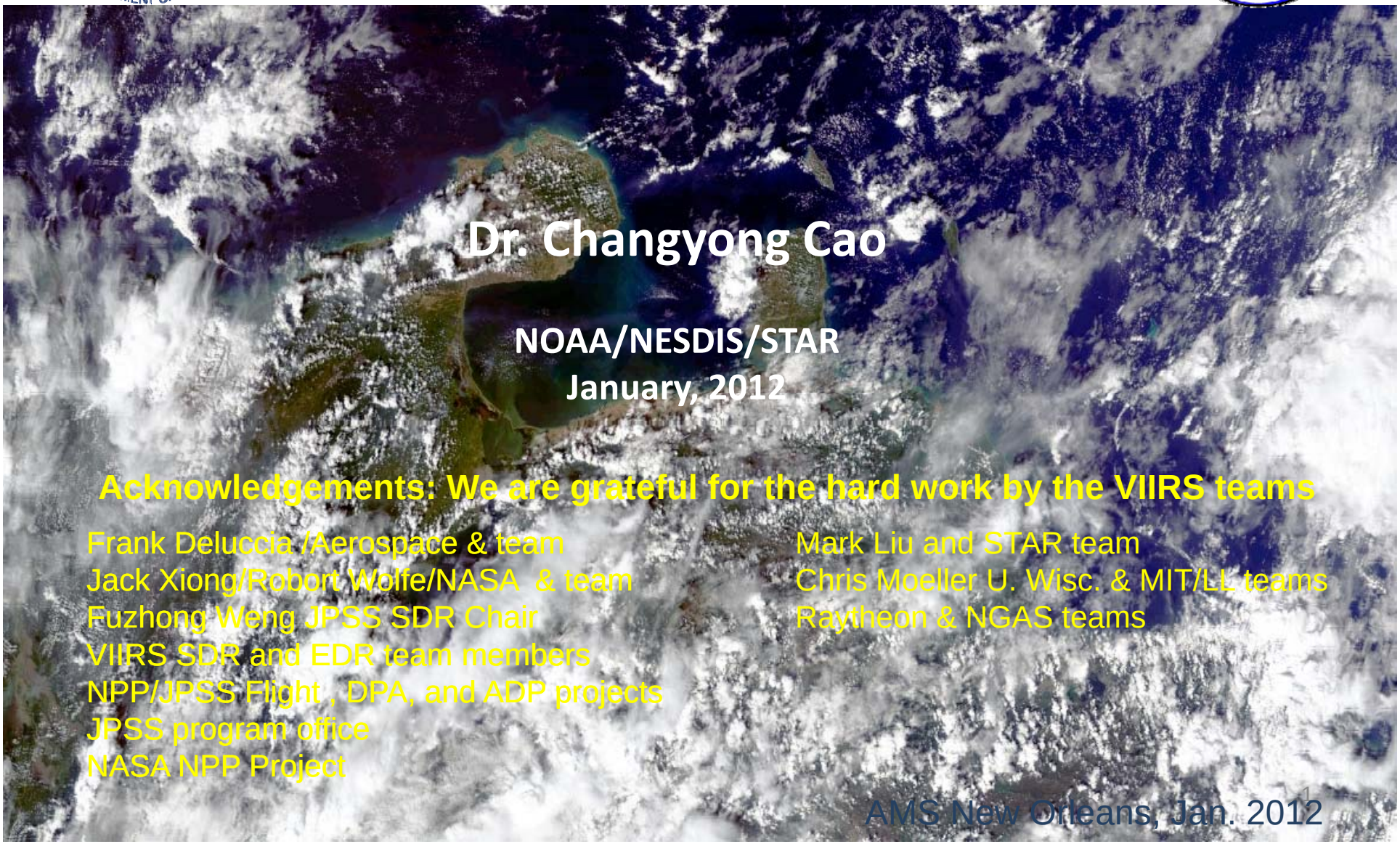
NPP VIIRS SDR Postlaunch Calibration/Validation



Dr. Changyong Cao

NOAA/NESDIS/STAR

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Frank Deluccia /Aerospace & team
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VIIRS SDR and EDR team members
NPP/JPSS Flight , DPA, and ADP projects
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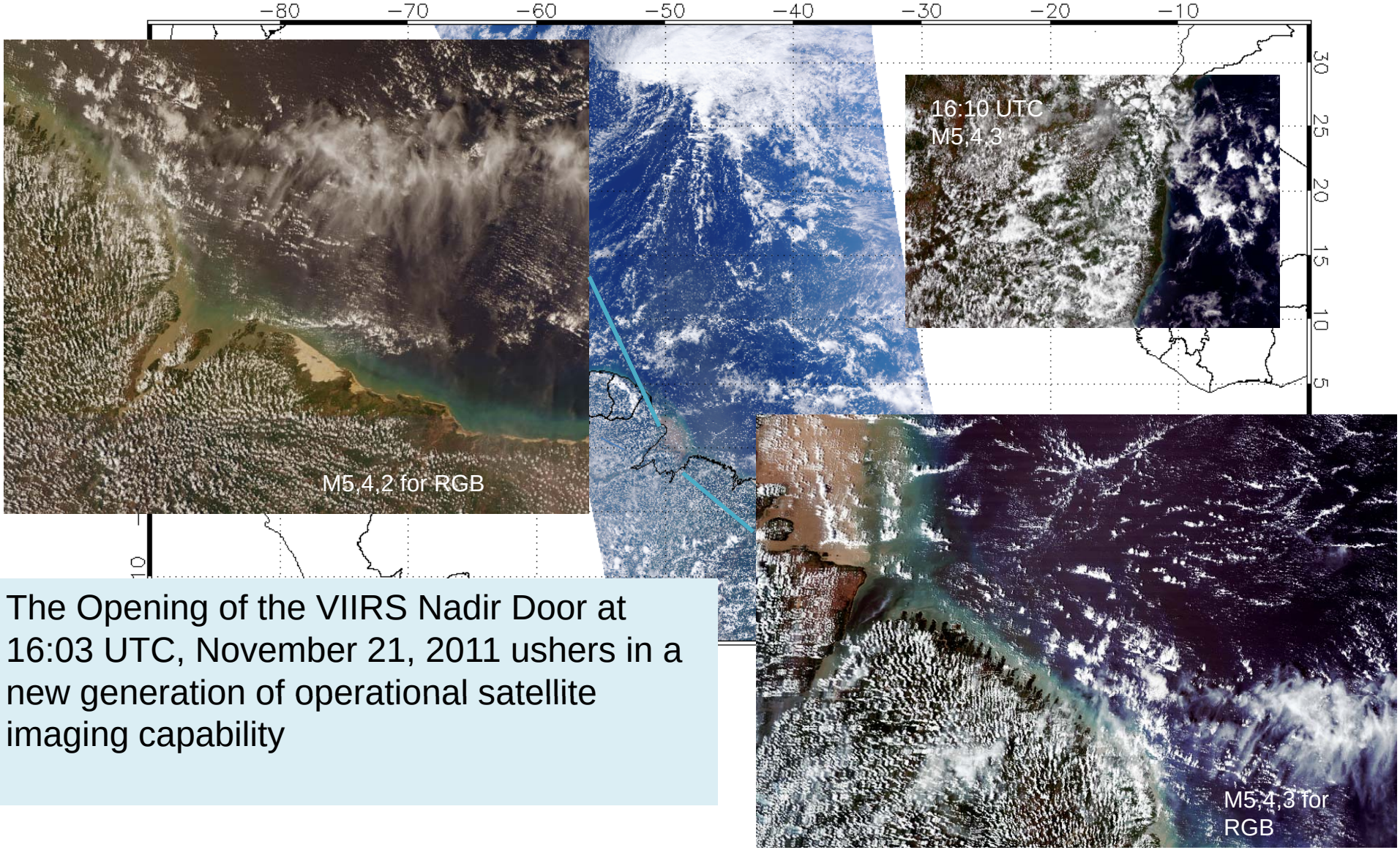
Outline

- VIIRS Early Images
- VIIRS SDR data characteristics
- VIIRS SDR Postlaunch Cal/Val and Intercomparisons
- VIIRS SDR data access, visualization, and analysis tools
- Resources and references
- Summary

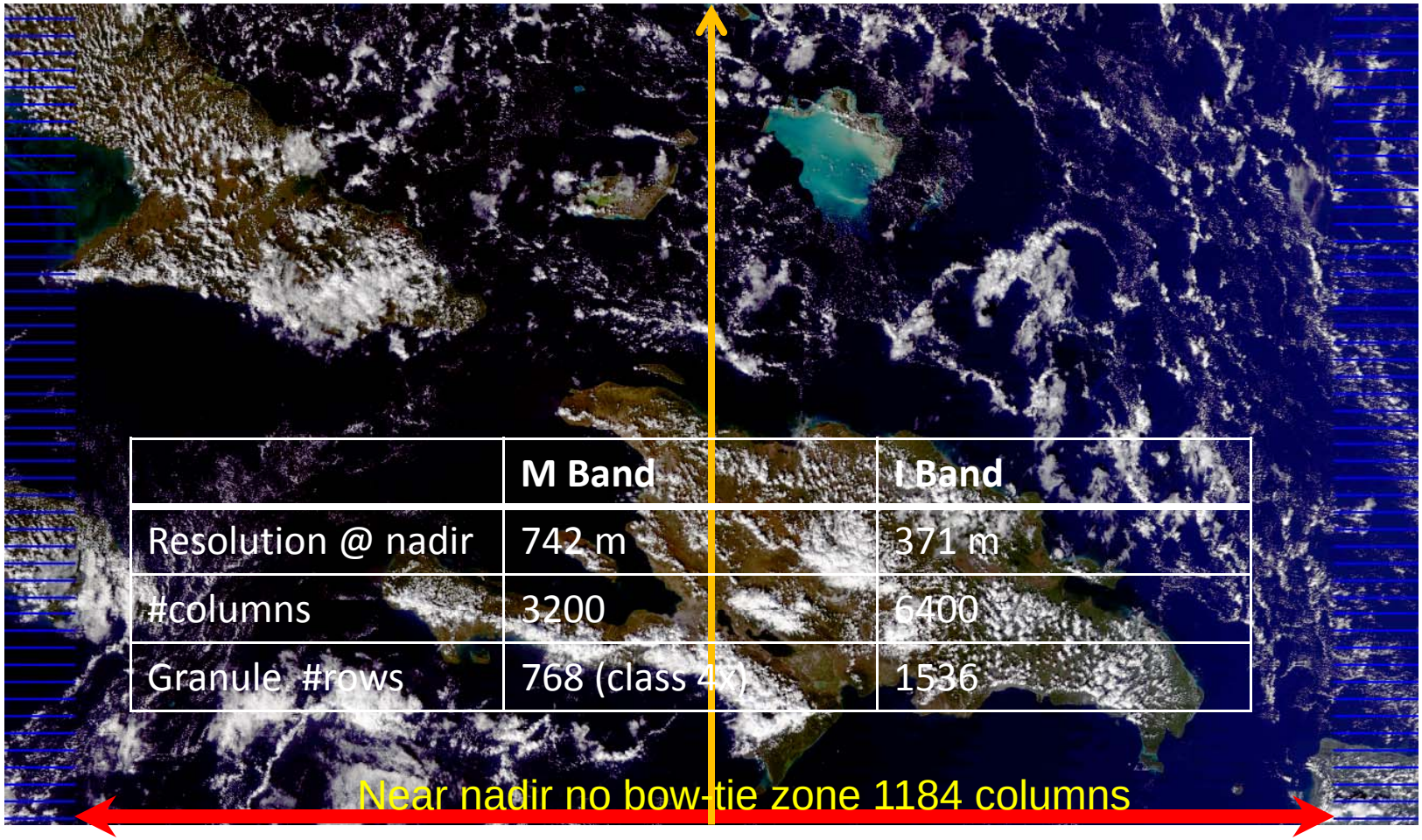
First Images from the NPP/VIIRS

(Radiometric M Bands)



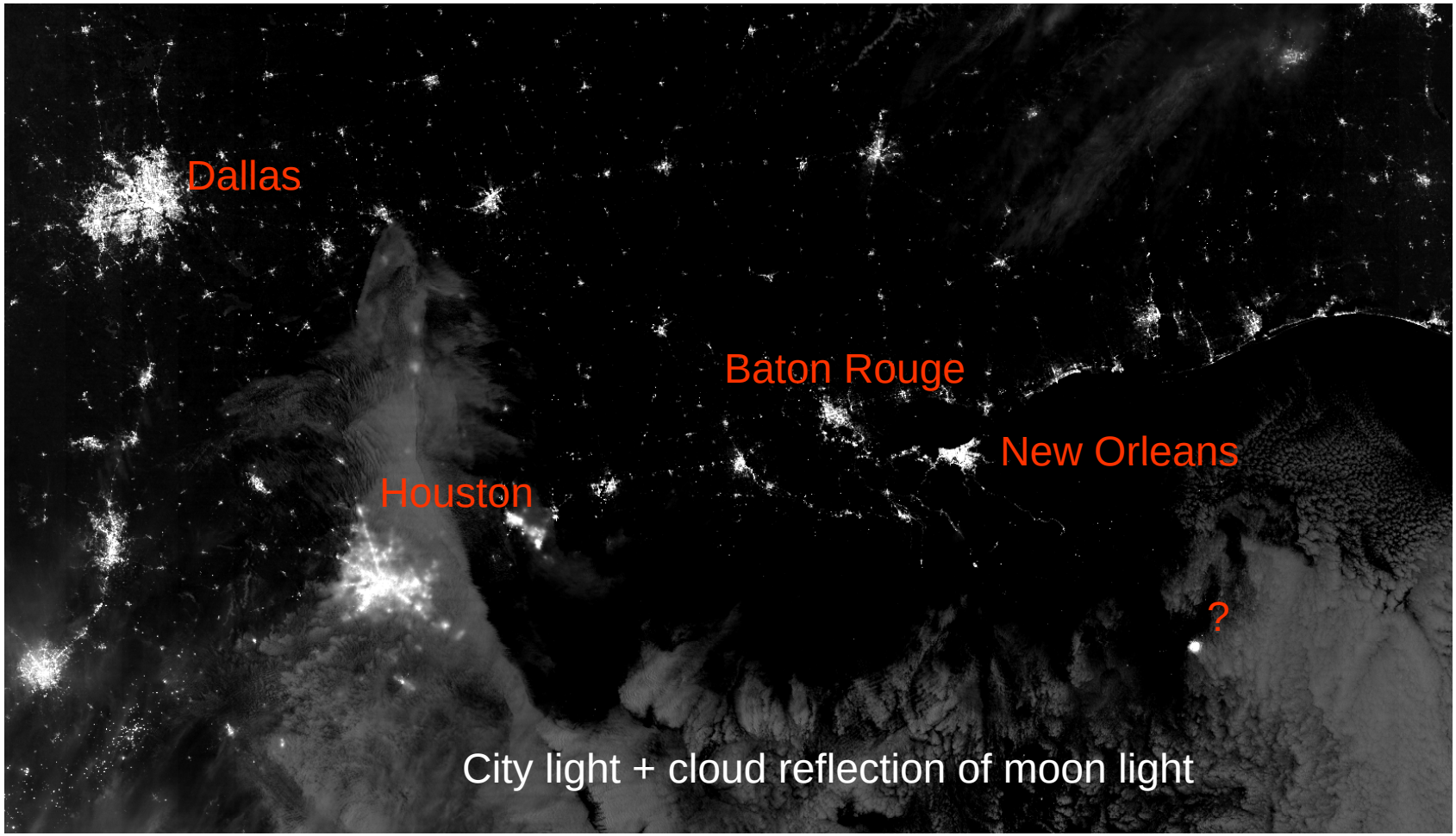
The Opening of the VIIRS Nadir Door at 16:03 UTC, November 21, 2011 ushers in a new generation of operational satellite imaging capability

VIIRS Image Characteristics



	M Band	I Band
Resolution @ nadir	742 m	371 m
#columns	3200	6400
Granule #rows	768 (class 4)	1536

VIIRS Day Night Band (DNB) Sample Image



VIIRS Overview

•**Purpose:** Global observations of land, ocean, & atmospheric parameters with high temporal resolution (~ daily)

•**Heritage:** VIIRS builds on a long heritage of operational and research earth observing imaging radiometers with moderate resolution :

- •Advanced Very High Resolution Radiometer (AVHRR) on NOAA and MetOp satellites, with 5 (6) bands, since 1979.
- •Moderate-Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua, with 36 bands, since 1999.
- •Sea-viewing Wide Field-of-view Sensor (*SeaWiFS*), since 1997.
- •Operational Linescan System (OLS) on DMSP, since 1972.

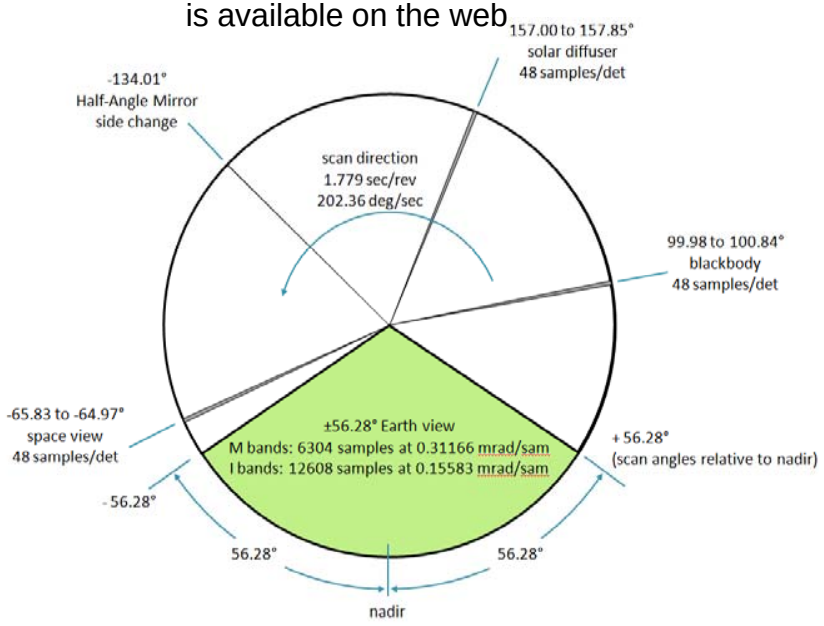
- Multi-spectral scanning radiometer (22 bands between 0.4 µm and 12 µm) 12-bit quantization
- **Swath width:** 3000 km

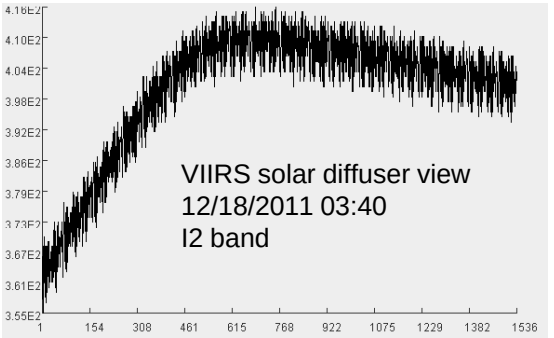
Onboard Calibrator Comparisons

VIIRS	MODIS	AVHRR
Rotating telescope w/ half angle mirror	Paddle Mirror (large RVS effect)	45 deg mirror (image pixel rotation at high scan angles)
V-Grooved Blackbody	V-Grooved Blackbody	Honeycomb Blackbody
Space view	Space view	Space view
Solar diffuser + screen (VISNIR+DNB)	Solar diffuser +screen+door (VISNIR)	Vicarious (desert)
Solar diffuser stability monitor	Solar diffuser stability monitor	-
Lunar cal	Lunar cal	-
None	SRCA	None

VIIRS Scan Pattern

Updated from VIIRS calibration ATBD which is available on the web





VIIRS Prelaunch Performance

(NPP F1 Bands and SNR/NEDT)

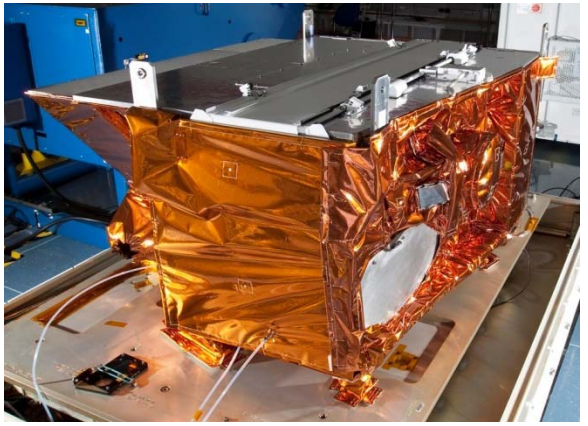
		Specification									
		Band No.	Driving EDR(s)	Spectral Range (um)	Horiz Sample Interval (km) (track x Scan) Nadir	Horiz Sample Interval (km) (track x Scan) End of Scan	Band Gain	Ltyp or Ttyp (Spec)	Lmax or Tmax	SNR or NEdT (K)	Measured SNR or NEdT (K)	SNR Margin (%)
Reflective Bands	VisNIR	M1	Ocean Color Aerosol	0.402 - 0.422	0.742 x 0.259	1.60 x 1.58	High Low	44.9 155	135 615	352 316	723 1327	105% 320%
		M2	Ocean Color Aerosol	0.436 - 0.454	0.742 x 0.259	1.60 x 1.58	High Low	40 146	127 687	380 409	576 1076	51.5% 163%
		M3	Ocean Color Aerosol	0.478 - 0.498	0.742 x 0.259	1.60 x 1.58	High Low	32 123	107 702	416 414	658 1055	58.2% 155%
		M4	Ocean Color Aerosol	0.545 - 0.565	0.742 x 0.259	1.60 x 1.58	High Low	21 90	78 667	362 315	558 882	54.1% 180%
		I1	Imagery EDR	0.600 - 0.680	0.371 x 0.387	0.80 x 0.789	Single	22	718	119	265	122.7%
		M5	Ocean Color Aerosol	0.662 - 0.682	0.742 x 0.259	1.60 x 1.58	High Low	10 68	59 651	242 360	360 847	49% 135%
		M6	Atmosph. Correct.	0.739 - 0.754	0.742 x 0.776	1.60 x 1.58	Single	9.6	41	199	394	98.0%
		I2	NDVI	0.846 - 0.885	0.371 x 0.387	0.80 x 0.789	Single	25	349	150	299	99.3%
		M7	Ocean Color Aerosol	0.846 - 0.885	0.742 x 0.259	1.60 x 1.58	High Low	6.4 33.4	29 349	215 340	545 899	154% 164%
	S/WMIR	M8	Cloud Particle Size	1.230 - 1.250	0.742 x 0.776	1.60 x 1.58	Single	5.4	165	74	349	371.6%
		M9	Cirrius/Cloud Cover	1.371 - 1.386	0.742 x 0.776	1.60 x 1.58	Single	6	77.1	83	247	197.6%
		I3	Binary Snow Map	1.580 - 1.640	0.371 x 0.387	0.80 x 0.789	Single	7.3	72.5	6	165	2650.0%
		M10	Snow Fraction	1.580 - 1.640	0.742 x 0.776	1.60 x 1.58	Single	7.3	71.2	342	695	103.2%
		M11	Clouds	2.225 - 2.275	0.742 x 0.776	1.60 x 1.58	Single	0.12	31.8	10	18	80.0%
Emissive Bands		I4	Imagery Clouds	3.550 - 3.930	0.371 x 0.387	0.80 x 0.789	Single	270	353	2.5	0.4	84.0%
		M12	SST	3.660 - 3.840	0.742 x 0.776	1.60 x 1.58	Single	270	353	0.396	0.12	69.7%
		M13	SST Fires	3.973 - 4.128	0.742 x 0.259	1.60 x 1.58	High Low	300 380	343 634	0.107 0.423	0.044 --	59% --
	LWIR	M14	Cloud Top Properties	8.400 - 8.700	0.742 x 0.776	1.60 x 1.58	Single	270	336	0.091	0.054	40.7%
		M15	SST	10.263 - 11.263	0.742 x 0.776	1.60 x 1.58	Single	300	343	0.07	0.028	60.0%
		I5	Cloud Imagery	10.500 - 12.400	0.371 x 0.387	0.80 x 0.789	Single	210	340	1.5	0.41	72.7%
		M16	SST	11.538 - 12.488	0.742 x 0.776	1.60 x 1.58	Single	300	340	0.072	0.036	50.0%

HSI uses 3 in-scan pixels aggregation at Nadir

Courtesy of Gleason et al. 2011

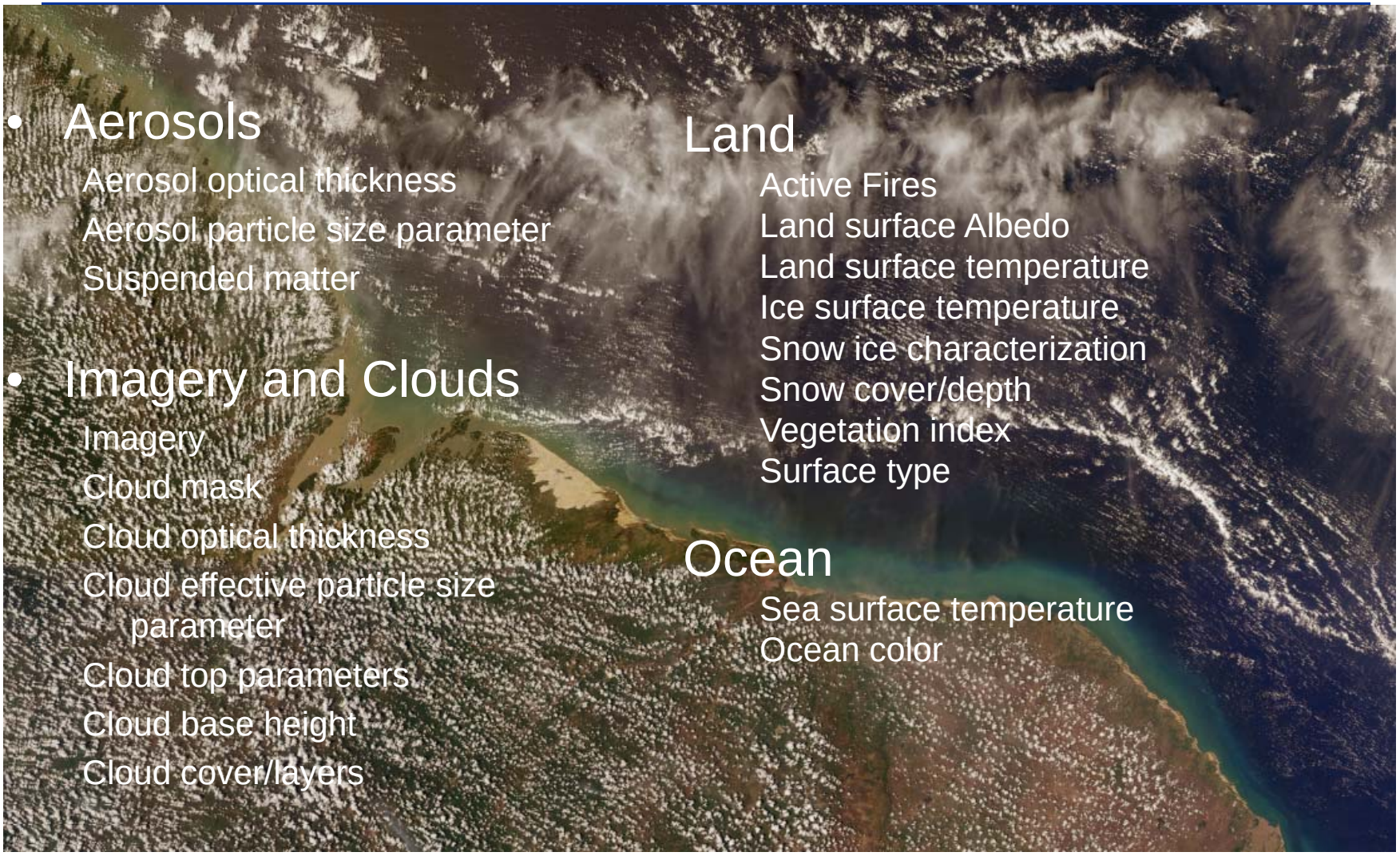
Overview of VIIRS Data Products

- VIIRS data products include SDRs: Calibrated and geolocated radiance and reflectance (SDR ≈ Level 1B)
- 22 types of SDRs
  - 16 moderate resolution, narrow spectral bands
    - 11 Reflective Solar Bands (RSB)
    - 5 Thermal Emissive Bands (TEB)
  - 5 imaging resolution, narrow spectral bands
    - 3 RSB
    - 2 TEB
  - 1 Day Night Band (DNB) imaging, broadband



- Input to 21 Environmental Data Records (EDRs)
  - Two "Key Performance Parameters" based on the Integrated Operational Requirements Document (IORD) II
    - SST and Imagery

VIIRS EDRs



- Aerosols
  - Aerosol optical thickness
  - Aerosol particle size parameter
  - Suspended matter
- Imagery and Clouds
  - Imagery
  - Cloud mask
  - Cloud optical thickness
  - Cloud effective particle size parameter
  - Cloud top parameters
  - Cloud base height
  - Cloud cover/layers

Land

- Active Fires
- Land surface Albedo
- Land surface temperature
- Ice surface temperature
- Snow ice characterization
- Snow cover/depth
- Vegetation index
- Surface type

Ocean

- Sea surface temperature
- Ocean color

Cal/Val to Ensure Product Maturity

- Beta
  - Early release product, initial calibration applied, minimally validated and may still contain significant errors
  - Available to allow users to gain familiarity with data formats and parameters
  - Product is not appropriate as the basis for quantitative scientific publications studies and applications
- Provisional
  - Product quality may not be optimal
  - Incremental product improvements are still occurring as calibration parameters are adjusted with sensor on-orbit characterization
  - General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
  - Users are urged to contact NPOESS NPP Cal/Val Team representatives prior to use of the data in publications
- Validated/Calibrated
  - On-orbit sensor performance characterized and calibration parameters adjusted accordingly
  - Ready for use by the Centrals, and in scientific publications
  - There may be later improved versions

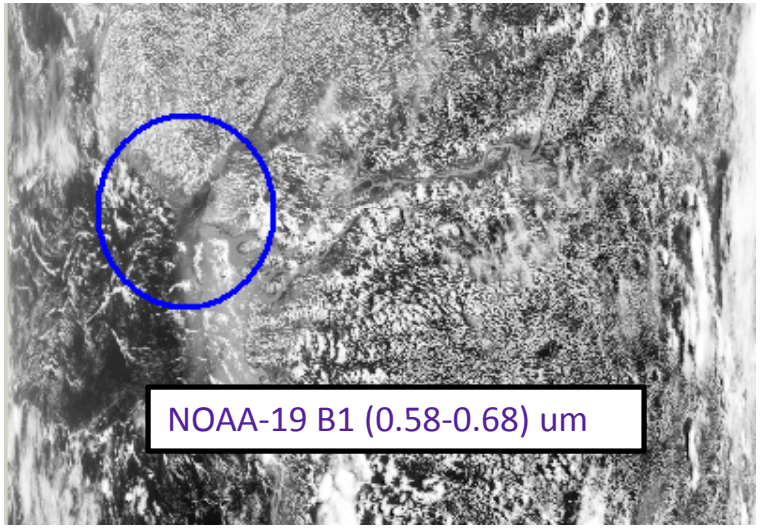
VIIRS 57 Cal/Val tasks

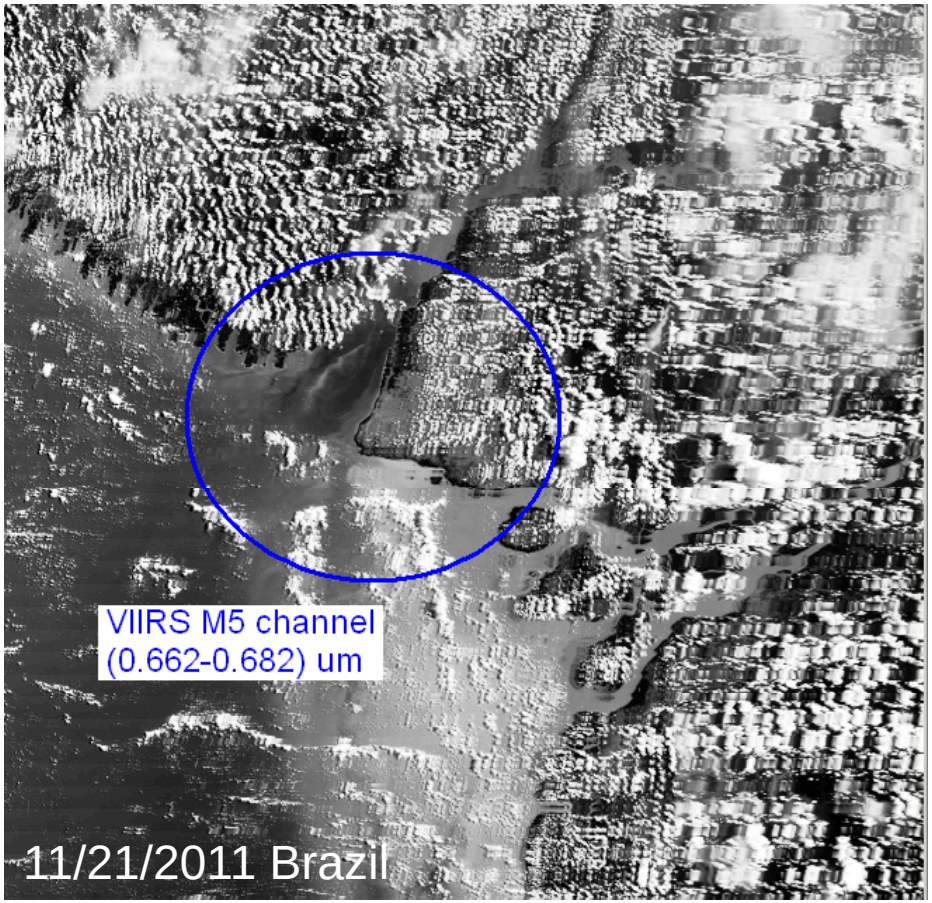
- Functional Performance & Format Evaluation (7)
- Calibration System Evaluation (7)
- Image Quality Evaluation (4)
- Radiometric Evaluation (25)
- Geometric Evaluation (9)
- Performance and Telemetry Trending (5)

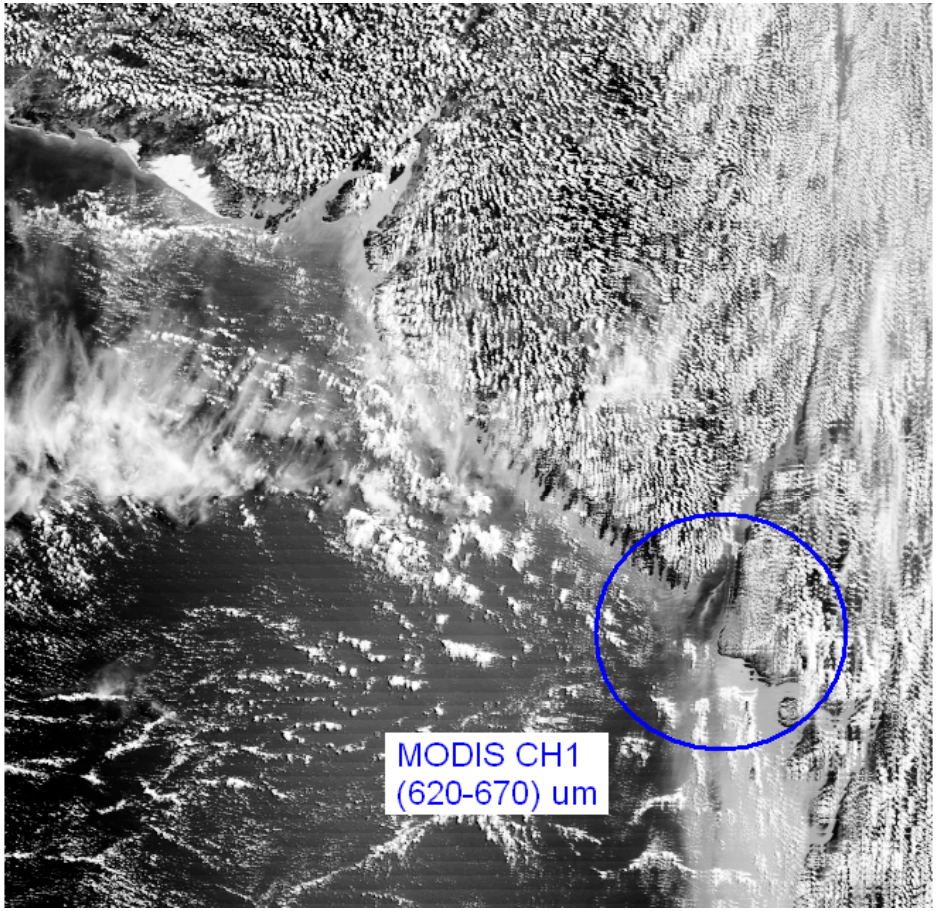
VIIRS SDR team Weekly telecons, reports, technical tagup, SDR/EDR interactions, blogs, and wiki.

Qualitative Comparisons between NPP/VIIRS, Aqua/MODIS, NOAA19/AVHRR

- VIIRS M5 band w/ 740 m resolution
- MODIS B1 w/ 1 km resolution (8 mins after VIIRS on same ground track)
- NOAA-19/AVHRRGAC at 5 km resolution (50min later to the west)







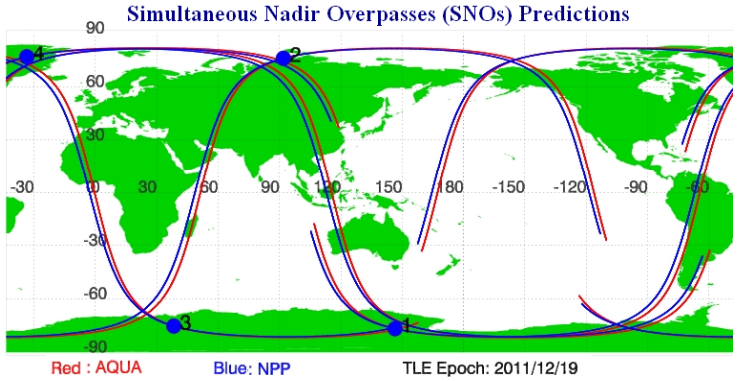
New Progress in SNO Prediction and Routine Use for NPP

- The Simultaneous Nadir Overpass (SNO) prediction software has been upgraded with the latest version of the orbital perturbation algorithm and a graphic interface

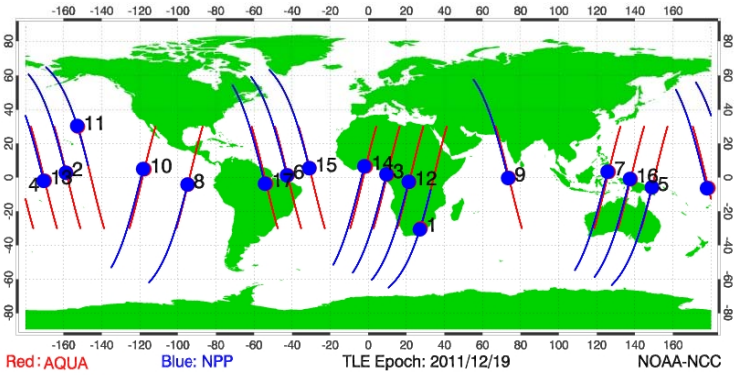
- New capabilities developed to predict both traditional SNOs and SNOx extended to the low latitudes

- The new system has been predicting routinely since NPP launch, and predicted SNOs with Aqua/MODIS are being used for VIIRS channel responsivity diagnosis

- The SNOs as well as daily NPP orbital predictions are readily available on the NCC website at: https://cs.star.nesdis.noaa.gov/NCC/SNOPredictions



Index	Date	Time (AQUA)	AQUA Lat,Lon	NPP Lat,Lon	Distance(km)	Time Diff (sec)
1	12/21/2011	06:20:44	-76.77, 146.48	-76.77, 146.53	1.13	39
2	12/23/2011	21:47:58	75.93, 91.98	75.93, 91.93	1.46	11
3	12/26/2011	13:15:08	-75.29, 38.37	-75.29, 38.38	0.26	62
4	12/29/2011	06:20:26	76.76, -33.47	76.76, -33.49	0.67	43

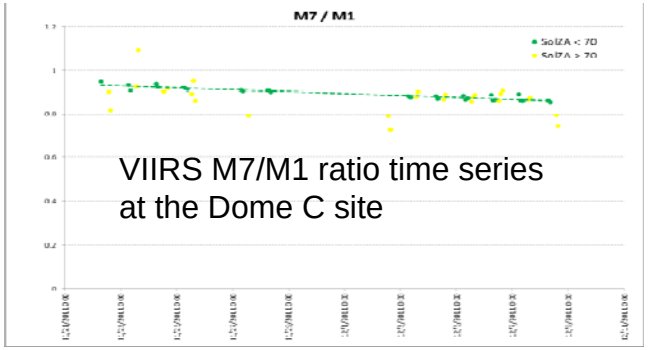


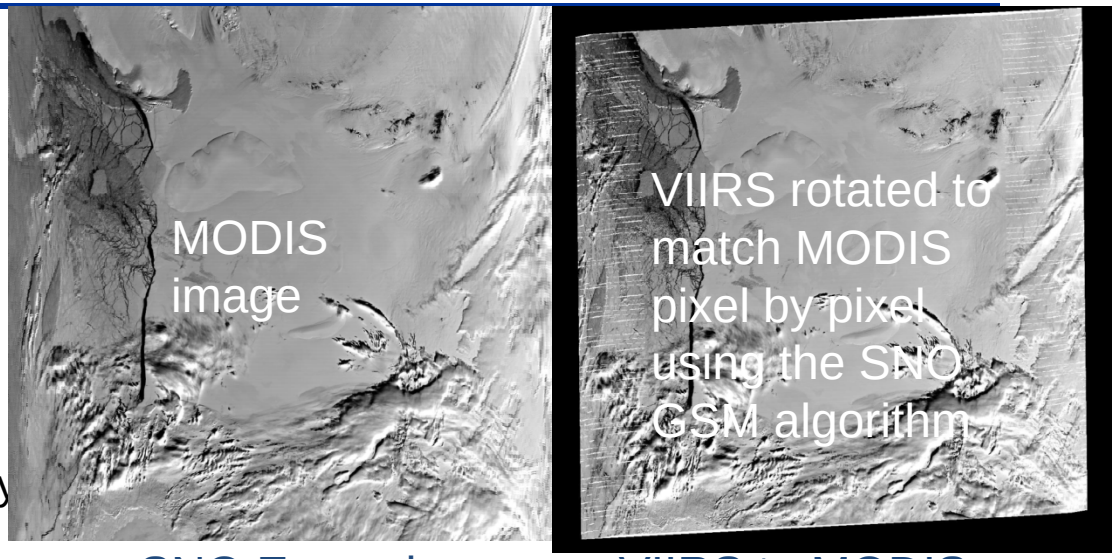
NPP VIIRS Channel Responsivity Monitoring in the Antarctica

•VIIRS responsivity change is closely monitored at the Simultaneous Nadir Overpass (SNO) between VIIRS and MODIS, as well as at the Dome C

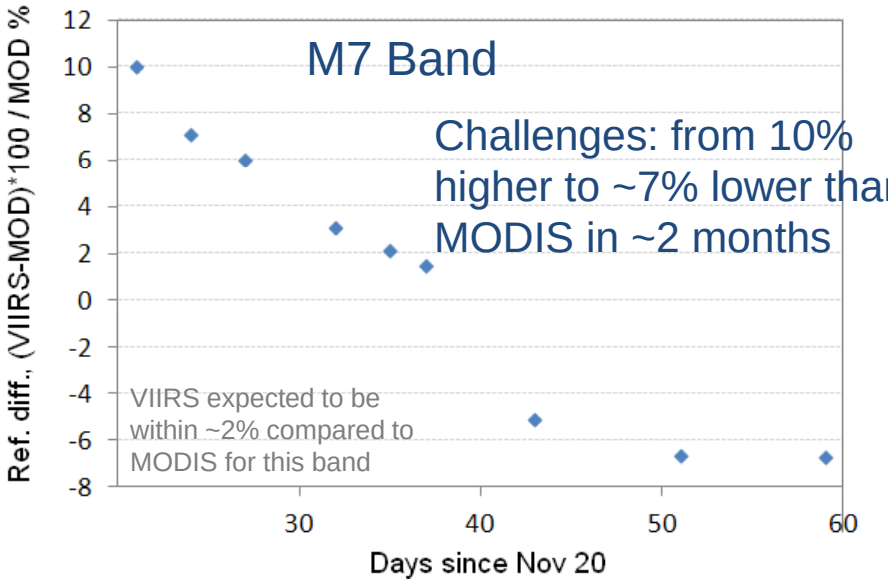
• A new SNO fast GeoSpatial Matching (SNO GSM) algorithm has been applied remap VIIRS image to MODIS which greatly facilities the comparisons pixel-by pixel with fully size

•VIIRS monitoring leverages previously published work on the Dome C (Cao et al. 2010, CJRS), and allows us to develop time series for comparison with established community reference standard

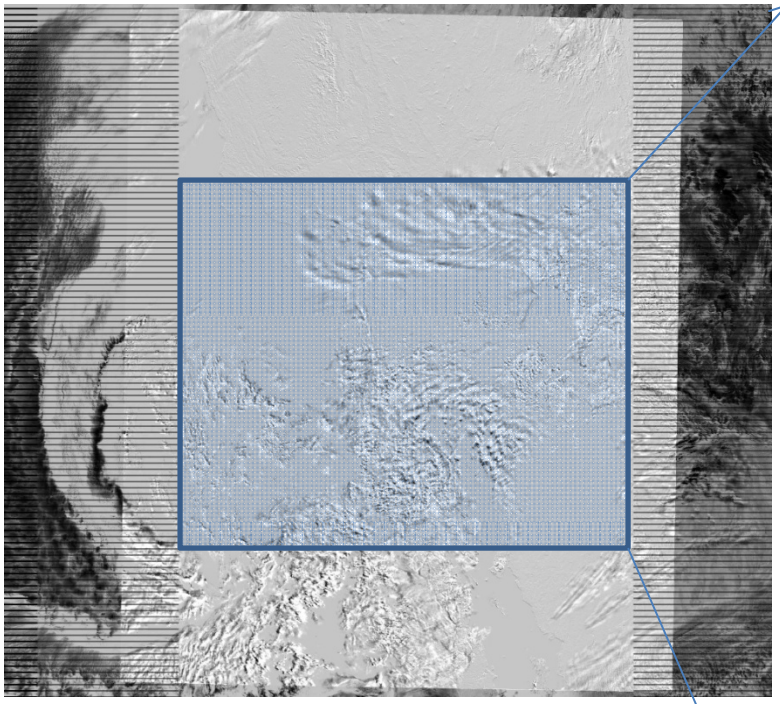


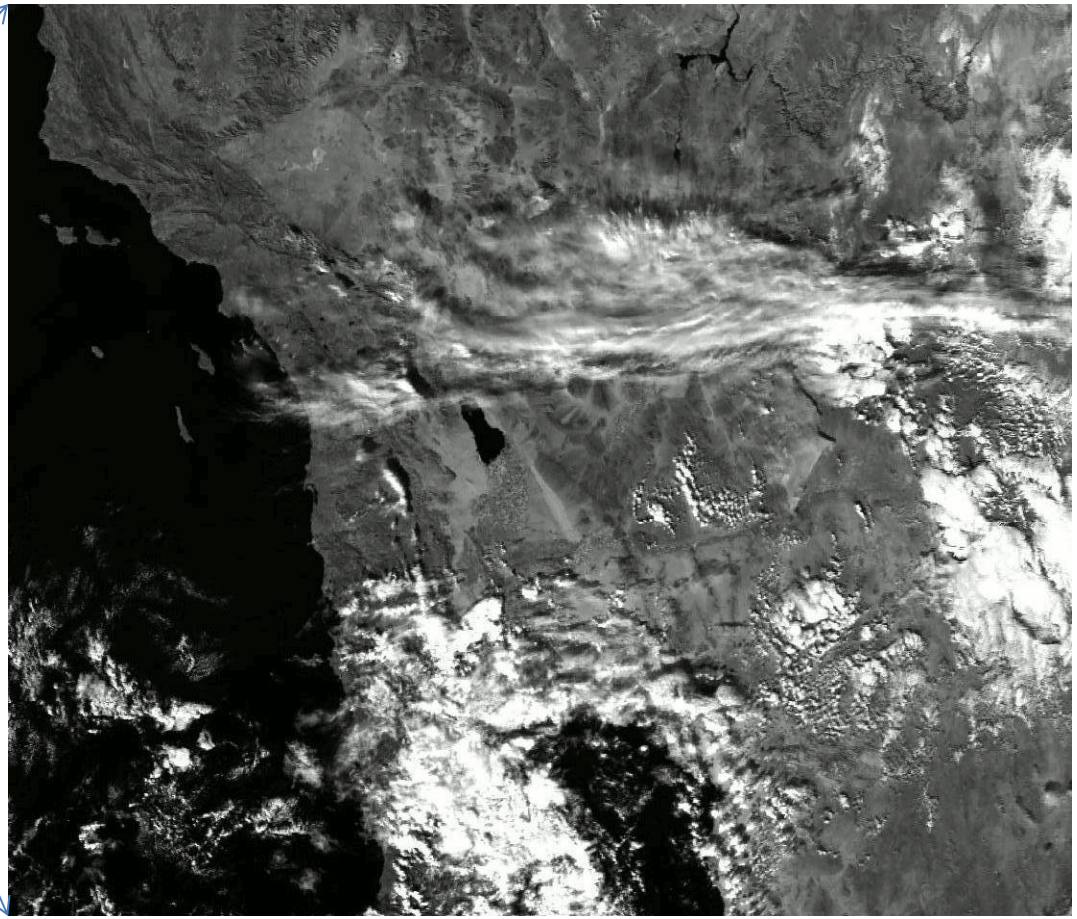


SNO Example: remap VIIRS to MODIS



Radiometric and Geospatial Differences between VIIRS and MODIS



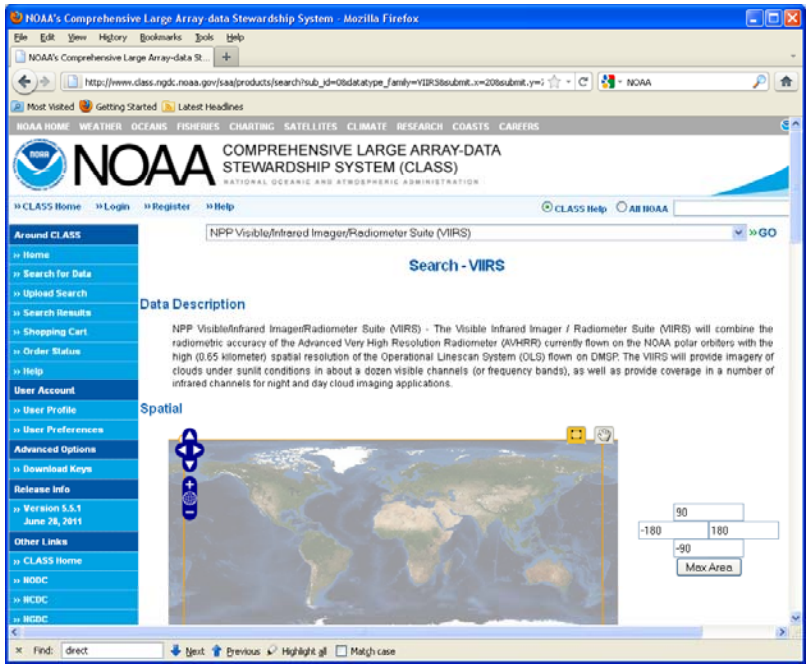


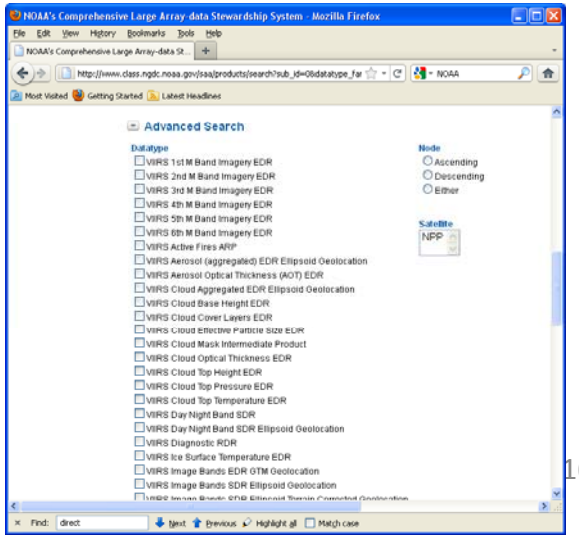
After pixel by pixel remapping using fast GSM, the difference image can be analyzed for both radiometric and geospatial differences between VIIRS and MODIS

Differencing image not only shows cloud movement (within ~10mins), but also geolocation discrepancies for land features

VIIRS Data Distribution and Access

- CLASS: www.class.noaa.gov
  - Combined granules (4x for M bands)
  - Online order and ftp
  - Large file size: ex: 365 MB per band per (4xM-band) granule (1 GB needed to make a color image w/ size 3200x3000)
  - Currently restricted to team members
- Centrals:
  - NOAA/NESDIS, Suitland, MD
  - Air Forcre Weather Agency (AFWA), Offutt Air Force Base, Omaha, NE
- GRAVITE: for team members
- NASA PEATE
- Direct Readout





Resources & References

- Software tools:
  - HDF viewer 2.7+ (http://www.hdfgroup.org/hdf-java-html/hdfview/)
  - ENVI (COTS software package) w/ HDF5 plugin
  - IDL & Matlab

- VIIRS Info: http://www.star.nesdis.noaa.gov/jpss/VIIRS
  - Algorithm Theoretical Basis (ATBD)
  - SDR data format
  - NPP VIIRS Spectral Response Functions

- VIIRS Wiki page: https://cs.star.nesdis.noaa.gov/NCC/VIIRS

Summary

•NPP VIIRS early on-orbit cal/val demonstrated excellent image quality

•Synergistic effort is needed to address calibration challenges

•Intercomparison and validation at the SNO, SNOx, and cal/val sites such as Dome C complements onboard calibration

•Inter-consistency with MODIS can be established with more rigorous calibration effort

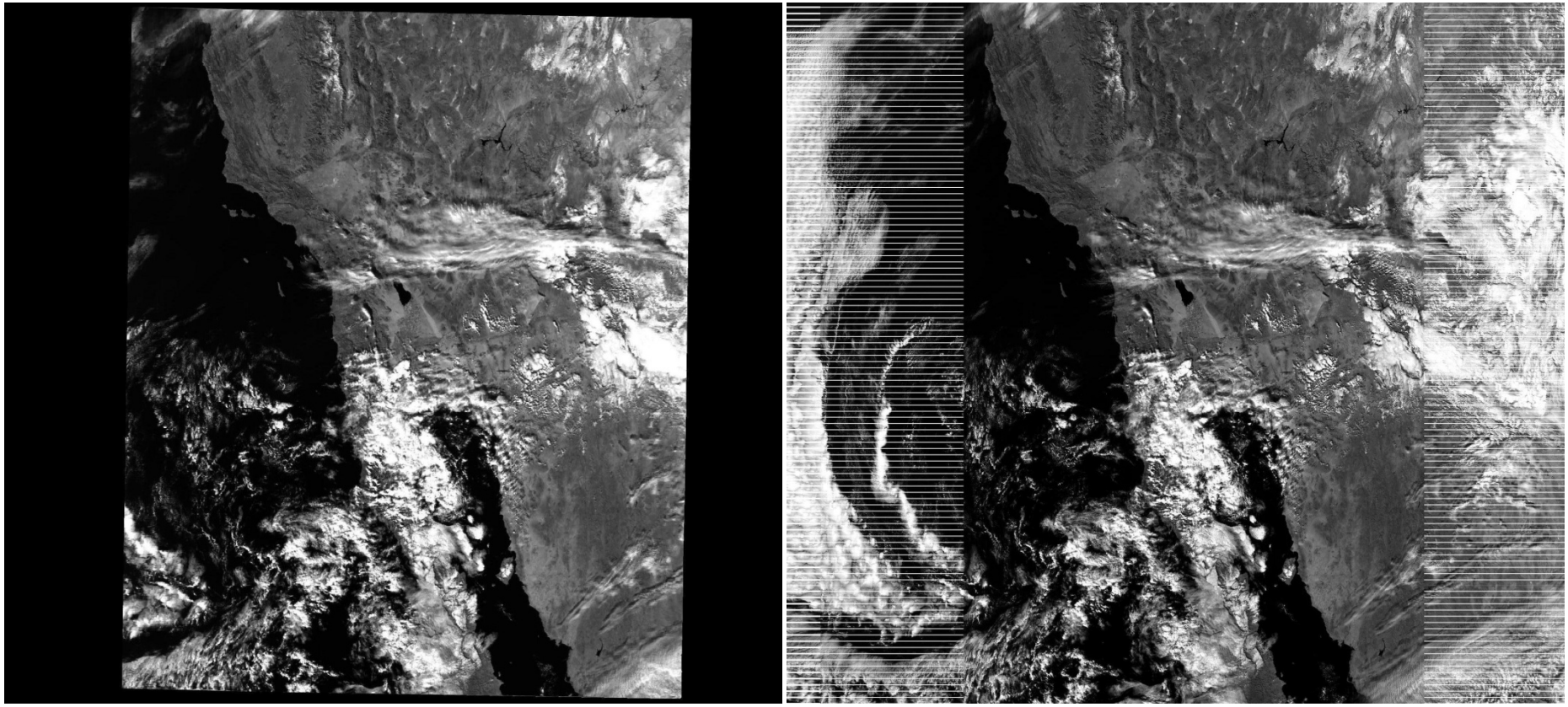
•Additional and up-to-date information is available on the VIIRS website: http://www.star.nesdis.noaa.gov/jpss/VIIRS/

Backup

SNOx Example: Remap MODIS to VIIRS using SNO fast GSM

MODIS granule rotated to match VIIRS

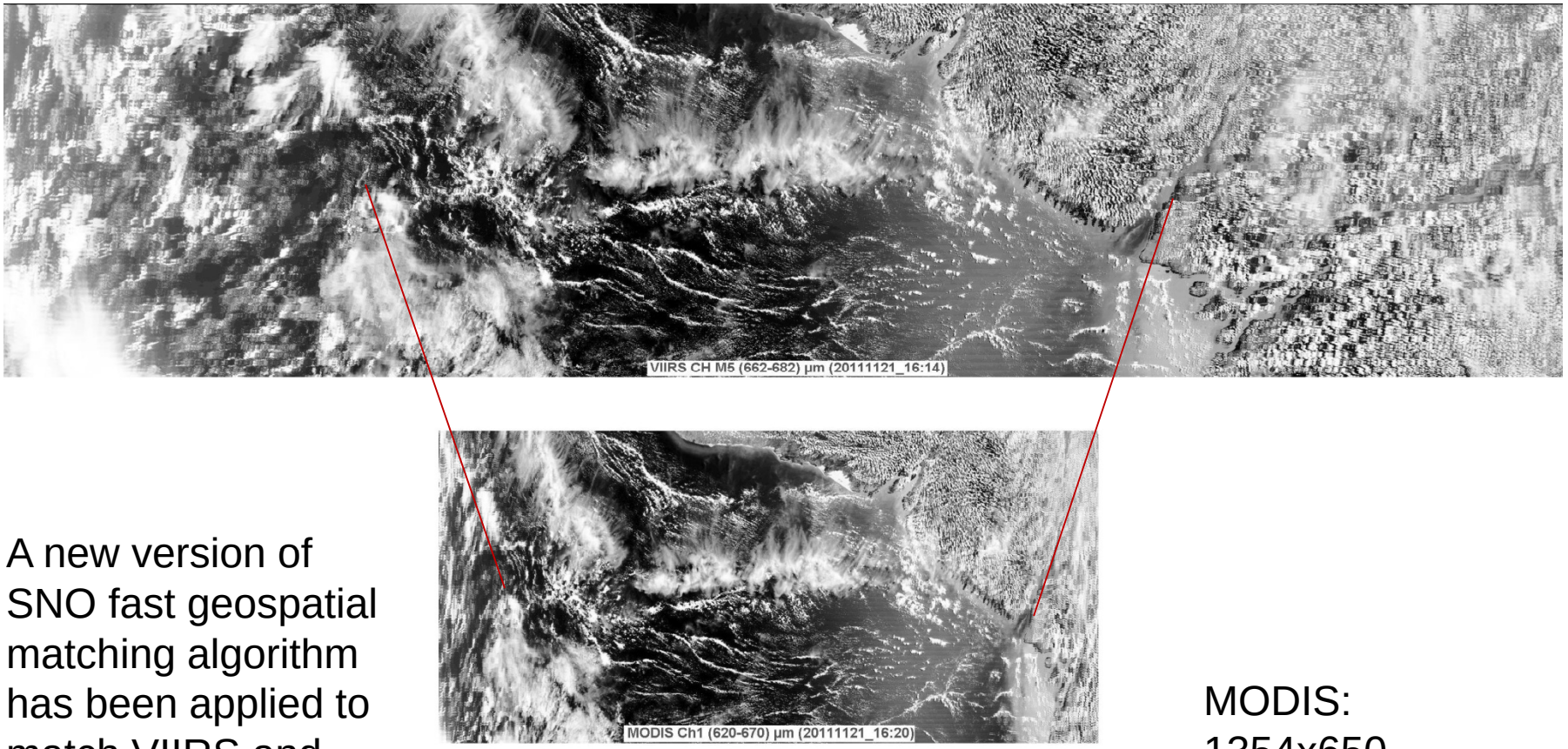
VIIRS 4xgranule (3200x3000)



•SNOx (extension to the low latitudes) occurs between NPP &Aqua, and NPP&NOAA19 regularly within ~10 – 3 minutes on same ground track

•Pixel-by-pixel geospatial matching is computational expensive. With the fast GSM algorithm, it still takes ~ 20 minutes for a half size image.

VIIRS & MODIS Full Swath Comparison



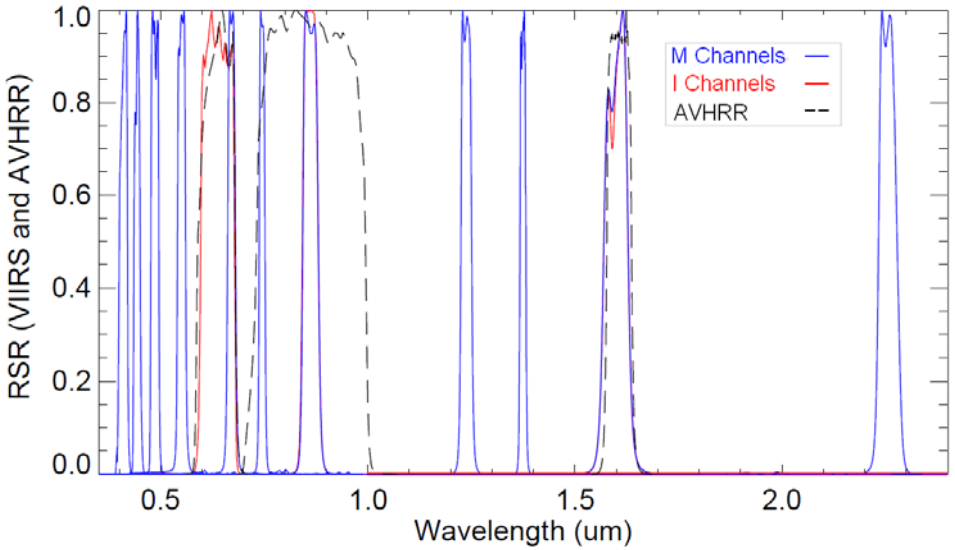
A new version of SNO fast geospatial matching algorithm has been applied to match VIIRS and MODIS pixel by pixel.

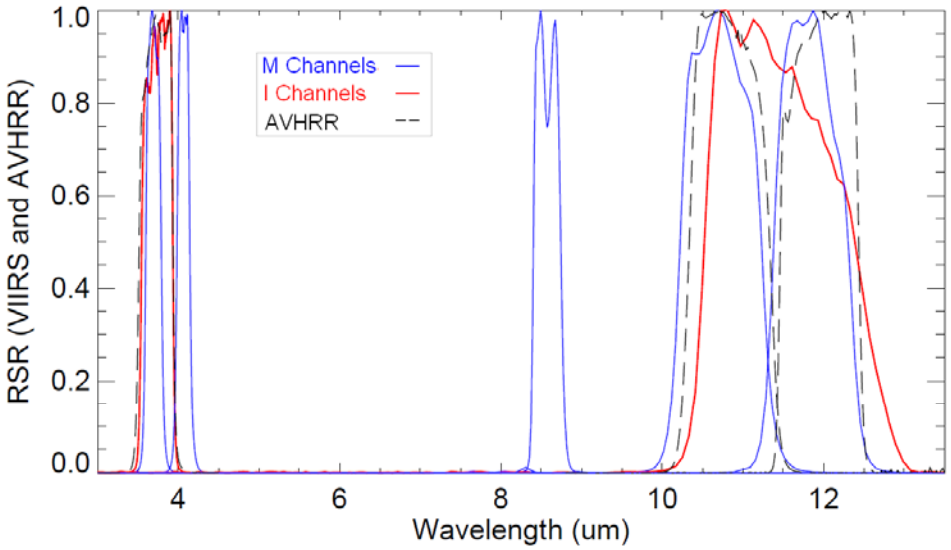
MODIS: 1354x650
VIIRS: 3200x768

Image courtesy of S. Uprety, NOAA/NESDIS/STAR

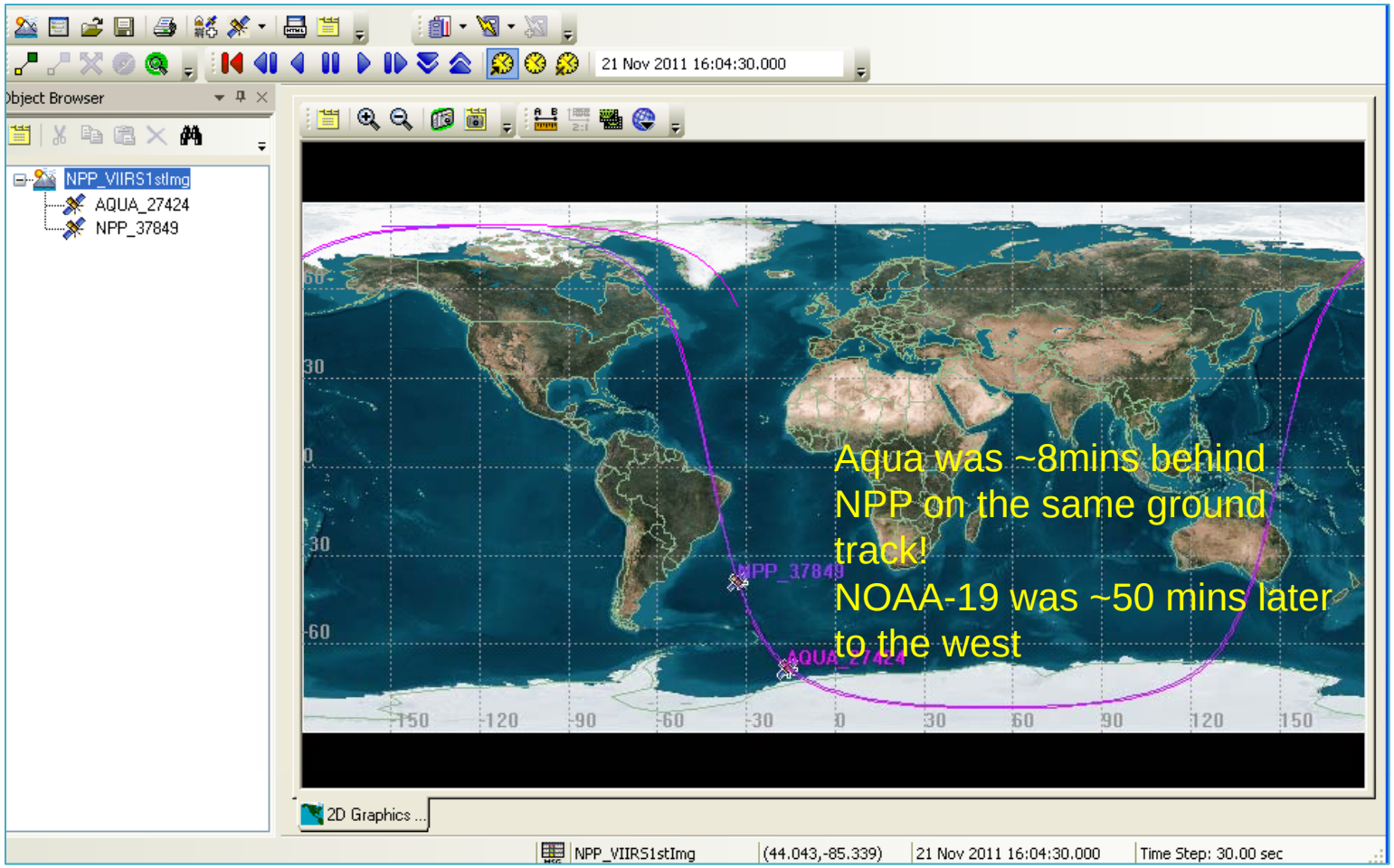
VIIRS Relative Spectral Response (RSR)

- VIIRS SRF(RSR) now available at https://www.star.nesdis.noaa.gov/jpss/VIIRS
  - Spacecraft-Level Testing
  - Instrument-Level Testing
- Provided by the government team
- Comparison with AVHRR (to the right)

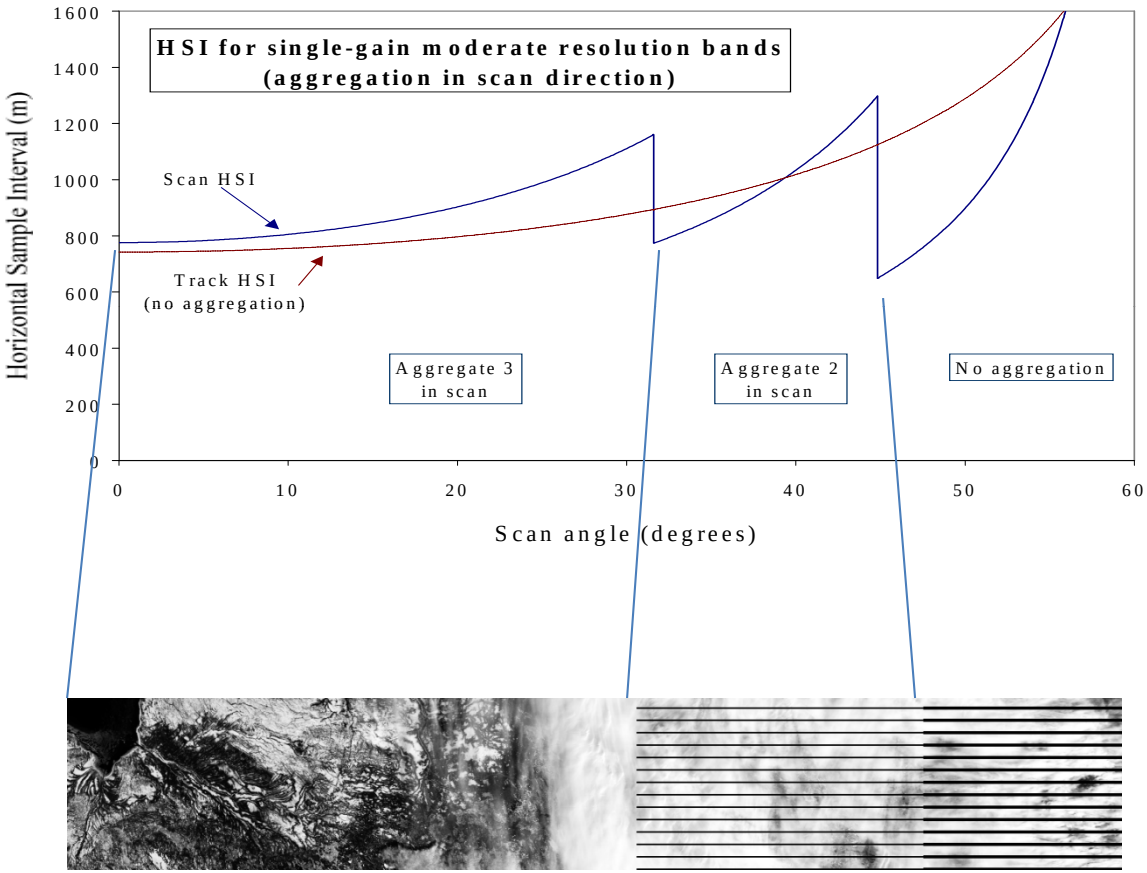




NPP and Aqua Orbital Overlap leads to SNOx extension to the low latitudes

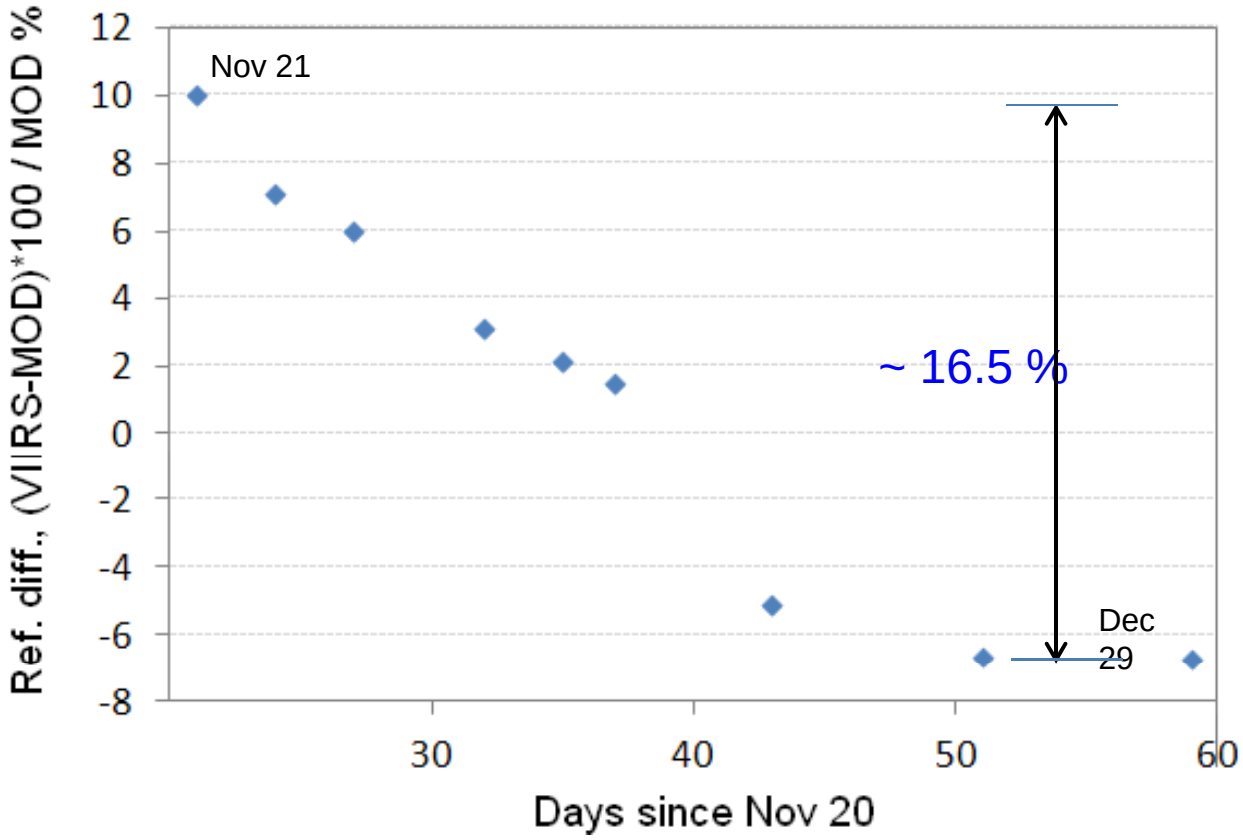


VIIRS Spatial Sampling Characteristics



M7 Channel Degradation

Date	VIIRS/MODIS reflectance difference
21-Nov	10.0% +/- 0.16%
24-Nov	7.10% +/- 0.33%
27-Nov	6.00% +/- 0.17%
02-Dec	3.10% +/- 0.19%
05-Dec	2.10% +/- 0.15%
07-Dec	1.50% +/- 0.15%
13-Dec	-5.10% +/- 0.21%
21-Dec	-6.65% +/- 0.13%
29-Dec	-6.69% +/- 0.27%



Note: the degradation (%) is calculated wrt MODIS as a reference (@ ~80% reflectance in the polar region).