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DISSEMINATION AND END-USER INTERACTIONS OF CLIMATE CHANGE IMPACT ON WATER RESOURCES

Spridning av resultat och användarkontakter för klimatförändringens påverkan på vattenresurser

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Abstract

During three years there have been continuous activities on dissemination of results from the Swedish research project HYDROIMPACTS2.0, including dialogues and outreach to stakeholders and end users. Besides the traditional dissemination towards the academic community (e.g. scientific papers and conference contributions), the project included various web-based tools to facilitate hydrological climate change impact assessment as well as production of pedagogical material and intensive end-user interaction. In this paper, we describe the tools developed, the material produced and the activities performed. The main aim is to help the interested reader getting access to the project's results, but we hope that this overview may also serve as inspiration for designing the dissemination in future projects.

Key words – climate change; hydrology; impacts; downscaling; web-based tools; end users

Sammanfattning

Under tre år har vi drivit återkommande aktiviteter för att sprida resultat från det svenska forskningsprojektet HYDROIMPACTS2.0, inklusive dialoger med intressenter och utåtriktad verksamhet till slutanvändare. Förutom den traditionella resultatspridningen riktad till forskarsamhället (t.ex. vetenskapliga artiklar och konferensbidrag), innehöll projektet utveckling av olika webbaserade verktyg för att underlätta bedömningen av klimatförändringens hydrologiska effekter samt utveckling av pedagogiskt material och intensiv interaktion med slutanvändare. I denna artikel beskriver vi de utvecklade verktygen, det producerade materialet samt de utförda aktiviteterna. Det huvudsakliga syftet är att hjälpa den intresserade läsaren få tillgång till projektets olika resultat, men vi hoppas också att denna översikt kan tjäna som inspiration för utformningen av resultatspridning i framtida projekt.

1 Introduction

In all types of scientific research proper dissemination of the results is a key issue. The strategic research project HYDOIMPACT2.0 was funded by the Swedish research council "Formas" and run 2010–2013 as collaboration between Swedish Universities and the Swedish Meteorological and Hydrological Institute (SMHI). The overall goal was to advance methods for climate change impact studies on water resources at various scales in time and space, including outreach activities. There are different target audiences for the dissemination, the main ones being the academic community, various stakeholders (with various degree of expertise) to whom the results are of importance, and the public. Obviously the dissemination must be tailored to the type of audience considered. In the academic community, dissemination is made mainly though scientific papers, conference proceedings and technical reports. For the public, the main means are popular scientific contributions in newspapers, other media or at outreach events. Stakeholder dissemination needs always be tailored to the particular category considered, in terms of both contents and technical level.

Dissemination of research results to non-experts is always challenging, in particular with respect to the associated uncertainties. In the case of hydrological climate change impacts, there is a long chain of methods and models involved, each with its own assumptions and uncertainties. Firstly, climate projection data (mainly precipitation and temperature) are retrieved from models that are known to have biases and that use highly generalized assumptions about future global development. Secondly, the climate model data are generally statistically post-processed (bias corrected). The methods used increase the applicability of the model results, but at the same time add uncertainty by modifying the data and possibly disturbing their internal consistency. Thirdly, a hydrological model is used to make projections of future water resources. Finally, results of different variables from the hydrological model are extracted and post-processed into various indices and mean or extreme values, which are normally plotted on maps and graphs for further assessment.

Each model in the production chain above typically has a lot of parameters that need to be calibrated and it needs to be assumed that the calibration is suitable also for future climates, which is not certain. In the end, the accumulated uncertainty surrounding the final result becomes very large. However, stakeholders often ask for a best estimate or at least a limited interval, and how to provide this and at the same time communicate the uncertainties in a complete and transparent way is a very challenging issue.

In the research project HYDROIMPACTS2.0 a workpackage called "Analysis, result extraction and outreach activities", was entirely devoted to dissemination of results from the project. In this paper, we start by outlining the objectives of WP4 and describe the various ways in which these objectives have been achieved. While the main aim of this paper is to help the interested reader getting access to the project's results, we hope that it may also serve as inspiration for designing the dissemination in future projects. It should be remarked that the paper does not give a complete description of all dissemination in the project, there are more, but it highlights some of the main achievements.

2 Work Package 4 in HYDROIMPACTS2.0

WP4 primarily aimed at enabling deliverables to various types of relevant stakeholders. The work was intended to be based on the methods used at SMHI in the Water Framework Directive programme, in which web-based tools are developed, and focus on adaptation to data and methods produced in the project as well as relevant analyses for various users. Four deliverables were defined in the project proposal and these are listed in Table 1 along with a brief description of key associated work per-

Table 1. *WP4 deliverables and associated work performed.*

Nr.	Description of deliverable	Key work performed	Sec.
4.1	Methods for downscaling of climate signal to more detailed climate scenarios to the more initiated end-user. Guide-lines on which method/data to be used in to different applications.	Development of a web-based tool for downscaling climate model projections (precipitation and runoff) local scales.	3.2
4.2	Databases with free access to climate and hydrological variables with high resolution in time and space for present and future climate, covering Sweden and Europe.	Provision of HYPE climate projections for Sweden and Europe on the HYPE web (so far in the form of maps, but data access will be implemented at a later stage).	3.3
4.3	(1) Illustrations and pedagogic pre-views of key results, uncertainties and comparisons between different impacts.	(1) Production of a popular scientific video about urban hydrological climate change impacts.	4
	(2) Adaptation of a visualization tool linked to the databases, for users to navigate and explore the model results of climate change.	(2) Development of a web-based tool for climate model data visualization.	3.1
		(3) Interactive shows in a portable Geodome for many different audiences.	5
4.3	Interactions through workshops and possibly reference group meetings with (1) Swedish end-users (water authorities at various levels) for final design of tools and databases and (2) policy makers and international stake-holders to promote links to relevant international databases.	(1) On-going discussion with the water authorities regarding design of web-based delivery of open data. This includes special activities for evaluation of web based climate tools. (2) Workshop with European stake-holders in the fall 2012.	6

Figure 1. *The start page of HYDROIMPACTS2.0 web site.*

formed as well as references to the associated sections of this paper.

The main way to access the results of HYDROIMPACTS2.0 is through the project web site:

http://www.smhi.se/en/Research/Research-departments/Hydrology/hydroimpacts2-0-1.9564

The start page is shown in Figure 1. Dissemination intended for an academic audience is made by brief descriptions of key results in each of WPs 1–3 as well as through lists of scientific publications and conference contributions. Dissemination towards stakeholders and the public, which is the main focus in this paper (see Sections 3.5 below), is accessed through the WP4 results at the web site.

3 Web-based services

Dissemination by providing web-based services for different types of end-users has been a main outreach activity within HYDROIMPACTS2.0. In this section, the main services are described along with information about how to access them.

3.1 Climate model data visualization

A lot of climate model data are readily available for download on the web. Thus, in theory any user can access them and perform visualization or calculations. However, as the sizes of the data sets are huge and the formatting often specific for this type of data, in practice only experts can handle the data by using tailored software. An interested user with limited time and resources available is thus generally referred to publications where general information is given. More specific information, such as the expected future climate change in a certain area within a certain time horizon is generally difficult to find.

In collaboration with the SUDPLAN project, a tool for easy visualization and download of climate model data has been developed (Figure 2). In the tool, the user may view precipitation and temperature from climate model projections in various ways. The default view is a map over Europe onto which 10-year averages of precipitation and temperature may be projected by using a simple sliding bar. Specific locations may be selected and the corresponding time series viewed and compared (Figure 2). The time series can also be downloaded with different time resolutions. It is possible to download both original, "raw" climate model data and data that have been bias corrected against observations using the DBS method (Yang et al., 2010). Currently (2013) an ensemble of four climate projections, representing different global models and different IPCC emission scenarios, are available but the intention is to add more projections and thus improve the possibilities for uncertainty assessment.

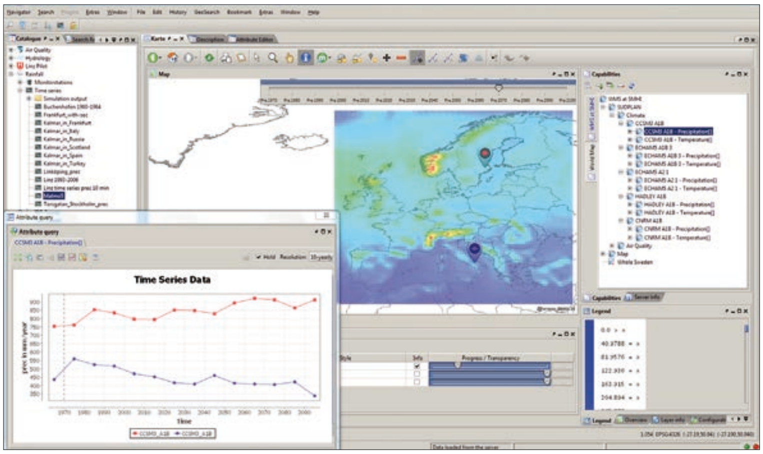

Figure 2. *Web-based tool for climate model data visualization.*

More information about the tools is available at the SUDPLAN website: http://www.smhi.se/sudplan. Contact information for a user interested in the tools is available on the web site.

3.2 Downscaling tools

There is often a need to downscale the results from climate models as well as impact models, in order to make the results applicable locally. The main reason for this is that climate models typically provide the results (e.g. rainfall) as averages over 25×25 km or 50×50 km grid cells. In some key aspects, these data differ substantially from local data and some form of statistical downscaling is required to make climate model results applicable for local climate change impact assessment (see e.g. Olsson et al., 2013; this issue). Also the results from large-scale impact modeling may need to be downscaled to improve the performance in specific locations. In collaboration with the SUDPLAN project, tools for observation-based rainfall and runoff downscaling have been developed (the graphical interface is the same as in climate model data visualization; Figure 2).

The rainfall downscaling is based on the Delta Change approach, i.e. observations are modified in line with the expected future relative changes as compared with a historical reference period, as estimated from climate projections. Functionalities for downscaling of both continuous time series and extreme statistics (in the form of Intensity-Duration-Frequency (IDF) curves) are included (Olsson et al., 2012). In practice, the user uploads a historical time series or IDF curve representative of the location considered. After selecting which climate projection and which future time horizon to use, downscaling may be performed and the results downloaded (i.e. data representing a future climate).

The runoff downscaling is based on Pan-European hydrological climate projections with the E-HYPE model (see Section 3.3 below). This model is designed for large-scale assessment and may not be accurate for an individual catchment, in particular not if it is below a size of ~5 000 km². However, by adding local runoff data the user may create a local model for the catchment and in this sense downscale the large-scale E-HYPE set-up on the basis of local observations. The E-HYPE model parameters may be automatically re-calibrated to optimize the agreement with the local observations. The locally calibrated model may then be used for climate change impact modeling by using bias-corrected climate model data as input.

Similarly to the climate model data visualization tool, further information and contact details are available on the SUDPLAN web site:

http://www.smhi.se/sudplan.

3.3 HYPE climate projections

In HYDROIMPACTS2.0, the HYPE model (Hydrological Predictions for the Environment; Lindström et al., 2010) has been used to produce hydrological climate projections (see e.g. Arheimer et al., 2013; this issue). Two set-ups have been used, one for Sweden (S-HYPE) and one for Europe (E-HYPE). To date, data from two climate model projections have been used but more projections are underway.

Results from the hydrological climate projections are freely available on the HYPE web:

http://hypeweb.smhi.se/

The results are displayed in the form of maps over Sweden or Europe (Figure 3). The rows represent the two different underlying climate projections, denoted

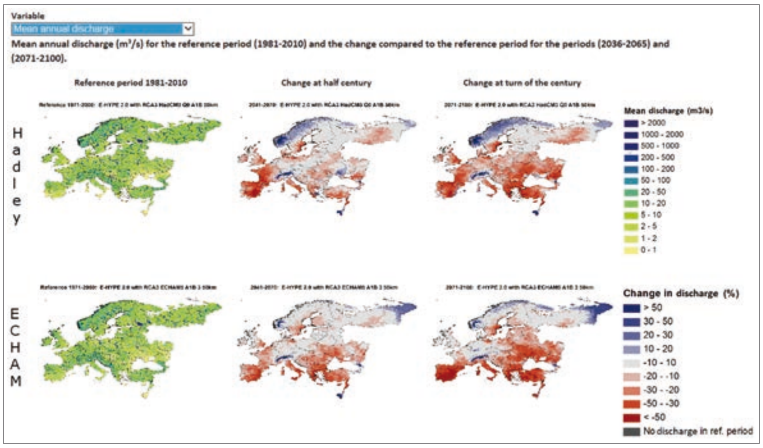

Figure 3. *Visualization of hydrological climate projections by E-HYPE.*

Hadley and ECHAM. The map to the left shows the result for a historical reference period (1981–2010) in absolute values. The map in the middle shows the relative change until the middle of this century and the map to the right until the end of this century. Variables available for visualization include: precipitation and temperature (bias corrected); local and accumulated runoff; depth and duration of snow cover; groundwater level; high and low flows; extreme flows (return periods 10 and 50 years); soil moisture deficit. The maps are accompanied by brief comments as well as a description of the methodology and a discussion on uncertainties.

4 Video production

Disseminating research in the form of "motion pictures" is becoming more and more common. Many projects produce their own videos and distribute it through their web sites, Youtube, etc. While a potential means of reaching new audience categories, making a good video is a challenging task that requires a lot of resources. Preferably the video should be interesting for experts, stakeholders and the public, which requires a well thought-out synopsis with a careful balance between general issues and technical details. Further, video-technical expertise is required to create animations that make the most out of the video format.

For a number of years, SMHI has been collaborating with Norrköpings Visualiseringscentrum C (Norrköping Visualization Center C). The collaboration has focused particularly on climate-related visualization and resulted in visualization tools as well as videos. A particular specialty of C is the use of a so-called Geodome (http://www.elumenati.com/products/geodome/), an inflatable dome on the ceiling of which video is projected. The capacity is ~25 persons who sits or lies down on the floor. The half-spherical projection surface in combination with good audio facilities makes video viewing in such a dome rather spectacular.

Within HYDROIMPACTS2.0, a video called "Urban Water Vision" was produced for Geodome as well as flat-screen projection. The video focuses on urban hydrology and gives an overview of expected climate change impacts. Particular emphasis is put on the difference in scale between on one hand the output from climate models, and on the other hand the input needed in urban hydrological climate change impact assessment. The scale issue is illustrated by moving between the extremely local (a storm-water sewer) and the extremely global (space) as well as gradual zooms to explain key implications of climate model resolution. The video attracted a large audience at its premiere on the World Water Week in Stockholm 2011 and has since then been shown at several occasions (see WP4 Results at the HYDROIMPACTS2.0 web site) and viewed 630 times on vimeo.com (2013-10-04).

5 End-user interactions in a Geodome

Interactive productions of climate change impact on nutrient load to the Baltic Sea and effects on the marine ecosystem (called "Baltic Visions") were produced in cooperation with the Visualization center C and the CSPR department at Linköping University. The performance was done in cooperation with the BONUS+ funded project ECOSUPPORT, which won the BONUS+ reward for best outreach activity in December 2011 in Gdansk. The productions were organized so that a library of results in maps and graphs was available for the show, which took place in the mobile Geodome theatre (see above). A live speaker then followed a very rough manuscript with an open story line, which left to the audience to decide geographic location to study or assessments to make. Sometimes equipment was used so that the audience could answer questions or give opinions on statements, to monitor the knowledge in the group with immediate response and feedback during the show. These interactive productions in the mobile Geodome became very popular and about 20 shows in a row were normally given during a couple of days at each event. In total, the mobile Geodome was used at some 15 events at different locations (see WP4 at the HYDROIMPACT2.0 project web site) often during conferences or on request. In this way, the climate change impact results were shared and discussed with a broad range of stakeholders at various levels in Sweden and other countries surrounding the Baltic Sea during 2010–2012. The visualization was tested on different audiences including policy makers, politicians, researchers and university students. Overall, the response was overwhelmingly positive with the audience expressing the view that the used visualization technique enhanced their understanding and receptiveness. This view was shared with the scientific presenters (Andersson et al., 2010).

However, the shows were labor intense as they requested one or two technicians with special competence of the unique projector and visualization platform (UNIVIEW), as well as one or two speakers with very good insight in the scientific topics. In addition, the transport and insurance of the portal Geodome became expensive. Sometimes it was possible to retrieve external funding for the show but finally it was judged as too expensive and labor intense to be used as a regular outreach activity.

6 End-user interactions in reference groups and workshops

The HYPE web (http://hypeweb.smhi.se) contains data from Sweden as well as for Europe. The Swedish part of this website (http://vattenweb.smhi.se) is developed in cooperation with the Swedish water authorities. The main users of the site are the Swedish water authorities and municipalities that need this data as background for decisions and reports. The development of the site has been done in close cooperation with the end users at the water authorities to meet their needs and requirements. The users have been active in the design of the site and are involved in all steps of the development of new features. In practice, users are welcome to suggest new data and new features. These features are discussed and prioritized together with the existing development plan in a selected group consisting of SMHI officials and representatives for the users in the water authorities. Moreover, users take part in the development phase of the new features as participants in reference and expert groups.

This process has been very important for the design of the site. As expected, large parts of the discussions with end users focus on exactly which data to publish, what it represents and how it is computed. However, during this process it became obvious that an as important issue for the end users is to understand the S-HYPE simulation model and its underlying encoded assumptions in order to assess how to use the results in relation to a specific task. There were also many questions regarding quality of the results. This interaction has given a web site which allows the end user to explore not only the model results, but also give transparency in the form of detailed information about the model setup and an interactive application for evaluation of the results (see Strömbäck et al., 2013).

In addition to this we have performed a special evaluation of the web-based tools described in section 3.1 and 3.2. For this evaluation a group of end users with special interest and responsibility for climate change have been selected. This group of end-users from the Swedish Water authorities have volunteered to learn about, perform experiments with and validate the tools. The validation was performed during fall 2012. The purpose of the activities was that the end users should learn the tools well enough to be able to use it for a task relevant for their local setting.

This evaluation consisted of several activities. It started with an introduction to the tools on a 1-day workshop. This introduction gave the basic knowledge the tools and planned the rest of the activities. After this introduction, users provided input to and participated in a workshop in Wuppertal, Germany, for potential European stakeholders. All end-users involved in the evaluation performed experiments with the tools for their local settings. This resulted input an evaluation workshop and report. The general impression was that the users were positive to the functionality provided by the tools. In addition the evaluation gave valuable input on future improvements.

Also a number of other stakeholder meetings and user seminars have taken place during the project, see further the HYDROIMPACTS2.0 web site.

7 Concluding remarks

Disseminating the results of scientific research is an important and far from trivial task. Tailoring the dissemination to the receiver takes a lot of time and resources, that are not always (or, rather, very seldom) fully available. For obvious reasons dissemination is generally supposed to take place in the end of projects, when the results have been produced. However, at that stage the remaining funding may be very limited. Further, new projects have started that require attention and may feel more motivating to work with. Therefore proper, comprehensive, meaningful dissemination is a rather unusual thing.

We do not claim to have fully succeeded in HYDROIMPACTS2.0, but we had rather ambitious goals for the dissemination and we believe they have been overall well reached. We started the outreach activities already at the project start and thus we allocated time and resources throughout the project. The web-based services serve their purposes and are useful platforms for further development. The video production was a very interesting learning process and the result has indeed helped communicating some of the key issues in hydrological climate change impact assessment. The interactive shows in the mobile Geodome became a success over expectations, although maybe not cost-effective. The end-user interactions have increased our understanding of their needs and increased our chances to deliver even better results next time.

Concerning future work, one key issue is the communication of uncertainty, as discussed in Section 1. We have in HYDROIMPACTS2.0 tried to improve this in some respects, e.g. by providing not only results from several projections but also some assessment of their characteristics and likelihood. Results from large (15–20) ensembles of hydrological climate projections are being analyzed, which may make probabilistic statements possible (e.g. risk of exceeding certain discharge levels during the present century). However, by only focusing on "climate projection production" there is a risk that too much emphasis is put on statistics and uncertainty estimates. Proper dissemination of climate change impacts must be based on knowledge of the (hydrological) system considered as well as of which future changes that are robust and credible. More attention must also be focused on post-processing and delivery of indices normally used by the stakeholders, to make the results easy to apply and digest in different sectors of the society. Only then can they be used for adaptation.

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