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A Visual Analysis of Citizens' Weather Reports for the Characterization of High-Impact Weather Events

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Abstract:

In this work, we describe the research, methodology, and results of our approach to visually explore, analyze, and extract potentially relevant information captured by the citizens' weather reports. Citizens' observations of weather phenomena represent a unique data set that can complement other authoritative data, such as remote sensing, weather stations, and other sensing devices. Scientists can benefit from using these reports as a new enhanced data source to enrich their analyses.

For these purposes, we started our project at the beginning of 2022 when MeteoSwiss shared their collection of citizens' observations on weather conditions reported by users of the MeteoSwiss mobile application. For several years, MeteoSwiss has been collecting citizens' reports of hail events through their mobile application and using these reports for scientific purposes (Barras et al. (2019)). Since November 2021, MeteoSwiss has started gathering a more comprehensive list of weather conditions, such as lightning, hail, wind, icy conditions, and fog. Users of the mobile application can report weather conditions in their surrounding areas, with the option of including images. Some of these conditions are difficult or even impossible to capture by remote sensing, which makes the utilization of citizens' reports of high value to complement or verify data from remote sensing devices. We followed an iterative and participatory design process divided into three main phases. In each phase, we developed prototypes, gathered experts' requirements, designed and ran domain experts' studies, and collected feedback to improve our solution's features.

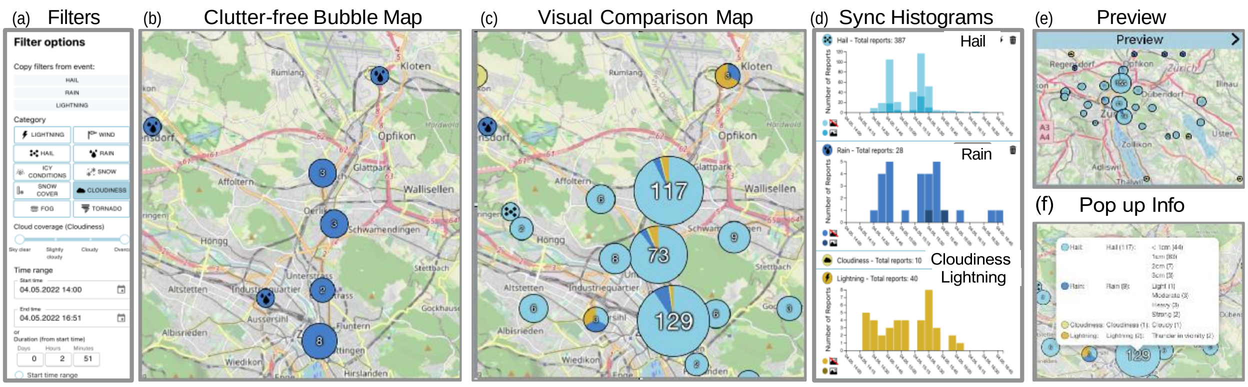

Figure 1. Results of Phase 1. (a) shows the filtering options users' can configure in order to explore specific events, (b) shows the novel clutter-free map visualization, (c) shows the visual comparison of multiple categories in the map by using pie charts, (d) shows the temporal distribution of reports per category, (e) shows a preview of the whole map view without zoom-in, and (f) additional statistical information of the reports.

The main goal of *Phase 1* was to facilitate the characterization of high-impact weather events over time and space, as reported by citizens. We formulated the following research questions: What characteristics of weather events are reported by citizens, and how are they linked through the reports? What patterns or unexpected activities can be detected by visually inspecting weather reports?

We proposed a visual analysis tool to answer these questions. Our tool facilitates the exploration and comparison of multiple weather conditions reported by citizens and their underlying weather events (see Fig 1). We presented our solution to key domain experts, gathered their feedback, and iterated our design. Our visual design combined spatial and temporal views and a flexible set of parameters and filters to assist the user in characterizing weather events, identifying temporal spikes for particular events, and the spatio-temporal evolution of citizens' contributions (Haessig et al. (2024)). We validated our visual design through a series of interviews with domain experts from Switzerland, Austria, and Argentina. The main feedback from the experts was the need for features to compare weather reports and radar observations and to explore metadata and images submitted with the reports interactively.

We iterated our visual design incorporating the domain experts' requirements in *Phase 2*. The main goal of this phase was to facilitate the visual comparison of radar data and citizens' reports, explore reports' images and image metadata, and re-engineer the tool to make the software more robust. In addition to the research questions of *Phase 1*, we tackled the following question: How much visual correlation do citizens' reports and radar observations have over time and space? We added a new radar data layer to the current map view and explored diverse alternatives to juxtapose the reports without causing information overload and clutter. We redesigned our tool by using complementary color schemas to differentiate the two sources of information and limited the clutter-free map visualization to individual glyphs. These design decisions allowed us to maintain a simple and clean visual design (see Fig 2). We used animations as an interactive feature to explore the spatio-temporal evolution of the radar data and reports. We added the option to show the accumulated reports over time to provide a qualitative estimation of the spatial coverage of the reports. Finally, we added a new feature that, given a subset of selected reports, visualizes nearby similar reports and their images. This new feature was implemented by using spatial clustering and by matching the names of report categories. A prototype is available at https://weatherva.ifi.uzh.ch/. During this phase, the software implementation was re-engineered to improve component loading and to increase the software's performance.

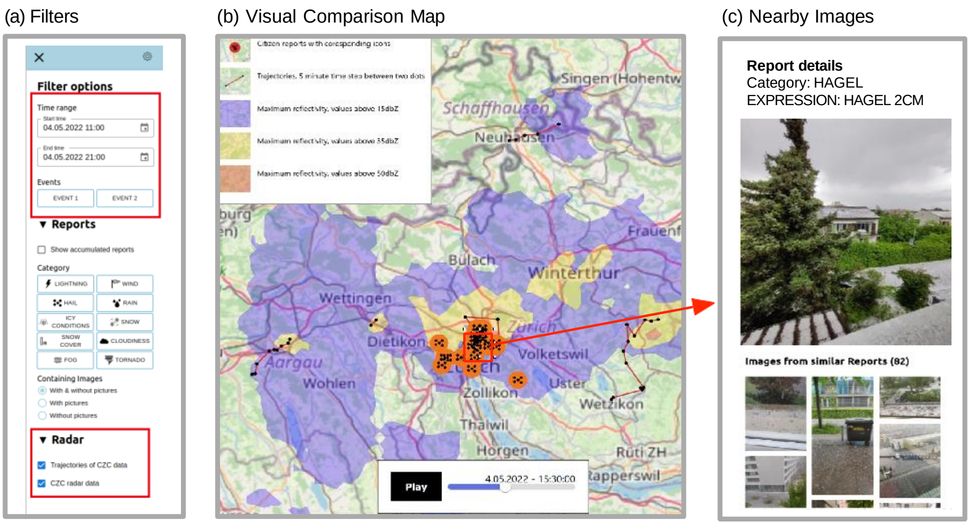

Figure 2. Results of Phase 2. (a) shows the filter options that users can configure to explore specific events, (b) shows the map view comparing radar data, citizen reports, and trajectories, (c) shows a detailed view of the selected reports and nearby images of similar reports.

Ongoing efforts in *Phase 3* include further research on analyzing impacts and damage on the ground based on information provided by citizens' reports and additional authoritative data sources. We foresee the need to develop new information layers, such as land use maps and demographic information, and to apply AI-based algorithms to extract relevant information from the images. We are also working on further re-engineering *Phase 2* visual tool as open-source.

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