Introduction
Professional users can benefit greatly from knowing the inherent uncertainty in numerical weather predictions. This uncertainty can be expressed in an objective, quantitative and reliable manner using Model Output Statistics (MOS1).

Objectives
Probabilistic forecasting research at KNMI aims at implementing MOS techniques in support of:
- The use of ensemble predictions (EPS)
- The shift of forecast attention towards extreme and hazardous weather
- The statistical improvement of field forecasts
- The verification of small-scale information in high-resolution forecasts

The interpretation and use of probabilistic forecasts is a notoriously difficult subject for the untrained mind. Substantial effort therefore is put in educating forecasters in this area with a focus on the potential benefits for end-users.

Results
Predictors from EPS have been included in many probabilistic and deterministic MOS products. Also ‘direct’ probabilistic information from EPS is used. An extensive calibration of these probabilities obtained from EPS weather parameter time-series has been carried out. This has resulted in improved applicability of probabilistic forecasts of temperature, precipitation, cloudiness and wind speed for 6 land stations and wave height predictions for 3 North Sea platforms2. An example is given in Figure 1.

In cooperation with the Union of Water Boards, a project was initiated aiming at providing optimal meteorological information in cases of risk of flooding. Water Boards need such information for taking adequate precautionary actions, and thus preventing large economic losses. A skilful and reliable probabilistic forecasting system for precipitation amounts exceeding critical levels for individual Water Boards is under development. This system is to be combined with cost-loss analyses of precautionary measures, which can be used in decision-making models of the Water Boards. Analyses are made for each of the 5 Water Boards participating in the project for a number of critical precipitation levels in the forecast range up to 9 days.

In the INDECS (Indices for Extreme Convective Situations) project, traditional hazardous weather indices are assessed on their predictive potential for severe weather events in the Netherlands. The most skilful combination of predictors, derived from the HIRLAM and ECMWF deterministic models and

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Figure 1. Example of calibrated wave height probability forecasts (right) for platform Meetpost Noordwijk (MPN). It is based on cumulative rank histograms for each forecast time (+168 is shown on the left) in which EPS probabilities (in steps of ~2%) are verified against the frequency of observation on a 2-year dataset.
including these indices, has been determined statistically. This has resulted in a Perfect Prog\(^1\) forecasting system for the probability of thunderstorms in 6-hour time intervals for 12 regions covering the Netherlands (Figure 2). It will soon be replaced by a MOS system and extended to more hazardous weather phenomena\(^3\).

A well-known problem in the comparative verification of deterministic forecasts is that high-resolution forecasts, while providing useful additional information, often verify worse on traditional scores than their low-resolution counterparts. A MOS technique has been applied to assess objectively the skill of small-scale information contained in high-resolution models; the added value of high-resolution models is quantified by the improvement of probabilistic forecasts using their small scales. The method thus objectively rates the presence of the ‘right indications’ that can be inferred from the small scales, much as a human forecaster does. The validity of this approach has been demonstrated in a simplified setting\(^4\).

**Outlook**

Probabilistic forecasting by Model Output Statistics remains a powerful and cost-effective tool for adding value to deterministic and ensemble prediction forecasts.

Probabilistic forecasting by Model Output Statistics remains a powerful and cost-effective tool for adding value to deterministic and ensemble prediction forecasts. The research focus will shift further to short-range, high-resolution forecasts of extreme and hazardous weather. Realization of its potential benefit to end-users will require an investment in the maintenance of statistical knowledge and the transfer of this knowledge to forecasters/advisers and end-users.

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