Utvikling av et verktøyspanel som visualiserer naturskadeutbetalinger

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Tomasz Opach and Jan Ketil Rød: Developing a dashboard visualizing compensation data on damages caused by extreme events

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As a response to the demand for visualization supporting climate change adaptation, we present a visual dashboard that visualizes insurance compensation data on damages caused by weather-related extreme events. Open access is appreciated by users and we have therefore developed the dashboard with open source JavaScript libraries. The dashboard consists of coordinated and multiple views, since this kind of configuration has been recognized as suitable for presenting multivariate time-series data. Focused interviews held with emergency officers confirmed that a dashboard for visualizing insurance compensations could be of great value to stakeholders. Such configuration is indeed effective and triggers discussion on climate change impacts. Our further plan for the tool, therefore, includes a crowdsourcing functionality that collects local perspectives on what constitutes a resilient community.

Keywords: geographic visualization, open source, visual dashboard, insurance compensation, natural hazards

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1. Introduction

A growing need to understand climate change effects calls for easily available climate-related data as well as information on places at risk (Overpeck et al., 2011). Such data are typically provided through climate services, and many experts advocate the use of visualization tools to support climate change adaptation and mitigation actions among emergency managers and urban planners (Johansson et al., 2016, Kvitsjøen et al., 2018). Further, various assessment methods exist that enable individuals to identify communities particularly exposed and vulnerable to climate change induced risks. Although such assessment are generally available, they are for many not easy to deal with and not always trusted (Rød et al., 2015). To succeed with climate change communication, there is therefore a growing recognition that information must be credible, localized and visualized (Shaw et al., 2009).

Insurance compensation is a common societal resilience strategy as it increases the ability of a community to recover from adverse events (Cutter et al., 2014). Visualizing insurance compensation data may therefore have a potential to be useful for increasing local communities' resilience. Unfortunately, insurance data are seldom publically available. During the last few years, however, the Norwegian insurance sector has changed its policy regarding open data (Brevik et al., 2014). Our main contribution to this new opportunity is an attempt to use data on insurance compensation covering damages caused by natural extreme events, and to design a dashboard for conveying such information to stakeholders. Moreover, although many commercial technologies for visual dashboards exist such as Cluvio or ClickData, our ambition is to develop the dashboard only with freely available open source web technologies. Here, we report on our research that aimed at:

– designing a visual dashboard that lets users investigate the geographical and historical variations in insurance compensation related to damages caused by extreme events (storms, river flooding, storm surges, landslides, and pluvial flooding),
– using available open source software and web technologies to design the dashboard in a way that can be replicated by others, also by low-cost initiatives,
– designing a crowdsource platform that allows users to identify and weight factors important for how resilient a municipality is, and to use this collected information to generate a bottom-up created resilience index for Norwegian municipalities.

Neither specific plugins nor a specific web browser is needed to use the tool, but it performs best with Google Chrome. The most recent version of the tool can be freely accessed via a link: http://folk.ntnu.no/opach/CLIMRES.

2. Visualization tools facilitating adaptation to climate change

There are many examples of successful visualization tools for decision-making purposes. They support policy-making processes through information foraging and possible impact analysis (Kohlhammer et al., 2012); they are also used in epidemiology (Edsall, 2003) and in climate change adaptation (Neset et al., 2016, Kvitsjøen et al., 2018). Regarding the latter, climate services mainly focus on climate data and models (Overpeck et al., 2011) as well as on the primary impacts of climate change such as precipitation or temperature change (Neset et al., 2016). Climate services are therefore often ineffective in meeting the needs of planning communities that rather expect support to develop applicable climate change adaptation strategies (Goosen et al., 2014) and to monitor the scale of potential damage. Still there is a need for better climate-change-related communication (Wibeck et al., 2013), easy-to-understand climate-related data (Bohman et al., 2015), climate change adaptation measures (Neset et al., 2016), and successful participatory functionalities that collect local knowledge (Simão et al., 2009).

From previous research (Rød et al., 2015) we have experienced that visualization of factors making local communities exposed and vulnerable to natural hazards are tabloid material. Although it may be important to identify *where* the most exposed and vulnerable local communities are in order to carry out strategic climate change adaptation, one always needs to take a number of methodological choices that may influence the results. Consequently, the ranking that such assessments imply is debatable. It is therefore likely that local societies marked as very exposed and/or vulnerable, simply will not accept the assessment. Instead of constructed indices, we believe using insurance compensation data is more likely to be accepted as objective facts. This is data about the cost to cover damages due to extreme weather related events such as landslides, storm and storm surges, riverine flooding and pluvial flooding. Climate scientists have long anticipated an increase in the frequency and intensity of extreme weather events, and have recently been able to establish this relationship with high certainty (Herring et al., 2018).

Using data on payments from insurance claims for damages caused by extreme events still rank local societies, but our hope is that the discussion that these visualizations may trigger will be about the societies' preparedness to cope with such extreme events, and not about methodological issues. Visualization of insurance damage data may therefore better fulfil stakeholders' needs for strategic adaptation to climate change since such data depict the spatial and temporal consequences of weather related extreme events in a straightforward way.

3. Data on compensation for damage caused by extreme events

A major problem with insurance compensation data is that they are generally unavaila-

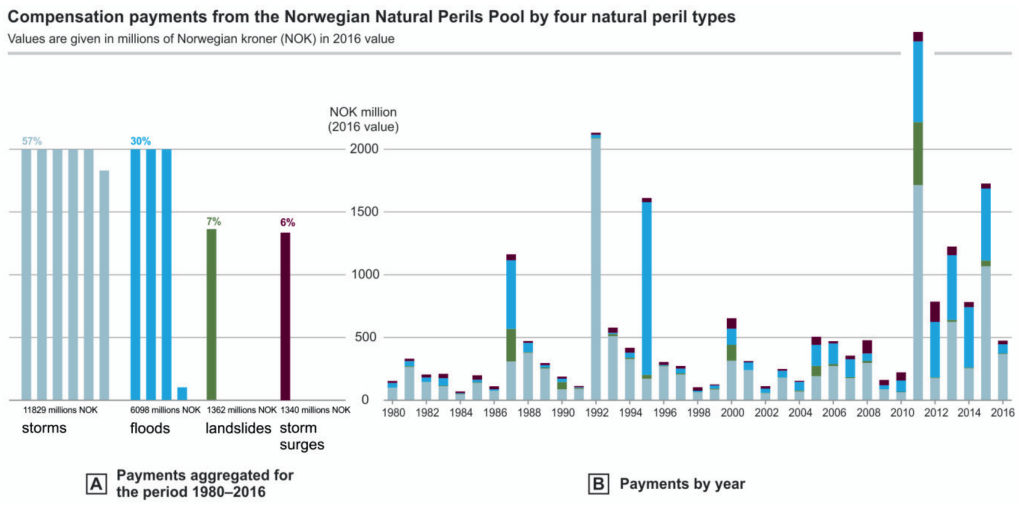

Figure 1: Compensation payments from the Norwegian Natural Perils Pool during the period 1980–2016 by four natural peril types: A, payments aggregated for the whole period 1980–2016 and B, payments by year. Values are in millions of Norwegian kroner (2016 value)

ble. Insurance companies are typically restrictive because such data are necessary to optimize and plan insurance products, and their availability could give other companies competitive advantages. However, the situation is different in Norway that has one of the most comprehensive insurance arrangements in Europe regarding compensation for damage to buildings caused by natural events. The arrangement is called the Norwegian Natural Perils Pool (NPP). It was established in 1979 and has registered compensation payments since 1980. All buildings with fire insurance, in Norway, are by law also insured against losses caused by extreme events including storms, floods, landslides, storm surges, volcanic eruptions, and earthquakes. Because all insurance companies that sell fire insurance in Norway subscribe to the NPP arrangement, there is no competition between them, and it is less important to have restrictions on the availability of insurance-compensation data (Rød, 2013).

Figure 1 provides an overview of the NPP data for the period 1980–2016. Storms are the most damaging extreme event in Norway (see [A] in Figure 1). Huge parts of the storm-related compensations were paid for damage caused by winter storms. One example is the 'New Year's Day' storm that hit Norway 1 January 1992. For a long time afterwards, the year 1992 featured as one of the years with the highest payment from the NPP (see the peaks in [B]), but in 2011, the total payments rose higher because of a several extreme events of all four peril types.

Figure 2 provides a general overview of the geographical variation of insurance compensation due to damages from storms, floods, storm surges, and landslides. Whereas the coastal municipalities from the southwest to the north have received higher compensation for damages caused by storms than the inland municipalities, the Lofoten islands and the southern coastal municipalities have received the majority of payments relating to damage caused by storm surges. Flood compensations have been the highest for the eastern inland parts of Norway, whereas western Norway has had a higher compensation for damages caused by landslides.

According to Fisher et al. (2001), geovisualization tools that feature extensive interaction capabilities work better than simple static maps in conveying messages and informing users on shown ideas because they engage them with those ideas through interaction. Interaction is a prerequisite for these qualities to be realized. Users need to be able

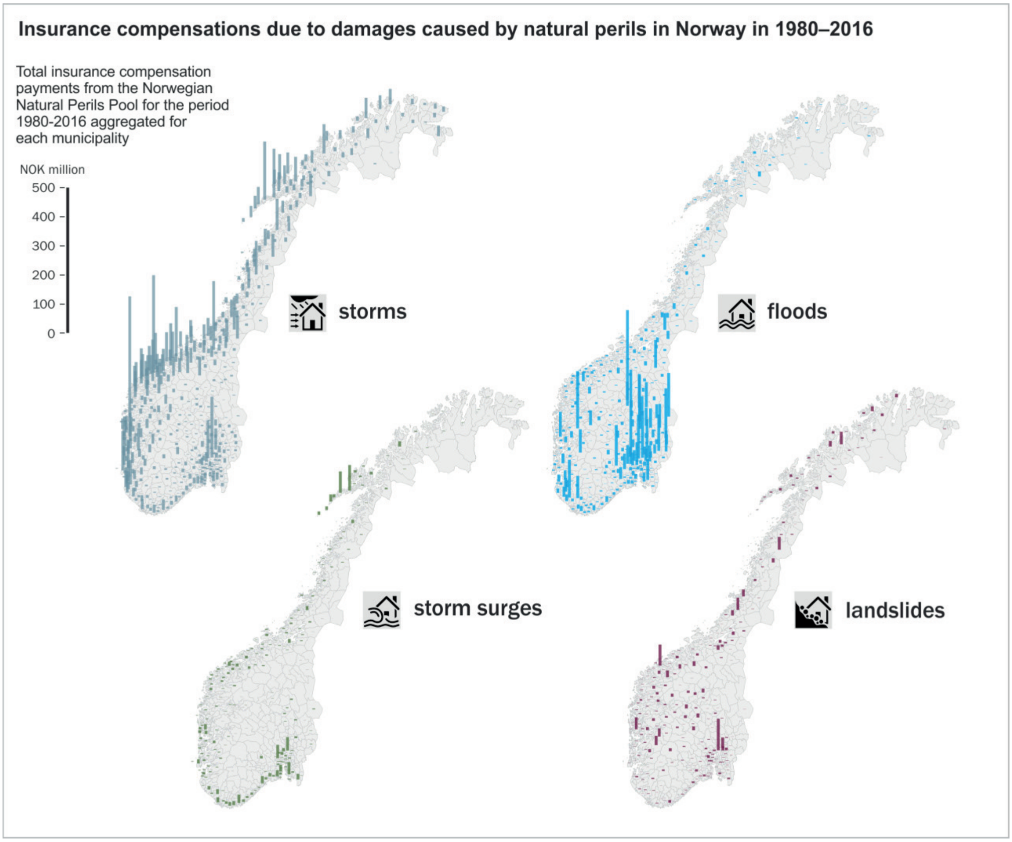

Figure 2: Geographies of compensation payments from the NPP by type of extreme event. Values are in millions of Norwegian kroner (2016 value) summed for the period 1980–2016.

to actively interact with the data, and not only to view data in a static form. Although insurance compensation data are easy to understand, their investigation needs proper tools that give users ready access to particular data items. Visual dashboards make such exploratory analyses more productive because they facilitate the discovery of spatio-temporal patterns and even new knowledge (MacEachren and Kraak, 2001).

4. The ClimRes visual dashboard

Four main stages constituted the sequential software-development framework applied when working on the dashboard: identification of requirements, prototyping, verification, and improvement (Figure 3). The dashboard was called ClimRes as the research was conducted as part of the project aimed to seek solutions to facilitate making places more resilient to climate change.

4.1 Requirement identification

Drawing upon previous feedback was the starting point. Then, the needs for visualization tools facilitating adaptation to climate change were analyzed. Next, in the input-data analysis the concern was about proper dimensionality representation of the NPP data. It was of importance to provide not only their absolute values but also their normalized scores in order to be able to compare municipalities that either prospered or declined in terms of population. Two decisions were made: to adjust the data for inflation and to normalize them by using population data and number of compensation claims.

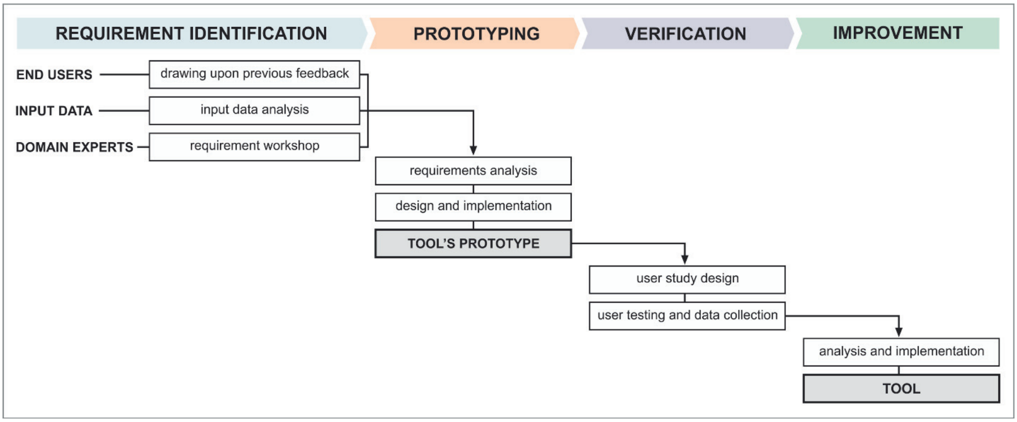

Figure 3: Conceptual framework for the geovisualization-tool development applied in the study.

Finally, we were not concerned with controlling the spatial resolution, because the NPP data were available only as aggregated figures at the municipal level. As a result, we gathered a dataset comprising 426 polygons (municipalities) where each polygon featured 37 timestamps (the years from 1980 to 2016) described by 9 variables: compensation payments in NOK by natural peril type (storms, floods, storm surges, and landslides), number of compensation claims by natural peril type, and number of inhabitants. Hence, each polygon was described by 333 variables (37 timestamps × 9 variables). This has later been extended by further 9 variables on water intrusion damage due to pluvial flooding, which are available since 2008.

The requirement workshop with six academic colleagues resulted in most operational decisions. The workshop was structured around the tool's data content and its functionality. Regarding the tool's functionality, four key tasks with suggestions on how these could be executed were determined; however, no particular task taxonomy was followed in order to define them. They were formulated as specific for the tool's context. No particular user scenario was established. The tasks mainly concerned the 'retrieve value' operation known from Amar et al.'s taxonomy (2005) and the 'locate' operation known from Wehrend's (1993). We thereafter determined visualization and interaction techniques of importance for the tasks.

Because three visual components, a map, a chart, and a table, appeared frequently in the suggestions, we recognized them to be of value to the tool. This finding along with the need for showing the multidimensionality of the NPP data influenced the decision to design the tool as a coordinated and multiple views (CMV) dashboard but not overloaded with interactive functions and fitting moderate user capabilities. The latter requirement was necessary because we hope the tool can trigger and support the engagement of stakeholders without any GIS skills. According to findings reported in the literature (Bohman et al., 2015, Hallisey, 2005, Wang Baldonado et al., 2000), CMV tools can work for a wide spectrum of users under the condition that visualization and interaction techniques are not too sophisticated and their number and variety is not too extensive. Therefore, the identified requirement was to keep the tool's functionality and design as simple as possible and consisting of only three views. Because usability encompassed low training demand, broadly known choropleth mapping technique and a bar chart were used for the map and the data display, respectively, whereas the raw data were shown in the table display (datagrid). Additionally, bar chart glyphs (small and simplified bar charts) have been embedded into one of the table's columns. For the interaction techniques, we included the most common functions such as zooming, panning, and selecting.

Table 1. Four key tasks that the ClimRes tool is intended to support.

#	Key task	Execution
1	How much compensation have inhabitants in a particular municipality received due to damages from a certain extreme event?	• Search by location (map) and read the value (from map, chart, or table) • Search by name (searching mechanism or table) and read the value (from map, chart, or table)
2	How is the spatial variation among Norwegian municipalities in terms of compensation due to various natural extreme events?	• Search by location (map), change variables (map layers), read the values (from map, chart, or table) • Search by name (searching mechanism or table), change variables (map layers), read the values (from map, chart, or table)
3	How is the temporal variation within certain municipalities in terms of compensation due to a certain extreme event?	• Search by location (map), change year (map, chart, or table) and read the value (from map, chart, or table) • Search by name (searching mechanism or table), change year (map, chart, or table) and read the value (from map, chart, or table)
4	How does a particular region (e.g., county) vary in terms of compensation due to a certain extreme event?	• Search by location (map) and read the values (from map, chart, or table)

4.2 Prototyping: Design and implementation

The tool has been developed as a single-page application based on HTML, CSS, and several open-source cross-platform JavaScript libraries. Its structure was built with the AngularJS JavaScript-based open-source front-end web application framework that provides a client-side model–view–controller (MVC). The AngularJS framework reads the HTML page with additional tag attributes and interprets those attributes as directives to bind input or output parts of the page to a model that is represented by standard JavaScript variables. For the tool's visualizing components, we used free JavaScript libraries such as OpenLayers3 for interactive web mapping and D3 for data-driven displays. We employed these two libraries as they both have an extensive and freely available documentation with many examples and tutorials. Furthermore, in contrast to other similar libraries, they allow control over the final visual result.

Apart from the above libraries, several others were also used to implement specific functionalities: jQuery was used for interactive effects, SlickGrid for an interactive spreadsheet, and jQuery Sparklines in order to display small inline charts. The use of a single-page application strategy with open-source libraries causes that no extra plug-in is needed to run the tool (i.e., thin-client strategy). The benefit of this approach is the ability to update and maintain the tool without distributing and installing software on the client's computers.

No specific map server has been established for the tool. Its map display uses – as a georeference background map layer – a commonly available WMS provided by the OpenStreetMap (OSM) collaborative project. Furthermore, the tool's insurance data are stored on the server as JSON files separately for polygons (municipalities and counties) and points (proportional point symbols). The data from JSONs are retrieved by OpenLayer3's methods that symbolized them on the client side. As a result, no symbolization is executed on the server side.

Although the ClimRes tool's interactive functions were designed to be conceptually similar to the linkages offered in other multiple-view visualization environments, the goal was not to try an innovative visualization approach, because this could cause stakeholders' reluctance to participate. We therefore followed the rule of parsimony (Wang Baldonado et al., 2000) (minimal use of multiple views) and designed a simple tool with basic visualization techniques. The tool's views are dynamically linked and equipped with a range of interaction techniques. Nevertheless, as decided at the requirement identification phase, the variation in the techniques has been intentionally limited to common techniques only, such as map panning and zooming.

4.3 Verification with end users

Feedback was gathered at an early stage of development through two separate meetings organized in two emergency-preparedness and crisis management offices of two Norwegian counties in January 2015. The directors of the offices along with their deputies attended the meetings. Four people in total were thus interviewed. Because it is the responsibility of emergency offices to follow up on how well municipalities adapt to climate change, we believe that the individuals, as directors of emergency bureaus, were suited as participants for the empirical verification. They had comprehensive experience and knowledge about the stakeholders' needs because they manage, direct, and plan their actions.

As the individuals were experts in the matter both meetings were arranged as focused interviews. First, we sent out information with the tool's URL address ahead of time and asked the individuals to get acquainted with the dashboard before the interviews. Introductions along with software demonstrations were given before the interviews so individuals had opportunity to recall the dashboard's features. Each interview lasted two hours and was recorded with the permission of the participants. The interviews were arranged around two issues concerning the functionalities of two of the tool's four modes (Table 2). Moreover, the individuals' concerns about the tool's content and overall design were gathered; we asked them whether they liked splitting the tool's functionality into separate modes and whether they would be eager to use the tool in their tasks.

Table 2. Interview guide for the focused interviews.

#	General issue	Detailed questions
1	Usability of the 'map display' mode	▪ Is the interface easy to understand and learn? ▪ Is such a simple functionality desirable for specific tasks or purposes? ▪ Which mapping technique seems to be more meaningful regarding the NPP data (gives better visual effect), choropleth or symbol mapping technique?
2	Usability of the 'interactive dashboard' mode	▪ Is a combination of three views easy to learn and use? Would a tutorial be desirable? ▪ Is such an approach desirable for some purposes? ▪ Are there any clear benefits of using a bar chart along with a map and a datagrid? ▪ Would the functionality of the tool benefit from the incorporation of any other visualization techniques?

The map display mode and the dashboard mode received positive comments. The tool's unique combination of modes was judged to fulfil the needs of meetings with local decision-makers who often lack proper visualization measures. No particular tutoring was needed; the interface was confirmed to be easy to understand and learn. The tool was also claimed to be suitable for emergency situations if, as one individual put it,

> *… you have to, quickly, get an impression. I can go to the storm in '92, in the New Year's Eve, and see how it inflicted on this area. Everyone, in my age, actually, remembers that episode. Then it is okay to relate the emergency situation you have, actually, to the compensation payment.*

The layout configuration can be easily altered on demand; therefore, the interface can be customized on the fly to fit particular requirements. The participants claimed that both choropleth and symbol mapping techniques are suitable for the insurance compensation data. However, they stated that symbol maps are better for absolute data, whereas the choropleth mapping technique is better for relative data. No need for extra visualization components was reported. As one of the individuals claimed, the addition of extra views could have a negative influence on the tool's effectiveness. However, they suggested adding an animated map to the map display and visually summarizing scores for a selected municipality.

The tool's data content, which is unavailable elsewhere, was commented as one of its major advantages. The participants claimed that access to insurance compensation data can help users to find the costs of historical extreme events that people remember in cases where they are not able to recall their locations and dates. Regarding other data desired to be visualized, only one participant asked for data on historical hazard occurrences as well as for climate and climate-related data and suggested that such information could be beneficial for more demanding users. Apart from that, no other wishes were reported and, as one of the individuals concluded, more data often means more demanding interpretations, which are not desirable when organizing meetings with local decision-makers with either very little or limited data management skills. When being asked about the tool's overall design, individuals were enthusiastic. Two of them spontaneously and independently stated that the tool looked and worked like Google Maps, which is positive because – as one individual said – 'people want Google Maps'. There is no room to discuss whether the tool appears similar to Google's product, but we interpreted the feedback as recognition that the tool resembles a solution that is considered as a standard. Such recognition may influence the successfulness (and thus acceptance) of the tool (Güttler et al., 2001).

4.4 Improvement: The current ClimRes visualization tool

User may enter the current tool via four different modes: 1) data display, 2) map display, 3) dashboard, and 4) participatory tool (see Figure 4). The first mode concerns an interactive data display that provides a general overview of the insurance payments over the period 1980–2016, whereas the second mode – "map display" provides an initial insight into the geography of the payments. The third and the fourth mode provide more sophisticated functionality and will be described more extensively.

4.4.1 Data display

Figure 5 shows the tool's interface, in which one investigates a bar chart on the insurance compensations paid due to five different extreme events. Data is organized annually from 1980 and currently updated up to 2016. The bar chart is the same as the one shown in Figure 1 B, but this chart is interactive. By default, all five types of extreme events display. In Figure 5, the display of water intrusion is turned off. By default, and as shown in Figure 5, the diagram is sorted chronologically. Sort bars by year is selected in Figure 5,

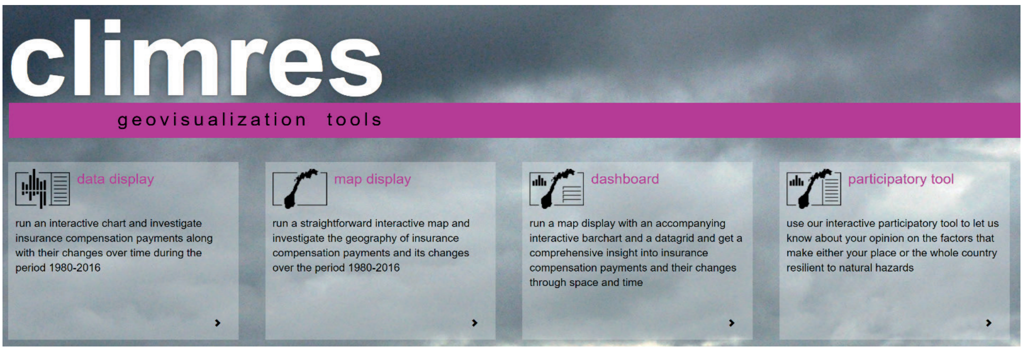

Figure 4: Four entry modes of the ClimRes tools

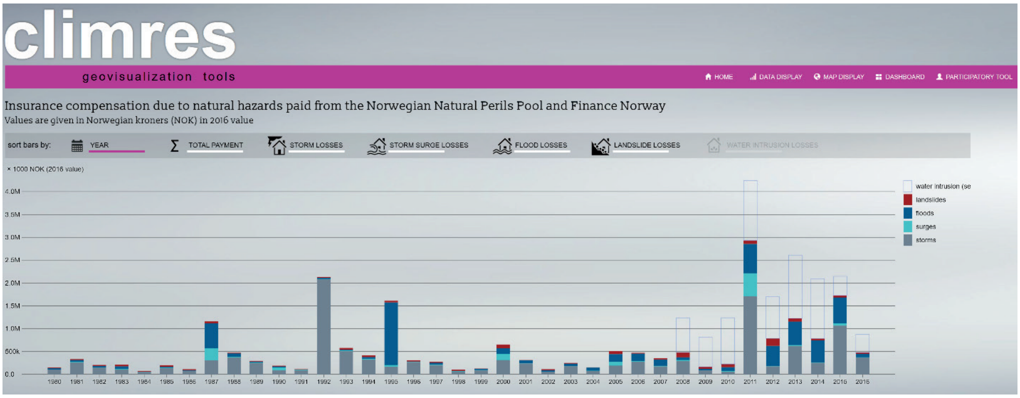

Figure 5: The data display entry mode

but this can be set to total payment (to more easily identify which years had the highest and lowest total compensation, respectively), or to any of the extreme events (to more easily identify which years had the highest and lowest compensation due to damages caused by the particular extreme event).

4.4.2. Map display and Dashboard

Figure 6 shows another example where one investigates the compensation concerning a particular municipality. If the 'map display' mode is chosen from the entry mode (see Figure 4), only the map view will be enabled, and the user can view the geography of compensation payments (see Figure 6). One can next select a municipality to investigate its compensation records. By default, the map view shows the total insurance compensation payments for losses caused by storm hazards in 2016. However, this data content can be altered easily. The user can change the type of extreme event causing the losses ([F]), the normalization method [G], and the timestamp [H]. If the map view alone is not enough to investigate the data, the 'dashboard' mode has two auxiliary views, which can be used: an interactive bar chart and a

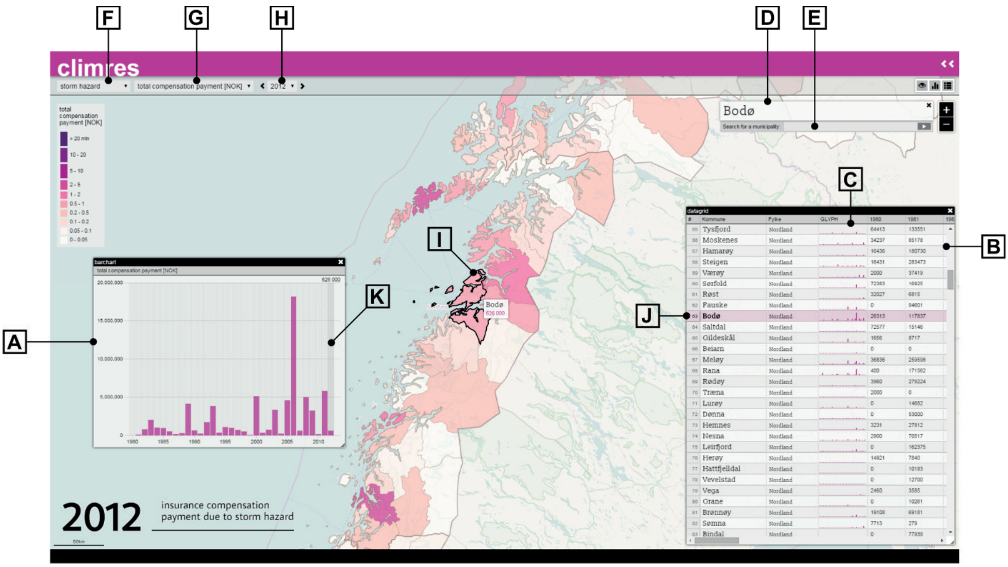

Figure 6: A screenshot of the prototype interface (see text for details).

datagrid ([A] and [B], respectively). In this mode, coordinated and multiple views are provided. Hence, if the user selects a municipality on the map view (the municipality of Bodø – [I]), the bar chart view is adjusted to the selected data item ([A], time-series data concerning the municipality of Bodø), and the datagrid display [B] scrolls to the corresponding row [J]. The same result can be achieved differently by performing the selection in other ways. For example, to investigate a particular municipality, the user can click on the corresponding datagrid row [J], and then, both the map and the bar chart [A] will be adjusted to the selection. In turn, if the user knows a named municipality, he or she can search for it using the search panel [E]. If the system finds the name, all views will be automatically adjusted. The selection can also be done through the bar-chart view [A]; however, the year can only be selected by using this component [K].

4.4.3 Data on water intrusion due to surface runoff

A prerequisite for insurance compensation from the Norwegian Natural Perils Pool to cover damages caused by flooding is that the damaging floodwater come from rivers. As an effect of climate change, however, climate scientist expects more extreme rainfall and thus, possibly more damages due to pluvial flooding or flood caused by surface runoff of rainwater (IPCC, 2012, Hov et al., 2013). An increase of damage due to pluvial flooding in urban area is not due to climate change alone. Additional factors explaining increasing compensation of water damages include higher densification that increase the amount of impermeable surfaces as well as more expensive houses and furnishings that are more exclusive. Consequently, management of surface water is high on the agenda (e.g. Kvitsjøen et al., 2018, Junker, 2018, Bratlie, 2015), but historical records of damages caused by surface water runoff is not part of the data from the Norwegian Natural Perils Pool. We therefore extended the tool's data content by including data on insurance compensation from private insurance companies covering damages caused by water intrusion. These data exist for all municipalities for the period starting from 2008 and Figure 7 shows how this data is visualized for the eastern Norway for the year 2012. Nedre Eiker was one of the municipalities dramatically affected by pluvial flooding in 2012.

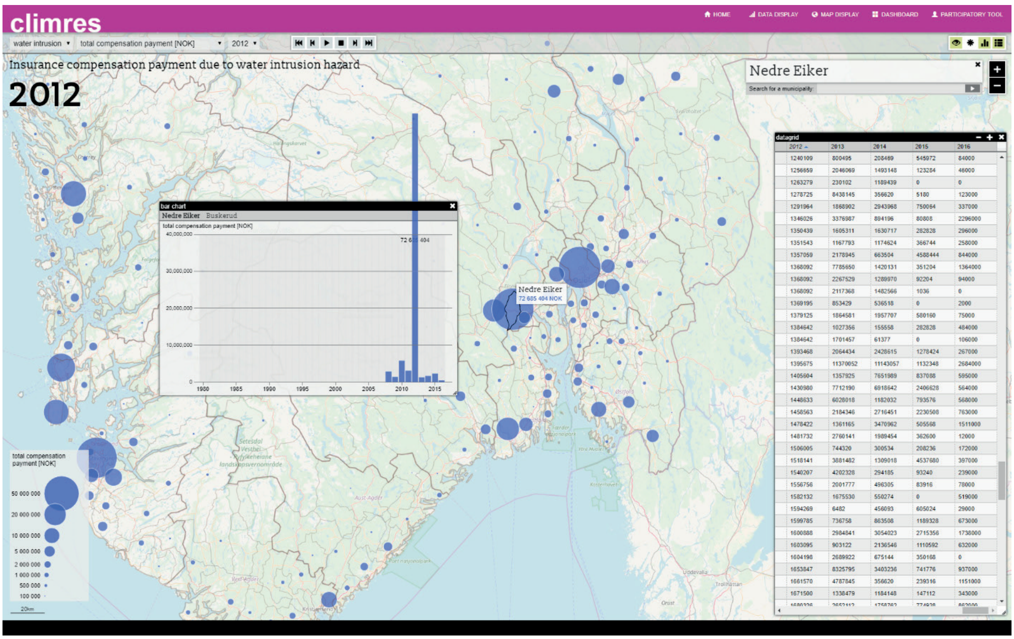

Figure 7: A screenshot of the tool with the water intrusion records for 2012.

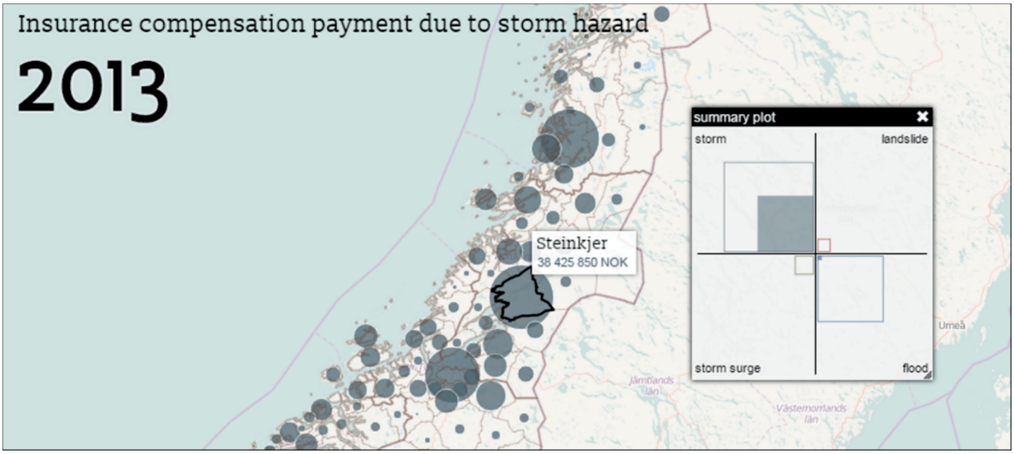

Figure 8: The summary plot summarizes information about the NPP payments for a selected municipality (here Steinkjer).

4.4.4 Animation and summary plot
Animated display functionality was next added to the map display. Proportional symbols were used for showing absolute data, whereas the choropleth mapping technique was used for relative data. The summary plot (Figure 8) was also added as our response for the suggestion that a summary on the values concerning a selected municipality should be provided. Its design however was simplified so there are neither labels nor a key provided in this panel. The summary plot has four outer squares, without fill, that represent total payments from the Norwegian Natural Perils Pool recorded for the entire period from 1980 to 2016. It also has four inner squares that represent compensations paid for the given year (here 2013). As storm is the extreme event that is being visualized, the inner square representing storm compensation in 2013 is shown with fill symbology. The relationship between the inner and outer squares represents the share of the total damage that took place at that certain year.

5. An issue for future development
A visual dashboard that visualizes insurance compensation data and that is developed with commonly available open source technologies, can work for emergency managers and planners in Norwegian municipalities. We thus believe that such tools can work for other countries or areas as well if compensation data are publicly available. The interviews revealed that a basic CMV tool could provide both a general overview of the compensation payment spatiotemporal variability and useful insights into particular data records (municipalities). This finding confirms a common opinion that, if multivariate data are to be conveyed and linkages between places, timestamps, or variables are to be revealed, a CMV geovisualization approach can be more powerful as a vehicle for visual data analysis than a singular map display without data displays. Furthermore, as the interviewees claimed, a basic CMV tool could also support discussions with local emergency officers and planners about the required financial assistance necessary either to undertake or to continue actions for adaptation to climate change, because such assistance can easily be related to historical losses. This, in turn, helps discuss on a more general level how resilient Norwegian municipalities are to an intensification of natural perils due to climate change.

5.1 Crowdsourcing factors that make municipalities resilient
The latter relates to our third aim that is, to design a crowdsource platform that allow users to identify and weight factors important for how resilient a municipality is, and to use this collected information to generate a bottom-up created resilience index for Norwe-

gian municipalities. From previous experience (Rød et al., 2015), maps on top-down generated vulnerability and exposure indices that rank Norwegian municipalities trigger engagement, possibly for two reasons. First, they stigmatize places, and people want to oppose (or confirm) such markers. Second, vulnerability is a contested notion and, as a consequence, people feel the need to discuss issues related to data sources and/or method rather than issues related to measures that may increase resilience. Because data on historical compensation are less contested, we hope that visualizing these data will make it easier to have resilience measures in focus. An important considerations forwarded by the participants were that access to insurance compensation data opens new opportunities for meetings with local planners because such data can support those who aim to convince the planners to undertake adequate adaptation actions. The insurance compensation data can facilitate discussions on areas at risk and possible natural threats as well as their potential negative consequences (in terms of economic costs of reconstruction). The insurance compensation data attracted the stakeholders' attention, and we assume therefore that visualizing such data may make people eager to discuss the reasons for the level of compensation payments in general, and ways to avoid future occurrences of extreme weather related events.

Figure 9 demonstrates our initial ideas on how this participatory mechanism may work. The interface is split where the two left panels consist of a map of an integrated resilience index and a table of content of the variables that constitute the index. The integrated resilience index is an ongoing unpublished work inspired by Susan Cutter's community resilience index (Cutter et al., 2014). The current integrated resilience index has 56 variables grouped into six resilience concepts. The two right panels consist of an empty "blind" map, and a table of content listing the variables selected by the user. As the user selects indicators of resilience, the map updates with a choropleth map based on a weighted combination of the selected variables. In Figure 9, two resilience variables are selected ("Distance to nearest hospital" and "Wealthy household") and their default weighting is 50% to each. If the user considers a variable particular important for local resilience, the weighting for this variable can be increased. For more details on the participatory mode, please refer to the instruction movie at YouTube (https://youtu.be/LcH59ptGt0g).

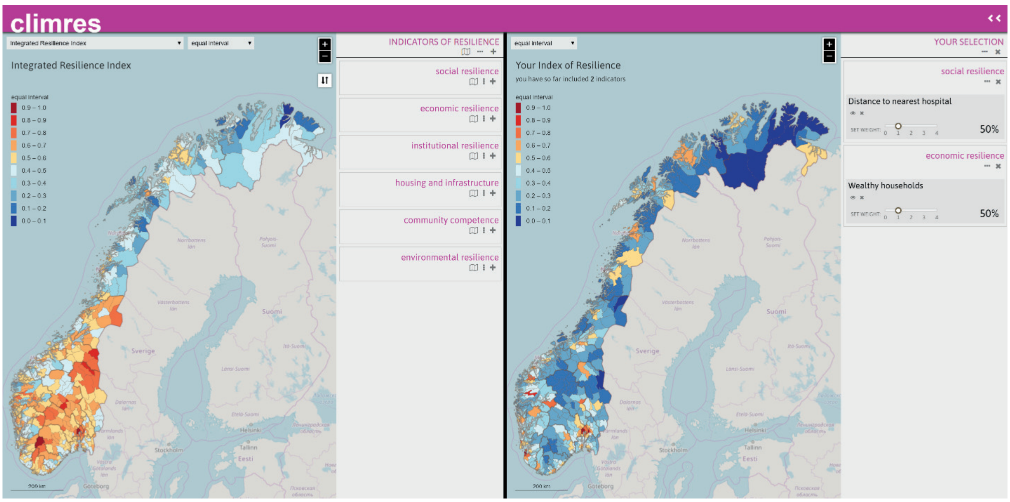

Figure 9: A screenshot of the interface with the 'participatory tool' mode enabled.

6. Conclusions

We have demonstrated how to visualize insurance compensations for damages caused by weather related extreme events through a visual dashboard developed with commonly available open source software for web mapping and data visualization. The data content with efficient visualization can attract attention from local and regional officers involved in emergency management and planning who can easily access the tool, link compensation payments with corresponding extreme natural events and thereby recall executed procedures and dramatic memories. Hence, such data can motivate emergency officers to discuss the formal shortcomings of existing crisis management and response procedures. Furthermore, when our test individuals found the ClimRes tool featuring coordinated and multiple views user-friendly and suitable for showing vast volumes of multivariate compensation data, they acknowledged that it could be an effective solution for conveying compensation data to those with whom they administrate and collaborate.

We did not want to investigate innovative visualization approaches but rather propose a low-cost solution based on open source technologies that can serve as a reliable device for making the history and geography of compensation payments generally known. The ClimRes tool does so by showing compensation data at the municipal level in both spatial (the map display) and temporal (the bar chart and the animation) contexts. The ClimRes tool has been primarily designed to facilitate intuitive foraging of compensation data. However, it has also been experimentally equipped with a participatory mechanism where users are presented numerous variables that each "tell their story" about what constitute a resilient municipality, and where they can make a selection of these. Further research will show if this could constitute a bottom-up construction of a resilience index based on spatial crowd sourcing.

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References

AMAR, R., EAGAN, J. & STASKO, J. Low-level components of analytic activity in information visualization. IEEE Symposium on Information Visualization, 2005. INFOVIS 2005., 23–25 Oct. 2005. 111–117.

BOHMAN, A., NESET, T.-S., OPACH, T. & RØD, J. K. 2015. Decision support for adaptive action: Assessing the potential of geographic visualization. *Journal of Environmental Planning and Management* 58**,** 2193–2211.

BRATLIE, R. 2015. Beregning av flomveier med eksempler på bruk i kommunal forvaltning. *Kart og Plan,* 75**,** 24–34.

BREVIK, R., AALL, C. & RØD, J. K. 2014. Pilot project on testing of damage data from the insurance industry for assessing climate vulnerability and prevention of climate-related natural perils in selected municipality.

CUTTER, S. L., ASH, K. D. & EMRICH, C. T. 2014. The geographies of community disaster resilience. *Global Environmental Change,* 29**,** 65–77.

EDSALL, R. M. 2003. Design and Usability of an Enhanced Geographic Information System for Exploration of Multivariate Health Statistics. *The Professional Geographer,* 55**,** 146–160.

FISHER, P., ARNOT, C., BASTIN, L. & DYKES, J. 2001. Exploratory visualization software for reporting environmental survey results. *Journal of Environmental Management,* 62**,** 399–413.

GOOSEN, H., DE GROOT-REICHWEIN, M. A. M., MASSELINK, L., KOEKOEK, A., SWART, R., BESSEMBINDER, J., WITTE, J. M. P., STUYT, L., BLOM-ZANDSTRA, G. & IMMERZEEL, W. 2014. Climate Adaptation Services for the Netherlands: an operational approach to support spatial adaptation planning. *Regional Environmental Change,* 14**,** 1035–1048.

GÜTTLER, R., DENZER, R. & HOUY, P. 2001. User interfaces for environmental information systems – interactive maps or catalog structures? Or both? *Advances in Environmental Research,* 5**,** 345–350.

HALLISEY, E. J. 2005. Cartographic Visualization: An Assessment and Epistemological Review*. *The Professional Geographer,* 57**,** 350–364.

HERRING, S. C., CHRISTIDIS, N., HOELL, A., KOSSIN, J. P., SCHRECK III, C. J., STOTT, P. A. (Eds.) 2018. Explaining Extreme Events of 2016 from a Climate Perspective. Special Supplement to the *Bulletin of the American Meteorological Society,* 99**,** S1–S157.

HOV, Ø., CUBASCH, U., FISCHER, E., HÖPPE, P., IVERSEN, T., KVAMSTØ, N. G., KUNDZEWICZ, Z. W., REZACOVA, D., RIOS, D., SANTOS, F. D., SCHÄDLER, B., VEISZ, O., ZEREFOS, C., BENESTAD, R., MURLIS, J., DONAT, M., LECKEBUSCH, G. C. & ULBRICH, U. 2013. Extreme Weather Events in Europe: preparing for climate change adaptation. Oslo: Norwegian Meteorological Institute.

IPCC 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge, UK, and New York, NY, USA, 582 pp.

JOHANSSON, J., OPACH, T., GLAAS, E., NESET, T.-S., NAVARRA, C., LINNÉR, B.-O. & RØD, J. K. 2016. VisAdapt: A visualization tool to support climate change adaptation. *IEEE Computer Graphics and Applications,* http://dx.doi.org/10.1109/mcg.2016.49.

JUNKER, E. 2018. Forenklinger i plan- og bygningsloven og TEK: Helles barnet ut med overvannet? *Kart og Plan,* 78**,** 45–50.

KOHLHAMMER, J., NAZEMI, K., RUPPERT, T. & BURKHARDT, D. 2012. Toward Visualization in Policy Modeling. *IEEE Computer Graphics and Applications,* 32**,** 84–89.

KVITSJØEN, J., HARSTAD, C. H., KARLSSON, D., FINSLAND, W. & FETT, T. K. 2018. Visualisering av data i kart er nødvendig for effektiv klimatilpasning. *Kart og Plan,* 78**,** 5–15.

MACEACHREN, A. M. & KRAAK, M.-J. 2001. Research Challenges in Geovisualization. *Cartography and Geographic Information Science,* 28**,** 3–12.

NESET, T.-S., OPACH, T., LION, P., LILJA, A. & JOHANSSON, J. 2016. Map-Based Web Tools Supporting Climate Change Adaptation. *Professional Geographer,* 68**,** 103–114.

OVERPECK, J. T., MEEHL, G. A., BONY, S. & EASTERLING, D. R. 2011. Climate Data Challenges in the 21st Century. *Science,* 331**,** 700–702.

RØD, J. K. 2013. Naturskadeforsikring og utbetalinger etter 1980. In: BYE, L. M., LEIN, H. & RØD, J. K. (Eds.) Sårbarhet, klimaendringer og risikohåndtering. Trondheim: Akademika. 157–189.

RØD, J. K., OPACH, T., & NESET, T. S. 2015. Three core activities toward a relevant integrated vulnerability assessment: validate, visualize, and negotiate. *Journal of Risk Research*, 18, 877–895.

SHAW, A., SHEPPARD, S., BURCH, S., FLANDERS, D., WIEK, A., CARMICHAEL, J., ROBINSON, J. & COHEN, S. 2009. Making local futures tangible – Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. *Global Environmental Change,* 19**,** 447–463.

SIMÃO, A., DENSHAM, P. J. & HAKLAY, M. 2009. Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites. *Journal of Environmental Management,* 90**,** 2027–2040.

WANG BALDONADO, M. Q., WOODRUFF, A. & KUCHINSKY, A. 2000. Guidelines for using multiple views in information visualization. *Proceedings of the working conference on Advanced visual interfaces.* Palermo, Italy: ACM.

WEHREND, S. 1993. Appendix B: Taxonomy of visualization goals. In: KELLER, R. P. & KELLER, M. M. (eds.) *Visual Cues: Practical Data Visualization.* Los Alamitos, CA: IEEE Computer Society Press.

WIBECK, V., NESET, T.-S. & LINNÉR, B.-O. 2013. Communicating Climate Change through ICT-Based Visualization: Towards an Analytical Framework. *Sustainability,* 5**,** 4760.