BGD Reply to Referee comment 2, David Hutchins

Some of the issues might already have been discussed in our response to Referee comment #1, so we apologize for redundancy.

Air-water gas exchange

The estimate for wind speed for our calculations of gas exchange is based on observed changes in the carbon budget:
Of course, their was no actual wind in our culture rooms. Wind speed in our calculations for gas exchange was adjusted, in order to account for mechanical mixing of the water column in the mesocosms. Without gas exchange, the amount of total carbon (DIC+POC+DOC) should not increase, as biological processes only lead to shifts between the different pools. Therefore any change in this mass balance is attributable to gas exchange, assuming no loss of carbon e.g. through sinking. The temporal development of total carbon (DIC+POC+DOC) in the mesocosms suggests a net carbon uptake of ~200, 310 and 420 µmol C L^{-1} at low, intermediate and high temperatures, respectively, over the course of the experiment (Fig. 4B). To account for this increase, wind speed was adjusted and a value of 6 m s^{-1} was assumed, yielding the best fit to the observed net carbon uptake in the mesocosms at different temperatures.
Of course, this number for wind speed seems quite high for an indoor experiment. However, high rates of gas exchange are facilitated through continuous mixing of the water column by propellers attached to the mesocosms. Thereby, the boundary layer, which is exchanging gas with the atmosphere, is constantly renewed and rapid air-water gas exchange is facilitated even at virtually zero wind speed. Furthermore, the positive effect of temperature on gas transfer velocity resulted in higher rates of gas exchange at higher temperatures.
In fact, the magnitude of gas exchange in our mesocosms setup has been tested in a follow-up experiment (data not published yet) and supports rates of gas exchange in the same magnitude as observed in the presented experiment.

To make these considerations clear, the issue of gas exchange will be discussed in more detail in our revised manuscript.

Nitrogen budget / Loss of organic matter

The temporal development of total nitrogen (PON+DON+DIN), which decreased in all mesocosms over the course of the experiment, indeed suggests a loss of organic matter in our experiment.
Mechanisms that may potentially lead to a loss of nitrogen (and carbon as well) include sinking of organic matter to the bottom of the mesocosms, wall growth or mesozooplankton dynamics. It is difficult to quantify the proportional effect of the above mechanisms for the observed loss in our experiment. However, both wall growth and grazing effects cannot explain the observed large loss of organic matter. Therefore we reckon that sinking of particles is the most likely reason for the observed loss of organic matter during the bloom phase Previous studies have shown, that sinking of organic matter can lead to a considerable loss of biomass from the surface layer in mesocosm experiments [Keller et al., 1999; Wohlers et al., 2009].

Since high concentrations of POC and PON were reached very rapidly in our experiment, it is possible that some of this newly produced biomass has sunken to the bottom of the mesocosms. Although mixing of the water column by the propeller should minimize particle settling, this can obviously not excluded entirely. While we did not measure TEP in our experiment, POC data suggests that TEP might have contributed substantially to the observed POC dynamics. Since TEP also plays an important role in particle aggregation, this mechanism could have potentially facilitated sinking of organic matter to the bottom of the mesocosms.
Degasing of regenerated ammonium might have contributed further to the observed loss of nitrogen.

We note that neither gas exchange nor sinking of organic matter affect the main findings and conclusions of our study, i.e. the effect of temperature on build-up of POC and DOC and C:N ratios of particulate and dissolved organic matter

Stationary phase dynamics

It is true, that most of the carbon overconsumption took place after nutrient exhaustion. Since nutrients ran out very quickly, it is hard to quantify temperature effects in that short period of time. However, the temporal development of POC:PON and DOC:DON suggests, that the temperature effect mainly occurred – or at least was stronger – under nutrient limitation. This is in accordance with the studies mentioned by the Referee, where a temperature effect on C:N ratios could not be observed in cultures in exponential growth.
Of course, it is likely that bacterial influence increased during the experiment. Most studies suggest increasing bacterial activity at higher temperatures. However, this would counteract the observed effects of temperature in our experiments: enhanced bacterial degradation at higher temperatures should result in higher consumption of POC and DOC, i.e. the observed concentrations would be lower than without bacterial activity. In our experiment, the exact opposite occurred, and therefore we believe that the observed temperature effect on POC and DOC is driven mainly by phytoplankton physiology.

Missing parameters

It is indeed very unfortunate that there are no measurements of bacteria, particulate P and Si. The main focus of our investigation was the carbon cycle and the leaving out certain measurement parameters was mainly attributable to logistics. However, the drawdown of inorganic N, P and Si does not suggest a substantial effect of temperature on the uptake ratio of these elements. While data on particulate P and Si might have been useful for calculations of budgets and the loss of organic matter, we believe our dataset is still very expressive without these variables.
The role and fate of copepods will be discussed in a separate paper (in preparation). Since their impact on carbon and nitrogen cycling seemed to be minor, we decided to keep the discussion on this issue rather short and focus on the more likely mechanisms behind the observed biogeochemical response to temperature.

Implications of the low temperature treatments:

We are careful with extrapolating the findings of our study to large spatial or temporal scales.

Our study is a one-time experiment and our experimental design is not necessarily representative for field conditions, as a “non-blooming” plankton community was enclosed in mesocosms and a bloom was induced via nutrient addition. However, the purpose of this mesocosm study was to investigate how temperature changes relevant to climate change might affect certain patterns of biogeochemical cycling in a natural pelagic plankton community. We did not attempt to mimic natural conditions in the field, leading to obvious differences between the experimental setup and natural conditions in the real ocean. Thus, possible indirect effects (changes in stratification and nutrient supply) that are related to temperature are not considered here.

Furthermore, we discussed the possible major influence of the dominant phytoplankton species for the response of biogeochemical cycling to temperature. Future experiments have to be carried out, to investigate how different phytoplankton species respond, and if there is a consistent pattern in the response to temperature.

These aspects should be kept in mind when interpreting the results or when considering extrapolation to larger spatial and longer temporal scales and field conditions.