Point Process Modelling of Deaths in Patients with Psychiatric Disorders: Linking Event Patterns to Climate Variables

Diana Antonio [1,2,3] Manuel Moreno [1,3] Ferran Blanco [2] Marc Saez [1,3]
Maria A. Barceló [1,3]

[1]Universitat de Girona [2]Fundació Support Girona [3]CIBER Epidemiologia i Salut Pública

Motivation — How Does Climate Affect Psychiatric Patients?

+2.2% mortality per °**C** rise **+9.7%** hospital admissions.

- Psychotropic drugs impair thermoregulation — sweating, vasodilation, and fluid balance are all disrupted.
- Patients with schizophrenia were **16% of Heat Dome deaths** (Yoon, 2025) despite representing 1% of the population.
- Italian cohort: +5.5% mortality per °C above 24 °C in mental health service users vs. +1.9% in the general population (Stivanello,2020).

Study Design — Data Sources & Linkage

- **Point pattern:** georeferenced deaths of individuals under social care through the Fundació Support Girona with date and residence location.
- **Climate data:** daily ERA5-Land reanalysis (0.1° grid) and Copernicus regional downscaling; spatially joined to subject's residence.
- **Covariates:** greenness (NDVI), urbanization (LST), deprivation index, care facility proximity.
- **Study window:** Observations in the period 2016-2025.

Subjects' death registry + Climate grid (ERA5 / Copernicus) $\rightarrow$ Marked spatio-temporal point process.

Statistical Framework — From Death Events to Point Process Models

Each individual death is a location–time event (s, t). The observed point pattern is treated as a realisation of a **Log-Gaussian Cox Process (LGCP)**, a doubly stochastic Poisson process whose log-intensity is itself a Gaussian random field.

The goal is to estimate a spatio-temporal intensity function $\lambda(s, t) > 0$ that depends on climate covariates $\mathbf{z}(s, t)$ while accounting for residual spatial structure not explained by observed predictors.

Death locations (point pattern) $\rightarrow$ LGCP $\lambda(s, t) \rightarrow$ Climate covariate effect β.

$$\log \lambda(s,t) = \log E(s,t) + \alpha + \beta_1 \,\mathrm{Temp}(s,t) + \beta_2 \,\mathrm{HI}(s,t) + \beta_3 \,\mathrm{HW}(s,t) \cdot \mathrm{Temp}(s,t) + W(s,t)$$

- $\log E(s, t)$ as an offset for the population at risk, ensuring $\lambda(s, t)$ models death rates rather than raw counts.
- α is the overall intercept.
- $\mathrm{HI}(s, t)$ is the Heat Index (a standard temperature–humidity composite), replacing an unspecified humidity term.
- $\mathrm{HW}(s, t) \in \{0, 1\}$ is a binary heat-wave indicator entered as an **interaction** with $\mathrm{Temp}(s, t)$.
- $W(s, t)$ is a **zero-mean Gaussian random field** with a spatio-temporal covariance structure, modelling residual overdispersion relative to the Poisson assumption; a separable Matérn(ν, κ) spatial covariance combined with an AR(1) temporal component (Lindgren,2011).

Fit via `INLA+SPDE`.

References

Selected References: Baddeley et al. (2015) *Spatial Point Patterns* · Diggle (2013) *Spatio-Temporal Point Patterns* · Basu et al. (2022) *JAMA Psychiatry* · Thompson et al. (2021) *Environ Int* 101:105232 · Ewing et al. (2026) *Infect Dis Model* · Zhu et al. (2025) PMC12319355 · Colicino et al. (2024) *Environ Health Perspect* · Meyer & Warnke (2016) *Stat Methods Med Res* · Diggle et al. (2013) *Stat Science* · RCP Advisory (2025) *Heatwaves and Mental Health*

Climate Variables — Priority Variables for the Intensity Function

- **Maximum Daily Temperature ($T_{\max}$).** Primary driver of heat stress; threshold effects above the 90th–95th percentile are most predictive of mental-health mortality.
- **Absolute Humidity / Dew Point.** Most frequently selected predictor for cause-specific mortality in multi-variable weather studies; limits evaporative cooling.
- **Heat Wave Index (HWI).** Binary or count measure of days with $T > 90$th percentile for $\geq$3 consecutive days; captures duration effect on mental-health scores (-0.027 per event).
- **Apparent Temperature (AT).** Combines T, relative humidity, and wind speed (Steadman); perceived heat load; optimal spatio-temporal EHE delineation metric.
- **Nocturnal $T_{\min}$.** Warm nights prevent physiological recovery; associated with worsening psychiatric outcomes even without extreme daytime heat.
- **Urban Heat Island (LST).** MODIS Land Surface Temperature as a spatial modifier — urban patients face systematically higher exposures driving intensity heterogeneity.

Expected Outputs — Key Results to Present

- **Intensity maps:** $\hat{\lambda}(s, t)$ across warm seasons — spatial hotspots of psychiatric mortality, overlaid on temperature anomaly.
- β **estimates:** effect of $T_{\max}$, HWI, AT on log-intensity with 95% credible intervals; comparison across diagnosis subtypes.
- **Threshold detection:** non-linear spline of temperature vs. intensity — estimate risk inflection point for Mediterranean climate.
- **Space–time clustering during heat waves:** $K_{\mathrm{ST}}(s, t)$ function — does spatial clustering *intensify* on days 3–5 of a heat event?

Preliminary Results

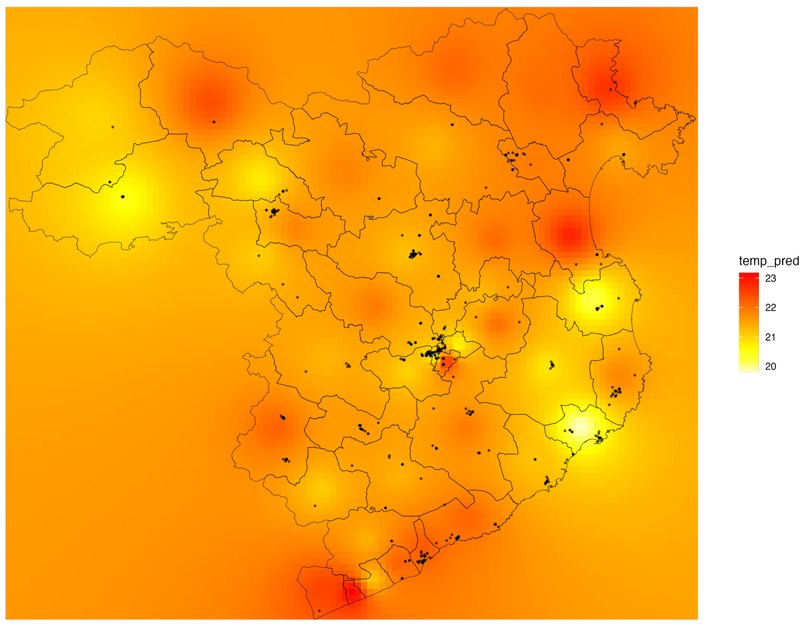

Figure 1. Death ocurrences and average temperature by region of Girona province.

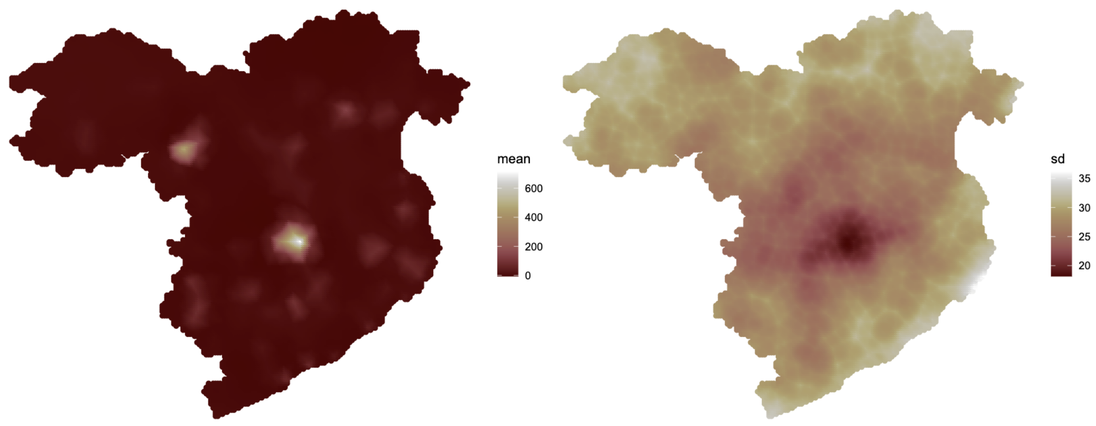

Figure 2. Mean and standard deviation of the spatial GF.