Forest fires cluster detection with space-time scan statistics

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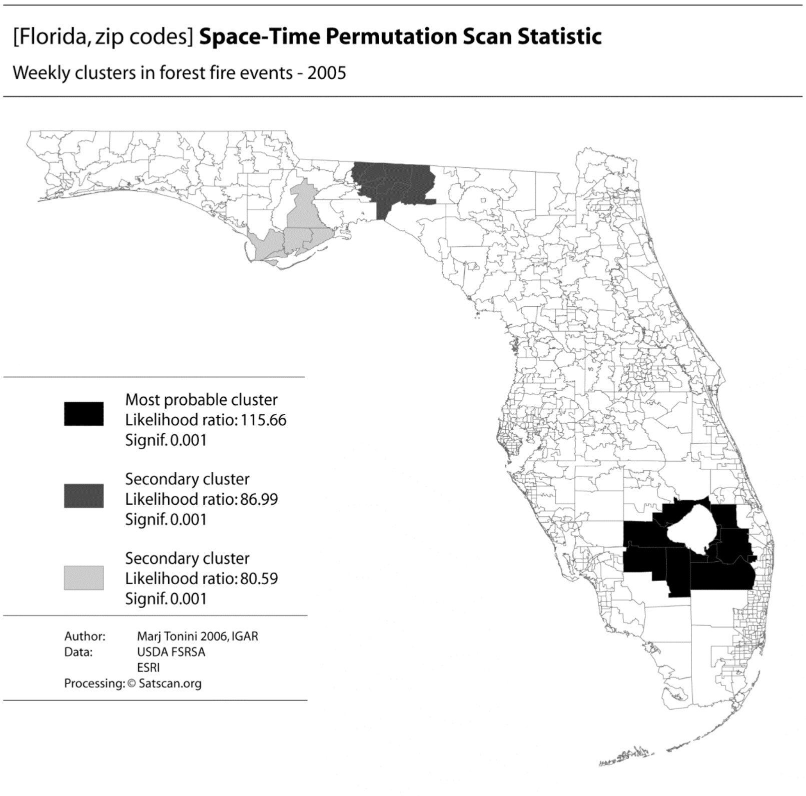
Forest fires are defined as uncontrolled fires often occurring in wildland areas, but that can also affect houses or agricultural resources. Causes are both natural (e.g., lightning phenomena) and anthropogenic (human negligence or arsons).
Major environmental factors influencing the fire ignition and propagation are climate and vegetation. Wildfires are most common and severe during drought period and on windy days. Moreover, under water-stress conditions, which occur after a long hot and dry period, the vegetation is more vulnerable to fire.
These conditions are common in the United State and Canada, where forest fires represent a big problem. We focused our analysis on the state of Florida, for which a big dataset on forest fires detection is readily available.
USDA Forest Service Remote Sensing Application Center, in collaboration with NASA-Goddard Space Flight Center and the University of Maryland, has compiled daily MODIS Thermal Anomalies (fires and biomass burning images) produced by NASA using a contextual algorithm that exploits the strong emission of mid-infrared radiation from fires. Fire classes were converted in GIS format: daily MODIS fire detections are provided as the centroids of the 1 kilometer pixels and compiled into daily Arc/INFO point coverage.

The purpose of this paper is to illustrate, by means of a case study (Florida daily fire detection, year 2005), the use of a space-time scan statistic to detect spatio-temporal fire clusters over a specific region and a given time frame. This approach is specifically designed to detect clusters and assess their significance.
Scan statistics have been developed in health sciences, where they have been widely applied (Kulldorff 1997). Up to now, they have been rarely applied in ecology (Coulston and Riiters 2003).
Basically, scan statistics work by comparing a set of events occurring inside a scanning window (or a space-time cylinder for spatio-temporal data) with those that lie outside. Under the null hypothesis of spatial and temporal randomness, these events are distributed according to a known discrete-state random process (Poisson or Bernoulli), which parameters can be estimated. Given this assumption, it is possible to test whether or not the null hypothesis holds in a specific area.
In a first step, data are aggregated in spatial windows and the likelihood ratio, representing the probability that a certain area (or cylinder) contains a cluster, is computed for every possible window. The second phase of the analysis aims at evaluating the significance of the retained potential clusters. For each of them, a Monte Carlo simulation is performed, with at least 1000 replications, under the null hypothesis. If the cluster of interest contains, for instance, more events than 95% of the replications, the cluster is said to be significant at a 95% level.

This study uses the SaTScan software. An extension of the original model, the space-time permutation scan statistic (Kulldorff et al. 2005), has been used. The goal is to detect spatio-temporal cluster of forest fires daily detection for the year 2005 in

the state of Florida. The detected forest fires data points have been aggregated into the administrative boundaries, and the centroid of the latter areas corresponds to the centroids of the scanning windows used to perform the analysis. Regarding the temporal component, a minimal time step must be chosen in order to aggregate data in a given time frame.
We show the results for weekly-aggregated clusters. The most likely cluster is located south of Lake Okeechobee, during the month of December. Two secondary clusters, highly significant, have been identified in the north of Florida, around March and April.



The space-time permutation model can be applied for forest fires cluster detection to analyse fire persistence, location of most vulnerable areas and definition of highly susceptible fire events time-periods.
The use of remote sensing data for fire detection gives many advantages: it provides a complete coverage over large areas with high temporal resolution and it is easily available, even in inaccessible zones.

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