Spatio-temporal Bayesian modelling of hydrometeorological risk in Venezuela

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Summary

Decision-makers can greatly benefit from risk assessment tools, especially when combining environmental risk in a social context. We present a novel Bayesian spatial-temporal statistical procedure that meshes hazard, vulnerability, exposure and risk. The work is centered on hydrometeorological hazards directly related to climate variability. Its aim is to provide a prospective analysis that considers climate change as an element to modulate hazard.

Data and methodology

The described methodology was applied to the Vargas state (Venezuela) using measure rainfall data from the hydrometeorological stations of the Instituto Nacional de Meteorología e Hidrología. Victim registry was collected from local newspaper sources, the Centre for Research on the Epidemiology of Disasters (CRED) and the website Desinventar, while census data was provided by the Instituto Nacional de Estadística. Macroclimatic variables were taken directly from the National Oceanic and Atmospheric Administration site (NOAA[a]). The methodology was applied over a temporal monthly frequency and spatial resolution of 0.05×0.05 degrees. Methodology outputs are a set of hazard, vulnerability and risk maps that could be presented at any given quantile. Rainfall hazard maps are produce by interpolating point data via a spatial-temporal hierarchical Kriging procedure in which model parameters are estimated using a Bayesian paradigm (see [2]). Vulnerability maps are built using Zero-Inflated Negative Binomial models that include social and climatic explanatory variables. Exposure maps are produced by estimating-temporal projections from official census data.

[a]http://www.nhc.noaa.gov/

Risk model

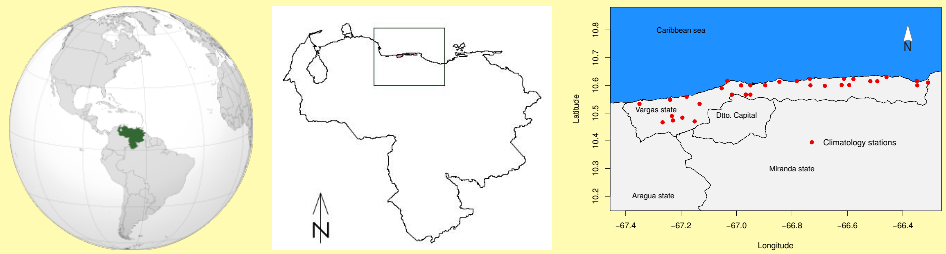
Risk is defined as the expected losses (total population affected) using the following equation

$$R_{t,s} = E_{t,s} \int_{\Omega_H} \int_{\Omega_V} V_{t,s}\, \mathsf{P}(V_{t,s}|H_{t,s})\, \mathsf{P}(H_{t,s})\, dV_{t,s}\, dH_{t,s}.$$

where Ω_H y Ω_V are the hazard and vulnerability domains, $E_{t,s}$ is the exposure at a given time t and location s, $\mathsf{P}(H_{t,s})$ is the probability of hazard (rainfall) at time t and location s, and $\mathsf{P}(V_{t,s}|H_{t,s})$ is the probability of vulnerability conditioned on the hazard at t, s.

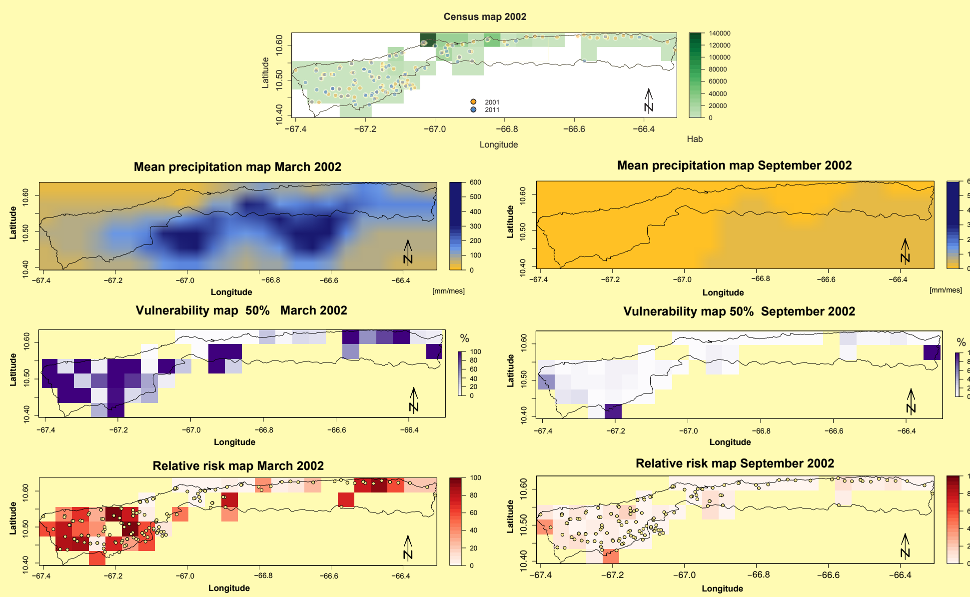
Geographic area of study

The figures show the world relative geographic location of Venezuela (left), Vargas state in Venezuela (center) and Vargas state with the climatological stations' locations (right).



Results

Hazard, vulnerability and risk maps for March (left hand side) and September (right hand side) (two contrasting months) for the year 2002. Maps values are the medians for each variable.

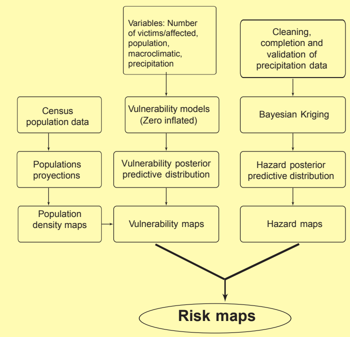


Maps of hazard, vulnerability and risk, March 2002.

Maps of hazard, vulnerability and risk, September 2002.

Diagram of methodology

Flow diagram for the production of vulnerability and risk maps.



Conclusions

- Given a level of hazard of hydrometeorological origin and a defined vulnerability level, the model identifies and quantifies zones of high risk.
- The vulnerability model consider the ENSO, precipitation and population density over the number of people affected.
- The methodology consider uncertainty in rainfall measure and the affectation level and combine the two sources of uncertainty into a single measure.

References

[1] Villalta, D., Bravo de Guenni, L. and Sajo-Castelli, A. Spatio-temporal Bayesian modelling of the hydrometeorological risk in Venezuela. Stochastic Environmental Research and Risk Assessment (SERRA) (paper in preparation). 2017.

[2] Le, N., Sun, L., y Zidek, J. (1997). Spatial prediction and temporal backcasting for environmental fields having monotone data patterns. Canadian Journal of Statistics, 29:516–529.

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