

Review of thunderstorm activity in June 2023

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Introduction

During the period from 12th to 25th June 2023, Ireland experienced extensive convective activity. Thunderstorms occurred on 12 out of the 14 days during this time. This was an unusual length of time for thunderstorm activity over Ireland. On average, monthly rainfall amounts for June in Ireland are between 60 and 95mm (based on Long Term Average from 1981 – 2010). During this two-week period, there were eight consecutive days of thunderstorms and the showers which contributed to higher than average rainfall in some parts of the country, with up to 124.5mm recorded at Valentia, Co. Kerry (131% of its LTA).

Several status yellow and orange warnings were issued during the period. Aviation warnings were also issued when thunderstorms were expected at an airport, and SIGMETs (Significant meteorological information) for the Irish FIR (Flight Information Region) were issued for frequent and embedded thunderstorms on some of the more active days during the period.

The tables below detail the criteria for issuing rainfall and thunderstorms warnings by Met Éireann, the Irish National Meteorological Service.

Yellow	Not unusual weather. Localised danger.
Orange	Infrequent. Dangerous / disruptive.
Red	Rare. Extremely dangerous / destructive.

Table 1: Warning Thresholds

YELLOW LEVEL	ORANGE LEVEL	RED LEVEL
Rainfall	Rainfall	Rainfall
20-30mm in 6 hours	30-50mm in 6 hours	Exceeding 50mm in 6 hours
30-40mm in 12 hours	40-60mm in 12 hours	Exceeding 60mm in 12 hours
30-50mm in 24 hours	50-80mm in 24 hours	Exceeding 80mm in 24 hours

Table 2: Rainfall Warning Thresholds

YELLOW LEVEL	ORANGE LEVEL	RED LEVEL
Thunderstorm	Thunderstorm	Thunderstorm
Thunderstorms/lightning activity/ heavy rainfall/hail	Widespread Thunderstorms/severe lightning/activity/ heavy rainfall/large damaging hail	Exceptional

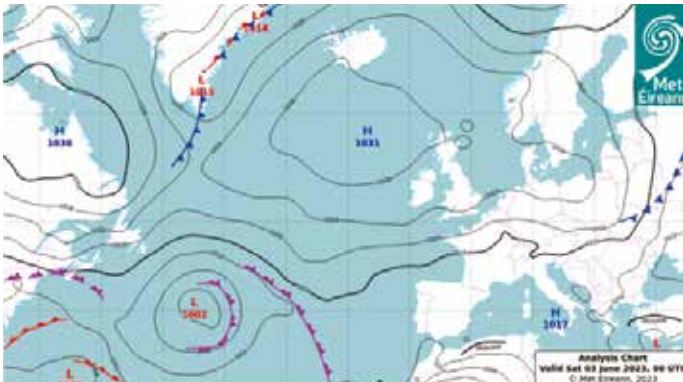
Table 3: Thunderstorm Warning Thresholds

Forecasting exact locations of thunderstorms and estimating the intensity of the rainfall associated with them can be a difficult task. At the time of the event, Met Éireann used a semi continuous or lagged ensemble prediction system (EPS) known as IREPS (Irish Regional Ensemble Prediction System); a 1+15 member lagged EPS based on the HARMONIE-AROME model, providing 54-hour ensemble forecasts eight times per day. All members of IREPS used the latest IFS-HRES forecasts in boundary data formulation and updated every 3-hours. During this period, the Shannon Airport RADAR was undergoing replacement. Forecasters relied on data from a temporary X-band RADAR located in the south of the country in Co. Cork and the C-band single-polarisation RADAR at Dublin Airport with regions in the northwest not adequately covered. Forecasters applied an ingredients-based methodology for forecasting thunderstorms. Throughout the period, moisture and instability were frequently present while lift was supplied by a variety of forcings. Some days, surface heating, orography and convergence provided lift; other days this lift was provided by dynamic upper air forcings. Throughout the two-week spell, Ireland lay in a warm, moist, and unstable airmass which had advected northwards from the Bay of Biscay and was characterised by high wet bulb potential temperatures at 850hPa of between 14 and 16°C. Surface dewpoints were greater than 14°C on some of the days with daytime surface air temperatures generally ranging from 20 to 28°C.

This article concentrates on the experience of operational meteorologists forecasting thunderstorms for one day during this period (Saturday June 17th), as an illustrative case study of the experience of forecasters during this spell of exceptional convective activity. It will examine what the models were indicating, what occurred and the impacts that were reported

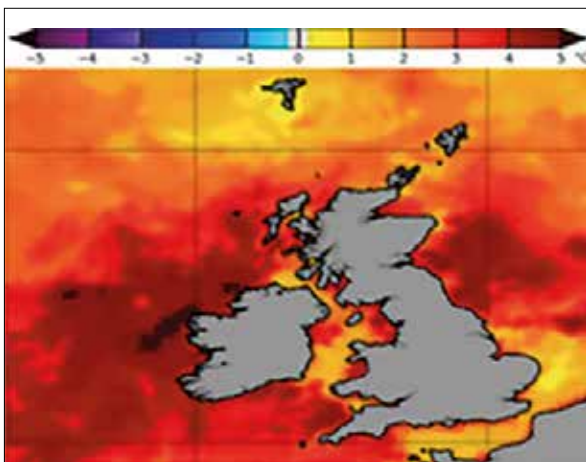
Background

There had been an extended settled period across Ireland in the run-up to the event. High pressure



▲ Figure 1: Surface pressure analysis chart 0000UTC June 03rd

rage off Irish coasts. During June, a category 4 marine heatwave had developed in parts of the north Atlantic off the coast of Ireland (Figure 2) [6]. Some areas near the west and northwest coasts of Ireland reached a category 5 marine heatwave. A specific attribution study would be required to understand the exact impact these factors had on this event, but it is likely that the high SSTs and SMDs exacerbated the thunderstorms and associated impacts during mid-June. The breakdown of high pressure occurred during the second week of June, allowing a transition to a more unstable synoptic setup with thunderstorms first developing on the 12th of June.



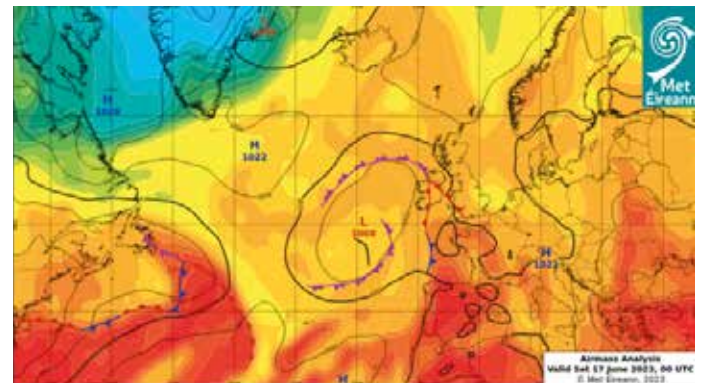
▲ Figure 2: Daily 5 km SST Anomalies June 20, 2023 (NOAA Coral Reef Watch)

Case study: Saturday June 17

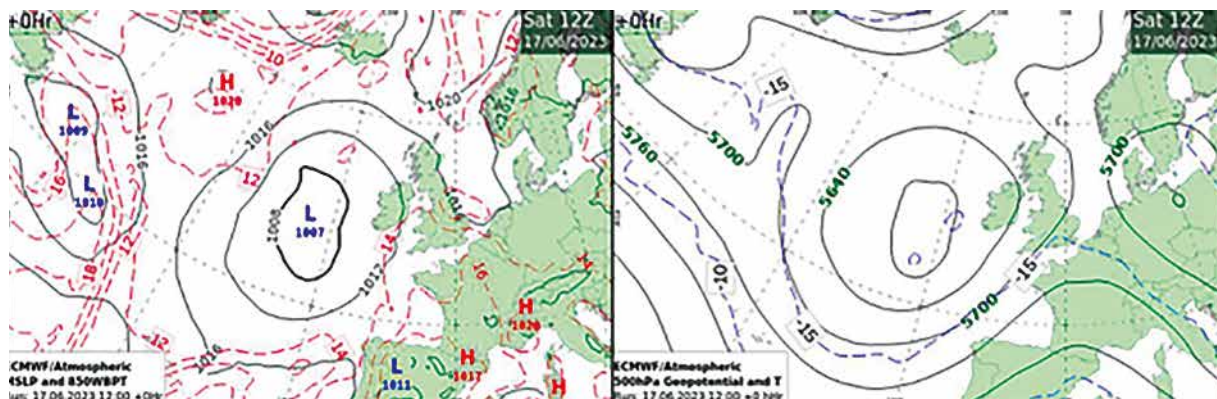
Meteorological Situation

A low pressure system was centred to the southwest of Ireland by the early hours of Saturday, June 17th 2023, establishing a southerly airflow over the country with frontal troughs embedded in the flow (Figure 3). An occlusion associated with this depression tracked northwards across the country overnight Friday and early on Saturday morning. This front generated

was blocked over the country for approximately three weeks at the end of May and the beginning of June (Figure 1). This resulted in small amounts of rainfall in the weeks preceding June's thunderstorms and high soil moisture deficits (SMDs) of between 50mm and 75mm, leading to near drought conditions for parts of the country. Sea surface temperatures (SSTs) had also risen during the run-up to this spell of thunderstorm activity, increasing by up to 4 degrees above ave-



▲ Figure 3: Airmass analysis chart 0000UTC June 17th

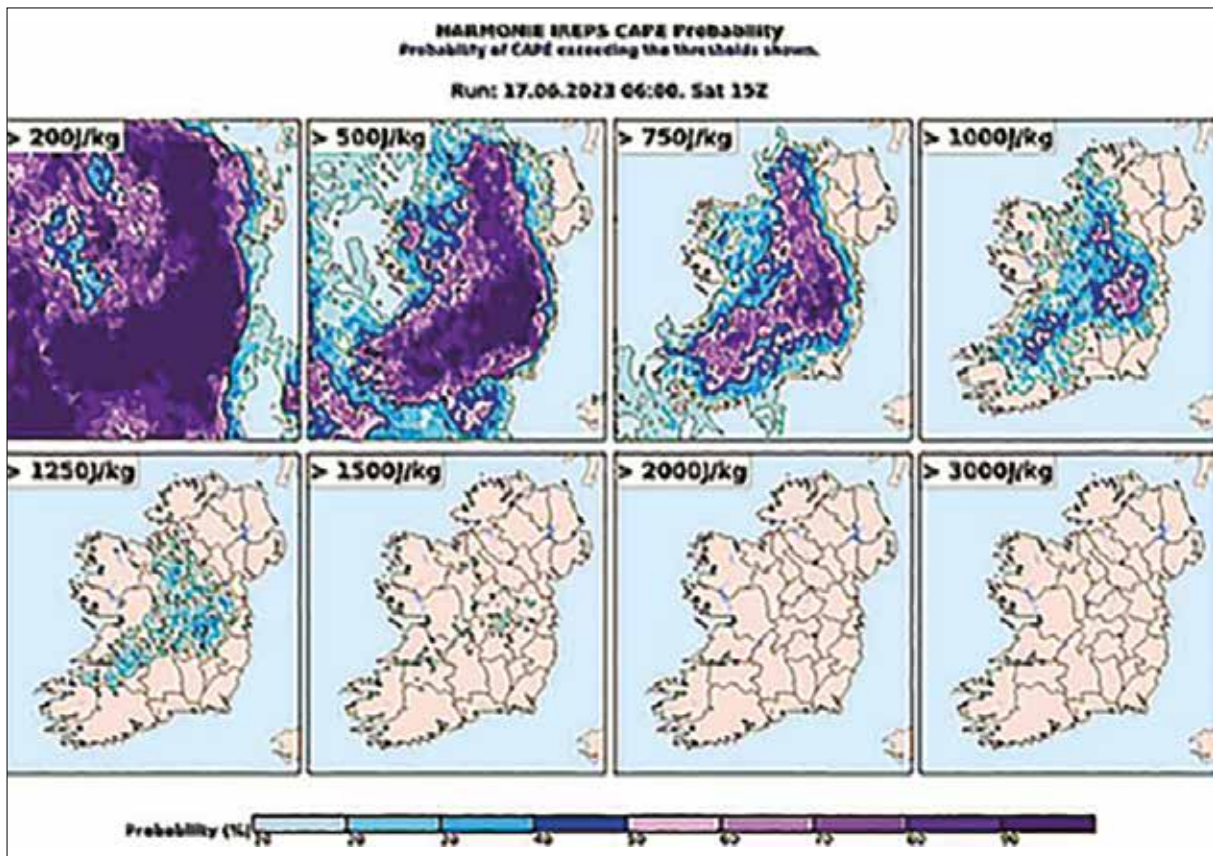


▲ Figure 4: ECMWF MSLP and 850hPa BPT (left) and 500hPa geopotential and temperature (right), 1200UTC June 17th

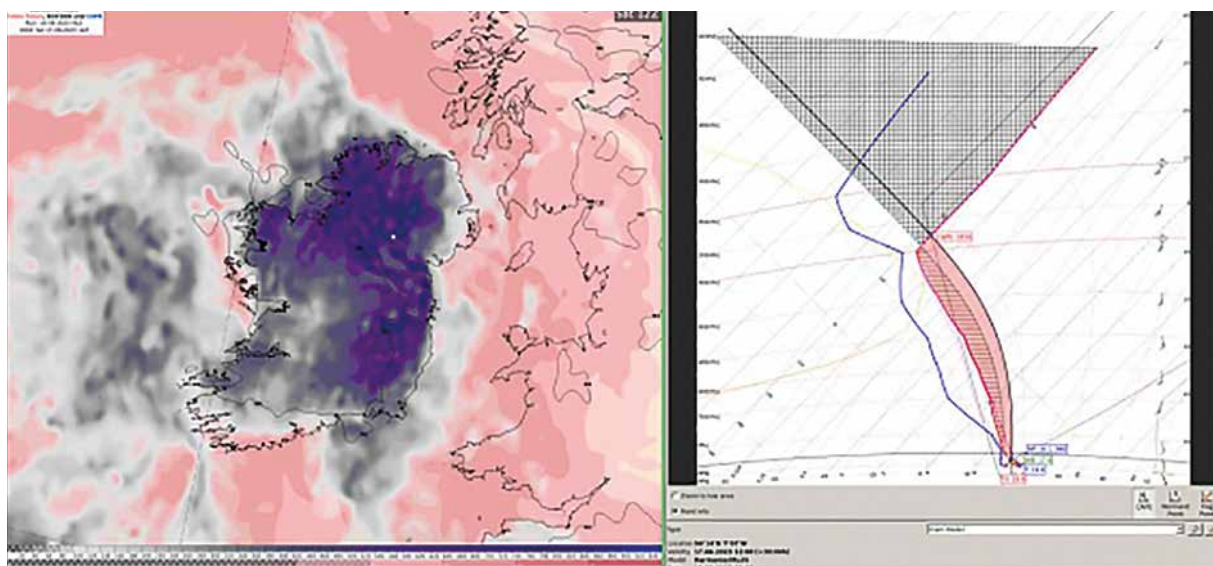
thunderstorms over the southern half of the country, which cleared to the southeast around 0800UTC. Ireland remained in a mild and moist airmass thereafter, with 850hPa wet bulb potential temperatures of 12 to 14°C. As can be seen in Figure 4, a defined upper air trough and cold pool had also developed across Ireland, providing further forcing for the thunderstorms to come.

Model Guidance

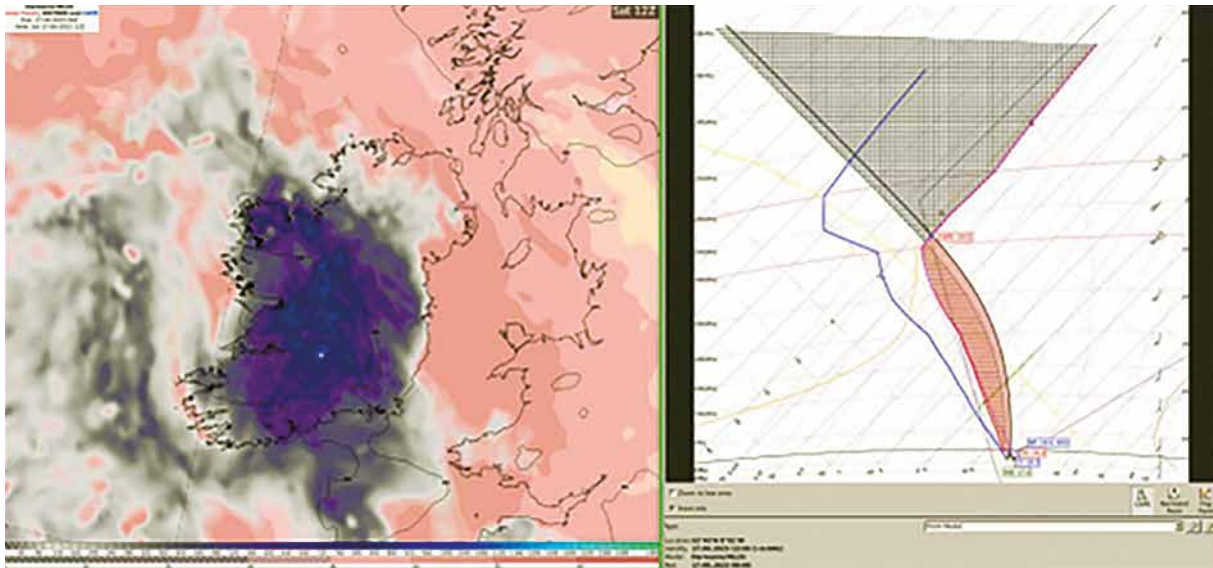
When forecasting thunderstorms, several indices are considered. This article focusses on Convective Available Potential Energy (CAPE), which is an indicator of the energy available for thunderstorm development. Other indices considered were the Boyden index, which is a measure of atmospheric instability below 700hPa, and the Total To-



▲ Figure 5: IREPS MUCAPE probability at 1500UTC June 17th (0600UTC run on June 17th)



▲ Figure 6: IREPS control member instability indices (Total totals, Boyden & CAPE) for 1200UTC June 17th (0600UTC run June 16th)



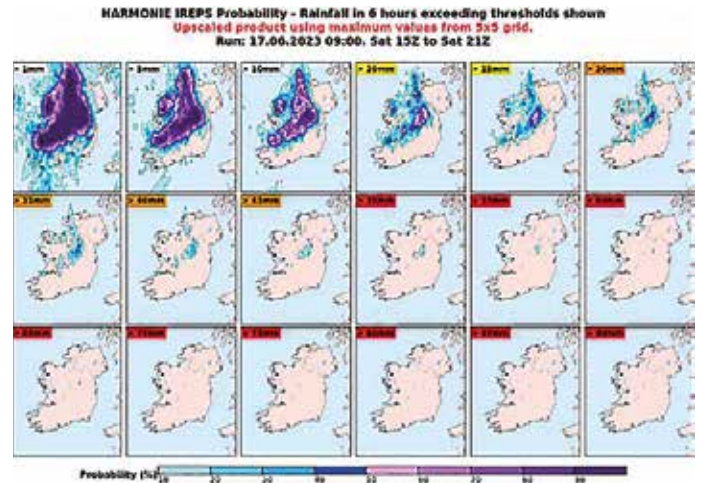
▲ Figure 7: IREPS control members instability indices (Total totals, Boyden & CAPE) for 1200UTC June 17th (0600UTC run June 17th)

tals index, a combination of the Vertical Totals and Cross Totals indices.

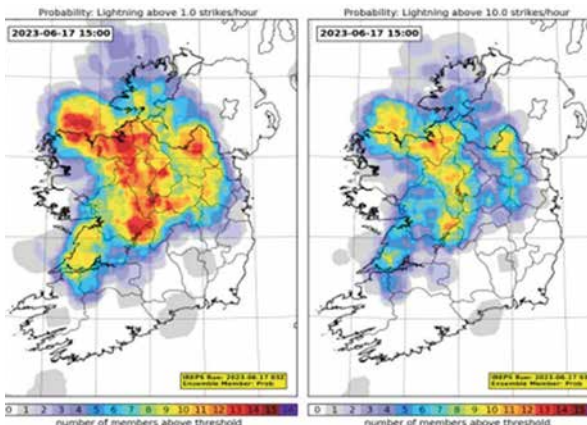
Instability was clearly indicated by IREPS in the run-up to the day. MUCAPE (most unstable CAPE) values were forecast to be near 1000J/kg in places (see Figure 5 below), with SBCAPE (surface-based CAPE) forecast to be almost 2000J/kg.

There were inconsistencies in the region predicted to have the greatest instability from run to run. The area of highest instability was forecast to be in the east and north of the country in model runs on the preceding day, June 16th (Figure 6). This region transferred further westwards and southwards in model runs on June 17th (Figure 7). The charts on the left in Figures 6 and 7 show IREPS forecast instability indices such as the Boyden index, Total Totals index and Mixed Layer CAPE. The indices are a measure of thunderstorm potential. The

chart on the right in Figures 6 and 7 is a modelled tephigram generated in the approximate centre of the highest CAPE values. All indices were indicating a strong probability of thunderstorm development.



▲ Figure 9: IREPS rainfall probability of 6 hourly totals exceeding threshold.

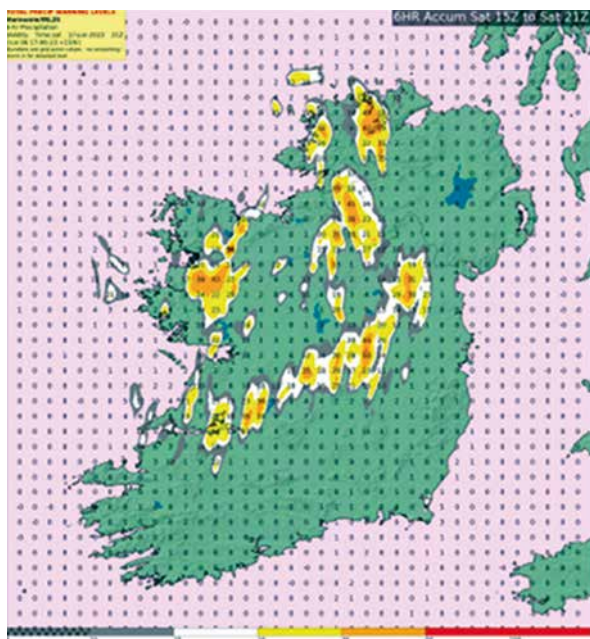


▲ Figure 8: IREPS Lightning probability of >1 strike per hour and >10 strikes per hour on 1500UTC June 17th (0300UTC 17th June)

While there was high confidence in the presence of instability on June 17th and in the subsequent development of thunderstorms, there was uncertainty in the location of the most severe storms, as further illustrated by the IREPS lightning probability maps in Figure 8.

Upscaled rainfall is used in higher resolution models to account for rainfall in neighbouring grid points and can be very useful in convective situations by giving a more realistic representation of such highly localised precipitation events. Examining the upscaled rainfall product from IREPS for

June 17th a high probability of 6-hour accumulations exceeding 25mm was indicated in parts of the west and midlands (see Figures 9 and 10). There was also up to a 30% chance of 6-hour rainfall exceeding 30mm in the same regions. Uncertainty in the exact location of the thunderstorms made it more difficult to pinpoint areas at highest risk of flooding and any other impacts due to this rainfall. IREPS forecast runs on June 17th indicated that thunderstorms were most likely to occur in these western and midland counties. However, as mentioned previously, IREPS runs from the previous day showed a higher probability of thunderstorms further to the south and east of the country. This variation in model forecasts exacerbated the uncertainty forecasters faced when considering warnings for this event.



▲ Figure 10: IREPS control 6-hourly rainfall accumulations and warning colours, 1500UTC – 2100UTC June 17th (0600UTC run 17th June)

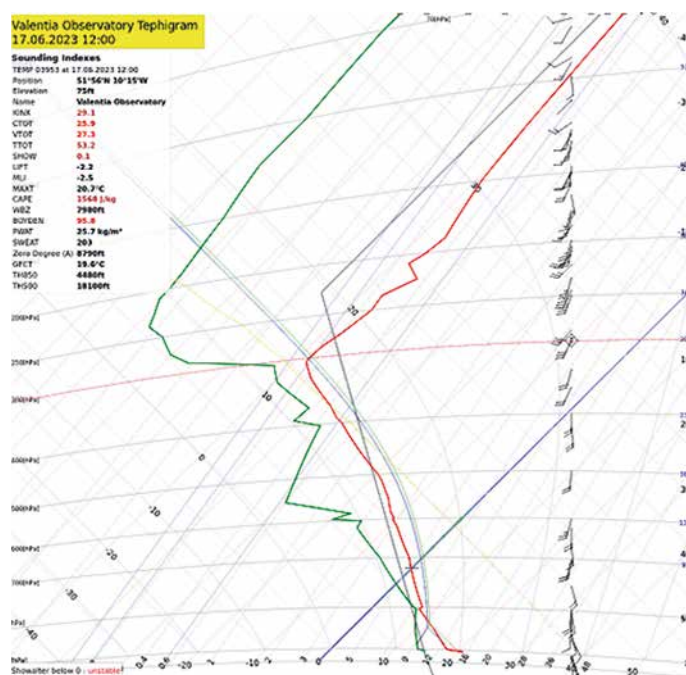
Warnings Issued

A yellow level thunderstorm warning was issued in the morning of June 17th for counties in the west, northwest and midlands. Counties in the southwest were added to the yellow level warning in the early afternoon as thunderstorms had started to develop over the mountains in Co. Cork and were expected to track northwards into Co. Kerry. As the day progressed, thunderstorm activity became more widespread and intense in some locations and the warnings were updated accordingly.

Observations

The 1200UTC observed tephigram taken at Valentia, Co. Kerry in the southwest of Ireland (Figure 11) showed a very unstable set up with high SBCAPE of 1568J/kg and other instability indices also indicating probable thunderstorm activity. The boundary layer was adiabatic with surface temperatures of nearly 21°C and surface dewpoints of 15 °C. Plenty of moisture was available in the lower layers with a dry layer visible in the mid-levels enhancing the unstable set up. Parcel top temperatures were very cold at about -40°C. Moderate windshear of approximately 15 to 20 knots was not deemed to be conducive to squall lines or supercells but was considered sufficient to produce multicell clusters.

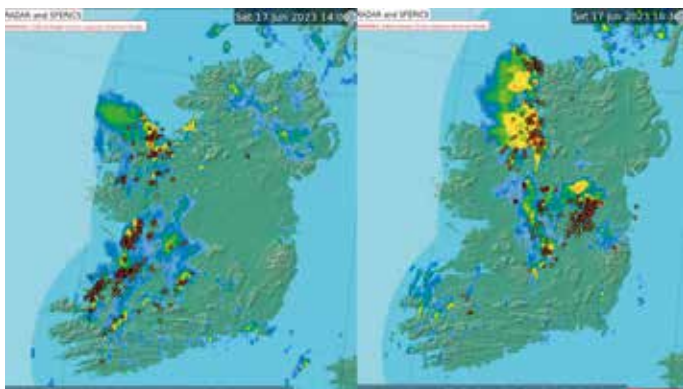
Intense thunderstorms were more widespread and frequent than initially indicated by the models. The core of the thunderstorm activity was in the west and midlands, and was captured well by IREPS in the hours leading up to the event, however, many thunderstorms developed further east and south than IREPS forecast on the day of the event (Figure 12). Most notable was the development of thunderstorms in Co. Cork and Co. Kerry, where IREPS completely missed the orographic lift that sparked the thunderstorms in this area (Figure 13). A possible reason for this was that IREPS forecast a southwest airflow over the region, whereas a southeast airflow was observed, allowing for the orographic lift to occur (Figure 14). Another



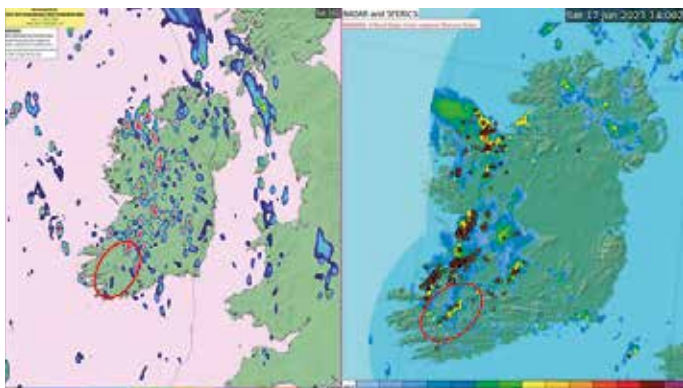
▲ Figure 11: 1200UTC Valentia observatory Tephigram June 17th

consideration is that the model does not accurately represent the height of the mountains in the southwest of Ireland.

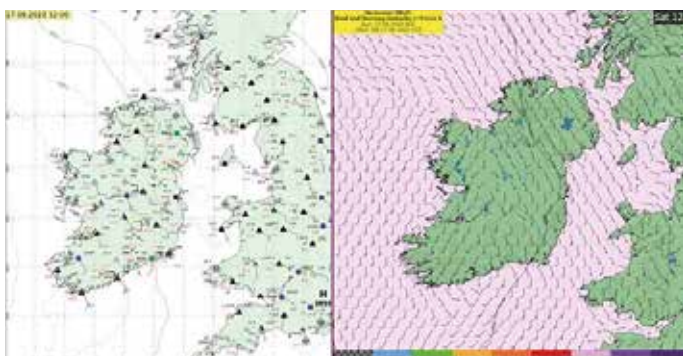
Rainfall in many stations exceeded 10mm in one hour, with a number of stations reaching or exceeding 15mm in one hour (Figures 15 and 16). These stations were mostly located in the south and west.



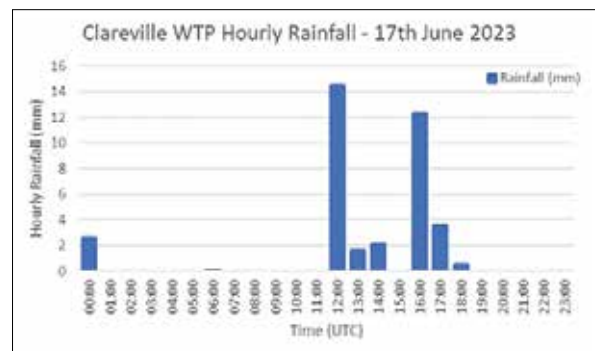
▲ Figure 12: RADAR and sferics for 1400UTC (left) and 1830UTC (right) June 17th



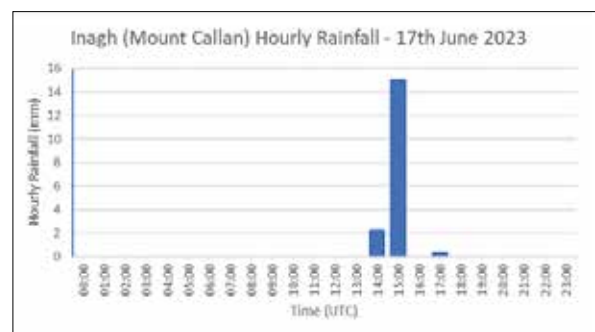
▲ Figure 13: IREPS control instant rainfall forecast (left) and RADAR (right) Saturday June 17th 1400UTC



▲ Figure 14: Synoptic observations (left) and IREPS control 10m mean wind speed (right) on Saturday June 17th 1200UTC



▲ Figure 15: Hourly rainfall at Clareville WTP, Co. Limerick, June 17th 2023



▲ Figure 8: IREPS Lightning probability of >1 strike per hour and >10 strikes per hour on 1500UTC June 17th (0300UTC 17th June)

Impacts

Heavy rainfall caused flooding in Tralee, Co. Kerry in the southwest of the country [2], and there were reports that two lifeguards were injured by a lightning strike on a beach in Co. Kerry [5] (Figure 17). This county was not initially included in any warnings. Frequent lightning strikes caused power outages in many areas [1] and there were also reports of a house fire caused by lightning (Figure 18) [4]. Additionally, there were social media reports of a funnel cloud in the northeast of the country.

Discussion and conclusion

The prolonged nature of the event was unusual for Ireland but not unique as another similar event occurred in 2013, with 9 days of consecutive thunderstorm activity in July 2013. This event was also preceded by a drought and a high SST anomaly of 4 to 5 degrees (Figure 19) [6]. The marine heatwave may have exacerbated both events. Thus, it is possible that Ireland will experience thunderstorms of this severity and frequency more often with a changing climate.



▲ Figure 17: Two lifeguards injured in lightning strike on Kerry beach with image showing flooding in Tralee Co. Kerry (Kelleher, Evans and Brouder, *SundayWorld.com*, 2023)

Overall, the NWP models performed well, indicating the unstable airmass and probability of thunderstorms well in advance of the event. The upper air forcings were well highlighted and the forecast locations of the thunderstorms improved as the week progressed. However, small scale forcings at the surface, such as orographic factors, were not captured at times by IREPS, as highlighted in this case study. The impactful weather Ireland experienced during this time in June 2023 was not always captured by the observation network. Social media was useful through the two-week period as it enabled the recording of localised impacts from the thunderstorms. There were reports on social media on various days of large hail, flooding, and funnel clouds, including video footage of a small tornado taken on one of the more active days during the event.

While thunderstorms were expected throughout the period, the impacts were more severe than originally anticipated. The uncommon nature of this event, along with the uncertainty in model guidance presented challenges to operational forecasters at the time. This also led to short lead times for some warnings, which impacted the preparations that could be made by the public and stakeholders. However, overall model guidance on the areas most impacted was sufficient to allow adequate warning.



▲ Figure 18: House catches fire after being struck by lightning in Co. Clare (Flynn, *breakingnews.ie*, 2023)

References

- [1] Cox, J., ESB crews responding to lightning-related power outages (2023, June 17), *breakingnews.ie*, Retrieved from <https://www.breakingnews.ie/ireland/esb-crews-responding-to-lightning-related-power-outages-1490705.html>
- [2] Cox, J. Tralee hit with flash flooding and torrential rain (2023, June 17), *breakingnews.ie*, Retrieved from <https://www.breakingnews.ie/ireland/tralee-hit-with-flash-flooding-and-torrential-rain-1490675.html>
- [4] Flynn, P., House catches fire after being struck by lightning in Clare (2023, June 17), *breakingnews.ie*, Retrieved from <https://www.breakingnews.ie/ireland/house-catches-fire-after-being-struck-by-lightning-in-clare-1490680.html>
- [5] Kelleher, S., Evans, T., and Brouder, S., Two lifeguards injured in lightning strike on Kerry beach, (2023, June 17), *SundayWorld.com*, Retrieved from <https://www.sundayworld.com/news/irish-news/two-lifeguards-injured-in-lightning-strike-on-kerry-beach/a649084768.html>
- [6] NOAA Coral Reef Watch (2024), updated daily. *NOAA Coral Reef Watch Version 3.1 Daily Global 5km Satellite Coral Bleaching Degree Heating Week Product*, Jul. 21, 2023; Jun. 2, 2023. College Park, Maryland, USA: NOAA Coral Reef Watch. Data set accessed 2023-08-04 at <https://coralreefwatch.noaa.gov/product/5km/index.php>