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EU-CIRCLE: A pan-European framework for strengthening critical infrastructure resilience to climate change
Project taxonomy and methodology – Climate-weather change terminology and methodology

Keywords

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Abstract

The paper presents climate-weather change terminology, selected from the fourth chapter of the report prepared in the scope of the EU-CIRCLE project. This project titled "A pan-European framework for strengthening Critical Infrastructure resilience to climate change – EU-CIRCLE" is realized under the European Union's Horizon 2020 research and innovation program. The improved terms and definitions coming from this chapter are presented. Moreover, methodology related to climate-weather change in the scope of project issues is introduced.

1. Introduction

Observed climate changes in last decades and their consequences indicate importance of the climate change topic and its growing significance in the future. These climate-weather changes include changes in the atmosphere, oceans, cryosphere and sea level. Extreme weather events occur more and more often, having significant impact and sometimes catastrophic consequences for critical infrastructures and functioning of a whole society. Some trends, as for example precipitation trends, are varied for different regions, however climate changes are projected to continue and extreme weather events to be more frequent in the coming decades. According to [11], climate change is one of the main long term drivers of economic, social and environmental change. In recent years, climate changes have had impact on natural and human systems, making them to face drought, heat waves, forest fires, coastal erosion and flooding. Challenge is also mitigation of greenhouse gas emissions. The impact of climate change can be felt to varying degrees depending on the region, the infrastructure's vulnerability and ability of adopting these climate-weather changes. In this context, analysis of climate change and actions taken for strengthening critical infrastructure resilience to climate change belong to main challenges. The climate-weather change terminology and methodology has been prepared in the scope of the EU-CIRCLE project "A pan-European framework for strengthening Critical Infrastructure resilience to climate change – EU-CIRCLE" and preliminarily presented in [10].

2. Climate-weather change terminology

The fourth chapter of the report [10] – Critical Infrastructure Terminology, has been outlined in respect to climate change and extreme weather events. In the revised version of this report this chapter has been divided into two sections. The first one includes terms and definition concerned with climate-weather change terminology and the second

one is devoted to climate-weather change methodology. Below terms and definitions, concerned with climate-weather change, are presented in alphabetical order.

Adaptation. The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

- Incremental adaptation: Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.
- Transformational adaptation: Adaptation that changes the fundamental attributes of a system in response to climate and its effects. [27]

Annual exceedance probability is the estimated probability of a flood of given magnitude occurring or being exceeded in any year. Expressed as, for example, 1 in 100 chance or 1 per cent. [38]

Atmosphere. The layers of gases surrounding the earth. The atmosphere is broken down into five layers:

- the troposphere, which begins at the surface and extends 5 to 10 miles up into the atmosphere,
- the stratosphere, which near the poles begins 5 miles above the surface, while down at the equator it starts higher up at 10 miles (8 and 16 km),
- the mesosphere, which starts just above the stratosphere, 31 miles (50 km) above the surface and extends up to 53 miles (85 km),
- the mesosphere is the thermosphere, which extends from 53 - 621 miles (90 - 1,000 km) up into the atmosphere,
- the exosphere, which is the uppermost layer of the atmosphere. [14]

Autonomous adaptation. Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market orwelfare changes in human systems. Also referred to as spontaneous adaptation. [19]

Average recurrence interval. The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20yr ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (see also annual exceedance probability). [9]

Backfire. A fire set along the inner edge of a fireline to consume the fuel in the path of a wildfire and/or change the direction or force of the fire's convection column. [36]

Base flood. The flood having a one percent chance of being equalled or exceeded in any given year. [13]

Base flow. Sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced stream flows. Natural base flow is sustained largely by ground-water discharges. [45]

Burning index. Relative measure of fire-control difficulty; doubling the index means twice the effort may be needed to control the fire (e.g., wind shift, heavier fuel load, etc). [36]

Burning period. The part of each 24-hour period when fires spread most rapidly; typically from 10:00 AM to sundown. [36]

Catchment. The area drained, either naturally or with artificial assistance, by a watercourse, including all drainage channels, tributaries, floodplains, estuaries and areas of water storage. [38]

Climate. Dynamic interactions of several components including atmosphere, hydrosphere, cryosphere, land surface and biosphere. [10]

Climate change. Any changes in climate over time, either due to natural variability or as a result of human activity. [10]

Climate model. A numerical representation of the climate system that is based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and that accounts for all or some of its known properties. The climate system can be represented by models of varying complexity, that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterizations are involved. [21]-[28]

Climate prediction. A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, e.g., at seasonal, inter-annual or long-term time scales. See also climate projection and climate (change) scenario. [19]

Climate projection. A projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon the

emission/concentration/radiative-forcing scenario used, which are based on assumptions concerning, e.g., future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty. [21], [22]

Climate scenario. A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. [21]

Climate sensitivity. The equilibrium temperature rise that would occur for a doubling of CO2 concentration above pre-industrial levels. [19]

Climate system. The climate system is the highly complex system consisting of five major components: the atmosphere, the oceans, the cryosphere, the land surface, the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcing such as volcanic eruptions, solar variations, and anthropogenic forcing such as the changing composition of the atmosphere and land use change. [21]

Climate threshold. A critical limit within the climate system that induces a non-linear response to a given forcing. See also Abrupt climate change. [21], [22]

Coastal flooding. An overflow of sea water onto the coastal that are not normally covered by water. [10]

Coastal inundation. The flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coasts, estuaries, and adjoining rivers. [34]

Combined sewer overflow. Combined sewer overflow is the discharge of untreated wastewater from a sewer system that carries both sewage and storm water (a combined sewerage system) during a rainfall event. The increased flow caused by the storm water runoff exceeds the sewerage system's capacity and the sewage is allowed to overflow into streams and rivers through CSO outfalls. [6]

Cyclone. An atmospheric disturbance state involving significant perturbations of the prevailing pressure and wind fields on scale of 2000-3000 km across. [10]

Desertification. The persistent degradation of dry land ecosystems by human activities − including unsustainable farming, mining, overgrazing and clear-cutting of land − and by climate change. Desertification occurs when:

- the tree and plant cover that binds the soil is removed. It occurs when trees and bushes are stripped away for fuelwood and timber, or to clear land for cultivation.
- animals eat away grasses and erode topsoil with their hooves.
- intensive farming depletes the nutrients in the soil.

Wind and water erosion aggravate the damage, carrying away topsoil and leaving behind a highly infertile mix of dust and sand. It is the combination of these factors that transforms degraded land into desert. [41]

Digital elevation model. A model of the elevation of the ground surface and includes building, vegetation etc. [6]

Digital terrain model. A model of the terrain of the earth's surface ('bare earth') Discounting A method used to convert future benefits or costs to present values, using the discount rate. [6]

Downscaling. Downscaling is a method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses. [22]

Drainage basin. Land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. [45]

Drought. A drought is the absence or marked deficiency of precipitation characterized by abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance [10].

Dust storm. An area of raised dust that moves with the prevailing wind system. The size of the dust particles can range from 0-1000 micro-meters. Dust storms have been known to dust particles as high as 4.5 km into the atmosphere with the average height of a dust storm being 1-2 km. [2]

El Niño-Southern oscillation phenomenon. A complex interaction of the tropical Pacific Ocean and the global atmosphere that results in irregularly occurring episodes of changed ocean and weather patterns in many parts of the world, often with significant impacts over many months, such as altered marine habitats, rainfall changes, floods, droughts, and changes in storm patterns. [29]

Environmental impact. Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects. [30]

Erosion. The process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles in the stream. [45]

Exceedance flows. Excess flow that appears on the surface once the capacity of the underground drainage system is exceeded. [6]

Expected annual frequency. Expected number of occurrences per year (reciprocal of the return period of a given event). [15]

Extratropical cyclone. A large-scale of order 1000 km storm in the middle or high latitudes having low central pressure and fronts with strong horizontal gradients in temperature and humidity. A major cause of extreme wind speeds and heavy precipitation especially in wintertime. [10], [25], [26]

Extreme coastal high water (also referred to as extreme sea level). Extreme coastal high water depends on average sea level, tides, and regional weather systems. Extreme coastal high water events are usually defined in terms of the higher percentiles (e.g., 90th to 99.9th) of a distribution of hourly values of observed sea level at a station for a given reference period. [21], [40]

Extreme cold. What constitutes extreme cold and its effects can vary across different areas of the country. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered "extreme cold." Whenever temperatures drop decidedly below normal and as wind speed increases, heat can leave your body more rapidly. These weather-related conditions may lead to serious health problems. Extreme cold is a dangerous situation that can bring on health emergencies in susceptible people, such as those without shelter or who are stranded, or who live in a home that is poorly insulated or without heat. [39]

Extreme dryness. A very long time (last for years, usually more than a decade) and deep drought causing exceptional and widespread crop/pasture losses, shortages of water in reservoirs, streams and wells creating water emergencies. [10]

Extreme heat. Conditions of extreme heat are defined as summertime temperatures that are substantially hotter and/or more humid than average for location at that time of year. Humid or muggy conditions, which add to the discomfort of high temperatures, occur when a "dome" of high atmospheric pressure traps hazy, damp air near the ground. Extremely dry and hot conditions can provoke dust storms and low visibility. Droughts occur when a long period passes without substantial rainfall. A heat wave combined with a drought is a very dangerous situation. [39]

Extreme precipitation. Expresses large precipitation amounts or intensities, or long-duration dry spells. Even though droughts can be considered as extreme precipitation events, we address here mainly events of increased precipitation intensity. [3]

Extreme weather event. Meteorological conditions that are dangerous and happen at a particular place and time and can generate severe hazards. [10]

Extreme wind is a wind which is strong enough to be dangerous for people, or cause significant damage to buildings and property, usually faster than 100 km/h (>118 km/h = 12 Beaufort scale, hurricane). Extreme wind can cause:

- destruction of buildings, including roofing being blown off, broken windows, and other flying debris
- large scale forest damage and fallen trees or branches falling onto power-lines
- high-sided vehicles and outdoor equipment being blown over
- very tall buildings, suspension bridges and transmission lines can suffer structural failures. [10]

Fire danger. A general term used to express an assessment of both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control, and impact. Fire danger is often expressed as an index. [12]

Fire environment. The surrounding conditions, influences, and modifying forces of topography, fuel, and weather that determine fire behaviour, fire effects and impact. [12]

Fire hazard. A measure of the fire danger contributed by fuels available for burning. [5]

Fire regime. Description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval. [1]

Fire weather. Weather conditions that influence fire ignition, behaviour and suppression. [33]

Fire weather index. A numerical rating in the Canadian fire danger rating system, based on meteorological measurements of fire intensity in a standard fuel type. (The standard fuel type is representative of jack pine and lodge pole pine.) The FWI is comprised of three fuel moisture codes, covering classes of forest fuel of different drying rates, and two indices that represent rate of spread and the amount of available fuel. [33]

Fire whirl. Spinning vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame. [12]

Fire wind. The inflow of air close to a fire caused by the action of convection. Fire winds influence fire spread. [12]
Firebreak. A natural or constructed barrier used to stop or check fires that may occur, or to provide a control line from which to work. [36]
Fireline. The part of a control line that is scraped or dug to mineral soil. Also called fire trail. More generally, working a fire is called being "on the fire line." May also refer to a "wet line" where water has been used to create a burn boundary in light fuels such as grass. [36]
Firestorm. Extreme fire behaviour indicated by widespread in-drafts and a tall column of smoke and flame, where added air increases fire intensity, creating runaway fire growth. [36]
Flash flood (Flash flooding). (1) A flood that crests in a short period of time and is often characterized by high velocity flow—often the result of heavy rainfall in a localized area. (2) A rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). [39]
Flood. The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. [22]
Flood crest. The highest stage or flow occurring in a flood. [44]
Flood inundation maps. Maps that present the water level and area prone to flooding. In some European countries it is connected with a given return period. As for instance; 10 years floods, 50 years floods, 100 years floods etc. [16]
Flood peak. Highest water level recorded in the river during a flood. [15]
Flood stage. The stage at which water overflowing the banks of a river, stream or body of water begins to cause damage. [44]
Floodplain. Area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist. [38]
Floodway. The channel of a river or stream and the parts of the floodplain adjoining the channel that are reasonably required to efficiently carry and discharge the flood water or flood flow of a river or stream. [45]
Fluvial flooding or River flooding. Occurs when water levels in a channel overwhelm the capacity of the channel. [37]
Forest fire. Uncontrolled fire on lands covered wholly or in part by timber, brush, grass, grain, or other flammable vegetation. [10]
General Circulation Models (GCMs). Numerical models representing physical processes in the atmosphere, ocean, cryosphere and land surface. The most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. GCMs depict the climate using a three dimensional grid over the globe, typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and sometimes as many as 30 layers in the oceans. [24]
Glacial lake outburst flood. Flood associated with outburst of glacial lake. Glacial lake outburst floods are typically a result of cumulative developments and occur (1) only once (e.g., full breach failure of moraine-dammed lakes), (2) for the first time (e.g., new formation and outburst of glacial lakes), and/or (3) repeatedly (e.g., ice-dammed lakes with drainage cycles, or ice fall). [21]
Global surface temperature. The global surface temperature is an estimate of the global mean surface air temperature. However, for changes over time, only anomalies, as departures from a climatology, are used, most commonly based on the area-weighted global average of the sea surface temperature anomaly and land surface air temperature anomaly. [21]
Greenhouse effect. Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average, -19°C, in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, 14°C. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect. [21]
Greenhouse gas. Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by

the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Besides CO_2, N_2O, and CH_4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). [21]

Ground fire. Fire that consumes the organic material beneath the surface litter ground, such as peat fire. [36]

Groundwater. Water below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. [38]

Groundwater flooding. Occurs when water levels in the ground rise above the natural surface. Low-lying areas underlain by permeable strata are particularly susceptible. [37]

Hazard caused by weather change. An event associated with extreme weather that may cause the loss of life or severe injury, property damage, social and economic disruption or environmental degradation. For instance: a dangerous chemical realise into the sea water as a result of ship accident cause by severe storm. [10]

Hazard map. Hazard maps show the extent of flood prone areas considering hydrodynamic impacts on buildings, infrastructure and environment and considering the variability of magnitudes of the expected events. Different zones are designated classifying the intensity of danger related to the probability of occurrences. [16]

Head of a fire. The most rapidly spreading portion of a fire's perimeter, usually to the leeward or up slope. [36]

Heat wave. Marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks. [18]

Heavy rain. Rainfall greater than or equal to 50 mm in past 24 hours. [10]

Hurricanes, cyclones and *typhoons* are tropical cyclones with maximum sustained wind speed exceeding 119 km/h near their centers. "Hurricane", "cyclone" and "typhoon" are different terms for the same weather phenomenon which is accompanied by torrential rain and maximum sustained wind speeds (near centre) exceeding 119 kilometers per hour. [10]

Hydrograph. A graph showing how a river or creek's discharge changes with time. [9]

Hydrologic cycle. The cyclic transfer of water vapor from the earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans. [45]

Hydrological drought occurs when there is a deficit in the supply of surface and subsurface water. It occurs due to precipitation deficits over a prolonged period that affect surface or subsurface water supply, thus reducing streamflow, groundwater, reservoir, and lake levels. [17]

Hydro-meteorological hazard is process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. [29], [42]

Hygrometry. Humidity of the air, that is to say the quantity of water present in its gas form in humid air. It does not take into account the water present in its liquid or solid form. [1]

Intense rain. A rain characterized by a rainfall rate greater than or equal to 50 mm/h. [10]

Land surface air temperature. The air temperature as measured in well-ventilated screens over land at 1.5 to 2 m above the ground. [21]

Landslide. A mass of material that has moved downhill by gravity, often assisted by water when the material is saturated. The movement of soil, rock, or debris down a slope can occur rapidly, or may involve slow, gradual failure. [22]

Levee. A natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees. [45]

LiDAR. Light Detection and Ranging – a technology that employs an airborne scanning laser rangefinder to produce a topographic survey and image of ground features [8]

Main river. A watercourse shown as such on a main river map. All other watercourses are defined as "ordinary watercourses". [46]

Mean sea level. Sea level measured by a tide gauge with respect to the land upon which it is situated. Mean sea level is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides. [21]

Mesoclimate. The climate of small areas of the earth's surface which may not be representative of the general climate of the district. [5]

Metadata. Metadata can be described as 'data about data'. For example, it can contain information about

when data was created, who created it, or when it was last updated. [6]

Microclimate. A climate of small area, especially insofar as this differs significantly from the general climate of the region. [5]

Modes of climate variability. Natural variability of the climate system, in particular on seasonal and longer time scales, predominantly occurs with preferred spatial patterns and time scales, through the dynamical characteristics of the atmospheric circulation and through interactions with the land and ocean surfaces. Such patterns are often called regimes, modes, or teleconnections. Examples are the North Atlantic Oscillation (NAO), the Pacific-North American pattern (PNA), the El Niño-Southern Oscillation (ENSO), the Northern Annular Mode (NAM; previously called the Arctic Oscillation, AO), and the Southern Annular Mode (SAM; previously called the Antarctic Oscillation, AAO). [21]

Natural hazard (Hazard). The source of harm or difficulty created by a meteorological, environmental, or geological phenomenon or combination of phenomena. It can occur without warning. [7]

Overtopping. The passage of water over a component such as a flood-bank or seawall, due to high water levels or wave action Overtopping does not necessarily represent 'failure' of a flood defence to perform its function. [8]

Peak fire season. The period of the fire season during which fires are expected to ignite most readily, to burn with greater intensity and to result in a High level of damage . [5]

Peak flow. The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage. [45]

Peaks-over-threshold, POT series. Series of data giving all the events when the river flow (or level) exceeds a specified threshold. [8]

Permeability. The ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas unpermeable material, such as clay, don't allow water to flow freely. [45]

Photogrammetry. The technology used to obtain reliable measurements, maps, digital elevation models, and other GIS data primarily from aerial photography. probable maximum flood (PMF) An extreme flood deemed to be the maximum flood likely to occur. [9]

Pluvial flooding or Surface water/runoff flooding. Occurs when the level of rainfall overwhelms the capacity of the drainage system to cope. [37]

Precipitation. Any product of the condensation of atmospheric water vapor that falls under gravity. [1]

Pressure on drain. The stress of flows within the drainage system. [10]

Prolonged drought (mega-drought). A very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more. [10]

QMED. Median of the annual maximum flow series – the flow that has an annual exceedance probability of 50% or a return period of two years. [8]

Radiant Heat Flux. The amount of heat flowing through a given area in a given time, usually expressed as calories/square centimetre/second. [33]

Reanalysis. Reanalyses are atmospheric and oceanic analyses of temperature, wind, current, and other meteorological and oceanographic quantities, created by processing past meteorological and oceanographic data using fixed state-of-the-art weather forecasting models and data assimilation techniques. Using fixed data assimilation avoids effects from the changing analysis system that occur in operational analyses. [21]

Regional Climate Models (RCMs). Climate models designed for a specific region, with much in common with global climate models. Some main differences include lateral boundaries imposed on the results at the edge of the region described. The RCMs are nested into global climate model results, taking the results from the global climate models (GCMs) as boundary values. They may also differ in the way they represent cloud processes, exchanges of heat and mass at the surface, atmospheric composition, solar energy and volcanism. Furthermore, RCMs tend to include a more detailed description of orography, with higher mountains, and therefore provide a different description of the surface winds and orthographically forced precipitation to that of the GCM results in which it is embedded. [3]

Relative and absolute sea level trends. The two types of sea level data (relative and absolute) complement each other, and each is useful for different purposes. Relative sea level trends show how sea level change and vertical land movement together are likely to affect coastal lands and infrastructure, while absolute sea level trends provide a more comprehensive picture of the volume of water in the world's oceans, how the volume of water is changing, and how these changes relate to other observed or predicted changes in global systems (e.g., increasing ocean heat content and melting polar ice caps). [43]

Representative Concentration Pathways (RCP). The Representative Concentration Pathways (RCPs) describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. The RCPs have been developed using Integrated

Assessment Models (IAMs) as input to a wide range of climate model simulations to project their consequences for the climate system. [28]

Return period. An estimate of the average time interval between occurrences of an event (e.g., flood or extreme rainfall) of (or below/above) a defined size or intensity.[23]

Return value analysis. A method for estimating the average recurrence time between events (return period) or the magnitude of an event (return value). [3]

Runoff (1) that part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (2) the total discharge described in (1), above, during a specified period of time. (3) also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it. [45]

Runup. The upper level reached by a wave on a structure, relative to the still water level. [8]

Salinity. The content of salts in soil or water. [10]

Scenario. A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a 'narrative storyline'. [20]

Scour. Erosion of the bed or banks of a watercourse by the action of moving water, typically associated with the presence of a feature such as bridge pier or abutment that constricts the flow. [8]

Sea-level rise. An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall. [20]

Severe storm. The sea water state characterised by the high increase in sea level caused by the combined effects of low atmospheric pressure, strong wind and a high tide. [10]

Significant wave height. The average height of the highest one-third of the wave heights (trough to peak) from sea and swell occurring in a particular time period. [23]

Socio-economic drought. A combination of meteorological, hydrological and agricultural drought leading to undesirable social and economic impacts. [23]

Socio-natural hazard. The phenomenon of increased occurrence of certain geophysical and hydro-meteorological hazard events, such as landslides, flooding, land subsidence and drought, that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources [39]

Soil moisture or agricultural drought. An agricultural drought arises due to a deficit in soil moisture, driven by meteorological and hydrological drought, that reduces the supply of moisture for vegetation (Drought: Past Problems and Future Scenarios). Agricultural drought relates to moisture deficits in the topmost 1 metre or so of soil (the root zone) that affect crops. [20]

Spatial and temporal scales. Climate may vary on a large range of spatial and temporal scales. Spatial scales may range from local (less than 100 000 km2), through regional (100 000 to 10 million km2) to continental (10 to 100 million km2). Temporal scales may range from seasonal to geological (up to hundreds of millions of years). [23]

Storm. High wind speed, above some defined threshold. [4]

Storm surge. The increase in sea level caused by the combined effects of low atmospheric pressure, strong wind and a high tide. [10] [38]

Storm tide. The water level rise during a storm due to the combination of storm surge and the astronomical tide e.g. A 15 ft. storm surge on top of a high tide that is 2 ft. above mean sea level produces a 17 ft. storm tide. [35]

Streamflow. The water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation. [45]

Subtropical cyclone. A non-frontal low pressure system that has characteristics of both tropical and extratropical cyclones. The most common type is an upper-level cold low with circulation extending to the surface layer and maximum sustained winds generally occurring at a radius of about 100 miles or more from the centre. In comparison to tropical cyclones, such systems have a relatively broad zone of maximum winds that is located farther from the centre, and typically have a less symmetric wind field and distribution of convection. A second type of subtropical cyclone is a mesoscale low originating in

or near a frontolyzing zone of horizontal wind shear, with radius of maximum sustained winds generally less 30 miles. The entire circulation may initially have a diameter of less than 100 miles. These generally short-lived systems may be either cold core or warm core. [10]

Surcharge, surcharged. Flow conditions in an enclosed water conduit (pipe or culvert) in which the water pressure is higher than atmospheric, resulting in water levels at the inlet, outlet or access shafts higher than the soffit level of the conduit (in contrast to 'free surface flow'). [8]

Surface fire. Fire that burns loose debris on the surface, which include dead branches, leaves, and low vegetation. [36]

Surface water. Water that is on the earth's surface, such as in a stream, river, lake, or reservoir. [45]

Surface water flooding. In this context, surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, small water courses and ditches that occurs as a result of heavy rainfall. [6]

Thermal expansion. In connection with sea level, this refers to the increase in volume (and decrease in density) that results from warming water. A warming of the ocean leads to an expansion of the ocean volume and hence an increase in sea level. [23]

Tropical cyclone. A warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and closed surface wind circulation about a well-defined centre. [10]

Tsunami. The giant waves generated by sudden displacements in the sea floor (most commonly caused by earthquakes in marine and coastal region), landslides, or volcanic activity. [10]

Watershed. The land area that drains water to a particular stream, river, or lake. [45]

Weather. Short-term dynamically changing states of the atmosphere characterised by the values of several parameters including temperature, pressure, humidity and direction and force of wind. [10]

Wind. Horizontal movement of air caused by differences in pressures. Movement of an atmosphere. [1]

Wind model. Physical and mathematical model to predict wind velocity and direction at arbitrary locations given a set of discrete measurements or estimated of wind velocity and direction at know locations. [5]

Wildfire. A fire occurring on wild land that is not meeting management objectives and thus requires a suppression response. [36]

Wildland. An area in which development is essentially non-existent, except for roads, railroads, power lines, and similar transportation facilities. Structures, if any, are widely scattered. [36]

Winter flooding. Flood that occur in winter. May be caused by ice jams on the rivers, rapid snow melting, or by storm winds that push water level up on one side of the sea. [10]

3. Climate-weather change methodology

In this section the climate-weather state is defined and the interpretation of climate-weather states is given. The climate-weather change process for a critical infrastructure operating area and this process parameters are described. Further, using these parameters, i.e. probabilities of the process staying at the initial climate-weather states, probabilities of the process transitions between the climate-weather states and distribution functions of the process conditional sojourn times at the climate-weather states, a semi-Markov approach is used to construct a general probabilistic model of this process [32]. There, a general safety analytical model of a critical infrastructure related to the climate-weather change process in its operating area is proposed.

Next, the definition of the climate-weather change process identification and prediction is given and the procedure of the climate-weather change process characteristics prediction is proposed. To these characteristics include distribution functions of the process unconditional sojourn times and limit transient probabilities of the process. Finally, short-term and long-term climate-weather change prediction are defined and methods of these changes prediction are suggested.

The methodology introduced in the report [10] and in this section below will be used in further parts of the EU-CIRCLE project for that purposes. The climate-weather change process, defined and described in this paper, is used in the scope of the EU-CIRCLE project for safety analysis of critical infrastructures related to climate-weather change process and finally can be applied for analysis of CI resilience to climate-weather change.

Climate-weather change process. The process of the climate-weather states changing considered in time for a fixed area.

Climate-weather state. To define the climate-weather state in the fixed area, we distinguish a parameters that describe the climate-weather state in this area and mark the values they can take by $w_1, w_2, \ldots, w_a$. Further, we assume that the possible values of the i-th patameter w_i can belong to the interval $< b_i, d_i)$, $i = 1,2,...,a$. We divide each of the intervals $< b_i, d_i)$, $i = 1,2,...,a$, into n_i, $n_i \in N$, dicjoint

subintervals $<b_{i1}, d_{i1})$, $<b_{i2}, d_{i2})$, …, $<b_{in_i}, d_{in_i})$ such that

$<b_{i1}, d_{i1}) \cup <b_{i2}, d_{i2}) \cup \ldots \cup <b_{in_i}, d_{in_i}) = <b_i, d_i)$, $b_{ij_i} = d_{ij+1_i}$, $j_i = 1,2,...,n_i - 1$, $i = 1,2,...,a.$

Thus, the vector $(w_1, w_2, \ldots, w_a)$ describing the climate-weather state can take values from the set of the a dimmensional space points of the Cartesian product

$<b_1, d_1) \times <b_2, d_2) \times \ldots \times <b_a, d_a)$

that is composed of the a dimmensional space domains of the form

$<b_{1_{j_1}}, d_{1_{j_1}}) \times <b_{2_{j_2}}, d_{2_{j_2}}) \times .. \times <b_{aj_a}, d_{aj_a}),$

where $j_i \in \{1,2,...,n_i\}$, $i = 1,2,...,a.$

The domains of the above form are called the climate-weather states of the climate-weather change process and numerated from 1 until the value $w = n_1 \cdot n_2 \cdot \ldots \cdot n_a$ and mark by $c_1, c_2, \ldots, c_w$.

The interpretation of the states of the climate-weather change process in the case $a = 2$ is given in Figure 28. In this case, we have $w = n_1 \cdot n_2$ climate-weather states of the climate-weather change process represented in Figure 1 by the squares marked by $c_1, c_2, \ldots, c_w$.

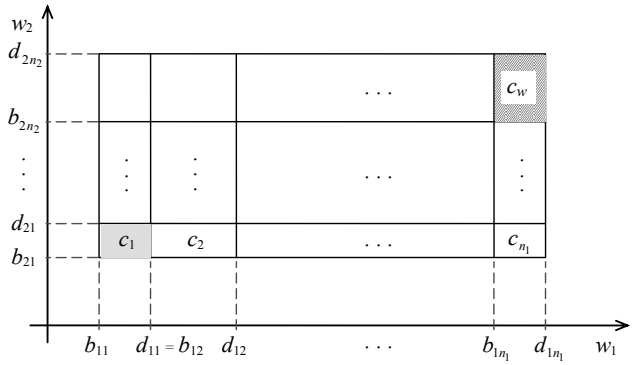


Figure 1. Interpretation of the climate-weather change process two dimensional climate-weather states.

Climate-weather change process model. To model the climate-weather change process for the critical infrastructure operating area we assume that the climate-weather in this area is taking $w, w \in N$, different climate-weather states $c_1, c_2, \ldots, c_w$. Further, we define the climate-weather change process $C(t)$, $t \in <0,+\infty)$, with discrete operation states from the set $\{c_1, c_2, \ldots, c_w\}$.

Climate-weather change process parameters. The system operation process may be described by:

- *number of climate-weather states* $w, w \in N$;
- *initial probabilities* $q_b(0) = P(C(0) = c_b)$, $b = 1,2,...,w$, of the climate-weather change process $C(t)$ staying at particular climate-weather states c_b at the moment $t = 0$;
- *probabilities of transitions* q_{bl}, $b, l = 1,2,...,w$, $b \neq l$, of the climate-weather change process $C(t)$ from the climate-weather states c_b to c_l;
- *conditional distribution functions* $C_{bl}(t) = P(C_{bl} < t)$, $b, l = 1,2,...,w$, $b \neq l$, of the conditional sojourn times C_{bl} at the climate-weather states c_b when its next operation state is c_l, $b, l = 1,2,...,w$, $b \neq l$;

Climate-weather change process identification. The statistical identification of the unknown parameters of the process of climate-weather change, i.e. estimating the probabilities of this process of staying at the states at the initial moment, the probabilities of this process transitions between its states and the parameters and forms of the distributions fixed for the description of this process conditional sojourn times at their states can be performed in the similar way to that presented in [31].

Climate-weather change prediction. Finding the characteristics of the process of climate-weather change like ones listed below and other.

Climate-weather change process characteristics. The climate-weather change process may be characterized by:

- *unconditional distribution functions* $C_b(t) = P(C_b < t)$ of the sojourn times C_b, $b = 1,2,...,w$, of the climate-weather change process $C(t)$ at the climate-weather states c_b, $b = 1,2,...,w$;
- *limit transient probabilities* q_b, of the climate-weather change process $C(t)$ staying at particular climate-weather states $q_b(t) = P(C(t) = c_b)$, $t \in \langle 0,+\infty \rangle$, $b, = 1,2,...,w$.

Short-term climate-weather change prediction. Climate-weather change prognosis for the nearest future time in the fixed area/environment.

Short-term climate-weather change prediction method. Climate-weather change prognosis using Monte Carlo simulation technique based on the *initial probabilities* of the climate-weather change process $C(t)$ staying at the climate-weather states, the *probabilities of transitions* of the climate-weather

change process $C(t)$ between the climate-weather states and the *conditional distribution functions* of the climate-weather change process $C(t)$ conditional sojourn times at the climate-weather states.

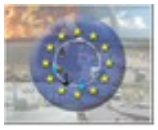
Long-term climate-weather change prediction. Climate-weather change prognosis for the far future time in the fixed area/environment.

Long-term climate-weather change prediction method. Climate-weather change prognosis using analytical methods based on the *probabilities of transitions* of the climate-weather change process $C(t)$ between the climate-weather states, the *conditional distribution functions* of the climate-weather change process $C(t)$ conditional sojourn times at the climate-weather states, *the unconditional distribution functions* of the climate-weather change process $C(t)$ unconditional sojourn times at the climate-weather states and the *limit transient probabilities* of the climate-weather change process $C(t)$ at the particular climate-weather states.

4. Conclusions

The paper is the improved modification of the fourth chapter of the report [10] prepared in the scope of EU-CIRCLE project activity deliverable. It includes climate change terminology and climate-weather change methodology.

Acknowledgements



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