Spatial patterns of the wave climate in the Baltic Proper and the Gulf of Finland*

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Abstract

We make an attempt to consolidate results from a number of recent studies into spatial patterns of temporal variations in Baltic Sea wave properties. The analysis is based on historically measured and visually observed wave data, which are compared with the results of numerical hindcasts using both simple fetch-based one-point models and contemporary spectral wave models forced with different wind data sets. The focus is on the eastern regions of the Baltic Sea and the Gulf of Finland for which long-term wave data sets are available. We demonstrate that a large part of the mismatches between long-term changes to wave properties at selected sites can be explained by the rich spatial patterns in changes to the Baltic Sea wave fields that are not resolved by the existing wave observation network. The

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spatial scales of such patterns in the open sea vary from > 500 km for short-term interannual variations down to about 100 km for long-term changes.

1. Introduction

The Baltic Sea is a challenging area for regional marine science (Leppäranta & Myrberg 2009) and especially for wave scientists in terms of both wind wave modelling and measurements. Numerically reconstructed global wave data sets such as the KNMI/ERA-40 Wave Atlas (Sterl & Caires 2005) allow a quantification of the wave climate and its changes in the open ocean, but their spatial resolution ($1.5° \times 1.5°$) is insufficient for Baltic Sea conditions. Numerical simulations of the Baltic Sea wave climate require a high spatial resolution because of the extremely complex geometry and high variability of wind fields in this basin. The presence of sea ice often complicates both visual observations and instrumental measurements. As floating devices are normally removed well before the ice season (Kahma et al. 2003), the measured wave statistics has extensive gaps for the windiest period that frequently occurs just before the ice cover forms. Relatively shallow areas, widely spread in this basin, may host unexpectedly high waves, formed in the process of wave refraction and optional wave energy concentration in some areas (Soomere 2003, 2005, Soomere et al. 2008a).

Systematic studies into the properties of waves in the Baltic Sea go back more than a half-century (see Soomere 2008 and the references therein) and have resulted in several generations of wave atlases for this region. Several attempts to reconstruct the wave climate based on measured or visually observed data and/or numerical hindcasts have been undertaken for many areas of the Baltic Sea (e.g. Mietus & von Storch 1997, Paplińska 1999, 2001, Blomgren et al. 2001, Cieślikiewicz & Herman 2002, Soomere 2005, 2008, Broman et al. 2006, Soomere & Zaitseva 2007). Many of these studies cover either relatively short periods (a few years) or concentrate on specific areas of the Baltic Sea. This is not unexpected because long-term reconstructions of the Baltic Sea wave fields are still an extremely complicated task and usually contain extensive uncertainties (Cieślikiewicz & Paplińska-Swerpel 2008, Kriezi & Broman 2008). An overview of the relevant literature until 2007 and a description of the basic features of the wave climate (empirical distribution functions of the basic sea state properties such as wave heights and periods as well as a description of wave extremes and decadal changes to wave conditions) are presented in Soomere (2008).

As wave height is often proportional to wind speed squared, wave fields can be used as a sensitive indicator of changes in wind properties (Weisse & von Storch 2010). Storminess in the Baltic Sea region was relatively high at the beginning of the 20th century, decreased in the middle of that