# Ocean Carbon From Space 2022 Workshop

# An OC-CCI-based Ocean Colour Dataset of Particle Size Distribution and Phytoplankton Carbon Using a 2-component Coated Spheres Algorithm

Tihomir S. Kostadinov & co-authors

California State University San Marcos

Feb. 16, 2022

Presented research has been sponsored by NASA grant #80NSSC19K0297

# Co-authors & Acknowledgements


- Co-authors: Lisl Robertson-Lain, Christina Eunjin Kong, Xiaodong Zhang, Stéphane Maritorena, Stewart Bernard, Hubert Loisel, Daniel S.F. Jorge, Ekaterina Kochetkova, Shovonlal Roy, Bror Jonsson, Victor Martinez-Vicente, Shubha Sathyendranath
- NASA Funding – grant # 80NSSC19K0297
- ESA/PML BICEP/POCO projects, all in-situ PSD (compilation in Kostadinov et al., 2009 + ERI Plumes and Blooms Project), POC and pico C data providers (compilations by POCO (Martinez-Vicente et al., 2017) and BICEP)
- More acknowledgements can be found at the PANGAEA data set:
  - https://doi.pangaea.de/10.1594/PANGAEA.939863


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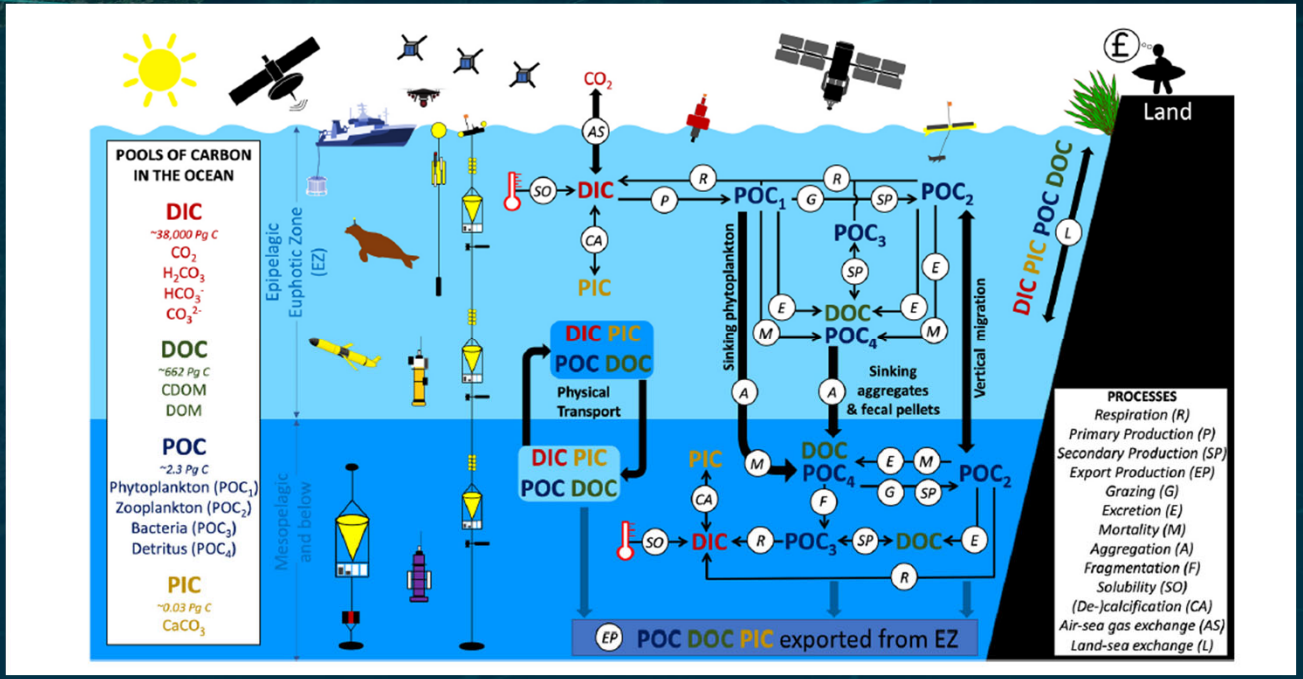
# The Biological Pump




Brewin et al. (2021), ESR

- The biological pump plays an important role in the carbon cycle and climate.
- Size is a master trait (Marañon, 2015) that affects biogeochemical role (e.g. sinking), and it also affects optical properties.
- The PSD links ocean ecology and biogeochemistry with ocean optics/ocean color remote sensing. Need to retrieve PSD from space & link it to phytoplankton size structure. Best to retrieve both chlorophyll and carbon, as they can vary & co-vary in complex ways & are both important.

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# Mechanistic, First-Principles Based PSD Algorithm

- PSD parameterized as a power-law
- Two particle populations
  1. Phytoplankton as coated spheres (modeled based on the Equivalent Algal Populations (EAP) framework (e.g. Robertson-Lain and Bernard, 2018))
  2. NAP as homogeneous spheres
- Hyperspectral forward modeling using Mie code (Zhang et al., 2002)
- Inversion via Spectral Angle Mapping (SAM), using modeled $b_{bp}$ end-members
- Monte Carlo simulations for uncertainty estimation
- Simplifying assumptions
  - One common PSD slope for phyto and NAP
  - No_NAP = 2*No_phyto ~ Phyto C = (1/3)*POC

$$b_{bp}(\lambda) = \int_{D_{\min\varphi}}^{D_{\max\varphi}} \frac{\pi}{4} D^2 Q_{bb\varphi}(D, \lambda, m_{\varphi}) N_{o\varphi} \left(\frac{D}{D_o}\right)^{-\xi} dD + \int_{D_{\min NAP}}^{D_{\max NAP}} \frac{\pi}{4} D^2 Q_{bbNAP}(D, \lambda, m_{NAP}) N_{oNAP} \left(\frac{D}{D_o}\right)^{-\xi} dD$$

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# Forward modeled hyperspectral $b_{bp}(\lambda)$ & operational multi-spectral end-members. Link & to 'Why the Sky is Blue'.

- bbp spectral shape exhibits strong dependence on the PSD slope, supporting the theoretical basis of the algorithm
- Generally, the more dominant smaller particles are, the "bluer" backscattering is – e.g. Rayleigh scattering from air molecules is very "blue" ($\lambda^{-4}$)
- The novel PSD algorithm was applied operationally to the merged OC-CCI v5.0 data set (Sathyendranath et al, 2019, 2021)
- The PSD was used to estimate size-partitioned phyto Cand POC via volume & allometric relationships

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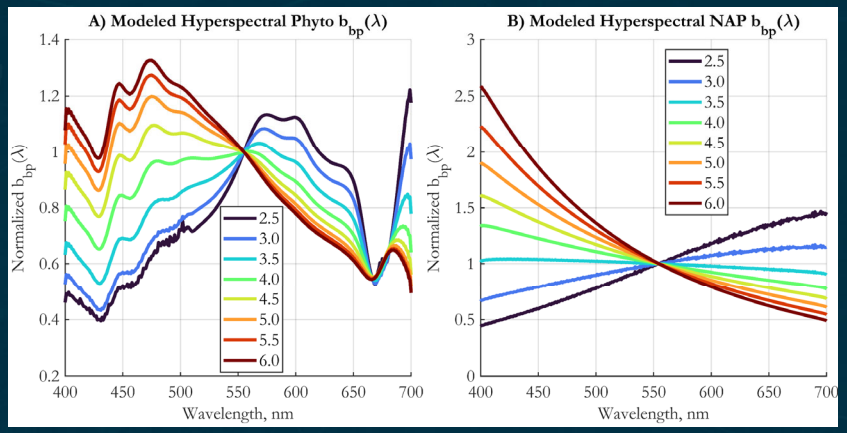
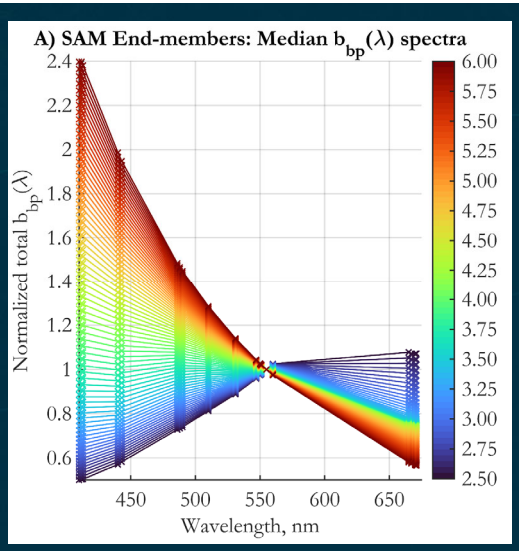
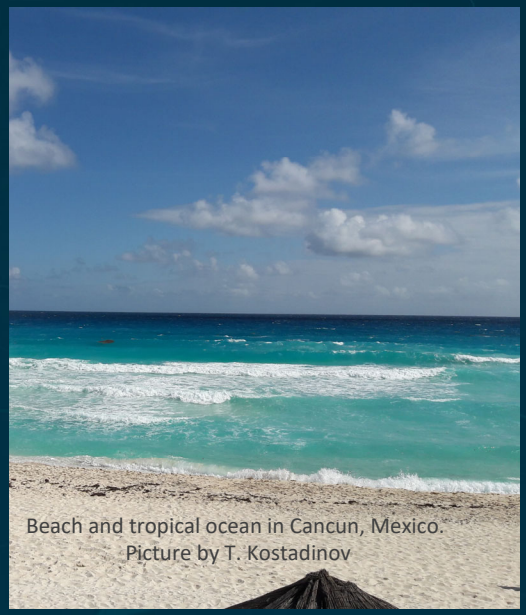


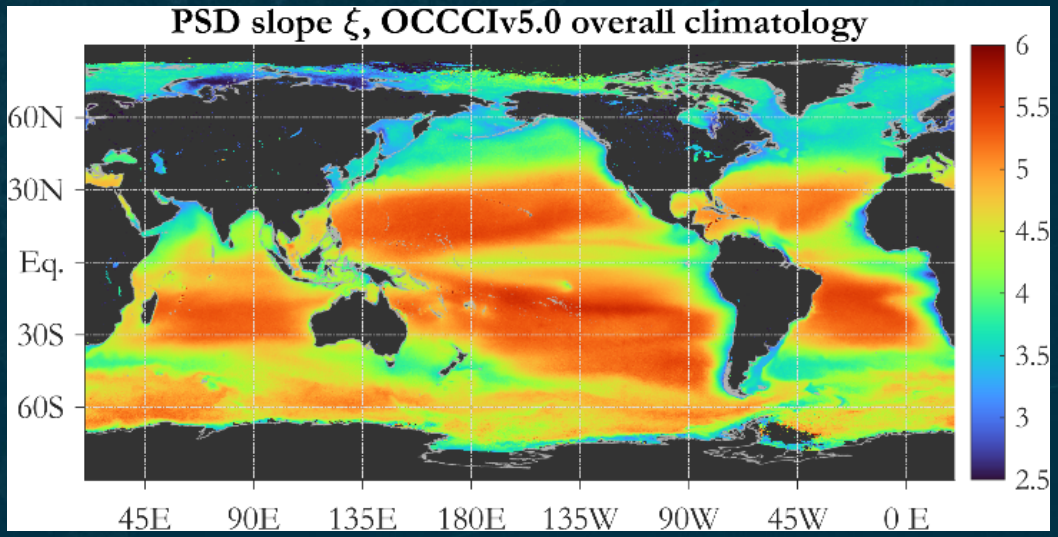



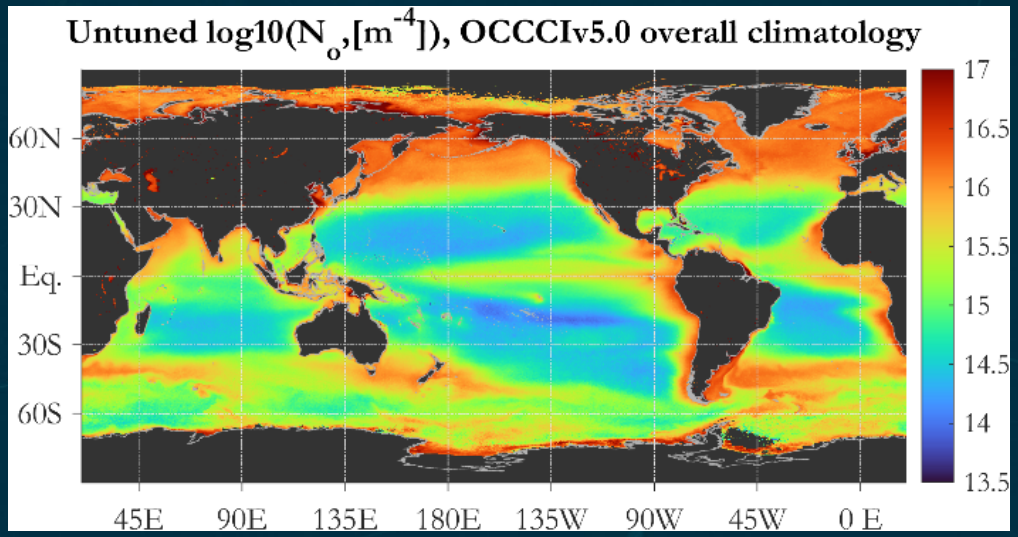

Kostadinov et al. (in prep.)




Rayleigh scattering partially explains the blue color of both the sky and pure seawater

# PSD Retrievals Climatology (Using OC-CCI v5.0)

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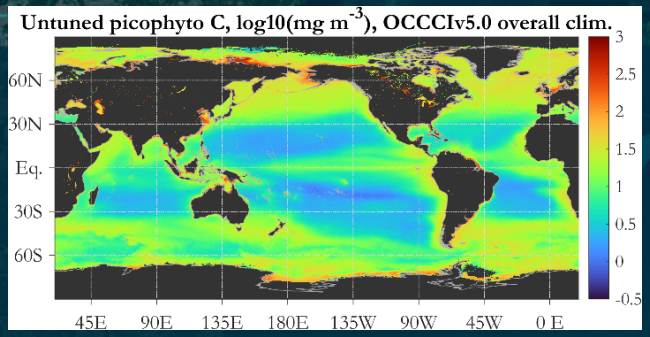
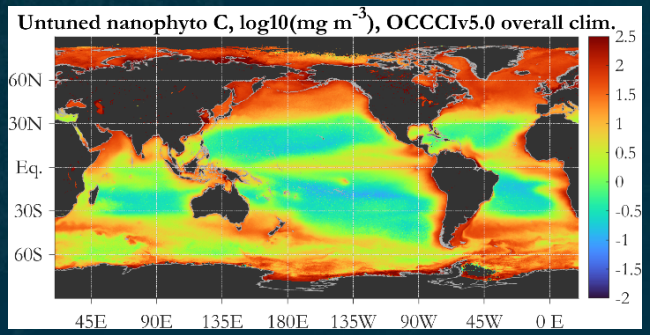
# Phytoplankton Carbon from the PSD

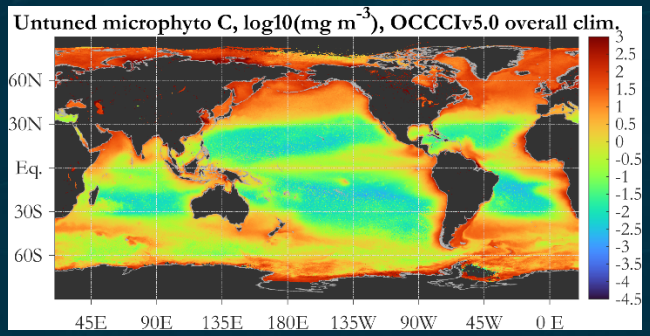
$$PhytoC = \int_{D_{\min\varphi}}^{D_{\max\varphi}} a\left(\frac{\pi}{6}D^{3b}\right)^{b} N_{o\varphi}\left(\frac{D}{D_o}\right)^{-\xi_\varphi} dD$$

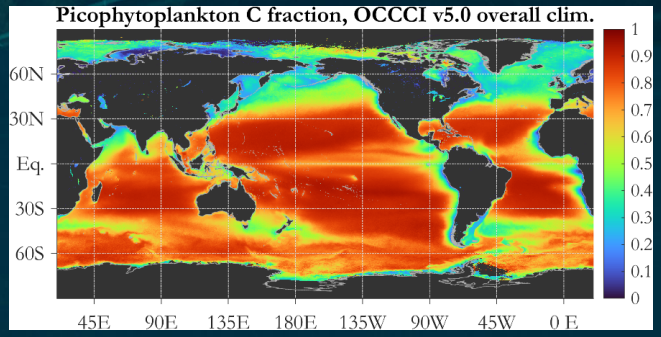
- A key assumption is that No_phyto = (1/2)*No_NAP, leading to
  - phyto C = (1/3)*POC if same limits of integration are used.
- This assumption needs to be investigated and relaxed in future improvements.
- POC is approximated by 3*phytoC
- a & b are from Roy et al. (2017)

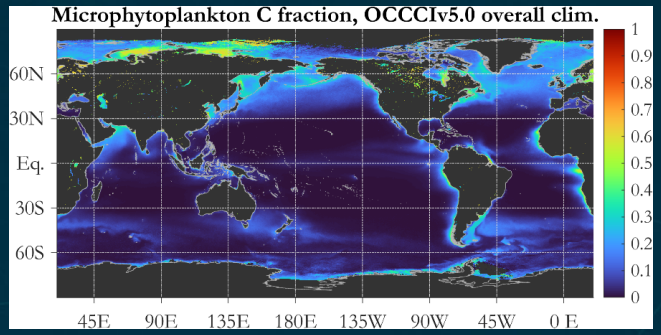
# Absolute and Fractional Size-partitioned Phyto C

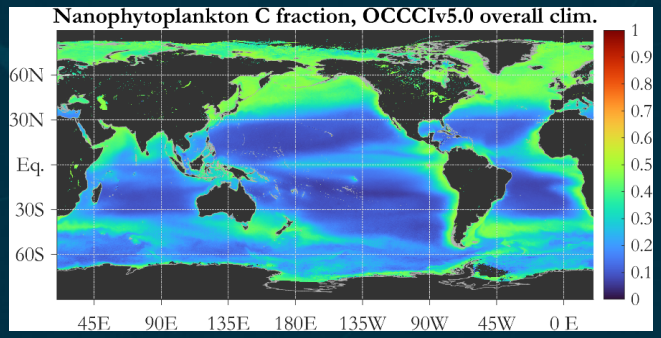
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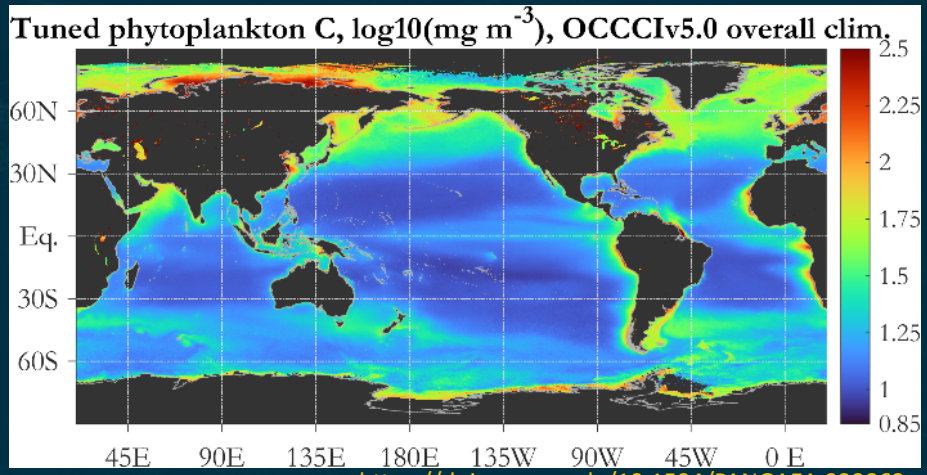
# Validation & Empirical Tuning

- Validation data compilations & match-ups provided by BICEP & POCO teams, and others! Thank you ESA BICEP project - Christina, Shubha, Bror, and Victor!
- Empirical tuning proposed to yield more realistic POC & Chl results.
- POC validation better *with* empirical tuning, pico C validation better *without* tuning (but is noisy)
- Roy et al (2017) compares better with untuned retrievals, but Graff et al. (2015) (NASA OBPG) compares better with tuned retrievals.
- Indicates lack of complete optical closure of model
- Further validation needed

Empirically tuned phyto C

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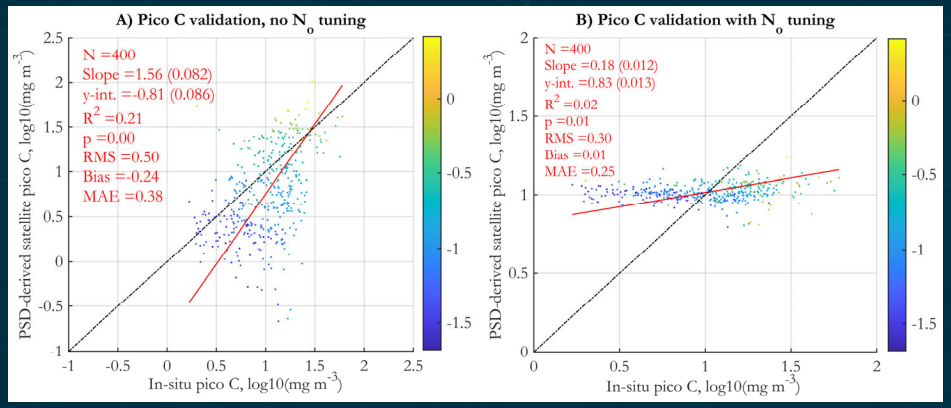


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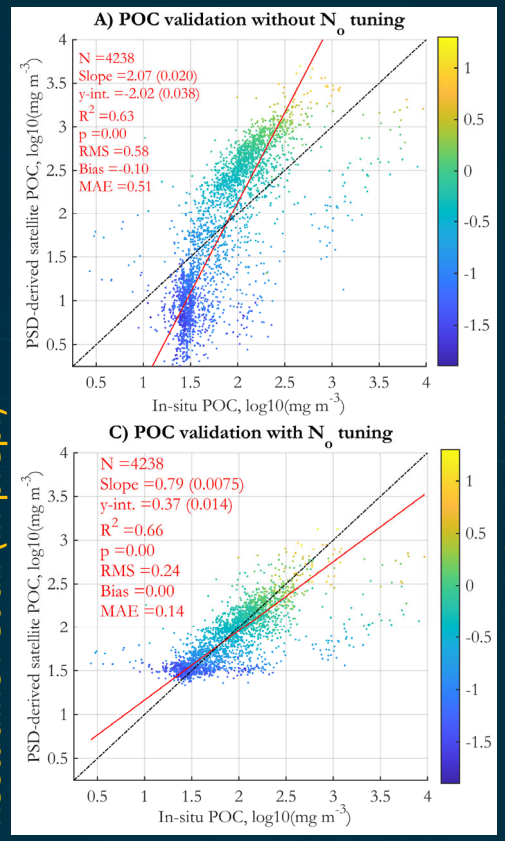


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# OC-CCI v5.0 based PSD and Phyto C Data Set

- Available at PANGAEA (just published yesterday!):
  - https://doi.pangaea.de/10.1594/PANGAEA.939863
  - Use with caution for now (accompanying manuscript in prep.), contact me (email below) if you use, please, and if you notice anything unusual/issues.
- Operational Algorithm available for BICEP purposes – further validation and inter-comparison efforts, which are essential
- Send inquiries & suggestions to: tkostadinov@csusm.edu

# Knowledge Gaps, Challenges, Opportunities & Priorities

- Lack of comprehensive global in-situ data sets of phyto C for algorithm development.
- Difficulty separating POC from living phyto C – emerging technologies.
- Need to develop more mechanistic models, based on first principles
  - Resilient to changes in the future ocean
  - Limits of multispectral data to retrieve multiple variables with many degrees of freedom (limits to mechanistic models of a complex particle assemblage)
  - Hopefully hyperspectral data (e.g. PACE) should alleviate some of this
- PSD-algorithm specific: Need to address key algorithm assumptions, such as phyto C = (1/3)*POC and that same PSD slope applies. Effects of assuming a power-law PSD & limits of integration. Dealing with complex particle assemblages with variable minerogenic input.

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# The End.
# Thank You!

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