Assessing PS-InSAR ground motion data toward stability monitoring of coastal flood protection dikes

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Introduction

Sea level rise caused by climate change represents a challenge to coastal flood protection measures, particularly in regions such as the federal state of Schleswig-Holstein. We examined InSAR time series data from the German Ground Motion Service along the entire west coast to estimate how these data can be used to detect and monitor ground motion processes at dikes. These data are based on Synthetic Aperture Radar images acquired by ESA's Sentinel-1 satellites. Time-series analyses are possible for temporally stable backscattering objects (persistent scatterers) on the ground (Fig. 1).

Methods

We used a buffer of 125 m from the center line of the dike seaward (Fig. 2). Along dikes, this buffer was divided into segments of 50 m length. For each of the segments, we calculated a weighted mean vertical ground motion velocity from scatterer velocities of both orbit directions (Fig. 5 and 6). For more specific areas with a high number of scatterers, as in the case of the "Klimaschutzdeich Alter Koog" on the peninsula Nordstrand, we additionally divided the buffer into segments of 20m length each.

For the dam of the Dagebüll-Oland-Langness island railway we carried out ensemble statistics on the time series. Before examining the time series statistically, we filtered the time series with a 3rd-order Butterworth low-pass filter to remove position changes with a period shorter than 90 days. For every acquisition day of the filtered time series we calculated the median, the mean as well as the 15%- and the 85%-percentile position values. Individual scatterers' time series were then compared with respect to the 15% to 85% percentile corridor to detect those with a statistically unusual behavior (Fig. 4).

Preliminary Results

Only in dike sections with a high scatterer density, the monitoring of ground motion processes is possible (Fig. 5 and 6). Jointly analyzing filtered time series and scatterer statistics in time may allow to automatically detect unusual behaviour at a dike segment.

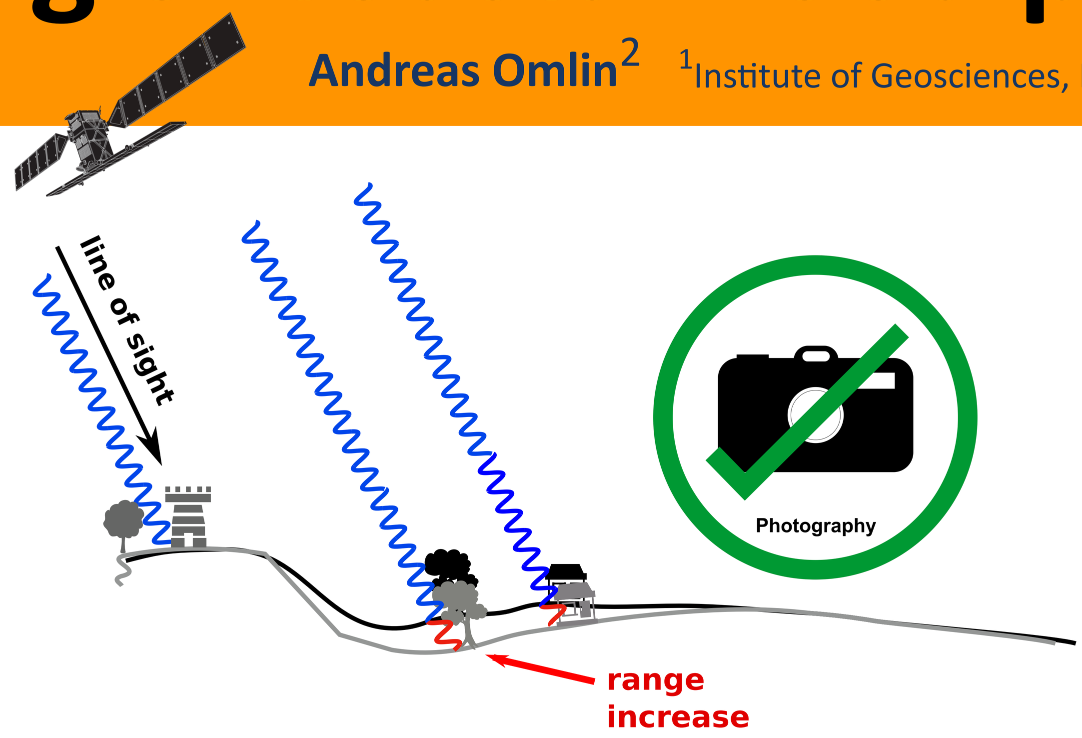
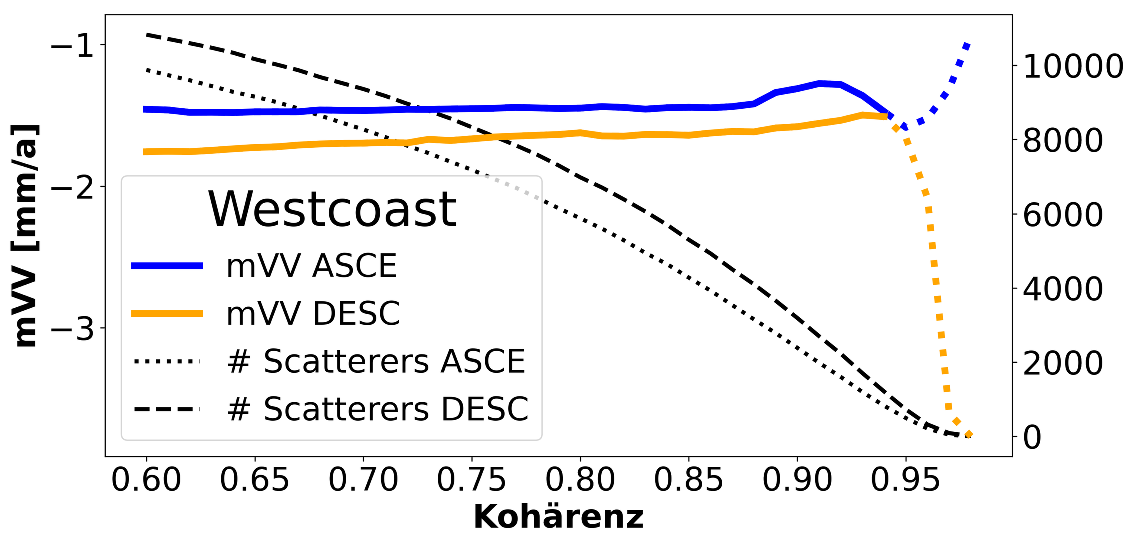


Fig. 1 (above): The basic principle of the SAR acquisition geometry and InSAR method [1]

Fig. 2 (right): Areas along the Westcoast of Schleswig-Holstein with high scatterer density along the dike (green) and those areas without or with only a small number of scattering points (red)

Fig. 3 (beneath): Seen over the whole dike, there is no correlation between the the temporal coherence and mean velocity values.



Conclusions

Simple artificial scatterers could help to fill the abundant data gaps along the dikes (Fig. 2). The scatterer behaviour shows a large variety of characteristics. We anticipate a high potential for machine learning techniques in the future analysis of these time series.

Acknowledgements

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References

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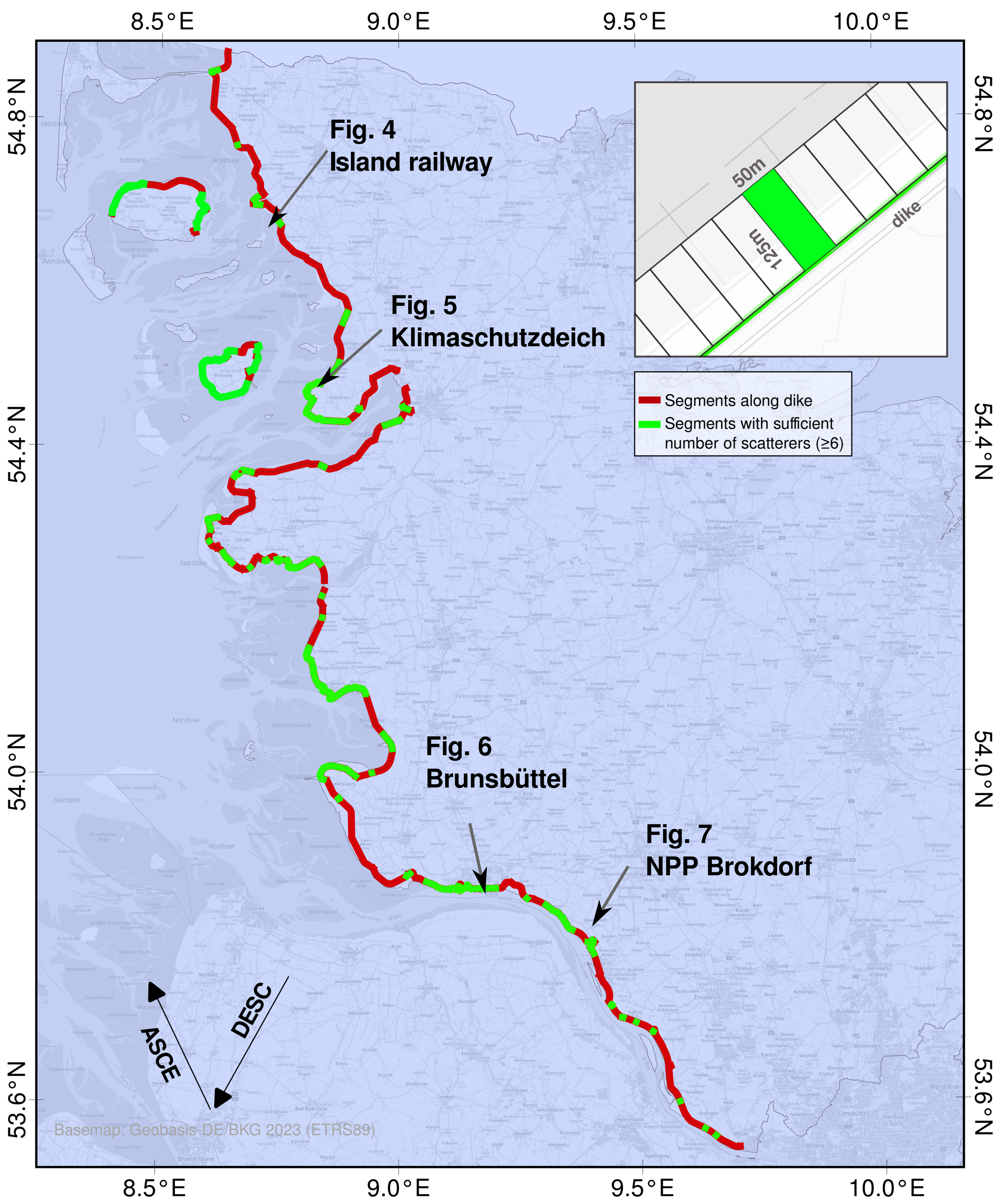

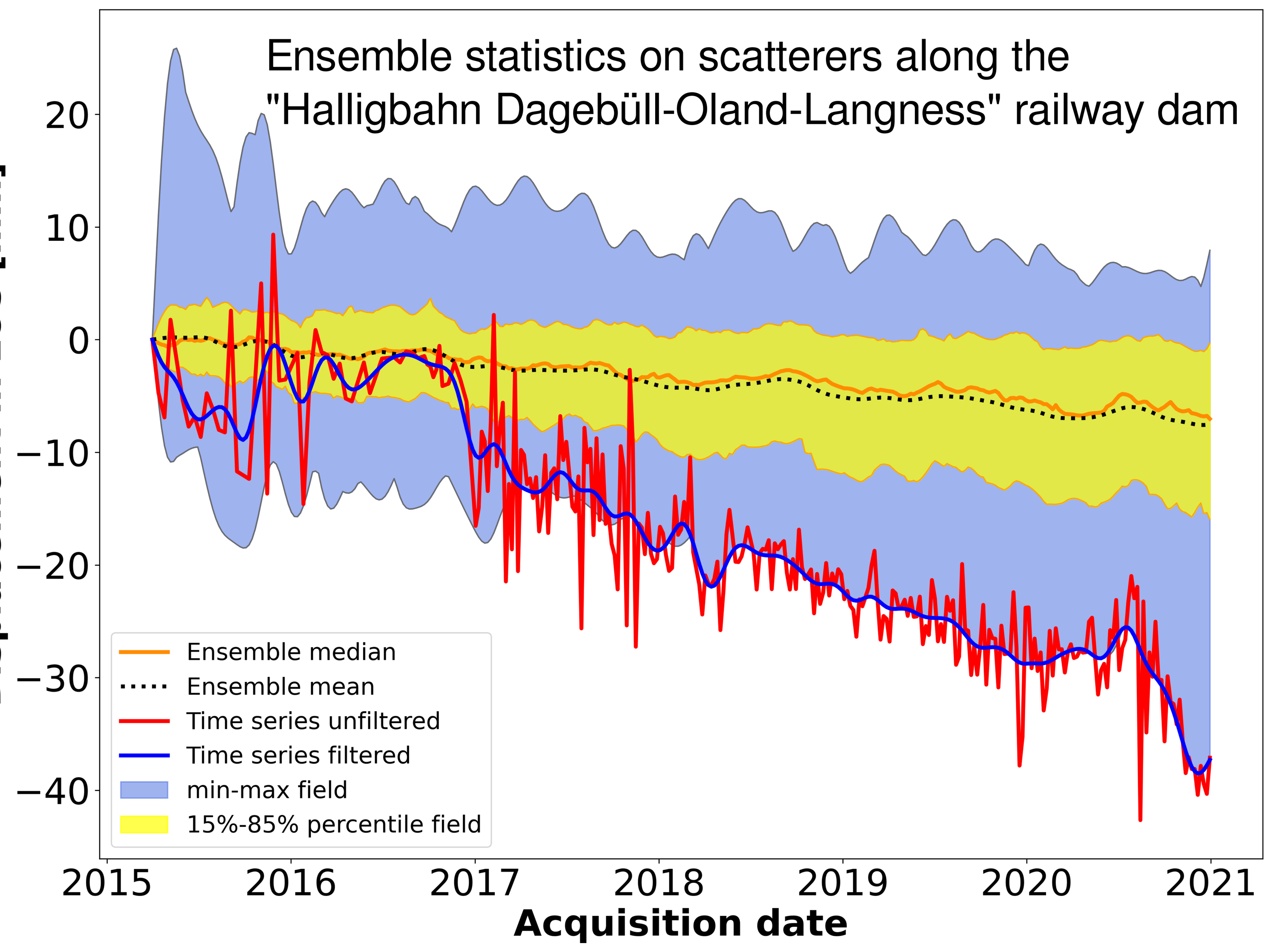

Fig. 4: Scatterer behavior in time: Comparing a single time series with the ensemble statistics of spatially close measurements allows the identification of scattering points with unusual behavior.

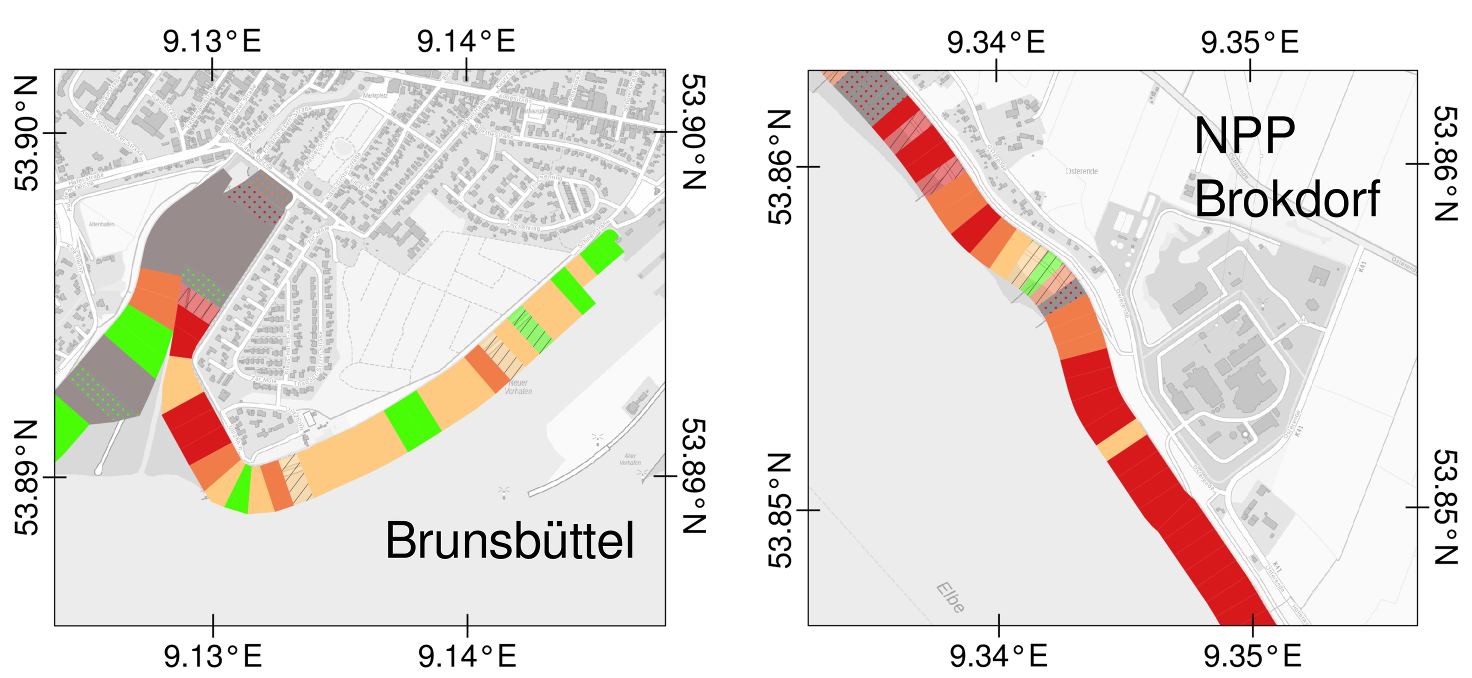

Fig. 6: Mean vertical motion along "old" dikes at the Elbe river mouth: We find a couple of apparently subsiding section of "old" dikes, e.g. (left) east of the marina Brunsbüttel. (right) We find another fast subsiding dike section next to the nuclear power plant at Brokdorf. This motion is quite steady and has been observed in ERS satellite time series for the time 1992 to 2001 already [2].

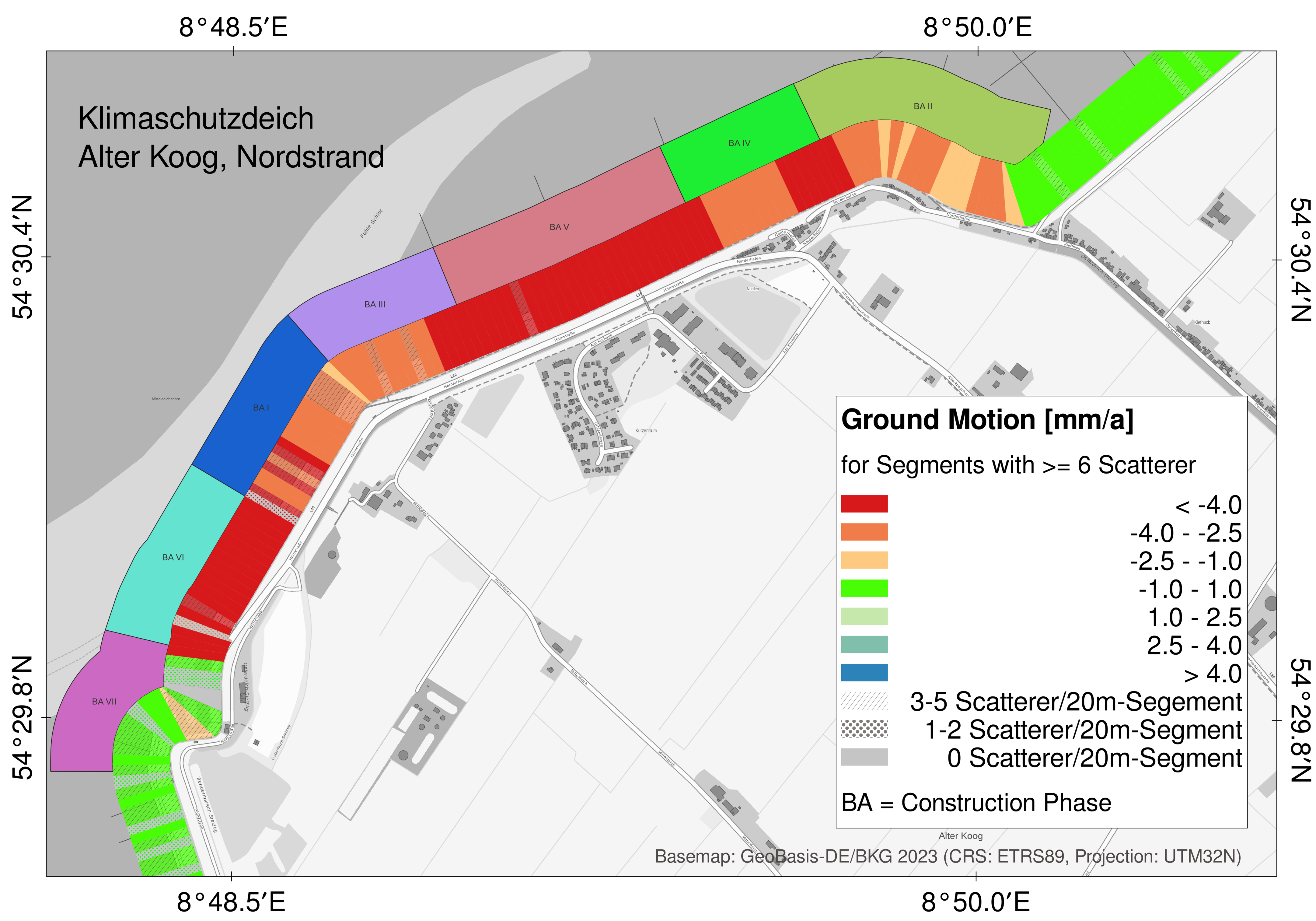

Fig. 5: Mean vertical motion for reconstructed dike sections at Nordstrand: Between 2014 and 2016 and in seven construction phases, a dike section on the peninsula Nordstrand was reinforced to a higher and stronger so-called "Klimaschutzdeich". The newly equipped seaward side shows strong and stable backscattering. Interestingly, the motion of these scatterers is characteristic and we are able to distinguish the different construction phases.

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