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Production and use of regional climate model projections – A Swedish perspective on building climate services

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ABSTRACT

We describe the process of building a climate service centred on regional climate model results from the Rossby Centre regional climate model RCA4. The climate service has as its central facility a web service provided by the Swedish Meteorological and Hydrological Institute where users can get an idea of various aspects of climate change from a suite of maps, diagrams, explaining texts and user guides. Here we present the contents of the web service and how this has been designed and developed in collaboration with users of the service in a dialogue reaching over more than a decade. We also present the ensemble of climate projections with RCA4 that provides the fundamental climate information presented at the web service. In this context, RCA4 has been used to downscale nine different coupled atmosphere-ocean general circulation models (AOGCMs) from the 5th Coupled Model Intercomparison Project (CMIP5) to 0.44° (c. 50 km) horizontal resolution over Europe. Further, we investigate how this ensemble relates to the CMIP5 ensemble.

We find that the iterative approach involving the users of the climate service has been successful as the service is widely used and is an important source of information for work on climate adaptation in Sweden. The RCA4 ensemble samples a large degree of the spread in the CMIP5 ensemble implying that it can be used to illustrate uncertainties and robustness in future climate change in Sweden. The results also show that RCA4 changes results compared to the underlying AOGCMs, sometimes in a systematic way.
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Practical implications

Climate information derived from an ensemble of simulations with the Rossby Centre regional climate model (RCA4) is the foundation of the climate service presented here. A central facility is the material presented at the SMHI climate scenario web pages (http://www.smhi.se/en/climate/climate-scenarios) that has been in operation since the start of October 2013. The actual content and format of what is displayed at the web site has been developed during the last decade in an iterative process involving a close dialogue with a range of users of the services as described in more detail in this study. Here, we first give a short description of what is currently published on the web page that presents both traditional climate change information in the form of maps and diagrams but also more detailed information on what is shown and guidance documents on how the results could be interpreted and further used. There are also links that can be used to download the data. The displayed material is stratified along several dimensions: area, forcing scenario, seasons and climate index. For each of these there are a number of options for what can be displayed at the screen by a user.

In the dimension of area, results from the global scale down to the local scale are presented. At the global scale information from the underlying ensemble of global climate models, which have been used as input data to the more detailed regional model, is used to produce the maps presented. By looking at these maps one can get consistent information about how the regional and local climate change signal compares to that in other areas of the world. At the global level focus lies only on seasonal mean temperature and precipitation. For the European and Swedish areas results from RCA4 have been used. At the Swedish level, which contains most information, data can also be displayed in diagram form as averages for different regions (all country, administrative counties, weather forecast districts, main catchment areas). For Swedish conditions also observational data are shown. This allows the user of

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the web site to get an idea about the observed interannual variability of the displayed climate index in the region. This can then be considered in relation to the future variability as projected by the climate model.

Forcing scenarios include both the newer generation of RCPs (representative concentration pathways) being used in the most recent IPCC assessment reports (IPCC, 2013) and older Special Report of Emission Scenarios (SRES, Nakic̈enovic̈ et al., 2000) used in earlier IPCC assessment reports. By displaying results from different generations of scenarios users of climate information can compare between what they have used previously with the more recent information.

Currently, 14 different indices, as listed in Table 1, are shown in the maps for the four seasons and for annual mean conditions. The indices have been chosen as they; i) are of interest to the users as they typically have some impact and ii) that they represent features for which RCA4 performance has been evaluated against the observed climate. We note here that this does not imply that the model results are perfectly matching the observations but that we have a good picture of how large the biases may be. It is clear from the results that the inclusion of indices that take into account length of certain periods or relation to specific thresholds broadens the picture of the changing climate compared to simpler indices only taking into account direct changes in the underlying variables (e.g. average change in temperature, change in maximum daily precipitation amount).

Data are presented both as ensemble means and in terms of spread between the different RCA4 runs (Fig. 1). The spread is given as the standard deviation calculated from the nine different runs. Also maps indicating how many out of the nine ensemble members that show positive changes in an index are displayed. Taken together this information can be used to assess the main direction and amplitude of climate change as well as the spread around the central value and also give an indication of the robustness of the results.

After a few years of operation it stands clear that the climate service described here and provided through the SMHI web site is of good practical use in the Swedish work on adaptation to climate change. This has been indicated by feedback from the Swedish County administrative boards that are responsible for regional coordination of climate change adaptation in Sweden. We can also note that the web service has a high rate of access (Fig. 2) with more than 125.000 exclusive page views since its launch in October 2013. The time line of Fig. 2 shows that the web service is accessed throughout the year, albeit with a minima in the summer (vacation) period. It also indicates that the usage is larger at some points in time coinciding with certain events or promotional activities. The most prominent ones include: the launch of the web service (October 2013), launch of new RCP2.6 scenarios (November 2014), presentation of governmental assignments and publishing of a user guide for climate scenarios (December 2014), launch of a +2 °C scenario (November 2015) and the COP21 climate meeting in Paris (December 2015). In addition, our experience is that the material is most useful in contacts with journalists.

1. Introduction

As a designated national expert agency for weather, climate, hydrology, and oceanography in Sweden, SMHI has a long experience of communicating with a wide range of users. With the raising awareness of climate change and its impacts a need has emerged for "actionable" information on climate and climate change (Asrar et al., 2013). To meet these new challenges SMHI activities pertaining to climate and climate change communication has over the last decades evolved to not only *inform* society about weather and climate, and *discuss* the information *after it has been presented*, but to more actively *involve the users* of that information already in *the early stages of production and design* of the presentation material.

In particular, three milestone events have shaped the development of SMHI's climate change information activities over the last two decades: i) in 1997 the SWECLIM research programme was initiated and the Rossby Centre was formed at SMHI as central hub for building capacity for regional climate model research and development. As a result of this research programme, the Rossby Centre built a viable capacity in regional climate modelling (Rummukainen et al., 2004) thus providing the scientific foundation for the production of climate change information; ii) in 2005 the Government appointed the Swedish Commission on Climate and Vulnerability that initiated a broad cross-sectoral assessment of climate vulnerability (SOU, 2007). SMHI worked closely with the Commission and its working groups to provide extensive information and expert support and through this process built substantial experience in communicating climate change information with a broad spectrum of stakeholders; iii) in 2011 the Coordinated Regional Downscaling Experiment (CORDEX, initiated in 2009) began to gain momentum (Jones et al., 2011). To meet the increasing need for production and publication of regional climate scenarios outlined by CORDEX the Rossby Centre developed a more streamlined technical production process permitting multiple ensembles of scenarios to be produced and presented. After this brief historic overview we now introduce the different stages and their role in forming the current provision of climate services and its uptake within Sweden.

Over the years, a number of coupled model intercomparison projects (CMIPs) have produced a vast amount of global climate model (GCM) results that can be used to assess possible future cli-

Table 1
Climate indices presented at www.smhi.se derived from the RCA4 50 km ensembles.

Parameter	Climate indices	Description
Temperature	Mean, minimum and maximum temperature	Seasonal means based on daily averages calculated from 3-hourly data
Vegetation period	Length, Start day and End day	The vegetation period is defined as days in a year when the daily mean temperature exceed 5 °C. Single warm days in winter have been left out by starting the vegetation period only in the first period with at least 4 consecutive days with temperatures exceeding 5 °C
Zerocrossings	Number of days	Number of days when the temperature is both below and above 0 °C during parts of the day. Information from the model from each time step
Spring frost	Last day in spring with frost	The last day in spring when the temperature is below 0 °C during some part of the day
Precipitation	Monthly sum, maximum daily amount	Daily precipitation is accumulated over all time steps in the 24-hourperiod
Heavy precipitation	Number of days with heavy precipitation	Number of days with more than 10 mm precipitation. Can be considered heavy precipitation in a climate model context, not in single point observations
Wet period	Yearly maximum weekly precipitation	Maximum of consecutive 7-day running sum precipitation
Dry period	Longest dry period in a year	Longest period with less than 1 mm/day in any day
Wind speed	Maximum yearly gust wind speed	Strongest wind in a year, based on 30-min data from the model

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