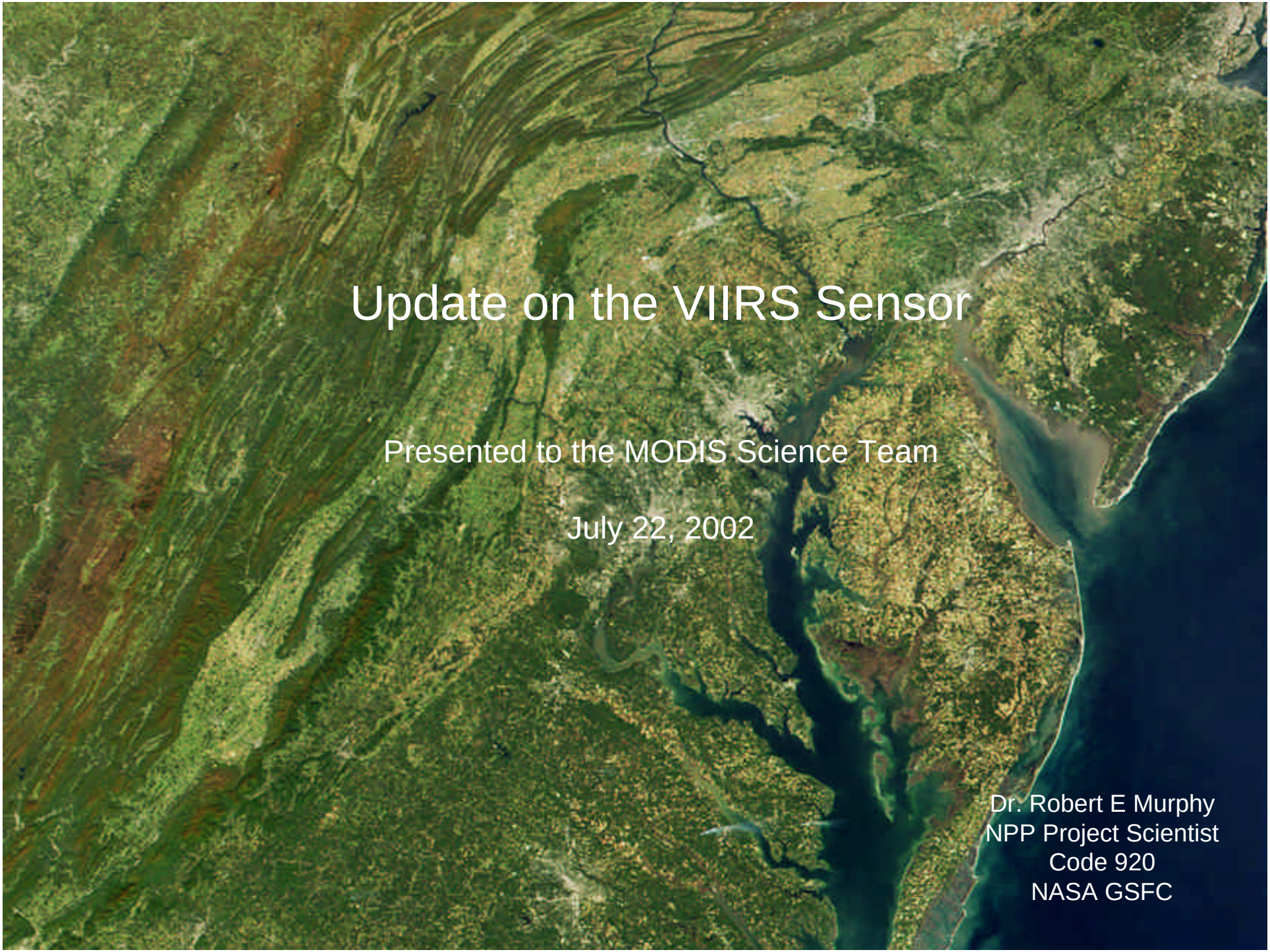


Update on the VIIRS Sensor

Presented to the MODIS Science Team

July 22, 2002

Dr. Robert E Murphy
NPP Project Scientist
Code 920
NASA GSFC

What is NPP?

- **NPP is a "bridging mission" that provides for the continuation of measurement series initiated with EOS Terra & Aqua for NASA's global change research**
  - **Climate change**
  - **Global carbon cycle**
  - **Global water cycle**
- **NPP provides risk reduction for the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) which will continue these measurements into the indefinite future**
- **NPP is a joint program of NASA and the Integrated Program Office (IPO), the tri-agency activity that is responsible for NPOESS**

What is the NPOES Mission?

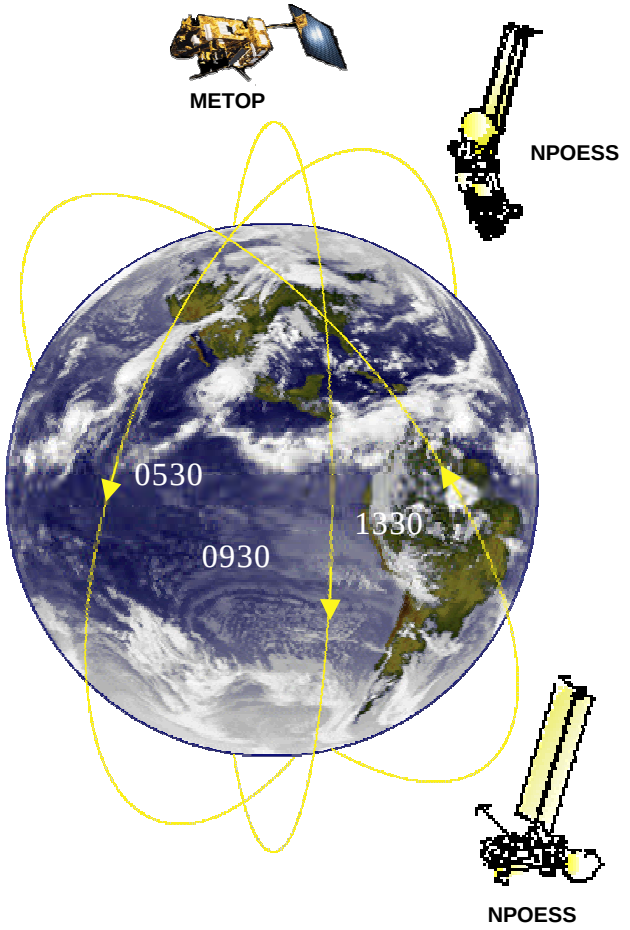
Mission

Provide a national, operational, polar-orbiting environmental capability

Achieve National Performance Review savings by converging DoD and NOAA polar satellite programs

Incorporate new technologies from NASA and others

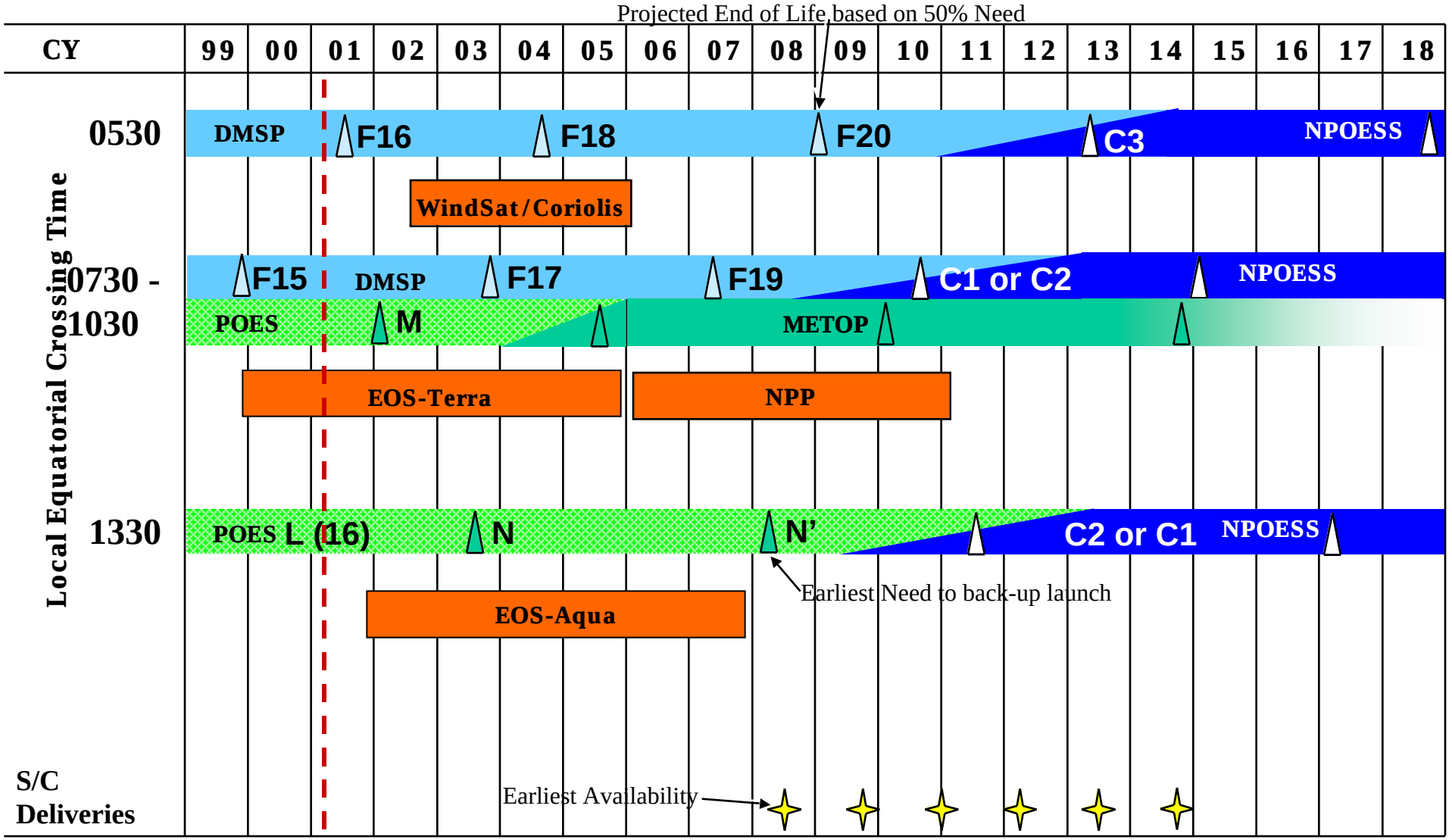
Incorporate, where appropriate, International Cooperation (EUMETSAT)



Satellite Transition Schedule

(9 March 2001)

Slopes indicate 10-90% need (NPOESS GAP 5b)



NPP Sensors

- **The Visible Infrared Imaging Spectroradiometer Suite (VIIRS) extends measurement series initiated by MODIS on EOS Terra & Aqua**
  - **Design is evolutionary from MODIS**
- **The Cross-track Infrared Sounder (CrIS) continues measurement series initiated by AIRS on EOS Aqua**
  - **Utilizes a Michelson interferometer in contrast to AIRS, which is a spectrometer**
- **The Advanced Technology Microwave Sounder (ATMS) continues the measurement series initiated by the AMSU on NOAA-15**
  - **MMIC Technology used to reduce mass, power & volume**
- **An Instrument of Opportunity is under consideration**
  - **Aerosol Polarimeter Sensor**
  - **CERES**
  - **OMPS**
  - **SAGE III**
  - **Code S payload**
  - **Decision August 2002**

NPP & NPOESS Orbits

- **NPP has 824 km Sun synchronous orbit**
  - **10:30 AM descending node**
  - **98.74° inclination**
  - **Mimics Terra ground track repeat**
    - **16 day ground-track repeat**
  - **Swath width 0f 3,000 Km (±56.06°)**
- **NPOESS has 833 km Sun synchronous orbits**
  - **All 3 satellites will carry a VIIRS**
    - **09:30 descending node**
    - **13:30 ascending node**
    - **17:30 ascending node**
  - **Swath width of 3,000 km (±56.06°)**

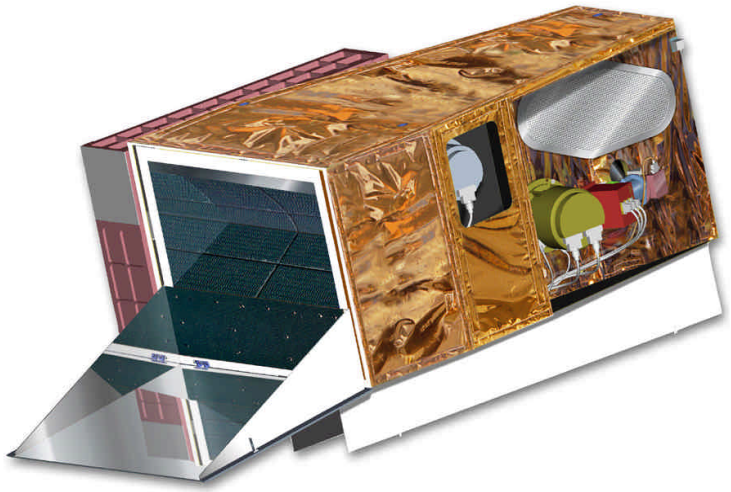
Operational & Research Data Products

- **The operational system (NPOESS) will produce Environmental Data Records (EDR's) of geophysical products in less than 90 minutes from acquisition**
  - **Timeliness requirement limits accuracy & consistency that can be obtained**
  - **Yesterday's weather is of limited use**
- **NASA's program requires maximum accuracy and consistency over many years**
  - **Timeliness is not an issue**
- **NASA will produce similar geophysical products in the form of Climate Data Records (CDR's)**

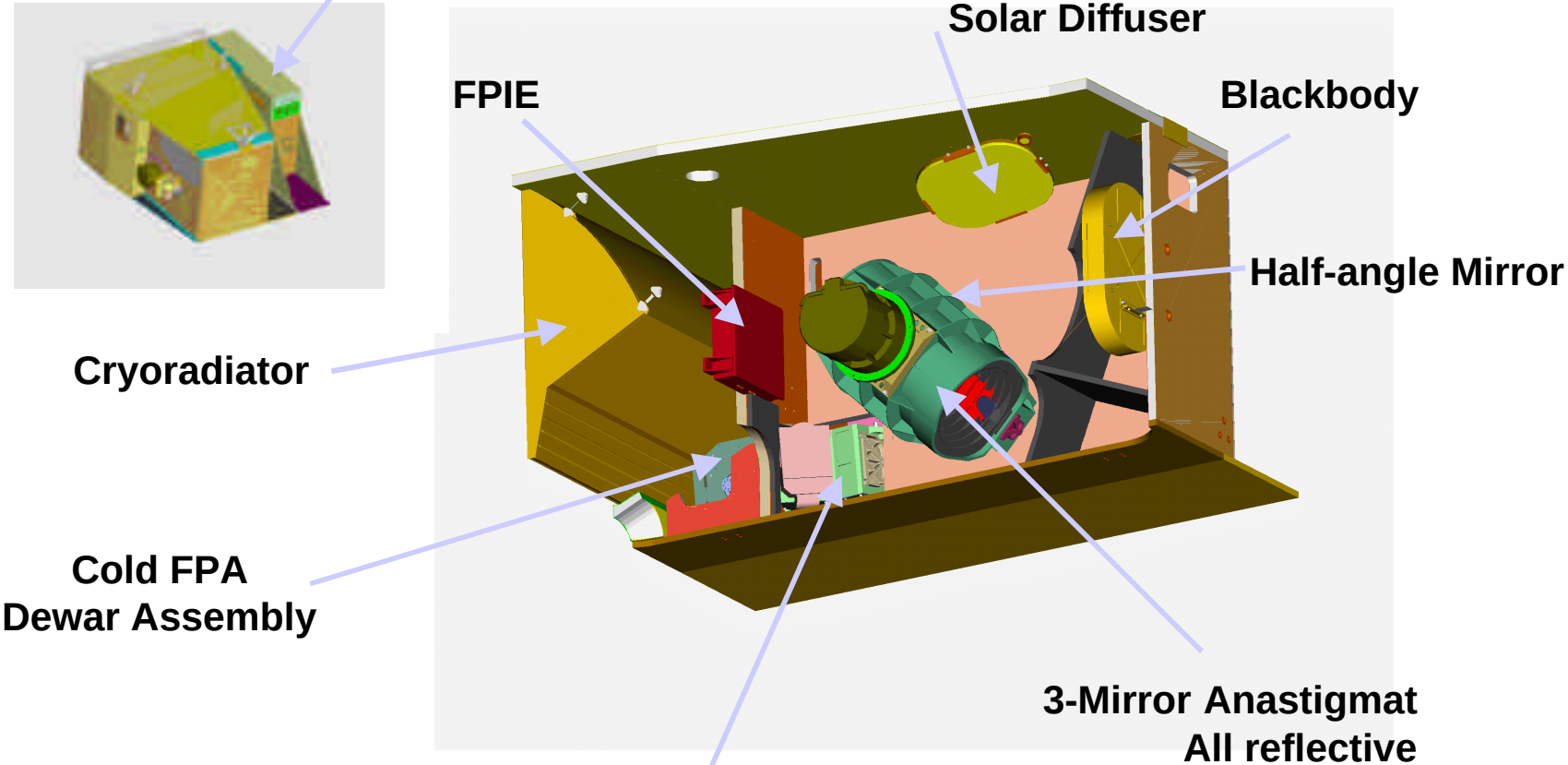
Visible Infrared Imaging Radiometer Suite (VIIRS)

- **Purpose: Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)**
- **Predecessor Instruments: AVHRR, OLS, MODIS, SeaWiFS**
- **Management: Integrated Program Office**
- **Status: Phase C/D (Raytheon)**
- **Approach: Multi-spectral scanning radiometer (22 bands between 0.4 μm and 12 μm) 12-bit quantization**
- **Swath width: 3000 km**

- **Changes to specifics of band dynamic ranges, bandpasses & band centers negotiated**
- **Consideration of adding 6.7 micrometer water vapor band to FM3 & later models**
- **CDR Completed March 2002**



Visible Infrared Imaging Spectroradiometer (VIIRS)

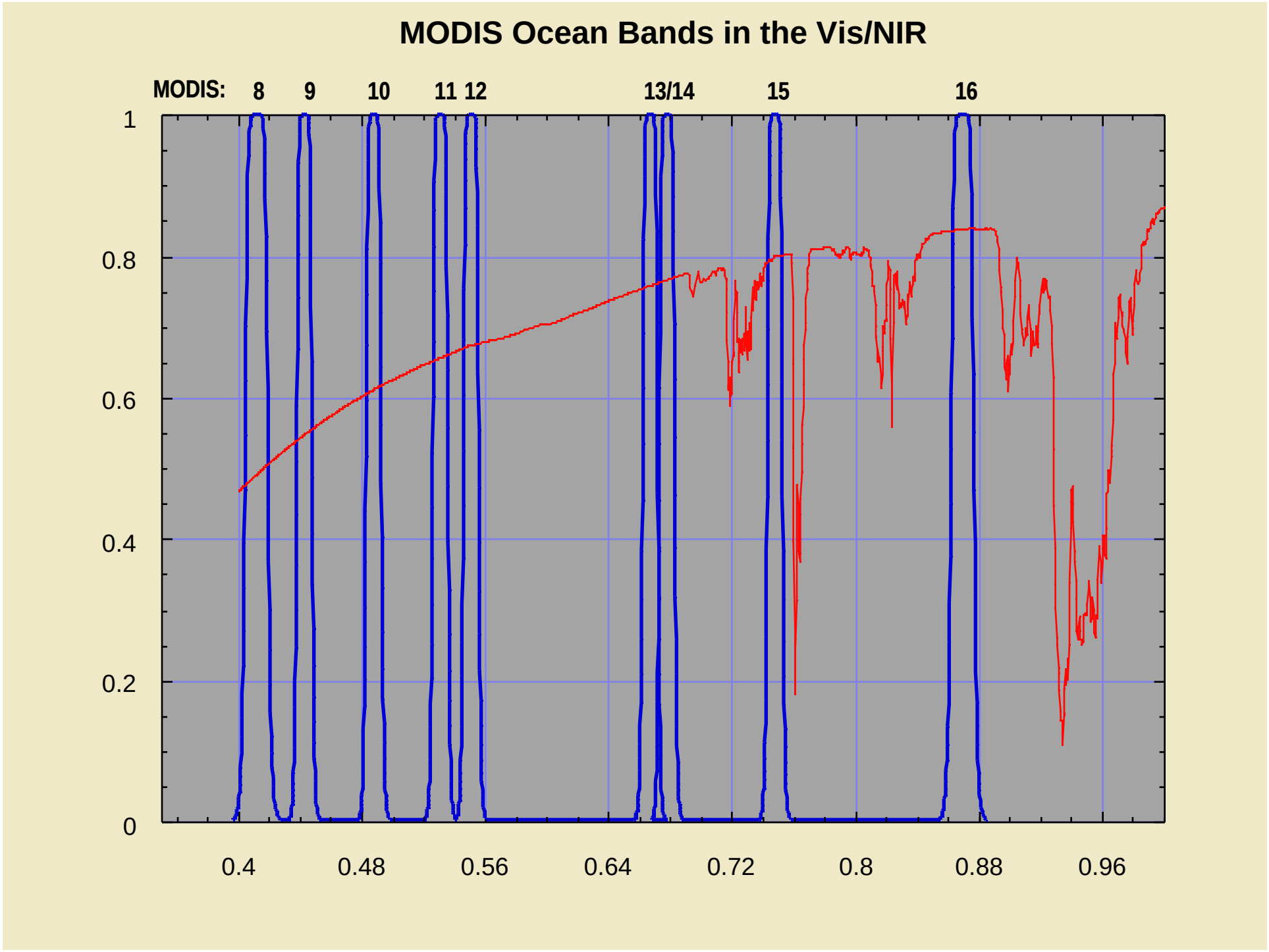


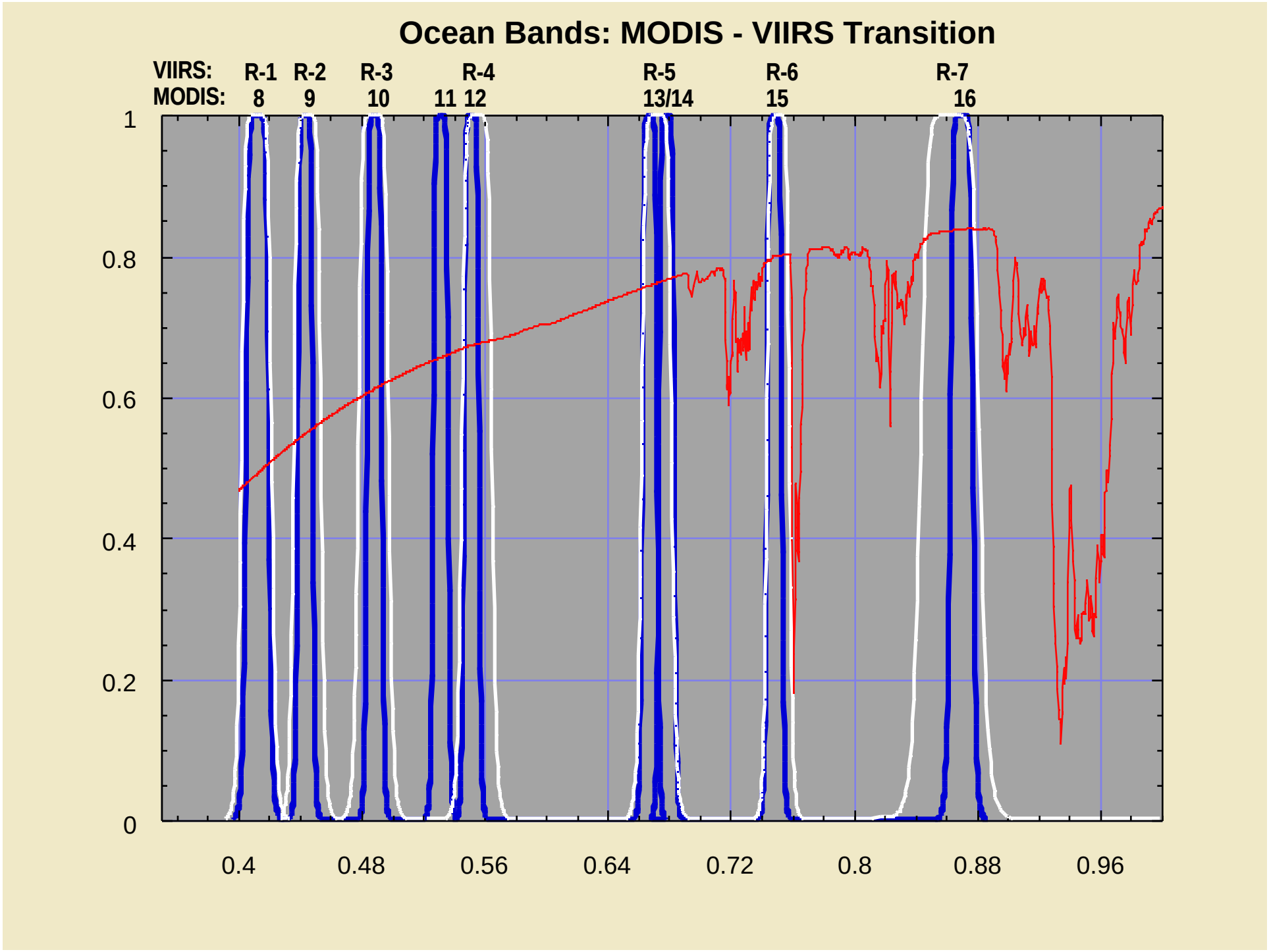
VIIRS Spectral Bands

- **22 Bands**
  - **Subset of MODIS bands plus day-night panchromatic band**
- **Two spatial resolutions**
  - **Imagery resolution bands: 370 m at nadir**
  - **Moderate resolution bands: 740 m at nadir**
- **Features**
  - **8 (Moderate) or 16 (Imagery) detectors per scan**
  - **Bands spatially nested**
  - **Some bands have dual gain**
    - > **Maximize dynamic range without precision penalties**
- **Constrained pixel growth with scan angle**

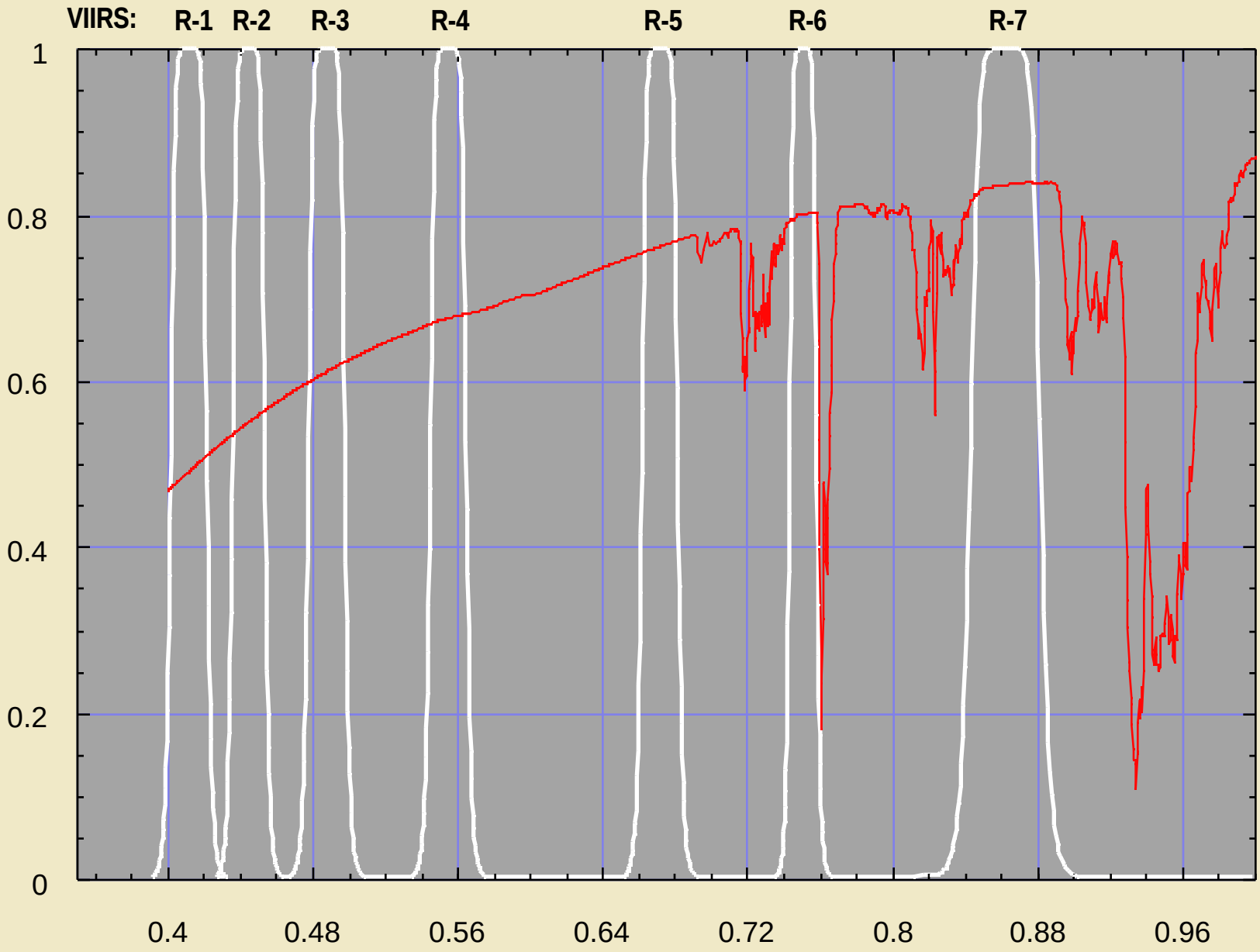
VIIRS Optimized Bandset Supports All EDRs

Band name	DNB	M1	M2	M3	M4	I1	M5	M6	M7	I2	M8	M9	M10	I3	M11	M12	I4	M13	M14	M15	I5	M16
Band position	700	412	445	488	555	645	672	751	865	865	1.2	1.4	1.6	1.6	2.3	3.7	3.7	4.1	8.6	10.8	11.5	12.0
Band width	400	20	18	20	20	50	20	15	39	39	0.02	0.015	0.06	0.06	0.05	0.18	0.38	0.16	0.30	1.00	1.90	0.95
Imagery	■		■			■				■		■		■	■		■	■	■	■	■	■
Sea Surface Temp.																■		■		■		■
Soil Moisture							■		■													
Cloud Cover/Layers	■					■	■		■	■		■	■	■	■	■	■	■	■	■	■	■
Cloud Partical Size							■				■		■			■				■		
Cloud Thickness							■				■		■			■				■		
Cloud Top Height							■									■				■		
Cloud Top Pressure							■									■				■		
Cloud Top Temp.							■									■				■		
Land Surface Temp.																■		■		■		■
Fire											■		■		■		■	■		■	■	
Vegetation Index				■	■	■				■				■								
Snow Cover (Binary)						■				■				■								
Snow Cover (Fraction)		■	■	■	■	■	■		■	■			■	■	■							
Vegetation/Type			■		■	■				■	■			■		■				■		■
Albedo		■	■	■	■	■				■	■			■	■							
Fresh Water Ice						■				■											■	
Ice Surface Temp.																				■		■
Littoral Transport					■		■															
Net Heat Flux		■	■	■	■		■	■	■			■	■		■							
Ocean Color/Chloro.		■	■	■	■		■	■	■													
Sea Ice age/motion		■	■	■	■	■	■		■	■			■	■	■							
Mass (turbidity)		■	■	■	■		■	■	■													
Aer Opt Thick (Ocean)		■	■	■	■		■		■				■		■	■						
Aer Opt Thick (Land)		■	■	■	■		■								■	■				■		■
Aer Part Size (Ocean)		■	■	■	■		■		■				■		■	■						
Aer Part Size (Land)		■	■	■	■		■								■	■				■		■
Suspended Matter		■	■	■	■		■									■		■	■	■		■
Total Prec. Water																■		■	■	■		■
Cloud Mask	■					■	■		■	■		■	■	■	■	■	■	■	■	■	■	■

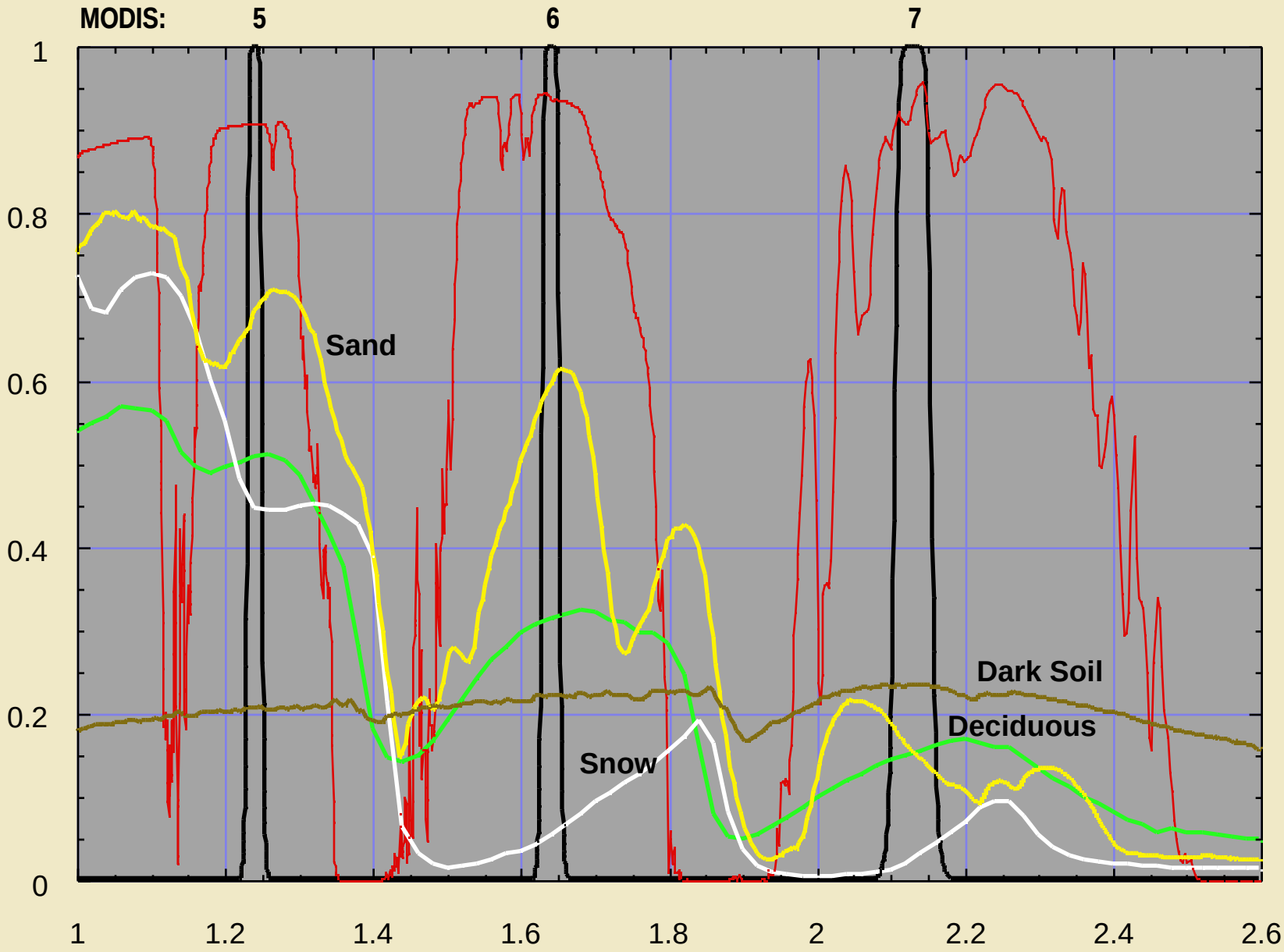

MODIS Ocean Bands in the Vis/NIR
MODIS:
8
9
10
11
12
13/14
15
16
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96

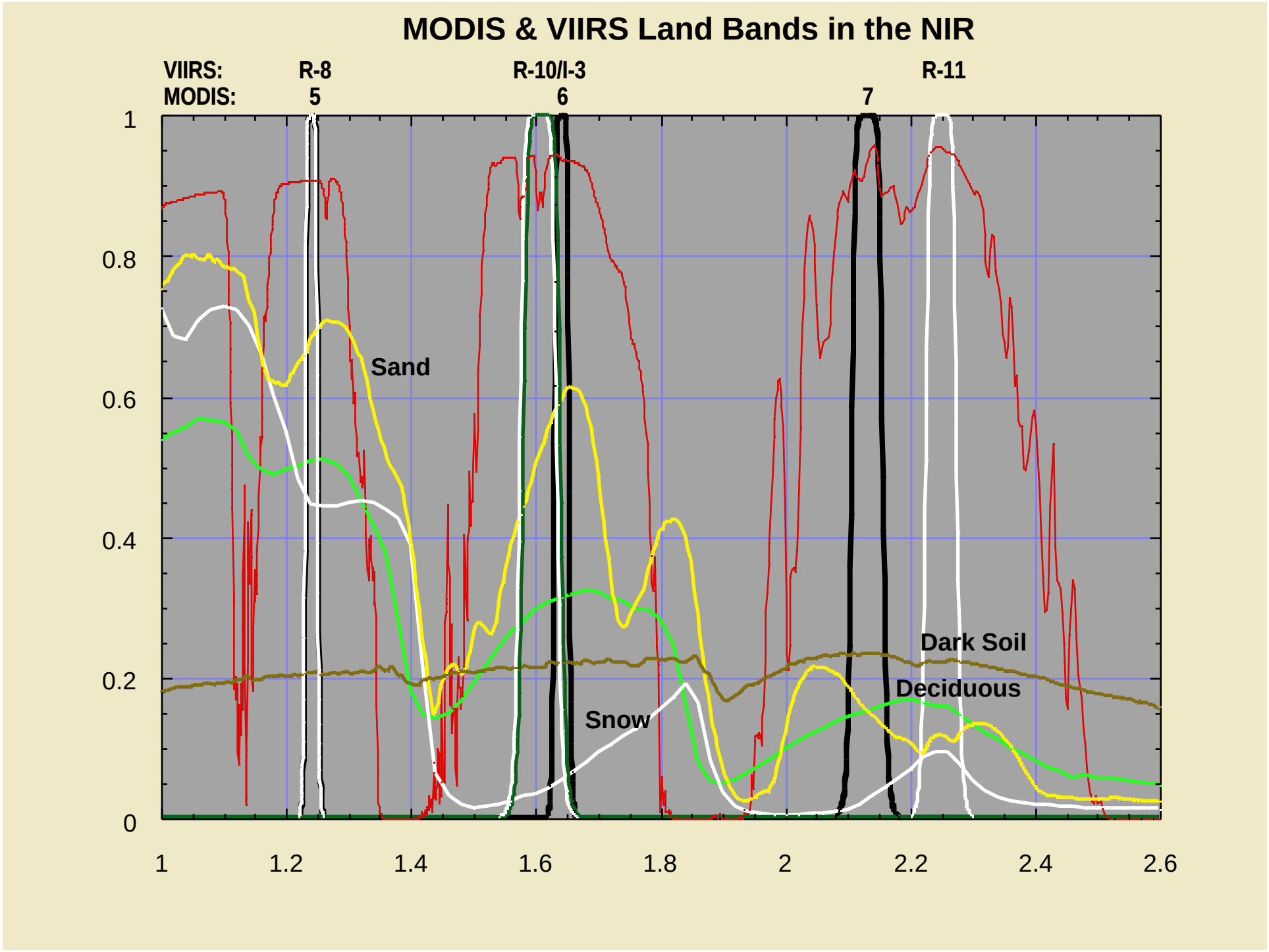

Ocean Bands: MODIS - VIIRS Transition
VIIRS:
MODIS:
R-1
8
R-2
9
R-3
10
11
R-4
12
R-5
13/14
R-6
15
R-7
16
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96

VIIRS Ocean Bands in the Vis/NIR

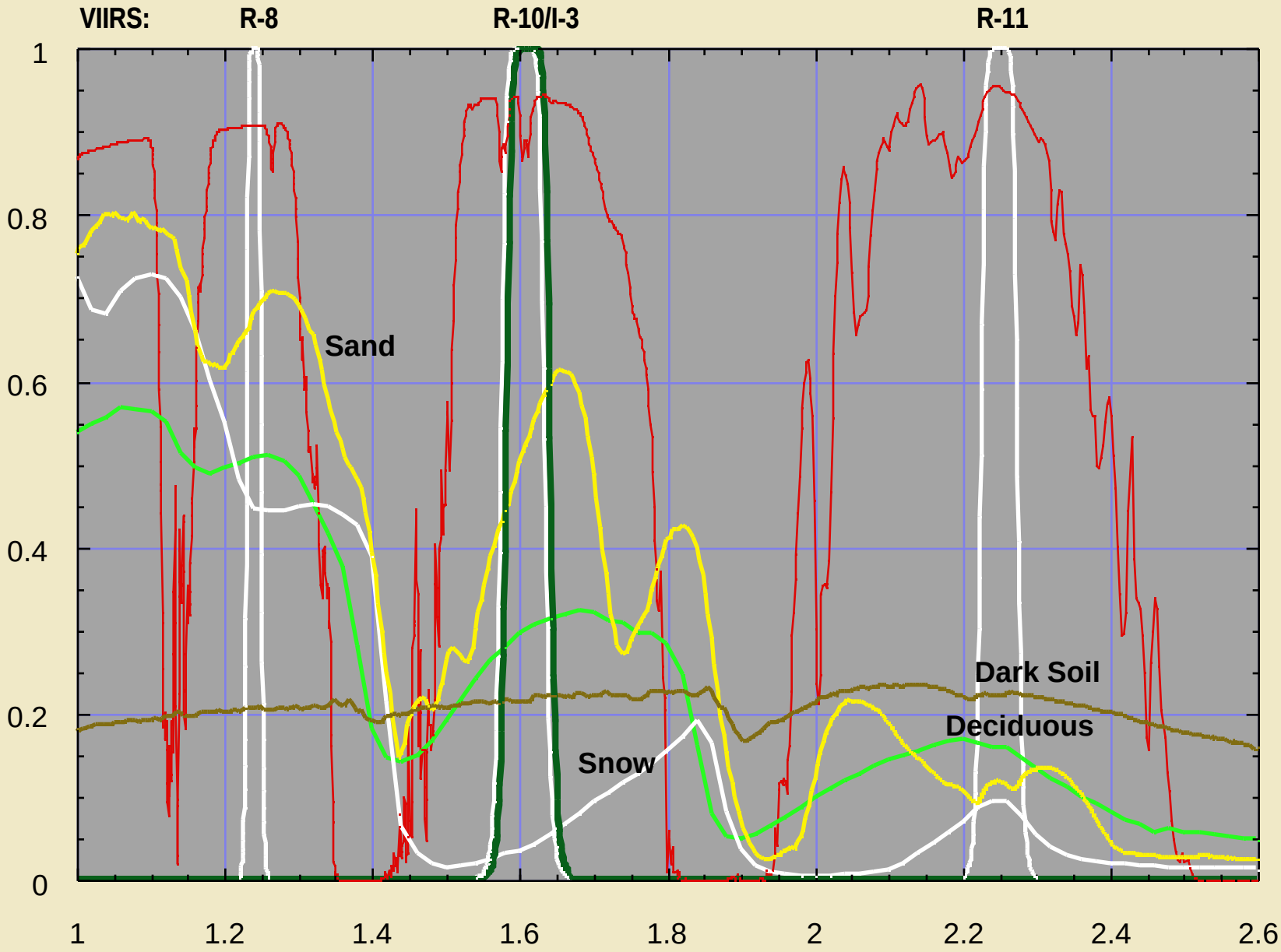


MODIS Land Bands in the NIR

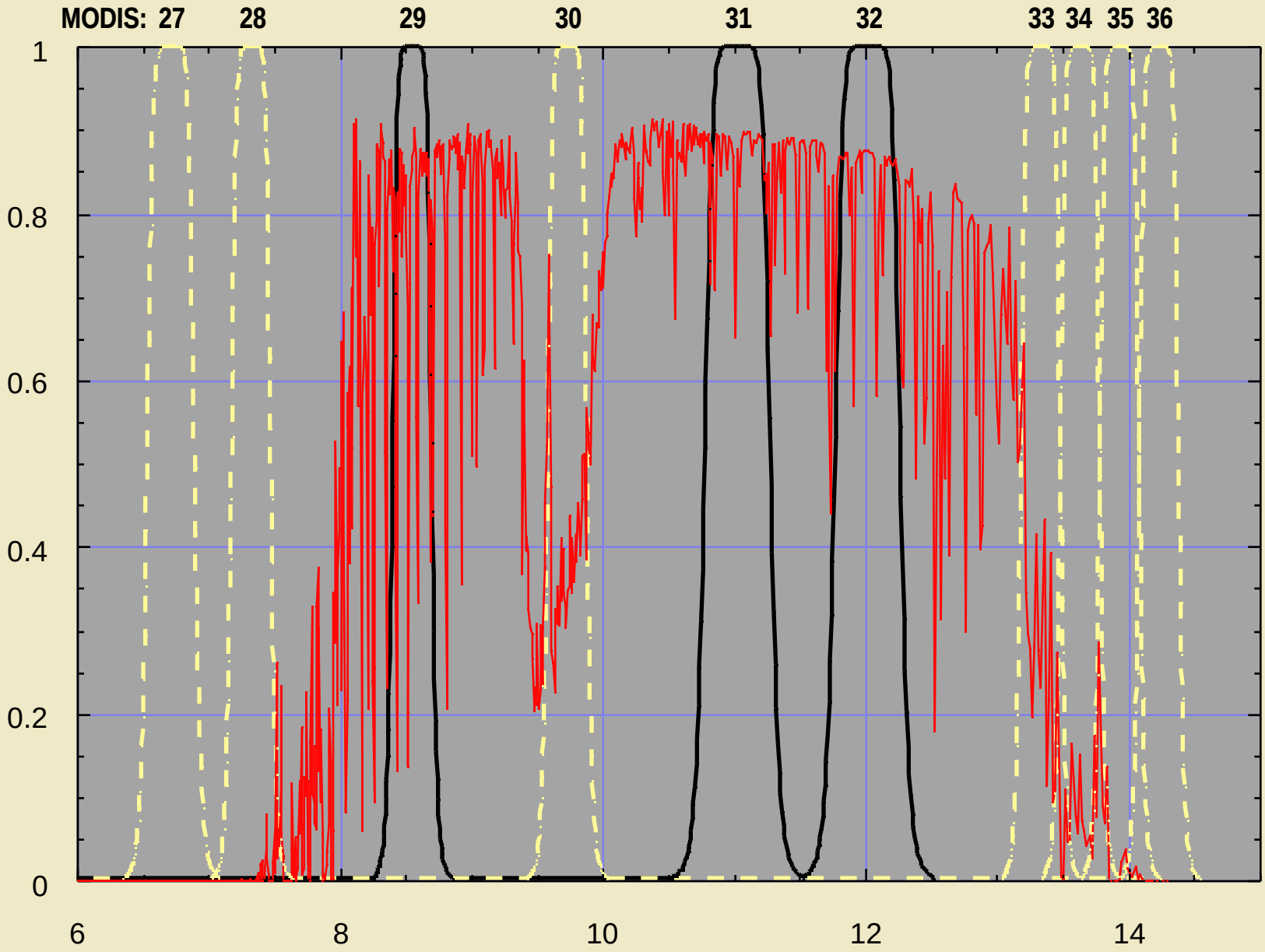



MODIS & VIIRS Land Bands in the NIR
VIIRS:
MODIS:
R-8
5
R-10/I-3
6
7
R-11
1
0.8
0.6
0.4
0.2
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
Sand
Dark Soil
Deciduous
Snow

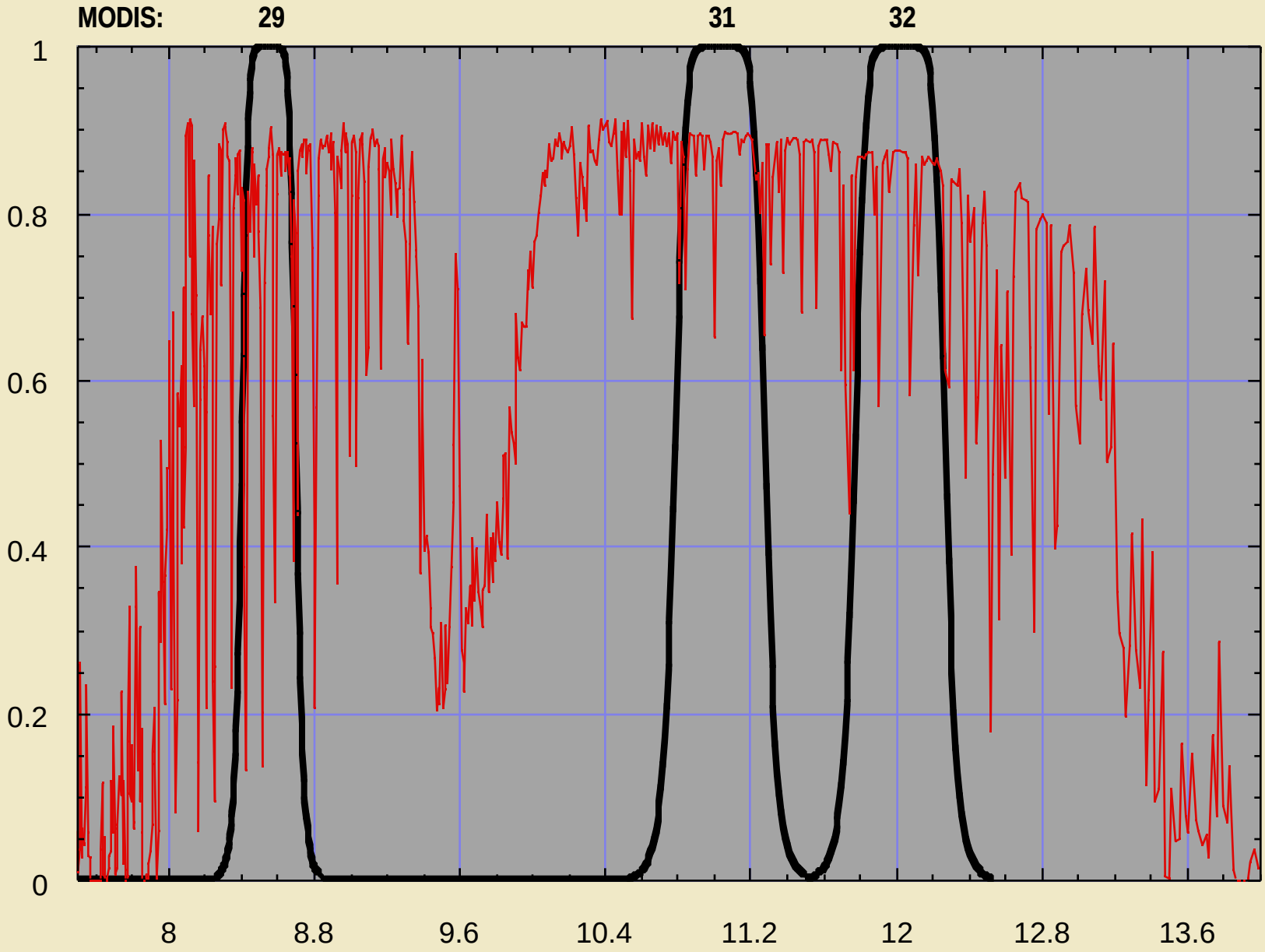
VIIRS Land Bands in the NIR

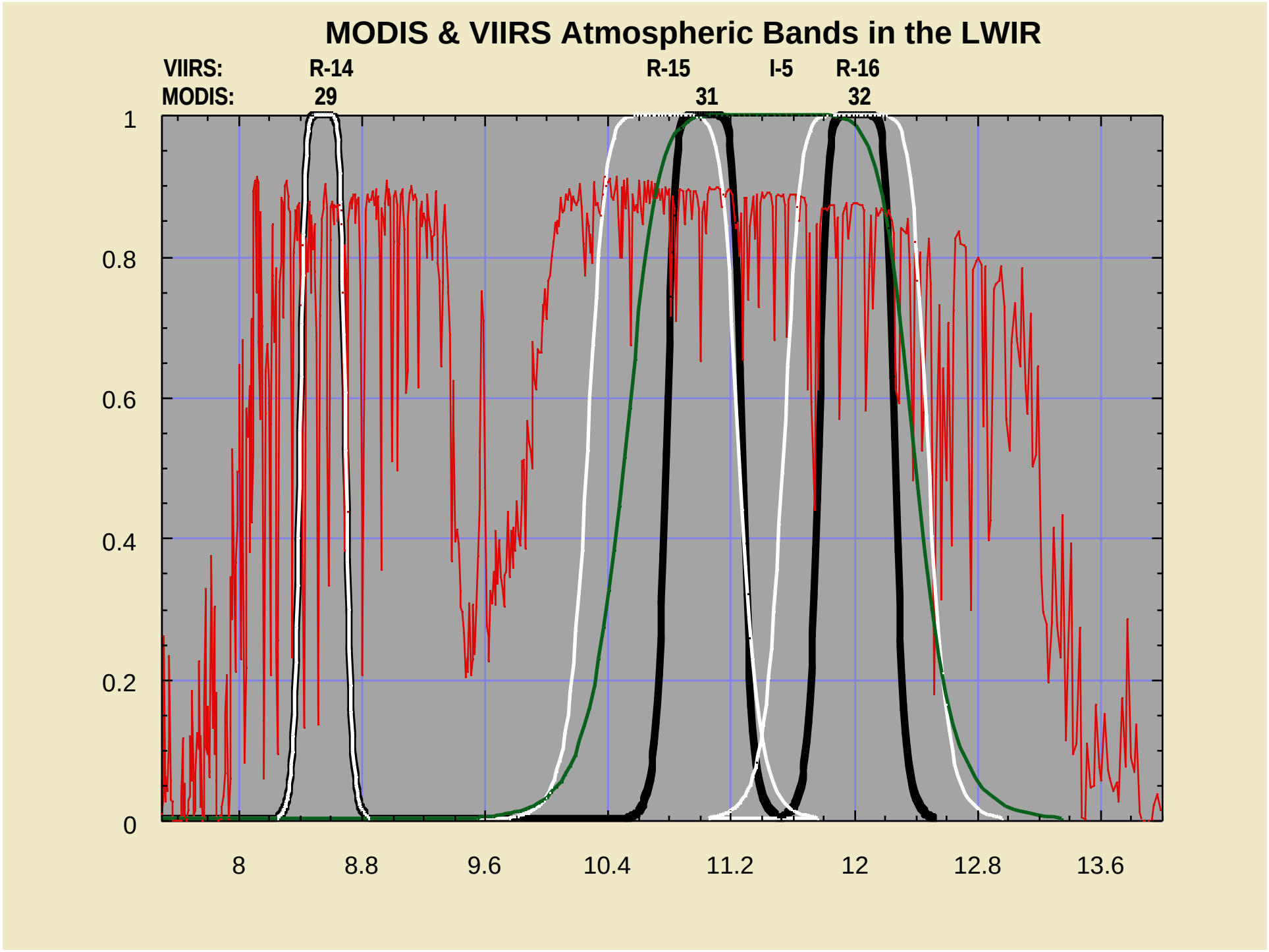


MODIS Atmospheric Bands in the LWIR

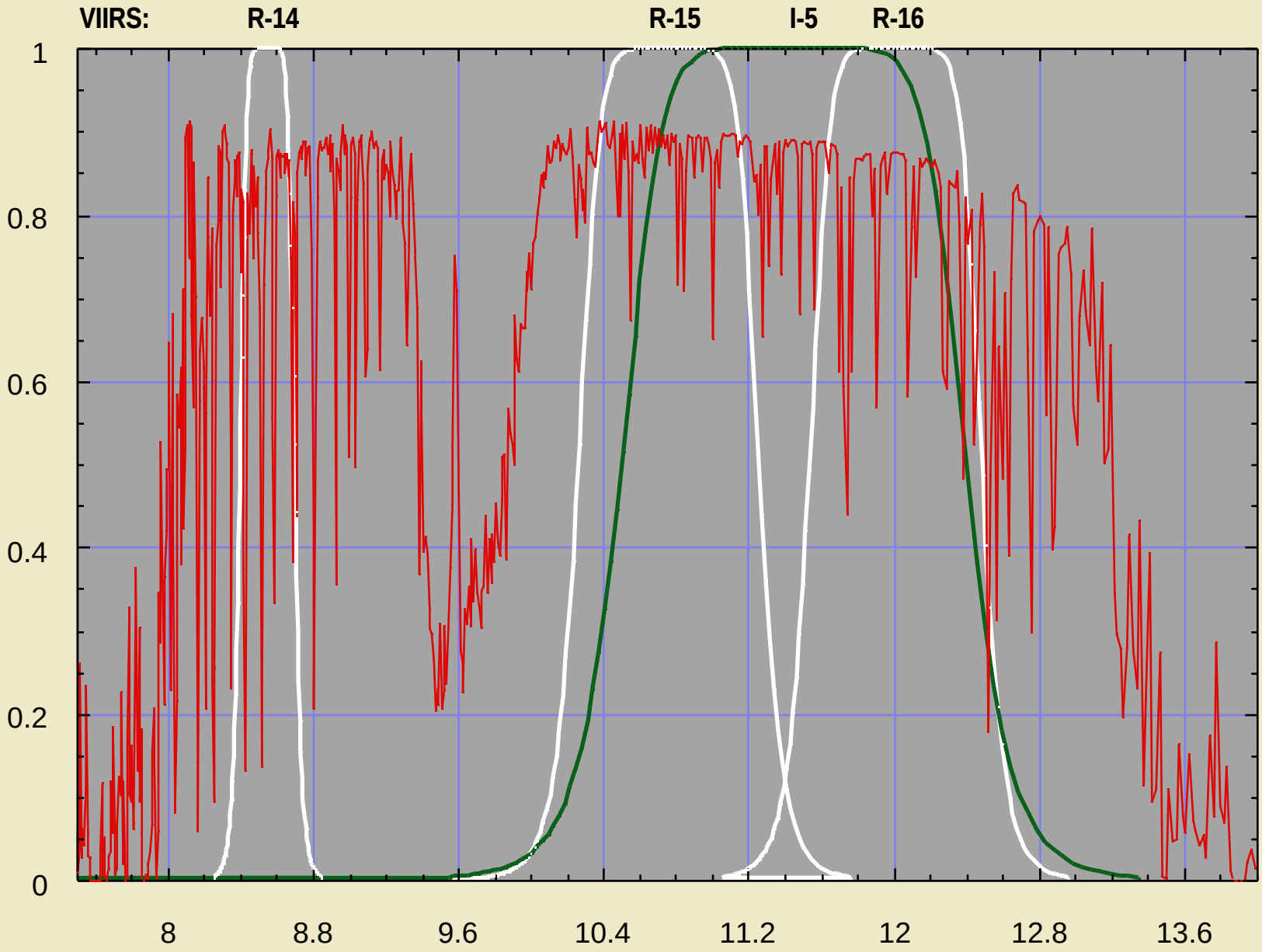


MODIS Atmospheric Bands in the LWIR




MODIS & VIIRS Atmospheric Bands in the LWIR
VIIRS:
MODIS:
R-14
29
R-15
31
I-5
R-16
32
1
0.8
0.6
0.4
0.2
0
8
8.8
9.6
10.4
11.2
12
12.8
13.6

VIIRS Atmospheric Bands in the LWIR



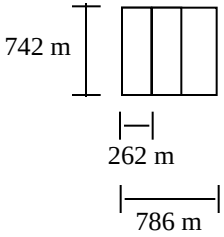
Detector Aggregation Reduces Pixel Growth

VIIRS Reduces Pixel Size Along Scan:

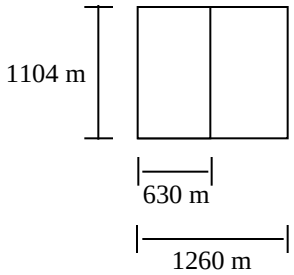
Much Better HSR, SNR Toward Nadir

Radiometric ("Moderate-Resolution") Bands

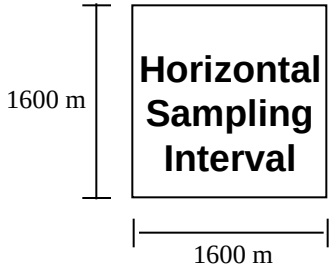
Nadir to 1060km
- aggregate 3 samples
- SNR increases by sqrt(3)



To ~1700 km
- aggregate 2 samples
- SNR increases by sqrt(2)

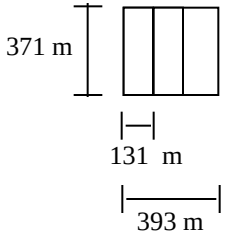


To 3000 km
- no aggregation

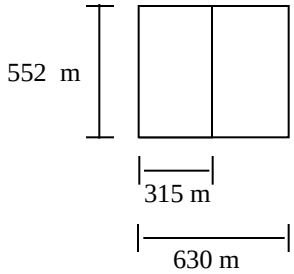


Imaging ("High-Resolution") Bands

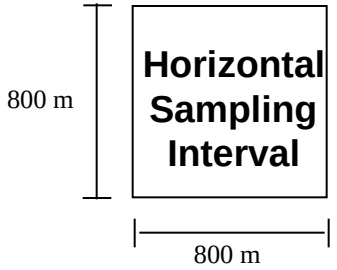
Nadir to 1060km
- aggregate 3 samples
- SNR increases by sqrt(3)



To ~1700 km
- aggregate 2 samples
- SNR increases by sqrt(2)



To 3000 km
- no aggregation



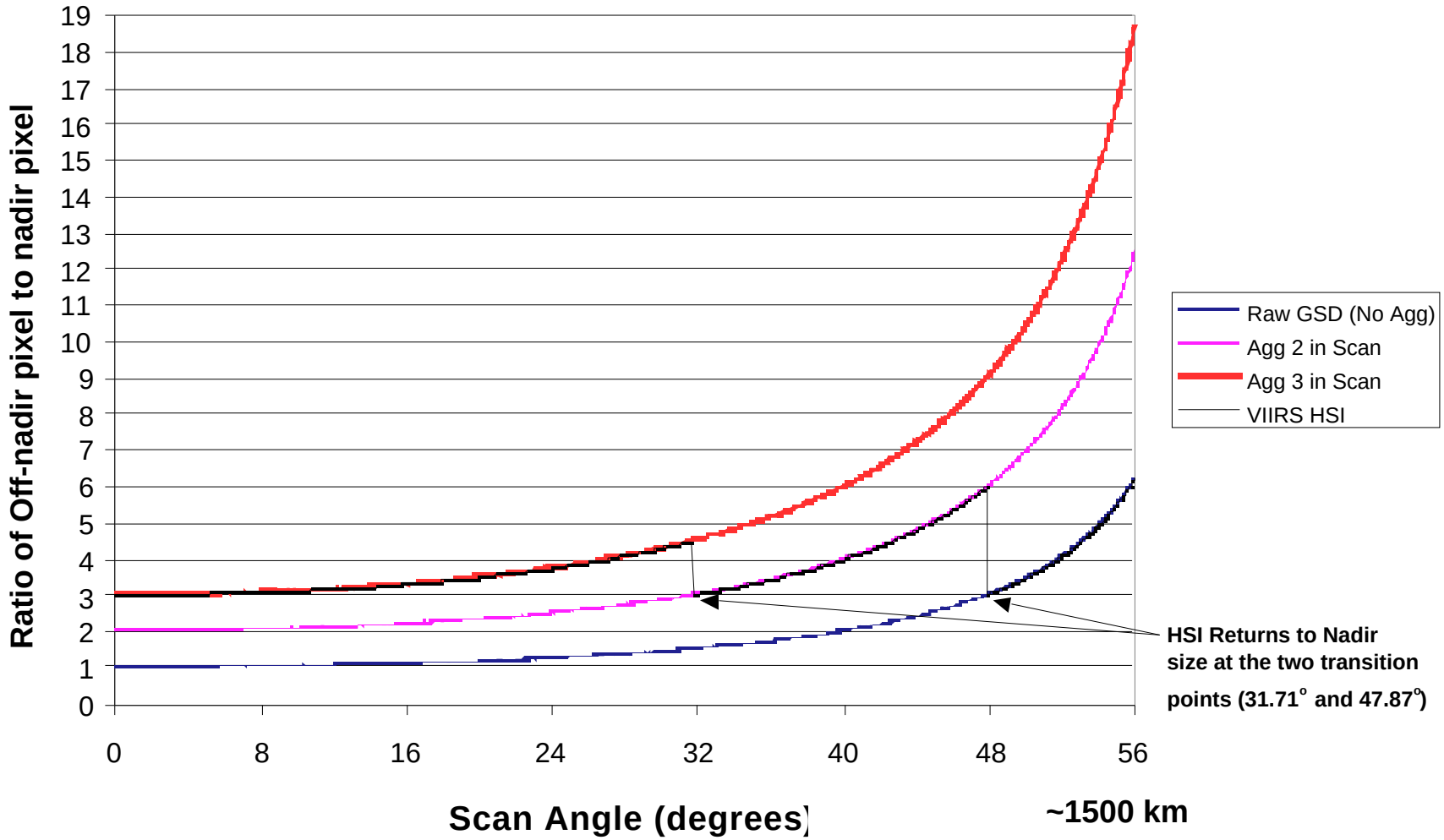
AVHRR & MODIS "1 km" Bands: ~2x6km At Edge

Vs.

VIIRS 1.6x1.6 km At Edge

Moderate and Imaging bands nest 2x2

Reduced Pixel Growth Along Scan



Calibration

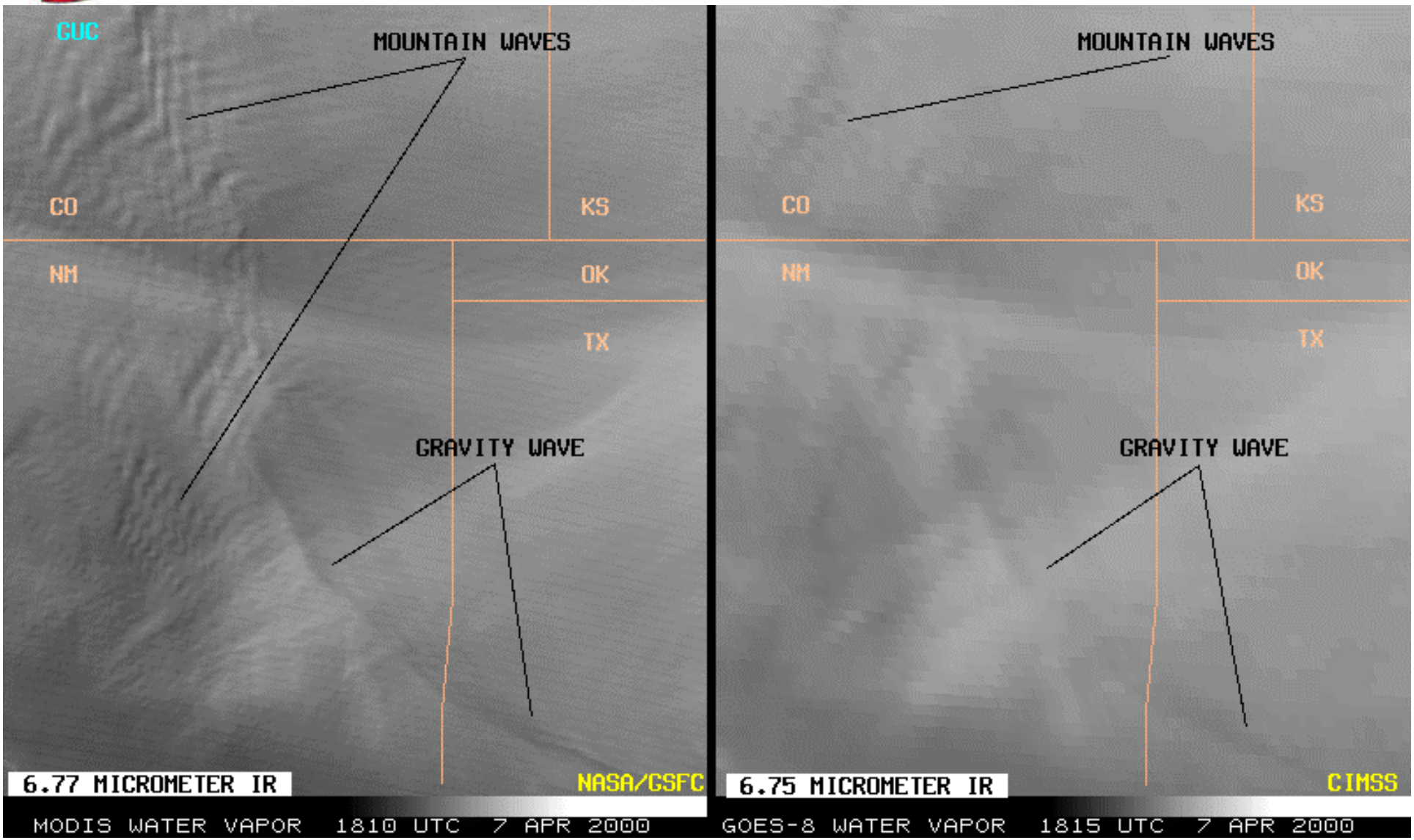
- **Stray light much better than MODIS**
  - **Driven by needs of the day-night (DNB)**
  - **Rotating telescope, extensive baffling reduces scattered light**
- **V-grove blackbody similar to MODIS**
  - **Baffled to avoid Earth illumination**
  - **Emissivity of 0.9998**
  - **Controlled to 290K by pulsed voltage**
  - **Heat to 315K**
- **Solar Diffuser (SD) evolutionary from MODIS**
  - **1 time door**
  - **New design eliminates “ripples”**
- **Solar Diffuser Stability Monitor (SDSM) evolutionary from MODIS**
  - **7 bands**
  - **Views 70% of SD area**
- **Planning to use 2nd order polynomial for all bands**
- **Characterization plan similar to MODIS**
- **Lunar views possible**

Some Issues

- **Dynamic range for fire is inadequate**
  - **Similar issue faced on MODIS**
  - **“Imagery” & SST are the two highest priority EDRs for the IPO**
  - **“MODIS compromise” not acceptable**
  - **Multi-band algorithmic solution may be possible**
- **645 nm band (I-1) dynamic range increased to avoid saturated pixels for imagery**
  - **Spectral requirements changed from center wavelength of 645nm (50 nm wide) to 640nm (80nm wide)**
  - **Modest compromise to VI work**
- **751 nm band (M-6) center wavelength changed from 751nm to 746nm**
- **NASA geolocation requirement (200 m 3 σ) not an IPO requirement**
  - **Margin is eroding to achieve this accuracy**
- **Consideration being given to adding 6.7 micrometer band for FM3 & beyond**

Fine Scale WV Depiction

MODIS 1 km resolution reveals mountain waves



Algorithm Development Status (1 of 3) and Delivery of the V5 ATBDs

EDR	Final Baseline	Adopted/Adapted/Developed	ATBD#
Imagery	Energy Budget/Spectral	Adapted	Y2466
SST	4-Channel Skin--ATSR, MODIS Air-mass classification Cirrus, aerosol mitigation	Adapted (ATSR, Brown, Emery)	Y2386
Soil Moisture	CMIS/VIIRS Data Fusion	Adapted (Carlson)	Y2387
Aerosol Optical Thickness, Particle Size, Effective Radius	Dark Pixel Method	Adapted (Kaufman, Tanre, Vermote) Developed radius (Vermote)	Y2388
Suspended Matter	Multiple Indices & Dominant Type	Adapted	Y2390
Cloud Base Height	Cloud Property LUT	Adapted (Hutchison, Wilheit)	Y2391
Cloud Cover/Layers	Clustering based on cloud properties	Adapted	Y2392
Cloud Effective Particle Size	UCLA Ice & Water	Adapted (Ou, Liou)	Y2393
Cloud Top Height, Temp., Pressure	UCLA Ice & Water IR	Adapted (Ou, Liou)	Y2395

Algorithm Development Status (2 of 3)

EDR/SDR	Final Baseline	Adopted/Adapted/Developed	ATBD#
Albedo, Surface	**Bright surfaces: Linear regression** **Dark surfaces: MODIS kernel-driven**	**Adapted (Liang)** **Adapted (Strahler, Lucht, Schaaf)**	**Y2398**
Land Sfc. Temp	**4-Channel Land Cover**	**Adapted**	**Y2399**
Vegetation Index	**NDVI, EVI** **FPAR, LAI, NPP, PSN**	**Adapted (Tarpley, Deering, Huete)** **Adapted (Running, Knyazikhin, Myneni)**	**Y2400**
~~Snow Cover/Depth~~	**~~Spectral Mixture~~** **and MODIS** **threshold**	**~~Adapted (Hall, Dozier)~~**	**~~Y2401~~**
Surface Type	**Decision Tree**	**Adapted (Townshend, DeFries)**	**Y2402**
~~Fresh Water Ice~~	**~~Energy Budget/Spect. Mix.~~**	**~~Adapted~~**	**~~Y2404~~**
Ice Surface Temp.	**Split Window**	**Adapted**	**Y2405**

Algorithm Development Status (3 of 3)

EDR	Final Baseline		Adopted/Adapted/Developed	ATBD#
Net Heat Flux	Regression/Neural/Bulk		Adapted (Ruprecht, Liu)	Y2407
OC/Chlorophyll	Carder/MODIS Case 2 Regionally tuneable		Adapted (Carder)	Y2408
Ocean Atmos. Corr.	Improved SeaWiFS With full residual polarization handling		Adapted (Gordon, Wang, Liu)	Y2411 (IP)
Sea Ice Age/Edge	Maximum Cross-Correlation	Adapted (Emery)	Y2409	
Land Atmos. Corr. (Surface Reflectance)	Radiative Transfer LUT (MODIS)		Adapted (Vermote)	Y2411 (IP)
Cloud Mask	Thresholding/Phase		Adapted (MODIS/CLAVR, Stowe)	Y2412
Precipitable Water	Five-band TIR		Adapted (Huang)	Y3251
Active Fires	Raytheon HSS/MODIS		Adapted (HSS, Giglio/Justice/Kaufman)	Y3252 (ARR)

NRA Status

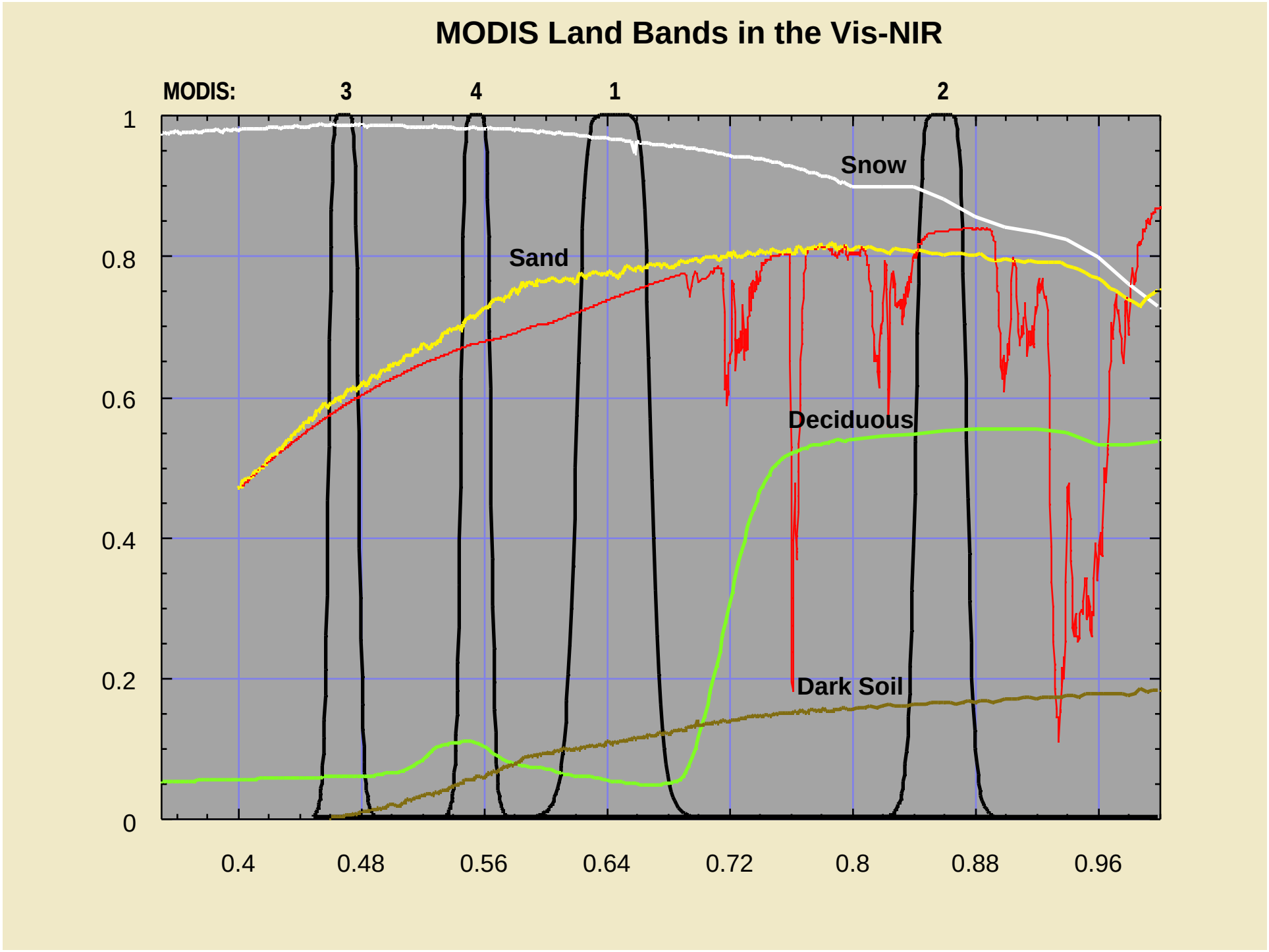
- **An NRA for an initial science team for NPP is nearing release**
- **The team will assist NASA in preparing to use the operational system for long term climate research**
  - **Which EDRs can be used as CDRs?**
  - **What steps need to be taken to assure climate quality data?**
  - **Use simulations based on real and synthetic data sets**
  - **Provide insight into sensor characterization**
- **A second science team selection will be made closer to the launch of NPP**

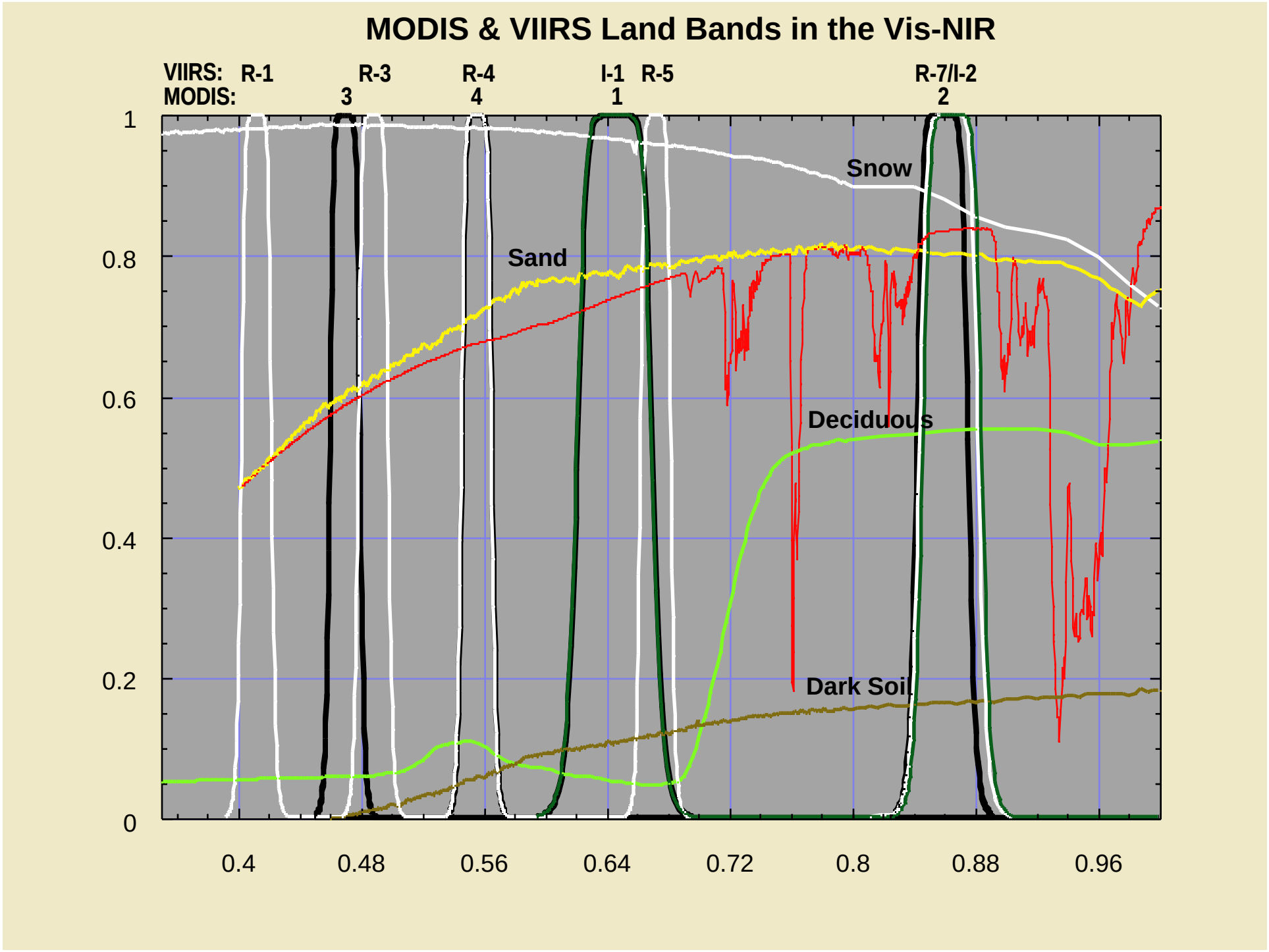
Summary

- **MODIS quality measurements will be continued in the operational system (NPOESS)**
- **VIIRS draws heavily on its MODIS heritage**
- **Some research capabilities (e.g. fluorescence, CO_2 slicing bands) are not continued**
- **Overall similar radiometric quality**
- **Improved geometric resolution**
- **Continued commitment to characterization and calibration**
- **NASA science team to be competed soon**

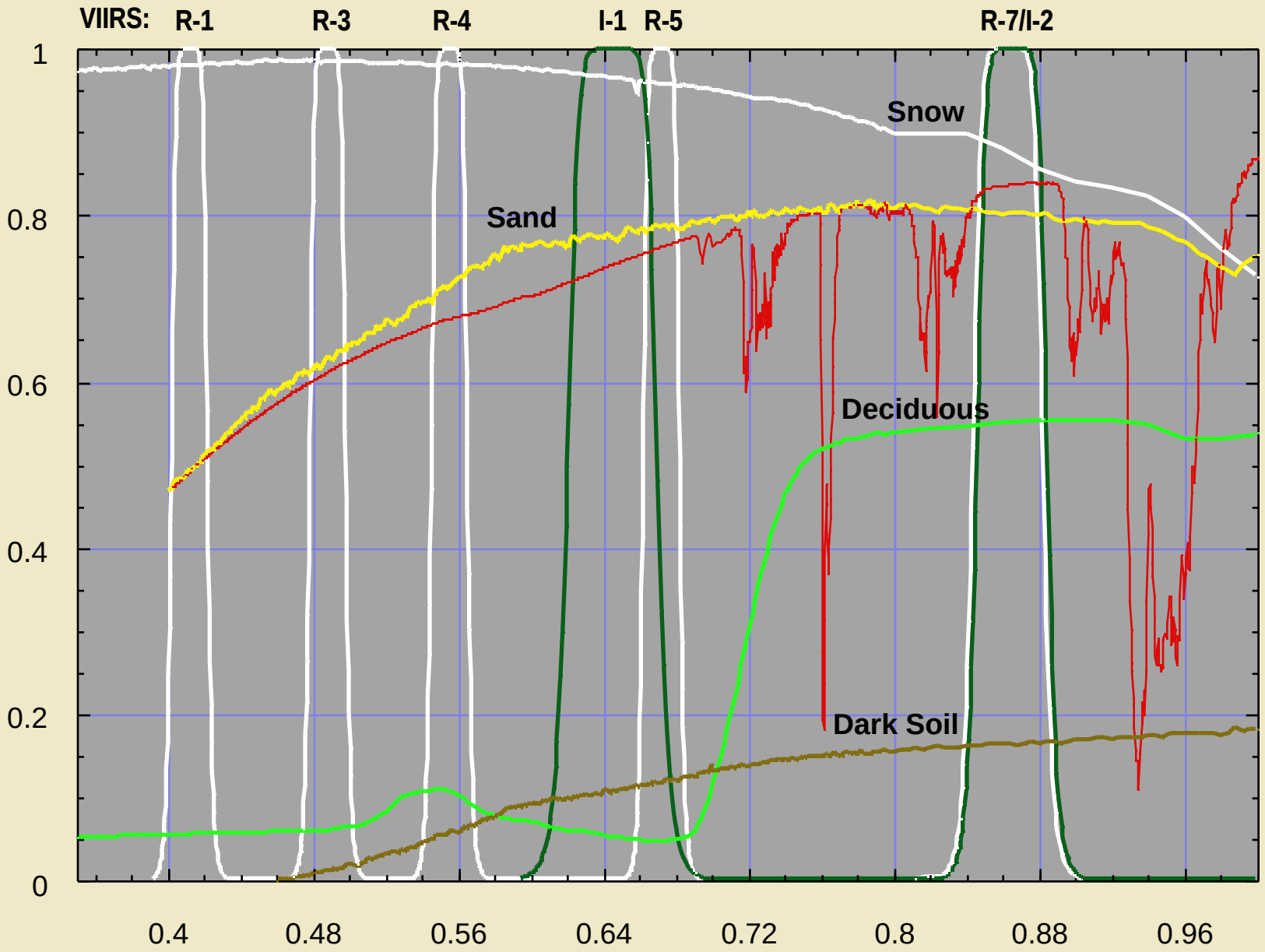
Back-Up Charts

- **Land Vis-NIR Bands**
- **Ocean SWIR Bands**
- **Atmosphere Vis-NIR Bands**
- **Atmosphere SWIR Bands**
- **Atmosphere MWIR Bands**


MODIS Land Bands in the Vis-NIR
MODIS:
3
4
1
2
Snow
Sand
Deciduous
Dark Soil
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96


MODIS & VIIRS Land Bands in the Vis-NIR
VIIRS: R-1 R-3 R-4 I-1 R-5 R-7/I-2
MODIS: 3 4 1 2
Snow
Sand
Deciduous
Dark Soil
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96

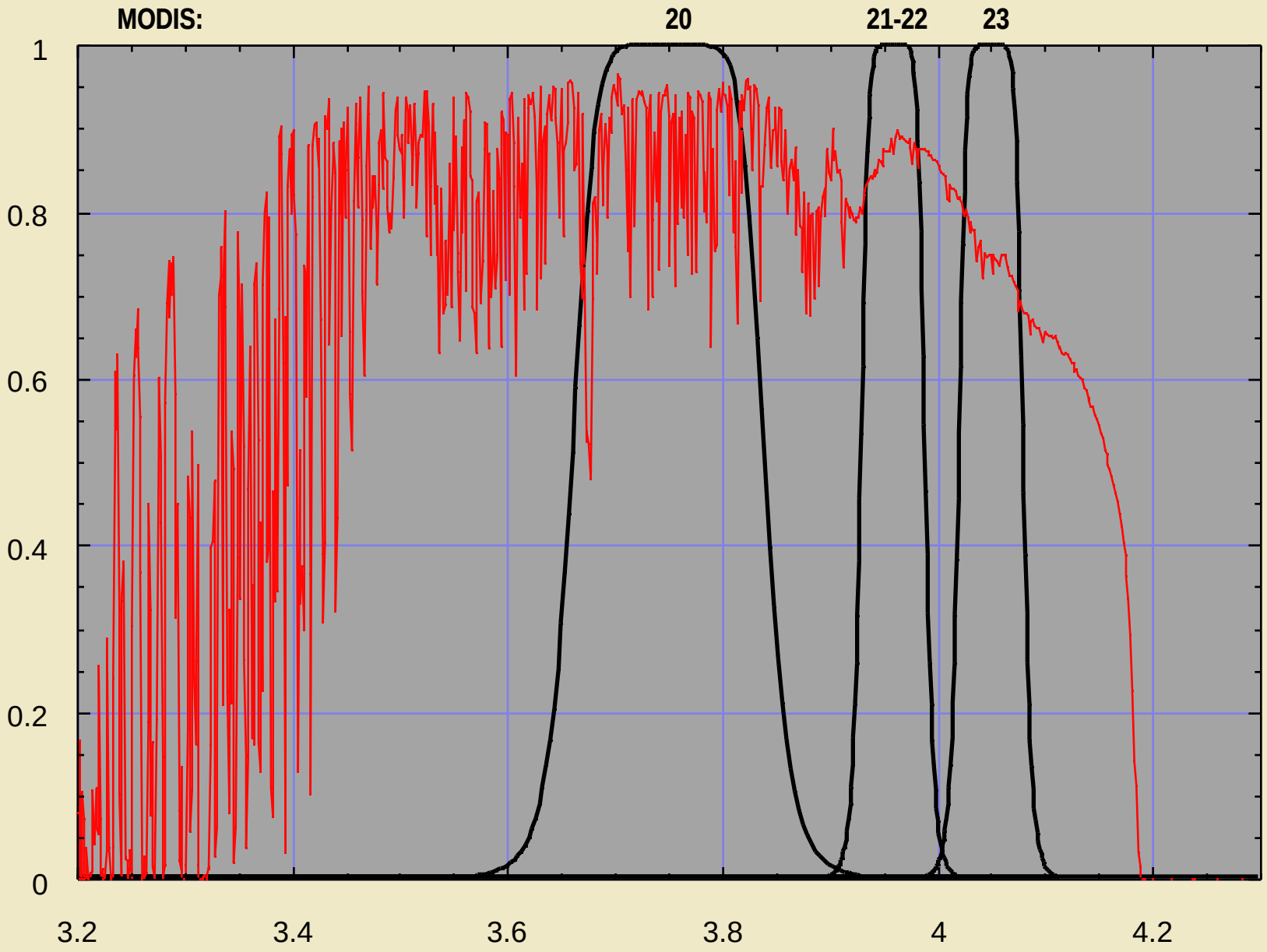
VIIRS Land Bands in the Vis-NIR

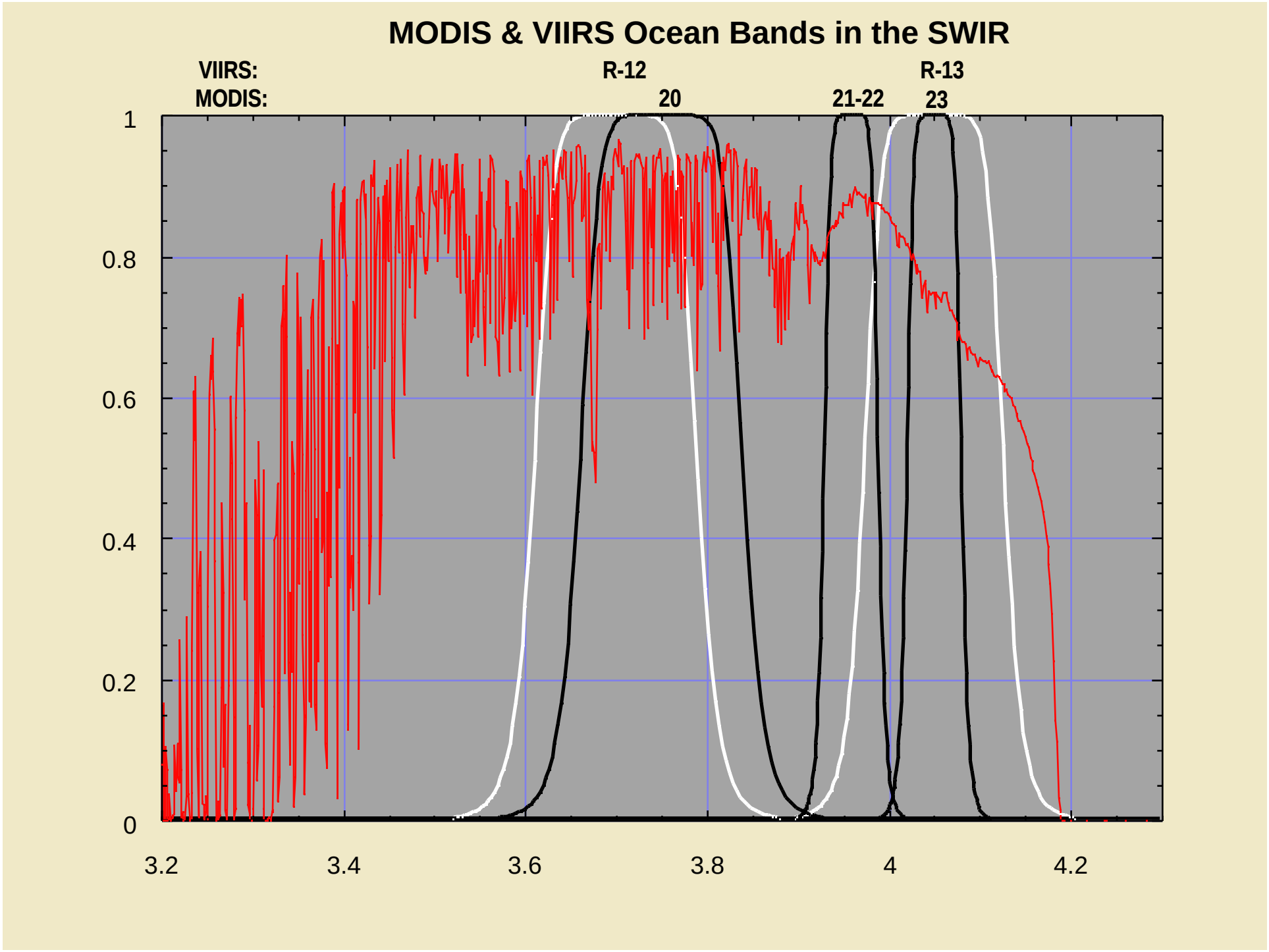


Back-Up Charts

- **Land Vis-NIR Bands**
- **Ocean SWIR Bands**
- **Atmosphere Vis-NIR Bands**
- **Atmosphere SWIR Bands**
- **Atmosphere MWIR Bands**

MODIS Ocean Bands in the SWIR

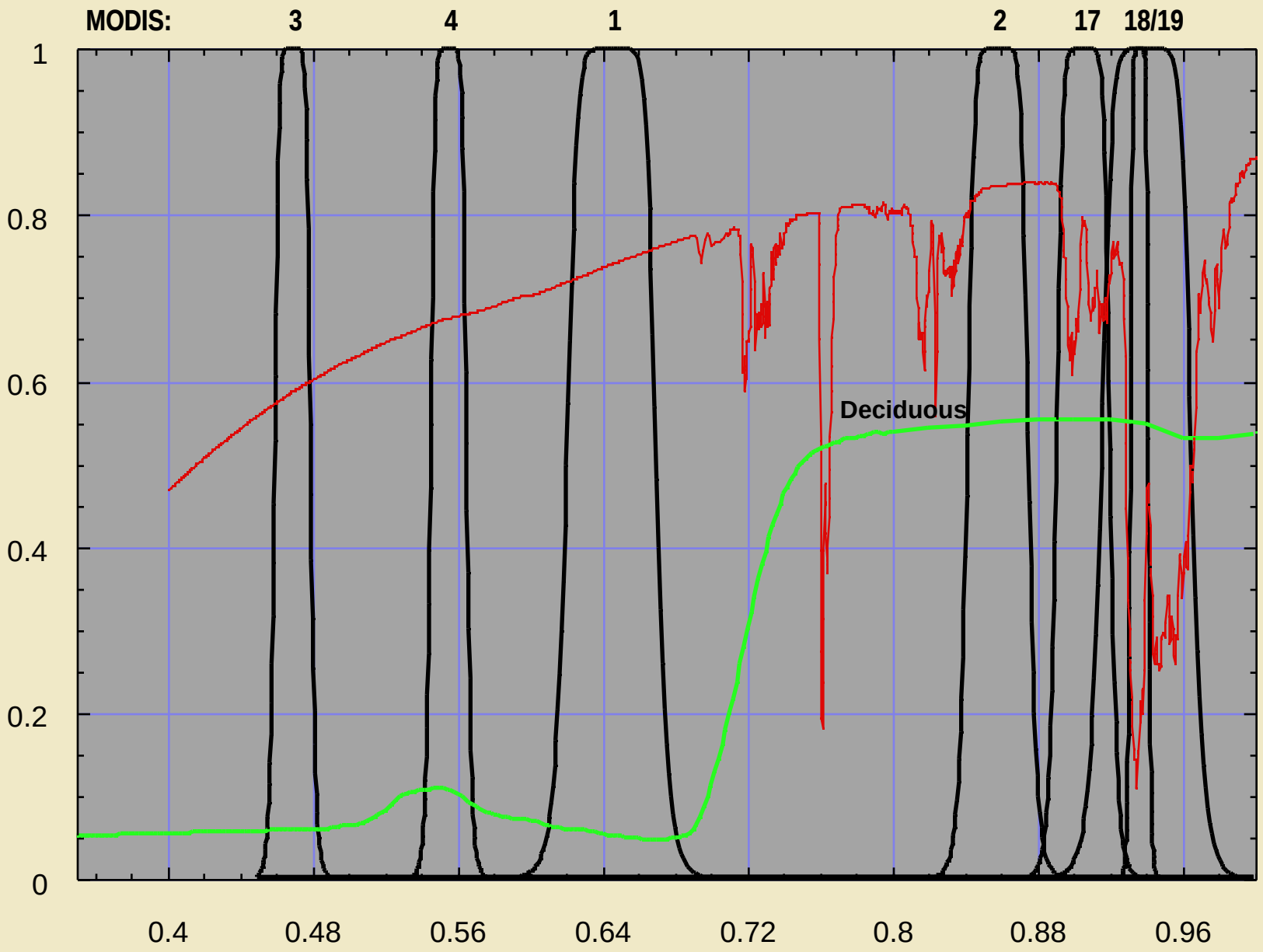



MODIS & VIIRS Ocean Bands in the SWIR
VIIRS:
MODIS:
R-12
20
21-22
R-13
23
1
0.8
0.6
0.4
0.2
0
3.2
3.4
3.6
3.8
4
4.2

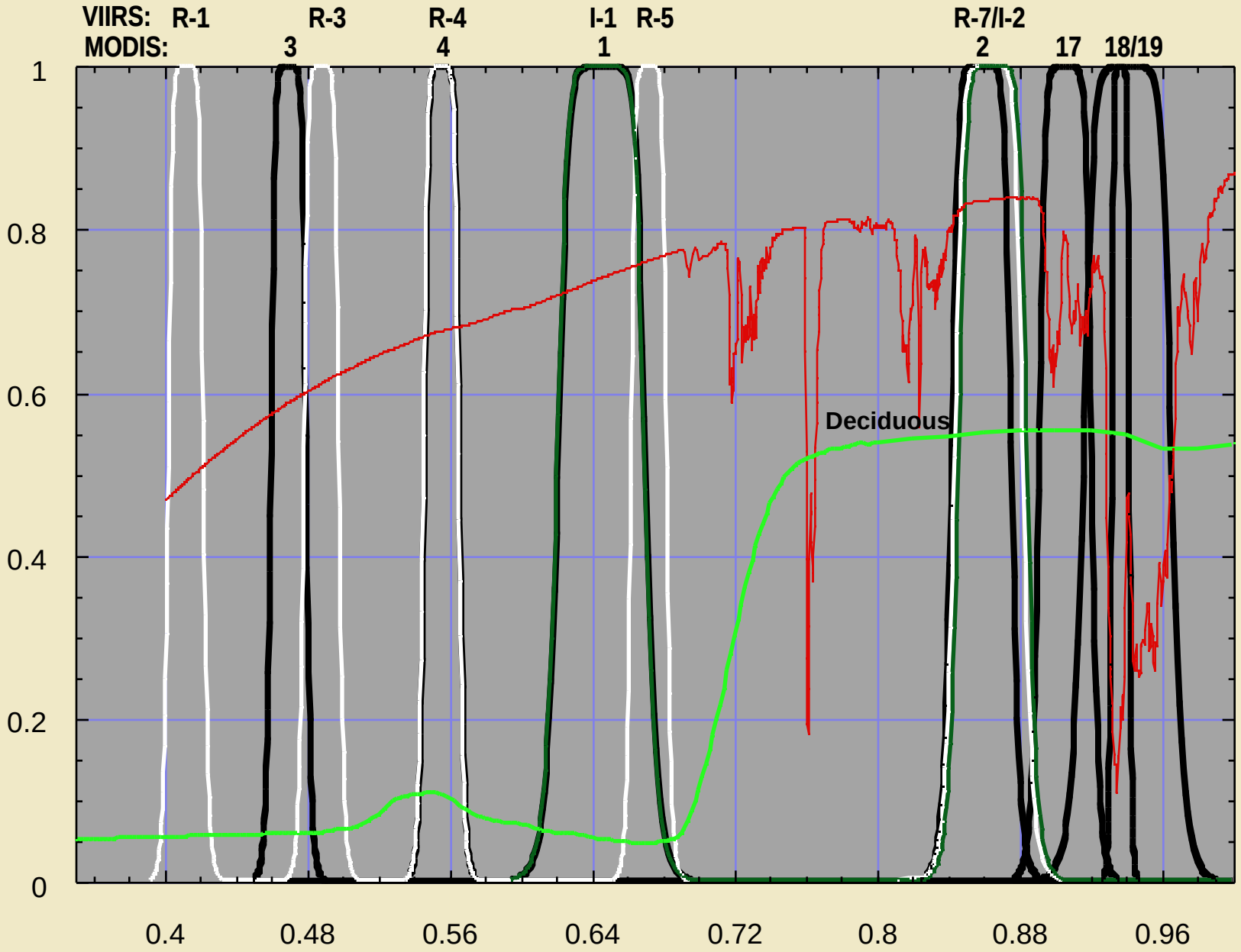
Back-Up Charts

- **Land Vis-NIR Bands**
- **Ocean SWIR Bands**
- **Atmosphere Vis-NIR Bands**
- **Atmosphere SWIR Bands**
- **Atmosphere MWIR Bands**

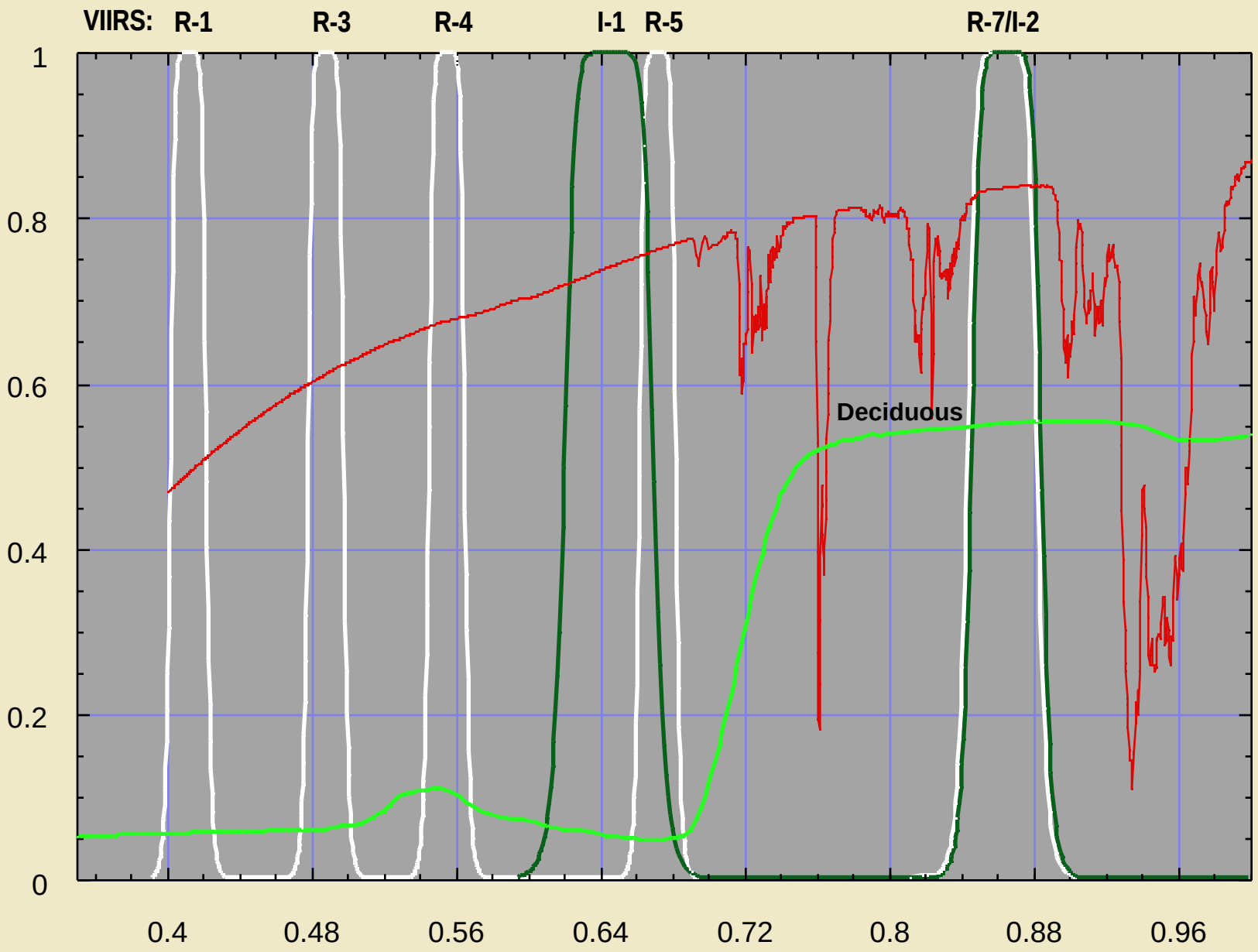
MODIS Atmospheric Bands in the Vis-NIR



MODIS & VIIRS Atmospheric Bands in the Vis-NIR



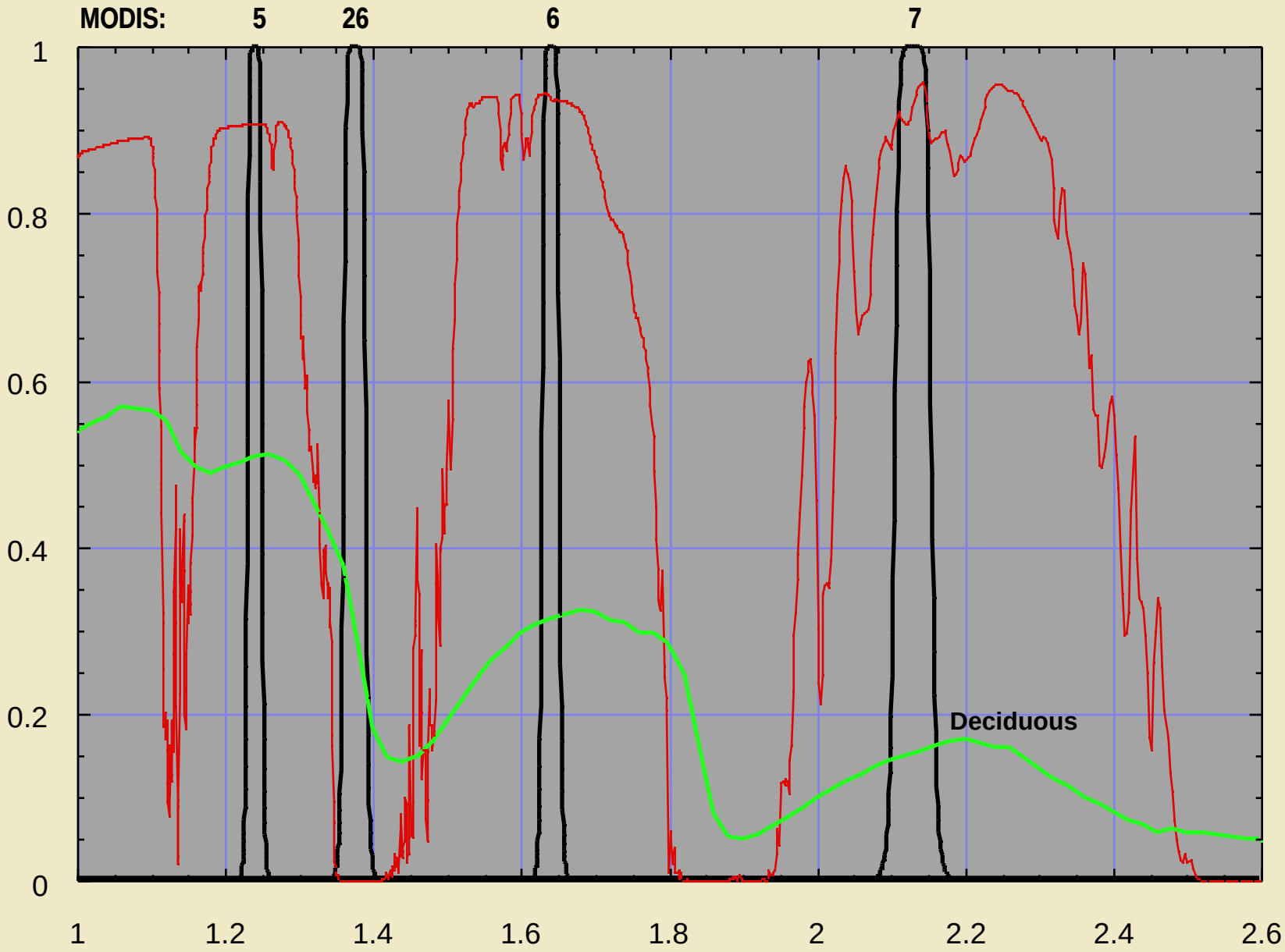
VIIRS Atmospheric Bands in the Vis-NIR

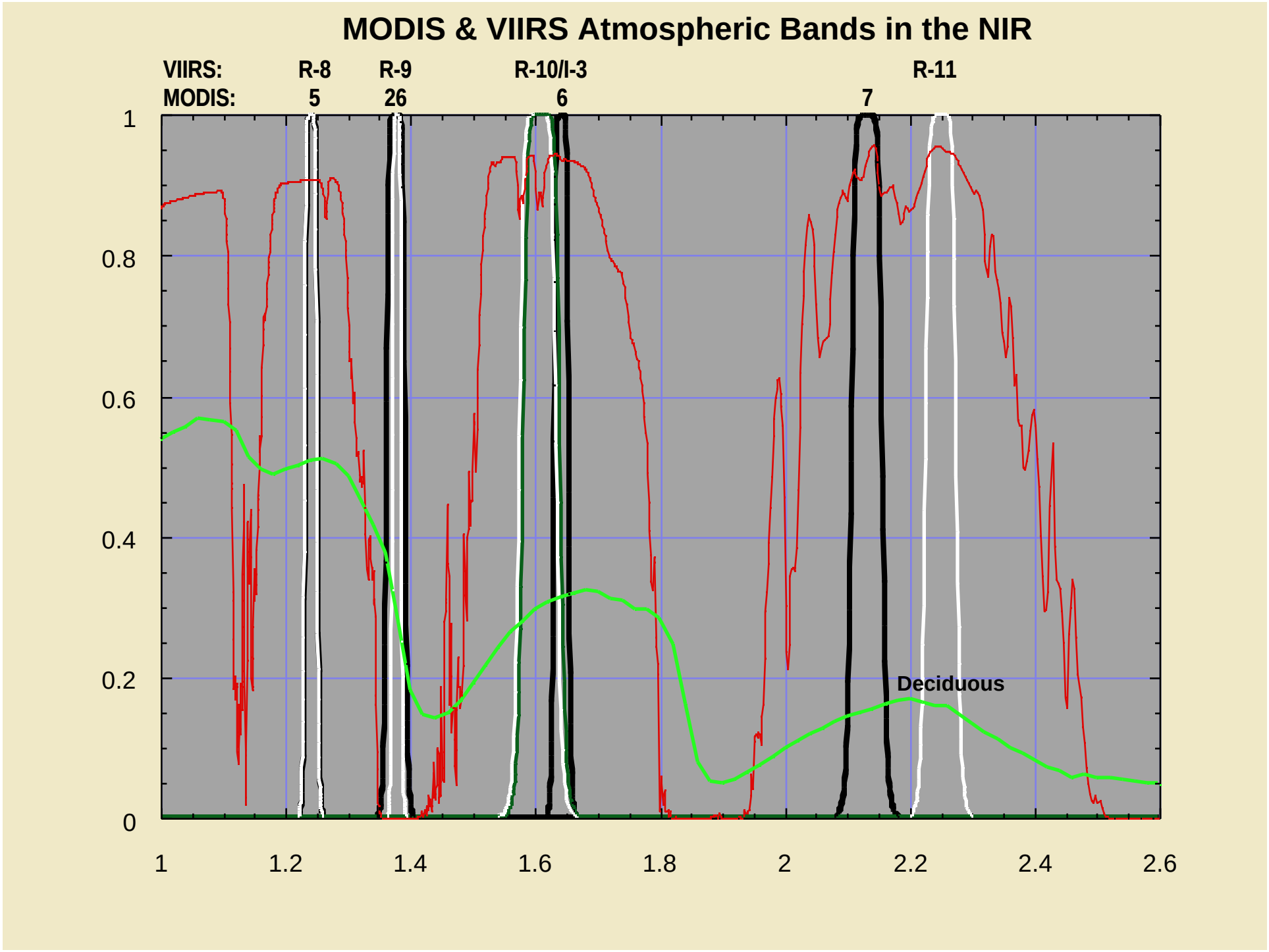


Back-Up Charts

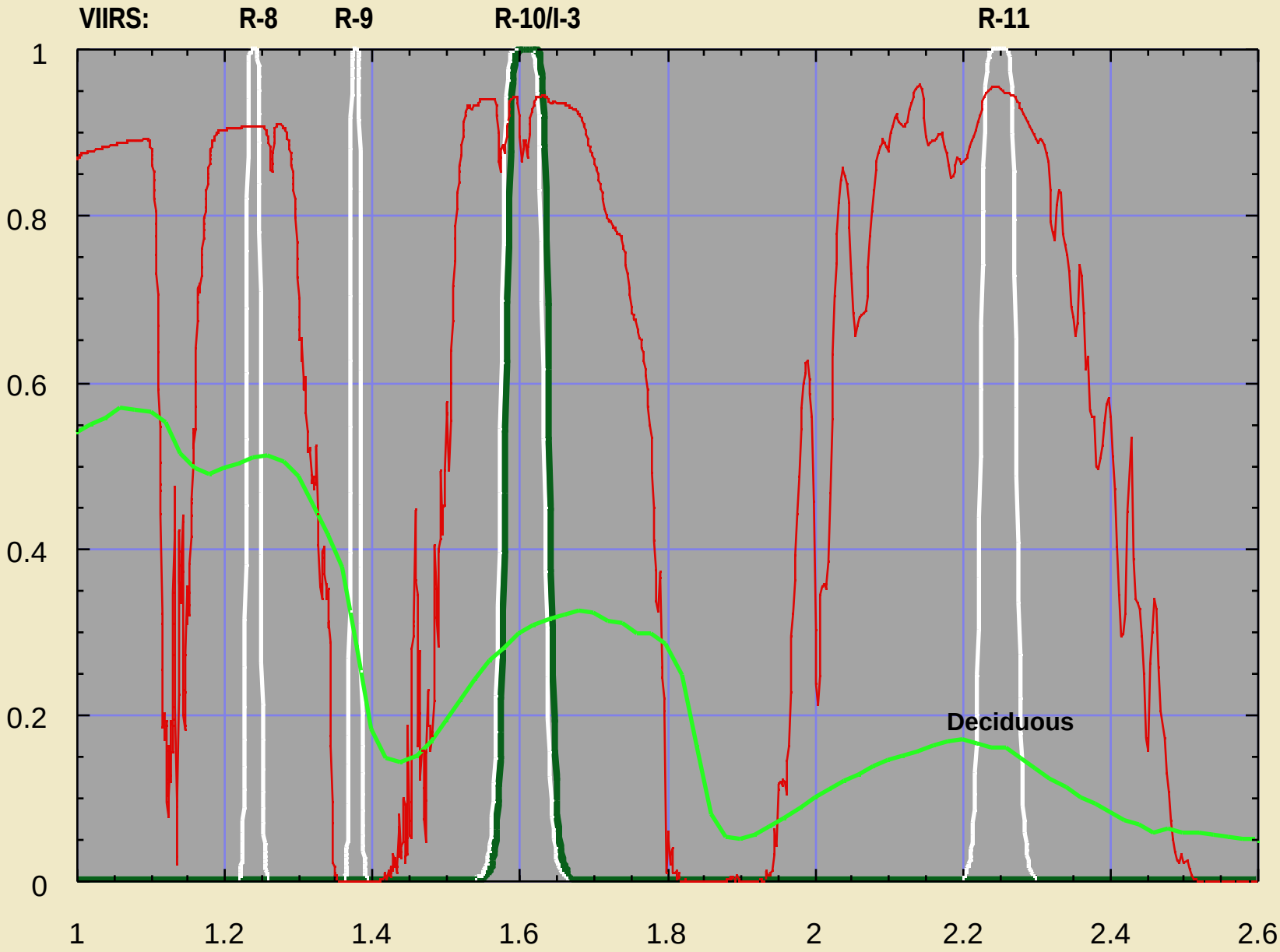
- **Land Vis-NIR Bands**
- **Ocean SWIR Bands**
- **Atmosphere Vis-NIR Bands**
- **Atmosphere SWIR Bands**
- **Atmosphere MWIR Bands**

MODIS Atmospheric Bands in the NIR




MODIS & VIIRS Atmospheric Bands in the NIR
VIIRS:
MODIS:
R-8
5
R-9
26
R-10/I-3
6
7
R-11
Deciduous
1
0.8
0.6
0.4
0.2
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6

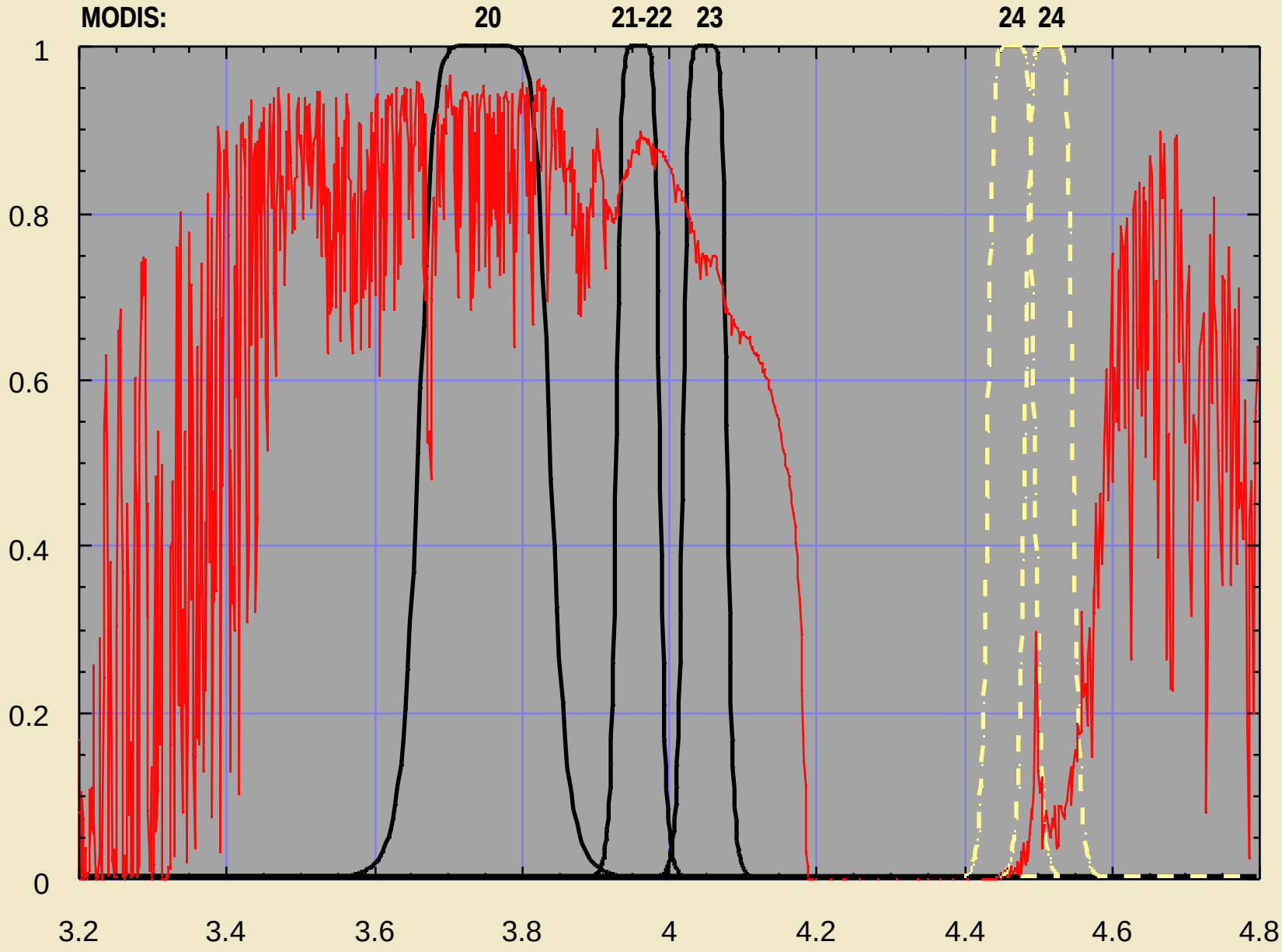
VIIRS Atmospheric Bands in the NIR



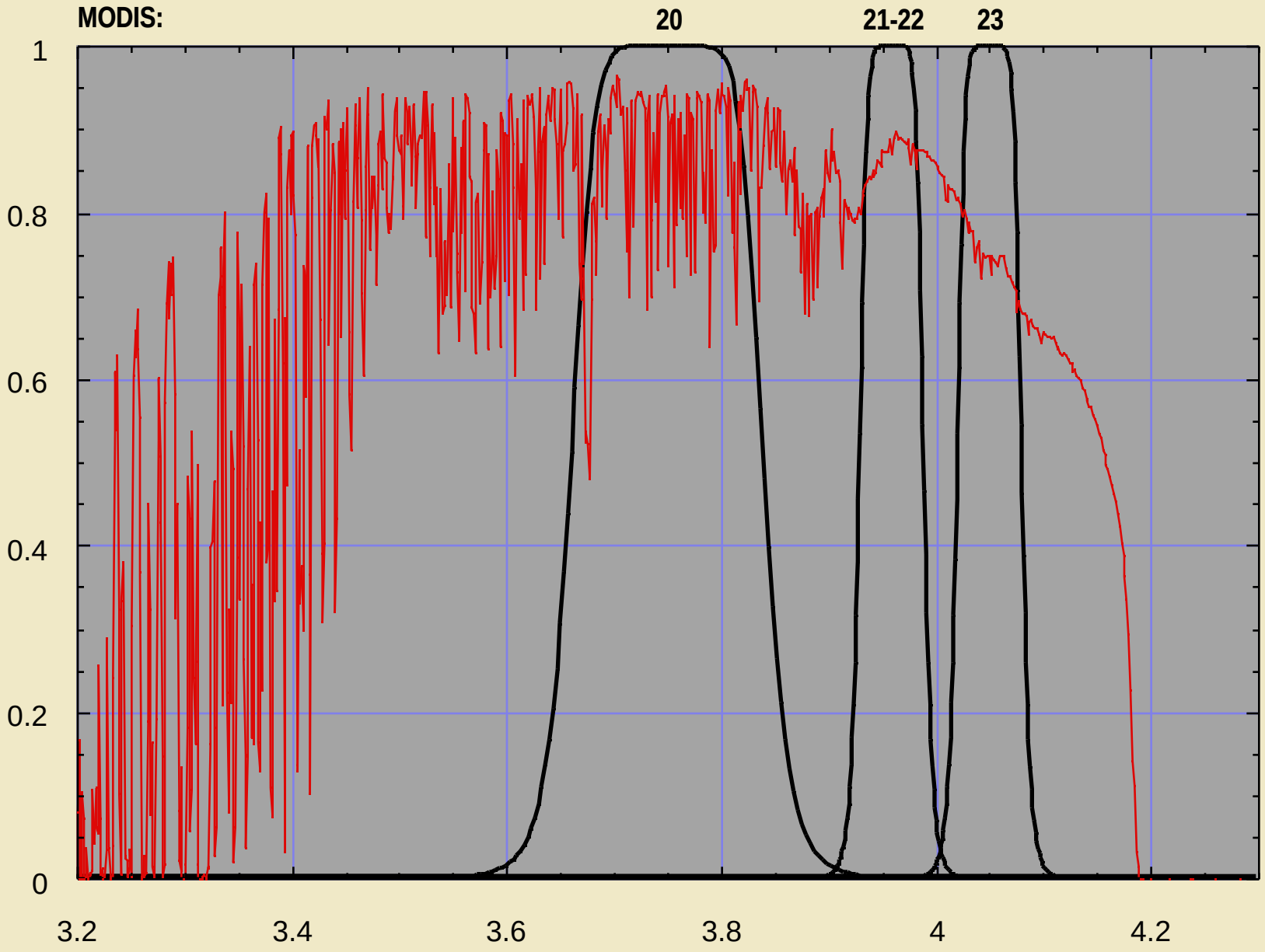
Back-Up Charts

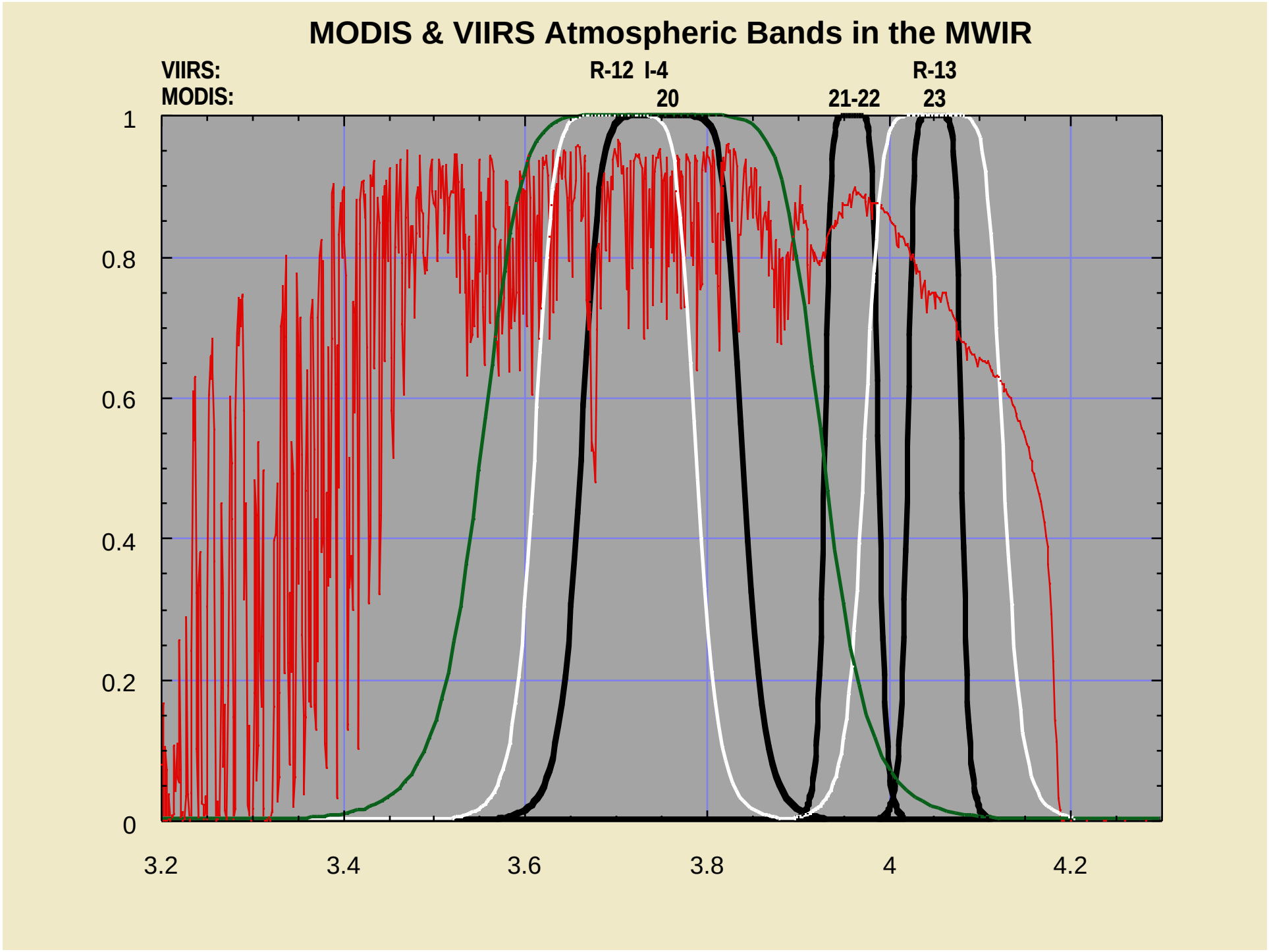
- **Land Vis-NIR Bands**
- **Ocean SWIR Bands**
- **Atmosphere Vis-NIR Bands**
- **Atmosphere SWIR Bands**
- **Atmosphere MWIR Bands**

MODIS Atmospheric Bands in the MWIR



MODIS Atmospheric Bands in the MWIR




MODIS & VIIRS Atmospheric Bands in the MWIR
VIIRS:
MODIS:
R-12
I-4
20
21-22
R-13
23
1
0.8
0.6
0.4
0.2
0
3.2
3.4
3.6
3.8
4
4.2

VIIRS Atmospheric Bands in the MWIR