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Particulate organic carbon and phytoplankton carbon: algorithm comparisons

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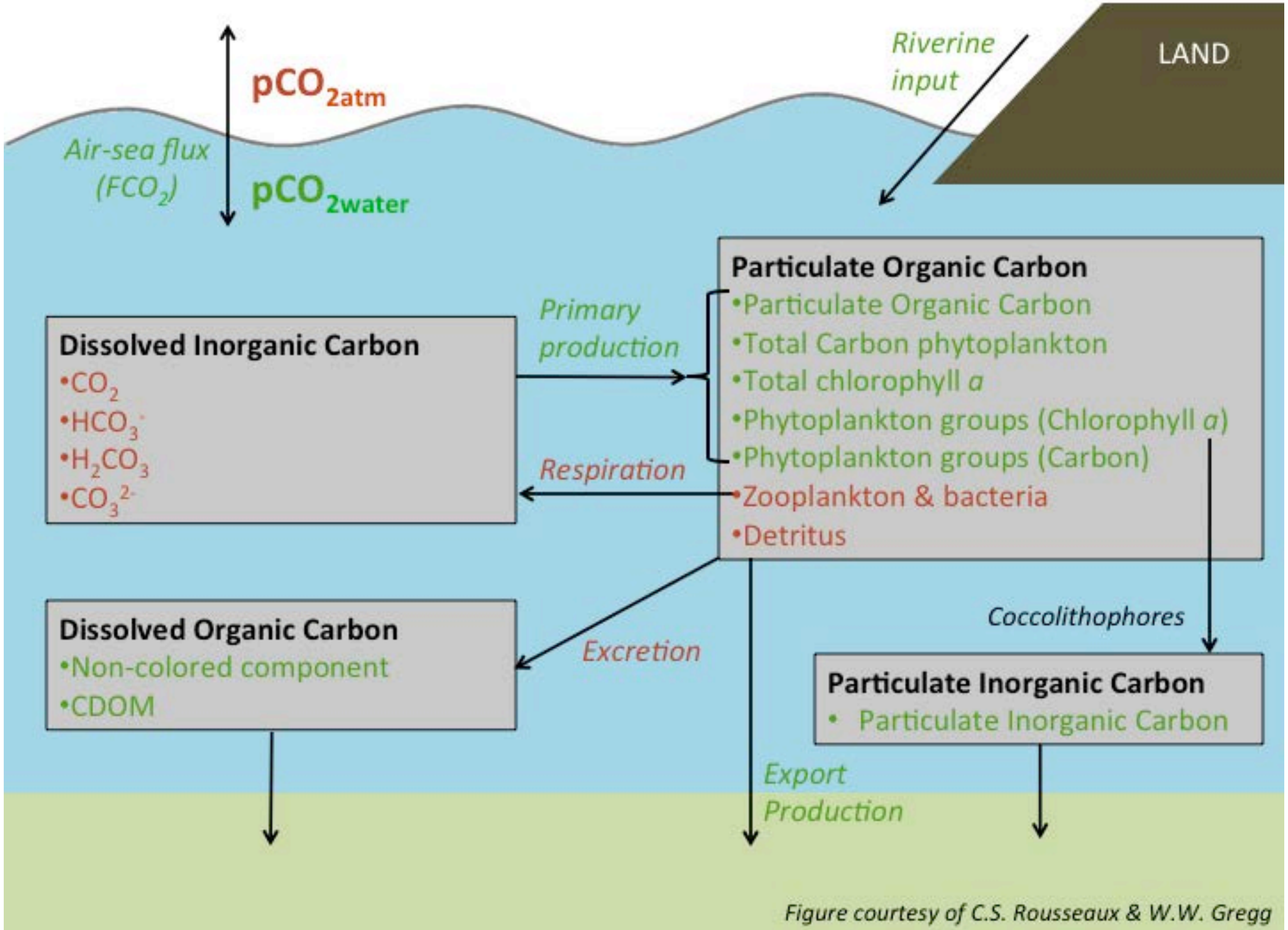
Outline

- Particulate carbon pools
- Why and how - POC, PIC, C_{phy}
- What do users want?
- *In situ* measurements
- Algorithm validation
- Theoretical considerations
- Recommendations and points for discussion

Particulate Carbon Pools

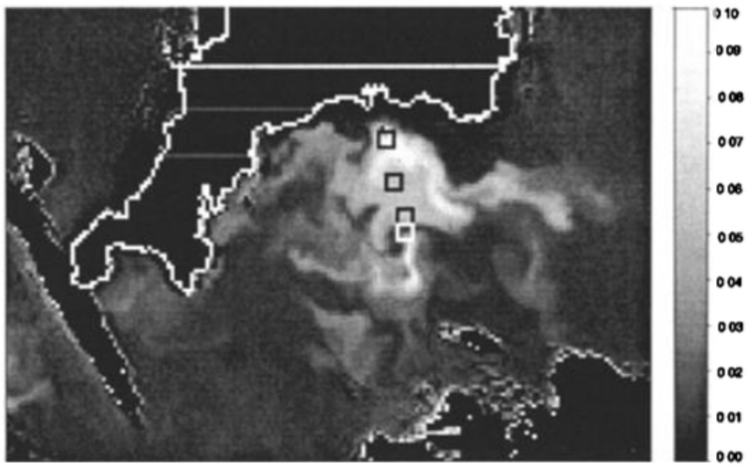


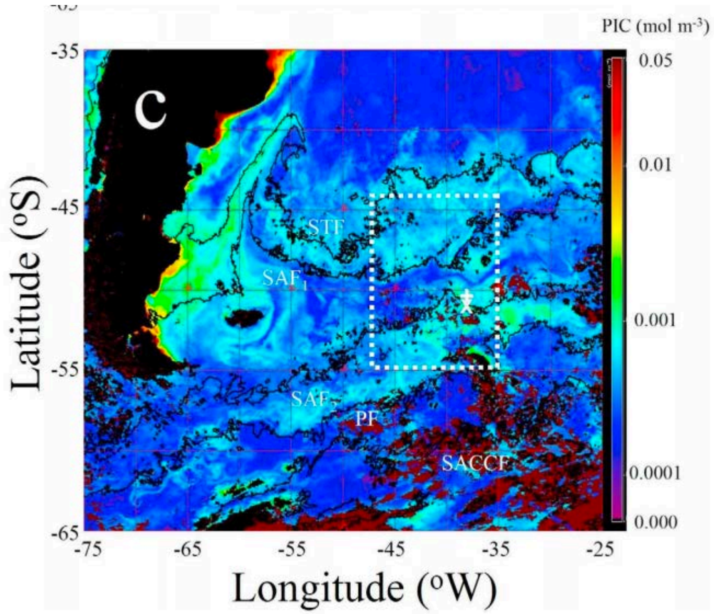
POC and phytoplankton carbon

- POC – multiple ways to detect from satellite as [POC] linked to optics in a variety of ways:
  - Phytoplankton contribute, therefore some link with [Chl]
  - POC is particulate, therefore linked with absorption and scattering.
- Phytoplankton carbon – as above [Chl], a_{ph}, b_{bp}.

PIC

- PIC in the ocean is dominantly from calcifying organisms such as coccolithophores and foraminifera.
- Interesting due to role in carbonate system and ecosystem role.
- Detectable from space due to high scattering, algorithms based on R_{rs} ratios, b_{bp} etc.

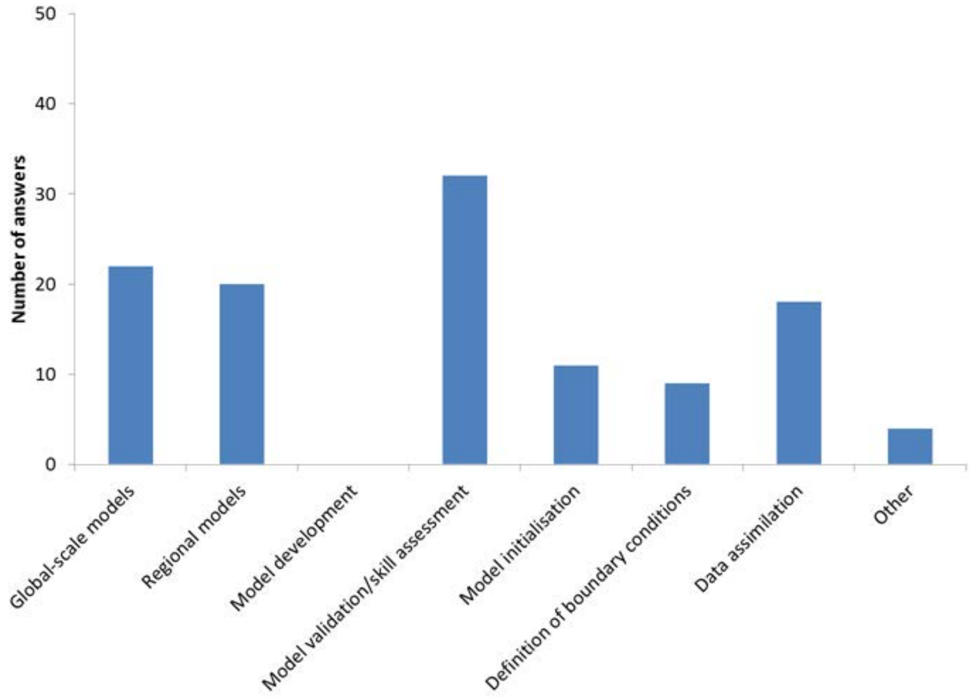


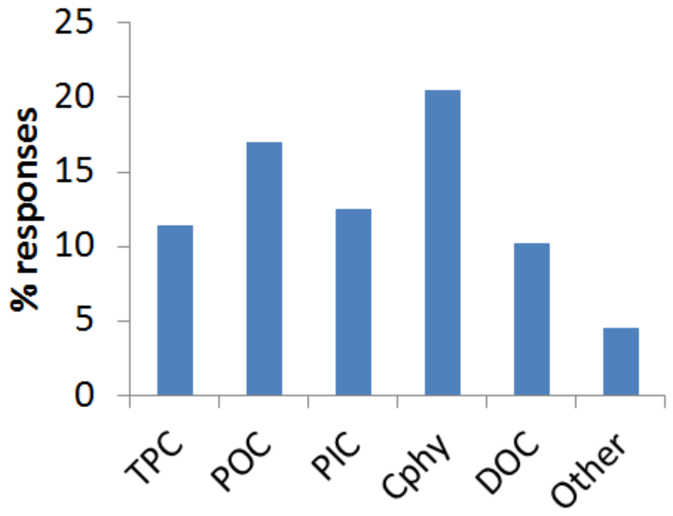


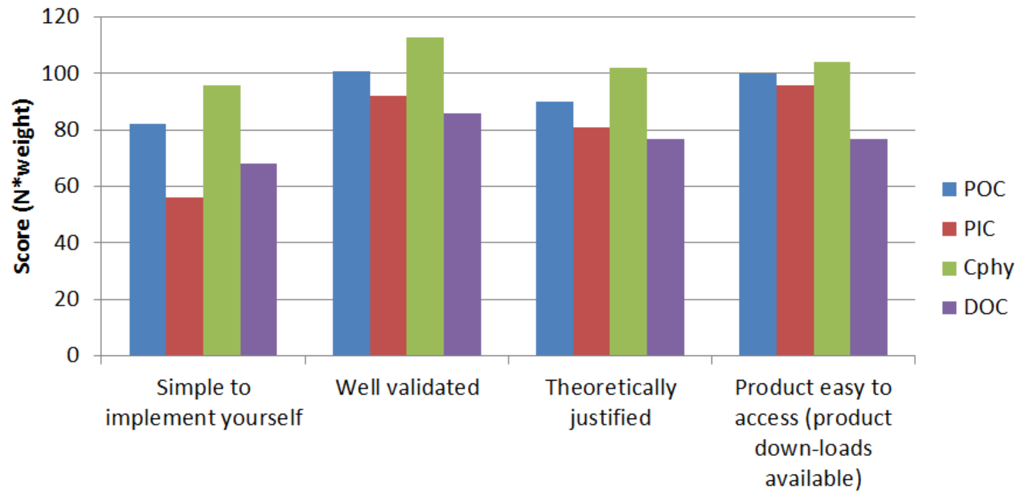
See work by Gordon, Balch, Shutler and others…

What do users want?

- Users surveyed:
  - Interest for model validation
  - POC and C_{phy}
  - Uncertainties are important
    - Range of 10-25% = good. More also acceptable for some users.







Validation

- POCO project recently undertook an algorithm intercomparison exercise for both POC and C_{phy} algorithms.
- Collation of large *in situ* databases for POC and C_{phy}
  - Uncertainties in this, particularly for C_{phy}:
    - Blanks for POC (see Cetinic *et al*., 2012)
    - Proxies (with challenging assumptions – discussed by Heidi)
    - More direct methods (e.g. Casey *et al*., 2013; Graff *et al*., 2015)
- Matchups extracted from OC-CCI version 2.
- Algorithms applied:
  - POC: Stramski *et al*., 2008, R_{rs} (A), Stramski *et al*., 2008, b_{bp} (B), Loisel *et al*. 2002, b_{bp} and [Chl] (C), Gardner *et al*., 2006, $K_d(490)$ (D), Konstadinov *et al*., 2016, b_{bp} to derive PSD (E)
  - C_{phy}: Sathyendranath *et al*., 2009, [Chl] (A), Maranon *et al*., 2014, [Chl] (B), Behrenfeld *et al*., 2005, b_{bp} (443) (C), Martinez-Vicente *et al*., 2013, $b_{bp}(470)$ (D), Kostadinov *et al*., 2016, b_{bp} PSD (E), Roy *et al*., 2017, [Chl], $a_{ph}(676)$.

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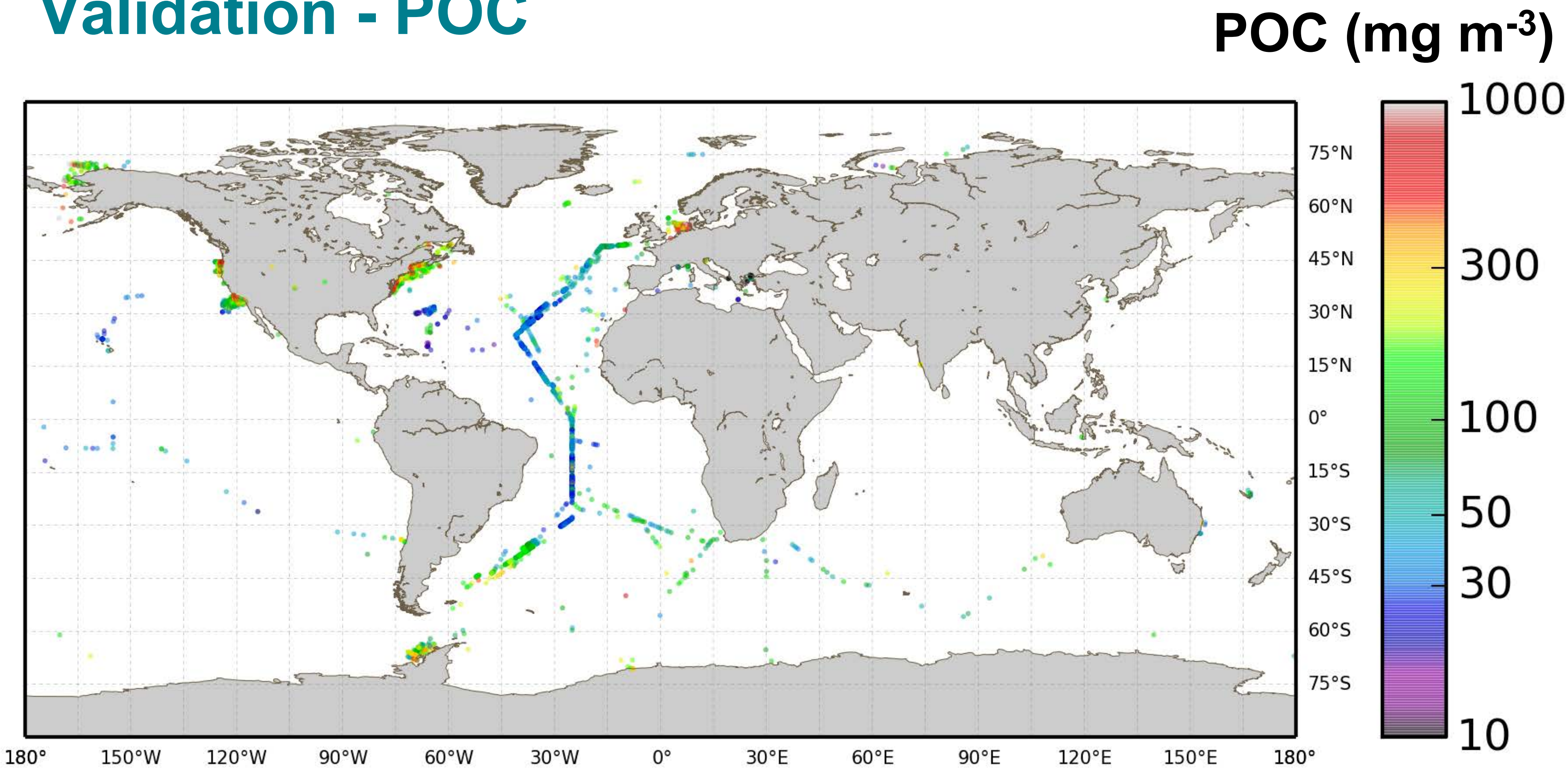
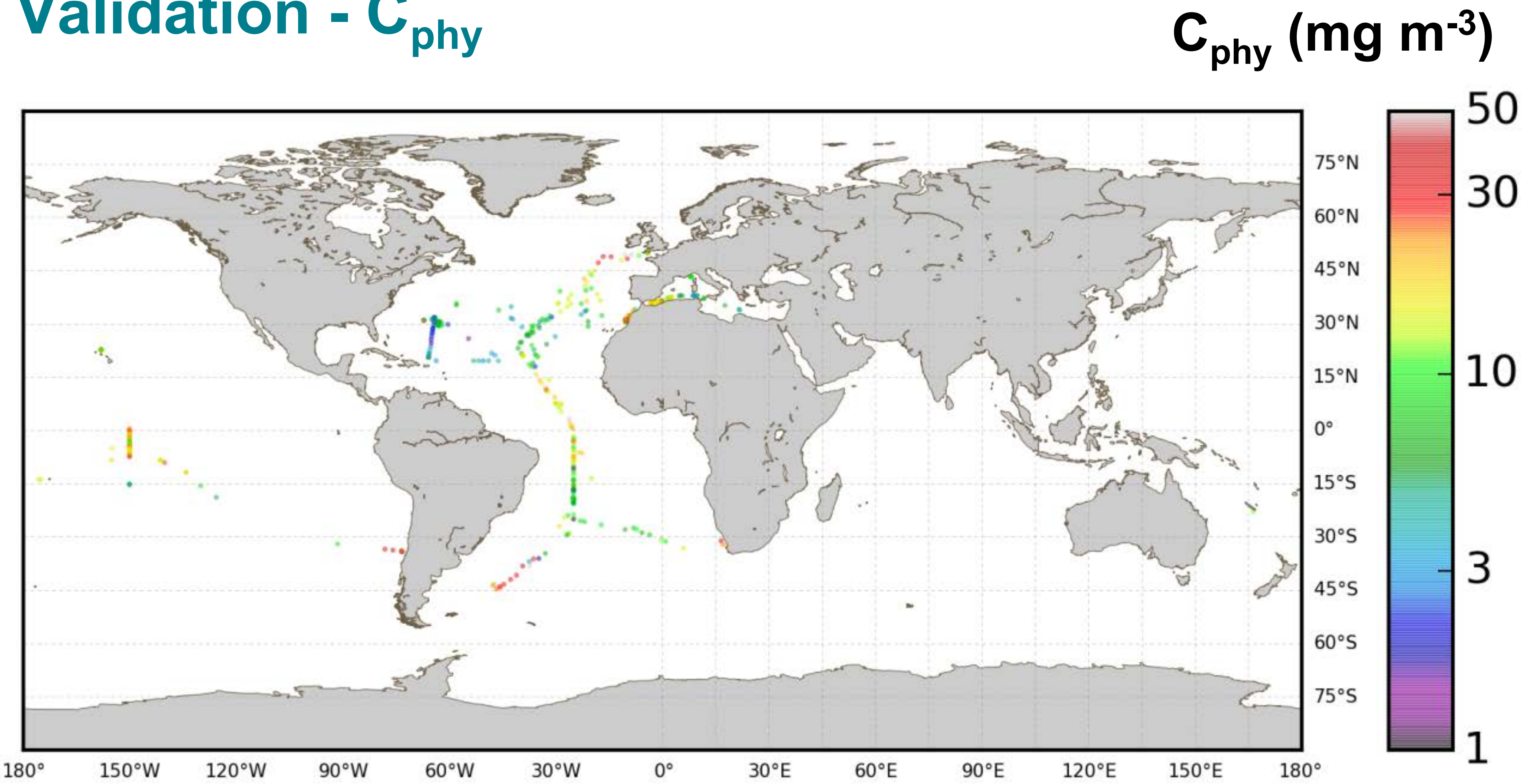
Validation - POC



~63000 points, 3891 matchups, biased towards Atlantic (AMT)

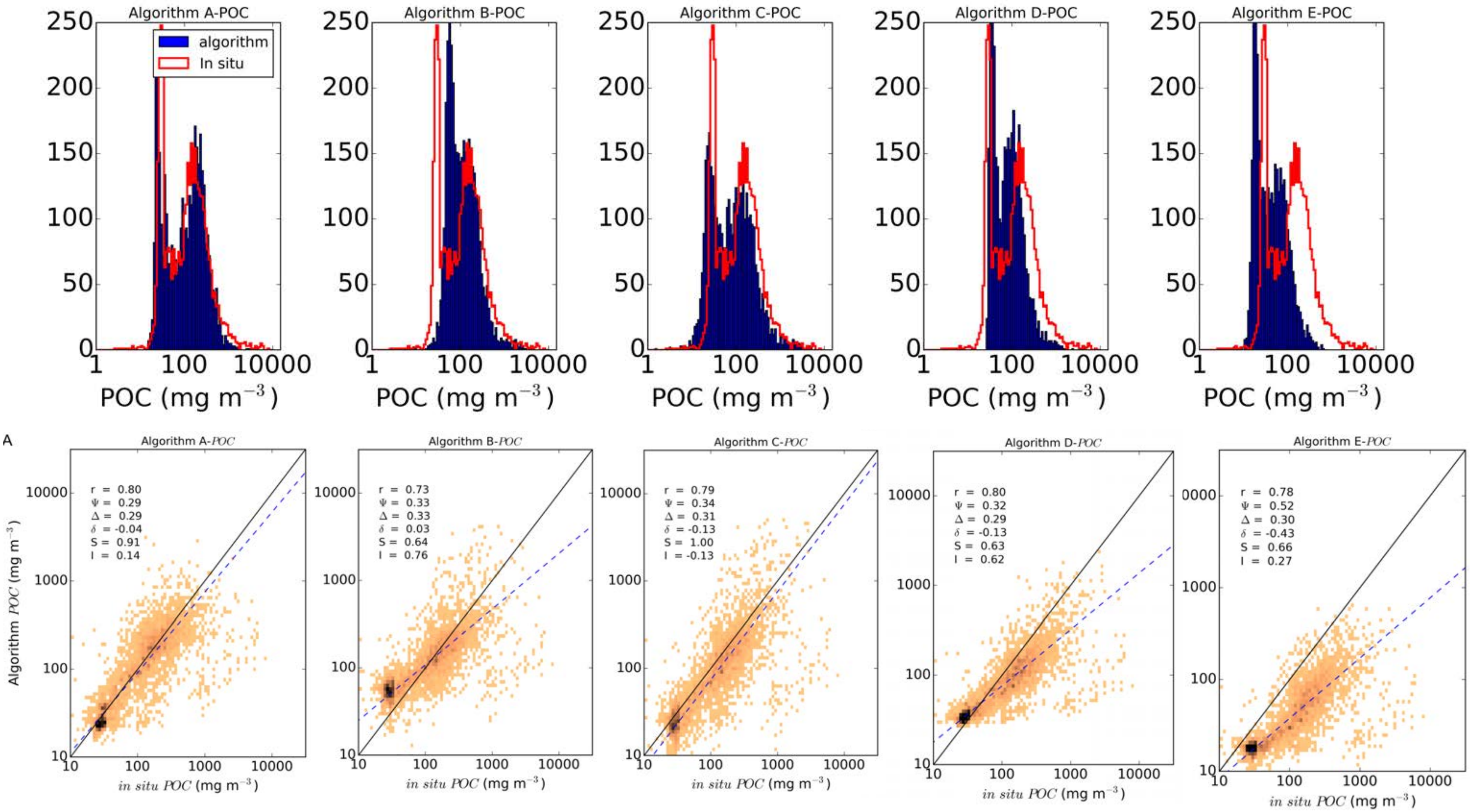
Validation - C_{phy}



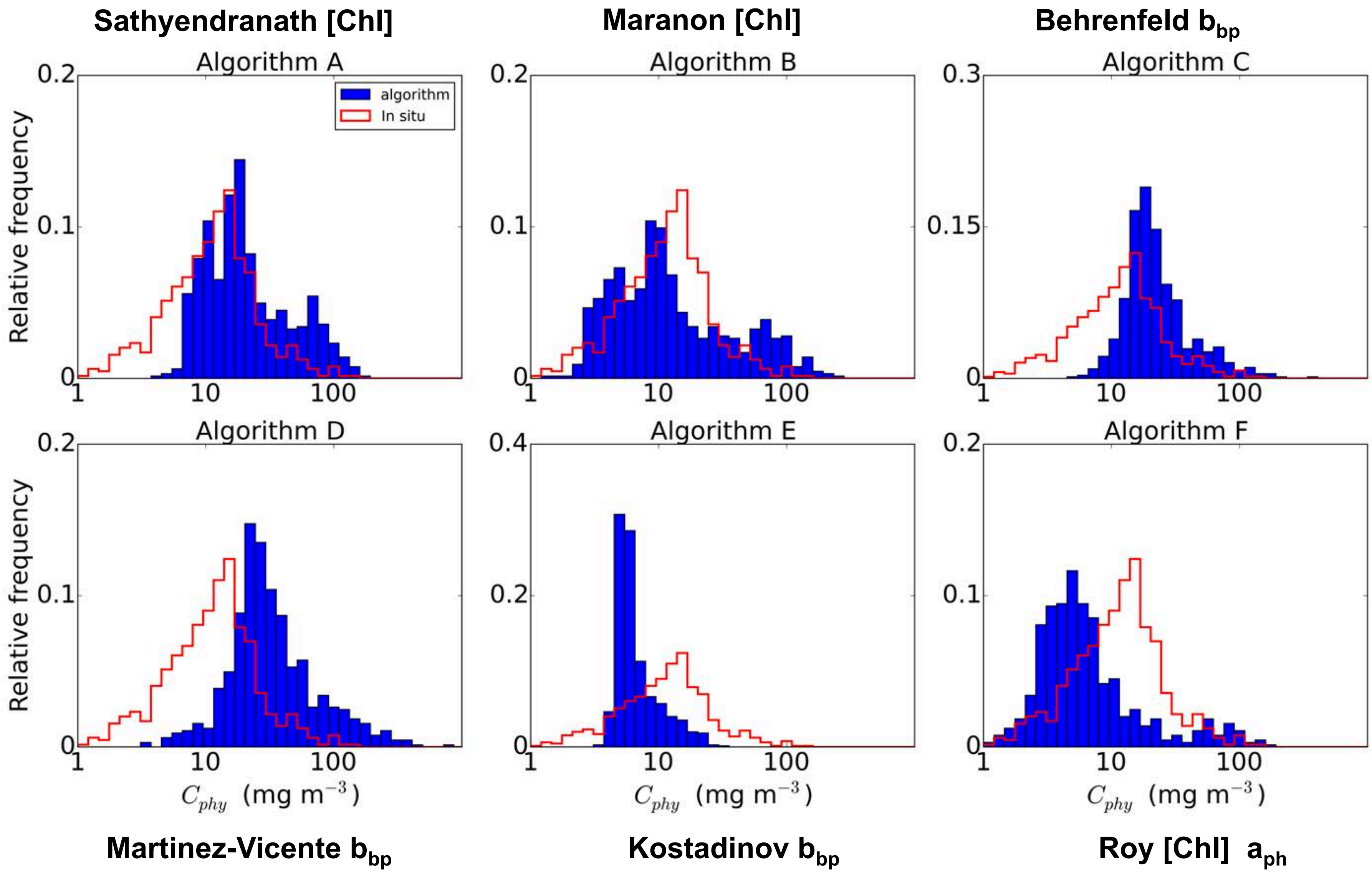
~50000 points, 593 matchups, biased towards Atlantic (AMT)

Algorithm intercomparison - POC

Stramski R_{rs} | **Stramski b_{bp}** | **Loisel, b_{bp} [Chl]** | **Gardner K_d** | **Kostadinov, b_{bp} PSD**

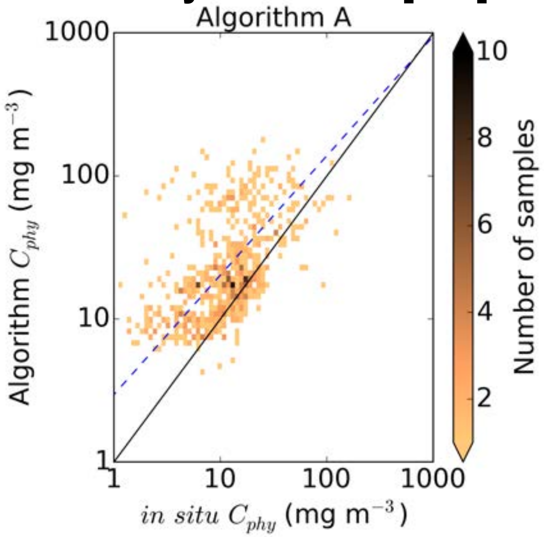


Algorithm intercomparison - C_{phy}

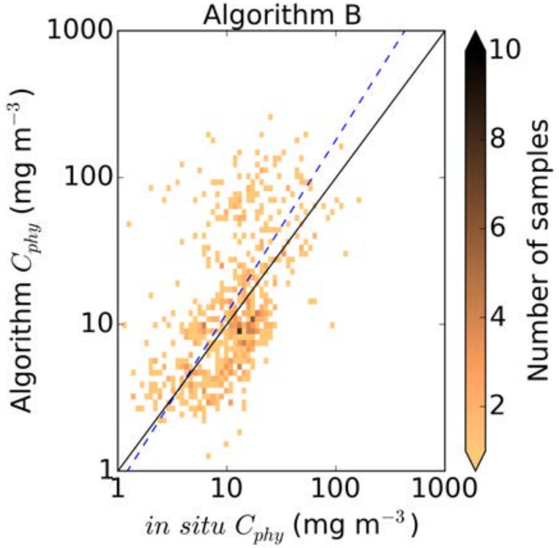


Algorithm intercomparison - C_{phy}

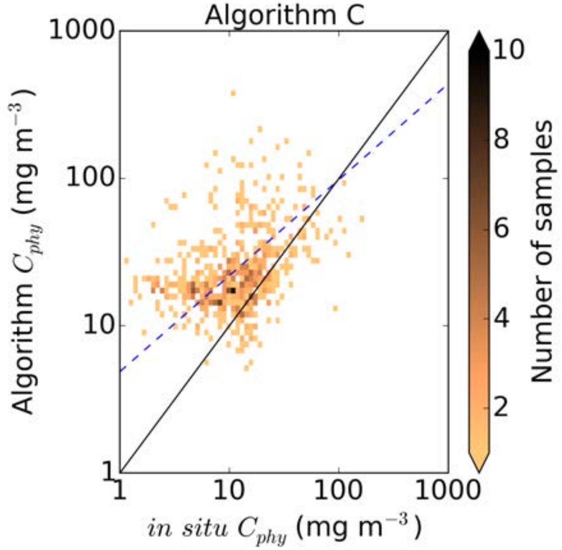
Sathyendranath [Chl]



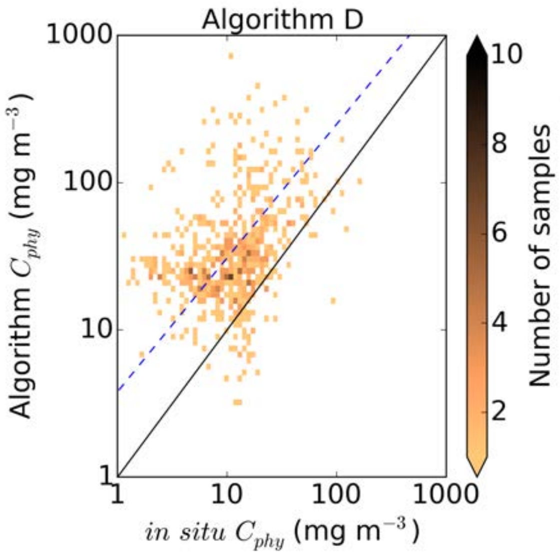
Maranon [Chl]



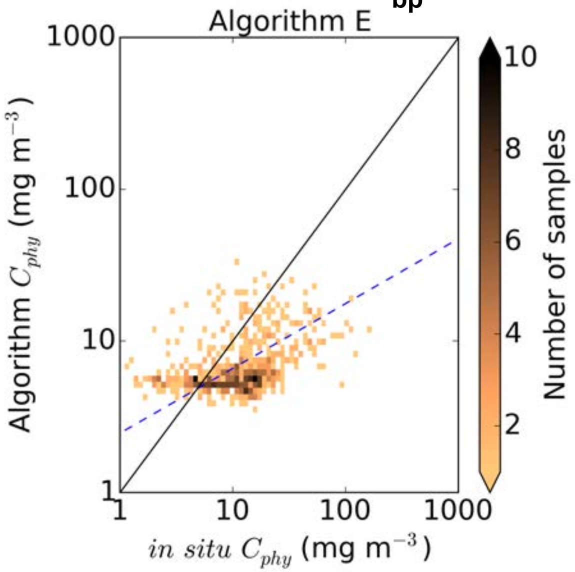
Behrenfeld b_{bp}



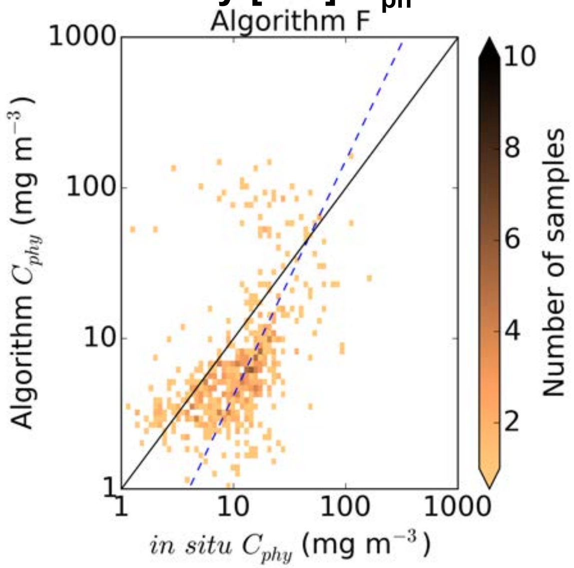
Martinez-Vicente b_{bp}



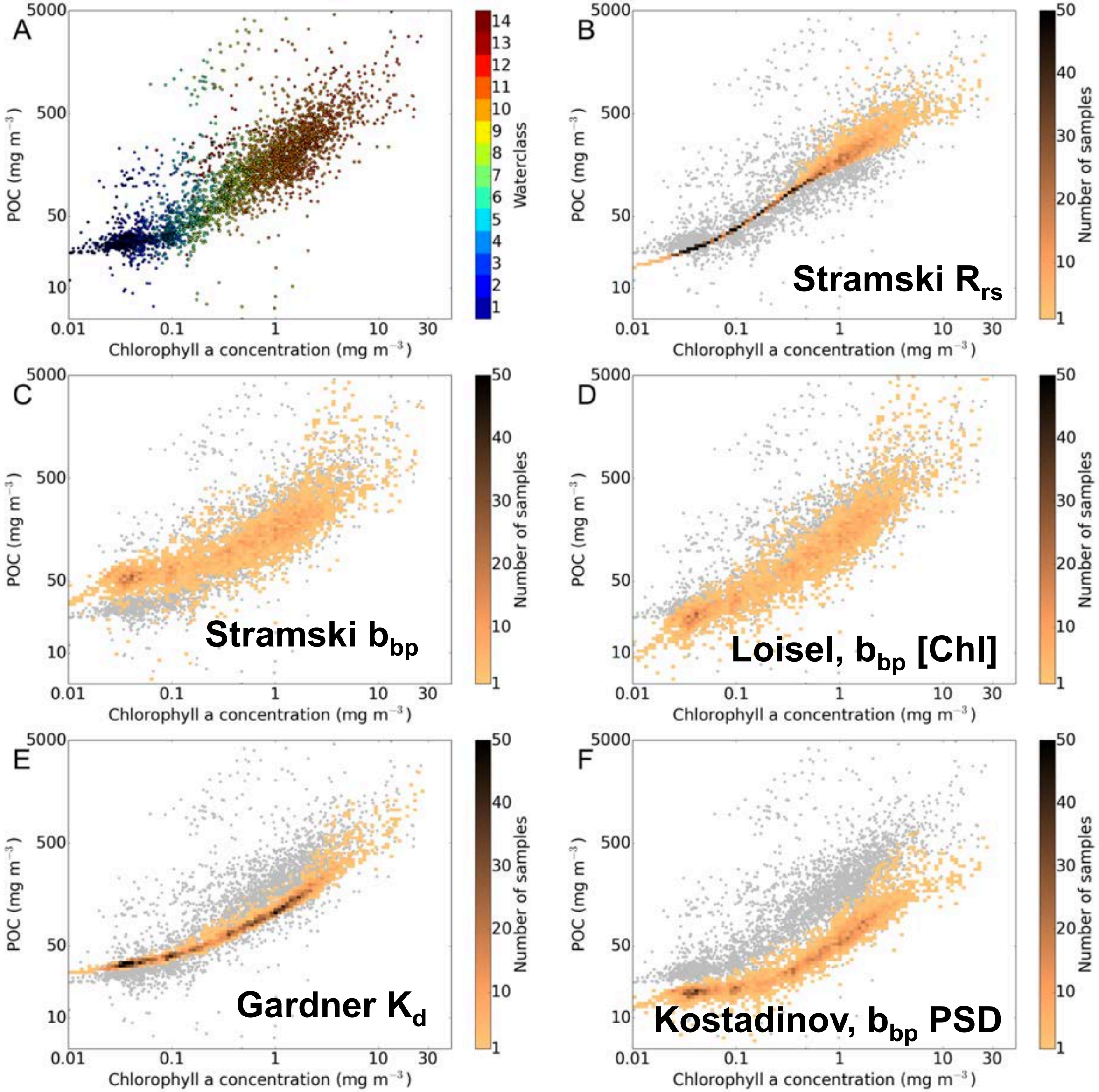
Kostadinov b_{bp}



Roy [Chl] a_{ph}



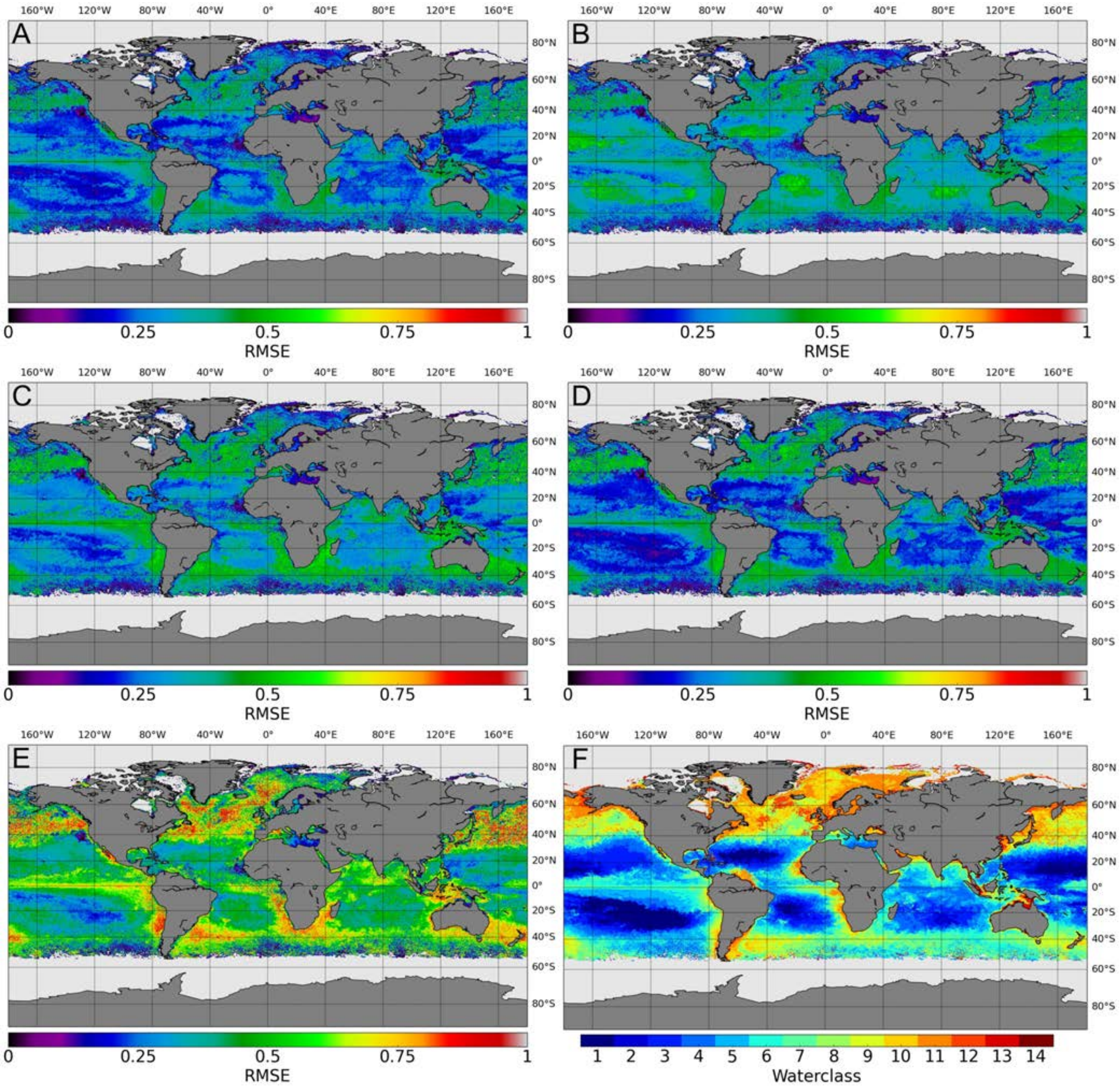
Theoretical considerations, C:Chl



- Scatter between *in situ* POC and satellite [Chl].
- Algorithms should be able to capture this variability.

Product maturity

- Validation of POC for optical waterclasses as per OC-CCI
- Errors per waterclass assigned to each pixel.
- Weighted sum when there is multiple membership.
- Errors close to user requirements.



Outstanding theoretical questions?

- Beyond empirical to understand the scatter we see in relationships:
  - What causes this?
  - We have lots of ideas – size/particle structures/PFTs/ photosynthesis/irradiance parameters, growth rates?
  - How do we quantify these routinely and evolve understanding towards new algorithms?
  - Semi-analytical/models probably necessary for this.

- Assumptions invoked to interpret optical data also influence algorithm design/choice of validation data
  - e.g. phytoplankton carbon from cell counts (what size range?)
  - Backscattering…
  - Assumptions – consistent between *in situ* data and algorithm?

Discussion points

- Where are the critical shortcomings and needs?
- What is ready for operational agencies to pick up
- Algorithms development and validation: what actions are needed?
- What is needed from *in situ* observations?
- What are the priority directions, evolution of needs?

Discussion points

- Where are the critical shortcomings and needs?
  - Lack of *in situ* phytoplankton carbon data
    - Lots from indirect, fewer from more direct methods.
    - Lots of uncertainties and assumptions.

Discussion points

- Algorithms development and validation: what actions are needed?
  - Improving semi-analytical algorithms to account for factors that affect POC/C_{phy}
  - Cell size and other parameters
  - Testing routinely against open databases – as we have for other OC parameters historically.
  - Metrics for selection – discussed in other sessions too…
    - Which statistics to use? How to combine?

Discussion points

- What is ready for operational agencies to pick up
  - Can derive POC to reasonable error in global open ocean with empirical relationships.
  - OC-CCI type methodology can be applied for carbon errors, and potentially used for blending where justified.

Discussion points

- What is needed from *in situ* observations?
  - More *in situ* data collection – community data bases (e.g. from modellers) have been very useful, but need work to improve accuracy and detail for satellite validation.
    - Community to derive a list of parameters
    - Community to develop best practice protocols as have been done for other variables. (keep in mind uncertainty calculations)
      - e.g counts to carbon

Discussion points

- What are the priority directions, evolution of needs?
  - Multiple, varied, lines of development for C_{phy} algorithms, necessary for improvement.
  - Continued work with modelling community – lots to be gained on this i.e. wrt C:Chl dynamics and physiology.
  - Community building in terms of *in situ* measurements (suggested by Heidi this morning)

Discussion points

- Where are the critical shortcomings and needs?
- What is ready for operational agencies to pick up
- Algorithms development and validation: what actions are needed?
- What is needed from *in situ* observations?
- What are the priority directions, evolution of needs?

Thanks to all co-authors, algorithm providers, contributors to CLEO session on carbon, ESA (funding and management of POCO).