RV Heincke
HE 491
07 July to 27 July 2017

Investigation of bio-optics and spatial heterogeneity of phytoplankton populations near the sea surface and their effects on air-sea gas exchange

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Summary

The overall objective of the proposed cruise is to characterize the near-surface layer (e.g. < 5m) and sea-surface microlayer on spatial heterogeneity of bio-optical properties and phytoplankton communities (diversity and activities), as well to study their effects on air-sea CO_2 exchange. A total of 15 stations were occupied in the North Sea, Sogne Fjord, Trondheim Fjord and the Norwegian Sea. A remote-controlled catamaran to sample the sea-surface microlayer were deployed with a buoy to measure gas transfer velocity. Optical properties oft he water column were assessed with a free-falling profiler. Discrete water samples for the analysis of optical properties, pigment analysis and phytoplnakton taxonomy were taken from the catamaran, a hand-deployed vertical samples (up to 2 m depth) and the CTD. Continuous measurements of hydrographical parameters from the upper surface layer were conducted using a FerryBox. The primary major findings are (i) the sea-surface microlayer is clearly distinct from the underlying water mass and enrichment processes of organic matter is driven by different bulk water masses, wind speed and solar radiation, (ii) fjords are sink for atmospheric CO_2, (iii)…

Participants:

Name	Duty as	Institute
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Nur Ili Hamizah Mustaffa	Graduate student	ICBM
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Oliver Ferdinand	Graduate Student	ICBM
Klas Möller	Scientist	Helmholtz Center Geesthacht

Generally objectives:

(1) We addressed the abundance and biodiversity of phytoplankton communities residing in near-surface layer and sea-surface microlayer of well-mixed and stratified water columns.

(2) We attempt to link hyperspectral light availability and bio-optical environment with phytoplankton biogeography in near-surface layer incorporating the meteorological and hydrodynamic conditions in an attempt to explain potential heterogeneity.

(3) We attempt to link air-sea CO2 exchange rates with biological activity and phytoplankton biogeography at different depths within the near-surface layer.

Specific tasks:

The group Sea Surface (Institute for Chemistry and Biology of the Marine Environment, ICBM) deployed state-of-the-art technology at 14 stations to make observations close to the sea surface including a hyperspectral radiometric profiler, a remote-controlled research catamaran and an autonomous gas flux buoy. In addition, a High-volume Sampler for the Verticals (HSV) has been developed for the expedition and successfully deployed to collect discrete water samples in the upper 2 meter from six different depths. The catamaran was deployed at each station for up to 7 hours retrieving up to 2500 in situ data points from the sea-surface microlayer and 1 meter depth for pH, salinity, temperature and chromophoric dissolved organic matter (CDOM) as well discrete water samples for lab analysis.

The work of the group "Marine Sensor Systems" (ICBM) covered on the one hand classical CTD measurements as well as the analysis of discrete water samples. The discrete water samples were analyzed with respect to chlorophyll-a concentration, suspended matter concentration, light absorption and CDOM fluorescence. Furthermore, vertical measurements of the underwater light field were conducted utilizing a free-falling profiler. Other important work was the testing and demonstration of newly developed sensors, partly in the course of the EU-project NeXOS. The instruments continuously measured the light absorption and fluorescence of the optically active constituents in the water (primarily dissolved organic compounds and phytoplankton).

The work of the group "In-situ measuring systems" from the Helmholtz-Zentrum Geesthacht (HZG) involved real-time measurements of hydrographical parameters from the upper surface layer using a FerryBox. Water samples from the surface and the deep chlorophyll maximum (DCM) taken with the rosette-water sampler were imaged using the FlowCam system on board to determine the taxonomic composition and abundance of the phytoplankton community. Finally, water samples from different depths were taken and preserved for later analysis of total alkalinity and dissolved inorganic carbon.

The group “Planktology” (ICBM) investigated the community composition of phytoplankton, nutrient concentrations (dissolved and particulate) and pigment concentrations in the surface micro layer and the upper meters of the water column (highly resolved sampling of the upper meters). Furthermore, three incubation experiments were conducted investigating the growth and stoichiometry of different phytoplankton communities of different origin (open ocean, outer fjord, inner fjord) at different light conditions and under different nutrient gradients (N and P addition).

Course of cruise

A station map is shown in the appendix (Figure 1), as well positions and date/time for each station summarized (Table 1). RV Heincke embarked from Bremerhaven (Germany) on 8 July in the morning, and occupied the first station in the North Sea in the afternoon. Further stations in the North and Norwegian sea were occupied until 11 July 2017. From 12 July to 17 July 2017, we conducted research in the Sogne Fjord (Station 5 to 9). Station 10 and 12 were located offshore the Norwegian coast (occupied on 19 July and 22 July, respectively), whereas Station 11 near-shore the island Runde. At Runde, Norwegian collaborators of the EU project NEXUS came onboard to learn about the optical and other measurements undertaken during the cruise. Station 13-15 (23 July to 25 July 2017) were located in the Trondheim Fjord. The RV Heincke steamed into the port of Trondheim in the morning of the 26 July 2017.

Prelimnary results

(i) Sea-surface microlayer: The microlayer is the thin uppermost boundary layer oft he ocean. With the catamaran, we conducted high-resolution observations of fluorescent-DOM (FDOM) at 13 stations in the coastal and open Atlantic Ocean to understand the enrichment processes of organic matter in the microlayer. Results show that enrichment FDOM in the microlayer varied between 0.8 and 2.0 (in comparison to the concentrations in the underlying mixed layer), and FDOM enrichment is a common feature of the microlayer despite the varied distances to the terrestrial sources. At six stations, the FDOM concentration in the microlayer was less variable over the sampling period (> 5 h) compared to FDOM concentrations in the underlying water characterized with sudden changes. Even so we observed slightly lower enrichments with increasing wind speeds and solar radiation, changes in ULW concentrations forced the enrichment to change. In addition, we found evidences for the occurrence of photochemical degradation of FDOM in near-shore microlayer with implications on coastal carbon cycling. Overall, the results show that the processes leading to the enrichment of DOM in the SML are more complex than previously assumed. Given the importance of the organic-rich microlayeras a diffusion layer in the air–sea exchange of climate-relevant gases and heat, understanding the layer's enrichment processes is crucial.

(ii) CO_2 air-sea exchange: Gas transfer velocities were related to wind speed and turbulence. Data from this cruise shows a similar trend to existing wind-based parameterizations, although open ocean gas transfer velocities were higher than predicted with the parameterizations (up to 86.9 cm h^{-1}). In the fjords, 25 CO_2 transfer velocities in the range of 0 to 4 m s^{-1} wind speed were obtained. Generally, results indicate that fjords and the Norwegian coastal waters take up CO_2 from the atmosphere, i.e., they might play an important role as a sink for anthropogenic CO_2.

(iii) Phytoplankton growth: The aim was to determine the responses of different phytoplankton communities to light and nutrients. the results from the outer fjord community can be seen in Figure 1. Overall, optical density increased over time with higher nutrient supply. Additionally, differences due to light treatment and origin can be seen, these differences tend to be affected by nutrient addition. More detailed results will be available after statistical analysis of the data, planned for May-June 2018.

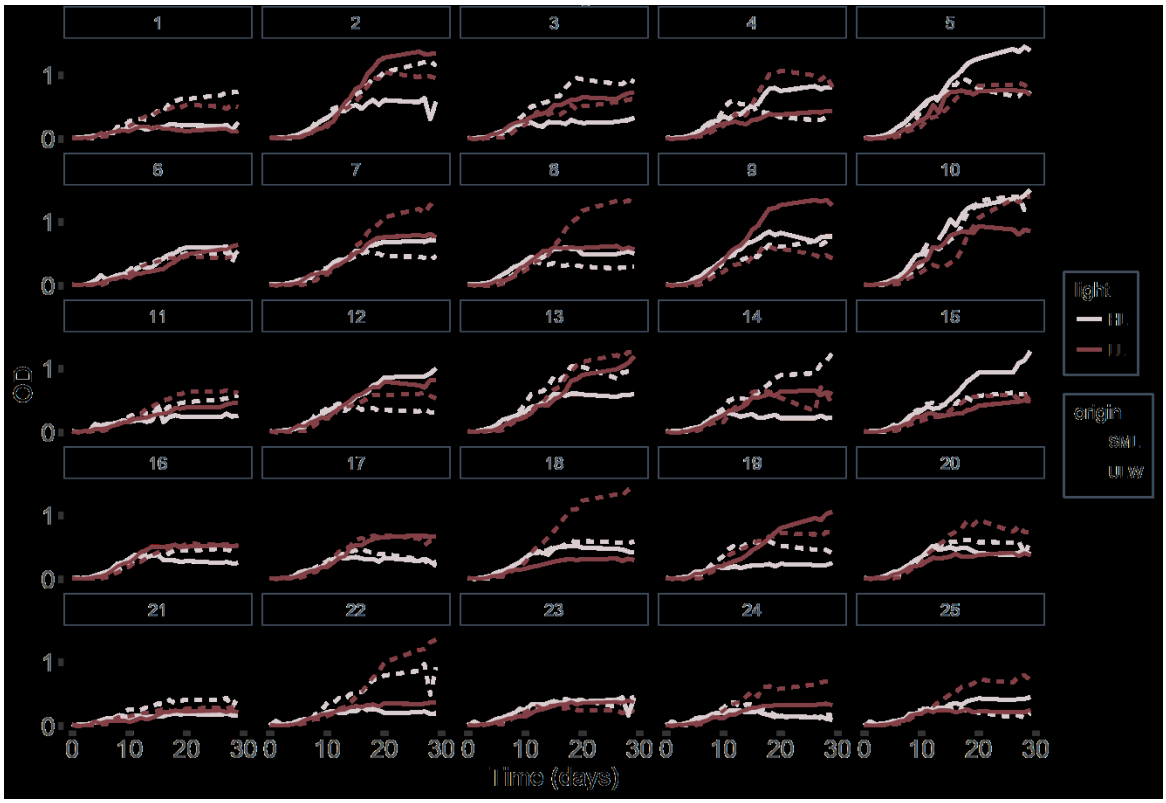

Figure 1: Optical density measurements over time from the outer fjord community. Nitrogen addition increased from the left to the right panels and phosphorus addition increased from the bottom to the top, resulting in the highest nitrogen and phosphorus concentrations in treatment 5, lowest concentrations in treatment 21. Communities from the surface micro layer (SML) are displayed as solids lines and communities from the underlying water (ULW) as dashed lines. Communities incubated at low light intensity are shown with dark red lines while communities incubated under high light are shown as light red line.

Appendix

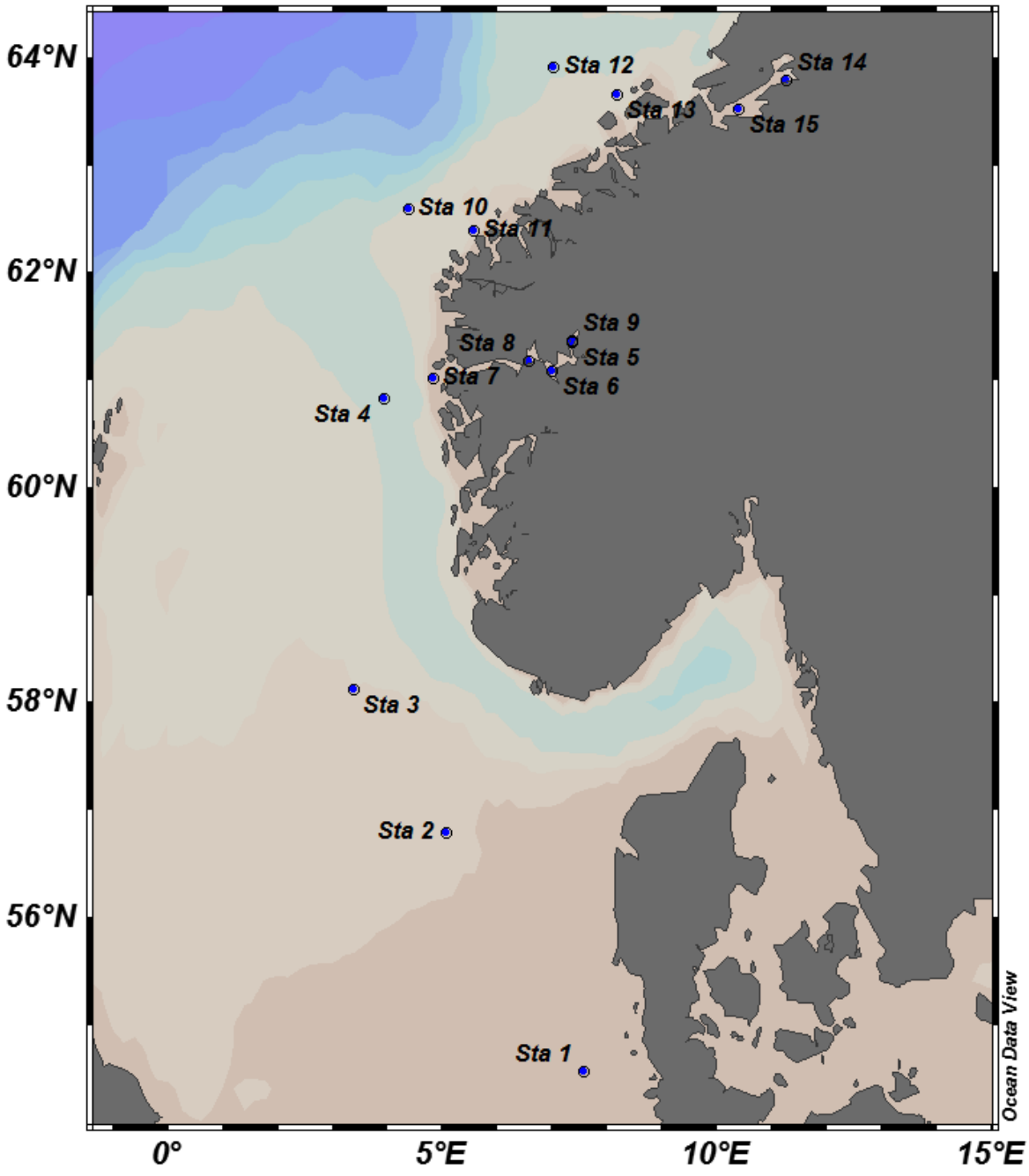

Figure 1: Station map for cruise HE491

Table 1: Details on stations for cruise HE491

Station	Longitude[degrees_east]	Latitude[degrees_norths]	Date	Time UTC
Sta 1	7.975	53.932	08.07.2017	11:20
Sta 2	5.063	56.787	09.07.2017	8:00
Sta 3	3.374	58.117	10.07.2017	6:45
Sta 4	3.931	60.829	11.07.2017	7:30
Sta 5	7.367	61.358	12.07.2017	7:00
Sta 6	6.999	61.089	13.07.2017	6:45
Sta 7	4.827	61.013	15.07.2017	7:00
Sta 8	6.560	61.184	16.07.2017	8:47
Sta 9	7.368	61.362	17.07.2017	6:47
Sta 10	4.382	62.595	19.07.2017	7:00
Sta 11	5.564	62.387	20.07.2017	11:10
Sta 12	7.026	63.918	22.07.2017	6:40
Sta 13	8.170	63.652	23.07.2017	7:00
Sta 14	11.278	63.796	24.07.2017	6:50
Sta 15	10.409	63.524	25.07.2017	7:00