

Exploratory Spatial Data Analysis

Part III Analysis of spatial time series

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 - Exploring changes of spatial patterns
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 - Investigating local behaviours

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Types of Temporal Variance

- Existential changes: appearing and disappearing of objects; events
 - e.g. earthquakes, traffic incidents, observations of rare plants or animals
- Changes of spatial properties: location, size, shape, orientation, altitude, etc.
 - e.g. movement of vehicles, urban growth
- Changes of thematic properties (attributes)
 - e.g. district population, daily temperature

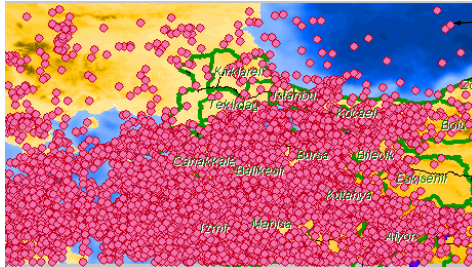
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Event Exploration: Major Questions

- How are the events distributed in space?
 - at a particular time moment or all events that occurred over a time period
- How are the event occurrences distributed over time?
 - E.g. how does event frequency vary?
- How does the pattern of spatial distribution of the events change over time?
- How are the events distributed in space-time? Are there any spatio-temporal clusters or/and trends?

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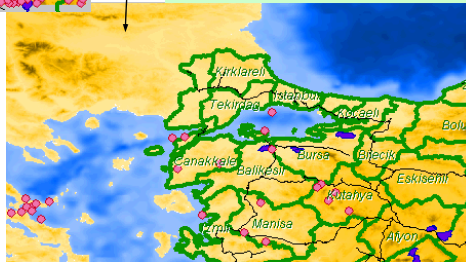
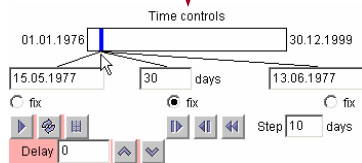
Spatial Distribution of Events



The small circles represent the earthquakes that occurred in Western Turkey and the neighbourhood between 01.01.1976 and 30.12.1999

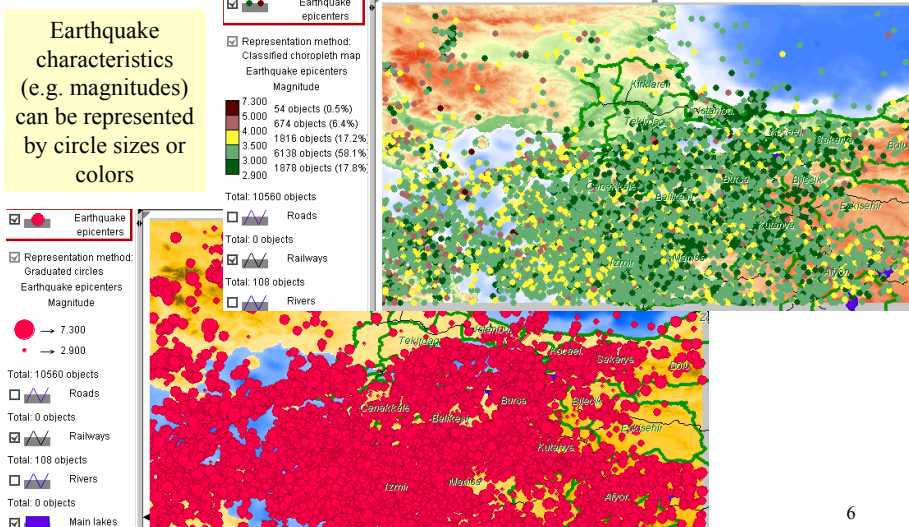
Here we see only the earthquakes that occurred during 30 days from 15.05.1977 to 13.06.1977

By applying the **temporal filter**, we can investigate the spatial distribution on any time interval



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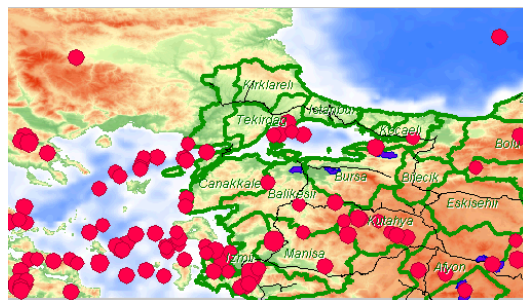
Spatial Distribution of Event Characteristics (1)



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Spatial Distribution of Event Characteristics (2)

To explore the spatial distribution of earthquake characteristics, we can also apply the thematic filter (dynamic query)

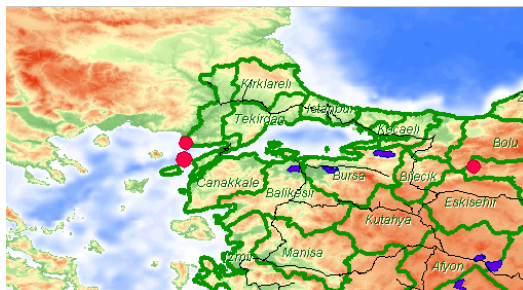
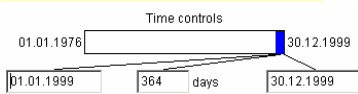


Now we see only the earthquakes with magnitudes 4 and more that occurred at depths not less than 20 meters

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Spatial Distribution of Event Characteristics (3)

The temporal and thematic filters may be combined

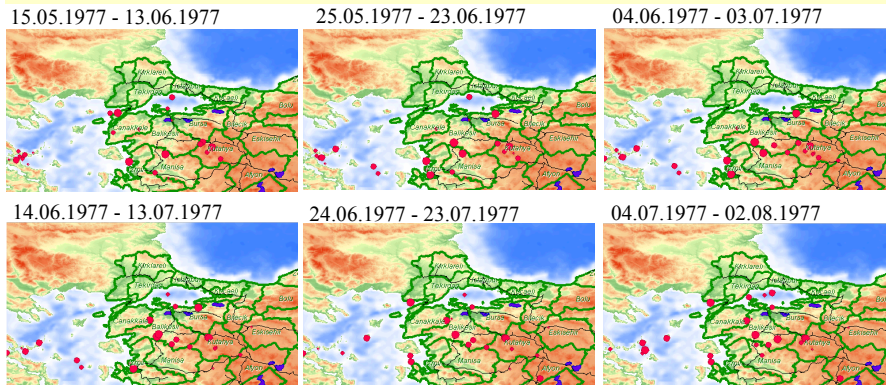


Now we see only the earthquakes with magnitudes 4 and more that occurred at depths not less than 20 meters during the year 1999

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Progress of Spatial Patterns over Time

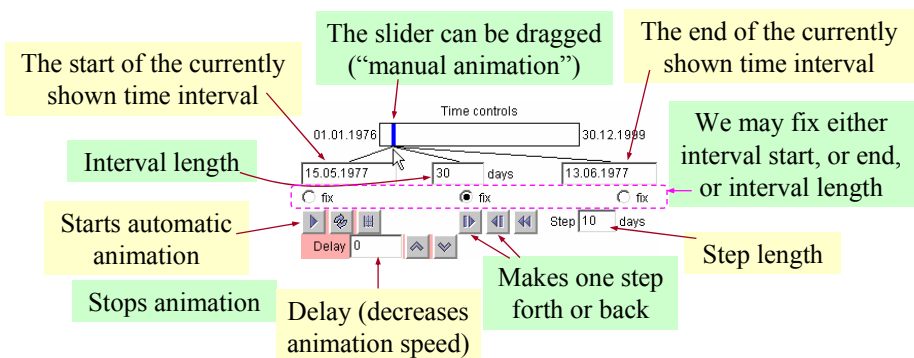
Map animation allows us to see how the spatial distribution of events and their characteristics evolve over time



Each animation frame in this example covers 30-days time interval. The step between the frames is 10 days. Hence, there is 20 days overlap between the adjacent frames.

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Controls for Time Filtering and Animation

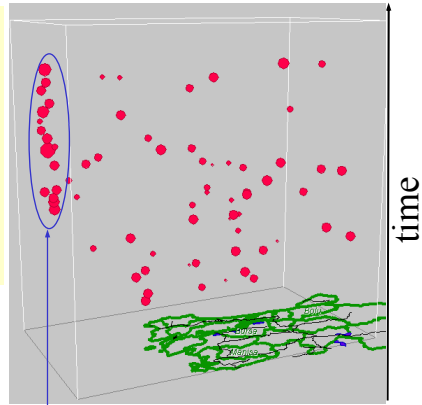
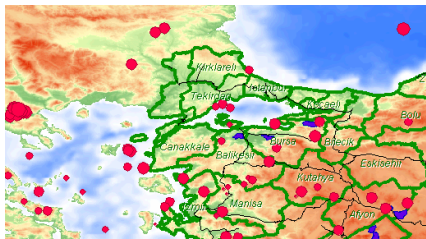


Fix interval start: on each step, step length is added to the interval end
Fix interval end: on each step, step length is added to the interval start
Fix interval length: on each step, step length is added to both interval start and end
 If the step length is less than the fixed interval length, we will have a time overlap between adjacent map states (animation frames)

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Event Distribution in Space-Time

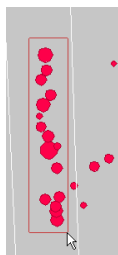
The perspective view (space-time cube) uses the vertical dimension to represent time while two other dimensions represent geographical coordinates. Events are placed in the cube according to their spatial locations and time of occurrence.



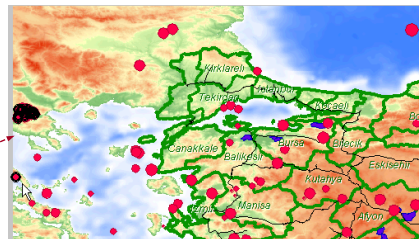
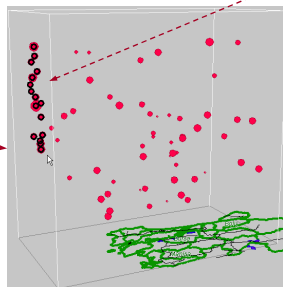
This is how a spatio-temporal cluster looks like, i.e. sequence of events close in space and time

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Using Display Links for Exploring Spatio-Temporal Distribution (1)



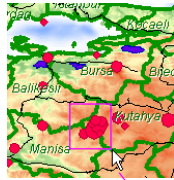
Let us select this "snake" in the cube and look where these events are on the map



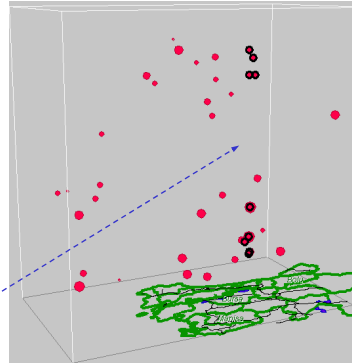
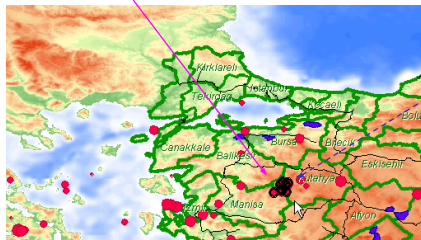
We see that all but one events really occurred very close to each other. We can conclude that this is indeed a spatio-temporal cluster and, hence, there may be a relationship between these events

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Using Display Links for Exploring Spatio-Temporal Distribution (2)



This is a spatial cluster of events. Let us see whether they are close in time

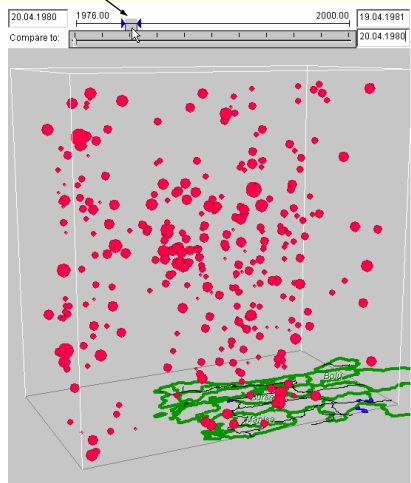


We see that the events seem to split into two sequences with a certain time lapse between them

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Manipulating Perspective View

Time focuser: defines the time subinterval to show



Viewpoint position: from what side and what height we look into the cube

Stretches the chosen time interval to the whole height of the cube

Dynamically updates the view in the process of time focusing and viewpoint changing

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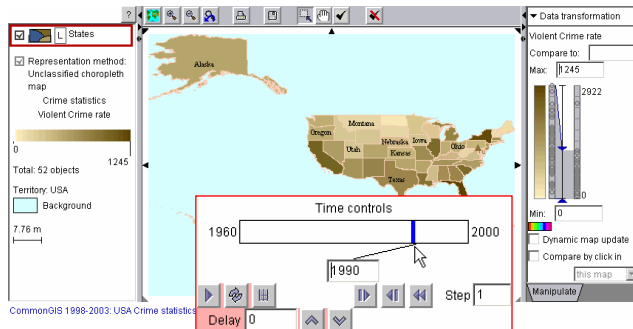
Exploring Thematic Changes: Major Questions

- How are attribute values distributed over the territory at a given time moment?
- How do the attribute values at a given place vary over time? (*local behaviour pattern*)
- How does the overall spatial pattern of value distribution evolve over time?
- How are different behaviour patterns distributed over the territory? Are there spatial clusters of similar behaviours?

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Exploring Spatial Distribution

Time-dependent data may be represented on a time map, which is manipulated through time controls and, in particular, allows animation

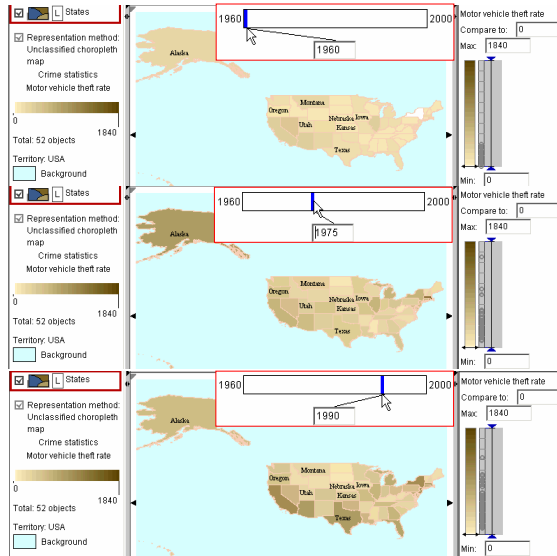


For a time map, we can use any representation method which is suitable for time-irrelevant data. Thus, a choropleth map is good for exploring spatial patterns

Using the temporal controls, we can look at the spatial distribution at any time moment. We can also run map animation and see how the pattern evolves over time.

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Time Map Properties

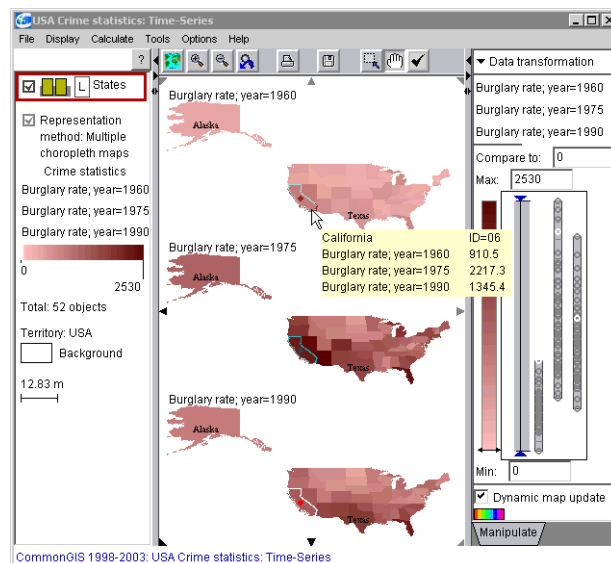


On a time map, the colour scale or diagram sizes are calculated taking into account the minimum and maximum attribute values on the whole time period. Therefore, for a particular time moment, the darkest or lightest shades (or largest/smallest diagram sizes) may not be present on the map.

Time maps allow all interactive operations available for usual maps, e.g. outlier removal

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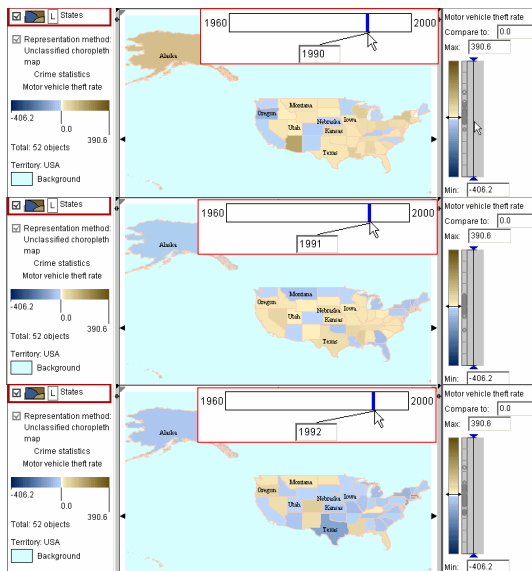
Map Series



Map animation is good for revealing general trends in the development of spatial patterns but less suitable for a more detailed investigation of changes.

For comprehensive comparison of states at two or more time moments, these states need to be visible on the screen simultaneously. Best of all is to use multiple maps displayed in a common panel and manipulated through a common set of controls.

Exploring Distribution of Changes



Instead of original attribute values, a time map can represent changes, that is, differences or ratios to the previous moment or to any selected moment

Here the maps correspond to years 1990, 1991, and 1992 and represent differences to the previous years. Positive differences (i.e. increased values) are shown in brown and negative differences (i.e. decreased values) in blue

How to Transform Data for Change Exploration

1) Click here!

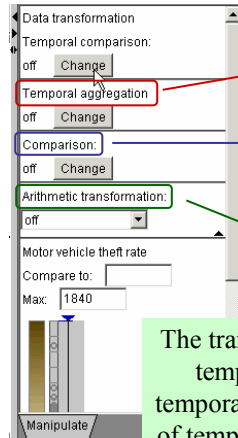
2) Push here!

3) Select one of these options

4) Select either differences or ratios

5) Enter the reference moment

Other Useful Data Transformations



Smoothing, value accumulation, residuals

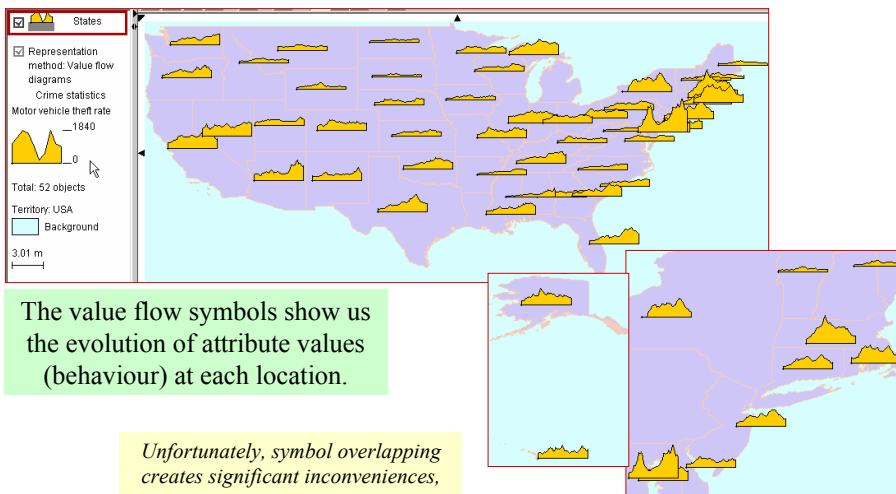
For each time moment computes differences or ratios to a particular object or value, to the mean or median among all objects at this moment

Value scale transformation, e.g. logarithmic

The transformations can be applied in a sequence. Thus, temporal aggregation may be applied to results of temporal comparison, general comparison – to the output of temporal aggregation, and arithmetic transformation – to results of all previous transformations

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Exploration of Behaviours (1)

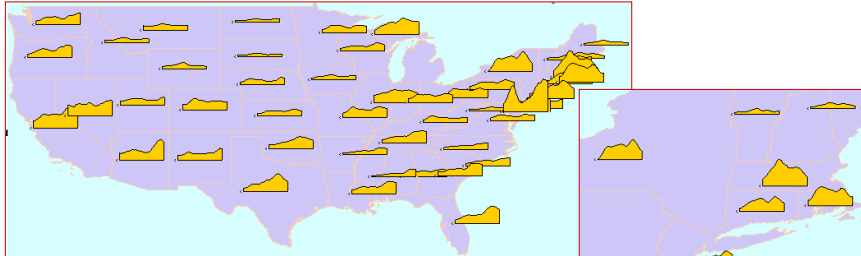


The value flow symbols show us the evolution of attribute values (behaviour) at each location.

Unfortunately, symbol overlapping creates significant inconveniences, and zooming does not always help

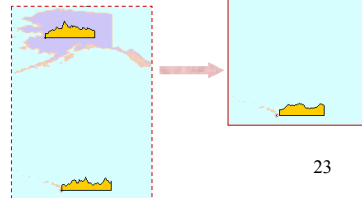
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Exploration of Behaviours (2)



Temporal smoothing allows us to disregard small fluctuations and see development trends.

Here the values for each year have been replaced by 5-year means. You can compare to the previous variant and see the effect of the smoothing.

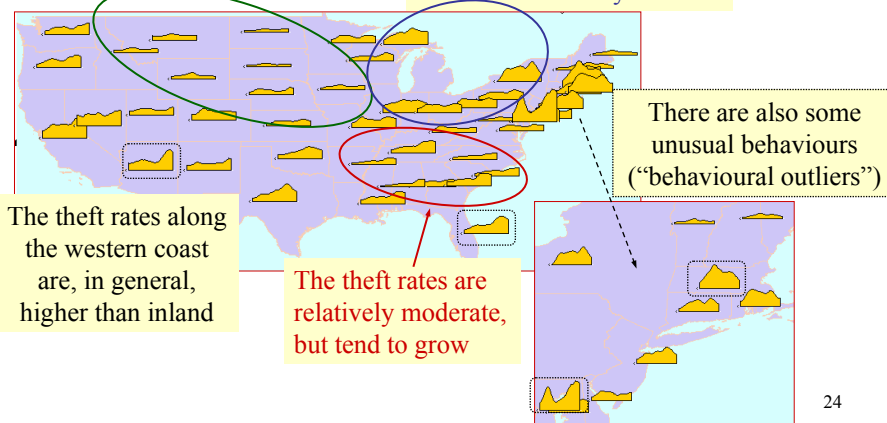


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Exploring Spatial Distribution of Behaviours

This appears to be a spatial cluster of similar behaviours

Around the Great Lakes, the theft rates are high, but tend to decrease in last years



The theft rates along the western coast are, in general, higher than inland

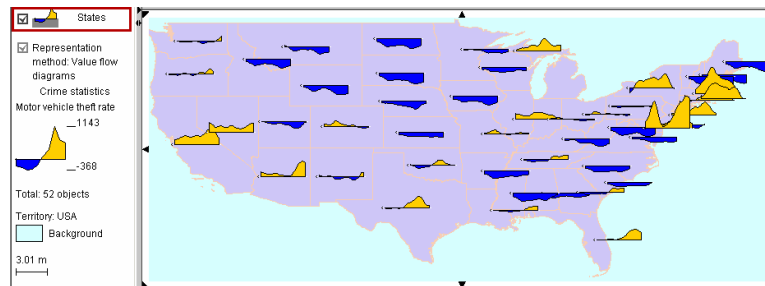
The theft rates are relatively moderate, but tend to grow

There are also some unusual behaviours ("behavioural outliers")

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Data Transformations for Behaviour Exploration

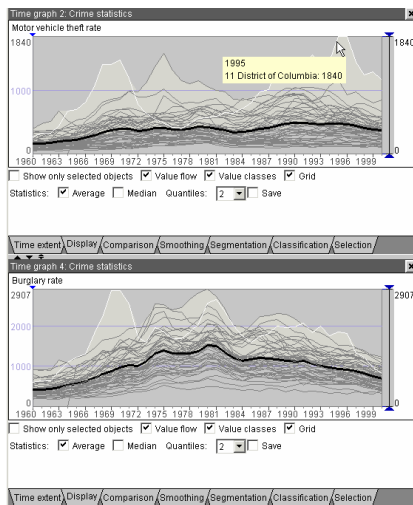
As with time maps, various data transformations can be applied to value flow maps.



Here we have applied the comparison to the mean: the values for each moment are replaced by their differences to the country's mean at the same moment. Yellow colour corresponds to positive differences, and blue – to negative. We have received a rather clear spatial pattern.

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Comparing Behaviours and Detecting General Trends

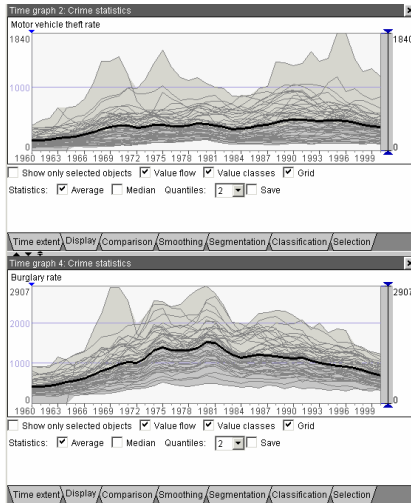


Putting all behaviours together, as in these time graphs, makes their comparison more convenient. When we point on any line, we may see the corresponding object's name and value.

Besides lines for individual objects, a time graph can also show us the “mean behaviour” (the line obtained by connecting each year means) or the “median behaviour” (obtained from each year medians). This helps us to understand the general development trends for the whole set of objects.

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Comparing Variations and Trends of Different Attributes (1)

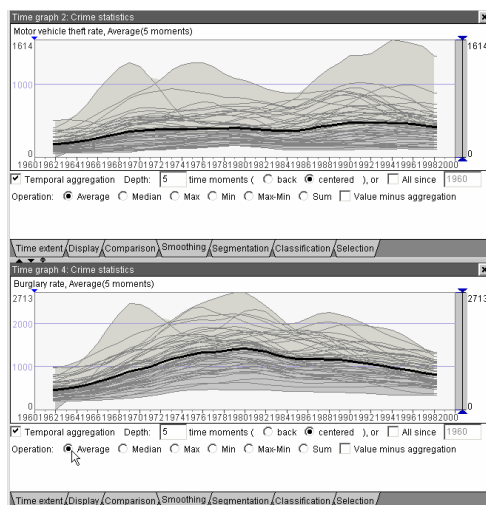


Time graphs are suitable for comparing temporal variations of two or more attributes.

Here we observe that the attributes “Motor vehicle theft rate” and “Burglary rate” have quite different trends of general development.

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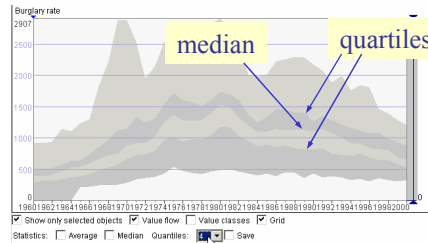
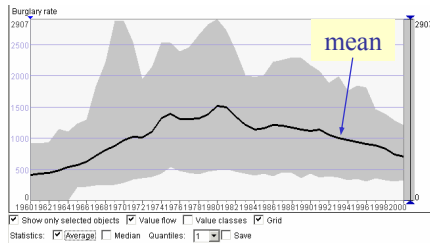
Comparing Variations and Trends of Different Attributes (2)



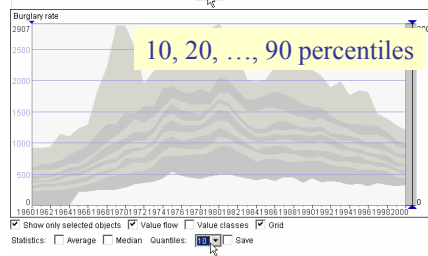
Smoothing (value averaging over intervals) mitigates small fluctuations and exposed the trends more clearly.

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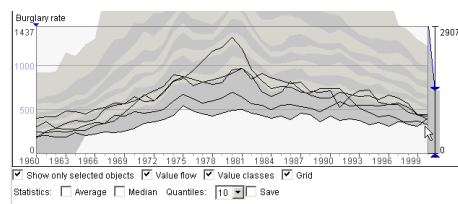
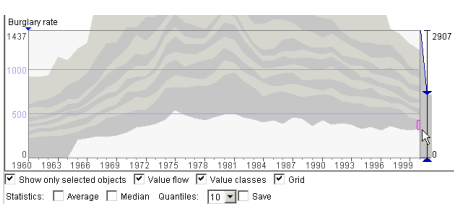
Varying Level of Detail in Trend Analysis



The mean or median behaviour line gives only a very coarse picture of the general properties of value variation. For a finer analysis, we may prefer to look also at the quartile lines or even smaller percentiles

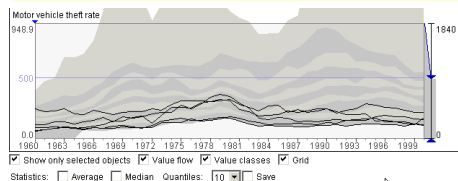
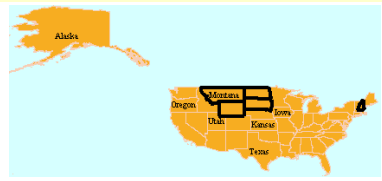


Combining Generic and Specific Information Display (Example)



1) We select the counties with burglary rates in 2000 fitting in the bottom 10%...

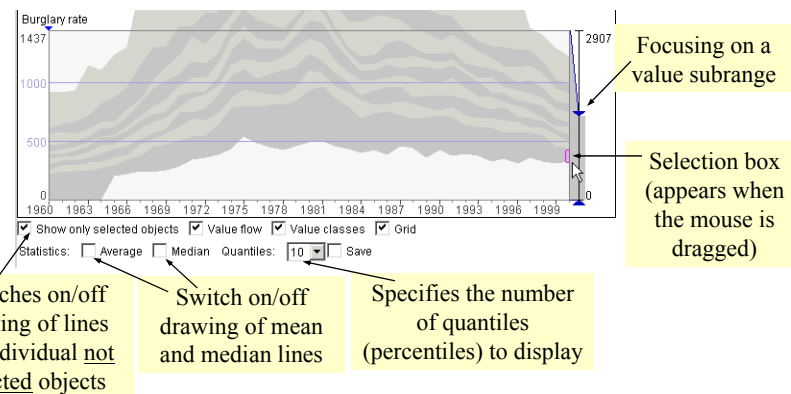
2) ...and look how these counties behaved over the whole time period 1960-2000



3) We also see where these counties are on the map...

4) ...and how motor vehicle theft rates progressed there

Explanation of Some Controls



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Summary

This lecture was supposed to

- explain what types of temporal variation may happen to spatial phenomena
- demonstrate that different tools are needed for analysing each type of variation
- show some state-of-the-art tools for exploratory analysis of spatio-temporal data
- explain what tasks each tool is good for

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