Long Island Sound Coastal Observatory (LISCO): Multi and Hyperspectral Above-water Measurements for Satellite Validation & Times Series Production

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- Long Island Sound Coastal Observatory (LISCO) characteristics
- Use of LISCO Collocated Above Water Measurements: Uncertainty Assessment
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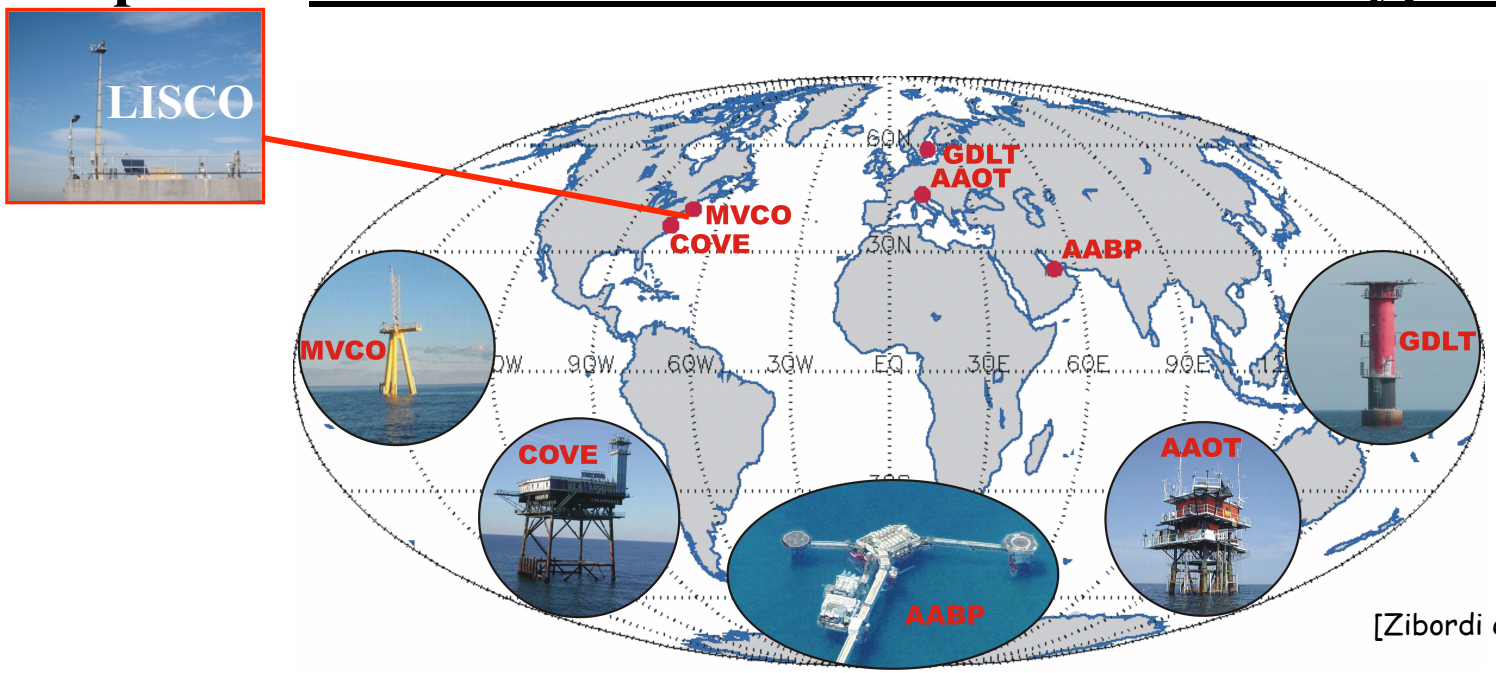
- Hyperspectral Polarization Measurements
- Conclusion and perspectives

LISCO Site Characteristics

LISCO Multispectral SeaPRISM system
as part of AERONET – Ocean Color network +HyperSAS



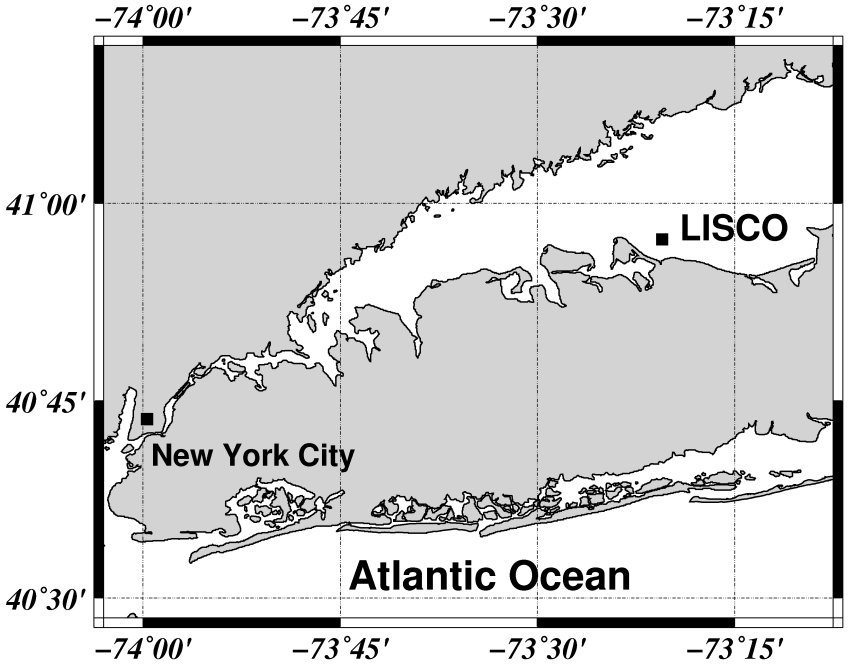
[Zibordi et al., 2006]

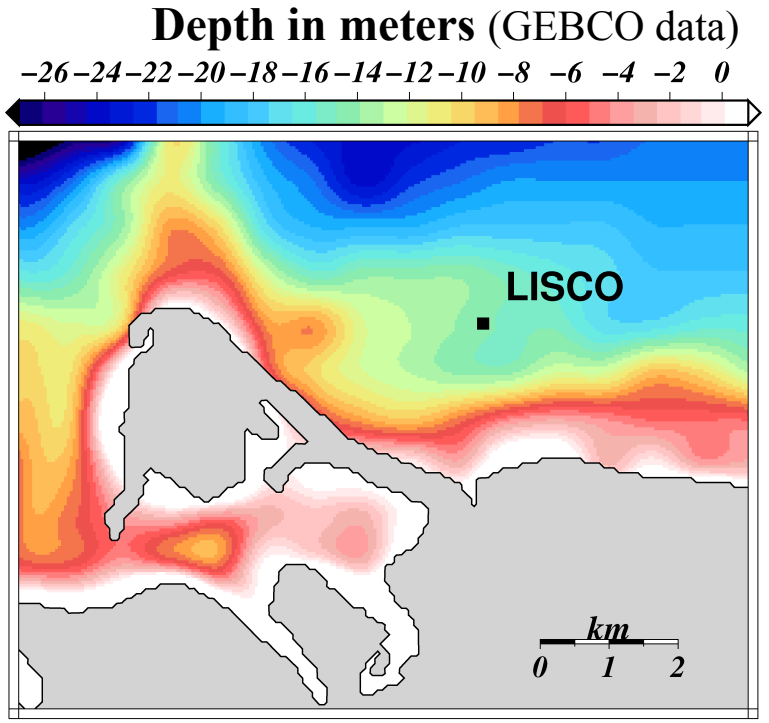
- Identical measuring systems and protocols, calibrated using a single reference source and method, and processed with the same code;

→ **Standardized products of exact normalized water-leaving radiance and aerosol optical thickness**

LISCO Site Characteristics

Location and Bathymetry





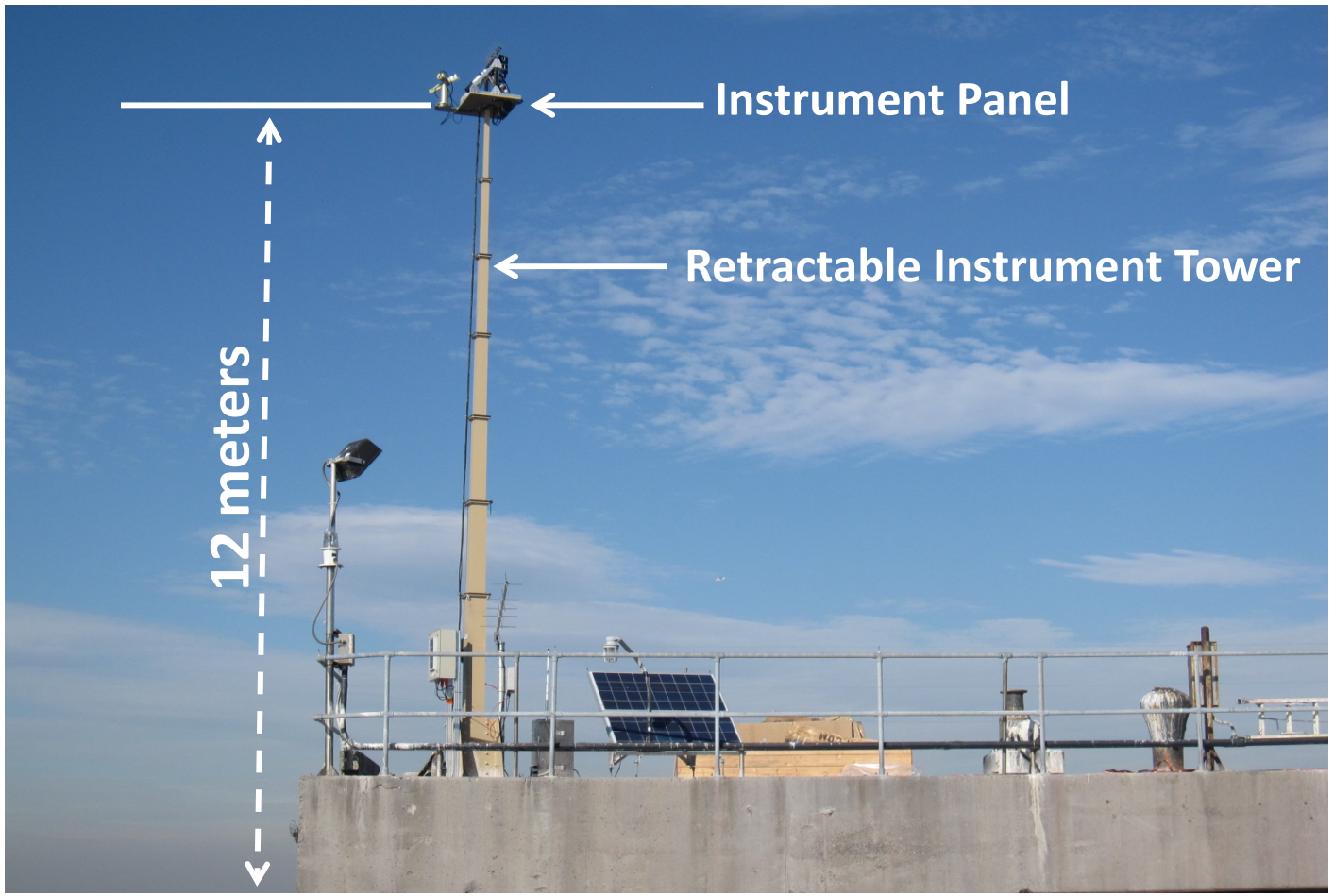
Water type: Moderately turbid and very productive (Aurin et al. 2010)

Bathymetry : plateau at 13 m depth

LISCO site Characteristics

Platform: Collocated multispectral **SeaPRISM** hyperspectral **HyperSAS** instrumentations

Since October 2009



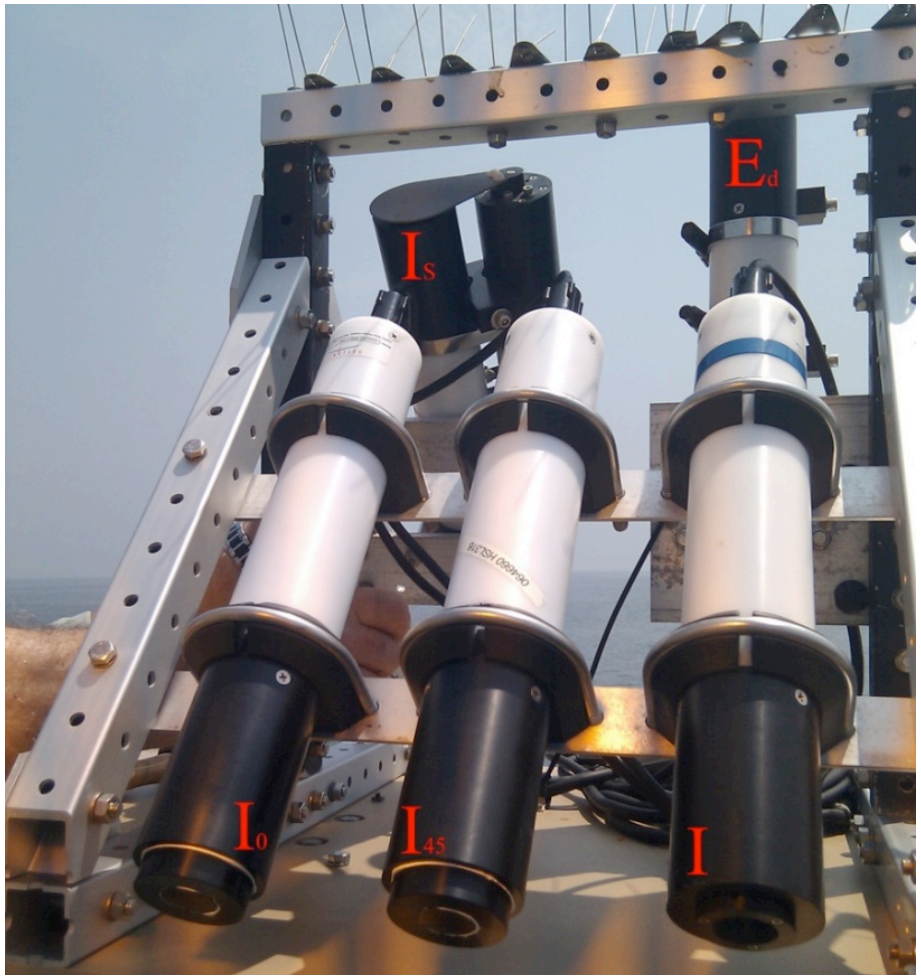
LISCO Site Characteristics

SeaPRISM and HyperSAS instruments installed on the tower

SeaPRISM data are transmitted through the satellite to NASA AERONET group. Processed data are posted on AERONET site

LISCO Instrumentations

HyperSAS Instrument



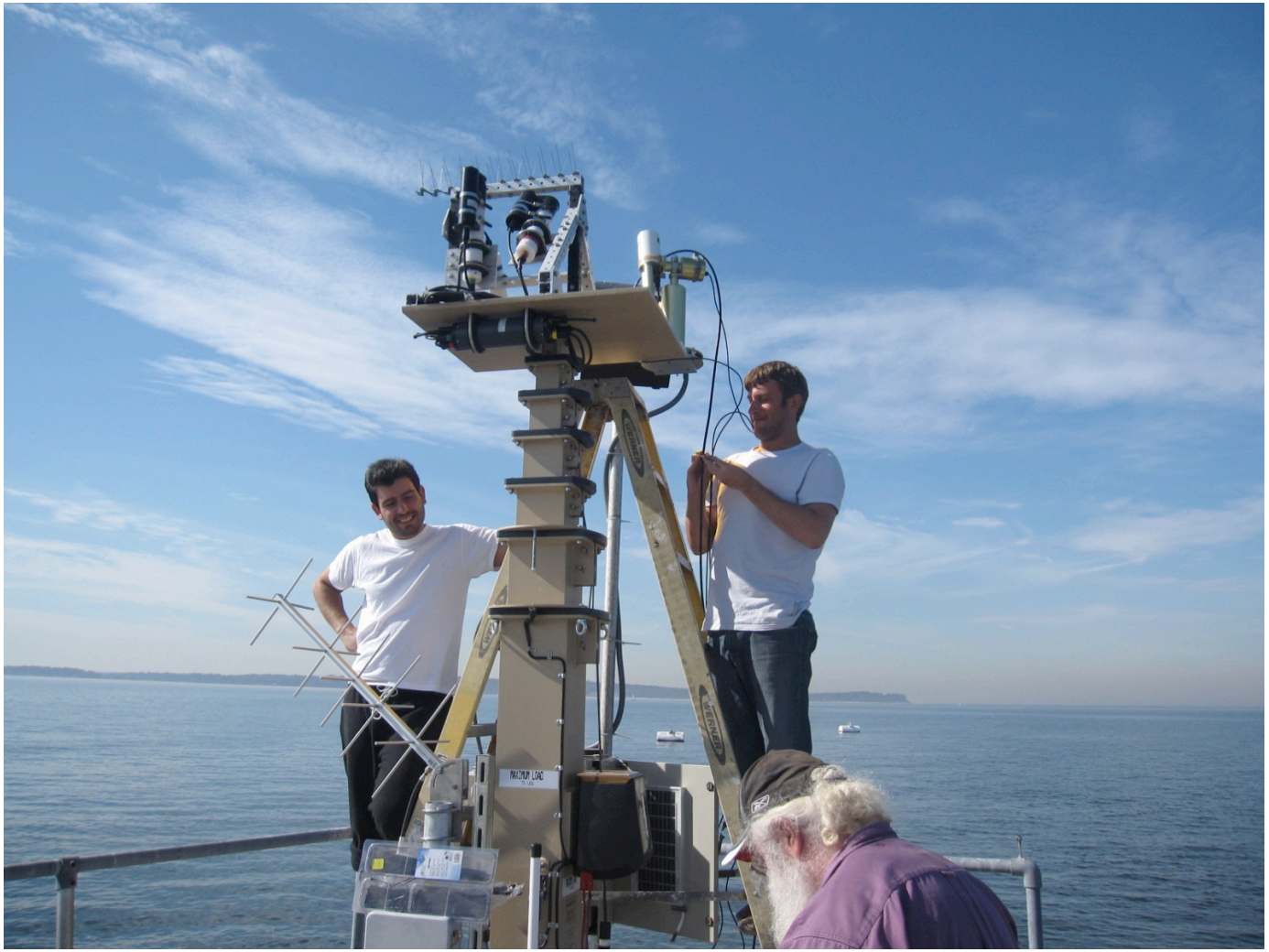
- Sea Radiance
- Sky Radiance
- Downwelling Irradiance
- Linear Polarization measurements
- Hyperspectral: 180 wavelengths [305,900]nm

Data acquisition every 30 minutes for high time resolution time series

Data are transmitted to CCNY server through broadband connection

This makes site very attractive for HICO validation

Installation of the instruments on the retractable tower



HyperSAS Data Processing

HyperSAS data processing

Above Water Signal decomposition

Total radiance

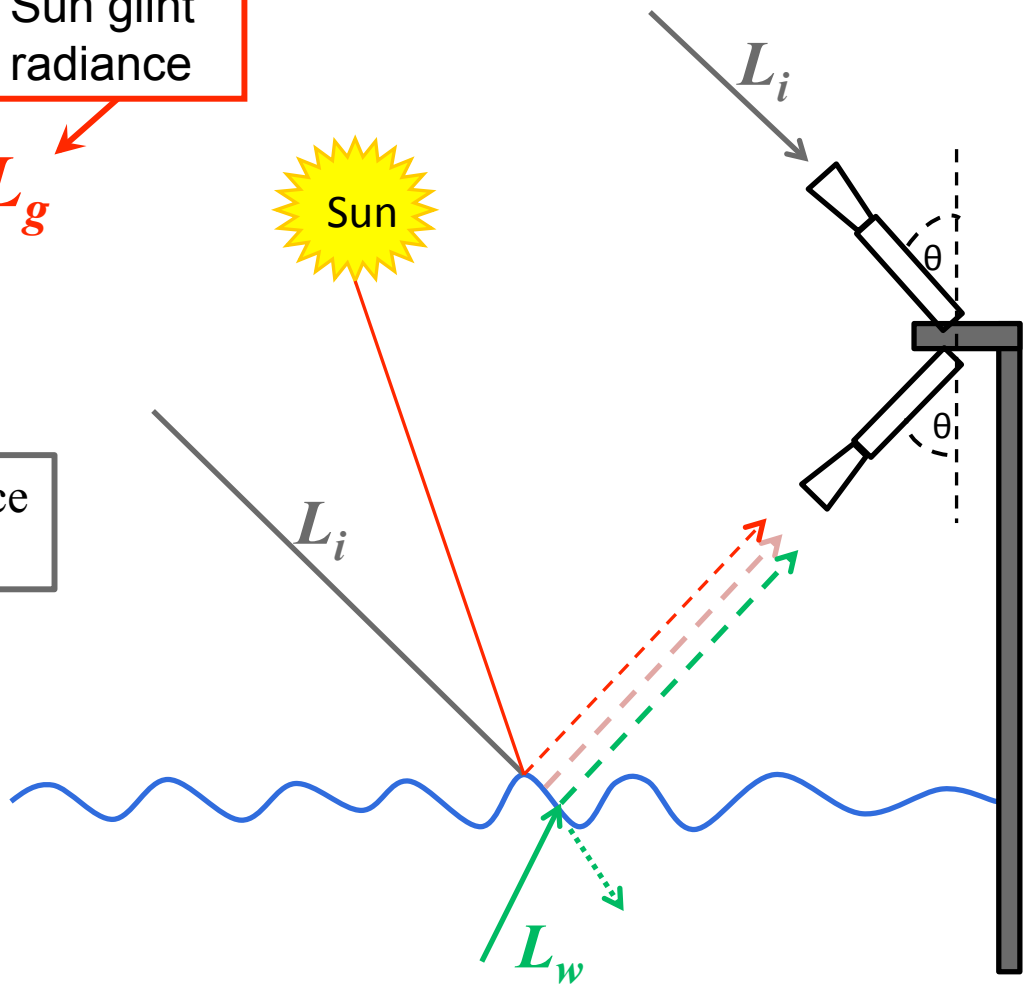
Sky radiance

Sun glint radiance

$$L_T = L_w + \rho(W)\, L_i + L_g$$

Water leaving radiance

Sea surface reflectance factor



HyperSAS data processing

Above -water Signal Processing

i. $L_T = L_w + \rho(W)\, L_i + L_g$

measured by numerous acquisitions within 2-minute time window (11 for SeaPRISM and > 44 for HyperSAS)

ii. *The lowest 20% are taken, to minimize* L_g *(~ 0) impact*

iii. L_i *is measured*

ρ *is calculated for a given wind speed* [Mobley et al., 1999]

iv. L_w *is corrected for the bi-directional effect (BRDF,* [Morel et al., 2002]*)*

v. *Divided by the atmosphere transmittance to get:*

→ L_{WN} ***the exact normalized water-leaving radiance***

(i.e. radiance for a nadir view and the sun at the zenith without atmosphere)

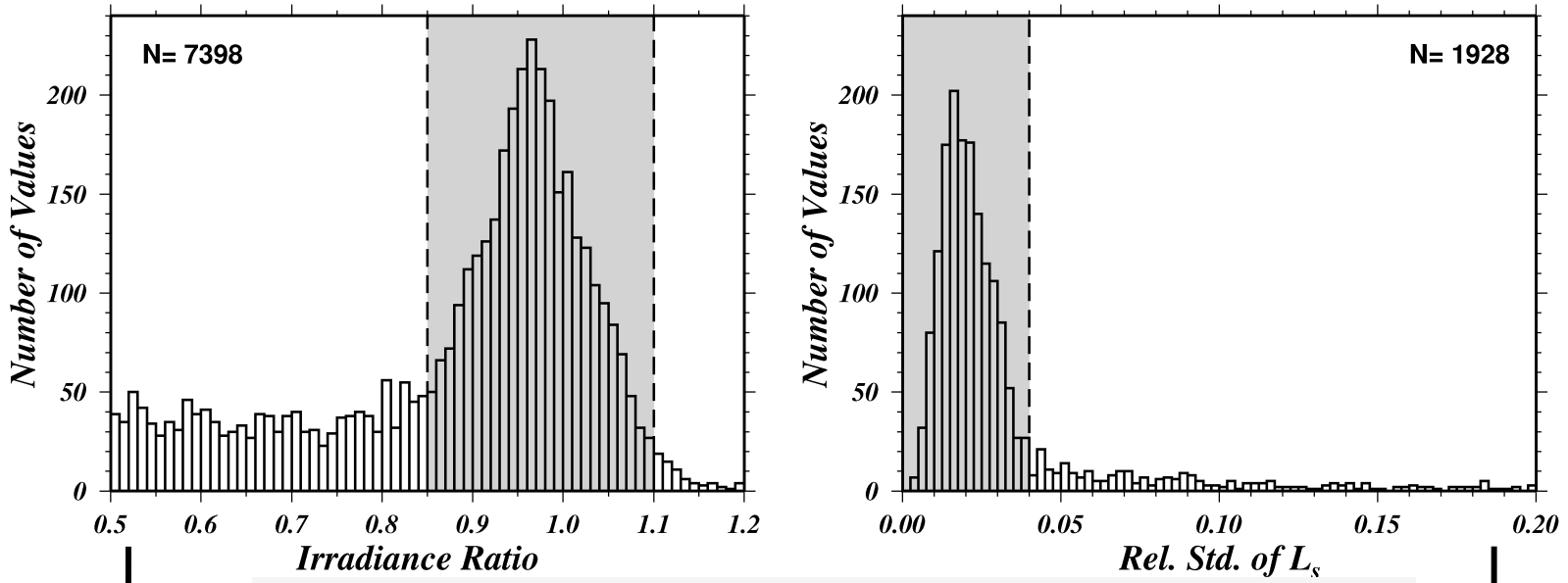
Data processing procedure equivalent to SeaPRISM was developed to compare datasets from both instruments

HyperSAS data processing

Data Quality Process

Ratio of the irradiance measured at 443 nm by HyperSAS to its theoretical clear-sky value

Relative standard deviation of sky radiances L_s having passed the Irradiance ratio filter



Values in shaded area pass the data quality process

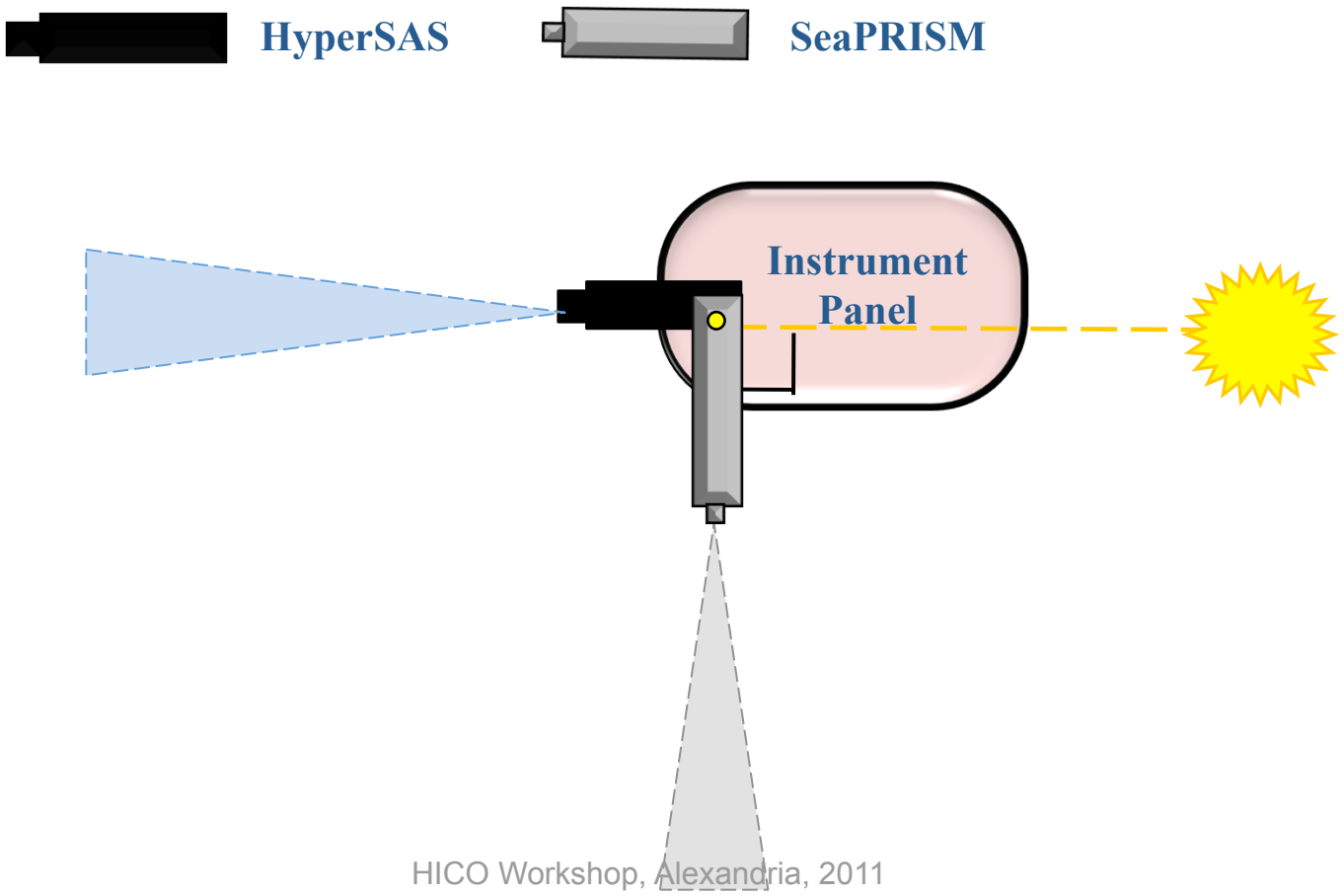
Elimination of overcast conditions

Elimination of fast sky variation: scattered clouds, birds…

HyperSAS Intrinsic Uncertainty

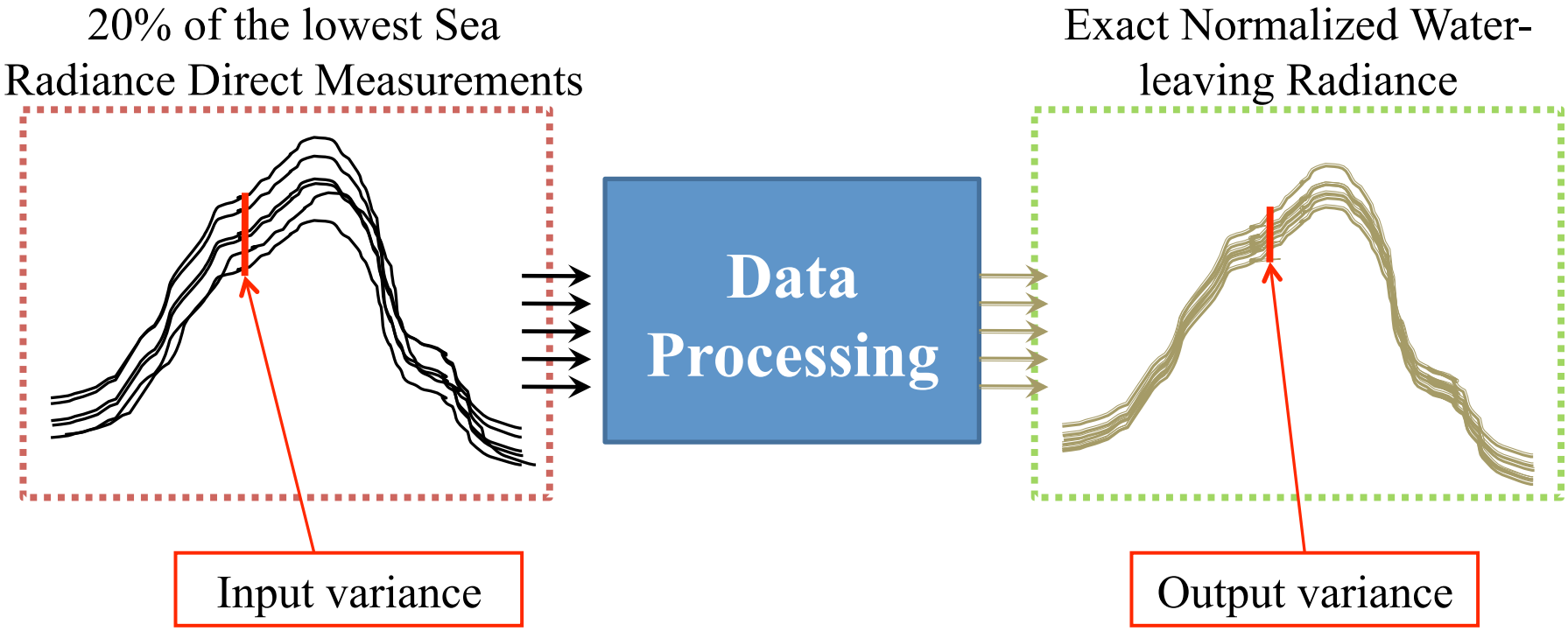
Technical Differences between HyperSAS and SeaPRISM
Two Geometrical Configurations

Instrument Set Up Looking Down on Instruments



HyperSAS data Intrinsic Uncertainties

Uncertainty estimation scheme



- Data Processing applied to each direct measurements of a sequence separately
- **Intrinsic Uncertainty = Output Standard Deviation**

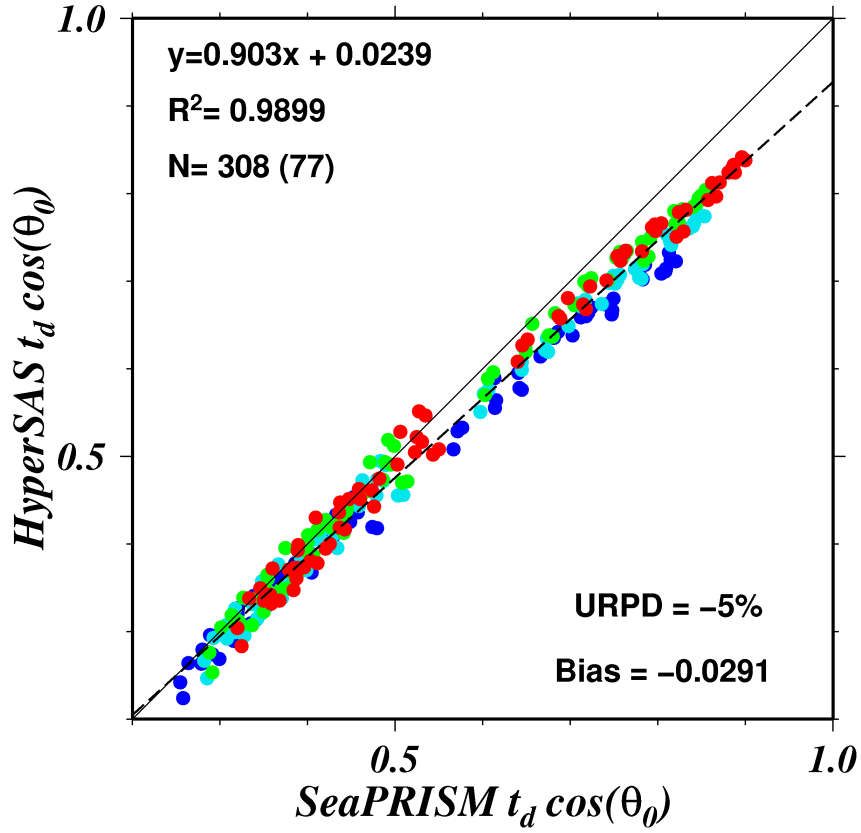
Uncertainties are below 5% for the spectral range of 330 to 750 nm until 2pm

Collocated SeaPRISM and HyperSAS Data Comparison

Collocated SeaPRISM and HyperSAS Data Comparison

Differences between HyperSAS and SeaPRISM

Two Atmospheric Transmittance (T_d) Computations



- **SeaPRISM** (parameterization)

$$t_d(\lambda) = \exp\left\{\frac{-[\, C_1\tau_R(\lambda) + C_2\tau_A(\lambda) + \tau_O(\lambda)\,]}{\cos\theta_0}\right\}$$

Optical thickness: Rayleigh Aerosol Ozone

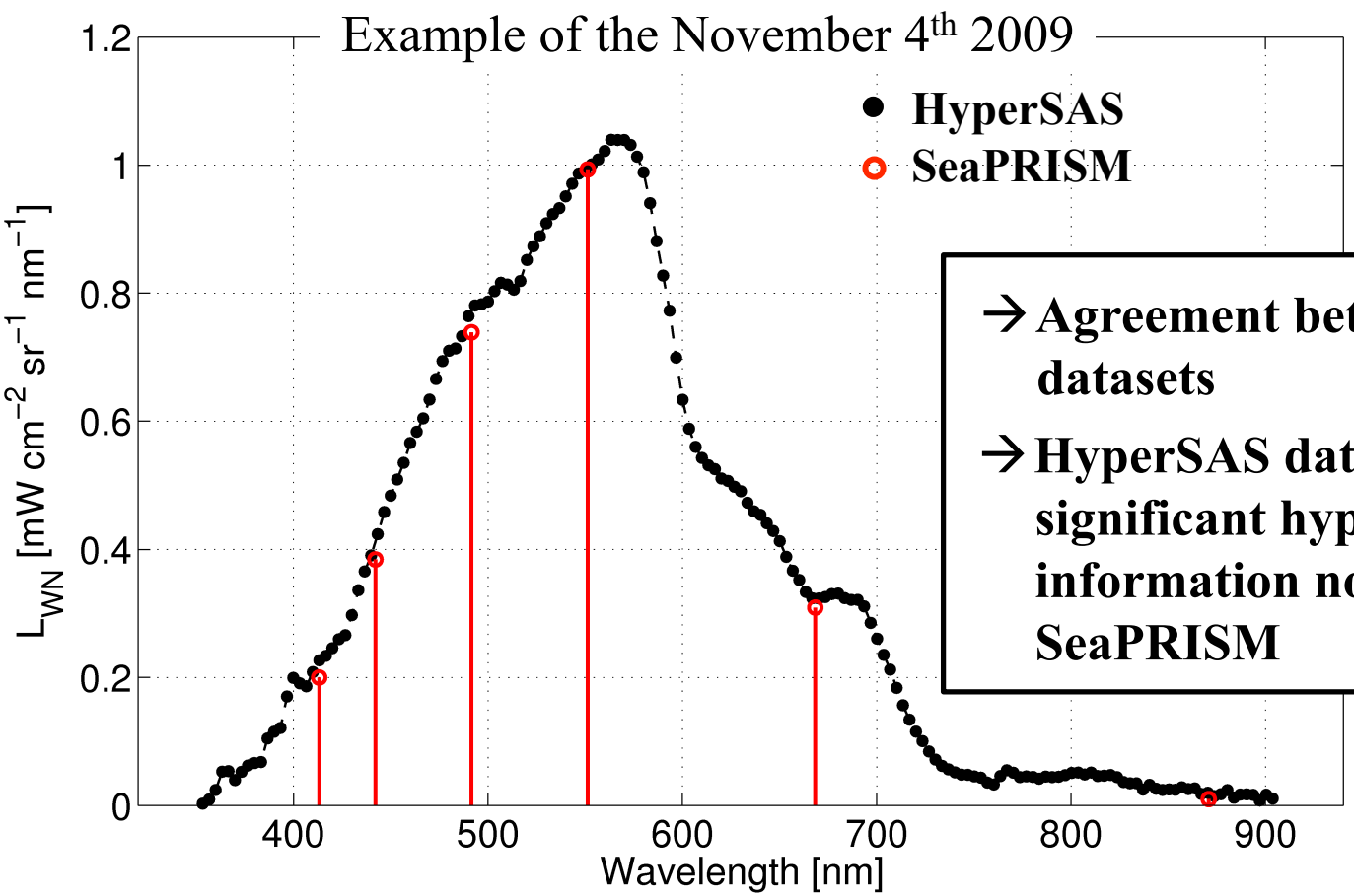
- **HyperSAS** (direct measurement)

$$t_d(\lambda) = \frac{\text{Measured Downwelling Irradiance}}{\text{Extra-terrestrial Solar Irradiance}}$$

→Needs to improve the SeaPRISM model

HyperSAS-SeaPRISM comparison data

…Finally, the quality-checked exact normalized water-leaving radiance is obtained from HyperSAS measurements



→ Agreement between the two datasets

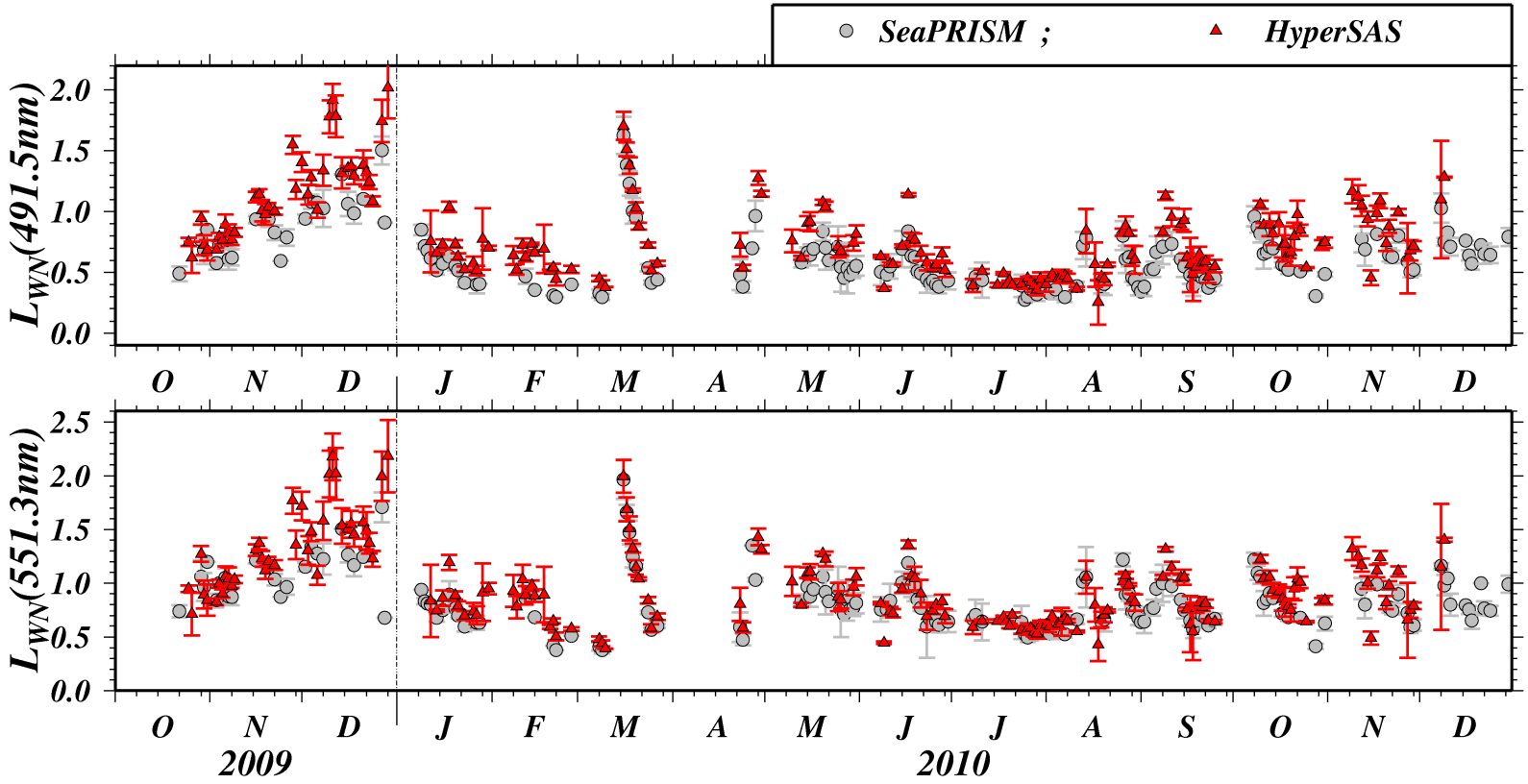
→ HyperSAS data contain significant hyperspectral information not sensed by SeaPRISM

→ Possibility of satellite spectral band matching by spectral integration

Collocated SeaPRISM and HyperSAS Data Comparison

1-year datasets → full natural variability of atmospheric and water conditions

- HyperSAS data integrated on the SeaPRISM bandwidth



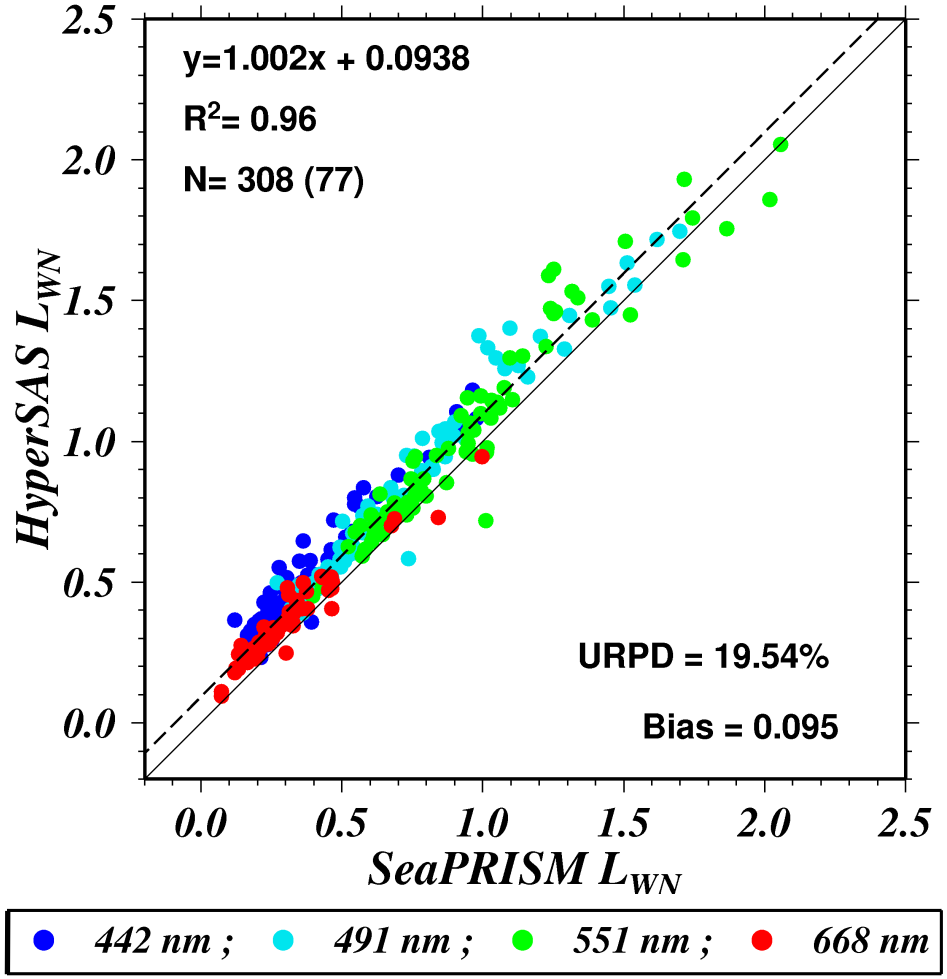
→ Qualitative agreement despite :

- different atmospheric transmittance calculation and viewing geometrical configuration
- Windy weather conditions

→ Consistency of the multi- and hyper-spectral datasets

Intercomparison of SeaPRISM and HyperSAS data

Uncertainty Estimation

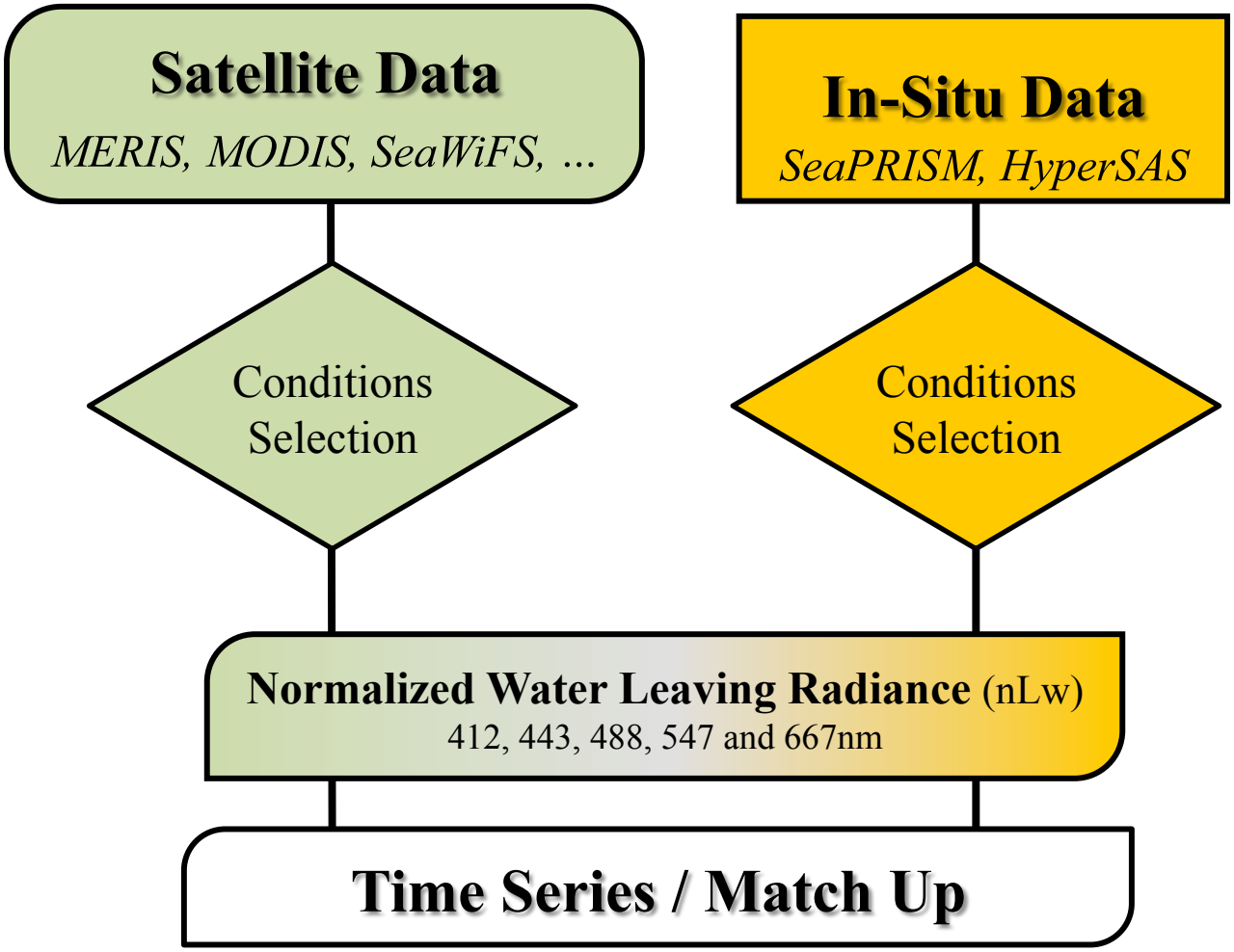


- → Strong Correlation
- → Regression Line Slope ~1
- → Dispersion induced by
  - Sun glint: 2.5%
  - Sky glint: 6%
  - Bidirectionality: -1.5%
  - Atm. Transmittance: 5%
- → Positive Bias in HyperSAS induced by the different Atmospheric Transmittance Derivations of the two systems

[Harmel et al., submitted]

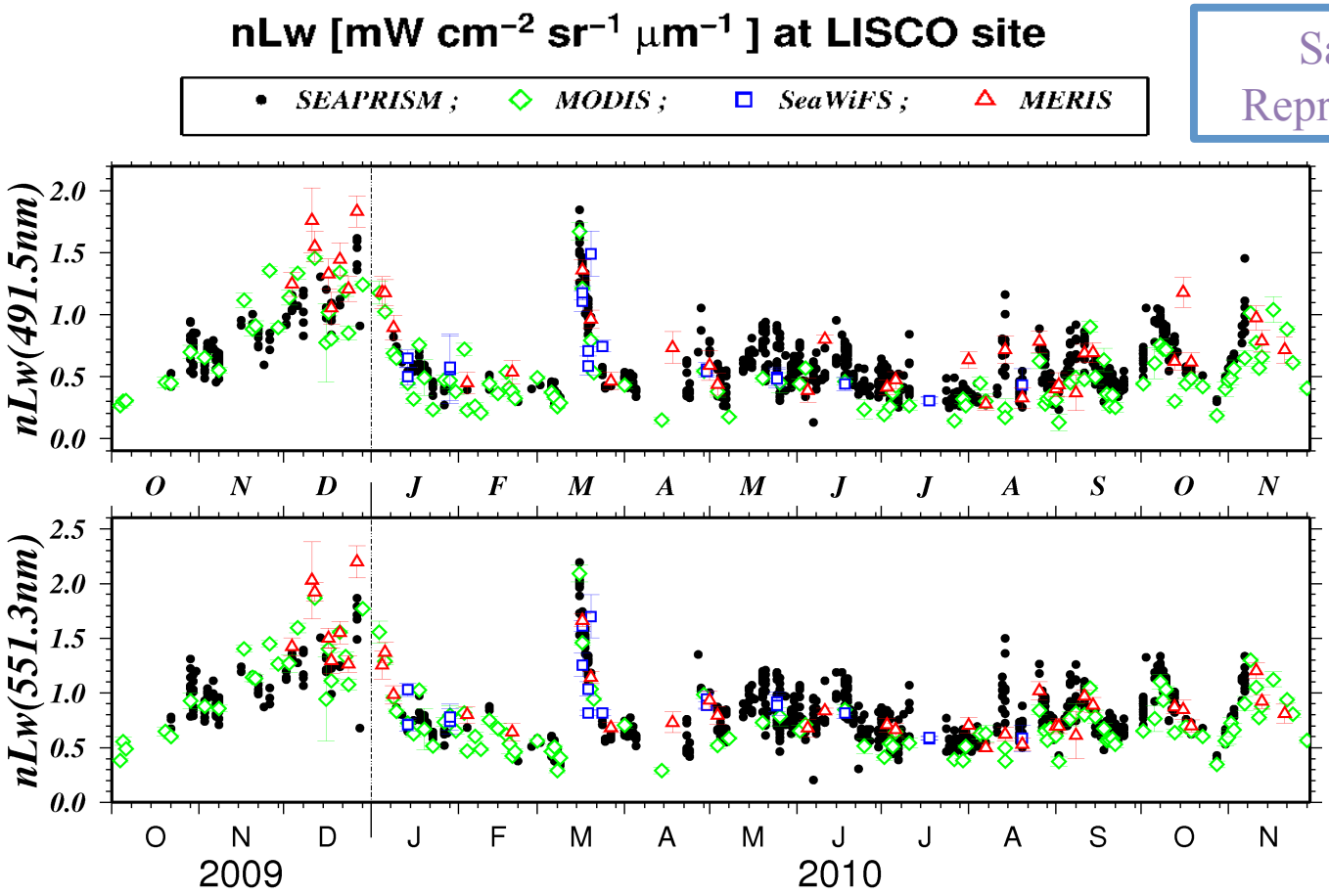
Satellite Validation

Comparison Strategy



Satellite Validation

Time Series Normalized Water Leaving Radiance(nLw)

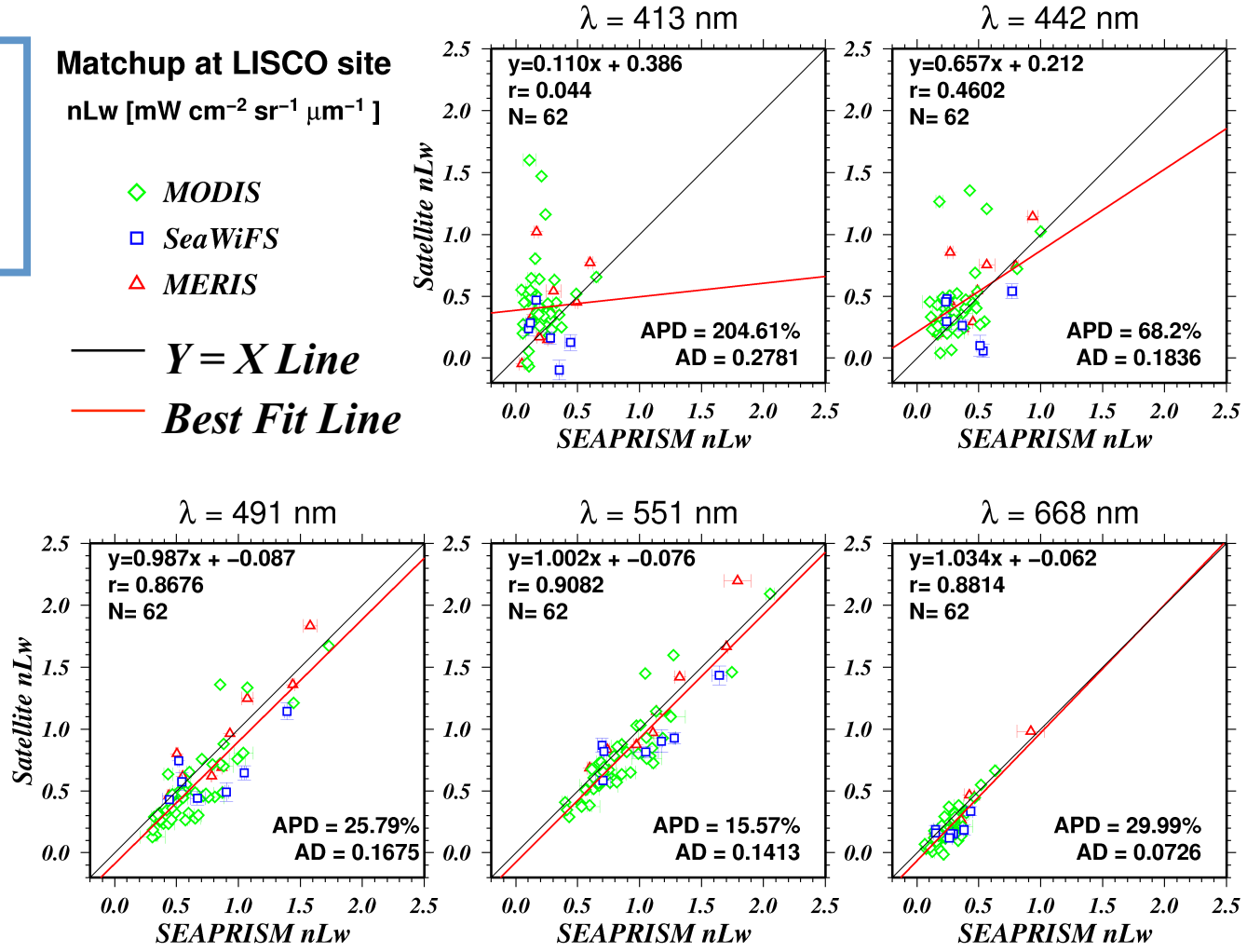


Satellite data Reprocessing 2009

→ **Consistency in seasonal variations observed from the platform and from space**

Satellite Validation vs SeaPRISM

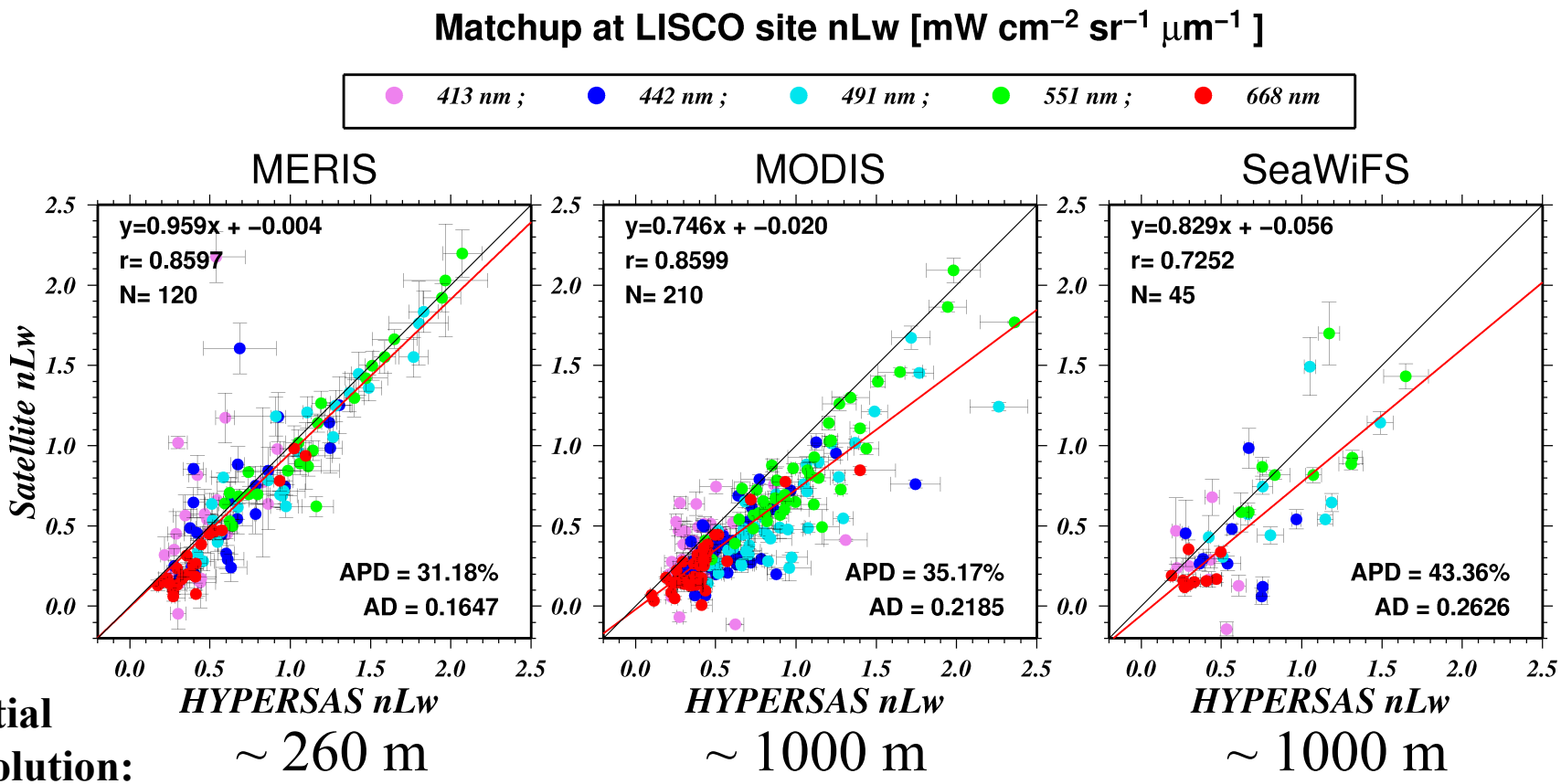
SeaPRISM vs Satellites



→ **Same order of Absolute Percentage Difference (APD) and Absolute Difference (AD) as the other sites of AERONET-OC [Zibordi et al., 2009]**

Satellite Validation against HyperSAS Data

Satellite Intercomparison against LISCO Data



Spatial Resolution: ~ 260 m ~ 1000 m ~ 1000 m

Satellite comparison for the same target size and location and same data processing (R2009.1)

→ **Higher spatial resolution improves statistics of comparison against ground-based data in coastal area – this hypothesis should be checked with HICO data**

Near-real-time Satellite Validation Tool

Webtool Design

SeaWIFS, MODIS, MERIS, VIIRS, …
from Navy APS operational processing at NRL

From NRL

MySQL Database

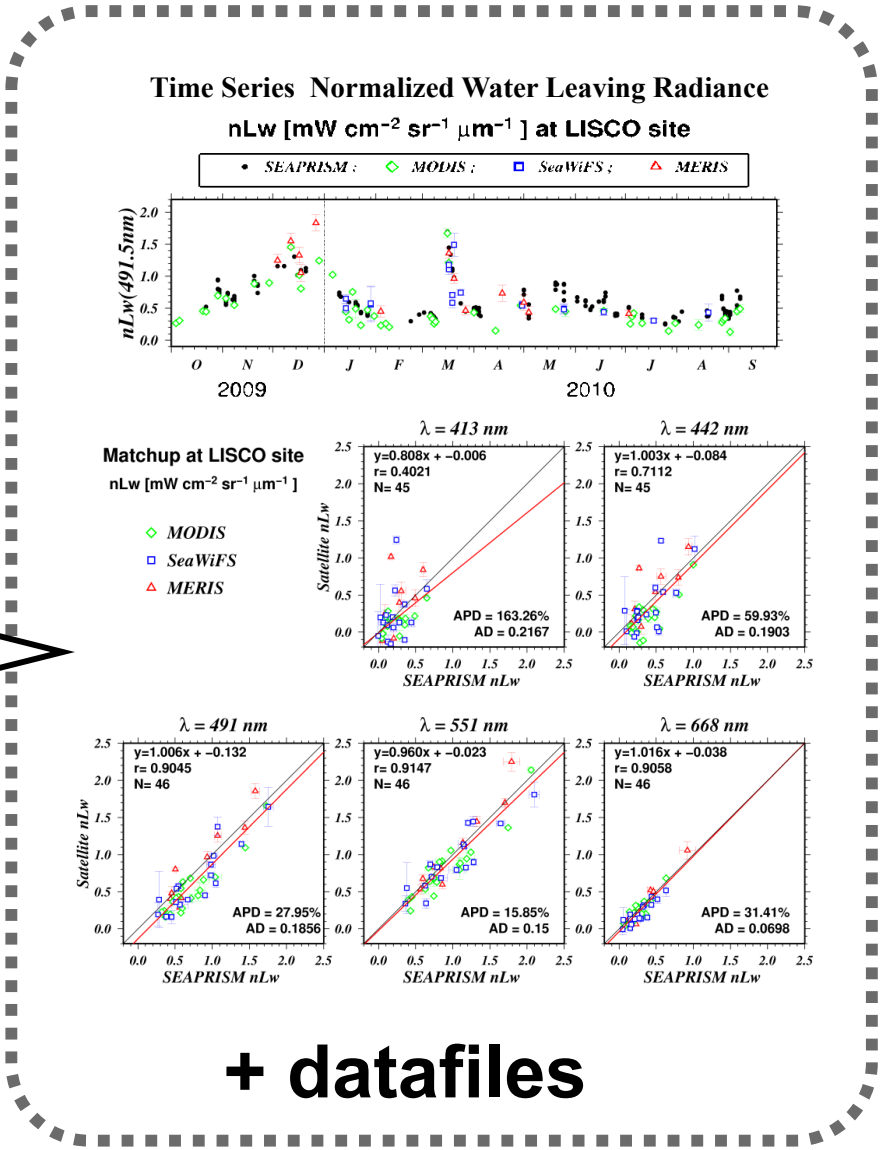
Web interface

From NRL

From CCNY

SeaPRISM data

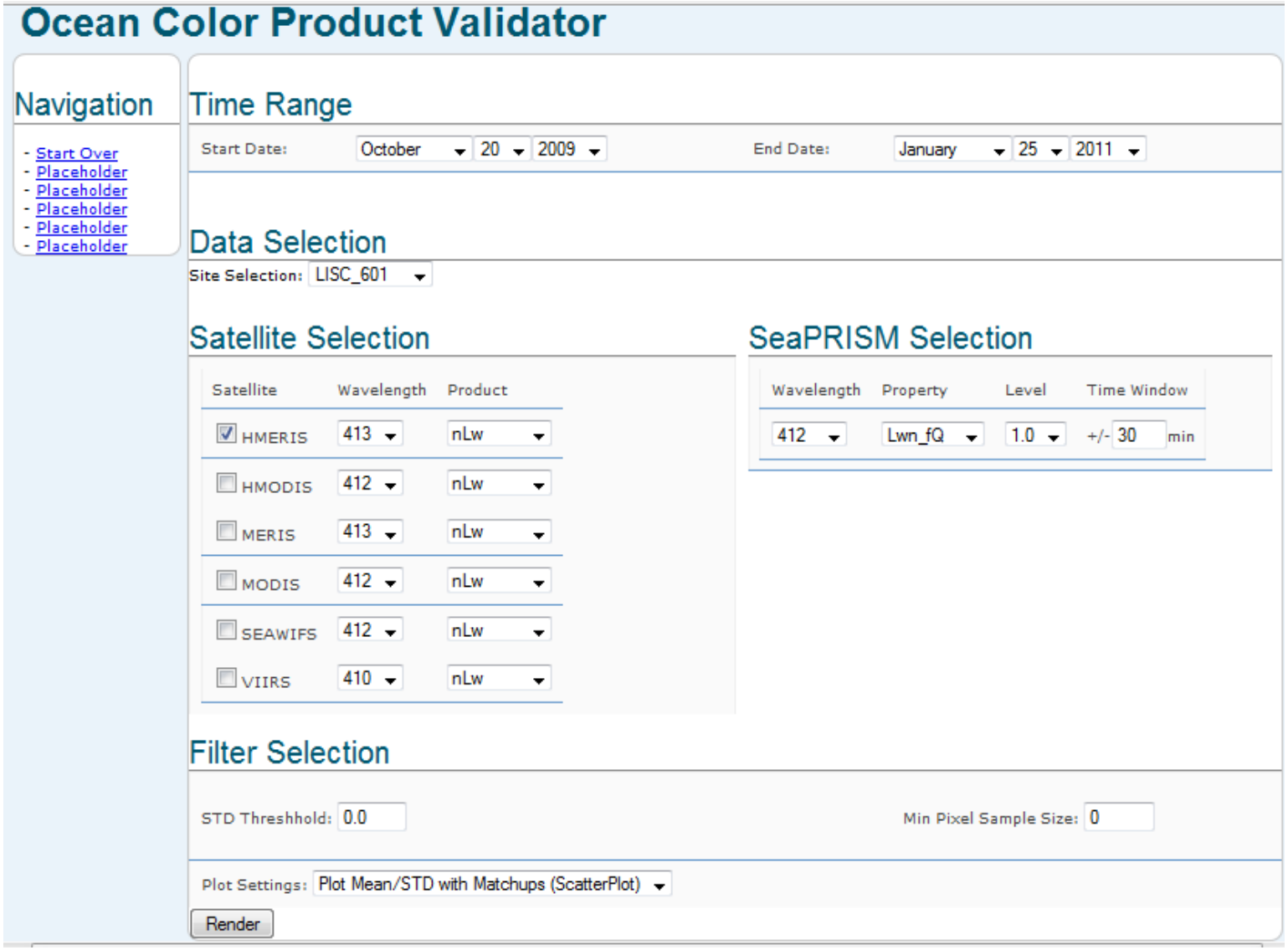
HyperSAS data



+ datafiles

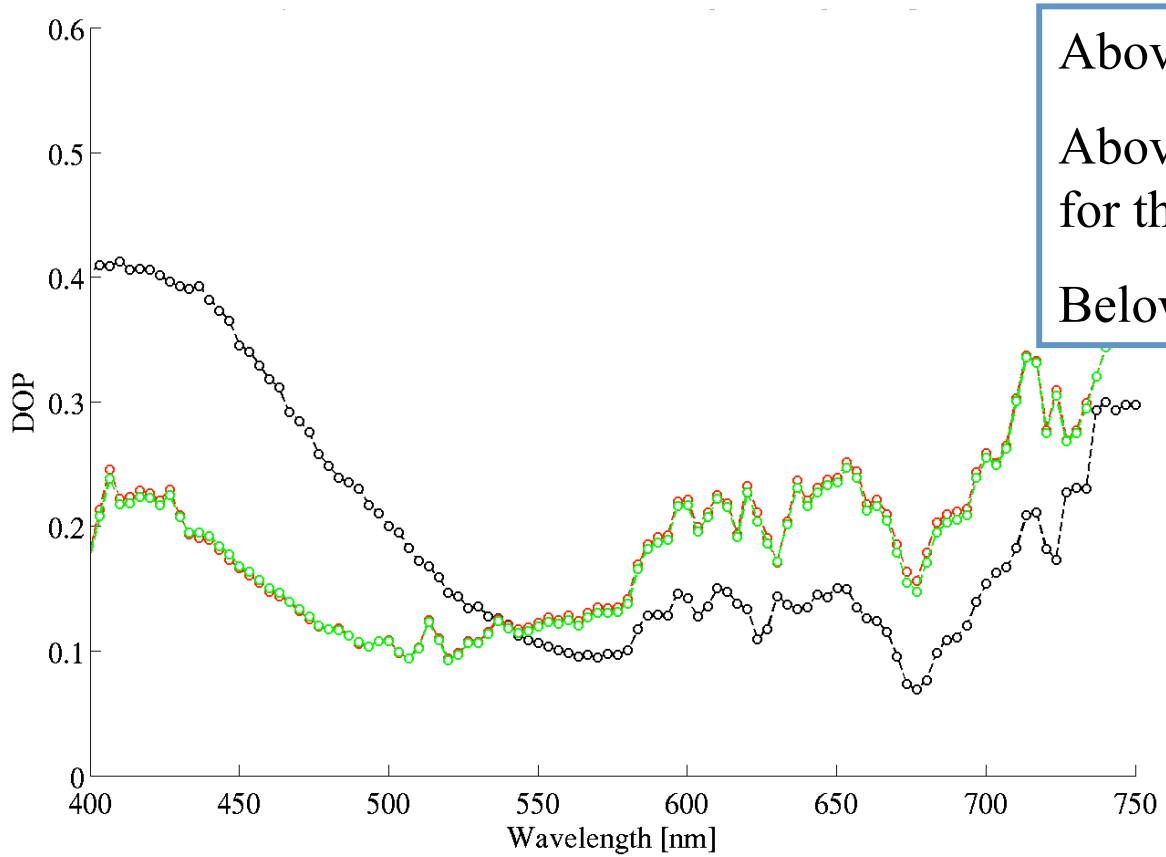
Near-real-time Satellite Validation Tool

Web Interface Screenshot



Polarization Measurements

Development of algorithm to derive below-water polarization from above-water measurements



Above water DOP_t – black

Above water DOP corrected for the sky glint - red

Below water DOP_w- green

Above water DOP_t and below water DOP_w retrieved from the HyperSAS-POL measurements of August 19th 2010 at 12:30 PM local time.

Conclusions

- **Comparison between nLw data of SesPRISM and HyperSAS shows excellent consistency.**
- **Co-located instruments give us the quality assurance data to compare with the satellite remote sensing data.**
- **Hyper -Spectral instrument gives us the advantage in making nLw match-up with multiple satellites data with different center wavelengths.**
- **Comparison with the satellite data show significant correlations and relatively low Absolute Percent Difference at 488, 551 and 668 nm.**
- **Initial results proved that the LISCO site is appropriate for effective calibration/validation of the current and future ocean color remote sensing sensors in coastal water area as a key element of the AERONET-OC network**

On-going works

- **Improvement of the bi-directionality models for the normalized water-leaving radiance derivation by using radiative transfer calculation for typical coastal waters (PhD student on this purpose)**
- **Development of a web tool designed for near-real-time comparison of satellite and LISCO data (Collaboration with NRL)**
- **Application to the validation of hyperspectral satellite imagery of HICO**
- **LISCO as a basis for the validation scheme of the future VIIRS satellite mission**

Acknowledgments

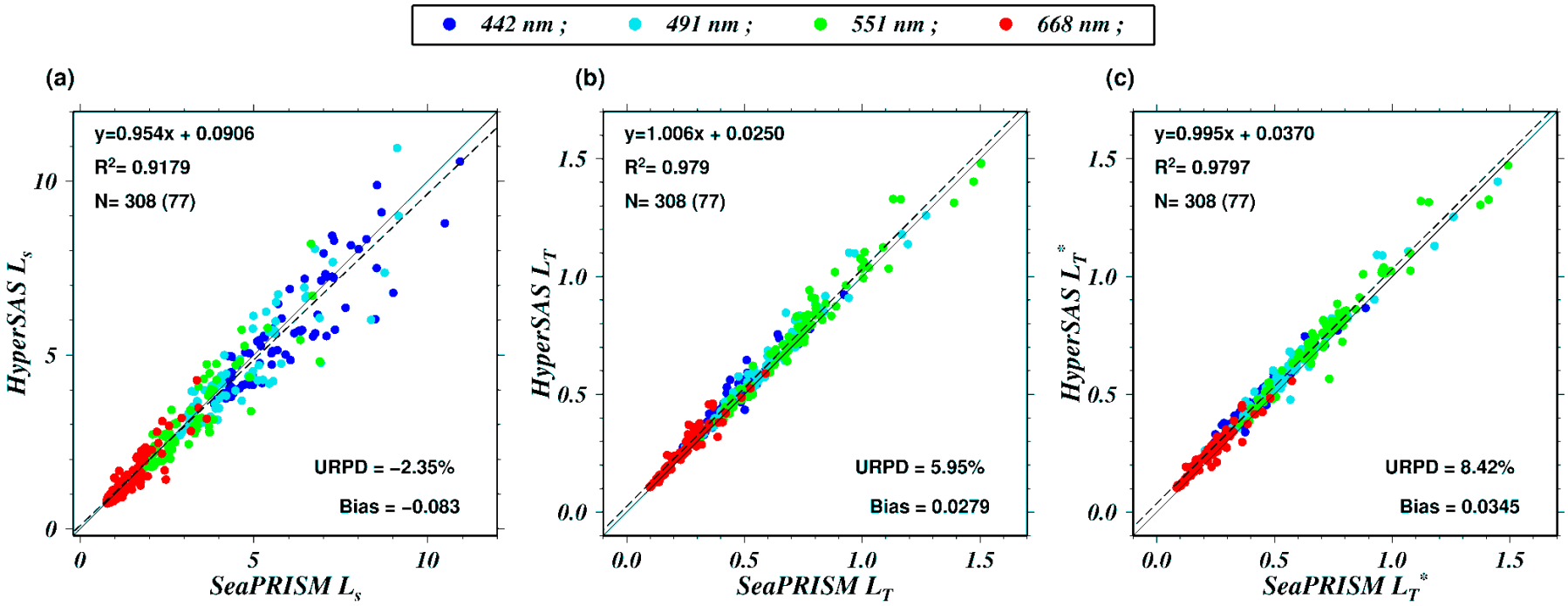
Partial support from:

- **Office of Naval Research**
- **National Oceanographic and Atmospheric Administration**

Collocated SeaPRISM and HyperSAS Data Comparison

Intercomparisons of direct measurements

L_S: sky radiance; L_T: sea radiance; L_T^*: 20% of lowest sea radiance



→ Strong Correlation; Regression Line Slope ~1

→ Dispersion of 6% in L_T : need of accurate cross-calibration

→ Dispersion induced by Sun glint removal : 2.5% (between L_T and L_T^*)