Caribbean Heat Stress Atlas

Interactive Web-Based Visualization of Observational Heat Metrics Across Puerto Rico

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Scan: Live Map (left) | GitHub Repo (right)

Abstract

Extreme heat in Puerto Rico is increasing risks to health, outdoor work, and energy demand. The Caribbean Heat Stress Atlas (Puerto Rico module) is an interactive web tool that converts NOAA GHCN-Daily station observations (1960–2025) into two frequency metrics: Hot Days (Tmax ≥ 32 °C) and Warm Nights (Tmin ≥ 24 °C). A reproducible Python/pandas pipeline applies quality control (station-years with ≥200 valid days), counts annual exceedances, and summarizes change by comparing early vs. late halves of the record across seven stations. The Leaflet map lets users toggle metrics, change year, and view station time series. Results show strong coastal intensification (e.g., San Juan ~120→~200 warm nights/year; Ponce ~110→200+ hot days/year), while high-elevation Aibonito remains near zero. The framework is designed to expand to humidity-based indices and other Caribbean locations.

Introduction

Extreme heat is one of the most direct climate risks for Puerto Rico, affecting health, outdoor work, and energy use. People experience heat through how often thresholds are exceeded, not through annual mean temperature. This project builds a station-based atlas that turns observations into interpretable frequency metrics and an easy, interactive map for non-specialists.

Background

Heat-stress frequency metrics (chosen for interpretability):
- Hot Days: Tmax ≥ 32°C (~90°F) — limits safe outdoor activity and work
- Warm Nights: Tmin ≥ 24°C (~75°F) — reduces nighttime relief and sleep quality
- WHO heat guidance emphasizes keeping indoor temperatures below these ranges during heat events (especially for vulnerable groups).

Puerto Rico has warmed since the late 20th century, with particularly consistent increases in minimum temperature. Station observations provide local detail that complements coarse gridded climate products.

Problem

Why this is needed:
- Many climate portals are too coarse for municipalities
- Technical formats limit use by non-specialists
- Annual means hide actionable extremes that drive health and energy impacts

Project objectives:
- Build a reproducible NOAA→metrics→web pipeline
- Quantify early vs. late changes for each station
- Provide an interactive map + station time series for exploration
- Publish an open, lightweight site that can be extended to new stations/metrics

Methodology

- Data: NOAA GHCN-Daily (1960–2025), 7 Puerto Rico stations
- Quality control: station-years with ≥200 valid Tmin/Tmax days
- Metrics: annual counts of threshold exceedances
- Hot Days (Tmax ≥ 32°C) , Warm Nights (Tmin ≥ 24°C)
- Change summary: early vs. late halves of record
- Products: annual CSV + GeoJSON layers
- Web app: Leaflet + OpenStreetMap; static deploy (GitHub Pages)

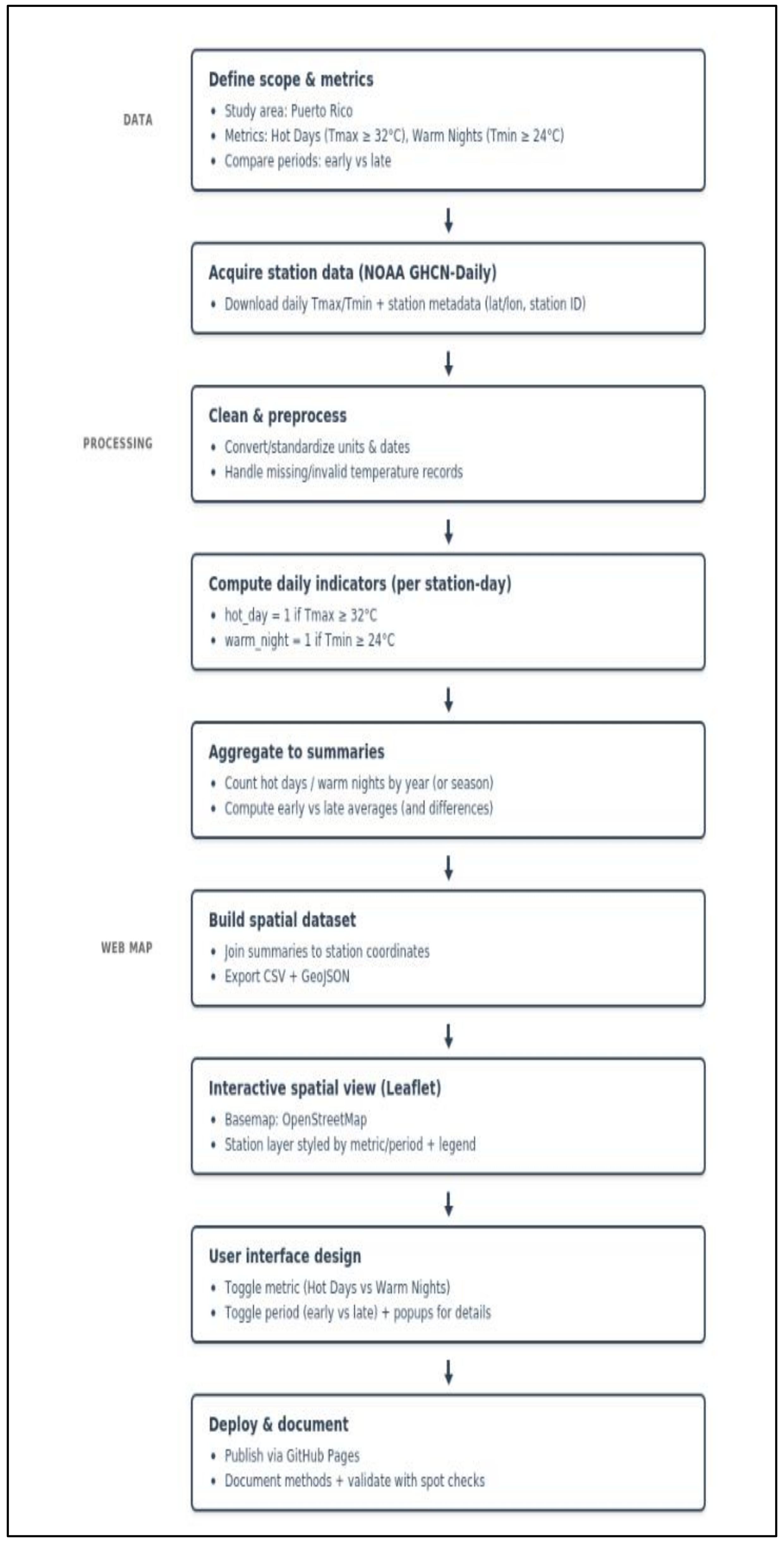

Figure 1. End-to-end workflow from metric definition to deployment.

Results and Discussion

Key changes (early→late):

Hot Days (Tmax ≥ 32°C)
- San Juan: 47 → 84 days/yr (+79%)
- Ponce: 110 → 200+ days/yr (+82%)
- Ceiba: 22 → 50 days/yr (+127%)

Warm Nights (Tmin ≥ 24°C)
- San Juan: 120 → 200 nights/yr (+67%)
- Ceiba: 132 → 166 nights/yr (+26%)
- Ponce: 22 → 31 nights/yr (+41%)

Spatial pattern: coastal/urban stations warm fastest; highland Aibonito stays near zero.

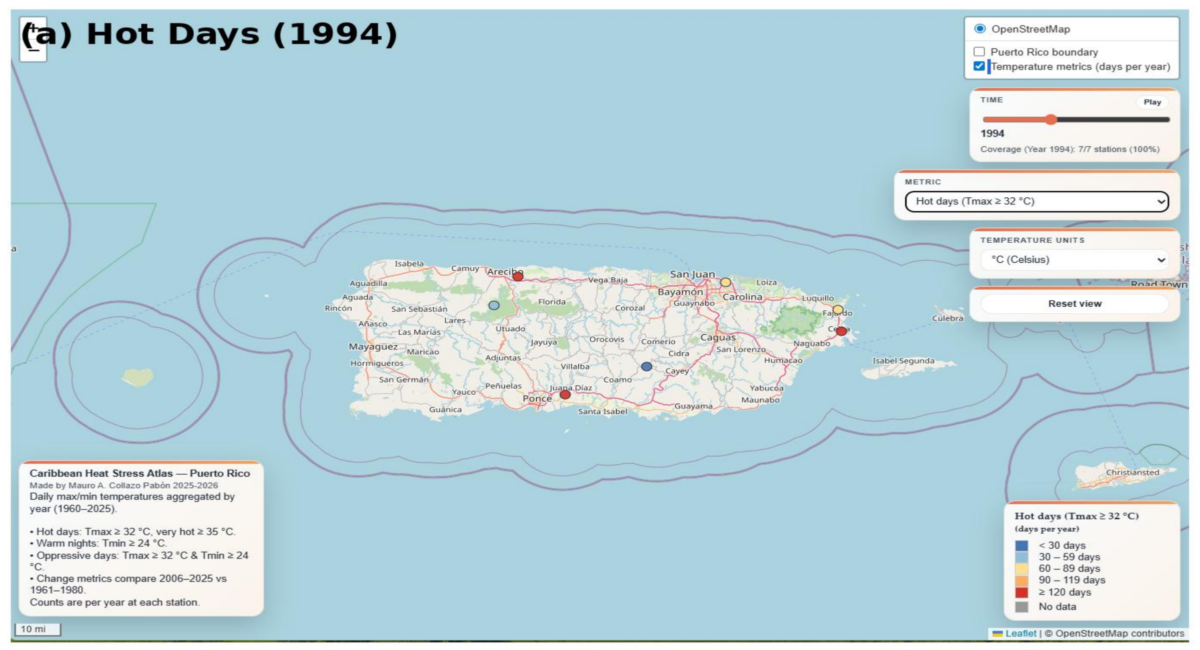

Figure 2a. Hot days snapshot (1994).

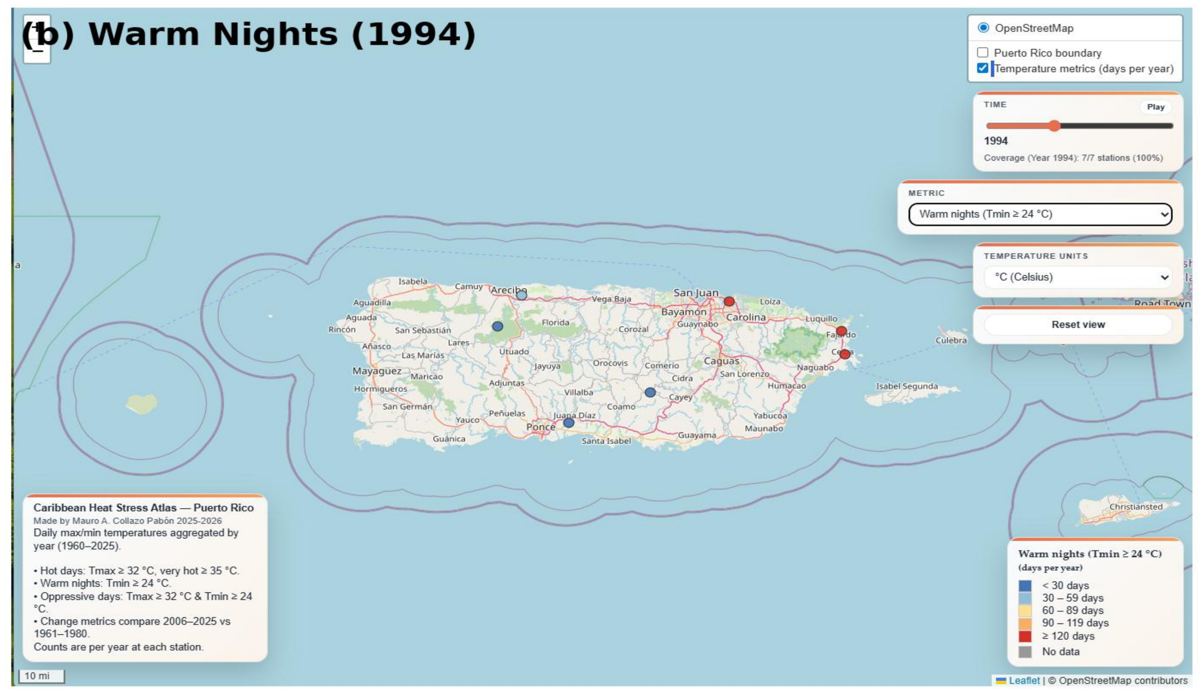

Figure 2b. Warm nights snapshot (1994).

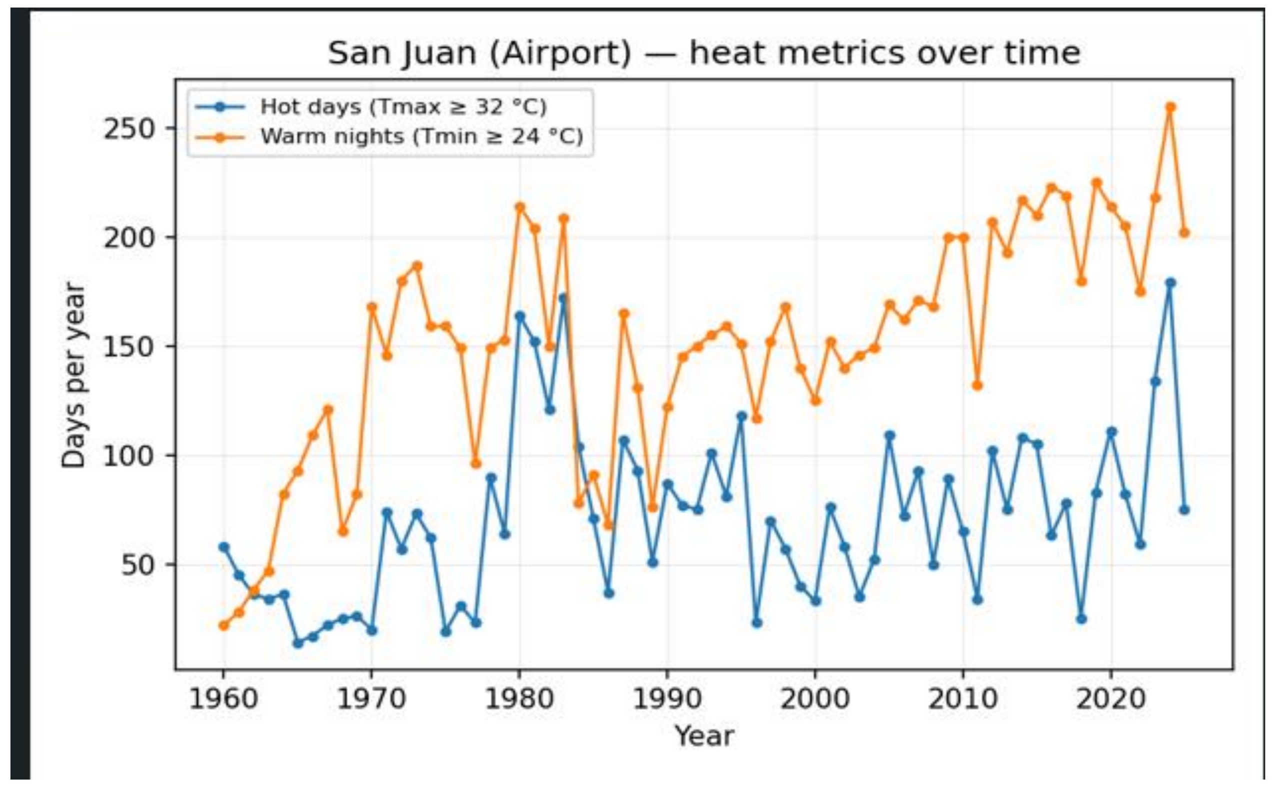

Figure 3. San Juan annual hot days & warm nights (1960–2025).

Conclusions

- Converts station observations into interpretable frequency-based heat metrics
- Coastal/urban Puerto Rico shows large increases (≈60–80%) in hot days and warm nights
- Highland sites show minimal exposure, confirming elevation as a key moderator
- Station-point approach improves local relevance without interpolation
- Framework supports adding humidity metrics and expanding across the Caribbean

Future Work

- Add humidity-informed metrics (heat index, wet-bulb temperature)
- Increase station density and extend to other Caribbean islands
- Incorporate downscaled climate projections for risk planning
- Add downloads (CSV/GeoJSON) and station-comparison views in the UI
- Build sector story views (health, energy, labor) for communication

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Data: NOAA NCEI Climate Data Online (GHCN-Daily).
Tools: Python/pandas; Leaflet; OpenStreetMap; GitHub Pages.
This work supports climate communication for Caribbean communities.

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