A sensor network for long-term monitoring of sediment transport in the coastal region

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***Abstract* - We introduce a sensor network suitable for measuring pressure and light transmission in coastal seas over time periods of several months. The purpose is to use the collected data for the investigation of sediment transport processes in the tidal flats of the North Sea in particular during extreme events like storm surges and high tides.**
The main development objectives were to conceive a modular system that is mobile and can be easily relocated in order to be able to respond quickly to emerging scientific demands. The system design builds up a controller system with CAN bus, which proved to be robust and reliable. Design considerations have been spent on what type of cable could be used under the expected adverse conditions and alternative designs using single buoy deployments have been evaluated as well. The electronic is designed to accommodate a variety of interfaces to be able to integrate the type of sensors that are important for the process study. To that end CAN bus is offering commercially available adapters that facilitate the interfacing process significantly. Special care has been taken to exclude a malfunction of the network if only one sensor fails.
The pressure sensor has been selected based on considerations in regard to cost/performance ratio. Minimum requirements exist because of the needed fast and precise resolution in pressure to resolve wave heights. With the selected pressure sensor a prototype underwater device has been constructed and lab and field tests were carried out. A newly developed hyperspectral transmissometer allows deriving data on suspended matter concentration and size distribution. The sensor casing has been specifically designed to protect against biofouling. The capsulated sensors get only in contact with seawater on demand, e.g. prior to a storm surge. The sensor system will result in a better understanding of the dynamics of sediment transport and changes of seafloor morphology which cannot be observed with conventional methods during storm events.
First results from deployments and algorithms for data processing algorithms are presented.

Index Terms—Sensor network, pressure transducer, wave measurement, sediment transport, transmissometer, multispectral.

I. Introduction

There is growing consensus, that large-scale sediment transport in the German Bight is primarily controlled by rare storm events rather than by mean conditions (fair weather). Our primary goal is therefore to develop a sensor system for measuring the bottom pressure and the multispectral light transmission over a wide range in the water column in the Wadden Sea that is fully operational during storm surges. In order to stay operational over a time period of several months, the sensor system must have sufficient protection against biofouling .

The deployed sensors have been either newly developed or specifically adapted to the anticipated measurement scenario. They employ mostly well-known methods however in the case of the transmissometer with new optoelectronic components that are ensuring a higher cost-benefit ratio while at the same time enhancing the reliability and requiring less space. With this sensor network the erosion and transport characteristics shall be determined that are mobilized by the swell and that may lead to an enduring change of the bottom topography of the Wadden Sea.

With the collected knowledge a parameterization of the hydrodynamic models shall be achieved that will enable a better prediction of the impact of storm events on the transport of sediment and suspended matter.

In figure 1 the necessity of carrying out this type of measurements is depicted as it shows that the inclusion of

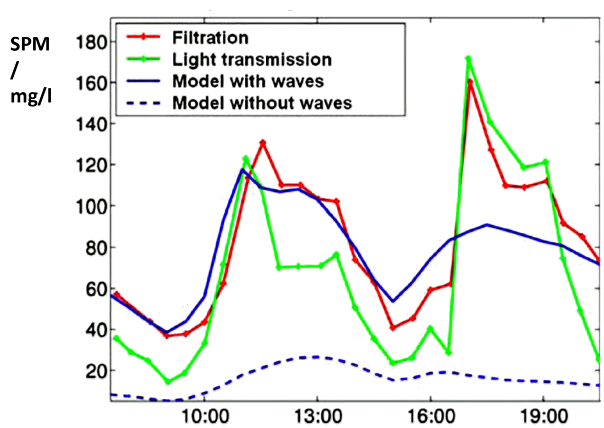

Figure 1.Time series data of suspended particulate matter (SPM) in the water column measured at the Spiekeroog inlet demonstrating the strong influence of waves on the amount of SPM in the water column (Red and green line measurements, solid and dotted blue line modeling results) [1]

wave action in the modeling effort leads to a significant improvement of the calculation of the concentration of suspended particulate matter in the water column.

Figure 1 also shows the need of calibrating and validating models that shall assist in quantifying the transport of sediment and particulate matter.

II. Description of the Sensor Network

A. General system design

The sensor network consists of an array of pressure sensors and multispectral transmissometer systems that are connected to a measuring pole in the Spiekeroog inlet that serves as data communication and energy supply hub. The pole is located in a water depth of 15 m where tide currents can reach maximum speeds of 1.5 m/s. The network design allows for an overall length of 500 m and a maximum number of sensor nodes of 10 (Fig. 2).

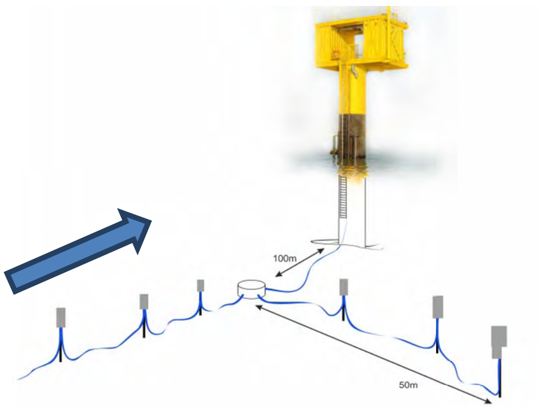

Figure 2. Basic deployment scheme of the sensor network. The grey cylinders are representing the network nodes where the pressure transducers and the transmissometers are connected to. The blue arrow shows the main current direction

To realize the scientific purpose the pressure sensor network is laid out in a pattern alongside and perpendicular to the main current direction.

B. Technical implementation – network, capsule

The sensor network serves the purpose to collect data from spatial distributed sensor systems and to control sampling time and other sensor parameters from shore. Additionally adaptive sampling mechanism can be implemented. The communication outside the water is utilizing 3G modems to allow for larger amounts of data to be transferred. The latest measuring values coded in ASCII are uploaded as data packages on an FTP server or will be send by e-mail automatically.

Figure 3. Stackable printed circuit boards exemplifying our approach to the modular design

The package size will be adjusted according to the transmission quality and the number of requested parameters. As a backup the GSM net can be used to carry out a remote analysis of the system or retrieve limited amount of data. The communication link already passed several tests where typically a data throughput of 1 MByte/h was achieved.

Within the measurement area bio-fouling is posing a massive problem for all long-term observations. To overcome this problem, a special protective casing has been developed that remains closed until the measurement is remotely initialized. This leads to a significant improvement in regard to the effects of fouling.

The main focus of the development work has been on the design of a suitable network architecture. The CAN bus provides a robust and flexible data communication system [2]. The electronic controller was designed as a modular system that provides for an easy extension to different sensor interfaces like RS232 for the Hamamatsu spectrometer, RS422 for the RDI ADCP current meter, RS485for the Keller pressure sensor, I²C for the extension of the electronic and an analogue interface for instance for oxygen sensors like the Aanderaa O_2-Optode.

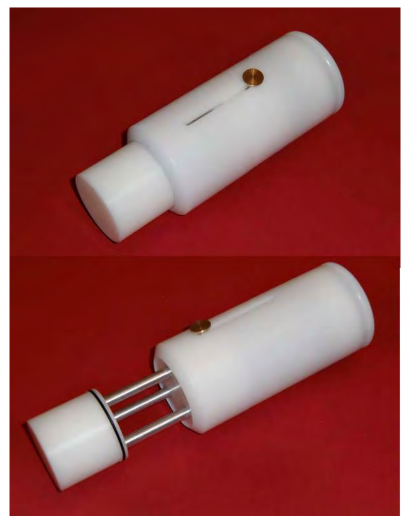

Figure 4. Construction of a protective cover for the deployed sensors shown in closed and open position

TABLE I
NETWORK DESIGN FEATURES

Feature	Description
Design depth	50 m
Deployment duration	6 months
Length of network	up to 500 m
Overall available power	150 W
Number of nodes	10
Sensors	11 pressure sensors 10 transmissometers
Bus type	CAN bus
Communication bandwidth	125 Kbit/s

Supply voltage	24 V DC
RF transmission	UMTS/GPRS package based transmission
Anti-fouling measure	Closed volume
Additional scientific payload	Oxygen sensors will be integrated in a next step

C. *Technical implementation – the pressure sensor*

As pressure sensor a commercially available device from Keller AG has been used (see figure 5). The transducer was packed in a Delrin housing with a membrane on top. The sensor has been selected to meet the requirements of measuring wind-induced waves, tidal waves and water level gradient caused by the tide pools morphology of the North Sea.

TABLE II
SPECIFICATIONS OF THE PRESSURE SENSOR

Feature	Description
Range	0 – 6 bar
Resolution	0.12 mbar
Accuracy	12 mbar
Sampling frequency	10 Hz
Dimensions of the transducer	19 mm diameter, 7 mm thick
Interface	RS 485
Communication bandwidth	9600 Baud

Figure 5. The high precision, miniaturized pressure

D. *Technical implementation – transmissometer*

For the transmissometer a miniaturized spectrometer has been used that allows for particular small structural shape. It is able to discriminate 256 spectral bands in the range of 340 – 750 nm with a resolution of 14 nm.

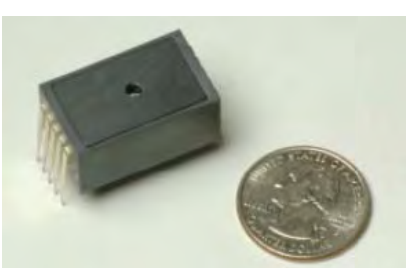

Figure 6. A miniaturized spectrometer (Hamamatsu C10988MA) based on MEMS technology is integrated into the transmissometer with the input window on the top.

The diffraction grating of the spectrometer is made with a nano imprint on a lens surface. A white light LED serves as a multispectral light source in the range of about 420 to 680 nm. The resulting data will be interpreted using well established algorithms [3] for determining the concentration and size distribution of suspended particulate matter, phytoplankton/ chlorophyll α and yellow substance.

III. FIELD TESTS

Field tests at the North-Sea coast, carried out in 2011, resulted in first results for the performance of the network. At Bunkerhill Beach on the island of Sylt, measurements were obtained using three pressure sensors which recorded continuously at a frequency of 4-5 Hz at depths of 0.5 to 5 m. Additional sensors were used to measure atmospheric pressure. The collected pressure data have been compared with videos of the wave field to correlate both observations. The data gained from the pressure sensors at Bunkerhill Beach show significant wave transformations associated with tidal changes. By comparing the spectra at different stages of the tide, the influence of tidal changes on the wave characteristics can be examined. With the incoming tide, wind waves are dominant throughout the whole record. However, the peak frequencies change at both locations.

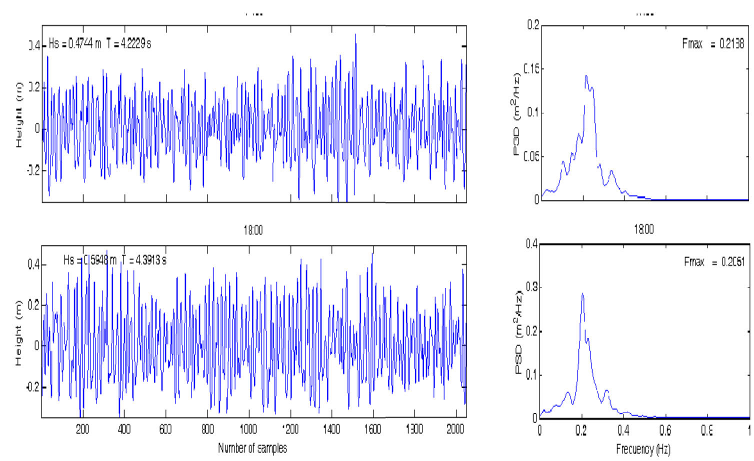

Figure 7. **Records of raw wave data and wave energy spectra obtained by pressure sensor C3 on Bunkerhill Beach. Hs= significant wave height; T = mean wave period; Fmax = peak frequency; PSD = Power Spectral Density**

IV. CONCLUSIONS

We developed a novel sensor design for studying key parameters of sediment transport in coastal seas during and after storm surges. Special emphasis has been placed on coping with biofouling as well as remote data access. Proof of the concept was demonstrated during initial field tests. The next step will be to test the sensor network over a longer time duration. By means of comparison with other methods like in the case of the transmissometer systems comparative measurements will be performed with a commercially available system from the German company TRIOS which has been already successfully tested at the measuring pole close to Spiekeroog. Together with laboratory tests the new transmissometers will be both validated and calibrated. The integration of the pressure sensor and transmissometer systems will be finalized in 2012 and subsequently long-term deployments will be carried out.

Another important aspect is the definition of the measuring process and the according implementation on the hardware and software level. Particular attention will turn on the fast data acquisition and evaluation to reach an adequate temporal resolution and to demonstrate the availability of significant data in real time. For the comprehensive evaluation and quantification of concentration and size distribution of suspended particulate matter data from large areas have to be acquired and transmitted.

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