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Presentation of uncertainties on web platforms for climate change information

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Abstract

Adaptation to climate change is gaining attention and is very challenging because it requires action at a local scale in response to global problems. At the same time, spatial and temporal uncertainty about climate impacts and effects of adaptation projects is large. Data on climate impacts and adaptation is collected and presented in web-based platforms such as ci:grasp, which is unique in its structuredness and by explicitly linking adaptation projects to the addressed climate impacts. The challenge to find an adequate and readable representation of uncertainty in this context is large and research is just in the initial phase to provide solutions to the problem. Our goal is to present the structure required to address spatial and temporal uncertainty within ci:grasp.

We compare existing concepts and representations for uncertainty communication with current practices on web-based platforms. From our review we derive an uncertainty framework for climate information going beyond what is currently present in the web. We make use of a multi-step approach in communicating the uncertainty and a typology of uncertainty distinguishing between epistemic, natural stochastic, and human reflexive uncertainty. While our suggestions are a step forward, much remains to be done.

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Keywords: climate change information; uncertainty; uncertainty representation; web platform;

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1. Introduction

Global greenhouse gas emissions continue to rise and already have impact on the global climate, such that adaptation is gaining attention. Data about climate impacts and adaptation is collected and presented in web-based platforms such as ci:grasp (Climate Impacts: Global and Regional Adaptation Support Platform). In contrast to various other platforms, ci:grasp is unique, to our knowledge, in its structuredness and by explicitly linking adaptation projects to the addressed climate impacts via the concept of impact chains. An adequate and readable representation of uncertainty is still missing. The challenge of a user-friendly representation and quantitative/qualitative depiction of the relevant uncertainties in this context is large and research is just in the initial phase to provide solutions to the problem.

Uncertainties in climate change assessment may become substantial and care has to be taken to find the right balance between avoiding the impression of overcertainty for policy advice [1] and nevertheless communicating what is known. We give a short review about existing work related to communication of uncertainty (section 2), present existing approaches on web-based platforms (section 3) and make a suggestion for steps forward based on the existing work for our platform (section 4).

2. Communication and presentation of uncertainties

Various guidelines exist for dealing with uncertainties in the policy analysis context [2] for integrated environmental models [3] and in the climate change community [4-6]. The impact of climate change and related uncertainties are spatially heterogeneous. However, spatial uncertainties are not discussed explicitly in these guidelines. Communication of spatial uncertainties occurs in four subsequent steps according to Reinke and Hunter [7], notification (1) about the existence, identification, i.e. describing the type of uncertainty and its spatial extent (2), presenting the quantitative information (3) and finally enabling an evaluation (4) of the relevance of the uncertainty.

For the identification (2 – see section 4 for notification), we propose a typology of uncertainty based on work by Dessai and Hulme [8], distinguishing between epistemic (not enough knowledge available), natural stochastic (random processes cannot be fully described), and human reflexive (statements about possible futures trigger societal action) uncertainty. Epistemic uncertainty originates from incomplete knowledge of the processes. For example unknown values for sea-level rise depending on increasing temperature or parameters required for an impact model. Natural stochastic uncertainty originates from random processes, for which only statements about probable outcomes are possible. One example is the non-linear dependence of the climate model as described by the Lorenz attractor [e.g. 9]. These first two types of uncertainties may be represented, with some limitations, with probability distributions of possible events. Human reflexive uncertainty originates from the fact that predictions about social systems influence the decisions within this social system, thus reducing the prediction itself to a base for discussions. Thus, climate change scenarios are used to describe possible future development of the society [10]. We argue that the representation of uncertainty is determined by its type, i.e. epistemic and stochastic uncertainties are best represented with ensemble or grid uncertainty maps while human reflexive uncertainty should be represented with a number of scenarios.

Quantitative uncertainty visualization (3) has generally become of rising interest in the last two decades [11]. Visual mappings representing both data and uncertainty using position for the data and color maps for uncertainty [12], contour plots with different line shapes (Fig 1. B1) [13], colored height fields representing ensemble distributions and their statistics [13], textures (Fig 1. C) [14], and blurring in texture-based flow visualization [15]. For an overview see [16].

Visser et. al [16] provide a checklist for dealing with uncertainties in spatial information. They emphasize that map representations appear to raise too much trust in the represented information [16]. Thus uncertainty communication is of high importance. The checklist discusses the right format of uncertainty representation (e.g. difference maps, scenarios, ensemble maps and grid uncertainty maps) and the presentation format (combined maps, separate maps, or dynamic presentations).

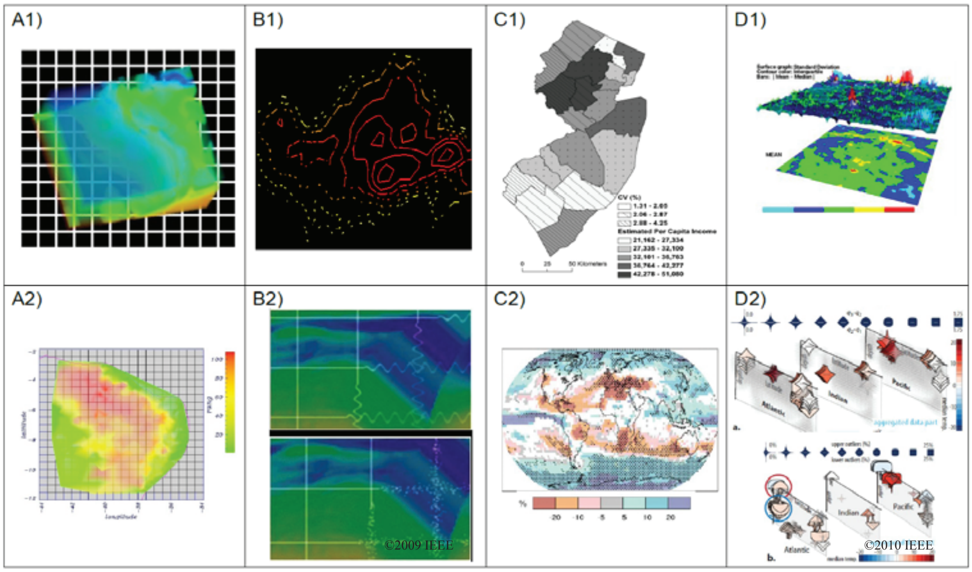

Fig. 1. Examples for a combined presentation of information and related uncertainty using transparency (A1: Djurcilov 2002 [17] and A2: Nocke et al. 2007 [18]), changing line style (B1: contour lines in Pang 2001 [13] and B2: grid drawing in Cedilink 2000 [19]), 2D textures (C1: Sun and Wong 2010 [14] and C2: IPCC 2007 [20]) and more complex detail mappings (D1: difference between mean and median visualized by bars in Pang et al. 2001 [13] and D2: glyphs indicating ensemble distribution properties such as no. of positive or negative outliers in Kehrer et al. 2010 [22])

We focus on the spatial uncertainty representations of climate data. Examples of uncertainty representation range from textures mapping (Fig 1. C2) [20], spatial bar charts (Fig 1. D1) [21] and glyphs for cluster uncertainties and for ensemble statistics [22], over color mapping of uncertainties in a separate image [23] and opacity mapping (Fig 1. A) [17,18]. In the next section, we review how uncertainties are presented on a number of web-based platforms, and we will show that concepts are very heterogeneous on these platforms.

3. Presentation of uncertainties on web-based platforms

User interfaces of web-based platforms aiming at improved access to climate change information show a remarkable degree of external inconsistency [24]. The same holds true for visual representations of uncertainties utilized by such interactive applications. We conducted a review of a sample of web-based platforms displaying projected climate change information to identify typical techniques used to represent uncertainty (Table 1). While not comprehensive, we can draw the following conclusions from this review. First, there is no standardized approach to represent uncertainty up to now: different platforms use different techniques in different combinations. As a consequence, information about uncertainty is not always easy to identify, indicating that the notification step [7] is often insufficiently considered. Second, while concepts and representation techniques for uncertainties are heterogeneous across different platforms, they are limited to relatively simple representations without arriving at the possibilities from current visualization research and existing practices in the climate change community, such as maps indicating both projected meteorological parameter changes and climate model (dis-)agreement thereupon (Fig 1 C2). This is especially noteworthy since interactive visualization, as can be utilized for web based platforms, offers options for information presentation exceeding those of static visual representations typically used in print-based scientific communication.

Table 1: examples for representation techniques for uncertainty related to climate change projections in web-based platforms

representation technique		examples representing uncertainty addressed with	
		multiple GCMs (epistemic)	multiple SRES scenarios (human-reflexive)
single user-selectable representations on a map		ClimWiz[a]; IPCC[b]; CCR[c]; PCIC[d]	ClimWiz; IPCC; CCR; PCIC
display statistical measures on a map		ClimWiz; CCR	ClimWiz
detail on demand (picking on map)	tabular text	World Bank[e]	
	scatter plot	ClimWiz	ClimWiz
	multiple time series plot	World Bank	
multi-view	one map below the other	PCIC	PCIC
	tabular set of maps	CCR, ClimWiz	ClimWiz
whisker / box plot		PCIC	PCIC
map of future climate analogues		CCR-A[f]	

4. Structured approach for the presentation of uncertainties in ci:grasp

Based on the existing work about communication of spatial uncertainty (section 2) and our review of approaches on existing platforms (section 3) we developed a concept building on the idea of multiple, interactive steps [7] for the presentation of uncertainties in ci:grasp. The complexity of the information presented increases from one step to the next. With respect to the notification and identification, we extended the underlying database to include a short explanation about the three types of uncertainty [8] for each element along the impact chain on the platform. For the notification, we use icons as shown in Figure 2 next to each element, indicating the presence of uncertainty. For the identification, the user can access the underlying explanation. For example, the explanation for a map related to land loss caused by sea-level rise of one meter is shown in Figure 2. For the quantification, a link to a map representation of the uncertainty is optional for cases where this makes sense. For example, we present maps about the agreement of different models about the direction of future change for climate projections.

A fundamental decision is whether to represent the full uncertainty propagated to each element from its precursors or to restrict it to a “local” uncertainty derived from the current assessment. For example, sea-level rise includes all three types of uncertainties, as the future emission pathways are unknown

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[a] The Climate Wizard: http://www.climatewizard.org/

[b] IPCC Data Distribution Centre Visualisation: http://www.ipcc-data.org/maps/

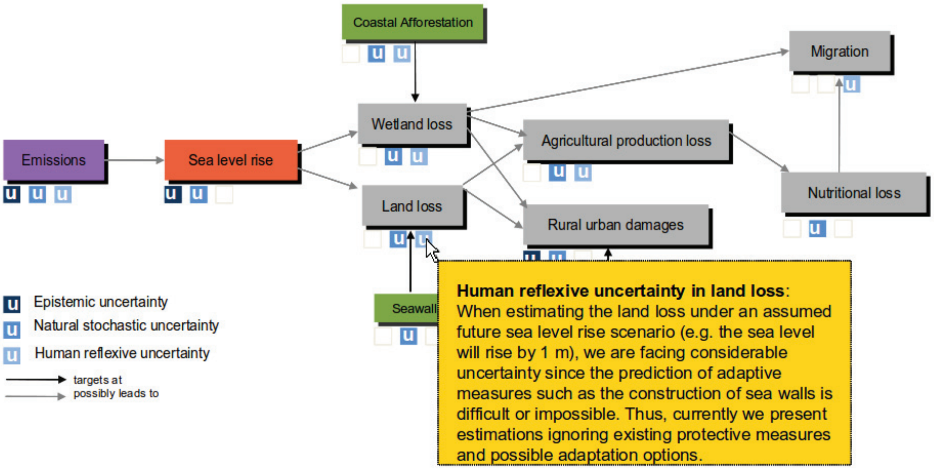
[c] Center for Climatic Research: IPCC Results http://ccr.aos.wisc.edu/model/visualization/ipcc/

[d] Pacific Climate Impacts Consortium: http://www.pacificclimate.org/tools/select

[e] The World Bank Climate Change Knowledge Portal: http://sdwebx.worldbank.org/climateportal/

[f] Center for Climatic Research: Wisconsin Climate Analogs: http://www.wicci.wisc.edu/climate-map.php

(human reflexive), the processes leading to sea-level rise are not fully understood (epistemic) and stochastic processes are involved. Thus, all impact assessments related to sea-level rise would include this uncertainty, leading to very complex chains of uncertainty propagation which are likely to render the information useless due to the high complexity [1]. Therefore we decided to only include the "local" uncertainty. In the case of sea-level rise we solved this by making assessments for a 1 m and a 2 m scenario without defining whether and when this will happen.



Human reflexive uncertainty in land loss: When estimating the land loss under an assumed future sea level rise scenario (e.g. the sea level will rise by 1 m), we are facing considerable uncertainty since the prediction of adaptive measures such as the construction of sea walls is difficult or impossible. Thus, currently we present estimations ignoring existing protective measures and possible adaptation options.

Figure 2: Notification and identification of uncertainty on the climate change information platform ci:grasp. The concept is illustrated using the impact chain and indications for relevant (blue) and irrelevant (white) uncertainties. Boxes stand for climate drivers (purple), climate stimuli (red), climate impacts (grey) and adaptation measures (green). The mouseover displays an example of a short text explaining the origin and spatial extent.

5. Discussion

During our survey we were challenged by the missing standard structure of web based platforms, often leaving the discovery of existing representations of uncertainty to chance. Keeping this limitation in mind, our analysis indicates that existing web-based platforms do not meet the capabilities currently developed with innovative visualization techniques and as presented in reports on climate change. Various reasons may exist for this difference, among which we suspect technology driving development, missing best practices for communication of uncertainties, and the danger of over-complex representations carrying the danger of being misunderstood [15]. Despite good reasons for simple representations on web-based platforms, we argue that there may be cases where more sophisticated approaches are beneficial, especially in view of the fact that maps are commonly used to spatially present the "way it is", or "way it was", thus being accepted as reality [15]. In the context of mapping possible futures, they are commonly used to present information we cannot know whether it is "the way it will be". It often does so without indicating this uncertainty, regardless of whether information is at hand to quantify this or not.

We suggest that web-based platforms should follow an interactive multi-step approach when communicating uncertainties as presented in section 4. We are aware that this is just an initial step towards a best practice and much remains to be done. We see the highest priorities in studies about effectiveness of each of the steps of communication of uncertainties, especially of more complex, combined presentations of maps and the related uncertainty.

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