Norwegian Centre for Climate Services

User needs for post processed climate data

A survey of the needs for output from the research project PostClim

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Photo: Hans Olav Hygen

The Norwegian Centre for Climate Services (NCCS) is a collaboration between the Norwegian Meteorological Institute, the Norwegian Water Resources and Energy Directorate, Uni Research and the Bjerknes Centre for Climate Research. The main purpose of NCCS is to provide decision makers in Norway with information relevant regarding climate change adaptation. In addition to the partners, the Norwegian Environment Agency is represented on the Board.

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Abstract

The primary objective of the NCR-project PostClim is to improve methodologies for producing tailored climate information for key users of climate services. This is not a new challenge, and the present report summarises experiences from some other projects where the Norwegian Centre for Climate Services has been or is involved. These experiences are supplemented with feedback from the PostClim key users within the agriculture and the municipality sector. A general conclusion is that the needs for climate information differ widely between user groups. In particular, the priorities among climate impact modellers are very different from the priorities among end users. In spite of this there are some clear messages to take home: Climate data with high resolution, both in time and space, are demanded by several users. Impact researchers need high resolution data as input in their models, while others, e.g. municipal planners need high spatial resolution to illustrate the climate impact in their geographical area of interest. There are several challenges connected to developing useful datasets on the local scale. Some are connected to specific variables, some are connected to conserving consistency in the dataset, and some are connected to evaluation and communication of uncertainty. Continuous communication between climate scientists, impact researchers and end users is essential for overcoming these challenges.

Keywords
User needs, climate adaptation, PostClim, agriculture sector, municipality sector.

Disciplinary signature

Responsible signature

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1 Introduction

1.1 Scope and limitations

The primary objective of the research project “Post-processing Climate Projection Output for Key Users in Norway” (PostClim; NFR No. 255517) is to improve the methodology for producing tailored climate information for selected groups of practitioners. Long-term planning and decision-making in the context of climate impacts, adaptation and vulnerability requires information on future climate and potential risks that are tailored to the individual stakeholder's needs. In PostClim, partners from the Norwegian Centre for Climate Services (NCCS) and Norwegian Computing Center (NR) are joining forces with decision-makers from Norwegian municipalities and the agricultural sector to produce appropriate climate projections for decision-making under an uncertain future climate. To this aim, post-processing techniques for statistical downscaling and bias adjustment will be employed, and further developed as necessary, to bridge the gap between the raw output from global and regional climate model and the needs of the decision-makers. A number of different techniques will be validated according to criteria that are important for the stakeholders. The further development of methods and climate indices will also be based upon user needs.

The present report aims to give an overview of our present knowledge of needs and priorities for the PostClim key practitioners. Chapter 2 sums up experiences and conclusions from other relevant projects and activities, while chapter 3 summarizes the preliminary response from the PostClim practitioner panel.

1.2 Who are the users

The mission for NCCS is to “provide a common knowledge basis for climate adaptation in Norway”, and according to the mandate, the need for climate information among decision makers at all administrative levels (state, county, municipalities), as well as climate impact research and key industries should be mapped. Municipality administrations and the agriculture sector were chosen as key user groups in PostClim. They are both among the high priority stakeholders for the NCCS, and they are expected to represent rather different needs concerning climate data. The municipality administrations are represented by the the Norwegian Association of Local and Regional Authorities (KS). They are expected to expose needs for data and services typical for infrastructure owners and land-use planners. The agriculture sector was originally represented by the Norwegian Farmers' Union (NFU) and The Federation of Norwegian Agricultural Co-operatives (FNAC). Later, also the Norwegian Institute of Bioeconomy Research (NIBIO) and the Norwegian Agricultural Extension Service (NLR) were included in the user panel. The needs for climate data in this sector are expected to be rather complex, as not only the direct effects of the climate will be important, but also the indirect effects through the entire ecosystem.

There are multiple ways to categorize the users and stakeholders. One such attempt was provided by ClipC (CLIPC Deliverable, D - N: 2.1 User Requirements part 1, Strategies for consultations and engagement and user requirements: Synthesis of past efforts, Groot et al. 2014), where the users were divided in 4 groups according to their knowledge of the climate science:

1. Climate scientist,
2. Impact researcher,
3. Boundary worker / Knowledge purveyor
4. End user (e.g. policy maker)

For PostClim the main user categories according to this classification belong to group 2 Impact researchers (NIBIO), 3 Boundary worker / Knowledge purveyor (NLR) and 4 End users (KS, NFU, FNAC).

2 Selected relevant projects

For a long time climate scientists have been collaborating with various user groups. Through this collaboration knowledge of user needs has been acquired. Unfortunately, most of this knowledge has not been formalized in reports or papers. Below is a survey of recent projects where the PostClim partners have been dealing with provision of climate projections for climate adaptation purposes within different user communities.

2.1 Noradapt

NORADAPT, Community Adaptation and Vulnerability in Norway, was a project where benefits of close cooperation between climate researchers, social scientists and municipalities was explored in a climate adaptation context. One of the conclusions was the need of a close dialogue between all three parts throughout all stages of the project. Regarding climate projections and downscaled climate projections, a set of indices was identified and tailored in close cooperation with the users. The knowledge of the climate researchers in cooperation with the social scientists was used to establish products the user could understand and benefit from for climate adaptation purposes in further planning. The identified climate indicators were based on the local needs, e.g. number of days with temperatures below -30 °C was important in Finnmark, while Høylandet was more concerned with number of days with frost. (Oort et al. 2012).

The project demonstrated that most municipalities do have the ability to put climate adaptation on the agenda, utilize scientific knowledge and implement climate adaptation measures. However, this implementation depends on several factors, such as capacity, knowledge and involvement in municipalities, access to relevant knowledge and tools, and clear guidance and follow-up from regional and national authorities.

2.2 Klimaprosjekt Troms

The project “Klimaprosjekt Troms” (Fylkesmannen i Troms, 2015) was run by the county governor of Troms with participants from Norwegian Centre for Climate Services (i.e. MET and NVE), the Norwegian Directorate for Civil Protection (DSB) and selected municipalities. The project's aim was to integrate climate adaptation in the municipal planning, and a key product was "Klimahjelperen" (DSB, 2015); a guide in how to perform this integration in practice. The project clearly revealed a need for easy access to relevant tailored climate information. High resolution information was useful to create understanding in the user groups, but just as useful were interpreted information with a highlight of elements of specific concern for the region. Another main result from this project is thus "Klimaprofil Troms" (Climate factsheet for Troms County), giving a brief summary of the main climate related concerns for the region. The factsheet was intended used as a regional supplement to the guide "Klimahjelperen", and was developed in close collaboration between scientists and users. In the wake of this project, Climate factsheets have been produced for all Norwegian counties (available at https://klimaservicesenter.no). These factsheets contain graphs presenting the projected temperature and precipitation development in the 21st century. They also give advice concerning changes in design values for heavy precipitation, river floods and storm surges, and concerning risk for avalanches and landslides.

2.3 ClipC

ClipC (www.clipc.eu) is a project within the Copernicus Climate Change services (C3S). ClipC provides access to climate information of direct relevance to a wide variety of users, catering for consultant advisers, policy makers, private sector, decision makers and scientists;- but also for interested members of the general public. The ClipC "one-stop-shop" allows users to find answers to questions related to climate and climate impact. In the initial phase, ClipC had an extensive user interaction starting with a summary of previous projects and analysis of existing portals. Two main conclusions from the summary (Groot et.al. 2014) are:

- It is not possible to create a portal that caters for everybody. ClipC tried to solve this by splitting the users into four main groups: Climate Scientists, Impact researchers, Knowledge purveyors and End users. To further make it possible to create a useful portal, ClipC defined the end users to be outside the scope of the project.
- Data-driven portals are doomed to be a failure. Here a data-driven portal is defined by: "We have these great data-sets that 'everybody' should be able to access", while, the opposite, a user-driven portal is driven by the tasks a user wants to perform with the portal.

ClipC provided a continuous interaction between the developers and potential users, aimed at refining the portal to a useful tool. The portal provides a good interaction to a broad range of datasets, and quite advanced analysis tools. The users praise the easy access to fairly high resolution of the datasets, and the possibility to analyse datasets from various sectors together. However, the system, as presented at the end of the project, lacks the possibility to analyse the data based on combination of different elements linked in time.

2.4 Klima 2050

Klima 2050 (http://www.klima2050.no) is a Centre for Research-based Innovation (SFI) financed by the Research Council of Norway and the consortium partners. The SFI status enables long-term research in close collaboration with trade and industry, as well as other research partners aiming to strengthen Norway's innovation ability and competitiveness within climate adaptation. The built environment is particularly vulnerable to climate change. Changes in climate will increase the need for maintenance and the renewal of robust key societal infrastructure. Klima 2050 will reduce the societal risks associated with climate changes and enhanced precipitation and flood water exposure within the built environment. Emphasis is placed on development of moisture-resilient buildings, storm water management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision-making processes. Both extreme weather and gradual changes in the climate is addressed.

Buildings and infrastructure represent huge values in the society. “SINTEF building and infrastructure” (http://www.sintef.no/en/building-and-infrastructure1/) has documented that, historically, the main problems have been caused by faults in the construction phase. Through “Klima 2050” and the earlier project “Klima 2000”, climate projections with high temporal (daily, and sub-daily) and spatial (~km) resolution have been shown to be useful. Though the spatial scale is far below the “skilful scale” of climate models (see e.g. Castro et al. 2005), such data can be applied to illustrate the challenges facing the planning of future infrastructure and built environment. The main challenges are related to temperature and precipitation, combinations of these, as well as their hydrological consequences. Wind and the combination of wind and rain, is also of great interest. For the planning of architecture and in particular for the assessment of the potential for solar energy, data for sunshine duration are useful.

2.5 EDGE

The on-going Copernicus project EdGE (“End-to-end Demonstrator for improved decision making in the water sector in Europe”; http://edge.climate.copernicus.eu/) aims at delivering a demonstration water-oriented information system implemented through a web application. The system will be based on climate data and state-of-the-art hydrological model output. European stakeholders representing four “Focus Groups”: water supply, catchment planning, hydropower and local authorities, are involved in the project. The early deliverables in the project include a “Stakeholders mapping and information analysis” (Allen et al. 2016), from which we below cite some relevant conclusions. Despite the wide range of hydro-climatic regions and different water uses, there was a degree of consistency between the Focus Groups.

Concerning variables and scales:

- A requirement for skilful seasonal hydrological forecasts. All users agreed that high quality seasonal forecasts looking 3 to 6 months ahead would improve decision-making. However, most users suggested that it is unlikely that seasonal forecasts would offer sufficient skill to change the need to plan for the worst.
- Some users seek high time and space resolution information about the future climate that is not currently available, e.g. for analysing rainfall intensity.
- For several purposes, understanding how drought indices may change is important.
- Most users identified understanding changes in evapotranspiration as important.

Concerning presentation:

- Users want to be able to download data in accessible formats. Some people were concerned that the need to process data acts as a barrier to their use.
- Users want maps and graphs, and would like to be able to download these in ways that they can use in presentations and reports.
- Users want to see specific results set in a wider context of other climate change projections, so that they can make comparisons with other results and understand any differences.
- Users identified the importance of access to information in the local language.

It was also found that users are willing to adopt new indicators and approaches provided that the presentation makes them easy to understand and use. Users look to scientists to provide the best possible indicators and information, and generally trust scientists to make good decisions about how these should be defined.

2.6 ExPrecFlood

The national project ExPrecFlood («Extreme precipitation and rapid onset flooding implications for design values") has direct involvement by key users of design values for rainfall and flooding. ExPrecFlood is partly funded by the Norwegian Research Council, and partly by the Norwegian Road and Railway authorities. The main objective of the project is to quantify the effect of projected climate change on short duration extreme rainfall events and related rapid onset flooding, and to estimate the implications of these design values for infrastructure. This is achieved by detailed studies of spatial and temporal distribution of short-duration rainfall extremes and flash-floods in present-day as well as future climate.

New information and products are being developed in close communication with the users, and will be disseminated through NCCS. A map-based tool for estimating Intensity-Duration-Frequency (IDF) values for arbitrary sites in Norway will be made operative at the NCCS web-site. Present-day statistics will be available for measuring stations as well as for ungauged sites. Projected IDF-estimates up to year 2100 will be based on downscaled regional climate models. The outcome of the project will potentially become a valuable resource for long term planners of surface water management, spillway-systems, land-use, infrastructure, transportation etc.
The present dialogue with users through workshops and questionnaires has demonstrated that:

- Users are applying rainfall/runoff design-values for mapping of potentially flooded areas, for dam security, for designing urban spillway-systems, and for planning and maintenance of roads and railways
- Concerning planning for future climate, just a few users are applying climate change information from NCCS. Most users apply other sources, or do not consider future climate at all
- Dataproducts used for designing new constructions are partly IDF-statistics from MET Norway, and partly products provided by NVE (NEVINA: http://nevina.nve.no, NVE Atlas: https://atlas.nve.no and SeNorge: http://www.senorge.no.

- Most users have experienced easy data availability both at MET Norway and NVE, and particularly useful information from the NVE-products NEVINA and NVE Atlas
- Users are requesting further education on design values. The education may partly be by info on the web or short courses, but most user would prefer longer courses
- Most users want more information on how to consider uncertainty in their calculations

2.7 Klimavakten (“The climate watch”)

“Klimavakten” is not a project as such, but a continuous activity with an open line (phone and e-mail) for public contact at MET Norway. The main inquiries are for observations related weather incidents, as well as climate statistics. This section summarizes the needs for climate change info based on the response to the “Klimavakten”- service.

There is special interest in design values for heavy rainfall; i.e. statistical return values for the precipitation value that is estimated to be exceeded once in a x years’ period; e.g. x=50, 100 or 200 years. These products are called IDF statistics (Intensity - Duration - Frequency). The return values are important in planning of surface water management, land-use, and infrastructure for transportation. IDF products are also requested by insurance companies. There is a need for IDF estimates everywhere in Norway, both for current and future climate. The ExPrecFlood project tries to meet this need as described in the section 2.6.

Design values for snow and ice loads are in demand for planning building constructions and infrastructure. Modelling of future snow loads is thus essential for assessing the need for reconsidering snow load standards in a changing climate. Global warming is projected to lead to reduced length of the snow season everywhere in Norway. However, changes in the maximum snow amount, depends on timescale as well as region.

Several practitioners show an interest in how global warming will affect wood decay. This is an important issue for e.g. property management and development of house painting products. Change in number of days with zero degree crossings may affect decay of old stone and brick buildings, but is also important within agriculture. Change in frequency of freezing rain events is of great interest to the road maintenance sector and insurance companies, and will also affect wildlife and farming.

There is an interest in seasonal forecasting among practitioners e.g. within farming, hydropower production, energy consumption and snow removal businesses. Unfortunately the seasonal forecasts for temperature and particularly precipitation have little skill in our part of the globe, and are presently categorized as useless by most of these sectors. Further, seasonal forecasting is closer to weather forecasting than to climate analysis and climate modelling, and is thus not a theme for the PostClim project.

2.8 Response on NCCS-web

Users would like to have easy access to the concise information they need to solve their specific climate-related problems, preferably all in one website. This is a great challenge!

There is great interest and need for climate change information for a variety of climate indices, from regional to site-specific spatial resolution. Climate change considerations also require a best estimate of the current status of the climate indices.

Counties and municipalities are interested in climate changes with the most important impacts for their own areas. They would like estimated values that can be applied in their planning work, such as sea level change, changes in rainfall intensity and changes in flooding. NCCS has now produced 8-pages “Climate factsheets” for all counties (see Section 2.2). These were produced in close collaboration with county administration, to meet their need for concise information in an optimal way. The intention is that the Factsheets will be updated when new synthesised information is available. Still, many users ask for more local detailed info than the Factsheet can provide.

Researchers often need fine-scale numerical data to apply in their own research studies, particularly in impact studies. Some gridded datasets with1x1 km resolution are already available:

- NCCS offers climate projections for the period 2071-2100 for two emission scenarios (RCP8,5 and RCP4,5) and 10 different model combinations, with diurnal resolution (http://tst-h-web03.nve.no/gridown/kss). Available climate indices are temperature, precipitation, runoff, soil moisture deficit, and snow water equivalent.
- Similar observationally based grids are presently not available through NCCS, but are visualized in another web site (http://www.senorge.no/aboutSeNorge.htm).
- Average temperature and precipitation for normal periods (30 years) are available through the NCCS web site.

A map-based tool for estimating rainfall design values (IDF-statistics) for arbitrary sites in Norway is presently under evaluation and will be made operative at the NCCS web-site (cf. chapter 2.6).

3 Preliminary experience from PostClim

In cooperation with the NRC project R3 (255397), PostClim arranged a user workshop in connection with the 4th Nordic Conference on Climate Change Adaptation on August 31st 2016. On the 27th of September 2016, the first PostClim scientific meeting was held in Oslo. This section summarizes the lessons learned from these two events.

3.1 Workshop 31.08.2016

The workshop followed a concept where the discussion is structured through a pre-assigned “XLRM-form” (Lempert et al. 2006), where one would bring up the various aspects related to uncertainties (X), the decision making options (L), contexts and models (R) and score goals, communication and implementation (M). After an introduction to the research projects R3 and PostClim, and to the XLRM concept, the participating stakeholders were divided into three groups according to sectors: “Energy/hydropower”, “Local/regional Management” and “Agriculture”. The participants from the PostClim project (stakeholders and scientists) mainly split between the last two groups. The paragraphs below summarize the output from these two groups.

Agriculture

The Agriculture group chose to interpret uncertainty as "risk factors", and discussed such factors related to future climate projections including increased temperature and precipitation, more intense rainfall but also possibilities for longer dry spells in summertime. Several risk factors connected to water were identified, as precipitation affects the risks for drought, flooding, soil erosion and earth slides. Precipitation conditions and wet soil also affect the farmers’ access to their fields, which may cause problems especially in spring and autumn. The combination of temperature and humidity also potentially affects the spread of plant diseases and pests, and thus the need for use of pesticides.

For decision making options, the group was concerned about strategies for reducing risks, as well as exploiting the opportunities in a changed climate. Risk reduction measures include designing drainage- and irrigation systems for future rainfall conditions, but also the development of new technology. An example is the development of smaller agriculture machines that do less damage to wet soil. Changed land use, breeding for new varieties of agricultural crops and introduction of new crops, may not only reduce harm but also give opportunities for increased agriculture production in a changed climate.

The need for models as a tool for decision making was discussed in a short-term and a long-term perspective. In the short-term perspective, the further development of fine-scale weather forecast models was emphasized. High quality 7-days forecasts, including probability estimates, are valuable for farmers' every-day planning, and the value of these forecasts may increase in a changing climate as the validity of traditional knowledge may be reduced. In the long-term perspective, the identification of future challenges is crucial. Seen in the context of the identified risk factors, this implies the need for models that can calculate changes in key meteorological and hydrological variables that directly or indirectly affect the agriculture sector. Output from the climate- and hydrological models should thus not only be useful for describing the changes in the physical parts of the climate system, but also be a useful basis for assessing/modelling impacts on plants, livestock and ecosystems.

The discussion concerning score goals, communication and implementation was not detailed. The needs for detailed long-term climate projections on "sufficient resolution in space and time", for assessing both direct and indirect impacts were nevertheless emphasized in a general way. Concerning communication, the importance of easily available information in Norwegian was stressed by the end users, while this is not important for impact researchers.

Management

In the Management group, different aspects of uncertainty were discussed. It was agreed that a high degree of uncertainty is connected to political decision-makers: To what extent is planning for climate change followed up in political decisions? Uncertainty is also connected to the sharing of responsibilities between different administration levels (municipality/county/national). Finally, concerning the integration of climate change in the planning process, the model uncertainties connected to intense rainfall, frequency of days with temperatures around 0 ^{o}C, and wind conditions were listed as serious.

For improving the decision making, it was seen as crucial to secure the political fundament at local as well as on regional level. High quality data on climate change and good communication of the results, as well as relevant visualizations of expected consequences were suggested as means for improving the political fundament.

For improving the practical follow-up in the planning process, it was suggested to clarify the distribution of responsibility between different levels, but also to promote/increase cooperation/networking between municipalities. Pooling of resources was also suggested. Examples: Maintenance of local roads as well as flood protection along rivers that are crossing municipality borders should be coordinated. Coordination is also crucial for planning of infrastructure connected to communication and electric power transmission. The importance of seeing different challenges in context was also agreed upon. E.g. urban development aimed to reduce greenhouse gas emissions may increase the risk for urban flooding caused by the projected increase in heavy rainfall.

Concerning the need for models, the Management group mentioned cost/benefit models for assessing different measures, and downscaling models for calculation and visualizing consequences of climate change on the local scale.

Finally the importance of communicating the long-term economic benefit of investments in climate adaptation was underlined.

Some reflections after the workshop

There are some similarities concerning the needs for basic climate and climate change information in the two user categories, but also some interesting differences. Both groups are highly concerned about changes in precipitation, including short-duration rainfall, and consequences for storm water, urban runoff, floods and droughts. This implies that hydrological modelling will be necessary, which again requires consistency between temperature and precipitation as well as consistence in time and space. The temperature itself seems to be more important for the agriculture sector than for local management. However, both groups expressed their interest for the frequency of days when the temperature crosses 0^{o}C. The agriculture group expressed an interest for air humidity, and they will also need output from relevant biological/ecological impact models, which again will depend on input of climate variables.

There is also a difference between the groups concerning the need for different scenarios. Climate adaptation is the main concern for the Management group. The Norwegian white paper on climate adaptation (Meld. St. 33 (2012-2014) states that the precautionary principle should be followed, thus when assessing risks connected to consequences of climate change, the high emission scenario should be applied. We thus apply emission scenario RCP8.5 for this purpose. For planning e.g. drainage or other infrastructure within the agriculture sector, it seems reasonable to use the same. However, for exploiting opportunities, the perspective is somewhat different, and cost-benefit analyses are probably more fit than the precautionary principle. It would thus probably be good to look at different possible futures and include also e.g. emission scenario RCP4.5.

3.2 Scientific Meeting 27.09.2016

The user panel did not participate in the scientific meeting, but the main conclusions from the workshop were discussed. An important message from the workshop was that the practitioners, when assessing risks and opportunities connected to climate change, depend not only on climate information, but also on information on the consequences of climate change for hydrology and biota. The needs for input of climate information in hydrological models and in agricultural research were thus discussed at the meeting. Hydrological modelling is part of the PostClim project, and thus a main theme for the scientific meeting. Agricultural modelling is, however, not included in the project, and a presentation from NIBIO was invited to elucidate this theme.

Climate data input to hydrological models

Practitioners both from the municipality- and the agriculture sector depend on information on hydrological conditions as e.g. snow amounts and flooding conditions. For agriculture, the probability for droughts is also crucial. Though regional climate models (RCMs) offer some relevant variables or indices, they are mostly of limited value in Norway because of the complex topography with mountains, valleys and fjords, as well as the systematic biases in the RCMs. Running hydrological models with sufficient spatial resolution to describe the main features of the landscape, and using bias adjusted input data, is necessary to provide the practitioners with useful information. The need for bias adjusted climate data input to hydrological models is thus a major concern for PostClim.

In the PostClim project, the HBV-model (Bergström, 1995) will be applied to model hydrology, and the climate input variables are:

- Ta (°C) – daily average temperature
- Tmax (°C) – daily maximum temperature
- Tmin (°C) – daily minimum temperature
- Rs (MJ/m^2/day) – daily radiation
- Rhmax (%) – daily maximum relative humidity
- Rhmin (%) – daily minimum relative humidity
- Wind (m/s) – daily wind speed
- P (mm/day) – daily precipitation

Having realistic, bias adjusted values at least for Tmax, Tmin, wind and P is important for the hydrological modelling. Daily temperature, radiation and air humidity may be simulated. As the bias adjustment is performed independently for the different temperature indices, the consistency between Ta, Tmax and Tmin needs to be checked. Further, the consistency between temperature and precipitation should be realistic.

Especially for modelling of floods and droughts, consistency in space and time is also essential.

Climate data input in agricultural research

Climate affects agriculture in a number of ways; both directly and through its effects on e.g. soil, plant diseases and pests. In a climate change adaptation perspective, the agriculture researchers would ideally want the ability to compare the current situation with the situation under projected future climates. Thus, the need for data on future climate would be similar to the need for historical data which are presently applied in agricultural research.

Climate data are presently used as input in models for plant growth, runoff and soil erosion, loss of nutrients and pesticides, decomposition rates, epidemiology (risk-calculations for diseases and pests), as well as growing season. For soil related models, the input variables largely overlap with the input variables for hydrological models. For evaluating impacts of climate on plant growth and overwintering (including forests), and the epidemiology of plant pests and diseases, more detailed information on parameters such as wind, air humidity and radiation, as well as snow loads, are needed.

The most important variables largely overlap with the above mentioned input variables for hydrology models:

- Air temperature: average, max and min.
- Precipitation
- Relative humidity
- Global radiation
- Wind speed

Important indices which can be derived from these data are:

- Growing degree days
- Length of growing season
- Potential evapotranspiration
- Leaf wetness

Other variables needed in models related to agriculture and for risk evaluations for forest damage and agricultural plants include:

- Wind:
    - Probability for extreme winds
    - Dominating wind direction
- Soil temperature (from 10cm to 1m depth)
- Snow
    - Coverage
    - Snow depth
- Icing conditions
    - Freezing – thawing indices
    - Risk of frost nights
    - Length of frost season
- Net radiation
- Cloud cover

Concerning resolution in time and space, there is literally no lower limit for what might be useful in agricultural research, e.g. for the modelling the development and spread of pathogens. Most models will however rely on hourly or daily values. Resolution in space will depend on geography and topography, with higher demands to local resolution in areas with mountains and fjords than in flat areas. Parameters related to predefined geographical points or areas will cover most needs. Further, it was underlined that - depending on the context - local or regional data on daily, monthly or even seasonal time-scale may be useful.

4. Summary and discussion

Preliminary experiences from user communication in the PostClim project are in general in line with similar results from other climate service related projects concerning the practitioners' priorities and needs for climate data and information. Below, we sum up some main conclusions, and specific implication for the further work in the PostClim project.

It is evident that different user groups have different needs and priorities. End users prefer easily available tailored products in their national language, and they ask for guidance concerning how to apply or implement the products in their own routines and analyses. Impact modellers, on the other hand, usually need more comprehensive and detailed datasets to feed into their impact models. Language is not an issue, but metadata and data formats are important. Often, end users depend on products based upon impact models as well as the pure climate products. This is definitely the case in PostClim. Consistency between the climate products and the climate impact products is then an issue, and three-way-communication between climate scientists, impact modellers and end users is thus important.

There is obviously a huge gap between output from climate models and the optimal climate data set for assessing direct and indirect impacts of climate change for the hydrological system and for agriculture research. Climate models have a "skilful scale", which by far exceeds the spatial scales on which impacts of climate changes are requested. The concept "skilful scale" should thus be communicated to the practitioners. But in spite of the relatively large skilful scale of the climate change signal, post-processing the climate model output data e.g. by taking into account sub-grid features like the local topography before applying them in impact models, can add value to the results. Further, experience from several projects specifically points out that modelling climate change impacts on the local scale is very helpful for communicating the importance of climate adaptation. It is, however, crucial to include information on uncertainty. Results from single models should be presented in a multiple model context.

The PostClim practitioners, including end users and impact modellers, list temperature and precipitation as the two most important meteorological variables to post-process, but state that also air humidity, wind and global radiation are important, e.g. for modelling hydrological as well as agricultural impacts of climate change. From the climate scientist's side, when choosing variables for post-processing, it is necessary to take into account also if the variables are estimated reasonably well by the climate models, and whether useful evaluation datasets exist. For wind, the climate model performance is questionable. For air humidity and global radiation evaluation may be problematic. Another challenge is that the consistency in time and space, as well as between variables usually not will be conserved during the post-processing. The post-processing technique can be designed to reduce these problems, but then priorities concerning what kind of consistency to conserve have to be given, and the practitioner's priorities are not clear at this stage.

Close communication between climate scientists, climate impact researchers and practitioners from the agricultural and municipality sectors have been required to arrive at the conclusions of the preceding paragraphs. Continued collaboration will be required for deciding the final priorities concerning variables and post-processing techniques, for evaluating results, and for developing and designing the end products of the PostClim project.

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