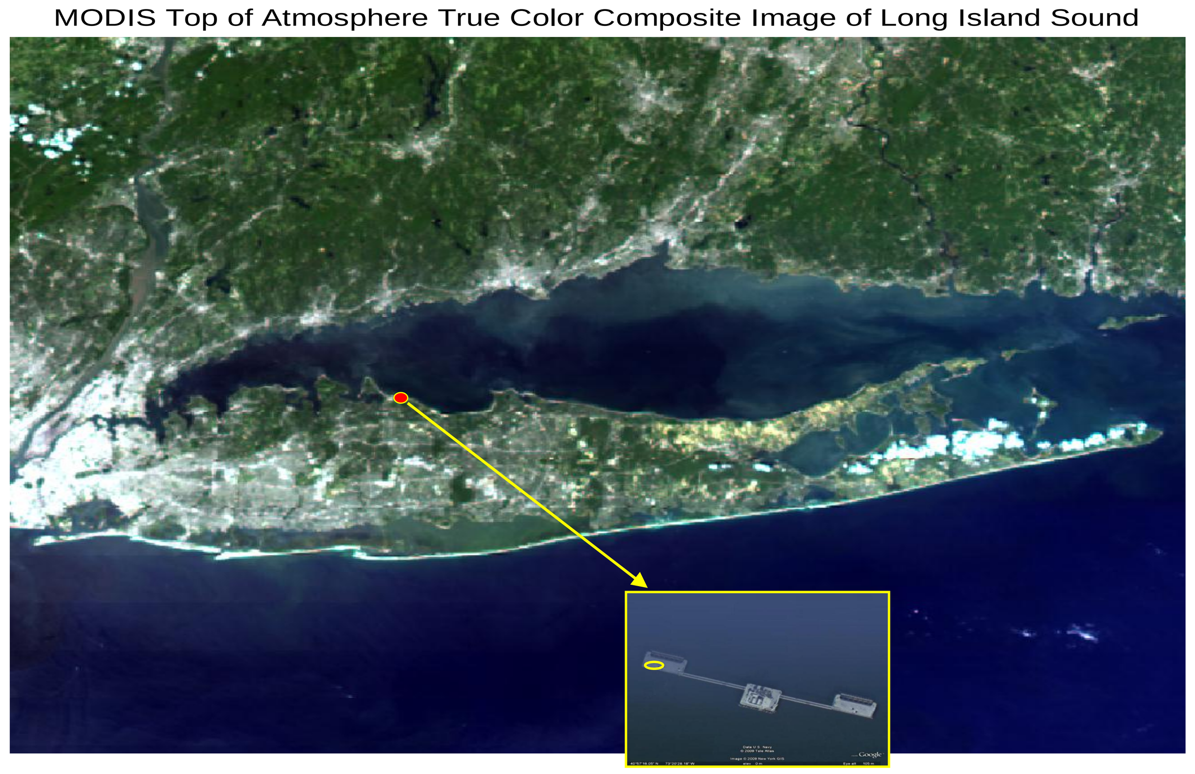
Assessments of the retrieval performances of JPSS-VIIRS sensor in coastal water environment through time-series measurements at Long Island sound coastal observatory site and heritage ocean color satellite missions

S. Hlaing[1], I. Ioannou[1], A. Gilerson[1], S. Ahmed[1], A. Weidemann[2]; R. Arnone[3]
[1] Optical Remote Sensing Laboratory, City College, New York, NY 10031, United States
[2] Naval Research Laboratory, Stennis Space Center, MS 39529, United States
[3]University of Southern Mississippi, MS 39529, United States

Introduction

- ✓ This study addresses the evaluations of the VIIRS sensor's Ocean Color (OC) data retrieval performances in typical coastal water environments.
- ✓ VIIRS's retrieval performances are evaluated based on in-situ AERONET-OC SeaPRISM data as well as heritage OC satellite missions (MODIS & MERIS).
- ✓ Time-series and match-up comparisons between in-situ (SeaPRISM) and satellite retrieved normalized water leaving radiance and aerosol optical thickness data are carried out. The impact of aerosol mode selection on OC data retrieval at the LISCO location is also assessed.
- ✓ VIIRS's retrieval performances in coastal water conditions are statistically compared to those of heritage OC satellite missions based on time-series in-situ data from LISCO.

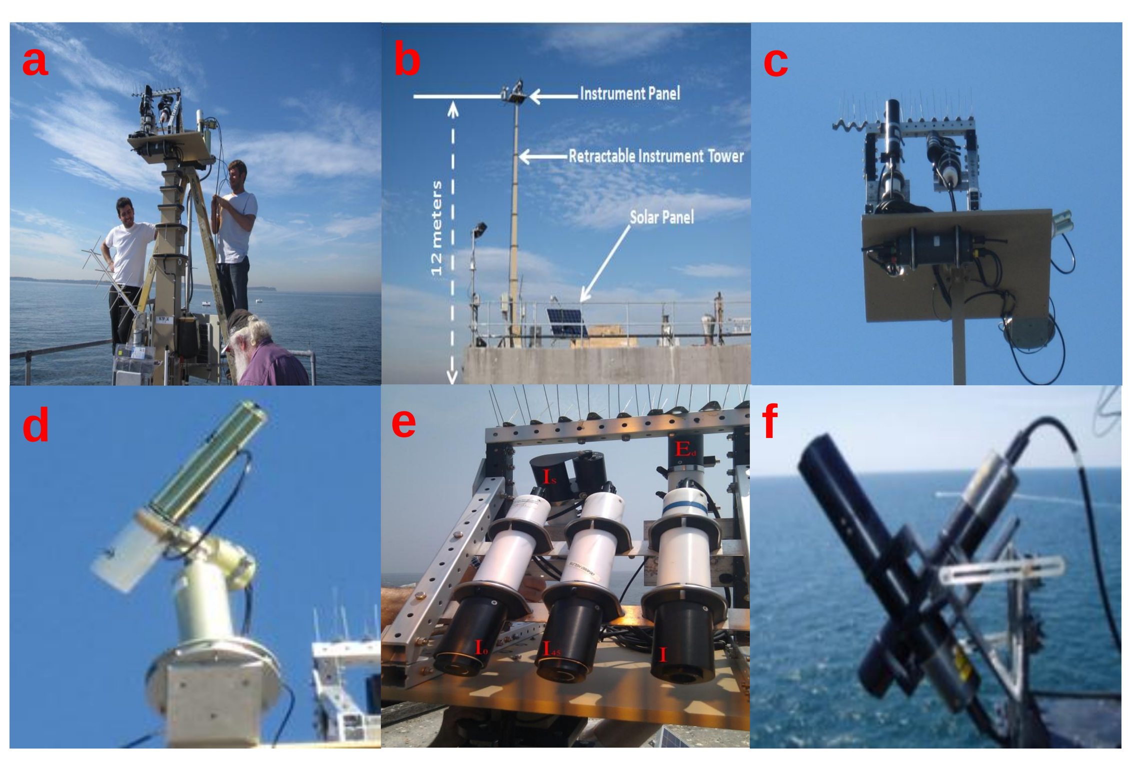
MODIS Top of Atmosphere True Color Composite Image of Long Island Sound



● Location of the platform

Long Island Sound Coastal Observatory (LISCO)

- ✓ LISCO uniquely combines a SeaPRISM, part of the NASA AERONET – Ocean Color Network, with a co-located HyperSAS for multi and hyperspectral radiometer measurements.
- ✓Instruments are installed at the top of a 12m high retractable tower constructed on a platform ~ 4km away from the coast.
- ✓SeaPRISM autonomously performs multiple sky- and sea-radiance observations at programmable viewing and azimuth angles at eight center wavelengths in the 412-1024 nm spectral range.
- ✓The HyperSAS optical remote sensing system provides high precision hyperspectral measurements of sky and upwelling spectral radiance, and down-welling spectral irradiance.
- ✓HyperSAS polarization channels permit polarized hyperspectral measurements of water leaving radiance, that are shown to provide insights to inherent optical properties and glint effects.
- ✓The whole system provides comprehensive in-situ time series dataset for satellite ocean color data validation activities.



(a) Retractable Instrument Tower (b) LISCO Tower (c) Instrument Panel (d) SeaPRISM Instrument (e) Hyper-OCR with Polarization Filters (f) Total Sea and Sky Radiance sensors

Data processing, extraction and filtering procedures

- ➢ MERIS, MODIS and VIIRS level 2 images processed with the version 6.4 of the SeaDAS software package using standard iterative NIR atmospheric correction algorithm. Images are obtained for Long Island Sound area.
- ➢ For the MODIS and VIIRS images, data of the 3x3 pixel box centering the location of the LISCO platform are obtained, and a 7x7 pixel box is selected for MERIS images due to the sensor's higher (300m) resolution data.
- ➢ Flag conditions: land, cloud, failure in atmospheric correction, reduced or bad navigation quality, glint, negative water leaving and Rayleigh-corrected radiance, viewing angle larger than 60°, and solar zenith angle larger than 70°.
- ➢ SeaPRISM data used in all comparisons are retrieved from the measurements made ±2hrs of satellite over pass time.

Statistical parameter

$$PD_i(\lambda) = 100\% \times \frac{y_i(\lambda) - x_i(\lambda)}{x_i(\lambda)}$$

Overall mean values of $PD_i(\lambda)$s are further calculated in order to assess the average percent differences between the two data being compared.

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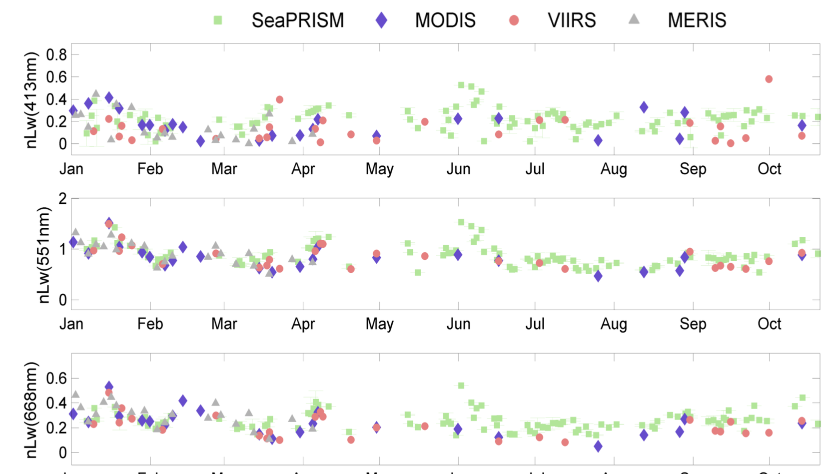
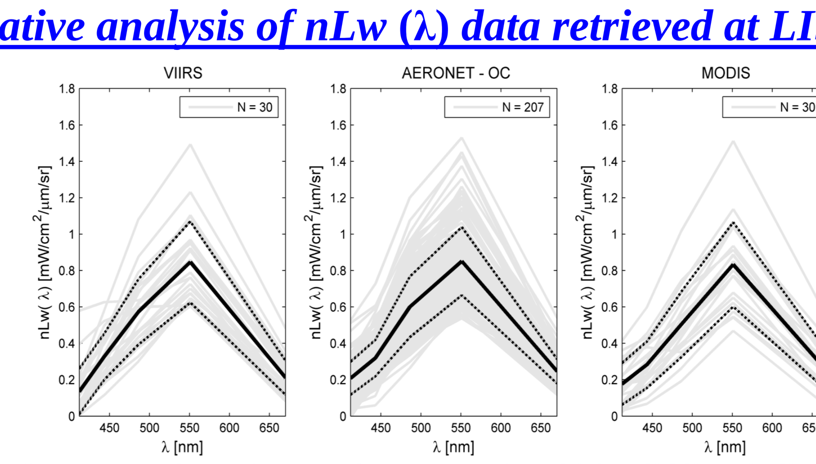
Evaluations of the water leaving radiance retrieval performance

Time series analysis of normalized water leaving radiance, nLw (λ), data

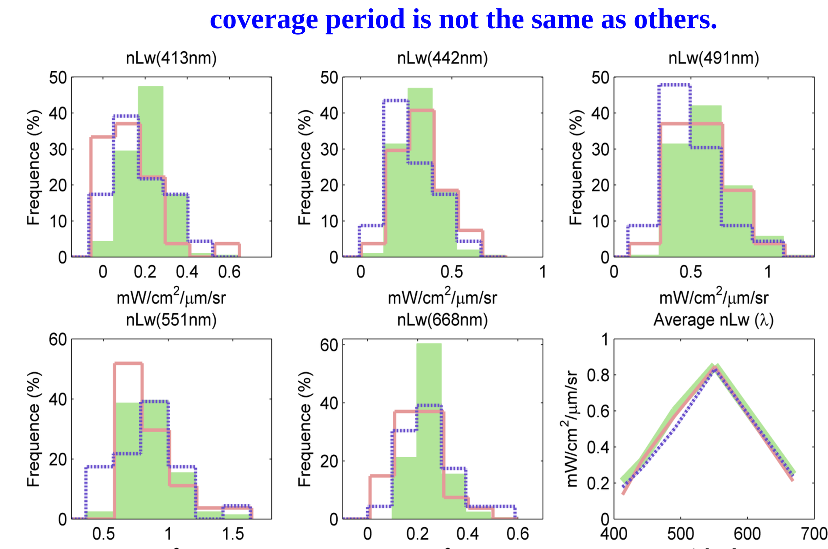


Time series of nLw(λ), in mW/cm²/µm/sr, derived from SeaPRISM (green squares), MODIS (blue diamonds) VIIRS (brown circles) and MERIS (grey triangles) at the spectral bands closest to 413nm (1st row), 551nm (2nd row) and 668nm (3rd row) respectively.

Qualitative analysis of nLw (λ) data retrieved at LISCO location

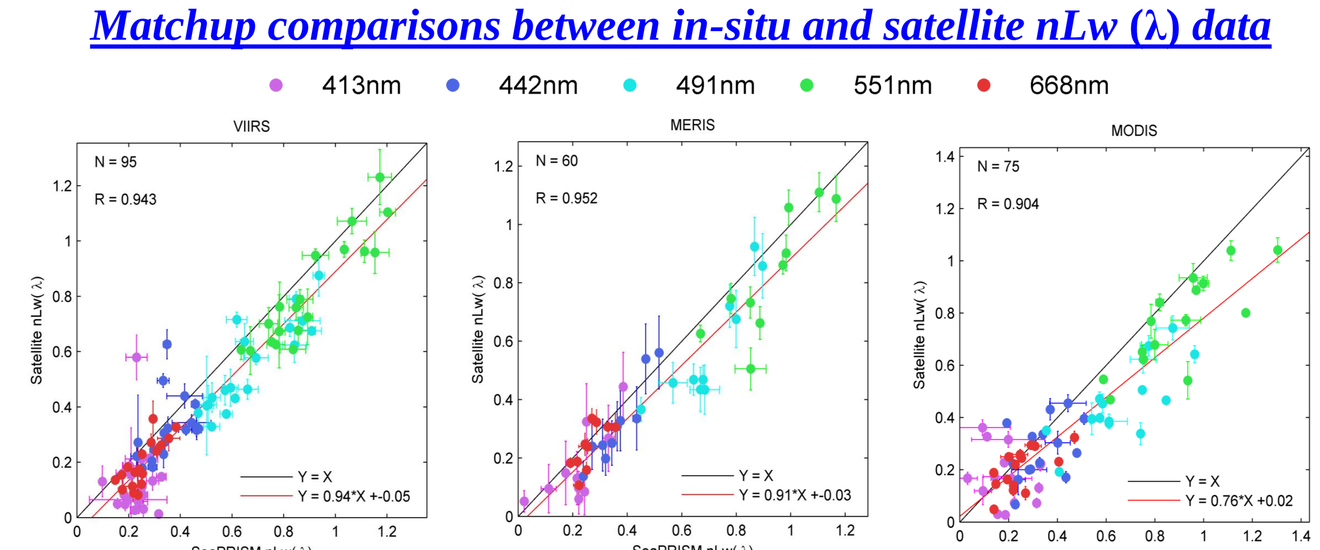


Match-up *nLw* (λ) spectra (shown in grey) for LISCO site (thick solid lines indicate average, thick dashed lines indicate ± one standard deviation). MERIS data is not shown here because the sensor's data coverage period is not the same as others.



Distributions of *nLw* (λ) data retrieved from SeaPRISM (plotted in green), MODIS (blue dotted lines) and VIIRS (brown lines) are shown along with the seasonal average spectral recorded by three sensors. Data shown here are for the time period between January to the end of October 2012.

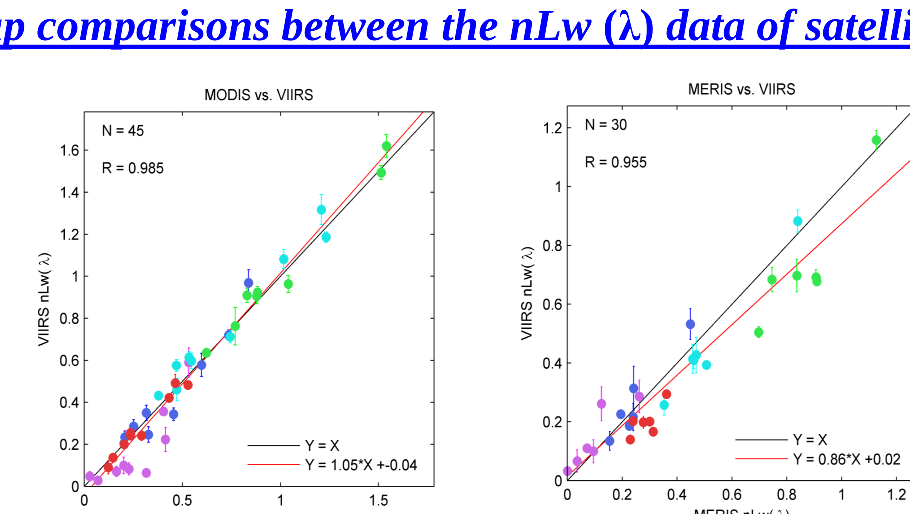
Matchup comparisons between in-situ and satellite nLw (λ) data



Matchup comparison between the normalized water leaving radiance nLw(λ) (in mW/cm2/µm/sr) retrieved from SeaPRISM data and (Left) VIIRS, (Middle) MERIS and (Right) MODIS data. N is the total number of satellite images considered in each matchup comparison. Horizontal and vertical error bars represent the temporal and spatial variations in SeaPRISM and satellite data respectively.

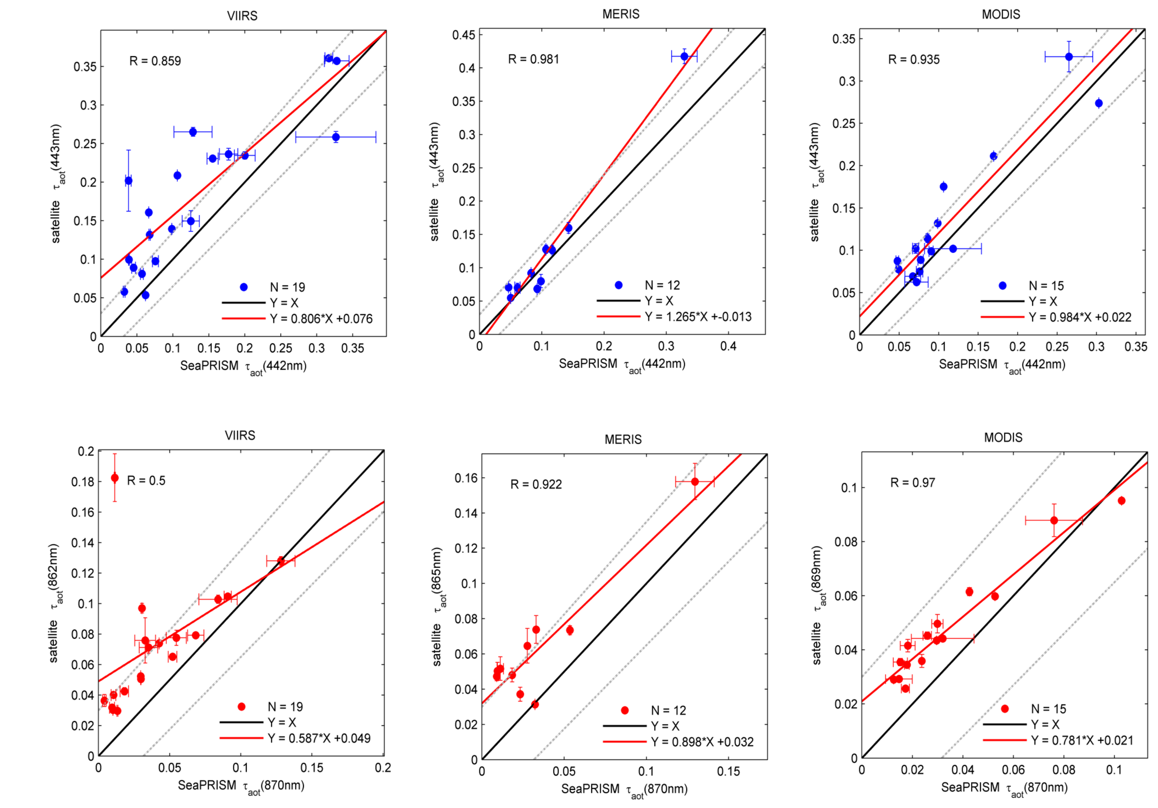
- ❑ All three sensors (VIIRS, MERIS and MODIS) underestimate *nLw*(λ) data retrievals with overall spectral PD values -18, -12 and -14.62% respectively.
- ❑ For VIIRS, correlation coefficient R value is 0.92 at 551nm and greater than 0.78 for all wavelengths longer than 443nm. Nevertheless, there is no correlation at all at 412nm.
- ❑ On the other hand, MERIS retrieved *nLw*(λ) data shows strong correlation with the SeaPRISM data exhibiting R values greater than 0.77 at every wavelengths and as high as 0.94 at the 443nm wavelength.

Matchup comparisons between the nLw (λ) data of satellite OC sensors



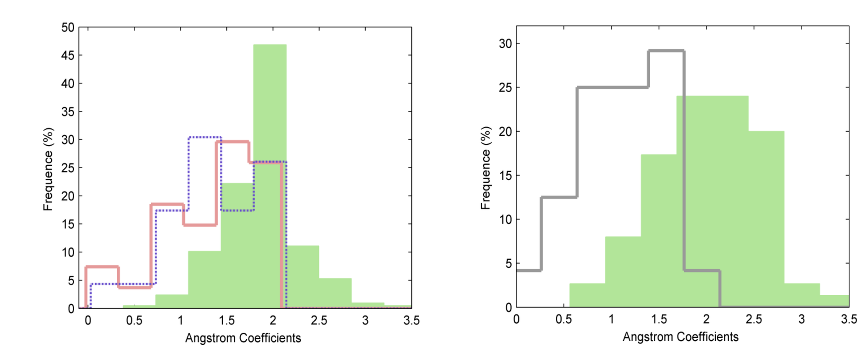
Retrieval performance of atmospheric parameters

Matchup comparisons between in-situ and satellite aerosol optical thickness, τ_{aot}, data



Matchup comparisons of τ_{aot} derived from satellite and SeaPRISM measurements (NASA processing) at LISCO site from January to October 2012. Comparisons are shown for two SeaPRISM wavelengths, 442nm (1st row) and 870nm (2nd row). The red line is the regression line whose y is the equation and the dotted gray lines are the uncertainty level (defined as $\pm 0.05*\tau_{aot} \pm 0.03$) of the AERONET data. N is the total number of satellite images considered in each matchup comparison. Horizontal and vertical error bars represent the temporal and spatial variations in SeaPRISM and satellite data respectively.

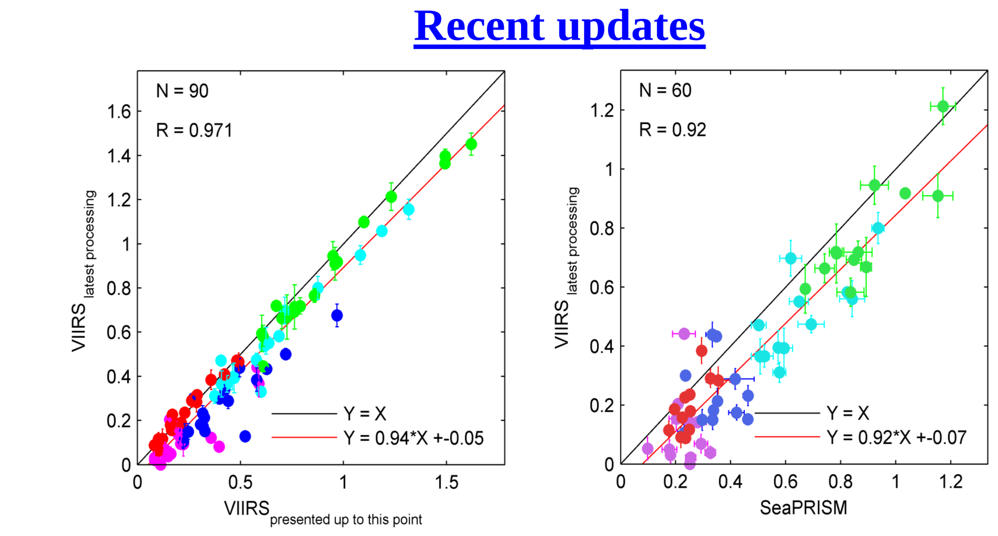
Quality of Aerosol Type Detection



Histograms of the % distributions of the Angstrom exponent. SeaPRISM (plotted in green), VIIRS (brown line) and MODIS (blue dotted line) are shown in left figure. Angstrom distributions of MERIS (plotted in grey) together with SeaPRISM are shown separately in right figure for MERIS's different coverage period.

- ❑ Seasonal and temporal changes in the aerosol optical thickness data are captured well by the satellite missions.
- ❑ The regression lines for all three sensors are very close to the line which defines the upper limit of the uncertainty of the AERONET data.
- ❑ Overestimations in τ_{aot} data are observed for all three sensors. This may also suggest overestimations in aerosol radiance, which is directly proportional (through single scattering albedo and phase function parameters) to τ_{aot}. This observation might at least partially explain underestimations observed in water leaving radiance.
- ❑ High values of Angstrom exponent retrieved by SeaPRISM suggest that aerosols over LISCO site are typically dominated by fine mode aerosol particles. In contrast, the satellite Angstrom exponents are found to be always smaller than 2.2 and very frequently lie between 0 (spectrally flat coarse mode aerosols) and 2. It should be noted here that these observations are not limited to LISCO location and similar trends are seen in other AERONET sites (Brookhaven in Long Island & COVE in Chesapeake Bay areas).
- ❑ This erroneous aerosol mode selections by satellite sensors can result in incorrect aerosol radiance estimations. These observations may probably suggest atmospheric correction procedures currently in use need to be revised for coastal environment.

Recent updates



As of December 12, 2012, NASA Ocean Biology processing group reprocessed the VIIRS data for the whole mission period. This reprocessing is carried out to address the vicarious calibration factors and the temporal calibration is now applied in the Level-1A to Level-2 processing.

- ❑ We have observed that this newly re-processed water leaving radiance data are lower (spectral average PD value equal to -12%) than that of previous processing.
- ❑ On the other hand, aerosol data are not affected much by this reprocessing: almost the same at 862nm and about -3% lower at 443nm.
- ❑ More occurrences of water leaving radiance retrievals at 412nm with negative values are observed for LISCO site . Correlation between the VIIRS and SeaPRISM data is degraded through out the spectrum. At 443nm R value is equal to 0.48 with previous processing but almost zero correlation with the new processing.
- ❑ We are currently investigating the reasons and causes of these occurrences and impacts of this re-processing on coastal areas OC retrievals in broader scale by analyzing data from other coastal AERONET-OC sites.

Summary

Based on the investigations over the ten month period dataset of VIIRS operation:

- ➢ Normalized water leaving radiance data of VIIRS achieve strong correlation with in-situ data of LISCO exhibiting spectral average R value equal to 0.943 demonstrating the spectral shape consistency between the satellite and in-situ retrieved water leaving radiance data.
- ➢ Seasonal average nLw(λ) data of VIIRS closely match that of SeaPRISM. This demonstrates the VIIRS data is suitable for creating the long term composite images for OC study.
- ➢ In addition, R values computed at each wavelength are also high (equal to 0.87 at 488nm and higher than 0.78 for all wavelengths greater than 443nm) demonstrating the potentials of the VIIRS sensor for improved retrieval performances in the estimation of water leaving radiance data from coastal areas.
- ➢ Comparisons with heritage OC missions show that VIIRS data is strongly correlated with both MERIS and MODIS assuring the continuity of reliable OC data streams.
- ➢ On the other hand, issues with the atmospheric correction process which are typical for coastal areas are still observed and investigations focused on these issuers are under way.