

A shiny web application for disease mapping.  
Making easy the fit of spatio-temporal models.

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**UseR! 2019**

Toulouse, 9-12 July 2019

- **Spatial and spatio-temporal analyses of count data** are crucial in epidemiology and other fields to
  1. provide accurate estimates of mortality and/or incidence risks.
  2. unveil the underlying spatial and spatio-temporal patterns.
- However, fitting spatial and spatio-temporal models is not easy for non-expert users.
- Here, we present the **interactive web application SSTCDapp** for the analysis of spatial and spatio-temporal mortality (or incidence) count data, which is addressed at

<https://emi-sstcdapp.unavarra.es/>

# The SSTCDapp application

**SSTCDapp**<sup>1</sup> is an interactive and user-friendly web application designed for the following purposes:

- To perform descriptive analyses in space and time of mortality/incidence risks or rates.
- To fit an extensive range of fairly complex spatial and spatio-temporal models for areal data commonly used in disease mapping.

It is built with Shiny and relies on the well-founded integrated nested Laplace approximation (INLA) technique for Bayesian inference<sup>2</sup> is used for model fitting through the [R-INLA](#) package.

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<sup>1</sup>Adin, A., Goicoa, T., and Ugarte, M.D. (2019). Online relative risks/rates estimation in spatial and spatio-temporal disease mapping. *Computer Methods and Programs in Biomedicine*, 172, 103-116

<sup>2</sup>Rue, H., Martino, S., and Chopin, N. (2009). Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations, *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 71, 319-392

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## Main characteristics:

- Users can access the application directly from the web browser **without installing any software in their computers.**
- All the analysis and **computations are made in a remote server.**
- The users can **submit a model** to the remote server and **collect the results** when the computations are finished.
- **A desktop version is also available to run the application locally** in those cases in which data confidentiality could be a serious issue.

# The SSTCDapp application

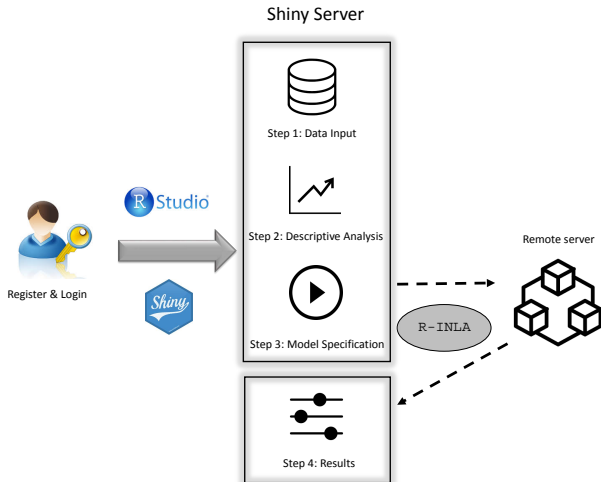


Figure 1: Workflow of the SSTCDapp application.

# Example: Breast cancer mortality data in Spanish provinces

## 1. Data Input:

- The data and the associated cartography are uploaded by the user, and automatically previewed on the screen.
- Several formats for both data and cartography are supported.

The screenshot displays the 'Map file input' tab in the SSTCDapp. On the left, a dark sidebar contains navigation links: Home, Data Input, Data file, Map file, Descriptive Analysis, Model Specification, Results, Help, and Logout. The main content area is split into two panels. The left panel, titled 'Map file options', includes a 'Format' section with radio buttons for '.Rdata' (selected), '.rds', and '.shp', a 'Reset' button, and a URL link to the GADM database of Global Administrative Areas. The right panel, titled 'Upload map file', features a 'Browse...' button, a text input field with 'Carto\_SpainPROV.Rdata', an 'Upload cartoline' button, a map preview of Spain's provinces with a coordinate grid (36°N to 44°N, 10°W to 5°E), and a dropdown menu for 'Select the area variable in the map' with 'ID.area' selected.

Figure 2: *Map file* input tab in SSTCDapp.

## 2. Descriptive Analysis:

- The target variables are selected and standardized mortality ratios (SMR) or standardized rates (SR) are calculated.
- Descriptive graphs of the spatial, temporal, and spatio-temporal distribution for the variables of interest (crude rates, SMR or SR) are generated.

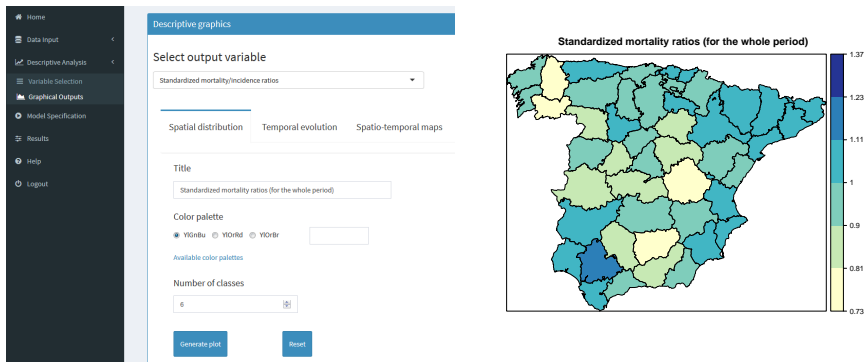


Figure 3: Plot generated from the *Graphical Outputs* tab in SSTCDapp.



## 3. Model Specification:

- A wide variety of spatial or spatio-temporal models commonly used in disease mapping can be fitted using the R-INLA package.
- The model is submitted to a remote server. Once the calculations are finished the user will receive a notification by email.

The screenshot displays the 'Model Specification' tab in the SSTCDapp interface. The left sidebar contains navigation options: Home, Data Input, Descriptive Analysis, Variable Selection, Graphical Outputs, Model Specification (selected), Results, Help, and Logout. The main content area is titled 'Select model options' and includes the following sections:

- R-INLA project website**: Model name (optional) set to 'Breast Cancer'.
- Spatial prior distribution**: Radio buttons for ICAR, BYM, Leroux (selected), and BYM2.
- Temporal prior distribution**: Radio buttons for RW1 (selected) and RW2, and a checkbox for 'Include temporally unstructure component'.
- Spatio-temporal interaction**: Radio buttons for None, Type I, Type II, Type III, and Type IV (selected).
- INLA approximation strategy**: Radio buttons for Gaussian (selected), Simplified Laplace, and Full Laplace.

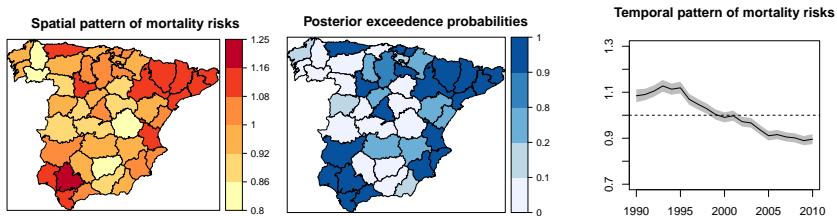
Additional options include 'Show/hide advanced options', 'Run INLA', and 'Reset' buttons. The 'Spatial neighborhood matrix' section features a dropdown menu set to 'Compute from the map file' and a checked checkbox for 'Show neighborhood graph'. A map of Spain shows a network of regions with their neighbors. A text box on the right provides the following 'Neighbour list object' statistics:

```
Neighbour list object:  
Number of regions: 47  
Number of nonzero links: 224  
Percentage nonzero weights: 30.14803  
Average number of links: 4.765927  
Link number distribution:  
 2 3 4 5 6 7 8  
 2 9 8 12 4 5 2  
3 least connected regions:  
4 15 17 with 2 links  
2 most connected regions:  
9 58 with 8 links
```

Figure 4: Model Specification tab in SSTCDapp.

## 4. Results:

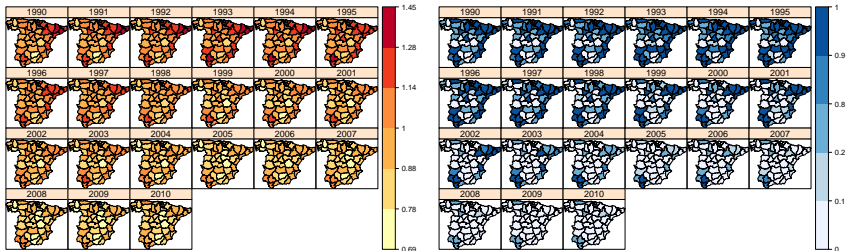
- Summary measures are provided for the posterior distribution of model hyperparameters; relative mortality/incidence risks (or rates); and spatial, temporal, and spatio-temporal patterns.



**Figure 5:** Posterior mean estimates of spatial and temporal patterns of breast cancer mortality risks.

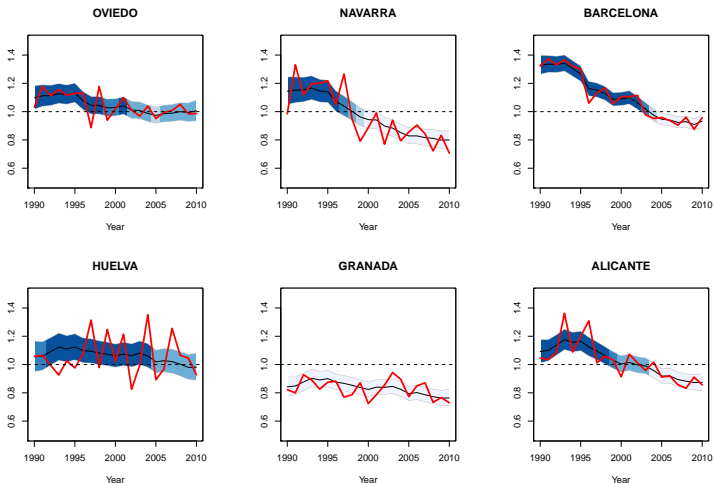
## 4. Results:

- Maps with the geographical distribution of the disease risks and area-specific temporal evolutions are also generated.



**Figure 6:** Posterior means of relative risks (left) and posterior exceedence probabilities (right) for breast cancer mortality in Spanish provinces.

# Example: Breast cancer mortality data in Spanish provinces



**Figure 7:** Temporal evolution of breast cancer mortality relative risks for six selected Spanish provinces and 95% two-sided credible intervals. The colors used in the bands are associated to the posterior exceedence probabilities of relative risks being greater than one.

# Conclusions

- The SSTCDapp was mainly developed to estimate relative risks using spatial and spatio-temporal disease mapping models.
- It provides separate spatial, temporal, and spatio-temporal patterns together with the corresponding exceedence probabilities and/or credibility intervals.
- The key advantage of this application in comparison with other software commonly used in disease mapping is that it provides an easy-to-use interface that facilitate the fit of fairly complex models without installing any software in user's computer.

# Future development of the application

- Integration of `sf` ([simple feature](#)) objects as cartography files to generate maps.
- To include interactive data visualization graphs using the R packages `leaflet` and `tmap`.
- To implement other spatio-temporal model proposals such as
  - B-spline models accounting for both spatial and temporal correlation.<sup>3</sup>
  - Models for age-specific mortality/incidence patterns.<sup>4</sup>
  - Models to estimate disease risks in the presence of local discontinuities and clusters.<sup>5</sup>

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<sup>3</sup> Ugarte, M.D., Adin, A., and Goicoa, T. (2017). One-dimensional, two-dimensional, and three dimensional B-splines to specify space-time interactions in Bayesian disease mapping: model fitting and model identifiability. *Spatial Statistics*, 22, 451-468

<sup>4</sup> Goicoa, T., Adin, A., Etxeberria, J., Militino, A.F., and Ugarte, M.D. (2019). Flexible Bayesian P-splines for smoothing age-specific spatio-temporal mortality patterns. *Statistical Methods in Medical Research*, 28, 384-403

<sup>5</sup> Adin, A., Lee, D., Goicoa, T., and Ugarte, M.D. (2019). A two-stage approach to estimate spatial and spatio-temporal disease risks in the presence of local discontinuities and clusters. *Statistical Methods in Medical Research* (in press)

The **SSTCDapp application** was developed by Aritz Adin together with the Spatial Statistics Group of the Public University of Navarre (Spain) under the following grants:

- Spanish Ministry of Economy and Competitiveness (Project MTM2014-51992-R).
- Health Department of the Navarre Government (Project 113, Res.2186/2014).
- AEI/FEDER, UE (Project MTM2017-82553-R).

For bug reports and support, please use the following email account:

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