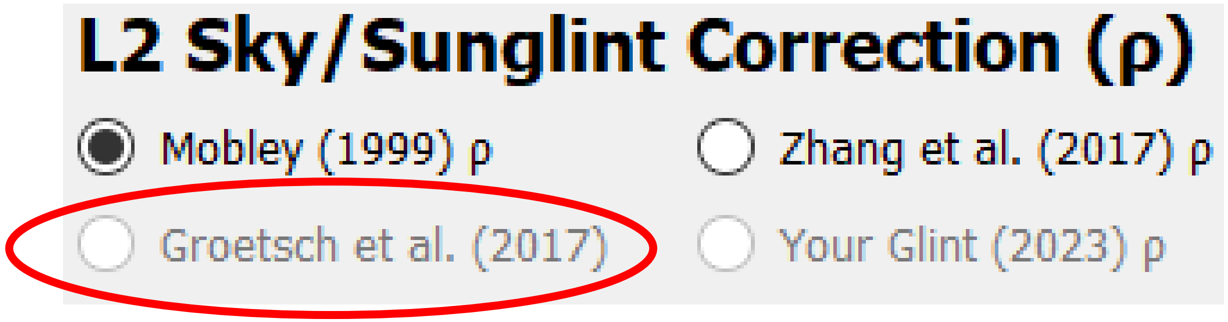
The 3C method for glint removal from above-surface radiometry

A summary and an update

HyperCP



Research Article
Vol. 25, No. 16 | 7 Aug 2017 | OPTICS EXPRESS A742
Optics EXPRESS

Validation of a spectral correction procedure for sun and sky reflections in above-water reflectance measurements

PHILIPP M. M. GROETSCH,[1,2,*] PETER GEGE,[3] STEFAN G. H. SIMIS,[4] MARIEKE A. ELEVELD,[2,5] AND STEEF W. M. PETERS[1]

Research Article
Vol. 28, No. 11 / 25 May 2020 / *Optics Express* 15885
Optics EXPRESS

Determination of the remote-sensing reflectance from above-water measurements with the "3C model": a further assessment

JAIME PITARCH,[1,*] MARCO TALONE,[2] GIUSEPPE ZIBORDI,[2] AND PHILIPP GROETSCH[3]

A MAJOR UPDATE

O25: validation

- O25 has been built on very solid physical principles and supported by empirical evidence
- But how does O25 perform with independent data, compared to previous methods?

Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Comparison of correction methods for bidirectional effects in ocean colour remote sensing

Davide D'Alimonte [a,*], Tamito Kajiyama [a], Jaime Pitarch [b], Vittorio Ernesto Brando [b], Marco Talone [c], Constant Mazeran [d], Michael Twardowski [e], Srinivas Kolluru [e], Alberto Tonizzo [f], Ewa Kwiatkowska [g], David Dessailly [g], Juan Ignacio Gossn [g]

Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Analytical modeling and correction of the ocean colour bidirectional reflectance across water types

Jaime Pitarch [a,*], Vittorio Ernesto Brando [a], Marco Talone [b], Constant Mazeran [c], Davide D'Alimonte [d], Tamito Kajiyama [d], Ewa Kwiatkowska [e], David Dessailly [e], Juan Ignacio Gossn [e]

Ms. Ref. No.: **RSE-D-25-00819R**
Title: Analytical modeling and correction of the ocean color bidirectional reflectance across water types
Remote Sensing of Environment

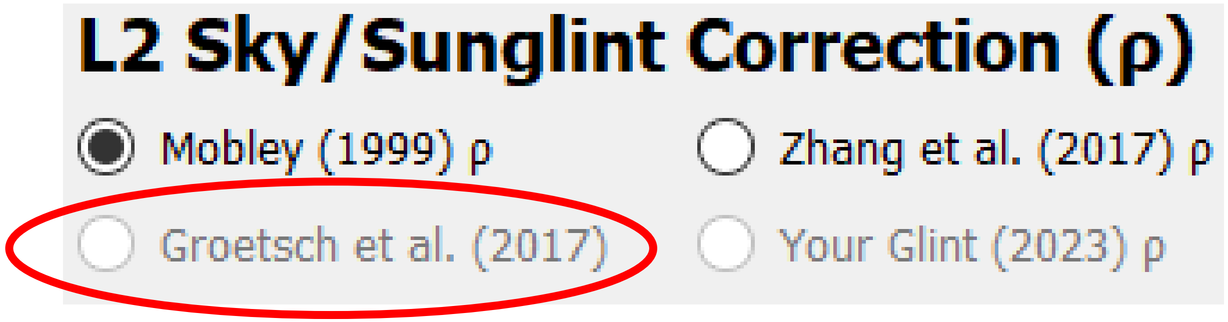
Dear Dr. Pitarch,

I am pleased to report to you that your paper, "Analytical modeling and correction of the ocean color bidirectional reflectance across water types," has been accepted for publication in Remote Sensing of Environment. Thank you for making the necessary revisions.

The 3C method for glint removal from above-surface radiometry

A summary and an update

HyperCP



Research Article Vol. 25, No. 16 | 7 Aug 2017 | OPTICS EXPRESS A742
Optics EXPRESS

Validation of a spectral correction procedure for sun and sky reflections in above-water reflectance measurements

PHILIPP M. M. GROETSCH,[1,2,*] PETER GEGE,[3] STEFAN G. H. SIMIS,[4] MARIEKE A. ELEVELD,[2,5] AND STEEF W. M. PETERS[1]

Research Article Vol. 28, No. 11 / 25 May 2020 / *Optics Express* 15885
Optics EXPRESS

Determination of the remote-sensing reflectance from above-water measurements with the “3C model”: a further assessment

JAIME PITARCH,[1,*] MARCO TALONE,[2] GIUSEPPE ZIBORDI,[2] AND PHILIPP GROETSCH[3]

DISCLAIMER

- Not suitable for satellite validation
- Potentially harmful
- Use at your own risk

You have been warned!

A remark on "$\boldsymbol{\rho}$"

- $L_w = L_t - \rho L_i$
- But what is ρ?
- ρ is the result of averaging Monte Carlo calculations over a large number of realizations for the PDF of the sea state given the wind speed
- Therefore → $L_w = \langle L_t \rangle - \rho \langle L_i \rangle$ (assuming ergodicity)
- Giuseppe underestimates $\langle L_t \rangle$
- But Mobley's ρ is also too low
- L_w ends up being ok

$$\overset{\text{OK}}{L_w} = \overset{\text{low}}{\langle L_t \rangle} - \overset{\text{low}}{\rho} \langle L_i \rangle$$

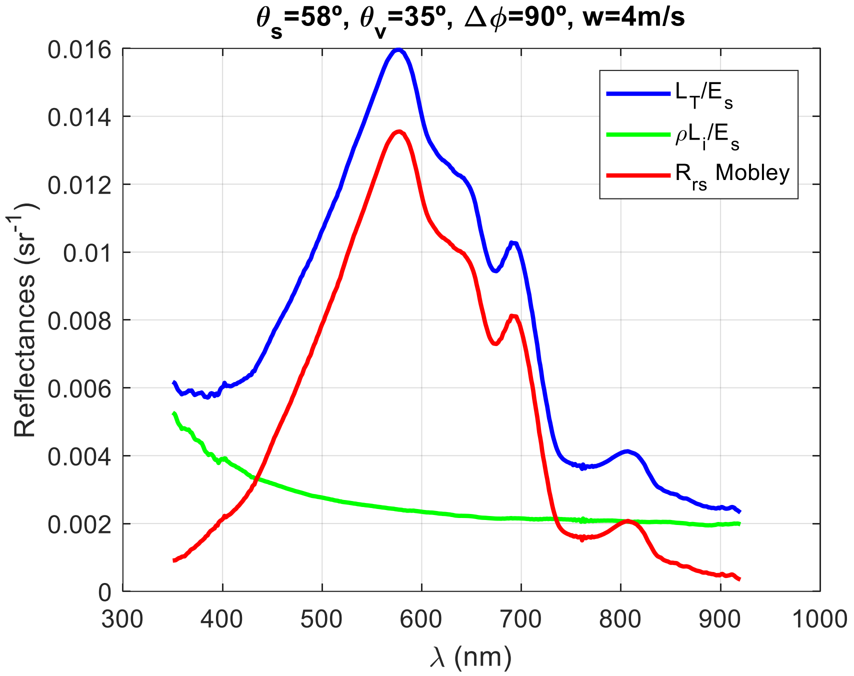
In the framework of the 3C model, and for visualization purposes, instead of:

- $R_{\mathrm{rs}} = \frac{L_{\mathrm{t}} - \rho L_{\mathrm{i}}}{E_{\mathrm{s}}}$

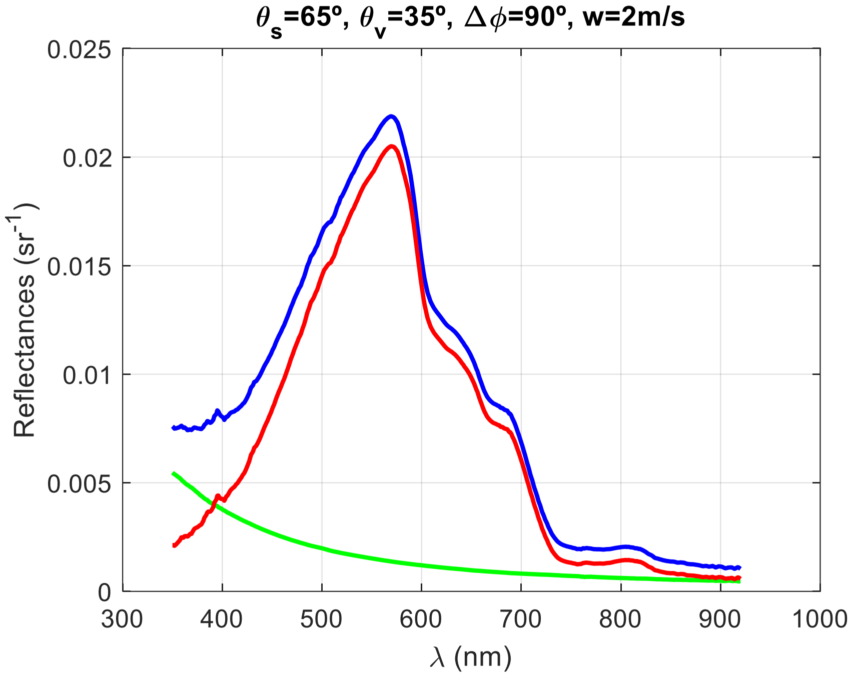
I prefer to have it like this:

- $R_{\mathrm{rs}} = \frac{L_{\mathrm{t}}}{E_{\mathrm{s}}} - \frac{\rho \mathrm{L}_{\mathrm{i}}}{E_{\mathrm{s}}}$

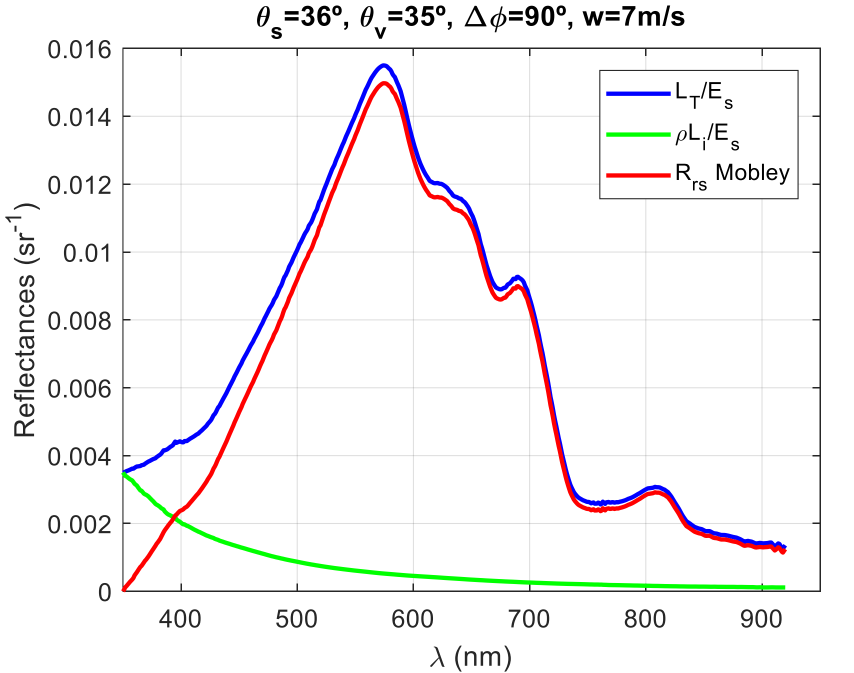
This way, you are always working with reflectances (they do not show al those nasty atmospheric traits)



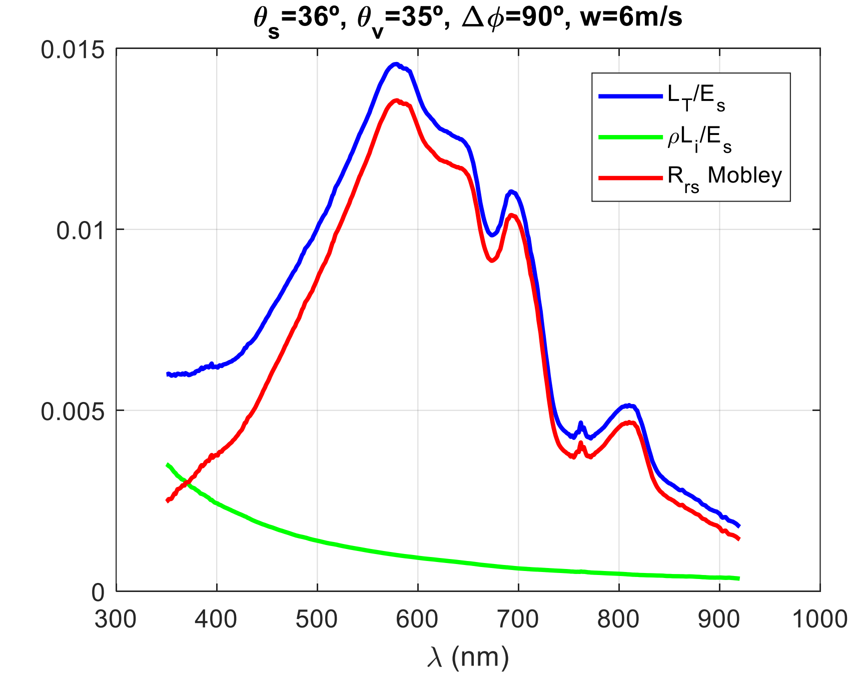
θ_s=58º, θ_v=35º, $\Delta\phi$=90º, w=4m/s
Reflectances (sr^{-1})
λ (nm)
L_T/E_s
$\rho L_i/E_s$
R_{rs} Mobley



θ_s=65º, θ_v=35º, $\Delta\phi$=90º, w=2m/s
Reflectances (sr^{-1})
λ (nm)

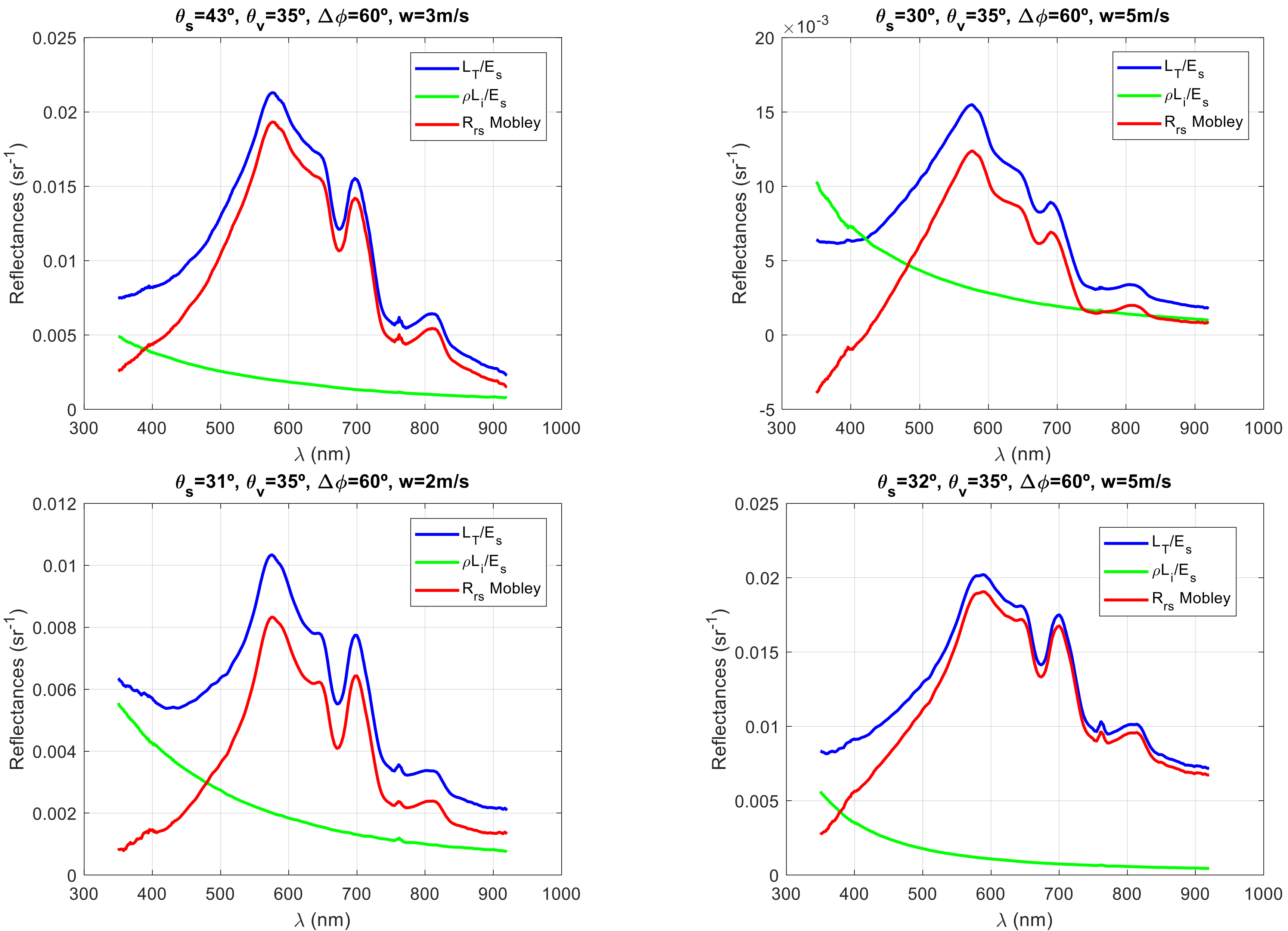


θ_s=36º, θ_v=35º, $\Delta\phi$=90º, w=7m/s
Reflectances (sr^{-1})
λ (nm)
L_T/E_s
$\rho L_i/E_s$
R_{rs} Mobley

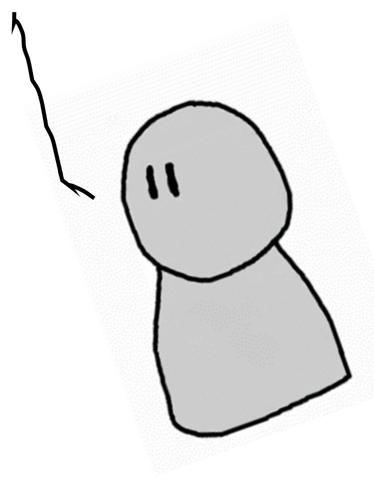


θ_s=36º, θ_v=35º, $\Delta\phi$=90º, w=6m/s
λ (nm)
L_T/E_s
$\rho L_i/E_s$
R_{rs} Mobley

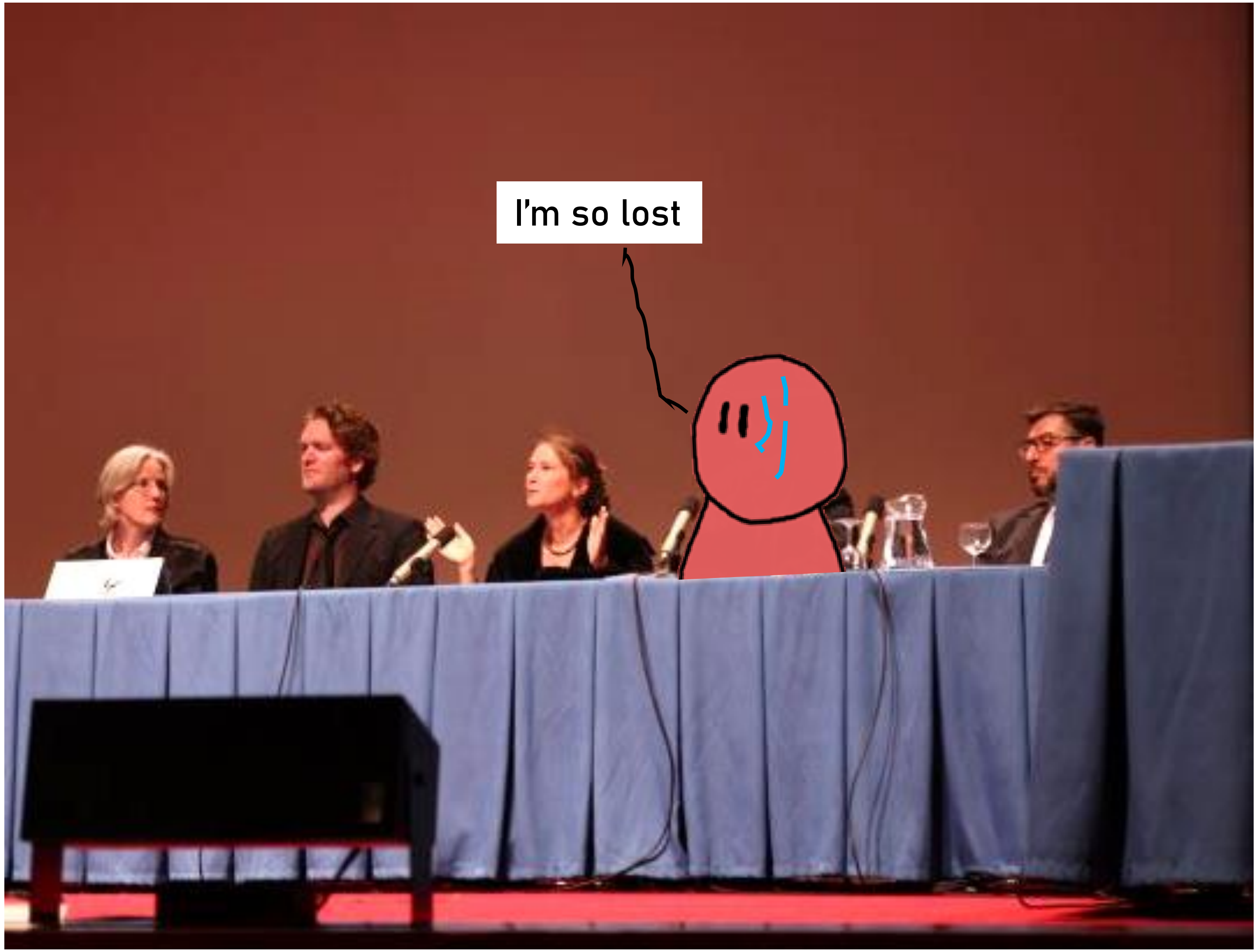
With lower azimuths, Mobley does even worse. Case study (ex. $\Delta\phi = 60°$)

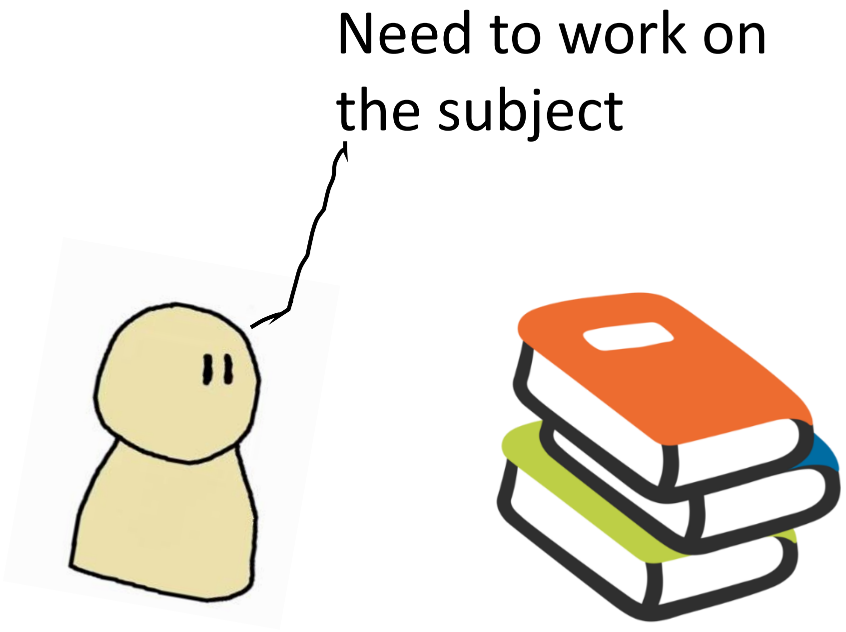


sad




Philipp Groetsch
VU VRIJE UNIVERSITEIT AMSTERDAM


I'm so lost


Need to work on the subject

- It looks like, sometimes, the glint is not well represented by Mobley
- Let's sum up the formulas

$$\mathrm{R}_{\mathrm{rs}} = \frac{L_{\mathrm{T}}}{E_{\mathrm{s}}} - \rho\frac{L_{\mathrm{i}}}{E_{\mathrm{s}}} \rightarrow \frac{L_{\mathrm{T}}}{E_{\mathrm{s}}} = R_{\mathrm{rs}} + \rho\frac{L_{\mathrm{i}}}{E_{\mathrm{s}}} \rightarrow \frac{L_{\mathrm{T}}}{E_{\mathrm{s}}} = R_{\mathrm{rs}} + R_{\mathrm{g}}$$

$$\frac{L_{\mathrm{T}}}{E_{\mathrm{s}}}(\theta_{\mathrm{s}}, \theta_{\mathrm{v}}, \Delta\phi) = R_{\mathrm{rs}}(\theta_{\mathrm{s}}, \theta_{\mathrm{v}}, \Delta\phi) + R_{\mathrm{g}}(\theta_{\mathrm{s}}, \theta_{\mathrm{v}}, \Delta\phi)$$

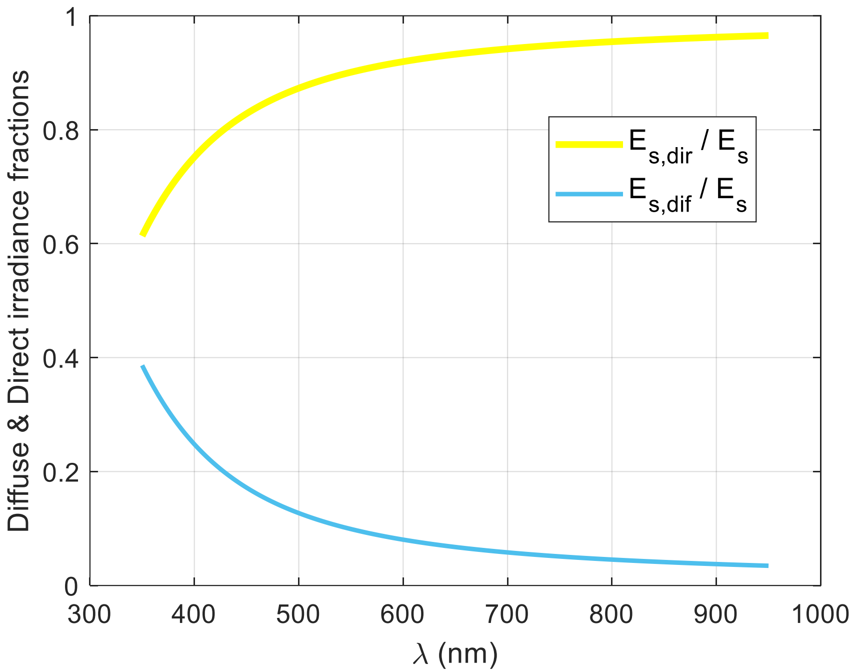
- This is what you measure
- It is the sum of two reflectances, each one with its distinct angular variation

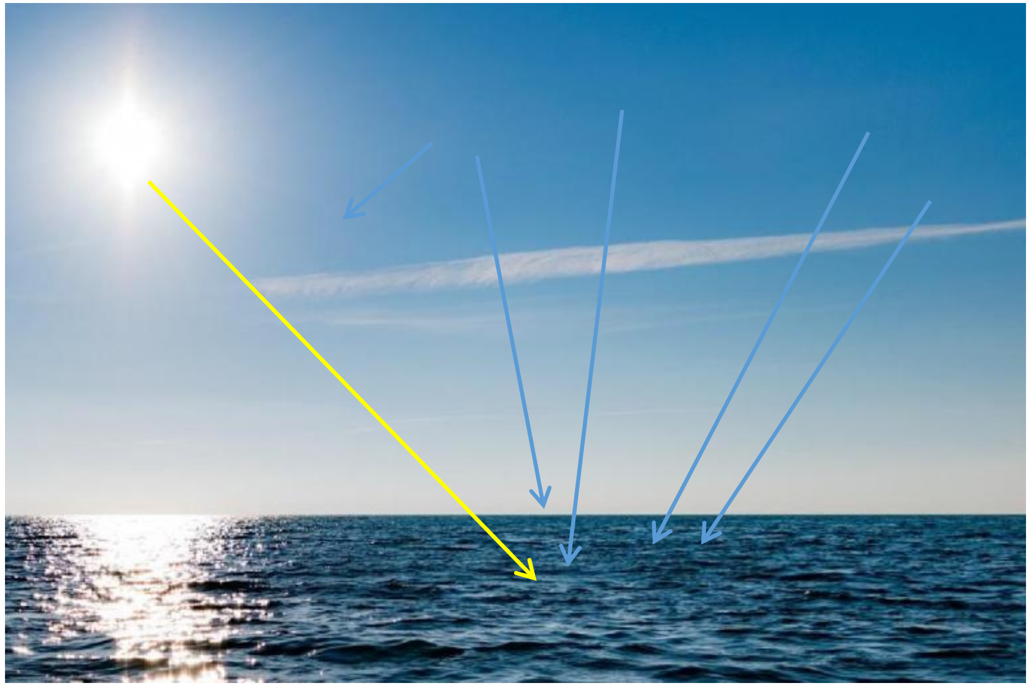
- Mobley says:

$$R_g = \rho \frac{L_i}{E_s}$$

- Assumptions:
  - Data from the L_i sensor represents the glint very well
  - Glint is only made of reflected skylight
  - Sun glint is inexistent or minimal

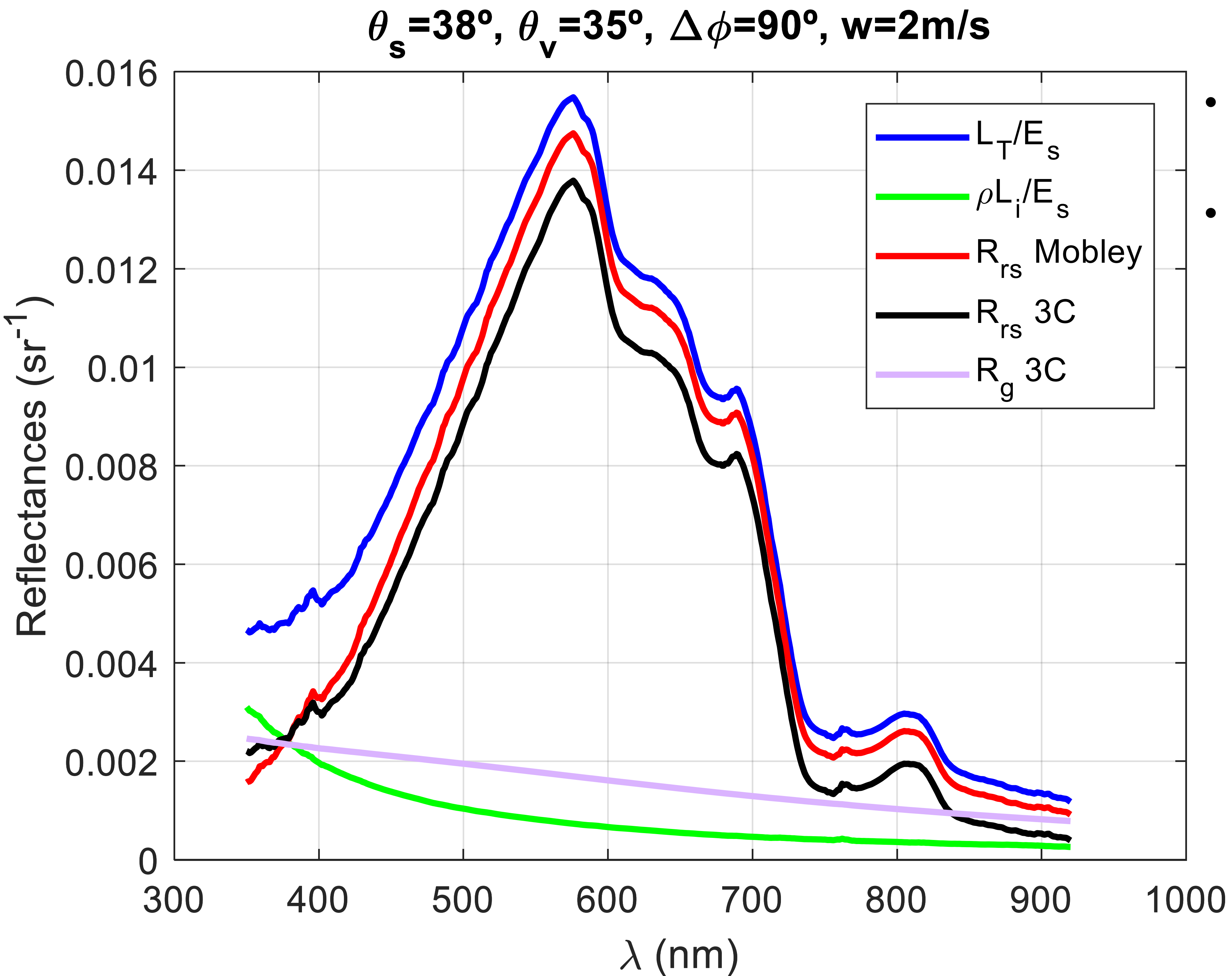
- How do the spectra of direct and diffuse irradiance incident onto the sea look like?



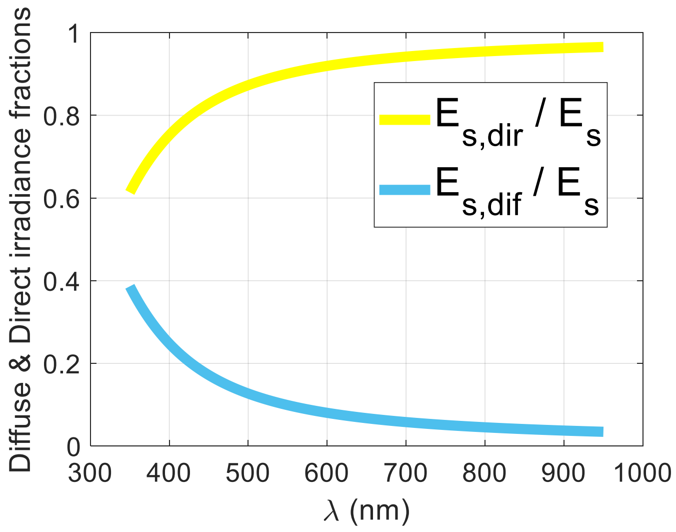


- These irradiance fractions (mostly) vary as a function of:
  - Aerosol
  - Sun zenith angle

- These downwelling irradiance fractions are reflected by the sea surface and go into your L_{T} sensor



- You are getting direct light in your L_{T} sensor
- This is evidenced by:
  - An offset in the NIR
  - A low value in the UV



- Let's reformulate the glint
- Instead of assuming that glint = diffuse light…
- Now we asume that glint = diffuse light + direct light

$$R_{\mathrm{g}} = \rho \frac{L_{\mathrm{i}}}{E_{\mathrm{s}}} + \Delta$$

Only diffuse ($\rho \frac{L_{\mathrm{i}}}{E_{\mathrm{s}}}$)

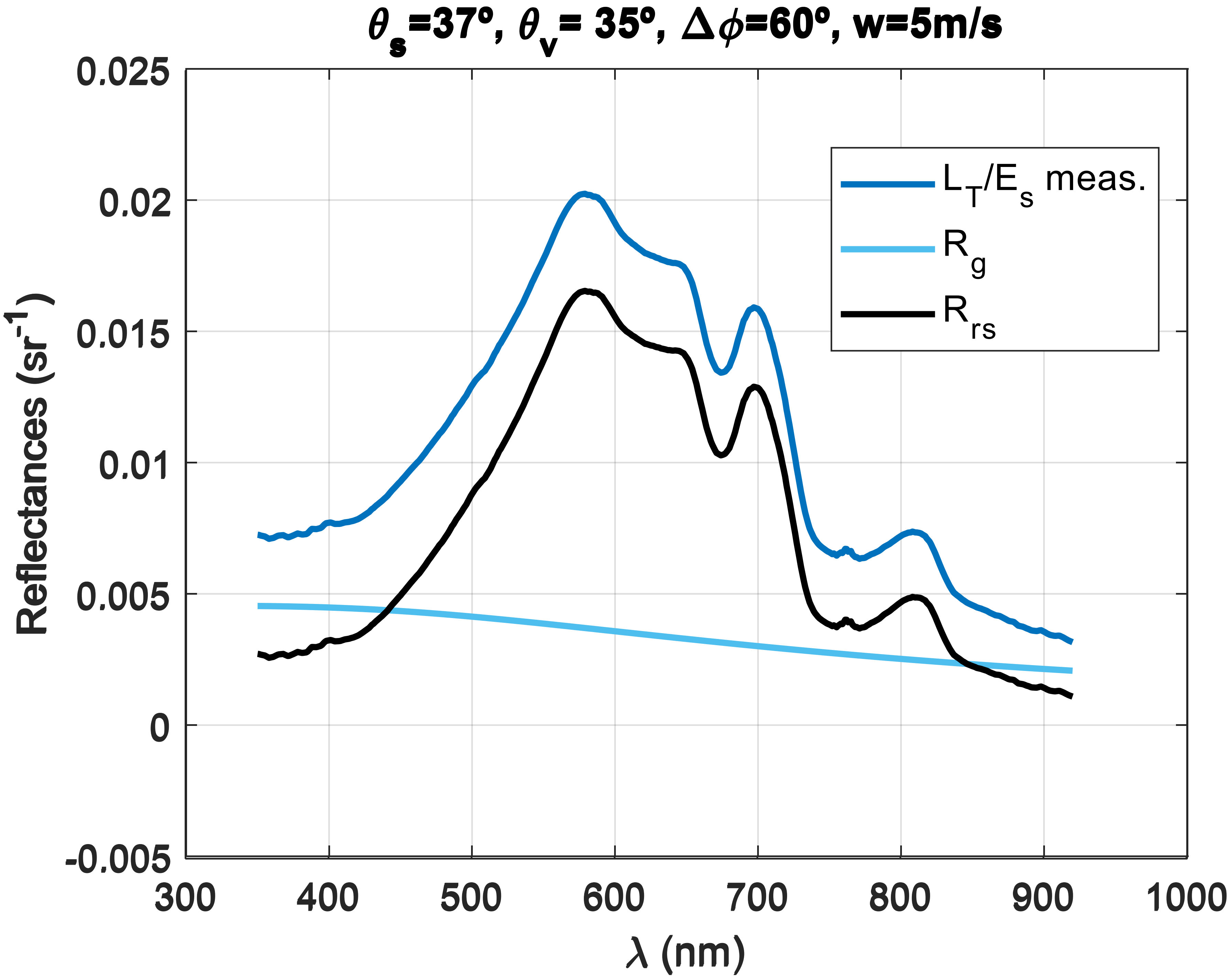
Direct + a fine correction for the diffuse (Δ)

- But how do you calculate Δ?

- You calculate Δ with minimization
- You fit your $\frac{L_T}{E_s}$ with a model
  - R_{rs} → aquatic reflectance model
  - R_g → atmospheric model

$$\frac{L_T}{E_s}(\theta_s, \theta_v, \Delta\phi) = R_{rs}(\theta_s, \theta_v, \Delta\phi) + R_g(\theta_s, \theta_v, \Delta\phi)$$

- Unlike Mobley, 3C calculates the glint by looking at it
- Similar strategy as in atmospheric correction



- You calculate Δ by minimization
- You fit your $\frac{L_T}{E_s}$ with a model
  - ➢ R_{rs} → aquatic reflectance model
  - ➢ Δ → atmospheric model

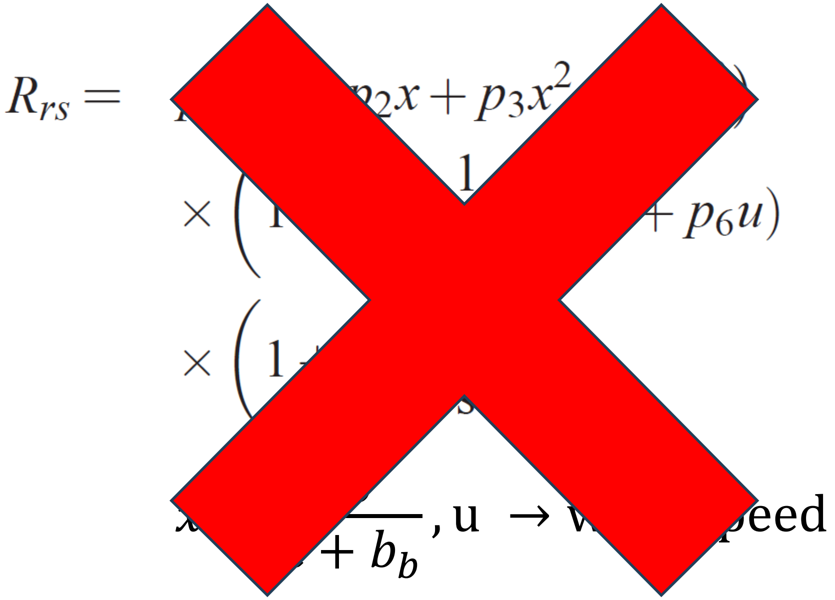
$$\frac{L_T}{E_s} = R_{rs} + R_g$$

$$R_g = \rho \frac{L_i}{E_s} + \Delta$$

Analytical model of R_{rs}

- Published 3C (Groetsch et al. ,2017) uses Albert and Mobley (2003)
- But you cannot model R_{rs} without taking into consideration the azimuth
  - ➢ I reprocessed all my data with Lee et al. (2011) (unpublished)
- Then, EUMETSAT funded the BRDF study
  - ➢ Plan to recode 3C incorporating O25

    (actually, I almost completed it here at San Servolo)



$$R_{\mathrm{rs}} = G_0^{w}\omega_{\mathrm{w}} + G_1^{w}\omega_{\mathrm{w}}^2 + G_0^{p}\omega_{\mathrm{p}} + G_1^{p}\omega_{\mathrm{p}}^2$$

$$\omega_{\mathrm{w}} = \frac{\mathrm{b_{bw}}}{\mathrm{a+b_b}} \quad \omega_{\mathrm{p}} = \frac{\mathrm{b_{bp}}}{\mathrm{a+b_b}}$$

- The “G” parameters depend on $(\theta_{\mathrm{s}}, \theta_{\mathrm{v}}, \Delta\phi)$ → known
- ω_{w} and ω_{p} are found by parameter search

Analytical model of Δ

- Remember: Δ is the part of the glint unaccounted by $\rho L_{\mathrm{i}}/E_{\mathrm{s}}$

$$\Delta = k_1 \frac{E_{\mathrm{s}}^{\mathrm{dir}}}{E_{\mathrm{s}}} + k_2 \frac{E_{\mathrm{s}}^{\mathrm{dif}}}{E_{\mathrm{s}}}$$

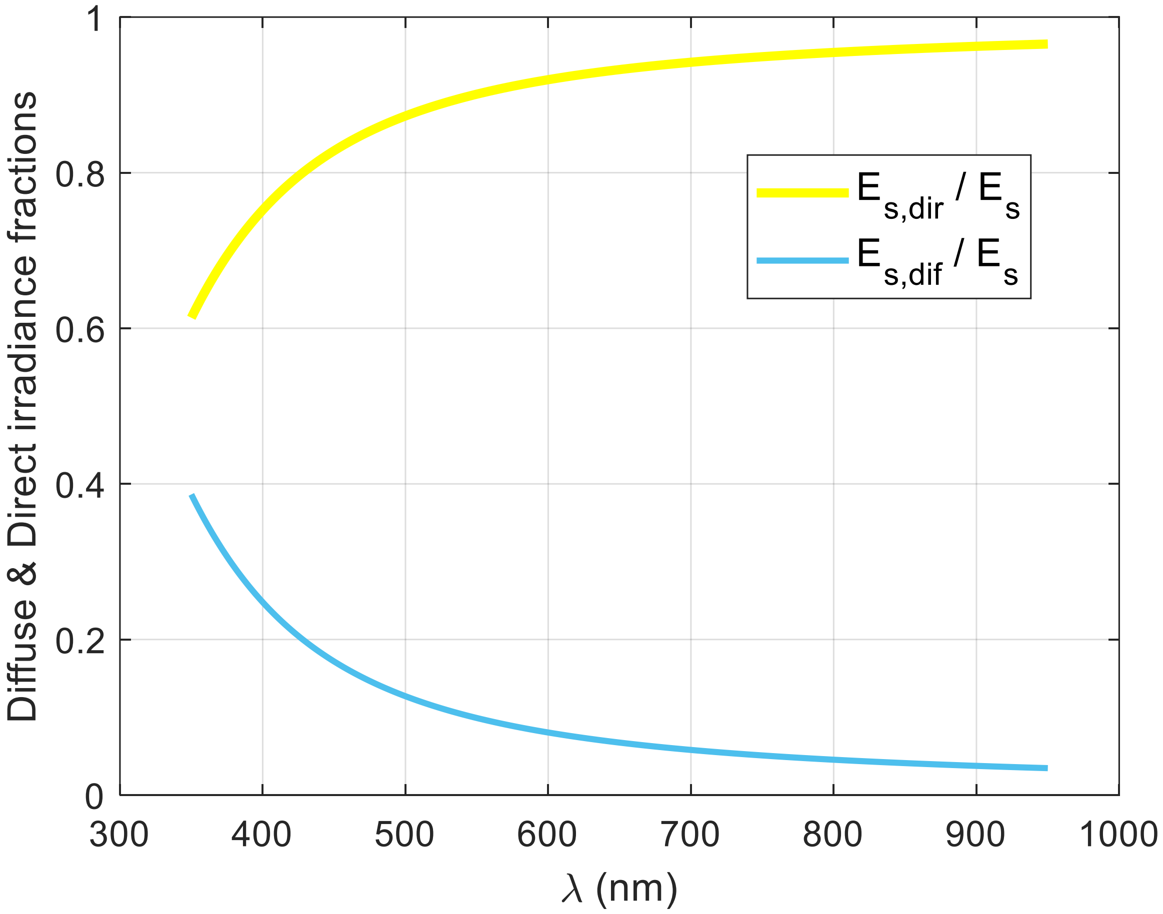
Direct — Diffuse

$\frac{E_{\mathrm{s}}^{\mathrm{dir}}}{E_{\mathrm{s}}}, \frac{E_{\mathrm{s}}^{\mathrm{dif}}}{E_{\mathrm{s}}}$ are **basis functions** for Δ

$\frac{E_{\mathrm{s}}^{\mathrm{dir}}}{E_{\mathrm{s}}}, \frac{E_{\mathrm{s}}^{\mathrm{dif}}}{E_{\mathrm{s}}} = f(\theta_{\mathrm{s}}, AOD)$, Gregg and Carder (1990)

θ_{s} → known

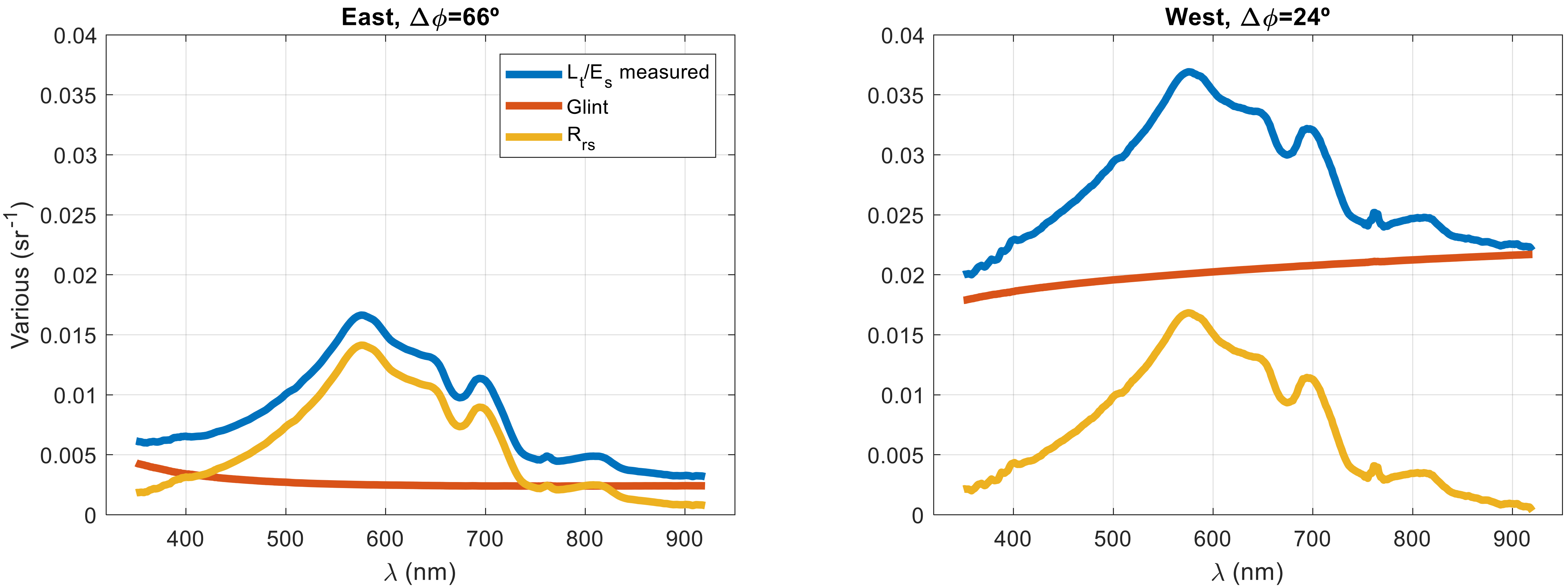
AOD → Found by parameter search



- $\frac{E_{\mathrm{s}}^{\mathrm{dir}}}{E_{\mathrm{s}}}, \frac{E_{\mathrm{s}}^{\mathrm{dif}}}{E_{\mathrm{s}}}$ may be measured directly if you have a moving band over your irradiance sensor
- Nevertheless, k_1 and k_2 must always be guessed by parameter search

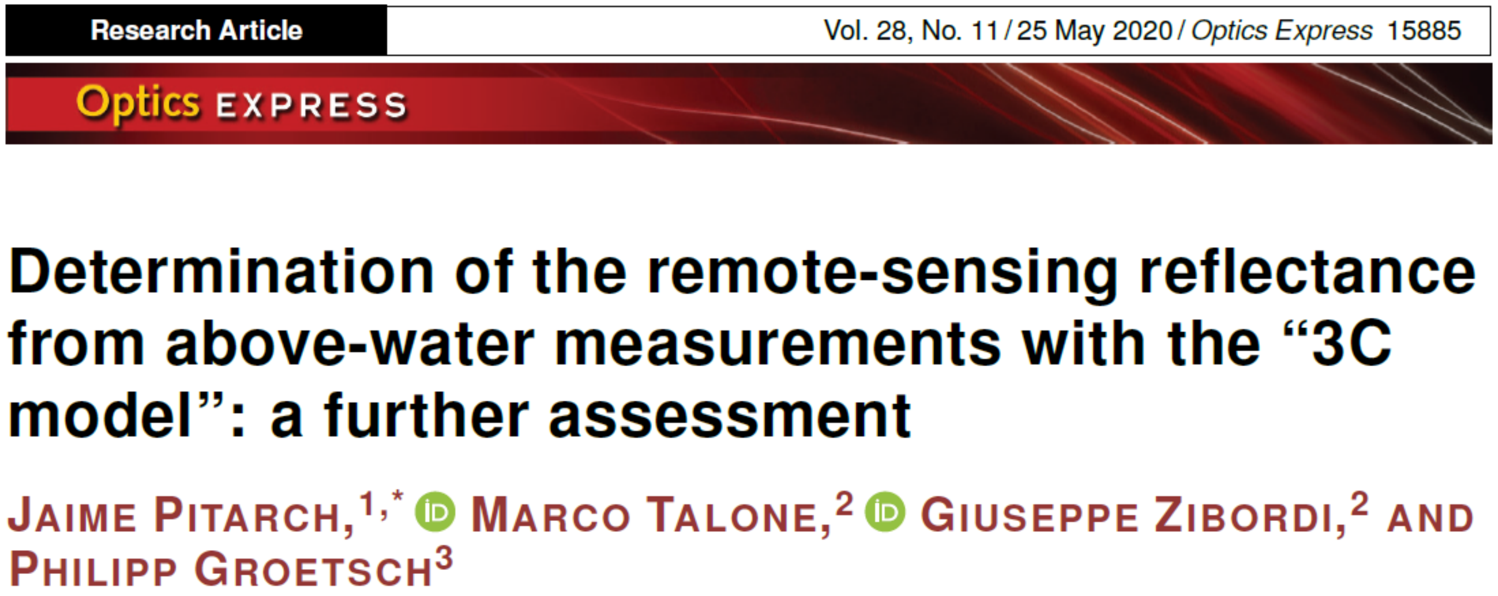
An example result for the NIOZ jetty

- simultaneous measurement, same water, different azimuths
- Low glint in the east sensors (high azimuth), dominated by diffuse radiation
- High glint in the west sensors (low azimuth), dominated by direct radiation
- After removing the glint, why are R_{rs} from both sides not yet equal?? → Because R_{rs} is directional!!!



Summary

- Mobley's ρ may sometimes fail to capture diffuse/direct nature of the glint, even for $\Delta\phi = 90°$ or higher
- The 3C model guesses the glint by "looking at it" (L_T sensor)
- Glint is expressed as diffuse and direct components
- For Giuseppe's "ideal conditions", 3C is most often overkill, although it simplifies to Mobley
- Likely to outperform the ρ method for $\Delta\phi < 90°$
- Operational 3C model is bugged
    - https://gitlab.com/pgroetsch/rrs_model_3C in Python
    - https://gitlab.com/jaipipor/rrs_model_3c_matlab in MATLAB
- A few model upgrades in mind (generous funding welcome)
    - Update of the in-water model with O25
    - Incorporate the possibility of having measured $\frac{E_\mathrm{s}^\mathrm{dir}}{E_\mathrm{s}}, \frac{E_\mathrm{s}^\mathrm{dif}}{E_\mathrm{s}}$
    - Replacement of Theano (discontinued) with numpy + various other code fixes



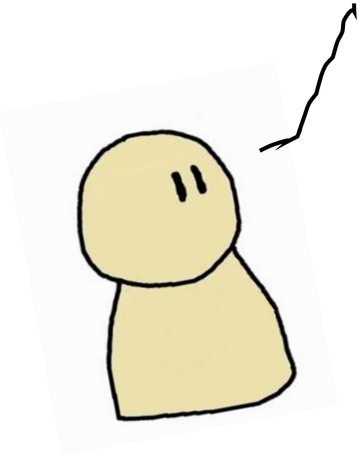
Research Article Vol. 28, No. 11 / 25 May 2020 / *Optics Express* 15885

Optics EXPRESS

Determination of the remote-sensing reflectance from above-water measurements with the "3C model": a further assessment

Jaime Pitarch,[1,*] Marco Talone,[2] Giuseppe Zibordi,[2] and Philipp Groetsch[3]

Read our paper



Our synthetic dataset → https://doi.org/10.5281/zenodo.11637178

I have a GitHub too! → https://github.com/jaipipor/

- O25
- Some BGC-Argo stuff
- 3C in Python coming soon

Thank you!