The Meteorological Vigilance: Météo-France Warning System *Brief history, Description and Reflections*

bruno.gillet-chaulet@meteo.fr, **Météo France (DIROP/PG)**

Introduction

Established in 2001, the Meteorological Vigilance (Calmet, 2018) is the facility used by Météo-France to warn* the authorities and the population of the occurrence of dangerous weather phenomena or floods. It is deployed in metropolitan France and in the French overseas territories. This article gives a brief history of the system, describes its operation, and offers some thoughts on its development and use.

Brief history

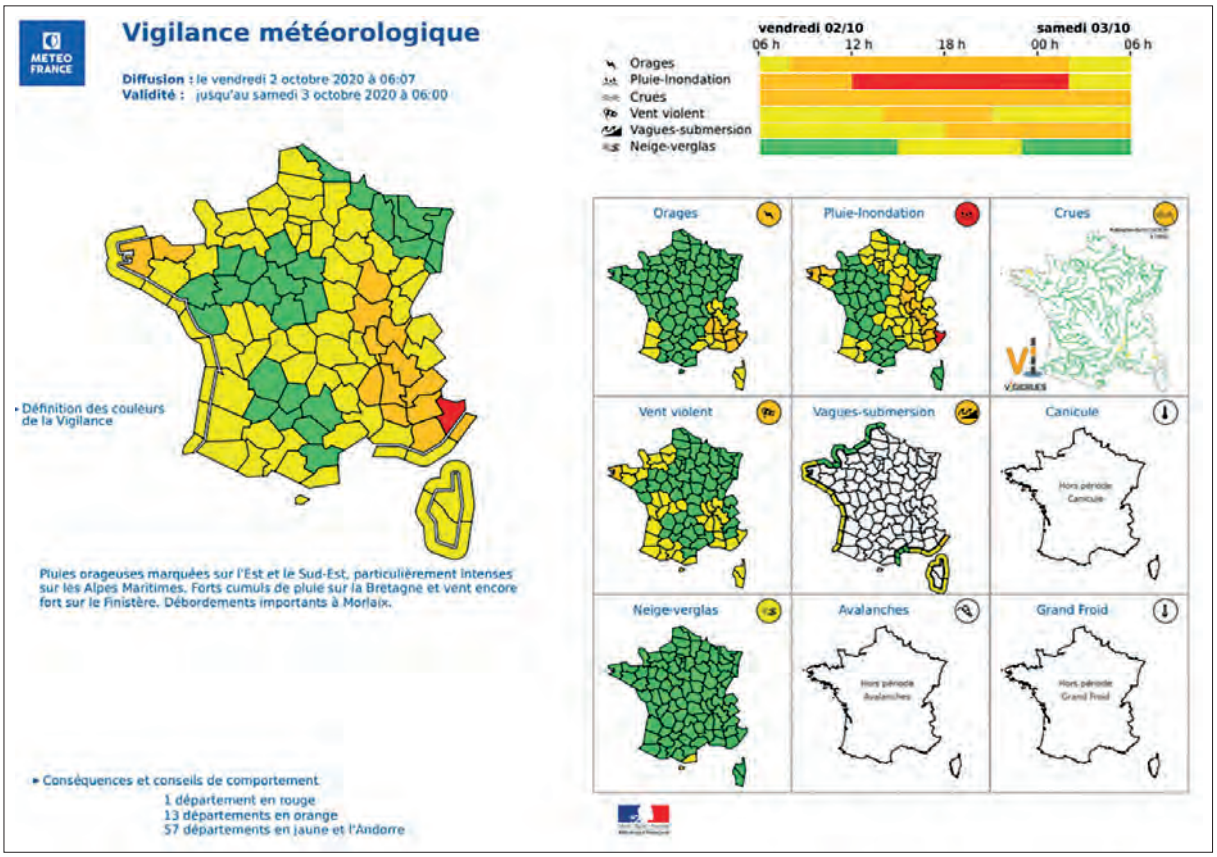
In December 1999, the consequences of the windstorms *Lothar* and *Martin* (92 casualties in France) highlighted the ineffectiveness of the meteorological/weather warnings at that time. These consisted of specific "text" bulletins issued to the authorities on the one hand and special "communiqués" sent to the media on the other (Lepape, 2004). A lack of "meteorological risk culture" clearly appeared during these episodes.

This observation led to the idea of a simpler system, giving the authorities AND the general public the same level of information, describing the expected consequences of the predicted meteorological events and prescribing the behaviours to adopt in order to cope with them. The stated aim was to involve the citizen in their own safety (and that of others). This system was inspired by those already in place in the French overseas territories, used and tested for the management of recurrent risks linked to tropical cyclones. It took advantage of the development of the Internet to allow graphics to become a more important constituent of the information available. Called "Meteorological Vigilance" (https://vigilance.meteofrance.fr/fr), this system was implemented on October 1, 2001 based on the main principles described below. It has undergone evolutions and has been improved to adapt itself permanently to the needs. Some of the milestones are presented below. Originally designed to cover 5 different phenomena (Wind, Rain, Thunderstorm, Snow or Ice and Avalanches), it was extended in 2004 to cover High Temperature and Low Temperature. In 2007, the Central Service of Hydro-meteorology and Flood Forecasting Support (Schapi) of the Ministry of Ecological Transition produced the Flooding Vigilance (Météo-France now relays information from the "Vigicrues" network of rivers monitored by the State, https://www.vigicrues.gouv.fr/), and the Rain phenomenon became Rain-Flood to integrate this new element. Since 2011, the Vigilance has also provided information on the phenomenon Coastal Event (storm surge), produced with a contribution from the Hydrographic and Oceanographic Service of the Navy (Shom). Initially valid for the coming 24 hours, the time-frame covered by the Vigilance was extended in 2022 to the entire next day in the form of a "double map" showing the days "Today" (D) and "Tomorrow" (D+1) **(figure 1)**.

In France, this system is regulatory i.e. it is the subject of an inter-ministerial "circular" (https://www.legifrance.gouv.fr/circulaire/id/45225?origin=list&page=4, involving the Ministries of Ecological Transition, the Interior and Solidarity and Health) which "specifies and reaffirms the guiding principles of the Vigilance and its articulation with crisis management systems".

Fundamental principles

1. At any given moment, the Vigilance indicates the level of danger to which a territory is subject for the upcoming deadlines with 4 colours: Green, Yellow, Orange and Red associated with the following definitions:



▲ *Figure 1: Example of a Vigilance map available on the Météo France website. The maximum colour level over the period considered applies to the French "departments". The temporal evolution is displayed at the top with the chronology of the events for each parameter. Case of the memorable "Alex" event of October 2, 2020. This is a simulated "Today" (D) day map for this episode before the implementation of this new presentation in 2022.*

Green Vigilance:

No particular vigilance.

Yellow Vigilance:

Be careful. If you practice activities that are sensitive to meteorological risks or are exposed to floods. Phenomena that are usual in the region but are occasionally and locally dangerous (e.g.: Mistral wind, summer thunderstorm, rising water) are indeed expected. Keep yourself informed of the evolution of the situation.

Orange Vigilance:

Be very vigilant. Dangerous phenomena are expected. Keep yourself informed of the evolution of the situation and follow the safety advice issued by the authorities.

Red Vigilance:

Absolute vigilance is required. Dangerous phenomena of exceptional intensity are expected. Keep yourself regularly informed of the evolution of the situation and follow the safety advice issued by the public authorities.

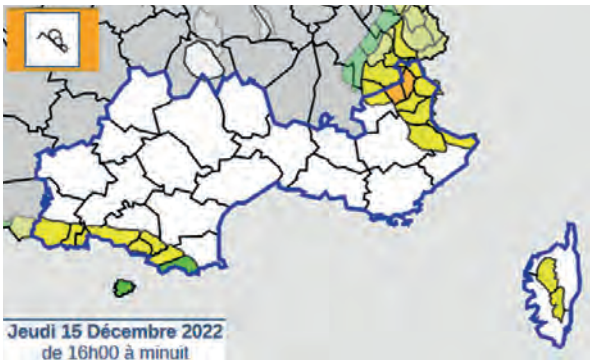
The colour level corresponds to a risk in the sense that it is "a combination of the probability of a meteorological or hydrological event and its consequences" (ISO definition). Thus, decision support criteria have been defined on the basis of thresholds relating to the various parameters monitored and the vulnerability of the concerned territories. These criteria can be modulated according to specific contexts: more intense road traffic during vacation periods, soil moisture, pandemic (as seen with Covid19) etc. This approach is similar to that of an "impact matrix" as proposed in the United Kingdom's weather warnings system ("NSWWS", Suri and Davies, 2021), although the forecast does not explicitly indicate the position of an event in this matrix.

The colour is complemented by text specifying the intensity of the phenomena, their location, their chronology, and the uncertainty inherent in the forecast.

In this system, the meteorological danger information is always available: a territory is constantly placed in a "state of Vigilance". It is not subject to

an "alert*" in the sense described by Suri and Davies, 2021. Thus, unfortunately, the Yellow colour (the equivalent of the first "alert" level defined by these authors) is sometimes discredited in France. Indeed, often triggered at very low thresholds, this colour is very frequently used and does not attract the attention it should, especially for events at the limit of the Orange colour. For these events, special messages (called - SPEZF -) are issued to the authorities (they could be considered as similar to the "Yellow Warnings" of the British system). From 2022, for these cases, a highlighting of bulletins on the Vigilance website seeks to overcome this difficulty.

2. Vigilance is presented at a departmental scale. In France, the department is the administrative unit that plans and manages crises (under the direction of a Prefect, representing the State). Its spatial scale is adapted to the predictability of the phenomena for the targeted deadlines. However, since administrative boundaries do not necessarily correspond to the contours of meteorological events, a reflection is underway to move away from this departmental constraint. In addition, progress in weather forecasting sometimes allows increased geographical accuracy: for the parameters Coastal Event and Avalanches, a visualization at sub-departmental scale was deployed in 2022 **(figure 2)**. For some overseas territories, a division of the department had already been applied.



▲ *Figure 2: Example of sub-departmental visualization for the Orange Vigilance Avalanches episode of December 15, 2022 in the Alps. The colour applies to the division by "massifs" of the mountain ranges.*

3. Determining the level of vigilance is a matter of judgment or decision making (Cadet and Chasseigne, 2009, Klein, 1999). The choice of the colour is made in a collegial manner. It is the result of an exchange between forecasters working at the national level on the one hand, and at the regional level on the other. These players discuss the predicted weather scenario, its uncertainty, the possible consequences and the context of the moment. A representative of the management of Météo-France intervenes when a Red Vigilance is envisaged, this colour being likely to have a significant impact which may place the establishment in the spotlight. In a 2021 "bestseller", Daniel Kahneman and his co-authors (Kahneman and al., 2021) warn against the harmful effects of noise (in the statistical sense) in many fields where these notions of judgment and decision making are involved. We are pleased to note that many of the recommendations advocated by these authors have already been applied through the development of Vigilance at Météo-France: use of objective criteria, aggregation of independent judgements, good knowledge of the "prime rates" (i.e. the climatology of the phenomena), continuous evaluation of situations through active research of new information, training of the operators, systematic feedback on the situations with publication of indicators (described below), etc.

4. The Vigilance is updated at least twice a day at 6 a.m. and 4 p.m. and as much as necessary according to the situation. An update of the Flood parameter is carried out daily at 10 a.m. For the Orange and Red colours, accompanying bulletins are mandatory. They are issued from the "time of the Vigilance" (first map with an Orange or Red colour level) until the end of the event requiring this colour level, with a frequency of 3 hours at the regional level, 6 hours at the national level (from the effective beginning of the event).

From an operational perspective, Vigilance management has two distinct moments: 1. Anticipation (the framework established beforehand) and 2. Monitoring (the follow-up of the weather situation) of hazardous weather events (see an example in "The European Forecaster", Newsletter of the WGCEF N°27, September 2022). The monitoring phase sometimes puts forecasters in difficulty. Thus, when an unexpected event goes out of the framework that has been set upstream (because it was not anticipated!), from what level of severity should we trigger the aggravation of the colour level of the Vigilance? The usefulness of a last minute warning must then be weighed against

* In France, a distinction is made between the notions of *warning* and *alert*. Vigilance refers to the first term. It is thus considered as a first level of information (*warning*) which can lead the authorities, if necessary, to take particular measures (*alert*) concerning the population (evacuations, sheltering, traffic bans, etc.). The alert is the responsibility of the crisis management authorities and not of Météo-France.

the complexity of a procedure that impacts many stakeholders. The decision is sometimes delicate.

To carry out the Vigilance (at the anticipation stage), the Numerical Weather Prediction (NWP) is the main tool used by the forecasters. To date, there is no automatic initialization of the Vigilance from the NWP. However, it should be mentioned that automatic products exist and are consulted. In addition, research using Artificial Intelligence (AI) techniques is currently being conducted, crossing weather predictors and data on field consequences. Operational implementations are not envisaged in the short term however.

Vigilance Evaluation

Vigilance performance is closely monitored. A committee, made up of the stakeholders (see the inter-ministerial circular), meets several times a year for a shared evaluation of the episodes treated with an Orange or Red colour level, or which should have been (we speak of Non-Detection in this last case "ND"). An annual report is published (posted on the Météo France website: https://meteofrance.fr/actualite/publications/documents-institutionnels/les-bilans-vigilance). Indicators have been defined. Some of them have a legal value (i.e. they are taken into account in the French State Budget). More anecdotally, some of them are taken into account in the calculation of the variable part of the remuneration of Météo-France agents! In particular, the following indicators should be mentioned for the phenomena of Wind, Rain, Thunderstorm, Snow or Ice and Coastal Event (on a departmental scale):

– ***The relevance rate.*** It measures the correspondence between the colour issued on a territory and the observation of the phenomenon (intensity, location, chronology). The complementary value corresponds to a False Alarm rate (FA, for example, a department was placed in Orange Vigilance, the expected phenomenon did not occur there or with a lesser intensity). In 2022, the relevance rate amounts to 87% for a target objective ≥ 84% (i.e. a FA rate of 13% for a target ≤ 16%).

– ***The Non-Detection rate.*** Defined above, in 2022 it is 1.4% for a target goal ≤ 2%. FA and ND are in a subtle balance. They depend on the quality of weather forecasts but also on the type of phenomenon, their occurrence (natural annual variability) and their predictability (localized severe thunderstorms are much less well predicted than a large wind-storm...). The target objectives also reflect a social acceptance depending on the state of the art of weather forecasting. Expectations may differ depending on the user! Thus, the general public is particularly sensitive to NDs and these can cause a strong backlash with a questioning of the forecasters' work. Crisis managers are more sensitive to false alarms because of the protection costs that may be incurred (wrongly).

– ***The Detection rates with at least 6 hours and at least 3 hours lead time.*** They reflect the time between the issuance of an Orange or Red Vigilance and the actual onset of an event. In 2022, they are 74% and 90% respectively for targets ≥ 60% and 86%. There is a strong relationship between sufficient anticipation and forecast reliability (in terms of FA and ND). Moreover, finding the right anticipation window can be a challenging issue: is it necessary (or useful) to issue an Orange Vigilance on a Sunday morning at 6 a.m. valid for a wind-storm forecast the next evening (Monday)?

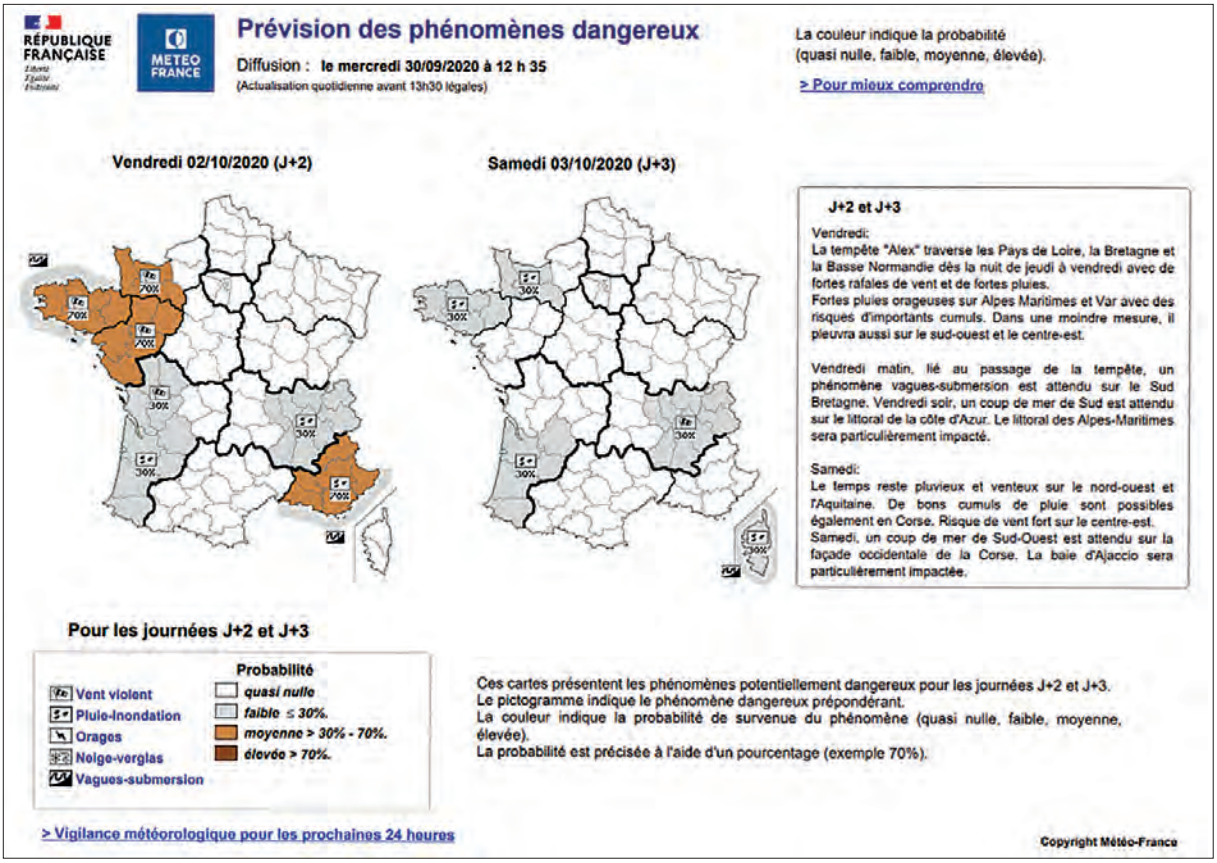
– ***Sub-departmental indicators for the following day (D+1) are currently being developed to take into accou***nt the changes in the Vigilance in 2022.

Associated products

– The production entitled Hazardous Phenomena Forecast is designed to warn of the risk of *occurrence of hazardous weather phenomena*, defined as situations that may fall under Orange or Red Vigilance levels, in metropolitan France, beyond the deadlines covered by the Vigilance **(figure 3**).

It is provided daily (around 1:30 p.m.) and has been available since June 2020 in the tab "NEXT DAYS" of the website https://vigilance.meteofrance.fr/fr. The maps provide forecasts in the form of probabilities from the first day after the Vigilance covered period (D+2), and up to 7 days (D+7). The spatio-temporal scale is dilated with the deadlines. This approach makes it possible to take into account the uncertainty about the location, chronology and intensity of the targeted phenomena, which generally increases as the deadlines lengthen.

The probabilities are reliable in the sense that the values displayed correspond to the observed frequencies: thus, taking 10 cases with a probability of 30%, there are 3 Orange level Vigilance warnings, for the geographical location and the timeframe considered. The evaluations show very encouraging detection and false alarm rates.



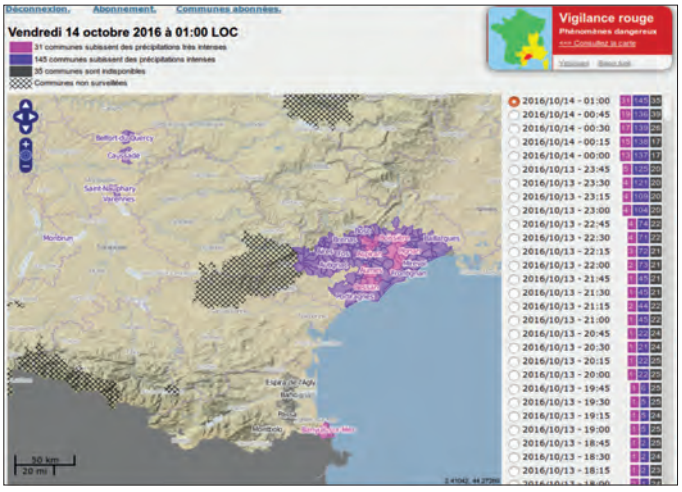
▲ *Figure 3: Example of the production realized on September 30, 2020 for the days D+2 and D+3 ("Alex" event). To be compared with the Vigilance map issued on October 2 at 6:07 a.m. for the corresponding day (Figure 1). Only some phenomena are covered by this production.*

- The Intense Rainfall Warning at a municipality scale (APIC) is an automatic precipitation observation product that aims to warn of an immediate risk of run-off or sudden water rises. It compares, in real time and at high frequency, the rainfall totals deduced from radars and rain gauges to local climatological references (at a kilometre resolution). When thresholds of 10-year (*intense rainfall*) or 50-year (*very intense rainfall*) return periods are exceeded, for time steps ranging from 1 to 24 hours, they are mapped **(Figure 4)** and subscribers are warned. This system must allow for placing the emergency within the framework of a Municipality Safeguard Plan ("Plan Communal de Sauvegarde -PCS-") which each French municipality must legally have. A similar product exists for flash floods (Vigicrues Flash).

A universal system?

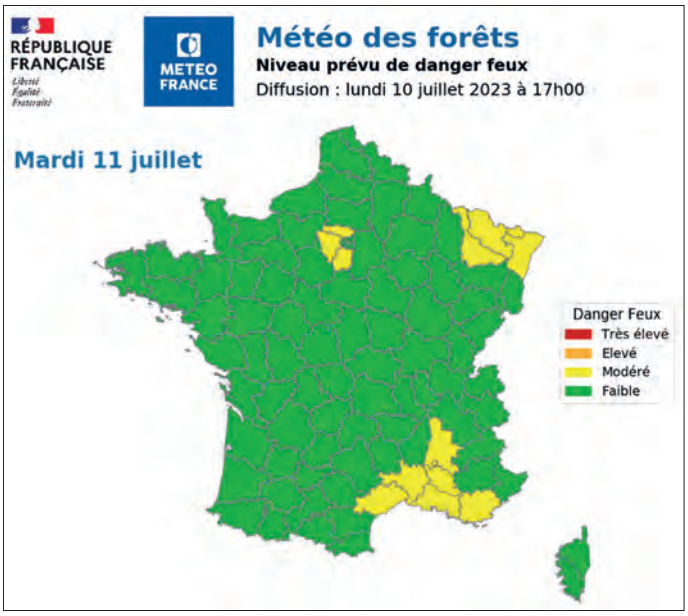
One sometimes wonders why such a simple facility (derived from a traffic light type of signal), immediately understandable and largely universal, did not appear more quickly in the history of weather warnings. This is probably due to a combination of factors, some of which have been mentioned in this article. The fact remains that this type of representation is reproduced (copied!) in many sectors of activity. Air quality, risk of pollen allergy, the Covid-19 pandemic (see "**The European Forecaster", Newsletter of the WGCEF N°25, September 2020**) or forest fire prevention are some examples.

In this last field, at a request of the President of the French Republic, Météo France is inaugurating this year (2023) a new production (called Forest Weather) for the general public. Indeed, in France, after a dramatic 2022 summer in terms of fires in natural areas (an article on this subject



▲ *Figure 4: Example of an "APIC" map during a Red Vigilance episode on October 14, 2016. Municipalities affected by intense precipitation are highlighted with 2 colour levels (intense or very intense rainfall).*

will be eventually published in The European Forecaster) and in a context of increasing risk with climate change, maps adopting the symbolism of the Vigilance will be produced automatically (without human expertise in real time) and published on the institutional site of Météo-France (https://meteofrance.com, tab: Forest Weather). Between June and October, for the next day (D+1) and the day after (D+2), the French departments coloured in Green, Yellow, Orange or Red will warn of the fire danger (**figure 5**). This information should encourage caution in order to avoid fire outbreaks. At this stage, Météo-France does not wish to integrate this parameter into the Vigilance and insists on making it a separate element.



▲ *Figure 5: Example of a D+1 Forest Weather map. The presentation is very similar to that of the Vigilance.*

Conclusion

Vigilance should allow each individual to be warned of his or her exposure to dangerous meteorological or hydrological phenomena and to adopt a behaviour accordingly. The system is an essential part of daily life and is widely known (CREDOC surveys: https://www.credoc.fr/download/pdf/Rapp/R308.pdf). It has become the basic tool for crisis management in meteorology and hydrology. Since its creation, this system has undoubtedly contributed to saving hundreds, perhaps thousands of lives. But as a victim of its fame, it is sometimes criticized for erroneous forecasts while competitors seek to imitate it. In the future, the challenges are numerous. Vigilance will have to maintain the confidence of the authorities and the general public as societal expectations continue to grow. The system will have to keep its simplicity, a guarantee of its effectiveness, despite a complexity that is increasing with more precise forecasts with ever more distant deadlines, but which will always include an element of uncertainty. Taking into account the consequences on the ground will have to be constantly improved. At the heart of this system, forecasters will have to process, with the same efficiency, an ever-increasing amount of data.

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