Deliverable Phase 2 – Climate risk assessment

RISC-RA

France, Reunion

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HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	Hydro-climatic risk assessment on Reunion Island. The document contains: • Scoping and risk exploration • Complete risk analysis for meteorological drought and extreme precipitation risks. • Methodological development of torrential floods • Perspectives for the last phase of CLIMAAX/RISC-RA project
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Leading Institution	Région Réunion
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1.0	26/01/2026	Region Réunion	Deliverable submitted
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Abbreviations and acronyms

Insert here all acronyms appearing along the deliverable in alphabetical order. This text marked in green should be deleted before submitting the deliverable.

Abbreviation / acronym	Description
ADEME	French Agency for Ecological Transition
AGORAH	Réunion Island's urban planning agency
BRGM	French Geological Survey
BRIO	Building Resilience in the Indian Ocean
CatNat	Insurance regime for natural disaster (Catastrophes Naturelles)
CCAS	Municipal Center of Social Action
CEREMA	Centre for Studies on Risks, the Environment, Mobility and Urban Planning
CMIP6	Coupled Model Intercomparison Project Phase 6
CNL	National Housing Confederation
CNRS	National Center of Scientific Research
CRA	Climate risk assessment
CPM	Convection-Permitting regional climate Models
DAAF	Department of Food, Agriculture and Forestry
DEAL	Department of Environment, Planning, and Housing
DIROI	Indian Ocean Regional Directorate
DROM	Département et Région d'Outre-mer / Overseas Department and Region
EARDF	European Agricultural Fund for Rural Development
ERDF	European Regional Development Fund
ESF+	European Social Fund Plus
FEI	Exceptional Investment Fund
FSOM	Fonds de Secours des Outre-mer / Overseas Aid Fund
GEV	Generalized Extreme Value
GCLA	General code of local authorities
INSEE	The National Institute of Statistics and Economic Studies
IO	Indian Ocean
IRIS	Îlots regroupés pour l'information statistique (Statistical information groupings)
OPAR	Observatoire de Physique de l'Atmosphère de La Réunion / Atmospheric Physics Observatory of La Réunion

OSU-Réunion	Universe Sciences Observatory of La Réunion
PAPI	Flood Risk Prevention and Management Programme
PCAET	Plan Climat Air Energie Territorial / Territorial Climate-Air-Energy Plan
PCS	Plan Communal de Sauvegarde / Local Emergency Plan
PDU	Plan de Déplacement Urbain / Urban Travel Plan
PIROI	French Red Cross's International Operations Division
PLH	Plan Local de l'Habitat / Local Housing Plan
PLU	Plan Local d'Urbanisme / Local Urban Development Plan
PPE	Programmation Pluriannuelle de l'Energie / Multi-Year Energy Plan
PPRI	Plan de Prévention des Risques Inondation / Flood Risk Prevention Plan
PPRL	Plan de Prévention des Risques Littoraux / Coastal Risk Prevention Plan
PRIT	Planification Régionale d'Intermodalité / Regional Intermodal Transport Plan
RISC-RA	Réunion Island's Climate Risks Atlas
RPCC	Regional Panel on Climate Change
RSMC	Regional Specialized Meteorological Centre
SAR	Schéma d'Aménagement Régional / Regional Land Development Plan
SCoT	Schéma de Cohérence Territoriale / Territorial Coherence Scheme
SDAGE	Schéma Directeur d'Aménagement et de Gestion des Eaux / Water Management Master Plan
SI	Supplementary Information
SRB	Schéma Régional de la Biomasse / Regional Biomass Scheme
SRCAE	Schéma Régional Climat Air Energie / Regional Climate, Air, and Energy Scheme
SRIT	Schéma Régional des Infrastructures et des Transports / Regional Transport Infrastructure Scheme
SSP	Shared-Socioeconomic Pathways
SWIO	South Western Indian Ocean
WMO	World Meteorological Organization

Executive summary

Réunion Island's Climate Risks Atlas project (RISC-RA) is the implementation of the European CLIMAAX initiative on Réunion Island, a French overseas territory exposed to intense natural hazards. Thanks to a regional Climate Risk Assessment (CRA), focusing on significant hazards and vulnerable sectors, the project supports the establishment of a **Regional Panel on Climate Change (RPCC/GREC)** and the ongoing **Regional Land Development Plan (SAR)** revision.

For the past 18 months, Réunion Island's Regional Council (Region Réunion), has led the project in collaboration with a scientific research group (OSU-R/CNRS, Météo France and BRGM), focusing on water-related risks. Phase 1 selected two main climate hazards: Droughts and Heavy Rainfall. The general CLIMAAX framework was adapted to the local insular context, using available high-resolution climate data and local exposure and vulnerability datasets, and gave preliminary results. From April 2025 to January 2026, the second phase of RISC-RA was dedicated to refining these analyses through a year-long study. This deliverable presents the updated context, methodology, and results achieved at the conclusion of this second phase.

Phase 2 in a nutshell

Phase 2 of the project refined the methodological risk analyses developed in Phase 1 (**focused on Meteorological droughts and Extreme rainfall**) and introduced a new risk assessment dedicated to **Torrential flooding**. Strong emphasis was placed on **stakeholder engagement**, particularly with water-sector actors, in order to integrate field-based expertise into the methodology.

Figure 1 : Workflows pictograms created for communication purposes on RISC-RA project (Drought, Extreme precipitation and torrential floods)

A key innovation of Phase 2 within the CLIMAAX framework was the identification and use of an **unpublished high-resolution simulation from a CPM**, developed as part of the BRIO project. This simulation is based on the AROME CPM, driven by the ALADIN Regional Climate Model (RCM). Additional exposure and vulnerability datasets from national, regional, and local sources were also incorporated. Main achievements were:

Meteorological drought: Three major improvements were introduced into this workflow: (i) the integration of evolving exposure to reflect demographic dynamics in addition to climatic hazards; (ii) the use of ground-truthed vulnerability indicators aligned with the operational realities of water resource managers; and (iii) the selection of the most relevant geographical units to ensure results are clear, interpretable, and directly usable for local planning and decision-making.

Extreme precipitation: the single impact threshold of 220 mm/day seemed too low. The new workflow relies on new spatialized impact thresholds derived from the “heavy rain/storm” vigilance system across La Réunion’s ten climatic zones. The results of extreme precipitation are more consistent than in phase 1. Still, they remain contrasted with a strong dependence on the climate scenario. Further analyses are required, particularly to better understand the role of the number of simulated tropical cyclones in the projected risk.

Torrential flooding: Flash flood risk was introduced in Phase 2 to extend and complement the extreme precipitation analysis by explicitly addressing hydrological responses on a mountainous island such as La Réunion. This workflow is currently under development in collaboration with the CRAHI team. Exchanges with Flood alert services and Météo-France highlighted the critical importance of sub-daily hydrometeorological data for this assessment. As a result, the analysis relies on hourly outputs from the AROME model. The hazard assessment was thus conducted by aggregating precipitation data over key (or critical) watersheds for sub-daily durations of 1-hour, 3-hour, 12-hour, and 24-hour.

Main findings

The risk assessment analysis provided a clearer understanding of the **main hydro-climatic risks** on Réunion Island, as well as the **priorities for action** based on their projected evolution and the territory’s resilience capacity. Although **extreme precipitation risk** projections show contrasting results, **this risk must be taken seriously due to its substantial severity**, as evidenced by recent catastrophic impacts, and the **urgent need for response measures**. While droughts are slower-onset processes with less catastrophic impacts on the island to date, the recent drought events observed during the last decade, combined with projected trends and the **high vulnerability of certain areas**, elevate this risk to a **key priority requiring immediate action**. Finally, **Phase 2 of the risk assessment methodology** provided a valuable opportunity to **"build connections"** with water stakeholders and align initiatives aimed at enhancing the territory’s adaptation.

Phase 2 scientific results must now be translated into a final version of **Réunion Island’s Climate Risks Atlas for the general public** (phase 3). The last months of the RISC-RA project will be dedicated to disseminate and use those results locally (SAR’s Regional Adaptation Strategy, local planning documents). This study will also constitute a starting point of a new Region Réunion’s project as part of the “Pathways to Resilience” European initiative.

1 Introduction

1.1 Background

Reunion Island is a 55 km-diameter tropical volcanic island in the South-Western Indian Ocean (SWIO). Known as a hotspot of natural disasters, the island's complex and prominent topography (up to 3,000 m) significantly influences and amplifies climate and geological risks, to which the territory is highly vulnerable. La Réunion is characterized by great ethnic diversity (European, Malagasy, Indian, Asian and African origins). However, an unemployment rate of 17% in 2024 (more than double the rate of 7% in metropolitan France) and the high cost of living (+37% for food compared to mainland France) contributes to poverty and wealth inequality, further increasing vulnerability to climate risks.

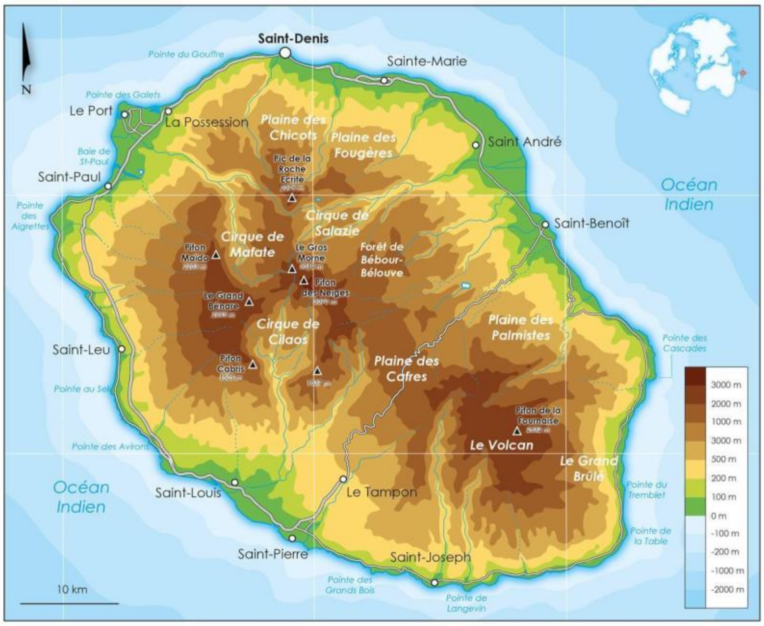

Figure 2 : Geographical context of La Réunion territory (Bart, 2016)

The Regional Council of Réunion, referred to hereafter as Région Réunion, acts as the island's local authority since 1982. It leads economic development, research, training, sustainable development, and land-use planning. Through a key planning document, the Regional Land Development Plan (SAR), it defines guidelines for sustainable development and climate adaptation. Currently under revision to meet 2050 challenges, the SAR will incorporate local climate projections (TRACC) and public contributions, with finalization expected in late 2026. In 2023, the President of Région Réunion launched the Regional Panel on Climate Change (RPCC) to strengthen collaboration among experts, policymakers, and citizens in addressing climate risks.

1.2 Main objectives of the project

This initiative behind the project represents Réunion Island's first comprehensive regional Climate Risk Assessment (CRA), focusing on significant hazards and vulnerable sectors. By analyzing observed and projected climate data, as well as vulnerability and exposure under various scenarios, the RISC-RA project evaluates future climate change impacts on the territory, its population and infrastructures. The findings will be disseminated locally through the publication of a climate risk atlas.

Guided by the CLIMAAX methodology and adapted to La Réunion's specific context, the CRA enhances local knowledge of climate risks and raises awareness among stakeholders. The analysis clarifies how territorial vulnerabilities shape risk, providing standardized, spatialized risk indicators for public authorities and researchers. The CRA and atlas will serve as decision-support tools for risk management and adaptation in a context of climate change, directly informing the ongoing revision of the Regional Land Development Plan (SAR) and related strategies.

The phase 2 refines the methodological analyses of risks proposed in Phase 1 and develops a new risk assessment. A key focus was placed on engaging local stakeholders, particularly water sector actors, to incorporate their field expertise into the methodology. This collaborative approach strengthens the relevance and applicability of the CRA's findings.

Ultimately, the project supports the establishment of the Regional Panel on Climate Change (RPCC/GREC) and the Regional Land Development Plan Revision, fostering collaboration among experts, policymakers, and the public. It also advances Région Réunion's goals for health, energy, and food sovereignty in the face of climate risks (citation article).

1.3 Project team

The RISC-RA project team is the same since the first phase of the project. It is composed of a scientific research group working in collaboration with the Réunion Regional Council. The Core Team include:

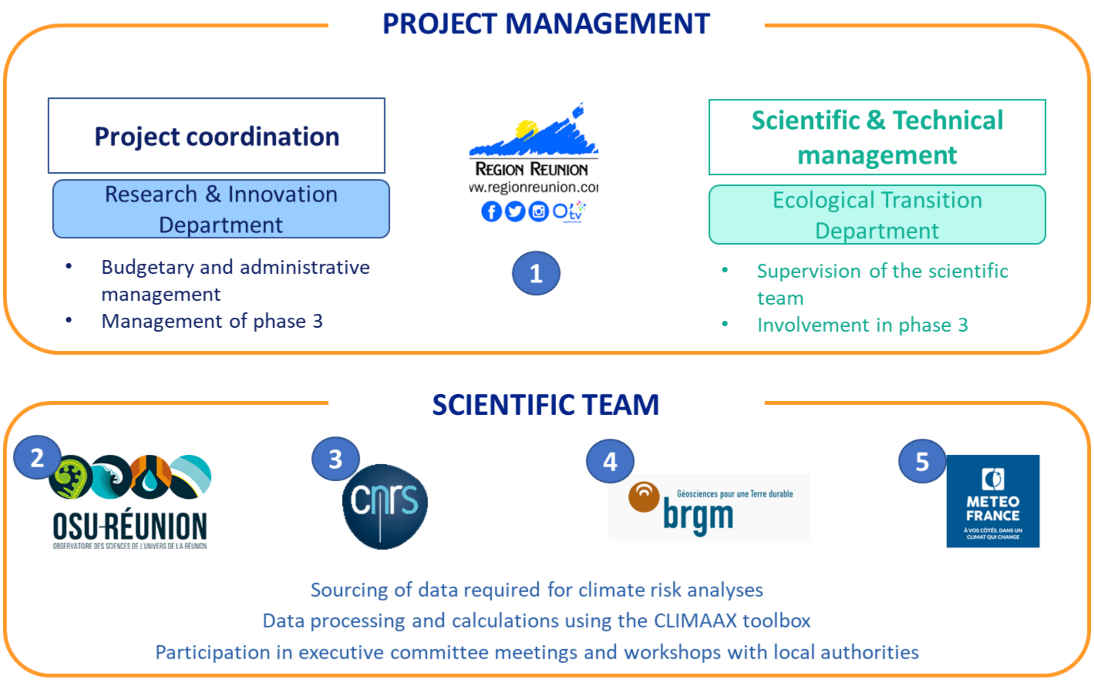

Figure 3 : RISC-RA Project organizational chart

1: **Kevin Lamy**, Natural Risks and Climate Project Manager, Ecological Transition Department, and **Elodie Marpinard**, Research and Innovation Officer, Research, Innovation and Technologies Department, Region Réunion
2: **Nils Poncet**, Scientific provider of the RISC-RA project, OSU-Réunion.
3: **Jean-Pierre Cammas**, Research Director, CNRS, OSU-Réunion.
4: **Rémy Belon**, French Geological Survey on the coastal risks (BRGM).
5: **Clotilde Dubois**, Climate Services, Indian Ocean Regional Directorate (DIROI) of Météo-France.

Nils Poncet joined the project at the end of February 2025, assuming the main scientific contribution during the phase 2.

1.4 Outline of the document’s structure

This report is organized as follows:

Section 2 describes the operational framework for climate risk assessment (CRA) for Réunion Island, detailing the steps involved in scoping, risk exploration and risk analysis. It also presents the complete and validated results of the assessment of two key risks explored in phase 1 and details the methodology and the data preparation of a brand-new workflow. It then concludes with observations from the monitoring and evaluation phase. Section 3 summarizes the main conclusions and key results of this phase of the project. Section 4 clarifies the links between this deliverable; its results and the activities planned for the next phases of the project. Finally, sections 5 and 6 provide the documentation and references produced during this phase.

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

The RISC-RA project transcends technical mapping by serving as a strategic tool to strengthen climate literacy across multiple governance levels—regional, municipal, and inter-municipal.

Reminder of key objectives:

- **Policy integration**: Directly informs the revision of the Regional Land Development Plan (SAR), ensuring consistency across local planning frameworks (PLU, SCoT).
- **Regulatory support**: Provides data for updating Natural Risk Prevention Plans (PPRI, PPRL) to regulate land use effectively.
- **Institutional building**: Contributes to the establishment of the RPCC through the collaborative work conducted with institutions and research partners on the RISC-RA project.
- **Capacity building**: Translates complex climate data into accessible knowledge for non-experts and local authorities to guide practical adaptation strategies.

Since Phase 1, the governance context has evolved. The **GREC-Réunion** has been established and will be launched in January 2026, with the CRA to be published and disseminated through this new science–policy interface. The Regional Adaptation Strategy linked to the SAR is now advanced and will integrate selected CRA indicators. Together, the CRA and the Adaptation Strategy will underpin La Réunion's participation in the "Pathways2resilience" programme, for which the region has been selected in December 2025 as part of the second cohort.

Several constraints from Phase 1 CRA remain, including limited data resolution for small island contexts, gaps in high-frequency climate observations, and the inadequacy of standard European risk assessment methodologies for a mountainous tropical environment.

Phase 2 introduced new challenges:

- **Spatial scale and mapping consistency**: Integrating heterogeneous data scales within a single workflow complicated the cartographic output. This challenge was further amplified by the diverging visualization preferences of local stakeholders.
- **Methodological appropriation:** Significant efforts in simplification and pedagogy were required to explain the internal logic of each workflow, ensuring local stakeholders were fully engaged in the methodology.
- **Choice of level of detail:** During methodological refinement, it was difficult to strike a balance between a general, simplified application of the methodology, or taking into account the very specific realities of the territory, which required significant methodological development and sometimes a loss of automation.
- **Interpretation of complex results:** The lack of convergence between certain results in the different scenarios, as well as their counterintuitive nature, highlights significant uncertainties related to the methodology in the case of Réunion (e.g. extreme precipitation), making it extremely difficult to understand the results and draw reliable conclusions.

2.1.2 Context

Current Climate Monitoring and Risk Assessment on Reunion Island

Réunion Island possesses world-class atmospheric physics and weather observation infrastructure and expertise, notably through the OPAR (Observatoire de Physique de l'Atmosphère de La Réunion) and its status as a WMO Global Specialized Meteorological Centre. While these systems ensure excellent documentation of hazards like cyclones, some gaps remain in impact-observation systems, and corresponding long-term climate metrics for extreme weather events.

Despite the recent availability of high-resolution (3 km) climate datasets and future projections based on CMIP6 models from the BRIO (Building Resilience in the Indian Ocean) project, a comprehensive analysis of natural risks (vulnerability and exposure) is still lacking. Current impact research is limited to specific studies on agriculture, biodiversity (Christina et al., 2023), and health (UV radiation : Lamy, 2018; Cadet et al., 2020 - vectorial diseases : Lamy et al., 2023).

The island maintains a robust risk and disaster management framework, including advanced alert systems (FR-ALERT), dedicated insurance compensation funds (CATNAT), and regional emergency response through the Red Cross (PIROI). Current initiatives (SYNERGIES project and the "Paré pa Paré" educational platform) demonstrate the commitment of local stakeholders to promoting culture and raising awareness of risks.

The recent deployment of the **TRACC** (Trajectory of Reference for Adaptation to Climate Change) framework provides a new national standard, anticipating a local warming of **+2.0°C by 2050** and **+2.9°C by 2100** for Réunion Island relative to pre-industrial period (French Government, *Décret n° 2026-23, 2026*). TRACC framework shifts the climate impact studies paradigm from "when will impacts occur?" (e.g., by mid-century) to 'if warming reaches X°C, what will happen?' replacing the focus on global warming levels (+1.5°C, +2°C, +3°C) rather than fixed time horizons. This harmonizes climate research with the Paris Agreement's targets while enabling localized action, such as Réunion's SAR or PCAET adaptation plans. To follow this standard, Météo-France has adapted its high-resolution projections by warming level and released the simulations on the DRIAS portal, as well as a municipal-level diagnostic tool (**Climadiag**) in late 2025. This initiative aims to standardize climate knowledge across the territory.

Linking the RISC-RA Project to Réunion Island's Resilience Challenges

The core challenge for the island's resilience is the need for a comprehensive risk framework that integrates hazards, vulnerability, and exposure. A structured "risk knowledge" document is essential to align national management strategies with local realities. To solve this, the RISC-RA project aims to bridge the gap between bottom-up needs and top-down policies. Key challenges underlined in phase 1 remain, including:

- **Capacity gaps**: A shortage of qualified researchers and engineers, and a need for better climate adaptation expertise among local decision-makers.
- **Knowledge gaps**: Insufficient data on urban resilience regarding population growth and soil artificialization.

- **The science-society gap**: While local research is abundant, it is rarely translated into actionable tools for public policy, resulting in a lack of transdisciplinary studies involving actual stakeholders.

La Réunion also faces significant external vulnerabilities, primarily driven by a heavy reliance on imports that undermines food sovereignty and leaves the island exposed to global market shocks (e.g., price volatility, rising transport costs). Additionally, while illegal immigration is currently a minor issue compared to neighboring Mayotte, experts warn that accelerating climate change and geopolitical instability could increase migration pressures on the territory in the future (Wu-Tiu-Yen, 2015; Cole & Cabestan, 2024).

Governance context

La Réunion, as a French overseas region, operates within French and EU environmental and risk management regulations (e.g., Floods Directive 2007/60/EC). Climate change adaptation is guided by a multi-level policy framework that integrates regional, inter-municipal, and municipal planning instruments.

At the regional level, the **Regional Land Development Plan (SAR)** serves as the main land-use planning framework and is under revision since 2023, with the Climate Risk Assessment (CRA) expected to significantly inform climate adaptation measures. The SAR includes a dedicated "**Climate, Air, and Energy**" chapter, which defines mitigation and adaptation objectives for 2030 and 2050, assesses territorial vulnerability to climate change, and establishes a **Regional Adaptation Strategy**. Since 2024, significant progress has been made on this regional strategy which provides a structural framework to align urban planning with evolving climate risks.

Additional regional instruments include the **Multi-Year Energy Plan (PPE 2019-2028)**, which steers energy policy and renewable development, and the **Water Management Master Plan (SDAGE 2022-2027)**, which guides water resource protection. In accordance with the European Floods Directive, flood management is structured around six **high-risk areas in La Réunion (TRI)**. integrated into the PGRI (State-led Flood Risk Management Plan) and the SLGRI (Local Flood Risk Management Strategy). Other sectoral plans—such as those related to transport, mobility, biodiversity, and biomass—may also benefit from CRA findings.

At sub-regional and local levels, the CRA is relevant for inter-municipal planning documents such as **SCOTs (territorial coherence plans)** and **PCAETs (territorial climate-air-energy plans)**, as well as municipal tools including **local urban plans (PLU)**, natural risk prevention plans **(PPRI, PPRL**), and local emergency plans (**PCS**), which connect risk prevention with crisis management.

Alongside planning documents, several initiatives have been consolidating local governance of risks and adaptation to climate change since 2024.

The **GREC-Réunion (RPCC for La Réunion)**, launched in January 2026 marks a decisive milestone in the island's long-standing commitment to addressing the climate emergency. Building upon historical collaboration with the IPCC, this new body reflects a bold political ambition reaffirmed in 2023 by the president of the regional council. Designed as a collaborative science-policy interface, GREC-Réunion's will conduct territorial research and expertise on climate impacts and adaptation, and will work to improve coordination, cooperation, and financing for climate change adaptation -

both within La Réunion and across the broader South-West Indian Ocean region. By simultaneously signing the European Union's "Adaptation to Climate Change" charter, La Réunion pledges to transform expertise into concrete action.

GREC-Réunion appears as the regional platform that will serve as a bridge between ongoing initiatives, such as the local Coastal Observatory for example, and the French State's Adaptation Mission (a set of coordinated missions led by the State), which delivers for instance local engineering support services in line with **PNACC 3 (the National Climate Change Adaptation Plan)**.

In parallel, the recent recruitment of local researchers specializing in climate change adaptation is actively reducing human resource gaps and strengthening local expertise. Notable CNRS-led initiatives include the **project "Knowledge and Solutions for Climate Change Adaptation in Overseas Territories",** which undertakes a review of the scientific literature on observed and projected climate change in French overseas territories, as well as the ongoing **project "Barriers, Levers and Constraints to Adaptation in Territorial Public Policy"**. The latter operates at the interface of social sciences, political science, and climate science.

Mapping climate impacts across key sectors

Réunion Island, a remote and geographically constrained territory, faces significant climate change threats due to its concentrated coastal population and economic activities. Its vulnerability spans multiple sectors, each critically exposed to evolving climatic risks.

Agriculture, a cornerstone of the local economy (notably sugarcane, vanilla, fruits, and vegetables), suffers recurrent losses from tropical cyclones, with compensations exceeding €43 million between 2010 and 2022. Tropical cyclones Belal (2024) and Dina (2002) alone caused damages estimated at €100 million and €169 million, respectively. Beyond cyclones, **droughts and extreme rainfall** further threaten agricultural productivity (Christina et al., 2021, 2024).

The **energy sector**, in transition toward 100% renewable energy by 2030, remains highly vulnerable to climate shocks. Cyclone Garance (2025) left 180,000 customers—41% of the island—without power for nearly a month leading to water shortages, highlighting the fragility of energy security.

As a **biodiversity hotspot,** Reunion island exposes its unique terrestrial and marine ecosystems to direct and indirect climate impacts, including ocean acidification, habitat degradation, and invasive species proliferation.

Infrastructure and transport networks are repeatedly disrupted by cyclones, coastal floods, flash floods, and landslides. The island's main airport, located along the coast, is particularly vulnerable to wind gusts and flooding, risking prolonged isolation during disasters. Long-term coastal erosion further threatens its viability. Road closures due to severe weather or landslides frequently disrupt mobility and intertown connections.

Housing, especially social housing occupied by the island's most vulnerable populations, suffered major damage during Cyclone Garance (2025), exacerbating socio-economic inequalities.

The **water supply** system grapples with extreme spatial and temporal precipitation variability, ranging from 500 mm/year on the west coast to over 12000 mm near the eastern volcano. Droughts and cyclone-induced pollution or pipe damage regularly strains water resources. An underground aqueduct transfers water from the east to the west to mitigate these disparities.

Finally, **tourism**, a growing sector representing 3.3% of GDP and employing 13,550 people in 2018 (Perrain et al., 2022), faces mounting threats from climate-related hazards. Trail closures, water pollution, network disruptions, and ecosystem degradation jeopardize this vital economic pillar.

2.1.3 Participation and risk ownership

Stakeholders' presentation and involvement process

The **Executive Committee (COMEX)** meeting is the main expert and governance body for the RISC-RA project. COMEX brings together:

- Three **departments from the Region Réunion**: the Directorate for Ecological Transition, the Directorate for Research, Innovation and Technology, and the Directorate for Planning and Housing.
- A **scientific group** composed of members from four institutions: OSU-R, CNRS, the University of La Réunion (UR), Météo-France and BRGM.

This consortium enables interdisciplinary scientific collaboration in order to cross-check data and assess risks in the region. The consortium's objective is to pursue long-term collaboration through GREC-Réunion.

In addition, the **two main stakeholder groups** in the project are:

- **Local public authorities**: municipal and inter-municipal authorities responsible for local planning and the implementation of a wide range of climate change adaptation measures. This is also the level closest to the specific characteristics and daily realities of the population, particularly vulnerable neighborhoods and disadvantaged communities.
- **Regional technical actors**: in particular regional actors (such as the Water Office, AGORAH-planning agency) and representatives of State services in La Réunion (INSEE, DEAL, ARS, etc.). These actors are valuable providers of data and technical references for the project methodology.

The stakeholder engagement process in the RISC-RA project is carried out through:

- **General communication** on LinkedIn and institutional websites
- **Short presentations of the project** during thematic regional meetings or technical committees (Technical Committee on Risks in La Réunion, SAR Development Commission, Météo-France thematic days, Mayors' Fair, etc.)
- **RISC-RA local meetings** held in 2025 and an online survey related to water risks.

The table below presents the relevant stakeholders of the project and their role, including Risk ownership in Réunion Island.

Table 1: RISC-RA Stakeholders mapping and relevance for the project

Stakeholder	***Description***	***Risk ownership***	***Involvement in RISC-RA***
Region Réunion	Regional Council	Main authority in charge of regional planning, economic development, and environmental policy	RISC-RA project pilot GREC-Réunion pilot
OSU-R/CNRS	Scientific body in University of La Réunion, Regional observatory	Data provider and local expert on Climate change	RISC-RA COMEX Member Scientific provider of the project
Météo-France Réunion	National weather services in La Réunion	Main climate data provider, local expert on climate models et projections	
BRGM	Regional Directorate of the National Geological Service	Local expert on hydrologic and coastal risks	
CASUD, Territoire de l'Ouest, CIVIS, CINOR, CIREST	Inter-municipal communities of La Réunion. A focus has been made on the environment and water departments.	Local planning and implementation of climate change adaptation actions	RISC-RA local meetings participation 2-hour on-site meetings and online survey to improve the phase 2 methodology on water risks Exclusive or sensitive local data were also shared by some stakeholders
SOURCEO, CISE	Water services providers (delegatee)	Water services management	
DEAL Réunion	State department of Environment, Planning and Housing	Environmental and risk management through the creation of the PPR, sustainable development and resources preservation.	
Office de l'eau (Water Office)	Water institution attached to the Department of La Réunion	Study of water resources, technical assistance to local authorities	
ARS Réunion	Regional Health Agency of Réunion (designated as ARS in the report)	health monitoring, water and environmental quality control, and health prevention	
CVH	Hydrological Vigilance Unit	Specialized service of the DEAL monitoring and alerting to flood risks	Expertise regarding the flash flood risk methodology
INSEE	National Institute of Statistics and Economic Studies	Data provider and expert on economy and society	Local socio-economic data provider 1 short meeting to discuss population projections
AGORAH	Réunion Island's urban planning agency	Data provider and expert on planning and local development	Local data provider

Stakeholder	Description	Risk ownership	Involvement in RISC-RA
AFD, Banque des territoire	Banks for the territories	funding for ecological transition in Réunion	Specific meetings about RISC-RA, Informed through the GREC-Réunion specific communications
Department	Départmental council of Réunion Island	Departmental roads. Natural sites protection. Developing social policies minimizing social inequalities	Informed through the SAR or GREC-Réunion specific communications
Towns and municipalities	Towns and municipalities of Réunion Island	Municipalities manage local planning and implement adaptation actions	

As detailed in the above table, while the French State retains primary authority over risk management, climate adaptation in La Réunion is a collaborative effort across multiple scales. Region Réunion leads regional planning and this specific project, supported by Departmental social and infrastructure policies, intercommunal implementation, and municipal local planning or regulations. This framework is further reinforced by state agencies like DEAL and ARS, which provide environmental and health oversight, ensuring that technical assessments are integrated into local development and long-term resilience strategies.

Vulnerable groups and levels of risks

The **RISC-RA project addresses water-related risks on Reunion Island**—specifically drought, extreme rainfall, and flash floods—focusing on their impact on drinking water access, housing, and infrastructures. Because **36% of the population lives in poverty**, the project prioritizes the vulnerabilities of the most disadvantaged groups, including those in **substandard housing**, **coastal zones**, **dense urban areas**, or **isolated areas**.

Due to this methodological focus on water risks affecting the general population, we have turned our attention primarily to **inter-municipal authorities**, **water concessionaires** and **government departments** directly involved in these risks (prevention, planning, public information). These actors are familiar with the infrastructural vulnerabilities and social realities of the most disadvantaged groups. Due to time constraints, we have decided to focus our indicators on the general population rather than on the agricultural or other economic sectors.

The project's core mission is to safeguard human life and secure people, property, and essential infrastructure, ensuring that vulnerable communities—particularly those in dense urban areas, social housing or isolated zones—are not left behind. Beyond immediate protection, the goal is also to maintain and swiftly restore the population's quality of life by ensuring access to drinking water, electricity, and transportation infrastructure following the occurrence of a natural hazard (e.g., a tropical cyclone).

Beyond the urgent response to natural risks, the priority lies in preserving public safety and resilience, safeguarding critical infrastructure, maintaining a satisfactory quality of life, and supporting the rapid resumption of economic activities.

The challenge for phase 3 of the RISC-RA project will be to integrate the results obtained into urban planning and prevention plans to secure the most vulnerable groups and areas.

2.1.4 Application of principles

As far as possible, the RISC-RA methodology incorporates the principles of the CLIMAAX framework.

Social justice, equity, inclusivity

The socio-economic indicators used in the "Drought" workflow primarily target vulnerable populations: **Poverty rate**; share of **social housing**; **cost of water relative to the income of the lowest-income group** of **the population in each inter-municipal authority**. The latter indicator was developed and integrated following consultations with local public stakeholders during Phase 2, in order to capture the economic burden of water costs on the most disadvantaged populations.

In addition, r**emote, mountainous, or steep areas** (such as the Mafate cirque, for example) are subject to specific treatment in the **calculation of infrastructure vulnerability indicators** within the "Drought" workflow. These areas lie outside the boundaries of water distribution units and face significant vulnerability in terms of water access infrastructure for the population.

Regarding the "Torrential Flooding" workflow, the work conducted at the scale of the **Areas of Significant Flood Risk (TRI)** in La Réunion directly targets zones known for the pronounced presence of informal housing and populations that are extremely exposed in the event of cyclones or heavy rainfall.

Quality, rigour, transparency and precautionary approach

Region Réunion chose to mobilize a renowned scientific consortium to work on the RISC-RA project, supported by a full-time postdoctoral researcher. The work and methodology are closely monitored and discussed within the Executive Committee (COMEX). Project progress is presented very regularly during local technical meetings and at gatherings of the territorial stakeholders involved. The precautionary approach is embedded in the whole process of analyzing and disseminating results.

2.1.5 Stakeholder engagement

During Phase 2 of the RISC-RA project, the team placed a strong emphasis on designing a robust stakeholder engagement process as a core component of the methodology. Initially, two workshops with priority stakeholder groups were planned during Phases 1 and 2. However, because stakeholders were geographically dispersed and already engaged in other regional initiatives (such as GREC-Réunion and the SAR revision), the project team adapted its engagement strategy.

Instead of centralized workshops, the two main stakeholder groups—**local public authorities and regional technical stakeholders**—were engaged through **on-site local meetings** complemented by **an online survey**. The RISC-RA team organized meetings across the territory (see Figure 4) to reduce mobility constraints and encourage informal, in-depth exchanges. These stakeholders corresponded to the target audience originally identified for the Phase 1 and Phase 2 workshops.

Between **23 September and 18 November 2025**, the RISC-RA team organized **nine local meetings**, involving representatives from five inter-municipal communities and four regional technical stakeholders. In total, **25 participants from local and national public authorities contributed to the Phase 2 methodology on water-related risks.** Each meeting included a brief project overview, followed by a detailed presentation of the methodology. Participants were invited to provide **feedback on the methodology** (including datasets, mapping outputs, and indicators) and to share their **local experience of water-related risks**, such as historical events and particularly vulnerable areas. This information are detailed in Appendix 3 – Communication & dissemination.

Following each meeting, participants received a summary document and **an online survey** to further refine and deepen their contributions. **All stakeholders completed the survey**, confirming the effectiveness of the **proximity-based engagement approach**.

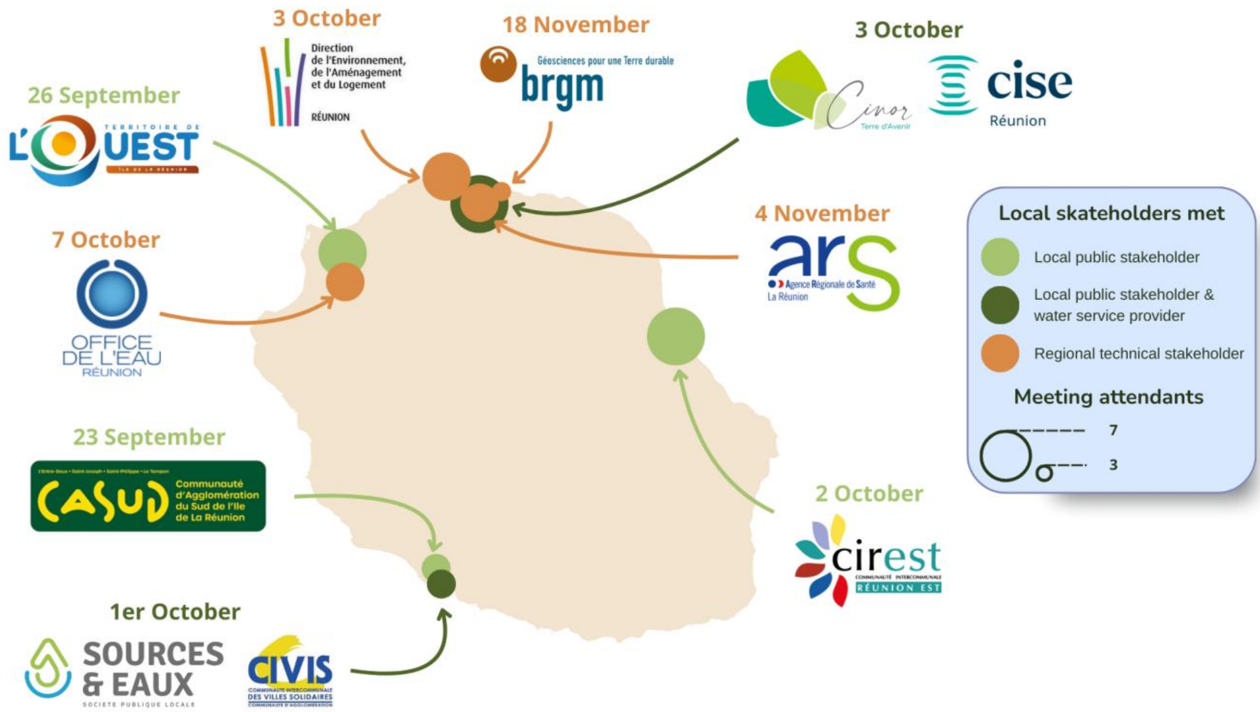

Figure 4 : 2025 Calendar of consultation meetings with local stakeholders - Figure source: Nils Poncet

In parallel, several complementary communication actions were implemented to share project progress and outcomes locally, including:

Table 2: Summary of communication and dissemination actions (see Appendix 3 Communication -Dissemination)

Type of communication	Actions
Online video clip	French video clip of the project objectives
Dedicated webpage	CLIMAAX/RISC-RA webpage on Region Réunion's website
LinkedIN posts	3 institutional LinkedIN posts since the beginning of the project. In addition, there has been 1 online communication via the REGILIENCE project and personal posts by the team on LinkedIn.
Presentation delivered at regional or professional events	Météo-France technical days (April and June 2025), SAR development board (June 2025), training session for the Red Cross (November 2025), Technical Risk Committee (December 2025), GREC-Réunion launching (January 2026)

2.2 Risk Exploration

Risk exploration starts with a broad screening of the risks (their underlying hazards, exposures and vulnerabilities) that are most apparent or of significant concern to key stakeholders and the wider public.

2.2.1 Screen risks (selection of main hazards)

Réunion Island faces a complex and interconnected range of natural hazards, many of which are projected to worsen due to climate change. Seven of the eight major natural hazards threaten the territory. Tropical cyclones (TC) are a striking example of compound hazards simultaneously triggering destructive winds, extreme rainfall, landslides, coastal and river flooding (Ranjan & Karmakar, 2024). According to CCR, the average annual cost of all combined hazards is €9 million and is projected to rise to €30 million/year for cyclones alone.

Main risks

The main risks concerning Reunion Island are summarized as follows. More information is available in the first phase deliverable.

- **Droughts** on Réunion Island lead to water shortages for population and economic losses, through reduced agricultural yields (Christina et al., 2021, 2023). The west coast, usually protected from the wind and precipitation by the relief, is the most affected region. However, over the last decade, some drought crises have also occurred on the wet eastern coast, due to both delays in the rainy season and vulnerable infrastructure. Future projections indicate a possible lengthening of the dry season and a shift in the wet season (Leroux et al., 2024), likely increasing the drought risk.

- **Cyclonic winds** represent a major threat across the entire island, and particularly the coastline population. Tropical cyclones damage critical infrastructure, such as communication and energy networks, leading to isolation and water shortages, as well as damaging homes. The proportion of intense TC is expected to increase in the future, suggesting an increase of the wind-related risk (Cattiaux et al., 2020; Leroux et al., 2024).
- **Extreme precipitation**: Réunion Island holds several world records for rainfall, including 6,083 mm over 15 days. Extreme rainfall causes intense runoff leading to diverse effects: flash floods along rivers, landslides, rockfalls and soil erosion in mountainous areas. The most vulnerable areas are located on intermittent watercourses, where flooding can take people by surprise. Pedestrians and cars attempting to cross flooded fords are responsible for many fatalities.
- **Flooding**: Exclusively triggered by extreme rainfall, combined with the island's complex topography, floods in Reunion Island are highly dynamic. Urban areas, particularly those with impermeable surfaces, are prone to dangerous flooding when drainage systems are overwhelmed. 13.2% of the population is directly exposed to flood risks. Low-lying coastal cities, often crossed by ravines, are especially vulnerable, while inland villages may face prolonged isolation due to disrupted water and electricity networks.
- **Wildfire**: The most fire-prone areas on Réunion Island include the highly combustible sugarcane fields in the east and the dry savannahs in the west. The island experiences several hundred fires annually, most of them during the dry and windy periods of austral winter. Recent examples include fires in 2010 (800 ha burned at Le Maïdo) and 2011 (2800 ha burned), both of which affected the National Park and UNESCO World Heritage sites.
- **Coastal Flooding:** Coastal flooding on Réunion Island are consecutives of austral swells affecting the southern and western coasts, and cyclonic swells, which can impact the entire island. These events often lead to sudden coastal erosion, threatening housing and infrastructure. Approximately 5000 people are exposed to this risk. The island was also affected by the 2004 tsunami, which followed the Sumatra earthquake.
- **Heatwaves**: Heatwaves primarily affect low-elevation coastal areas (below 150 meters), where more than half of the island's population resides. These events occur during the austral summer and are often accompanied by high humidity levels, which increases the health impacts. Heatwaves pose a significant mortality risk, particularly for the elderly, and can exacerbate mosquito-borne diseases such as dengue fever. Sixteen of the 20 heatwaves recorded between 1995 and 2021 occurred after 2010, and this trend is expected to intensify, with temperatures above 31°C potentially lasting for up to six months per year in the future (see DRIAS portal).

In this climate risk assessment, among all the potential risks mentioned above that can occur on Reunion Island, we have chosen to focus on three main water-related risks:

1. **Meteorological drought**
2. **Extreme precipitation**
3. **Torrential flooding**

The first two risks have been assessed from the first phase of CLIMAAX project, whereas the torrential flooding workflow has been selected during the second phase of the project in order to extend and complement the analysis of extreme precipitation by examining its hydrological consequences on an island such as La Réunion. This workflow is still under development, in collaboration with the CRAHI team.

Several important reasons guided us in selecting these risks:

- The three climatic risks have had a significant impact recently. On the one hand, recent droughts have been intense on the territory, as evidenced by the extreme drought in December 2024 and January 2025, the driest months recorded in 50 years of measurements. On the other hand, the recent TC Garance occurring in February 2025, brought up to 300 mm of rain in 3 hours, causing catastrophic flooding in the urban area of Saint-Denis. These recent disasters have unfortunately had a considerable impact on the region, yet they have opened a window during which individual and collective memories of these risks remain vivid, facilitating awareness and the implementation of adaptation measures by decision-makers.
- No studies or research projects have assessed these risks in the context of climate change in La Réunion, unlike coastal flooding (destination earth, project in BRGM), heatwaves (doctoral project at Météo-France) and fires (wildfire index being developed at DIROI).
- Technical choice : climate data from BRIO project (Leroux et al., 2024) is available and adapted for these risk assessments (cf. following paragraphs). After some hesitation, and consultation with other climatology experts in La Réunion, we did not choose the cyclonic winds workflow because these events are too sporadic and subject to biases. A single climate simulation would not be informative enough about the evolution of this hazard.

Data

The main difficulty of working on an overseas territory lies in the scarcity of datasets. We could not use all the European datasets, and relied mainly on national or local datasets from the beginning of the project. Global datasets are not precise nor accurate enough to finely represent Reunion Island complexity.

Climate

In the first phase, we used a recent climate dataset developed in the framework of the BRIO project, covering the South-West Indian Ocean (SWIO) including Indian Ocean Commission (IOC) member countries (Leroux et al., 2024). Over La Reunion, this dataset offers gridded climate information from observation and climate projections. Climate simulations are generated either from an ensemble of Global Climate Models (GCMs) or from ALADIN Regional Climate Models (RCM), and are published on a daily basis after undergoing bias correction and statistical downscaling to 3 km. Unfortunately, due to its remote location, La Réunion is not covered by international coordinated modeling efforts like CORDEX-Africa, which primarily focus on continental regions.

To study local scale extreme hydro-climatic phenomena, often initiated by deep convection, either Global Climate Models GCM or RCM show limitations. Indeed, the coarse resolution of these models (approximately 100 km and 15 km, respectively) requires the presence of deep convection parametrization scheme, often resulting in an underestimation of the local scale phenomena intensity as extreme precipitation, even after bias-correction.

When grid resolution is 4km or finer, the climate model is able to explicitly simulate deep convection processes, offering a more accurate depiction of convective phenomena. These models are called Convection-Permitting climate Models and offer great potential to assess risk derived from small-scale extreme climatic events (Lucas-Picher et al., 2021; Prein et al., 2025).

The **novelty for the second phase** of CLIMAAX was the identification and the use of an unpublished additional simulation from a CPM, also launched as part of the BRIO project. This simulation comes from AROME CPM, driven by ALADIN RCM (Termonia et al., 2018; Fumière et al., 2020). While the simulated data retrieved are not bias-corrected, their hourly resolution and explicit representation of deep convection processes.

Exposure and Vulnerability

Exposure and vulnerability data comes from national data providers, through nationally harmonized datasets, and are available for all territories, including overseas departments and territories. However, when it comes to highly localized data or very specific/technical areas such as drinking water infrastructure, we have encountered significant difficulties in retrieving, harmonizing and therefore exploiting the data.

In phase 1, vulnerability and exposure data came from mainly from national sources:

- **IGN**: The BDTopo dataset is a vector description (structured into objects) of the elements of the territory and its infrastructure and divisions at all administrative levels.
- **INSEE**: Provides population census data at 200m resolution through the Filosofi product and socio-economic indicators in partnership with IGN at the infra-municipal level IRIS.
- **SISPEA**: dataset on water prices, consumption and infrastructure efficiency at municipal level.

In Phase 2, we added other datasets for our refinement and development purposes from national, regional and local sources:

- **SDAGE:** Regional water mass assessment of quantitative and qualitative pressures on groundwater and watercourses (see section Governance context)
- **TRI**: Flood footprint of flood-prone areas developed by specialised state services (DEAL)
- **IGN**: BD Alti dataset provides a 25-meter-resolution digital elevation model for metropolitan France and overseas departments.
- **ARS:** Regional health agency providing, upon request, the footprint and information of drinking water distribution units (UDI) as well as confidential data on water abstraction.

For further details on the data used for each risk, their temporal and spatial resolution, and other relevant information, the reader is invited to refer to the corresponding section and the Appendix 1 containing the supplementary materials relative to the deliverable.

Knowledge

With the expansion of national climate services and their growing inclusion of overseas territories, future climate change projections for La Réunion are becoming increasingly well-documented and accessible. However, while these advancements provide robust insights into average climate trends, they still leave critical gaps in our understanding of extreme events and their associated risks on the territory.

Moreover, these knowledge gaps are compounded by the limited density and qualifications of scientific personnel, with very few experts specializing in the various aspects of climate change impacts. As a result, knowledge of climate risks remains inconsistent across La Réunion, with a clear lack of studies on future hydro-climatic impacts as well as comparative analyses needed to validate the limited research available and to build robust knowledge. Nevertheless, as highlighted in a previous section, some targeted work is currently underway, focusing on heatwaves and health impacts, coastal flooding, and wildfire risks in a climate change context.

2.2.2 Choose Scenario

Climate scenarios

The climate scenario choices were primarily guided by data availability.

After ruling out the use of GCMs for the reasons previously explained, given the uniqueness of the models used (one RCM for Drought and Extreme Precipitation analysis, and one CPM for torrential floods), we chose to make profit of all the scenarios at our disposal, except scenario SSP3 7-0, which is available but not officially communicated by national climate services. This multi-scenario approach makes it possible to examine different possible future and associated climatic conditions, while keeping in mind the uncertainties involved. This allows us to move away from a pseudo-deterministic vision, which can have harmful impacts on decision-making for adaptation to catastrophic events.

The Table 3 below summarizes the IPCC socio-economics scenarios and time horizons chosen through climate simulations for this study.

Table 3 : Overview of climate simulations scenarios and horizons choices

Risk	*Climate model (availability)*	*Scenario*	*Horizons*
Drought	ALADIN (1981-2014 & 2015-2100)	SSP1-2.4 SSP2-4.5 SSP5-8.5	Mid-century: 1985-2014, 2035-2064
Extreme precipitation	ALADIN (1981-2014 & 2015-2100)	SSP1-2.4 SSP2-4.5 SSP5-8.5	Mid and end of century: 1985-2014, 2035-2064, 2071-2100
Torrential floods	AROME (1991-2010 & 2081-2100)	SSP5-8.5	End of century 1991-2010, 2081-2100

For **drought risk** assessment, we selected a mid-century time horizon (2035–2064) centered on 2050 as it aligns with the planning and action framework of the SAR (see section 2.1.2). Additionally, the population projections available to us do not extend beyond 2050.

For **extreme precipitation** risk assessment, both mid and end of century horizons have been selected. For scientific understanding and analysis purposes, some results have been produced by testing the longest period of historical data (1981-2014, 2029-2062, 2067-2100)

For the **torrential floods** risk assessment, due to the high computational costs of producing CPM simulations, only two 20-year timespans for a single scenario were available.

Considering the recent release of the TRACC framework, time slices of continuous ALADIN simulation should be adapted for Extreme precipitation risk assessment to fit with the different warming levels in the last phase of the project.

Socio-economics and vulnerability scenarios

The future socio-economics developments will be considered only for the drought methodology, through growth rate projection (https://www.insee.fr/fr/statistiques/6664672). These projections are released by the French National Institute of Statistics and Economic Studies (INSEE) for three scenarios and are independent of IPCC Shared Socio-Economics pathways. They are based on assumptions of stable fertility, continuing growth in life expectancy and a slight net migration deficit of 1800 people per year. Hence, the projections make no allowance for potential tipping points linked to changes in the global geopolitical context or climate change. In this study, we used the reference population projection scenario.

The vulnerability parameters and indicators were assessed on a contemporary basis (2019 to 2025), and no studies or data were available to indicate how they might evolve in the future. For this phase 2, these contemporary indicators were therefore transposed as they stand for future horizons. However, in the final phase of the project, we will vary these parameters to establish possible “adaptation trajectories” and assess the impact of reducing certain vulnerability components on drought risk. It will be translated into a “what if” approach, hopefully helping decision-makers realizing that drought risk is not solely consecutive to hazard and that they have the power to reduce it through simple measures (improving the water network, diversifying supply sources, preserving water bodies, etc.).

2.3 Regionalized Risk Analysis

2.3.1 Hazard #1 - Relative Drought

Several important considerations motivated us to improve the drought risk assessment methodology compared from Phase 1:

1. Integrating evolving exposure to avoid basing risk assessment solely on changes in hazard
2. Leveraging vulnerability indicators that truly reflect on-the-ground realities faced by technical teams and drinking water resource managers, and that can reliably inform the analysis of adaptation trajectories.

3. Identifying the most relevant geographical or administrative unit at each methodological stage to enhance the relevance, clarity and impact of the results.

The Table 4 illustrates the hazard, exposure and vulnerability datasets used for the drought risk assessment.

Table 4 : Data overview workflow #1 (see Table 3 for scenarios and horizons information). Data fields and indicators used to compute vulnerability are further detailed.

Hazard data	***Vulnerability data***	***Exposure data***	***Impact metrics/Risk output***
Precipitation *→ BRIO: Simulated & observed precipitation (ALADIN RCM model)*	***Socio-economic indicators*** *→ IGN & INSEE: IRIS infra-municipal dataset (sub-municipality polygons).* ***Water services*** *→ SISPEA : Public Water and Sanitation Services observatory (annual data by municipality).* ***Water resources status*** *→ SDAGE: qualitative and quantitative water resource assessment (reports on groundwater and rivers entities).* ***Drinking water infrastructures*** *→ UDI : drinking water distribution units (GIS polygons) subject to unified health monitoring (on request to ARS).* *→ Drinking water intake data: Confidential data about location and characteristics of water intake, provided by ARS.* ***General territory information*** *→ BDTopo: GIS data on administrative units (from municipalities to regions) and various territorial information (infrastructure, transport, services, locations, etc.)*	***Population*** *→ Filosofi : 2019 Population census data (gridded 200m)* *→ INSEE population projection study up to 2050 (by microregions)*	***Relative Drought Risk indicator*** *Following the CLIMAAX methodology*

Hazard assessment

The hazard assessment followed the same approach as in Phase 1 of the project. The Figure 5 shows the complete results of the hazard assessment for all scenarios and temporal horizons at the native climate model grid resolution. The drought hazard index is higher on the North-West part of the island and lower on the Eastern part. In the future, the hazard index is expected to keep this spatial pattern with the western and central part of the island the most exposed. No clear changes of the hazard intensity are expected on the mid-century horizon, although a general increase of the drought hazard is expected for the most pessimistic scenario at the end of the century.

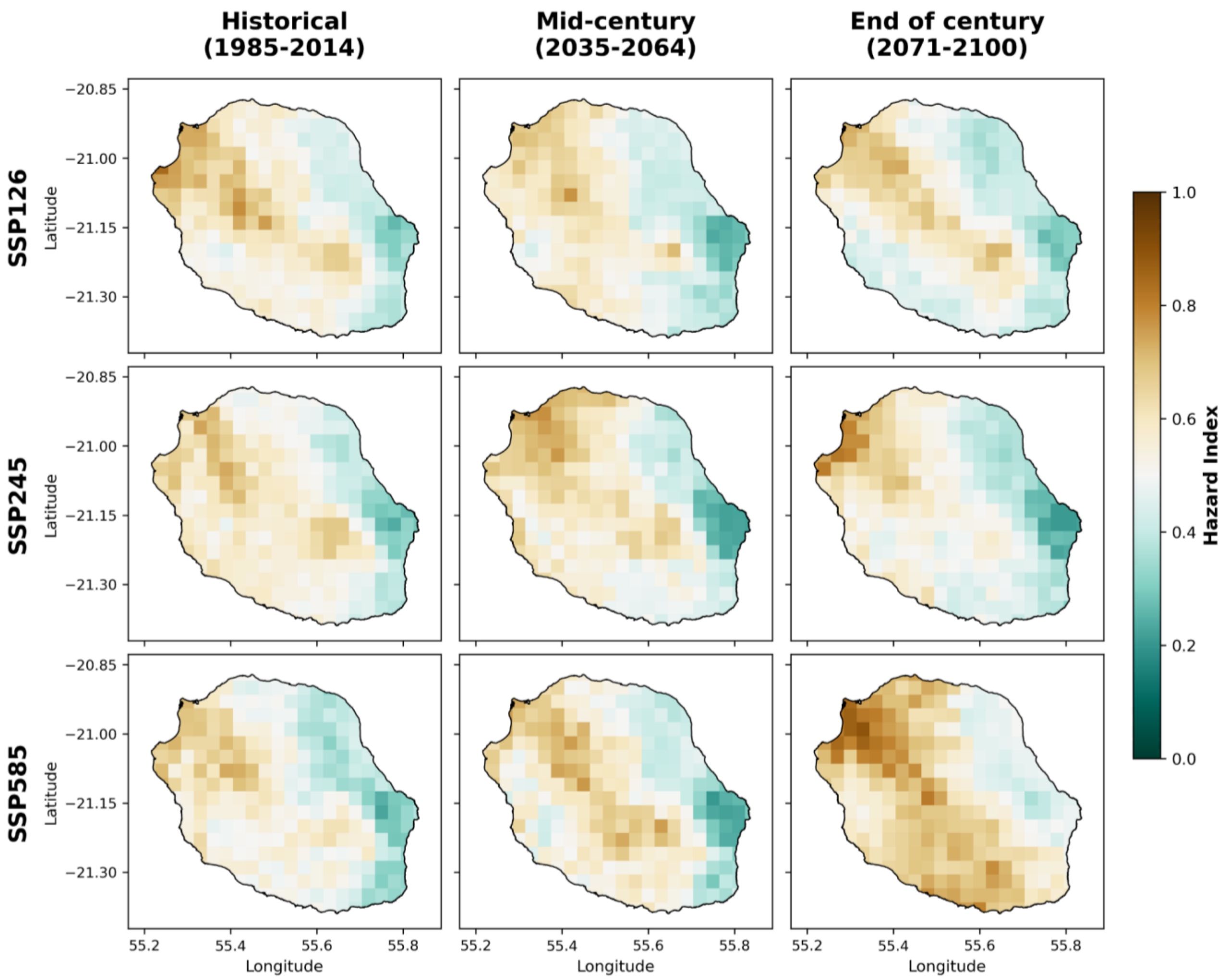

Figure 5 : Drought Hazard index on Reunion Island for different scenarios (rows) and horizons (columns) at the native resolution of climate dataset.

Given the variety of indicators and the heterogeneity of the administrative units they depend on, we chose to work at the most relevant scale to capture drought impacts on the territory: the Drinking Water Distribution Unit (UDI) scale. As UDIs do not cover the entire island, we incorporated groundwater bodies boundaries (MES) located outside these units to complete the island-wide geographical dataset.

To assess drought hazard at the desired geographical resolution, we performed a spatial aggregation of the hazard index, tailored to the specific type of administrative or hydrological unit:

- **At the UDI level**, we first identified the supply areas of each UDI by linking them to their corresponding water bodies. Groundwater body (MES) boundaries were directly extracted from the relevant GIS layer (see Datasets section), while surface water body (MECE) catchments were delineated using a Digital Elevation Model (DEM). The delineation followed the methodology established for torrential flood mapping, by selecting river outlets. In cases where a UDI is supplied by multiple water bodies, the geographical union of these features was computed to define the supply area.
- **For the remaining MES areas** (those not linked to UDIs), we aggregated the hazard index across the entire MES boundaries.

The resulting hazard change maps for each scenario and time horizon are presented in the figure S-13 in the Supplementary Materials.

Risk assessment

Consultations with Territorial and Technical Water Stakeholders

We organized meetings with local and technical water stakeholders to present and compare the project's methodology with on-the-ground realities (see section 2.1.5). Following these meetings, a form was developed using ODK Collect (see Supplementary Materials Appendix). Participants and their colleagues were asked to:

- Rate the relevance of all indicators on a scale of 1 to 4 stars;
- Draw one or more vulnerability polygons to delineate single-resource supply points;
- Provide feedback (free expression boxes) on the indicators and methodology.

The questionnaire was a success, with **17** respondents. Detailed results are presented in the supplementary materials (Figures S-9, S-10, and S-11), and Table 5 summarizes the selected indicators.

Table 5 : Overview of Phase 1 indicator (yellow) and considered indicators for Phase 2 after the meetings (Green). The final indicator selection is indicated along with the reasons for rejection or selection

Vulnerability Indicator (provider)	*Type*	*Mean Rating*	*Selection Phase 2*	*Reason*
Linear Loss Index/ILP (SISPEA)	*Infra-resource*	*3.41*	❌	*Redundant with "network efficiency" indicator and less used than it*
Linear consumption index/ILC (SISPEA)	*Soc-eco*	*2.53*	❌	*Redundant and less relevant than "network efficiency" indicator*
Social housing proportion (INSEE)	*Infra-resource*	*2.53*	✅	*Necessary to balance soc-eco indicator number*

Vulnerability Indicator (provider)	*Type*	*Mean Rating*	*Selection Phase 2*	*Reason*
Water price (SISPEA)	*Soc-eco*	*2.41*	❌	*"Percentage of income spent on water" indicator more popular and relevant for soc-eco indicator*
Network efficiency (SISPEA)	*Infra-resource*	*3.35*	✅	*Most relevant among ILP, ILC: standardized and used*
network renewal (SISPEA)	*Infra-resource*	*3.12*	❌	*Redundant: causal relationship with ILP and network efficiency*
Poverty rate (INSEE)	*Soc-eco*	*3*	✅	*Important soc-eco indicator*
Unpaid bills rate (SISPEA)	*Soc-eco*	*2.71*	❌	*Comments: Not necessarily linked to vulnerability (e.g. social landlords)*
Weight of irrigation	*Infra-resource*	*3*	❌	*No harmonized data*
Percentage of income spent on water (SISPEA/INSEE)	*Soc-eco*	*2.82*	✅	*Stakeholder popularity Further modification to include low income (price of water relative to first decile of income)*
Water resource dependency - monoresource areas	*Infra-resource*	*3.47*	❌	*No access to pipe infrastructures to identify mono-resource areas Not enough respondents drew maps in the survey (see Fig S-11)*
Water mix (ARS/SDAGE)	*Infra-resource*	*3.53*	✅	*Popular and Important to assess vulnerability linked to sources diversification*
State of water resources (SDAGE)	*Infra-resource*		✅	*Add after the survey because we obtained reports from the 2025 SDAGE assessment*

Indicators developments

Unlike in the first phase of the project, we grouped the vulnerability indicators into two balanced categories to avoid arbitrarily giving too much weight to any one component:

- Soc-Eco indicators relative to population social and economic conditions
- Infra-resource indicators relative to drinking water network infrastructure and state of water resources

The steps involved in constructing composite indicators are explained in great detail in the Appendix 1, section "Drought indicators survey". The other indicators used as is were only extracted at their native resolution. Indicators were then merged in accordance with the CLIMAAX methodology.

Exposure

Figure 6 shows the population projection on each microregion of La Reunion under the INSEE reference scenario by 2050.

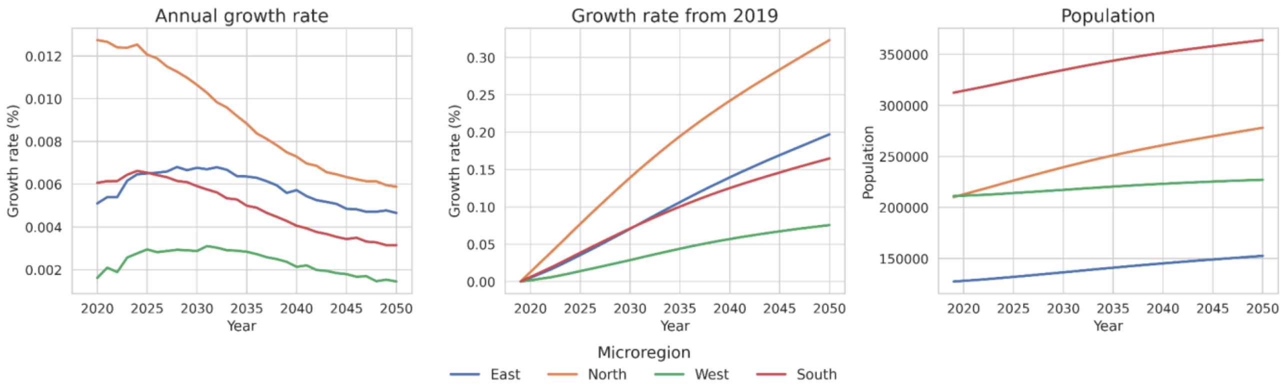

Figure 6 : Population projection on Reunion Island by 2050 under the INSEE reference scenario

The growth rate from 2019 per microregion is then applied over the individuals count in each corresponding gridded 200m filosofi entity to get the 2050 population and density. Thus, this global projection approach scaled down to the local level cannot take into account urban planning and urban expansion projects, but it is the only one available for reporting population growth on a small scale.

Vulnerability

Figure 7 and Figure 8 illustrate the components of socio-economic and infra-resource vulnerability, respectively. The black boundaries delineate the Drinking Water Distribution Units (UDIs), while the areas surrounded by light grey represent the groundwater bodies (MES) located outside these UDIs.

The socio-economic vulnerability highlights both the most densely populated areas, such as the major coastal cities, and certain isolated zones where precarious populations are concentrated, including the cirques and specific Drinking Water Distribution Units (UDIs) in the highlands. The main areas of socio-economic vulnerability are the city of Le Port, certain neighborhoods in Saint-Denis, the south coast, Le Tampon, the eastern coastline between Saint-André and Saint-Benoît, as well as the cirques of Cilaos and Salazie.

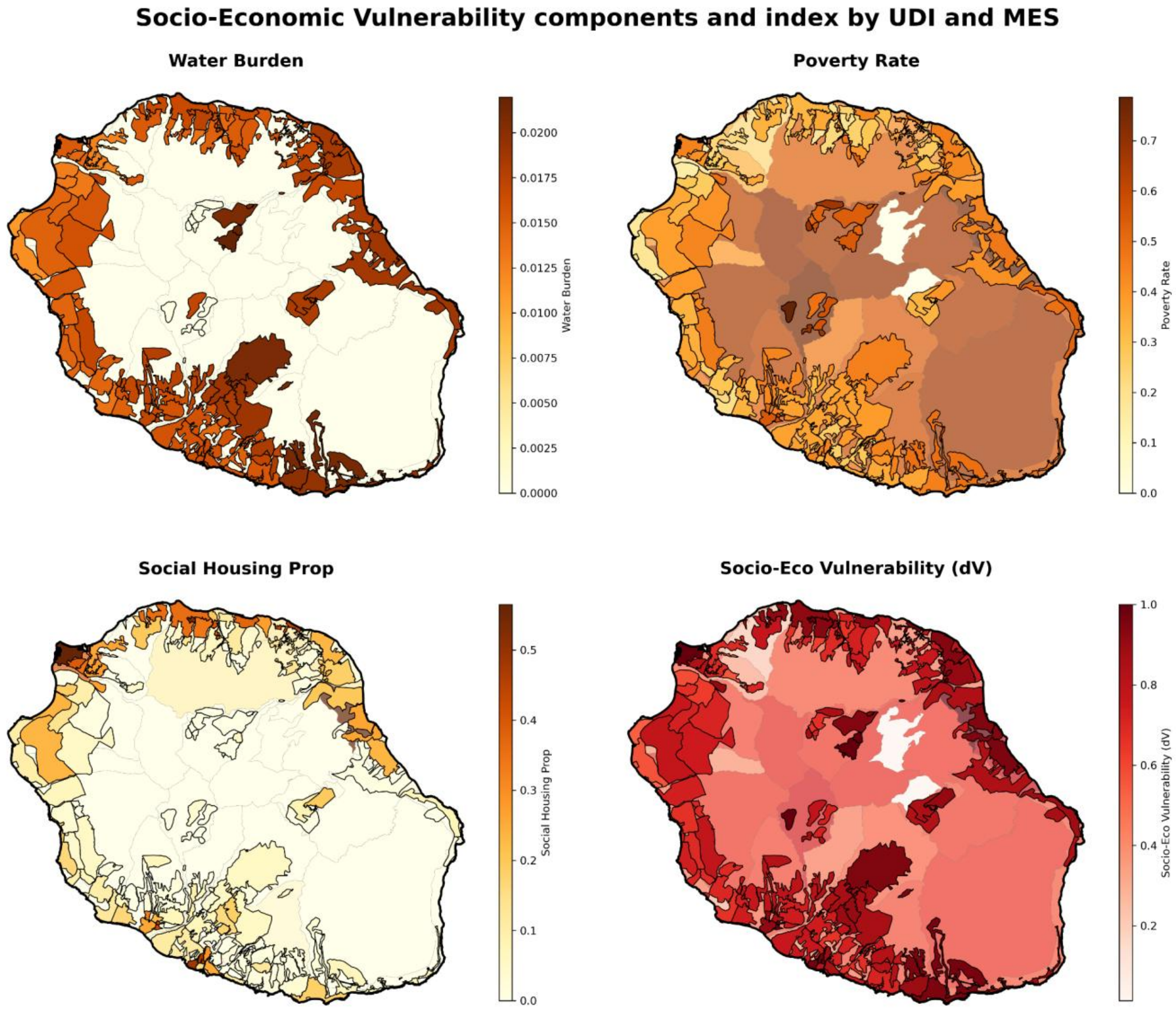

Figure 7 : X Socio-economic Vulnerability components and computed Infra-Resource Vulnerability (dV - bottom right) represented by UDI and groundwater bodies (MES). The water burden is computed by dividing the water price for 100m3 by the income first decile of population, representing the modest population difficulty to pay water

The three components of infra-resource vulnerability are specific to UDIs, which explains the absence of data for groundwater bodies outside these units. Following the combination of these components, the infra-resource vulnerability values for these external groundwater bodies were assigned the maximum score. This decision is justified by the fact that the few inhabitants in these areas are not connected to any drinking water distribution network, resulting in a lack of water treatment and a heightened vulnerability to both quantitative and qualitative water issues.

The results of the assessment of this vulnerability show that many UDIs are connected to only a single water body, resulting in a maximum score for the water resource mix component. This score significantly impacts the final infra-resource vulnerability. However, this component remains uncertain, as precise infrastructure data were lacking to trustfully link UDIs to specific water bodies. The status of water bodies indicates a degraded resource along the west and southwest coasts, both in terms of water quality and the impact of withdrawals. These findings align with field observations and feedback from technical and territorial stakeholders collected during the meetings. Additionally, water network efficiency percentages are particularly low in the East, the Plaine des Palmistes, and Salazie.

Overall, the combination of degraded water bodies, poor infrastructure performance, and limited water mix increases La Réunion's vulnerability to drought.

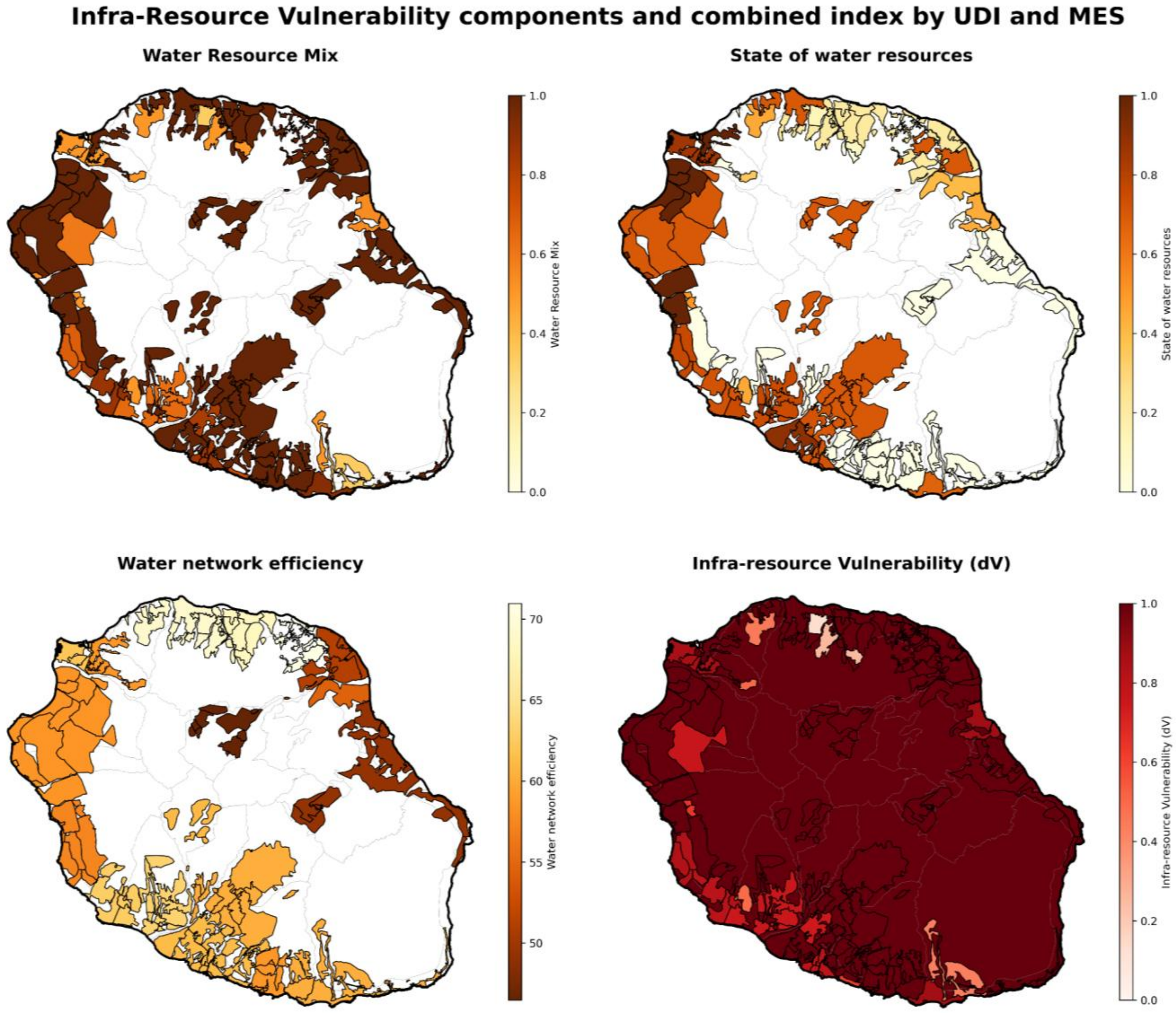

Figure 8 : Infra-Resource Vulnerability components and computed Infra-Resource Vulnerability (dV - bottom right) represented by UDI and groundwater bodies (MES)

Risk

The final results of the risk analysis are shown hereafter for the observed and multi-scenario projected risk normalized categories (Figure 9) and for the risk index relative changes (Figure 10).

To better visualize the spatial distribution of risk, we proposed to derive risk categories by normalizing the risk index across all scenarios and time horizons. Risk categories computed with CLIMAAX methodology are shown on the figure S-14, in supplementary materials (Appendix 1).

Under historical conditions, risk is moderate to high in the cities of Le Port, Saint-Denis, and in the southern region (Le Tampon, Saint-Pierre, and Saint-Louis). An increase in risk toward higher categories is projected for these areas under future scenarios, particularly the intermediate (SSP2-4.5) and high-emissions (SSP5-8.5) scenarios. The highest risk is projected in some UDIs of Saint-Denis, Saint-Louis and Saint-Pierre, the three main cities of La Reunion.

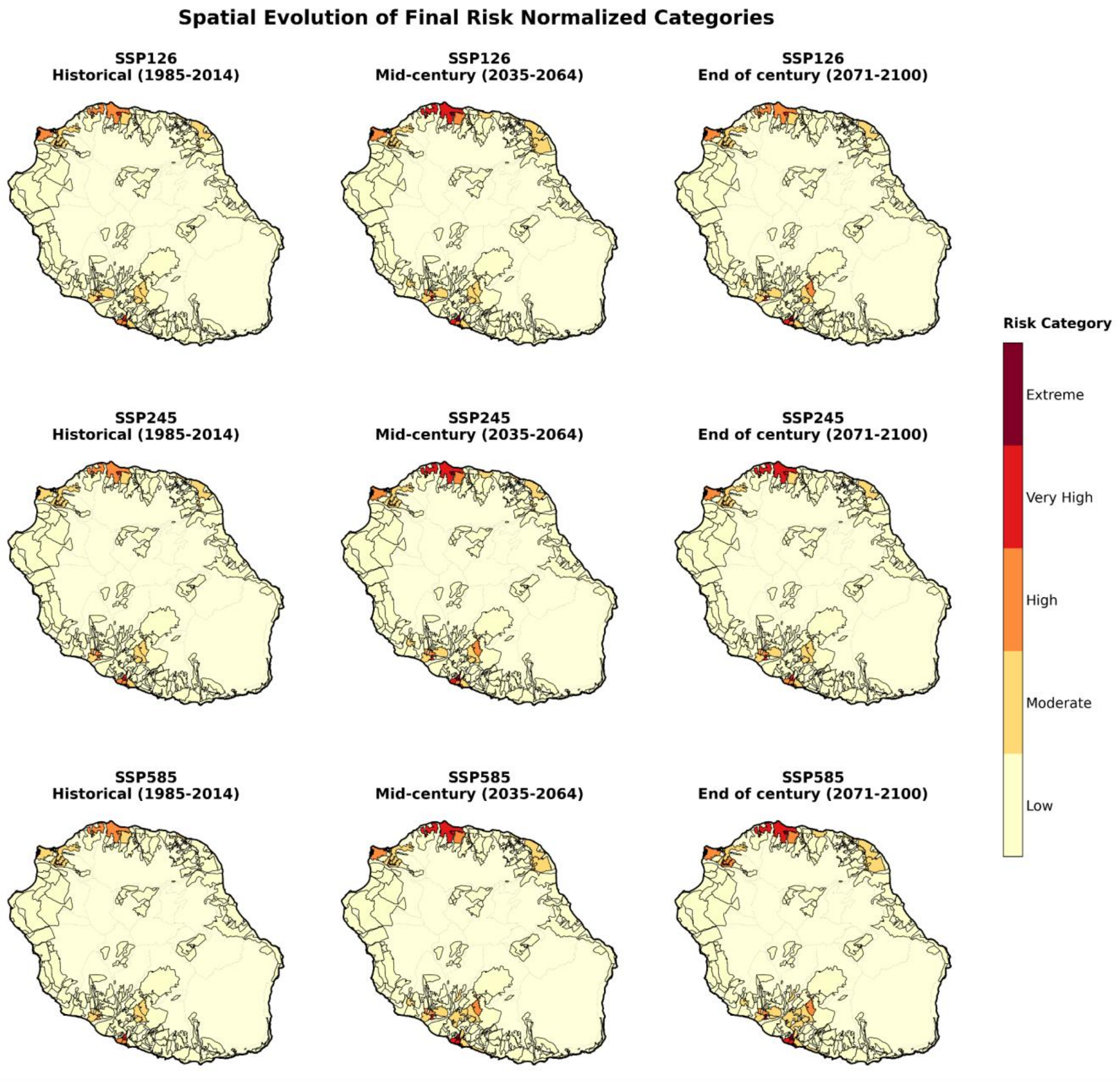

Figure 9 : Normalized drought risk categories on Reunion Island under different ssp scenarios (rows) and for mid-century and end of century time horizons (columns). Future exposure for all horizons was computed following 2050 population projections.

An intensification of risk is projected along the north and southwest coasts across all scenarios, beginning as early as the mid-century horizon. This trend is driven by the combined effects of increasing population density and evolving hazards (see Figure 10). Under the SSP1-2.6 and SSP2-4.5 scenarios, the risk increase is more pronounced at mid-century than at the end of the century. The most significant risk signal emerges under the SSP5-8.5 scenario by the end of the century, with a strong positive signal generalized across the island. This signal reaches up to +50% in Saint-Denis and along the southern coast.

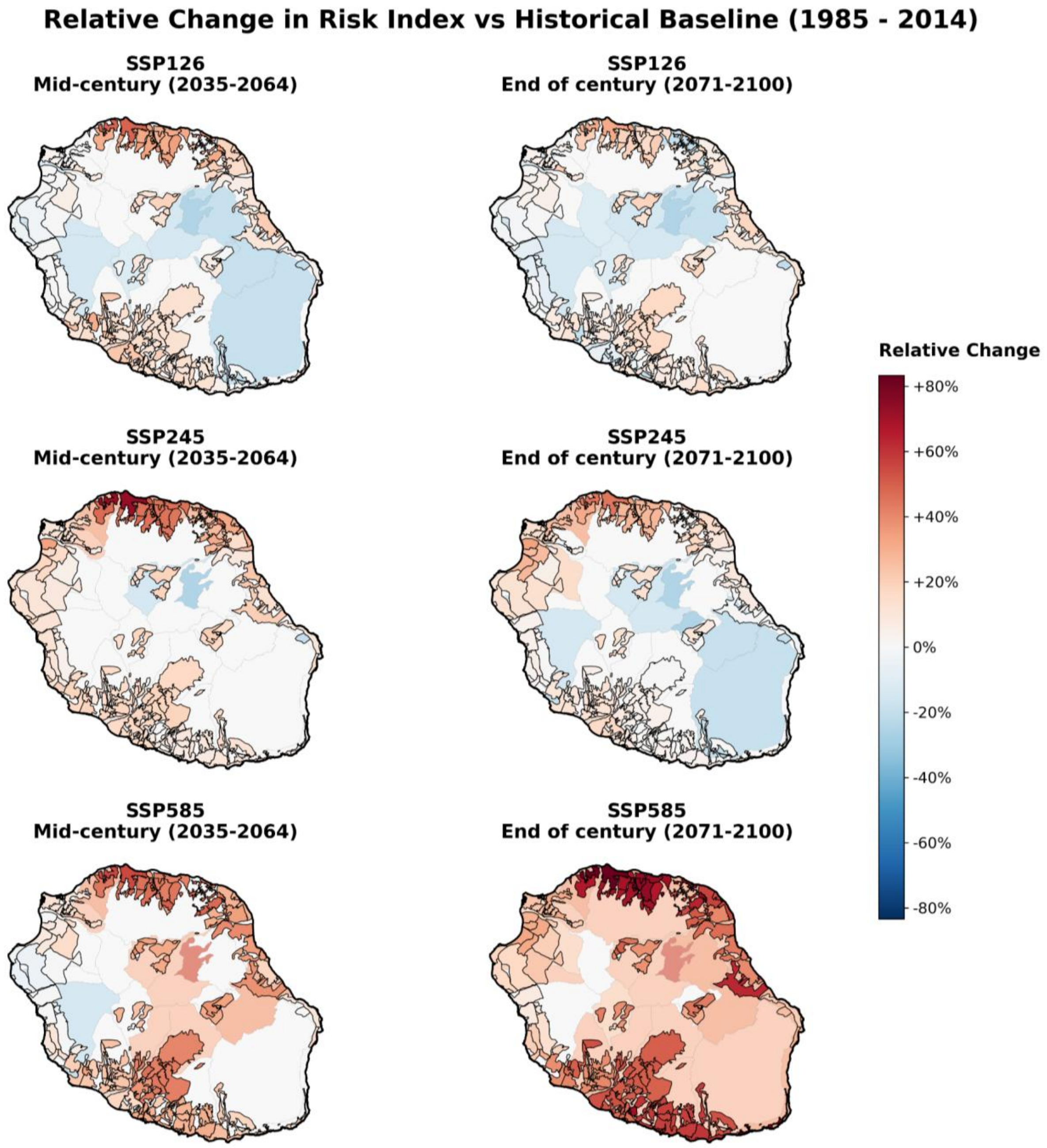

Figure 10 : Drought risk index projected changes on Reunion Island under different ssp scenarios (rows) and for mid-century and end of century time horizons (columns), relative to historical baseline (1985-2014). Future exposure for all horizons was computed following 2050 population projections.

2.3.2 Hazard #2 – Extreme precipitation

The results of the extreme precipitation risk assessment provided during the first phase were unsatisfactory, with very inconsistent and inconclusive results. During the second phase, we decided to understand these signals, which led to a complete overhaul of the risk assessment and the integration of new impact thresholds (see Table 1 below and Figure 13). Despite these efforts and the improvement in the overall quality of the methodology, the results are still quite divergent, scenario- and horizon- dependent. Some hypotheses have been elaborated that will guide future analysis in the objective to provide clear and usable information for decision makers, stakeholders and civil society.

Table 6: Data overview workflow #2

Hazard data	***Impact data***	***Risk output***
Precipitation *→ BRIO: Simulated & observed precipitation (ALADIN RCM model)*	***Heavy Rain Warning thresholds*** *→ Distributed warning threshold for low, (Yellow) moderate (Orange) and high (Red) 24h precipitation impacts. Provided by Météo-France for homogeneous climate zones (GIS polygons and map)*	***Extreme Precipitation risk*** *Frequency and intensity changes and potential impacts on related natural disasters*

Hazard assessment

The hazard assessment was performed following the CLIMAAX methodology steps on each gridpoint of the ALADIN climate model:

1. Extracting annual maximum precipitation timeseries from ALADIN climate simulation (see figure S-1 in supplementary material for Saint-Pierre location)
2. Computing GEV distribution law fitting over historical and future periods (see figure S-2), extracting return periods and confidence intervals.
3. Comparison of historical and future extreme precipitation hazard for a given return period (10 years)

The Figure 11 shows the projected changes in extreme precipitation hazard over La Réunion considering a 10-year return period. Although the analysis was also carried out for a return period of up to 100 years, given the confidence intervals on the GEV adjustments (see supplementary material for Saint-Pierre case) and the length of the simulations (30 years), we considered that the best compromise between potential impact and reliability of the result was a return period of 10 years. Moreover, this return period corresponds approximately to the thresholds for heavy rain red watches, and therefore to a potential significant impact.

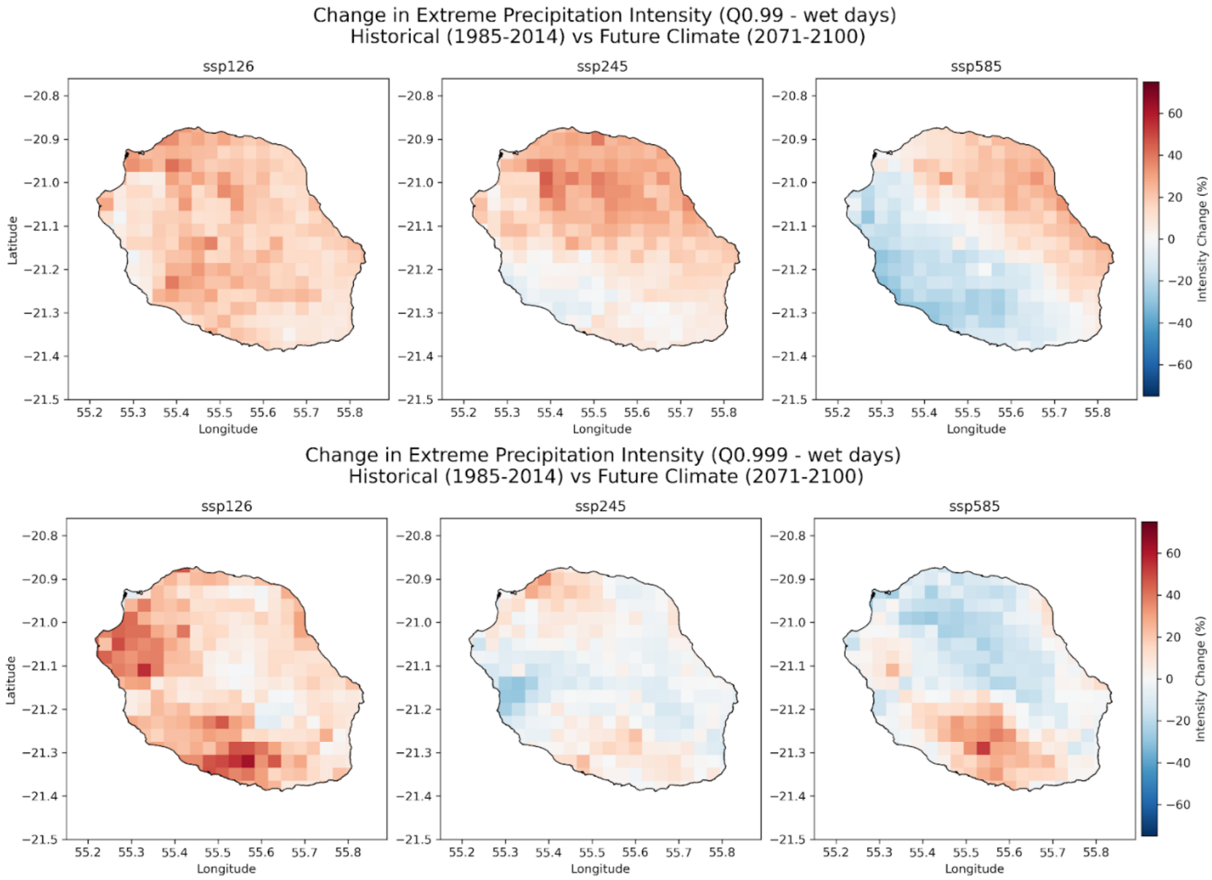

Figure 11 : Projected changes in extreme precipitation hazard for different scenarios at the end of century (2071-2100) relative to historical (1985-2014). The top row shows the changes of the top 1% wettest days (Q0.99) and the bottom row considers the top 0.1% wettest days (Q0.999). Changes are displayed at the climate dataset native resolution.

Given the contrasting and divergent results of the frequency analysis, we conducted an additional hazard analysis to investigate the potential role of GEV adjustment on the divergence of results. We simply assessed the evolution of the extreme quantiles (0.9, 0.95, 0.99, 0.999) of total daily precipitation (all days considered) and wet precipitation (> 1mm). The results are shown in Figure 11. The results show the same variability between emission scenarios and temporal horizons then the risk results (Figure 14 later).

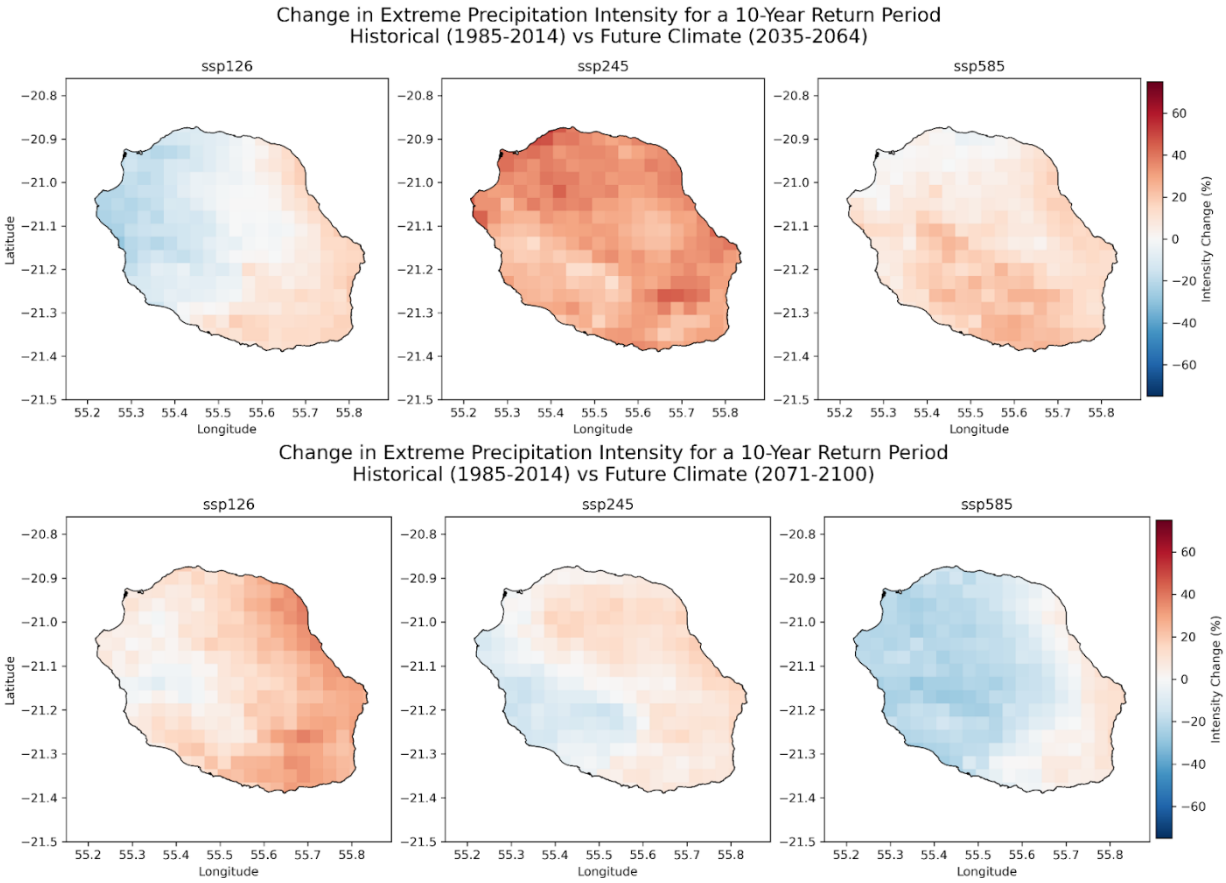

Figure 12 : Projected changes of 10-year return period daily precipitation for mid-century (2035-2064, top row) and end of century (2071-2100, bottom row) relative to 1985-2014 historical period under the three considered SSP scenarios. Changes are displayed at the climate dataset native resolution

Risk assessment

A detailed analysis of the results of phase 1 revealed that the impact threshold had been set too low. For both technical and logical reasons, extreme frequency analysis cannot be performed for return periods of less than two years. The return values obtained were biased, and so was the risk change assessment across most of the island.

Given the highly variable rainfall patterns on Réunion Island, we integrated distributed impact thresholds derived from Météo-France's warning levels for heavy rainfall and flooding hazards (presented on Figure X). The Yellow, Orange, and Red thresholds correspond to low, moderate, and high probabilities of impact, respectively. The Red threshold is based on daily precipitation levels associated with a decadal event. To ensure our analysis only includes return periods exceeding 2 years, we excluded the Yellow threshold from our assessments.

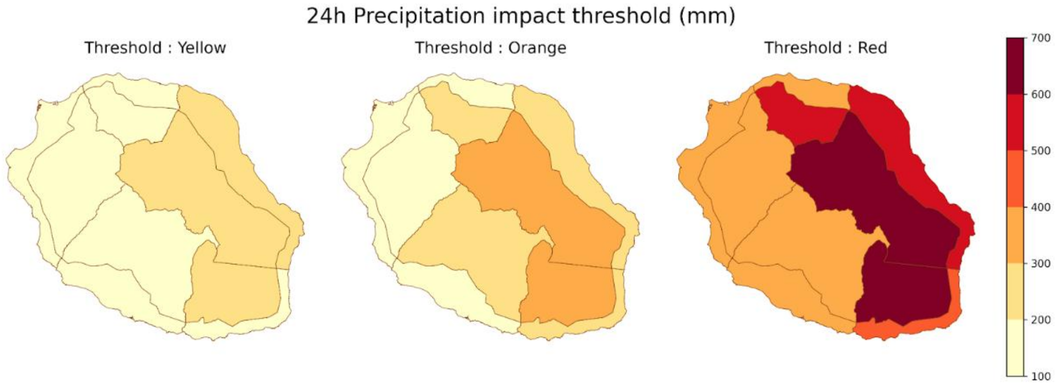

Figure 13 : Distributed impact threshold considered for the second phase of the project. These impact thresholds are directly based on the trigger thresholds for Météo-France's yellow, orange, and red heavy rainfall watches.

The Figure 14 shows the frequency shifts of medium (top) and high (bottom) impact 24h precipitation events for three SSP scenarios for the end of the century. The results for the middle-of-the century scenario are shown on Fig S-7 in supplementary materials.

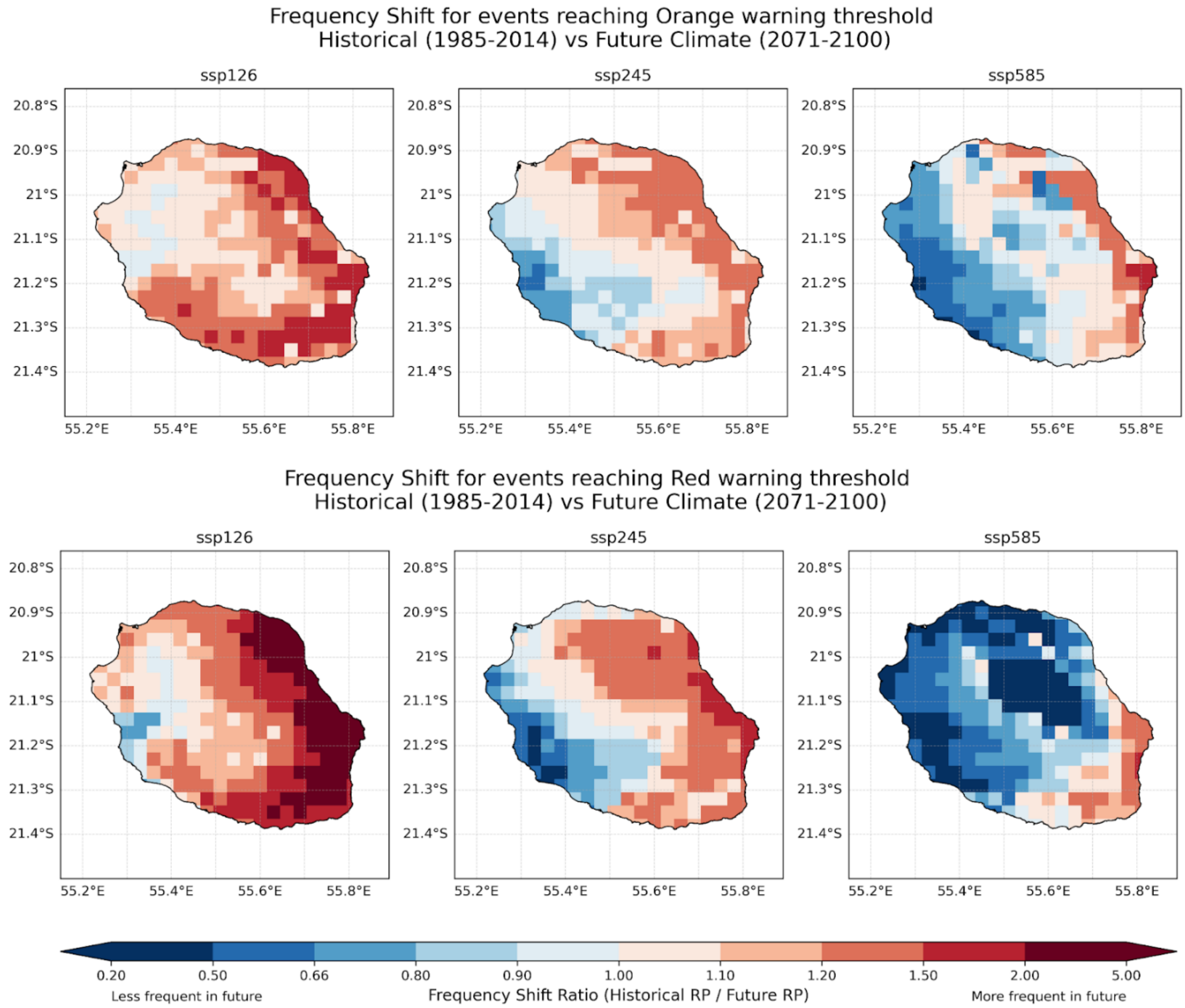

Figure 14 : Frequency shifts of medium (Orange - top row) and high (Red - bottom row) impact extreme precipitation events under different climate change scenarios between historical (1985-2014) and end of century (2071-2100) periods.

Results interpretation and hypothesis

The various hazard and risk analyses show very divergent results with little room for general interpretation:

- Strong dependence on the emission scenario and time horizon
- Shift in the sign and intensity of the signal depending on the intensity (rarity) of events: cf. Figure 11 on extreme quantiles, and Fig S-6 (Appendix 1) comparing return periods between 2 and 20 years
- West-East or North-South geographical contrasts
- By the end of the century, at the territorial scale, a trend toward increased risk under the least emissive scenarios appears to emerge. Conversely, a reduction in risk is projected for SSP585. This trend contradicts the Clausius-Clapeyron relationship, further casting doubt on these findings.

The analysis of 24h precipitation annual maxima for certain locations (see Fig S-1 in Appendix 1 Supplementary Materials) revealed a strong variability of annual maxima over time. For example, in Saint-Pierre city, annual maximum precipitation values range from 50mm in normal years to more than 200mm when a tropical storm or cyclone hits this part of the territory.

A study conducted Leroux et al. (2024) analyzed the evolution of the frequency and intensity of tropical systems (depressions, storms, tropical cyclones…) across the entire Southwest Indian Ocean (SWOI) domain for ALADIN model simulations (2066–2100 compared to 1980–2013). The study reveals a general decrease in the frequency of tropical systems across the basin, with the following specific findings corroborating the trends identified in extreme precipitation risk evaluations (see Figure 15):

- **SSP1-2.6**: Stagnation or slight increase in the frequency of tropical systems of all intensities.
- **SSP2-4.5 and SSP5-8.5**: Significant decrease in the frequency of tropical systems, but an increase in the proportion of very intense tropical cyclones.

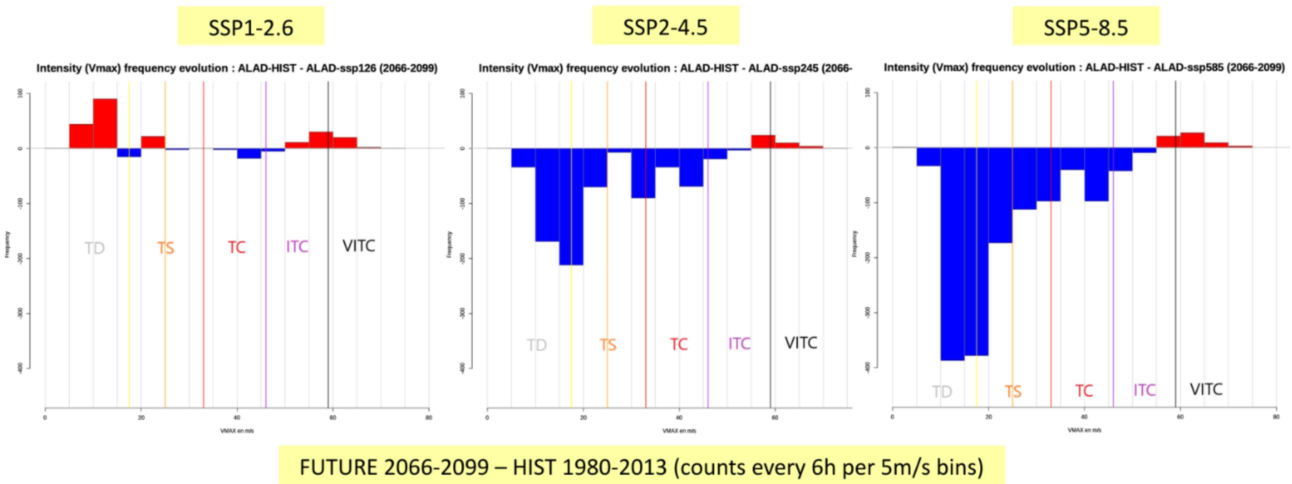

Figure 15 : Tropical systems frequency evolution in ALADIN RCM over all SWIO domain for each category of system (Leroux et al., 2023). TD : Tropical Depressions, TS : Tropical Storms and TC tropical Cyclones with different intensity classes.

Notably, tropical systems, especially tropical cyclones, contribute significantly (55%), to extreme rainfall events in La Réunion, with a huge difference between mountainous (higher contribution) and coastal (lower contribution) areas (Cornillault et al., 2024). **We therefore hypothesize that the extreme precipitation hazard and risk change are highly sensitive to the number of tropical systems (storms, depressions and cyclones) in the simulations.** The frequency shifts in tropical cyclones occurring near or over Réunion across a 30-year simulation may play a critical role in shaping precipitation outliers. Such changes would modify the statistical adjustment parameters and, ultimately, the evolution of extreme precipitation risk. The use of a single climate model therefore poses a significant methodological obstacle to obtaining robust results.

As such, the immediate perspectives for this work are:

- The use of the AROME CPM
- counting the number of cyclones in each simulation passing on or near and comparing the analyses with and without tropical cyclones

2.3.3 Hazard #3 - Torrential floods

This methodology is currently under development in collaboration with the CRAHI team. We proceed only to the first methodological treatments i.e the input data preparation. Hazard and Risk Assessment will be produced during the last phase of the project. However, we will detail hereafter the envisaged methodological steps.

Table 7 : Data overview workflow #3

Hazard data	*Topographic data*	*Impact data*	*Risk output*
Precipitation *→ AROME-SWIO hourly at 3km, uncorrected (part of BRIO but unpublished) - CPM explicitly resolve deep convection*	***Digital Elevation Model*** *→ IGN : BD Alti dataset at 25m resolution over La Reunion*	***Flood maps area*** *→ TRI : Flood footprint of flood-prone areas provided by DEAL*	***Torrential flood risk*** *→ IDF changes of catchment aggregated precipitations and hydrological related impacts.*

Three main methodological steps are identified:

1. GIS processing from DEM to delineate catchments on the territory
   - Flow direction map (see Figure 16)
   - Flow accumulation map (see Figure 17)
   - Catchment delineation (see Figure 18)
2. Hazard Evaluation:
   - Masking precipitation data by desired catchment footprint and precipitation aggregation over these catchments and for various duration
   - IDF analyses of catchment aggregated precipitation
3. Risk assessment: coupling to known events and floods maps to proxy damages

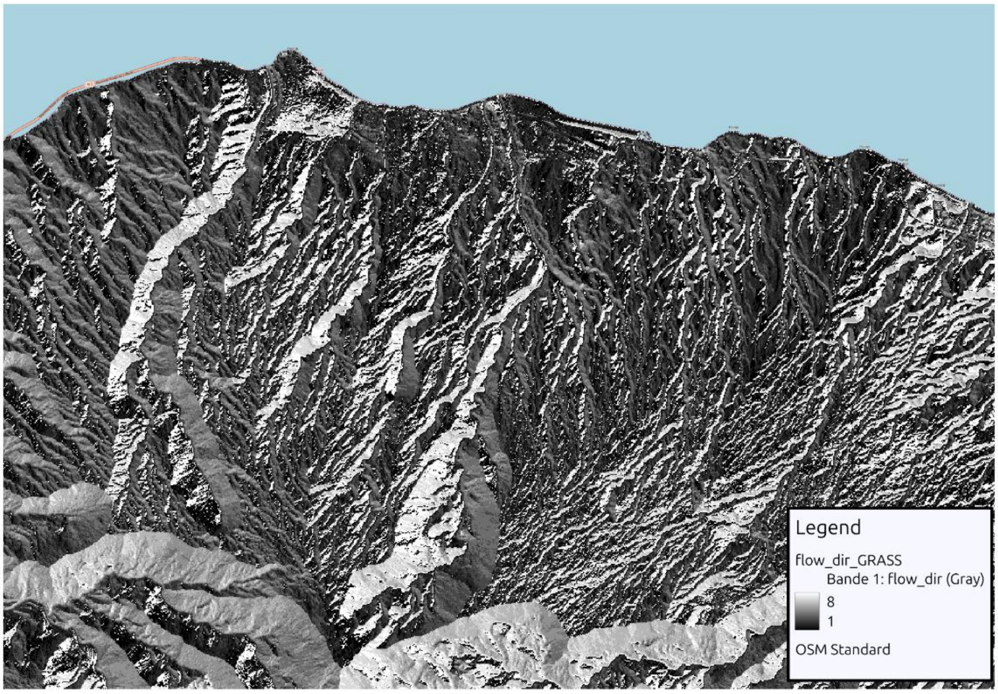

Figure 16 : Example of flow direction map over Northern Island

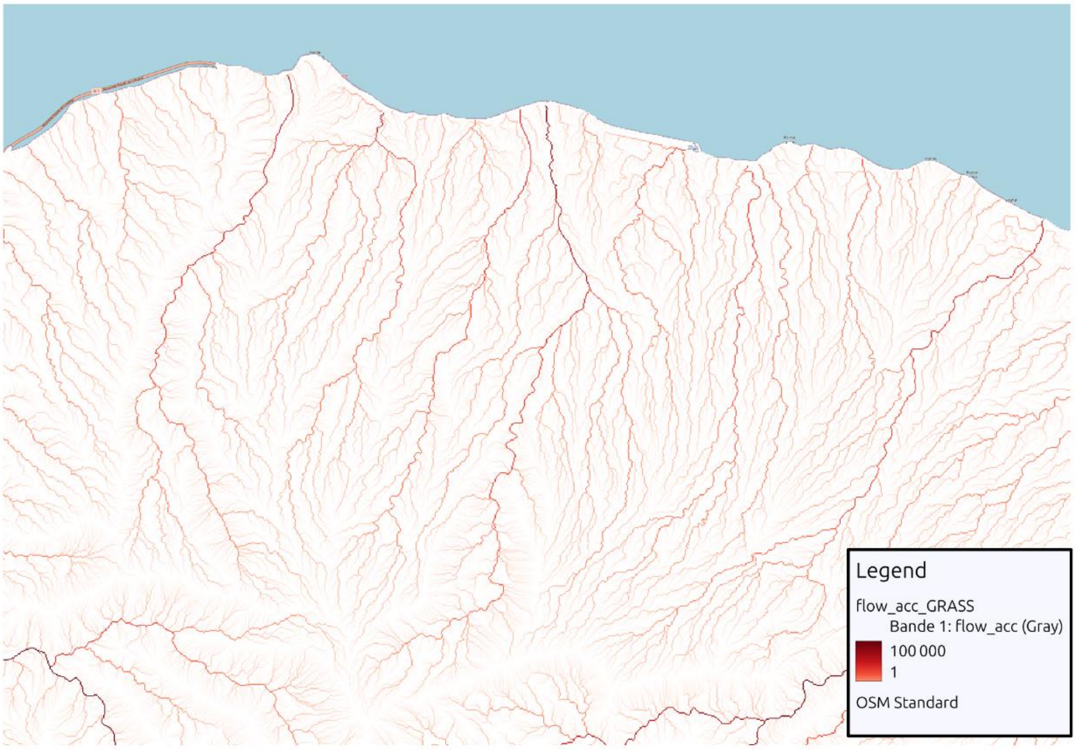

Figure 17 : Example of flow accumulation map over Northern Island.

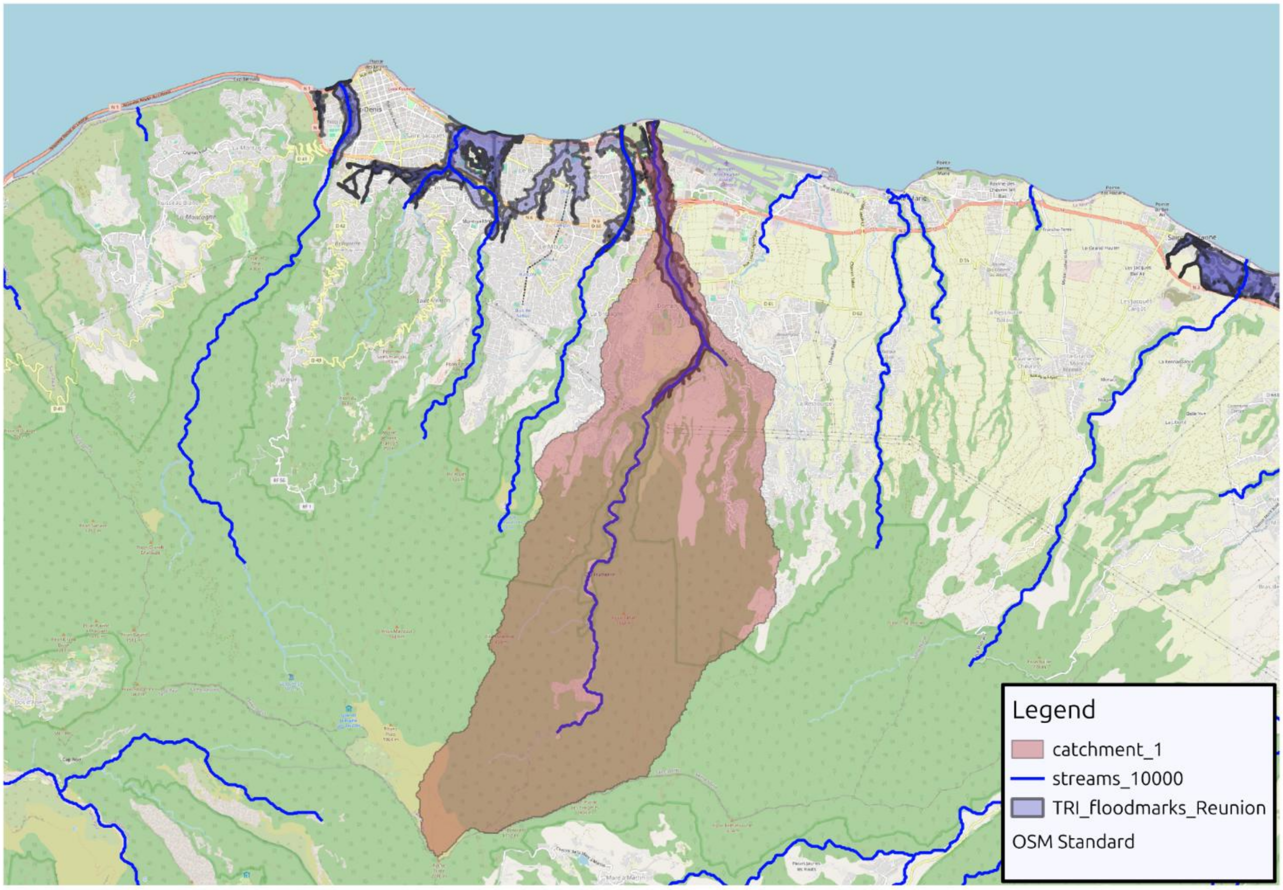

Figure 18 : Example of catchment delineation (Riviere des Pluies) on eastern part of the Saint-Denis TRI.

2.4 Key Risk Assessment Findings

2.4.1 Mode of engagement for participation

During Phase 2 of the project, we undertook extensive stakeholder engagement and consultation efforts involving key territorial actors. This participatory process targeted different stakeholders depending on the risk under consideration:

1. The primary participatory process focused on technical and territorial actors in the water sector, specifically addressing drought risk. The general engagement framework is detailed in Section 2.15, while technical aspects and results are presented in Section 2.3.1.
2. We also engaged with state hydrological forecasting services, including the Hydrological Vigilance Unit (CVH) a specialized service of the DEAL, to gather their expertise and recommendations regarding the flash flood risk methodology.
3. As in Phase 1, we maintained close collaboration with the technical teams at Météo-France and BRGM, whose scientific support has been essential within the scientific consortium for all risks studied. This interdisciplinary scientific collaboration, which also involves 3 departments of the regional council, enables data to be cross-checked and risks in the region to be assessed.

Our experience mobilizing stakeholders for drought risk was highly successful and smoother than anticipated. Territorial and technical stakeholders made themselves easily available, both for meetings and to respond to questionnaires, with 17 respondents from 10 different organizations. They showed strong interest and engagement in the drought risk thematic. The meetings concerning the drought risk were highly enriching and enabled to:

- Gain a better understanding of the territory's realities and specificities, particularly regarding drinking water supply;
- Identify new vulnerability indicators, which could complement or replace those previously used;
- Raise awareness of the RISC-RA project and expand the network of contacts on the island.

Stakeholders in La Réunion are generally aware of the challenges and the importance of the various risks affecting the territory, which is why they were easily mobilized. However, a few key obstacles remain:

- Science-Operational-Society Interface: There is a poor understanding of the concept of risk evolution in a climate change context. The focus is not on predicting a single event but on assessing long-term trends and the probability of occurrence over extended periods. This sometimes leads to a mismatch with the expectations of operational teams.
- Heterogeneity across the territory: It is challenging to regionalize an approach on such a complex territory using identical regional indicators for each part of the island, given the diverse issues at stake (e.g., agricultural pollution, saltwater intrusion, pipeline ruptures due to landslides, water theft reducing yield, etc.).

2.4.2 Gather output from Risk Analysis step

We based the risk evaluation on different outputs:

1. For **extreme precipitation**, the results are hardly interpretable. We analyzed all available content to identify trends and formulate a message for the risk evaluation. We primarily based the analysis on extreme precipitation impact thresholds frequency shifts over which we cross the risk output with hazard extreme quantiles (hazard evolution). Further external resources from Météo-France helped us to understand the explanation of our signals (role of simulated tropical cyclones). Despite all these outputs and resources, the results still need to be consolidated by the contribution of another climate model.
2. For **drought risk** evaluation, the main output we use is the final risk change map. All the intermediate outputs are informative to understand the risk sensibility of certain areas but do not allow a proper conclusion for the final risk.
3. **Torrential floods** workflow is still being developed; we have not yet carried out a risk assessment.

2.4.3 Assess Severity

Droughts

Observed trends

Meteorological drought is an increasingly significant risk on Réunion Island, with a marked intensification over the recent years. While the island has historically benefited from abundant rainfall, recent years have revealed a structural shift. While rainfall interannual variability is important in Reunion Island, a statistically significant cumulative rainfall decrease have been measured in the south-west (-36% in 60 years). More recently, a delay of a wet season was observed, coming together with and a lengthening of the dry season. In particular, the months of December and January have become notably drier than the historical average. A spatially widespread and exceptionally severe drought episode struck the island in December 2024 and January 2025, representing the driest two-month period recorded in 50 years of observations. This event caused water shortages across the island, including the traditionally wetter eastern coast.

Drought is increasingly recognized by local water managers as a "new" hazard for La Réunion, as the island's water systems were historically designed around water abundance. Today, the combination of a lengthening dry season with growing population and increasing water consumption creates compounding pressure on the system. Furthermore, other hazards can act as drought triggers or amplifiers: pipeline ruptures caused by landslides during heavy rainfall events, electricity cuts following cyclonic winds disrupting pumping stations, and sanitary closures of water intakes due to pollution following intense precipitation (e.g., from wastewater treatment overflow). These compound dynamics underscore the multi-hazard dimension of drought risk on the island.

Projected trends

According to Météo-France, the dry season is likely to extend to the first month of the wet season under all emission scenarios. The projection (BRIO and TRACCS) used in this study confirm an increase of the drought risk on the island, no later than at the middle of the century. The risk is projected to become critical in the main cities of the North coast (Saint-Denis) and the Southern cities (Saint-Louis, Saint-Pierre). Although population projections were taken into account in our analysis, we were not able to predict urban expansion. The latter will likely result in a more widespread risk than suggested by the risk assessment, increasing demand on already-stressed water resources.

Consequences and cascading effects

Drought on Réunion Island can trigger a chain of interconnected consequences. The most immediate impact is the disruption of drinking water supply, particularly in single-source supply zones. When resource availability decreases, water quality also deteriorates. We can cite saltwater intrusion into coastal aquifers, reduced dilution of pollutants in rivers and groundwater, and regulatory closures of contaminated water abstraction points, all of this further constrain supply options, creating a vicious cycle. Emergency responses such as bottled water distribution or tanker delivery represent reactive adaptation measures with significant logistical and financial costs, which may become unsustainable if events increase in frequency and severity.

Beyond drinking water, the drought also affects the island's school calendar (documented disruptions during the exceptional 2025 drought), agricultural productivity, and wildlife (especially when river bed ecological continuity is disrupted). In the event of severe resource scarcity, a prioritization order is applied: drinking water first, then environmental flows, followed by water for livestock, which can result in cascading economic impacts including livestock losses and food insecurity.

Stakeholders and expert perspectives

Consultations with inter-municipal water managers and technical actors confirmed and enriched this severity picture. CIREST representatives noted a clear shift observed over the past decade, with a significant precipitation deficit at the start of the rainy season. Participants in the SAR working groups described the situation as rapidly evolving and unprecedented for the island, and flagged the underfunding of network maintenance and renewal as a critical structural vulnerability. These perspectives reinforce the conclusion that the current level of risk is already tangible and that adaptation is both overdue and urgent.

Final assessment

Drought risk is assessed as *Substantial* rather than *Critical* at this stage because the risk has not yet reached a level of systemic collapse. The situation remains manageable, with emergency response mechanisms in place. However, the trend is clearly worsening, and without structural intervention, the risk could escalate toward *Critical* within the 2050 planning horizon of the SAR (see Table 8).

Table 8: Severity summary of Drought risk on Reunion Island

Observed Trends	Future Trends	Consequences and Cascading effects	Stakeholders' perspectives	Severity Final Evaluation
Substantial	Substantial/Critical	Critical	Substantial	**Substantial**

Extreme precipitation and torrential floods

Given that extreme precipitation is a direct precursor to torrential flooding, and that both risks share a large proportion of their consequences and impacts, they are jointly assessed for severity, urgency, and resilience capacity.

Observed trends

Réunion Island holds several world records for extreme rainfall (6083 mm over 15 days; 1825 mm in 24 hours). Extreme precipitation events affect the island regularly and with high intensity, particularly during the austral cyclone season (November to April). While no clear long-term trend in the frequency of extreme events has been statistically established over the historical period, individual events have caused catastrophic consequences. The most recent and illustrative example is Tropical Cyclone Garance (February 2025), which generated record-breaking sub-daily rainfall accumulations over the northern and northwestern parts of the island — up to 300 mm in 3 hours in some locations, causing severe flash flooding in the urban area of Saint-Denis, the island's capital. This event resulted in loss of life, major infrastructure damage, and prolonged disruption to water supply and mobility.

Projected trends

The projections show scenario-dependent results (see Section 2.3.2). A plausible explanation for this divergence lies in the simulated frequency of tropical cyclones near the island, which are known to contribute significantly to extreme rainfall events on La Réunion (Cornillault et al., 2024). Under high-emission scenarios (SSP5-8.5), a reduction in the overall frequency of tropical systems combined with an increase in their intensity may explain the counterintuitive projected risk signals. Despite these methodological limitations, the potential for increased risk intensity during extreme precipitation events is physically well-founded through the Clausius-Clapeyron relationship, which links atmospheric temperature to precipitation intensity.

Consequences and cascading effects

Extreme precipitation events on La Réunion can unleash a wide range of direct and cascading consequences: loss of human life; destruction of and damage to residential properties, particularly those situated near ravines and rivers, and critical infrastructures; disruption of road networks, leading to the isolation of highland hamlets and villages for extended periods; rupture of drinking water infrastructures, resulting in water supply cuts; bank erosion leading to the collapse of riverside buildings; and widespread debris flows and rockfalls. From a public health perspective, post-flood environments are highly conducive to the proliferation of vector-borne and infectious diseases (e.g. dengue, leptospirosis), which compound the direct impacts and increase the overall vulnerability of affected populations to future events. The systemic disruption caused by a major event can therefore degrade the capacity of the territory to cope with subsequent hazards.

Stakeholders and expert perspectives

Technical consultations with the DEAL Hydrological Vigilance Unit (CVH) and Météo-France highlighted the central importance of sub-daily hydrometeorological monitoring for this risk and confirmed that existing response infrastructure is stretched during major events. Local authorities and emergency services acknowledged that the risk is not yet fully under control, as evidenced by the impacts of Cyclone Garance (2025) despite existing prevention frameworks (PPRI, ORSEC plan, etc.).

Final assessment

Extreme precipitation and torrential flooding are assessed as Substantial. The risk is frequent, affects large parts of the territory, causes significant human and material damage, and generates cascading effects. The threshold for Critical is not yet reached because existing early warning systems and emergency response mechanisms provide meaningful mitigation. However, the gap between existing capacity and the scale of major events — as demonstrated by Garance — underscores the precarity of this assessment (see Table 9).

Table 9 : Severity summary of Extreme precipitation and relative hydrological risks on Reunion Island

Observed Trends	Future Trends	Consequences and Cascading effects	Stakeholders' perspectives	Severity Final Evaluation
Substantial	Substantial/Critical	Critical	Substantial	**Substantial**

2.4.4 Assess Urgency

Relative Drought

Severity change

The severity of drought risk on La Réunion is already tangible and is projected to increase over the coming decades, driven by both climatic trends (lengthening dry season, shifting precipitation patterns, statistically significant decrease in some regions) and socio-demographic dynamics (population growth, increasing water demand). Preliminary results from the Phase 2 risk assessment suggest that certain inter-municipal territories and single-source supply zones are particularly exposed and could face significant resource stress by mid-century under moderate to high emission scenarios.

Timeframe for major impact

Given the planning horizon of the SAR (2050) and the typical **lead times for infrastructure development in the water sector (5–15 years), adaptation measures must be initiated in the immediate term to become operational when risk levels peak**. Several water infrastructure projects — such as the extension of the cross-island aqueduct, the development of new water intake points, and network renewal programmes — are already in advanced planning stages and confirm the relevance of this timeframe.

Nature of the hazard

Drought is a slow-onset hazard, which is in some respects an advantage: it can be anticipated, monitored, and mitigated over time. However, this characteristic can also lead to inertia in a sense that the situation is always "manageable." The exceptional drought of 2024–2025 served as a critical wake-up call, highlighting that the progressive nature of drought does not prevent it from reaching crisis levels with significant social and economic impacts. **Early and sustained action — rather than reactive crisis management — is therefore essential.**

Persistence and compounding

Drought episodes on La Réunion are becoming more prolonged. Once an event triggers the cascade of impacts described above (saltwater intrusion, intake closures, emergency supply measures), recovery of the resource to pre-drought levels can take weeks to months. This persistence amplifies the social and economic burden on the territory and on the most vulnerable households. Moreover, if the next wet season is not rainy enough to fully replenish water resources, water insecurity may be compounding and higher during the next drought event.

Stakeholders' perspectives

Local water managers and inter-municipal authorities were unanimous in their assessment that drought risk demands priority attention. Several stakeholders noted the underfunding of water infrastructure and network maintenance and renewal and the shortage of qualified technical staff as factors that further reinforce urgency, as they limit the territory's capacity to implement adaptation measures swiftly.

Final assessment

Urgency score: Immediate action needed

Given the already observed severity of recent drought events, the clear upward trend in hazard intensity, the long lead times for infrastructure adaptation, and the structural vulnerabilities of the water supply system on the island, immediate action is warranted. The current planning cycle — particularly the SAR revision — represents a critical and time-limited window to embed drought resilience into the territory's long-term development framework.

Extreme precipitation and torrential floods

Severity change

Réunion Island is already at high risk from extreme precipitation and associated hydrological consequences. As demonstrated by Tropical Cyclone Garance in February 2025, the territory can be exposed to catastrophic rainfall intensities with insufficient response capacity, even with existing prevention and warning systems in place. From a climate perspective, projected signals remain highly uncertain and scenario-dependent (see Section 2.3.2); however, the physical basis for increased precipitation intensity during tropical systems events under higher warming scenarios is well-established.

Timeframe for major impact

Extreme precipitation events are by nature sudden and unpredictable in their exact timing and location. Unlike drought, these events risk cannot be addressed reactively: structural and systemic measures must be in place before the next major event. Due to the cyclone season extending from November to April, the risk window mainly spans half of the year, although certain extreme precipitation events may occasionally occur during the austral winter.

Nature of the hazard

Extreme precipitation is a sudden-onset hazard, often further amplified by La Réunion's steep topography. These events, combined with small catchment sizes, can produce extremely rapid hydrological responses. Torrential floods can form and reach populated areas in minutes to hours following intense precipitation upstream. Some flash floods can occur on downstream areas that have not received any precipitation. This requires not only robust early warning systems but also long-term land-use planning measures — such as restrictions on construction in flood-prone areas and investment in natural flood management — that take many years to deliver results.

Persistence and compounding

While individual extreme precipitation events are brief, their hydrological and social impacts can persist for extended periods: road closures for weeks, water supply disruptions for days to weeks, and ecosystem degradation over months. The successive occurrence of multiple events within a season can significantly degrade community and ecosystem resilience as well as infrastructure integrity.

Stakeholders' perspectives

Hydrological forecasting services (CVH/DEAL) and Météo-France confirmed that the current level of risk is not fully controlled during major events. The absence of systematic sub-daily hydrometeorological monitoring over key watersheds limits the effectiveness of early warning systems. Extending and strengthening this monitoring network was identified as a priority by technical stakeholders.

Final assessment

Urgency score: More action needed / Immediate action needed

The urgency is assessed as being between more action needed and immediate action needed, reflecting the tension between the already-demonstrated severity of the risk (which justifies immediate action) and the significant uncertainty in projected future trends (which complicates the prioritization of long-term investments). Actions that reduce current risk exposure, such as early warning improvements, land-use restrictions in high-risk zones, and drainage infrastructure upgrades are urgent regardless of long-term projection uncertainty.

2.4.5 Understand Resilience Capacity

Relative Drought

Financial resilience

Several financial mechanisms are available to address drought-related crises. Emergency public relief funds can be mobilized following declared natural disasters, notably the Overseas Aid Fund (FSOM) and Exceptional Investment Fund (FEI). European Regional Development Fund (ERDF) resources and national investment envelopes co-finance water infrastructure projects. However, significant weaknesses remain. Maintenance budgets for water distribution networks are chronically underfunded, resulting in high rates of water loss (leakage) across much of the island. If a territory is already struggling to maintain its drinking water distribution infrastructure, how could it realistically develop and diversify pumping infrastructure to cope with future drought risk? The combination of deferred maintenance and growing demand creates a structural financial vulnerability that emergency funding cannot address.

A fundamental tension further undermines the system's financial sustainability. The EU Water Framework Directive (WFD) requires that water services recover their costs through tariffs ("water pays for water"), yet this principle is only partially applied on the island. Several inter-municipal authorities maintain politically sensitive low water tariffs, which, while protecting low-income households in the short term, generate insufficient revenue for infrastructure renewal and investment. This creates a structural contradiction: authorities are required to improve water quality and safety, including enforcing drinking water treatment standards, while operating with structurally inadequate resources. Resolving this tension requires both technical investment and political reform of water pricing frameworks, neither of which can be achieved quickly.

Human and institutional capacity

A critical weakness identified by local stakeholders is the shortage of qualified engineering and technical staff within water management services, both at the inter-municipal and concession levels. This limits the capacity to plan, implement, and monitor infrastructure adaptation. Awareness of drought risk among decision-makers is growing, notably after 2024–2025 event but remains uneven across the territory.

Physical capacity

The island's drinking water supply relies on a network of surface water intakes, springs, and boreholes, with significant geographic disparities in resource availability. A major cross-island aqueduct transfers water from the resource-rich eastern catchments to the drier west, which has historically contributed to a certain complacency regarding water security in the west. Indeed, the aqueduct's capacity supported rapid population growth and the development of water-intensive activities, including agriculture and tourism, in areas that are naturally arid. The perception of unlimited water availability fostered by this infrastructure now represents itself a form of vulnerability, as the system was not designed for the scale of demand it currently serves, nor for the conditions of an increasingly prolonged dry season. Beyond this structural dependency, several inter-municipal territories remain reliant on single water sources (mono-resource zones), with limited redundancy in the event of source failure. The rehabilitation and renewal rate of distribution networks remains below the level required to maintain system efficiency, with significant volumes lost to leakage before reaching end users.

Natural capacity

The long-term health of La Réunion's water resources depends on the integrity of upland ecosystems and infiltration zones. Urban expansion and soil sealing reduce natural aquifer recharge and increase diffuse pollution from non-compliant domestic wastewater systems, representing a significant problem given the high proportion of non-collective sanitation installations that fail to meet current environmental standards. Decades of non-virtuous agricultural practices have additionally contributed to the degradation of soil quality and the contamination of water bodies through pesticide and fertilizer runoff.

Groundwater resources are under both quantitative and qualitative pressure, as assessed in the 2025 SDAGE review, with several water bodies already showing signs of overexploitation or contamination. The sustainability of water resources in the long term therefore requires not only infrastructure investment but also changes in land-use and agricultural practices that are difficult to implement rapidly.

Social capacity

Public awareness of drought risk is relatively low compared to other hazards, consistent with the historical perception of La Réunion as a water-abundant island. The 2024–2025 drought event significantly raised public awareness and created a political window for structural reform. Social vulnerability to drought is concentrated among low-income households, for whom the cost of water relative to income is already a burden, particularly in inter-municipal territories with higher water tariffs.

Specific interventions

Drought management on Réunion Island is governed by a series of administrative and technical instruments:

- Drought vigilance and alert systems managed by DEAL and the Office de l'eau, with tiered restriction measures (vigilance, alert, reinforced alert, crisis);
- Operational water resource monitoring through hydrometric and piezometric station networks managed by the Office de l'eau;
- Prefectoral drought orders (arrêtés sécheresse) imposing usage restrictions during shortage periods;
- Emergency water distribution plans coordinated with CCAS and municipal social services for the most vulnerable households;
- Medium-term investment plans for infrastructure renewal and diversification of supply sources.

Final assessment

Resilience capacity score: MEDIUM

Despite the existence of alert systems and emergency response protocols, the combination of chronic underfunding of infrastructure maintenance, structural mono-resource dependency in several territories, limited human capacity within water services, low baseline public awareness of drought, and a historically unsustainable development trajectory (fast urbanization and growing population) results in an overall assessment of medium resilience capacity. Targeted investments in network rehabilitation, source diversification, and institutional capacity building could meaningfully improve this score within the SAR timeframe.

Extreme precipitation and torrential floods

Financial resilience

Financial capacity to respond to extreme precipitation events relies primarily on the CatNat insurance regime, the FSOM, and the Barnier Fund for prevention works. ERDF resources also co-finance structural flood protection works under the PAPI (Flood Risk Prevention and Management Programme) framework (in application of the Flood European DIRECTIVE 2007/60/EC). However, a major structural weakness undermines the effectiveness of this system: only approximately 60% of households in La Réunion hold home insurance (compared to 96% in metropolitan France), leaving 40% of households, predominantly the most economically precarious, without coverage under the CatNat regime. This gap is particularly concerning given the greater exposition of poorest households' homes to risks. The insurance premium surcharge for overseas territories has recently increased (from 12% to 20% in 2025), further discouraging uptake and risking additional exclusions.

Human and institutional capacity

Réunion Island benefits from world-class meteorological expertise through Météo-France's Regional Specialised Meteorological Centre (RSMC) and the Atmospheric Physics Observatory (OPAR). The island's early warning infrastructure for cyclones and severe weather is well-developed, with established crisis management protocols. The DEAL Hydrological Vigilance Unit (CVH) provides hydrological forecasting support. However, the monitoring network for sub-daily rainfall over key watersheds remains sparse, limiting the lead time available for flash flood warnings in fast-responding catchments.

Emergency response frameworks include the ORSEC Cyclone plan, communal emergency plans (Plans Communaux de Sauvegarde, PCS) across municipalities, and the French Red Cross's operational capacity through PIROI. Public awareness campaigns ("Paré pas Paré", AFPCNT) contribute to building individual preparedness. Nevertheless, the proportion of municipalities with fully operational and regularly updated PCS remains below target, limiting local response capacity.

Physical capacity

The island has invested in significant flood protection infrastructure along the most populated and risk-exposed river corridors, including major embankment works along the Rivière des Galets, Ravine Butor, and Rivière des Pluies. Coastal protection works and road infrastructure reinforcement have also been implemented in certain areas. However, the rapid urbanization of flood-prone areas (ravine margins and alluvial plains) has outpaced the development of protective infrastructure in some municipalities. The dimensioning of existing drainage networks and protective structures is challenged by the return of extreme events beyond their design thresholds, as illustrated by Cyclone Garance (2025).

Beyond major watercourses, urban runoff management represents a critical and underaddressed vulnerability. As impermeable surfaces have expanded with urban growth, the capacity of drainage systems has increasingly been challenged, leading to surface flooding during moderate to intense rainfall events. Complementing this, ravine maintenance — including the removal of vegetation debris and sediment that accumulate and can cause devastating log-jam flooding in urban areas — is carried out but at an insufficient scale given budget constraint. Catchment erosion, driven by land-use change and intense rainfall, further aggravates this dynamic by increasing the sediment and woody debris load transported during flood events. These interconnected processes are recognized by technical stakeholders as among the highest-priority areas for intervention.

Natural capacity

Natural flood regulation through riparian vegetation, wetlands, and upland forests is identified but insufficiently integrated into catchment management strategies. Riverbank vegetation management consisting in the removal of debris and invasive species that can cause log-jam flooding during high flows, is carried out but at insufficient scale and frequency given budget constraints. Ecosystem-based approaches to flood risk reduction (e.g. restoration of natural floodplains, coastal dune systems) remain at an early stage of development on the island.

Social capacity

The level of risk culture on La Réunion is relatively high for cyclone-related hazards, given the island's long history of major cyclone events. However, awareness of flash flood risk remains insufficient with a high proportion of flood related casualties related to pedestrians and motorists swept away when attempting to cross flooded fords, despite awareness campaigns. Social inclusion in disaster risk management is progressing but remains incomplete, with the most vulnerable populations (households of social housing, without insurance, in informal housing or isolated) facing the greatest structural barriers to adequate protection.

Specific interventions

A range of structural and non-structural measures are currently deployed:

- Meteorological and hydrological vigilance and alert systems (Météo-France, CVH/DEAL);
- ORSEC Cyclone plan and Communal Emergency Plans (PCS);
- Natural Risk Prevention Plans for flooding (PPRI) and coastal risks (PPRL);
- Flood Risk Management Programmes (PAPI) with associated engineering works;
- Flood risk management framework within the six High-Risk Flood Areas (TRI) of La Réunion;
- Public awareness campaigns coordinated by AFPCNT, PIROI, and local authorities;
- Major river embankment infrastructure along key urbanized watercourses.

Final assessment

Resilience capacity score: Medium

The combination of high-quality meteorological monitoring and early warning capacity, established crisis management frameworks, and significant physical infrastructure places La Réunion above a **Low resilience level**. However, the significant gap in insurance coverage, the insufficient scale and pace of natural flood management, the rapid urbanization of exposed areas, and the persistent flash flood fatality rate prevent the assessment from reaching **Substantial.** Strengthening the monitoring network for sub-daily hydrometeorological variables, extending the PCS coverage, and accelerating ecosystem-based flood risk reduction measures would be among the most impactful levers for improving this capacity.

2.4.6 Decide on Risk Priority

The risk prioritization is derived from the combined evaluation of current and future severity, urgency, and resilience capacity, summarized in Table 10 below. Both risks assessed in Phase 2 — meteorological drought and extreme precipitation / torrential flooding — are ranked as high priorities, though different pathways. Drought's priority reflects the combination of a clear and worsening trend, immediate infrastructure adaptation needs, and the time-sensitive planning window provided by the SAR revision. Extreme precipitation and torrential flooding's priority reflect the already-demonstrated catastrophic potential of individual events, the structural gap between existing resilience capacity and the scale of exposure, and the urgency of action in the most densely urbanized and exposed sectors.

Table 10: Risk assessment analysis prioritization combining severity, urgency and capacity evaluation

Risk	*Severity (Current)*	*Severity (Future)*	*Urgency*	*Resilience Capcity*	*Risk Priority*
Drought	*Substantial*	*Substantial to Critical*	*Immediate action needed **in some areas***	*Medium*	***High***
Extreme Precipitation /Torrential floods	*Substantial*	*Substantial*	*Immediate action needed*	*Medium*	***High***

2.5 Monitoring and Evaluation

2.5.1 What did we learn from Phase 2, and where were the main difficulties?

The most significant lesson was the complexity and heterogeneity of water-related risks on La Réunion. Drought in particular is a multidimensional challenge: its dynamics depend simultaneously on infrastructure characteristics (water mix, mono-source dependencies, network efficiency, types and vulnerabilities of water resources depending on water body type), socio-economic factors (water pricing, economic vulnerability, political acceptability of tariff increases), and the spatial mosaic of very different territorial realities across the island. Designing vulnerability indicators that are scientifically rigorous and operationally meaningful required a greater effort than anticipated.

The extreme precipitation workflow has shown that sub-daily climate data are essential for accurately capturing the dynamics of torrential flooding on a mountainous island. The use of daily RCM data alone introduced significant limitations in the analysis of extreme precipitation evolution.

A major methodological difficulty was the reliance on a single climate model for both the drought and extreme precipitation workflows. This single-model approach yielded results that were difficult to interpret for extreme precipitation, due to the high sensitivity of the signal to the simulated frequency of tropical cyclones in the model domain. Without a multi-model ensemble, it is not possible to robustly distinguish the climate change signal from internal model variability. This represents the most significant scientific limitation of Phase 2 analysis and will be directly addressed in Phase 3 through the addition of the AROME CPM simulation.

2.5.2 What role do stakeholders play in Monitoring and Evaluation?

Stakeholder engagement in Phase 2 served a dual function: it improved the scientific methodology of the CRA, and it initiated a process of appropriation of the results by the institutions that will ultimately be responsible for translating findings into action. The meetings with inter-municipal water authorities and regional technical actors not only improved the relevance of the vulnerability indicators, but also built a shared understanding of the methodology and its outputs among practitioners who will need to integrate these results into local planning and prevention documents.

Looking ahead, the CRA results will be integrated into the SAR's Monitoring and Evaluation framework as quantitative and spatialized indicators of climate risk change. This integration will ensure that the CRA is not a one-off exercise but contributes to an ongoing, iterative cycle of risk knowledge production and policy response. The GREC-Réunion, launched in January 2026, is expected to play a central role in maintaining the continuity of this process, acting as the institutional interface between scientific updates and policy adaptation.

Stakeholder feedback on the CRA was broadly positive, with participants welcoming the rigour and transparency of the methodology as well as the accessibility of the spatial outputs. The main point of tension lies in the difficulty of communicating probabilistic, long-term risk change to operational teams accustomed to event-based risk management. This remains an ongoing challenge that will require sustained capacity-building and pedagogical efforts in Phase 3 and beyond.

2.5.3 Is learning ensured?

Learning from Phase 2 is being consolidated and disseminated through multiple channels. Within the scientific consortium, regular Executive Committee (COMEX) meetings ensure methodological continuity and collective validation of results. Externally, the project has been presented at multiple events ensuring that findings reach both technical specialists and policy decision-makers :

- the launch of the Regional Panel on Climate Change (RPCC, or "GREC-Réunion" in french)
- Technical Risk Committee (DEAL events)
- Météo-France thematic days
- SAR diagnostic and adaptation strategy workshops
- Red Cross practitioner training sessions — ensuring that findings reach both technical specialists and policy decision-makers.

Moreover, the launch of GREC-Réunion creates a durable institutional platform for embedding this learning into the territory's long-term science-policy interface.

In Phase 3, learning will also be consolidated through a public-facing communication strategy, including a local CLIMAAX conference, online educational resources, and a documentary-style webinar targeting both the general public and the school system. These efforts aim to embed a culture of climate risk awareness in society more broadly, complementing the technical and policy dimensions of the CRA.

2.5.4 What new data are available, and what is still needed?

Phase 2 significantly expanded the data foundation of the project through the integration of confidential datasets from ARS (abstraction point characteristics), the 2025 SDAGE water resource quality and quantity assessments, and the unpublished AROME CPM simulation from the BRIO project. These additions materially improved both the vulnerability assessment for drought and the hydrometeorological basis for flash flood analysis.

Despite this progress, important data gaps remain. For drought, a long time series of water body quality indicators would enable a more complete assessment of the compound vulnerability of water resources to both quantity and quality stresses. To reinforce the methodology, we would need more specific water infrastructure data such as pipelines location to more robustly link each UDI to the water body supplying it. Additionally, data on groundwater resource sensitivity to meteorological drought, including recharge dynamics and residence times for the different aquifer types on the island, would substantially improve the scientific basis of the hazard assessment. For extreme precipitation and torrential flooding, the primary remaining gap is the absence of a second independent climate model to validate or contrast the ALADIN RCM signals. The addition of AROME CPM hourly data in Phase 3 will partially address this, but multi-model robustness will remain a limitation until broader regional climate modelling programmes provide additional simulations over the South-West Indian Ocean domain.

2.5.5 What worked well, and what did not?

The stakeholder engagement process was one of the clearest successes of Phase 2 (cf section 2.1.5). The proximity-based meeting format, combined with the online survey tool, generated high-quality, actionable input from a diverse range of practitioners, with a 100% survey completion rate, significantly exceeding initial expectations and reflecting both the relevance of the topics and the trust built through the engagement approach. This process not only improved the methodology but expanded the project's institutional network in ways that will facilitate the dissemination and uptake of results in Phase 3.

On the other hand, the reliance on a single climate model for the extreme precipitation analysis was the most significant scientific limitation of the phase (cf section 2.3.2). The counterintuitive results produced by the ALADIN RCM, may reflect the stochastic variability of simulated tropical cyclone frequency rather than a robust climate change signal and made it very difficult to draw actionable conclusions from the risk assessment for this hazard. While the scientific hypotheses developed to explain these signals are plausible and will guide the Phase 3 analysis, they also illustrate the inherent fragility of single-model assessments for a territory where the dominant driver of extreme precipitation is itself highly uncertain in future projections.

2.5.6 Resource efficiency

The project benefited from a well-configured consortium in which each partner contributed complementary expertise: Météo-France provided essential climate data and expert interpretation of climate projections; BRGM contributed expertise in cascading natural hazards; Région Réunion led stakeholder engagement and institutional coordination; and OSU-Réunion/CNRS provided the scientific backbone for climate impact and adaptation research. The arrival of a dedicated postdoctoral researcher in February 2025 was a decisive factor in the scientific productivity of Phase 2, enabling the depth of methodological work that would not otherwise have been achievable within the project timeline.

The primary source of inefficiency was the time required to access, harmonize, and validate sensitive and locally-produced datasets which constitutes a challenge inherent to working in an overseas territory context where data is scattered across multiple institutions with varying data-sharing policies and formats. In Phase 3, the relationships built with data providers during Phase 2 should reduce this friction.

2.5.7 How do the CRA outcomes contribute to an improved understanding of risk?

The Phase 2 CRA outcomes have already demonstrated tangible value in terms of local engagement and institutional capacity. The interest generated by the project among inter-municipal water authorities, state services, and planning bodies confirms that a structured and spatialized risk assessment fills a genuine knowledge gap in the territory. The coincidence of the project's timeline with the SAR revision process represents a particularly valuable policy window: for the first time, climate risk indicators produced at the scale of the territory will be available to directly inform the Regional Adaptation Strategy of the SAR, ensuring that the planning framework is grounded in the best available scientific evidence.

The selection of La Réunion as part of the second cohort of the European "Pathways to Resilience" programme in December 2025 further validates the regional and European relevance of the RISC-RA approach, and opens a pathway for the continuation and deepening of this work beyond the CLIMAAX project.

2.6 Work plan Phase 3

2.6.1 Scientific completion of the workflows

Meteorological drought

The drought risk assessment will be finalized through:

- a cross-validation of the WASP index against the SPI index used in earlier phases, tested over documented past drought events on La Réunion
- a prototype of "adaptation trajectory" which will explore the potential of targeted interventions (water network efficiency improvement, source diversification, demand management) to reduce future drought risk through a "what if" approach that varies vulnerability parameters alongside the climatic component, providing decision-makers with actionable levers beyond hazard control alone.

Extreme precipitation

Two analyses will address the main limitations of Phase 2:

- First, the hourly AROME CPM simulation will be integrated into the risk assessment, providing an independent and physically more realistic estimate of extreme precipitation changes for comparison with the ALADIN RCM results.
- Second, a dedicated analysis will quantify the role of tropical cyclones in shaping the projected signal, by comparing extreme precipitation statistics computed with and without cyclone-influenced days. This will clarify whether the counterintuitive results obtained under the high-emission scenario reflect a genuine thermodynamic signal or simply a reduction in simulated cyclone frequency.

Torrential flooding

The workflow will be completed in two steps:

1. IDF analyses over the selected critical catchments, comparing historical (1991–2010) and future (2081–2100, SSP5-8.5) AROME CPM simulation to quantify projected changes in sub-daily precipitation extremes
2. Coupling of these hazard outputs with TRI flood maps and exposed infrastructure datasets to produce a first-order risk estimate in terms of territorial exposure.

2.6.2 Integration into public policy and risk governance

Beyond the scientific outputs, Phase 3 will be primarily dedicated to ensuring that the results of the CRA are effectively transferred into public policy, territorial planning, and risk governance instruments. This integration will take place through multiple activities.

Project restitution event

A dedicated CLIMAAX/RISC-RA restitution event will be organized for a wide audience of local stakeholders, decision-makers, and the scientific community. This event will present the complete results of the three workflows, discuss the methodology and its limitations in accessible terms, and open a dialogue on the implications of the findings for territorial adaptation. It will serve as the primary vehicle for the public launch of the Climate Risk Atlas.

Integration into risk governance bodies

The results will be formally presented within existing risk governance structures, in particular the Technical Risk Committees (Comité Technique des Risques) organised by DEAL, which bring together the institutional actors responsible for Natural Risk Prevention Plans (PPR, PPRI, PPRL) and other risk management instruments. Presenting the CRA findings within this framework will ensure that the updated risk knowledge is available to the practitioners directly responsible for translating risk assessment into regulatory land-use and prevention tools.

Contribution to the SAR Regional Adaptation Strategy

The RISC-RA results will directly feed into the revision of the Regional Land Development Plan (SAR), which is expected to be finalized in late 2026. Specifically, the CRA outputs will inform three components of the SAR:

- The diagnostic chapter on natural risks and water security (providing updated, spatialized risk indicators)
- The planning principles and zoning rules (particularly regarding construction restrictions in high-risk areas and water infrastructure security requirements)
- Potentially the SAR's Monitoring and Evaluation indicators, which will track the evolution of risk over the lifetime of the plan.

This integration represents the most direct and durable policy impact of the RISC-RA project, embedding the results into the territory's primary spatial planning framework for the coming decades.

Contribution to the GREC-Réunion Climate Knowledge Centre

Région Réunion and the University of La Réunion, through OSU-Réunion, are responding to a national call for projects to develop a scoping study for a Climate Change Adaptation Knowledge Centre within GREC-Réunion. This center would serve as a permanent resource platform for climate change adaptation knowledge in the South-West Indian Ocean region. The RISC-RA results — comprising the first comprehensive, spatialized, and multi-hazard climate risk assessment for Réunion Island — are expected to constitute one of the founding knowledge bricks of this center, ensuring the long-term accessibility and institutional continuity of the project's outputs beyond the CLIMAAX project lifetime.

3 Conclusions Phase 2- Climate risk assessment

The second phase of the RISC-RA project achieved significant progress in consolidating Réunion Island's first comprehensive climate risk assessment, while also revealing the inherent complexity of assessing water-related risks on a small, mountainous tropical island.

Main challenges addressed

Phase 2 successfully addressed several key challenges identified at the end of Phase 1.

The meteorological drought workflow was substantially improved through three major refinements: the integration of evolving demographic exposure, the elaboration of vulnerability indicators co-constructed with water-sector stakeholders, and the identification of the most operationally relevant geographical units (Drinking Water Distribution Units along with Groundwater bodies) for mapping and communicating results.

For extreme precipitation, the single impact threshold used in Phase 1, which had produced inconsistent results was replaced by spatially distributed thresholds derived from Météo-France's heavy rainfall vigilance system, significantly improving the methodological coherence of the analysis.

A third workflow on torrential flooding was introduced during this phase, extending the assessment to the hydrological consequences of extreme rainfall by leveraging hourly outputs from the AROME convection-permitting model. This addition directly responded to feedback from flood alert services and Météo-France, who emphasized the critical importance of sub-daily data for capturing the rapid hydrological dynamics characteristic of La Réunion's steep catchments.

A central achievement of Phase 2 was the stakeholder engagement process. Nine local meetings with representatives from five inter-municipal communities and four regional technical organizations, complemented by an online survey achieving nearly 100% completion, generated high-quality feedback that directly informed and shaped the methodology. This participatory approach enhanced both the scientific rigor and the operational relevance of the assessment, while fostering the institutional relationships essential for integrating the results into local planning

The identification and use of an unpublished high-resolution simulation from the AROME convection-permitting model, developed as part of the BRIO project, represents a key methodological innovation within the CLIMAAX framework and opens important perspectives for the torrential flooding analysis in Phase 3.

Challenges not fully addressed

Despite this progress, several significant challenges remain. The most important scientific limitation is the use of a single climate model (ALADIN RCM) for both the drought and extreme precipitation workflows. For extreme precipitation, this single-model approach yielded results that are highly scenario-dependent and, in some cases, counterintuitive, likely reflecting the sensitivity of the signal to the simulated frequency of tropical cyclones rather than a robust climate change signal. Without a multi-model ensemble, it is not possible to distinguish climate change trends from internal model variability with confidence.

Furthermore, accessing and harmonizing sensitive, locally produced datasets, particularly confidential data on drinking water infrastructure from health authorities, has proven to be a tedious task and remains a structural challenge inherent to working in an overseas territory where data is scattered across different institutions with varying sharing policies. Finally, communicating probabilistic concepts of long-term risk evolution to operational actors accustomed to event-based risk management remains an ongoing educational challenge.

Key findings

The risk assessment confirmed that both meteorological drought and extreme precipitation (including torrential flooding) constitute high-priority risks for Réunion Island, through different pathways.

Drought risk severity is assessed as substantial and worsening, driven by a lengthening dry season, growing population pressure, and structural vulnerabilities in the water supply system — including mono-resource dependencies, ageing infrastructure, and chronic underfunding of network maintenance. The exceptional drought of December 2024–January 2025, the driest two-month period in 50 years, served as a stark illustration of the territory's exposure. Drought is therefore considered a **“High priority risk”**.

Extreme precipitation severity is assessed as substantial. While the analysis is more prone to uncertainty, according to the precautionary principle this risk must be taken with extreme caution given the substantial severity demonstrated by recent catastrophic events such as Tropical Cyclone Garance in February 2025. It was assessed as **“High priority risk”**.

Both risks were assigned a medium resilience capacity, reflecting the existence of alert systems and emergency mechanisms but also significant gaps in insurance coverage, infrastructure maintenance, and institutional capacity.

Perspective

These scientific results must now be translated into the final version of Réunion Island's Climate Risk Atlas for the general public during Phase 3. The remaining months of the project will focus on different technical and communication objectives completing the torrential flooding workflow, integrating the AROME CPM simulation into the extreme precipitation analysis to address the single-model limitation, and above all ensuring that the CRA outputs are effectively embedded into the SAR Regional Adaptation Strategy, local planning documents, and the newly launched GREC-Réunion science-policy interface. This work will also constitute the foundation for Région Réunion's new engagement as part of the European "Pathways to Resilience" initiative.

4 Progress evaluation

The second phase of the RISC-RA project focused on consolidating initial results, leveraging the active involvement of local stakeholders and the acquisition of new data, including some sensitive and confidential datasets. This period was also marked by a technical collaboration with CRAHI to develop a new workflow.

In parallel, the past twelve months saw the deployment of an effective dissemination strategy, featuring a dedicated video capsule, a flyer, a webpage, and several technical presentations (for weather services, regional technical risk committee, etc.).

This second scientific deliverable will be refined during Phase 3 to produce a version tailored for the general public. These results will be integrated into the 'Adaptation' chapter of the new Regional Land Development Plan (SAR) and shared through the GREC-Réunion (new Regional Panel for Climate Change), which is launched this month.

Finally, Phase 2 further strengthened inter-regional cooperation through participation in the CLIMAAX Workshop in Barcelona, collaboration with the REGILIENCE European project and the application for the “Pathways to Resilience" project (for the continuation of the RISC-RA project).

The results of the first phase on Key Performance Indicators (KPIs) and milestones are presented on the followings tables.

Table 11 : Overview key performance indicators completed during phase 2

KPIs for phase 2	***Progress***
2 European missions to meet the CLIMAAX consortium and CLIMAAX stakeholders (Workshop in Barcelona for phase 2)	**Completed** - 3 members of the RISC-RA team participated in the CLIMAAX workshop held in Barcelona: Kevin Lamy (project manager), Nils Poncet (scientific expert) and Elodie Marpinard (administrative and financial manager).
2 workflows successfully applied on Deliverable 2	**Completed** - Refined results for meteorological droughts and heavy precipitation Workflows completed for historical data and projections (using refined data, expert advice and consultation with local authorities). Third workflow applied: Flash floods
1 Atlas of climate risks projections for La Reunion (1 scientific version in phase 2 and 1 version for the general public in phase 3)	**Completed** - Climate risk maps for La Réunion based on the methodology of phase 2 on water risks. In accordance with the IFP, the final version intended for the general public should be released during phase 3 of the project.
1 note for the President of Region Reunion about the Regional Panel for Climate Change (RPCC)	**Completed** - Note dated 21 March 2025 approved by the President of Region Réunion concerning the agreement establishing GREC-Réunion (La Réunion's RPCC). Official launch of GREC-Réunion in the presence of more than 20 national and local institutions on 27 January 2026.

Table 12 : Other KPIs impacted during phase 2

Other KPIs impacted during phase 2	*Progress*
4 online communications about the project (Regional website, LinkedIn, Region open data portal, etc.)	**100%** - Since the start of the project, the Region Réunion has already published 4 institutional communications online (3 posts on LinkedIn + 1 web page). In addition, there has been 1 online communication via the REGILIENCE project and personal posts by the team on LinkedIn.
3 dedicated CLIMAAX workshops for local authorities of Reunion Island	**75%** - Because stakeholders were geographically spread out, the project team adapted its approach. 2 main stakeholder groups (local public authorities and regional technical stakeholders) were involved through local meetings and an online survey. These groups are the target audience for the 2 workshops initially planned for phase 1 and 2 of the project.
6 Executive Committee meetings with selected scientific and institutional partners in the climate field	**67%** - 4 meetings of the Executive Committee have already been organized since the beginning of the project, attended by 10 participants on average including scientific experts and representatives of Réunion Regional Council.

Table 13 : Overview milestones

Milestones for phase 2	*Progress*
Attend the CLIMAAX workshop held in Barcelona	**Completed** - 3 members of the RISC-RA team participated in the CLIMAAX workshop held in Barcelona. Interview with the team conducted by the CRAHI, project presentation in plenary session and active networking.
4th Executive Committee meeting	**Completed** - 4th meeting of the Executive Committee on 20 November 2025
2nd version of the climate risk atlas based on the 2nd regional risk assessment (1 version for the general public of the Atlas for phase 3)	**Completed** - Climate risk maps for La Réunion based on the methodology of phase 2 on water-related risks. In accordance with the IFP, the final version intended for the general public should be released during phase 3 of the project.
1st workshop with local public authorities	**Completed** - Between 23/09/25 and 18/11/25, the RISC-RA team organized 9 local meetings (5 inter-municipal communities with delegates and four regional technical stakeholders). 25 people from local public authorities and national authorities were involved in phase 2 methodology.

Documents and detailed information relating to the monitoring and management of the RISC-RA project are available in the appendix.

5 Supporting documentation

Supporting documentation is accessible at this zenodo link.

The supporting documentation contains 4 appendices:

- **Appendix 1**: Supplementary material of M16 Deliverable containing additional figures and results, and technical details about the methodology
- **Appendix 2:** Files about stakeholder engagement process (consultation meetings with local stakeholders), governance of the RISC-RA project (Executive Committee and Regional Panel for Climate Change) and Communication-Dissemination activities (video clip, webpage, LinkedIN posts, presentations at regional and professional events)
- **Appendix 3:** Compilation of Communication and Dissemination Materials (Presentations, Posts, Flyers, and Outreach Activities)
- **Appendix 4:** Executive Committees listing, content (presentation) and Key Governance Actions for Risk Management (GREC Launch...)

Given the extensive range of datasets used in the risk assessment, listing them here is not considered pertinent. Public raw datasets are referenced in Section 2.2.1, while post-processed data and final outputs have been released on Zenodo and documented within the corresponding CLIMAAX platform.

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