A study to use wind damage events to design a decision support model for impact-based forecasting

Nicolai Proksch, Patrick van den Hoek, Jos Diepeveen

Introduction

The warning system of the KNMI (Royal Dutch Meteorological Institute) is based on pre-set criteria for specific weather events. For example, when looking at strong winds, a code yellow will be issued when gusts of more than 75 km/h are expected and a code orange will be issued when gusts of more than 100 km/h are expected. For gusts that occur near thunderstorms a code yellow may be issued if speeds of more than 60 km/h are expected or a code orange may be issued when gusts of more than 75 km/h are expected. For a code red we use the same criteria but forecasted impacts are also taken into account. This hybrid system of weather warnings has been discussed in previous newsletters.

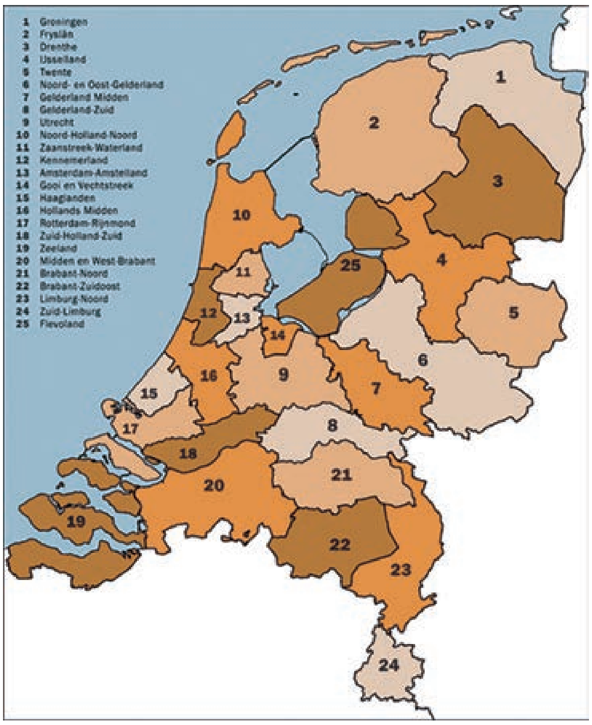
In the near future, the KNMI wants to warn the public more and more on an impact-oriented basis. This means that the weather warnings are based on the expected impact rather than a certain criterion. To achieve this, research is needed into the relationship between extreme weather events and associated damage that has occurred. In this research focus will be on maximum gust speeds. Our main goal is to find a relationship between the strength of gusts observed and the resulting damage. Our secondary objective (if a relationship is found), is to see if it is possible to make a small impact-based model.

Observations

To find a relationship between gusts and damage occurring we need two kinds of observations, the meteorological data and information about the damage that occurred.

Meteorological data:
This research uses hourly data from the KNMI measurement network. The data consists of the station number, hour of the day, wind direction and maximum gust speed in the previous hour. The hour of the day is from 01 until 24 UTC. From hour 01 UTC we get the maximum gust between 00 UTC and 01 UTC. The wind direction is given in degrees and is the average over the last 10 minutes of the last hour. The maximum gust is given as the highest wind speed in m/s to one decimal place over the past hour.

Occurred damage data:
The KNMI does not have data detailing the damage occurred, so we use data from the P2000 network. P2000 is a network used to call the emergency services. A P2000 message comprises of both date and time, which kind of emergency service, safety region and a description of the emergency. An example of a P2000 message is: 20150331032301 ; Brandweer ; Rotterdam-Rijnmond ; PRIO 2 TS33 Sint Pietersweg 6 Nieuwe-Tonge Stormschade Vak: 5590147.



▲ *Figure 1: Safety regions in The Netherlands*

Date and time: 31-03-2015 03:23:01
Emergency service: Brandweer (Fire fighter)
Safety region: Rotterdam-Rijnmond
Description: PRIO 2 TS33 Sint Pietersweg 6 Nieuwe-Tonge Stormschade Vak: 5590147

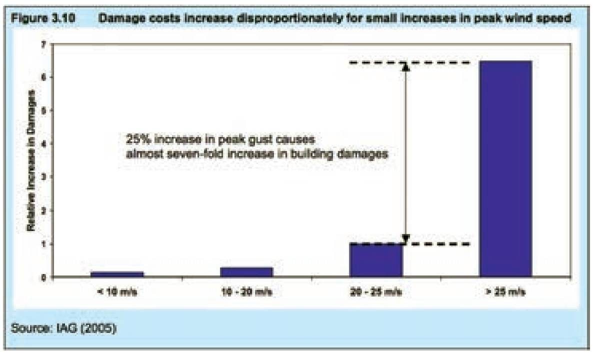
In the description there is a word Stormschade which stands for storm damage. This word in the description describes that in safety region Rotterdam-Rijnmond there is one notification of storm damage. In the Netherlands we have 25 different safety regions, see figure 1.

Theory

The Insurance Australia Group (IAG) did research into the relationship between the severity of a storm and the amount in damage in 2005. This research shows that the damage to buildings increases sharply if a certain critical limit is exceeded. A small increase in storm intensity (<10%) can cause a sharp increase in damage. The IAG stated that an increase of 25% in the maximum gust speed results in an increase in damage by a factor of 6.5. Figure 2 shows the results of this research, showing the strong increase in damage above a certain critical limit.

Method

KNMI wind measurements are collected for all 34 measurement stations in The Netherlands. These stations are grouped by province and at each timestep the highest measured wind speed is picked. From this we collect a maximum wind speed per province for every timestep. This data will be used later in the research.



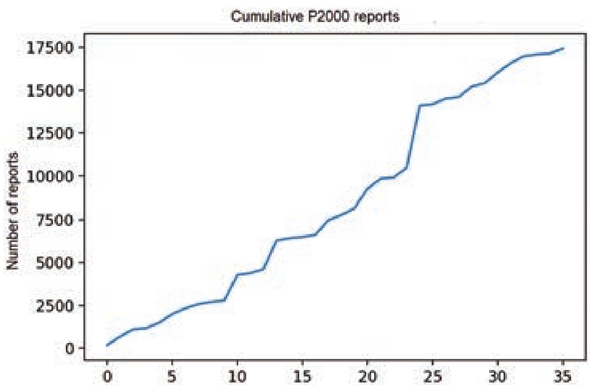
▲ *Figure 2: The relative increase in damage plotted against the maximum gust speed. (IAG, 2005)*

Beside the wind measurements we need the P2000 data. We get the P2000 real-time (every 5 minutes) from a database. The P2000 dataset must be filtered before it can be used as it contains much more than only reports of storm damage; therefore, we search for the term 'Stormschade' in the description of the P2000 message. These messages are combined per safety region in hourly steps. After this, the security regions are grouped into the corresponding provinces. In the Netherlands the weather warnings are issued per province by the KNMI.

We now have the maximum wind speed and the amount of storm damage reports per province for every timestep.

Results

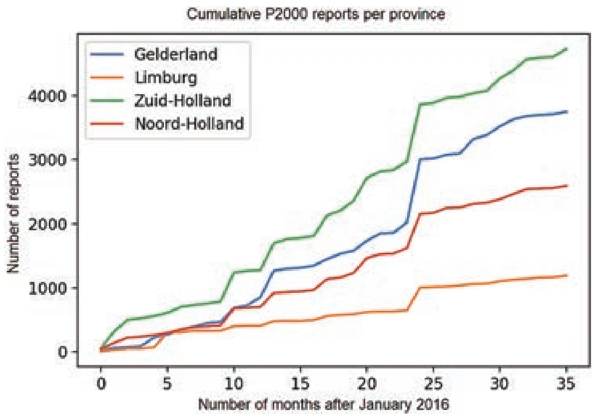
We have collected P2000 data since January 1, 2016. Since then there have been approximately 17,000 P2000 messages with the description stormschade in it, see figure 3.



▲ *Figure 3: Cumulative amount of P2000 calls with stormschade in the description plotted against the time from January 2016.*

The number of damage reports per province differs per storm. Figure 4 shows that the number of reports can vary greatly per province and per storm. The difference in the number of reports per province could be explained by: the difference in the size, the difference in population density, the difference in the number of trees and the difference in gusts. It is therefore not possible to make a comparison between the number of reports in the different provinces. However, it is possible to make a comparison between the various storms in a province.

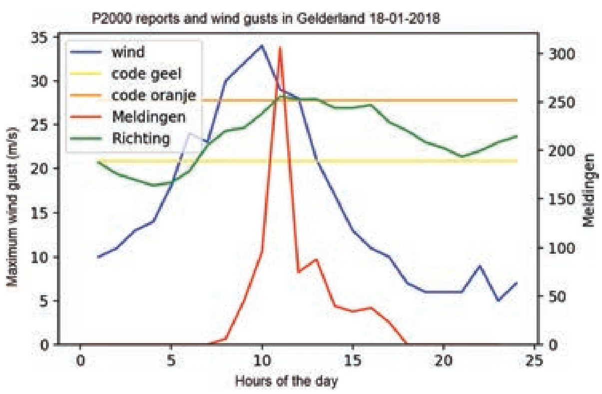
KNMI issues warnings for severe gusts with a strong gradient wind. Code yellow is issued for gusts of more than 75 km/h (20,83 m/s) (for the



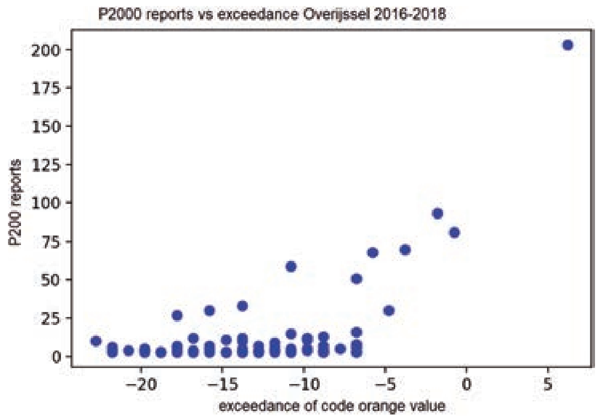
▲ *Figure 4: Cumulative amount of P2000 calls with stormschade per province since January 2016.*

coastal area this criterium goes up to 90 km/h (25 m/s) during the winter). Code orange is issued for gusts of more than 100 km/h (27,78 m/s) (for the coastal area this criterium goes up to 120 km/h (33,33 m/s) in the winter). Code red is issued when extreme weather occurs that has a major impact on the public. This weather situation can cause so much damage, injury and nuisance that it can be disruptive to society.

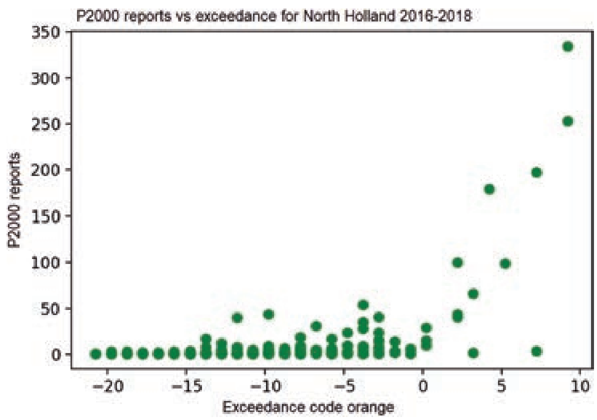
One of the research questions that has been asked is to find a relationship between the storm damage reports and the severity of the storm. One way to do this is to compare the number of P2000 reports with the strength of the gusts that occurred during a storm. Figure 5 gives the maximum gust, the wind direction and the amount of storm damage reports against time for the province of Gelderland. The date which is used is the 18th of January, 2018, when the Netherlands was hit by Storm David. The horizontal yellow and orange lines represent respectively the criteria of code yellow and orange of the KNMI in m/s. It can be seen that the maximum gust that



▲ *Figure 5: The maximum gust in m/s (blue), the wind direction (green) and the amount of storm damage reports (red) plotted against time during the storm of January 18, 2018 for the province of Gelderland.*



▲ *Figure 6: The amount of storm damage reports as function of the exceedance value of the code orange criterium for 'Overijssel' in the period 2016-2018.*



▲ *Figure 7: The amount of storm damage reports as function of the exceedance value of the code orange criterium for 'Noord-Holland' in the period 2016-2018.*

occurred exceeded code orange. Further, the number of P2000 reports peaks when the storm has peaked.

We have all the data collected, so we can start to investigate a relationship between the storm damage reports and the severity of the storm. To categorize the storms, we created a so-called *exceedance value* (overschrijdingswaarde). The *exceedance value* is defined as the maximum gust speed minus the code orange criterium (25 m/s). The *exceedance value* is calculated for every province, every hour. This *exceedance value* can be both positive or negative, with a positive value the maximum observed gust speed is higher than the code orange criterium. If the value is negative than the maximum gust speed is below the code orange criterium. Figure 6 shows the amount of storm damage reports against the *exceedance value* for the province of Overijssel in the period 2016-2018. When a severe storm hits the Netherlands it is possible that damage is reported the day after the storm. Therefore, it has been decided to add up the number of notifications of two days in a row if there is no exceedance of the yellow criterion code on the second day.

Furthermore figure 6 does not show the days with less than five storm damage reports. Figure 6 shows that below the *exceedance value* of -6 m/s there are hardly any storm damage reports. From about 6 m/s below the orange criterion, the number of damage reports starts to rise sharply.

The same principle is used for the province of Noord-Holland. These two provinces are chosen due to their locations. The province of Overijssel is an inland province while Noord-Holland is a coastal province. Figure 7 shows the same data as in figure 6, but for the province of Noord-Holland. It shows that the number of storm damage reports up to the code orange criterium (*exceedance value* = 0 m/s) is quite low. From this point the number of storm damage reports increases strongly. From the results at figure 6 and 7 we can conclude that the tipping point in the province of Noord-Holland is higher (*exceedance value* = 0 m/s) than for the province of Overijssel (*exceedance value* = -6 m/s).

If we examine all provinces apart from each other it is difficult to make a conclusion, due to the low amount of data points. Climatology shows that the mean wind speeds and gust values are higher in the coastal regions than inland. So, we divide The Netherlands in two regions: the coastal regions and inland regions, the division is shown in table 1.

Figure 8 and 9 show the amount of storm damage reports for the coastal and inland provinces as a function of the maximum exceedance value in the region. The number of reports from the two provincial groups is added up per day and plotted on the maximum exceedance value. It is noticeable that for the coastal provinces the number of notifications increases sharply from the code orange criterion. For the provinces inland this increase in the number of reports occurs at a slightly lower value than the orange criterion.

Table 1: The division between coastal and inland provinces

Coastal provinces	Inland provinces
Groningen	***Drenthe***
Friesland	***Overijssel***
Noord-Holland	***Gelderland***
Zuid-Holland	***Utrecht***
Zeeland	***Noord-Brabant***
Flevoland	***Limburg***

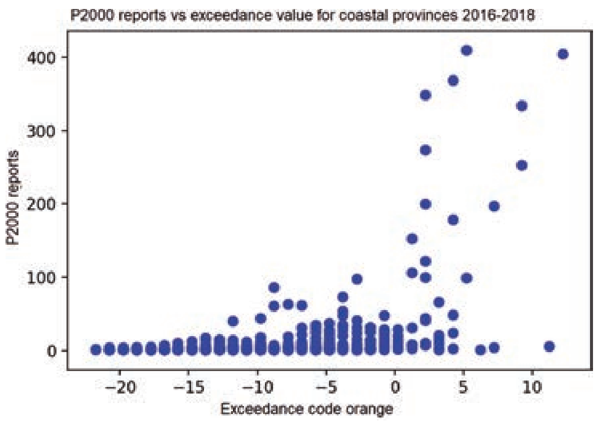


Figure 8: The amount of storm damage reports as function of the exceedance value of the code orange criterium for the coastal provinces in the period 2016-2018.

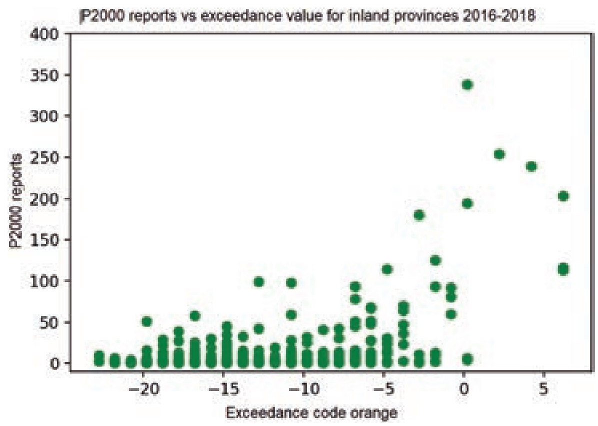
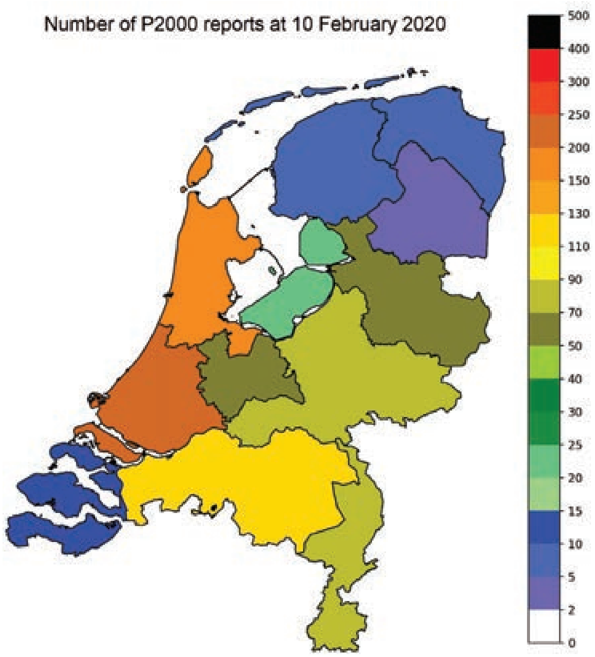


Figure 9: The amount of storm damage reports as function of the exceedance value of the code orange criterium for the inland provinces in the period 2016-2018.

The tipping point for the coastal provinces is exceedance value = around +1 m/s, for the inland provinces it is at exceedance value = around -3 m/s, but the uncertainty is large. The figures also show a lot of noise in the dataset around the number of reports. For example, even with values up to 10 m/s below the orange criterion, there have sometimes been many damage reports. These storm damage reports could have different causes. This method does not account for the different seasons. During the winter half of the year, most damage is caused by storms, but during the summer half of the year most damage is caused by thunderstorms. The winter storms have a large gradient wind field, so the probability of measuring those strong gusts is high. Thunderstorms are very local and the probability of observing those strong gusts is lower. Therefore, in the case of thunderstorms it is possible that the maximum wind speed that occurred is much higher than the values measured by the monitoring network. As a result, the number of reports may not correlate exactly with the exceedance value. Viewing the winter and summer separately may reduce this noise.

The KNMI issued 116 code yellow warnings, 6 code orange warnings and one code red warning for severe gusts during the period January 2016 to June 2019. Severe gusts that occur near thunderstorms have a separate weather warning. Table 2 shows the number of damage reports per warning issued per code. During this period a code red warning is only issued once, and therefore no conclusion can actually be drawn from it. It can be concluded that on average over ten times more reports are received with an orange code than with a yellow code. In the 5th column the standard deviation is determined for all three issued warnings. For code yellow it can be seen that the standard deviation is 2.5 times larger than the average number of reports. For code orange, the standard deviation is smaller than the average number of reports, but more than half of the average. In the period from 2016, a code orange was issued six times. Again this is too small a data set to be able to draw solid conclusions, alarger dataset is needed to draw well-founded conclusions.

A real-life dashboard has been developed to continuously process the number of storm damage reports during a storm for the different provinces. This dashboard is shown in figure 10 and is also available in the operational weather office for the meteorologists. Recently we applied additional filters to the P2000 messages, namely water impacts and weather/water impacts. The weather/water message is also used for storm damage and therefore is also included in the storm damage reports. The dashboard can also be used to visualize the water impacts, such as flooding reports in heavy precipitation. This information can be viewed by selecting the province in question.



▲ *Figure 10: A dashboard with real live visualization of the damage reports per province for storm David on 10 February 2020.*

Conclusion

There is a desire to change warning systems from a threshold-based system to an impact-based system. This is inspired by recommendations of the WMO. However, it seems to be rather complicated to translate impact information from after a strong wind event into useful information for future events. Impact-partners like Civil Protection Authorities don't have large databases and occurrences are not always logged systematically which makes this even more complicated. However, with use of the Dutch P2000 system we managed to relate storm impact to wind measurements and different warning thresholds to see if warning criteria coincides with observed impacts.

Table 2. For each issued yellow / orange / red warning the number of times issued, the sum of the number of P2000 reports, the average number of reports per code issued and the std of these. Over the period 2016-Jun 2019.

	Number of times issued	Sum of damage reports	Average number of damage reports	STD
Code yellow	116	8063	70	186
Code orange	6	4266	711	414
Code red	1	2192	2192	0