Introduction

Late February and early March 2018 saw some remarkable weather conditions across the United Kingdom, as an omega block over Europe led to an easterly flow and a polar continental air mass becoming established across the UK. The 'Beast from the East' (as the UK press dubbed the spell of bitterly cold wintry weather) brought significant snowfall, remarkable low temperatures and severe travel disruption. In fact, it was the most significant spell of snow and low temperatures for the UK overall since 2010 - a year which stands out in the record books for having the coldest December in the UK Series (one of the standard datasets used by the Met Office to contextualise weather events, and which dates back to 1910). In particular, the night of March 1st and morning of March 2nd 2018 saw a significant freezing rain event that affected south-western parts of the UK and which will be the focus of this article.

Synoptic Situation:

Despite being the first day of Meteorological Spring, March 1st was in fact bitterly cold. The surface analysis chart in Figure 1 shows how high pressure positioned over Scandinavia and low pressure in the Bay of Biscay led to a strong, deeply unstable easterly flow becoming established across the UK. This brought a bitterly cold polar continental air mass (with origins in Finland and north-east Russia) to our shores. The air mass was unstable both to sea surface temperatures and daytime temperatures, with the strong easterly flow helping the westward propagation of snow showers inland and low level convergence lines developing over north-eastern Britain acting as a focus for more continuous snow showers through the day.

Meanwhile, the deep area of low pressure located to the north of Spain on the 12 UTC analysis chart (named Storm Emma by the Portuguese Institute for Sea and Atmosphere, IPMA) continued to track northwards, still in a deepening phase as it crossed the Bay of Biscay, before gradually starting to slow and fill as it neared the south coast of Devon. Warm advection ahead of Storm Emma led to quite a complex frontal analysis in the vicinity of the UK, with an upper warm front indicating the leading edge of the milder air overriding the extremely cold polar continental air at the surface. This led to an area of precipitation blossoming ahead of the main surface front, which fell initially as snow, but turned increasingly to freezing rain, as warm advection continued to occur at mid-levels. By 00 UTC on Friday 2nd March, the leading warm front associated with Storm Emma had crossed northern France and the English Channel, pushing north across southern coastal
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counties of England. As Storm Emma moved slowly north-westward towards the coast of Cornwall, veering flow on the north-east flank of the system continued to import milder (or less cold) air from the south, allowing a gradual thaw to take place through late Friday and into Saturday 3rd March.

Mid to Long-Range Forecast

Prior to the event in question, a prolonged cold spell had been well forecast several weeks in advance. For example, the Met Office product Decider had highlighted a significant cold spell as early as 7 February 2018, some three weeks beforehand. Decider is a medium-to-long range forecasting tool which aids meteorologists by categorising ensemble members by matching their synoptic pattern to a range of idealised synoptic patterns. It is updated several times a day using output from a variety of ensemble model forecasting systems, including MOGREPS-G (Met Office), GloSea5 (Met Office), ECMWF medium range (ECMWF) and GEFS (NCEP) output. Ensemble members are assigned to the closest matching weather regime out of a set of 30 possible predefined weather regimes across Europe. To help reduce the typical spread in output at longer range timescales, these are then grouped into one of 8 general patterns (by looking at the correlation between the 30 regimes in terms of their MSLP anomalies). This allows the user to take a probabilistic view of which weather regime is most likely through the forecast period.

Figure 2 shows the output from Decider, based on the GloSea5 00 UTC run on Wednesday 7th February. This indicated an unusually high forecast probability for Regime 1 to occur later through the month. As can be seen in figure 2, Regime 1 refers to a generally blocked pattern with little Atlantic mobility. The image depicts an idealised version of what Regime 1 looks like in terms of PMSL and temperature biases relative to average. This shows a positive PMSL anomaly to the north of the UK and a negative PMSL anomaly to the south of the UK, resulting in a blocked pattern and leading to an easterly flow being set up, signalling the potential for a significant cold spell for the country.

By the following week, it was possible to refine the medium-range forecast further, with a strong signal for Regime 27 to take hold during the last week of February. Figure 3 shows the Decider output based on the ECMWF 00 UTC run on Tuesday 13th February, highlighting high forecast confidence in Regime 27 taking hold. An idealised version of how Regime 27
looks in terms of PMSL and temperature biases relative to average is shown in Figure 3. This once again depicts an area of high pressure to the north of the UK, with an area of low pressure to the south, indicating a strong easterly flow with a negative temperature anomaly becoming dominant during the end of the month.

The general weather pattern based on these regime forecasts were highly confident for both the long range and medium range forecasts, though there was still uncertainty in the detail, with small changes in the exact position of the anticyclone leading to variation in the surface flow and the sensible weather at any given location, as a result.
By Sunday 25th February, there was very high confidence in the synoptic pattern, with deeply unstable, cold air and unusually low 1000-500hPa thickness spreading across the country. This meant most areas were expected to see snow at some point, and significant accumulations were expected in places. There was also some signal for potential blizzard conditions to develop through Thursday 1st and Friday 2nd March as Storm Emma was forecast to track northwards towards the UK, though there was uncertainty in the timing of this feature, as different model runs gave differing solutions.

Figure 4 shows the ensemble output from MOGREPS-G, the Met Office’s global ensemble forecasting system, using the 06 UTC run on Sunday 25th February, valid at 12 UTC Friday 2nd March. At the time of writing, MOGREPS-G is comprised of 18 ensemble members (1 control and 17 perturbed members) with a vertical resolution of 70 levels (with a model top of 80 km) and horizontal resolution of approximately 20km at mid-latitudes. At this stage, there was a strong signal for the low pressure system and associated fronts to affect the southern half of the UK, with many members suggesting the possibility of a significant blizzard affecting southern and central parts of the UK through Thursday and into Friday.

**Short-Range Forecast**

Other model output nearer the time in the lead up to Friday 2nd March indicated some substantial snowfall accumulations, as well as a significant freezing rain signal across southern parts of the UK. Figure 5 shows the UKV models snow depths in the 24 hours up to 09 UTC on Friday 2nd March, using the 09 UTC run on Thursday 1st March 2018. This model output was considered a good broad guide by the duty Chief Meteorologist on the day, but some spatial errors were anticipated across northern areas due to the exact location of snow showers and the convergence bands that were forecast to develop. What is more, the model diagnostics assume a snow to liquid ratio of 10:1, but due to the extremely cold, low dewpoint characteristics of the air mass, a ratio of 12:1 or 15:1 was considered more appropriate. However, this adjustment was expected to apply less and less across southern and south-western areas through the course of Thursday evening, as warm advection and increasing dewpoints would lead to a wetter type of snow falling here. Some 5-10 cm were expected widely across parts of Devon, Somerset and east Wales, with areas of 10-20 cm and possibly 30-50cm over higher ground, through the course of the evening.

However, the approach of the higher wet bulb potential temperature air mass associated with Storm Emma, was expected to have an impact on the type of precipitation falling. Not only was snow across this region expected to become ‘wetter’, but the risk of freezing rain became evident. Figure 6 shows high resolution model output from the UKV model showing ‘precipitation type’ forecast for 00 UTC and 06 UTC respectively, on Friday 2nd March. Here, swathes of red indicate areas where precipitation is expected to fall as freezing rain or sleet. This was a particularly strong signal in the NWP forecast, most notable for the size of the area covered, which by UK standards was large.

In general, freezing rain events are infrequent across the UK and when they do occur are usually fairly localised and transient in nature, so an event on this scale had the potential to be very disruptive, as well as climatologically quite rare.

Figure 7 shows output from the 03 UTC run on 1st March of MOGREPS-UK showing the forecast risk of freezing rain at 00 UTC and 06 UTC Friday 2nd March 2018, on the left and right respectively, with the area shaded red indicating where more than 80% of ensemble members are forecasting freezing rain to occur. This area highlighted the far north-east of Cornwall and parts of Devon, including the higher ground of Dartmoor and Exmoor, as being most at risk.
Upon further investigation, and by looking at the forecast tephigram profiles, as shown in Figure 8, it was possible to see a clearly defined, classic ‘warm nose’ developing as warm advection began to take place aloft. The elevated melting layer evident on the profiles would allow any frozen precipitation to change phase back to liquid before falling through the sub-zero surface layer and hence become supercooled - posing a severe icing threat on contact with any sub-zero surface. Interestingly, by 09 UTC, the elevated melting layer was becoming less pronounced, perhaps as the milder air aloft began to occlude out, with the effect of potentially allowing freezing rain to turn back to sleet or wet snow. At the same time, the slight deepening of the boundary layer shown by the 09 UTC profile, may also mean that freezing rain or sleet falling from the melting layer may have time to re-freeze as it fell, reaching the ground as ice pellets instead. Although subtle, these nuances in the forecast were significant in terms of impacts, as supercooled rain freezing on contact on the ground would give a greater ice risk and be considered more hazardous than that of frozen precipitation falling.
The Met Office operate an impacts-focused National Severe Weather Warning System (NSWWS). In light of the high confidence in the general forecast, the Guidance Team Meteorologists who are responsible for the public weather service warnings were able to issue a yellow warning for the evening of Thursday 1st March some 4 days in advance. The warning level is assessed using a ‘likelihood’ versus ‘impact’ matrix, and initially the yellow warning was issued with the low likelihood of having a high impact. Figure 9 shows the area covered by the yellow warning that was issued at 12:54 local on Sunday 25th February. This warning was updated at 04:59 local on Thursday 1st March, to increase the areal coverage into north Wales and across southern coastal counties of England.

As forecast confidence increased, further evidence was gathered to indicate that there was a greater likelihood of some significant impacts occurring. There was concern that roads would become blocked due to drifting snow, trees and infrastructure would be damaged and interruptions to power supplies and other utilities may occur. As a result, an amber warning (see figure 9) was issued at 12:16 local on Tuesday 27th February, this time falling into the medium likelihood of high impacts. Finally, by the morning of Thursday 1st March, all the evidence available pointed to the potential for a severe weather event over parts of Devon, Somerset and south Wales, posing significant threat to life and limb and culminating in the issue of a red warning, which fell in the category of high likelihood of high impact. This warning (see figure 9) was issued at 08:13 local on the morning of Thursday 1st March 2018.
Impacts and Historical Context

There were many significant impacts across south-western parts of the UK due to the weather through the 48 hour period from 1st March to 2nd March 2018, with numerous requests for military support across Devon, Cornwall, Avon and Somerset. There was disruption on the road network across the region. For example, one of the main routes in east Devon - the A380 - was closed, so that the authorities could focus resources on keeping the main coastal routes open, whilst another main trunk road, the A38 – which runs over high ground on the eastern side of Dartmoor - was closed following a number of road traffic accidents. Similarly, the A303, a main road through parts of East Devon and Somerset, came to a standstill later in the day, with drivers stranded there for 12 hours. Overnight into Friday 2nd March, many roads across southern parts became treacherous after freezing rain fell across the region, with reports of glazed ice in Hampshire, Dorset and Devon.

There was also an impact on the train lines, with National Rail reporting mass disruption across the south-west, whilst a South Western Railway train to Weymouth in Dorset, broke down during the evening, leaving passengers trapped onboard for 11 hours. Meanwhile, over 5000 schools were closed across England, as frozen pipes caused issues with water supplies in places. It was reported that there were 10 weather-related deaths from across the country.

Figure 10 shows a cross-section of the solid precipitation that fell through Thursday 1st March into Friday 2nd March, captured at Uffculme in East Devon, 30 miles north-east of Exeter, whilst Figure 11 shows photographs taken of ice glazed vegetation and vehicles following the freezing rain event on Friday 2nd March.

Figure 10. Cross-section of solid precipitation that fell on Thu 1 Mar into Friday 2 Mar, Uffculme, Devon. Several hours of dry, powder snow in a very cold and dry environment ahead of approaching ‘warm’ front. As surface warm front approached, with increasing dew (frost) points and warming of boundary layer, snow turned increasingly wet with a short period of sleet. By midnight Friday a ‘warm’ melting layer is established aloft and the cold, near surface layer had become shallow, preventing the rain from re-freezing until impacting surfaces as ‘freezing’ rain. By day break on Friday morning the cold, near surface layer had deepened sufficiently again to allow the rain (melted snow from the elevated melting layer) to re-freeze, reaching the surface as ice pellets.

Figure 11. Images of ice glazed vegetation and vehicles taken following the freezing rain event on March 2nd 2018 in Exeter, Devon.
To give this some historical context, it is interesting to note that settling snow does not occur frequently in the south-west of the UK. In fact, lowland areas do not record any lying snow in roughly one out of every 3 years. In coastal areas of Devon and Cornwall, the average number of days of lying snow (defined as a day where more than 50% of the ground is covered at 0900 at the observation site) is typically less than 3 per year. This figure increases to around five to ten days per year for inland areas, whilst the highest ground in the region – that of Dartmoor and Exmoor – have more than 20 days per year on average. Figure 12 shows a table of monthly averages of snow falling and lying at a variety of different sites at different altitudes.

Meanwhile, true freezing rain events – where super-cooled rain droplets fall, as opposed to ordinary rain falling onto frozen surfaces – are climatologically rare in the UK. In the past century, only a handful of notable freezing rain events have occurred. In particular, one event occurred across mid-Wales, the Midlands and Norfolk in January 1996, when an intense area of high pressure over western Russia fed polar continental air across the UK, and a series of weather fronts began to push in from the south. A similar synoptic situation led to an event that occurred across southern England and south Wales during the last two days of December 1995, where sections of the M4 motorway were closed for almost two days when a series of road traffic accidents occurred as a result of icing. It was thought that traffic accidents were actually fewer than might have been due to the fact that the event fell on a day where many people were on holiday between Christmas and New Year. Widespread freezing rain also occurred on the 20th to 21st January 1966, as well as on Christmas Eve in 1968 when Wales and the west Midlands were badly affected. During the period of the 17th to the 19th March 1969, there was another freezing rain event, this time across the eastern Pennines, whilst a more notable and widespread glazed frost occurred in January 1940.

In comparison, it is clear that the event of this March, was remarkable and relatively speaking, climatologically rare.

**Acknowledgements and References**


Information and data, including climate summaries and statistics, is compiled by the Met Office National Climate Information Centre [https://www.metoffice.gov.uk/climate](https://www.metoffice.gov.uk/climate).

Information, including synoptic charts and forecast data, as well as information on the NSWWS can also be found online at the Met Office Digital Library and Archive: [https://digital.nmla.metoffice.gov.uk/archive/](https://digital.nmla.metoffice.gov.uk/archive/)

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