Observatory in the Wadden Sea: Nutrient cycling and export to the North Sea

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Abstract-**In the southern North Sea, an observatory is permanently installed in the tidal flat area of Spiekeroog Island. The observatory permits continuous nutrient (silica, phosphate, nitrate, nitrite) measurements in the open water column. Nutrients vary on tidal and seasonal time scales depending on phytoplankton dynamics and nutrient recycling in tidal flat sediments. Model results indicate that dissolved nutrients are exported from the tidal flat system to coastal waters of the North Sea. Thus, nutrient cycling in tidal flat areas may influence nutrient and phytoplankton dynamics in coastal waters of the southern North Sea.**

I. INTRODUCTION

In the southern North Sea, a large tidal flat area extends between the coastline and a chain of barrier islands. Tidal inlets between the barrier islands enable water exchange between the tidal flat area and the North Sea. Over-all, the nutrient budget in the open water column is influenced by three water masses: (1) North Sea water entering the tidal flat area during high tide, (2) Fresh water inflow from the hinterland, (3) Pore water release from tidal flat sediments.

On the one hand, our studies focus on nutrient cycling in the tidal flat area. On the other hand, we estimate whether nutrients are exported from the tidal flat area to coastal waters of the North Sea. Consequences of internal nutrient cycling in the tidal flat area and nutrient export towards the North Sea on biogeochemical processes and phytoplankton dynamics will be evaluated.

II. MATERIAL AND METHODS

A. Study area

The Wadden Sea is one of the largest tidal flat areas worldwide and extends along the southern North Sea coastline for almost 500 km between Den Helder (The Netherlands) and Skallingen (Denmark) (Fig. 1). In the study area, tidal flats are bordered by the coastline and a chain of barrier islands located some kilometers offshore. This study was carried out in the tidal inlet between the two barrier islands Spiekeroog and Langeoog, NW Germany (Fig. 1).

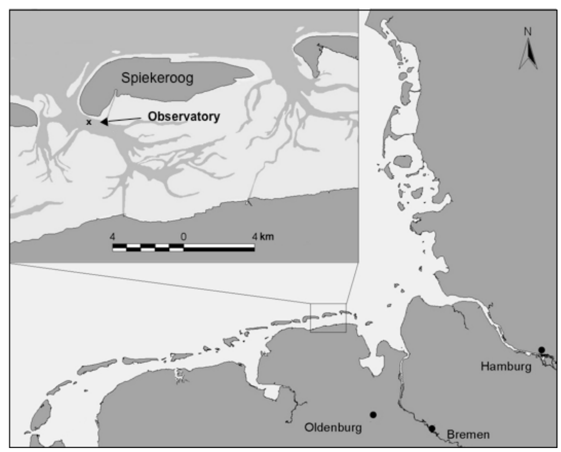

Figure 1. Study area in the Wadden Sea close to Spiekeroog Island, NW Germany.

B. Observatory

The observatory is permanently installed and is designed for operation throughout the year (Fig. 2). This permits measurements even during storm surges. The observatory consists of a 35 m long steel pole with a diameter of 1.6 m. About 15 m of the pole are driven into the sediment to assure stability during periods of strong tidal currents and wind. The mean seawater depth at the observatory is about 13 m. A platform on the top is equipped with two containers for the electrical system and the station computer controlling measurements, data storage, and power management. All analysis systems can be maintained on site as well as via a land-based computer station connected to the station via modem and wireless LAN.

The submerged part of the pole contains ten through-flow tubes, ranging from 0.5 m to 11.5 m above sea floor. Water is flowing through these tubes in the direction of the tidal current. The through-flow tubes are installed at different depths to identify possible vertical gradients. Inside the tubes, sensors are mounted to measure physical parameters such as temperature, pressure, and conductivity.

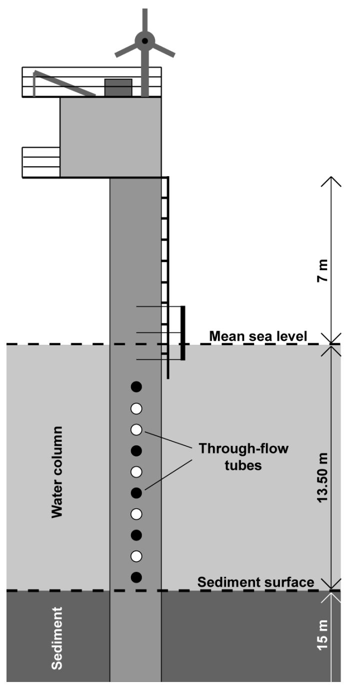

Figure 2. Sketch of the observatory (modified after [3]). Through-flow tubes marked in white are equipped with sensors, whereas tubes in black are closed.

C. *Nutrient analyses*

Nutrients are measured in surface waters sampled from the uppermost through-flow tube at 9 m above seafloor. For filtration, a cellulose filter belt is used (length 100 m; Schleicher & Schuell, No. 1574, Germany). Prior to analysis, the entire tubing from the inlet via the belt filter towards the outlet is rinsed for three minutes. Afterwards, the nutrient analyzers are rinsed with filtered water for five minutes.

Silica, phosphate, nitrate, and nitrite are measured hourly by nutrient analyzers (Systea µM1000, Systea, Italy) installed inside the observatory. These analyzers are based on a loop-flow reactor and loop-flow analysis technology. The filtered sample is pumped into the analyzers where the reagents are added automatically and nutrients are determined photometrically. A detailed description of the operation of the nutrient analyzers is given in [3].

III. Results and Discussion

Nutrients are essential for phytoplankton dynamics. For example, diatoms, which are one of the most common types of phytoplankton, have a cell wall made of silica. Thus, silica is essential for their growth. During winter and early spring, silica concentrations are high in the open water column of the tidal flat area of Spiekeroog Island (Fig. 3). In combination with increasing water temperature and light, this favours diatom blooms in spring. During the algae bloom, silica concentrations decrease sharply resulting in a silica deficit. When environmental conditions turn unfavourable due to the depletion of silica, diatom cells stop to grow or even die.

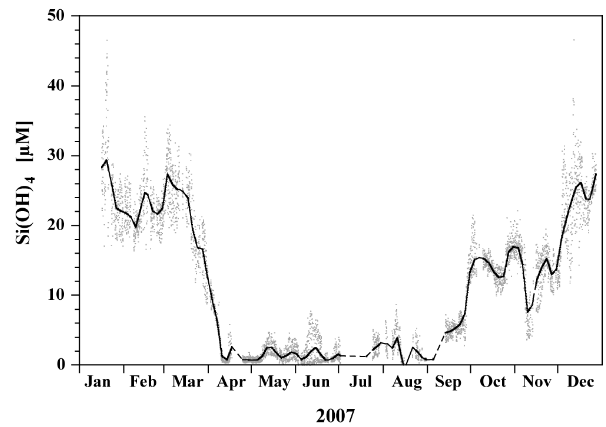

Figure 3. Seasonal silica pattern in 2007. The grey dots indicate single measurements, whereas the black line shows the average concentration.

Subsequently, diatom frustules are deposited on or incorporated into sediment surfaces where they are slowly degraded. Thereby, silica is recycled and released into pore waters. This leads to higher silica concentrations in pore water compared to seawater. Due to water exchange between sediments and the overlying water column, nutrient-rich pore waters are discharged from surface sediments into the open water column [2]. Further, silica is enriched in deep pore waters, which are released from permeable tidal flat margin sediments during low tide [1]. Both, pore water advection in surface and deep sediments lead to the discharge of nutrients from tidal flat sediments to the open water column.

The discharge of nutrient-rich pore waters is further reflected in tidal nutrient dynamics in the open water column. Silica and phosphate show maximum concentrations during low tide, when pore water discharge is highest (Fig. 4).

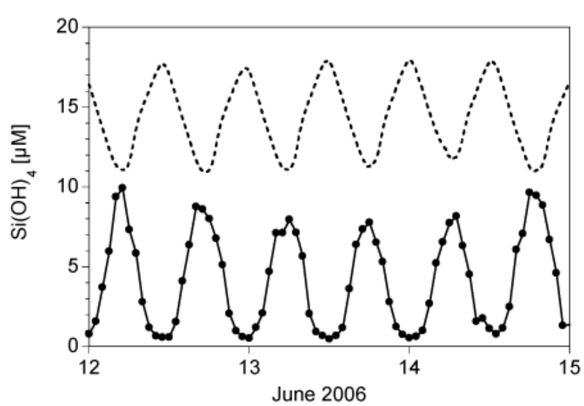

Figure 4. Tidal silica pattern. The dashed line indicates the water level.

IV. CONCLUSIONS

Fresh water inflow was found to be a minor nutrient source to the tidal flat area. In contrast, pore water discharge enriches the tidal channels in species such as nutrients and methane [4]. Due to the high nutrient concentrations in pore water compared to seawater, the tidal flats are a significant nutrient source to the tidal flat area. Pore water discharge supplies nutrients to the open water column on tidal and seasonal time scales.

Water exchange between the tidal flat area and the North Sea leads to a coupling of processes in both systems. Using the Ecological Tidal Model EcoTiM [5] to describe seasonal pattern has shown that dissolved inorganic nutrients like silica and phosphate are exported from the tidal flat system to the open North Sea. The model indicates that export of inorganic silica from the tidal flat system exceeds the import from the North Sea by about 8% (based on annual averages). Consequently, nutrient cycling in tidal flat areas may influence nutrient and thus phytoplankton dynamics in coastal waters of the southern North Sea.

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