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EDITORIAL

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Editorial: Recent developments and application examples on forecast verification

Some seven years after the last special issue on forecast verification in *Meteorological Applications* (Ghelli *et al.*, 2013), it is the right time to put together a special issue that reviews the recent progress in this field. The issue is directed to all readers interested in verification from different points of view, but is specifically targeted to end-users.

New model developments, for example, with increasing model resolution or model ensembles, are just a few of the challenges that verification methods face in order to provide additional verification tools to assess the forecast quality of non-traditional, user-oriented forecast variables and process-based quantities, for example, risk warning and/or extremes. Verification of user-oriented forecast variables and process-based verification are key areas for verification methods research nowadays and in the near future.

The special issue papers illustrate how this central research topic in forecast evaluation covered by previous special issues has evolved, ranging from verification methodology developed for specific applications to spatial verification and other general challenges in evaluating forecasts. A variety of targeted developments of verification methodology adapted to specific applications and user groups indicate a trend in the way verification methods are evolving. While illustrating the advancement of forecast evaluation methods overall, general challenges remain to be addressed, in particular regarding forecasts for extreme events, accounting for observation error and spatial verification.

The first group of papers contains more theoretical papers that discuss general issues, look at properties of various scores and other tools for verification, and introduce new diagnostic techniques.

Gilleland and Roux (2015) promote the use of Diebold–Mariano tests for predictive accuracy that are popular in the literature of economics, but which are not yet widely used in atmospheric sciences. Using simulation and case studies, the authors demonstrate the usefulness of such tools in combination with a loss function based on dynamic time warping if timing errors are a concern. Wilks (2016) proposes three new diagnostic verification diagrams for non-probabilistic forecasts of discrete predictands and for probabilistic forecasts of continuous predictands. These settings previously lacked appropriate graphical diagnostic tools. A recent focus of research in verification methodology has been on techniques that account for observation error. Jolliffe (2017) addresses probability forecasts of binary events evaluated with the Brier score and investigates what forecast should be made in order to minimize the expected value of the score when errors are present in the observations. It is found that the answer depends on whether the error mechanism is unknown or can be modelled, and that the forecasters may need to disregard their belief about the true probability of the event in the first case.

A second group of papers continues one of the central themes of the two previous special issues on forecast evaluation (Ghelli and Ebert, 2008; Ghelli *et al.*, 2013) and studies methods for spatial verification.

Ben Bouallègue and Theis (2014) propose two neighbourhood methods for spatial verification of ensemble forecasts based on smoothing and upscaling. In an application to precipitation forecasts, the paper explores how these spatial techniques can be used to characterize better the performance of a high-resolution ensemble forecasting system. Skok (2015) analyses properties of the popular fraction skill score (FSS) based on a compact analytical expression derived for a case with a single displaced rainband in a rectangular domain. The author investigates how domain borders and the size of displacement influence the usefulness criterion of the FSS for a specific rainband configuration. Amodei *et al.* (2015) investigate the quality of high-resolution forecasts of precipitation and wind gusts using a regional Brier score to account for positional errors of storm structures. Scores for the two physical parameters are combined into a synthetic index to monitor the evolution of the quality of the forecasts over several years.

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Verification of non-traditional and user-oriented forecast variables are included in the third group of papers. These present verification of variables that are not necessarily direct model output, but have been further manipulated, such as, for example, weather warnings, advisories and weather symbols.

Sharpe (2016) describes a system for verifying warning services implemented at the Met Office. This generic warnings verification system introduces additional "near-hit" categories and considers the neighbourhood around examined areas to account for situations where warnings do not exactly correspond to observed events. Rakesh and Goswami (2016) discuss a strategy for evaluating precipitation forecasts for specific agricultural applications. The overall aim is to design specific forecast advisories for when to avoid the application of either fertilizers or pesticides because rain is predicted with high probability. A system for evaluating a weather symbol forecasting product is introduced by Tam and Wong (2017). Cloud cover forecasts from ensemble predictions are evaluated at observation sites around Hong Kong to discuss the potential of deriving site-specific weather symbol forecasts. Storto and Masina (2017) discuss the role of changing verifying observations in space and time on verification metrics for ocean reanalyses for a 30-year period. They propose a randomized observation selection method to disentangle the true accuracy evolution of the reanalysis from the effect of the changing verifying data set.

The final group of papers deals with operational verification systems at weather services. Heming (2017) describes the system for tracking and objective verification of tropical cyclones at the Met Office. The system is further used to produce real-time forecast guidance products based on deterministic and ensemble prediction systems. Yu *et al*. (2020) present a benchmark rainfall verification study of landfall tropical cyclone forecasts over China. They use the spatial verification method of contiguous rain area (CRA) to diagnose the source of systematic errors of the forecasted rain fields. Applying the displacement and rotation adjustment of the CRA method, the systematic errors could be reduced by a noticeable amount. Sharpe *et al*. (2018) investigate the forecast quality of the Met Office post-processed forecasts for extreme events considering different verification methods.

The selection of papers to include in this issue was guided by questions raised by modellers, forecasters or customers of specific forecast products. It was not possible to include all verification-related papers that appeared in *Meteorological Applications* within the last seven years for space reasons, but this special issue should give a representative sample of what verification is about.

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