



GUIDELINES ON THE DEFINITION AND MONITORING OF EXTREME WEATHER AND CLIMATE EVENTS

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1. Introduction

Climate encapsulates the description of how the atmosphere behaves over a long period of time (typically defined as a 30-year period), informing us on the “average of weather”, as well as the description of other aspects of weather patterns and parameters distribution, including anomalous, rare and extreme weather events. Some examples of extreme events include, but are not limited to, heat waves, cold waves, floods, heavy precipitations, drought, tornadoes, and tropical cyclones. Even though extreme events do not occur often, they can be harmful to our health, can cause great devastation to infrastructures, can affect our economy, and can even cause the loss of life (IPCC 2012). It is therefore necessary for Meteorological communities to improve the understanding and characterization of extreme weather and climate events in time and space with consistent methodologies for their definition and the computation of their thresholds, so that efficient systems for monitoring and forecasting these events can be deployed as part of building resilient societies coping with climate variability and adapting to climate change.

As climate differs from location to location, the definition of an extreme event (weather or climate) and its threshold also differ from location to location. In other words, what is considered an extreme value of a given climate element in one location can be considered as being within the normal range in a different location. In addition to natural reasons, there are also practical reasons for the varying definitions; for example the need to focus on a particular sector of applications that requires specific thresholds to take actions. This is the case, for example, in defining heat-waves in a heat-health warning system for which a heat wave can be described specifically according to the potential impacts on human health.

In its attempt to provide guidance on best practices in the domain of weather and climate extremes, the WMO Commission for Climatology (CCI) established a Task Team on the Definition of Extreme Weather and Climate Events (TT-DEWCE) back in 2010. The Task Team based its work on reviewing the existing literatures in the subject. The summary focuses on extreme events that are derived from Temperature and Precipitation, in particular the following type of events: Heat Waves, Cold Waves, Heavy Precipitation, Wet Spells, Drought, and Dry Spells. In addition to the review of the literatures, the Task Team surveyed the National Meteorological and Hydrological Services (NMHSs) to assess the current status of practices in defining and monitoring these types of extreme events.

In addition, meteorological hazards, which are not listed in the above survey, but which usually occur as part of changing weather conditions, can also induce high impacts, such as hail storms, sand storms, dust storms, wind storms, snow storms, among others are also considered in chapter IV. The goal is to list the existing definitions of hazards and develop their catalogue for easy reference in the process of establishing and operating Multi-Hazards Early Warning Systems as

well as to contribute in the efforts of assessing loss and damages which are hydro-meteorological related.

This document will inform on the scientific and technical background, as well as provide guidelines to define and characterize extreme weather and climate events and will provide some examples that were provided through the country survey.

2. Scientific and Technical Background

2.1 Review of Existing Literature on Extreme Weather and Climate Events (EWCEs)

Analysis at a global scale for a given extreme—such as heat waves, cold waves, heavy precipitation—may be particularly problematic because of, in various parts of the globe, lack of high-quality daily observation records covering multiple decades that are part of integrated data sets. Likely as a partial result of this, the Intergovernmental Panel on Climate Change (IPCC 2007, 2013) has noted that for many regions of the world it is not yet possible to make firm assessments of how global warming has affected extremes. Existing literatures concerning extremes mainly addressed related issues from the following perspectives:

a) Basic descriptive variables

Early studies for extremes simply consider maximum/minimum temperature and total cumulative precipitation at a given time scale (e.g. daily, monthly, seasonal and annual). (e.g. Karl et al. 1993, Karl and Knight 1998, Zhai et al. 2005). Such simple analysis fails to capture the high and low tails (i.e., “extremes”) of the distribution.

b) Derived variables

Derived values of precipitation and temperature have also been used in scientific evaluation. Diurnal Temperature Range (DTR, the difference between maximum and minimum temperature) is one of the illustrating derived variables used in climatic extremes research. Precipitation intensity (precipitation per unit of time, e.g., mm/day) is one of the more common derived variables used in climatic extremes research involving precipitation variability (e.g., Mason et al. 1999). Another derived variable involves computing peaks in specific precipitation events over the values of mean precipitation. Acero et al. (2011) used a statistical approach to analyze such data in their study of extreme rainfall over the Iberian Peninsula

c) Threshold categorization

A simple method is to establish specific threshold for temperature and extreme precipitation events and evaluate the extremes that occur over (or under) that given threshold. For example, Dash and Mamgain (2011) categorized heat waves and cold spells in India using thresholds with

daily maximum temperatures over 40°C (heat waves) and wind chill effective minimum temperatures less than or equal to 10°C, respectively. Another common mean of ascertaining thresholds is based on selecting the tail of distributions for temperature and precipitation. Statistical partitions such as by quartiles or percentiles of the distribution have provided a means for evaluating extremes. Heat waves, for example, have been defined as “temperatures above the 90th percentile, persisting for three or more days” for a heat wave study for southern Australia (Pezza et al. 2012). For precipitation, other segregations have used variant distributions other than a standard ‘normal’ distribution to base classification schemes. For example, some researchers have employed a generalized extreme value (GEV) distribution or a Pareto distribution to approximate precipitation distributions.

d) Human perspective of extremes

In terms of heat waves, considering human perception through derived indices that include other variables than simply temperature (e.g. humidity) becomes another means of analysis. For example, Metzger et al. (2010) used a Forecast Heat Index in excess of 95°F (35°C) to evaluate summer heat waves for New York City. Willett and Sherwood (2012) employed a wet bulb globe temperature above 35°C as their threshold in their study of heat waves.

e) Hydrological/agriculture

Hydrologists and engineers often employ a probability recurrence interval as a means of classifying extreme precipitation events. Such “return period” analyses have also been employed by climatologists (e.g., Kunkel et al. 1999, Kharin et al. 2007) as a means of establishing trends and variations in extreme precipitation occurrence.

f) Derived indices

A new set of indices have gained prominence over the last decade in the study of climate extremes. The set of indices used in this analysis are based on the 27 indices of temperature and precipitation from daily data formulated and internationally coordinated by the joint CCI/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) (WMO-TD. No 1500, 2009). Many ETCCDI indices are based on percentiles with thresholds set to assess moderate extremes that typically occur a few times every year rather than high impact, once-in-a-decade weather events.

In particular, in the study of heat waves, two of the most popular indices have been the *Warm (Cold) spell duration index (WSDI / CSDI)*: Annual count of days with at least 6 consecutive days when the maximum (minimum) temperature is in the 90th (10th) percentile (5-day window) of a base period. An issue with such definitions is that the criteria can be met in any season such that a “heat (cold) spell” can be defined in the winter (summer). They also have limited global utility, as runs of 6 or more consecutive days above the 90th (or below the 10th) percentile are rare or unknown in many climates (Alexander et al. [2006]).

g) Basic hydrologic/climatological indices

Indices constructed from a combination of soil moisture and climatic parameters have been used in drought assessment for decades. One of the earliest and widely used indices is the Palmer Drought Severity Index (PDSI) that was developed by Wayne Palmer in the 1960s. It employs temperature and rainfall information in a formula to determine dryness. The Palmer Index is most effective in determining long term (with length of several months) drought. Recently, one of the most used drought rainfall indices has been the Standardized Precipitation Index (SPI). SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). Please see section 3.4 for additional information on SPI.

h) Expert interpretation / classification of drought

A fundamental problem of all drought indices is that no single index works under all temporal and geographical circumstances (Heim, 2002). Consequently, many countries have undertaken a blend of mathematical (objective) and perception/observational (expert) assessments of drought. As example, the US and North American Drought Monitors (Svoboda et al. 2001) has been very successful in assessing and communicating the state of drought in the US on a weekly basis. The people assessing drought for these regions use a process that synthesizes multiple indices, outlooks and local impacts, into an assessment that best represents current drought conditions.

In the special report of the IPCC on managing the risks of extreme events and disasters to advance climate change adaptation (IPCC, 2012), extremes are understood from the following three general categories:

(1) Extremes of atmospheric weather and climate variables

An extreme (weather or climate) event is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable. Some climate extremes (e.g., droughts, floods) may be the result of an accumulation of weather or climate events that are, individually, not extreme themselves (though their accumulation is extreme).

(2) Large-scale phenomena accounting for extremes (e.g., tropical and extratropical cyclones, ENSO [El Niño/La Niña], and monsoons)

A weather system such as a tropical cyclone can have an extreme impact, depending on where and when it approaches landfall, even if the specific cyclone is not extreme relative to other tropical cyclones. Conversely, not all extremes necessarily lead to serious impacts. Many weather and climate extremes are the result of natural climate variability (including phenomena

such as El Niño/Southern Oscillation), and natural decadal or multi-decadal variations in the climate provide the backdrop for anthropogenic climate changes. Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur.

(3) Collateral effects of extremes on the physical environment

Weather or climate events, even if not extreme in a statistical sense, can still lead to extreme conditions or impacts, either by crossing a critical threshold in a social, ecological, or physical system, or by occurring simultaneously with other events. Droughts, floods, extreme sea level, waves, storm surges and coastal impacts are typical cases that exert severe impact on the physical environment. Other physical impacts, including cryosphere-related impacts, landslides, and sand and dust storms, can also be included. These extremes are not caused by variations in a single atmospheric weather and climate variable, but are generally the result of specific conditions in several variables, as well as of some surface properties or states. For instance, both floods and droughts are related to precipitation extremes, but are also impacted by other atmospheric and surface conditions.

Nevertheless, among climate science communities, extreme weather and climate events tend to be categorized into the following three types,

[1] Extremes of a single variable

An extreme can be identified when a single climate variable (e.g. precipitation or wind) exceed its specific thresholds, which can be varying percentile-based values, fixed absolute values and return period. Not all extremes necessarily have extreme impacts. Extreme weather or climate event can vary from place to place in an absolute sense (e.g., a hot day in the tropics will have a different temperature than a hot day in the mid-latitudes) and society tends to adapt to its climate historical ranges of the intensity of extremes.

[2] Compound (multivariable) extremes

Some climate extremes (e.g., droughts, floods) may be the result of an accumulation of moderate weather or climate events (this accumulation being itself extreme). In climate science, compound events can be (1) two or more extreme events occurring simultaneously or successively, (2) combinations of extreme events with underlying conditions that amplify the impact of the events, or (3) combinations of events that are not themselves extremes but lead to an extreme event or impact when combined. The contributing events can be of similar (clustered multiple events) or different type(s). There are several varieties of clustered multiple events. Examples of compound events resulting from events of different types are varied – for instance, high sea level coinciding with tropical cyclone landfall, or cold and dry conditions (e.g., the Mongolian Dzud), or the impact of hot events and droughts on wildfire, or a combined risk of flooding from sea level surges and precipitation-induced high river discharge (Svensson and Jones, 2002; Van den Brink

et al., 2005). Compound events can even result from ‘contrasting extremes’, for example, the projected occurrence of both droughts and heavy precipitation events in future climate in some regions.

[3] Weather phenomenon associated with extremes (e.g. thunderstorms and hail)

Some extremes may be linked with weather phenomenon, which themselves may be not extreme. For example, sand storm forms in the arid region when strong winds blow loose sand.

2.2 WMO and IPCC Terminology

Extreme Event: The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. In many cases, a weather or climate event with high impact is also deemed as extreme event. In this guideline, frequently occurring high impact weather and climate extremes such as heat wave, cold wave, extreme precipitation and drought are the main focus.

Hazard: The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.

Climate indices: Are indices derived from measured meteorological parameters that are used to diagnose and describe the state of a climate system.

Regional extreme event: an extreme event covers a large space, or many places at the same time period.

Early Warning: The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

Climate Prediction: A climate prediction or climate forecast is the result of an attempt to produce a most likely description or estimate of the actual evolution of the climate in the future (e.g., at seasonal, interannual, or long-term time-scales).

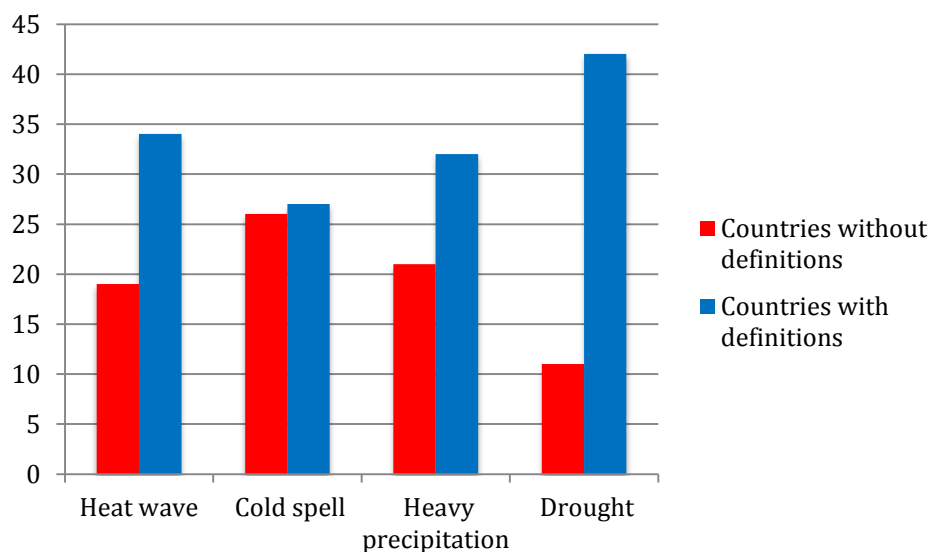
Climate Watch: A “Climate Watch” can serve as a mechanism to heighten awareness in the user community that a significant climate anomaly (or climate extreme) exists or might develop and that preparedness measures should be initiated. In general, as part of a Climate Watch system, the NMHS would continuously monitor and assess the state of the climate, evaluate available climate forecasts, and, when conditions warrant, issue formal climate watches to alert end users. End users would then be in a position to undertake actions to mitigate the climate-related impacts.

3. Definition and characterization of Extreme Weather and Climate Events

3.1. General aspects

In developing this guideline, the TT-DEWCE disseminated a survey for WMO Members requesting the information on the definitions and criteria of extreme weather and climate events that are used operationally in their National Meteorological and Hydrological Services. The survey mainly focused on four types of high impact extreme events, namely heat wave, cold wave, drought and heavy precipitation. By the time of writing of this guideline, 53 countries responded to the survey, with very good geographical representation of the continents, and of the climate characteristics, which include countries with tropical wet and dry climate, arid and semi-arid climate, continental and subarctic climate. According to their memberships of the Regional Associations (RA), the number of countries which has responded are 11 from RA-I, 9 from RA-II, 5 from RA-III, 5 from RA-IV, 5 from RA-V, and 18 from RA-VI.

From the 53 countries which responded, 7 of them have no criteria on any of the extreme events. The graph and text below summarizes the number of countries with and without definitions for each extreme event



For heat wave and cold wave, all countries having tropical climate responded that they have no definition or criteria for those events. The other countries located in the higher latitudes or in the Middle East generally have the following criteria for heat waves: the temperature exceeds a certain threshold (based on absolute value or percentiles) and persist longer than a certain amount of days. In the contrary for cold waves, the criterion is that the temperature is less than a certain threshold and persists longer than a certain amount of days. From the survey, only around 65% of the responded countries have criteria on heat wave, and around 50% have criteria on cold spell. Among them, around 60% of countries that responded having criteria for heat wave, used absolute value for the threshold and around 30% uses percentile based thresholds. While for cold

spells, around 60% of countries having criteria for cold wave used absolute value for the threshold and around 25% used percentile based threshold.

For drought, around 80% of the countries responded that they have criteria and indices for drought. Among those countries which have indices for drought, the majority (around 70%) follow the recommended drought index from WMO which is the Standardized Precipitation Index (SPI). There are several countries which used (combinations of) various indices, besides the SPI, such as the SPEI, the Palmer drought index (SPDI) and expert assessments, and also using hydrological criterion for drought.

For heavy precipitation, around 60% of countries responded that they have criteria and indices for heavy precipitation. Around 70% of those countries used criteria for heavy precipitation with absolute value threshold for a certain amount of time (hourly, 3 hours, 6 hours, or daily). Other criterion which is quite commonly used by Member countries is using percentiles as the threshold, for instance the 95th or the 99th percentile, which amounts around 30% of the countries which have responded. A small percentage of countries, around 10%, uses return period criteria or based on rainfall distribution consideration.

More details on the types of extreme weather and climate indices used by countries are summarized in the table below:

Table 3.1 Summary of the survey on extremes for WMO Members

Event:	Heat wave	Cold spell	Heavy precipitation	Drought
#countries with definitions:	34	27	32	42
Absolute value threshold	20	16	23	1
Percentile based threshold	11	7	9	10
Extreme Heat Index (EHI)	5	1		
Heat-health index	3			
Temperature drop		4		
Return period / distribution based criteria			3	

SPI	29
SPEI	5
Palmer	3
Water balance & agriculture related	18

With regard to the question of support from WMO for extreme weather and climate events, responses of the countries mostly can be categorized into two objectives, which are the need for a guideline for extreme events definitions and the need for capacity building to improve climate monitoring and predictions.

The summary of the survey is presented in the appendix and available online in <http://location>.

The following section aims to present a general framework of the definition of extremes, by proposing characterization aspects that is necessary to describe an extreme event. Members are encouraged to determine their own definitions and criteria according to their specific climate and needs. Showcases for the four extreme events are presented in the appendix as a means to complement the general framework that is given.

3.2. Specific guidance for selected Extreme Weather and Climate Events

3.2.1 Heat wave

Heat wave is a pervasive meteorological phenomena resulting in the mortality of people, agricultural losses, and increases many risks such as health-related risks, wild fires, power shortage and accidents, among others. NMHS are mandated to provide heat wave advisories to help decision making by the various sectors to minimize these risks and potential damages. Currently, there is no universal accepted definition of heat waves. However, many countries have adopted local criteria for issuing heat wave advisories. Recently, from a health perspective, guidance on heat-health warning has been issued by WMO (WMO-No 1142, 2015).

To meet NMHS needs for providing consistent information on heat waves, there is a need to standardize the definition of a heat wave. The definition should address the physical, temporal and spatial characterization of the event. The aim is to help develop a system that can inform more consistently on the occurrence and evolution of the event including information on its magnitude, duration, extent and severity. The definition should also allow developing inter-operable data bases on heat waves worldwide for use in research and applications.

Heat wave definition

According to WMO's Meteorological vocabulary, a heat wave is an extreme weather event with 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. In the IPCC glossary, heat wave is a period of abnormally and uncomfortably hot weather. Even though the WMO and IPCC definition describes broadly the event, the definitions are not sufficient in guiding NMHSs to develop practical methodologies and tools for a heat wave monitoring system that would allow comparisons across borders. The WMO TT-DEWCE recommends using a practical and qualitatively oriented definition of a heat wave. A heat wave is defined as follows:

A marked unusual hot weather (Max, Min and daily average) over a region persisting at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds.

Heat waves differ from warm spells. Similar to heat waves, warm spells are defined as a persistent period of abnormal warm weather. Warm spell can be defined in terms of top 5th or 10th percentile of Tmax of the time of year. It usually occurs during the cold period of the year, not during the climatologically hot period.

Recommendation for standard characterization of a heat wave

To quantitatively reflect a heat wave event, the definition of heat wave should be complemented by characterization with the following 4 metrics:

1. **Magnitude:** it should be computed based on an index or a set of indices of thermal condition(s) exceeding certain threshold(s). Such thermal index can be as simple as one meteorological element (i.e., Tmax) or as complicated as a combined index by multiple variables such as temperature, humidity or even including wind speed. Threshold reflects the abnormal condition or extremity of the event. Indices, criteria and thresholds should be defined by NMHS at national and sub-national scale, according to its own climate conditions and applications. They should be maintained in an official data base and communicated to WMO.
2. **Duration:** will lead to the computation of the persistence of a heat wave and should be based on recording the starting time and the ending time of the event.
3. **Severity:** is a measure which integrates two aspects of the event, its magnitude, and its persistence.
4. **Extent:** is computed to inform on the geographical area affected and the widespread aspect of the heat wave.

Both, Severity and Extent, should be monitored and communicated to the users to inform on the incurred risks. To practically monitor a heat wave event, the Task Team recommends computing certain values pertinent to these metrics and reflecting the physical, temporal and spatial characterization of a heat wave (see table3).

WMO guide on developing warning systems for heat waves

Past occurrences of heat waves had significant impacts on several aspects of society. On health sector, mortality and morbidity have increased. Ecosystem services can be affected, as well as increased pressure on infrastructures that support society, such as water, transportation and energy. Recognizing the vast impact of heat waves, especially on the health aspect, the WMO and the WHO have co-published a document titled *Heatwaves and Health: Guidance on Warning-System Development* (WMO-No. 1142). This document describes several key aspects to develop warning systems for heat waves, starting from assessments of heat waves, definitions and methodologies, communication of warnings, intervention strategies, and longer term planning perspectives for managing heat wave events. In supporting one of the Global Framework of Climate Services goals, which is to develop effective climate services for the health sector, this document is aimed to enable and assist NMHSs to develop this sector specific services together with their health related counterpart.

Quantitative description:	Thermal Index (Thm)	Threshold (Thms)	Temporal information	Spatial information
	Daily values of Tmax, or/and Tmin, or a combination of these two with other variables such as relative humidity (RH) and wind speed	Thresholds are computed based on historical values of Thm. It should provide a limit beyond which Thm values are statistically rare(*), or having potential negative impacts on one or several application sectors. (*) The WMO Climatological Standard normal should be used to the extent possible to define the base period and departure from the average and percentiles.	Record at station level information on the start time and end time of heat wave events and keep the information in a database.	As a heat wave evolves with time it is important to use, preferably, GIS(*) to: 1. Calculate the area affected by the event and at which degree. 2. Locate the coordinates of the impacted stations and the center with the highest thermal index value. (*) Geographical Information Systems Another way to characterize the extent of the area affected in case GIS software is not available, would be to provide the percent of stations where the observed temperature surpassed Thms.
Event characterizations:	Magnitude		Duration	Extent
	Values of Thm-Thms; Can be computed with a synthesized method.		Computed at station level which is a number of consecutive days with $Thm > Thms$.	Area computed using a gridding technique applied on Thm or using objective criteria applied on one or several elements included in computing Thm.
	Severity: An aggregate of several measures through a formula or set of logical criteria applied on magnitude and duration . It should be categorized in three levels: moderate, severe and extreme.			

Data requirements:	Historical and real time daily values of Tmax, Tmin, RH, windspeed and direction	Multi-day observation	Multi-station observation which can be complemented by other means such as remotely sensed data when observational network is not sufficiently dense.
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350 Table 3.2 Characterization of a heat wave event

3.2.2 Cold wave

Cold wave is a meteorological event generally characterized by a sharp drop of air temperature near the surface leading to extremely low values, steep rise of pressure, and strengthening of wind speed, or associated with hazardous weather, like frost and icing. It often causes severe impacts on human health, agriculture and high heating cost, or even resulting in mortality for human beings and livestock. IPCC (2007) noted: cold-waves continue to be a problem in northern latitudes, where very low temperatures can be reached in a few hours and extend over long periods. However, there is still a lack of a clear and consistent definition for cold wave events in the world. Thus, after reviewing the existing definitions in publications and some countries' operational activities, the TT-DEWCE has developed the Guideline for definition and characterization of the cold wave for WMO members.

Cold wave definition

According to WMO's Meteorological vocabulary, a cold wave is "marked cooling of the air, or the invasion of very cold air, over a large area". The U.S. National Weather Service defines a cold wave as a rapid fall in temperature within a 24-hour period, requiring substantially increased protection to agriculture, industry, commerce, and social activities. In China, a cold wave is defined as a dramatic cooling weather process, with large scale cold air from the high latitudes invading the middle and lower latitude regions. Cold waves are also simply defined as persistent extreme low temperature events sustaining specified temperatures below some thresholds over some minimum number of days (Djuro Radinović and Mladjen Ćurić, 2012; Peterson et al, 2013).

The existing terminology helps provide a broad scope for understanding the subject matter of the phenomena and its underlying physical factors. Therefore the Task Team recommends building on the existing terminology to guide Members on a standard approach for defining cold waves.

It considers also that it is important for NMHSs to use methods and tools that help objectively characterize a cold wave in space and time with indices that allow recording its start, duration and cessation at the site where it was recorded. In addition it is also important to provide information on the severity and the geographical extent of the event. Both severity and extent are very important information for using in early warnings, risk assessment and climate change research.

A cold wave is defined in this guideline in general terms as

A marked and unusual cold weather characterized by a sharp and significant drop of air temperatures near the surface (Max, Min and daily average) over a large

area and persisting below certain thresholds for at least two consecutive days during the cold season.

The thresholds for a cold wave are determined by the rate at which the temperature falls, and the minimum to which it falls. This minimum temperature is dependent on the geographical region and time of year. Typically, a cold wave is associated with invasion of very cold air caused by a polar or high latitude air-mass displacement to lower latitudes, or in some cases associated with or enforced by long radiative cooling during a blocking and clear sky atmospheric circulation.

Cold waves can also occur during spring and autumn. However, during summer the cooling of the air near the surface that can be caused by atypical seasonal temperature conditions and/or winds can lead to cold spells, which is a period of time during which temperatures drops significantly below the normal conditions. Nevertheless, the Task Team recommends preserving the use of cold wave definition only during the cold season with a certain margin period of time around it.

Recommendation for standard characterization of a cold wave

To quantitatively reflect a cold wave event, the definition of cold wave should be complemented by characterization with the following 4 metrics:

1. **Magnitude:** it is computed based on an index or a set of indices measuring the temperature drop below certain threshold(s) to measure the intensity of the event. Index and indices are normally used to measure the rate of the temperature dropping or/and the minimum pic values. Thresholds can be an absolute value or percentiles. The magnitude reflects the abnormal cold condition or extremity of the outbreak of the cold event. The detailed indices, criteria and thresholds should be defined by NMHS at national and sub-national scale, according to its own climate conditions and applications. They should be maintained in an official data base and communicated to WMO.
2. **Duration:** it will lead to computing the persistence of a cold wave and should be based on recording its starting time and ending time. The starting time of cold wave is marked by the day with sharp drop of temperature below the threshold and extreme cold condition, or only with extreme cold conditions reaching the threshold. When the temperature returns to the degree not satisfying the extreme conditions anymore, the cold wave ends. The time between ending and starting is the duration.
3. **Severity:** is a measure which integrates two aspects of the event: its magnitude and its persistence.
4. **Extent:** is computed to inform on the geographical area affected and the widespread aspect of the cold wave.

Quantitative description:	Temperature index: Ti	Threshold (Ts; or Ts ₁ and Ts ₂)	Temporal information	Spatial information
	Ti ₁ :Computed using daily values of Tmin, Tmax and average temperature. A separate index Ti ₂ can be computed using temperature change in the last 24 hours.	Computed based on historical values of the index. It should provide a limit beyond which, values are statistically rare(*), or a certain threshold value having potential negative impacts on one or several application sectors. (*) The WMO Climatological Standard normal should be used to the extent possible to define the base period and departure from the average and percentiles.	Persistent at least 2 days. Record at station level information on the starting time, ending time and duration of cold wave. Keep the information in a database.	As a cold wave evolves with time it is important to use preferably a GIS to: 1. Calculate the area affected by the event and at which degree. 2. Locate the coordinates of the impact stations and the center with the peak values of the indices. Another way to characterize the extent of the area affected in case GIS software is not available, would be to provide the percent of stations where the observed temperature surpassed Ts.

Event characterizations:	Magnitude	Duration	Extent
	Value of Ti-Ts; or defined by a synthesized method that could include also the drop rate in the past 24 hours and the lowest temperature during cold wave process.	Computed at station level, which is the number of consecutive days satisfying the criteria.	Computed based on multi-station data with gridding. It is possible to use model analysis when observing networks are not dense (such as with temperature profile at 1000, 950, 900, 850 mb)
	Severity: An aggregate of several measures through a formula or set of logical criteria applied on magnitude and duration . It should be categorized in three levels: moderate, severe and extreme.		

Data requirements:	Historical and real time daily Tmax, Tmin.	Multi-day observation	Surface observation which can be complemented by other means such as reanalysis, model analysis or remotely sensed data when observational network is not sufficiently dense.
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Table 3.3 Characterization of a cold wave event

3.2.3 Extreme precipitation and wet spells

The occurrence of heavy precipitation events is a major hazard that has often led to floods, landslides, as well as the loss of human lives and major economic losses. In many regions of the world it is likely that there have been statistically significant increases in the number of heavy precipitation events although it is not uniform in all regions (IPCC 2013). It is also reported that for a range of emission scenarios, the projections until the end of the 21st century indicate that it is likely that events of annual maximum 24-hour precipitation rate having a 1-in-20 year return period (for the baseline period 1961-1990) will become a 1-in-5 to 1-in-15 year event, indicating a trend of more frequent extreme heavy precipitation events (IPCC, 2012).

There is a strong spatiotemporal inhomogeneity of extreme precipitation since precipitation values as heavy will vary from region to region and will also depend on the season. To provide a consistent general guidance in defining extreme precipitation, some basic parameters, including magnitude (intensity), duration, severity and spatial extent affected, should be included. These parameters should be enabled on multiple time scales of precipitation extremes, such as hourly, daily, and multi-day scales.

Extreme precipitation definition

Since there are large variations in precipitation patterns throughout the world, it is not possible to define a single definition of heavy precipitation that is suitable for all regions. In the International Meteorological Vocabulary (WMO-182), heavy rain is defined only as “rain with a rate of accumulation exceeding a specific value”. It is recognized generally that when a precipitation event is considered to be extreme, it relates to one of the following two contexts: (1) a precipitation event is considered to be extreme when it exceeds a certain threshold that has a certain associated impact, i.e. a fixed threshold, or (2) a precipitation event is considered to be extreme due to its rarity, i.e. a percentile-based threshold. The rarity of occurrence tends to take the form of upper 90th, 95th, and 99th percentile of precipitation. Such percentile-based threshold is usually derived from statistical cumulative density function or some conceptual distributions for precipitation extremes (such as Generalized Extreme Value, GEV). Building on the existing definitions, scientific literatures and practices among the WMO Members, this guide aims to guide Members on a standard approach to define heavy precipitation.

The outcome of heavy precipitation from the survey of extremes disseminated to the countries, presents several key findings, which are, that the majority of countries defined heavy precipitation with a certain threshold on varying time periods, ranging from 1 hour to 48 hours, and also taking into account seasonality. In some cases, percentile based threshold is also used by the countries. Having considered these, heavy precipitation is defined in this guideline in general terms as

A marked precipitation event occurring during a period of time of 1h, 3h, 6h, 12h, 24h or 48 hours with a total precipitation exceeding a certain threshold defined for a given location.

It is recommended that for reporting heavy precipitation events at regional level (for example to Regional Climate Centres [RCCs]), to use 24hours time-scale as a period for a common criteria for heavy precipitation.

Generally, the most commonly used approach in practice by the Members of the WMO when defining thresholds for heavy rainfall, are categorized into above two: (1) by absolute value threshold and (2) by statistical segregation / relative threshold, such as percentiles or return periods. Specific definitions for the two categories used by the WMO Members are presented in the Appendix (XX) of this document or available online in (site location).

While value-threshold based characterization of extremes are more closely related to application purposes, percentile based thresholds are more evenly distributed in space and is meaningful and applicable when sufficient observation data exists. The flexibility to define the percentile level for extremes will also allow users to define a very rare event, for instance an event exceeding the 99th percentile, or a record breaking event which exceeds the highest percentile. Of particulate note is that based on such percentile thresholds, even very rare events in some arid and semi-arid regions may have not high disaster-causing potential.

Wet spell definition

According to WMO's Meteoterm vocabulary and the International Meteorological Vocabulary (WMO-182), a wet spell is defined as "a period of a number of consecutive days in which precipitation exceeding a specific minimum amount has occurred". Although the number of consecutive days is not specified, in this guideline it is suggested to use five consecutive days as the reference time for a wet spell. The reason for this is because of the existing index from the ETCCDI, which is the monthly maximum consecutive 5-day precipitation (Rx5day), which can be used for long term evaluation of the wet spells for climate monitoring. Building on these and the definition of a wet day, a wet spell is defined in this guideline as

A period of at least five consecutive days with daily precipitation exceeding 1 millimeter.

In addition to ordinary wet spells, long-lasting precipitation extremes, as an extreme case of wet spells, also need to be paid particular attention to, because of their high-impact property. At individual station level, combined thresholds of intensity and duration threshold is utilized to define persistent precipitation extremes. Fixed absolute values depending on locations seem more proper to represent the disaster-causing potential, and at least three days are required to satisfy preliminary duration. For regional scales, transient event

identification approach (Ren et al. 2013) is used to trace multi-day processes moving from location to location; quasi-stationary identification scheme (Chen and Zhai 2013) is used to guarantee stationary front related persistent heavy precipitation, whose major amount pours into a highly concentrated area. The latter one tends to trigger severe floods during a few days.

Below a general framework for defining heavy precipitation is proposed.

Recommendation for standard characterization of heavy precipitation

To quantitatively reflect a heavy precipitation event, the definition of heavy precipitation should be complemented by characterization with the following 4 metrics:

1. **Magnitude:** it is computed based on an index or a set of indices measuring the precipitation total on various time scales to measure the intensity of the event.
2. **Duration:** it is computed by the number of isolated or consecutive time unit the precipitation satisfying the extreme criteria.
3. **Severity:** is a measure which integrates two aspects of the event. Its magnitude and its persistence.
4. **Extent:** describes the area impacted by the heavy precipitation event.

Table 3.4 Characterization of a heavy precipitation event

Quantitative description:	Precipitation index: Pi	Threshold (Ps)	Temporal information	Spatial information
	Pi: measured or analyzed for 1hr, 6hr, 12hr, 24h or 48h total precipitation	Computed based on historical values of the index. It should provide a limit beyond which, values are statistically rare(*), or a certain threshold value having potential negative impacts on one or several application sectors. (*) The WMO Climatological Standard normal should be used to the extent possible to define the base periods and departure from the average and percentiles.	Record at station level information on the starting time, ending time and duration of heavy precipitation. Keep the information in a database.	As heavy precipitation evolves with time it is important to use preferably a GIS to: 1. Calculate the area affected by the event and at which degree. 2. Locate the coordinates of the impact stations and the center with the peak values of the indices. Another way to characterize the extent of the area affected in case GIS software is not available, would be to provide the percent of stations where the observed precipitation surpassed Ps.

Event characterizations:	Magnitude	Duration	Extent
	Value of Pi-Ps	The time period considered in the index	The geographical area computed based on multi-station data with gridding when observing networks are dense. Another option is to use remote sensing and NWP model analysis output
	Severity: It should be established as function of the magnitude only (the duration is fixed). It should be categorized in three levels: heavy, very heavy and extreme.		Another way to characterize the extent is to provide the percent of stations that were affected.

Data ents:	Historical and real time precipitation data on hourly and daily timescales		Continuous observation	Surface observation which can be complemented by other means
Quantitative descripti	Precipitation index: Pi	Threshold (Ps)	Temporal information	Spatial information
	Total precipitation	1mm in 24-hr	Record at station level information on the	As a wet spell evolves with time it is important to use preferably a

Table 3.5 Characterization of wet spells

		starting time, ending time and duration of wet spell. Keep the information in a database.	GIS to: 1. Calculate the area affected by the wet spell 2. Locate the coordinates of the impact stations and the center with the peak values of the index
Event characterizations:	Magnitude	Duration	Extent
	Percent of total precipitation during the spell compared to the seasonal average.	Computed at station level which is a number of consecutive days satisfying the threshold.	The geographical area computed based on multi-station data with gridding when observing networks are dense. Another option is to use remote sensing and model analysis.
	Severity: Is based on duration. It should be categorized in three levels: minor, long, and very long. Additional information can be provided in terms of maximum daily total recorded during the spell.		
Data requirements:	Historical and real time daily precipitation data.	Continuous observation	Surface observation which can be complemented by other means such as remotely sensed data and NWP model analysis when observational network is not sufficiently dense.

3.2.4 Drought and dry spells

Drought, a natural weather phenomenon that occurs in all climates, can differ greatly from other extreme events. Unlike other extreme events, such as floods, tornadoes, and hurricanes, which are weather events that are immediately detectable, drought, on the other hand, develop slowly and steady, making it difficult to determine the onset and end. Albeit its development, drought can end up being extremely devastating and costly, affecting society, the economy, natural habitats, and ecosystems. In order to facilitate communication, management, and response, drought can be categorized into four general types: 1) meteorological, 2) agricultural, 3) hydrological, 4) and socio-economic. Meteorological drought is the atmospheric conditions resulting in the absence or reduction of precipitation over a period of time. Meteorological drought can lead to impacts to agriculture due to precipitation shortages, higher evapotranspiration, and soil moisture deficits, which results in an agricultural drought. Meteorological drought can also lead to hydrological drought, which occurs from depleted surface or subsurface water supplies. Socioeconomic drought is the imbalance in supply and demand or the effect of water shortages on the economy (e.g. crop losses) and society (e.g. health). All of these different types of drought have one thing in common; they all begin with a deficiency of precipitation (meteorological drought).

Drought can be numerically defined using indices that integrate temperature, precipitation and other variables that affect evapotranspiration and soil moisture. Several indices in different countries assess precipitation deficits in various ways, such as the Standardized Precipitation Index. Other indices make use of additional weather variables. The most commonly used index is the PDSI (Palmer, 1965) that uses precipitation, temperature and local available water content data to assess soil moisture (IPCC, 2007).

Because of drought's complexity and how it affects many aspects of our lives and a wide variety of sectors, it is difficult to develop a single definition of drought since no single definition works in all circumstances. But in order to take initial steps in defining drought, we are going to focus solely on meteorological drought and its indices for the purpose of this document.

Drought definition

Drought, as defined by WMO's Meteoterm, is prolonged absence or marked deficiency of precipitation; a period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance. It is also defined as a deficiency of precipitation relative to what is expected that, when extended over a season or a longer period of time, results in the inability to meet the demands of human activities and the environment (Hayes 2011). Drought is defined in this guideline in general terms as

A marked unusual period of abnormally dry weather characterized by prolonged deficiency below a certain threshold of precipitation over a large area and persisting for timescale longer than a month.

Drought shouldn't be confused with aridity, which is a characteristic of a climate relating to insufficient or inadequate precipitation to maintain vegetation—according to WMO's Meteoterm. In other words, drought is a temporary climate phenomenon, while aridity is a permanent climate feature in areas that typically experience low precipitation throughout the year. An example of an arid place is the Saharan Desert, where the annual precipitation total is approximately below 25 mm per year.

Drought typically begins as a dry spell—a period of abnormally dry weather; however, the conditions are less severe than those of drought. Once dry conditions begin to affect society and the economy by not being able to meet the demands of human activities and the environment, then it's no longer a dry spell, but drought.

Dry spell definition

As indicated above, dry spell conditions usually initiates drought, although not all dry spells lead to drought condition. As defined in WMO Meteoterm, a dry spell is a period of abnormally dry weather, where the conditions are less severe than those of a drought. In this guideline, dry spell is defined in general terms as

A period of unusually dry conditions() of at least five consecutive days with daily precipitation less than 1mm.*

() i.e. to exclude usually dry periods, such as during dry seasons*

The choice of the five days period in the definition is for consistency with the definition of wet spell given above.

WMO recommendation for drought index

In December 2009, 44 drought experts from 22 countries met in Lincoln, Nebraska, USA to discuss the development of standards for drought indices and guidelines for drought early warning systems. One of their recommendations was to encourage the use of the Standard Precipitation Index (SPI) to characterize meteorological droughts and provide this information on their web sites, in addition to the indices currently used. Another outcome from this meeting was the creation of a comprehensive user manual for the SPI, which provides a description of the index, the computation methods, examples of where it is currently used, its strengths and limitations, mapping capabilities, and how it can be used. For additional information on the recommendations from the meeting, please see The Lincoln Declaration on Drought Indices: Universal Meteorological Drought Index Recommended.

The suggestion to use SPI as a drought index is mainly due to its simplicity—considering only precipitation as a variable—and effectiveness. SPI helps quantify the precipitation deficit since it is based on the probability of precipitation for any time scale. The probabilities are standardized, where zero would represent the median precipitation amount, a negative index would represent dry conditions (less than median precipitation), and a positive index would represent wet conditions (greater than median precipitation).

When using SPI, drought is considered to have started when the SPI value is ≤ -1.0 and drought ends when the SPI value becomes positive. Dry spell is considered to have started when the SPI value is between -0.5 and -1.0.

For more information on how to compute the SPI, please see WMO's SPI User Guide.

Recommendation for standard characterization of drought

When characterizing a drought event, the following four metrics should be considered:

1. **Magnitude:** Identifies the strength of the drought, whether it is abnormally dry, moderate drought, severe drought, extreme drought or exceptional drought. The classification of the magnitude of the drought will be determined on the drought index value.
2. **Duration:** The duration of the drought will be determined based on when it started and ended. When using the SPI index, drought is considered to have started when the SPI index value is ≤ -1.0 and drought ends when the SPI value becomes positive
3. **Severity:** is a measure which integrates two aspects of the event. Its magnitude and its persistence.
4. **Extent:** Will inform on the geographical area affected and the widespread aspect of drought.

Quantitative description:	Drought index: Di	Threshold (Ds)	Temporal information	Spatial information
	Di: Computed using monthly or longer timescale precipitation totals, or in combination with other variables such as evaporation, temperature and relative humidity.	Computed based on historical values of the index. It should provide a limit beyond which, values are statistically rare(*), or a certain threshold value having potential negative impacts on one or several application sectors. (*) The WMO Climatological Standard normal should be used to the extent possible to define the base periods and departure from the average and percentiles.	Persistent for timescales longer than a season. Record at station level information on the starting time, ending time and duration of drought. Keep the information in a database.	As a drought evolves with time it is important to use preferably a GIS to: 1. Calculate the area affected by the event and at which magnitude or severity.

Event characterizations:	Magnitude	Duration	Extent
	Value of Di-Ds; or defined by a synthesized method.	Computed at station level which is the number consecutive months, seasons, or years satisfying the criteria.	The geographical area computed based on multi-station data with gridding when observing networks are dense. Another option is to use remote sensing precipitation data when only precipitation data is considered.
	Severity:	An aggregate of several measures through a formula or set of logical criteria applied on magnitude and duration . It should be categorized in 3 categories: moderate, severe and extreme.	

ata its:	Historical and real time data needed to compute Di.	Continuous observation	Surface observation complemented by other means such as remotely
Qu an tit	Precipitation index: Pi	Threshold (Ps)	Temporal information Spatial information
requi re			network is not sufficiently dense.

Table 3.6 Characterization of a drought event

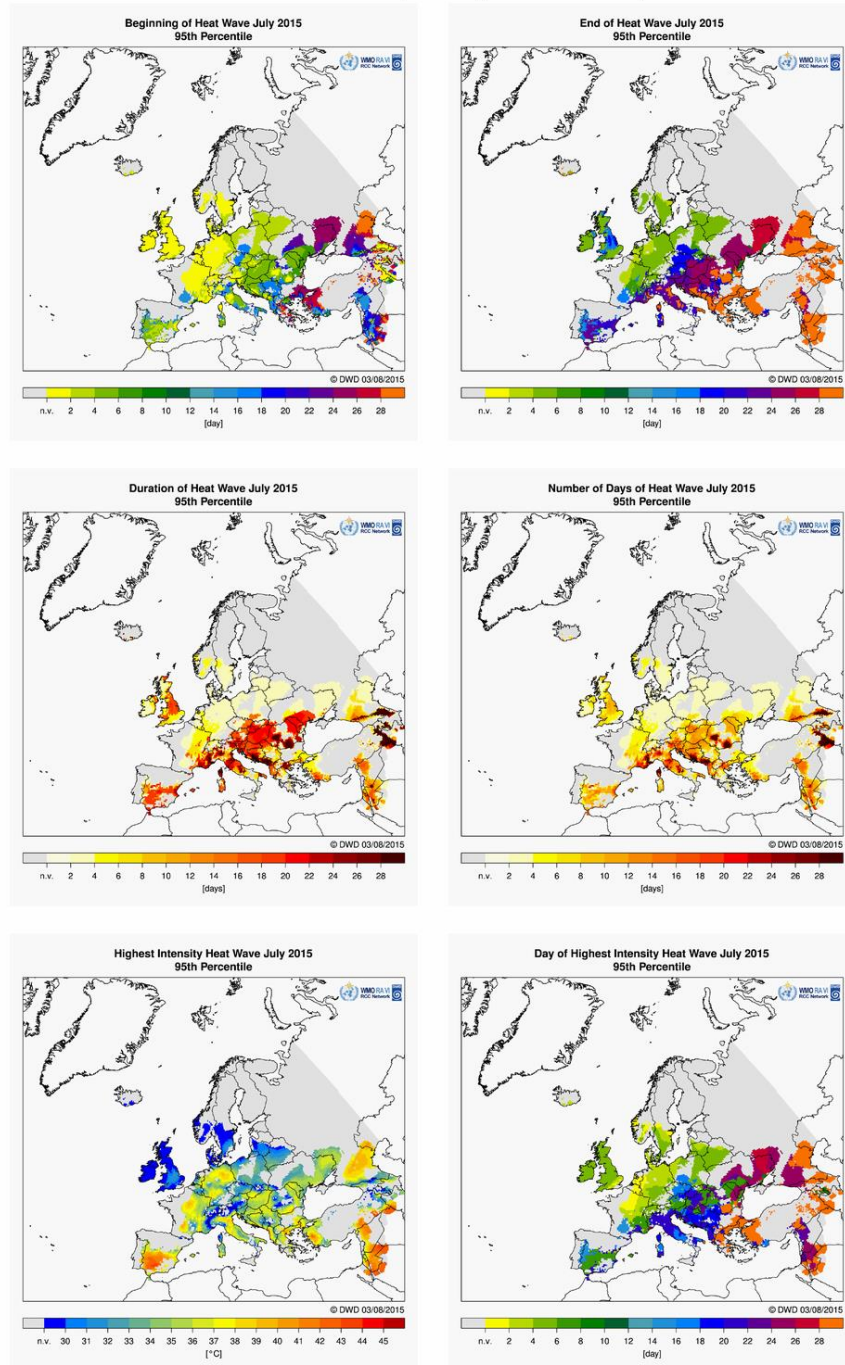
Table 3.7 Characterization of a dry spell

	Total precipitation in $P_i < 1\text{mm}$ 24 hours.	Record at station level information on the starting time, ending time and duration of wet spell. Keep the information in a database.	As a dry spell evolves with time it is important to use preferably a GIS to: 1. Calculate the area affected by the wet spell 2. Locate the coordinates of the impact stations and the center with the peak values of the index
Event characterizations:	Magnitude	Duration	Extent
	Percent of total number of days with precipitation $< 1\text{ mm}$ compared to the average length of the season. Dry periods, such as during dry seasons in arid or semi-arid areas should not be accounted. Note: the definition of the wet/dry season is defined by each country, where the start and end of the season should also be defined based on average conditions.	Computed at station level which is a number of consecutive days satisfying the threshold.	The geographical area computed based on multi-station data with gridding when observing networks are dense. Another option is to use remote sensing and model analysis.
	Severity:		
	Is based on duration. It should be categorized in three levels: minor, long, and verylong.		
Data requirements:	Historical and real time daily precipitation data.	Continuous observation	Surface observation which can be complemented by other means such as remotely sensed data and NWP model analysis when observational network is not sufficiently dense.

638 **Showcases for heat wave**639 **Showcase 1:**

640 Below is an example of a heat wave monitoring product by the European Regional Climate
641 Center. The heat wave duration index is defined by maximum period > 5 consecutive days with
642 Tmax above 95th percentile of the 1961–1990 daily Tmax.

Heat Wave July 2015 (95th Percentile)



643

Showcase 2:

A more complicated approach that considers human comfort and the magnitude definitions is shown below. In China, to specifically define a heat wave and its intensity, a thermal index is defined based on perceivable temperature, a threshold based on percentile to reflect extremity and an excess heat index to quantify the magnitude of the heat wave event. The steps are as follows:

Firstly, an extreme hot day index is calculated when T_{max} is over 33°C.

$$T_i = 1.8T_{max} - 0.55(1.8T_{max} - 26)(1 - 0.6) + 32; RH \leq 60\%;$$

$$T_i = 1.8T_{max} - 0.55(1.8T_{max} - 26)(1 - RH) + 32; RH > 60\%$$

Then, a threshold T_{is} for hot day is defined over the 50th percentile over all the sample days with T_{max} over 33°C during May-Sept for 1981-2000 reference period. If T_i of a typical day is over T_{is} , that day will be classified as a hot day.

Further, a heat wave (severity) index is defined by H_i , an index taking into account impacts of excess heat of the typical day, and the previous days, as well as impact of the heat wave duration.

$$H_i = 1.2(T_i - T_{is}) + 0.35 \sum_{i=1}^{N-1} 1/nd_i(T_{i_i} - T_{is}) + 0.15 / \sum_{i=1}^{N-1} 1/nd_i + 1$$

where N is the persistent time of the extreme hot weather process (day), T_i the typical day Heat index, T_{is} the threshold of heat wave, T_{i_i} previous i day of the heat wave and nd_i the number of heat wave days from day i before the typical day.

Based on H_i , magnitude of the heat wave can be assessed by on the following table.

Classification of Heat wave Magnitude in China

Magnitude	Light Heat wave (Class 3)	Moderate Heat wave (Class 2)	Sever Heat wave (Class 1)
H_i	$2.8 \leq H_i < 6.5$	$6.5 \leq H_i < 10.5$	$H_i \geq 10.5$

Showcase 3:

The Australian Bureau of Meteorology provided services for heat wave assessments as well as heat wave forecast services through their website in the following link www.bom.gov.au/australia/heatwave/. The forecast of the heat wave is given over a three-day period for lead times up to six days. The assessment and the forecast inform users on the level of heat waves for the following level of severity: low-intensity heat wave, severe heat wave and

extreme heat wave. The heat wave definition used in this service is three or more days of high maximum and high minimum temperature that are unusual to a certain location.

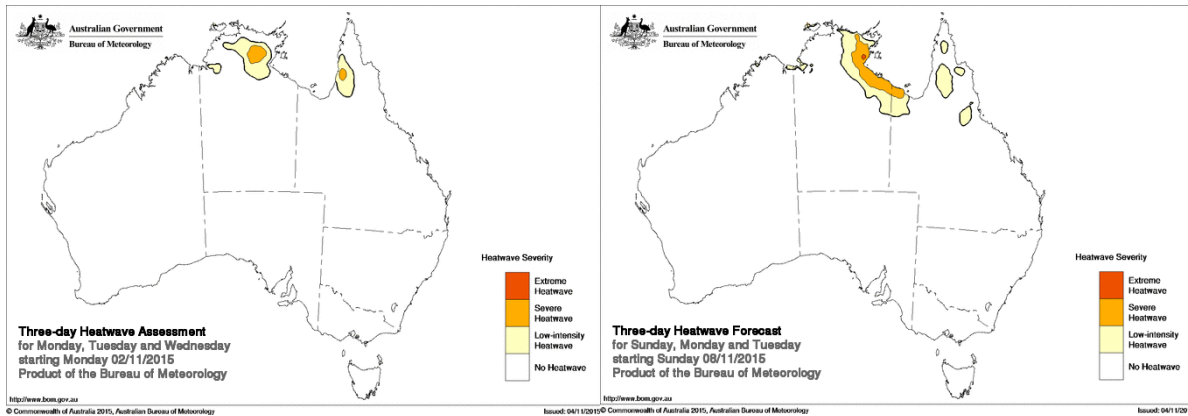


Figure S1. Products of the Bureau of Meteorology for a three-day heat wave assessment for the period of 2-4 November 2015 (left), and heat wave forecast for 8-10 November 2015 (right).

Showcases for cold wave

Showcase 1:

As a simple case, to produce comparable results for different geographical locations, relative thresholds (e.g., 10th percentile or a value of 2 standard deviation below normal) from statistical distribution can be used. A cold wave can be considered to have occurred when there are two or more consecutive days on which the maximum and minimum temperature anomalies are simultaneously lower than the thresholds established by the corresponding 10th percentiles or well below normal (Djuro Radinović & Mladjen Ćurić, 2012).

Showcase 2: In China, the thresholds include sharp drop of temperature in 24, 48, 72 hours and some absolute thresholds for low temperature. For southern and northern regions, the thresholds are different.

Showcases for drought

Other drought indices

Other indices that only consider precipitation as a variable that were recommended in the December 2009 expert team meeting in Lincoln, Nebraska, that could also be used to monitor and/or characterize drought are:

1. **Percent of normal precipitation:** this is a simple measure for precipitation. It is computed by dividing the observed precipitation by the 30-year average precipitation. The quotient is then multiplied by 100%.

$$\text{Percent of normal precipitation} = \frac{\text{observed precipitation}}{\text{average precipitation}} * 100\%$$

2. **Percentile ranking (deciles, terciles, quartiles):** is also a simple computation, but requires a long historical precipitation data record. The percentile ranking is done by simply sorting the data record from the lowest to the highest value and then ranking each value from driest (#1) to wettest (# of years in the record). The numeric rank of each value indicates the position of the sorted value throughout the historical record.

Examples of classification:

a)

Percentile Classification	
Lowest Decile	Much below normal
Lowest Tercile	Below normal
Middle Tercile	Near normal
Upper Tercile	Above normal
Upper Decile	Much above normal

Source: [NOAA's NCEI](#)

b)

Decile Classification	
Deciles 1-2: Lowest 20%	Much below normal
Deciles 3-4: Next Lowest 20%	Below normal
Deciles 5-6: Middle 20%	Near normal
Deciles 7-8: Next Highest 20%	Above normal
Deciles 9-10: Highest 20%	Much above normal

Source: [National Drought Mitigation Center](#)

Although it has been shown by multiple studies that precipitation is the major variable in defining and characterizing drought, an index that uses both temperature and precipitation data can also be useful to characterize drought. This index is the Standard Precipitation Evapotranspiration Index (SPEI), which uses temperature and precipitation data. SPEI is very similar to the SPI, but also takes into consideration evapotranspiration, which is the combined processes by which water is transferred from the Earth's surface to the atmosphere by evaporation from the land and ocean surfaces and by transpiration from vegetation, according to WMO's Meteoterm. This is an important and useful index because evapotranspiration processes

could potentially increase the drought severity (warmer temperatures tend to increase the evapotranspiration and thus exacerbating drought conditions).

Guidance and software to compute SPEI were developed by Spain's "Consejo Superior de Investigaciones Científicas" (CSIC) and can be accessed at the following link:
<http://sac.csic.es/spei/index.html>

A global monitoring map of SPEI is also available on a monthly basis, courtesy of CSIC, at
<http://sac.csic.es/spei/map/maps.html>

Timescale

All of the indices recommended in this showcase for drought can be computed on a range of timescales, from monthly to longer timescales.

Showcase 1:

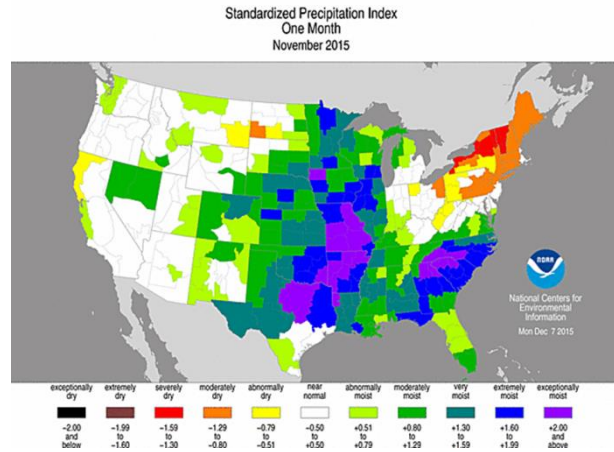


Fig S1.1: Standardized Precipitation Index map for the contiguous U.S.

The U.S. Drought Monitor assesses and communicates the state of drought in the United States on a weekly basis. It is a synthesis of multiple indices and local impacts to best represent the current drought conditions.

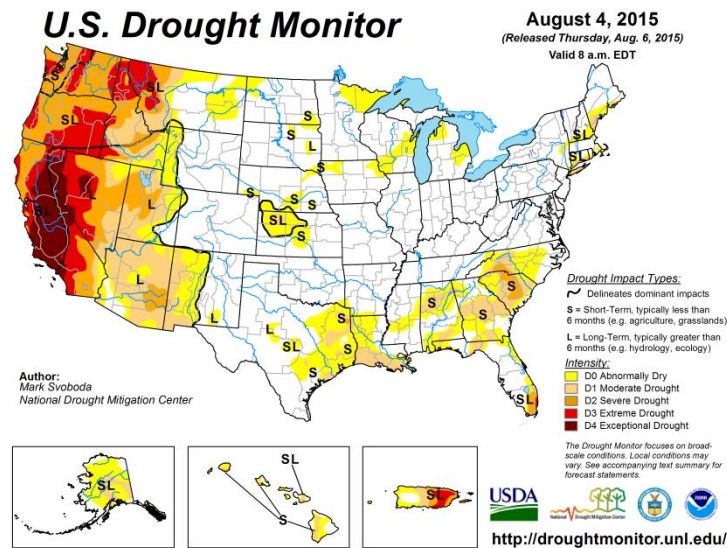


Figure S1.2: U.S. Drought Monitor Map (Source: drought.gov)

The U.S. drought monitor identifies the intensity using five indicators, drought impacts, and local reports from expert observers around the country. The table found below shows the ranges for each indicator for each dryness level.

Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common, water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

Figure S1.3: Table shows the ranges for each indicator for each dryness level in the U.S. Drought Monitor. (Source: drought.gov)

Showcase 2:

The Drought monitoring in Montenegro is based on precipitation percentiles, SPI index in daily/monthly basis and remote sensing data, i.e. FVC (fraction of vegetation cover) and LAI (leaf area index) indexes for selected area in Montenegro computed from the LANDSAF data within DMCSEE (Drought Management Centre for Southeastern Europe).

SPI values are computed separately for 1, 3, 6, 9 and 12 months and 1, 2, 3, 4, 5, 6, 9 and 12 in days.

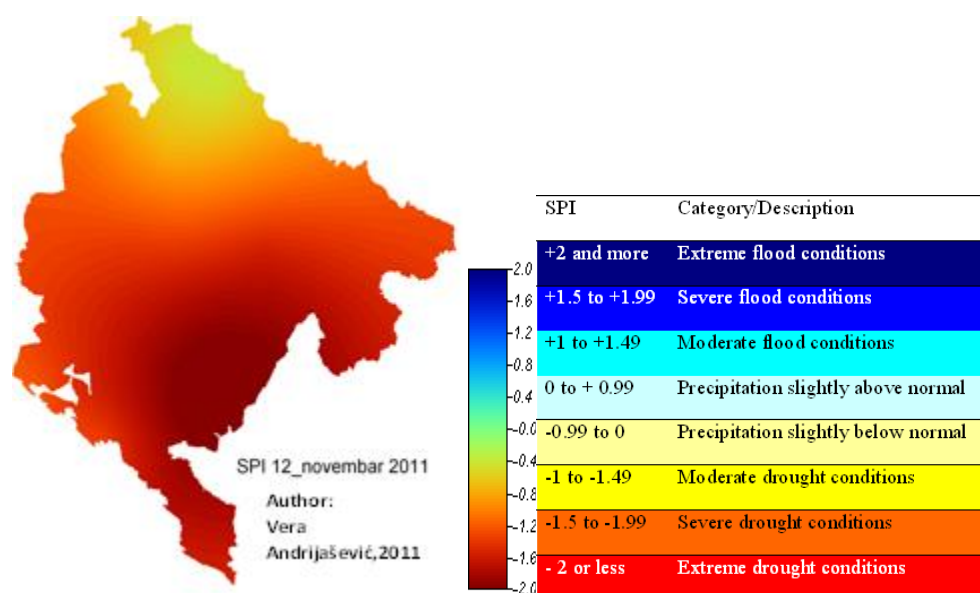


Figure S2.1: National level: SPI 12 shows intensity of hydrological drought in November 2011

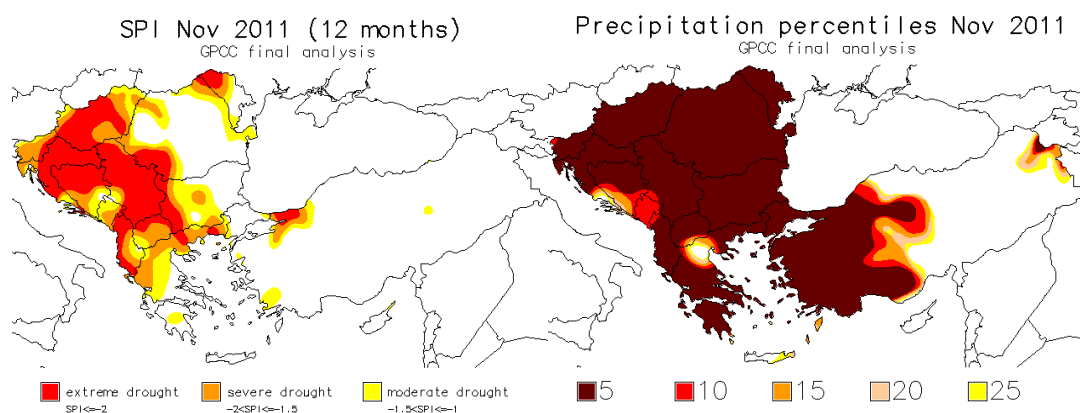


Figure S2.2: Regional level: SPI 12 and precipitation percentiles in November 2011 (Source: Drought Management Centre for Southeastern Europe (DMCSEE), www.dmcsee.org)

In order to perform early warning on drought, there are several available options through national and regional products exchange that are used:

- National weather forecast of precipitation 3 days in advance
- Regional products through SEEVCCC (Southeastern Europe Virtual Climate Change Centre in Belgrade, Republic of Serbia) and such as SEECOF climate outlook for the summer and winter season as well as MEDCOF climate outlook for Mediterranean region coordinated by Spain.
- Regional products through DMCSEE such as precipitation and SPI maps for Southeastern Europe, monthly drought bulletin for SEE region with temperature, precipitation and SPI overview, FVC and LAI for defined surfaces in Montenegro
- Seasonal weather forecast from Meteo France
- Climate watches advisory through the RA VI RCC Network Offenbach Node on Climate Monitoring (RCC-CM) and from RCC- LRF websites concerning Long-Range Forecast.

Showcase 3:

The Climate Regional Center for Southern South America (RCC-SSA) uses five indices for drought monitoring: Standardized Precipitation Index (SPI), Standardized Precipitation Evaporation Index (SPEI), precipitation deciles, categories of precipitation levels used by collaborators at Brazil's Instituto de Meteorologia de Brasil (INMET), and the percentage of normal precipitation. All drought indices are calculated for scales of 1, 2, 3, 6, 9, 12, 18, 24, 36 and 48 months. Various visualization displays are produced to facilitate perception of current drought conditions throughout the countries in the RCC-SSA. Source: http://www.crc-sas.org/es/monitoreo_sequias.php

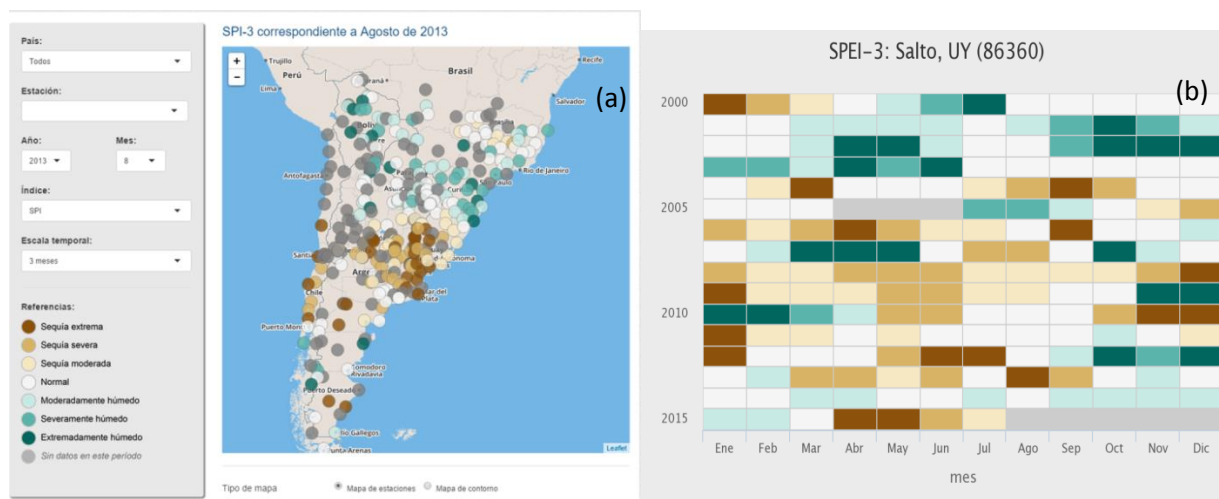


Figure S3.1: (a) SPI for a 3-month scale as of August 2014. Dots indicate the location of meteorological stations for which SPI was calculated. The dark brown shade indicates extreme drought conditions. (b) “Heatmap” of SPEI-3 values in Salto, Uruguay. Each cell represents a month in the period 2000 through July 2015. Months are shown along the x-axis and years are indicated in the y-axis.

Showcase 4:

The assessment of meteorological drought in Indonesia is done by the Agency for Meteorology Climatology and Geophysics (BMKG). Several products to monitor drought are Standardized Precipitation Map, Percent of Normal map, and continuous dry days map. The examples below show the status for October 2015, when the 2015 El Niño impacts were at its peak for the region.

The SPI values plotted on the map in S4.1. follows the definition given by McKee (1991). While for the percent to normal of precipitation, BMKG classifies precipitation values above 115% of the average to be above normal and precipitation values below 85% of the average to be below normal. The above normal and below normal classification is further divided into three subclasses for more detailed classification, as shown by the legend in Figure S4.2 below. The last map in Figure S4.3 below is produced by simply counting the number of continuous dry days for each monitoring location.

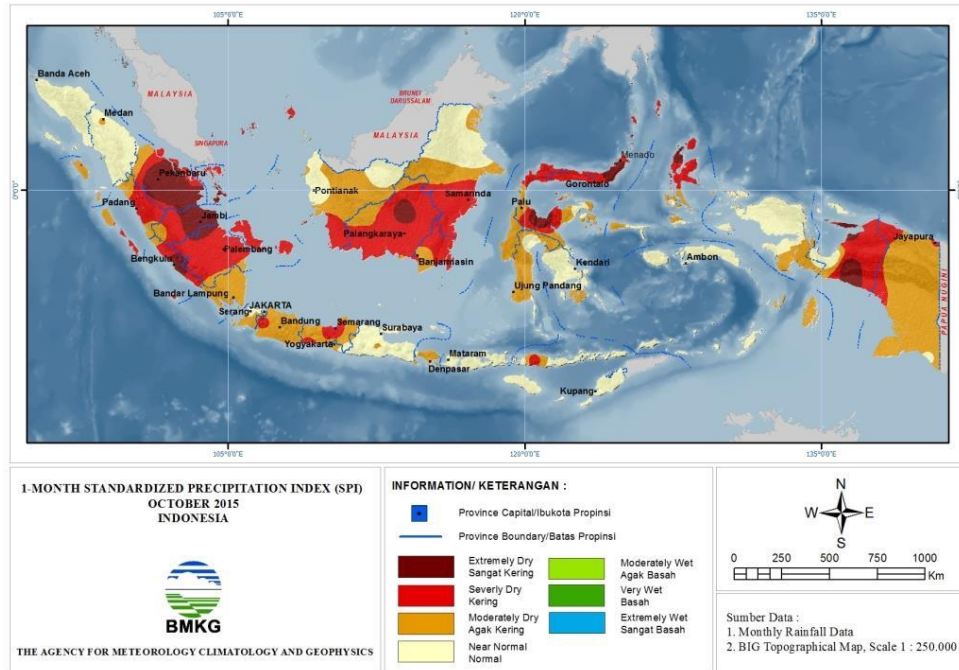


Figure S4.1.SPI for 1-month for October 2015.Colors denotes the classification of the SPI value, according to McKee.

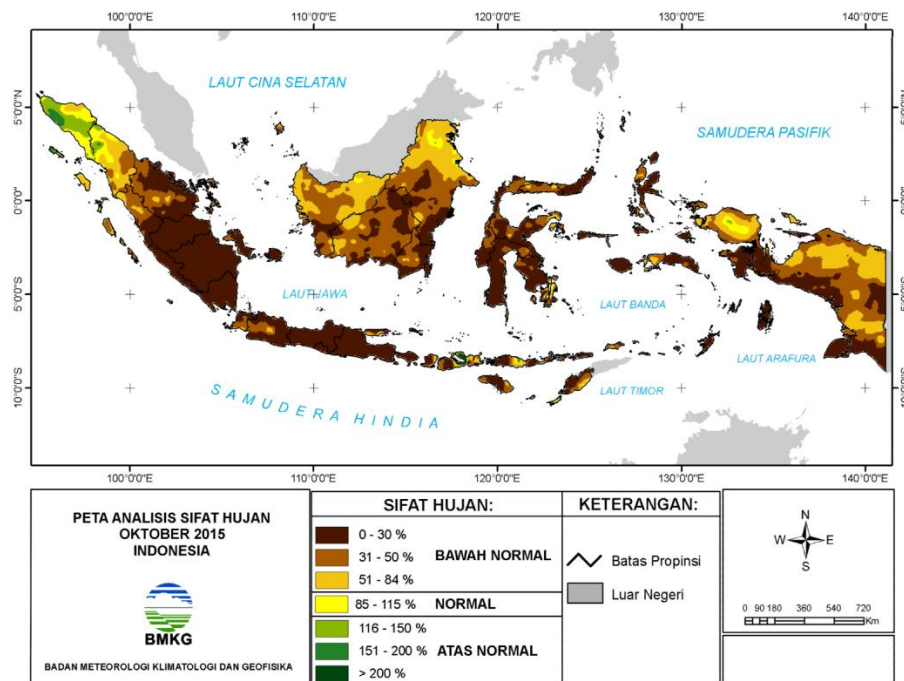


Figure S4.2. Percent to normal map for October 2015. The map shows the extent of the dry conditions during the peak of the 2015 El Niño in the Indonesian area. Note that from East to West spans around 46 degrees, showing the vast regional scale of the drought condition.

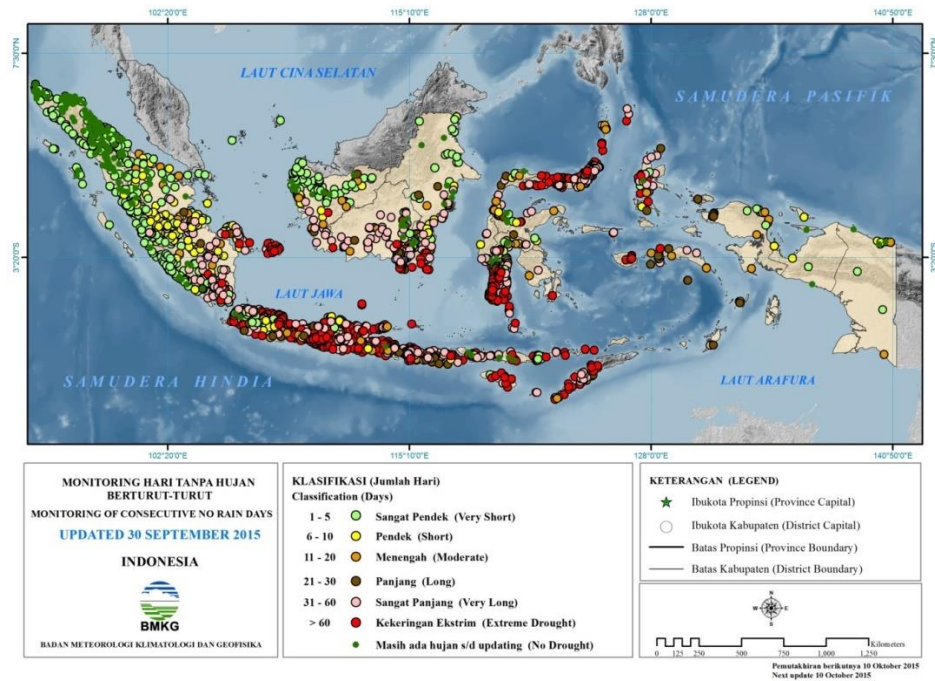


Figure S4.3. Continuous Dry Days map showing the condition for early October 2015. Colors of the circles denote the length of the dry days, ranging from short (green) to long (red).

Showcase 5:

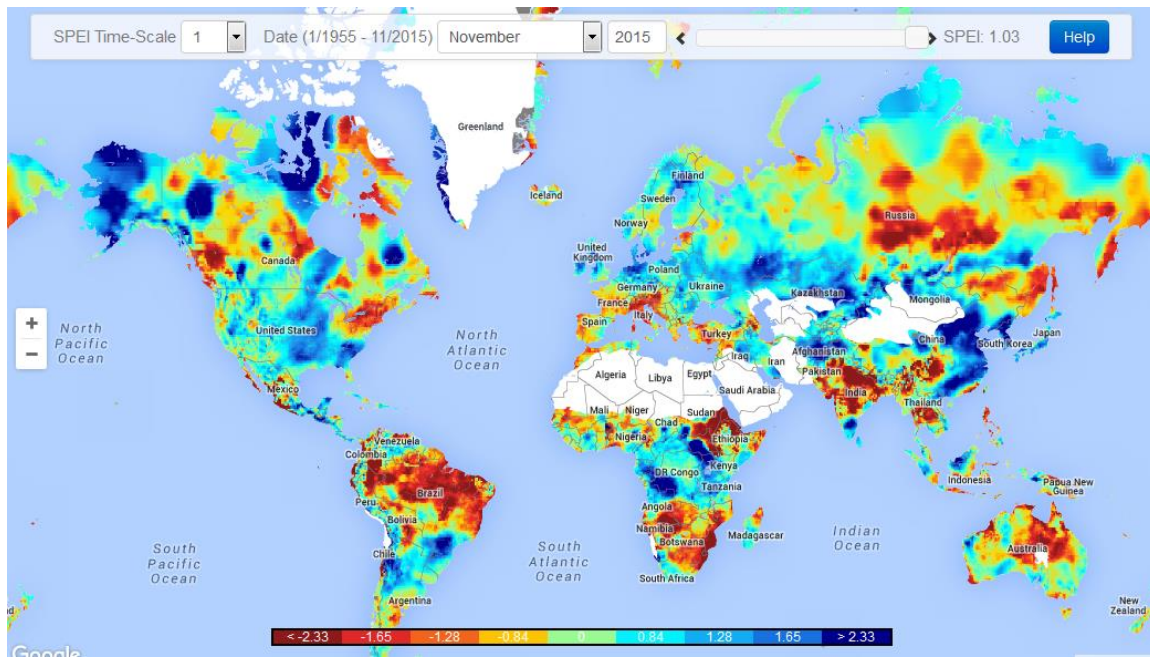


Fig S5.1: Global SPEI Drought Monitor (Source: Consejo Superior de Investigaciones Científicas [CSIC])

Showcases for heavy precipitation

Showcase 1:

Examples from the Bureau of Meteorology Australia showing characterization of rainfall with percentiles and its corresponding return period. These examples were from 21 February 2015 when two tropical cyclones (Lam and Marcia) made simultaneous landfall on the northern part and eastern part of Australia.

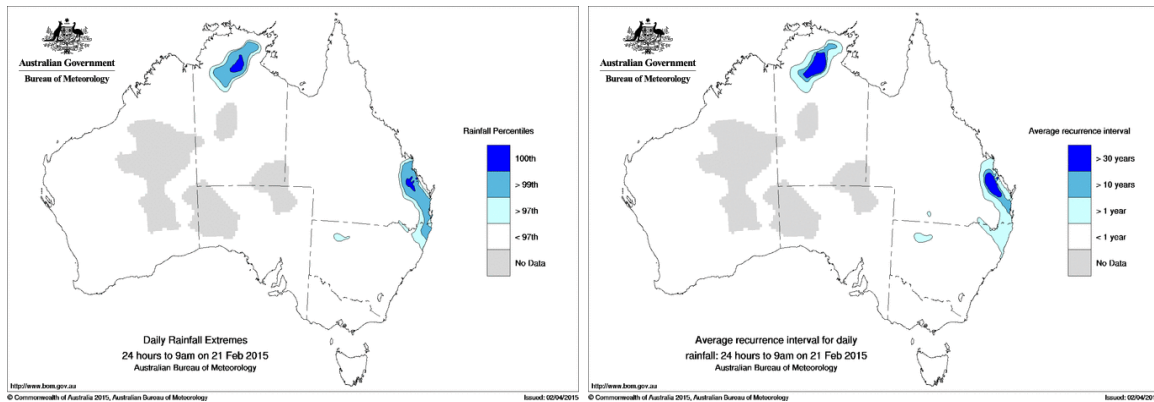
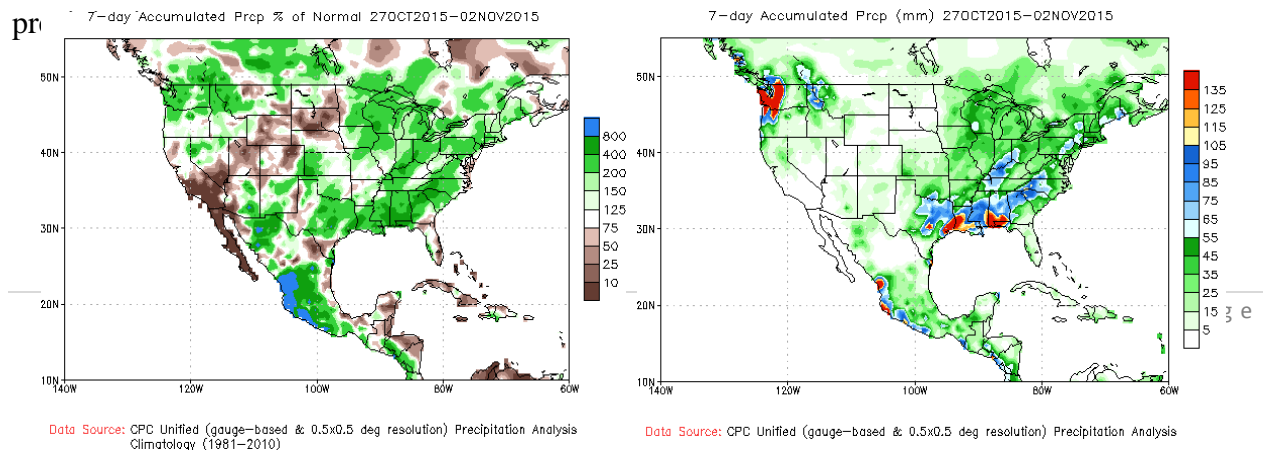


Figure S1. Left panel shows the percentile categorization of the rainfall during the land fall of two tropical cyclones (Lam and Marcia), and on the right shows the corresponding recurrence interval for the same event.

Showcase 2:

Examples of monitoring products from the Climate Prediction Center of NOAA, showing weekly accumulation of rainfall and its associated percent to normal categorization. These examples are weekly accumulation for the period of 27 October 2015 to 2 November 2015. The example shows contrasting percent to normal ratio, while the majority is experiencing much above normal rainfall category, there are areas in the west coast showing much below normal



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889 Figure S2.Examples of weekly rainfall accumulation from CPC NOAA on the left panel and
890 its corresponding percent to normal categorization on the right.

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Showcase 3. Examples of monthly rainfall analysis from the UK Met Office, for the month January 2015. The examples are taken from the website of the UK Met Office, for the climate summary page: www.metoffice.gov.uk/climate/uk/summaries/anomacts.

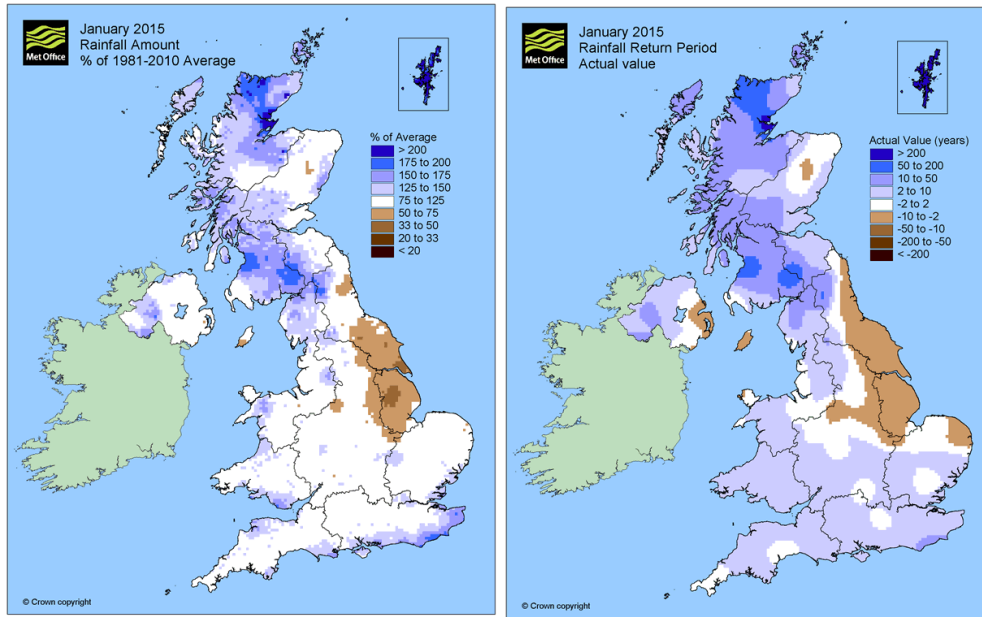


Fig for the month of January 2015 (left) and its corresponding return period (right).

Showcase 4:

A simple year to year heavy rainfall characterization from Indonesia. Operationally the characterization of rainfall that is used in the Agency for Meteorology Climatology and Geophysics (BMKG) is the following:

- Light rain : 5 - 20 mm/day
- Moderate rain : 20 - 50 mm/day
- Heavy rain : 50 - 100 mm/day
- Very heavy rain: >100 mm/day

The figures below show the number of heavy rain and very heavy rain from year to year for the city of Bogor.

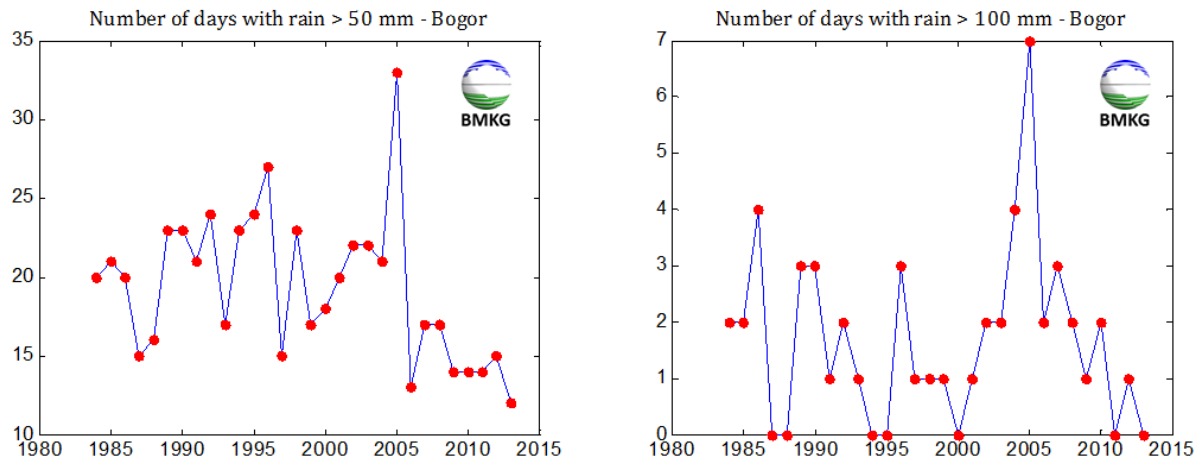


Figure S4. Year to year values of the number of days with heavy rainfall (>50mm/24hr) on the left, and year to year values of the number of days with very heavy rainfall (>100mm/24hr) on the right, for the city of Bogor in Indonesia.

Showcase 5:

A simple case of persistent precipitation extremes provided by Chen and Zhai (2013). This case occurred during 1st July -11th July 1991. Every station experienced at least three consecutive days with heavy precipitation of at least 50mm day⁻¹ and at least one overlapping day existed during the durations between neighboring stations.

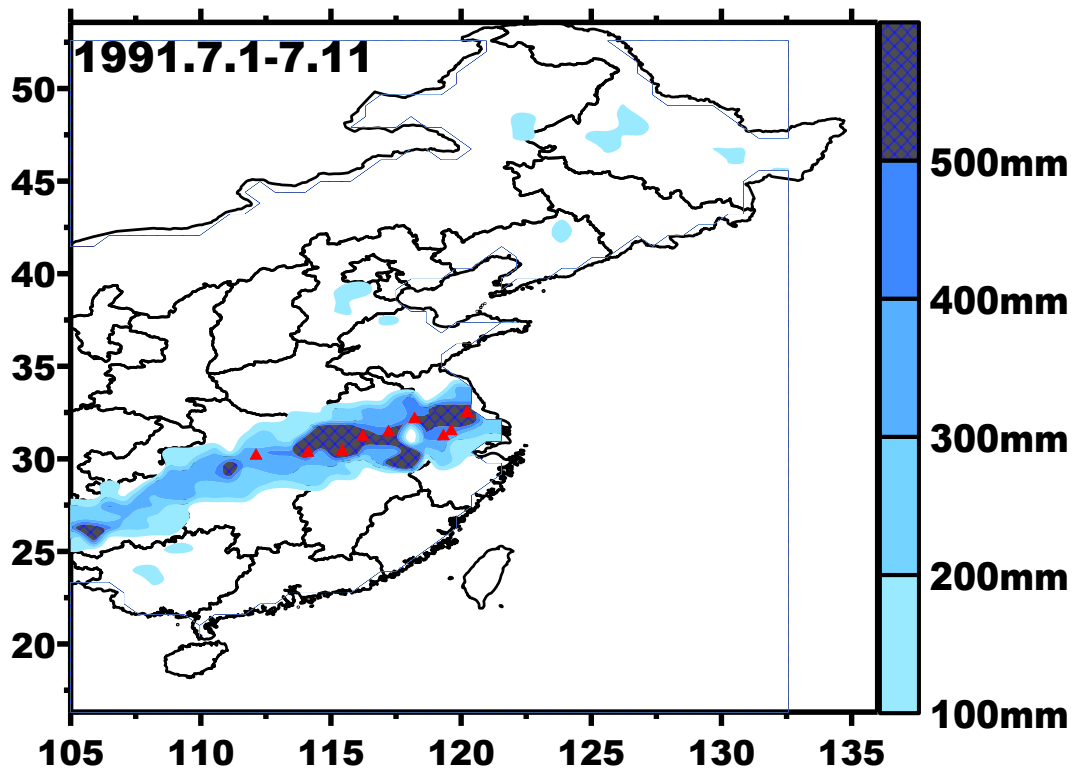


Figure S5.A typical case of persistent precipitation extremes, which occurred during 1st July - 11th July 1991. Shadings indicate accumulated precipitation (mm), and red triangles label the stations which experienced at least three consecutive days with heavy precipitation of at least 50mm day⁻¹

4. Catalogue and data bases on Hazards and Extreme Weather and Climate Events

A standard approach for the characterization and reporting of extreme events is necessary to support global assessment of the climate, which will be the input for the WMO annual, multiyear climate statements and special climate reports. It will be possible to identify and report regional extreme events routinely by the WMO member countries' NMHSs, albeit having different operational definition of the extreme events. For example, it will be possible to identify the spatial extent of a regional heat wave event by consolidating national-level reports.

A standard approach for characterization and reporting extreme events is also required for implementing climate watch systems in a harmonized manner. The National Meteorological and Hydrological Services will be able to provide input on the extreme events for the consolidation of the climate watches by the Regional Climate Centers based on a standard coding system of the events, such that near-real time assessments of the origin, characteristics and evolution of events will be possible. Other international climate assessments may also benefit from the analysis of extreme events.

For the operational monitoring of hazards and extreme weather and climate events, it is necessary that the underlying information on the occurrence (time and location), duration, magnitude and extent should be systematically recorded by the operational entities at the national level. These entities are usually the NMHS. At the regional level, the RCCs also have a mandate to monitor climate anomalies and climate extremes occurring in the region of their mandate. The role of RCCs in monitoring extremes is critically important as it provides a larger geographical context that is necessary to understand the dynamical mechanisms that trigger the extremes, such as, for example, the large scale climate variability modes, including the atmospheric and oceanic changing patterns, oscillations and dipoles. This in turn helps in enabling an efficient climate watch system at national and regional levels. Therefore, recording hazards and extreme events both at regional and national level should be based on a well-defined catalogue which informs on the terminology, definitions and codes.

A standard database model should be built in compliance with the definitions provided in such catalogue at the extent possible, to allow an easy use in the monitoring of the hazards and extremes.

4.1 Cataloguing Hazards and Extremes

4.1.1 Structure

The focus will be made on cataloguing major hydro-meteorological hazards and extreme events. The corresponding catalogue is a table (Table 4.1) with a structure that includes brief codes of the hazards and extremes, their terminology and definitions mostly according to the definitions given in the International Meteorological Vocabulary (WMO No. 182).

Table 4.1

Code	Terminology of the Extreme Event	Definition
Code	Extreme Event	Definition
...
Code	Extreme Event	Definition

A completed table with content is provided in the appendix (it will be available online in <http://location>)

4.1.2 Update of the Catalogue

The catalogue should contain standard content, which needs to be maintained based on WMO technical regulations. The review of the Catalogue will be decided by the CCI in collaboration with the Commission for Basic Systems (CBS), the Commission for Agriculture Meteorology and the Commission for Hydrology. It is recommended that the Catalogue be published as an appendix of the WMO Manual on Global Data Processing and Forecasting System (GDPFS). For operational use of the catalogue, it is recommended that a web searchable version be made online through the global portal on hazards and extremes (Chapter 5).

4.2 Database for recording extremes

It is therefore important that the recording of the extreme events should be undertaken in a consistent and systematic way so that integration of information from national data bases to regional databases and vice versa is made with a minimum transformation and interface software.

4.2.1 Data Base Model

The database model provides a general structure used for the information on hazards and extremes that is required to be stored in a data base in an operational mode. This subsection describes key elements in the logical structure of the database and in which manner data can be stored, organized, and manipulated.

It is recommended (but not necessary) for NMHSs that the database be built as part of a single integrated and administrated Climate Data Management Systems (CDMS, Climate Data Management System Specifications, WMO-No 1131, 2014). This would allow optimization of IT and Staff resources. It would also allow benefiting from a single governance and system administration which are critical for an efficient upgrade, security

and maintenance of the database. The proposed data model describes the data structure on hazards and extremes. The Structure should consist of: metadata records and data records.

4.2.1.1 Metadata Records

They describe the context in which the recording of the hazards and extremes was done, including administrative information and brief citation and reference of the methodology and the data type used to record the extreme event in the data base.

Administrative metadata

Region (according to the WMO definition), Country Name, Operational entity name and focal point contact information.

Methodology metadata

Description of the method used to define and characterize the hazards and extremes including, terminology, indices, and thresholds, methods for computing extent, duration and magnitude. It will also be useful, if available, to provide references to the key relevant publications.

Data type metadata

Describe the type of data used in recording the hazards and extremes, such as observations network, remote sensing, or model analysis, among others.

4.2.1.2 Data Records

It is the data that helps characterize the various aspects of the extreme events, such as duration, location, magnitude and extent.

Type of the hazard or extreme

The type of extreme will depend on the country's definition of the extreme(See 4.5) and the WMO catalogue of hazards(see 4.xx).

Date of occurrence

- Start Date: YY-MM-DD

- End Date: YY-MM-DD

Note: For long term events like drought, YY-MM will be sufficient

Geographical location

Describe the location affected by the hazards and extremes during their occurrence, from Start Date to End Date. It should be described with general position identification and in geographical coordinates

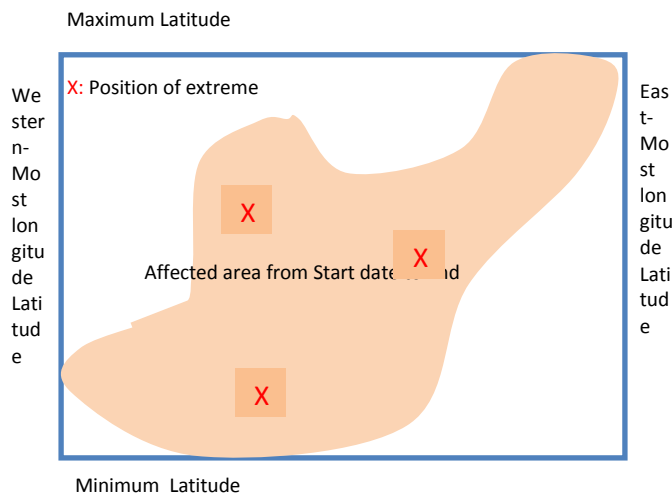
General Position

The name of the area affected during the date of occurrence and its position relative to North, South, East and West. The position is given in general terms, such as North, North West, the southern part of, etc.

Geographical coordinates

Provides the coordinate of the box which delineate the location affected by the hazard or extreme event during the data of occurrence, in terms of

- Minimum Latitude, Maximum Latitude
- Eastern Longitude, Western longitude



Daily Positions of extreme value during the period of record (Start date and End Date).

- Name of the locations: City, town, district, village, etc.
- Coordinate of the locations: latitude, longitude
- Magnitude: The Magnitude at the position of extreme value
- Date of extreme value: Day: DDMMYYYY

Note: Daily positions of extreme event can be multiple if such extreme is recorded in several positions. For long term events based on monthly data, such as drought, this record might be omitted.

Extent

Total area (km², hectares, other units.) affected by the extreme event during the period of occurrence from Start date to End date.

4.2.2 Data Base Management

4.2.2.1 Operational characteristics

Inter-operability

- i. The system used to store the data should be inter-operable and has at least English version.
- ii. Readily for easy update, upgrade and maintenance (preferably locally, with a minimum external intervention)
- iii. Allow import and export of at least one of most popular data file format such as text files and spreadsheet files

Practical usability

- i. It should allow practical and easy retrieval and manipulation (recording, correction and visualization, etc.) of the information in the database.
- ii. It should allow the use of criteria for selection of entry variables (metadata and data records) to be retrieved or manipulated individually or in groups.
- iii. Relational Data bases are preferable, data bases such as those build on standard spreadsheet could be also usable if more sophisticated database are not affordable

Products generation

- i. It is recommended that the database system allows generation of quick summaries of the data such as number of hazards or extremes recorded of each category during a predefined period of time, week, month, season, year, etc. This can also be made more flexible by allowing such summaries on a non-fixed period of time, such as periods with starting and ending dates selected at the choice of the user.
- ii. It should also allow generation of customized files with easy data format and structure to conduct in-depth assessment using sophisticated statistical tools which are not part of the database system.

4.2.2.2 Archiving Requirements

Storage

The database system should allow sufficient local storage capacity for storing data that can be accessible on operational mode. Data should cover a period at least 30 years of climatology based on the WMO definition of Climatological Standard normal, currently (1981-2010) and data for reference period (1961-1990) for climate change assessment as well as the most recent data available.

All data need to be duplicated in a back-up data base to ensure continuity as well as archived in external archiving digital storage.

Historical Data Recovery

In many cases complete data in digital form and complying with the structure of the data model described above is not readily available. It is therefore very important to quickly recover the paper archives that include this information and make it available in digital format for use in operational climate monitoring and watch systems, as well as for assessing the changing behavior of the hazards and extremes in response to the changing climate.

Reconstructing extremes from past data

It is possible to use tools that can use the archived basic climate data to reprocess the information on extremes based on the definitions and the thresholds that describe for example, heat-waves, cold waves, heavy precipitation and wet spells, drought and dry spells.

4.3 Unique identifier of extreme events

The identifier is a mean to code an event in the way that its monitoring and tracking from its onset to cessation is made in a consistent way at national level but also across the borders. It helps communicate the characteristics of the event, in a minimum text message using standard agreed codes. These codes should encapsulate briefly the type of the event and its fundamental characteristics, particularly the location and magnitude.

4.3.1 Role in communicating in a consistent and standard way

4.3.1.1 Climate watches

Identifiers for weather and climate extreme events can provide a useful and simple tool for improving the provision and communication of information that is required as input for climate watches which are coordinated regionally by the RCCs and issued at national level by the NMHS to the authorities in managing impacts of extremes (Disaster Risk Reduction [DRR], emergency, etc.).

As part of a Climate Watch system (WMO TD No 118), the NMHS should continuously monitor and assess the state of the climate, evaluate available climate forecasts, and, when conditions warrant for adverse climate-related impacts, issue formal climate watches to alert end users. Stakeholders would then be in a position to undertake actions to mitigate the climate-related impacts.

For example, excessive rainfall over a period of weeks may saturate soils, leading to higher-than-average probabilities for flooding, land erosion and mudslides; while rainfall deficits may lead to crop failures, famine and economic loss.

A Climate Watch uses operational climate monitoring and forecasts, to produce proactive alert of impending unfavorable climate anomalies with potential high impacts.

While efforts have been progressed in establishing climate watches at regional level using available observations and model products at the regional climate centers and global forecasting centers, there is a lack of systematic communication of hazards and extremes from national to regional level in a standard format. This hampers the near-real time assessment of the origin, characteristics and evolution of these events.

It is expected that a standard identification of the events would help establish such a systematic communication for provision of data on hazards and extremes in an easy and inter-operable coding system.

4.3.1.2 Role in the assessment of losses and damages

Developing identifiers for cataloguing weather and climate extreme events in cooperation with institutions that have the capability to identify the possible impact of those weather events can provide also an unambiguous reference for associated losses and damages and can promote consistency in the characterization of extreme events. Furthermore, consistent event characterization in terms of type of event, location, duration, magnitude and timing would allow for better evaluation of the types of losses and damages associated with different types of events, and the most damaging events and thresholds, and trends.

Developing identifier is an important prerequisite for the Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes and the United Nations Office for DRR Global Assessment Reports on DRR, and it could greatly assist the Global Framework for Climate Services by bringing a standardized approach of NMHSs to the analysis and recording of extreme hydro-meteorological events in national databases, and by supporting the international exchange and validation of these data. (Resolution 9 (Cg-17)).

4.3.2 The proposed approach for coding extreme events

4.3.2.1 Coding

The table below proposes the coding for identifying and characterizing weather and climate extreme events.

Table 4.2

Metadata Record	Event Code	Region	Country
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Data Record 1	Date	General Position	Position Extreme Value-	...	Position Extreme Value-	Max Magnitude	Extent
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			1		n				
Data Record 2	Start date	End Date	General Position	Min Lat	Max Lat	W Long	E Long	Severity	Total Extent

Events Code: See catalogue in Appendix

Region: WMO definition of the region: RA-1, RA-2,...,RA-6

Country: Country code using ISO Standard.

Data Record 1: Daily records (recorded each day during the period of the event). For drought the records can be on weekly or dekadal time periods

Date: Date of communication of the event, after it has been declared. YY/MM/DD/HH, HH is the hour of recording the first position of extreme value. For long term event YY-MM-DD will be sufficient

General Position: Describe the location of the event relative to the country: N, NW, NE, S, SW, SE, W, E, etc.

Position Extreme Value 1: Latitude and Longitude, see 4.2

Position Extreme Value n: Same as before

Max Magnitude: Maximum Magnitude recorded during the period of the day

Extent: Extent recorded during the day (km², Ha, etc.)

Data record 2: Summary during the period of the event. For drought the summary should be done on seasonal time scale

Start Date: See 4.2

End Date: See 4.2

Min Lat: See 4.2

Max Lat: See 4.2

W Long: See 4.2

E Long: See 4.2

Severity: Highest category recorded during the event, or a season for drought.

Total Extent: Total area affected by the event since its start until its end (km², Ha, etc.)

4.3.2.2 Communicating extreme events

It is important that Metadata record and Data Record-1 be communicated on daily basis, after the event has been declared, to Regional Specialized Meteorological Centers (RSMCs) and RCCs. For long term event like drought it will be sufficient to communicate Record-1 on weekly, ten day (dekad) or monthly basis. Data Record-2 can be communicated after the event ended. In case the existing capability doesn't allow communication of the whole records, shorter version of the information can be communicated as follows:

Table 4.3

Metadata Record	Event Code	Region	Country
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Data Record 1	Date	General Position	Position Extreme Value-1	Max Magnitude
Data Record 2	Start Date	End Date	General Position	Severity

4.4 The role of the WMO Information System and the Global Data Processing and Forecasting System

4.4.1 WMO Information System role in Extremes and Hazards

The WMO Information System (WIS) is the WMO's single coordinated global infrastructure for managing and exchanging weather, climate and water information. The WIS functions that are carried out by the WIS centers include:

- 1) Collect observations, generate products, create metadata and archive information;
- 2) Assign user role,
- 3) Maintain and expose a catalogue of services and information;
- 4) Authorize access to information by users
- 5) Deliver information to users
- 6) Manage System performance

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1276 4.4.2 Global Data Processing and Forecasting System Role

1277 The current version of the GDPFS doesn't accommodate appropriately the requirements for
1278 processing and monitoring information on extreme weather and climate events as described
1279 in the context of these guidelines. It is hoped that the new version of GDPFS which is under
1280 preparation will allow this possibility. In this regards, for example the content of the
1281 catalogue on extremes and hazards can be maintained within the planned GDPFS, in such an
1282 Annex form or appendix. In addition, the regulations on processing information on extremes
1283 and hazards as described in chapter 3 and mechanisms such as climate watches and climate
1284 risk warning issued in real or quasi-real time basis can also be described. The provisions on
1285 extremes and hazards in the GDPFS should be defined more clearly in consultation between
1286 CCI and CBS.

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5. WMO portal on Extreme Weather and Climate Events

5.1 Present status of information on extremes weather and climate extremes

A wide range of information is available on the meteorological and climatological aspects¹ of extreme weather and climate events, or hazards. At the national level, much information is produced by NMHSs and other relevant official agencies. Several agencies, as well as regional organisations such as RCCs (especially the RA-II Centre in Japan and the RA-VI Centre in Germany) and the European Centre for Medium Range Weather Forecast (ECMWF), also produce information relating to extreme events on a global and continental scale, drawing on a variety of sources, including Global Telecommunication System (GTS) data and material supplied by individual countries. Information on extreme events also form a significant part of international publications such as the annual WMO Statement on the Status of the Global Climate and the State of the Climate report published as a supplement to journals such as the Bulletin of the American Meteorological Society.

There are also many sources of information on such events from non-official sources, including media outlets, Wikipedia and similar sites, and blogs (some specific examples of which are cited later in this report). Sometimes such information is traceable back to an official source, sometimes not. On occasions, extensive coverage of an extreme event can result in the widespread propagation of incorrect information (e.g. the widely reported claim that the 2010 Pakistan floods inundated 20 per cent of Pakistan's land area. Also, it was reported by a number of credible, but non-official sources, that 18 countries had set national temperature records in 2010, but only four of these could be confirmed with the countries concerned for use in the WMO Statement.

Access to authoritative official information, either at the national level or through organizations such as the RCCs, is important to make the best possible information on extreme weather and climate events available to the global community. Such a portal would also be a very useful source of information for publications such as the WMO Statement.

Information on extreme events can be found on national websites in local languages. The wide availability of automatic translators online often allows useful information to be obtained from such products, if they can be located. It is, however, often very difficult.

5.2 Purpose of the WMO portal

¹ Information on the impacts of extreme weather and climate events is outside the scope of TT-DEWCE, although some national/international products referred to in this paper contain information.

The purpose of the WMO portal on extreme weather and climate events, or hazards is to provide a single point of access to a wide range of national and regional material on extreme weather and climate events, thus assisting in making such information accessible and disseminating it to the widest possible audience. A great deal of material is being produced by NMHSs on extreme weather and climate events, but it is spread across a very large number of national-level sites and is often difficult to locate and access, especially for those unfamiliar with the local language. In other cases, such material is not available on line even if it exists.

An NMHS or other institution is sought to be the host for the infrastructure for the portal. This could be done by the NMHS alone or with the support of a group of relevant experts from elsewhere. In the first instance, it is not proposed that the host of a portal carry out any data analysis of its own, although that could be part of a longer-term extension in a second or subsequent stage development.

5.3 Functions of the portal

The following products are proposed for inclusion in a first-stage portal:

- Links to published national monthly, seasonal and annual climate summaries.
- Links to known, stable sources of national-level information on extreme events (e.g. the Special Climate Statements produced by Australia).
- Providing the capacity for NMHSs to upload information on high-impact events which have taken place in their country, using a defined catalogue of extreme weather and climate events and data base model.
- Analyses, using GTS data, of extreme values at the monthly timescale. (In the first instance it is suggested that the Tokyo Climate Centre or NCEI be approached to make their analyses available to the portal, but at a later stage such an analysis could be carried out independently).
- A consolidated set of tropical cyclone information available soon after each cyclone. (This is suggested as a good initial option because there are only a relatively small number of data centres to deal with).
- An extension of the existing global and continental records portal, currently hosted by Arizona State University, to cover national and location-specific record information. An alternative platform for this could be a WMO climate normals page, if one is likely to go online in the foreseeable future.
- A list of recommended documents (or links to these documents) that can help members in reporting about the extremes (this includes WMO, TT-DEWCE documents and others).
- A link to the recommended software (if any) for calculations with a downloading possibility.

It is expected, on the basis of experience with the RA-VI RCC (which is seen as a possible model for the proposed portal), that the host will need to play a reasonably active role in collecting and curating content; some countries will actively send material but other material will need to be actively sought if the portal is to have reasonable global coverage.

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