Severe weather

The impact of severe weather on society and the economy

Weather-related natural disasters have major consequences for society and the economy. Over the last two decades, many thousands of lives have been lost as a result of windstorms, tropical cyclones, floods, drought, cold outbreaks and heat waves. In Europe alone, overall losses from severe weather total billions of Euros annually. The storms Lothar and Martin of December 1999, which affected France and Germany, resulted in catastrophic damage to property, forests and electricity distribution networks. Lothar alone killed 125 people; and total losses due to windstorms in 1999 exceeded €13 billion. The exceptional heat wave that affected most of Western Europe in August 2003 killed over 20,000 across Europe and caused economic losses of €8 billion.

Forecasts of severe weather events are vital to warn authorities and the public, and to allow appropriate mitigating action to be taken. Early warnings, made a few days ahead of potential events, are of significant benefit, giving additional time to allow contingency plans to be put into place.

A train is blown off its tracks, caused by the winter storm Kyrill in 2007. **Photograph** – picture-alliance/ dpa.

Forecasting severe weather

The European Centre for Medium-Range Weather Forecasts (ECMWF) provides 3 to 15 day weather forecasts to its Member States and Co-operating States. These are used by the national weather services to provide early warnings of severe weather to their customers, including civil protection agencies and the general public. At shorter range, national weather services issue more detailed warnings, using local observations and additional information from their own regional and local short-range forecast models.

ECMWF is an intergovernmental organisation supported by more than 30 states. Its principal objective is to produce operational weather forecasts for up to two weeks ahead and to disseminate this information to the national weather services of its Member States.

The ECMWF ten-year strategy places particular emphasis on improving our capability to provide our Member States and Co-operating States with early warnings of severe weather. This has already yielded a number of innovative products, including the Extreme Forecast Index, and tropical cyclone tracks and strike probability maps.

The ECMWF forecasting system provides users with operational forecast guidance twice daily for the medium range. The high-resolution deterministic forecast is run at 16 km resolution and has 91 levels from the surface to a height of 80 km.

While the deterministic model provides a detailed weather forecast for up to ten days ahead, it is also important for users to know how confident they can be in the forecast. For this reason, at ECMWF the deterministic forecast is complemented by an Ensemble Prediction System (EPS). This is a set of 50 forecasts, each started from a slightly perturbed version of the operational analysis. The perturbed forecasts represent the range of possible future atmospheric states consistent with the small but sometimes significant uncertainty in the initial state. In addition, small perturbations are also applied during the forecast to represent uncertainty in the model formulation. The EPS uses the same model as the deterministic forecast, but at lower resolution. The EPS is run to 10 days at 32 km horizontal resolution, and continues out to 15 days run at a reduced 65 km resolution. Once a week, the forecast is extended out to 32 days to provide an outlook for the month ahead. From day 10 onwards, the atmospheric model is coupled to an ocean circulation model.

The predictability of the atmosphere can vary from day to day. The EPS provides a way to quantify the uncertainty in the forecast of specific weather situations. There are times when all ensemble members give similar forecasts for a particular event, indicating that this is a predictable situation and high confidence can be placed in the forecast. On other occasions, there may be a wide range of solutions in the ensemble, indicating low predictability. The proportion of ensemble members forecasting a specific weather event gives an indication of the probability for it to occur. End users - such as civil protection agencies, health authorities, and local authorities - combine this probability with their own information about their sensitivity to certain weather events to manage risk. Early warnings even at relatively low probability alert users to a potential severe weather event and allow them to begin contingency planning.

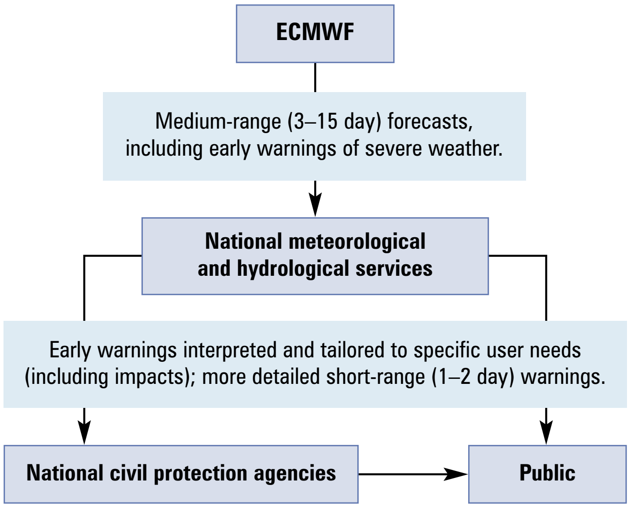
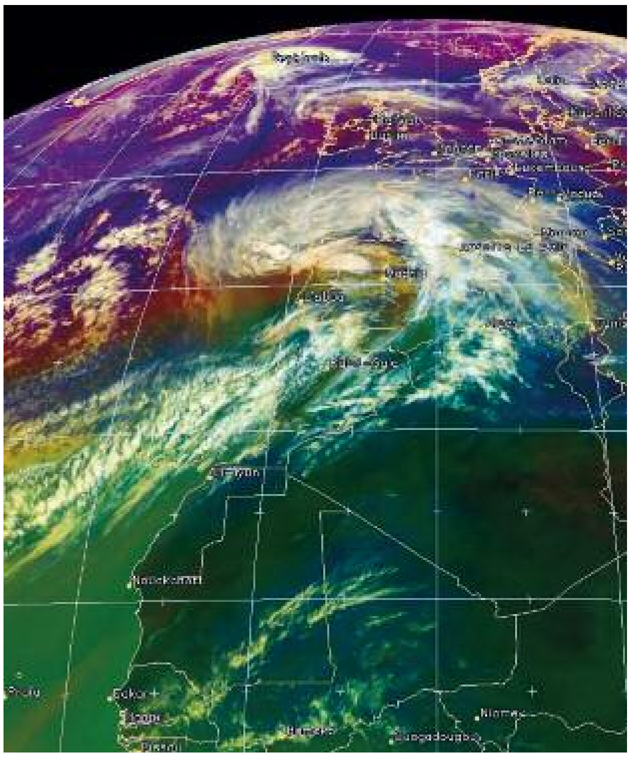


Figure 1 The role of ECMWF and the National Meteorological Services in the provision of warnings of severe weather events.

Used together, the EPS and deterministic forecasts provide users with a flexible warning system that can provide both early warnings of potential severe weather and more precise and detailed information on the location and intensity as the event approaches. The following sections illustrate some of the ways that ECMWF forecasts are used to provide early warnings of severe weather and highlight a number of innovative products that have been developed specifically for this purpose.



Xynthia, a violent European windstorm which crossed Western Europe on 26–28 February 2010. © EUMETSAT, 2010.

Early warnings for severe weather events

The Extreme Forecast Index

The Extreme Forecast Index (EFI) was developed at ECMWF as a tool to provide forecasters with general guidance on potential extreme events. The EFI summarises the information in the EPS in a simple map that can be used by forecasters as an "alarm bell" for a potential severe weather event. The map highlights places where the current forecast is indicating a significantly increased risk of a severe weather event. The EFI does this by comparing the current EPS forecast with a large set of EPS forecasts run over previous years (the model climate). If the current forecast shows a much larger probability than usual for a severe weather event to occur then the EFI will be high and awill be indicated on the map. If the EFI indicates a potential severe weather event, the forecaster can then examine more detailed information from the forecast to make a more thorough assessment of the risk to their customers.

Since the model climate takes account of the variability of the weather parameters in both geographical location and time of year, the EFI allows the user to identify an anomalous weather situation without having to define specific thresholds for an extreme event. Verification results show that the EFI has substantial skill in providing early warnings of extreme events, confirming the subjective experience of forecasters in the Member States where the EFI is widely used to provide guidance on the possible occurrence of extreme weather events.

Flooding

In July 2008, heavy rain in the Carpathian Mountains triggered severe flooding in Ukraine, Moldova, Romania, Hungary and Slovakia, causing serious damage: 36 people died and more than 35,000 were evacuated; total losses amounted to €600 million. As shown in Figure 2, the EPS gave a clear early signal of the risk of heavy precipitation over an extended period.

Precipitation forecasts are increasingly used as input to hydrological models used for operational flood forecasting. The ECMWF EPS forecasts are used in the European Flood Alert System (EFAS) which provides local water authorities and the European Commission with early flood warning information up to 10 days ahead.

The EPS has also been used to drive river discharge models for Bangladesh: all severe flooding events between 2003 and 2008 were operationally forecast up to 10 days ahead, allowing the early evacuation of thousands of people and livestock.

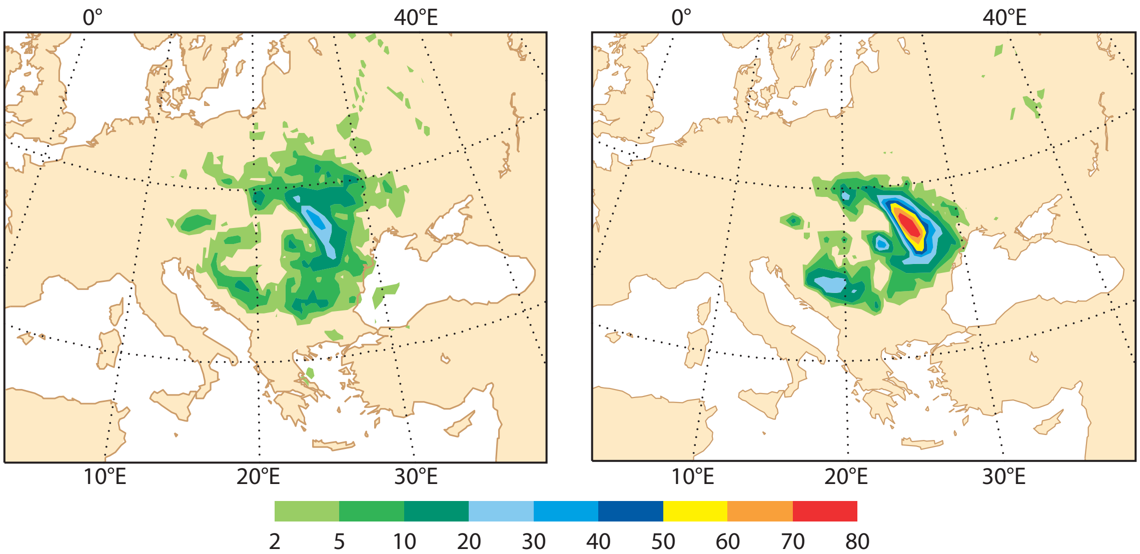


Figure 2 Central and eastern European floods in July 2008. The figures show the EPS probability forecasts for more than 50 mm in the 2-day period 24-26 July. Forecasts from 19 July (5 days before event) already show up to 40% probability for heavy rainfall (left). The signal is much stronger (over 70%) in the forecast from 20 July (right).

Tropical cyclones

ECMWF has developed specialised products for tropical cyclone forecasts (hurricanes and typhoons). If a tropical cyclone is observed at the start of a forecast, its path is automatically tracked throughout the forecast in both the deterministic and ensemble predictions. The ensemble of tracks is used to generate a strike probability map. This shows the probability that the cyclone centre will pass within 120 km of a location within the next 120 hours. The ensemble quantifies the uncertainty in the cyclone track prediction, which can vary substantially from case to case. These ECMWF tropical cyclone products are available to all World Meteorological Organization (WMO) members. The skill of the ECMWF forecasts in predicting both the track and intensity of tropical cyclones has increased considerably over recent years, a consequence of increased resolution and better physics in the model. As well as tracking existing storms, ECMWF forecasts are increasingly able to predict the formation of tropical cyclones up to a week in advance.

Figure 3 shows an intensive period of the 2008 Atlantic hurricane season when three hurricanes (Gustav, Hanna and Ike) were active at the same time. This increased hurricane activity was well captured in the forecasts even before the storms were officially reported. Table 1 shows that on average in this period, the genesis of tropical cyclones was predicted by the model 5 to 7 days ahead of the time they were first observed.

In May 2008, tropical cyclone Nargis struck Myanmar (Burma), causing over 130,000 fatalities, one of the most severe natural disasters of recent decades. The genesis of a tropical cyclone in the Bay of Bengal was predicted up to a week ahead of the observed formation with a probability of 50% for this to occur (Figure 4, left panel). On average only five tropical cyclones occur each year in the north Indian Ocean, so this is a very strong signal for a potential cyclone. Closer to the actual genesis, the probability increased significantly and the uncertainty in location decreased. From the time that Nargis was officially reported as a tropical storm, the track was consistently forecast to make landfall in Myanmar (Figure 4, right panel); initial uncertainty on the location of the landfall reduced during later forecasts.

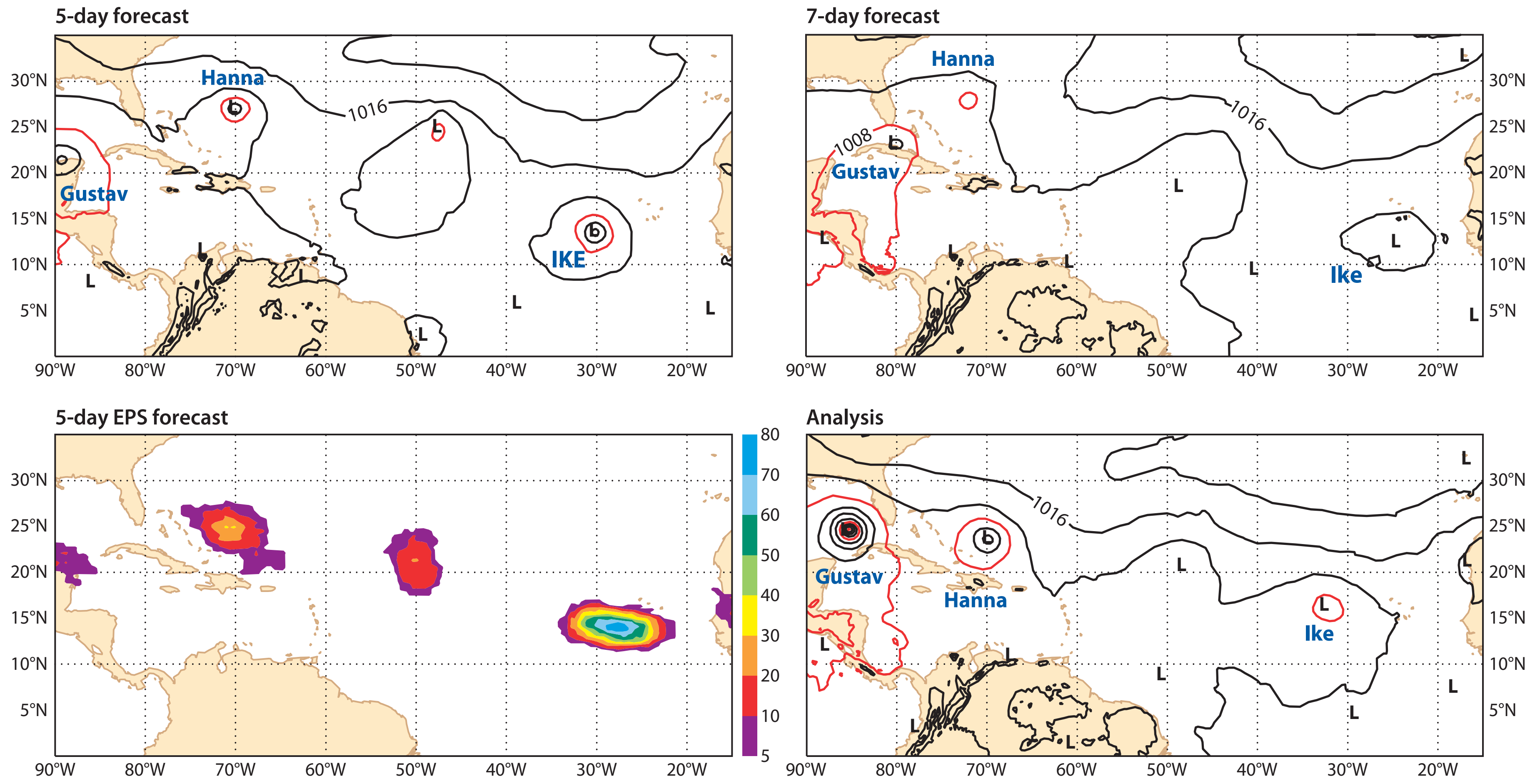


Figure 3 An intensive period of the 2008 Atlantic hurricane season. Top panels show the 5-day and 7-day deterministic forecasts of mean sea-level pressure verifying at 12 UTC on 31 August. These forecasts started before hurricanes Hanna and Ike had been officially observed. The lower-left panel shows the EPS probability for tropical cyclones to be in the region in the 24-hour period between 12 UTC on 31 August and 12 UTC on 1 September. The lower-right panel shows the verifying ECMWF analysis for 12 UTC on 31 August.

Tropical storm	First observed date as tropical cyclone	Genesis first predicted in forecast from
Fay	16 August 2008	10 August (6 days in advance)
Gustav	25 August 2008	20 August (5 days in advance)
Hanna	28 August 2008	23 August (5 days in advance)
Ike	2 September 2008	26 August (7 days in advance)
Josephine	3 September 2008	29 August (5 days in advance)

Table 1 Genesis of Atlantic tropical storms in active period of 2008 hurricane season

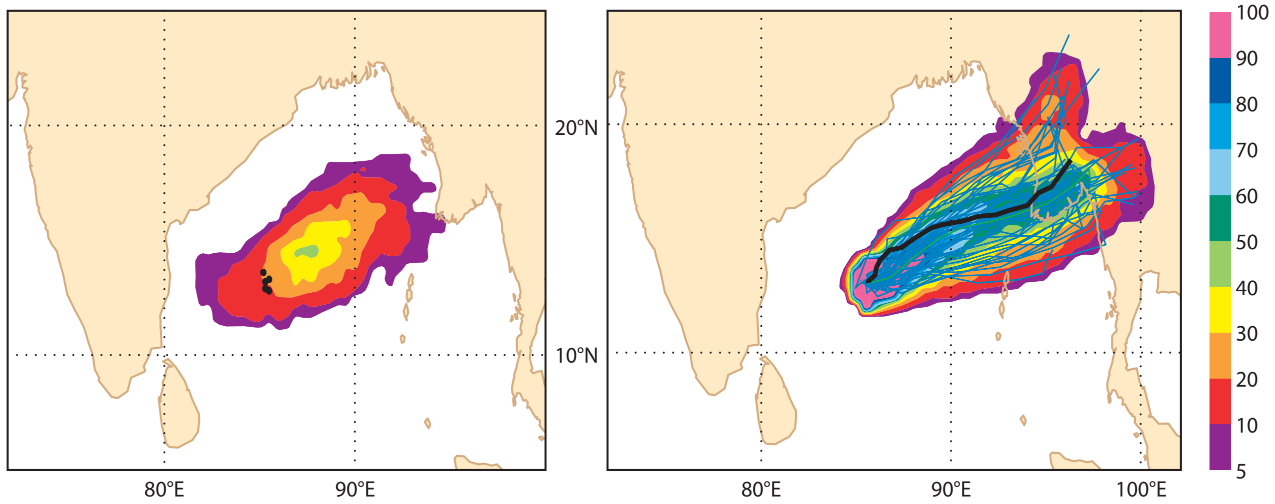


Figure 4 Tropical cyclone Nargis developed during 27 April 2008 and was named on 28 April (as the winds reached tropical storm strength); it made landfall in Myanmar on 2 May 2008. Left panel shows the EPS forecasts from 00 UTC on 23 April 2008: the shading shows the forecast probability for a tropical cyclone to be in this region in the 24 hours between 00 UTC on 28 May and 00 UTC on 29 May; the black dots indicate the observed positions of Nargis during this 24-hour period. Right panel shows the forecast from 12 UTC on 28 April: black line shows the track from the high-resolution forecast, blue lines show the tracks of EPS members, shading indicates strike probability.

Winter storms

In February 2010, winter storm Xynthia caused significant destruction across Western Europe, along its path from Portugal through Spain and France to Germany. Over 70 people lost their lives, and economic losses are estimated at several billion Euros. Xynthia developed from a subtropical low-pressure system in the Atlantic during 27 February and developed into an intense storm during the day, striking Portugal and northern Spain. Xynthia reached the French Atlantic coast during the night of 27–28 February and continued north-eastwards the following day, leaving a trail of damage from extreme winds and heavy rain and also storm surge along the Vendée and Charente Maritime stretches of the French coast. The development of Xynthia was consistently forecast by both the deterministic forecast system and the EPS several days in advance. Figure 5 shows the forecasts for 28 February initialised at 00 UTC on 26 February. The track of Xynthia was well forecast by the high-resolution model. The EPS confirmed extreme winds and heavy rainfall were very likely, giving forecasters high confidence in the predictions.

In January 2007, another severe winter storm (Kyrill) affected many areas of northern Europe, crossing from the UK into northern Germany on 18 January and continuing eastwards to affect Poland, the Czech Republic, and Austria. Extreme winds caused extensive damage over large areas. With total losses put at around €8 billion, this ranks as the second most damaging storm event to affect Europe, exceeded only by Lothar in 1999. Medium-range forecasts gave early warning of a storm affecting the region, with increasing probability of extreme winds as the event approached. Based on the ECMWF forecasts, the German Weather Service, DWD, issued advance warnings as early as 13 January, 5 days ahead. This provided the disaster management agencies with key planning information, enabling the Federal Office for Civil Protection and Disaster Assistance to set up an emergency task force, and giving time for staffing levels to be increased in crisis management centres.

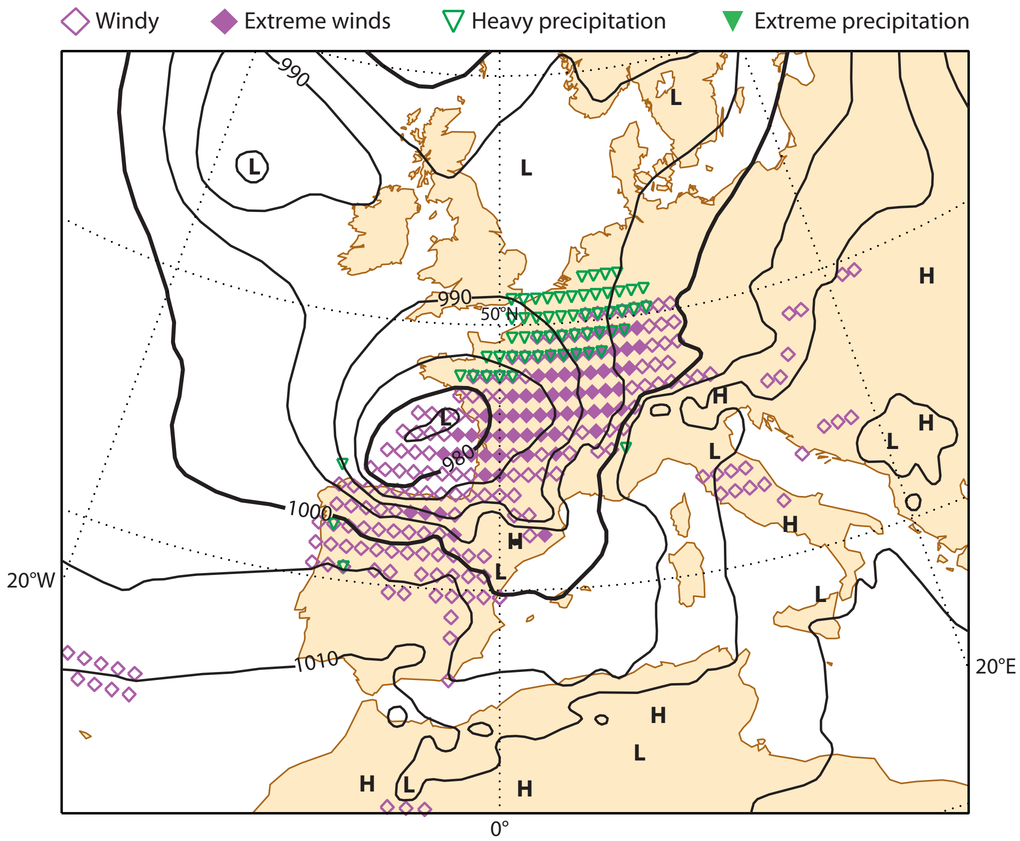


Figure 5 Early warning for winter storm Xynthia, February 2010: high-resolution deterministic model and EPS forecasts initialised at 00 UTC on 26 February. Contours show the sea-level pressure field for 00 UTC 28 February as forecast by the deterministic model. Coloured symbols show the Extreme Forecast Index (EFI) warnings of extreme winds (purple symbols) and heavy rainfall (green symbols) to occur during the 28 February (00 on 28 to 00 on 1 March). Filled-in symbols indicate greater risk of extreme events.

Heat waves

In July 2007, much of south-eastern Europe was affected by a heat wave. The event lasted about one week centred on 20 July 2007, with temperatures rising above 40°C. Many casualties were reported as a result of the sustained high temperatures. The ECMWF forecasting system gave good early warnings, already apparent in the 15-day forecast. Figure 6 shows the 15-day and 10-day EFI for temperature for 20 July, giving a clear indication of extreme warm temperatures over Italy and the Balkans at the 15-day range (left), which is confirmed in the 10-day forecast (right) issued 5 days later.

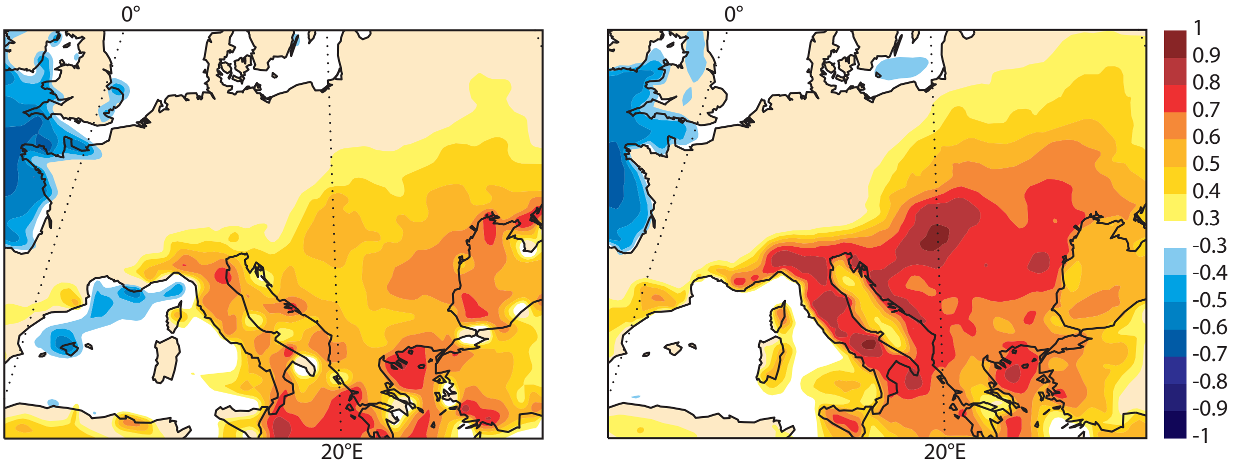


Figure 6 Heat wave in south-east Europe, July 2007. The two panels show the Extreme Forecast Index (EFI) for temperature over Europe on 20 July from forecasts made on 5 July (left) and 10 July (right).

Developing countries

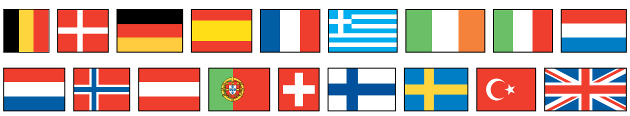
ECMWF provides access to a range of its products, including the EFI and tropical cyclone forecasts, for member states of the World Meteorological Organization (WMO). The WMO has recently initiated a series of Severe Weather Forecast Demonstration Projects (SWFDP) to improve the ability of national meteorological and hydrological services (NMHS) to forecast severe weather events and to improve the interaction between NMHSs and disaster management and civil protection authorities. ECMWF is supporting the SWFDPs by providing additional products relevant for the early warning of severe weather in the regions covered by the project.

Outlook

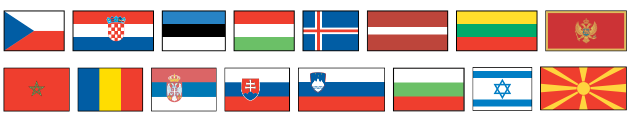
The frequency and economic impact of weather-related natural disasters have been increasing over recent decades. Broad consensus exists amongst scientists that climate change will lead to an increase in the frequency and intensity of extreme weather events, and wind storms, heat waves, floods and droughts are all likely to become more common and more severe in future. Although forecasts cannot prevent these disasters, advance warnings are vital to allow authorities to take appropriate action to mitigate the effects of these events.

ECMWF will continue to work in close co-operation with its Member States and Co-operating States to develop and validate further products to meet the operational needs for severe weather warnings.

Member States



Co-operating States



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