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)*. The methodology was applied over a temporal monthly frequency and spatial resolution of 0.05 x 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 produced 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.

References
[2] Le, N., Sun, L., y Zidek, J. (1997). Spatial prediction and population density over the number of people affected. The methodology consider uncertainty in rainfall measurement and the affectation level and combine the two sources of uncertainty into a single measure.

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

\[ R_{t,s} = E_{t,s} \int_{\Omega_H} V_{t,s} P(V_{t,s}|H_{t,s}) dV_{t,s} dH_{t,s} \]

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

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.

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 measurement and the affectation level and combine the two sources of uncertainty into a single measure.

Diagram of methodology
Flow diagram for the production of vulnerability and risk maps.

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