Investigation of the role of phytoplankton functional types in CO_2 flux variability
Stage 1 Intercomparison of PFT techniques: Microplankton

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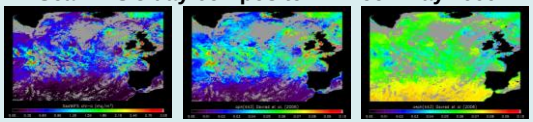
ABSTRACT

Satellite remote sensing of ocean colour is currently the only way of measuring synoptically wide-area ocean properties such as phytoplankton abundance (Lavender et al. 2005). Recent bio-optical and ecological methods have been established that use satellite data to differentiate between certain phytoplankton functional types (PFTs) e.g. Ciotti *et al.* (2002); Sathyendranath *et al.* (2004); Alvain *et al.* (2005); Uitz *et al.* (2006); Devred *et al.* (2006); Raitsos *et al*. (2008); and Hirata *et al.* (In press). We apply these techniques to an 8 day SeaWIFS ocean colour dataset from May 1999, and compare the results to an *in situ* dataset from the CPR database, in order to assess their ability to detect microplankton in the North Atlantic. Uitz *et al.* (2006) and Devred *et al.* (2006) were found to have the closest degree of correlation, and Hirata *et al.* (In press) and Alvain *et al*. (2005) were found to predict the highest amount of dominant microplankton pixels. From the *in situ* comparison, Hirata *et al.* (In press) was found to have the highest percentage match up (60-63%), and Devred *et al.* (2006) and Raitsos *et al.* (2008) had the highest non-dominance factor, indicating that these three techniques were most accurate at identifying microplankton. However, a need for more *in situ* data was highlighted. For future work, focus will also be put on picoplankton and nanoplankton, and output from the intercomparison will be compared to CO_2 flux variation hindcasts developed within the FOAM-HadOCC system, to better understand the contribution of different PFTs to global CO_2 flux variability.

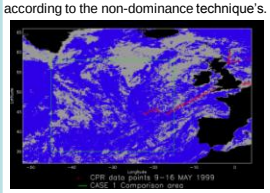
SeaWIFS 8 day composite 2nd week May 1999



Chl-a $a_{ph}(443)$ $a^*_{ph}(443)$

METHODOLOGY

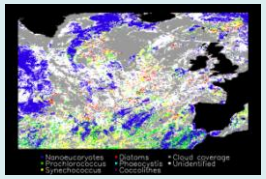
SeaWIFS 8 day composite for the 2nd week of May 1999 was downloaded from the NASA Oceancolor website (http://oceancolor.gsfc.nasa.gov/). $a_{ph}(\lambda)$ and $a^*_{ph}(\lambda)$ data for the week was calculated according to Bricaud et al. (1995), Sathyendranath *et al.* (2001) and Devred *et al.* (2006). Apparent Optical Property (AOP) approaches of Alvain et al. (2005, In press), Uitz et al. (2006), Raitsos et al. (2008), and Hirata et al. (In press) (using Chl-a), were applied to the dataset, and output from the NASA Ocean Biogeochemical Model (NOBM) for the week was also utilised. The Inherent Optical Property (IOP) approaches of Hirata *et al.* (In press) (using $a_{ph}(443)$), Devred *et al.* (2006), and Ciotti *et al.* (2002) (using $a^*_{ph}(443)$) were also applied to the dataset. Output was then split between the techniques that calculate dominance and those that calculate non-dominance (e.g. probability, percentage), and sub-sected to the CASE 1 comparison area (shown by the green box in the figure below). The non-dominance techniques were then regressed against each other in order to assess similarities and differences between the techniques, and the dominance techniques were compared by assessing the amount of pixels that identified microplankton. These two approaches were then combined by assessing where the dominance technique's assigned microplankton, to the respective values calculated according to the non-dominance technique's.



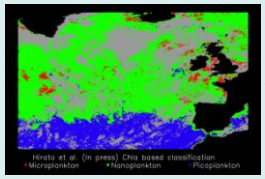
CPR data for the same week was used to provide *in situ* validation (as shown by the red points in the left figure), and output from the various PFT techniques were matched up with the *in situ* data on a pixel by pixel basis, in order to determine the most appropriate approach for detecting microplankton.

Methods of Identifying PFT from space (AOP)

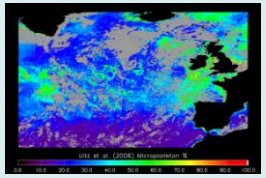
Alvain *et al.* (2005, In press)



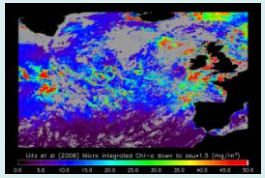
Hirata *et al.* (In press) Chl-a



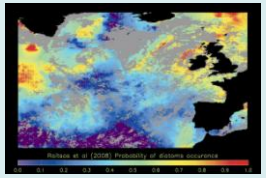
Uitz *et al.* (2006) % Micro



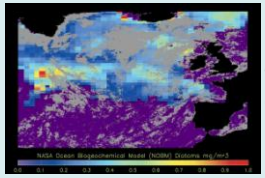
Uitz *et al.* (2006) 1.5*Z_{eu} Micro



Raitsos *et al.* (2008)

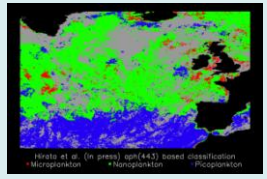


NASA Ocean Biogeo-chemical Model (NOBM)

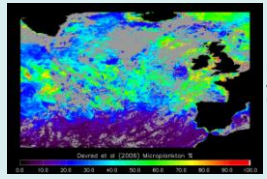


Methods of Identifying PFT from space (IOP)

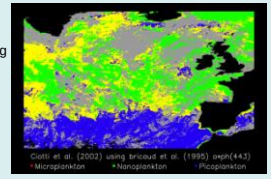
Hirata *et al.* (In press) $a_{ph}(443)$



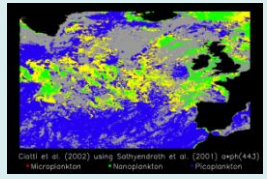
Devred *et al.* (2006)



Ciotti *et al.* (2002) using Bricaud *et al.* (1995) a*ph(443)



Ciotti *et al.* (2002) using Sathyen-dranath *et al.* (2001) a*ph(443)



RESULT 1: Intercomparison between the different PFT methods

X	Y	Pearson correlation coefficient
Raitsos *et al.* (2006)	NOBM	0.43
Raitsos *et al.* (2006)	Devred *et al.* (2006)	0.35
Raitsos *et al.* (2006)	Uitz et al. (2006) Integrated micro chla (1.5*Zeu)	0.22
Raitsos *et al.* (2006)	Uitz et al. (2006) Micro %	0.25
NOBM	Devred *et al.* (2006)	0.65
NOBM	Uitz et al. (2006) Integrated micro chla (1.5*Zeu)	0.47
NOBM	Uitz et al. (2006) Micro %	0.47
Devred *et al.* (2006)	Uitz et al. (2006) Integrated micro chla (1.5*Zeu)	0.86
Devred *et al.* (2006)	Uitz et al. (2006) Micro %	0.88

Table 1: Regression between non-dominance techniques

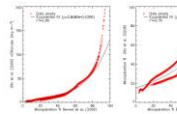


Figure 1: Devred *et al.* (2006) and Uitz *et al.* (2006)

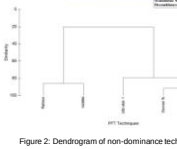


Figure 2: Dendrogram of non-dominance techniques

The non-dominance techniques were regressed against each other, and it was found that Devred *et al.* (2006) and Uitz *et al*. (2006) were the most similar, with a Pearson correlation coefficient of between 0.86 and 0.88 (see Table 1). These were plotted against each other (Figure 1) and an exponential relationship was found with an r^2 value of 0.96. Multivariate statistics were applied to the non-dominance techniques and a dendrogram based on hierarchical cluster analysis was produced (Figure 2), which also highlighted the similarity between Uitz *et al.* (2006) and Devred *et al.* (2006) with an 89% similarity, and Raitsos *et al*. (2008) and the NOBM model with 84% similarity.

The amount of pixels that each dominance technique identified as microplankton were compared. Hirata *et al.* (In press) identified the greatest amount of pixels followed by Alvain *et al*. (2005, Inpress) (see Table 2). The techniques were then compared to establish whether the same techniques identified the same pixel as microplankton. It was found that the two techniques of Hirata *et al*. (In press) and that of Alvain *et al*. (2005, In press) identified the most (see Figure 3)

PFT Dominance technique	Identification Number	Micro / Diatom pixel identified in study area
Ciotti *et al.* (2002) using Sathyendranath *et al.* (2001) a*ph(443)	1	0
Ciotti *et al.* (2002) using Bricaud *et al.* (2001) a*ph(443)	2	6
Hirata *et al.* (In Press) (Chl-a based)	3	1340
Hirata *et al.* (In Press) (aph(443) based)	4	11106
Alvain *et al.* (2005, In press)	5	1983

Table 2: Pixels identified as microplankton

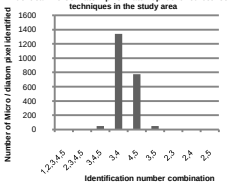


Figure 3: Histogram of identical microplankton pixel match up

Dominance PFT technique	Raitsos *et al.* (2008) Probability of occurance		NOBM diatoms mg/m³		Devred *et al.* (2006) % Micro		Uitz *et al.* (2006) Micro integrated 1.5* Zeu (mg/m³)		Uitz *et al.* (2006) Micro integrated 1.5* Zeu (mg/m³)	
	mean	95% Confidence Limit (±)	mean	95% Confidence Limit (±)	mean	95% Confidence Limit (±)	mean	95% Confidence Limit (±)	mean	95% Confidence Limit (±)
Ciotti *et al.* (2002) using Bricaud *et al.* (2001) a*ph(443)	0.30	0.25	0.17	0.05	93.67	0.39	184.97	6.40	90.90	0.00
Hirata *et al.* (In Press) (Chl-a based)	0.41	0.01	0.31	0.01	73.85	0.29	55.75	0.96	57.81	0.29
Hirata *et al.* (In Press) (aph(443) based)	0.37	0.00	0.28	0.00	56.98	0.15	28.64	0.26	41.18	0.18
Alvain *et al.* (2005, In press)	0.36	0.01	0.18	0.01	43.90	0.51	17.28	0.40	33.03	0.37

Table 3: Intercomparison of all techniques

The dominance and non-dominance techniques were then compared to each other by calculating the mean non-dominance factor (e.g. % or <Chla>$_{Zeu}$) at the pixels where the dominance techniques identified microplankton. It was found that the techniques of Ciotti et al. (2002) and Hirata et al. (In press) provided the highest indication of microplankton when compared to non-dominance, and Devred et al. (2006) and Uitz et al. (2006) showed the highest non-dominance factors (see Table 3)

RESULT 2: In-situ validation

Dominance PFT technique	*In situ* diatom match up of a possible 22 pixels	%	*In situ* diatom and dinoflagellates match up of a possible 25 pixels	%
Ciotti *et al.* (2002) using Sathyendranath *et al.* (2001) a*ph(443)	0	0.0	0	0
Ciotti *et al.* (2002) using Bricaud *et al.* (2001) a*ph(443)	0	0.0	0	0
Hirata *et al.* (In Press) (Chl-a based)	3	13.6	3	12
Hirata *et al.* (In Press) (aph(443) based)	14	63.6	15	60
Alvain *et al.* (2005, In press)	1	4.5	1	4

Non-dominance PFT techniques	Mean values of *in situ* diatom match ups	95% Confidence Limit (±)	Mean values of *in situ* diatom and dinoflagellates match ups	95% Confidence Limit (±)
Raitsos *et al.* (2008) Probability of occurance	0.55	0.05	0.55	0.55
NOBM diatoms mg/m³	0.11	0.06	0.12	0.06
Devred *et al.* (2006) % Micro	50.00	5.78	49.33	5.55
Uitz *et al.* (2006) Micro integrated 1.5* Zeu (mg/m³)	23.78	5.00	22.93	4.82
Uitz *et al.* (2006) Micro %	42.92	3.98	42.66	3.82

From a possible 66 *in situ* points, 22 diatom and 25 diatom and dinoflagellates were utilised, taking account of cloud coverage. It was found that the dominance technique of Hirata *et al.* (In press) $a_{ph}(443)$ identified the highest amount of match ups between 60 and 63.4% of the *in situ* data. The non-dominance technique of Devred *et al.* (2006) was also found to have a mean of 50% ± 5.8% of microplankton at all the 22 and 25 *in situ* data points, and Raitsos *et al.* (2008) was found to have a probability of 0.55 ± 0.05%

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CONCLUSION

- An intercomparison between non-dominance techniques found that Uitz *et al.* (2006) and Devred *et al.* (2006) show the highest degree of similarity. Hirata et al. (In press) and Alvain *et al*. (2005, In Press) were found to predict the highest amount of dominant microplankton pixels in the study area. From a basic comparison of dominance and non-dominance techniques, the dominance technique of Ciotti *et al*. (2002) and Hirata *et al.* (In press) provided the highest non-dominance factors (e.g. % or probability) indicating a more accurate prediction, and the non-dominance techniques of Devred *et al*. (2006) and Uitz *et al*. (2006) revealed the highest factors at these points.
- From the *in situ* validation Hirata *et al*. (In press) $a_{ph}(443)$ was found to have the highest percentage match up (60-63.4%), and both Devred *et al*. (2006) and Raitsos *et al*. (2008) were found to have higher non-dominance factors, indicating these three techniques are more accurate at predicting microplankton from satellite data.
- However, in order to accurately conclude upon the most validated method a far greater amount of in situ data will need to be used, with increased spatial and temporal coverage. Future work will also need to focus on other PFTs such as nanoplankton and picoplankton, before being compared to the FOAM-HadOCC system.