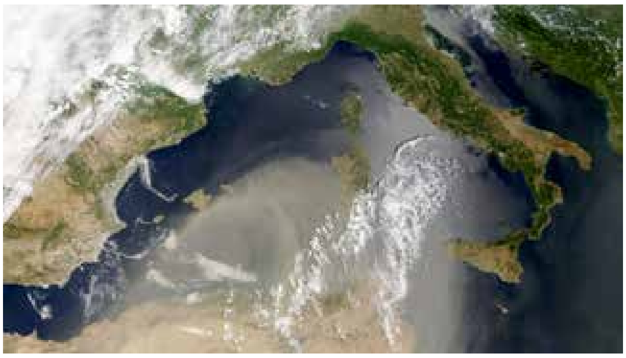
The European Forecaster

Newsletter of the WGCEF N° 29
September 2024

Contents



Crédit Meteo France

Cover:
Desert Dust Plumes : more frequent with Climate Change ?

Editors: Nicholas Roe - Met office
Bruno Gillet-Chaulet - Météo-France

Published by Météo-France
COM/CGN/PPN
Trappes, Jean-Louis Soubiès

Introduction

Dear Readers and Colleagues

It's a great delight and honour to introduce the 29th edition of our newsletter 'The European Forecaster'. The success of a publication on a regular yearly basis is only possible because of the excellent work of many colleagues. Therefore we would like to say thank you to Mr. Bruno Gillet-Chaulet and his colleagues at Meteo France for publishing our first all electronic newsletter, which you will also find on our WGCEF website www.euroforecaster.org. Many thanks go to Mr. Nicholas Roe and his colleagues at the Met Office for reviewing the incoming articles. We kindly address our warmest gratitude to all the authors for writing articles about new ideas, recent developments and interesting case studies in the field of weather forecasting.

Severe weather hazards have strong impact on humans, infrastructure, vegetation and ground. Therefore precise severe weather warnings in time, location and intensity can minimize or even prevent damages, save lives and reduce financial loss. This is one major -even the most important- mission of weather forecasters. With their expertise, knowledge and experience forecasters are able to provide excellent advice to the public, stakeholders and all kind of weather-depending users by issuing impact-oriented weather and warning information. Various requirements are necessary to be able to do this job accurately: regular training, good IT-infrastructure, intelligent tools, sufficient meteorological and non-meteorological data sources, scientific exchange and cooperation.

To keep or even improve the high quality of forecasts cooperation and scientific exchange between the different NMSs is essential, which is one important goal of our working group WGCEF.

In this newsletter we have tried to make an interesting compilation of articles dealing with the above mentioned critical aspects of the forecaster's job. As always, our warning systems are under continuous construction and new developments are presented.

We hope that you will find this newsletter interesting, enjoyable and informative and we wish you a nice reading!

Best regards,,

Jos Diepeveen (KNMI) and Thomas Vanhamel (RMIB)
Chairpersons, WGCEF

NMS news from the September 2023 meeting in Tallinn, Estonia.

AEMET (Spain – Jesus Barroso)

Provision of services: Since last year forecasters are allowed to work from home for up to 60 % of their shifts. This organisational change has had preapproved by the aeronautical supervision authority and is expected to become permanent with minor changes.

Integration of new ECMWF cycle: The new ECMWF cycle has been implemented in the internal production, initially with 18 km with a higher resolution following in late 2023. There is also a project to define new ensemble derived products.

Verification of post-processing of temperature: In spring 2023 the verification of statistical post-processing of maximum and minimum temperature was implemented daily and the scores show a much better behaviour of the post-processing respect to the direct model output (ECMWF or HARMONIE-AROME). As the post-processing is strictly statistical, it shows worse behaviour the first and second day after strong changes in the meteorological situation.

Products oriented to forest fires: Development of a viewer of the main variables for the management of forest fires (model output of temperature, humidity and wind intensity and direction), with thresholds chosen by the users in order to detect severe conditions. There is also a temporal meteogram in the forest fire coordinate available on request and precharged imagery for reporting the meteorological situation.

CHMI (Czech Republic – Marjan Sandev)

New organizational structure

From 1st of January 2023, a new Forecasting Service Division was established, separated from the Meteorology and Climatology Division. This division incorporates the Meteorological Forecasting Section, the Hydrological Forecasting Department and the Forecasting Service Development Department. The aim of this change is to focus on the expertise of forecasting offices and communication both between departments and sections, as well as towards the public and customers.

Warning System updates:

Changes of display alerts on the CHMI websites. Approved version of two maps: the first map displays information about all severe phenomena, and second map inform about observed severe phenomena, which require extraordinary attention and possibly quick response to protect property and health of the population; From 1st of May 2022 a support expert team, the Convective Group, started to work to help operational forecasters in decision-making process with severe convective storm forecasting and nowcasting. In the convective season (from May to September), forecasters from the Convective Group have shifts every day, when storms are expected. They prepare alert proposals and summary reports for media and social networks, explain forecast uncertainty, prepare case studies, and train the forecasters. The working group for new (Impact based/oriented) warning system has been working since the summer of 2022. A group consists of sub-groups with different tasks. I. group - Limits, Impact, II. group – Hydrology, III. group - CAP, Alert Editor – meteorological workstation, distribution, IV. group: Education, V. group: Communication;

ČHMÚ developed a mobile application: SMS alert for mayors – access to the application only for mayors and external employees of the regions, and also participates in distribution of alerts for state and local government organizations through many other applications operated by partners; Ambulance, Munipolis, etc.

International and national cooperation with organizations and customers:

Preparation of interdepartmental cooperation in the rental of drones for terrain/damage survey activities, the purchase and training of pilots is planned

Cooperation with an Amateur Meteorological Society, who prepare an application - browser and database for reporting severe weather phenomena from the field (similar to ESWD of ESSL). Preparation of a cooperation with the Mountain Rescue Service on sharing warnings (avalanches probably will be a part of the NMS warning system, assumes distribution to Meteoalarm)

HAMR (Hydrology – Agronomy – Meteorology - Retention) – as part of the PERUN project (Prediction, Evaluation and Research for Understanding National sensitivity and impacts of drought and climate change for Czechia) was developed. The goal of HAMR is drought status information with a resolution of the region level on surface and underground waters with a prediction for 1 week, not currently part of the warning system.

FROST – a part of TAČR grant project cooperated with Institute of Atmospheric Physics. The aim is to better predict the surface temperature and condition of the Czech motorway network (linear forecasting). The project supposes the use of new data sources, especially satellite measurements, which will be used for a cloud extrapolation;

In cooperation with the organization CzechGlobe, the FIRERISK model was innovated. FIRERISK is a forecast model for predicting the risk of occurrence and spread of fires. Based on the experience of the fire in the Czech Switzerland National Park, the model was updated. It uses the outputs of the ALADIN model (from 00 UTC). The overall risk is a combination of the Haines index, drought conditions, and the FWI Fire Danger Index itself.

Automatic creation and distribution of products at the request of customers from the energy suppliers (ČEZ, ČEPS) , transport (road – ŘSD, railway – SŽ) and public services segments (WOLT). Data, text, graphic forecasts of severe weather phenomena with a large impact - e.g. wind gusts, storms, snowfall, icing, rime.

Education and Training

Coordination of preparation, creation of online meteorological courses in MOODLE (mandatory, optional) for newcomers as well as operational forecasters. Examples of courses: Convective storms (mandatory), Road meteorology (mandatory), Integrated warning system and meteorological workstation Visual Weather – Alert Editor (mandatory), other optional courses: Basics of synoptic meteorology, Satellite and radar meteorology, numerical weather forecast etc.

Final note

Due to the recent economic crisis, CHMI was forced to reduce the number of employees by 3% (23 employees) from 1st October 2023. Unfortunately, the reduction mainly fell on forecasters from the meteorological and hydrological section (10 forecasters in total).

DMI (Denmark - Janne Rydhof Thor Hansen)

HQ is moving - Operation department on October 4th, rest of DMI will follow November 6th. New organization unit of the Operation department with focus on projects. We are now issuing warnings to the Greenlandic public. Lastly, we have started a new team of seven to become forecasters with two of them to be posted in Jutland.

DWD (Germany – Robert Hausen)

Forecasters more involved in project work and education which has led to the cancellation of zoomed in 3 hourly analysis charts over central Europe. Forecaster staffing at regional offices has become limited as it has been hard to hire suitable candidates (shift work not attractive enough anymore despite home office and dislocated work has been established in recent years for some shifts). Finally some significant rainfall during winter and spring with slow recovery of the groundwater table, but drought returned since mid of May 2023 with short interruption in July.

A new warning project called „RainBow“ has started. It will automate the warning process for some events with individualization of warning information for key customers and expert users. This will give harmonization of thresholds between general, aviation as well as maritime warnings and include consideration of impacts. It is hoped it will bring improved communication.

FMI (Finland – Juha Sihvonen)

No big changes but a focus on a goal of continuous improvement including monthly 1-page verification reports for the whole Weather and Safety Centre unit since April 2021 and Short (3 pages?) verification reports for aviation weather since Sep 19, 2023.

GeoWeb development: Together with KNMI/ Netherlands and MET Norway. Mainly used for viewing satellite and radar imagery but also some use with surface observations. Some forecasters use it for viewing model information too. KNMI is further with developing & implementing weather warning and TAF tools, not yet confirmed but probably going to adopt the TAF tool as only a backup system initially.

International projects. Training projects in various countries, often jointly financed with foreign aid funding from the Ministry for Foreign Affairs of Finland, EU, World Bank loans etc and also as commercial projects where target country buys training with no outside funding. Currently projects in Central Asia (Tajikistan, Uzbekistan, Kyrgyzstan), eastern Africa (Rwanda, Tanzania, Kenya, Ethiopia) and Nepal.

ILM (Estonia - Taimi Paljak)

Three new forecasters started work in the spring and general forecasters are working from home for about 65% of their hours. The HQ building is quite old so work has started on renovation in forecasters rooms, requiring a move to the temporary place. There is also a plan for a new building near the sea to be called Environment House.

A very dry spring in April and May and again at the beginning of Summer followed by rain at times in July which helped to mitigated a catastrophic situation for agriculture. September brought very heavy rain, that was forecasted by MetCoop and also ECMWF, Extreme forecast Index was with high values.

Two VAISALA radars with IRIS software scanning every 5 minutes are working quite fluently, perhaps thanks our radar specialists. They have developed nowcasting product for 2 hours ahead based on radar observation (the main parameter is wind vector). We have a project for renewing the forest fire charts and other production. Our warning system needs more personal approach to the clients and after active discussions with our IT company we have decided to start with development project for warnings. ILM is participating in modelling development in group MetCoop. Our mobile application ILM+ (weather +) is now quite widely used although it needed many corrections at first, there is still a issue with warnings.

IMGW (Poland - Szymon Ogórek)

Further steps of the reorganisation: Improvement of measurement network, further automatization of SYNOP stations, working on new products (nowcasting for example), new layout of website.

Change in operational structure: Currecnt structure is 6 regional forecasters, 1 forecaster responsible for warnings (extended team) in summer (mid May until mid September) for 8 hours 12-20, 1 forecaster responsible for Poland and coordination, 1 media forecaster (8 hours in Warsaw) and 3 short comercial shifts (4-6 hours). From 2024 there will be 4 regional forecasters, 1 forecaster responsible for warnings (extended team), 1 forecaster responsible for Poland and coordination, 1 media forecaster (8 hours in Warsaw) and 4 commercial shifts (8 hours).

The trend is for a shrinking team (recently few people went on retirement) so few will do more with no option for replacing missing workers

Quite calm storm season, warm August and September

IMS (Israel - Shai Katz)

- Establishing the Israeli Radars Network in collaboration with the Airforce, Israeli Government Water and Sewage Authority and Cyprus, maybe the Jordanian Radar will also be added.

- Strengthening the new Floods forecasting centre.

- Now a High-resolution fire danger model and a new wildfire model.

- A lot of new features for the website: models, new marine and aviation pages, climate changes, portal for the National Fire and rescue authority and a new page especially for the municipal authorities.

- New HPC with 1344 processors and 112 TFlops. 20 million NIS (€ 5 million) are allocated for this project by the government. Adoption of the German model – will be used by all the Israeli meteorological community.

- Storm naming project - cooperation with Greece and Cyprus.

- Cooperation with the Jordanian and Palestinian meteorological services under European auspices, including flash floods courses and warnings for the various emergency authorities.

- South-East Europe Meteorological International Training Workshop – SEEMET.

- Collaboration effort between the Israeli government, academy and IMS to rise a National Climate Calculation Centre.

IPMA (Portugal - Paula Leitao)

In 2023:

One new forecaster at the Aeronautical Weather Centre - now operational under supervision, soon to be certified. 3 new forecasters at the General Forecast Centre - now fully operational.

Ongoing project of collaboration with local authorities for improving the weather station network is allowing for an increase in the quantity and quality of surface data. New HPC (high performance computer) is pre-operational now. Several operational problems with VAISALA / Iris Focus radar software update. Updating radar network on the Portuguese Mainland: 2 single-polarization radars will be completely replaced by dual-polarization doppler radars.

Looking forward to 2024:

The implementation of 2 new dual-polarization doppler radar systems in São Miguel island and in Flores island of the Azores archipelago. Implementation of a lightning network in Azores.

Hiring new technicians including: 15 meteorological observers for aeronautic proposes, 15 weather meteorologists and 3 climatologists. This is a longstanding project to fill in existing gaps in development and forecasting teams as well as filling gaps left by soon retiring forecasters.

Thresholds established at the beginning of the METEOALARM project, based on impact and/ or climatology, are now under study:

- Snow – impact-based thresholds recently reviewed

- Wind – impact-based threshold

- High/ Low Temperature – climatology-based threshold – under study change into impact-based

- Costal Event – impact-based thresholds – under study to better include wave energy and damage

- Fog - seriously difficult to assess impacts and set thresholds

- Thunderstorm – seriously difficult to assess impacts and set thresholds

- Rain – impact-based thresholds – under study

KNMI (Netherlands – Jos Diepeveen)

Last 4 years of KNMI program Early Warning Center, funding will stop next year 2024. This included Renewal warning system, My KNMI, extranets, New KNMI app, Verification.

Redesign of IT system, which is a spaghetti of software. Often including tools made by forecasters under pressure. Most crucial software now running in AWS (Amazon).

Ongoing development web based Meteo Work Station Geoweb with FMI Met Norway etc.

Operational forecasters took part in the Cycle 4 Climate 250 KM bike ride up the length of the Netherlands to bring attention to the impacts of climate change.

LVGMC (Latvia – Valerija Kostevica)

New developments include: MODES data from airplanes are being visualized for operational work use, giving opportunity to have more often vertical observation data for temperature and wind. A nowcasting radar product has been developed. Post processing data of HAR/ECMWF now available for editing wind speed/RH/temperature/pressure. A heat record and precipitation monitoring system.

During last year improved collaboration with Radiation Safety Centre where we prepare additional information about potential spread of nuclear pollution because of war in Ukraine.

Four new employees hired in the forecast division: two forecasters completed training as aviation forecaster, one in progress and a further trainee completed their training as general forecaster.

In 2021 we started work on a project with the main goals of improved joint LEGMC and SFRS impact-oriented early warning system of dangerous hydrometeorological conditions.

Met Éireann (Ireland – Liz Coleman)

Met Éireann switched to DINI and DINI-EPS for operational purposes; with Harmonie and IREPS disabled. Moving from a new model run every 3hrs to a new model every 1hr. Also moving from 15 ensemble members to 30 ensemble members. A huge increase in the volume of data for forecasters to analyse.

High-resolution model of horizontal grid resolution of 750m is continuing to be developed, mainly for Aviation forecasting services.

A lot of IT overall with finalisation of design of new text-based forecasting system. Tenders for visualisation model, Web Services and Weather Warning System are being prepared.

A new team called Collaborative Re-engineering in AI For Transformation (CRAFT) has been created in Met Éireann which will act as a bridge between Met Éireann and the forthcoming University College Dublin (UCD) professorship in in Data Science for Weather and Climate. It will also interlink with other local, national, and international organisations to help progress AI/ML service and research projects.

Flood Forecasting Division became operational, providing daily guidance to local authorities and issuing High Tide and Flood advisories.

Forecasters have been taking part in ESSL training course and testbeds on severe convection and MTG products.

Recruitment ongoing for operational forecasters.

Met Eireann has been liaising with Health Service Executive to develop guidance for public during Heatwaves.

MET Norway (Leonidas Tsopouridis)

GeoWeb:

A new meteorological workstation: An application used by the forecasters to visualize meteorological data and produce weather forecasts is under development. So far it has been presented in workshops/ training courses and is on display in our forecasting room in Bergen.

New staff have been hired mainly in Bardufoss, Orland. KraK (deep convection) group is looking into methodology, tools, database and new criteria. Strom Hans: was an extreme storm to remember causing difficulty between “a lot of rain” and “torrential” rain warnings so will develop tools to aid prediction of intense convective rain in.

Met Office (UK – Nick Roe)

Exploiting ensemble strategic action will see the UKMO moving to ensemble only NWP rather than a deterministic model in 2024/2025. This will be based on the 18 member MOGREPs 10 KM out to 14 days with the global model deterministic control and MOGREPs 1.5 KM to 7 days with the UKV as the control. Visual Weather forecasting tool will be replaced by the fully online Vortex, all meteorologists are engaging with development via sandbox versions and surveys. Until this goes live ~800 new parameters have been added to Visual Weather via cloud based servers which can be viewed as images overlayed on the ingested data. LEELA has now replaced ADT as a new lightning detection system. 1.5KM UKV data is now freely available on Windy.com as it is so widely used by the public as part of the “stay safe and thrive” value.

Civil and Defence forecasting branches have now been merged with a joint management team. Product streamlining is ongoing to reduce duplication and identify automation potential. Operational Meteorologist staffing level has dropped to a challenging low, PDev (UKMO College) are running surge courses to get more people qualified and Op Met Technicians have become Foundation Meteorologists with a faster route from joining the office being fully operational. UKMO is now a Category 2 emergency responder, elements of the national security risk register that it is responsible for include heat, storms, snow and ice as well as space weather.

Proposal to create a database of national records, starting with Europe. This is following recent increased number s of requests from the media it has been found to be difficult to get reliable data on other nations national extremes. It would be available to all but only editable by the NMS who owns the data so that each NMS can be responsible for updating as records are broken. Challenges are differences in what data each nation retains, how to judge what is a usable extreme record (e.g. should an alpine mountain top site hold a record low temperature etc) and where the database should be hosted.

Météo-France
(France - Bruno Gillet-Chaulet)

Weather Events:

“Ciaran" windstorm with exceptional winds in north-west France (sometimes exceeding the values of the 1999 storms Lothar and Martin). Read the article about this system in this Newsletter, with the interest of AI model forecasts.

Major flooding in northern France (Pas-de-Calais) with unprecedented rainfall sequences in autumn and winter. At the same time, exceptional drought continued in the south of the country (Pyrénées-Orientales): climate change is amplifying extremes! Several cyclones in overseas territories.

Observations:

Deployment of an 'Ajaccio' buoy (off Corsica) to better observe conditions following the devastating storms of summer 2022 on the island. Additional buoys to come. New station in the Mont Blanc massif to monitor avalanche risk.

Production:

Changeover to a new production chain at the end of 2023, called ALPHA. The database, initialized automatically, contains observed and forecast meteorological data from hour H to D+14 over France. ALPHA is supervised at a national level (creation of a dedicated forecaster position) and can be corrected "manually", if necessary, with proposals from forecasters at a regional level. ALPHA then feeds all Météo France productions. Adjustments have been (and will continue to be) made.

NWP:

New chain under test, with modifications in the assimilation of observations in AROME and awaiting observations from MTG-I1 satellite! AROME at 500m resolution deployed for the Paris Olympics (See previous Newsletter).

A great deal of work in progress on the use of artificial intelligence (AI). In particular, the aim is to develop a fine-scale AI emulator based on ‘deep-learning’ from AROME analyses.

Weather Warnings:

Production of bulletins at a ‘departmental’ level (administrative division), until now these have been national and regional. 73% of the 2023 warnings were anticipated with more than 6 hours' notice, against a target of 60% (see article on "Vigilance" in previous issue of the Newsletter). Enhanced meteorological support for forest fire fighting.

Climate:

Météo France provides a *‘Reference Trajectory for Adaptation to Climate Change’* (TRACC in French). This is a 'framework' to which society must adapt. By the end of the century, France should be +4°C warmer than in the pre-industrial era!

Trade and Services:

Availability of public data (European ‘directives’) on the meteo.data.gouv.fr portal. Very strong mobilization for assistance (institutional and commercial) to the Paris Olympic and Paralympic Games.

Staff and Corporate Responsibility:

Another increase in the workforce, with 25 additional jobs planned for 2024!

Energy-efficient renovation of buildings. Tree planting on the ‘Météopole’ site in Toulouse. Development of a gender equality plan for the coming years.

MeteoSwiss (Switzerland - Andre-Charles Letestu)

Autometar : AutoMetar LSGG 24/24 from June 2024 (already in use during the night) with TRENDS, lightning and wind warnings issued from the office In WMO's building. Autometar LSZH 24/24 in 2026 and regional airports after that. Future of the SYNOP : not decided yet.

www.drought.ch: A project between MeteoSwiss and BAFU (hydrological institute) showing measurments and forecasts.

Weather 4 UN: Prototype of a Global HydroMet Scanning Capability providing hydromet information and expert advice to the Humanitarian Actors (HA). Data from different sources are collected, analyzed and compiled, providing added-value advice. This part of the project is developed in close collaboration with the WMO Secretariat in Geneva. Development of a tool to estimate the combined risks and impacts of forecasted natural hazards. Based on a globally consistent probabilistic risk model (CLIMADA) coupled with probabilistic weather forecasts from WMO Member countries and territories, the estimation of multi-hazard impacts will enable humanitarian actors to plan and anticipate the best responses to protect the most vulnerable populations.

Severe events 24.7 : Storm in La Chaux-de-Fonds (Jura) 217 km/h recorded with heavy damage. Heat wave mid-august record of 0°C height at 5298 m on the 21 August, the snow limit droped to 1800 m on the 28th. Flooding in Ticino, 358 mm in Biasca between 26 and 27 august.

The ICON ensemble model will replace COSMO : operational: 9.4.2024 and from 14.9.2024 MeteoSwiss has been on Instagram.

RMI (Belgium – Thomas Vanhamel)

Climate centre: new (sort of spin-off) institute at the site in Uccle with separate funding; 8 full time meteorologists covering climate services, climate communication and scientific liaison between other scientific centres and stakeholders (e.g. media, private sector, public sector).

New pollen forecasts together with the health agency.

Implementation of a "mini EPS" in the road model for forecasting slippery roads

Migration of models from our HPC to ECMWF infrastructure (ALARO-14, ALARO-40, AROME-BE). BC from IFS instead of arpege.

Implementing a flash flood nowcast warning derived from radar products.

Tornado outbreak of 20 May 2022 - statistic classification and analysis at DWD

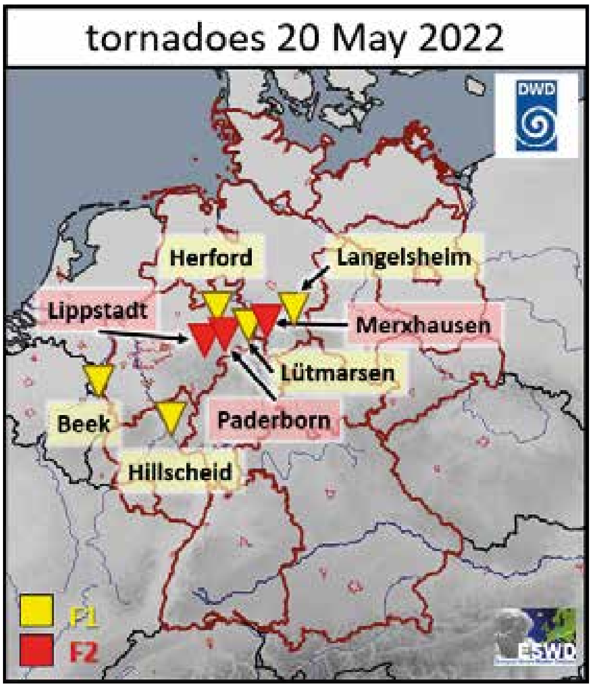
Marcus Beyer, Deutscher Wetterdienst (DWD)

On the 20th of May 2022, a severe weather outbreak took place over parts of Central Europe, including Germany. Besides excessive rain, large hail, and a severe windstorm at least eight tornadoes occurred, three of them were rated F2. This event can therefore be denoted as a tornado outbreak.

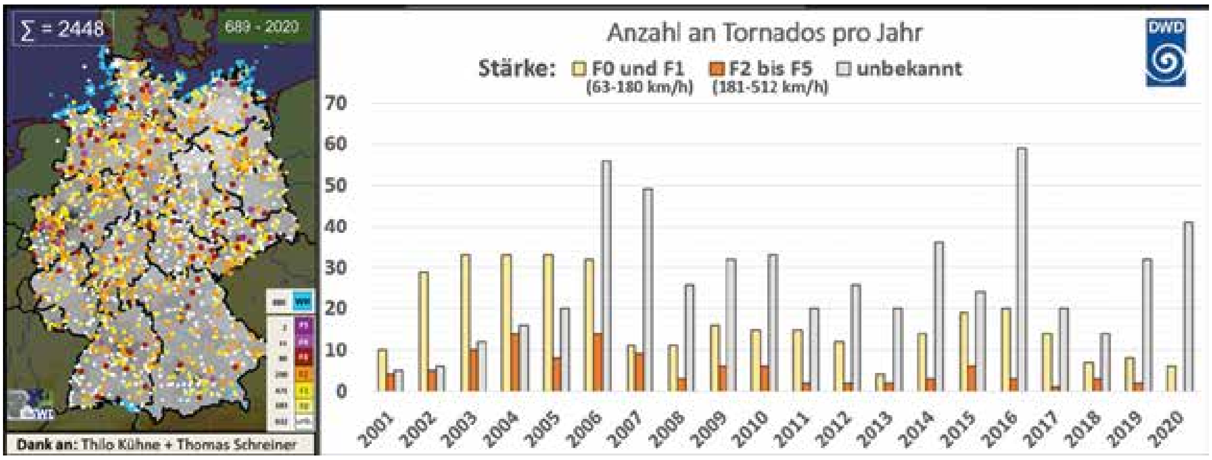
As a first step, this tornado outbreak is brought into context with the current tornado statistics for Germany. Thereafter, the weather situation and the ingredients that led to the tornadic storms are analysed and compared to the findings of the study about strong tornadoes in Germany between 2013 and 2020 [1].

Robust statistics about tornadoes in Germany are only available for the last twenty years. Before the Millennium, the statistics were not sufficient since the internet and digital photography were not available to the general public or were still in their infancy. The following numbers are thus based on the years 2001 to 2020 (20 years). Taking this period, about 49 tornadoes occur on average each year (including 17 waterspouts). Likely, there are still a few weak cases each year that do not end up in the statistics (suspected cases).

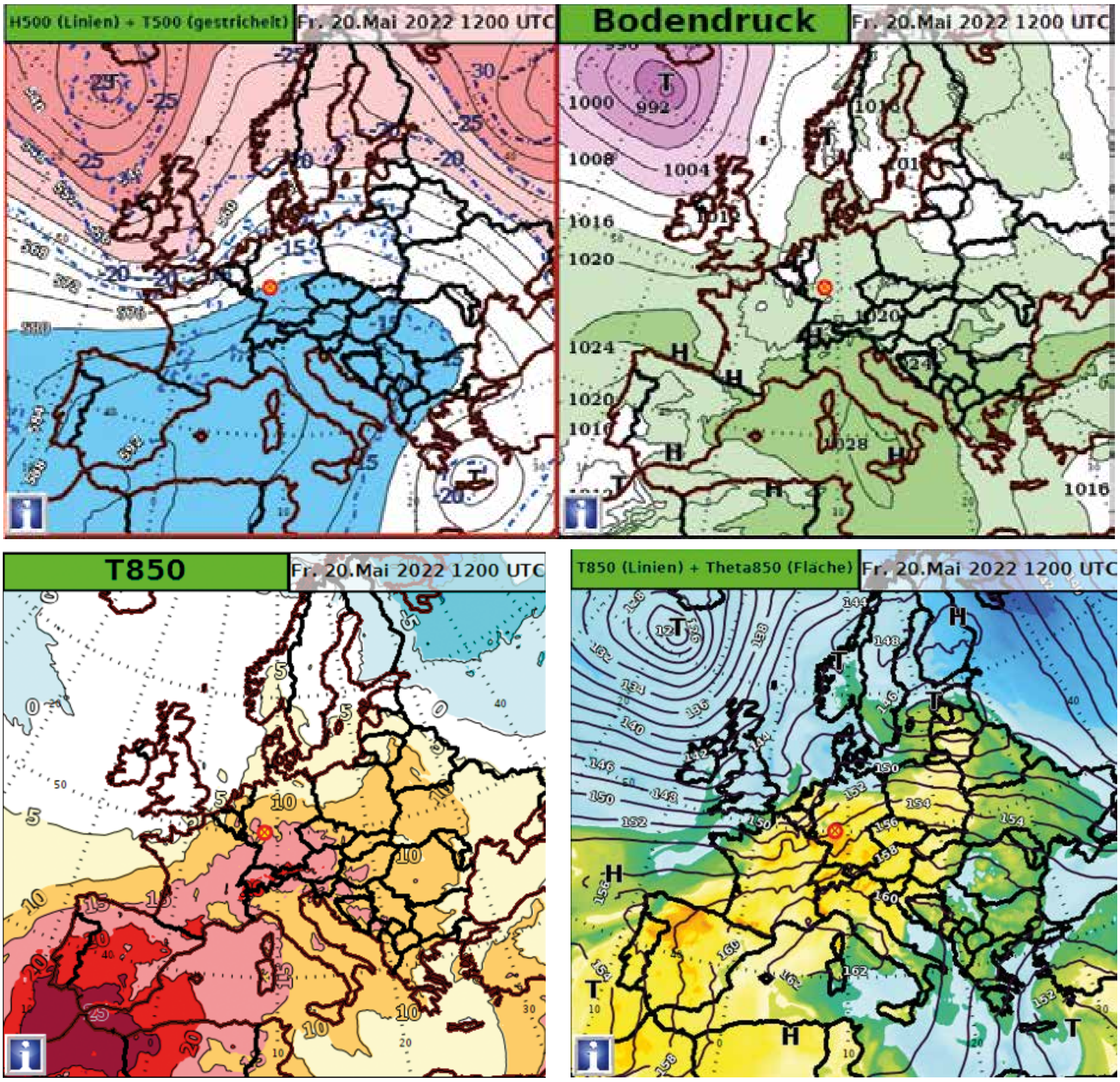
For sinificant tornadoes that have a strength of at least F2 one may be quite sure that all of them are indeed documented. On average five significant



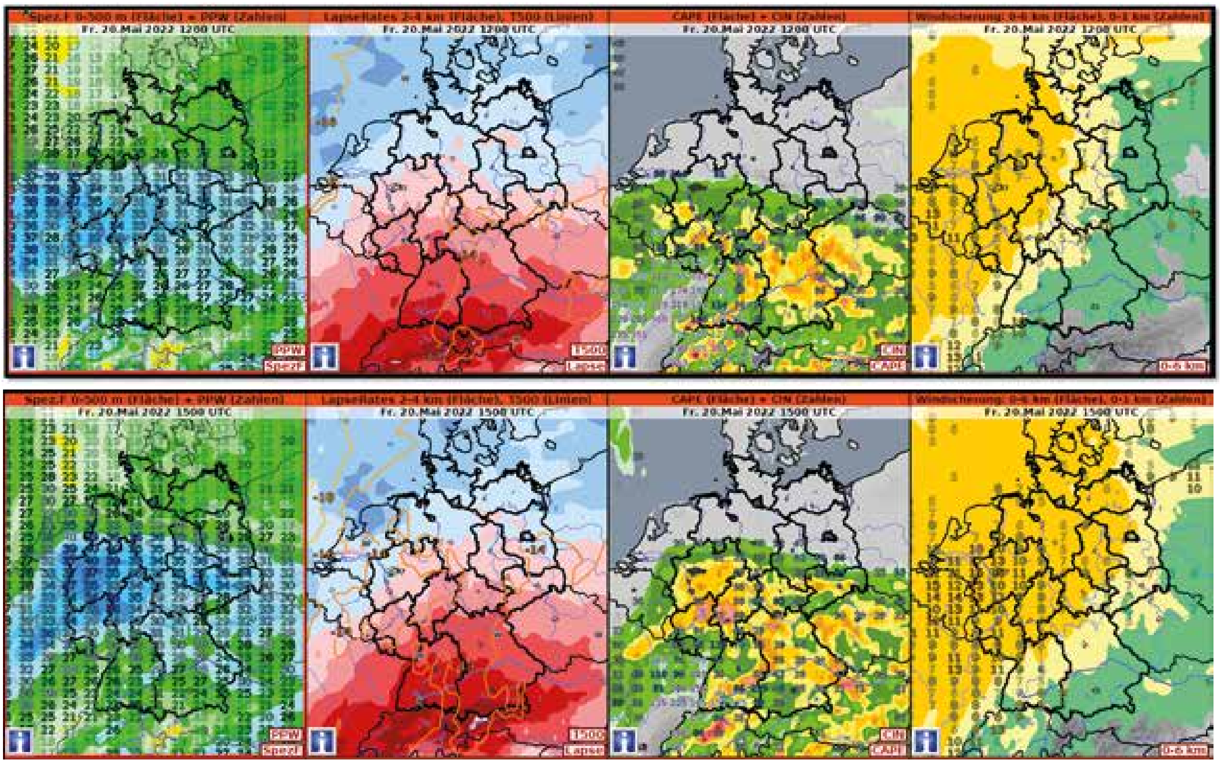
▲ *Figure 2: This map shows all tornadoes reported on 20 May 2022 named by the place of occurrence and coloured by their strength.*



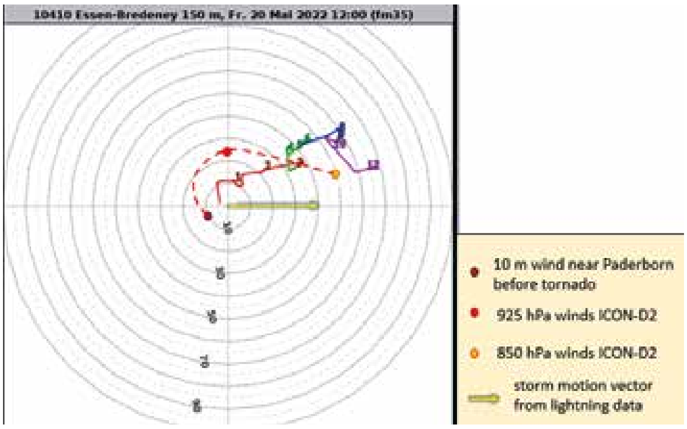
▲ *Figure 1: This graphic shows a statistic about tornadoes in Germany. The map plots all reported tornado cases in Germany from 689 until 2020. The graphic illustrates the development of numbers of tornado reports since 2001 divided into weak and significant tornadoes.*



▲ *Figure 3: Those maps illustrate the general weather pattern of 20 May 2022.*



▲ *Figure 4: Basic ingredients for severe convection for 20 May 15 UTC (top) and 18 UTC (bottom).*



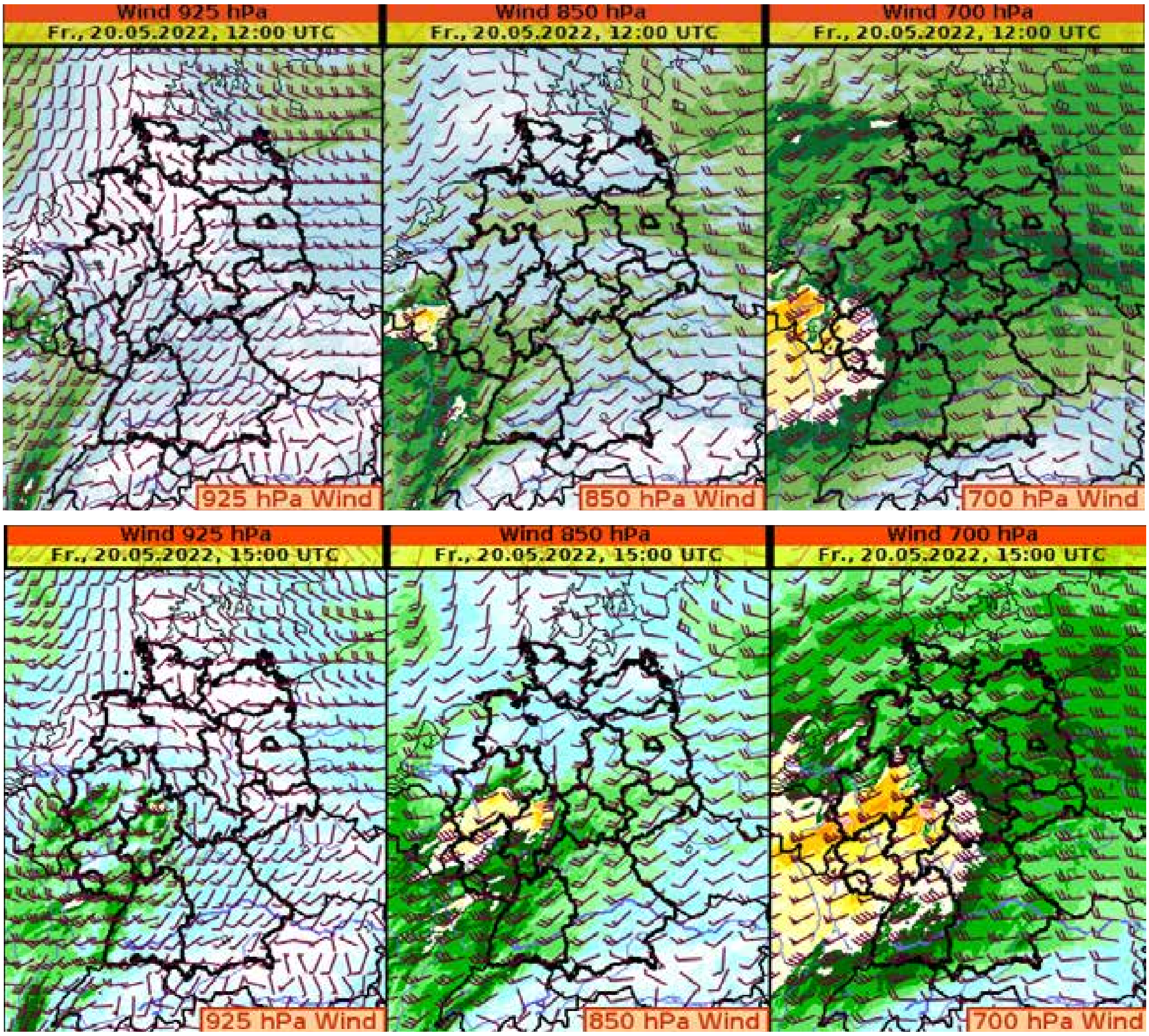
▲ *Figure 5: Hodograph of 20 May 12 UTC sounding of Essen, adapted.*

tornadoes occur every year in Germany (four F2 and one F3). The ESWD database also includes violent tornadoes (F4 and F5) but their return period is much higher. The last F4 tornado happened on the 24th of May 1979 in Bad Liebenwerda.

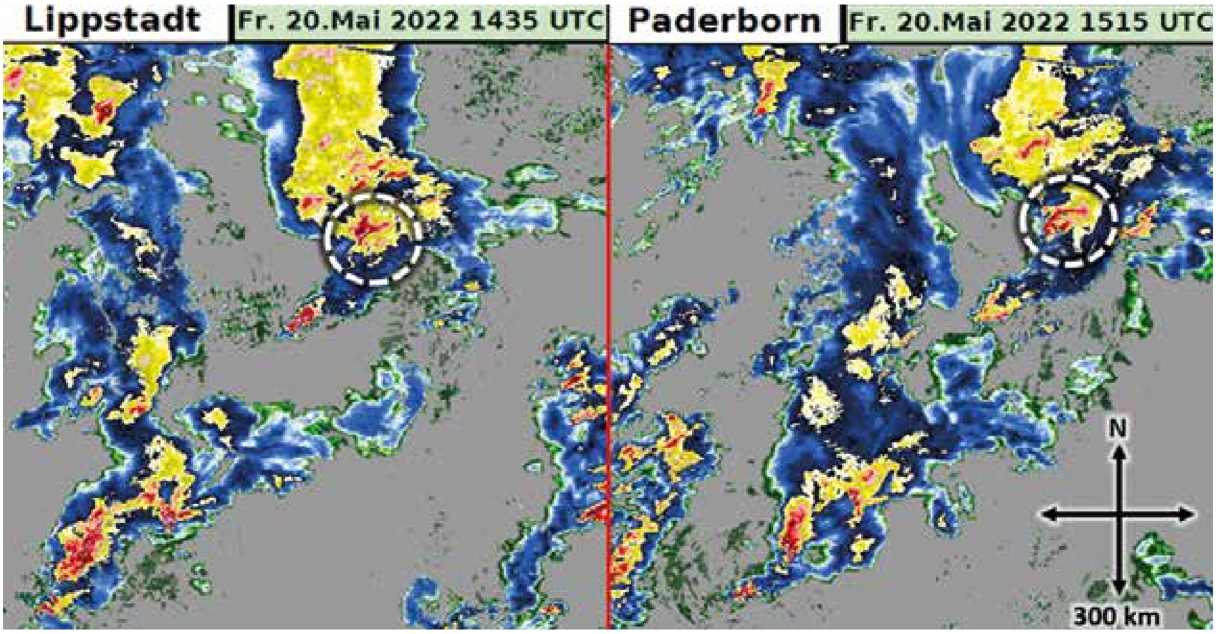
The past few years have been quite calm concerning significant tornadoes (2019: only one F2 and one F3, 2020: no significant tornado, 2021: one F2).

Tornado outbreaks in Europe can be defined in the following way: At least five tornadoes occurred and could be attributed to the same synoptic-scale weather pattern. In addition one of these tornadoes has to have a rating of F2+. The latter restriction was made to ensure of a mesocyclonic tornado event. Using that definition, 20 May 2022 was the first outbreak of tornadoes in Germany since 2016 when six tornadoes were documented. Most of the site surveys and case studies are done and can be found at tornadomap.org [2].

They are all related to the surface low "Emmelinde" that was moving from Benelux to Northern Germany while intensifying. One of them affected far southeastern Netherlands close to the German



▲ *Figure 6: Wind speed and direction at 925 hPa, 850 hPa and 700 hPa (left to right) at 20 May 12 UTC (top) and 15 UTC (bottom).*



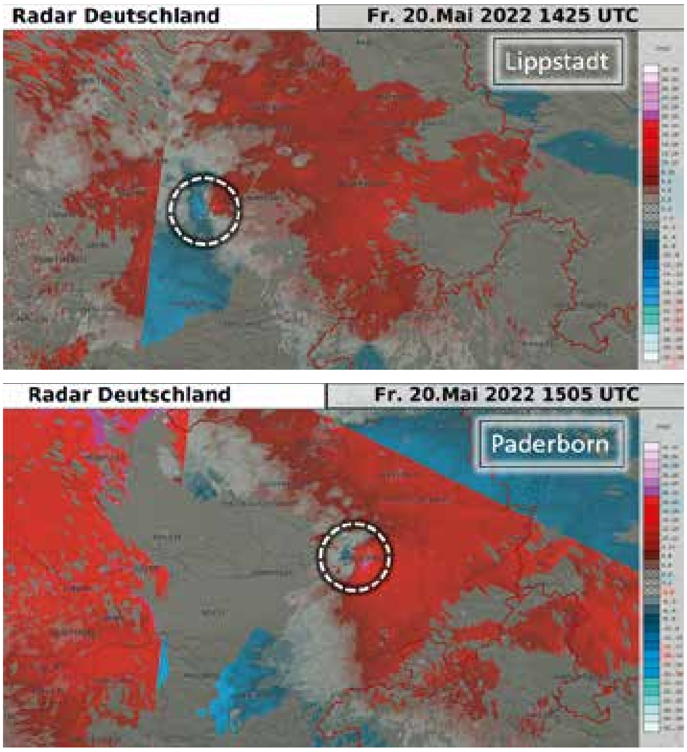
▲ *Figure 7: Radar reflectivity images taken at the time of occurrence of the two F2 tornadoes in Lippstadt and Paderborn.*

border. The other seven occurred mainly over W Germany while three of them had a strength of F2 (Lippstadt, Paderborn, and Merxhausen)

Now let us have a look at the general ingredients on 20 May and compare them to recent findings about significant tornadoes in Germany [1]. This study investigates all significant tornadoes between 2013 and 2020 (20 tornadoes on 17 different days). The 20 May was a rather typical setup with a pronounced short wave trough moving from W Europe into Germany. This was the second most frequent setup in the study. The trough led to an intensification of a downstream surface low that was moving from Benelux into N Germany during the day. The warm front of that surface low was the starting point for the first convective activity already in the morning hours. The following warm sector influenced central and southern parts of Germany with moist and unstable airmasses.

Specific humidity was highest over W Central Germany, while the steepest lapse rates could be found in S Germany. The overlap should have led to moderate values of MLCAPE of around 1000 J/kg following ICON-EU. However, soundings in W Germany only showed values of around 500 J/kg with one (Idar-Oberstein) or two (Essen) capping inversions. It seems likely that those were broken with enhanced lift due to the approaching cold front in the afternoon hours. It is also possible that CAPE values were a bit higher than measured.

Shear values were extraordinarily high for both DLS (deep layer shear, 0-6 km) and LLS (low-level shear, 0-1 km) with the best values to the north. In the region of interest DLS at 12 UTC was around 25 m/s at the sounding station in Essen. LLS was only around 6 m/s during noon but models showed that



▲ *Figure 8: Radar doppler wind at 0.5° elevation angle taken at the time of occurrence of the two F2 tornadoes in Lippstadt (top) and Paderborn (bottom).*

it should have significantly strengthened during the afternoon hours, with the approaching surface low. The same is true for storm-relative helicity which was only 200 m²/s² (0-3 km) and around 100 m²/s² (0-1 km) at 12 UTC. ICON-EU forecasted values >500 m²/s² (0-3 km) at 15 UTC for W Germany.

Wind shear was not only due to speed shear. Monitoring the 10 min winds at 10 m height one could see that several surface stations had a clear easterly wind component before the storms arrived. That was also true for Lippstadt, Paderborn, and further downstream. With the passing thunderstorm, a clear wind shift of almost 180° to westerly winds occurred.

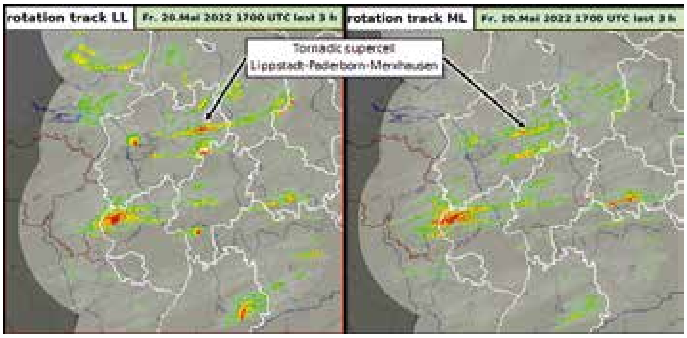
The backing surface wind with a strength of around 5 m/s should also have improved the 12 UTC hodograph of Essen, making it more favourable for tornadoes.

Comparing the findings of thermodynamic and dynamic parameters of this tornado outbreak with the values of the study one can conclude that they have been quite typical. Most of the significant tornadoes occurred in a HSLC situation

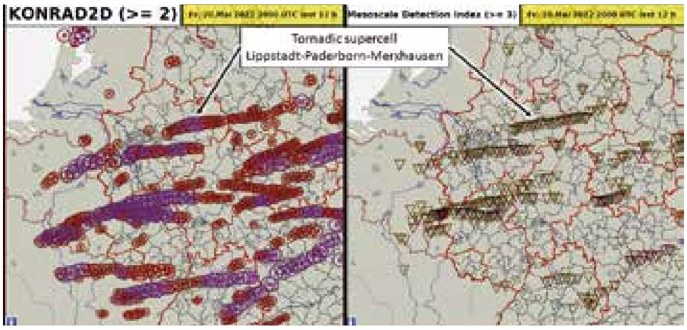
There is another interesting thing that one can mention. In the afternoon hours, a distinctive jet maximum at 850 hPa was developing and moving over the area of interest in W Germany. ICON-D2 simulated wind velocities of 25 to 30 m/s and a shift from southerly to westerly directions right at the time of the occurrence of the tornadoes. Unfortunately, this was also not covered by the 12 UTC soundings of Essen or any other neighbouring sounding station. It is likely that this jet maximum also has improved shear conditions and enhanced the probability of tornadoes.

Finally, two other typical things were figured out in the tornado study. It was found that in most of the cases it was raining a few hours before the event or another shower/storm was moving over the region just before the tornadic supercell occurred. This was also the case for the Lippstadt-Paderborn-Merxhausen case. Radar images reveal convective activity before the supercell arrived. This activity may have moistened the lower troposphere and may have additionally lowered the LCL. It is also interesting to note that there was another supercell just to the south of the tornadic storm. This non-tornadic supercell was even stronger concerning the rotation of the mesocyclone. However, its track was free of any previous convective activity and thus rain.

Finally, the study revealed that on most days with more than one tornado, several tornadoes were produced by the same storm. This was also the case on 20 May when the tornadoes of Lippstadt, Paderborn, and Merxhausen were all produced by the same storm. At least one or even two other tornados can be attributed to its lifetime. On the other hand, there have been several strong supercells on that day not producing any tornadoes.



▲ *Figure 9: Low level (left) and mid level (right) rotation tracks summarising the last 3 h hours between 14 and 15 UTC on 20 May 2022.*



▲ *Figure 10: Konrad2D cell detection and MDA (mesoscale detection algorithm) for the time between 08 UTC and 20 UTC on 20 May 2022.*

One can summarise 20 May 2022 as a day with a classic tornado setup that led to an outbreak of at least eight tornadoes. This outbreak fits very well with the recent Wapler & Beyer study about significant tornadoes [1]. After several calm years concerning significant tornadoes, this was the first notable event.

[1] Analysis of significant tornado events in Central Europe: synoptic situation and convective development, Wapler K., Beyer M., Meteorologische Zeitschrift 2022, Vol. 31 No. 5, p. 367 – 388. DOI: 10.1127/metz/2022/1126. At: https://tinyurl.com/TornadoStudyGermany

[2] tornadomap.org (https://www.tornadomap.org/analysen/2022/).

Medium Range Forecast of Ciaràn Storm Using Artificial Intelligence (AI)

PARDE Mickaël, mickael.parde@meteo.fr

Abstract

Over the past year or so, the performance of neural network-based weather forecasting models has progressed significantly and has begun to attract the interest of forecasters. Using the example of the passage of the Ciaràn windstorm over western France, we evaluate the strengths and shortcomings of four of them, namely: GraphCast (Google Deepmind), Pangu-Weather (Huawei), AIFS (European Center for Medium-Range Weather Forecasts, ECMWF) and FourCastNet (NVIDIA). We show that, although far from being operational, AI-based forecasting models are able to propose useful information to anticipate damaging storms.

Introduction

During 2023, the race to simulate weather forecasts using artificial intelligence (AI) accelerated dramatically. NVidia published the results of FourCastNet, then Huawei shared the results of Pangu-Weather, and Google DeepMind presented the GraphCast model (later we saw the arrival of Fudan University's FuXi model). These models use deep-learning to make weather forecasts; they are presented in Lguensat's article [1], in French, which also summarizes how they work. A recent evaluation showed that Pangu-Weather and GraphCast were sometimes better than current deterministic models [2]. Since then, the creators of Pangu-Weather have published their work in Nature [3], Google DeepMind has published the GraphCast model in Science [4] and the European Centre for Medium-Range Weather Forecasts (ECMWF) has made forecasts from its own emulator, AIFS (Artificial Intelligence/Integrated Forcasting Model), available on an experimental basis.

Since October 2023, these four models have been used by ECMWF to calculate, on the basis of analyses of its IFS (Integrated Forecasting System) model, a number of variables over ten day forecasts at six hourly time steps. The data are shared in the form of maps for each of these time frames on the public website https://charts.ecmwf.int/.

Various studies have already highlighted the weaknesses of the forecasts proposed by these systems: lack of physical consistency on the one hand (for example, the fundamental principle of conservation of mass is not respected); and smoothing of the forecast fields with increasing time scales on the other [5]. Nevertheless, it is almost certain that in the years to come, these models, and new ones such as FuXi (available as of December 2023 on the ECMWF website), will become more and more efficient and will significantly improve the quality of forecasts.

Let's recall a few characteristics of these 4 AI-based models:
- They are all based on ERA5 reanalysis data from the European center. Their resolution is 0.25°, like the reanalyses, except for AIFS whose resolution is 1° (until January 2024, when the resolution was also changed to 0.25°). For comparison, the European IFS model is available at 0.1° resolution.
- FourCastNet and Pangu-Weather use vision transform architectures combined with spectral transforms for FourCastNet [1, 6].
- GraphCast and AIFS use a combination of an encoder-decoder model and a graph-based neural network.
- These models simulate 13 (FourCastNet, AIFS and Pangu-Weather) and 37 (GraphCast) atmospheric levels, in addition to surface fields. The number of levels available in IFS is 137.
- The parameters simulated are very similar. On several vertical levels we have: the two wind components, geopotential and humidity; for the surface: sea level pressure, temperature at 2m and wind at 10m. On the other hand, only the GraphCast model forecasts precipitation.

In November 2023, a severe windstorm named *Ciaràn* hit France and the south of the UK [7]. It reached the 'Finistère' coast on the evening of November 1st, then moved along the English Channel, causing widespread damage and loss of life, with at least 16 fatalities in Europe. We used this violent storm as a case study to make an initial assessment of these 4 models, which are already showing very interesting metrics, often better than those of the European IFS model. Are they already capable, as the authors announce in their respective articles, of correctly forecasting violent events earlier, requiring only a few minutes of calculation?

We worked on two parameters available on a daily basis for all the models studied: atmospheric pressure at sea level (MSLP) and wind strength at 850 hPa (FF850). This wind at 850 hPa corresponds to the wind at an altitude of around 1.5 km, it is easily calculated by AI-based models as it corresponds to the geostrophic wind and is unaffected by friction with the surface so is therefore less turbulent.

Three physical model calculations are used as a reference. The Arpège model analysis provides the most accurate representation possible of the situation on the night of 1st into 2nd of November, at 00 h UTC when the storm was at its strongest (all the figures concerning forecasts in this article are for this hour). This analysis corresponds to the atmospheric state we wish to forecast. Both of the forecasts of ECMWF's IFS deterministic model, and the average of the 51 members of its ensemble forecasting system (EPS) [8] (resolution of around 9 km) will serve as a reference for the forecast.

We propose here a subjective assessment of the operational efficiency of methods still under development using artificial intelligence. We compare the medium-term forecasts (4 to 10 days ahead) of deep learning-based models with those provided by the physics-based IFS model and its ensemble version EPS.

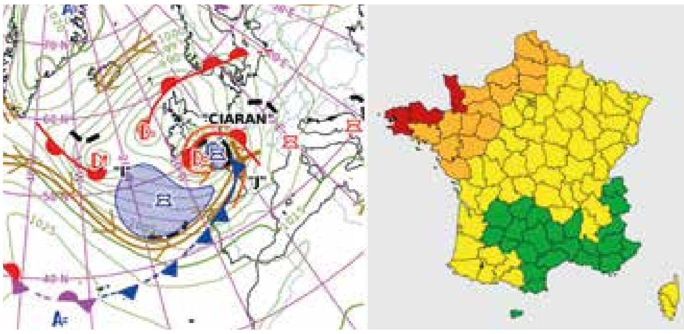
Three criteria are used in our study:
- position and deepening of the depression,
- extent and strength of FF850 winds,
- stability of forecasts from several successive production networks.

The *Ciaràn* windstorm

Ciaràn formed from a low-pressure system initially located to the east of the United States. As it moved across the Atlantic, the low found itself north of a powerful upper-level jet, and its deepening accelerated. Around Tuesday the 30th of October, it came into phase with an altitude (PV) anomaly, and its deepening became even more intense, falling around 34 hPa in 24 hours, corresponding to explosive cyclogenesis. Violent winds were noted in the southwest quadrant of the low, and the temporary presence of a sting jet could not be ruled out [7].

On Thursday the 2nd of November, 2023 at 00 h UTC, *Ciaràn* was located south of the tip of Cornwall, with a deepening that reached 955 hPa (figure 1a). A red warning for violent winds (figure 1b) was issued by Météo-France on the morning of 1st November for the Brittany departments, excluding Morbihan and Ille-et-Vilaine, which were expected to be less affected by the strongest gusts. The storm's trajectory took it to cover the Cotentin region, which was also covered by the same red warning.

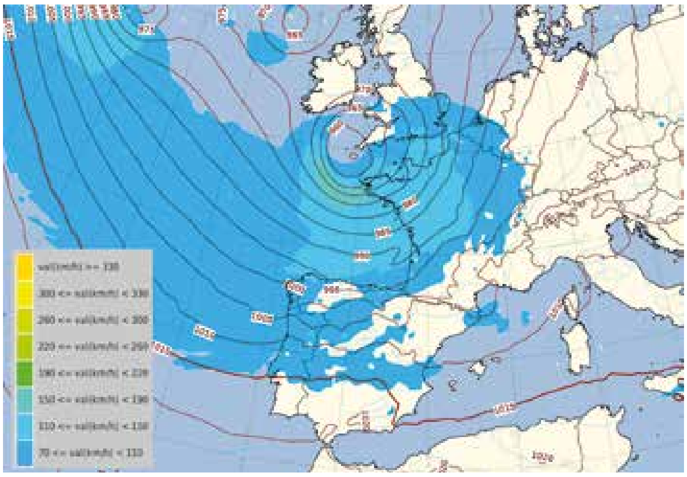
Ciaràn made landfall on the Brittany coast, causing considerable damage to people and property. Across Europe, at least 16 people lost their lives, millions were cut off from the electricity and telephone networks, and many flights were cancelled. Exceptional wind speeds were recorded. For instance, the 193 km/h gust with an average wind speed of 141 km/h recorded at Pointe St Mathieu (Finistère, a French department), which for sailors corresponds to 12 on the Beaufort scale. The maximum gusts recorded on the island of Batz reached 196 km/h.



▲ *Figure 1. (a) Surface Pressure Chart the 2nd November at 00 h UTC; (b) wind warning map ('Vigilance') issued on 1st November at 6 h UTC. Source : Météo-France.*

State of the atmosphere on Thursday, 2nd of November at 00 h UTC

On Thursday, 2nd November at 00 h UTC, storm *Ciaràn* reached the tip of Finistère, and was at its strongest around this time. All the forecasts



▲ *Figure 2. Analysis at 0.25° resolution (different from the native resolution of 5km over France) from Arpège on Thursday, 2nd November. The isolines correspond to the pressure at sea level and the shades of blue represent the winds at 850 hPa (~1.5 km above sea level). Source : Météo-France.*

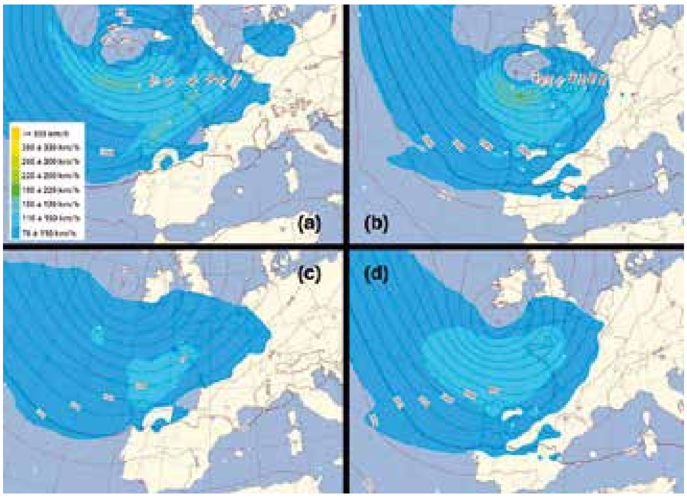
we compare in this article are for that hour. Figure 2 shows the Arpège analysis of surface pressure and wind strength at 850 hPa for 2nd November at 00 h UTC. This figure will be the reference for the rest of this article, as it is the best global map of the atmospheric state available at time of writing. It shows: surface pressure at 955 hPa over the tip of Cornwall, and winds aloft between 150 km/h and 190 km/h off the Iroise Sea (West of Finistère) in the south-western quadrant of the low. Over a large north-western part of France, winds are estimated at between 110 and 150 km/h.

IFS model and EPS ensemble forecasts

The reference for medium-range forecasting is the ECMWF IFS model which is highly regarded for its accuracy. IFS forecasts in its high-resolution HRES version are available on a 0.125° × 0.125° grid resolution, up to 10 days ahead at an hourly timestep. For the two parameters of interest to us, forecasts from both AI-based models and IFS are available at https://charts.ecmwf.int/.

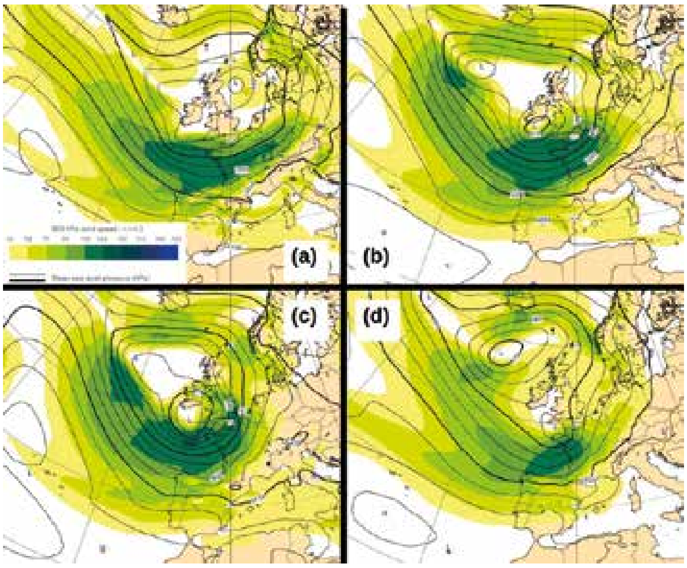
Analysis of the various IFS model forecasts of the event with a lead time of between 10 and 5 days enables us to assert several points: (i) from Wednesday 25th October to Saturday 28th October, the MSLP and FF850 field forecasts for Thursday 2*nd* November place the low-pressure system to the west of Ireland (forecasts not shown in this article), i.e. far from its final position; (ii) the forecast of Thursday 26th of October at 00 h UTC (figure 3a) indicates a low-pressure center that is already deep (951 hPa) but poorly positioned; (iii) between Saturday 28th October and Sunday 29th October, the forecast shifted this center increasingly towards the tip of Cornwall, and by 29th October (figure 3b), the forecast winds were very close to what was actually observed, with a slight shift towards the Atlantic. The central pressure is now forecast to be 956 hPa, a value that will actually be observed on Thursday 2*nd* November.

The average forecasts of the ECMWF's EPS ensembles are, by their nature, smoothed fields, so that lows appear to be less deep as the time horizon lengthens. The forecast for Thursday 26th of October (Fig. 3c) is comparable to that of the IFS deterministic model: the low-pressure system, with a central value of 966 hPa, is still a long way from its final position, and will move closer to the correct position in the subsequent simulations. In the forecast for Sunday 29th of October (Figure 3d), the position is much better and the depression deeper. What's interesting about these simulations is their statistical stability, an important element in operational forecasting. Nevertheless, the average of the ensemble forecast (Ensemble Mean) was not the best indicator of an extreme event to come.

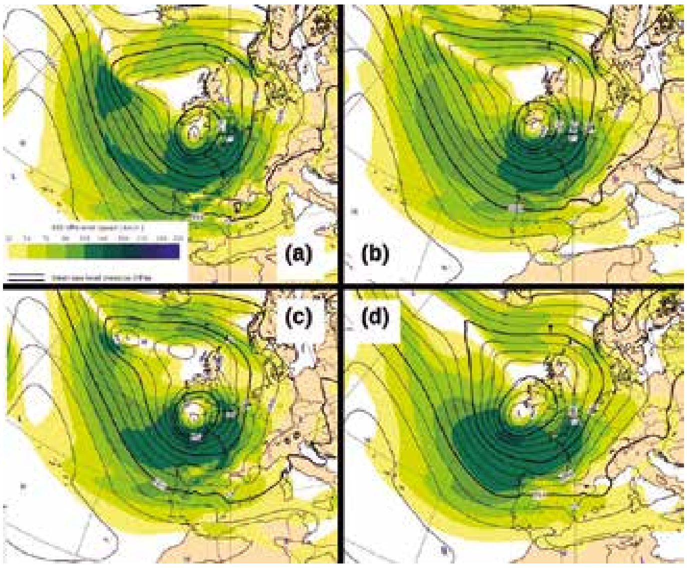


◀ *Figure 3. Wind at 850 hPa (blue colours) and sea level pressure (isolines). (a) IFS forecast base time Thursday 26th October validity time for Thursday 2nd November. (b) IFS forecast base time Sunday 29th October valid for the same date. (c) Average forecast of the EPS ensembles (Ensemble Mean) base time Thursday 26th October, valid for the same date. (d) Average forecast of the EPS ensembles (Ensemble Mean) base time Sunday 29th October valid for the same date. Source : Météo-France.*

Comparison of AI-based models



▲ *Figure 4. Forecasts of sea level pressure fields and wind speed at 850 hPa base time Thursday 26th of October by the 4 AI-based models for Thursday 2nd of November (168 h lead time) (a) GraphCast, (b) AIFS, (c) Pangu-Weather and (d) FourCastNet. Source: ECMWF.*



▲ *Figure 5. As in Figure 4 with a forecast base time of Sunday 29th of October for Thursday 2nd of November (96 h time horizon). Source: ECMWF.*

For Google's GraphCast model, the forecast of Thursday 26th of October (Figure 4a) is relatively far from the final situation: the position and deepening of the depression are not yet correct. The first simulation to show the presence of a storm over the correct zone of France is that of Thursday 26th October at 12:00 UTC (not shown), but forecasts would continue to fluctuate until Sunday 29th October at 0:00 UTC (figure 5a). In the final figure, the position and deepening are now perfectly forecast, with a zone of strong winds (between 144 and 180 km/h) present in the same quadrant as that finally observed. Nevertheless, operational forecasting can hardly rely on such variable forecasts from one simulation to the next.

For the ECMWF's AIFS model, as of Wednesday 25th of October (not shown), the low-pressure area was very deep, with strong winds in its southern part (but still below 144 km/h) covering the entire northwest of the country. However, it is not yet correctly located (positioned over Ireland), and the winds are generally lower than the final analysis. Nevertheless, it is possible to identify the presence of a storm over a large part of France very early on, as the simulation of Thursday 26th October at 00 h UTC (Figure 4b) already shows very good placement unlike GraphCast. The simulation of Sunday 29th October at 00 h UTC (figure 5b) was the first to suggest strong winds aloft in the southern zone of the low-pressure system, a zone that was to disappear from subsequent forecasts.

Huawei's Pangu-Weather model quickly simulated a low-pressure system to the south of Cornwall, with strong winds covering much of France. By Thursday 26th October at 00 h UTC (Figure 4c), all the elements were already in place, even if the low had not yet deepened sufficiently. Pangu-Weather forecast a restricted zone of stronger winds, between 144 and 180 km/h, off the Iroise achieving the best lead time of any model. The later simulations still show significant variations, but remain close to the final result. The calculation for Friday 27th October at 12:00 UTC (not shown) gives an excellent representation of Ciaràn, with a central pressure of 955 hPa over the tip of Cornwall.

For NVidia's FourCastNet model, the first satisfactory simulation occurs on Saturday 28th October at 12:00 UTC. Figure 4d shows that wind location and strength are not correctly forecast on Thursday 26th October at 00 h UTC. On Sunday 29th October at 00 h UTC (Figure 5d), the location of the low is good, but the central pressure is still insufficiently deepened. Nevertheless, like the other models, FourCastNet was forecasting a south-westerly direction for the low-pressure area, with stronger winds.

Current limitations of AI

The AI-based forecasting models currently available to the public are embryonic models that offer a very partial representation of the atmosphere,

still far from the richness of forecasts derived from physical modeling. Among the major shortcomings for weather forecasting, we can mention:
- the absence of many important parameters such as CAPE (Convective Available Potential Energy), CIN (Convective INhibition), hourly precipitation totals and cloud cover,
- the smoothing of certain fields with time lag; this limitation has been noted for Pangu-Weather [3], and Bonavita [5] has shown that the energy spectrum of the fields (after Fourier transform) falls more sharply than with the IFS model as time lag increases,
- the small number of levels simulated, which makes it difficult to analyze vertical profiles, an important tool for forecasters,
- finally, the forecasting of surface phenomena, such as gusts, which are absent from the forecasts even though they are essential for operational forecasting.

Conclusions

We observed during the *Ciaràn* storm that these models were already producing pressure and wind fields that could be used for operational forecasting. The subjective analysis made here (which should be repeated for different situations) shows that the storm was correctly predicted by these models a few days before the deterministic IFS model: even if still very unstable, with a more fluctuating forecast of the most violent winds in these models by AI. The forecasts (not all shown in this article for reasons of readability) indicate that they were able to anticipate *Ciaràn* with respectable lead times. Special mention should be made of Pangu-Weather, which performed particularly well in anticipating strong winds above the boundary layer. The other models had variable performance at longer lead times, but also provided excellent forecasts comparable to IFS.

However, this situation is unusual in that storms are weather events for which forecasting has made particular progress in recent years. At present, AI-based models are still unable to predict thunderstorms, heavy snowfall and freezing rain for example. However, we can be sure that in the coming years, these models will make significant progress, and that others will undoubtedly enter the competition (in 2024, high-resolution models such as FengWU-GHR are expected). The work of forecasters is likely to benefit rapidly from this information, improving the quality of their broadscale forecasts.

Finally, a recent study [9] complements this one, offering a similar comparison of short-term forecasts from the same models for the *Ciaràn* storm.

Bibliographie

[1] Lguensat R., 2023. Les nouveaux modèles de prévision météorologique basés sur l'intelligence artificielle : opportunité ou menace ? *La Météorologie*, 121, 11-15

[2] Ben-Bouallegue Z., Clare M. C. A., Magnusson L. et al., 2023. The rise of data-driven weather forecasting. *arXiv preprint* arXiv:2307.10128

[3] Bi K., Xie L., Zhang H. et al., 2023. Accurate medium-range global weather forecasting with 3D neural networks. *Nature*, 619.7970, 533-538. DOI : 10.1038/s41586-023-06185-3

[4] Lam R., Sanchez-Gonzalez A., Willson M. et al, 2023. Learning skillful medium-range global weather forecasting. *Science*, 382, 6677, 1416-1421. DOI: 10.1126/science.adi2336

[5] Bonavita M., 2023. On the limitations of data-driven weather forecasting models. *arXiv preprint* arXiv:2309.08473

[6] Bonev B., Kurth T., Hundt C. et al., 2023. Spherical Fourier neural operators: learning stable dynamics on the sphere. *arXiv preprint* arXiv:2306.03838

[7] Kreitz M., Sorel M., 2024. Un automne 2023 très perturbé. *La Météorologie*, 124, 49-56

[8] Bouttier F., Buizza R., 2018. La prévision d'ensemble. *La Météorologie*, 100, 29-36

[9] Charlton-Perez A. J., Dacre H. F., Driscoll S. et al., 2024. Do AI models produce better weather forecasts than physics-based models? A quantitative evaluation case study of Storm Ciaràn. *arXiv preprint* arXiv:2312.02658

Operational Forecasting Assistance for Forest and Vegetation Fires at Météo France

Catherine.Robert@meteo.fr,
Romaric.Cinotti@meteo.fr,
Bruno.Gillet-Chaulet@meteo.fr

Meteorological assistance to help prevent and fight wildfires has existed in France for a long time. In 2023, following an exceptionally busy 2022 wildfire season over the French territory, this service was stepped up significantly. This article briefly presents a few aspects of the current wildfire system implemented at Météo France as of 2024.

A brief history

Meteorological assistance for forest fires began in France in the 1960s. To ensure the protection of Mediterranean forests, which are particularly vulnerable to wildfires, there has been close collaboration for several decades between Civil Protection, the National Forestry Office (ONF) and Météo France (previously known as the National Meteorological Service). Initially tested on a single department (the French administrative unit) with a meteorological fire danger map and a text bulletin, the scope of the fire assistance provided was gradually extended to the entire French Mediterranean area in 1979. To create a wildfire forecast, the forecaster assesses and examines "fire" indices. Fire indices have evolved considerably over the years as a result of research and feedback from various forest fire-fighting services (Civil Protection and ONF).

Prior to 1987, a single fire index was used to determine the risk of wildfire. This single index combined modelled vegetation dryness with forecast wind (called the "Thornthwaite reserve") [1].

Thereafter, three new fire indices were developed: one qualifying the overall level of fire risk, another indicating fire *outbreak potential* and the last estimating fire propagation speed (South-East Propagation Index, pronounced “Ipse” in French). From 1995 onwards, the *Canadian Forest Fire Weather Index* (FWI, “IFM” in French) [2] also began to be incorporated into wildfire modelling work. Since then, weather forecaster and firefighter experience and expertise, combined with these advances in numerical weather prediction have contributed to notable improvements in the quality and reliability of fire indices and the spatial resolution of fire forecasting.

The French firefighting doctrine

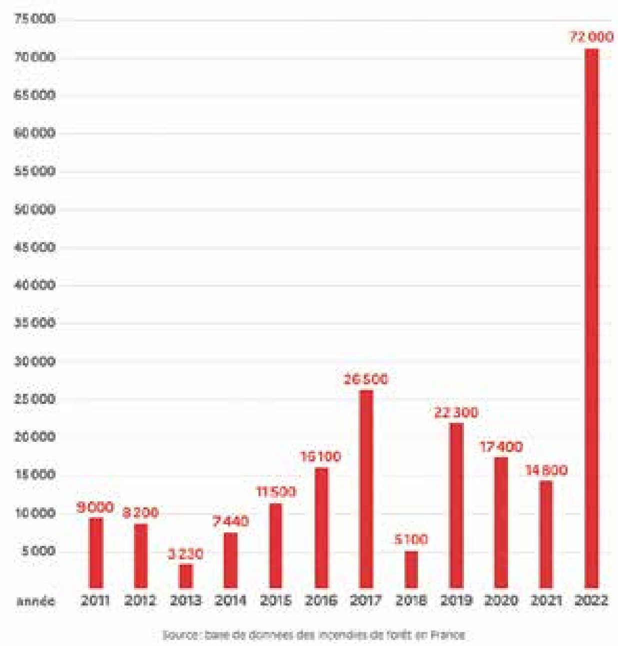
The Civil Protection forest fire-fighting doctrine advises that any wildfire must be attended and targeted within 10 minutes in order to prevent the fire spreading across an area of 1 hectare (10,000 m^2) and becoming uncontrollable. This theory is based on the predicted time needed to successfully mobilise land and air fire-fighting resources, however the operational danger of the fire is often also closely linked to the day's weather conditions.

2022: An exceptional year with wildfires in France and Europe

The end of 2021 into early 2022 saw a period of low rainfall, followed by particularly hot weather in April and May 2022. The subsequent summer of 2022 was dry and very hot, with successive heatwaves. As a result, the vegetation was particularly dry during the summer season, creating conditions highly conducive to the development of fire and leading to exceptional wildfire activity.

A total of 19,711 fires were recorded in 2022 in France burning a surface area of 72,000 hectares of forests, natural areas and crops **(Figure 1)**. This made 2022 a historic year for wildfires, not only in terms of the ecological toll the wildfire had on the environment, but also in terms of the resources that were deployed to protect the human population and control these fires. Of particular note in 2022 was the number of large scale fires and their distribution across the whole of mainland France.

A total of 90 departments recorded a significant wildfire events in 2022. During 2022 97% of fires in France were treated by fire-fighting resources before they exceeded 5 hectares, successfully achieving the goal set out in the French fire-fighting doctrine.



Source : base de données des incendies de forêt en France

▲ *Figure 1: Area burnt over 11 years in France (hectares)*

Today the risk of forest fires provides concern not just for the Mediterranean region but for Europe as a whole. The total area of land in Europe affected by wildfire was more than 780,000 hectares, confirming the extraordinary intensity of this 2022 year's fires. In Spain alone, almost 10,000 fires destroyed 265,000 hectares, while in Portugal, 10,000 fires destroyed more than 110,000 hectares.

As a result of the significant wildfire activity in 2022, the French government has increased supporting resources available for fire-fighting and in response Météo France have now implemented the following:

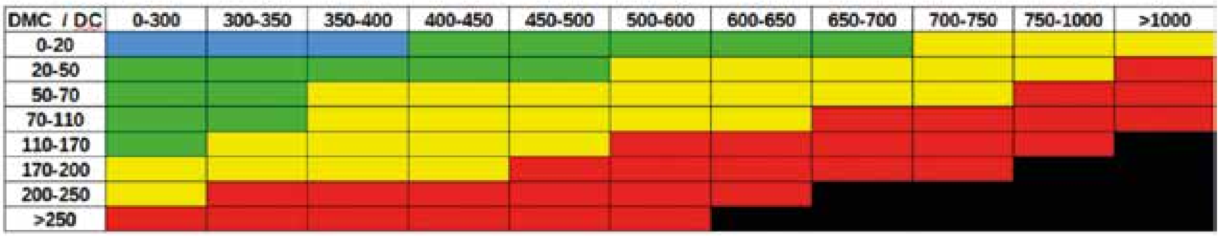
- Increased Météo France's operational support to the French Civil Protection Service
- Introduction of a wildfire prevention tool to inform the general public of wildfires and raise the awareness of the danger of forest fires: called “Forest Weather” [3].

Using meteorology to help forecast fire danger

Forecasting the level of "forest fire danger” can be achieved by assessing the dryness of the living vegetation at the time together with the expected meteorological conditions.

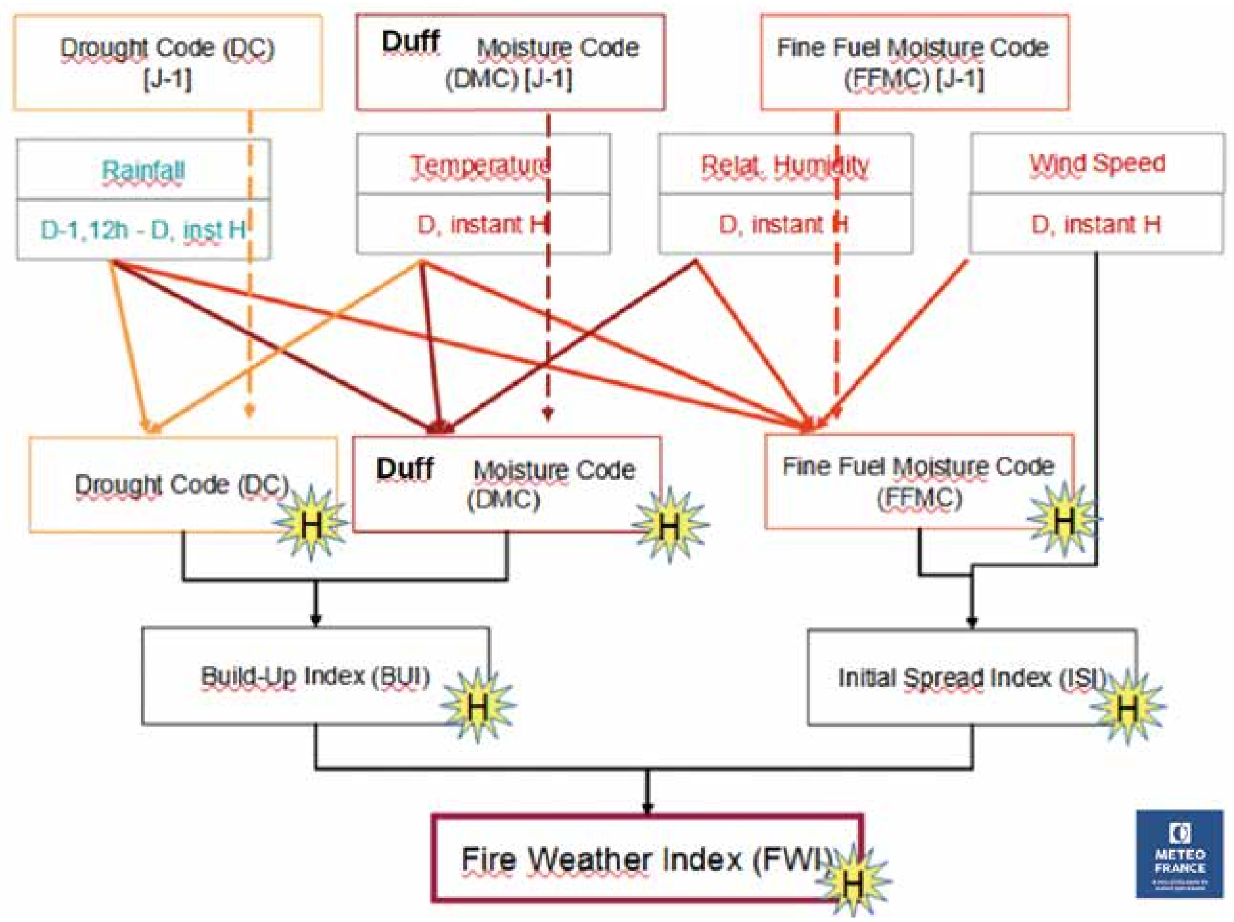
Various specific indices have been developed to help forecast wildfire. The historical Canadian method [2] provides indices valid at 12 UTC. Météo France has adapted this model to calculate them at hourly time steps, over a range from 08 to 18 UTC. These hourly indices make it possible for the forecaster to estimate the timing of maximum wildfire risk during the day. These are known as ‘MAX indices’ (IFMx, IEPx, etc). This approach allows the forecaster to better define the danger timings for events occurring before or after 12 UTC.

To determine the level of dryness of living vegetation, a ‘*Vegetation Drought Sensitivity Index*’ (NSV2) is used. This index combines the ‘*Humus Index*’ (called IH or DMC) and the ‘*Drought Index*’ (called IS or DC) **(Figure 2)**. This NSV2 index is close to the Canadian “Build-up Index” (BUI, called ICD in French), but has been adapted to include the characteristics of French forests. In some regions actual field observations of vegetation dryness can be carried out by forestry agents which are then fed into modelling to ground truth and improve the NSV2 index for these areas.



DMC / DC	0-300	300-350	350-400	400-450	450-500	500-600	600-650	650-700	700-750	750-1000	>1000
0-20	🟦	🟦	🟦	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨
20-50	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟥
50-70	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟥	🟥
70-110	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥
110-170	🟩	🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛
170-200	🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	⬛
200-250	🟨	🟥	🟥	🟥	🟥	🟥	🟥	⬛	⬛	⬛	⬛
>250	🟥	🟥	🟥	🟥	🟥	🟥	⬛	⬛	⬛	⬛	⬛

▲ *Figure 2: Showing how the ‘Humus Index’ (DMC, columns) and ‘Drought Index’ (DC, rows) are combined to provide the ‘Vegetation Drought Sensitivity Index’ (NSV2).*



▲ *Figure 3: Components of the IFMx (FWI) System. Calculation of the components "H" is based on consecutive hourly data.*

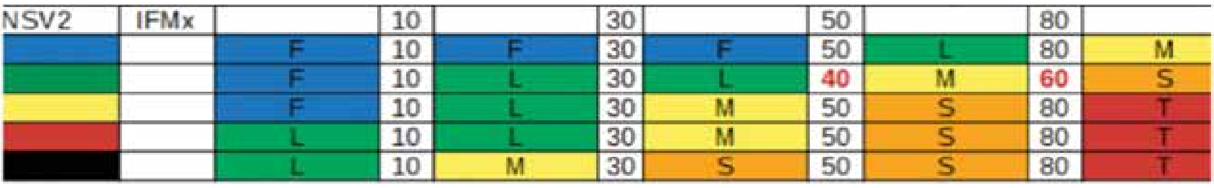
Once the living vegetation drought has been validated, the forecaster studies the day's weather conditions, assessing:

- Working Wind: the average wind direction, strength and gusts
- Temperature
- Air Humidity
- Expected Rainfall
- Cloud Cover

The forecaster assesses the variation of these parameters over the day, focusing on the most sensitive time slot, and studies their impact on various fire indices, in particular the '*Fire Weather Index*' (IFMx, FWI) which is used to determine the meteorological fire danger level **(Figure 3)**.

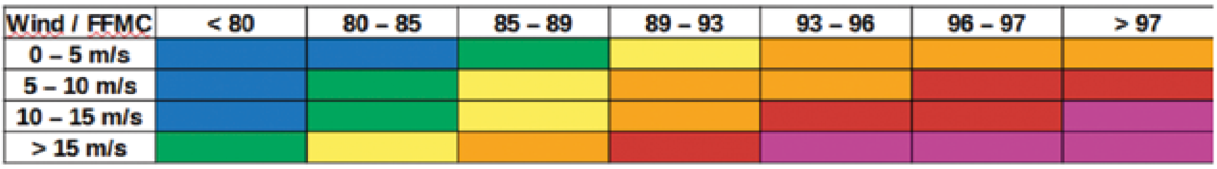
Like the NSV2, the *'Fire Weather Index'* is also corrected for vegetation conditions in France to create the *'Integrated Danger'* as studies have shown that this index is affected by significant biases in the case of light or severe drought in living vegetation. In turn the *'Meteorological forest fire danger'* is determined and expressed on a scale of 6 levels, from Low to Extreme (the Extreme level being possible only after expert consideration, **Figure 4**).

This information is supplemented by a *'Danger Index for dead vegetation*' (IEPx) it is a combination of the 'Fine Fuel Moisture Code' (FFMC, ICL in French) and the 'working wind' parameter. This index is used to characterise the danger of fires breaking out and spreading **(Figure 5)**. It is used



NSV2	IFMx		10		30		50		80	
🟦		F	10	F	30	F	50	L	80	M
🟩		F	10	L	30	L	40	M	60	S
🟨		F	10	L	30	M	50	S	80	T
🟥		L	10	L	30	M	50	S	80	T
⬛		L	10	M	30	S	50	S	80	T

▲ *Figure 4: 'Integrated danger' is a combination of 'Vegetation Drought Sensitivity' (NSV2) and 'Fire Weather Index' (IFMx, FWI). The scale is Low (F), Light (L), Moderate (M), Severe (S), Very Severe (T). An Extreme class is possible for critical drought situations.*



Wind / FFMC	< 80	80 – 85	85 – 89	89 – 93	93 – 96	96 – 97	> 97
0 – 5 m/s	🟦	🟦	🟩	🟨	🟧	🟧	🟧
5 – 10 m/s	🟦	🟩	🟨	🟧	🟧	🟥	🟥
10 – 15 m/s	🟦	🟩	🟨	🟧	🟥	🟥	🟪
> 15 m/s	🟩	🟨	🟧	🟥	🟪	🟪	🟪

▲ *Figure 5: Scale of IEPx, from level 1 (blue) to level 6 (purple).*

to estimate the possibility of fire "outbreaks". It is particularly relevant for crop and low vegetation (grass) fires, and outside the summer season.

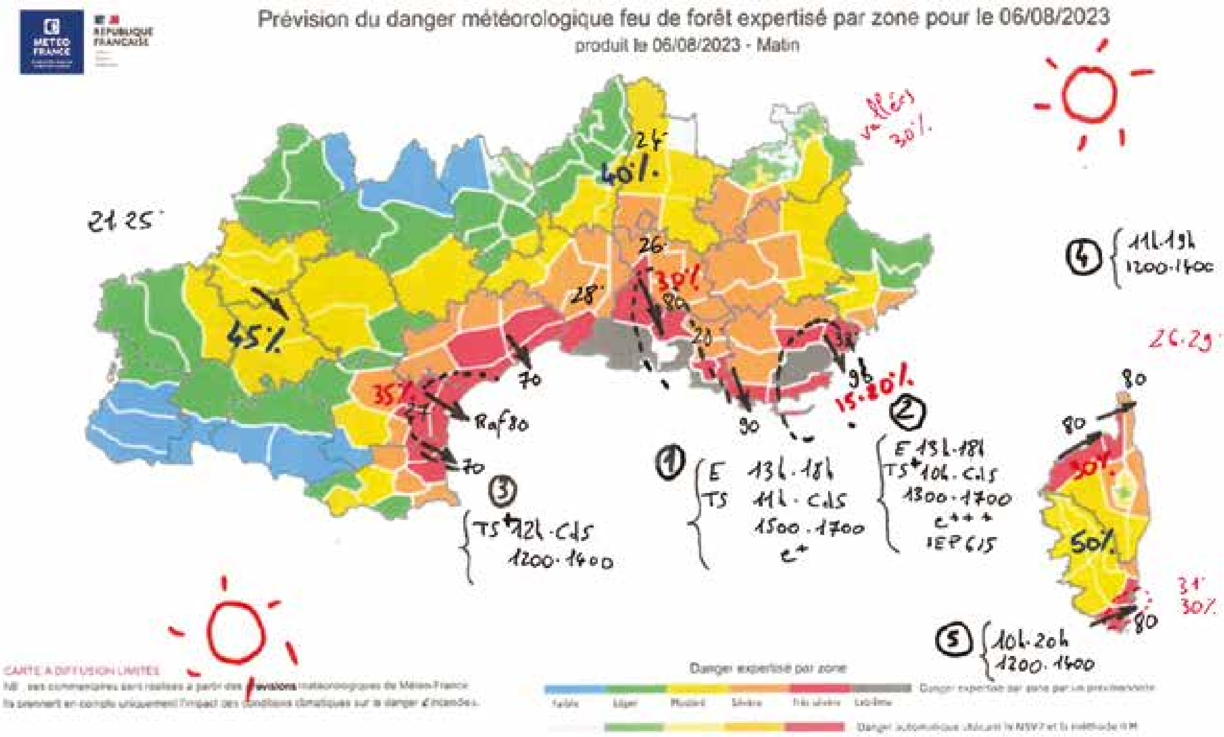
These products are then combined to form the wildfire advice and guidance production provided to the Civil Protection below **(Figure 6)**.

Operational support

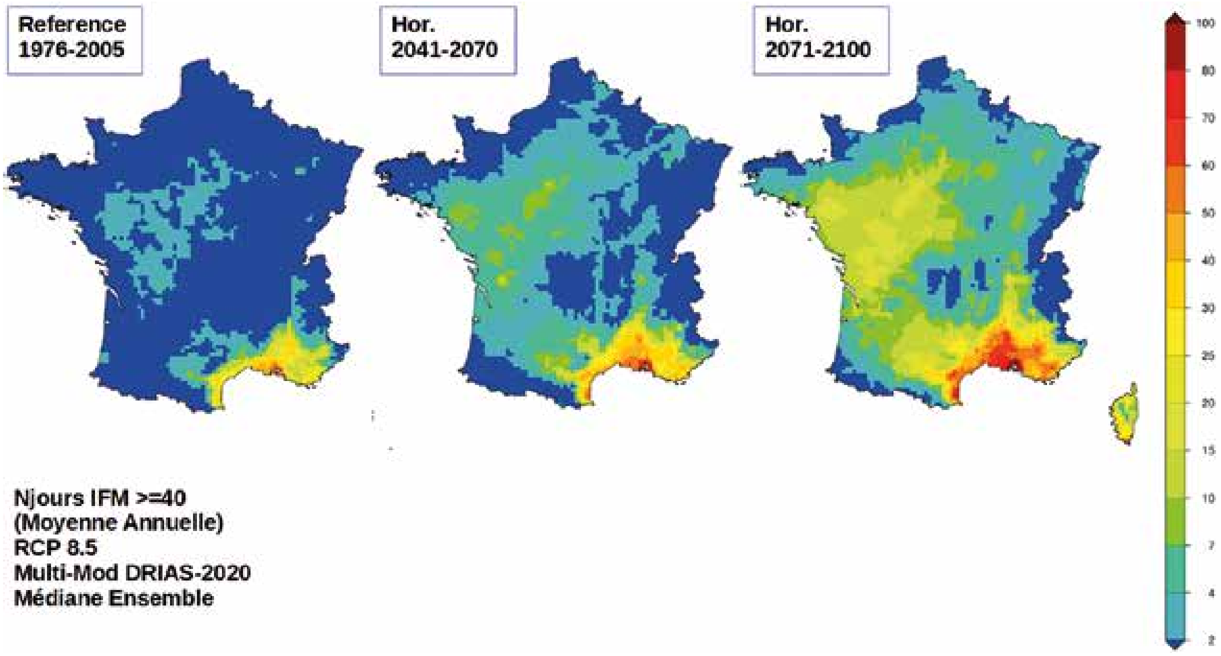
Since 2023, Météo France has provided wildfire forecasting assistance to the whole French territory. In terms of Civil Protection, a national coordination centre for fire-fighting resources has been set up in Nîmes in the south of the country. It operates daily between June and September. A forecaster is seconded to the Centre where they provide the meteorological fire danger assessed on a national scale for the current day (D), the following day (D+1) and gives a trend in the evolution of these dangers from D+2 to D+7, depending on the weather scenario forecast.

The forecaster responds in real time to Civil Protection requests. The system has been strengthened in the south-west of France and is predominantly modelled on the historic one in place in the Mediterranean area with local fire-fighting authorities. It is at this regional level that the most accurate forecasts are provided (for sub-departmental sensitivity areas), thanks to forecasters who are particularly experienced in this type of hazard. This system should be extended to the other French regions in the coming years.

Outside the summer season, wildfire forecasters provide basic national forecasts on a weekly basis to the civil protection authorities. In addition, other Météo France forecasters provide the ERCC with fire weather hazard data as part of the ARISTOTLE project [4].



▲ *Figure 6: Example of production provided to Civil Protection. Morning "annotated" map of the assessed "meteorological forest fire" danger and relevant weather parameters/fire indices valid for the Day, 06/08/2023.*



▲ *Figure 7: Maps of annual average number of days with IFM □40 for RCP8.5, by time horizon, Ensemble Median [6].*

Effects of climate change and provisional conclusion

Global warming, combined with changes in forest vegetation as fuels, will have very tangible effects on forest fires in France [5]:

The following affects are expected in the future in response to these changes:

- Intensification: an 80% increase in the land areas burnt by wildfire by 2050
- Geographical extension: almost 50% of moorland and woodland in mainland France will be at high risk of wildfire by 2050
- Temporal extension: the wildfire risk period will be three times longer (from June to October) and contribute to more winter or spring fires
- an increase in the number of vegetation and farmland fires, including in peri-urban areas

Global warming is predicted to cause more fires than ever before **(Figure 7)**. Three of the biggest fires that hit France in the last 40 years occurred in 2021 and 2022. In its sixth assessment report, the Intergovernmental Panel on Climate Change (IPCC) warns of an increase in the probability of "catastrophic forest fires" of between 30% and 60% by the end of the century. Furthermore, these extraordinary fires pose public health problems. In this context, the assistance of Météo France will be essential.

Glossary:

(French acronym between brackets)

FFMC (ICL):

The Fine Fuel Moisture Code is a numeric rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and the flammability of fine fuel.

DMC (IH):

The Duff Moisture Code is a numeric rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.

DC (IS):

The Drought Code is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs.

ISI (~IEP):

The Initial Spread Index is a numeric rating of the expected rate of fire spread. It is based on wind speed and FFMC. Like the rest of the FWI system components, ISI does not take fuel type into account. Actual spread rates vary between fuel types at the same ISI.

BUI (ICD, ~NSV2):

The Buildup Index is a numeric rating of the total amount of fuel available for combustion. It is based on the DMC and the DC. The BUI is generally less than twice the DMC value, and moisture in the DMC layer is expected to help prevent burning in material deeper down in the available fuel.

FWI (IFM):

The Fire Weather Index is a numeric rating of fire intensity. It is based on the ISI and the BUI, and is used as a general index of fire danger throughout the forested areas of Canada [7].

[1] **Thornthwaite C. W., 1948.** *An Approach toward a Rational Classification of Climate*. Geographical Review 58, 55-94.

[2] **Van Wagner C.E., 1987.** É*laboration et structure de la méthode canadienne de l'Indice Forêt-Météo*. Service canadien des forêts, Administration centrale, Ottawa (Ontario). Rapport technique de foresterie 35F. 34 p.

[3] "The European Forecaster", Newsletter of the WGCEF N°28, September 2023. http://www.euroforecaster.org/gpeasy/gpEasy_CMS/Archive

[4] http://aristotle.ingv.it/

[5] *Lutte contre les feux de forêt: protéger les populations, les biens et l'environnement*. Dossier de Presse 2023. available at https://www.interieur.gouv.fr/sites/minint/files/medias/documents/2023-04/DP_Feux_foret_10EP_HD.pdf

[6] DRIAS les futurs du climat, https://www.drias-climat.fr/.

[7] https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi

A LEWP tornado in Coastal mainland Portugal (Murtosa)

08th April 2024

Paulo Pinto
Paula Leitão

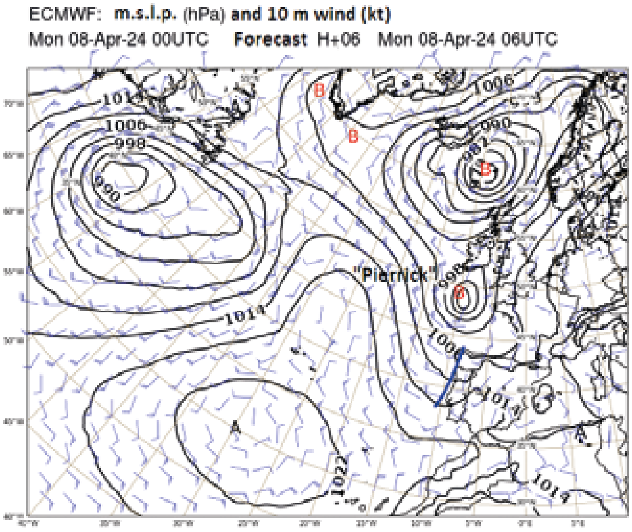
Introduction

According to a systematic data collection and study of tornadoes over Portugal, conducted for the first two decades of the current century in Leitão and Pinto (2020), it was found that these phenomena were more frequent during autumn, winter, and spring and that the most intense ones were spawned by supercells. However, quite a large proportion of weaker, shorter-lived, but still damaging tornadoes were found to be associated with quasi linear convective systems (QLCS). And of these, nearly 70% originated specifically from line echo wave patterns (LEWP). The sorting of tornado types considered in that study has followed the taxonomy proposed by Agee (2014). Weather radar observations of mainland Portugal were accessed to classify the tornado types following such conceptual taxonomy.

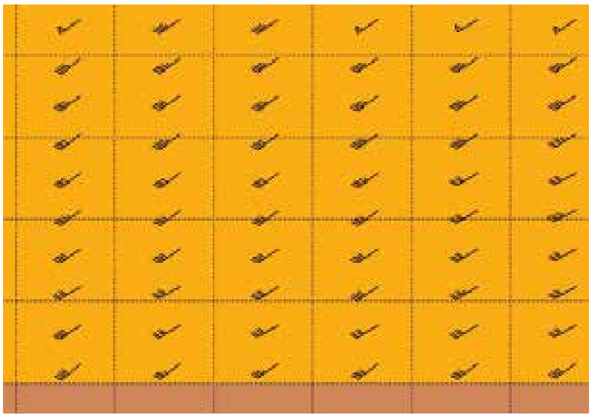
On 8th April 2024, in the Murtosa municipality (40.752 N, 8.648 W), western coastal area of mainland Portugal, strong winds caused a property wall to topple along an extension of more than 30 m. Other locations very close to this one also reported, during the early morning, damaging winds that caused destruction in a farm, uprooted trees and left several other houses roofless. As it was not possible to precisely locate these other occurrences, a trail of destruction could not be identified. However, the photographic evidence showed that all these effects were typical of tornado damage. Observations from a nearby radar have shown rotation over the location in Murtosa between 05:05 and 05:10 UTC (hereby, time is always referred to as UTC).

Synoptic and Atmospheric Environment

The ECMWF m.s.l.p. short-term forecast shows, in the early hours of 8th April 2024, a complex low system with its main core located to the north-northwest of the British Isles, affecting a large part of western Europe. On its southern edge, a secondary low named as storm "Pierrick", was visible to the west of Brittany (France) (Figure 1). A cold frontal surface was associated with this low and, by 06 UTC, was positioned close to the western coast of mainland Portugal (Figure 1). This frontal boundary crossed the Portuguese territory. In the pre-frontal environment, a moderate to strong south-southwesterly flow was advecting a moderate-high pseudo wet-bulb potential temperature airmass (12-16 °C) with moderate precipitable water content (22.5-27.5 mm) and reduced instability (a relative maximum of up to 100-300 J/Kg over the northern part of the west coast, but generally < 50 J/Kg in the environment). The post-frontal environment was characterized by a cool and relatively moist airmass with a pseudo wet–bulb potential temperature below 10 °C. The jet streak, with its right entrance located over the Portuguese coast, was reinforcing lift conditions there and creating a moderate 0-6 km layer shear, of the order of 16-



▲ *Figure 1 – Mean sea level pressure (solid contours, 4hPa intervals) and wind (barbs), 10 m wind, of ECMWF model short term forecast (H+06) at 06 UTC. 08th April 2024. Storm "Pierrick" is referenced and cold front position at surface is depicted by a blue line.*



▲ *Figure 2 – Vertical wind profile of horizontal wind (barbs), VVP algorithm, 04:26-05:26 UTC, 08th April 2024, Arouca radar.*

18 m/s. However, it was a shearing situation with negligible veering in the layer (Figure 2). It is also interesting to note that the wind shear above 3000 m was, indeed, very small. This wind profile was computed from radar data taking an atmospheric volume with 25 km radius from it. Thus, it was considered as representative of the atmosphere in which the phenomenon was generated.

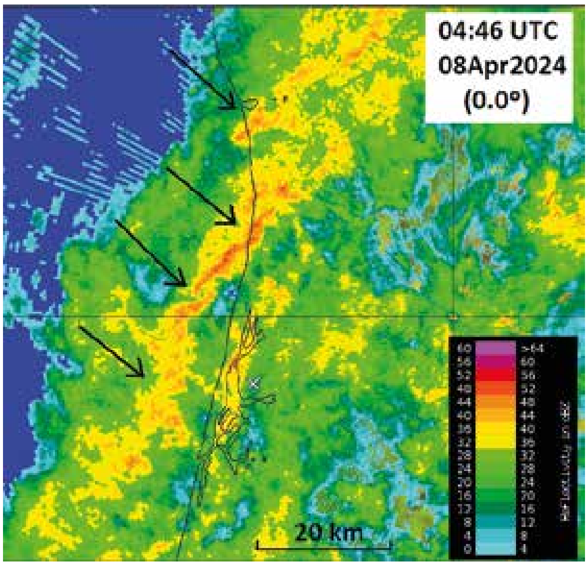
According to these elements, the ingredients of low instability, moderate low-level moisture, considerable vertical wind shear in the deep layer (although weak above 3000 m) and some lift, coincided by 06 UTC in the area where the damaging wind event occurred.

Radar analysis

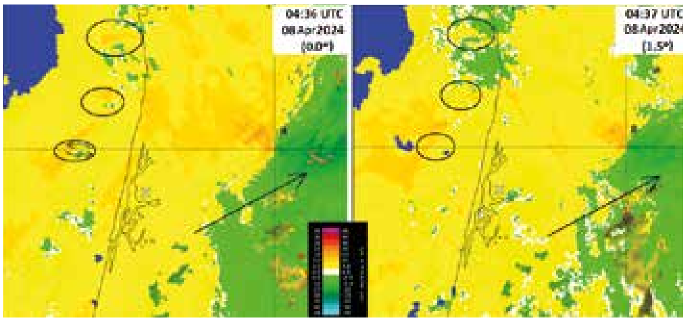
The referred environment and the corresponding synoptic regime were similar to the ones that have been described in Leitão and Pinto (2020), as being typical of the Type IIa tornado types (Agee, 2014) occurrence in Portugal. These types were usually observed along a cold frontal boundary. Even if upper level jet streaks were present, usually they were not overlapping large instability areas and/or deep layer shear. So, the underlying environments were, in fact, not favorable to the formation of supercells, in the sense that deep and persistent rotating updrafts were not observed on radar, during those cases. Instead, multiple short-lived mesovortices (MV) were frequently identified, embedded in the Line Echo Wave Pattern (LWEP) of a Quasi linear convective system (QLCS). There is no universal definition for a QLCS. In Portugal, a quasi-linear pattern of low-level reflectivity above 35 dBZ, with no gaps over at least 40 km, is taken as a QLCS. Radar observations reveal that these QLCS may appear as LEWP on reflectivity patterns. These patterns correspond to a squall line of convective storms that indicate the presence of low pressure areas that are the cause of the formation of characteristic bowing structures.

On 8th April 2024, as the frontal boundary was approaching the coast, low-level radar observations (PPI, Plane Position Indicator) were accessed. Those observations revealed a LEWP, observed in detail during the period 04:36 – 05:06 UTC. An example of the squall line of convection and its reflectivity pattern is presented at 04:46 UTC (Figure 3).

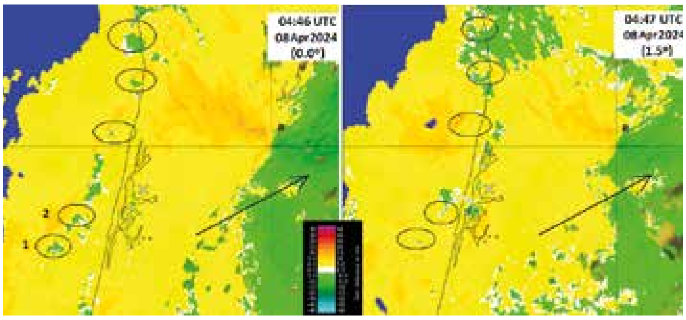
The QLCS was followed on Doppler radar imagery during the referred period (figures 4–7), in order to detail several aspects of the animation of the system. At 04:36 UTC (figure 4, left), there were noted 3 rotation signatures at approximately 1200 m a.m.s.l., as seen by the lowest tilt. At almost the same time (figure 4, right), the rotation signatures were noted at around 2300 m a.m.s.l., as seen by a higher tilt. These rotation patterns, defined as couplets (inbound-outbound) in Doppler velocity, were easier to identify at the lower altitude, as they were better defined there. These signatures corresponded to vortices that developed along the bowing parts of this QLCS. The mesovortices (MV) have distinctive characteristics as compared to supercells. Their small-scale rotation is, typically, firstly identified at very low-levels (as in this case, below 2500 m a.m.s.l.) and tends to build



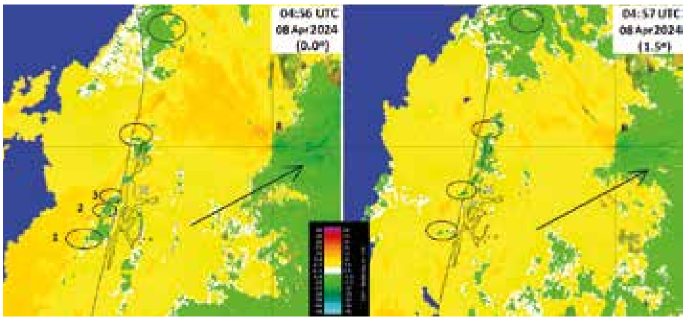
▲ *Figure 3 – PPI of reflectivity (Z, dBZ), 0.0° tilt, 04:46 UTC, 08th April 2024, Arouca radar. Arrows point to bowing structures that define a squall line, forming a LEWP in the frontal boundary. "X" marks the location that would be affected by damaging winds by 05:06 UTC.*



▲ *Figure 4 – Left: PPI of storm-relative velocity (m/s), 0.0° tilt, 04:36 UTC. Right: PPI of storm-relative velocity (m/s), 1.5° tilt, 04:37 UTC. 08th April 2024, Arouca radar ("R"). Mesovortices (MV) locations are depicted by circles. Curved arrows define a cyclonic rotation signature, as an example. Large arrow represents average advection of the MV. "X" marks the location that would be affected by damaging winds at 05:06 UTC.*



▲ *Figure 5 - Left: PPI of storm relative velocity (m/s), 0.0° tilt, 04:46 UTC. Right: PPI of storm relative velocity (m/s), 1.5° tilt, 04:47 UTC. 08th April 2024, Arouca radar ("R"). Mesovortices (MV) locations are depicted by circles. "1", "2" represent MV followed over time. Large arrow represents average advection of the MV. "X" marks the location that would be affected by damaging winds at 05:06 UTC.*



▲ *Figure 6 - Left: PPI of storm relative velocity (m/s), 0.0° tilt, 04:56 UTC. Right: PPI of storm relative velocity (m/s), 1.5° tilt, 04:57 UTC. 08th April 2024, Arouca radar ("R"). Mesovortices (MV) locations are depicted by circles. "1", "2", "3" represent MV followed over time. Large arrow represents average advection of the MV. "X" marks the location that would be affected by damaging winds at 05:06 UTC.*

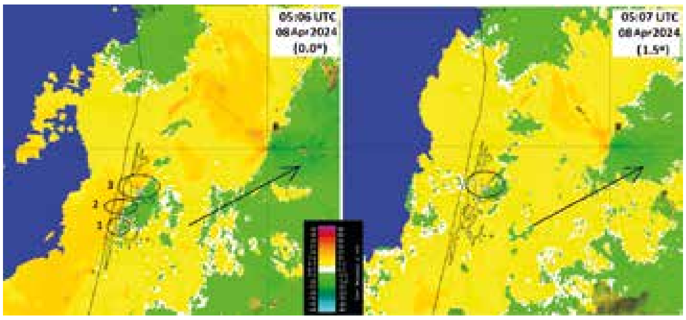
upwards in time, although this is not always easy to confirm in observations. This rotation is co-located with the bowing structures on reflectivity and is, in fact, the primary cause for the bowing. This can be confirmed by comparing low-level reflectivity at 04:46 UTC (figure 3) with low-level Doppler velocity at the same time (figure 5, left). It is clear that each bowing structure identified on reflectivity to the north of the radar site, over the coast, is collocated with each rotation center.

At 04:46 UTC, five MV rotation signatures were noted, as two new patterns were identifiable at an altitude of 1200 m (figure 5, left, marked as "1", "2"). Higher, at approximately 2300-2500 m a.m.s.l. (figure 5, right) the signatures were also identified but, once again, it is clear that they are better defined at the lower levels.

At 04:56 UTC, the MVs were identified close to the coastline or even inland, at the low levels (figure 6, left), at around 1200 m altitude. Again, the signatures were also followed above, at 2200 – 2400 m altitude (figure 6, right) but, once more, are less clearly resolved than at the lower levels. The MVs that were marked as "1" and "2" at 04:46 UTC (figure 5, left) have progressed northeastwards by 04:56 UTC and a new MV is, now, identifiable as "3" (figure 6, left).

Finally, by 05:06 UTC, three MVs were identified inland at the lowest level (figure 7, left). Around 1000 m above (figure 7, right) only the signature of MV "3" was identifiable. The azimuthal shear was computed at both levels (not shown) to evaluate the magnitude of rotation associated with each rotation center observed during the entire period. It was found that the strongest rotation was associated with this MV "3" at 05:06 UTC. Furthermore, the rotation was similar at both levels only for this stronger MV, at the time it was over the location where damaging winds were reported.

There is an observational characteristic suggesting that a MV has a genesis quite distinct from that of a supercell (SC). The SC is generated by a mechanism that converts horizontal vorticity that is available at low levels in the environment (through favorable wind shear in the boundary layer), into vertical



◀ *Figure 7 - Left: PPI of storm relative velocity (m/s), 0.0° tilt, 05:06 UTC. Right: PPI of storm relative velocity (m/s), 1.5° tilt, 05:07 UTC. 08th April 2024, Arouca radar ("R"). Mesovortices (MV) locations are depicted by circles. "1", "2", "3" represent MV followed over time. Large arrow represents average advection of the MV. "X" marks the location affected by damaging winds at this time (MV "3").*

▲ *Figure 8 - General view of a property wall (left), in Murtosa. Damaged wall after the strong wind event of the 08th April 2024 (right) (photo in public circulation on the Internet).*

vorticity, through the ascending updraft that forms the mesocyclone. This SC could, then, spawn a tornado originated from its mesocyclone. The SC is the most long-lived mesoscale storm in the atmosphere, due to its prolonged steady state. The MV is thought to be formed as the result of convergence between air masses, perhaps similar to, although with more intense atmospheric circulation than, the case seen in the formation of land/water spouts. In a QLCS the convergence is provided by a squall. If the convergence ensures availability of vertical vorticity and there is enough instability in the environment at low levels to produce a strong ascending current, should the two be collocated, this updraft may acquire rotation. In this case no mesocyclone forms, and by stretching mechanisms a vortex will start from the surface, upwards.

Radar observations of this event seem to support this mechanism. For each rotation center, the signatures detected at lower levels were always more clearly resolved and detected earlier than the ones observed at higher levels. Furthermore, the magnitude of rotation in each center was always greater at lower levels. Only in the case of the vortex that affected the surface with damaging winds, the magnitude of rotation was similar at lower and higher levels. This suggests a larger upward extension of the rotation in the stronger MV that was observed in the area.

Damaging wind event

According to available documentation and reports, it was found that this phenomenon of strong wind caused a property wall to topple along more than 30 m (figure 8). This location corresponds to the one marked in the radar imagery. The level of destruction can be seen by comparing the situation before (figure 8, left) and after (figure 8, right) the event. For places not far from the location, and at the same time, the destruction of an agricultural farm, two houses left roofless, and trees uprooted were also reported, however, the locations could not be confirmed and for this reason, it was not possible to identify a trail of destruction.

The application of technical procedures to the analyzed elements, allowed to assess that the intensity of this event was F1/T2 (F, Fujita scale, 1971; T, Torro scale, 2012).

Nowcasting challenge

These phenomena have a significant impact at the local level but are extremely difficult to forecast due to the very short life span and the reduced spatial scale. First, it is not possible to predict the exact location and time of formation of the vortices. Then, from the available observation, including the always difficult interpretation of radar images, it is not possible to distinguish from all the vortices that are active, which one has the characteristics that allow it to evolve until effects are noticed.

However, the regions of the country that may be affected, the synoptic environments in which they may occur, and the necessary ingredients for their formation have been identified. This allows the reporting of the risk to the Civil Protection authorities and close monitoring.

IPMA has been working on a nowcasting warning dedicated to small-scale convective phenomena, to be made available to the public. However, without a consistent forecast of location, time, and intensity, it is a challenge to raise public awareness of the risk and propose a reliable warning.

Bibliography

A Recommendation for an Enhanced Fujita-Scale (EF-Scale), Wind Science and Engineering Research Center, Texas Tech University, June 2004

An illustrated verbal description of the TORRO-and Fujita-Scales adapted for central Europe consideringbuilding structure and vegetation characteristics, Feuerstein B., Dirksen E., Dotzek N., Groenemeijer P., Holzer A., Hubrig M., Rauch E., 5th European Conference on Severe Storms, October 2009, Germany

Proposed conceptual taxonomy for proper identification and classification of TornadoEvents, Agee, E., Jones, E., Wea. Forecasting 2009, 24, 609–617, doi: 10.1175/2008WAF2222163.1

Tornadoes in Portugal: An Overview, Paula Leitão and Paulo Pinto

http://www.torro.org.uk/site/index.php

Review of thunderstorm activity in june 2023

Jennifer Foran and Aoife Kealy, Met Eireann

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

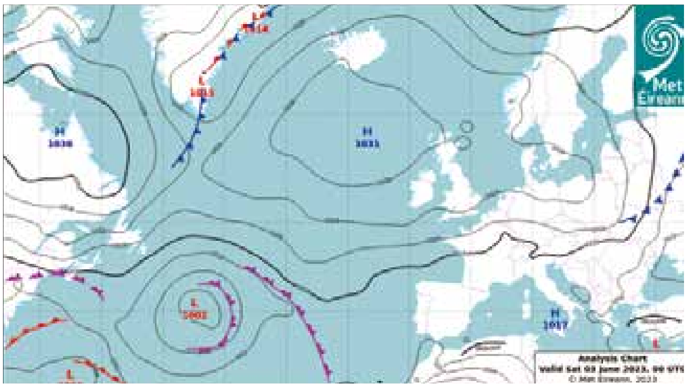
Table 3: Thunderstorm Warning Thresholds

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.

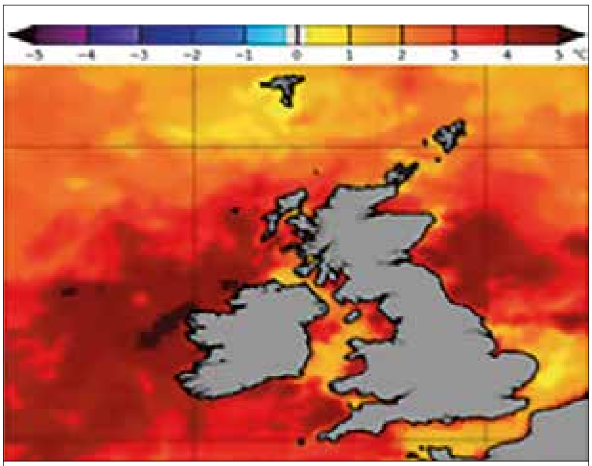
This article concentrates on the experience of operational meteorologists forecasting thunderstorms for one day during this period (Saturday June 17th), as an illustrative case study of the experience of forecasters during this spell of exceptional convective activity. It will examine what the models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



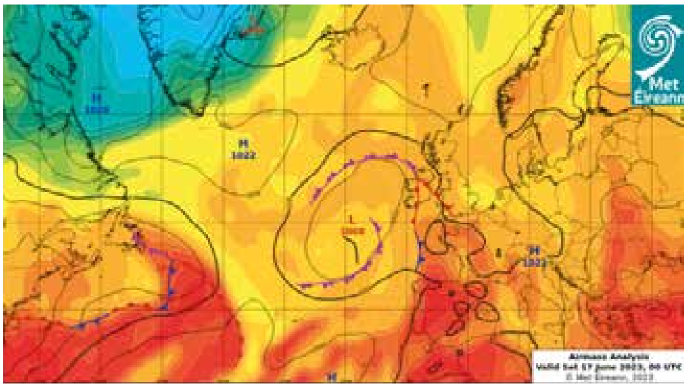
▲ *Figure 2: Daily 5 km SST Anomalies June 20, 2023 (NOAA Coral Reef Watch)*

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 average 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.

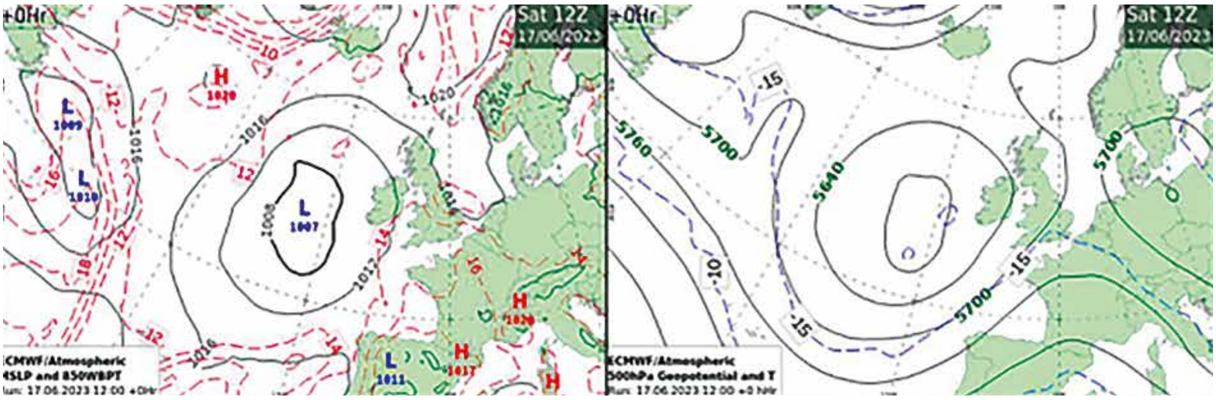
Case study: Saturday June 17

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



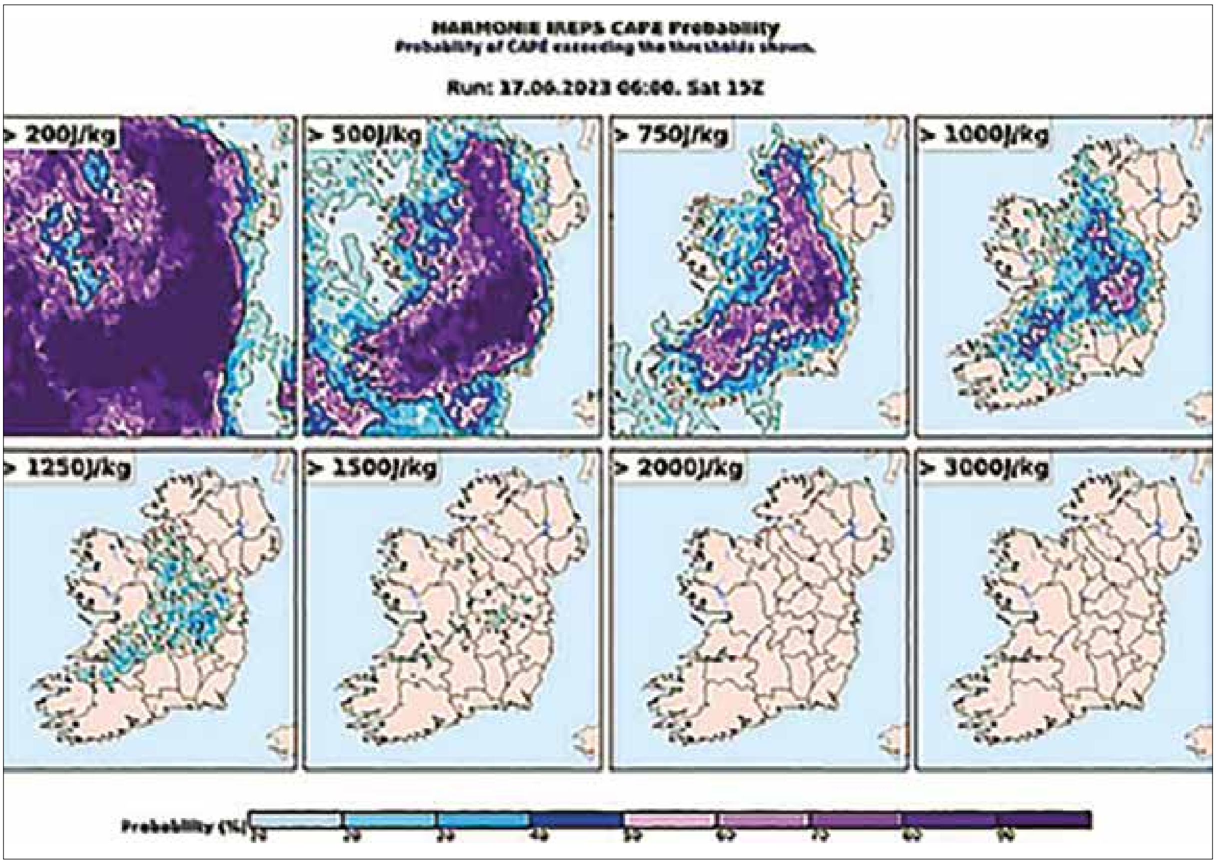
▲ *Figure 3: Airmass analysis chart 0000UTC June 17th*



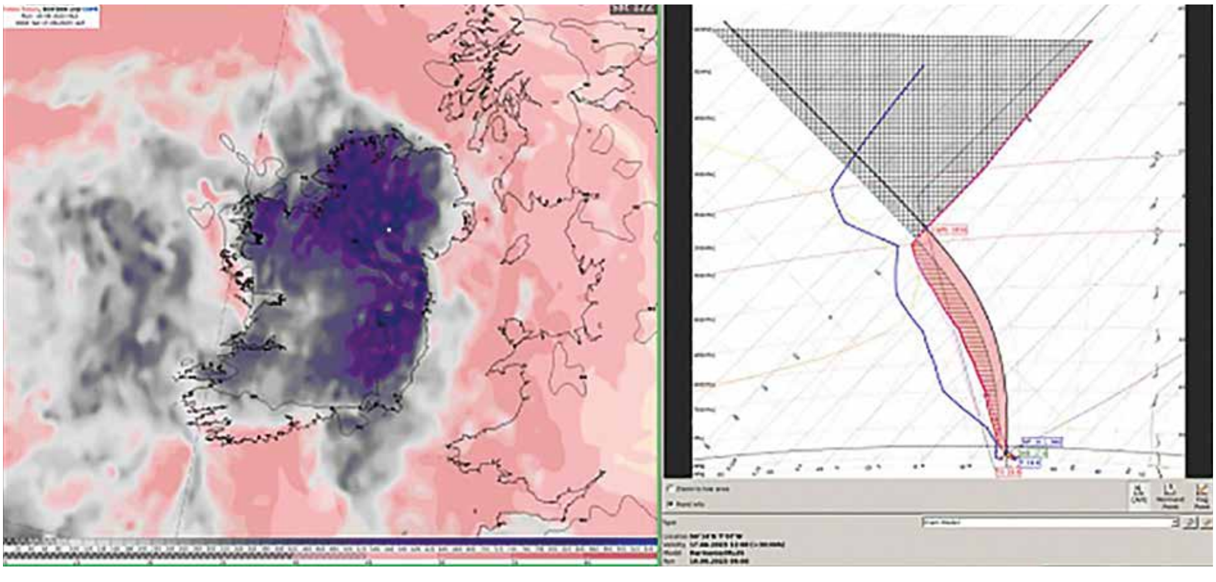
▲ *Figure 4: ECMWF MSLP and 850WBPT (left) and 500hPa geopotential and temperature (right), 1200UTC June 17th* thunderstorms over the southern half of the country, which cleared to the southeast around 0800UTC. Ireland remained in a mild and moist airmass thereafter, with 850hPa wet bulb potential temperatures 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

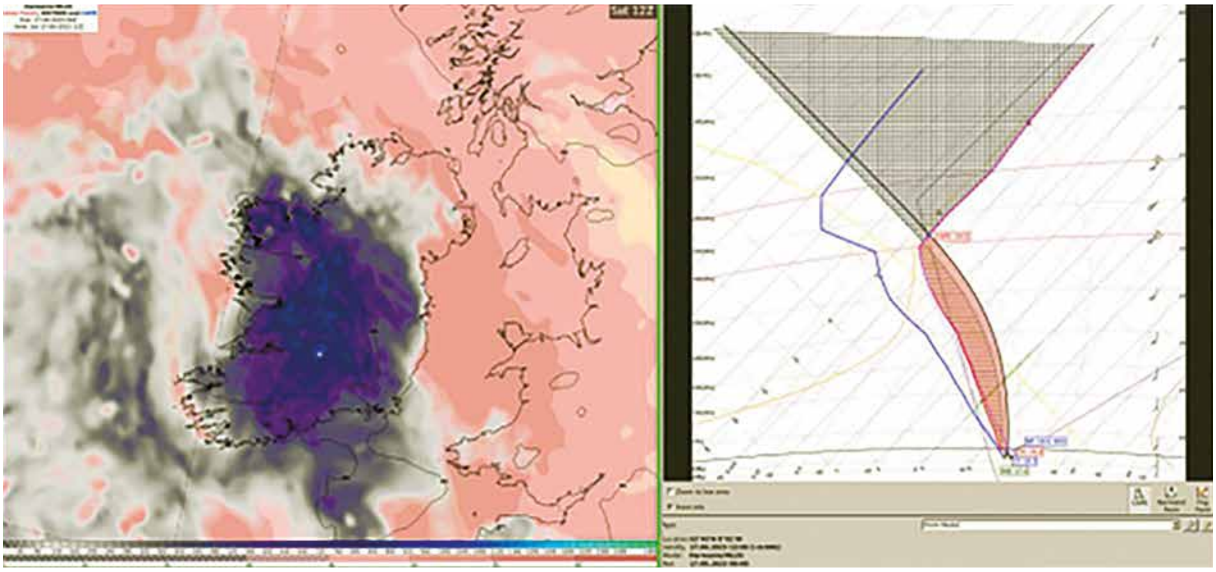
When forecasting thunderstorms, several indices are considered. This article focusses on Convective Available Potential Energy (CAPE), which is an indicator of the energy available for thunderstorm development. Other indices considered were the Boyden index, which is a measure of atmospheric instability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

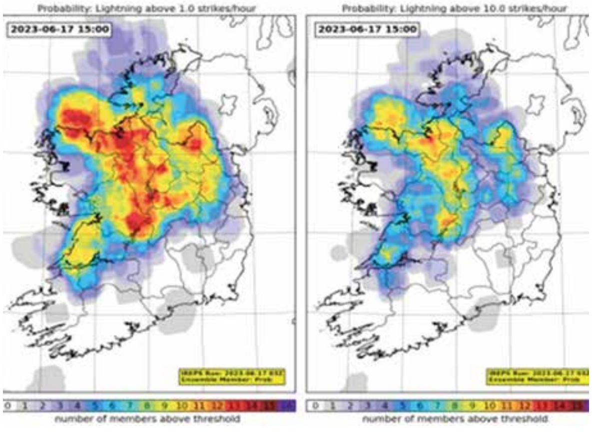


▲ *Figure 7: IREPS control members instability indices (Total totals, Boyden & CAPE) for 1200UTC June 17th (0600UTC run June 17th)*

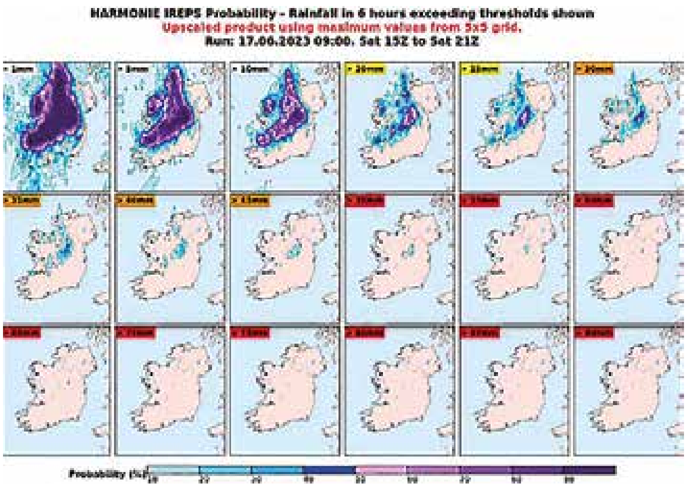
tals index, a combination of the Vertical Totals and Cross Totals indices.

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

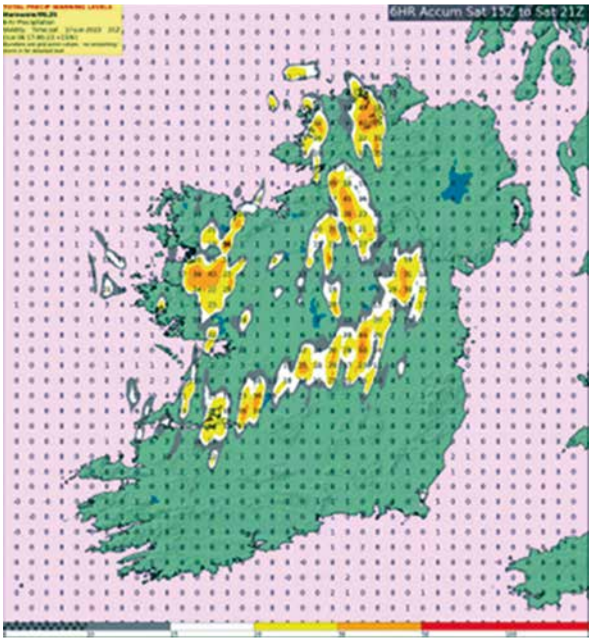


▲ *Figure 9: IREPS rainfall probability of 6 hourly totals exceeding threshold.*

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)*

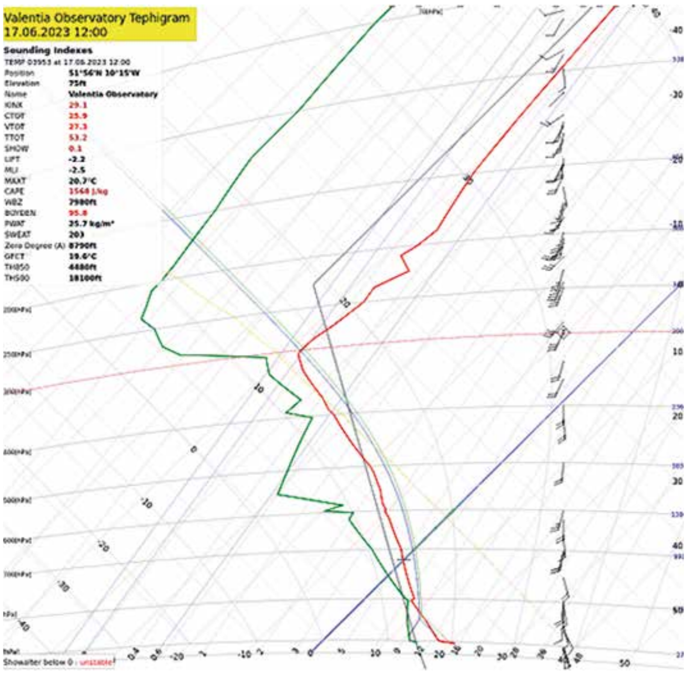
Warnings Issued

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

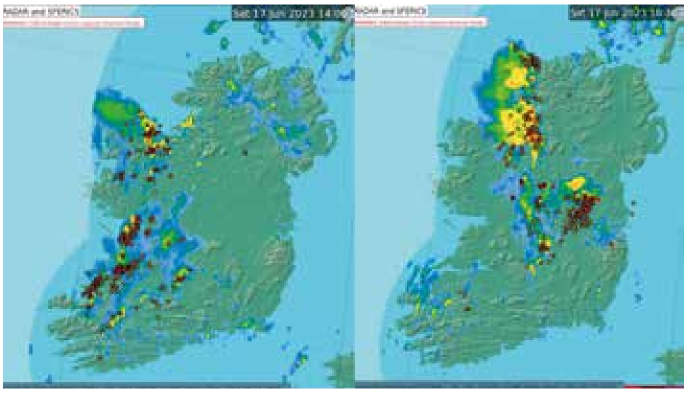
The 1200UTC observed tephigram taken at Valentia, Co. Kerry in the southwest of Ireland (Figure 11) showed a very unstable set up with high SBCAPE of 1568J/kg and other instability indices also indicating probable thunderstorm activity. The boundary layer was adiabatic with surface temperatures of nearly 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

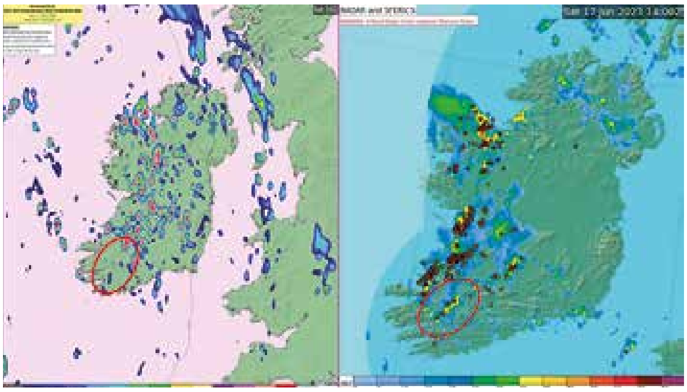


▲ *Figure 11: 1200UTC Valentia observatory Tephigram June 17th* consideration is that the model does not accurately represent the height of the mountains in the southwest of Ireland.

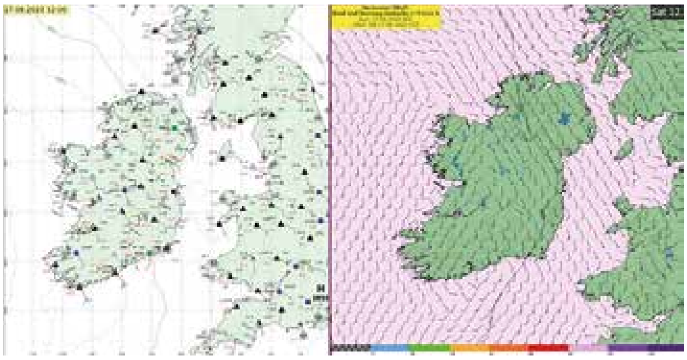
Rainfall in many stations exceeded 10mm in one hour, with a number of stations reaching or exceeding 15mm in one hour (Figures 15 and 16). These stations were mostly located in the south and west.



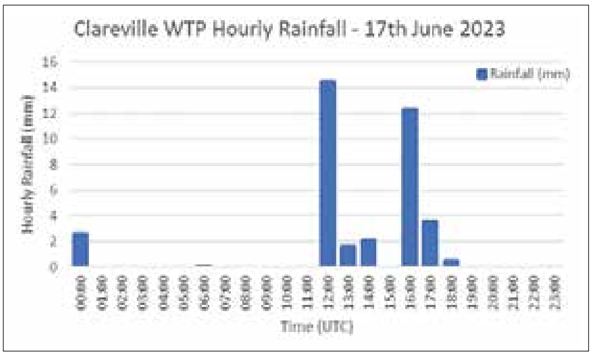
▲ *Figure 12: RADAR and sferics for 1400UTC (left) and 1830UTC (right) June 17th*



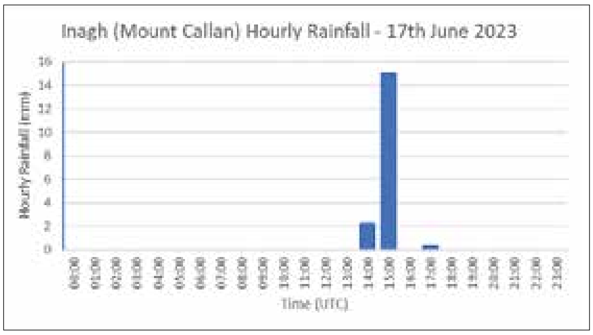
▲ *Figure 13: IREPS control instant rainfall forecast (left) and RADAR (right) Saturday June 17th 1400UTC*



▲ *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.

HOME | NEWS | IRISH NEWS

SHOCKING | Two lifeguards injured in lightning strike on Kerry beach

Several other town centre buildings are understood to have suffered flood damage

Flooding in Tralee this afternoon

Sinead Kelleher, Tadhg Evans and Simon Brouder
Sat 17 Jun 2023 at 17:37

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.

House catches fire after being struck by lightning in Clare

IRELAND

Fire crews remain at the scene of a house fire in north Clare on Saturday afternoon believed to have been started by a lightning strike during a thunderstorm. Photo: Press 22

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