Simulation of nutrient transport from different depths during an upwelling event in the Gulf of Finland*

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Abstract

Numerical simulation experiments with a high-resolution circulation model were carried out to study nutrient transport from different depths to the surface 10-m layer during an upwelling event along the northern coast of the Gulf of Finland in July 1999. The initial nutrient distribution is based on field measurements performed in the north-western part of the Gulf. Wind forcing covering the period of the upwelling along the northern coast was turned through 180° to simulate an upwelling along the southern coast. The simulation results showed that the main phosphorus transport to the upper 10-m layer occurred from depths shallower than 30 m for the upwelling events along both the northern and the southern

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coasts. Nitrogen transport to the upper 10-m layer was the largest from depths of 40–55 m for the upwelling along the northern and 40–65 m for the upwelling along the southern coast. Simulated cumulative volume transports to the upper 10-m layer from different depths showed that the contribution from deeper layers was larger in the case of the upwelling along the southern coast. The reduction of wind stress had a bigger influence on water transport from the deeper layers.

1. Introduction

Wind-driven coastal upwelling is a typical phenomenon in the Baltic Sea (Gidhagen 1987, Myrberg & Andrejev 2003) with strong upwelling events occurring with an annual average frequency of up to 30% in some parts of the Baltic (Kowalewski & Ostrowski 2005).

In the Gulf of Finland, a sub-basin of the Baltic Sea oriented from west to east, wind-driven coastal upwelling events are caused by either westerly or easterly wind forcing, which must have been operating for at least 60 h to generate an upwelling in the Gulf (Haapala et al. 1994). Upwellings and related mesoscale structures (meanders, filaments and eddies) in the region have been studied with different methods – field observations (e.g. Haapala et al. 1994, Lips et al. 2009, Kuvaldina et al. 2010), remote sensing (Kahru et al. 1995, Uiboupin & Laanemets 2008) and model simulations (Myrberg & Andrejev 2003, Zhurbas et al. 2008, Laanemets et al. 2009). Because the prevailing wind in the region blows from the south-west (e.g. Soomere & Keevallik 2003), upwelling events along the northern coast are more frequent.

Coastal upwelling typically transports nutrient-rich deeper water to the surface euphotic layer. Simulations with the ecohydrodynamic model by Kowalewski (2005) in the Hel region (the Baltic Sea) during an upwelling event showed an elevation of nutrient concentrations and an increase of phytoplankton biomass in the surface layers, especially during the spring bloom. Owing to the difference in vertical locations of the summer nutriclines in the thermocline (the phosphacline is shallower than the nitracline in the Gulf of Finland, as shown by Laanemets et al. (2004)), nutrients may be transported with an excess of phosphorus, compared with nitrogen according to the Redfield ratio. During the nutrient-depleted summer period, an upwelling is probably one of the main phosphorus sources for the formation of nitrogen-fixing cyanobacteria blooms (Vahtera et al. 2005).

Comprehensive reviews of upwelling in the Baltic Sea, its dynamics and effects on the ecosystem have been presented by Lehmann & Myrberg (2008) and Myrberg et al. (2008).

Previous numerical studies showed that the instability of longshore baroclinic jets and related thermohaline fronts caused by coupled upwelling