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Utilizing GeoTemCo for Visualizing Environmental Data

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Abstract

We demonstrate the use of the open source library GeoTemCo for the visualization and exploration of geospatial-temporal datasets from environmental sciences. With use cases from biodiversity, climatology and geophysics we investigate the capabilities and limitations of GeoTemCo, which types of research questions can be handled and how the observer is able to gain new insights about the given data.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology

1. Motivation

Many systems provide interactive visualizations to support the exploration and analysis of environmental datasets with geospatial and temporal metadata. Sometimes, these systems can be seen as isolated applications that are designed to answer a broad palette of research questions within a specific research area (see Section 2). This circumstance hampers the adoption of already developed problem-solving strategies for other disciplines. On the other hand, interoperable geographic information systems (GIS) are frequently used, e.g., for visualizing climate data [NSBW08], but well developed systems are expensive and their utilization is often challenging for users [GIS].

GeoTemCo [Geo] is a web-based open source libarary that provides a flexible interface for the visualization of geospatial-temporal data in the browser independent on the research field. The only requirement is that a given data item contains a valid location in form of a single latitude/longitude pair and a timestamp in XML time format [XML]. A map widget shows the geospatial distribution in form of non-overlapping circles whereas a time widget highlights the trend within a given dataset. The design of GeoTemCo [JHSS12, JHS13] allows for the comparative visualization of various datasets within one set of map and time widget. Various means of interaction support the comparative analysis of different topics in space and time and cooccurrences between datasets sharing the same place and time can be detected.

The benefit of using GeoTemCo to answer various research questions in domains like humanities or politics has already been proven. In this paper, we want to illustrate the utilization of GeoTemCo for visualizing, exploring and analyzing environmental data as an alternative to established solutions. For this purpose, we exemplify use cases from three environmental science research fields: biodiversity, climatology and geophysics.

2. Related Work

Visualizations play an important role when modelling and analyzing environmental data [KM04]. A lot of research has been done in the subdomains addressed in this paper. In the following, we give a brief overview over related approaches.

In his article [Bow00], Bowker pointed out the importance and mentioned the challenges for GIS when mapping biodiversity. GenGIS is one of the applications that transform genetic sequence data with given geospatial and ecological information into visual interfaces [PMZ*13]. Furthermore, visual analytics strategies can help to explore changes in biodiversity [SvL13].

Not only due to TV weather forecasts [HBH*00], meteorological visualizations have a long tradition. In Nocke's overview on the visualization of climate data, he declares visualization as one of the key technologies to be used by climate scientists [NSBW08]. Next to the analysis of recorded data, the ability to generate predictions with the help of visual interfaces is of particular importance in climatology [KLM*08, SBHS13].

Illustrative maps also play a substantial role when analyzing past natural hazards and assessing future risks [Dil05].

(a) Comparative Tagcloud (b) Locally extinct Species (c) Immigrated Species

Figure 1: *Discover extinct and migrated species with the comparative tagcloud*

Several providers of such data offer interactive maps on web-based platforms to explore natural hazard events [GPCC11, Natc]. Furthermore, the importance of a geospatial-temporal analysis of earthquakes in the vicinity of an active volcano has been shown in [HSX*12].

3. Visualizing Biodiversity Data with GeoTemCo

The European project BioVeL [Biob] provides a platform consisting of various computerized analysis methods for biodiversity data from cross-disciplinary sources. These so called workflows support researchers dealing with biodiversity issues in handling a broad palette of research questions. Under the name BioSTIF [Bioa], GeoTemCo is integrated in several workflows as one of the major visual interfaces the researcher interacts with. The map visualizes the geospatial distribution of a species' occurrences and the timeline shows the dates of a species' sightings.

The purpose of the Ecological Niche Modelling Workflow is to examine the predictions of future geospatial migrations of a species [SHBO13]. By overlaying a prediction map with the given occurrences, ecological niches can be explored by the observer. An example is given in Figure 2. Of particular importance for the researchers is also the ability to efficiently edit and clean aggregated data from many different sources. In the so called Data Refinement Workflow, GeoTemCo supports this task by enabling the user to visually pick and edit individual occurrences. Furthermore, the comparative tagcloud provided by GeoTemCo can be used to determine if a species is locally extinct or immigrated to a specific region. Figure 1 illustrates an example. Based upon two surveys on benthic fauna from 1921-1939 (red circles) and 2005-2009 (blue) in the vicinity of Kattegat and Skagerrak, a comparative tagcloud shows the species sighted on the Norwegian island Nordre Sandøy (Figure 1(a)). By displaying the tag *Not available* when the user highlights a desired species tag, locally extinct (Figure 1(b)) as well as immigrated species (Figure 1(c)) can be detected.

Overall, the researchers were able to discover a significantly impoverished benthic invertebrate fauna, approximately half of the species richness got lost during the past decades. As major reason for this fact the researchers mention industrial activities and the associated effects [OVB*14].

4. Visualizing Climate Data with GeoTemCo

The Storm Events Database, provided by the National Climatic Data Center [Nata], contains all significant weather phenomena in the United States from January 1996 to December 2013. For all entries, a date and the corresponding U.S. state is given and often also a precise location.

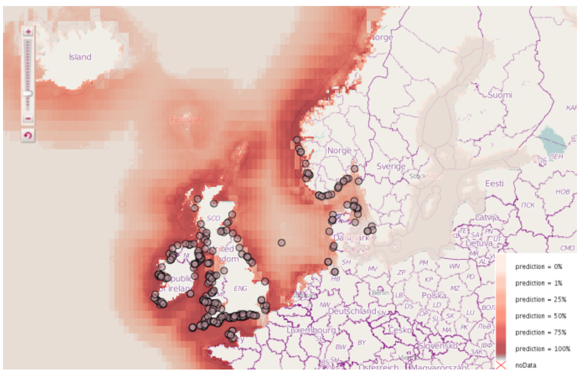


Figure 2: *Ecological Niche Modelling Workflow example*

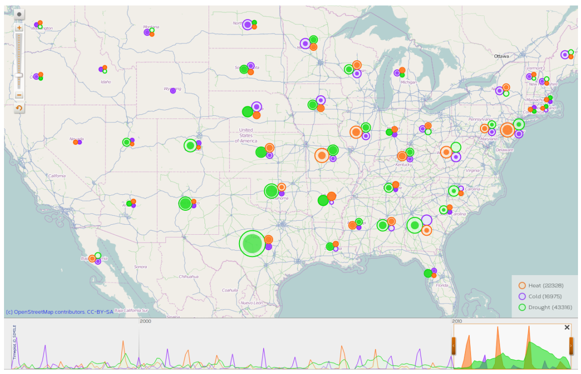


Figure 3: *Periods of heat, cold and drought mapped*

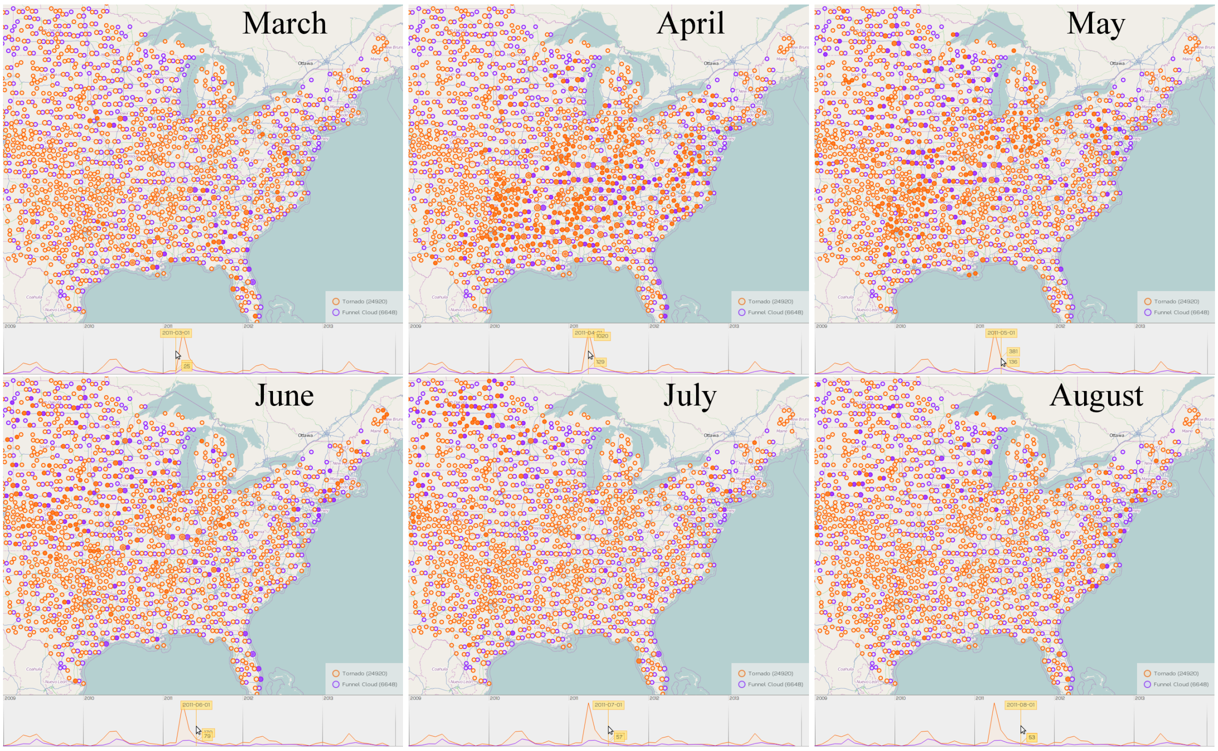


Figure 4: *Tornados (red) and funnel clouds (blue) in 2011*

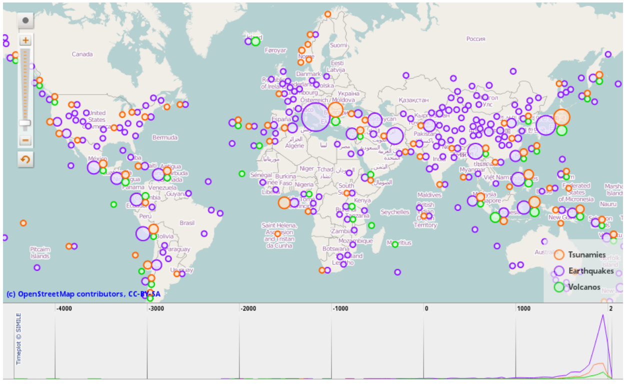
With the help of GeoTemCo, one is able to explore this data geospatially and temporally. Figure 3 shows all reported heat waves (red) and cold snaps (blue) in the given 18-year time frame in dependency of the state. Additionally, drought periods (green) are visualized. Before 2010, we can see a steady change between heat waves in summer and cold snaps in winter seasons of similar intensity. But from 2010-2012, this relationship breaks as we detect a vast number of heat waves in summer against a decreasing number of cold snaps in winter. Especially in the southern states (e.g., Alabama, Georgia), no cold snaps are reported anymore. As a consequence of the hot summer seasons, also the number of drought periods increased to a hitherto unknown extent (45% of all reported drought periods in the 18 year time frame have been reported in the last 4 years). These facts might be an indication for global warming and the subsequent climate change in the United States.

Another weather phenomenon is visualized in Figure 4. For the occurrences of tornados (red) and funnel clouds (blue) exact locations are given (if a funnel cloud touches the ground and causes damage, it becomes a tornado). From March to July 2011, we discover a movement of the tornado season from south-east (Florida) to north (North Dakota). In August, the season seems to be over. A similar behavior could also be detected for other years (2000, 2003, 2010). Furthermore, it seems that the farther away from the temporary center with most tornados, the lesser the probability that a funnel cloud turns into a tornado, since lots of individual funnel clouds appear without tornados in the immediate vicinity (e.g., individual funnel clouds in the south eastern states in June).

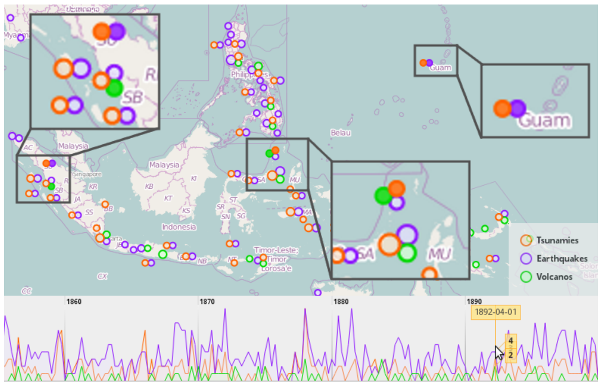
5. Visualizing Natural Hazards Data with GeoTemCo

The National Geophysical Data Center [Natb] provides long term data about significant earthquakes [Ear], tsunamies [Tsu] and volcanic eruptions [Vol] in the last 6000 years. Each of these events is associated with a timestamp and a geographical location in form of a latitude/longitude pair. The given timestamps have a varying granularity, but for most of the events a date is given. The Natural Hazards Viewer [Natc] visualizes these events as different shapes indicating different event types on a map. Shape size is used to codify the intensity of an event and color gives a hint about the number of victims (0 or unknown, 1-10, 11-50, 51-100, 101-1000, >1000). But the given timestamps are not utilized, so that a geospatial-temporal exploration is not possible. Furthermore, the enormous amount of occlusions hampers the geospatial comparison and the accessibility of individual events.

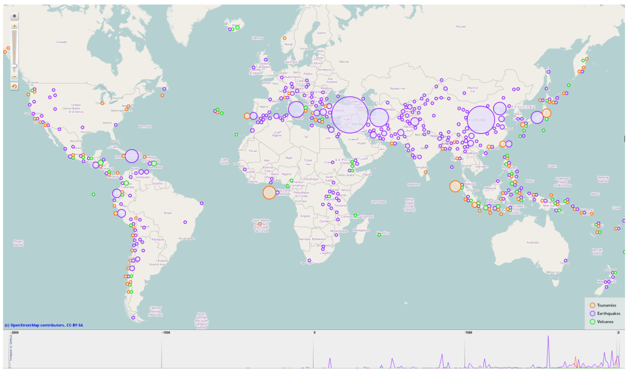
Figure 5(a) shows the same data visualized with GeoTemCo. The geospatial aggregation highlights that lots



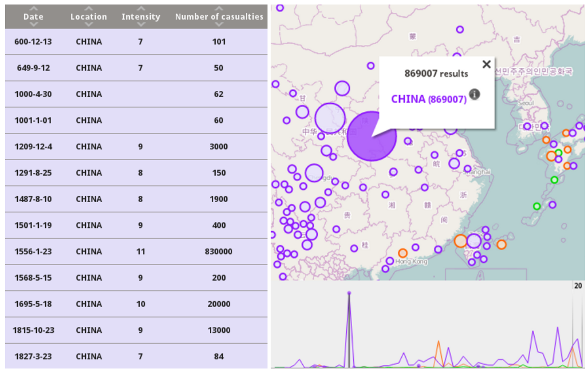
(a) Natural hazards overview



(b) Cooccurring natural hazards in Oceania in 1892



(c) Number of victims overview



(d) Earthquake victims in central China

Figure 5: *Natural Hazards visualized with GeoTemCo*

of earthquakes and tsunamies have been reported for the Mediterranean, which is not visible in [Natc]. The provided timeline enables the discovery of cooccurring natural hazards at the same location and with the same date. Examples in Oceania are shown in Figure 5(b).

Multiple metadata information cannot be displayed in one instance, but shape size can also be used to codify, e.g., the number of victims (Figure 5(c)). It now appears that earthquakes (≈7.5m) caused significantly more victims compared to tsunamies (≈1m) and valocano eruptions (≈0.2m). Most deaths have been reported for the Middle East (≈2.6m). Periodically, earthquakes occured in central China (Figure 5(d)), the most destructive one in 1556 with around 830.000 victims. The last reported earthquake for this region in 1827 should be a reason for particular attention in the near future.

6. Summary

In this paper, we demonstrated the utilization of the library GeoTemCo for visualizing environmental data in three scenarios. Firstly, we showed how changes in biodiversity, e.g. locally extinct or immigrated species, were discovered within the European project BioVeL. Secondly, we were able to visualize effects of global warming and relationships between several weather phenomena in the United States. Thirdly, we used GeoTemCo to display and compare significant natural hazards geospatially and temporally. Cooccurring natural hazards could be found and the visualization gave occasion to speculate about potential future risks for certain regions.

We were able to show that a utilization of GeoTemCo in the field of environmental sciences facilitates the discovery of certain geospatial-temporal patterns and coherences between various datasets. But despite its offered capabilities, the usage of GeoTemCo is limited to processing data elements with exact locations in form of single latitude/longitude pairs and single timestamps. For instance, some of the climate events in Section 4 comprise a start and an end date as well as a start and an end location. An extension of GeoTemCo that compares such trajectories of various datasets in space and time could answer a broader set of research questions.

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