Project Report
EO-1-2

Earth Observing-1 Advanced Land Imager:

Spectral Response Calibration

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Abstract

An Advanced Land Imager (ALI) will be flown on the first Earth Observing mission (EO-1) under NASA's New Millennium Program (NMP). The focal plane of the ALI contains silicon and non-cryogenic HgCdTe multispectral and panchromatic (MS/Pan) detector arrays with a total of 10 spectral bands spanning the 0.4 to 2.5 μm wavelength region. These bands have been defined to correspond with heritage Landsat bands and provide 2 additional bands centered at 0.44μm and 1.25μm. The partially populated focal plane provides a 3° cross-track coverage corresponding to 37 km on the ground and the focal plane temperature is maintained at 220 K by means of a passive radiator. This document outlines the techniques adopted during spectral calibration of the Advanced Land Imager and presents results derived from subsystem and system level measurements.

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1. Introduction

The Advanced Land Imager (ALI) focal plane contains 9 multispectral bands and a single panchromatic band (Table 1)[1-5]. These bands have been designed to mimic five Landsat[6] spectral bands and provide two additional bands covering 0.433-0.453 and 1.20-1.30 µm. Furthermore, Landsat Band 4 has been divided into two separate bands (4, 4p) in order to avoid a water vapor line at 0.825 µm.

Ground calibration of the Advanced Land Imager occurred from September 1998 through January 1999 at the Massachusetts Institute of Technology-Lincoln Laboratory[7-10]. Included in this characterization period was the system level spectral calibration of one of four focal plane Sensor Chip Assemblies (SCAs). This paper provides a review of the techniques employed during spectral calibration and the results for the VNIR, SWIR and Panchromatic bands. These results are compared to subsystem measurements obtained before the instrument was assembled.

Table 1: Spectral and spatial definitions for the ten EO-1 ALI bands.

Band	Wavelength (µm)	Ground Sampling Distance (m)
Pan	0.48 – 0.69	10
MS-1p	0.433 – 0.453	30
MS-1	0.45 – 0.515	30
MS-2	0.525 – 0.605	30
MS-3	0.633 – 0.69	30
MS-4	0.775 – 0.805	30
MS-4p	0.845 – 0.89	30
MS-5p	1.2 – 1.3	30
MS-5	1.55 – 1.75	30
MS-7	2.08 – 2.35	30

2. Focal Plane Construction

Although the ALI optical system supports a 15° wide FOV, only 3° was populated with detector arrays, as illustrated in Figure 1. Four sensor chip assemblies (SCA's) populate the 3° cross-track segment of the focal plane to form the focal plane array or FPA. Each MS band on each SCA contains 320 detectors in the cross-track direction, while each pan band contains 960 detectors. The total cross-track coverage from the single MS/Pan module is 37 km.

The MS/Pan arrays use silicon-diode VNIR detectors fabricated on the silicon substrate of the Readout Integrated Circuit (ROIC). The SWIR detectors are mercury-cadmium-telluride (HgCdTe) photo-diodes that are indium bump-bonded onto the ROIC that services the VNIR detectors. These SWIR detectors promise high performance over the 0.9 to 2.5 µm wavelength region at temperatures that can be reached by passive or thermoelectric cooling. The nominal focal plane temperature is 220K and is maintained by the use of a radiator and heater controls.

The spectral bands for each multispectral channel are defined by filters lying above the silicon and HgCdTe detectors (Figures 1, 2). A cross sectional view of an individual SCA is provided in Figure 3 and a table of materials used in the filters is provided in Table 2. A three-piece sandwich design is used to construct the filters for bands 1p, 1, 2, and the panchromatic band. All other band filters use a single glass design. All glass segments are cemented together using Epotek 301 and the ten filters together form an assembly, which resides in a bezel, mounted directly above the detector arrays.

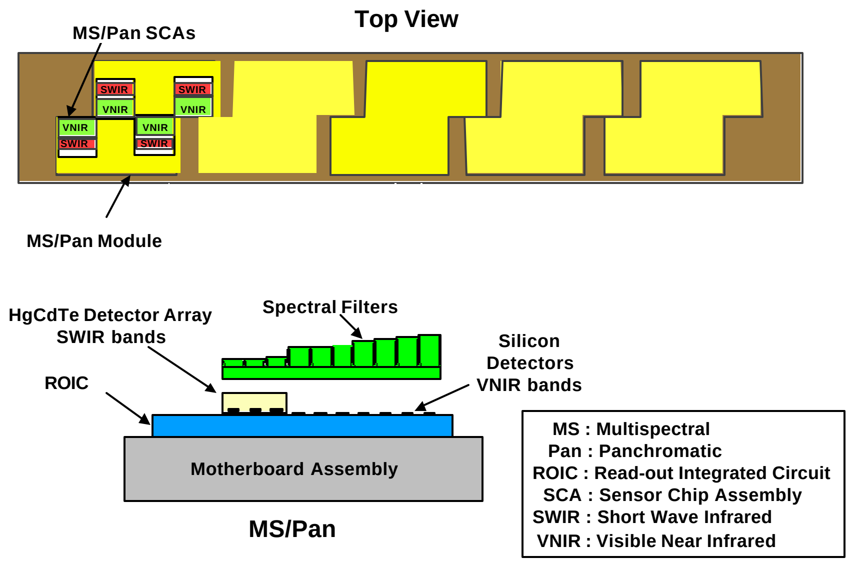

Figure 1: Advanced Land Imager Focal Plane Assembly.

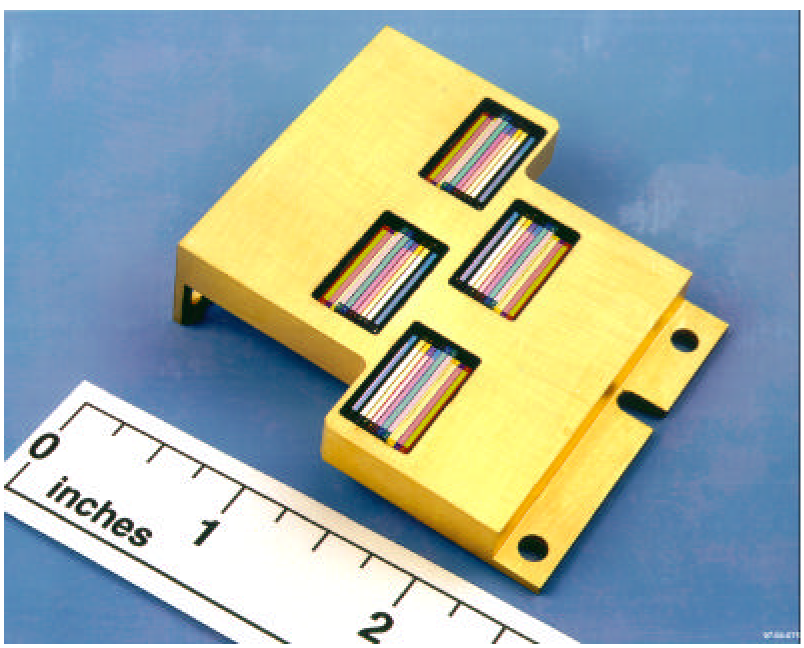

Figure 2: Photograph of populated Sensor Chip Assemblies.

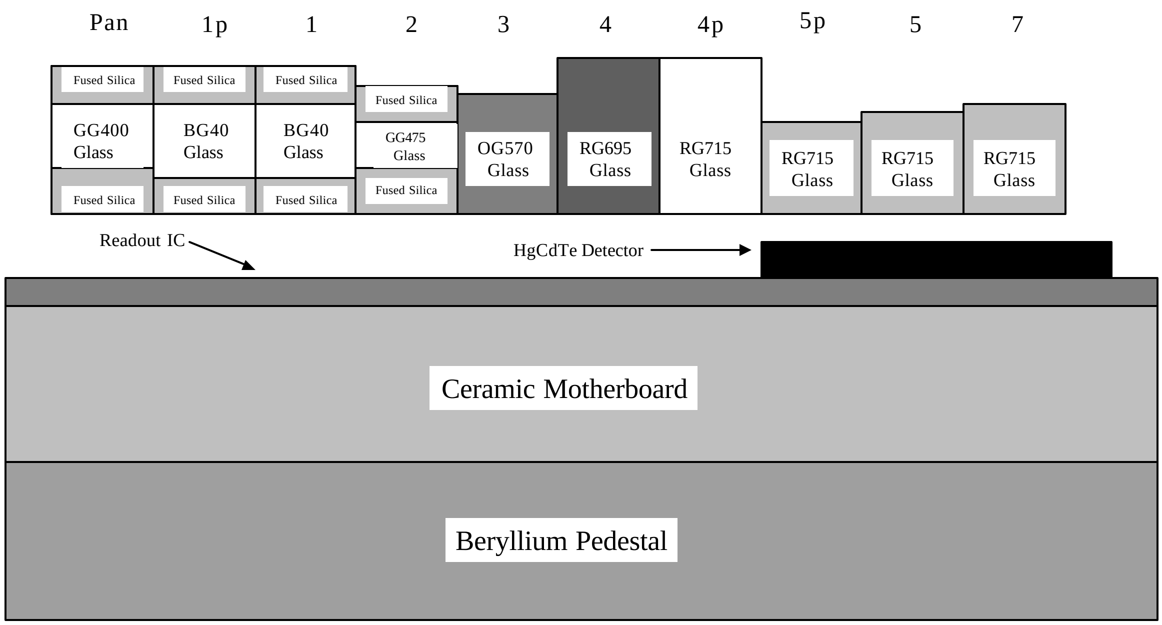

Figure 3: Focal plane array Sensor Chip Assembly cross-section.

Table 2: Materials used for focal plane filter construction.

Band	**Material**
Pan	Fused Silica + GG400
1p	Fused Silica + BG40
1	Fused Silica + BG40
2	Fused Silica + GG475
3	OG570
4	RG695
4p	RG715
5p	RG715
5	RG715
7	RG715

3. Spectral Response Measurement Techniques

Spectral calibration of the Advanced Land Imager was conducted on both the subsystem and the system level.

3.1. Subsystem Level

The predicted system level spectral response for each band has been calculated analytically as the product of the spectral responses of individual ALI optical components. Component level spectral characterizations include measurements of witness sample detector responsivities by the Santa Barbara Research Center (now the Ratheon Infrared Center of Excellence), filter transmissions by Barr Associates, and M1-3 and F1 mirror reflectivities by SSG Incorporated.

3.2. System Level

System level spectral calibration of the fully assembled flight instrument was performed at Lincoln Laboratory under vacuum and operating at expected flight temperatures. A spectral collimator was used to project a monochromatic beam into the vacuum tank via a quartz window. Data were collected from 400 nm to 2500 nm to map both in-band and out-of-band response for pixels in each of the multispectral and panchromatic bands of SCA 3.

The collimator used during system level spectral characterization of the ALI may be divided into three sections: source, collimating optics, and beam monitor (Figure 4). The source is composed of a quartz tungsten halogen lamp assembly, monochromator, integrating sphere, and condensing lens. The halogen lamp assembly provides a stable broadband source and is used to fill the f/4 entrance cone of the monochromator. The wavelength and spectral bandwidth passed through the system are defined by the order sorting filters, diffraction gratings and slit widths of the *Oriel* MS257 monochromator. Upon exiting the monochromator, the beam was randomized into a uniform 0.5" diameter spot using a 2" diameter (I.D.) *Labsphere Spectralon* integrating sphere. A condensing lens (01 LPX 245) was positioned to expand the output of the integrating sphere and provide a 3" diameter field for calibration.

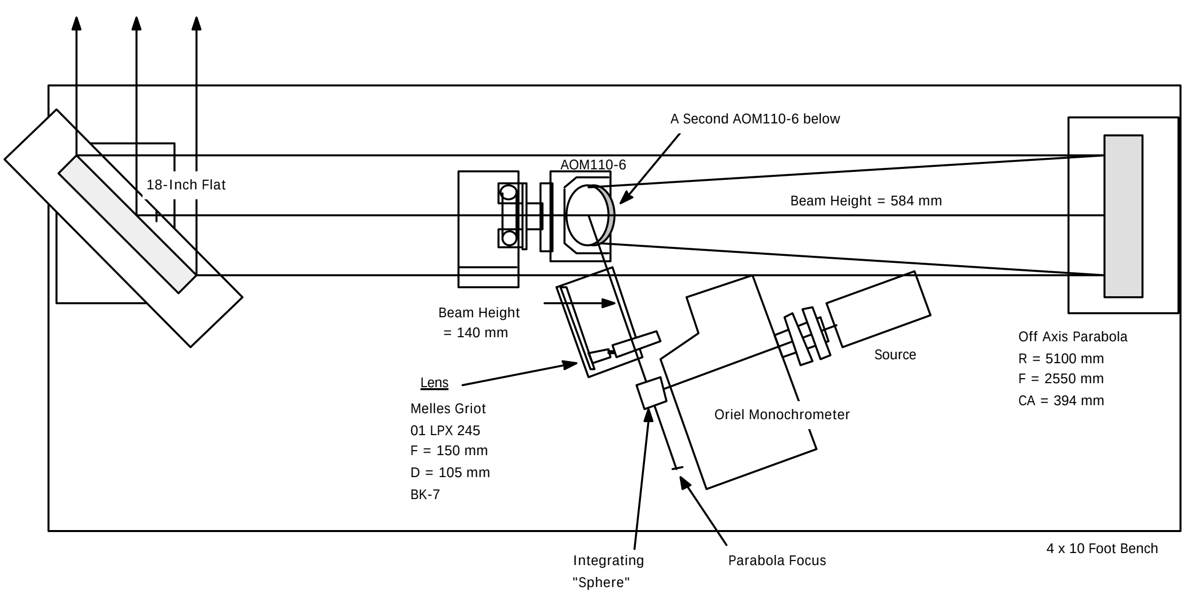

Figure 4: Collimator used during spectral calibration of the EO-1 Advanced Land Imager.

The primary component of the spectral collimating optics was a 17” diameter, 100” focal length off-axis parabola. This mirror was mounted such that its focus was colocated with the virtual image of the integrating sphere output formed by the condensing lens. Collimated radiation reflected from the parabola was directed into the vacuum tank window using a large (18” diameter) flat mirror. A light tent was positioned around the spectral collimator and an intricate baffling scheme was adopted to prevent stray light from contaminating the dim monochromatic output for this measurement.

The collimator also contained two reference detectors, used to monitor the beam stability and flux throughout spectral calibration of the instrument: a silicon detector for VNIR measurements and a lead sulfide detector for SWIR measurements. Each detector, located between the 18” flat mirror and the vacuum tank window, was chopped and a lock-in amplifier was used to accurately subtract dark current drift and background radiation.

System level spectral calibration data were collected in December 1998 and January 1999 in a class 1,000 clean room at Lincoln Laboratory. This calibration was conducted with the ALI as a fully assembled instrument in a thermal vacuum chamber at operational temperatures.

A DELL 266 MHz PC (Windows 95 platform) controlled the monochromator scanning and beam sampling using a GPIB interface and LabVIEW control software. For visible near infrared (VNIR) measurements (400-1000 nm) a spectral bandwidth and sampling interval of 2 nm was used. For short wave infrared (SWIR) measurements (1000-2500 nm) a spectral bandwidth and sampling interval of 4 nm was used.

Data collection consisted of iteratively sampling the beam with the reference detector and the ALI at each wavelength interval. Initially, a wavelength and bandpass are set by the monochromator. A translation stage then positions the silicon or lead sulfide detector and chopper between the18” flat mirror and vacuum tank window. After sampling the beam, the detector is moved to an out-of-beam position. All bands of the ALI then sample the monochromatic beam. Finally, a filter wheel, acting as a shutter between the light source and monochromator, blocks the incident beam to provide a dark ALI reference for each spectral sample.

4. Analysis

4.1. Subsystem Level

The generation of system level spectral response functions based on component level measurements must account for all elements that affect the response of an assembled instrument: mirror reflectivities, filter transmissions, and detector responsivities. Reduced witness sample data for each of these components were provided by each manufacturer as a part of MIT/LL quality control during instrument construction. Five VNIR and sixty SWIR detector responsivity measurements, 20 nm interval mirror reflectivity measurements, and 0.5 and 1nm interval filter transmission measurements were used in this analysis. Each of these data sets was interpolated onto a 1nm spectral sampling interval and the overall system level performance was calculated for each band as the product of component measurements as a function of wavelength, normalized to unity at the peak response.

4.2. System Level

Analysis of the ALI system level spectral calibration data was conducted at Lincoln Laboratory and centered on the normalization of a given pixel’s response (dn) to account for beam intensity and vacuum tank window transmission artifacts as a function of wavelength (λ). Initially, the ALI pixel response is offset corrected by subtracting dark scene values for each wavelength. A plot of spectral transmission versus wavelength is then generated for a given pixel by accessing data for a particular spectral calibration run and the wavelengths covered at that time. Artifacts induced by the vacuum tank window are then removed by dividing the pixel’s spectral response by the window’s previously measured spectral transmission. Next, the varying intensity of the incident beam as a function of wavelength is accounted for by dividing the pixel spectral response by the beam intensity measured at each wavelength by the silicon or lead sulfide detectors. Finally, the spectral response of the reference detector itself is removed by dividing the beam intensity measurement by the detector's responsivity for the spectral range of interest. The above technique may be shown analytically using the following relation

$$S_P(\lambda) = \frac{A_P(dn, \lambda)\, R_d(\lambda)}{T_W(\lambda) F(\lambda)}.$$

Here, $S_P(\lambda)$ is the derived spectral response for pixel P as a function wavelength λ, $A_P(dn, \lambda)$ is the ALI focal plane response for pixel P as a function of wavelength , $T_W(\lambda)$ is the spectral transmission of the vacuum tank window, and $F(\lambda)$ is the measured reference detector response to the beam as function of wavelength. $R_d(\lambda)$ is the spectral responsivity of the detector used to measure the beam.

Once the above corrections are applied, the resulting spectral response function for a given pixel is normalized to unity at the peak response. Responses for 200 pixels are then averaged and compared to the theoretical spectral response of the ALI (generated from the component measurements).

5. Results

We have measured the system level spectral response function for each ALI VNIR, SWIR and panchromatic band. Figures 5-14 compare the measured spectral response functions near band cut-on and cut-off wavelengths to the theoretical response functions generated from component level measurements. We find excellent morphological agreement (<5% near peak transmissions) for all bands. The panchromatic band (Figure 14) in particular reveals good agreement between system and component level measurements despite intricate variability across this band's spectral bandpass. We also find the cut-on and cut-off wavelengths agree with subsystem level measurements to within 1 nm for VNIR bands and 2 nm for SWIR bands.

Broad band responses, calculated from component measurements, are provided in figures 15-26. These measurements demonstrate out of band responses less than 0.03% for all bands. System level measurements revealed no out of band response for all bands down to the noise level of the ALI.

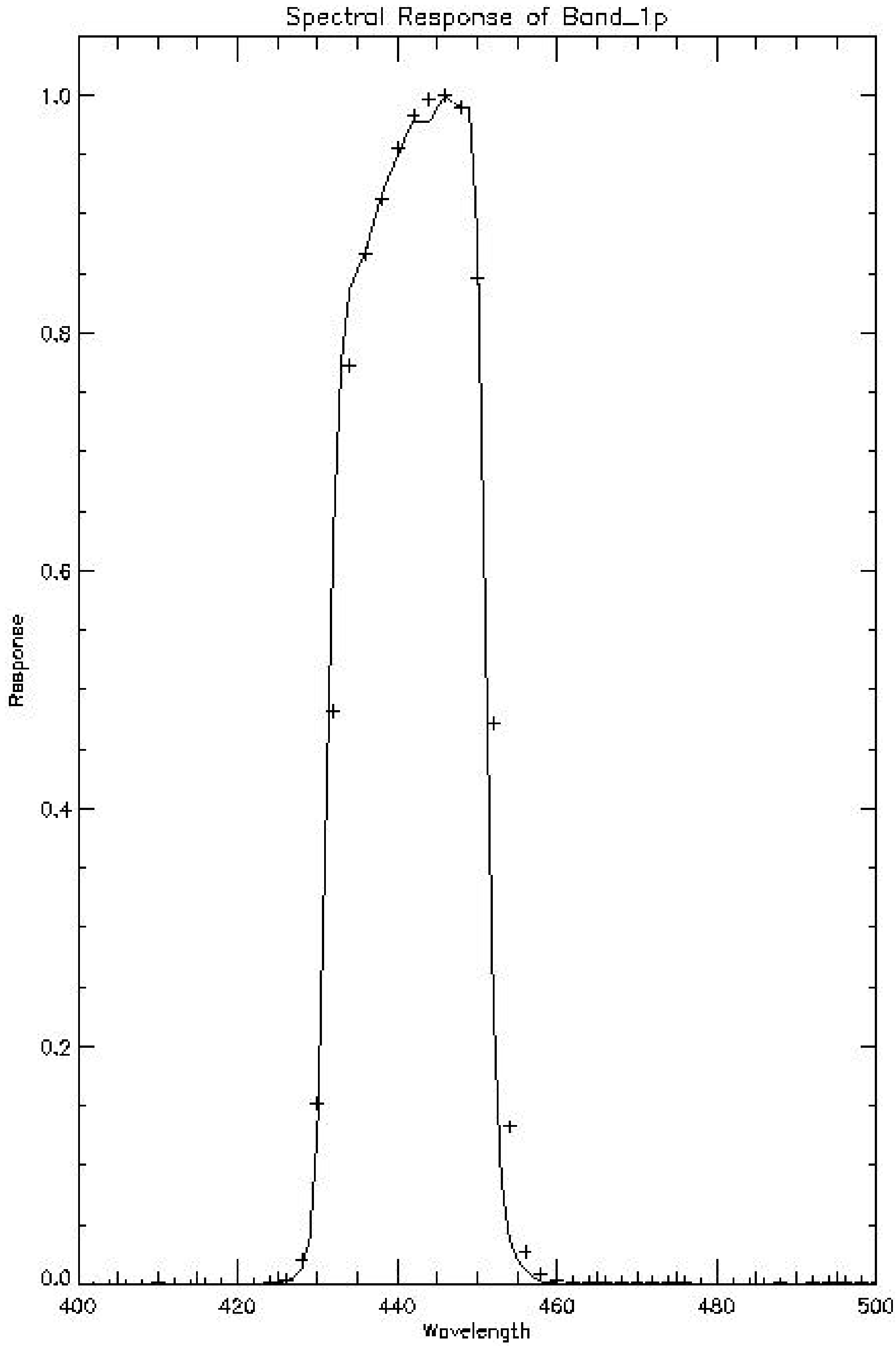

Figure 5: Spectral response of band 1p. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

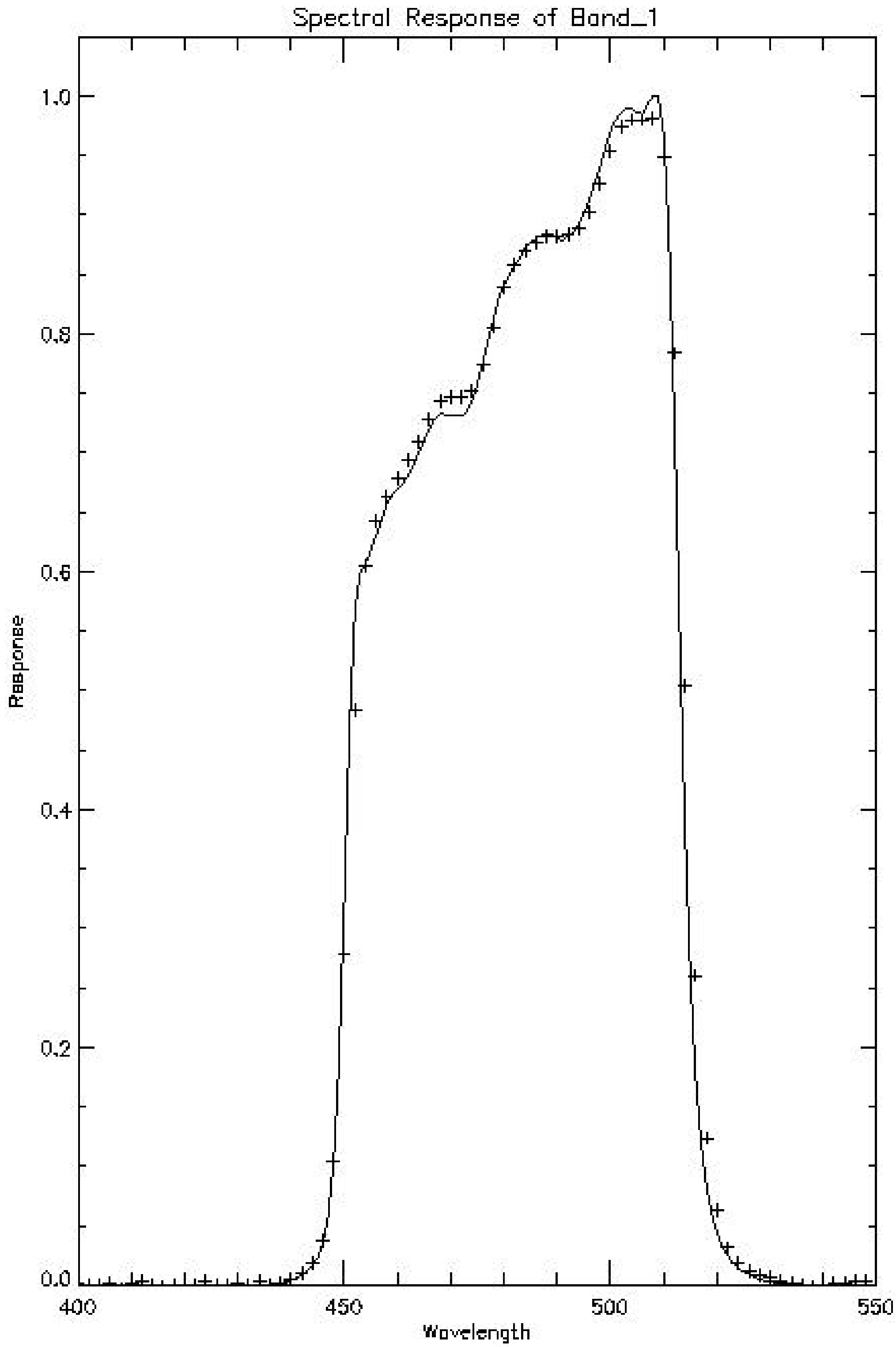

Figure 6: Spectral response of band 1. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

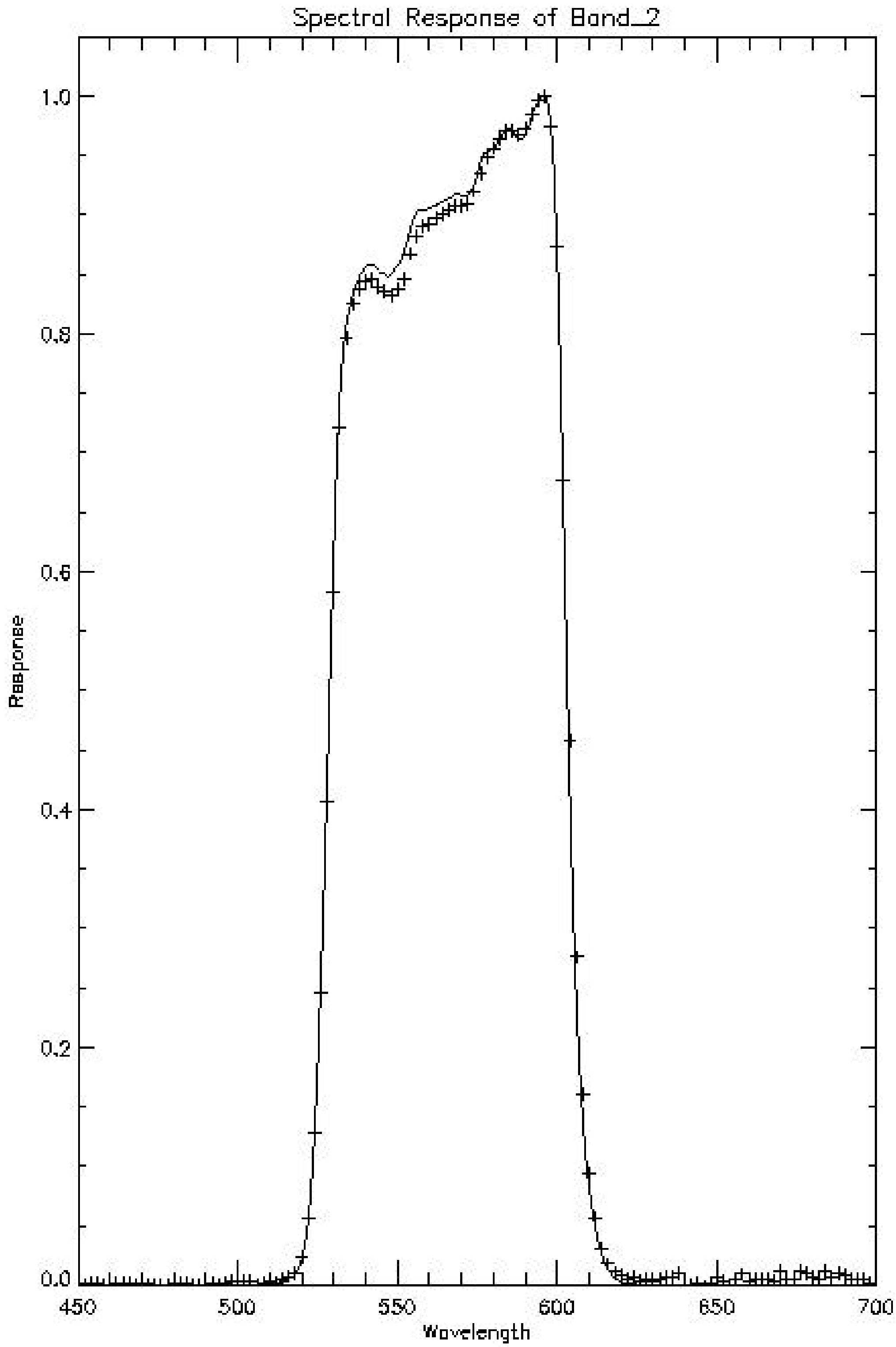

Figure 7: Spectral response of band 2. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

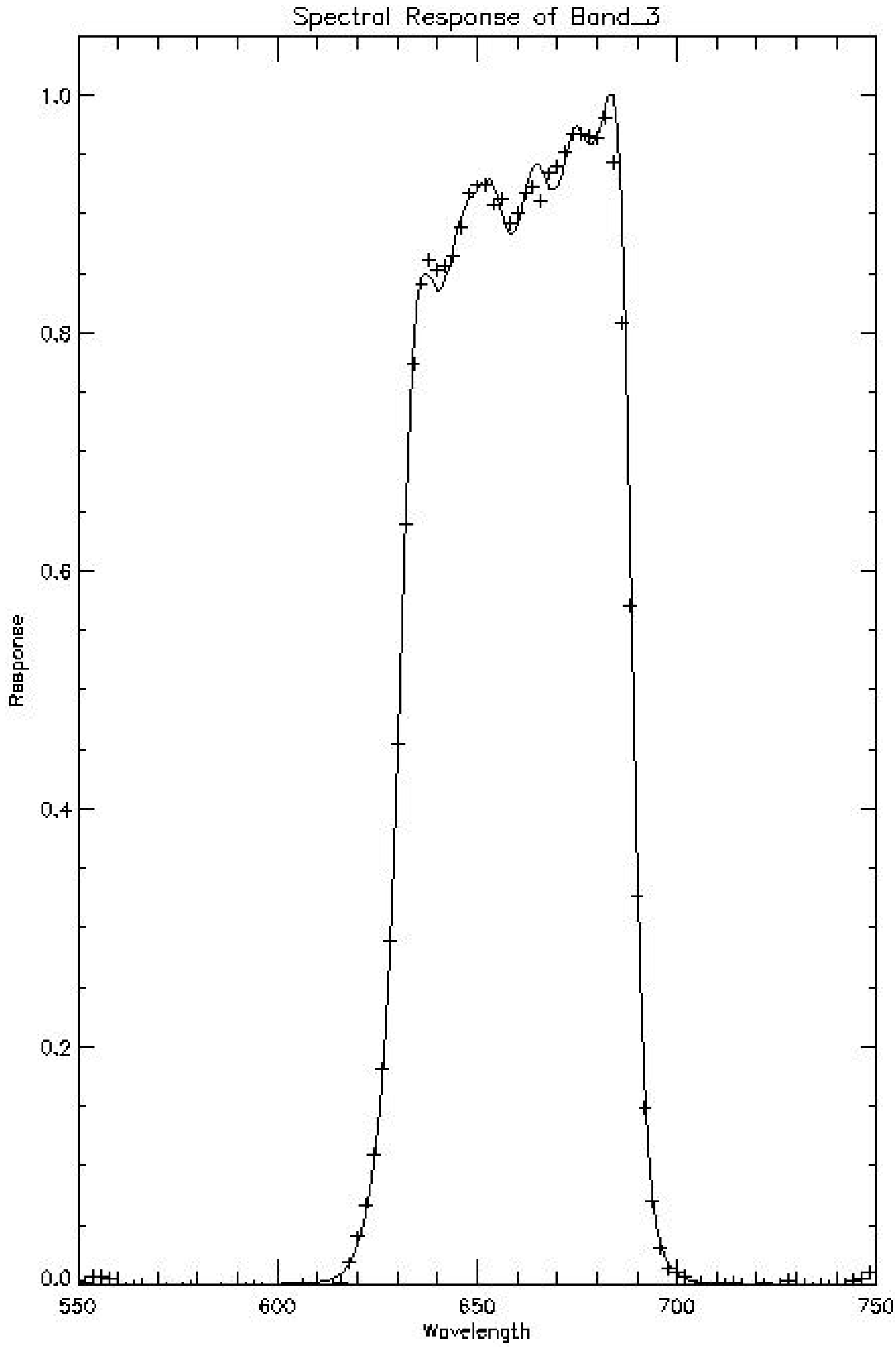

Figure 8: Spectral response of band 3. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

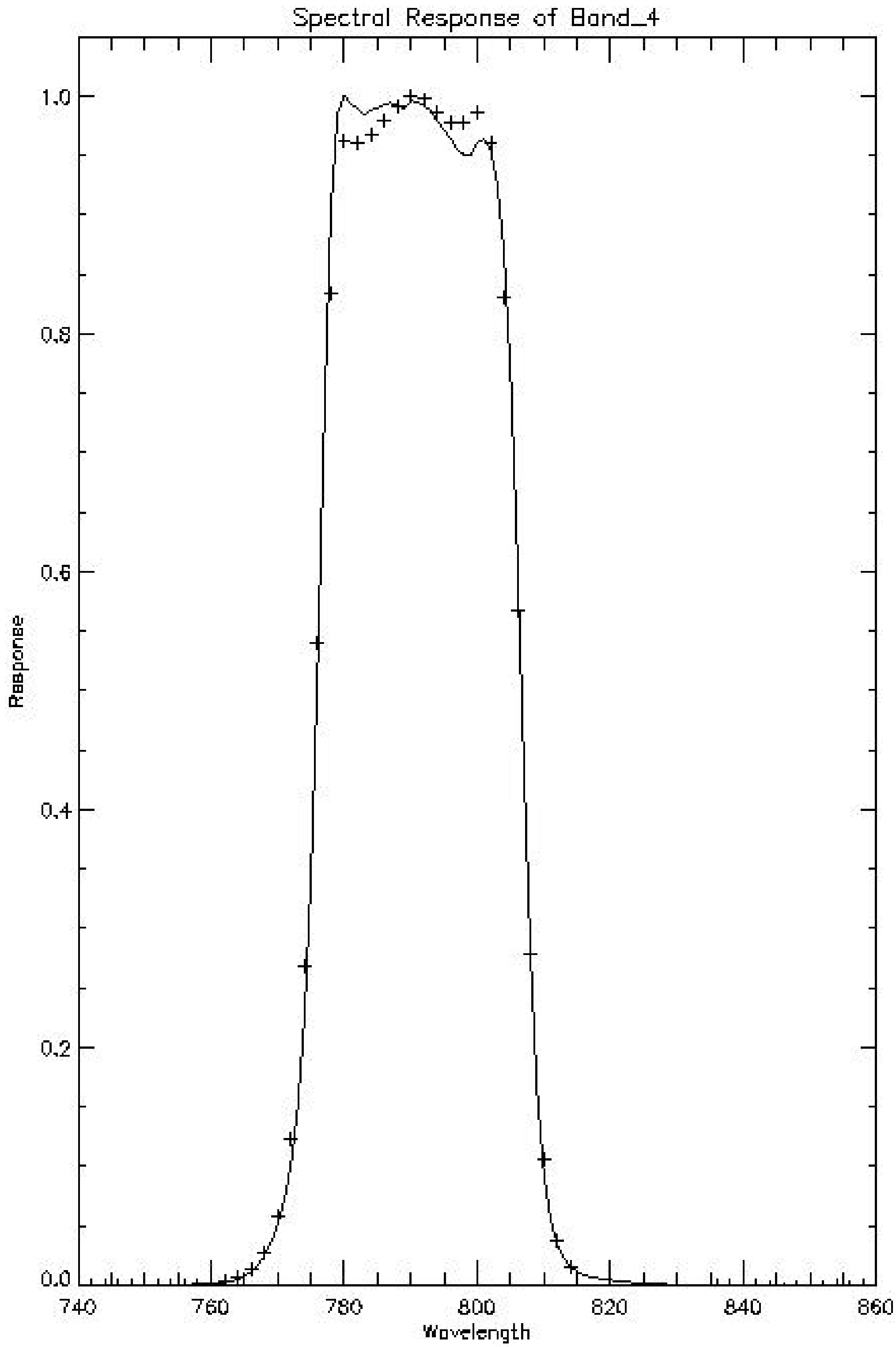

Figure 9: Spectral response of band 4. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

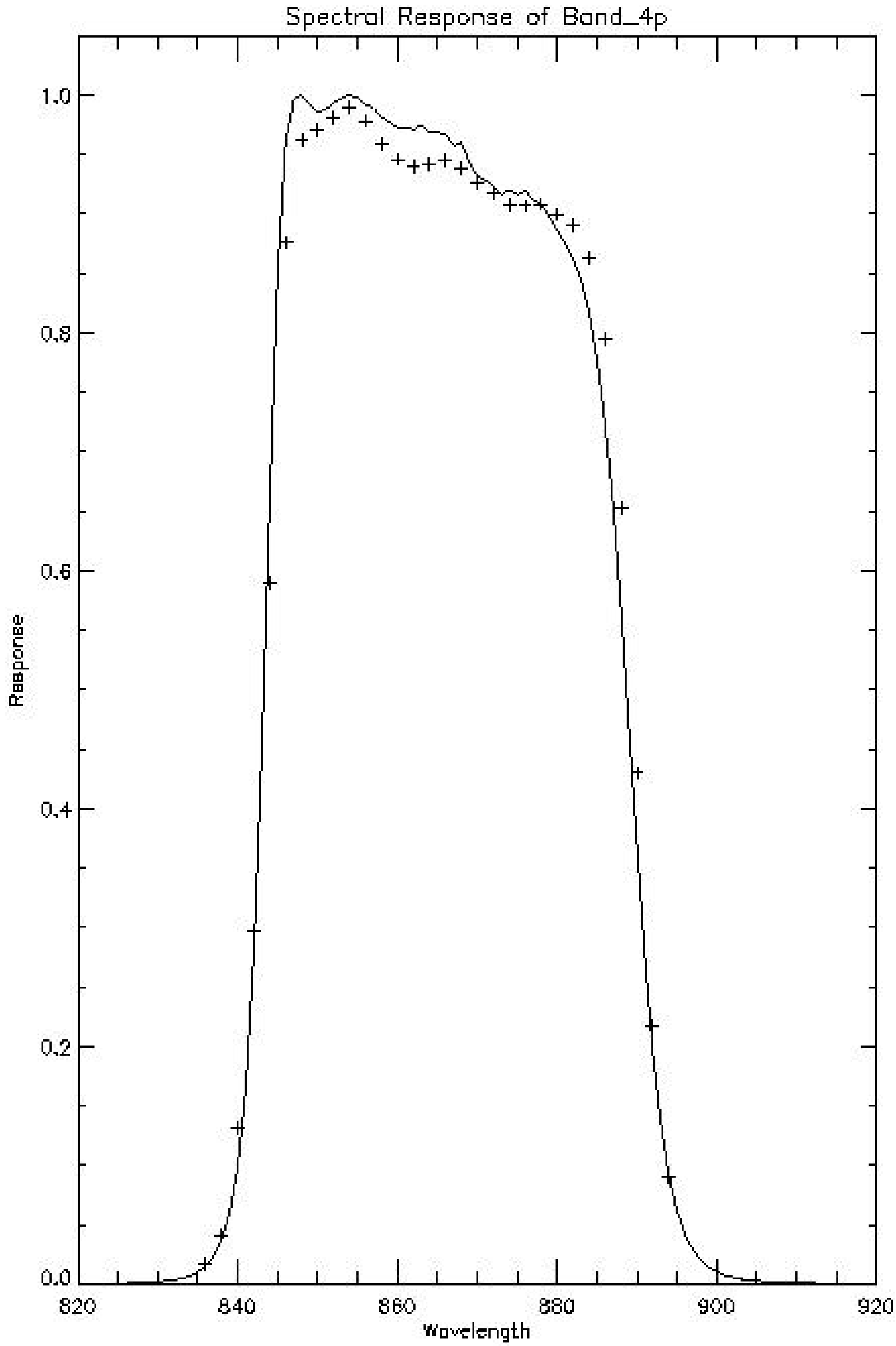

Figure 10: Spectral response of band 4p. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

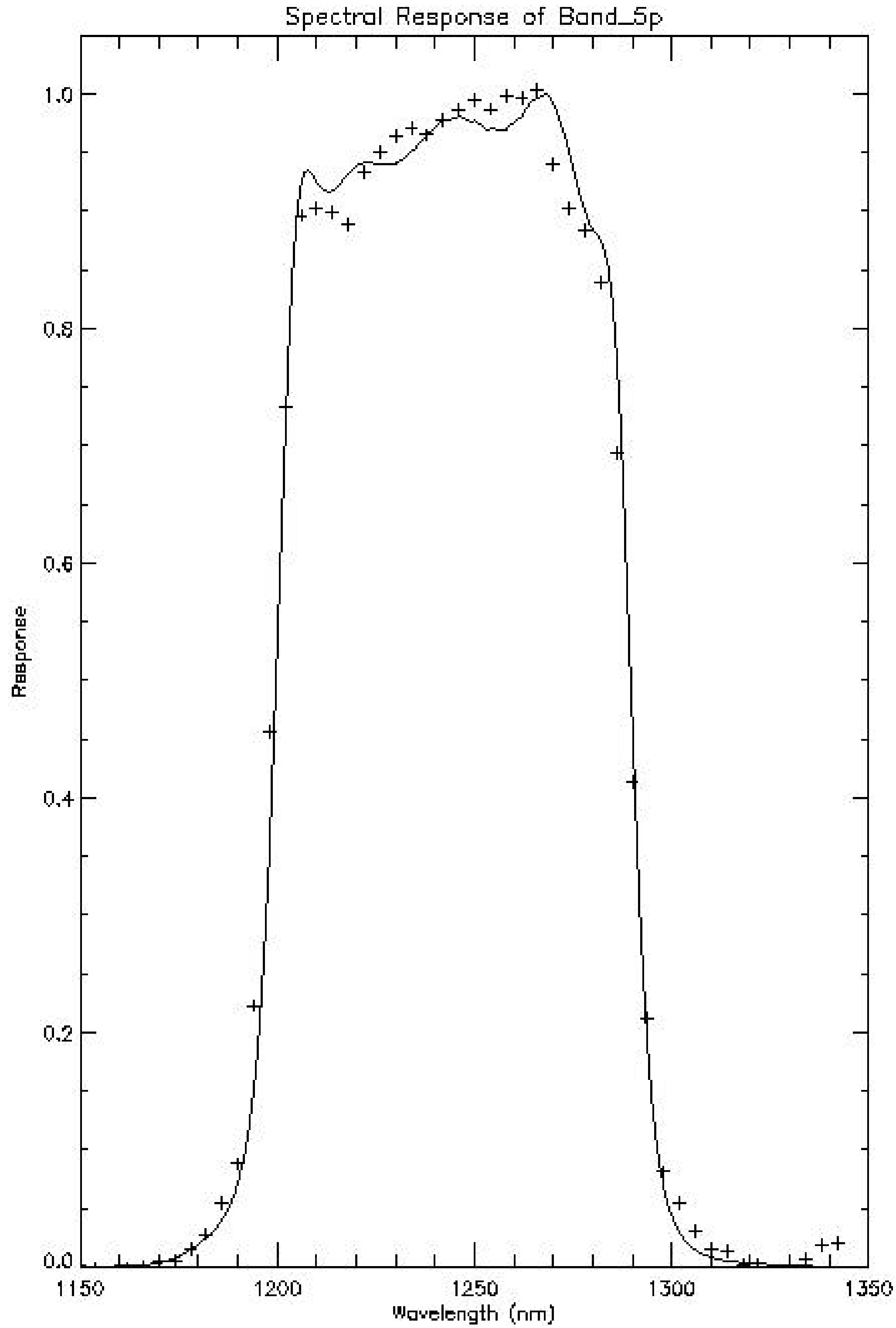

Figure 11: Spectral response of band 5p. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

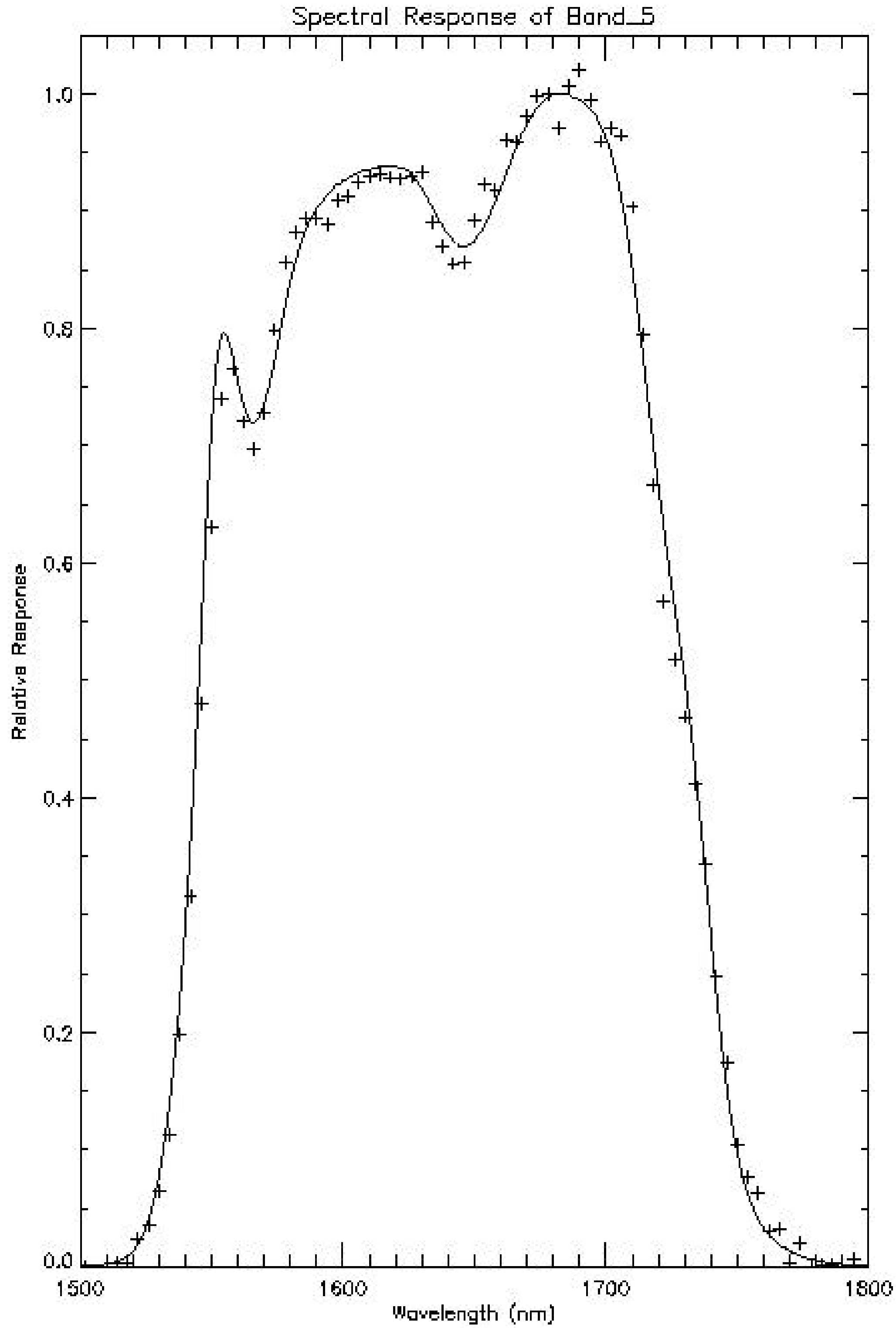

Figure 12: Spectral response of band 5. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

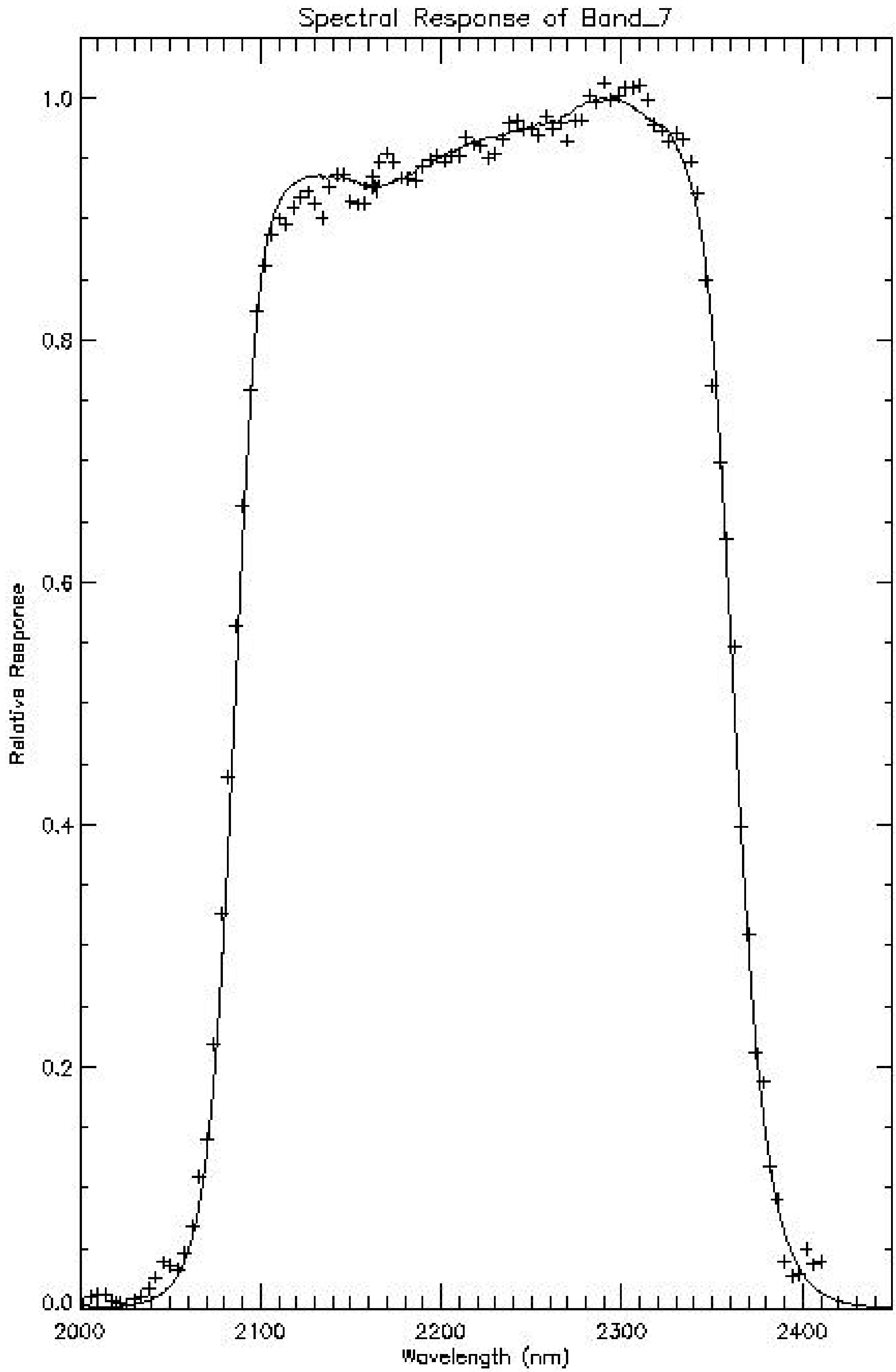

Figure 13: Spectral response of band 7. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

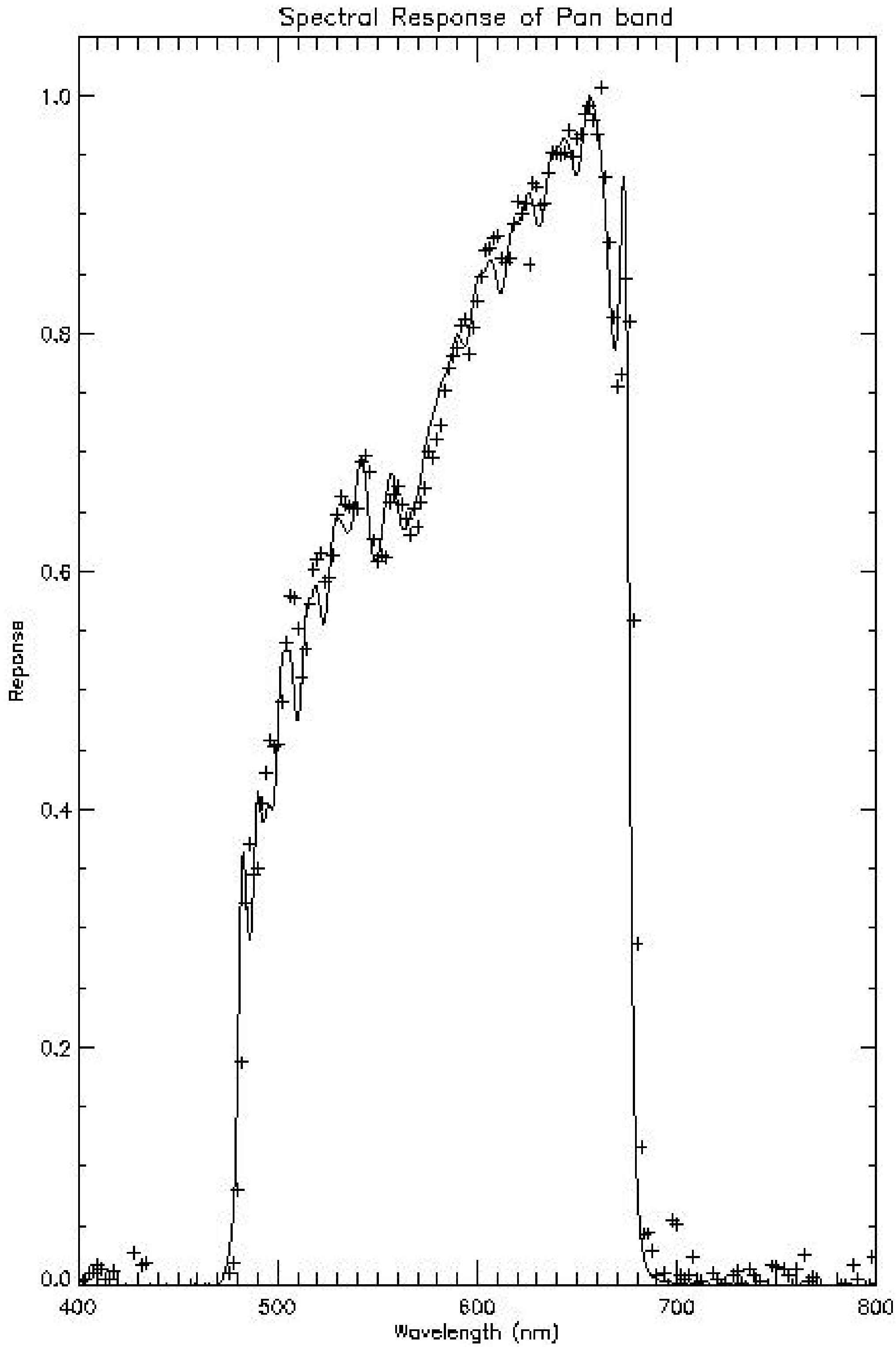

Figure 14: Spectral response of the panchromatic band. The crosses represent the mean system level measured response for 200 pixels. The solid line represents data collected during subsystem level measurements.

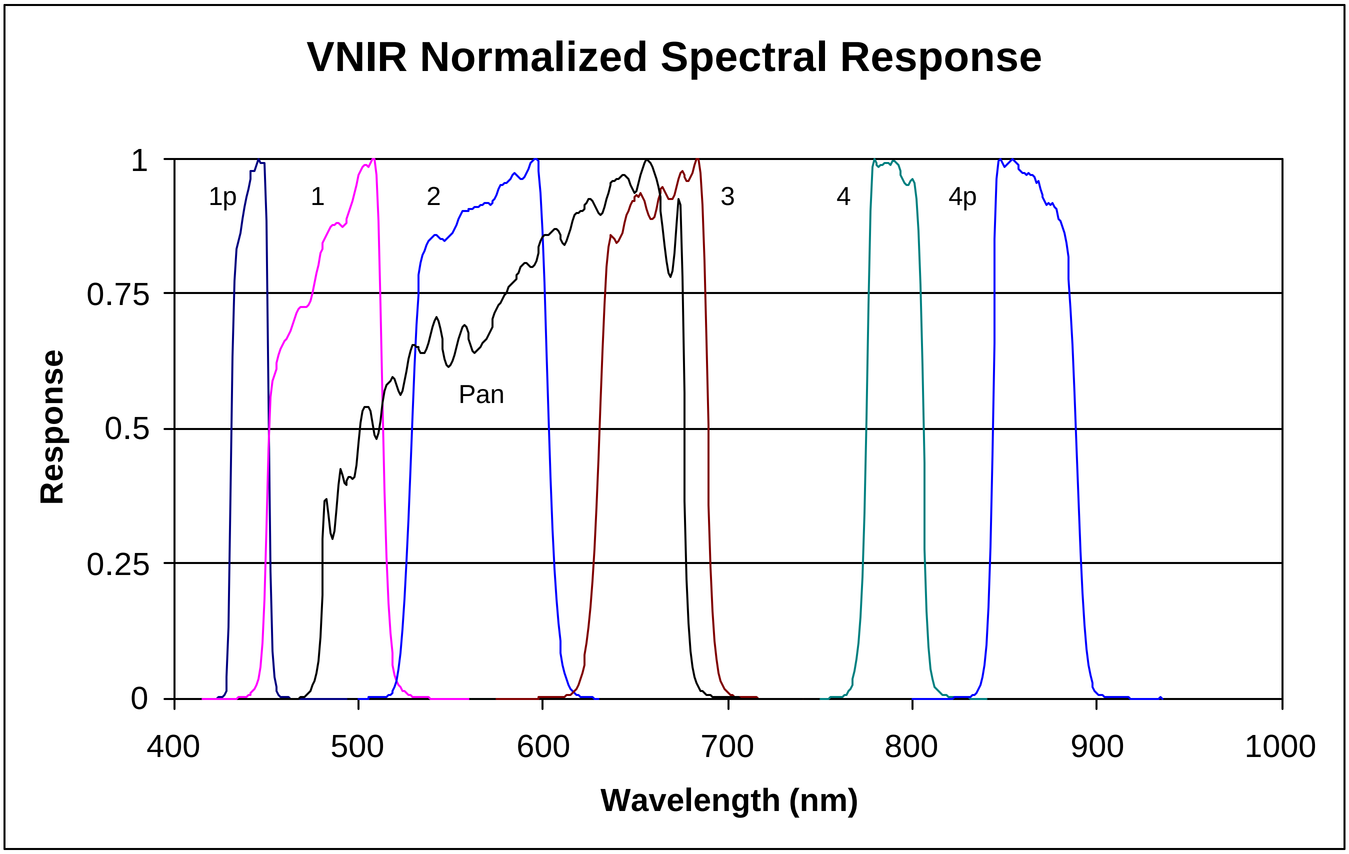

Figure 15: Normalized visible and near infrared spectral response functions based on subsystem level measurements.

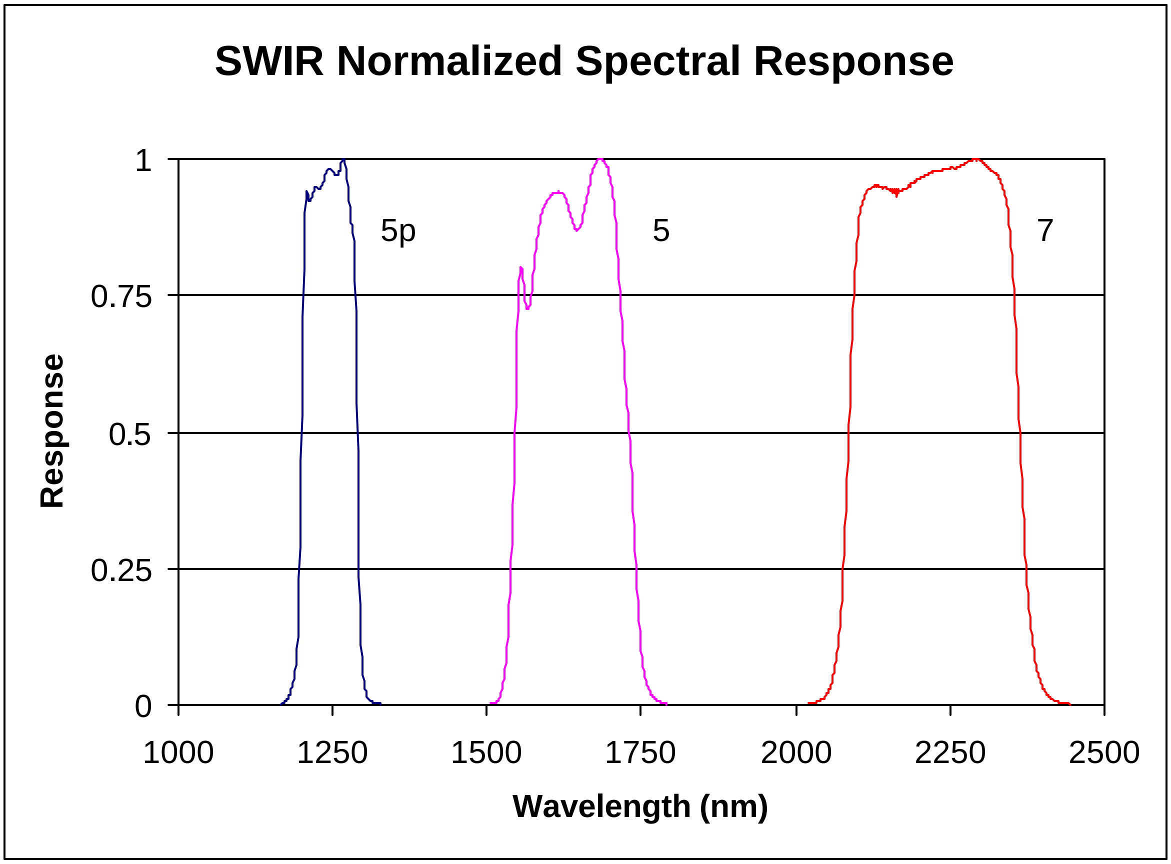

Figure 16: Normalized short wave infrared spectral response functions based on subsystem level measurements.

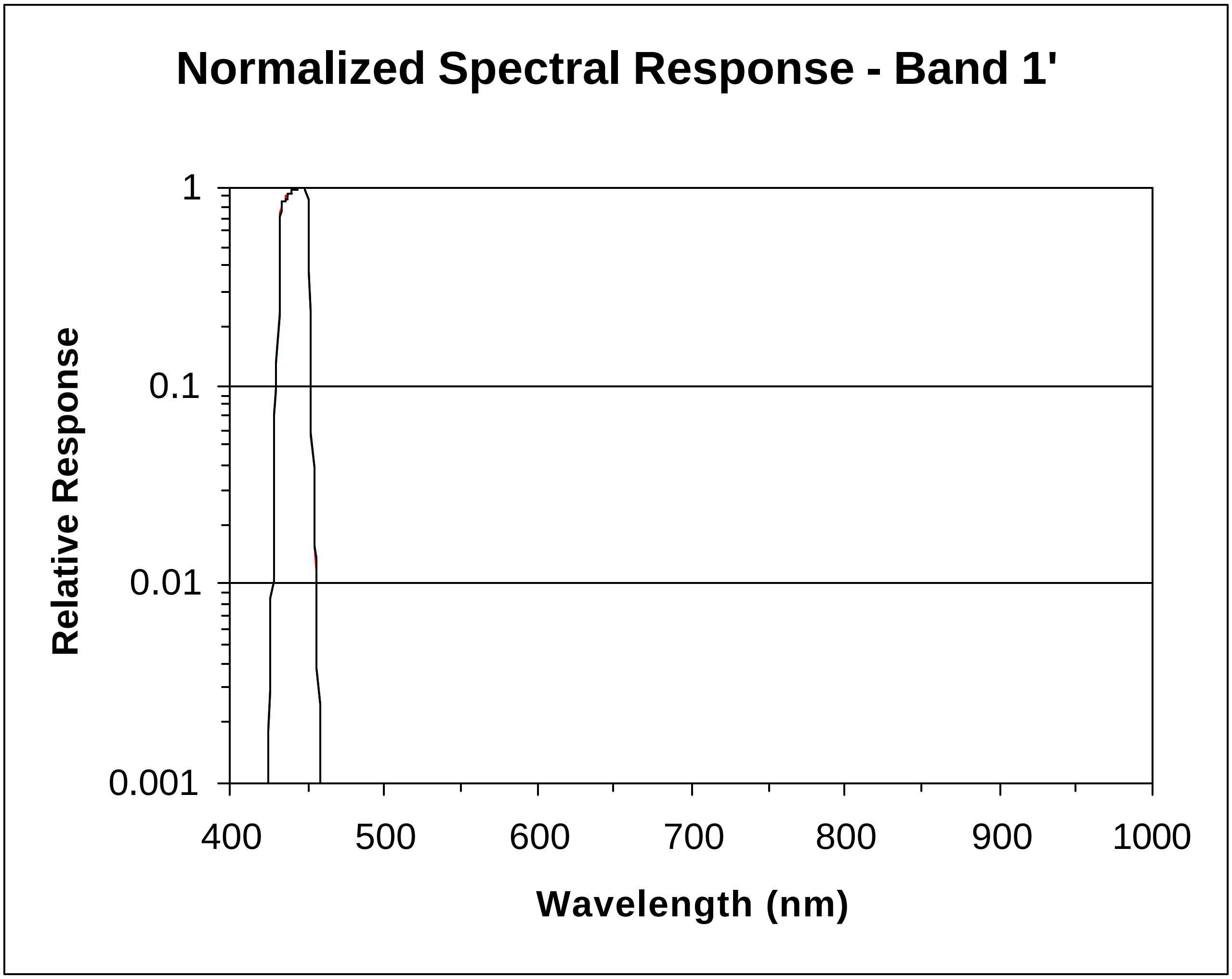

Figure 17: Spectral response of Band 1p calculated from subsystem level measurements.

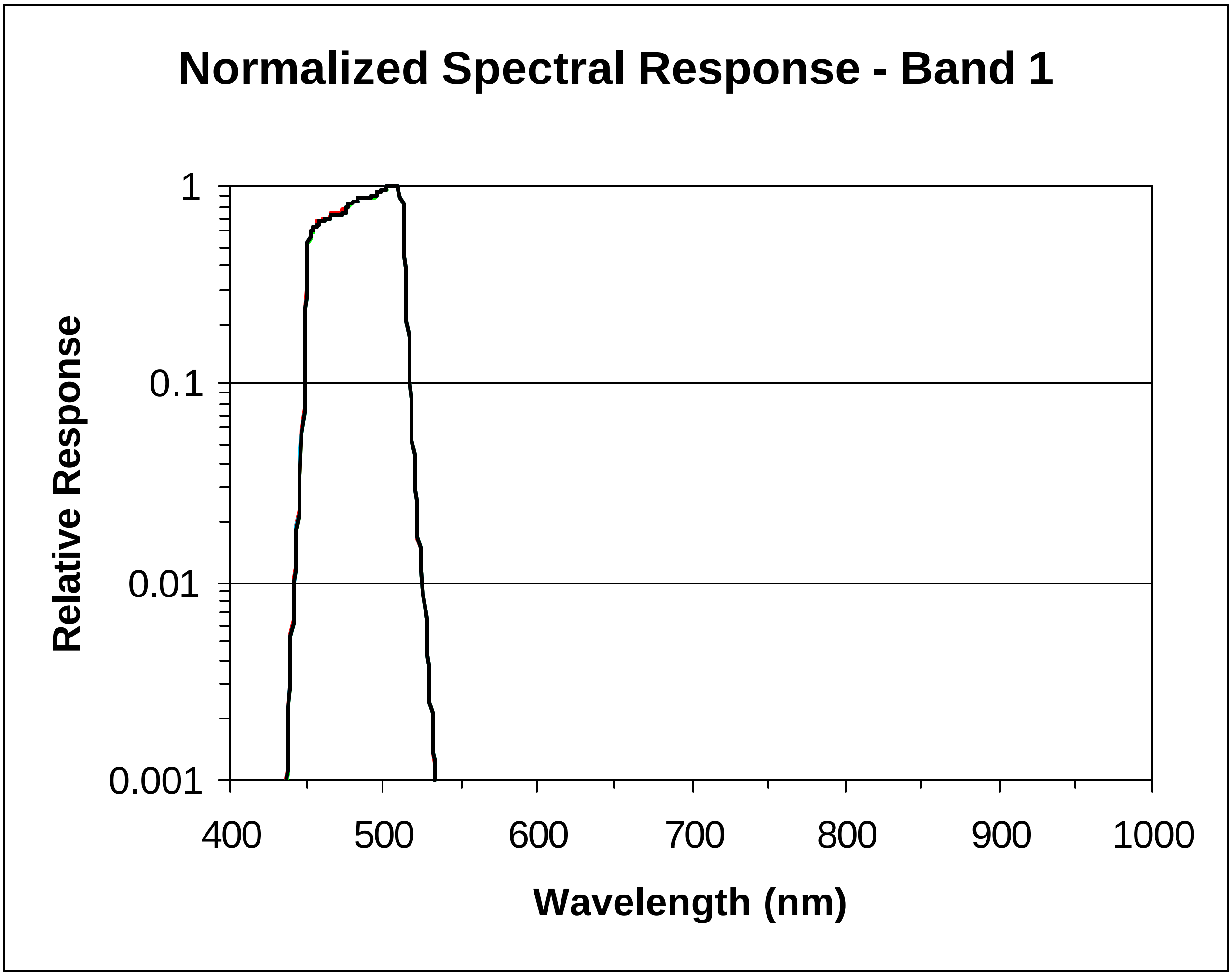

Figure 18: Spectral response of Band 1 calculated from subsystem level measurements.

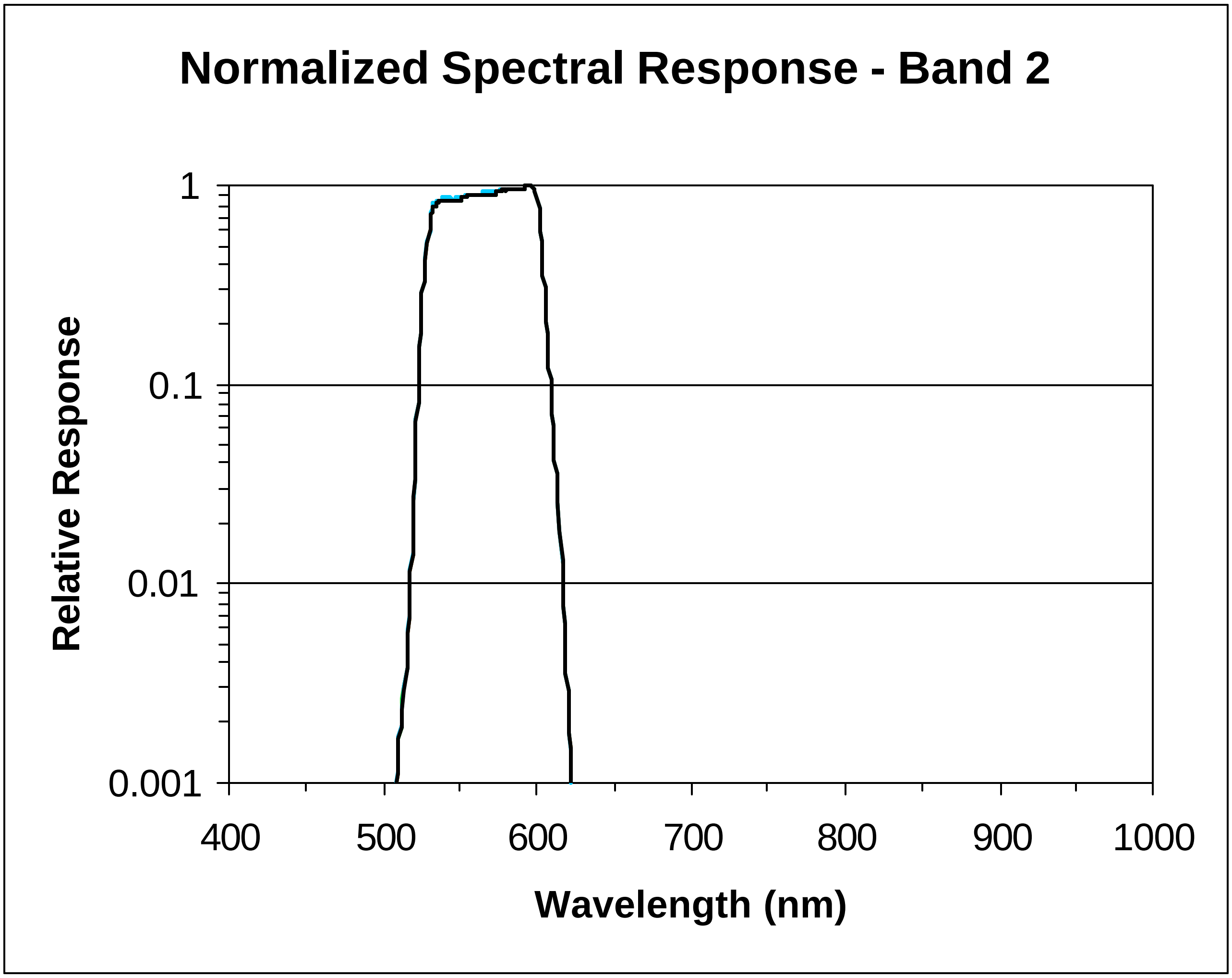

Figure 19: Spectral response of Band 2 calculated from subsystem level measurements.

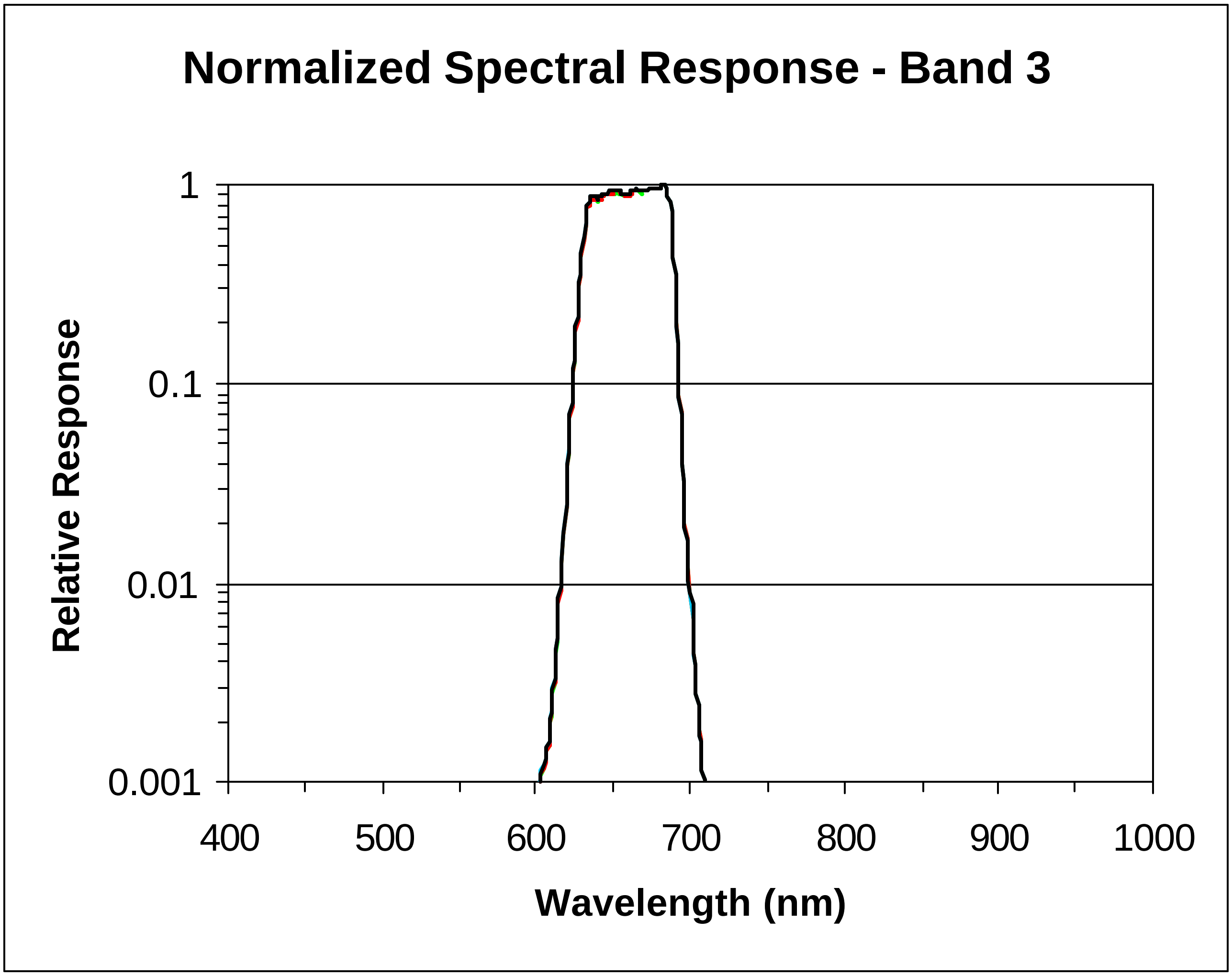

Figure 20: Spectral response of Band 3 calculated from subsystem level measurements.

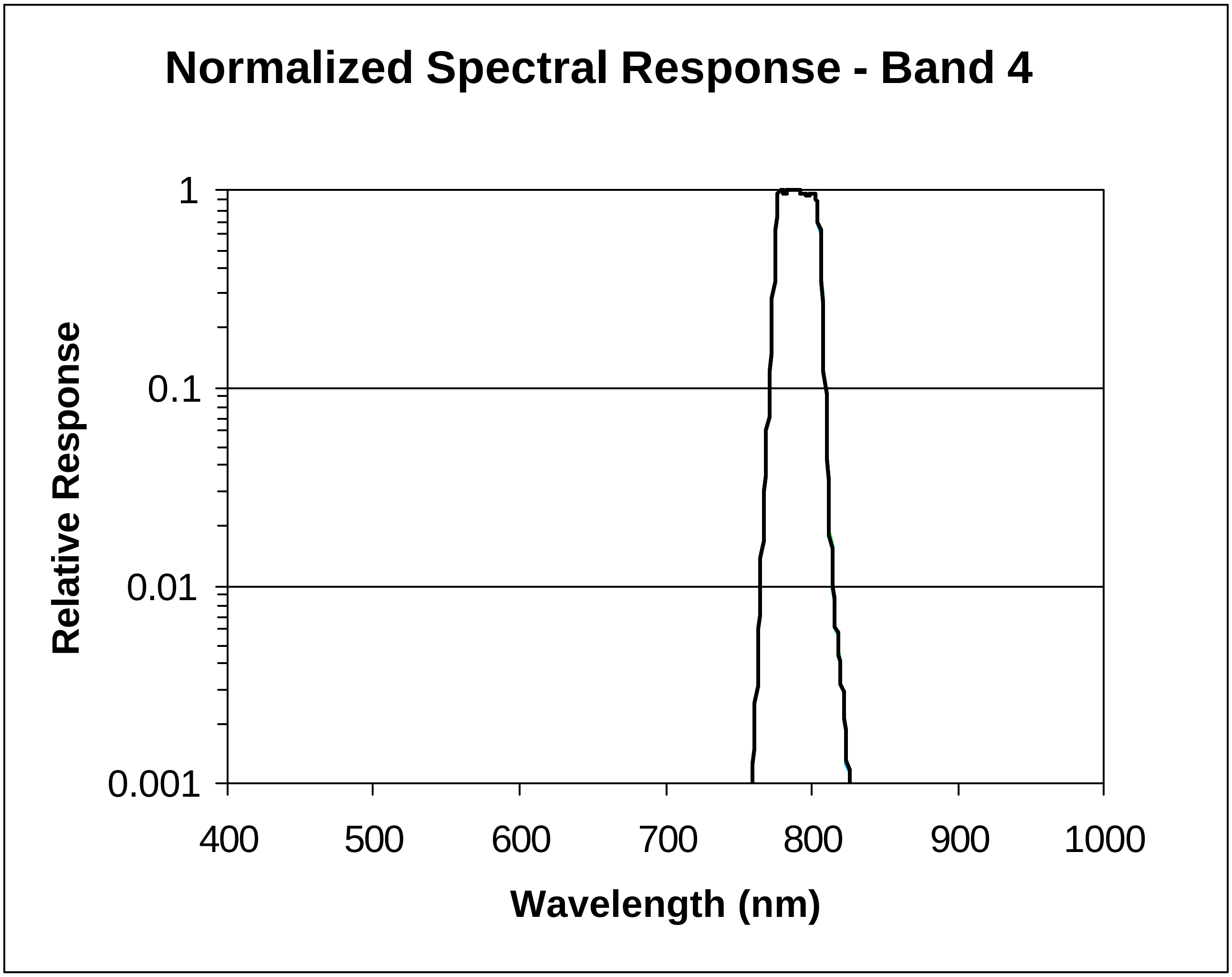

Figure 21: Spectral response of Band 4 calculated from subsystem level measurements.

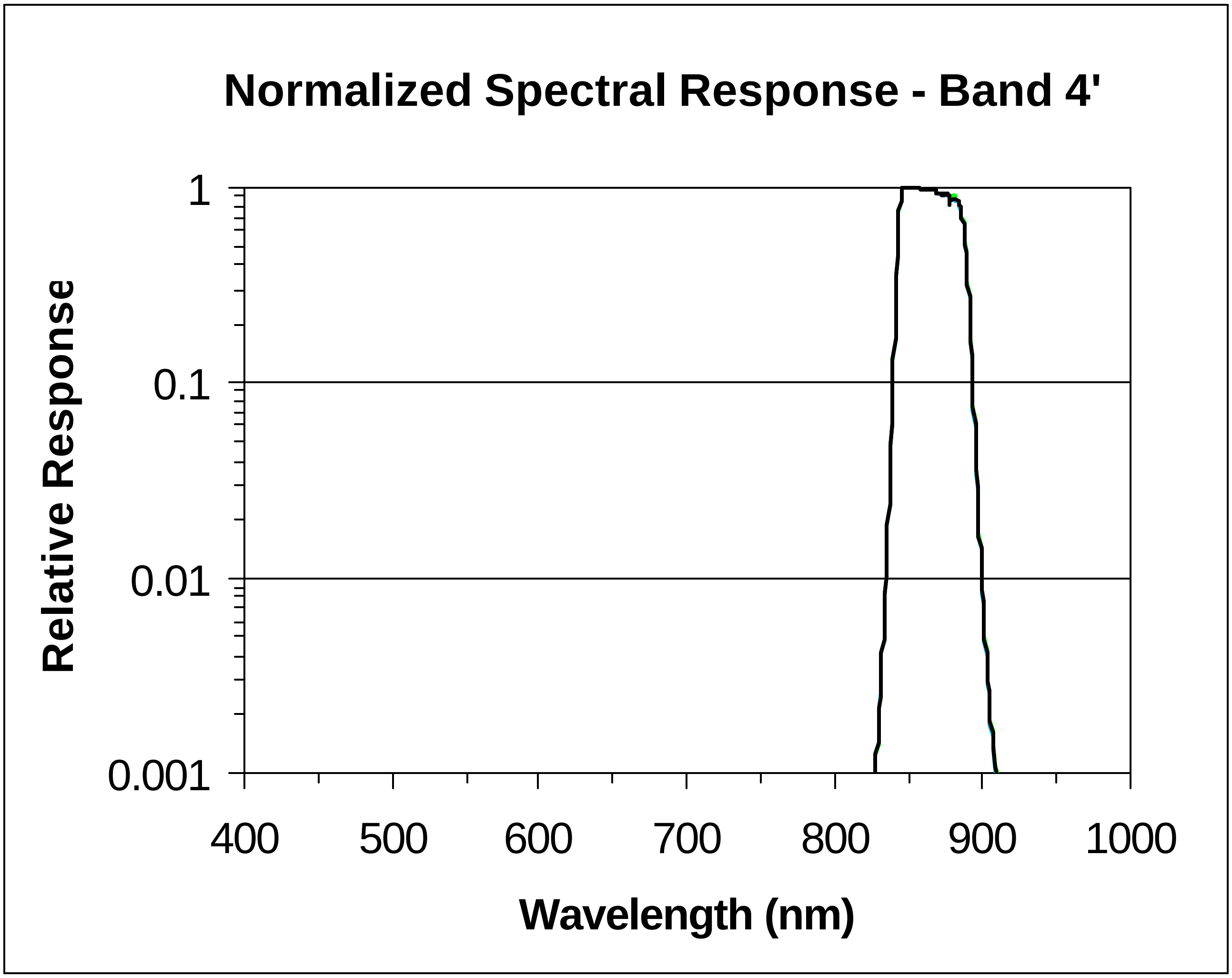

Figure 22: Spectral response of Band 4p calculated from subsystem level measurements.

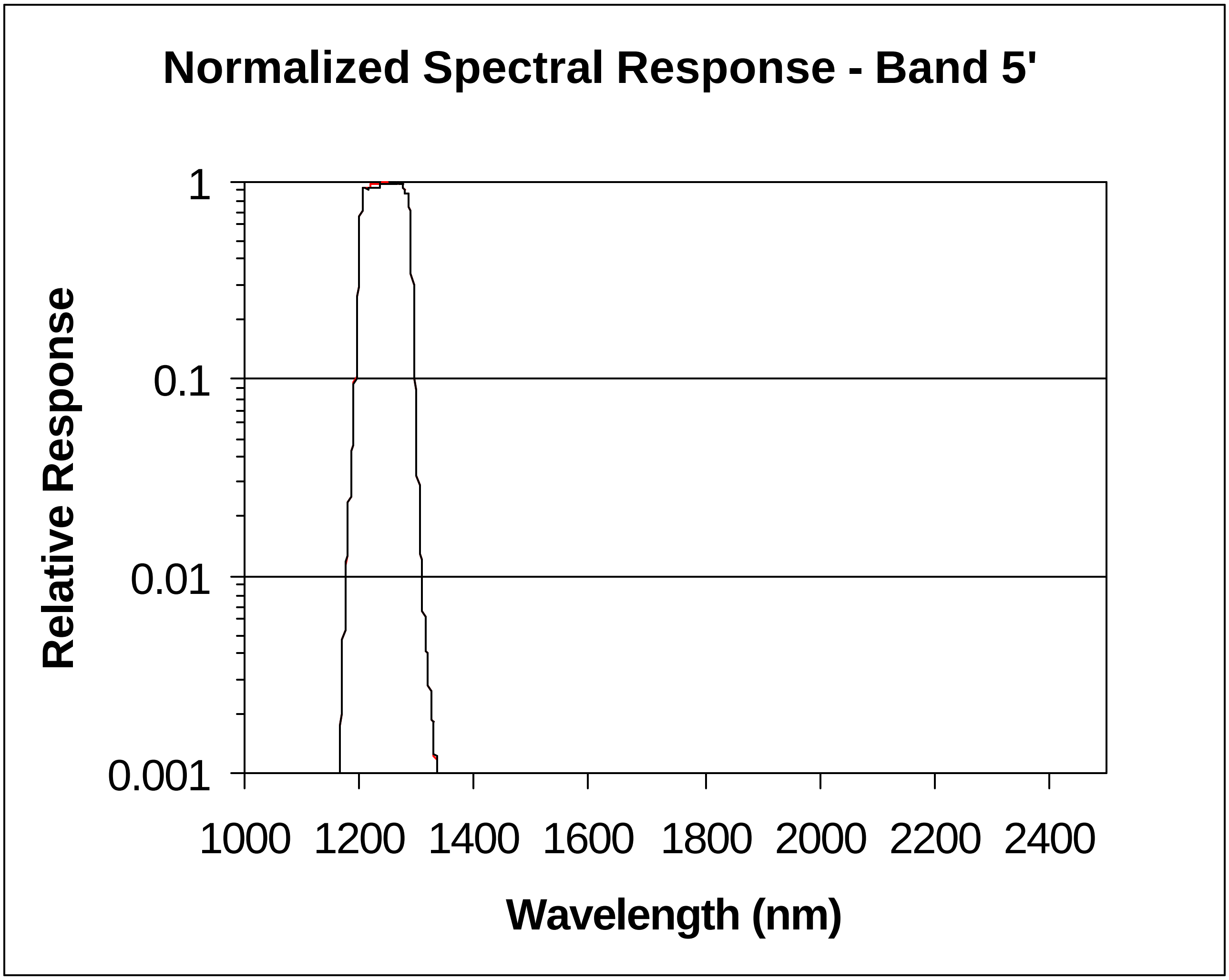

Figure 23: Spectral response of Band 5p calculated from subsystem level measurements.

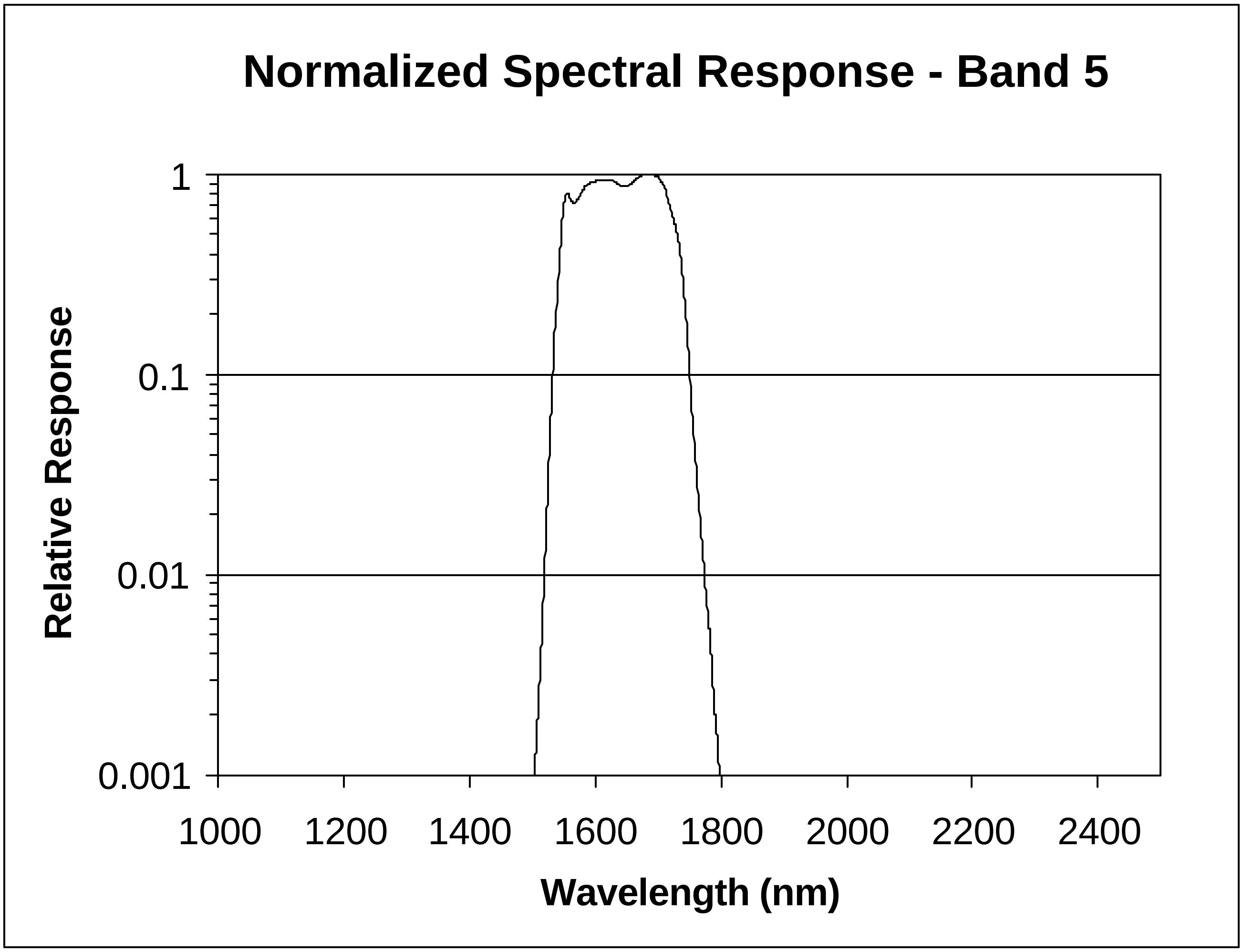

Figure 24: Spectral response of Band 5 calculated from subsystem level measurements.

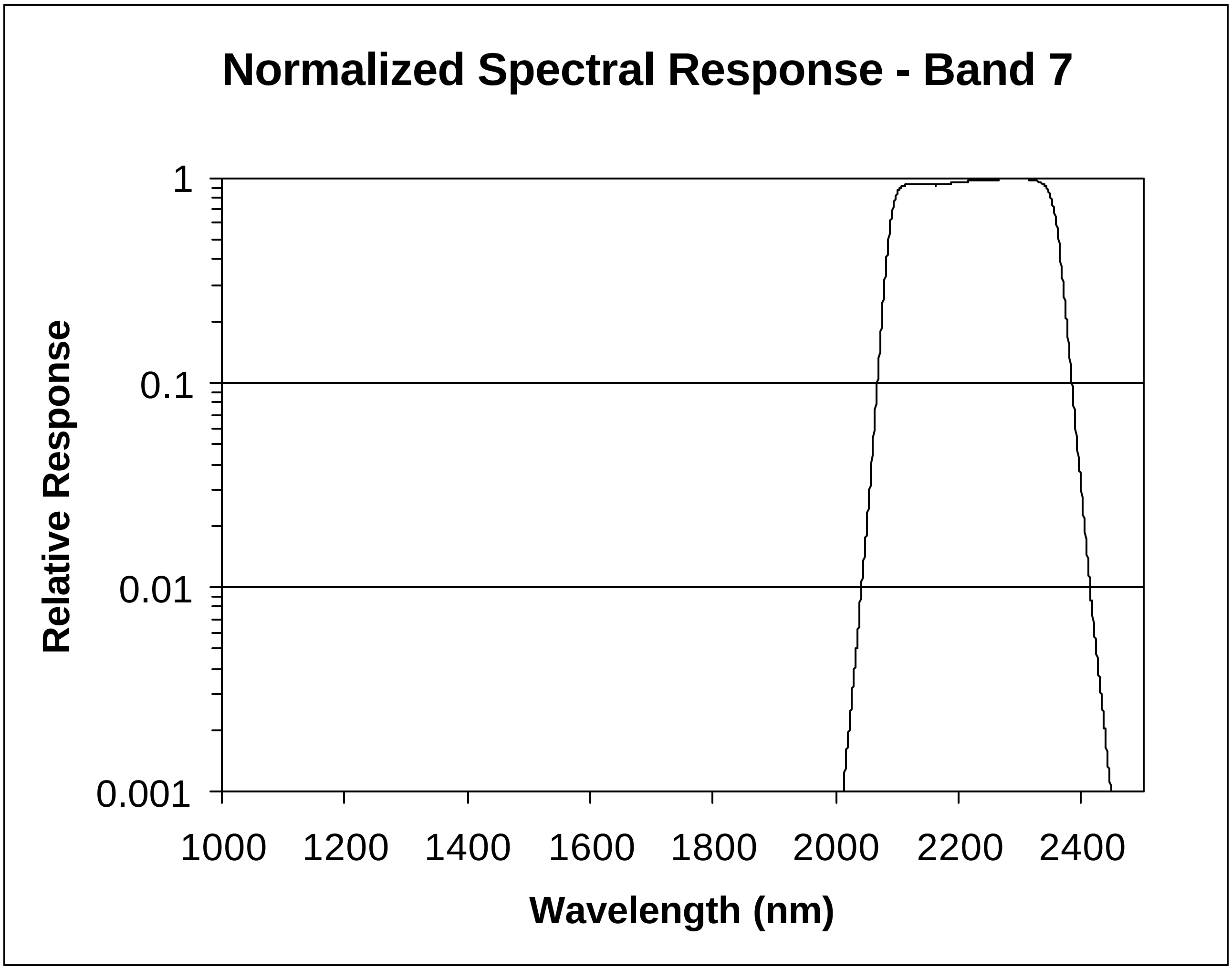

Figure 25: Spectral response of Band 7 calculated from subsystem level measurements.

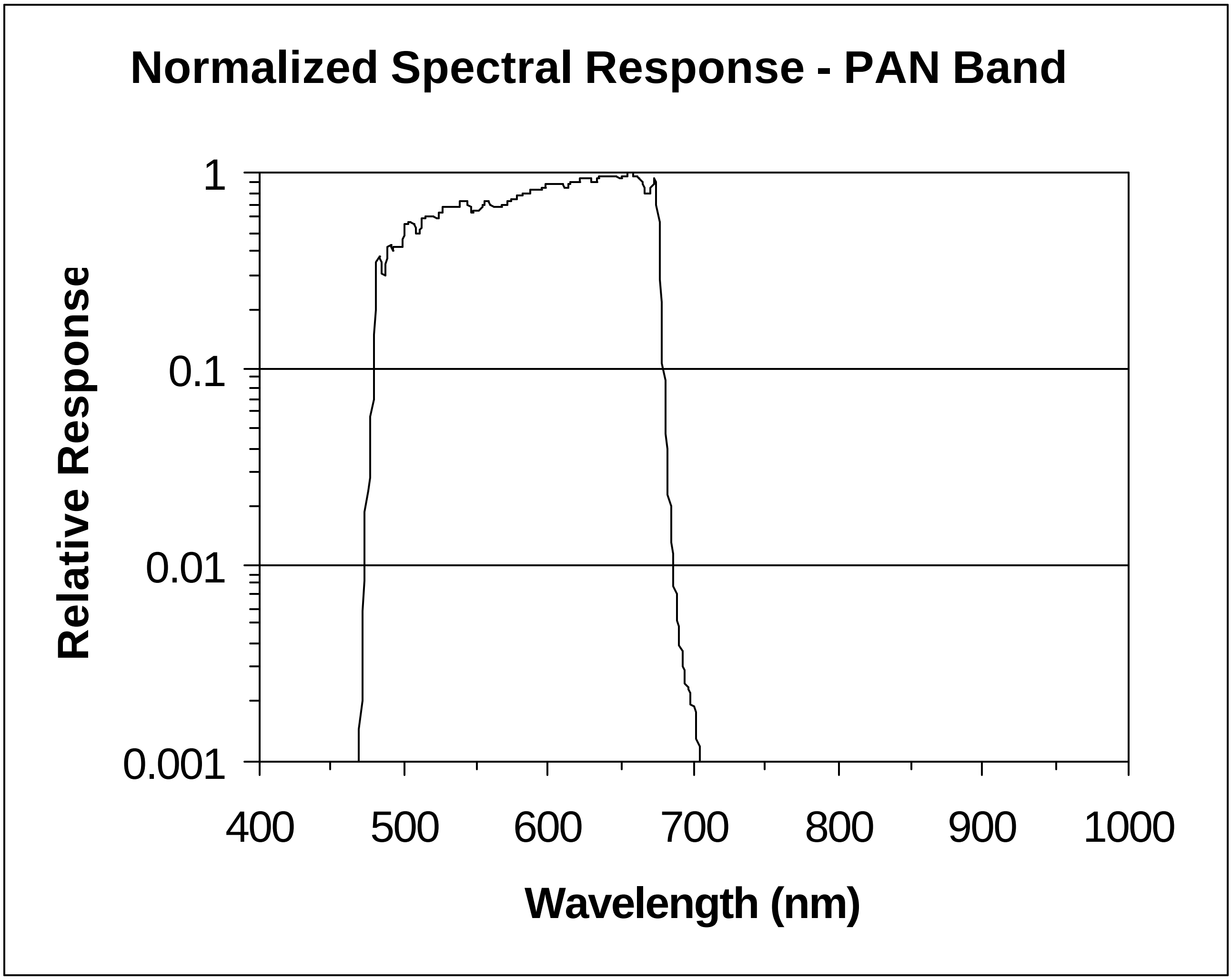

Figure 26: Spectral response of panchromatic band calculated from subsystem level measurements.

6. Discussion

We find the system level ALI VNIR, SWIR and panchromatic spectral response measurements are in excellent agreement with theoretical models generated from component measurements. We find the spectral response of the ALI to be primarily dependent on the spectral response of the band defining filters lying directly above the focal plane. Detector responsivities also have a small effect on the spectral response of this instrument. This is particularly true for bands with larger bandpasses, such as the panchromatic band. For this band, the gradually increasing efficiency of the silicon material must be accounted for to accurately predict the spectral response of the ALI. Finally, mirror response has little effect on the spectral response of the instrument above 500 nm, providing a global diminution of ~5% which is not a factor when band responses are normalized to unity. However, mirror reflectivities do fall off (down to 80%) below 500 nm and so must be properly accounted for when considering bands in this spectral range.

We have adopted response functions based on the finer spectrally sampled component measurements as the spectral response of the Advanced Land Imager for the VNIR, SWIR and panchromatic bands (Figures 15-26). These responses will be used to define the spectral bandpass for each band during the analysis of in-flight data. These responses have also been adopted for calculating the in-band radiance of each pixel during radiometric calibration of the ALI (see *Earth Observing-1 Advanced Land Imager: Radiometric Response Calibration*).

Tables 3-12 provide lists of the spectral response of each band near their respective cut-on and cut-off wavelengths. No measurable transmission (<0.01%) was recorded for spectral ranges not listed. An Excel file entitled 'EO1_ALI_SPECTRAL_RESP.XLS' has been generated and is available through the GSFC EO-1 project office. This file contains the in-band and out of band response of each ALI band listed in the above tables.

7. Spectral Response Tables

Table 3: Band 1p Spectral Response

Wavelength (nm)	Response
415	0.00001
416	0.00001
417	0.00001
418	0.00002
419	0.00005
420	0.00002
421	0.00004
422	0.00006
423	0.00012
424	0.00033
425	0.00112
426	0.00294
427	0.00592
428	0.01290
429	0.03775
430	0.13134
431	0.37654
432	0.63138
433	0.77226
434	0.83116
435	0.84806
436	0.86361
437	0.88850
438	0.91209
439	0.92965
440	0.94517
441	0.96242
442	0.97607
443	0.97575
444	0.97628
445	0.98894
446	1.00000
447	0.99352
448	0.99135
449	0.99052
450	0.88463
451	0.55995
452	0.23447
453	0.08814
454	0.03889
455	0.02077

456	0.01179
457	0.00572
458	0.00246
459	0.00114
460	0.00063
461	0.00044
462	0.00032
463	0.00021
464	0.00010
465	0.00004
466	0.00003
467	0.00001
468	0.00001
469	0.00004
470	0.00002
471	0.00003
472	0.00002
473	-0.00002
474	-0.00002
475	0.00002
476	0.00000
477	0.00002
478	0.00000
479	0.00002
480	0.00000
481	0.00000
482	0.00002
483	0.00000
484	0.00000
485	0.00002
486	0.00002
487	0.00007
488	-0.00002
489	0.00000
490	0.00002
491	0.00000
492	0.00002
493	0.00000
494	0.00000

Table 4: Band 1 Spectral Response

Wavelength (nm)	Response
415	-0.00004
416	-0.00003
417	-0.00004
418	-0.00004
419	-0.00003
420	-0.00003
421	-0.00002
422	-0.00002
423	0.00001
424	0.00002
425	0.00001
426	0.00002
427	0.00002
428	0.00002
429	0.00003
430	0.00004
431	0.00006
432	0.00009
433	0.00016
434	0.00021
435	0.00039
436	0.00067
437	0.00110
438	0.00184
439	0.00291
440	0.00443
441	0.00623
442	0.00839
443	0.01139
444	0.01566
445	0.02255
446	0.03517
447	0.05748
448	0.10196
449	0.18264
450	0.31656
451	0.46250
452	0.55808
453	0.58908
454	0.59755
455	0.60835
456	0.62161
457	0.63420

458	0.64768
459	0.65556
460	0.66082
461	0.66457
462	0.67297
463	0.68120
464	0.69173
465	0.70316
466	0.71233
467	0.72016
468	0.72509
469	0.72471
470	0.72492
471	0.72439
472	0.72452
473	0.72742
474	0.73752
475	0.75121
476	0.76916
477	0.78729
478	0.80520
479	0.82417
480	0.83452
481	0.84409
482	0.85321
483	0.85862
484	0.86760
485	0.87198
486	0.87556
487	0.87814
488	0.88039
489	0.87934
490	0.87749
491	0.87441
492	0.87891
493	0.88112
494	0.88960
495	0.89782
496	0.90930
497	0.92310
498	0.93652
499	0.95340
500	0.96872
501	0.97846
502	0.98377
503	0.98798
504	0.98831
505	0.98540

506	0.98426
507	0.99277
508	0.99912
509	1.00000
510	0.96800
511	0.88388
512	0.72901
513	0.54907
514	0.38372
515	0.26095
516	0.17493
517	0.12051
518	0.08465
519	0.06078
520	0.04416
521	0.03304
522	0.02508
523	0.01909
524	0.01471
525	0.01128
526	0.00873
527	0.00668
528	0.00502
529	0.00383
530	0.00288
531	0.00216
532	0.00162
533	0.00125
534	0.00099
535	0.00078
536	0.00059
537	0.00046
538	0.00035
539	0.00030
540	0.00023
541	0.00021
542	0.00014
543	0.00012
544	0.00011
545	0.00010
546	0.00009
547	0.00008
548	0.00005
549	0.00005
550	0.00005
551	0.00002
552	0.00004
553	0.00004

554	0.00005
555	0.00002
556	0.00003
557	0.00002
558	0.00001
559	0.00002

Table 5: Band 2 Spectral Response

Wavelength (nm)	Response
500	0.00006
501	0.00007
502	0.00009
503	0.00010
504	0.00016
505	0.00022
506	0.00031
507	0.00042
508	0.00060
509	0.00084
510	0.00111
511	0.00143
512	0.00191
513	0.00234
514	0.00299
515	0.00379
516	0.00493
517	0.00676
518	0.00963
519	0.01413
520	0.02166
521	0.03329
522	0.05270
523	0.08222
524	0.12653
525	0.18246
526	0.25315
527	0.33383
528	0.42369
529	0.51961
530	0.61307
531	0.69206
532	0.74734
533	0.78427
534	0.80615
535	0.81964
536	0.83077
537	0.83893
538	0.84611
539	0.85127
540	0.85540
541	0.85825
542	0.85711

543	0.85607
544	0.85258
545	0.85019
546	0.84993
547	0.84812
548	0.85074
549	0.85392
550	0.85730
551	0.86113
552	0.86887
553	0.87774
554	0.88815
555	0.89690
556	0.90286
557	0.90407
558	0.90407
559	0.90389
560	0.90618
561	0.90787
562	0.90849
563	0.90949
564	0.91082
565	0.91263
566	0.91389
567	0.91521
568	0.91836
569	0.91772
570	0.91696
571	0.91492
572	0.91721
573	0.92045
574	0.92582
575	0.93290
576	0.94443
577	0.95132
578	0.95154
579	0.95563
580	0.95369
581	0.95866
582	0.96390
583	0.96879
584	0.97226
585	0.97166
586	0.96948
587	0.96714
588	0.96326
589	0.96344
590	0.96763

591	0.97323
592	0.98217
593	0.99015
594	0.99470
595	0.99949
596	1.00009
597	0.99433
598	0.97685
599	0.93763
600	0.86768
601	0.76963
602	0.64506
603	0.52314
604	0.40830
605	0.31429
606	0.23953
607	0.18306
608	0.14002
609	0.10708
610	0.08244
611	0.06265
612	0.04782
613	0.03530
614	0.02565
615	0.01820
616	0.01282
617	0.00901
618	0.00626
619	0.00432
620	0.00292
621	0.00207
622	0.00147
623	0.00102
624	0.00075
625	0.00059
626	0.00044
627	0.00034
628	0.00026
629	0.00021
630	0.00017

Table 6: Band 3 Spectral Response

Wavelength (nm)	Response
575	0.00000
576	0.00000
577	0.00001
578	0.00003
579	0.00004
580	0.00004
581	0.00003
582	0.00004
583	0.00004
584	0.00003
585	0.00003
586	0.00003
587	0.00004
588	0.00004
589	0.00004
590	0.00004
591	0.00005
592	0.00007
593	0.00009
594	0.00011
595	0.00014
596	0.00019
597	0.00023
598	0.00031
599	0.00043
600	0.00054
601	0.00072
602	0.00087
603	0.00100
604	0.00110
605	0.00120
606	0.00131
607	0.00143
608	0.00158
609	0.00183
610	0.00221
611	0.00261
612	0.00323
613	0.00406
614	0.00524
615	0.00696
616	0.00941
617	0.01278

618	0.01759
619	0.02448
620	0.03337
621	0.04550
622	0.06016
623	0.07930
624	0.10217
625	0.13175
626	0.16791
627	0.21572
628	0.27544
629	0.35354
630	0.44384
631	0.54546
632	0.64489
633	0.73004
634	0.79863
635	0.83734
636	0.85565
637	0.86014
638	0.85607
639	0.85171
640	0.84349
641	0.84554
642	0.85532
643	0.86361
644	0.88001
645	0.89600
646	0.90471
647	0.91358
648	0.92119
649	0.92226
650	0.92710
651	0.93298
652	0.93059
653	0.93710
654	0.92905
655	0.92086
656	0.90809
657	0.89671
658	0.88900
659	0.88949
660	0.89394
661	0.90559
662	0.92354
663	0.93587
664	0.94358
665	0.94627

666	0.94172
667	0.93366
668	0.92460
669	0.92369
670	0.92638
671	0.93358
672	0.94790
673	0.96099
674	0.97228
675	0.97591
676	0.97022
677	0.96448
678	0.95961
679	0.95992
680	0.96566
681	0.97469
682	0.98972
683	0.99998
684	0.99968
685	0.97325
686	0.91412
687	0.80932
688	0.66334
689	0.50773
690	0.35971
691	0.24415
692	0.16300
693	0.10750
694	0.07135
695	0.04828
696	0.03305
697	0.02307
698	0.01653
699	0.01183
700	0.00889
701	0.00670
702	0.00503
703	0.00392
704	0.00308
705	0.00245
706	0.00192
707	0.00161
708	0.00125
709	0.00103
710	0.00082
711	0.00071
712	0.00063
713	0.00053

714	0.00043
715	0.00037
716	0.00032
717	0.00024
718	0.00020
719	0.00018
720	0.00016
721	0.00015
722	0.00012
723	0.00010
724	0.00009
725	0.00004
726	0.00004
727	0.00005
728	0.00001
729	0.00002
730	0.00003
731	0.00000
732	0.00002
733	0.00002
734	0.00000
735	0.00000
736	0.00000
737	0.00002
738	0.00002
739	-0.00001
740	-0.00002

Table 7: Band 4 Spectral Response

Wavelength (nm)	Response
750	0.00018
751	0.00015
752	0.00014
753	0.00018
754	0.00020
755	0.00027
756	0.00040
757	0.00055
758	0.00073
759	0.00108
760	0.00150
761	0.00217
762	0.00312
763	0.00493
764	0.00725
765	0.01135
766	0.01701
767	0.02492
768	0.03600
769	0.05093
770	0.07174
771	0.10145
772	0.14875
773	0.22369
774	0.34435
775	0.51863
776	0.72925
777	0.90468
778	0.98523
779	1.00000
780	0.99355
781	0.98928
782	0.98333
783	0.98836
784	0.98918
785	0.99286
786	0.99384
787	0.99177
788	0.98929
789	0.99566
790	0.99487
791	0.99191
792	0.98710

793	0.97841
794	0.97103
795	0.96383
796	0.95439
797	0.95076
798	0.95070
799	0.96036
800	0.96334
801	0.95443
802	0.92595
803	0.86804
804	0.76570
805	0.61815
806	0.43490
807	0.27562
808	0.16107
809	0.09372
810	0.05492
811	0.03439
812	0.02246
813	0.01563
814	0.01140
815	0.00862
816	0.00691
817	0.00582
818	0.00488
819	0.00420
820	0.00351
821	0.00291
822	0.00235
823	0.00189
824	0.00143
825	0.00116
826	0.00085
827	0.00070
828	0.00058
829	0.00053
830	0.00047
831	0.00034
832	0.00030
833	0.00024
834	0.00016
835	0.00012
836	0.00007
837	0.00006
838	0.00002
839	-0.00001
840	-0.00001

Table 8: Band 4p Spectral Response

Wavelength (nm)	Response
800	0.00000
801	0.00002
802	0.00001
803	0.00000
804	0.00002
805	0.00004
806	0.00002
807	0.00004
808	0.00002
809	0.00005
810	0.00004
811	0.00005
812	0.00004
813	0.00006
814	0.00006
815	0.00007
816	0.00009
817	0.00009
818	0.00013
819	0.00014
820	0.00017
821	0.00021
822	0.00026
823	0.00031
824	0.00040
825	0.00051
826	0.00062
827	0.00082
828	0.00106
829	0.00143
830	0.00190
831	0.00252
832	0.00351
833	0.00488
834	0.00693
835	0.01027
836	0.01541
837	0.02366
838	0.03771
839	0.06070
840	0.09974
841	0.16736
842	0.28099

843	0.44911
844	0.65757
845	0.84970
846	0.96108
847	0.99613
848	0.99970
849	0.99172
850	0.98548
851	0.98814
852	0.99320
853	0.99655
854	1.00000
855	0.99721
856	0.99146
857	0.98930
858	0.98107
859	0.97739
860	0.97231
861	0.97260
862	0.97077
863	0.97435
864	0.96801
865	0.96842
866	0.96663
867	0.95686
868	0.95986
869	0.94339
870	0.93157
871	0.92832
872	0.92322
873	0.91609
874	0.91985
875	0.91582
876	0.91916
877	0.91088
878	0.90749
879	0.81349
880	0.88573
881	0.87418
882	0.86148
883	0.84307
884	0.81707
885	0.77645
886	0.72258
887	0.65382
888	0.56468
889	0.46442
890	0.36796

891	0.27361
892	0.19381
893	0.13567
894	0.09122
895	0.06098
896	0.04167
897	0.02872
898	0.01965
899	0.01412
900	0.01008
901	0.00745
902	0.00575
903	0.00411
904	0.00326
905	0.00263
906	0.00211
907	0.00160
908	0.00135
909	0.00106
910	0.00079
911	0.00073
912	0.00080
913	0.00031
914	0.00049
915	0.00051
916	0.00052
917	0.00045
918	0.00024
919	0.00014
920	0.00026
921	0.00025
922	0.00028
923	0.00012
924	0.00016
925	0.00018
926	0.00022
927	0.00004
928	0.00018
929	0.00011
930	0.00026
931	0.00005
932	0.00017
933	0.00016
934	0.00033
935	0.00010

Table 9: Band 5p Spectral Response

Wavelength (nm)	Response
1130	0.00011
1131	0.00008
1132	0.00009
1133	0.00011
1134	0.00026
1135	0.00009
1136	0.00004
1137	0.00012
1138	0.00018
1139	0.00010
1140	0.00025
1141	0.00019
1142	0.00014
1143	0.00024
1144	0.00025
1145	0.00019
1146	0.00010
1147	0.00023
1148	0.00019
1149	0.00020
1150	0.00033
1151	0.00022
1152	0.00033
1153	0.00033
1154	0.00039
1155	0.00043
1156	0.00045
1157	0.00041
1158	0.00051
1159	0.00069
1160	0.00079
1161	0.00076
1162	0.00076
1163	0.00108
1164	0.00141
1165	0.00149
1166	0.00157
1167	0.00202
1168	0.00247
1169	0.00315
1170	0.00342
1171	0.00419
1172	0.00527
1173	0.00631
1174	0.00790

1175	0.00920
1176	0.01061
1177	0.01274
1178	0.01520
1179	0.01714
1180	0.01923
1181	0.02211
1182	0.02519
1183	0.02822
1184	0.03152
1185	0.03546
1186	0.04035
1187	0.04661
1188	0.05311
1189	0.06108
1190	0.07231
1191	0.08645
1192	0.10160
1193	0.12343
1194	0.15188
1195	0.18580
1196	0.23111
1197	0.29089
1198	0.35359
1199	0.44511
1200	0.53275
1201	0.62402
1202	0.71211
1203	0.79742
1204	0.86092
1205	0.90174
1206	0.92834
1207	0.93889
1208	0.93974
1209	0.93554
1210	0.92967
1211	0.92586
1212	0.92318
1213	0.92169
1214	0.92310
1215	0.92602
1216	0.92970
1217	0.93397
1218	0.93821
1219	0.94150
1220	0.94458
1221	0.94700
1222	0.94756
1223	0.94807

1224	0.94801
1225	0.94719
1226	0.94683
1227	0.94604
1228	0.94550
1229	0.94568
1230	0.94671
1231	0.94786
1232	0.95064
1233	0.95256
1234	0.95567
1235	0.95836
1236	0.96239
1237	0.96617
1238	0.97012
1239	0.97272
1240	0.97553
1241	0.97837
1242	0.98061
1243	0.98106
1244	0.98137
1245	0.98236
1246	0.98331
1247	0.98238
1248	0.97917
1249	0.97860
1250	0.97868
1251	0.97658
1252	0.97434
1253	0.97124
1254	0.97138
1255	0.97151
1256	0.97064
1257	0.96939
1258	0.97053
1259	0.97402
1260	0.97648
1261	0.97859
1262	0.98136
1263	0.98739
1264	0.99241
1265	0.99513
1266	0.99592
1267	0.99839
1268	1.00000
1269	0.99718
1270	0.99096
1271	0.98288
1272	0.97345

1273	0.96248
1274	0.94962
1275	0.93565
1276	0.92160
1277	0.91033
1278	0.89953
1279	0.88971
1280	0.88328
1281	0.87933
1282	0.87460
1283	0.86534
1284	0.85013
1285	0.82150
1286	0.77784
1287	0.72296
1288	0.64128
1289	0.55132
1290	0.46611
1291	0.37849
1292	0.29824
1293	0.23618
1294	0.18329
1295	0.14018
1296	0.11109
1297	0.08671
1298	0.06765
1299	0.05409
1300	0.04397
1301	0.03536
1302	0.02907
1303	0.02415
1304	0.02004
1305	0.01693
1306	0.01460
1307	0.01226
1308	0.01053
1309	0.00930
1310	0.00824
1311	0.00719
1312	0.00629
1313	0.00562
1314	0.00515
1315	0.00485
1316	0.00418
1317	0.00403
1318	0.00360
1319	0.00327
1320	0.00309
1321	0.00298

1322	0.00267
1323	0.00248
1324	0.00239
1325	0.00217
1326	0.00193
1327	0.00183
1328	0.00183
1329	0.00158
1330	0.00135
1331	0.00126
1332	0.00120
1333	0.00098
1334	0.00082
1335	0.00074
1336	0.00062
1337	0.00058
1338	0.00048
1339	0.00039
1340	0.00032
1341	0.00029
1342	0.00025
1343	0.00020
1344	0.00005
1345	0.00015
1346	0.00020
1347	0.00016
1348	-0.00011
1349	0.00017
1350	0.00007
1351	0.00008
1352	-0.00015
1353	-0.00008
1354	0.00008
1355	0.00007
1356	0.00009
1357	0.00001
1358	0.00020
1359	0.00012
1360	0.00007
1361	-0.00004
1362	0.00010
1363	0.00020
1364	0.00031
1365	0.00014
1366	0.00000
1367	-0.00001
1368	0.00008
1369	-0.00001
1370	-0.00004

1371	0.00012
1372	0.00008
1373	0.00000
1374	-0.00016
1375	-0.00014
1376	0.00003
1377	0.00003
1378	-0.00001
1379	-0.00012
1380	-0.00001
1381	0.00004
1382	0.00017
1383	-0.00011
1384	-0.00008
1385	0.00012
1386	0.00017
1387	-0.00004
1388	-0.00008
1389	0.00004
1390	0.00006
1391	0.00012
1392	-0.00003
1393	-0.00006
1394	0.00007
1395	0.00012
1396	-0.00015
1397	-0.00015
1398	0.00008
1399	0.00003
1400	0.00003

Table 10: Band 5 Spectral Response

Wavelength (nm)	Response
1460	-0.00004
1461	0.00005
1462	-0.00001
1463	0.00000
1464	0.00015
1465	0.00003
1466	-0.00004
1467	-0.00003
1468	0.00000
1469	0.00009
1470	-0.00001
1471	0.00009
1472	0.00009
1473	0.00009
1474	0.00011
1475	0.00009
1476	0.00013
1477	0.00018
1478	0.00006
1479	0.00028
1480	0.00012
1481	0.00020
1482	0.00020
1483	0.00016
1484	0.00023
1485	0.00018
1486	0.00019
1487	0.00025
1488	0.00035
1489	0.00033
1490	0.00036
1491	0.00043
1492	0.00045
1493	0.00044
1494	0.00044
1495	0.00055
1496	0.00053
1497	0.00069
1498	0.00066
1499	0.00057
1500	0.00085
1501	0.00087
1502	0.00095
1503	0.00118

1504	0.00128
1505	0.00132
1506	0.00150
1507	0.00185
1508	0.00204
1509	0.00223
1510	0.00260
1511	0.00299
1512	0.00339
1513	0.00404
1514	0.00471
1515	0.00567
1516	0.00663
1517	0.00786
1518	0.00942
1519	0.01121
1520	0.01347
1521	0.01608
1522	0.01938
1523	0.02350
1524	0.02792
1525	0.03341
1526	0.04009
1527	0.04762
1528	0.05643
1529	0.06714
1530	0.07824
1531	0.09136
1532	0.10654
1533	0.12285
1534	0.14079
1535	0.16125
1536	0.18364
1537	0.20654
1538	0.23308
1539	0.26230
1540	0.29337
1541	0.32852
1542	0.36737
1543	0.40615
1544	0.45084
1545	0.49826
1546	0.54405
1547	0.59284
1548	0.64023
1549	0.68359
1550	0.72173
1551	0.75357
1552	0.77747

1553	0.79223
1554	0.80116
1555	0.80176
1556	0.79820
1557	0.79068
1558	0.78129
1559	0.77084
1560	0.75957
1561	0.74928
1562	0.74068
1563	0.73295
1564	0.72784
1565	0.72493
1566	0.72389
1567	0.72565
1568	0.72857
1569	0.73355
1570	0.74086
1571	0.74789
1572	0.75644
1573	0.76678
1574	0.77698
1575	0.78859
1576	0.80016
1577	0.81189
1578	0.82298
1579	0.83396
1580	0.84427
1581	0.85336
1582	0.86176
1583	0.86922
1584	0.87644
1585	0.88282
1586	0.88883
1587	0.89463
1588	0.89837
1589	0.90238
1590	0.90555
1591	0.90816
1592	0.91116
1593	0.91374
1594	0.91618
1595	0.91957
1596	0.92109
1597	0.92405
1598	0.92575
1599	0.92606
1600	0.92782
1601	0.92917

1602	0.93016
1603	0.93204
1604	0.93329
1605	0.93412
1606	0.93516
1607	0.93597
1608	0.93607
1609	0.93705
1610	0.93679
1611	0.93713
1612	0.93786
1613	0.93847
1614	0.93923
1615	0.93963
1616	0.93899
1617	0.93832
1618	0.93866
1619	0.93823
1620	0.93881
1621	0.93756
1622	0.93722
1623	0.93675
1624	0.93489
1625	0.93379
1626	0.93049
1627	0.92718
1628	0.92550
1629	0.92209
1630	0.91864
1631	0.91514
1632	0.91158
1633	0.90620
1634	0.90271
1635	0.89895
1636	0.89404
1637	0.89075
1638	0.88613
1639	0.88319
1640	0.88026
1641	0.87750
1642	0.87481
1643	0.87285
1644	0.87052
1645	0.86985
1646	0.86978
1647	0.87063
1648	0.87083
1649	0.87287
1650	0.87407

1651	0.87854
1652	0.88025
1653	0.88460
1654	0.88820
1655	0.89282
1656	0.89770
1657	0.90340
1658	0.90824
1659	0.91417
1660	0.91971
1661	0.92522
1662	0.93159
1663	0.93837
1664	0.94240
1665	0.94932
1666	0.95389
1667	0.95941
1668	0.96633
1669	0.96978
1670	0.97402
1671	0.97830
1672	0.98111
1673	0.98514
1674	0.98823
1675	0.99056
1676	0.99256
1677	0.99507
1678	0.99667
1679	0.99884
1680	0.99956
1681	0.99936
1682	0.99954
1683	0.99974
1684	1.00000
1685	0.99971
1686	0.99904
1687	0.99746
1688	0.99642
1689	0.99564
1690	0.99449
1691	0.99323
1692	0.99058
1693	0.98880
1694	0.98714
1695	0.98383
1696	0.98225
1697	0.97716
1698	0.97219
1699	0.96832

1700	0.96193
1701	0.95676
1702	0.94942
1703	0.94059
1704	0.93118
1705	0.92202
1706	0.90882
1707	0.89676
1708	0.88262
1709	0.86662
1710	0.85115
1711	0.83431
1712	0.81647
1713	0.79793
1714	0.77850
1715	0.75847
1716	0.73952
1717	0.72123
1718	0.70163
1719	0.68298
1720	0.66518
1721	0.64823
1722	0.63061
1723	0.61392
1724	0.59742
1725	0.58027
1726	0.56461
1727	0.54968
1728	0.53352
1729	0.51798
1730	0.50098
1731	0.48294
1732	0.46398
1733	0.44484
1734	0.42333
1735	0.40141
1736	0.37931
1737	0.35556
1738	0.33102
1739	0.30729
1740	0.28232
1741	0.25705
1742	0.23357
1743	0.21224
1744	0.19031
1745	0.17142
1746	0.15353
1747	0.13685
1748	0.12177

1749	0.10911
1750	0.09720
1751	0.08667
1752	0.07752
1753	0.06926
1754	0.06200
1755	0.05574
1756	0.05005
1757	0.04498
1758	0.04055
1759	0.03677
1760	0.03320
1761	0.03017
1762	0.02752
1763	0.02508
1764	0.02287
1765	0.02093
1766	0.01910
1767	0.01748
1768	0.01606
1769	0.01467
1770	0.01345
1771	0.01239
1772	0.01136
1773	0.01042
1774	0.00954
1775	0.00871
1776	0.00797
1777	0.00728
1778	0.00663
1779	0.00606
1780	0.00559
1781	0.00519
1782	0.00451
1783	0.00415
1784	0.00391
1785	0.00342
1786	0.00314
1787	0.00286
1788	0.00250
1789	0.00243
1790	0.00205
1791	0.00193
1792	0.00178
1793	0.00155
1794	0.00145
1795	0.00136
1796	0.00107
1797	0.00107

1798	0.00107
1799	0.00083
1800	0.00079
1801	0.00066
1802	0.00055
1803	0.00073
1804	0.00062
1805	0.00069
1806	0.00044
1807	0.00051
1808	0.00032
1809	0.00046
1810	0.00029
1811	0.00032
1812	0.00032
1813	0.00036
1814	0.00035
1815	0.00011
1816	0.00024
1817	0.00029
1818	0.00028
1819	0.00019
1820	0.00018
1821	0.00031
1822	-0.00006
1823	0.00033
1824	0.00011
1825	0.00019
1826	0.00019
1827	0.00005
1828	0.00018
1829	0.00011
1830	0.00007
1831	0.00013
1832	0.00014
1833	0.00017
1834	0.00008
1835	0.00009
1836	0.00015
1837	0.00014
1838	0.00010
1839	-0.00004
1840	-0.00012

Table 11: Band 7 Spectral Response

Wavelength (nm)	Response
1980	0.00014
1981	0.00021
1982	0.00017
1983	0.00021
1984	0.00025
1985	0.00026
1986	0.00019
1987	0.00026
1988	0.00031
1989	0.00027
1990	0.00022
1991	0.00035
1992	0.00038
1993	0.00038
1994	0.00031
1995	0.00041
1996	0.00036
1997	0.0005
1998	0.00037
1999	0.00048
2000	0.00056
2001	0.00048
2002	0.00051
2003	0.00066
2004	0.00053
2005	0.00067
2006	0.00078
2007	0.0007
2008	0.00092
2009	0.00084
2010	0.00088
2011	0.001
2012	0.00099
2013	0.00106
2014	0.00117
2015	0.00123
2016	0.0014
2017	0.00152
2018	0.00163
2019	0.0017
2020	0.0018
2021	0.00193
2022	0.00215

2023	0.00236
2024	0.00249
2025	0.00268
2026	0.00285
2027	0.00312
2028	0.00341
2029	0.00358
2030	0.00387
2031	0.00424
2032	0.00453
2033	0.00494
2034	0.00524
2035	0.00578
2036	0.00618
2037	0.00661
2038	0.00725
2039	0.00785
2040	0.00843
2041	0.0094
2042	0.00989
2043	0.01095
2044	0.01187
2045	0.01262
2046	0.01385
2047	0.01518
2048	0.01642
2049	0.0179
2050	0.01967
2051	0.02117
2052	0.02335
2053	0.02551
2054	0.02791
2055	0.03066
2056	0.03372
2057	0.03684
2058	0.04044
2059	0.04461
2060	0.04925
2061	0.05404
2062	0.05953
2063	0.06546
2064	0.07182
2065	0.07928
2066	0.0877
2067	0.09613
2068	0.10619
2069	0.11685
2070	0.1283
2071	0.14167

2072	0.15662
2073	0.17203
2074	0.18963
2075	0.20804
2076	0.22796
2077	0.25009
2078	0.27406
2079	0.29895
2080	0.32498
2081	0.35437
2082	0.38334
2083	0.41447
2084	0.44666
2085	0.47978
2086	0.51165
2087	0.54447
2088	0.57797
2089	0.60982
2090	0.64019
2091	0.67014
2092	0.69809
2093	0.72426
2094	0.7494
2095	0.77323
2096	0.79444
2097	0.81453
2098	0.83124
2099	0.84595
2100	0.85951
2101	0.87247
2102	0.88251
2103	0.89228
2104	0.89986
2105	0.90562
2106	0.91136
2107	0.91619
2108	0.92149
2109	0.92459
2110	0.92812
2111	0.93116
2112	0.93421
2113	0.93659
2114	0.93833
2115	0.94012
2116	0.94241
2117	0.94373
2118	0.9444
2119	0.94596
2120	0.94586

2121	0.94652
2122	0.94673
2123	0.94853
2124	0.94905
2125	0.94996
2126	0.9501
2127	0.94998
2128	0.95052
2129	0.95057
2130	0.95093
2131	0.95048
2132	0.9512
2133	0.95098
2134	0.94969
2135	0.94866
2136	0.94872
2137	0.94838
2138	0.94892
2139	0.94866
2140	0.94849
2141	0.94789
2142	0.94679
2143	0.94715
2144	0.94704
2145	0.9481
2146	0.94738
2147	0.94731
2148	0.94579
2149	0.94676
2150	0.9445
2151	0.94526
2152	0.94288
2153	0.94548
2154	0.94268
2155	0.94438
2156	0.93979
2157	0.94313
2158	0.93709
2159	0.94404
2160	0.93796
2161	0.94232
2162	0.93382
2163	0.94628
2164	0.93076
2165	0.94448
2166	0.93935
2167	0.94114
2168	0.94026
2169	0.94164

2170	0.94068
2171	0.9424
2172	0.94213
2173	0.9442
2174	0.94348
2175	0.94538
2176	0.94511
2177	0.94593
2178	0.94578
2179	0.94654
2180	0.94663
2181	0.94921
2182	0.94832
2183	0.95229
2184	0.94928
2185	0.95249
2186	0.9503
2187	0.95495
2188	0.95753
2189	0.95553
2190	0.95715
2191	0.95623
2192	0.95821
2193	0.95752
2194	0.959
2195	0.9594
2196	0.96185
2197	0.96256
2198	0.96294
2199	0.96357
2200	0.96423
2201	0.96508
2202	0.96664
2203	0.96719
2204	0.96818
2205	0.96773
2206	0.96827
2207	0.96805
2208	0.96916
2209	0.96973
2210	0.97098
2211	0.97151
2212	0.97222
2213	0.9724
2214	0.97222
2215	0.97264
2216	0.97415
2217	0.97548
2218	0.97617

2219	0.97603
2220	0.97633
2221	0.97583
2222	0.97657
2223	0.97697
2224	0.97783
2225	0.97788
2226	0.97839
2227	0.97723
2228	0.97758
2229	0.9771
2230	0.97751
2231	0.97817
2232	0.97957
2233	0.97934
2234	0.97922
2235	0.97899
2236	0.97945
2237	0.97949
2238	0.98107
2239	0.98148
2240	0.98162
2241	0.98027
2242	0.98072
2243	0.9803
2244	0.98081
2245	0.98128
2246	0.98203
2247	0.98199
2248	0.98203
2249	0.98189
2250	0.98204
2251	0.98161
2252	0.98362
2253	0.98406
2254	0.9846
2255	0.98377
2256	0.9832
2257	0.98276
2258	0.98335
2259	0.98323
2260	0.98447
2261	0.98506
2262	0.98417
2263	0.98493
2264	0.98352
2265	0.98471
2266	0.98523
2267	0.98698

2268	0.9875
2269	0.988
2270	0.98853
2271	0.98874
2272	0.98975
2273	0.991
2274	0.99264
2275	0.99386
2276	0.9944
2277	0.99424
2278	0.99426
2279	0.99532
2280	0.99651
2281	0.99749
2282	0.99721
2283	0.99768
2284	0.99772
2285	0.99765
2286	0.9979
2287	0.99873
2288	0.9991
2289	1
2290	0.99961
2291	0.99917
2292	0.99858
2293	0.99813
2294	0.99912
2295	0.99919
2296	0.99923
2297	0.99833
2298	0.99741
2299	0.99646
2300	0.99632
2301	0.99504
2302	0.99503
2303	0.99418
2304	0.99305
2305	0.99168
2306	0.99084
2307	0.9895
2308	0.98811
2309	0.98754
2310	0.98707
2311	0.98604
2312	0.98492
2313	0.98272
2314	0.98093
2315	0.9805
2316	0.9795

2317	0.97897
2318	0.97825
2319	0.97711
2320	0.9764
2321	0.97491
2322	0.97483
2323	0.97377
2324	0.97351
2325	0.97328
2326	0.97155
2327	0.96923
2328	0.96701
2329	0.96426
2330	0.96265
2331	0.96033
2332	0.95824
2333	0.95503
2334	0.95232
2335	0.94846
2336	0.9449
2337	0.94123
2338	0.93783
2339	0.93272
2340	0.92813
2341	0.92202
2342	0.91502
2343	0.90767
2344	0.89894
2345	0.88981
2346	0.87966
2347	0.86743
2348	0.85398
2349	0.83998
2350	0.82276
2351	0.80392
2352	0.78296
2353	0.76193
2354	0.73887
2355	0.71547
2356	0.68978
2357	0.66259
2358	0.63582
2359	0.60853
2360	0.58083
2361	0.55199
2362	0.52532
2363	0.49658
2364	0.4679
2365	0.44151

2366	0.41435
2367	0.38851
2368	0.36417
2369	0.3401
2370	0.31716
2371	0.29515
2372	0.27461
2373	0.2549
2374	0.23656
2375	0.22078
2376	0.20399
2377	0.1892
2378	0.17561
2379	0.16219
2380	0.15002
2381	0.13912
2382	0.12842
2383	0.11846
2384	0.10987
2385	0.10131
2386	0.09368
2387	0.0866
2388	0.08005
2389	0.07417
2390	0.06873
2391	0.06375
2392	0.05885
2393	0.0546
2394	0.05065
2395	0.04689
2396	0.0434
2397	0.04051
2398	0.0375
2399	0.03491
2400	0.03238
2401	0.02997
2402	0.02772
2403	0.02587
2404	0.02394
2405	0.02226
2406	0.02065
2407	0.01919
2408	0.01782
2409	0.0167
2410	0.01551
2411	0.01446
2412	0.01351
2413	0.01252
2414	0.01175

2415	0.01094
2416	0.01016
2417	0.00959
2418	0.00895
2419	0.00838
2420	0.00784
2421	0.00733
2422	0.00683
2423	0.00648
2424	0.00606
2425	0.00563
2426	0.00526
2427	0.00498
2428	0.00466
2429	0.00439
2430	0.00413
2431	0.00387
2432	0.00367
2433	0.00334
2434	0.00328
2435	0.00298
2436	0.00288
2437	0.00265
2438	0.00254
2439	0.00242
2440	0.00224
2441	0.00212
2442	0.00198
2443	0.00189
2444	0.00179
2445	0.00163
2446	0.00154
2447	0.0015
2448	0.00138
2449	0.0013
2450	0.00123
2451	0.00117
2452	0.00109
2453	0.00104
2454	0.001
2455	0.00093
2456	0.00085
2457	0.00086
2458	0.00078
2459	0.00071
2460	0.00067
2461	0.00066
2462	0.00061
2463	0.0006

2464	0.00056
2465	0.00051
2466	0.00049
2467	0.00045
2468	0.00047
2469	0.00039
2470	0.00042
2471	0.00035
2472	0.00039
2473	0.0003
2474	0.00032
2475	0.00031
2476	0.00028
2477	0.00027
2478	0.00023
2479	0.00025
2480	0.00025
2481	0.00021
2482	0.00023
2483	0.00017
2484	0.00020
2485	0.00021
2486	0.00019
2487	0.00018
2488	0.00016
2489	0.00017
2490	0.00017
2491	0.00017
2492	0.00016
2493	0.00012
2494	0.00014
2495	0.00013
2496	0.00014
2497	0.00013
2498	0.00013
2499	0.00010
2500	0.00011
2501	0.00013
2502	0.00013
2503	0.00012
2504	0.00010
2505	0.00012
2506	0.00011
2507	0.00011
2508	0.00010
2509	0.00011
2510	0.00007
2511	0.00009
2512	0.00009

2513	0.00010
2514	0.00008
2515	0.00008
2516	0.00007
2517	0.00009
2518	0.00006
2519	0.00007
2520	0.00007
2521	0.00008
2522	0.00006
2523	0.00006
2524	0.00009
2525	0.00006
2526	0.00007
2527	0.00006
2528	0.00007
2529	0.00006
2530	0.00007
2531	0.00006
2532	0.00004
2533	0.00003
2534	0.00005
2535	0.00005
2536	0.00004
2537	0.00003
2538	0.00005
2539	0.00006
2540	0.00005
2541	0.00005
2542	0.00004
2543	0.00005
2544	0.00007
2545	0.00004
2546	0.00002
2547	0.00007
2548	0.00002
2549	0.00004
2550	0.00004

Table 12: Panchromatic Band Spectral Response

Wavelength (nm)	Response
440	-0.00002
441	-0.00002
442	-0.00002
443	-0.00002
444	-0.00001
445	-0.00002
446	0.00000
447	0.00000
448	-0.00001
449	-0.00001
450	-0.00001
451	-0.00001
452	-0.00001
453	-0.00002
454	-0.00001
455	-0.00001
456	-0.00001
457	0.00002
458	0.00003
459	0.00008
460	0.00018
461	0.00020
462	0.00020
463	0.00016
464	0.00015
465	0.00017
466	0.00020
467	0.00029
468	0.00040
469	0.00060
470	0.00104
471	0.00197
472	0.00395
473	0.00809
474	0.01470
475	0.02302
476	0.03224
477	0.04532
478	0.06908
479	0.11437
480	0.19273
481	0.29555
482	0.36617

483	0.37063
484	0.33898
485	0.30672
486	0.29457
487	0.31019
488	0.34952
489	0.39698
490	0.42308
491	0.41387
492	0.39830
493	0.39453
494	0.40177
495	0.41136
496	0.40960
497	0.40520
498	0.40955
499	0.43200
500	0.47119
501	0.50972
502	0.53379
503	0.54163
504	0.54133
505	0.54115
506	0.54048
507	0.53067
508	0.51015
509	0.48883
510	0.48042
511	0.49043
512	0.51575
513	0.54636
514	0.57019
515	0.58164
516	0.58556
517	0.58682
518	0.59395
519	0.59668
520	0.59176
521	0.58076
522	0.56983
523	0.56235
524	0.56869
525	0.58637
526	0.60697
527	0.62970
528	0.64545
529	0.65430
530	0.65559

531	0.65142
532	0.65008
533	0.64711
534	0.64155
535	0.64099
536	0.64155
537	0.64596
538	0.65644
539	0.67206
540	0.68972
541	0.70046
542	0.70618
543	0.69963
544	0.68590
545	0.66664
546	0.64612
547	0.62803
548	0.61720
549	0.61517
550	0.61946
551	0.62609
552	0.63774
553	0.65222
554	0.66604
555	0.67844
556	0.68779
557	0.69094
558	0.68812
559	0.67763
560	0.66608
561	0.65347
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563	0.64176
564	0.64284
565	0.64675
566	0.65268
567	0.65729
568	0.66144
569	0.66508
570	0.67184
571	0.67914
572	0.68976
573	0.70260
574	0.71348
575	0.72163
576	0.72921
577	0.73354
578	0.74037

579	0.74644
580	0.75287
581	0.76139
582	0.76641
583	0.77090
584	0.77360
585	0.77717
586	0.78250
587	0.78864
588	0.79972
589	0.80318
590	0.80863
591	0.80607
592	0.80246
593	0.79902
594	0.79771
595	0.80144
596	0.80957
597	0.82430
598	0.83593
599	0.84763
600	0.85393
601	0.85837
602	0.85788
603	0.85911
604	0.86135
605	0.86650
606	0.87082
607	0.86974
608	0.86664
609	0.85922
610	0.85146
611	0.84347
612	0.84138
613	0.84883
614	0.85749
615	0.87106
616	0.88417
617	0.89491
618	0.90017
619	0.90109
620	0.90273
621	0.90351
622	0.90720
623	0.91298
624	0.91871
625	0.92525
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627	0.92259
628	0.91491
629	0.90655
630	0.89971
631	0.89732
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633	0.91063
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637	0.95519
638	0.95862
639	0.96003
640	0.96305
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644	0.96909
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647	0.95182
648	0.94484
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650	0.93579
651	0.94039
652	0.95425
653	0.96930
654	0.98034
655	0.99100
656	1.00000
657	0.99738
658	0.99197
659	0.98417
660	0.97323
661	0.96243
662	0.94622
663	0.92725
664	0.90348
665	0.87391
666	0.84001
667	0.81078
668	0.78992
669	0.78176
670	0.79121
671	0.82587
672	0.87759
673	0.92530
674	0.91290

675	0.78159
676	0.56647
677	0.36547
678	0.22298
679	0.13749
680	0.08821
681	0.05754
682	0.03915
683	0.02721
684	0.01999
685	0.01494
686	0.01145
687	0.00888
688	0.00720
689	0.00590
690	0.00488
691	0.00419
692	0.00359
693	0.00321
694	0.00301
695	0.00266
696	0.00245
697	0.00237
698	0.00226
699	0.00203
700	0.00194
701	0.00169
702	0.00146
703	0.00121
704	0.00094
705	0.00067
706	0.00048
707	0.00029
708	0.00022
709	0.00012
710	0.00004
711	0.00003
712	-0.00007
713	-0.00007
714	-0.00002
715	-0.00010
716	-0.00009
717	-0.00008
718	-0.00013
719	-0.00014
720	-0.00011
721	-0.00010
722	-0.00012

723	-0.00010
724	-0.00019
725	-0.00013
726	-0.00020
727	-0.00015
728	-0.00016
729	-0.00018
730	-0.00016
731	-0.00023
732	-0.00016
733	-0.00016
734	-0.00018
735	-0.00018
736	-0.00023
737	-0.00015
738	-0.00019
739	-0.00020
740	-0.00024

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