It has been estimated that phytoplankton contribute to about a half of the world's primary production and to over 90% of marine primary production. Phytoplankton are, therefore, responsible for releasing half of the world's oxygen and for removing large amounts of carbon dioxide from the surface waters. Without phytoplankton, atmospheric carbon dioxide concentration would increase by more than 200 ppm. In addition to this role, phytoplankton support essentially all life in the oceans despite their low biomass (1% of the Earth biomass). To evaluate how marine phytoplankton influence the carbon cycle, oxygen concentrations and affect the ocean food web, an accurate knowledge of marine primary production, seasonal cycle of phytoplankton and their inter-annual changes are required. Currently, the world marine primary production estimates range by a factor of two between different models. When only the Arctic Ocean is taken into account, this factor rises to fifty, because the optical properties of the water constituents as well as the vertical distribution of phytoplankton differ from those of the global ocean. Nowadays, Arctic phytoplankton deserve special attention as they are already living in waters with the most prominent climate change effect. The Arctic waters are beginning to show a shift towards a fresher surface layer, thinner sea ice, more open water area and are very likely to experience ice-free summers in the near future. These changes in turn alter solar irradiation, nutrient transport and plankton seasonality. Whether such an impact will result in an increase or a decrease of phytoplankton remains questionable.

The current study combines remote sensing, simulated and field data for the years 1998-2012, to investigate the seasonal cycle, variability and productivity of phytoplankton in the Greenland Sea, which is one of the most productive regions of the Arctic Ocean, as well as the most sampled region in terms of field data Specific objectives for this case study in the Greenland Sea were: 1) to study the interaction between phytoplankton and physical factors, such as sea ice concentration and thickness, water temperature and salinity; 2) to investigate temporal trends, seasonal cycle and spatial variability of phytoplankton; and 3) to obtain more accurate estimates of primary production.

First, we focused only on the northern part of the Greenland Sea (Fram Strait). The western, sea ice-dominated, part of the Fram Strait, proved to have short, late (mid-May) and time varying phytoplankton blooms. At the marginal sea ice zone of the western Fram Strait, a stratification induced by sea-ice melt was shown to have promoted phytoplankton growth, which resulted in the enhanced biomass observed in May. The eastern part, dominated by warm and salty Atlantic waters, experienced earlier (end of April) and longer blooms. Moreover, in the eastern Fram Strait, stratification due to solar warming proved to act as a guiding factor for the the open ocean phytoplankton blooms, while the declining coastal ice was seen to promote the phytoplankton blooms along the coast of Svalbard. We have not observed a direct effect of the Arctic sea ice decrease in the time series of the Greenland Sea

phytoplankton. However, we have observed that the enhanced stabilization of the water column, which was very likely caused by sea ice melt, promoted phytoplankton blooms. In the summer months, generally, the phytoplankton are concentrated in the upper ocean layer and are not limited by the light availability. The concentration of nutrients in this layer will, hence, determine the threshold up to which the primary production at these polar latitudes can increase in the future, provided the environmental changes continue.

We have also studied the whole Greenland Sea to investigate and prove that the Greenland Sea chlorophyll vertical profiles largely deviate from the generalized schemes proposed earlier for global waters, which are usually used in primary production models. We developed a Greenland Sea specific algorithm which allowed accurate (only 4% underestimation when compared to in-situ data) estimation of the chlorophyll vertical profile based on the surface value. The global primary production model (Antoine and Morel, 1996) was then adapted to the Greenland Sea environment using this developed algorithm.

Our Greenland Sea-adapted version of the Antoine and Morel (1996) primary production model reproduced field data with higher accuracy and less bias as compared to the global version of the same model and the, more commonly used, satellite primary production model by Behrenfeld and Falkowski (1997a). Over thirteen years of observations, the primary production showed an increasing trend in the north-eastern open ocean area of the Greenland Sea (which is mainly influenced by the Atlantic waters), where, for the same period, an increase in water temperatures and decline of coastal Svalbard ice was seen. We thus conclude that the observed increase in chlorophyll in the southern Fram Strait is most likely to have resulted from an increase in sea surface temperatures and from better availability of light for phytoplankton.

These newly derived Greenland Sea primary production estimates can be used in the future for validation of primary production obtained from biogeochemical models, which are based e.g. on the climatology of nutrients. On a local scale, it would be interesting for marine biologists to thoroughly compare our estimates with the benthic data, to study the part of the carbon cycle which links the increasing primary production of the Greenland Sea to the carbon stored in the sediments.

To my current knowledge, this study in the Greenland Sea, has for the first time: 1) analyzed the influence of the physical environment on phytoplankton using coupled sea ice-ocean-circulation model, microwave satellite and optical satellite data; 2) investigated the onset and duration of phytoplankton bloom based on satellite data; 3) developed a region-specific primary production model and, based on it, derived basin primary production estimates; and 4) modeled in-situ primary production from available in-situ irradiance, biomass, absorption and temperature profiles data.