HACID - Deliverable

Demonstration of the HACID-DSS for climate services

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[1] The following codes are admitted:
- R: Document, report (excluding the periodic and final reports)
- DEM: Demonstrator, pilot, prototype, plan designs
- DEC: Websites, patents filing, press & media actions, videos, etc.
- DATA: Data sets, microdata, etc.
- DMP: Data management plan
- ETHICS: Deliverables related to ethics issues.
- SECURITY: Deliverables related to security issues
- OTHER: Software, technical diagram, algorithms, models, etc.

[2] The following codes are admitted:
- PU – Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)
- SEN – Sensitive, limited under the conditions of the Grant Agreement
- Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444
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1. Introduction

This deliverable documents the demonstration of the HACID Decision Support System (HACID-DSS) for climate services. The HACID-DSS integrates human expertise with AI-enabled knowledge retrieval to support complex decision-making challenges in the subject area of climate services. It draws on hybrid collective intelligence to improve the transparency, robustness, and efficiency of climate services development decision workflows.

This report provides an overview of the HACID-DSS, the methodology and outcomes of its demonstration.

2. The HACID-DSS for Climate Services

2.1 Overview of the DSS

The HACID-DSS enables climate-service practitioners to create, compare, and evaluate structured workflows for service development, which is how a climate service is built, not just what is delivered. In HACID, we define a workflow as a structured, end-to-end description of how a climate service request is addressed, capturing the sequence of reasoning steps, data, methods, tools, and judgments that a human expert would use to produce a response.

The DSS consists of a web application conceived for a community of climate scientists, in which requests for climate services are published and workflows for service development are proposed.

The various components of the system are detailed in [Annex 1](#). In brief, the system combines:

- Community Board, listing publicly shared cases available for exploration. For each case it is displayed the title, the organisation requesting the service, and the case author.
- Case creation, representing the need of the customer for a climate service including the decision context, geography, temporal scale
- Interactive visualization of the domain knowledge graph, encoding climate science concepts and relationships to support solution-building.
- Climate service workflows, representing operations to be executed to retrieve the information necessary to deliver the requested climate service.

Figure 1 presents the complete workflow, encompassing both case-creation and case-solving stages. The HACID-DSS provides support for both, but only the case-solving stage is explicitly displayed as a workflow when contributions are submitted.
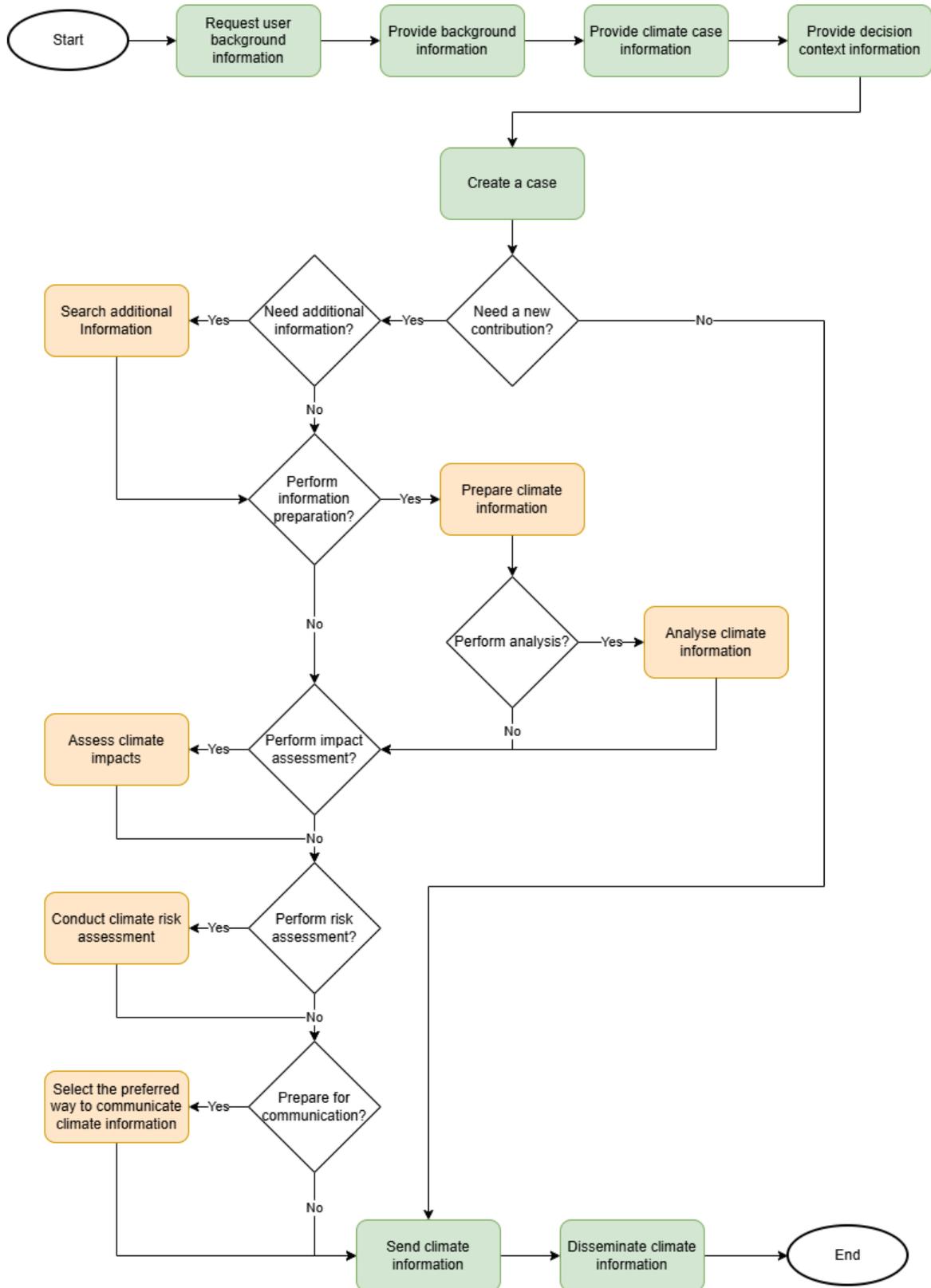
Figure 1. Climate information request handling process. Orange boxes indicate the process that is optional, while green boxes show the obligatory processes.

2.2 Climate Case Creation

A case creator (often a climate scientist or service provider) works with a requester to define a climate-service problem with minimal back-and-forth communication (see the initial operations depicted in the generic workflow of Figure 1).

Within HACID, we assume that these tasks have been conducted previously and that sufficient information is available to the case creator to perform the "*create case*" operation. Here, the DSS collects two categories of information for each case: general case information and information relating to the key questions posed by the case requester, referred to as *climate questions*.

A form requires the case creator to add data to determine detail about the climate service requester organisation, as well as data related to the geographic area, decision time-scale, customer needs (for example, improving access to climate information for local decision-makers), goals (e.g., to inform climate risk assessment) and decision context (e.g., climate information used for adaptation planning and reporting). To create a case, the user must add at least one climate question, i.e., a query that asks how projected climate change will affect a specific decision or problem. Each climate question is characterised by one or more hazards (climate-related physical events or trends with the potential to cause harm or damage like heatwaves, droughts, floods, severe storms, etc.), to be accompanied by a description of the relevance of the hazard for the case, as well as by additional information to provide sufficient context for the case solvers. Multiple climate questions may be assigned to a single case.

For a detailed description of the case creation procedure, refer to [Annex 1](#).

2.3 Creating a Contribution

The DSS enables users—called *case solvers*—to design and manage contributions for an existing climate case. A contribution represents an actionable workflow composed of tasks and dependencies that together address a requester's climate-service need. While the DSS structures these workflows (as discussed in the following paragraph), it does not evaluate the quality of analytical choices i.e. explicit, inspectable decisions that a user makes while constructing a workflow in the DSS.

Context within the Case-Creation Process

Once the case is published in the DSS, case solvers submit proposed workflows describing tasks, methods, datasets, and analytical choices. The DSS supports solvers through its climate-science knowledge graph, helping them identify relevant methods and information.

Tasks and Dependencies

Tasks are the basic operations needed to deliver a climate service and are chosen from a taxonomy of generic and specific operations.
- Generic operations (e.g., data preparation, impact assessment) are used when no suitable specific option exists.
- Specific operations guide key analytical decisions (e.g., selecting variables, scenarios).

Each task includes:

- Operation type (e.g., prepare climate information, define emission scenarios, quantify uncertainty)
- Task description (free text)
- Task rationale (free text)
- Structured information (e.g., selected variables, climate models, date ranges)

This set of components specifies both what the task is and why it matters. The operation type identifies the operation being performed. The task description further specifies the content and purpose of the task, while the task rationale explains the reasoning or justification behind it. Finally, any structured information captures the information—possibly taken from the KG—that is needed for execution.

Dependencies show how outputs from one task feed into another, enforcing logical workflow order and improving transparency, traceability, and reviewability.

Managing and Editing Contributions

Contributions can be created while exploring a case or accessed via the *My Contributions* page. Key actions include:

- Add new task: Create a new task—using either a predefined template or a generic operation—to serve as a foundational building block in contribution development.
- Reorder tasks: Adjust the position of tasks in the list by moving them up or down to modify their order.
- Add or remove dependencies: Create or remove dependency links between tasks to represent prerequisite relationships or associations.
- Copy a task: Create a duplicate of an existing task, copying all its associated information into a new task.
- Delete a task: Remove the task from the list.

Draft contributions are automatically saved and remain editable until published.

Publishing and Copying Contributions

By choosing to publish a contribution, the case solver finalizes the workflow, making it visible to the case creator and other users. Note that published contributions cannot be edited or deleted.

Given that contributions for different cases may have common parts, the copy contribution function creates a fully editable duplicate for another climate question or case. Users first select the target case, then a climate question that does not have a contribution yet.

For a detailed description of this section, refer to Annex 1.

2.3 Evaluating a Contribution

Users evaluate workflows submitted by others based on clarity, methodological soundness, relevance, and alignment with user needs. AI-generated workflows are included alongside human contributions to explore hybrid human-AI performance.

users are shown two main contributions:

- the case creator's official contribution (labeled "HACID Contribution")
- their own submitted contribution (linked under "Show Contribution")

All other users' contributions can be reached from the Contributions list, allowing users to explore how different experts structured their tasks, rationale, and analytical workflow.

Access to other's contributions is however possible only after publishing their own contribution, to promote independent judgements.

Rating Method

Contributions are evaluated using a five-point Likert scale (1–5 stars), where:
- 1 star = very poor
- 5 stars = excellent

For example, five stars in accuracy means all content is correct and aligned with trusted sources.

Evaluation Dimensions

Users assess contributions across seven dimensions:
1. Accuracy – factual correctness and alignment with credible knowledge.
2. Credibility – trustworthiness, consistency, and absence of contradictions.
3. Actionability – usefulness for decision-making and clarity of next steps.
4. Relevance – how well it stays focused on the case question.
5. Specificity – precision, level of detail, and use of concrete examples or entities.
6. Completeness – whether the contribution fully addresses all tasks, including uncertainty or bias.
7. Clarity – quality of writing, terminology, structure, and explanation of reasoning.

2.4 Visualization

The DSS integrates interactive visualisations, e.g., knowledge-graph exploration tools, to support workflow definition and refinement. The visualization tool has been described in Deliverable D3.2. Here, we summarise the main features.

The KG visualisation and querying system uses a node-link approach, in which KG information is displayed as a network of nodes (representing concepts or entities) connected by links (representing relationships between concepts or entities). This approach was selected by participants in the KG Visualisation and Values Elicitation Workshop (see Deliberable D5.2), who noted that it supports the identification of gaps within the knowledge graph. It was also regarded as more intuitive and easier to navigate than alternative visual-querying approaches.

The visualisation system provides several tools for exploration and querying, including instance searching, a radial context menu, visual querying, filtering, and tagging.
- **Instance searching** allows users to quickly locate and visualise a specific KG entity as a starting point for exploration. Through an instance-search interface, the user selects a class and types a label to find the desired instance. This delivers an immediate point of entry into the graph, enabling users to focus on a concept of interest and rapidly begin exploring its connections within the wider KG.
- The **radial context menu** is an intuitive right-click menu that appears around a selected node, offering quick access to functions relevant to that node. Choosing the relationship-exploration option opens a panel showing all predicates and connected classes for that node, enabling users to expand those relationships and reveal linked nodes. This design streamlines interaction with individual nodes, making it straightforward to view and manage node-level details and connections in a single location.

- The system also supports **visual querying** through the use of group nodes, which represent collections of instances from the same class (shown in Figure 2). Rather than starting from a specific instance, users can create a group node for a class of interest (e.g. all instances of a given type) and incrementally expand its relationships via the radial menu. Each expansion adds connected classes or filters the group using selected relationships, effectively building a query across the graph. This visual-querying capability transforms the interface into a flexible query-building environment, allowing users to explore the knowledge-graph schema and retrieve relevant subsets of data in an interactive and intuitive manner.
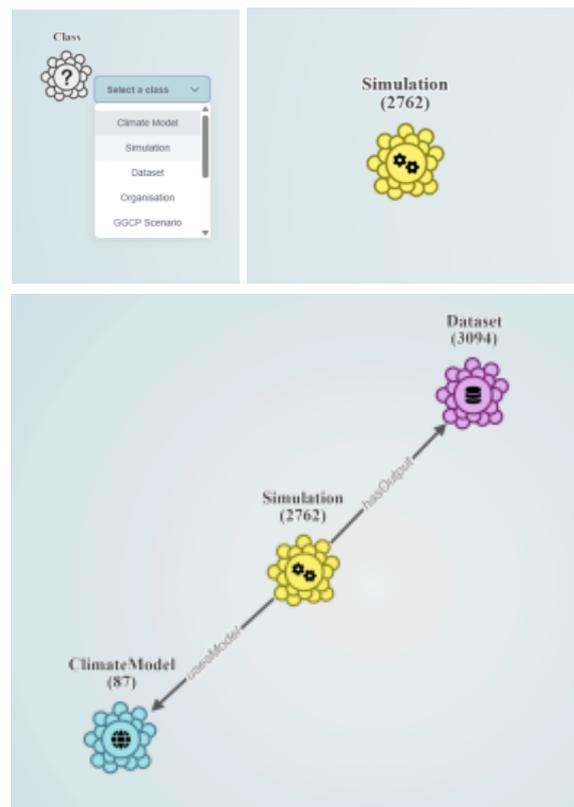

Figure 2. Group node tool for visual querying. Top left: selecting the class type for the group node tool. Top right: after selecting the class type. Bottom: expansion of the relationships.

- **Filtering functions** help users refine the information shown in group nodes. One method is relational filtering, where connecting a group node to a specific instance restricts the group to members that have a relationship with that instance. Another method is attribute-based filtering. In both cases, filters are visualised alongside the node, and the group-node count is updated to indicate how many items meet the criteria. These filtering tools support the visual-querying workflow by allowing users to incrementally narrow down large result sets, reduce visual clutter, and focus on the most relevant knowledge.
- The **tagging feature** allows users to mark nodes as important or relevant to their work. Accessed through the radial context menu, tagging highlights the node with a coloured outline to indicate user interest or endorsement. This action also creates a corresponding "judgement" entry in the knowledge graph (following a pattern defined in the project's ontology, see Deliverable D2.1), linking the tagged node to the user who applied the tag and the climate case under investigation. Each tag is thus recorded as a semantic annotation identifying which user considered which

information noteworthy for a specific case. This enhances the visualisation system by introducing a layer of user feedback and curation, enabling tagged nodes to be later queried, identified, or aggregated.

Advanced users can also make use of an embedded query editor available directly within the application. This editor is based on YASGUI (Yet Another SPARQL GUI), a web-based interface for querying RDF data using SPARQL.

Owing to these features, case creators and solvers can explore the KG while producing content within the HACID-DSS, and use the identified information to inform the case or the workflow definition.

3. AI Generation of Workflows

We have developed AI-enabled automated generation of candidate workflows. These workflows:

- Use large language models (LLMs) to extract relevant climate-service methods, data needs, and decision steps.
- Leverage the HACID Climate Services Domain KG (CS-DKG) for grounding of AI responses where the DKG can provide relevant information.
- Are subsequently evaluated and compared with human-generated workflows, allowing assessment of hybrid intelligence performance.

The HACID AI workflow-generation system is implemented as a LLM–based chat-completion smart agent capable of calling tools that extract and select relevant components of the CS-DKG. Figure 3 illustrates the basic configuration of the system. The system first produces a draft answer, which is then augmented with information extracted from the CS-DKG by a set of agents. The final stage is an LLM-driven decision-making agent responsible for approving or rejecting the inclusion of KG information in the final answer. The resulting output is a simplified workflow, or "recipe", for the specific climate service.
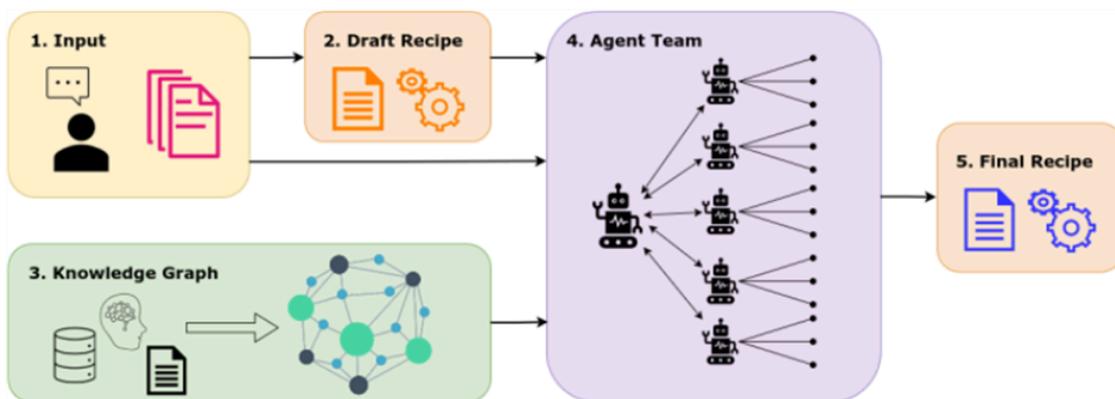

Figure 3. Schematic of the open-domain question answering agentic system for the creation of simplified climate service workflows. Adopted from Williams et al. (2026)[3].

Within the HACID AI workflow generation system, task names are initially converted into expert-curated corresponding queries. While automated query creation is possible, task

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[3] Williams et al. (2026). *Developing trustworthy AI for climate services at scale*. [submitted]. Nature Climate Change.

names remain stable, and expert curation ensures more reliable results by attending to detail, semantic nuance, and vocabulary familiar to climate scientists.

The system can respond to any query, not only the expert-curated translations of tasks into questions. Although the KG serves as a source for the agentic system, the draft answer is generated using a prompt-engineered, off-the-shelf LLM. This LLM is restricted from calling external tools such as web search, and the prompt enforces strict adherence to the climate-services domain. This design supports future integration directly within the DSS, enabling ad hoc exploration. While such an architecture introduces guardrailing risks, the intended users are domain experts. The system is designed to assist them by offering more tractable solution pathways and signposting for non-climatic information not present in the DKG. As a result, the system does not require the same degree of restriction necessary for a public-facing chatbot.

At present, the system can respond to queries but does not create directed acyclic graphs (DAGs) linking factoids or recognised entities across tasks. Although it can identify URIs for entities from the KG, the instances selected by the agentic system may not always be included in the final output due to the answer refinement process.

The system has been developed using LangChain for prompt management and agentic workflow construction, and LangGraph for agent orchestration. It is currently implemented using OpenAI GPT models (via API): o1 for KG information processing, GPT-4o for summarisation, and GPT-5.1 for draft answer creation. Substituting OpenAI LLMs with open-weight or open-access LLMs is feasible with relatively minor adjustments.

4. The Demonstration of the HACID-DSS

4.1 Objective and Scope

The demonstration aimed to:
- Test the usability, transparency, and scalability of HACID-DSS for climate-services development.
- Assess the system's ability to structure workflows, support decision traceability, and incorporate hybrid human-AI insights.

4.2 Methodology

The demonstration was conducted with climate scientists recruited from the Met Office and academic partner universities including University of Exeter and University of Leeds. Please refer to Annex 3 for the recruitment letter sent to recruit relevant climate scientists. Set up of the demonstration included:
- Case introduction: 2–3 use cases were included to the DSS per week, enabling distributed participation at flexible times.
- Hands-on interaction with the DSS: Participants created and evaluated workflows, interacting with both human and AI-generated solutions.
- Support infrastructure: Quick-start guide, and access to the HACID team at the Met Office for Q&A ensured consistent user support.
- Data capture: Workflow content, evaluation scores, and qualitative rationale were recorded for analysis.

4.3 Demonstration Outcomes

A total of 8 participants have contributed to at least one of the offered use cases in the DSS as of February the 18th, 2026. Table 1 shows the names of cases offered and the number of participant contributions for each case (excludes HACID and AI contributions). A complete participant contribution in Table 1 refers to a published contribution with more than one task, description and rationale provided for most (>50%) tasks, and with at least one associated entity.

Table 1. Use cases and published participant contributions.

Use case title	Short identifying name	Geographical area	Date of case publication	Number of published participant contributions	Number of complete participant contributions
Climate projections for the Duchy of Cornwall UK agricultural holdings	Agriculture	UK (south)	19/01/2026	4	2
Projected change in heating and cooling energy demand across all UK local authorities	Energy demand	UK	21/01/2026	5	1
Thermal performance of high rise building in Singapore	Built environment	Singapore	21/01/2026	1	0
BBC Sport Weather Forecast for 2050: climate change impacts on future Wimbledon Championships?	Sporting	UK (London)	09/02/2026	0	0
Climate information for London transport infrastructure using UK Climate Projections	Transport	UK (London)	09/02/2026	0	0
Risks to the sea rescue charity's assets from coastal flooding under projected climate change scenarios	Coastal management	UK	09/02/2026	0	0

Overall, we received 10 published contributions. Of those, most were for either the energy demand or agriculture use case. Three use cases did not receive any contributions. One

user published three contributions; the rest published only one contribution. Three examples of participant contributions are shown in [Annex 4](#).

Only three contributions are complete, though more were partially completed, just missing either rationale or descriptions. Out of 10 cases, four were severely incomplete, having only one task. One user systematically provided one-task contributions, where the user described multi-step operations but did not use the provided workflow structure to show it. The remaining severely incomplete case is associated with a user who pointed out a particular data product that provides high-level information that the customer is interested in rather than developing a climate service *de novo*.

Evaluation of the contribution

We have only received four evaluations as of February the 18th, 2026. Of those, two relate to the agriculture case (one participant, one AI contribution) and two relate to the energy demand case (one HACID—i.e., the original solution provided by the expert— and one AI contribution). For each case, one user provided an evaluation. From the evaluation results, we can see that for the agriculture case the user preferred the AI contribution (4.1) to the other participant's contribution (2.4), especially for **completeness**, where the AI contribution received five stars out of five. The AI contribution also scored higher in relevance, specificity, accuracy, and credibility, but received the same score for actionability and clarity. For the other use case, the user scored the expert contribution higher (3.4) than the AI contribution (3.1) due to higher scores for accuracy and relevance. Both contributions overlapped in clarity (which was rated as 2 stars out of 5), specificity, and completeness, but the AI contribution had a higher score for credibility (3 versus 2). Unfortunately, we received too few evaluations to establish a robust trend. From the current results, we can see high case-by-case variation.

Feedback from participants

A few participants have provided feedback after usage of the HACID-DSS, about the concept and usability of the web application. A transcript of such feedback is provided in [Annex 5](#).

Annex 1: HACID-DSS Technical Manual

A quick start guide to HACID DSS

This guide is targeted at the contributors to help them navigate the HACID-DSS. It provides an overview of the main parts that compose the DSS, providing a description of the information that can be displayed and the actions that can be performed.

Community Board

Here we describe the Community Board page in the HACID DSS web app.

The **Community Board** page lists publicly shared cases available for exploration. For each case it is displayed the title, the organisation requesting the service, and the case author. Moreover, the DSS provides the possibility to view details for the case with the means of the **Detail** button located under the author name for each case. By clicking on this button, the user is directed to the **Explore Case** view.

Explore Case

The **Explore Case** page provides a structured overview of the selected climate case. It provides essential background information that situates the case within its organisational, temporal, and decision-making context. A geographic map highlights the region of interest.

- **Responsible organization**: the organization requesting the service.
- **Organization type**: institutional ownership and governance.
- **Decision time scale**: the temporal horizon relevant to the case, indicating the period over which decisions and impacts are considered.
- **Customer needs**: specific needs associated with the case.

- **Goals or objectives**: what the case seeks to address.
- **Decision context**: how the case supports decision-making or broader strategic aims
- **Risk tolerance**: the measure of the extent to which the organization is willing to accept uncertainty and potential adverse outcomes related to climate risks.

Details of the case

For each case, one or more questions may be available. A *"Detail"* button enables users to expand each climate question with all associated details, as described below.

- **Climate question:** the central issue being examined and the scope of the analysis.
- **Description:** the purpose of the analysis and the intended use of the information, particularly in relation to decision-making or communication needs
- **Additional information:** further clarification such as relevant indices or metrics that are important for interpreting the case.
- **Hazards:** the type of climate hazards (one or more) under consideration.
- **Hazard description:** the nature and potential impacts of the hazard.

Together, these fields structure the problem definition and support a clear understanding of the case context. Given this information, the user can give its contribution by clicking the **Contribute** button.

Contribute to a case

By clicking on the "Contribute" button, the user can create a new contribution to the case. To learn how to create your contribution, have a look at the Section [Creating a Contribution](#).

Explore contributions

Once a contribution for a climate question has been published, it is possible to access it by clicking on the **Show Contribution** button (see Figure below). Additionally, it is possible to explore the contributions provided by the case creator (if any), as well as the contributions from other users. The former is referred to as the "HACID Contribution" and is accessible from a dedicated button. The latter are accessible from a drop down menu that shows the list of all available contributions.

My Cases

In this section, users can see their own cases, both published and draft.
The **published cases** section displays the cases that have been finalised and a contribution count for each published case. Meanwhile, the **draft cases** section displays cases that are not yet published, and provides the option of editing or deleting the case.

From this page, the user can create a new case by clicking the **Create New Case** button, which opens the case-creation form, which requires both information about a case and about the climate questions associated with the case.

General case information includes:
- Case title
- Customer organisation name
- Organisation type. The DSS provides a drop-down list of eight options:
  Private (business, science and technology advisory);
  Third sector (academic/education/research, NGO/charity);
  Public (central, local, devolved, regulators).
  The case creator must select the option that best fits the customer organisation type.
- Spatial region of interest.The case creator first selects one of 14 regions from a drop-down list, and then specifies the precise boundaries of the geographic area using a map tool.
- Decision time-scale (start to end date), that is, the overall time horizon for which climate information is required. If multiple horizons are relevant, the user should provide the time horizon that encompasses them all. If the required horizon is unclear or not explicitly defined, the typical planning time horizon for the organisation should be provided. The input is a date range from an exact start date to an exact end date.
- Customer needs describing the climate-related challenges faced by the organisation or by its operational activities.
- Goals or objectives, stating the main goals for which the customer is seeking climate information.
- Decision context, that is, the decisions or actions that could be better informed through improved climate information for the identified hazards.
- Risk tolerance rating (high, medium, low), indicating the extent to which a user is willing to accept uncertainty and potential adverse outcomes relating to climate risks.
  For example, a low risk tolerance reflects a preference for detailed quantification of even extreme climate scenarios to support proactive planning and adaptation aimed at minimising potential impacts.
  The case creator must select one of three categories: high, medium, or low.

Additionally, the case creator may add an illustration—an image associated with the case. This serves an aesthetic purpose.

Information about climate questions includes:
- Main question, that formulates the key questions concerning climate information that the customer seeks to answer.
- Hazards
  - Hazard selection: the identification of the climate hazards (climate-related physical events or processes) that affect the customer organisation. The list of hazards is provided in the [Hazards](#) section of Annex 2.
  - Hazard description: allows the case creator to refine a general hazard definition or add specific information relevant to the case.
- Hazard impact on organisation, describing how climate hazards affect the organisation's activities and how these relate to the proposed case.
- Additional information, allowing the requester to supply any information they deem useful for the case solver. This may include preferred metrics (indices), specific emission scenarios, global-warming levels, and related details.

Each question must have one or more hazards associated with it. Contributions are per question - each question should have its own contribution, i.e. solver cannot provide a contribution across the questions. Solvers must provide the contribution to each question separately, including by copying contributions where appropriate.

Using the available controls, the user can choose to publish the case, save it as a draft, or discard it. To publish a case, the user must add at least one climate question. Once a case is saved or published, it appears in the **My cases** page.

My Contributions

This page presents the fields used to display and manage a user's individual contributions within the application. It includes:

- **Contribution panel**: each panel corresponds to a specific contribution made by the user. Each card contains fields indicating the associated case, the climate question, and the date of creation.
- **Task count**: the number of tasks linked to the contribution.
- **Contribution's status**: on the bottom left of each panel, indicates whether the contribution is published or saved as a draft, supporting clear differentiation between completed and in-progress work.
- **View details**: - allows the user to access the full content and associated tasks of the selected contribution.

In the image below two contributions are displayed, one already published and the other in a draft state. Both contributions were created on Dec 4, 2025 and include 3 tasks.
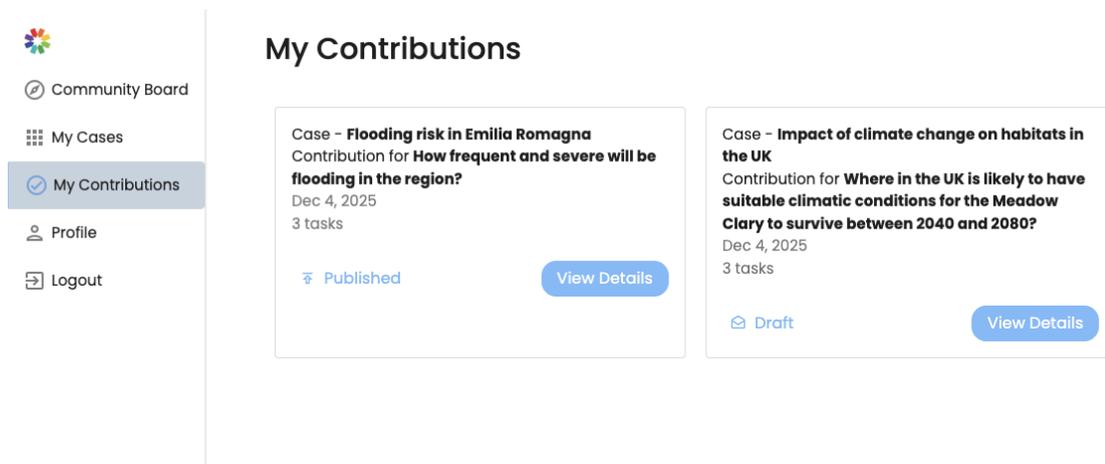
Profile view

When the user is logged in, they can view their profile details in the *Profile* section. The information includes the name, the surname, the email and the company the user is affiliated to, as shown in the image below.
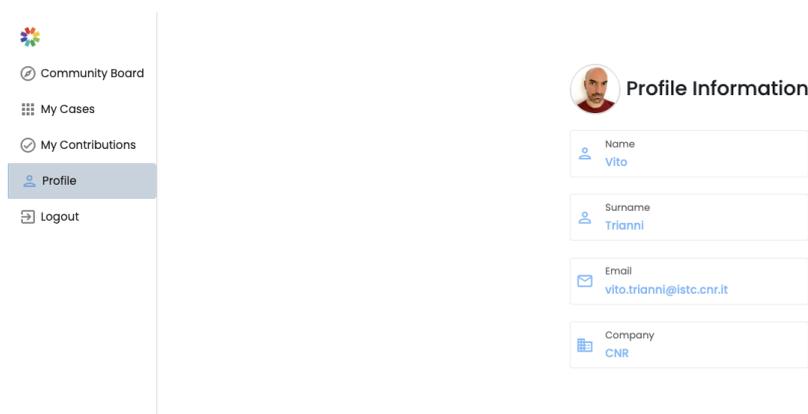
Creating a Contribution

The DSS allows users to develop and manage their contribution to an existing climate case. A contribution to a climate case is a list of tasks and dependencies among tasks that represent an **actionable workflow** for climate services. While the DSS supports the solver in

providing structured contributions, it is not intended to provide an evaluation of alternative choices the solver may consider.

- **Tasks** are the basic operations to be performed to provide a climate service, to be selected from the provided taxonomy
- **Dependencies** are introduced between tasks and reflect data or information flow. Dependencies explicitly highlight how the output of one task is used as the input for another, and help structure contributions so that tasks follow a logical order of information processing. For instance, the task **Filter climate simulations by selection criteria** should receive as input the selection criteria of interest from the user, that can be specified by other tasks such as *Choose global warming level* or *Define relevant spatial resolutions*. Similarly, the task *Evaluate climate simulations* should identify what parent tasks produce the simulations to evaluate, either from filtering or from manual selection. Making dependencies explicit also improves transparency and traceability, helping users see how information is passed between steps, and should be considered when **Evaluating a Contribution**.

Basic actions for contributions

The page for creating and editing contributions can be accessed while exploring the details of a case. Alternatively, draft contributions can be edited starting from the My Contributions section. The following actions are available:

- **Publish**: allows to finalize the contribution and make it available to the case creator and other users for evaluation. Once published, a contribution cannot be edited/deleted anymore. **A contribution is valid only when published.**
- **Copy contribution**: contributions can be copied to a climate question.
- **Delete contribution**: draft contributions can be discarded.
- **Add new task:** insert a new task in the list

Contributions get saved while the user edits them. Once saved, they can be found in the My Contributions section as editable drafts. It is possible to seamlessly switch between case exploration and contribution editing views.
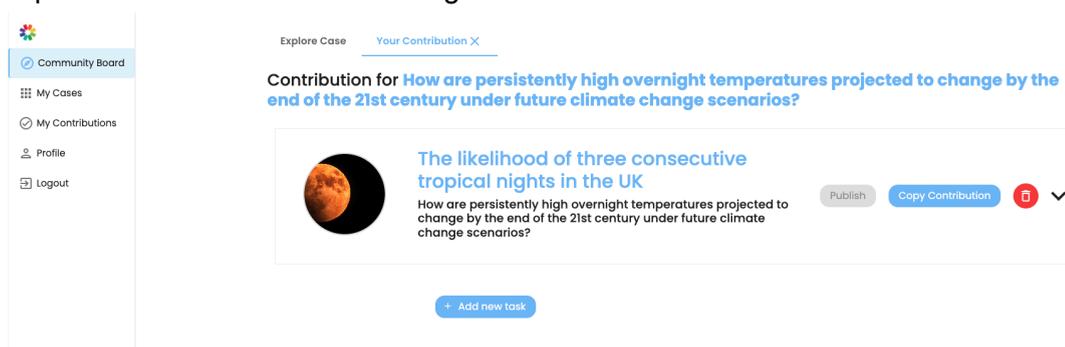
Defining a new task

To define a task, the following information must be provided:

- **Operation**: By clicking *Add new task*, a menu appears with a set of predefined operation types grouped into categories:
  - **Generic operations** that include finding additional information, preparing and analysing climate data, assessing impacts, assessing risks, and presenting

results.[4] Generic operations should be used only when a desired specific operation is not available among those listed.

- ○ **Specific operations** that help users make key analytical choices, such as selecting variables, time periods, scenarios, or filtering criteria. Specific operations should always be preferred.

The full list and definition of all the available operations is provided in the Glossary.
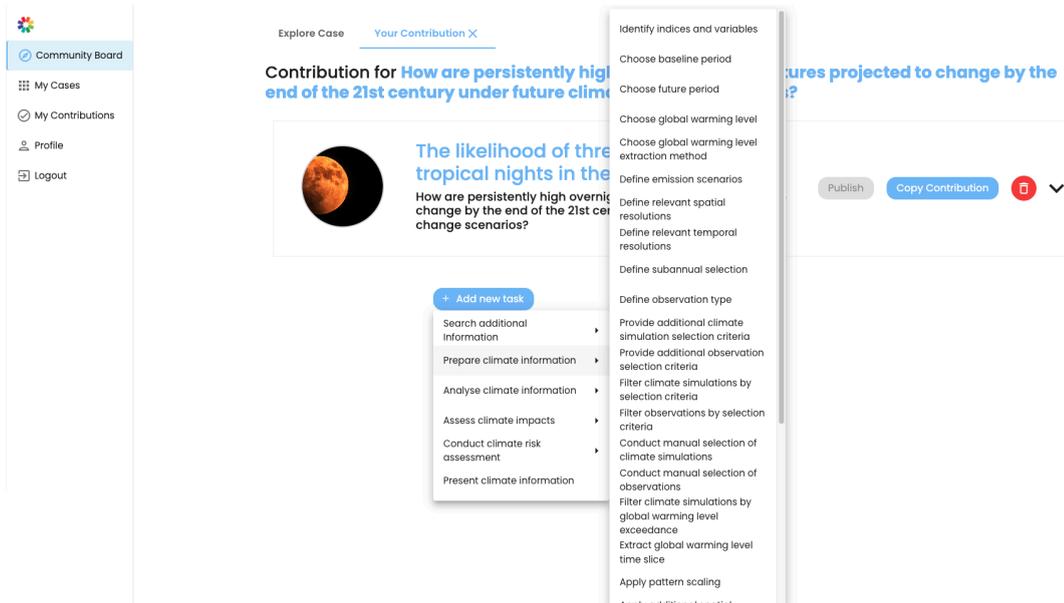
- ● **Task description**: a short textual description of the actions to be performed related to the operation
- ● **Task rationale**: a short textual rationale for choosing and executing the specific operation in the content of the created task
- ● **Structured data associated with the operation**: structured data complete the task description linking the operation with information available in the climate service knowledge graph, such as name of indices or variables, climate models or simulations.

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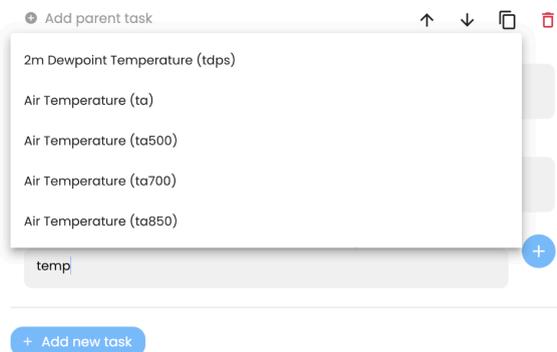
[4] Climate impact assessment and risk assessment operations are not mandatory but can be attempted if needed.

Adding structured information to tasks

Different operations may require different types of structured information, offering users the possibility to specify what is actually needed for a task. The DSS provides the following possibilities:

- **Selection of a single or multiple items from a list**: in this case, the structured information to be provided must be chosen from a list of possibilities (e.g., a list of variables and indices, or a list of climate projections). To filter long lists, the user can type in the text field **one or more keywords separated by a comma and without spaces**, and all the elements in the list that contain all the specified keywords will appear. If multiple items are allowed, the **"+" sign** on the right allows users to add another field.

- **Definition of a date range**: in this case, a range of dates can be specified. The dates must be selected from the calendar interface associated with the data field (see the example of the task *Choose baseline period* below*)*.

- **Definition of a value or a range of values:** the structured information can be given in the form of a single value or of a range of values (min-max). It is also possible to define open ranges (up to, from). First, the input type must be selected. Then, the

desired values must be specified.

- **Subannual period**: The task *Define subannual selection* takes as input a special case of structured data. This is a part of the year, which can be specified in different ways: as a range of days of the year (e.g., from December the 15th to May the 3rd), as a single month, as a month range, as months blocks or seasons. For each type, a specific interface allows the user to provide the desired data.

Managing the task list and dependencies

Once a task has been defined, the following actions are possible
Adding dependencies: the button *Add a parent task* supports the organisation of tasks into a hierarchy. Only tasks preceding the current task in the list can be selected, simulating a top-down information flow. One or multiple parent tasks can be added, and a list of parent task ids is displayed.
Removing dependencies: each element in the list of parent task ids can be removed by clicking on the cross sign.
Reordering tasks: arrows can be used to move a task up or down in the list. Note that tasks cannot be moved above parent tasks or below child tasks.
Copying a task: a task is duplicated and positioned at the end of the list. All information is copied but dependencies.

Deleting a task: a task can be removed from the list by clicking on the trash bin icon.
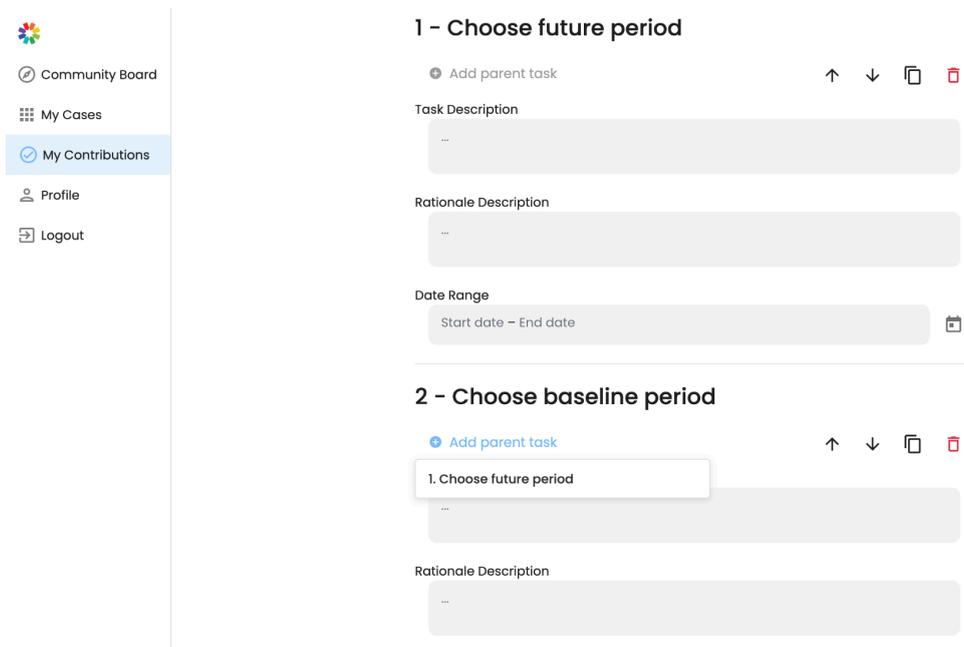
Publishing a Contribution

When a contribution is complete, it can be published and made accessible to the case creator and the other users with access rights. A popup window requires a confirmation, warning about the fact that contributions, once published, cannot be edited or deleted any more.
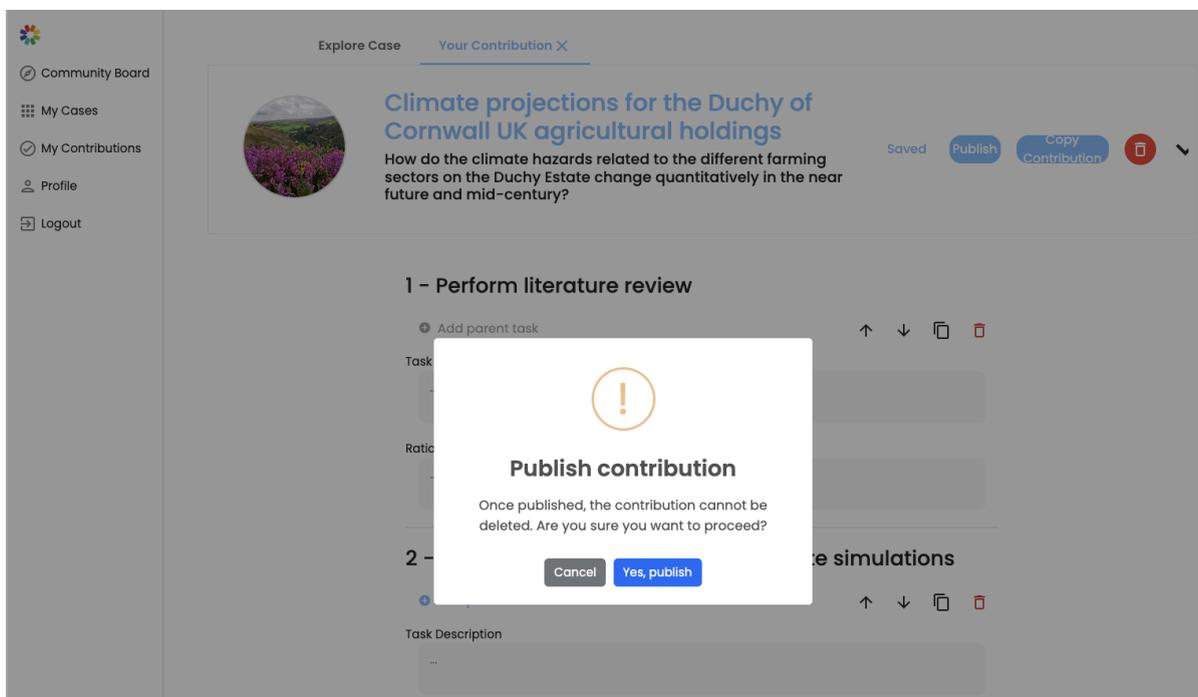
Copying a contribution

The **Copy Contribution** button allows the user to create a duplicate of the current contribution, including its structure and tasks, without affecting the original version. This is useful when the user wants to reuse an existing contribution as a starting point for a similar analysis, explore alternative approaches, or adapt the contribution to a different case or scenario. Copying a contribution helps save time by preserving previously defined tasks, descriptions, and selections, while allowing the new copy to be edited independently. If the user opts to use this option, a pop up will require the user to first select a case where the contribution will be copied.
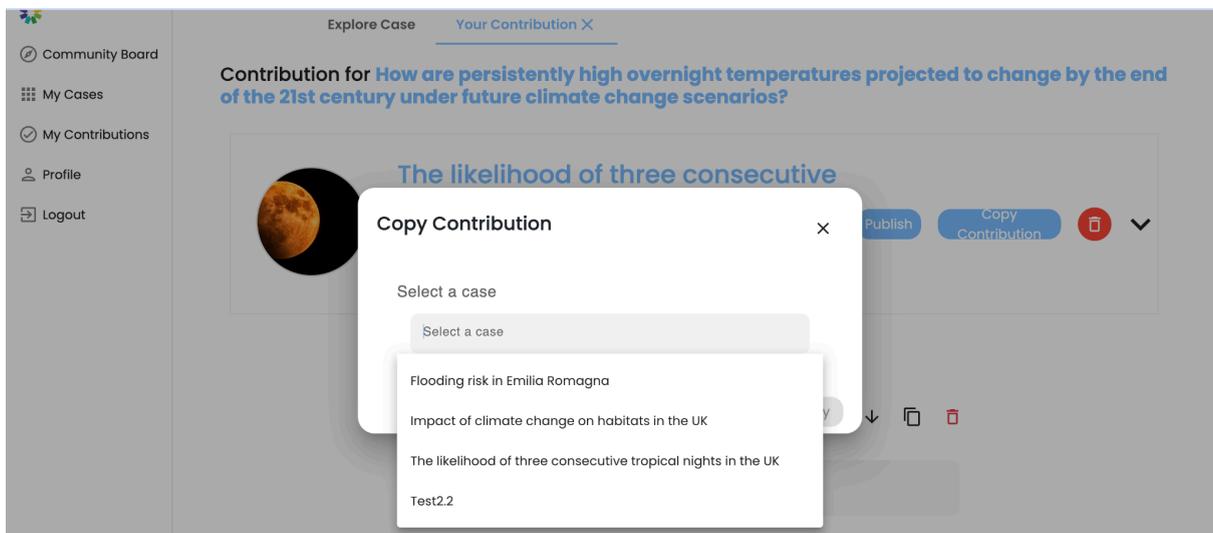
Then, the user is invited to select a climate question from the case where to copy the contribution. Only climate questions for which a contribution was not yet created are displayed.
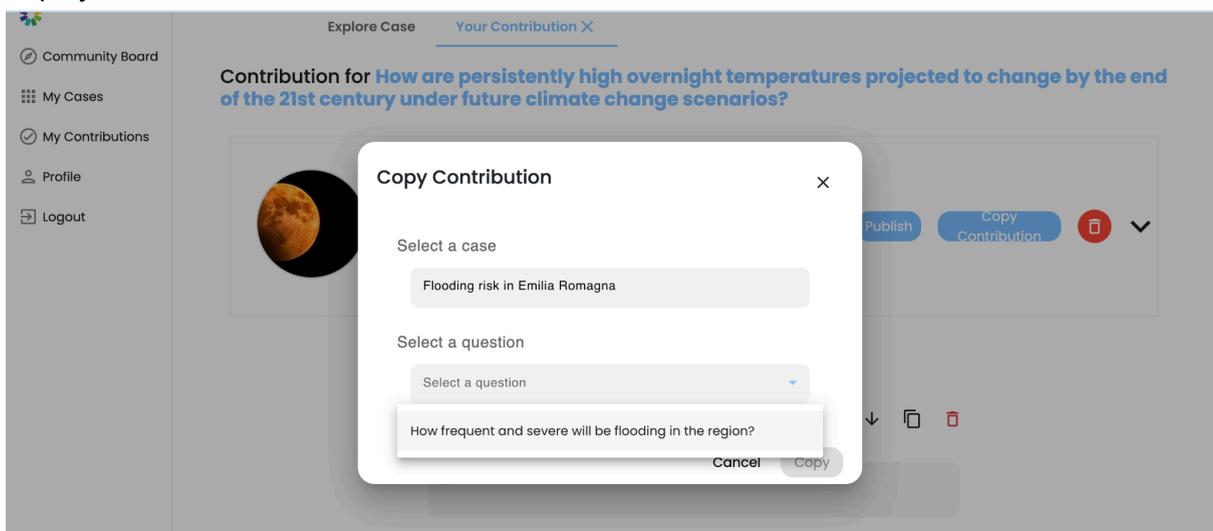
Evaluating a Contribution

After a user has added their own contribution to a case, they can access and explore contributions made by other experts. Two buttons provide quick access to two specific contributions:

- **HACID Contribution**: this is the contribution provided by the case creator
- **Show Contribution**: this is the contribution provided by the user

Additionally, users can get access to the contributions provided by all other users through the **Contributions list** section on the case page. By selecting a contribution from the list, the user can open and review how others have approached the same question, including their tasks, rationale, and analysis steps.

At the bottom of the page, the user can evaluate the contribution as described in Section 2.3 Evaluating a Contribution.

Annex 2: Glossary

This glossary provides the definitions for some important elements that can be manipulated within the HACID-DSS, namely operations that can be used for defining the tasks of a contribution, methods that can be used for certain tasks of climate information processing, hazards defined for each cases, and indices used to provide relevant climate information.

Operations

In this section, we provide all the definitions of the operations that can be exploited for the creation of a workflow, when a contribution to a case is created (see Creating a Contribution). Below you can find the name of the operation, its description, a reference source for the description if available, and the URI of the task in the knowledge graph.

Search additional information

Term	Definition
Search additional information	The operation that requests external expertise such as an expert or literature review. Sub-operations of this category can be found in the table below.
Perform literature review	The operation that looks for additional information from existing literature.
Search for external expertise	The operation that requests external expertise from an expert.
Provide non-climatic information	The task of describing the non-climatic information.

Prepare climate information

Term	Definition
Prepare climate information	The operation that prepares the climate information. Sub-operations of this category can be found in the table below.
Identify indices and variables	The operation that identifies the climate indices (e.g., number of tropical nights per calendar year, standardised precipitation index) or variables (e.g., max temperature, monthly rainfall) if no suitable indicator is found relevant to the study or decision-making context.
Choose baseline period	The operation that chooses a historical reference period (e.g., 1850–1900 as pre-industrial baseline, 1986–2005 in IPCC AR5, 1995–2014 in IPCC AR6) to serve as a baseline for comparing future climate projections or for global warming level extraction
Choose future period	The operation that chooses the future time horizons of interest (e.g., specific period in the future like 2080–2100, 2030–2080) for climate information or risk or impact assessment.

Term	Definition
Choose global warming level	The operation that selects specific global warming levels (e.g., +1.5°C, +2°C).
Choose global warming level extraction method	The operation that chooses a method to extract regional climate change data in relation to selected global warming levels above pre-industrial (default: 1850-1900).
Define emission scenarios	The operation that defines appropriate representative concentration pathways (RCPs) or shared socioeconomic pathways (SSPs) to explore a range of future climate outcomes.
Choose climate models	The operation that selects the climate models.
Define relevant spatial resolutions	The operation that selects the required spatial resolution (e.g., 1 km, 60 km, 0.25°) range for the output climate data.
Define relevant temporal resolutions	The operation that selects the required temporal resolution (e.g., daily, monthly, annual, seasonal) range for the output climate data.
Define subannual selection	The operation that selects a sub-annual period (e.g. month, season, period in year) of interest (e.g. boreal winter (DJFM), austral spring (SON), Januarys, Julys).
Define observation type	The operation that defines the preferred observation type (e.g., station-based, gridded).
Provide additional climate simulation selection criteria	The operation that provides additional constraints to the climate simulation selection like origin of source (e.g., institution, country of origin), etc. Provide information with URIs taken from the KG where possible.
Provide additional observation selection criteria	The operation that provides additional constraints to the observation selection, such as the origin of the source (e.g., institution, country of origin), etc. Provide information with URIs taken from the KG where possible.
Filter climate simulations by selection criteria	The operation that applies filtering criteria to the list of climate simulations and shortlisting matching entries. The case solver may add reasoning for choosing particular filtering criteria.
Filter observations by selection criteria	The operation that applies filtering criteria to the list of observations and shortlisting matching entries. The case solver may add reasoning for choosing particular filtering criteria.
Conduct manual selection of climate simulations	The operation that selects the climate simulations. If all ensemble members are selected, choose the parent simulation (those without an ensemble identifier in the name).
Conduct manual selection of climate projections	The operation that selects the climate projections
Conduct manual	The operation that selects the observations

Term	Definition
selection of observations	
Filter climate simulations by global warming level exceedance	The operation that selects simulations exceeding the specific global warming level. This operation relates to providing information about climate simulations that reach the relevant global warming level within the period of interest (usually by 2100), based on previous studies or work.
Extract global warming level time slice	The operation that extracts the time slice centered around the point in time when the specific global warming level is exceeded. This operation requires defining the duration of the time slice. The case solver may also provide information—based on dataset guidance or previous studies—regarding the relevant start and end dates of the time slices.
Apply pattern scaling	The operation that conducts pattern scaling of climate response to the global warming level.
Apply additional spatial and/or temporal downscaling	The operation that applies statistical or dynamical downscaling techniques to increase the spatial and/or temporal resolution of global or regional climate model outputs. This task is normally unnecessary if the selected data is already downscaled.
Apply data preprocessing	The operation that performs data preprocessing (e.g., regridding, gap-filling, aggregation, filtering, bias correction) on raw climate model output and observations to ensure it is accurate, consistent, and suitable for analysis.
Compute climate indices	The operation that computes relevant climate indices from both observational and climate model datasets. Possibly, emulators could be used to obtain relevant information for index computation.
Compute slice statistic	The task of computing a statistic, for example the mean, over the time slice.
Compute change	The task of calculating the change of the slice statistic with respect to baseline period.
Conduct observation analysis	The operation that analyzes observational datasets to establish historical trends and variability.
Conduct spatial aggregation	The operation that aggregates calculated indices.
Evaluate climate simulations	The operation that evaluates the performance of climate simulations against observations, by comparing how well climate models reproduce historical climate conditions for selected indices or variables. This evaluation helps determine which models could be more reliable for projecting future climate changes.
Choose the criteria for selecting or rejecting climate simulations	The operation that rejects the climate model simulations that do not meet the evaluation criteria or the ad hoc selection by the case solver.

Analyse climate information

Term	Definition
Analyse climate information	The operation that analyses the climate information to understand what future climatic changes are simulated and associated uncertainties. Sub-operations of this category can be found in the table below.
Quantify future climate change	The operation that analyses and projects the future climate by creating an output metric based on the selected climate simulations.
Quantify uncertainty	The operation that quantifies the uncertainty in projections of the selected climate simulations.
Estimate subjective confidence	The operation that indicates the subjective level of confidence in future climate change and uncertainty quantification.
Postprocess climate information	The operation that postprocesses (e.g., spatially aggregating) provided climate information

Assess climate impacts

Term	Definition
Assess climate impacts	The operation that conducts the climate impact assessment to understand the impacts of each hazard.
Select impact model	The operation that identifies models, transfer functions or datasets that can translate climate information into an impact assessment.
Conduct impact analysis	The operation that applies impact models, transfer functions or datasets to simulate, quantify, or describe the impacts
Postprocess impact analysis	The operation that postprocesses the provided climate impact information (e.g., spatial aggregation, regridding) as necessary

Conduct climate risk assessment

Term	Definition
Conduct climate risk assessment	The operation that conducts climate risk assessment.
Identify vulnerability	The operation that provides vulnerability information.
Identify exposure	The operation that provides exposure information.
Assess risk	The operation that conducts the climate risk assessment.

Select the preferred way to communicate climate information

Term	Definition
Select the preferred way to communicate climate information	The operation that selects how to communicate the climate or climate-impact information to the customer through visual (e.g., plot, diagram, flowchart, graph, map), quantitative (e.g., table), or qualitative (e.g., narrative) formats.

Methods

Below you can find the name of the method, its description, a reference source for the description if available, and the URI of the method in the knowledge graph.

Term	Definition
AI methods (experimental)	As for statistical downscaling, but using more complex models with multiple steps and layers that typically cannot be expressed in a single equation. Source: https://apps.epri.com/climate-data-user-guide/en/climate-model-downscaling.html
Bias correction	Algorithms that correct and minimise systematic differences of simulated GCM and RCM outputs relative to observational data. Source: Cannon et al. (2015) https://doi.org/10.1175/JCLI-D-14-00754.1
Bias quantification	Model bias is defined as the average of the difference between a GCM's simulations and some baseline values. The baseline values can come from observations or a benchmark model simulation, or ensemble mean. Bias indicates a systematic difference, and bias relative to reliable observations is interpreted as "error". [1] Bias can be quantified by a mean of differences between a simulation member and baseline (or mean absolute error, MAE, in the case of deriving absolute errors) or quantile difference (especially considering extremes). Source: https://glisa.umich.edu/wp-content/uploads/2021/03/Global-Climate-Model-Bias-and-Bias-Correction.pdf
Bilinear	A regridding method that uses a weighted average of the four nearest cells to determine a new cell value. Source: https://support.esri.com/en-us/gis-dictionary/bilinear-interpolation
CDF-t	A non-parametric quantile mapping method that attempts to be trend-preserving in all quantiles. CDFt applies a concatenation between a quantile mapping of future and historical climate model data and a quantile mapping of the future climate model with historical observations. It also includes a running window over the future period to account for changes in the simulated trend. Source:

	https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-cdft-class
Clustering	Clustering is performed to select representative simulations and thus reduce the number of members in a model ensemble (e.g. model culling). It can be accomplished by performing hierarchical cluster analysis on the patterns of climate change at a certain height k, which corresponds to the desired number of clusters [1,2]. Clustering using nonhierarchical k-means clustering algorithm is a method to derive weather patterns from observational data [3]. Source: Mendlik & Gobiet (2015) https://doi.org/10.1007/s10584-015-1582-0; Wilcke & Bärring (2016) https://doi.org/10.1016/j.envsoft.2016.01.002; Pope et al. (2022) https://doi.org/10.1007/s00382-021-06031-0
Cumulative Distribution Function	The cumulative distribution function (CDF) is the probability that a continuous random variable has a value less than or equal to a given value. The Probability Density Function (PDF) is the first derivative of the CDF. [1] The CDF is useful for those who want to know the probability of climate change being less than some threshold where an impact of interest starts to occur. [2] Source: https://confluence.ecmwf.int/display/FUG/Section+8.1.9.1+Cumulative+Distribution+Function,+Probability+Density+Function; https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---how-to-use-the-cdf-and-pdf-plots.pdf
Delta method	The delta change method applies the climate change trend from the model to historical observations, therefore generating modified observations rather than a modified model output. So the output from this method has the same number of timesteps as the observations data, and not the same number as the future climate model like other debiasers. Multiplicative change is typically used for precipitation and additive scaling for temperature. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-deltachange-class
Descriptive statistics	Field of quantitative research: the process of using and analysing quantitatively described or summarised features from a collection of information Source: https://www.wikidata.org/wiki/Q380344 + https://en.wikipedia.org/wiki/Descriptive_statistics

Difference Quantification	The difference can be quantified either by absolute delta, relative delta (percentage change between the future climate and baseline relative to baseline, pre-processed similarly), or standardised anomaly calculation among other methods. Absolute delta is the difference between the future climate and baseline of the variable. In both cases variables are annual climatological normals, i.e. averaged over the 30 years (Navarro-Racines et al., 2020). Relative delta is the percentage change between the future climate and baseline relative to the baseline. As previously, the variables are annual climatological normals. [1] The standardised anomalies, also referred to as normalised anomalies, measure the magnitude of climate change, at local level, by quantifying the distance, measured in standard units, between a data value at a location and its corresponding mean. The metric is calculated by dividing anomalies – with anomalies being defined as the deviation observed in each time from a baseline – by the standard deviation of the interannual variability during the baseline period. The Standardized local anomalies measure the degree of similarity and dissimilarity between two distinct time periods (e.g. between a baseline and future period) using the standardized Euclidean distance (SED). Higher SED scores correlate with more significant local climate change and incorporate alterations across all considered variables. [2,3] Source: Navarro-Racines et al. (2020) https://doi.org/10.1038/s41597-019-0343-8; Taheri et al. (2024) https://doi.org/10.1111/ecog.07176; Hubbard et al. (2025) https://doi.org/10.1111/ecog.07614
Duration	Physical quantity for describing the temporal distance between events Source: https://www.wikidata.org/wiki/Q2199864
Dynamical downscaling using climate models	Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information. Dynamical downscaling uses a limited-area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a domain area of 106 to 107 km2 and a resolution of 20 to 60 km. Source: https://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/dynamical_downscaling.pdf

Empirical Distribution Function	The empirical cumulative distribution function (ECDF) is a step function estimate of the CDF of the distribution underlying a sample. Source: https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.ecdf.html
Ensemble mean	The ensemble mean is the average of the output values of the ensemble members (i.e. the sum of the values divided by the number of ensemble members unless models are weighted). Each ensemble member result is the sum of a smooth forced signal and the accompanying natural variability noise. The natural variability is different for each model/ensemble member and tends to average out so that the ensemble mean estimates the smooth forced signal. The multi-model ensemble mean represents those features of projected climate change that survive ensemble averaging and so are common to models as a group. Source: https://confluence.ecmwf.int/display/FUG/Section+8.1.2+ENS+Mean+and+Spread; https://archive.ipcc.ch/ipccreports/tar/wg1/347.htm
Ensemble median	The ensemble median is the middle value of the output values of the ensemble members when sorted into a list (i.e. the same number of ensemble member values below and above the middle value). The median lies at the centre of the range of the ensemble members and can be more descriptive of the data set than the mean. Source: https://confluence.ecmwf.int/display/FUG/Section+8.1.2+ENS+Mean+and+Spread
Ensemble range	The ensemble range (also known as ensemble value range) is a confidence measure that provides information about the ensemble spread of the projected climate change signals. The ensemble range indicates the range of the central half of the models, i.e. the models that group around the median of the models (i.e. the interquartile range). Source: https://climateinformation.org/knowledge-base/how-to-interpret-ensemble-value-range/
Ensemble standard deviation	The multi-model ensemble variance, assuming no correlation between the forced and variability components, measures the inter-model scatter of the forced component and the natural variability. The scatter of results about the ensemble mean (measured by the ensemble variance/standard deviation) is an indication of uncertainty in the results and is seen to increase with time. Source: https://archive.ipcc.ch/ipccreports/tar/wg1/347.htm
Ensemble statistics	A sub-category of descriptive statistics dedicated to ensemble analysis.

Equidistant CDF matching	A parametric quantile mapping method that attempts to be trend-preserving in all quantiles. It applies quantile-wise correction by adding the difference between a quantile mapping of observations and future values and a quantile mapping of historical climate model values to the future climate model ones. In essence, this method says that future climate model data can be bias-corrected directly with reference period observations, if the quantile specific difference between present-day and future climate model simulations is taken into account. This allows for changes in higher moments in the climate model, compared to standard Quantile Mapping where just the mean is assumed to change in future climate. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-ecdfm-class
Exceedance probability	For any threshold, x, the probability that during the period (e.g., a year) the random variable in question, X, will exceed some x [1]. The inverse of the return period [2]. Source: https://glossary.ametsoc.org/wiki/Exceedance_probability; https://thefloodhub.co.uk/blog/understanding-flood-risk/#:~:text=This%20method%20is%20useful%20because%20it%20helps%20people,the%20return%20period,%20and%20is%20expressed%20as%20%E2%80%98AEP%E2%80%99.
Extreme value distribution	Probability distribution of the largest or smallest observations in a sample. Source: https://unterm.un.org/unterm2/en/view/1f90fcbf-c795-4d8a-9f78-21673465c159
Frequency analysis	Procedure used to estimate the probabilities of occurrence of hydrometeorological events based on interpretation of past records of these events. Source: https://unterm.un.org/unterm2/en/view/722911fe-712e-482b-a881-f8a42f5967df
Global warming level extraction	Global warming levels (GWLs) offer a way to communicate future climate change. In this approach, the regional climate change response is shown relative to the average global warming (e.g., 0.5°C, 1.0°C, 1.5°C, 2.0°C) above a specified period, typically pre-industrial (1850-1900). Source: https://climatedata.ca/resource/introduction-to-global-warming-levels/
Inferential statistics	Inferential statistics refers to the branch of statistics that is used to draw conclusions and make decisions about a population based on samples, often through hypothesis testing. It helps determine whether the observed differences or relationships in the data are significant and not due to chance. Source:

	https://www.sciencedirect.com/topics/social-sciences/inferential-statistics
Inverse distance weighting	An interpolation method that assigns influence or weight values to spatial features relative to a specific point—often using a power function based on distance. Nearby features have greater weight or influence on the initial point than features that are farther away. Source: https://support.esri.com/en-us/gis-dictionary/inverse-distance-weighting
ISIMIP3BASD	A semi-parametric quantile mapping method that attempts to be trend-preserving in all quantiles by generating 'pseudo future observations' and executing the quantile mapping between the future climate model and the pseudo future observations. Refer to Lange et al. (2019) for further information. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-isimip-class; Lange, S.: Trend-preserving bias adjustment and statistical downscaling with ISIMIP3BASD (v1.0), Geosci. Model Dev., 12, 3055–3070, https://doi.org/10.5194/gmd-12-3055-2019, 2019.
Linear regression	Simple linear regression is used to estimate the relationship between two quantitative variables. Source: https://unterm.un.org/unterm2/en/view/8218159a-1d23-45b0-a108-fe6e49776f97
Linear scaling	Linear scaling corrects a climate model by the difference in the mean of observations and the mean of the climate model on the reference period, either additively or multiplicatively. The present day model bias is calculated and then either subtracted or divided from the future climate model data. Multiplicative scaling is classically used for precipitation and additive scaling for temperature. Additive scaling amounts to a simple mean bias correction, whilst multiplicative one adjusts both mean and variance, but keeps their ratio constant. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-linearscaling-class
Maximum	Greatest or largest value or element Source: https://www.wikidata.org/wiki/Q10578722
Mean	Sum of a collection of numbers divided by the number of numbers in the collection Source: https://www.wikidata.org/wiki/Q19033
Median	Middle quantile of a data set or probability distribution Source: https://www.wikidata.org/wiki/Q226995
Minimum	Lowest or smallest value or item in a partially ordered set Source: https://www.wikidata.org/wiki/Q10585806

Model sub-selection	The model sub-selection approach involves filtering climate model simulations to include only those that reach or exceed a specific global mean temperature threshold (e.g., 1.5°C, 2°C, 4°C). This method enables the analysis of regional climate impacts at distinct global warming levels by selecting subsets of underlying GCM runs based on their temperature response. Source: Copilot-modified from James et al. (2017) https://doi.org/10.1002/wcc.457
Model weighting	Climate model weighting is a technique used to improve the reliability and reduce bias and spread of climate projections by giving different climate models in an ensemble different levels of influence. Instead of averaging all models equally, this approach assigns weights to each ensemble member. Weights are typically calculated based on historical model performance in several metrics as well as by their independence to all the other models in the ensemble based on their output fields in several metrics. Source: Knutti et al. (2017) https://doi.org/10.1002/2016GL072012; https://docs.esmvaltool.org/en/latest/recipes/recipe_climwip.html
Nearest neighbour	A regridding technique in which the new cell value is calculated using the value of the nearest cell. It is often used to resample categorical or integer data (for example, land use, soil, or forest type). Source: https://support.esri.com/en-us/gis-dictionary/nearest-neighbor-resampling (modified to remove references to raster processing)
Pattern matching	A weather pattern refers to a specific daily circulation type over a defined geographical domain. Weather patterns are matched based on their closest distance—defined as the area-weighted sum of squares difference at each grid point of model output. Source: Neal et al. (2016) https://doi.org/10.1002/met.1563; Pope et al. (2022) https://doi.org/10.1007/s00382-021-06031-0
Pattern scaling	Pattern scaling is an emulation technique that takes advantage of the fact that local and seasonal changes in surface climate are often approximately linear in the rate of warming over land and across the globe. This allows interpolation away from a limited number of available GCM simulations, to assess alternative future emissions scenarios. Climate-change patterns (or "patterns") are coefficients of the regression between areal mean warming over Earth's land regions and local changes in surface climatology. They are derived by comparison against outputs from GCMs, and presented as local monthly mean changes over land per degree of mean warming over land. Pattern scaling is a simple procedure in which these patterns are multiplied by areal mean warming over land to give local monthly changes in climatology. Source: Zelazowski et al. (2018) https://doi.org/10.5194/gmd-11-541-2018

Peaks-over-threshold	Peaks-over-threshold analysis is used to obtain a sample defined by all peak values that lie above a certain truncation level (usually called the threshold or base level). Together with block (typically annual) maxima, it is one of the methods to identify extreme values. Source: From Bezek at al. (2014) https://doi.org/10.1080/02626667.2013.831174
Probability Density Function	A probability density function (PDF) is a function that indicates the relative chances of occurrence of different outcomes of a variable. The function integrates to unity over the domain for which it is defined and has the property that the integral over a sub-domain equals the probability that the outcome of the variable lies within that sub-domain. For example, the probability that a temperature anomaly defined in a particular way is greater than zero is obtained from its PDF by integrating the PDF over all possible temperature anomalies greater than zero. Probability density functions that describe two or more variables simultaneously are similarly defined. Source: https://unterm.un.org/unterm2/en/view/9f18f708-7341-44e9-96f8-d29d49ba2cdb
Quantile delta mapping	A parametric quantile mapping method that also attempts to be trend-preserving. This method bias corrects the future climate model data directly using reference period observations. This is then multiplied by the quotient of future climate model data and a quantile mapping between past and future climate model data to account for the change from past to future period in all quantiles. Delta Quantile Mapping is approximately trend preserving in all quantiles because the absolute or relative change is calculated and applied for each quantile individually. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-quantiledeltamapping-class
Quantile mapping	Quantile mapping maps every quantile of the climate model distribution to the corresponding quantile in observations during the reference period. Optionally, additive or multiplicative detrending of the mean can be applied to make the method trend preserving in the mean. Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-quantilemapping-class
Quantile regression	Quantile regression is defined as a statistical technique that estimates the conditional quantiles of a response variable distribution, allowing for the modeling of the effects of predictor variables on different points (quantiles) of the response distribution rather than just the mean. It is particularly useful for identifying limiting constraints by examining upper regression quantiles, which can reveal relationships not detectable by traditional linear

	regression. Source: https://www.sciencedirect.com/topics/mathematics/quantile-regression
Quantiles	A quantile defines a particular part of a data set, i.e., a quantile determines how many values in a distribution are above or below a certain limit. Special quantiles are the quartile (quarter), the decile (tenth), and percentiles (hundredth). Source: https://www.statista.com/statistics-glossary/definition/356/quantile/
Return period analysis	An estimate of the average time interval between occurrences of an event (e.g., flood or extreme rainfall) of (or below/above) a defined size or intensity. See also Return value. https://unterm.un.org/unterm2/en/search?searchTerm=return%20period&searchType=0&searchLanguages=en&languagesDisplay=en&acronymSearch=true&localDBSearch=true&termTitleSearch=true&phraseologySearch=false&footnoteSearch=false&fullTextSearch=false&facetedSearch=false&buildSubjectList=true
Scale distribution mapping	Scale distribution mapping (SDM) is a parametric quantile mapping approach that also attempts to be trend preserving in all quantiles. In addition to the quantile mapping the method also contains an event likelihood adjustment. SDM scales the observed distribution by changes in magnitude and additionally likelihood of events – either multiplicatively (for precipitation) or additively (for temperature). Source: https://ibicus.readthedocs.io/en/latest/reference/debias.html#ibicus-debias-scaleddistributionmapping-class
Significance testing	Significance testing is used to establish the robustness of simulated climate change driven by external forcing (the signal) relative to model internal variability (the noise). Signal in climate simulations is usually calculated as the difference between the average of a simulation with external forcing and a hypothesised value (in a one-sample test) or the average of a simulation with basis forcing (in a two-sample test). Noise in climate simulations refers to internal variability, and it is estimated from the variability information in the sample (or samples in case of a two-sample test). Source: Decremer et al. (2014) https://doi.org/10.3402/tellusa.v66.23139
Spatial downscaling	Downscaling is a method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution or high-resolution global models. The empirical/statistical methods develop statistical relationships that link the large-scale atmospheric variables with -local/-regional climate variables. In all cases, the

	quality of the driving model remains an important limitation on the quality of the downscaled information. Source: https://unterm.un.org/unterm2/en/search?searchTerm=downscaling&searchType=0&searchLanguages=en&languagesDisplay=en&acronymSearch=true&localDBSearch=true&termTitleSearch=true&phraseologySearch=false&footnoteSearch=false&fullTextSearch=false&facetedSearch=true&buildSubjectList=false
Spatial interpolation	Used for regridding and gap-filling. Regridding is the process of interpolating from one grid resolution to a different grid resolution. This could involve temporal, vertical or spatial ('horizontal') interpolations. However, most commonly, regridding refers to spatial interpolation. There are numerous grid interpolation methods and users should choose the method appropriate for the intended task. Using an inappropriate interpolation scheme may lead to misleading results. Further, most climate grids are georeferenced on a sphere where pole singularities and the convergence of the longitude meridians can be issues that need to be addressed. Source: https://climatedataguide.ucar.edu/climate-tools/regridding-overview
Spectral analysis	Spectral analysis is defined as a set of mathematical tools that characterise signals based on their frequency content [1]. Spectral analysis was initially developed to analyse time-dependent functions and time series, aiming to identify underlying spectral content. This typically involved identifying frequencies within the series that contain significant amplitudes. Nonparametric or parametric methods are applied to a time series, or to any sequential data with at least one independent variable such as spatial coordinates. The analysis separates out spectral content such as waves or oscillations, extracting data or filtering the data to simplify future processing [2]. Source: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/spectral-analysis; Silversides (2020). https://doi.org/10.1007/978-3-030-26050-7_309-1
Standard deviation	Dispersion of the values of a random variable around its expected value Source: https://www.wikidata.org/wiki/Q159375
Statistical downscaling	Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information. Statistical downscaling first derives statistical relationships between observed small-scale (often station level) variables and larger (GCM) scale variables, using either analogue methods (circulation typing), regression analysis, or neural

	network methods. Future values of the largescale variables obtained from GCM projections of future climate are then used to drive the statistical relationships and so estimate the smaller-scale details of future climate (see also weather generators). Source: https://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/statistical_downscaling.pdf
Temporal smoothing	An averaging of data in time, designed to compensate for random errors or fluctuations of a scale smaller than that presumed significant to the problem at hand. Source: https://glossary.ametsoc.org/wiki/Smoothing
Threshold analysis	Threshold analysis refers to the selection of all values that are higher or lower than a reference bound, based on a mathematical inequality. For climatic suitability studies, values must fall between two reference (i.e., threshold) values—an upper and a lower bound—to be deemed climatically suitable for each relevant variable. This selection creates a binary mask, which can be combined with other masks according to set theory. No source
Thresholds	Mathematical values with different meanings by domain; a quantitative threshold Source: https://www.wikidata.org/wiki/Q3754024
Time series analysis	Area of statistics: methods for analysing time series data in order to extract meaningful statistics and other characteristics of the data Source: https://www.wikidata.org/wiki/Q11850042 + https://en.wikipedia.org/wiki/Time_series
Time slice	The time slice method identifies the point in time when a specific global mean surface temperature increment (e.g., 1.5°C, 2°C) above pre-industrial (usually 1850–1900) is reached in each GCM simulation. A multi-year period - 10 years on either side of this central estimate - is selected (to account for uncertainty in the timing of reaching a given warming level) and extracted from each respective RCM as a 21-year time slice. Source: Combined James et al. (2017) https://doi.org/10.1002/wcc.457 and Hanlon et al. (2021) https://doi.org/10.1007/s10584-021-03100-5
Transfer function	Spatiotemporal modeling covers a broad spectrum of algorithms dealing with spatiotemporal data and a wide range of applications in many fields. The generic idea behind these modeling approaches is to analyse the temporal pattern of target variables within a spatial domain of interest. Source: Bhattacharjee et al. (2022) https://doi.org/10.1007/978-3-030-26050-7_418-1
Trend analysis	Given a time series of climate variable, the trend is the rate at which the variable changes over a time period. The trend may be linear or nonlinear. However, generally, it is synonymous with the linear slope of the line fit to the time series.

	Source: https://climatedataguide.ucar.edu/climate-data-tools-and-analysis/trend-analysis
Uncertainty quantification	Characterization and reduction of uncertainties in both computational and real world applications Source: https://www.wikidata.org/wiki/Q7882499

Hazards

Below you can find the name of the hazard, its description, a reference source for the description if available, and the URI of the hazard in the knowledge graph.

Term	Definition
Agricultural drought	Conditions that result in adverse crop responses, usually because plants cannot meet potential transpiration as a result of high atmospheric demand and/or limited soil moisture. Source: https://glossary.ametsoc.org/wiki/Agricultural_drought
Avalanche (aka snowslide)	A mass of snow (perhaps containing ice and rocks) moving rapidly down a steep mountain slope. Avalanches may be characterized as loose and turbulent, or slab; either type may be dry or wet according to the nature of the snow forming it, although dry snow usually forms loose avalanches and wet snow forms slabs. A large avalanche sweeps a current of air along with and in front of it as an avalanche wind, which supplements its already tremendous destructive force. Source: https://glossary.ametsoc.org/wiki/Avalanche
Blizzard	A blizzard is a severe snow storm characterised by poor visibility, usually occurring at high-latitude and in mountainous regions. A blizzard is defined as moderate or heavy falling snow (either continuous or in the form of frequent showers) with winds speeds of 30 mph (48 km/hr) or more and a reasonably extensive snow cover reducing visibility to 200 metres (0.13 miles) or less. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0034 + https://weather.metoffice.gov.uk/learn-about/weather/types-of-weather/snow/blizzard
Coastal erosion	Coastal erosion is the process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast. Source: https://toolkit.climate.gov/hazard/erosion-and-shoreline-recession
Coastal inundation	Coastal Flooding is when water inundates or covers normally dry coastal land as a result of high or rising tides or storm surges. Source: https://www.fema.gov/sites/default/files/documents/fema_coastal-glossary.pdf
Cold wave (aka cold snap)	A cold wave is a rapid fall in temperature within 24 hours and extreme low temperatures for an extended period. The temperatures classified as a cold wave are dependent on the location. Extreme cold is sometimes accompanied

	by winter storm events in which the main types of precipitation are snow, sleet, or freezing rain. Source: https://www.rmets.org/metmatters/cold-waves
Drought	A drought is a deficiency of precipitation over an extended period of time resulting in a water shortage. Drought conditions range from dry weather patterns and low water supply to impacts on crops, ecosystems, and disruptions in supply and demand for various commodities. Source: https://www.drought.gov/what-is-drought/drought-basics
Ecological drought	An episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems. Source: https://doi.org/10.1175/BAMS-D-16-0292.1
Estuarine flooding	Estuaries are inlet areas of the coastline where the coastal tide meets a concentrated seaward flow of fresh water in a river. The interaction between the seaward flow of river water and landward flow of saline water during high tides may cause a build-up of water or inland-moving tidal bore. Frequently, the funnel shape characteristic of many estuaries causes an increase in high water levels in the upper, narrowing reaches of the associated river. These types of flood are mostly experienced in deltaic areas of rivers along the coasts, for example the mouths of the Ganges. They are more frequent and less severe in terms of inundated depth and area than flooding caused by storm surges. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0005
Extratropical cyclones	An extra-tropical cyclone is a storm system that primarily gets its energy from the horizontal temperature contrasts that exist in the atmosphere. Extra-tropical cyclones (also known as mid-latitude or baroclinic storms) are low pressure systems with associated cold fronts, warm fronts, and occluded fronts. Extra-tropical cyclones occur in the extra-tropics (generally more than 30° latitude away from the equator). They consist of an approximately circular region of low surface pressure, of a radius of 100–2000 km. At the same time, high up in the atmosphere (around 10 km altitude) a jet stream is typically found relatively close by. In fact, the intensity of an extra-tropical cyclone is closely related to the strength of this jet stream. The strongest extra-tropical cyclones occur in the winter months when the jet stream is at its strongest. Periods when the jet stream is unusually strong can lead to two or more strong cyclones occurring within days of each other. The total lifecycle of an extra-tropical cyclone from birth (genesis) through to development and on to decay (lysis) can occasionally be more than 10 days, although somewhere in the range of 2 to 5 days is more typical. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0031
Flash drought	An unusually rapid onset drought event characterized by a multiweek period of accelerated intensification that culminates in impacts to one or more sectors (agricultural, hydrological, etc.). Source: https://glossary.ametsoc.org/wiki/Flash_drought
Flash flooding	A flash flood is a flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood

	is less than four to six hours. A flash flood is generally characterised by raging torrents after heavy rains, a dam or levee failure or a sudden release of water in a previously stopped passage (i.e., by debris or ice) that rips through riverbeds, urban streets, or mountain canyons sweeping away everything in its path. Steep terrain tends to concentrate runoff into streams very quickly and is often a contributory factor. Changes in soil properties (e.g., burn areas from wildfires), hydrophobic or impervious soils, removal of surface vegetation, and excess runoff from warm rainfall on significant snowpack can also be important contributors. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0006
Flooding	
Fluvial flooding	Fluvial flooding, which is also referred to as river or riverine flooding, is caused by unusually high water levels in rivers, caused by increased runoff from heavy or prolonged rainfall. Flooding occurs when the amount of water exceeds the capacity of the river channel, and overtopping of river banks occurs. Source: https://handbook.climaax.eu/notebooks/workflows/FLOODS/02_River_flooding/FLOOD_RIVER_intro.html
Frost	The condition that exists when the temperature of the earth's surface and earthbound objects fall below freezing. Depending upon the actual values of ambient-air temperature, dewpoint, and the temperature attained by surface objects, frost may occur in a variety of forms. These include a general freeze, hoarfrost (or white frost), and dry freeze (or black frost). If a frost period is sufficiently severe to end the growing season (or delay its beginning), it is commonly referred to as a killing frost. Source: https://glossary.ametsoc.org/wiki/Frost
Gales	A gale is a wind with a speed between 34 and 40 knots (62–74 km/h or 32–38 mph). Gales correspond to force 8 on the Beaufort scale (also called Beaufort wind force scale), which is an empirical measure that relates wind speed to observed conditions at sea or on land. Source: https://www.preventionweb.net/understanding-disaster-risk/terminology/hips/mh0054
Groundwater drought	Groundwater drought is the sustained and extensive occurrence of below average availability of groundwater. Groundwater droughts are marked by lower than average water levels in aquifers, borehole and wells, and by reduced flows to groundwater-fed rivers and wetlands. Related to hydrological drought. Source: https://www.bgs.ac.uk/groundwater/flooding-and-drought/groundwater-drought-research-overview/
Groundwater flooding	Groundwater flooding occurs when the water table in permeable rocks rises to enter basements/cellars or comes up above the ground surface. Groundwater flooding is not necessarily linked directly to a specific rainfall event and is generally of longer duration than other causes of flooding (possibly lasting for weeks or even months).

	Source: https://www2.bgs.ac.uk/groundwater/flooding/groundwaterHomesFAQ.html
Heatwave	A heatwave can be defined as a period where local excess heat accumulates over a sequence of unusually hot days and nights. Heatwaves consist of period of abnormally hot weather that can last from a few days to months where the maximum and minimum temperatures are unusually high to a location. The minimum temperature is as important as the maximum temperature as cooler nights allow the body to recover and if the nights are unusually hot, higher temperatures will be reached earlier in the day and last for longer. Source: https://wmo.int/topics/heatwave
High tide flooding	High tide flooding is the overflow or excess accumulation of water that covers typically dry coastal land and occurs during high tides (especially, perigean). As relative sea levels rise, high tide flooding is occurring more frequently, even on sunny days. By definition, a coastal storm is not necessary for high-tide flooding to occur. However, even relatively weak onshore winds can increase the level of flooding. High tide flooding creates short-term impacts like road closures, overflowing storm drains, and temporary business closures. Over the long term, recurrent high tide flooding causes more severe impacts, like damage to below-ground infrastructure and degraded wetlands. Source: https://tidesandcurrents.noaa.gov/high-tide-flooding/ + https://coast.noaa.gov/stormwater-floods/understand/
Hydrological drought	Prolonged period of below-normal precipitation, causing deficiencies in water supply, as measured by below-normal streamflow, lake and reservoir levels, groundwater levels, and depleted soil moisture content. Source: https://glossary.ametsoc.org/wiki/Hydrological_drought
Ice-jam flooding	An ice jam flood is caused by an accumulation of ice in a river, stream or other flooding source that reduces the cross-sectional area available to carry the flow and forces an increase in water-surface elevation Source: https://www.fema.gov/sites/default/files/2020-02/Ice_Jam_Guidance_Feb_2018.pdf
Icestorm	An ice storm is a storm characterised by a fall of freezing precipitation. The attendant formation of glaze on terrestrial objects creates many hazards. Ice storms result from the accumulation of freezing rain, which is rain that becomes supercooled and freezes upon impact with cold surfaces. Freezing rain is most commonly found in a narrow band on the cold side of a warm front, where surface temperatures are at or just below freezing. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0037
Landslide	A landslide is a mass movement of material, such as rock, earth or debris, down a slope. They can happen suddenly or more slowly over long periods of time. When the force of gravity acting on a slope exceeds the resisting forces of a slope, the slope will fail and a landslide occurs. External factors can lead to landslides happening, including:heavy rainfall leading to saturation of the ground; erosion of the base of a slope; and changes to the material's strength through weathering.

	Source: https://www.bgs.ac.uk/discovering-geology/earth-hazards/landslides/
Marine heatwave	Marine heatwaves are periods of persistent anomalously warm ocean temperatures, which can have significant impacts on marine life as well as coastal communities and economies. Source: https://psl.noaa.gov/marine-heatwaves/
Meteorological drought	Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. For example, some definitions of meteorological drought identify periods of drought on the basis of the number of days with precipitation less than some specified threshold. This measure is only appropriate for regions characterized by a year-round precipitation regime such as a tropical rainforest, humid subtropical climate, or humid mid-latitude climate. Locations such as Manaus, Brazil; New Orleans, Louisiana (U.S.A.); and London, England, are examples. Other climatic regimes are characterized by a seasonal rainfall pattern, such as the central United States, northeast Brazil, West Africa, and northern Australia. Extended periods without rainfall are common in Omaha, Nebraska (U.S.A.); Fortaleza, Ceará (Brazil); and Darwin, Northwest Territory (Australia), and a definition based on the number of days with precipitation less than some specified threshold is unrealistic in these cases. Other definitions may relate actual precipitation departures to average amounts on monthly, seasonal, or annual time scales. Source: https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx
Ocean acidification	Increased acidity (reduction in pH) of seawater over an extended time period, as a result of increased carbon dioxide concentration in the ocean, primarily due to uptake of carbon dioxide from the atmosphere. Source: https://changingclimate.ca/CCCR2019/definitions/
Ocean deoxygenation	In ocean and freshwater environments, the term "hypoxia" refers to low or depleted oxygen in a water body. The amount of oxygen in any water body varies naturally, both seasonally and over time. This occurs due to a balance between oxygen input from the atmosphere and certain biological and chemical processes, some of which produce oxygen while others consume it. Stratification in the water column, which occurs when less dense freshwater from an estuary mixes with heavier seawater, is one natural cause of hypoxia. Limited vertical mixing between the water "layers" restricts the supply of oxygen from surface waters to more saline bottom waters, leading to hypoxic conditions in bottom habitats. Hypoxia is often associated with the overgrowth of certain species of algae, which can lead to oxygen depletion when they die, sink to the bottom, and decompose. In some cases, vast stretches of open water become hypoxic. Unable to sustain life, these areas, called dead zones, may cause die-offs of fish, shellfish, corals, and aquatic plants. Source: https://oceanservice.noaa.gov/hazards/hypoxia/
Sea level rise	Change to the height of sea level, both globally and locally (relative sea level change) at seasonal, annual, or longer time scales due to (1) a change in

	ocean volume as a result of a change in the mass of water in the ocean (e.g., due to melt of glaciers and ice sheets), (2) changes in ocean volume as a result of changes in ocean water density (e.g., expansion under warmer conditions), (3) changes in the shape of the ocean basins and changes in the Earth's gravitational and rotational fields, and (4) local subsidence or uplift of the land. Global mean sea level change resulting from change in the mass of the ocean is called barystatic. The amount of barystatic sea level change due to the addition or removal of a mass of water is called its sea level equivalent (SLE). Sea level changes, both globally and locally, resulting from changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric. Barystatic and steric sea level changes do not include the effect of changes in the shape of ocean basins induced by the change in the ocean mass and its distribution. Source: https://www.ipcc.ch/srocc/chapter/glossary/
Severe thunderstorms	In general, a local storm, invariably produced by a cumulonimbus cloud and always accompanied by lightning and thunder, usually with strong gusts of wind, heavy rain, and sometimes with hail. It is usually of short duration, seldom over two hours for any one storm. A thunderstorm is a consequence of atmospheric instability and constitutes, loosely, an overturning of air layers in order to achieve a more stable density stratification. A strong convective updraft is a distinguishing feature of this storm in its early phases. A strong downdraft in a column of precipitation marks its dissipating stages. Thunderstorms often build to altitudes of 40 000–50 000 ft in midlatitudes and to even greater heights in the Tropics; only the great stability of the lower stratosphere limits their upward growth. A unique quality of thunderstorms is their striking electrical activity. The study of thunderstorm electricity includes not only lightning phenomena per se but all of the complexities of thunderstorm charge separation and all charge distribution within the realm of thunderstorm influence. In U.S. weather observing procedure, a thunderstorm is reported whenever thunder is heard at the station; it is reported on regularly scheduled observations if thunder is heard within 15 minutes preceding the observation. Source: https://glossary.ametsoc.org/wiki/Thunderstorm
Severe winter weather	Severe winter weather consists of winter storm events in which the main types of precipitation are snow, sleet, or freezing rain. Source: https://toolkit.climate.gov/hazard/severe-winter-weather
Snow drought	Snow drought occurs when there is a period of abnormally low snowpack for the time of year in question. Snow drought is described as either dry or warm, depending on whether the drought is a result of below-normal cold-season precipitation (dry) or a lack of snow accumulation despite near-normal precipitation, usually as a result of warm temperatures that cause precipitation to fall as rain rather than snow or an unusually early snowmelt (warm). Source: https://glossary.ametsoc.org/wiki/Snow_drought
Snowmelt flooding	A snowmelt flood is a significant flood rise in a river caused by the melting of snowpack accumulated during the winter. In upland and high-latitude areas where extensive snow accumulates over winter, the spring thaw produces meltwater runoff. If temperature rises are rapid, the rate of melting may

	produce floods, which can extend to lower parts of the river systems. The severity of meltwater floods will increase if the thaw is accompanied by heavy rainfall and can be further exacerbated if the subsoil remains frozen. Although a seasonal occurrence where major snowfields exist in headwaters, which may produce beneficial flooding in downstream areas, severe effects can occur on smaller scales, especially in areas subject to changes between cold and warmer rainy winter weather. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0011
Snowstorms	A snow storm is a meteorological disturbance giving rise to a heavy fall of snow, often accompanied by strong winds Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0039
Storm surge	Storm surge is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The amplitude of the storm surge at any given location depends on the orientation of the coast line with the storm track; the intensity, size, and speed of the storm; and the local bathymetry. Source: https://oceanservice.noaa.gov/facts/stormsurge-stormtide.html
Surface water flooding	Pluvial (also known as surface water) flooding is caused when the volume of rainwater falling does not drain away through the existing drainage systems or soak into the ground but lies on or flows over the ground instead. This type of flooding is usually short-lived and associated with heavy downpours of rain, thunderstorms, etc. This often occurs in urban areas due to artificial impermeable surfaces, e.g. concrete, roads, and paths, and can worsen when drains become blocked. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0012
Tornado	A tornado is a rotating column of air, extending from the base of a cumuliform cloud, and often visible as a condensation funnel in contact with the ground, and/or attendant circulating dust or debris cloud at the ground. A large tornado in which the condensation funnel is at least as wide horizontally at the ground as it is in height from the ground to the cloud base may be referred to as a wedge tornado. During the dissipation stage of a tornado, the condensation funnel will shrink and narrow in width, becoming rope-like (a rope funnel), and may also become contorted. Some tornadoes may contain secondary vortices within the main circulation (suction vortices or subvortices). The strength of a tornado can be estimated from the degree of damage caused using the Enhanced Fujita scale. Tornadoes can be classified into the following distinct formation groups: Type I (in association with supercells), Type II (in association with quasi-linear convective systems), and Type III (localised convective and shear vortices – these comprise landspouts, waterspouts and cold-air funnels). Landspout is a tornado that does not arise from organised storm-scale rotation and is therefore not associated with a wall cloud (murus) or a mesocyclone. Waterspout is a tornado occurring over water; normally a relatively small, weak rotating column of air over open water below a Cumulonimbus or Cumulus congestus cloud. Source:

	https://www.preventionweb.net/understanding-disaster-risk/terminology/hips/mh0059
Tropical cyclones	A tropical cyclone is a warm-core, non-frontal, synoptic-scale cyclone that originates over tropical or subtropical waters. It is characterized by organized deep convection and a closed surface wind circulation around a well-defined center. Tropical cyclones that form in the Northwestern Pacific Basin (between 180° and 100°E in the Northern Hemisphere) and produce sustained winds of at least 33 m/s are called typhoons. If a tropical cyclone with sustained wind speeds exceeding 33 m/s develops in the North Atlantic Ocean, the Northeast Pacific Ocean (east of the International Date Line), or the South Pacific Ocean (east of 160°E), it is referred to as a hurricane. Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0057 + https://gpm.nasa.gov/education/articles/what-hurricane-typhoon-or-tropical-cyclone
Wildfire	Wildfires (also known as landscape fires) are any unplanned or uncontrolled fire affecting natural, cultural, industrial and residential landscapes. Unplanned or uncontrolled landscape fires (wildfires) are either started by natural causes (lightning, occasionally by burning coal seams or volcanic activity) or – predominantly at global level – by human activities and primarily by burning live or dead vegetation in natural or anthropogenically altered ecosystems. These include forests, grasslands, bush (shrub, scrub), and organic terrain (peatlands, wetlands), cultivated lands (agricultural and pasture lands, plantations, abandoned formerly cultivated lands) as well as protected lands (wilderness, conservation sites). In addition, unplanned landscape fires may affect residential and industrial areas (houses and other structures, peri-urban fringes, infrastructure including critical infrastructure) and remnants of human activities (waste deposits, remediated and un-remediated mine sites, contaminated lands), resulting in co-burning of hazardous / toxic substances. Landscape fire attributes and descriptions include: fuel type (type of vegetation / combustible material burned, such as grass, shrub, forest, peat); fire type (ground, surface, crown fire); fire behaviour, energy release and emission characteristics (fire spread, fire intensity, fire severity, radiative power, smouldering vs. flaming combustion, gas and particle emissions); and temporal and spatial dimension (e.g., creeping fires in organic terrain, spotting flashovers, short- to long-lasting events; single vs. multiple fires). Source: https://www.undrr.org/understanding-disaster-risk/terminology/hips/en0013
Wind drought	A period where the instantaneous power output from wind farms is continuously below a specified threshold. Alternatively, wind droughts can be defined in terms of being below a specified threshold of the moving average of the wind energy time series, which can result in identification of longer drought period. Source: https://doi.org/10.1016/j.renene.2023.119847
Wind storms	A storm in which winds (that could be damaging) are its most impactful or distinctive aspect. Windstorms may be accompanied by precipitation (e.g., during a downburst or a derecho) or not (e.g., during a duststorm or a

| | sandstorm). Source: https://glossary.ametsoc.org/wiki/Windstorm |

Indices

Below you can find the name of the indice, its description, a reference source for the description if available, and the URI of the indice in the knowledge graph.

Term	Definition
12-Month River Drought (Extreme)	Number of months with a Standardised Streamflow Index (calculated from 12-month accumulated river flow) less than -1.5. Source: UK CRI
12-Month River Drought (Severe)	Number of months with a Standardised Streamflow Index (calculated from 12-month accumulated river flow) less than-2.0. Source: UK CRI
24-Month River Drought (Extreme)	Number of months with a Standardised Streamflow Index (calculated from 24-month accumulated river flow) less than -1.5. Source: UK CRI
24-Month River Drought (Severe)	Number of months with a Standardised Streamflow Index (calculated from 24-month accumulated river flow) less than -2.0. Source: UK CRI
Accumulated Frost	Sum of minimum temperatures below 0°C Source: UK CRI
altCDD	Similar to CDD. For CDD, the spells can span years, while for altCDD the spells cannot span years. Source: ETCCDI
altCSDI	Similar to CSDI. For CSDI, the spells cannot span years, while for altCSDI the spells can span years. Source: ETCCDI
altCWD	Similar to CWD. For CWD, the spells can span years, while for altCWD the spells cannot span years. Source: ETCCDI
altWSDI	Similar to WSDI. For WSDI, the spells cannot span years, while for altWSDI the spells can span years. Source: ETCCDI
Amber Heat-Health Alert	Occurrence of a public health heat-health alert: potential warning if medium heat-health alert thresholds reached for maximum daytime temperature (32.0°C to 39.9°C for London, 30.0°C to 37.0°C for other areas) and night-time temperature (95th percentile or higher of summer "nights"). Definitions valid only for the UK. Source: UK CRI
Amount of cold nights (TN10p)	Percentage of days when TN < 10th percentile Source: CLIMDEX
Amount of cool days (TX10p)	Percentage of days when TX < 10th percentile Source: CLIMDEX

Amount of hot days (TX90p)	Percentage of days when TX > 90th percentile Source: CLIMDEX
Amount of warm nights (TN90p)	Percentage of days when TN > 90th percentile Source: CLIMDEX
Annual total wet-day PR (PRCPTOT)	Sum of daily PR >= 1.0 mm Source: CLIMDEX
Apparent Temperature Heatwave Days	The Apparent Temperature Heatwave Days Index (Number of Days) is defined as a period of at least two consecutive days during the summer months (June, July, August) in which both the daily apparent temperature and the daily minimum temperature exceed their monthly 90th percentiles defined over a reference period. Apparent temperature is a linear function of temperature and dew point temperature to account for humidity conditions. Source: Climate ADAPT
Aridity Actual	The ratio between mean annual actual evapotranspiration and mean annual precipitation, generally calculated over a reference period of 30 years. Actual evapotranspiration is estimated using hydrological models and, in contrast to potential evapotranspiration, accounts for the limited water content actually available in the soil when estimating the evapotranspiration demand. Source: Climate ADAPT
Average Temperature	Seasonal average temperature Source: UK CRI
Climatological Heatwave Days	The count of days under climatological heatwaves conditions (Number of days). A climatological heatwave is a period of at least three consecutive days exceeding the 99th percentile of the daily maximum temperatures of the May to September season during a reference period. Source: Climate ADAPT
Cold spell duration indicator (CSDI)	Annual number of days contributing to events where 6 or more consecutive days experience TN < 10th percentile Source: CLIMDEX
Cold Weather Alert	Occurrence of a public health cold weather alert: potential warning if daily mean temperature below 2.0°C for 5 days AND below 0.0°C for 48hrs or more. Definitions valid only for the UK. Source: UK CRI
Coldwave amplitude (CWA) as defined by the Excess Cold Factor (ECF). (CWA_ECF)	The minimum daily value in the coldest 'coldwave' (defined as the coldwave with lowest ECF_HWM). Source: CLIMDEX

Coldwave duration (CWD) as defined by the Excess Cold Factor (ECF). (CWD_ECF)	The length of the longest 'coldwave' identified by ECF_HWN. Source: CLIMDEX
Coldwave frequency (CWF) as defined by the Excess Cold Factor (ECF). (CWF_ECF)	The number of days that contribute to 'coldwaves' as identified by ECF_HWN. Source: CLIMDEX
Coldwave magnitude (CWM) as defined by the Excess Cold Factor (ECF). (CWM_ECF)	The mean temperature of all 'coldwaves' identified by ECF_HWN. Source: CLIMDEX
Coldwave number (CWN) as defined by the Excess Cold Factor (ECF). (CWN_ECF)	The number of individual 'coldwaves' that occur each year. Source: CLIMDEX
Consecutive Dry Days	The longest period of consecutive days with daily precipitation below 1 mm in a year (day). In weather and climate models temperature is the variable simulating atmospheric air temperature at 2m above the surface. This Index is usually presented as annual, seasonal or monthly values over a reference period. Source: Climate ADAPT
Consecutive Dry Days (CDD)	Maximum number of consecutive dry days (when PR < 1.0 mm) Source: CLIMDEX
Consecutive Frost Days (CFD)	Let TX_{ij} be the daily maximum temperature at day i of period j. Then counted is the largest number of consecutive days where daily maximum temperature is less than 0 degrees Celsius ($TX_{ij} < 0$). Source: Copernicus CCS
Consecutive Summer Days (CSD)	Let TX_{ij} be the daily maximum temperature at day i of period j. Then counted is the largest number of consecutive days where daily maximum temperature exceeds 25 degrees Celsius ($TX_{ij} > 25$). Source: Copernicus CCS
Consecutive Wet Days (CWD)	Maximum annual number of consecutive wet days (when PR >= 1.0 mm) Source: CLIMDEX

Contribution from extremely wet days (R99pTOT)	100*r99p / PRCPTOT Source: CLIMDEX
Contribution from very wet days (R95pTOT)	100*r95p / PRCPTOT Source: CLIMDEX
Cooling Degree Days	Average annual cooling degree days: relative to 18°C and 22°C Source: UK CRI
Cooling Degree Days (CDDcoldn)	Annual sum of TM - n (where n is a user-defined location-specific base temperature and TM > n) Source: CLIMDEX
Crop Growth Duration	Time to accumulate the 1981-2010 average growing degree days Source: UK CRI
Daily PR intensity (SDII)	Annual total PR divided by the number of wet days (when total PR >= 1.0 mm) Source: CLIMDEX
Daily Temperature Range (DTR)	Mean difference between daily TX and daily TN Source: CLIMDEX
Dairy Cattle Heat Stress	Days with a Temperature Humidity Index above 70. Source: UK CRI
Days Above Field Capacity	Number of days with soil moisture at or above field capacity Source: UK CRI
Dissolved Oxygen Level	The Dissolved Oxygen Level index (mol / m³) is the concentration of dissolved oxygen at a certain depth. Oxygen concentrations above 190 mmol m³ are considered to be sufficient to support healthy marine communities with minimal problems, while oxygen concentrations below 62.5 mmol m³ are considered to be a source of serious concern. Source: Climate ADAPT
Extreme Precipitation Days	The count of days in a year with daily precipitation exceeding the 95th percentile threshold of rainy days over a reference period, here the 1981-2010 period (day). In weather and climate models total precipitation is the flux of water equivalent (rain or snow) reaching the land surface (expressed as kg.m-2.sec-2 and converted to mm day-1). This Index is usually presented as annual, seasonal or monthly cumulated values over the considered period. Source: Climate ADAPT
Extreme Precipitation Total	The total sum in a year of daily precipitation values exceeding the 95th percentile of the reference period (mm). In weather and climate models total precipitation is the flux of water equivalent (rain or snow) reaching the land surface (expressed as kg.m-2.sec-2 and converted to mm/day). Precipitation is usually presented as annual, seasonal or monthly cumulated values over the considered period but extremes are cumulated on shorter periods (eg daily, 3-Days, or 5-Days maximums). Source: Climate ADAPT

Extreme Sea Level	The Extreme Sea Level index (m) is the Total water level value for a return period of 100 years caused by tidal and surge levels as well as their interactions but without including sea level rise. Source: Climate ADAPT
Extreme Temperature Range (ETR)	Mean difference between monthly TX and monthly TN Source: CLIMDEX
Extreme Wind Days	The count of days in a year with daily 10m wind speed exceeding the 98th percentile threshold over a reference period, here the 1981-2010 period (days). Source: Climate ADAPT
Fire Weather Index	The Fire Weather Index (FWI) is a meteorologically based index used worldwide to estimate fire danger. It is developed by the Canadian Forestry Service to estimate forest fire ignition and spread conditions based on several weather variables (temperature, precipitation, relative humidity, and wind speed). Source: Climate ADAPT
Fraction of days with temperatures above the median (TXgt50p)	Percentage of days where TX > 50th percentile Source: CLIMDEX
Frost Days	Days with Tmin below 0°C Source: UK CRI
Frost Days (FD)	Number of days when TN < 0 °C Source: CLIMDEX
Growing Degree Days	Accumulated degree-days relative to 5.6°C Source: UK CRI
Growing Degree Days (GDDgrown)	Annual sum of TM - n (where n is a user-defined location-specific base temperature and TM > n) Source: CLIMDEX
Growing Season Length	Length between start and end of growing season Source: UK CRI
Growing Season Length (GSL)	Annual number of days between the first occurrence of 6 consecutive days with TM > 5 °C and the first occurrence of 6 consecutive days with TM < 5 °C Source: CLIMDEX
Heat Stress	Days with shade Wet Bulb Globe Temperature (WBGT) above 25 Source: UK CRI
Heating Degree Days	Average annual heating degree days: relative to 15.5°C and 18°C Source: UK CRI
Heating Degree Days (HDDheatn)	Annual sum of n - TM (where n is a user-defined location-specific base temperature and TM < n) Source: CLIMDEX

Heatwave amplitude (HWA) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWA(EHF/Tx90/ Tn90))	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM). Source: CLIMDEX
Heatwave amplitude (HWA) as defined by the 90th percentile of TN (HWA_Tn90)	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM). Source: CLIMDEX
Heatwave amplitude (HWA) as defined by the 90th percentile of TX (HWA_Tx90)	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM). Source: CLIMDEX
Heatwave amplitude (HWA) as defined by the Excess Heat Factor (EHF) (HWA_EHF)	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM). Source: CLIMDEX
Heatwave duration (HWD) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWD(EHF/Tx90/ Tn90))	The length of the longest heatwave identified by HWN. Source: CLIMDEX
Heatwave duration (HWD) as defined by the 90th percentile of TN (HWD_Tn90)	The length of the longest heatwave identified by HWN. Source: CLIMDEX

Heatwave duration (HWD) as defined by the 90th percentile of TX (HWD_Tx90)	The length of the longest heatwave identified by HWN. Source: CLIMDEX
Heatwave duration (HWD) as defined by the Excess Heat Factor (EHF) (HWD_EHF)	The length of the longest heatwave identified by HWN. Source: CLIMDEX
Heatwave frequency (HWF) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWF(EHF/Tx90/ Tn90))	The number of days that contribute to heatwaves as identified by HWN. Source: CLIMDEX
Heatwave frequency (HWF) as defined by the 90th percentile of TN (HWF_Tn90)	The number of days that contribute to heatwaves as identified by HWN. Source: CLIMDEX
Heatwave frequency (HWF) as defined by the 90th percentile of TX (HWF_Tx90)	The number of days that contribute to heatwaves as identified by HWN. Source: CLIMDEX
Heatwave frequency (HWF) as defined by the Excess Heat Factor (EHF) (HWF_EHF)	The number of days that contribute to heatwaves as identified by HWN. Source: CLIMDEX

Heatwave magnitude (HWM) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWM(EHF/Tx90/Tn90))	The mean temperature of all heatwaves identified by HWN. Source: CLIMDEX
Heatwave magnitude (HWM) as defined by the 90th percentile of TN (HWM_Tn90)	The mean temperature of all heatwaves identified by HWN. Source: CLIMDEX
Heatwave magnitude (HWM) as defined by the 90th percentile of TX (HWM_Tx90)	The mean temperature of all heatwaves identified by HWN. Source: CLIMDEX
Heatwave magnitude (HWM) as defined by the Excess Heat Factor (EHF) (HWM_EHF)	The mean temperature of all heatwaves identified by HWN. Source: CLIMDEX
Heatwave number (HWN) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWN(EHF/Tx90/Tn90))	The number of individual heatwaves that occur each summer (Nov – Mar in southern hemisphere and May – Sep in northern hemisphere). A heatwave is defined as 3 or more days where either the EHF is positive, TX > 90th percentile of TX or where TN > 90th percentile of TN. Where percentiles are calculated from base period specified by user. Source: CLIMDEX
Heatwave number (HWN) as defined by the 90th	The number of individual heatwaves that occur each summer (Nov – Mar in southern hemisphere and May – Sep in northern hemisphere). A heatwave is defined as 3 or more days where TN > 90th percentile of TN. Where percentiles are calculated from base period specified by

percentile of TN (HWN_Tn90)	user. Source: CLIMDEX
Heatwave number (HWN) as defined by the 90th percentile of TX (HWN_Tx90)	The number of individual heatwaves that occur each summer (Nov – Mar in southern hemisphere and May – Sep in northern hemisphere). A heatwave is defined as 3 or more days where TX > 90th percentile of TX. Where percentiles are calculated from base period specified by user. Source: CLIMDEX
Heatwave number (HWN) as defined by the Excess Heat Factor (EHF) (HWN_EHF)	The number of individual heatwaves that occur each summer (Nov – Mar in southern hemisphere and May – Sep in northern hemisphere). A heatwave is defined as 3 or more days where the EHF is positive. Where percentiles are calculated from base period specified by user. Source: CLIMDEX
High Fire Danger Days	The count of days in a period with a FWI value greater than 30 (Number of days) based upon the European Forest Fire Information System (EFFIS) classification. The Fire Weather Index (FWI) is a meteorologically based index used worldwide to estimate fire danger. It is developed by the Canadian Forestry Service to estimate forest fire ignition and spread conditions based on several weather variables (temperature, precipitation, relative humidity, and wind speed). Source: Climate ADAPT
High Snow Days	The High Snow Days index (days) counts the number of days where the water equivalent of natural snow is above a given threshold (here 120 kg m-2) from august to july of the following year. Source: Climate ADAPT
High UTCI Days	The UTCI is an equivalent temperature (°C) and is a measure of the human physiological response to meteorological conditions that also takes into consideration the clothing adaptation of the population in response to outdoor temperature. It is based on four surface variables: air temperature, relative humidity, wind speed and mean radiant temperature. UTCI values are divided in 5 classes of heat stress: no thermal stress (9°C-26°C), moderate heat stress (26°C-32°C), strong heat stress (32°C-38°C), very strong heat stress (38C°-46C°), and extreme heat stress (>46°C). The index refers to the number of days in the category of strong heat stress or stronger (>32°C). Source: Climate ADAPT
Huglin Index	The Huglin Index is an index specifically aimed at grap growth and defined using daily averaged temperature TG_i and the daily maximum temperature TX_i for day i in the period 1 April to 30 September: $K/2 * SUM((TG_i - 10) + (TX_i - 10))$, where K is a daylength coefficient. The daylight coefficient is a function of the latitude of the station but a clear definition is absent. The value of K is 1 (<= 40°N) or 1.02 (40-42°N), increasing at increment of 0.01 for each 2 degrees of latitude until 50°N and reaching 1.06. Source: Copernicus CCS

Ice Days (ID)	Number of days when TX < 0 °C Source: CLIMDEX
Low Flows (10-Year Return Period)	Change in the 10-year lowest 7-day average river flow Source: UK CRI
Low Flows (2-Year Return Period)	Change in the 2-year lowest 7-day average river flow Source: UK CRI
Low Flows (Likelihood of Current 10-Year Event)	Likelihood of 20-year low river flows Source: UK CRI
Marine Heatwaves Days Index (MHD)	The Marine Heatwaves Days index (MHD) is defined as the count of days under marine heatwaves conditions (days). A Marine Heatwave day is a day exceeding the daily climatological 90th percentile of SST during the May to September season and a reference period. Source: Climate ADAPT
Max 1-day PR (Rx1day)	Maximum 1-day PR total Source: CLIMDEX
Max 5-day PR (Rx5day)	Maximum 5-day PR total Source: CLIMDEX
Max TN (TNx)	Warmest daily TN Source: CLIMDEX
Max TX (TXx)	Warmest daily TX Source: CLIMDEX
Maximum Consecutive Five-Day Precipitation	Maximum five days cumulated precipitation (mm). In weather and climate models total precipitation is the flux of water equivalent (rain or snow) reaching the land surface (expressed as kg.m-2.sec-2 and converted to mm/day). Precipitation is usually presented as annual, seasonal or monthly cumulated values over the considered period but extremes are cumulated on shorter periods (eg daily, 3-Day, or 5-days maximums). Source: Climate ADAPT
Maximum Temperature	The maximum value of daily maximum temperature over a period (°C). In weather and climate models temperature is the variable simulating atmospheric air temperature at 2m above the surface. This Index is usually presented as annual, seasonal or monthly values over a reference period. Source: Climate ADAPT
Maximum Temperature	Seasonal average maximum temperature Source: UK CRI
Mean Soil Moisture	The soil moisture is defined as the monthly mean values of soil moisture in the root zone as the fraction of the field capacity volume over a 30 year period. Source: Climate ADAPT

Mean Temperature	The mean of 2m temperature (°C) values during a given period. In weather and climate models temperature is the variable simulating atmospheric air temperature at 2m above the surface. This Index is usually presented as annual, seasonal or monthly values over a reference period. Source: Climate ADAPT
Mean TM (TMm)	Mean daily mean temperature Source: CLIMDEX
Mean TN (TNm)	Mean daily minimum temperature Source: CLIMDEX
Mean TX (TXm)	Mean daily maximum temperature Source: CLIMDEX
Mean Wind Speed	The mean daily 10m wind speed over a period (m s-1). Source: Climate ADAPT
Met Office Fire Danger	Days with the MOFSI index above specific thresholds: >17.35 for very high, >52.538 for exception. Definitions valid only for the UK. Source: UK CRI
Met Office Heatwave	Occurrence of heatwave following Met Office definition: heatwave threshold is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold [set between 25 (most of the country) and 28 (London and certain surrounding counties)]. Definitions valid only for the UK. Source: UK CRI
Meteorological Drought Duration	The count of months in a year with anomalously low precipitation conditions based on the 3-month Standardised Precipitation Index (SPI-3) relative to a reference period, here 1981-2010 (month). A drought event starts when SPI-3 values fall below -1 for at least two consecutive months and ends when the index returns positive. Source: Climate ADAPT
Meteorological Drought Magnitude	The cumulative severity of drought events in a year based on the 3-month Standardised Precipitation Index (SPI-3) relative to a reference period, here 1981-2010 (dimensionless). A drought event starts when SPI-3 values fall below -1 for at least two consecutive months and ends when the index returns positive. The magnitude of the event is defined as the sum of SPI-3 absolute values in the months of the drought episode. Source: Climate ADAPT
Min TN (TNn)	Coldest daily TN Source: CLIMDEX
Min TX (TXn)	Coldest daily TX Source: CLIMDEX
Minimum Temperature	The minimum value of daily minimum temperature over a period (°C). In weather and climate models temperature is the variable simulating atmospheric air temperature at 2m above the surface. This Index is usually presented as annual, seasonal or monthly values over a reference period.

	Source: Climate ADAPT
Minimum Temperature	Seasonal average minimum temperature Source: UK CRI
Number of customised rain days (Rnnmm)	Number of days when PR >= nn Source: CLIMDEX
Number of heavy rain days (R10mm)	Number of days when PR >= 10 mm Source: CLIMDEX
Number of very heavy rain days (R20mm)	Number of days when PR >= 20 mm Source: CLIMDEX
Ocean pH Level	The Ocean pH Level index (dimensionless) is the seawater pH at a certain depth. pH is a measure of the concentration of hydrogen ions in a solution. The more hydrogen ions that are present, the more acidic is the solution. The pH scale ranges from zero (very acidic) to 14 (very basic). The scale is logarithmic, meaning a single unit corresponds to a ten-fold difference. A pH of 7 is neutral, a pH less than 7 is acidic, and a pH greater than 7 is basic. Source: Climate ADAPT
Potential Evapotranspiration (PET: Makkink)	This formulation of Reference Evapotranspiration is a simplification of the more comprehensive Penman-Monteith parameterization and recognizes that evapotranspiration is determined primarily by the radiation and the ambient air temperature. A further simplification is that Global Radiation is used rather than the net radiation which is used in more comprehensive formulas. Source: Copernicus CCS
Potential Evapotranspiration (PET: Penman-Monteith)	PET is an index which gives the FAO-endorsed potential evapotranspiration as calculated by the Penman-Monteith parametrization. Here reference crop evapotranspiration is a measure for potential evapotranspiration. Reference crop evaporation is defined as the rate of evaporation from an idealized grass reference crop with a fixed crop height of 0.12 m, an albedo of 0.23, and a surface resistance of 70 s m−1 . In terms of of its evaporation rate, such a crop closely resembles the reference crop of an extensive surface of short green grass cover of uniform height, actively growing, completely shading the ground, and not short of water. Source: Copernicus CCS
Potential Soil Moisture Deficit	Average annual maximum cumulative difference between rainfall and potential evaporation Source: UK CRI
Rail: Bad Weather Days	Days with temperature, rainfall and/or windspeed beyond thresholds (not defined) Source: UK CRI
Rail: High Temperatures	Days with Tmax above thresholds (>21, 24, 26, 30°C) Source: UK CRI

Rainfall	Seasonal total rainfall Source: UK CRI
Record-Breaking Weather (Hottest Day)	Number of days per year at least as hot as the hottest day (Tmax) between 1981 and 2010 Source: UK CRI
Record-Breaking Weather (Hottest Month)	Number of months per year at least as hot as the hottest month (Tmax) between 1981 and 2010 Source: UK CRI
Record-Breaking Weather (Wettest Month)	Number of months per year at least as wet as the wettest month between 1981 and 2010 Source: UK CRI
Relative Sea Level Rise	The Relative Sea Level Rise index (cm) is the annual mean sea level height relative to the 1986-2005 period. Source: Climate ADAPT
River Discharge	The River Discharge index is defined as the annual mean daily river discharge ($m^3 \cdot s^{-1}$). Source: Climate ADAPT
River Flood	The River Flood index is the 50-year (also 10-, 5- and 2-year) flood recurrence value based on maximum river discharge. It is estimated from annual daily maximum river discharge using a Gumbel distribution. Source: Climate ADAPT
River Flood (10-Year Return Period)	Magnitude of the 10-year flood Source: UK CRI
River Flood (2-Year Return Period)	Magnitude of the 2-year flood Source: UK CRI
River Flood (5-Year Return Period)	Magnitude of the 5-year flood Source: UK CRI
River Flood (Likelihood of Current 10-Year Event)	Likelihood of the 10-year flood Source: UK CRI
River Runoff	Annual and seasonal river runoff Source: UK CRI
Road Accident Risk	Days with Tmin below 0°C Source: UK CRI
Road Melt Risk	Days with Tmax above 25°C Source: UK CRI
Sea Surface Temperature	The Sea Surface Temperature index represents the mean sea surface temperature over different timescales (°C). Source: Climate ADAPT

Self-Calibrating Palmer Drought Severity Index (scPDSI)	The Palmer Drought Severity Index (PDSI) is a measure of regional moisture availability that has been used extensively to study droughts and wet spells in the contiguous USA. The computation of the index involves a classification of relative moisture conditions within 11 categories as defined by Palmer (1965), ranging from extremely dry with PDSI, to extremely wet with PDSI values. The index is based on water supply and demand which is calculated using a water-budget system based on historic records of precipitation and temperature and the soil characteristics of the site being considered. The scPDSI as put forward by Wells et al. (2004) is more appropriate for geographical comparison of climates of diverse regions. Wells et al. (2004) improve the performance of the PDSI by automating the calculations Palmer made when he derived the empirical constants used in the PDSI algorithm. Source: Copernicus CCS
Snowfall Amount	The Snowfall Amount index (mm) corresponds to the cumulative value of snowfall precipitation over the winter season from November to April. Source: Climate ADAPT
Soil Moisture	Average seasonal soil moisture content Source: UK CRI
SPEI Drought	Number of months with a Standardised Precipitation Evaporation Index (calculated from 6-month accumulated rainfall minus potential evaporation) less than -1.5. Source: UK CRI
SPI Drought	Number of months with a Standardised Precipitation Index (calculated from 3-month accumulated rainfall) less than -1.5. Source: UK CRI
Standardised Precipitation Evapotranspiration Index (SPEI)	Measure of "drought" using the Standardised Precipitation Evapotranspiration Index on time scales of 3, 6 and 12 months. See [Vicente-Serrano et al. (2010)](#appendixa_refs) for details. Calculated using the [SPEI R package](https://cran.r-project.org/web/packages/SPEI/index.html). Source: CLIMDEX
Standardised Precipitation Index (SPI)	Measure of "drought" using the Standardised Precipitation Index on time scales of 3, 6 and 12 months. See [McKee et al. (1993)](#appendixa_refs) and the [WMO SPI User guide (World Meteorological Organization, 2012)](#appendixa_refs) for details. Calculated using the [SPEI R package](https://cran.r-project.org/web/packages/SPEI/index.html). Source: CLIMDEX
Start of Crop Growing Season	First day of first five-day period with average temperature above 5.6°C Source: UK CRI
Start of Field Operations (Tsum200)	Day when accumulated temperatures above 0°C reach 200°C Source: UK CRI
Summer days (SU)	Number of days when TX > 25 °C Source: CLIMDEX

Tiger Mosquito Climatic Season Length	The season length of the climatic suitability of tiger mosquito presence (Days). The Tiger mosquito's climatic suitability seasonal presence is determined by temperature thresholds and hours of sunlight (photoperiod) during spring (when egg hatching occurs) and autumn (a period of suspended development or diapause). In spring the temperature should be above 10.5°C and the photoperiod above 11.25 hours and in autumn the temperature should be below 9.5°C and the photoperiod below 13.5 hours. The latter is conditioned by the ability of the mosquito to survive the winter combined with a threshold on annual rainfall. Survival conditions are considered as unsuitable for January temperatures below 0°C and annual rainfall below 500 mm. Source: Climate ADAPT
Tiger Mosquito Climatic Suitability	The Climatic Suitability index of Tiger mosquito (Aedes albopictus) presence (Dimensionless, from 0 to 100). The Tiger Mosquito Climatic Suitability index is relevant to human health. The tiger mosquito is an invasive species from south-east Asia favoured by a warmer climate and represents a serious threat as it transmits vector-borne diseases such as dengue and chikungunya. Environmental factors, among which weather conditions, affect both the potential presence and seasonal activity of the tiger mosquito. The Tiger mosquito's climatic suitability is determined by summer temperatures, January temperatures and annual rainfall. The suitability is null for summer temperatures lower than 15°C or higher than 30°C, with a maximum between 20°C and 25°C. It is null for January temperatures lower than - 1°C and annual rainfall lower than 450 mm, and maximal for January temperatures above 3°C and annual rainfall above 800 mm. Source: Climate ADAPT
TM below 10°C (TMlt10)	Number of days when TM < 10 °C Source: CLIMDEX
TM below 5°C (TMlt5)	Number of days when TM < 5 °C Source: CLIMDEX
TM of at least 10°C (TMge10)	Number of days when TM >= 10 °C Source: CLIMDEX
TM of at least 5°C (TMge5)	Number of days when TM >= 5 °C Source: CLIMDEX
TN below -20°C (TNltm20)	Number of days when TN < -20 °C Source: CLIMDEX
TN below -2°C (TNltm2)	Number of days when TN < -2 °C Source: CLIMDEX
TN below 2°C (TNlt2)	Number of days when TN < 2 °C Source: CLIMDEX
Total annual PR from heavy rain days (R95p)	Annual sum of daily PR > 95th percentile Source: CLIMDEX

Total annual PR from very heavy rain days (R99p)	Annual sum of daily PR > 99th percentile Source: CLIMDEX
Total Precipitation	The cumulated precipitation over a period (mm/period). In weather and climate models total precipitation is the flux of water equivalent (rain or snow) reaching the land surface (expressed as kg·m⁻²·sec⁻² and converted to mm/day). This Index is usually presented as annual, seasonal or monthly cumulated values over the considered period. Source: Climate ADAPT
Tropical Nights	Days with minimum temperature above 20°C Source: UK CRI
Tropical nights (TR)	Number of days when TN > 20 °C Source: CLIMDEX
TX of at least 30°C (TXge30)	Number of days when TX >= 30 °C Source: CLIMDEX
TX of at least 35°C (TXge35)	Number of days when TX >= 35 °C Source: CLIMDEX
User-defined consecutive days PR amount (RXdday)	Maximum d-day PR total Source: CLIMDEX
User-defined consecutive number of cold days and nights (TXbdTNbd)	Annual number of d consecutive days where both TX < 5th percentile and TN < 5th percentile, where 10 >= d >=2 Source: CLIMDEX
User-defined consecutive number of hot days and nights (TXdTNd)	Annual count of d consecutive days where both TX > 95th percentile and TN > 95th percentile, where 10 >= d >= 2 Source: CLIMDEX
User-defined CSDI (CSDId)	Annual number of days contributing to events where d or more consecutive days experience TN < 10th percentile Source: CLIMDEX
User-defined WSDI (WSDId)	Annual number of days contributing to events where d or more consecutive days experience TX > 90th percentile Source: CLIMDEX
Very Hot Days	Days with maximum temperature above 35°C Source: UK CRI
Very warm day threshold (TX95t)	Value of 95th percentile of TX Source: CLIMDEX
Warm spell duration indicator (WSDI)	Annual number of days contributing to events where 6 or more consecutive days experience TX > 90th percentile Source: CLIMDEX

Warmest Three-Day Period	The highest daily mean temperature averaged over a three-day window over a period (°C). In weather and climate models temperature is the variable simulating atmospheric air temperature at 2m above the surface. This Index is usually presented as annual, seasonal or monthly values over a reference period. Source: Climate ADAPT
Wheat Heat Stress	Days between 1 May and 15 June with maximum temperature above 32°C Source: UK CRI
Wildfire: Daily Hazard Assessment	Days with MOFSI components above specific thresholds. Components are FFMC (Fine Fuel Moisture Code), ISI (Initial Spread Index), DMC (Duff Moisture Code), DC (Drought Code) and FWI (Fire Weather Index). Thresholds are season-specific and available for FFMC, ISI, and FWI. Relates to amber and red warning conditions. An 'amber' warning level means that severe wildfire conditions are forecast with a likelihood of difficult-to-control wildfires. The 'red' level means extreme wildfire conditions are forecast, and occurs when the amber thresholds are passed and other weather conditions are conducive to fire (persistent high temperatures, low humidity and high windspeeds). Source: UK CRI
Wildfire: FFMC 99th Percentile	Days with Fine Fuel Moisture Code component of MOFSI above the 99th percentile over the period 1981-2010, calculated by season. FFMC index represents the availability of dry 'tinder' material in and around the vegetation susceptible to ignition. Source: UK CRI

Annex 3: Participant recruitment letter

We're looking for people with experience in climate science and services to participate in testing the Decision Support System (DSS) for climate-services developed within the HACID project (Hybrid Human Artificial Collective Intelligence in Open-Ended Decision Making, https://www.hacid-project.eu/).

Participation benefit: By participating in this activity, you will learn how HACID has structured workflows for developing climate services, and discover how DSSs and AI can support climate scientists in addressing the climate information needs of its customers. You will contribute invaluable data for improving future hybrid collective intelligence approaches to climate services. Besides, you will get access to a glossary of

Timeline: The next round of experiment will commence during the week of 2nd February and will run for up to 2 weeks. We will introduce 2 or 3 use cases per week. You can contribute at any time that suits your schedule during this period. Each contribution will

require around 1 hour plus a brief evaluation. The minimum expected time commitment is approximately 1 to 1.5 hours to contribute to a single case.

Your Role: You will provide workflows and evaluate those provided by others, including AI-generated workflows.

Participation: Participation is voluntary, and you may withdraw at any time. You can contribute to as many or as few use cases as you wish, even just one. After contributing to a case, you will be able to see and evaluate the contributions of others, including AI-generated ones. Your contributions will be anonymised and will be visible to others only in the form of an ID. Further information about data privacy and handling can be accessed [here.](#)

Support: We will provide a quick-start guide to help you navigate the DSS. If you require immediate support, you are free to reach out to us.

Further information about the project and your participation: [Participant information and Consent form.](#)

If you are interested, please get in touch with us by 30th January. We will then send you your unique login ID to access the HACID DSS and the quick-start guide including a glossary of terms and methods.

If you have any further questions regarding your participation, please do not hesitate to get in touch.

Many thanks,

Met Office UK

Annex 4: Participants' sample contributions

We present three sample contributions by three participants. The contributions are presented in textual format and have been retrieved from the database storing the DSS information.

For the use case "Projected change in heating and cooling energy demand across all UK local authorities", user2 has provided the following contribution:

```
1 - Perform literature review
Task Description: Review literature on extreme heat in the UK
Rationale Description: Conduct a literature review on UK climatic drivers of
heating and cooling demand—identifying the variables and indicators used, assessing
historical trends and change points, mapping key data sources, and synthesising
future projections.
2 - Identify indices and variables
Task Description: Selection of base data and computation of indices.
Rationale Description: Identify the UK climate variables that influence heating and
cooling, and record both the raw inputs and the derived indicators/metrics. Give
special attention to each heat/cool indicator, define it, show how it is
calculated, and list the raw variables required to compute it.
Associated entities: Air Temperature (ta), Heating Degree Days, Cooling Degree Days
Daily Minimum Near-Surface Air Temperature (tasmin), Daily Maximum Near-Surface Air
Temperature (tasmax), Heatwave duration (HWD) as defined by either the Excess Heat
```

Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWD(EHF/Tx90/Tn90)), Heatwave frequency (HWF) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWF(EHF/Tx90/Tn90)), Heatwave magnitude (HWM) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN (HWM(EHF/Tx90/Tn90)), Coldwave duration (CWD) as defined by the Excess Cold Factor (ECF) (CWD_ECF), Coldwave frequency (CWF) as defined by the Excess Cold Factor (ECF). (CWF_ECF), Coldwave magnitude (CWM) as defined by the Excess Cold Factor (ECF). (CWM_ECF).

3 – Define observation type
Task Description: Select the appropriate observational data type
Rationale Description: The model data to be used would be in a gridded format, therefore, select a corresponding gridded observation to bias correct the model data later.
Associated entities: gridded

4 – Conduct manual selection of climate simulations
Task Description: Select high resolution model simulations
Rationale Description: Choose all ensemble members under UKCP18 local as climate simulations for analyses to capture changes in climate extremes at the local scale.
Associated entities: ukcp18.local.rcp85

5 – Define emission scenarios
Task Description: Select the best emission scenario
Rationale Description: The climate simulations from UKCP are at a high resolution of 2.2km, however only one emission scenario exists (RCP8.5).
Associated entities: Representative Concentration Pathway 8.5

6 – Choose baseline period
Task Description: Select baseline or reference period
Rationale Description: The baseline period will be the reference against which to compare for climate change signals in the future.
Date Range: 01/12/1979–30/11/2005

7 – Choose future period
Task Description: Future time period selection
Rationale Description: Note the appropriate and recommended future period as needed by the customer.
Date Range: 01/01/2030–31/12/2099

8 – Choose global warming level
Task Description: GWLs selection
Rationale Description: Select the global warming levels applicable for the analysis, noting the year ranges corresponding to each GWL for each ensemble member in the UKCP18.
Input Type: Range
Minimum warming level: GWL1.5
Maximum warming level: GWL4

9 – Apply additional spatial and/or temporal downscaling
Task Description: Bias correction
Rationale Description: Perform bias correction on the UKCP18 members. Correcting from historical with observations to future scenarios. Test various bias correction methods and utilise the one with the least bias in maximum, minimum and mean temperature bias for further analysis.
Associated entities: Bias correction (Bias adjustment, Calibration, Bias calibration, Bias correction using statistical techniques)

10 – Compute climate indices
Task Description: Compute climate indicators.
Rationale Description: Compute the climate indices: heat(cold)wave frequency, heat(cold) wave length, heating degree days and cold degree days and others for each bias corrected UKCP18 ensemble member.
Associated entities: Ensemble statistics – Ensemble range

11 – Quantify future climate change
Task Description: Trend analysis of indicators
Rationale Description: Assess whether future changes in extreme indices show increasing or decreasing trends for each global warming level (GWL) and for each ensemble member, from baseline to future projections.
Associated entities: Time series analysis – Trend analysis

12 – Filter climate simulations by global warming level exceedance
Task Description: Slice climate indicators in each model according to GWLs
Rationale Description: For each bias corrected ensemble member and climate indicator, filter or extract for each global warming level (GWL), noting that each member has different year ranges for the GWLs.

13 - Quantify future climate change
Task Description: Quantify future changes in climate indices
Rationale Description: For each bias-corrected ensemble member and climate
indicator, subset the data by global warming level (GWL), noting that GWL year
ranges vary by member (i.e., each member has its own GWL time window).
Associated entities: Time series analysis - Difference Quantification
14 - Quantify uncertainty
Task Description: Uncertainty quantification of model ensemble members
Rationale Description: Quantify the uncertainty associated with each model member
projections in the climate indices and GWL and plot as a probability density
function.
Associated entities: Uncertainty quantification - Probability Density Function
(PDF)

For the use case "Climate projections for the Duchy of Cornwall UK agricultural holdings", we
provide two contributions. user3 has provided this contribution:

1 - Perform literature review
Task Description: Explore whether past studies have already explored these weathers
in this area.
Rationale Description: ...
2 - Identify indices and variables
Task Description: Identify the variables needed to meet the requirements for
climate information. Heatwaves through tasmax and tasmin. Air frost through tasmin.
Ground frost through surface temperature. Flooding from precipitation. Agricultural
drought from soil moisture and evaporation.
Rationale Description: ...
Associated entities: Surface Temperature (ts), Precipitation (pr), Daily Maximum
Near-Surface Air Temperature (tasmax), Daily Minimum Near-Surface Air Temperature
(tasmin), SPEI Drought
3 - Define relevant spatial resolutions
Task Description: ...
Rationale Description: ...
Input Type: Range
Minimum spatial resolution (km): 1
Maximum spatial resolution (km): 15
4 - Define relevant temporal resolutions
Task Description: ...
Rationale Description: ...
Input Type: Range
Minimum temporal resolution: 1H
Maximum temporal resolution: 1M
5 - Conduct manual selection of observations
Task Description: Identify observations that represent the indices, that can be
compared to climate model output in the baseline period
Rationale Description: ...
6 - Choose baseline period
Task Description: Depends also on the availability of observations
Rationale Description: ...
Date Range: 01/01/2000-31/12/2020
7 - Choose future period
Task Description: Taking the last 20 years of user-specified period. Possibly could
repeat analysis for more than one 20-year period. Needs to be at least 20 years
long, and the same length as the baseline period.
Rationale Description: ...
Date Range
01/01/2040-31/12/2060
8 - Define emission scenarios
Task Description: Identify what emissions scenarios would best meet the user's
needs. They have a high tolerance to risk, so I would suggest a middle emissions
scenario. Also need to consider how different are the projections of each variable,
for different emissions scenarios - there may only be small differences by 2060.
Rationale Description: ...
Associated entities: Representative Concentration Pathway 4., Shared Socioeconomic
Pathways 2
9 - Choose climate models

Task Description: Identify the climate datasets that include the variables
required, for the time period of interest. Given UK focus, likely to be UKCP Local.
Rationale Description: ...
Associated entities: HadREM3-GA705
10 - Evaluate climate simulations
Task Description: How well does the climate model compare to the observations for
the chosen climate indices, in the baseline period?
Rationale Description: ...
11 - Choose the criteria for selecting or rejecting climate simulations
Task Description: Identify if there are any climate models that are so different
from the observations
Rationale Description: ...
12 - Apply data preprocessing
Task Description: Identify the best bias correction technique to use on the climate
simulation data in the present climate, and also apply it to the future climate
data.
Rationale Description: ...
Associated entities: Descriptive statistics - Bias quantification
13 - Quantify future climate change
Task Description: ...
Rationale Description: ...
Associated entities: Ensemble statistics - Ensemble mean
14 - Quantify future climate change
Task Description: ...
Rationale Description: ...
Associated entities: Thresholds - Peaks-over-threshold (POT, Peaks over threshold)
15 - Quantify uncertainty
Task Description: ...
Rationale Description: ...
Associated entities: Ensemble statistics - Ensemble range
16 - Quantify uncertainty
Task Description: ...
Rationale Description: ...
Associated entities: Uncertainty quantification - Extreme value distribution
17 - Evaluate climate simulations
Task Description: Use the summary statistics to evaluate how much the metrics are
projected to change in the future period, compared to the baseline.
Rationale Description: ...
18 - Select the preferred way to communicate climate information
Task Description: Summarise and deliver the climate information in the format
preferred by the user.
Rationale Description: ...

For the same case, user11 has provided the following contribution:

1 - Identify indices and variables
Task Description: Identify climate indices needed, such as daily values of maximum
and minimum temperature and daily rainfall totals. Also soil moisture for
calculation of hydrological drought.
Rationale Description: These climate variables can be used to calculate the indices
required to assess heatwaves, growing seasons lengths, frost, surface water
flooding and agricultural drought. The wind speed can be used in combination with
surface air temperature to estimate the severity of frost.
Associated entities: Air Temperature (ta), Precipitation (pr), Soil Liquid Water
Content (mrlso), Near-Surface Wind Speed (sfcWind)
2 - Provide non-climatic information
Task Description: A variety of crops grow on the Duchy land. Find their seed
germination and flowering times. Also identify all land owned by the Duchy, so the
study can focus on those land areas.
Rationale Description: Understanding when seeds germinate and the crops flower are
important to assess impacts of low or high soil moisture levels and the timing and
severity of frosts on growth and crop yields.
3 - Choose baseline period
Task Description: Choose a suitable period for which climate observations and crop
growth and yield data are available.
Rationale Description: The data for this period will be used to assess climate

model performance by comparing the models' output with observed values. A simple model of crop yields could be constructed, using temperature as the primary variable. Any bias adjustment of the climate model output would use observed and modelled data for this baseline period.
Date Range: 01/01/1990–31/12/2020

4 – Choose future period
Task Description
Choose future years which include the customer's requirement (2021 to 2060)
Rationale Description
The future years must either match or include include the customer's years of interest.
Date Range: 01/01/2021–31/12/2060

5 – Define relevant spatial resolutions
Task Description: Choose a high spatial resolution for observed and modelled data which captures local variations in climate.
Rationale Description: Crop growth is very sensitive to temperature and rainfall. Climate and observational data with a high spatial resolution (a few km or smaller) are needed to capture local variations in climate.
Input Type: Range
Minimum spatial resolution (km): 1
Maximum spatial resolution (km): 5

6 – Choose climate models
Task Description: Identify climate models from which the relevant variables have been archived and have a high spatial resolution.
Rationale Description: Need models which were executed at a high spatial resolution.
Associated entities: WRF

7 – Define observation type
Task Description: Identify gridded observation datasets whose coverage includes the whole of England,
Rationale Description: A dataset which would covers all of England will include all land owned by the Duchy. This dataset can be used to assess climate model performance and to bias adjust the climate model data if necessary.
Associated entities: gridded

8 – Evaluate climate simulations
Task Description: Compare modelled and observed climate variables
Rationale Description: This task will allow model performance to be assessed. If necessary, some form of bias adjustment could be made to the climate model data.
Associated entities: Bias correction (Bias adjustment, Calibration, Bias calibration, Bias correction using statistical techniques)

9 – Compute climate indices
Task Description: Calculate indices needed to answer customer's concerns.
Rationale Description: The raw observational and modelled data need to be used to calculate indices relevant to the customer's requirements, such as growing season length.
Associated entities: Descriptive statistics

10 – Quantify future climate change
Task Description: Use the modelled data to calculate how the climate over land owned by the Duchy could change out to 2060.
Rationale Description: The indices calculated in the previous step will show how the growing season, occurrence of heatwaves and agricultural droughts could change out to 2060.
Associated entities: Ensemble statistics

11 – Select the preferred way to communicate climate information
Task Description: Identify the best way to present and communicate the results to the customer.
Rationale Description: The customer may want specific information or the results presented in certain way. The results should be presented in a way they can be understood and used by the custom

Annex 5: Participants feedback on the HACID-DSS

What did you like most about the HACID DSS?

Participant 1: "The procedure to follow to evaluate the workflow was simple and easy to understand. The questions were laid out in a logical order."

Participant 2: I liked the workflow to signpost different stages of the contribution, which can be very useful for new users trying to understand the overall process. The idea of having a central space for tracking contributions has the potential to support collaborations and knowledge-sharing.

Recommendations for Improving HACID DSS

Participant 1: "It was not clear which workflow was AI-generated. Some of the aspects of each part of the solution were harder to rate. For example, a response might contain a short sentence which is technically correct but lacks some further detail - so it is relevant but perhaps lacks the depth of a better answer."

Participant 2: "Overall Complexity: The current workflow appears overly long and complex, which may make it difficult for users to navigate effectively. The number of steps and the level of detail can be overwhelming, especially for new contributors, and it is not immediately clear how each stage fits into the end-to-end process. The final version can benefit from a sample case study demonstration as an example either on the interface or documentation to help users navigate any complexities.
Lack of Clear Target Audience: The workflow does not clearly specify its intended user group. It is unclear whether it is designed for beginners, intermediate users, expert climate scientists, or individuals working within specific sub-fields. Clarifying the target audience would help ensure the workflow is pitched at an appropriate level and supports users with varying levels of experience.
Ability to Reuse or Copy Contributions: It would be beneficial if the system allowed users to copy or reuse contributions made by others (currently only possible for individual projects) once a project becomes publicly available. This functionality would support continuity and enable users to build on existing work more efficiently. On the other hand, a possibility for collaborators to build workflows for a project together and not individually may be a real asset.
Uncertainty Around Required Steps: The workflow does not make it explicit whether all signposted steps must be completed sequentially. Users may be unsure whether they are expected to follow the entire workflow or only the steps relevant to their role or expertise. Adding clearer guidance or indicating which steps are mandatory versus optional would greatly improve user clarity and workflow adoption."