



Rialtas na hÉireann
Government of Ireland



Storm Emma

An Analysis of Storm Emma and the cold spell which struck Ireland between the 28th of February and the 4th of March 2018



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1. Introduction

Many Irish winters are free from major snowstorms, but because of its infrequent and irregular occurrence, snow in large quantities causes serious disruption. A marked feature of snowfall in Ireland is its variation in depth from place to place. Some heavy snowfalls can be quite localised. Drifting complicates measurements of snow depths. Drifts of six meters or more have been reported in upland areas. Even in flat countryside, noticeable drifting can occur especially near buildings or on some roads where nearby fields have much smaller depths of snow. Therefore, snow depths are recorded at locations that are relatively free of drifting. Systematic measurements of snow depths have been recorded at our Synoptic stations since 1942.

Occasionally, in winter, significant snowfall occurs with blocking high pressure to the north of Ireland pushing the North Atlantic jet stream and associated storm systems south, bringing an easterly Polar Continental airflow. Under these conditions, Eastern and Midland areas are more affected. This type of pattern can follow a phenomenon called a Sudden Stratospheric Warming (SSW). Weather in Ireland during the period 27th February to the 4th March saw temperatures drop to record lows with widespread snowfalls across the country. Temperatures didn't rise above freezing even during the day as bitterly cold easterly winds swept in over the country due to anti-cyclonic conditions over Scandinavia. This caused widespread disruptions to roads, rail and air travel with work and school closures, as well as water shortages. A depression named 'Emma' further developed over the Bay of Biscay and tracked northwards towards the country with its associated frontal systems during the first few days of March. It yielded widespread snow, ice and record low daily maximum temperatures.

This report describes what a Sudden Stratospheric Warming is and how on the 12th February 2018, a Sudden Stratospheric Warming influenced the synoptic weather patterns in the Northern Hemisphere a few weeks later, which led directly to the cold spell in Ireland. It gives a detailed account of the cold spell, dubbed the 'Beast from the East', and storm Emma's development and path towards Ireland. It also provides an account of the warnings and advisories issued by Met Éireann and the impacts the cold spell had on the country.

2. Event Evolution

It is now generally accepted that during the Northern Hemisphere winter, winds in the polar stratosphere play a significant role in determining the synoptic weather patterns in the Mid Latitudes. This section of the report describes what a Sudden Stratospheric Warming is and how a Sudden Stratospheric Warming on the 12th February 2018 led to the extremely cold Polar Continental air mass dubbed by the media as 'The Beast From The East', which affected Ireland from the 28th February to the 4th March 2018.

2.1 What is a Sudden Stratosphere Warming

A Sudden Stratospheric Warming (SSW) of the atmosphere refers to a rapid jump in temperatures in the winter polar stratosphere, the layer of the atmosphere extending from approximately 10 km to 50 km above the ground, which can then lead to the onset of cold weather in the troposphere (the lowest layer of atmosphere) of the mid-latitudes. This rapid stratospheric warming (which can be up to 50 degrees Celsius in a couple of days) can be triggered by a disruption of the normal westerly flow by disturbances, usually anticyclone wave breaking around areas of high pressure, propagating upwards from the troposphere into the stratosphere.

This disruption leads to a 'wobbling' of the stratospheric jet stream (a zone of very strong westerly winds propagating around the pool of very cold air which is present in the stratosphere over the North Pole in winter, known as The Polar Vortex). These 'wobbles' or waves, as they break, can be strong enough to weaken or even reverse the normal westerly winds in the stratospheric jet stream, leading to easterlies. As this is happening, the air in the stratosphere starts to collapse and compress, leading to a rapid rise in temperature.

The easterly winds in the stratosphere eventually sink to the troposphere, the lowest layer of the atmosphere, altering weather patterns in the northern hemisphere by pushing the jet stream further south leading to the development of blocking high pressure systems at higher latitudes. Blocking highs can remain in place for several days or even weeks, causing the areas affected by them to have the same kind of weather for an extended period of time. If these blocking highs become established between Scandinavia and Greenland, a synoptic pattern can evolve which leads to bitterly cold air from eastern Europe/Russia or Scandinavia advecting in over Ireland.

Many of the extreme cold and snowy spells that occurred in the past over Ireland can be associated with SSWs, but only just over half of SSWs lead to cold spells here. Cold spells can also occur before the onset of a SSW due to persistent high latitude blocking setting up over Scandinavia for long periods leading to the wave breaking that causes the SSW. It is important to emphasise that whilst a SSW increases the chances of a cold outbreak, it doesn't guarantee one. This is because not all SSWs are the same. Depending on the type of wave breaking the polar vortex can be displaced from the north pole while keeping its overall shape but weakened, or split into 2 or more separate daughter vortices such as the below scenario in 2009. A similar split also happened in February 2018 which led to the cold outbreak a few weeks later over Ireland.

Evolution of the sudden stratospheric warming event in 2009

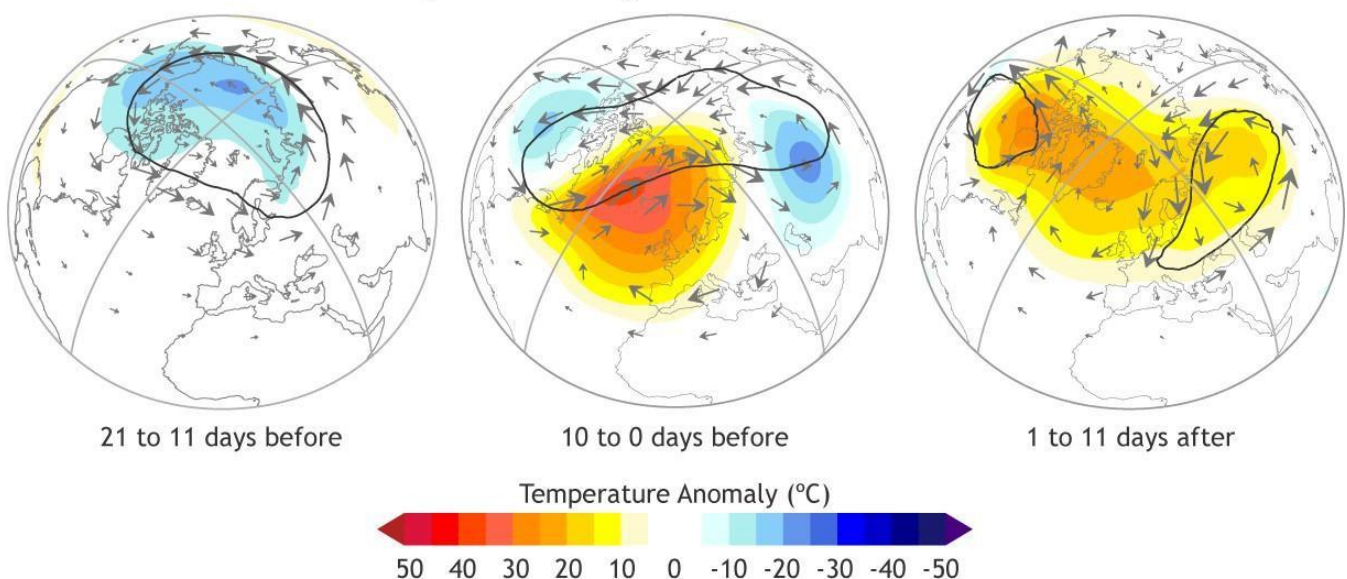


Figure 1 The evolution of a polar vortex collapse in January 2009. Prior to the event (left), stratospheric winds (gray arrows) circle counterclockwise, from west to east, around the pole. The vortex (solid black line) is nearly circular, and the temperatures at 10 hPa (roughly 31 km in altitude) are cooler than usual. (middle) As the waves from below break in the stratosphere, the vortex elongates and wobbles (like a spinning top that you nudge). Temperatures warm rapidly. (right) The vortex splits into two pieces, and the winds near the pole reverse direction. (NOAA)

2.2 February 2018 Sudden Stratosphere Warming

Sudden Stratospheric Warmings over the arctic tend to occur between late November and late March, historically they are less likely in November and December and more likely January through to late March. If they occur after late February, it's usually too late in the season to cause a severe cold spell here. A schematic of typical stratospheric and tropospheric polar vortices is shown in Figure 2.

There was a split in the stratospheric polar vortex over the north pole on the 11th February 2018 just before the SSW happened (Figure 3). One part of the vortex was pushed over Canada and the other into Asia. It can take 2 weeks or more for the reverse in the zonal winds in the stratosphere to propagate downwards into the troposphere where our weather happens.

The wave breaking during this SSW was ideal for high pressure to set up first in Scandinavia, then retrograde towards Greenland, leading to the cold Siberian air mass moving over Ireland from the east dubbed the 'Beast From The East'.

The spike in the temperatures and reversal in the mean zonal winds in the stratosphere at 60°N and 10hPa can be seen in Figure 4, associated with the SSW.

Following a SSW, the major pattern change that is happening present a deterministic challenge to the global weather models. When the reverse in the zonal winds reach the troposphere the global models start firming up on the synoptic patterns that are likely to become established.

From the 16th February the ECMWF deterministic model picked up the possibility of high latitude blocking building to the north or north east around the 24th, but the following runs were inconsistent as to where and when the high pressure would establish. From the 20th, the model runs became more consistent as to the position and timing of the high pressure set up and the very cold air mass advecting around it from Siberia towards Ireland, reaching us around the 27th or 28th. However there was still uncertainty as to the exact position of the anticyclone. If the high pressure stayed very close it would be cold and mainly dry, but if the high pressure set up a bit further north a more unstable easterly flow with snow would be more likely. In these types of situations this is often the last piece of the puzzle to be clarified even when the synoptic setup is accurately forecasted.

A typical tropospheric response to a SSW, in our area of the Northern Hemisphere, is that low pressure systems are pushed southwards with blocking high pressure to the north between Scandinavia and Greenland. This explains why Storm Emma took the track it did. After forming in the mid Atlantic on the 25th and 26th of February, it was steered by the jet stream toward the Azores and then Portugal. Only then did it start to move northwards towards Ireland pushing up against the established anticyclone and cold air mass over and to the north of Ireland.

SSWs can now be reliably predicted a few weeks in advance, and can be detected by observations. This gives forecasters a few weeks lead time to see how they develop and how they are going to impact our weather.

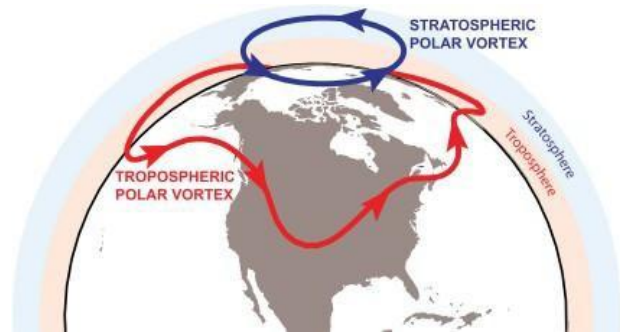


Figure 2 Schematic of Stratospheric and tropospheric polar vortices. Dar-ryn W. Waugh, Adam H. Sobel, and Lorenzo M. Polvani

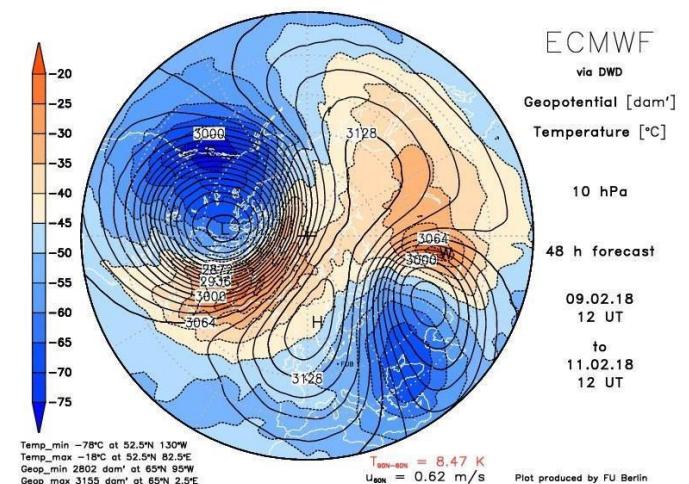


Figure 3 EMCW F chart of Geopotential height and Temperature over the North Pole showing the split polar vortex at 10hPa on the 11th Feb 2018 at the onset of the SSW

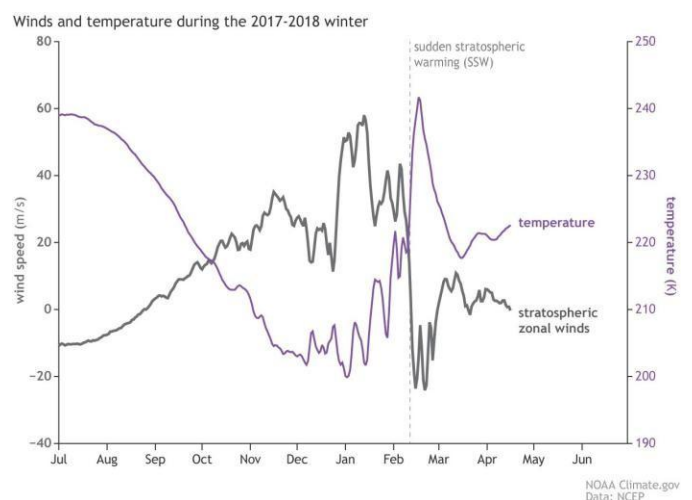


Figure 4 Stratospheric temperature (purple line) and westerly zonal winds (gray line) from July 2017-March 2018 at approximately 32 km altitude (10 hPa) and 60°N. As they do in most years, the westerly zonal winds creating the Northern Hemisphere stratospheric polar vortex, formed in late August and strengthened through January. As the winds strengthened, the temperatures dropped. When the zonal winds dipped below 0 meters/second (changed to easterly) on February 12, a sudden stratospheric warming occurred. NOAA Climate.gov graph adapted from original by Amy Butler.

2.3 Overview of the meteorological conditions leading up to Storm Emma

Saturday 24th and Sunday 25th February:

Ireland lay in a southeasterly airflow, as an area of High pressure extending from Northern Europe into Russia, began to drift westwards. At the same time storm 'Emma', which was named by the Portuguese Meteorological Service on the 1st of March, was forming in the north Atlantic and moving towards the Azores.

Monday 26th to Wednesday 28th February:

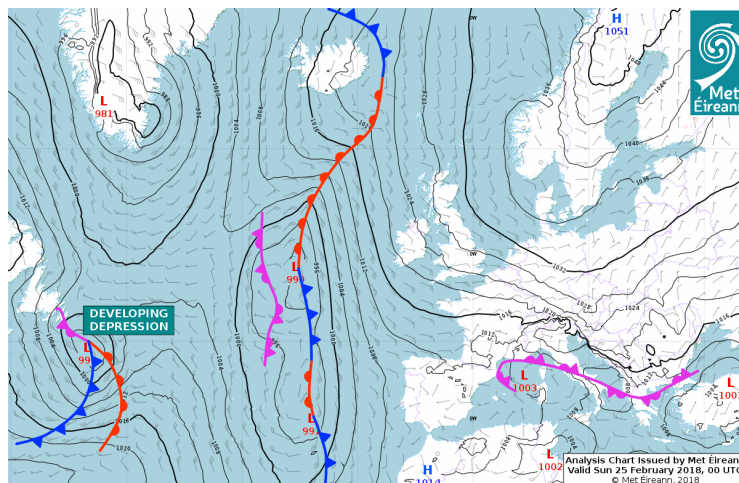
The area of high pressure, of Arctic origin, had an exceptionally cold airmass advecting clockwise around it from Siberia towards Ireland. On Monday and Tuesday a ridge of high pressure had extended westwards over and to the north of Ireland, with colder air gradually becoming established over the country in an Easterly airflow. Daytime air temperatures fell from near normal values (5-8 degrees Celsius) to 1 or 2 degrees above freezing. On Tuesday snow showers began to affect coasts in the South and East as the very cold, dry, unstable air picked up moisture from the Irish sea. During Tuesday night and Wednesday these snow showers moved further Westwards across the country bringing accumulation of snow to many locations. During this period Storm Emma, had brought heavy rain to Portugal and Spain and was situated off the west coast of Portugal, and began to move Northwards on Wednesday night.

Thursday 1st March and Friday 2nd March:

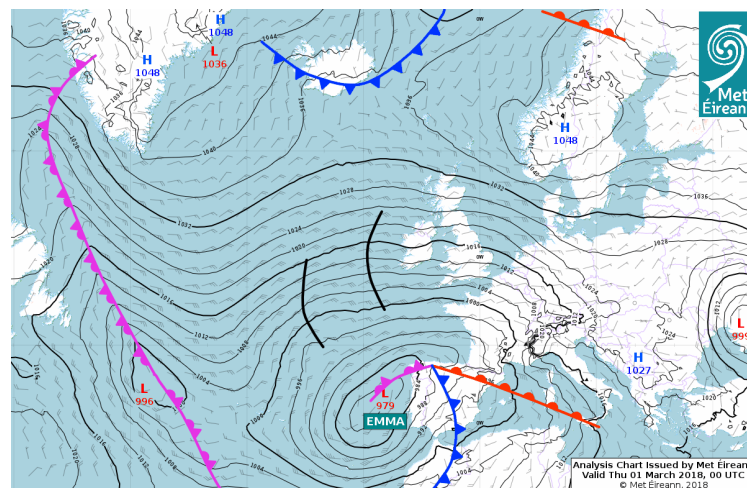
These days were bitterly cold with daytime air temperature not rising above freezing in many locations. Early on Thursday snow showers continued to feed in across the country from the Irish Sea. Storm Emma continued to move northwards and by 6pm persistent outbreaks of snow had begun to affect the South and Southeast of the country, and this spread to the rest of the country overnight. The heavy snowfall associated with Storm Emma occurred as the moisture-rich air associated with the storm, met the sub-zero temperature air mass which had become established over Ireland and the UK. As Storm Emma pushed against the high pressure to the north of Ireland, it squeezed the isobars together over Ireland, strengthening the easterly winds. These strong winds caused drifting, blizzard conditions and extremely high waves in the Irish Sea for a time. During Friday storm Emma became slow-moving to the Southeast, and continued to steer bands of snow across the country, with the East and Southeast worst affected.

Saturday 3rd and Sunday 4th March

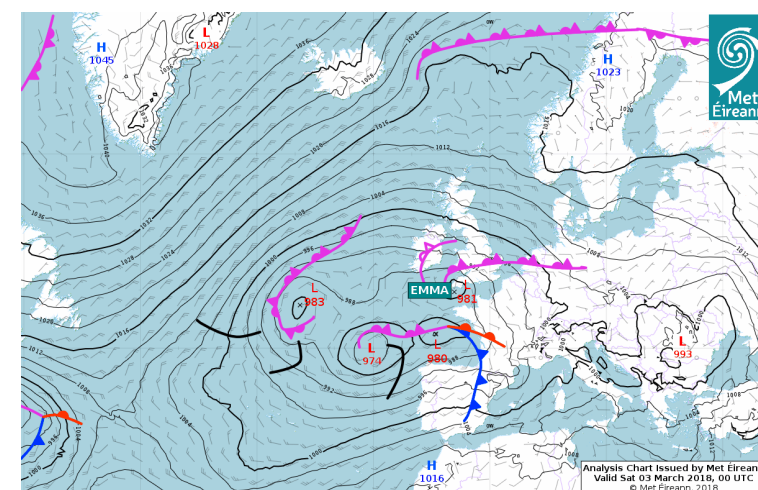
During Saturday as storm Emma passed westwards close to the South coast of Ireland, somewhat milder air slowly extended Northwards across the country, with snow showers turning to rain or sleet from the South. Sunday saw a further slow rise in temperatures, but still some sleet or rain showers and a continuing slow thaw of lying snow.



Analysis chart valid 00 UTC Sunday the 25th February showing the 'Developing Depression' that became Storm Emma in the northwest Atlantic and Ireland in a southeasterly airflow



Analysis chart valid 00 UTC Thursday the 1st March showing Storm Emma west of Portugal pushing northwards and Ireland in a strong easterly airflow



Analysis chart valid 00 UTC on Saturday the 3rd March showing Storm Emma to the southeast of Ireland with frontal bands of snow over

2.4 Red Warnings issued by Met Éireann during the event.

Early on Wednesday morning the 28th February, Met Éireann issued its first Status RED Warning of the event for Dublin, Kildare, Louth, Wicklow and Meath:

Heavy overnight snowfall has led to accumulations of snow between 5 and 10cm. Snow showers will continue to occur during today and again tonight with further accumulations. Total snowfall up to midday Thursday may reach 25cm.

Warning Issued: 05:00, Wednesday the 28th February 2018

Later on Wednesday morning the 28th February, Met Éireann issued another Status RED warning, this time for Munster and Leinster, as the developing situation regarding Storm Emma came into focus:

Blizzard-like conditions will develop in heavy snow and strong easterly winds on Thursday evening and will continue Thursday night and Friday morning giving significant snow drifts in many areas.

Warning Issued: 11:00, Wednesday the 28th February 2018

On Wednesday Evening the 28th February, Met Éireann updated its previous RED warning to include Dublin, Kildare, Louth, Wexford, Wicklow, Meath, Cork and Waterford:

Update Further disruptive heavy snow showers are expected overnight with significant accumulations.

Warning Issued: 20:00, Wednesday the 28th February 2018

On Wednesday night the 28th February, Met Éireann further updated its RED warning to include the whole of Ireland:

Further heavy snow showers will bring accumulations of significant levels with all areas at risk. Blizzard conditions will develop from the south Thursday afternoon and evening as heavy snow and strong easterly winds bringing snow drifts northwards over the country. Eastern and southern coastal counties will be worst affected.

Warning Issued: 23:00, Wednesday the 28th February 2018

On Thursday afternoon the 1st of March, Met Éireann issued 2 updated RED warnings, first for Munster and Leinster:

Update: Sub-zero temperatures and further heavy snow showers this afternoon. Blizzard like conditions will develop in the southeast and south this evening and extend northwards tonight. Southern and eastern coastal counties will be worst affected.

Warning Issued: 12:00, Thursday the 1st March 2018

And then for Connacht, Cavan, Monaghan and Donegal:

Update: Sub-zero temperatures and icy conditions continuing for the rest of today and tonight in strong easterly winds. Scattered heavy snow showers will lead to significant accumulations in some areas.

Warning Issued: 13:00, Thursday the 1st March 2018

Later that day the 1st March, Met Éireann further updated their RED warnings first for Munster and Leinster:

Update: Blizzard conditions tonight and during Friday in Leinster and Munster. Southern and eastern coastal counties expected to receive exceptionally high accumulations.

Warning Issued: 18:00, Thursday the 1st March 2018

And then for Connacht, Cavan, Monaghan and Donegal:

Update: Sub-zero temperatures and icy conditions continuing tonight in strong easterly winds with heavy snow showers and high accumulations in some areas.

Warning Issued: 19:00, Thursday the 1st March 2018

Early on Friday morning the 2nd March, Met Éireann updated their RED warning again to include Munster, Leinster and Galway:

Update: Blizzard conditions during Friday in Galway, Leinster and Munster. Exceptionally high accumulations expected in Eastern and Southern coastal areas.

Warning Issued: 00:00, Friday the 2nd March 2018

Later on Friday morning the 2nd March, Met Éireann updated their RED warning for Munster, Leinster and Galway:

Update: Snowfall will continue today across Munster, Leinster and Galway in strong easterly winds.

Warning Issued: 06:00, Friday the 2nd March 2018

On Friday afternoon the 2nd March, Met Éireann issued their final RED warning of the event to include Dublin, Kildare, Wexford, Wicklow and Meath:

Update: Snow accumulations continuing to increase significantly due to further heavy falls of snow.

Warning Issued: 15:00, Friday the 2nd March 2018

A complete list of all Met Éireann's advisories and warnings for the event are available in the appendix 1.

3. Comparison with other Severe Cold Spells

There are many historical references to severe winters in Ireland. An extraordinary snowfall, which lasted three months, is reputed to have occurred around 764 A.D. In years 1433/1434, Ireland suffered another severe winter. There was a great snow in 1635 (Boate, 1652). From the late 17th century onwards, weather diaries and newspapers provided information on the weather and there are many such recorded events from the 17th and 18th centuries. From 1800 onwards, meteorological observations were recorded at an increasing number of locations and extreme cold spells were more accurately documented. Daily observations commenced at the Phoenix Park, Dublin in 1829. There are many such documented events from the 19th and 20th centuries but here we will concentrate on some of the events since the 1940s.

Up to 24 SSWs have been documented between December 1st and February 20th from 1958 to 2013 by A. H. Butler et al.: 'A sudden stratospheric warming compendium' and by Cohen and Jones 'Tropospheric Precursors and Stratospheric Warmings' using several reanalysis data sets. The documented SSWs that influenced each severe cold spell in Ireland during that time are written in bold.

1947: The early months of 1947 saw one of the most persistent cold spell of the century, with snowfalls affecting all parts of the country from late January until mid-March. Although heavier individual snowfalls have been recorded, notably in January 1917, at no other time in the recent past has there been such a period of continuous cold weather.

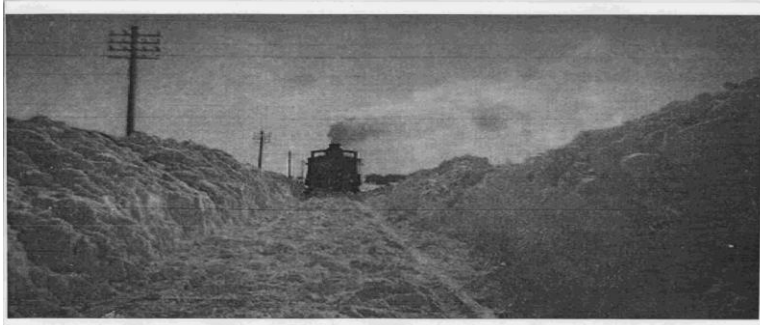


Figure 8 1947 Steam engine coming into Boyle Station

1951: Considerable snow fell on the 8th March in midland and eastern areas and was succeeded by a spell of cold easterly winds. Mullingar recorded a depth of snow of 15cm.

1955: A very cold northerly or easterly airstream dominated the country from the 10th to 25th February giving wintry showers and outbreaks of snow with prolonged periods of icy roads. There were 10 consecutive days with snow lying at Dublin Airport from 18th to 27th February where a depth of 13cm was recorded on the 22nd and 25th February.

1958: A cold north-westerly airflow set in on the 19th January, giving wintry showers, especially in the Northwest and west Munster. Malin Head recorded a depth of snow of 20cm on the 21st February. A depth of 17cm was recorded at Belmullet on the 24th, the greatest depth of snow recorded at this station. **SSW on 31st January 1958.**

1960: Snow fell countrywide on a large number of occasions in February. Dublin Airport had 9 days with snow lying from the 11th to 19th February where a depth of 11cm was recorded on the 13th February. **SSW on 17th of January 1960.**

1962/63: Bitterly cold weather set in around the Christmas period and persisted with only brief milder periods until early March. During this period easterly winds were directed over Ireland by a large Scandinavian anticyclone, with occasional depressions bringing falls of snow, some of which were heavy. On the morning of the 31st December 1962, a depth of 45 cm of snow was recorded at Casement Aerodrome in an area where there was no significant drifting. **SSW on 28th January 1963.**



Figure 9 River Shannon on 3rd January 1963

1973: Widespread snow fell during the period 14th to 17th of February, heaviest in the Midlands. A snow depth of 25cm was recorded at Clones, Co. Monaghan. **SSW on 31st January 1973.**

1978/79: Appreciable falls of snow between 28th and 31st December 1978 were followed by frosts of unusual severity. This cold spell ended on January 6th but there were further snowfalls later in the month. The highest depths of snow recorded during this spell were Casement Aerodrome 26 cm, Claremorris 16cm and Cork Airport 15cm.

1981/1982: A very cold December 1981 continued into January and on the 8th January 1982 there was widespread snow, heaviest in the East, where there was considerable drifting due to strong easterly winds. A severe cold spell followed and snow remained on the ground until 15th January. Dublin was badly affected. Snow was reported at most synoptic stations with the greatest depths as follows: Dublin Airport 25 cm, Casement Aerodrome 16 cm and Kilkenney 16cm. **SSW on 4th December 1981.**

1987: This spell started on the 11th January. By the 14th, appreciable depths of snow were reported particularly in the East and Midlands. Moderated north-easterly winds caused drifting. Temperatures rose a little above zero on the 15th and a slow thaw set in. Highest snowfalls recorded were as follows: Dublin Airport 19 cm; Casement Aerodrome 12 cm; Birr 12cm; Mullingar 12 cm. Roches Point recorded its highest ever depth of snow at 12 cm and a minimum temperature of -7.2 degree Celsius, the lowest there since records began in 1867. **SSW on 23rd January 1987.**

2000: On the 27th December a shallow polar depression crossed the north of the country, bringing outbreaks of snow, heavy in parts of the west and north. Snow showers were widespread in all but the southeast on the 28th, giving significant accumulation of snow in many places. A depth of 19 cm was recorded at Knock Airport. **SSW on 16th December 2000 and 11th February 2001.**

2001: Bitterly cold northerly winds brought falls of snow on the 26th – 28th February, heaviest in the north and east. Snow depths up to 10cm were recorded in the east and northwest, 75cm of snow was measured in the Mourne Mountains on the 27th February. **SSW on 11th February 2001.**

2009/10: This was the coldest winter since 1962/3, temperatures were around two degrees below average. There were between 20 and 30 days with snow in many places, mainly in the form of showers, but snowfall accumulations were generally slight except on high ground. **SSW on 9th February 2010.**

2010/11: From the middle of November 2010, the weather turned progressively colder. By the end of the month, there were accumulations of snow over most of the country, accompanied by extremely low temperatures. Both Dublin Airport (-8.4°C) and Casement Aerodrome (-9.1°C) had their lowest November temperatures on record on the 28th. The very cold weather continued into early December with further sleet and snow, accompanied by daytime temperatures close to freezing and night-time values dropping below -10°C (-16°C at Mount Juliet on 3rd). After an improvement in temperatures for 5 or 6 days, although still cold, it became extremely cold again from 16th with snow at times leading to significant accumulations and record low December temperatures. Snow depths of between 10 and 25 cm were recorded at many locations. Casement Aerodrome recorded a depth of 27cm. **Although not a full SSW, there were warmings in November and December and a split polar vortex which delayed it strengthening into its typical winter mode.**



Figure 10 The Exceptional snow of January 1982 (Photo: scene at Rathfarnham, county Dublin, by P.A. O'Dwyer)



Figure 11 Ice and snow covered the top of Croagh Patrick, Co. Mayo, on New Year's Day 2010.

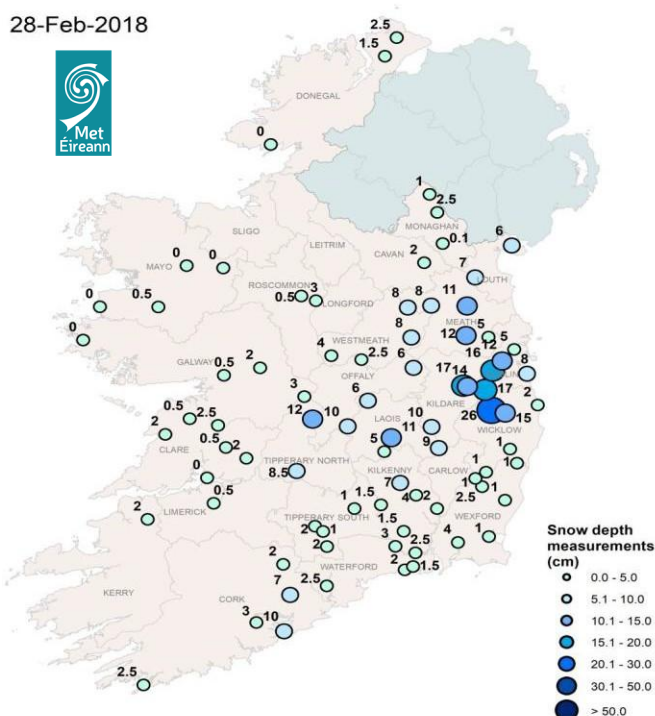


Figure 12 Satellite showing Ireland was almost completely covered by snow and ice on Christmas Day 2010, one of the coldest days ever recorded in Ireland.

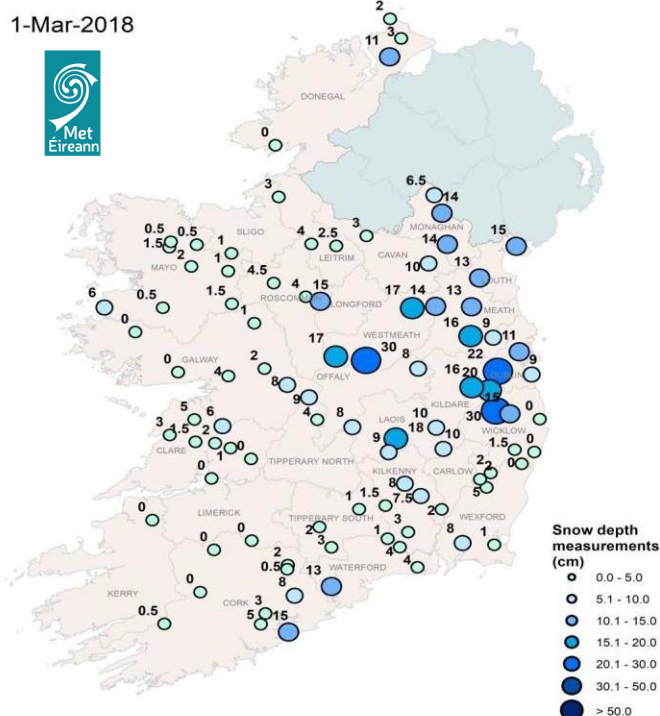
4. Storm Event Analysis

Much of the snow that fell in the first few days of the event fell in the form of showers or bands of snow as the strong bitterly cold easterly winds picked up moisture from the Irish sea. At first the East and Midlands received the bulk of the snow as shown in figure 10 below, however the showers pushed well inland at times with strong winds giving accumulations in places that might not normally receive much snow in this kind of setup. Storm Emma pushed persistent frontal snow up from the south from late on Thursday the 1st which lead to snow accumulations in many other parts of the country.

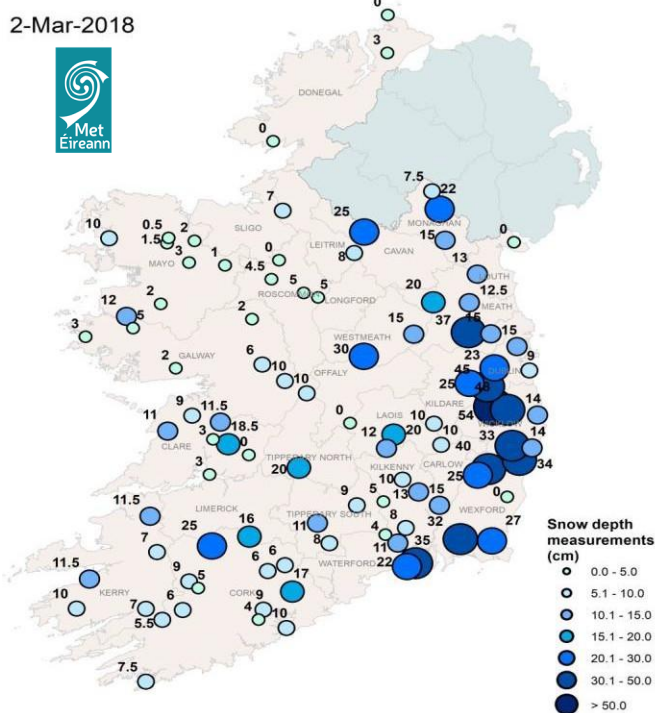
28-Feb-2018



1-Mar-2018



2-Mar-2018



3-Mar-2018

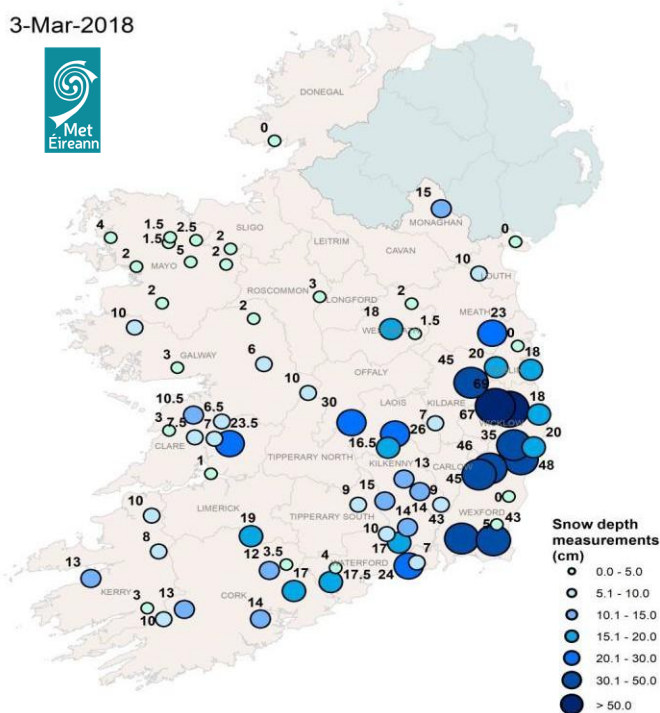


Figure 13 Snow depths recorded at Met Éireann climate and synoptic stations between the 28th Feb and the 3rd March 2018.

Table 1: Snow depths (cm) at 9am from a selection of Met Éireann stations, 28th Feb - 4th Mar 2018 (all other snow depth measurements available in the appendix)

Station	28 th Feb	1 st Mar	2 nd Mar	3 rd Mar	4 th Mar
Ardee (Co. Louth)	7	13	13	10	2
Ballyroan (Co. Laois)	11	18	20	26	12
Buncloody (Co. Wexford)	1	2	25	45	28
Cork Airport (Co. Cork)	3	5	4	14	7
Glenmacnass (Co. Wicklow)	15	15	48	69	53
Knock Airport (Co. Mayo)	0	1	1	2	2
Dun Laoghaire (Co. Dublin)	8	9	9	18	4
Dublin Airport (Co. Dublin)	5	11	15	17	13
Casement Aerodrome (Co. Dublin)	16	22	23	20	14
Mullinavat (Co. Kilkenny)	1.5	3	8	14	5
Naas (Co. Kildare)	14	16	25	45	20
Shannon Airport (Co. Clare)	0	0	3	1	0
Woodlawn (Co. Galway)	2	2	6	6	6

Snowfall was variable across the country with the South, East and Midlands recording the highest depths, especially over hills in these areas. However, in general, amounts on snow decreased further north and west. This reflects the initial showery nature of snow in the easterly flow, and also later the more general bands of frontal snow that moved up from the southeast as Storm Emma approached. Table 1 shows snow depths recorded at a selection of stations during the event. Snow depths became unmeasurable at times in some places due to significant drifting in the strong easterly winds. Drifts of over 2 meters were measured in places.

Table 2: Maximum and minimum temperature from a selection of Met Éireann synoptic stations, 28th Feb - 2nd Mar 2018 (the coldest 3 days of the event). *record low temperatures.

Station	Wed 28 th Feb		Thur 1 st Mar		Fri 2 nd Mar	
	Max T °C	Min T °C	Max T °C	Min T °C	Max T °C	Min T °C
Cork Airport (Co. Cork)	-1.1	-5.1	-1.8*	-7.0*	-0.4	-2.3
Dublin Airport (Co. Dublin)	-0.4	-4.9	-0.5*	-5.1	-0.2	-1.2
Casement Aerodrome (Co. Dublin)	-0.5	-4.5	-0.7*	-5.1	-0.5	-1.2
Shannon Airport (Co. Clare)	0.3	0.8	0.0*	-5.0	0.9	-0.8
Knock Airport (Co. Mayo)	-0.5	-5.4*	-1.2*	-6.8*	0.9	-2.4
Johnstown Castle (Co. Wexford)	0.0*	-3.8*	-0.2*	-3.8*	-0.1	-1.1
Finner (Co. Donegal)	0.9*	-4.5	0.8*	-5.0	2.0	-0.3
Valentia Obs. (Co. Kerry)	2.0	-3.0	0.7*	-5.0	1.5	-1.2
Mullingar (Co. Westmeath)	-0.5	-4.8	-0.8*	-5.1	1.3	-1.0

Ice days, where the maximum temperature in a day does not rise above freezing, are very rare in Ireland on lower ground. During this event, ice days were recorded at a number of stations on the 28th February and on the 1st March 2018. This is the only time since at least 1942 (as far as our digitised records go back), that ice days were recorded in Ireland in March at any Met Éireann stations. There were a number of stations that had record low maximums for March and a few stations with record low maximum for February. A few stations, such as Cork Airport and Knock Airport also had record low minimum temperatures for March on the 1st. This is illustrated in table 2.

5. Impacts

The impacts of Storm Emma and 'The Beast from the East' were widespread across the country. Although most people heeded the warnings not to travel, there was severe disruption to the transport network. Deep drifting on roads was a major issue causing cars to be abandoned in many places.

Travel:

- Air transport was severely disrupted with over 70,000 air passengers stranded due to flight cancellations and airports closures.
- Some remote locations were cut off for a number of days due to the heavy snow and drifting making roads impassable.
- Many colleges, schools and businesses shut down.
- Public transport nationwide including bus, rail and Luas came to a stand still due to widespread cancellations to services.
- Many ferry services were cancelled.

Power outages and water:

- The ESB said over 100,000 homes and businesses lost power.
- More than 10,000 eir customers were without telephone, broadband and mobile services.
- 18,000 people without water across the country.

Disruption to other services:

- Fire crews had to assist ambulances in getting to some calls while other crews had to dig themselves out.
- Fire service and civil defence personnel assisted key workers in the HSE, hospitals and wider community to get to work in extremely difficult conditions.
- There was closures to sports and leisure centres , public libraries, community centres, swimming pools and other public offices and facilities.
- Some coastal flooding in towns along the East and South coasts was reported during high tides.

Farming:

- Some farmers, especially the Southeast and East, suffered significant losses. A number of sheds collapsed due to the weight of the snow leading to the loss of livestock and machinery.
- There was fodder shortages and food shortages as farmers struggled to get supplies to supermarkets.
- Growers in the soft fruit and nursery stock sectors were also badly hit by the heavy snowfall with tunnels and glass houses collapsing.



Figure 14 Snow on the beach, Skerries Co Dublin on the 28th February.



Figure 15 Road conditions in Dublin City on the 28th February were treacherous.



Figure 16 A farm in Mullingar on the 28th February

6. Conclusions and Summary

This was the most significant spell of snow and low temperatures to affect Ireland since December 2010. The synoptic setup however, compares more favourably to the cold spell in January 1982 with large snowfall totals and blizzard conditions affecting the East and South especially. Both the 1982 and 2018 cold spells followed several weeks after Sudden Stratospheric Warming (SSW) events.

When a SSW of the atmosphere occurs in the northern hemisphere in winter, it causes a rapid rise in temperatures in the polar stratosphere and a reversal in the zonal winds that sometimes leads to a cold spell over Ireland several weeks later. Our prevailing wind direction is from the west, giving us relatively mild Atlantic air. Sometimes after a SSW however, an easterly airflow can set up with high pressure forming between Scandinavia and Greenland. This blocks the mild Atlantic air and brings in cold air from the east. Currently we can reliably predict individual SSWs about 2 weeks in advance, but we cannot yet predict which SSWs will lead to cold spells over Ireland and which ones will not. What is understood however, is that SSWs increase the chances of a cold spell with snowfall occurring.

This event started with high pressure setting up over Scandinavia feeding an exceptionally cold airmass towards the UK and Ireland from Siberia. The snow showers started on Tuesday the 27th, affecting the East of the country first, but penetrated inland more and more in the strong easterly winds over the following few days giving accumulations of snow in many locations. The snow stayed on the ground as the temperatures stayed below freezing even during the day. Storm Emma approached from the south on Thursday evening squeezing the isobars together even further, thus increasing the strength of the easterly wind, and sending frontal bands of snow northwards giving blizzard conditions and significant drifting.

The country effectively came to a standstill for several days. There was widespread disruption to the road network with many roads impassable. Public transport shut down in most locations as people were advised to stay indoors. It was not a particularly long lasting spell but it had severe impacts. Naas Co. Kildare and Bunclody Co. Wexford reported 45 cm of snow on the ground on the 3rd of March, with Glenmacnass in Co. Wicklow reporting 69 cm. The very strong easterly winds led to significant drifting with up to 7 meter drifts reported in Wicklow and Wexford. The M2 buoy recorded a maximum individual wave of 9.84 m on the 2nd March. The previous highest was 9.6 m recorded on the 30th December 2015. This buoy has been operating since 2001. Temperatures were also record breaking with record low daily maximum temperatures for March being reported in many locations on the 1st. This is the first time since digitised records began in 1942 that ice days, where the temperature doesn't rise above freezing for the whole day, were reported at any of our stations in March.

The communication of Met Éireann's weather advisories, forecasts and warnings played a pivotal role in helping the country prepare for, and manage its way through this event. Met Éireann also contributed to the briefings at the NCEG (National Emergency Coordination Group) meetings. The synoptic configuration for this event was accurately forecasted from the 20th February onwards. Met Éireann issued its first advisory for the event on Friday the 23rd stating that disruptive snow and exceptionally cold weather was expected from the following Tuesday the 27th onwards. As the event came closer Met Éireann used its high resolution 54-hour Harmonie model to forecast specifics on where and how much snow would fall, however the initial showery nature of the snow made it very difficult to pinpoint the intensity and location of the showers, and on the morning of the 28th February Met Éireann issued its first red warning.

The Fifth Assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) concluded that 'human influence on the climate system is clear' and that 'changes in many extreme weather and climate events have been observed since about 1950'. An increase in the frequency of extreme weather events has been attributed to climate change and is linked to human activity. Climate attribution of SSW events has received less attention. Some recent studies suggest an increased frequency of SSW events in a warming climate, but the mechanisms that trigger SSW and the way in which these will be affected by climate change need to be better understood in order to predict whether SSWs will be more frequent in the future.

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Appendix 1: Advisories and Warnings

Issue Date, Time	Level	Area	Text	valid from	valid to
12:00 hours Friday, 23-Feb-2018	Weather Advisory	Ireland	Exceptionally cold weather is forecast for next week with significant wind chill and severe frosts. Disruptive snow showers are expected from Tuesday onwards, particularly in the east and southeast.	12:00 hours Fri, 23-Feb-2018	12:00 hours Fri, 02-Mar-2018
17:00 hours Saturday, 24-Feb-2018	Weather Advisory	Ireland	Update on previous Advisory. Exceptionally cold weather is forecast for next week with significant wind chill and severe frosts. Disruptive snow showers are expected from Tuesday onwards, particularly in the east and southeast. Snow showers perhaps merging into more persistent bands of snow from midweek.	00:00 hours Tue, 27-Feb-2018	18:00 hours Sat, 03-Mar-2018
11:00 hours Sunday, 25-Feb-2018	Weather Advisory	Ireland	Update on previous Advisory. Exceptionally cold weather will occur this week. Air and ground temperatures will be 5 to 10 degrees below normal, with significant wind chill and penetrating severe frosts. Snow showers, mainly affecting eastern areas on Tuesday, will progressively become more widespread and heavier through midweek, with significant and disruptive accumulations.	00:00 hours Tue, 27-Feb-2018	18:00 hours Sat, 03-Mar-2018
11:00 hours Monday, 26-Feb-2018	Weather Advisory		Exceptionally cold weather will occur this week. Air and ground temperatures will be 5 to 10 degrees below normal, with significant wind chill and penetrating severe frosts. Snow showers, mainly affecting eastern areas on Tuesday, will progressively become more widespread and heavier through midweek. A spell of persistent and heavy snow is expected to extend from the south late Thursday and Thursday night, with significant and disruptive accumulations. Please also see winterready.ie.	Valid from 00:00 hours Tue, 27-Feb-2018	Valid until 18:00 hours Sat, 03-Mar-2018
11:00 hours Monday, 26-Feb-2018	Weather Warning Orange	Dublin, Carlow, Kildare, Laois, Louth, Wicklow and Meath	Scattered snow showers later Tuesday and Tuesday night will lead to accumulations of 4 to 6 cm by Wednesday morning. Widespread frost and icy conditions also. Updates to follow. Please see Weather Advisory.	Valid from 15:00 hours Tue, 27-Feb-2018	Valid until 11:00 hours Wed, 28-Feb-2018
11:00 hours Monday, 26-Feb-2018	Weather Alert Yellow	Kilkenny, Longford, Wexford, Offaly, Westmeath, Cork,	Scattered snow showers later Tuesday and Tuesday night will lead to accumulations of up to 3 cm in some parts by Wednesday morning. Widespread frost and icy conditions also. Updates to follow. Please see Weather Advisory.	Valid from 18:00 hours Tue, 27-Feb-2018	Valid until 11:00 hours Wed, 28-Feb-2018
11:00 hours Monday, 26-Feb-2018	Weather Alert Yellow	For Ireland	Air temperatures of 0 to minus 5 Celsius tonight, with widespread severe frost.	Valid from 17:00 hours Mon, 26-Feb-2018	Valid until 12:00 hours Tue, 27-Feb-2018
17:00 hours Tuesday, 27-Feb-2018	Yellow	For Ireland	Very cold overnight with temperatures falling to between -1 and -5 degrees Celsius, possibly slightly lower in some western and Northwestern counties and temperatures tomorrow struggling to get above zero	18:00 hours Tue, 27-Feb-2018	11:00 hours Wed, 28-Feb-2018

Appendix 1: Advisories and Warnings

at 05:00 hours Wednesday, 28-Feb-2018	Red	Dublin, Kildare, Louth, Wicklow and Meath	Heavy overnight snowfall has led to accumulations of snow between 5 and 10cm. Snow showers will continue to occur during today and again tonight with further accumulations. Total snowfall up to midday Thursday may reach 25cm.	05:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
06:00 hours Wednesday, 28-Feb-2018	Orange	Wexford, Cork and Waterford	Heavy snow showers will continue today, tonight and during tomorrow for Wexford, Waterford and south Cork with snow accumulations up to 8cm.	06:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
08:00 hours Wednesday, 28-Feb-2018	Orange	Carlow, Kilkenny, Laois, Longford, Wexford, Offaly, Westmeath, Cork, Tipperary and Waterford.	Update: Scattered heavy snow showers continuing today, tonight and tomorrow with further accumulations.	06:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
08:00 Wednesday, 28-Feb-2018	Yellow	Donegal, Galway, Clare and Limerick	Scattered heavy snow showers today, tonight, and tomorrow.	08:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
11:00 hours Wednesday, 28-Feb-2018	Yellow	Connacht, Cavan, Monaghan, Donegal, Clare and Limerick	Scattered heavy snow showers today, tonight, and tomorrow.	08:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
11:00 hours Wednesday, 28-Feb-2018	Red	Munster and Leinster	Blizzard-like conditions will develop in heavy snow and strong easterly winds on Thursday evening and will continue Thursday night and Friday morning giving significant snow drifts in many areas.	16:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
11:00 hours Wednesday, 28-Feb-2018	Orange	Connacht, Cavan and Monaghan	Persistent snow will develop on Thursday night and will continue into Friday. Together with strong easterly winds this may lead to snow drifts.	20:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
14:00 hours Wednesday, 28-Feb-2018	Orange	Dublin, Kildare, Louth, Wicklow and Meath	Update: Showers will be more scattered this afternoon, but further heavy snow showers are expected over night with significant accumulations.	14:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
14:00 hours Wednesday, 28-Feb-2018	Red	Dublin, Kildare, Louth, Wicklow and Meath	Update Showers will be more scattered this afternoon, but further heavy snow showers are expected overnight with significant accumulations.	14:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
17:00 hours Wednesday, 28-Feb-2018	Orange	Carlow, Kilkenny, Laois, Longford, Wexford, Offaly, Westmeath, Cork, Tipperary and Waterford	Update: Scattered heavy snow showers continuing tonight and tomorrow with further accumulations.	06:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018
17:00 hours Wednesday, 28-Feb-2018	Orange	Connacht, Cavan, Monaghan and Donegal	Persistent snow will develop on Thursday night and will continue into Friday. Together with strong easterly winds this may lead to snow drifts.	20:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
17:00 hours Wednesday, 28-Feb-2018	Red	Dublin, Kildare, Louth, Wicklow and Meath	Update: Further disruptive heavy snow showers are expected overnight with significant accumulations.	15:00 hours Wed, 28-Feb-2018	12:00 hours Thur, 01-Mar-2018
17:00 hours Wednesday, 28-Feb-2018	Orange	Carlow, Kilkenny, Laois, Longford, Wexford, Offaly, Westmeath, Cavan, Galway and Cork	Further snow showers tonight and on Thursday morning with significant accumulations expected.	17:00 hours Thu, 01-Mar-2018	12:00 hours Thu, 01-Mar-2018
17:00 hours Wednesday, 28-Feb-2018	Yellow	Donegal, Monaghan, Leitrim, Mayo, Roscommon, Sligo, Clare, Kerry, Limerick, Tipperary and Waterford	Update: Scattered snow showers tonight and on Thursday morning with some accumulations.	17:00 hours Thu, 01-Mar-2018	12:00 hours Thu, 01-Mar-2018
20:00 hours Wednesday, 28-Feb-2018	Red	Dublin, Kildare, Louth, Wexford, Meath, Cork and Waterford	Update Further disruptive heavy snow showers are expected overnight with significant accumulations.	20:00 hours Wed, 28-Feb-2018	12:00 hours Thu, 01-Mar-2018

Appendix 1: Advisories and Warnings

20:00 Wednesday, 28-Feb-2018	Orange	Carlow, Kilkenny, Laois, Longford, Wexford, Offaly, Westmeath, Cavan and Galway	Update Further snow showers tonight and on Thursday morning with significant accumulations expected.	20:00 hours Thu, 01-Mar-2018	12:00 hours Thu, 01-Mar-2018
20:00 Wednesday, 28-Feb-2018	Yellow	Donegal, Monaghan, Leitrim, Mayo, Roscommon, Sligo, Clare, Kerry, Limerick and Tipperary	Scattered snow showers tonight and on Thursday morning with some accumulations.	20:00 hours Thu, 01-Mar-2018	12:00 hours Thu, 01-Mar-2018
21:00 Wednesday, 28-Feb-2018	Orange	Connacht, Cavan, Monaghan and Donegal	Persistent snow will develop on Thursday night and will continue into Friday. Together with strong easterly winds this may lead to snow drifts.	20:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
21:00 Wednesday, 28-Feb-2018	Orange	Connacht, Cavan, Monaghan and Donegal	Persistent snow will develop on Thursday night and will continue into Friday. Together with strong easterly winds this may lead to snow drifts.	20:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
23:00 Wednesday, 28-Feb-2018	Red	Ireland	Further heavy snow showers will bring accumulations of significant levels with all areas at risk. Blizzard conditions will develop from the south Thursday afternoon and evening as heavy snow and strong easterly winds bring snow drifts northwards over the country. Eastern and southern coastal counties will be and southern coastal counties will be worst affected.	23:00 Wednesday, 28-Feb-2018	15:00 hours Fri, 02-Mar-2018
12:00 Thursday, 01-Mar-2018	Red	Munster and Leinster	Update: Sub-zero temperatures and further heavy snow showers this afternoon. Blizzard like conditions will develop in the southeast and south this evening and extend northwards tonight. Southern and eastern coastal counties will be worst affected.	13:00 hours Thu, 01-Mar-2018	12:00 hours Fri, 02-Mar-2018
13:00 Thursday, 01-Mar-2018	Red	Connacht, Cavan, Monaghan and Donegal	Update: Sub-zero temperatures and icy conditions continuing for the rest of today and tonight in strong easterly winds. Scattered heavy snow showers will lead to significant accumulations in some areas.	13:00 hours Thu, 01-Mar-2018	06:00 hours Fri, 02-Mar-2018
18:00 Thursday, 01-Mar-2018	Red	Munster and Leinster	Update: Blizzard conditions tonight and during Friday in Leinster and Munster. Southern and eastern coastal counties expected to receive exceptionally high	19:00 hours Thu, 01-Mar-2018	18:00 hours Fri, 02-Mar-2018
19:00 Thursday, 01-Mar-2018	Red	Connacht, Cavan, Monaghan and Donegal	Update: Sub-zero temperatures and icy conditions continuing tonight in strong easterly winds with heavy snow showers and high accumulations in some	19:00 hours Thu, 01-Mar-2018	06:00 hours Fri, 02-Mar-2018
00:00 Friday, 02-Mar-2018	Red	Munster, Leinster and Galway	Update: Scattered heavy snow showers and icy conditions during Friday.	00:00 hours Fri, 02-Mar-2018	18:00 hours Fri, 02-Mar-2018
00:00 Friday, 02-Mar-2018	Red	Munster, Leinster and Galway	Update: Blizzard conditions during Friday in Galway, Leinster and Munster. Exceptionally high accumulations expected in Eastern and Southern coastal	00:00 hours Fri, 02-Mar-2018	18:00 hours Fri, 02-Mar-2018
00:00 Friday, 02-Mar-2018	Orange	Cavan, Monaghan, Donegal, Leitrim, Mayo, Roscommon and Sligo	Update: Scattered heavy snow showers and icy conditions during Friday.	00:00 hours Fri, 02-Mar-2018	18:00 hours Fri, 02-Mar-2018
06:00 Friday, 02-Mar-2018	Red	Munster, Leinster and Galway	Snowfall will continue today across Munster, Leinster and Galway in strong easterly winds.	06:00 hours Fri, 02-Mar-2018	18:00 hours Fri, 02-Mar-2018
15:00 Friday, 02-Mar-2018	Red	Dublin, Kildare, Wexford, Wicklow and Meath	Update: Snow accumulations continuing to increase significantly due to further heavy falls of snow.	16:00 hours Fri, 02-Mar-2018	09:00 hours Sat, 03-Mar-2018

Appendix 1: Advisories and Warnings

15:00 Friday, 02-Mar-2018	Orange	Munster, Carlow, Kilkenny, Laois, Longford, Louth, Offaly, Westmeath, Cavan, Monaghan	Snow accumulations continuing to increase due to further falls of snow.	16:00 hours Fri, 02-Mar-2018	09:00 hours Sat, 03-Mar-2018
15:00 Friday, 02-Mar-2018	Yellow	Donegal, Leitrim, Mayo, Roscommon and Sligo	Scattered snow showers	16:00 hours Fri, 02-Mar-2018	09:00 hours Sat, 03-Mar-2018
20:00 Friday, 02-Mar-2018	Orange	Kildare, Louth and Munster	Snow accumulations continuing to increase overnight, in strong easterly winds. Snow turning to rain/sleet and easing early Saturday	20:00 hours Fri, 02-Mar-2018	09:00 hours Sat, 03-Mar-2018
06:00 Saturday, 03-Mar-2018	Orange	Munster, Leinster, Cavan and Monaghan	Update: Some snow this morning, widespread treacherous surfaces due to ice and lying snow. Rain will begin to spread from the south today and this will start the melting process with potential flooding. Updates will follow.	07:00 hours Sat, 03-Mar-2018	18:00 hours Sat, 03-Mar-2018
06:00 Saturday, 03-Mar-2018	Yellow	Connacht and Donegal	Some snow today with treacherous surfaces due to ice and lying snow.	07:00 hours Sat, 03-Mar-2018	18:00 hours Sat, 03-Mar-2018
08:00 Sunday, 04-Mar-2018	Orange	Munster, Leinster, Cavan and Monaghan	Widespread lying snow and ice will continue to lead to hazardous conditions. River levels will rise due to snow melt, leading to localised flooding, especially in mountainous catchments and in urban areas.	08:00 hours Sun, 04-Mar-2018	12:00 hours Sun, 04-Mar-2018
12:00 Sunday, 04-Mar-2018	Orange	Leinster, Cavan, Monaghan, Cork, Tipperary and Waterford	Widespread lying snow and ice will continue to lead to hazardous conditions. There will be a risk of localised flooding due to rising river levels and there will be areas of surface water pooling. Mountainous catchments and urban areas most affected.	12:00 hours Sun, 04-Mar-2018	12:00 hours Mon, 05-Mar-2018
11:00 Sunday, 04-Mar-2018	Yellow	Connacht, Donegal, Clare, Kerry and Limerick	Lying snow and ice will continue to cause hazardous conditions	12:00 hours Sun, 04-Mar-2018	12:00 hours Mon, 05-Mar-2018
09:00 Monday, 05-Mar-2018	Orange	Leinster	Deep lying snow remaining in places. A continuing potential for localized flooding due to the thaw. Frost and icy conditions tonight and Tuesday morning.	10:00 hours Mon, 05-Mar-2018	10:00 hours Tue, 06-Mar-2018

Appendix 2: Snow Depths

Snow depths (cm) at Met Eireann climatological and synoptic stations, 28 February - 5 March 2018						
	28th Feb	1st Mar	2nd Mar	3rd Mar	4th Mar	5th Mar
Ardee (Co. Louth)	7	13	13	10	2	
Ardfinnan (Co. Tipperary)	2	3	8			
Arklow (Co. Wicklow)		0	14	20		
Ashford (Co. Wicklow)			14	18	6	
Athenry (Co. Galway)	0.5	4				
Athlone (Co. Westmeath)	4	17				
Athy (Co. Kildare)	10	10	10	7		
Aughrim (Co. Wicklow)	1	1.5	33	35		
Bailieboro (Co. Cavan)	2	10				
Ballina (Co. Mayo)		0.5	2	2.5		
Ballinagare (Co. Roscommon)		4.5	4.5			
Ballinamore (Co. Leitrim)		2.5				
Ballincurrig (Co. Cork)	7	8	17	17		
Ballyconnell (Co. Cavan)		3	25			
Ballycroy (Co. Mayo)			10	4		
Ballyhaunis (Co. Mayo)		1.5				
Ballyhooley (Co. Cork)			6	12		
Ballymore (Co. Westmeath)						
Ballyroan (Co. Laois)	11	18	20	26	12	
Ballyshannon (Co. Donegal)	2	2	2	2		
Blessington (Co. Wicklow)	17	20	45			
Bruckless (Co. Donegal)	0	0	0	0		
Buncloody (Co. Wexford)	1	2	25	45	28	16
Cahir (Co. Tipperary)	1					
Callan (Co. Kilkenny)	1.5	1.5	5	15		
Cappoquin (Co. Waterford)			4			
Carheeney Beg (Co. Galway)	2.5	6	11.5	6.5	0	
Carndonagh (Co. Donegal)	2.5	3				
Carnew (Co. Wicklow)	1	2	40	46		
Carrick-on-Suir (Co. Tipperary)		1	4	10		
Carrigallen (Co. Leitrim)			8			
Carron (Co. Clare)	0.5	5	9	10.5	4	
Casement Aerodrome (Co. Dublin)	16	22	23	20	14	9
Castlebridge (Co. Wexford)				5		

Appendix 2: Snow Depths

Castleisland (Co. Kerry)			7	8		
Castleshane (Co. Monaghan)	2.5	14	22	15	9.5	
Clifden (Co. Galway)	0		3			
Clonaslee Waterworks (Co. Laois)	6					
Cloyne (Co. Cork)	16	24	36	40	14	6
Collinstown (Co. Westmeath)	8	17		2		
Coolgreaney (Co. Wexford)	1	0	34	38		
Cork Airport (Co. Cork)	3	5	4	14	7	2
Corofin (Co. Clare)		1.5	3.7	7.5		
Croagh (Co. Limerick)	0.5					
Crossmolina (Co. Mayo)		0.5	0.5	1.5		
Crusheen (Co. Clare)		2	3	7		
Curreeny (Co. Tipperary)	8.5	20	27			
Curry (Co. Sligo)		1		2		
Derriana (Co. Kerry)			10			
Dooks (Co. Kerry)			11.5	13		
Dromahair (Co. Leitrim)			6			
Drumshanbo (Co. Leitrim)		4				
Dublin Airport (Co. Dublin)	5	11	15	17	13	3
Dun Laoghaire (Co. Dublin)	8	9	16	18	4	0
Dungarvan/Castlefields (Co. Waterford)	4	7.5	13	14	4	0
Dungarvan/Carriglea (Co. Waterford)		2				
Dunmow (Co. Meath)	11	13	12.5			
Dunsany (Co. Meath)	12	16	37			
Durrow (Co. Laois)	5	9	12	16.5	6	1
Edenderry (Co. Offaly)	6	8	7	7		
Emyvale (Co. Monaghan)	1	6.5	7.5			
Ennistymon (Co. Clare)	2	3	11	3		
Fenor South (Co. Waterford)	2		22	24	7	
Ferns (Co. Wexford)	2.5	5				
Fethard (Co. Tipperary)	1	1	9	9	2	
Foulkesmill (Co. Wexford)	4	8	32	43	13	
Freemount (Co. Cork)		0	25			
Gernapeka (Co. Cork)		0.5	5.5	10		
Glenamaddy (Co. Galway)		1	2	2		
Glenbride Lodge (Co. Wicklow)	26	30	54	67		
Glenmacnass (Co. Wicklow)	15	15	48	69	53	44
Graigueananagh (Co. Kilkenny)	2	2	15	9		

Appendix 2: Snow Depths

Graigueananagh (Co. Kilkenny)	2	2	15	9		
Greenshill (Kilkenny)	7	8	10	13		
Gurteen (Co. Tipperary)	12	4				
Horseleap (Co. Westmeath)	2.5	30	30			
Illies/Pollan Dam (Co. Donegal)	1.5	11	3			
Johnstown II (Co. Wexford)		1	27	43		
Kilbane (Co. Clare)	2					
Kilcoole Treatment Wks. (Co. Wicklow)	2					
Kilgarvan (Co. Kerry)			7	3	Thaw	
Killadoon (Co. Mayo)	Trace	6				
Kilskyre (Co. Meath)	8	14	20			
Kiltormer (Co. Galway)		8	10			
Kilworth-Kilally (Co. Cork)	2	2				2
Knock Airport (Co. Mayo)	0	1	1	2	2	1
Knockanore (Co. Waterford)	2	13		17.5		
Laherdane (Co. Mayo)		1.5	1.5	1.7		
Leenane (Co. Galway)			12			
Listowell (Co. Kerry)	2	0	11.5	10		
Lough Glencar (Co. Sligo)		3				
Maam Valley (Co. Galway)		0	5	10		
Macroon (Co. Cork)			6	13		
Malin Head (Co. Donegal)		2	Trace			
Meelick (Co. Mayo)	3	9	10	10		
Millstreet (Co. Cork)			9			
Monamolin (Co. Wexford)	1					
Montenotte (Cork City)		3	9			
Moore Park (Co. Cork)		0.5	6	3.5		
Mt Dillon (Co. Roscommon)	3	15	5	3		
Mount Russell (Co. Limerick)		Trace	16	19	5	2
Moycullen (Co. Galway)		0	2	3		
Mullinavat (Co. Kilkenny)	1.5	3	8	14	5	2
Mullingar (Co. Westmeath)				18		
Mushera (Co. Cork)		0	5			
Naas (Co. Kildare)	14	16	25	45	20	10
Naas/Oberstown (Co. Kildare)	17					
Nealstown (Co. Laoise)	10	8		30		
Newport (Co. Mayo)				2		

Appendix 2: Snow Depths

Newtown (Wexford)	1					
Oak Park (Co. Carlow)	9	10	10			
Phoenix Park (Dublin)	12					
Portlaoise (Co. Waterford)	3	4	11	13	Thaw	
Rathwire (Co. Westmeath)		8	15	1.5		
Ratoath (Co. Meath)	5	9	15	23	8	
Riverstown (Co. Sligo)	6	15				
Roches Point (Co. Cork)	10	15	10			
Shannon Airport (Co. Clare)	0	0	3	1	0	0
Shantonagh (Co. Monaghan)	0.1	14	15			
Sherkin Island (Co. Cork)	2.5		7.5			
Straide (Co. Mayo)	Trace	2	3	5		
Strokestown (Co. Roscommon)	0.5	4	5			
Tourmakeady (Co. Mayo)	0.5	0.5	2	2		
Tramore (Waterford)	1.5	4	35	7		
Tulla (Co. Clare)	0.5	1	18.5	23.5	10	
Tycor (Waterford)	2.5					
Woodlawn (Co. Galway)	2	2	6	6	6	

A special thanks to all the voluntary observers for submitting the snow depth returns in very difficult conditions.



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