VIIRS GSFC Ocean Science Team Report and Ocean Color Environment Data Record (EDR) Assessment

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Final version

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VIIRS GSFC OCEAN TEAM REPORT

CURRENT NPP CDR SHOWSTOPPERS

CALIBRATION MANEUVERS ARE NOT YET APPROVED

• **Lunar roll maneuvers** are a minimum requirement for NASA data continuity; needed to track trends in detector degradation during the mission.
• **Yaw maneuver** is required to characterize calibration system on-orbit only once or twice during the mission.
• [One-time **pitch-over maneuver** is also necessary to characterize RVS for SST.]

THERE IS NO MISSION-LEVEL REPROCESSING

There is no support for the application of vicarious gain across the entire data record, or to address on-orbit anomalies, or to address major algorithm changes. Mission-level reprocessing is a critical minimum requirement for a climate data record or to meeting product performance specifications.

ALGORITHMS ARE OUTDATED AND INCONSISTENT

Current operational NPP algorithms are inconsistent with NASA climate data record. Atmospheric correction is missing several years of development. Chl-***a*** algorithm was demonstrated to perform more poorly than current NASA selected algorithm.

These are currently unresolved, and preclude NPP from producing ocean color climate data records (CDR).

RISKS: Instrument Performance

Crosstalk - Optical crosstalk could have a significant impact on ocean color data quality. Polarization sensitivity, electronic crosstalk, and other uncertainty sources hamper characterization.

Out-of-Band Response - Larger than MODIS light leaks have be found in VIIRS; especially high in 412 & 551nm channels.

Spectral Characterization Uncertainty - characterization of crosstalk and out-of-band response show signs of significant uncertainty, which could hamper on-orbit correction. **There is a plan for NIST to test spectral response at S/C level with SIRCUS.**

High Risk*

SNR - Signal-to-noise ratio is comparable, but lower than MODIS in the 3:1 agg zone, but drops at higher scan angles. Impact to coverage needs to be evaluated.

Moderate Risk

Gain switch anomaly - at ~90% gain switch point, VIIRS has increased non-linearity and noise. Note that detectors do not switch at the same radiance (0-20% of L_{max}(HG)). M1 was observed switching below the L_{max}(HG) switch point, but red light leak may have pushed gain transition low in lab.

Low Risk

*** Risks to meeting NASA's data continuity requirements.**

RISKS: Calibration System

System Level Calibrator Test - RSB Calibrator system remains untested and considered at high risk. **There is a plan for NIST to test calibrator at S/C level with SIRCUS.**

High Risk — REDUCED

Calibration Packets for band M4 & M5 - Calibration packets were being substitute by DNB data during calibration, but this has been remedied. This was verified in FP-18 Day-in-the-Life testing data. It was noted however that transition between day and night mode is staggered over at least three scans.

High Risk — RESOLVED

SDSM misalignment - SDSM was manufactured with wrong orientation; may reduce number of measurements of the sun with characterized portion of SDSM screen.

Low Risk

RISKS: Postlaunch Activities

Vicarious Calibration Infrastructure Support - Potential assets and resources identified in IPO Ocean Cal/Val Plan: future support not completely clear.

High Risk

Validation Data Collection - Tasks and potential resources are identified in the IPO Ocean Cal/Val Plan. NASA SeaBASS possible repository for data. Are enough resources adequately supported?

Moderate Risk

OC Calibration Analysis Team - To meet minimum requirements it is critical to have a dedicated team to evaluate calibration data, including vicarious and lunar calibration data, and handle instrument calibration trends or anomalies. Personnel are identified in IPO Ocean Cal/Val Plan, but agency agreements are not in place.

Moderate Risk

Independent Assessment Team - An independent team to evaluate data quality is recommended. Tasks and personnel are identified in the IPO Ocean Cal/Val Plan, but agency agreements are not in place.

Moderate Risk

Recommendation: Perform gap analysis for Cal/Val resources and assets, in context of what is now known about VIIRS performance.

RISKS: Postlaunch Activities

Algorithm Change Pathway Long and Slow -

There are too many decision gates to approve algorithm changes. Working with the ocean color community for algorithm development is likely to be hampered.

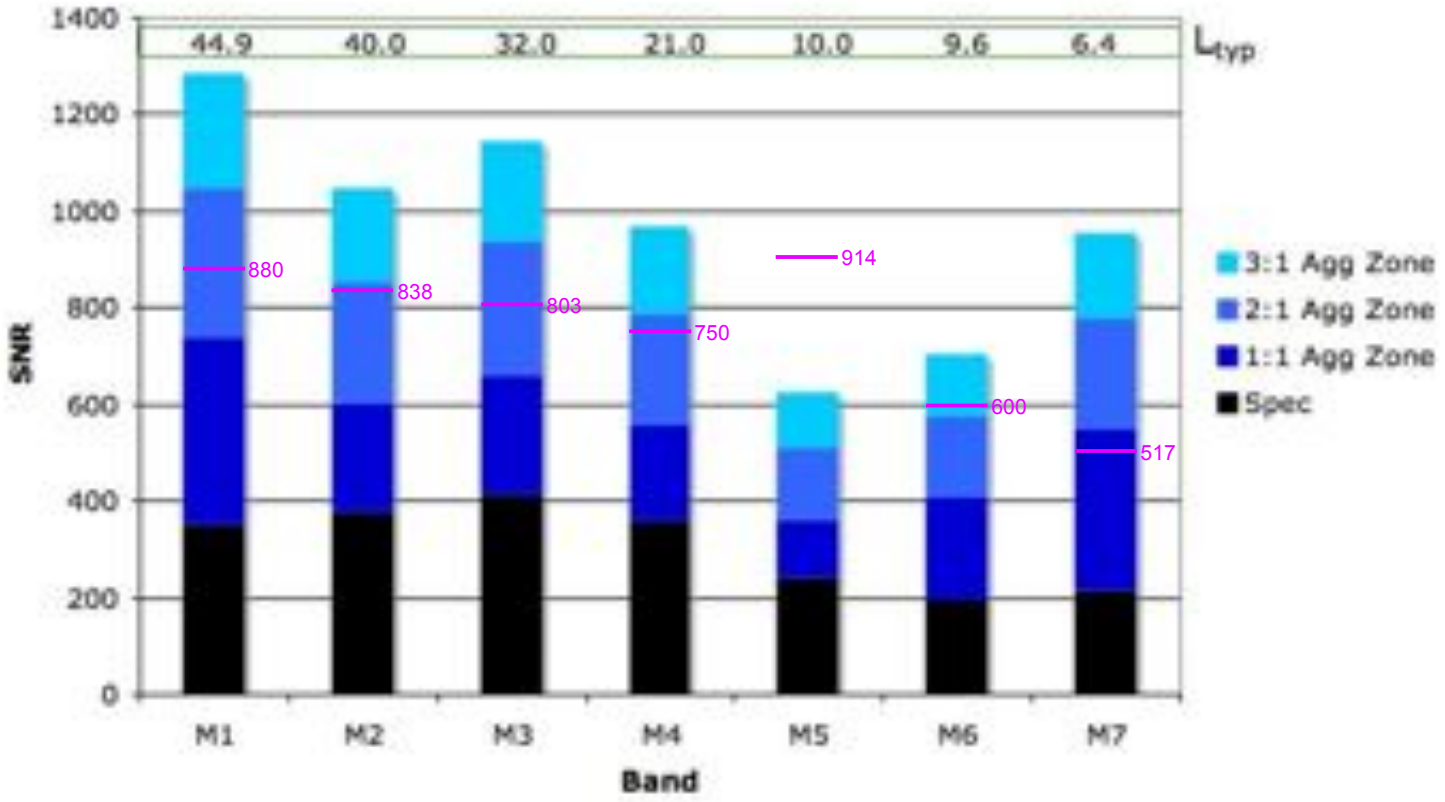
Moderate Risk


INSTRUMENT
PERFORMANCE

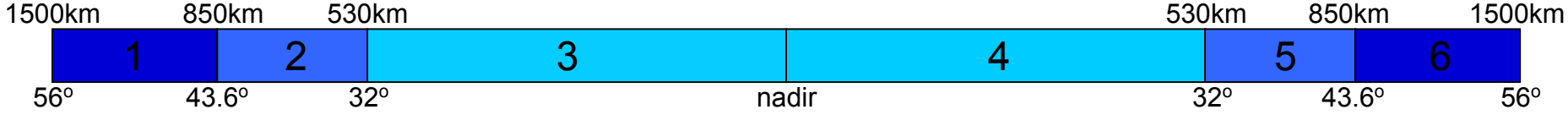
NPP VIIRS Radiometric Performance

Polarization Sensitivity		< MODIS, better characterized
Signal-to-Noise Ratio		< MODIS in visible bands, best in 3:1 agg zone, high in NIR
Noise		Systematic noise spikes, esp. blue bands (M1-3), ~3:10^{-6} freq.
Resolution		12 bits. (+1 for dual gain bands)
Dynamic Range		M1 (412nm) and M8 (1240nm) thought to switch gain lower than expected, but M1 probably due to red light leak artifact.
Linearity		Linearity < 0.15% for ocean bands. Characterization Uncertainty in spec.
Uniformity		Only the NIR (748 & 865nm) bands pass spec for gain uniformity.
Stability		Within 0.3% over one orbit for bus voltage, temperature.
Response Verses Scan		Meets requirements.
Near-field Response		comparable to MODIS, better than SeaWiFS. M7 does not pass EOL specification.
Stray Light		Meets spec with large margin (50-100%)

SNR@L_{typ} by Aggregation Zone



Scan Aggregation Zones



Dual-gain Bands - samples aggregated on ground.
Singe-gain Bands - samples aggregated on-board (only M6 for ocean bands).

source: MDFCB, 4 Nov 2004

NPP VIIRS Spectral Performance

• During EDU, anomalies in various tests were observed that were traced back to communication between band detectors.

• Three main types crosstalk were identified (other flavors exist of much less concern):

  • Optical
  • Static Electronic
  • Dynamic Electronic

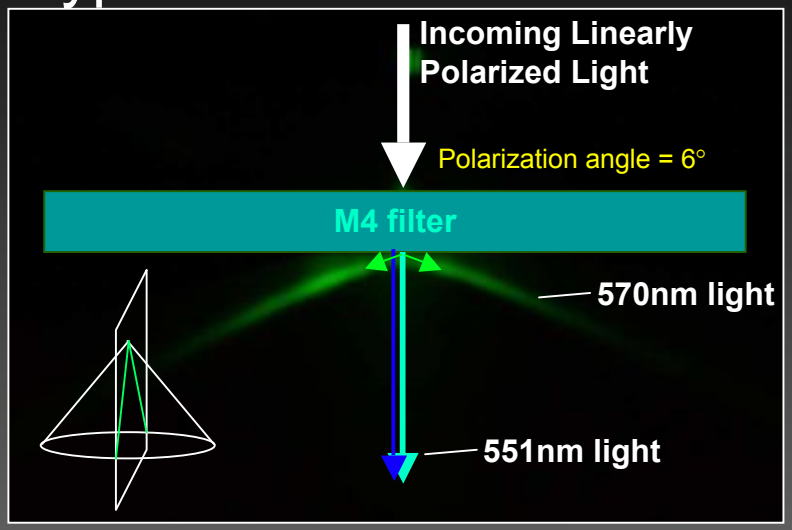
• Optical crosstalk is claimed to be an order of magnitude larger than static electronic crosstalk and has been considered the main concern.

• Dynamic crosstalk was greatly reduced by adding bonding wires to the focal plane assembly and is only expected to produce an effect along edges of very bright targets.

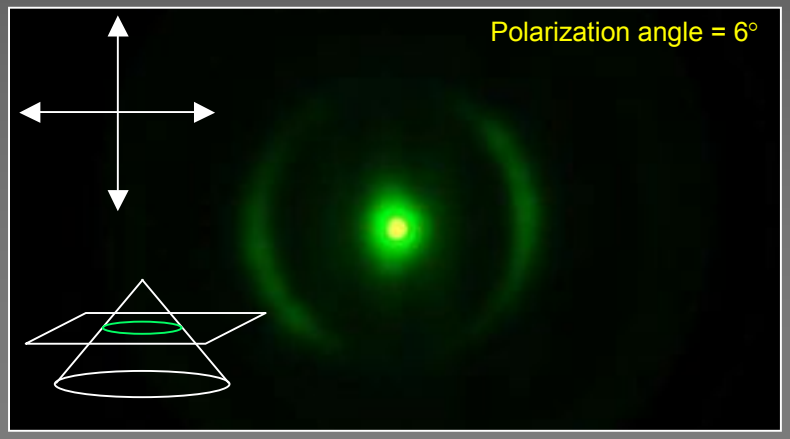
• In addition, a strong out-of-band response was discovered in FU1 during spectral response characterization.

FILTER LEAKS IN NPP VIIRS

Hyperbolic Cut

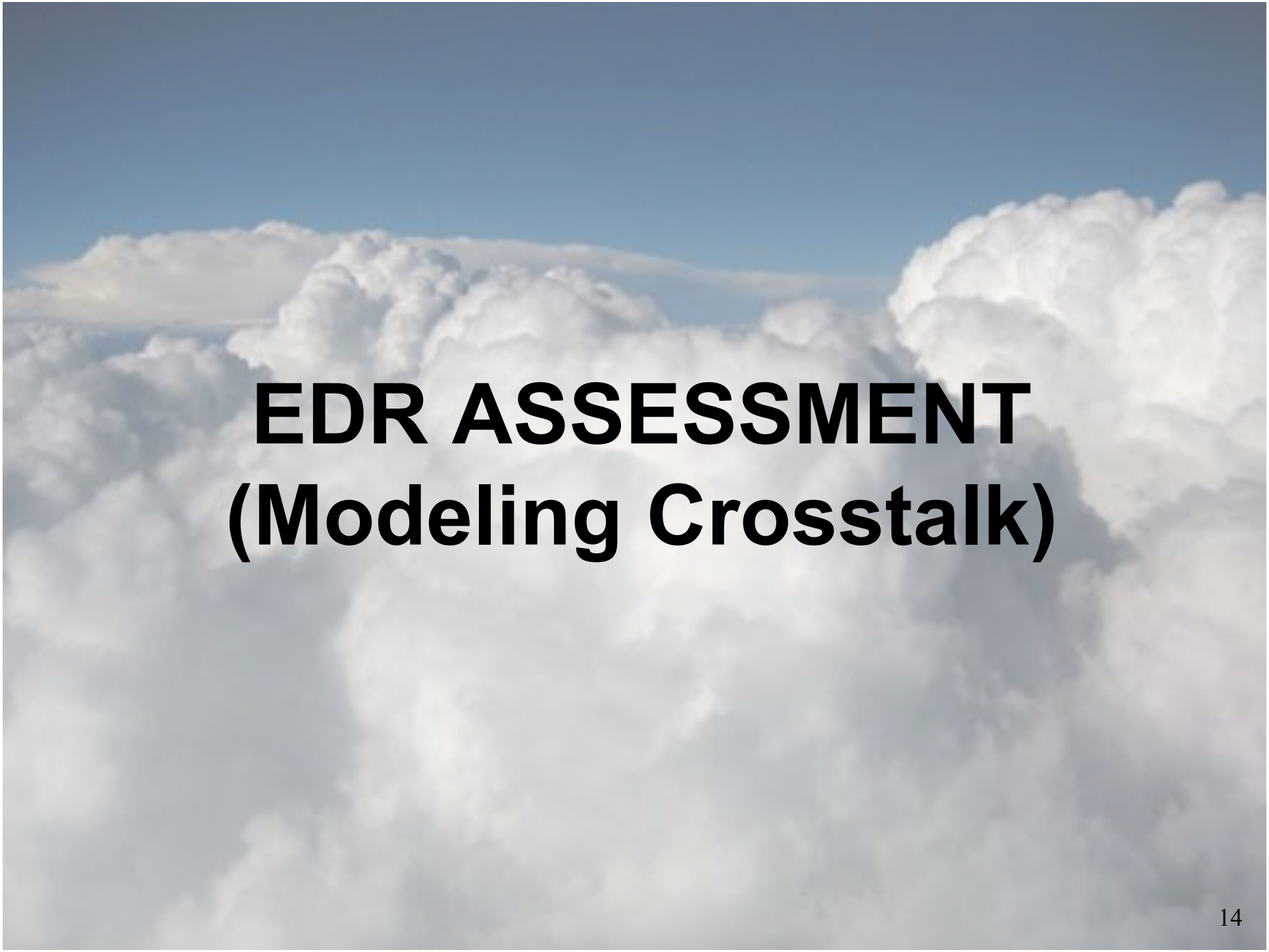


Circular Cut



- Scatter centers in filter direct light at specific out-of-band wavelengths to exit the filter in high-angle cones.
- In the scan direction, this extraneous out-of-band light is transmitted to other bands as “inter-band” optical crosstalk.
- In the track direction, the same produces out-of-band stray light that has been called “intra-band” crosstalk.
- In the principal tests to characterize spectral response, “intra-band” crosstalk is indistinguishable from directly transmitted (non-scattered) out-of-band leakage.
- Polarization causes exiting light to form lobes in the direction of the E vector.

Based on 5-10 second exposure photos by Pete Fuqua (Aerospace Corp.)
Feb 11, 2009


EDR ASSESSMENT
(Modeling Crosstalk)

NPP VIIRS Crosstalk Impact Assessment

- Work by Northrop Grumman, Raytheon, MIT Lincoln Labs, Aerospace and NASA have contributed over three years to understanding crosstalk in VIIRS, leading to a model heavily based on characterization data.
- As a numerical experiment, this model was extended to predict the result if MODIS had crosstalk similar to VIIRS.
- Unlike previous exercises that focused on the worst case scenario, this current experiment excludes the out-of-band influence in the crosstalk model.
- Out-of-band effects are more difficult to evaluate since their characterization are an integral part of the ocean color algorithm.

NPP VIIRS Crosstalk Impact Assessment

LIMITATIONS

The current model and this analysis of the results are **entirely preliminary** (caveat emptor!).

There are many sources of uncertainty that have not been bounded.

In modeling VIIRS crosstalk in MODIS :

- A crude model of point-to-point propagation is applied,
- Interpolation and weighting schemes are used to map to and between MODIS bands, and
- Electronic crosstalk is not included in the modeling.

Also, further stratification of results will be needed to assess impact to specific science questions.

NPP VIIRS Crosstalk Impact Assessment

L2 Flags used to select high quality pixels

ATMFAIL	Atmospheric correction failure
LAND	Pixel is over land
CLDICE	Probable cloud or ice contamination
HILT	TOA radiance is high
STRAYLIGHT	Straylight contamination is likely

200 pixels trimmed from swath edge to remove bow tie effect.

HISATZEN	satellite zenith threshold < 60 degree
COCCOLITH	Coccolithofores detected
LOWLW	Very low water-leaving radiance (cloud shadow)
CHLFAIL	Derived product algorithm failure
CHLWARN	Derived product quality is reduced

NAVWARN	Bad navigation
MAXAERITER	Aerosol iterations exceeded max
ATMWARN	Atmospheric correction failure
HISOLZEN	High solar zenith
NAVFAIL	Bad navigation

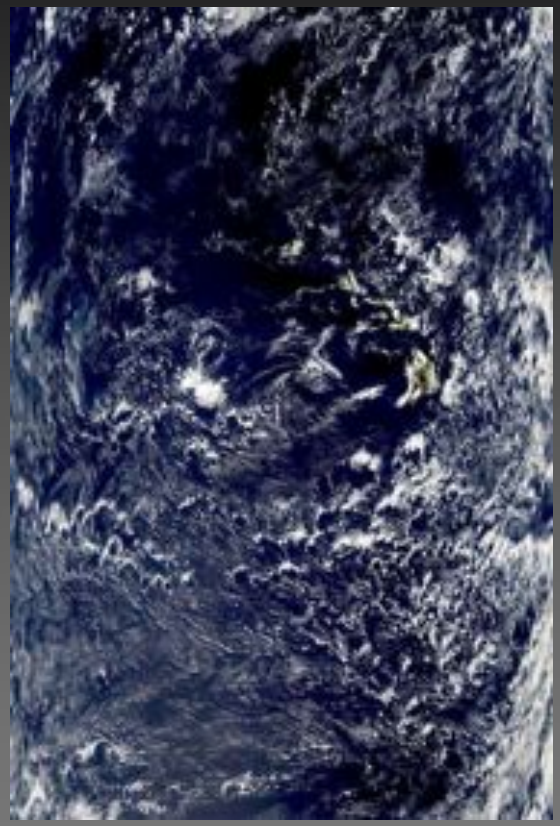
FILTER	Pixel rejected by user-defined filter
SSTWARN	SST quality is reduced
SSTFAIL	SST quality is bad
HIGLINT	High sun glint

RED - Flags used for coastal scenes with fewer ideal pixels

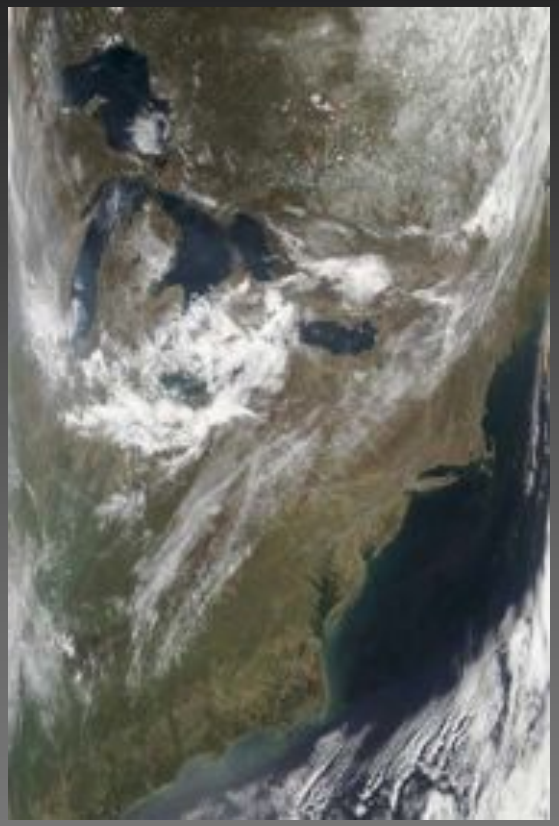
NPP VIIRS Crosstalk Impact Assessment

A20031711810
Argentina, 20 June 2003

A20040332355
Hawaii, 2 February 2004



A20051071815
East USA, 17 April 2005

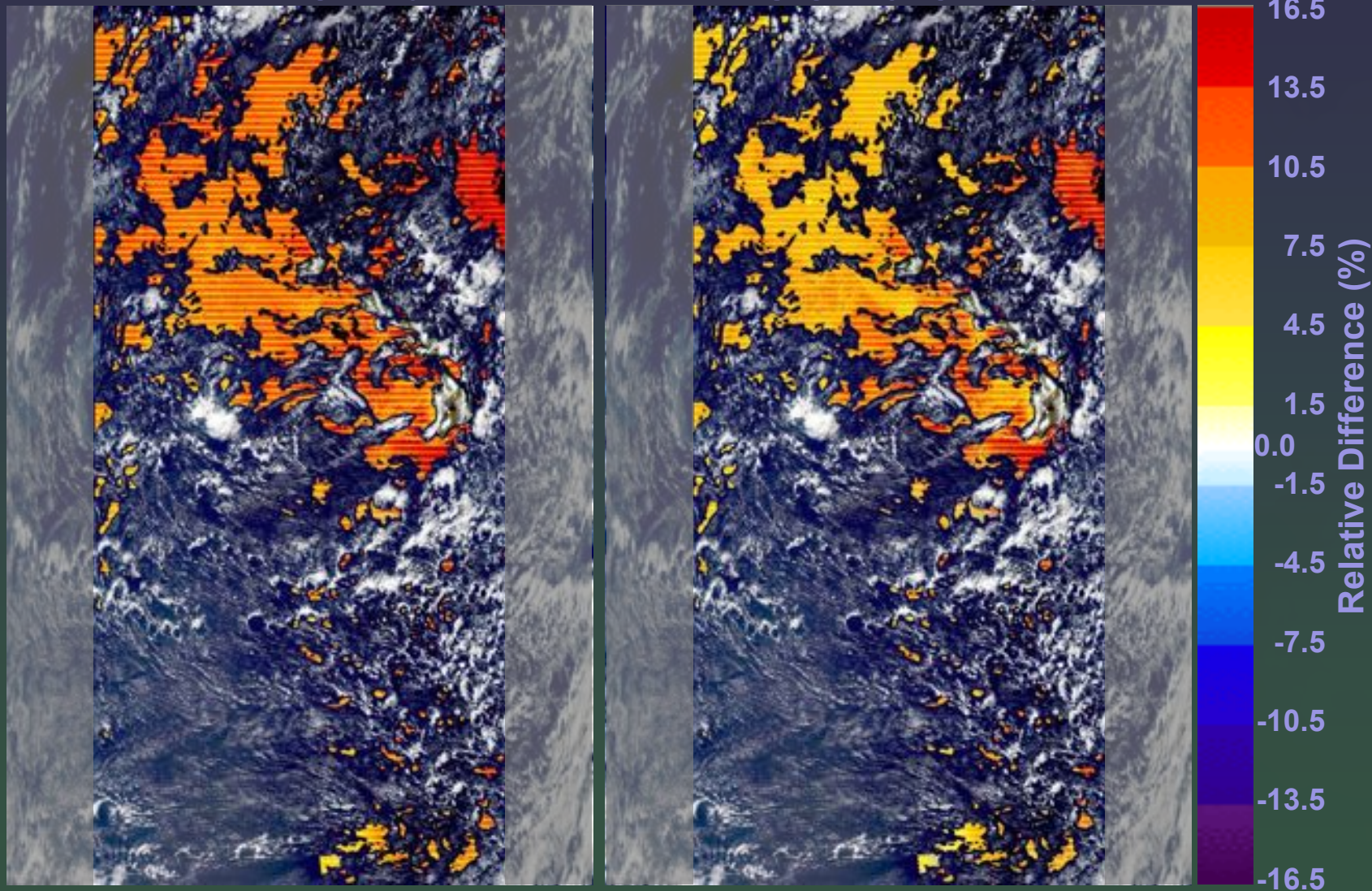


Three scenes were selected: one open ocean near the vicarious calibration site and the other two with coastal and in-land waters.

Special thanks to NICST for all their hard work in creating these modeled scenes.

NPP Chl-a

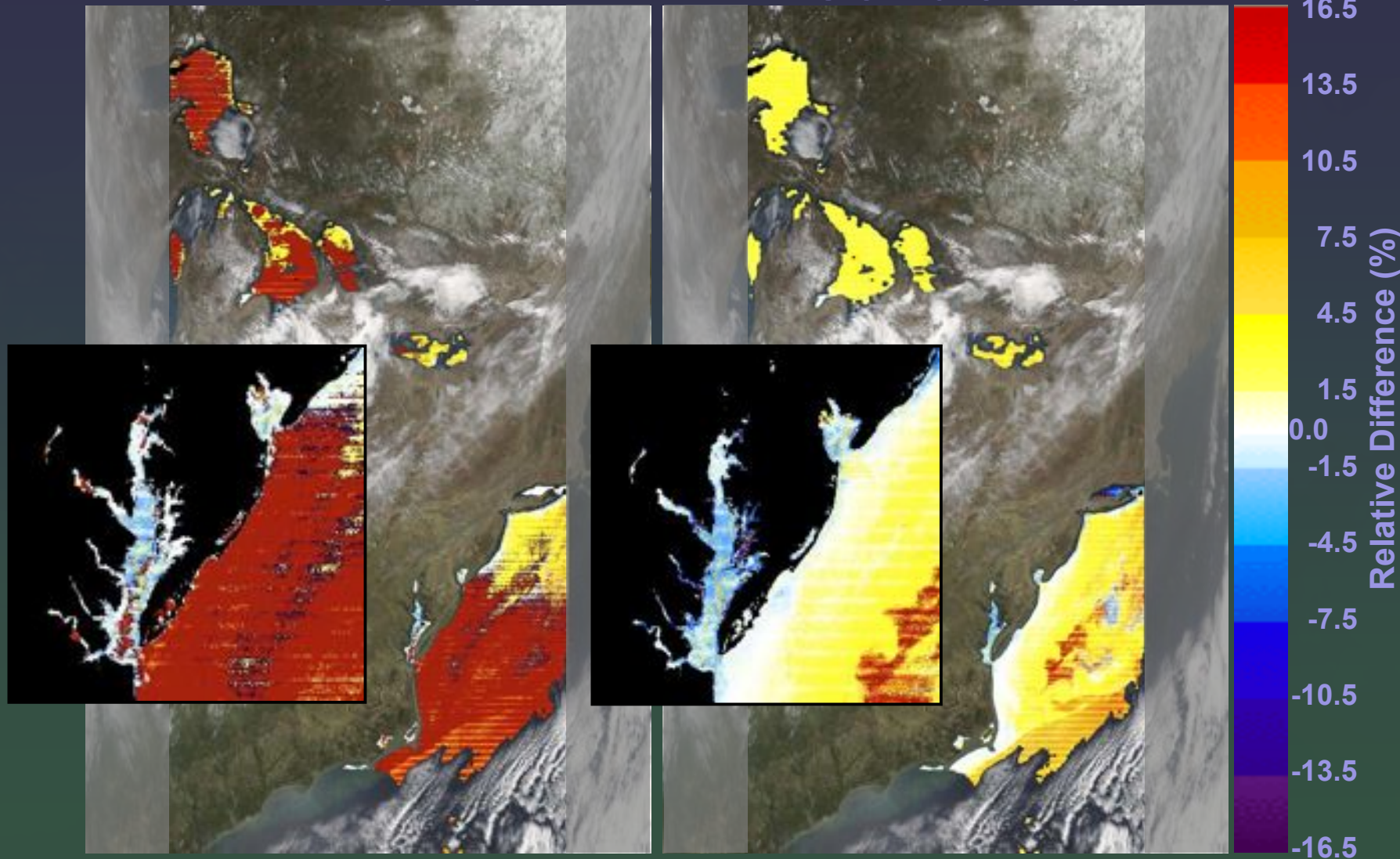
OCM3 Chl-a



A20040332355 - Hawaii 2 February 2004

NPP Chl-a

OCM3 Chl-a



A20051071815 - East USA 17 April 2005

NPP VIIRS Crosstalk Impact Assessment

Region Bias and Variation Summary Stats

REGIONAL BIAS

	A20031711810 Argentina	A20040332355 Hawaii	A20051071815 East USA
Chl a			
OCM3	3.7%	8.8%	2.8%
NPP	16.6%	11.0%	21.1%
nLw			
412 nm	-1.9%	0.2%	3.3%
443 nm	-7.0%	-1.1%	-1.7%
488 nm	-1.7%	0.0%	0.8%
547 nm	0.2%	2.8%	1.9%
667 nm	3.2%	**14.2%**	9.8%
Lt			
412 nm	-0.1%	-0.1%	-0.1%
443 nm	**-0.3%**	**-0.3%**	**-0.3%**
488 nm	-0.1%	-0.1%	-0.1%
547 nm	0.0%	0.0%	0.0%
667 nm	0.1%	0.1%	0.1%
748 nm	0.1%	0.1%	0.1%
869 nm	**0.5%**	**0.4%**	**0.5%**

REGIONAL VARIATION

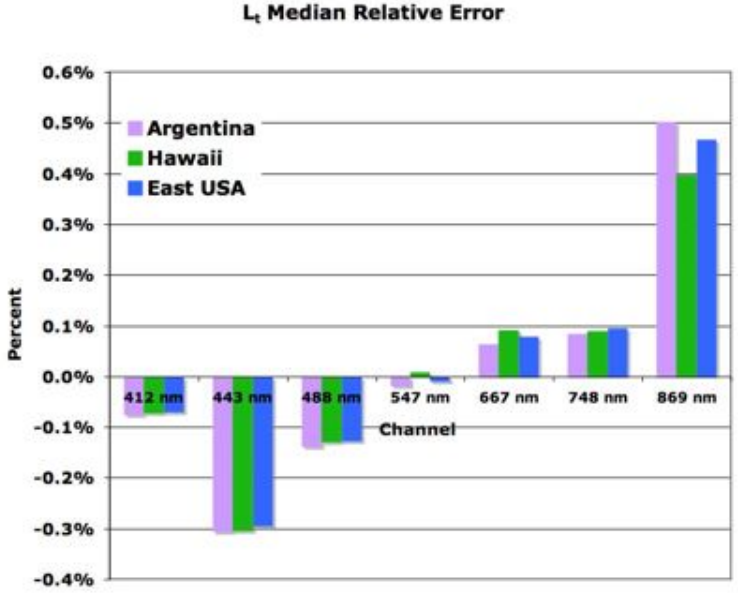
	A20031711810 Argentina	A20040332355 Hawaii	A20051071815 East USA
Chl a			
OCM3	2.86%	2.85%	2.41%
NPP	11.36%	2.81%	**87.33%**
nLw			
412 nm	1.21%	0.27%	**9.23%**
443 nm	2.40%	0.32%	3.43%
488 nm	0.83%	0.31%	2.30%
547 nm	0.92%	1.25%	2.20%
667 nm	2.38%	**10.00%**	**10.33%**
Lt			
412 nm	0.01%	0.01%	0.01%
443 nm	0.04%	0.04%	0.04%
488 nm	0.02%	0.02%	0.02%
547 nm	0.01%	0.01%	0.01%
667 nm	0.01%	0.02%	0.01%
748 nm	0.02%	0.03%	0.02%
869 nm	0.12%	0.12%	0.10%

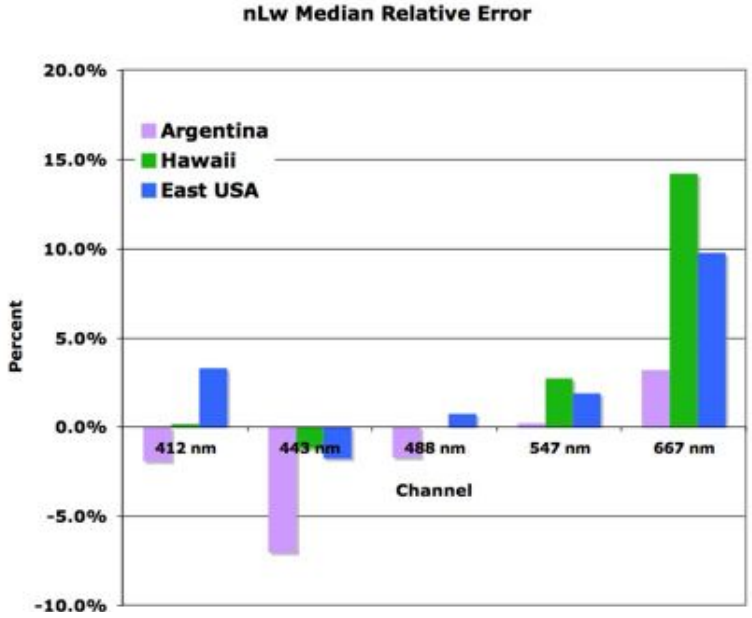
869 and 443nm bands show the most effect for TOA radiance. Other bands show tolerable levels of crosstalk impact.

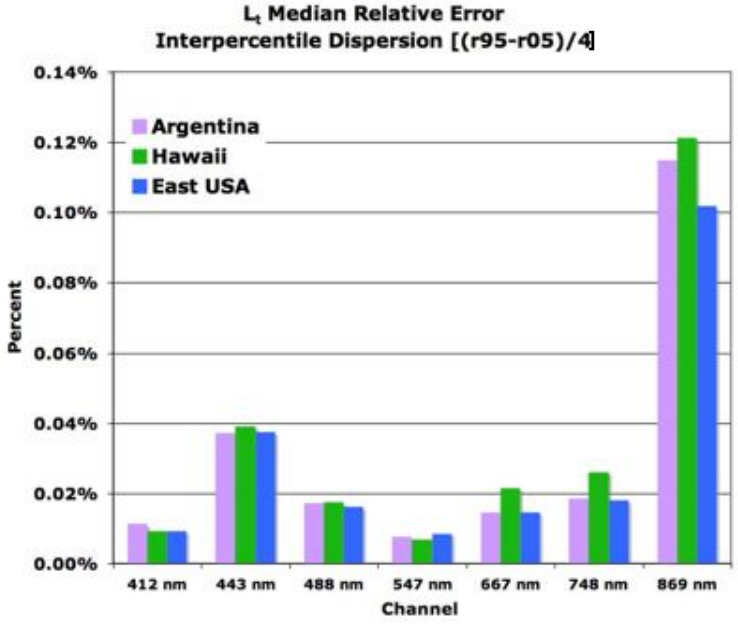
Based on current data, optical crosstalk alone produces a modest, but significant impact to ocean color products - but less than previous worst case scenarios.

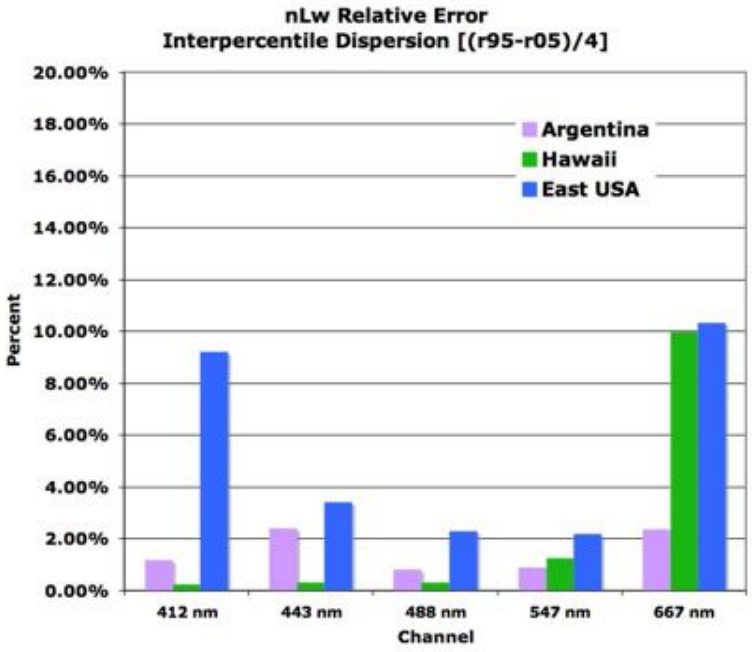
NASA algorithm is more resilient to crosstalk than the operational NPP alogorithm which appear to be devastated by this effect.

Region Bias and Variation Summary Stats





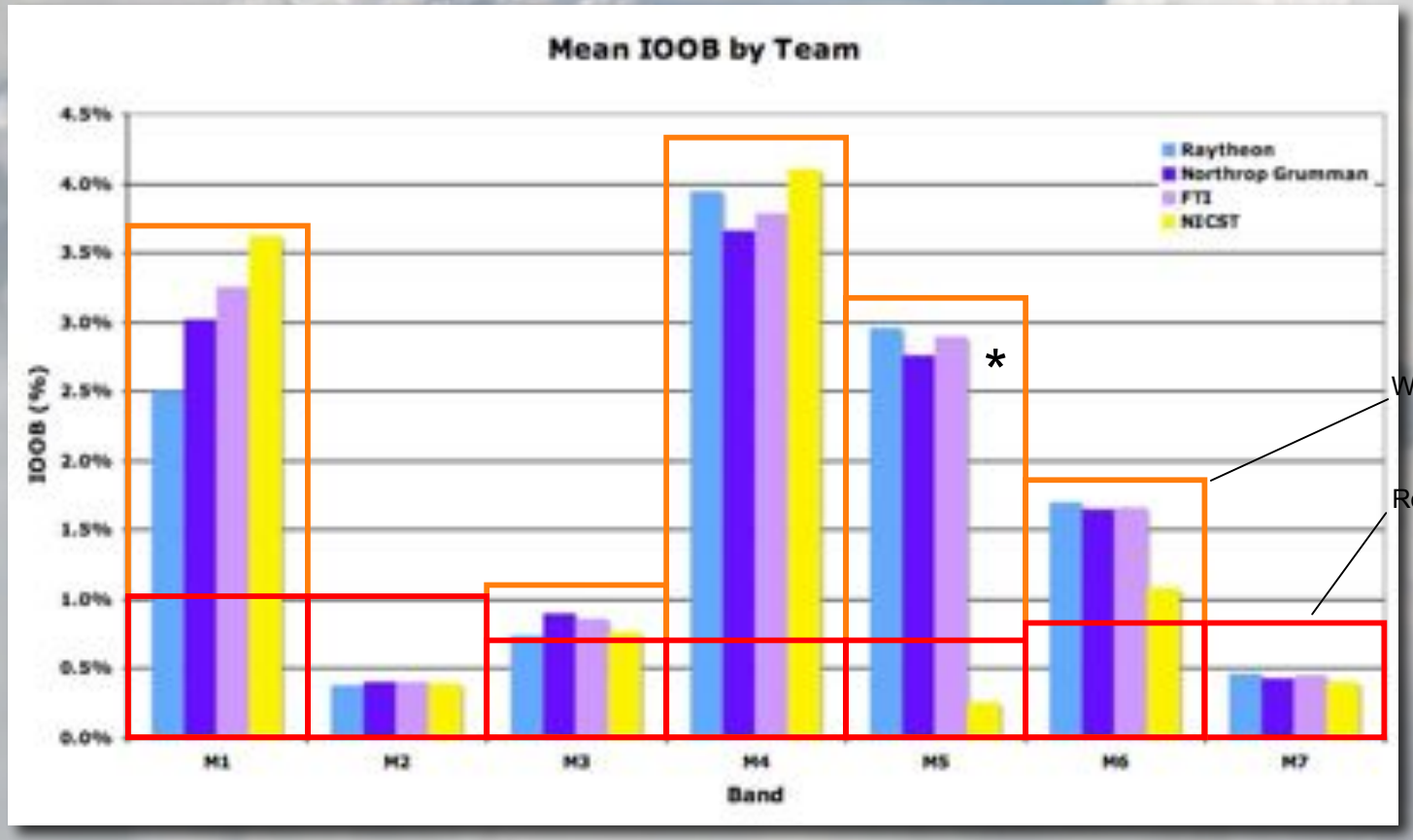




EDR ASSESSMENT
(Out-of-Band Light Leaks)

NPP VIIRS Spectral Performance

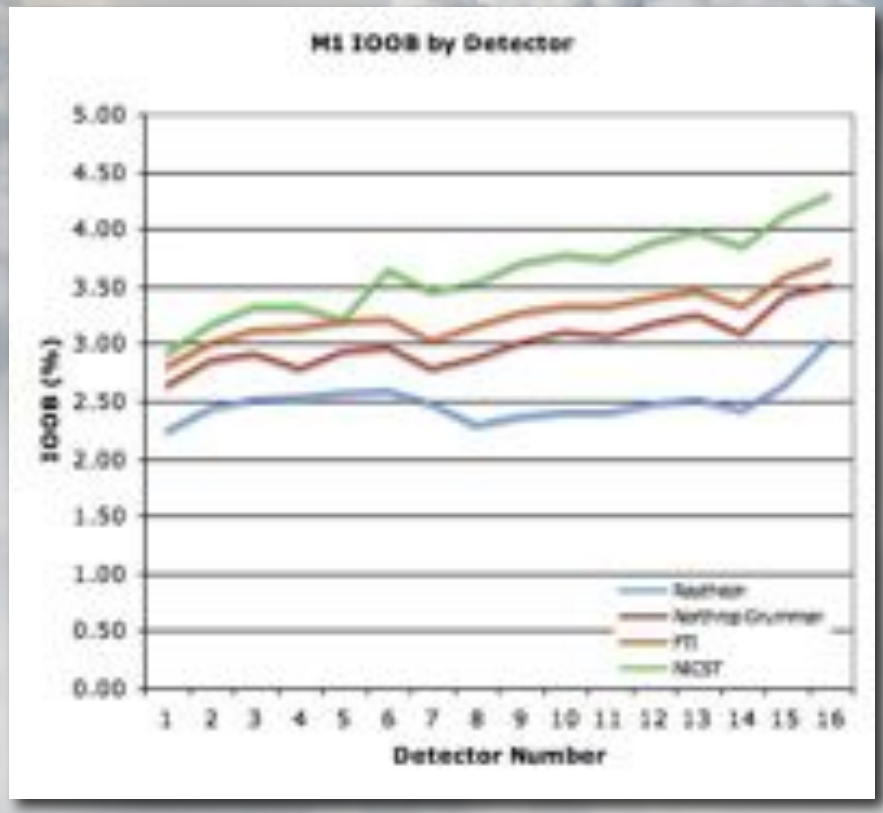
NPP VIIRS FU1 has a much larger out-of-band response than EDU (or MODIS).

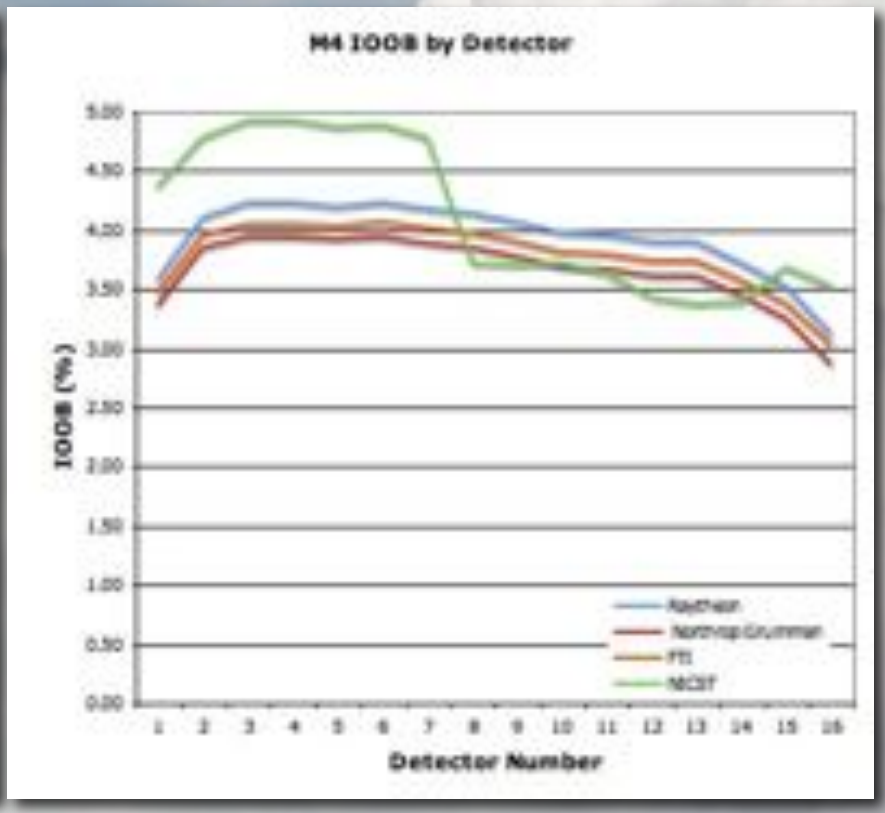


* NICST now predicts a value comparable to the other teams for M5.

NPP VIIRS Spectral Performance

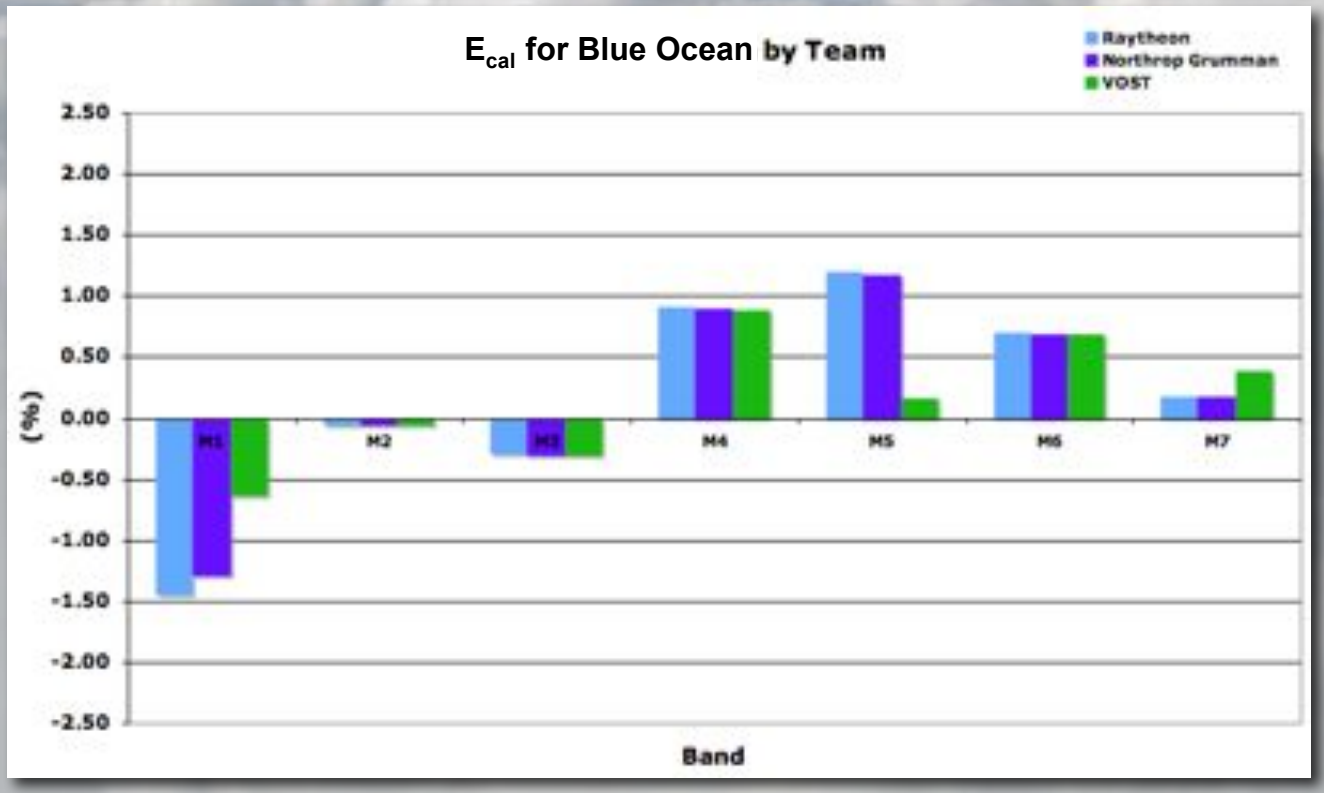
NPP VIIRS FU1 results have yielded significant differences between detectors and between analysis teams.





NPP VIIRS Spectral Performance

Taking the differences of the radiometric errors from the OOB response when measuring a blue ocean and the solar diffuser provide an estimate of the reflectance error.




SUMMARY

SUMMARY

NPP VIIRS RISKS:

- **NPP VIIRS simply cannot produce science or climate quality ocean color data without 1) reprocessing, 2) maneuvers, and 3) current NASA selected and developed algorithms.**

- A gap analysis is recommended for Cal/Val resources and assets in the context of what is now known about VIIRS performance; agency agreements need to be in place for IPO Cal/Val plan to be successful.

- VIIRS spectral response and crosstalk issues remain a major concern, especially regarding uncertainty and whether any on-orbit correction will be viable.

- VIIRS radiometric performance would otherwise be good, barring concern for moderate SNRs and possible striping.

SUMMARY

CROSSTALK EDR ASSESSMENT:

Very preliminary, crosstalk model, based on the latest data, was applied to three MODIS scenes (one open ocean, two with coastal and in-land waters).

RESULTS

- Impact is smaller without out-of-band, but significant crosstalk was still produced in the 443nm and 869nm channels of the MODIS data (~0.3% and ~0.4%, respectively, for TOA radiance).
- Normalized water-leaving radiance and Chl-*a* showed regional biases and variation that often met NPP EDR performance requirements, but consumed a large amount of the error budget.
- Data products for coastal and in-land water had the greatest impact.
- NASA Chl-*a* algorithm (OCM3) was more robust in the presence of crosstalk than the NPP operation algorithm, especially in coastal waters.

SUMMARY

OUT-OF-BAND LIGHT LEAK:

- **A significant out-of-band response was found in the FU1 spectral characterization.**

- Only the 443nm and 865nm channels remain clearly within specifications; all other ocean bands fail spec.

- It is not clear, given the currently poorly bounded uncertainties, whether conventional methods of correction would be adequate.

- Further study of correction method's efficaciousness will be needed to complete EDR assessment.

Uncertainty and complexity in the characterization/modeling of crosstalk and out-of-band response are of great concern.

SUMMARY

PATH FORWARD:

- Determine an upper bound for uncertainty in the effects of crosstalk and out-of-band response.

- NIST SIRCUS might assist in quantify some of the net uncertainty.

- Assess the viability of existing out-of-band correction schemes given magnitude and uncertainty of the behavior.

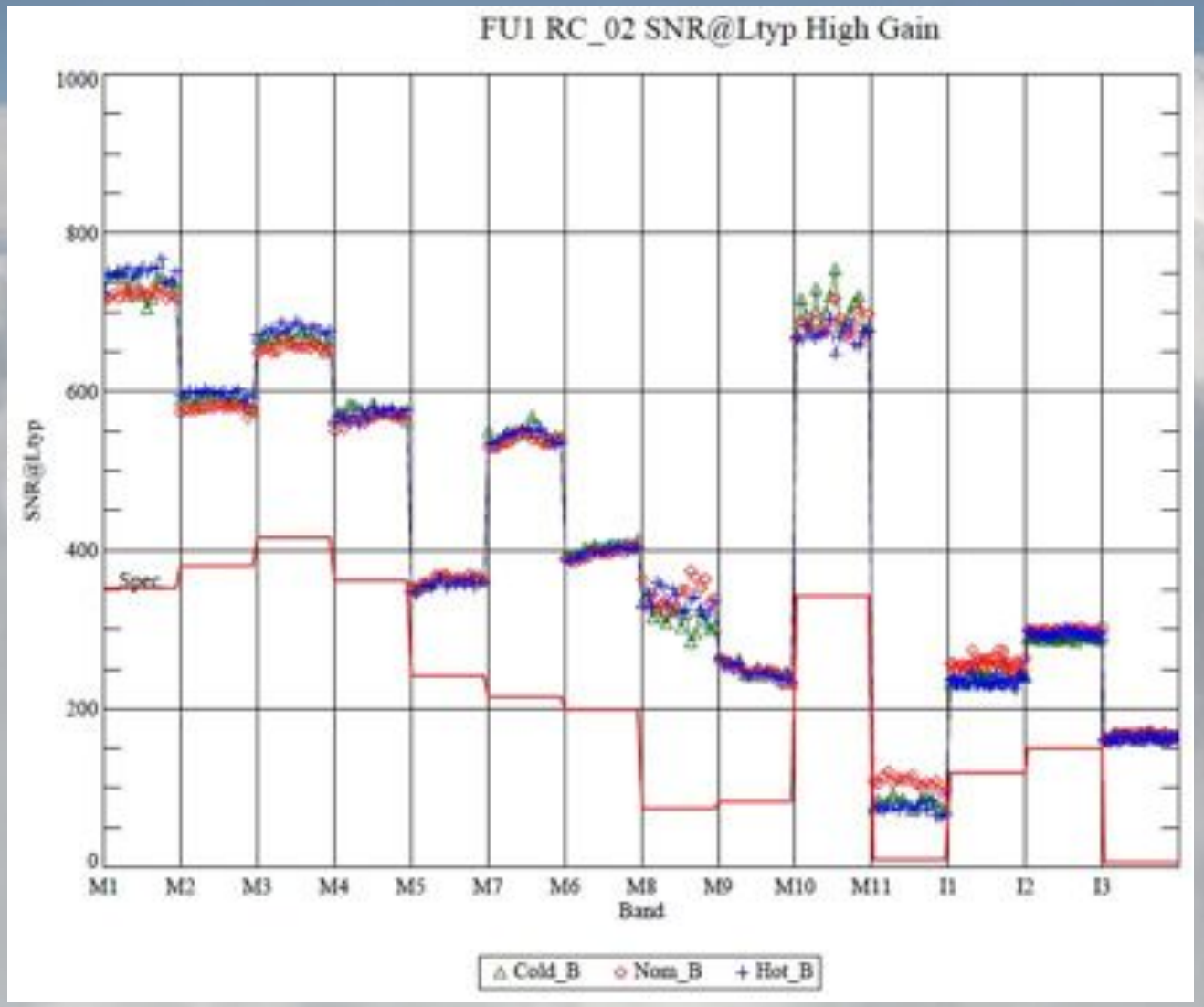
- Evaluate techniques to mitigate crosstalk effects, given uncertainty.

- Assess performance on-orbit in context of what was learned prelaunch.


BACKUP SLIDES

SNR

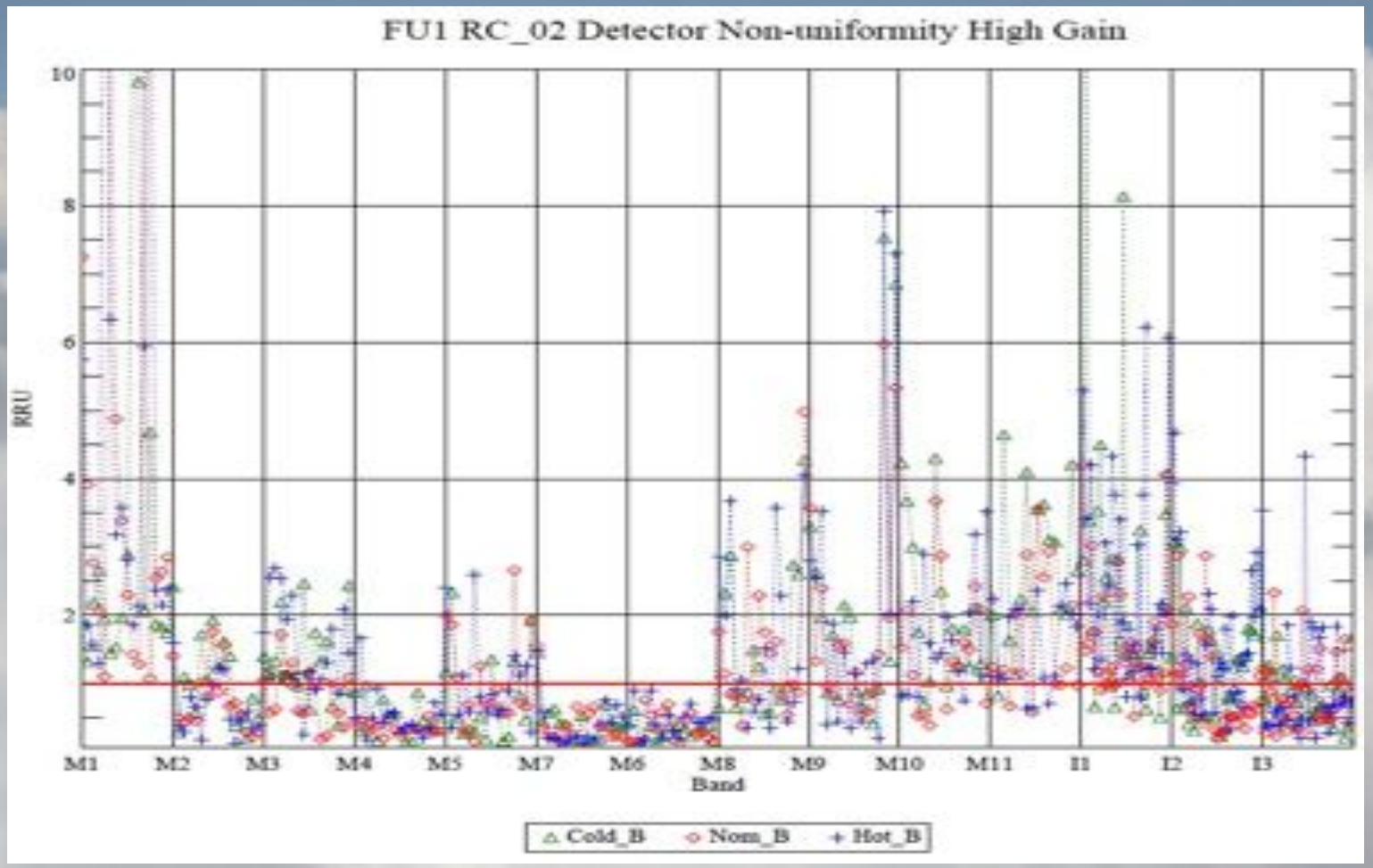
Performance



From Junqiang Sun (NICST), 25 Jan 2010. VIIRS F1 Pre-Launch Calibration and Characterization: *Reflective Solar Band Radiometry,* slide 19.

Uniformity

Performance

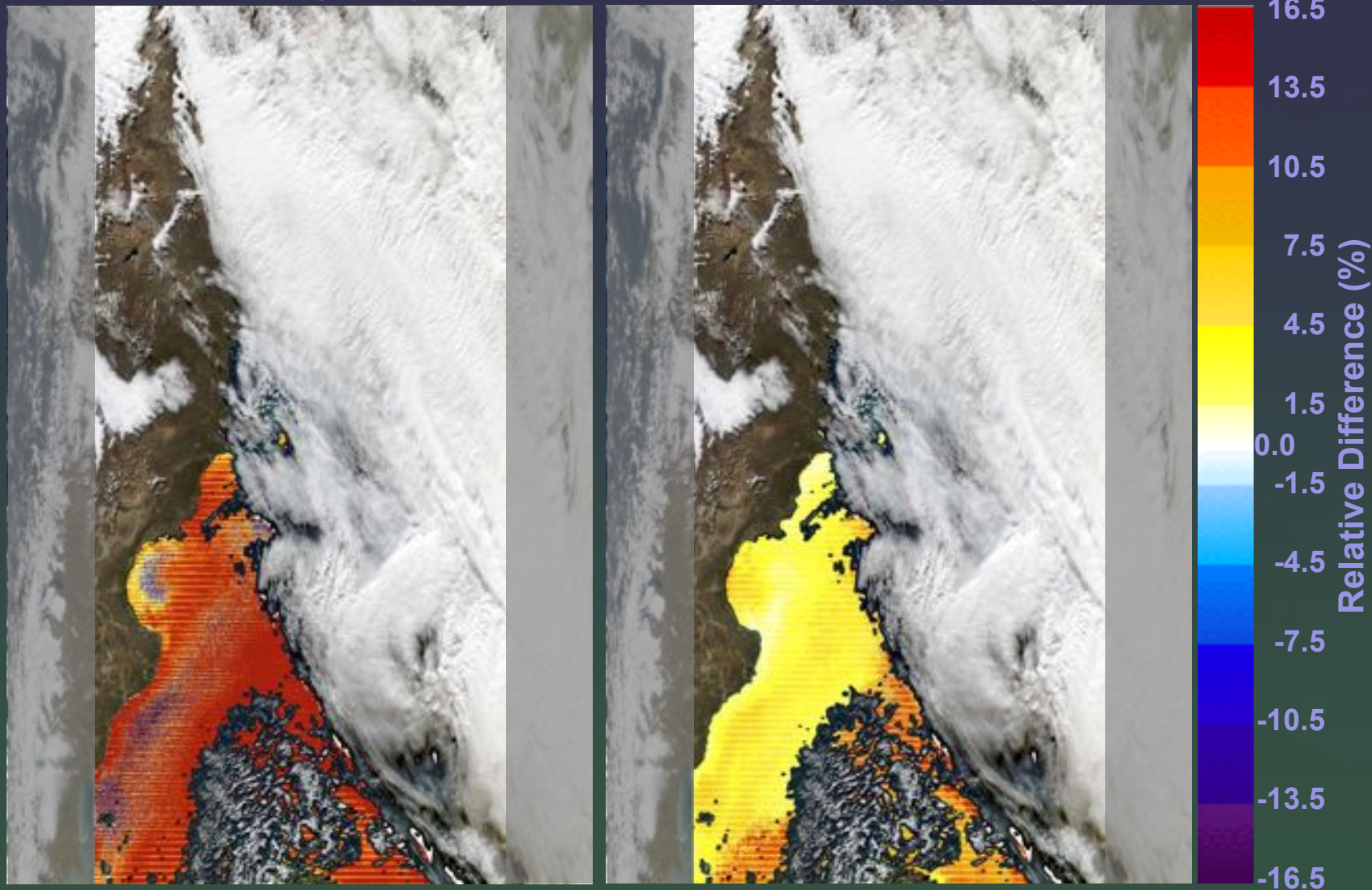


There are detectors in all bands except M6-M7, which do not satisfy the specification

From Junqiang Sun (NICST), 25 Jan 2010. VIIRS F1 Pre-Launch Calibration and Characterization: *Reflective Solar Band Radiometry,* slide 26.

NPP Chl-a

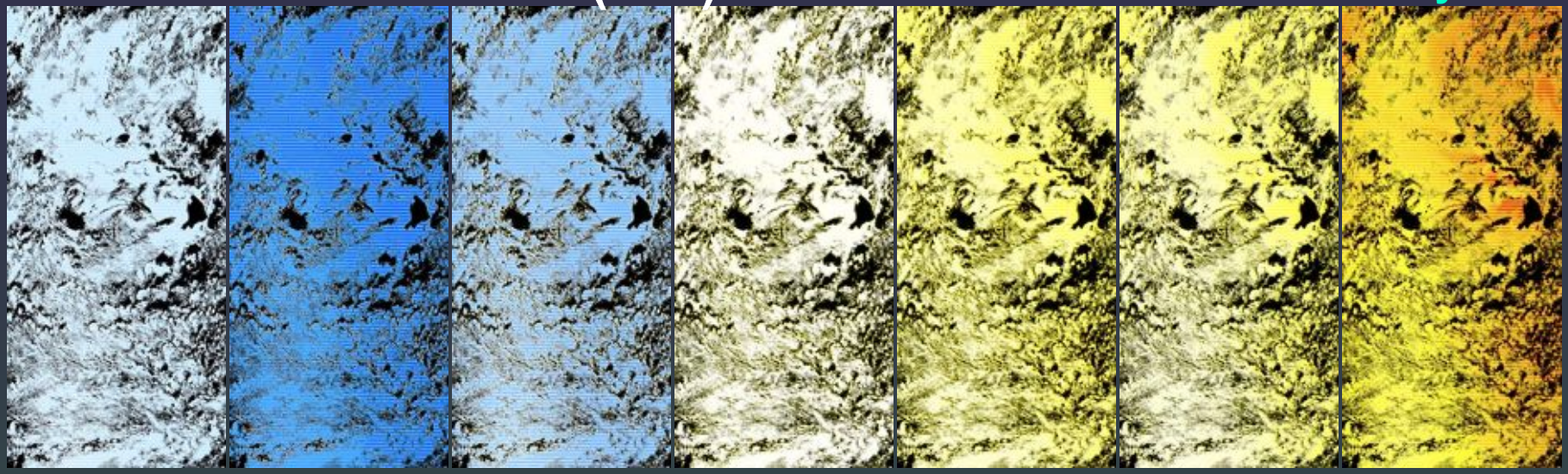
OCM3 Chl-a



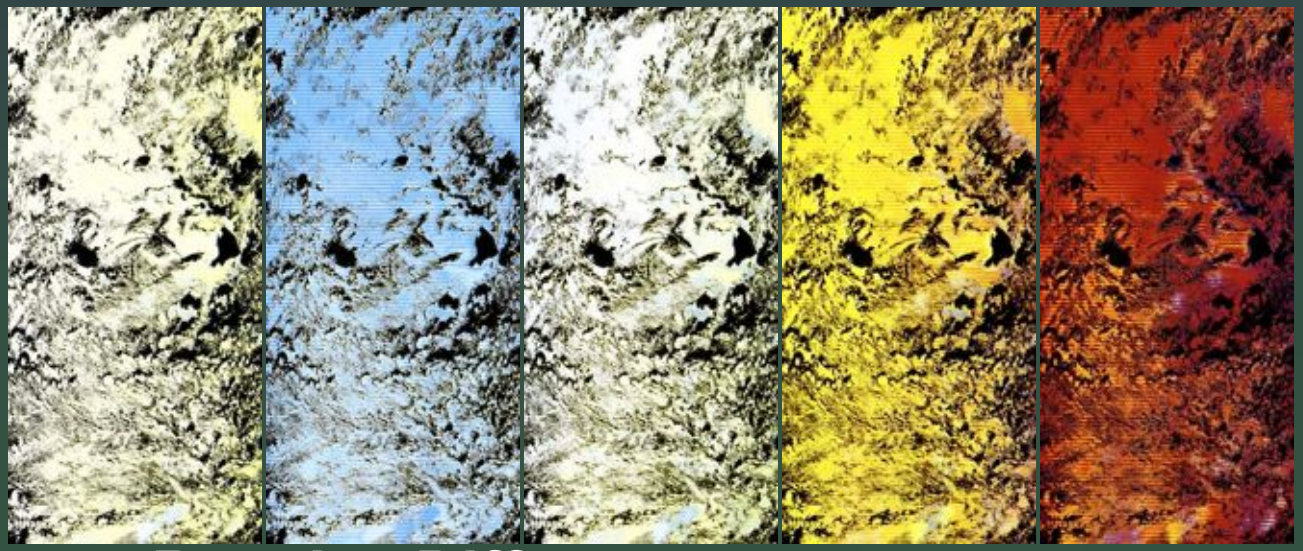
A20031711810 - Argentina 20 June 2003

Lt Relative Difference (x10)

A20040332355 - Hawaii 2 February 2004



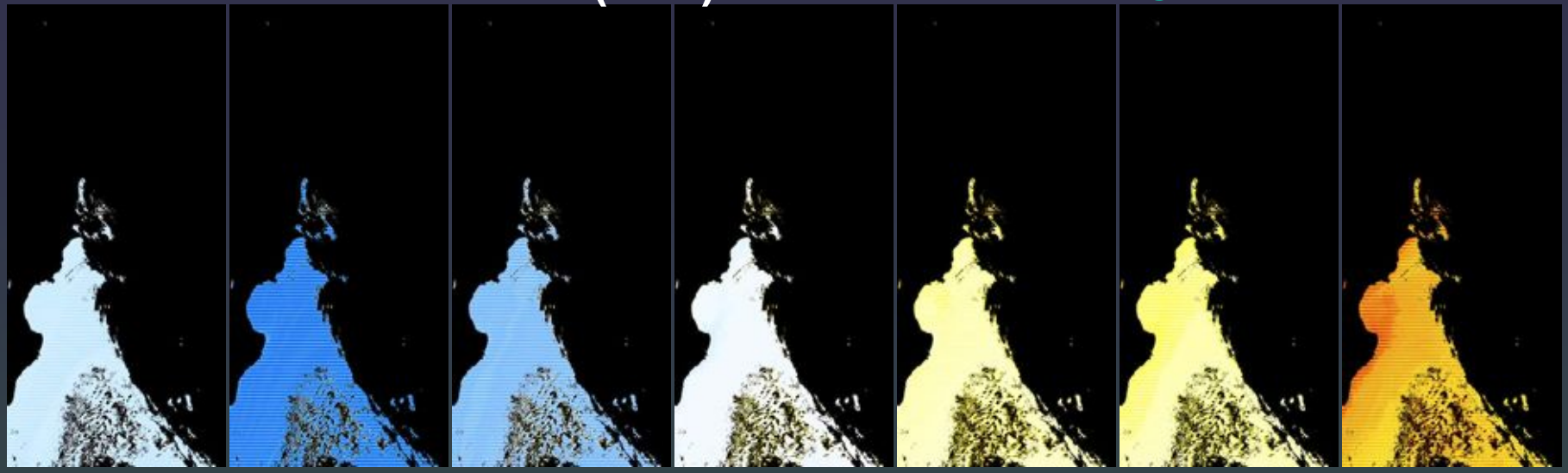
412nm 443nm 488nm 547nm 667nm 748nm 859nm



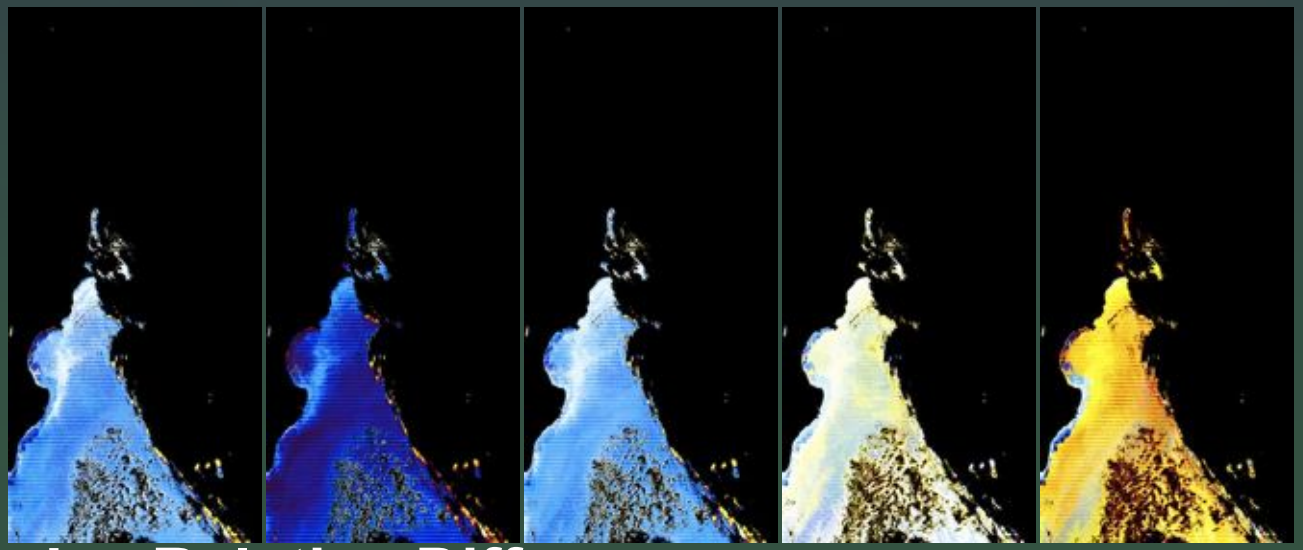
nLw Relative Difference

Lt Relative Difference (x10)

A20031711810 - Argentina 20 June 2003



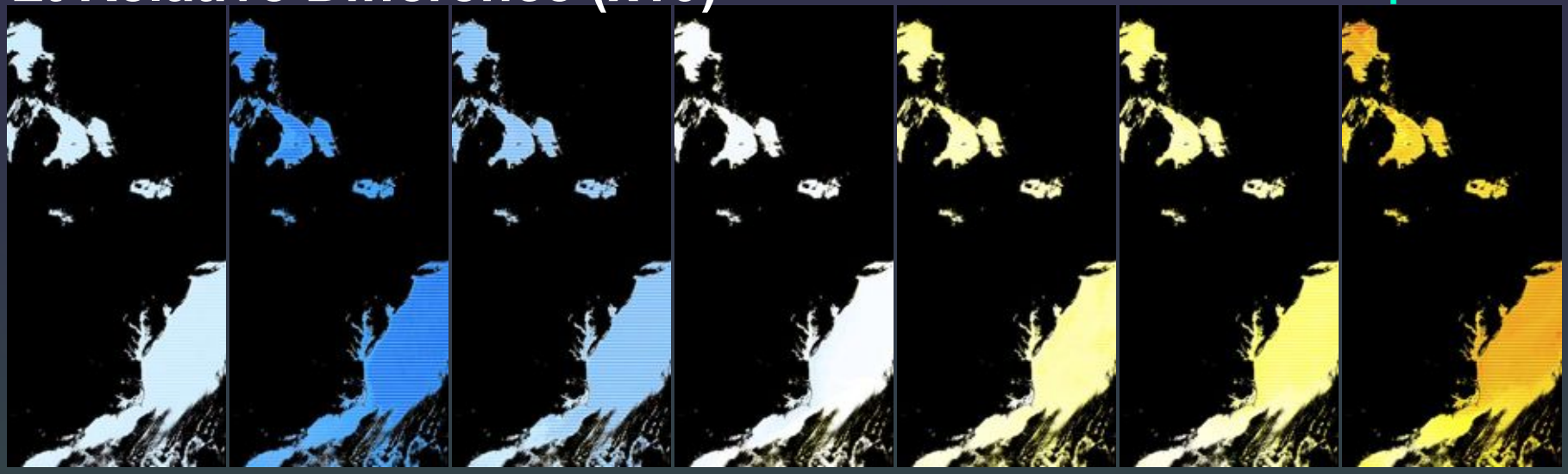
412nm 443nm 488nm 547nm 667nm 748nm 859nm



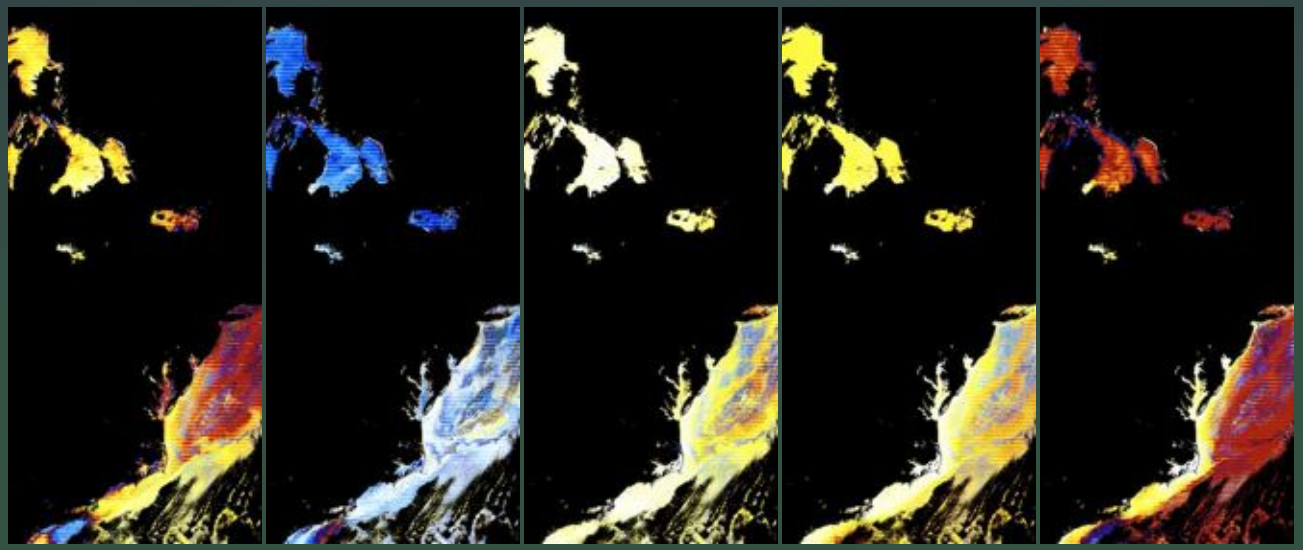
nLw Relative Difference

Lt Relative Difference (x10)

A20051071815 - East USA 17 April 2005



412nm 443nm 488nm 547nm 667nm 748nm 859nm

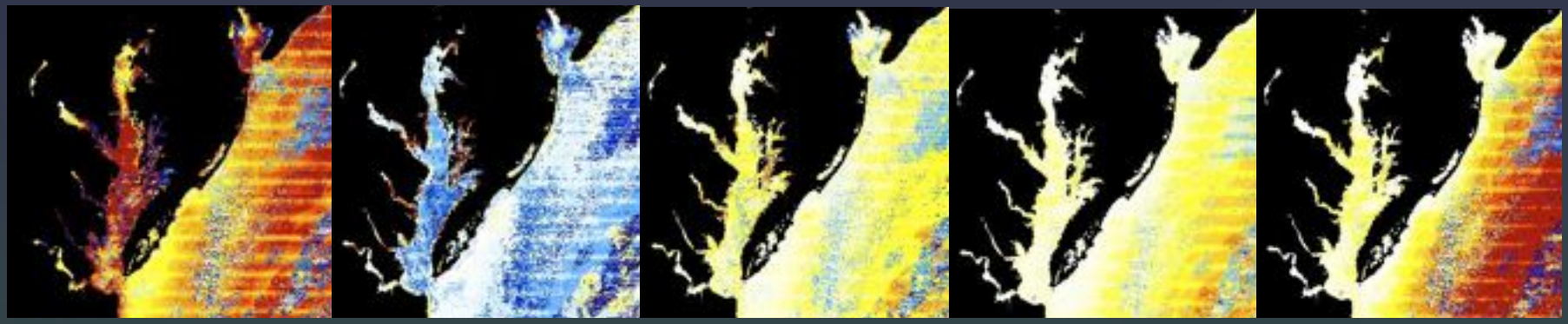


nLw Relative Difference

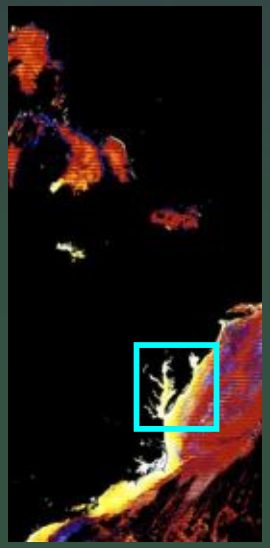
A20051071815 - East USA 17 April 2005

Blow-up of DelMarVa Penninsula Region

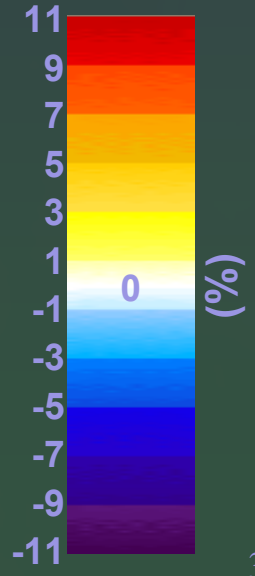
nLw Relative Difference



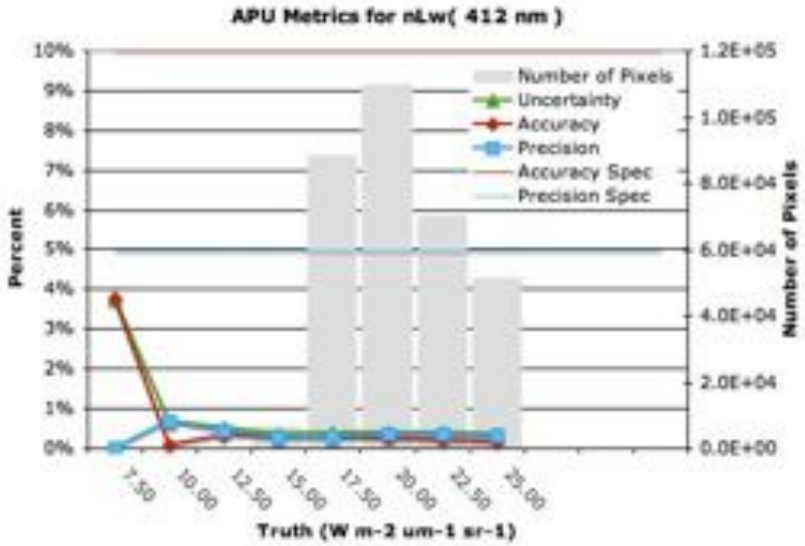
412nm 443nm 488nm 547nm 667nm

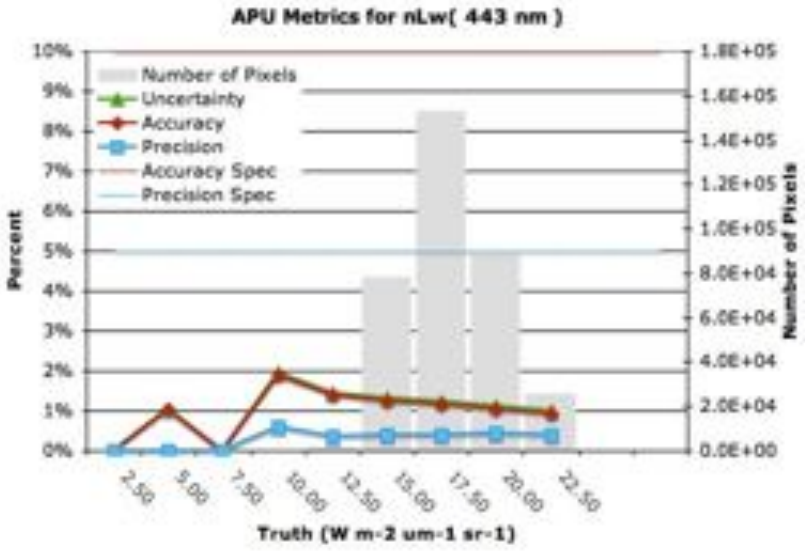


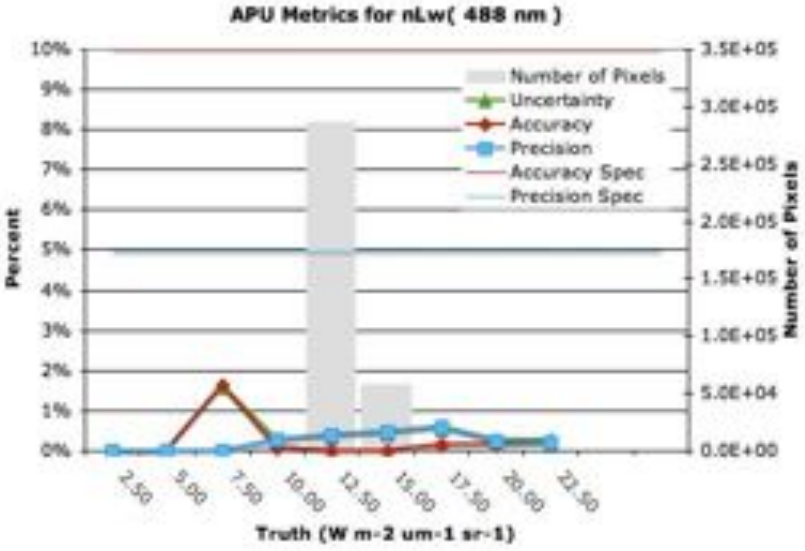
The East USA scene was specifically selected to look at particular geographic regions. The above inset shows the neritic Atlantic waters that are fed by the Chesapeake and Delaware bays. Differences in response between turbid and clearer water can be seen.

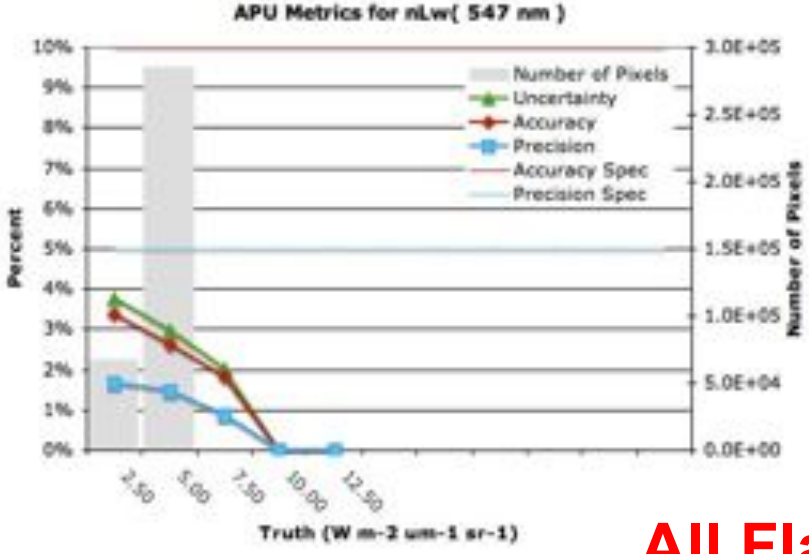


Region Bias and Variation Stratified by Value





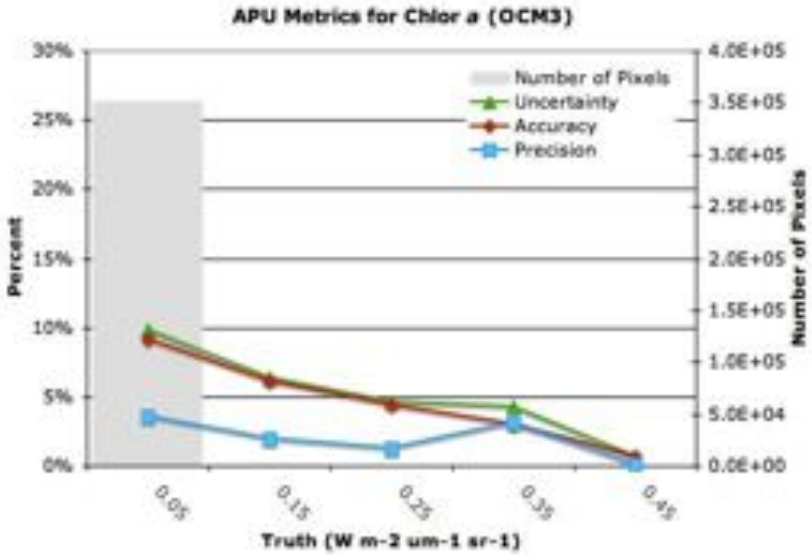


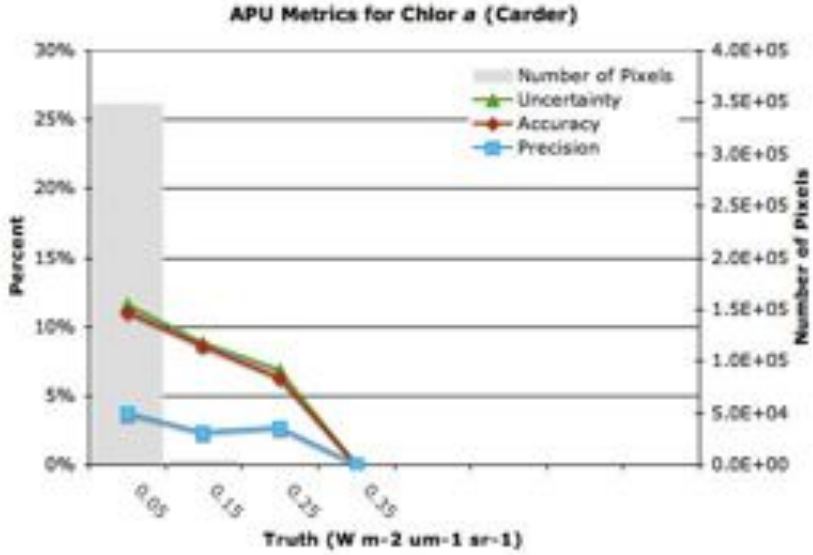


A20040332355 - Hawaii 2 February 2004

All Flags Used

Region Bias and Variation Stratified by Value

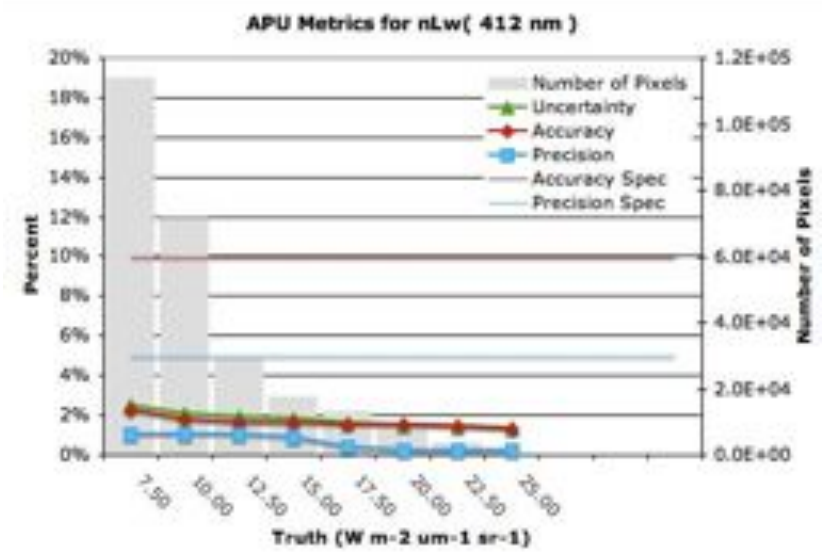


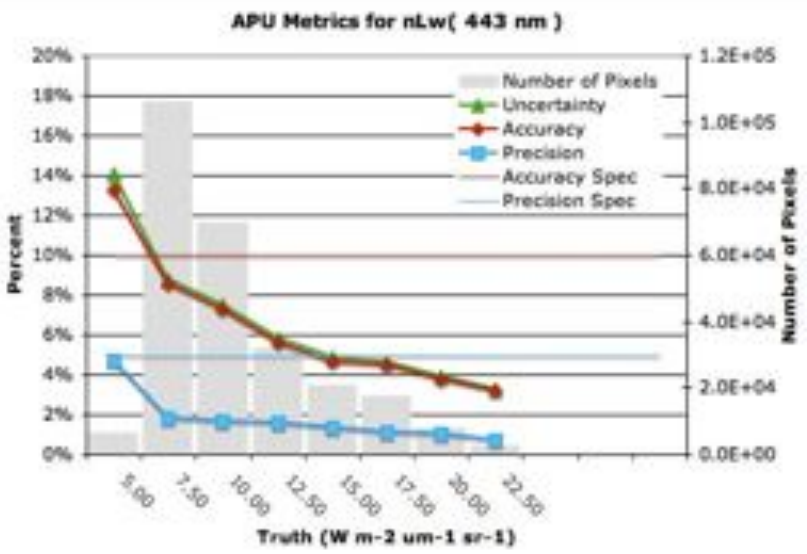


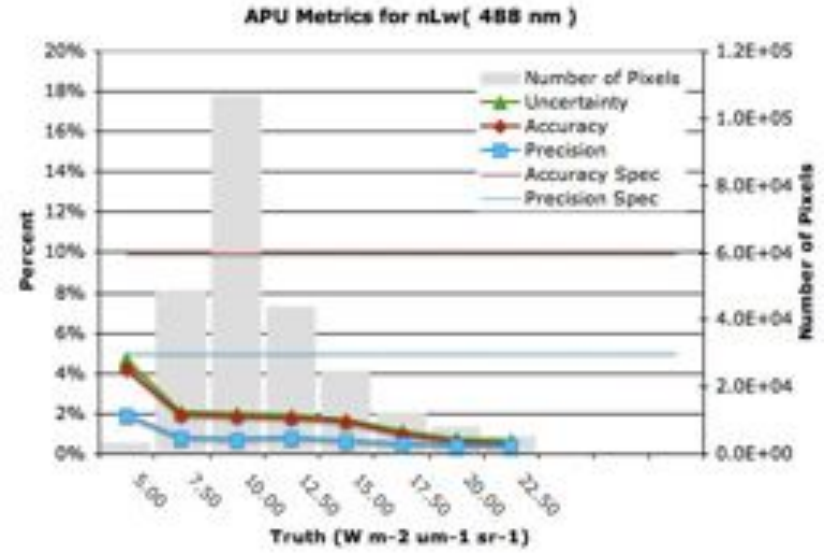
A20040332355 - Hawaii 2 February 2004

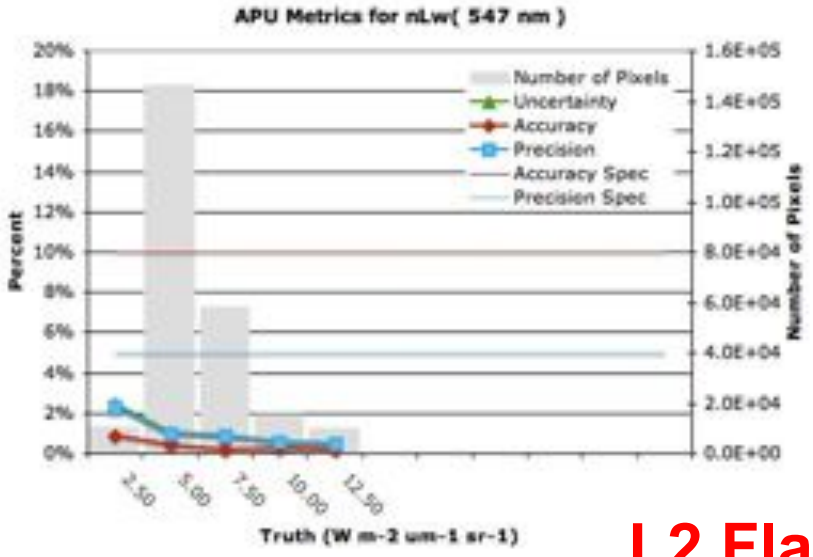
All Flags Used

Region Bias and Variation Stratified by Value





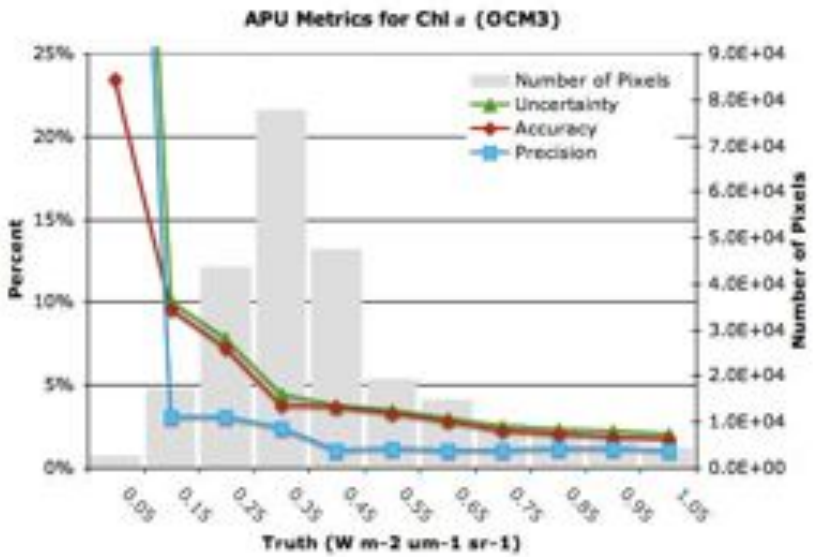


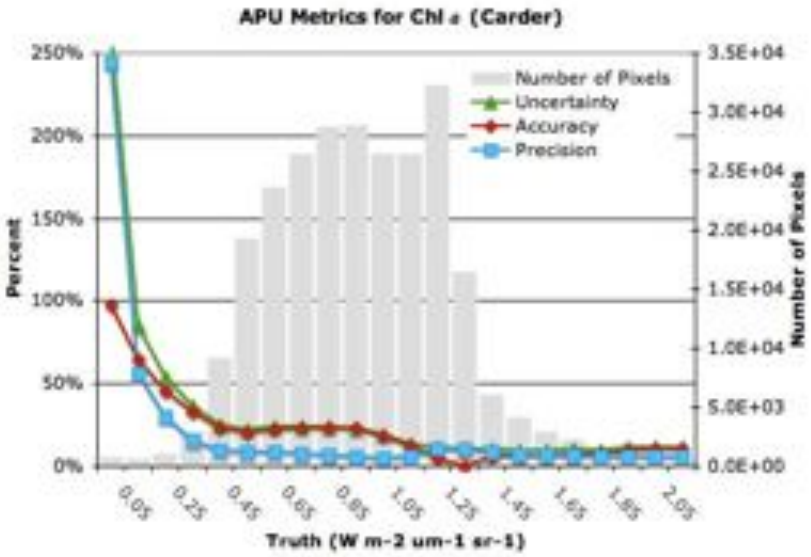


A20031711810 - Argentina 3 June 2003

L2 Flag Subset

Region Bias and Variation Stratified by Value

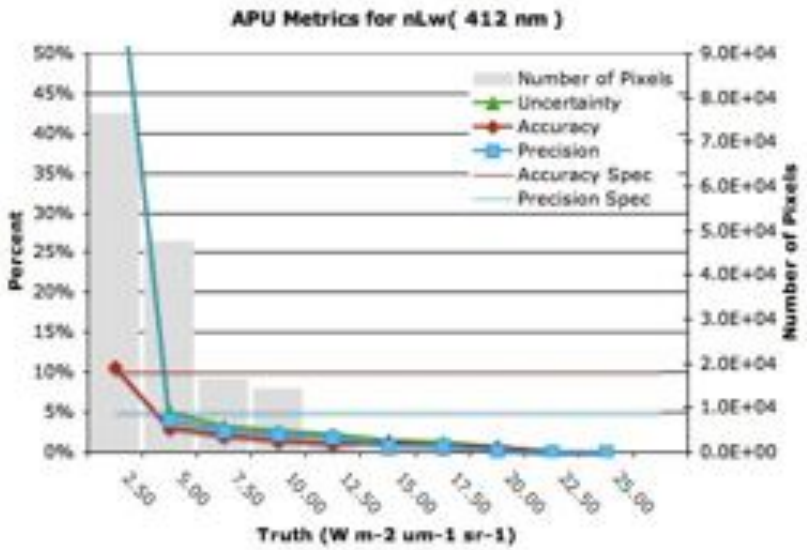


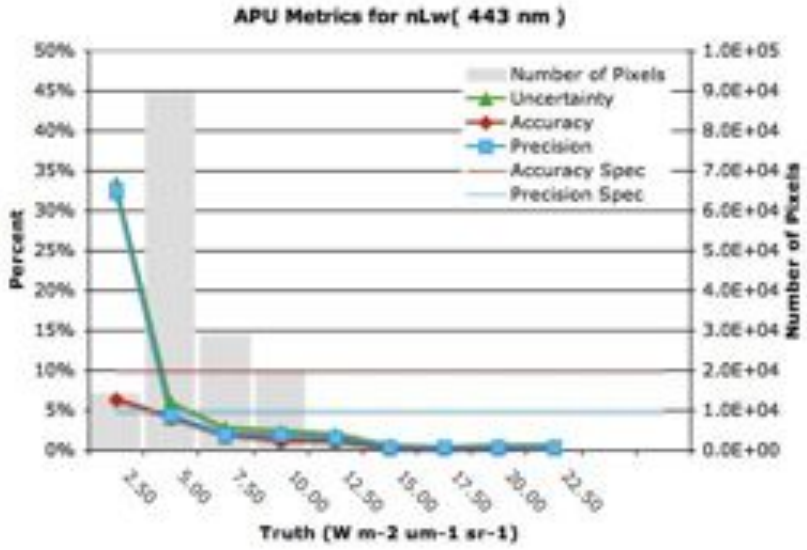


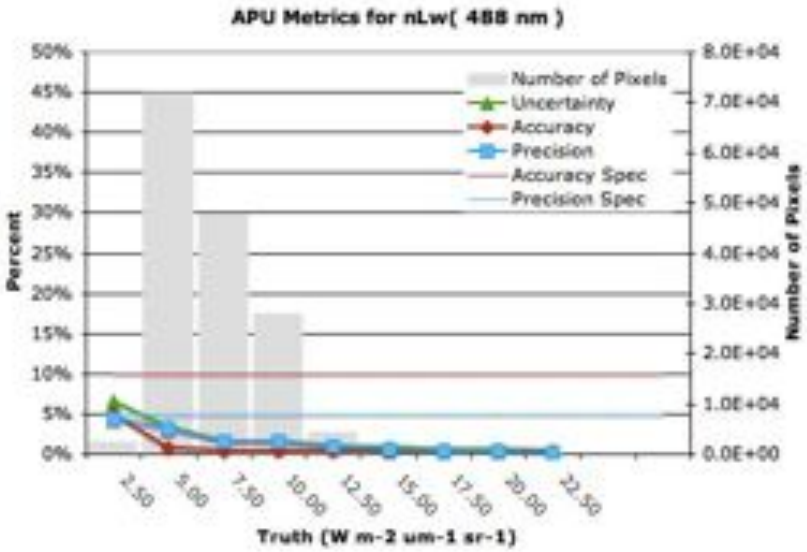
A20031711810 - Argentina 3 June 2003

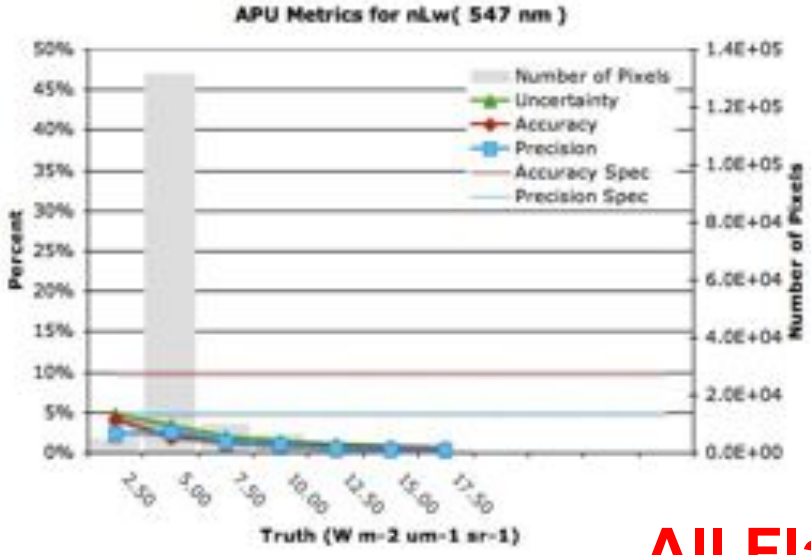
L2 Flag Subset

Region Bias and Variation Stratified by Value





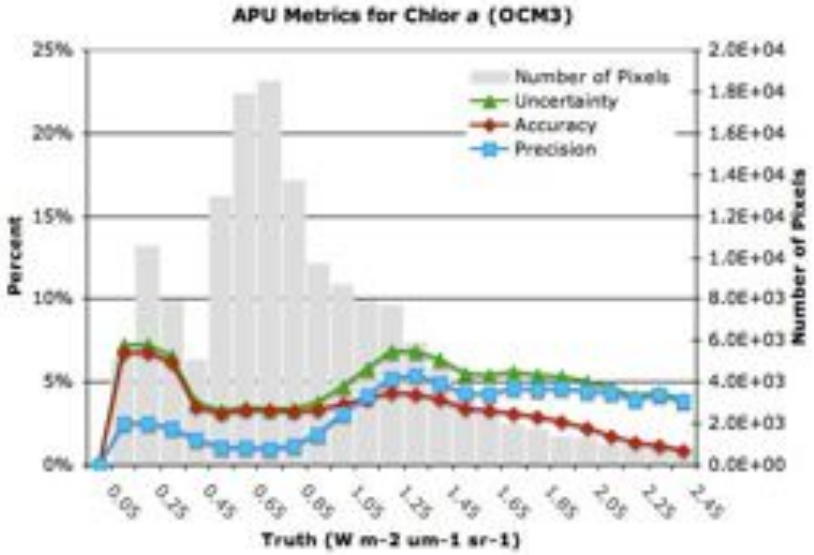


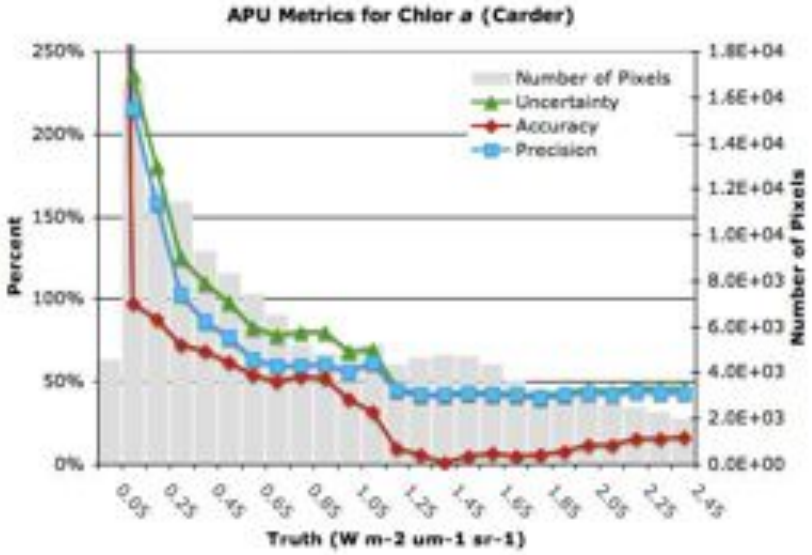


A20051071815 - East USA 17 April 2005

All Flags Used

Region Bias and Variation Stratified by Value





A20051071815 - East USA 17 April 2005

All Flags Used

NPP VIIRS Spectral Performance

NOTES ON SOURCES OF UNCERTAINTY FOR OCEAN BANDS:

- Test Configuration:
  - ➞ Detector-to-detector differences were observed, possibly from slit alignment and non-uniformity in source along track.
  - ➞ Bulb instability was possibly observed, especially in toward the blue end; there has been resistance to further evaluation.
  - ➞ Bulb used to measure 865nm band (M7) burnt out before it was properly characterized.
  - ➞ TVAC chamber window characterization.
- Polarization:
  - ➞ Source is polarized; VIIRS crosstalk and OOB RSR are polarization sensitive.
  - ➞ Degree of Polarization can be high for crosstalk, moderate for RSR OOB.
  - ➞ Polarization uniformity along track of source not verified.
  - ➞ Polarization response of crosstalk was measured for only a few wavelengths, for a few bands, at only for polarization angles.

NPP VIIRS Spectral Performance

NOTES ON SOURCES OF UNCERTAINTY FOR OCEAN BANDS:

- Point-to-point Propagation:
  - ➔ Tests only characterized a fully illuminated filter and may not translate well to partial illumination from spatial structure in image.
  - ➔ Point-to-point propagation of light from is roughly known and behavior is not completely consistent from band to band, detector to detector, or wavelength to wavelength.
  - ➔ Current point-to-point model predicts striping from crosstalk.
  - ➔ Maybe impossible or infeasible to model point-to-point propagation on orbit to remove striping.

NPP VIIRS Spectral Performance

NOTES ON SOURCES OF UNCERTAINTY FOR OCEAN BANDS:

- Measurement and Processing Error:
  - ➞ Measurement noise (inc. dark count); repeatability has been demonstrated to be poor.
  - ➞ Biases from stitching together in-band and out-of-band data sets.
  - ➞ Electronic crosstalk could produce an addition uncertainty in optical crosstalk characterization and on-orbit correction.
  - ➞ 1nm uncertainty in wavelength calibration could also introduce biases. May also be smile uncertainty along track.

NIST is expected to use SIRCUS to characterize the VIIRS spectral response after the instrument is integrated on the spacecraft.