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AERONET-OC: an overview

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in collaboration with

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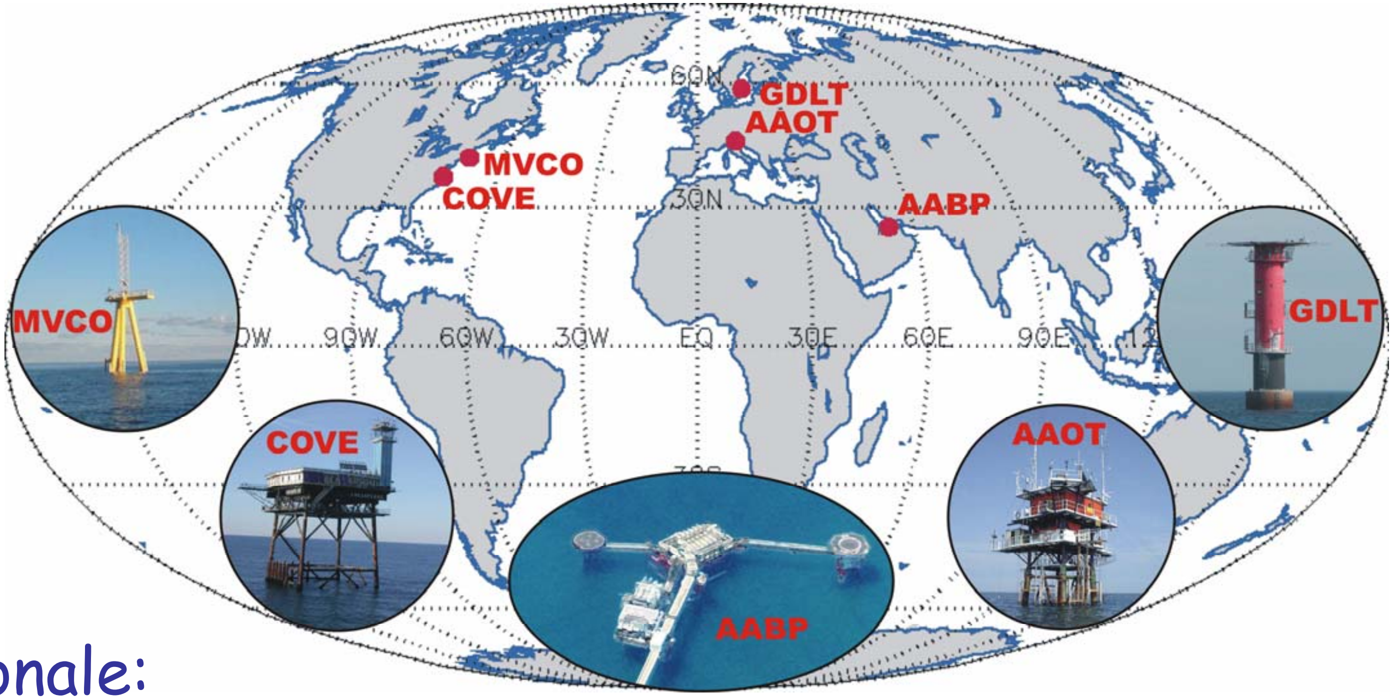
CEOS WGCV IVOS Workshop - October 20, 2010

Requirements for field data supporting cal/val programs

1. Traceable (with defined uncertainties quantified, when appropriate, through reference standards);
2. Globally distributed (ideally representing the wide range of geophysical conditions that remote sensing products are expected to observe);
3. Continuous (time-series of quality assured data are fundamental for assessing remote sensing products from successive space missions);
4. Cross-site consistent (uncertainties should be likely the same for all measurement sites and measurement conditions);
5. Accessible (availability, through suitable data policy, is a key element for any cal/val program).

AERONET-OC

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 $\tau_a(\lambda)$.

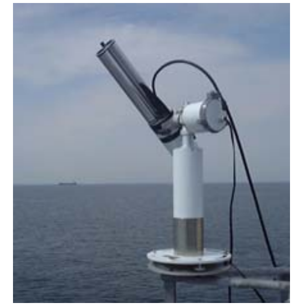


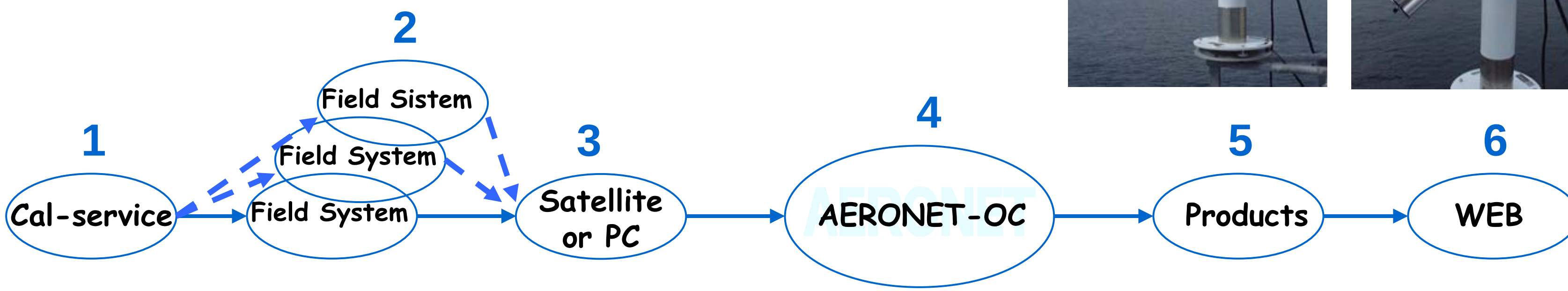
Rationale:

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

G.Zibordi et al. A Network for Standardized Ocean Color Validation Measurements. Eos Transactions, 87: 293, 297, 2006.

AERONET-OC: the network elements





1. Calibration service performed by JRC (from 2002 to 2008) and GSFC (from 2009) for above-water radiometric measurements (comparisons between JRC and NASA have shown differences on average below 2%).
2. AERONET-OC instruments operated from fixed deployment platforms.
3. Meteorological satellites (i.e., METEOSAT, GOES) or computers.
4. AERONET-OC data handling system (part of AERONET).
5. Marine and atmospheric products (i.e., L_{WN} and $\tau_a(\lambda)$ at the 412, 443, 488, 531, 551, 667, 870 and 1020 nm nominal center-wavelengths).
6. Products accessibility through internet with a specified data policy.

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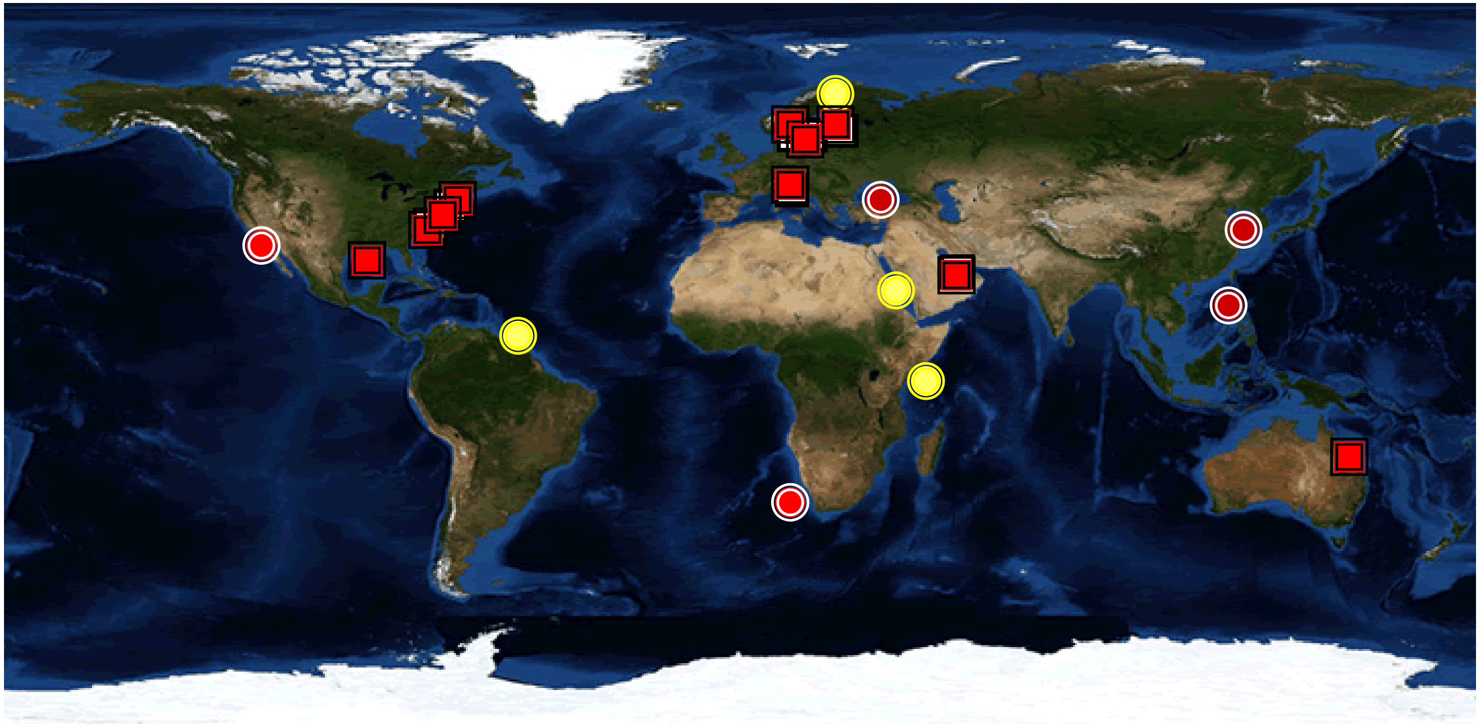
AERONET-OC (2002-present)



Current sites · Planned sites · Potential sites

Current management and responsibilities

- **NASA** manages the network infrastructure (i.e., handles the instruments calibration and, data collection, processing and distribution within AERONET).
- **JRC** has the scientific responsibility of the processing algorithms and performs the quality assurance of data products.
- **PIs** are responsible for establishing and maintaining AERONET-OC sites.

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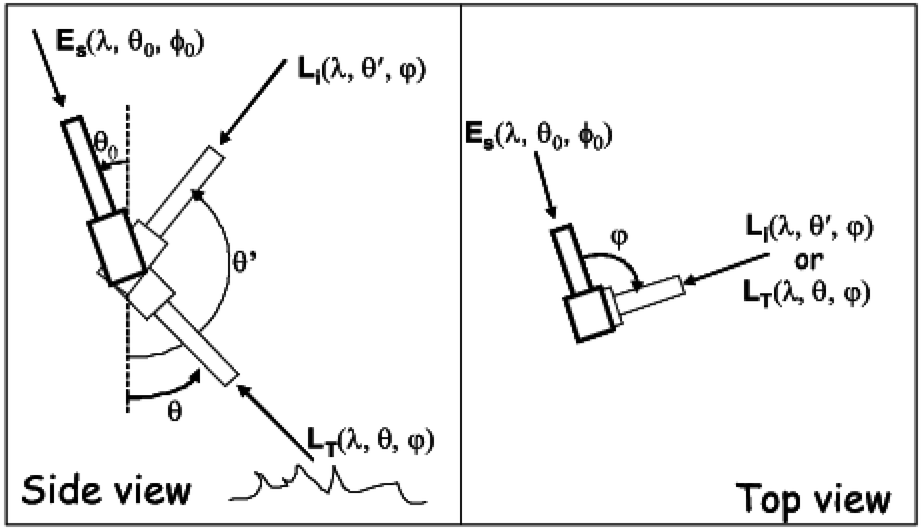
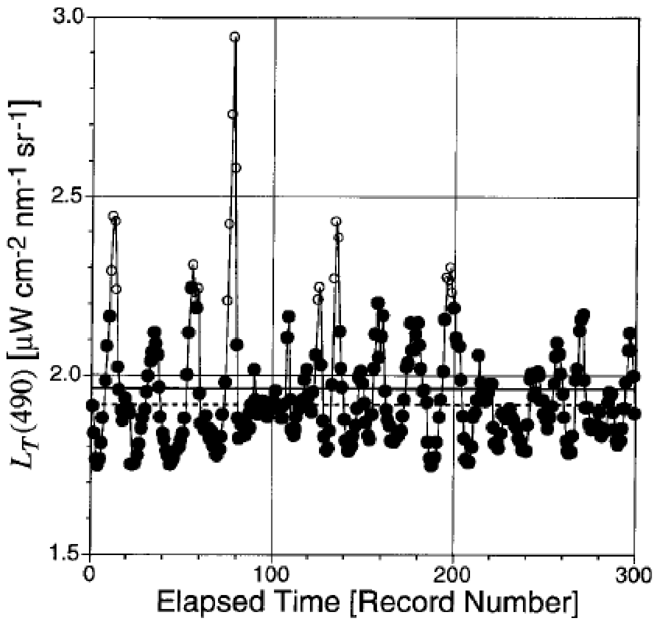
The Measuring Protocol





E_s: Direct solar irradiance

L_T: Total radiance from the sea

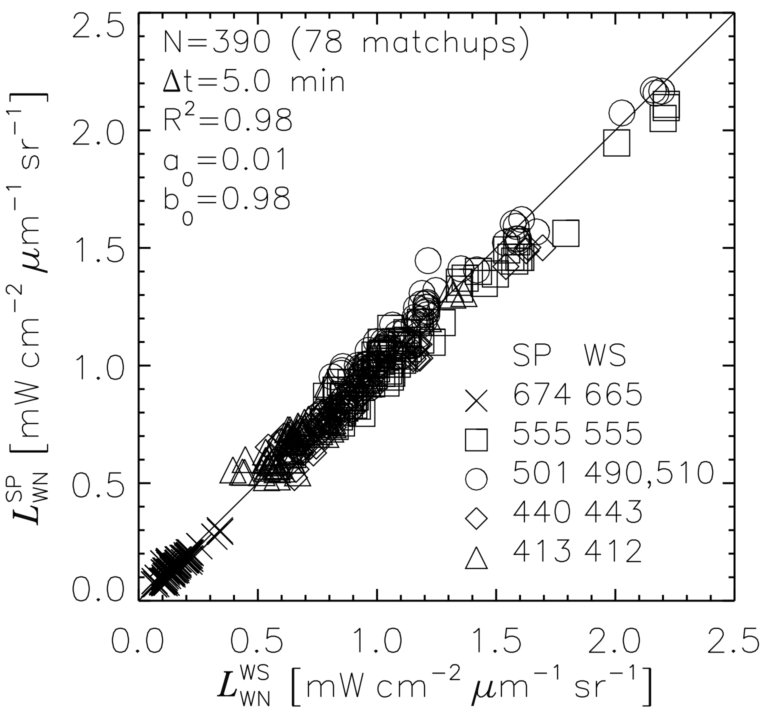
L_i: Sky-radiance

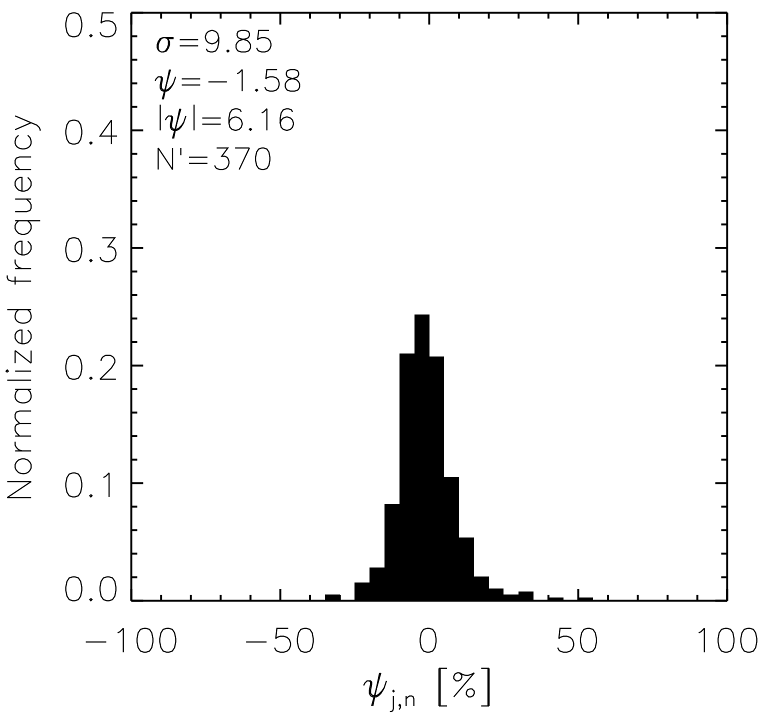
$$L_W(\varphi,\theta,\lambda) = L_T(\varphi,\theta,\lambda) - \rho(\varphi,\theta,\theta_0,W)L_i(\varphi,\theta',\lambda)$$

$$L_W(\lambda) = L_W(\varphi,\theta,\lambda)C_{\Im Q}(\lambda,\theta,\varphi,\theta_0,\tau_a,IOP,W)$$

$$L_{WN}(\lambda) = L_W(\lambda)\left(D^2 t_d(\lambda)\cos\theta_0\right)^{-1} C_{f/Q}(\lambda,\theta_0,\tau_A,IOP)$$

Consistency of L_{WN}





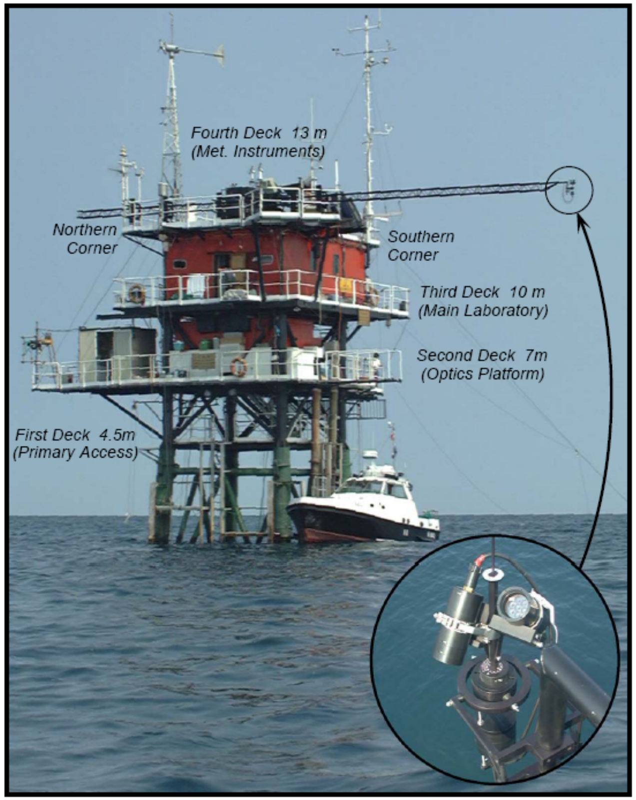
G.Zibordi, F. Mélin, S. B. Hooker, D. D'Alimonte and B. Holben. An autonomous above-water system for the validation of ocean color radiance data. *IEEE Transactions in Geoscience and Remote Sensing*, 42:401-415, 2004.

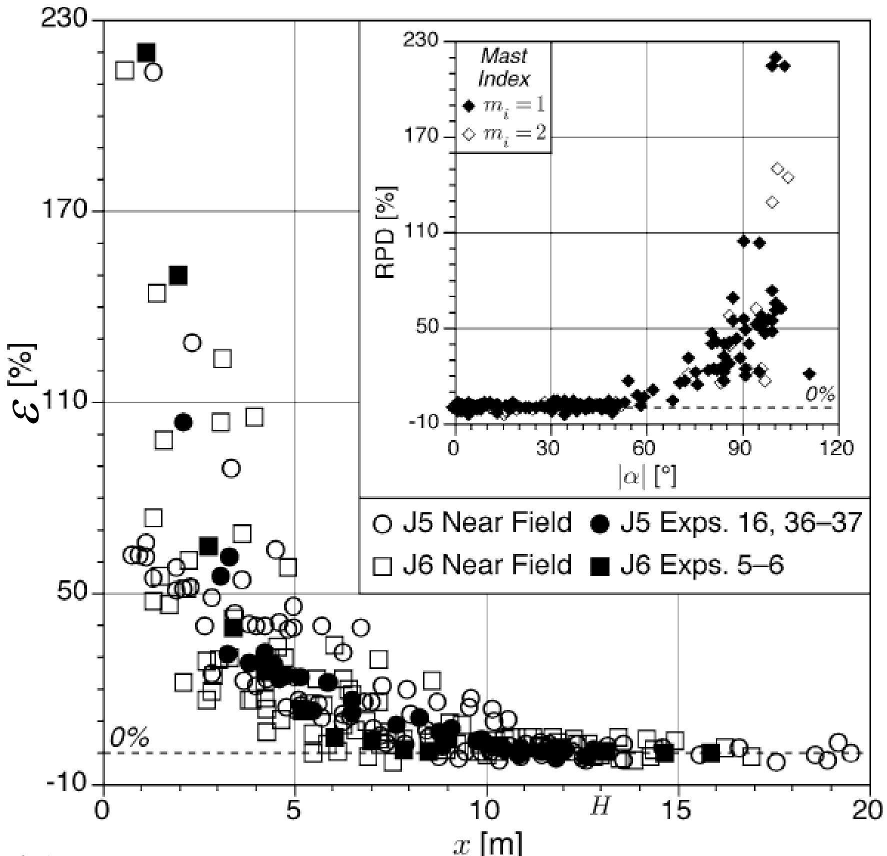
AERNOTE-OC deployment Requirements

- Fixed deployment platforms to allow for accurate pointing
- Relatively deep waters to minimize bottom perturbations
- Selected deployment configurations to minimize superstructure perturbation
- Away from land to minimize adjacency effects in remote sensing data

G.Zibordi, B.Holben, I.Slutsker, D.Giles, D.D'Alimonte, F.Mélin, J.-F. Berthon, D. Vandemark, H.Feng, G.Schuster, B.Fabbri, S.Kaitala, J.Seppälä. AERONET-OC: a network for the validation of Ocean Color primary radiometric products. *Journal of Atmospheric and Oceanic Technology, 26, 1634-1651*, 2009.

Superstructure Perturbations





$$\varepsilon(x,x_0,\lambda_0)=100\frac{\rho(x,\lambda_0)-\rho(x_0,\lambda_0)}{\rho(x_0,\lambda_0)}$$ *where* $$\rho(x,\lambda_0)=L_T(x,\lambda_0)/L_i(\lambda_0)$$

The observed surface area should be at a distance from the main superstructure larger than the height of the superstructure itself.

S. B. Hooker and G. Zibordi. Platform perturbation in Above-Water Radiometry. *Applied Optics*, 44, 553-567, 2005.

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Quality Assurance

AERONET-OC products are classified at different quality assurance levels:

Level 1.0 -> ▪ $L_{WN}(\lambda)$ determined from complete measurement sequences.

Level 1.5 -> ▪ Cloud screened aerosol optical thickness data exist;

- Replicate sky and sea radiance measurements exhibit low variance;
- Empirical thresholds are satisfied (e.g., exceedingly negative values or high reflectance in the near infrared);

Level 2.0 -> ▪ Pre- and post-deployment calibration coefficients exhibit justifiable differences within 5% (typically within 1%);

- $L_{WN}(\lambda)$ spectral shapes are consistent based on statistical approaches;
- A final spectrum-by-spectrum screening is passed.

Fully quality assured data typically include 10-15% of the initial measurements

G.Zibordi, B.Holben, I.Slutsker, D.Giles, D.D'Alimonte, F.Mélin, J.-F. Berthon, D. Vandemark, H.Feng, G.Schuster, B.Fabbri, S.Kaitala, J.Seppälä. AERONET-OC: a network for the validation of Ocean Color primary radiometric products. *Journal of Atmospheric and Oceanic Technology, 26, 1634-1651*, 2009.

Uncertainties

Source	L_{WN}				
	412	**443**	**488**	**551**	**667**
Absolute calibration	2.7	2.7	2.7	2.7	2.7
Sensitivity change	0.4	0.2	0.2	0.2	0.2
Correction	1.6	2.0	2.8	2.9	1.9
t_d	1.5	1.5	1.5	1.5	1.5
ρ	1.8	1.3	0.7	0.6	2.5
W	1.1	0.8	0.4	0.4	0.4
Environmental effects	3.1	2.1	2.1	2.1	6.4
Quadrature sum	**5.1**	**4.5**	**4.7**	**4.7**	**7.8**

~5% (400-600 nm)

G.Zibordi, B.Holben, I.Slutsker, D.Giles, D.D'Alimonte, F.Mélin, J.-F. Berthon, D. Vandemark, H.Feng, G.Schuster, B.Fabbri, S.Kaitala, J.Seppälä. AERONET-OC: a network for the validation of Ocean Color primary radiometric products. *Journal of Atmospheric and Oceanic Technology* , 26, 1634-1651, 2009.

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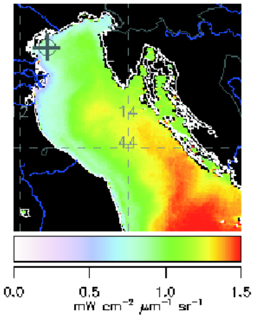
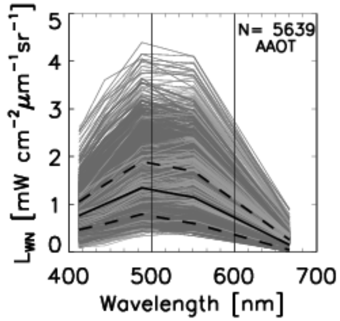
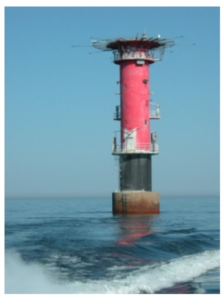
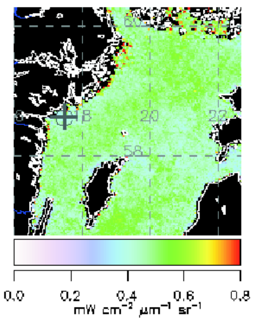
Examples of AERONET-OC Sites

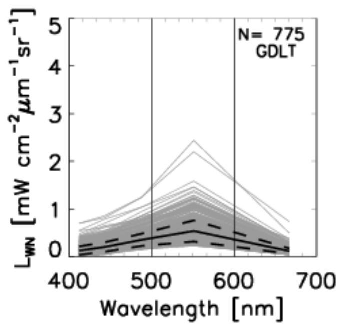




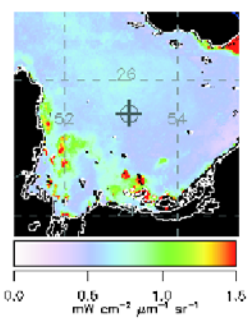
Site: AAOT
Location: Northern Adriatic Sea
Water type: Case-1/Case-2
Period: 2002-present

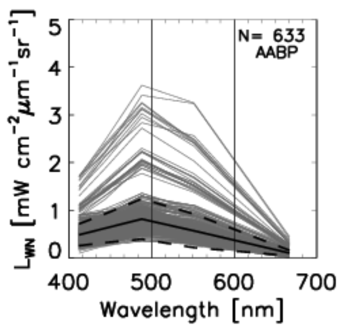






Site: GDLT
Location: Northern Baltic Proper
Water type: Case-2
Period: 2005-present (summer)





Site: AABT
Location: Persian Gulf
Water type: Case-1 (?)
Period: 2005-2008

Zibordi, G., Holben, B., Slutsker, I., Giles, D'Alimonte, D., Mélin, F., Berthon, J.-F., Vandemark, D., Feng, H., Schuster, G., Fabbri, B. E., Kaitala, S., Seppälä, J. (2009). AERONET-OC: a network for the validation of Ocean Color primary radiometric products. *J. Atmos. Oceanic Technol., 26, 1634-1651.*

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Band-Shift Correction

AERONET-OC data are produced at fixed center-wavelengths not necessarily matching those of the satellite sensors of interest.

Current band-shift correction, not included in the operational processing, is applied for several sites relying on the following scheme:

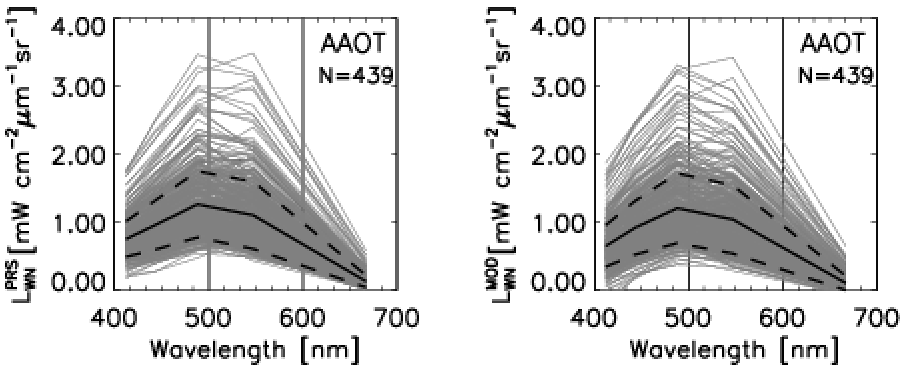
$$L_{WN}(\lambda) = L_{WN}(\lambda_0)\frac{E_0(\lambda)}{E_0(\lambda_0)}\cancel{\frac{f'(\lambda)}{Q_n(\lambda)}\frac{Q_n(\lambda_0)}{f'(\lambda_0)}}\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)}\frac{a(\lambda_0)+b_b(\lambda_0)}{b_b(\lambda_0)}$$

Where synthetic values at λ are computed from values at λ_0

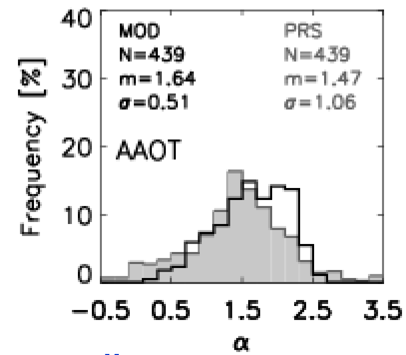
1. assuming λ is close to λ_0 so that $f'(\lambda)/Q(\lambda)\times Q(\lambda_0)/f'(\lambda_0)\approx 1$;
2. determining a and b_b using empirical regional algorithms relying on $L_{WN}(\lambda)$ *ratios.*

G.Zibordi, J.-F. Berthon, F. Melin, D.D'Alimonte and S. Kaitala. Validation of satellite ocean color primary products at optically complex coastal sites: northern Adriatic Sea, northern Baltic Proper and Gulf of Finland. *Remote Sensing of Environment* (in press), 2009.

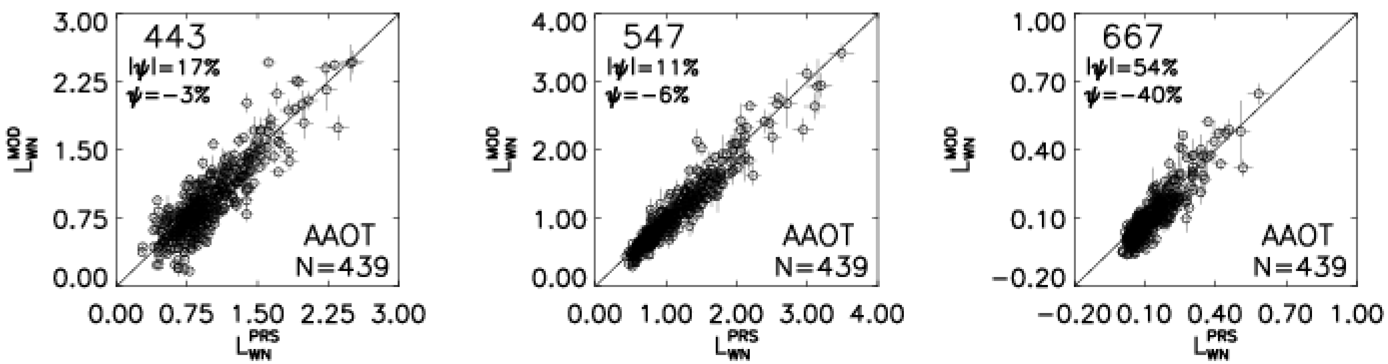
Validation of Satellite Products (MODIS)



***In situ* and satellite derived L_{WN} spectra**



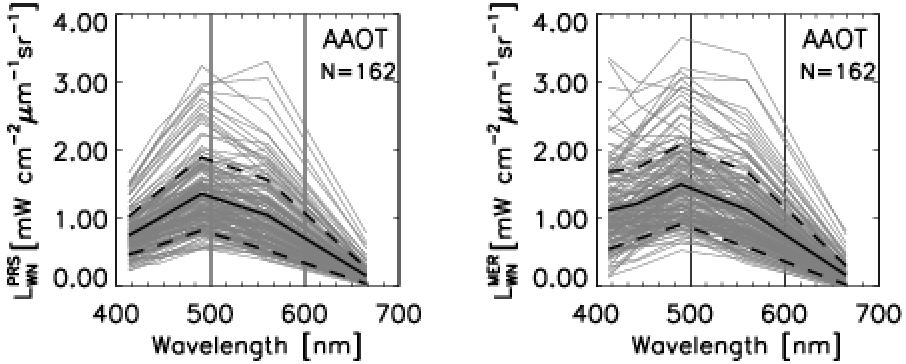
Ångström exponents



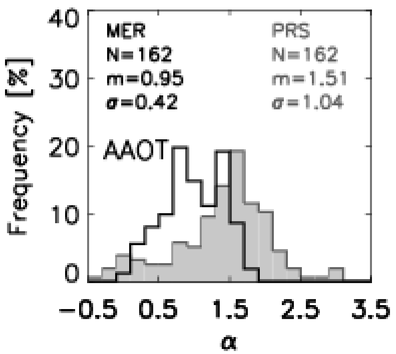
Satellite (MODIS) versus *in situ* (AERONET-OC) L_{WN} match-up analysis

G.Zibordi, J.-F. Berthon, F. Melin, D.D'Alimonte and S. Kaitala. Validation of satellite ocean color primary products at optically complex coastal sites: northern Adriatic Sea, northern Baltic Proper and Gulf of Finland. *Remote Sensing of Environment*, in press, 2009

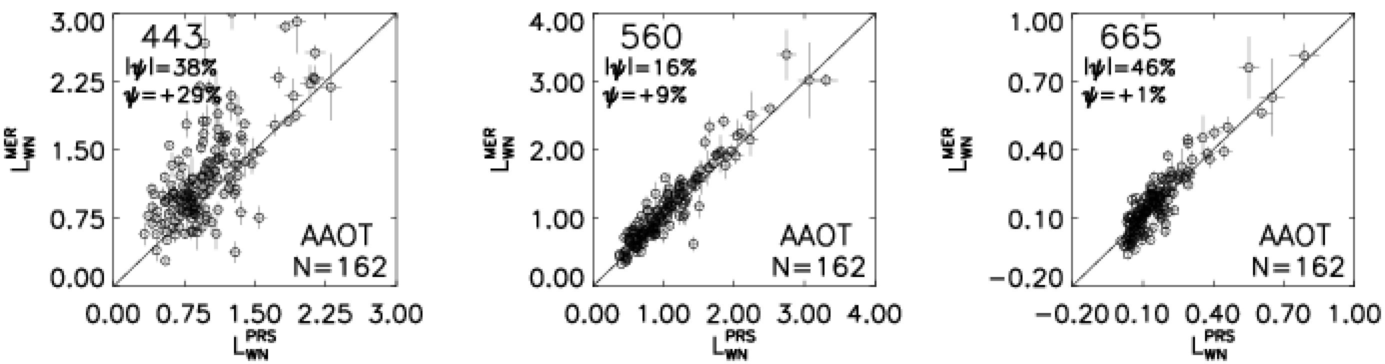
Validation of Satellite Products (MERIS)



In situ and satellite derived L_{WN} spectra



Ångström exponents



Satellite (MERIS) versus *in situ* (AERONET-OC) L_{WN} match-up analysis

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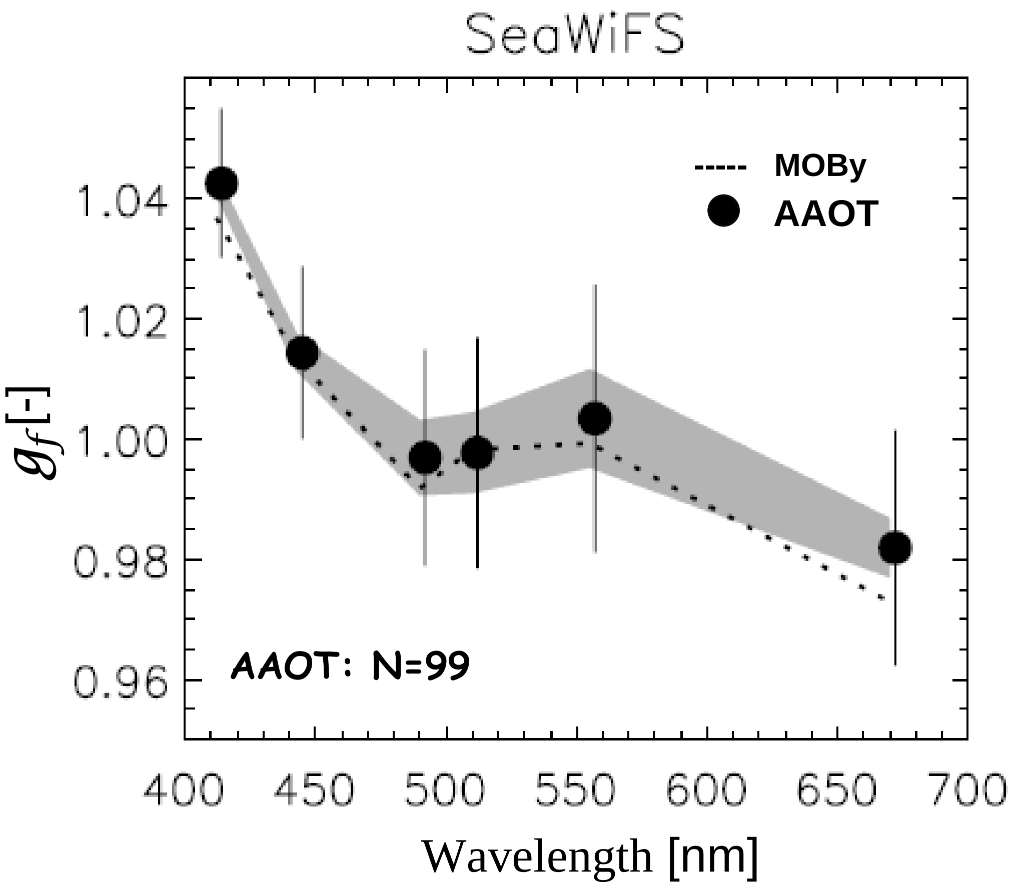
Vicarious Calibration (SeaWiFS)



$$g_f(\lambda) = \frac{L_{ToA}^{COMP}[L_{WN}(\lambda)]}{L_{ToA}^{SAT}(\lambda)}$$

Criteria

i. satellite and *in situ* data collected within +/-1 h;
ii. satellite viewing angle lower than 56 and sun zenith lower than 60 degrees;
iii. 5x5 pixels centered at the site free of cloud and glint contamination;
iv. variation coefficient of the 3x3 pixels centered at the site lower than 20%

Principles

The correction factors g_f are determined using AERONET-OC data from AAOT by applying the methodology established for MOBY data (Bailey et al. 2008)

F.Mélin and G.Zibordi. Vicarious calibration of ocean color data using coastal sites. *IEEE Transactions in Geoscience and Remote Sensing*, Applied Optics, March 2010.

Minimization of systematic errors in L_{WN}

Match-up criteria

i. satellite and *in situ* data collected within +/-2 h;
ii. satellite viewing angle lower than 56 and sun zenith lower than 70 degrees;
iv. 3x3 pixels centered at the site free of cloud and glint contamination;
v. variation coefficient of the 3x3 pixels lower than 20%

Principles

$$< L_{WN}^{MOD}(\lambda) > = L_{WN}^{MOD}(\lambda) + < \Delta L_{WN}^{MOD}(\lambda) >$$

$$< \Delta L_{WN}^{MOD}(\lambda) > = L_{WN}^{PRS}(\lambda) - L_{WN}^{MOD}(\lambda)$$

$$< \Delta L_{WN}^{MOD}(\lambda) > = a_0(\lambda) + \sum_{i=1}^{n} a_n(\lambda) X_n$$

where X_n indicates:

$L_{WN}^{MOD}(\lambda)$, θ_0, φ_0, θ_V, ϕ_V

D.D'Alimonte, G.Zibordi and F.Mélin. A statistical method for generating cross-mission consistent normalized water-leaving radiances. *IEEE Transactions in Geoscience and Remote Sensing*, 46, 2008.

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Strengths and Weaknesses

Strengths:

1. Use of standardized instruments, calibration and data processing.
2. Continuous and autonomous data collection with near-real time processing and open access to products through a specified data policy.
3. Relatively small costs to equip and maintain sites (on the average in the range of 20-50 KUS$ per year).

Weaknesses:

1. Execution of sequential measurements at different time for different center-wavelengths, which increases the *inter-channel uncertainty* of $L_{WN}(\lambda)$ with respect to the case of measurements performed at the same time at all center-wavelengths.
2. Limited number of spectral channels.
3. Lack of operational tables for the determination of viewing angle and f/Q corrections, applicable to optically-complex coastal waters.

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Concluding remark

- AERONET-OC satisfies the major requirements of traceable, globally distributed, continuous, cross-site consistent and accessible measurements.

- AERONET-OC, likely expanded to include sites representative of additional water types, is a major source of data for satellite ocean color validation and development activities

Aside the NASA-GSFC AERONET Team, acknowledgment is due to ESA for contributing to support the AAOT, GDLT and Gloria sites.

Thanks