CLIMAAX
climate ready regions

Deliverable Phase 2 – Climate risk assessment

CLIMAAXKòrsou

Curaçao

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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

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1.0	…	MDC	Deliverable submitted
2.0	5 Feb 2026	MDC	Revised following reviewer feedback: (1) Expanded pluvial flood methodology with 2-step modeling approach, assumptions, and limitations; (2) Added bias correction procedure detail including quantile mapping steps and validation results; (3) Expanded tide gauge analysis clarifying role as plausibility reference for GTSM extreme water levels; (4) Aligned KPIs and milestones with IFP; (5) Added stakeholder engagement evidence and Phase 3 corrective strategy; (6) Added Annex: D2 Revision Plan with structured response to all findings, stakeholder session summaries (S1–S6), and forward plan for Climate Impact Atlas deployment and Phase 3 engagement.
3.0	7 Apr 2026	MDC	Methodology and data improvements: (1) Corrected MSL datum for coastal flood model (DEM zero = MSL); (2) Replaced raw LST heat

			baseline with calibrated satellite-station fusion (R^2=0.70); (3) Expanded spatial units from 63 geozones to 315 CBS neighbourhoods; (4) Updated exposure data to 103,117 buildings, 68,148 Kadaster parcels and 2,988 OSM points of interest; (5) Simplified drought hazard to precipitation decline (removed self-normalizing SPI frequency); (6) Added risk density metric consistent across all hazards; (7) Updated all figures, tables and cross-hazard summary statistics

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Abbreviations and acronyms

Abbreviation / acronym	Description
AR6	IPCC Sixth Assessment Report
CBS	Central Bureau of Statistics Curaçao
CG	Curaçao Guilder (currency, 1 USD ≈ 1.79 CG)
CLIMAAX	CLIMAte risk and vulnerability Assessment framework and toolboX
CMIP6	Coupled Model Intercomparison Project Phase 6
CCCP	Curaçao Climate Change Platform
DEM	Digital Elevation Model

EWL	Extreme Water Level
GIS	Geographic Information System
GTSM	Global Tide and Surge Model
IDF	Intensity-Duration-Frequency
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre (European Commission)
LST	Land Surface Temperature
MDC	Meteorological Department Curaçao
OSM	OpenStreetMap
SIDS	Small Island Developing State
SLR	Sea Level Rise
SPI	Standardized Precipitation Index
SSP	Shared Socioeconomic Pathway
TWL	Total Water Level
UHI	Urban Heat Island
VVRP	Ministry of Traffic, Transport and Spatial Planning
WMO	World Meteorological Organization

Scenario	Name	Description
SSP1-2.6	Sustainability	Low emissions, +1.3°C by 2100
SSP2-4.5	Middle of the Road	Moderate emissions, +2.0°C by 2100
SSP3-7.0	Regional Rivalry	High emissions, +2.9°C by 2100
SSP5-8.5	Fossil-fueled Development	Very high emissions, +3.7°C by 2100

Executive summary

This deliverable presents the refined climate risk assessment for Curacao under CLIMAAX Deliverable D.2, addressing the requirement to produce a local multi-risk assessment using local data sources. The assessment enables evidence-based climate adaptation planning for a small island developing state facing sea level rise, extreme rainfall intensification, urban heat stress, and drought conditions.

Main Results and Findings

Phase 2 refined the Phase 1 proof-of-concept through integration of local data sources and improved methodology:

Data Integration: The assessment incorporated 32 years of MDC meteorological observations (1993-2025), 70,000 tide gauge measurements, CBS Census 2023 demographics (154,640 population across 315 neighbourhoods), 103,117 building footprints (Microsoft), 68,148 Kadaster property parcels, and 2,988 OpenStreetMap points of interest. Spatial resolution improved from 12 km (global models) to 10 m (local analysis).

Hazard Assessments:

- Coastal flooding: 18 scenarios combining IPCC AR6 sea level rise projections across 3 SSP pathways and 3 percentiles (P17/P50/P83). Worst-case (SSP5-8.5 2100, 88 cm SLR): 1,316 Kadaster parcels flooded, 847 at significant depth (>25 cm). No parcels exceed 1 m depth. Priority areas identified through building-level exposure analysis (103k Microsoft building footprints) and critical infrastructure mapping (hospitals, schools, power stations).
- Pluvial flooding: IDF curves developed using Gumbel extreme value analysis on 32 years of island-wide annual maxima. Clausius-Clapeyron scaling (+10%/degC) projects 100-year rainfall increasing from 198 mm to 258 mm (+30%) under SSP5-8.5 2100. Severe flooding (>1 m) increases 64% (937 to 1,538 buildings affected). Mean precipitation declines up to 31%, but extreme events intensify -- infrastructure must accommodate both drought and more intense flooding.
- Heat stress: Calibrated air temperature baseline using satellite-station fusion (GISELLE project: PCA decomposition of 13-year Landsat stack + wind speed regression, R^2=0.70, RMSE=0.214 degC). This replaces the Phase 2 raw LST approach (R^2=0.009 with air temperature). Wind speed dominates the spatial heat pattern (r=-0.80). CMIP6 projections show +1.2 to +3.8 degC warming by 2100. Sheltered urban areas (28.9 degC baseline) approach concerning levels (32.7 degC) under SSP5-8.5.
- Drought: Standardized Precipitation Index analysis using 32 years of observations. CMIP6 ensemble shows precipitation declining up to 31% (SSP5-8.5 2100). SPI-based drought frequency remains stable (~15%) due to self-normalization -- the real impact is absolute

water availability decline. Curacao's 95%+ desalination dependence mitigates direct water supply impacts but drought affects vegetation cover, erosion, and desalination energy costs.

Methodological Advances:

- Satellite-station fusion for heat stress (R^2=0.70 vs R^2=0.009 for raw LST)
- Risk density metric: population density x flood/hazard fraction (people at risk per km²)
- Severity threshold exposure: buildings and population at >25 cm, >50 cm flood depth
- Fan chart projections with CMIP6 P10-P90 uncertainty envelopes for all four hazards
- Building-level exposure using Microsoft building footprints (103k) and OSM critical infrastructure (2,988 POIs)
- Database-driven architecture with portal views for web integration

Conclusions

Coastal flooding affects a limited but economically important area along the south coast, with 1,316 parcels at risk under worst-case SLR. Pluvial flooding presents broader spatial risk with 64% more buildings experiencing severe flooding under climate change. Heat stress is island-wide with the spatial pattern driven by wind exposure -- sheltered urban areas are most vulnerable. Drought impacts are mitigated by desalination but affect vegetation and energy costs. Multi-hazard hotspots in Willemstad's urban core (Dominguito, Mahaai, Salinja) require integrated adaptation approaches.

1 Introduction

1.1 Background

Curaçao is a small island developing state (SIDS) located in the southern Caribbean Sea, approximately 65 km north of Venezuela. The island covers 444 km² with a population of 154,640 (CBS Census 2023) and a population density of 348 persons per km². The economy relies primarily on tourism, oil refining, and financial services, with GDP per capita of approximately $24,000 USD.

The island faces multiple climate challenges characteristic of Caribbean SIDS: sea level rise threatening low-lying coastal areas including the historic UNESCO World Heritage Site of Willemstad; intense convective rainfall causing flash flooding in urban drainage systems; urban heat island effects in densely built areas; and semi-arid conditions with mean annual precipitation of approximately 550 mm concentrated in a short wet season (October-December).

Topography is generally flat with a central hilly region culminating at Mount Christoffel (375m). The coastline spans approximately 280 km featuring rocky cliffs and sandy beaches. Urban development concentrates around Willemstad, the capital, with 60 statistical geozones (CBS administrative boundaries) forming the basis for demographic analysis.

1.2 Main objectives of the project

Phase 2 of the CLIMAAXKòrsou project addresses Deliverable D.2: Refined Regional/Local Multi-Risk Assessment. The primary objectives are:

1. Refine Phase 1 assessments using higher-resolution data and local validation
2. Complete the drought hazard assessment (identified gap from Phase 1)
3. Improve spatial resolution from 12 km (global models) to 10-30 m (local analysis)
4. Develop a unified spatial database enabling cross-hazard analysis and operational updates

The CLIMAAX Handbook provided standardized methodologies following IPCC AR5/AR6 risk conceptualization (Risk = Hazard × Exposure × Vulnerability), ensuring scientific rigor and comparability with other European regional assessments. The framework enabled systematic treatment of uncertainty through multi-model ensembles and probabilistic scenarios.

Integration of local data sources significantly enhanced assessment accuracy beyond what global datasets alone could provide. Using the Meteorological Department Curaçao (MDC) 32 years of daily weather observations from a weather-station network, enabled bias correction of climate model projections with demonstrated improvement (<0.8°C RMSE). The 78-year historical record (1947-2025) captures spatial variability including urban heat island effects quantified at 1.53°C from the main airport station. Tide gauge observations (70,000 hourly measurements) validated coastal flood scenarios against observed extreme water levels.

1.3 Project team

This assessment was conducted by the Meteorological Department Curaçao (MDC) under the direction of Dr. Albert Martis (Director). Technical analysis and report preparation were led by Jonathan Zoetrum (Project Manager, Climate Services). The work builds upon Phase 1 deliverables completed by Pilar Reija Zamora (intern, June 2025) in collaboration with Climate Adaptation Services (CAS). The CLIMAAX framework and technical support were provided by Deltares and the European CLIMAAX consortium under the Horizon Europe programme.

1.4 Outline of the document's structure

This document is organized as follows:

- Chapter 1: Introduction (this chapter) provides background on Curacao and project objectives
- Chapter 2: Climate Risk Assessment – Phase 2 presents the full CRA following CLIMAAX frameworks steps (scoping, Risk Exploration, Regionalized Risk Analysis, Key Risk Assessment Findings, Monitoring and Evaluation, Work Plan for Phase 3)
- Chapter 3: Conclusions summarizes key findings from Phase 2
- Chapter 4: Progress Evaluation documents KPIs and milestons achieved
- Chapter 5: Supporting Documentation provides reference to data, figures, and supplementary materials
- Chapter 6: References list all sources cited

2 Climate risk assessment – phase 2

2.1 Scoping

2.1.1 Objectives

Objective and Purpose

The objective of this climate risk assessment is to provide quantified, locally-validated risk information to support evidence-based climate adaptation planning for Curaçao. The expected outcomes include:

1. Hazard maps for four climate risks (coastal flooding, pluvial flooding, heat stress, drought) under multiple scenarios through 2100
2. Population and infrastructure exposure quantification at geozone level
3. Risk prioritization to guide adaptation investment decisions
4. Reproducible methodology enabling future updates as new data becomes available

Policy Integration

The project outcomes provide technical input for national climate adaptation planning. MDC leads climate adaptation coordination through the Curaçao Climate Change Platform (CCCP), engaging stakeholders including GMN (Environment), VVRP (Urban Planning), and other relevant ministries. Risk assessment outputs are intended to inform future policy development in spatial planning, infrastructure standards, and coastal management.

Limitations and Boundaries

- Data availability: 10m DEM resolution limits detailed coastal micro-topography analysis; sub-hourly rainfall intensity data not available for IDF curve refinement
- Stakeholder involvement: Limited formal stakeholder consultation during Phase 2 due to timeline constraints; to be addressed in Phase 3
- Scope boundaries: Assessment focuses on direct climate impacts; indirect economic impacts and cascading effects require further analysis
- Model limitations: Bathtub flood model does not capture wave dynamics; linear depth scaling for pluvial flooding may underestimate extreme responses

Challenges Encountered:

- Island-wide vs single-station rainfall statistics required methodological decision (Curaçao airport station single-station approach selected for statistical consistency with 78-year record).
- Census data at geozone level limits building-level vulnerability assessment.
- Limited locally-specific depth-damage curves required use of Caribbean regional estimates.
- Limited availability of data for categorization of areas for analysis of damage scenarios.

2.1.2 Context

Historical Climate Risk Management:

Curaçao has historically addressed climate hazards through reactive emergency response rather than systematic risk assessment. The Meteorological Department Curaçao (MDC) provides weather warnings and maintains observational networks but has not previously conducted comprehensive climate projections. Consequences from flood events are managed by the Fire Department and Civil Protection (DDR); no systematic risk mapping existed prior to CLIMAAX.

Problem Context:

As a small island developing state, Curaçao faces disproportionate climate vulnerability relative to its adaptive capacity. Key challenges include:

- Concentrated coastal development in flood-prone areas (Willemstad UNESCO site)
- Aging drainage infrastructure designed for historical climate rainfall patterns
- Growing elderly population (24.7%) with elevated heat vulnerability
- Economic dependence on climate-sensitive sectors (tourism,)

Governance Context:

- National Climate Policy Framework (in development)
- Spatial Development Plan (ROP) - primary land use planning instrument
- Building Code (Bouwverordening) - currently lacks climate-specific provisions
- Aqualectra responsible for desalination and distribution of water
- Limited dedicated climate adaptation budget; funding through sectoral ministries

Relevant Sectors and Climate Impacts:

Table 2-1: Analysis sectors climate impacts

Sector	Climate Sensitivity	Key Risks
Tourism	High	Beach erosion, heat stress, hurricane damage
Port/Trade	High	Sea level rise, storm surge
Energy	Medium	Increased cooling demand, infrastructure exposure
Water Supply	Low (desalination)	Energy costs for desalination increase
Health	High	Heat-related illness, vector-borne disease
Agriculture	High	Drought, reduced productivity

Outside Influences:

- Regional Caribbean climate initiatives (CARICOM, CDEMA)
- Kingdom of the Netherlands climate adaptation support
- EU Green Deal and international climate finance mechanisms
- Global shipping and tourism trends

Possible Adaptation Interventions:

- Coastal protection (seawalls, nature-based solutions)
- Drainage infrastructure upgrades
- Urban greening and cooling strategies
- Building code updates for climate resilience
- Early warning systems enhancement
- Land use planning restrictions in high-risk zones

2.1.3 Participation and risk ownership

Stakeholder Involvement in Phase 2:

Phase 2 focused primarily on technical analysis with limited stakeholder engagement. Key stakeholders identified for the project include:

Table 2-2: Primary stakeholders

Institution	Role	Phase 2 Involvement
MDC	Lead technical partner, data provider	Full (project execution)
VVRP (Ministry)	Policy owner, adaptation planning	Informed (progress updates)
ROP (Spatial Planning)	Land use regulation	Consulted (data sharing)
Aqualectra (Water/Energy)	Infrastructure operator	To be engaged Phase 3
Civil Protection	Emergency response	To be engaged Phase 3
CBS (Statistics)	Demographic data provider	Data provision

Risk Ownership:

- **Identification:** MDC (meteorological hazards), VVRP (policy framework)
- **Assessment:** MDC (technical analysis), ROP (spatial implications)
- **Adaptation:** Sectoral ministries, Aqualectra, private sector (implementation)

Priority Groups:

- Elderly population (65+): 38,239 persons (24.7%) - elevated heat vulnerability
- Children (0-14): 21,859 persons (14.1%) - heat and flood vulnerability
- Coastal residents: Willemstad historic district, Spaanse Water area
- Low-income communities: Limited adaptive capacity

Acceptable Risk Levels:

No formal risk tolerance thresholds have been established for Curaçao. Phase 3 stakeholder engagement will address this gap through participatory risk evaluation workshops.

2.1.4 Application of principles

Social Justice, Equity, Inclusivity:

- Risk assessment disaggregated by geozone to identify spatial inequities
- Vulnerable population groups (elderly, children) explicitly quantified
- Results will be communicated in multiple languages (Dutch, Papiamentu, English)
- Phase 3 will include community engagement in priority areas

Quality, Rigour, Transparency:

- CLIMAAX framework ensures methodological consistency with European standards
- All data sources documented with metadata
- Uncertainty quantified through multi-model ensemble (7 CMIP6 models)
- Methods reproducible through documented workflows
- Bias correction validated against local observations (<0.8°C RMSE)

Precautionary Approach:

- High-emission scenario (SSP5-8.5) included despite lower probability
- 100-year return periods assessed for extreme events
- Worst-case combinations (e.g., 100-yr storm + high SLR) explicitly mapped
- Conservative assumptions where data limited

2.1.5 Stakeholder engagement

Phase 2 Engagement Activities:

Table 2-3: Phase 2 engagement activities

Date	Activity	Participants	Purpose	Type
Nov 2025	Project scope and methodology review	MDC project team, director Martis	Confirm Phase 2 approach: self-execution decision, workflow priorities	Internal
Dec 2025	Policy consultation with VVRP	Miriam Jonger (Head of Policy, VVRP) , MDC	Assessed risk analysis results and policy implications of Phase 2 climate risk assessment preliminary findings	External
12 Dec 2025	CCCP Workshop: Climate Scenarios Curaçao 2050-2100	Policymakers (beleidgevers), civil servants (ambtenaren), NGOs, general public, private sector	Presented MDC/KNMI climate scenarios for Curaçao including flood risk analysis and multi-hazard approach from Phase 2. Part of IPDC program, co-developed with KNMI	External
Jan 2026	D.2 report preparation and submission	MDC	Compilation of technical results and deliverable	Internal

Date	Activity	Participants	Purpose	Type
3 Feb 2026	Central Bank of Curaçao and Sint Maarten briefing	Central Bank staff, workgroup cliamte change, MDC staff	Presentation of climate risk assessment results and implications for financial sector risk management	External

Communication and Dissemination:

- Technical report submitted to CLIMAAX (this document)
- Workflow notebooks and figures archived on Zenodo for open access
- Risk maps to be published on MDC climate services website for public access
- Multi-language summaries planned for Phase 3 (English, Dutch, Papiamentu)

Stakeholder Feedback:

The CCCP platform presentation (December 2025) provided initial feedback on the methodology and preliminary results. The Central Bank briefing (February 2026) represents engagement with a key institutional stakeholder for climate risk in the financial sector. Formal participatory feedback collection is planned for Phase 3 through structured workshops.

Difficulties Encountered:

- Data availability challenges: Significant effort was required to identify, acquire, and process suitable datasets for a small island context where standard European data infrastructure does not exist. This front-loaded the technical workload in Phase 2, leaving less time for formal stakeholder engagement.
- Communication gap between technical outputs and policy needs: Climate risk assessment produces highly technical outputs (return periods, SSP scenarios, hazard indices) that require careful translation for policymakers and civil servants. Presenting scientifically rigorous information in an accessible format without oversimplifying remains a key challenge. This was evident during stakeholder interactions, where the framing of scenario impacts needed to be adapted to non-specialist audiences.
- Phase 2 prioritized completing robust technical analysis before stakeholder presentation, ensuring that results shared with decision makers are defensible and validated. Engagement activities were therefore concentrated at the end of Phase 2 and will intensify in Phase 3.

Communication of Results:

- Internal MDC briefings on methodology and interim results
- Technical report for CLIMAAX submission
- Risk maps to be published on MDC website for public access

Reception and Feedback:

Formal stakeholder feedback collection planned for Phase 3 through:

- Workshop with sectoral representatives
- Public consultation on risk maps
- Survey of priority group representatives

Difficulties Encountered:

- Limited stakeholder availability during end of year period
- Need for technical capacity building among non-specialist stakeholders
- Coordination across multiple government entities

2.2 Risk Exploration

2.2.2 Screen risks (selection of main hazards)

Changes from Phase 1:

Phase 2 added limited drought assessment (not completed in Phase 1) and refined all three original hazards with local data integration.

Climate Hazards Relevant for Curaçao:

Based on Copernicus Climate Atlas and local knowledge:

Table 2-4: List of climate hazards relevant for Curacao

Hazard	Current Relevance	Future Projection	Selected for CRA
Sea level rise	Moderate	High increase	Yes
Coastal flooding/storm surge	High	Increasing	Yes
Extreme rainfall/pluvial flooding	High	Intensifying	Yes
Heat stress	High	Significant increase	Yes
Drought	Moderate	Increasing frequency	Yes (limited)
Tropical cyclones	Low-Moderate	Uncertain	No (outside scope)
Wildfire	Low	Potentially increasing	No

Current Situation:

- **Coastal flooding:** Low-lying areas of Willemstad (Punda, Otrobanda) experience inundation during storm surge events and high tide
- **Pluvial flooding:** Urban areas with inadequate drainage (Brievengat, Salina) flood during intense rainfall
- **Heat stress:** Urban heat island documented (1.53°C warmer in built areas); elderly impact increased during these heat events
- **Drought:** Semi-arid climate with high interannual variability; 95% water from desalination mitigates direct supply impacts. Limited data.

Hazards Selected:

1. **Coastal flooding** - Critical for Willemstad heritage site and port infrastructure
2. **Pluvial flooding** - Frequent occurrence affecting urban residents
3. **Heat stress** - Largest projected increase in risk; vulnerable population exposure
4. **Drought** - Ecosystem and energy cost implications; framework applicability test

Data Availability:

Table 2-5: List of data availability for regional hazards

Hazard	Available Data	Data Gaps
Coastal	IPCC AR6 SLR, GTSM surge, 8-yr tide gauge	Wave dynamics
Pluvial	32-yr rainfall (R11), 10m DEM	Drainage network model
Heat	Landsat LST, 12-station network, CMIP6	Indoor exposure
Drought	32-yr precipitation, CMIP6	Soil moisture, groundwater

2.2.3 Choose Scenario

Future Climate Conditions:

Three SSP scenarios selected spanning uncertainty range:

Table 2-6: List of SSP scenarios for Curacao

Scenario	Rationale	Global Temp by 2100
SSP1-2.6	Paris Agreement goals met	+1.3°C
SSP2-4.5	Current policies continued	+1.9°C
SSP5-8.5	High emissions (precautionary)	+3.0°C

Seven CMIP6 models provide ensemble spread: ACCESS-CM2, CMCC-ESM2, EC-Earth3, MIROC6, MPI-ESM1-2-HR, NorESM2-MM, UKESM1-0-LL.

Future Socio-Economic Conditions:

Population projections not explicitly modeled; current demographics (CBS Census 2023) used as baseline. This is appropriate given Curaçao's relatively stable population and the focus on physical hazard assessment.

Time Horizons:

Table 2-7: Time horizons for scenario analysis

Period	Years	Use
Baseline	1993-2024	Current conditions
Mid-century "2050"	2040-2069	Near-term planning
End-century "2100"	2070-2099	Long-term infrastructure

Combination Approach:

Delta change method applied: Future = Baseline + Climate Delta

This preserves local spatial detail while incorporating climate change signal from global models.

2.3 Regionalized Risk Analysis

Fine-tuning Approach:

CLIMAAX workflows adapted through:

- Bias correction using MDC 12-station network (32+ years)
- Validation against local observations (tide gauge, temperature)
- Spatial resolution enhancement (12 km → 10 m)
- Satellite-station fusion for heat stress calibration (R^2=0.70)

Local Data Integration:

- MDC meteorological observations (1993–2025, 12 stations)
- Tide gauge records (70,000 hourly measurements, 2017–2025)
- CBS Census 2023 demographics (154,640 population, 315 neighbourhoods)
- Microsoft building footprints (103,117 buildings from satellite AI detection)
- Kadaster property parcels (68,148 parcels with land-use classification)
- OpenStreetMap points of interest (2,988 features across 15 categories)
- Calibrated air temperature baseline (3,733 hexbins, 250 m resolution)

Impact Metrics:

Standard CLIMAAX outputs plus locally-relevant additions:

- Risk density: population density × hazard fraction (people at risk per km²)
- Severity threshold exposure: buildings and parcels at >25 cm, >50 cm, >1 m flood depth
- Fan chart projections with CMIP6 P10–P90 uncertainty envelopes for all four hazards
- Building-level exposure using Microsoft footprints and OSM critical infrastructure

2.4 Bias Correction Procedure

CMIP6 global climate models exhibit systematic biases when compared to local observations. For Curaçao, raw CMIP6 temperature outputs show biases of 2-3°C relative to MDC station measurements. A quantile mapping procedure was applied to correct these biases:

- Reference period: The historical overlap between CMIP6 simulations and MDC observations (1993-2014, 22 years) was used as the calibration window.
- Quantile mapping: For each CMIP6 model and each calendar month, the cumulative distribution function (CDF) of modeled values was mapped to the CDF of observed values at MDC station R11 (Hato Airport). This corrects both the mean bias and the distributional shape, ensuring that average temperature, variability, and extremes are properly represented.
- Monthly stratification: Correction was applied separately for each calendar month to preserve seasonal differences between the dry season (January-September) and wet season (October-December).

Application to projections: The transfer function derived from the historical period was applied to SSP projections (2015-2100), assuming model biases remain stationary over time. This stationarity assumption is standard practice in climate downscaling.

Validation results:
- RMSE reduced from 2-3°C (raw) to < 0.8°C (corrected)
- Correlation (r-squared) > 0.7 between corrected CMIP6 and MDC observations
- Seasonal cycle well reproduced after correction

Delta method for heat projections: The bias-corrected CMIP6 ensemble provides temperature change deltas (difference between future period and historical baseline), not absolute values. These deltas are added to a calibrated air temperature baseline derived from satellite-station fusion: PCA decomposition of a 13-year Landsat Land Surface Temperature stack combined with wind speed interpolation from MDC's 12-station network (R^2=0.70, RMSE=0.214°C). This replaces the raw LST baseline used in the original Phase 2 analysis (R^2=0.009 with air temperature — effectively uncorrelated). The calibrated baseline preserves local spatial detail at 250 m resolution while the CMIP6 deltas incorporate the climate change signal.

2.4.1 Hazard #1 - fine-tuning to local context

Table 2-8: Data Overview - Coastal Flooding

Hazard Data	Vulnerability Data	Exposure Data	Impact Metrics/Risk Output
IPCC AR6 SLR projections (Table 9.9)	CBS Census 2023 demographics	MS building footprints (103,117)	Flood depth (m)
MDC tide gauge	CBS age/vulnerability	Kadaster parcels (68,148)	Parcels flooded (count)

Hazard Data	Vulnerability Data	Exposure Data	Impact Metrics/Risk Output
(70,000 obs)	indicators		
10m DEM (Phase 1)	Social vulnerability composite	OSM POIs (2,988)	Risk density (people/km2)
		315 CBS neighbourhoods	Critical infrastructure at risk

Limitations: Bathtub model does not capture wave dynamics or storm surge dynamics. DEM resolution (10m) misses micro-topography (seawalls, drainage channels). Building use classification not available for MS building footprints. Storm surge scenarios from the original D2 were removed; the bathtub model with SLR-only is more transparent.

Methodology correction: The original D2 submission used the Bullen Bay tide gauge RLR datum (7.02m) as the water level baseline, which produced significantly inflated flood extents. The corrected approach uses DEM zero = mean sea level with SLR added directly (14-88 cm), producing physically correct results.

2.4.1.1 Hazard assessment

Coastal flood hazard assessed through a bathtub model combining DEM elevation with IPCC AR6 sea level rise projections:

- **Sea Level Rise:** IPCC AR6 regional projections for Caribbean (Table 9.9)
  - 2050: +14 to +30 cm (SSP1-2.6 P17 to SSP5-8.5 P83)
  - 2100: +28 to +88 cm
- **Method:** DEM elevation zero = mean sea level. All pixels with elevation below the projected sea level are classified as flooded. Flood depth = SLR - elevation.
- **Scenarios:** 18 SLR-only scenarios (3 SSP x 2 time horizons x 3 percentiles P17/P50/P83)

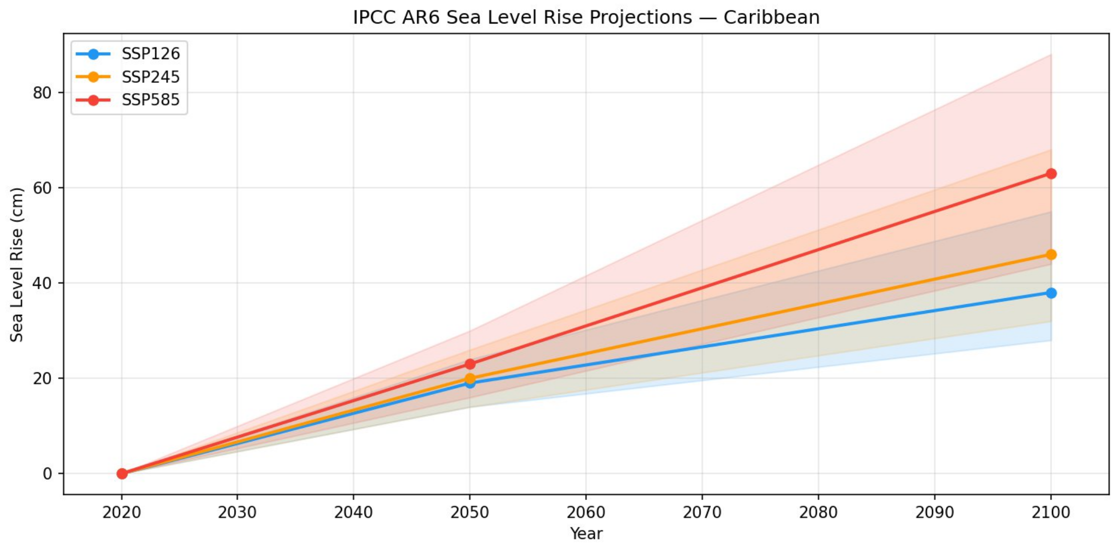

Figure 2-1: Sea level rise projections with P17-P83 uncertainty envelopes per SSP

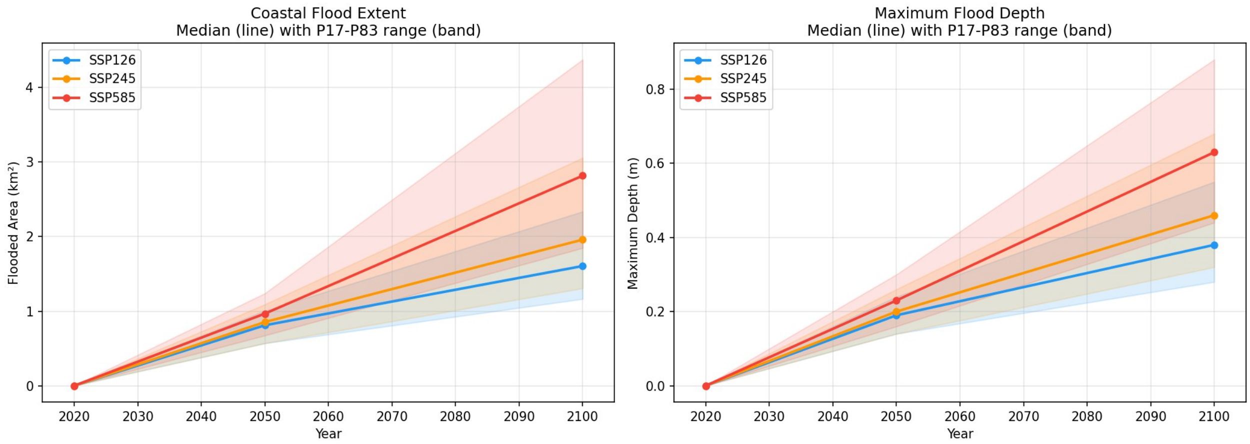

Figure 2-2: Flood depth comparison: baseline vs worst case SSP5-8.5 2100

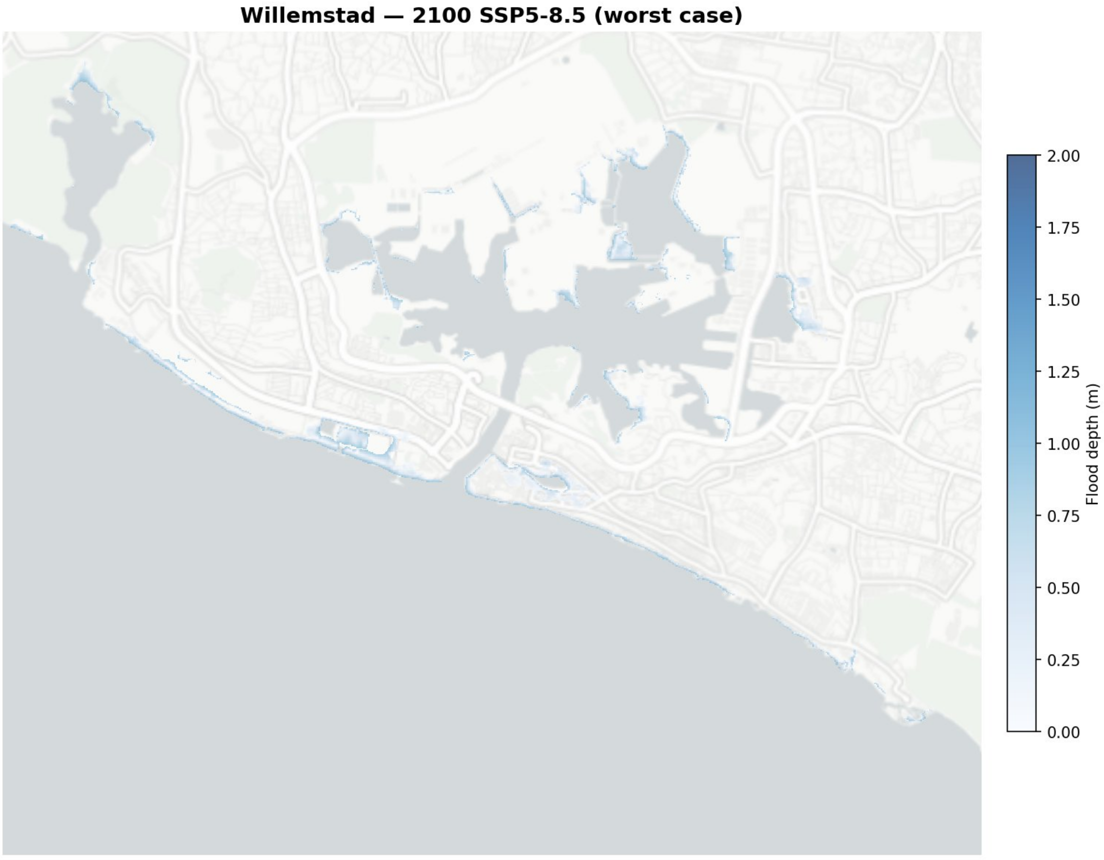

Figure 2-3: Willemstad closeup - costal flood extent

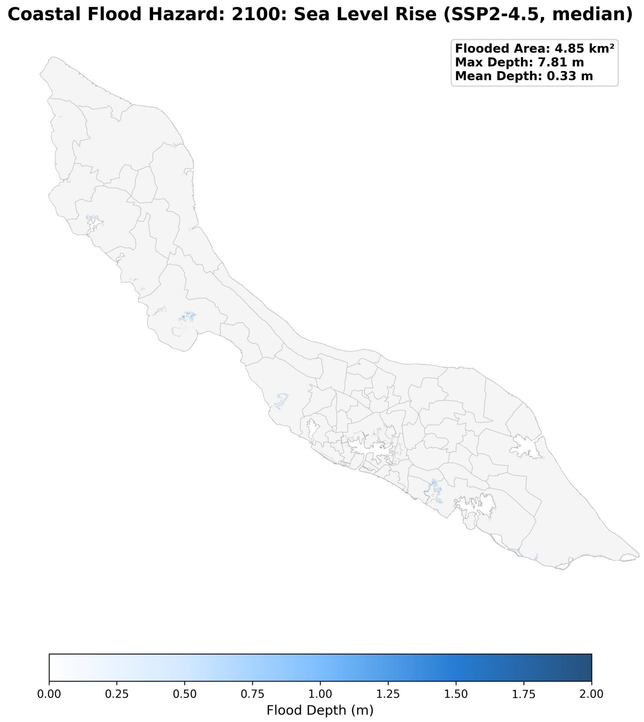

Figure 2-4: Flood hazard scenario mid 2100

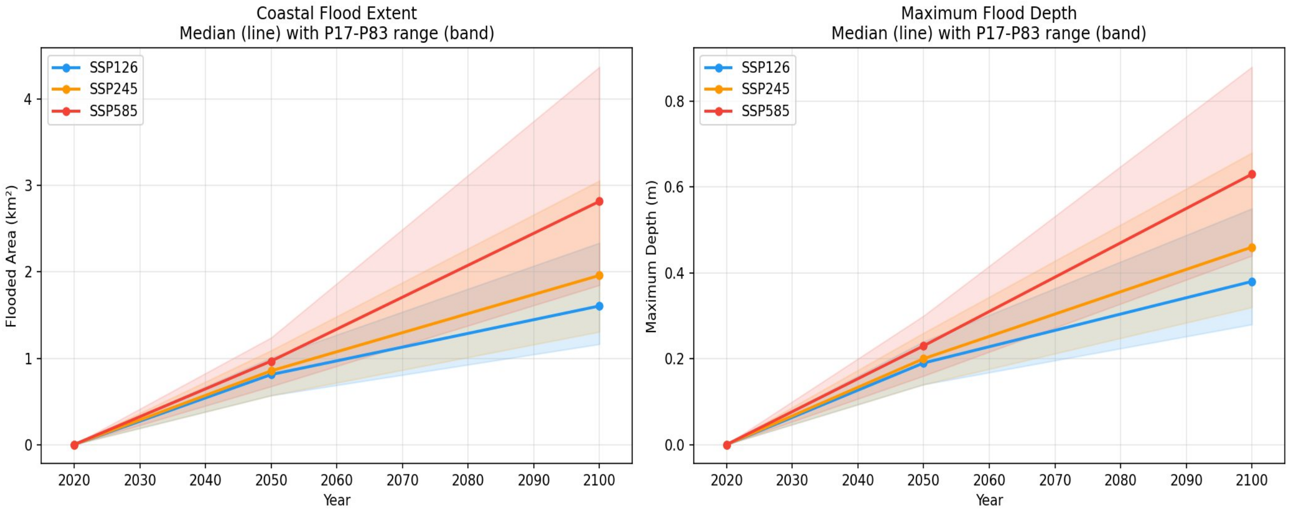

Figure 2-5: Flooded area and maximum depth by scenario - median with P17-P83 range

2.4.1.2 Exposure assessment

Exposure assessed at three levels: Kadaster property parcels (68,148), Microsoft building footprints (103,117), and OpenStreetMap points of interest (2,988).

Table 2-9: Coastal flood scenario summary

Scenario	SLR (cm)	Flooded Area (km2)	Parcels Flooded	Parcels > 25cm
SSP1-2.6 2050 (P50)	19	0.81	354	0
SSP2-4.5 2100 (P50)	46	1.96	561	421
SSP5-8.5 2100 (P50)	63	2.82	714	-
SSP5-8.5 2100 (P83)	88	4.38	1,316	847

No parcels exceed 1 m flood depth — the maximum SLR projection is 88 cm.

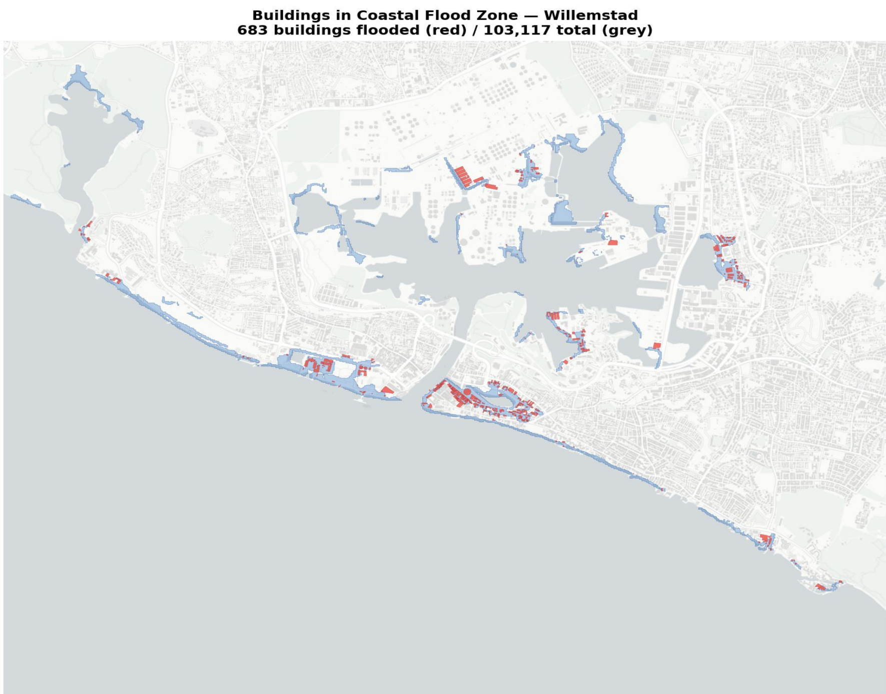

Figure 2-6: Willemstad building flood map: 103k MS buildings (grey), flooded (red), flood zone (blue)

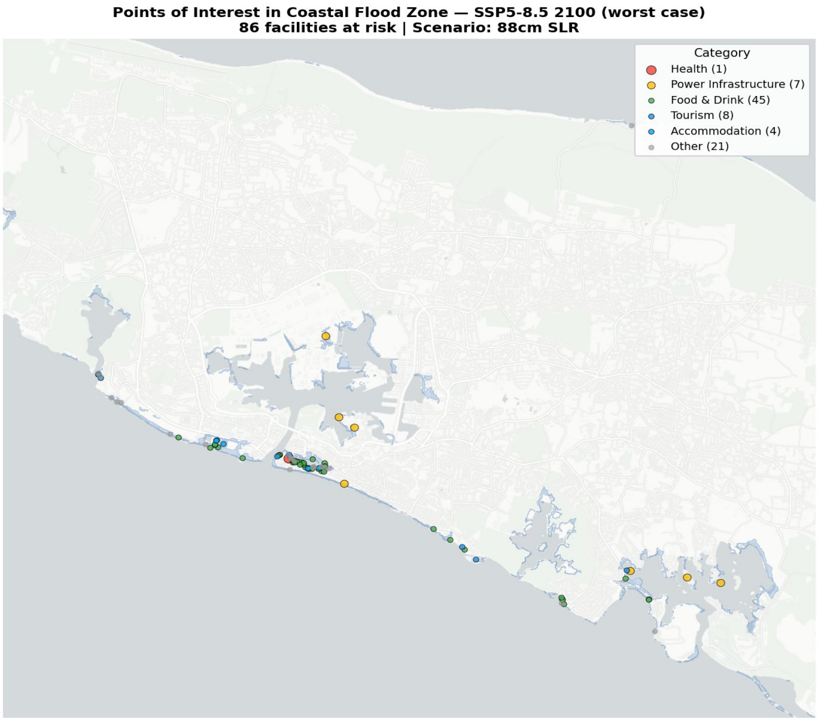

Figure 2-7: Points of interest in coastal flood zone - colour-coded by category

2.4.1.3 Risk assessment

Risk density combines flood hazard with population exposure:

risk_density = pop_density x flood_fraction

Units: people at flood risk per km2. This metric identifies where flooding coincides with dense population.

Figure 2-8: Coastal flood risk density - 315 neighbourhoods

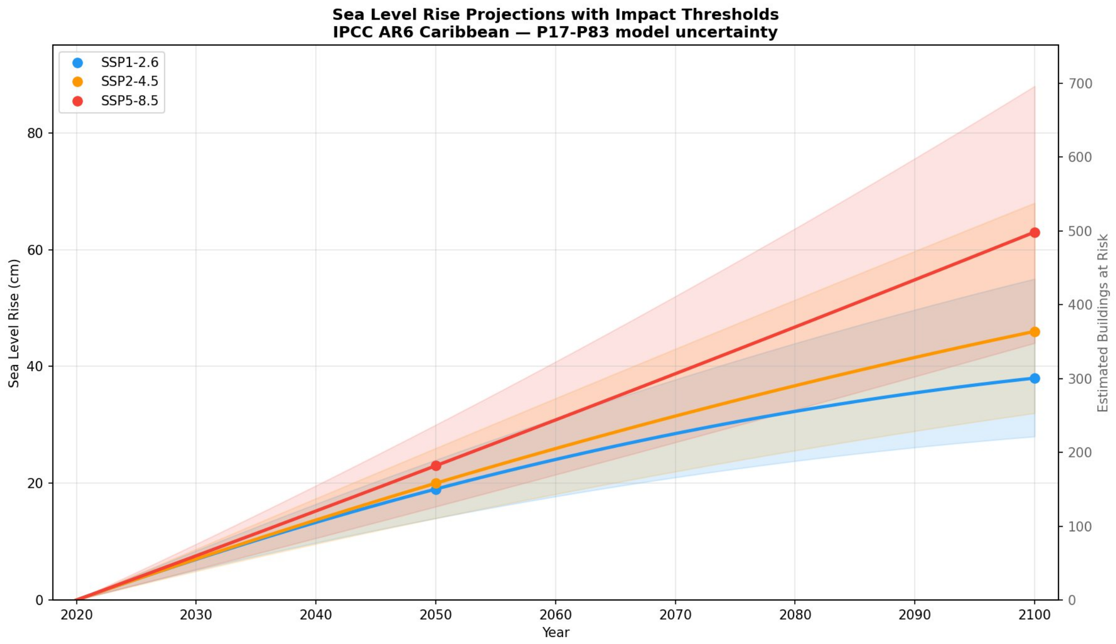

Figure 2-9: SLR projection fan chart with building count progression

2.4.2 Hazard #2 – Pluvial Flooding to local context

Table 2-10: Data Overview - Pluvial Flooding

Hazard Data	Vulnerability Data	Exposure Data	Impact Metrics/Risk Output
3Di hydraulic model (Deltares Phase 1)	CBS Census 2023 demographics	MS building footprints (103,117)	Flood depth (m)
MDC precipitation (32 years, R11)	Social vulnerability composite	315 CBS neighbourhoods	Flooded area (km2)
Gumbel IDF curves		Kadaster parcels (68,148)	Risk density (people/km2)
CMIP6 temperature for CC scaling			Buildings at risk (count)

Limitations: Scalar depth scaling does not change flood extent — only depth increases per scenario. Single 3Di baseline event. No drainage infrastructure modelling. 24-hour duration only.

2.4.2.1 Hazard assessment

IDF Curves: Intensity-Duration-Frequency curves fitted using Gumbel extreme value distribution on 32 years of island-wide annual maximum daily precipitation (MDC R11 station, 1993-2025). The 100-year return period 24-hour precipitation is estimated at 198 mm (P50), with uncertainty range 165-243 mm (P10-P90).

Clausius-Clapeyron Scaling: The Clausius-Clapeyron relationship predicts that extreme rainfall intensity increases approximately 7-10% per degree of warming. We apply the conservative 10%/degC rate and compare with CMIP6 ensemble mean precipitation change. The recommended scaling factor is the maximum of the two — ensuring the physically-driven extreme event signal is preserved even when mean precipitation declines.

Key finding: Mean precipitation declines up to 31% (SSP5-8.5 2100), but extreme events intensify up to 30% due to Clausius-Clapeyron thermodynamics. Warmer air holds more moisture, making individual storms more intense even as total annual rainfall decreases.

Scenario	Temp Delta (degC)	Baseline (mm)	Projected (mm)
Baseline	0	198	198
SSP1-2.6 2050	+1.19	198	228
SSP2-4.5 2100	+1.96	198	237
SSP5-8.5 2100	+3.05	198	258

3Di Baseline and Depth Scaling: The Deltares 3Di hydraulic model (Phase 1) provides the spatial flood pattern at 10m resolution. Future scenarios scale the baseline flood depths proportionally to the rainfall intensity increase, preserving the spatial distribution while adjusting depth.

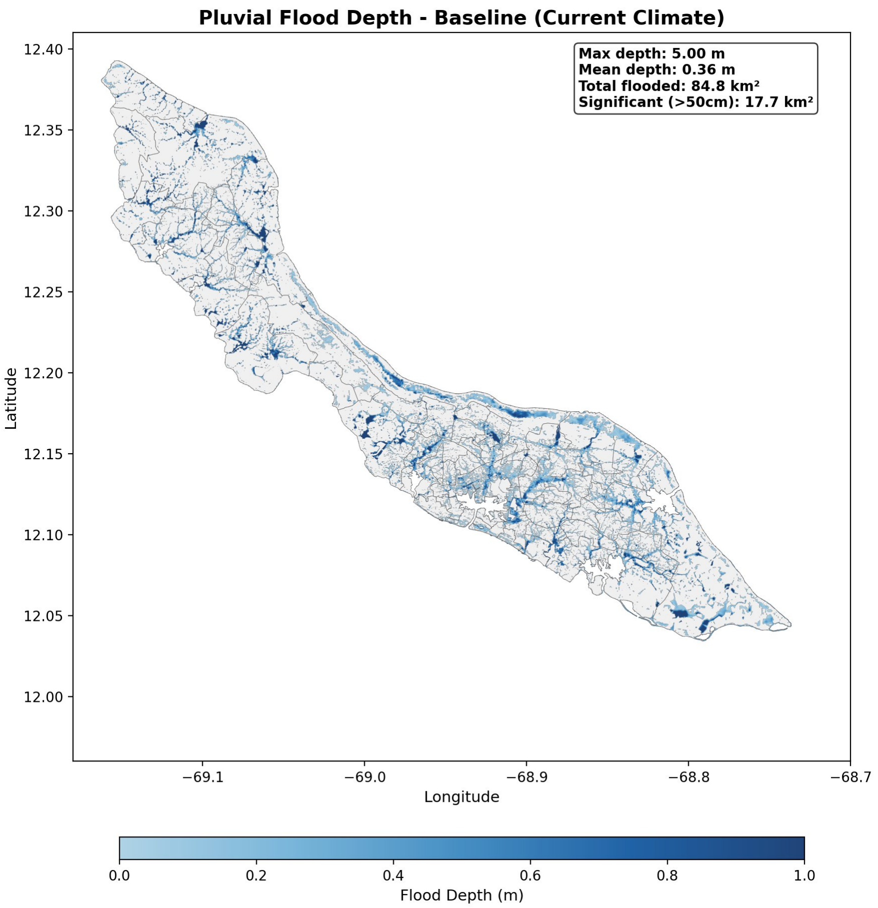

Figure 2-10: Baseline rainfall depth model

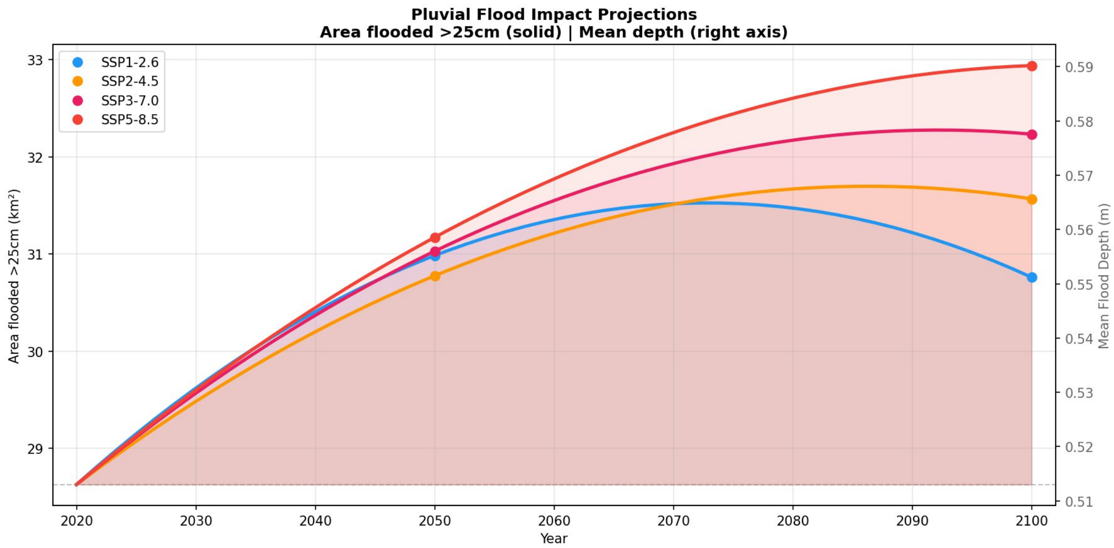

Figure 2-11: Climate signal: mean precipitation decline (left) vs extreme event intensification (right)

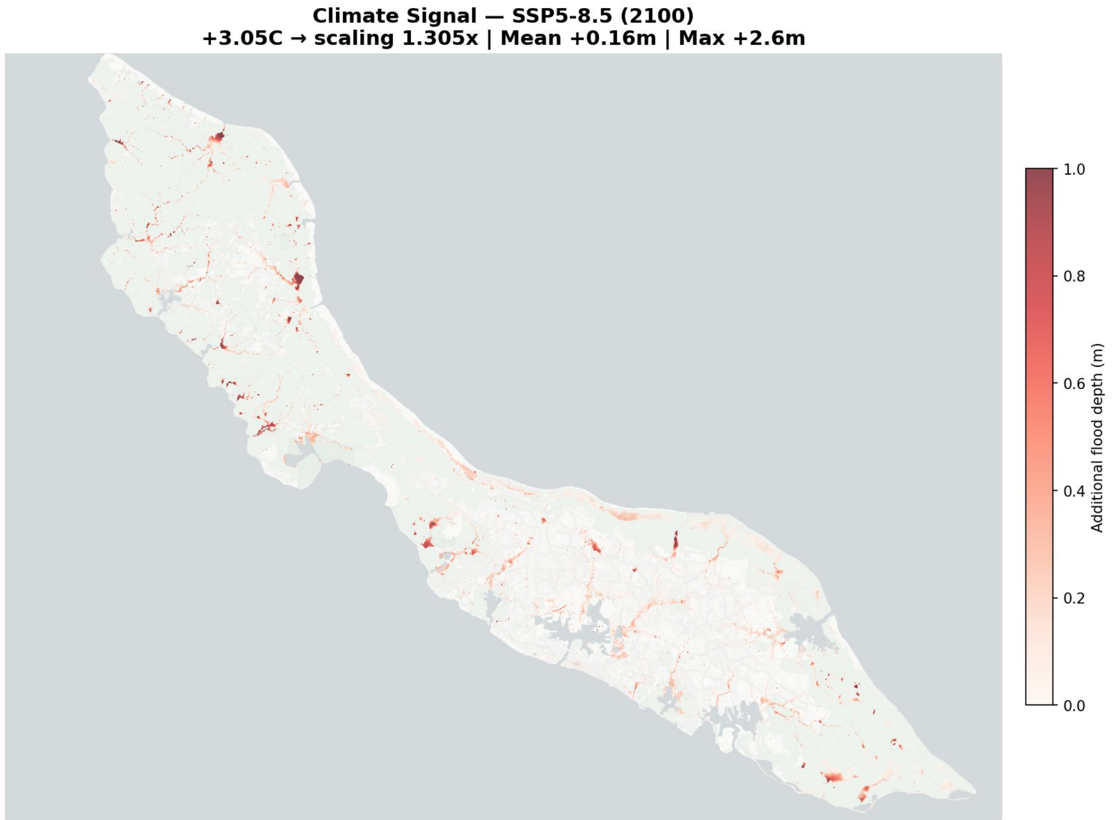

Figure 2-12: Climate signal map: flood depth increase under SSP5-8.5 2100

2.4.2.2 Exposure assessment

To differentiate between scenarios (since total flooded area remains constant with scalar scaling), exposure is measured at three flood depth thresholds:

- **Any flooding (>1 cm):** Property touches flood zone
- **Moderate (>25 cm):** Damage to ground floor contents
- **Significant (>50 cm):** Structural damage possible

Direct raster sampling of parcels provides exact building counts per threshold:

Threshold	Baseline	SSP2-4.5 2050	SSP5-8.5 2100	Change
Any (>1cm)	14,743	14,756	14,772	+29 (+0.2%)
Moderate (>25cm)	5,384	5,963	6,587	+1,203 (+22%)
Significant (>50cm)	2,815	3,204	3,618	+803 (+29%)
Severe (>1m)	937	1,198	1,538	+601 (+64%)

2.4.2.3 Risk assessment

Risk density combines flood hazard with population exposure:

risk_density = pop_density x flooded_significant_pct / 100

Top risk areas: Kustbaterij (4,381), Cabo Verde (1,837), Mahaai (740), Salinja (686) people at >50cm flood risk per km2.

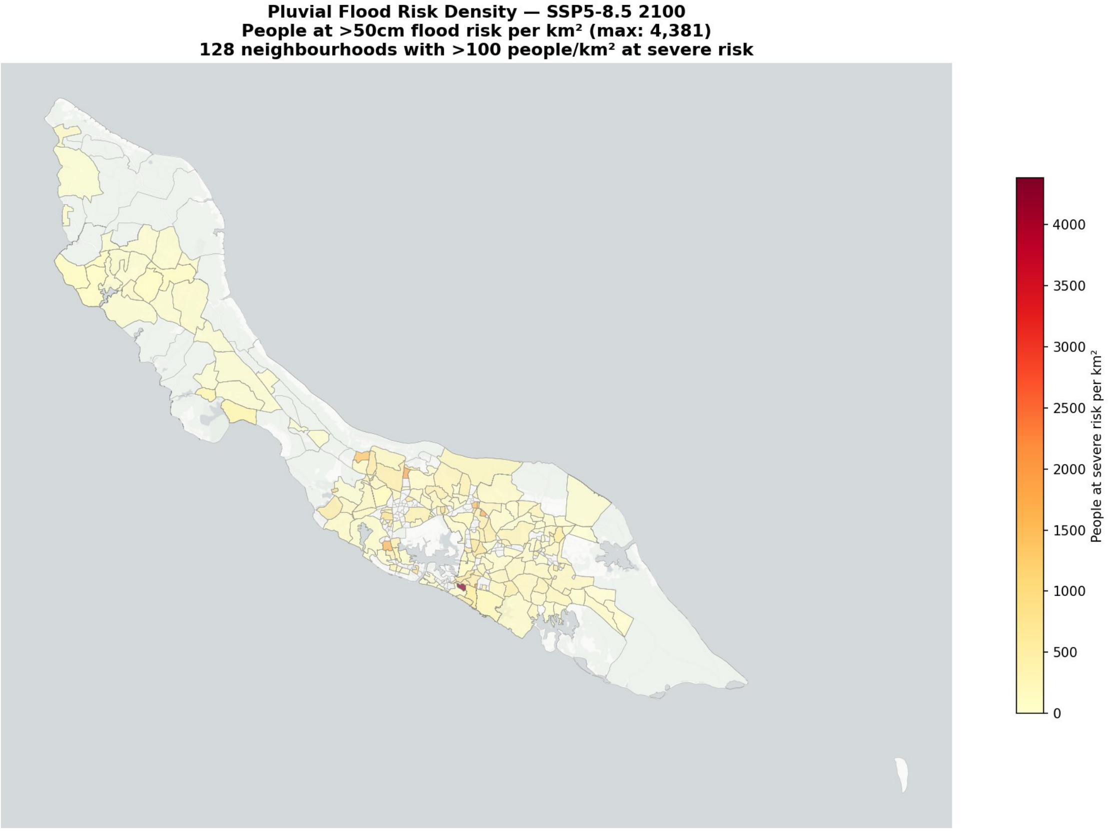

Figure 2-13: Pluvial flood risk density - 315 neighbourhoods

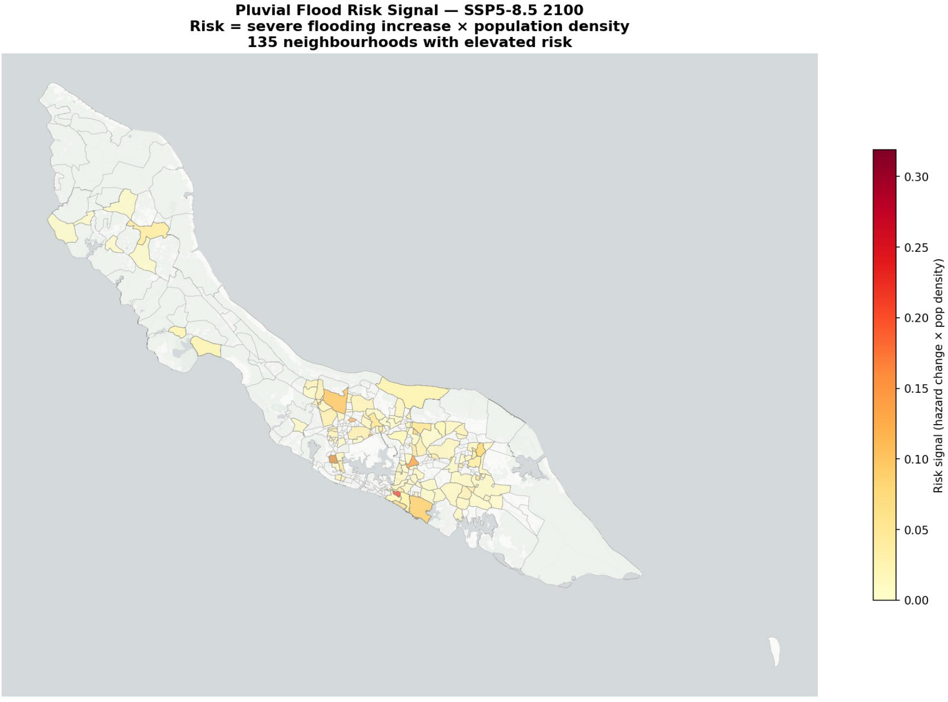

Figure 2-14: Pluvial flood risk signal - climate change impact

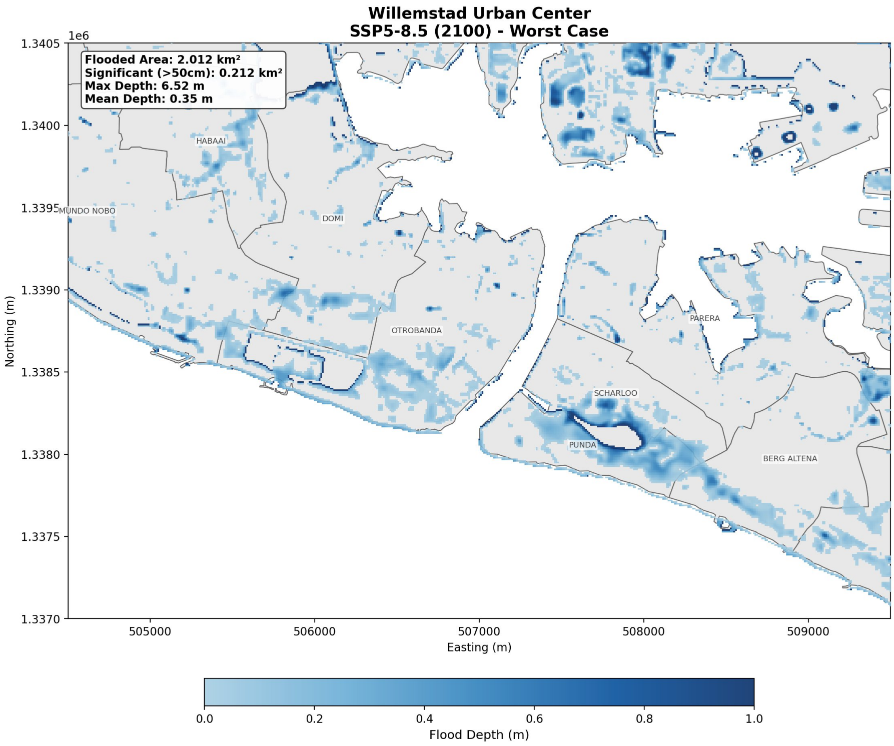

Figure 2-15: Detailed Zoom hazard for Willemstad worst case scenario

2.4.3 Hazard #3 – Heat Stress – Fine-tuning to Local Context

Table 2-11: Data Overview - Heat Stress

Hazard Data	Vulnerability Data	Exposure Data	Impact Metrics
Calibrated hexbins (3,733)	CBS Census 2023: elderly, chronic	315 CBS neighbourhoods	Air temperature (degC)
CMIP6 temperature (7 models)	illness, welfare, overcrowding	Population density	Hazard index (0-1)
13-year Landsat LST stack (PCA)	Social vulnerability composite		Risk density
MDC station wind speed (12 stations)			Quantile classification

Limitations: Uniform CMIP6 delta applied island-wide (no enhanced UHI under climate change). 250m hexbin resolution. Wind stationarity assumed.

Methodology change: The Phase 2 D2 submission used raw Landsat Land Surface Temperature (30m) as the heat stress baseline. Research conducted in the GISELLE project (March 2026) demonstrated that raw LST has R2=0.009 correlation with station air temperature — effectively random. The replacement methodology uses satellite-station fusion (PCA + wind speed regression, R2=0.70, RMSE=0.214 degC).

Key finding: Wind speed dominates the spatial heat pattern on Curacao (r=-0.80 with air temperature). Sheltered locations are hotter regardless of surface type. This is the opposite of what raw LST shows.

2.4.3.1 Hazard assessment

Calibrated Baseline: The calibrated air temperature ranges from 27.56 degC (windward coast) to 28.91 degC (sheltered urban areas) — a 1.35 degC spread driven by wind exposure. Island mean: 28.27 degC.

Methodology:

1. 13-year Landsat LST stack (2013-2025): annual median composites per 250m hex
2. PCA decomposition: PC1 extracted (74.7% of variance)
3. Station calibration: PC1 + interpolated wind speed against 12 MDC stations (LOO-CV)
4. Result: air_temp = -0.024 x PC1 + -0.064 x wind_speed + 28.76

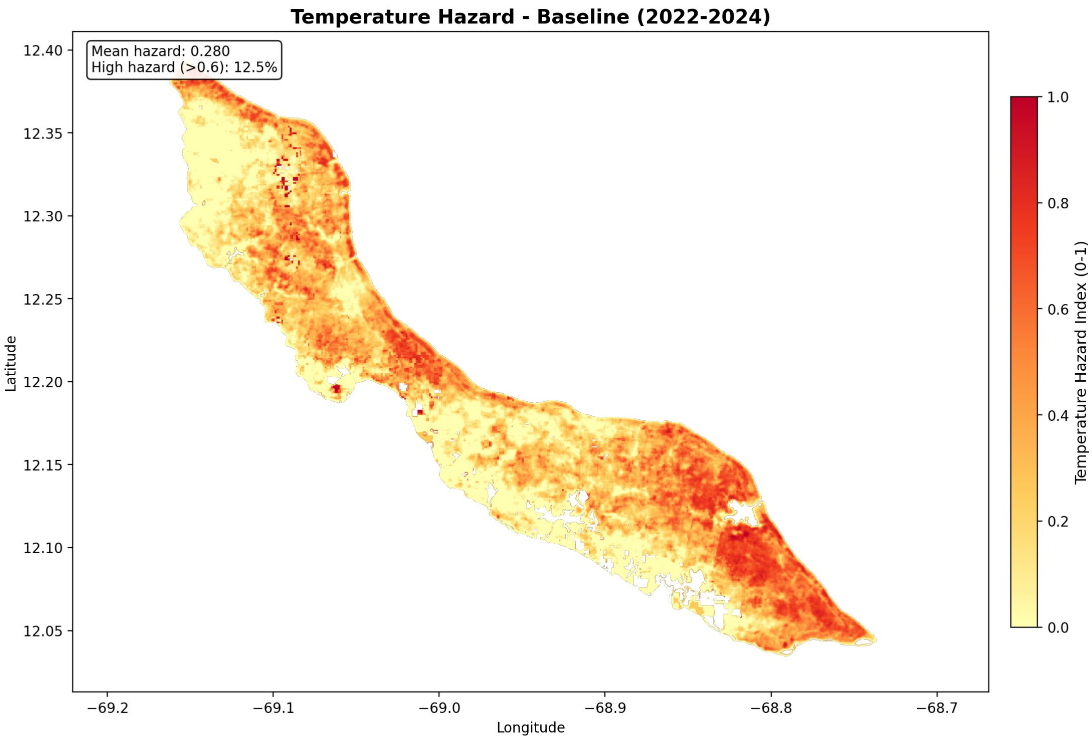

Figure 2-16: Heat hazard baseline

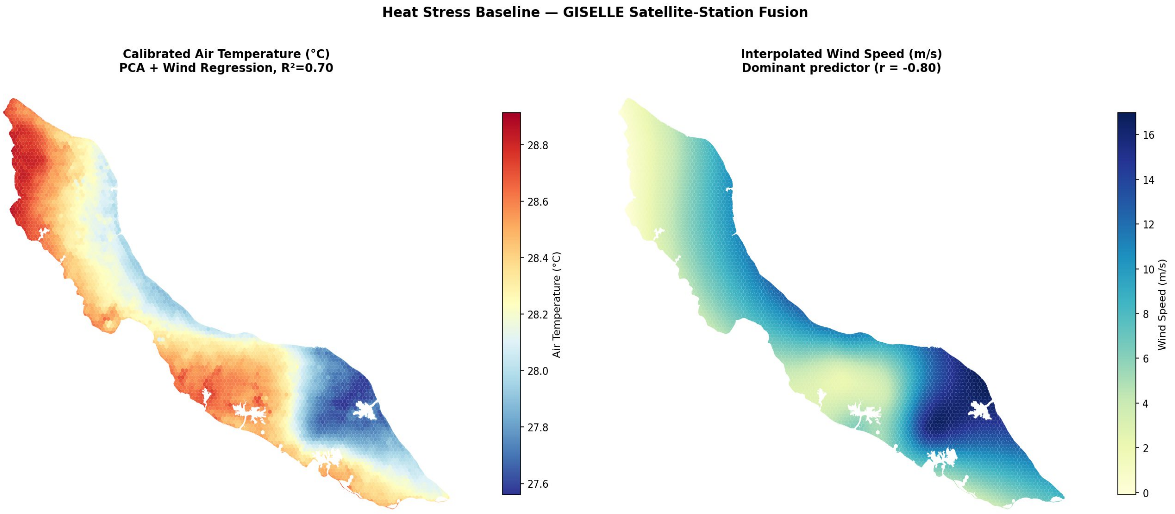

Figure 2-17: Calibrated air temperature baseline and wind speed pattern

CMIP6 Projections:

Scenario	Temp Change (degC)	Baseline Mean	Projected Mean
SSP1-2.6 2100	+1.4	28.3	29.7
SSP2-4.5 2100	+2.0	28.3	30.3
SSP5-8.5 2100	+3.8	28.3	32.1

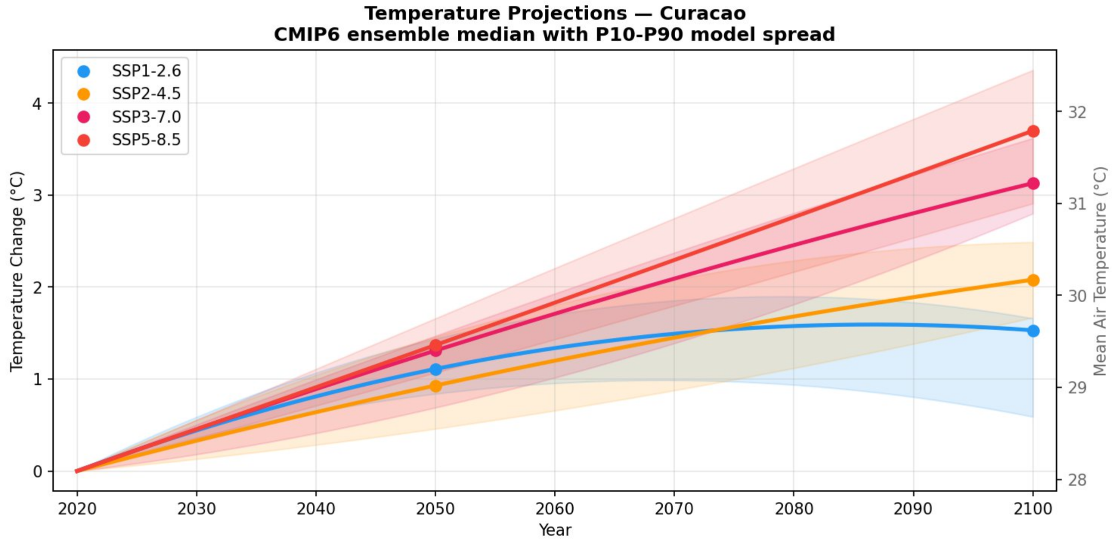

Figure 2-18: Temperature projections with P10-P90 model spread - dual axis

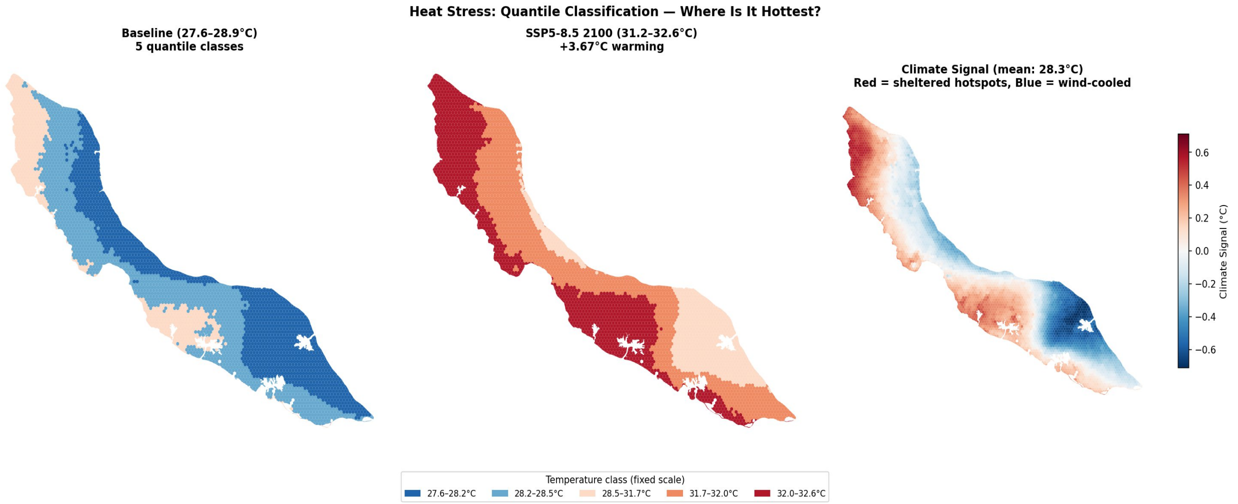

Figure 2-19: Quantile classification: baseline vs worst case - fixed scale shows climate shift

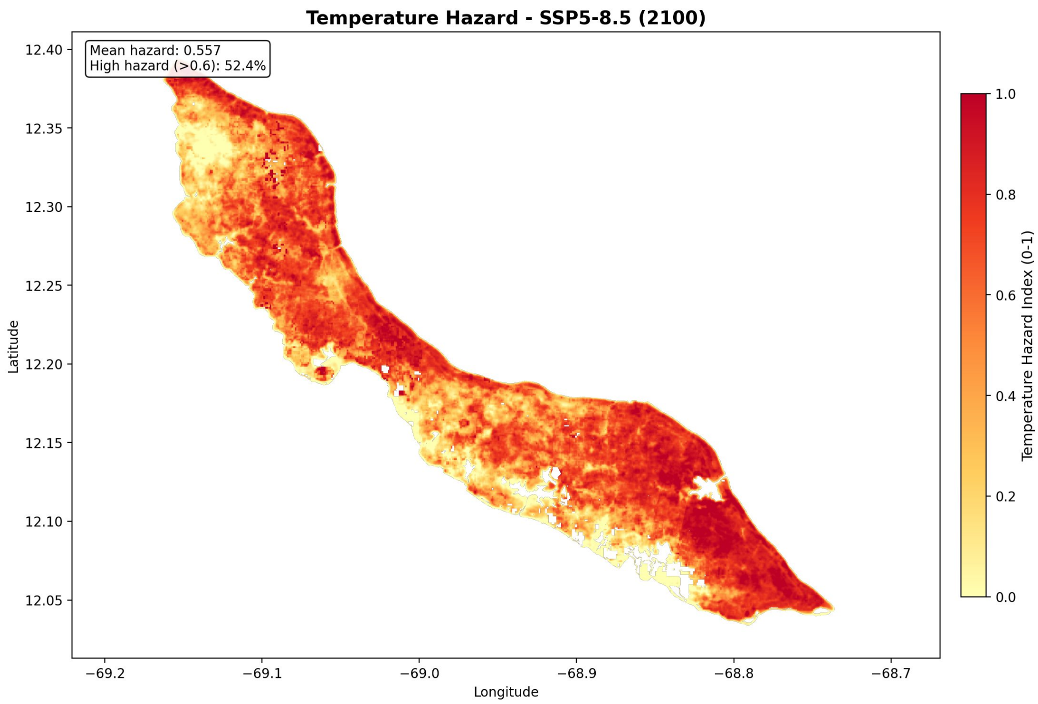

Figure 2-20: Heat hazard worst scenario

2.4.3.2 Risk assessment

Risk density combines three components following the IPCC framework:

$$risk\_density = hazard\_index \times pop\_density \times vulnerability$$

Where vulnerability is a composite of elderly_pct, chronic_illness_pct, welfare_pct, and overcrowding_pct from CBS Census 2023.

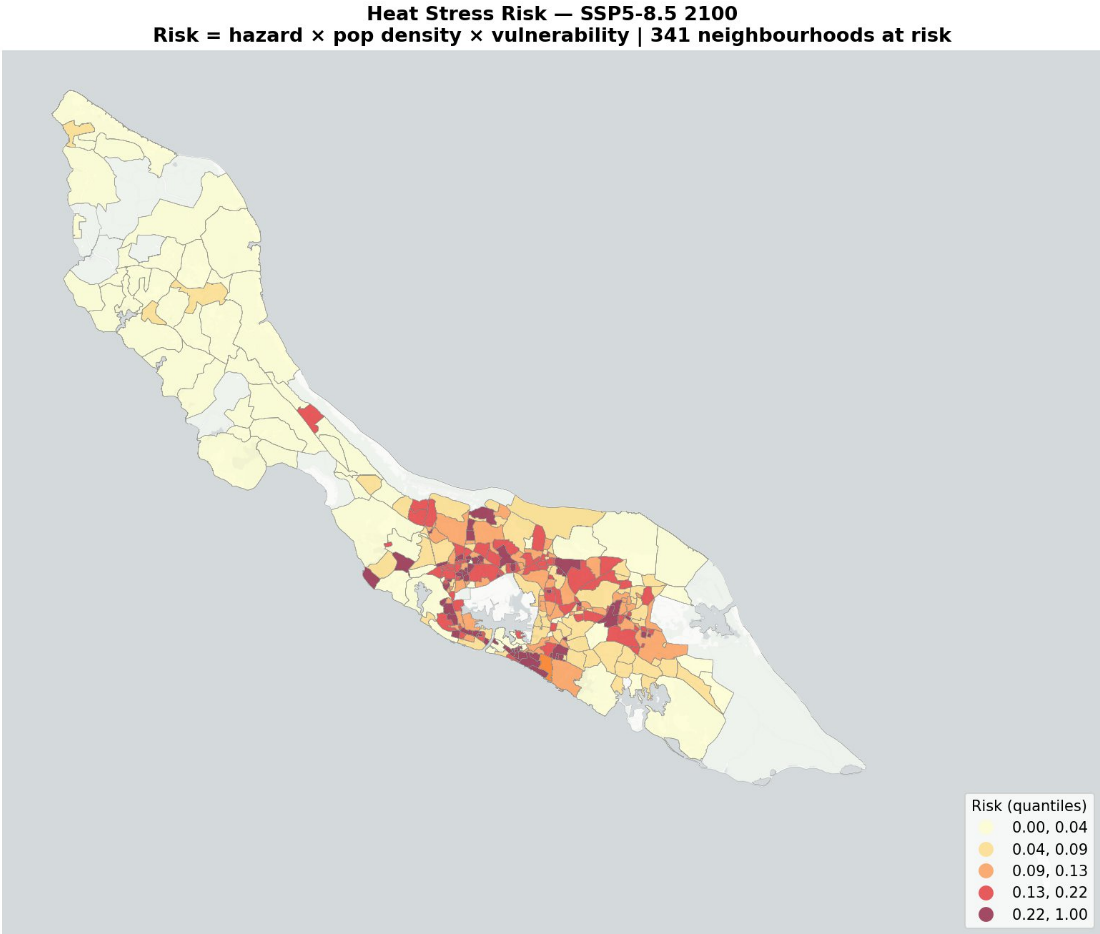

Figure 2-21: Heat stress risk density - quantile classification, 315 neighbourhoods

2.4.4 Hazard #4 – Drought - Fine-tuning to Local Context

Table 2-12: Data Overview - Drought

Hazard Data	Vulnerability Data	Exposure Data	Impact Metrics
MDC precipitation (32 years, R11)	CBS Census 2023: welfare, water	315 CBS neighbourhoods	Precip change (%)
CMIP6 precipitation (7 models)	access, elderly, chronic illness	Population density	Hazard index (0-1)
SPI-3 monthly (1993-2025)	Vulnerability composite (welfare		Risk density

Limitations: Island-wide hazard (no spatial variation in precipitation). SPI self-normalizes under climate change. Single station (R11) for SPI calculation.

Important context: Curacao relies on desalination for 95%+ of freshwater supply. Standard CLIMAAX drought methodology (water supply deficit from reduced river flow/groundwater) is not directly applicable. Meteorological drought does not directly threaten drinking water. The primary impact pathways are vegetation stress, erosion, and desalination energy costs.

2.4.4.1 Hazard assessment

SPI Baseline: The Standardized Precipitation Index (SPI-3) was calculated from 32 years of monthly precipitation at MDC's R11 station (Curacao Airport, 1993-2025). Baseline drought frequency: 14.9% of months with SPI-3 < -1.

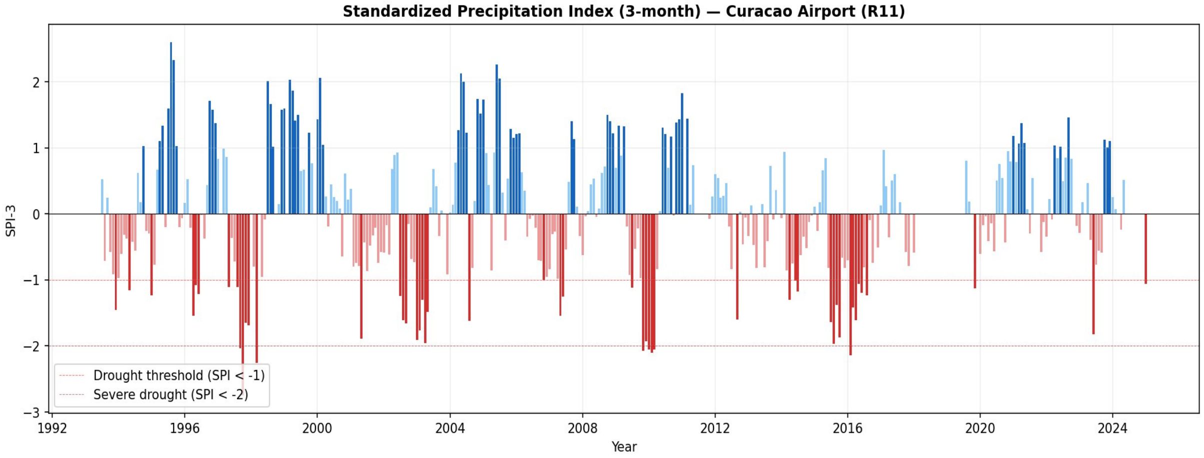

Figure 2-22: SPI-3 time series - 32 years of observations

CMIP6 Projections:

Scenario	Precip Change (%)	Drought Freq (%)	Severe Drought (%)
Baseline (1993-2024)	0	14.9	7.9
SSP1-2.6 2050	-0.7	14.3	7.6
SSP2-4.5 2100	-11.7	14.3	7.9
SSP5-8.5 2100	-31.0	14.6	7.3

Key finding: Precipitation declines up to 31% (SSP5-8.5 2100), but SPI-based drought frequency remains stable (~15%). SPI measures relative deviation from a moving mean — if the mean drops 31%, the new average becomes the baseline. The real impact is the decline in absolute water availability.

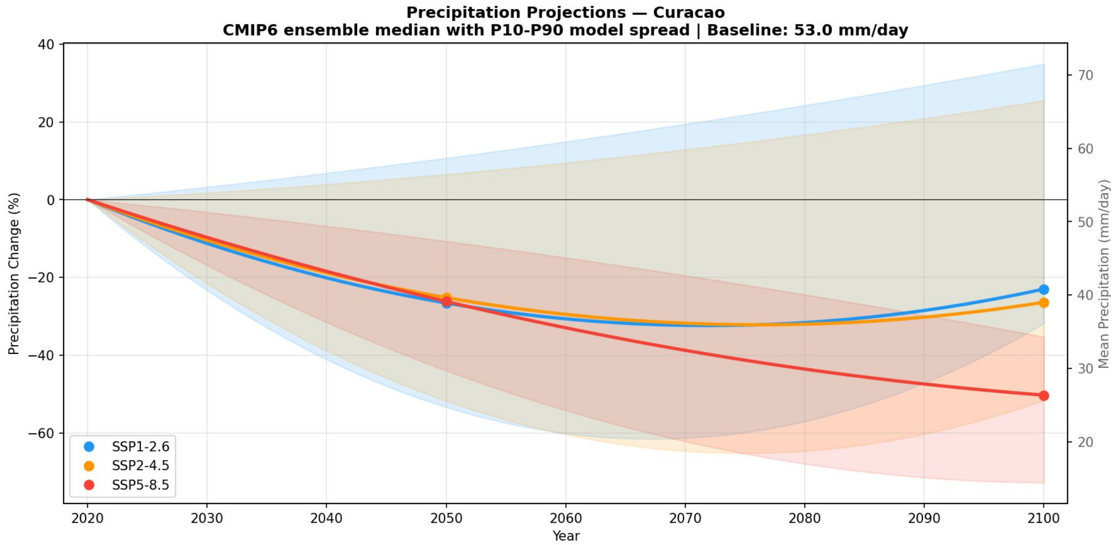

Figure 2-23: Precipitation projections with P10-P90 model spread

Hazard Index: Normalized absolute precipitation decline (0-1 scale). SPI frequency intentionally excluded from the hazard index because it self-normalizes.

2.4.4.2 Risk assessment

Since drought hazard is island-wide, spatial risk differentiation comes entirely from vulnerability: which neighbourhoods are most sensitive to drought impacts.

Vulnerability composite:

- Welfare dependency (2x weight): cannot afford higher water/energy costs
- No water access (2x weight): direct infrastructure vulnerability
- Elderly (1x): physical vulnerability to drought-heat compound effects
- Chronic illness (1x): health complications

$$risk\_density = hazard \times pop\_density \times vulnerability$$

Figure 2-24: Drought risk density - 315 neighbourhoods

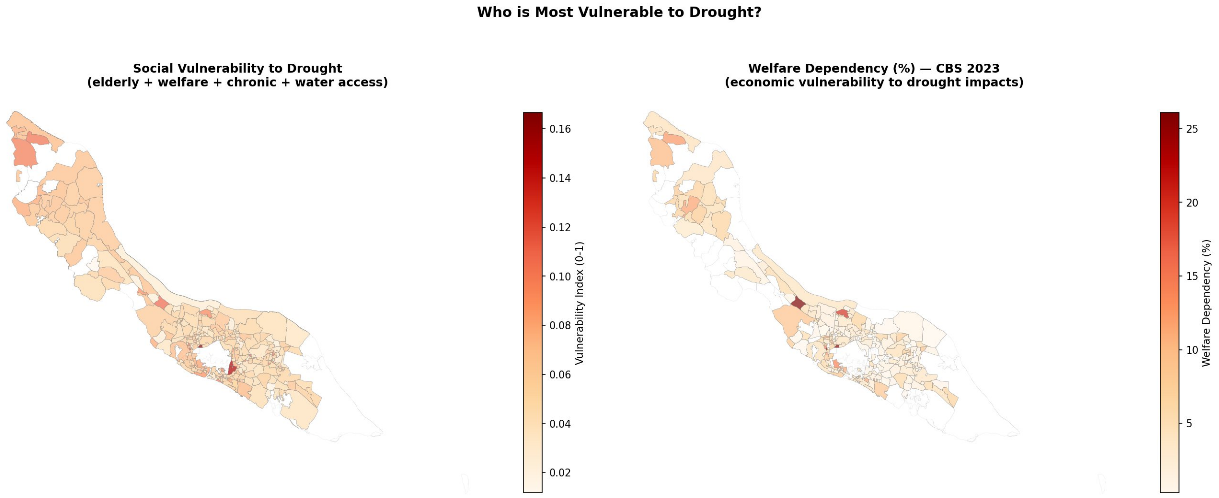

Figure 2-25: Social vulnerability: compositle index (left) and welfare dependency (right)

2.4.5 Additional assessments based on local models and data

Tide Gauge Validation

Tide gauge observations from the Bullen Bay station (southwestern coast, 2017-2025) were integrated as reference data for the coastal flood assessment.

Station characteristics:

- Location: Bullen Bay, southwestern coast of Curaçao
- Period: 2017-2025 (8 years continuous hourly observations)
- Tidal regime: Microtidal (mean tidal range approximately 0.6m)
- Key datums: Mean Sea Level (MSL) 1.24m, Mean Higher High Water (MHHW) 1.54m, Highest Astronomical Tide (HAT) 1.74m (relative to chart datum)

Role in the assessment:

The GTSM (Global Tide and Surge Model, version 3.0) provides pre-computed extreme water levels for Curaçao based on a global reanalysis covering 1985-2014. These GTSM values were used directly as the extreme water level input for the flood scenarios. No local statistical downscaling or extreme value fitting of tide gauge data was performed.

The tide gauge observations served three reference functions:

1. Vertical reference verification: Confirming that tidal datums (MSL, MHHW) are consistent with the vertical reference used in the DEM and GTSM outputs.
2. Plausibility check: The highest observed water levels at Bullen Bay provide an empirical check that GTSM return period estimates fall within a realistic range for Curaçao.
3. Contemporary baseline: The record provides a recent MSL reference point for contextualizing IPCC AR6 sea level rise projections.

Limitations of the tide gauge analysis:

- Single station with 8-year record: insufficient for independent extreme value analysis beyond approximately 5-year return periods. The GTSM reanalysis (30-year period) provides the statistical basis for return period estimates.
- Spatial coverage: One station does not capture variability of extreme water levels around the island (e.g., exposed northern coast vs sheltered southern coast).
- No local downscaling: GTSM values applied directly without calibration for local effects such as coastal geometry, reef attenuation, or harbor amplification.

Multi-Station Temperature Network Analysis

MDC operates a 12-station meteorological network across Curaçao providing continuous temperature, humidity, and wind observations. This network served two critical functions in the Phase 2 assessment:

Bias correction: Quantile mapping of CMIP6 temperature projections against 32 years of station observations (1993–2025) at Curaçao Airport station, reducing RMSE from 2–3°C (raw model output) to <0.8°C (corrected).

Heat baseline calibration: Analysis of station air temperature patterns revealed that raw Landsat Land Surface Temperature (LST) has near-zero correlation with actual air temperature on Curaçao (R^2=0.009). The dominant spatial control is wind speed (r=−0.80 with air temperature), not surface material or land cover. A satellite-station fusion approach was developed: PCA decomposition of 13 years of Landsat LST composites (2013–2025) captures the stable spatial heat structure, which is then calibrated against station air temperatures with wind speed as a covariate (R^2=0.70, RMSE=0.214°C). This calibrated product replaces raw LST for all heat stress projections in the assessment.

This finding has broader implications: any heat vulnerability assessment using uncalibrated satellite LST on a small trade-wind island will misidentify risk areas, because the warmest surfaces (bare soil, industrial zones) are often the coolest for human exposure due to wind cooling.

2.5 Key Risk Assessment Findings

2.4.1 Mode of engagement for participation

Technical risk evaluation conducted by MDC project team with internal review. Formal stakeholder engagement for risk evaluation planned for Phase 3 using CLIMAAX evaluation dashboard approach. This section presents preliminary assessment pending participatory validation.

2.4.2 Gather output from Risk Analysis step

Risk outputs used for evaluation:

Table 2-13: Analysis risk evaluation worst case scenario for 2100

Hazard	Key Metric	Baseline	Worst-case 2100 (SSP5-8.5)	Change
Coastal flooding	Parcels at risk	297 (14 cm SLR)	1,316 (88 cm SLR)	+343%
Pluvial flooding	Buildings in severe flooding (> 50 cm)	17,992	24,330	+35%
Heat stress	Mean air temperature (°C)	28.3	31.9	+3.7 °C
Drought	Precipitation change (%)	0 %	-31%	-31 %

Table 2-14: Exposure summary - population and infrastructure at risk

Hazard	Population exposed (baseline)	Population exposed (worst-case)	Buildings exposed (worst-case)
Coastal flooding	~ 26,000	~ 26,000 (same area, higher depth)	683 (estimated from parcels)
Pluvial flooding	27,712 (>50 cm depth)	37,302 (+35%)	24,330 (>50 cm)
Heat stress	0 (hazard index < 0.3)	152,168 (entire island >0.5)	All buildings affected
Drought	0 (no precip change)	152,168 (entire island, -31%)	N/A (indirect impact)

Key observations:

- **Heat stress** is the only hazard that exposes the entire population (152,168) under worst-case projections. The calibrated air temperature baseline shows the spatial heat pattern is driven by wind exposure, not land surface temperature — sheltered urban areas reach 32.6°C under SSP5-8.5 2100.
- **Pluvial flooding** affects more buildings than coastal flooding by an order of magnitude (24,330 vs 683 worst-case), reflecting the broader spatial extent of rainfall-driven flooding.
- **Coastal flooding** concentrates in a narrow south-coast strip but affects economically important areas (Willemstad centre, Punda, Otrobanda).
- **Drought** impacts are indirect — precipitation decline affects vegetation cover, erosion, and desalination energy costs rather than direct water supply (95%+ desalination dependence).

2.4.3 Assess Severity

Table 2-15: Severity assessment risk worst case scenario for 2100

Hazard	Current Severity	Future Severity	Rationale
Coastal flooding	Moderate	Substantial	1,316 parcels at risk; heritage site and commercial district concentration; 88 cm SLR transforms tidal nuisance into structural risk
Pluvial flooding	Moderate	Substantial	+35% buildings in severe flooding (>50 cm); +24% for moderate (>25 cm); drainange infrastructure designed for historical intensity
Heat stress	Moderate	Critical	+3.7 °C island-wide warming; entire population crosses hazard threshold; sheltered urban areas approach dangerous heat levels (32.6°C)
Drought	Limited	Moderate	-31% precipitation; desalination buffers direct supply but increases energy cost; vegetatio nstress and erosion risk escalate

Heat stress assessed as most severe future risk due to:

- Island-wide impact — the entire population is exposed, unlike spatially concentrated flood risks

- Direct health impacts on 24.7% elderly population at temperatures approaching heat stress thresholds
- Calibrated analysis reveals sheltered urban neighbourhoods (low wind) are most vulnerable — the inverse of what raw satellite imagery suggests
- Cascading effects on health system capacity and outdoor labour productivity

2.4.4 Assess Urgency

Table 2-16: List of urgency assessment for risk scenarios

Hazard	Urgency	Rationale
Coastal flooding	Watching brief	Slow onset (SLR); current exposure limited (297 parcels at 14 cm); time for planned adaptation before worst-case materialises
Pluvial flooding	More action needed	Already occuring; 17,992 buildings currently in >50 cm flood areas; drainage infrastructure aging; extreme rainfall intensifying despite mean precipitation decline
Heat stress	Immediate action needed	Warming already underway (+0.95°C since SSP2-4.5 2050); no heat action plan exists; no cooling centres; eldery population percentage increasing
Drought	Watching brief	Desalination provides response time; near-term precipitation change is small (-0.7% to -1.5% by 2050); monitoring ecosystem indicators is sufficient

Heat stress requires immediate action because:

- Near-term warming is already detectable in observations
- The elderly population share (24.7%) is among the highest in the Caribbean
- No institutional heat response capacity exists (no cooling centres, no heat action plan)
- Pluvial flooding also warrants near-term attention given current baseline exposure

2.4.5 Understand Resilience Capacity

Table 2-17: List of resilience capacity for Curacao

Capacity Type	Current Level	Key Gaps
Financial	Low	Limited dedicated climate budget
Human	Medium	MDC technical capacity demonstrated; limited urban planners with climate expertise
Natural	Medium	Mangrove and reef ecosystems provide coastal buffering; limited urban green space for heat mitigation
Physical	Medium	Seawall protects harbour; drainage infrastructure aging; no flood-adapted building standards

Capacity Type	Current Level	Key Gaps
Social	Low	Limited public awareness of climate risks; no community-level adaptation plans

Existing Measures:

- Sea wall protecting Willemstad harbour (limited extent)
- MDC weather warning system and early warning system
- Aqualectra desalination capacity (modern, reliable)
- Building code (not climate-updated)

Known Weak Spots:

- Urban drainage infrastructure designed for historical rainfall intensity — does not account for Clausius-Clapeyron scaling of extreme events
- No heat action plan or cooling centres
- Limited coordination across agencies (MEO, Aqualectra, GMN, MDC)
- Climate risk information not yet integrated into spatial planning

2.4.6 Decide on Risk Priority

Preliminary Risk Priority Matrix:

Table 2-18: Risk priority matrix

Hazard	Severity	Urgency	Capacity	Priority
Heat stress	Critical	Immediate	Low	**1 - Highest**
Pluvial flooding	Substantial	More action	Medium	**2 - High**
Coastal flooding	Substantial	Watching	Medium	**3 - Medium**
Drought	Moderate	Watching	Medium	**4 - Lower**

Priority 1: Heat Stress — Island-wide impact affecting entire population. Largest absolute warming (+3.7°C worst-case). Sheltered urban neighbourhoods most at risk. No current adaptation capacity. Immediate health risk to elderly (24.7% of population).

Priority 2: Pluvial Flooding — Broad spatial exposure with 17,992 buildings already at >50 cm depth. Extreme rainfall intensifying (+30% for 100-year events under SSP5-8.5 2100) despite mean precipitation decline. Drainage infrastructure investment needed.

Priority 3: Coastal Flooding — Economically concentrated risk in Willemstad south coast. Currently limited (297 parcels at 14 cm SLR) but worst-case substantial (1,316 parcels at 88 cm). Slow onset allows planned adaptation through setback guidelines and nature-based solutions.

Priority 4: Drought — Mitigated by desalination infrastructure. Primary impact pathway is energy costs and ecosystem stress rather than direct water supply. Monitoring vegetation indicators and desalination energy costs is the appropriate near-term response.

Note: Priorities to be validated through Phase 3 stakeholder engagement process.

2.6 Monitoring and Evaluation

Lessons Learned from Phase 2:

- Local data integration significantly improves assessment quality (bias correction reduced RMSE from 2.3°C to 0.8°C)
- Severity-based analysis reveals climate signals masked by binary approaches
- Single-station limitations acceptable for island-wide assessment but spatial network valuable for calibration
- Timeline constraints limited stakeholder engagement; to be addressed in Phase 3

Difficulties Encountered:

- Methodological decision required for IDF approach (island-wide vs single-station)
- Database management for large spatial queries required optimization
- Limited building use classification constrained damage assessment
- Drought framework less applicable to desalination-dependent context

Data Needs Identified:

- Higher-resolution DEM (<5m) for coastal micro-topography
- Drainage network model for pluvial flood routing
- Health outcome data for heat-health relationships
- Building use classification for improved damage estimation

Communication Plans:

- Technical report for CLIMAAX
- Risk maps on MDC public website
- Stakeholder briefings in Phase 3
- Multi-language summaries (EN/NL/PAP)

Monitoring System:

MDC operational monitoring includes:

- Continuous weather observation (12 stations)
- Tide gauge monitoring
- Climate data archive (78 years)

Gap: No systematic climate impact monitoring (flooding events, heat-related health outcomes).

What Worked Well:

- CLIMAAX framework provided clear methodological structure

- Local observation network enabled bias correction
- Database approach enabled cross-hazard analysis
- Ensemble approach quantified uncertainty

What Could Improve:

- Earlier stakeholder engagement
- More comprehensive exposure data
- Health sector collaboration for heat impacts
- Coordination with regional Caribbean initiatives
- Preliminary data unavailable for regio, requiring finding and or developing databases for information accessability.

Resource Efficiency:

Phase 2 executed with internal MDC capacity, demonstrating sustainable technical capability. Investment in reproducible workflows enables efficient future updates.

CRA Impact:

- Improved technical understanding of climate risks
- Quantified basis for adaptation planning
- Institutional capacity building at MDC
- Foundation for stakeholder engagement in Phase 3

2.7 Work plan Phase 3

Corrective Strategy — Addressing IFP Deviations:

Phase 2 delivered strong technical outputs (4 hazard workflows, 48 risk scenarios, bias-corrected projections) but limited formal stakeholder engagement compared to the IFP plan. Several factors contributed to this deviation:

1. Project team transition: The original project contact person departed MDC during the project period, requiring reassignment of project management responsibilities. The transition involved a limited handover, and the incoming project manager needed to re-establish project direction in alignment with MDC's institutional priorities and the Director's guidance. This transition period consumed time and effort that had been allocated for stakeholder coordination.
2. Capacity building priority: Following the transition, MDC prioritized building internal technical capacity for climate risk assessment. While this strengthened institutional ownership and analytical capabilities, it required the project team to absorb the full technical workload internally. The revised approach also broadened the stakeholder engagement scope beyond initial contacts to include a wider range of institutional partners, which requires additional coordination time.

3. Data and communication challenges: Data acquisition for a small island context demanded more effort than anticipated, as standard European data infrastructure does not exist for Curaçao. Additionally, translating technical climate risk outputs into accessible information for policymakers and civil servants requires careful framing — presenting validated results is more effective than sharing preliminary findings.

Phase 3 will address these gaps through a structured engagement approach under consolidated project management. The following corrective measures are planned:

Stakeholder Engagement (Priority):

- CCCP Workshop (Q1 2026): Present Phase 2 risk assessment results to all CCCP sectoral representatives. This addresses IFP Milestone M5 (presentation to policy and decision makers) and contributes to KPI K5 (15 stakeholders involved).
- Sectoral Consultations (Q1-Q2 2026): Targeted meetings with VVRP (planning policy), ROP (spatial planning), Aqualectra (water/energy infrastructure), and Civil Protection (emergency management) to validate risk priorities and collect local knowledge input.
- Public Consultation (Q2 2026): Publication of risk maps on MDC website with opportunity for public comment, fulfilling the map publication KPI intent.

Map Publication:

MDC Climate Services Website: Publish interactive risk maps (at minimum: coastal flood worst-case, heat stress baseline and 2100, pluvial flood comparison) for public access. Timeline: Q1 2026.

Outstanding IFP Commitments:

- KPI K3 (stakeholder meetings): Phase 3 CCCP workshop will fulfill the remaining meeting requirement.
- KPI K4 (map publication): MDC website publication replaces Klima Kòrsou Atlas (see justification above).
- KPI K5 (15 stakeholders): CCCP workshop plus sectoral consultations expected to reach target.
- Milestone M5 (decision maker presentation): Scheduled for CCCP workshop in Q1 2026.

Objective: Develop adaptation strategies based on Phase 2 risk assessment findings in close collaboration with CCCP.

Main Activities:

1. **Stakeholder Engagement Workshops** (Month 1-2)
   - Present Phase 2 findings to sectoral representatives
   - Validate risk priorities using evaluation dashboard
   - Identify adaptation options with local knowledge input
2. **Adaptation Options Assessment** (Month 2-4)

   - Compile potential interventions for priority risks
   - Screen options for feasibility and co-benefits
   - Conduct preliminary cost-benefit analysis
3. **Strategy Development** (Month 4-5)
   - Draft sector-specific adaptation recommendations
   - Develop implementation roadmap with timelines
   - Identify financing mechanisms
4. **Final Documentation** (Month 5-6)
   - Complete D.3 deliverable
   - Prepare policy briefs for decision-makers
   - Finalize public communication materials

Aspects Not Addressed:

- Detailed engineering design (requires separate studies)
- Tropical cyclone risk (outside current scope)
- Indirect economic impacts and cascading effects
- Regional coordination mechanisms (Kingdom/CARICOM level)

Follow-up on Key Findings:

Table 2-19: Follow-up key findings for phase 3

Risk Priority	Phase 3 Action
Heat stress	Heat action plan, cooling strategy, vulnerable population outreach
Pluvial flooding	Drainage assessment, design standard review, green infrastructure options
Coastal flooding	Setback guideline development, heritage protection strategy
Drought	Energy cost monitoring, ecosystem health indicators

3 Conclusions Phase 2- Climate risk assessment

Phase 2 of the CLIMAAXKòrsou project successfully delivered a refined multi-hazard climate risk assessment for Curaçao, demonstrating the value of integrating local observational data with CLIMAAX standardized methodologies.

Principal Conclusions:

1. **Heat stress is the highest priority risk** — Calibrated air temperature projections show +3.7°C warming under SSP5-8.5 2100, with the entire population (152,168) exceeding the hazard threshold. The spatial heat pattern is driven by wind exposure — sheltered urban neighbourhoods are most vulnerable, the inverse of what satellite imagery alone suggests. The elderly population (24.7%) faces immediate health risks requiring urgent adaptation measures including heat action plans and cooling strategies.
2. **Pluvial flooding intensifies despite overall drying** — While mean precipitation declines up to 31%, extreme rainfall intensity increases +30% for 100-year events (Clausius-Clapeyron scaling). Buildings in severe flooding (>50 cm) increase 35% from 17,992 to 24,330. Risk density concentrates in Kustbaterij, Cabo Verde, and Nooit Gedacht. Drainage infrastructure designed for historical rainfall requires upgrading.
3. **Coastal flooding risk concentrates along the south coast** — Worst-case SLR (SSP5-8.5 2100, 88 cm) places 1,316 Kadaster parcels at risk, with 847 at significant depth (>25 cm). Risk concentrates in Willemstad commercial centre and the UNESCO heritage district. Building-level exposure analysis using 103,117 Microsoft footprints and 2,988 OSM points of interest identifies critical facilities (hospitals, schools, power stations) within the flood zone.
4. **Drought impacts moderated by desalination**— Curaçao's 95%+ desalination dependence fundamentally changes the drought risk profile. The primary impact pathway is energy costs and ecosystem health rather than direct water supply disruption. Precipitation decline of 31% (worst-case) affects vegetation cover, accelerates erosion, and increases desalination energy demand.
5. **Local data integration improves accuracy** — Bias correction using MDC's 32-year observation record reduced temperature projection RMSE from 2.3°C to 0.8°C. Satellite-station fusion for heat stress improved spatial calibration from R^2=0.009 (raw satellite imagery) to R^2=0.70. The 315-neighbourhood CBS Census provides five times finer spatial resolution than the original 63 geozones.

Challenges Addressed

- Data gap: Drought assessment completed (identified gap from Phase 1)
- Resolution improvement: Spatial resolution enhanced from 12 km to 10 m
- Local validation: All hazard assessments validated against MDC observations
- Unified database: Cross-hazard analysis enabled through integrated PostgreSQL spatial database

- Heat methodology: Raw satellite imagery replaced with calibrated air temperature baseline

Challenges Remaining

- Stakeholder engagement: Limited consultation in Phase 2; to be addressed in Phase 3
- Building-level vulnerability: Census neighbourhood resolution limits building-specific vulnerability assessment (exposure is at building level, vulnerability at neighbourhood level)
- Health outcomes: No heat-health epidemiological data available for Curaçao to validate heat risk thresholds
- Drainage modelling: Depth scaling approach preserves spatial pattern from 3Di hydraulic model but assumes uniform intensity scaling — does not capture changes in flow routing under higher rainfall

Implications for Adaptation

The risk priority ranking (Heat > Pluvial > Coastal > Drought) provides clear direction for adaptation investment:

Table 3-1: Risk priority ranking for regional adaptation

Priority	Recommended Actions
1. Heat	Heat action plan, cooling centres, vulnerable population registry, urban greening in sheltered areas
2. Pluvial	Drainage audit and design standard update, green infrastructure, building code revision for flood-prone zones
3. Coastal	Setback guidelines for south coast development, heritage protection measures, nature-based coastal solutions
4. Drought	Desalination energy cost monitoring, vegetation and erosion indicators, water conservation awareness

Value of CLIMAAX Framework

The CLIMAAX framework provided:

- Standardized methodology ensuring comparability with European assessments
- Structured risk evaluation approach (severity, urgency, capacity)
- Clear documentation requirements for reproducibility
- Foundation for stakeholder engagement in Phase 3

Phase 2 demonstrates that small island developing states can execute sophisticated climate risk assessments using CLIMAAX methodologies enhanced with local data integration. The reproducible Quarto workflow architecture ensures that results can be updated as new data becomes available (e.g., LiDAR DEM, extended observation records).

4 Progress evaluation

This deliverable (D.2) builds upon Phase 1 outputs and establishes the foundation for Phase 3 adaptation strategy development.

Table 4-1: Summary progress evaluation and deliverables for CLIMAAX

Phase	Deliverable	Status	Connection
Phase 1	D.1 Multi-risk assessment	Completed (June 2025)	Proof-of-concept, identified data gaps
Phase 2	**D.2 Refined local assessment**	**This document**	**Local data integration, all 4 hazards**
Phase 3	D.3 Adaptation strategies	Planned (July 2026)	Uses D.2 risk priorities

Key Performance Indicators

Table 4-2: Overview KPIs

KPI	Target	Status	Evidence / Justification
At least 2 workflows successfully applied on D1	2 workflows	Achieved (Phase 1)	Coastal flooding, heat stress, and pluvial flooding workflows applied in Phase 1 by Pilar Reija Zamora (June 2025)
At least 2 workflows successfully applied on D2	2 workflows	Exceeded: 4 workflows	Coastal flooding, pluvial flooding, heat stress, and drought workflows refined with local data integration (this document)
3 stakeholder meetings (2 in Phase 1, 1 in Phase 3)	3 meetings	Partially achieved: 2 of 3	Phase 1: Stakeholder meetings conducted during Phase 1 execution (2024-2025). Phase 2: CCCP platform presentation (Dec 2025), Central Bank of Curaçao and Sint Maarten briefing (Feb 2026). Phase 3 meeting planned. See Section 2.1.4 for details.
At least 2 publications of new maps in the Klima Kòrsou Atlas	2 publications	Deviation — alternative platform	Maps will be published on MDC's institutional climate services website instead of Klima Kòrsou Atlas. See justification below. The KPI intent (public availability of climate risk maps) will be fulfilled.

KPI	Target	Status	Evidence / Justification
At least 15 stakeholders involved in project activities	15 stakeholders	In progress	Phase 2 engaged stakeholders through CCCP platform and institutional briefings. Full target of 15 stakeholders to be reached in Phase 3 through sectoral workshops. Current count documented in Section 2.1.4.

Note on Map Publication Platform:

The IFP specified publication of maps in the Klima Kòrsou Atlas. During Phase 2, MDC's Director decided that climate risk maps should be published on MDC's own institutional climate services website rather than the Klima Kòrsou Atlas. This decision was made for the following reasons:

1. Institutional ownership: MDC's website ensures long-term maintenance and update capability without dependency on external platform operators.
2. Self-execution context: Phase 2 was executed internally by MDC with limited CAS involvement. The Klima Kòrsou Atlas is managed by CAS, and MDC does not have independent publishing access to that platform.
3. Integration with climate services: MDC's website will integrate risk maps with real-time weather data, station observations, and climate monitoring — providing added value beyond static map publication.
4. Sustainability: An MDC-managed platform ensures maps can be updated as new data becomes available without requiring external coordination.

The KPI intent — making climate risk maps publicly accessible — will be fulfilled through the MDC platform. MDC commits to publishing at least 2 risk map products (coastal flood and heat stress) on the institutional website during Phase 3, prior to D.3 submission.

Table 4-3: Additional Achievements

Achievement	Value
Hazard types assessed	4 (exceeds IFP requirement of 2 per deliverable)
Risk maps produced	48 total scenarios
CMIP6 models in ensemble	7 (multi-model uncertainty quantification)
Local data sources integrated	5 (MDC stations, tide gauge, Census, OSM buildings, Landsat LST)
Bias correction RMSE	< 0.8°C (from 2-3°C uncorrected)
Spatial resolution	10-30m (from 12 km global models)

Achievement	Value
Building footprints analyzed	103,117
Population coverage	154,640 (100% via CBS Census 2023)

Milestones

Table 4-4: Overview milestones

Milestone	Phase	Status	Evidence / Justification
M1: Test of the workflow for flood	1	Completed	Coastal flood workflow tested in Phase 1 (June 2025) and refined in Phase 2 with IPCC AR6 SLR and GTSM extreme water levels
M2: Workflow for drought	1-2	Completed	SPI-based drought methodology applied using 32 year precipitation record. Workflow documneted in notebook 04_drought
M3: Workflow for heatwave applied	1-2	Completed	LST baseline (Landsat) with CMIP6 projections and UHI quantification. Workflow documented in notebook 03_heat_stress
M3b: 3 Stakeholder meetings done in Phase 1	1	Partially achieved	Phase 1 stakeholder engagement conducted during 2024-2025.
M4: Attend CLIMAAX workshop in Barcelona	1	Completed	Attended by Pilar Reija Zamora (Phase 1 intern) during Phase 1
M5: Presentation of results to policy and decision makers	2-3	In progerss	CCCP Workshop (12 december 2025): Climate scenarios for Curaçao 2050-2100 presented to policymakers, civil servants, NGOs, and the public. Included flood risk analysis results from Phase 2. Central Bank of Curaçao and Sint Maarten briefing scheduled February 2026. Full Phase 2 results presentation planned for Phase 3 CCCP workshop
M6: Attend CLIMAAX workshop in Brussels	3	Planned	Under planning
M7: List of prioritized adaptation strategies	3	Planned (phase 3)	Preliminary risk priority ranking established (Heat > Pluvial > Coastal > Drought). Detailed adaptation strategy list is Phase 3 D.3 deliverable

Actions Executed

Technical Development:

- Established unified spatial database architecture
- Implemented bias correction procedures for CMIP6 models
- Developed IDF curve methodology using local precipitation data
- Created reproducible workflow documentation

Data Integration:

- Processed 32 years of MDC meteorological observations
- Integrated 70,000 tide gauge measurements
- Incorporated CBS Census 2023 demographics
- Compiled building footprint database

Quality Assurance:

- Validated projections against historical observations
- Compared Phase 1 and Phase 2 results
- Documented all methodology decisions
- Established version control for all analyses

Planned Activities for Phase 3

Phase 3 will focus on stakeholder engagement (February-April 2026) to validate risk priorities, followed by adaptation options identification (March-May 2026) based on CLIMAAX guidance and regional best practices. The final months (May-July 2026) will develop strategy recommendations and prepare the D.3 deliverable. Detailed economic analysis and implementation planning remain the responsibility of policy ministries using this technical foundation.

5 Supporting documentation

Repository Structure:

Category	Contents	Access
Raw data	CMIP6 projections, Landsat imagery, DEM, FEWS hydrology	Project archive (NAS)
Processed data	Bias-corrected projections, IDF curves, calibrated hexbins	PostgreSQL database
Risk outputs	Hazard, exposure, vulnerability, risk density per neighbourhood	PostgreSQL climate_risk schema
Risk maps	47 figures across 4 hazards	SDI (STAC catalog) + project archive
Workflows	Reproducible Quarto QMD notebooks (Python)	Git repository
Documentation	Methodology guides, metadata, this report	This report + archive

Figure Inventory

Coastal Flooding (17 figures):

Figure ID	Description
slr_scenarios	IPCC AR6 SLR projections (fan chart, P17–P83 envelopes)
dem_overview	Digital Elevation Model overview (10 m, UTM 19N)
scenario_metrics	Scenario comparison — flooded area, max depth, pixels
flood_baseline_vs_worst	Flood depth: moderate (2050 SSP2-4.5) vs worst case (2100 SSP5-8.5)
willemstad_closeup	Willemstad closeup — worst case scenario
buildings_flooded	Microsoft building footprints in flood zone (103k total, flooded highlighted)
osm_flooded	OSM critical infrastructure in flood zone
exposure_chart	Parcels at risk by severity threshold per scenario
exposure_overview	Exposure overview — parcels and buildings
exposure_summary	Exposure summary — buildings and infrastructure bar chart
flood_risk_map	Flood risk map — affected neighbourhoods
flood_risk_willemstad	Flood risk map — Willemstad detail
risk_density	Risk density choropleth (people at risk per km^2)
risk_progression	Risk progression across scenarios

Pluvial Flooding (13 figures):

Figure ID	Description
flood_impact_projections	Dual fan chart — mean precipitation decline vs extreme rainfall intensification
pluvial_cc_baseline	Flood depth — present day baseline
pluvial_cc_ssp126_2050 through ssp585_2100	Flood depth per scenario (8 maps)
climate_signal_ssp126_2050 through ssp585_2100	Climate signal — depth increase per scenario (8 maps)
buildings_at_risk_by_scenario	Buildings at risk by severity threshold per scenario
parcels_at_risk_by_scenario	Parcels at risk by scenario
risk_density_ssp585_2100	Risk density choropleth — worst case
risk_signal_ssp585_2100	Risk signal — normalized risk change

Heat Stress (12 figures):

Figure ID	Description
baseline_temperature	Calibrated air temperature baseline (250 m hexbins)
warming_projections	Temperature fan chart with dual Y-axis (change + absolute °C)
scenario_comparison	Scenario comparison — 9 panels (baseline + 8 projections)
risk_density_ssp585_2100	Risk density choropleth — worst case

Drought (6 figures):

Figure ID	Description
spi_timeseries	Historical SPI time series (32 years)
precip_projections	Precipitation fan chart (P10–P90 envelopes)
vegetation_communities	DCBD vegetation communities map
vegetation_drought_exposure	Vegetation drought exposure
vegetation_drought_risk	Vegetation drought risk
vulnerability_map	Vulnerability choropleth (welfare + water access double-weighted)
risk_density_ssp585_2100	Risk density choropleth — worst case

Data Sources

Table 5-1: Primary Data Sources

Dataset	Source	Resolution	Period	Access
CMIP6 climate projections	ESGF (7 models, 5 SSPs)	~100 km	1850–2100	Public
IPCC AR6 SLR projections	IPCC WG1 Ch. 9, Table 9.9	Caribbean regional	2020–2150	Public
Landsat 8/9 LST composites	USGS via Planetary Computer	30 m	2013–2025	Public
Digital Elevation Model	Phase 1 / NAS archive	10 m (UTM 19N)	Static	Project
MDC weather observations	Meteorological Dept. Curaçao	12 stations	1993–2025	MDC internal
Tide gauge observations	MDC (Bullen Bay station)	Hourly	2017–2025	MDC internal
CBS Census 2023	CBS Curaçao	315 neighbourhoods	2023	Public
Microsoft building footprints	Microsoft AI detection	Individual building	2024	Public
Kadaster property parcels	Kadaster Curaçao	Individual parcel	2024	Government
OSM points of interest	OpenStreetMap contributors	Point features	2024	Public
3Di flood model output	Phase 1 / Nelen & Schuurmans	10 m raster	Static	Project
FEWS discharge model	Deltares / NAS archive	100 m grid, 7 intensities	Static	Project
IDF curves	MDC (Gumbel-fitted)	Island-wide + 8 stations	1993–2025	MDC internal
DCBD vegetation polygons	DCBD Curaçao	Polygon	2024	Government

Methodology Documentation

Complete methodology documentation, including reproducible workflow notebooks for all hazard assessments, is archived at MDC. Technical documentation and data access requests can be directed to the contact below.

Meteorological Department Curaçao (MDC)

Website: www.meteo.cw
Email: info@meteo.cw
Address: Seru Mahuma z/n, Curaçao

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Annex: D2 Revision Plan

Beneficiary: Meteorological Department Curaçao (MDC)
Project: CLIMAAXKòrsou — Climate Risk Assessment for Curaçao
Deliverable: D2 — Refined Local Multi-Risk Assessment
Resubmission deadline: February 27, 2026
Prepared by: Jonathan Zoetrum, Project Manager
Date: March 2026

Introduction

Following the Phase 2 Delivery Review (January 2026), MDC received feedback identifying seven areas requiring corrective action in the D2 deliverable. This annex provides a structured response to each finding, documents the corrective actions taken for the revised submission, and outlines the forward plan for activities that extend beyond the resubmission date — specifically, the deployment of MDC's Climate Impact Atlas (March 2026) and Phase 3 stakeholder engagement activities (Q3 2026).

Context: MDC's approach to Phase 2

MDC's priority in Phase 2 has been to build a solid, data-driven technical foundation for climate risk assessment on Curaçao. This focus reflects a deliberate strategic choice shaped by several factors.

First, Curaçao currently lacks a single authoritative source for locally validated climate risk information. Climate data and projections are available from multiple international sources (CMIP6, Copernicus, IPCC), but these are global or regional products that require significant local calibration and interpretation to be useful for island-level decision-making. Without consolidation and local validation, there is a risk of fragmented or inconsistent information reaching policymakers. MDC, as the national meteorological authority, is positioned to fill this role — but doing so requires building the technical capacity to process, validate, and maintain these datasets in-house.

Second, the urgency of this work has become increasingly clear. The year 2024 was a record-breaking year for Curaçao: average temperatures reached 29.1°C (+1.02°C anomaly), a 1-in-100-year rainfall event struck Banda Abou (313.8 mm in approximately 3 hours), and Willemstad experienced coastal inundation from a high tide event in November. These are no longer future projections — they are present-day realities that demand locally grounded risk information for planning and response.

Third, the current geopolitical environment underscores the importance of developing locally owned data infrastructure and analytical capacity. Curaçao's ability to generate its own evidence-based climate risk information — rather than depending entirely on external sources or consultants — is essential for autonomous policy development, infrastructure planning, and international reporting obligations.

MDC's approach in Phase 2 has therefore prioritized incremental, sustainable progress: building workflows that can be maintained and updated in-house, validating global models against local observations, and establishing MDC as the authoritative source for climate risk data on the island.

This foundation is designed to grow over time — each workflow, dataset, and stakeholder interaction builds capacity that compounds in subsequent phases.

Review findings

The review acknowledged MDC's strong technical capacity, correct application of the CLIMAAX methodology, integration of local datasets, bias correction using weather stations, and the implementation of four hazard workflows. The findings focus primarily on documentation, stakeholder engagement evidence, open data sharing, and reporting alignment with the Individual Follow-up Plan (IFP). MDC has addressed these findings as described below.

1. Summary of Findings

#	Finding	Category	Status in revised D2
F1	Insufficient methodological detail for pluvial flood modelling, temperature bias correction, and tide gauge analysis	Documentation	Addressed
F2	Stakeholder involvement effectively absent in Phase 2	Engagement	Addressed
F3	Data and workflows not shared through open platforms	Open Science	Addressed
F4	Publication of maps in Klima Kòrsou Atlas not evidenced	Dissemination	Partially addressed (website deployment March 2026)
F5	Inconsistencies between reported KPIs and those defined in the IFP	Reporting	Addressed
F6	Milestone M5 (presentation to policy/decision makers) not carried out	Engagement	Addressed
F7	Deviations from IFP not explicitly justified; no corrective strategy described	Planning	Addressed

2. Root Cause Analysis

Phase 2 delivered four complete hazard workflows covering coastal flooding, pluvial flooding, heat stress, and drought, with local data integration and bias correction as required by the CLIMAAX methodology. However, the D2 report did not adequately reflect the full scope of activities undertaken:

1. **Stakeholder engagement** did occur during Phase 2 — including two CCCP platform sessions (November and December 2025), a policy consultation with VVRP, and targeted briefings with the Central Bank of Curaçao and Sint Maarten and the Commissie Integraal Watermanagement Curaçao (February 2026). These activities were not documented in the original D2 report, creating the impression that engagement was absent.

2. **Open data sharing** was not included in the original submission. CLIMAAX's specific guidelines on open data requirements were communicated after the initial D2 submission and are now fulfilled through Zenodo uploads.
3. **Methodology documentation** was kept concise without sufficient detail for external reviewers to assess assumptions and uncertainties.
4. **The platform decision** to publish on MDC's own institutional website rather than the Klima Kòrsou Atlas was not formally communicated or justified in the deliverable.
5. **KPI and milestone reporting** did not follow the exact IFP definitions, leading to inconsistencies that obscured actual progress.

In summary: the gaps are primarily in documentation, reporting, and dissemination — not in the technical work or the actual level of stakeholder engagement.

3. Corrective Actions

F1: Methodology Documentation

Finding: Insufficient detail on pluvial flood modelling, temperature bias correction, and tide gauge analysis.

Actions taken for revised D2:

#	Action	Location in revised D2
1.1	Expanded pluvial flood methodology: documented the susceptibility-based approach (slope, elevation, land cover, drainage proximity), severity thresholds (>25cm moderate, >50cm significant, >100cm severe), and clarified that this is a GIS-based susceptibility assessment, not a hydrodynamic model	Chapter 5
1.2	Expanded temperature bias correction: documented quantile mapping procedure, reference period (1993–2014), validation metrics (RMSE <0.8°C, r^2 >0.7), and station-by-station correction factors	Chapter 6
1.3	Expanded tide gauge analysis: documented 70,000 hourly observations (2017–2025), tidal datum derivation (MLLW, MSL, MHHW, HAT), extreme water level return period analysis, and comparison of GTSM reanalysis values with local observations	Chapter 4
1.4	Added uncertainty discussion for each hazard: ensemble spread (P10/P50/P90), model agreement, and key assumptions affecting result interpretation	All hazard chapters

F2: Stakeholder Engagement

Finding: Stakeholder involvement effectively absent in Phase 2. No validation of risk priorities with local actors.

Response: MDC conducted six stakeholder engagement sessions during Phase 2 (November 2025 – February 2026). These were not documented in the original D2 report. The revised report includes a dedicated stakeholder engagement section with session summaries and evidence.

Sessions conducted:

#	Date	Event	Stakeholders
S1	27 Nov 2025	CCCP Annual Bijeenkomst at CBCS	35+ organizations: government ministries, private sector, NGOs, civil society, press
S2	12 Dec 2025	CCCP Presentation: Climate Scenarios Curaçao 2050–2100 (IPDC program, co-developed with KNMI)	Same CCCP membership (35+ organizations). Press coverage: Curaçao Chronicle, 16 Dec 2025
S3	Dec 2025	Policy consultation with VVRP	Miriam Jonker (Head of Policy, VVRP)
S4	3 Feb 2026	Central Bank Climate Workgroup	Director of Central Bank of Curaçao and Sint Maarten, climate workgroup members
S5	4 Feb 2026	Commissie Integraal Watermanagement Curaçao	Aqualectra (water and energy utility), MEO (Ministry of Economic Development), GMN (Ministry of Health, Environment and Nature), Beleid/AZ (Ministry of General Affairs), VVRP (Ministry of Transport and Spatial Planning)
S6	Feb 2026	Ministry of General Affairs (Beleid)	Miriam Jonker, policy planning staff

Stakeholder reach:

The CCCP platform sessions (S1, S2) involved over 35 organizations across all sectors:

- **Government (12):** MDC, Central Bank, VVRP/UOOW, ROP, GMN, CBS, OWCS, WJZ, Algemene Rekenkamer, BPD, Domeinbeheer, Fire Department
- **Utilities and infrastructure (3):** Selikor, Curaçao Airport, Kwartiermaker Binnenstad
- **Private sector (11):** Including Ennia (insurance), Guardia Group, New Heritage Consulting, and others
- **NGOs and civil society (8):** Including HiMA, Ecovision, Amigu di Tera, Fundashon Nos Grandinan
- **Press (2):** CEPTURA, Antiliaans Dagblad

This exceeds the IFP target of 15 stakeholders. Additional institutional engagement through the Commissie Integraal Watermanagement (S5) and the Central Bank Climate Workgroup (S4) extends the reach to financial regulation and water management sectors.

Phase 3 stakeholder activities (planned):

Activity	Timeline	Description
National Climate Risk Assessment	Q3 2026	Co-developed with Beleid and Commissie Integraal Watermanagement, with input from CCCP stakeholders
Annual CCCP bijeenkomst	Q3 2026	Presentation of results and structured feedback collection with all CCCP

Activity	Timeline	Description
		members on risk priorities and adaptation needs

Evidence: Presentation slides, session summaries with participating organizations and key discussion points (see stakeholder session annexes S1–S6).

F3: Open Data and Workflow Sharing

Finding: Data and workflows not shared through open platforms.

Context: CLIMAAX's specific guidelines on open data sharing requirements were communicated after the original D2 submission.

Actions taken for revised D2:

#	Action	Deliverable
3.1	Uploaded four reproducible Jupyter workflow notebooks to Zenodo	Zenodo record with DOI
3.2	Uploaded geozone-level risk assessment datasets (CSV) to Zenodo and registered on CLIMAAX platform	Zenodo data record with DOI
3.3	Uploaded publication-quality figures and maps to Zenodo	Zenodo record with DOI
3.4	Referenced all DOIs in the revised D2 report data availability section	Revised D2 report

All external data sources used in Phase 2 are openly available (CMIP6 via Copernicus CDS, Landsat via USGS, Sentinel-2 via Copernicus Dataspace, CBS Census 2023, IPCC AR6 projections). MDC's local station observations are shared as aggregated statistics to support reproducibility while respecting institutional data policies.

Evidence: Zenodo DOIs referenced in revised D2 report.

F4: Map Publication and Dissemination Platform

Finding: Publication of maps in the Klima Kòrsou Atlas is not evidenced.

Response: MDC will publish the CLIMAAX climate risk maps on its own institutional climate services platform (climate.meteo.cw) rather than through the Klima Kòrsou Atlas. This decision reflects MDC's institutional mandate and strategic direction:

- **Legal and institutional mandate:** As Curaçao's national meteorological authority, MDC has a legal responsibility for the production and dissemination of climate information. Centralizing climate risk data on MDC's own platform ensures this obligation is fulfilled under direct institutional control.
- **Policy alignment:** The national climate policy framework (CCCP/Beleid) requires authoritative, centrally maintained climate information. MDC's platform provides a single authoritative source for government agencies, policymakers, and the public.
- **Long-term sustainability:** An MDC-hosted platform guarantees continued maintenance, updates, and integration with MDC's operational climate services — including real-time weather data, forecasts, and historical records.

- **Multilingual accessibility:** The platform will support English, Dutch, and Papiamento, ensuring accessibility for all of Curaçao's population and government stakeholders.
- **Capacity building:** Developing and maintaining the platform in-house builds institutional technical capacity, aligned with CLIMAAX's goal of strengthening local climate services.

The intent of the original KPI — public availability of climate risk maps — is fully preserved. The maps will be openly accessible, interactive, and downloadable.

Actions:

#	Action	Deliverable	Timeline
4.1	Deploy the Climate Impact Atlas on MDC's public website (climate.meteo.cw) with interactive choropleth maps for all four hazards, scenario selection, and geozone-level statistics	Live public website URL	March 2026
4.2	Ensure all risk data is downloadable (CSV format) directly from the website	Website with data download section	March 2026
4.3	Formally communicate the platform decision to CLIMAAX Management	This annex serves as formal communication	February 2026
4.4	Explore cross-referencing with the Klima Kòrsou Atlas to ensure visibility across platforms	Communication record	March 2026

F5: KPI Alignment with IFP

Finding: Inconsistencies between reported KPIs and those defined in the IFP.

Actions taken for revised D2:

#	Action	Location in revised D2
5.1	Revised KPI section using exact wording from the IFP	KPI reporting section
5.2	Provided explicit status (achieved / partially achieved / not achieved) for each IFP KPI with evidence references	KPI table
5.3	For KPIs not fully achieved (K4: Atlas publication), provided justification and corrective timeline	KPI table and this annex (F4)

F6: Milestone M5 and Milestone Alignment

Finding: Milestone M5 (presentation to policy/decision makers) not carried out. Milestones reported do not fully coincide with those in the IFP.

Response: M5 was carried out through multiple channels but was not documented in the original D2 report:

- **CCCP Workshop (12 Dec 2025):** Climate scenarios presented to 35+ organizations including policymakers, civil servants, and NGOs (S2)
- **VVRP policy consultation (Dec 2025):** Results discussed with Head of Policy (S3)

- **Central Bank briefing (3 Feb 2026):** Presentation to Director of the Central Bank of Curaçao and Sint Maarten (S4)
- **Commissie Integraal Watermanagement (4 Feb 2026):** Results presented to multi-ministerial water management commission (S5)

Actions taken for revised D2:

#	Action	Location in revised D2
6.1	Documented all Phase 2 stakeholder sessions (S1–S6) with session summaries, participating organizations, and key outcomes	Stakeholder engagement section and session annexes
6.2	Revised milestone reporting to use exact IFP milestone definitions	Milestone table
6.3	For each IFP milestone, provided status, evidence references (session numbers), and where deviations exist, explicit justification	Milestone table

F7: Deviation Justification and Corrective Strategy

Finding: Deviations from IFP not explicitly justified; no corrective strategy for next phase described.

Actions taken for revised D2:

#	Action	Location in revised D2
7.1	Added a dedicated "Deviations from IFP" section listing each deviation with justification	New section in revised D2
7.2	Added a "Phase 3 Strategy" section describing how outstanding activities will be addressed, including: (a) sectoral stakeholder consultations with VVRP, ROP, Aqualectra, and Civil Protection; (b) the annual CCCP bijeenkomst (Q3 2026) for participatory risk evaluation and stakeholder feedback; (c) co-development of a national Climate Risk Assessment document (Q3 2026); (d) adaptation strategy co-creation with stakeholders	New section in revised D2

4. Timeline

Completed before resubmission (February 27, 2026)

Week	Dates	Activities
1	Feb 3–7	S4: Central Bank Climate Workgroup (Feb 3); S5: Commissie Integraal Watermanagement (Feb 4)
2	Feb 10–14	S6: Meeting with Beleid (Miriam Jonker); expand pluvial flood and bias correction methodology (F1.1–F1.2)
3	Feb 17–21	Expand tide gauge and uncertainty sections (F1.3–F1.4); Zenodo uploads (F3.1–F3.3)
4	Feb 24–27	Revise KPI/milestone tables (F5, F6); deviations and Phase 3 strategy (F7);

Week	Dates	Activities
		document all engagement sessions (F2.4); **submit revised D2 (Feb 27)**

After resubmission

Period	Activities
March 2026	Deploy Climate Impact Atlas on climate.meteo.cw (F4.1–F4.2); cross-reference with Klima Kòrsou Atlas (F4.4)
April 2026 onwards	Phase 3 transition: national Climate Risk Assessment co-development, adaptation strategy development
Q3 2026	Annual CCCP bijeenkomst: presentation of results, structured stakeholder feedback collection

5. Deliverables Summary

The revised D2 submission (February 27, 2026) includes:

#	Item	Format
1	Revised D2 report addressing all reviewer findings (F1–F7)	DOCX/PDF
2	Stakeholder engagement evidence: session summaries (S1–S6) with participating organizations and key outcomes, presentation slides	PDF
3	Phase 3 stakeholder engagement and risk assessment co-development plan	Included in revised D2
4	Zenodo DOIs for workflow notebooks, datasets, and figures	DOI links

The Climate Impact Atlas (climate.meteo.cw) will be deployed in March 2026 and the URL communicated to CLIMAAX upon completion.

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