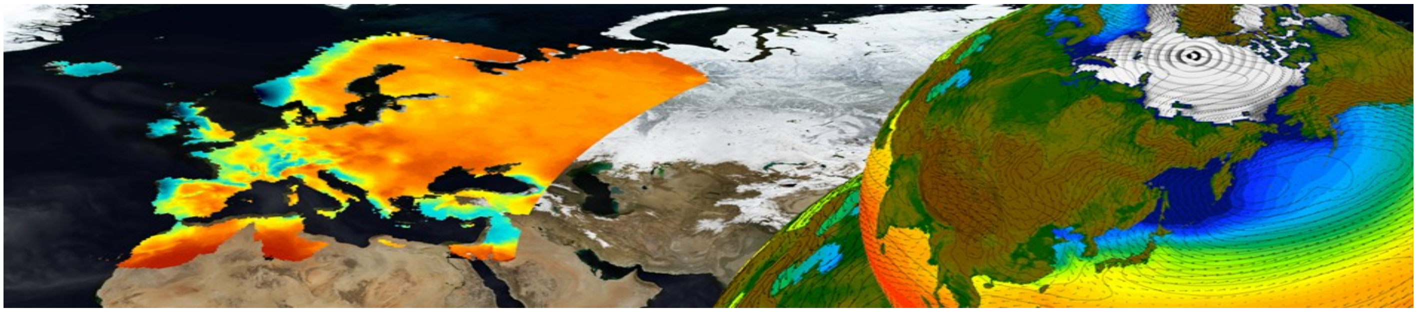

COST ES1102-VALUE, working group 1: 2013 White paper on climate change data for end-user

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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 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.

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 that 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 bride 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 people who actually does the research rather than administration.

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.

1 What are end-users needs for climate information

The end-users needs clearly depend on the type of end-user:

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 changes in the impacts (heat waves, floods, wind damages, etc.), 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 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 on 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 interrogated. 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. They 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 belong (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 need be to reflect the rareness 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-user made use of the confidence intervals by taking certain range 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 appreciate to be in .ncdf 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 that the accuracy for a key variable is the same for all parts of Europe, but both the duration and magnitude of extreme events 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.

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 what 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. This is to evaluate the other end of the needs asked about. 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
- Better data dissemination - look to economic data and financial data providers

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 Austria

Survey performed in Austria

A survey was made in Austria in 2012, were 800 scientists and stakeholder were 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 we 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, 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 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 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;

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

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

3 http://cdn.fmi.fi/legacy-fmi-fi-content/documents/cccrp/CCCRP_survey_of_user_needs.pdf

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 have 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 Norwaegian Meteorological Institute has long experience working with end-users through various projects, web-postals (all data is free) 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. A great deal of the information 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, making 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 prarie dogs in the US.

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.

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).

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 have been interested in gridded observations for the past. For Norway, there are 1x1 km grids for daily precipitation and temperature[4].

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.

The perspective from the climate-information providers

The experience with end-users from a climate science perspective has sometimes been summarised sentiments such as "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*

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

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). If we know the statistics such as the PDF and the auto-correlation function, we can make a prediction of these statistics even if we cannot identify and dependencies which may suggest 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 regarded as stochastic and we do not know if this components 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?

Is it 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: human relationships; infrastructure and collaborative networks; organised information.

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Appendix - Table with response from pre-survey

Appendix - Programme from the Kiel meeting.

Appendix – Complete survey

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.