PFT satellite algorithm intercomparison + validation plan

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International Ocean Colour Science Meeting 2013
Advancing Global Ocean Colour Observations

Acknowledgements

Algorithm developers for PFT data processing

IOCCG for project endorsement

JAXA for PFT workshop support under Global Change Observation Mission (GCOM-C)
(1st WS@Sapporo 2011, 2nd WS@Glasgow 2012)

NASA for SeaWiFS data (2003-2007) used in our analysis

ESA for SCHYMACHY data (2003-2007) used in our analysis

Many others for supporting PFT intercomparison activities

MEETING

EOS. Member Newspaper

Comparing Satellite-Based Phytoplankton Classification Methods

Satellite Phytoplankton Functional Type Algorithm Intercomparison Workshop; Sapporo, Japan, 22–23 November 2011

1st Intercomparison WS, Sapporo, 2011

2nd Intercomparison WS, Glasgow 2012

To obtain a community consensus as to spatial and temporal variability of PFTs as observed by satellite

→ To deliver our knowledge derived by ocean colour science to other disciplines

→ Not to reveal which algorithm is good or bad!

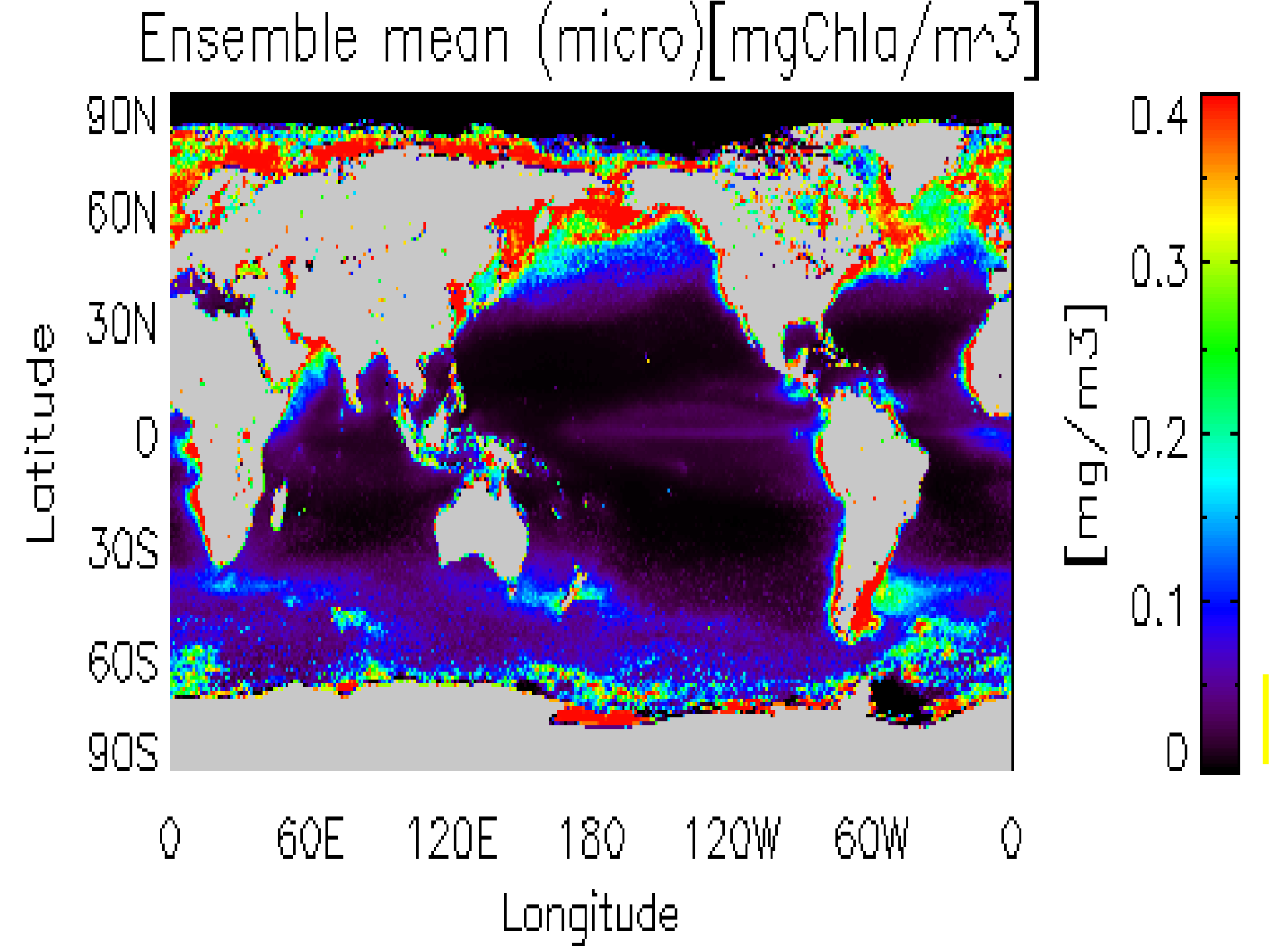
Working Group	Leaders
User Guide	N. Hardman-Mountford, C. Mouw
In situ Data	L. Clementson, R. Barlow, T. Hirawake
Algorithm Intercomparison	T. Hirata, T. Kostadinov
Algorithm Validation	R.J.W. Brewin, A. Bracher

Algorithms used for intercomparison

Algorithm providers	References	Approach	PFTs retrieved	Satellite data
Alvain et al. (CNRS)	Alvan et al., DSR, 2005, Alvain et al., GBC, 2008	Optical (nLw)	Diatoms, Nanoeucaryotes, Prochlorococcus sp., Cyanobacteria, Phaeocystis-like, cocolithophores	SeaWiFS R2010
Bracher et [illegible] (U. Bremen/ AW[illegible]	Bracher et al., Biogeosci., 2009, Sedaghi et al., [illegible]geosci., 2012	Optical (a_{ph})	Diatoms, Cocolithophores, Cyanobacteria	SCHYMACHY
Brewin et al.(PML)	Bre[illegible]Ecological Modelling[illegible]	Abandance (Chla)	Micro, Nano, Pico	SeaWiFS R2010
Bricaud et al. (LOV)	Ciotti & Bricaud, L&O[illegible] Methods, 2006, Bricaud et al., GBC, 2012	Optical (a_{ph})	Micro, Pico	SeaWiFS R2010
Hirata et al. (Hokkaido U)	Hirata et al., Biogeosci., 2011	Abandan[illegible] (Chla)	Micro, Nano, Pico, Diatoms, [illegible]hytes, Green Algae, Pico-E[illegible] Cyanobacteria, Prochl[illegible]	SeaWiFS R2010
Hirawake et al. (Hokkaido U)	Fujiwara et al., Biogeosci., 2011	Optical (a_{ph})	Micro, Nano, Pi[illegible]	SeaWiFS R2010
Kostadinov et al. (U. of Richmond)	Kostadinov et al., Biogeosci., 2010	Optical (b_{bp})	Micro, Nano, Pico	[illegible]WiFS R2010
Uitz et al. (LOV)	Uitz et al., JGR-Oceans, 2006	Avandance (Chla)	Micro, Nano, Pico	SeaWiFS R2010 NOTE: MLD required
Roy et al. (U. Oxford)	Roy et al., J. Roy. Soc. Interface, 2011	Optical (a_{ph})	Micro, Nano, Pico	SeaWiFS R2010

Only Microplankton and Picoplankton (most common among these algors) are analyzed

Preliminary Results of Spatial Comparison


Ensemble mean (micro)[mgChla/m^3]
90N
60N
30N
0
30S
60S
90S
Latitude
0
60E
120E
180
120W
60W
0
Longitude
0.4
0.3
0.2
0.1
0
[mg/m3]

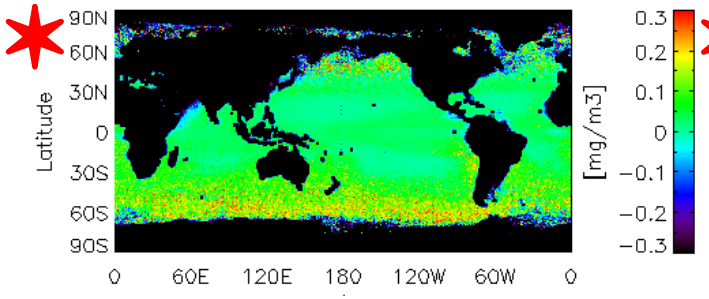
2003-2007 Bias Field (Micro-EnMean [mg/m^3])

Opitcs

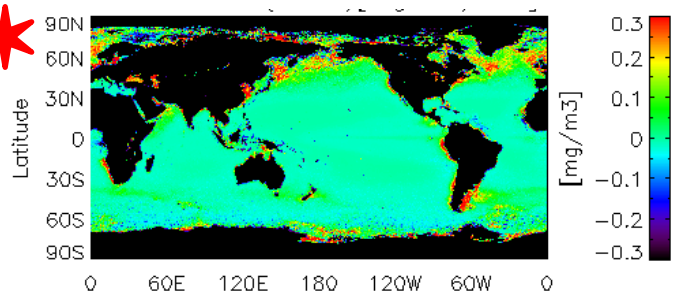
Abundance

Tends to agree among algorithms, except in higher latitudes

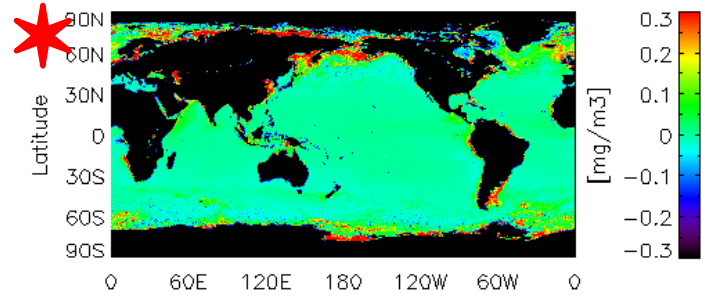
Bracher et al. (SCHIMACHY Diatoms)



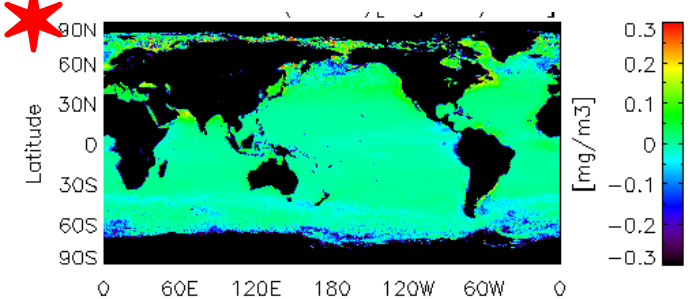
Bricaud et al..



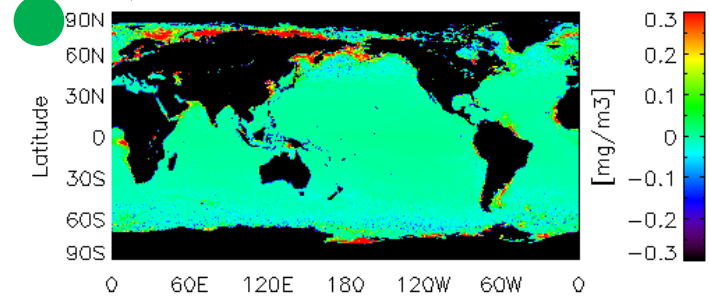
Hirawake et al



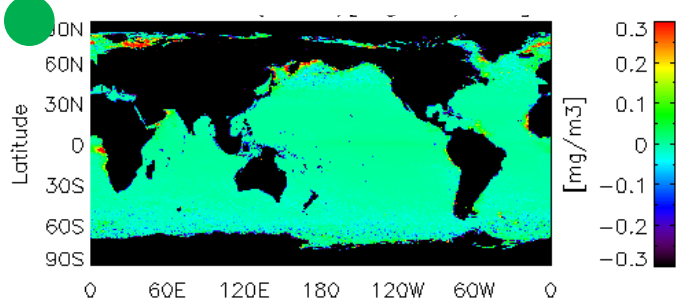
Roy et al.



Brewin et al.

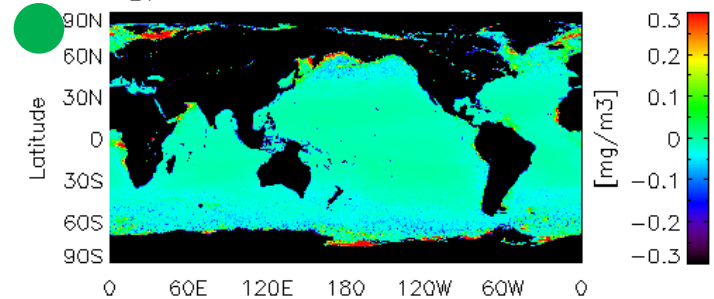


Uitz et al.

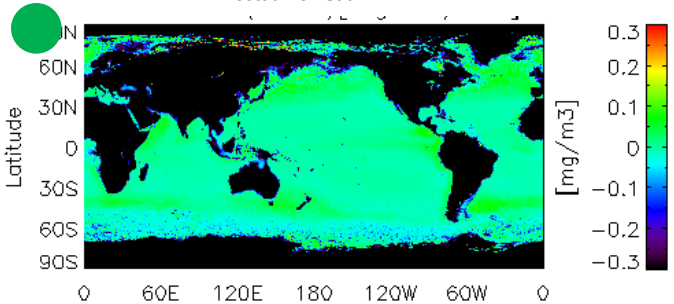


Bi

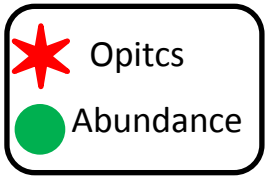
Hirata et al.



Kostadinov et al.



Microplankton [mg/m^3] Basin Average (2003-2007)



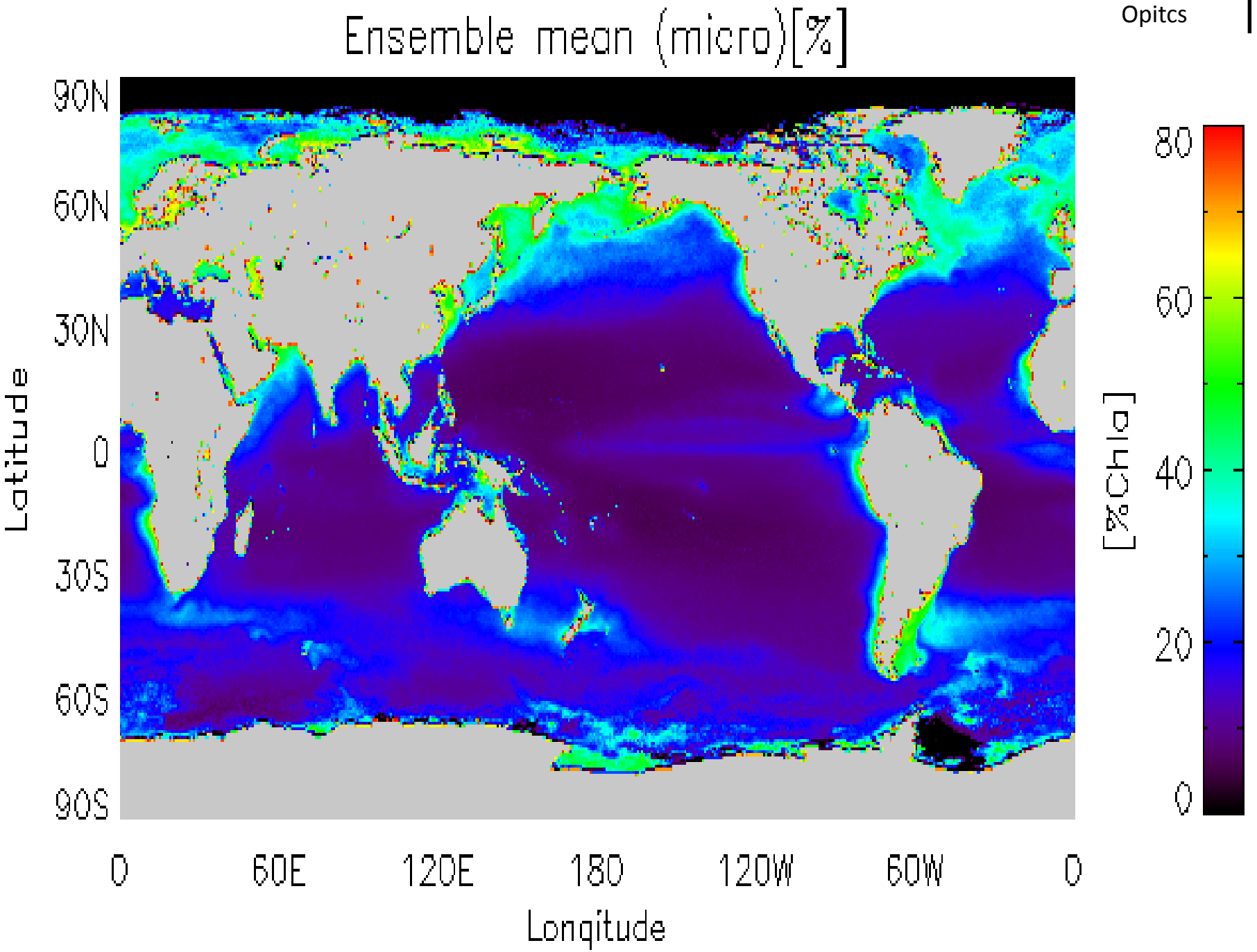
	Bracher et al.	Bricaud et al.	Hirawake et al.	Roy et al.	Kostadinov et al.	Brewin et al.	Uitz et al.	Hirata et al.	Ave
ARC	0.319	0.759	0.866	0.359	0.495	0.892	0.399	0.400	0.561
SOC	0.356	0.243	0.294	0.089	0.117	0.231	0.152	0.231	0.214
NAT	0.076	0.247	0.252	0.138	0.155	0.229	0.116	0.092	0.163
SAT	0.143	0.071	0.069	0.051	0.059	0.061	0.039	0.023	0.064
NPC	0.066	0.190	0.198	0.115	0.131	0.191	0.081	0.081	0.132
SPC	0.072	0.060	0.064	0.047	0.054	0.069	0.052	0.044	0.058

	Optics	Abundance	Relative diff.[%]
ARC	0.639	0.432	19.351
SOC	0.243	0.167	18.541
NAT	0.188	0.121	21.667
SAT	0.079	0.041	31.752
NPC	0.152	0.098	21.667
SPC	0.062	0.050	10.972

1. Optical > Abundance in general

1. Difference due to approach is evident

2. ARC > SOC > NAT > NPC > SAT > SPC

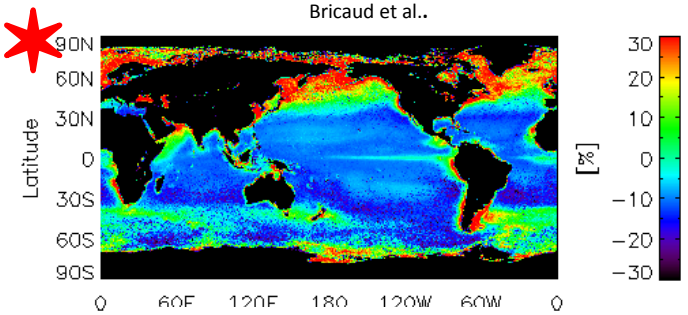

Ensemble mean (micro)[%]
90N
60N
30N
0
30S
60S
90S
Latitude
0
60E
120E
180
120W
60W
0
Longitude
80
60
40
20
0
[%Chla]
Longitude
Longitude

2003-2007 Bias Field (Micro [%]-EnMean)

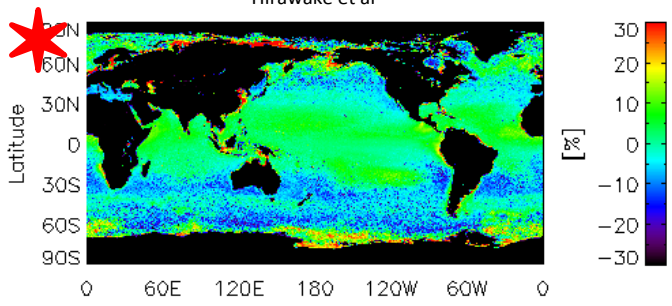
Opitcs

Abundance

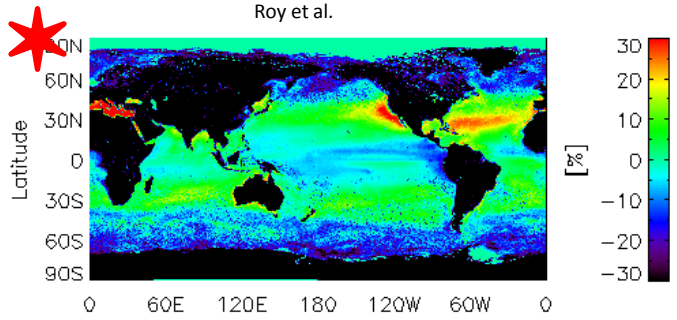
Bricaud et al..



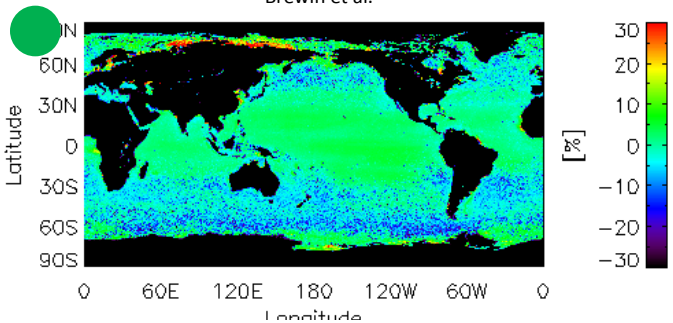
Hirawake et al



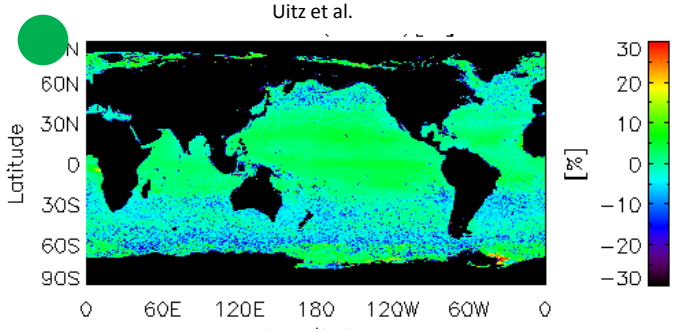
Roy et al.



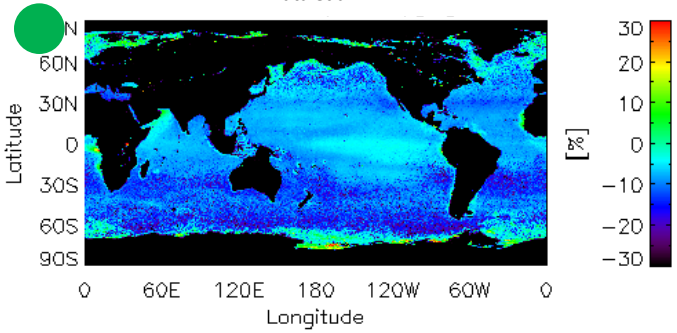
Brewin et al.



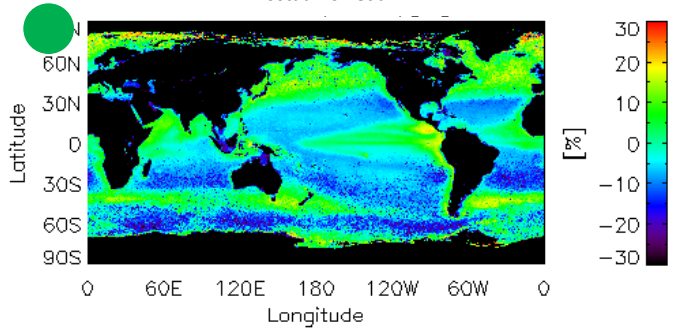
Uitz et al.



Hirata et al.

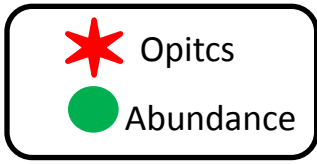


Kostadinov et al.



More difference is found in [%] than in [mg/m^3]

Microplankton [%] Basin Average (2003-2007)



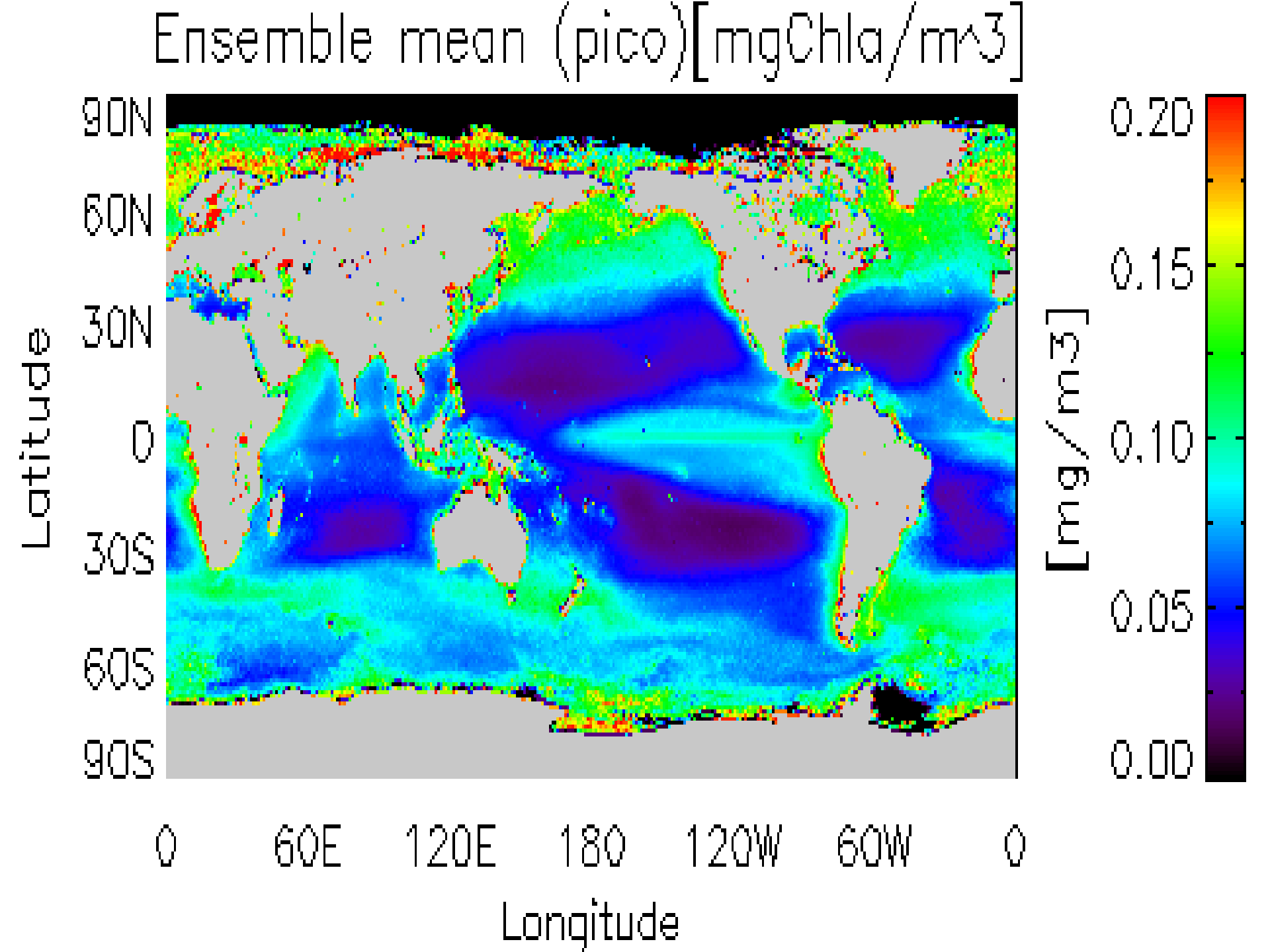
	Bracher et al.	Bricaud et al.	Hirawake et al.	Roy et al.	Kostadinov et al.	Brewin et al.	Uitz et al.	Hirata et al.	Ave
ARC	N/A	62.67	39.43	3.22	40.73	36.61	31.63	27.09	34.4
SOC	N/A	27.05	29.46	5.45	20.32	22.80	24.81	16.77	20.95
NAT	N/A	21.82	23.93	16.89	19.24	21.04	18.59	9.57	18.72
SAT	N/A	13.91	17.61	17.16	17.60	17.46	17.46	8.17	15.62
NPC	N/A	19.93	23.49	27.73	21.29	20.59	18.90	10.78	20.38
SPC	N/A	11.55	16.40	19.02	15.33	16.79	17.23	8.16	14.92

	Optics	Abundance	Relative diff [%]
ARC	36.51	31.77	6.93
SOC	20.57	21.46	-2.11
NAT	20.47	16.40	11.03
SAT	16.57	14.36	7.13
NPC	23.11	16.75	15.93
SPC	15.57	14.06	5.11

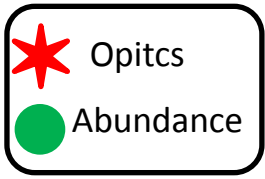
1. Optical > Abundance in general but values are more similar than the comparison in [mg/m^3]

2. Difference due to approach is more remarkable in NAT & NPC

3. ARC > SOC > **NPC > NAT** > SAT > SPC


Ensemble mean (pico)[mgChla/m^3]
90N
60N
30N
0
30S
60S
90S
Latitude
0
60E
120E
180
120W
60W
0
Longitude
0.20
0.15
0.10
0.05
0.00
[mg/m3]

Picoplankton [mg/m^3] Basin Average (2003-2007)

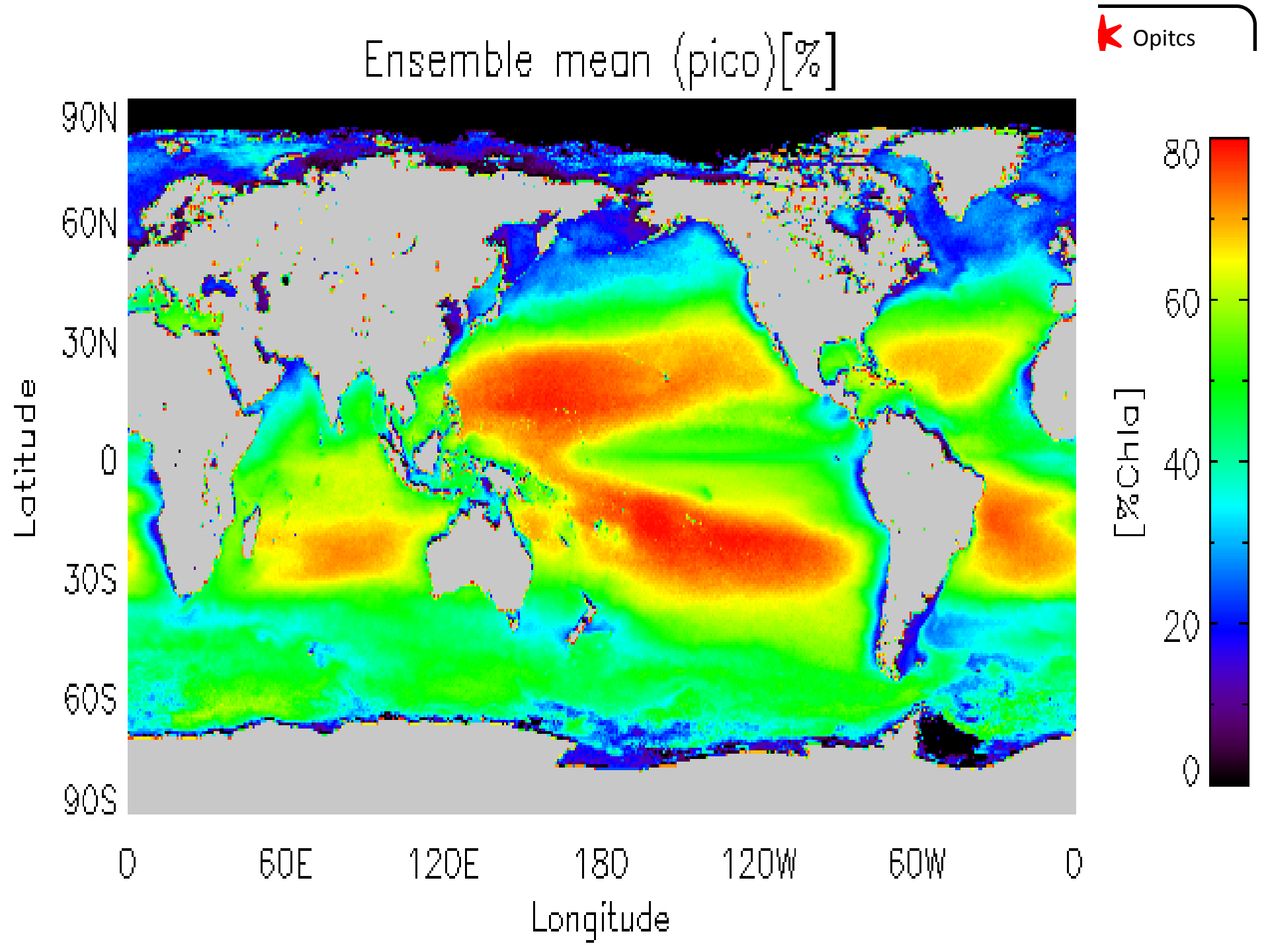


	Bracher et al.	Bricaud et al.	Hirawake et al.	Roy et al.	Kostadinov et al.	Brewin et al.	Uitz et al.	Hirata et al.	Ave
ARC	0.237	0.192	0.223	0.103	0.102	0.103	0.135	0.161	0.157
SOC	0.002	0.168	0.114	0.128	0.081	0.082	0.085	0.109	0.096
NAT	0.010	0.134	0.102	0.053	0.063	0.064	0.065	0.072	0.070
SAT	0.024	0.150	0.101	0.066	0.065	0.069	0.065	0.069	0.076
NPC	0.008	0.157	0.108	0.050	0.067	0.072	0.073	0.082	0.077
SPC	0.015	0.142	0.093	0.062	0.057	0.064	0.063	0.068	0.070

	Optics	Abundance	Relative diff.[%]
ARC	0.171	0.133	12.614
SOC	0.098	0.092	3.462
NAT	0.072	0.067	3.873
SAT	0.081	0.067	9.090
NPC	0.078	0.075	1.518
SPC	0.073	0.065	6.340

1. Optical > Abundance (especially in high latitudes = ARC) but the difference between optics- and abundance-based is less than in Micro

2. ARC > SOC > NPC > SAT ≥ NAT ≥ SPC


Opitcs
Ensemble mean (pico)[%]
90N
60N
30N
0
30S
60S
90S
Latitude
0
60E
120E
180
120W
60W
0
Longitude
80
60
40
20
0
[%Chla]

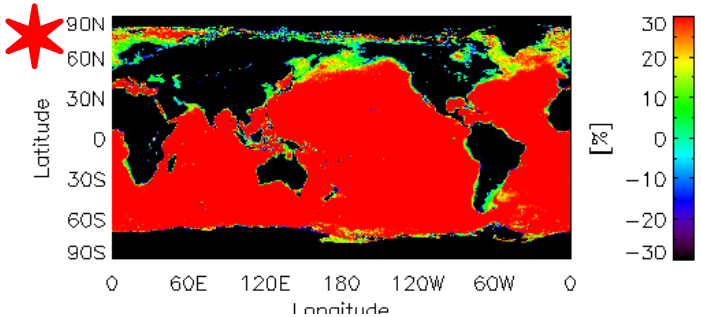
2003-2007 Bias Field (Pico -EnMean[%])

Opitcs

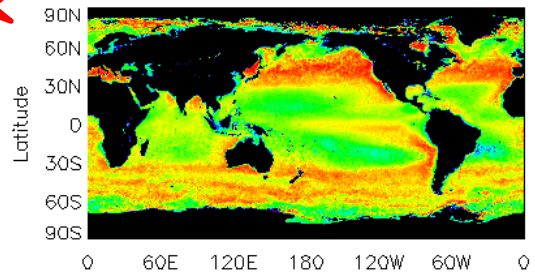
Abundance

In general, bias is larger in the subtropical gyres and/or Antarctic polar front, regardless of algorithms

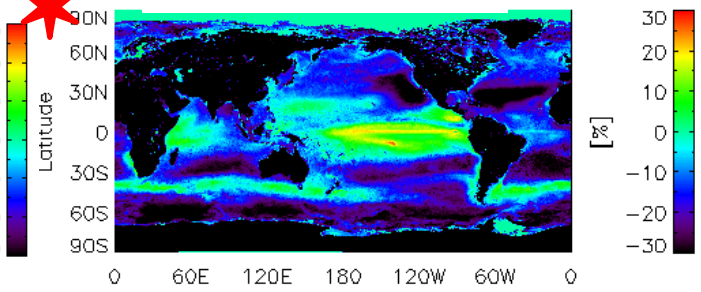
Bricaud et al..



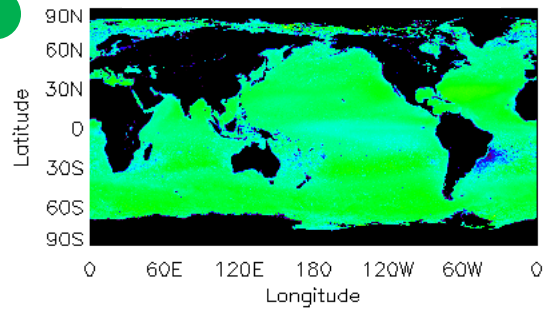
Hirawake et al



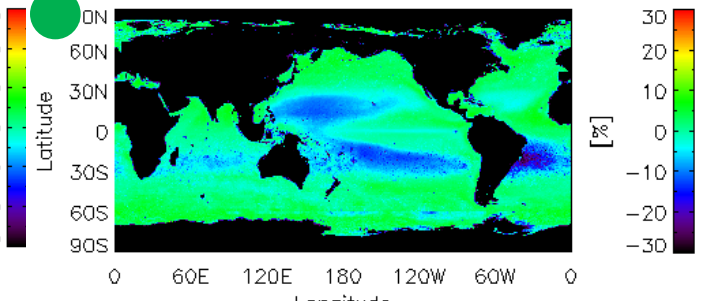
Roy et al.



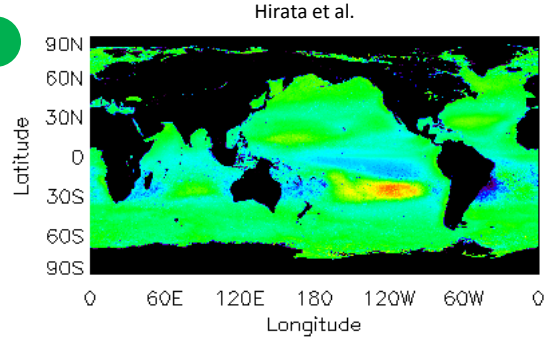
Brewin et al.



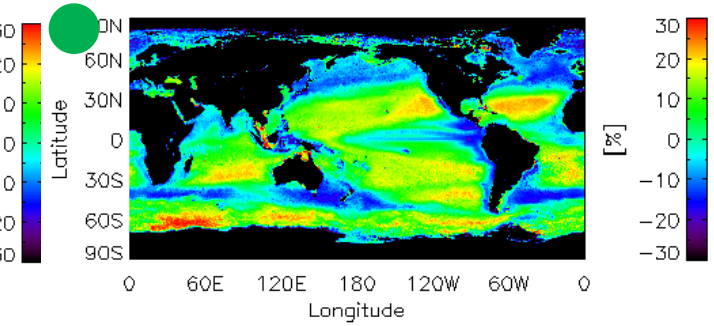
Uitz et al.



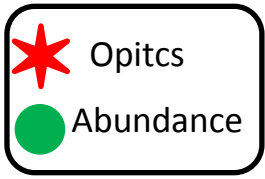
Hirata et al.



Kostadinov et al.



Picoplankton [%] Basin Average (2003-2007)



	Bracher et al.	Bricaud et al.	Hirawake et al.	Roy et al.	Kostadinov et al.	Brewin et al.	Uitz et al.	Hirata et al.	Ave
ARC	N/A	37.26	34.80	0.72	13.50	18.39	24.65	29.92	34.48
SOC	N/A	71.81	43.86	5.22	40.50	34.84	33.00	36.51	20.95
NAT	N/A	49.67	55.04	32.71	44.66	43.02	42.80	49.30	18.72
SAT	N/A	80.55	59.12	32.16	42.97	43.18	41.51	43.21	15.62
NPC	N/A	69.41	54.42	18.46	37.90	40.04	41.06	43.15	20.38
SPC	N/A	78.56	60.77	31.23	48.03	45.75	42.54	45.45	14.92

	Optics	Abundance	Relative diff.[%]
ARC	36.51	31.77	6.93
SOC	20.57	21.46	-2.11
NAT	20.47	16.40	11.03
SAT	16.57	14.36	7.13
NPC	23.11	16.75	15.93
SPC	15.57	14.06	5.11

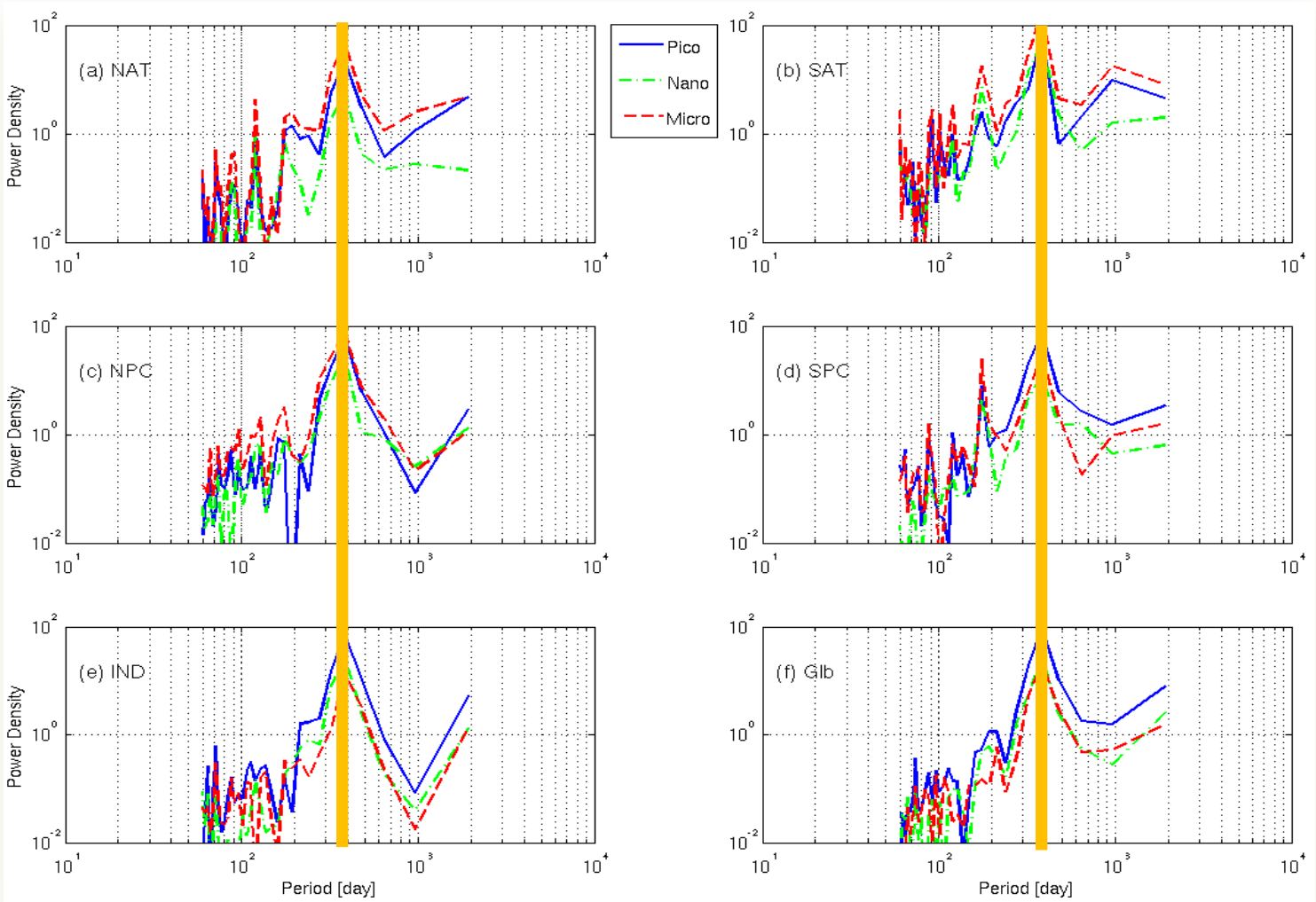
1. Optical > Abundance in general

1. Difference due to approaches is more remarkable in NAT & SAT

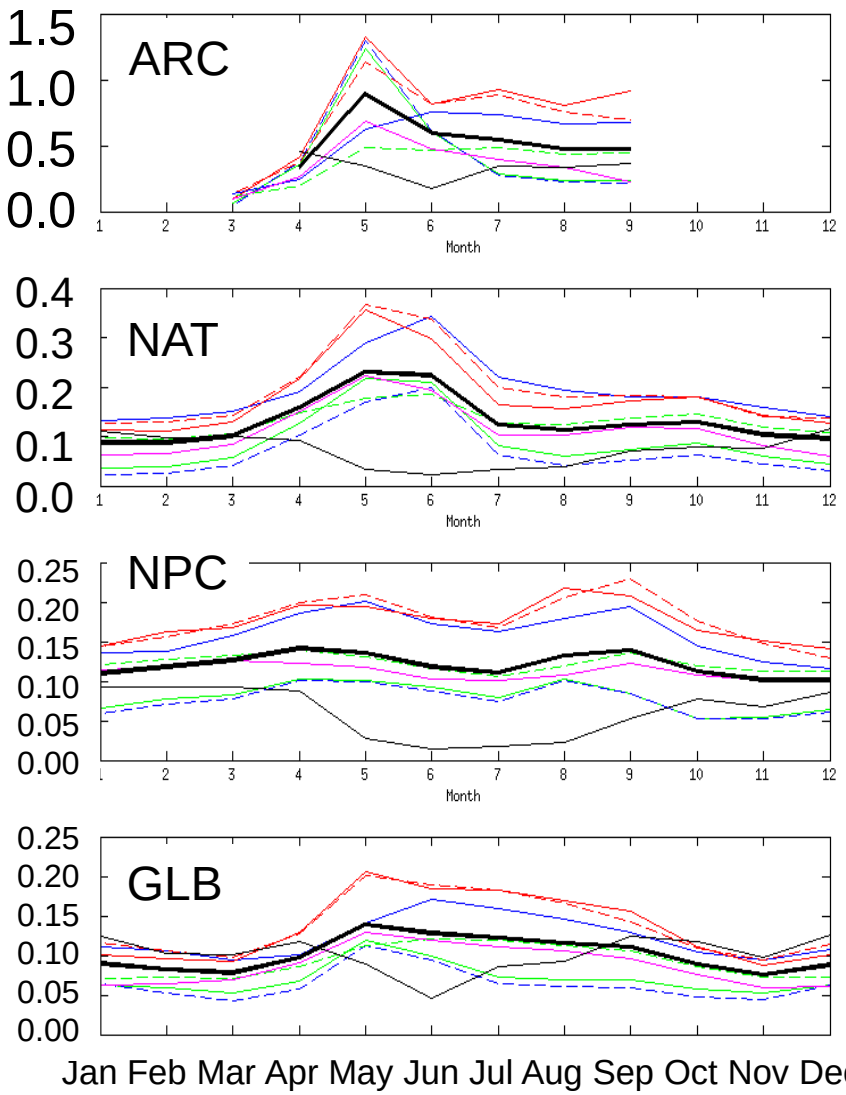
3. ARC > SOC > NPC > NAT > SAT > SPC

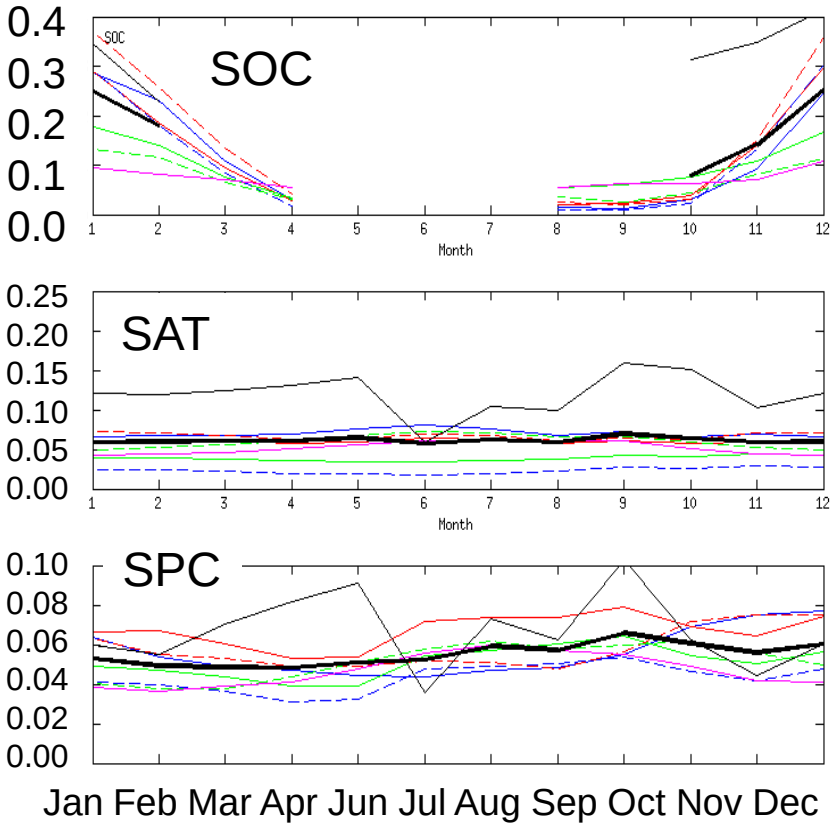
Preliminary Results of Temporal Comparison

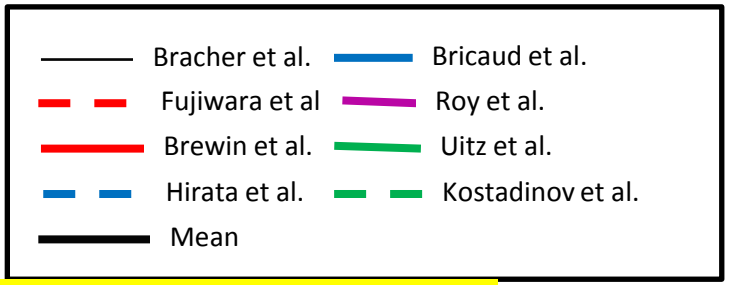
Seasonality is most dominant in PFT dynamics



Microplankton [mg/m^3]: Seasonality (monthly climatology)

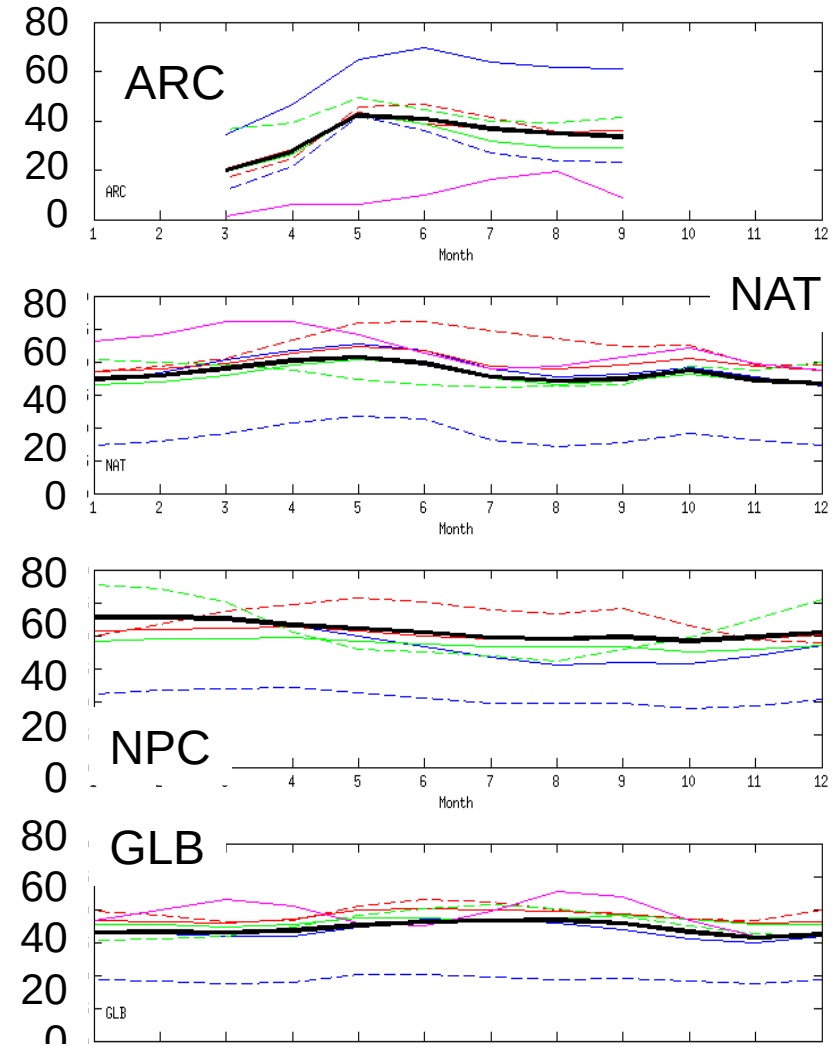


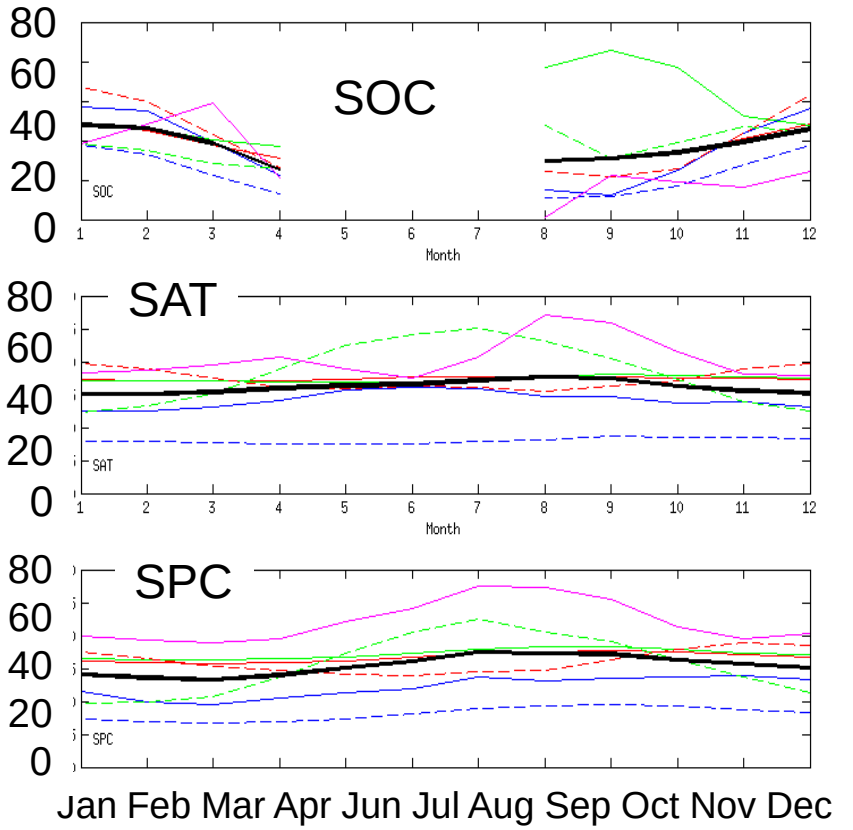




Peak timing generally agrees

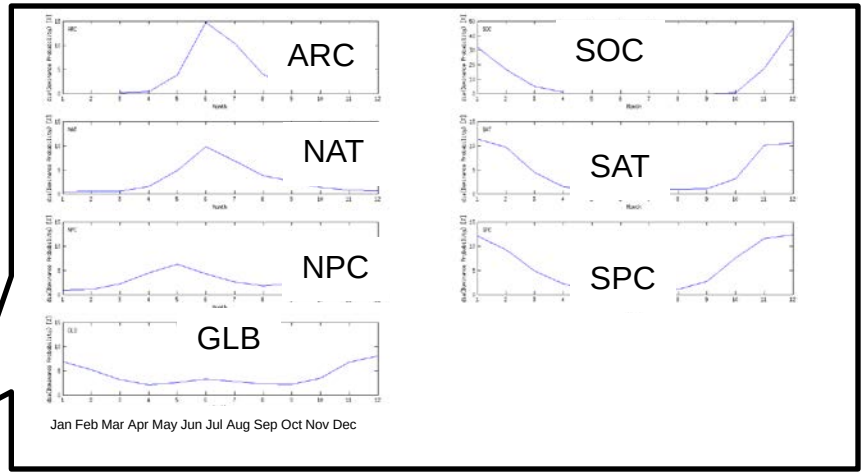
Microplankton [%]: Seasonality (monthly climatology)



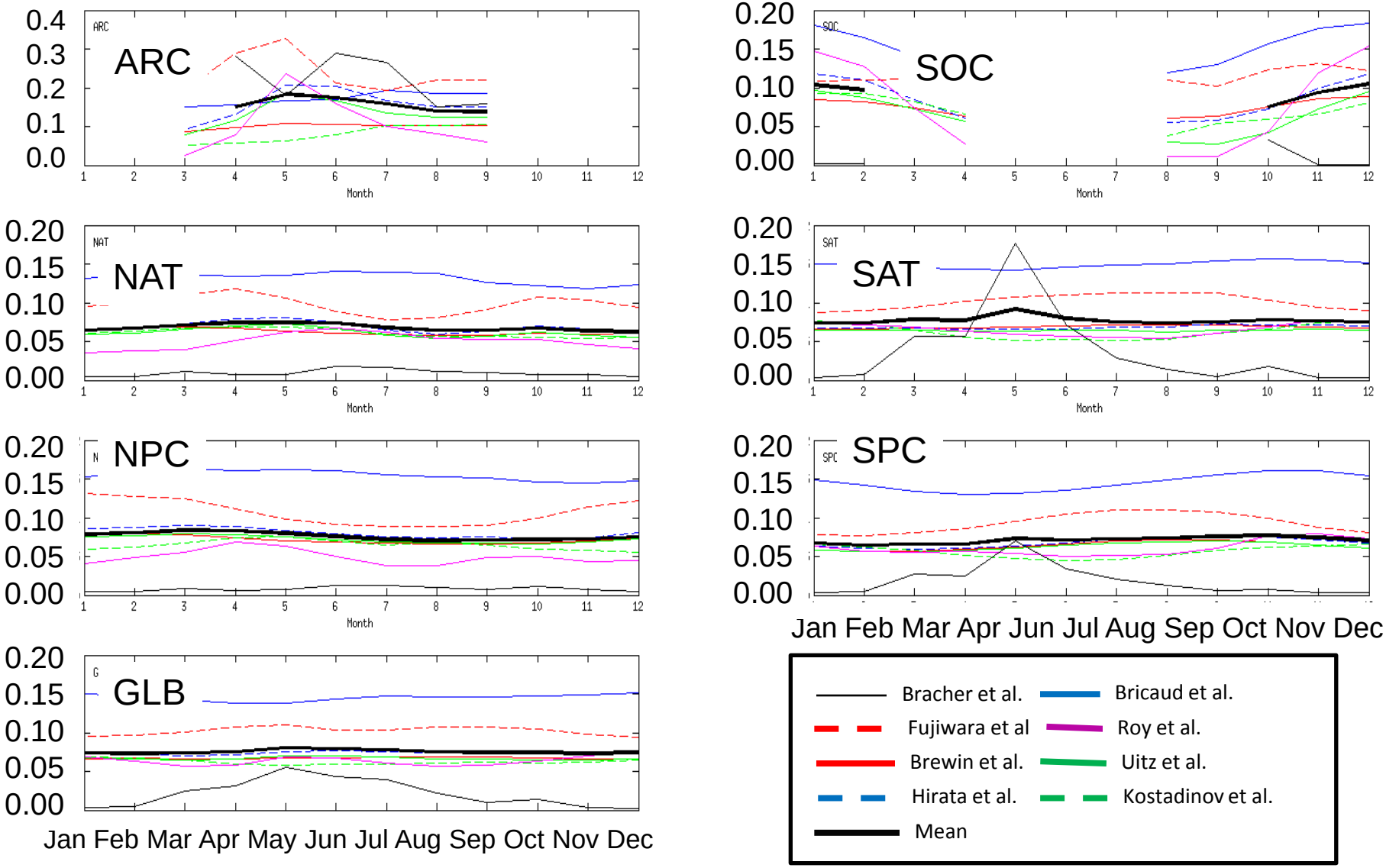


Bracher et al.
Fujiwara et al
Brewin et al.
Hirata et al.
Mean
Bricaud et al.
Roy et al.
Uitz et al.
Kostadinov et al.

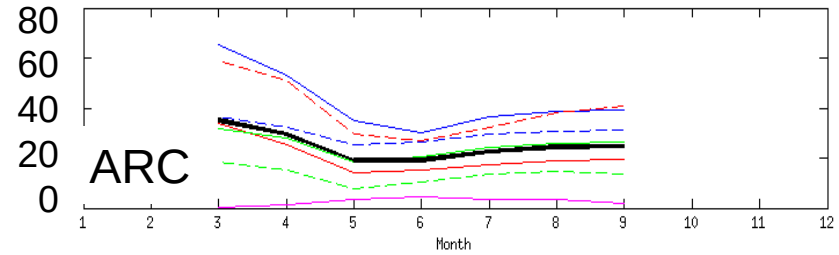
Alvain et al.
Diatom algor.

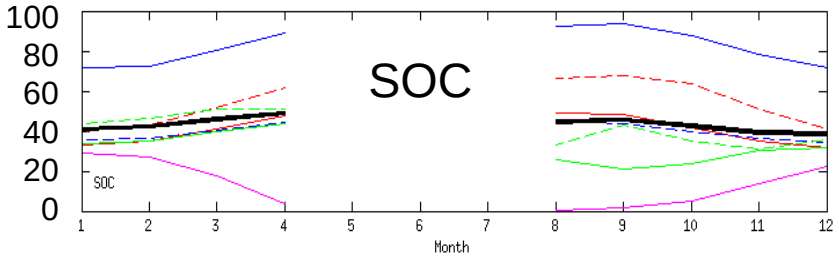


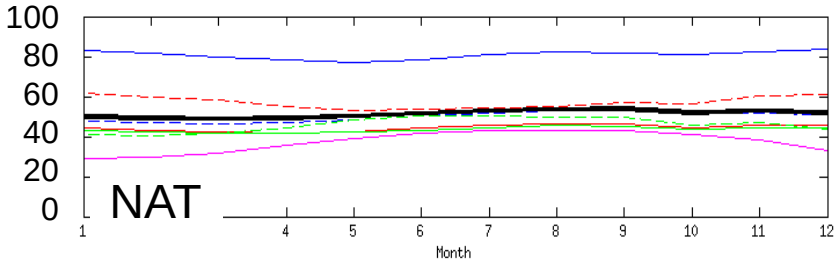
Picoplankton [mg/m^3]: Seasonality (monthly climatology)

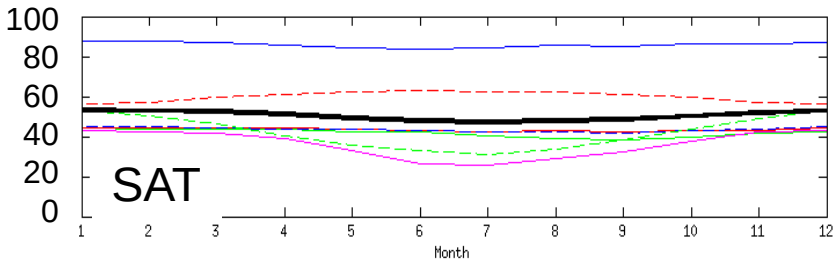


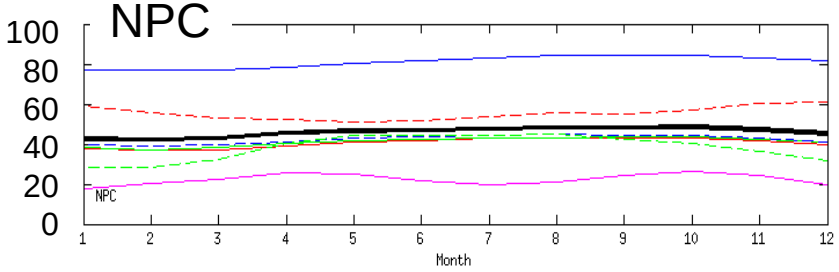
Picoplankton [%]: Seasonality (monthly climatology)

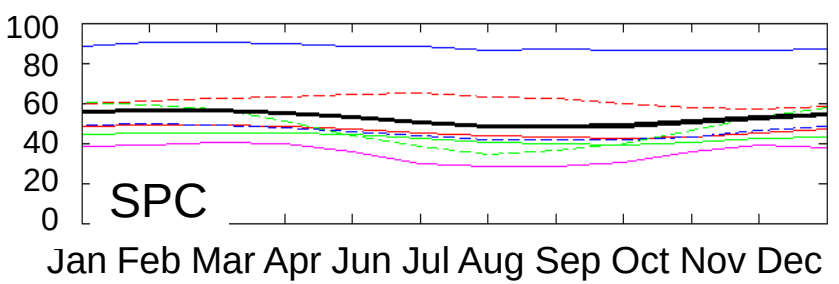


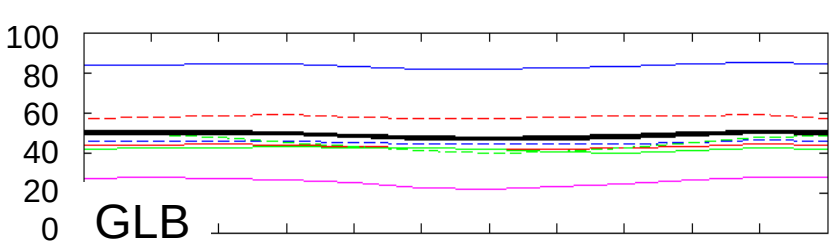


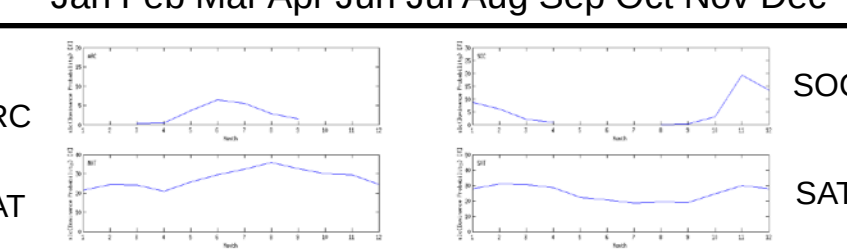












Bracher et al.
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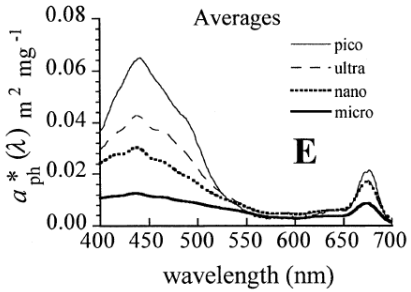
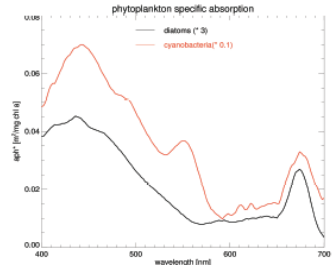
Roy et al.
Brewin et al.
Uitz et al.
Hirata et al.
Kostadinov et al.
Mean

Alvain et al. Synecho-like algor.

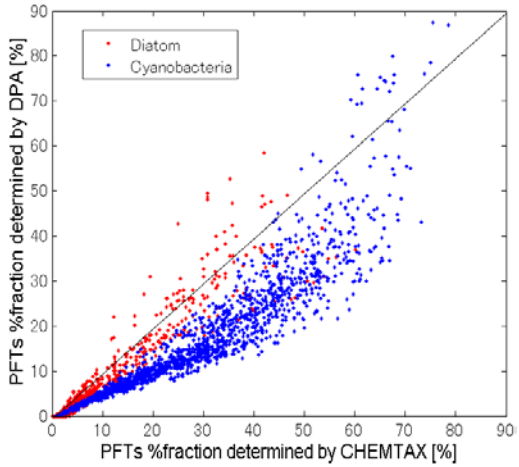
	Micro	Pico	Algorithm
Size Definition	> 20µm	< 2µm	Kostadinov et al.
HPLC Definition	Fucoxanthin (DPA, CHEMTAX etc)	Zeaxanthin (DPA, CHEMTAX etc)	Alvain et al., Brewin et al., Hirata et al., Uitz et al.
a_{ph} Definition	a_{ph}* for > 20µm a_{ph}* from dominant Fuco samples	a_{ph}* vs for < 2µm a_{ph}* from dominant Zea samples	Bricaud et al. Hirawake et al. Roy et al. Bracher et al.



Ciotti et al., 2002



Bracher et al., 2009



Comparison between DPA & CHEMTAX using NOMAD data set (Werdell and Bailey, 2005)

Algorithm Validation Plan

Algorithm Comparison: Guiding Principles

- Approach should be independent from the algorithm developers
- Need to consider what is important for the eventual end users e.g. oceanographic model assimilation
- Need to find parameters for comparison;
  - May not exist within the outputs of all the algorithms or be an indirect output (e.g. dominance frequencies)
  - It's likely to require an element of modelling and/or making certain assumptions for the in-situ data.
- Where possible, validation in-situ data should not have been used in algorithm development or (if not possible) dependency needs to be quantified
- Should the PFT algorithms be partitioned into common categories? Or perform an overarching comparison incorporating all techniques?

Algorithm Comparison: Proposed Steps

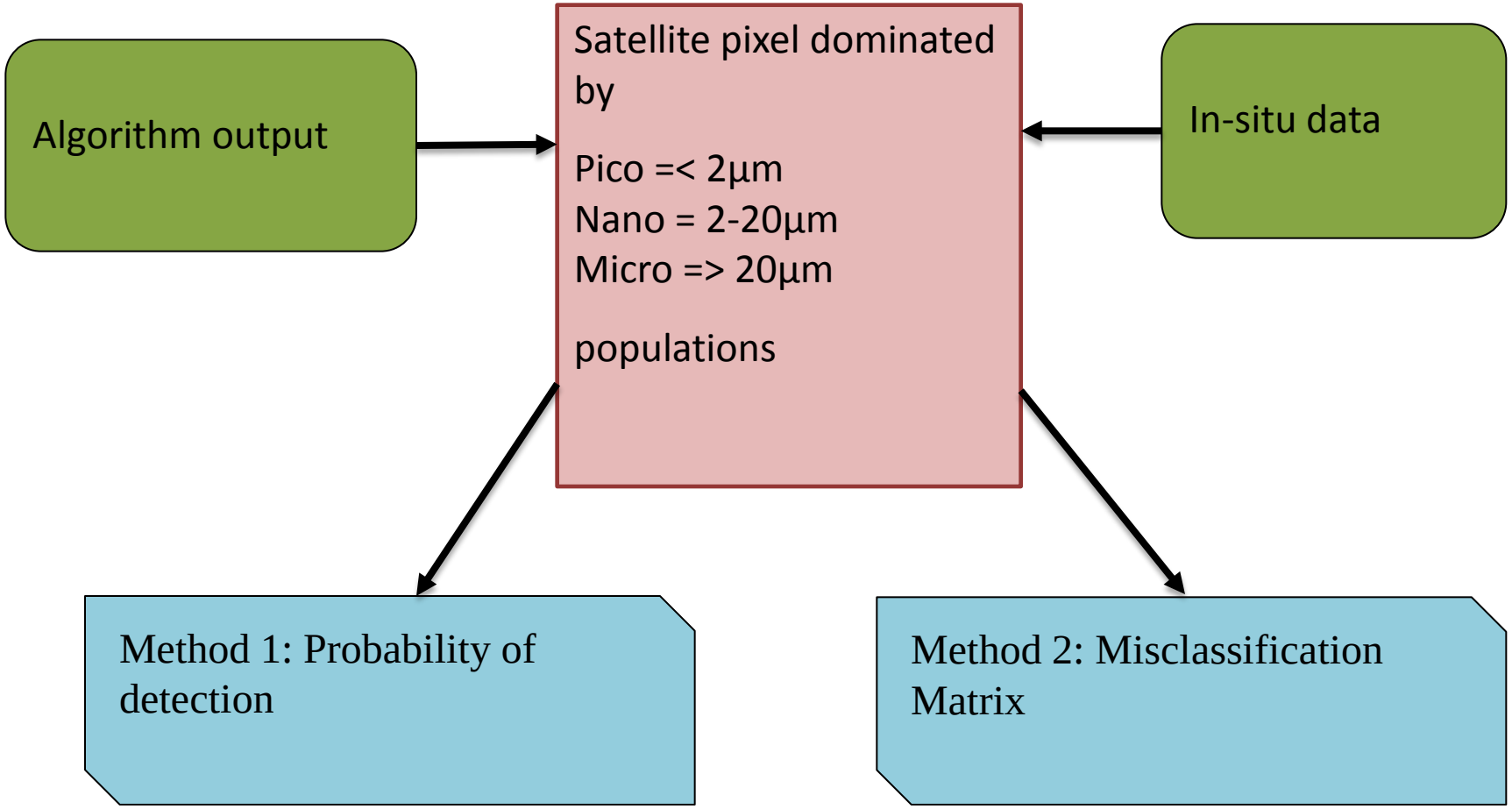
PFT workshops @ Sapporo 2011, @Glasgow 2012

1) Repeat previous work as conducted by Brewin et al (2011, RSE):
   - To see if there have been improvements since the previous comparison and included further algorithms where available.
   - However, the approach may be deemed biased toward size-models and less suitable for PFT models.
   - Also, fractionation rather than just dominance may now be considered more relevant.
   - Therefore, include further approaches…

2) Independent validation against most-relevant in-situ data

3) Time-series analysis as PFT vs. in-situ and PFT vs. PFT comparisons

1) Dominant Phytoplankton Size Class Comparison on Pixel Basis i.e. repeat Brewin et al (2011, RSE)

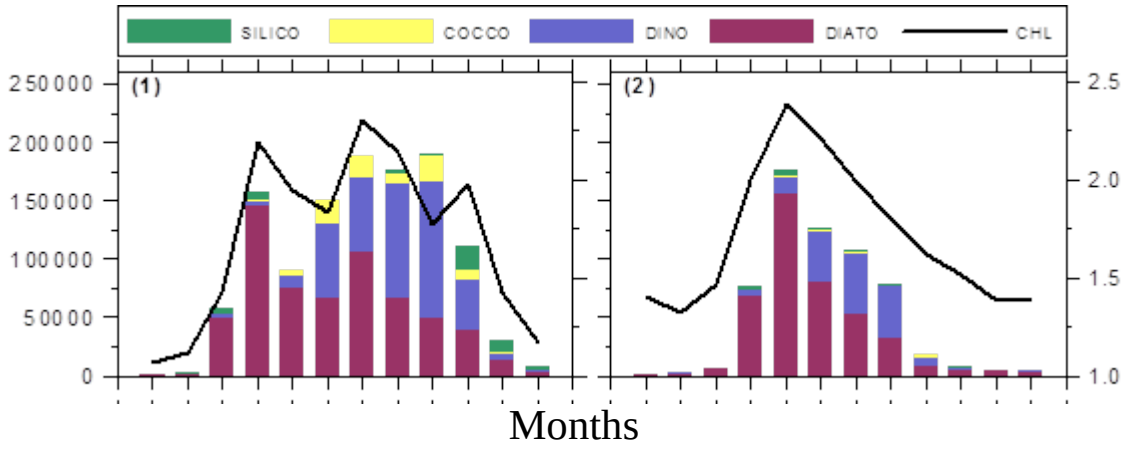


2) Independent Validation Against In-Situ Data

- Independent validation against in-situ data
  - Satellite input is fraction / percentage of each PFT population
  - Estimate of uncertainty for both in-situ and satellite data needed
- Approach:
  - Calculate statistics: Pearson correlation coefficient (r); Type 2 regression (slope and intercept); Root Mean Square Error (RMSE); Bias; Number of samples
  - Score statistics .e.g. as undertaken within Ocean Colour CCI intercomparison on basis of mean of all models
  - Plot frequency distribution, Taylor and Target diagrams

2) Time-Series Analysis

- Ability to produce a realistic time-series (phytoplankton seasonality) e.g.
  - plotting of time-series (Hoffmueller) diagrams and climatological plots (see below)
  - calculating time-lagged correlation coefficients
- Potential PFT comparison data sources: BATS, CPR, HOTS & L4



Example for plotting: part of Fig. 8.2 from Lavender et al. (2008, RS of the European Seas) showing climatological monthly plots for CPR cell counts and Chl-a

Summary

1. Optical- approach tends to show higher values than abundance-based in Microplankton

2. Discrepancy among algorithms using different sensors are obvious (but need an attention to interpret this result)

3. Generally, larger discrepancy among algorithms tends to appear in higher latitudes, and in [%] than in [mg/m^3]
   (more focus should be directed to higher latitudes)

4. Picoplankton [%] showed a relatively larger discrepancies among algorithms
   (more focus should be directed to Picoplankton than Microplankton)

- Microplankton abundance:
  ARC > SOC > NAT > NPC > SAT > SPC in [mg/m^3]
  ARC > SOC > NPC > NAT > SAT > SPC in [%]

- Picoplankton adundance:
  ARC > SOC > NPC > SAT ≥ NAT ≥ SPC in [mg/m^3]
  ARC > SOC > NPC > NAT > SAT > SPC in [%]

Validation protocol is being constructed in reference to Brewin et al., 2011