GCA Learning from Practice

CLIMATE DATA FOR RISK ASSESSMENTS

1 - Climate Hazard Indices for Risk Assessments: The Importance of Thoughtful Selection

This guidance note serves as a technical reference for practitioners conducting or supervising Climate Risk Assessments (CRAs).

It is part of a package of three complementary guidance notes on the use of climate data in CRAs, which outline minimum standards and recommended practices to enhance the consistency, credibility, scientific robustness, and usability of climate analytics—particularly in data-scarce environments.

The package is structured around three complementary and foundational pillars:

1. **Climate hazard indices**, used to characterize climate extremes and relevant metrics ;
2. **Climate data validation**, defining minimum requirements to assess the reliability of climate data and models;
3. **Uncertainty management**, providing approaches to interpret and communicate the range and confidence of possible outcomes.

This note focuses on **Climate hazard indices**.

1 - CLIMATE HAZARD INDICES FOR RISK ASSESSMENTS: THE IMPORTANCE OF THOUGHTFUL SELECTION

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Introduction

Climate risk assessments (CRAs) rely on a combination of climate indicators and climate hazard indices to understand current and future risks (IPCC, 2021; Wilby & Dessai, 2010).

- **Climate indicators** are direct observations or measurements of the climate system, such as temperature, precipitation, or sea level.
- In contrast, **climate hazard indices,** are derived or calculated metrics that combine or transform one or more indicators to characterize a more complex component of the climate system, such as the pattern, frequency, intensity, or duration of climate extreme phenomena (e.g., heatwaves and consecutive number of hot days, heavy rainfall, drought).

These two types of metrics serve complementary roles: **indicators** describe the state and evolution of the climate system, while hazard **indices** translate this information into forms that are more directly relevant for risk assessment and decision-making.

Climate data used in CRAs can come from multiple sources, including ground-based observations, satellite products, reanalysis datasets, and climate model outputs (Hersbach et al., 2020). To assess future risks, CRAs rely on projections from global and regional climate models, typically using standardized scenarios such as Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) to explore different possible futures across various time horizons (van Vuuren et al., 2011; O'Neill et al., 2016). Standard projection outcomes from climate models typically provide core weather and climate indicators such as temperature, precipitation, wind, solar radiation, etc. Based on these primary variables, more specific climate hazard indices, such as annual maximum daily rainfall, the number of consecutive hot days, or drought indices, can be derived to better assess potential future climate extremes and hazards, such as heatwaves or extreme precipitation.

In addition, many important risks—such as floods, landslides, or wildfires—result from the interaction between climate variables and environmental or human factors. In these cases, climate hazard indices remain essential inputs but must be combined with additional data (e.g., topography, land use, or hydrology models). This distinction reflects the difference between primary climate hazards and derived hazards, which require further analysis to assess impacts.

This document presents a non-exhaustive set of commonly used climate hazard indices used to support CRAs, covering both rapid-onset events (e.g., heatwaves, heavy precipitation, strong winds) and slow-onset processes (e.g., drought). The selection of appropriate indices depends on project objectives, scale, data availability, and decision context. In practice, this requires informed judgment, guided by factors such as the hazard of interest, the sensitivity of exposed systems, and the intended use of the analysis (e.g., planning, design, or risk management).

This note provides a structured reference to support that selection process and to promote more consistent and robust use of climate data in CRAs.

Climate Hazard Indices

Guiding Principles for Selection

When selecting indices, consider the following general principles:

- **Align indices with project objectives.** For example, port infrastructure requires wind and storm surge indices, whereas water supply and irrigation projects depend on drought and precipitation indices.
- **Use standardized definitions.** Where possible, adopt indices recommended by the World Meteorological Organization or the Expert Team on Climate Change Detection and Indices (ETCCDI), which facilitates comparison across studies and ensures technical rigor.
- **Draw from multiple data sources.** For current conditions, combine ground-based observations, satellite data, model results (e.g., climate, hydrological models, etc.) and reanalysis data; for future conditions, use ensembles of global and regional climate models.
- **Document choices and assumptions.** Clearly state the indices used, the data sources selected and any thresholds or baselines applied.

An Overview of Key Climate Indices

The **temperature and precipitation indices** listed are consistent with those developed by the Joint CCl/WCRP/JCOMM Expert Team on ETCCDI (Zhang et al., 2011 ; https://www.wcrp-climate.org/etccdi-members). Established to support the objective measurement and characterization of climate variability and change, these indices are now widely used in national and international climate monitoring efforts due to their robustness and standardization.

Extreme precipitation indices (e.g., Rx1day, or R95p) are often used as proxies for pluvial flood hazards, and in some contexts, as indicators of potential fluvial flood hazards, particularly in data-scarce regions. However, for a more direct and accurate assessment of flooding hazards, hydrological indices such as maximum river discharge and water level exceedance are also included. A comprehensive flood risk assessment should consider different types of flooding, including pluvial, fluvial, and coastal flooding, and combine climate and hydrological indices with additional contextual information such as topography, land use, soil type, and drainage infrastructure. Streamflow indices alone are insufficient to characterize how flooding manifests on the ground (e.g., water depth and flood extent). Flood modeling, including hydraulic modeling, is therefore needed to provide more detailed, site-specific assessments of flood hazards and risks.

Drought indices vary in complexity and focus. Some, such as the Standard Precipitation Index (SPI), reflect precipitation deficits alone, while others, such as the Standardized Precipitation-Evapotranspiration Index (SPEI), also incorporate evapotranspiration to capture the combined effects of temperature and precipitation. These drought indices primarily characterize drought intensity and can be complemented by metrics that capture the frequency and duration of drought events, as well as longer-term climatic conditions such as aridity and the number of consecutive dry days. Most drought severity indices are unitless and categorized into different levels of intensity.

Wind speed indices are generally less standardized and less extensively studies than many other climate hazard indices, partly because wind-related hazards can have highly localized impacts and are often assessed using hazard-specific modeling approaches. Climate models also show lower skill and greater uncertainty in projecting future wind conditions compared with other climate variables. Nevertheless, several commonly used wind indices are included here to support basic hazard screening. In geographies exposed to tropical cyclones, more specialized indices that incorporate cyclone-specific data and modelling may be needed for a more comprehensive assessment.

Together, these indices (see Table 1 to Table 7) form a flexible toolkit for characterizing climate extremes and for informing climate adaptation and disaster risk management strategies.

Extreme Temperature Indices – Heat

Table 1: Extreme Temperature Indices – Heat[1]

Acronym	Index description	Definition	Units
SU	Number of summer days	Annual count of days when the maximum temperature is > 25°C	days
TR	Number of tropical nights	Annual count of days when the minimum temperature is > 20°C	days
TMx	Yearly/Seasonal/Monthly max of daily mean temp	Yearly/Seasonal/Monthly maximum of the daily mean temperature	°C
TXx	Yearly/Seasonal/Monthly max of daily max temp	Yearly/Seasonal/Monthly maximum of the daily maximum temperature	°C
TNx	Yearly/Seasonal/Monthly max of daily min temp	Yearly/Seasonal/Monthly maximum of the daily minimum temperature	°C
TX90p	Warm days percentage	Percentage of days with daily max temperature > 90th percentile of associated baseline	%
TN90p	Warm nights percentage	Percentage of days with daily min temperature > 90th percentile of associated baseline	%
WSDI	Warm spell duration index	Number of days with consecutive days (generally at least 6) when max temp > 90th percentile of associated baseline	Days
GDD	Growing degree days	Accumulated temperature above a defined base temperature over a specified period	°C
THI	Temperature, Humidity Index	Annual count of days when THI exceeds a predefined threshold (e.g., 25°C, 35°C, or 45°C), indicating heat stress	Days

[1] Note that climate models often provide temperature outputs in Kelvin, which must be translated to degrees Celsius.

Extreme Temperature Indices – Cold

Table 2: Extreme Temperature Indices – Cold

Acronym	Index Name	Description	Units
FD	Number of frost days	Annual count of days with minimum temperature < 0°C	days
ID	Number of icing days	Annual count of days with maximum temperature < 0°C	days
TMn	Monthly min of daily mean temperature	Lowest daily mean temperature in a month	°C
TXn	Monthly min of daily max temperature	Lowest daily maximum temperature in a month	°C
TNn	Monthly min of daily min temperature	Lowest daily minimum temperature in a month	°C
TX10p	Cool days percentage	Percentage of days with daily max temperature < 10th percentile of 1961–1990	%
TN10p	Cool nights percentage	Percentage of days with daily min temperature < 10th percentile of 1961–1990	%
CSDI	Cold spell duration index	Number of days with at least 6 consecutive days when daily minimum temperature < 10th percentile of 1961–1990	days

Extreme Precipitation Indices – Dry

Table 3: Extreme precipitation indices – Dry

Acronym	Index Name	Description	Units
CDD	Consecutive dry days	Maximum number of consecutive days with precipitation < 1 mm	days
AA or AET/P	Actual Aridity or Evaporative Index	The ratio of the mean actual evapotranspiration to the mean annual precipitation over a certain period	ratio
AI	Aridity Index	Ratio of mean annual precipitation to potential evapotranspiration (PPT/PET).	Unitless

Extreme Precipitation Indices, Wet

Table 4: Extreme precipitation indices, Wet

Acronym	Index Name	Description	Units
PRCPTOT	Annual total precipitation	Annual total precipitation	mm
Rx1day	Yearly/Monthly Maximum 1-day precipitation	The highest daily precipitation amount in a specified period	mm
Rx5day	Yearly/Monthly Maximum 5-day precipitation	The highest 5-day consecutive precipitation amount in specified period	mm
R10mm	Number of heavy precipitation days[2]	Annual count of days with precipitation ≥ 10 mm	days
R20mm	Number of very heavy precipitation days	Annual count of days with precipitation ≥ 20 mm	days
CWD	Consecutive wet days	Maximum number of consecutive days with precipitation ≥ 1 mm[3]	days
WD	Wet days	Annual count of days when daily precipitation ≥ 1 mm	days
R95p	Very wet day precipitation	Annual total precipitation when daily precipitation exceeds the 95th percentile	mm
R99p	Extremely wet day precipitation	Annual total precipitation when daily precipitation exceeds the 99th percentile	mm
SDII	Simple daily intensity index	Ratio of annual total precipitation to number of wet days (precipitation ≥ 1 mm)	mm/day
T10, T100[4]	(10 year /100 years) return level	The precipitation associated with a return period of 10 or 100 years (i.e., the estimated intensity expected to be exceeded, on average, once every 10 or 100 years).	mm

[2] These thresholds are based on ETCCDI (Expert Team on Climate Change Detection and Indices) standards and are widely used for global comparability. However, in monsoon-dominated climates, such as Bangladesh, or countries experiencing high rainy seasons, contextualization may be thought of, as 10 mm may not represent a meaningful threshold for heavy rainfall, particularly for risk assessment purposes.

[3] Please consider and seek inputs on the use of a 1 mm threshold (ETCCDI standard) versus 2.5 mm (commonly used in local practice). As climate risk assessment (CRA) is context-specific, it is important to evaluate whether a 1 mm threshold adequately represents meaningful rainfall events in the local context. It would be useful to verify whether weather stations record rainfall below 2.5 mm, or whether there is a practical threshold in data recording. While global standards ensure comparability, CRA prioritizes local relevance to achieve accurate risk characterization.

[4] Return levels differ from standard climate hazard indices, as they are not directly derived from basic rainfall indices. Instead, they are **statistical estimates** calculated from fitted probability distributions of rainfall indices. These return levels represent theoretical extremes, which therefore cannot be physically observed.

Streamflow Indices – Flooding Related Indices

Table 5: Streamflow indices – Flooding-related indices.

Extreme precipitation indices often indicate flooding. Besides those, additional streamflow indices are included below.

Acronym	Index Name	Definition	Units
WLmax	Maximum water level	The highest water level recorded at a gauging station during a period	meters (m)
FloodD	Flooding days	Number of days water level exceeds a predefined threshold	days
Qtotal	Annual total discharge	Sum of daily mean river discharge values over the entire year	m^3/year
QAmax	Annual maximum daily discharge	The highest recorded river discharge on a single day in a given year	m^3/s

Common Drought Indices

Table 6: Common drought indices, providing an indication of how severe the drought condition is.

Acronym	Index Name	Description	Units
SPI	Standardized Precipitation Index	Standardized precipitation anomaly over a selected timescale (e.g., 1, 3, 6, 12 months) computed using a fitted probability distribution.	unitless (typically -2.00 to 2.00)
SPEI	Standardized Precipitation Evapotranspiration Index	Similar to SPI but includes evapotranspiration, making it sensitive to temperature changes	unitless (typically -2.00 to 2.00)
PDSI	Palmer Drought Severity Index	Soil moisture-based index using temperature and precipitation data to estimate long-term drought	unitless (−10 to +10)
RAI	Rainfall Anomaly Index	Compares current precipitation to long-term average; used to classify drought intensity	% or unitless
NDVI	Normalized Difference Vegetation Index	Satellite-based index that indicates vegetation condition; used to infer agricultural drought	unitless (−1 to +1)

Wind Speed Indices

Table 7: Wind speed indices. (WMO requires wind speed to be measured at 10 m height above ground level[5] (WMO, 2018).

Acronym	Index Name	Description	Units
Wmean	Mean wind speed	Average wind speed over a specified period (hourly or daily).	m/s or km/h
Wxmax	Maximum wind speed	The highest wind speed recorded in a day	m/s or km/h
GUSTmax	Maximum wind gust	Peak instantaneous wind speed (gust) recorded during a period	m/s or km/h
W99p	Extreme wind speed days	Number of days in a year with daily maximum wind speed above the 99th percentile over a reference period.	days

[5] This reflects a common gap between standard practice and field reality. While WMO recommends wind measurements at 10 m above ground level, in practice anemometers are often installed at lower heights (e.g., 3–4 m). In such cases, measurements can be adjusted to the standard 10 m height using appropriate wind profile relationships.

Recommendations: How to Apply Climate Hazard Indices Across the CRA Project Cycle

Project sponsors should consider Climate Hazard Indices when framing Terms of Reference, evaluating proposals, and during project implementation.

i. **Request For Proposal (RFP) / Terms of Reference (ToR) stage** for a Climate Risk Assessment or integration of it into the specifications of a project:

   a. Clearly define relevant climate hazards, accordance with the geography and the studied sector, requiring consultants to propose and justify appropriate indices.

   b. Provide the list above (Table 1 – Table 7) for reference, and subject to adjustments based on geography and sector, included as part of an RFP annex.

ii. **Proposal review** stage

   a. Check that proposed indices match the project's exposure (e.g., drought indices for agricultural projects, flood indices for water infrastructure) and that baseline data sources are credible.

   b. Encourage the use of multimodal model ensembles for future projections.

iii. **Inception report** stage

   a. Require the consultant to finalize the list of indices based on available data, stakeholder priorities, and site-specific risk factors.

   b. Insist on a clear mapping between indices and the project's decision context, including assumptions and thresholds used.

iv. **Final output review** stage

   a. Ensure that all selected indices are analyzed, that results are clearly presented (including figures and tables), that implications for design and adaptation options are clearly outlined and explained, and that data sources, baselines and reference periods are transparent, well-documented, and reproducible.

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