Severe weather and snow conditions on Cairngorm summit in February to March 2018

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Introduction

Severe winter weather from late February to early March 2018 brought widespread snowfalls and temperatures below freezing across the UK, especially across upland areas of northern England and Scotland most exposed to the strong easterly airflow. Cairngorm summit recorded unusually severe conditions, with wind chill temperatures approaching −30°C. This article compares air temperatures and wind speeds observed at Cairngorm summit with observations made over the last 25 years. It also provides a perspective of snowpack conditions and avalanche hazard on the ground from the Scottish Avalanche Information Service (SAIS).

Challenges of high-level stations

The Cairngorm mountains are home to the coldest and windiest conditions in the UK, with the most extensive land area above 4000 feet (1219m amsl), and snow and freezing weather may occur at almost any time of year. The weather station on the summit of Cairngorm (1237m amsl) is one of six high-level stations across Scotland and northern England maintained as part of the Met Office observing network.¹ The tower infrastructures at these stations were installed between 1984 and 2001. They provide observations representative of conditions at high levels which could not be provided by nearby low-level stations and therefore form an important part of the UK observing network from a climate monitoring perspective. Their data are also used directly to support search and rescue operations, avalanche forecasts and verification of regional mountain forecasts.

The severe weather conditions these stations observe present significant challenges for both meteorological equipment and supporting engineering teams. Visits for maintenance may be impossible for periods of the winter season. The mountain environment means that normal instruments present at a Met Office standard low-level weather station would not function, so the instruments are non-standard. They

¹Other stations include Aonach Mor, Inverness-shire (1130m amsl), Cairnwell, Aberdeenshire (928m amsl), Great Dun Fell, Cumbria (847m amsl), Bealach-na-Ba, Wester Ross (773m amsl) and Glen Ogle, Perthshire (564m amsl).

Figure 1. Instruments on Cairngorm summit showing ultrasonic anemometers, whip and screen-mounted thermistors and humidity sensors in housing tubes.

Figure 2. Time-series of hourly air temperature at Cairngorm summit and Aviemore, and hourly mean wind speed and maximum gust speed at Cairngorm summit from 24 February to 6 March 2018. There are some gaps in the Cairngorm wind speed data.
must reliably withstand water penetration and strong winds, and ideally prevent ice accretion.

Dry-bulb temperatures are recorded by two whip thermistors as well as two screen-mounted thermistors. The screen-mounted sensors are susceptible to ice build-up, whereas the exposed and flexible nature of the whip thermistors does not allow ice to settle on them easily; these are used for duty or standby measurements depending on weather conditions. Wind speed and direction are recorded by two ultrasonic anemometers. These have no moving parts, which helps to avoid issues such as bearing failures and makes them less susceptible to ice build-up; heating elements in the arms also reduce this risk. The sensors are arranged as two parallel systems, and parallel data loggers and a dual-modem solution for retrieving observations give the installation a high level of resilience. Cabinets containing these loggers and other equipment are rated to IP68, one of the highest standards for (resisting) dust and moisture ingress set by the International Electrotechnical Commission (IEC, 2013). Figure 1 shows the layout of these instruments on the tower.

Weather observations from February to March 2018

Figure 2 shows hourly air temperature, hourly mean wind and max gust speed recorded by these instruments at Cairngorm summit from 24 February to 6 March. For comparison, air temperature at Aviemore (228m amsl, around 15km to the north-west) is also shown. During 28 February, the air temperature at Cairngorm summit was −13 to −14°C, coinciding with an hourly mean wind speed of around 30–40kn, gusting at around 50kn. From the 1st to 2nd of March, the temperature rose slightly to around −10°C, but the wind increased correspondingly, with an hourly mean speed of 40–60kn and a high gust of 87kn (100mph). The diurnal temperature variation at Aviemore present from 24 to 27 February is largely absent at Cairngorm summit, and disappeared altogether from both stations as the strong easterly winds became established across the UK.

Historical context

How unusual are temperatures and wind speeds such as this in the Cairngorms? Cairngorm summit is both the coldest station in the UK, with a 1981–2010 annual average temperature of 0.9°C (for comparison, the Aviemore value is 7.4°C) and also the windiest, with an annual mean wind speed of 29kn (33mph), so low temperatures and strong winds are clearly to be expected. The Cairngorms bear the brunt of winter storms; this station recorded an hourly mean wind speed of 100kn (115mph) on 8 December 2011 and holds the UK’s gust speed record of 150kn (173mph) on 20 March 1986.

A scatterplot of air temperature against hourly mean wind speed at Cairngorm summit based on data from January 1992 to March 2018, comprising around 230 000 observations held in the Met Office Integrated Data Archive System (Met Office, 2012). Data points in orange are from 27 February to 3 March 2018 inclusive.

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A scatterplot of air temperature against hourly mean wind speed at Cairngorm summit shows the historical observations lying within a well-defined envelope (Figure 3). The very strongest winds with hourly mean speed above 80kn tend to occur during major autumn and winter storms, coinciding with temperatures approximately in the range −5 to +5°C, with the highest wind speeds reducing for temperatures outside this range. The combination of air temperatures of −13 to −14°C and mean wind speeds of 30–40kn recorded on 28 February 2018 fell well outside this envelope.

Figure 4 shows a histogram of hourly air temperature at Aviemore and Cairngorm summit for the same period. Air temperatures at Cairngorm summit are most frequently in the range −5 to +5°C, with values above 15°C or below −10°C being comparatively unusual (the latter perhaps less common than might be expected). The curious shape of the Cairngorm air temperature distribution around 0°C is likely to be due to the effect of icing (since for obvious reasons the tempera-
Severe weather and snow on Cairngorm (Oscevski and Bluestein, 2005). Cairngorm WCT is typically in the range –15 to +5°C, with a mean value of −5.3°C and a broader distribution, since this variable encompasses the variability of both temperature and wind speed. Although the WCT is frequently below −10°C, values below −20°C are comparatively unusual. At 0100 GMT on 1 March 2018 (ironically, the first hour of meteorological spring), the air temperature of −13.9°C and hourly mean wind speed of 38kn corresponded to a WCT of −28.9°C, the lowest at Cairngorm summit for at least 25 years. Even for Scotland’s mountain summits in winter (when freezing conditions and strong winds are to be expected) the wind chill conditions were therefore exceptionally severe.

Snowpack conditions
What were the implications for snowpack conditions in the Cairngorms? The UK’s mountains are subject to highly variable weather, presenting challenges to both outdoor enthusiasts and avalanche forecasters. SAIS provides avalanche hazard information on a daily basis for six mountain areas of Scotland: Torridon, northern and southern Cairngorms, Creag Meagaidh, Lochaber...

Figure 5. Air mass types and implications for general snowpack characteristics and stability in Scotland’s winter mountains.

Figure 6. Snow profile from 1 March 2018 at a sample site at 1060m amsl on a west aspect in the northern Cairngorms. Note also the summit air temperature and wind speed and direction. (To find out more about interpreting snow profiles see: https://www.sais.gov.uk/how-to-interpret-snow-profiles/.)
and Glencoe. The Met Office forecast team in Aberdeen provides bespoke mountain weather forecasts for these areas, including hourly wind speed, precipitation, and temperature, and SAIS observers make daily assessments of snowpack conditions in the field. The accuracy of the forecasts enables SAIS to determine with greater confidence the effect on snow stability, snow distribution by aspect and expected density, which in turn helps them create the avalanche forecasts.

Avalanche hazard is assessed by travelling through the mountains on foot or ski, carrying out snow profiles and field observations, in combination with other factors. Analysis of the snow layer interfaces are made in an excavated snow-profile. Temperatures taken at regular intervals throughout the depth of the snowpack provide valuable information about stability processes taking place. Observing how the snow ‘behaves’ between layers also provides an indication of snow stability. These observations and their interpretation play a part in the assessment of the overall avalanche hazard across the mountain as the SAIS observer travels to different aspects and altitudes during their daily task.

Figure 5 shows general air mass types that affect the Scottish mountains and the implication for snow stability. The mountains are most often subject to a maritime air mass with short-term instabilities during storms, while a mixed type of air mass presents dynamic and therefore challenging conditions for forecasting. During late February and early March 2018, the UK experienced a sustained period of cold weather from a continental air mass, with a strong easterly wind interspersed with calmer periods. This led to a layered snowpack of varying density, with a temperature gradient regime transforming buried snowpack layers into areas of developing weakness. Unusually, these weak layers persisted in the snowpack for many days.

Figure 6 shows snow profile data collected by an SAIS avalanche forecaster from a sample site on 1 March 2018, including hardness, grain type and temperature relative to the depth of the snowpack. Sample sites are identified as safe locations at which persistent weak layers or new snowpack accumulations are estimated to be located before going in the field. The grey shaded areas indicate the density or hardness scale: ice, knife, pencil, one gloved finger, two gloved fingers; four gloved fingers, and then fist. The red line indicates the temperature gradient, which is an important indicator of the regime of change within the snowpack. Gradients greater than 1 degC/10cm indicate potential instability, whereas less than 1 degC/10cm indicates stabilisation and grain bonding. In this case, the temperature through the snowpack varied from around –2°C at 80cm depth to –10°C at the surface, consistent with the ambient air temperature. The greatest temperature gradient exceeded 2 degC/10cm, an indicator that grains will change shape, become weakly bonded and/or weak grains will be preserved. The hazard observation on this day was that an unstable snowpack was present but limited in extent. However, this would become an increasingly widespread and serious issue in view of the forecast for continued low temperatures and strong easterly winds redistributing any snow in the next few days, as shown later.

The weather forecast information provided by the Met Office and interpretation and field activity by the SAIS avalanche forecasters results in the provision of daily avalanche reports and weekly snowpack summaries. These provide a continual source of information advising the public of the current avalanche situation and likely conditions for the days ahead. The daily avalanche reports provide layers of historic and current information, including observed and forecast snowpack stability and hazard roses which illustrate graphically the hazard distribution by aspect and altitude. SAIS blogs also provide an opportunity to illustrate the situation with photographs and video clips.

Figure 7 shows an avalanche report for the northern Cairngorms on 1 March 2018. The avalanche hazard for this date and for the following 6 days was assessed as ‘considerable’ – meaning natural avalanches are possible and human-triggered avalanches are likely – with the hazard rose indicating southwesterly to northerly aspects would be affected above 800m amsl, due to the redistribution of snow in the strong easterly winds. At the same time, the continued forecast low temperatures would maintain the potential for hidden instability in the snowpack. Reports such as this go a long way towards helping outdoor enthusiasts use this information in their planning before going into the mountains, resulting in a safer experience and fewer avalanche victims.

![Figure 7. Public avalanche report from the SAIS website issued on 1 March 2018 for the northern Cairngorms outlining the avalanche hazard situation. The weekly snowpack summary states ‘A very thin surface layer of isolated windslab that formed on top of the very firm snowpack on some NW to N aspects on the 22 Feb is now buried under the recent windslab accumulations. This layer is now a very weak layer and consists of loose sugar like grains under a very thin crust. Currently this is presenting a widespread unstable snowpack situation which will persist within the current cold temperature regime.’](image-url)
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Figure 8. Snow profile from 3 March 2018 at a sample site at 1070m amsl on a west aspect.

Figure 9. Detailed image of a sample taken from the profile site in Figure 8 at 39cm depth, showing faceted grains on a metal crystal screen (3mm grid). Square faces and striations on the grains indicate a more advanced development.

Figure 10 shows natural avalanche activity observed on 8 March 2018 on a northwesterly aspect at 1100m amsl from avalanches occurring during the previous two days. These avalanches failed on the weak layer identified in Figures 6, 8 and 9. They were size 3+ on an international scale (with a volume of 10000–15000m³ and a mass of 7000–12000t), large enough to bury and destroy cars, trucks and small buildings. The consequences for anyone caught in such an avalanche could well be fatal. No persons were caught in this avalanche, which took place in Coire an t’Sneachda, one of the most popular locations for winter climbing in Scotland. Other avalanches occurred throughout the forecast area in the same period on the same aspects and altitudes.

Summary

Temperatures and wind speeds at Cairngorm summit during late February and early March 2018 were not in themselves close to record values for the UK. The low of −14.0°C fell well short of the UK record of −27.2°C, and temperatures below −10°C to −15°C occur in the UK during most winters. In the UK these low temperatures tend to occur more typically during periods of light winds, clear skies and lying snow cover, particularly at low-level stations in frost hollows where cold air tends to flow. Similarly, hourly mean wind speeds of 60kn with gust speeds exceeding 100kn are not exceptional across Scotland’s mountain summits during major autumn and winter Atlantic storms, and for the most severe storms they can be well in excess of this. What was particularly unusual during the spell from late February to early March 2018 was the combination of low temperatures and strong winds resulting from the unusually strong easterly wind drawing air from Finland, northwest Russia and the Barents Sea. This resulted in the lowest WCT – approaching −30°C – at Cairngorm summit for at least the last 25 years. These conditions therefore arguably represent some of the most severe weather that may be experienced anywhere in the UK.

Through their daily assessments in the field, SAIS forecasters are well placed to understand the implications of conditions such as this, particularly with regards to snowpack
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During winter 2017/2018 there were four periods of a persistent weak layer problem due to the cold conditions: 25 days in January, the first 15 days of February, the first 22 days of March and finally a 5-day period in April. This led to a significant possibility of large avalanches in specific areas being triggered by people, due to a buried weak layer in the snowpack. These conditions were alleviated only when short periods of thaw saturated the snowpack to depth and eliminated the weakness. The automated meteorological observations from Cairngorm summit provide an interesting contrast to these detailed manual observations and interpretation of snowpack conditions made by SAIS observers in the field, based on judgement and experience, and demonstrate the complexity of the processes involved in the development of the snowpack.

The Cairngorm Mountains are a remarkable and unique landscape in the UK, described eloquently in *The Living Mountain* (Shepherd, 1977). It is no surprise that many thousands enjoy outdoor activities at this location in both summer and winter. However, the environment is challenging and dynamic, and historically accidents have occurred, as in November 1971 when six teenage students died in a blizzard (*Mountain Magazine*, 1972). Fatalities from avalanches are thankfully rare but unfortunately still occasionally occur; for example, at least three occurred during the 2015/2016 winter (SAIS, 2016). The conditions in late February and early March 2018 are a continuing reminder of the respect needed for the UK’s mountain environment. Thanks to the avalanche forecasters that go into the field on a daily basis and the mountain forecasts provided by the Met Office, Scotland’s winter mountains can truly be enjoyed by all.

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Figure 10. Avalanche crown wall and debris on 8 March 2018 on a northwest aspect in Coire an t’Sneachda, northern Cairngorms – the consequence of instability in the snowpack. The back wall of this coire is just over 200m in height.