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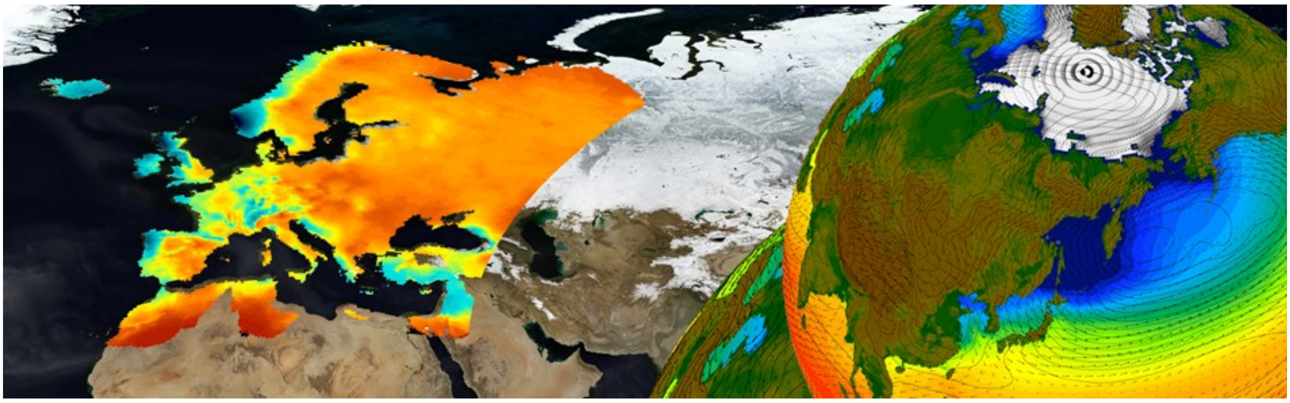

COST ES1102-VALUE, working group 1: 2014 White paper on climate change data for end-user

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What are end-users needs for climate change data

Climate change and its impact on natural systems, society or economy is still one of the most important challenges of our time. This is not only expressed by the vast number of research projects that has been accomplished in this field, but also in the demand of society, authorities and institutions, as well as the private sector (e.g., re-insurance companies) to receive answers to climate change related questions. The required information cover direct effects of climate change like heat waves, storms, thunder storms etc. as well as climate change induced impacts like changes in flood frequencies, agricultural production, or economic losses, just to name some of the possible impacts.

In 1998, Wigley showed that even under the consideration of an unlikely post-Kyoto emission reduction, climate change is still likely to occur (Wigley, 1998). Thus, the development of mitigation and adaptation strategies is regarded as a reasonable reaction to ecosystem changes (IPCC 2001, Smit and Wandel 2006). Feenstra et al. (1998) pointed out that it is essential to assess the severity of climate change impacts to develop strategies that modify or prevent these impacts. Hence, robust climate change impact assessment studies are needed, to assess the vulnerability of given systems and to develop reliable adaptation strategies.

For each of these climate change impact assessment studies, climate data are either directly interpreted or used in impact models by end-users. In this context we refer to end-users as the community of impact model operators, users of climate information and institutional program initiators. As most of these end-users are experts on their own topic, but not on climate or climate data, end-users are often unsure about the data access, quality of data, and correct usage of data. Barsugli et al. (2013) observed that the “practitioner’s dilemma” is no longer the lack of data and information, but rather how to choose appropriate information, assess its quality, and use it wisely. There has been a proliferation of web-based portals with high-resolution climate information based on a wide range of analyses, methods, and models.

For end-users the decision on how and which climate data to use is getting even more complex, as climate data is mainly based on General Circulation Models (GCMs), but end-users need information on local or regional scale. Hence, downscaling techniques have to be accomplished that not only bridge the spatial resolution gap between GCM and local information in a sound way, but are also suitable to provide direct information for the purpose intended by the end-user (e.g. heavy rain or summer temperature analyses). End users require precisely tailored downscaling products with detailed guidelines on their interpretation and limitations. Consequently, there is a need to improve the communication between the downscaling community and stakeholders, with a more targeted exchange of information about what is needed from the end user, and what can and cannot be provided by downscaling methods (MoU, Cost 2011).

To overcome limitations in the communication, there are multiple activities going on regarding end-users needs, especially in connection with the initiative from the World Meteorological Organization (WMO) on a global framework for climate services (GFCS) after the world climate conference-3 (WWC-3). The second international conference on climate services (ICCS2) was held in Brussels on September 5-7, 2012, and the joint programming initiative (JPI-Climate) was launched in March 2008. In parallel, the Coordinated Regional Climate Downscaling Experiment (CORDEX) organized the first meeting in Lille, 2012, and the World Climate Research Program (WCRP) organized the first open science conference (OSC) in Denver 2011. All of these initiatives recognized the need for involving end-users at an early stage in order for people to make effective use of the results, based on experience from the work of the international research institute (IRI) in the US and the European Centre for Medium-range Weather Forecasts (ECMWF) in Europe.

The COST-action project VALUE is a European effort to bring together the providers of climate information and the end-users and to bridge gaps between scientists and stakeholders as well as between climate scientists and statisticians. As opposed to many of the previous efforts which have been characterized by a top-down structure, VALUE is a bottom-up initiative which involves climate researchers and end-users of the climate data.

One starting point of the VALUE project and the members of the VALUE working group (WG) 1 was to provide inputs to an inventory of end-users from their respective countries. Then a pre-survey was made before the first end-user needs conference in Kiel March 7-9, 2012, to which nine responded - see spreadsheet in the appendix. Afterwards, based on the results and experiences form the pre-survey, a more comprehensive survey was accomplished. The questions and results are listed in the appendix. The general ideas are described in the next section, which describes the variables which were requested, the needed accuracy and precision, and other specifics. In addition to this limited inventory, a survey on findings on end-users needs of other initiatives has been accomplished. Finally, in spring 2013, WG1 interviews with experts from different countries and sectors was accomplished to gain a more detailed insight to the needs of end-users and to start a more direct and personal communication between the downscaling community and the end-users.

What are end-users needs for climate information

The end-users needs clearly depend on the level:

1 Decision makers and program initiators may need climate projection results on a single page (see ICCS2 impressions) aggregated in an understandable way.

2 1st-order end-users with regional focus: Natural science impact modellers need the “raw data” in a way they are familiar with (time-series of station data, or if they work on the broader scale gridded data (cp. IMPACT2C).

3 2nd-order end-users: E.g., end-users from the economy research or end-users from the private sector. They need information about changes in the impacts (heat waves, floods, wind damages, etc.), and are often satisfied with (regional) changes in the changes in occurrence probability of the impacts, either from the climatological community or from the impact modelling community.

Since impact research usually originates from analyzing climate observations of the past many end-users expect (or whish or demand) climate model data with the same characteristics like observations, i.e. spatial and temporal resolution, reliability (an observation is “the truth”, while model results are only “some possible truths”), accuracy, data format, and accessibility.

This obviously poses serious problems for both sides in the communication between climate model data providers and climate model data requesting end-users.

The idea behind surveys conveyed so far (including the VALUE survey) was to ask the users: "What data do you need for your research, your decisions, or field of interest?"

Further question should ask the end-users (mainly the 1st- and 2nd-order end-users):
"What are the worst data you can still work with and generate reasonable impact assessment from."

The general picture provided by the VALUE pre-survey:

First, we asked the Cost-VALUE participants in a pre-survey which variables and indices they found to be most important in climate change assessment studies. Table 1 summarizes all named variables and indices from the pre-survey. While the direct climate variables are mostly used in impact models like hydrological models, the indices refer more to the direct use of climate data. Temperature and precipitation are considered as the most important meteorological variables, followed by wind speed, humidity and radiation dependent variables like global radiation, cloud cover, or sunshine duration. Dependent variables of interest are variables either related to soil moisture or snow cover. Finally, some indices have been defined that mainly refer to temperatures like tropical nights or frost days. In terms of accuracy, the answers of the end-user gave more a feedback on what they would like to have instead of what is feasible for their study. Accuracy needed was stated for temperature (+/- 0.1 - 0.5 K) and precipitation (1mm, 5 - 10%) with a precision that is as high (temperature) or higher (precipitation) than obtained by observations in the field. The same holds true for radiation (+/- 5%) and wind speed (0.5 m/s). The spatial resolution of interest is mainly point data (synthetic climate station data) with an hourly to daily temporal resolution. This is related to the observational data needed by the impact models as spatial climate data sets of observation are widely not present for the resolution of interest. The needed spatial resolution depends on the region and the research question and stretches from 100x100m to 20x20 km and is regionalized directly by the end-users.

Further general needs of the end-user community in this pre-survey were inter- and intra-annual variability of variables including extremes, expressed as time-series from today to 2100. Probability estimates (e.g. PDF) of certain time periods are not relevant, but confidence intervals of the time-series are helpful. End-users like to have some guidance with the data like the information which climate model is most extreme or sensitive to single factors. Data should be easily downloadable from the web as ascii, excel or netcdf files.

Table 1: Meteorological variable of major importance for the end-users, related indices and temporal and spatial resolution

Meteorological Variables	dependend Variables	Indices	Temporal resolution	Spatial resolution
Temperature	Evaporation	Chill factor	Hours, days	Point data
Precipitation	Soil heat flux	Date of max. SWE	Hours, days	Point data, but spatially coherent
	Snow water equivalent	Date of 90% SWE melt		
Wind speed	Snow depth	Tropical nights	Hours, days	Point data
Radiation		Frost days	Hours, days	Point data
Humidity		Probabilities for t > 25-30 °C	Hours,days	Point data
Sunshine duration	Evaporation	Chill factor	days	Point data
Cloud cover			days	Point data

The picture gained from a more detailed and comprehensive survey

Although the results of the pre-survey were very telling, we were very cautious about the validity of the results as only nine experts out of the Cost VALUE milieu were interviewed. To overcome this limitation, we developed a new online survey based upon the result of this pre-survey. In total 62 experts from all parts of Europe and different climate change impact sectors responded – most of them impact modellers. We asked 26 questions about the key variables needed for climate change impact assessment, their temporal and spatial structure and accuracy, the data structure of interest (e.g., PDF or time series, means or extremes), about the application of climate data (file format and guidance), and the background of the participants. The results of every question can be found in the appendix. Here, we summarize the main results:

60 participants from all parts of Europe found temperature and precipitation to be by far the most important variable across all regions and elevations in Europe. Relative humidity, global radiation, and wind speed were found to be less important but complete the typically named five major climate variables. All other variables like vapor pressure, sea level pressure or wind direction were just claimed sporadically. Alike our pre-survey, these variables are demanded on hourly or daily time steps as time series and corresponds with the meteorological data end-users usually are familiar with. This is also reflected in the statements made about data accuracy needed that was found to be in the same range as observed meteorological data or even below (e.g., accuracy of precipitation, 5-10%) as well as in the demanded temporal structure: day-to-day variability was found most and multi-decadal variability least important. Extreme values are as equally important as mean values and important aspects are intensity, frequency, extent, and the duration of an event. Inter-variable dependencies are needed as well. The spatial resolution required though differs very much as all proposed spatial units – from point scale via 10 km * 10 km resolution to aggregation over certain regions – were named. Most participants (70%) stated that confidence intervals would be useful for their study. End-users made use of the confidence intervals by taking certain ranges of the values like quantiles, standard deviations, or min/max values as input for their impact studies. Presumable, this reflects the different scales of the end-users application of the climate data. Finally, climate data are preferred to be in netCDF or .txt format and some guidance along the use of the data is requested. In this survey, most experts were impact modellers doing research from hydrology (56%, agriculture (28%), forestry (17%), soil, and energy (both 15%)). To prevent any bias from this uneven distribution of participants, we analyzed the survey without the responses of all hydrologists and came up with the same results. This result gives us some confidence in the validity of the survey for different disciplines.

What can be learned from this survey?

To boil down the information given by the respondees in the surveys above, data requested for climate projections is basically the same one can receive from today's meteorological stations. Most important variables are temperature and precipitation at hourly or daily resolution with spatially coherent time-series including extreme values from now until 2100. This need is directly related to the standard modeling and analytics methods applied by the end-users. Unlike in climate sciences, probability distributions of the variables (like probability density functions, PDF) are seldom used to validate models but instead the performance on a day to day sequence is assessed. This is partly due to best practice in their research field, partly to lack of knowledge. Hence, climatologists need to be aware of this strong affinity towards observation. The end-user favored downscaling approach "delta change" (Arnell and Reynolds 1996) might be an expression of this affinity, too. This interpretation is supported by statements like "should reproduce today`s runoff" or the wish for unbiased representation of the current climate. Two other challenges in the communication between the climate model output downscaling community and the end-users are addressed in our surveys: a) the very specific needs for data accuracy depending on the considered impact and the region of interest, b) the temporal scale discrepancy between some impact models input data demands and climate models data output.

The latter – the temporal scale discrepancy – points to the fact that some end-user needs are related to weather conditions lasting only hours or even minutes that cannot be projected by climate models per se. This discrepancy is partly met in the Cost VALUE approach by working on subdaily downscaling techniques. The former refers to a statement of an end-user in the pre-survey who stated from his perspective that the accuracy for extreme rainfall is not as important as for consecutive dry days. This statement surely holds true for an agricultural impact study in the Mediterranean, but it is the other way round for future flood estimation in central Europe. In the more comprehensive study we could show that the accuracy for a key variable is the same for all parts of Europe. For extreme events, both the duration and magnitude are equally important. But, end-user demands about the accuracy of the key variables are still a very huge challenge for the downscaling community as claimed accuracy is nearly as precise as observations – or even higher. We also asked the end-user about the worst accuracy of data end-users can work with and still receive reasonable results. While for temperature and precipitation the answer was one answer-class worse, most participants simple didn`t know the answer. Joined sensitivity studies performed by the end-users with different accuracy levels provided by the downscaling community might be a solution to estimate a reasonable accuracy for the respective field of research both communities are satisfied with.

General picture from past studies

There have been a number of similar efforts/surveys in the past (i.e. UKCIP, KLIWAS, BALTEX, JPI-Climate, IMPACT2C, EAA, The World Bank, etc) and hence there is a lot of additional information to be gleaned from past studies, both from these activities/projects as well as from publications in the scientific literature.

Selected results from previous surveys and publications:

An impression from the ICCS2 expressed from Dr. Daniela Jacob at the German Climate Service Center (CSC) in Hamburg was that people wanted all the information but on one page only and with a simple graphical illustration. One can draw associations to the Douglas Adam's '*Hitchhikers guide to the Universe*' where the answer was '42' but that nobody remembered what the question was. David Behar, of the San Fransisco Public Utility Comission emphasised during the ICCS2 that there were 3 important aspects: **relationships**, infrastructure and **collaborative networks**, and organised information. Instead of looking at the information as a parcel being passed down the line, he viewed the team who handle this information from the start to the end as important if they can involve the other team members in all the different parts of the process. This way, everybody in the process has an understanding of where the information/knowledge comes from and what its limitations are.

An impression expressed at the ICCS2 was that in many cases, the end-users do not really know what they want but want everything. This led to the feeling that surveys were considered more of a wish-list than a list of absolutely necessary information. Even though we did not find this tendency in our own survey, we recognize this perception as a part of the current state of the communication between climate model data providers and climate model data users.

It may be a solution to find out exactly the kind of information on which the impact modelers previously have made their decisions. It is clear that there are some information which the climate scientists can provide and there are some demands which are unrealistic. Furthermore, there are also some information that the climate scientists can provide of which the end-users are unaware of (Franco Molteni, ECMWF, private communication). However, it might also be true that some needs of the impact modeling community are still not met anywhere yet. It is thus an important research question for the future how the impact research methods derived from observational data can be fitted to work with climate model output data – which has inherently different properties such as spatio-temporal resolution, reliability and accuracy.
The type of information given by the respondees in the survey above hints to the same situation - people ask for information of a character that one doubts that they have had earlier. It might help for the providers to know how the end-users intend to use the data. In some cases, there may be some solution in terms of inter-dependencies, scale dependencies, and the type of predictions a statistician can provide. For instance, temperature anomalies are described by smooth functions in space, which may enable the construction of high-resolution data sets.

Another idea would be that end-users in further questionnaires are asked about the worst data they can still deal with to receive reasonable responses. Presumable, the answers will be much more differentiated than the answers given in this survey; and a question most end-users haven't really thought about in the past.

In connection to the ICCS2, several documents were distributed:
- 'Advancing adaptation through climate information service' (UNEP Finance Initiative & Sustainable Business Institute, January 2011, German Federal Ministry of Education and Research)
- Advancing Adaptation through Climate Information for Financial Institutions' (AACIFI), August 2012, UNEP Finance Initiative & Sustainable Business Institute, CSC.

- Principles for Sustainable Insurance (PSI), UNEP Finance Initiative, 2012.

A closed-door side meeting was held at the ICCS2 discussing AACIFI. Participants from Axa, Munich Re, HSBC, Allianz SE, Scottish Widows Investment Partnership, and KfW Entwicklungsbank were present. Two concerns were expressed:

- Lack of belief that climate change will have a strong impact on the next couple of decades. In many cases, the investors may have a time horizon that doesn't extend more than a couple of decades, and the expected life time of some infrastructure may be less than a century.
- Better data dissemination - look to economic data and financial data providers. Financial analysts are accustomed to certain data formats and ways of presenting data, and may find it difficult to deal with unfamiliar data structures or information. There seems to be a culture difference between the financial and climate research communities.

Callahan et al. (1999) identified several barriers to using climate projections: low forecast skill, lack of interpretation and demonstrated applications, low geographic resolution, inadequate links to climate variability related impacts, and institutional aversion to incorporating new tools into decision making. Their study, 'Policy implications of climate forecasts for water resources management in the Pacific Northwest' (Policy Sciences 32: 269-293), examined a water management project in the Columbia River Basin (USA) where climate projections were only used for background information. They also proposed a set of strategies to overcome these barriers: technical improvements to the forecast products, and joint efforts between forecast producers and the management community to develop and demonstrate climate forecast applications through reciprocal and iterative education.

Lee & Whitely Binders (2010; “Data-needs survey for water planners and policy makers”) identified organizational barriers in the North West USA to the utilisation of climate information as: “*limited staff capacity, lack of clear guidance on how to integrate climate change into planning, lack of management support, institutional inertia, limited data availability, limited funding, lack of a mandate to plan for climate change, and complexity of the problem.*” According to this survey, the end-users preferred daily time step data in accessible Excel or ASCII (text) file formats through conventional web services. Meta-data was also seen to be useful.

Within the EU FP7 project “IMPACT2C”, the data needs for the several work packages ranging from coastal applications in the Maldives to tourism aspects in Europe were assessed. Overall temperature and precipitation, as well as derived indices and extremes were needed for most applications. For special investigations also wind information, evapotranspiration, radiation and sunshine duration data and data for sea level rise and sea surface temperature were demanded. Temporally the data should be provided on daily scale and gridded ranging between 10 km and 200 km spatial resolution. Station scale information was not requested. The respondents generally work with time series in their models, and not probabilistic information. For the assessment of uncertainty, mostly several time series are implemented. Additionally the survey asked if the variable’s intercorrelation is important for the impact analysis, and many respondents agreed in the general importance of physical consistent data. Only few also take care of this issue in their models and applications. Finally, the respondents were also very interested in bias corrected data, but only few of them can also provide sufficiently long observational data for the correction.

Themessl (2011) defined a theoretical basis for “useful data” based on McNie (2007), and proposed that they should be salient, credible and legitime. Jacobs et al. (2005) furthermore defined 6 phases for creating useful data which include creating data, but also promoting data by scientists, implementing, applying and finally terminating if the data is not useful any more. Themessl furthermore defined user groups for climate data as well as sectors based on Swart (2011). This classification is needed as users range from scientists who primarily need data to policy makers who primarily need guidance along with the data. According to the listed sectors, Themessl listed science, education, hydrology and water management, energy, tourism, agriculture-forestry and ecosystems, health, infrastructure, insurance and finances, and civil protection. The type and level of specificity of data needs from these very different users and sectors will vary according to their specific research or policy questions, and will evolve over time as one moves from identification and analysis of potential climate threats to evaluation of the effectiveness of possible climate response options. Finally based on Swart (2012), categories of useful data are defined as metadata, observational data, direct (climate) model results, error corrected and post processed (climate) model results and derived indices.

It is important to maintain a dialogue and find out exactly what kind of information on which they previously have made their decisions. The type of information given by the respondees in the survey above hints to the same situation - people ask for information of a character that one doubts that they have had earlier.

Experience from Germany

Selected experiences from Germany

There are lots of ongoing activities with respect to communicating climate model results to end-users (either in impact research, in economy or in administration and politics). Two institutions are directly tasked with provision of climate information to the public, namely the Climate Service Centre (CSC) and the German Weather Service (DWD). Furthermore, some research institutions provide climate information on web-sites and in research projects (e.g. Helmholtz-Centres, PIK-Potsdam). Additionally, in several university research projects the task of communicating the results to the wider public and the intended users is under way.
In the following, only three examples are given on communicating climate information to end-users, none of them is from any of the above mentioned institution (even though some of the institutions are involved in the examples). The interested reader is referred to the respective web-pages of the above mentioned institutions for further examples and products resulting from the experiences there.

Examples:
1. A twice annual meeting series of the representatives of environmental agencies of the German federal states is taking place since 2005, discussing the use and interpretation of regional climate model data. Since in administration often the responsible persons are not specialized in meteorology or climate research, but these people are nevertheless responsible for developing regional to local mitigation and adaptation strategies, a clear need was seen to further develop the respective competences. In the meantime, a set of guidelines for good use of regional climate data was developed (and is still under further development). The guidelines can be found under

http://klimawandel.hlug.de/fileadmin/dokumente/klima/fachgespraech/Leitlinien_zur_Interpretation-reg-KMD-05-2011.pdf (in German). A paper was published (http://www.environmentalsystemsresearch.com/content/1/1/9, in English, 2013) on the subject for a wider discussion. The meeting series has proven extremely useful. The continuous exchange between experts with different backgrounds (a few with background in meteorology and climate modeling, most with other backgrounds) has over the years enabled all participants (and their respective colleagues concerned with climate change issues in their home institutions) to understand and handle regional climate model output much better than before. This example might serve as a "best-practice" example since it was quite effective in educating the participants and spreading the knowledge further in the institutions.

2. A research effort by the federal state of Hessen (called INKLIM-A) has instigated now over 20 research projects on different aspects of climate change (like further development of two regional climate models) and climate change impacts (e.g. on forests, viticulture, biodiversity, vegetable crops, etc.) in the federal state of Hessen. From the beginning (2009), all projects were required to attend annual workshops where all projects presented their interim results. Additionally all projects were required to use the same data base for evaluation data (historical) and projections. The goal was to ensure the comparability and coherence of the results of the different projects with one another. Several impact projects soon discovered substantial problems to work with the projection data (e.g. the viticulture experts tried to assess future soil water availability in some steep terrain along the Rhine river, which was not resolved in the dynamic model outputs). As part of the multi-project initiative INKLIM-A a data workshop was held where selected groups presented their problems (e.g. the viticulture group) and partners from other projects discussed possible solutions with each other. Following this workshop the need for bias correction of the projection data became apparent and thus a multi-project group was established to discuss and perform a bias correction for all projects (consisting mostly, but not only, of meteorologists). All further INKLIM-A results were now requested to indicate whether they were derived using the bias corrected data or the direct model output. While there are always some people who think that rules and guidelines only apply to others, the overall experience was extremely positive. First: the presentation of data problems from the impact research groups themselves helped pinpoint the exact nature of

the problems. Second: The discussion not only with climate experts, but also with other impact researchers helped developing solutions and facilitating the exchange (sometimes climate scientists tend to argue a bit overwhelming). While the experience in the project INKLIM-A itself was quite positive, the example might only serve as a "second-best-practice" example, because the effort is quite high and the further distribution of the new knowledge is relatively limited.

3. Several research projects are or have been conducted in Germany on the impact of climate change on water, particularly on flood and drought risks along rivers. One such project is the KLIWAS project, which used a large ensemble of climate projections and a quite sophisticated ensemble analysis to assess future changes along major shipping routes in Germany. The German Weather Service (DWD) was strongly involved in this project and contributed a large share of the climate data analyses. Another such project is the KLIWA project. Here, mainly hydrologists from the southern German federal state agencies are involved, who are tasked with developing climate adaptation strategies e.g. on flood protection along major rivers (like deciding on climate change related dike increases). In this project considerable reluctance prevails with respect to using the output from dynamical regional models since they show partly (relatively) large biases for the current climate. Thus, in several cases the analyses only use statistical model results. While there is a willingness to discuss the use of dynamical model results, the overall request seems to be that the simulation results first of all need to be bias-free. Recently, a dynamical regional simulation was bias corrected for temperature, precipitation, relative humidity and wind speed (all of them independently from each other), which is now used by some groups in their impact models, ignoring the inter-variable inconsistencies arising from these multiple independent bias corrections.

Experience from Austria

Survey performed in Austria

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A survey was made in Austria in 2012, were 800 scientists and stakeholder swere asked to contribute. 111 finally contributed, from which 31 % belonged to the field of climate and climate impact researcher. More than 50% where returned by non-scientific stakeholders as from agriculture, civil protection, energy sector, flood protection .

- *The results from the Austrian study:*

Climate model data as well as empirical observations are equally important.

- *Variables*: In decreasing order of importance, the Austrian survey revealed temperature, precip, wind (all needed by around 80-90% of the endusers) followed by humidity, radiation/cloud cover and snow depth and snow water equivalent in decreasing order. Also requested were indices as frost days, heating degree days, tropical nights or drought indicators (further indices are e.g. defines in Stardex or at the ECA&D homepage)

- *Spatial resolution:*

Point and raster data are equally important, however surprisingly regional means are not really requested

- *Temporal resolution:*

- Precip: Hourly, daily and yearly sums are equally important
- Temp..same situation as for precip
- Snow: regional information more important than point information. Sub-daily data not so important as monthly or seasonal data
- Wind: hourly and daily data needed, energy sector also requests yearly data

Data are needed for historical periods (observational data) as well as for future periods (mainly either until 2050 or 2100). Economical applications prefer data until 2020, 2030.

Data should be provided on common grid and if possible in .xls or .csv format. Raster data is preferred in ASCII Grid and GeoTIFF. NetCDF format is only accepted by 20-40% in the survey. Vectordata should be preferably provided via ESRI shape format.

Question according to non-climatic additional information

Additional Meta information would be highly appreciated especially providing digital elevation models, land cover data, but also information on the credibility of data

Swart 2011: In the IS-ENES working paper, Swart refers to an European Environment Agency (EEA, 2010) working paper where appropriate information for climate change impacts, vulnerability and adaptation assessments includes:

- *geographical coverage* (the impacts of climate change transcend the boundaries of individual countries, thus there is a need for alternative analysis units such as catchments, sea basins, bio-geographic regions);
- *record length* (increased length: allowing for the detection of significant trends/changes in the environment);
- *consistency*, in time (homogeneity considerations for time steps and reference period, to allow for data comparability) and in space (e.g. in the analysis across national boundaries to allow for pan-European comparability of assessments), and between variables/indicators (also for non-physical and non-chemical variables such as socio-economic variables);
- *spatio-temporal resolution*, (e.g. regional reanalysis, link with other spatial data);
- *quality* (fit-for-purpose);
- *transparent format of data and accessible and available to stakeholders/users.*

Within the Is-ENES programme a questionnaire was also sent out to end-users. This survey, however, can be considered as biased towards responses from southern Europe as well as from land and water related climate impact researchers. This survey concluded that

- climate model output on extremes in temperatures and precipitation are most frequently demanded
- In general almost all respondents focus on two major categories: temperature and precipitation.
- Less but increasingly interesting is snow depth and glacier data, as well as groundwater an runoff data

- Other variables, such as those related to marine and coastal variables (temperatures, waves, local sea level rise) to air quality, or wind patterns are required for more specific applications
- Temporal resolution needed from is mainly daily, also for the assessments of extreme indices
- Spatial resolution: from 1x1km to 100 x 100 km

The survey also assessed how respondents address the issue of uncertainty. 50% were interested in probabilistic scenarios. 50% prefer to use a set of scenarios. Swart however indicated that producing and communicating probabilistic scenarios is very resource intensive, while they still do not capture all uncertainties, and their complexity tends to make them difficult to interpret for practitioners and policy makers.

40% of the respondents use SRES scenarios or new RCP (paper from 2011 - this may have changed since then and will change along with EURO CORDEX). Often used terms in this context is “worst” and “best” scenario.

Of the 228 respondents that were analyzed, 131 reported that they experienced difficulties and limitations related to current or past availability of climate modeling information. These were: data format, user-friendly access, required spatial and temporal resolution, reliability and uncertainty and specific local needs.

One issue to put upfront is the need for guidance along with the data in order to turn data into information.

The EEA has established a web site for climate change adaption in Europe[1] called Climate-adapt in order to help users to access and share information on climate change. For climate projections, the site refers to the FP7 ENSEMBLES project and the IPCC (2007) report. Links are also made to the CLIMSAVE impact assessment platform which “is a user-friendly,

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1 http://climate-adapt.eea.europa.eu/

interactive web-based tool that allows stakeholders to assess climate change impacts and vulnerabilities for a range of sectors, including agriculture, forests, biodiversity, coasts, water resources and urban development”[2].

Experience from Cyprus

(by Paul Christodoulides and Georgios Florides, Cyprus University of Technology)

A. In the framework of a Cyprus University of Technology internal research project led by the Department of Environmental Science and Technology, in collaboration with the Cyprus Agricultural Payments (National) Organization (end users) av agro-climate model was developed for the computation of the use of water in the whole agriculture domain of Cyprus for the years 1996-2009 (Zachariadis, 2012). To this end, data from the Cyprus Agricultural Payments Organization, adapted data from the international data base FAOSTAT as well as climatic data from 31 meteorological stations of the Cyprus Meteorology Service were used. The model can compute the change in agriculture production per cultivation per community as a function of climatic factors such as temperature, humidity, precipitation. Adopting 2 different climate scenarios based on past data led to the conclusion that the annual national crop production for 2013/14-2019/2020 is to be reduced on average by 42%, while the average loss of irrigated production will be 205×103 ton/year, with the average rain-fed production loss to be 129×103 ton/year. These results indicated that within the near future water management policies could be critical for agriculture.

B. In principle, energy saving is the result of the reduction of the total amount of consumed energy without seriously affecting the process or the end result. Any reduction in the consumption of energy always yields greater amounts of energy savings in the production sites. A method used to achieve reduction of consumed energy is to use or increase the thermal insulation of buildings. To this end the Ministry of Energy, Commerce, Industry and Tourism implemented Directive 2010/31/EU on the energy performance of buildings, which is the main legislative instrument to reduce the energy consumption of buildings. Under this Directive, the Cyprus government has established and now applies

2 http://www.climsave.eu/climsave/index.html

minimum energy performance requirements for new and existing buildings, and a relevant body issues certifications of building energy performance. Moreover, the appropriate authority provides a software package that calculates the building thermal requirements that incorporates the mean present climatic conditions in various places in Cyprus as provided by the Cyprus Meteorology Service. By 2021 all new buildings must be so-called "nearly zero-energy buildings" (NZEB), i.e. their thermal needs must be covered in place. A first project was funded between 2008 and 2010 by the Research Promotion Foundation of Cyprus and was entitled "Categorization of buildings in Cyprus according to their energy performance." [code: ΑΕΙΦΟΡΙΑ/ΑΣΤΙ/0308/(ΒΙΕ)/02] Specifically, in this project a sample of 500 dwellings located in various places throughout Cyprus was chosen and extensively analyzed in order to allow for gaining knowledge on the characteristics as well as on the energy behavior of dwellings in all climatic zones of Cyprus. The results of this project revealed the weaknesses of dwellings in Cyprus and gave insight information concerning their energy behavior. Based on the identification of the typical type of dwelling in Cyprus theoretical scenarios of the most important energy conservation measures (ECMs) in view of defining the cost-optimal solutions so as to achieve a NZEB was applied on both conventional and innovative thermal insulation materials on the envelope of the dwelling. Also, in order to achieve a NZEB the optimum renewable energy system (RES) was defined between a number of systems for both standalone and grid-connected applications. The building and any RES behavior depends greatly on the climatic conditions and how they will vary by 2021. Therefore a study is to be performed that will indicate the increased energy needs in buildings by 2021 adopting different climate scenarios.

Experience from Italy

In Italy, differently from most other European countries, there is not a national central office covering all monitoring, previsional and prevention activities in the fields of climatology. As a consequence, these activities are covered by several different institutes or research centres, each focussing on a particular field and oriented to provide products to a selected group of users.

In particular, climate monitoring is covered by a multitude of national and regional services (Pavan et al, 2013), while climate modelling is mostly covered by two research centres: ICTP and CMCC. ICTP is more internationally oriented due to its mission, while CMCC is more nationally oriented, but it is not meant to provide services to public, or to local public offices. Finally, several institutes or research groups have developed instruments for predicting and mitigating the impacts of several type of geophysical hazards on local population and economical activities, including energy and agricultural production. Sometimes these research groups are connected with local Universities (CIMA), other times with national research institutes (CNR, ENEA,…), national governmental agencies (CRA-CMA, AUSL), or regional agro-met-hydro-climatological services (ARPAs, National and Regional Civil Protection Agencies). In Italy, the growth of the impact modellers' community is favoured by the vulnerability of the Italian territory to several types of geophysical hazards, including heat waves, intense wind storms, floods and landslides.

Problems normally encountered in the relation between climate and impact modellers' communities depends on the impact considered. In all cases, the discrepancy between CGCM and observed climate may be a problem and several strategies to reduce its consequences on impact studies must be put into action, either calibrating the CGCM output or evaluating only changes in impacts. The calibration process and the evaluation of local climate variability require the availability of local climate observations, which in Italy are difficult to obtain due to the complexity of the climate monitoring community (Pavan et al, 2013).

Hydrological models used in climate applications are adapted from those used in short term hydrological predictions, and they often require relatively large computer resources. The strong dependency of these models on the local morphology of the basin considered make result in a multiplicity of models each of them strongly liked to local research groups. All hydrological models need as input, data characterised by high horizontal and temporal resolution, not usually provided by CGCM. These data can be obtained only downscaling either dynamically or statistically the original CGCM outputs, by means of weather generators or dynamical downscaling models, producing ensembles of different realizations for each modelled event. In this case, one problem encountered is the amount of computer time required to produce large ensembles of ensembles of possible future scenarios.

In the case of agronomical impacts, most problems encountered are linked with calibration and downscaling of CGCM outputs. These activities require the access to local climate observations, or to downscaled CGCM output which may be very expensive to obtain. Some indications of these problems and of the path followed to solve them can be found in the white book for agricultural policy, describing possible mitigation and adaptation strategies to future climate change (Ministero delle politiche agricole, alimentari e forestali, 2012). This publication is the result of the research activities produced within two subsequent national projects, coordinated by CRA-CMA, funded by the Italian Agricultural Ministry and aimed at quantifying the impacts on this field of future climate changes (CLIMAGRI and AGROSCENARI).

In other fields like biology, coastal impacts, local economy, or urban studies, consequences of climate change on a specific system are quantified by evaluating the impacts of representative intense or extreme past climate events (droughts, heat-waves, floods,…). Then, the impacts of climate change under scenario conditions are evaluated as function of the expected modification in the frequency of extreme climate events, described by the pdfs of local climate indices. Example of these type of studies can be found in Castellari and Artale (2009). These approaches require the availability of three type of data: local climate observations, data describing the impacts of past strong climate anomalies and downscaled climate change scenarios. In Italy all these three type of data are difficult to access. Local climate observations are affected by the complexity of the current climate monitoring network. In addition to this, observed impact data-bases for past climate events are available only for selected fields. Furthermore local climate change evaluations under scenario conditions are difficult to access and are often very expensive, especially in the case of dynamically downscaled data. For this reason, the statistical downscaling approach is often adopted, when a partnership between impact modellers and local climate services can be found.

One last problem encountered is related to the time extent of climate scenarios into the future. Local administrations often require information related to climate change impacts on time scales of the order to one or at most two decades. These type of scenarios are characterised by smaller uncertainties, but have started to be produced and analysed only recently.

Date: 04-03-14

Experience from Portugal

At Instituto Dom Luiz there are interactions with three main production sectors: energy, forestry and wine.

The contacts in the energy sector are with the main energy producing company in Portugal (which is an international energy producer), with the power grid company and a coop of wind energy producers. For the first company they have been approached to provide reports with precipitation and extreme events climatologies, as well as hydroelectric forecasts. The validity of the results is conveyed through error and confidence measures which seem to be well understood by our end-users. In the case of the forecasts, while the short terms meets their expectations and are used on a daily to weakly bases, the long term (seasonal) forecasts are below their expectations and the uncertainty associated with them renders them useless. In the reports, the main variables the end-users are interested in are precipitation and wind speed which are transformed into power production and are provided in a graphical form. In the case of the forecasts, the raw variables are given. The power grid company and the wind energy producers are only interested in short term forecasts which they tailor to suit their needs by transforming the raw data into power. Both have a good understanding of the validity of the results and a similar opinion on long term forecasts.

In the forestry sector the contact is with the main paper producing company in Portugal and the 6th largest producer in the world. They manage 120 thousand hectares of forest. The link is with their research team. They have meteorological stations in some of their sites and are regular users of meteorological data. Their initial approach was for a Climate Change assessment on temperature and precipitation. More recently the focus of their interests is extreme weather events and monthly data for fire and water management. The data (precipitation, temperature, wind and radiation) is provided in the form of maps. This data does not fulfil all their expectations since the purpose of its use is not solely dependent on meteorological variables and they are not fully aware of the uncertainty associated with the data provided.

In the wine sector the interaction is with one of the main wine producing companies in Portugal (this is an international wine producer) and a coop of Port wine producers. Both have meteorological stations in their vineyards and need this data to plan field operations and phytosanitary measures. The interaction aims at the development of a statistical downscaling model which uses long term forecasts in order to develop a wine quality index and the choice of species, in a climate change scenario. Their understanding of uncertainty associated to the data is limited. No raw data is provided, only geo-referenced maps.

Experience from Czech

The experiences from Czech are rather based on the personal experiences of Martin Dubrovsky, based on his (a) collaboration with impact-modellers since 1995 and (b) participation in agroclimatic projects (e.g. CECILIA; CLIMSAVE www.climsave.eu). The end-users are primarily educated agriculturist working in research – especially Mirek Trnka, and his colleagues who used climate (change) scenarios developed using my weather generator linked with outputs from GCMs and RCMs.

Agriculturists use various impact models, which require various meteorological input variables like

- T average (or TMAX and TMIN), PREC, SRAD, RHUM, WIND,

  as

- time series (multiple variables in various time step, most frequently daily step) or "climatologies" (e.g. long-term monthly means of selected meteo-variables).

The requirements demanded by the impact modelers have changed over the last decades:

1) stage 1 (last century): impact modelers required future climate scenarios (climatologies or weather time series representing future climate) and they cared only little about the source of climate data and methodology used to create the data they needed)

2) later, the impact modelers became better aware what is available. They found:

   (a) not only GCMs, but also RCMs exist

   (b) there are many uncertainties in projecting the future climate…

As a result, they started to require (for their impact analysis) a set of scenarios, which represent known uncertainties (due to emissions, climate sensitivity, inter-GCM variability, natural climate variability); to get the reasonable number of scenarios (sometimes it is not acceptable to use ALL available scenarios, e.g. due to insufficient computer resources) this may imply a necessity to reduce a number of GCMs (or RCMs) involved in the impact analysis (Dubrovsky et al., submitted to Climatic Change). Some impact modelers required a specific source of the data:

(i) GCMs (earlier taken from CMIP2 or CMIP3 databases, now they start to require CMIP5), or

(ii) RCMs (typically taken from ENSEMBLES dataset or CORDEX);

(iii) a specific model, which comes from their country (e.g., impact modellers coming from UK ask for the CC scenarios based on UKCP09 – this was also the case of CLIMSAVE project)

Unfortunately, the use of different sources of data [(i) or (ii) or (iii)] may imply different impacts. E.g., we compared UKCP09-based vs CMIP3-based scenarios for a territory of UK and found significant differences.

In agroclimatic impact studies, the input climatic data are very often in form of multivariate daily weather series and are commonly created by various stochastic weather generators, e.g., LARS-WG by Semenov (e.g., Semenov & Barrow, 1998), and M&Rfi by Dubrovsky (Dubrovský, 1997; Dubrovský et al., 2000; Dubrovský et al., 2004). I dare say that WG is the most frequent method used to create input weather series for agroclimatic CC impact studies).

In the following, I will give two examples describing two approaches to creating climatic data for the impact studies:

(A) Example Czech impact studies: Agroclimatic impact studies made by Mirek Trnka & his colleagues (Mendel University, Brno, Czech Republic), for whom I created climate change scenarios and daily or monthly multi-variate weather series representing present and future climate. The synthetic weather series representing the present climate are generated by the parametric M&Rfi weather generator (WGEN-like generator), which is calibrated using the station-specific observed weather data or interpolated from the surrounding stations where the observed data are available. To generate weather series for the future climate, the WG parameters are modified according to the climate change scenarios, which consist of changes in monthly climatic characteristics (typically changes in monthly means/sums of SRAD, TEMP and PREC; changes in interdiurnal and/or intermonthly weather variability may be also included. The future climate scenarios are mostly created using the pattern scaling method, in which the standardized GCM-based climate change scenarios are multiplied by change in global mean temperature determined by simple one-dimensional climate model MAGICC. To represent various uncertainties and have an ensemble of scenarios of reasonable size, we use typically 5 GCMs (the subset is based on an objective methodology, which is a topic of the paper quite recently submitted to *Climatic Change*) × 3 values of ΔT_{GLOB}, where the three values represent low, medium and high values related to 3 combination of climate sensitivity and emissions used as an input to MAGICC model (low ΔT_{GLOB} ~ [clim sens = 1.5K & SRES-B1 emissions]; medium ΔT_{GLOB} ~ [clim sens = 3.0K & SRES-A1b emissions]; high ΔT_{GLOB} ~ [clim sens = 4.5K & SRES-A2 or SRES-A1FI emissions]; note that this approach allows to account for uncertainties coming from 4 sources: (1) several GCMs/RCMs ~ modeling unc., (2) unc. in emissions, (3) unc. in climate sensitivity, (4) natural climate variability (relates to use of the weather generator)]

(B) Example CLIMSAVE project (www.climsave.eu, in which I participated in developing the climate change scenarios): one of the main aim of the project was a development of the web-based interactive tool (I.A.P. = Integrated Assessment Platform, available from the project's web), which links various agroclimatic (& other) metamodels and run them with climatologies (monthly means of selected climatic characteristics including TEMP, PREC, SRAD, HUMID and WIND representing present & future climate) and allows to map climate change impacts for a majority of Europe (where the gridded baseline data were available) for various climate change scenarios. The scenarios for this project were based on CMIP3 GCMs. To represent uncertainties, we used a technique similar to our experiments [previous paragraph (A) related to Czech impact studies]:

ensemble of CC scenarios used for whole Europe (10′×10′ spatial resolution) =
(“representative subset” of 5 GCMs) × (4 emission scenarios) × (3 climate sensitivities)

Within the frame of the CLIMSAVE project, a special attention was paid to Scotland. Considering the request from the stakeholders involved in this project, alternative ensemble of climate change scenarios was developed for Scotland based on UKCP09 dataset. The selected ensemble of 27 scenarios represents the internal variability within the original ensemble of 10000 scenario members within the original UKCP09 database.

Finally, some notes on the impact modeller’s requirement on the accuracy of input climatic data:

- For the present climate, they often accept “any” weather data, which are from a reliable source. These may be either observed (including post-processed: homogenized and/or gaps filled), interpolated, synthetic (generated by stochastic weather generator) … Impact modelers commonly do the routine validation test to examine how the output from their impact model differ when fed with data from a given database (gridded, interpolated, synthetic) vs. reference observational data. If the difference between the two outputs is small, they accept the data. Then they run the model with future climate data and analyse the CC impacts (= differences between the outputs obtained with the future climate vs. present climate).
- For the future climate data, they accept the facts that the accuracy of the projected climate is not easy to assess, it varies in space and is different for individual climatic characteristics. Instead of the requirement on the accuracy of future climate data, they rather require to get an ensemble of scenarios, which represents the known uncertainties (see e.g. paragraph A)

Experience from Hungary

General knowledge about the climate change in Hungary

A specific impact user and decision-maker (end-user) survey was not made yet in Hungary, but at the Hungarian Meteorological Service we carried out two general questionnaires on climate change in

2011. Approximately 950 people took the survey in the first round and 350 in the second one, majority was educated people aged between 26-40, coming from cities. The most important conclusions of these questionnaires are as follows:

- Half of the respondents trust what is written, communicated under the topic of climate change, but 1/4 of them do not find it trustworthy, thus, more active and targeted promotional activity is required.
- 3/4 of the sample say that climate change is among the biggest threats nowadays, but scepticals are among graduated people mostly and think that we should deal with a more important issue, as well.
- When we talk about climate change we have to consider its long-term character, also, to mention the reference period. WMO defines climate and climate processes starting from at least 30 years.
- The asked persons trust more global scale changes than local observed ones: for instance they are afraid more of a climate change-induced migration than an increase of heatwaves during summer in Hungary.
- Regarding temperature and precipitation change, half of the respondents “extrapolate” the observed data and say it is not very important to do climate change simulations for the future, even though they rush to false conclusions (e.g., the climate of Hungary will be humid sub-tropical like at the Mediterranean).
- Users have reservations about quantitative climate change results, since they are not very familiar with the basis of climate modelling, also, they still hardly notice uncertainties even today and rarely use it in practice.

Experience with the users of climate data

Besides the general climate change survey we collected the researchers, partners, impact study makers and end-users whom we ever co-operated with or approached since we started our regional climate modelling activity. We are going to send them an invitation for a bigger meeting in 2014 in Budapest, where each sector can introduce their work connected to climate change, their results and further needs and supply regarding climate change.

1. Sectors involved:

- transportation (motorway, road construction, inland waterway)
- ecology (bird and insect population, vulnerability and exposition, ragweed and pollen, soil and water supply, botany and genetics, tourism, municipality)
- agriculture (cereals and breeding, frost damage, air pollution)
- hydrology (lake evaporation and hydrological changes)
- air pollution (circulation and air pollution, atmospheric chemistry)
- energy (wind, nuclear power plant)
- health (heat stress, heat–related death)
- disaster recovery (complex)
- forestry (forest and vegetation)
- architecture (building stability and extremes, concrete acidity)
- urban climate (comfort index, urban heat island)
-

2. Geographical coverage, spatial resolution:

- Some users want one single point data only, but we try to convince them about the spatial limitations of model results. Consequently, we give data either for spatial average on a local scale, or we interpolate them from several points into one and never provide one single raw model output point.
- Regarding observations, both homogenized interpolated and station time series are requested. The gridded observation data have a basic resolution of 10 km,, while model results have 10-25 km resolution, and a dynamically downscaled wind climatology database is available on 5 km. Users always want a better spatial resolution than available, but we do not provide data on finer resolution than that of the original outputs.
- Pointwise data are usually requested for closest points to lakes, rivers, cities, power plants, but users require sometimes a county, a country or a smaller rectangular shaped box (30-50 km), which can come in a less-interested spatial average, as well.

3. Temporal resolution:

- Users sometimes ask for seasonal forecast, which has weak performance in our region, thus, we do not advise them to use seasonal forecasts.
- The largest interests of model outputs are 1961-1990 and 1971-2000 as the reference period, while 2011-2040, 2021-2050, 2041-2070, 2071-2100 as the projections.
- Basically, always a climatological period of 30 years is handed in, even though users sometimes request data on a smaller time-scale like 10 years. We never give to them very short time slices, rather we try to apply the moving average for 30-year periods.
- Observations are available from 1901 until now, but it has better quality (more stations are involved) from 1971, furthermore, we try our best to harmonize our model reference period with the period where observations are available.

4. Variables in order of importance and their requested temporal resolution:

- Precipitation: annual, seasonal, monthly amount, standard deviation, linear trend (monthly is less-interested)
- Temperature: annual, seasonal, monthly average, standard deviation, linear trend, hourly data (rarely requested)
- Precipitation-related indices: spells, exceedance values, percentiles based on daily data
- Temperature-related indices (based on average, maximum, minimum temperature): sums, spells, exceedance values, percentile based on daily data
- Wind: hourly and daily (directions, wind speed), annual (wind direction, prevailing wind)

- Seldom asked variables are humidity, global radiation, ozone, CO_2.
- Sometimes combined indices are requested (e.g., high wind speed and high precipitation values happening at the same time; snow and/or wind together in winter days; evaporation and precipitation balance; heat stress based on humidity, radiation, windspeed and temperature).

5. 5. Format:

- Pointwise data are normally provided in ASCII format, always with a descriptor file since users can get easily confused reading in the requested data format.
- Yet most impact study makers cannot read NetCDF format, but besides ASCII they want data in a simple spreadsheet (Excel) format. Sometimes data are requested in a very specific (e.g., Arc View/GIS/info) format.
- When an assessment report is demanded, we have much more flexibility about finalizing figures, tables or diagrams since we only agreed previously on the content of the requested variables.
- Decision makers at higher position usually ask us to make a ready-made report for them, and most of the time they do not want alphanumerical data. The PhD students, impact experts, national or an international project partners primarily request data along with a smaller report.
- We always ask our partners to give us feedbacks about their needs and results. It is useful to avoid misinterpretation of the data and have a cooperative relationship instead of a financial liaison only.

Outlook

National Climate Change Strategy (NÉS) in Hungary has been prepared in 2008 and revised in late 2013. The new strategy will bring some operational steps in adaptation in 2014. It follows the policy of from-climate-to-impacts-to-decisions based on locally run climate models and quality-checked observations. The meteorological data serve as inputs for local impact and vulnerability studies of many sectors, taking into account the uncertainty at all levels. The final step is putting forward the outcomes of impact assessments to the end-users, the stakeholders and the policymakers. The coordinated adaptation strategy will be supported by the National Adaptation Geographical Information System (NAGIS), which will provide a commonly-formatted, detailed sectoral and geographical information for that.

Experience from Finland

In Finland, a survey was carried out by Climate Change Community Response Portal (CCCRP)[3]. The survey of user needs included feedback from an internet survey, discussions

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from 2 workshops, and one meeting organised during the preparation phase of the CCCRP's climate change portal project. The internet survey was associated with a description the project, and was sent to thousands of stakeholders. Of these, only 35 responded to the internet survey.

Although the report is written in Finnish, it provides an overview in English which names cost-efficiency as a key issue in terms of mitigation and adaptation actions. As the immediate impacts of climate change in Finland seem to concentrate around water issues, these will be highlighted in the portal.

The expectations about the information provided on the portal involved following criteria: Scientifically based; local or regional dimension; layered for different knowledge needs; easy to find; presented in an inviting way; target decision makers (as opposed to the portals available, aimed for the public); tailored for different users' needs, clear and focused. Furthermore, the designing of the user interface of the portal would take following aspects into consideration: quick overview on climate change issues on each sector and subsector; regional focus (as climate model runs are less reliable on local level); 'near future' (2030); time scales matching municipal decision-making cycle; a possibility to deepen knowledge and to study the impacts and adaptation means on a 100-year time horizon; tools for making preliminary emission calculations and costeffectiveness analyses.

Experience from Norway

There has not been a survey of end-users in Norway as in Austria and Finland, although a 'national dialogue' is planned as part of the national contribution to *JPI-Climate WG2*. Neverheless, the Norwegian Meteorological Institute has long experience working with end-users through various projects, web-postals (all data is free: http://eklima.met.no) and hotline (telephone and e-mail: 'klimavakten@met.no'). A good deal of insight into the end-users' needs have been gathered through dialogues and reports containing the demanded input. The end-users include hydrologists, hydro-electric power companies, impact researchers, biologists, farmers, municipalities, and authorities. Some of the information

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http://cdn.fmi.fi/legacy-fmi-fi-content/documents/cccrp/CCCRP_survey_of_user_needs.pdf gathered is available on the ministry of environemnt web portal http://www.klimatilpasning.no.

Climatic parameters may be important for biological studies, but the nature of the data collected by biologists and climatologists can be quite different. One problem may be that the data are not in time series with a time stamp, which makes it difficult to relate to the large scale conditions. Often, information is wanted for areas where there are no observations, for instance rain on snow over parts of the Arctic affecting the grazing of animals (rain on snow, followed by cold periods cause ice layers, makes it difficult for the animals to get access to the vegetation below on which they graze). A project called EALAT involved a study of climate variables relevant for reindeer herding. The most important information may concern the structure and strength of the ice layers in the snow, preventing the grazing, but also monthly mean temperature and precipitation have been of interest (Vikhamar-Schuler, et al., 2013; Benestad, 2010).

In other cases, successful collaborations have involved close collaborations and dialogues between biologists and climate scientists (Snäll et al, 2009) where the monthly precipitation and number of hot days (daily maximum temperature exceeding 35 °C) were used as input to population models for black tail prairie dogs in the USA.

Other type of data requested for the end-user has been geographical maps of frequencies for short-term precipitation intensity for radio transmission, with emphasis on the most severe events corresponding to a duration of 5 minues each year (Mamen et al, 2011). IDF (intensity-duration-frequency) curves for precipitation are traditionally used by some sectors. The insurance companies have requested information about daily precipitation, such as exceedance values, probabilities, and spatial correlation (extent). Extreme daily and short-term rainfall can result in mud and rock slides, however, long-term precipitation may also soak the soil and lead to unstable conditions where there is quick clay (Dyrrdal, et al., 2012). For regions with permafrost, long term thawing may present a problem for built structures, and Isaksen et al. (2008) made use of downscaled monthly temperatures for Svalbard to make inferences about soil conditions.

Dialogue with farmers

Bark beetles present a problem to the forestry, and outbreaks often follow extensive wind falls. Hence, there has been some interest in storms and windfalls in order to study bark beetle outbreak, and hence the character, position, and trends in the storm tracks have been of interest (Benestad, 2005). Wind speed measurements are often sparse and affected by local conditions, and for most intents and purposes, wind speeds derived from barometric pressure are used to derive wind statistics for the study of long-term trends. However, it is the wind associated with phenomena such as mid-latitude storms which is responsible for much of the damage, and hence it may suffice to examine the storm tracks and their intensities to provide useful information about past and future risks. Recently, an international project, IMILAST, has provided an intercomparison between the most common storm track analyses (Neu et al., 2012). Benestad (2005), however, used the Benestad and Chen (2006) storm statistics without the tracking in order to estimate the recurrence of storms. Farmers and other sectors also have been interested in gridded observations for the past. For Norway, there are 1x1 km grids for daily precipitation and temperature[4]. Other requests has been about the wet-to-dry day ratio (wet-day frequency) during summer and autumn. Another impression from dialoggues with farmers is that they are more concerned with the subsequent season (seasonal forecasts) rather than the long-term aspects.

Collaboration with hydro-power producers

The power producers tend to be concerned about changing climate and its implications for energy supply and demand. A collaboration between MET Norway and a hydroelectric power production company has been initiated to assess the climate footprint of renewable energy production. An increase in the frequency of extreme weather is seen as a threat to infrastructure and changes in the hydrological cycle is expected to have consequences for energy management. The main weather elements involved in this analysis is temperature (run-off from snow melt and snow pack in the mountains), precipitation (reservoirs, river run-off), and wind. A more tentative aspects includes storm tracks; their paths, duration, intensity, and frequency.

4 ftp://ftp.met.no/projects/klimagrid/

Also hydroelectric power production and associated network planning/maintainace have requested data, especially for - extreme seasons (Benestad, 2011). For most of the cases, the important time scales are seasonal means, but also daily data are requested to plan for cold events (3-day running means over a region extending southern Scandinavia). The hydrolelectric power producers are interested in knowing the likelihood of a dry autumn followed by a cold winter, as they want to be able to make most out of the water reservoirs. If the dams are tapped too much during autumn, there may not be sufficient left to produce the energy needed for heating during the latter part of the winter. On the other hand, too much precipitation and snow melt may overload the dams. Heating degree and cooling degree days have also been important for energy production (Førland et al, 2004; Benestad 2008a, 2008b), but hydroelectric energy producers have also been interested in monthly precipitation, temperature, and run-off series (Engen-Skaugen, 2008).

From dialogue with Norwegian farmers:

Good seasonal forecasts are more needed for making better decisions regarding plowing the field in the autumn or the spring. The problem is when the fields are getting too wet. On longer planning horizons, issues such as dimensioning for drainage are needed (units specific drainage: litre/s per hectar; link J. Delstraa, Bioforsk).The run-off from fields may deplete nutrients as well as erode soil. Another aspect important for Norwegian agriculture is the question whether the proportion of wet days will change, as this will have relevance for the practical work on the field.

Experience with collaborating with municipal authorities

A collaboration between climate information providers and municipal authorities in Norway (*Troms fylke*) gave some insight into a number of aspects. Some of the lessons learned was that the level of climate science understanding was low and that the people working for the municipal authorities often feel a time pressure. These factors imply that climate information and knowledge will only be considered in the context of planning if the information is tailored and suitable adapted for the use by policymakers. The primary type of product sought after by the local authorities tends to be different types of maps for different factors, ones which they may overlay and combine other factors (e.g. area usage). Examples include maps of flood risk, avalanches.

Collaboration between climate data providers and the transport sector

The Norwegian research project *'Infrarisk'* involved a joint study involving the Norwegian geological survey, MET Norway, CICERO, the transport research institute (TØI), road and rail authorities, and authorities for civil protection, looking into conditions that cause disruption and damage for road and rail (Frauenfelder et al., 2013). A particular focus was on extreme events, leading to avalanches, land slides, and flooding. Great precipitation intencities are regarded as a major cause for increased loads on drainage systems. Frauenfelder et al. (2013) observed that precipitation is the most common cause for avalanches and rock/mud/land slides, and that the number of days with high precipitation resulting in such events, has increased in many parts of Norway. High wind is seen as a triggering mechansism for avalanches (snow) in Northern Norway, whereas precipitation was regarded to be more important along the mountainous western coast. Sometimes intense rainfall combined with snow melt has resulted in flooding and slides. Intense (1-hr to 24-hr) or persistent precipitation is the number one event causing problems, but ice on rail too is problematic. Temperatures around zero may affect rock slides, and all these events cause disruptions and damages on the infrastructure.

The most important climate parametres used for road and rail planning included statistical distributions (intensity, and frequencies) for the different events. The type of variables and parameters would include annual maximum 24-hr precipitation, annual maximum 10-day precipitation, and number of days with more than 10 mm/day. In addition, 5-day totals exceeding 44mm and 10 day-totals greater than 60 mm were used. The climate data is used for making hazard geographical maps, showing return intervals for specific events. The data is also used as input in modelling of avalanche trails. Some of the variables used for climate adaption are listed in the table below:

Variable/parameter	Duration	Threshold
Annual max precip.	1,5,10 days	

Peak over threshold	1,5,10 days	10mm. 40mm, 60mm
Annual max snow depth	1 day	
Snow fall – peak over threshold	1,3,5	5mm, 30mm,50mm,80mm
Near zero temperature	1	-1.5C - +1.0C

Temperature and precipitation on a $1x1km^2$ grid are used as input for a hydrological model for simulating daily snow parameters. The annual max snow depth is used as an index of snow accumulation.

For wind, Frauenfelder et al. (2013) examined the annual maximum for 1-hr and 3-hr wind speeds. A regional reanalysis-driven model simulation has also been used to derive further climate statistics, such as the 97.5 percentiles for 24-hr precipitation (all days) and 98 percentiles for 1-hr precipitation. Annual maximum 1-hr precipitation has also been estimated for different regions, as well as number of events with 24-hr precipitation greater than 10 mm/day. Frauenfelder et al. (2013) discussed storm statistics, but such information does not seem to be of much practical use yet. Wind atlases with threshold values exceeding 6.0 m/s and 13.9 m/s were based on regional simulations with reanalyses/analyses as boundary conditions. Trends in the annual 99 percentile for wind speed and annual maximum in 1-hr, 3-hr, 6-hr, 12-hr, and 24-hr data both suggest that there has been a slight strengthening of extreme winds.

As opposed to many other end-users and practitioners, the road and rail community seem to be accustomed to probabilities and return value analyses. Some of this information is used as input into hazard maps and design values for protection measures (dimension values).

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Winter time recreation

A dialogue with people concerned about cross-country skiing in Norway and winter time recreation has revealed some needs regarding climate information and what type of advice is called for. In many parts of Norway, the number of days with snow depth greater than 25 cm (regarded as a minimum for skking) has diminished in low-lying areas. The questions have been about advice where to place new trails for cross-country skiing (higher or lower altitude or a hillside with more shadow rather than sun). Other questions have been about wind direction or snow conditions for ski lifts (alpine skiing), and snow conditions in general for holiday cabins in the mountains (cabins – '*hyttekultur*' – is an important ingredient to Norwegian way of life). The organization P*rotect Our Winters* (POW) was established by skiers and snowboard enthusiasts (Jeremy Jones) in the USA, but now also has a branch in Norway. They are concerned about diminishing snow and want to bring attention to the future snow prospects in a *business-as-usual* scenario 2039. The experience with POW is useful for providers of climate services, as they follow an American shopping list with very specific type of information; they ask for similar information as in the USA where the Northeast ski season will last less than 100 days; the probability of being open by Christmas will decline below 75%; western snowpack could decline 70-100%.

Involving professional societies

Tekna Klima is a professional-society-cum-trade-union that was established within the organization *Tekna* in order to enhance the flow of know how and information between different professionals and decision-making. Tekna (www.tekna.no, The Norwegian Society of Graduate Technical and Scientific Professionals) is Norway´s largest society of professionals with a master´s degree or equivalent in science or technology. It has more than 60,000 members, and *Tekna Klima* is a small subgroup for members with professional interest in climate with more than 500 members who typically are interested in climate sciences, climate adaptation, or energy solutions. It differs from other organizations and network in being based a personal and volunteer network, however, *Tekna* can have an influence on decision-making. The forum which *Tekna* provides can also bring end-users into contact with climate information providers and foster a dialogue that is useful for the provision and validation of downscaled climate model results.

Experience from Sweden

An overview of experience from end-user interviews in Sweden is provided in the appendix, based on 6 responses. The response in the survey reflect views from the hydro-power industry, impact modelers and provincial municipal authorities, and concluded that there is a need for climate information over a wide range of sophistication. The survey also revealed that there is no single end-user, but rather a chain of end-users.

The perspective from the climate-information providers

The experience with end-users from a climate science perspective has sometimes been summarised sentiments such as “they want everything”, “they don’t know what they want”, or “they want all the information on one page and shown in one figure”. This of course depends on with whom one speaks, and there seems to be a misunderstanding between peoples needs and abilities.

In Norway, there have been requests for information about the frequency of dry autumns followed by cold winters, which would be valuable for the water management and the hydroelectric power production/consumption. Sometimes, the sectors would like to have precipitation statistics for hourly or even shorter time scales for certain parts of a city - to plan the dimensioning of draining systems. The farmers would like to know the amounts of rain and the temperatures for their fields, and biologists want to know if there will be layers of ice in the snow in the area where animals graze. In many cases, it is impossible to provide reliable information for such demands, however, it may be useful to ask what kind of information they have used in the past. There are perhaps some dependencies to large-scale conditions which can provide a little more information to what has been used previously.

Ideas and possible solutions

For many end-users, there is a problem making use of the large ensemble of scenarios and probabilistic information. For instance, hydrological models are sometimes computer intensive and the end-user wants only one of a couple of scenarios, and finds it difficult to include a range reflecting all the GCMs and the different downscaling strategies. Sensitivity tests are essential, but are often only invoked as a very minor aspect of the analysis. One possibility could be to bypass problem by *emulate* the hydrological models with simple and fast statistical models to give a description of the range and distribution of the ensemble. This requires some effort and that the end-user and the data-provider get more involved in the whole chain of analysis. The crucial question is: can the efficiency of the impact models be improved? And is it possible to find a middle ground and change the ways of doing things - break with traditional roles?

An evaluation of the end results and testing the models must be key - are the requested variables simulated well? How well does the model perform if applied to describe past changes? Sometimes, the end-user wants very high resolution in space or time, which traditional models cannot provide. However, there is often a great deal of dependency between the scales since many climate variables are smooth functions in space and/or time. Hence, the information content in data matrices describing these high-resolution fields may not be much higher than for a corresponding data matrix describing low-resolution data. At least, one may be able to model the large spatial/temporal structures, and through statistical models superpose the information describing the smaller details. One crucial question is how many degrees of freedom (DOFs) are involved and whether all the small-scale details are signal or if they also are due to noise.

For downscaling, it is important to the make most out of the information we have about the character of randomness (use statistical models) and dependencies according to known physics. The local climate may be viewed as consisting of two parts: one part that depends on the large-scale situation - the potentially predictable character -and one arising from local processes - stochastic noise. Even for the stochastic part, it may be possible to specify the main characteristics (distribution, persistence, and so on). The main goal of downscaling is to identify the predictable part and make projections for the future. Since the unpredictable part is indeed unpredictable in terms of phase and amplitude, we know of no dependency that may affect the unpredictable component (if we did, it would be more predictable). Since we know the statistics such as the PDF and the auto-correlation function, we can make a prediction of these statistics assuming these are stationary if no dependencies have successfully been identified, suggesting they will change with external conditions. One solution may therefore be to assume that this unpredictable component is stationary also for the future and use Monte-Carlo simulations to represent this part. It should be stressed that further research may be in order to try to identify unknown dependencies associated with the part of the data that seem stochastic.

In many cases, statistical models may indicate that only a portion of the variability can be associated with large-scale conditions or is predictable. The remainder which is not predictable may be regarded as stochastic and we do not know if this component has dependencies on other factors. For truly stochastic (and independent) noise, this is no problem as long as the character (PDF and persistence) of this noise can be specified. Climate change projections should only deal with the predictable aspects of the variability, and the noise can then be superposed onto this. For end-users who cannot use PDFs, it may be possible to incorporate these into weather generators to produce time series with realistic time structure, range, and probabilities.

As with spatial scales, there may be dependencies across a range of time scales that can be exploited. Standard intensity-duration-frequency (IDF) curves tend to take on a smooth and fairly uncomplicated shape, which involves a small number of DOFs. This may imply a potential opportunity to extrapolate results through statistical and mathematical means. Another important limitation is the models' minimum skillful scale (Benestad et al, 2008).

Guide lines and Ethics?

Visibility and open data access is important for making an impact and building up authority. However, there will always be an ethical aspects to the data provision, if indeed the data or projections misrepresent the real outcome. Appropriate evaluation and skill estimates are a minimum, and should be accompanied by confidence intervals. Furthermore, the concept of minimum skillful scales should be explained. For good use, a dialogue is necessary, with special efforts devoted to bridging language and cultural barrier through iterative training. The dialogue should include questions such as on what type of information have past decisions been based and why? Is the steady availability of data crucial for its application? What type of empirical data is there? It is important that not just model results are presented.What was a successful practical example on useful climate data? Are there limitations for using data, e.g. biases? Which biases are acceptable?

It is important to acknowledge that all model simulations may potentially miss important aspects. The RCMs may contain flawed physical 'consistency' if they create water and energy (evaoprate or rain more or less than the GCM used to provide the boundary conditions), and it is important to evaluate these physics-based biases by comparing aggregated area mean precipitation, temperature, and radiation (short wave and outgoing long-wave radiation). In addition, statistics-based evaluation should involve traditional skill-estimation as well as the testing of distributions, and should reflect the models ability to reproduce the observed (point) measurements rather than their consistency with the driving GCM physics.

In addition to traditional evaluation, there is a need for a range of sensitivity tests for the different parameters and choices involved to explore the range of uncertainties. One idea may be to investigate which parameters e.g. the rainfall amount are critical and which are secondary. The sensitivity testing should involve parameters, such as spatial resolution, surface schemes, cloud parametrisation, RCM, driving GCM, and emission scenario. Statistical methods, such as (factorial) regression can be used for such studies. Before the results can be used by end-users, the data providers should have a clear idea about on what conditions these hinge and what caveats are involved.

Understanding and explaining uncertainties are important aspects of data provision. One should not use the word 'uncertainty' for lay people, but there are also a number of other terms which mean different things to climate scientists and the general public (eg. positive feedback, error bars). The concept of uncertainty requires a measure of skill and evaluation. Is propagation of errors and full accounting possible? During the OSC and ICCS2 the buzz was making climate sciences "actionable". WUCA (wucaonline.org) "Co-production of knowledge". Knowledge is never going to be downloaded from a web site. There are three important features involved in the provision of climate know how: collaboration as a team (humans); infrastructure and collaborative networks (computers, data bases, web portals, and buildings housing climate serivces); organised information (data, model results, scientific publications).

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Appendix

Appendix - Table with response from pre-survey

Appendix - Programme from the Kiel meeting.

Appendix – Complete survey

Date: 04-03-14

Accuracy:

-unbiased representation of current climate is important, so impact models are operating within their calibration range.

-Confidence Intervals are useful.

-The industrial informants complain that weather information does not provide them with specific risk values. Business people cannot contribute resources to mitigation or preemption of weather-induced.

-Should reproduce today's runoff (frequency, seasonal profile etc) when run through hydrological models.

-Bias in wet end of precipitation distribution is acceptable, but bias in dry end is not desirable as we tend to work in semi-arid region where water stress is a concern for agriculture. For temperature, bias in cold end is more acceptable than that in warm end.

Precision:

-Temperature +/- 0.5 K, wind +/- 0.5 m/s, radiation +/- 5%, precipitation +/- 10%, relative humidity +/- 5%

-0.1 degree C and 1 mm/day

-0.5 degree C and +/- 10% for precipitation

Spatial resolution:

-generally point (synthetic climate station data)

- If the region is highly orographic (with strong gradients of climate elements) even 1 km x 1 km would be to coarse, otherwise 20 km x 20 km could be sufficient.

-same as observations

-Hydrology model tends to require higher resolution than crop models (often higher than 1km).

-1/16 deg, approx. 6km x 6km

-100m x 100m

Time resolution:

-daily/hourly
-10-daily, monthly (depends on models)

Further characterisation:
-Precipitation is important in combination with other weather dimensions: temp and wind strength/direction
-good representation of extreme events is desirable (droughts, floods, heat wave, typhoons etc) as they often are a determining factor for season's crop yields
-inter-dependencies between different elements is often important
-Time structure and chronology is often important
-timing may be important.
-Confidence interval based on emission scenarios/GCMs.
-PDFs not useful, and the story line is sometimes important.
-Time horizon: 2050-2100/ 20-50 years ahead.
- Planning horizon for end-users: next week/next hours to 50 years.
- all seasons are of interest.
- Guidance to using the data is needed. Often analysis of the data is sufficient.
- downloadable netCDF from the web
-possible changes in variability (inter-annual, for instance dry year / wet year, also from month to month) are very very important to evaluate risks and to develop suitable adaptation strategies for agriculture.
- heat waves: both precipitation and temperature.
- floods: spatial extent is important.
- sensitivity of single model to external factors and information about most extreme models.

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Experience with end-users of climate change information in Sweden

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Cost Action VALUE, Working group 1

Table of Contents

Appendix A. Introduction

This report summarizes interviews with climate model, bias-correction as well as adaptation experts, held in November 2013. It is meant to provide an overview of the experience with end-users of climate model data that various experts had in Sweden. It is not complete as the range of end-users is too wide to be fully covered within this report. Instead, this report rather focuses on some examples of individual experience. The hope is nevertheless to capture the main patterns and most important issues related to collaboration with end-users in Sweden.

As the notion of end-user is a central aspect of this report, we define it here as every person or institution that makes use of information that is originally based on climate model data, and that has the intention to use it for decision making, adaptation planning, impact modeling or climate change impact communication.

In this report, we use the term climate expert as a general term for experts having a background in the climate science (climate modeling, bias-correction, impact-modeling, adaptation) and who is, within the context of this report, communicating the climate change information to the end-users.

Appendix B. Interview statistics

Number of experts interviewed: 6

Kind of interview: 5 oral interviews (total length: 273 min), 1 written interview

The oral interviews were held as open discussions, taking the written questionnaire (see Appendix A) as a guideline.

Sectors covered: 2 bias-correction experts, 2 impact modeling experts, 2 adaptation experts. All experts work at the Swedish Meteorological and Hydrological Institute.

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Appendix C. Summary of the interviews

The summary of the interviews is structured by some main issues/points that could be identified during the interviews.

C.1 Types of end-users

The end-users specifically mentioned in the interviews were the hydropower industry, various impact modelers and provincial (in Swedish: Län) as well as municipal authorities. It was stated that the end-users have very different degrees of sophistication in terms of climate related information. The hydropower industry was named several times as a very highly knowledgeable end-user which is also willing to invest a lot of resources (time and money) into climate impact research. The collaboration with the hydropower industry also resulted in a sort of institutionalized body consisting of representatives of various stakeholders and climate change experts who meet on a regular basis (see also Bergström and Andréasson, 2013). The contact with provincial authorities is institutionalized as well and regular meetings take place.

Some key climate impact issues relevant to the end-users named in the interviews were dam safety, flood protection, energy production, sea level rise, agriculture, heat waves, ice cover on roads, and other general climate related indices.

It became evident in the interviews that there is no single end-user but rather a chain of end-users. This implies that every end-user is both a receiver and communicator of climate related information.

C.2 Relevant points in the collaboration with end-users

All interviewees mentioned transparency as a key point in the communication with the end-users. This means to tell them about limitations and opportunities that the climate projection data has – in short to be honest to the end-users and to base the communication on sound scientific knowledge. Also, the language is very important – one has to speak the language of the end-users. All this will lead to a high degree of trust. This process requires a long time, most often several years of continuous collaboration. At the same time that there is a need for transparency, the information quantity should be limited to a reasonable amount to prevent overloading the end-users with too much information. In the interviews, it became clear that the degree to which one can go into details depends on the closeness of the interaction with the end-users as well as the knowledge of the climate expert that communicates the results. Tailoring of the information to the end-user needs was also mentioned several times in the interviews. This means not to provide information about just mean changes but rather to provide some user-relevant climate change information.

Although not explicitly stated by the interviewees, it seemed that all good-practice examples required a lot of personal contact and discussion with the end-users. The communication of climate change information should not be just a one-way thinking in a way that climate experts deliver data and/or information but one needs to have several meetings, preferably multi-year collaboration with the end-users to get some common understanding.

C.3 Requirements by the end-users

It was reported that most often, the end-users have just a vague and general picture of what they require from the climate experts. No interviewee except for one mentioned that the end-users have specifically requested a bias-correction. In general, the end-users relied on the advice by climate experts who should tell them what can be provided and what type of processing that is necessary (e.g. bias-correction). Furthermore, it was mentioned that the requirement definition is a very iterative process.

The interviewees said that most often, the end-users' requirements could be fulfilled satisfactorily. There are only a few requirements that were not met. Those were i) a higher spatial resolution of the climate information down to the very local level of a few kilometers, ii) the provision of climate change information about wind data and iii) climate impact model projections in which expert end-users (e.g. hydrologist) immediately could see some short-comings in the performance during the historical period, which lead to skepticism about the usefulness of the information.

C.4 General attitude of the end-users towards climate projections

Most interviewees reported that the end-users' attitude towards climate-projections was very positive. They trusted the information given by the climate experts and biases and uncertainties did not prevent them from using the information. This was somewhat different in international projects in Africa where a poor performance in the historical period lead to the total disregard of a particular climate model.

C.5 Use of the climate change information by the end-users

Overall, the interviewees reported that the use of the climate change information by the end-users was in-line with the scientific understanding. Some interviewees said that often, the misuse of climate change information by the end-users could already be prevented in the course of the projects by interactive communication.

A somewhat ambivalent picture was reported when it comes to the treatment of uncertainty. Some end-users can easily handle uncertainties, whereas others just would like to have one number and consider the uncertainty merely as an indication of trustworthiness.

Only one example of a misuse was reported. This was related to projections of sea-level rise in a very important climate adaptation project which also received some media-attention. Whereas the climate experts have given ranges of probable sea-level rise and recommended to plan for the upper range, the media reported the upper range as the most-likely. So, the communication of uncertainty failed at some stage.

Apart from clear misuse, a few interviewees have observed that the climate change information has not been used any further at all.

C.6 Knowledge of the end-users about the nature and limitations of climate projection information

Here, the interviews gave an ambivalent picture. Some interviewees reported that the end-users have no knowledge about the properties of climate projections whereas others reported that the end-users are very well able to understand the climate change information given to them. The interviews themselves were not structured in a way to find the reasons for this discrepancy. Based on all the discussions, a reason could be that different climate experts have different ambitions on what the end-users should understand. For example, some of them would explain bias-correction to the end-users, while others would not go into details regarding bias-corrections.

Some general points that caused difficulties for the end-users were mentioned to be

- the interpretation of ensemble projections rather than just using one projection giving one number,
- the judgment of the reliability of a climate projection (or how to weight members of an ensemble),
- the spatial resolution limits of climate model data,
- biases of the climate projections,
- to interpret climate change in the light of natural variability, and
- changing or contradicting information between different ensembles of climate projections (e.g. different generations of GCM-RCMs or different ensembles used by different climate experts).

For an international project, it was reported that also prejudices about the whole phenomenon of climate change existed and needed to be overcome. For example, climate change was thought to be a policy instrument of the Western countries and this prejudice hindered an objective discussion about the climate projections.

In the interviews, it was said that most difficult points listed above could be overcome by a close and honest communication.

C.7 General issues mentioned by the interviewees

The interview itself did not contain a question about general problems and issues. Nevertheless, some general issues were mentioned in the discussion as well and are summarized here.

First, it was reported that clearly, there are different time horizons relevant for the end-users and for climate projections. Most end-users are interested in the next 10-20 years whereas climate projections are only useful on time scales beyond that.

Also, conflicting interests in adaptation projects in which climate change is just one aspect might be a risk for sound use of the climate change information. One example was an adaptation project in Stockholm. In this project, the sea level rise projections were questioned because a strong lobby wanted to have higher protection levels than would have been justified by the sea level rise projections.

It was also mentioned that the climate experts need to be able to come up with recommendations for which projections to be used and how to deal with an ensemble using an unbalanced set of GCMs and RCMs. This is to make the results comparable because right now, different climate experts work with different ensembles (see also the point contradicting information in section 3.6).

Another issue mentioned by two interviewees was the need for “climate information translators”. Such translators are meant to provide the link between the climate model projections and the information required by the end-users. Bias-correction experts were particularly named to have this kind of role. The need for translators is motivated by both the scientific and technical know-how required on how to actually use the climate model data, because currently, most end-users lack this know-how and/or have limited resources to deal with the climate model data.

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C.8 Evolvement of the interaction with end-users over time

This point was discussed both in a long-term perspective as well as in the project specific perspective.

On the long-term, a few tendencies were identified by the interviewees:

- The end-users became more knowledgeable during the last few decades and know better now what they can request.
- The climate experts changed their way how to communicate with the end-users, i.e. more tailored information and interactive communication.
- The end-users nowadays really use the climate change information for decision making whereas in the past, such information was noticed but not really included in decision making

It should also be noted that a few interviewees have not seen much change in the interaction between climate expert and end-users.

On the project specific perspective, it was said that the climate experts sometimes had to adapt their language to the end-users needs during the course of a project and that a common basis was reached by an active dialogue. At the same time, the end-users learned about the limitations and properties of climate projections.

Appendix D. References

Bergström, S., Andréasson, J., 2013: Accounting for climate change and uncertainty: experience from strategic adaptation projects in Sweden, Climate and Land Surface Changes in Hydrology, Proceedings of H01, IAHS-IAPSO-IASPEI Assembly, 11-16, IAHS Publ, 359

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Appendix E. Questionnaire

COST Action VALUE

Questionnaire for collecting experience with end-users of bias-corrected climate projections

Note: This is meant as a rough guide through the interviews with experts. Feel free to add your own comments/questions to the questionnaire if you think that particularly your case does not fit into the outlined questions. Also, there is no need to answer to all questions if you think they do not suit your examples.

1) What examples of projects/experiences with end-users of bias-corrected climate projections have you got? If possible, please list 3 and try to come up with a good and bad example as well as a normal example. The definition of good and bad is up to you, but it should relate to qualifying the interaction between researchers and end-users.

2) How would you describe the attitude of the end-users towards climate model projections in general, given the fact that there is a large uncertainty involved combined with considerable biases?

3) Did the end-users themselves request a bias-correction of the climate model projections or did they agree on a bias-correction proposed by the researchers?

4) How did the end-users interpret/discuss the biases of uncorrected climate projections? This question is related to questions 2 and 3, but here, you could give more details specifically about biases.

5) What requirements/expectations for the bias-corrected projections were expressed by the end-users?

6) Have the end-users been satisfied with the provided bias-corrected projections? If not, what remaining issues would they have liked to be resolved by the bias-correction?

7) How would you describe the knowledge/experience of the end-users of how to interpret climate projections in general?

8) Do you think the end-users are aware of the limitations of the climate-projections?

9) Do you think the end-users have used and/or interpreted the data in a correct way?

10) What were the main difficulties in the communication with the end-users regarding the use of the data (i.e. bias-corrected projection) produced by climate researchers?

11) In the course of the project, could you observe changes in the way end-users interpreted the strengths/limitations of climate-projections (with and/or without bias-correction)? If yes, what kind of changes could you observe what were the probable reasons for this change in attitude?

12) Over the course of years/decades, could you observe any changes in the knowledge of end-users about the properties of climate-projections? E.g., do they know more about it nowadays than let's 20 years ago? Have the requests become more demanding? …