KA Köln.Assekuranz Agentur
Ein Unternehmen der ERGO

K.A.R.L.® RELEASE 2022

Technical Revision - Tornado - Protection Goals

K.A.R.L.®
Köln.Assekuranz Risiko Lösungen

K.A.R.L.® Release 2022

The best K.A.R.L.® ever just keeps getting better!

The team at KA Köln.Assekuranz Agentur GmbH is constantly developing K.A.R.L.® system further - both technically and in terms of content. New insights and data have been gained since the last release and are now waiting to be used. The innovations of the current release include:

- **fundamental technical revision of K.A.R.L. with translation into a new programming language**
- **revision of the tornado model**
- **separation of the protection goal for flooding and storm surge**
- **update of the earthquake and tsunami database**

1. Fundamental Technical Revision of K.A.R.L.®

The biggest change made to K.A.R.L. in this release does not affect risk modelling and is not visible to the user. It is about the fact that the complete programme code of K.A.R.L. has been converted from the programming language Visual Basic Classic 6.0 (VB6, year of publication 1991) to Visual Basic.NET (technical status 2021). Converting the programme code to Visual Basic.NET brings the following improvements:

- The changeover eliminates minor rounding errors (effect on risks in the area of the 4th decimal place) that are based on a bug in the compiler of Visual Basic 6.0
- Ensuring the future viability of the K.A.R.L. computing core in the longer term
- The system becomes more maintenance-friendly overall, which can lead to shorter release cycles
- Compiling as a 64-bit application achieves better memory management and thus higher processing speeds

2. Revision of the Tornado Model

The new version of K.A.R.L. contains a further developed tornado model. Comparisons with a number of current study results (e.g. Ashley 2007; Grieser & Haines 2020; BlueSkies 2014; Strader et al. 2017) have shown that the tornado hazard was estimated as too high by the previous K.A.R.L. model in many regions. The aim of the revision of the tornado model is therefore a more realistic assessment of tornado frequency. The new findings and the revision of the model are presented below.

Hazard analysis - calculation of tornado frequencies

In order to estimate the tornado risk at a location, information is first required about the hazard situation, or more precisely the frequency of occurrence of tornadoes. The procedure for determining tornado frequencies is essentially based on two assumptions (schematic representation in Figure 1):

- Tornado frequency correlates with the frequency of hail events
- Tornado frequency depends on the relief energy resulting from height differences in the vicinity of the investigated site

Since both hail and tornadoes always form in connection with thunderstorm cells, K.A.R.L. assumes that wherever hail is possible, tornadoes are also likely to occur. Accordingly, the classification of the tornado hazard is based in a first approximation on the hail potential calculated by K.A.R.L.. High hail potential values indicate an increased probability of the occurrence of hail and larger hailstones (further explanation of the hail model in K.A.R.L. Release 2019).

Worldwide tornado frequencies are determined from the correlation between hail potential and tornado observations in the USA

To revise the tornado model, tornado frequencies (in number per year and 10,000 km²) from various scientific studies (e.g. Ashley 2007 and Storm Prediction Center, USA) are correlated with the hail potentials calculated by K.A.R.L., assuming that the tornado hazard is also increased in regions with a high hail potential. In this analysis, only tornadoes with an intensity greater than or equal to 2 on the Fujita or Enhanced Fujita scale (see also https://www.weather.gov/oun/efscale) are taken into account, as tornadoes only cause significant damage above this intensity.

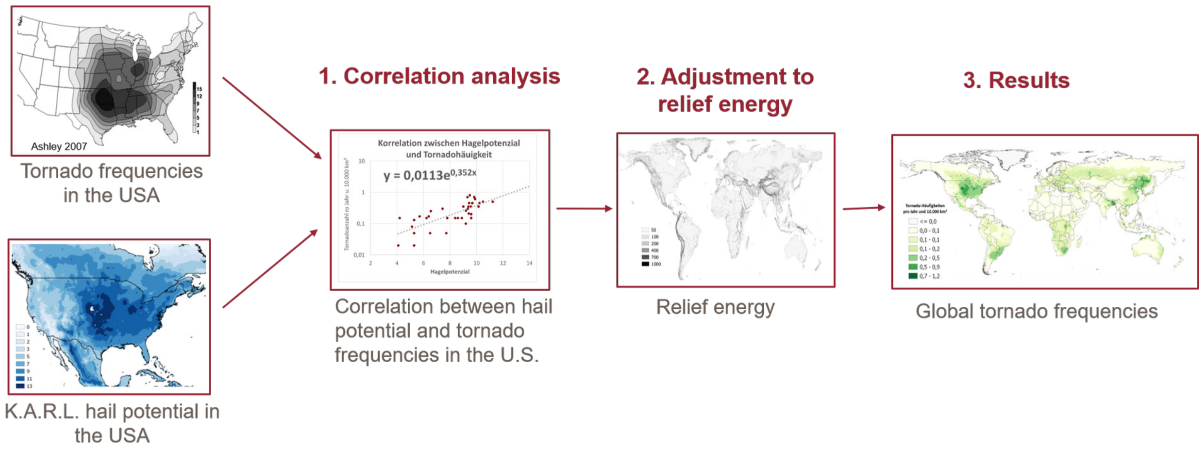

Fig. 1: Schematic representation of the process for determining global tornado frequencies.

The applied statistical evaluation is mainly based on data from the area of the USA, as the most reliable observation data is available for this region for a period of more than 20 years. For final validation, however, the output of the tornado model is compared with worldwide tornado observations.

The statistical correlation determined from the correlation is applied in a further step to the worldwide hail potentials in order to obtain an approximation of the global tornado frequencies.

Finally, the worldwide tornado frequency calculated in this way is modified again as a function of the regional relief energy. The relief energy describes the relative height differences of a terrain - independent of the absolute height above sea level. It is thus a measure of the potential energy of the terrain forms.

To modify the tornado frequencies, it is assumed that the formation of tornadoes is highly favoured at a low regional relief energy <50 m (slightly hilly terrain, flat areas), but almost impossible at a pronounced relief energy >150 m (alpine high mountains).

The result of the calculations described here is shown in Figure 2 as tornado potential. The tornado potential indicates the average number of F2 to F5 tornadoes that can be statistically expected per year over an area of 10,000 km².

The statistical evaluation of tornado events in the USA by Ashley (2007) over the years 1950 to 2004 showed that during this period more than 15 severe tornadoes (classes F2, F3, F4 and F5) occurred over an area of 60 km x 60 km in the most frequently hit areas of the US Midwest. This corresponds to approx. 0.8 tornadoes per year on an area of approx. 10,000 km² (corresponds to a square area with an edge length of 100 km).

The revised tornado model in K.A.R.L. determines about 1.0 severe tornado per year on an area of about 100 km x 100 km in the extremely stressed zone in the Texas/Oklahoma border area. The K.A.R.L. values are thus slightly above the observed frequencies and thus fulfil the precautionary principle applied in K.A.R.L..

Within Europe, the values modelled by K.A.R.L. range between 0.01 and 0.25 tornadoes per year and 10,000 km². The fewest tornadoes are to be expected in the Alpine regions and the most tornadoes in lower plains, e.g. south of the Alps in the Northern Italian Plain. The tornado frequencies determined by K.A.R.L. are in good agreement with observations and scientific findings from current literature in many regions outside Europe and the USA.

Risk analysis - calculation of the tornado risk

Scientific studies (e.g. Groenemeijer & Kühne, 2014) show that the size of the destroyed area varies greatly, especially depending on the intensity of the tornado.

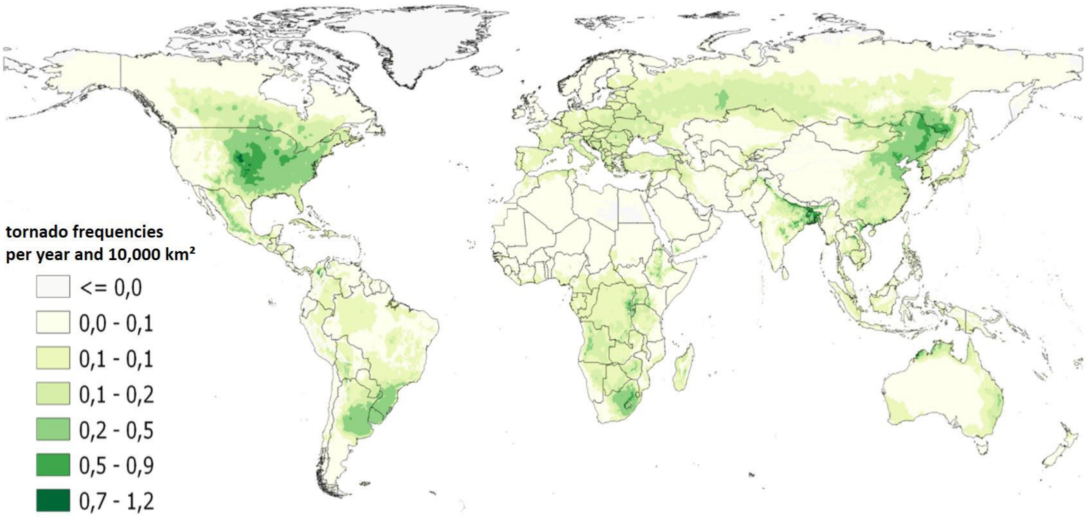

Figure 2: Tornado potential - Estimated tornado frequency in number of tornadoes per year and an area of 10,000 km². The tornado potential was calculated by K.A.R.L. using the method described here.

For the calculations of the tornado risk in K.A.R.L., average values from the upper value range (from Groenemeijer & Kühne, 2014) were again selected due to the precautionary principle. This results in the following framework data for calculating the area destroyed by a tornado:

- Length of the tornado path: approx. 20 km
- Width of the tornado track: approx. 0.5 km

This results in an average area in which a tornado can cause destruction:

- Mean destroyed area =20 km * 0.5 km = 10 km²

Assuming an average affected area of 10 km², this results in a return period of 1,000 years for regions with 1 tornado per year and 10,000 km² for the destruction of an object by a tornado.

To calculate the risk, a simplified assumption is made that a tornado always causes 100 % damage to directly hit objects. Thus, the average annual risk in the severely affected regions of the USA is approx. 0.1 % per year (see Figure 3). This corresponds to a conspicuous risk. In less severely affected regions, a low to very low risk can be assumed.

Risk per location in the USA in heavily affected regions (with 1 tornado per 10,000 km²):

1 tornado / 10.000 km² * 10 km² * 100 % = 0.1 % p.a. → **notable risk**

(Tornado frequency per year) (Destruction area) (Damage potential)

Figure 3: Formula for calculating the tornado risk using the example of a location in the USA

3. Separation of the Protection Goals for Storm Surge and Flooding.

A protection goal quantifies a technical measure against the ingress of water (e.g. dyke, wall or an artificial elevation of the terrain), which should provide protection up to a certain level against inland flooding and/or against storm surge and tsunami on coasts. In order to assess the respective risks, K.A.R.L. checks whether such protection should be available against the respective hazard. If the user is aware of a protection target that protects the property or site from a flood event up to a certain annuality, this information can be passed on to K.A.R.L., which uses it in its analysis.

If no such protection target is specified by the user for a high-risk site, K.A.R.L. automatically estimates some protection for properties in high-risk areas. This procedure is based on the assumption that, as a rule, no buildings or other objects are erected in regions that are recognisably flooded on a regular basis without appropriate protective measures being in place. In estimating the protection target, K.A.R.L. is guided by the level of relative risk. The higher the relative risk of the respective natural hazard has been calculated, the higher the protection target is set - up to a maximum of 100-year protection.

What is new?

So far, K.A.R.L. has worked with one and the same protection target for flood and storm surge and, for sites that could be affected by both hazards, has usually considered the higher estimated protection target. For all sites that are not in the immediate vicinity of a river or the sea, this approach is not wrong. However, there are isolated sites that may be at risk from both river flooding and storm surges. In these cases, it is necessary to separate the protection objectives, as otherwise one of the two risks would be underestimated. In the following, this problem is explained using a site example

Example of a location in the Netherlands

The site selected for an example analysis is located in the Netherlands on the island of Goeree-Overflakkee, about 15 km from the North Sea coast and in the immediate vicinity of the Haringvliet. The Haringvliet is an inland water body, which is separated from the North Sea by a dam on one side and is part of the lower course of the Rhine at the other end.

For the site studied here, according to Kok et al. (2017 and Dutch Water Act), a 1,000-year protection target against storm surge and tsunami was constructed on the North Sea coast, but only a 300-year protection target towards the inland watercourse Haringvliet (see Figure 4). These different protection targets can now be taken into account in the new version of K.A.R.L..

For the site shown, this means that the flood risk almost doubles (from 0.0348 % p.a. to 0.065 % p.a.) and changes from low to conspicuous. Previously, K.A.R.L. only ever considered the higher protection target for both natural hazards, which resulted in an underestimation of one of the two risks for those sites that may be affected by both hazards.

Fig. 4: Demo site in the Netherlands at a distance of approx. 12 km from the North Sea and a few metres to the inland water body Haringvliet. Map with probabilities of occurrence is from Kok et al. (2017).

4. Update of the Earthquake and Tsunami database

For the calculation of earthquake and tsunami hazards, K.A.R.L. uses two data sets with worldwide observations of earthquake and tsunami events. These data sets must be updated in K.A.R.L. at regular intervals so that, if possible, all newly observed events are always included in the K.A.R.L. analyses. Due to changes in the data formats of the sources, these updates had to be suspended for a longer period of time. For the upcoming release, the earthquake and tsunami data have been updated again.

- The current earthquake observations come from a database of the United States Geological Survey (USGS)
- Tsunami observation data is provided by the U.S. Weather and Oceanographic Administration (NOAA, National Oceanic and Atmospheric Administration

5. Outlook

The team is already working on the further development of K.A.R.L. Two major innovations are planned for the near future:

- Integration of climate simulations for the assessment of future natural hazards
- Implementation of a new, much higher resolution elevation model

The natural hazard analysis tool K.A.R.L. is currently being used to model the meteorological hazards of flooding, storm surge, storm, tornado, hail and heavy rain as well as a snow load index for current climate conditions. In addition, the geophysical hazards earthquake, volcanism and tsunami are also analysed. These are reflected in the description of the „acute" hazards.

In the course of 2022, climate model data (CMIP6) will also be incorporated into the modelling of these hazards in order to be able to calculate future risks. Data from an ensemble of global climate models as well as different emission scenarios (SSP scenarios) and different future time periods up to the year 2100 will be taken into account.

Currently, K.A.R.L. is being expanded so that, in addition to acute hazards, chronic hazards and their future changes can also be assessed. For this purpose, climate indices are calculated on the basis of climate model data (CMIP6), which primarily describe the changes in temperature and precipitation extremes associated with climate change. Thus, these indices essentially map the requirements for chronic risks from the EU taxonomy. Different climate models, emission scenarios as well as time periods are also analysed when calculating the chronic risks.

Another major development project is the implementation of a new, much higher resolution elevation model in K.A.R.L. So far, K.A.R.L. has been using the SRTM500 elevation model with a node resolution of about 500 metres. In the future, this is to be replaced by a more closely meshed elevation model with a node resolution of approx. 90 metres, which is based on the ALOS elevation model of the Japan Aerospace Exploration Agency (JAXA). Since this is a surface model which still contains the height values of, for example, forests or artificial buildings, complex correction calculations are necessary in order to be able to represent the height of the terrain over the entire area. As the following figure (Ahrtal near Altenahr, Fig. 5) shows, river and stream courses can be identified much more precisely and zones at risk of flooding can therefore be delimited and assessed more accurately.

6. A little something to finish off

With this release, K.A.R.L. receives a version number according to the „classic" IT scheme. Since K.A.R.L. with its approx. 14 years of „professional experience" is already far away from a version 1.0, we start with the version number 5.0.0.0. We will only increase the first digit in case of major changes in K.A.R.L. (e.g. with the integration of the new height model). The second digit marks smaller changes with an impact on the results of the risk calculation. We will increase the third digit with changes in the database. Finally, the fourth digit will mark smallest changes that have no impact on the results of the calculations (such as a text change in the results report).

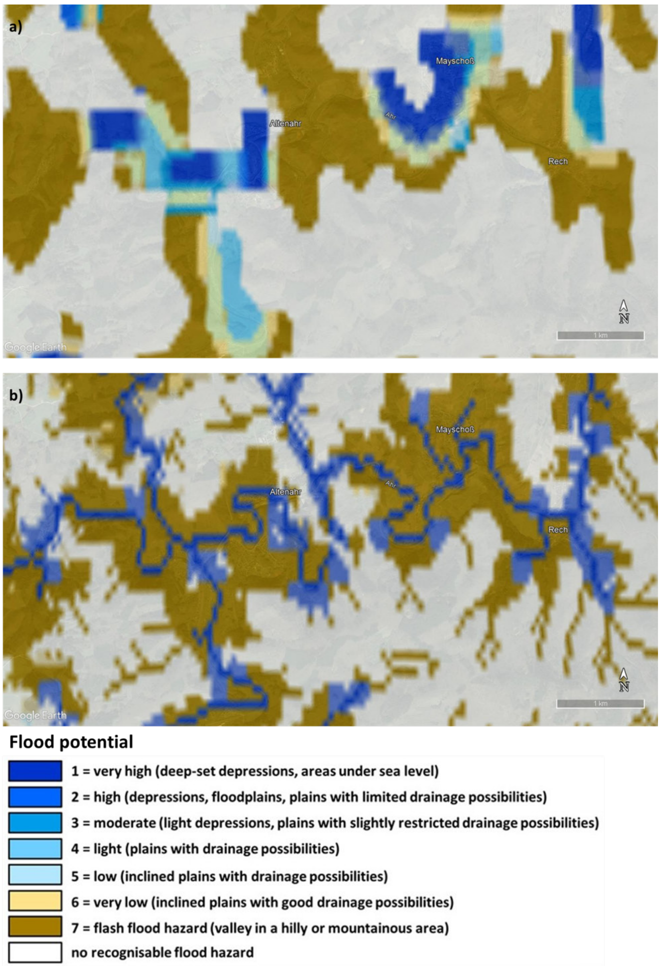

Fig. 5: Flood potential in the Ahr valley near Altenahr for the a) old elevation model SRTM500 and b) new, significantly higher resolution elevation model ALOS.

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