# Extreme Weather: Mitigation Enhancement by Better Forecasts or by Better Knowledge on Event Frequencies?

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## Summary

The quality of forecasts can be measured with a wide variety of indices and formulae. All these approaches rely basically on the relation between the numbers of correct forecasts, wrong forecasts, false alarms and rejected cases. In the case of extreme events damage is the major topic. All extreme events by definition are more or less rare events. In many applications the events frequency of an extreme event is selected to be one event per 100 hundred years. Depending on the application other such event frequencies are in use. The mitigation of damage mainly uses rules for the design structures such as buildings. In principle their proper application would allow damage to occur only if a meteorological event oversteps a certain predefined threshold value. In practice the threshold proves to represent more something like a soft shoulder and damage is already observed to be caused by events somewhat smaller than the damage threshold value for the extreme weather case. No matter what its exact definition each threshold value is connected to an event frequency. This event frequency is hard to obtain in particular in the vicinity of the threshold of the extreme event case, because it has to be derived from data scarce by definition, however long the observation time series are. Therefore, these threshold values are subject to a certain inaccuracy. In addition, the low frequencies show some variability with time. Recently, climate changes support the idea that also the occurrence frequency of extreme values will change, increase, in the future. Calculating the forecast quality using the basic data leads to two formulations of the forecast quality, both based on the same principles. The fraction formulation correctly is free from any absolute damage height, it is sufficient to find one reference value. When going to the cumulative formulation the role of the effect of the frequency of occurrence can clearified. The two equations allow to compare the effects of long term changes and inaccuracies of the frequency of occurrence of extreme events with the effects of the improvements of the weather prediction.

The results show that the improvement of the weather prediction and the better establishment of long term data, in particular the better accuracy of frequencies of occurrence, do contribute to damage mitigation in about the same order of magnitude, both of them being primary tasks of public weather services needing a similar degree of attention.

## Zusammenfassung

Die Bemessung der Qualität der Vorhersage verwendet eine ganze Reihe von unterschiedlichen Methoden und Verfahren. Die Einteilung erfolgt in Kategorien, die meist als Treffer, Fehlvorhersagen, Fehlalarme und als nichtzutreffende Fälle bezeichnet werden. Extreme Ereignisse sind per Definition seltene Ereignisse und verbunden mit solchen seltenen Wetterereignissen treten Schäden auf. Daraus ergibt sich auch die Motivation, sich mit der Kombination von Schäden und seltenen Ereignissen zu befassen. Quantitativ werden als seltene Ereignisse solche bezeichnet, die im Mittel seltener auftreten als einmal pro 100 Jahren. In der Praxis werden auch andere Wiederholfrequenzen verwendet. Zur Vorbeugung werden die Dimensionierungen von Bauwerken an solchen Ereignissen orientiert, z.T. in Baunormen fixiert. Legt man die in den Baunormen enthaltenen Grenzwerte zugrunde, so dürften Schäden durch Wetterereignisse nur selten auftreten. In der Praxis werden Schäden aber schon weit unterhalb der Bemessungsgrenzen beobachtet. Aber unabhängig vom gewählten Schwellwert besteht

das Problem, diesen Schwellwert zu quantifizieren. Je seltener ein Wert auftritt, desto schwieriger ist er festlegbar und desto ungenauer ist er. Darüber hinaus ist es besonders schwierig, langfristige Veränderungen solcher Schwellwerte zu ermitteln. Daher ist die Quantifizierung der Vorbeugungsmaßnahmen bis zu einem gewissen Grad willkürlich und vom a priori gewählten Sicherheitskonzept bestimmt. Die Vorbeugung besteht auch in der Bereitstellung von Vorhersagen für den Fall des Überschreitens der Dimensionierungslasten durch Wetterereignisse. Die Formulierung von vorab normierten Schäden erfolgt hier relativ und absolut. Das ermöglicht den Vergleich der Wirkung von Vorhersageverbesserungen mit denjenigen der Verbesserung der Genauigkeit der Schwellwerte, d.h. insbesondere der Verringerung der Sicherheitszuschläge aus Unkenntnis. Die Ergebnisse zeigen die Vergleichbarkeit der Wirkungen beiden Verbesserungen. Insofern sind es zwei gleichrangige Aufgaben, die Wettervorhersage zu verbessern und die Kenntnis über die extremen Ereignisse durch die Sicherung von Langzeitbeobachtungen zu verbessern.

## Introduction

All weather forecasts rely on the calculations produced by numerical models of the atmosphere (e.g. Greene and Morrissey 2001, Kalnay 2002, Spekat (ed.) 2002). These forecasts are the basis of all warnings. For simplification in the following forecasts and warnings are regarded as identical, though warnings to become effective in reality do need far more than a weather forecast alone. The forecast intervals extend from about one hour well into the range of many year. The standard operational weather forecast predicts in the time interval from about one day to about ten days. Since the first introduction of the numerical weather forecast more than 50 years ago, quite a lot of experience has been gathered on the matter and substantial progress was achieved with respect to all weather prediction (e.g. Zipser 1990, Buizza et al. 1999, Tetzlaff et al. 2001, Thorpe 2004). Shorter term forecasts for minutes or a few hours require the application of special tools, as do the longer term forecasts going beyond about 10 days. The long term climate predictions are particularly used in terms of statistical information. These usually are the mean values of parameters like the temperature and to a certain extent the frequency distribution as well. It is in the tail part of these distributions that the most interesting information is found, the frequency of large and thus rare events. The deterministic models of the atmosphere producing all forecasts make use of the same basic equations. They also have in common that the very small scale atmospheric processes, in particular everything in turbulence and water droplet formation is included in parametric form alone, because an explicit description is not possible. Regarding the wide range of forecast time scales it is not surprising, that spatial resolution of the forecast parameters as well as the quality and reliability of the forecasts also show a wide range. As a consequence the usefulness for warnings differs depending on the combinations of scale, initial data quality, and the parameter considered. There is an extensive scientific discussion going since the very beginning of weather forecasting on the possibilities and the limits of weather forecasts (e.g. Lorenz 1969, Shukla 2005, Beare 2003, Hudak 2003).

In practice the wide range of forecasts denotes quite different fields of the application. A very short term warning of some minutes can only be issued for a similarly short time in advance of an event, and it can only be restricted to very local events. This is because of the close interrelation of time and space scales of atmospheric processes. Small scale allow very little reaction time, hence short term forecasts have to be specifically designed and used in particular fields of application, i.e. when high “mobility” allows to successfully react. The standard forecasts extend from one day in advance to about ten days. Within this period of time reactions allow to include more time consuming measures. A typical example is the evacuation of a region because of a tropical cyclone. In addition such time span at hand it is possible to secure valuable property, i.e. by fastening of exposed structures.

Going to longer time scales means to change the whole perspective. First of all long term forecasts are not valid for individual events, such as an individual winter cyclone. The relevance of all long term predictions grows with the deviation from the measured current conditions. Therefore, it is of major interest to find the future changes of the frequency of occurrence of rare events. The quantification of the current conditions is based on the observational time series. From these data all information on how frequent a particular value is exceeded are derived. In practical use, e.g. building codes, the knowledge on the frequencies appears in the form of threshold or design values. These design values define the resistance of a building towards an extreme weather event, in other words the susceptibility towards damage. The proper application of such codes makes sure that any damage only occurs with a frequency that is generally acceptable. To find the optimum threshold value is a permanent task. Pushing the design threshold values upwards means to rise the cost, but makes the structures more damage resistant. Allowing lower thresholds brings damage more frequently, at lower initial cost. It should be noted that the subject here is only the quantification of the frequency of occurrence of potentially and thus rare weather events. However, the quantifications from basic statistical considerations (e.g. Wilks 1995) is only possible with an error, which increases with the size of the events, or with decreasing frequency if occurrence. In practice there is a mixture of influences on the values used in codes. After almost each major occurrence of damage an adaptation of the threshold values occurred. This leads to a certain creeping increase of safety standards and consequently a loss of sharpness in the definition of a threshold value. The threshold values are hence neither very precise nor are they stable with time. This simply is due to the fact that the quantification of event frequencies for events to be expected to occur once per 100 years is hard to calculate. The average life span of most structures like buildings is 100 years and longer, needing a projection of the design values into this time span into the future. It is not to be expected that the climatic conditions will remain constant and with the climatic change the frequencies of occurrence of extreme weather events will change together with the frequency of damaging events. It is of some interest to compare the effects of forecast improvements with the inherent inaccuracy of the present day threshold values with respect to damage, and with future changes of these same frequency values.

## Forecast Quality

All weather forecasts are limited in their accuracy (e.g. Smith 1999, Palmer et al. 2000, Palmer et al. 2001, Georgakakos 2001, Jung and Tompkins 2003). There are many reasons for this. As most limiting proves the fact that atmospheric processes can only partly be represented in the forecast models, and that the observations to define the initial state of the atmosphere are inaccurate and incomplete (e.g. Spekat (ed) 2002). It should be kept in mind that the forecast quality shows some relation to frequency of the event, and that extreme events are particularly hard to predict correctly (Lalaurette 2003, Deutscher Wetterdienst 2004, Berliner Wetterkarte 2004). The use of forecast products is almost completely restricted to such parameters that describe parameters that show themselves at the earth’s surface. This means that the free atmosphere forecasts are not of significance here. The quality of the latter ones is in every respect higher that for the surface parameters. There are recent efforts to improve the forecast quality for the surface bound parameters (e.g. Meehl et al. 2000, Molteni et al. 2001 WMO 2005). Recently it became apparent that in particular extreme surface weather needs better forecasts (e.g. Palmer et al. 2001, Hollingsworth et al. 2002). Recently was established the relation between the quality of the extreme weather forecast and the damage, i.e. the economic value (e.g. Zhu et al. 2001, Richardson et al. 2000, Smith et al. 2001, Smith 2003). From the economic side emerges a certain justification to further invest in the improvement of weather forecasts. How to quantify the economic value of weather forecasts altogether proves to be an extremely difficult task if a comprehensive quantitative answer is requested (e.g. Gunasekara 2004). Therefore here the attempt is limited to relative calculations on a scalable basis.

The basis of any estimate of the value of a weather forecast is the verification. There exist quite a number of concepts and ideas of how to evaluate forecasts (e.g. DWD 2004, Lalaurette et al. 2003, Wilks 1995). It is a particularly wide field if economic considerations should be enclosed (e.g. Anderson-Berry et al. 2004, Stewart 2004, Gerapetritis et al. 2004). Therefore the following ideas base on the simple distinction between a correct and missed forecast. In practice this means to summarize the possible cases in a contingency table, which knows the categories “observed” and “forecast”, and the categories “yes” and “no”. These distinctions are standard procedure (e.g. DWD 2004). An event is counted as observed, when the observed parameter exceeds a certain threshold value. Each threshold value is connected to a frequency of occurrence. The threshold is taken preferably from a event size that is expected to cause some damage. This means that the forecast quality is investigated here only for weather events which on average occur less than once per year. All occurring events than are assigned either to be predicted correctly (hit h) or not correctly forecast, i.e. missed (m). The total number of occurrences of events beyond the threshold is then counted as t. Here the quantity t denotes the frequency of event occurrences per year. In the cases considered the magnitude of t will always be smaller than 1, what would designate one event per year on average. In the case an event is forecast, but the threshold is not reached, a “false alarm” is produced. The majority of the cases will be in the category of the correctly forecast weather parameter that does not reach the beforehand defined threshold value.

Figure 1: Contingency table for weather prediction. The total number of cases t consists of two components: the correct forecasts (hits h) and the misses (m). The remaining cases mostly consist of the many cases with no extreme event detected and no such event being forecast (rejection). In some cases however, the transgression of a threshold is forecast without its occurrence (false alarm).

| | | **Forecast** | |
|---|---|---|---|
| | | Yes | No |
| **Observation** | Yes | HIT h | MISS m |
| | No | FALSE ALARM f | REJECTION |

For the moment there is no further specification given on the type of event, which can wind speed, rain amount, hail, tornado, gale force wind or any other weather parameter. It makes the following reasoning simpler without being compulsory, if the maximum number of events per day is limited to one.

In terms of weather forecasts the total number of cases splits into the correctly predicted ones the hits h and the not predicted ones the misses m (equation 1).

$$t = h + m \qquad (1)$$

The damage due to a weather event depends on the size of the event. However, there certainly will be no such damage when the event is very small. A simple estimate is to assume that damage requires an event of size that is rarer than one event per three years, that means t reaches at least 0.33, or more probable 0.2. However, this certainly is not the design load for planned structures. The standard design value for private home buildings in many countries for the frequency is of a magnitude of 0.02 to 0.01, that means one damaging event per 50 or 100 years. The lower threshold is found in practice and due to the facts that the susceptibility to damage increases with the age of the structures, and the inhomogeneity of the damaging weather event. The latter one means that measurements are taken at one particular site, in a distance of 10 or even 100 kilometers from the damage location. Some of the extreme weather events, such as a tornado are of much smaller size and can therefore in most cases not be directly detected. The functional dependency of the damage is proportional to some power of the event size, the power being in the range of about 3 and 4. There is some discussion in the literature as which power is the most realistic one (MunichRe 1993, Wills et al. 1998). The power n is selected to be 3 here, a rather conservative estimate in the light a recent damage events.

Here all weather event beyond a reference threshold with an occurrence of lower than 0.2 events per year are considered and all these events are called extreme events here. The damage inflicted when events greater than the above mentioned occur is denoted with D. If an appropriate weather prediction is available, the purpose for issuing it, is to achieve mitigation by taking precautions. These precautions cause some cost C. Altogether it is clear, that the damage D can be split into two parts, keeping in mind that all what follows happens in the range of meteorological events that exceed the damage threshold. Of this damage some part will occur anyway, no matter what measures are taken. This part of the total damage is called unavoidable damage u. This in any case is the greater part of the total damage D. A smaller part of the damage can be avoided by the precautions. This part is called a. The damage partition can be expressed in a simple equation :

$$D = ( a + u ) D, \qquad \text{with } a + u = 1 \qquad (2)$$

**The Consideration of the Frequency of Occurrence in the Height of the Damage**

As mentioned the damage D depends on the size of the event, if beyond the threshold value for t. Damage is proportional to the third power of the event size, this means reciprocal to the frequency of occurrence. This allows to write the damage D in relation to a reference damage D* using the formulation for t, the frequency of occurrence. To achieve dimensional neutrality the reference frequency $t_0$ is introduced to normalise the effects of t. The numerical value is selected to be 0.2, in practice implying that damage begins to occur when the threshold of an event size is reached, which on average occurs every five years. Then the damage D can be described by equation 3a :

$D = D^* / ( t / t_0 )^n$ with $t_0 = 0.2$ and $t < t_0$ ( 3a )

The same applies for the cost C to avoid damage. It is assumed that C can be treated identically to D.

$C = C^* / ( t / t_0 )^n$ with $t_0 = 0.2$ and $t < t_0$ ( 3b )

When the frequency of occurrence is not constant but subject to changes these might be expressed as an additional contribution to t, in the form of $\Delta t$. This then brings the frequency of occurrence to the more general term $(t + \Delta t)$. The sign of $\Delta t$ may be positive or negative. This then has to be applied to equations 3a and 3b in order to make the damage adjust to changes of t. This adjustment is then normalised with the frequency t, and finally taken to the n-th power. This power is assumed to be same as for the damage, what is plausible. This then leads to the increase or decrease of the damage in the same proportionality as it was applied for the frequency, however in an inverse proportionality, because an increase in the number of events has to increase the damage. The change of t has to be introduced into equations 3a and 3b as well in the denominator as $(t + \Delta t)$ instead of t alone. This added to equations 3a and 3b results in the equations 3c and 3d.

$D = D^* ((t + \Delta t) / t )^n / ((t + \Delta t) / t_0 )^n = D^* ( t_0 / t )^n$ ( 3c )

$C = C^* ((t + \Delta t) / t )^n / ((t + \Delta t) / t_0 )^n = C^* ( t_0 / t )^n$ ( 3d )

These equations take care of the effects that damage is proportional to the event size as coupled to the frequency of occurrence. Furthermore it takes care of changes of t. Assuming n to similar in both cases simplifies the equations to the above shape.

**The Fractional Equation**

The interesting part is now to find an expression that considers the quality of the weather predictions and couples this to the damage. Here it is avoided to have to insertion absolute numbers of damage etc. If real cases are investigated it is necessary to define the type of event with the reference frequency and a possibly different damage functional power.

The positive effects appear in figure 1. These consist of the number of cases with correct forecasts multiplied with the avoidable damage. From this the cost for the precautionary measures have to be deducted. On the other part the losses occur in all cases with no proper weather prediction. In these cases the full damage (equation 2) has to be taken into account.

In addition, in the cases of false alarms the cost for the mitigation measures has to taken on the cost/damage side. In the case of the non events there is no cost to be considered, except the cost for the existence of the weather service itself. The latter cost is assumed to be zero.

With these components a relative “gain function” G can be defined. In the numerator is put the product of the hits with the avoidable damage $((h + \Delta h)aD)$ and on the negative side the cost $((h + \Delta h) C)$. The denominator consists of the misses m multiplied with the damage D plus the cost for the false alarms fC. Taken together this brings an equation for the relative gain G’ :

$$G' = ( h + \Delta h ) ( aD – C ) / (( m + \Delta m ) (uD + aD ) + fD) \qquad ( 4a )$$

Introducing the reference damage value D* instead of D, and using that the product fC is always small, leads to a formulation that is not any longer dependant on the event frequency. The same applies to the product fD in the cases realistic prediction successes are assumed. It should be noted that repeated false alarms may result in indirect negative effects. Using equation 1 then brings the formulation of G in equation 4b :

$$G = ( h + \Delta h ) ( aD^* -C^*) / ( ( m + \Delta m )D^* ) \qquad ( 4b )$$

In the case of constant conditions for damage and cost this equation simplifies to equation 4c :

$$G'' = X ( h + \Delta h ) / ( m + \Delta m ) \qquad \text{with } X = ( aD^* - C^* ) / D^* \qquad ( 4c )$$

This is clearly shows the effects of improvements of weather forecasts. The simplicity emerges, because in the cases considered the role of false alarms is small.

The results from equation 4b depend on the interrelations between the parameters of the normalised damage D*, the normalised precautionary cost C*, the fraction of the avoidable damage a, the frequency of occurrence per year t and the relative number of correct forecasts h. From the structure of the equation it is clear that G depends in a non linear way from the combination of these parameters. Taking the reference damage D* to 1.00 it is clear that the avoidable part of the damage is considerably smaller than the damage itself. Furthermore it is clear that any measures to avoid damage have to be also considerably smaller than the avoidable damage altogether. In both cases for simplicity a ratio of one to ten is assumed. The occurrence frequency per year is taken to 0.2, with half of these events correctly forecast. The exemplary data are summarised in table 1.

Table 1: Selected quantities for the calculation of the relative gain G. The assumption are based on the data for wind gust forecasts in northern Germany (Berliner Wetterkarte 2004). The estimates for parameters h and a are optimistic.

| | | | | |
|---|---|---|---|---|
| D* | 1.00 | $t + \Delta t$ | 0.2 | |
| a | 0.10 | $m + \Delta m$ | 0.1 | G = 0.09 |
| C* | 0.01 | $h + \Delta h$ | 0.1 | |

with improved forecasts (h = 0.12; m = 0.08), and with a case of low forecast quality (h = 0.02; m = 0.18) the quantity G changes, all other parameters assumed to be constant :

| | |
|---|---|
| h = 0.12 | G = 0.135 |
| h = 0.02 | G = 0.001 |

Going to a really extreme weather event the pattern changes. The hit rate is much lower (Smith 2003), the avoidable damage fraction is much lower as well. An example for the results is shown in table 2. Inserted into equation 4b the results show the drastic effect on the relative gain G.

Table 2: Selected quantities for the calculation of the relative gain G. The data are typical for an extreme events of the class once per 100 years.

| | | | | |
|---|---|---|---|---|
| D* | 1.00 | $t + \Delta t$ | 0.01 | |
| a | 0.02 | $m + \Delta m$ | 0.009 | G = 0.0011 |
| C* | 0.01 | $h + \Delta h$ | 0.001 | |

The results shows the drastic reduction of the forecast benefits when going to extreme events.

## The Cumulative Formulation

Instead of using the fraction as in equations 4a, 4b and 4c, the summation of the damage holds some additional information. The basis again is the contents of figure 1. The gains and the damage/cost are taken as in the examples above. This brings a cumulative parameter M, which is shown in equations 5. Again the dependency of the damage on the event size is inserted according to equations 3a and 3b. As in equations 4 the influence of the false alarms is neglected and the cost to sustain the weather service is assumed to be zero. This summation then brings equations 5a (with the analogue equation 4a and 5b with the analogue equation 4b) :

$$M' = ( h + \Delta h ) ( aD – C ) – (( m + \Delta m ) D) \qquad ( 5a )$$

$$M = ( t_0 / t )^n ( (h + \Delta h ) ( aD^* - C^* ) – ( m + \Delta m )D^* ) \qquad ( 5b)$$

It should be kept in mind that equation 5b already comprises the effects of any changes in the frequency of occurrence $\Delta t$. The changes in the frequency are fully taken care of in the h- and m- terms which do depend on the absolute number of occurrences per year. D* and C* refer to the reference value $t_0$. M in all realistic basically is a negative number, because no matter what the forecast can mitigate, the unavoidable damage will be greater. However, it should be noted, that M certainly is dependent on any changes that happen to the value of D*. Changes may be systematic when e.g. building codes are adjusted to real or expected changes in the occurrence frequencies.

Equation 5b makes it easy to make the influences of forecast improvements, of threshold value inaccuracies, systematic changes of the frequency of occurrence on the economic benefits transparent. To demonstrate the effects of climatic change or frequency inaccuracies and of forecast improvements, the numbers as presented in tables 1 and 2 are inserted into equation 5b.

Table 3: Results for M based on the quantities of table 1. The values of the normalised damage M per year are here demonstrated with respect to changes of the frequency of occurrence.

| | | | | | |
|---|---|---|---|---|---|
| $t + \Delta t = 0.2$ | | $t + \Delta t = 0.22$ | | $t + \Delta t = 0.18$ | |
| $h + \Delta h = 0.1$ | M = - 0.091 | $h + \Delta h = 0.11$ | M = - 0.100 | $h + \Delta h = 0.09$ | M = - 0.082 |
| $m + \Delta m = 0.1$ | | $m + \Delta m = 0.11$ | | $m + \Delta m = 0.09$ | |

Inserting the numbers of table 2 into equation 5b brings drastic changes for the damage height M (table 4).

Table 4: Results for the normalised damage M per year based on the quantities of table 2.

| | | | | | |
|---|---|---|---|---|---|
| $t + \Delta t = 0.01$ | | $t + \Delta t = 0.011$ | | $t + \Delta t = 0.009$ | |
| $h + \Delta h = 0.001$ | M = - 72 | $h + \Delta h = 0.0011$ | M = - 79 | $h + \Delta h = 0.0009$ | M = - 65 |
| $m + \Delta m = 0.009$ | | $m + \Delta m = 0.0099$ | | $m + \Delta m = 0.0081$ | |

The results in tables 3 and 4 show the effects of the changes in the basic event frequency t quite distinctly. The combined effects of the changes of the small change and the overall effect result in a non-linearity as can be derived from equation 5b as well.

Equation 5b is also capable to handle the effects of improvements of the weather prediction. The two standard cases are presented as examples in table 5.

Table 5: Results of M based on the quantities from tables 1 to 4 applied to forecast improvements.

| | | | |
|---|---|---|---|
| $t + \Delta t = 0.2$ | | $t + \Delta t = 0.01$ | |
| $h + \Delta h = 0.12$ | M = - 0.069 | $h + \Delta h = 0.002$ | M = - 62 |
| $m + \Delta m = 0.08$ | | $m + \Delta m = 0.008$ | |

Assuming the time scales of the changes to be some ten years it results that the changes as presented in tables 3, 4 and 5 exhibit economic effects of similar magnitude. That means effects of the projected long term changes of the events frequencies and the ones of the forecast improvements are of similar magnitude. The inaccuracies of the event frequencies are also of the same magnitude as the projected long term changes.

## Conclusion

The assumptions presented in the equations applied here simplify the complexity of the problems considerably. Whether or not the results are subject to essential changes in the case of less parameterised approaches needs closer inspection. Meanwhile it may be allowed to state that the simplistic approach was driven by the immense needs to shape preparedness, as e.g. formulated recently in the WMO Long-tern Plan (WMO 2005) and the lack of more correct and comprehensive information on the matter.

Further conclusions turn out to be rather straightforward. Both mentioned components, that is on the one hand the improvement of the weather prediction, and on the other one the better quality of long term data, in particular the higher accuracy of frequencies of occurrence of extreme weather events, do contribute to damage mitigation in about the same order of magnitude in terms of the economic value, and the provision of both are a primary fields of action for public weather services and thus do need similar attention.

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