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Creating a vocabulary of climate change hazards for heritage

Helen Thomas, Kate Guest, Philip Carlisle, Neil Guiden, and Scott Allan Orr

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Volume 1 of 1

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Summary

Climate change hazards are the potential occurrences of natural or physical events that may cause damage or loss. They are currently ill-defined for heritage. The distinction between the related terms hazard, impact, threat, and driver is not always clearly drawn and there is no definitive list of climate hazards for heritage that is directly connected to changing climatic processes. This project addresses these gaps by creating a standardised vocabulary of climate hazards for heritage. It adapts the methods and definitions of the Intergovernmental Panel on Climate Change (IPCC), aligning cultural heritage with international climate change science. The final hazard list is published on the Forum on Information Standards for Heritage (FISH) as a controlled vocabulary. The creation of these standardised terms allows heritage professionals to consistently record what at-risk sites are actually at risk from. This can inform assessments of climate change impacts on both single heritage sites and the wider historic environment.

Contributors

The author is Helen Thomas (UCL and Historic England) with contributions from Dr Scott Allan Orr (UCL), Kate Guest, Philip Carlisle, Neil Guiden and Claire Hedley (Historic England). Figure 1 was made in collaboration with Andy Crispe at Historic England.

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Front cover image: View over Greenwich Park, London, in summer of 2022 © Alisdare Hickson CC BY-SA 2.0 via Wikimedia Commons.

Archive location

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Date of research

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Acronyms

AR – Assessment Report

CID – Climatic Impact-Driver

FISH – Forum on Information Standards in Heritage

HE – Historic England

IPCC – Intergovernmental Panel on Climate Change

NAP – National Adaptation Programme

RCP – Representative Concentration Pathway

WGI – Working Group I: The Physical Science Basis

1. Introduction

Sea level rise, heat waves, ocean acidification, permafrost thaw – all of these are examples of climate change hazards that will have drastic impacts on global cultural heritage. This report defines climate hazards (versus other related climate-change terminology), introduces a standardised hazard vocabulary for heritage, and discusses how this vocabulary can be used.

The project focusses on bridging the gap between international climate science and heritage management by creating an accessible list of climate hazards that are clearly connected to the climatic processes that drive them.

Previous hazard lists have been created for cultural heritage, though there is often a conflation of hazard, threat, driver and impact; for example, ICOMOS' 2019 Future of the Pasts has two impact tables and a climate driver list for heritage, none of which correlate (ICOMOS, 2019). Other hazard lists have been compiled for specific types of heritage – see (Sesana et al., 2021) for built heritage – but there is no hazard vocabulary nor method for determining hazards for heritage that is connected to the climate science of the IPCC.

The IPCC is the UN body responsible for global climate change science. Aligning cultural heritage with the IPCC allows for easier integration of cultural heritage into future assessment reports, collaboration beyond our disciplinary boundaries, and a harmonisation of terminology within them. While the vocabulary has been produced by two England-based institutions, Historic England and UCL, the IPCC terminology was deliberately used to ensure the terms were globally relevant.

The report has seven sections: definitions of key terms; the methodology for determining climate hazards and the structure of the hazard vocabulary; how change in climate hazards can be profiled; the limitations of the approach; a short discussion of how the vocabulary can be used; an overview of compound hazards; and an introduction to the forthcoming climate change recording module in the software Arches for HER.

The hazard vocabulary itself can be found: in an abridged version in this report's Appendix 2; on FISH where it is accessible in multiple formats including linked data (Historic England, 2024); and on Zenodo in its original .xlsx form (Thomas et al., 2024).

2. Key terminology and definitions

The terms driver, threat, impact, and hazard are commonly used when discussing at-risk heritage and disaster risk reduction, but they have specific meanings in the climate change context. The definitions summarised in Table 1 follow the IPCC and are discussed further below:

Table 1: Definition of key terms according to the IPCC

Term	IPCC Definition	Citation
Driver	Any natural or human-induced factor that directly or indirectly causes a change in a system	AR6 WGII Annex II (IPCC, 2022, p. 2906)
Climatic Impact-Driver (CIs)	A physical climate condition that directly affects society or ecosystems	AR6 WGI Annex VII (IPCC, 2021, p. 2224)
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources	AR6 WGI Annex VII (IPCC, 2021, p. 2233)
Impact	The consequence of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial	AR6 WGI Annex VII (IPCC, 2021, p. 2235)
Compound hazards/climate event	The combination of multiple drivers and/or hazards that contributes to societal and/or environmental risk	AR6 WGI Annex VII (IPCC, 2021, p. 2225)

Note: the term ‘threat’ does not have an IPCC definition. It is a generic term and should not be used in evaluations of risk, though is useful in wider work on climate action.

Hazards and impacts

Climate change hazards and impacts are often conflated. Hazards are potential negative events, while impacts are the consequences or outcomes of these events. This report does not define climate change impacts on heritage, while a definitive list of relevant impacts does not exist (this is explored more in Section 6) it was outside the scope of the project.

Hazards are extrinsic to cultural heritage. They are potential external climate events and are not altered by the presence of the heritage asset. Impacts, however, are intrinsic to the

asset and therefore are dependent on other risk determinants, such as heritage type, age, material, and condition of the asset.

A useful way of distinguishing between them is to consider if an impact could occur in all heritage asset types, for example corrosion will not occur in all heritage materials or sites despite the same climatic hazards (precipitation and humidity changes, for example). It is material and location dependent and therefore is an impact.

Table 2: Summary of the main definitions with examples

Term	Definition	Example
Climatic Impact-Driver	A physical climate condition	Mean wind speed
Hazard	Potential negative event	Wind-driven rain
Impact	Consequence of the event for heritage	Water penetration

Climatic Impact-Drivers (CIDs) and hazards

The concept of Climatic Impact-Drivers was introduced by the IPCC in the latest assessment report AR6 in 2021/22. It came through a collaboration between the IPCC's Working Group I (which looks at the physical science) and Working Group II (which covers climate change impacts and risk). CIDs can be used in the context of risk management to bridge the gap between climate science and those working with stakeholders to better understand the implications of our changing climate (Ruane et al., 2022).

CIDs are physical climate conditions and include both sudden-onset events such as severe windstorms or hail, and long-term changes in the earth's climate, for example mean air temperature or ocean salinity.

CIDs can be both positive or negative, this is unlike hazards which always have the potential to be detrimental. The use of the more neutral term CIDs acknowledges that context determines the impacts of climatic changes; for example, hot days are not necessarily hazards if they lead to increased sales of ice cream at heritage sites but may be hazardous for the collections inside. Therefore, in any risk assessment CIDs become hazards (as potential damage or loss is being considered) and hazards should be considered holistically with the other risk determinants (vulnerability, exposure, and response). In summary, a climate hazard is a CID with the potential to harm natural systems or society.

Figure 1 defines the key terms and gives two examples for marine heritage. It shows that CIDs can be linked to impacts via hazards but that recorded damage on a site level

(impacts) can be connected to hazards and the climatic processes behind them. This is discussed further in Section 6: Using the vocabulary list.

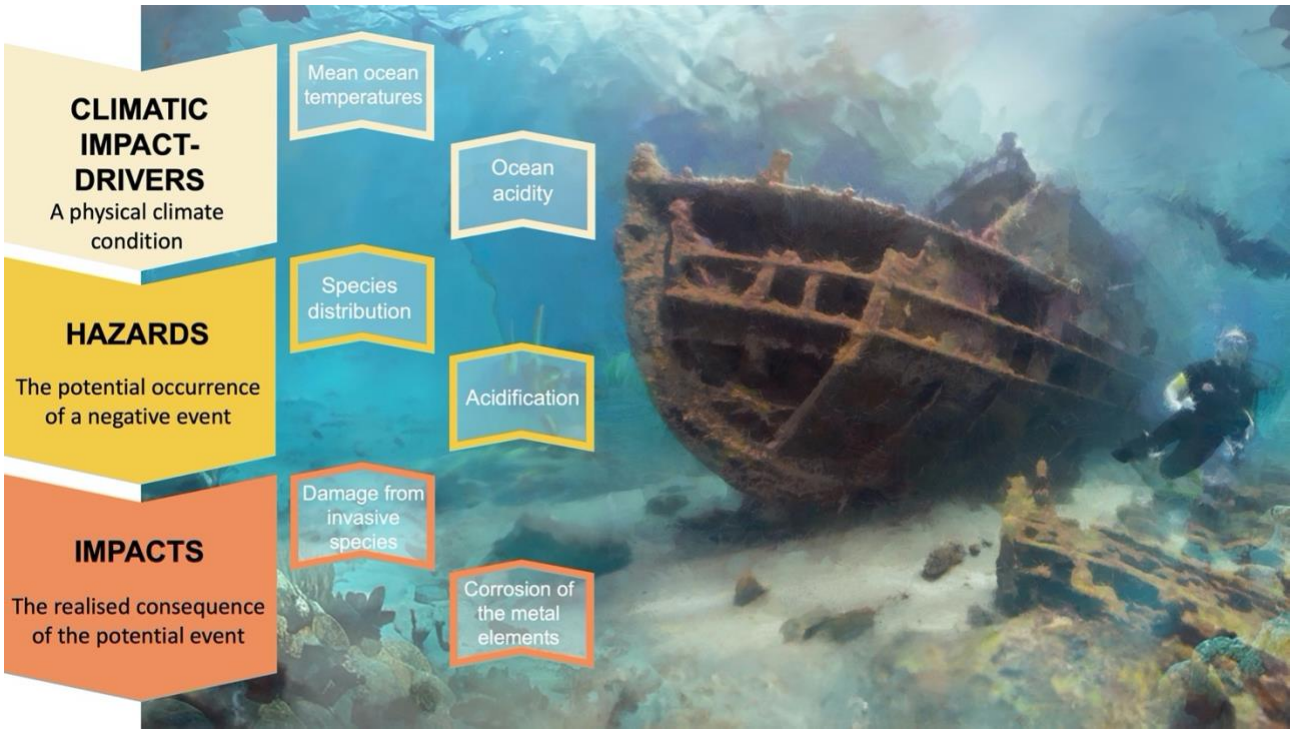


Figure 1: Definitions of key terms and examples for marine heritage.

3. Structure of the hazard vocabulary

The vocabulary list of hazards has been published as a FISH list. FISH publishes controlled terminologies for heritage recording and organisations that use them are compliant with the UK's MIDAS data standard. The terms can be downloaded from FISH in various formats (including as linked data) and can be used in isolation. However, they were developed to link to the IPCC CIDs and to their related hazards and these connections are presented in the abridged tables in Appendix 2 and in the unabridged Excel workbook on Zenodo (Thomas et al., 2024).

There are seven tables which correspond to each of the seven IPCC CID types, sometimes referred to as essential climate variables. These are:

- Heat and cold (primarily associated with air temperature).
- Wet and dry (associated with precipitation or lack thereof).
- Wind (atmospheric circulation and storms).
- Snow and ice (associated with many aspects of the cryosphere)
- Coastal (associated with land/sea interface)
- Open ocean (ocean thermal structure and chemistry)
- Other (atmospheric chemistry and radiation)

For each of these seven types, the IPCC has defined relevant CID categories. There are 33 CID categories, these can be found in Appendix 1 and in the tables in Appendix 2. The CID categories have determined how the tables are structured and how the hazards have been defined.

These are the columns of the hazard tables:

Column	Name	Description
A	CID category	From the IPCC AR6 WGI Chapter 12 (Ranasigne et al., 2021).
B	CID type	From the IPCC AR6 WGI Chapter 12 (Ranasigne et al., 2021).

C	Time frame	Defined by this project in reference to the IPCC CID descriptions.
D	CID type description	Description of the CID type from the IPCC AR6 WGI Chapter 12 (Ranasigne et al., 2021).
E	Primary hazard	The main hazards for heritage for each of the CIDs. They include both long-term change and sudden onset events. Change for all of these is assumed, therefore the terms are 'species distribution' not 'changing species distribution'. Profiling climate hazard change is discussed further in Section 4.
F	Scope note	Definition of the hazard and outline of how the term should be used.
G	Also known as	Alternate terms for the preferred term in column E.
H	Key related hazards	Related hazards connected to the primary hazards either by: ▪ Parent-child relationships where the key related hazards are subcategories of the primary hazard. For example, mudslide which is a type of landslide (primary hazard); or ▪ A relational link where the related hazard is caused by the primary hazard but is also a primary hazard in its own right. An example of this is ground water flooding; it is both a primary hazard and a key related hazard to the primary hazard of changes in the water table levels.
I	Scope note	Definition of the key related hazard and outline of how the term should be used.
J	Also known as	Alternate terms for the preferred term in column H.
K	Example impact	Examples of the consequences for heritage for each of the hazards. These are not exhaustive.

L	Literature	Key academic articles or resources for the hazards. It is not a definitive reading list but rather aims to link to one climate change, or ideally climate change and heritage, article when relevant. The bibliography is not reproduced in Appendix 2 but is found in the master spreadsheet (Thomas et al., 2024).

4. Profiling hazards

All the hazards defined here are expected to change with increasing global temperatures. This change will not be the same for each region or heritage type; changes in ocean temperatures, for example, will have little impact on built urban heritage. The hazard terms and definitions deliberately do not state the direction of change (increasing or decreasing) in recognition of regional variation, uncertainty in climate projections, and the fact that no change can still be detrimental.

The IPCC outlines that hazards can change in six ways (Figure 2). When assessing the impact of climate hazards on the historic environment, adopting these profiling mechanisms ensures that all types of changes are accounted for. Change in hazards are characterised in these ways:

1. Intensity and magnitude
2. Frequency
3. Duration
4. Timing – seasonal shift
5. Timing – shift in speed of onset
6. Spatial extent

It should be assumed that all hazards in the vocabulary could change in these ways, though change may not always be significant for heritage.

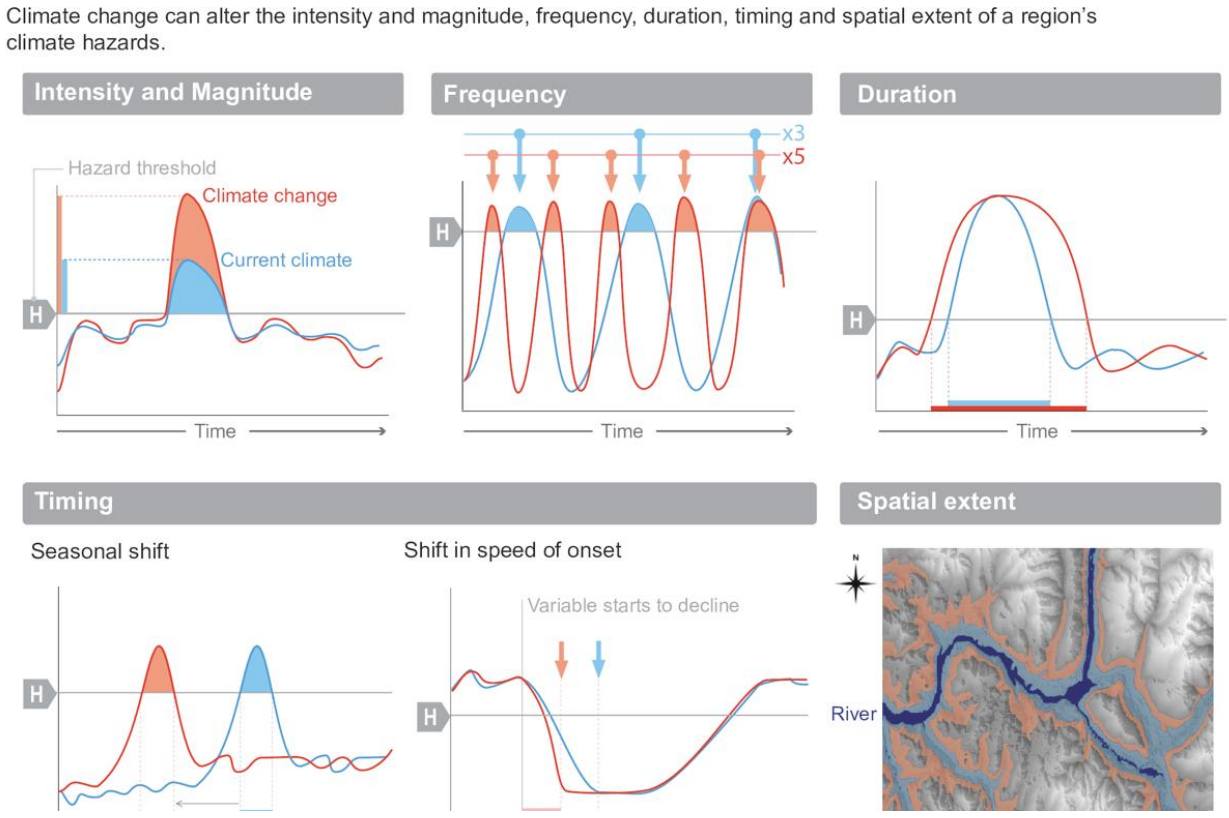


Figure 2: FAQ 12.3, Figure 1 | Types of changes to a region's hazard profile. The first five panels illustrate how climate changes can alter a hazard's intensity (or magnitude), frequency, duration, and timing (by seasonality and speed of onset) in relation to a hazard threshold (horizontal grey line, marked 'H'). The difference between the historical climate (blue) and future climate (red) shows the changing aspects of climate change that stakeholders will have to manage. The bottom right-hand panel shows how a given climate hazard (such as a current once-in-100-year river flood, geographic extent in blue) may reach new geographical areas under a future climate change (extended area in red). FAQ 12.3 Figure 1 in IPCC, 2021: Chapter 12. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Ranasigne et al., 2021, p. 1876). Reproduced under IPCC copyright.

5. Limitations

The list has been deliberately developed for international use. This does mean, however, that terms may not align with those commonly used in local contexts. For example, the UK's National Adaptation Programme (NAP) considers extreme weather while in this list the broad category of extreme weather is divided into types (extreme wind speeds, tornados, dust storms, etc). The NAP's hazard of increased temperatures is also not found in this vocabulary, instead there are two categories: average temperature patterns (long-term change) and high temperatures events (episodic). While the intention of this project was to make it widely applicable, the terms may require some modification to suit specific policy contexts. Furthermore, it is currently only published in English though translation into other languages is being explored and all IPCC definitions are published by the IPCC in the UN languages. There are also two key hazards for heritage that do not fit easily into the CID structure. These are:

Humidity

Relative humidity levels and its fluctuations are of particular concern to heritage management (for example, low humidity can lead to drying out of collections while high humidity can encourage mould growth). Humidity has been recognised as a key impact of climate change, yet it can be overlooked with emphasis often being placed on temperature and precipitation (Met Office, 2020).

One of the limitations of aligning climate hazards for heritage with the CIDs is that humidity is not a CID as determined by the IPCC. The hazard of 'average humidity patterns' has been linked in this project to the CID of mean air temperature, mean precipitation, mean wind speed, and aridity, while the hazard 'rapid humidity fluctuations' is linked to the CID of extreme heat. This ensures the humidity-related hazards are acknowledged, but it does not have the same prominence in the CID structure.

Shrink-swell

Shrink-swell is another major hazard for cultural heritage. The vocabulary uses this term as a primary hazard with soil heave and subsidence as key related hazards – this aligns with how terms are defined by the British Geological Survey (British Geological Survey, 2023). In the structure of the vocabulary, however, they are linked to the CID of landslide which is defined as "ground and atmospheric conditions that lead to geological mass movements". While shrink-swell is mass movement of the earth caused by both ground and atmospheric conditions, the link to the CID landslide is not intuitive as heave and subsidence are not commonly thought of types of landslides.

6. Using the vocabulary list

The hazard vocabulary bridges two scales of assessment: the first is the site level where the impacts of climate change can be recorded and then linked to climatic change; the second is looking at changing climate patterns and downscaling these observations to analyse how this will impact multiple sites. How the list can work with both approaches is outlined below.

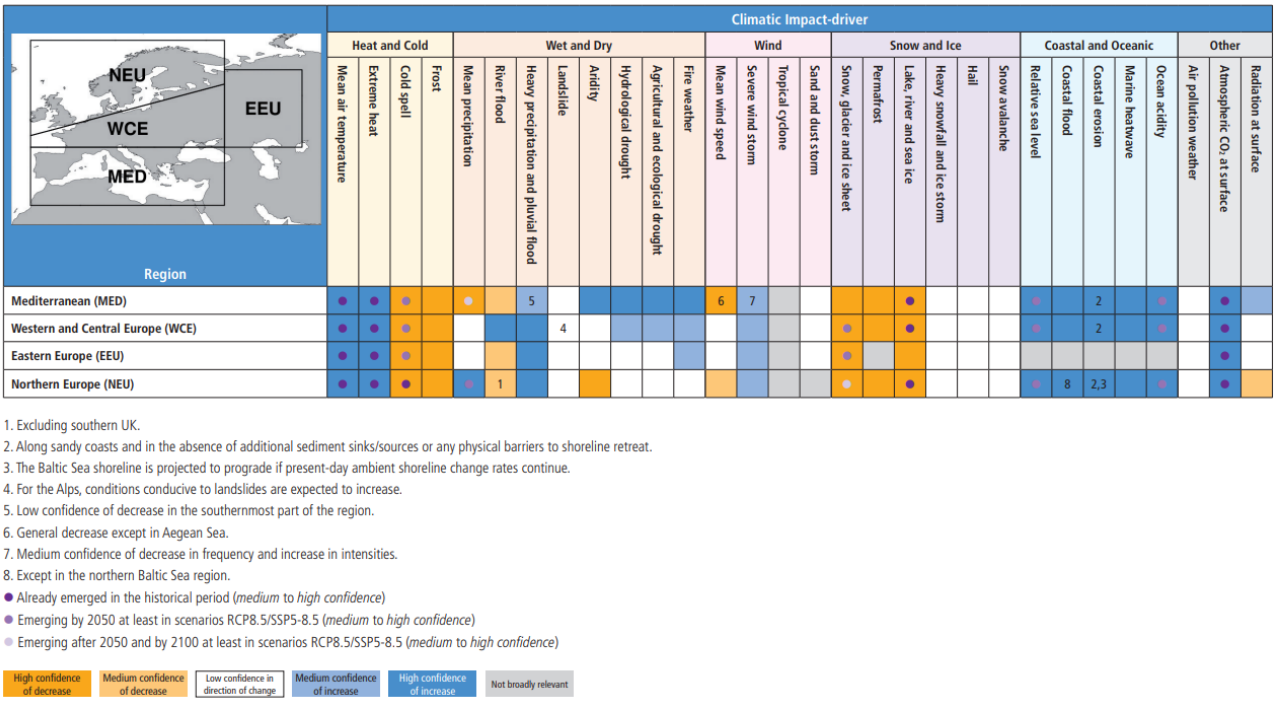
Single sites

Looking at climate trends can, of course, inform site level assessment but changes noticed on site can also be linked to hazards and their CIDs. This project has not created a list of impacts so connections will have to be made between observed damage and climate hazards. This can be relatively intuitive if processes of damage are understood, for example, detachment of wall surfaces can be linked to the hazards of salt crystallisation, humidity fluctuations, heavy precipitation events, wind-driven rain, extreme wind speed, or all of them depending on the local environmental conditions. If the root cause of damage is not known or if certain hazards are observed but have no impact (or no impact yet) then the connected hazards can still be added.

Multiple sites

Assessing the risk climate change hazards pose to multiple cultural heritage sites can be informed by future climate trends. There are multiple sources for climate change projections and assessments can vary in complexity. Linking hazards to the CIDs allows heritage professionals to connect current and future IPCC projections to their own context.

The IPCC publishes expected changes in CIDs for all geographic regions. Figure 3 shows the trends for the European CIDs. By looking at the CIDs where the IPCC has a medium or high level of confidence in change – for example, extreme heat in Northern Europe – allows future threats to be easily connected to the related hazards for heritage (high temperature events, rapid humidity fluctuations, and heat waves). This in turn can determine the focus of subsequent analysis and be updated alongside the projections published by the IPCC.



Region	Climatic Impact-driver																												
	Heat and Cold				Wet and Dry								Wind				Snow and Ice						Coastal and Oceanic					Other		
	Mean air temperature	Extreme heat	Cold spell	Frost	Mean precipitation	River flood	Heavy precipitation and pluvial flood	Landslide	Aridity	Hydrological drought	Agricultural and ecological drought	Fire weather	Mean wind speed	Severe wind storm	Tropical cyclone	Sand and dust storm	Snow, glacier and ice sheet	Permafrost	Lake, river and sea ice	Heavy snowfall and ice storm	Hail	Snow avalanche	Relative sea level	Coastal flood	Coastal erosion	Marine heatwave	Ocean acidity	Air pollution weather	Atmospheric CO_2 at surface	Radiation at surface
Mediterranean (MED)	●	●	●		○		5						6	7					●				○		2		○		●	
Western and Central Europe (WCE)	●	●	●					4									●		●				○		2		○		●	
Eastern Europe (EEU)	●	●	●														●												●	
Northern Europe (NEU)	●	●	●		○	1											○		●				○	8	2,3		○		●	

1. Excluding southern UK.
2. Along sandy coasts and in the absence of additional sediment sinks/sources or any physical barriers to shoreline retreat.
3. The Baltic Sea shoreline is projected to prograde if present-day ambient shoreline change rates continue.
4. For the Alps, conditions conducive to landslides are expected to increase.
5. Low confidence of decrease in the southernmost part of the region.
6. General decrease except in Aegean Sea.
7. Medium confidence of decrease in frequency and increase in intensities.
8. Except in the northern Baltic Sea region.

● Already emerged in the historical period (*medium* to *high confidence*)
● Emerging by 2050 at least in scenarios RCP8.5/SSP5-8.5 (*medium* to *high confidence*)
○ Emerging after 2050 and by 2100 at least in scenarios RCP8.5/SSP5-8.5 (*medium* to *high confidence*)

High confidence of decrease | Medium confidence of decrease | Low confidence in direction of change | Medium confidence of increase | High confidence of increase | Not broadly relevant

Figure 3: Table 12.7 | Summary of confidence in direction of projected change in climatic impact-drivers in Europe, representing their aggregate characteristic changes for mid-century for scenarios RCP4.5, SSP2-4.5, SRES A1B, or above within each AR6 region (defined in Chapter 1), approximately corresponding (for CIDs that are independent of sea level rise) to global warming levels between 2°C and 2.4°C (see Section 12.4 for more details of the assessment method). The table also includes the assessment of observed or projected time-of-emergence of the CID change signal from the natural interannual variability if found with at least medium confidence in Section 12.5. Table 12.7 in IPCC, 2021: Chapter 12. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Ranasigne et al., 2021, p. 1827). Reproduced under IPCC copyright.

7. Compound hazards

Hazards rarely occur in isolation. Heavy precipitation can come with high winds and hail; heat waves with drought and uncontrolled fires. These are often referred to as compound hazards and can be broken down into four types (Zscheischler et al., 2020):

1. Preconditioned

   Preconditioned events are when hazards are exacerbated by previous weather or climate conditions. For example, when rain falls on snow causing flooding or when rain falls on saturated soil leading to landslides.

2. Multivariate

   Multivariate events are where multiple hazards occur together leading to compound event types, such as compound flooding. Compound flooding is when two or more floods occur simultaneously, such as when a single storm causes coastal and groundwater flooding.

3. Temporally compounding

   This is when a succession of hazards occur in the same temporal period, such as multiple days of extreme heat leading to heat waves and drought.

4. Spatially compounding

   When hazards in connected locations impact on each other, for example heavy rain and storm surges occur in the same location leading to increased flooding.

The hazards in the vocabulary are both single hazards (mean wind conditions) and compound hazards (wind-driven rain). There is no distinction between these two groups in the vocabulary. The four types of compound hazards are introduced here to foreground the complexity of predicting and analysing compounding events and to highlight an important research gap in current hazard assessments for heritage.

8. Arches for HER – climate change module

These two approaches (site and landscape level) have informed the creation of the climate change recording module in Arches for HER. Arches for HER is a data management platform for UK Historic Environment Records (HERs), it is built using Arches which is open source data platform for the heritage field. Arches for HER uses controlled vocabularies and conforms to the standards specified by FISH and is therefore compliant with the MIDAS Heritage standard. It will use the list of climate hazards created in this project.

Arches for HER consists of multiple modules that allow users to record heritage assets, but also activities such as consultations and site visits. Rather than only building a hazard recording page for the software, the project is creating a climate change recording module. Initially this will only consider hazards but could be expanded to include other risk determinants.

The module is still in development at the time of the report's publication, but it will allow users to:

- Link individual cultural heritage sites to climate hazards
- Create polygons of hazards and automatically 'tag' all heritage sites located in this area with the hazard

Hazards can be recorded at different timescales, climate scenarios, and connected to site visits. While the module is currently only created in Arches for HER, it provides a mechanism to use the vocabulary in practice and can be adapted by any user of the Arches software.

9. Conclusion

This project has created a heritage-specific vocabulary of direct (primary) and indirect (related) hazards caused by increasing global temperatures. By establishing terminology aligned with that used by the IPCC and building a mechanism to connect sites to the climate hazards they are at risk from, this project addresses some of the challenges faced by the heritage sector to discuss and prepare for climate change. It also builds capacity through the Arches for HER recording module for future climate change related vocabularies to be developed and incorporated into current heritage management.

Climate change is an unprecedented threat for cultural heritage and appropriate tools must be developed to assess and record current and future at-risk sites. Heritage is managed by multiple organisations with different geographical remits, yet climate change is transboundary requiring organisations to work together to share resources and develop standardised approaches to assess risk. This vocabulary provides a mechanism to encourage collaboration and aid future assessments of climate change risk and impact.

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Appendix 1

Table 3: CID types and categories from Chapter 12 of Working Group 1: The Physical Science Basis (Ranasigne et al., 2021)

Climatic Impact-Driver Type	Climatic Impact-Driver Category
Heat and Cold	Mean air temperature
	Extreme heat
	Cold spell
	Frost
Wet and Dry	Mean precipitation
	River flood
	Heavy precipitation and pluvial flood
	Landslide
	Aridity
	Hydrological drought
	Agricultural and ecological drought
	Fire weather
Wind	Mean wind speed
	Severe wind storm
	Tropical cyclone
	Sand and dust storm
Snow and ice	Snow, glacier, and ice sheet
	Permafrost
	Lake, river and sea ice
	Heavy snowfall and ice storm
	Hail
	Snow avalanche
Coastal	Relative sea level
	Coastal flood
	Coastal erosion
Open Ocean	Mean ocean temperatures
	Marine heatwaves
	Ocean acidity
	Ocean salinity
	Dissolved oxygen
Other	Air pollution weather
	Atmospheric CO_2 at surface
	Radiation at surface

Appendix 2

The appended tables have been re-formatted from the original and are abridged. The original Excel workbook is available on Zenodo (Thomas et al., 2024).

In this format, each CID category is in its own table (see Appendix 1 for the list of CIDs).

CID – Heat and Cold

CID type: mean air temperature

Time frame: long-term

Description: Mean surface air temperature and its diurnal and seasonal cycles

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Average temperature patterns	Changing diurnal and seasonal temperature patterns	Increasing temperature; decreasing temperature; changing temperature	Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations		Mechanical stress; thermoclastism; corrosion
			Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen	Biological colonization; biological colonisation	

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
				growth. Does not include changing species distribution		
			Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
Average humidity patterns	Changing diurnal and seasonal humidity patterns, including sustained high and low humidity events	Increasing humidity; decreasing humidity; changing humidity	Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	
			Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations	Salt crystallisation cycles	Mechanical stress
Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations	Salt crystallisation cycles				

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation				Damage from insects
Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species				Damage from invasive species

CID type: extreme heat

Time frame: episodic

Description: episodic high air temperature events potentially exacerbated by humidity

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Rapid humidity fluctuations	Rapid changes in relative humidity levels, can be due to diurnal cycles or fast-moving weather systems					
High temperature events	High temperature events, including heat waves		Heat wave	An extended period of high temperatures		Reduced visitor numbers

CID type: cold spell

Time frame: episodic

Description: episodic cold air temperature events potentially exacerbated by wind

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Low temperature events	Low temperature events. Includes the effects of wind-chill, does not include snow and ice conditions		Cold wave	A rapid fall in temperature	Cold snap; cold spell	Ice build-up

CID type: frost

Time frame: episodic / long-term

Description: freeze and thaw events near the land surface and their seasonality

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Freeze-thaw cycles	Diurnal or seasonal changes of freeze-thaw cycles					Mechanical stress
Freeze-thaw events	Freeze-thaw events					Cracking in masonry
Frost heave	Lifting of the soil due to swelling caused by the pressure of ice moving towards the surface of the ground					Instability of foundations

CID – Wet and Dry

CID type: mean precipitation

Time frame: long-term

Description: mean precipitation and its diurnal and seasonal cycles

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Average precipitation patterns	Changing diurnal and seasonal patterns of precipitation. Does not include high precipitation events	Average rainfall; Average rainfall patterns; increasing rainfall; decreasing rainfall	Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations	Salt crystallisation cycles	Discolouration
			Biological growth	Change in typical biological growth patterns, such as mould, fungi, algae, and lichen growth or presence of pests. Does not include changing species distribution		Increased algae
Average humidity patterns	Changing diurnal and seasonal humidity patterns, including sustained high and low humidity events		Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations	Salt crystallisation cycles	Loss of material

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Salt crystallization cycles	Crystallization and dissolution of salts caused by wetting and drying cycles, temperature, and humidity fluctuations	Salt crystallisation cycles				
Groundwater flooding	Flooding caused by sustained high water table levels					
Water table	Fluctuation in water table levels		Groundwater flooding	Flooding caused by sustained high water table levels		Inaccessiblity to parts of the site

CID type: river flood

Time frame: episodic

Description: episodic high water levels in streams and rivers driven by basin runoff and the expected seasonal cycle of flooding

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Fluvial flood	Rising levels of water in rivers, streams or creeks	River flooding; riverine flooding				Damp

CID type: heavy precipitation and pluvial flood

Time frame: episodic

Description: episodic high rates of precipitation and resulting localized flooding of streams and flat lands

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Heavy precipitation event	Episodic events of heavy precipitation	Extreme rainfall; heavy rainfall;	Wind-driven rain	Rain and wind occurring together, giving rain a horizontal velocity		Overtopping of rainwater goods
Pluvial flood	Localised flooding of low-lying areas due to heavy precipitation. Independent of nearby bodies of water	Surface water flooding				

CID type: landslide

Time frame: episodic

Description: ground and atmospheric conditions that lead to geological mass movements, including landslide, mudslide and rockfall

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Landslide	A geological mass movement of soil, debris, mud or rocks		Mudslide	Mass movement of fine or liquified debris		Burying of structures
			Rockfall	Rockslide or fall due to geological mass movement	Rockslide	
Shrink-swell	Volume changes in the soil as a result of changes in moisture content	Ground instability	Subsidence	Collapse or lowering of the ground due to soil shrinkage	Settling; ground instability	
			Soil heave	Lifting of the ground due to the swelling of the soil	Ground instability	Instability of foundations

CID type: aridity

Time frame: long-term

Description: mean conditions of precipitation and evapotranspiration compared to potential atmospheric and surface water demand, resulting in low mean surface water, low soil moisture and/or low relative humidity

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Desertification	Long-term land degradation in which one of the three (biological productivity, ecological integrity or value to humans) is reduced or lost		Biological growth	Change in typical biological growth patterns, such as mould, fungi, algae, and lichen growth or presence of pests. Does not include changing species distribution		
Desiccation	Extreme drying of hygroscopic materials					Formation of cracks
Average humidity patterns	Changing diurnal and seasonal humidity patterns, including sustained high and low humidity events	Increasing humidity; decreasing humidity; changing humidity				
Water table	Fluctuation in water table levels					Localised flooding

CID type: hydrological drought

Time frame: episodic

Description: episodic combination of runoff deficit and evaporative demand that affects surface water or groundwater availability

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Water table	Fluctuation in water table levels					
Drought	A period of drier-than-normal conditions for the area and season					Reduced visitor numbers

CID type: agricultural and ecological drought

Time frame: episodic

Description: episodic combination of soil moisture supply deficit and atmospheric demand requirements that challenge the vegetation's ability to meet its water needs for transpiration and growth. Note: “agricultural” versus “ecological” term depends on affected biome

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Biological growth	Change in typical biological growth patterns, such as mould, fungi, algae, and lichen growth or presence of pests. Does not include changing species distribution					Discolouration from biofilms
Drought	A period of drier-than-normal conditions for the area and season					Die-off of soft capping

CID type: fire weather

Time frame: episodic / long-term

Description: weather conditions conducive to triggering and sustaining wildfires, usually based on a set of indicators and combinations of indicators including temperature, soil moisture, humidity and wind. Fire weather does not include the presence or absence of fuel load. Note: distinct from wildfire occurrence and area burned

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Uncontrolled fire	A large unplanned fire, often spreading quickly	Forest fire; wildfire; bush fire				Loss of sites
Fire weather	Diurnal and seasonal periods when fires are likely to start and spread	Fire season				

CID – Coastal

CID type: relative sea level

Time frame: long-term

Description: The local mean sea surface height relative to the local solid surface

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Sea level rise	Rising mean sea surface height. Caused by melting ice sheets and glaciers and the expansion of seawater as it warms	Sea-level rise	Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation	Foreshore lowering
Storm surge	Rise of sea level due to high storm winds	Storm flood; tidal surge; storm tide	Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation	Storm damage
Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation				Salt mobilisation

CID type: coastal flood

Time frame: episodic

Description: flooding driven by episodic high coastal water levels that result from a combination of relative sea level rise, tides, storm surge and wave setup

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Coastal flooding	Episodic flooding of coastal areas. Connected to rising sea levels, storm surges, wave action, and high tides		Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation	Corrosion
Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation				

CID type: coastal erosion

Time frame: episodic / long-term

Description: long term or episodic change in shoreline position caused by relative sea level rise, nearshore currents, waves and storm surge

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Coastal erosion	Long term or episodic changes of shorelines. Caused by storms, rising sea levels, wave action, tides, wind-driven rain, ocean currents, and ice		Coastal landslide	Rapid loss or movement of coastlines	Coastal instability	Exposure and/or loss of buried deposits
Coastal landslide	Rapid loss or movement of coastlines	Coastal instability				Loss of shorelines

CID – Wind

CID type: mean wind speed

Time frame: long-term

Description: mean wind speeds and transport patterns and their diurnal and seasonal cycles

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Average wind speed	Changing patterns in average wind speed	Increasing wind speed; decreasing wind speed	Average humidity patterns	Changing diurnal and seasonal humidity patterns, including sustained high and low humidity events	Increasing humidity; decreasing humidity; changing humidity	
Average wind transportation patterns	Changing patterns in average wind movement, such as changing directions of prevailing winds	Changing prevailing winds				
Wind-driven rain	Rain and wind occurring together, giving rain a horizontal velocity					
Average humidity patterns	Changing diurnal and seasonal humidity patterns, including sustained high and low humidity events	Increasing humidity; decreasing humidity; changing humidity				Water penetration

CID type: severe wind storm

Time frame: episodic

Description: episodic severe storms including extratropical cyclones, thunderstorms, wind gusts, derechos, and tornados

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Extreme wind speed	Wind speed above typical levels	Wind gusts; high winds				
Heavy precipitation event	Episodic events of heavy precipitation	Heavy rainfall				
Hail	Pellets of solid precipitation	Hail storm				
Thunderstorm	A storm with thunder and lightning. Sometimes causes hail, heavy rain, and high winds		Extreme wind speed	Wind speed above typical levels		
			Heavy precipitation event	Episodic events of heavy precipitation	Heavy rainfall	
			Lightning	Flash of light produced by a discharge of atmospheric electricity	Heat lightning; lightning storm	Cracking of structures
			Hail	Pellets of solid precipitation	Hail storm	Surface erosion

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Tornado	A rotating column of air, connecting a cloud to the surface of the Earth		Extreme wind speed	Wind speed above typical levels	Wind gusts; high winds	
Derecho	A group of thunderstorms causing long-lived straight-lined windstorms		Extreme wind speed	Wind speed above typical levels	Wind gusts; high winds	Surface erosion
Extratropical cyclone	Low-pressure systems occuring in middle latitutdes, capable of causing extreme precipitation, storm surges, extreme winds, sea level and wave build up		Heavy precipitation event	Episodic events of heavy precipitation	Heavy rainfall	Water penetration
			Storm surge	Rise of sea level due to high storm winds	Storm flood; tidal surge; storm tide	
			Extreme wind speed	Wind speed above typical levels		
			Wave action	Wave movement and the related changes in connected forces (for example, buoyancy or hydrostatic force)		
Storm surge	Rise of sea level due to high storm winds	Storm flood; tidal surge; storm tide				

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Coastal flooding	Episodic flooding of coastal areas. Connected to rising sea levels, storm surges, wave action, and high tides		Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation	
Wave action	Wave movement and the related changes in connected forces (for example, buoyancy or hydrostatic force)		Coastal flooding	Episodic flooding of coastal areas. Connected to rising sea levels, storm surges, wave action, and high tides		Sedimentation; longshore drift

CID type: tropical cyclone

Time frame: episodic

Description: strong, rotating storm originating over tropical oceans with high winds, rainfall, and storm surges

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Tropical cyclone	Low-pressure systems forming over oceans characterised by high winds, heavy precipitation, and storm surge	Hurricane; typhoon; cyclone	Heavy precipitation event	Episodic events of heavy precipitation	Heavy rainfall	
			Storm surge	Rise of sea level due to high storm winds	Storm flood; tidal surge; storm tide	
			Extreme wind speed	Wind speed above typical levels	Wind gusts; high winds	
			Wave action	Wave movement and the related changes in connected forces (for example, buoyancy or hydrostatic force)		

CID type: sand and dust storm

Time frame: episodic

Description: storms causing the transport of soil and fine dust particles

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Sand storm	Strong winds causing the transportation of sand and soil					Sedimentation
Dust storm	Strong winds causing the transportation of dust and soil					Erosion of surfaces

CID – Snow and Ice

CID type: snow, glacier, and ice sheet

Time frame: episodic / long-term

Description: Snowpack seasonality and characteristics of glaciers and ice sheets including calving events and meltwater

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Water table	Fluctuation in water table levels		Groundwater flooding	Flooding caused by sustained high water table levels		Damp
Coastal erosion	Long term or episodic changes of shorelines. Caused by storms, rising sea levels, wave action, tides, wind-driven rain, currents, and ice		Coastal landslide	Rapid loss or movement of coastlines	Coastal instability	Exposure of buried deposits
Fluvial flood	Rising levels of water in rivers, streams or creeks	River flooding; riverine flooding				Inability to access sites
Glacial melt	Melting, shrinking, and calving of glaciers		Fluvial flood	Rising levels of water in rivers, streams or creeks	River flooding; riverine flooding	Destruction of habitats
Extreme melt event	Rapid melting of ice or snowpack		Fluvial flood	Rising levels of water in rivers, streams or creeks	River flooding; riverine flooding	

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
			Groundwater flooding	Flooding caused by sustained high water table levels		
Sea level rise	Rising mean sea surface height. Caused by melting ice sheets and glaciers and the expansion of seawater as it warms	Sea-level rise	Saltwater incursion	Movement of saline waters into freshwater zones	Salt-water inundation; saltwater inundation	Deterioration of materials
Acidification	Changing levels of water pH		Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	
Water temperature	Changing water temperatures		Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	Loss of species
Groundwater flooding	Flooding caused by sustained high water table levels					

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Shoreline erosion	Destabilisation of shorelines					Loss of sites

CID type: permafrost

Time frame: episodic / long-term

Description: snowpack seasonality and characteristics of glaciers and ice sheets including calving events and meltwater

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Permafrost thaw	Melting of the permafrost due to increasing global temperatures		Thaw slumps	A landslide in permafrost regions caused by sections of permafrost thaw	Ground instability	Instability of foundations
Frost heave	Lifting of the soil due to the swelling caused by the pressure of ice moving towards the surface of the ground					

CID type: lake, river, and sea ice

Time frame: long-term

Description: the characteristics and seasonality of ice formations on the ocean and freshwater bodies of water

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Ice extent	Changing patterns of ice formations, often leading to previously frozen areas becoming ice-free		Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation				
Shoreline erosion	Destabilisation of shorelines					

CID type: heavy snowfall and ice storm

Time frame: episodic

Description: high snowfall and ice storm events including freezing rain and rain-on-snow conditions

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Heavy snowfall	Higher than average snowfall events					Snow load
Fluvial flood	Rising levels of water in rivers, streams, or creeks	River flooding; riverine flooding				
Pluvial flood	Localised flooding of low-lying areas due to heavy precipitation. Independent of nearby bodies of water	Surface water flooding				
Freezing rain	Rain that freezes upon contact with cold surfaces		Ice storm	Storm characterized by freezing rain		Tree falls
Ice storm	Storm characterized by freezing rain					
Rain-on-snow	Rainfall on existing snowpack		Pluvial flood	Localised flooding of low-lying areas due to heavy precipitation. Independent of nearby bodies of water	Surface water flooding	

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
			Fluvial flood	Rising levels of water in rivers, streams, or creeks	River flooding; riverine flooding	Water damage

CID type: hail

Time frame: episodic

Description: storms producing solid hailstones

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Hail	Pellets of solid precipitation	Hail storm				Surface erosion

CID type: snow avalanche

Time frame: episodic

Description: cryospheric mass movements and the conditions of collapsing snowpack

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Avalanche	Mass movement of snow, ice and rocks, often in mountainous areas					Destruction of structures

CID – Open Ocean

CID type: mean ocean temperatures

Time frame: long-term

Description: mean temperature profile of ocean through the seasons, including heat content at different depths and associated stratification

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation				
Water temperature	Changing water temperatures		Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
Ocean currents	The continuous patterns of seawater movement					Sedimentation
Wave action	Wave movement and the related changes in connected forces (for example, buoyancy or hydrostatic force)					

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species				Damage from presence of novel species

CID type: marine heatwaves

Time frame: episodic

Description: episodic extreme ocean temperatures

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Marine heatwaves	Episodes of extreme high ocean temperatures		Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
			Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species					
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation				

CID type: ocean acidity

Time frame: long-term

Description: profiles of ocean pH levels and accompanying concentrations of carbonate and bicarbonate ions

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Acidification	Changing levels of water pH		Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	Corrosion
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation				

CID type: ocean salinity

Time frame: long-term

Description: profile of ocean salinity and associated seasonal stratification. Note: distinct from salinization of freshwater resources

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Ocean salinity	Amount of salt dissolved in sea water		Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
			Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	
Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species					
Biological growth	Change in typical biological growth	Biological colonization;				

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
	patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	biological colonisation				

CID type: dissolved oxygen

Time frame: episodic / long-term

Description: profile of ocean water dissolved oxygen and episodic low oxygen events

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species				
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not	Biological colonization; biological colonisation				

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
	include changing species distribution					
Low oxygen events	Episodes of extreme low oxygen levels in the ocean		Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	
			Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
Dissolved oxygen	Fluctuations in concentration of dissolved oxygen in seawater		Species distribution	Expansion and contraction of typical species distribution patterns, includes invasive species	Invasive species	
			Biological growth	Change in typical biological growth patterns, such as changing levels of	Biological colonization; biological colonisation	Corrosion

Primary hazard	Scope note	Also known as	Key related hazard	Scope note	Also known as	Example impact
				organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution		

CID – Other

CID type: air pollution weather

Time frame: episodic / long-term

Description: atmospheric conditions that increase the likelihood of high particulate matter or ozone concentrations or chemical processes generating air pollutants. Note: distinct from aerosol emissions or air pollution concentrations themselves.

Primary hazards	Scope note	Also known as	Key related hazard	Example impact
Air pollution weather	Weather that increases either the likelihood of high air pollution levels or chemical processes that generate air pollution		N/A	Corrosion

CID type: atmospheric CO_2 at surface

Time frame: long-term

Description: Concentration of atmospheric carbon dioxide (CO2) at the surface. Note: distinct from overall radiative effect of CO2 as greenhouse gas.

Primary hazards	Scope note	Also known as	Key related hazard	Example impact
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	N/A	Thickening of plant leaves

CID type: radiation at surface

Time frame: episodic / long-term

Description: balance of net shortwave, longwave and ultraviolet radiation at the Earth's surface and their diurnal and seasonal patterns.

Primary hazards	Scope note	Also known as	Key related hazard	Example impact
Biological growth	Change in typical biological growth patterns, such as changing levels of organisms, and mould, fungi, algae, and lichen growth. Does not include changing species distribution	Biological colonization; biological colonisation	N/A	Decreasing plant growth in gardens

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