Exploring algorithms for Meteosat-HIRS Inter-Calibration

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Contents

- HIRS v IASI as Inter-Calibration Reference
- Collocation criteria
- Spectral Convolution
  - Empirical Stepwise multiple regression
  - Manual Channel selection
  - Training dataset
  - Regression method
  - Model Errors
- Spatial Convolution
- Regression
- (Results)
- Conclusions

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Use of HIRS v IASI as a Reference

Meteosat Geostationary Imager

+

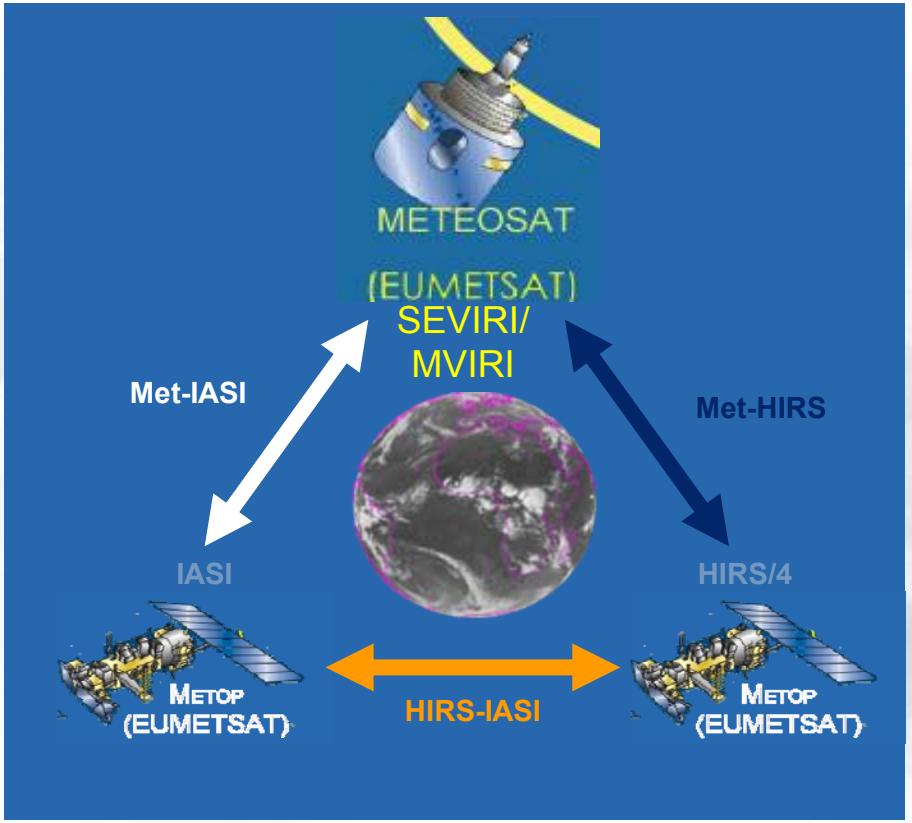
High-resolution InfraRed Sounder, HRIS, on Metop polar-orbiting satellite

Benefits of HIRS as reference:

- Established instrument
  - Operated by NOAA since 1970s
  - Used in climate records
  - Potential reference for archive data
- Includes on-board calibration
- On same platform as IASI
  - Well characterised against IASI
  - Can close inter-calibration triangle

Can cross-check with AIRS and other HIRSs:

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



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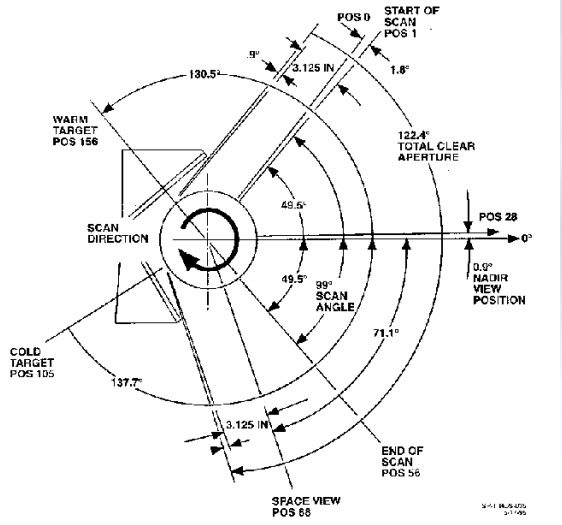
Introduction to Metop/HIRS/4

High-resolution Infrared Radiation Sounder on Metop/A in Sun-synchronous polar-orbit

19 Infrared Channels	3.8 – 15 µm
IFOV size at Nadir	10km (20km on HIRS/3)
Sampling at Nadir	26 km
Scan Rate	6.4 sec
Swath	±49.5°/56 pixels (± 1092 km)
Blackbody cal.	Every 256 sec



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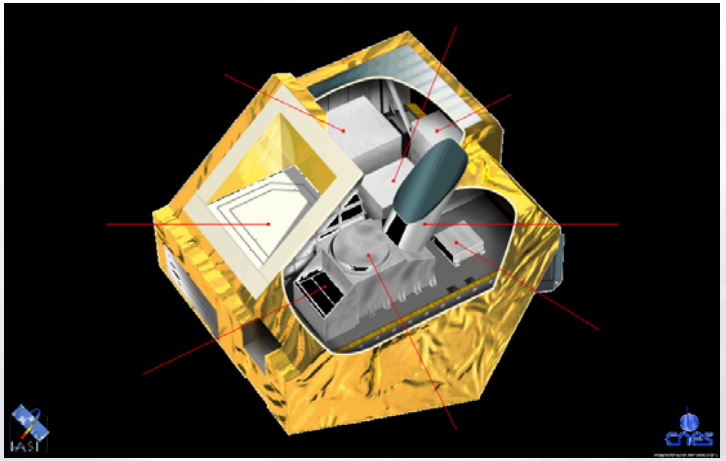
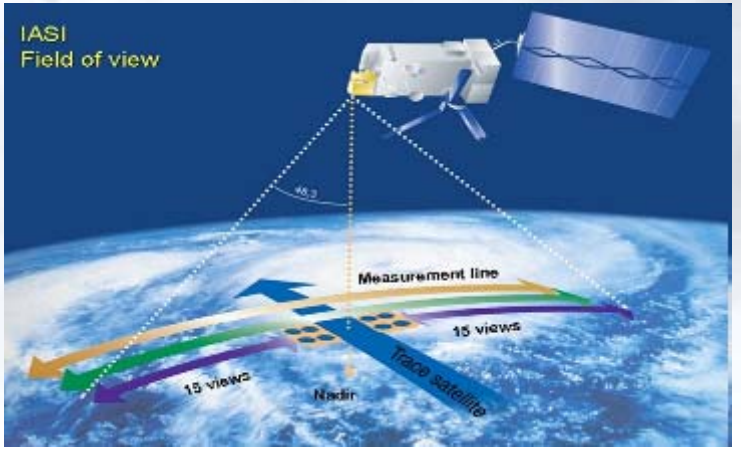
Introduction to Metop/IASI

Infrared Atmospheric Sounding Interferometer on Metop/A in Sun-synchronous polar-orbit

Spectral Range	645-2760 cm^{-1} (3-15 µm)
Spectral Sampling	0.25 cm^{-1}
IFOV size at Nadir	12 km
Sampling at Nadir	18 km
Scan Rate	8 sec
Swath	± 48.98° (± 1066 km)





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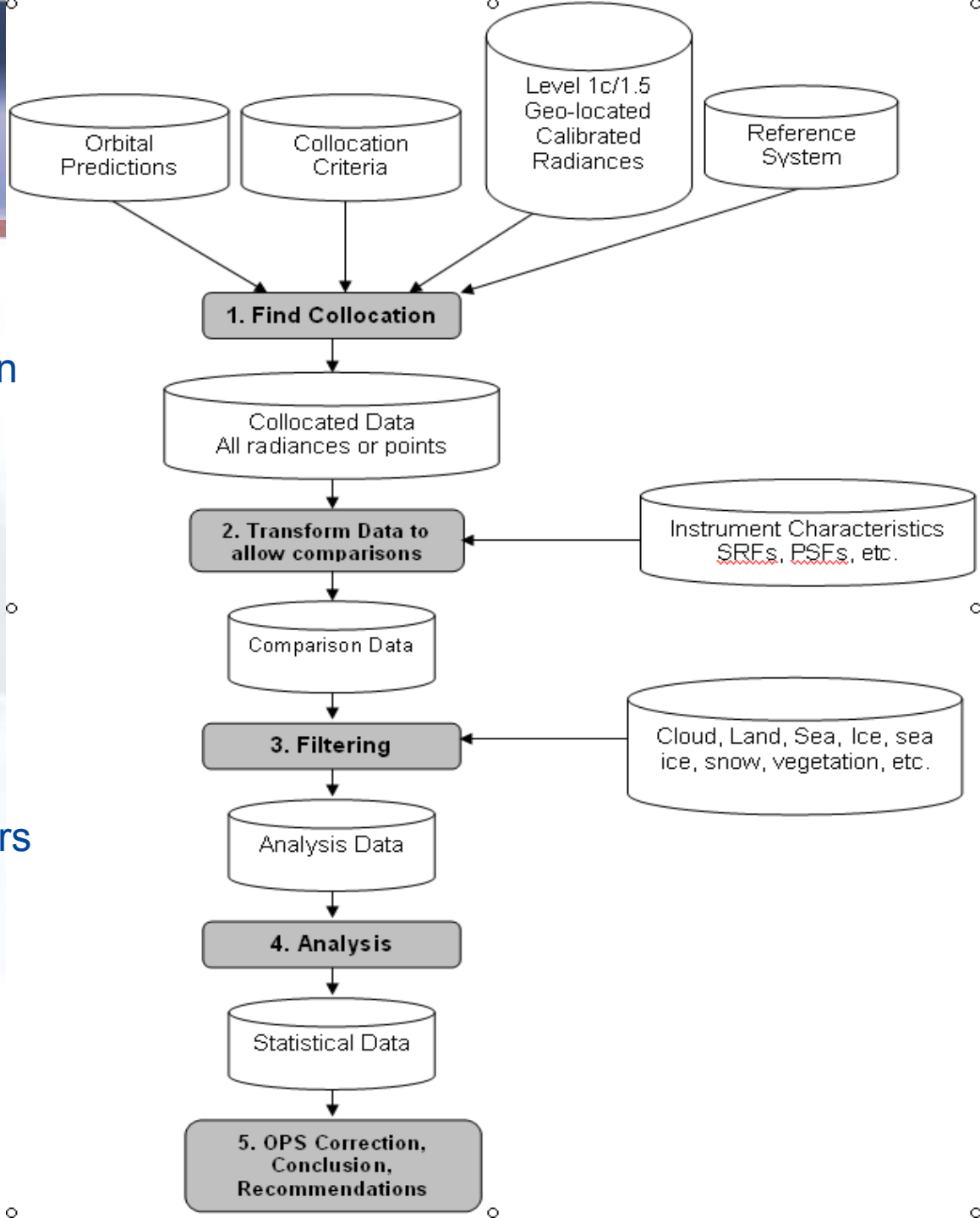
Data Processing Chain

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



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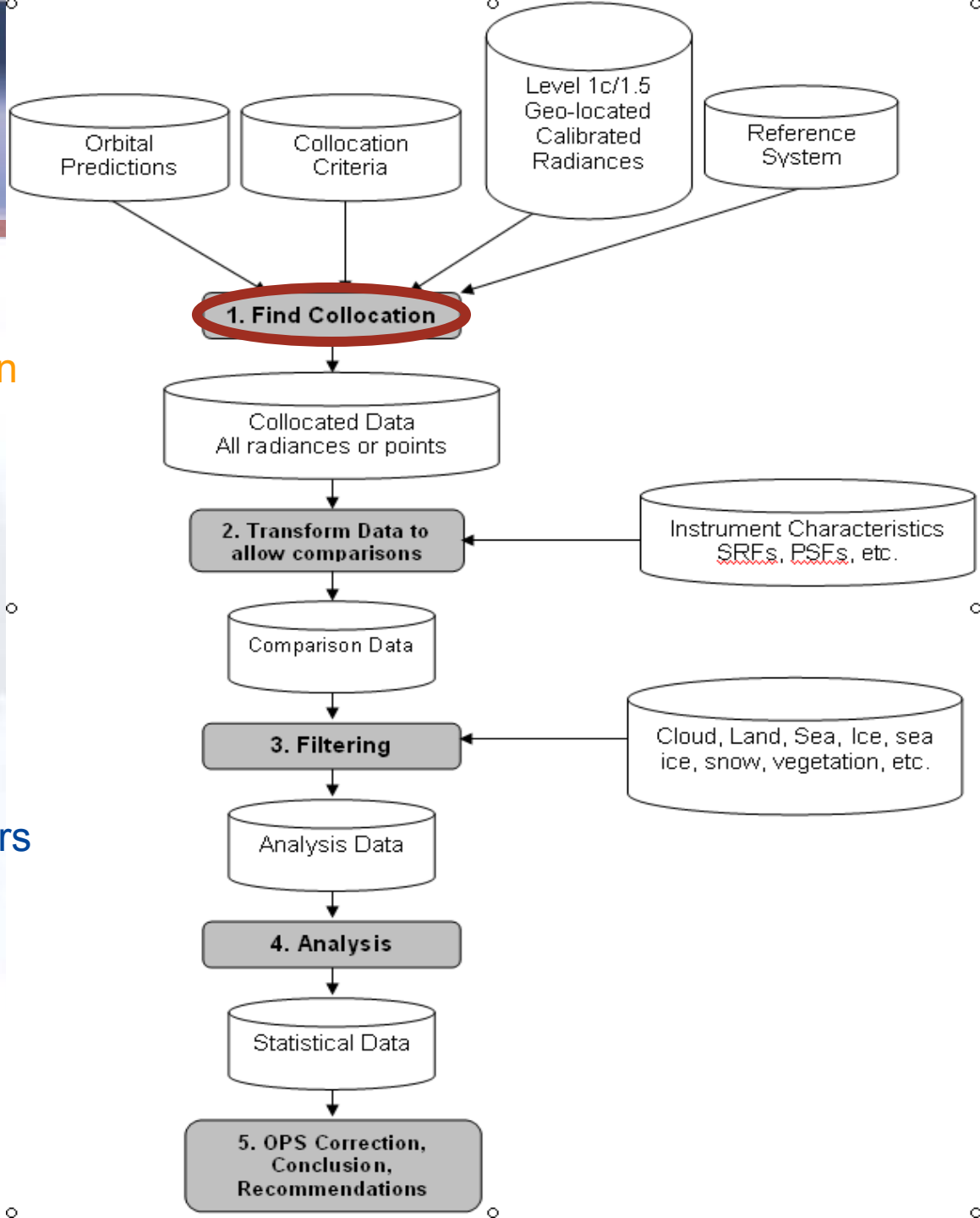


Collocation Criteria

Simultaneous near-Nadir Overpasses

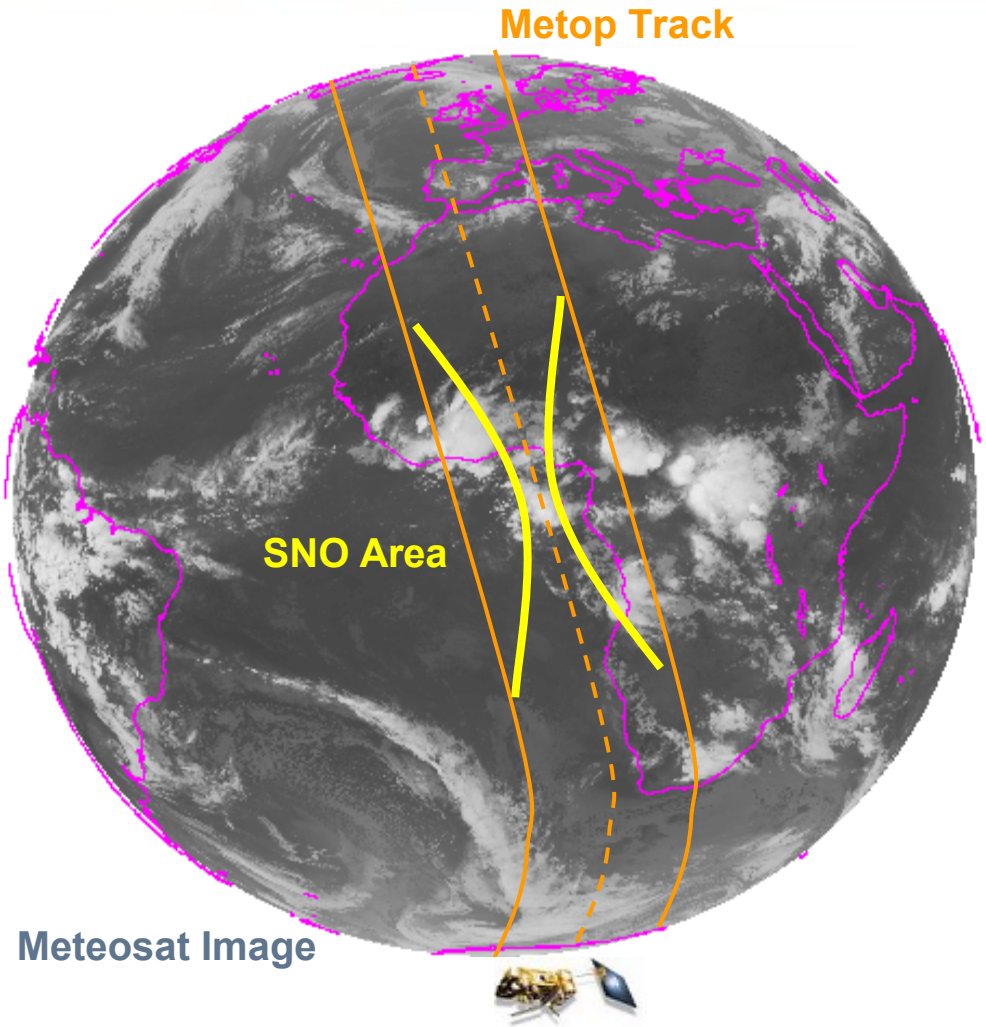
of Meteosat and Metop

- Only night-time data
- $\Delta Lat < 35°$, $\Delta Lon < 35°$ of SSP
- Δt < 15 mins (=scan period)
- $\Delta\theta < 1\%$ (Atmospheric path diff.)
- 3x3 MSG pixels / HIRS/4 iFoV

Restricts collocations to Tropics

~1 orbit/day

~200 good collocations?



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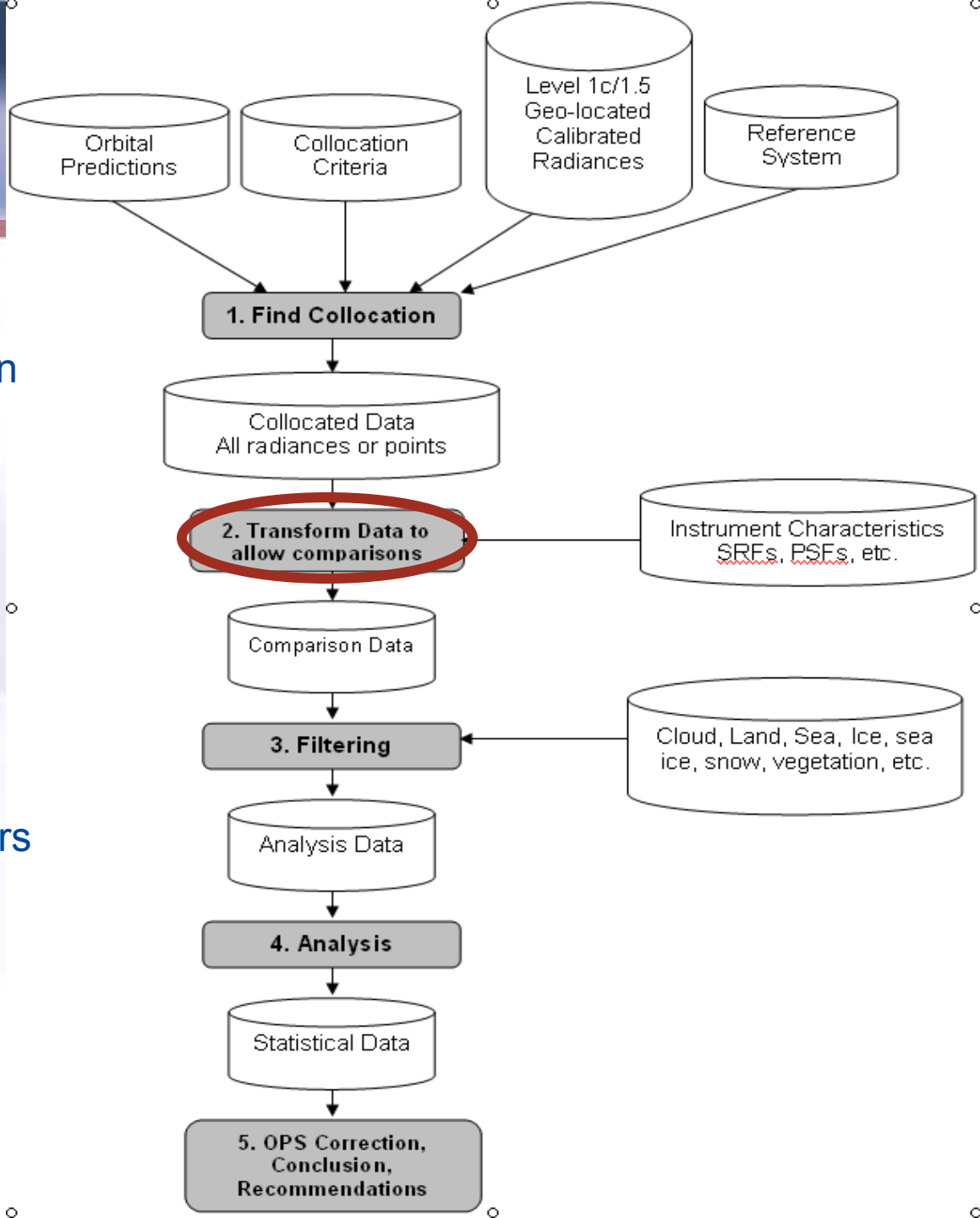
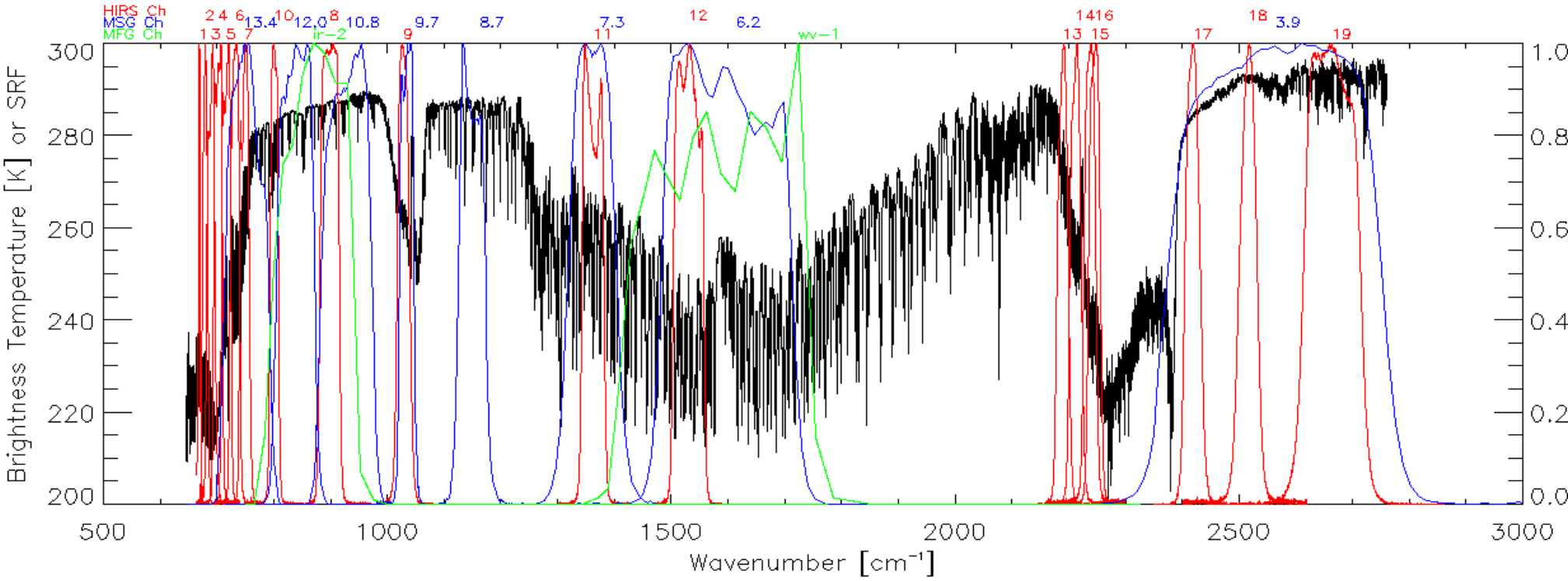


IASI T_b Spectrum + HIRS SRFs + MSG SRFs +MTP SRFs



IASI *Tb* Spectrum – Covers all HIRS IR channels

HIRS SRFs

MTP SRFs – WV Channel ~ HIRS Ch12, IR Channel ~ HIRS Ch8

MSG SRFs – 7.3 & 8.7µm Channels not covered by HIRS

Single Ch for 10.8/12.0 µm

3.9µm Ch covered by HIRS Ch17+18+19

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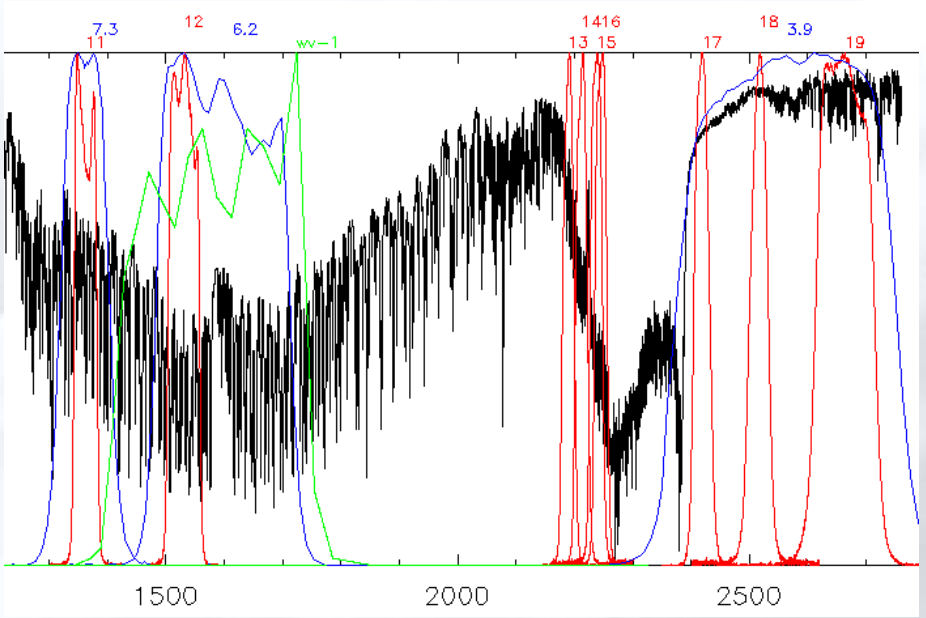
Accounting for SRF Differences

- Meteosat and HIRS have different SRFs
  - –Would introduce errors into direct comparisons of radiance
- Need to 'correct' HIRS radiances
  - – to account for spectral differences
- And/or combine HIRS channels
  - – with different weights
- Use Radiative Transfer Model (RTM)
  - – to generate synthetic radiances
  - – for Meteosat & HIRS
- Calculate coefficients by regression
  - – and uncertainty introduced
  - – compare this uncertainty with variability



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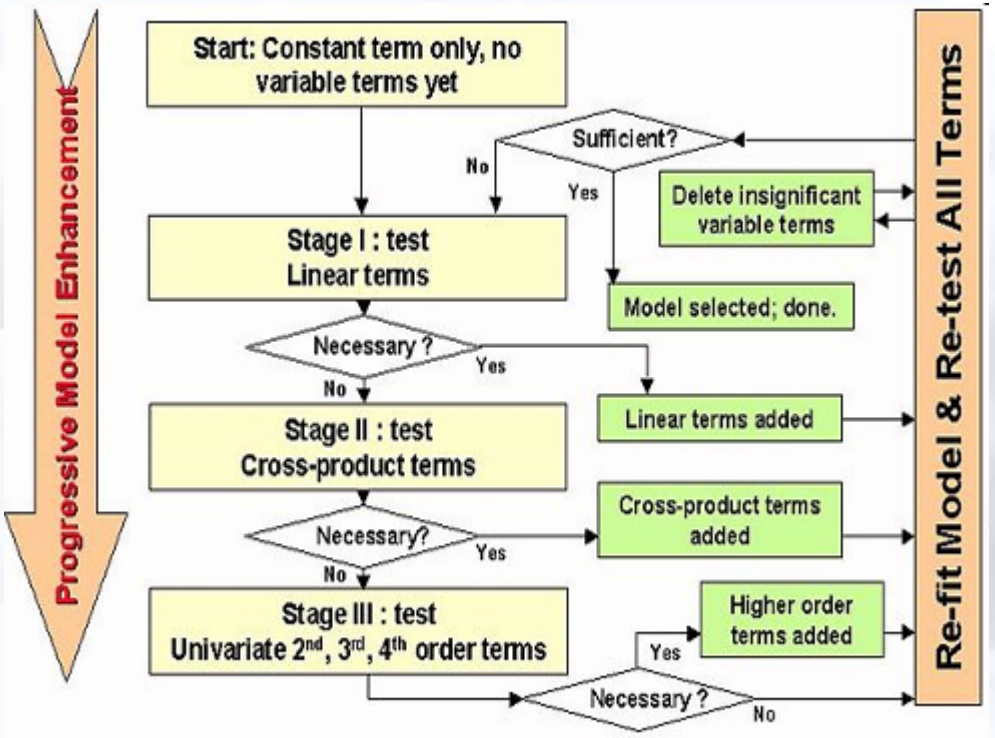
Stepwise Regression to Select Channels

- Attempted Stepwise Regression
  - to select channels match-ups
  - and estimate relative weights of each HIRS channel to simulate each Meteosat channel
  - Completely empirically
  - Results are obviously nonsense!
  - e.g. MSG 3.9µm channel fitted HIRS Ch18,13,5 & 11 (not 17&19)
  - Some HIRS channels can be given negative weights

- However, stepwise regression may be a useful tool to analyse results
  - e.g. dependence of bias on scan angle, latitude, time of day, phase of moon, etc.



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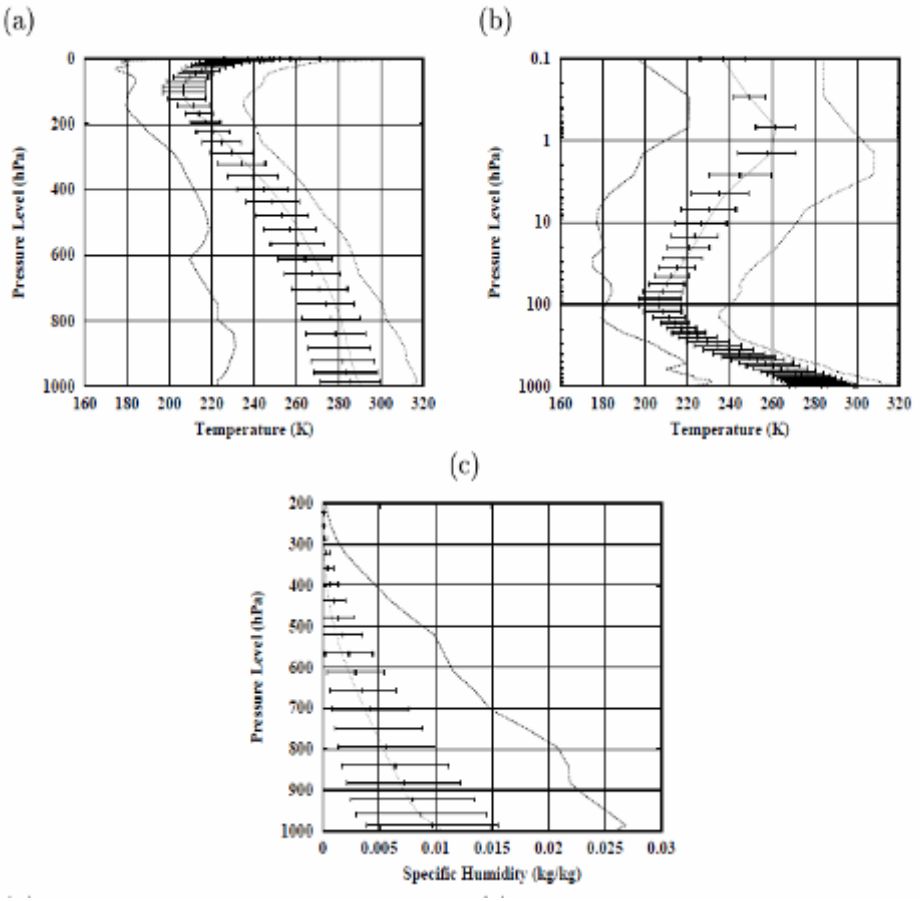
Selecting Channels for Comparison 'Manually'

MTP MVIRI	x	WV	x	x	x	IR	x	x
HIRS	x	Ch12	x	x	x	Ch8	x	x
MSG SEVIRI	3.9µm	6.2µm	7.3µm	8.7µm	9.7µm	10.8µm	12.0µm	13.4µm
HIRS	Ch17 Ch18 Ch19	Ch12	Ch11	N/A	Ch9	Ch8	Ch8	Ch7

Training Dataset to Calculate Correction Coeff.s

- RTTOV-9 Radiative Transfer Model
- Diverse 52 profiles at 60 levels
  - From ECMWF (Chevallier'01)
  - Temperature, Water Vapour and Ozone
  - Covers global range
  - Represents natural variability
- Duplicate profile set:
  - 1 set for clear sky
  - 1 set with mid-level cloud (700hPa)
  - 1 set with high cloud (100hpa)
- Run RTM twice at incidence angles:
  - Zenith
  - 60°



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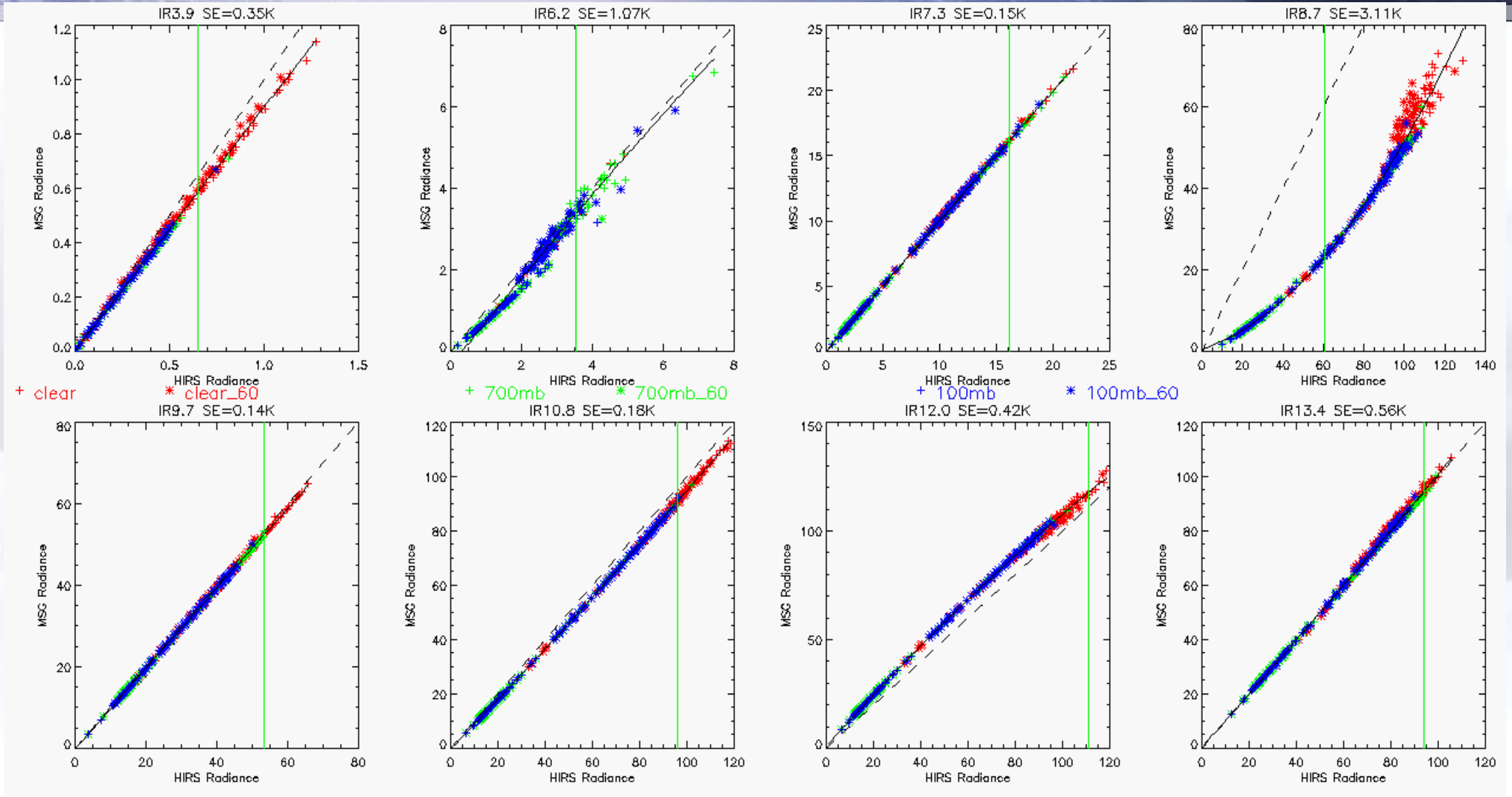
Quadratic Regression



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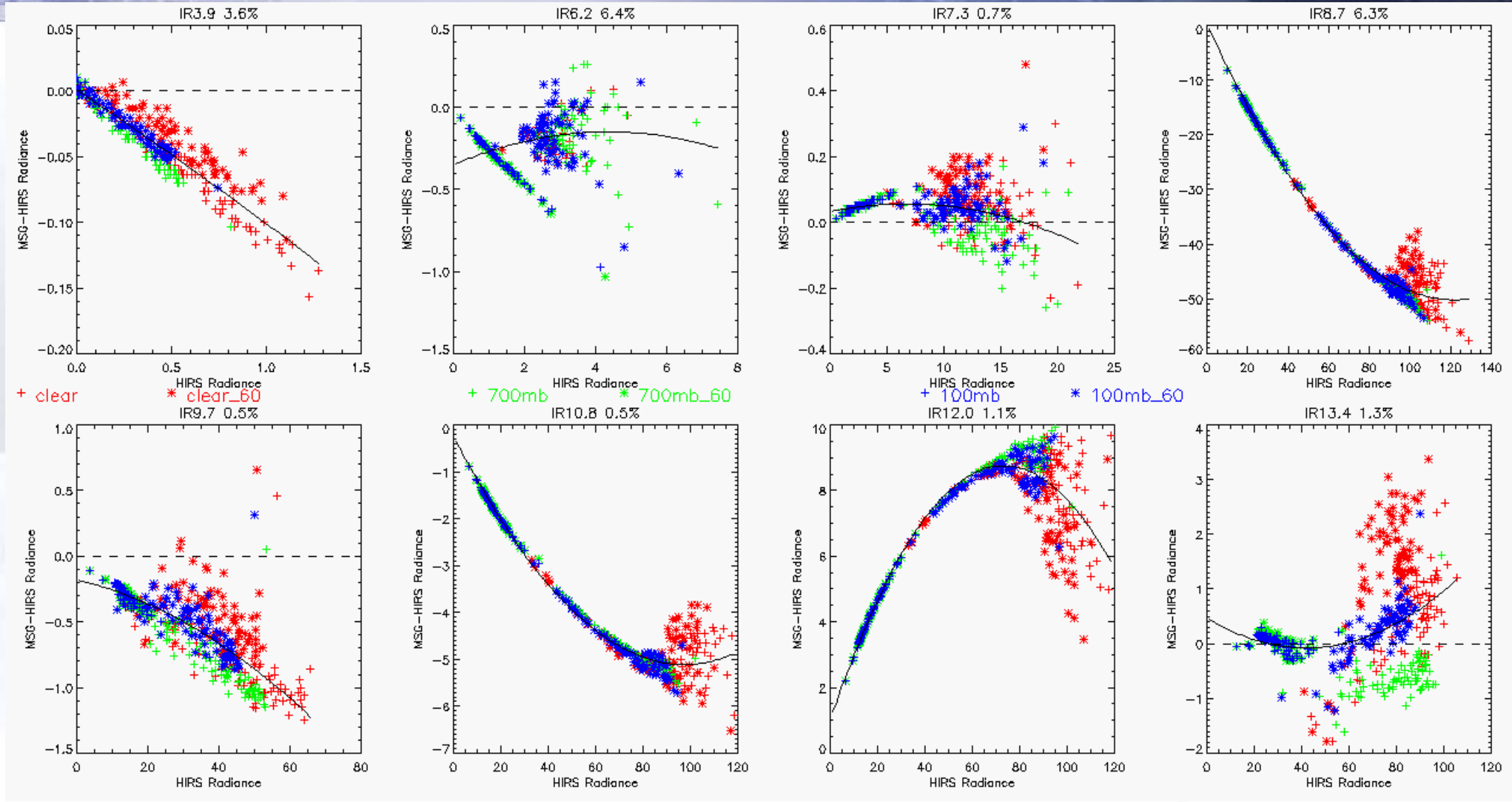
Quadratic Regression - residuals



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Regression Results

- Quadratic Regression gives better fit for IR10.8 and IR12.0
- IR6.2 show large scatter in clear sky (also IR3.9 in cloud)
  - IR6.2: Systematic difference between nadir and 60° views (WFs)
- IR8.7 doesn't match any HIRS channel – nonsense results
- Largest scatter in clear sky cases (most spectral information)
- Could improve fit by excluding arctic data
- Should validate using independent test dataset
- Should calc uncertainty at L_{ref} using coefficients full covariance
- Noise < Model Error < ~ Variability on single collocation
  - But, correlation in model errors between collocated pixels…

Compare Model Error with Variability

- Variability for 8 IR channels of MSG
  - *RMSDt*(Δt=15min)
  - *RMSDx*(Δx=10km)
  ≈ *RMSDy*(Δy=10km)
  Reduced by $\sqrt{n_{col}}$ e.g. n_{col}=100
- Model error >> Variability for
  - IR6.2 (different weighting functions)
  - IR8.7 (no HIRS equivalent)
- Model error ~ Variability
  - for other SEVIRI channels
  - Expect increased noise on inter-calibration results by ~$\sqrt{2}$

MSG SEVIRI Channel [µm]	Temporal Variability $RMSD_t$ (Δt=15min) /$\sqrt{100}$ [K]	Spatial Variability $RMSD_x$ (Δx=10km) /$\sqrt{100}$ [K]	MSG-HIRS Modelling Error [K]
3.9	0.30	0.25	0.35
6.2	0.08	0.12	1.07
7.3	0.17	0.22	0.15
8.7	0.32	0.40	3.11
9.7	0.19	0.30	0.14
10.8	0.35	0.40	0.18
12.0	0.36	0.40	0.42
13.4	0.25	0.30	0.56

Temporal and Spatial Variability of Meteosat brightness temperatures on scales of 15 min and 10 km, respectively, compared with MSG-HIRS modelling error.

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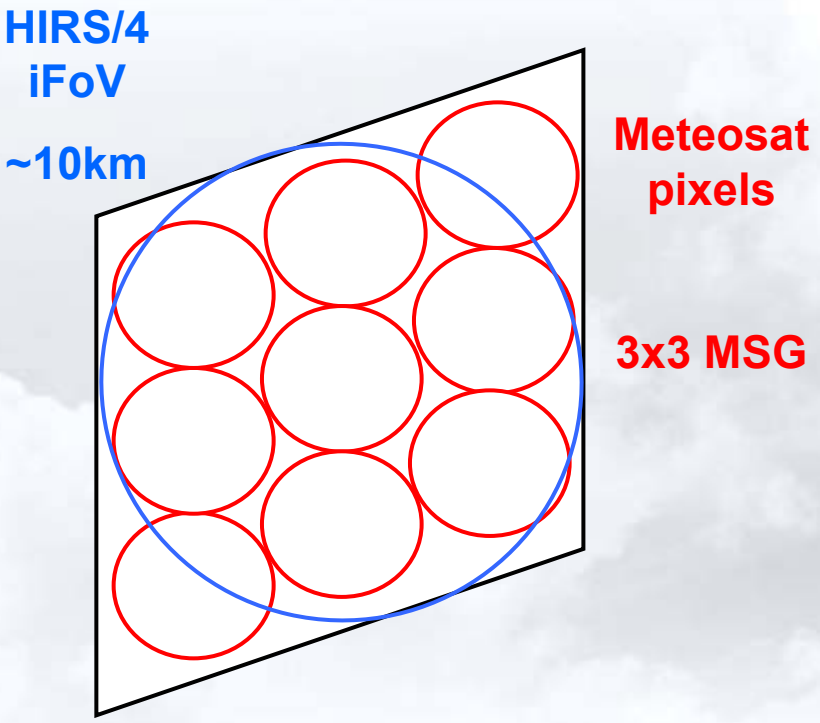
Spatial Averaging

Average Meteosat pixels within each HIRS iFoV

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

Use in weighted regression



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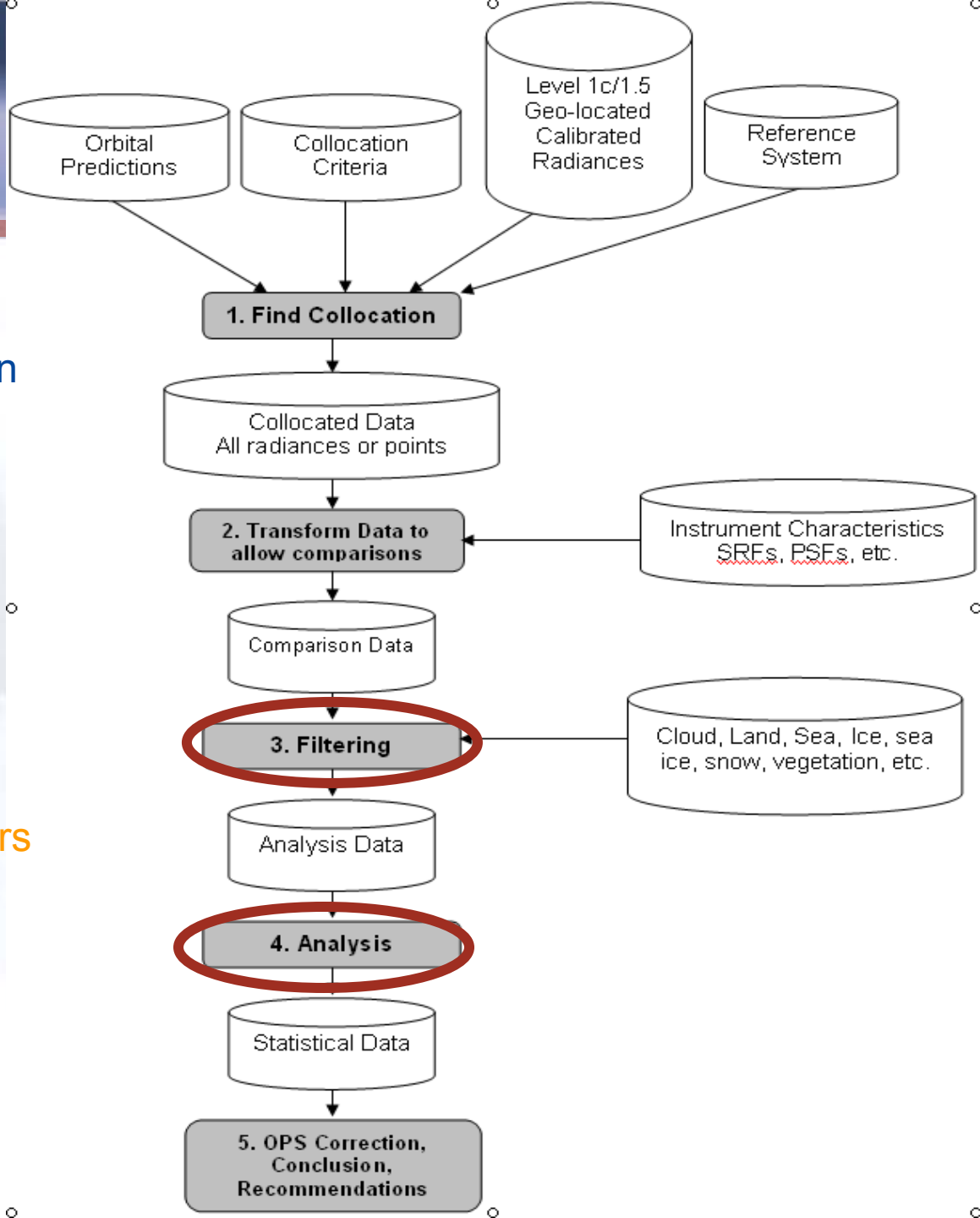

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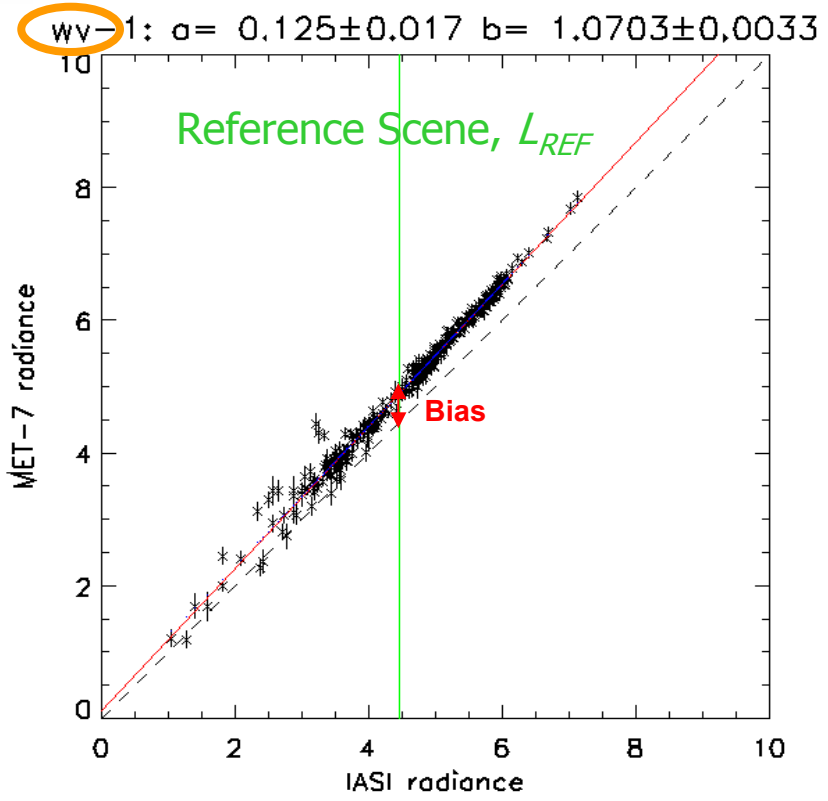
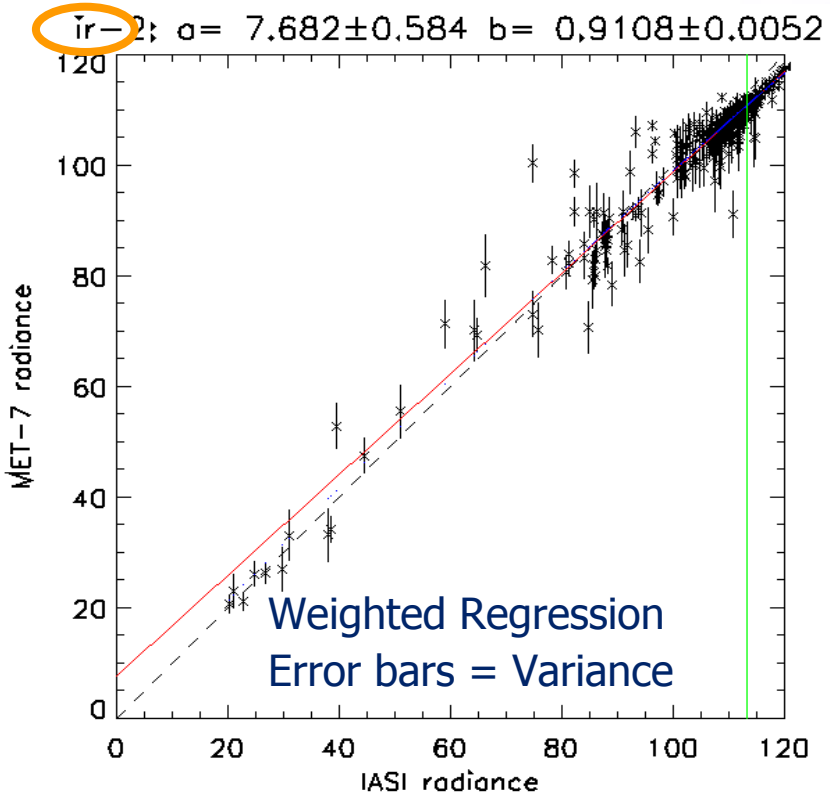
Regression

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





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

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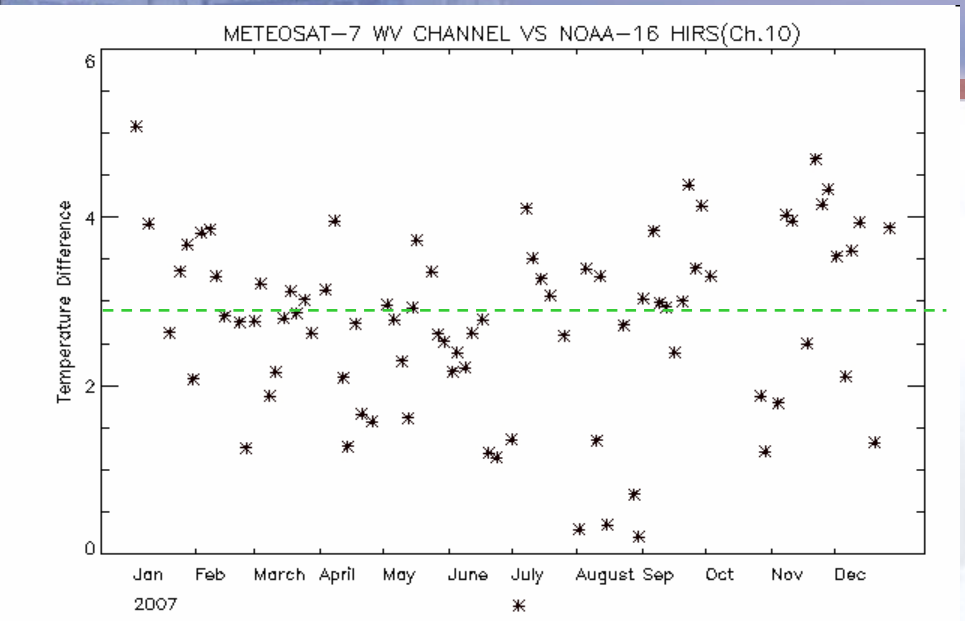
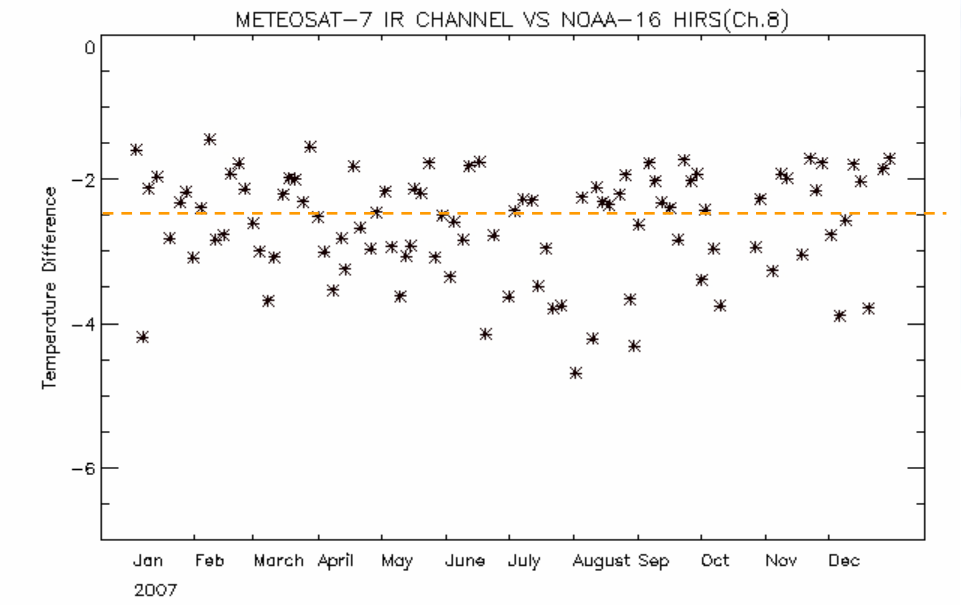
Meteosat-7 – HIRS Inter-Comparisons (not GSICS!)





- 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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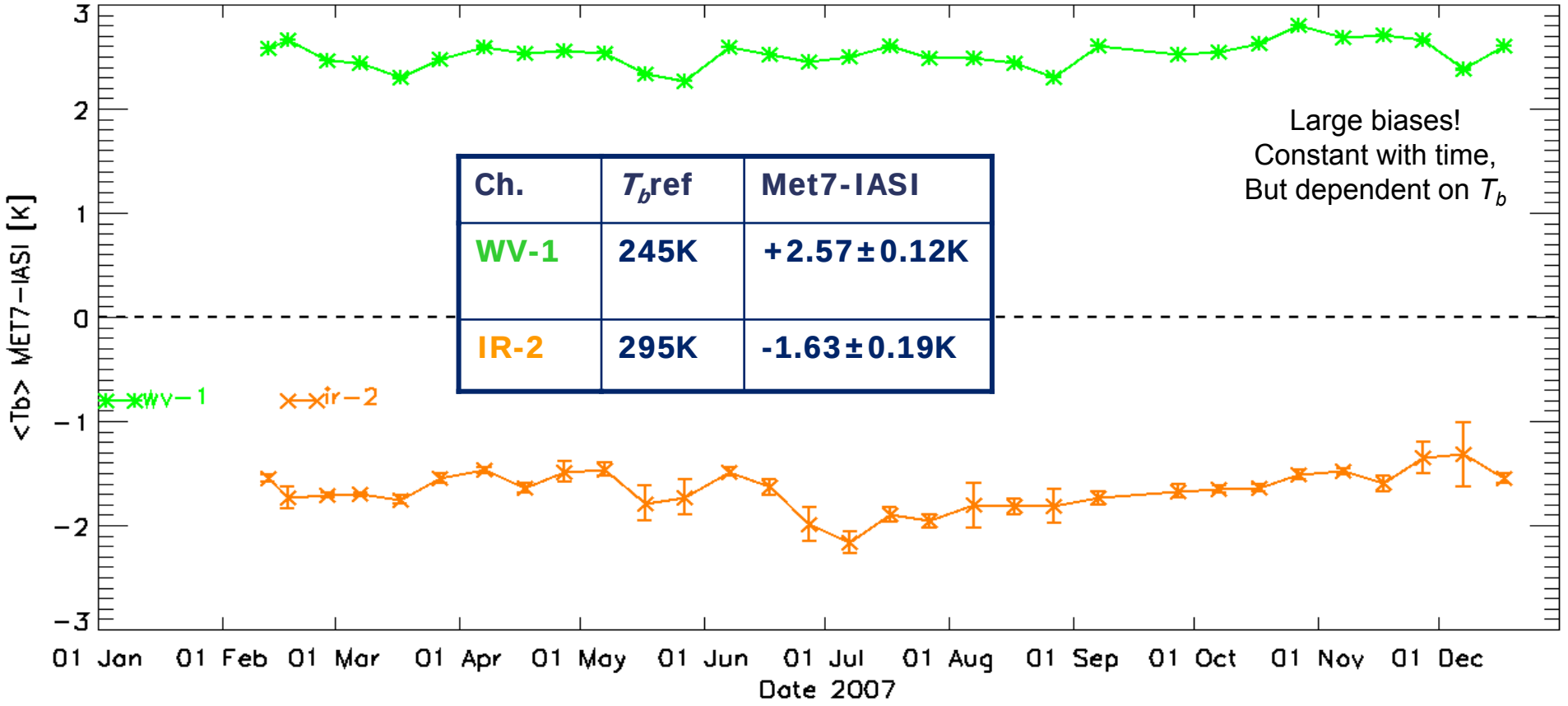
MVIRI on Meteosat-7 – IASI on Metop-A



Ch.	$T_b$ref	Met7-IASI
WV-1	245K	+2.57±0.12K
IR-2	295K	-1.63±0.19K

Large biases!
Constant with time,
But dependent on T_b

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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Conclusions

- Can use HIRS as inter-calibration reference for Meteosat
  - (instead of IASI)
- Need to account for spectral differences
  - Transform HIRS observations to Meteosat-space
  - Using coefficients derived from regression of modelled radiances
  - Based on RTTOV + data set of diverse profiles + cloud
  - Not possible for IR8.7
  - Noisy for IR6.2
  - Introduces error in inter-calibration ~ Variability (for ~100 collocations)
  - “Closing the triangle”: <MSG-IASI> ≠ <MSG-HIRS> - <HIRS-IASI>
- EUMETSAT plan to implement prototype in 2009

Thank you

Questions and Answers