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Field measurements of the spectral particulate light backscattering coefficient in turbid coastal waters: validity of measurement corrections recommended for widely-used sensors

ABSTRACT. The **particulate backscattering coefficient** (b_{bp}, in m^{-1}), a key parameter in **marine optics** and **ocean colour remote sensing**, is correlated to the **concentration of suspended solids**[a] and its spectral variations are representative of the **particle size distribution**[b], at least in sediment-dominated waters. However field measurements of b_{bp} in such waters is problematic mainly due to the (i) **saturation** of most sensors designed for the open ocean and (ii) difficult corrections of light absorption and scattering along the sensor pathlength.

The **Simulo Monte Carlo code**[c] was used to reproduce measurements carried out in virtual turbid coastal waters using widely-used scattering sensors (**Wetlabs ECO-BB and Hobilabs Hydroscat**) and assess the validity of measurements corrections recommended by the manufacturers. Our results confirm that measurements made with the small ECO-BB sensors should only be corrected for absorption losses along photon pathength but suggest a **slight revision** of the User's Guide provided by Wetlabs. Data recorded using the larger Hydroscat (HS-4 and HS-6) sensors should be corrected for both absorption and scattering losses, as stated by Hobilabs, but the **recommended sigma correction is proved to fail in (highly) scattering waters**. An **improved sigma correction** is proposed, tested and **validated** based on field measurements (optical closure).

Few valid field measurement of b_{bp} in turbid coastal/estuarine waters with sensors designed for oceanic waters:

Saturatation of **Wetlabs ECO-BB**[1] sensors (fixed gain) // Invalid correction for light attenuation (**Hobilabs HS**)

[1]

[1] measures light backscattered at 117°

Fixed gain / sensitivity for open ocean

Correction for absorption:

$$\beta = \beta_u \times \exp(0{,}0391 \times a) \quad \text{(Eq. 1)}$$

Correct…??

[2] measures light backscattered at 140°

Adaptative gain: clear to turbid waters

Correction for absorption and scattering[d]:

$$\beta = \beta_u \times \exp[k_{exp} \times (a + 0{,}4 \times b)] \quad \text{(Eq. 2)}$$

= K_{scat} = 0,4 coming from??

[2]

Modelling

Fig. 1

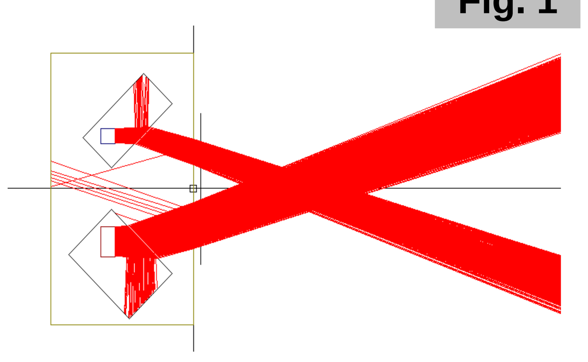
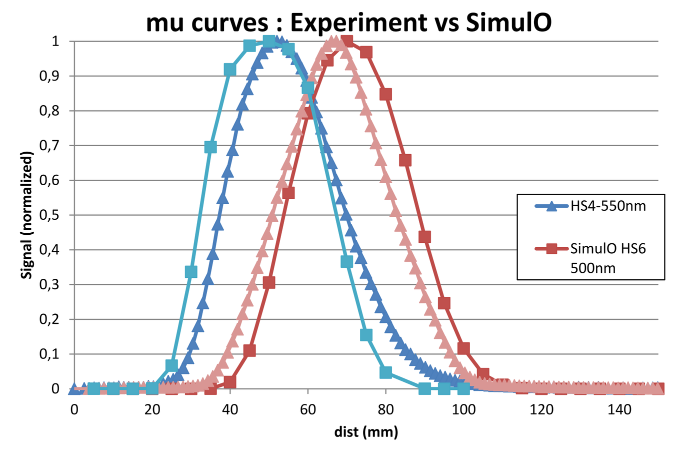


Fig. 2

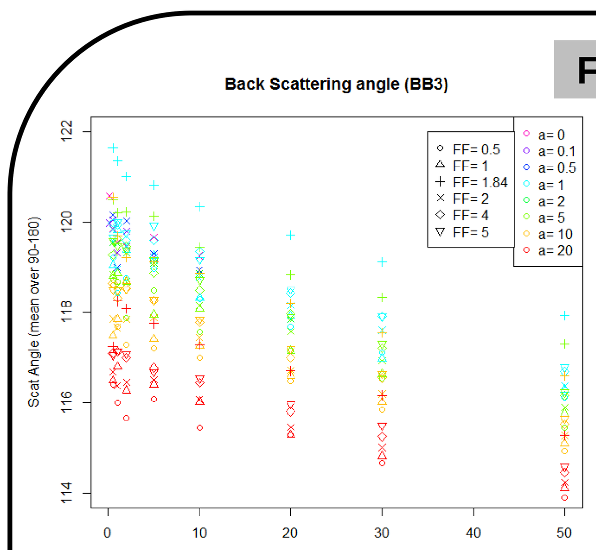


The **SimulO** Monte Carlo code[c] was used to reproduce the design of the **ECO-BB** and **Hydroscat** sensors (Fig. 1-2) then compare the true, measured and corrected β signals for a wide range of IOPs:

the **total absorption** and **scattering coefficients** were varied from 0 to 20 m^{-1} and 0 to 50 m^{-1}, respectively, to represent **various types of natural waters** and cover the **visible**, near-infrared (**NIR**) and shortwave infrared (**SWIR**) spectral domains. **Petzold** and **Fournier-Forand** particulate Volume Scattering Functions were used with b_{bp}/b_p ratios varying from 0.5 to 5%.

Results (ECO-BB)

Fig. 3



The ECO-BB actually measures scattering at 120 (and not 117). The actual theoretical distance is 16.35 mm, i.e.: $\beta = \beta_u \times \exp(0{,}01635 \times a)$ (Eq. 1').

Increasing light scattering significantly decreases the measured backscattering angle (Fig. 3-4) but recommended absorption corrections (Eq. 1') always provide accurate estimations of β despite multi-scattering events (Fig. 5).

Fig. 4

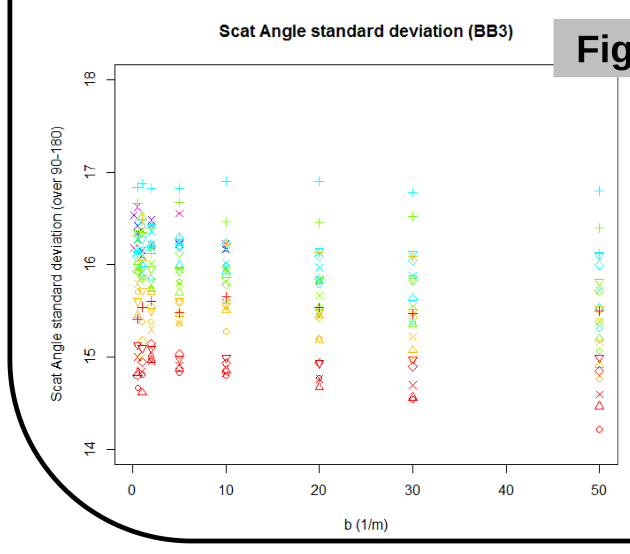
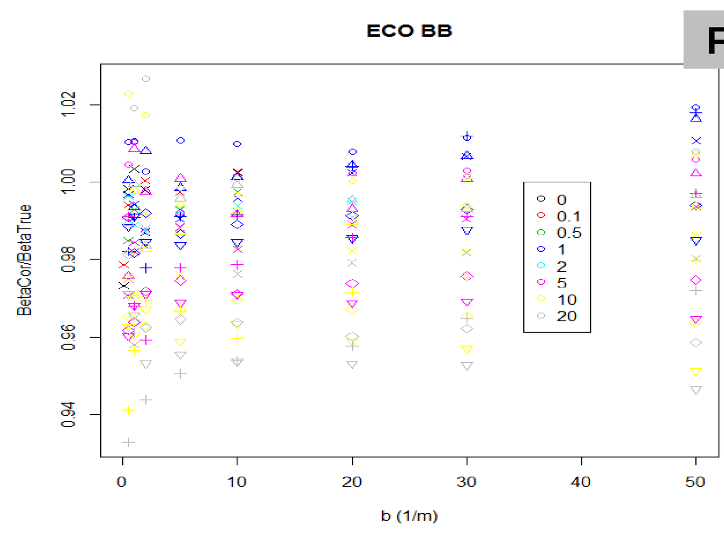
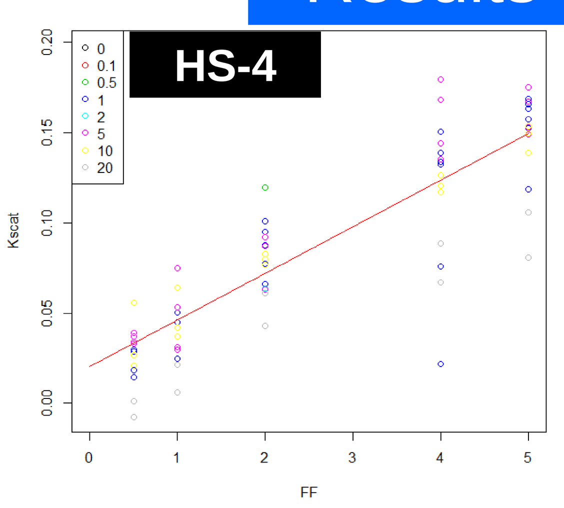
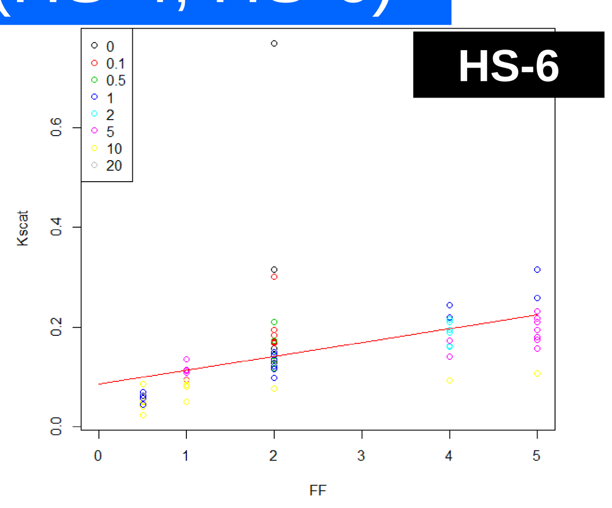


Fig. 5



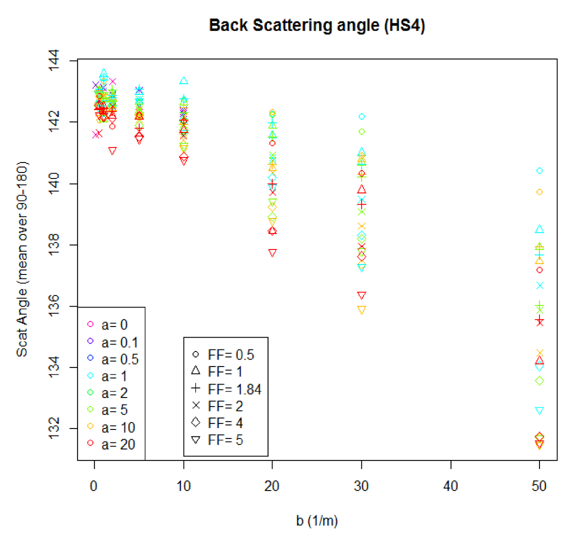
Results (HS-4, HS-6)

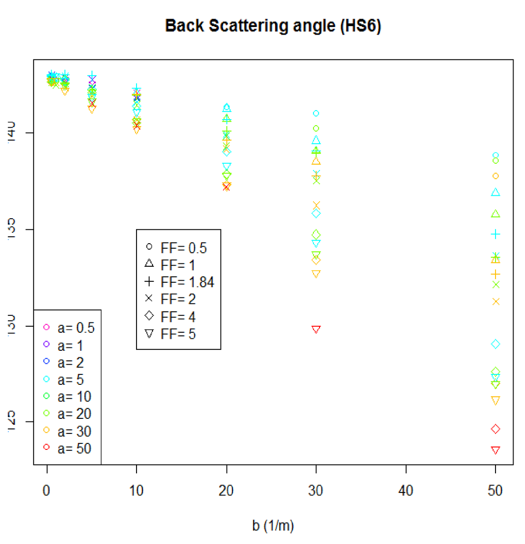


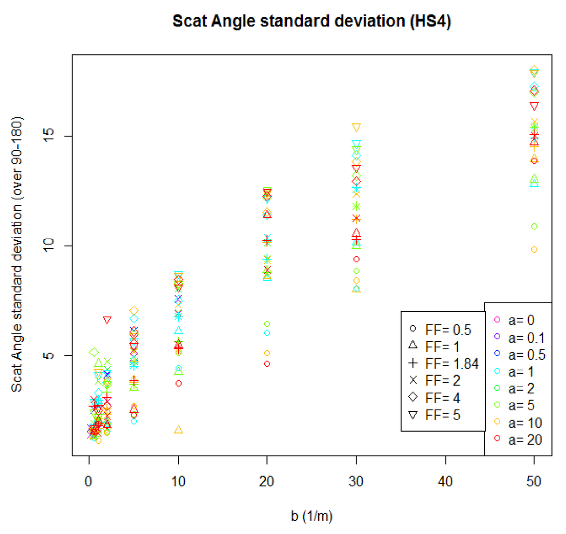


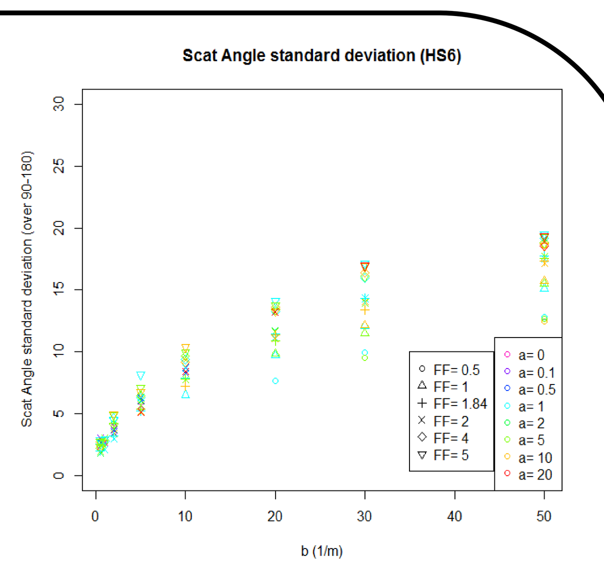
K_{scat} = 0.02035 + 0.02580 × FF (Eq. 3)

K_{scat} = 0.08648 + 0.02774 × FF (Eq. 4)



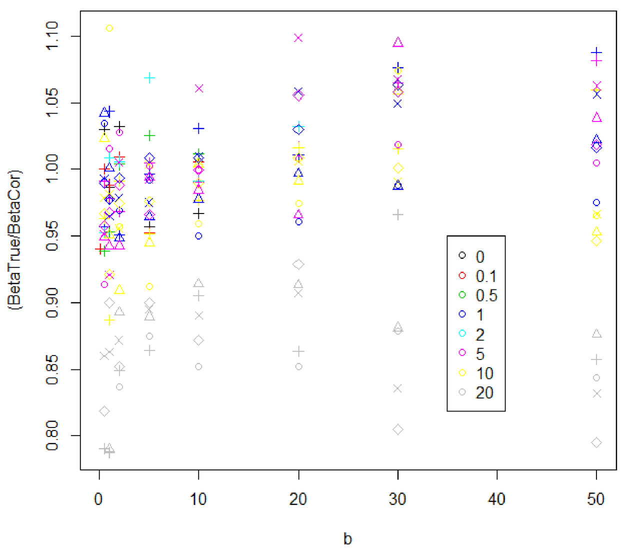


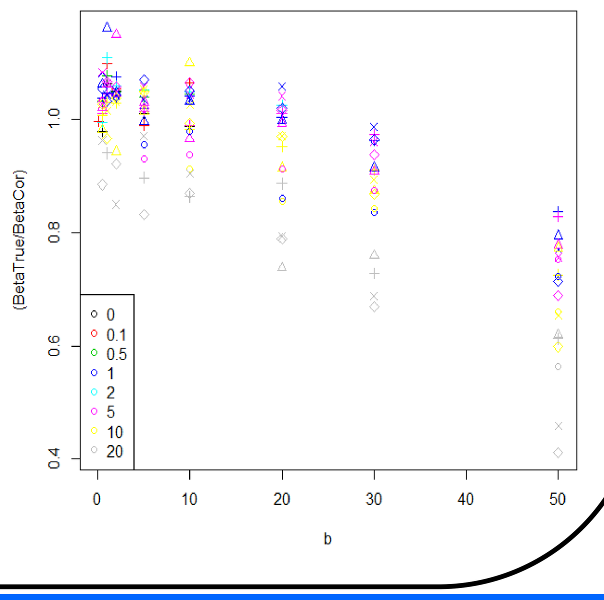




The K_{scat} **coefficient (Eq. 2) is much lower than 0,4 and is not a constant**. It mainly depends on the **particulate VSF** and on the **dimensions** of the light source to detector distance. An **improved formulation of the sigma correction** is proposed with a more **accurate parametrization of K_{scat}** for the HS-4 (Eq. 3) and for the HS-6 (Eq. 4). Increasing light scattering results in significantly lower measured backscattering angle over a broader range.

The standard sigma correction is valid in mainly absorbing waters (e.g. open ocean waters, at least out of phytoplankton bloom conditions) but **definitely fails in scattering (e.g., sediment-dominated) waters** where it results in **overestimation** (by more than 100%!) of the true β signal. Our improved correction provides reasonably **good estimates of β with typical errors of only few percents**, except for the HS-6 sensor which dimensions are unadapted to highly scattering waters.





Conclusions / References / Acknowledgements

Due to its minimized dimensions, the ECO-BB sensor is well designed to measure light backscattering with only absorption corrections needed (Eq. 1') to obtain accurate estimations of β_p, but its use in turbid coastal waters is actually limited because of its fixed and too high sensitivity.

The HS-4 sensor is better designed for measurements in scattering waters due to its adaptative gain (e.g., no saturation) but an improved version of the sigma correction must be used (Eq. 3) (careful: the standard sigma correction drives to a dramatic overestimation of β_p. Next step is to develop a correction method taking into account the variations of k_{exp} in Eq. 2.

Many thanks to Hobilabs (D. Dana) and Wetlabs (M. Twardowski) for their great help and support. Visit: www.hobilabs.com & www.wetlabs.com

References: a: Neukermans et al. (2012), b: Morel (1974), c: Leymarie et al. (2010), d: Dana & Maffione (2002)