Interactive Access to Climate Change Information

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Abstract

Communicating scientific research on climate change to decision-makers, stakeholders and the general public in an easily comprehensible manner is a challenging task. Against this background, interactive applications that facilitate intuitive access to relevant knowledge can play a crucial role. Nevertheless, the design of such applications is hampered by the heterogeneity of the field of climate change and climate impact research and the gap between climate experts, IT experts and end users. Facing these obstacles, this paper discusses three applications supporting access to different facets of climate change research.

1 Introduction

The design of interactive applications aiming at intuitive access to climate change information is generally confronted with two main challenges:

- Make a heterogeneous field accessible: Research on climate change is a comprehensive field, based on ongoing research of multiple scientific disciplines. Thus, typically several facets of the overall field have to be made available to inform the user (e. g., driving forces, impacts and vulnerabilities, mitigation and adaptation options). This may cover the presentation of results from various disciplines in an integrated manner; furthermore, complex interrelations might have to be presented in a comprehensible way. Due to the overwhelming amount of potentially relevant information, appropriate subsets have to be identified first. Since these subsets still can be sufficiently complex, means have to be provided supporting the user in gaining an overview on available information and to identify and extract information of interest.

- Bridge the gap between climate experts, IT experts and end users: Typically, climate change researchers cannot be expected to be as well experts in information technology or HCI concepts, and vice versa. Therefore, it is highly likely that applications cannot be specified completely in advance but will have to be derived in a mutual, ongoing learning process between domain and IT experts.
  The level of the end users' background knowledge on climate change, on the other hand, differs according to the intended audience. Applications that give access to simulation data have to take into account that the intended end users might not be familiar with the underlying concepts. Thus, means should be provided to communicate uncertainties and to prevent from potential misunderstandings, e. g., to misinterpret future projections of climate variables as exact weather predictions. End users in this context are not a homogenous group;

each of the applications presented targets at different main users, including managers of nature protection areas, decision-makers, and climate change scientists presenting model results to a (scientific or non-scientific) audience.

Facing these challenges, three applications have been designed, each regarding different requirement perspectives, ranging from interactive, visual representations of climate data to textual representations of current research knowledge:

1. Representation of measured and simulated climate data for German nature protection areas.
2. Representation of climate driving forces together with their possible impacts onto the biosphere.
3. Access to scientific results generated within two work packages of the integrated research project ADAM (Adaptation and Mitigation Strategies: supporting European climate policy).

Following a short outline of related work (sec. 2), the paper characterizes the three applications (sec. 3 to 5), and sums up with some concluding remarks (sec. 6).

2 Related work

An overview of the scientific basis of climate change and the standard of knowledge can be found in the last assessment report of the IPCC[1]. The demand for interactive online-access to information concerning climate change is reflected in a variety of approaches; including wikis like WikiADAPT[2], wizards like the UK Climate Impacts Programme Adaptation Wizard[3] or layers for digital globes [Aurambout and Pettit 2008] like Google Earth (e. g., the WeADAPT[4] Adaptation Layer or Climate Change in Our World[5]).

Appropriate graphical user interfaces can contribute to facilitated access to scientific data in the context of climate impact research [Wrobel et al. 2008, 2009]. For the design of improved interfaces, concepts in human computer interaction are essential [Shneiderman 1998]; web-based interface design should consider additionally UI specifics of this environment (e. g., [Nielsen 1999]). Visualization techniques have been established to filter, evaluate and explore data (e. g., [Bürger and Hauser 2007]) and can play a central role in analyzing and presenting measurement and simulation data in the context of climate change [Nocke et al. 2008].

3 Access to information on climate trends for nature protection areas

Climate change impacts ecosystems and biodiversity at various scales [Araújo and Rahbek 2006, Vohland 2008]. In a research project, the regionalized impact of climate change on nature conservation targets as well as management options were investigated [Badeck et al. 2007]. A

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[1] http://www.ipcc.ch/
[2] http://wikiadapt.org/
[3] http://www.ukcip.org.uk
[4] http://www.weadapt.org/
[5] http://www.defra.gov.uk/environment/climatechange/research/google-earth/

dry and a wet future climate scenario, generated with the statistical downscaling model STAR [Orlowsky et al. 2008], were selected and interpolated to the center points of 4352 German nature protection areas [Badeck et al. 2008].

To provide managers of the specific protected areas with demand-driven access to information on potential climate development, a web-based application has been designed and implemented. The application allows users, which do not necessarily have a natural scientist's professional background, to intuitively compare observed climate with future projections for protection areas of interest. The application supports the user in gaining an overview on available protection areas, in selecting specific areas and in displaying related time series.

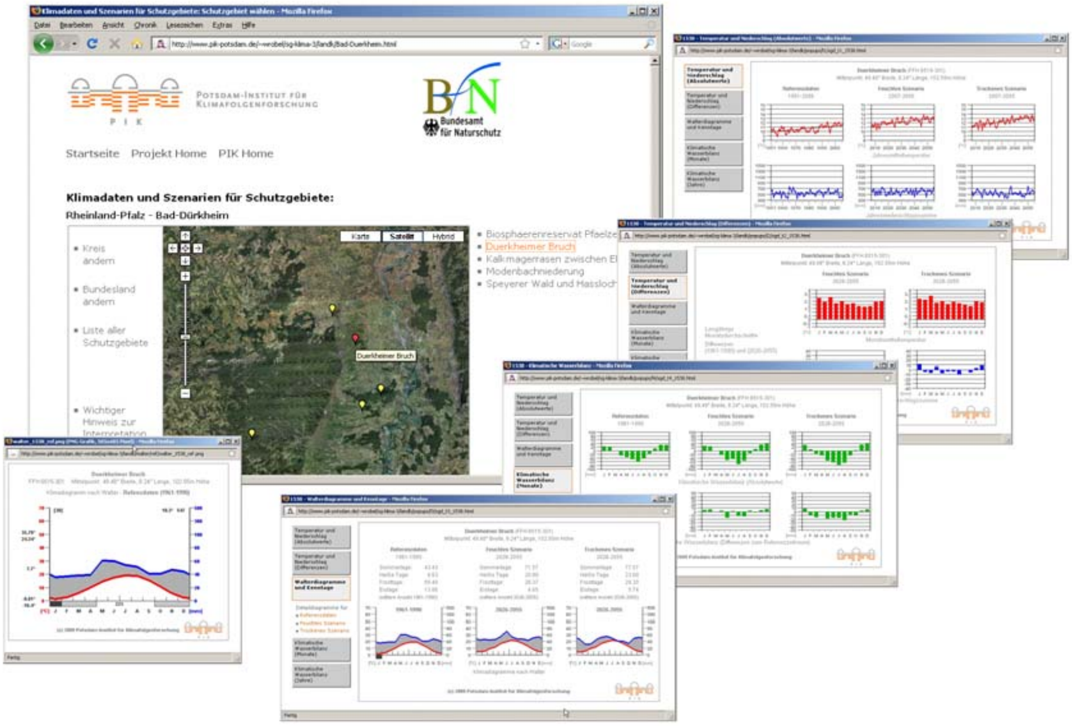

Figure 1: Displaying measured and simulated data for a protection area (Screenshots)

Feedback on an early prototype revealed that project members perceived it appealing to use Google Maps to display and select protected areas' center points in their spatial context. Tests also showed that it is unfeasible to display the more than 4000 points' symbols on a single map, resulting in a overcrowded map with poor responsiveness concerning loading, panning or zooming. Thus, we decided to follow the administrative hierarchy of Germany with its 16 federal states which are subdivided into several districts. For each district, a Google map is provided, displaying the center points of the protected areas located in this district (Fig. 1); areas attributed to more than one district are shown on all according maps. To navigate to a specific district map, the user can follow hyperlinks to select a federal state and a district subsequently or use alphabetical lists to select a protected area. The breakdown results in sufficiently clearly arranged and responsive maps; nevertheless, it should be noted that navigation to a different district cannot be performed by panning the currently selected map. To identify a specific protection area, the user can pick the related symbol on the map; alternatively, one can pick the name in an alphabetical list to highlight the according symbol.

To present details on selected time series, we use a tabular representation combining textual representation of threshold days, Walter diagrams, difference diagrams and trend diagrams (Fig. 1). At this, measured data can be compared with two future scenarios (dry and wet). The user gets access to the average numbers of threshold days, including heat days (t_{max}>30°C), summer days (t_{max}>25°C), frost days (t_{min}<0°C) and ice days (t_{max}<0°C). The Walter diagrams, traditionally used to indicate humid and water deficient conditions, are made available in two levels of detail. The representation is accompanied by trend diagrams, displaying annual mean temperature, annual precipitation sum and climatic water balance for each year of the measurement and scenario time frames.

4 PIK Vegetation Visualizer (PVV)

The Java-based PIK Vegetation Visualizer (PVV) [Nocke et al. 2009] targets at an interactive representation of biosphere change simulation data generated with the LPJmL model [Sitch et al. 2003, Gerten et al. 2004, Schaphoff et al. 2006] in combination with their driving forces. It aims to support scientists in communicating respective concepts, interrelations and results on workshops, information events or conferences. A central requirement for the design of this tool is the ability to intuitively and flexibly display the interrelationship between (a) different CO_2 emission scenarios, (b) derived temperature and precipitation projections of several climate models and (c) resulting projections for various vegetation variables simulated with LPJmL. Further requirements included ease-of-use, intuitive visualization metaphors, high robustness and responsiveness, and portability. To ensure high responsiveness[6] during presentation sessions, image generation is performed in advance and stored persistently to sets of files. Although this approach naturally limits the number of variables, scenarios, models and visualization options, it can contribute essentially to a high application reliability in presentation scenarios where time typically is limited and technical flaws are always undesirable.

PVV presents the various visualizations in a synchronized multi-view environment. It is a dynamic and augmented version of the static and exemplary visualization from [Lucht et al. 2006, Schaphoff et al. 2006] in the 4th IPCC Assessment Report[7]. PVV has been designed as a desktop application and can be run offline, thus ensuring applicability at places where no internet connection is available. In order to be versatile in various presentation scenarios, e. g., notebook-based presentation sessions or high resolution displays on exhibitions or information events, the user interface is scalable to different screen resolutions.

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[6] The supported presentation parameters result in ~0.5 $\ast$ 10^6 single images to be generated out of ~20 GB input data.
[7] IPCC Fourth Assessment Report. Working Group II Report: Impacts, Adaptation and Vulnerability, Chapter 4, fig. 4.3. http://www.ipcc.ch/ipccreports/ar4-wg2.htm

Main user tasks consist of gaining an overview over the parameterization parameters, their intuitive adjustment, and evaluation of the selected data. To support these tasks, a set of input controls is combined with altogether four synchronized display frames into one compact user interface (Fig. 2). The controls provide information on available parameter values as well as constant feedback on the currently selected parameterization. A first group of controls allows to specify a CO_2 emission scenario (SRES A1B, A2, B1), a climate model (ECHAM, HadCM3, CCSM-3), a vegetation variable simulated by LPJmL (area fraction of trees, grasslands and barren, net ecosystem exchange, carbon sequestration, two biosphere classifications) as well as a spatial region (world, continents). A second set allows to select time steps manually or to apply different animation modes; the third set of controls influences the representation of the selected data (absolute values vs. relative changes; data smoothing).

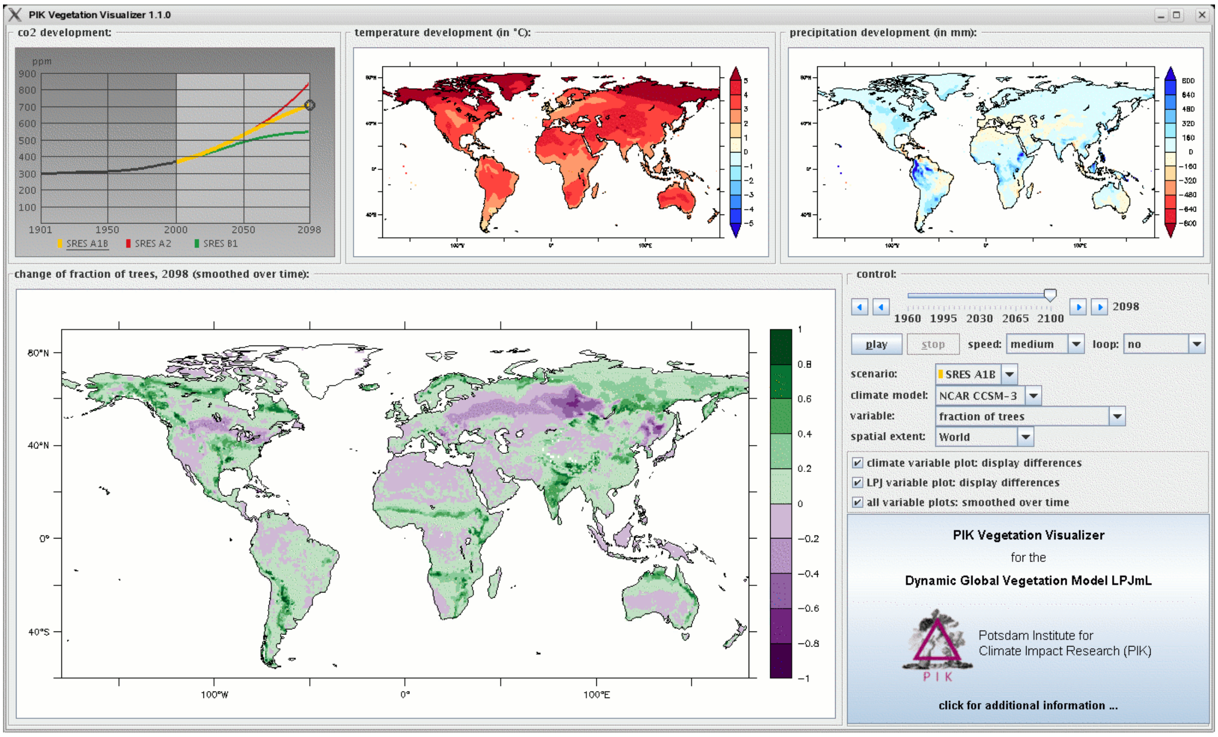

Figure 2: PVV's graphical user interface (Screenshot)

To ensure direct and intuitive feedback, the according multi-view display is updated immediately after each change in parameterization. The four display frames are arranged in a manner reflecting the chain of influences. Top left, a dynamic time chart represents the available CO_2 emission scenarios. The currently selected emission scenario is highlighted; in addition, a marker moving along the curve indicates the currently selected time step. Two small maps, displaying temperature (top center) and precipitation (top right), projected by the currently selected climate model, complement the row. Below, a larger map represents biosphere changes based on LPJmL output.

The current version of PVV enables the user to immediately obtain a large variety of the according multi-view representation. The tool has already been applied by several scientists at multiple occasions; it proved to be both useful and robust. It is envisaged to extend the approach to allow for a higher flexibility concerning user-definable sets of output variables, as well as to other simulation models.

5 The ADAM Digital Compendium

ADAM (Adaptation and Mitigation Strategies: supporting European climate policy) is an integrated research project funded by the European Commission aiming to lead to a better understanding of the trade-offs and conflicts that exist between adaptation and mitigation policies[8]. To complement the traditional, report and paper-based communication of scientific results, the web-based ADAM Digital Compendium has been designed[9]. It aims to support decision-makers in intuitive, integrated access to results generated within two of the project's work packages (Assessing Potential Impacts and Adaptive Capacity; Coping With Extremes). The content to be provided consists of five main sections:

- A set of textual result descriptions (learning examples) of actor-based research across a range of different case studies.
- Results generated with an integrated computable general equilibrium model for a macroeconomic analysis; dimensions include spatial resolutions, sectors and different temperature increase scenarios.
- A database with structured descriptions of scientific journal articles taken from the Europe chapter of the Working Group II contribution to the IPCC 4th Assessment Report.
- A set of crop yield and flood risk maps.
- A catalogue of adaptation options for extreme events (drought, flooding, sea level rise and heat waves).

The Digital Compendium was designed to accommodate the multitude of contents to be made available, as well the variety of content providers which are distributed over several European research institutes. Since the Digital Compendium was developed in parallel to ongoing research of the content providers, it was important to keep flexibility to integrate and present subsets of content in the way preferred by the providing scientists. On this account, the Digital Compendium was designed to allow for different levels of structure. Instead of striving for a 'one size fits all' approach – which was very likely to turn out be too rigid –, content is organized along the five main sections. Thus, each section can be treated with its own right[10] and obtain a suited substructure and presentation. Despite these degrees of freedom, homogenous appearance is ensured by applying a consistent overall look and feel (Fig. 3).

All content is free-text searchable; in addition, a consistent labelling of all content is applied, allowing the user to select content of interest by specifying sector, country or climate-related

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8 http://www.adamproject.eu/
9 http://www.digital-compendium.adamproject.eu
10 Content is partly managed in a CMS, in an additional RDBMS and structured files.

hazard. Users can hyperlink directly from each page to a list of other compendium pages labelled with the same keyword. Furthermore, additional access functionality for specific content sections can be provided, e. g., to search the study database by author, title or journal or to filter the adaptation catalogue by the type of option. To accommodate differences in user preferences, multiple representations of content can be provided where appropriate. E. g., in the macroeconomic analysis section, information for a given sector is displayed using an interactive map where the user can pick a region to view the according information. This representation displays regions in their spatial reference and supports a more playful user experience, but allows only viewing information for one region at a time. Thus, the user may alternatively select tabular representations by sector or region (Fig. 3c).

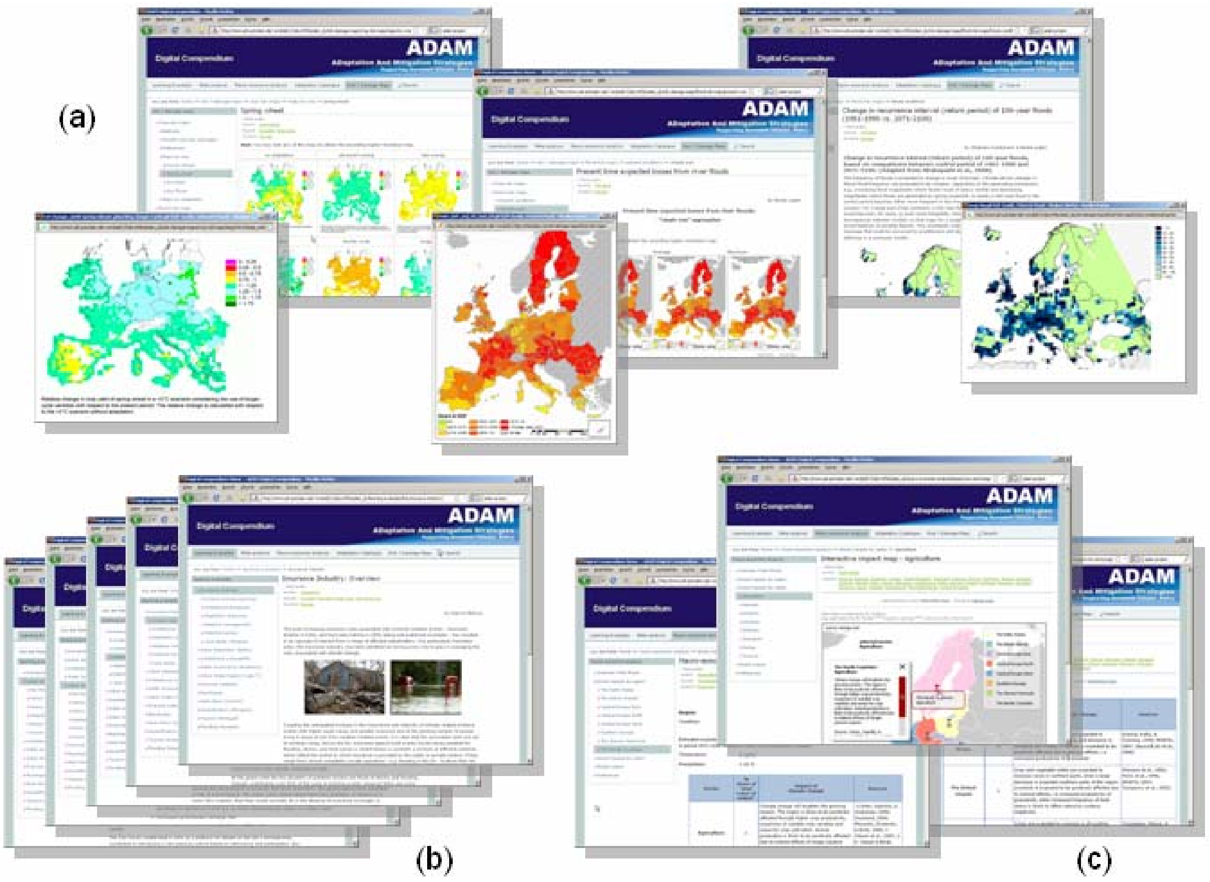

Figure 3: Screenshots of the ADAM Digital Compendium: (a) risk maps; (b) learning examples; (c) macro-economic analysis

6 Conclusion

Suited applications can support intuitive and flexible access to information in the context of climate change and contribute to improved information flow. This paper presented three applications addressing different aims and facets of this complex field. Experience gathered in this work can be summarized in the following conclusions.

- Close co-operation with domain experts: This first point should be self-evident but can nevertheless not be overemphasized. Successful applications in this context can only be developed in close and continuous co-operation with climate change experts, since they can provide the necessary expertise on the subject as well as valuable advice based on their experience in presenting and discussing scientific results to and with various audiences.
- Iterative approach: For all three applications, it showed that complete ex ante specifications could not be obtained due to the gap between required domain and IT knowledge. Prototypes proved especially useful to overcome these limitations. In all three cases, pilot applications have been developed, allowing to discuss functionality with domain experts in a less theoretical way. Thus, important feedback could be gained and used to further enhance and improve the applications.
- Visualization: Visualization can be especially beneficial in supporting users in accessing complex data and is often perceived as appealing and intuitive. All three applications use visualization but limit it mainly to selected presentation issues.
- Flexibility: It is a well-known fact that users tend to be different. Thus, where appropriate, the applications are designed to support flexible access. This includes, e. g., support for different navigation or filter strategies and alternative representations of content.

The user interface can be regarded as crucial in supporting interactive access to information on climate change. The complexity of the interface should be well-balanced, in order to both allow sufficient freedom and fast and intuitive access. The underlying “credo” here is to deliberately restrict specific degrees of user freedom (e. g., to certain color scales or time frames). Such well-motivated restrictions reduce the complexity of resulting applications, thus facilitating their usage, and can increase responsiveness. Furthermore, they can help to ensure consistency of presented results and to prevent interpretation errors. Again, appropriate functionality should be defined iteratively in close interplay with climate change experts.

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