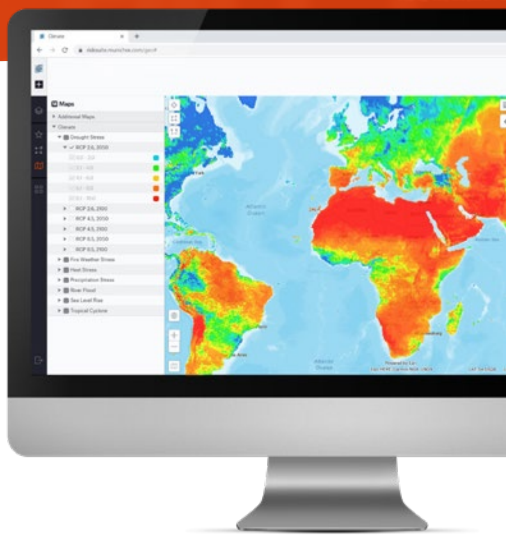
NOT IF, BUT HOW

Munich RE

Munich Re's Location Risk Intelligence
Climate Change Edition

Fact Sheet Version 2020/04



A modular software solution that supports companies in analysing and assessing the risks of future climate change.

From a single asset to multiple assets within a portfolio located in areas prone to the effects of future climate change, such as areas of extreme temperatures, extreme rainfall, drought, tropical cyclones, fire weather, floods, sea-level rise, etc.

In contrast to the "Natural Hazards Edition", risk assessments are not calculated on the basis of past events, but on forecasts of future events that are expected to occur as a result of climate change.

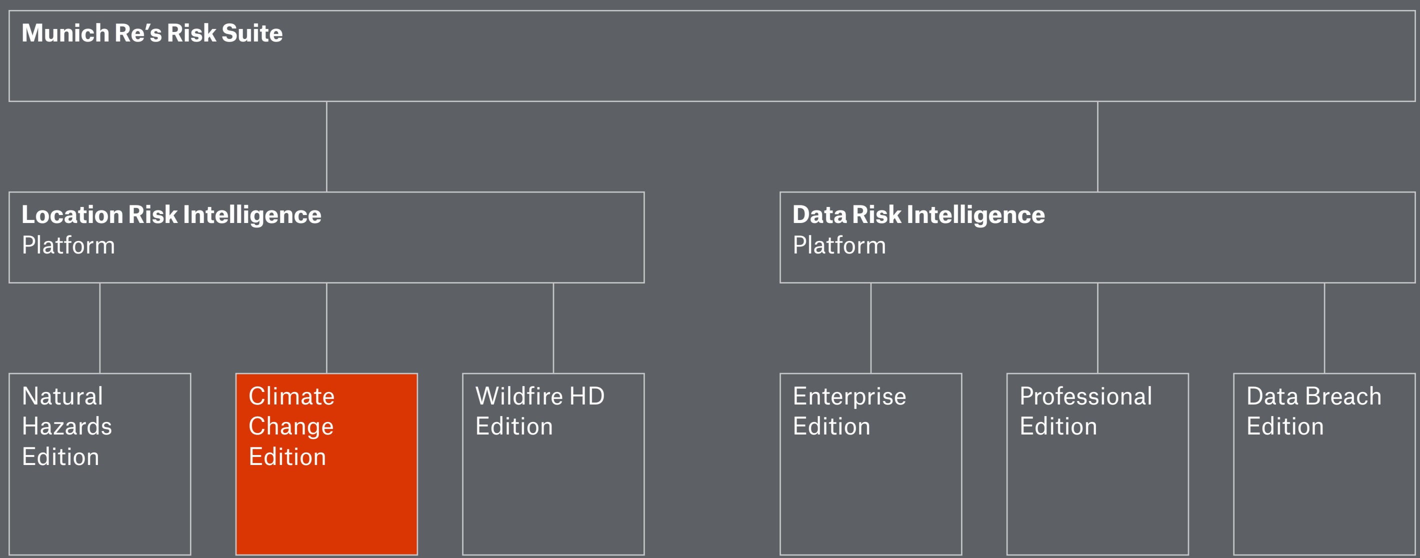
In order to generate an all-encompassing assessment, the "Climate Change Edition" can also be supplemented at any time with the functions of the "Natural Hazards Edition" and additional modules.

Munich Re's Risk Suite

Munich Re's Risk Suite is a range of modular risk solutions provided as a software portfolio by Munich Re Service GmbH, a wholly owned subsidiary of the world's leading reinsurer.

It offers companies access to the risk management tools developed in-house and the knowledge and experience of 140 years of one of the world's leading providers of reinsurance, primary insurance and insurance-related risk solutions. Since the introduction of Nathan (Natural Hazards Assessment Network), Munich Re has been a pioneer in the global assessment of natural hazard risks. Munich Re's Risk Suite builds on this expertise and offers a selection of well-engineered risk assessment solutions for technical underwriting, data protection, investment decisions and climate change analysis.

On the other hand, Munich Re's Risk Suite draws on years of experience in global data transfer under regulatory requirements. Against this extensive background of experience, highly efficient solutions for data protection and IT security management were developed, originally for internal use, which ideally complement Munich Re's Risk Suite and thus provide companies with a comprehensive set of tools that covers the management of all risk aspects relevant to a company and is continually being developed further in view of the expected further increase in complexity in the field of data and IT security protection.



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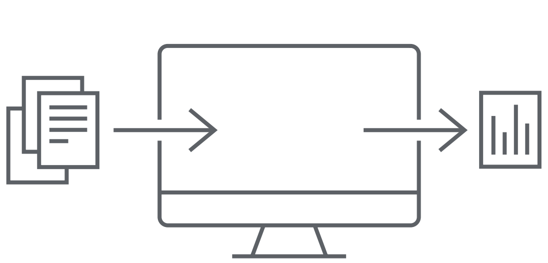
1. Potential and advantages of Climate Change Edition of Location Risk Intelligence

With the Climate Change Edition, you can create a basis for comparison for risk assessment and future prognoses regarding climate change with one of the world's most comprehensive databases for the analysis and evaluation of natural disasters.

The Climate Change Edition is easy and intuitive to use and transforms data into clear structures for individual risk assessment. You not only have access to Munich Re's extensive data material, but can also incorporate your own data into the assessment. Accelerate your business processes and support portfolio control and claims management.

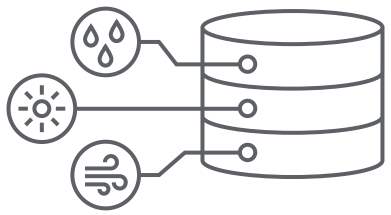


Easy input & output

The Climate Change Edition can be accessed via a web application as well as via an API. Because various export formats can be selected, it adapts completely to your needs.

Easy to interpret visualisation

Clear heatmap visualisation of hazards in different climate scenarios.



Largest global data collection on climate change

40 years of climate experience and data collection from Munich Re combined with state-of-the-art scientific data sets for future-relevant risk scores due to climate change in different RCP scenarios.

Climate Expert Mode

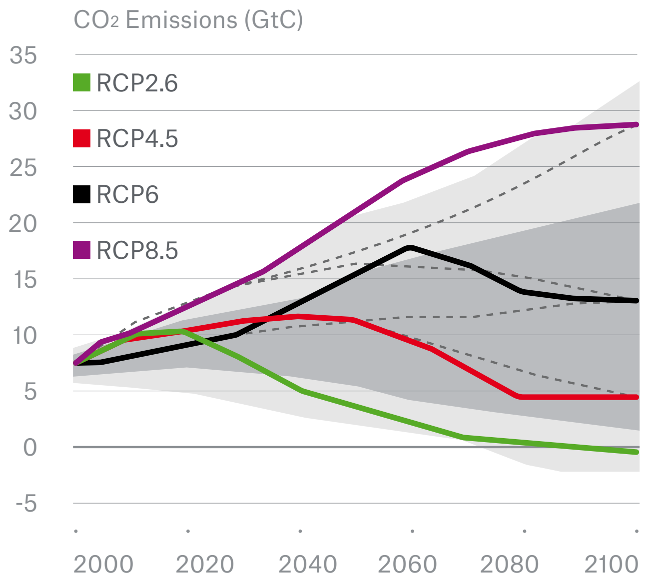
The Climate Expert Mode provides more detailed information to the climatological stress indices and is available via API.

Data Set	– Based on 40 years of climate experience and Munich Re's systematic recording of global hazard data over the past decades – Track record with Natural Hazard scores for current climate used for our own business – Additional data sets as optional modules: GEM, ZÜRS, Wildfire HD (USA, Canada) – Integration of own data sets like GEO data or BDC (Business Data Collection)
Maximum Flexibility	– Standard User – Expert Mode – API (Application Programming Interface) – 100% browser based, no plugin or download needed
Search Options	– Postal address – Regions, e.g. states – Geo-coordinates
Search Tools	– Text search – Latitude-longitude
Organisation Locations	– Easy management and organisation of the locations – Uploading your own portfolio from CSV or Excel (templates available)
Performance Indicators	– Peril-specific evaluations with seven different hazard categories – RCP scenarios (2.6, 4.5, 8.5) – Current and future projection years until 2100 – Different event families (geophysical, meteorological, hydrological, climatological) – Free marking options (Polygon, Oval, Circle, Freehand)
Visualisation based on KPIs (Key Performance Indicators)	– Cluster – Heatmap – Grid – Regions (administrative and postcode regions, CRESTA zones)
Map Views	– Streets – (Dark) grey – Hybrid – Satellite – OpenStreetMap – Topography – Terrain
Elevation Profiles	– Height difference between two locations displayable
Reports and Results	– Based on standard scientific scenarios (RCP) – For acute RCPs, based on established models used for (re)insurance business – Download as CSV, Excel or PDF – Share as link – API access for individual further processing of the data – Clear visualisation of the results/risk scores presented in number statistics, loss amount and pie charts, tables and coloured heatmaps – Peril-specific evaluations with seven different hazard categories

2. 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, established a framework which formed the basis for the Paris Agreement in 2015.

The new and innovative Munich Re physical climate hazard assessment services are based on this framework and use the Representative Concentration Pathway (RCP) scenarios for atmospheric greenhouse gas concentrations from the latest IPCC Assessment Report (IPCC AR5, 2014). The available RCP scenarios in Munich Re's climate services are:



Source: climatechangeinaustralia.gov.au

RCP 2.6:
Moderate scenario leading to a warming at the end of the 21st century of probably less than 2°C relative to the pre-industrial period (1850–1900)

RCP 4.5:
Intermediate scenario leading to a warming at the end of the 21st century of more than 2°C relative to the pre-industrial period (1850–1900)

RCP 8.5:
Most severe scenario leading to a warming at the end of the 21st century of probably more than 4°C relative to the pre-industrial period (1850–1900)

The projection years for the three emission scenarios (RCP2.6, RCP4.5 and RCP8.5) are 2050 and 2100. The projections are a hybrid composite of local high-resolution CORDEX (Coordinated Regional Climate Downscaling Experiment, ~25–55 km horizontal resolution) models and global CMIP5 (Coupled Model Intercomparison Project Phase 5) models. Data for the reference period are based on well-established current Nathan model data (for Tropical Cyclone, River Flood) and on ERA5 ECMWF atmospheric reanalysis data (for Heat Stress, Precipitation Stress, Fire Weather Stress). The reference period for the climatological parameters is 1986–2005 and 20-year periods are used for the projections for more robust trend estimates.

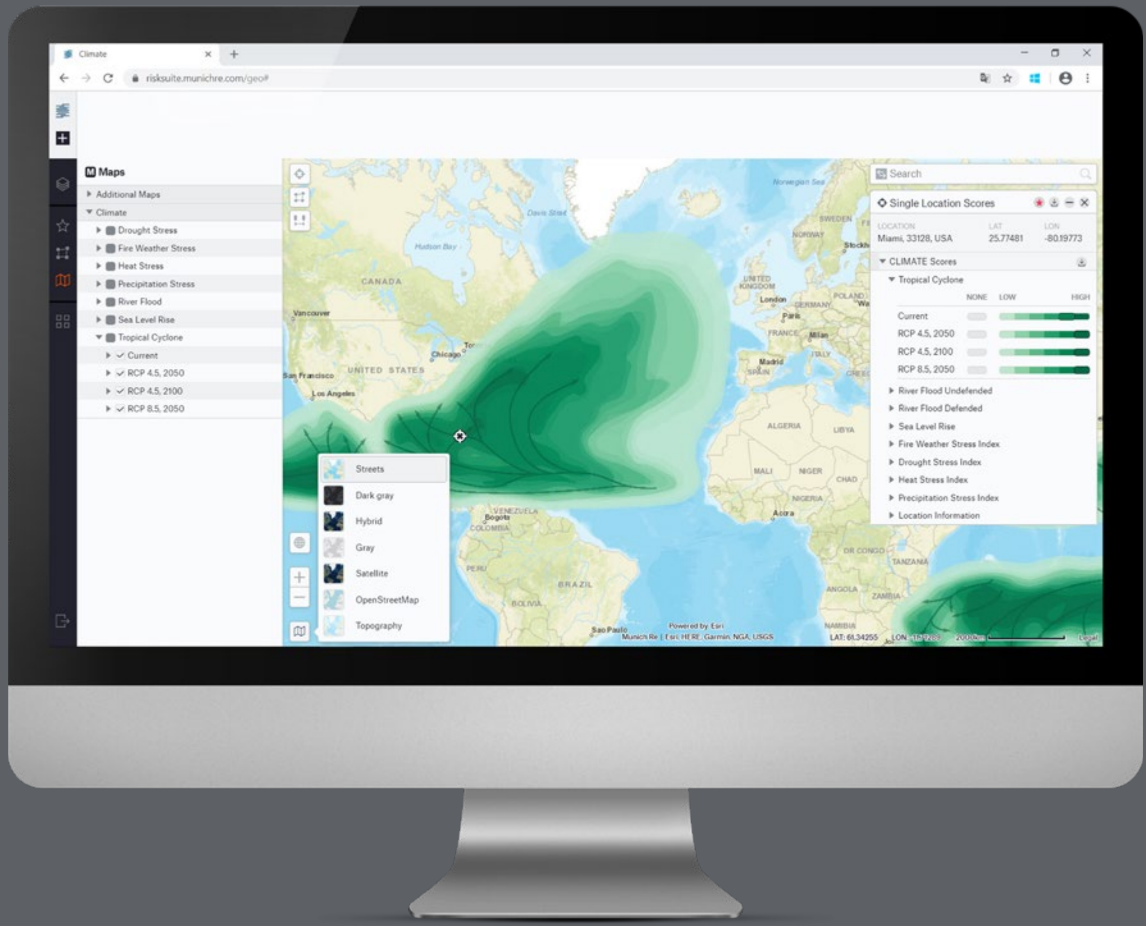
The scores also contain present-day values, allowing the user to compare two points in time and thus evaluate the changes in different climate related scenarios.

Overview of available climate hazard scores

by RCP scenario and projection year:

Climate Hazard Scores		Description of current and projected climate hazard scores	RCP Scenario	Projection Year
Acute	Tropical Cyclone	Tropical Cyclone zones (100 year return period)	4.5, 8.5*	2050, 2100
	River Flood	River Flood zones (100 & 500 year return period)	4.5, 8.5	2050, 2100
Chronic	Sea-Level Rise	Sea-Level Rise zones [projection only]	2.6, 4.5, 8.5	2100
	Heat Stress	Heat Stress Index based on range of high-temperature indicators	2.6, 4.5, 8.5	2050, 2100
	Precipitation Stress	Precipitation Stress Index based on heavy-precipitation indicators	2.6, 4.5, 8.5	2050, 2100
	Fire Weather Stress	Climatological index for wildfire hazard	2.6, 4.5, 8.5	2050, 2100
	Drought Stress	Drought Stress Index based on Standardized Precipitation-Evapotranspiration Index (SPEI) [projection only]	2.6, 4.5, 8.5	2050, 2100

* TC for RCP8.5, 2050 based on RCP4.5, 2100 modelling; TC for RCP8.5, 2100 not available yet



3. 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 current (present day) hazard analysis of Tropical Cyclone 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 main variables for modelling. The wind fields of all historical windstorms were 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) was 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 re-modeling the Nathan hazard zones, represented by the five-level scale for the probable maximum intensity with an exceedance probability of 10% in 10 years (equivalent to return period of 100 years). The projections are available for the RCP4.5 scenario for the projection years 2050 and 2100, and for the RCP8.5 scenario for the projection year 2050 (based on corresponding result for RCP4.5 and projection year 2100).

4. River Flood

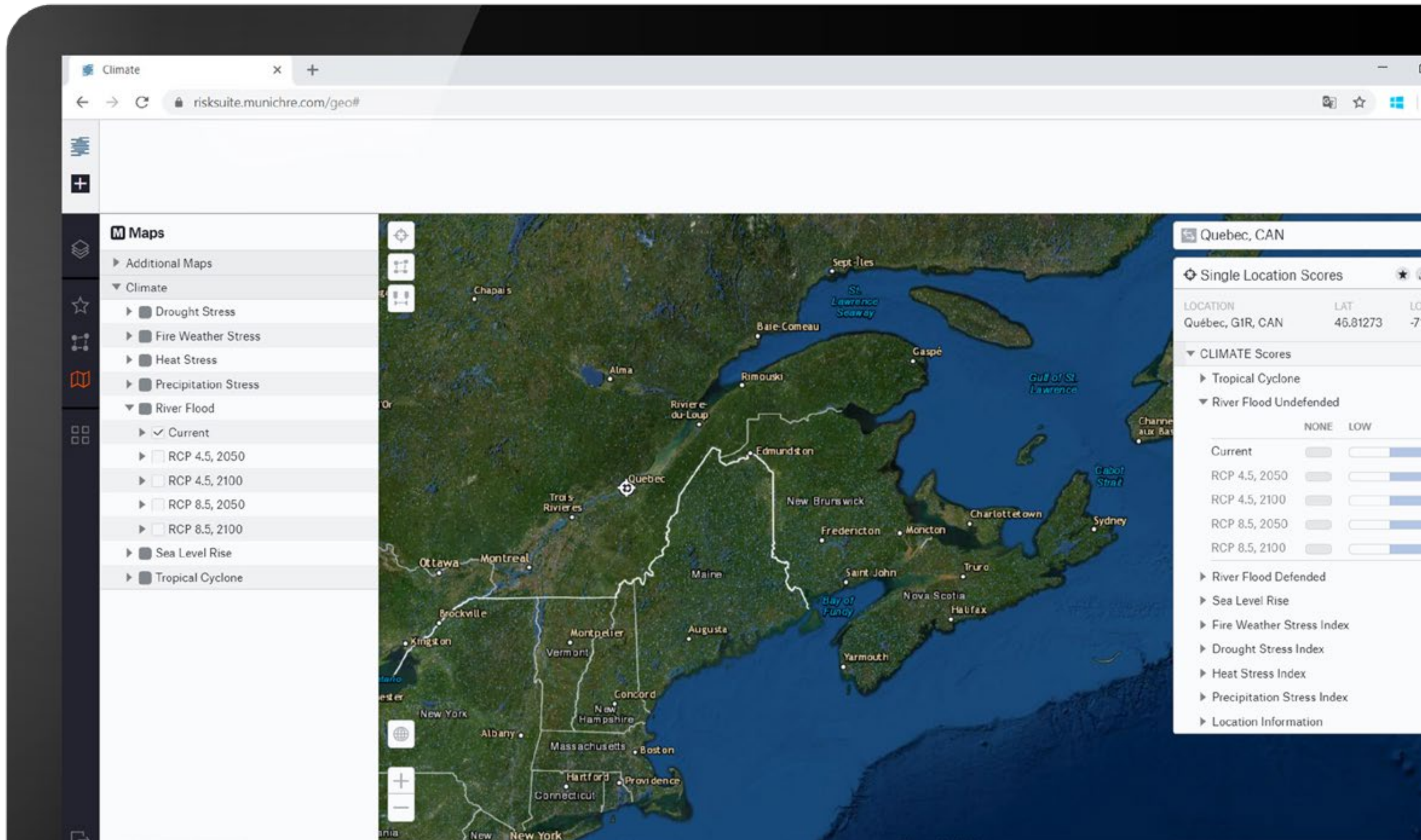
Munich Re's Nathan current river flood hazard data (provided by JBA Risk Management) offer state-of-the-art flood hazard information (with a 30m horizontal resolution), available on a global scale. The global flood maps are constantly improved and are a market standard.

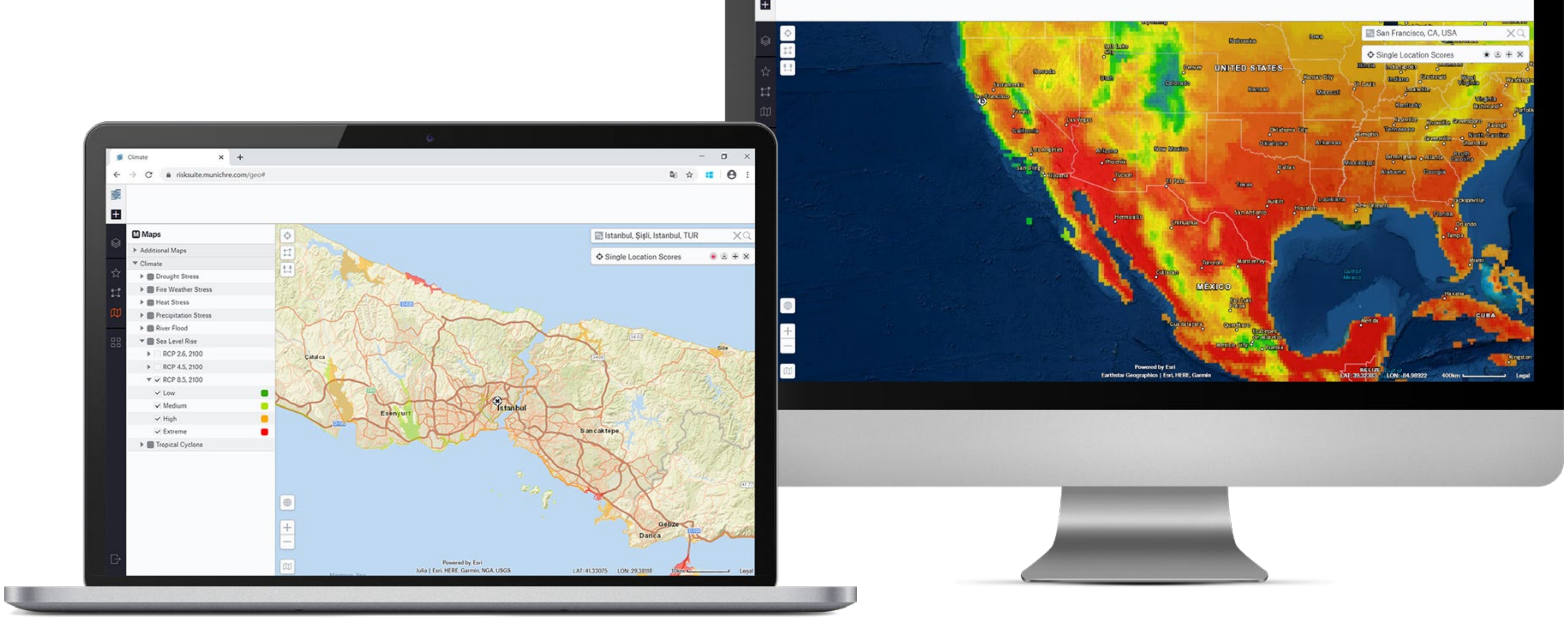
They are based on bare-earth digital terrain data and a consistent worldwide digital surface model. The river flood hazard is represented by three return period zones, ranging from Zone 0 (areas of minimal flood risk) to Zone 100 (100 year return period of river flood).

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)

Flood protection systems are defence structures to reduce the flooding to areas and properties. Globally, the quality of defence information and the structures themselves is highly variable. Hence, there is value in considering the undefended river flood hazard in order to keep global consistency. Munich Re provides both defended and undefended river flood hazard information. Information on the flood defences' standard of protection (SoP) is available upon request (for more information on the Climate Expert Mode see 10 Climate Expert Mode).

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 runoff at hydrological basin resolution. These changes in peak runoff 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 both projection years 2050 and 2100.





5. Sea-Level Rise

According to the IPCC Fifth Assessment Report, the global mean sea level has risen more than 20 centimeters 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 encroachment 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 were 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 hazard level by sea-level rise, from no hazard to extreme hazard.

The sea-level rise hazard information is available for the three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and the projection year 2100.

6. Heat Stress

Global warming is increasing the risk of heat stress which affects humans, infrastructure as well as 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 ERA5 ECMWF atmospheric reanalysis data (~25 km horizontal resolution) for the reference period and data from latest high-resolution local (CORDEX) and global (CMIP5) climate models for the future. 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 to scientific studies and climate extremes indices defined by the CCI/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI), with the aim of depicting heat stress consistently, locally and globally.

The following underlying heat stress parameters are available upon request (for more information on the Climate Expert Mode see 10 Climate Expert Mode):

Additionally available Heat Stress Parameters in Climate Expert Mode	Description
Annual Maximum Temperature	Annual No. of Days above 30°C
Mean Daily Maximum Temperature	Annual No. of Days above 40°C
Annual No. of Days in Heatwave	Annual No. of Tropical Nights

The Heat Stress Index and the underlying heat parameters are available for the reference period as well as the respective combination of the three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and projection years 2050 and 2100.

7. Precipitation Stress

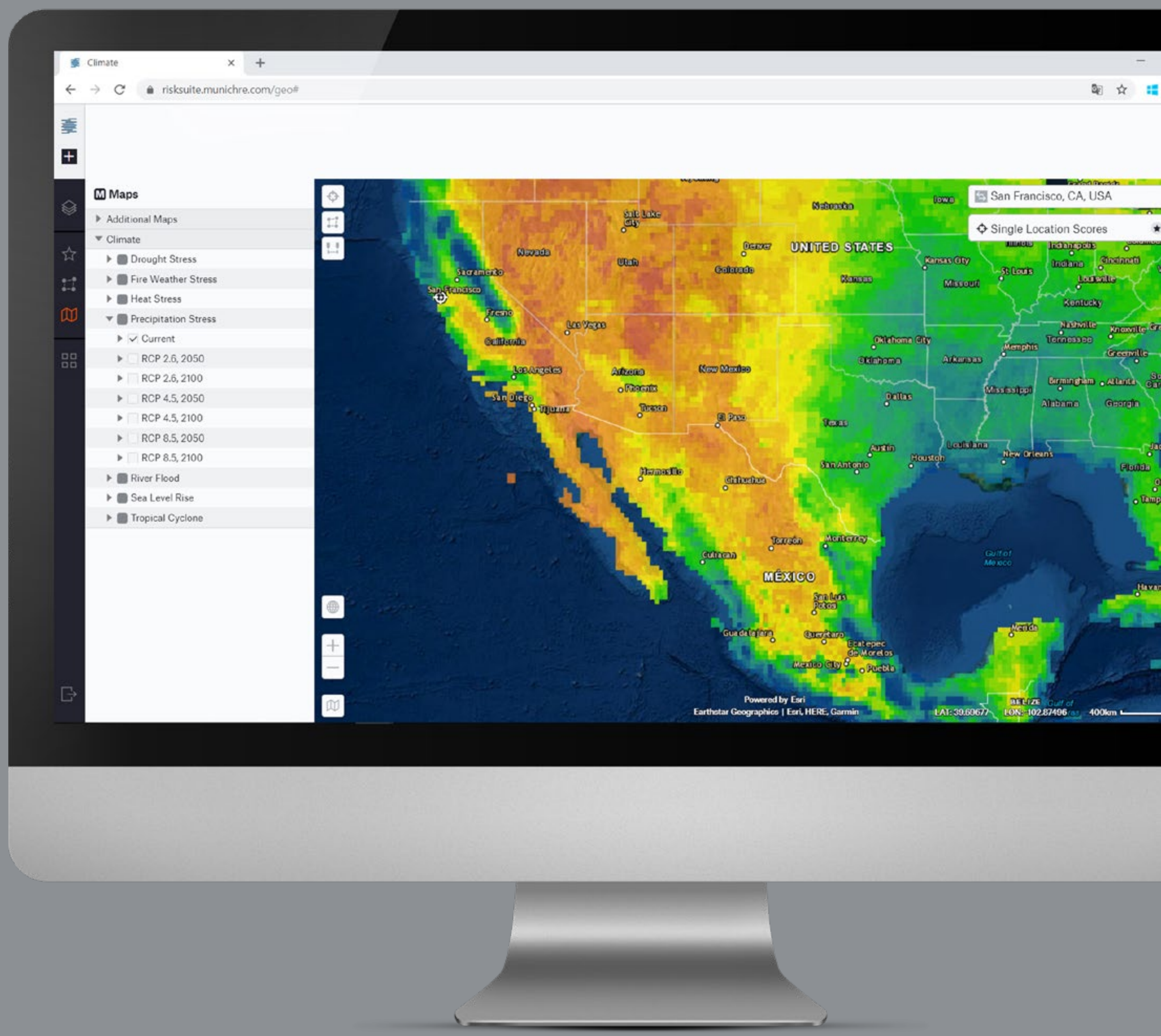
Due to global warming and particularly to warmer oceans, air contains more moisture. This might lead to an intensification of high-precipitation events and an alteration of the frequency of such events. The impact of climate change on precipitation is very heterogenous globally, which is caused by its fine-scale features. This makes it essential to use high-resolution climate models to capture the climate change impacts, which might lead to crop damage, soil erosion and increased flood risk.

Munich Re provides information on the threat 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 ERA5 ECMWF atmospheric reanalysis data for the reference period and data from latest high-resolution local (CORDEX) and global (CMIP5) climate models for the future.
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 to scientific studies and climate extremes indices defined by the CCI/WCRP/JCOMM ETCCDI, with the aim of depicting heavy-precipitation stress consistently, locally and globally.

The following underlying precipitation stress parameters are available on request (for more information on the Climate Expert Mode see 10 Climate Expert Mode):

Additionally available Precipitation Stress Parameters in Climate Expert Mode	Description
Maximum Daily Precipitation p.a.	Annual No. of Heavy Precipitation Days (> 30mm precipitation per day)
Maximum 5-Day Precipitation p.a.	Annual Precipitation Sum (Not used for calculation of Precipitation Stress Index)

The Precipitation Stress Index and the underlying precipitation parameters are available for the reference period as well as the respective combination of the three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and projection years 2050 and 2100.



8. Fire Weather Stress

Wildfires are a destructive hazard, which can occur naturally and be caused by humans. They burn down vegetation and lead to destruction of infrastructure and economic resources.

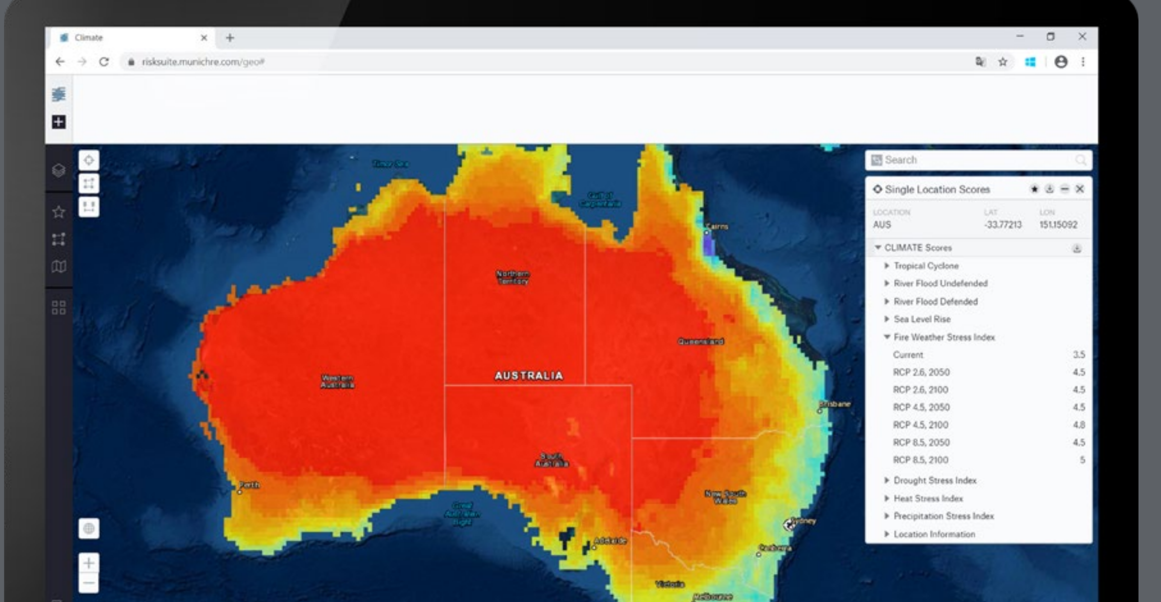
Fire events are often accompanied by secondary effects including erosion, landslides, impaired water quality and smoke damage. According to the European Commission's Joint Research Centre (JRC), climate change alters the relevant meteorological conditions impacting the ignition and spread of wildfires.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

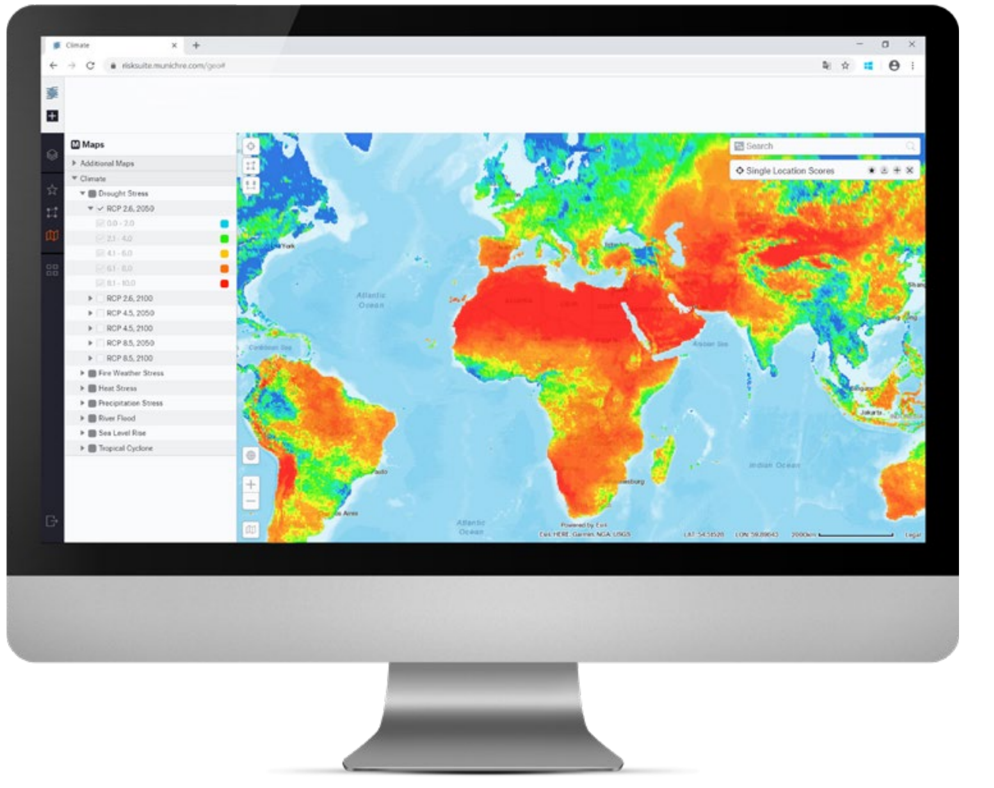
The Fire Weather Stress Index is based on the Fire Weather Index (FWI), which describes the climatological conditions for wildfire. The FWI is a widely used numeric rating, combining the probability of ignition, the speed and likelihood of fire spread and the availability of fuel. The FWI is modelled on the basis of daily information about temperature, precipitation, humidity and wind, using ERA5 ECMWF atmospheric reanalysis data for the reference period. The changes for the projection periods are derived on the respective data from latest high-resolution local (CORDEX) and global (CMIP5) 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 following underlying fire weather stress parameters are key parameters to describe climatological wildfire conditions and are available on a single basis upon request (for more information on the Climate Expert Mode see 10 Climate Expert Mode):

Add. available Fire Weather Stress Parameters in Climate Expert Mode	Description
Length of Fire Season p.a.	Annual No. of Days corresponding to the Fire Season
Extreme Fire Days p.a.	Annual No. of Days with extreme Fire Weather conditions (FWI > 30)
Annual FWI Sum	Annual Sum of daily FWI

The Fire Weather Stress Index and the underlying parameters are available for the reference period as well as the respective combination of the three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and projection years 2050 and 2100.





9. 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 the change in the water balance, characterised by the change in precipitation and potential evapotranspiration. It is derived from the Standardized Precipitation-Evapotranspiration Index (SPEI), which is the 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 duration, intensity and severity of drought conditions with respect to normal conditions in the reference period. The SPEI is modelled on the basis of daily information about temperature, precipitation and humidity, using data from latest high-resolution local (CORDEX) and global (CMIP5) climate models to assess drought conditions (calibrated over a 35-year period until 2005) for the projection periods. Information about projected drought durations and severities from the 9-month SPEI time series are combined to the Drought Stress Index, ranging from 0 (very low) to 10 (very high).

The following drought parameter is additionally available upon request (for more information on the Climate Expert Mode see 10 Climate Expert Mode):

Additionally available Drought Stress Parameters in Climate Expert Mode	Description
Meteorological Drought Days p.a.	Annual No. of Days with Precipitation less than 1mm*

*Not used for calculation of Drought Stress Index since measure is only appropriate for regions with year-round precipitation regime, e.g. humid mid-latitude regions.

The Drought Stress Index is available for the three RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and projection years 2050 and 2100, the meteorological drought parameter in the Climate Expert Mode is additionally available for the reference period (based on ERA5 ECMWF atmospheric reanalysis data).

10. Climate Expert Mode

The Climate Expert Mode contains valuable complementary information to the set of climatological stress indices (Heat Stress, Precipitation Stress, Fire Weather Stress and Drought Stress). Additionally, the Climate Expert Mode makes information on the flood defences' standard of protection (SoP) for river flood analyses available (provided by JBA Risk Management).

Common defence types, which are included in this dataset, are dams, levees and flood walls. The standard of protection is the return period of flood events, against which such engineered defences should be effective. A standard of protection of e.g. 500 years means that the corresponding flood protection should be effective against a 1 in 500-year flood event. Failure of flood defences can occur through the water exceeding this return period or due to weakness in a defence (for example caused by degradation over time). More detailed information is available upon request.

Climatological categories and parameters

The Climate Expert Mode for the climatological categories (Heat Stress, Precipitation Stress, Fire Weather Stress and Drought Stress) contains the underlying information for climatological parameters, which form an integral part of the aggregated stress indices.

Expert Parameters	**Description**
Heat Stress Parameters	
Annual Maximum Temperature	Annual No. of Days above 30°C
Mean Daily Maximum Temperature	Annual No. of Days above 40°C
Annual No. of Days in Heatwave	Annual No. of Tropical Nights
Precipitation Stress Parameters	
Maximum Daily Precipitation p.a.	Annual No. of Heavy Precipitation Days (> 30mm precipitation per day)
Maximum 5-Day Precipitation p.a.	Annual Precipitation Sum*
Fire Weather Stress Parameters	
Length of Fire Season p.a.	Annual No. of Days corresponding to the Fire Season
Extreme Fire Days p.a.	Annual No. of Days with extreme Fire Weather conditions (FWI > 30)
Annual FWI Sum	Annual Sum of daily FWI
Drought Stress Parameters	
Meteorological Drought Days p.a.	Annual No. of Days with Precipitation less than 1mm**

*Not used for calculation of Precipitation Stress Index
**Not used for calculation of Drought Stress Index since measure is only appropriate for regions with year-round precipitation regime, e.g. humid mid-latitude regions

Projected change of the underlying parameters

Additionally, the following information about statistical quantities describing the projected change of the underlying parameters from the set of available climate models is available:

Statistical Quantity	Description
Absolute Value	Absolute value of the underlying parameter (e.g. annual maximum temperature) for the reference period, derived from ERA5 ECMWF atmospheric reanalysis data
Absolute Change – Mean & Relative Change – Mean	Arithmetic mean of projected change (absolute or relative, depending on scale of parameter) from reference period to specified projection year, derived from a set of available CORDEX models (alternatively from CMIP5 climate models where CORDEX data not available)
Absolute Change – 0.1-quantile & Relative Change – 0.1-quantile	10th percentile of projected change (absolute or relative, depending on scale of parameter) from reference period to specified projection year, derived from a set of available CORDEX models (alternatively from CMIP5 climate models where CORDEX data not available)
Absolute Change – 0.9-quantile & Relative Change – 0.9-quantile	90th percentile of projected change (absolute or relative, depending on scale of parameter) from reference period to specified projection year, derived from a set of available CORDEX models (alternatively from CMIP5 climate models where CORDEX data not available)
Absolute Change – Std. Deviation & Relative Change – Std. Deviation	Standard deviation of projected change (absolute or relative, depending on scale of parameter) from reference period to specified projection year, derived from a set of available CORDEX models (alternatively from CMIP5 climate models where CORDEX data not available)
Change Robustness	Robustness of projected change, derived from 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 CORDEX models (alternatively of CMIP5 climate models where CORDEX data not available) used for parameter calculation

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