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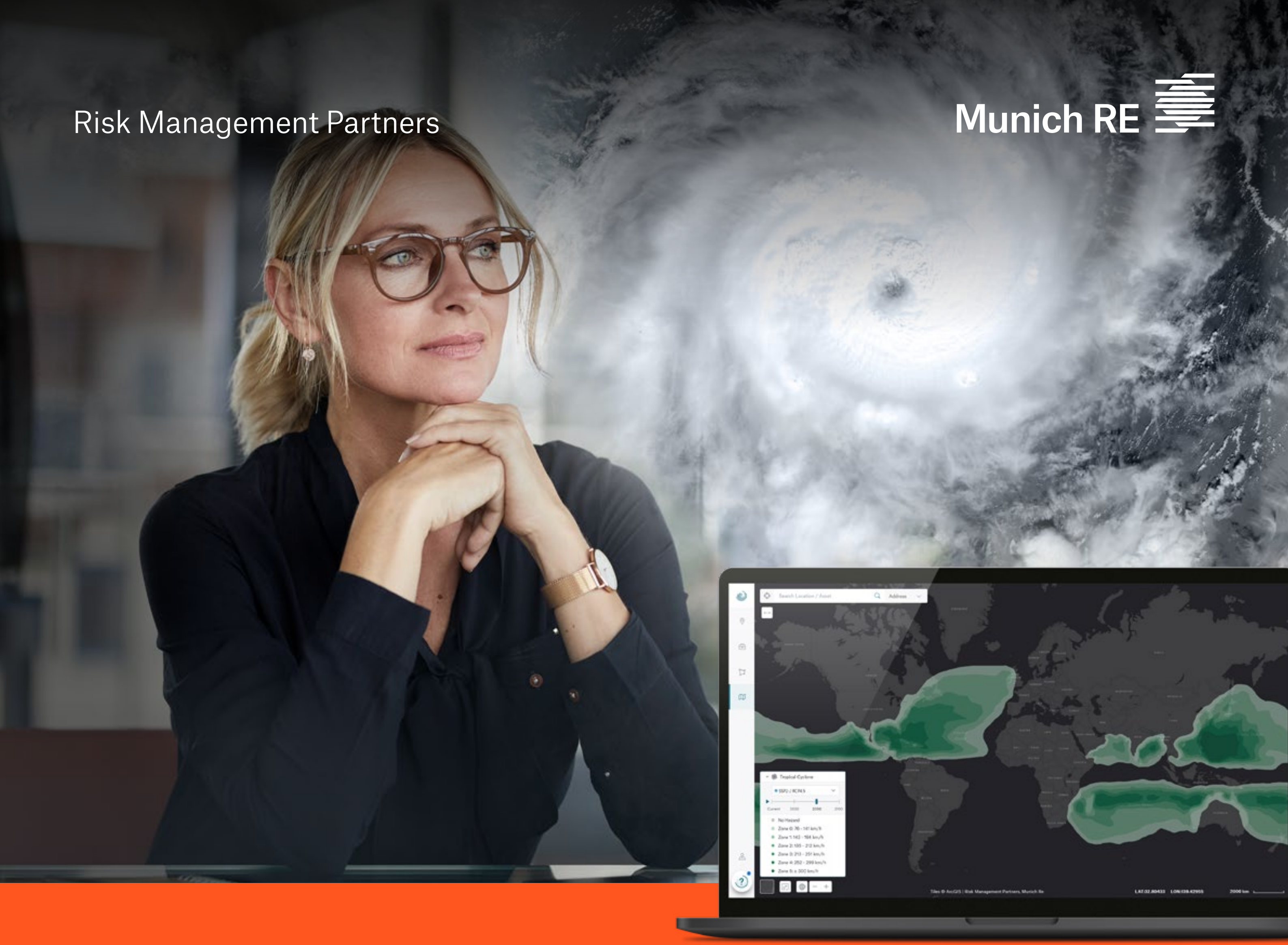

Location Risk Intelligence

Climate Change Edition. The solution for assessing and managing climate change risks

2/2

In-depth information

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Turn climate risks into business opportunities with Climate Change Edition

Climate Change Edition is a modular SaaS solution that helps you not only to understand your exposure to current physical risks, but more importantly to assess and understand the physical risks associated with climate change in different future scenarios.

Integrated into your digital workflows, Climate Change Edition supports your spatial exploration, visualisation and evaluation for purposes of global portfolio management and investment decisions. From a single property to entire portfolios which are vulnerable to acute and chronic climate risks such as extreme temperatures, extreme precipitation, sea level rise, etc. And not just based on data from past events, but as a scientifically sound projection into the future. The year 2100, to be precise.

Benefit from the integration of Munich Re's climate risk data into your business processes and decisions to stay ahead of the game:

- **Invest safely:** Check the risk of individual assets or entire portfolios using Climate Change Edition's set of global warming scenarios, looking up to 80 years into the future.
- **Avoid revenue losses and reputational damage:** Identify potential risks from climate change before they materialise in your assets and portfolios to proactively steer your investments towards profitable and secure returns now and in the future.
- **Maintain your business continuity and resilience:** With the globalisation of almost all business sectors, it is vital that your supply chains remain future-proof and exposed to as little climate risk as possible. With Climate Change Edition you can stay on top of things – worldwide.
- **Keep an eye on the future of your business:** With Climate Change Edition you can not only protect your business by anticipating the threat of natural disasters, but also assess how markets are changing and where new opportunities are emerging for your company.
- **Identify risks quickly and reliably:** Thanks to Climate Change Edition, you can easily identify areas of high risk concentration and assess them with an overall risk score or a detailed risk evaluation consisting of over 20 individual risk scores.
- **Meet your increasing disclosure obligations:** Climate Change Edition provides you with sound answers to the increasingly extensive regulatory and voluntary requirements relating to the disclosure of your climate change risk exposure, creating the transparency you need.

So you'd better take climate change into account

Especially in view of the fact that extreme weather events are becoming more likely, it is essential that climate risk data should be included as an integral part of your business decisions to protect your company from their increasingly frequent consequences.

Scientific framework and modelling approach

Climate change is a critical issue facing both the global community and businesses. The Intergovernmental Panel on Climate Change (IPCC), a United Nations body, has established a framework which formed the basis for the Paris Agreement in 2015.

With the release of its 6th assessment report in 2023, the IPCC redefined what “cutting edge” climate change modelling means. Previously, climate change scenarios had only considered the development of concentrations of greenhouse gases, characterised in a set of Representative Concentration Pathways (RCP), but now the IPCC has moved towards a more holistic approach to thinking about how the 21st century will develop. It now endorses using Shared Socioeconomic Pathway (SSP) scenarios in future modelling. These embed the existing RCP scenario framework into a more holistic set of realistic story lines for the ways in which humanity could respond to the challenges that change poses to us all. By providing climate risk data for a range of different SSP scenarios, Location Risk Intelligence supports the seamless integration of physical risks into risk-aware decision-making. The available SSP scenarios in Munich Re’s climate services are:

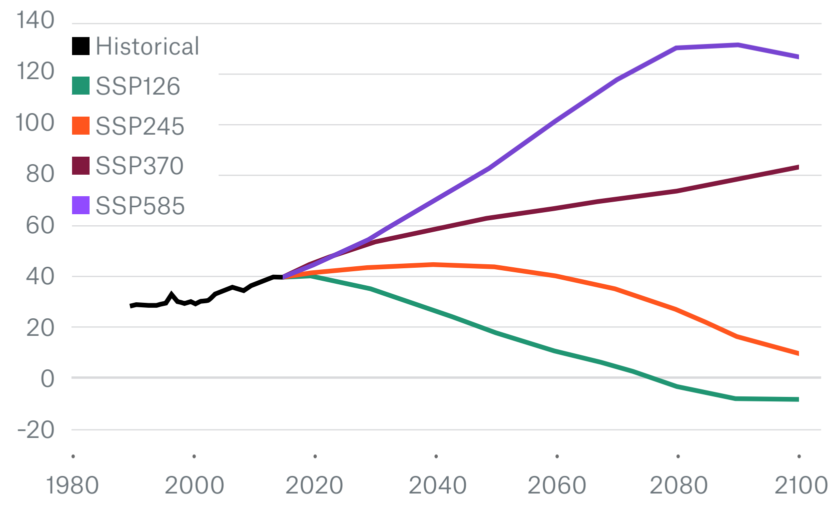
SSP1-2.6 Sustainability:
In this most optimistic scenario, all countries (with the strong supporting the weak) move gradually but consistently towards a more sustainable economic system. Inequality within and between countries is reduced and consumption is orientated towards lower material growth and lower resource and energy consumption. This moderate scenario leads to an expected warming at the end of the 21st century of around 1.0-2.4°C relative to the pre-industrial period (1850–1900). The SSP1-2.6 scenario is comparable to the RCP2.6 scenario.

SSP2-4.5 Middle of the road:
In this scenario, global and national institutions work towards sustainable development but make slow progress. Development and income growth proceed unevenly, with some countries making relatively good progress while others fall short of expectations. The environment experiences degradation but the overall intensity of resource and energy use declines. This scenario would be expected to lead to a warming by the end of the 21st century of between 2.1 and 3.5 °C relative to the pre-industrial period (1850–1900). The SSP2-4.5 scenario is comparable to the RCP4.5 scenario.

SSP3-7.0 Regional rivalry:
Under this scenario a resurgence in nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Achievement of national and regional food, energy, and security goals are prioritised above international cooperation to tackle shared goals. Economic development remains material-intensive and environmental degradation worsens. Under this scenario warming by the end of the 21st century is expected to be between 2.8 and 4.6 °C. The SSP3-7.0 scenario is comparable to the RCP7.0 scenario.

SSP5-8.5 Fossil-fuelled development:
In this scenario faith is placed in competitive markets and innovation. Fossil fuels are increasingly exploited and social and economic development drives the adaption of resources and energy intensive lifestyles around the world. Local environmental problems like air pollution are managed, but high greenhouse gas releases drive excessive global warming and related increases in natural catastrophe exposure. Under this scenario warming by the end of the 21st century is expected to be between 3.3 and 5.7 °C. The SSP5-8.5 scenario is comparable to the RCP8.5 scenario.

CMIP6 Scenarios – Global CO_2 Emissions ($GtCO_2$/yr)



Source: DKRZ

Example of an increase of exposure to river flood.
Comparing the timepoints “current”, 2030 and 2100, the location will become more and more exposed to river flood events, due to the impact of climate change.

Scores that score points when it comes to climate change

Climate Change Edition supports you not only with information regarding the exposure of your assets to current physical risks, but above all in analysing and assessing the physical risks associated with climate change in various future scenarios.

In terms of both acute and chronic climate risks, this edition includes not only 12 NATHAN Hazard Scores and four NATHAN Risk Scores, but also eight additional Climate Hazard Scores which consider the effects of climate change. And unlike the Natural Hazards Edition, the risk scores are not only calculated on the basis of past events, but also include projected changes in the intensity and frequency of future events under different climate scenarios and projection years right up to 2100.

Climate Hazard Scores

The Climate Hazard Scores cover either RCP scenarios[2] (RCP4.5 and 8.5) or SSP scenarios[3] (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) as well as the current, 2030, 2040, 2050 and 2100 projection years.[1]

[1]For some Climate Hazard Scores only a part of the scenarios or projection years is available.
[2]Representative Concentration Pathway
[3]Shared Socioeconomic Pathway

River Flood[1]
Munich Re models the future River Flood Hazard Score using the River Flood model for current atmospheric conditions as a basis and estimating changes in flood risk using an aggregate of climate and hydrological models.
Resolution: 30 m | RCP: 4.5, 8.5 | Projection years: Current, 2030, 2050, 2100

Tropical Cyclone[1]
Munich Re creates its future Hazard Scores by combining its proprietary tropical cyclone model with a high-atmospheric-resolution climate model to incorporate projected changes in the intensity and frequency of tropical cyclones.
Resolution: 5 km | RCP: 4.5, 8.5 | Projection years: Current, 2030, 2050, 2100

Sea Level Rise[1]
The Sea Level Rise Score shows the areas with elevated risk of flooding due to rising sea levels in 2100. The model is based on storm surge hazard zones, IPCC data on sea-level rise and elevation information.
Resolution: 30 m | RCP: 2.6, 4.5, 8.5 | Projection years: 2100

Fire Weather Stress
The Fire Weather Stress Index describes meteorological fire conditions based on the Fire Weather Index (FWI), combining the probability of ignition, the speed and likelihood of fire spread and the availability of fuel.
Resolution: 11km | SSP: 2.6, 4.5, 7.0, 8.5 | Projection years: Current, 2030, 2040, 2050, 2100

Drought Stress[1]
The Drought Stress Index is based on the Standardised Precipitation Evapotranspiration Index (SPEI) and dry-spell conditions. SPEI is a multi-scalar drought index that is used to determine the onset, duration and magnitude of drought conditions.
Resolution: 11km | SSP: 4.5, 8.5 | Projection years: Current, 2030, 2040, 2050, 2100

Heat Stress
The Heat Stress Index combines information on increasing temperatures, extreme heat and heat waves.
Resolution: 11km | SSP: 2.6, 4.5, 7.0, 8.5 | Projection years: Current, 2030, 2040, 2050, 2100

Precipitation Stress
The Precipitation Stress Index describes the meteorological threat from high precipitation, combining data on precipitation duration, intensity and frequency.
Resolution: 11km | SSP: 2.6, 4.5, 7.0, 8.5 | Projection years: Current, 2030, 2040, 2050, 2100

Cold Stress
The Cold Stress Index combines several temperature-related parameters and classifies climatological cold stress.
Resolution: 11km | SSP: 2.6, 4.5, 7.0, 8.5 | Projection years: Current, 2030, 2040, 2050, 2100

NATHAN Hazard Scores

NATHAN Hazard Scores describe the hazard level of a location for all hazards.

River Flood
The River Flood Hazard Score is based on a global flood model from JBA, describing flood extents for return periods of 50, 100 and 500 years, and is available on both an undefended and defended basis, i.e. taking flood protection into account.
Data type: Raster; Resolution: 30 m

Flash Flood
The Flash Flood Hazard Score describes the hazard level, based on meteorological data, soil sealing information as well as terrain and hydrographic data (slope and flow accumulation).
Data type: Raster; Resolution: 250 m

Storm Surge
Storm surges are coastal floods caused by storms such as tropical cyclones and extratropical storms. The Storm Surge Hazard Score reflects the inundation area for return periods of 100, 500 and 1000 years and is available in an undefended as well as defended view, i.e. taking flood protection into account.
Data type: Raster; Resolution: 90 m

Tropical Cyclone
The Tropical Cyclone Hazard Score is derived from globally consistent, basin-specific models for tropical cyclones, and is based on probable maximum wind intensities with a return period of 100 years.
Data type: Raster; Resolution: 5 km

Extratropical Storm
The Extratropical Storm Hazard Score shows the probable maximum wind intensity occurring during extratropical storms in the region (approx. 30 – 70° north and south of the equator) for a 100-year return period.
Data type: Raster; Resolution: 1 km

Tornado
The Tornado Hazard Score is based on the annual frequency of tornadoes over an area of 10,000 km^2, interpolated from meteorological data.
Data type: Vector geometry (Polygons)

Hail
The Hail Hazard Score describes the hail potential by combing meteorological data, elevation and the global distribution of lightning activity.
Data type: Vector geometry (Polygons)

Lightning
This Hazard Score shows the global frequency of lightning strikes per km^2 and year recorded by satellites and ground-based lightning detection networks.
Data type: Vector geometry (Polygons)

NATHAN Hazard Scores	**Earthquake**	The Earthquake Hazard Score is graded according to the probable maximum intensity of earthquakes on the Modified Mercalli Intensity (MMI) scale for an event with a return period of 475 years. Data type: Vector geometry (Polygons)
	Volcano	The Volcano Hazard Score is based on volcanic activities, which are classified depending on their VEI (Volcano Explosivity Index) and annual return periods. Data type: Vector geometry (Polygons)
	Tsunami	The Tsunami Hazard Score reflects the flood inundation areas for return periods of 100, 500 and 1000 years. Data type: Raster; Resolution: 90 m
	Wildfire	The Wildfire Hazard Score describes the hazard of wildfire, based on climatological data and land cover data. Data type: Raster; Resolution: 1 km
NATHAN Risk Scores NATHAN Risk Scores provide an overview and identify high-risk assets. They aggregate the risk of each asset in the portfolio in terms of geophysical, hydrological, meteorological and climatological hazards.	**Overall**	The Overall Risk Score can be used as a primary identifier of red flags. It combines the Earthquake, Storm and Flood Risks Scores, also taking Wildfire Risk into account.
	Earthquake	The Earthquake Risk Score can be used to identify earthquake-related risks and includes Earthquake, Volcano and Tsunami risks.
	Storm	The Storm Risk Score can be used to identify storm-related risks and includes Tropical Cyclone, Extratropical Storm, Hail, Tornado and Lightning risks.
	Flood	The Flood Risk Score can be used to identify flood-related risks and includes River Flood, Flash Flood and Storm Surge risks.

"Thanks to the detailed and meaningful assessment of physical risks from natural disasters and climate change using Climate Change Edition, **we can make an informed credit decision in our risk analysis.**"

Bayern LB

Patrick Th. Gruninger
Chief Specialist in Credit Management
Bayerische Landesbank

River Flood

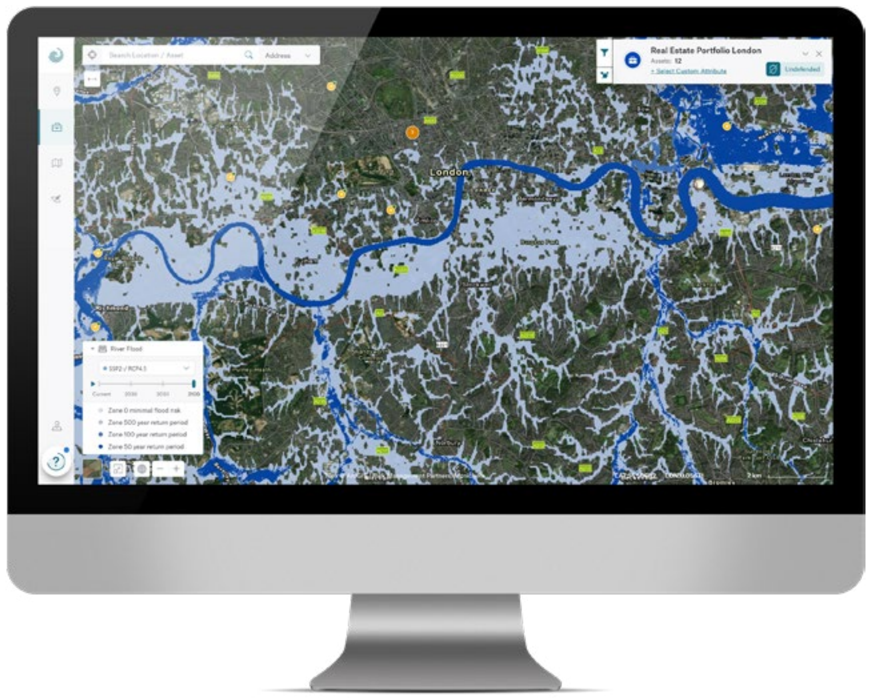
NATHAN current River Flood Hazard data (provided by JBA Risk Management) offers state-of-the-art flood hazard information (with a 30m horizontal resolution), available on a global scale. The global flood maps are constantly improved and are a market standard.

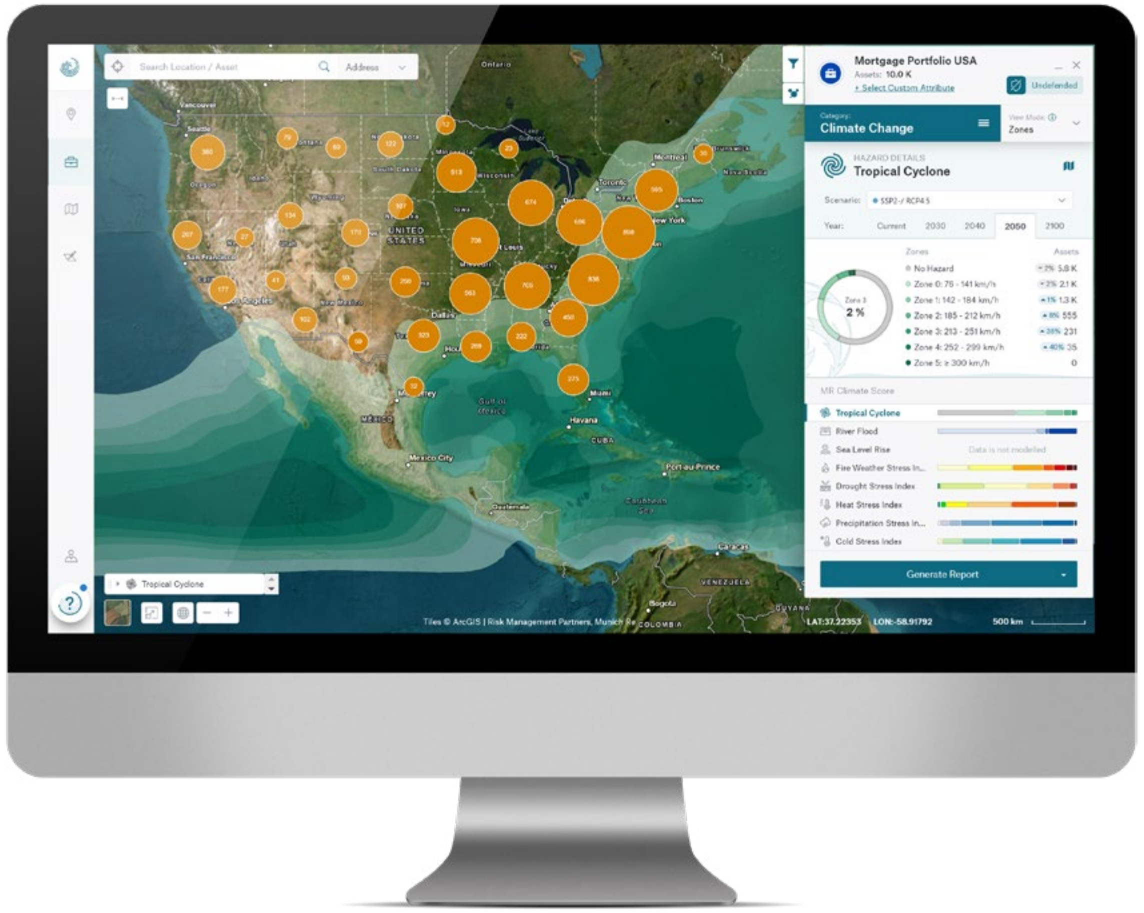
They are based on bare-earth digital terrain data and a consistent worldwide digital surface model. The River Flood Hazard is represented by four return period zones, ranging from Zone 0 (areas of minimal flood risk) to Zone 50 (50-year return period of river flood). The River Flood Hazard Score is available in two versions: Defended and Undefended. In the defended version the standards of protection provided by local flood defences is considered in the hazard calculation.

Flood zone	Description of flood zones
Zone 0	Areas outside the 0.2% annual chance floodplain
Zone 500	0.2% annual chance flood event (500-year return period)
Zone 100	1% annual chance flood event (100-year return period)
Zone 50	2% annual chance flood event (50-year return period)

Flood protection systems are defence structures to reduce the flooding of areas and properties. Globally, the quality of the information on flood defences and on the specific structures differs considerably. Hence, there is value in considering the undefended River Flood Hazard in order to maintain global consistency. Munich Re provides both defended and undefended River Flood Hazard information. Information on the standard of protection of flood defences (SoP) is also available.

The flood projections follow a hybrid method using the output from the latest high-resolution CMIP5 global climate model runs and global land surface models to estimate changes in peak water run-off at hydrological basin resolution. These changes in peak run-off are then used to scale current River Flood maps, using flood depth data from JBA Risk Management. The projections are available for two emission scenarios (RCP4.5 and RCP8.5) for the projection years 2030, 2050 and 2100.





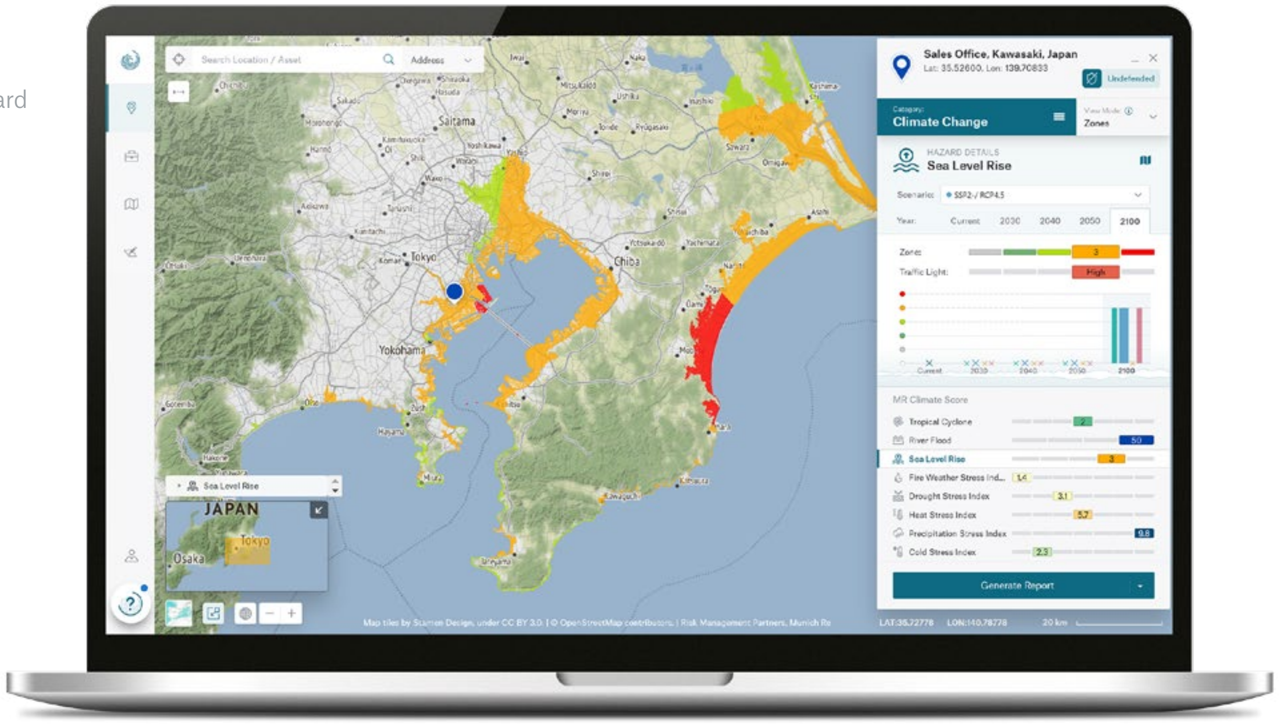
Tropical Cyclone

Tropical Cyclones are among the most destructive weather phenomena. Coastal regions and islands are particularly exposed as they are affected not only by the direct impact of a storm, but also by the secondary hazards, such as Storm Surges and pounding waves.

The intensity of a storm rapidly decreases as it moves inland because of the friction increase due to the roughness of the Earth's surface and reduction in the supply of energy (primarily from water vapour) to the storm system. Orographic effects can also lead to high amounts of rainfall, which in turn can result in severe flooding, producing multi-billion dollar losses in densely populated regions with high GDP.

The current (present day) Tropical Cyclone hazard analysis is based on Munich Re's Tropical Cyclone zoning in NATHAN, which uses forward wind, maximum wind speed, minimum central pressure, radius of maximum wind speeds and track of the centre ("eye") in 3- to 6-hourly intervals (in exceptional cases, 12-hourly intervals) as the main variables for modelling. The wind fields of all historical windstorms have been simulated and superimposed in a grid network with a mesh size of 0.1 x 0.1 degrees of geographical longitude and latitude. By means of a frequency analysis for each grid coordinate, the maximum wind speed to be expected (probable maximum intensity with an average exceedance probability of 10% in 10 years) has been derived for the return period of 100 years chosen for the world map. The hazard zoning is represented by a five-level scale (maximum wind speed that can be expected once in 100 years) based on the Saffir-Simpson scale, multiplied by a gust factor of 1.2.

The Tropical Cyclone projections are based on published model run results of the High-Resolution Forecast-Oriented Low Ocean Resolution (HiFLOR) model at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL). The HiFLOR model allows the user to assess how climate change will alter the frequency and intensity of Tropical Cyclones. The scientific results are used for remodeling the NATHAN hazard zones, based on a five-level scale for the probable maximum intensity with an exceedance probability of 10% in 10 years (equivalent to a return period of 100 years). The future projections are available for RCP 4.5 and 8.5 for the projection years 2030, 2050 and 2100.



Sea Level Rise

According to the IPCC Fifth Assessment Report, the global mean Sea Level has Risen more than 20 centimetres since 1880 and the trend is continuing at an unprecedented speed.

Sea Level Rise is primarily caused by processes linked to global warming, such as the melting of glaciers and ice sheets, and the thermal expansion of water. Furthermore, the rising sea level leads to multiple negative effects like coastal erosion, inundations, storm floods, tidal waters encroaching into estuaries and river systems as well as contamination of freshwater reserves.

Sea Level Rise can affect coastal regions worldwide, and regions will experience varying impacts based on their topography and mitigation measures. Munich Re provides hazard information on a 30m resolution for Flooding Hazard by sea-level rise globally. The extents of potentially flooded areas are given by Storm Surge events with a 100-year return period. Sea-level rise zones have been modelled on the basis of high-resolution elevation data from the ALOS elevation model and Sea Level Rise projections from climate models. This enables the identification of five different hazard classes describing the potential hazards represented by Sea Level Rise, from no hazard to extreme hazard.

Coastal topography → Elevation Index → Sea Level Rise Hazard zones

Sea Level Rise → Sea Level Rise Index → Sea Level Rise Hazard zones

The Sea Level Rise Hazard information is available for the three RCPs (RCP2.6, RCP4.5 and RCP8.5) and the projection year 2100.

Fire Weather Stress

Wildfires are a destructive hazard, which can occur naturally and can be caused by humans. Fire Weather Stress describes meteorological fire conditions on the basis of fire danger modelling, namely the Fire Weather Index (FWI).

The FWI combines the probability of ignition, the speed and likelihood of spread and the availability of fuel to a combined metric. Fire events are often accompanied by secondary effects including erosion, landslides, impaired water quality and smoke damage. According to the European Commission's Joint Research Centre (JRC), climate change alters the relevant meteorological conditions impacting the ignition and spread of wildfires. On the basis of fire danger modelling, Munich Re provides detailed information on wildfire conditions as well as an integrated Fire Weather Stress Index.

The Fire Weather Stress Index is based on the Fire Weather Index (FWI), which describes the climatological conditions for wildfire. The FWI is a widely used numeric rating, combining the probability of ignition, the speed and likelihood of fire spread and the availability of fuel. The FWI is modelled on the basis of daily information about temperature, precipitation, humidity and wind, using ECMWF ERA5 and ERA5-Land atmospheric reanalysis data for the reference period. The changes for the projection periods are based on the respective data from the latest high-resolution global (CMIP6) climate models. The Fire Weather Stress Index combines relevant information derived from the FWI time series and classifies the Fire Weather Stress situation on a scale ranging from 0 (very low) to 10 (very high).

The Fire Weather Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: Annual Fire Season Length, Fire Season Intensity, Annual FWI Sum, Annual Maximum FWI, Annual Number Of High Fire Danger Days.

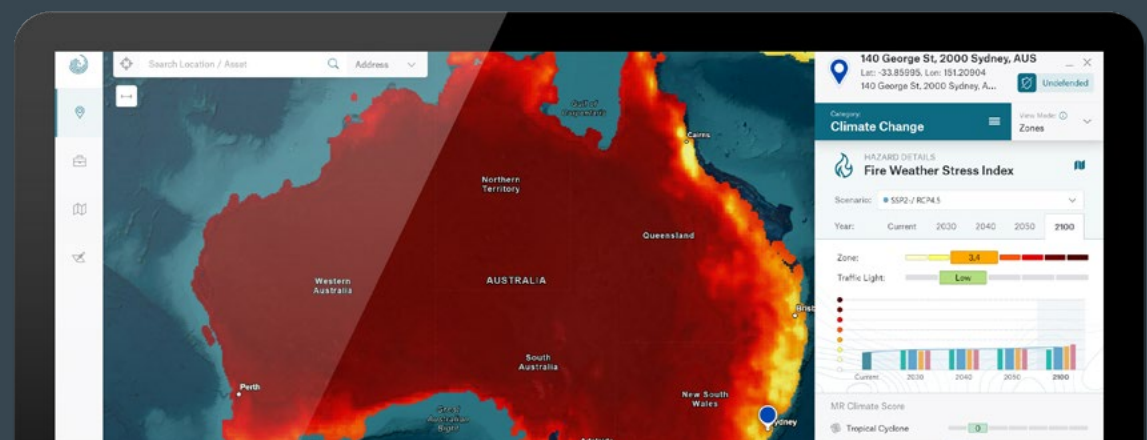
The Fire Weather Stress Index is calculated from a range of measures related to climatological wildfire conditions, including the following Climate Change Variables[1]:

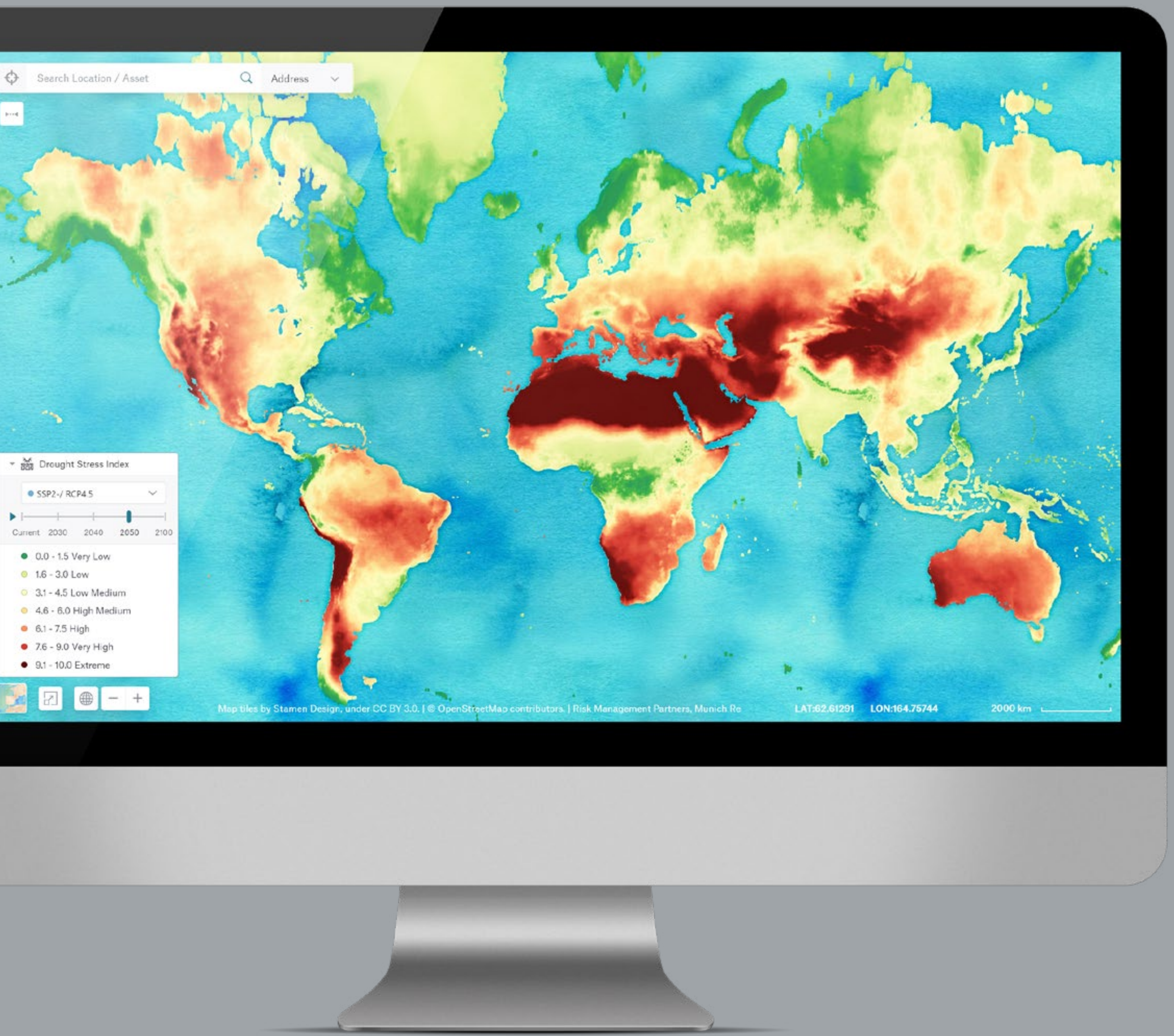
Utilised Climate Change Variables[1]	Description
Length Of Fire Season	Annual number of days corresponding to the fire season[2] [days]
Annual FWI Sum	Annual sum of daily Fire Weather Index (FWI)
Annual Maximum FWI	Annual maximum of daily FWI
Fire Season FWI Intensity	Average FWI value during the fire season[1]
Annual Number Of Moderate, High and Very High Fire Danger Days	Annual number of days with moderate (FWI>15), high (FWI>30) and very high (FWI>45) fire danger [days]

All scores and additional measures are available for the reference period as well as the respective combination of the four SSPs (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) and projection years 2030, 2040, 2050 and 2100.

[1] The underlying Climate Change Variables are also optionally available as individual values. You can find more information under Climate Change Expert Module.

[2] The start / end of the Fire Season is defined according to the FWI>=15 / FWI<15 being maintained for two consecutive weeks in the 7-day moving average FWI series





Drought Stress

Increasing temperature in addition to changes in precipitation patterns can cause drier weather conditions and hence more intense and frequent drought events, which can have severe economic, environmental and social impacts. Munich Re provides an integrated Drought Stress Index to identify the impact of climate change on current drought conditions globally.

The Drought Stress Index describes dryness conditions and changes in the water balance, characterised by the change in precipitation and potential evapotranspiration. It is derived from multiple dryness indices and the Standardized Precipitation-Evapotranspiration Index (SPEI), which is a state-of-the-art index for describing drought conditions. As a multi-scalar drought index, the SPEI is based on climatic data, used to determine the duration, intensity and severity of drought conditions with respect to historical conditions (calibrated over a 40-year period from 1950). The SPEI is modelled on the basis of daily information about temperature, precipitation and humidity, using data from the latest high-resolution global climate models (CMIP6) to assess drought conditions. Relevant dryness parameters are modelled on the basis of ECMWF ERA5 and ERA5-Land atmospheric reanalysis data (~10 km horizontal resolution) for the reference period[1], together with data from the latest high-resolution global climate models (CMIP6) for the future.

The Drought Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: Drought Durations, Drought Severity Per Event, and Annual SPEI Sum from the 9-month SPEI time series as well as Meteorological Dry Days, Maximum Dry Spell Duration and 10-Day Dry Spell Days.

The Drought Stress Index is calculated from a variety of scientific data, including the following Climate Change Variables[2]:

Utilised Climate Change Variables[2]	Description
Drought Duration Per Year	Annual number of months with drought conditions[3] [months]
Drought Severity Per Event	Annual average of accumulated sum of negated monthly SPEI values (i.e. SPEI values with reversed signs) in identified drought events, where drought events are episodes with SPEIs below -1[3]
Annual SPEI Sum	Annual sum of negated monthly SPEI values (i.e. SPEI values with reversed signs)
Meteorological Dry Days	Annual number of days with precipitation less than 1mm [days]
Maximum Dry Spell Duration	Annual maximum length of dry spells (consecutive days with precipitation less than 1mm) [days]
10-Day Dry Spell Duration	Annual number of days in dry spells that last a minimum of 10 days [days]

All scores and additional measures are available for the reference period as well as the respective combination of two SSPs (SSP2-4.5and SSP5-8.5) and projection years 2030, 2040, 2050 and 2100.

[1]The reference period is 1995 to 2014.

[2]The underlying Climate Change Variables are also optionally available as individual values. You can find more information under Climate Change Expert Module.

[3]Drought conditions are defined as occurring during months with a monthly SPEI of below -1.

Heat Stress

Global warming is increasing the risk of Heat Stress, which affects humans, infrastructure and ecosystems. Temperatures are rising and the intensity and frequency of heat waves are increasing. Munich Re provides detailed information on the meteorological threat by Heat Stress and an integrated Heat Stress Index.

Relevant heat parameters are modelled on the basis of ECMWF ERA5 and ERA5-Land atmospheric reanalysis data (~10 km horizontal resolution) for the reference period[1] and combined with data from the latest high-resolution global climate models (CMIP6) for the future projections. The Heat Stress Index combines relevant information from these parameters and classifies the climatological Heat Stress situation on a scale ranging from 0 (very low) to 10 (very high). The parameters were chosen in accordance with scientific studies with the aim of depicting heat stress consistently, locally and globally.

The Heat Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: Annual Days In Heat Wave, Annual Maximum Temperature, Annual Mean Daily Maximum Temperature, Annual Days Above 40°C and Annual Tropical Nights.

The Heat Stress Index is calculated from a variety of scientific data, including the following Climate Change Variables[2]:

Utilised Climate Change Variables[2]	Description
Annual Maximum Temperature	Annual maximum of daily maximum temperature[3] [°C]
Mean Daily Maximum Temperature	Annual mean of daily maximum temperature[3] [°C]
Days In Heatwave[1]	Annual number of days in a heatwave[4] [days]
Tropical Nights	Annual number of days when the night temperature (daily minimum temperature[3]) does not fall below 20°C [days]
Days Above 30, 35, and 40°C	Annual number of days with daily maximum temperature[3] exceeding 30, 35, and 40°C respectively [days]
Annual Number Of Days In Hot Period	Annual number of days that are part of a period, of a minimum of 3 days, in which the daily maximum temperature is at least 35°C. [days]
Annual Warm Spell Duration Index Days	The annual Warm Spell Duration Index (WSDI) days represent the annual number of days that are part of a series of at least 6 days in which the daily maximum temperature[3] surpasses the 90th percentile of daily maximum temperature observed during the reference period[1] [days]

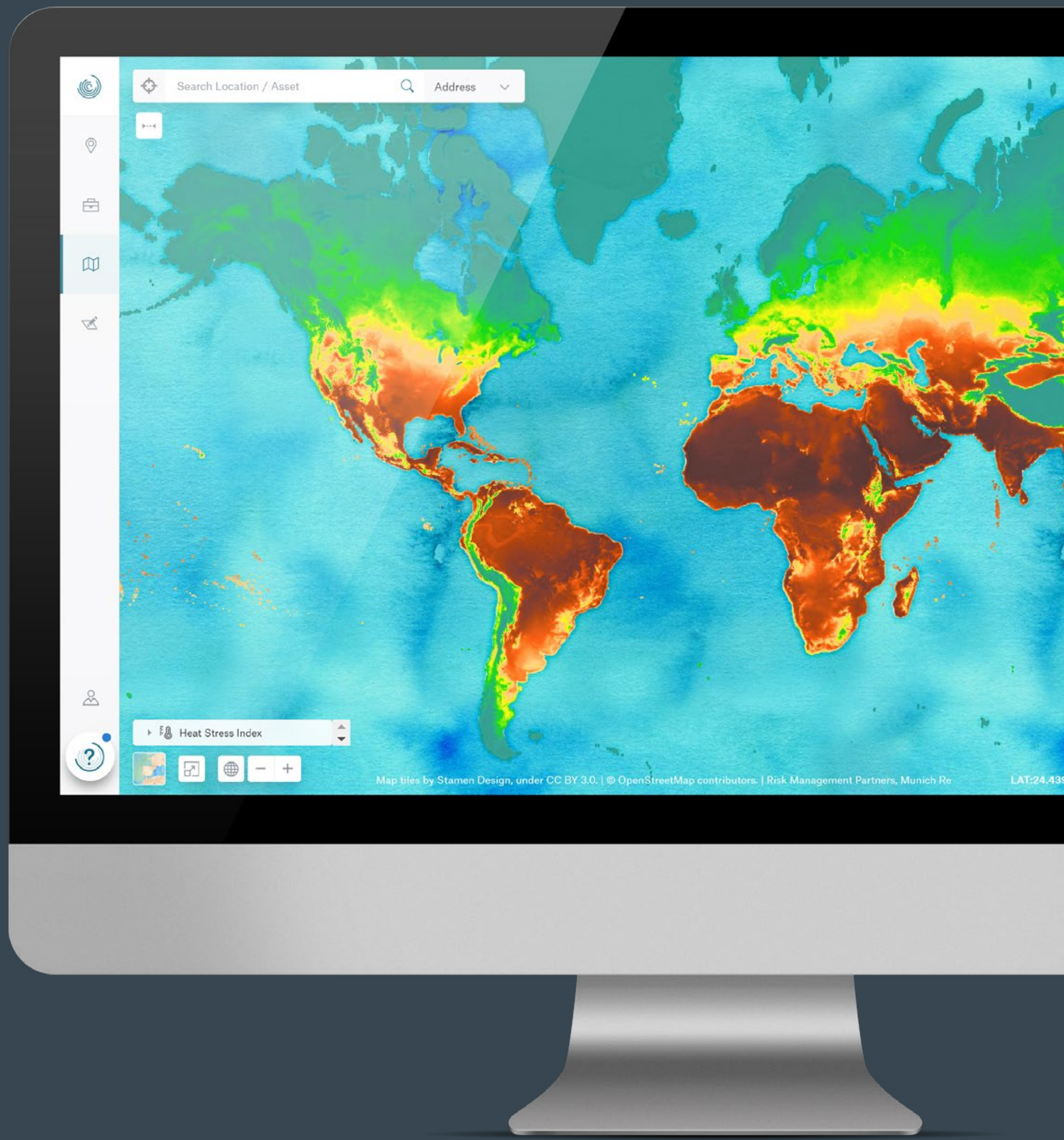
All scores and additional measures are available for the reference period as well as the respective combination of the four SSPs (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) and projection years 2030, 2040, 2050 and 2100.

[1] The reference period is 1995 to 2014

[2] The underlying Climate Change Variables are also optionally available as individual values. You can find more information under Climate Change Expert Module.

[3] Near-surface air temperature

[4] Heatwaves as days with daily maximum near-surface air temperature > 30°C for at least 3 consecutive days (which continue as long as the average maximum temperature remains > 30°C for the whole period and maximum temperature never falls < 25°C for any day).



Precipitation Stress

Due to global warming and particularly to warmer oceans, air contains more moisture. The impact of climate change on precipitation is very heterogenous globally, which is caused by its fine-scale features. Climate change can lead to an intensification of high-precipitation events and an alteration of the frequency of such events, which can cause crop damage, soil erosion and increase Flood Risk.

Munich Re provides information on the threat posed by heavy precipitation in the form of detailed precipitation information as well as an integrated Precipitation Stress Index. Relevant precipitation parameters are modelled on the basis of ECMWF ERA5 and ERA5-Land atmospheric reanalysis data for the reference period and data from the latest high-resolution global (CMIP6) climate models for the future projections. The Precipitation Stress Index combines relevant information from the parameters characterising heavy precipitation, and classifies the Precipitation Stress situation on a scale ranging from 0 (very low) to 10 (very high). The parameters were chosen in accordance with scientific studies with the aim of depicting heavy-precipitation stress consistently, locally and globally. The Precipitation Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: maximum daily precipitation, maximum 5-day precipitation, annual number of very heavy precipitation days, total precipitation of Very Wet Days.

The Precipitation Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: Maximum Daily Precipitation, Maximum 5-Day Precipitation, Annual Number Of Heavy Precipitation Days.

The Precipitation Stress Index is calculated from a variety of scientific data, including the following Climate Change Variables[1]:

Utilised Climate Change Variables[1]	Description
Maximum Daily Precipitation	Annual maximum of 1-day precipitation [mm]
Maximum 5-Day Precipitation	Annual maximum of 5-day consecutive precipitation[mm]
Moderate, Very Heavy, Extreme Wet Days	Annual number of days with a total precipitation > 10mm (moderate), 30mm (very heavy), 50mm (extreme) [days]
Annual Precipitation Sum	Total annually accumulated precipitation [mm]
Precipitation Sum On Very Wet Days and Extremely Wet Days	Annual sum of precipitation amount on days with more precipitation than in the historical 5% wettest days and 1% wettest days, for Very Wet Days and Extremely Wet Days respectively, observed during the reference period[2] [mm]

[1]The underlying Climate Change Variables are also optionally available as individual values. You can find more information under Climate Change Expert Module.

[2]The reference period is 1995 to 2014.

All scores and additional measures are available for the reference period as well as the respective combination of the four SSPs (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) and projection years 2030, 2040, 2050 and 2100.

Cold Stress

Climate change will alter not only maximum temperatures but also minimum temperatures in the future. These altered environmental conditions may have an impact on people, infrastructures and the biosphere. Therefore, Munich Re also provides detailed information on the meteorological threat of Cold Stress and an integrated Cold Stress Index.

Relevant heat parameters are modelled on the basis of ECMWF ERA5 and ERA5-Land atmospheric reanalysis data (~10 km horizontal resolution) for the reference period[1], together with data from the latest high-resolution global climate models (CMIP6) for the future projections. The Cold Stress Index combines relevant information from these parameters and classifies the climatological Cold Stress situation on a scale ranging from 0 (very low) to 10 (very high). The parameters were chosen in accordance with scientific studies with the aim of depicting Cold Stress consistently, locally and globally.

The Cold Stress Score is the categorised average of the following parameters normalised onto a 0-10 scale: Annual Days In Cold Spell, Annual Minimum Temperature, Annual Mean Daily Minimum Temperature, Annual Days of Frost and Annual Days of Ice.

The Cold Stress Index is calculated from a variety of scientific data, including the following Climate Change Variables[2]:

Utilised Climate Change Variables[2]	Description
Annual Minimum Temperature	Annual minimum of daily minimum temperature[3] [°C]
Mean Daily Minimum Temperature	Annual mean of daily minimum temperature[3] [°C]
Annual Number Of Frost Days	Annual number of days with daily minimum temperature < 0°C [days]
Annual Number Of Ice Days	Annual number of days with daily maximum temperature < 0°C [days]
Annual Cold Spell Duration Index Days	The Annual Cold Spell Duration Index (WSDI) Days represent the annual number of days that are part of a series of at least 6 days in which the daily minimum temperature[3] is below the 90th percentile of daily minimum temperature observed during the reference period[1] [days]

[1]The reference period is 1995 to 2014.

[2]The underlying Climate Change Variables are also optionally available as individual values. You can find more information under Climate Change Expert Module.

[3]Near-surface air temperature

All scores and additional measures are available for the reference period as well as the respective combination of the four SSPs (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) and projection years 2030, 2040, 2050 and 2100.

Climate Change Expert Module

Many business decisions depend on how accurately you can understand, measure and manage the risk of climate change, and the decision-making process therefore requires the latest and most relevant data.

Transparency and trust in the data form the basis for excellence in risk management and modelling. Climate Change Expert Module provides an extensive set of climate metrics which enable you to conduct in-depth analyses into the concrete climate risks threatening your business operations. It puts you in a position to provide very specific answers to the way in which climate change will affect your risk exposure, your investment and your decision-making. In addition to our globally consistent Climate Stress Indices from Climate Change Edition, which capture the different facets of climate risk (too hot, too cold, too wet, too dry...) in a high-level universal way, Climate Change Variables plus the Climate Change Statistics allow you to deep dive local, sector-specific drivers of climate risk threating your business success.

Climate Change Variables

35 Climate Change Variables or 35 ways to assess risks in more detail: Climate Change Expert Module provides you with a total of 35 additional detailed scores, the so-called Climate Change Variables, for the five Climate Hazard Scores (Fire Weather Stress, Drought Stress, Heat Stress, Precipitation Stress and Cold Stress) for an in-depth assessment of your assets.

Fire Weather Stress Index

Length Of Fire Season	Annual number of days corresponding to the fire season
Annual FWI Sum	Annual sum of daily Fire Weather Index (FWI)
Fire Season FWI Intensity	Average FWI value during fire season (i.e. cumulative FWI sum divided by number of days in fire season)
Moderate Fire Danger Days	Number of days with moderate (FWI>15) fire danger
Very High Fire Danger Days	Number of days with very high (FWI>45) fire danger
Maximum FWI	Annual maximum of the Fire Weather Index (FWI)

Drought Stress Index

Drought Duration Per Year	Annual number of months with drought conditions, where an SPEI (Standardized Precipitation Evapotranspiration Index) of -1 is the threshold for identifying drought conditions
Drought Severity Per Event	Annual average of accumulated sum of monthly SPEI in identified drought events (i.e. integrating drought magnitude along drought durations), where drought events are episodes with SPEIs below -1
Max. Dry Spell Duration	Annual maximum length of dry spells (consecutive days with precipitation less than 1mm)
Annual SPEI Sum	Annual sum of monthly SPEI values
Meteorological Dry Days	Annual number of days with precipitation less than 1mm
10 Day Dry Spell Duration	Annual number of days in a 10-day dry spell

Heat Stress Index

Annual Maximum Temperature	Annual max. of daily maximum temperature
Annual Mean Daily Max. Temperature	Annual mean of daily maximum temperature
Days above 30°C	Annual number of days with daily max. temperature higher than 30°C
Days above 35°C	Annual number of days with daily max. temperature higher than 35°C
Days above 40°C	Annual number of days with daily max. temperature higher than 40°C
Tropical Nights	Annual count of days when night temperature (daily minimum temperature) >20°C
Days In Heatwave	Annual number of days in heatwave with heatwave definition by Kyselý, Kalvová, & Kveton, 2000: Daily max. temperature above 30°C for at least three consecutive days (and continue to be counted as long as the average max. temperature remains above 30°C for the whole period and max. temperature never falls below 25°C for any single day)
Annual Number Of Days In Hot Period	Annual number of days that are part of a sequence with minimum 3 days in which the daily maximum temperature is at least 35°C
Annual Warm Spell Duration Index Days	Annual number of days that are part of a series of at least 6 days in which the daily max. temperature surpasses the 90th percentile of the period 1995-2014

Precipitation Stress Index

Maximum Daily Precipitation	Annual maximum of 1-day precipitation
Annual Precipitation Sum	Annually accumulated precipitation
Maximum 5-Day Precipitation	Annual maximum of 5-day consecutive precipitation
Moderate Precipitation Days	Annual number of days with more than 10mm precipitation
Very Heavy Precipitation Days	Annual number of days with more than 30mm precipitation
Extreme Precipitation Days	Annual number of days with more than 50mm precipitation
Precipitation On Very Wet Days	Annual sum of precipitation amount on days with more precipitation than in the 5% wettest days of the period 1995-2014
Precipitation On Extreme Wet Days	Annual sum of precipitation amount on days with more precipitation than in the 1% wettest days of the period 1995-2014

Cold Stress Index

Annual Minimum Temperature	Annual minimum of daily min. temperature
Annual Mean Daily Min. Temperature	Annual mean of daily min. temperature
Annual Cold Spell Duration Index Days	Annual number of days that are part of a sequence of at least six days where the daily minimum temperature is lower than the 10th percentile of the period 1995-2014
Frost Days	Annual number of days with minimum temperature < 0°C
Ice Days	Annual number of days with maximum temperature < 0°C

Climate Change Statistics

If you need to base your business decisions on highly detailed data assessments, our REST API allows you to seamlessly integrate all of the entire underlying statistical uncertainty measures data into your business systems. Each Climate Change Variable (absolute value) is based on six Climate Change Statistics to ensure highest data accuracy and provide maximum transparency.

Absolute/relative change

Median of projected change from reference period to specified projection year, derived from a set of available CMIP6 models.

0.1 quantile of absolute/relative change

10th percentile of projected change from reference period to specified projection year, derived from a set of available CMIP6 models.

0.9 quantile of absolute/relative change

90th percentile of projected change from reference period to specified projection year, derived from a set of available CMIP6 models.

Standard deviation of absolute/relative change

Standard deviation of projected change from reference period to specified projection year, derived from a set of available CMIP6 models.

Change of robustness

Robustness of projected change, derived from the statistical significance of change of set of available climate models and model agreement. (Values: -1 = lacking model agreement, 0= no significant change, 1 = significant change)

Number of models

Number of CMIP6 models used for climate variable calculation.

Please note: This data service requires an Enterprise platform subscription, which includes the use of our REST API for easy data integration into your own business systems.

River Flood

Munich Re's River Flood Hazard data (provided by JBA Risk Management) offers state-of-the-art flood hazard information (with a 30m horizontal resolution), available on a global scale. The global flood maps are constantly improved and are a market standard.

They are based on bare-earth digital terrain data and a consistent worldwide digital surface model. The River Flood Hazard is represented by four return period zones, ranging from Zone 0 (areas of minimal flood risk) to Zone 50 (50 year return period of River Flood). Information on the standard of protection of the flood defences (SoP) is available upon request. River Flood projections for the years 2030, 2050 and 2100 are available in Munich Re's Climate Change Edition.

Flood zone Description of flood zones

Flood zone	Description
Zone 0	Areas outside the 0.2% annual chance floodplain
Zone 500	0.2% annual chance flood event (500-year return period)
Zone 100	1% annual chance flood event (100-year return period)
Zone 50	2% annual chance flood event (50-year return period)

Summary:

Values on the map show: river flood hazard divided into four return periods (minimal risk 0, 500, 100, 50).

Spatial resolution: 30 metres
Coverage: global
Source: JBA Risk Management Limited

Flash Flood

Flash Floods are short-term events which can be produced by severe convective storms or heavy rain events over one area. Flash Floods can be heavily destructive due to the enormous amount of water which often carries rocks, debris and mud.

The hazard is represented by 6 zones, starting from Zone 1 (low hazard) to Zone 6 (high hazard). The Flash Flood map is based on meteorological data, as well as soil, terrain and hydrographic data (slope and flow accumulation). The meteorological data includes the amount, variability and extreme behaviour of rainfall. Munich Re uses soil-sealing maps (detected by looking at impervious surfaces), curvature (from global multi-resolution terrain elevation data with a resolution of 7.5 arcseconds), slope and flow accumulation (from conditioned terrain data based on SRTM elevation with a resolution of 15 arcseconds) as modifiers to generate the final Flash Flood map. The data is gridded on a 250-metre raster.

Summary:

Values on the map show: Hazard level of Flash Flood on a scale from 1 (low) to 6 (high).

Spatial resolution: 250 metres
Coverage: global
Source: Munich Re

Storm Surge

Storm Surges can occur along sea coasts if strong wind forces water towards the shore, which can measure up to several metres. In conjunction with the astronomic tide and high seas, extremely high water levels may therefore occur on certain sections of the coast. The geometry of the coast itself plays an important role regarding the exposure to Storm Surge. The effects of a rise in sea level also depend on the shape of the coast. The flatter the strip of the coast, the more extreme the effects will be.

Munich Re classifies the hazard into three categories: Zones 100, 500 and 1000. Coasts in Zone 100 are exposed to a 100-year return period of Storm Surge (1% annual exceedance probability of flooding), those in Zone 500 a 500-year return period (0.2% annual exceedance probability of flooding) and those in Zone 1000 a 1000-year return period (0.1% annual exceedance probability of flooding). The map is based on the MERRIT digital elevation model. The inundation area of these return periods are simulated by applying cost-weighted distance tools. Munich Re simulates multiple wave heights for each coast and calculates the maximum expansion. Wind speeds and bathymetry data are also taken into account.

Summary:

Values on the map show: Storm Surge Hazard divided into three return periods (100, 500 and 1000). The Storm Surge Map is based on MERRIT data.

Spatial resolution: 90 metres
Coverage: global
Source: Munich Re

Tropical Cyclone

Tropical Cyclones are among the most destructive weather phenomena. Coastal regions and islands are particularly exposed as they are affected not only by the direct impact of a storm, but also by the secondary hazards, such as storm surges and pounding waves.

The intensity of a storm rapidly decreases as it moves inland because of the friction increase due to the roughness of the earth's surface and reduction in the supply of energy (primarily from water vapour) to the storm system. Orographic effects can also lead to high amounts of rainfall, which in turn can result in severe flooding, producing multi-billion dollar losses in populated regions with high GDP.

The Tropical Cyclone zoning system uses forward wind, maximum wind speed, minimum central pressure, radius of maximum wind speeds and track of the centre ("eye") in 3- to 6-hourly intervals (in exceptional cases, 12-hourly intervals) as the main variables for modelling. The wind fields of all known tropical cyclones recorded since 19th century have been simulated and superimposed in a grid network with a mesh size of 0.1 x 0.1 degrees of geographical longitude and latitude. By means of frequency analysis for each grid coordinate, the maximum wind speed to be expected (probable maximum intensity with an average exceedance probability of 10% in 10 years) is derived for the return period of 100 years chosen for the world map. The hazard zoning is represented by a five-level scale (maximum wind speed that can be expected once in 100 years) based on the Saffir-Simpson scale, multiplied by a gust factor.

Summary:

Values on the map show: a mean exceedance probability of less than 10% in ten years (a probability of 10% in ten years is equivalent to a return period of one hundred years) for peak wind speeds of six different categories.

Spatial resolution: 5 kilometres
Coverage: global
Source: Munich Re

Extratropical Storm (winter storm)

Extratropical Storms are created in the transition region between subtropical and polar climatic zones, i.e. in the latitudes between about 30° and 70°. In these regions, cold polar air masses collide with tropical air masses, forming extensive low-pressure eddies.

The intensity of the storm areas within these eddies is proportional to the difference in temperature between the two air masses, and is therefore at its greatest in late autumn and winter, when the oceans are still warm but the polar atmosphere is already extremely cold. This is why Extratropical Storms are also referred to as winter storms. Blizzards and ice storms are variants of this type of storm and their potential for damage is often underestimated.

The Extratropical Storm Maps are based on reanalysis data sets which have been downscaled and calibrated by using data from various national weather services, as well as information from global digital terrain models. Gust information from the following centres has been used particularly intensively: the German Weather Service, the Royal Netherlands Meteorological Institute, the UK Met Office, Meteo France, the Bureau of Meteorology (Australia) and the National Oceanic and Atmospheric Administration (USA). An extreme value distribution approach (generalised Pareto distribution including an upper bound estimation) is used to calculate storm maps with higher return periods. The hazard map is classified into five zones based on peak wind speeds (3-sec gust in km/h). The most exposed areas with respect to Extratropical Storms are located between 30° and 70° north and south of the equator. The final resolution of the storm maps is 0.01 degrees (roughly 1 km).

Summary:

Values on the map show: peak wind speeds in five different categories. Probable maximum intensity with an average exceedance probability of 10% in 10 years (equivalent to a 'return period' of 100 years). Areas were examined in which there is a high frequency of Extratropical Storms (approx. 30°–70° north and south of the equator).

Spatial resolution: 1 kilometre
Coverage: global
Source: Munich Re

Tornado

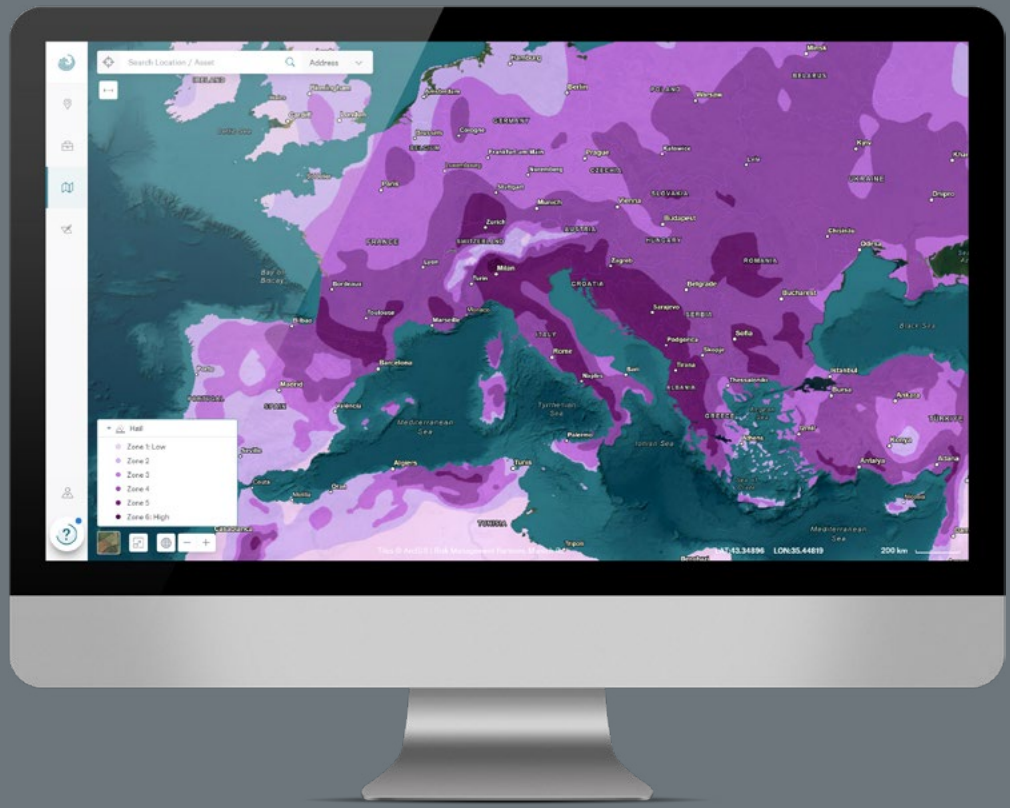
Tornadoes occur worldwide, but are undeniably most frequent in the USA. Tornadoes are very localised but extremely intense. The direct damage caused by the high wind speeds is exacerbated by the sharp drop in air pressure (10% or more) at the centre of the funnel.

The Tornado Zones are based on the annual frequency of tornadoes over an area of 10,000 km² and are interpolated from meteorological data. NOAA data serves as a meteorological parameter. The Tornado Map is a rough estimate of the global situation and is used to identify risk.

Summary:

Values on the map show: frequency of tornadoes on a scale from 1 (low) to 4 (high).

Data type: vector geometry (polygons)
Coverage: global
Source: Munich Re



Hail

Hailstorms cause extensive damage to agriculture, as well as to buildings and vehicles. Heavy hailstorms are usually triggered by wide cold fronts. Occasionally, local hot weather thunderstorms – a result of intense insolation over land or mountain slopes – also lead to severe localised hailstorms.

An important precondition for hailstorms is strong instability. This gives rising air at ground level a strong uplift and results in an even higher-reaching upwind zone with powerful cloud formations. In an upwind zone of this kind, hail particles are suspended in the upper section of the cloud so that water droplets and ice crystals are created and the hail seeds grow in layers as the winds successively carry them up. When the weight of the hail seeds becomes too great or the upwind weakens, the ice seeds fall from the cloud and it begins to hail.

The hailstorm map is based on the global distribution of lightning activity (lightning per km² and year). Data sources of the hailstorm map are OTD/LIS data from NASA, a DEM (interpolated from SRTM data), global temperature data and global precipitation data. Hail as a natural hazard is based on the frequency and intensity of hailstorms. Munich Re does not use statistics on the occurrence of hail events, as such global statistics are not available and/or comparable. For this purpose standardised global records of meteorological data are used. On the basis of this meteorological data it is possible to represent atmospheric conditions which have the potential to create a hailstorm. In fact, the hailstorm map is based on a number of atmospheric conditions with the potential to create a hailstorm.
The following parameters are taken into account for the calculation:
- Average annual evapotranspiration [mm]
- Average annual temperature gradient [°C/km]
- Average annual potential height of fall of hail [m]

Summary:

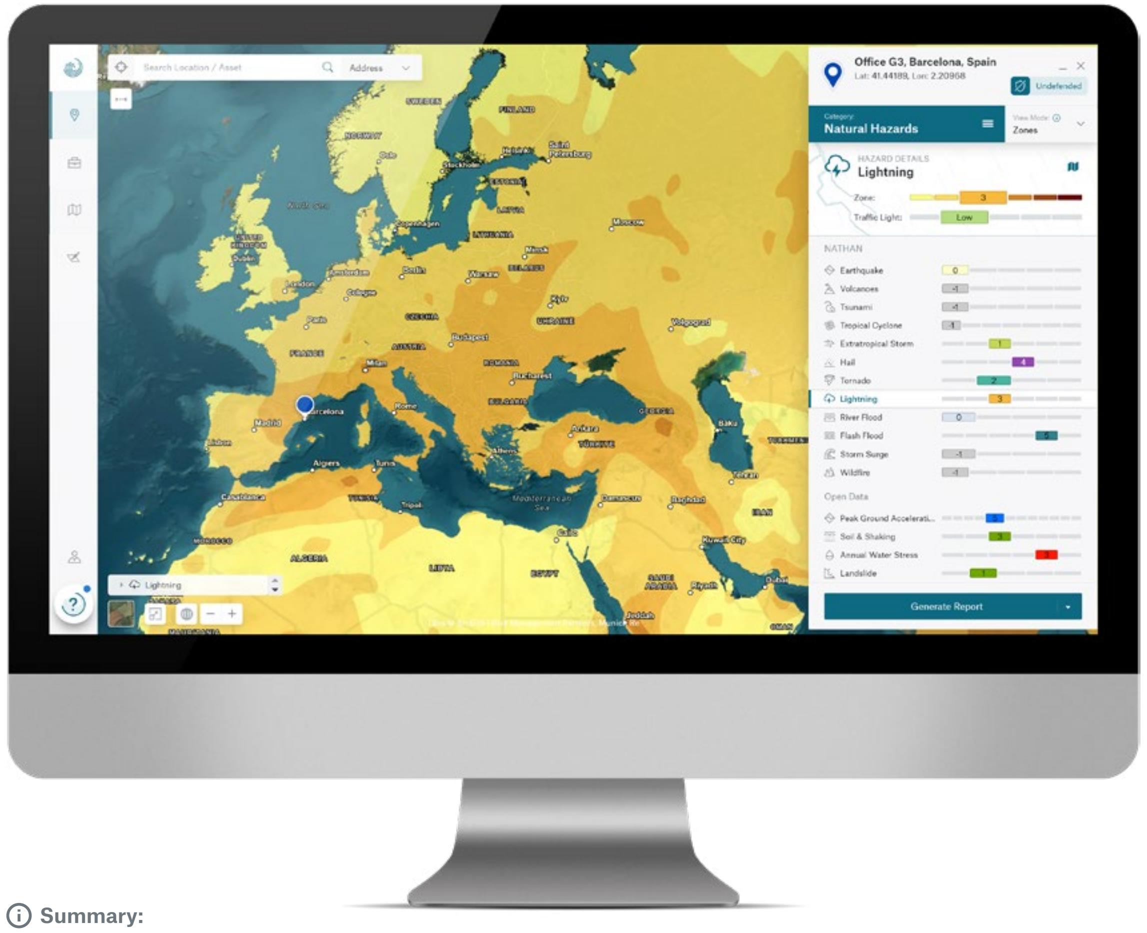
Values on the map show: potential of hailstorms on a scale from 1 (low) to 6 (high).

Data type: vector geometry (polygons)
Coverage: global
Source: Munich Re

Lightning

At any given time about 1500 thunderstorms are taking place all over the world, with hardly any region remaining unaffected. Lightning strikes are the main cause of natural fires, which can destroy whole forests and often buildings.

The Lightning Map shows the global frequency of lightning strikes per km² and year recorded by satellites and ground-based lightning detection networks. Munich Re classifies Lightning in 6 categories based on frequency of lightning strikes. It is based on data from NASA: the product (v2.2) is a 0.5 deg × 0.5 deg gridded composite of total (Intracloud + Cloud-to-Ground) lightning bulk production, expressed as a flash rate density (fl/km²/yr). Climatologies (v2.2) from the 5-yr Optical Transient Detector (OTD) (4/95-3/00) and 8-yr Lightning Imaging Sensor (LIS) (1/98-12/05) missions are included, as well as combined OTD+LIS climatology and supporting base data (flash counts and viewing times). Best-available detection efficiency corrections and instrument cross normalisations have been applied.



Summary:

Values on the map show: global frequency of lightning strikes per km² and year on a scale from 1 (low) to 6 (high).

Data type: vector geometry (polygons)
Coverage: global
Source: Munich Re

Earthquake

The Earthquake Map is graded according to the intensity that is to be expected once in a period of 475 years.

Intensity integrates a number of parameters such as ground acceleration and earthquake duration. The return period of 475 years corresponds to a 10% exceedance probability in 50 years, which represents the mean service life of modern buildings. The intensity is expressed in terms of the modified Mercalli scale (MM).

The Earthquake Map is based on an assemblage of existing hazard maps of individual countries.

The source maps show:
- The minimum intensity or peak acceleration to be expected for an exceedance probability of 10% in 50 years
- The same parameters but for a different reference period
- The maximum intensity observed
- Active or potentially active faults
- Epicentres of Earthquakes recorded by instruments and/or historical Earthquakes

Merging such heterogeneous sources presents enormous problems, beginning with the process of converting acceleration values into macroseismic intensity, for which various formulas have been proposed (e.g. Trifunac and Brady 1975, Murphy and O'Brien 1977).

Summary:

Values on the map show: probable maximum intensity (MM: modified Mercalli scale) with an exceedance probability of 10% in 50 years (equivalent to a return period of 475 years) for medium subsoil conditions.

Data type: vector geometry (polygons)
Coverage: global
Source: Munich Re

Volcano

The Volcano Hazard Map is based on the activities of volcanoes. All volcanoes are located and mapped by coordinates. Munich Re calculates the Volcanic Hazard on the basis of the VEI (volcano explosivity index, US Geological Survey) and its annual return periods given for each VEI index.

As far as technically possible, all volcanoes with known VEI data are classified. 719 volcanoes are therefore classified and the other 830 remain unclassified with no information, due to the fact that those volcanoes have not been investigated or are insufficiently investigated.

Each of the 719 volcanoes is given three buffer zones with a 10 km, 50 km and 100 km radius. Each buffer zone is assigned with an annual return period of being affected by volcanic hazard. For a 10 km buffer, VEI 2–7 are considered for the calculation of the return period, VEI 3–7 are considered for a 50 km buffer, and VEI 5–7 for a 100 km buffer. This is due to the fact that the area around a volcano affected by an eruption corresponds to the explosion intensity, e.g. a small radius area is affected by small to large eruptions while a large radius area is only affected by large eruptions. The buffer zones are given their different hazard index depending on the range of the return period. The 830 unclassified volcanoes are given a standard buffer of 50 km.

The volcano symbol itself derives its hazard index from the mean of the annual return periods of the three buffer zones.

The sources used were the reports from the University of Bristol:
- Identifying volcanoes with high hazard and economic exposure
- Frequency-magnitude relationships for active explosive (ash-producing) volcanoes worldwide

Accordingly, the volcanoes are categorised as follows:
- Zone 0: unclassified
- Zone 1: minor hazard (> 15,000-year return period)
- Zone 2: moderate hazard (200 to 15,000-year return period)
- Zone 3: high hazard (≤ 200-year return period)

There are several types of hazard associated with volcanoes, the principal hazards being:

- Ballistic debris av.
- Shockwaves
- Lava flows
- Pyroclastic flows
- Gases
- Lahars
- Lightning
- Acid rain
- Tephra fall

It is difficult to assess all the different types of hazard due to volcanism and classify their respective importance for the actual level of risk. As eruptions are typically rare events and systematic investigations on damage-related hazard parameters have just started in the recent past, an absolute measure of volcanic risk is prone to significant uncertainties. However, a relative measure of risk caused by different types of volcanic eruptions, their strengths and return periods seems to be a valid choice for volcanic risk classification for the moment.

Summary:

Values on the map show: volcanoes classified depending on their VEI (Volcano Explosivity Index) and their annual return periods.

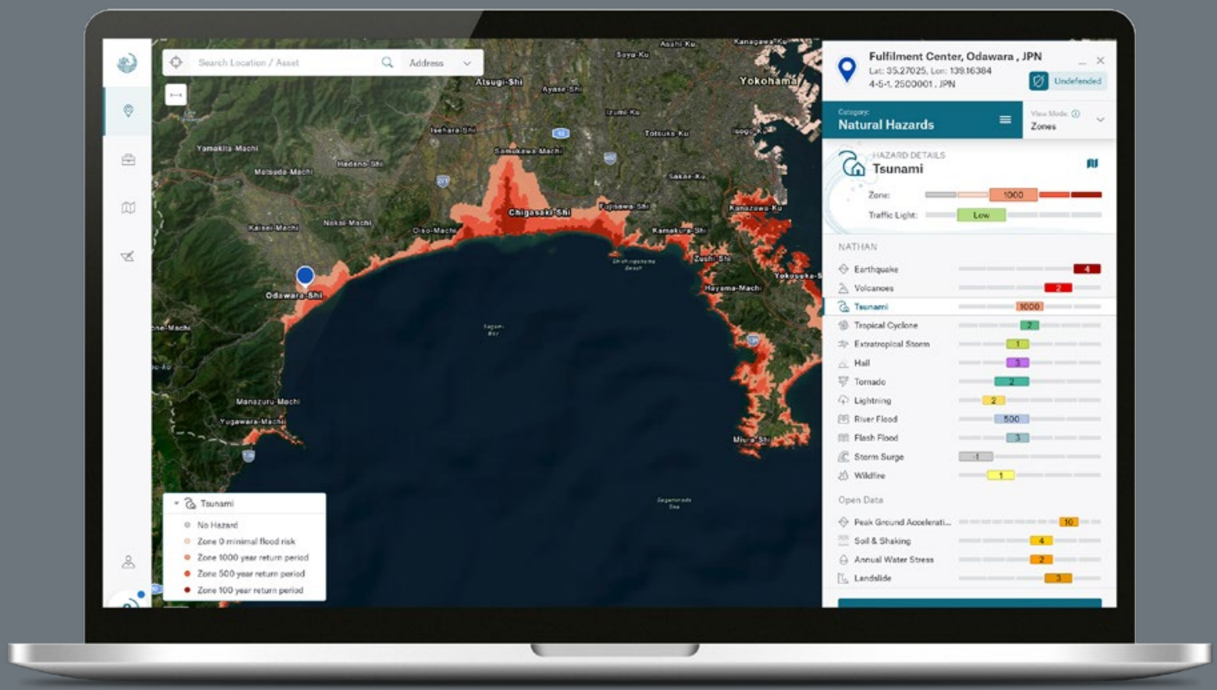
Data type: vector geometry (polygons)
Coverage: global
Source: Munich Re

Tsunami

Tsunamis are seismic sea waves and occur after strong seaquakes or large submarine landslides, often induced by earthquakes or volcanic eruptions in the sea or on the coast.

The greatest risk comes from Tsunamis generated by meteorites crashing into the sea. This risk exists throughout the world but, with very low occurrence probabilities, is very difficult to quantify and any discussion of this would go beyond the bounds of this account. Tsunami waves spread out in all directions at a great speed which depends on the depth of water. As the waves can travel 10,000 km or more without much attenuation, regions that have not experienced any direct earthquake effects can be affected.

Munich Re classifies the Hazard into four categories: Zone 0, 100, 500 and 1000. Coasts in Zone 100 are exposed to a 100-year return period of Tsunamis (1% annual exceedance probability of flooding), those in Zone 500 a 500-year return period (0.2% annual exceedance probability of flooding) and those in Zone 1000 a 1000-year return period (0.1% annual exceedance probability of flooding). Coasts in Zone 0 (minimal flood risk) have a very low Tsunami Risk. The Tsunami Map is based on SRTM data (Version 4.1.). The Hazard is calculated with a cost-distance function. Munich Re simulates multiple wave heights for each coast and calculates the maximum expansion. Historical Tsunami and Earthquake data is also taken into account.



Summary:

Values on the map show: Tsunami Hazard divided into four return periods (100, 500, 1000, minimal risk).

Spatial resolution: 90 metres
Coverage: global
Source: Munich Re

Wildfire

Wildfires are the result of a complex interaction between certain influencing factors, e.g. ignition of the fire, vegetation, meteorological conditions (El Niño/La Niña) and topography.

The Wildfire Map is based on historical climatological data and GlobeCover (ESA) land cover data:

- Wildfires are rare in areas where rain is frequent
- Regions with sparse vegetation are also unlikely to be affected by Wildfire
- Wildfire potential is particularly high when coniferous forests are exposed to dry spells lasting several weeks or even months

The model does not replace a probabilistic model, but it is nevertheless of great value in identifying areas at risk.

Summary:

Values on the map show: hazard of Wildfire in certain areas on a scale from 1 (low) to 4 (high). The effects of wind, arson and fire-prevention measures are not considered.

Spatial resolution: 1 kilometre
Coverage: global
Source. Munich Re

Understanding the Risk Scores

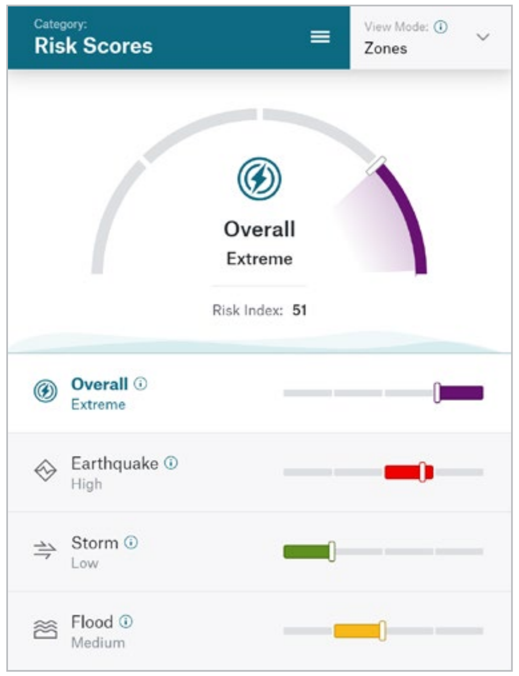
Munich Re's Location Risk Intelligence offers four Risk Scores:

– Overall Risk Score
– Earthquake Risk Score
– Storm Risk Score
– Flood Risk Score

The Risk Scores can be used as a traffic light style indication of the physical risk to a location for the above-mentioned 12 perils, giving first insights into a location's physical risk situation. The Risk Scores are categorised on the basis of Risk Index values. The risk indices incorporate Munich Re proprietary models and loss data to weight the hazards according to their damage potential, e.g. Tropical Cyclone events usually cause higher losses than Lightning. Therefore, locations in high hazard Tropical Cyclone zones will show higher Storm Risk Scores than a comparative location in the highest Lightning hazard outside of Tropical Cyclone Hazard zones, assuming no difference in the exposure to the other wind-related perils.

The Risk Indices are derived by normalising the average annual loss rates for property damage for standard facultative business within each Hazard Zone for the respective perils (Earthquake, Storm, Flood, Overall). This makes it possible to compare the average loss potential across different locations and zones, i.e. a globally distributed portfolio with locations in Zones with a Risk Index value of 40 is on average expected to experience twice as high annual losses as in Zones with a Risk Index value of 20. The Risk indices are classified into Risk Scores (Earthquake, Storm, Flood, Overall) with the following scheme:

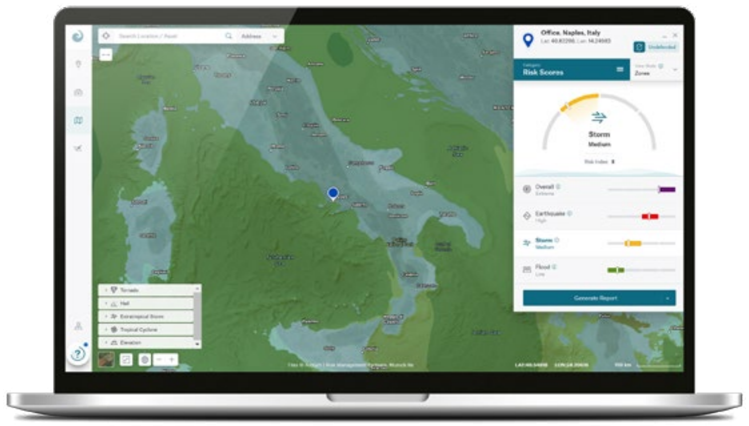
Risk Score	0 Unknown	1 Low	2 Medium	3 High	4 Extreme
Risk Index		0 – 5	6 – 15	16 – 34	35 – 450



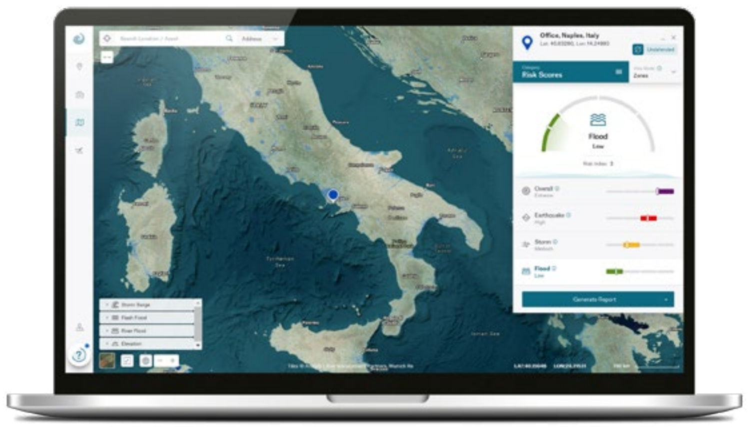
The Risk Index values can be seen in the Location Risk Intelligence Platform by hovering over the Risk Score bar.

Overall Risk Score
combines the Earthquake Risk Score, Storm Risk Score, Flood Risk Score as well as the location's Wildfire Risk, giving an normalised reflection of the Overall Risk of physical damage to a location.

Earthquake Risk Score
quantifies a location's risk of physical damage caused by Earthquakes, Volcanoes and Tsunamis.



Storm Risk Score
quantifies a location's risk of physical damage caused by Tropical Cyclones, Extratropical Storms, Hail, Tornados and Lightning.



Flood Risk Score
quantifies a location's risk of physical damage caused by River Flood, Flash Flood and Storm Surge.

Population Density

The Population Density Map is derived from global population distribution data (based on population counts) by LandScan™. LandScan™ is a community standard developed by the Oak Ridge National Laboratory and uses an algorithm to disaggregate census counts within an administrative boundary.

Using the LandScan™ global distribution data, Munich Re calculates the Population Density of each individual country and region. The Population Density is classified into five categories based on people per km². The Population Density represents a 24-hour average value. This means that the figures include daily movements, such as commuter journeys, and not just the night time population.

Population: LandScan™ Population Dataset created by UT-Battelle, LLC, the managing and operating contractor of the Oak Ridge National Laboratory acting on behalf of the U.S. Department of Energy under Contract No. DE-AC05-000R22725

ⓘ **Summary:**

Values on the map show: geographical distribution of population in 2016 over an average 24-hour period, classified into five categories.

Spatial resolution: approximately 900 metres
Coverage: global
Source: Oak Ridge National Laboratory

Elevation

The Elevation Map is composed of different models. The main component is the digital Elevation model "ALOS World 3D-30m (AW3D30; ©JAXA)", which is provided by the Japan Aerospace Exploration Agency (JAXA).

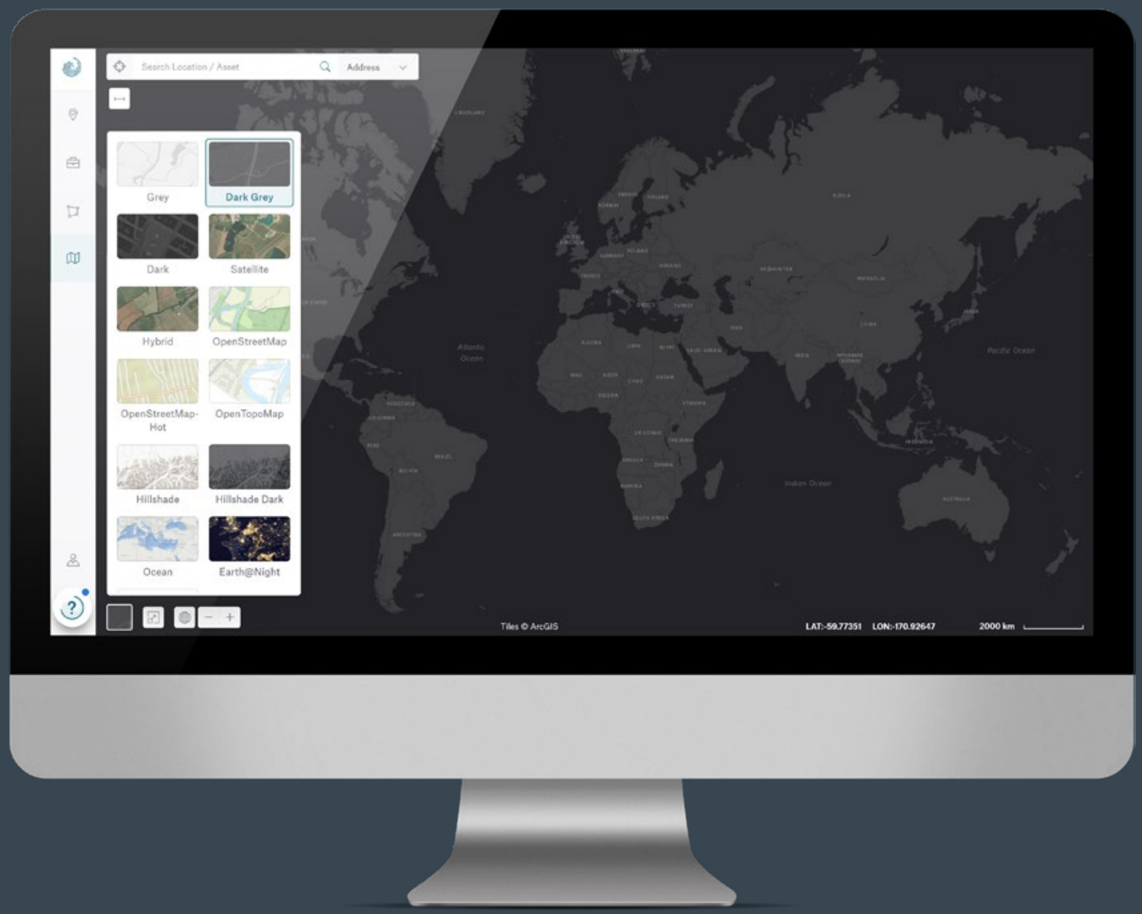
JAXA released AW3D30 in May 2016 with a horizontal resolution of approximately 30 metres mesh (1 arcsecond latitude and longitude) generated from 5m resolution DSM. Void height values in cloud and snow pixels between 60º north and 60º south are filled with existing DEMs using the Delta Surface Fill method from the update in March 2017. This dataset is highly expected to be used in scientific research and geospatial information application services.

In order to ensure global coverage, downsampled SRTM90 data is used to complete the dataset. The elevation is represented in metres.

ⓘ **Summary:**

Values on the map show: metre per pixel, classified into seven categories.

Spatial resolution: approximately 30 metres
Coverage: global
Source: Japan
Aerospace Exploration Agency (JAXA), United
States Geological Survey (USGS)



Base Maps

Understanding of risk exposure at a glance is facilitated by the best possible visualisation with a variety of different base maps.

The visualisation of risks on the digital world map simplifies the identification of the respective risks and thus ultimately improves any business decision based on them. Not all risks look the same. Shape, colours or resolution may vary, so it is important to have the flexibility within the visualisation to represent each risk according to the individual requirements. In addition to the individual maps that can be used for each single risk peril such as for Tropical Cyclones or Heat Stress, there is the option to choose from a variety of different base maps. The base maps are the underlying world maps that create a clear picture of where in the world a risk assessment is carried out. The maps can be freely selected in the “Base Maps” area. The maps differ in terms of colour selection, content focus and level of detail. This means that the ideal visualisation can be ideally adapted with a click of the mouse, regardless of whether a detailed look at a single asset at a specific location is needed or at a global portfolio with thousands or millions of assets.

The opacity of hazard maps or portfolio clusters can be adjusted to improve the visualisation. This can easily be done in the visualisation mode function of a portfolio or by clicking on the opacity icon of a hazard map. Opacity defines the transparency of an overlying object on the world map, and therefore how much of the underlying layer will be visible, leading to better analysis results and avoiding misunderstandings.

Defence Modes

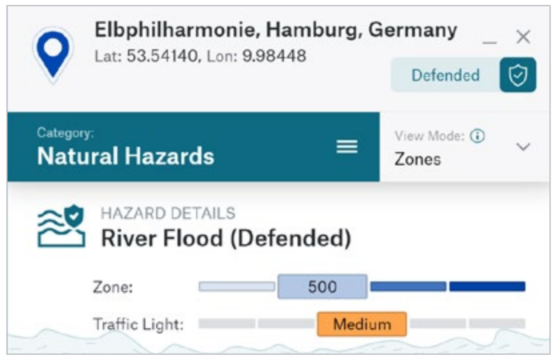
Defended and undefended calculations provide the best data for making informed decisions.

Munich Re provides climate risk data from experts for experts. When trying to understand the impact of climate change on an asset, it is important to have a detailed understanding of the surrounding environmental conditions.

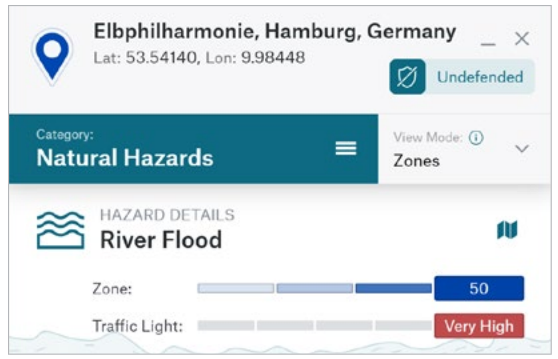
This is why Munich Re’s data includes undefended and defended data calculations for River Flood and Storm Surge Hazard Scores, as well as for the Flood Risk Score and the Overall Risk Score. Users can choose between both views to understand the different scores and their own risk exposure in detail.

The defended view is a specific dataset that includes all kinds of flood defences, such as flood walls, levels, and more. These defended areas are assigned a defined Standard of Protection (SoP) and provide a more realistic picture of an asset’s risk exposure. This enables more accurate business decisions to be made, as a deeper understanding allows risk to be accurately considered. The undefended dataset provides a clear picture of what the situation would be without defences, or what would happen if they occasionally failed. This enables accurate worst-case scenario planning.

Defended view



Undefended view



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