# Understanding Natural Variability of VSFs and Its Impact on Biogeochemical Retrieval from Ocean Color

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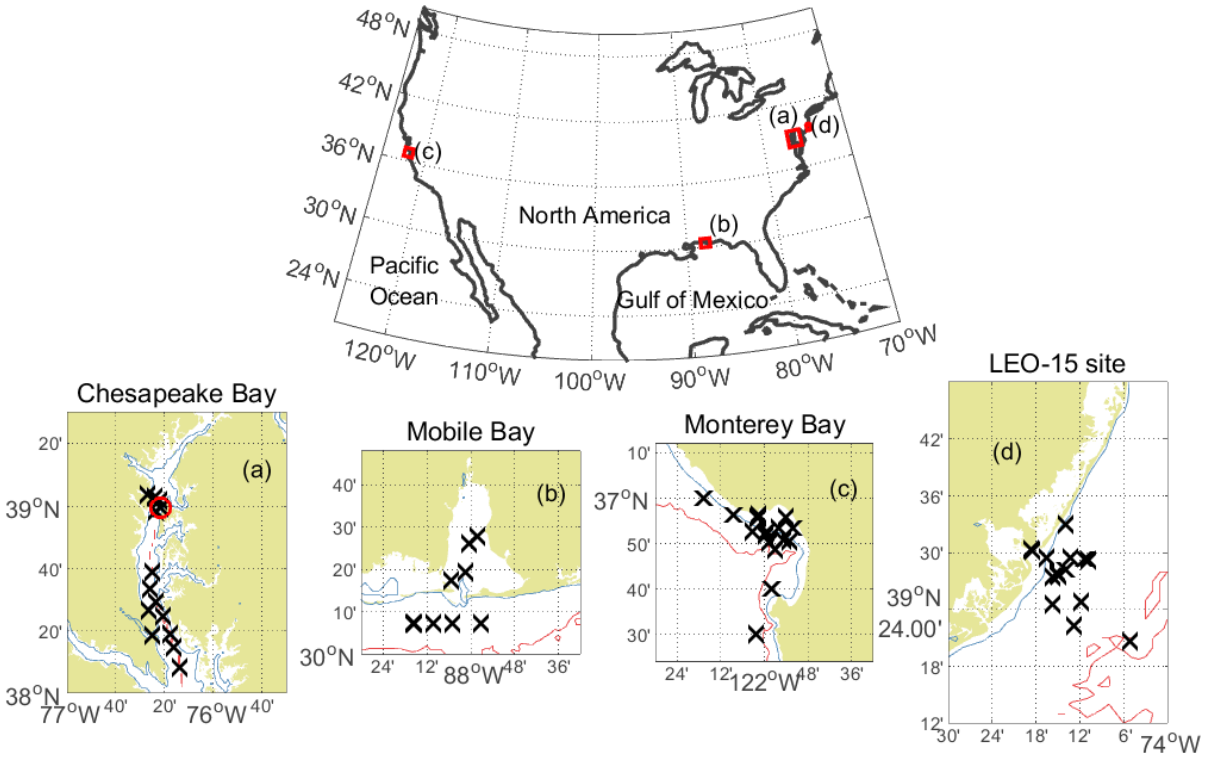
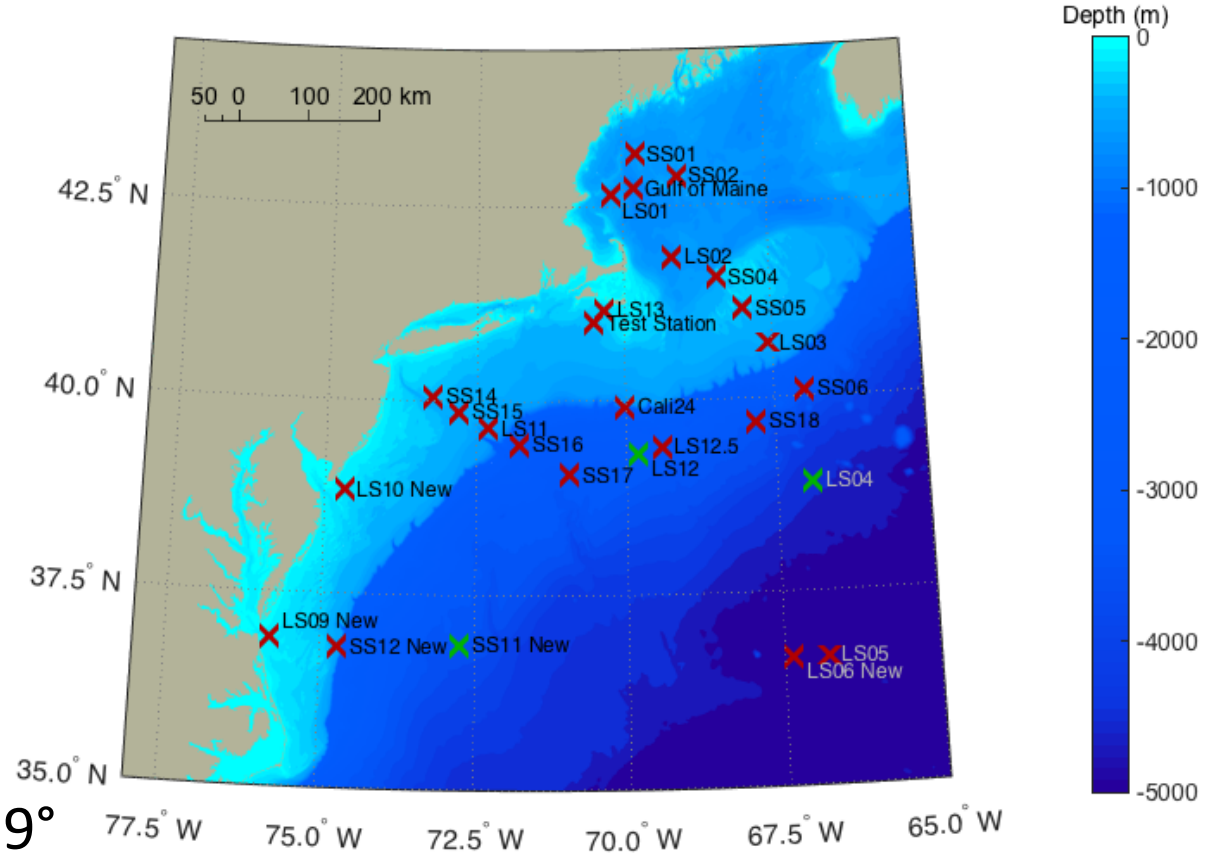
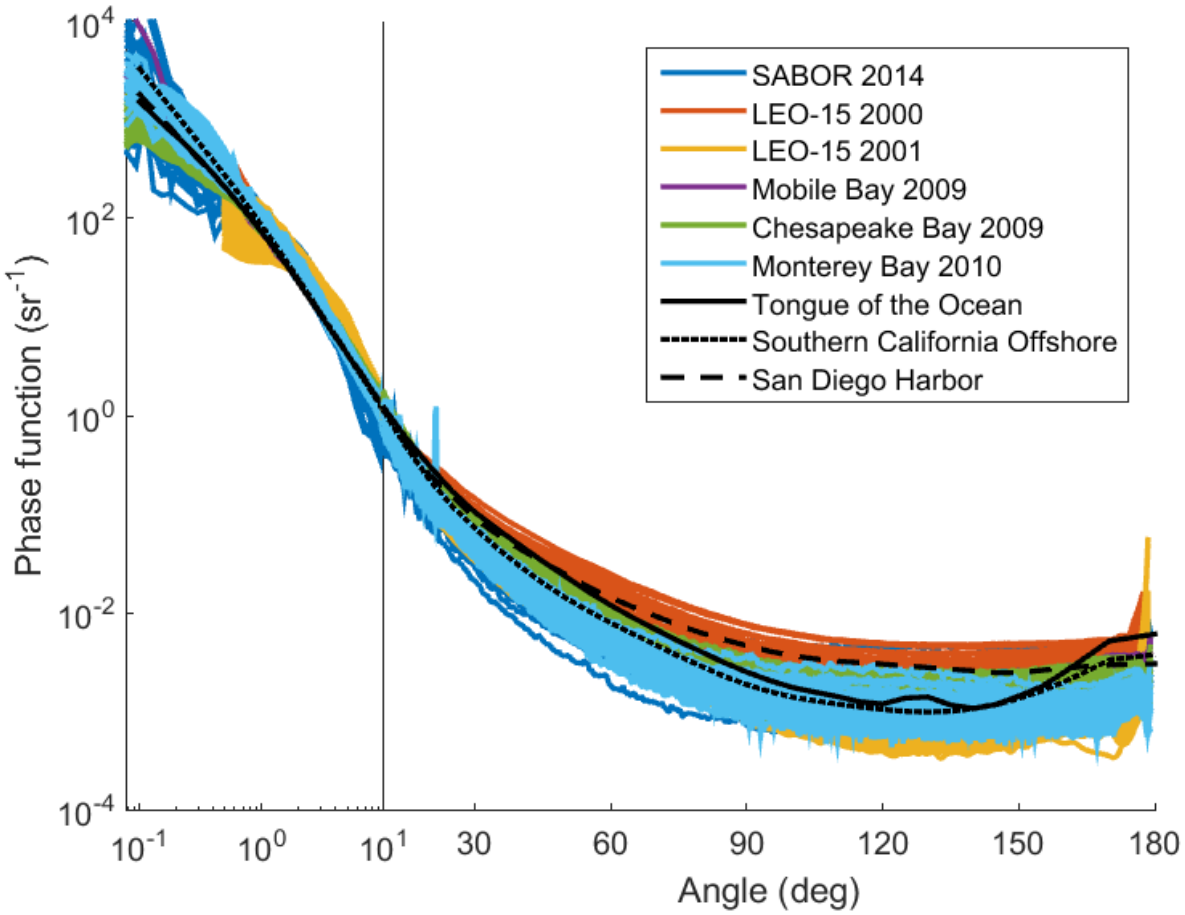
# 1. Spatial and temporal variability of VSFs

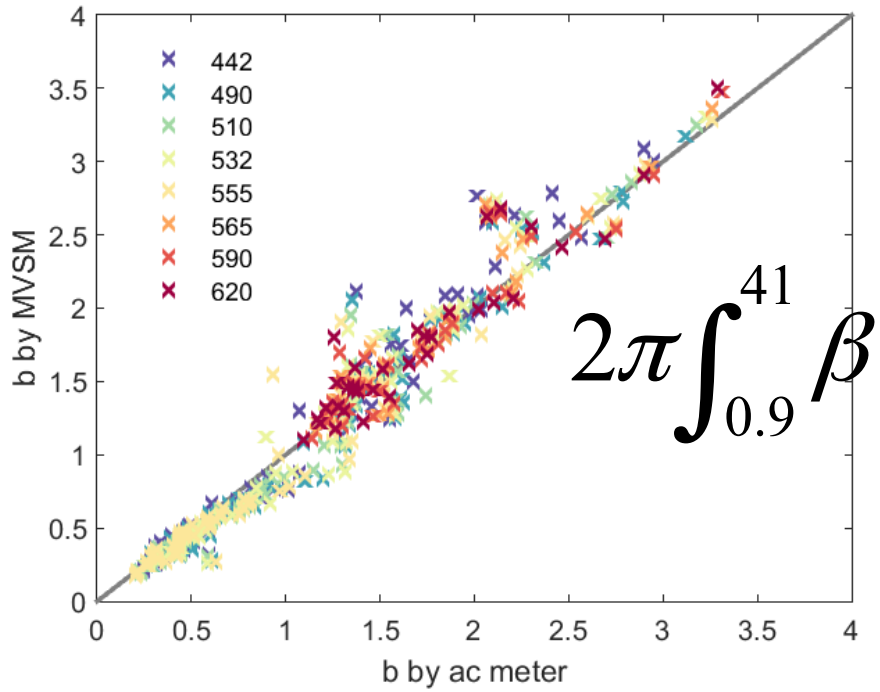



LISST, 532 nm, 32 angles 0.07 – 13.9°
VSM, 532 nm, 0.6:0.3:177.3°
MVSM, 8 wavelengths, ~~0.5~~(10):0.25:179°
ECO-VSF, 3 wavelengths, 100, 125, 150°
HydroScat, 6 wavelengths, 140°
Ac-9 or ac-s

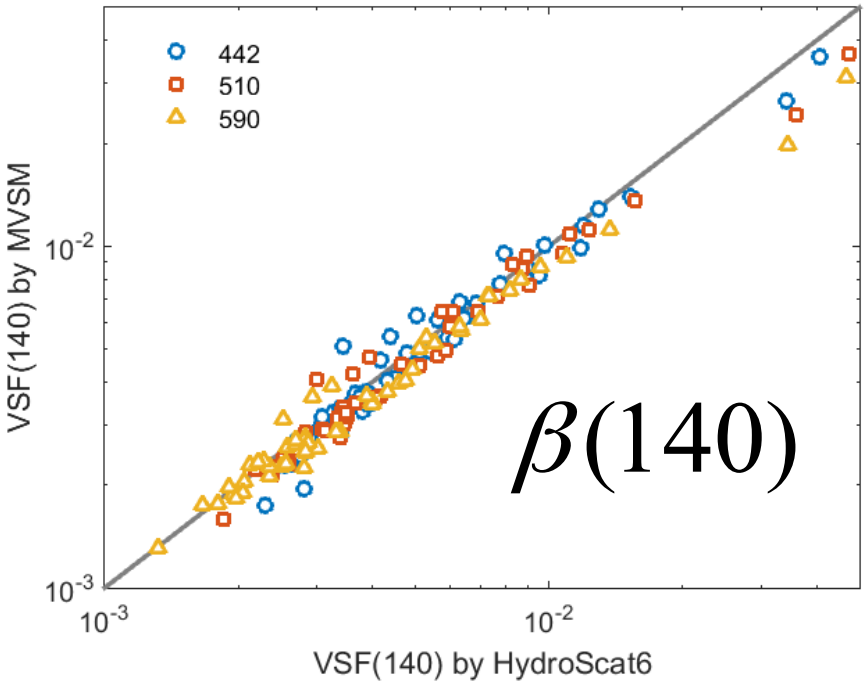
LISST+MVSM: 532 nm, complete VSFs 0.07 – 179°
MVSM, ECO, HS6: Spectral $b_b$
ac meters: Spectral c and a




$$2\pi\int_{0.9}^{41}\beta(\theta)\sin\theta d\theta$$

IOP agreement between different instruments:



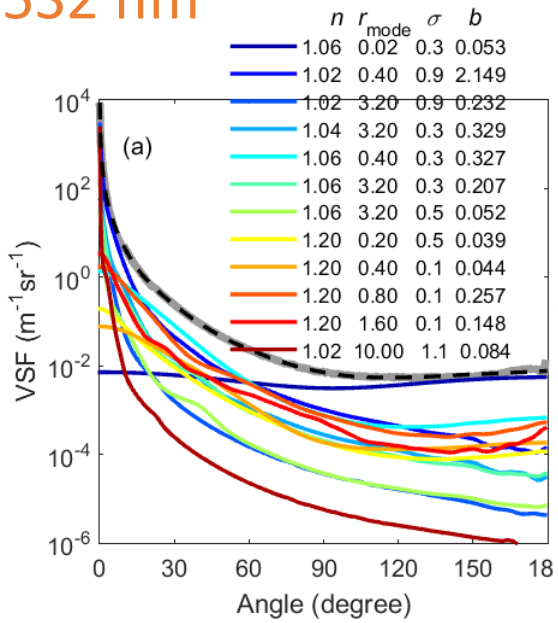

$$\beta(140)$$

R > 0.96

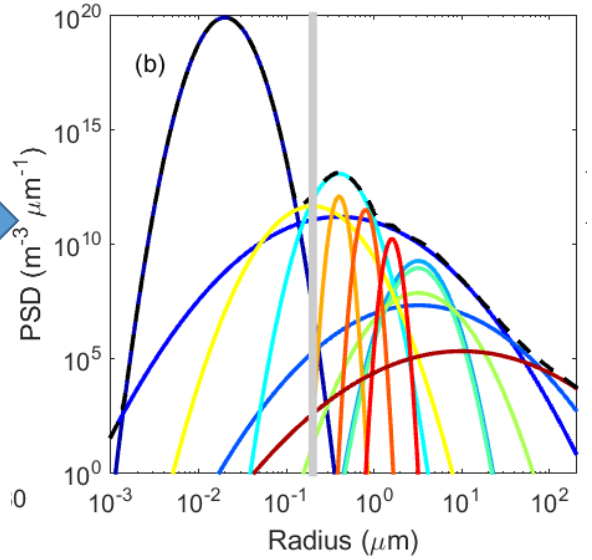
RMSD < 10%

# 2. Biogeochemical sources of $b_b$: A combination of inverse- and forward-modeling approach by analyzing measured VSFs

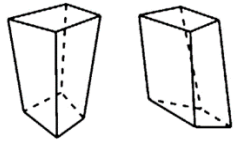
## VSF-Inverse modeling at 532 nm

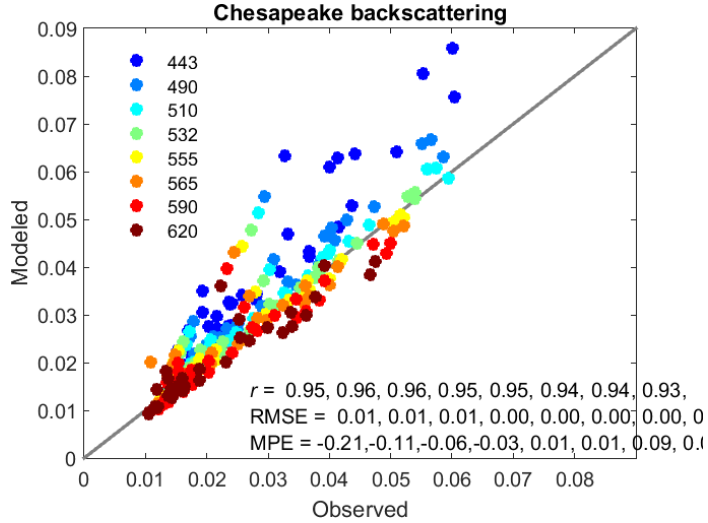


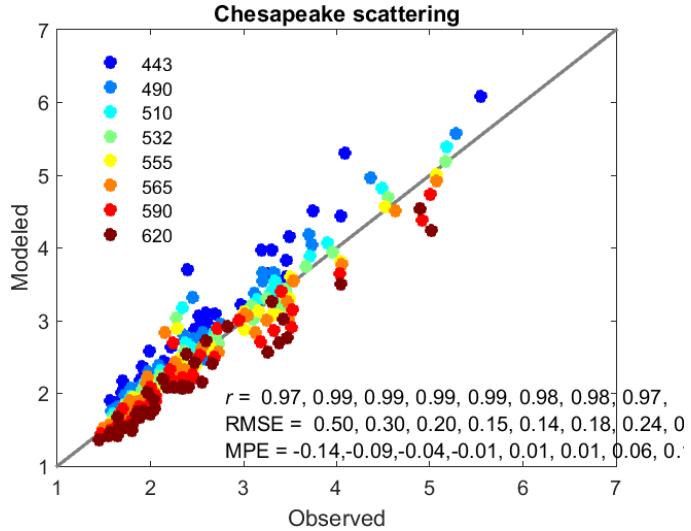

## Particle size distributions




Forward modeling at other wavelength





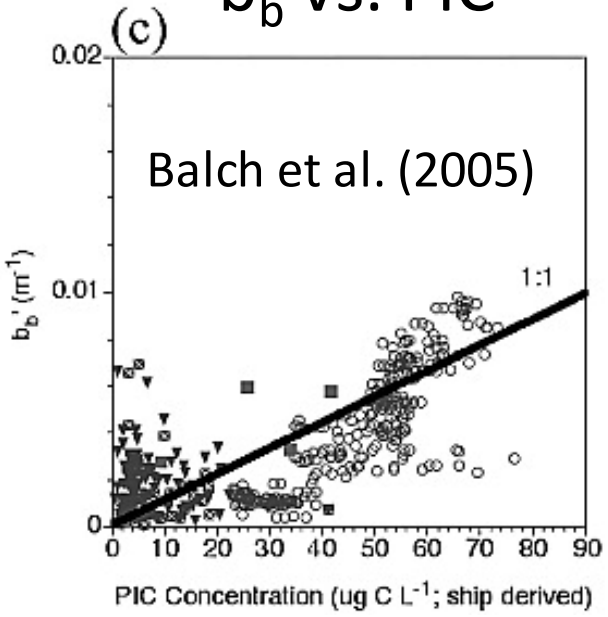

Assumptions

Oceanic particles comprise of sub-populations, each follows log-normal distribution and of the same composition (refract. Index) Zhang et al. (2011)

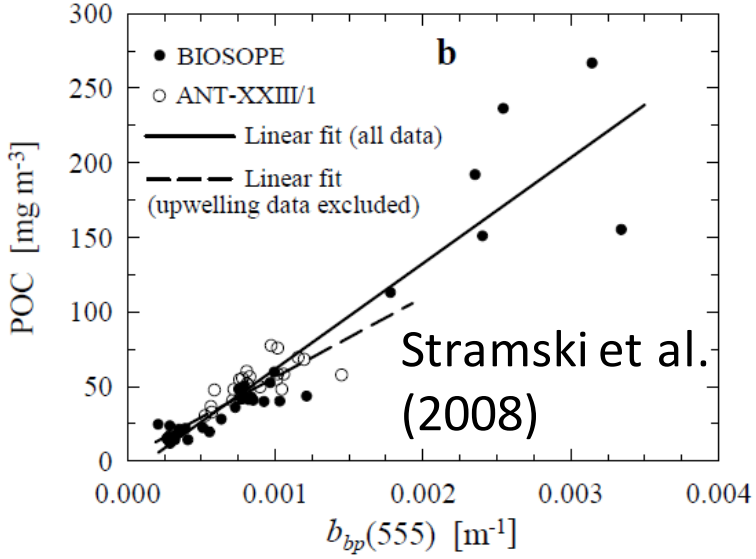
Sub-populations represent different biogeochemical stocks. Zhang et al. (2012; 2013; 2014), Czerski et al. (2011), Twardowski et al. (2012).

# $b_b$ has been empirically related to many things

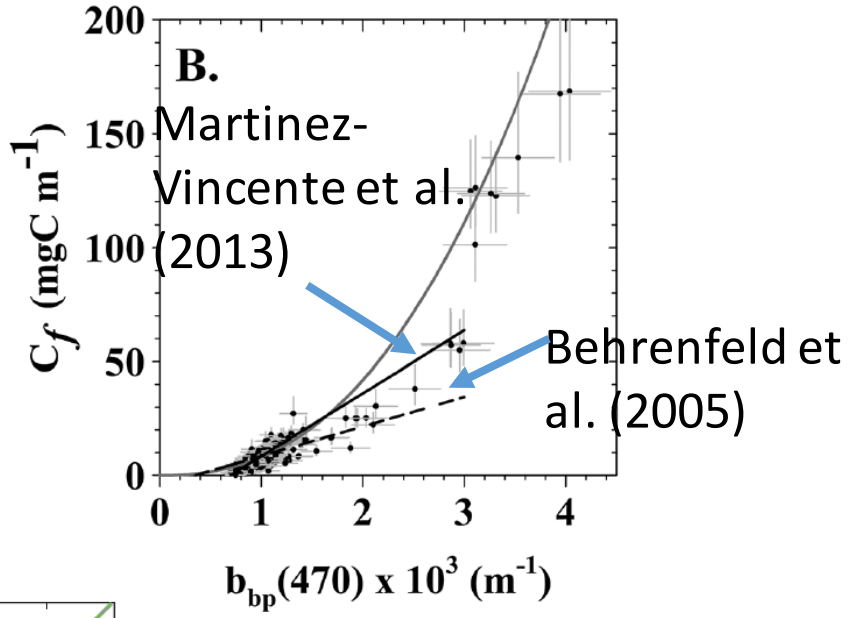
## $b_b$ vs. PIC



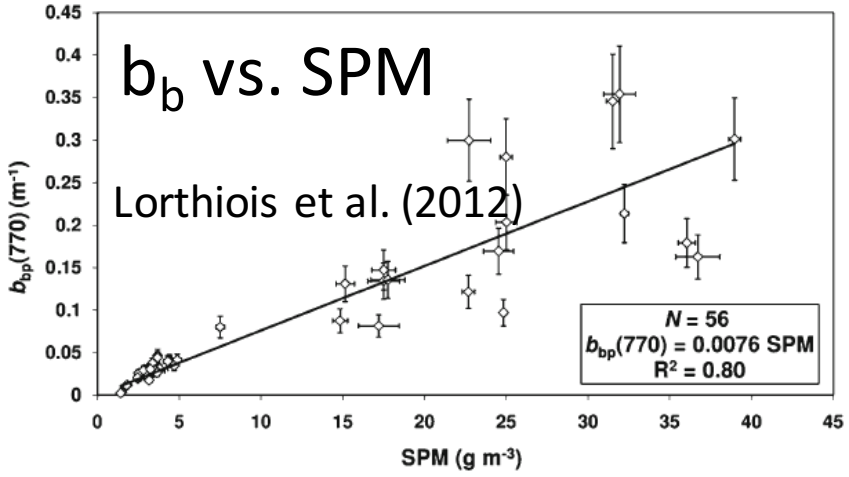

## $b_b$ vs. POC



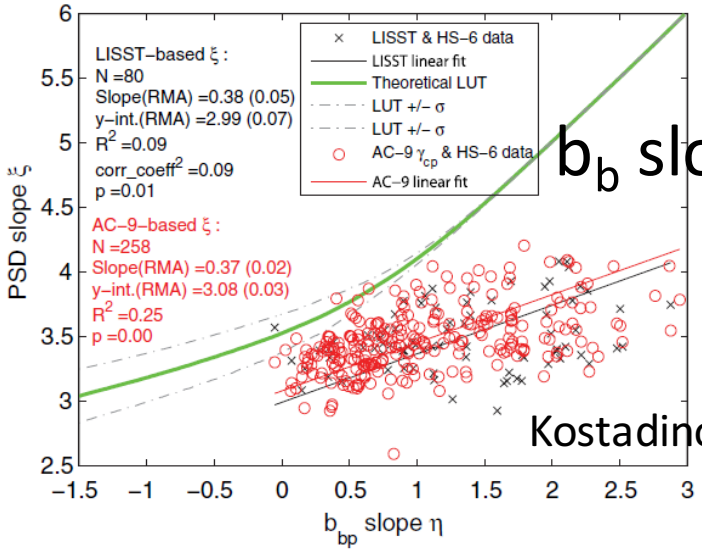

## $b_b$ vs. Phytoplankton-C




## $b_b$ vs. SPM



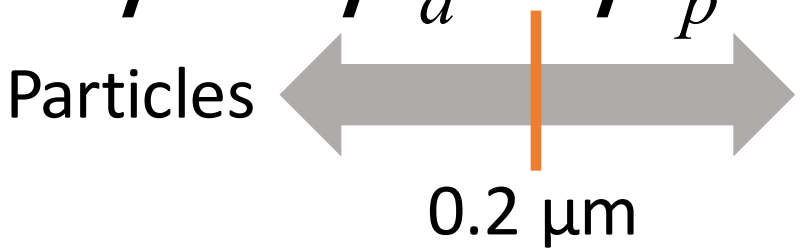

## $b_b$ slope vs. PSD slope

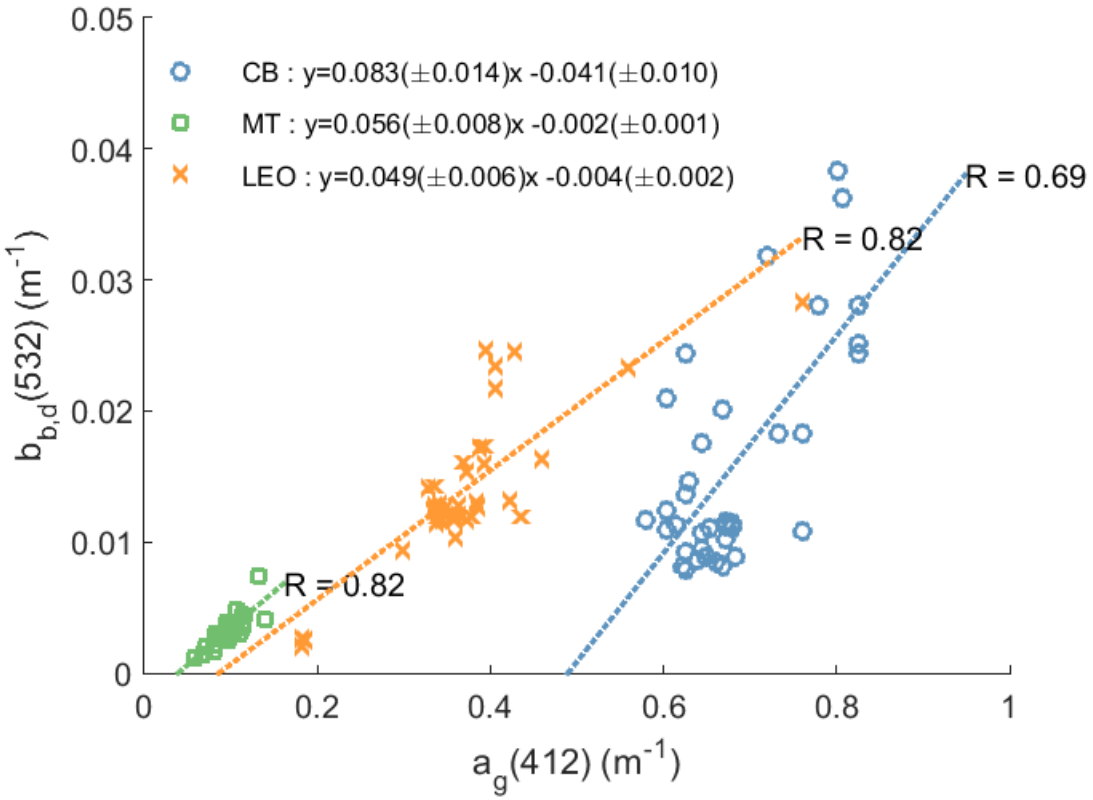



Kostadinov et al (2012)

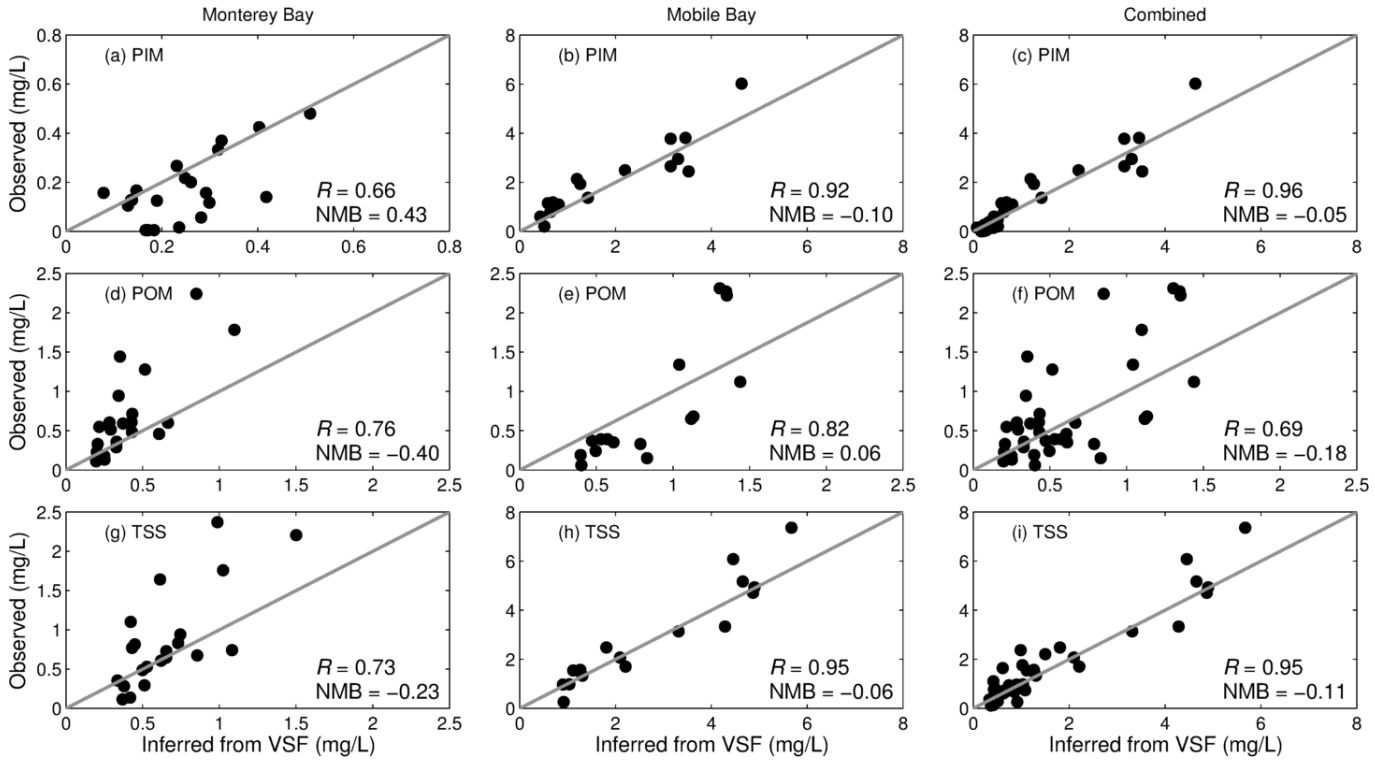
# Question: what contribute to $b_b$? Dissolved vs. Particulate

$$\beta = \beta_d + \beta_p$$



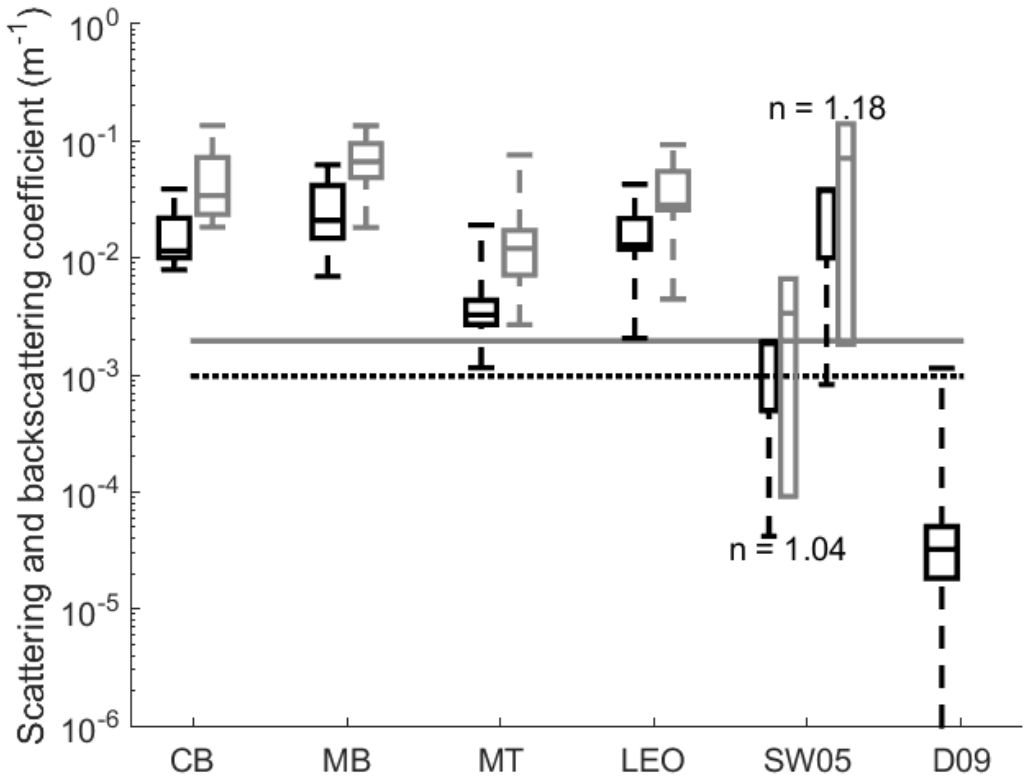



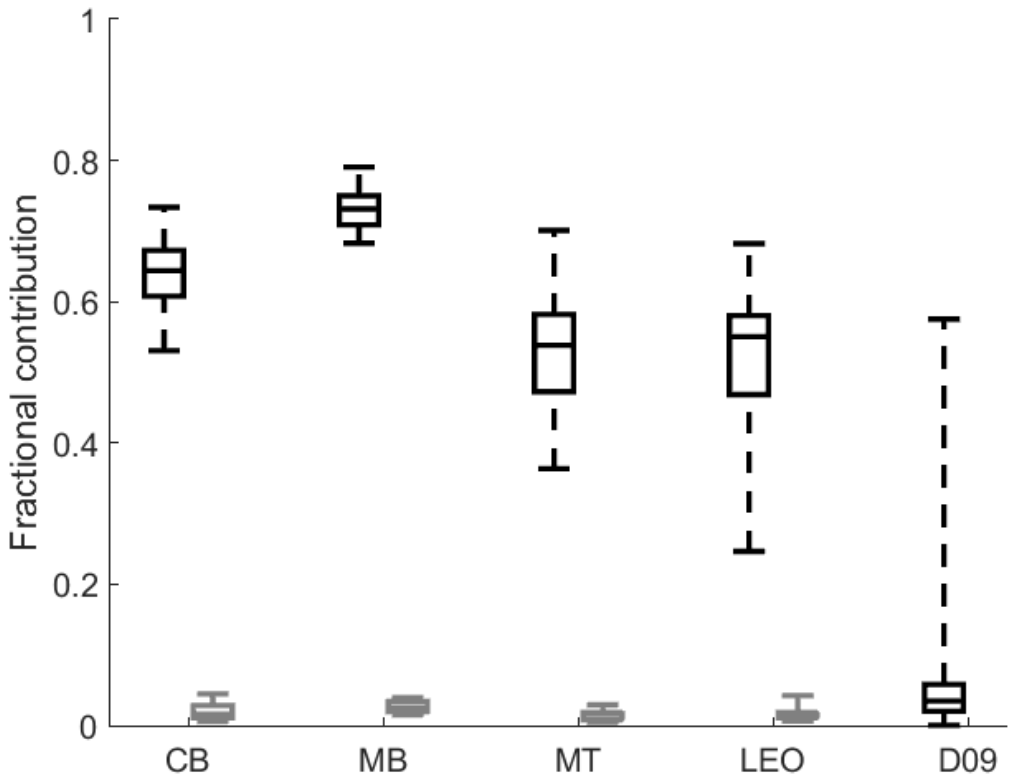

Zhang and Gray (2015)




Zhang et al. (2014)

# In coastal waters, “dissolved” portion of particles scatter light much greater than pure seawater and contribute 30-80% of total $b_b$

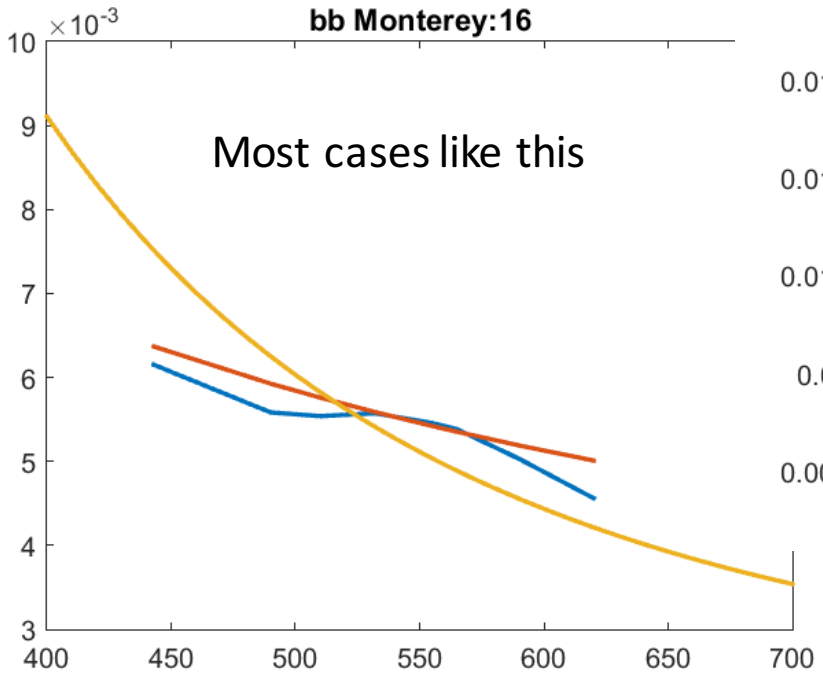


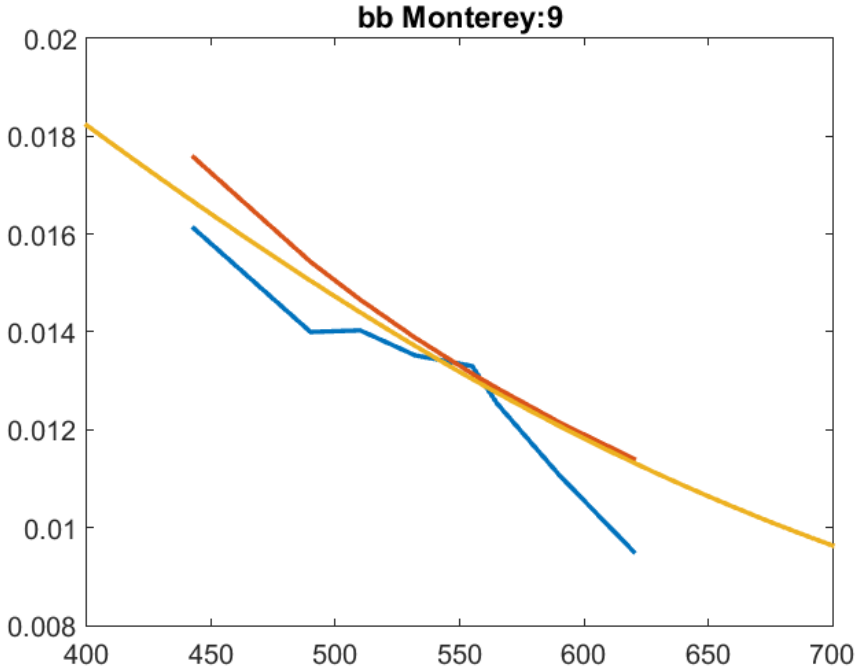



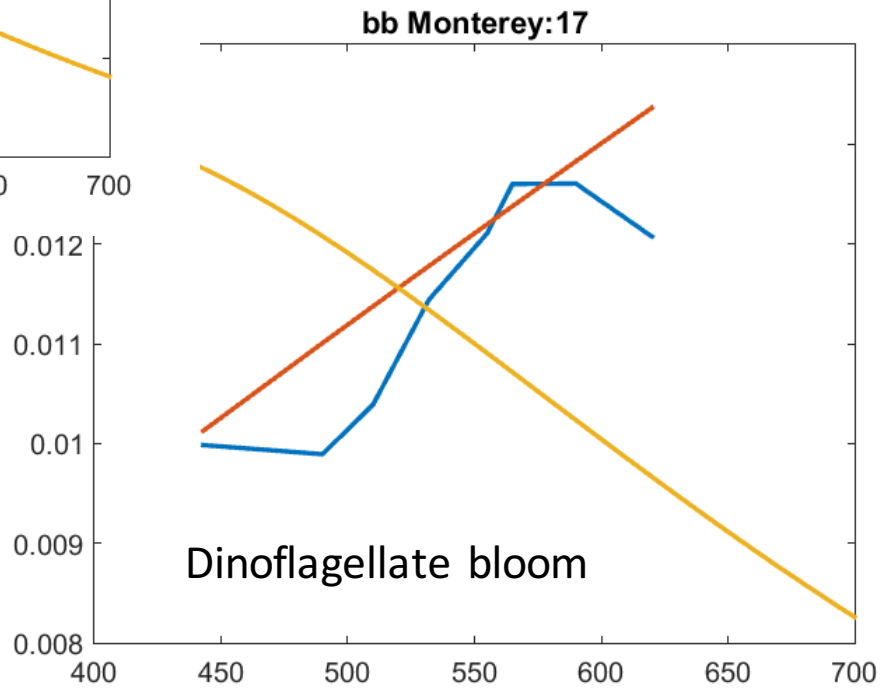

D09: Dall’Olmo et al. (2009) equatorial Pacific ocean
SW05: Stramski and Wozniak (2005) simulated colloidal scattering

Next step: Analyzing SABOR data

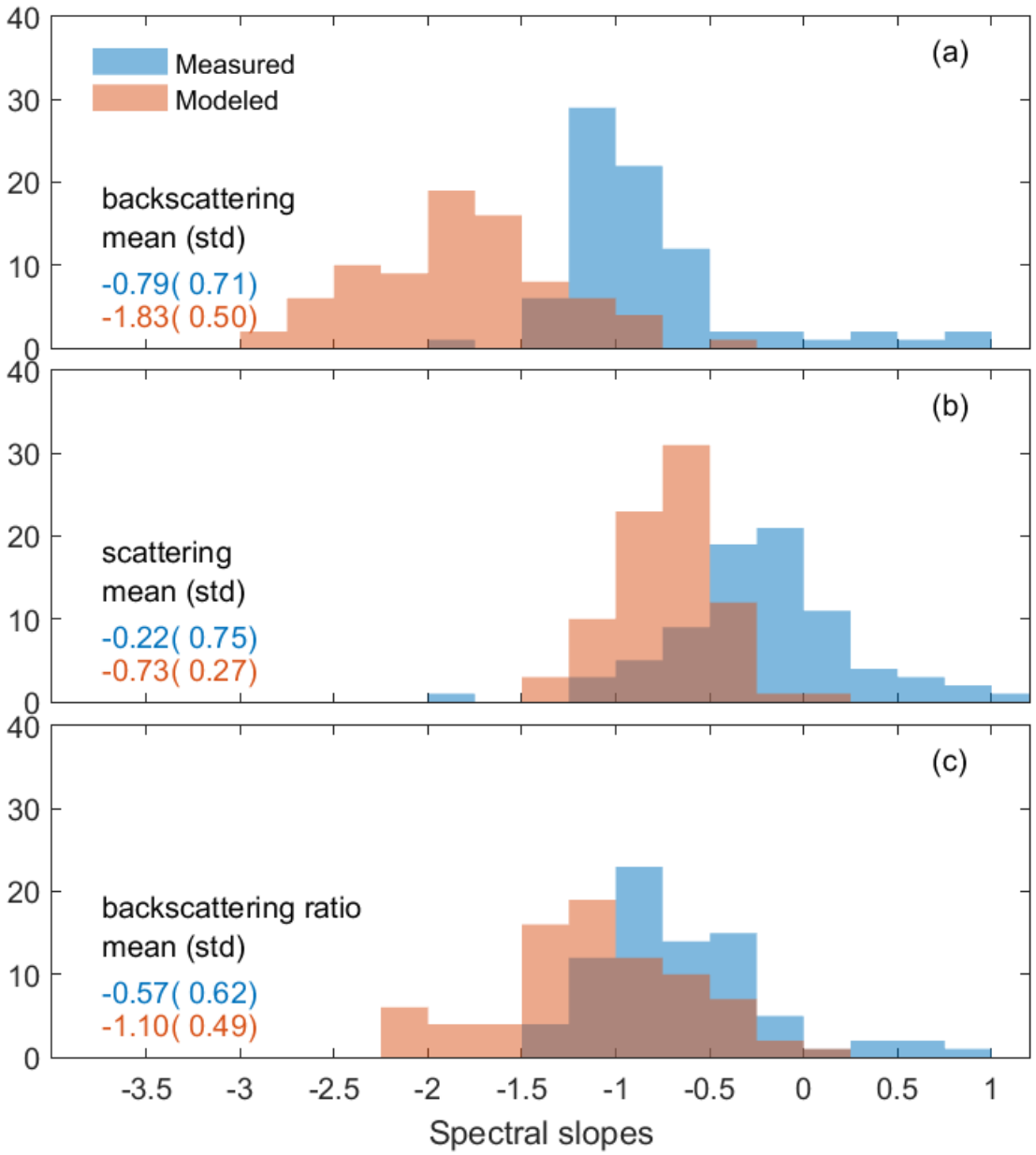
# Simulated vs. measured spectral $b_b$



# Simulated vs. measured spectral b, $b_b$, $b_b$ ratio




In general, simulation overestimate spectral slopes of $b_b$, slight overestimation in spectral slopes for b and bb ratio

In forward modeling, I assumed Refractive index does not change with wavelength. While this is ok for real part of the index, it is NOT ok for imaginary part of the index.

Next step

To account for absorption, i.e., change in imaginary part of the refractive index, in forward modelling for phytoplankton-type and very small (dissolved) particles.

# An unexpected challenge in using measured VSFs with HydroLight:

- To ingest measured VSFs, HL does this things
  - Estimate VSFs at 0.1:0.1:180 through interpolation or extrapolation with a user provided function
  - Estimate VSF slope at smaller angles using the measurements at 0.1 and 0.2 deg assuming $$\beta(\theta) \approx \beta(0.1)\theta^{-m}$$
  - Analytically integrate VSF between 0 and 0.1 using the above equation and between 0.1 and 180 numerically.

This only works if m < 2; otherwise you get negative integration value between 0 and 0.1, which in turn lowers the estimate b, increases bb ratio.