

Validation of VIIRS Ocean Color primary products in coastal regions

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Introduction

- ❑ The **Suomi National Polar-orbiting Partnership (SNPP)** spacecraft was successfully launched on October 28, 2011 bearing several Earth observing instruments, including the **Visible-Infrared Imager Radiometer Suite (VIIRS)**.
- ❑ The quality of the VIIRS OC primary products, **normalized water-leaving radiances (nLw)**, **aerosol optical thickness (τ_a)**, and **Angstrom exponent (γ)**, are evaluated for typical coastal waters conditions based on **MODIS** and **AERONET-OC** data.
- ❑ The impacts of the different processing schemes, **NASA's initial and version 2012.2**, as well as **NOAA's Interface Data Processing Segment (IDPS)**, on the VIIRS's OC data retrievals are assessed.
- ❑ In particular, the respective roles of the vicarious calibration procedures on the retrieved data quality are scrutinized in order to aid the scientific community to better interpret the physical or biogeochemical meanings of the VIIRS data in coastal areas.

Outline

- OC satellite data processing schemes.**
- AERONET-OC sites & data filtering procedures.**
- Spectral consistency of the VIIRS nLw retrievals of NASA OBPG processing schemes.**
- Uncertainty of VIIRS data through the time series and matchup comparison carried out with MODIS and SeaPRISM data.**
- Initial assessments of the VIIRS OC products of IDPS system.**
- Evaluations on the retrieval of atmospheric parameters.**
- Summary.**

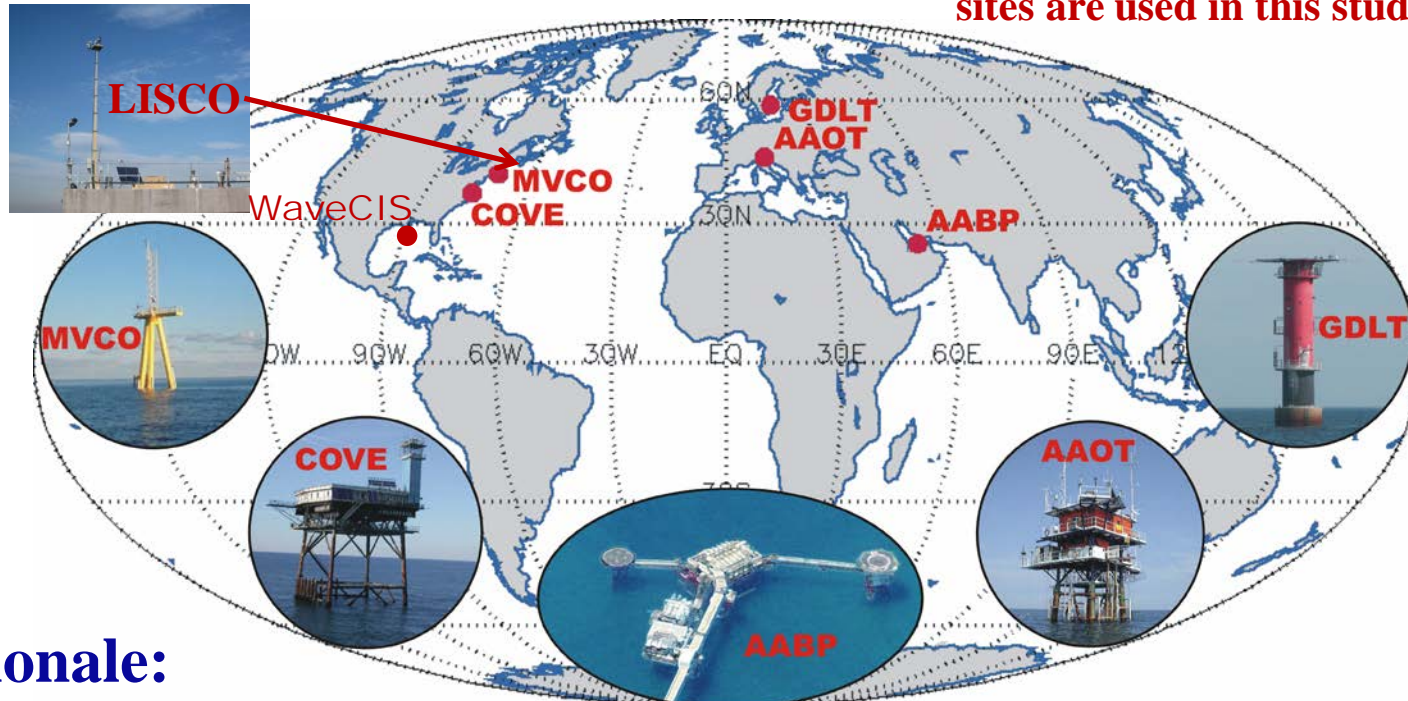
Processing schemes

- ❑ NASA is deriving a continuous temporal calibration based on the on-board calibration measurements for the visible bands, and then reprocessing the full mission to produce a **continuously calibrated sensor data record** (SDR) product.
- ❑ In the initial processing (**VIIRS^{initial}**), the **vicarious calibration reference was derived from a sea surface reflectance model** and a climatology of chlorophyll-a concentration.
- ❑ In the 2012.2 reprocessing (**VIIRS^{12.2}**), the **vicarious calibration is based on measurements from the Marine Optical Buoy (MOBY)** near Lanai Hawaii (the same reference is currently used for SeaWiFS and MODIS).
- ❑ In parallel with the NASA processing schemes, **Interface Data Processing Segment (IDPS)** provides all VIIRS operational data products including ocean color data.
- ❑ **Temporal calibration is changed at discrete intervals (currently daily). Vicarious gain is not implemented yet for the period of the data used in this study.**
- ❑ IDPS has gained beta status for evaluation.

AERONET-Ocean Color

AERONET – Ocean Color: is a sub-network of the Aerosol Robotic Network (AERONET), relying on modified sun-photometers to support ocean color validation activities with highly consistent time-series of $L_{WN}(\lambda)$ and $\tau_a(\lambda)$.

Data of the LISCO & and WaveCIS sites are used in this study.



Rationale:

- Autonomous radiometers operated on fixed platforms in coastal regions;
- Identical measuring systems and protocols, calibrated using a single reference source and method, and processed with the same code;
- Standardized products of normalized water-leaving radiance and aerosol optical thickness.

AERONET-OC sites used in the study

- ❑ AERONET-OC standard multi-spectral SeaPRISM instrument
- ❑ Measurement sequences are executed every 30 minutes 12:00 PM \pm 4 hrs of local time
- ❑ at OC bands: 413, 442, 491, 551 & 667nm.

The Long Island Sound Coastal Observatory (LISCO)

- ❑ Locate at approximately 3 km from the shore of Long Island near Northport, NY, USA.
- ❑ Particulate backscattering coefficient at 551 nm is in the range of 0.01 to 0.03 m^{-1} .
- ❑ Total absorption coefficient at 442 nm varies from 0.38 to 1.2 m^{-1} .
- ❑ The absorption due to Colored Dissolved Organic Matter (CDOM) at 442 nm is typically close to 0.4 m^{-1} and in few cases can be as high as 1 m^{-1} .

The WaveCIS site

- ❑ Locate at approximately 18 km from the shore of Timbalier Bay area, MS, USA.
- ❑ Particulate backscattering coefficient at 551 nm for WaveCIS water is usually around 0.01 m^{-1} but, in some rare cases, it reaches up to 0.04 m^{-1} .
- ❑ Unlike LISCO water, total absorption of the water body is low with its seasonal average value equal to 0.31 m^{-1} at 442 nm of which \sim 0.15 m^{-1} is attributed to CDOM.

AERONET-OC sites used in the study

SeaPRISM instrument

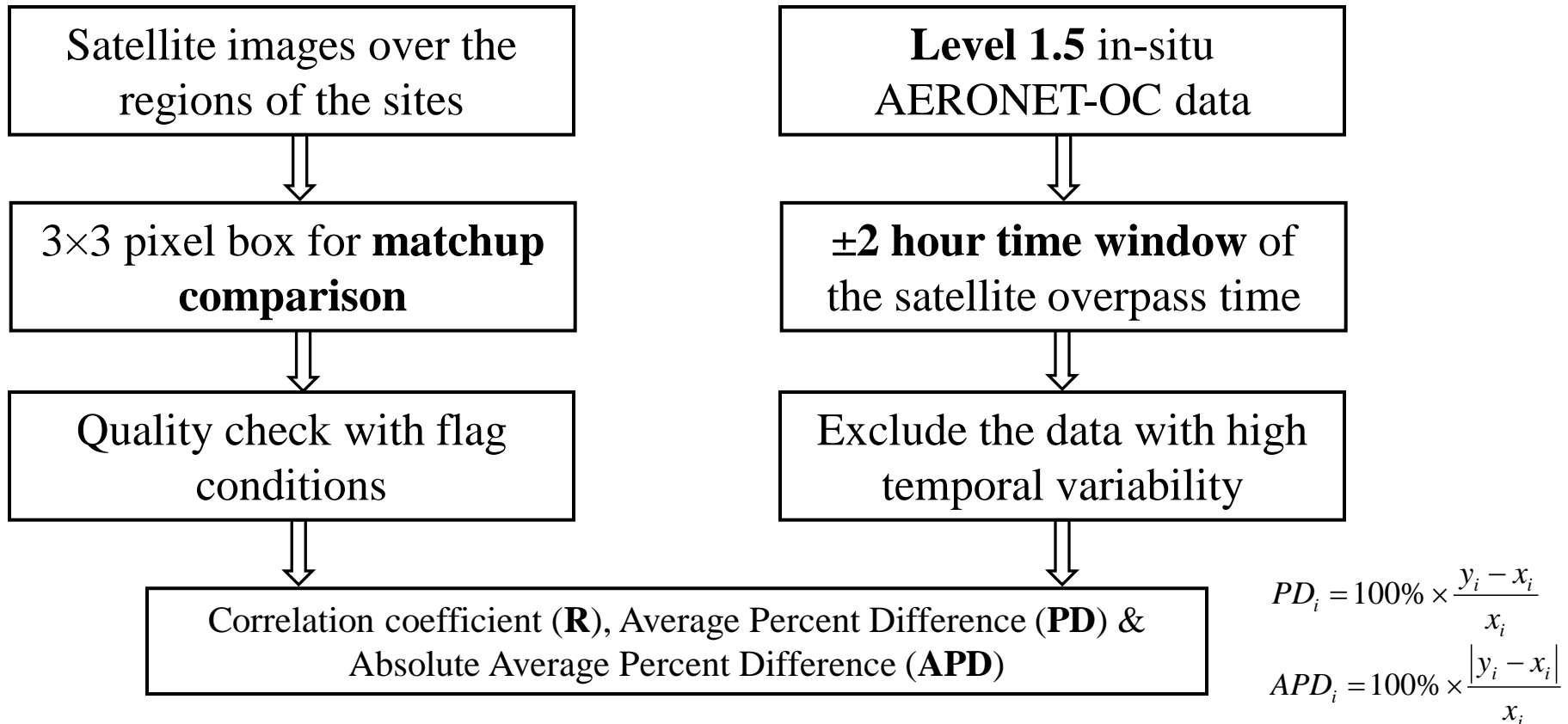


- Sea Radiance
- Direct Sun Radiance and Sky Radiance
- Bands: 413, 443, 490, 551, 668, 870 and 1018 nm
- **Data acquisition every 30 minutes for high time resolution time series**



Satellite Validation

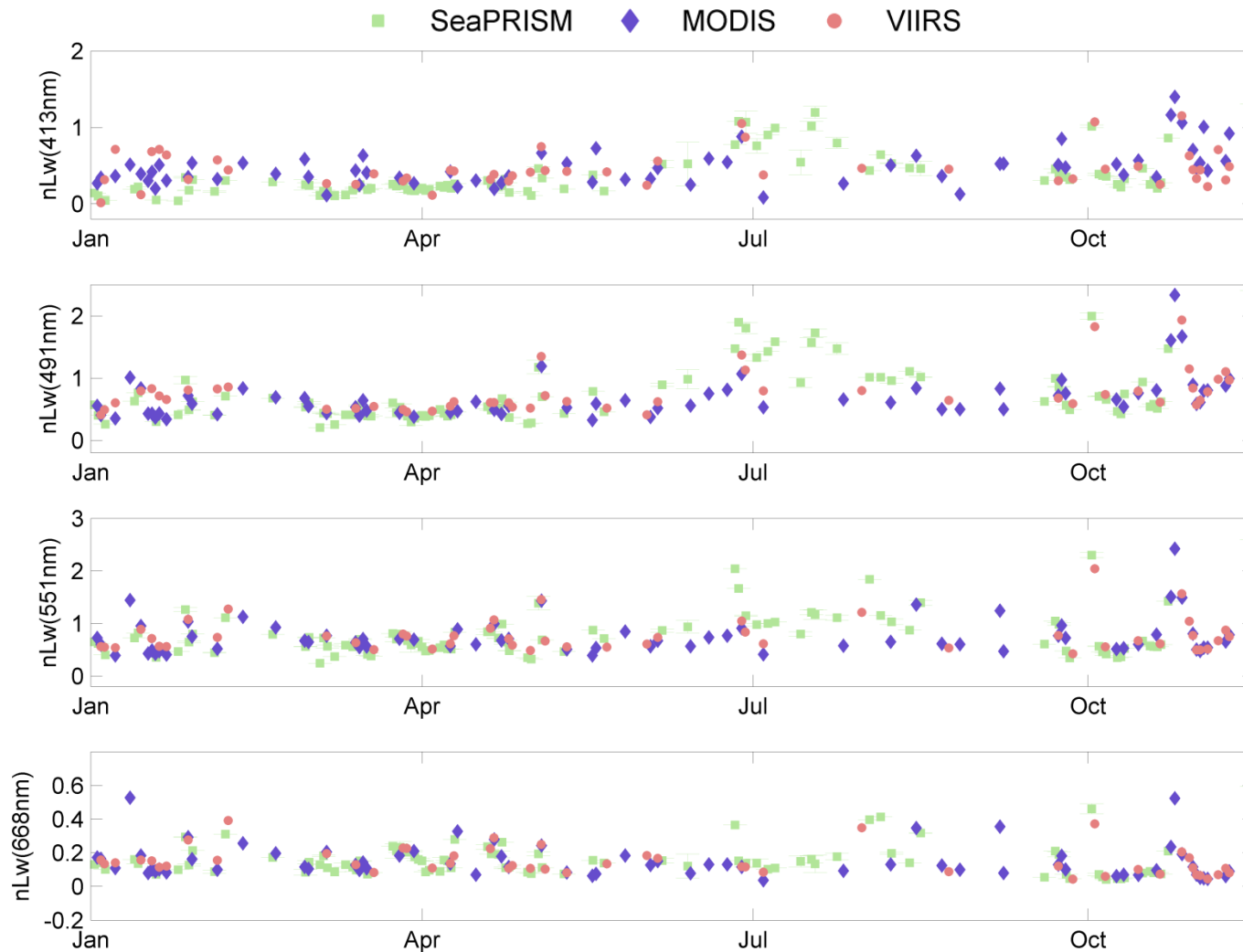
Data filtering procedures for matchup comparisons



Exclusion of any pixel flagged by the NASA data quality check processing

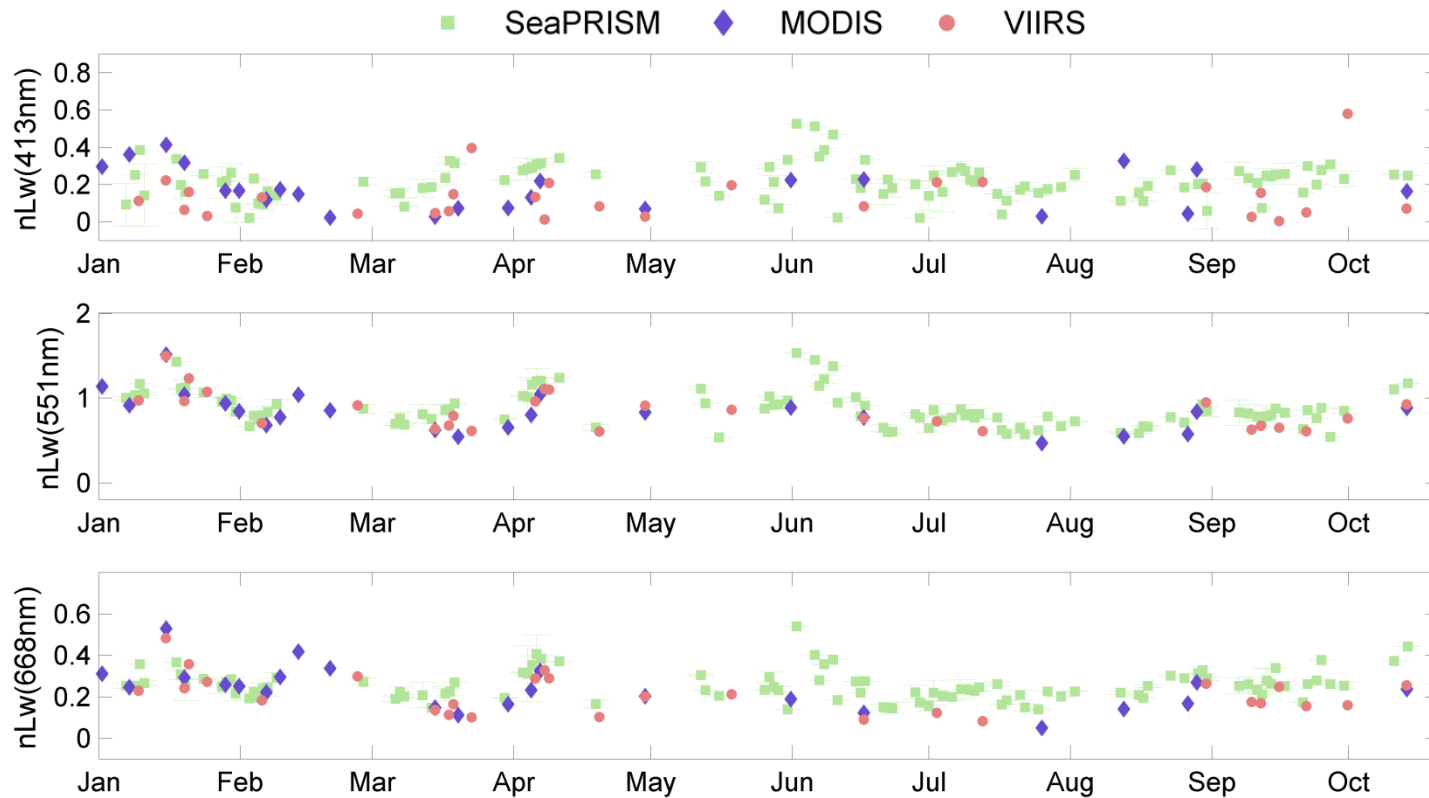
- Land & Cloud
- stray light contamination
- Atmospheric correction failure
- sun glint contamination
- reduced or bad navigation quality
- negative Rayleigh-corrected radiance
- $\theta_v > 60^\circ$,
- $\theta_s > 70^\circ$
- negative value in any one of the wavelengths

Time series of normalized water leaving radiance, $nLw(\lambda)$, for WaveCIS site (Year 2012)



- ❑ **Strong temporal agreement** between the satellites and in-situ data.
- ❑ **Seasonal variations** in the nLw data are captured well.

Time series of normalized water leaving radiance, $nLw(\lambda)$, for LISCO site (Year 2012)

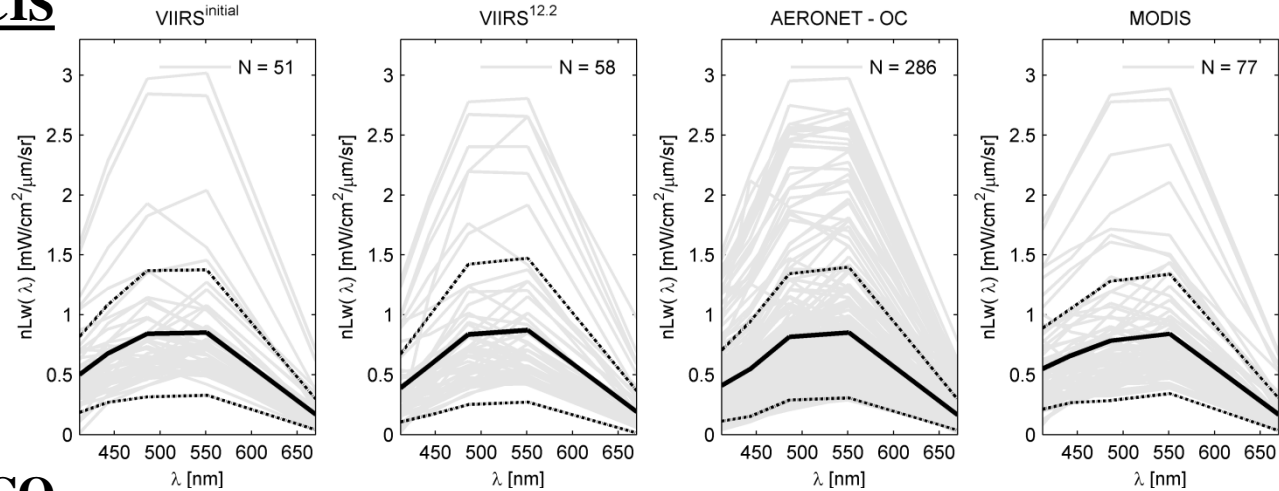


- ❑ **Strong temporal agreement** between the satellites and in-situ data at the 551 & 668 nm wavelengths.
- ❑ Seasonal variations in the nLw data are also captured well.
- ❑ Data availability is **lower** for LISCO mostly due to exclusion of the pixels with atmospheric correction failure and presence of **negative** values in water leaving radiance especially at violet (413 nm) and blue (442 nm).

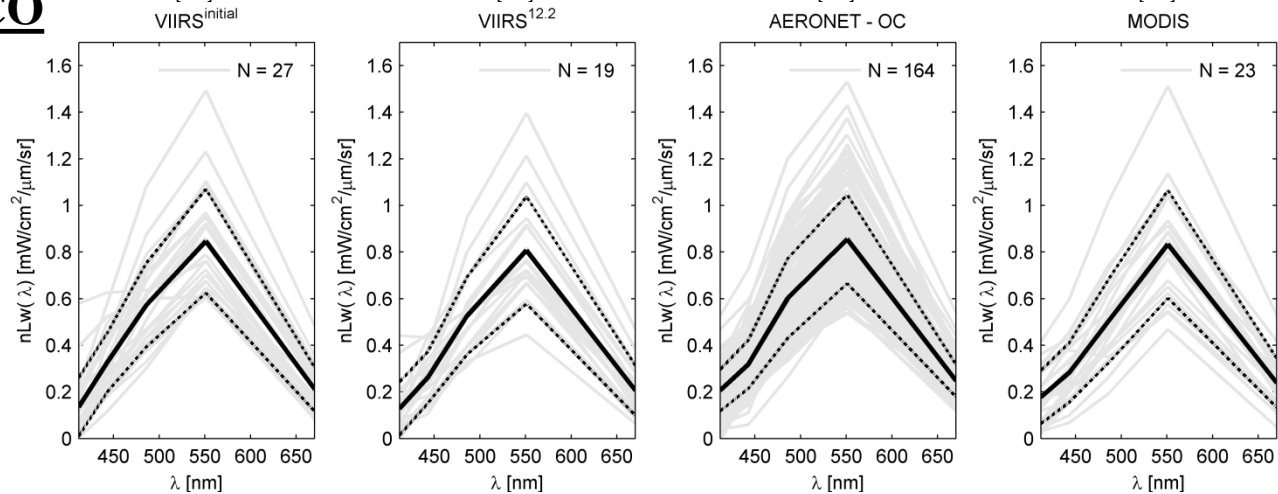
nLw spectral consistency analysis

WaveCIS

— Matchup nLw
— average
- - - average \pm 1std



LISCO



- Variation ranges of match-up spectra, and their averages & standard deviations indicates qualitative agreement between the satellites and in-situ nLw data for both sites. (LISCO lower absolute values (CDOM) WaveCIS generally more sediments from delta outflows)
- Average values and spectral shapes are also very consistent.

nLw Spectral consistency analysis

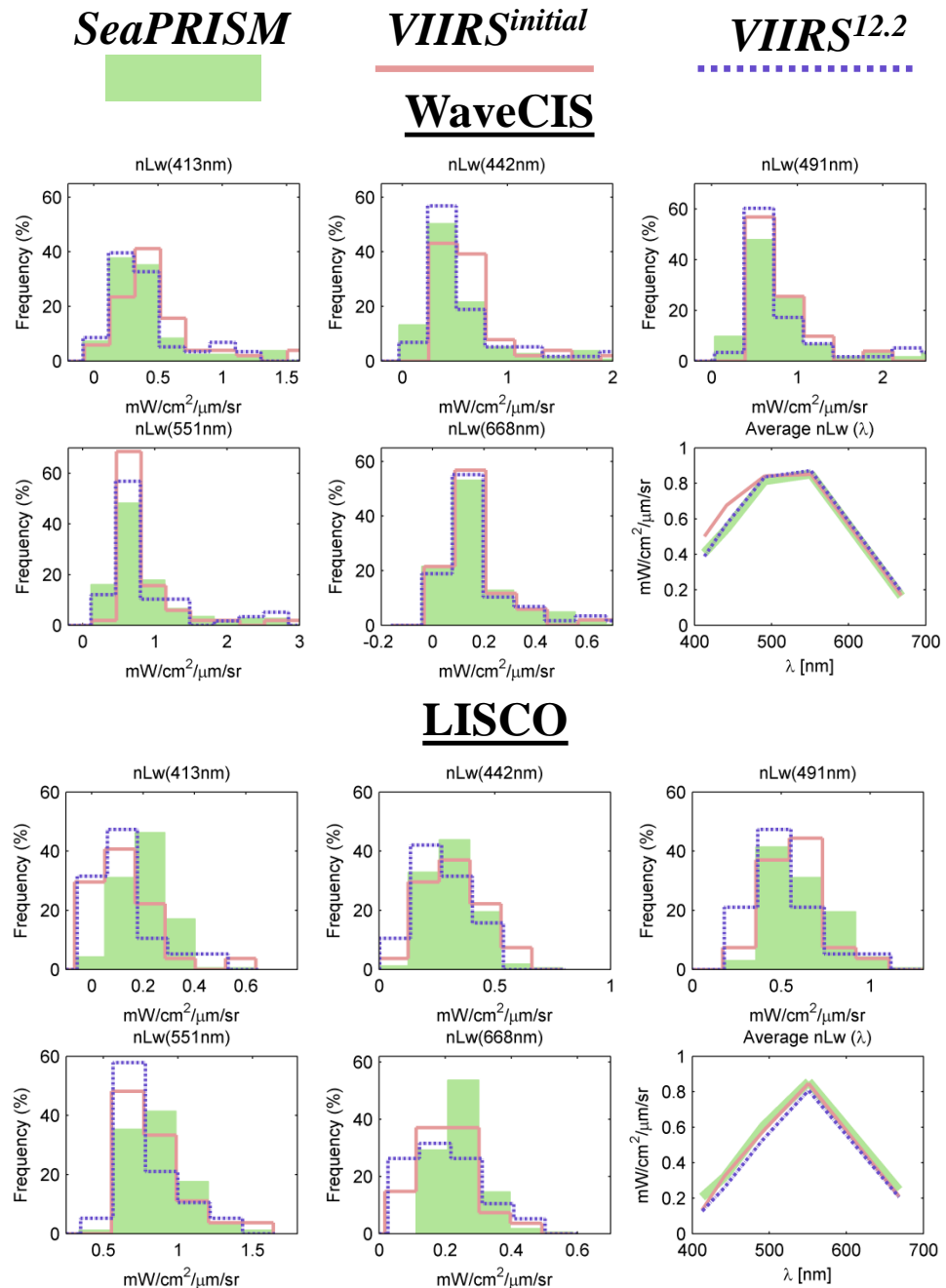
- ❑ Histograms of $nLw(\lambda)$ data of VIIRS^{initial}, VIIRS^{12.2} and SeaPRISM.
- ❑ Overall average nLw spectra calculated from all available spectral data of the entire VIIRS operational period are also shown.

WaveCIS

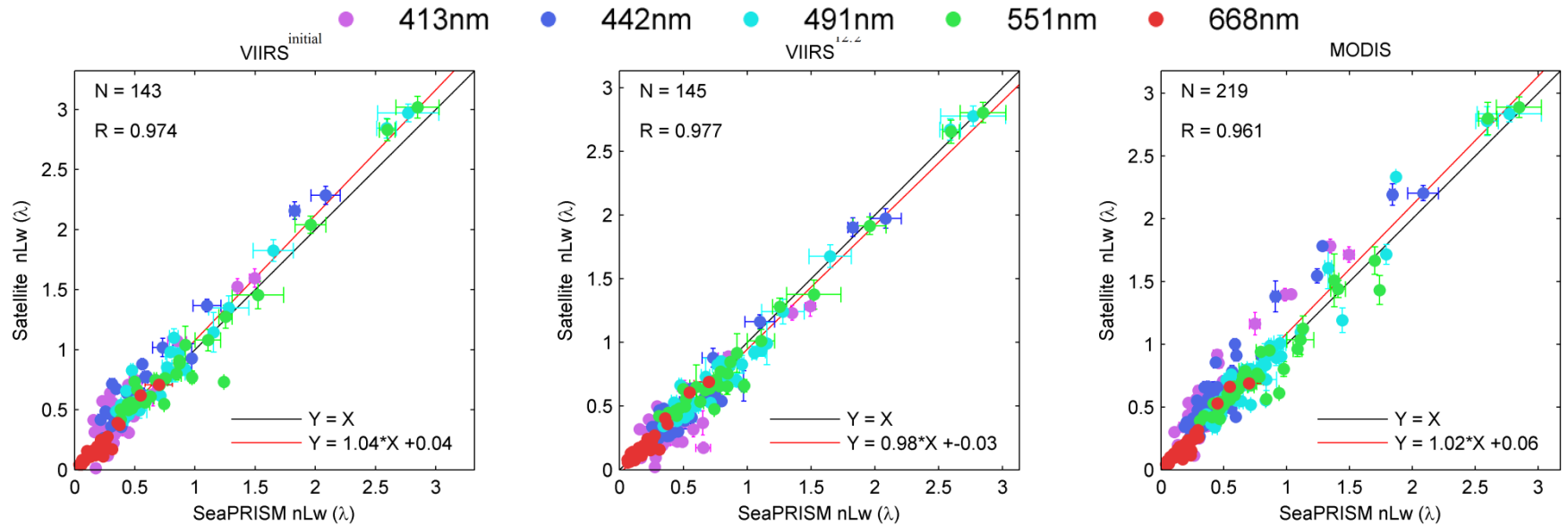
- ❑ Frequency distributions of the VIIRS^{12.2} match better the SeaPRISM distributions for all wavelengths than does VIIRS^{initial}.
- ❑ Inconsistent spectral shape in the blue part is observed for average VIIRS^{initial}.
- ❑ Retrievals appear to be enhanced with the new vicarious calibration gains (from MOBY).

LISCO

- ❑ VIIRS data for both processing skew to left at every wavelengths suggesting overall underestimations.
- ❑ Nevertheless, average nLw spectra closely match to SeaPRISM in spectral shapes, values and ranges.
- ❑ This demonstrates validity of VIIRS data in a qualitative sense as well as usefulness of the AERONET-OC sites for validation purpose.

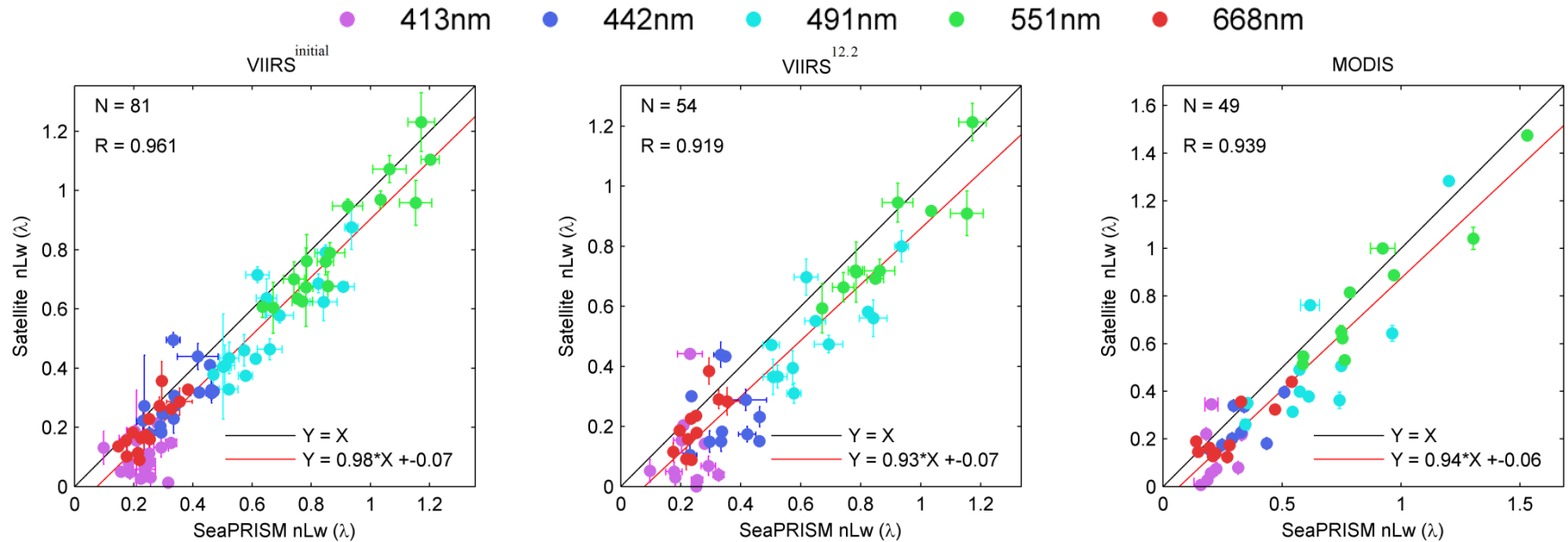


Matchup comparison analysis between the $nLw(\lambda)$ data of satellite and AERONET-OC for WaveCIS site



- ❑ Very high overall correlation between satellite and SeaPRISM data. **R values** for comparisons at each wavelength range from **0.92 at 412 nm to 0.987 at 491 nm** with VIIRS^{initial}.
- ❑ VIIRS^{12.2} is slightly underestimated in terms of SeaPRISM. Conversely, overestimation is observed in VIIRS^{initial}.
- ❑ MODIS exhibits similar regression lines with that of VIIRS^{initial}, nevertheless few outliers exist at 413 and 442nm wavelengths.
- ❑ Larger R values obtained for both VIIRS datasets compared with MODIS data may probably suggest VIIRS's superior performance.
- ❑ Overall percent difference **PD** values are -6.25 and 13.8 for VIIRS^{12.2} and VIIRS^{initial} comparisons respectively. Therefore, it can be concluded that **with the new processing scheme retrieval bias is reduced** compared to initial one.

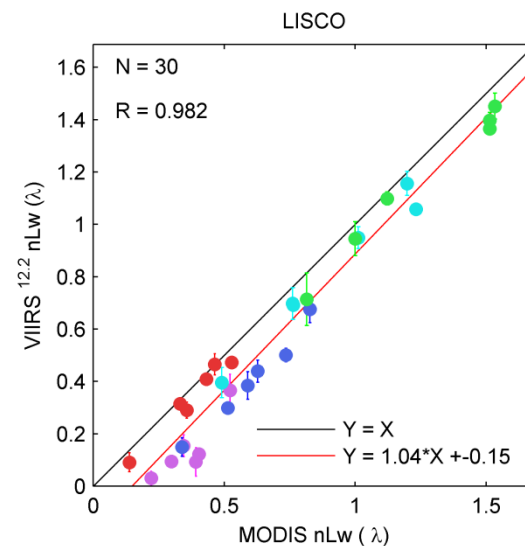
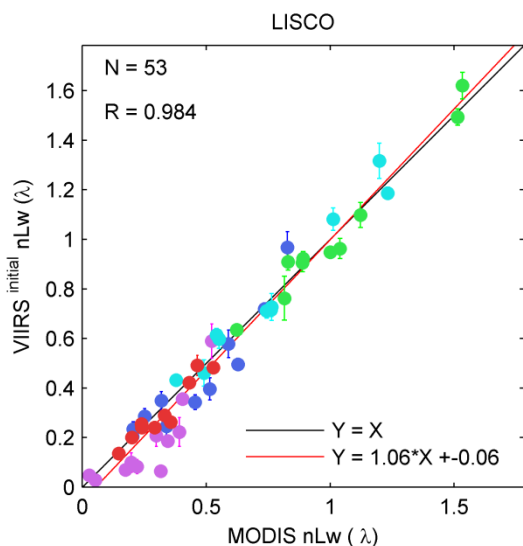
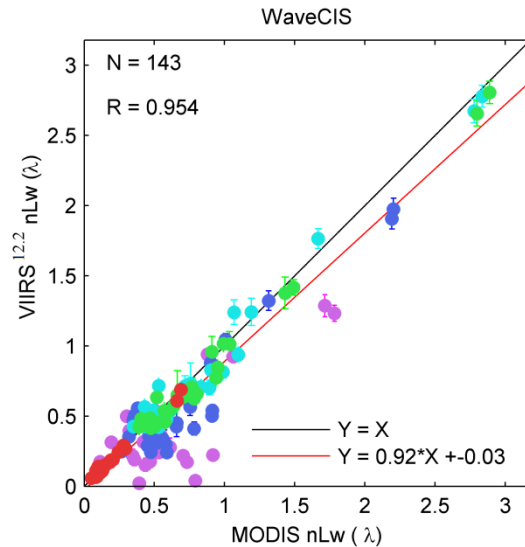
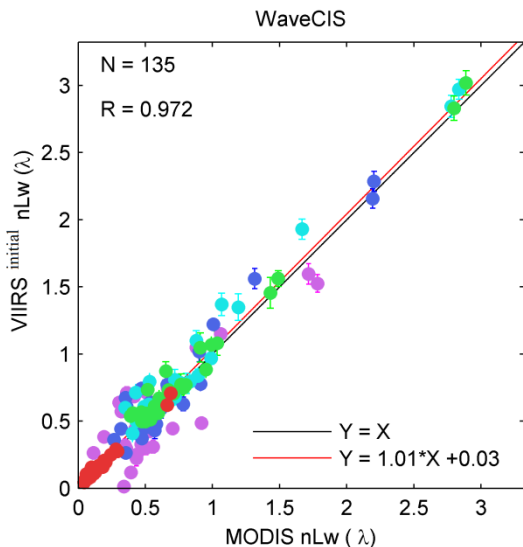
Matchup comparison analysis between the $nLw(\lambda)$ data of satellite and AERONET-OC for LISCO site



- ❑ Very high overall correlation coefficient (R) values between the satellite and SeaPRISM data.
- ❑ With VIIRS^{initial} R values are equal to 0.8618, 0.9361 and 0.8276 at 491, 551 and 668 nm, respectively.
- ❑ However, at 442nm only moderate correlation is attained with its R value equal to 0.5832. The degradation in the correlation is more likely to originate from the data processing rather than sensor's characteristics.
- ❑ This conclusion is based on the strong R value achieved at 668nm wavelength. It should be also noted here that signal to noise ratio (SNR) of VIIRS sensor is higher at 442 nm ($SNR \approx 490$) than at 668 nm ($SNR \approx 378$).
- ❑ With VIIRS^{12.2}, underestimations are further exacerbated to -26% from 22% with VIIRS^{initial} on spectral average.

Matchup comparison analysis between the $nLw(\lambda)$ data of VIIRS and MODIS for WaveCIS and LISCO sites

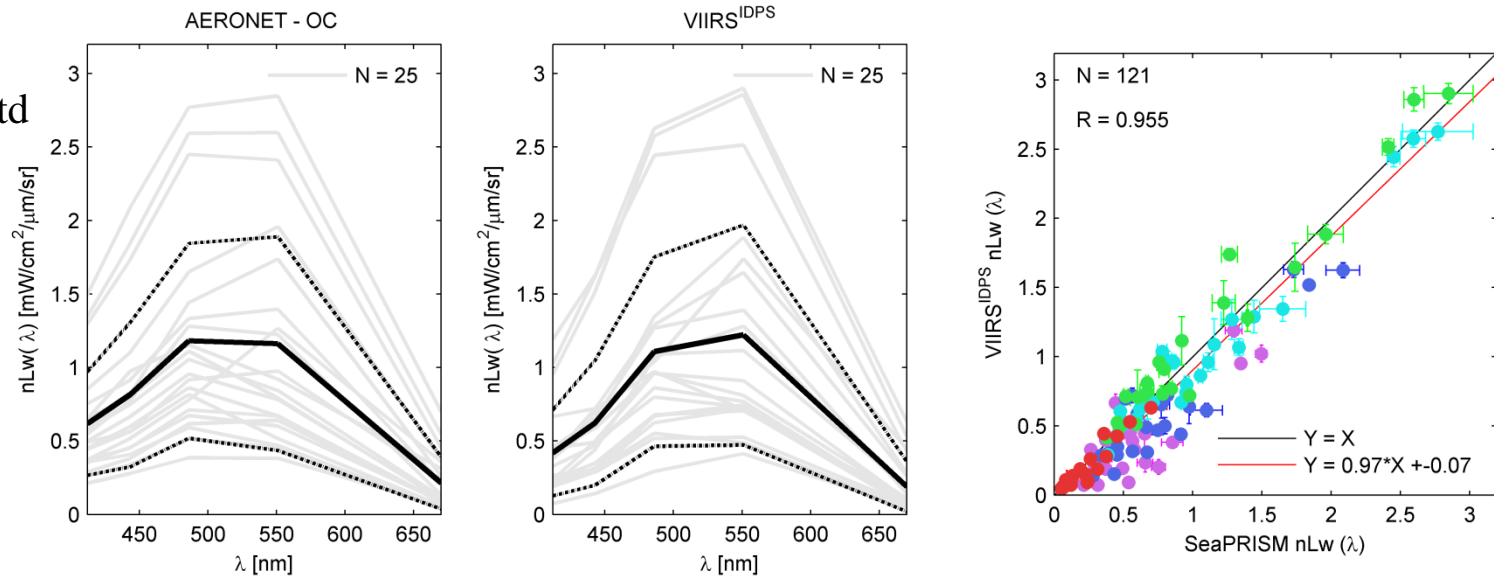
● 413nm ● 442nm ● 491nm ● 551nm ● 668nm



- ❑ Strong consistency between MODIS and VIIRS. $R \approx 0.745$ at 412nm and ≈ 0.994 at 551nm.
- ❑ With VIIRS^{initial} uncertainty between MODIS and VIIRS is very low with APD equal to 3.9% at 551nm for LISCO site.
- ❑ However, at 412nm APD is as high as 50%.
- ❑ Data processing procedures need to be improved for the consistent and accurate retrievals.
- ❑ Additional VIIRS to MODIS cross-calibration can be advocated for more consistent OC data records.

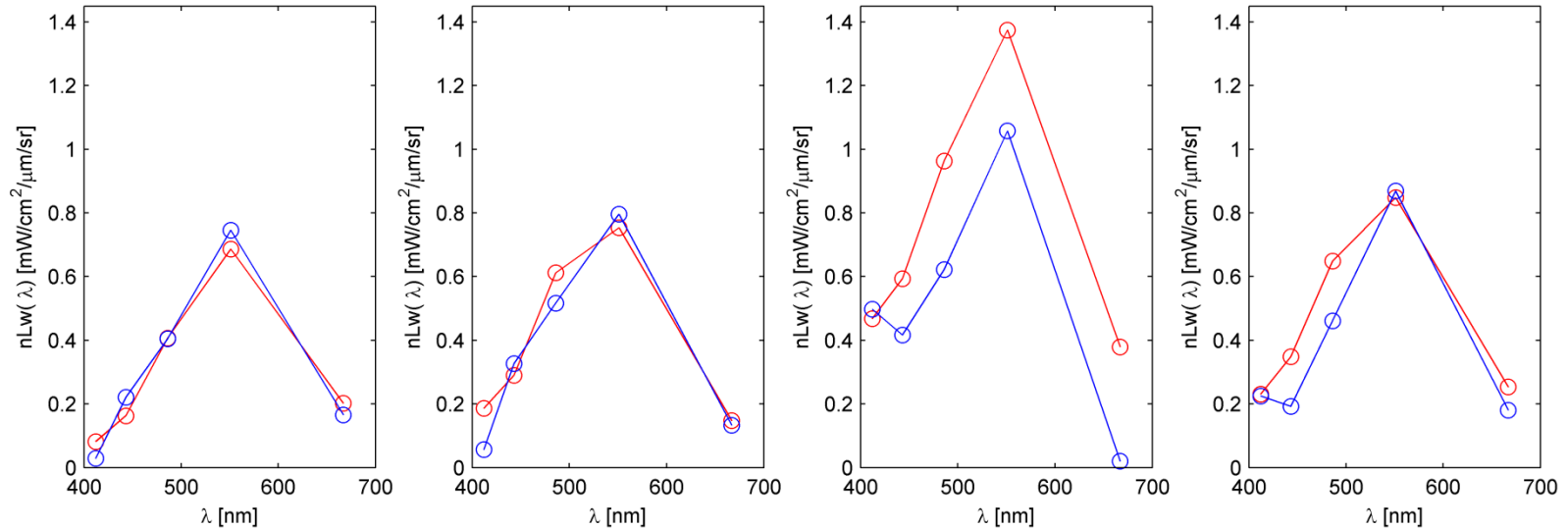
Preliminary assessments of the VIIRS IDPS $nLw(\lambda)$ data for WaveCIS site

— Matchup nLw
— average
- - - average \pm 1std



- ❑ As the processing system continue to evolve, we made initial assessments with a view for assisting the development of processing system for better retrieval of ocean color data especially in coastal zones.
- ❑ spectral variation ranges of the in-situ SeaPRISM and satellite data are consistent with one another.
- ❑ Nevertheless, the overall average spectral shapes are notably different: thus average nLw spectrum of VIIRS^{IDPS} exhibits a pronounced higher value at 551 nm.
- ❑ VIIRS^{IDPS} underestimate at every wavelength except 551 nm, where the overestimation PD value is 7.4%. Overall, VIIRS^{IDPS} underestimates about 13%.
- ❑ Correlations between the VIIRS^{IDPS} and SeaPRISM range from $R = 0.81$ at 412 nm to ~ 0.98 at 551 nm.

VIIRS IDPS $nLw(\lambda)$ data for LISCO site

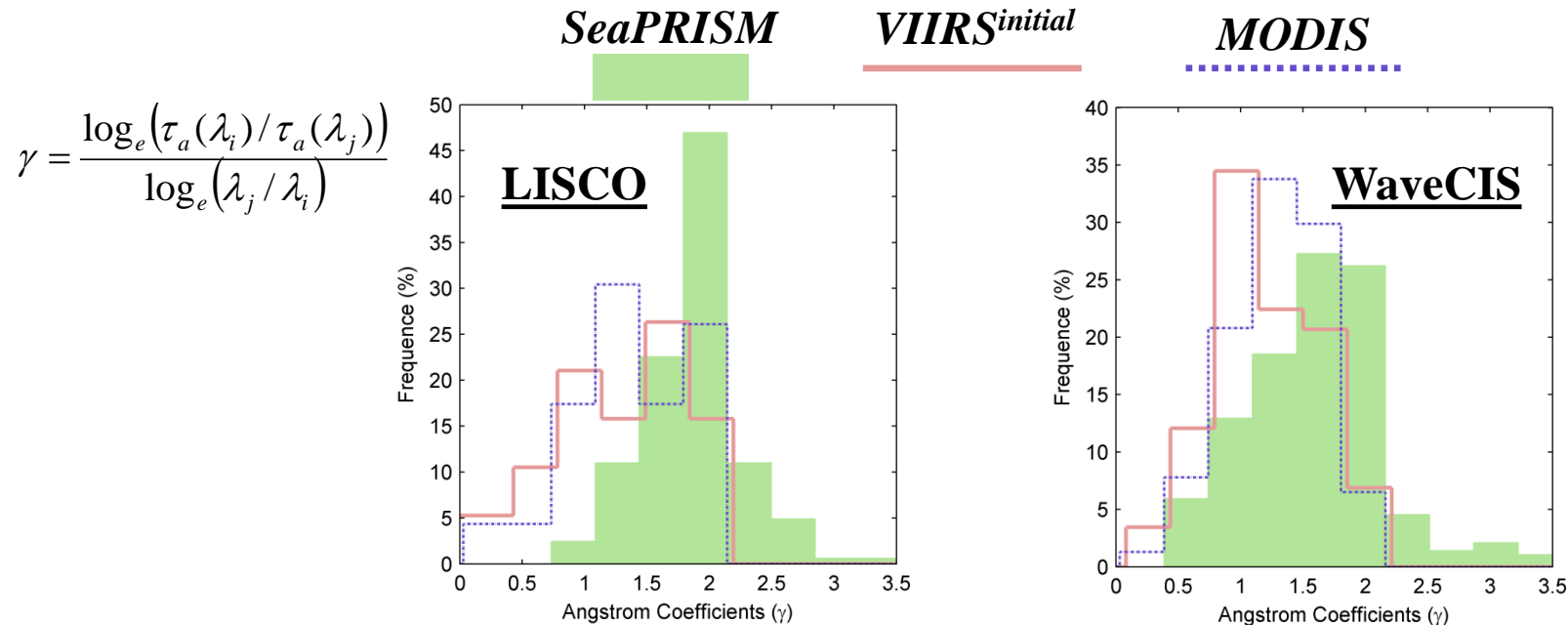


SeaPRISM (plotted in red) and VIIRS^{IDPS} (blue) of the LISCO site for March 8th (1st column), March 14th (2nd column), June 10th and September 30th of 2012.

- ❑ For the LISCO site, out of 32 VIIRS^{IDPS} spectrums, after applying filtering for : the land, high sensor & solar zenith flag conditions, only 4 passed the filtering standard that is applied to all the satellite data throughout this paper.
- ❑ This is mostly due to issues related to the masking of the pixels with fill values for specific reasons (e.g., edge of swath, exclusion of coastal areas).
- ❑ These issues have been identified and are being progressively resolved by the ocean color EDR team.
- ❑ Note that requirements for the IDPS system do not specify the retrieval of ocean color data for coastal and in land waters.
- ❑ Although data availability is low, the observed consistencies exhibit the potential of the IDPS system for the data retrievals of coastal areas.

Evaluations on the retrievals of atmospheric parameters

Qualitative analysis of Angstrom (γ) coefficient distributions

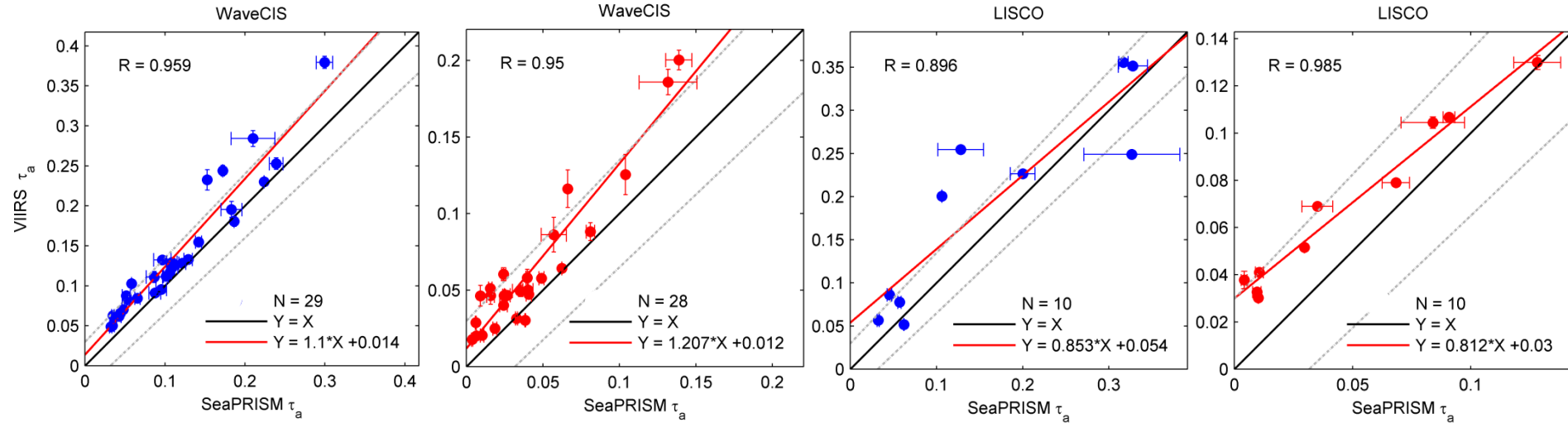


- ❑ Retrieval accuracy of γ is a good indicator of the quality of atmospheric correction process.
- ❑ γ distributions suggest satellite retrievals for the location are underestimated.
- ❑ On average satellite retrieved γ values are about 0.66 (LISCO) & 0.34 (WaveCIS) lower than those retrieved from SeaPRISM.
- ❑ Brookhaven (located in Long Island) and COVE (in Chesapeake Bay), show similar trends.
- ❑ This probably resulted from the limited set of aerosol models used for atmospheric correction, missing extra fine mode typical of coastal areas.
- ❑ It is also possible that it is at least partially resulted from the iterative procedures in the *NIR* atmospheric correction process.

Evaluations on the retrievals of atmospheric parameters

Matchup comparisons between the VIIRS and AERONET aerosol

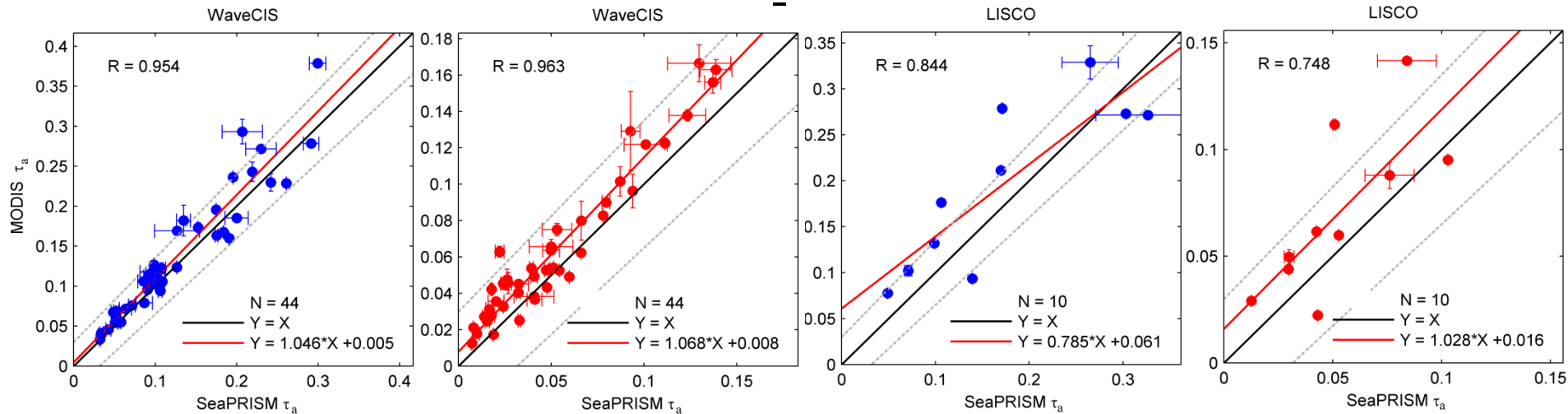
optical thickness (τ_a) at 442 nm & 870 nm



- ❑ Strong correlation coefficient values suggest variations in τ_a data can be captured well by VIIRS.
- ❑ **Overestimations in VIIRS retrieved τ_a values** are observed for both sites. For WaveCIS, *PD* values are 28% and 105% at 442nm and 870nm respectively. For LISCO, 38% and 108%.
- ❑ Relatively higher *PD* values at 442nm for LISCO site might be at least partially explained by the mismatch between the γ distributions of VIIRS and SeaPRISM data which in turn suggest possible inadequate aerosol (fine) mode selection for VIIRS.
- ❑ Validation study carried out for MODIS data based on the data of other coastal AERONET-OC sites (AAOT, GLT & HLT) had also displayed such discrepancy [Zibordi et. al 2009].

Evaluations on the retrieval of atmospheric parameters

Matchup comparisons between the MODIS and AERONET aerosol optical thickness (τ_a) at 442 nm & 870 nm



- ❑ MODIS retrieved τ_a values are also overestimated for WaveCIS and LISCO sites as in the case of VIIRS.
- ❑ Nevertheless, overestimations in MODIS retrieved τ_a values are much less than those observed for VIIRS.
- ❑ PD values are 9% and 37% at 442nm and 870nm respectively for WaveCIS site and 25% and 44% for LISCO site.
- ❑ VIIRS and MODIS data are processed with the same processing procedure. In addition, γ distributions observed for these two sensors closely match to each other for both sites. Yet retrieval biases are much less with MODIS than VIIRS.
- ❑ These significantly larger PD values observed for comparisons between VIIRS and in-situ SeaPRISM τ_a may originate from the uncertainties in the absolute radiometric calibration of the space sensor in the 862nm band of VIIRS.

Summary

- ❑ VIIRS sensor can capture well the seasonal and temporal variations in the water leaving radiance field of typical coastal locations used in the study.
- ❑ Impacts of the vicarious gain change on sensor radiance data in retrieving nLw data is not the same for the two locations with different water properties.
- ❑ These considerations probably suggest the need to take into account comparisons between AERONET-OC and satellite data for coastal sites before making decisions on changes of sensor gains.
- ❑ Strong consistency is shown between the time-series nLw data retrieved from the VIIRS and MODIS sensors.
- ❑ Spectral behavior of the aerosol optical properties may not be fully incorporated, resulting in underestimated VIIRS retrieved Angstrom exponent values, possibly indicating the failure of the current atmospheric correction procedure to include extra fine mode aerosols.
- ❑ Both VIIRS & MODIS overestimate aerosol optical thickness retrieval. Yet retrieval biases are much less with MODIS than VIIRS.
- ❑ The significantly larger PD values observed for comparisons between VIIRS and in-situ SeaPRISM τ_a may originate from the uncertainties in the absolute radiometric calibration of the space sensor in the 862nm band of VIIRS.