Beginning of Mission (BOM) Spectral Response Functions for CERES Instrument Sensors- Edition 3

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CERES Sensor Measurements

- CERES Measurement Channels:
  - *Shortwave* Channel: 0.3μm to 5μm
  - *Window* Channel: 8μm to 12μm
  - *Total* Channel: 0.3μm to 200μm

Sensor Counts $C = Gain * I_T^f + Offset$

Radiometric Gain= Counts/Watt

Filtered Radiance $I_T^f = \int_{\lambda=0}^{\infty} S_\lambda I_{\lambda,T_{Source}} d\lambda$

Spectral Response Function (SRF)

Source Radiance

CERES Spectral Response Function

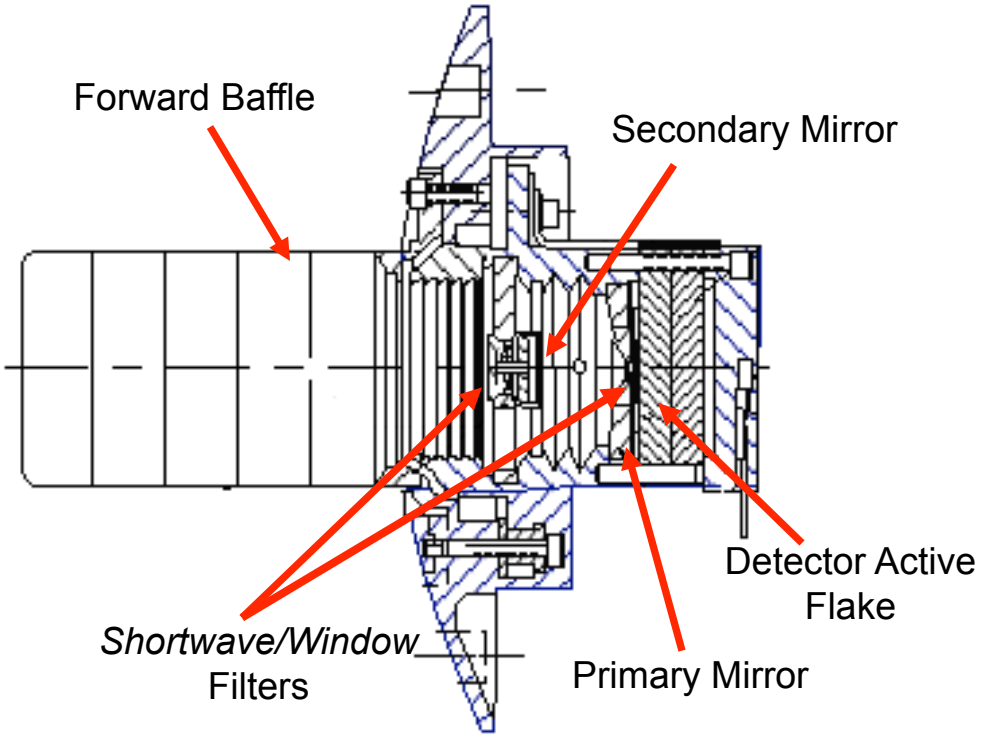
- Spectral response:

$$S_\lambda = \tau_\lambda \rho_\lambda^2 \alpha_\lambda$$

τ_λ Filter Transmission

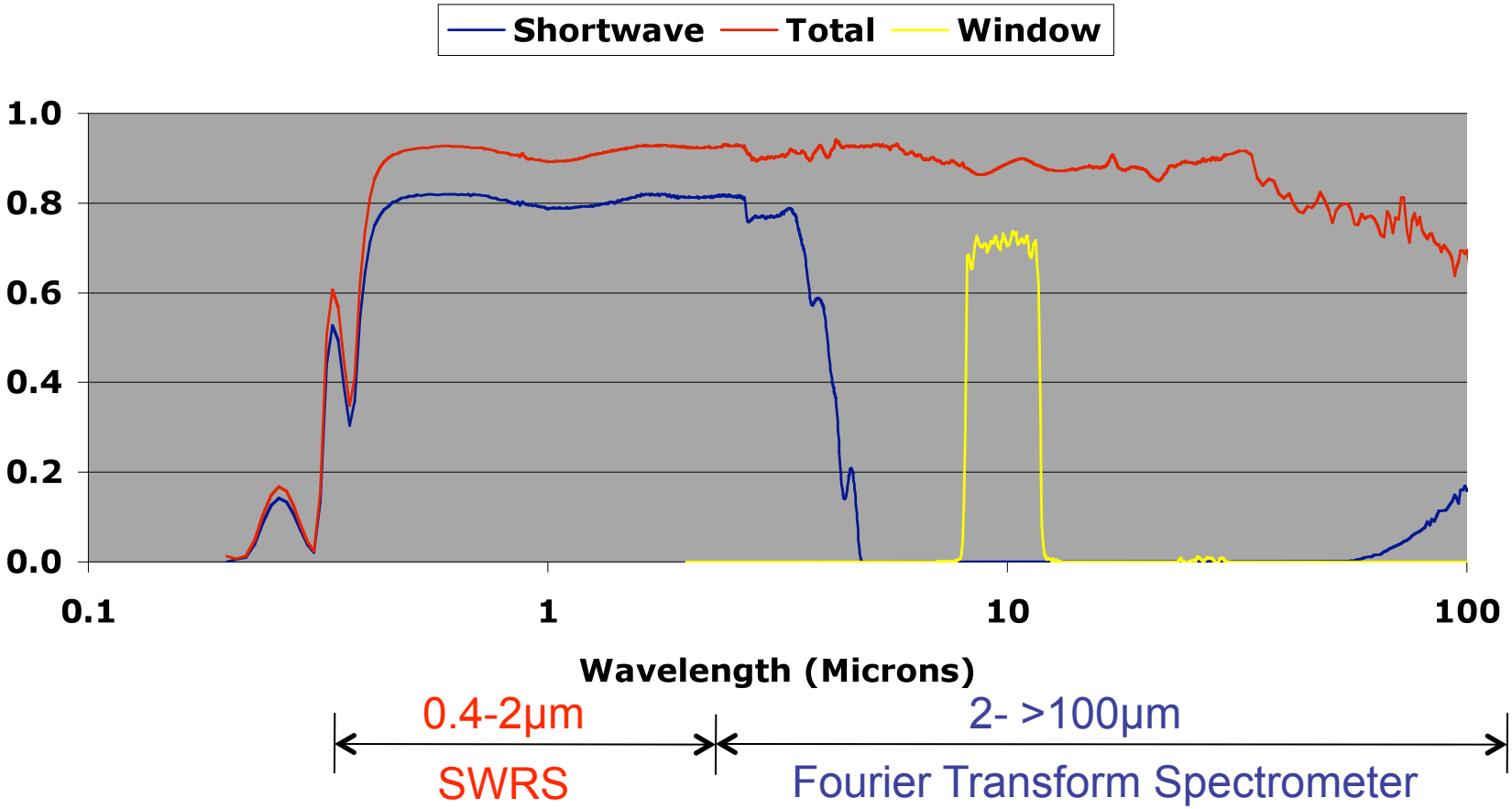
ρ_λ Telescope Mirror Reflectance

α_λ Black paint Absorbance



- Two setups used:
  - Shortwave Reference Source (SWRS): 0.4-2μm
  - Fourier Transform Spectrometer (FTS): 2-200μm

CERES Spectral Response Characterization



Shortwave Spectral Response Characterization: 0.3-2μm

Shortwave SRF Characterization: Technique

- Short Wave Reference Source (SWRS) uses band-pass filters to provide 13 narrowband sources between 0.4μm and 2μm.
- A cryogenically cooled Transfer Active Cavity Radiometer (TACR) is used to place these sources on the same radiometric scale as the Narrow Field-of-view Blackbody (NFBB).
- Relative spectral response for each of the narrow spectral bands (Δλ) are obtained for both *Shortwave* channel and shortwave portion of *Total* channel:

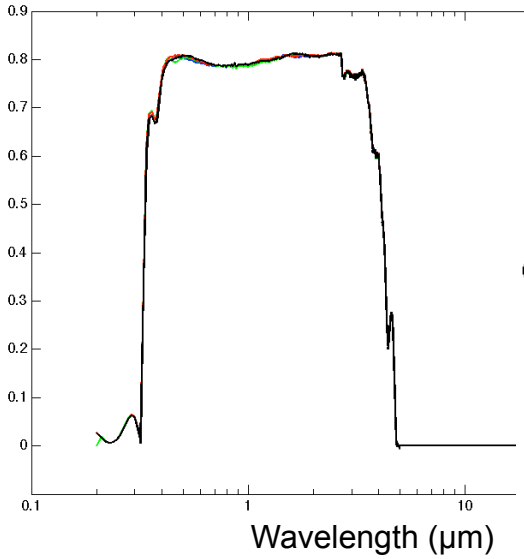
$$S^{SW}_{\Delta\lambda,CERES} = \frac{m_{\Delta\lambda,CERES}}{m_{\Delta\lambda,TACR}}$$

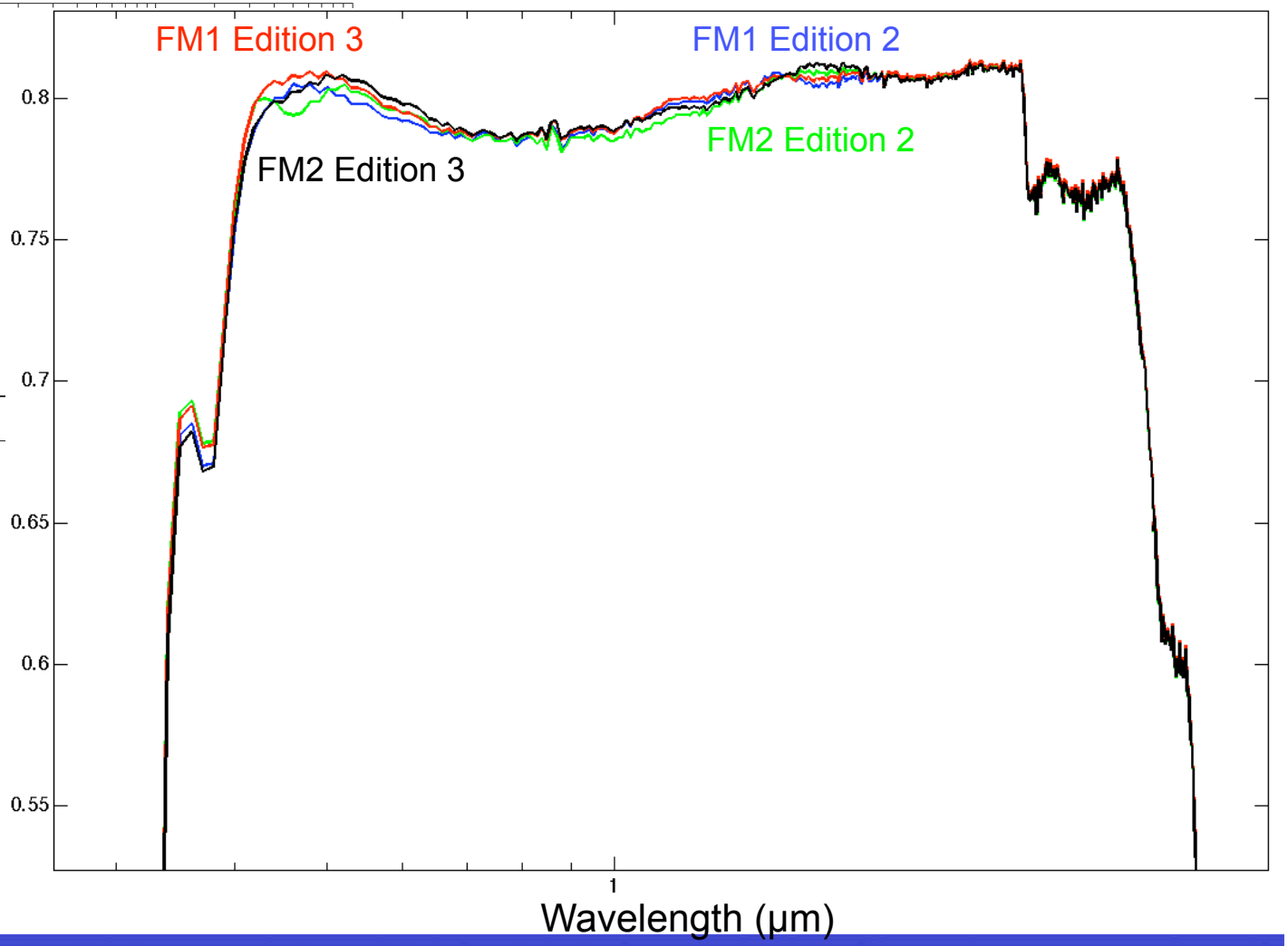
- Spectral measurements of the optical components are used to complete the spectral response between the narrowband SW sources and to extend the response below 0.3μm.
- Component measurements between 0.2-2.5μm were obtained using CARY5 spectrometer with the witness samples in a nitrogen purged chamber.

Shortwave SRF Characterization- Edition 3

- Revisited the various component measurements: Coating runs of silver mirrors.
- Revaluated the band-pass filter wavelengths used in the SW gain calculations.
- Various methodologies were evaluated to extend the response below 0.42μm.

Terra- Edition 2 and Edition 3 SW SRF





Longwave Spectral response Characterization: 2-200μm

FTS Spectral Characterization

- BIO-RAD Model 60A system with 896 interferometer is used as the source.
- Measurements taken by CERES instrument as well as a reference detector through the use of a flip mirror.
- Spectrally flat Lithium Tantalate Pyroelectric Reference Detector (PRD) is used as a reference.
- Various sources/beamsplitters used to cover the spectral range (2-200 microns).
- Spectral estimate for each band is obtained by normalizing transformed interferogram measurements of CERES sensor to those of PRD:

$$S_\lambda = \frac{m^f_{\lambda,CERES}}{m^f_{\lambda,PRD}}$$

FTS Wavelength Bands and Sources

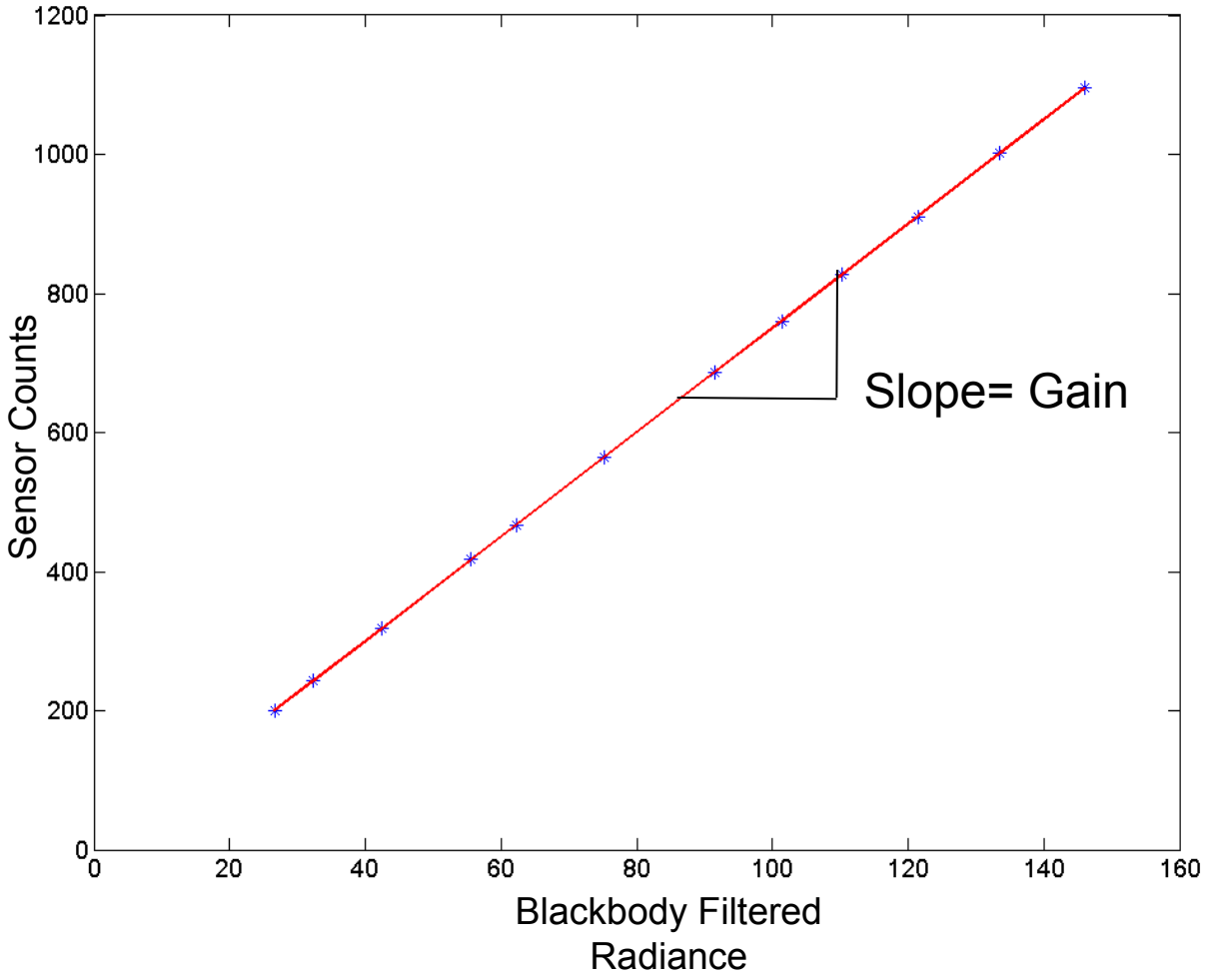
Band	Wavelength Band (μm)	Source	Beamsplitter	Window
NIR	2-4	Quartz Tungsten Halogen Lamp	Quartz	Cesium Iodide
MIR	2-20	Ceramic Glowbar	Potassium Bromide	Cesium Iodide
FIR	10-50	Ceramic Glowbar	Mylar	Cesium Iodide
VFIR	20-100	Ceramic Glowbar	Mylar	Silicon
XFIR	40-200	Ceramic Glowbar	Mylar	Silicon

End-to-end Spectral Response Function

- For each spectral band, an estimate of the relative spectral response function is obtained by taking the ratio of the transformed sensor output to the transformed PRD output.
- The overlap regions are used to tie adjacent spectral bands.
- Since the detector is broadband, the sensor gain is constant across all wavelengths.
- Blackbody calibration data is used to tie the various spectral estimates together by maintaining a constant gain across all wavelengths.
- LW spectral estimate is then tied with the SW spectral estimate (obtained from the SWRS) to obtain the *Total* channel end-to-end response function.

Blackbody Calibration Data

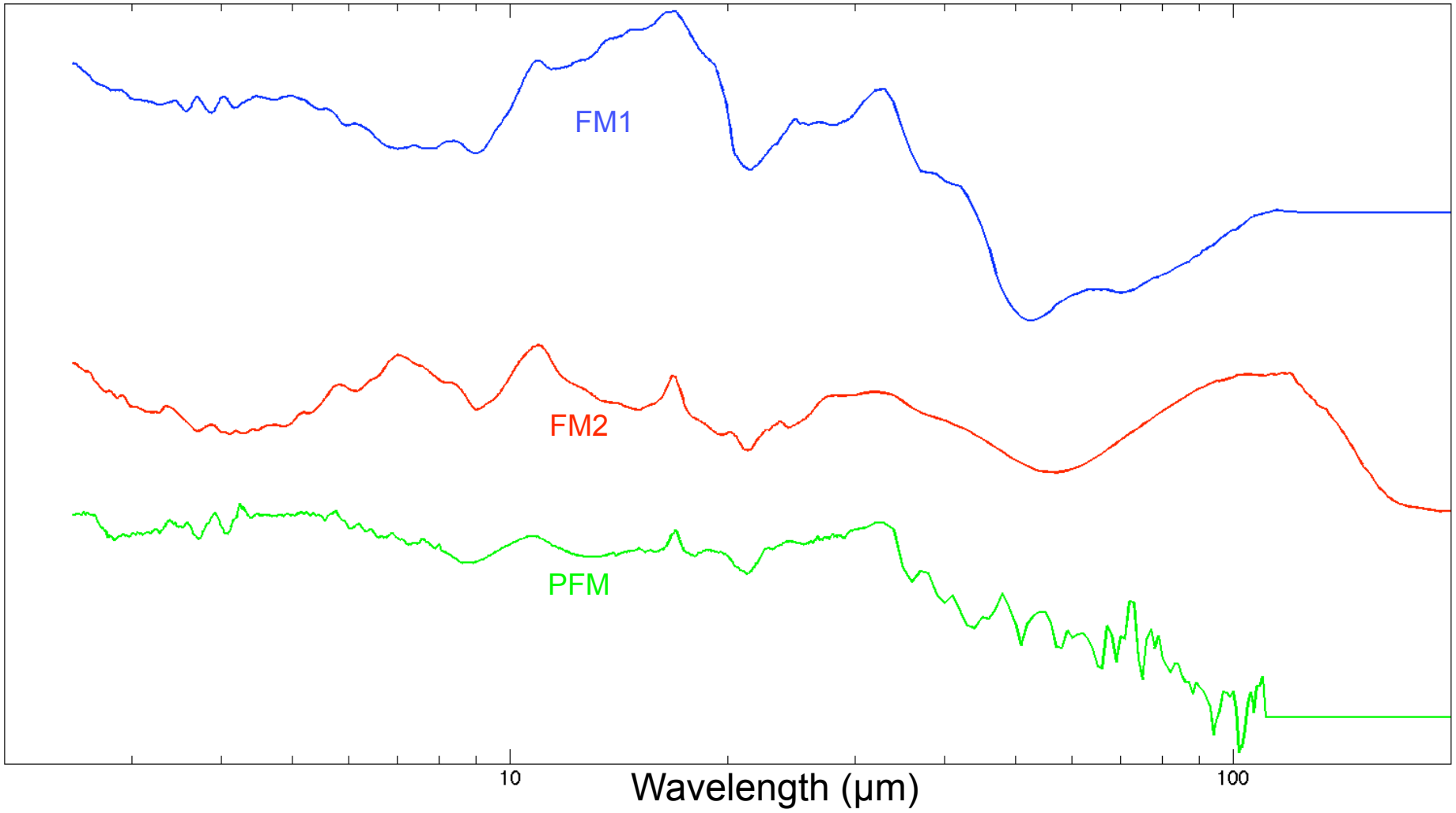
- Sensor measurements of a blackbody measurements at 12 temperatures between 205K-312K.
- The regression of the filtered radiance from the source with the sensor counts gives the radiometric gain of the sensor.



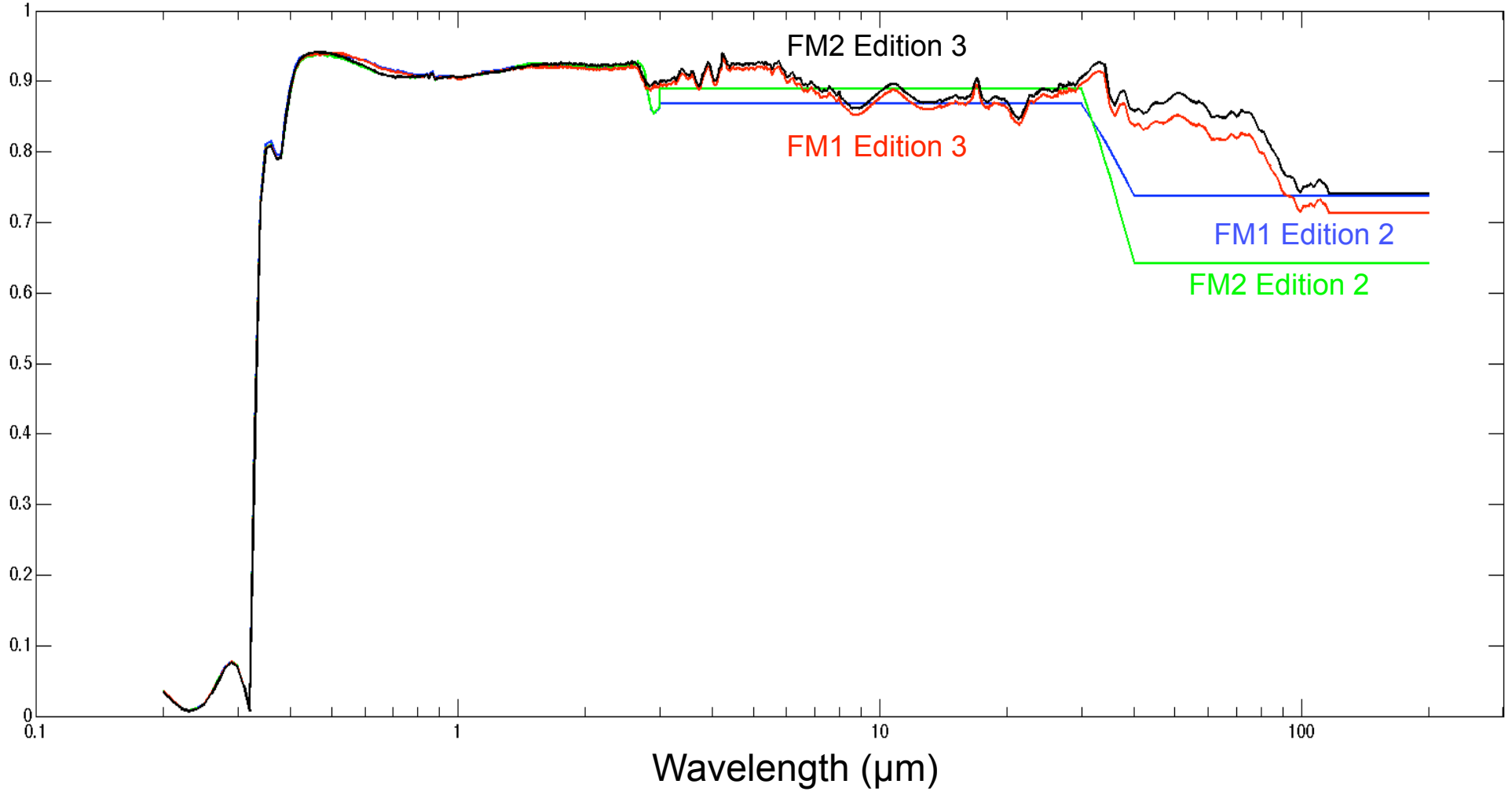
Total Channel Spectral Response – Edition 3

- Revisited the FTS data to extract spectral features in the longwave response that may have previously been ignored.
- FTS data is extremely noisy; extract spectral features that are consistent across all instruments.
- Obtained a candidate spectral response curve that would serve as the longwave response for all instruments (all have the same optical components) using the spectral features identified from FTS data.
- Tied the LW estimate with SW estimate and adjusted the response curves to maintain constant gain across all wavelengths.

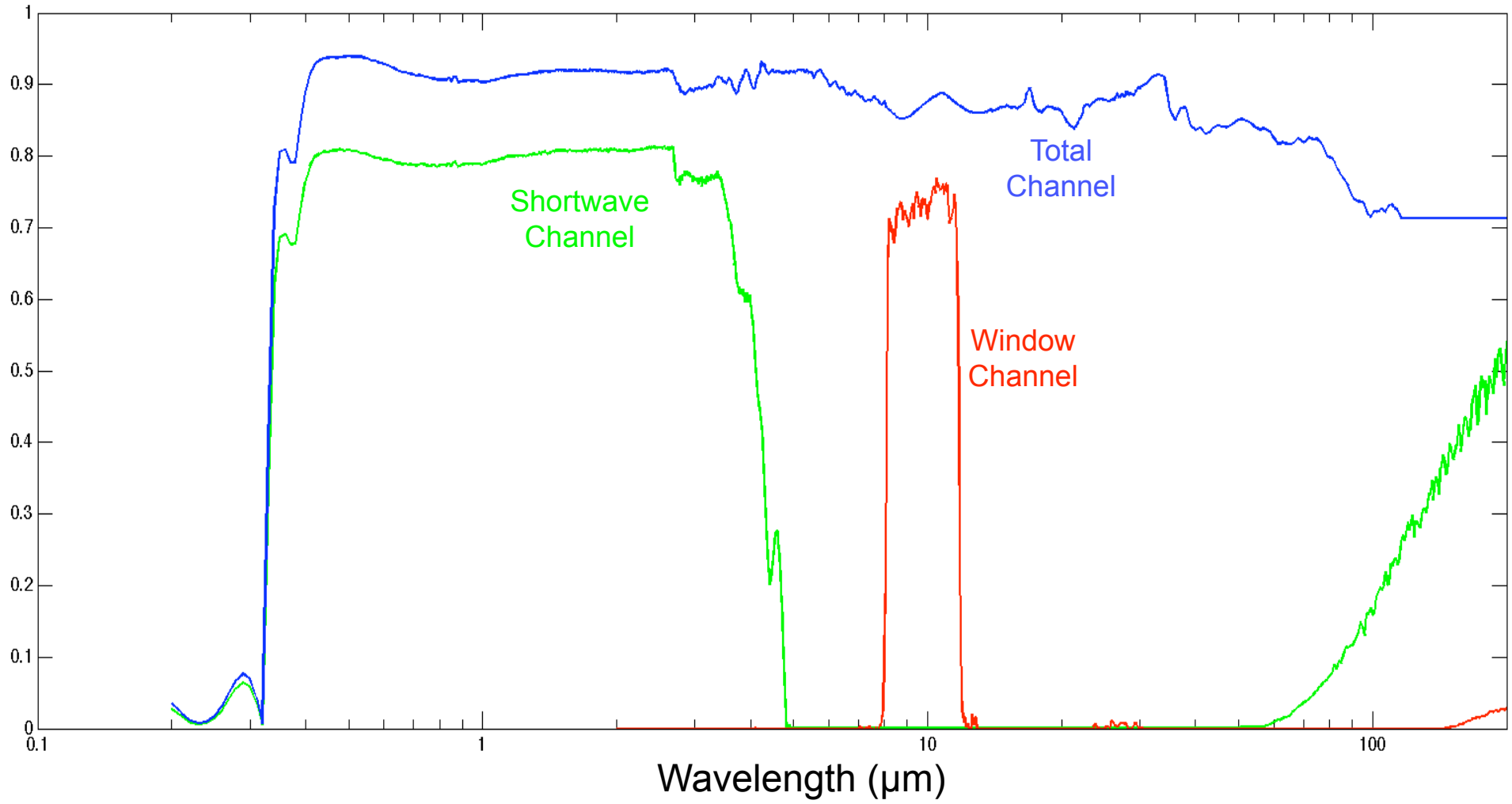
Spectral Features in FTS Data- Total Channel



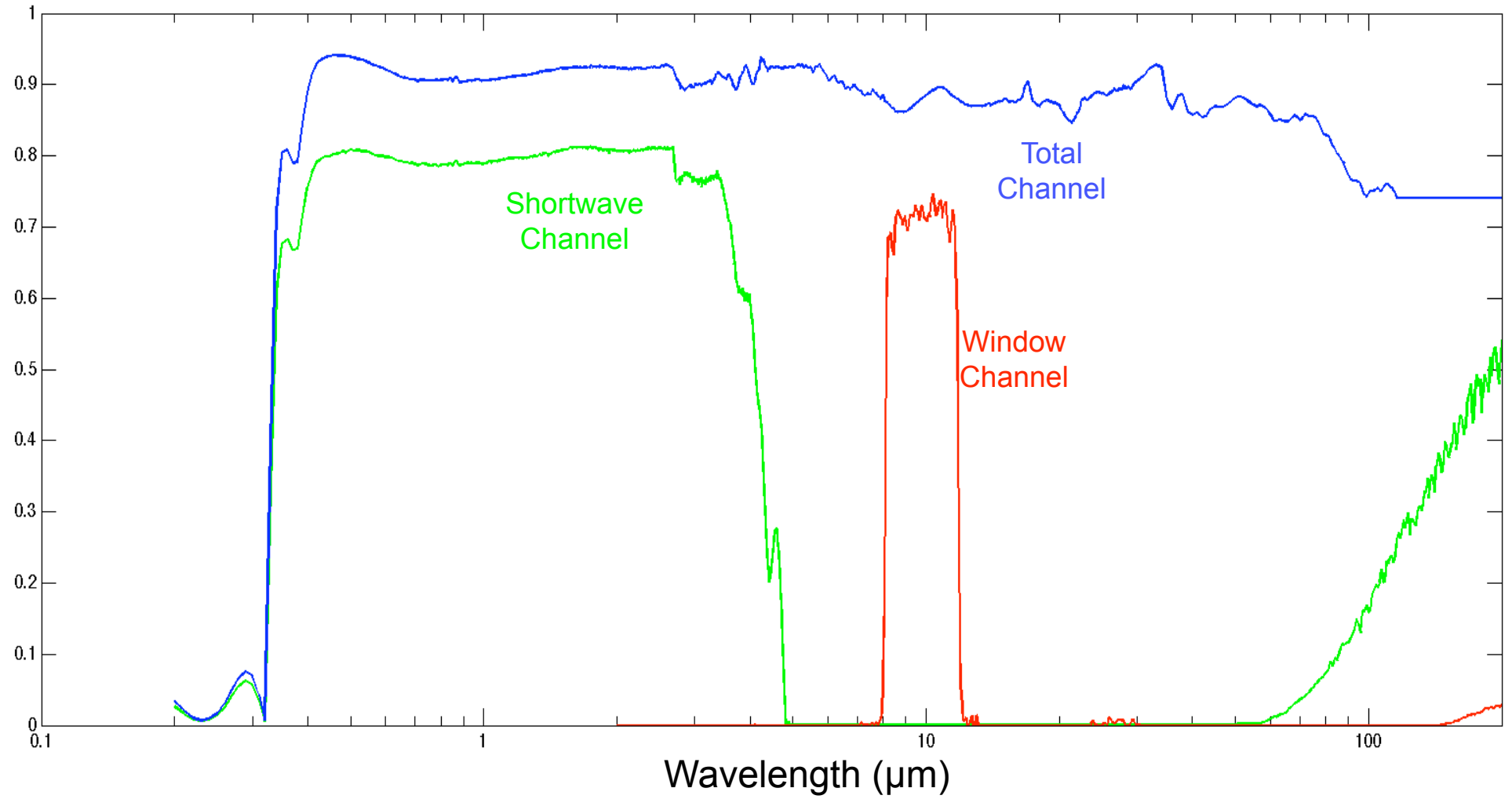
Terra-Edition 2 and Edition 3 TOT SRF



Terra – Edition 3 FM1 SRF



Terra – Edition 3 FM2 SRF



Scene Dispersion

- Difference in the *Direct Compare* between two instruments from *Overcast* and *Clear Ocean* (CLO) scenes.

- It gives a measure of discrepancies between the two instruments that are due to the spectral response.

$$DC_x = \frac{FM2_x - FM1_x}{FM1_x} \times 100\%$$

$FM2_x$= Radiance from FM2 corresponding to scene x.
$FM1_x$= Radiance from FM1 corresponding to scene x.

$$Dispersion = DC_{Overcast} - DC_{CLO}$$

Impact on Measurement of Earth-scenes

Erbe-like ES-8 global Nadir looking, March 2000

$$DC = \frac{FM2 - FM1}{FM1} \times 100\%$$

Edition 2

Scene- Clear Ocean	FM1 (W/m^2)	FM2 (W/m^2)	DC (%)
LW Day	287.76	287.32	-0.153
LW Night	294.51	293.23	-0.435
SW	93.00	93.23	0.247

Edition 3

Scene- Clear Ocean	FM1 (W/m^2)	FM2 (W/m^2)	DC (%)
LW Day	288.62	288.28	-0.118
LW Night	295.1	293.90	-0.407
SW	94.31	94.11	-0.212

Impact on Measurement of Earth-scenes

Erbe-like ES-8 global Nadir looking, March 2000

$$DC = \frac{FM2 - FM1}{FM1} \times 100\%$$

Edition 2

Scene- Overcast	FM1 (W/m^2)	FM2 (W/m^2)	DC (%)
LW Day	177.74	180.39	1.491
LW Night	174.98	175.35	0.211
SW	411.87	410.88	-0.240

Edition 3

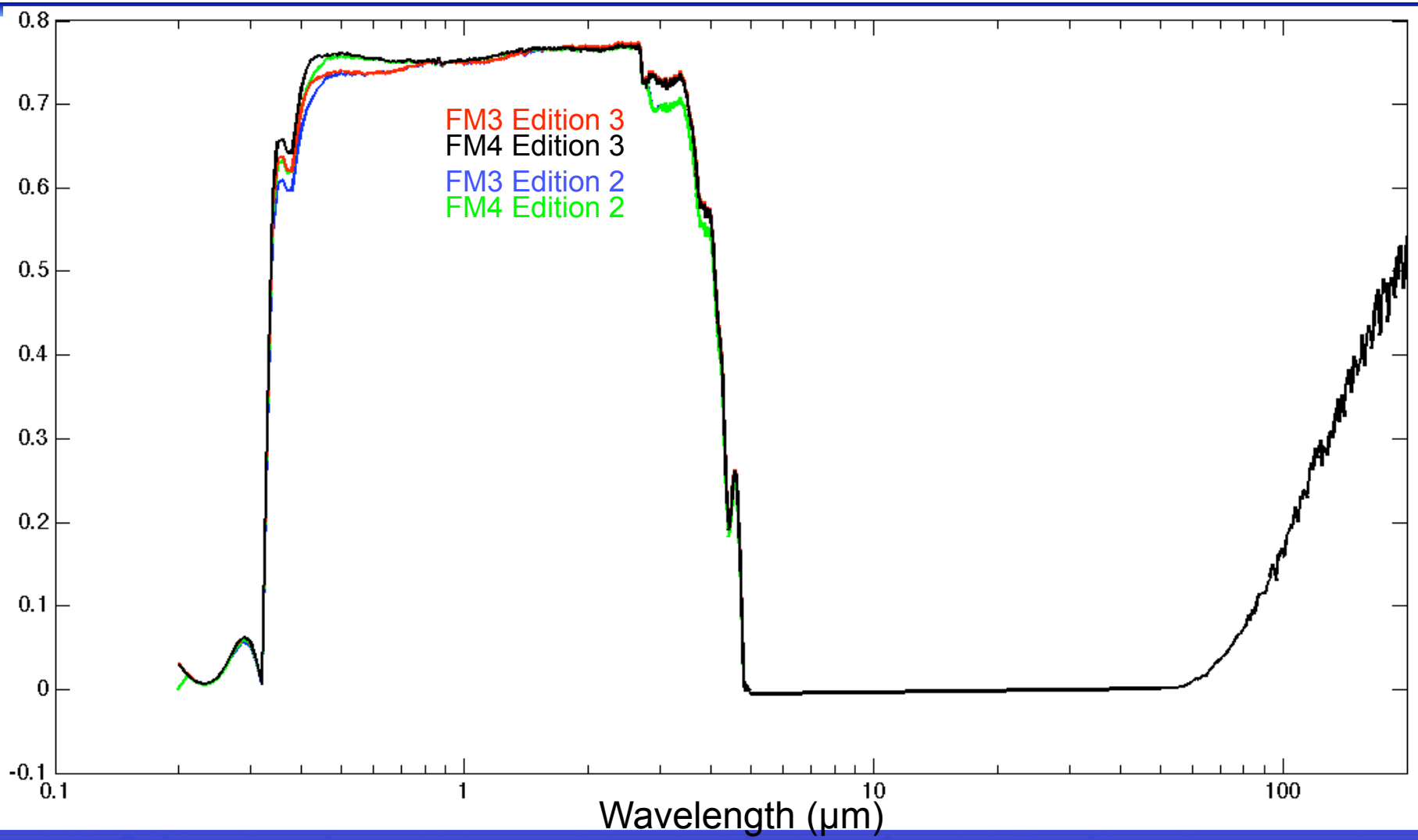
Scene- Overcast	FM1 (W/m^2)	FM2 (W/m^2)	DC (%)
LW Day	180.81	181.42	0.337
LW Night	174.88	174.10	-0.446
SW	412.27	410.77	-0.364

Scene Dispersion- Terra

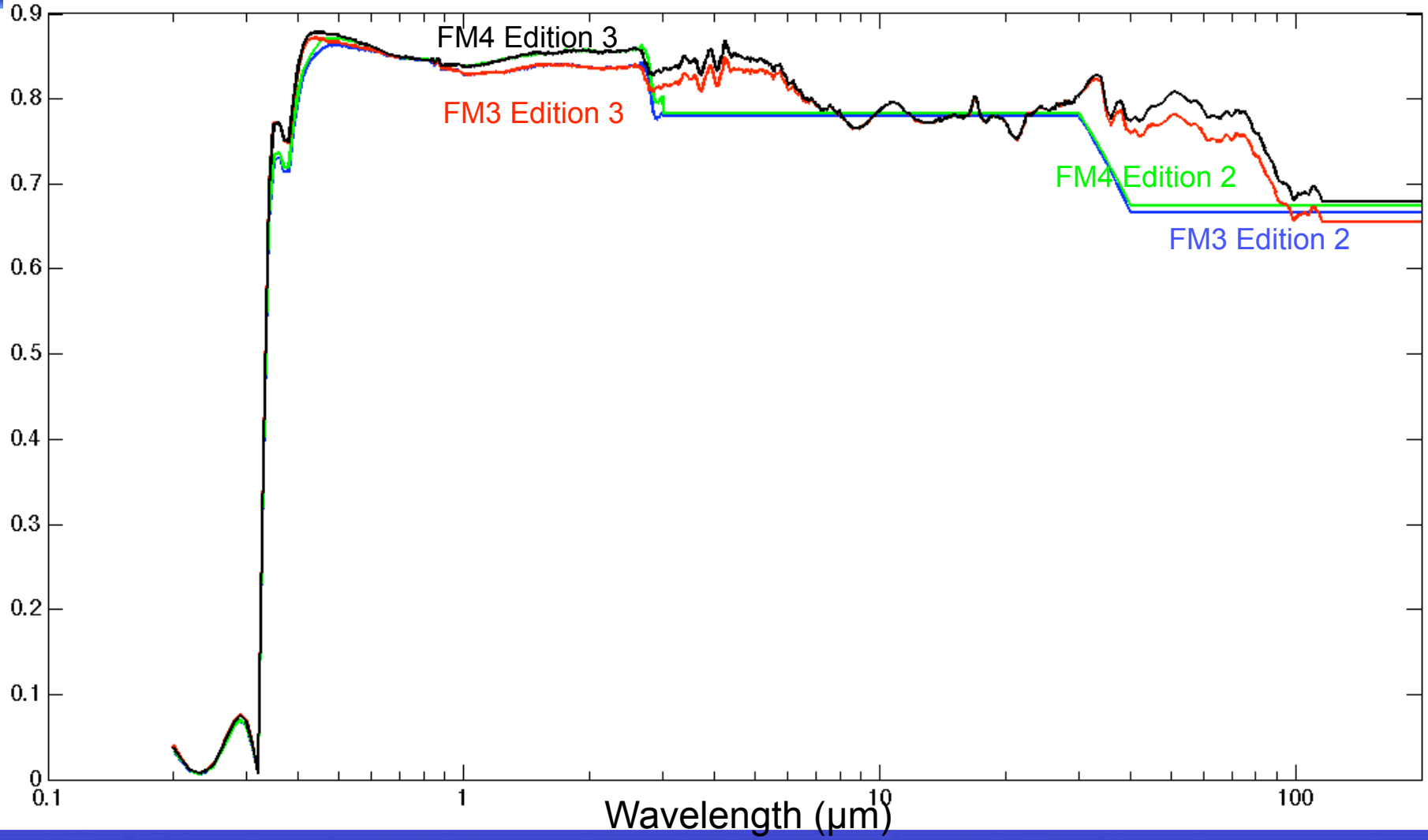
	Edition 2	Edition 3
LW-Day	1.644%	0.455%
LW- Night	0.646%	-0.039%
SW	-0.488%	-0.152%

$$Dispersion = DC_{Overcast} - DC_{CLO}$$

Aqua Edition 3 SW SRF- First cuts

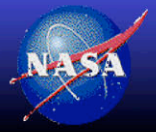


Aqua Edition 3 TOT SRF- First cuts



Summary

- Revaluated the Beginning of Mission (BOM) Spectral Response Functions (SRF) for FM1-FM4.
- Terra (FM1, FM2) Edition 3 SRFs have been tested, validated and delivered.
- The new SRFs for Terra instruments show an improvement in the scene-dispersion metric over Edition 2, most significantly in the longwave.
- Aqua SRFs first-cut responses are currently being evaluated.


NASA


CERES

All-Sky Edition 2 & Edition 3

Erbe-like ES-8, Nadir flux, March 2000

All Sky- LW Day	Edition 2 (W/m²)	Edition 3 (W/m²)
FM1	230.00	231.77
FM2	230.95	231.84
Direct Compare (%)	0.413	0.03
All Sky- LW Night	**Edition 2 (W/m²)**	**Edition 3 (W/m²)**
FM1	225.28	224.61
FM2	224.89	223.63
Direct Compare (%)	-0.173	-0.436
All Sky- SW	**Edition 2 (W/m²)**	**Edition 3 (W/m²)**
FM1	253.59	256.20
FM2	253.48	255.52
Direct Compare (%)	-0.043	-0.265