Above water-protocols, Past and present

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5/17/17, Advances in protocols for water-leaving radiance and related parameters

The parameter I will focus on is the Remote sensing reflectance:

$$R_{RS}(\lambda,\theta,\phi \in \Omega_{FOV};\theta_o) = \frac{L_w(\lambda,\theta,\phi \in \Omega_{FOV};\theta_o)}{E_s(\lambda;\theta_o)}$$

But to compare measurements we should probably be talking about, the exact normalized remote sensing reflectance:

$$R_{RS}^{Ex}(\lambda) = \frac{L_{WN}^{ex}(\lambda)}{\overline{F}_o(\lambda)}$$

Where appropriate corrections have been done to change L_w to the exact L_w, through some bi-directional reflectance model, and F_o is the mean solar extraterrestrial irradiance. Opens a long discussion on how to do the corrections….so will focus on R_{RS}.

There are actually three protocols currently listed:

1) Use a calibrated radiance detector and irradiance collector. Measure

$$L_{sfc}(\lambda,\theta,\phi \in \Omega_{FOV};\theta_o)\ ,\ L_{sky}(\lambda,\theta_{sky},\phi_{sky} \in \Omega'_{FOV};\theta_o)\ ,\ E_s(\lambda;\theta_o)$$

Combine these as $L_w = L_{sfc} - \rho L_{sky}$ then combine to get R_{Rs}

2) Use an uncalibrated radiance and reflectance plaque. Measure

$$S_{sfc}(\lambda,\theta,\phi \in \Omega_{FOV};\theta_o)\ \ S_{sky}(\lambda,\theta_{sky},\phi_{sky} \in \Omega'_{FOV};\theta_o)$$

Then measure the plaque (for which the BRDF is assumed to be lambertian) with radiometer (S_{plaque}), with plaque held horizontally.
Then:
$R_{RS} = (S_{sfc} - \rho S_{sky})/S_{plaque} * F$, where F includes factors such as the BRDF and π. **(note all terms can vary spectrally)**

3) Use a calibrated radiance detector, with a sunphotometer (to get aerosol properties. Measure the surface radiance, L_{sfc}, and calculate all the other required parameters to generate R_{RS}.

I will concentrate on methods 1 and 2, which are the most commonly used.

Different considerations on the radiance measurements:

1) Field of view of radiometer…small field of view: no averaging, large field of view: poor angular resolution for surface reflectance. Protocol says people have used 2-18 deg, with no recommendation.

2) Position on ship: towards bow (to get in front of wake).

3) angle: $(\theta,\Phi) = (40\text{-}45°,135°)$, also $\theta_o > 20°$

4) Make many measurements over a period of seconds or minutes for averaging.

5) suggest with a fiber optic spectrometer (now instrument of choice) repeating the sequence of plaque- surface- sky 5 or more times, with a dark reading between each reading. Before averaging throw out positive outliers (possible foam, whitecaps or strong glint).

6) Sky measurement should be done at reciprocal angles. If partly cloudy, adjust view angles to cover clear sky segment (?).

Considerations for downwelling irradiance measurements:
For method 1
1) mount irradiance collector in a location which has a clear sky view.

2) Eliminate any measurements where the tilt of the collector is more than 5° from the horizontal.

For Method 2 (plaque)

1) many used 10% reflectance plaques, but 99% plaques have better BRDF characteristics.

2) hold Plaque horizontal in a location exposed to the sun and sky in all directions.

3) Align the radiance sensor at an angle consistent with the solar direction and the plaques BRDF characteristics.

Ancillary data:

1) Date/Time
2) Position
3) viewing zenith and azimuth angles, and solar azimuth relative to ship heading
4) direction of sun relative to ships heading (redundant?)
5) cloud cover and sky conditions (picture?).
6) wind speed and direction
7) Sea state (wave height, whitecap coverage, direction, height and period of dominate wave swell.
8) barometric pressure
9) Secchi depth
10) Dark data filename logged
11) times, locations, and file id of associated CTD, insitu fluorescence, inwater radiometry, and IOP profiles
12) associated water samples
13) file names for portable radiometric reference standards (if any)
14) Instrument identification
15) calibration date and file identification

NOAA/STAR (Mike Ondrusek et al)

1) 10° field of view (ASD)

2) (θ,Φ) = (40°,135°)

3) 5 scans of sky, 5 scans grey card, 5 scans of water.

4) processed with NRL software, produces

R_{RS}_sfc no NIR reflectence
R_{RS}_fresnel Fresnel correction ommitted
R_{RS}_Carder and Steward (1985)
R_{RS}_Lee et al (1997)
R_{RS}_Gould et al (2001)

AERONET-OC, Zibordi et al.

1) Modified CIMEL ASSR radiometer, 1° FOV.

2) $(\theta,\Phi) = (40°,90°)$

3) automated system so takes many measurements, these are filtered according to Zibordi 2012 and Zibordi et al. 2009

4) Downwelling irradiance computed and Lw determined following Zibordi et al. 2009 for clear sky only.

5) several QC steps

UMB (Lee et al.)

1) Two instruments, Spectral Evolution instrument and Spectrix
Spectral Evolution has 10° FOV

2) For Spectral Evolution, measured downwelling irradiance with a cosine collector, For Spectrix a grey card was used.

3) $(\theta,\Phi) = (30°,90°)$

4) Processing follows Lee et al (1997, 2010).

USF (Hu et al.)

1) ASD HandHeld2-pro spectroradiometer, 7.5 degree field of view

2) $(\theta,\Phi) = (30°,90\text{-}120°)$

3) grey card was measured (assume 10%?) Instrument held 30 cm above reference plaque.

CCNY (Gilerson et al.)

1) GER 1500 Field Portable spectroradiometer, 4° FOV

2) $(\theta, \Phi) = (40°, 90°)$

3) use a white (99%) spectralon plaque to get irradiance

4) make 4 consecutive measurements of the surface, 4 consecutive measurements of the sky, and 4 consecutive measurements of the plaque. All measurements were averaged.

5) During processing (at least for the NOAA cruise), the $R_{RS}(750)$ is subtracted from the entire R_{RS} spectrum.

They also use an ASD Handheld 2 radiometer, and have a HyperSAS-POL which does above water measurements…but with alot of extra polarization information.

USM and NRL (Arnone et al.)

1) ASD FieldSpec radiometer, 10°FOV.

2) use 10% grey card with a known BRDF, assumed to be semi-lambertian

3) $(\theta,\Phi) = (45°,90\text{-}135°)$

4) 5 consecutive measurements of the grey card (S_g), water (S_{sfc}), and sky (S_{sky}). Before each type of measurement dark counts were obtained.

Open questions:

Field of view?

Sampling directions?

99% or 10% grey card?

Measurement sequence….5 samples, alternate? Average all? Throw out High values?

Is it better to do Method 1 (all radiometric measurements) then Method 2 (basically relative measurements).

Should Method 3 be in the revised protocols? Does anyone still use this method?

Spectral reflectance factor (rho)?

Open questions:

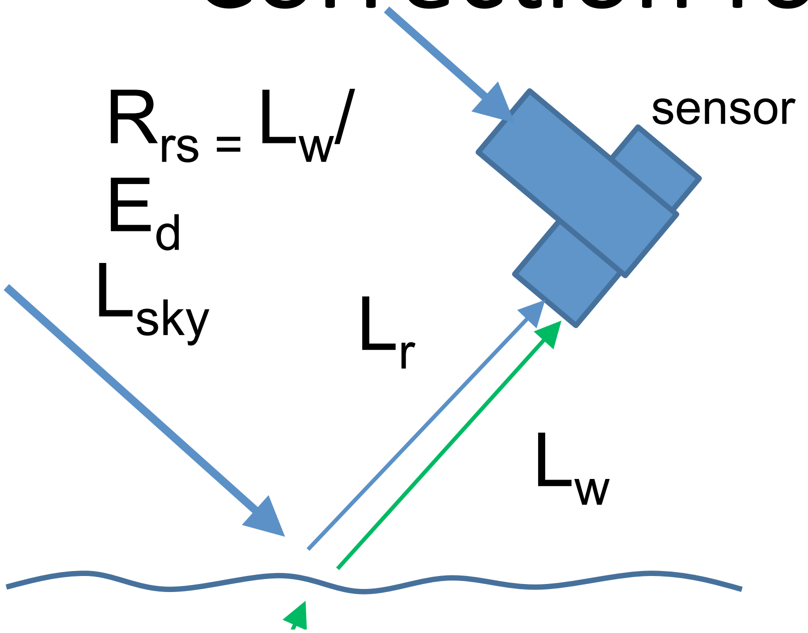
Polarization effects in rho?

Avoiding superstructure pertubations…

Associated...how do you measure a plaque with a radiometer, without perturbing the environment (my question....).

What steps should be done for QC and QA?

Correction for sky/sunglint



Measure $L_t = L_w + L_r$ and L_{sky}

Model $L_r = \rho_F * L_{sky}$ with ρ_F(Wind, SZA) Usually based on Cox-Munk and Hydrolight (scalar r/t) [Mobley, 1999]

BUT

- Polarisation is important — Use vector r/t [Harmel, 2012; Mobley, 2015; D'Alimonte, 2016]
- Waves may be not Cox-Munk, e.g. fetch-limited; swell — Limit ρ_F or model better?
- Sky contribution to Lr not just in Lsky direction and may be different from simulations
- Very local wind speed may be inaccurate — Add to uncertainty
- Fast sensor (e.g. multispectral) allows removal of sunglint flashes [Hooker, Zibordi] , slow sensor (e.g. hyperspectral) averages them
- Sunglint/Foam different colour to Skyglint (Lsky)

Model jointly Lw and Lr? [Lee, 1996]
… constrain Lw smooth across atmospheric absorption [Simis, 2013]

AND

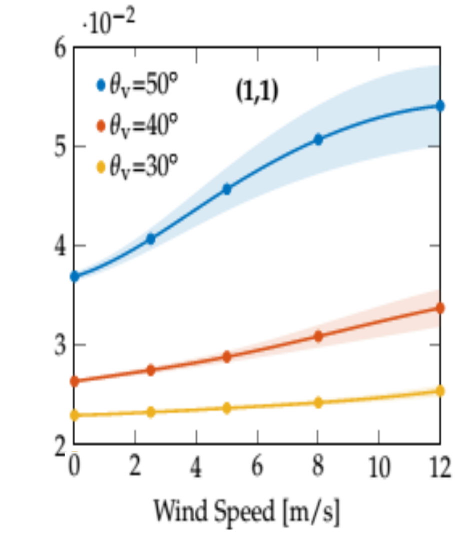
Note: uncertainty in $\rho_F * L_{sky}$ gives absolute uncertainty for Rrs

\+

Use NIR to constrain [Gould, 2001] or QC [Ruddick, 2005] Rrs

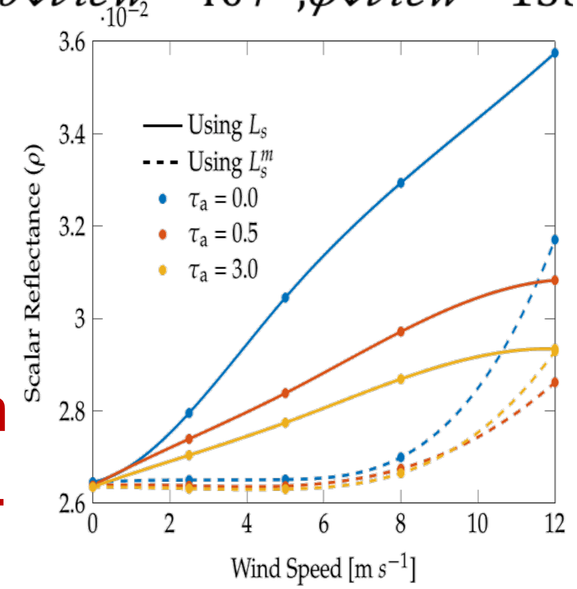
Dependence of ρ on Geometry, Wind speed, AOT, FOV

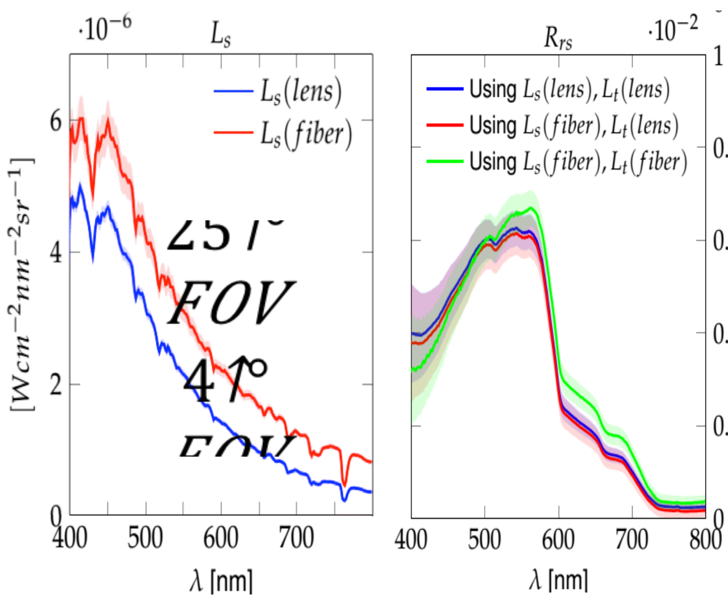
$\theta_{view} = 40^{\circ}$, $\varphi_{view} = 135$

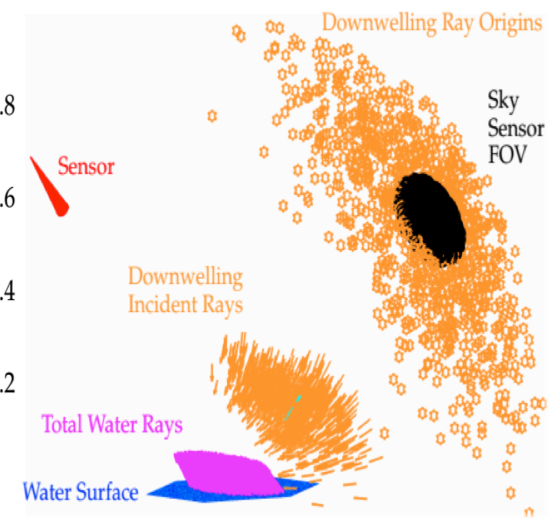


Highest dependence on viewing angle

Large dependence on wind speed and AOT.







Field-of-view effect

Black circle is the measured L_s (L_s^m)

Orange directions contribute to total water measurement. (actual L_s)

Foster and Gilerson, AO, 2016

Extra slides

Although this may seem a paradox, all exact science is dominated by the idea of approximation. When a man tells you that he knows the exact truth about anything, you are safe in inferring that he is an inexact man. Every careful measurement in science is always given with the probable error ... every observer admits that he is likely wrong, and knows about how much wrong he is likely to be.

— Bertrand Russell

In The Scientific Outlook (1931), 42.

(For “man/he” read “scientist/s/he”. For “error” read “uncertainty”)

No person will deny that the highest degree of attainable accuracy is an object to be desired, and it is generally found that the last advances towards precision require a greater devotion of time, labour, and expense, than those which precede them.

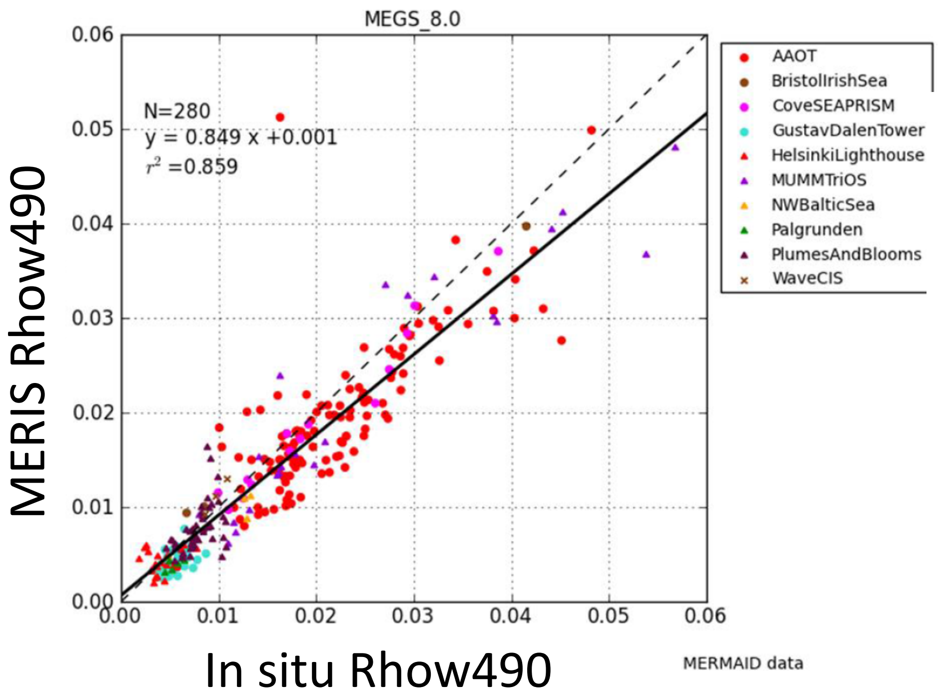
— Charles Babbage

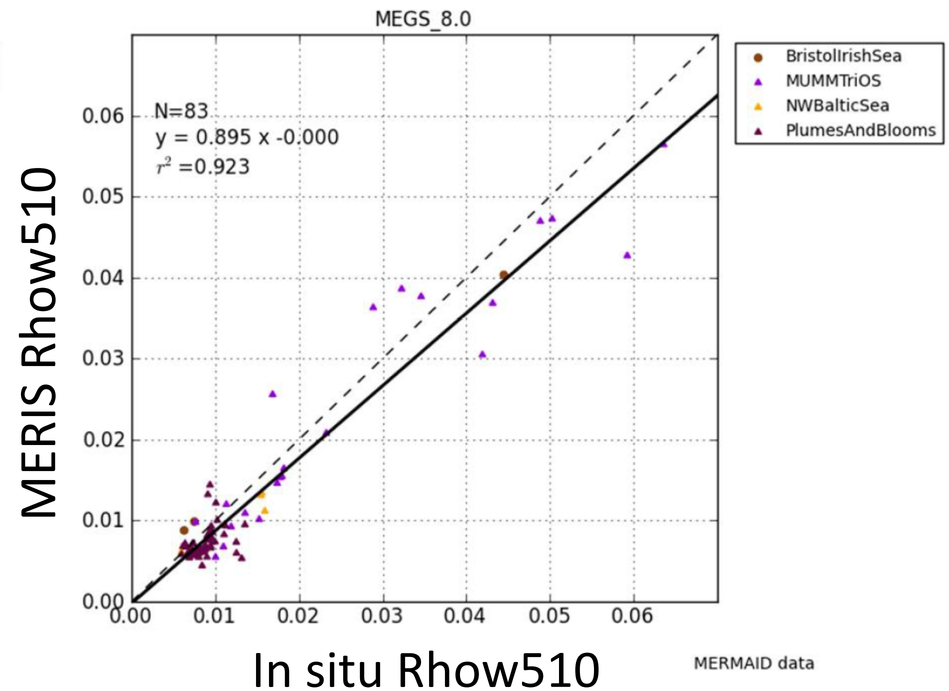
Reflections on the Decline of Science in England (1830), 167.

A measurement result is complete only when it is accompanied by a statement of the associated uncertainty [Wikipedia, Measurement Uncertainty, 2017

Motivation for uncertainty estimates - satellite validation

10 years of MERIS validation data, including a few years of AERONET-OC…



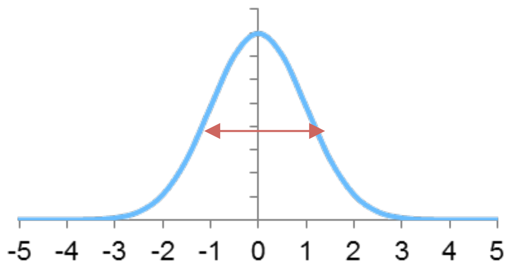


- 10 teams involved, diverse protocols and instruments
- BUT what is uncertainty of each measurement? Can we use them all?

[MERIS 3rd reprocessing data validation report, ACRI, 2012]
Data courtesy of PIs (D. McKee, K. Ruddick, D. Siegel, S. Kratzer) and AERONET-OC PIs (G. Zibordi, G. Schuster, S. Kratzer, B. Gibson), matchup using MERMAID

Uncertainty – Error – Correction

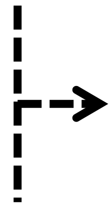
Uncertainty



Describes the spread

Drawn from a probability distribution described by uncertainty

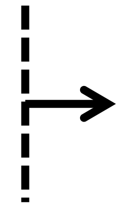
Error



Difference to the (unknowable) true value

Residual, uncorrectable, unknown error

Correction



Known offset from true value

[Slide from: NPL National Physical Laboratory

Traceability

"Property of a measurement result relating the result to a stated metrological reference (free definition and not necessarily SI) through an unbroken chain of calibrations of a measuring system or comparisons, each contributing to the stated measurement uncertainty"

Committee on Earth Observation Satellites (CEOS)

[Slide from: NPL National Physical Laboratory

Suggestion for Discussion

- NASA 2003 protocols have been very valuable in explaining and prescribing how measurements should be made

BUT

- The most important aspect is that each measurement should be accompanied by an uncertainty estimate … which has been validated

=> This should be added