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Co-production of climate services: A story map for future coastal flooding for the city of Flensburg

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A B S T R A C T

Story maps offer the possibility to visualise scientific information and climate data in an accessible format and, as web-based tools, reach a large audience. However, the use of story maps in the context of climate services has not yet been widely explored or implemented. In this study we present a story map for communicating the potential impacts of flooding due to sea-level rise for the city of Flensburg, situated at the German Baltic Sea coast. The map is developed in the form of a web-based tool and includes background information on sea-level rise and coastal flooding as well as on coastal adaptation measures; interactive maps with information on city landmarks; and maps of future flooding scenarios based on numerical modelling. To increase the usability of the climate service we have applied a co-production approach and collaborated with the general public to identify user needs in an iterative process. Our study highlights the user needs for detailed visualisation of potential flooding due to sea-level rise as well as for further information on adaptation measures. As a climate service, our story map serves as a starting point for raising awareness among the general public and for initiating action for adaptation to reduce vulnerability to coastal flooding in Flensburg.

Practical implications

In order to manage and adapt to the consequences of climate change, awareness raising among the general public is often a starting point of the adaptation process (ClimateADAPT, 2015). However, the communication of information related to climate change and its impacts is challenging as climate data are often complex and difficult to illustrate in a user-friendly way (Cope et al., 2018; Antoniou et al., 2018). For this purpose, communication tools that explain and visualise such information in an accessible format are essential. In this study, we introduce the production process of such a tool, namely a story map. This story map raises awareness and informs the general public about sea-level rise (SLR) and associated flooding, for the city of Flensburg, located at the German Baltic coast.

As story maps are web-based, they are easily accessible by a wide range of people. Different functionalities such as pop-ups, graphs, maps and videos are employed to present the information to the respective target group. The story map is developed in the context of the EVOKED project and involves the users of the tool. The interaction and collaboration of our interdisciplinary team with various users helped to identify their information needs to ensure the long-term utilisation of the climate service.

This paper describes the co-production process and its steps in detail. Instead of using already available solutions we have designed a new story map template in order to have greater flexibility in the visualisation of the scientific information and in adjusting the story map according to the users' feedback. Based on a web-based questionnaire survey in which we asked for further information needs and the technical handling of the users we adjusted the story map according to the users' responses and finally conducted a validation phase.

The story map presents information on sea-level rise and associated flooding for Flensburg and includes background information on global sea-level changes. It also specifies terms such as uncertainty, impacts and risk. In addition, low-lying parts of the city which are vulnerable areas to future flooding are highlighted. Following the users' feedback, additional sections were added to the story map, such as information on past sea-level changes and a photo gallery of past flooding events to better visualise the impacts

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of those events. A central part of the story map are flood maps, showing potentially flooded areas of the city for different sea-level rise scenarios. Two sea-level rise scenarios (0.5 m and 1.0 m SLR) are combined with the severe Axel storm surge event (January 2017) to visualise potential future impacts.

The developed story map serves as a starting point to initiate action for adaptation in the city as the general public can become aware of future sea-level rise and associated flooding. While potential adaptation options are presented, a more in-depth analysis is required for concrete adaptation planning in the city. Nevertheless, the story map is a useful climate service as it offers the possibility to visualise scientific information in different ways and can be applied for a range of climate-impact related topics and purposes beyond sea-level rise and associated flooding.

1. Introduction

Coastal cities are particularly exposed to flooding due to their high population density and the fact that they host a plethora of socio-economic activities (Gargiulo et al., 2020; Neumann et al., 2015). In the future, coastal flooding will become more frequent due to sea-level rise (SLR) and associated increases in storm surges (Church et al., 2013; Nicholls and Cazenave, 2010). Thus, there is a need for adaptation action in order to reduce the vulnerability of coastal communities and enhance their resilience to coastal flooding (Gargiulo et al., 2020; Le Cozannet et al., 2017). There are however certain barriers that hinder the (coastal) adaptation process (Bisaro and Hinkel, 2016). For example, Hoffmann et al. (2020) showed that the need for adaptation planning is partly not seen as a relevant topic for practitioners and it is difficult to reach citizens and to increase their awareness of the consequences of climate change. Additionally, Rouse et al. (2016) identified the lack of awareness of risks among communities and the provision of too complex scientific information as barriers for coastal adaptation activities.

Climate services help to overcome such barriers as they offer the opportunity to inform and communicate about climate change impacts, support adaptation processes, contribute to disaster risk reduction (DRR) and foster resilience (Street et al., 2015; WMO, 2020). Climate services need to be easy to understand, usable and relevant for the respective users (Guido et al., 2013; Hewitt et al., 2017; Räsänen et al., 2017; Swart et al., 2017). Lemos et al. (2012) identified a usability gap showing that climate services are often not used or applied by potential users due to lack of relevance or unsuitable presentation of the climate information (see also Brasseur and Gallardo, 2016; Vaughan and Dessai, 2014). Climate services can be used effectively when the consequences of climate change impacts are translated and the implications of those impacts are shown to the users (Goosen et al., 2013). To increase the usability of the service, the identification of user needs and the interaction between users and providers needs to be improved (Hewitt et al., 2012). For this purpose user-centred approaches should be applied to facilitate closer cooperation and communication between users, providers and researchers (Giannini et al., 2016; Laudien et al., 2019; Lourenço et al., 2016). Furthermore, a co-production process, characterised by collaboration between providers and users of climate information, can lead to an increased use of the services (Beier et al., 2017; Bremer et al., 2019; Leal Filho, 2020; Goosen et al., 2013; Hewitt et al., 2017; Lourenço et al., 2016; Räsänen et al., 2017; Vaughan and Dessai, 2014).

Coastal climate services can inform about the risks and potential impacts of flooding to coastal communities, particularly since low-lying coastal areas are vulnerable to SLR and to the associated increase in extreme flood events. Awareness raising through information among citizens is an essential part of the coastal adaptation process, hence coastal climate services addressing this aspect on the local level need to be compiled (ClimateADAPT, 2015; Khan et al., 2020; Le Cozannet et al., 2017; Tol et al., 2008). According to the coastal climate service framework BASIEC (Building capacity for Adaptation to Sea-Level rise through Information, Education and Communication for coastal communities) awareness raising has to be built on three “pillars”: information, communication and education about SLR (Khan et al., 2020).

Tools such as story maps can be considered as (coastal) climate services for implementing the BASIEC framework. Story maps are web applications and a useful tool to communicate and explain information in a compact and user-friendly format following a story. They are applicable to a range of themes (not exclusively related to climate change impacts) and are designed with a specific audience in mind (Cope et al., 2018; Antoniou et al., 2018). Story maps are constructed based on maps and are enhanced by different content and functions such as text, pop-ups, graphs, maps and videos. These visualisation tools offer the opportunity to translate and visualise complex data, including scientific data, in a more accessible way to a certain target group e.g. the general public (Cope et al., 2018; Harder and Brown, 2017; Kerski, 2015a; Marta and Osso, 2015; Patterson and Bickel, 2016). Due to their interactivity, they can be applied for education and information purposes to involve the audience (Marta and Osso, 2015). In the context of SLR communication, Gawith et al. (2009) and Frazier et al. (2010) recognized the potential of digital maps to visualise SLR scenarios to a specific target group. Covi and Kain (2016) state that a convenient framing, tempting visualisation and intuitive language of the information assists people to become active.

Certain web applications that inform and communicate about SLR and associated flooding are already available (DeLorme et al., 2018; Jones et al., 2017). These applications have primarily been designed for addressing multiple audiences ranging from politicians to knowledge providers and practitioners (Swart et al., 2017), with the aim to support the adaptation decision-making process. As such, they may therefore be too complex to inform and raise awareness among the general public, the target group that we are focusing on in our study. Only a small number of studies connect information and communication tools, such as web platforms or web portals, to the concept of climate services (Hoffmann et al., 2020). In one of the few studies that assesses web portals as climate services, Swart et al. (2017) recommend to include the users in the development of such portals; ensure the quality of used data; complement the portal by additional services; provide guidance for the used data; assure continuity (also after a project has finished); and allow user interaction after the portal development.

In the ERA4CS (European Research Area for Climate Services) project EVOKED (Enhancing the value of climate data – translating risk and uncertainty utilizing a Living Labs approach; https://www.ngi.no/eng/Projects/EVOKED/) we have designed a case-study-specific SLR story map (http://meeresspiegelanstieg-in-flensburg.info/) connected to the concept of climate services. Our study presents a practical application of a climate service development process aiming to increase the usability of the service. The purpose of the SLR story map is to raise awareness among the general public and to initiate action for adaptation in order to better cope with future coastal flooding in Flensburg, a city situated at the German Baltic Sea coast. To design the story map, we apply a co-production approach by involving local users, identify user needs and gain local knowledge (Leal Filho, 2020); these steps are described in detail in the methods section. Instead of using existing story map templates that are available, we have developed a new custom-made template to allow for more flexibility during the co-production process. In addition, as maps can be an effective tool for SLR scenario communication (Frazier et al., 2010; Gawith et al., 2009), we have produced and included a series of flood maps for the city of Flensburg. Those maps are a central element in the story map; a description of chosen scenarios is included in the methods section. In the results section, we highlight the outcome of the co-production process and elaborate on how we adjusted the story map based on user feedback. Finally, we discuss the potential of story maps as climate services and present insights gained from the co-production approach.

2. Study area and methods

The first part of this section gives a short overview of the study area and the EVOKED project. The second part describes the co-production process, including the feedback loop of the story map, and presents the user involvement approach. The third part focuses on the generation of the produced flood maps.

2.1. Study area and the EVOKED project

Flensburg is located in the north of Germany at the western Baltic Sea coast. Because of its location, regular coastal flooding occurs under strong northeasterly winds (Jensen and Mueller-Navarre, 2008) and low-lying parts of the city experience regular flooding. Coastal flooding is expected to increase in intensity and frequency in the Baltic Sea as a result of climate-induced SLR (Sterr, 2008; The BACC II Author Team, 2015; Weiße and Meinke, 2017; Wong et al., 2014). Large-scale protection measures against coastal flooding such as dikes are not in place (Hofstede, 2008; Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein (LKN.SH), 2015). So far, the city administration has mainly focused on the issue of climate mitigation and a climate adaptation initiative does not yet exist.

The overall objective of the EVOKED project has been to produce climate services that are understandable and relevant for their users. Within this context, we have developed a range of climate services in collaboration with key partners from the city administration of Flensburg as well as with other stakeholders to address SLR and associated flooding, with the aim to initiate adaptation action. Throughout this process we aimed at enhancing the use of these services via user interaction and by employing a co-production approach. For this purpose we have applied the Living Lab method, which involves co-creation and activities that take place in real-life environments (Almirall et al., 2012; Dell'Era et al., 2019; Dell'Era and Landoni, 2014; Evan et al., 2017; Steen and van Bueren, 2017; Zavratnik et al., 2019). Through co-creation, it is possible to access user ideas and knowledge, potentially leading to an innovative outcome (Schuurman et al., 2013; Ståhlbröst and Bergvall-Kåreborn, 2008) for the climate service; at the same time the real-life environment allows the production and testing of the climate service in the local context. Our co-production process has included a feedback loop to ensure that the presented information is user-driven (Swart et al., 2017).

Several activities took place within the Living Lab framework, including:

- the identification of stakeholders. Based on a stakeholder analysis following Reed et al. (2009) we identified relevant local and regional stakeholders as well as potential users (e.g. citizens, local and regional authorities) for the co-production process of climate services. Reimann et al. (2021) summarise the steps taken to identify relevant stakeholders.
- consultation meetings with our key partners for the identification of user needs. Following those consultations, we agreed with the key partners on focusing on SLR and associated flooding instead of present flooding, as the city administration aims to adapt to future climate change impacts.
- two workshops and a closing event with user involvement during the project lifetime. The first workshop consisted of two parallel sessions: 1. Discussion on future flood impacts based on flood maps (including different scenarios) and 2. Plausibility check of local Shared Socioeconomic Pathways (SSPs) (Reimann et al., 2021). The second workshop focused on the discussion of potential adaptation measures for Flensburg and also included a session for evaluating the SLR story map. In the closing event the project results were highlighted in a panel discussion. Based on the first workshop a mailing list with users (e.g. participants of the workshop) was compiled, which was also used within the SLR story map co-production process.

The SLR story map presented here is one of the climate services we co-produced in the frame of the Living Lab. We used the story map as a starting point to communicate project results and to raise awareness among the general public for SLR and associated flooding, its potential impacts and suggested adaptation measures.

2.2. Co-production of the story map

The research cycle of the Living Lab method, described in Pierson and Lievens (2005), was used for the production of the SLR story map. This cycle consists of different iterative phases, namely contextualisation, concretisation, implementation and feedback. These phases and their progress were adopted in our case study. For the development of the prototype, we decided to design a new story map template rather than use already available ones, such as the templates provided by the Environmental Systems Research Institute (ESRI) (Harder and Brown, 2017). This was done in order to allow greater flexibility in the visualisation and design of the scientific information and to be able to adjust the story map according to the feedback and requirements of the users. The co-production process involved a core team, which consisted of two scientists (social and natural scientists) and a professional web designer; a group of twelve coastal experts in the fields of coastal adaptation, engineering and modelling; the key partners of the city administration; a journalist; and the users (i.e. general public). Fig. 1 shows a schematic overview of the different co-production steps embedded in the Living Lab framework.

2.2.1. Compilation

The core team initially developed the content and the structure of the story map and came up with suggestions on how to visualise and present SLR-related information in a simplified manner, as SLR and associated risks is often communicated highly too technical (Covi and Kain, 2016). To address this challenge, a professional journalist worked on the linguistic expression to make the language more accessible for the target group. The group of coastal experts and the key partners gave feedback on the technical handling and the clarity of the content of a first story map draft. After minor changes, the demonstration phase began with the aim to obtain feedback from the users.

2.2.2. Demonstration and feedback

The aim of this step was to increase the usability of the climate service through user involvement. Thus, we combined the demonstration phase with an evaluation phase. In the first version of the story map, we included a web-based questionnaire survey. Goodess et al. (2019) pointed out the usability of feedback forms directly connected to the provided climate service. Following a short introduction on the aim of the story map and on the role of the users' feedback, the questionnaire comprised three parts. In the first part, we asked the users for their general opinion on the first version by giving a school mark from 1 (very good) to 6 (insufficient), followed by two open-ended questions asking for further content-related and technical needs. The second part consisted of closed format questions and concentrated on the visualisation and comprehensibility of the illustrated information within the story map, and on whether the tool has the potential to support the local adaptation process in its current phase. In the third part, the users were asked for personal information on the Big Five personality traits (Kayiş et al., 2016), the age and the role of the users. We used the open-ended questions of the first part to adjust the story map (see Section 3) and based on those questions we obtained concrete information for improving the story map. Parts two and three were used for quantitative analysis and are not the subject of this study. The completion of the questionnaire survey was anonymous. As a first step we sent out the story map link to a wide range of users (e.g. local and regional authorities, government, business/industry, citizens, NGOs, research institutes) who were identified based on the stakeholder analysis and through the mailing list. Furthermore, in order to reach a large number

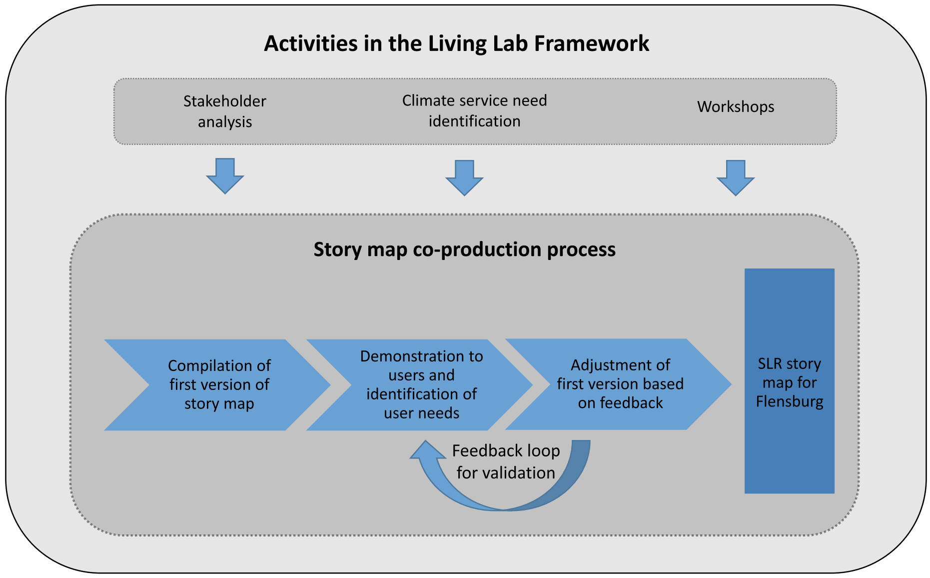

Fig. 1. Schematic overview of the Living Lab framework and SLR story map co-production process with different steps taken to involve users and identify their information needs. A feedback loop was implemented in the co-production process to validate the adjusted version.

of local citizens, we advertised the story map in the local German and Danish newspapers, used the Twitter account of our key partner, and distributed flyers, specifically designed for this purpose. The users were asked to participate in the production process of the SLR story map in Flensburg by using the web-based questionnaire survey. We also made use of regional events, such as the conference Coast and Prevention 2019, to invite external coastal experts to participate in the story map co-production process. The demonstration and evaluation phase took place from June to October 2019.

2.2.3. *Adjustment and validation*

We analysed and categorized the collected feedback (see Section 3.) and adjusted the story map based on the content-related feedback and on how to implement technical changes users asked for. Next, we set up a revised version and asked the group of coastal experts for feedback on the technical handling and clarity of content of the new version. We further used the opportunity to present the adjusted version at the second project workshop, which took place at the end of November 2019. As the evaluation phase was anonymous, we prepared a poster to better visualise the feedback that we received on the first version and how we implemented this feedback in the new version. This also gave those stakeholders who had not participated in the web-based feedback phase the opportunity to assess the revised version. Stakeholders also had the opportunity to express further content-related and technical needs during this workshop.

2.3. *Generation and evaluation of flood maps*

Exposure and vulnerability mapping is a commonly used tool for policy makers for supporting adaptation and land-use planning decisions (Neset et al., 2016; Patt et al., 2005), while at the same time educating the public about climate change and its interactions with coupled physical/environmental systems and motivating policy responses (Preston et al., 2011). In order to visualise the potential flooding of Flensburg due to storm surges under future SLR, to sensitize the key partners and the general public and to address the information needs of the key partners (see Section 2.1.), we developed a series of flood maps for different SLR scenarios. The communication of SLR projections is often challenging as future sea-level changes are connected with uncertainties (Covi and Kain, 2016; Oppenheimer et al., 2019). In the first workshop of the Living Lab process, we communicated and visualised the uncertainties related to SLR projections by suggesting plausible SLR scenarios for the city of Flensburg to be considered for the future adaptation process. Based on the IPCC (2014) estimates which projected a global mean sea level between 0.28 m and 0.98 m (likely range) until 2100, we used sea-level projections of 0.5 m and 1.0 m for compiling the flood maps. These values reflect a high-end scenario, the former depicting SLR shortly after the middle of this century, which corresponds to the time horizon for spatial planning decisions (Hinkel et al., 2019), and the latter corresponding to the end of the century, which is a commonly employed timeframe for impact assessments (e.g. Fang et al., 2020; Vafeidis et al., 2019). We chose a high-end scenario as such scenarios provide information that is particularly important for decision-making and planning (Stammer et al., 2019). During the co-production process of the story map the respondents assessed the visualisation of different sea-level rise scenarios or potentially flooded areas as an element of central importance (see Section 3.). For the generation of the flood maps we employed different modelling approaches i.e. a static inundation model (also termed as the “bathtub method”) to depict low elevation areas exposed to coastal flooding; and a process-based hydrodynamic model, namely DELFT3D (Deltares, 2018) to calculate flood characteristics (extent and depth) for the Axel storm, a severe storm that hit Flensburg in January 2017 and resulted in a high-water level of 1.78 m. As this was a recent storm, which resulted in extensive damages for the low-lying parts of the city (Flensburger Tageblatt, 2017), the stakeholders could directly associate to the different visualisations of flooding. We produced seven maps depicting flooding under the scenarios shown in Table 1. The technical details of the simulations are presented in the supplementary material.

The maps were presented during the first workshop, where

Table 1
Simulated events for the first workshop. Storm surge classes adopted from the “Fachplan Küstenschutz Ostseeküste” (LKN.SH, 2015).

Scenario	Peak water height [m]
Slight storm surge + 0.5 m SLR	1.5
Axel + 0.5 m SLR	2.28
Axel + 1 m SLR	2.78
Present-day very heavy storm surge + 0.5 m SLR	2.75
Present-day very heavy storm surge + 1 m SLR	3.25
Storm surge of 1872 + 1 m SLR	4.08
Axel	1.78

stakeholders had the opportunity to ask questions and collect first ideas for adaptation and also provided feedback on the map depicting the floodplain of the Axel storm, based on their knowledge of the event. Here, the participants used coloured stickers to indicate potential errors in the map or to confirm the output of the simulation. In this context, uncertainties related to the modelling process and to the magnitude of SLR were explained and communicated.

3. The story map

3.1. Sea-level rise story map for Flensburg

The first version of the story map consisted of three main sections. The first section included background information on global SLR and specifies terms such as uncertainty, impacts and risk. In the second section, we included a fly-by map to visualise geospatial information. In this map, we highlighted low-lying parts of the city, which are vulnerable to future floods due to e.g. the presence of infrastructure, such as the municipal utilities, the harbour, and the central bus station (Fig. 2). In the third section, we provided general information on adaptation measures and provided examples of potential adaptation strategies or measures for different locations using a pop-up map.

3.2. Feedback process

After reviewing the first draft of the story map, the group of coastal experts and the journalist provided comments for linguistic modifications. Some technical changes were also necessary as difficulties emerged depending on the type of browser used. During the user feedback phase, we received 46 returns of the web-based questionnaire survey. 36 responses contained feedback related to the open-ended questions, raising information needs and suggesting improvements of the technical handling. We synthesized and analysed the answers in order to categorise and translate user needs to adjust the story map. In total, we built three categories of further information needs: 1. Past SLR, 2. Visualisation of change of future water levels and SLR scenarios and 3. Adaptation measures. Table 2 summarises a representative sample of comments by the respondents allocated to the respective categories.

Table 2
Categorisation and extraction of user feedback based on the web-based questionnaire survey.

Category	Comments of participants (extract)
Past SLR	"How much has the sea-level risen over the last 100 years […]?"
	"How has the sea-level in the Flensburg Fjord changed over the last 70 years? […]"
Visualisation of change of future water levels and SLR scenarios	"Simulation of the different water levels to better visualise the flooded areas."
	"Visualisation of sea-level rise and flooded areas for the coming decades […]."
	"Change of water line incorporating different sea-level rise scenarios."
	"Besides the provided information also include the graphical representation on a city map of flooded areas […]."
	"Projections should be visualised on a map."
	"The mean sea-level will rise up to 110 cm. The impacted area should be shown on a map and also the flooded area of a one-year statistical flood should be visualised."
Adaptation measures	"Inclusion of in-depth information for the proposed adaptation measures, as not all measures are self-explanatory."
	"Sample images of the measures would be great."
	"Greater choice of measures that can be implemented and are effective."
	"Name more alternatives for every location."

3.3. Adjustment of story map

Based on the overall comments we adjusted the story map by developing additional sections. Due to the custom-made template, we were able to apply an optimal visualisation format for each of the requested categories. For the illustration of past sea-level changes, we included an interactive graph showing past water levels for Flensburg from 1954 to 2015 (Fig. 3). The visualisation of SLR and different scenarios was a central information request of the respondents. We received information requests to show the potential changes in future water levels and associated impacts, such as the permanently inundated area due to SLR (without considering adaptation) and the potential impacts of storm surge events combined with SLR projections. In response, we included a section with flood maps (Fig. 4) using the two approaches described in Section 2.3. In the first map, we displayed areas below one meter of elevation as a measure of exposure. As storm surges combined with SLR are expected to have a greater impact on low-lying areas of Flensburg and are likely to arise more often in the future, we also

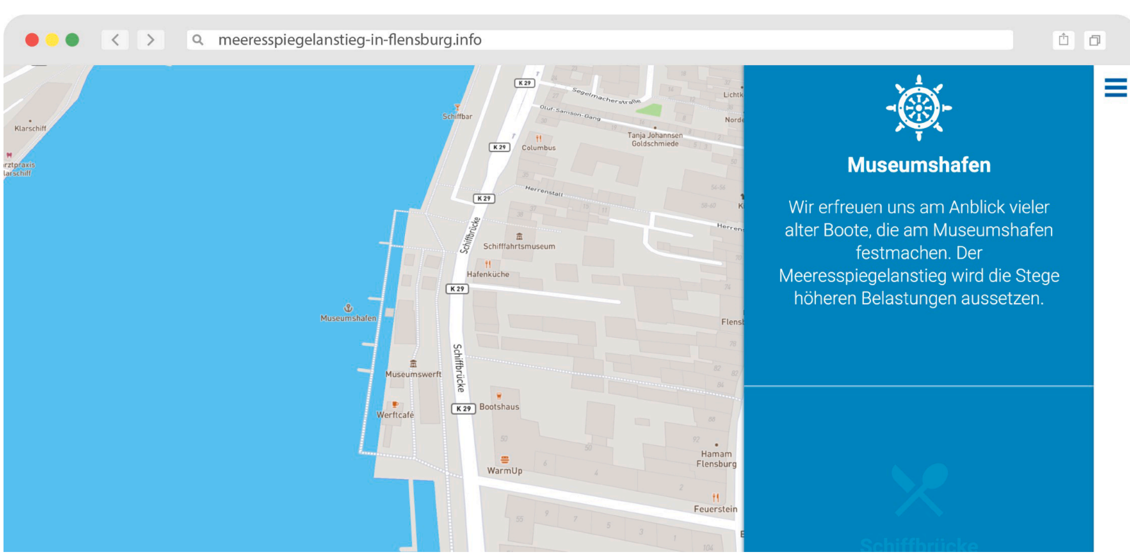

Fig. 2. A fly-by map visualises low-lying parts of the city, which are vulnerable to future floods. A short description is given on the potential impact of SLR to the area.

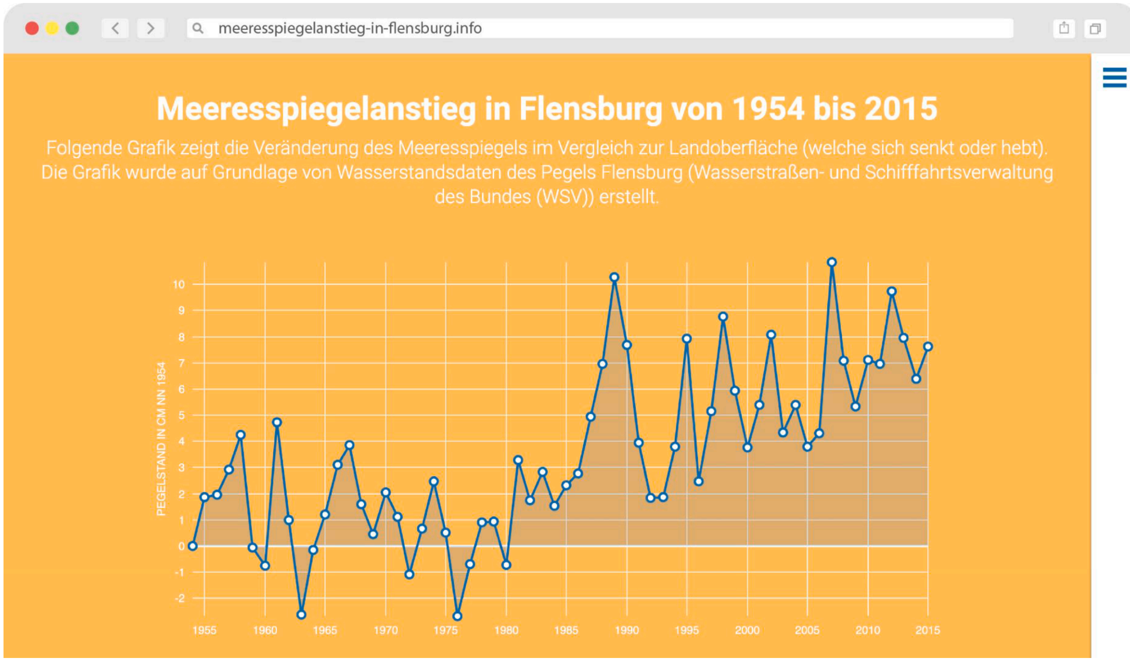

Fig. 3. Interactive graph displaying past water levels for Flensburg from 1954 to 2015. Section was added based on expressed information needs of respondents during the co-production process.

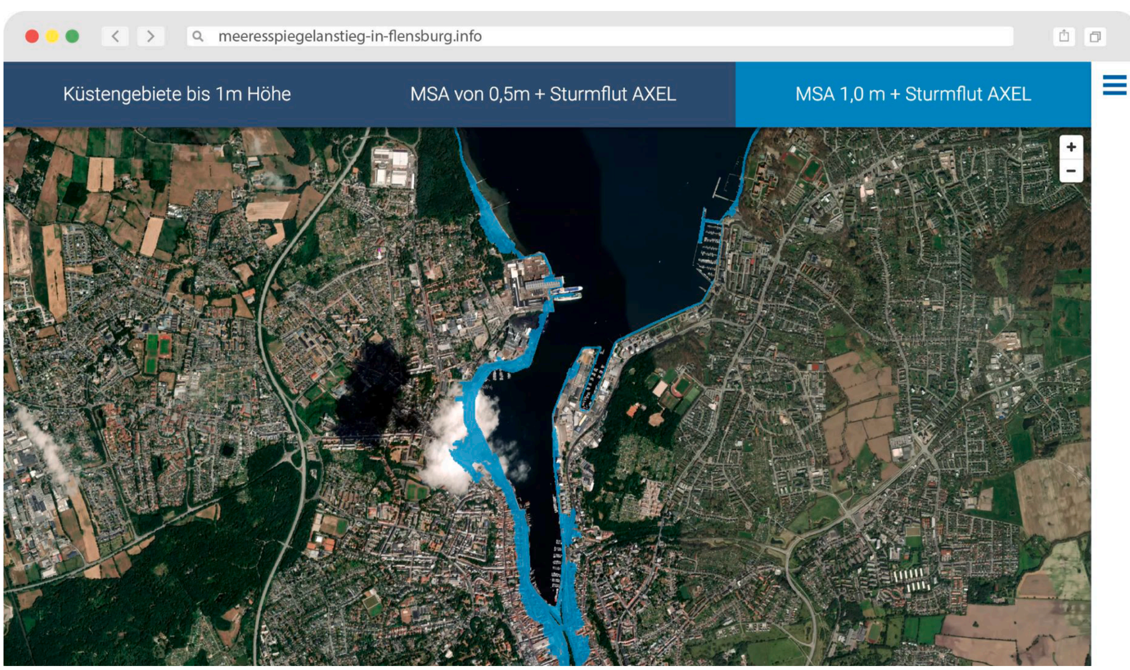

Fig. 4. Story map interface for visualising the flood extent of different SLR scenarios of the two approaches, static inundation and hydrodynamic modelling. The figure shows results of the hydrodynamic model and visualises the potentially flooded area of a storm similar to Axel, under an SLR scenario of 1.0 m.

included the results of the simulations with the hydrodynamic modelling approach. These maps visualise the potentially flooded areas of the recent storm event (Axel, January 2017), under two SLR scenarios (0.5 m and 1.0 m). The decision to integrate these two SLR scenarios in combination with the recent storm event was made with the key partners who deemed these scenarios as the most appropriate for illustrating impacts. As a time horizon, we communicated the potential development until 2100. We further integrated a photo gallery of past flood events in Flensburg to better visualise the impacts of such floods.

Besides the pop-up map providing suggestions on adaptation strategies in the first version, the respondents asked for more information and better visualisation of potential adaptation measures. Thus, as a last section of the story map, we included ten examples of potential adaptation measures, including a short description and photos of such measures (Fig. 5). Those measures were compiled based on workshop results and on expert knowledge.

During the feedback process, we received some responses that we chose not to incorporate in the new version of the story map. These responses did not fit the aim, scope, or content of the SLR story map e.g. information on climate mitigation, geodynamic processes, and costs of

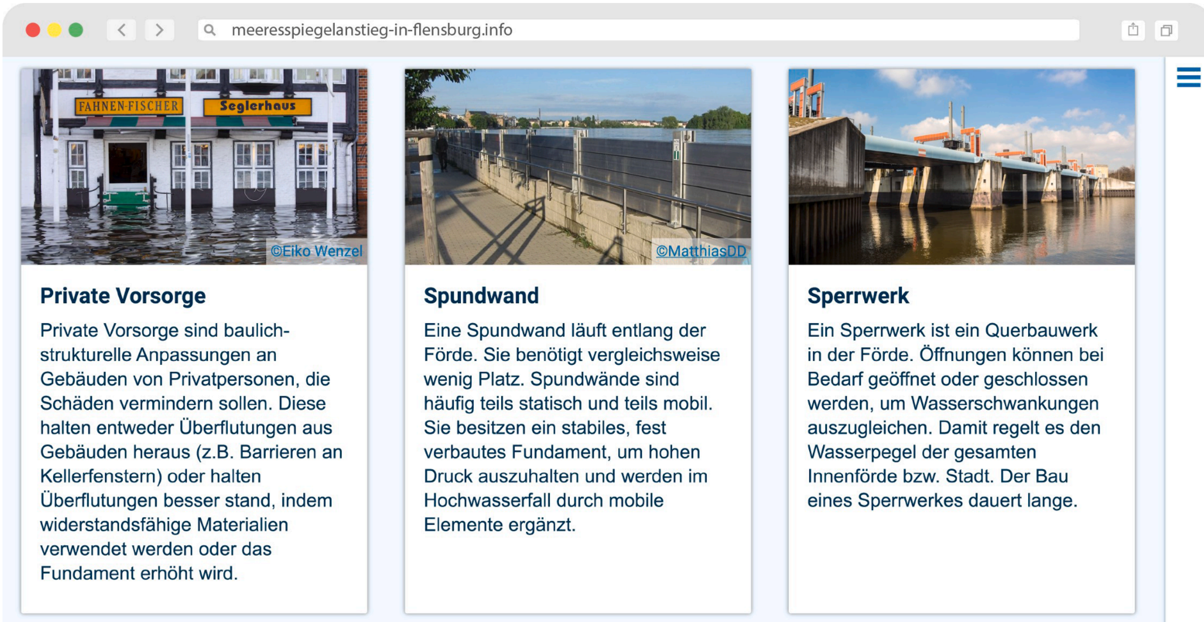

Fig. 5. Excerpt of adaptation measures presented in the story map.

adaptation measures. To address those information requests we included a Frequently Asked Questions (FAQ) section. In this section, we also added references, links to documents or web pages providing more in-depth information on e.g. return periods of storm surge events and the scientific basis for rising sea levels.

The story map was finalised during the validation in the November workshop in 2019, where participants (e.g. citizens, students, members of the city administration, political representatives, NGOs, businessmen) had the opportunity to provide feedback on the adjusted version. As we did not receive further suggestions during the workshop we considered the adjusted version as approved. The source code of the final story map is available upon request and a README.md file is available under (https://github.com/maureentsakiris/evoked).

4. Discussion

A starting point of a coastal adaptation process is to communicate information to communities and to raise awareness regarding SLR associated risks (Khan et al., 2020). At the same time, the lack of awareness of risks and the complexity of information have been identified as barriers for the adaptation process (Rouse et al., 2016). The SLR story map that we have produced helps to lower these barriers for the city of Flensburg and, as a new climate service web application, aims to raise awareness through communicating and providing information on SLR and associated flood impacts. Mees et al. (2018) highlight the need for accessible communication tools to raise awareness of climate change impacts. For this purpose, we have employed different formats to visualise scientific data and information in an accessible way. Our adopted approach is in line with the findings of Hoffmann et al. (2020) where respondents emphasise the need for different information formats such as figures, photos and maps, within climate service web portals. Generally, story maps can be applied for various topics and different target groups and have great potential to be used as climate service tools.

Following the BASIEC framework, raising awareness is an important part of the adaptation process and assists to reduce vulnerability. The increase of awareness of SLR-related risks can be established through information, communication and education (Khan et al., 2020). Following our co-production process, we focus on information and communication by displaying information on SLR, associated flooding and potential impacts in the story map. In the current state of our production approach, we do not focus on the educational aspect, which could be enhanced in future work by employing different learning techniques such as conferences and symposiums, workshops, training programs, and field visits (Khan et al., 2020). Our SLR story map can be used as a starting instrument for those learning techniques as other studies have shown that story maps are a useful tool for educational and learning purposes among students e.g. school and university (Cope et al., 2018; Kerski, 2015b; Marta and Osso, 2015). To foster awareness among the general public even after the project has been completed, it would be beneficial to make the story map known via the communication channels of the city of Flensburg on a regular basis. A live introduction at appropriate events connected to climate change and adaptation could be considered. Here a direct interaction with the user is possible and additional information needs can be disclosed to improve the story map tool even further.

Co-producing climate services, a central issue raised in the climate service literature, aims to identify user needs and to close the so-called usability gap. In order to identify needs and to close this gap the interaction between climate service providers and users is indispensable (Hewitt et al., 2012; Lemos et al., 2012). To this end, the close cooperation with local key partners was particularly valuable throughout the entire production process as it allowed us to clearly identify their specific points of interest. During our co-production process we, as a provider, also collaborated with other potential users of the service, who were given the possibility to engage in content development during all phases of the production process. The study of Giannini et al. (2016) highlights the importance of the recognition of user needs following a feedback phase. This was also proven across the responses of our evaluation phase, as we identified further information and user needs of climate information for the story map. In particular the need for visualising past SLR and future coastal flooding was strongly emphasized. The modelled flood maps for the city of Flensburg therefore constitute a central section of the adjusted story map. The feedback confirmed the results of previous studies that showed the need for local impact maps to first communicate SLR and its consequences; and to, improve the personal connection to these impacts (Frazier et al., 2010; Gawith et al., 2009; Nicholson-Cole, 2005; Rouse et al., 2013; Stephens et al., 2015). Whether our approach has closed the usability gap was not elaborated further in this study and requires additional evaluation. Following Swart et al. (2017) a combination of diverse feedback methods such as interviews, user panels and online questionnaires can be useful to engage users. Our feedback process included web-based testing with an online questionnaire survey and a workshop. For the web-based testing, we decided for anonymous participation, as it was not our intention to link the feedback to the respective user groups and we used diverse distribution channels to reach a wide range of potential users. We see some limitations in this approach as, after the adjustment, we were not able to receive feedback from the same respondents of the first evaluation phase. This was due to the fact that we introduced the adjusted version of the story map in the workshop and could not ensure that all workshop participants had seen the first version before or even participated in the web-based testing. During the feedback process, we received comments that could not be realised in the story map as they either did not fit the scope of the study within the EVOKED project or were too specific. This specific information request and its implementation would however turn our SLR story map into web portals or platforms targeted to more experienced users. As our purpose was to set up a story map for the general public, we integrated the FAQ section and further pop-ups for users who are interested in more detailed information. This allowed us to keep our story map short, not too text-heavy while also satisfying the more advanced users. This approach was also applied in other web application development processes (Giannini et al., 2016; Preuschmann et al., 2017).

Some studies discuss the advantage of interdisciplinary teams for the development of climate services (Christel et al., 2018, Rouse et al., 2013). During our production process, we found the interdisciplinary composition of our team extremely valuable. It was particularly helpful to find an accessible language and visualisation format to communicate the complex climate data and information, even though it was a more time-consuming process and needed more coordination. Depending on the content of the story map, we propose to always directly involve a web developer/designer in the process. The web developer/designer developed our custom-made template, which gave us high flexibility in the design and adjustment of the story map; and provided the possibility to chose different visualisation formats, based on the feedback, in order to meet user needs and to display data in an accessible format. Generally, the development of a custom-made template requires more time and resources as it needs to be adjusted for different devices and technical requirements. The involvement of a communication designer has proven very useful as they can visualise the scientific data in more understandable ways. The communication of information can be enhanced through the involvement of a person who is aware of local particularities and the local language, as well as a professional writer to ensure correct and accessible wording.

5. Conclusion

Web applications such as story maps help to communicate and visualise complex scientific data in an accessible format to specific target groups. By producing a SLR story map we have created a climate service for the city of Flensburg to raise awareness for SLR and associated flooding. Moreover, the story map can be used as a starting point to initiate action for coastal adaptation. Through a co-production approach user needs have been identified. These needs were addressed by adjusting the climate service. Independently of the thematic focus of such story maps, we found that an interdisciplinary team of experts is important for increasing the attractiveness and usability of the service. Additional assessment is needed to validate the extent to which the story map will be used and whether, and in which ways, it will contribute to adaptation decision-making in Flensburg in the long-term. For this purpose, further information demands of decision-makers need to be identified and included.

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CRediT authorship contribution statement

Bente Vollstedt: Writing - original draft, Methodology, Investigation. **Jana Koerth:** Conceptualization, Validation. **Maureen Tsakiris:** Software, Visualization. **Nora Nieskens:** Resources, Methodology. **Athanasios T. Vafeidis:** Supervision, Conceptualization, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cliser.2021.100225.

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