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Unusual wave conditions in the northern Baltic Sea during windstorm Gudrun in January 2005

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Windstorm Gudrun (known as Erwin in Ireland, the United Kingdom and Central Europe) was one of the strongest storms during the last four decades in the Nordic Region (Carpenter 2005). It hit many areas in northern Europe January 7–9^{th} 2005, causing widespread property damage and exceptionally high flood on its way, and killing at least 17 people (Carpenter 2005, Soomere 2005).

In the Baltic Sea region this storm almost reached hurricane level. The storm surge in the Estonian city of Pärnu (275 cm over mean sea level) was the highest ever recorded. The meteorological conditions, details of accompanying flooding, and modelling of the extraordinary reaction of the water masses of the eastern Baltic Sea to this storm have been analysed elsewhere (e.g. Carpenter 2005).

A major feature of Gudrun consisted in exceptional wave conditions in the north-eastern regions of the Baltic Sea. The maximum recorded significant wave height in the central part of the northern Baltic Proper was 7.2 m, which is slightly less than the historical all-time high of 7.7 m (Kahma et al. 2003). The dominating wave period was about 12 s in a large part of the northern Baltic Proper, and probably reached 13–14 s in its eastern sector. This long wave system penetrated into semi-sheltered areas such as the Gulf of Finland, where exceptionally long waves with peak periods up to 12 s created unusually high hydrodynamic loads in exposed shallow areas. In the central area of the Gulf of Finland, between Tallinn and Helsinki, the wave height probably exceeded 5 m but apparently was not considerably larger than the historical maximum (5.2 m). The highest recorded significant wave height in this region was

4.5 m (Soomere et al. 2006).

However, wave model results suggest that the roughest seas occurred remote from wave sensors. The operational wave models from the German Weather Forecast Service, the Danish Meteorological Institute and the Finnish Institute of Marine Research indicate that the highest waves occurred off the coasts of Saaremaa and Latvia, where the modelled significant wave height exceeded 10 m. These models, although some of them were not specifically tuned for the area in question, well captured the basic features of wave conditions 48–54 hours ahead, and accurately reproduced wave properties in 24–36 hour forecasts (Soomere et al. 2006). The actually measured wave properties were found between values predicted by these models. This suggests that ensemble modelling, based on analysis of the performance of different models in extreme conditions, might give the most accurate forecast for the next extraordinary storm.

The strong reaction of the water surface to windstorm Gudrun was not caused by extreme sustained wind speed or particularly favourable wave generation conditions. Both measured and analysed sustained wind speed did not exceed 29 m s^{1} in the Baltic Proper. Also, the wind direction was not particularly favourable for generation of high and long waves, because the effective fetch was about a half of that for southwesterly wind. A storm of the same strength and duration, but directed along the Baltic Proper, might create even higher waves. Theoretically, very high waves only occur when a strong and large cyclone, able to create an almost unidirectional wind field over the whole Baltic Proper for a long time, moves in the NNE direction over Swedish mainland. Such a 'perfect storm' is not likely to occur. However, if it would happen, significant wave heights in the northern Baltic Proper apparently may reach and even exceed 11 m.

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