Met Éireann

Technical Note No. 64

Impact of Storm Darwin on Ireland: description of the event and assessment of weather forecasts

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Glasnevin Hill, Dublin 9
2015

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1 Introduction

The geographical location of Ireland ensures that it is frequently exposed to the influence of storms from the North Atlantic, particularly in winter. The storms are typically extratropical cyclones that undergo cyclogenesis but occasionally the country experiences storms that originate from tropical cyclones that undergo tropical transition; such storms are often notable for their heavy rainfall and strong winds. Occasionally, extratropical cyclones can undergo very rapid deepening leading to a 'weather bomb" (Sanders and Gyakum, 1980).

The climate records from the Irish synoptic stations give an indication of the frequency and intensity of storms. Met Éireann's Valentia Observatory, for example, on average experiences gale force 8 winds ten days per year.[1] But sustained 10-minute winds, as opposed to gusts, above storm force 10 are relatively rare; violent storm force 11 sustained winds, for example, have only been recorded on four occasions since 1940 at the Observatory, the last occurrence in February 2014 associated with the Darwin storm.

This report describes the storm, its development over the Atlantic and passage over Ireland. The guidance provided by Numerical Weather Prediction (NWP) models, both in-house (ALADIN-HIRLAM) and from ECMWF, is assessed. The basic configuration of the ALADIN-HIRLAM system used in this study was HARMONIE-AROME based on Seity et al., 2011.The operational weather warnings posted in advance of and during the storm are also assessed in the light of recorded winds from the Met Éireann synoptic stations.

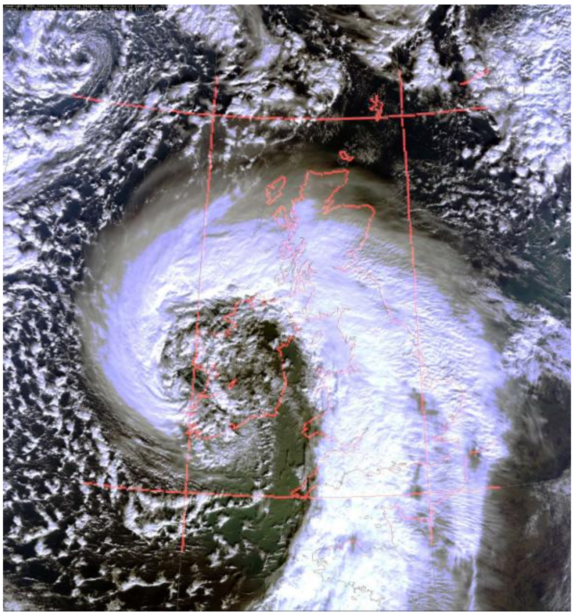
2 Evolution of the storm

Unlike hurricanes, the World Meteorological Organisation does not assign names to storms. Nevertheless, the naming of notable low pressure systems through initiatives such as 'Adopt-a-Vortex'[2] has become popular in recent years (Institut für Meteorologie). The so-called Darwin storm occurred during a particularly unsettled period over the 2013/14 winter, characterised by a strong upper level jet steam over the Atlantic that steered a succession of gale or storm force depressions over Ireland. This storm originated in a slack area of low pressure (~1005 hPa) south of Nova Scotia on 10 February and moved E/NE, rapidly deepening and accelerating in speed as it interacted with cold air from the north.

The most intense development occurred in the second half of 11 February when the storm was over the Atlantic but the system was still deepening as it approached the west of Ireland the following morning. The 24-hour pressure fall over the period ending at 12:00 UTC[3] on 12 February was approximately 39 hPa; this significantly exceeds the threshold of 21 hPa in 24 hours at latitude 50°N used by Sanders and Gyakum to define a 'weather bomb". In the same period the storm travelled over 2000 km. As the system tracked northeastwards over Ireland during the afternoon of 12 February the deepening rate slackened and the core pressure later began to rise from a minimum value of approximately 955 hPa. By 18:00 UTC the depression centre had cleared Ireland and the strong W/NW winds continued to ease. A MODIS RGB composite satellite image (NASA, 2014) of the storm, with its distinct comma-shaped cloud, is shown in Figure 1(a) while the analysis of the mean sea level pressure at 12:00 UTC is shown in Figure 1(b); the latter indicates a core low pressure of about 955 hPa, consistent with synoptic observations.

[1]Beaufort wind scale. There are four measurement units in use within the meteorological community: forecast models use m/s; forecasters use the Beaufort scale for the Sea Area Forecast; observed wind strengths are usually displayed in knots; weather warnings issued to the Public by Met Éireann use km/h.
[2] Adopt a Vortex form (English) http://www.met.fu-berlin.de/adopt-a-vortex/texte/Form14-1_Tief_engl.pdf
[3] Coordinated Universal Time; it coincides with local time in winter.

Figure 1 (a) **Figure 1 (b)**



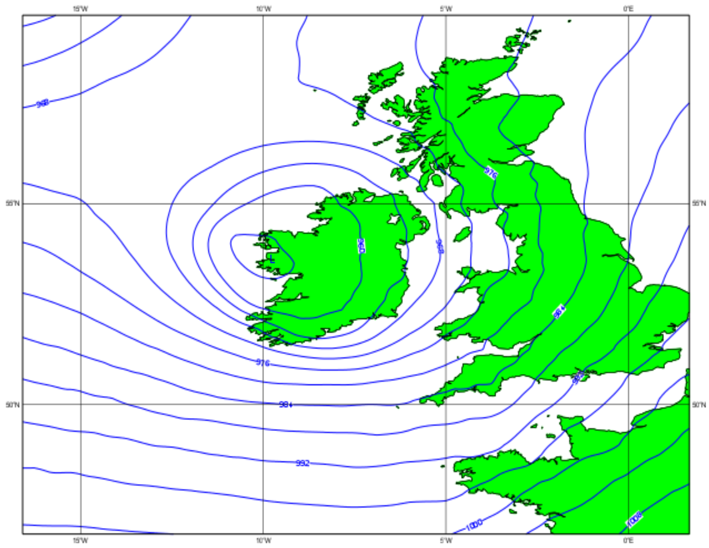


Figure 1 (a): RGB composite satellite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite for 11:45 UTC 12 February, 2014 (NASA, 2014; Dundee Satellite Receiving Station, 2014). **(b):** Mean sea level pressure analysis for 12:00 UTC.

The maximum sustained wind and gust speeds at the observing stations are listed in Table 1, which also includes information on the timing of the highest gust during the day. To aid comparison with the weather warnings, the wind speeds, observed in knots, are converted to km/h (i.e. multiplied by the factor 1.85). The maximum sustained wind and gust speeds were up to 120 and 160 km/h, respectively, with western and southern regions bearing the brunt of the storm. Higher values were probably experienced locally, particularly near the west and southwest coasts.

The 159 km/h (86 knots) gust at Shannon Airport was the highest February value recorded since 1945 and the highest overall since 1961. Mace Head recorded hurricane force winds (mean 10-minute wind speed above 63 knots or 117 km/h), the fifth highest wind speed recorded in Ireland.

The severity of the storm is highlighted in Figure 2, which shows the wind trace at Mace Head in the west of Ireland and the pressure trace at Valentia Observatory. As the storm centre passed north of the Observatory the recorded pressure came close to its long-term climate minimum. Over the ocean, record breaking waves of 25m were recorded at the Kinsale Energy Gas Platform off the south coast. A large-scale view of the peak sustained (10-minute) winds *during the day* is shown in Figure 3. In reality, local effects influencing exposure to the W/NW winds would lead to substantial departures from the smoothed picture. However, it indicates that the most severe winds were experienced in Galway, Clare, Limerick, Kerry and Cork but also included coastal areas in the south and northwest. The strong winds were also notable in regions around the M7 motorway corridor from Limerick to Dublin.

Station	Max speed	Max gust	Time of max gust
Athenry	68	102	1445
Ballyhaise	44	87	1742
Belmullet	76	102	1455
Casement	85	120	1637
Claremorris	61	98	1524
Cork Airport	93	130	1333
Dublin Airport	89	122	1703
Dunsany	70	117	1700
Finner	89	126	1747
Gurteen	85	120	1503
Johnstown II	74	117	1516
Knock Airport	81	115	1546
Mace Head	120	155	1349
Malin Head	87	107	1848
Moore Park	70	118	1408
Mount Dillon	57	91	1546
Mullingar	44	87	1621
Newport	98	139	1509
Oak Park	89	126	1526
Roches Point	100	142	1201
Shannon Airport	113	159	1343
Sherkin Island	113	155	1136
Valentia Observatory	98	137	1220

Table 1: Observed wind speeds (km/h) on 12 February 2014

Figure 2 (a)

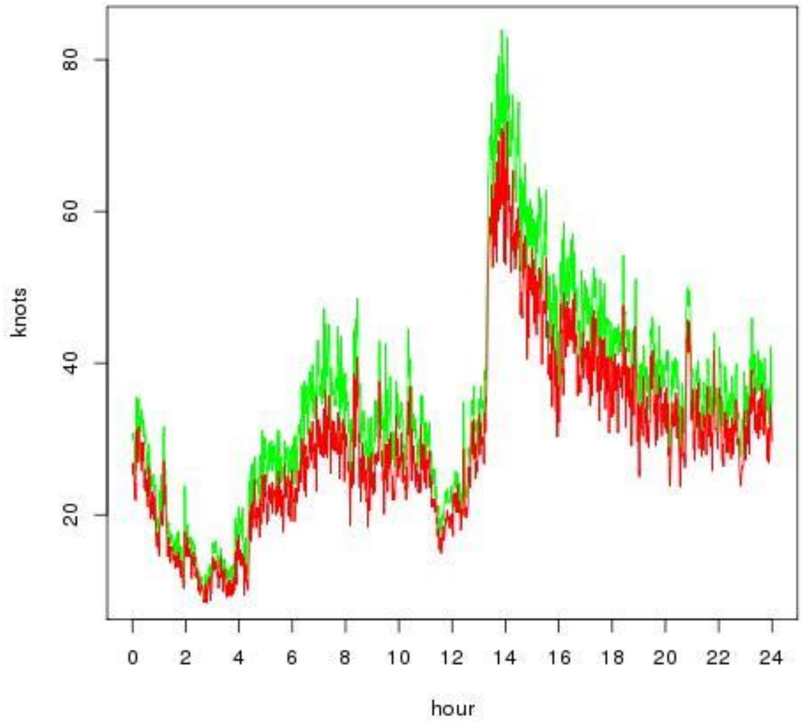


Figure 2 (b)

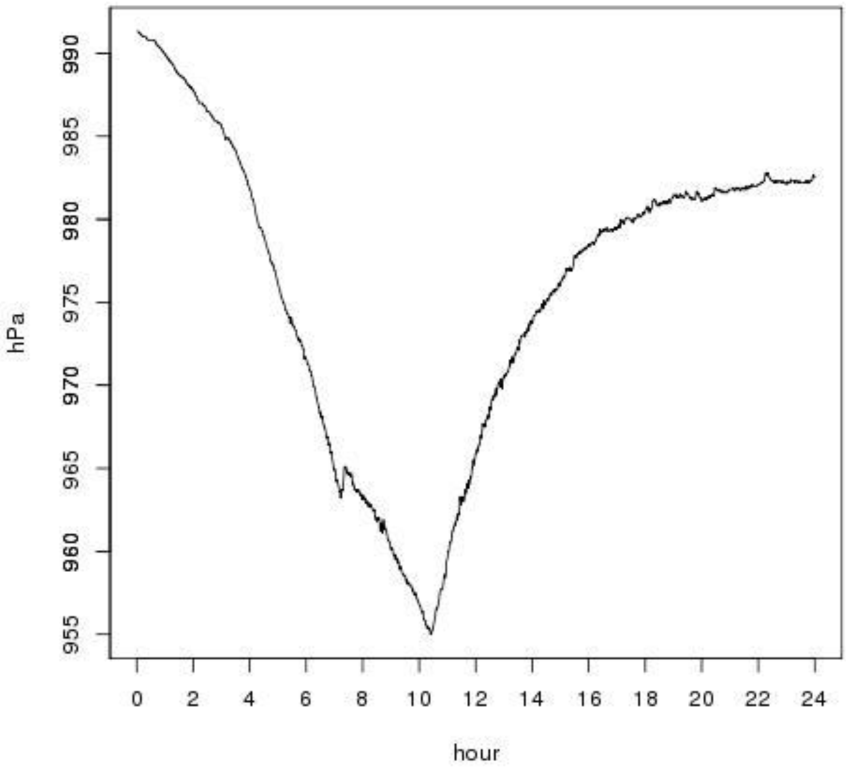


Figure 2 (a): Mace Head minute resolution wind trace (green curve: gusts; red curve: 10-minute winds); **(b):** Valentia Observatory pressure trace for 12 February, 2014.

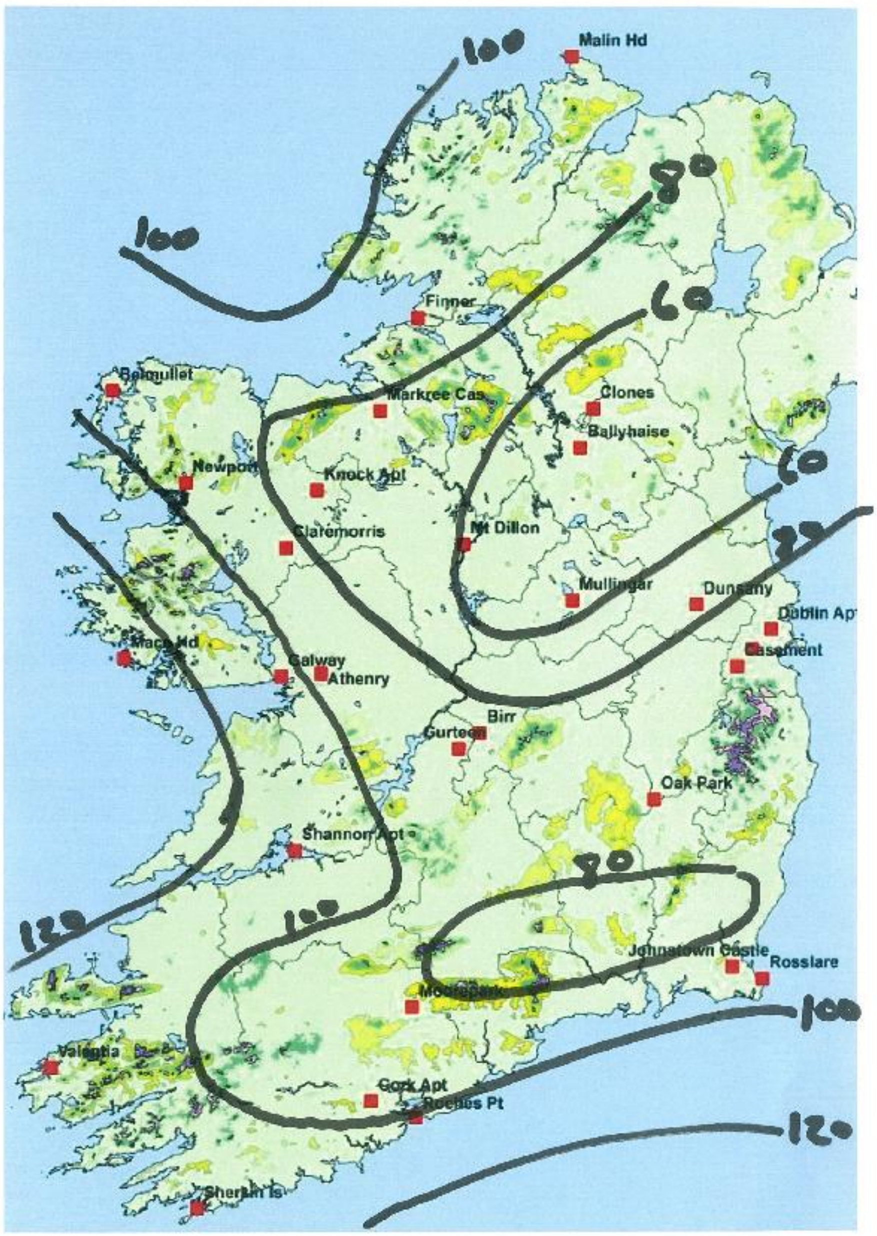


Figure 3: Suggested smoothed analysis of the maximum sustained wind speeds (km/h) during the passage of the storm on 12 February 2014.

3 Storm damage

The extreme west to northwest gusty winds behind the storm centre caused major damage. Remarkably, there was no reported loss of life due to the storm even though there was considerable damage to housing and other buildings. The forestry industry estimated that approximately 8000 ha (+/- 560ha) were damaged (Department of Agriculture, Food and the Marine, 2014). Figure 4 (provided by Copernicus Emergency Management Service, EU Commission) shows the forestry storm damage sample map based on “before” and “after” satellite imagery.

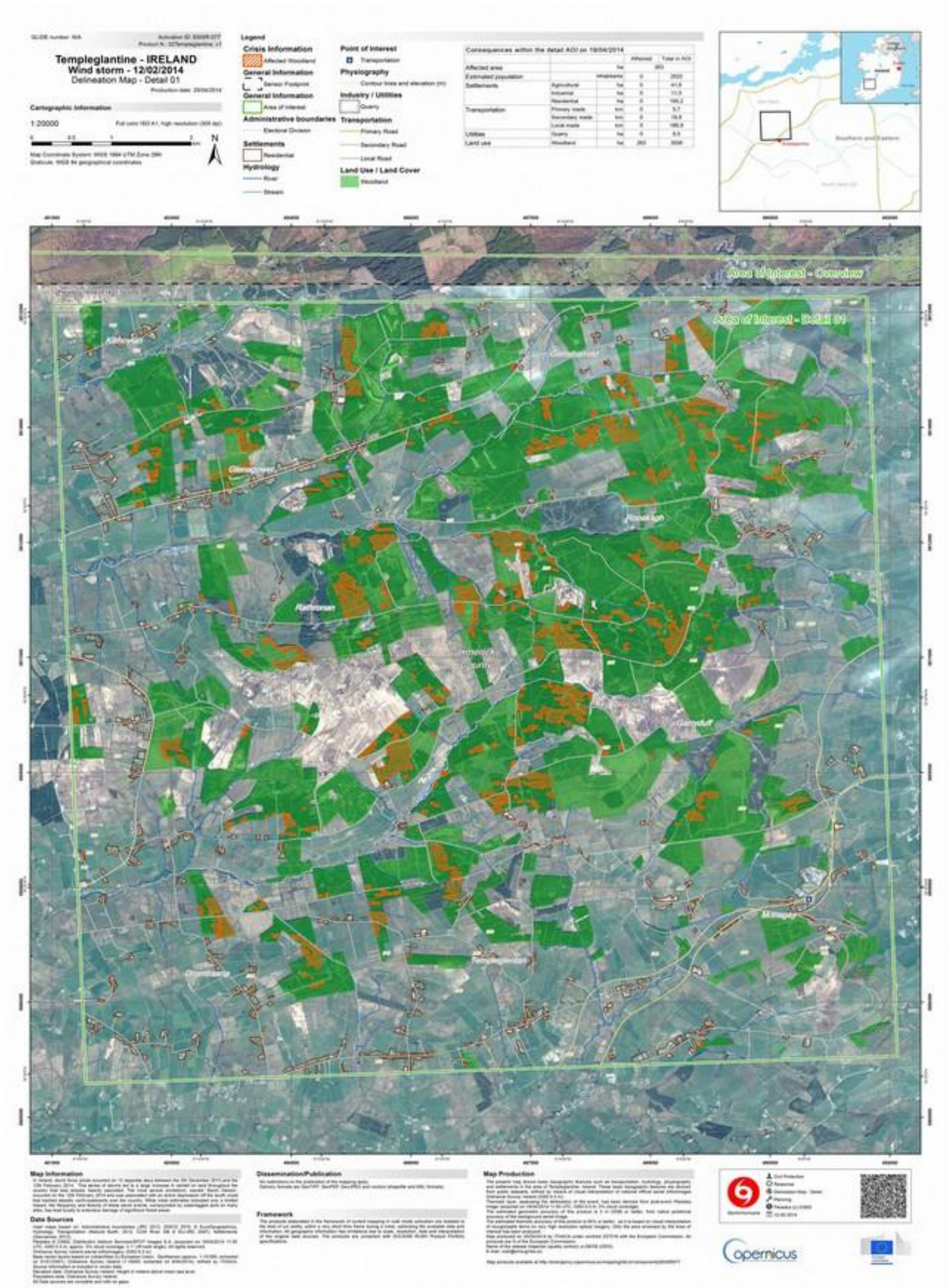


Figure 4: Damage to forestry, highlighted in red hatching, based on "before" and "after" Copernicus satellite imagery for an area shown in the top right corner. Severe damage was also caused in other forestry areas (Copernicus Emergency Management Service, 2014).

4 Storm structure

A striking feature of the storm was the presence of a relatively narrow band of extreme wind speeds near the tip of the wrapped-around occluded front (Figure 1(a)). A detailed examination of the storm structure shows that it shared many features associated with so called "sting-jet" cyclones: a low level jet in advance of the cloud head, descending to the surface (Smart and Browning, 2014; Baker et al., 2014, Clark et al., 2005).

The 12:00 UTC sounding from Valentia Observatory was delayed following a balloon burst due to the extreme winds but a manual launch was eventually successful at 12:46 UTC although the delay meant that the peak of the winds was missed as the jet axis had passed northwards. The low level jet (Figure 5(a)) is particularly striking in the vertical wind profiles created from the ECMWF and HARMONIE operational analyses for 12:00 UTC. In the absence of a direct observation at 12:00 UTC the actual strength of the jet is unknown but ECMWF and HARMONIE NWP models suggest a maximum speed of 53-56 m/s (191-202 km/h) at around 700m height over Valentia Observatory. As the storm matured, the jet weakened.

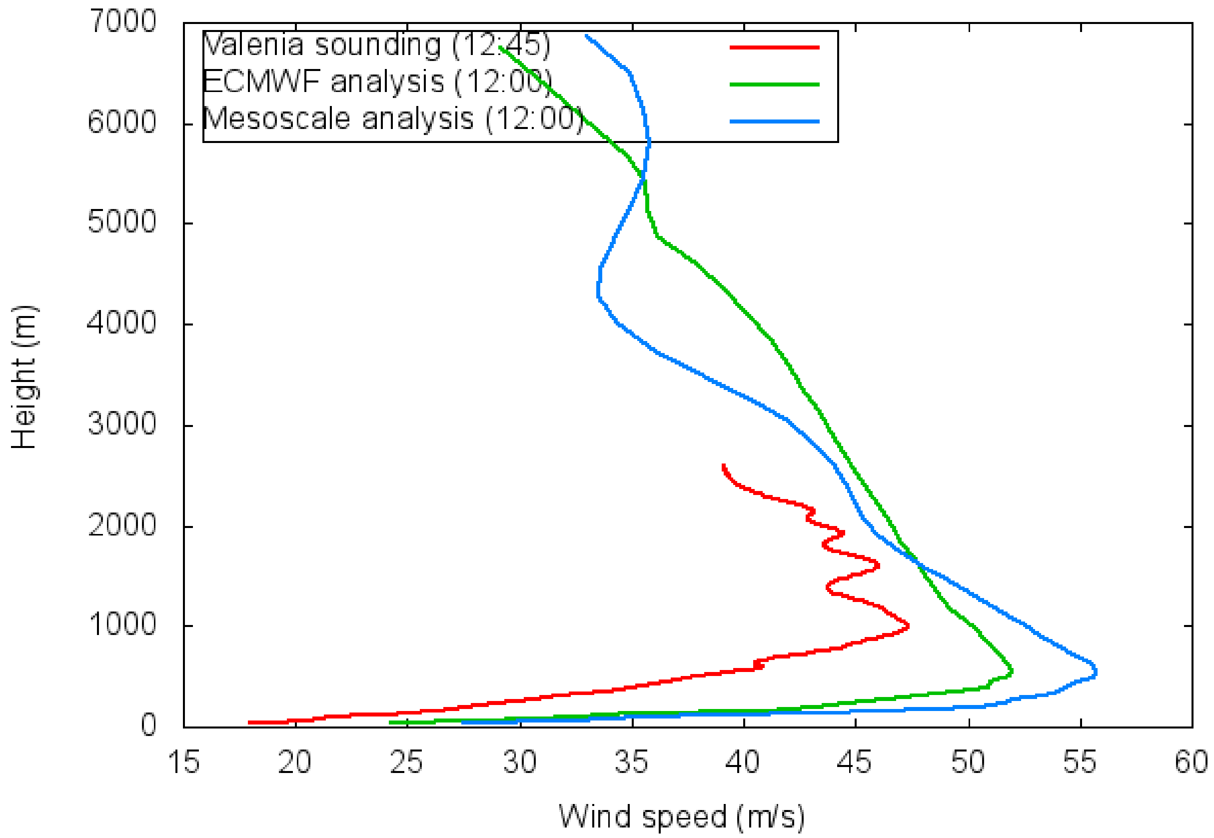


Figure 5: Atmospheric wind profiles at Valentia Observatory: red is observed (12:45 UTC) while the blue and green curves represent the ECMWF and mesoscale HARMONIE 12:00 UTC model level wind data.

5 Forecast performance

5.1 NWP forecasts

How well did the NWP models perform? Considering that there was a very mobile flow regime in the Atlantic at the time, with fast moving developing weather systems, it is not surprising that the early forecasts had difficulty in the timing, the intensification and the track of the storm. This is apparent in the ECMWF ensemble (ENS) forecasts from 08 February (Figure 6); it shows the scatter of depression tracks that were potential candidates for the actual storm, using a window of +/-18 hours, a central pressure <975 hPa and a latitude/longitude box of ~10 degrees centred on the actual storm position at 12:00 UTC on 12 February). The actual track of the depression is shown in Figure 6(b) (solid black line).

Figure 6 (a)

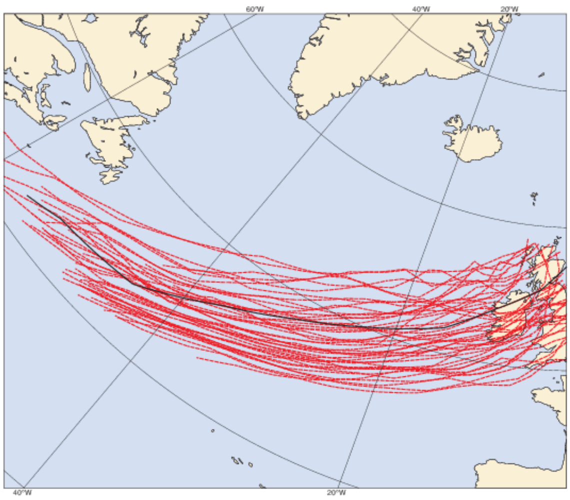


Figure 6 (b)

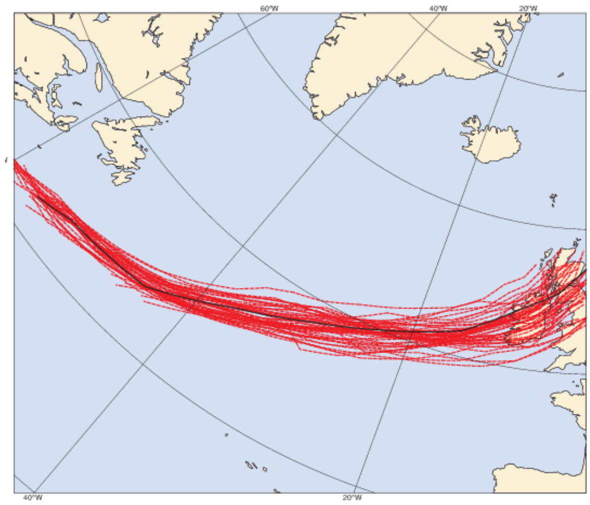


Figure 6: ECMWF ensemble forecast tracks of possible deep depressions impacting on Ireland (actual Darwin storm track in black) **(a)** forecasts from 08 February 12:00 UTC **(b)** forecasts from 10 February 00:00 UTC. The spread in the tracks is indicative of the reliability of the forecasts.

Many of these depressions were either not intense enough or too distant to be regarded as “hits” but some gave an indication of severe weather for Ireland. The forecasts sharpened over the next 2 days (Figure 6(b)) and from 12:00 UTC on 09 February (3-day forecasts) both the deterministic and ENS forecasts gave a very good indication of what was to come. A basic probability map, based on uncorrected ENS members from the 00:00 UTC suite on 10 February, shows that there was a 5-10% probability of 10m wind gusts exceeding 43 m/s over the south and southwest coastlines (Figure 7 (a) and (b)). Similarly, the Extreme Forecast Index (Petroliagis and Pinson, 2014) gave a useful indication of severe weather (not shown).

Short-range (0-48 hours) mesoscale limited-area forecasts based on the HARMONIE model also performed very well with Darwin. The 24- and 27-hour forecasts from 12:00 UTC on 11 February show excellent agreement with the observed system on 12 February (Figures 8 and 9).

Figure 7 (a)

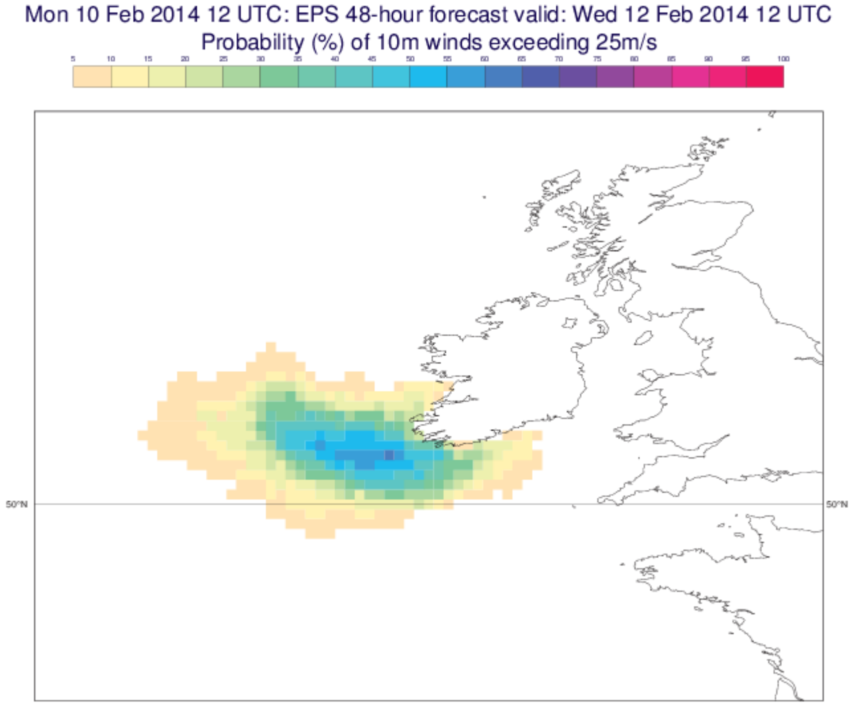


Figure 7 (b)

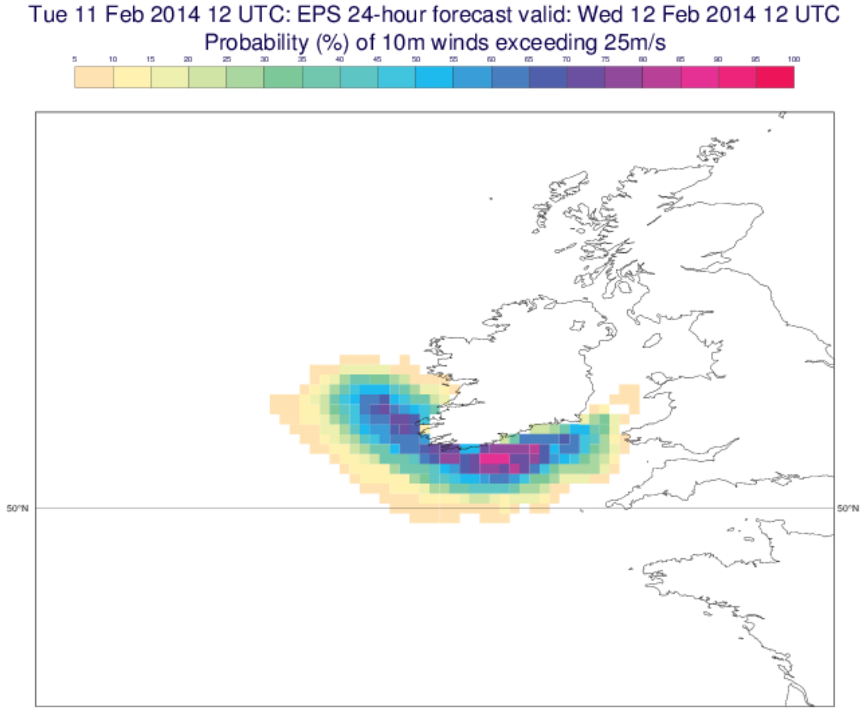


Figure 7: ECMWF ensemble forecasts valid for 12:00 UTC 12 February for **(a)** 48-hour forecast of the probability of winds exceeding 25 m/s **(b)** 24-hour forecast of the probability of winds exceeding 25 m/s.

Figure 8 (a)

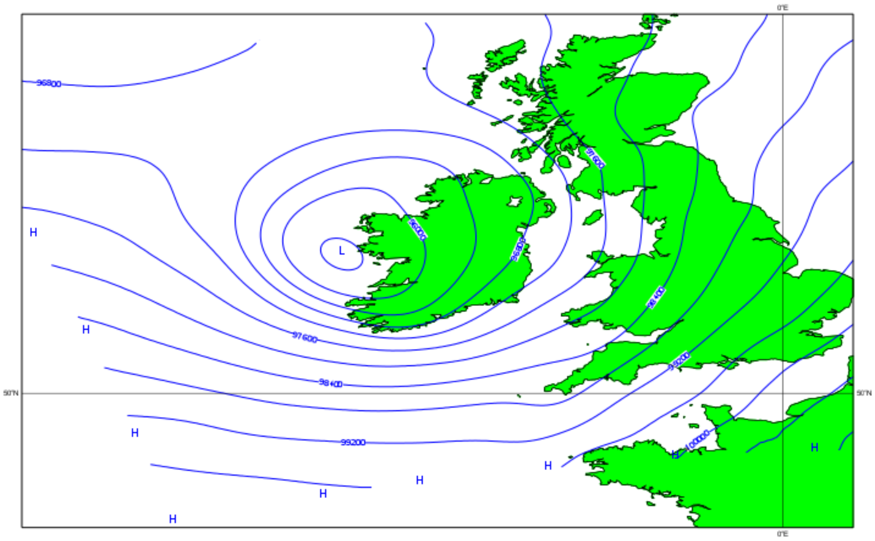


Figure 8 (b)

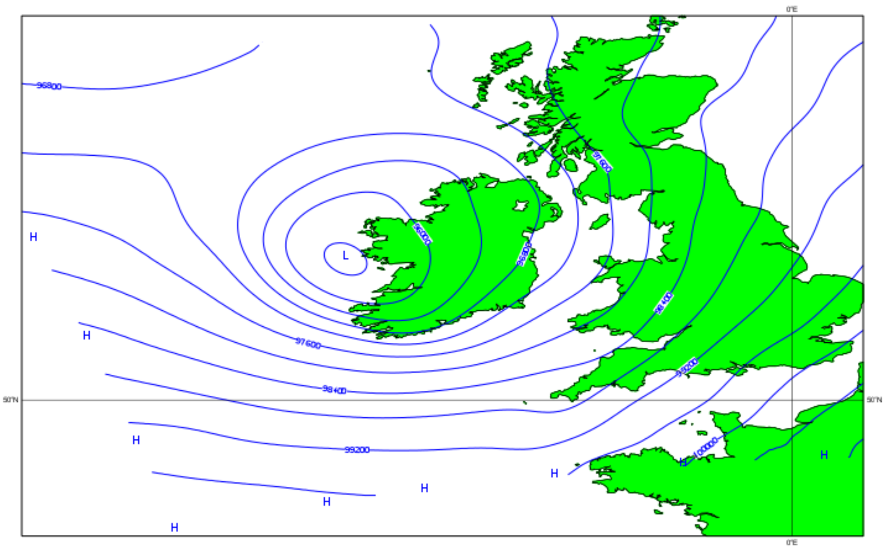


Figure 8 (a): HARMONIE MSLP 24 hour forecast for 12:00 UTC 12 February and **(b):** the corresponding observed /analysis of MSLP.

Figure 9 (a)

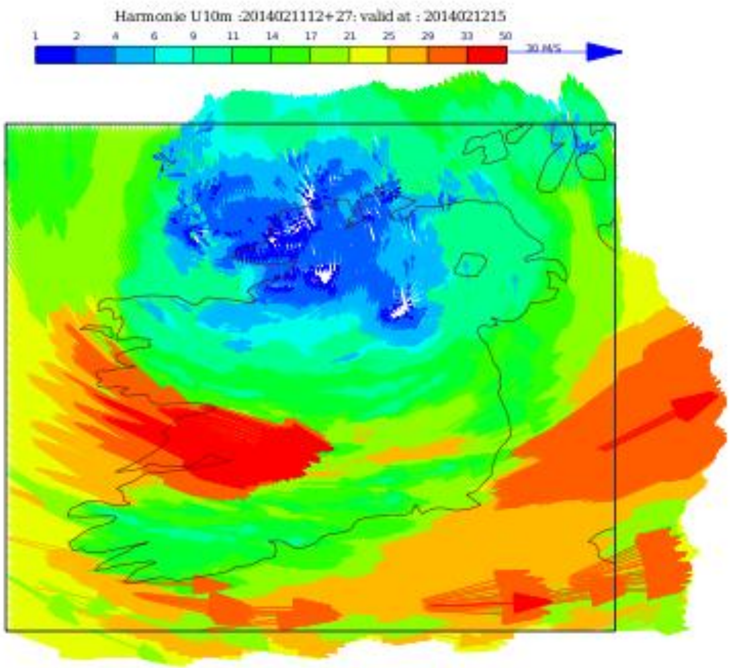


Figure 9 (b)

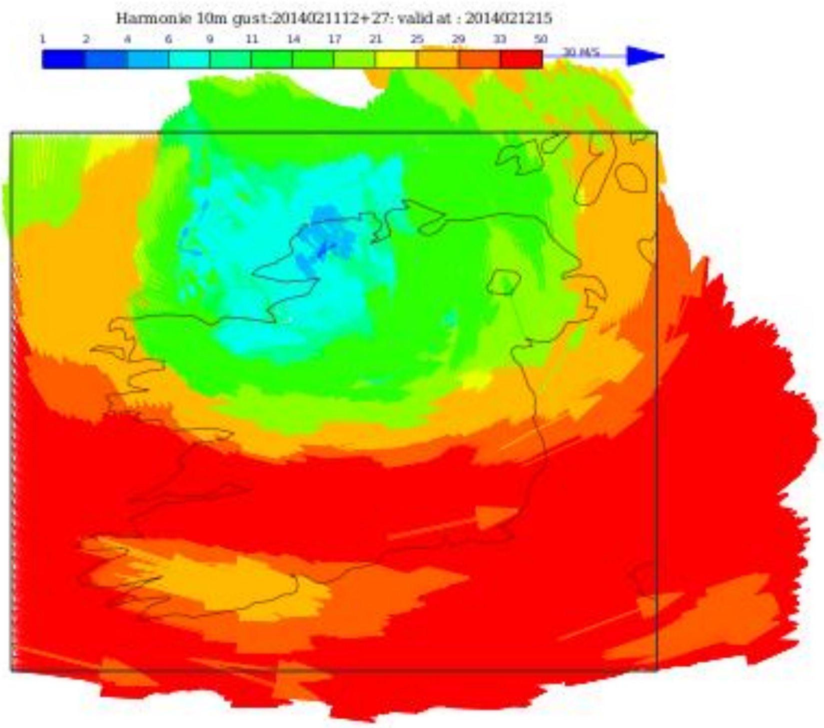


Figure 9(a) HARMONIE 27-hour forecasts of 10-minute surface winds and **(b)** HARMONIE 27-hour forecasts of 10-minute surface winds gusts in m/s for 15:00 UTC on 12 February 2015.

5.2 Operational warnings issued by Met Éireann

The general warnings issued on 11 and 12 February are listed in Table 2, together with comments based on the recorded weather.

Other wind warnings issued for specific customers set the "tone" for the expected weather but did not match the severity e.g. a wind warning for the ESB issued at 14:00 UTC on 11 February mentioned winds of 60-90 km/h gusting 90-130 km/h for the period 09:00 – 22:00 UTC on 12 February.

The "red" alert issued at 11:00 UTC on 11 February gave an excellent indication of the expected storm on 12 February although, geographically, it was too restricted. Subsequent warnings reduced the severity until the storm began to impact on western and southern regions in the late morning on 12 February; the warnings were upgraded and to an extent followed the weather as it evolved during the afternoon and early evening.

Date	Time Issued (UTC)	Area	Wind and Warning level	Comment
11 Feb	07:00	Wexford, Galway, Clare, Cork, Kerry, Limerick and Waterford (coast) 09:00 – 18:00 on 12th	70-80 km/h, gusts to 130 km/h. Level: **Orange**	"Stormy" mentioned; coasts only. Severity underestimated.
	11:00	Wexford, Galway, Clare, Cork, Kerry, Limerick and Waterford 09:00 – 18:00 on 12th	70-80 km/h, gusts to 130 km/h. Level: **Orange**	"Stormy" mentioned; coasts only. Severity underestimated.
	11:00	Cork and Kerry 06:00 – 15:00 on 12th	60-70 km/h, gust 120 km/h → 75-85 km/h, gusts to 130 -160 km/h. Level: **Red**	Extended to land areas; very good forecast of wind strengths but geographical extent underestimated.
12 Feb	00:00	Waterford, Wexford 09:00 – 17:00 Clare, Limerick, Galway, Mayo 12:00 – 17:00	60-70 km/h, gust 110 km/h → 60- 70 km/h, gusts to 120 -130 km/h. 60-70 km/h, gust 100-130 km/h Level: **Orange**	Previous warning scaled back. Still a reasonable forecast but underestimated severity.
	00:00	Inland areas (including Tipperary, Laois, Offaly, Carlow, Kilkenny, Kildare, Dublin and Wicklow) 14:00 – 23:00	50-65 km/h, gust 100-110 km/h Level: **Yellow**	Too weak
	00:00	14:00 – 23:00 Inland areas - extended (including	50-65 km/h, gust 100-110 km/h Level: **Yellow**	Too weak

		Cavan, Monaghan, Donegal, Dublin, Carlow, Kildare, Kilkenny, Laois, Longford, Louth, Wicklow, … Sligo and Tipperary)		
	00:00	14:00 – 23:00 Upgraded warning for Dublin, Kildare, Louth, Wicklow and Meath	50-65 km/h, gust 100-130 km/h Level: **Orange**	Too weak
	00:00	12:00 – 17:00 Connacht, Dublin, Carlow, Kildare, Kilkenny, Laois, Longford, Louth, Wicklow, Offaly, Westmeath and Meath	60-70 km/h, gust to 130 km/h Level: **Orange**	Too weak
	14:00	Munster and Wexford 14:00 – 18:00	80-90 km/h, gust 130-170 km/h Level: **Red**	Very good (mention of violent winds); storm already in progress
	14:00	Cavan, Monaghan and Donegal 14:00 – 23:00	55-65 km/h, gust 100-110 km/h Level: **Yellow**	Too weak
	15:00	Munster, Connaught and Leinster 15:00 – 19:00	80-100 km/h, gust 130-170 km/h Level: **Red**	Very good; storm already in progress
	15:00	Cavan, Monaghan and Donegal 15:00 – 20:00	60-80 km/h, gust to 130 km/h Level: **Orange**	Good; storm already in progress
	19:00	Munster, Connacht and Leinster 19:00 – 22:00	45-60 km/h, gust 80-100 km/h Level: **Yellow**	Good; storm weakening.
	21:00	Countrywide To 10:00 on 13th	45-55 km/h, gust 80-109 km/h Level: **Yellow**	Good; storm weakening.

Table 2: Weather warnings issued 11-12 February 2015

6 Conclusions and summary

The climate records suggest that the Darwin storm was broadly a 1 in 20 year event although locally, the categorisation as 'worst in living memory' may be appropriate in the worst affected regions. The most severe winds were experienced in Galway, Clare, Limerick, Kerry and Cork and in coastal areas in the south and northwest. The strong winds were also notable in regions around the M7 motorway corridor from Limerick to Dublin.

NWP forecasts provided a good indication of a storm tracking over Ireland from approximately 3 days in advance and the full severity of the system was captured by the HIRLAM ALADIN model 24 hours before it struck the country.

A “red” alert issued at 11:00 UTC on 11 February gave an excellent indication of the expected storm although subsequent warnings reduced the severity until the storm began to impact on western and southern regions in the late morning on the 12th, and were then upgraded. The lack of continuity in the warnings reflects the assessment process used by the operational forecasters who receive NWP guidance from different models and also have the latest observations to consult. It is known, for example, that the HARMONIE NWP model produces wind forecasts that are slightly biased; this may have prompted a more conservative approach by the forecasters.

Acknowledgements

The global operational NWP datasets were provided by ECMWF. Datasets from the operational HARMONIE forecast model were provided by Eoin Whelan, who also re-ran some of the forecasts to provide additional data. The satellite picture was provided by Emily Gleeson. Evelyn Murphy provided the weather warning data and Bing Li supplied the wind observations. Helpful comments on the text from Mairéad Treanor and Emily Gleeson are also acknowledged.

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