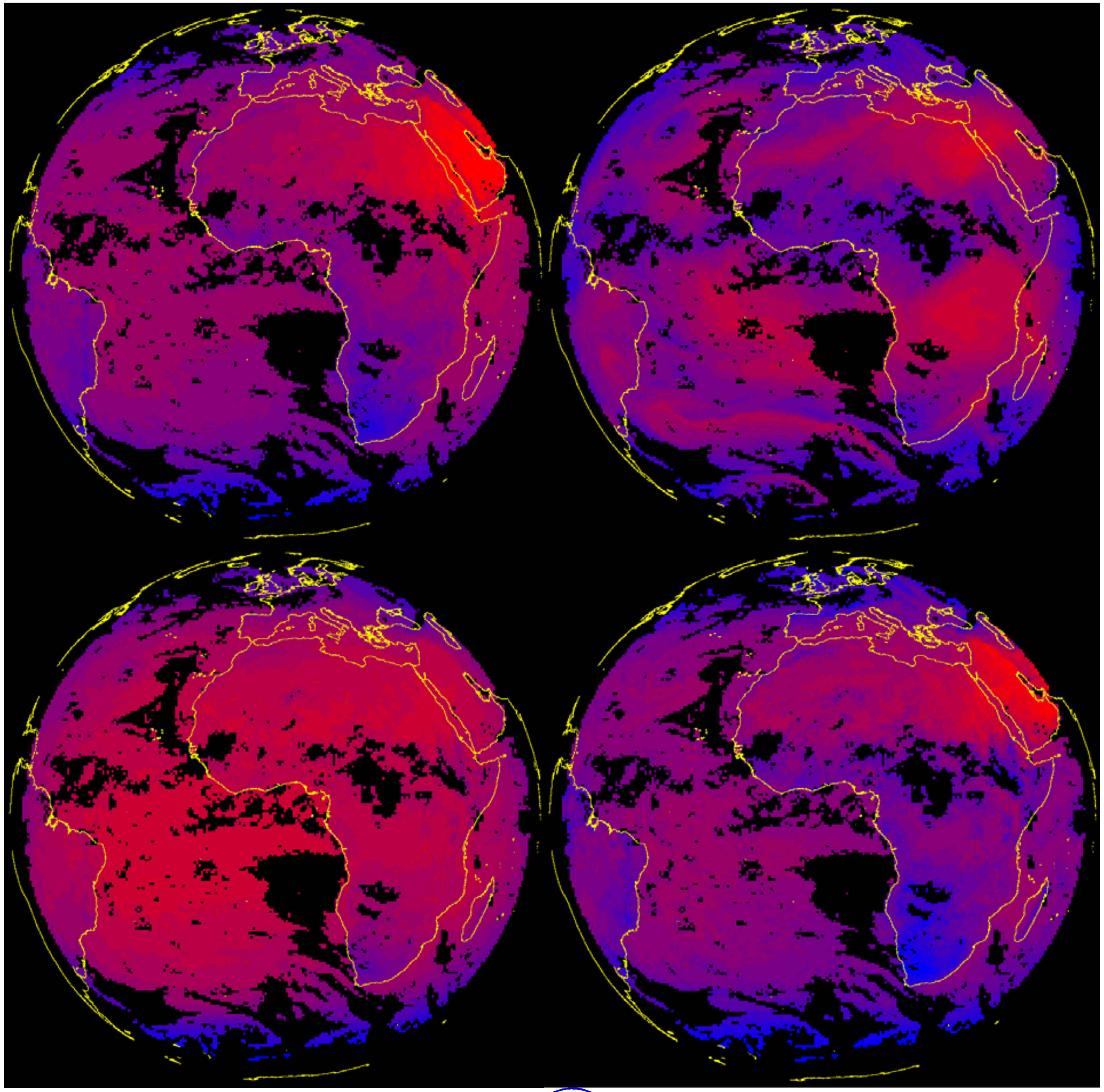


Clear Sky Radiance Product

- Pixel based cloud clearing
- Calibrated mean radiances
- 80 km resolution
- Hourly dissemination

Clear Sky Radiance

Calibration
Cloud clearing
Quality control



Clear Sky Radiance Product
Open issues

- All calibration related issues
- Cloud contamination
  - Gross errors
  - Diurnal variation (0.2 K)
- Quality Indicator

Image problems

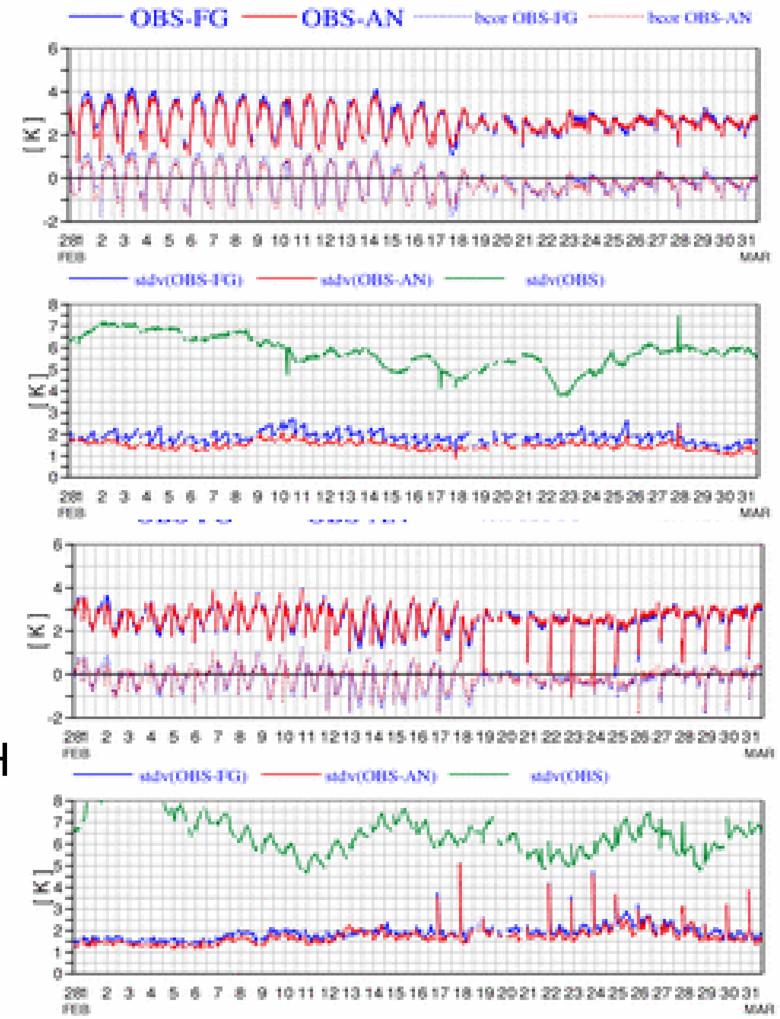
- High inclination orbits
  - Currently all Meteosat First Generation (MFG)
- Eclipse effects
  - Mainly MFG
- Rotating lense
  - Meteosat-5
- Loose front optics
  - Meteosat-6
  - On-ground correction s/w
  - Currently using Meteosat-7 as reference

High Inclination impact on CSR

("Wrong" sub-satellite point)

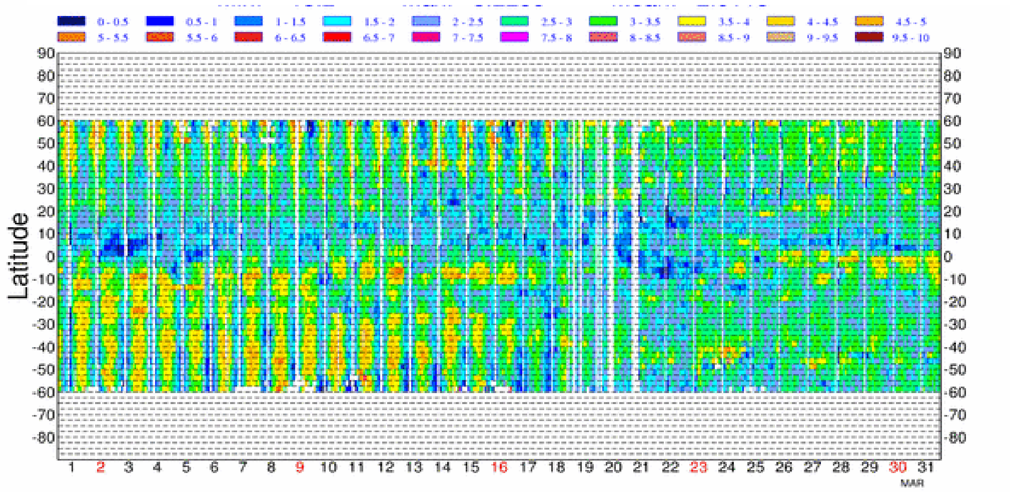
Correct viewing angle data provided as of 18 March 2003

SH



NH

- Oscillation virtually gone
- Small oscillations still on SH
  - changed phase
  - rather related to model FG ?



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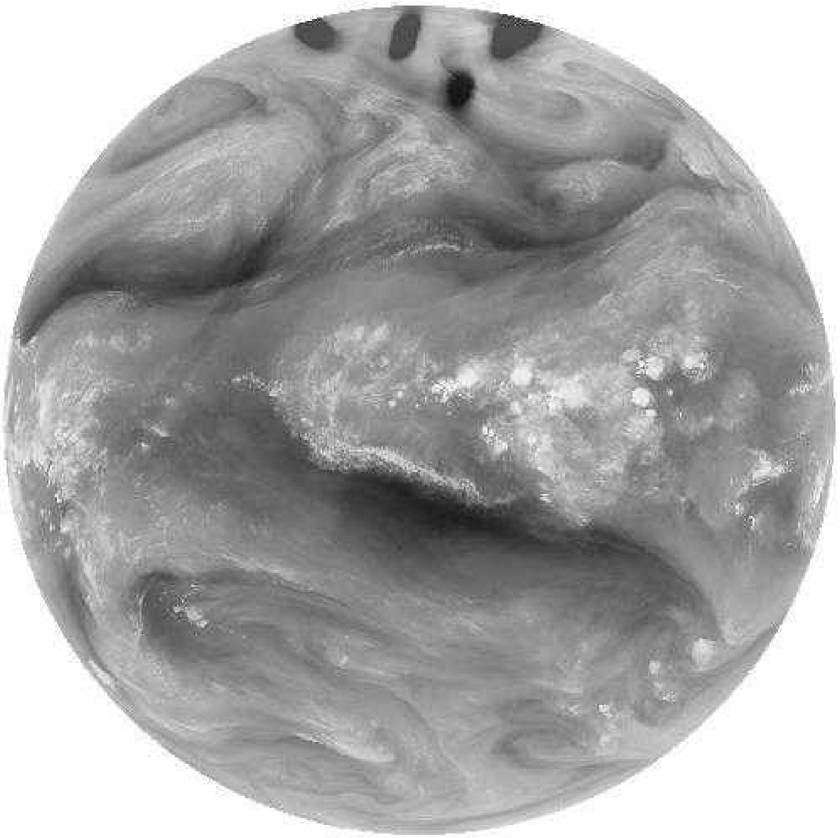
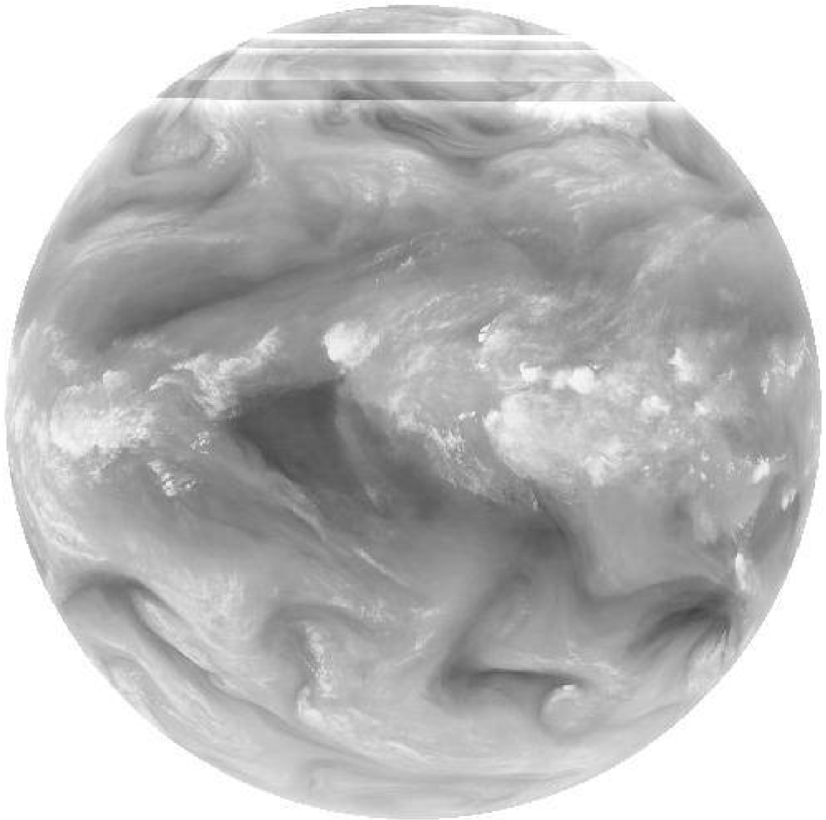
Examples on eclipse effects

For more examples and animations visit www.eumetsat.int





Examples on eclipse effects

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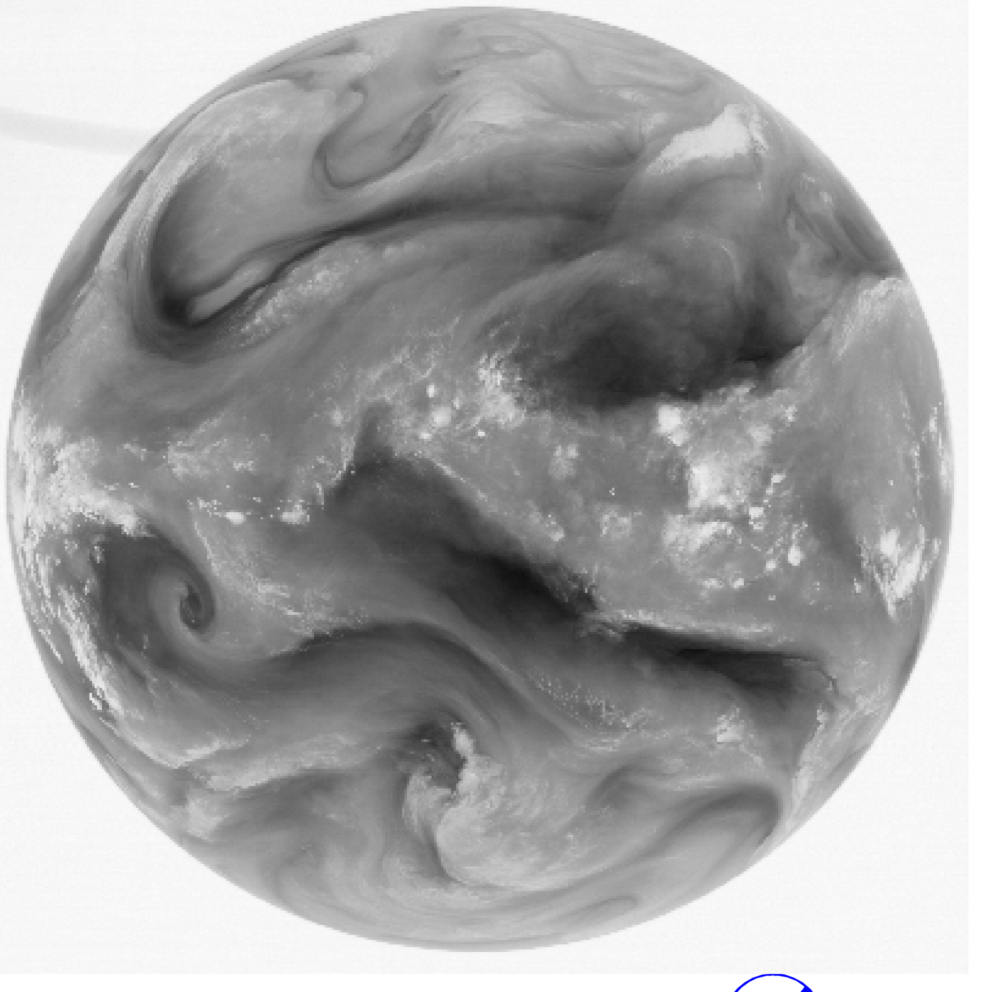
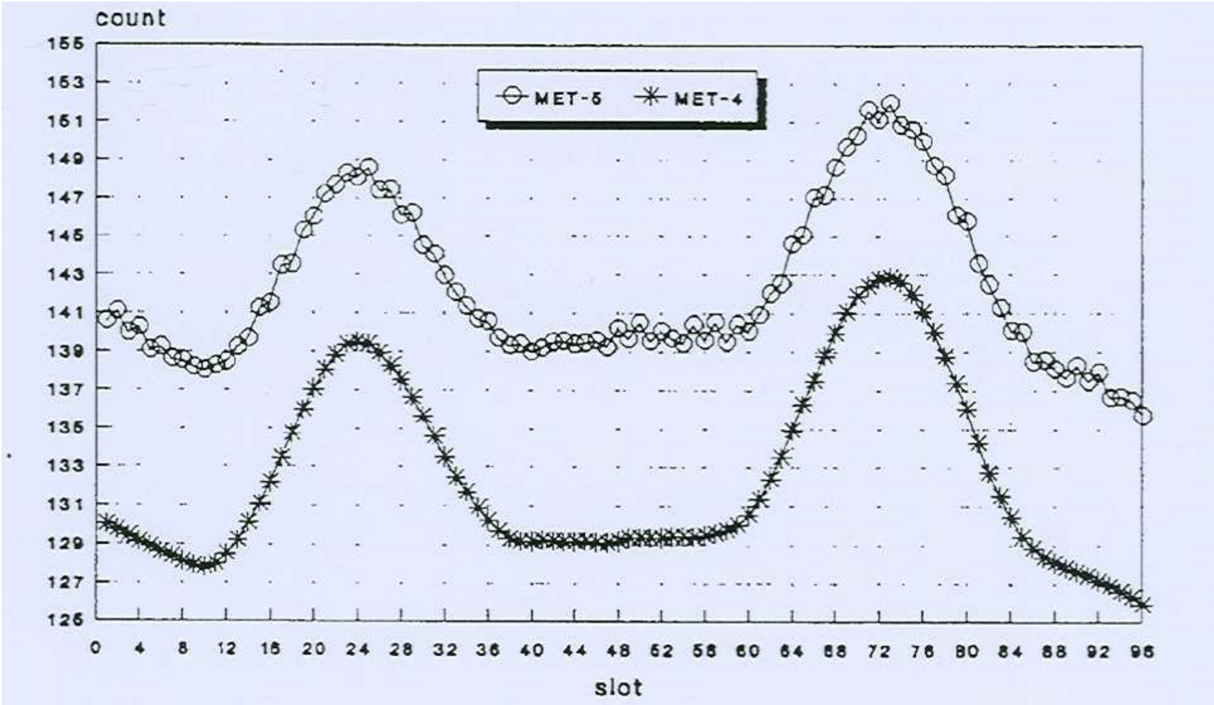


Meteosat-5

Rotating lense effect on observed radiance

1-2 June 1991 (Met-5 circles, Met-4 stars)

- Rotating lense (continuous)
- Effect on Mean Earth count
- Geometrical correction applied for dissemination
- Radiance variation 1-2% during one image not corrected



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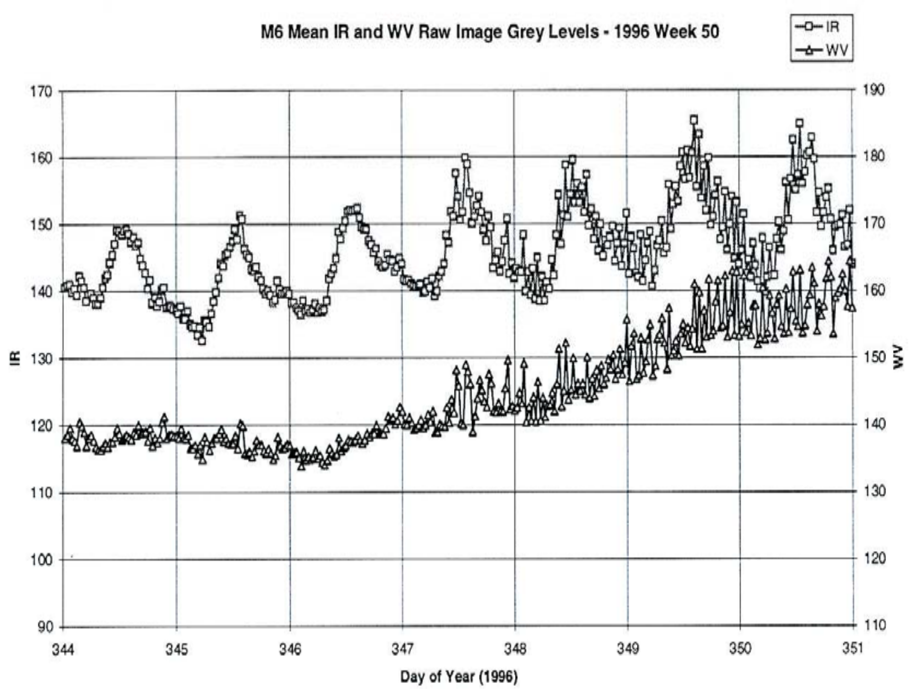
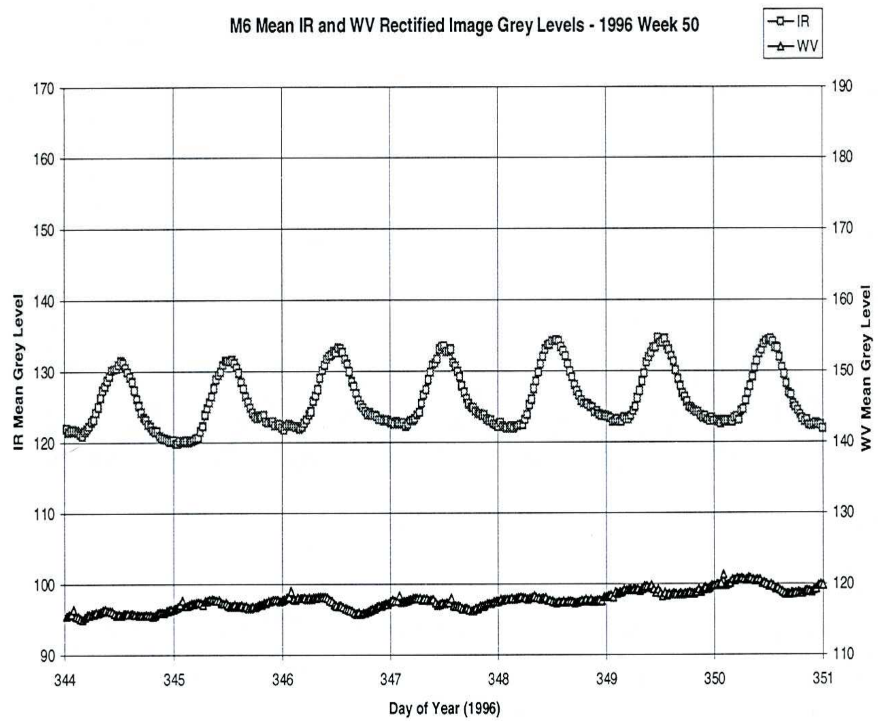
Meteosat-6 Spurious gain changes

week 50 1996 (IR circles, WV diamonds)

- Spurious gain changes (up to 20%) during scanning
- Effect on Mean Earth count (right)
- Correction (left) applied for dissemination





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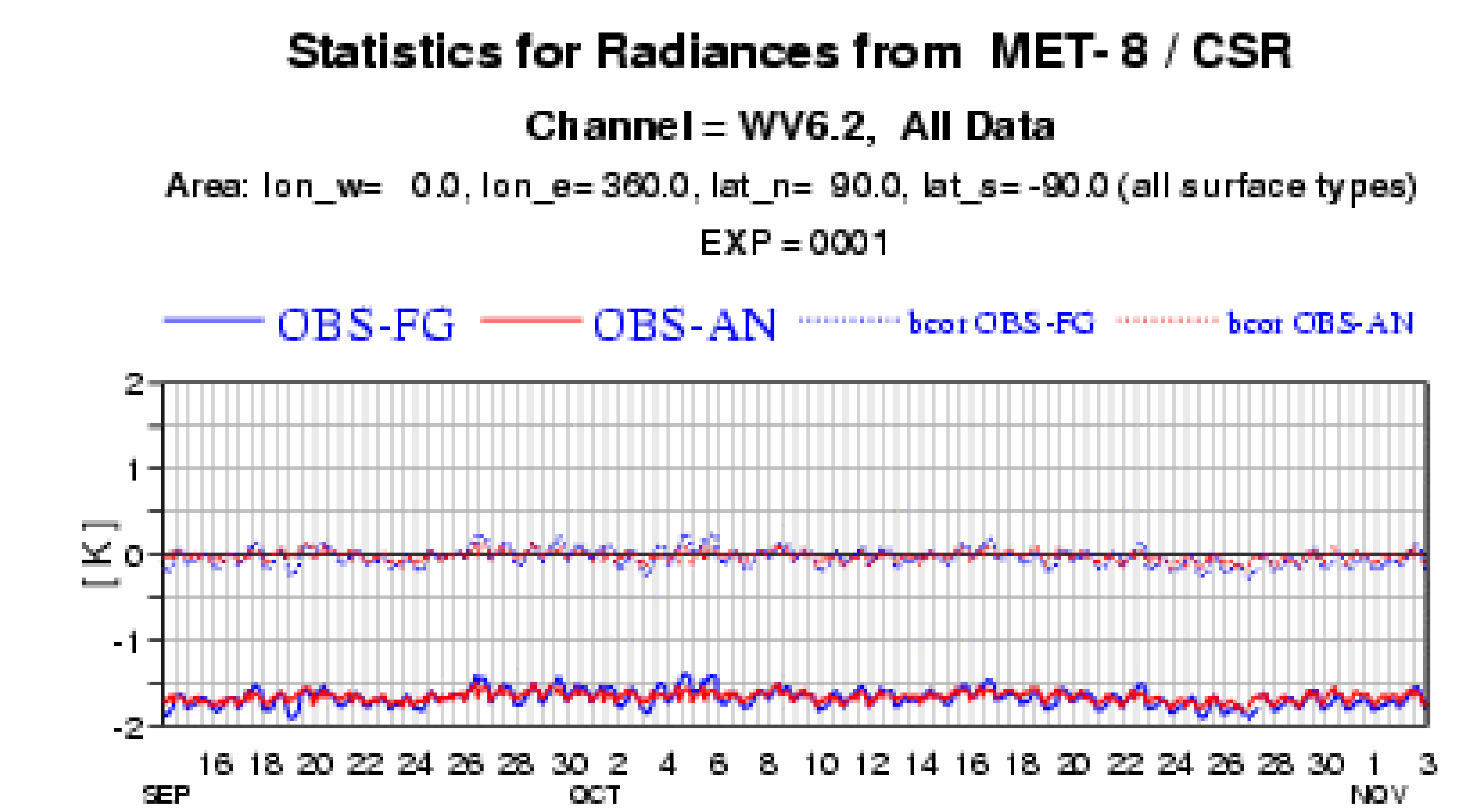
NWP SAF Monitoring



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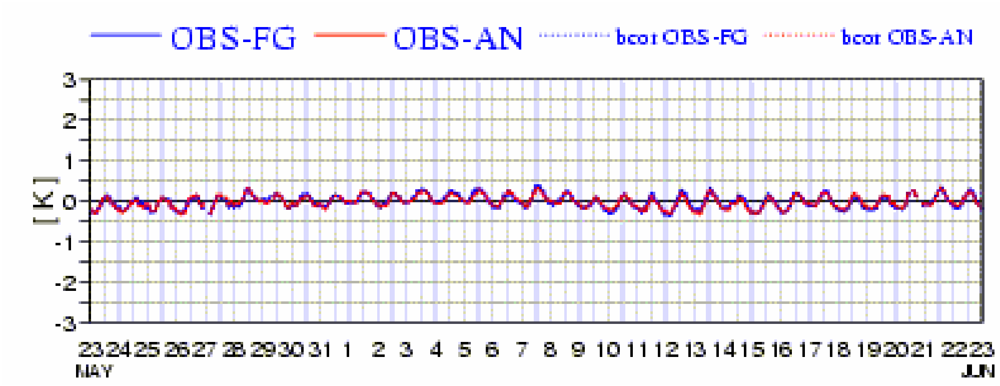
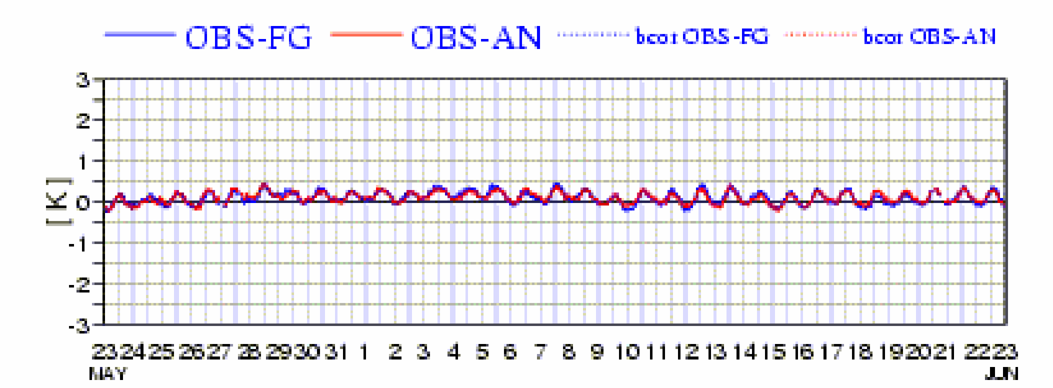
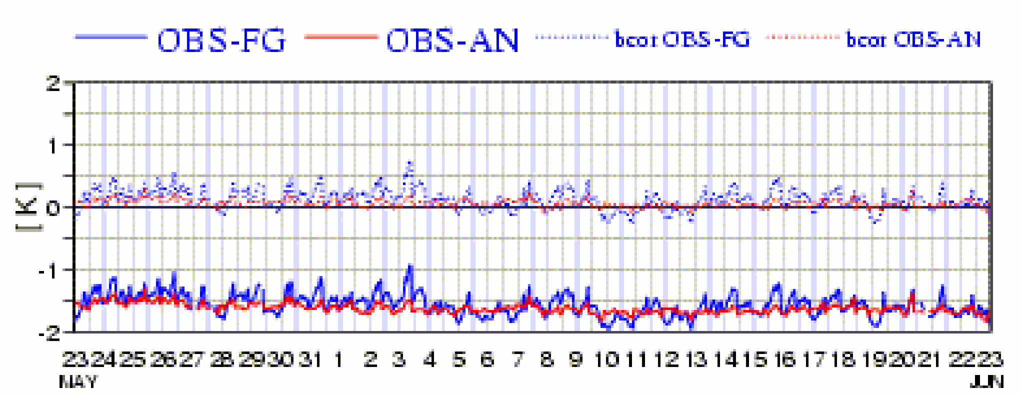
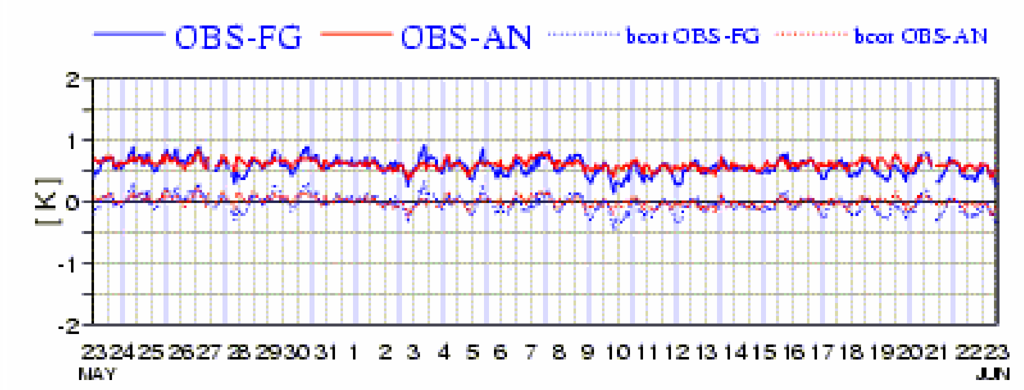
ECMWF Radiance statistics (MET-8)

100% clear (IR10.8 and 12.1 top, IR6.2 and 7.3 2 bottom)



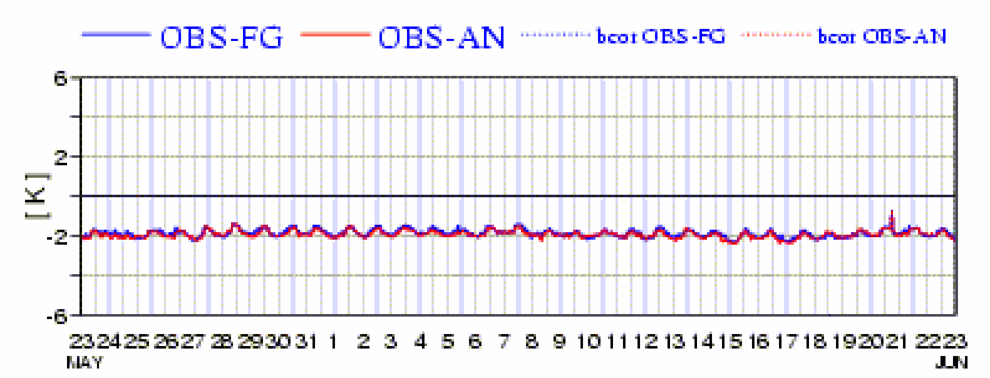


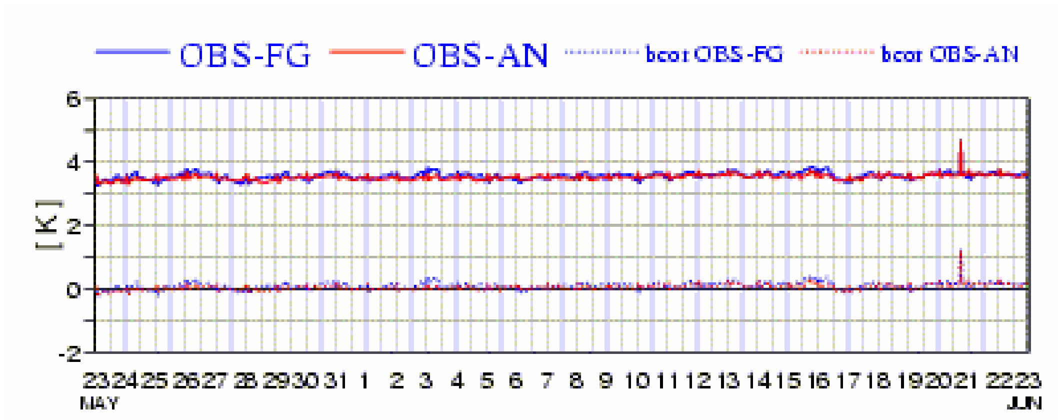


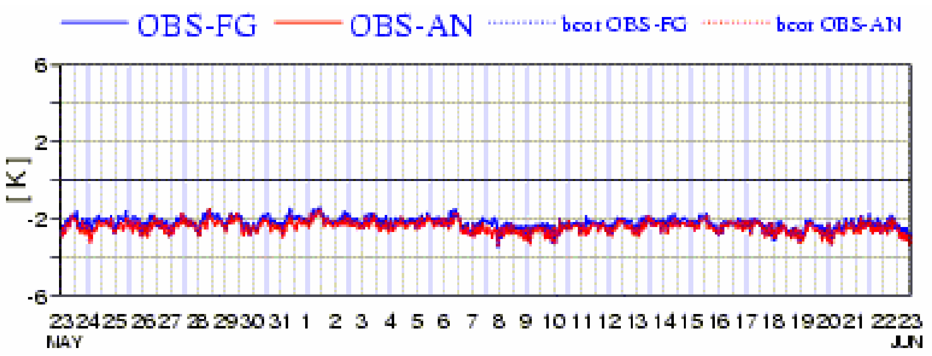


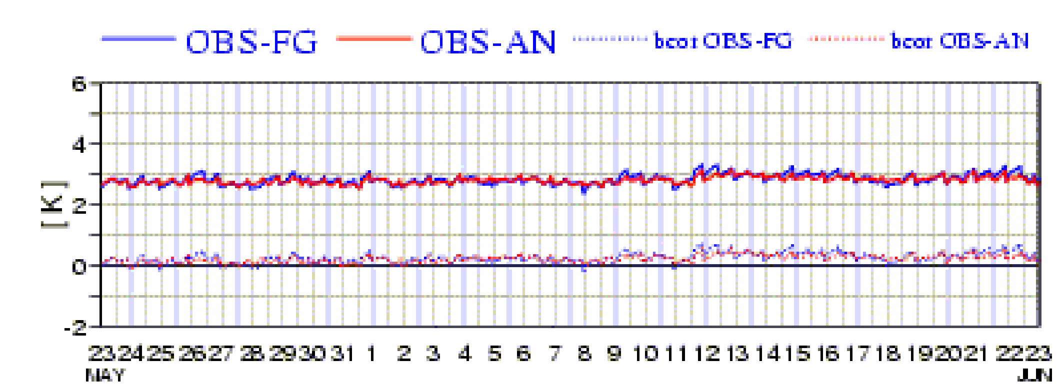
ECMWF Radiance statistics

IR and WV, 100% clear (Met-7 top, Met-5 bottom)

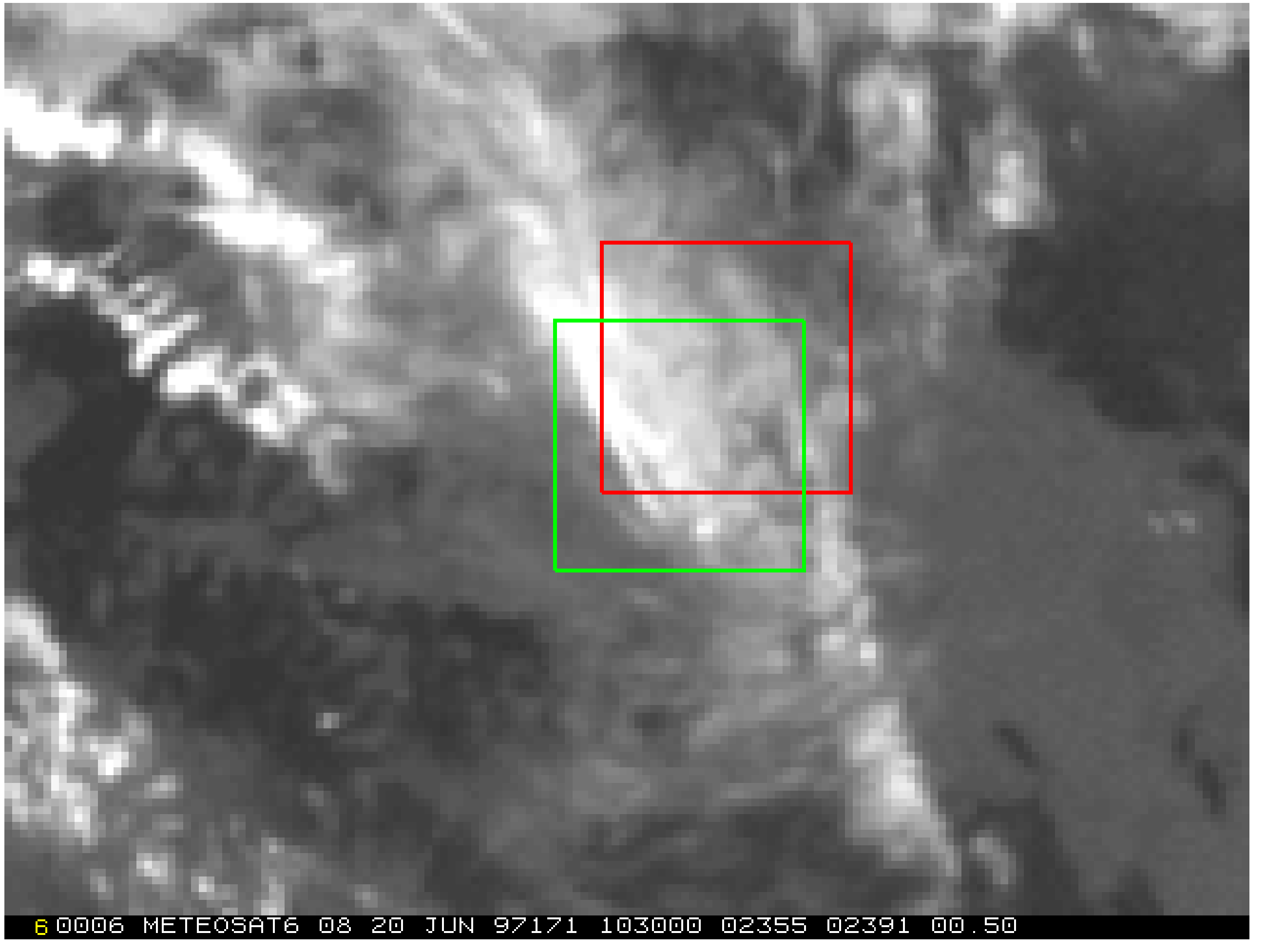




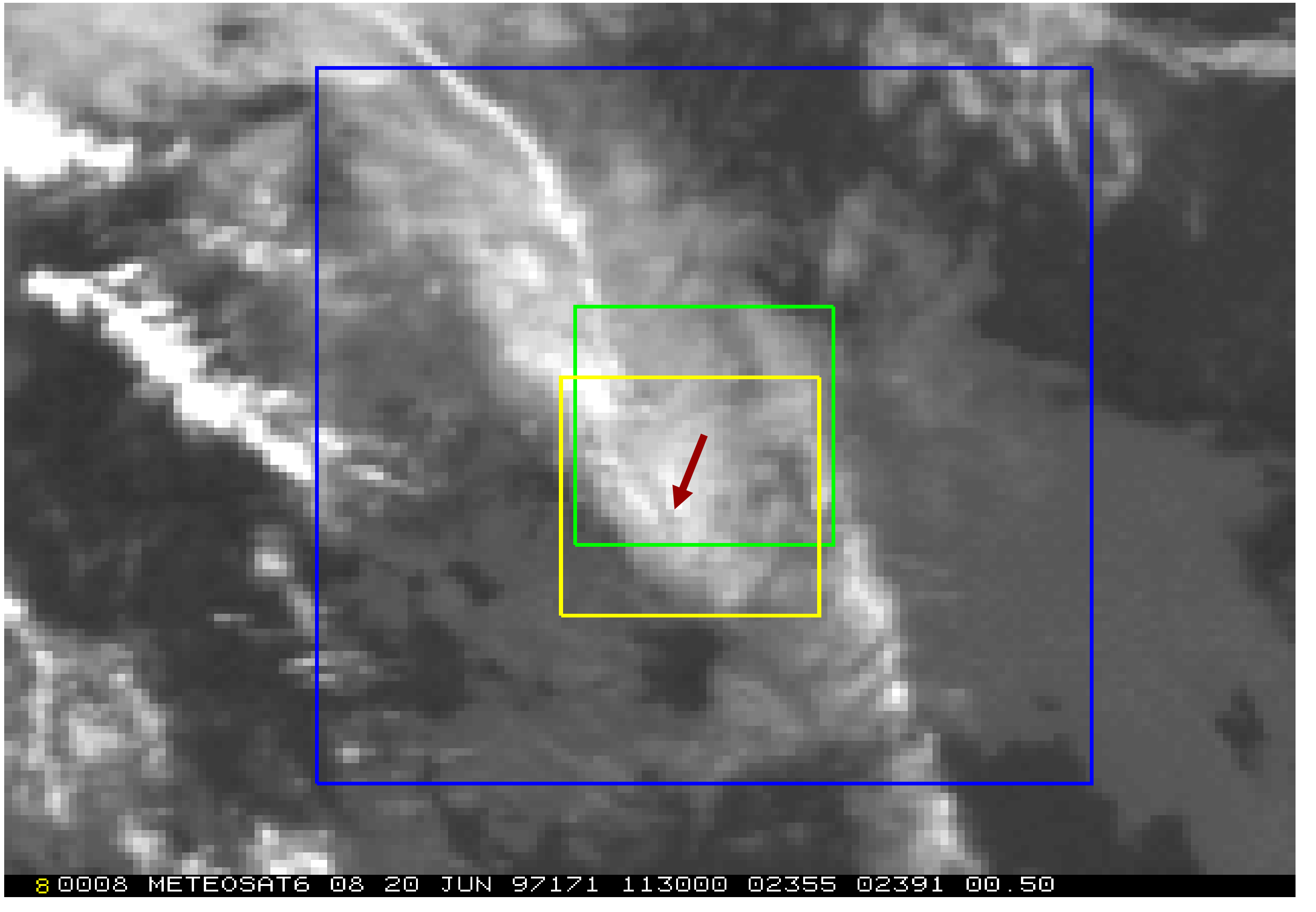




AMV Target Extraction



Tracking



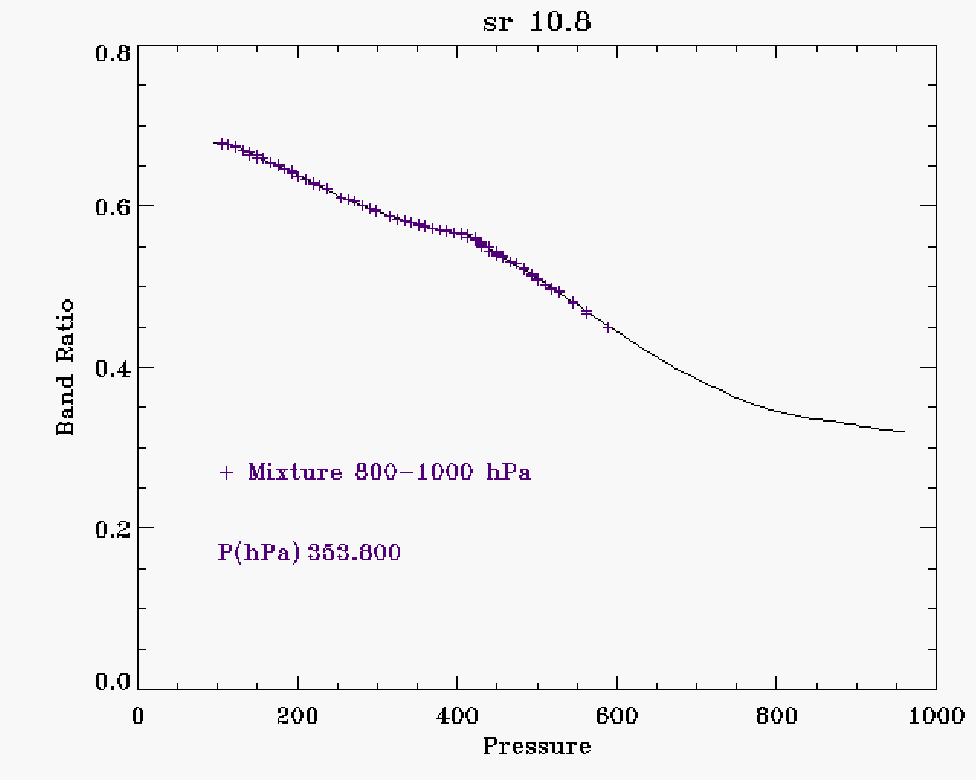
MSG AMV Height Assignment

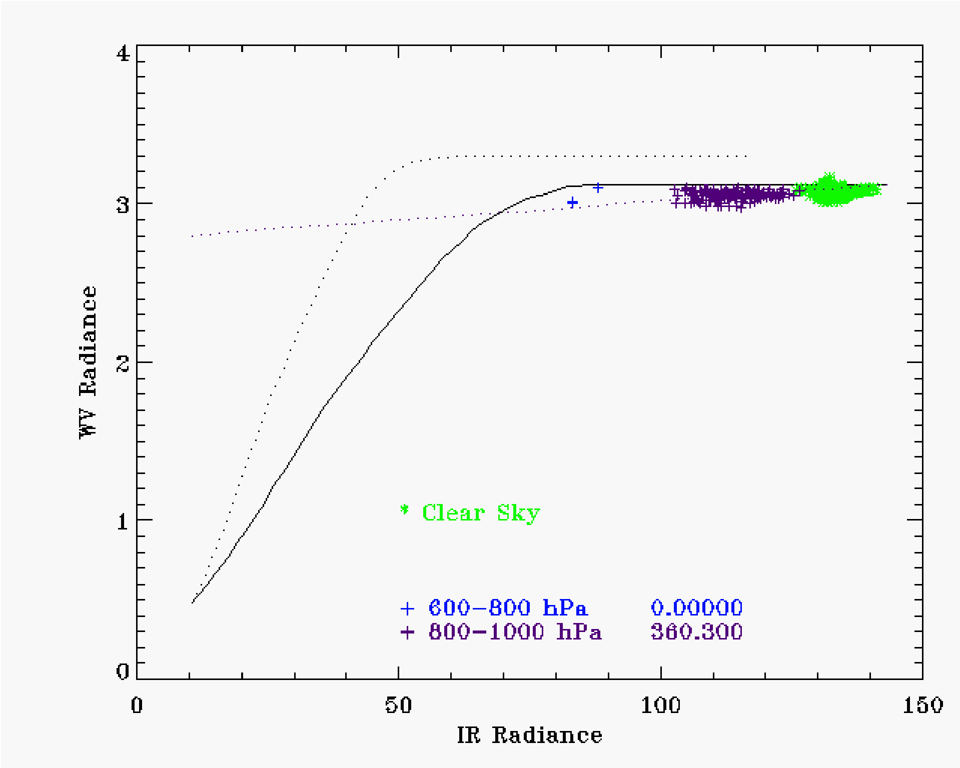
$$L_{wv} = \zeta^{ir}_{wv} L_{ir} \frac{L^{clr}_{wv} - L^{op}_{wv}}{L^{clr}_{ir} - B^{cld}_{ir}} + \frac{\zeta^{ir}_{wv} L^{op}_{wv} L^{op}_{wv} + (1 - \zeta^{ir}_{wv}) L^{clr}_{ir} L^{clr}_{wv} - L^{clr}_{wv} B^{cld}_{ir}}{L^{clr}_{ir} - B^{cld}_{ir}}$$

$$B^{cld}_{wv} \tau^{A}_{wv} + L^{A}_{wv} = f(B^{cld}_{ir})$$

$$\frac{R_{co_2} - R^{clr}_{co_2}}{R_{ir} - R^{clr}_{ir}} = \zeta^{co_2}_{ir} \frac{R^{op}_{co_2}(P) - R^{clr}_{co_2}}{R^{op}_{ir}(P) - R^{clr}_{ir}}$$

MSG AMV Height Assignment





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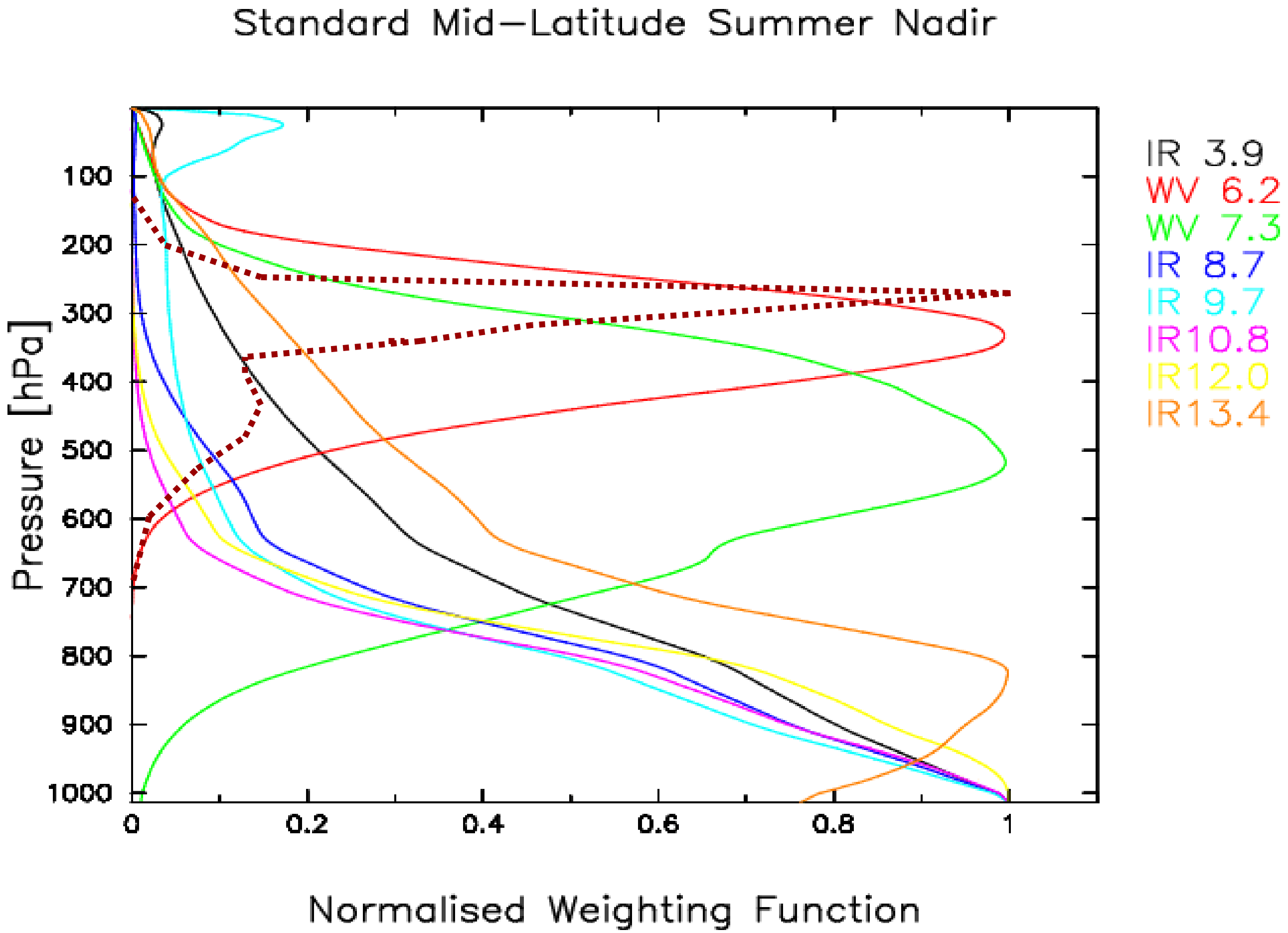
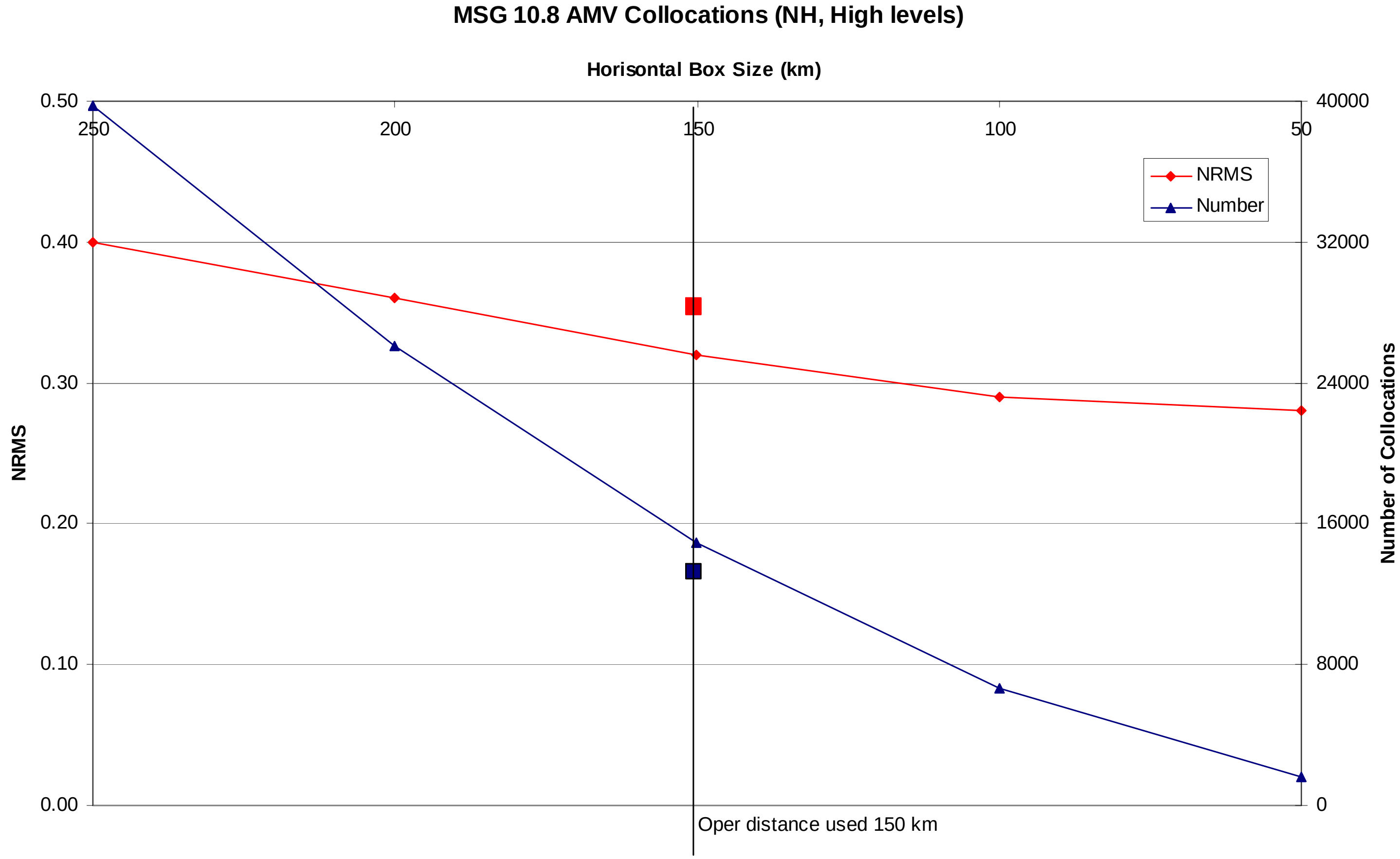
Weighting functions



Automatic Quality Control

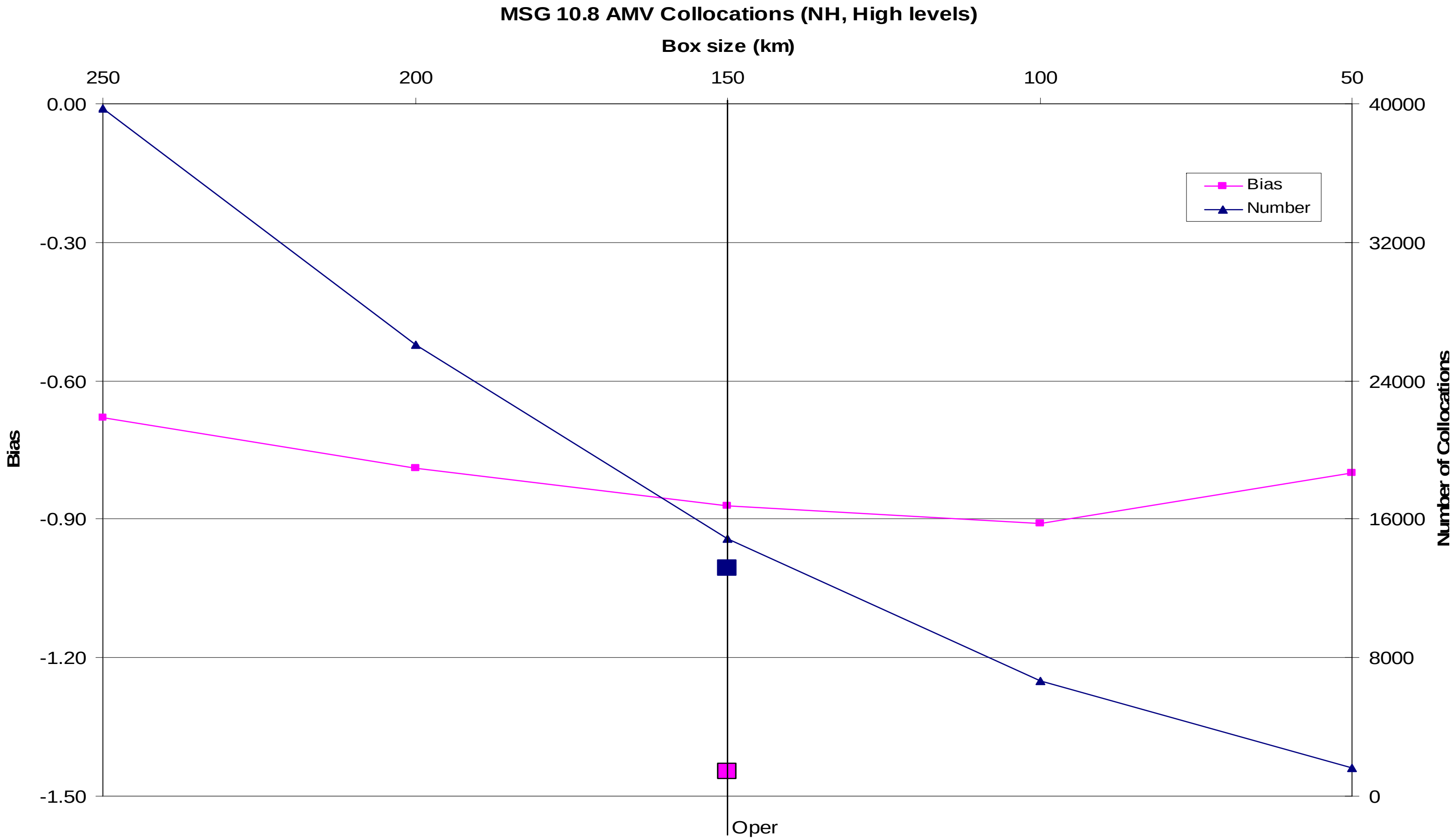
- Main goals:
  - Removal of gross errors
  - Indication of RMS error
- A set of consistency checks
- Image correlation
- Provision of a Quality Indicator
- No real height assignment QI
- Limited use for bias removal

Collocation statistics
NRMS vs collocation box size



Collocation statistics

BIAS vs collocation box size



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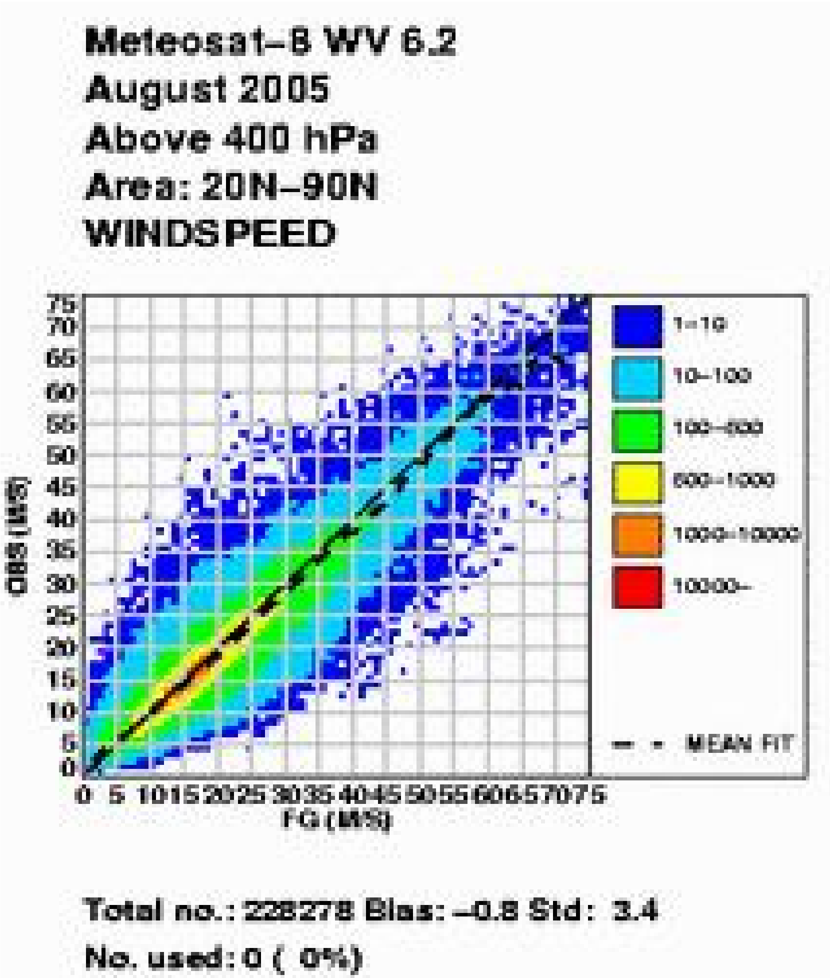
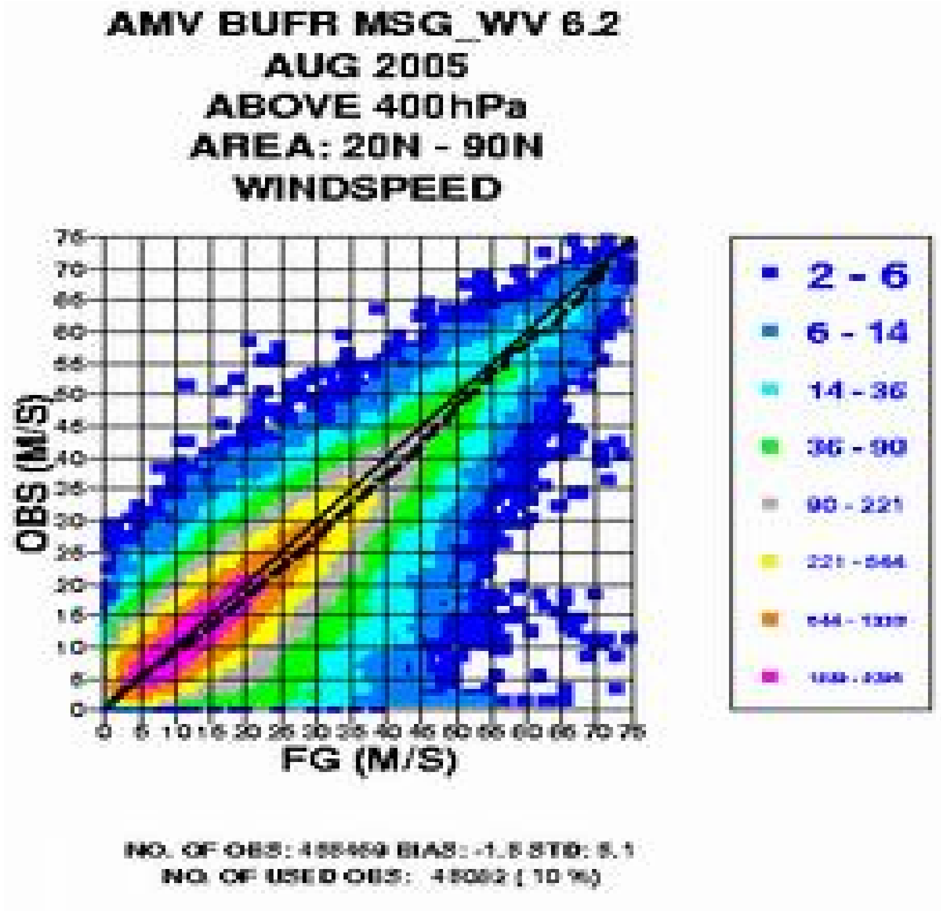
NWP Monitoring

Met Office bias: -0.8 m/s ECMWF bias -1.5 m/s





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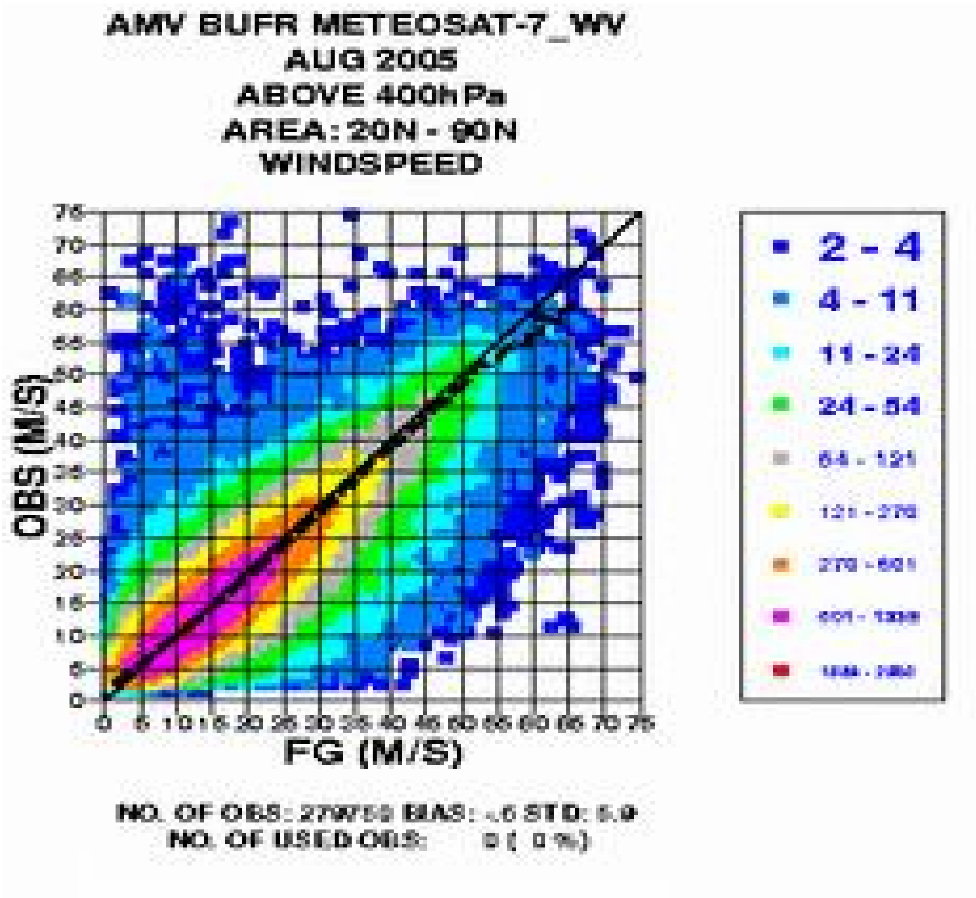
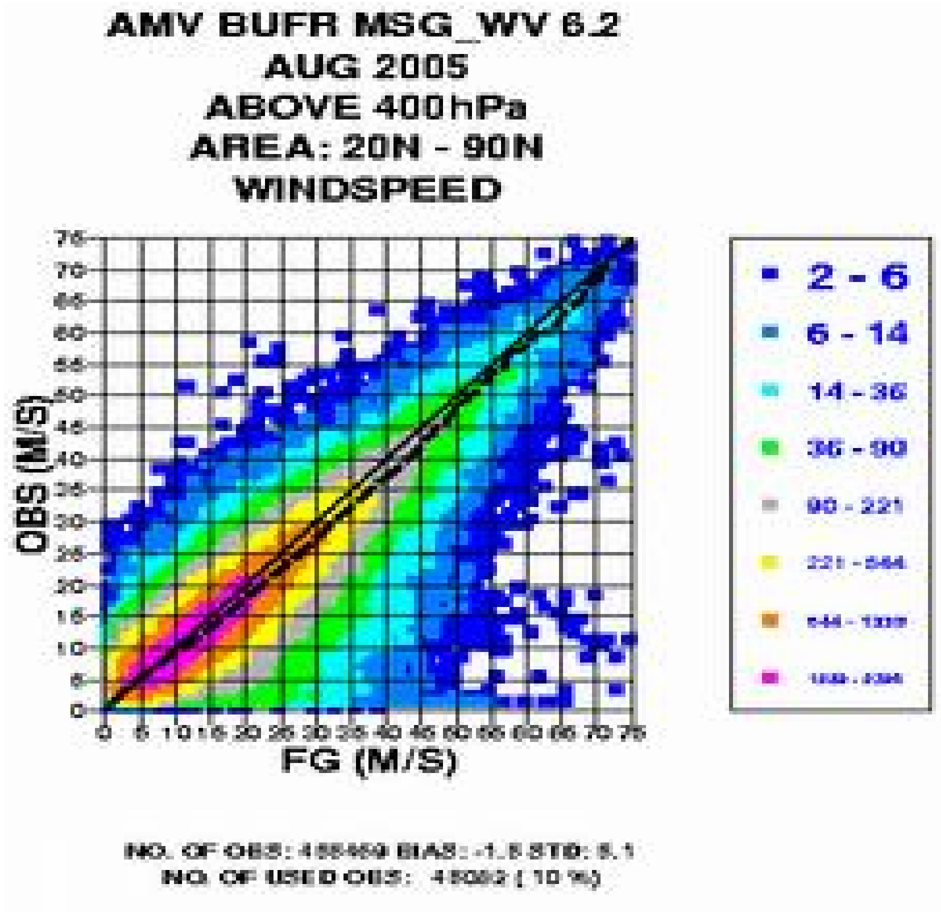
NWP Monitoring

Met-7 bias: 0.6 m/s, Met-8 bias -1.5 m/s





Reprocessing of Meteorological Products

- Using improved algorithms for better products
- Support to e.g. ERA-40 and Interim-ERA
- Re-Calibration of IR and WV Channels
- Calibration of VIS channels

- 0 Degree Service
- Meteosat-3: January till June 1989 Started
- Meteosat-3: January till April 1990 Started
- Meteosat-4: June 1989 – December 1989 Started
- **Meteosat-4: April 1990 till February 1994 completed**
- **Meteosat-5: February 1994 till February 1997 completed**
- **Meteosat-6: February 1997 till September 1997 completed**
- **Meteosat-6: February 1997 till June 1998 completed, with the exception of October 1997**
- **Meteosat-7: June 1998 till December 1999 completed**
- Meteosat-7: 2000 outstanding

- 63 Degree Service
- **Meteosat-5: June 1998 till December 2000 Started**

- ADC Service
- Meteosat-3: August 1991 till February 1993 Started

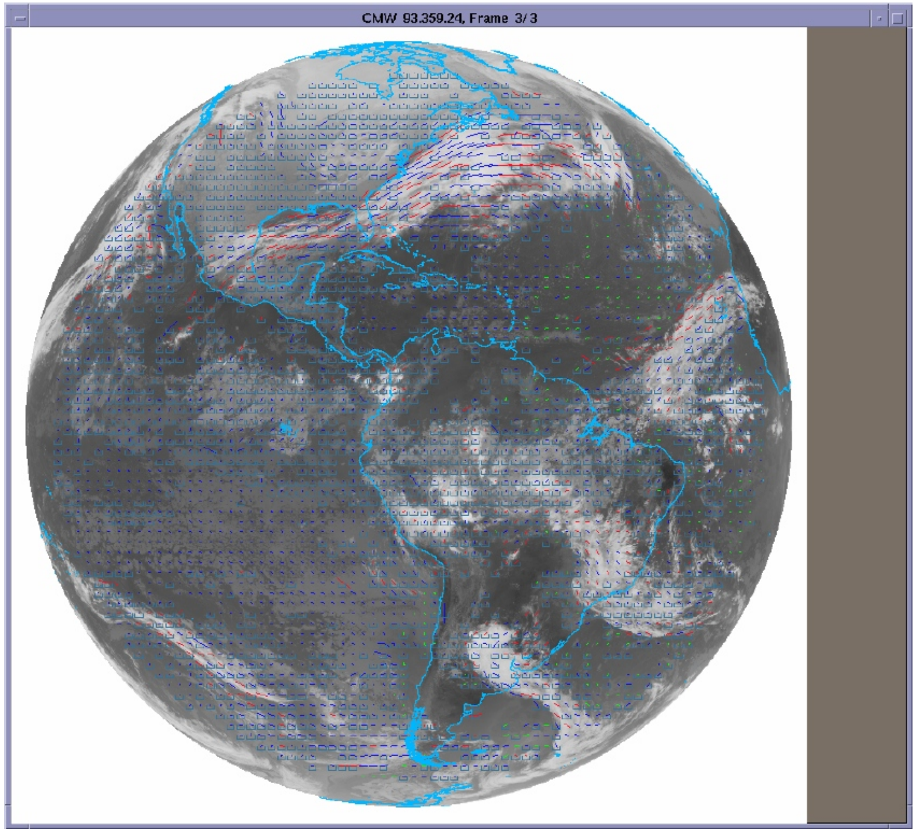
0 Degree Service
Meteosat-3: 0 Degree Service: **75.0 %** completed
Meteosat-4: June 1989 till February 1994: **71 %** completed
Meteosat-5: February 1994 till February 1997: **87.7 %** completed
Meteosat-6: February 1997 till June 1998: **94.8 %** completed
Meteosat-7: June 1998 till December 2000: **34.7 %** completed

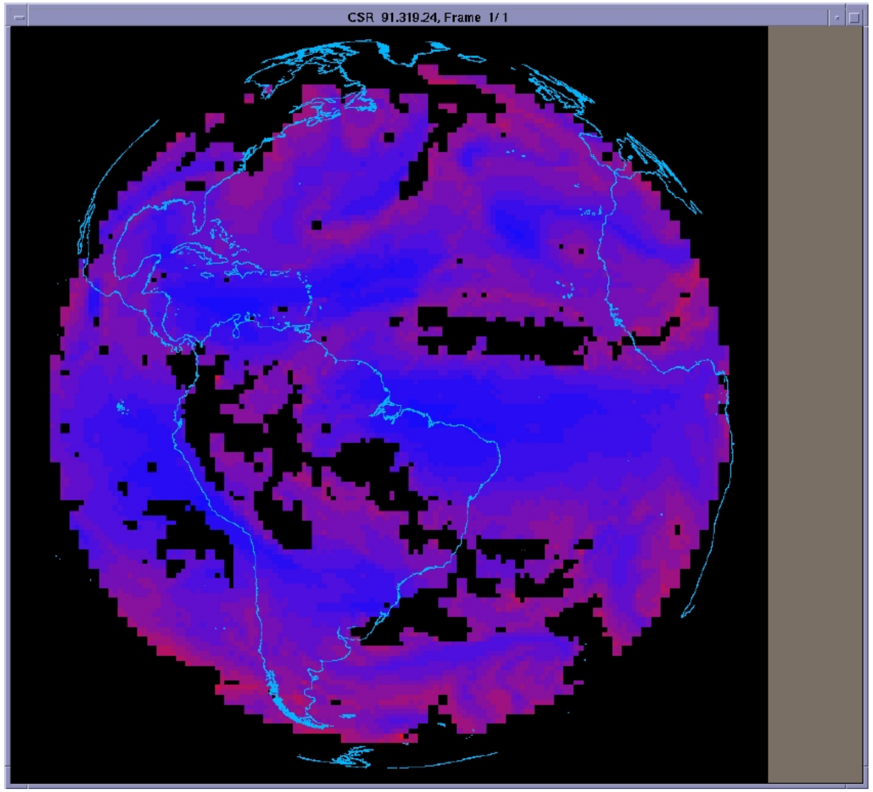
63 Degree Service
Meteosat-5: June 1998 till December 2000: **10.0 %** completed

ADC Service
Meteosat-3: August 1991 till February 1993 14 % completed

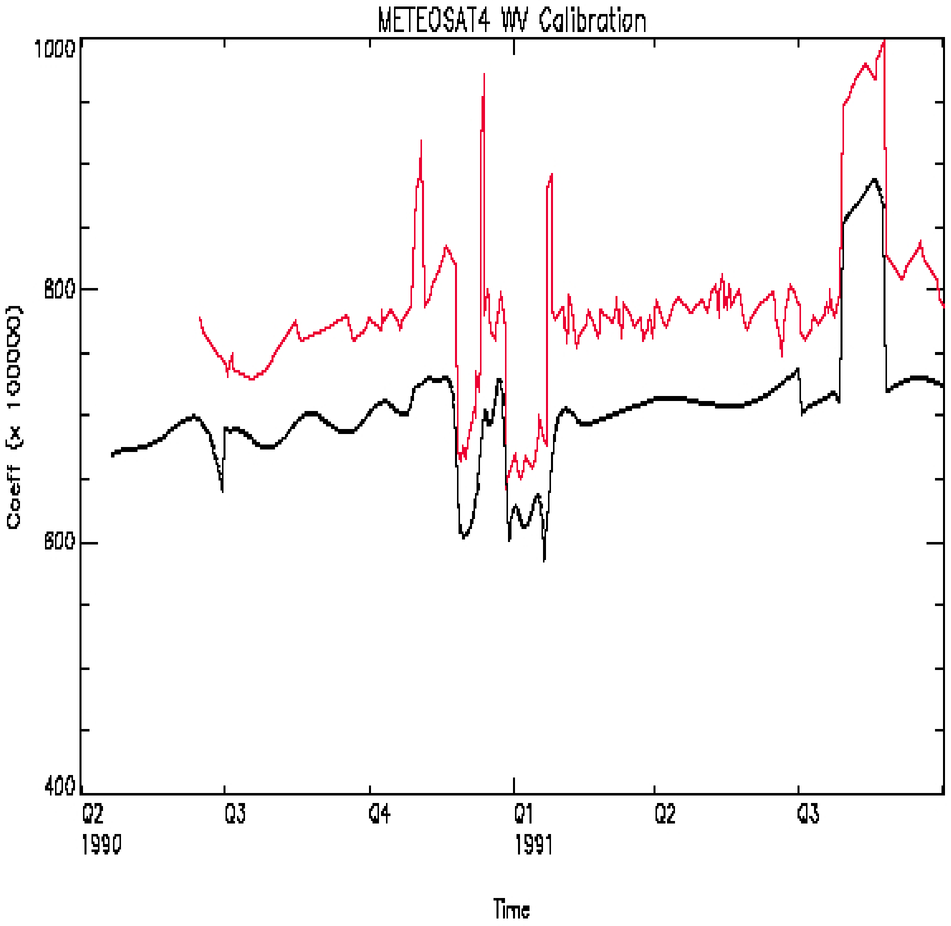
XADC Service August 1993 till May 1995 7 %

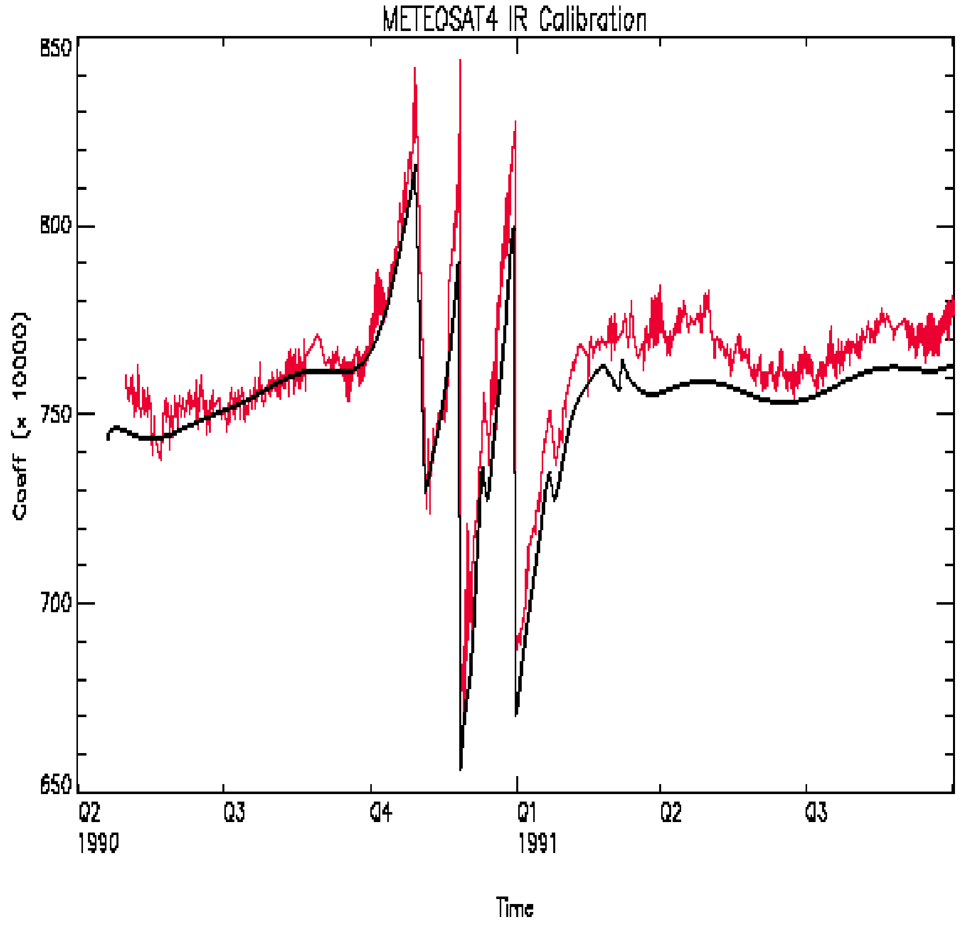
ADC and XADC processing



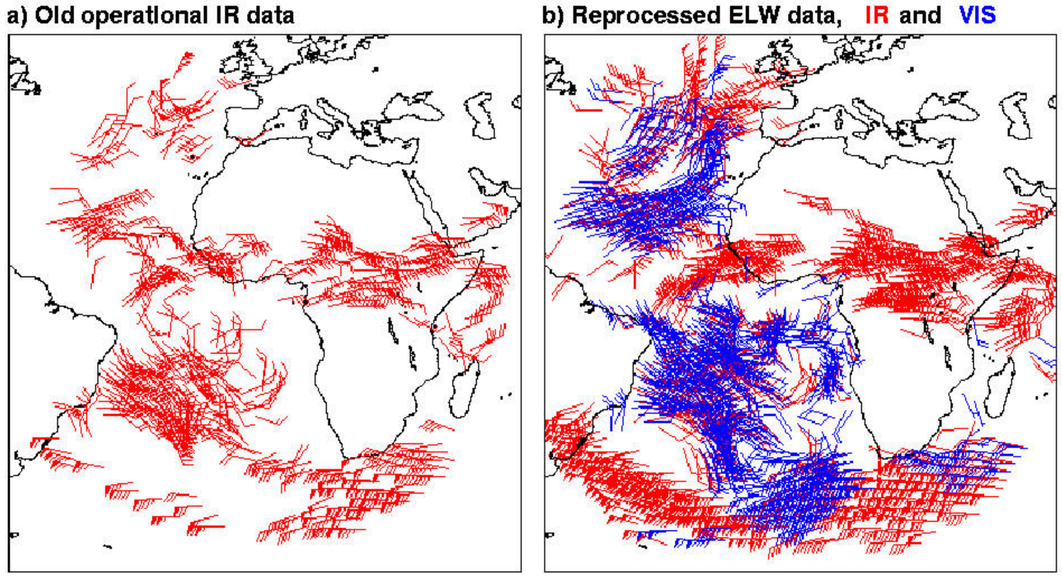


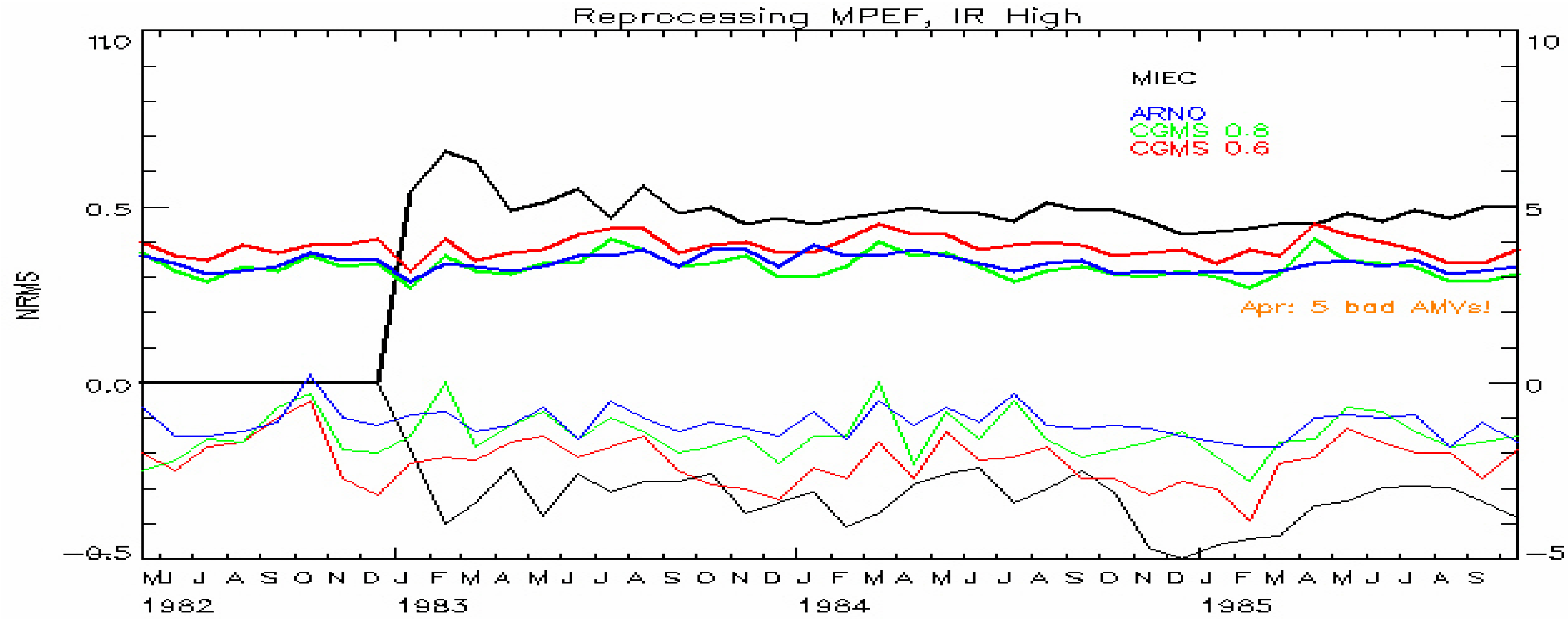
Re-calibration (reprocessing)





RMPEF AMVs


a) Old operational IR data
b) Reprocessed ELW data, IR and VIS


Reprocessing MPEF, IR High
MIEC
ARNO
CGMS 0.8
CGMS 0.6
Apr: 5 bad AMVs!
NRMS
1.0
0.5
0.0
−0.5
10
5
0
−5
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1982
1983
1984
1985

Summary

- MSG calibration bias 0.5 - 1.5 K
- MTP calibration shows significant biases (2 - 3 K)
- Cloud contamination affects CSR products (.2 K diurnal variation)

- AMV main source of error is height assignment
- AMVs are not true point measurements
- Use of forecast data enhances correlated errors?

- Rectification is generally within 1 pixel RMS, does not significantly impact NWP

Outlook

- Calibration
  - Adjustment of BB calibration model
  - Radiative transfer model
- Clear Sky Radiance Products
  - Improved cloud detection
  - Better image handling
- Atmospheric Motion Vectors
  - Improved Height assignment (Tuning, CO_2, str, moisture corrections)
  - Height assignment quality indicators
  - Observation operator improvements