Introduction
The highest resolution weather model at KNMI presently is the HIRLAM-11km model. For various important applications, however, wind information on smaller scales, 1 km or less, is required. Hence, techniques have been developed to downscale model winds to very high resolutions. These detailed wind fields are used for example as input for storm surge models, and to support runway allocation at Schiphol Airport.

Objectives
The objective was to develop an operational downscaling method for wind. Furthermore, the potential was investigated of combining physical and statistical methods in a downscaling approach capable of accounting also for large-scale model deficiencies.

Results
The downscaling method developed for operational use is based on a simple model of the Planetary Boundary-Layer (PBL) and on high-resolution surface roughness information. The PBL model consists of two layers: the Ekman layer and the surface layer. Roughness lengths $Z_0$ are determined for both layers, by averaging geographical variations in surface roughness over the upstream area of the airflow. The resulting high-resolution roughness lengths are wind direction dependent (Figure 1).

The two-layer PBL model can be used to derive the wind in the surface layer from the wind at the top of the PBL and vice-versa. At present the model transforms HIRLAM surface winds to the top of the PBL using a HIRLAM grid box roughness, and then down again to the surface, this time using high-resolution local roughness information. This leads to a reconstruction and refinement of HIRLAM surface wind to a much higher resolution.

The method has been validated successfully for locations near the coast and on land. Figure 2 presents verification results for location Hansweert on the northern shore of the Scheldt estuary. As downscaled wind fields are more representative for local conditions than the HIRLAM-11km results, downscaling leads to a significant reduction in mean wind speed error.

In contrast with purely physical downscaling methods, a combined physical/statistical approach is capable of handling large-scale model deficiencies. Key factor is the decomposition of the total error (model - observation) into a small-scale representation mismatch (difference between “true” model grid box mean and the observed local value) and a large-scale model error. For 10m-wind speed, the representation mismatch ($RM$) is dominated by the difference between model roughness and local roughness ($Z_0$).
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Figure 3 (left) shows a 10m wind field forecast [ms⁻¹] of HIRLAM-11km; (right) shows the downscaled wind speed field (1km resolution) following the combined physical/statistical approach. Outside the Netherlands no roughness information is available and local wind speeds over land should be ignored.

Verification shows that the combined physical/statistical approach results in an almost perfect reduction of wind speed bias. Comparison of the results of physical downscaling with those of the combined approach shows that the linear regression equation also applies to locations without observations.

Outlook
Combining physical and statistical techniques for downscaling turned out to be successful. Not only because in this way both representation mismatch and model error are corrected for, but also because this approach offers many opportunities to optimize the system for a particular use (such as high wind speeds). The combined statistical/physical approach might also be extended to other parameters. Finally, the concept of error decomposition is valuable in a more general sense (such as for validation purposes).

3) De Rooy, Wim C. and Kees Kok, 2003, A combined physical/statistical approach for the downscaling of model wind speed. Accepted for publication in Weather and Forecasting.