Estimating the effect of climate change on surface geostrophic winds in Northern Europe (contribution to CES Climate Modelling and Scenarios Deliverable D2.4, task II)

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Background and methods

We have used 10 global climate models (hereafter GCMs) to study future changes in geostrophic wind speeds in northern Europe. These 10 models are a subset of the 23 models used in the 4th Assessment Report of the Intergovernmental Panel on Climate Change. The models were found to represent the climate in the Nordic countries reasonably well. The grid size of the models varies between 100-300 km; therefore the grid point estimates from the models are more representative of spatial averages over the model grid boxes than truly local values. 24-hour mean values of sea level pressure were available for the model simulations and these pressure fields were used to calculate the daily mean geostrophic wind. The calculations concerning future changes in geostrophic wind speed are based on the SRES A1B-scenario. The changes are expressed as per cent differences in the average wind speed between the baseline (or control) period 1971-2000 and the scenario period 2046-2065. These periods were chosen based on the availability of model output at daily time resolution.

We have analyzed the surface geostrophic wind (hereafter *Vg*) rather than the actual simulated surface winds, because the latter are sensitive to the details of the boundary layer parameterization and surface description (e.g., land-sea distribution, sea ice cover, roughness and orography) in the models. Thus, the use of the geostrophic wind speed that is proportional to the surface pressure gradient allows a more straightforward comparison among the models and to observational data. For the analyses reported here, all model results were interpolated onto a common 2.5° × 2.5° latitude-longitude grid.

Verification

One grid point (60°N, 25°E) was selected for comparing the surface geostrophic wind speeds in the 10 GCMs with the corresponding observed geostrophic winds, which were derived from the ERA-40 reanalyses. In general, the monthly average *Vg* in the model simulations was found to be nearly equal to the corresponding observed mean (Fig. 1). However, during the windiest part of the year from November to January, the observed *Vg* is approximately 1 m/s higher than the 10-GCM mean.

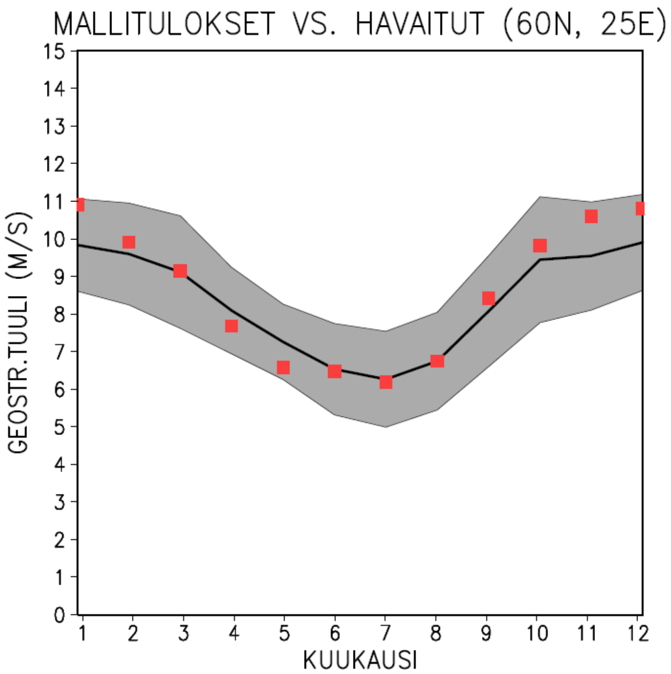


Fig. 1. The seasonal cycle of the geostrophic wind speeds at the grid point (60°N, 25°E), as averaged over the years 1971-2000. The solid line shows the 10-GCM average and the shading the mean ± one standard deviation between the model simulations. The red squares are observation-based geostrophic wind speeds calculated from the ERA-40 data.

Geographical distribution of geostrophic wind speeds

The 10-GCM average geostrophic wind speeds during the "windy season" September-April are shown in Fig. 2. The distributions during the control (1971-2000, left) and scenario (2046-2065, right) periods are very similar, with the strongest geostrophic winds in the Nordic area in its western parts (Denmark, west coast of Sweden and western Norway up to 69°N). Along with the simulated warming of the climate, the wind speeds increase in the southern part of northern Europe, the average *Vg* over the southern Baltic Sea being 9,5-10 m/s in the period 1971-2000 and 10-10,5 m/s in 2046-2065.

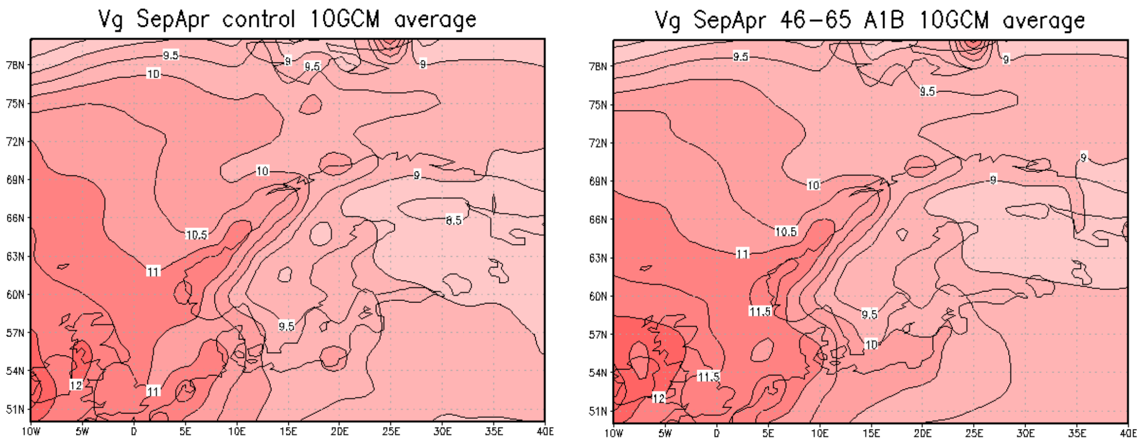


Fig. 2. 10-GCM mean of the simulated geostrophic wind speeds (m/s) in September – April for the periods 1971-2000 (left) and 2046-2065 (right).

Percent changes in the mean geostrophic wind speed from 1971-2000 to 2046-2065

According to the 10-GCM mean results, the average winds speeds will only change by a few percent from 1971-2000 to 2046-2065 (Figs. 3-5). An increase in wind speeds seems to dominate the southern part of northern Europe. The largest increase is simulated for the fall (SON, September-November), when the average *Vg* increases by 2 to 4 % (Fig. 4). In the area of highest statistical significance, 9-10 models out of 10 agree on the sign of the change. Considering the months of December-February (Fig. 5) or the whole windy season September-April (Fig. 3), the increase is mostly 0 to 2 %.

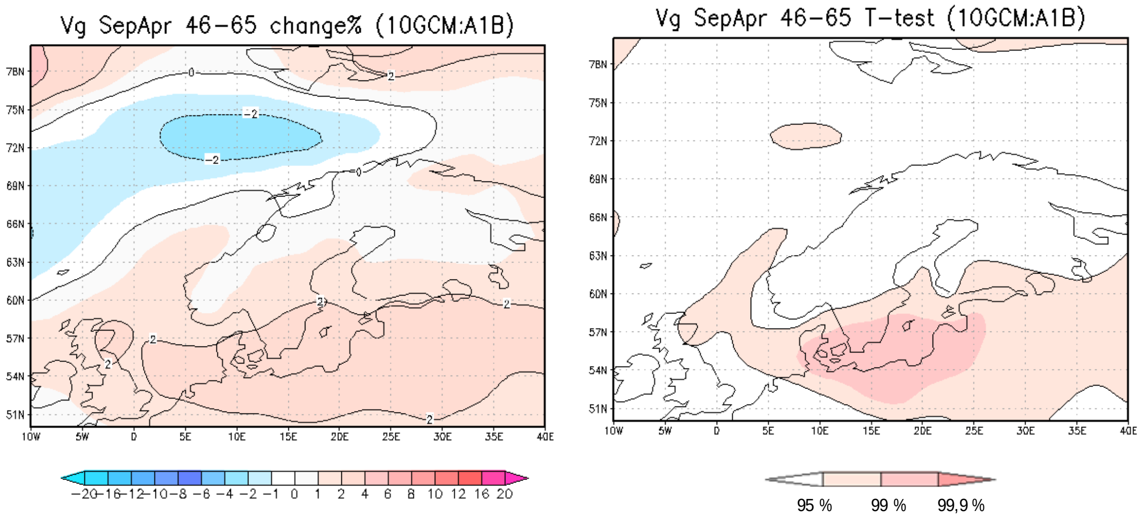


Fig. 3. 10-GCM mean per cent changes in the September-April mean geostrophic wind speed from 1971-2000 to 2046-2065 (left) and the statistical significance of the ensemble mean change according to a standard t test (right). Light, medium and dark red shading indicate significance at the 95%, 99% and 99.9% levels, respectively.

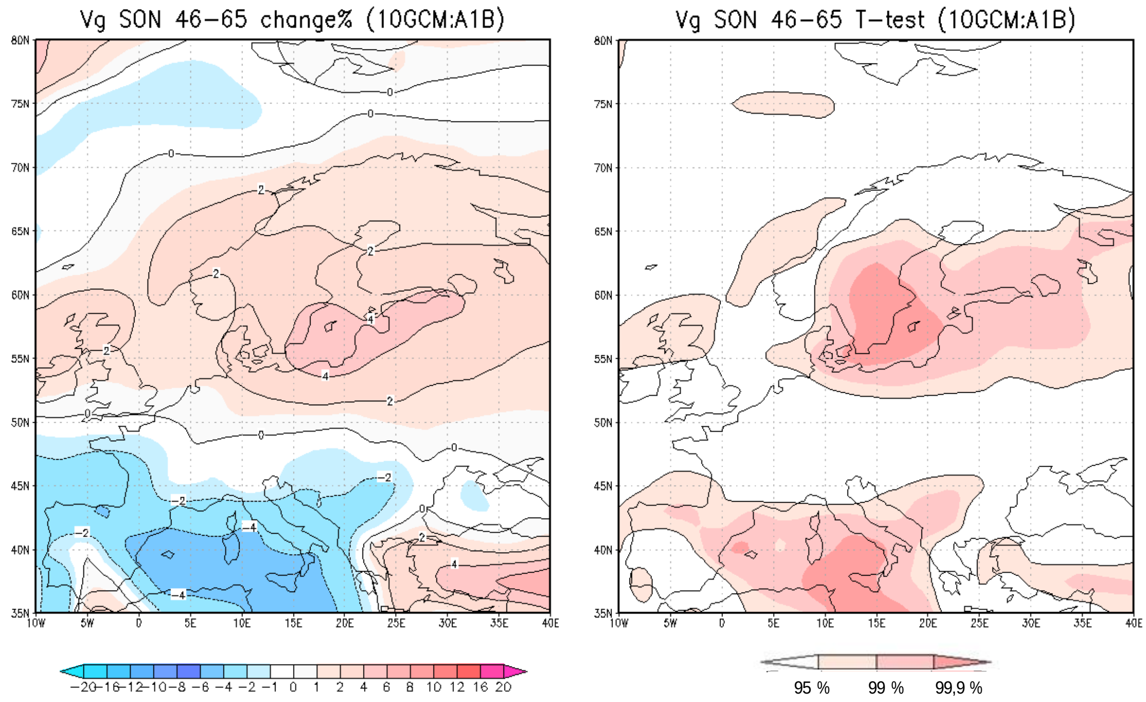


Fig. 4. As Fig. 3, but for the autumn (September-November).

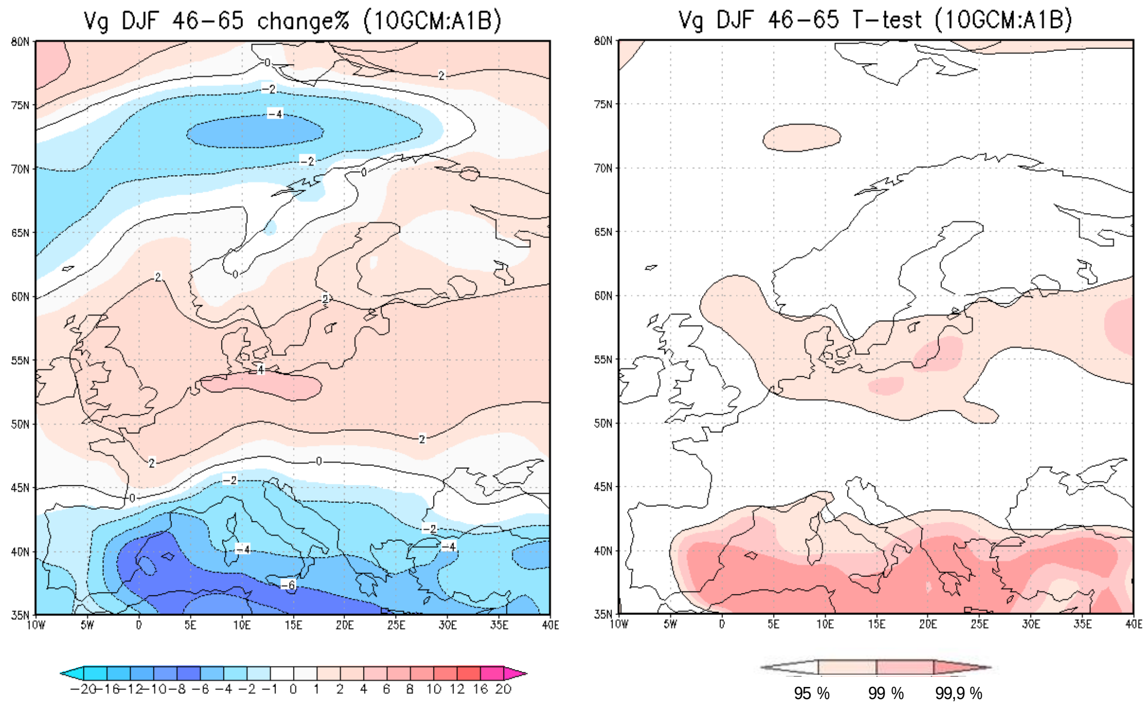
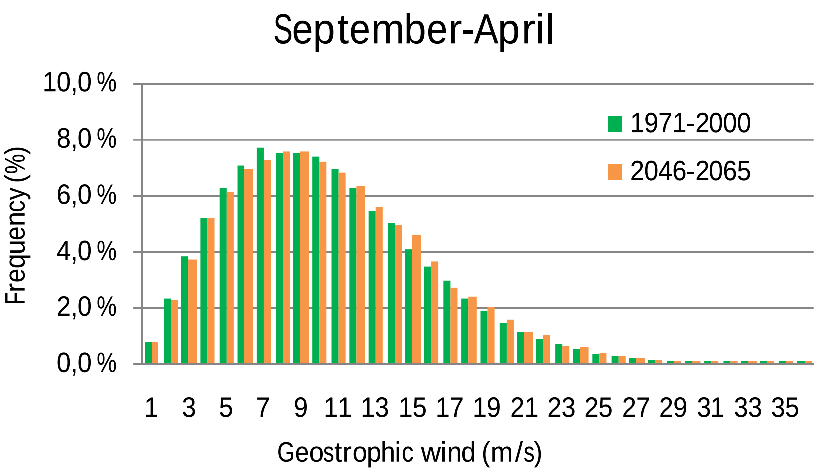


Fig. 5. As Fig. 3, but for the winter (December-February).

Frequency distribution of geostrophic wind speeds over the southern Baltic Sea

A closer look was taken at the southern part of the Baltic Sea (grid point 55°N, 15°E), where the increase in the mean wind speed is statistically most significant (ensemble mean change different from zero at the 95% or even the 99% level, according to a standard *t* test). Analyzing the daily mean wind speeds simulated for the periods 1971-2000 and 2046-2065, we find that the increase in the average *Vg* is associated with both a decrease in the frequency of low wind speeds and an increase in the frequency of strong winds exceeding 12 m/s (Fig. 6).



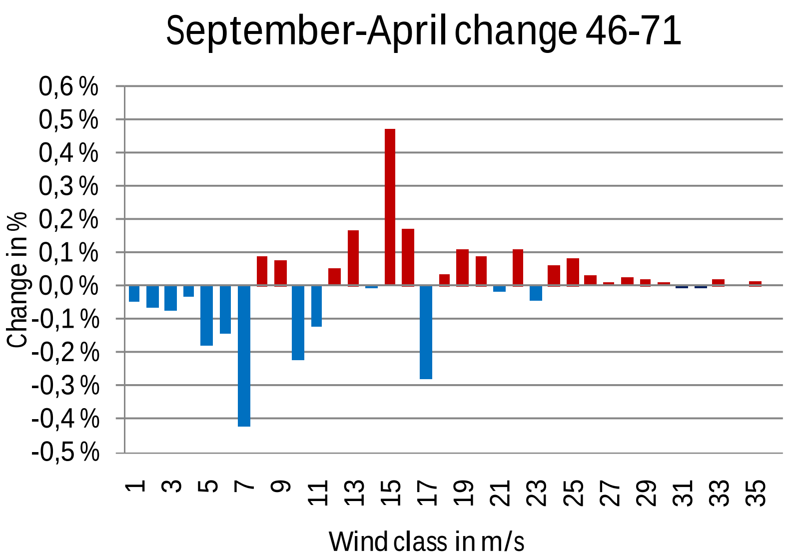


Fig. 6. Top: 10-GCM mean frequency distributions of daily average geostrophic wind speeds over the southern Baltic Sea (55°N, 15°E) during September-April in 1971-2000 (green bars) and 2046-2065 (yellow bars). Bottom: the change in the frequency distribution from 1971-2000 to 2046-2065 (blue bars for decrease, red bars for increase in frequency).