Universität Rostock

Traditio et Innovatio

Ism Universität Rostock

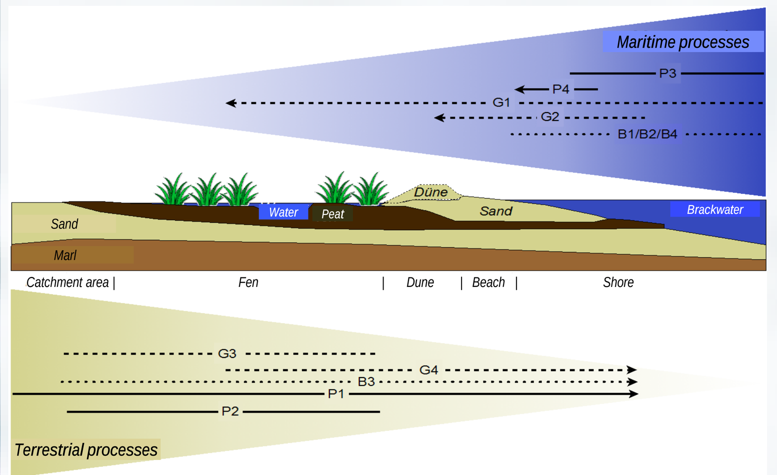
BALTIC TRANSCOAST

Ground water discharge and turbulent transport in oceanic bottom boundary layers in a flow channel


Martin Brede, Nils Karow and Sven Grundmann

Introduction

The **nutrient and oxygen input** into the Baltic Sea is one of the most important mechanisms for the survival of the local plants and animals as well as the entire ecosystem. The inflow of salt water from the North Sea and its mixture is well known.



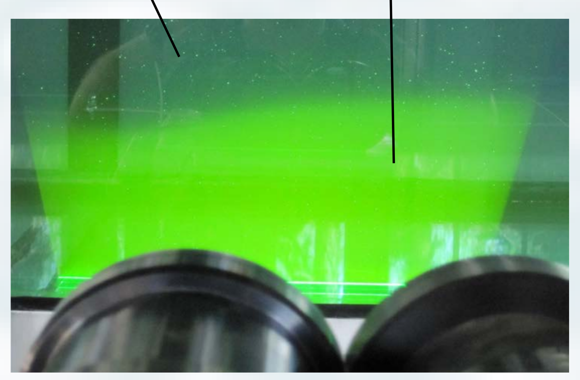
Processes in the tracer transport chain

Another, often underestimated source is the input of nutrients and oxygen through the **submarine groundwater discharge** [Burnett et al. 2006], [Leote et al. 2008], [Moore 2010], [Burnett et al. 2001], [Robinson et al. 2007]. The submarine groundwater discharge (SGD) is detected and investigated on various sites around the world [Beck et al. 2016], [Leote et al. 2008], [Taniguchi et al. 2006], [Rapaglia et al. 2012].Following [Slomp and Van Cappelen 2004] the SGD provides an important input of tracer substances in coastal waters.

The **transport fluxes**, particularly between the Baltic Sea and the coastal groundwater, are one main focus of the DFG graduate school Baltic Transcoast. In the subproject „Waves and Turbulence on permeable coastal seabeds inducing vertical scalar transport" the laboratory experiment described here quantifies the mixture of SGD above a permeable seabed.

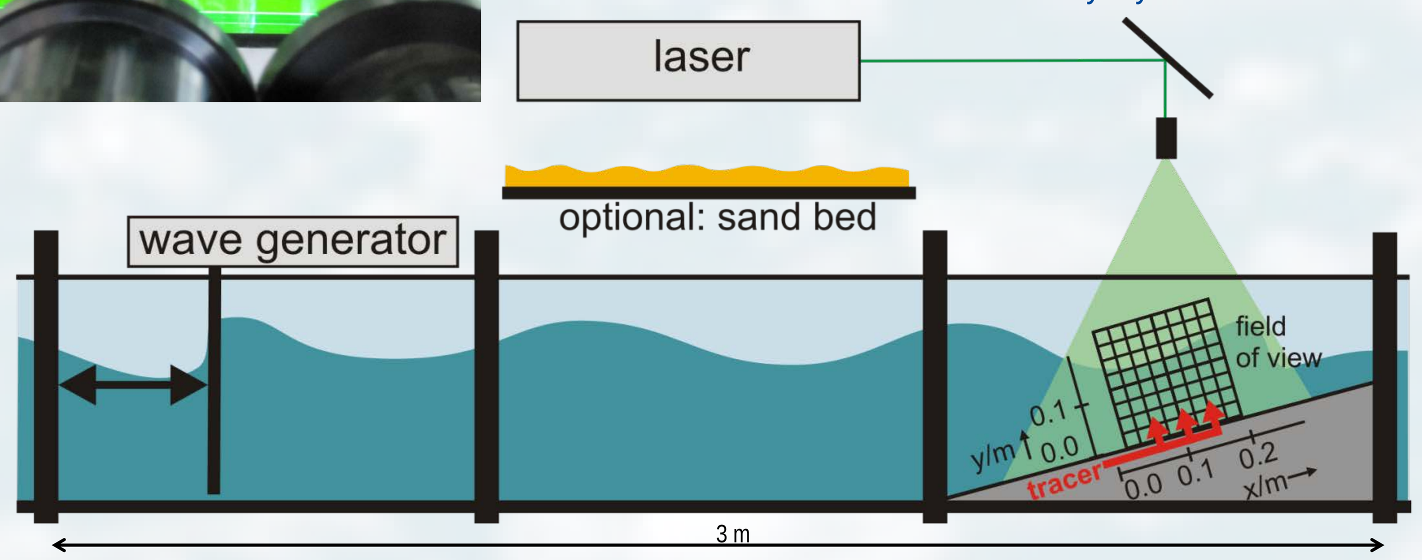
Experimental Setup

Measurement of flow and concentration using PIV (particle) und planar LIF (dye)



The experiments were conducted in a water channel using a laser-optical PIV/LIF measurement system. In the channel shallow water waves are produced employing a Piston-type wave generator. These waves propagate through the channel over a bottom segment with a porous media, which represents a permeable seabed model.

Laboratory experiment allowing the observation of the wave actuated benthic boundary layer with SGD

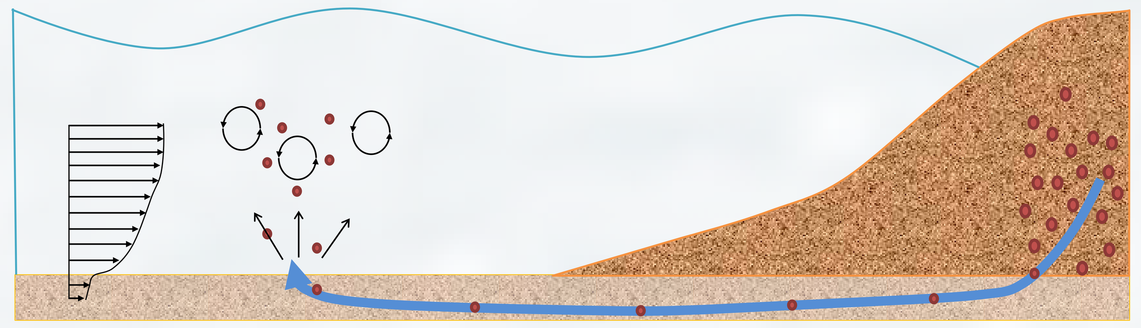


Through the seabed model a fluorescent tracer is injected which then can be detected by the laser-induced-fluorescence method (LIF) and allows a quantitative measurement of the tracer volume flow into the water column. Simultaneously images obtained by particle image velocimetry (PIV) provide instantaneous velocity fields of the unsteady mixing flow.

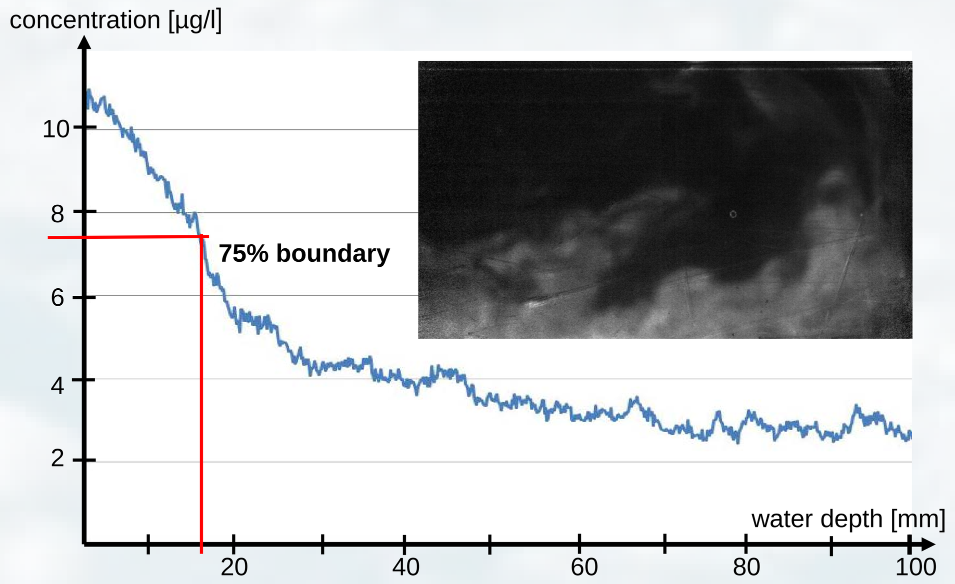
Results

The scientific gap the project intents to close is the connection between the turbulent mixing under different waves above a permeable ground model.

Bottom boundary layer and turbulent transport



First results show, that for a planar seabed the vertical transport is dominated by the diffusion velocity, whereas the horizontal transport is governed by the wave motion. The mixing however occurred in the porous media itself while the spatial transport of the tracer takes place in the water column.

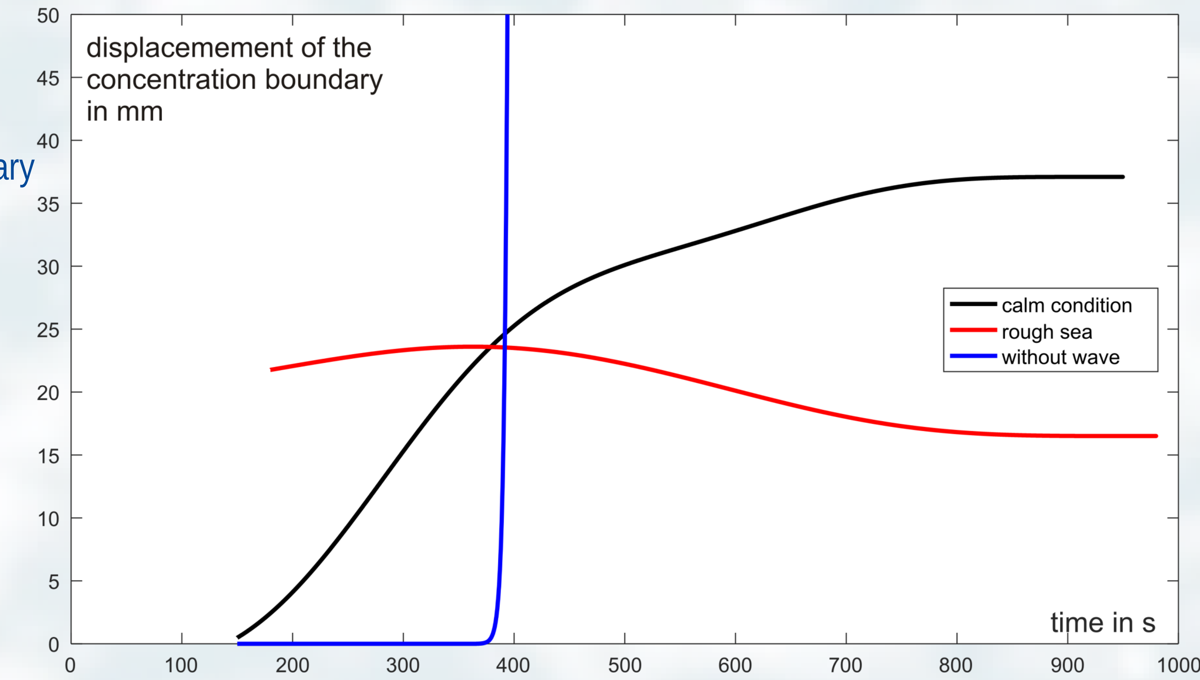


For the quantification of the distribution, a 75% boundary layer concentration was determined. This boundary was observed during a time period of 15 minutes. For the first experiments two different wave scenarios were produced.

Identifying the SGD concentration boundary using planar LIF (dye)

Three scenarios allow the observation of the turbulent transport in the concentration boundary layer using PIV for the velocity and planar LIF for the concentration (SGD) field.

Development of the concentration boundary layer in three wave scenarios

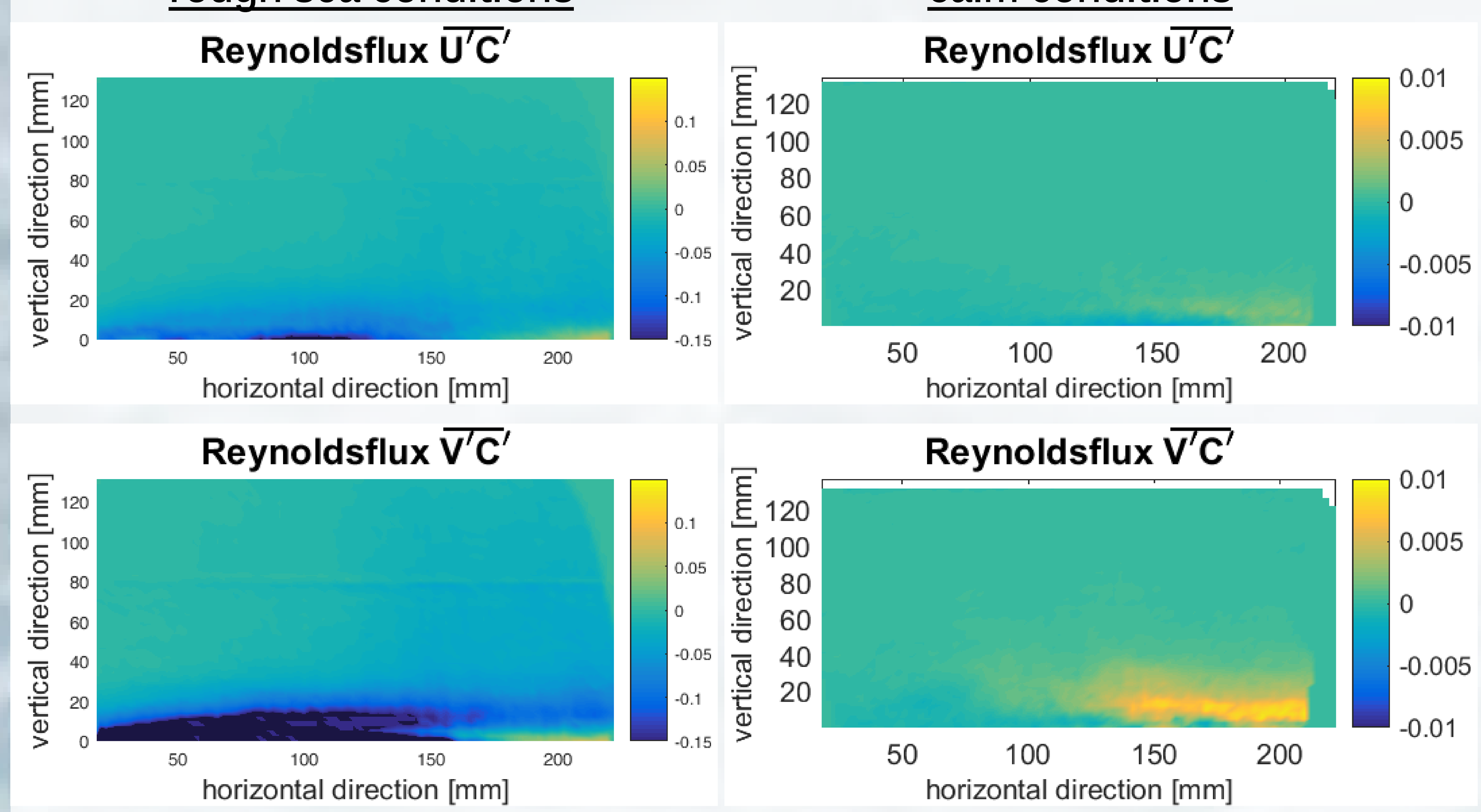


The rough sea scenario (max.velocity:2m/s, period: 3.3s) showed a very fast distribution of the tracer out of the ground into the water column. On the contrary the calm wave scenario (max.velocity:0.5m/s, period: 2s) shows a slow and continuous layering of the tracer above the ground. To compare those results the outflow of tracer without wave action is plotted.

Discussion

The core question of the BALTIC Transcoast project "*waves and turbulence on permeable coastal seabeds inducing vertical scalar transport*" is the quantification of the scalar transport process under different aspects. To investigate these effects PIV/LIF-measurements are used.

The Reynolds fluxes obtained from PIV/LIV show, that under rough sea conditions (left column) the turbulent transport is considerable larger than under calm wave conditions (right column).



Reynolds fluxes quantify the turbulent transport of the discharged groundwater

The fluxes reveal the interaction between wave action, turbulence and scalar transport in the shallow coastal zone. The cross correlation between the horizontal velocity and the concentration fluctuations constitutes the Reynoldsflux $\overline{u'c'}$. It indicates the horizontal turbulent transport, whereas $\overline{v'c'}$ indicates the vertical transport. Here, the turbulent vertical transport fluxes are always dominating over the horizontal fluxes.

The stormy wave conditions caused a much higher and faster transport of tracers near the permeable ground model than under calm wave conditions. However, the higher transport values do not result in a larger concentration boundary layer. Hence, the resulting transport indicates a horizontal efflux of c.

References

BECK, A.J., KELLUM, A.A., LUEK, J.L., AND COCHRAN, M.A. 2016. Chemical Flux Associated with Spatially and Temporally Variable Submarine Groundwater Discharge, and Chemical Modification in the Subterranean Estuary at Gloucester Point, VA (USA). *Estuaries and Coasts 39*, 1, 1–12.

BURNETT, W.C., AGGARWAL, P.K., AURELI, A., BOKUNIEWICZ, H., CABLE, J.E., CHARETTE, M.A., KONTAR, E., KRUPA, S., KULKARNI, K.M., LOVELESS, A., MOORE, W.S., OBERDORFER, J.A., OLIVEIRA, J., OZYURT, N., POVINEC, P., PRIVITERA, A.M.G., RAJAR, R., RAMESSUR, R.T., SCHOLTEN, J., STIEGLITZ, T., TANIGUCHI, M., AND TURNER, J.V. 2006. Quantifying submarine groundwater discharge in the coastal zone via multiple methods. *The Science of the total environment 367*, 2-3, 498–543.

BURNETT, W.C., TANIGUCHI, M., AND OBERDORFER, J. 2001. Measurement and significance of the direct discharge of grioundwater into the coastal zone. *Jounal of Sea Research*, 46, 109–116.

LEOTE, C., IBÁNHEZ, J.S., AND ROCHA, C. 2008. Submarine Groundwater Discharge as a nitrogen source to the Ria Formosa studied with seepage meters. *Biogeochemistry 88*, 2, 185–194.

MOORE, W.S. 2010. The effect of submarine groundwater discharge on the ocean. *Annual review of marine science 2*, 59–88.

RAPAGLIA, J., KOUKOULAS, S., ZAGGIA, L., LICHTER, M., MANFÉ, G., AND VAFEIDIS, A.T. 2012. Quantification of submarine groundwater discharge and optimal radium sampling distribution in the Lesina Lagoon, Italy. *Journal of Marine Systems 91*, 1, 11–19.

ROBINSON, C., LI, L., AND BARRY, D.A. 2007. Effect of tidal forcing on a subterranean estuary. *Advances in Water Resources 30*, 4, 851–865.

SLOMP, C.P., AND VAN CAPPELLEN, P. 2004. Nutrient inputs to the coastal ocean through submarine groundwater discharge. Controls and potential impact. *Journal of Hydrology 295*, 1-4, 64–86.

TANIGUCHI, M., ISHITOBI, T., AND SHIMADA, J. 2006. Dynamics of submarine groundwater discharge and freshwater-seawater interface. *J. Geophys. Res. 111*, C1.

CC BY

Institute of fluid mechanics, Faculty of mechanical engineering and marine technology, University Rostock

DFG Deutsche Forschungsgemeinschaft