Do marshes attenuate storm surges? A numerical study on the effects of marsh geometry and marsh size on storm surge reduction rates

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As ecosystem-based adaptation to global change is gaining ground, conservation and restoration of tidal wetlands and marshes is starting to be implemented in addition to conventional coastal defence structures to protect coastal and estuarine areas from increasing flood hazards (*Temmerman et al., 2013*). In this study, the capacity of tidal wetlands to locally attenuate peak water levels during storm tides is analysed using a two-dimensional hydrodynamic model (TELEMAC2D) for '*Het Verdronken Land van Saeftinghe*', a 3000 ha intertidal marsh in the Netherlands. The effect of marsh vegetation on tidal flow is implemented in the model by increased bottom friction. The model reproduces observed water level variations by *Stark et al. (2015)* reasonably well along a 4 km marsh channel transect. Scenario analyses are performed to study the effect of marsh geometry (i.e., platform and channel elevation) and marsh size (i.e., the position of the levees surrounding the marsh).

The model results indicate that peak water level reduction largely varies between individual flooding events and between different locations in the marsh. Scenarios with varying marsh channel depths show that attenuation rates on the marsh scale increase by up to 4 cm/km if the channel elevation is raised by 0.7 m on average. For scenarios in which the channels are lowered by 0.9 m on average, marsh scale attenuation rates decrease by up to 2 cm/km. The elevation of the marsh platform has little effect on the maximum attenuation, but it determines which tides are attenuated. In particular, only overmarsh tides that inundate the platform are attenuated, while undermarsh tides that only flood the marsh channels are not attenuated or even amplified. Furthermore, model scenarios with variable dike positions show that attenuation rates can be minimized by blockage and set up of water levels against dikes or other structures confining the marsh size. This blockage only affects peak water level attenuation across wetlands if the duration of the flood wave is long compared to the marsh size. A minimum marsh width of 6 to 10 km is required to completely avoid blockage effects for the storm tidal cases assessed in this study.

Finally, a relation is found between flood wave attenuation rates, local marsh geometry and the flood wave height. If blockage does not affect flood wave propagation, variations in attenuation rates between different locations in the marsh and between tides with varying high water levels can be explained with a single relationship (Eq. 1) based on the ratio between the water volume on the marsh platform and the total water volume on the platform and in the channels:

(1) $dHWL/dx = -36.2 * a_v + 8.0$

in which *dHWL/dx* is the flood wave attenuation rate in cm/km and a_v the ratio between the water volume above the vegetated platform and the total water volume in the marsh. Attenuation starts to occur when this ratio exceeds 0.2-0.4 and increases from there on up to a maximum of 29 cm/km for a ratio of about 0.85. The relationship holds for marshes covered with typical wetland grasses (i.e. *Spartina*, *Elymus* and *Scirpus* species) and only for higher storm tides that induce large-scale sheet flow over the marsh surface. These findings may assist coastal communities and managers in the optimization of the coastal protection function of tidal wetlands in combination with dikes.

References

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