MODIS

SCIENCE TEAM MEETING

COLLEGE PARK, MD

MAY 16, 1997

Agenda

- Introduction: MODIS Readiness to Ship
- Overview of Performance and Environmental Testing Program
- Calibration and Environmental Testing: Video
- Compliance Matrix
- Summary of Non-compliant Areas
- Open Issues and Concerns

Introduction: MODIS Readiness to Ship

- The Protoflight MODIS is in route to LMMS in Valley Forge, upon a successful conclusion of the preshipment review
- Comprehensive environmental tests have yielded a wealth (≈200 GBytes of data) validating the instrument's principal design features and demonstrating that MODIS is an excellent spectroradiometer
- SBRS met with GSFC MCST on Tuesday, May 13th in a comprehensive review of the data acquired since last September.
- Additional testing will begin at Valley Forge next week prior to integration to the EOS-AM1 spacecraft

PFM Integration and Test Overview

- Numerous performance tests completed the evaluation of the MODIS
- Ambient
  - Spatial: IFOV, LSFs, MTF, Field of View, Response vs Scan Angle, Pointing knowledge and co-registration
  - Stray Light, Near Field Resp., Point Spread Resp., Far Field Resp.
  - Crosstalk and Out-of-band Response
  - Polarization Insensitivity
  - Relative Spectral Response for all bands
  - Solar Diffuser BRDF
- Thermal Vacuum
  - Reflective Bands and IR Bands Radiometric Evaluations (Signal, responsivity, nonlinearity and noise)
  - OBC Blackbody Characterization
  - SRCA Spectral, Radiometric and Spatial Characterizations
  - Relative Spectral Response Repeat for Bands 1-28
  - Crosstalk and Out-of-band Response for Bands 5-28
  - Miscellaneous special tests

VIDEO

MODIS CALIBRATION AND ENVIRONMENTAL TESTING

Compliance Introduction

- Most major performance areas have some noncompliances
  - Sensor labeled non-compliant in area when as few as one of the 470 channels does not meet specification.
- The majority of the instrument performance is excellent
- Most waivers on special cases for particular bands
- Reference Documentation
  - MODIS PVP/PVS, CDRLs 022, and 308, DM VJ50-0063/005,PSR
  - SBRS Specifications and Drawings; e.g. 151840
  - Software Configuration Management Plan: CDRL 008C
  - Performance Verification Reports: CDRL 208,PSR
  - Specification Compliance and Calibration Data Books: CDRL 222
    - » Vol IX: Compliance Matrix
    - » Test Analysis Data Books
    - » Test Log Books
    - » Vol X: Calibration Analyses
  - Trend Analysis Reports: CDRL 215 PSR
    Viewgraphs of performance, Telemetry, Subsystems

Compliance Matrix: Part 1

Section	GSFC Specification 422-20-02	Test ID	Method	Status	Waiver	Stat
1	**Scope**		NA	NA		
2	**Applicable Documents**		NA	NA		
3	**Technical Requirements**		NA	NA		
3.1.	**Requirements Overview**		NA	NA		
3.1.1	General		I	P		
3.1.2	Spacecraft Interfaces		NA	NA		
3.1.3	Maintainability and Servicing		I	P		
3.1.4	Definitions of Instrument Models		NA	NA		
3.1.4.1	Radiometric Math Model		A	P		
3.1.4.2	Thermal Math Model		A	P		
3.1.4.3	Structural Math Model		A	P		
3.1.4.4	Structural Model		A	P		
3.1.4.5	Engineering Model		I	P		
3.1.4.6	Protoflight Model		I	P		
3.1.4.7	Flight Model		I	P		
3.2.	**Operational Requirements**		NA	NA		
3.2.1	Nominal Orbital Parameters		I	P		
3.2.2	Operational Modes		A	P		
3.2.3	Lifetime Requirements		A	P		
3.2.4	Natural Radiation Environment		A	P		
3.2.4.1	Total Dose Performance		A	P		
3.2.4.2	Transient Event Recovery		A	P		
3.2.4.3	...Effects Caused by Radiation		A	P		

Legend

A Analysis
T Test
D Demonstration
I Inspection
NA Not Applicable

P Pass
F Fail
N Incomplete
DV Deviation
WV Waiver

Compliance Matrix: Part 2
Noncompliances

Section	GSFC Specification 422-20-02	Test ID	Method	Status	Waiver	Stat
3.3.	**Optical Requirements**					
3.3.1.	Instantaneous Field of View	MFI-03	T	F	WV040,057	
3.3.2.	Field of View	PC20	T	P		
3.3.3.	Spectral Bands		T	F	WV075A	
3.3.3.1	Definitions		NA	NA		
3.3.3.2	Edge Range	PC07-I	T	F	WV075A	
3.3.3.3	Out-of-Band	PC07-N,D	T	F	WV063A	
3.3.3.4	Ripple	PC07-I	T	P		
3.3.4.	Sensitivity Requirements		A	F	WV073	
3.3.4.1	VIS/NIR/SWIR	RC01	T	F	WV073	
3.3.4.2	Thermal Emittance	RC02	T	F	WV073	
3.3.5.	Polarization Insensitivity	PC08	T	F	WV055A	
3.4.	**System Performance**		T	P		
3.4.1.	Dynamic Range	RC01,RC02	T	F	WV077	
3.4.2.	Modulation Transfer Function	MFI-03, PC17; PC02	T	F	WV087	
3.4.3.	Minimum Quantizing Resolution	MFI-10, RC01,RC02	T	F	WV056	
3.4.4.	Transient Response	PC04	T	F	WV054	
3.4.5.	Radiometric Performance		NA	NA		
3.4.5.1.	Spectral/Ampl Accy	RC01,RC02	A	P		
3.4.5.2.	Absolute Rad Accy	RC01,RC02	A	F	WV062,078	
3.4.5.3.	Relative Rad Accy		NA	NA		
3.4.5.3.1	RMS Deviation		NA	NA		
3.4.5.3.2	Ch-to-Ch Uniformity	RC01,RC02	T	F	WV079B	
3.4.5.3.3	X-Talk, Fixed Pattern	PC-07D, MFI-10 FPN	T	F	WV080	
3.4.5.4.	IFOV Uniformity	MFI-03	T	P	WV040	
3.4.5.5.	System Noise Meas.	RC01,RC02	T	P		
3.4.6	Geometric Performance		I	P		
3.4.6.1	Pointing Knowledge	PC06	T	P		
3.4.6.2	Alignment Changes	PC06	T	P		
3.4.6.3	Registration	PC02	T	F	WV081	
3.4.7	Radio. Ampl. Stability and Repeat.	RC01,RC02	T	P		
3.4.7.1	Short Term Stability	RC01,RC02	T	F	WV091	
3.4.7.2	Long-Term Stability	RC01,RC02	T	F	WV091	
3.4.7.3	Spectral Band-to-Band Stab.	RC01,RC02	T	F	WV091	
3.4.7.4	Wavelength Stability	PC07	T	P		
3.4.7.5	Wavelength Accy & Precision	PC07	T	P		

Legend

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Compliance Matrix: Part 3

Section	GSFC Specification 422-20-02	Test ID	Method	Status	Waiver	Stat
3.4.8	Stray Light		NA	NA		
3.4.8.1	Stray Light Rejection	PC12	T, A	P		
3.4.8.2	Bright Target ...		A	P		
3.4.8.3	Dark Target ...		A	P		
3.4.8.4	Warm Target ...		A	P		
3.4.9	In-Flight Calibration		D	P		
3.4.9.1	In-Flight Radiometric	MFI-09, PC17	T	P		
3.4.9.2	in-Flight Wavelength	MFI-15, PC17	T	P		
3.4.9.3	In-Flight Reflectance	MFI-14, PC18	T	P		
3.4.9.4	In-Flight Lunar		A	P		
3.4.9.5	In-Flight Electronics	MFI-10 Ecal	T	P		
3.4.10	Miscellaneous		NA	NA		
3.4.10.1	Passive Rad Cooler...		D	P		
3.4.10.2	Ambient Conditions Limits...		I	P		
3.4.10.3	Witness Mirrors		D	P		
3.4.10.4	Solar Flux		A	P		
3.5.	**CCC and Telemetry**		NA	NA		
3.5.1	Command & Control	MFI-07	D	P		
3.5.2	Instrument Data Stream	MFI-10	D	P		
3.5.2.1	Data Rates	MFI-10	T	P		
3.5.2.2	Data packet	MFI-10	T	P		
3.5.3	Instrument Health & Status	MFI-10	T	P		
3.5.3.1	Command Status	MFI-07,MFI-10	T	P		
3.5.3.2	Housekeeping ...	MFI-07	T	P		
3.6.	**Interface Requirements**		NA	NA		
3.6.1	General	GIIS				
3.6.2	Unique	UIID				
3.6.2.1	Power Consumption	MFI06, MFI13	T	P		
3.6.2.2	Mechanical Dimensions	PC14	I	P		
3.6.2.3.	Deleted		NA	NA		
3.6.2.4.	View Factors		NA	NA		
3.6.2.4.1.	Ground View		I	P		
3.6.2.4.2.	Sun View		I	P		
3.6.2.4.3.	Space View		I	P		
4	**Software Requirements**		NA	NA		
4.1	**General**		I	P		
4.1.1	Data Processing Software		I	P		
4.1.2	Instrument-Based SW/FW		I	P		
4.1.3	Software for Operations Anal		I	P		
4.1.4	Cmd List and Description		I	P		
4.2	Instrument Ground SW		I	P		

Legend

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WV Waiver

Compliance Matrix: Part 4

Section	GSFC Specification 422-20-02	Test ID	Method	Status	Waiver	Stat
5	**Verification and CAL Reqmts.**		NA	NA		
5.1	**General**		I	P		
5.1.1	Verification Plan		I	P		
5.1.2	Verification Specifications		I	P		
5.1.3	Verification Procedures		I	P		
5.1.4	Cal management Plan		I	P		
5.1.5	Calibration Procedures		I	P		
5.1.6	Doc of Test and Cal Data		I	P		
5.1.7	Limits Program		I	P		
5.1.8	Controlled Documents		I	P		
5.2	**Environmental Test Requirements**		NA	NA		
5.2.1	General		I	P		
5.3	**System Funct & Perf. Test Reqmts**		NA	NA		
5.3.1	General		I	P		
5.4	**System Calibration**		NA	NA		
5.4.1	Responsibility for Calibration		I	P		
5.4.2	Calibration of System Response		I	P		
5.4.2.1	Sources		I	P		
5.4.2.2	Rad Cal of Temp Plateaus	RC01,RC02	I	P		
5.4.2.3	Linearity Calibration	RC01,RC02, MFI-10	I	P		
5.4.2.4	Diffuser Calibration		I	P		
5.4.2.5	Instrument Cal Alg'm/SW		I	P		
5.4.2.5.1	Radiometric		I	P		
5.4.2.5.2	Spectral		I	P		
5.4.2.6	Formatted Real-Time Data		I	P		
5.4.3	Calibration Fixtures		I	P		
5.4.4	Cal of Temp and Volt Monitors		I	P		
5.5	**Special Data Requirements**		NA	NA		
5.5.1	History Storage Media		I	P		
5.5.2	Special Data History		I	P		
6	**Ground Support Equipment**		NA	NA		
6.1	**General**					
6.2	**Deleted**		NA	NA		
6.3	**System Test Equipment**		NA	NA		
6.3.1	General		I	P		
6.3.2	STE Requirements		I	P		
6.3.3	Calibration Equip & GSE SW		I	P		
6.3.4	Shipping container		I	P		
6.4	**Equipment for Ambient Operation**		I	P		
6.5	**Ancillary Equipment**		NA	NA		
6.5.1	Drill Templates		I	P		
6.5.2	Handling and Lifting Fixtures		I	P		
6.5.3	Spacecraft Interface Simulator		N/A	N/A		

Legend

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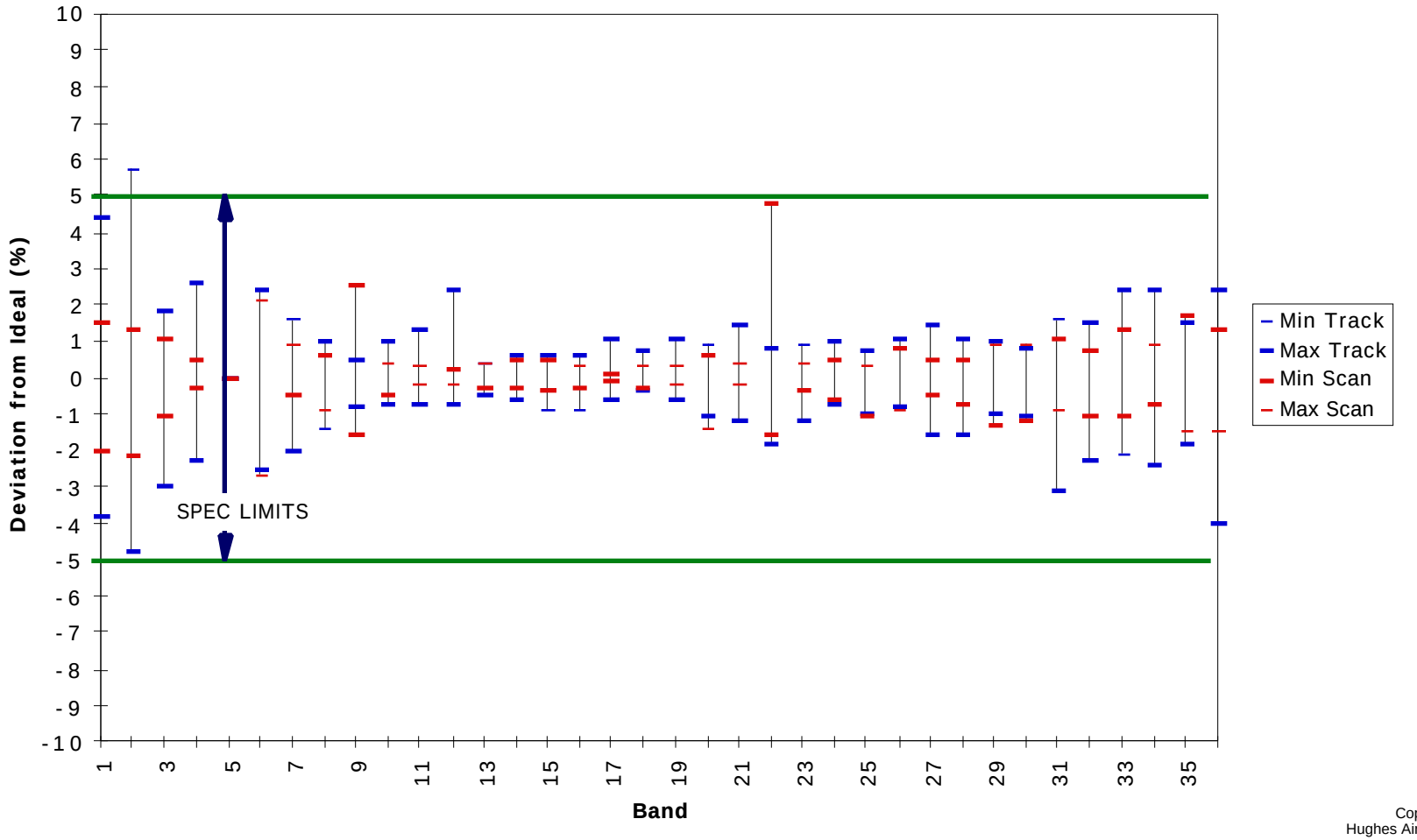
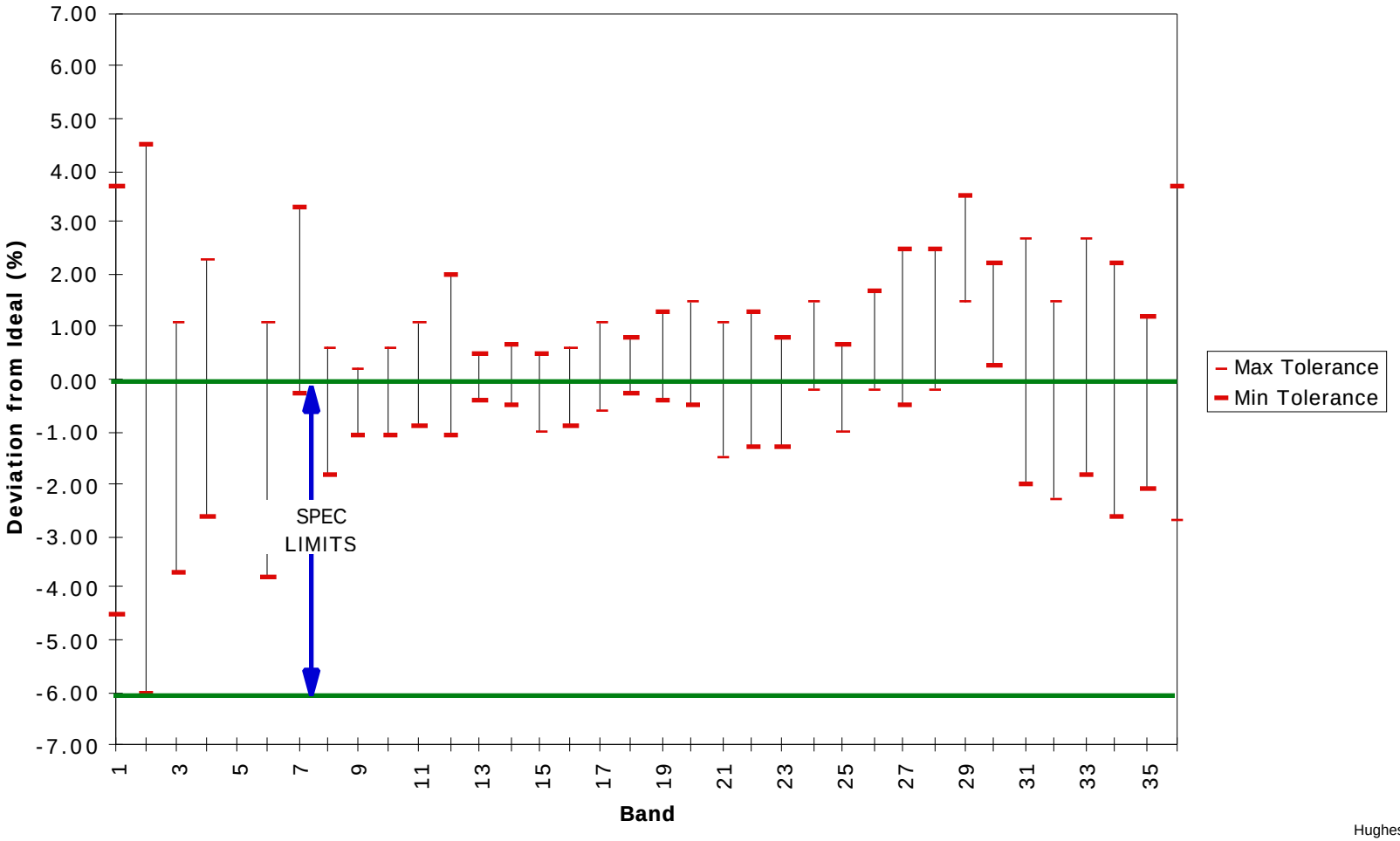
3.3.1. Waiver 057: IFOV Non-Uniformity

Deviation from mean IFOV size; scan and track



3.3.1. Waiver 057: IFOV Along-Track Tolerance

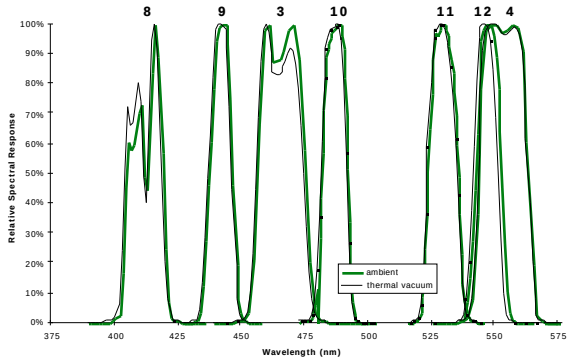


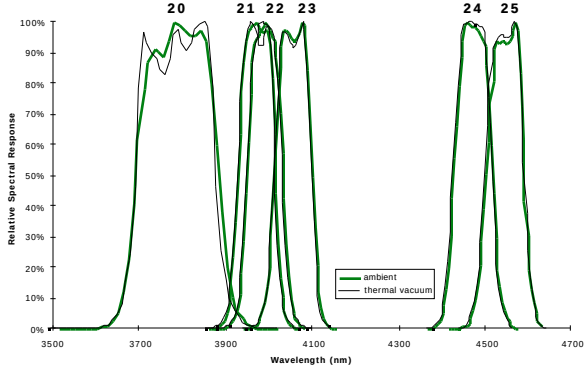
3.3.3.1,2. Waiver 075: Spectral Noncompliances

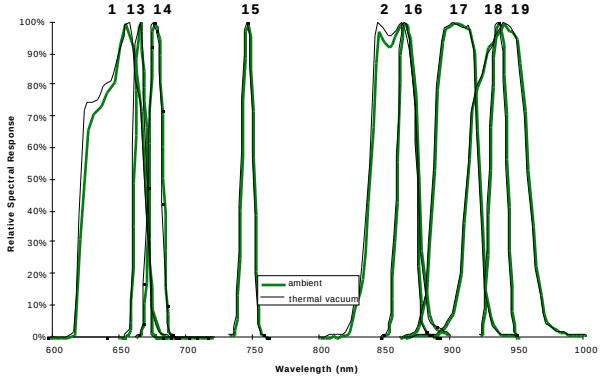
Spectral Response Analysis---Specifications Matching Report

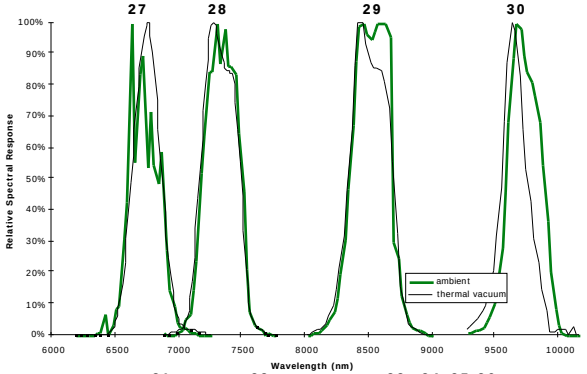
	Band	Channel		CW		BW		ER1		ER2		Ripple	1%_on	1%_off	Centroid
*	8	5		411.3		14.8	H	12.9		4.3		91.2%	399.5	423.1	411.7
	9	5		442.0		9.7		4.8		4.0		82.1%	432.9	450.9	441.9
	3	10		465.6		18.8		4.3		5.7		82.4%	451.3	480.5	465.5
	10	5		486.9		10.6		4.4		3.2		81.1%	477.2	495.3	486.8
*	11	5		529.6	H	12.0		4.2		5.0		80.3%	519.5	540.2	529.6
	12	5		546.8		10.3		4.6		4.4		80.5%	537.1	555.9	546.7
	4	10		553.6		19.8		4.8		4.6		90.8%	538.8	568.0	553.5
*	1	20		645.0		48.0	H	24.4		13.5		81.6%	614.0	681.2	646.1
*	13	5		665.5		10.1		4.9	H	5.8		90.6%	655.7	674.9	665.6
*	14	5	L	676.8		11.3	H	5.8		5.5		84.6%	665.1	687.7	676.7
*	15	5		746.4		9.9	H	5.7	H	5.4		85.5%	735.5	756.8	746.3
	2	20		856.5		38.4		16.1		12.1		90.6%	819.2	899.0	856.1
	16	5		866.2		15.5		7.5		6.8		82.3%	850.8	881.4	866.0
	17	5		904.0		35.0		13.2		12.4		91.1%	870.4	938.1	904.0
*	18	5		935.5		13.6	H	6.8		6.5		80.2%	922.3	948.4	935.4
*	19	5	L	935.2		46.1		21.7		19.4		82.9%	889.0	988.4	935.9
*	5	10		1241.6		24.0	H	13.8	H	13.4		83.0%	1214.0	1271.4	1241.7
*	26	5		1383.0		35.0	H	27.3	H	19.1		80.7%	1337.3	1421.1	1381.7
*	6	10	L	1629.1		28.6	H	14.6	H	16.1		84.4%	1596.4	1661.1	1628.9
*	7	10	L	2114.1		55.7		20.5	H	36.6		80.8%	2056.9	2175.1	2114.1
*	20	5	H	3785.0		187.7		49.8		54.2		82.8%	3621.1	3956.8	3786.7
*	21	5	H	3990.0	H	84.4		37.3		37.1		80.7%	3902.7	4079.3	3990.2
*	22	5		3970.1	H	87.6		38.5		31.8		84.1%	3878.5	4056.7	3970.1
*	23	5		4056.4	H	86.7		38.9		29.1		82.0%	3965.1	4137.3	4055.6
	24	5		4471.7		91.7		40.1		35.3		83.3%	4382.4	4559.7	4471.7
*	25	5	H	4545.2		92.0		43.4		34.8		87.4%	4452.1	4630.1	4544.9
*	27	5	H	6752.4	L	248.1	H	175.5	H	172.8		82.9%	6463.4	7145.1	6757.3
	28	5		7333.8		327.5		150.4		145.7		80.2%	6996.4	7660.2	7330.1
*	29	5		8526.2	H	361.1	H	215.3		168.2		80.5%	8090.3	8891.2	8512.5
*	30	5	L	9661.0	L	214.5	H	237.6	H	217.0		82.9%	9273.9	9940.2	9661.6
	31	5		11017.2		536.7		192.6		255.9		80.8%	10552.4	11526.5	11015.7
	32	5		12032.4		524.6		108.2		140.5		82.3%	11645.3	12422.2	12025.1
	33	5		13358.8		310.3		109.5		126.0		84.2%	13054.8	13671.5	13356.2
	34	5		13674.5		326.9		118.3		130.5		85.5%	13359.7	13984.7	13674.6
	35	5		13907.0		333.4		115.6		122.4		86.7%	13565.0	14212.1	13906.4
*	36	5		14191.5		289.8		130.6	H	227.2		81.3%	13882.3	14509.2	14189.7

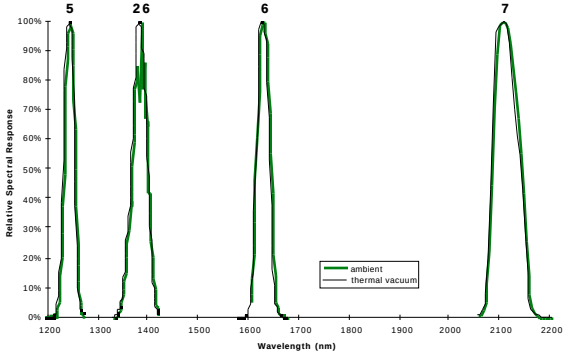
RSR MEASURED FOR ALL MODIS SPECTRAL BANDS

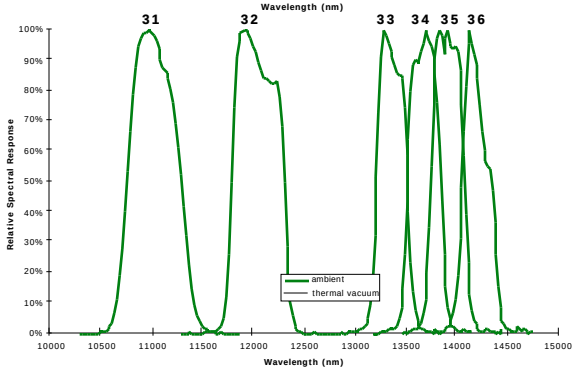






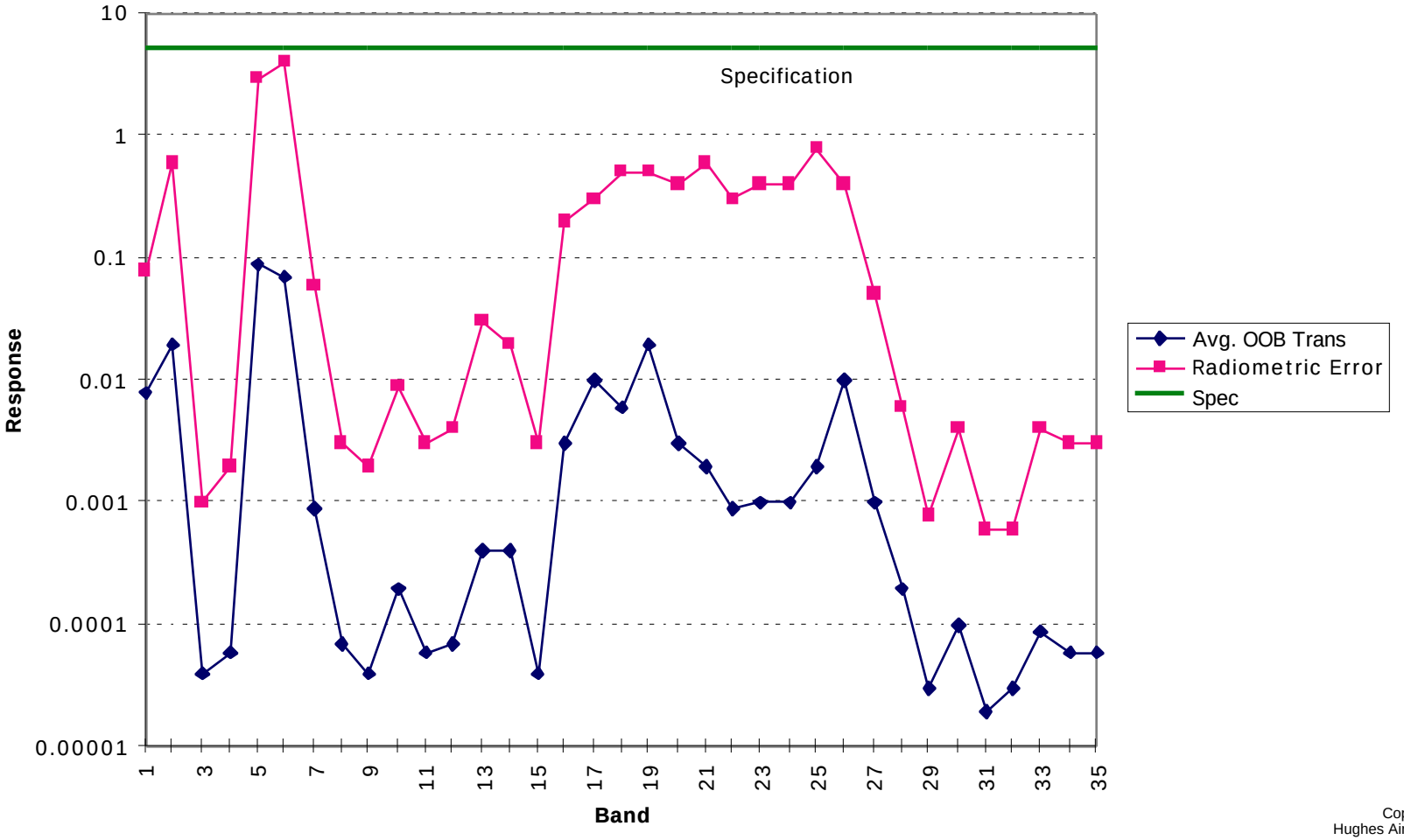






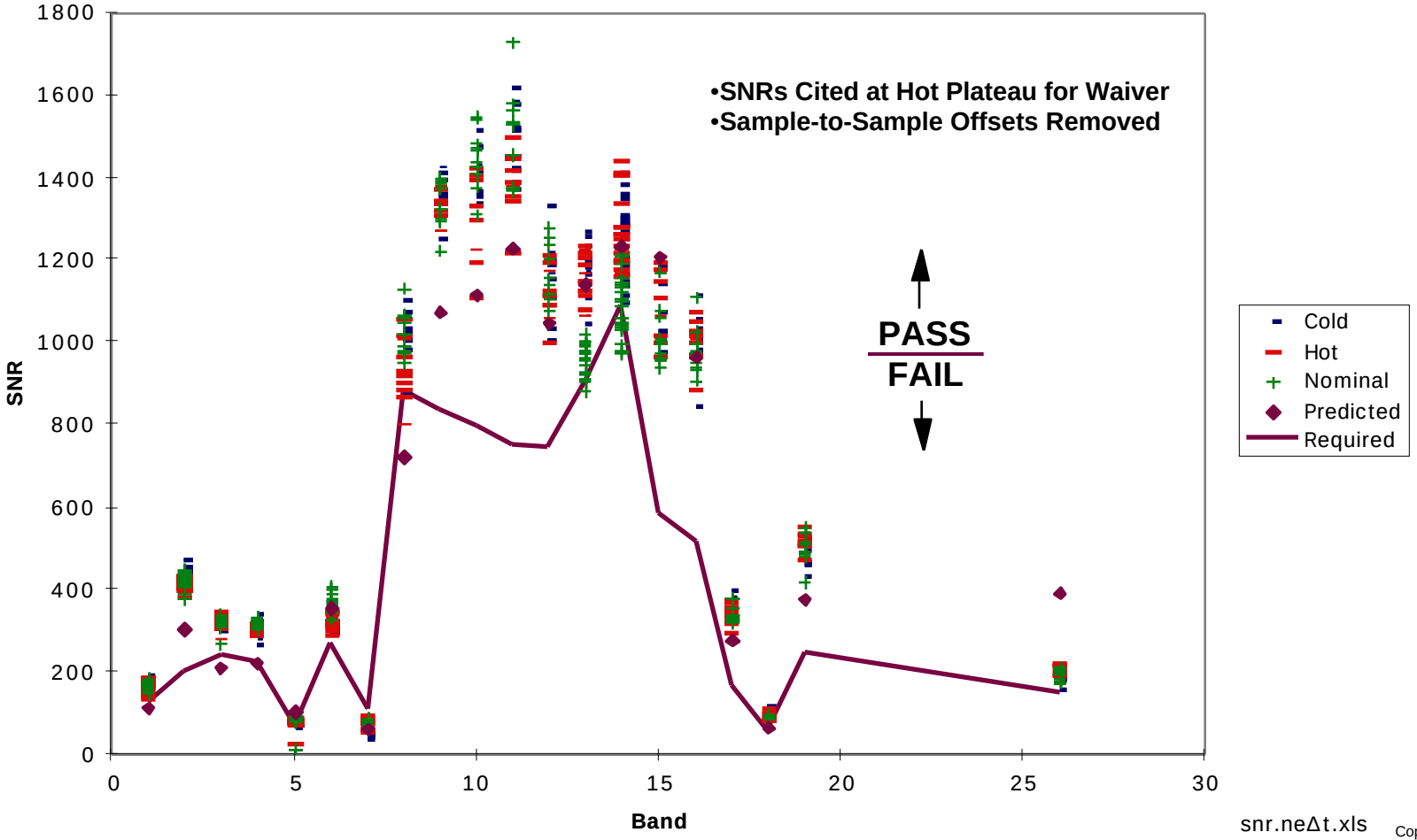
3.3.3.3. Waiver 063A: Out-of-Band Response

Out-of-Band Response Compliant with Specifications, Except No Band 36 Data



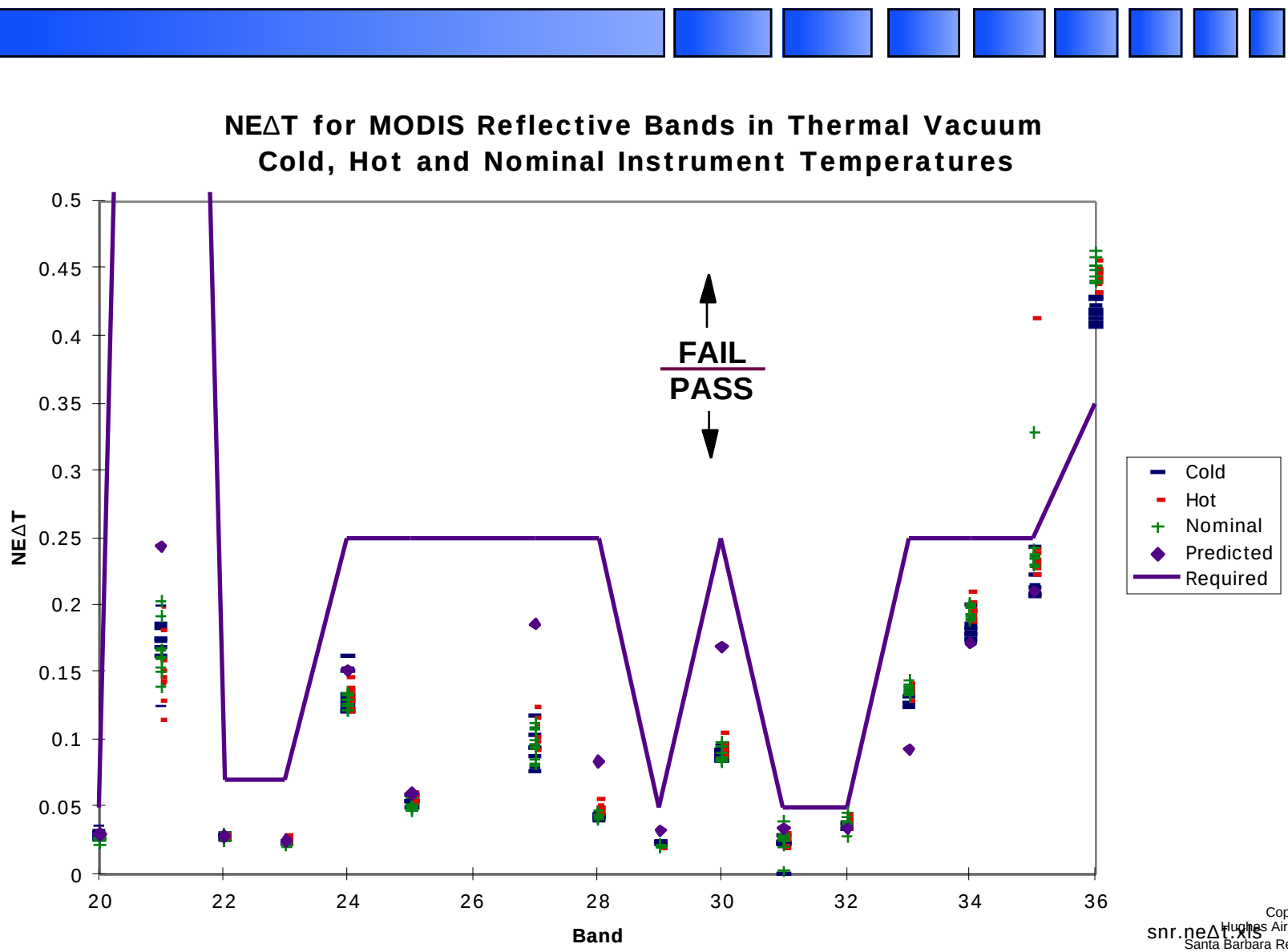
3.3.4.1. Waiver 073: SNR

SNR for MODIS Reflective Bands in Thermal Vacuum
Cold, Hot and Nominal Instrument Temperatures



snr.neΔt.xls

3.3.4.2. Waiver 073: NEΔT



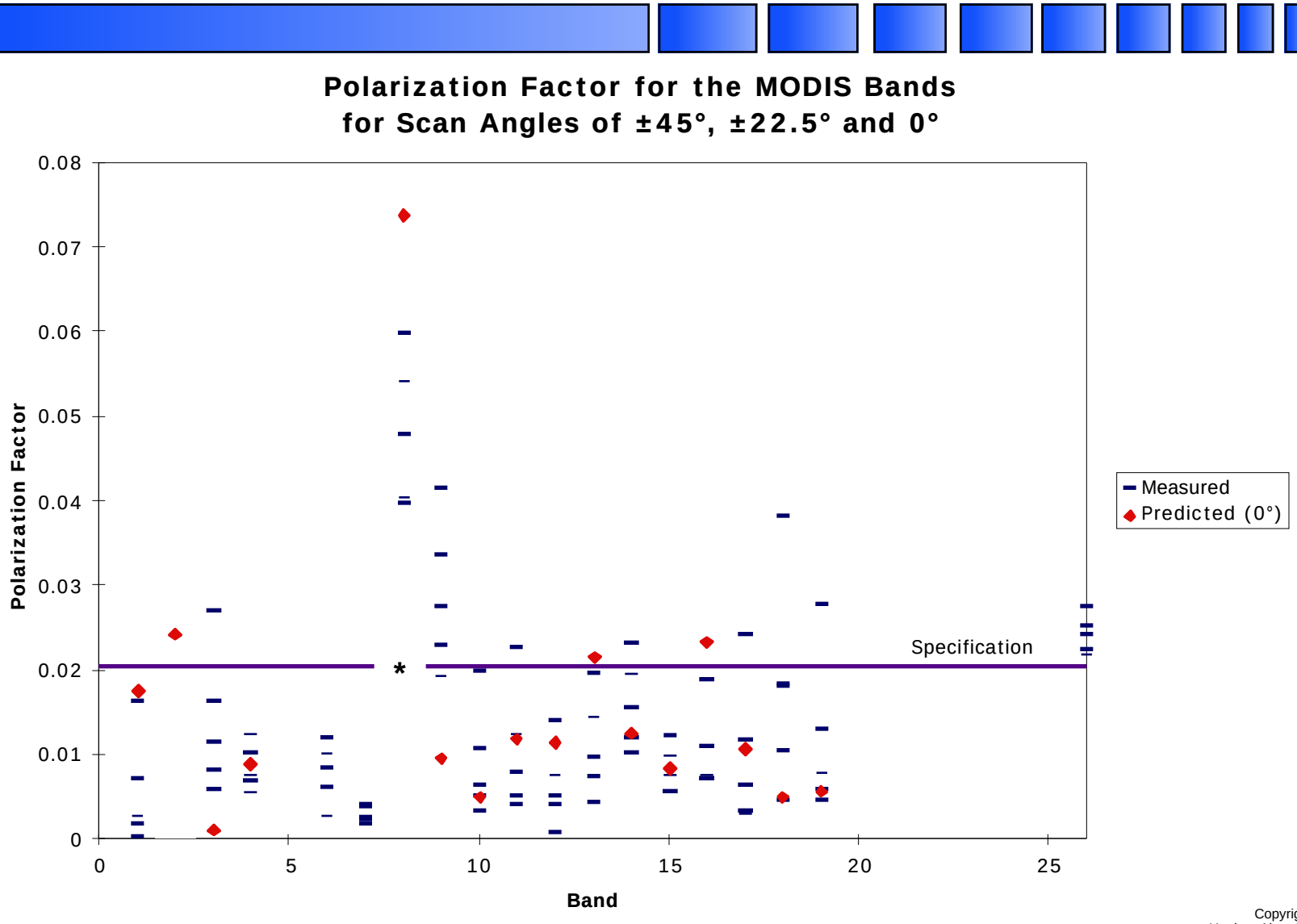
snr.neΔt.xls

3.3.4.2. Waiver 073: Fraction of full scale radiance at which SNRs/NEΔT's measured

- **Limitations due to GSE capabilities**

Maximum fraction of full scale radiance, Lmax, at which SNR's/NEΔTs were measured					
Spherical Integrating Source Bands			Blackbody Calibration Source Bands		
File:	snr.1403_SNR.det		File:	snr.1402_SNR.det	
Band	Lmeas_max/Lmax		Band	Lmeas_max/Lmax	
1	1.425	Pass	20	1.239	Pass
2	4.98	Pass	21	0.034	Fail
3	0.462	Fail	22	1.485	Pass
4	1.157	Pass	23	1.463	Pass
5	1.547	Pass	24	2.127	Pass
6	1.213	Pass	25	2.156	Pass
7	1.257	Pass	27	1.653	Pass
8	0.679	Fail	28	1.582	Pass
9	1.52	Pass	29	1.274	Pass
10	3.406	Pass	30	1.414	Pass
11	6.106	Pass	31	0.552	Fail
12	8.972	Pass	32	0.574	Fail
13	32.685	Pass	33	1.293	Pass
13	32.685	Pass	34	1.283	Pass
14	35.002	Pass	35	1.289	Pass
14	35.002	Pass	36	1.285	Pass
15	47.051	Pass			
16	56.241	Pass			
17	7.389	Pass			
18	4.564	Pass			
19	6.194	Pass			
26	1.307	Pass			

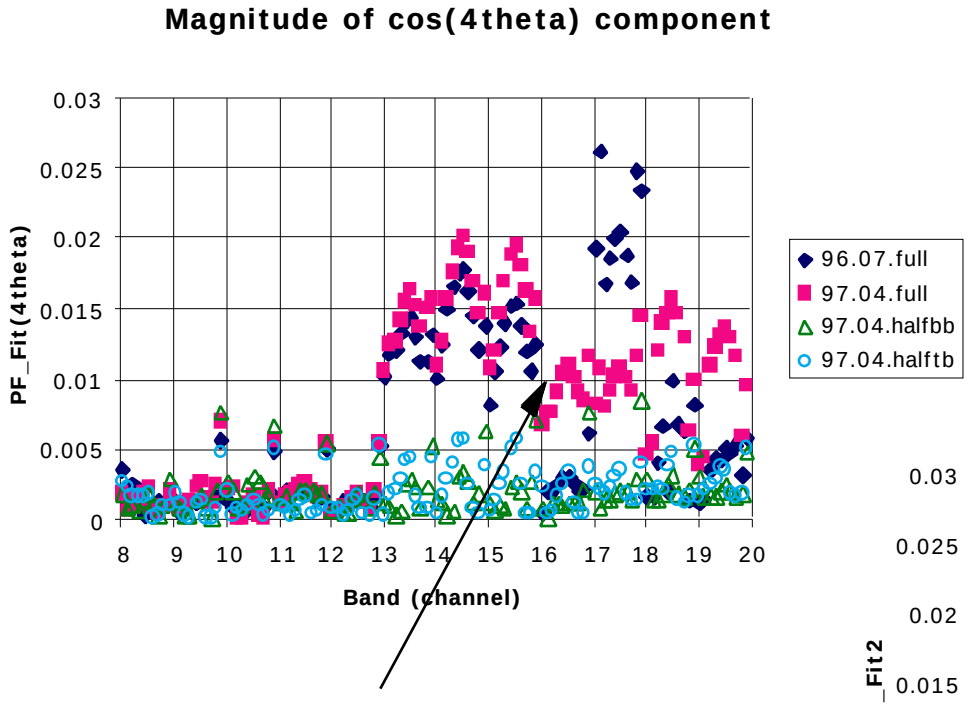
3.3.5. Waiver 055: Polarization



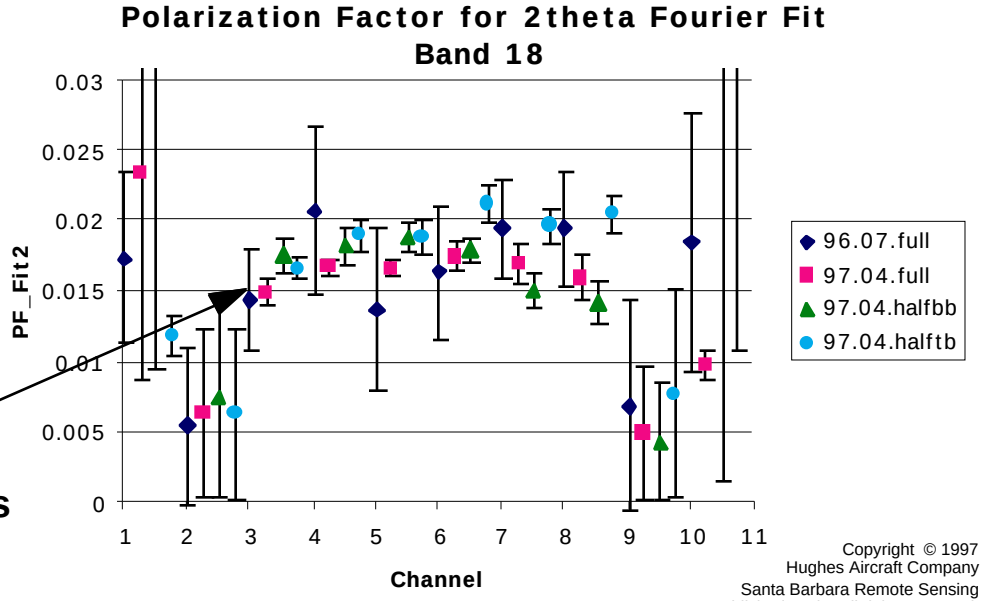
***Note: Low residual polarization desired for band 8, but not covered as a specification requirement**

POLARIZATION RETEST VALIDATED INITIAL DATA SET

- Polarization follows cos 2θ in MODIS
- Concern that Fourier Extraction not valid in presence of cos 4θ
- Re-test using 1/2 aperture removed mechanism in test equipment for cos 4θ behavior
- Results validate Fouier Extraction

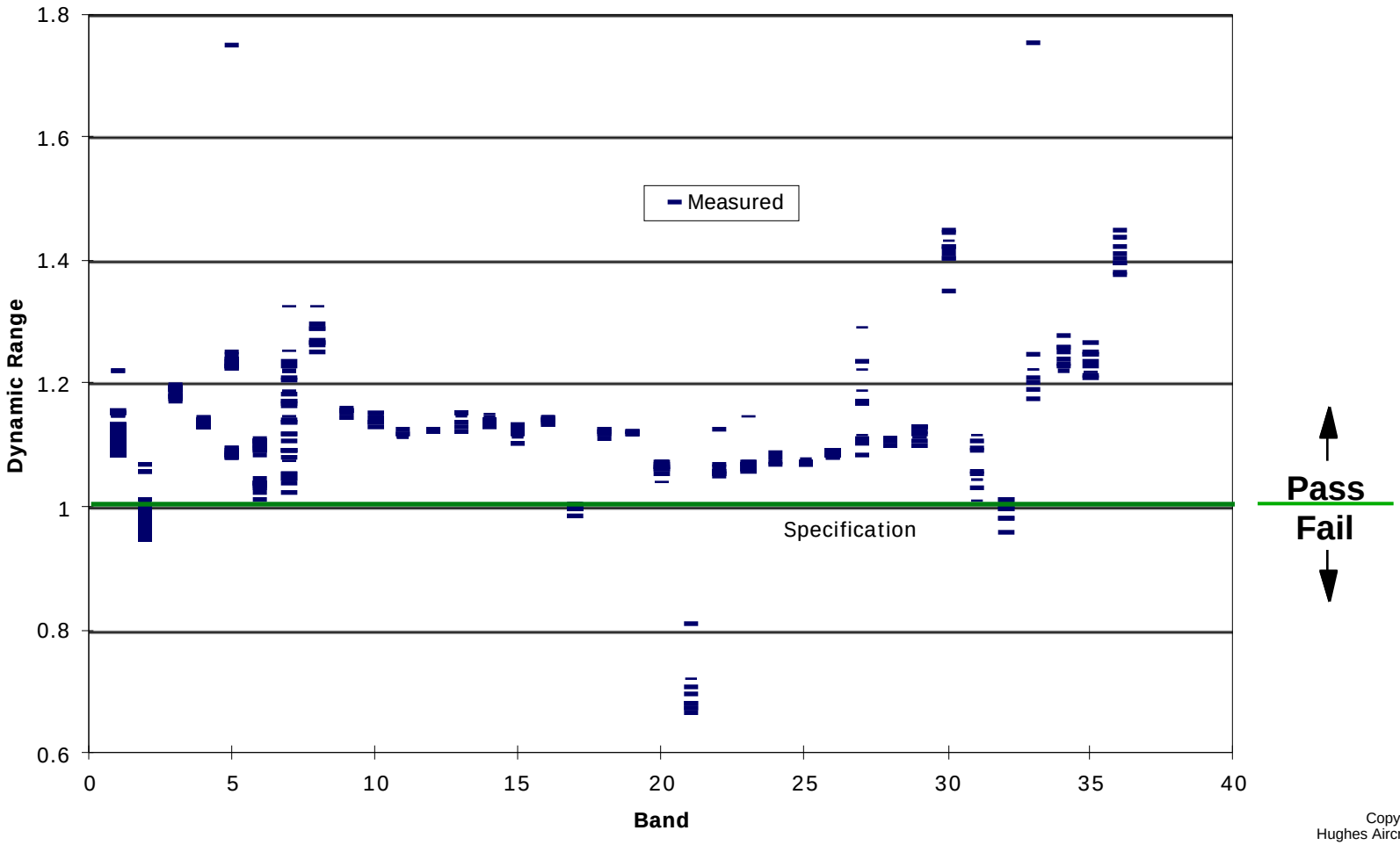


Cos 4θ greatly reduced in NIR

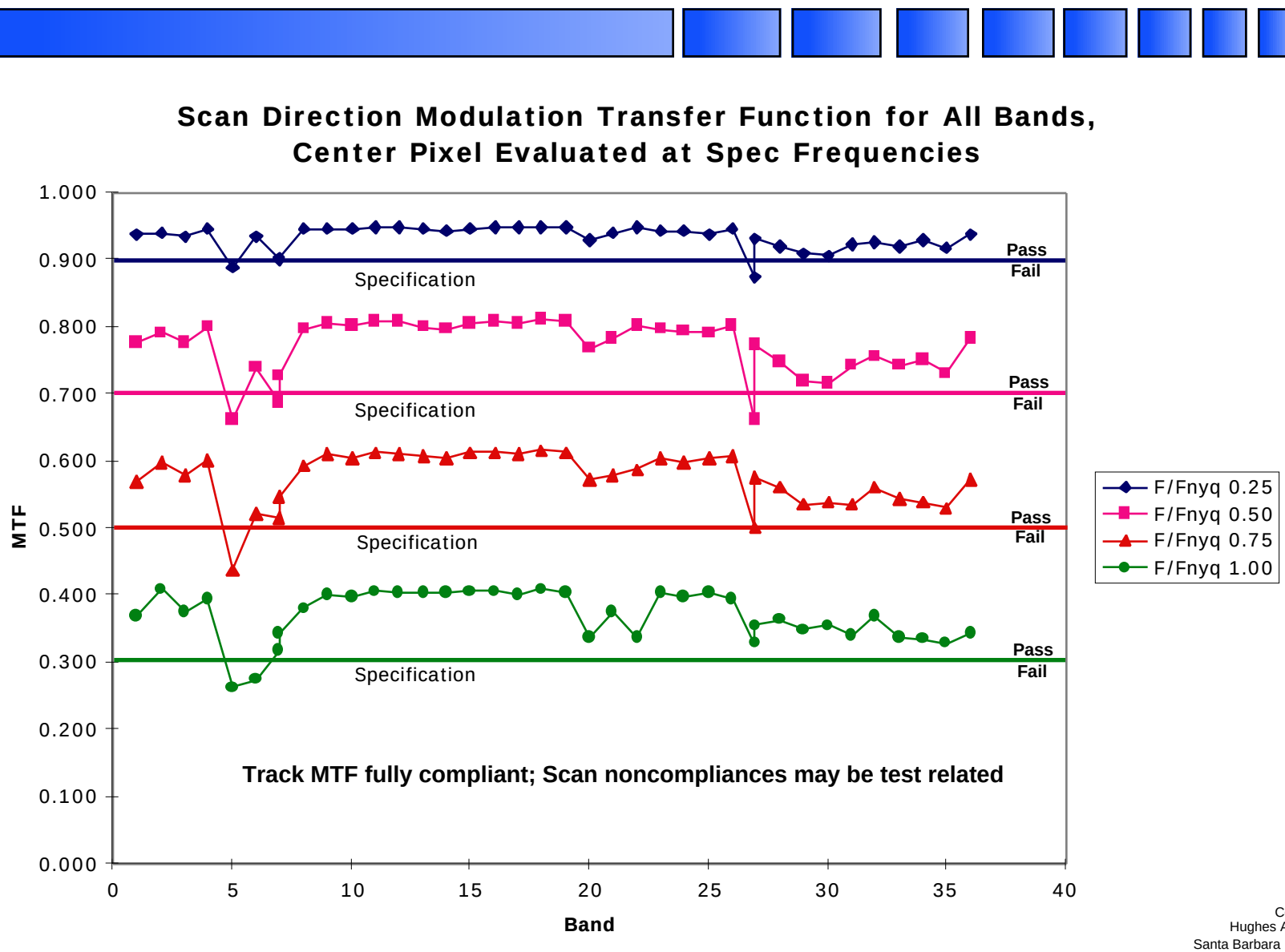


Cos 2θ component
roughly the same in both methods

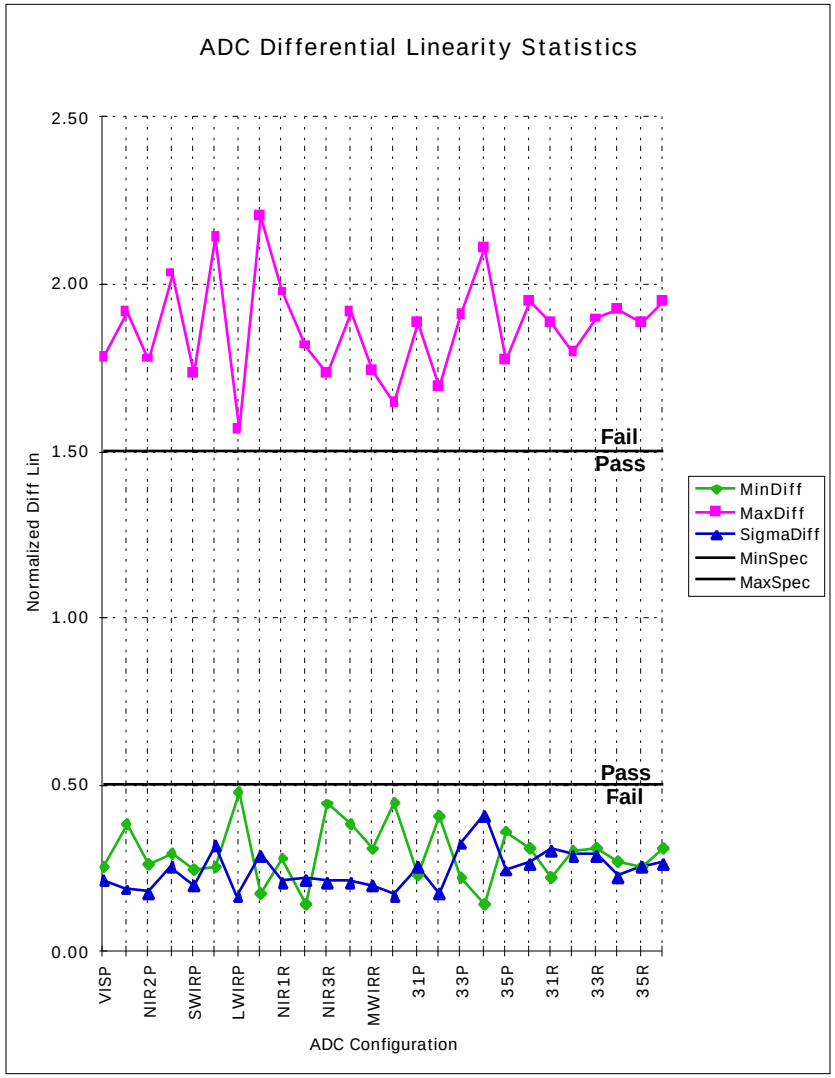
3.4.1. Waiver 077: Dynamic Range



3.4.2. Waiver 087: MTF



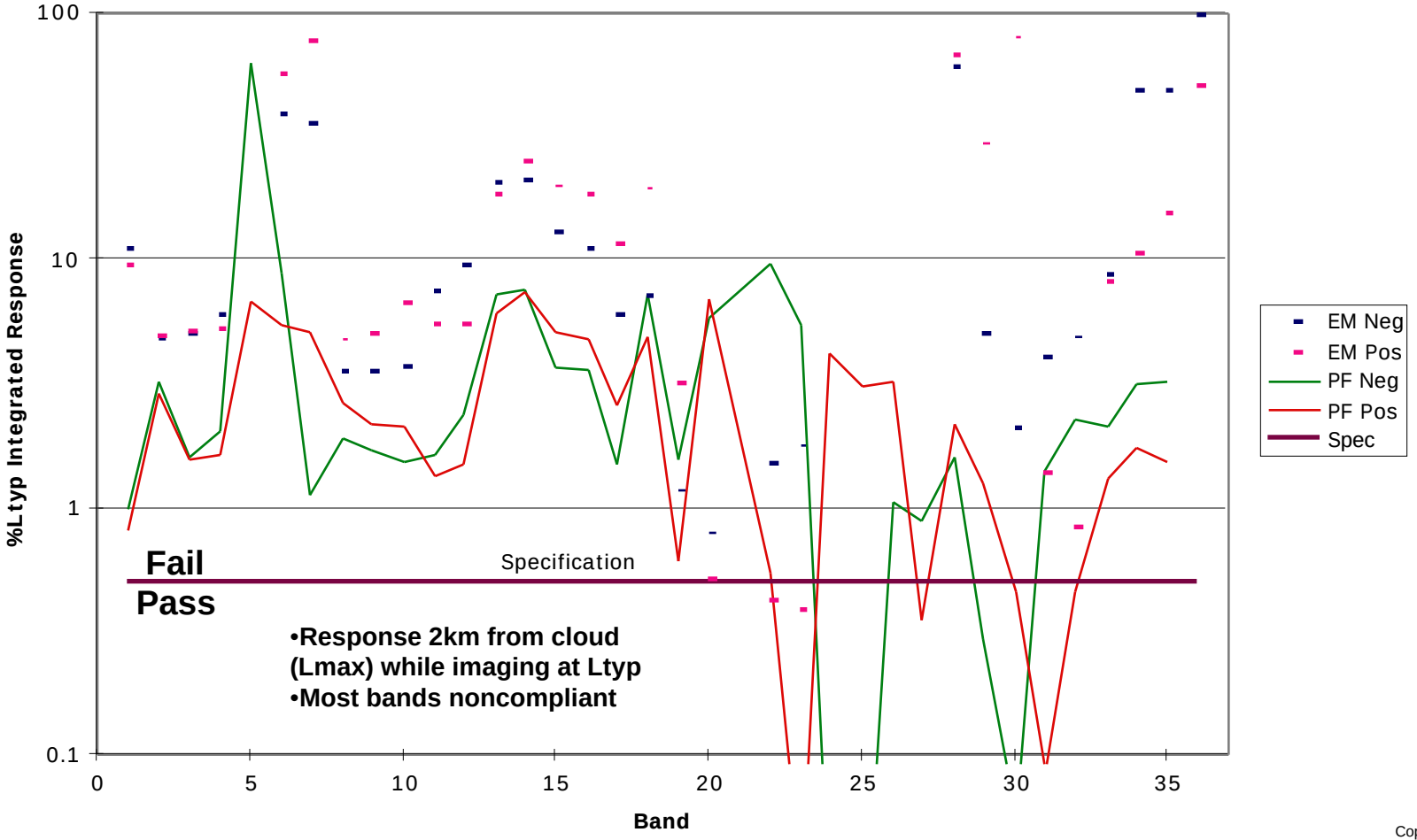
3.4.3. Waiver 056: Differential Nonlinearity



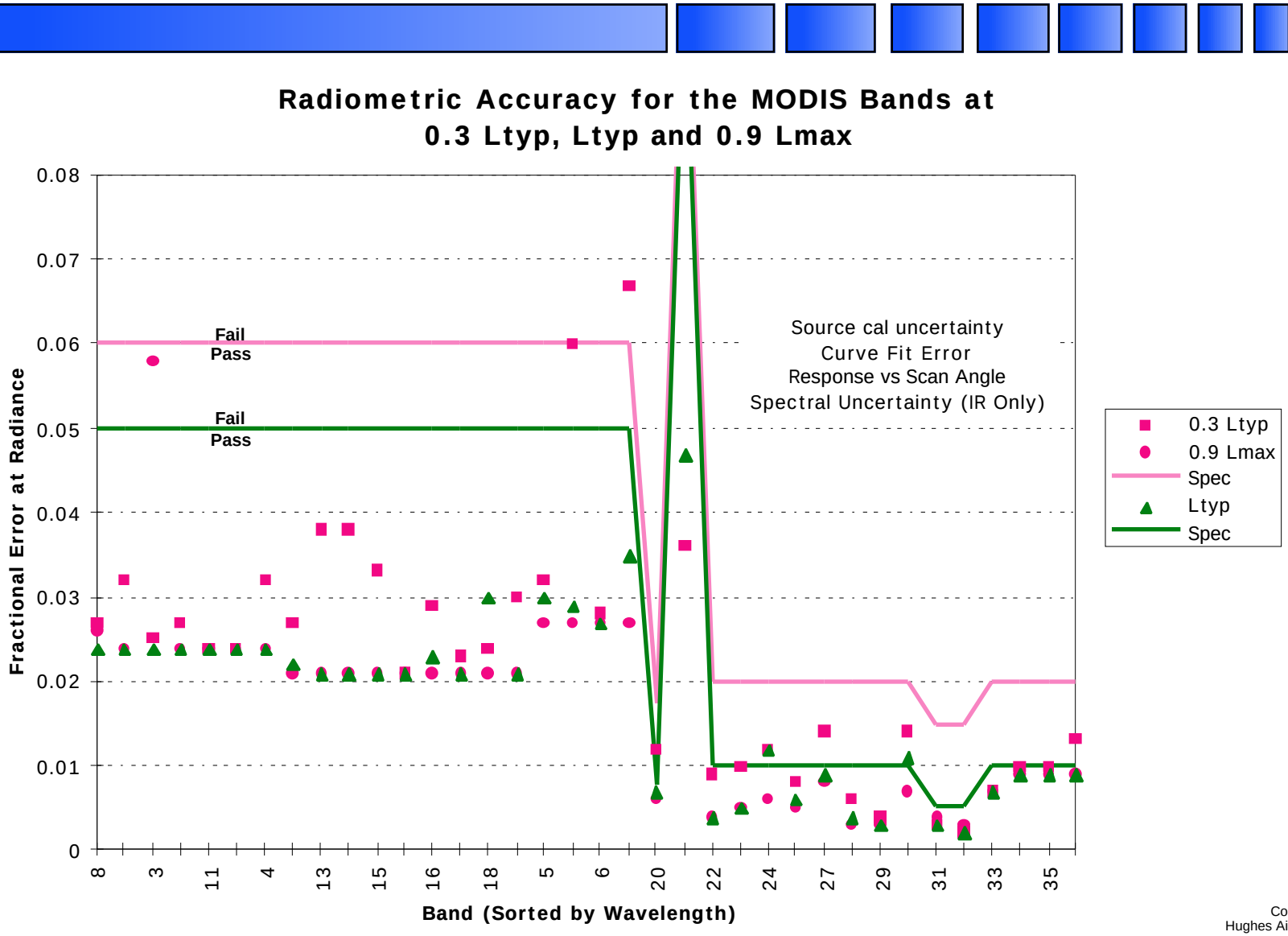
This EPS image does not contain a screen preview.
It will print correctly to a PostScript printer.
File Name : SMIR20A.EPS
Creator : GRAF/DRIVE PLUS

3.4.4. Waiver 054: Near Field Response

Integrated Near Field Response for MODIS PFM as % Ltyp Compared to EM

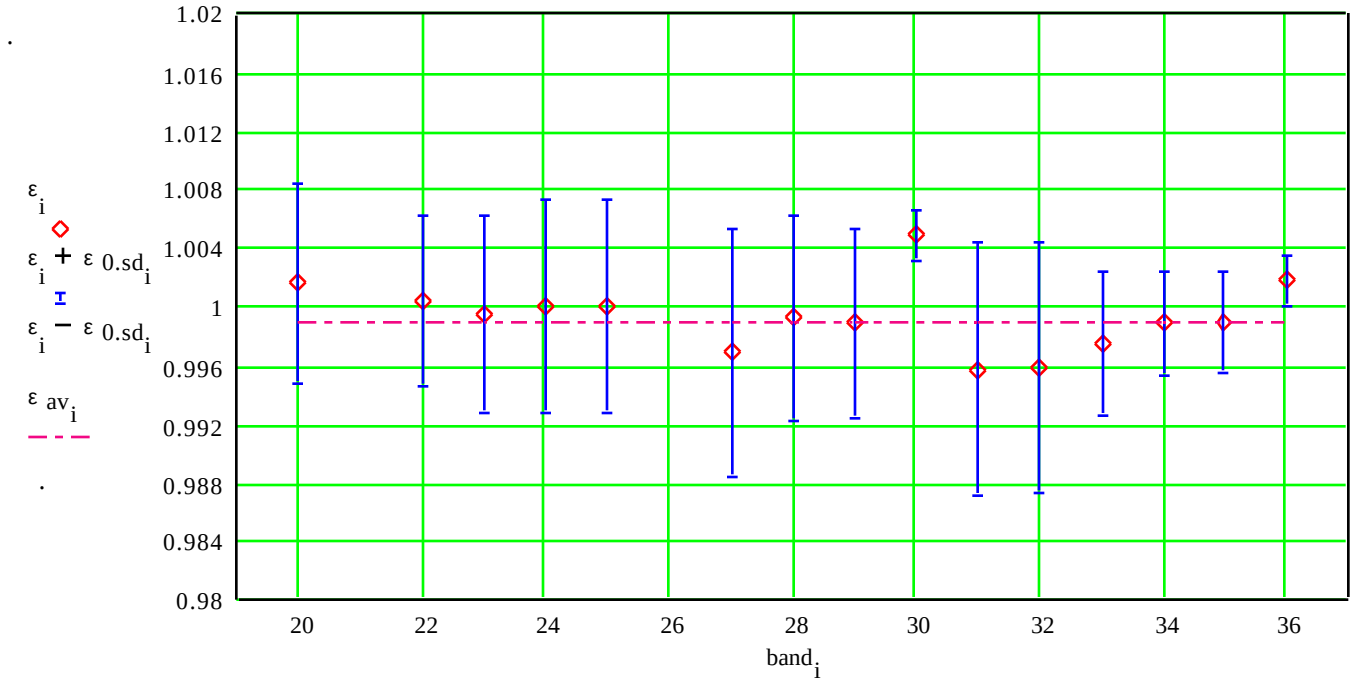


3.4.5.2. Waiver 062,078: Absolute Radiometric Accuracy

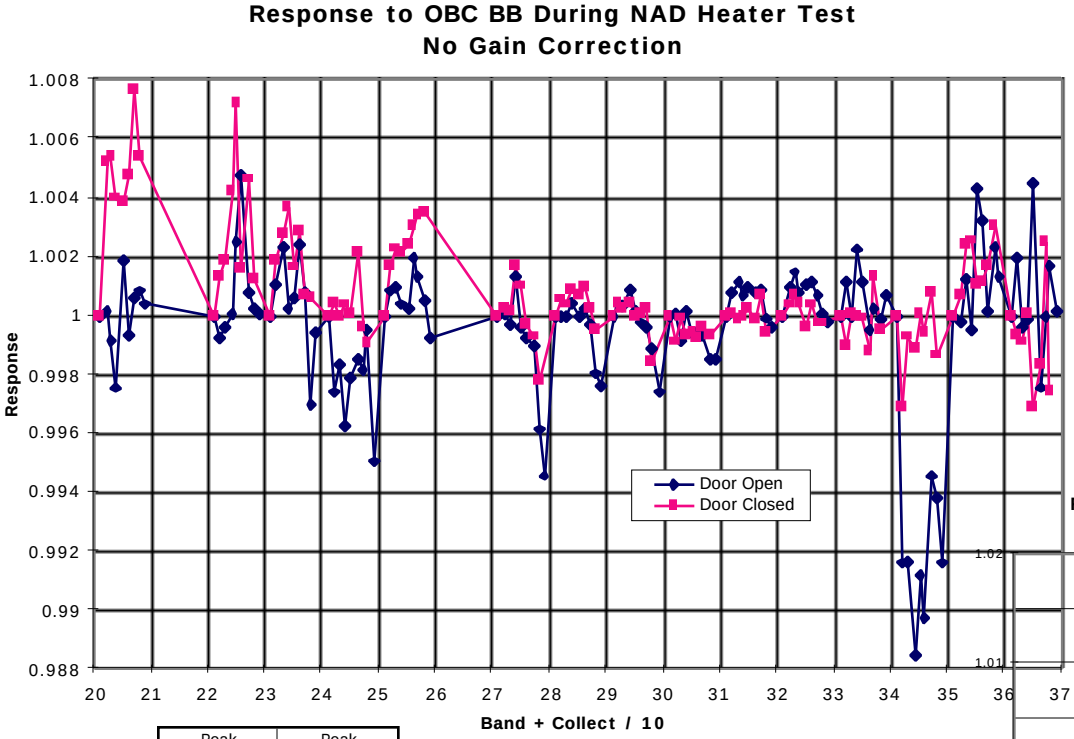


OBC BB EMISSIVITY MEASURED TO BE ABOUT 0.997

- Retrieved OBC BB emittance showed no spectral effects.



OBC BB CHANGE NOT OBVIOUS DUE TO CONTAMINANT



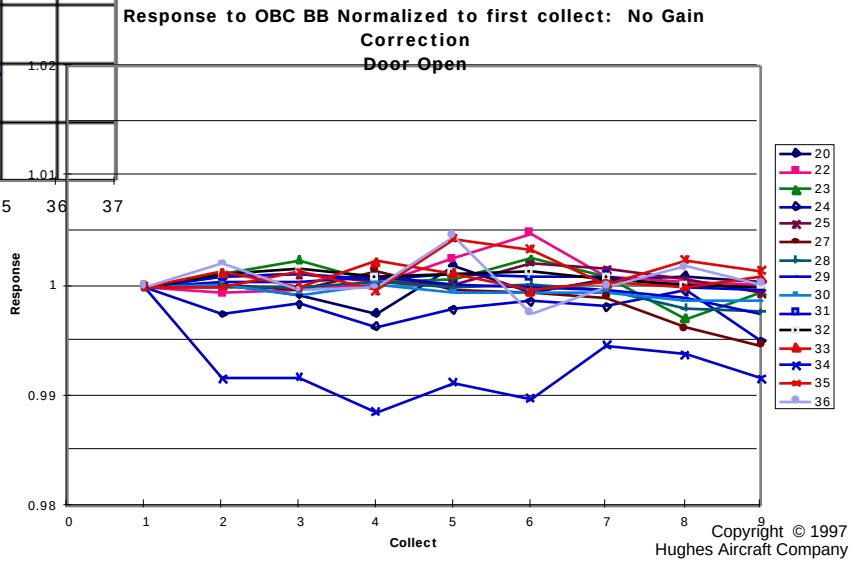
Peak (cm-1)	Peak (µm)
1075.23	9.30
1106.46	9.04
1222.11	8.18
1310.41	7.63
1373.97	7.28
1411.52	7.08
1456.9	6.86
1536.59	6.51
1597.03	6.26
1705.74	5.86
1731.06	5.78
2865.68	3.49
2928.92	3.41
2965.04	3.37
3301.06	3.03

Location of major peaks show B27 would be affected

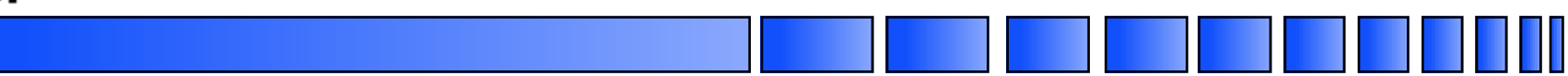
Data acquired before test through end of test

Signals on BB show no clear change.

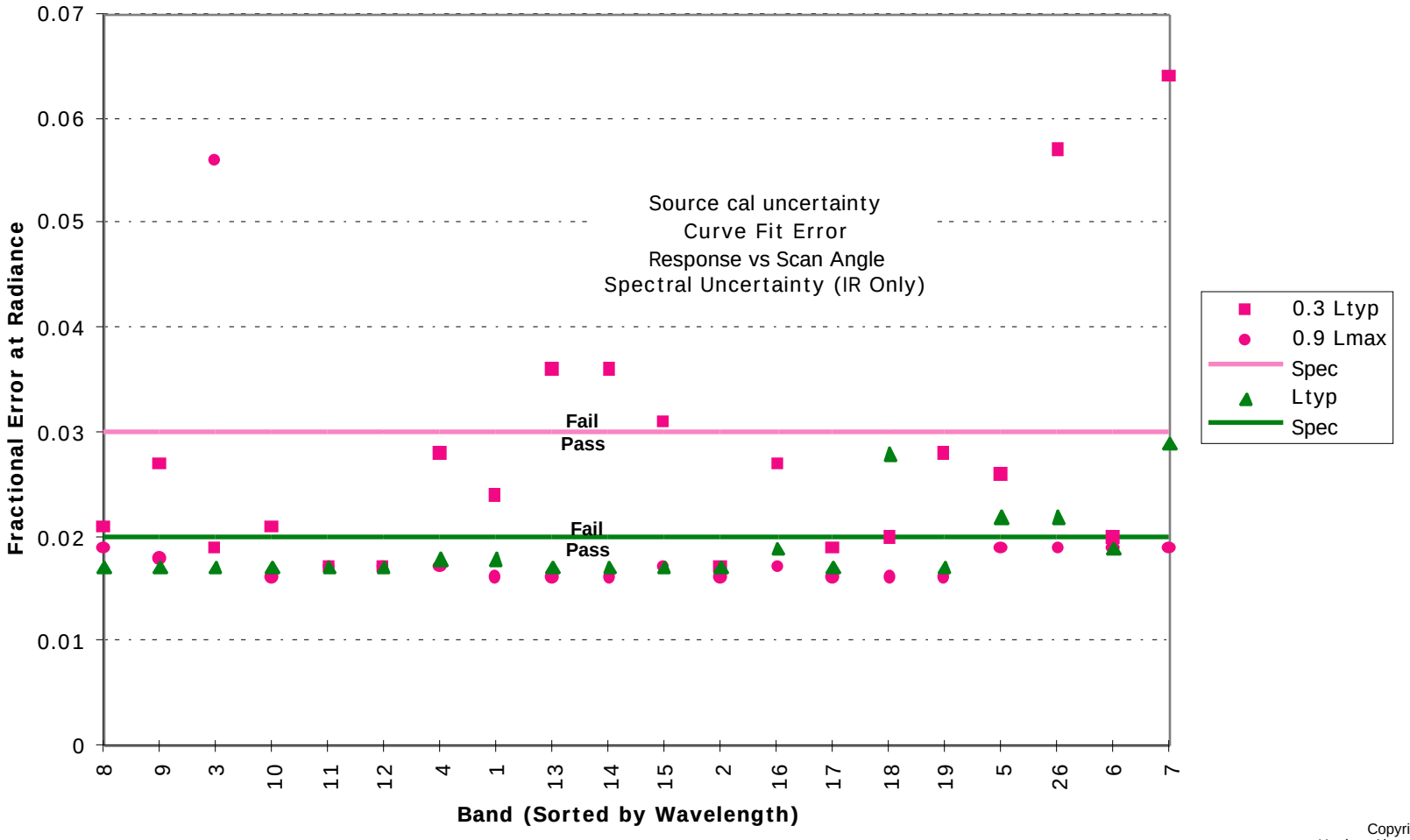
Some change seen on B27



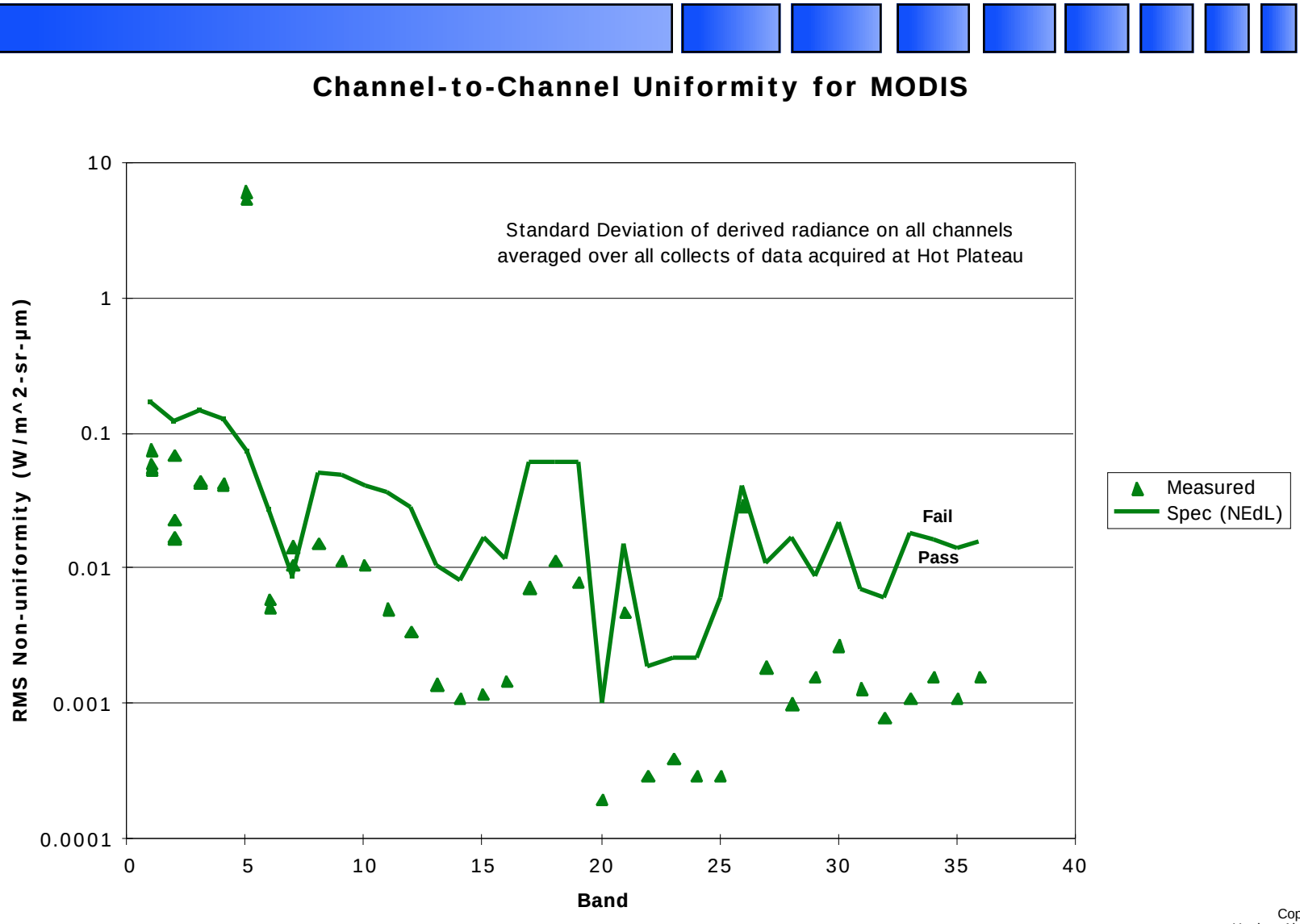
3.4.5.2. Waiver 062,078: Absolute Radiometric Accuracy (Reflectance)



Reflectance Accuracy for the MODIS Bands at 0.3 Ltyp, Ltyp and 0.9 Lmax



3.4.5.3.2. Waiver 079B: Channel-to-Channel Uniformity



3.4.5.3.3. Waiver 080: Crosstalk

- **VIS/NIR fully compliant (No crosstalk seen)**
- **IR data acquired in Thermal Vacuum**
- **Adjacent band effects may be test related**
- **Worst case alignment assumed (2x multiplyer)**

Observed crosstalk

Band	Xtalk received (counts)	Xtalk sent from band	Xtalk scaled by sender's Ltyp/Lpeak*	Pass/Fail (scaled Xtalk >1)	% Receiver Ltyp **
5	2772	7	2.7	F	1.6
	1265	6	2.0	F	1.2
	166	26	0.3	P	0.2
6	1803	7	1.8	F	0.5
7	354	26	0.7	P	0.4
	169	6	0.3	P	0.2
26	2147	7	2.1	F	0.9
	66	6	0.1	P	0.0
	20	5	0.0	P	0.0
20	467	21	3.9	F	0.4
	106	22	1.0	F	0.1
	100	23	1.3	F	0.1
	61	25	0.7	P	0.1
22	2034	23	26.0	F	2.1
	249	20	3.5	F	0.3
23	676	21	5.6	F	0.4
27	41	28	15.5	F	4.3
28	55	27	4.2	F	0.6
29	34	27	2.6	F	0.1
	24	28	8.8	F	0.4
30	62	27	4.8	F	0.7
	43	28	15.9	F	2.4

PC light leaks

Band	Xtalk received (counts)	Xtalk sent from band	Xtalk scaled by sender's Ltyp/Lpeak*	Pass/Fail (scaled Xtalk >1)	% Receiver Ltyp **
31	3.69	32	9.86	F	0.8
32	7.53	31	15.85	F	1.1
33	13.42	31	28.26	F	2.2
	14.00	34	15.99	F	1.2
	4.65	27/33+	6.60++	F	0.5
34	31.72	31	66.79	F	6.4
	13.16	35	15.03	F	1.5
35	55.38	31	116.60	F	13.4
36	No data				

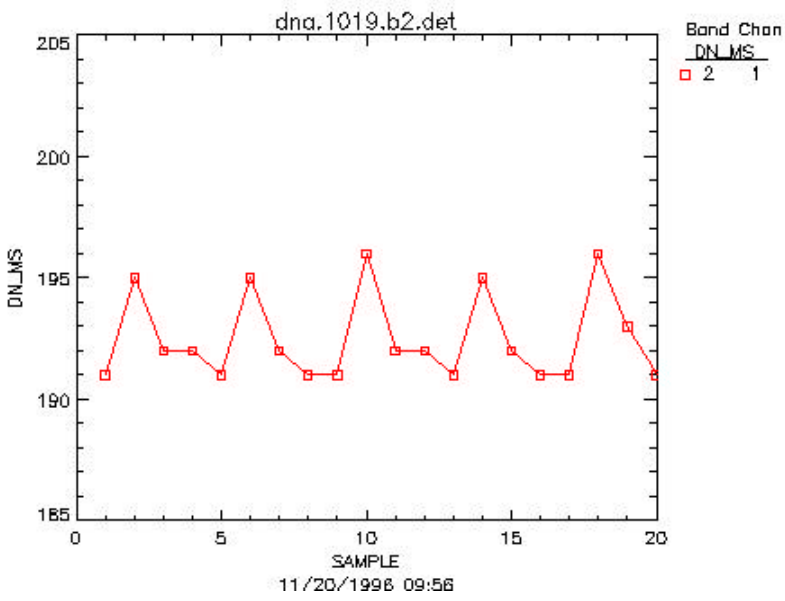
* Worst case alignment. No correction for test induced errors (shutter phase changes)
** For information only
\+ Region between 27 and 33
++ Scaled by receiver's Ltyp/Lpeak

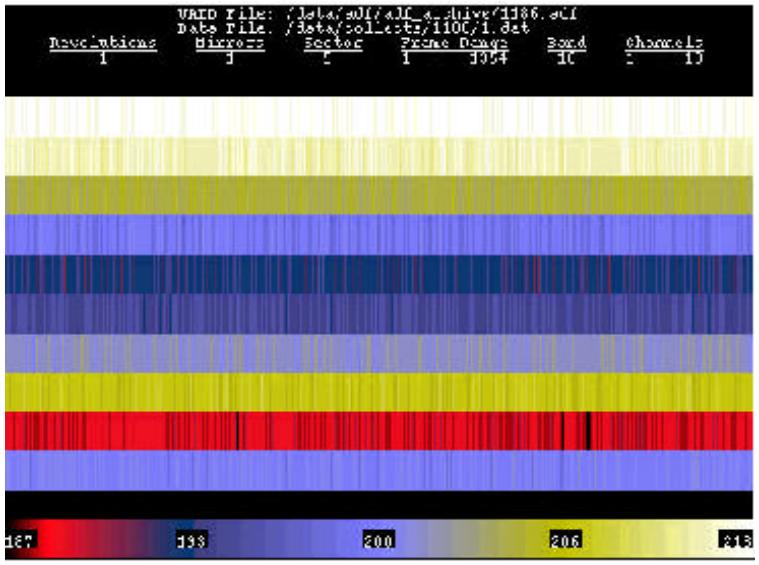
- **4x Improvement may be possible for PV with Vdet change. Impact to cal TBD**
- **Crosstalk from Band 31 Fixed for FM1**

3.4.5.3.3. Waiver 080: Pattern Noise

FIXED PATTERN NOISE

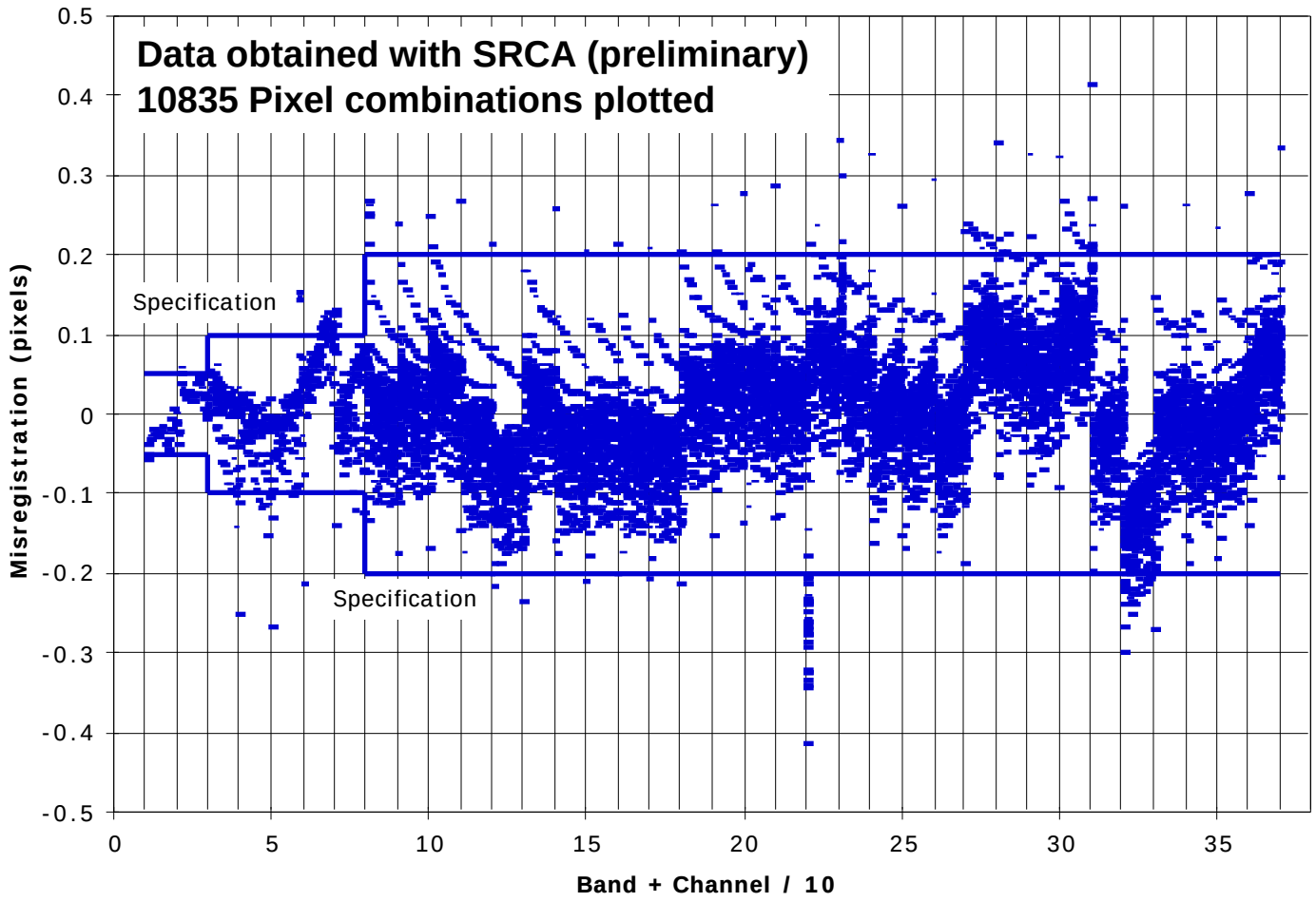
- Waiver applied to bands 1, 2, 3, 4, 5, 6, and 7
- Sub 1km Bands exhibit sample-to-sample offset
- Frame rate (1km) is 3 kHz
- Bands 1 & 2 have pattern at 6 kHz, and 3kHz
- Bands 3 through 7 have pattern at 3 kHz only (adjacent samples high, low)
- Raw 1km data has channel-to-channel offsets, but no fixed pattern noise





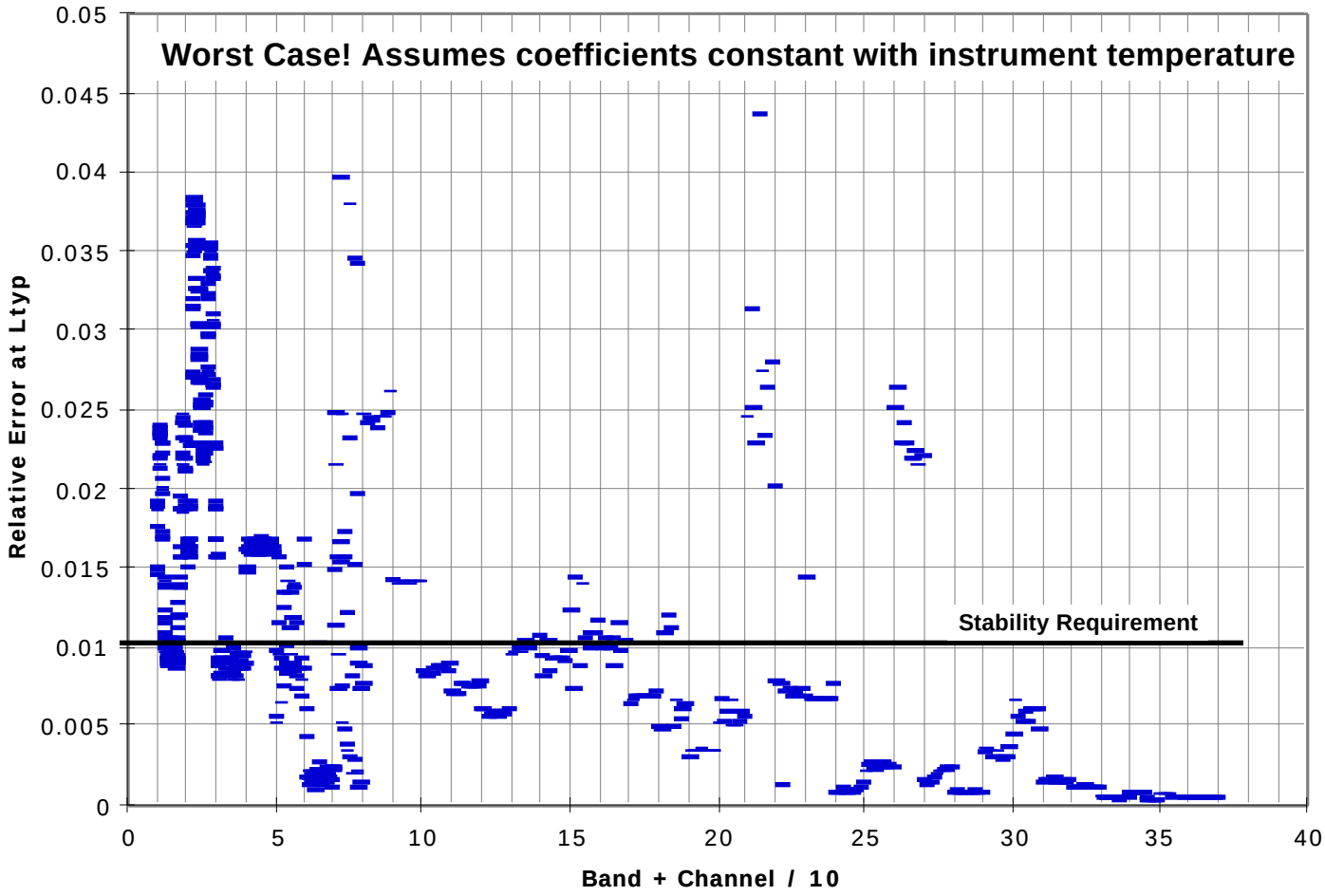
3.4.6.3. Waiver 081: Spectral Band Registration

MODIS Scan Direction Co-Registration



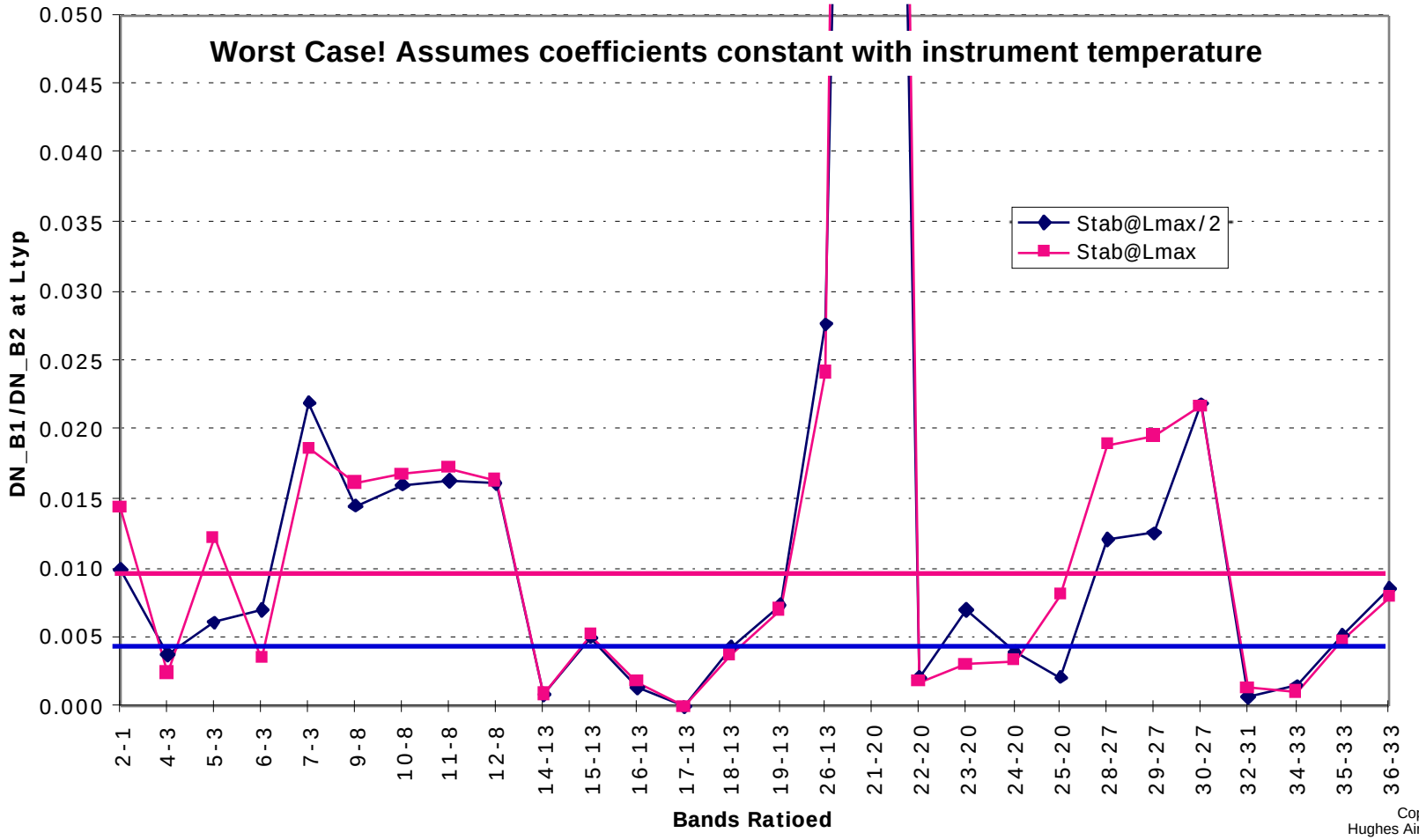
3.4.7.1,2,3. Waiver 091: Stability

RMS Radiometric Error Due to Variation in First (Refl) and Second (IR) Order Coefficients. Variance over Cold, Hot, Nom and Repeat Sets in T/V



3.4.7.1,2,3. Waiver 091: Stability

Band to Band Stability over Temperature and Repeat Collects



Summary

- Data presented for all non-conforming areas
- Most noncompliances are on small fractions of total data set
- FM1 expected to have similar performance except no B31 leak and perhaps improved co-registration
- Overall instrument performance is excellent. Expect better to come:
  - Big improvement in radiometric error expected with new curve fit to data
  - “Stability” numbers quoted to greatly reduce with temperature dependent coefficients or use of master curve technique.
- Concerns
  - Crosstalk seen is higher than expected. 4x Improvement may be possible
  - Near Field Response mostly noncompliant
  - Dynamic range noncompliant on several bands. Band 21 biggest concern
- All results are subject to change upon closer examination of data and further analyses.