

Interactive comment on “Spring phytoplankton communities of the Labrador Sea (2005–2014): pigment signatures, photophysiology and elemental ratios” by Glaucia M. Fragoso et al.

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We thank the reviewer for his/her comments and suggestions, which we feel have greatly improved the manuscript. Below we respond to each comment in detail. RC refers to “Reviewer’s Comments” and AC to “Author’s comments”. We have enumerated the reviewer’s comments to organise better our responses.

Reviewer #1:

RC1.1- General comments: This work provides information on the phytoplankton groups found in the surface waters of the Labrador Sea. Pigment signatures determined with HPLC were analyzed with CHEMTAX to obtain the contribution of the vari-

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ous algal groups to the total chlorophyll a concentration. The authors also related the phytoplankton biogeographic distribution to the properties of the various water masses and the photophysiology of cells during the late spring /early summer over a 10 year period. The use of CHEMTAX for this data set is a novel application, however, a previous publication by Fragoso et al. in 2016 described the phytoplankton communities linked to the various hydrographical areas of the Labrador Sea at depths less than 50 meters using microscopy. Although both microscopy and CHEMTAX analytical methods are critical to any biogeographic examination of phytoplankton, I feel the two methods should have been combined into a single manuscript as they complement one another.

AC1.1 - The first manuscript (Fragoso et al 2016, Progress in Oceanography) focused on phytoplankton taxonomy and includes only large phytoplankton ($>4 \mu\text{m}$). In addition the manuscript includes data from only 4 years (2011- 2014) and not all stations sampled along the AR7W transect line. The current manuscript focuses on additional algal groups, including those that were not considered in Fragoso et al 2016, in addition to covering a much larger dataset (10 years of data), many more stations from the AR7W line and includes biogeochemical aspects of the data. For these reasons, we decided to publish the two papers separately to ensure all aspects of phytoplankton (taxonomy, algal groups, biochemical and physiological aspects) are examined in full. This is explained in line 578.

RC1.2 Therefore, although I consider this work to be of value in its contribution to our understanding of the dynamics of the biogeochemical characteristics of the Labrador Sea, I feel its content fails to merit publication in present form. Key problems that I feel need to be addressed include: 1) the absence of the initial CHEMTAX matrices and RMS errors

AC1.2 - CHEMTAX input matrices have been inserted in the manuscript (Table 3). The output matrices and information about the range of RMS errors (in the legend of the Table S1) has now been inserted in the supplemental material. We have attached a pdf in this response letter that shows the new versions of Table 3.

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RC1.3 2) the organization of the methodology section; it is not well structured, it includes CHEMTAX results and lacks information (see specific comments)

AC1.3 - The method section has now been modified according to the reviewer's suggestions. For specific changes, see the specific comments (methods) below.

RC1.4 - 3) the amount of information presented regarding taxonomy; species-specific information for the encountered groups of diatoms would have helped to understand differences on the photoprotective responses observed.

AC1.4 - We agree with the reviewer and additional comments regarding distinct diatom species in influencing differences in the photoprotective response has now been added. See new text below (line 525 in revised manuscript).

Line 525- "Although both communities were co-dominated by diatoms (relative abundance > 70 % of total chlorophyll), the ratio logAP:logTChla varied considerably, suggesting that either 1) diatom species from both Arctic and Atlantic waters varied intrinsically in pigment composition, or 2) temperature had a physiological effect on the logAP:logTChla ratio. Fragoso et al (2016) has previously observed that the diatom species from Arctic and Atlantic waters of the Labrador Sea during spring varied in terms of species composition. According to the study by Fragoso et al. (2016), the diatoms *Ephemera planamembranacea* and *Fragilariopsis atlantica* were typically found in Atlantic waters, whereas polar diatoms, including *Thalassiosira* species (*T. hyalina*, *T. nordenskioeldii*, for example), in addition to *Bacterosira bathyomphala*, *Fossula arctica*, *Nitzschia frigida* and *Fragilariopsis cylindrus* were all found in Arctic-influenced waters. It is possible that the distinct composition of diatoms from these biogeographical regions might have influenced the pigment composition in these waters. Despite the observed trend of logAP:logTChla varying with temperature, a direct physiological temperature-induced effect in logAP:logTChla is currently unknown."

RC1.5 - 4) of all the identified pigments (presented in Table 2) only the (DD+DT): chl a and DT:(DT+DD) are included for discussion on cell physiology. The authors should

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at least have included why they did not use the PPC:PSC, PPC:chl a or the pigment chlorophyllide a

AC1.5 - We appreciate the reviewer's suggestion, however ratios of PPC:PSC would vary according to phytoplankton community structure, in addition to cell photophysiology. That is due to the inherent variations of PPC and PSC within different phytoplankton groups. So PPC:PSC ratios would likely reflect community composition, which would be difficult to extract information about cell photophysiology. The DD+DT:chl a ratio only pertains to taxa which possess a xanthophyll cycle with a photoprotective (DD) and photosynthetic (DT) component.

RC1.6 - 6) the use of accepted and standardized abbreviations for the marker pigments and the phytoplankton groups in Tables 2 and 3 and throughout the text and finally

AC1.6 - Accepted and standardized abbreviations for the marker pigments according to Higgins et al (2011) as suggested by the reviewer have been updated.

RC1.7 - 7) the correction of any incorrectly assigned references.

AC1.7 - References have now been corrected.

RC1.8 - Specific comments Introduction Line 54: change for *Phaeocystis* spp. colonies (> 100 μ m).

AC1.8 - This sentence has been removed. See the introduction in the new manuscript version.

RC1.9 Line 83: update references.

AC1.9 - This sentence has been removed. See the introduction in the new manuscript version.

RC1.10 - Line 84 what do you mean by "while the influence of phytoplankton composition on photophysiological patterns has not been investigated thoroughly?" please explain further.

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AC 1.10 - This sentence has been changed. See the introduction in the new manuscript version.

RC1.11 - Methods In general this section is not well structured and needs clarification and more detail. Sampling and analysis are combined throughout this section and need to be presented with more organization. I recommend organizing this section into separate Study Area, Sampling and Biogeochemical Analyses sub-sections and limiting relevant data to relevant sub-sections.

AC 1.11 An additional subsection named "Biogeochemical analysis" has been added including nutrient, POC:PON and chlorophyll a methodology.

RC1.12 - Line 138: please include the number of stations sampled before fixed stations (was it 28 as in the previous work?). The number of depths sampled at each station should appear in the text as well.

AC1.12 - Information about stations has now been added to the manuscript. See the sentence rewritten below. Samples for this manuscript were collected from the surface only and this information is included in line 147.

Line 138. "Fixed stations (total of 28), as well as some additional non-standard stations, were sampled across shelves and in the deep central basin on the AR7W section or slightly north or south of this transect (Fig. 1)."

RC1.13 - Line 141: please write the specifications of the Seabird CTD system.

AC 1.13 - Specifications of the Seabird CTD system (SBE 911) has been inserted.

RC1.14 - Lines 148-149: the description of how the total chl a was analyzed is presented before explaining how the collected samples for pigment analyses were filtered (probably on board?). Were samples for chl a fluorometric determination kept frozen at -20C until analyses or at -80C is a bit confusing. Was the extraction (90% acetone) performed by keeping the filters at -20C for 24 h? or rather the filters were kept at -20C until analysis (extraction for 24h with 90% acetone)? Was acidification of the samples

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performed?

AC 1.14 - We have rewritten this sentence from Line 149 for clarification (see sentence rewritten below). The analysis of chlorophyll a has now been inserted in the other subsection "Biogeochemical analysis". Chlorophyll determination by fluorescence according to the methodology of Holm-Hansen et al (1965) includes acidification of the samples. A sentence explaining this will be added in the new version of the manuscript (see below).

Line 149 – "Filters for chlorophyll a measurements were immediately put in scintillation vials containing 10 ml of 90% acetone, which were placed into a -20oC freezer and extracted for 24 h."

New added line - "Fluorescence was determined on board after 24 h of extraction using a Turner Designs fluorometer (Holm-Hansen et al., 1965). Fluorometric analysis of chlorophyll and phaeo-pigments, using the Turner fluorometer, was always within 48 h."

RC1.15 - Line 151: I recommend changing this line to "samples for detailed pigment analysis were filtered onto 25 mm Whatman GF/F filters".

AC 1.15 - We rewrote this sentence as: "...filtered onto 25 mm glass fibre filters (GF/F Whatman Inc., Clifton, New Jersey)".

RC1.16 - Lines 151-153 How much time passed between storage and analysis for the samples? Were the samples always analyzed in the same laboratory for every cruise over the 10-year period? Information on the maximum time of filtration is not provided and is very important for xanthophyll measurements. If too much passed while doing the filtration, the measurements of diatoxanthin are likely to be meaningless. This is also important for degradation pigment information, however the later data are not presented.

AC 1.16 - We have now added these information in the manuscript. The new sentence

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below would replace the sentence from Line 151.

Line 151 – “Samples for detailed pigment analysis were filtered onto 25 mm glass fibre filters (GF/F Whatman Inc., Clifton, New Jersey) and immediately flash frozen in liquid nitrogen and kept frozen in a freezer (at -80° C) until analysis in the BIO (2005-2013) or NOC (2014) laboratories within 2-3 months of collection. Volumes of water sampled for HPLC analysis were adjusted such that samples took less than 10 mins to filter.”

RC1.17 - Line 153: were the nutrient samples kept frozen or refrigerated until analysis?

AC 1.17 - We have added this information in the text. The new sentence below would replace the sentence from Line 153.

Line 153 – “Nutrient samples were kept refrigerated at 5° C and analysed at sea (within 12 h of collection) on a SEAL AutoAnalyser III.”

RC1.18 - Pigment analysis Line 166: Was calibration done with external pigment standards obtained from DHI? Was the precision of the instrument tested? Is there a variation coefficient? Do you have limits of detection? Please at least provide the limits of detection and quantification and how were they estimated and if the pigments with concentrations below this limit were reported or not. All this information is relevant and missing.

AC 1.18 - Information about the standards, calibration and quantification procedures are described in detail in Stuart and Head (2005). Information about precision, coefficient of variation and limits of detection have now been inserted in the new version of the manuscript. The new sentence below would replace the sentence from Line 160.

Line 160 – “Pigments (chlorophyll a and accessory pigments) were quantified using reverse-phase, High-Performance Liquid Chromatography (HPLC). Methods for 2005-2013 (Hudson cruises), including information about the standards, calibration and quantification procedures are described in detail in Stuart and Head (2005), known as the “BIO method”. Methods for samples collected in 2014 (JR302 cruise) are de-

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scribed in Poulton et al (2006). Quality control of both methods was applied according to Aiken et al (2009). Precision of the instruments was tested by running samples and standards and the coefficient of variation for pigments were < 10% of the mean. Limits of detection were ~0.01 and 0.002 mg m-3 for carotenoids and chlorins, respectively (Head, pers. comm, Poulton et al 2006). Pigments concentrations below detection limits were not reported.”

RC1.19 - Table 2: In this table and throughout the manuscript the authors should follow the abbreviations for phytoplankton pigments and pigment formulae suggested in the Scientific Council for Oceanic Research (SCOR), Jeffrey et al. 1997 or in Higgins et al. 2011 In: Roy S, Llewellyn CA, Egeland ES, Johnsen G (eds) Phytoplankton pigments: characterization, chemotaxonomy and applications in oceanography. Cambridge University Press, Cambridge, p 257

AC 1.19 - Pigment abbreviations were updated as suggested by the reviewer. We have added the new version of Table 2 as a pdf.

RC1.20 - This table should summarize the distribution of major taxonomically significant pigments found in the various algal groups during the study. This is poorly done in its current form. The authors should avoid ambiguity. For example when referring to 19'-hexanoyloxyfucocanthin (Hex-fuco), it should be mentioned that is a major pigment in haptophytes and dinoflagellates (Type-2, lacking peridinin), instead of “some dinoflagellates” or “various”. This information –if provided here–would improve significantly the reading of the few next sections dealing with the marker pigments used for the CHEMTAX analysis. Only if the authors are more specific, the use of the references Jeffrey et al. 1997 or Higgins et al. 2011 make sense. Please delete the reference column of this table unless is useful (not the case in its present form).

AC 1.20 - This table has been updated. We have included the more specific information requested following Jeffrey et al (1997), Higgins et al (2011) and Vidussi et al (2004). See the new version of the table updated.

RC1.21 - Chlorophyll c1 + c2 should stay as Chlorophyll c1 + c2. Please avoid the use

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of CHLC12.

AC 1.21 - Abbreviations were updated in the new version of the manuscript according Higgins et al 2011 as the reviewer suggested.

RC1.22- Zeaxanthin is a minor pigment present in various groups as cyanobacteria, however this group is supposed to be practically absent in polar waters. Although Blais et al. 2012 showed that cyanobacteria may be underestimated in polar regions (Beaufort Sea & Baffin Bay). Did the authors find presence of cyanobacteria using epifluorescence microscopy?

AC 1.22 - We did not count cyanobacteria but referred to information about the presence of *Synechococcus* in the Labrador Sea from previous reference (Li et al 2016) as stated in line 211.

RC1.23 - Also did the authors perform any correlation analyses between prasinoxanthin and zeaxanthin to prove that the zeaxanthin encountered did or did not correspond to a group of prasinophytes-containing zeaxanthin? Please provide this information.

AC 1.23 - We are not sure if we understand this point raised by the reviewer as a correlation between prasinoxanthin and zeaxanthin would not directly determine whether the zeaxanthin found belongs to prasinophyte-containing zeaxanthin or cyanobacteria. Zeaxanthin, in this study, represented not only prasinophytes type 2, but also chlorophytes and cyanobacteria. Moreover, species representing prasinophyte type 2, such as *Pyramimonas* and *M. pusilla* have been observed (qualitatively in our samples, although not directly counted due to difficulties in quantification) in the Labrador Sea from microscope observation of Lugols fixed samples. *M. pusilla* is abundant in the North Water Polynya in regions near the Labrador Sea (e. g. Buffin Bay) as stated in line 208.

RC1.24 - Pigment interpretation There are major problems with this section. The title itself is more like the title of a results section. Actually the authors use the title "CHEM-

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TAX interpretation" as a section included in the results. I suggest the authors change the title of the pigment interpretation section to HPLC pigment data or Clustering of HPLC data for CHEMTAX or CHEMTAX analysis or something similar-

AC 1.24 - The title of the section has been changed to "CHEMTAX analysis" as suggested.

RC1.25 - This section is not well structured and difficult to follow partially because the authors explain the use of the selected initial pigment ratios while presenting the output matrices after the CHEMTAX analyses (Table 3). This is confusing for the reader. The initial ratio matrices used to seed CHEMTAX are not presented or explained with detail. Instead ambiguous information is presented e.g. "diatoms were identified as containing high fucoxanthin to chl a ratios"

AC 1.25 - Initial pigment ratios have now been inserted in the new version of the manuscript (see the pdf with the new version of this table) and output ratio information has been moved to the supplemental material. Explanation for selected ratios are explained in line 197 onwards and we have included a column in the initial pigment ratios table mentioning the source reference where the ratios were taken from to seed initial CHEMTAX analysis.

RC1.26 - Line 171: change it for Mackey et al., 1996, version 1.95.

AC 1.26 - Changes updated.

RC1.27 - The following paragraph is not straightforward. The information on how CHEMTAX works in general and how version 1.95 works lacks clarity. This later version is a significant improvement on CHEMTAX application since the software sets up the multiple (60) initial pigment ratio matrices to obtain the more stable final values (as was recommended for example by Latasa 2007) and was actually used and described by Wright et al. 2009 and other authors before Coupel et al. 2015! Please add the references.

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AC 1.27 - This paragraph has been rewritten (see paragraph below) and the earlier references have been included.

Line 171 – “The CHEMTAX software (Mackey et al., 1996) was used to estimate ratios of abundance of distinct micro-algal classes to total chlorophyll a from in situ pigment measurements. The software utilises a factorization program that uses “best guess” ratios of accessory pigments to chlorophyll a that are derived for different classes from the literature available and marker pigment concentrations of algal groups that are known to be present in the study area. The program uses the steepest descent algorithm to obtain the best fit to the data based on assumed pigment to chlorophyll a ratios (for more detail, see Mackey et al 1996). Because CHEMTAX is sensitive to the seed values of the initial ratio matrix (Latasa et al 2007), we used a later version (1.95) to obtain the more stable output matrices. In this CHEMTAX version, the initial matrices are optimized by generating 60 further pigment ratio tables using a random function (RAND in Microsoft Excel) as described in Wright et al., (2009). The results of the six best output matrices (with the smallest residuals, equivalent to 10 % of all matrices) were used to calculate the averages of the abundance estimates and final pigment ratios.”

RC1.28 - Line 179 to the end of the paragraph: please use the standardized abbreviations and you should at least explain why you decided to choose these particular marker pigments for the CHEMTAX analysis. Your microscopy results from the previous work should help here in a more detailed way.

AC 1.28 - The explanation of why we used these pigments is mentioned later in the text (line 197). Thus, in the new version of the manuscript, we would include a new paragraph (before the sentence from Line 178), where we would insert sentences from Lines 197 – 204. To finalise this paragraph, we would add the sentence from line 178-181. We believe that this organisation in the text would better guide the reader.

RC1.29 - Line 183: Again, please refer to Mackey et al. 1996 before more recent

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studies.

AC 1.29 - Reference now added.

RC1.30 - Line 191 to 197: Is figure 2 referring to the mean relative concentration of the main marker pigments to total accessory pigments (wt:wt) encountered or to chl a or total chl a or is based on the pigments absolute values? Unclear. It would have been helpful to include in this figure the biogeographical region linked with each cluster (as in figure 3).

AC 1.30 - Figure 2 is the first statistical treatment using PRIMER to separate out samples based on a similarity index before applying CHEMTAX. It refers to the mean relative (transformed) concentration of each of the selected pigments (e.g. Fuco) to the total selected pigments (i.e. sum of Fuco + Chl c3 + Hex-fuco + Chl b + Peri + Allo + But-fuco + Pras + Zea+Lut). Further clarification has now been added to the legend of Figure 2 in line 985. We have now added to Figure 2 a biogeographical plot showing the cluster groups as depicted in Figure 3 (Fig. 2b). This figure will be moved to the supplemental material. (Please see the figure in pdf).

RC1.31 - Line 198: you already explained this earlier (lines 173-74). I think this is not very well explained and this may be the reason why you mentioned it again here. Line 199-200: “To satisfy this requirement, initial pigment ratios were carefully selected and applied to each cluster”. This should actually be mentioned earlier in this section when you explain and justify why you use the selected pigment markers that best describe the phytoplankton community of your study area.

AC 1.31 - We have reorganised these sentences and the order of explanation as mentioned in the comments above.

RC1.32- Line 204: The authors should justify why they have used the “high light” field ratios from Higgins et al. 2011. Moreover, considering the importance on the photo-physiological results obtained in this study why is there not more information beside the

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irradiance of the experimental incubations? Was the PAR incident irradiance measured at the sampling sites?

AC 1.32 - High light field ratios were chosen because the samples in our analysis were collected from surface waters (< 10 m) where they are likely to be exposed to high light levels; for example, in May and June daily irradiance levels may exceed >30 mol m⁻² d⁻¹ (see Figure 2a, Harrison et al 2013). In the new version of the manuscript, we have now added a sentence at line 204 explaining why we chose high light field ratios.

Line 204. "High light field ratios were chosen because samples were collected from surface waters during May and June (average monthly irradiance >30 mol m⁻² d⁻¹, Harrison et al 2013)."

RC1.33 - Line 205: "Prasinophytes were separated into type 1 (containing prasinoxanthin) and type 2 (lacking prasinoxanthin)". Both genera were observed in light microscope counts (Fragoso et al. 2016)" What do you mean? Fragoso et al. 2016 enumerated pico- phytoplankton (M. pusilla < 2 um)?

AC 1.33 - We apologise for the confusion. Pyraminomas and M. pusilla were observed qualitatively from microscope observations but not enumerated by Fragoso et al (2016). We have now changed the reference to (Fragoso, pers obs) in the text to avoid confusion.

RC1.34 - Line 209: Did the authors detect by HPLC the unknown carotenoid that characterizes the unique pigment signature of M. pusilla? Did they detect the pigment micromonal in their samples? or micromonol?

AC 1.34 - The pigment micromonal was not identified as part of the HPLC analytical protocol followed (i.e. it was not a pigment peak listed for identification).

RC1.35 - Line 211: "In addition to prasinophytes –type 2 (type 2A in Higgins et al. 2011- I assume), zeaxanthin is also the major accessory pigment of cyanobacteria etc.. unclear para- graph.

C13

AC 1.35 - The beginning of this sentence has been rewritten for clarification. See sentence below.

Line 211 – “Zea + Lut is not only found in prasinophytes –type 2, but is also the major accessory pigment of cyanobacteria...”

RC1.36 - Line 215: "Prasinophytes (type-1, Higgins et al. 2011) indeed contain chl b so do chlorophytes and they can be distinguished by their relative ratios of lutein to chl b (Higgins et al. 2011). Was lutein detected with the HPLC analyses? Again correlations would have helped here.

AC 1.36 - The BIO method does not separate lutein and zeaxanthin so we have now renamed it as Zea + Lut.

RC1.37 - Line 218: I suggest the authors change Dino-2 class for Dino2 (dinoflagellates type-2). Avoid the use of class, use what is suggested by Higgins et al. 2011. As mentioned before, this could have been nicely done in Table 2.

AC 1.37 - We have rewritten this sentence now using the best terminology. Table 2 has been updated (see table).

Line 218- “... (herein defined as dinoflagellates type-2 (DINO-2) according to Higgins et al (2011))...”

RC1.38 - Line 220: Why did the authors use the term Cryptophycea instead of cryptophytes?

AC 1.38 - Cryptophytes, instead of cryptophycea, is now used in the revised text.

RC1.39 - Line 256: Please refer to algal groups or phytoplankton groups based on pigment composition instead of “class”.

AC 1.39 - “Phytoplankton/algal class” has been changed to “phytoplankton/algal groups”.

C14

RC1.40 - Results Line 294-296: Where is cluster C1 mentioned in this section to explain Figure 4?

AC 1.40 - Cluster C1 has now been included in this sentence.

RC1.41 - Line 380: Why do you present saturation irradiances here as Wm-2 when in the methodology (line 237) you mentioned the 30 different irradiance levels is expressed as $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$. Please use same units everywhere.

AC 1.4 - Irradiance units used throughout are now "Wm-2" in the text.

RC1.42 - Line 382: What was the % contribution of DD, DT and,-carotene to the total PPC for clusters C3b and C2?

AC 1.42 - The percentage contribution of DD, DT and,-carotene to the total PPC would vary according to the total amount of PPC (similar situation as comparing to DD+DT/Chl a, see comments below). Moreover, as mentioned previously, we feel that this information is irrelevant for photophysiology because of the influence of phytoplankton community structure in the overall PPC values.

RC1.43 - Line 381: DD+DT/Chl a; clusters C3b and C2 have also the lowest chl a concentration. However the level of deepoxidation is higher for these two cluster. How do your DDDT/chla and PPC/PSC ratios compare with other studies for the Arctic during spring/summer transition? Actually you don't present PPC/PSC, why?

AC 1.43 - Again, ratios of PPC:PSC would vary according to phytoplankton community structure and not just cell photophysiology. For example, a community dominated by diatoms would have high PSC:PPC, while a community dominated by prasinophytes would have low PSC:PPC. Thus, we believe that this information is insufficient to discuss photophysiology in mixed phytoplankton communities. However, as the reviewer pointed out, the level of de-epoxidation was high, which suggests that these communities were exposed to high light levels. We changed the sentence from line 560, where we cite other studies (i.e., Alou-Font et al 2016) that show similar patterns.

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Line 560. "These communities also had high diatoxanthin levels compared with the other phytoplankton communities in this study, suggesting that the community was experiencing higher light intensities (Moisan et al., 1998). Increases in photoprotective pigments, including (DD+DT)/Chla, have been reported to occur in Arctic phytoplankton communities from spring to summer presumably as a response to higher irradiance (Alou-Front et al 2016). Thus, photoprotective capacity can be a key determinant for phytoplankton survival and may also be related to the taxonomic segregation observed in Arctic and Atlantic phytoplankton communities."

RC1.44 - Legend of figure 3: would be better if each variable and parameter is related to the corresponding panel.

AC 1.44 - We have now related each variable and parameter to the corresponding panel. See new sentence below.

Line 988 "Figure 3 – Map with sampling stations and distances from a fixed reference position (Northeast Gulf of St Lawrence) in the x-axis shown by the star (a). Values are given at individual stations sampled between 2005 and 2014 (y-axis) for the following variables: date of sample collection (b), temperature (c), salinity (d), stratification index (SI) (e), chlorophyll a (f), nitrate (NO₃⁻) (g), phosphate (PO₄³⁻) (h), silicate (Si(OH)₄) concentrations (i), ratios of particulate organic carbon (POC) to particulate organic nitrogen (PON) (j), silicate to nitrate (Si(OH)₄):NO₃⁻ ratios (k), and nitrate to phosphate (NO₃⁻:PO₄³⁻) ratios (l). LSh = Labrador Shelf, LSI = Labrador Slope, CB = Central Basin, GSI = Greenland Slope, GSh = Greenland Shelf."

RC1.45 - Discussion Very little information is discussed about spatial and temporal incident PAR irradiance variation.

AC 1.45 - Unfortunately we do not have PAR measurements for each site during the 10 years of cruise observations. However, we discuss PAR indirectly through mixed layer depth, stratification index and progression of solar incidence from May to June throughout the whole discussion section. We have also extended the discussion of the

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effect of irradiance on photosynthetic parameters in the new version of the manuscript (new version of Line 560 as mentioned above).

RC1.46 - Line 405: Chlorophytes have also been associated with land-fast ice in the Arctic (e.g. Palmer et al. 2011).

AC 1.46 - A reference including chlorophytes having been found in land-fast ice in the Arctic has now been added.

RC1.47 - Lines 524-529: I think this is a very interesting result and an interesting point for discussion. Here is where species identification for the diatom groups of Arctic and Atlantic waters would have been helpful. How do these results compare to other Arctic studies?

AC 1.47 - We have now added a sentence discussing the influence of distinct species in the variable AP:Tchla ratios (see comments above). There are few studies that have investigated what causes such distinct AP:TChla ratios. Changes in AP:TChla ratios vary with community structure and comparison with another Arctic study is discussed in line 514 (see new version of this sentence below). However, it is still unclear why this pattern is observed.

Line 514: Changes in the ratios of logAP:logTChla as a function of phytoplankton community composition has been previously observed by Stramska et al. (2006). These authors showed a higher slope of logAP:logTChla when dinoflagellates were dominant during summer in northern polar Atlantic waters as opposed to lower ratios associated with flagellates in spring.

RC1.48 - Lines 540 to 550: This paragraph deserves a better explanation with at least details on the microscopic most abundant genera for diatoms.

AC 1.48 - We agree with the reviewer and a discussion about distinct species of diatoms in influencing the AP:TChla has now been included in the text. See line our response to comment the reviewer comment above (RC 1.4).

C17

RC1.49 - Lines 564 to 575: is more a repeated line of the introduction.

AC 1.49 - This whole paragraph (lines 564 to 575) has been removed.

RC1.50 - Lines 564 to the end: The resulting ratios of the final CHEMTAX analysis should have been discussed here, at least accordance/discrepancies with past studies in the polar environment. The interesting comparison among the carbon biomass- estimated from CHEMTAX and the estimated by microscopic observations- should have been better structured and compared with other studies.

AC 1.50 - We have now included more references that compare the two methods of biomass estimations (CHEMTAX and microscopy) from polar environments. See the new version of the paragraph below.

Line 588 - *Phaeocystis* ($r^2 = 0.79$) and diatom ($r^2 = 0.74$) biomasses were well correlated when carbon biomasses estimated from microscopic counts when compared with CHEMTAX-derived algal chlorophyll a biomass (data not shown). Diatoms are the group that usually show the best agreement between the two methods of biomass estimations (Vidussi et al. 2004, Coupel et al 2015, Mendes et al 2012). For *Phaeocystis*, a positive relationship between the two methods of biomass estimation (CHEMTAX and microscopy) confirms that using chlorophyll c3 was appropriate for detecting and quantifying *Phaeocystis* biomass in the Labrador Sea. Similar associations have been observed for *Phaeocystis* from boreal waters (e.g. *P. pouchetii* and *P. globosa* ; Antajan et al., 2004; Muylaert et al., 2006; Stuart et al., 2000; Wassmann et al., 1990), while other pigment markers have been used elsewhere, e.g. 19- hexanoyloxyfucoxanthin, which is characteristic of *Phaeocystis antarctica* in austral polar waters (Arrigo et al., 2010, 2014; Fragoso and Smith, 2012; Fragoso, 2009). Dinoflagellates gave a poor correlation between biomass estimates made using the two methods ($r^2 = 0.12$, data not shown). A lack of or weak relationship between both biomass estimations for dinoflagellates has been previously reported in Artic waters (Vidussi et al 2004 Coupel et al 2005). The argument for this inconsistency is that some heterotrophic di-

C18

noflagellates, which usually lack photosynthetic pigments unless they ingest a prey that contains them, might have been included in the microscopic counts, and it is possible that the same occurred in Fragoso et al. (2016). Cryptophyte biomass estimates from both methods were not related (data not shown), likely as the biomass of this group was underestimated in microscopic counts. Inconsistencies between CHEMTAX and microscopy methods of estimating biomasses have also been observed in nanoflagellates and this is assumed to be because of the low accuracy of visual microscopic counts (Coupel et al 2015).

RC1.51 - Lines 987 to 993: please relate each variable to the corresponding panel.

AC 1.51 - We have now related each variable and parameter with the corresponding panel.

RC1.52 - References need further formatting review. Latasa M (2007) Improving estimations of phytoplankton class abundances using CHEMTAX. *Mar Ecol Prog Ser* 329:13

Wright SW, Ishikawa A, Marchant HJ, Davidson AT, van den Enden RL, Nash G (2009) Composition and significance of picophytoplankton in Antarctic waters. *Polar Biol* 32:797

AC 1.52 - References added.

Please also note the supplement to this comment:

<http://www.biogeosciences-discuss.net/bg-2016-295/bg-2016-295-AC1-supplement.pdf>

Interactive comment on Biogeosciences Discuss., doi:10.5194/bg-2016-295, 2016.