Event coordinators:

Lauryna Šidlauskaitė   Justas Kažys   Jonas Kaminskas

# PROCEEDINGS OF THE 20TH SIRWEC CONFERENCE, DRUSKININKAI, LITHUANIA (14-16TH JUNE 2022)

2022

# DEVELOPING PROBABILISTIC SURFACE TRANSPORT FORECASTS AT THE MET OFFICE

Joe Eyles, Alice Lake, Hannah C.M. Susorney
Met Office, Fitzroy Road, Exeter, Devon, UK, EX1 3PB,
*joe.eyles@metoffice.gov.uk*, ORCID: 0000-0002-5217-4366

## Summary

The Met Office is currently developing a new Surface Transport Forecasting (STF) system which makes uses of the Met Office's regional ensemble model, MOGREPS-UK, to produce probabilistic forecasts of road weather conditions. The outputs from this forecast will provide key road weather information to infrastructure decision-makers across the country. In this talk we will present initial results from our probabilistic STF system, show how these compare to a deterministic system, and give examples of how the outputs of this system can be used to aid decision-making.

## Abstract

Since the 1980s, the Met Office has produced so-called Surface Transport Forecasts (STF) for the United Kingdom. The output of these forecasts are of vital importance to key infrastructure decision-makers across the country; providing accurate and timely predictions of road conditions enables gritting services to operate efficiently and effectively, reducing risk to members of the public. With the growth of the Future of Mobility (including Connected Autonomous Vehicles) sector these requirements are changing, prompting a move to modernise the Met Office's STF capability (see associated abstract Lake et al., this conference). Here, the focus is specifically on how a probabilistic STF system is being built to enable the Met

Office’s new STF capabilities. This abstract starts with an outline of the current state of the deterministic STF system, followed by motivating a move to probabilistic ensemble-based forecasts. It then discusses the source of the ensemble inputs to the system, before describing the architecture of such a system, and finally reviewing the validation and verification of the new STF system.

The current operational STF system is a deterministic model. That is, for a given event (for example, whether or not there will be ice on the road surface at a particular location) it outputs only a binary “true or false”-style forecast, with no indication of how likely that particular event is to occur. Despite significant increases in forecasting capabilities over the past decades, weather such as the exact position of patchy rain showers, or the precise time a cloud will form and pass overhead, remain challenging to predict deterministically. Ensemble-based forecasting offers a solution to this problem: by producing multiple deterministic forecasts from slightly differing initial conditions (designed to all be equally likely to occur) and considering all of these forecasts in aggregate, a probabilistic view of the future can be gained. Therefore, the Met Office is currently developing a new STF system designed to make use of such ensemble forecasts in order to produce a probabilistic forecast of road state conditions (for example, dry, wet, or icy) to replace the current deterministic forecast.

The new STF system is centred on the Joint UK Land Environment System (JULES); a community model used as the land-surface component of the Met Office Unified Model (UM), but which can also be used – as the STF system does – as a stand-alone land-surface model driven by forecast output from Numerical Weather Prediction (NWP) models. In order to produce probabilistic forecasts for locations within the United Kingdom, the output from the Met Office regional ensemble model MOGREPS-UK is input to JULES. MOGREPS-UK is an 18-member ensemble model which produces hourly forecasts for the United Kingdom out to 5 days. It is generated by time-lagging over 6 hours, meaning there are three new ensemble members every hour (Fig. 1) generated from slightly differing initial conditions. The new STF system runs JULES driven by each ensemble member, which gives us a collection of 18 possible predicted road states. By combining these predictions, the probability of a given road weather condition occurring can be computed.

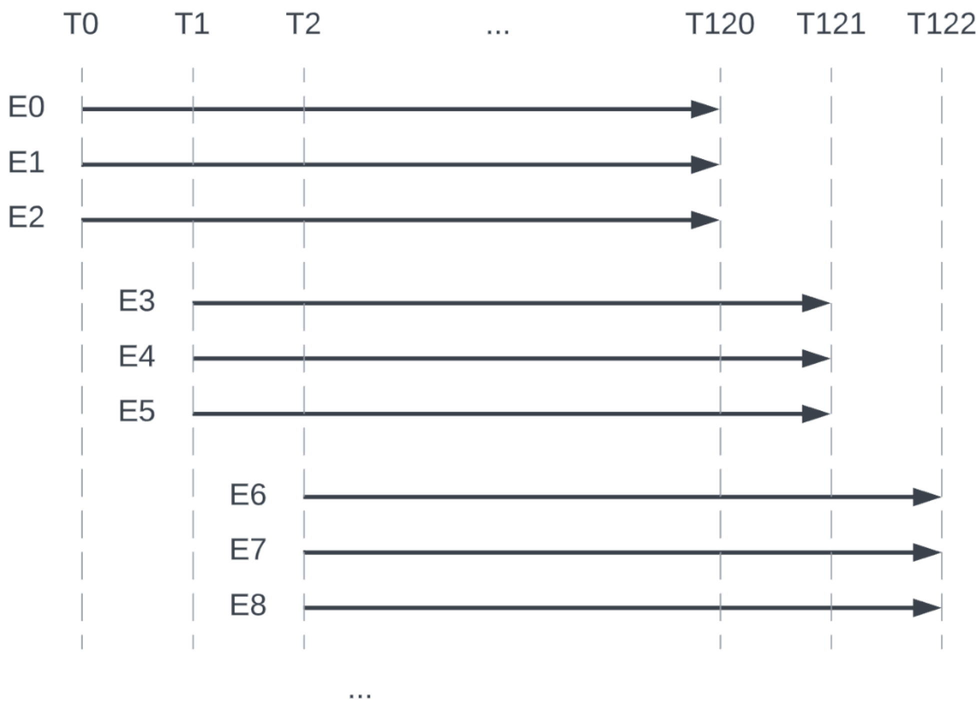


*Fig. 1. Schematic diagram of MOGREPS-UK ensemble members. At each time period (here denoted T0, T1, … T122) three new ensemble members (here denoted E0, E1, E2…) are generated, and provide forecasts out for 120 hours (5 days).*

The computational time of the new STF ensemble-driven system increases with the number of ensemble members. This can be mitigated by careful architectural design. In Fig. 2 we present a post-processing system (so called because the processing happens after the Met Office's main NWP model has run – in this case MOGREPS-UK), that allows much of the computation to happen in parallel. Since JULES is a physics scheme it requires initial conditions; in this example these are calculated from the previous forecasts, so this step happens before the parallel steps, at any time after the previous forecasts have run. Once the MOGREPS-UK driving data arrives, the computation splits into three parallel processes, one for each ensemble member. By introducing parallel processing here the run-time of the post-processing scheme is not significantly impacted by the increased workload. First the local effects of shading and traffic are applied to the MOGREPS-UK driving data. JULES is then run against each of the ensemble members to produce a set of initial forecasts. A machine learning bias correction step is then applied to each of the initial forecasts, yielding a set of improved forecasts. These are then considered in aggregate with the output from ensemble members at previous timesteps (since MOGREPS-UK is a lagged ensemble) to produce a probabilistic forecast.

Results from the new ensemble-driven STF system were initially compared against the same post processing steps driven by deterministic data. This has only been done in a qualitative manner, as the types of forecasts are quite different. In performing this comparison, it was found that the observed road surface temperature is generally captured within the range of road state predictions outputted by the ensemble-driven STF system, while the deterministic forecast, although accurate, can at times have a significant error. In the example in Fig. 3 the error is driven by incorrect night-time cloud cover in the deterministic NWP driving data. This error is mitigated in the ensemble driving data, since the two possible realities of cloudy or clear skies are captured in the spread of the ensemble. Accurately forecasting probabilities for nights when the sky is clear or cloudy is of particular importance, as the difference in radiative cooling can lead to a large variation in road surface temperatures. Thus, in challenging

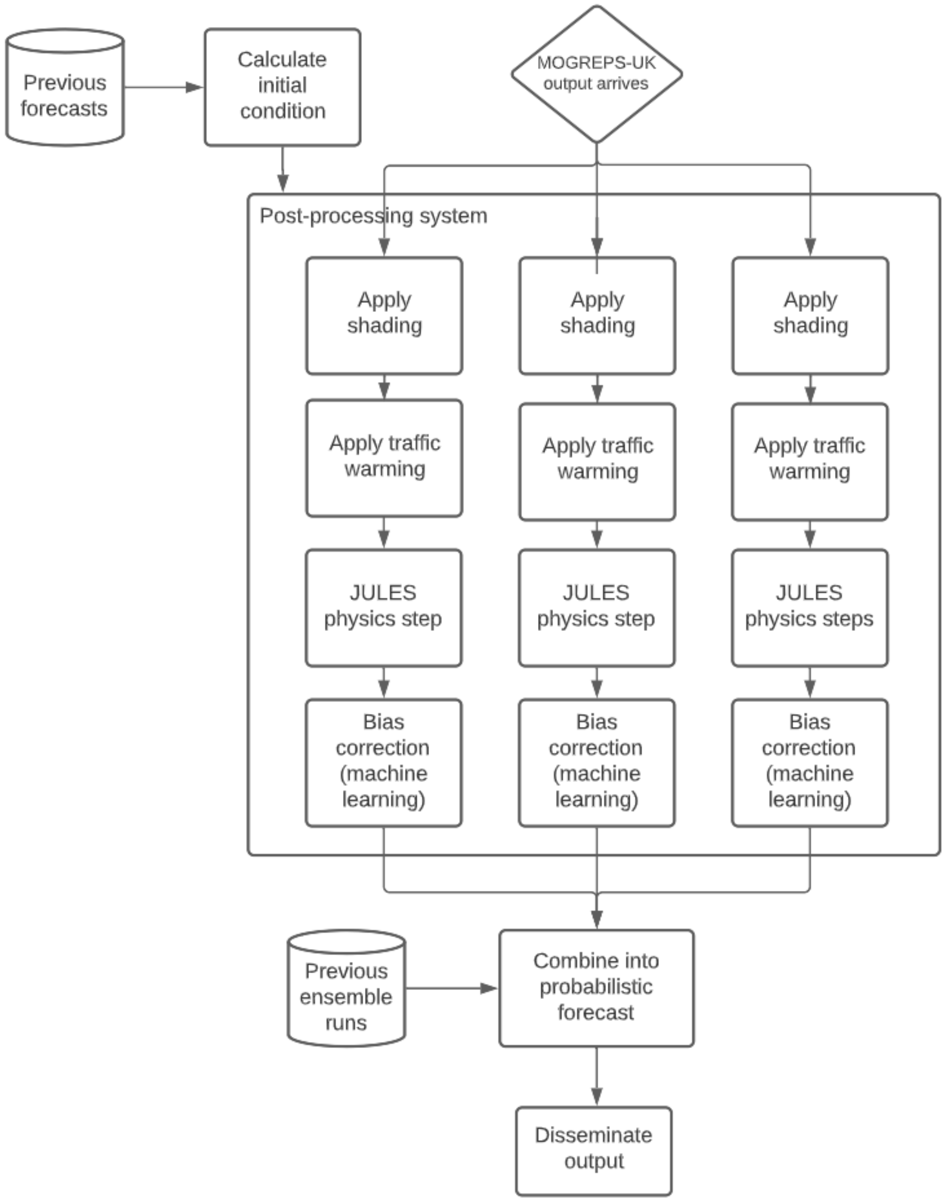


*Fig. 2. Schematic of the new ensemble-driven STF system, detailing the steps required to produce a probabilistic road surface forecast. Once the MOGREPS-UK output arrives, and we have generated initial conditions from the previous forecasts, the processing splits into three parallel threads (one for each ensemble member). Each thread applies local effects, the JULES physics scheme, and bias correction. This gives three forecasts, which are combined with previous ensemble runs to create a probabilistic forecast which can then be disseminated.*

meteorological conditions, for example in Fig. 3 where there is variable cloud cover, the probabilistic model allows an understanding of the uncertainty in the road state forecast in a way that the deterministic model does not.

We are currently verifying our probabilistic road surface forecasts at approximately 300 locations in the United Kingdom for which good quality road weather observation data are available between May 2019 and May 2021, using standard meteorological ensemble verification techniques, including rank histograms and reliability plots.

Future research will focus on how to best communicate a probabilistic forecast, as discussed in the advice and guidance laid out in [3]. This could include standard outputs such as RAG (Red Amber Green) statuses, updated to describe the probability of significant weather hazards such as ice on the road surface. It will also necessarily include probability- and ensemble-specific visualisations for both forecasts and verification of the current performance of the system. Carefully focussing on communication of

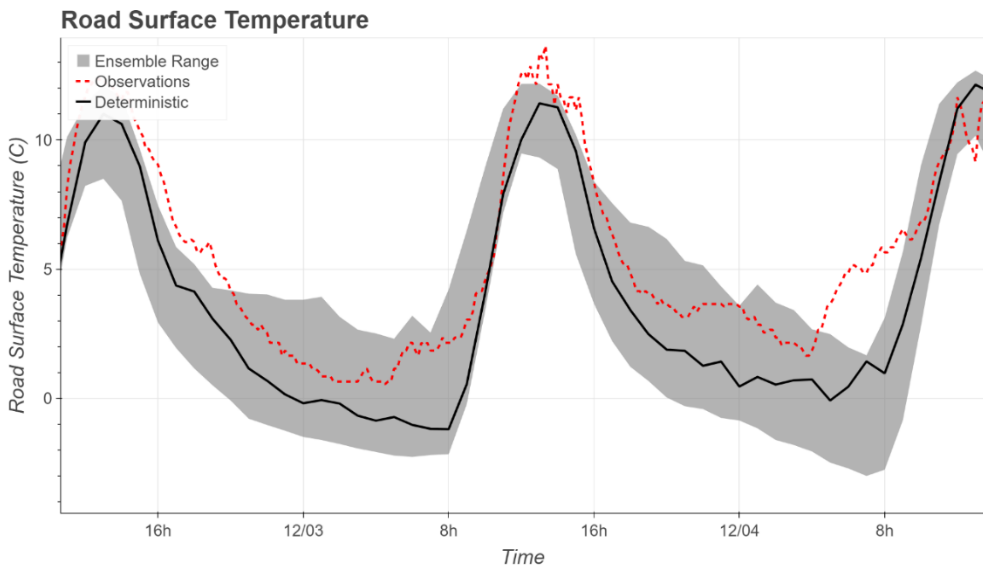


*Fig. 3. An example of two marginal nights in Cornwall (United Kingdom) in 2020. The deterministic forecast predicts sub-zero temperatures, while the observations remain above zero. The range of ensemble forecasts captures both possibilities.*

the forecasts ensures that end users are able to use probabilistic forecasts to enhance their decision-making.

In this talk we will present initial results from our probabilistic STF system, show how these compare to a deterministic system, and give examples of how the outputs of this system can be used to aid decision-making.

## References

[1] Rayer, P. J. **1987**. The Meteorological Office forecast road surface temperature model. *The Meteorological Magazine*, *Vol. 116*, 180-191. https://ci.nii.ac.jp/naid/10027716076/en/

[2] Best, M. et al. **2011**. The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes. *Geoscientific Model Development, Vol. 4.* 677-699. https://doi.org/10.5194/gmd-4-677-2011

[3] Steele, E. et al. **2021**. Using Metocean Forecast Verification Information to Effectively Enhance Operational Decision-Making. *Offshore Technology Conference. https://doi.org/10.4043/31253-ms*