Presentation 6.2

DECISION GUIDANCE WITH PROBABILISTIC ROAD FORECASTS

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The key objective of winter road treatment is to mitigate risk introduced by adverse weather conditions. In the UK and elsewhere winter road maintenance decisions are largely based on whether or not a deterministic road surface temperature forecast falls below some critical threshold. This approach has two key drawbacks: first, deterministic forecasts do not consider uncertainty or how different plausible future weather scenarios might drive different treatment decisions. Second, weather forecasts only convey information about the physical hazard (e.g., whether or not the road will be cold) and not about variations in other factors that affect risk (i.e. the likelihood of there being some loss due to the hazard). Using a hazard forecast to make a risk-based decision can therefore neglect important information, place inappropriate decision responsibility on forecast providers, or result in misinterpretation of forecast data. We present an approach to addressing these issues that combines probabilistic forecasting, and a framework for risk-based decision guidance.

Uncertainty is implicit and unavoidable in weather forecasting; the atmosphere is chaotic and our ability to understand and model its future state will always be incomplete. However, improving our knowledge of uncertainty can itself help forecasters to provide better advice to decision makers. This is particularly true for road forecasting in moderate climates, where marginal weather conditions – in which it may not be clear whether or not treatment is necessary – are common during winter months. A 'margin of error' is sometimes applied to forecast data to account for generalised uncertainty. On average, this leads to over-conservative mitigation (and associated costs) and does not reflect the reality that some forecasts are more certain than others. Alternatively, expert meteorologist interpretation of weather model data provides valuable commentary around forecast uncertainty. However, with increasing complexity and resolution of model data, numerical probabilistic forecasting becomes more attractive.

We explore the use of probabilistic data in operational road forecasting and demonstrate scenarios in which they should lead to better decision guidance. For example, Fig. 1 shows a scenario in which several key weather models forecast a minimum road surface temperature (RST, e.g. blue curve) comfortably above freezing; observed RST fell below 0°C, resulting in emergency reactive road treatment. A comparable probabilistic forecast (grey ribbon) shows wide uncertainty in the model data overnight, including the possibility of freezing RST. With this information, could the decision-maker have been better prepared?

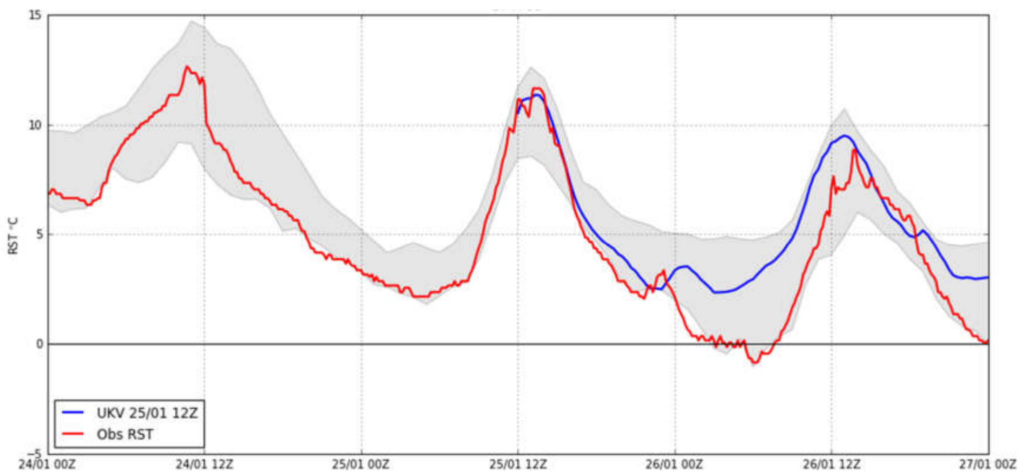

Fig. 1. Road Surface Temperature (RST) at a UK forecast location. Single model solution (blue curve) issued at 12Z on 25 January 2018, compared to observed RST (red). The range of plausible RST values, from all solutions of 4 NWP models, is shown by the grey ribbon.

A common concern with probabilistic methods is that they might introduce complexity that bloats or obfuscates the decision-making process in practice. This need not be the case. We define risk as the probability of incurring loss due to a hazard:

*Risk of loss due to hazard = Pr(hazard) * Pr(loss | hazard)* [1]

The weather forecast provides information about the hazard (e.g. ice on the road), but the *conditional* probability of loss (e.g. traffic disruption or a road incident) depends on other factors and may not be equivalent at all forecast sites. Considering hazard likelihood and conditional impact independently facilitates the use of a risk matrix approach (Fig. 2), providing support that is appropriate for risk-based decisions and straightforward to interpret.

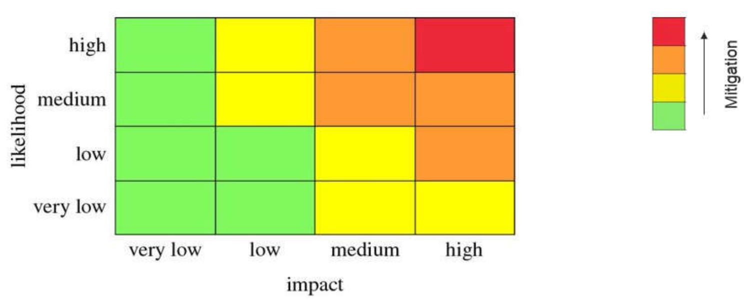

Fig. 2. Generalised risk matrix, after (1). Risk (coloured from low, green, to high, red) is the product of hazard likelihood and conditional impact. The extent of risk mitigation increases with higher risk of impact or loss.

To illustrate this concept, we report recent advances in the aviation sector: since 2014, Met Office risk-based decision support has been trialled at London Heathrow airport to modulate runway landing rates in low visibility (fog) conditions. Cost savings from reduced flight delays (at LHR, fog delays can cost €10s M per month) has resulted in the service being adopted by an increasing number of major hubs and the national air traffic service (NATS). We demonstrate how a similar risk matrix approach could be applied to winter road forecasts to guide risk-based decisions. We discuss the development of probabilistic and risk-based forecast services on a new Met Office cloud platform and considerations for integration with future technologies.

References:

1. Economou, T., Stephenson, D.B., Rougier, J.C. *et al.* **2016** On the use of Bayesian decision theory for issuing natural hazard warnings, *Proc. R. Soc. A.*, **472:** 20160295.