Development of adaption strategies for barrier islands (Halligen) in the German Bight

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IN A COLLABORATIVE PROJECT WITH

A Background and Introduction

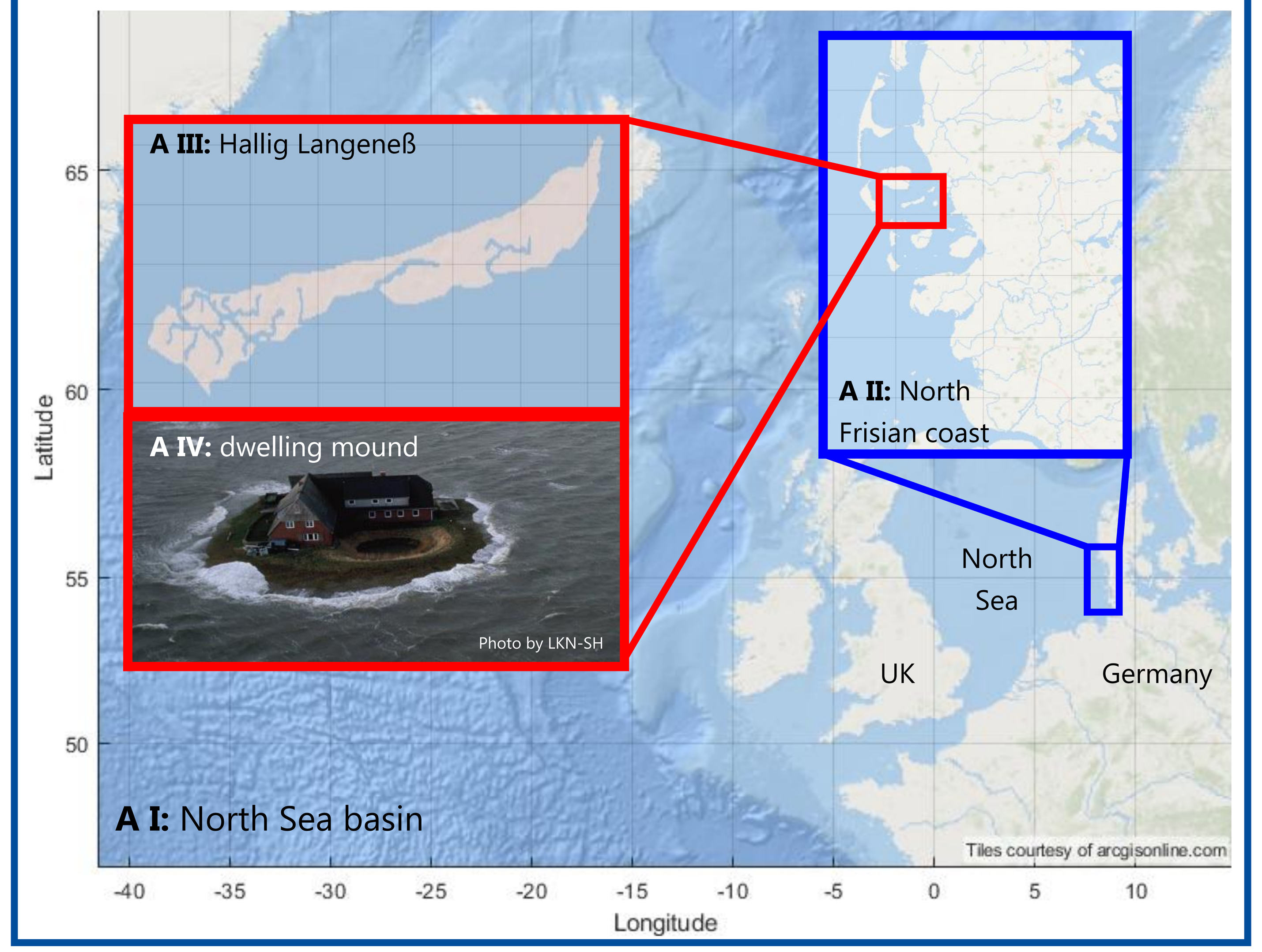
The Halligen are located off the North Sea coastline of Schleswig-Holstein, the most northern federal state of Germany (see **A I/A II**). They are surrounded by the Wadden Sea which was added to UNESCO's World Heritage List in 2009. The Halligen are small and low lying marsh islands that are inhabited by around 270 residents and most of them are involved in federal coastal protection activities. A Hallig essentially consists of the surface area that is frequently inundated and the artificially constructed dwelling mounds that prevent people's houses from flooding (see **A III/A IV**). Over the last centuries, the common **impact of cultivation, subsidence, sea level rise (SLR) and storm surges caused massive land losses** along the North Frisian coast. Hence, at the beginning of the 20th century revetments have been established and since then, the Halligen have mostly been stable in size while still being frequently inundated. Previous research projects (e. g. ZukunftHallig (Jensen et al., 2016)) concluded that the Halligen **benefit from these inundations due to sediment deposition and the subsequent vertical accretion** of the marshland. However, Schindler et al. (2014) showed that some of **the existing revetments can also act like a barrier, partly hindering the sediment transport onto the Halligen.** Furthermore, **SLR is expected to increase faster than the vertical accretion** throughout the last century.

The project **LivingCoastlab** has been initiated to develop sustainable coastal protection and management strategies for the Halligen. In particular we aim at answering the following question:

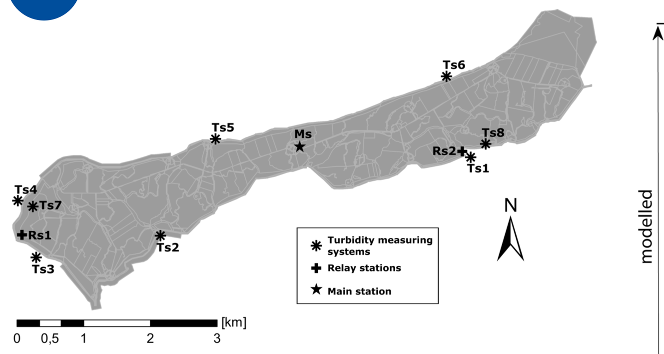
How to increase the natural adaptation capacity of the Halligen to SLR?

This question will be answered by:

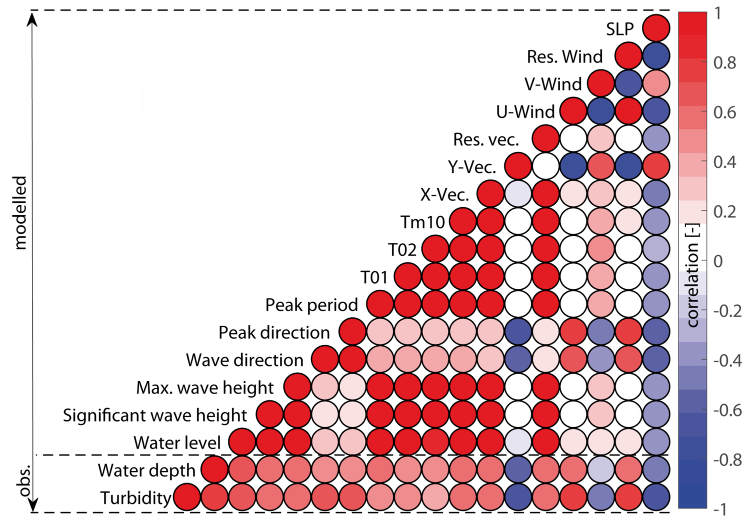
- **Modelling the hydrodynamic forcing and its feedback on sediment transport**
- **Providing long term estimates (for 2030, 2050, 2080) of the sedimentation**
- **Providing turbidity data and vertical accretion data for single storm surge events**
- **Providing optimized protection and management strategies for the Halligen**



B Data and Methods



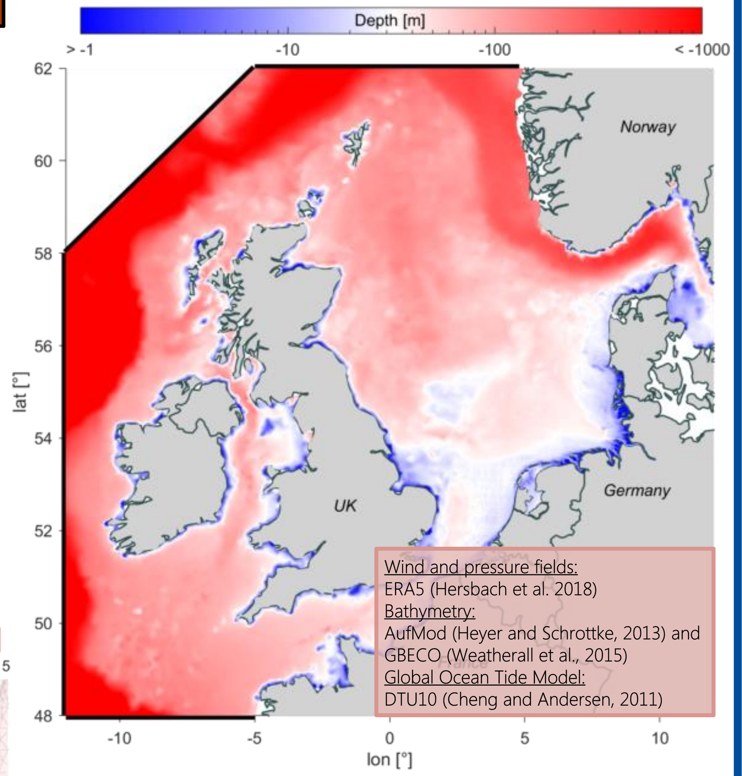
B I: Locations of the different components of the autonomous network of turbidity measuring stations and transmission units (Hache et al., 2019).



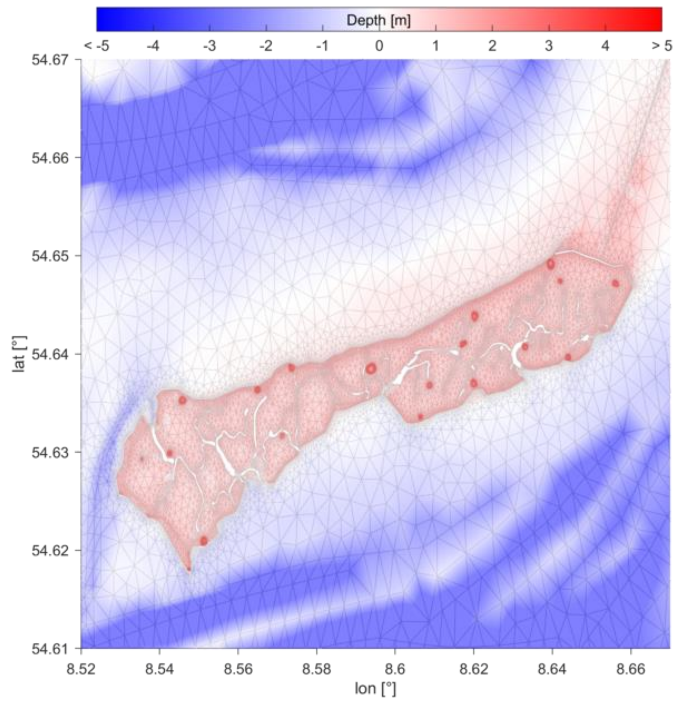
B II: Correlation between individual hydrodynamic variables from a numerical model study (modelled) and the observed (obs.) turbidity and water depth at for four tidal cycles; white indicates a non-significant correlation.

Name	Symbol	Settling velocity [m/s]	Critical bed shear stress [N/m²]	Mass [g]
silt	U	0,0005	0,415	3,746E-08
fine sand with silt as admixture	fSU	0,0037	0,615	7,104E-07
fine sand	fS	0,0122	0,79	4,683E-06
fine sand with medium sand as admixture	fSms	0,0194	0,878	1,029E-05
medium sand	mS	0,027	0,954	1,918E-05

B III: Grain size of bed sediments collected next to the measurment stations and base accumulators. The associated settling velocities, the critical bed shear stress and the individual mass of a particle is shown in the columns.

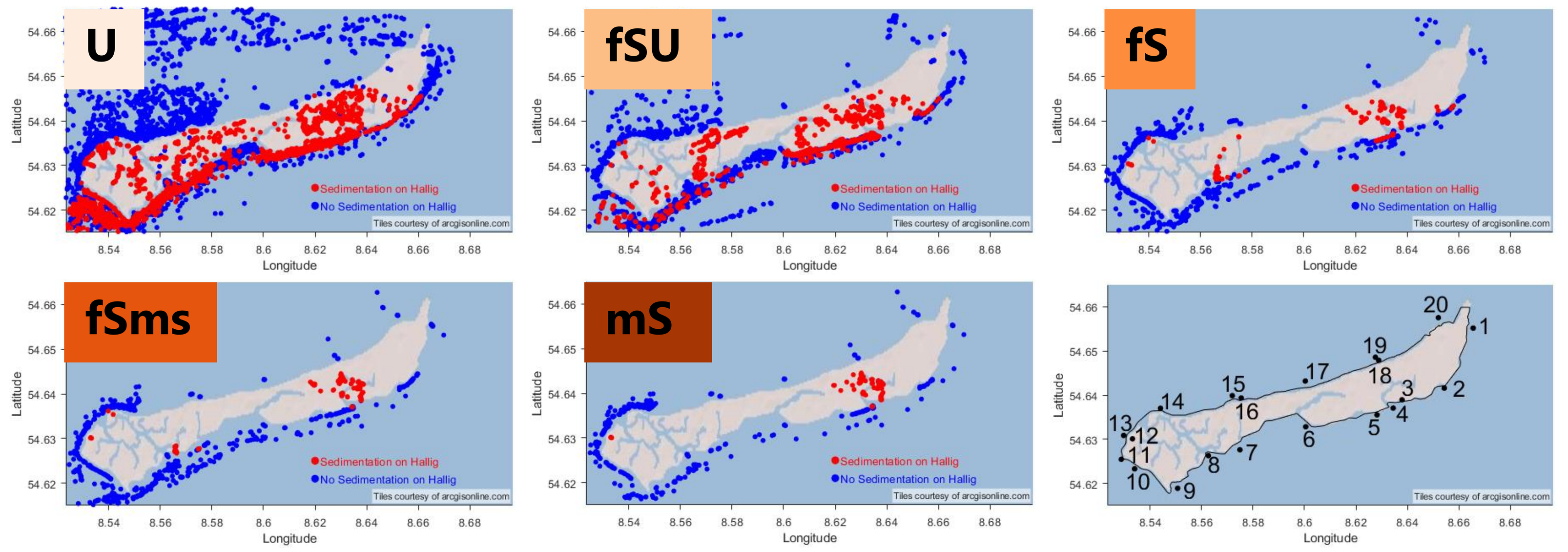


B IV: Model area of the North Sea model. The bathymetry is indicated by the logarithmically scaled colorbar. Striking are the very shallow areas near coastal tidal flats in the German Bight. The location of the boundary conditions are highlighted by the black lines. The calibration/validation of the model simulations is performed in Arns et al., 2015; 2017). The simulation results are used as (i) boundary conditions for the Detail Model of the Hallig Langeneß and (ii) as predictor variables for a regression model to assess the turbidity (response variable).



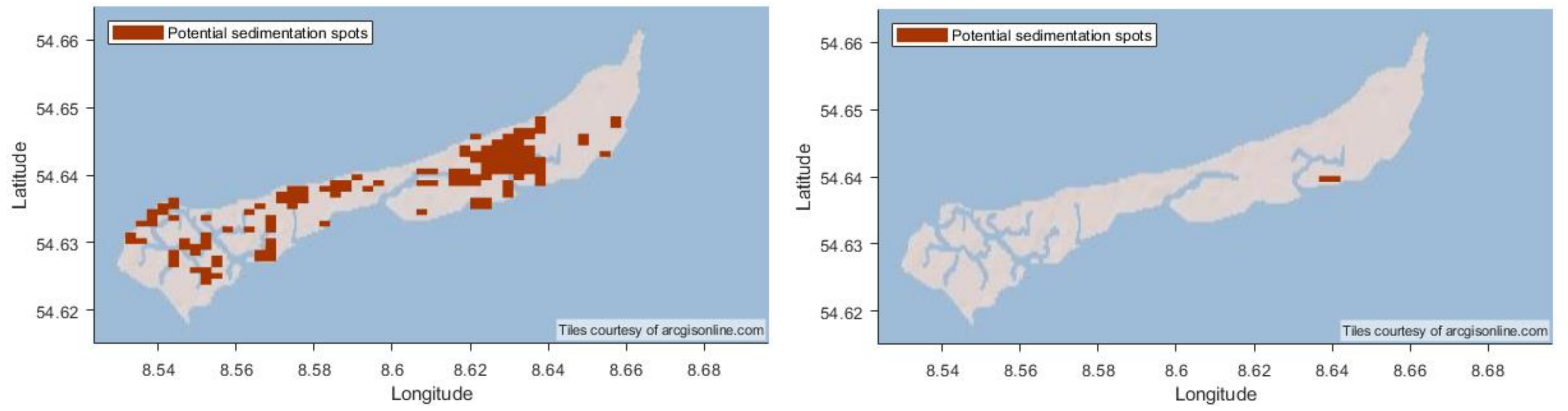
B V: Model area and mesh of the detail model of the Hallig Langeneß. The individual dwelling mounds are indicated by the red dots on the Hallig. Furthermore, the drainage channels connected to the sluices can be identified. The Detail Model of the Hallig Langeneß is calibrated using observations and experiences from the field measurements. The output in terms of the hydrodynamic conditions is used to perform particle tracking analyses which are also calibrated by observation and experiences from field measurements.

C Preliminary Results

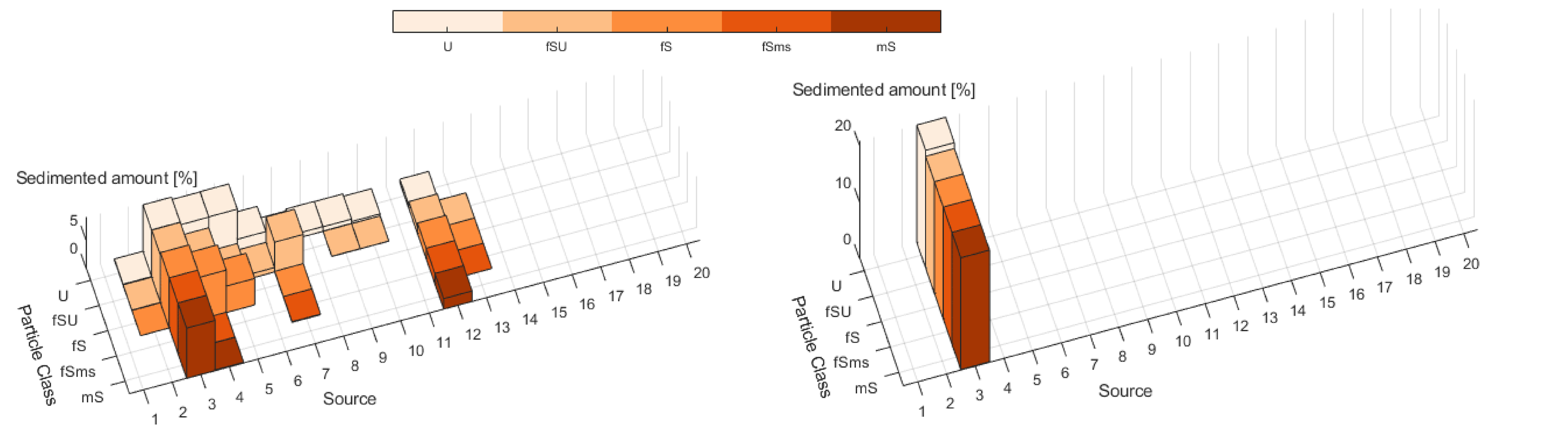


C I: Particle tracks indicating whether the individual particles sediment on (red) or off (blue) the Hallig Langeneß. Each figure shows the tracks for one of the considered grain sizes (see B III). The shown event is the storm surge "Xaver" on 6th December, 2013.

C II: Point sources around and on the Hallig Langeneß where the individual particles enter the model domain.



C III: Difference of sedimentation between the Xaver storm surge event (left) and a more common inundation event (29th October, 2017; right). During a storm surge event a potential sedimentation can occur on the Hallig Langeneß. The particular locations are highlighted in red. Comparing the locations with the ground level elevation shows, that the sedimation takes place especially in the low lying areas. During the common inundation event almost no potential sedimentation can be identified.



C IV: Difference of the sources and the grain sizes leading to a potential sedimentation on the Hallig Langeneß between the Xaver storm surge event (left) and a more common inundation event (29th October, 2017; right). During a storm surge event, particles leading to a sedimentation can be associated with sources from outside the Hallig Langeneß. The particles are mainly irrigated on the Hallig from southerly located sources. In comparison to the common inundation event, no particles are irrigated from outside the Hallig. We just found a potential sedimentation of particles associated with source 3 which is, however, located on the Hallig. Furthermore C III (right) shows that almost no movement of the particles takes place. The analysis of the turbidity measurements during this event reveals also no significant effects.

D Conclusions and Outlook

- **The calibration of the hydrodynamic feedback could be validated with observations during several common innundations.**
- **The model to simulate the sediment transport on and around the Hallig Langeneß shows plausible results in terms of the the movement of the individual particles → the finer the grain size, the slower and less the transport.**
- **The simulated sediment transport confirms the analyses of the measured turbidity as well as the opinion of the residents of the Hallig Langeneß → common innundations do not lead to significant vertical sediment accretion.**

Further research is performed on:

- **How sensitive is the sediment transport against changes in the number/ location of the point sources?**
- **Can a correlation between hydrodynamic/meteorological and the sedimentation be found by including more inundation events?**
- **How does SLR or changes in the topography of the Hallig Langeneß affect the sediment transport and erosion processes?**

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Acknowledgements

The presented research is part of the project "Living CoastLab" within the KüNO program, funded by the German Federal Ministry of Education and Research (BMBF). Project funding number: 03F0759A. Scientific supervision by the German Coastal Engineering Research Council (KFKI).

SPONSORED BY THE Federal Ministry of Education and Research