# Request for
# VIIRS Ocean Color EDR Beta Maturity

Menghua Wang
VIIRS Ocean Color EDR Team

Inputs & contributions from the OCC Cal/Val Team

# Summary of VIIRS OCC EDR Algorithms

- **Inputs**: VIIRS M1-M7 bands SDR data, terrain-corrected geo-location file, SST EDR data (not used for current OC3V chlorophyll-a algorithm), cloud mask Intermediate Product (IP), on-board calibrator IP, 7 ancillary data files, 7 lookup tables, and 1 configurable parameter file.

- **Outputs**: chlorophyll-a (Chl-a) concentration, normalized water-leaving radiance (nLw's) at bands M1-M5, Inherent Optical Properties (IOP-a and IOP-s) at VIIRS bands M1-M5, and quality flags. Primary outputs are chlorophyll-a and normalized water-leaving radiances.

- There are three sets of algorithms in the IDPS OCC-EDR data processing:
  - The Gordon & Wang (1994) atmospheric correction algorithm: including corrections for ozone, Rayleigh (molecules) and aerosols, ocean surface reflection, sun glint, whitecap, and sensor polarization effects.
  - chlorophyll-a algorithm: currently with OC3V algorithm (heritage algorithm), with option to switch between the OC3V and Carder chlorophyll-a algorithms.
  - IOP algorithm: Carder IOP algorithm.

# Users of VIIRS OCC EDR Products

- NOAA National Ocean Service (e.g., Chris Kinkade, Rick Stumpf, Varis Ransi)
- NOAA National Fisheries Service (e.g., Cara Wilson, Jeffrey Polovina, John Lamkin)
- NOAA Air Resource Laboratory (e.g., Daniel Tong, Pius Lee)
- NOAA CoastWatch (Kent Hughes)
- Other US Agencies (e.g., Navy)
- Ocean Community.

# History of Algorithm Changes/Updates

- Changed chlorophyll-a algorithm from Carder algorithm to OC3V algorithm (heritage algorithm) with updated coefficients (DR4247, implemented in Mx5.1).
- Retrieval and output of Chl-a and IOPs when M5 remote-sensing reflectance is negative (DR4814, implemented in Mx6.3).
- Processing Chl-a and IOPs for pixels with negative normalized water-leaving radiance nLw (or remote-sensing reflectance Rrs) at some of the VIIRS ocean color bands (M1-M5) (DR4869, fixes to be implemented).
- Retrieval and output of OCC over coastal and inland waters (DR4877, fixes to be implemented).
- Changed Ocean Color HRI from sensor-zenith angle of $53^{o}$ to $60^{o}$ for more data coverage (DR4898, fixes to be implemented).
- Updated OCC operational software to enable ocean color data processing up to solar-zenith angles of $80^{o}$ instead of $70^{o}$ (note: the high solar-zenith angle is still at $70^{o}$) (DR4940, fixes to be implemented).

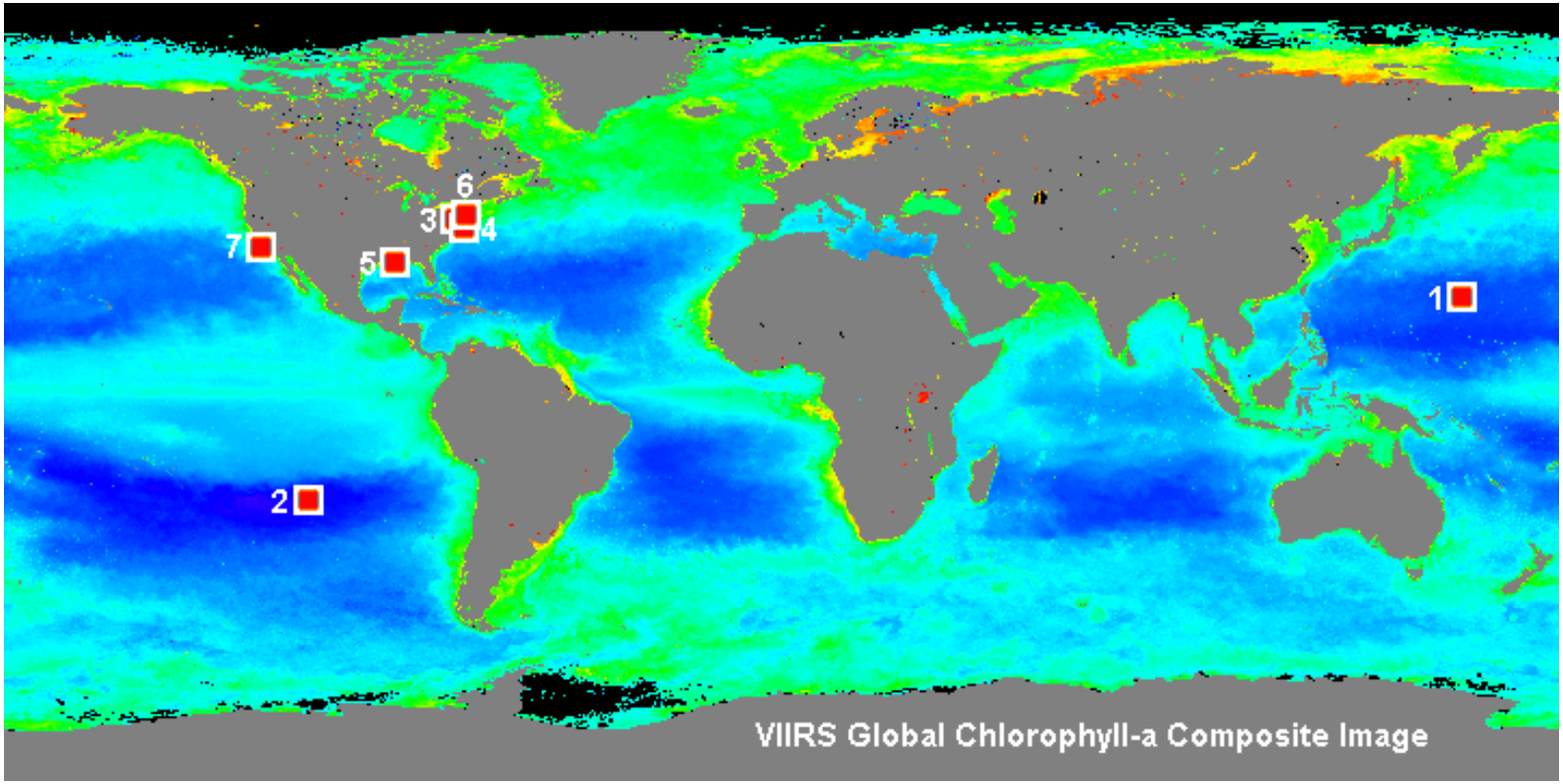
# Beta EDR Maturity Definition

- Early release product.
- Minimally validated.
- May still contain significant errors.
- Versioning not established until a baseline is determined.
- Available to allow users to gain familiarity with data formats and parameters.
- Product is not appropriate as the basis for quantitative scientific publication studies and applications.

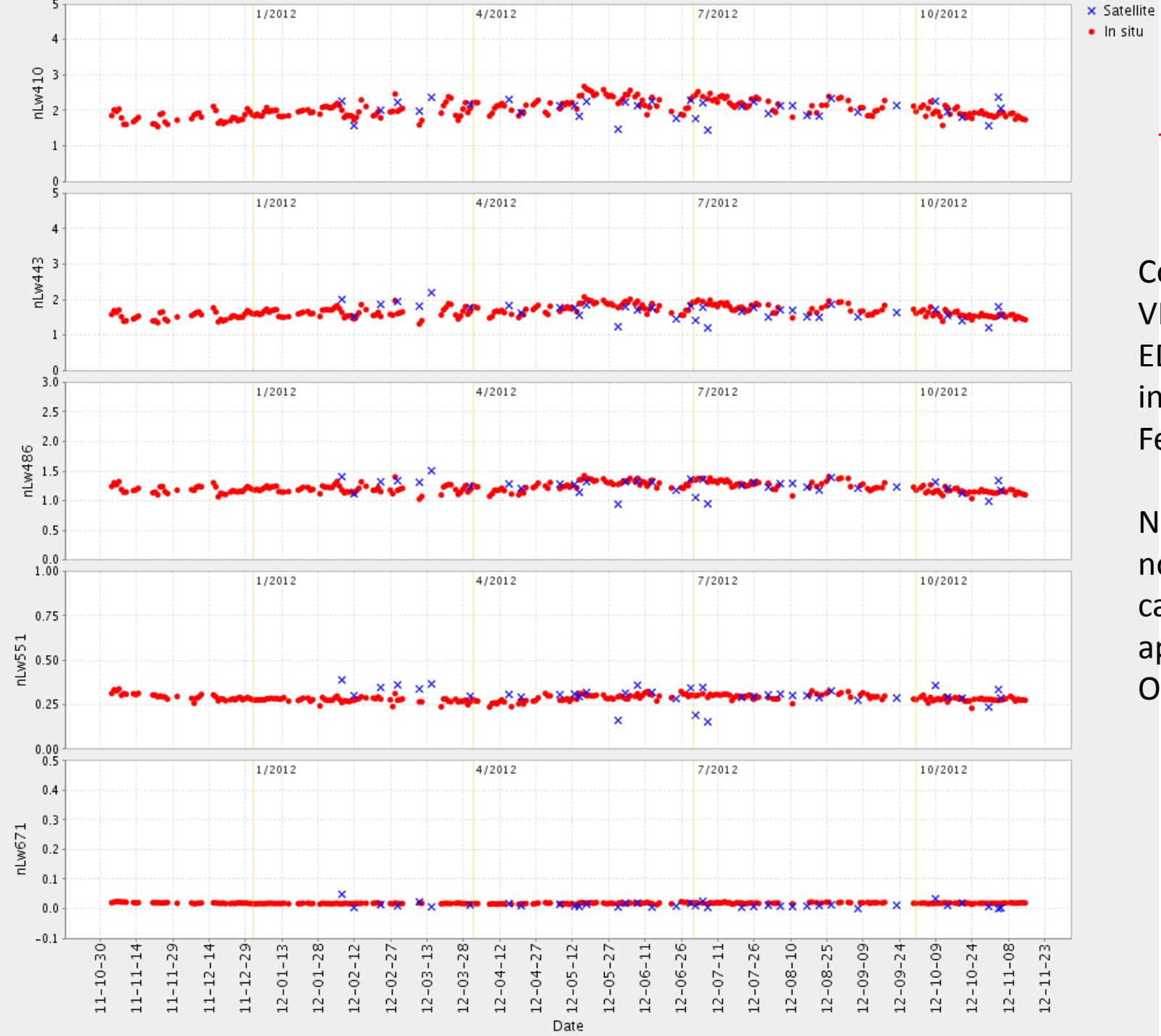
# Beta Maturity Evaluation

- Compared VIIRS OCC EDR data at MOBY site with MOBY in situ data since Feb. 6, 2012.
- Monitoring VIIRS OCC EDR data at the South Pacific Gyre.
- Compared VIIRS OCC EDR data with those form MODIS-Aqua.
- Compared VIIRS OCC EDR data with JPSS Algorithm Development Libraries (ADL) results.
- Compared VIIRS OCC EDR data with those from NRL-APS data processing.
- Some validation results from AERONET-OC in situ measurements.
- Compared VIIRS OCC EDR data with those from NOAA ocean color science processing (NOAA-MSL12). VIIRS RDR data were re-processed to SDR using ADL with updated daily F-LUTs, and then NOAA-MSL12 was used to process from SDR to ocean color Level-2 data (EDR).

# VIIRS Ocean Color EDR Monitoring Sites

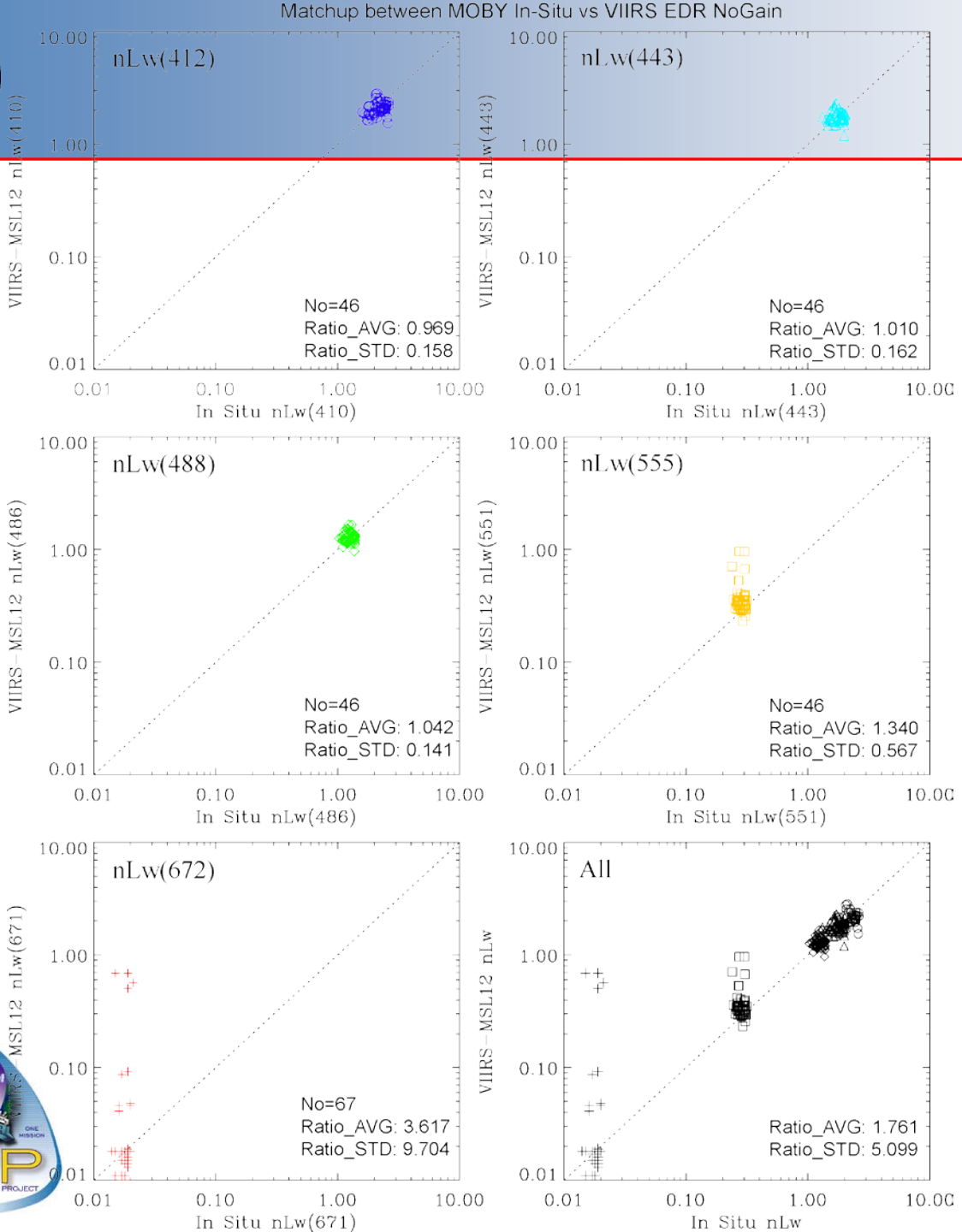



1. MOBY Site; 2. South Pacific Gyre; 3. Chesapeake Bay; 4. US East Coast; 5. AERONET-OC CSI Site; 6. AERONET-OC LISCO Site; 7. AERONET-OC USC Site.



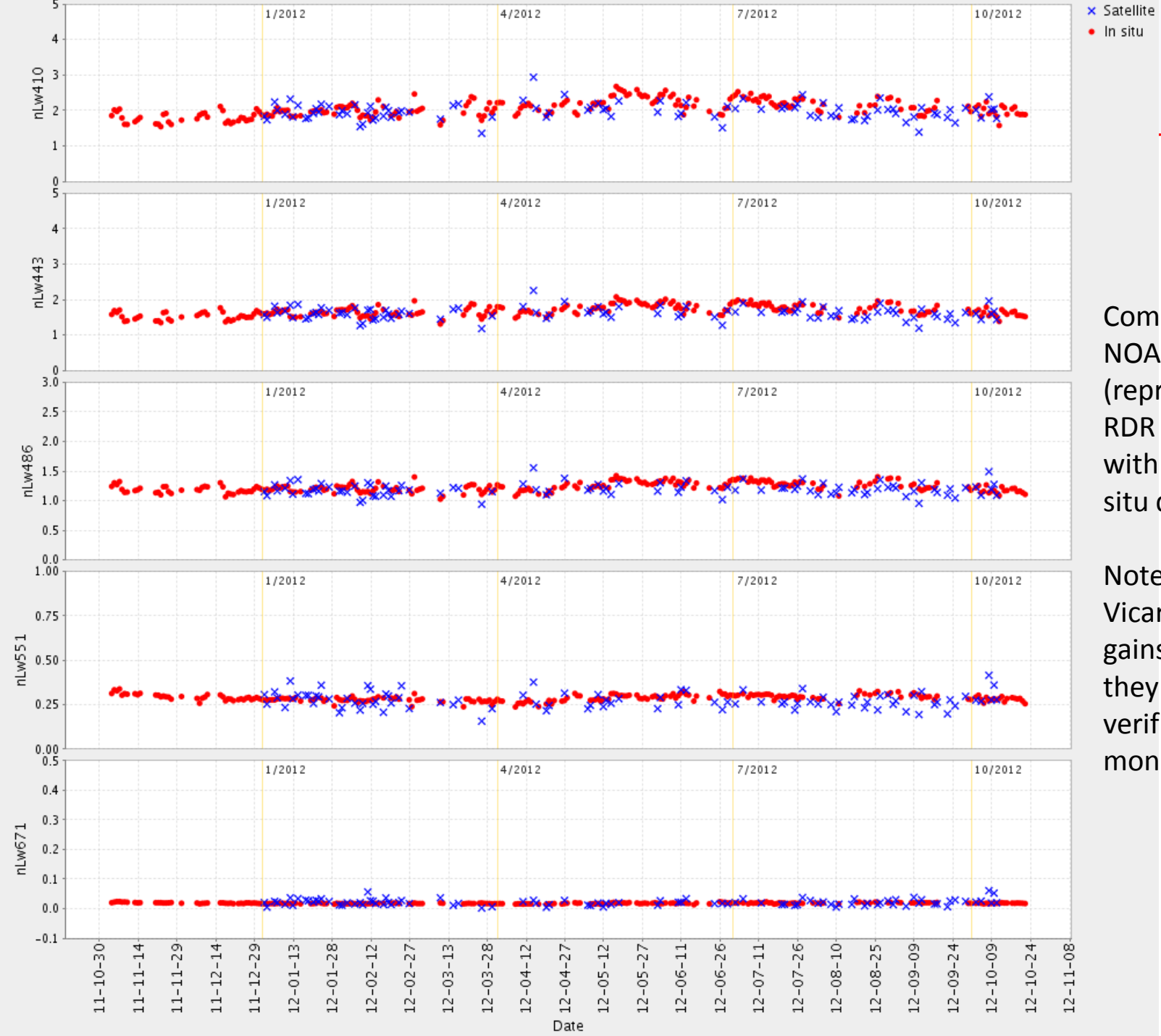

Comparison of VIIRS IDPS OCC EDR with MOBY in situ data since Feb. 6, 2012.

Note:
no vicarious calibration gains applied in IDPS OCC EDR.



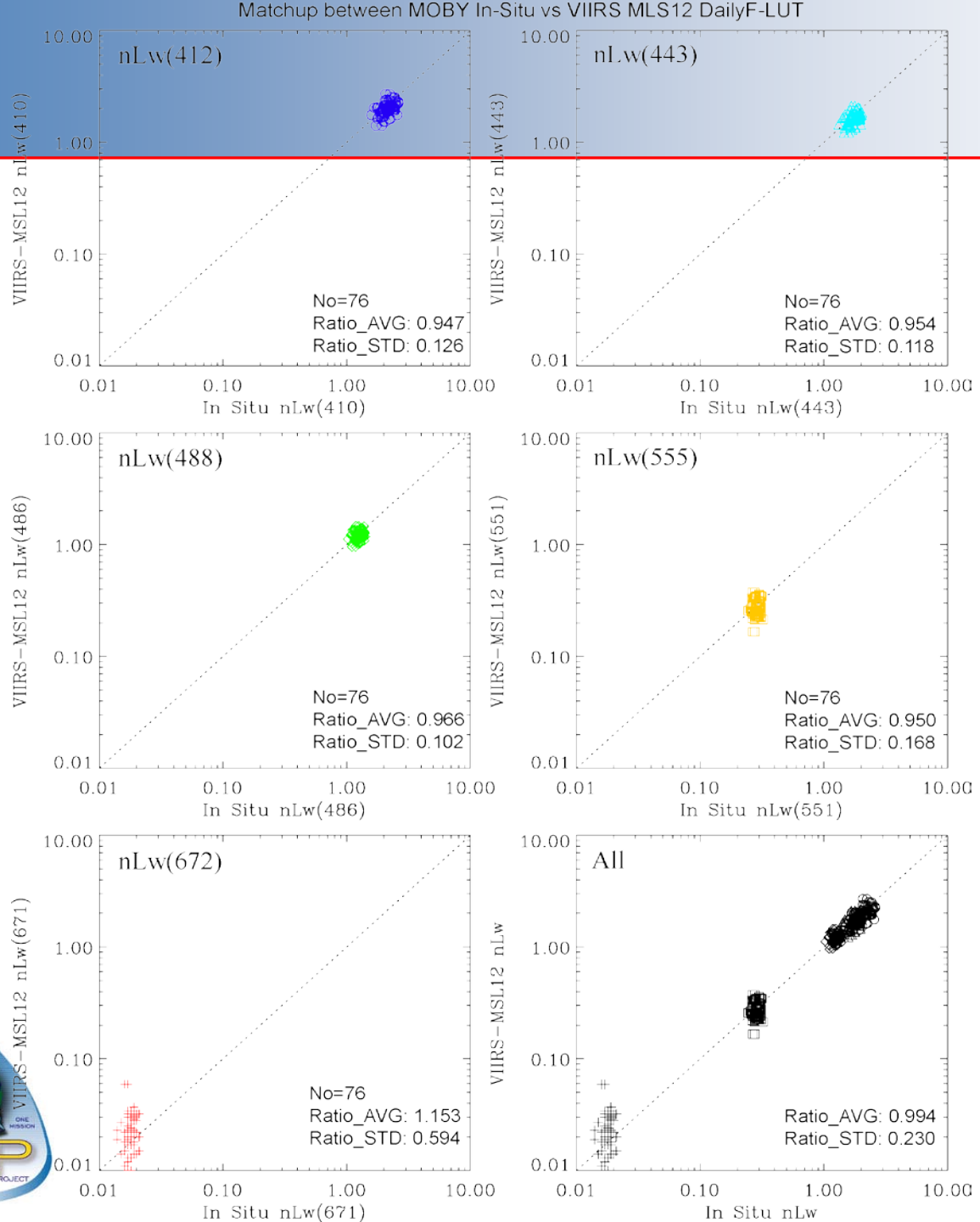

Scatter plots of VIIRS IDPS OCC EDR data match-up with MOBY in situ data since Feb. 6, 2012.

Note:
No vicarious calibration gains applied in IDPS OCC EDR.




Comparison of VIIRS NOAA-MSL12 results (reprocessed from RDR with daily F-LUT) with MOBY in situ data.

Note:
Vicarious calibration gains applied. Thus, they are used as verification and data monitoring.




Scatter plots of NOAA-MSL12 Level-2 data (reprocessed from RDR with daily F-LUT) match-up with MOBY in situ data.

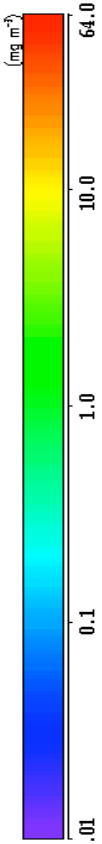
Note:
Vicarious calibration gains applied. Thus, they are used as verification.

# VIIRS vs. MODIS-Aqua Global Images

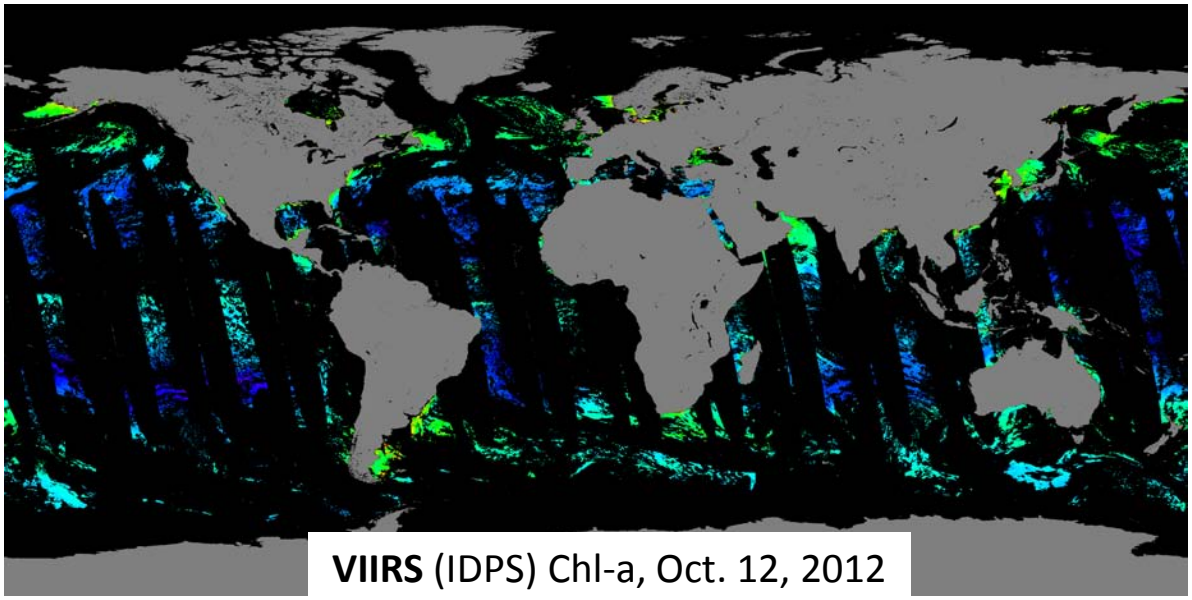
- VIIRS OCC EDR team has been routinely downloading MODIS-Aqua ocean color products from NASA/OBPG ocean color website since VIIRS launch.
- MODIS-Aqua ocean color data are converted to appropriate units for comparisons.
- Daily, 8-day, and monthly global MODIS-Aqua ocean color data have been produced and compared with those from VIIRS ocean color products.
- Example global ocean color data comparisons from VIIRS (IDPS) and MODIS-Aqua are provided.
- Results show that, although there are still some issues with VIIRS data, VIIRS (IDPS) and MODIS-Aqua nLw's and Chl-a data are generally quite comparable.

# VIIRS (IDPS) vs. MODIS-Aqua (Daily)

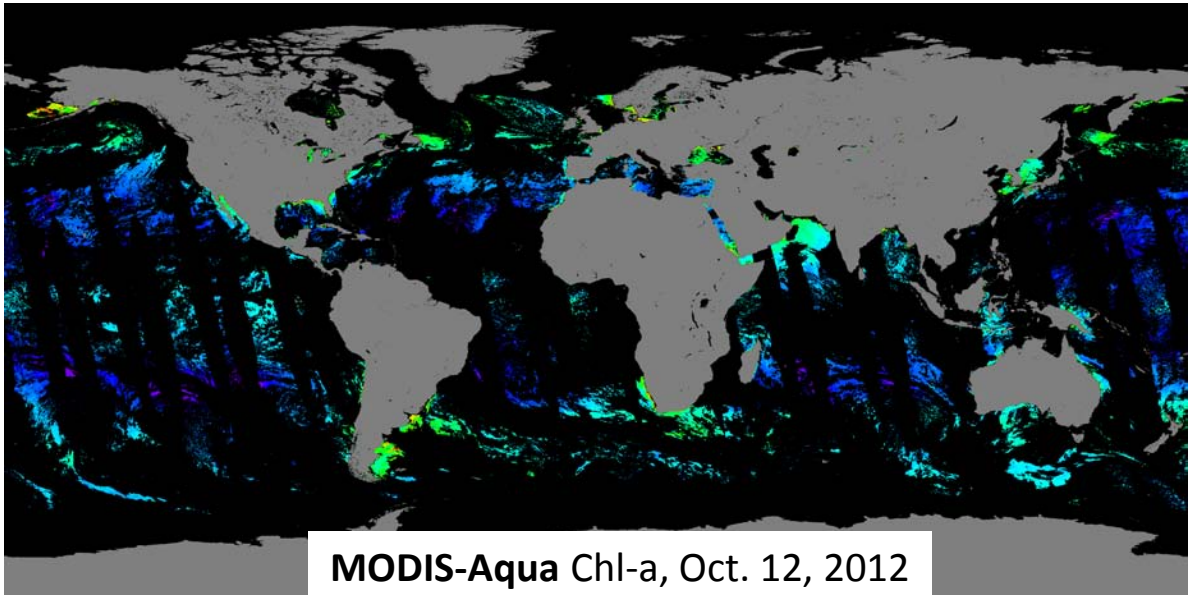
## Chlorophyll-a




Log scale:
0.01 to 64 mg/m3



**VIIRS** (IDPS) Chl-a, Oct. 12, 2012



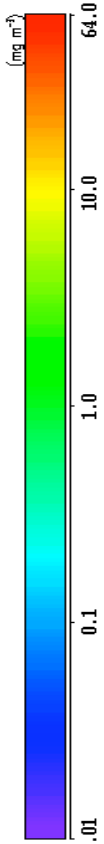
**MODIS-Aqua** Chl-a, Oct. 12, 2012

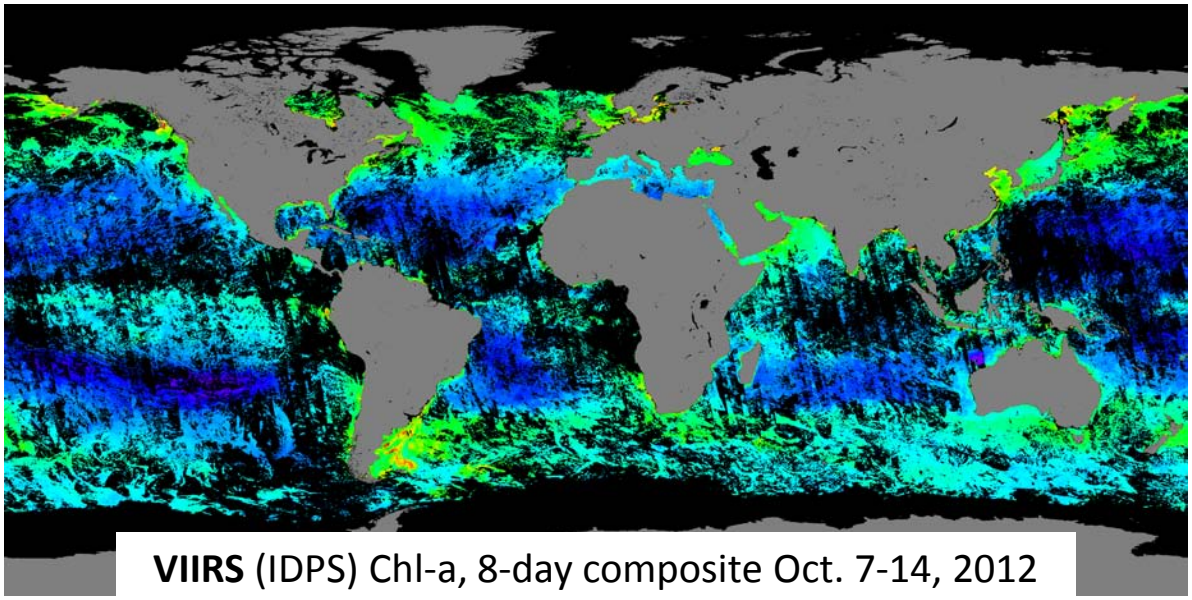
**MODIS-Aqua** data were obtained from NASA/OBPG ocean color website.

# VIIRS (IDPS) vs. MODIS-Aqua (8-Day)

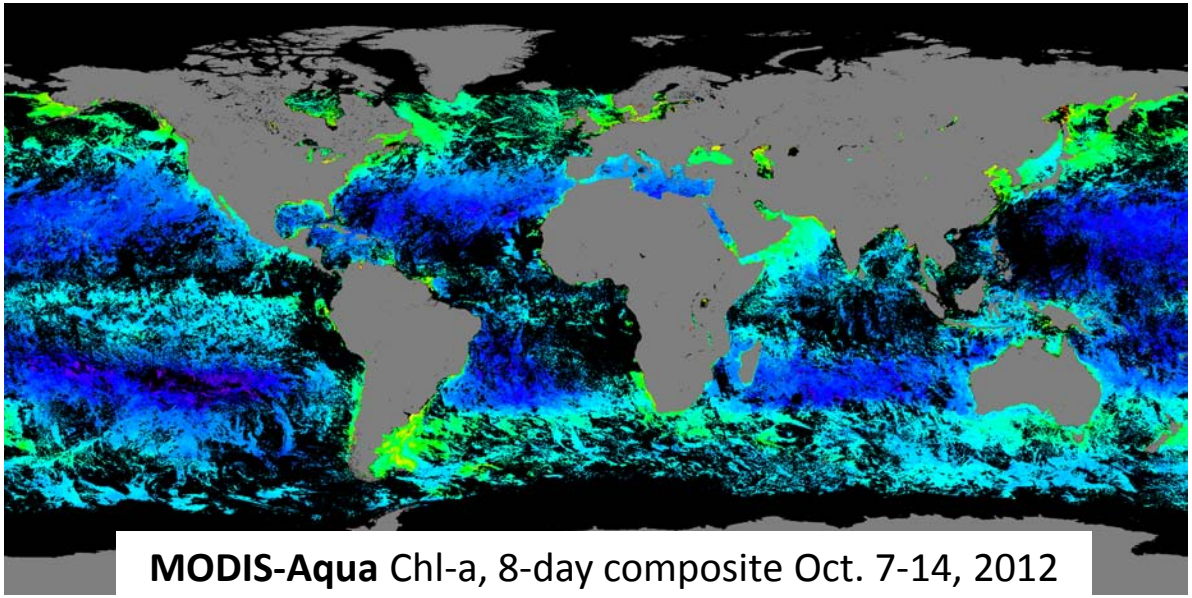
## Chlorophyll-a

Log scale:
0.01 to 64 mg/m3



**VIIRS** (IDPS) Chl-a, 8-day composite Oct. 7-14, 2012



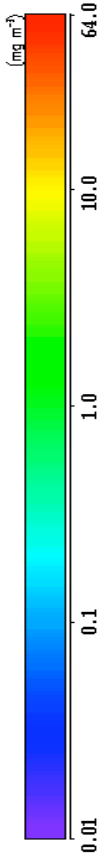
**MODIS-Aqua** Chl-a, 8-day composite Oct. 7-14, 2012

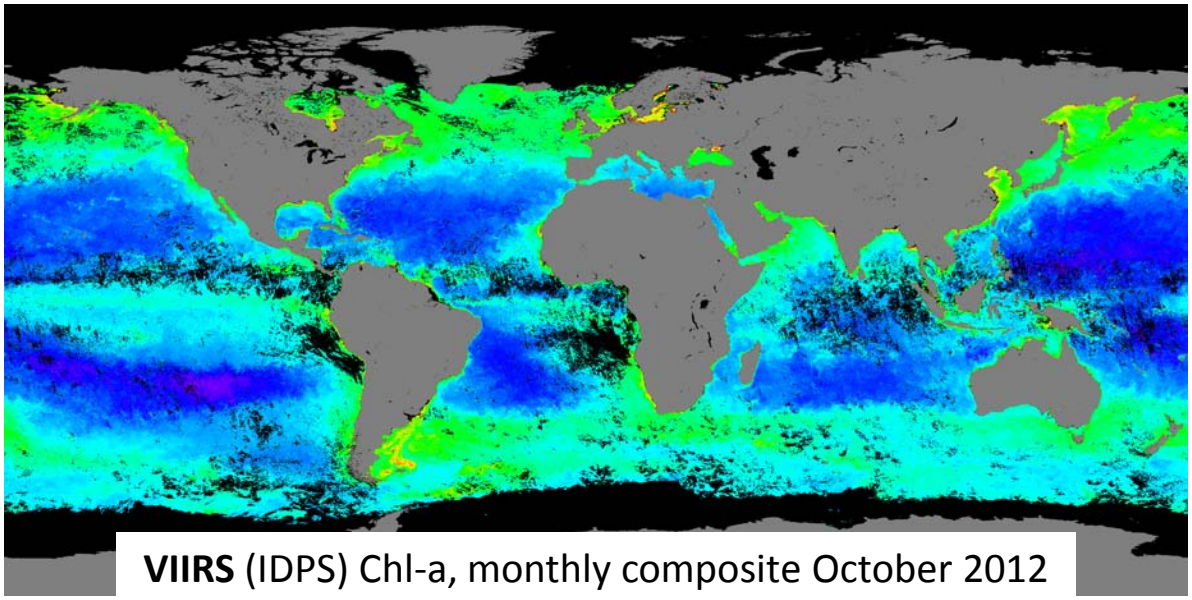
**MODIS-Aqua** data were obtained from NASA/OBPG ocean color website.

# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

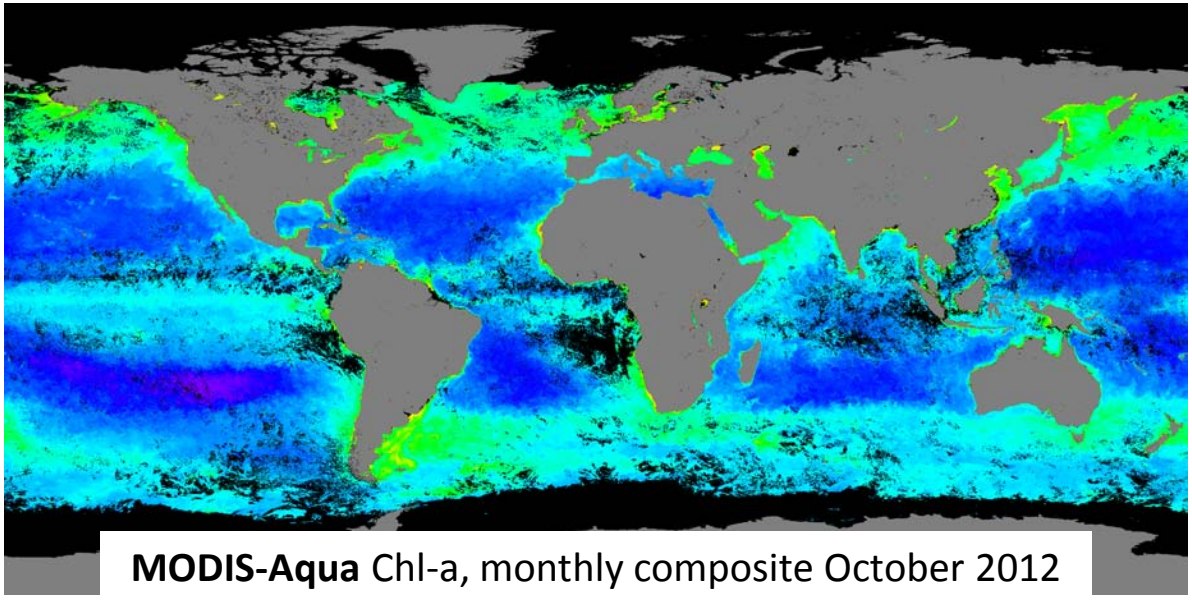
## Chlorophyll-a

Log scale:
0.01 to 64 mg/m3



**VIIRS** (IDPS) Chl-a, monthly composite October 2012



**MODIS-Aqua** Chl-a, monthly composite October 2012

**MODIS-Aqua** data were obtained from NASA/OBPG ocean color website.

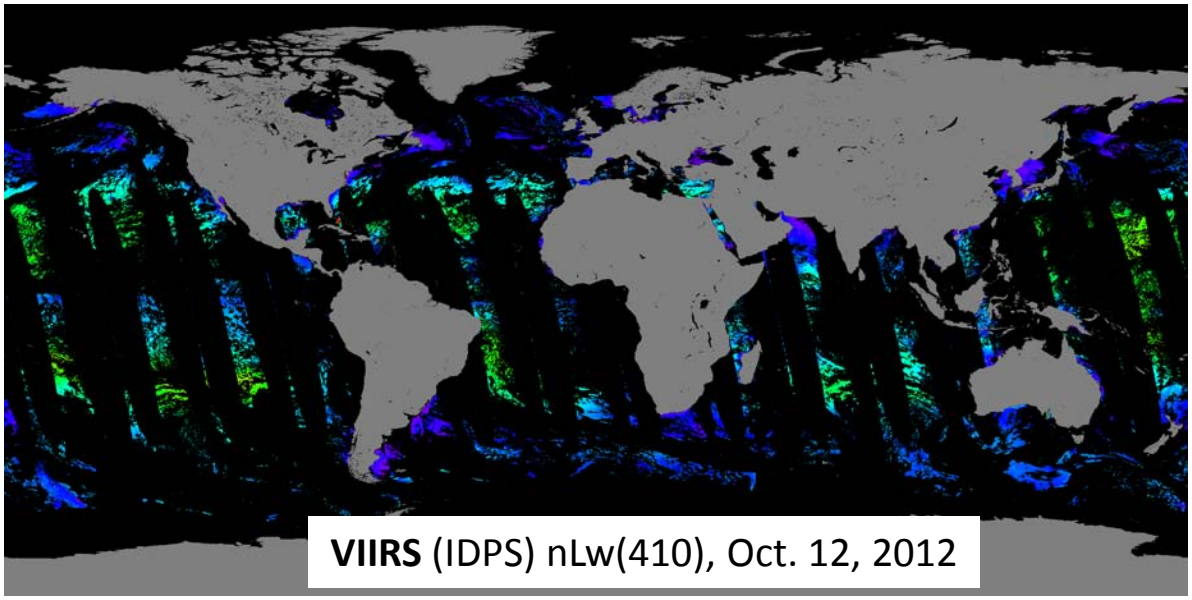
# VIIRS (IDPS) vs. MODIS-Aqua (Daily)

**nLw(412)**

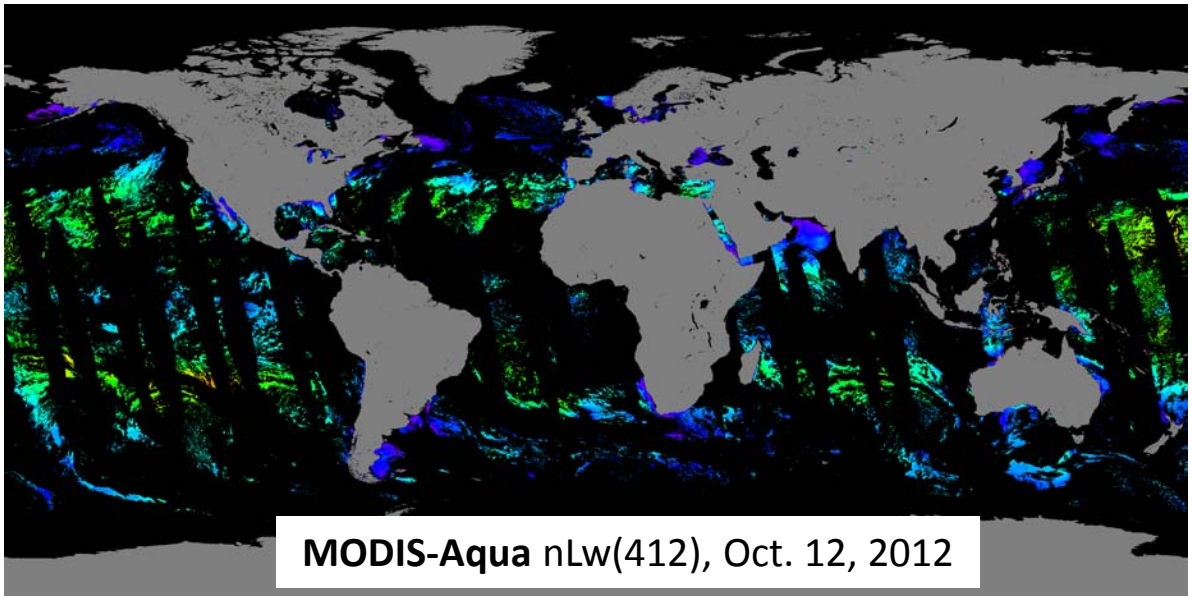
Linear scale:
0 to 5 mW cm$^{-2}$ µm$^{-1}$ sr$^{-1}$

5.0

0.0



**VIIRS** (IDPS) nLw(410), Oct. 12, 2012



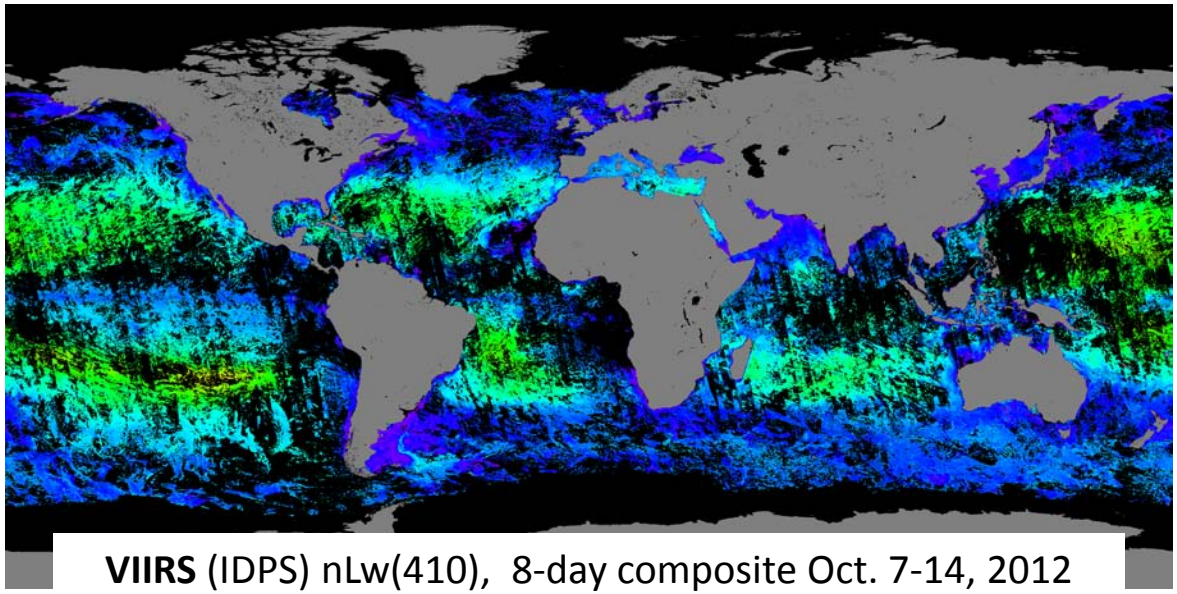
**MODIS-Aqua** nLw(412), Oct. 12, 2012

**MODIS-Aqua** data were obtained from NASA/OBPG ocean color website.

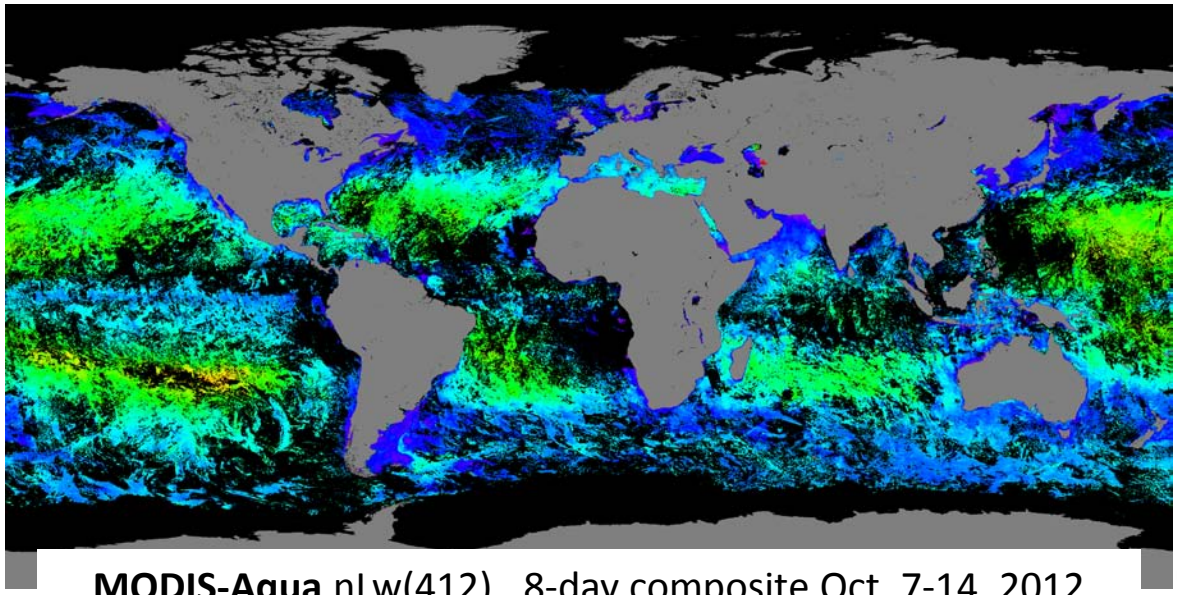
# VIIRS (IDPS) vs. MODIS-Aqua (8-Day)

**nLw(412)**


Linear scale:
0 to 5 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$



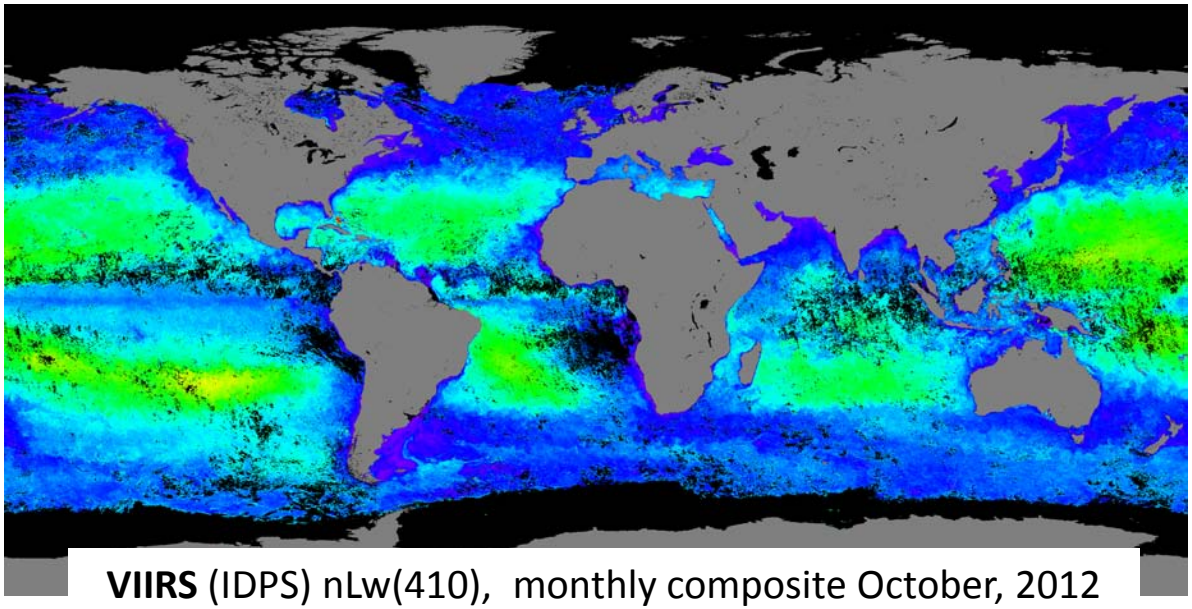
**VIIRS** (IDPS) nLw(410), 8-day composite Oct. 7-14, 2012



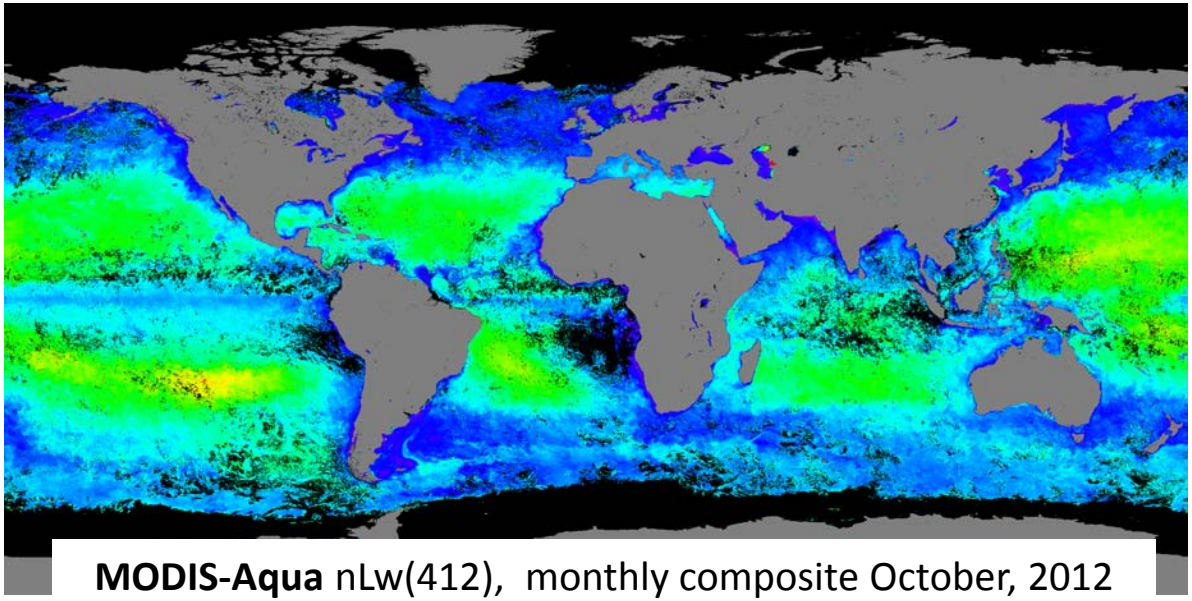
**MODIS-Aqua** nLw(412), 8-day composite Oct. 7-14, 2012

# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

## nLw(412)

**VIIRS** (IDPS) nLw(410), monthly composite October, 2012

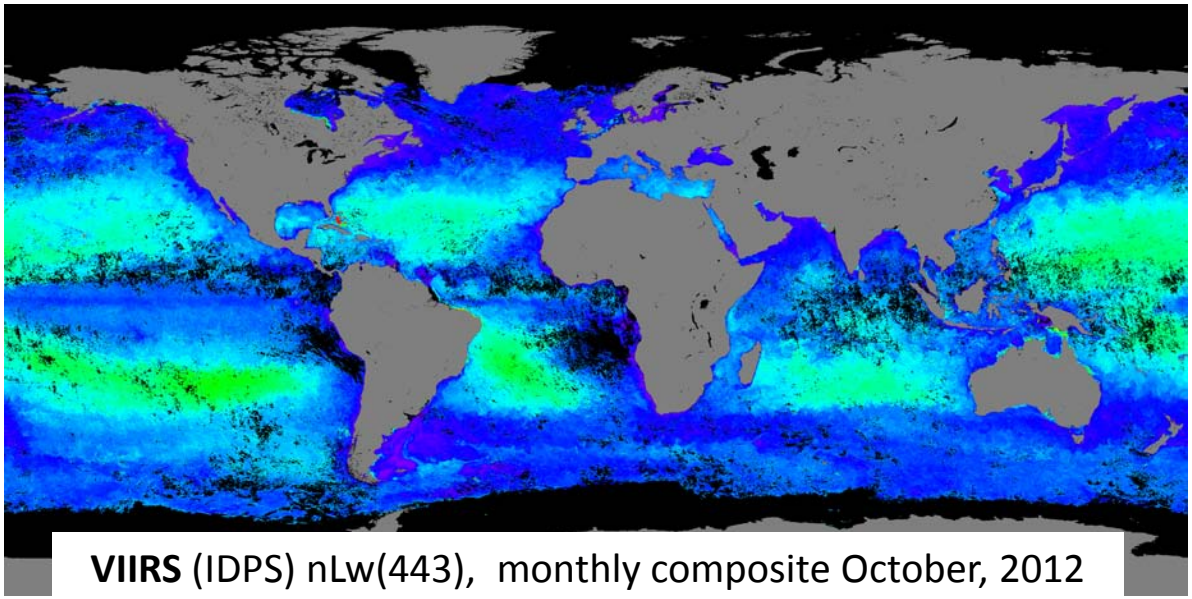


**MODIS-Aqua** nLw(412), monthly composite October, 2012

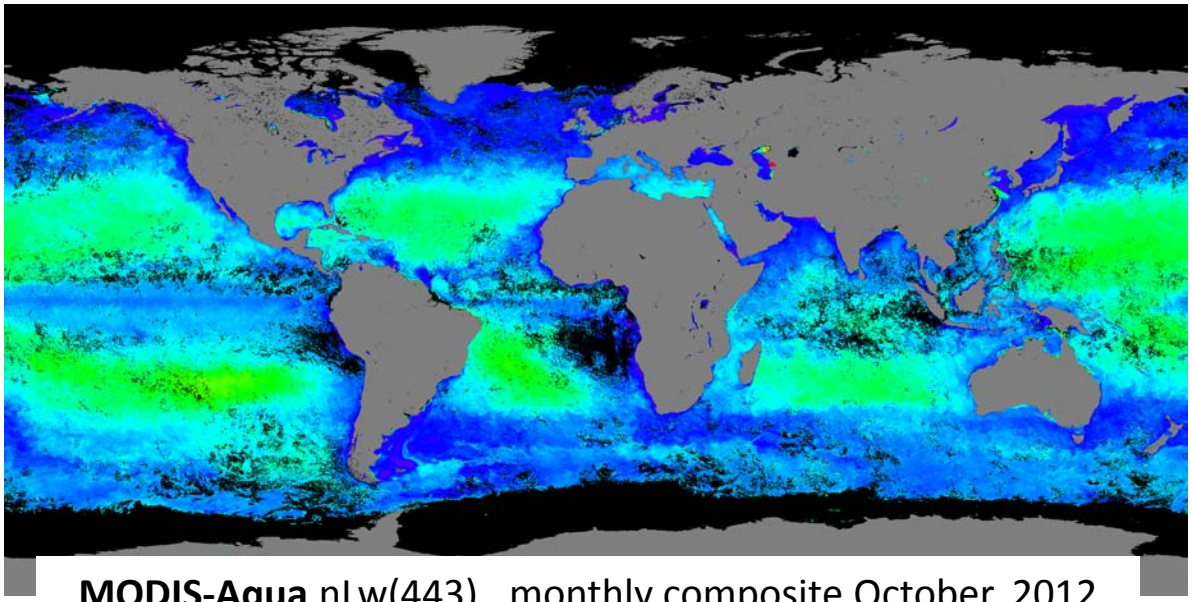
# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

## nLw(443)


Linear scale:
0 to 5 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$



**VIIRS** (IDPS) nLw(443), monthly composite October, 2012

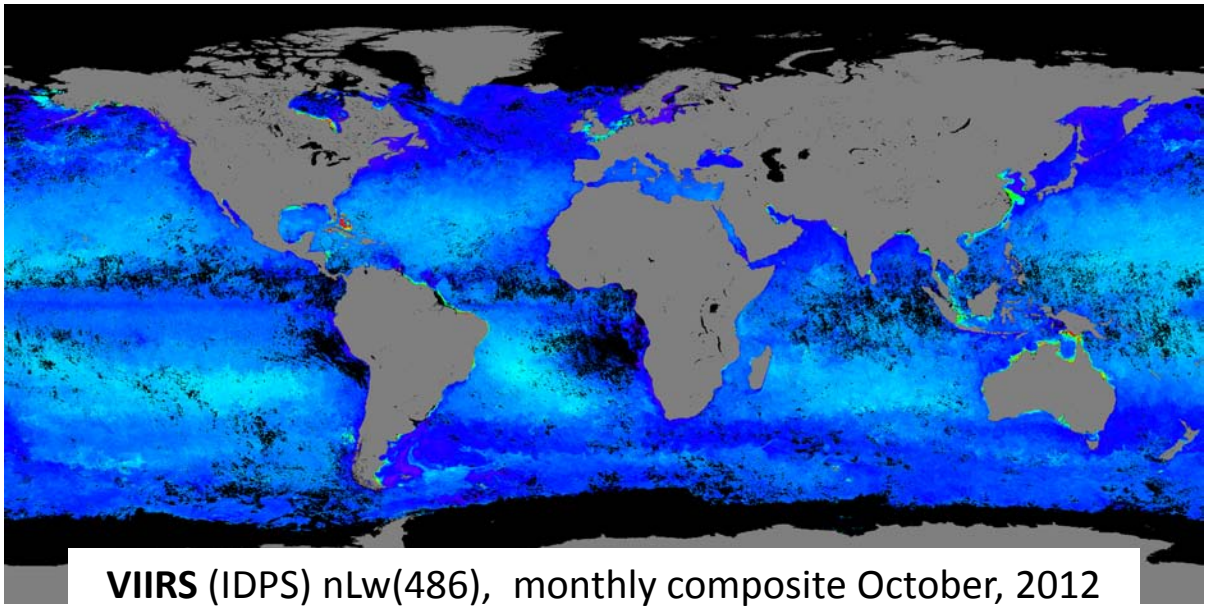


**MODIS-Aqua** nLw(443), monthly composite October, 2012

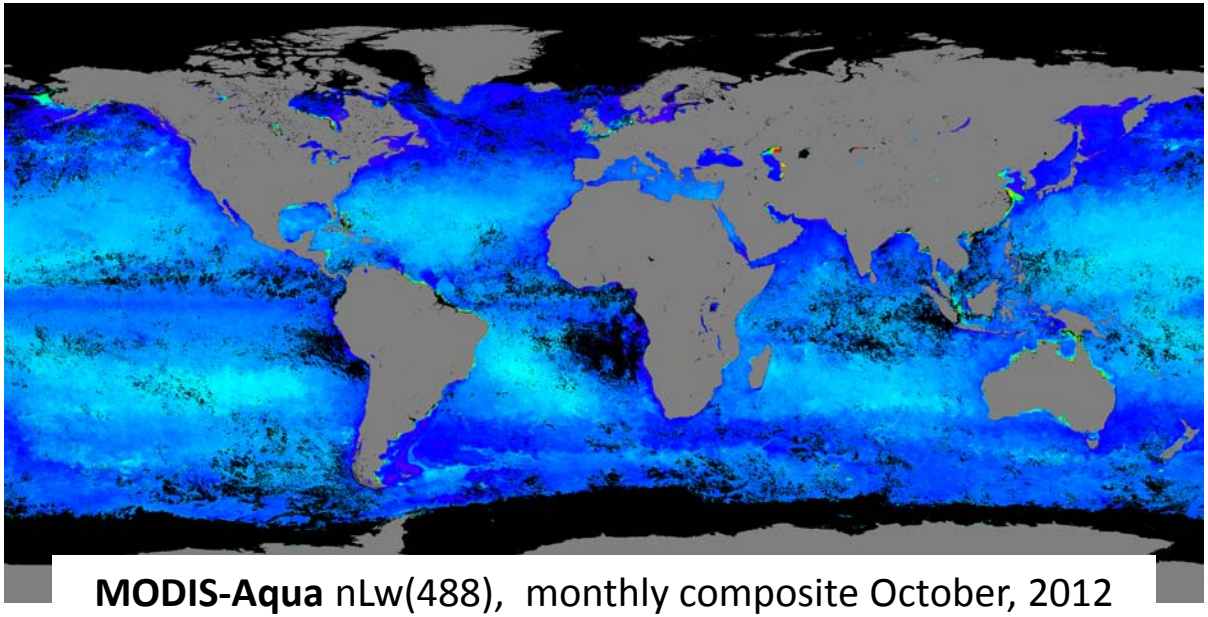
# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

## nLw(486)


Linear scale:
0 to 5 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$



**VIIRS** (IDPS) nLw(486), monthly composite October, 2012



**MODIS-Aqua** nLw(488), monthly composite October, 2012

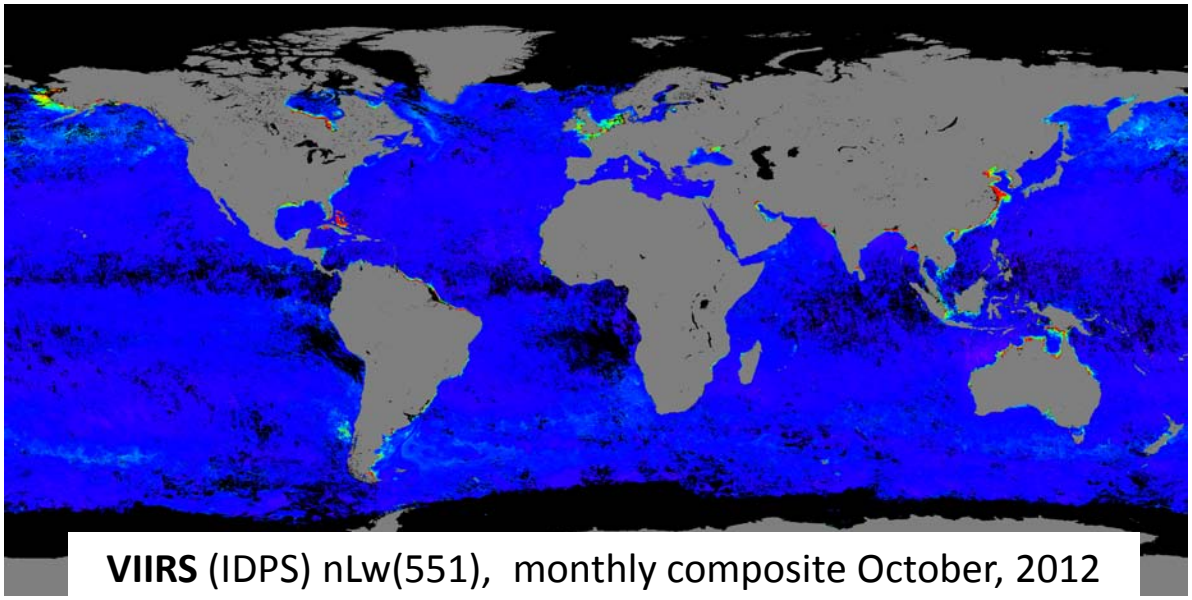
# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

## nLw(551)

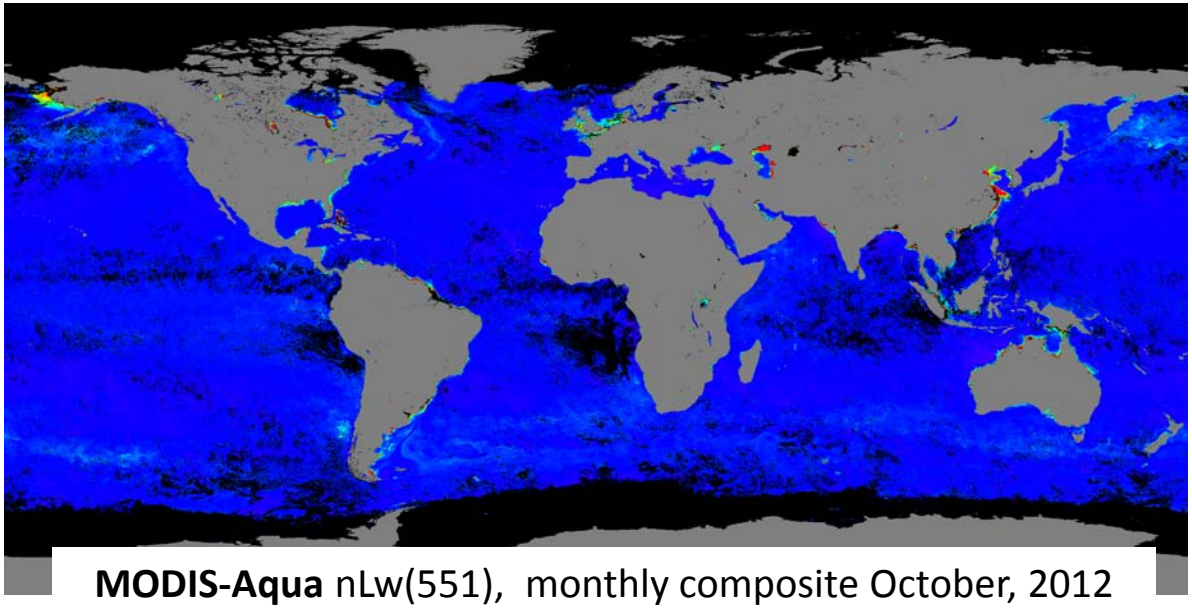
Linear scale:
0 to 3 mW cm$^{-2}$ µm$^{-1}$ sr$^{-1}$

3.0

0.0



**VIIRS** (IDPS) nLw(551), monthly composite October, 2012

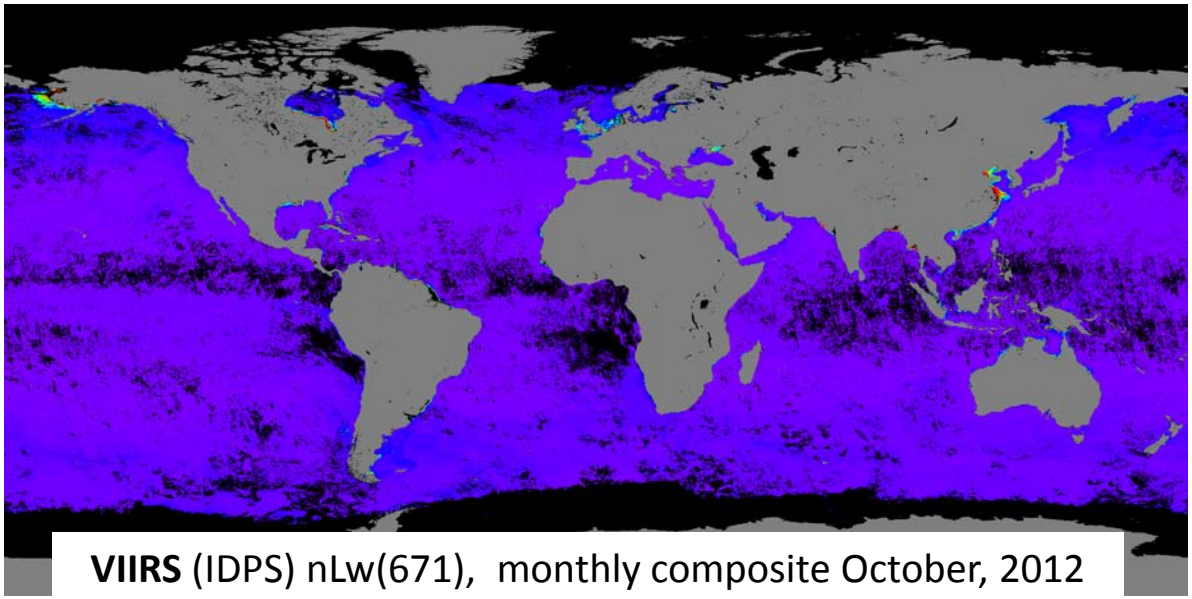


**MODIS-Aqua** nLw(551), monthly composite October, 2012

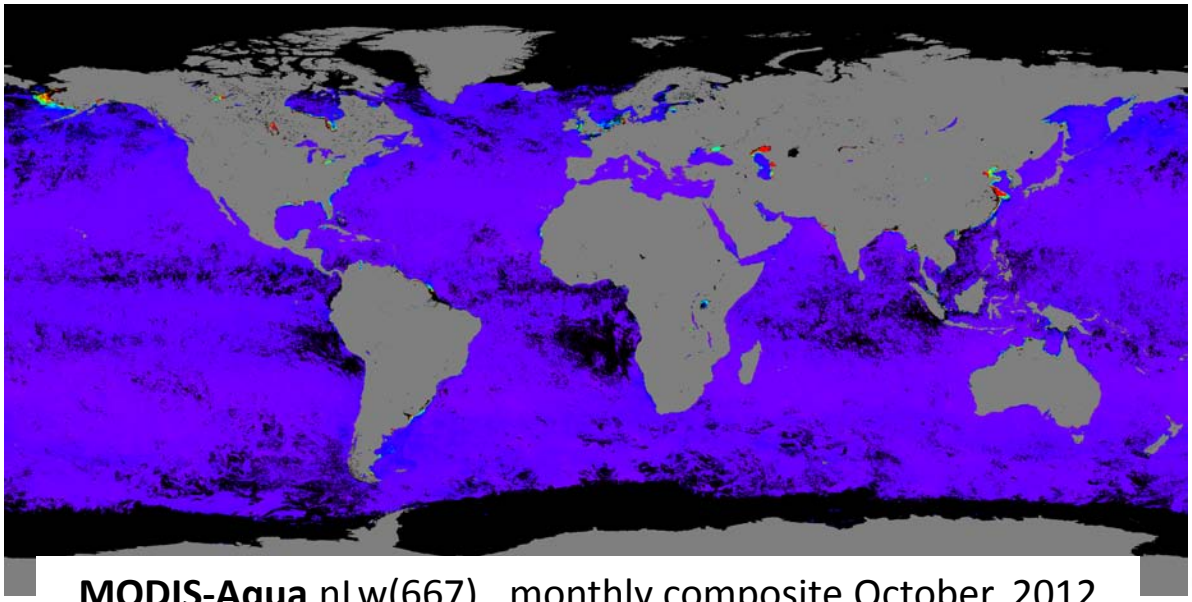
# VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

**nLw(671)**


Linear scale:
0 to 1 mW $cm^{-2}$ $\mu m^{-1}$ $sr^{-1}$

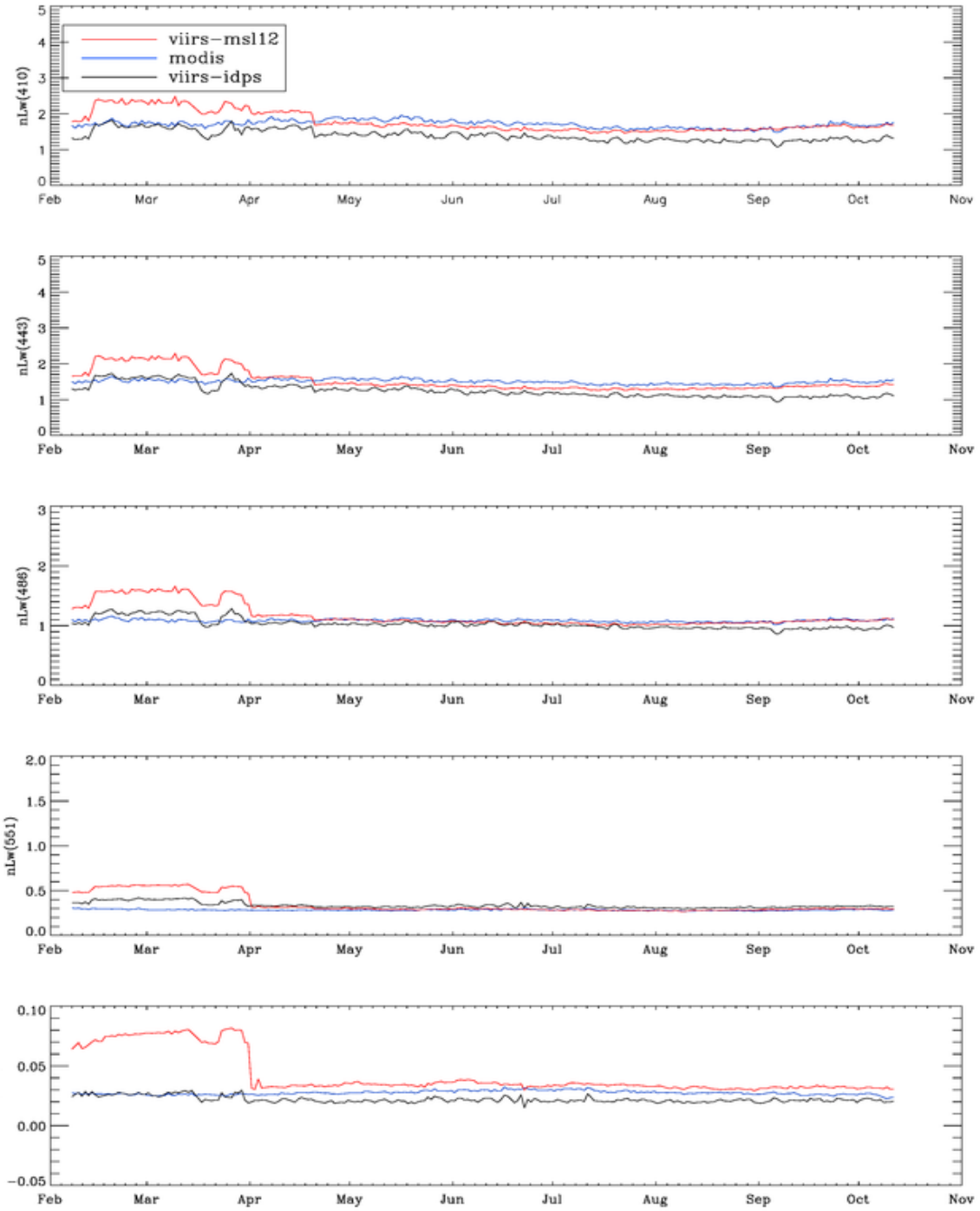


**VIIRS** (IDPS) nLw(671), monthly composite October, 2012



**MODIS-Aqua** nLw(667), monthly composite October, 2012

# VIIRS vs. MODIS Quantitative Comparisons



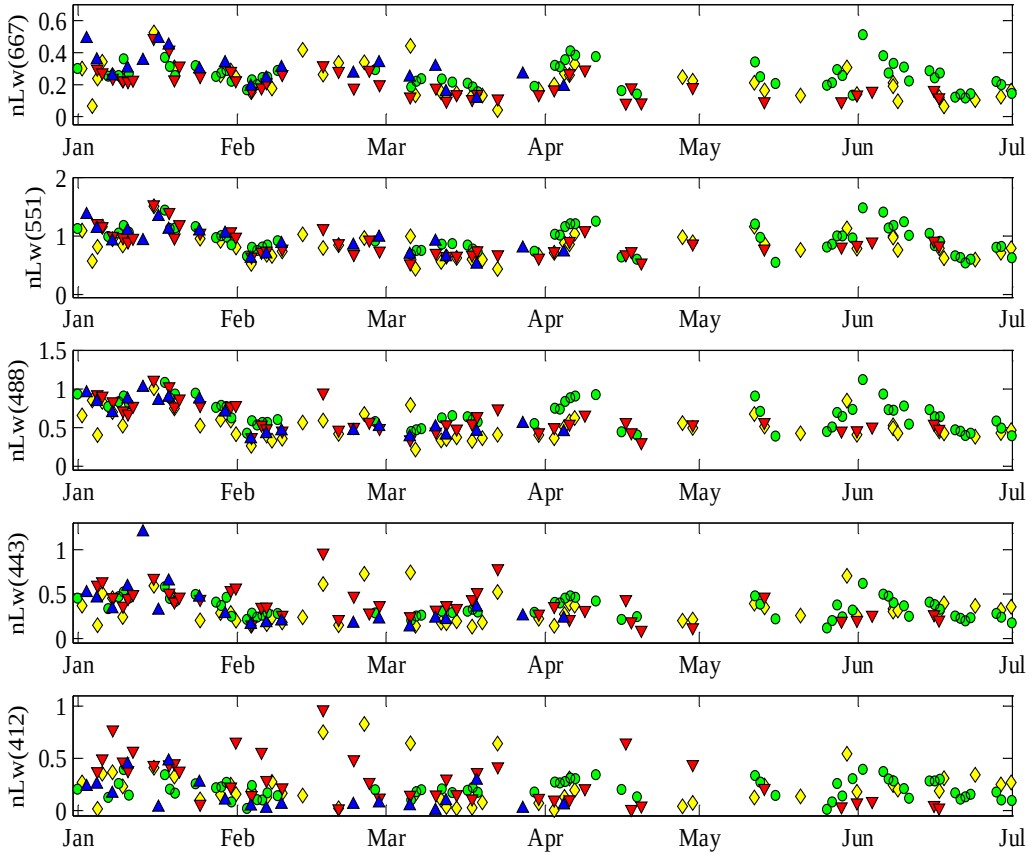

Comparison of VIIRS IDPS OCC EDR with MODIS-Aqua and NOAA-MSL12 results in **global deep-water** open oceans since **Feb. 6, 2012**.

Note:
No vicarious calibration has been applied in the IDPS VIIRS EDR; but vicarious calibration gains have been applied in the NOAA-MSL12 results after April 1, 2012.

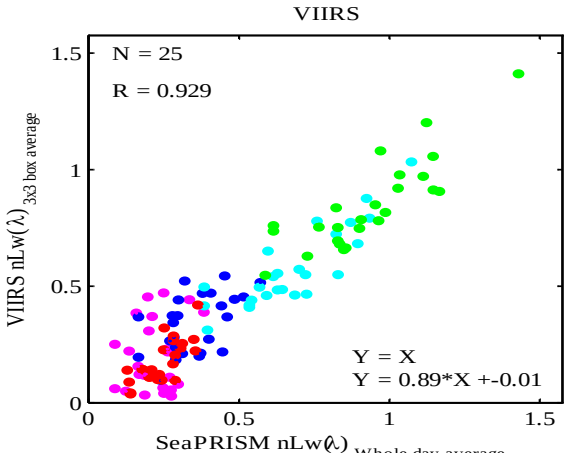
**MODIS-Aqua** data were obtained from NASA/OBPG ocean color website.

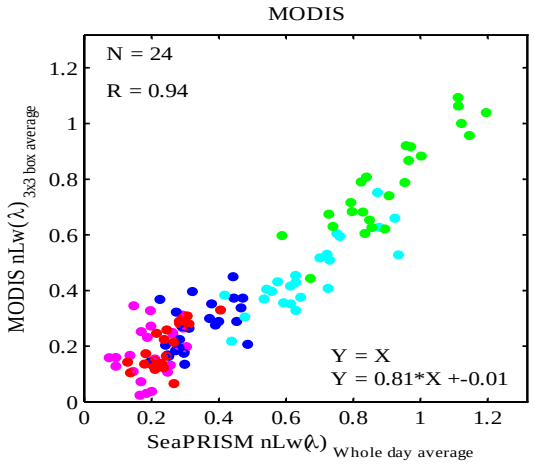
# OCC EDR Evaluation (AERONET-OC LISCO)

Principle investigator - Sam Ahmed **(CCNY)** - Coastal Site Data Uncertainties and In situ Validation-**LISCO**




Time series of normalized water leaving radiance, nLw(λ), retrieved from SeaPRISM (green dots), MODIS (yellow diamonds), VIIRS (red triangles) and MERIS (blue triangles) at the SeaPRISM spectral bands (NASA processing).



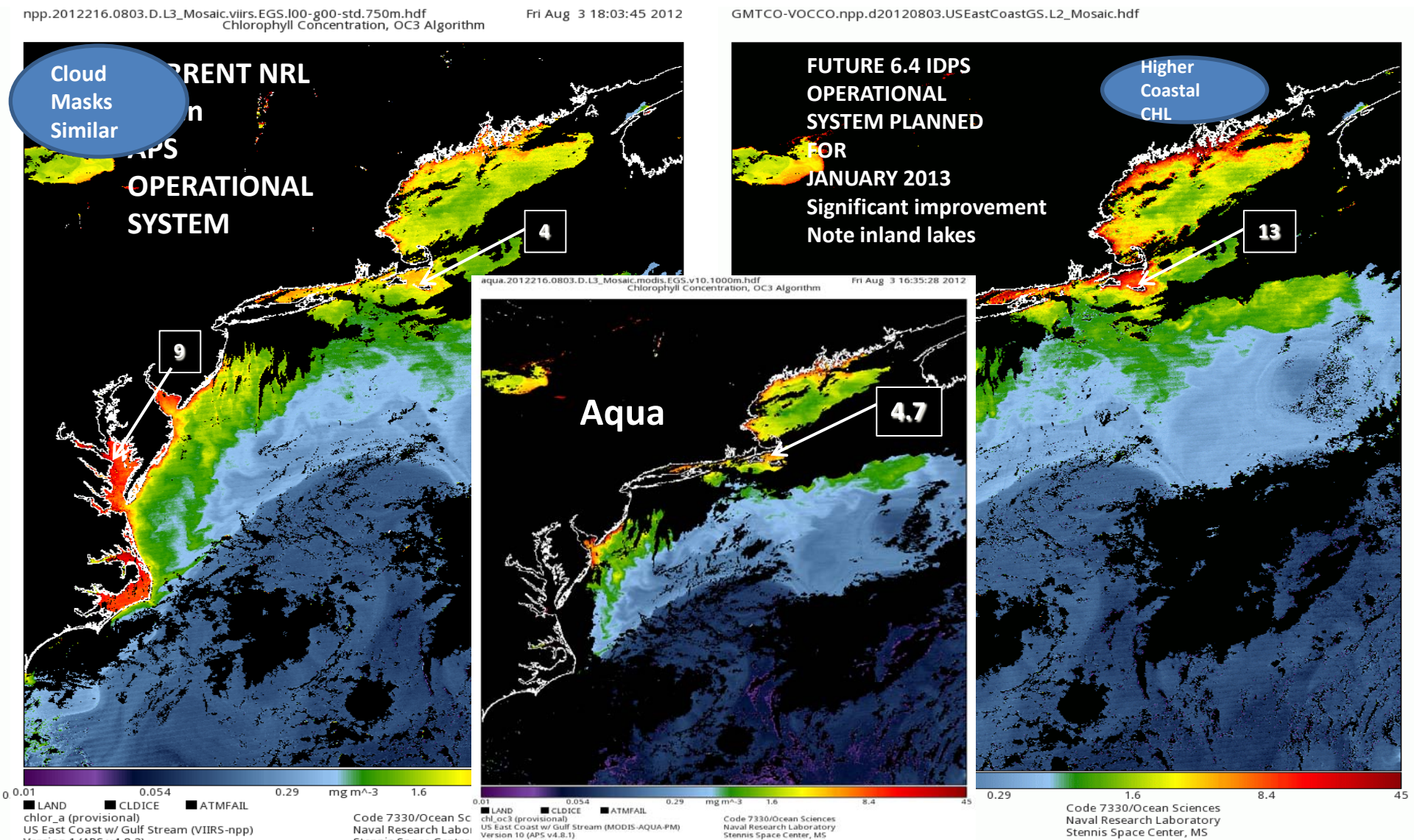




Matchups between SeaPRISM and VIIRS, MODIS nLw

Data were also compared from NASA, CLASS (NOAA) and NRL processing

# OCC EDR Evaluation (USM-NRL-SDSU)

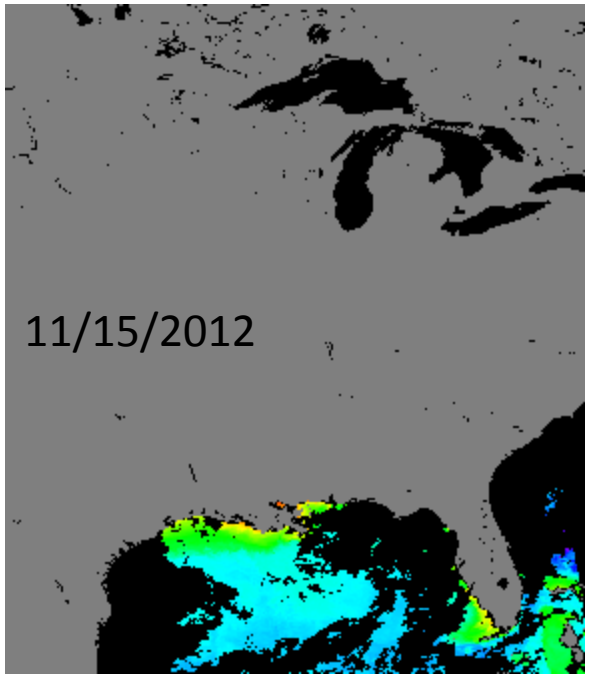
Evaluated and updated the IDPS EDR -- Continual upgrades planned for FY 13 tasking



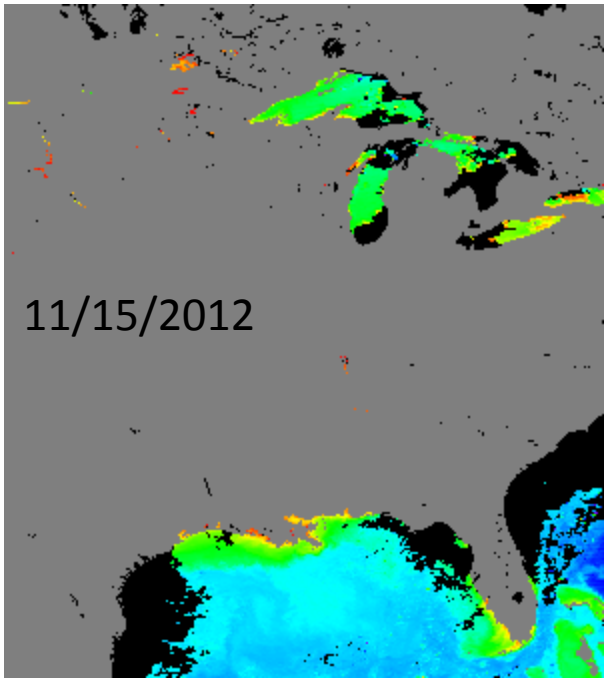
# Considerations/Known Issues

- No vicarious calibration has been applied in the operational IDPS OCC EDR processing.
- No Chl-a retrievals in case of negative remote-sensing reflectance in M1-M4 (to be fixed soon).
- No retrievals in coastal and inland waters (to be fixed soon).
- IDPS OCC EDR quality flags need significant modifications/improvements.
- Sun glint masking/correction algorithm needs to be modified/improved.
- IOP-a and IOP-s products have not been evaluated yet and these products are considered as experimental products. It may require a different IOP algorithm.
- There are atmospheric correction problems in coastal turbid and inland waters due to the algorithm issue. The required algorithm for correction of the near-infrared (NIR) water-leaving radiance contributions has not been implemented in the IDPS OCC EDR data processing.
- Known upstream SDR issues:
  - Sensor degradation (suggested to update F-LUTs daily, resolved and implemented in Mx6.2).
  - Duel gain switch issue (resolved and implemented in Mx6.3).
  - The issue with nLw bias in the VIIRS blue bands since mid-May of 2012 caused by SDR calibration (under investigation, there is a solution from the SDR team).

# Issues with IDPS Coastal/Inland Waters



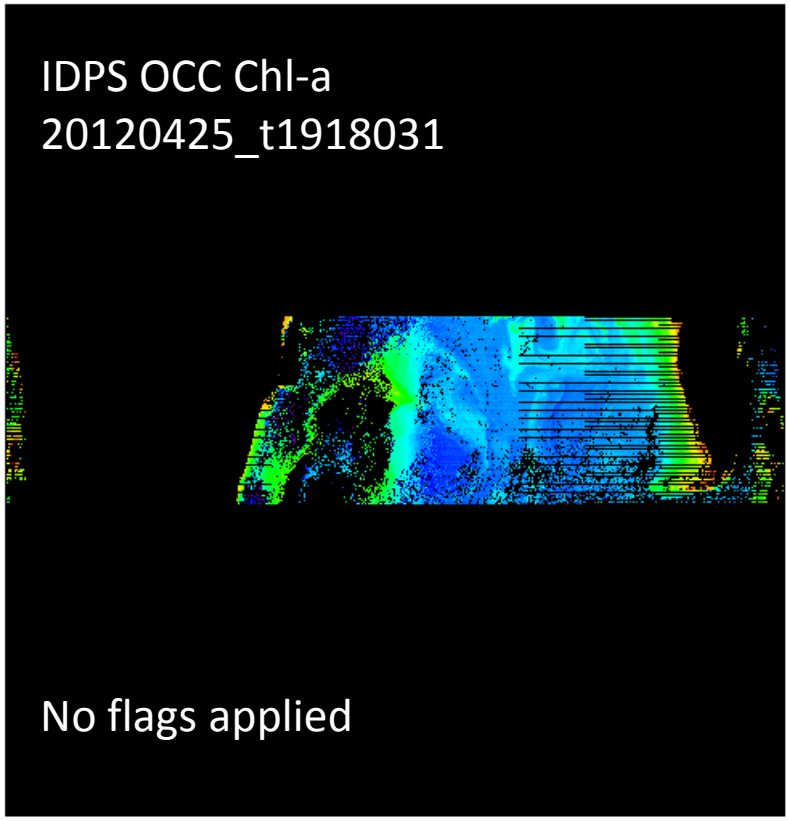

IDPS VIIRS OCC Chl-a

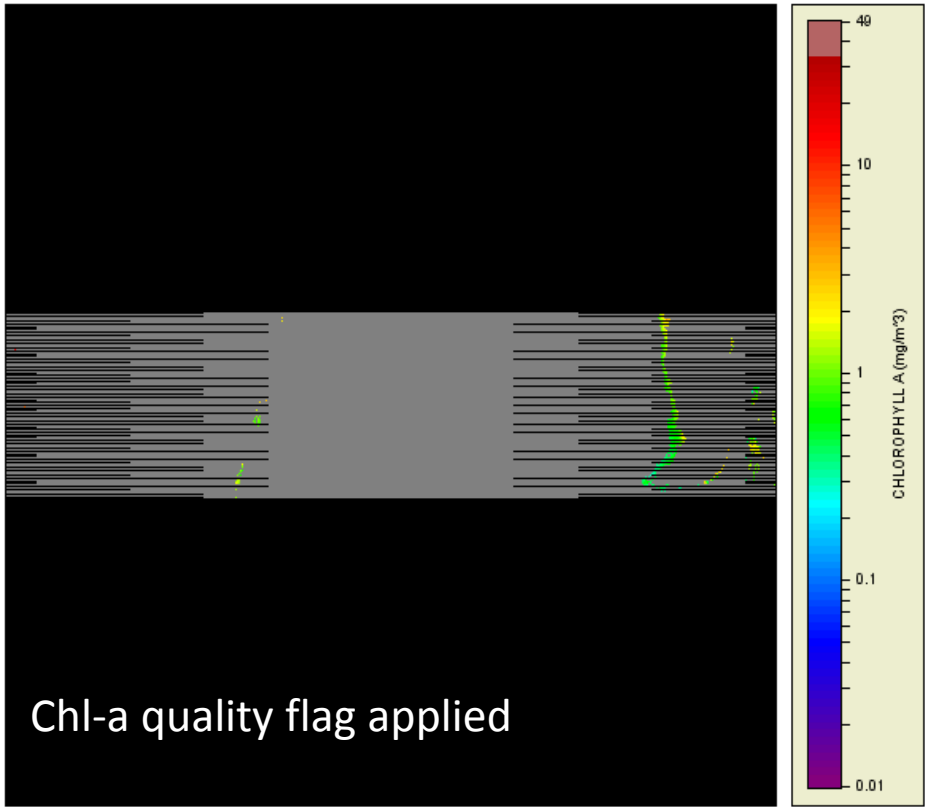



NOAA-MSL12 Chl-a

1. IDPS has no OCC retrievals in the Great Lakes
2. IDPS has less valid pixels in the turbid coastal waters near Mississippi River mouth

# Issues with IDPS Quality Flags



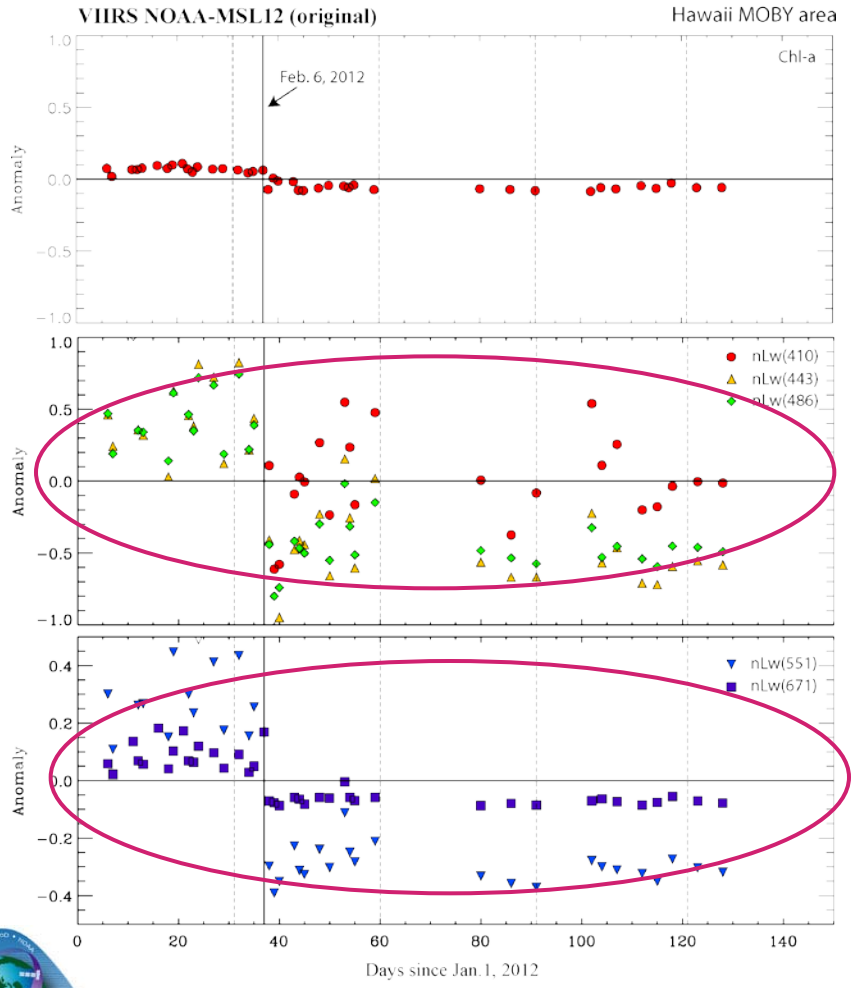

Chl-a

Chl-a flag “poor” masked

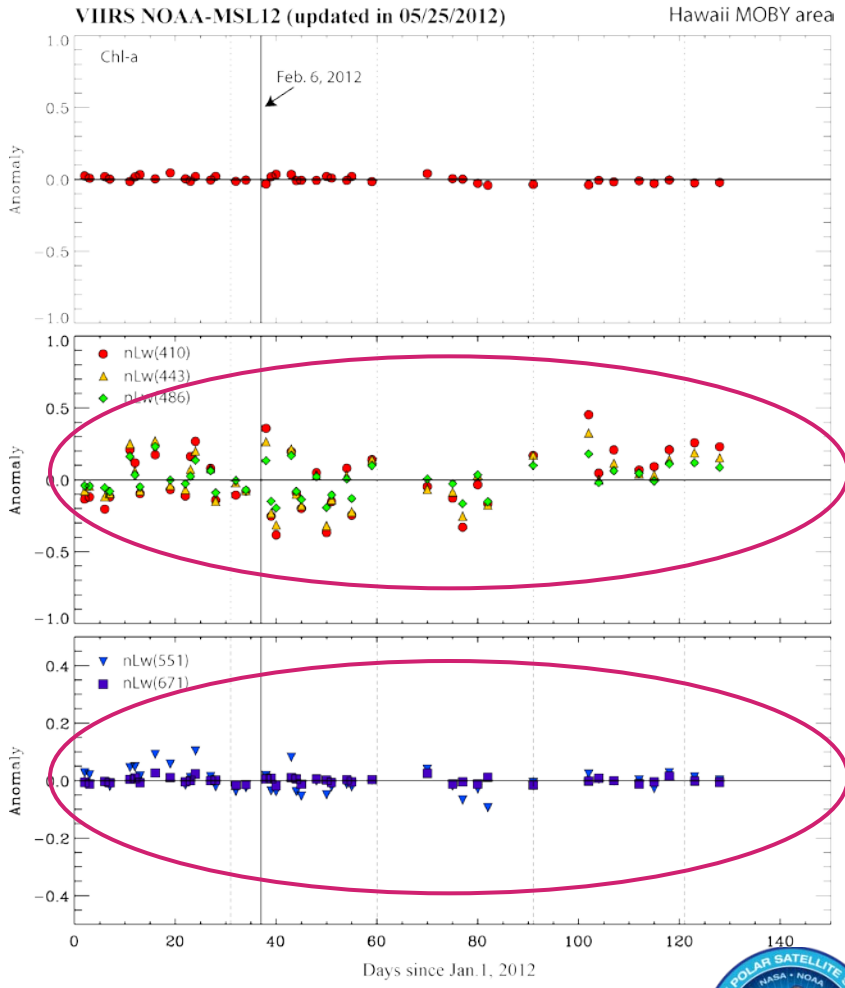
Most pixels, including many good pixels are flagged as “poor”

# Comparison of VIIRS Ocean Color Product Anomalies with Weekly and Daily Update F-LUT (Issue resolved)

## Weekly Update SDR




## Daily Update SDR




Daily improved Cal F-LUTs from **De Luccia** group, and we have **reprocessed** VIIRS RDR to SDR with new daily Cal F-LUTs.

# Beta Justification Summary (1/2)

- **Criteria:** Early release product
  - VIIRS OCC EDR is dependent on upstream SDRs
    - SDR product reached provisional maturity in October 2012
  - Minimum post-launch changes have been made to OCC EDR
- **Criteria:** Minimally validated
  - nLw's have been compared with MOBY in situ data, MODIS-Aqua, NRL-APS, AERONET-OC in situ data, and MSL12 science processing results.
  - Quality flags and IOPs need more evaluation/validation efforts
- **Criteria:** May still contain significant errors
  - No vicarious calibration has been applied in the IDPS OCC EDR processing.
  - Found significant biased low nLw at the blue bands since mid-May of 2012 due to upstream SDR issue.

# Beta Justification Summary (2/2)

- **Criteria:** Available to allow users to gain familiarity with data formats and parameters
  - VIIRS OCC EDR team and Cal/Val team have evaluated ocean color products from CLASS and GRAVITE
  - The nLw's and Chl-a values are reasonable compared with MOBY and other in situ data and those from MODIS-Aqua
  - NOAA-MSL12 science processing results show that VIIRS OCC EDR can be improved to a better quality with some algorithm refinements
  - Beta release will allow users to gain experience with the data formats and parameters for user validation and feedback
- **Criteria:** Product is not appropriate as the basis for quantitative scientific publication studies and applications
  - The product has known flaws (e.g., no vicarious calibration, known biases in nLw since mid of May due to upstream SDR issue)
  - No OCC retrievals if certain band nLw (or remote sensing reflectance) is negative
  - Quality flags need some significant improvements
  - Algorithms need refinements/improvements for coastal turbid waters

# Future Plans

- Continue Cal/Val activities for VIIRS OCC EDR.
- Continue working with the SDR team to improve SDR and OCC EDR products, in particular, the issue with significant sensor NIR & SWIR bands degradations.
- Evaluate and improve data quality flags.
- Apply vicarious calibration gain coefficients
  - We have completed the Cal/Val process using ADL4.0, and obtained preliminary vicarious calibration gains for M1-M7 as 0.9992, 0.9974, 0.9964, 0.9797, 0.9902, 0.9872, 1.0, respectively.
- Algorithms refinements and improvements, e.g., sun glint masking and correction, sea ice masking, etc.
- Algorithms improvements for coastal turbid and inland waters.

# Conclusions

- VIIRS OCC EDR has met the beta stage based on the definition and the evidence shown in the presentation.
- There are still some issues in the VIIRS OCC EDR products, but solutions have been evaluated and recommended.
- Some issues (e.g. negative nLw's and High Sensor Zenith Angle flags) will be resolved in next IDPS build (Mx6.5), and will be further reviewed in provisional maturity justification.
- Based on science processing results from RDR to SDR using ADL with updated daily F-LUTs, and SDR to EDR (or Level-2 data) using NOAA-MSL12, comparison results from MODIS-Aqua, as well as results from NRL-APS, VIIRS OCC EDR has great potential to be promoted into a high quality ocean color product with further algorithm refinements and improvements.