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Dynamics of nutrients and phytoplankton Chl a influenced by mesoscale and sub-mesoscale physical processes in the Gulf of Finland (Baltic Sea)

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Heterogeneity in distribution of nutrients and phytoplankton is in a great extent influenced by hydrophysical processes in mesoscale and sub-mesoscale. In order to understand these links and to estimate the role of physical processes versus vertical migrations and growth of phytoplankton, high-resolution measurements and sampling are needed.
We present the results of multiparametric observations in the Gulf of Finland (Baltic Sea) in spring-summer 2010. The measurement program was designed to map both, the horizontal and vertical distribution of ecological state variables with sufficient resolution, duration and extent. An autonomous measurement system (Ferrybox) installed on board a ferry travelling between Helsinki and Tallinn (distance – 80 km) was used for measurements and sampling in the surface layer (water intake at 4 m depth). Temperature, salinity, Chl a fluorescence and pCO2 were recorder along the ferry route twice a day with a time step of 20 s (corresponding approximately to a spatial resolution of 150 m) and weekly water sampling at 17 locations was conducted. Water samples were analyzed for nutrient ($PO4^{-}$, $NO2^{-}$+$NO3^{-}$) concentration (samples collected in March-May), Chl a content and phytoplankton species composition and biomass.
The vertical distributions of temperature, salinity and Chl a fluorescence were measured by a moored water column profiler deployed close to the ferry line. Vertical profiles acquired at the buoy station were transmitted after every profiling conducted with a time step of 3 hours in the layer from 2 to 45 metres. An acoustic Doppler current profiler (ADCP) was deployed near the autonomous buoy profiler to register the vertical flow structure in the whole water column (water depth 86 m). CTD measurements and water sampling on board the research vessel SALME were performed from early April until mid August. Water samples were analyzed for nutrient ($PO4^{-}$, $NO2^{-}$+$NO3^{-}$ and in July also NH4+) concentration, Chl a content and phytoplankton species composition and biomass. Satellite images allowed to see the horizontal distribution of the sea surface temperature and Chl a in a wider area adjacent to the study site. Surveys using a towed undulating vehicle equipped with temperature, salinity, phycocyanin and Chl a fluorescence sensors were conducted to map the horizontal distribution of phytoplankton in the sub-surface layers.
The results show high variability of Chl a distribution both in time and space. Spring bloom dynamics and heterogeneity was closely linked to physical forcing – prevailing circulation in the surface layer, development of stratification (including upward and downward movement of seasonal thermocline) and mesoscale features/processes. Surface layer in the regions of more intensive spring bloom became nutrient depleted faster than in the rest of the study area. Vertical distribution of nutrients left after the spring bloom (and its development) had a clear influence to the Chl a dynamics in the surface and sub-surface layers. Vertical Chl a dynamics revealed a diurnal signal (in summer) with downward migration of phytoplankton reaching greater depths when the nutriclines went deeper. Occurrence of sub-surface maxima of phytoplankton biomass were related to meso-scale features (eddies and fronts) while the highest Chl a values were observed in connection to the sub-mesoscale advection (intrusions). Relatively high nutrient concentrations were observed at the depths of sub-surface Chl a maxima. At the same time the water column above those maxima was almost nutrient depleted.