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Dissemination of climate change scenarios – a review of existing scenario platforms

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Abstract

In the framework of the recently founded National Center for Climate Services (NCCS), the new Swiss climate change scenarios "CH2018" will be calculated that replace the existing ones from 2011. These new scenarios should be elaborated in a way that it fulfills the needs of end-users in terms of content and dissemination. A specific website to CH2018 is currently under development. This review here should give an overview of already existing scenario web-platforms focusing on the limitations and possibilities in terms of visualization, dissemination, provision of data and interactions with the user. In total, 17 scenario platforms from 14 countries have been examined.

The dissemination of national climate scenarios on the web varies a lot from one provider to the other. Some of the analyzed websites restrict the presentation of climate change information to the download of a final report (e.g. in Switzerland). The functionalities are in such cases strongly restricted and the web-design also comes in a rather basic form. Other web-platforms incorporate climate information into the website from the respective national weather service (e.g. Germany or Sweden). Some providers of national scenarios, such as in the USA, France, California or Australia, operate very comprehensive and qualitatively high-level websites that come in professional layout and with a number of different functionalities for the user.

For visualization purposes these sophisticated websites provide complex tools that allow to display a multiplicity of information (e.g. climate change signal under different emission scenarios or time periods) that can be controlled by a browser menu. Some tools allow the user to interact with the graphic via the cursor. Examples thereof are the additional appearance of numerical values or pop-up windows to display additional information (e.g. interpretation help or additional climate information). For some websites such tools are also in operation for download possibilities of data. In general, around half of the investigated websites offer a service to download data, that usually come as NetCDF- and CSV-files. The dissemination of data is controlled by user registration.

Regarding the methodological approach some differences are identified among the 17 scenario platforms. Especially the approach to statistically downscale model data is very diverse and ranges from simple approaches such as a delta change approach, to complex methods such as the application of weather generators. Almost all scenario platforms are based on the analysis of multiple climate models. However, there are differences in the respective model generation: eight platforms have so far switched to the current CMIP5 global climate models and hence to the latest RCP-emission scenarios. In addition, many platforms base their scenarios on dynamically downscaled projections.

The scope of quantitative information on climate change varies a lot among the providers of national scenarios. All platforms provide information on mean temperature and precipitation change. However, on top of that, some initiatives also provide information on sector-specific indicators (as e.g. in Sweden or Germany). Furthermore, quite a few websites also provide information on extreme changes and other atmospheric parameters like wind, relative humidity or cloud cover. The scope of background information on climate modeling in general, on climate change, and on climate impacts vary in extent and format. Most background information is given in text format with „Frequently Asked Questions“ and glossaries as a popular mean of education. But other communication channels such as videos or other visual means become more and more popular.

From the findings of the present web review, important conclusions and recommendations for CH2018 can be derived. First, it shows that a clear structure and guidance of the website is crucial. This is especially true, if the site grows in complexity and comprehensiveness. Besides a good website structure, interpretations on graphics, manuals for tools and specific case studies are indispensable. The number of online tools should be held moderate, while the resources should rather be spent on its guidance. Very important is the definition of the target group. If it is the general public, the focus should be on easy and comprehensive information. This is often accomplished through "personalized" information, with which the user can establish an emotional connection. Example thereof include the communication of climate change information by referencing to an extreme event in the past (e.g. hot summer 2003), or by referencing to a (political) area, with which the user identifies himself (e.g. a canton).

Recommendations for CH2018

The collected information on scenario platforms will be used as a basis for planning the upcoming CH2018 website. In parallel, a user survey on dissemination of climate scenarios was performed within Switzerland by Ernst Basler & Partner on behalf of MeteoSwiss (Perch-Nielsen et al. 2016). Based on the experiences gained in this review, recommendations for the development of a new website for Swiss climate changes scenarios is given in the following.

The most important point to consider before planning a website is to think about the target group(s). This selection will ultimately define the overall structure of the website, the scope of the content, the amount of graphical tools and frame other important boundary conditions. Based on the results of the previously mentioned user survey, we are convinced that a user-oriented website should not target (impact) researchers in the first place. This type of users has already established a good connection to the providers of scenario data. Academics are very well informed about the complexity of climate change and they also have very specific needs that are most easily discussed bilaterally and not on a webpage designed to meet the needs of a more general community of users. According to the user survey, the largest fraction of users is likely to come from governmental agencies, private consultancy firms, engineering offices, schools and the general public (so-called “extensive users”). In our view, this type of users has received too little attention in the previous scenario initiative in Switzerland (CH2011). Their needs, in terms of content and dissemination, should be better explored and covered. If targeted at this group, the new website would maximize its impact on the user community of climate change scenarios.

Focusing the website on extensive users has implications for the specific setup of this new website. Extensive users often are people who have already some background knowledge on climate in general. But due to their working environment with a series of projects, not related to climate, they can only spend a limited time on the topic and hence on the website, typically a few hours. This means that the website must be very well structured and must be simple to use. Ideally, a site-map or a menu bar should be visible on all pages. Targeting the site to extensive users also means that the communication should be held in the language of the users, hence in three Swiss languages. The texts should be easy understandable, even for non-academics. The basic messages of graphics and larger texts should be conveyed in condensed form (e.g. as key messages) on a top level of the web-site structure.

Guidance through the website and helping the user understand graphical and textual output is key, when targeting the non-specialists of climate scenarios. In our view, more resources should be spent on interpreting the graphics and providing manuals for tools rather than simply increasing the number of (interactive) sophisticated tools. In our view, these tools are especially attractive to the general public to learn about climate change and to extensive users that like to retrieve specific information using the tools. But to increase the popularity of a graphics or a tool, one should provide personalized references when conveying climate information. For instance, in Switzerland this could be done by designing a tool that allows the user to retrieve climate change information for political districts (cantons). This usually gives a personal reference to the user. Furthermore, it is the politically-defined areas, where adaptation strategies are planned and measures taken. But also an analogue tool, similar to the one presented by CCA-Australia seems a promising way of conveying climate change information. In any case, a reference of the projected changes to the past that people remember (be it a norm period and/or an actual year as in DWD-Germany) is a simple but effective mean of increasing the popularity of a tool or a graphic.

The ability to download data is very important. Ideally, the data provided is “application-ready”, as it is termed at CCA-Australia. This means, for example, that observations and the expected changes are already merged so that the user gets the data in absolute entities. The format should be chosen in a way, that both, researchers and end-users can make use of the data (at least CSV, NetCDF, GeoTIFF). What seems to be very important is that the user can download observational data and climate projections together from the same website. Terms of use, limitations and a correct citation need to be prominent on the download site. In order to download data, the user needs to register. Like this, it is possible to get an overview of the users and their working fields. The download of single climate models in “raw” format should not be made possible directly from the site, but a contact could be given (e.g. email-address) for such a specific request. The download section of CH2018 should not only contain climate projections and observational data, but also graphics and written material. It should be considered to provide a brochure summarized from the website content, while methodological and technical information (model selection, statistical downscaling method, etc.) is provided in a technical report written in scientific language and not being layouted.

The review here showed that an overview about climate change, its causes and implications, is a good mean especially targeted to the general public. Whether extensive users do also need this kind of information needs to be better explored. For the CH2018 website we recommend to have such a section, but to start at a rather low level that could be later expanded with additional information. As a starting point, the combined FAQ from the different websites (see Appendix) could be used and adapted to Switzerland. An open point at the moment is the extent of sector-specific climate information that should be present on such a website. This needs to be better evaluated among the partner institutions.

The ideal website comes in a very professionally-made design that also attracts new users, who have not been engaged in climate change aspects so far. This also means, that large emphasis is put on an easy accessibility of the website, when browsing through search engines. One might consider buying “www.klimawandelschweiz.ch or www.klimawandel.ch” and redirect the user to CH2018. This would guarantee that a search request such as “Klimawandel Schweiz” (in English: climate change in Switzerland) would lead straight to CH2018. The attractivity of a website is also established by keeping the site up-to-date. This could be accomplished by a news-section or a blog-section that comments on climate-related news on a national and international level. This could for instance be new key findings from research, important political decisions (e.g. on international agreements on greenhouse gas emission reductions), case studies from the application of scenario data and many others. Such a section could also inform on important updates of the website.

A first attempt of a new CH2018 website is presented in **Figure 1** considering the raised points above. The design is aligned to the one of NCA-USA. The main structure to convey climate change information is according to geographical regions. On a top level, the user has additionally the possibility to get background information, to download data, to read publications and to stay updated with a news-blog (termed "services"). A contact with email-address and phone number is present on top level as well and can be reached from any sub-pages.

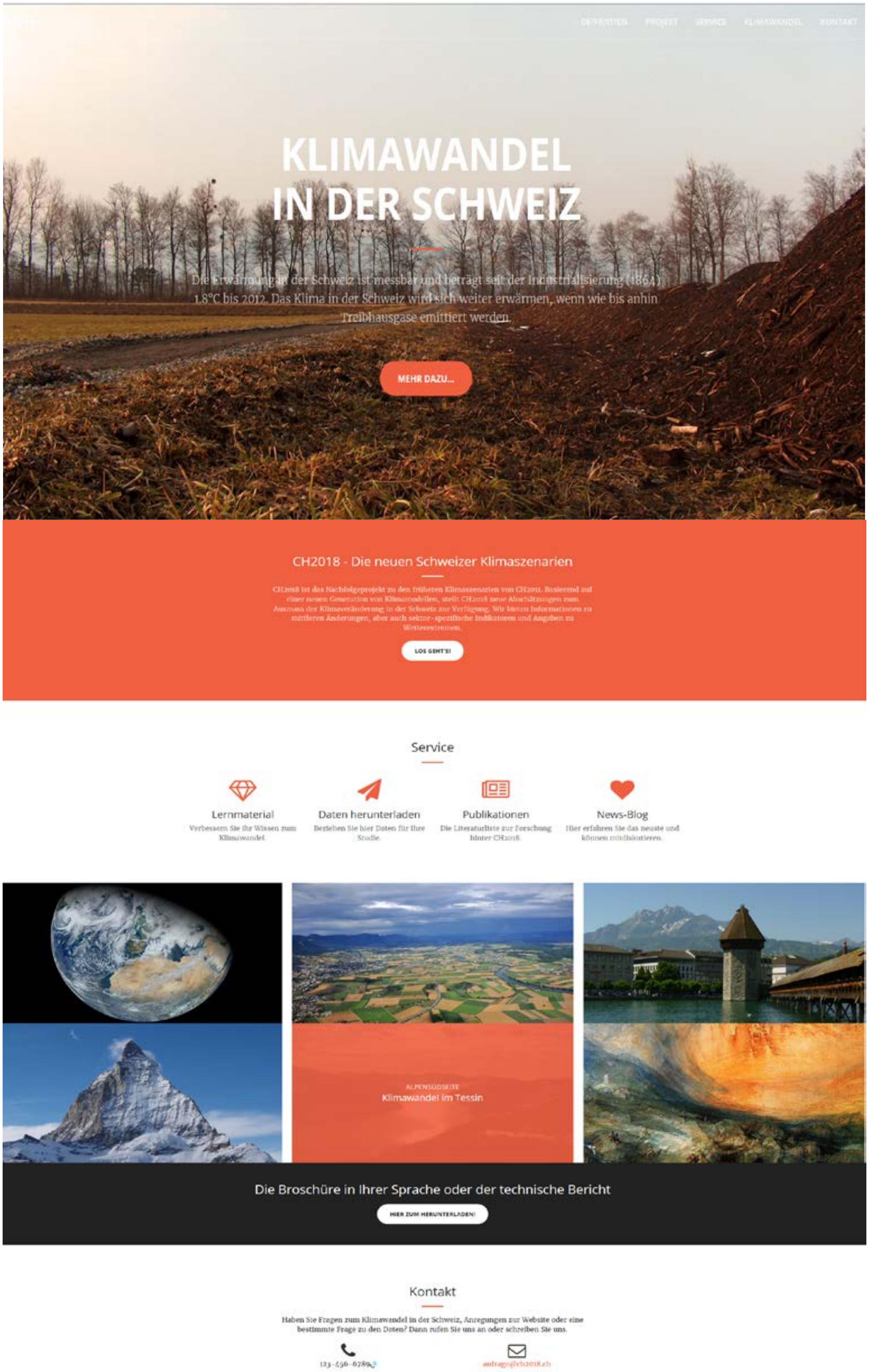


Figure 1: An illustrative example front page for the new CH2018 website. The lower part shows the different available menu points. As soon as the cursor moves over a picture, it is highlighted and additional information is displayed (here it is climate change information for the canton of Ticino).

The presented report lacks the mentioning of any (financial and personal) resources necessary to create a sophisticated website. This is a critical point at this stage. The recommendations given above must therefore be regarded as nice to have, rather than need to have. To get rough estimates for planning purposes, we contacted the developers of some of the more sophisticated scenario platforms. The answers reveal a substantial amount of resources that went into the construction of such portals. In case of France (DRIAS), and California this amounts to financial costs of more than 550'000 Swiss Francs for each of the two platforms. Several people have been working full-time over more than two years during the development phase. In both cases, external companies or institutions were involved that implemented the website. The maintenance of such websites, including the interaction with users, must not be underestimated. Still today, one person working full-time and one part-time are responsible for maintaining the site of California. In France, this amounts to a work-load of around 1 day per week. For the scenario website in Sweden, the resources are lower and the portal is less sophisticated. The website is integrated into the one of the national weather service. The development was done in-house ten years ago and since then has been continuously updated. The work-load to maintain this site is rather low.

In case of limited resources, synergies with already existing material on websites from the partners in CH2018 should be envisaged. For example, regarding background information to educate users, material from the MeteoSwiss website could be either integrated or linked. Information on climatic impacts could be directed to the portal of www.climate-change.ch (operated by Proclim). There are also a number of high-level videos posted on the website of ETH, that illustrate some aspects of climate science and modeling in a very intuitive way. In terms of the news-blog, synergies could be reached by the well-running climate blog from MeteoSwiss. Likewise, a lot of additional climate information could be provided on climate observations, when linking to the respective pages from MeteoSwiss. However, just linking to other websites brings a number of problems. First, it distracts the structure and design of the CH2018 website. Second, no responsibilities can be taken about the content. The links would also have to be regularly checked on possible errors.

Zusammenfassung

Im Rahmen des 2015 gegründeten National Center for Climate Services (NCCS) werden die neuen Schweizer Klimaszenarien „CH2018“ erstellt, welche die bisherigen Szenarien aus dem Jahr 2011 ablösen. Sowohl bezüglich Inhalt, als auch Bereitstellung sollen die Klimaszenarien möglichst Anwender-gerecht aufbereitet werden. Unter anderem ist eine spezifische Webseite zu CH2018 in Planung. Ein Überblick über bereits existierende Online-Plattformen rund um Klimaprojektionen soll dabei Aufschluss geben bezüglich Möglichkeiten und Grenzen der Visualisierung, Vermittlung, Bereitstellung von Daten und Nutzer-Interaktionen auf dem Web. Das vorliegende Review untersucht 17 Web-Plattformen aus insgesamt 14 Ländern.

Die Web-Bereitstellung von nationalen Klimaszenarien unterscheidet sich stark von Anbieter zu Anbieter. Einige der analysierten Websites beschränken sich für die Vermittlung von Informationen zur Klimaänderung auf die Download-Möglichkeit eines Abschlussberichts als PDF (z.B. in der Schweiz). Die Funktionalitäten sind somit stark eingeschränkt und auch das Design ist bei diesen Seiten eher einfach gehalten. Andere Seiten integrieren die Informationen zur Klimaänderung in die Website des jeweiligen Wetterdienstes (z.B. Deutschland oder Schweden). Einige Anbieter von Klimaszenarien, wie z.B. in den USA, Frankreich, Kalifornien oder Australien, betreiben jedoch sehr umfassende und qualitativ hoch-stehende Websites in professionellem Layout und mit unzähligen Funktionalitäten für den Nutzer.

Für die Visualisierung von Klimainformationen bieten solche Websites ausgeklügelte Tools an. Diese erlauben die Darstellung einer Vielzahl von Informationen (z.B. Klimaänderung unter verschiedenen Emissionsszenarien oder Zeit-Perioden), welche der Nutzer spezifisch für seine Zwecke durch Menu-Auswahl einschränken kann. Daneben kommen Möglichkeiten zur Interaktion mit der Grafik zum Einsatz, ausgelöst durch den Cursor. Beispiele davon sind das zusätzliche Einblenden von numerischen Werten oder Pop-Up-Fenster zur Darstellung von Zusatzinformationen (z.B. Interpretationshilfen, zusätzliche Klimainformationen). Bei einigen Websites kommen fortgeschrittene Tools auch für den Download von Daten zum Einsatz. Generell bieten etwa die Hälfte der untersuchten Websites Daten zum Download an, normalerweise als NetCDF- und CSV-Datei. Die Bereitstellung der Daten geschieht normalerweise über eine vorgängige Nutzer-Registrierung.

Bezüglich den methodischen Ansätzen sind einige Unterschiede unter den 17 Websites feststellbar. Besonders die Art des statistischen Downscalings ist sehr divers und reicht von einfachen Ansätzen wie Delta Change zu komplexen Methoden wie Wettergeneratoren. Praktisch alle Szenario-Plattformen basieren auf der Analyse von mehreren Klimamodellen. Hingegen gibt es Unterschiede in der analysierten Modellgeneration. Acht Plattformen haben bis jetzt auf die aktuellen CMIP5 Global-Modelle und somit den neuesten RCP-Emissionsszenarien umgestellt. Viele der Plattformen

basieren ihre Szenarien zudem auf Projektionen mittels dynamisch runterskalierten Regional-Modellen.

Der Umfang an quantitativen Informationen zur Klimaänderung ist stark unterschiedlich. Alle Plattformen bieten Informationen zu Mitteländerungen in Temperatur und Niederschlag an. Darüber hinaus stellen viele der Anbieter von Klimaszenarien auch Informationen zu Sektor-spezifischen Indikatoren zur Verfügung (z.B. in Schweden oder Deutschland). Auch quantitative Änderungen zu Extremen und weiteren atmosphärischen Parametern wie Wind, relative Feuchtigkeit oder Wolkenbedeckung werden von einigen Websites angeboten. Auch das Angebot an Hintergrundinformationen zur Funktion von Klimamodellen, zum Klimawandel und dessen Folgen sind im Umfang und in der Art der Vermittlung stark unterschiedlich. Ausser Informationen in Fliesstexten kommen vor allem „Frequently Asked Questions“ und Begriffsverzeichnisse als Mittel zum Einsatz. Immer häufiger werden aber auch weitere Kommunikationskanäle wie Videos oder andere visuelle Kommunikationsmittel eingesetzt.

Aus den Erkenntnissen des vorliegenden Web-Reviews lassen sich wichtige Schlussfolgerungen und Empfehlungen für CH2018 ableiten. Das Review zeigt, dass eine übersichtliche Struktur und Führung der Website zentral ist, um den Überblick nicht zu verlieren. Dies umso mehr, je komplexer und umfangreicher die Website gestaltet ist. Nebst eine guten Struktur der Website sind aber auch Interpretationshilfen zu Grafiken, Bedienhilfen für angebotene Tools sowie konkrete Fallbeispiele unverzichtbar. Die Anzahl an Online Tools sollten moderat gehalten werden. Dafür sollte vielmehr das Augenmerk auf Hilfestellung und Interpretation gelegt werden. Sehr wichtig ist die Definition des Zielpublikums. Liegt es in der breiten Öffentlichkeit, sollte der Fokus auf der allgemein-verständlichen Vermittlung liegen. Dies wird oft über „personalisierte“ Informationen erreicht, mit derer der Nutzer einen emotionalen Bezug herstellen kann. Beispiel hiervon sind die Vermittlung von Klimaänderung bezugnehmend auf ein Extrem-Ereignis (z.B. Hitzesommer 2003) oder bezugnehmend auf ein (politisches) Gebiet, mit dem sich der Nutzer identifiziert (z.B. Kantone).

Contents

1 Introduction

Earth's climate is changing and the consequences of global warming are expected to have a big impact on many sectors in Switzerland. To effectively design national adaptation strategies, local and reliable climate change scenarios are indispensable. In Switzerland, climate change scenarios are updated every few years in a coordinated effort among federal offices and academia. The climate scenarios released in 2007 ("CH2007") were based on reginal climate model (RCM) projections from the PRUDENCE project. They informed stakeholders and decision makers on climatic changes north and south of the Alps. The scenarios were documented as one chapter of a larger report that provided literature-based information about possible climatic impacts in Switzerland (OcCC and ProClim 2007). In 2011, updated climate change scenarios were released based on climate model simulations over Europe from the ENSEMBLES project. The "CH2011"-scenarios were documented in one report that covered methodological aspects to calculate the scenarios, the outcome of expected climate change over Switzerland, a comparison to precedent climate scenarios and background information. In addition, climate scenario users could download digital scenario data to run their impact models.

In the past few years, new model simulations with higher resolution than in ENSEMBLES became available (from CORDEX, www.cordex.eu). Furthermore, improved statistical downscaling methods have been developed and the physical understanding of climate change is rapidly improving. For these reasons, a new release of updated climate change information for Switzerland is necessary to provide up-to-date information to climate impact modelers and other end-users. Preparations are underway to publish new climate change scenarios for Switzerland in 2018 ("CH2018"). CH2018 runs as a focus area of the recently launched NCCS. One of the aims of NCCS is to bridge the gap between the providers and the users of climate projections. A market research has therefore been carried out to better understand the users' needs. One big aim of CH2018 is to disseminate the scenarios in a way that they easily reach the user community. The outreach through a website is considered as a powerful mean to tackle this challenge. Although the precedent project of CH2011 also included a website (www.ch2011.ch), the design and functionality was rather rudimentary. The website was static, allowing the user to download the PDFs of the print material and the digital data. No graphics or tools were presented as web-material. In CH2018, it is the plan to largely improve the website in terms of content and functionality.

On an international level, climate services and the provision of national climate scenarios are becoming an important issue. Several countries have recently established sophisticated websites as part of their climate service. Information on past, current and future climate largely differs, though, in extent and in presentation format among the different websites. This report supports the creation of a web-platform for CH2018 by providing an overview on many existing climate scenario platforms.

2 Scope of review

Usually, climate services are provided by national meteorological services and environmental agencies. To produce climate simulations and provide climate products of high quality requires substantial financial and scientific competences. Because of that, climate services are mainly provided by nations with a high Gross National Income. **Figure 2** shows the countries whose climate services have been evaluated. In In total, 17 websites from 14 countries have been examined.

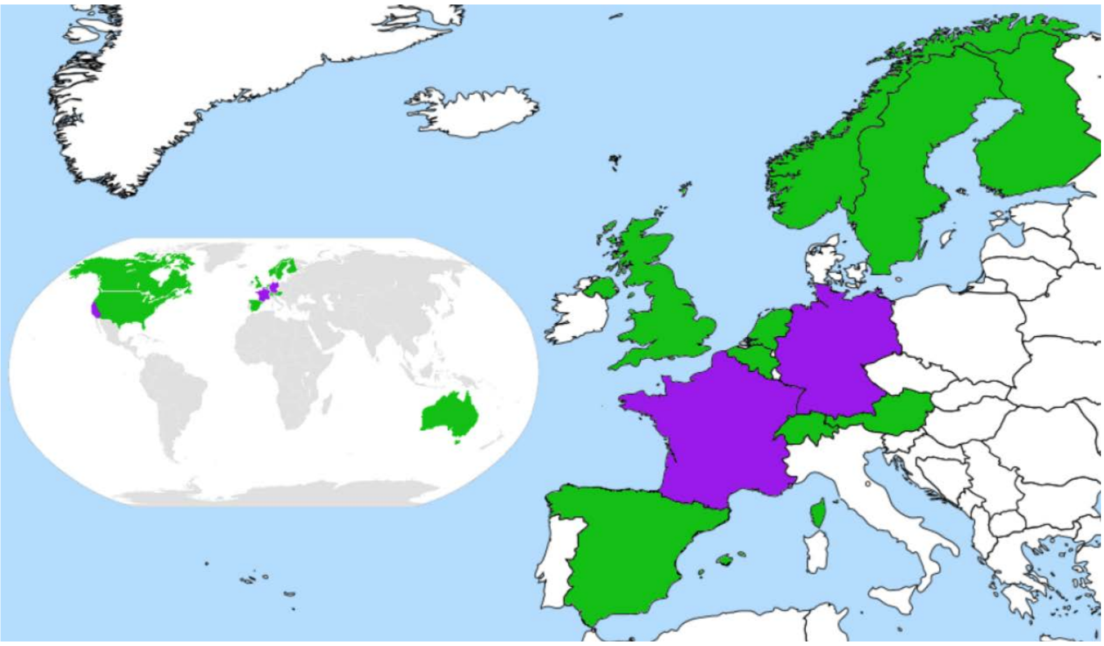


Figure 2: Map with marked countries, for which climate scenario platforms and initiatives were examined in this review. In total, 17 platforms from 14 countries have been examined. Countries with one platform are shown in green. Purple color indicates a country or region for which two platforms were evaluated (source: www.pixabay.com, www.weltkarte.com).

2.1 Investigated climate scenario platforms

In the following, we briefly introduce all 17 investigated scenario platforms with key characteristics and some background information:

US- National Climate Assessment (NCA-USA)

http://nca2014.globalchange.gov

- Launched in 2014 by several national agencies (i.e. National Oceanic and Atmospheric Association, Environmental Protection Agency and Department of Health and Human Services)
- Extensive website with a lot of sector-specific information on climate impacts
- A comprehensive report (Melillo et al. 2014) can be downloaded here

Climate Change Australia (CCA-Australia)

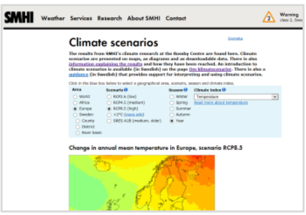
www.climatechangeinaustralia.gov.au/en/

- Launched in 2015 by the Australian Department of the Environment and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology
- Many different tools, graphics and data-download possibilities
- The technical report (CSIRO and Bureau of Meteorology 2015) is available here
- Regional summaries of the results are presented as “cluster reports”

UK Climate Projections (UKCP-UK)

http://ukclimateprojections.metoffice.gov.uk/

- Launched in 2009 and ever since regularly updated
- Produced by the Met Office, Environment Agency, Newcastle University and many more institutions
- Extensive download possibilities
- A comprehensive report on past changes and future projections (Murphy et al. 2009) can be downloaded here



SMHI Climate scenarios (SCS-Sweden)

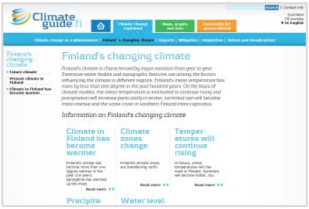
www.smhi.se/en/climate/climate-scenarios

- Launched in 2014 by the Swedish Meteorological and Hydrological Institute (SMHI)
- Website focuses on displaying climate model projections and data provision

Environment Norway (EN-Norway)

www.environment.no

- Relaunched in late 2015 by the Norwegian Environment Agency and several other national agencies
- Includes a lot of information beyond climate, but related to environment
- Based on a recently published report (Hanssen-Bauer et al. 2015) that is available in Norwegian only. For the current study, only the web-site content in terms of graphical display has been analyzed; the content of the projections has not been evaluated



Climate guide Finland (CGF-Finland)

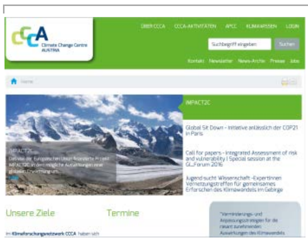
www.ilmasto-opas.fi/en

- Launched in 2009 and regularly updated by the Finnish Meteorological Institute, the Finnish Environment Institute and other institutions
- Detailed information on causes of the climate change, as well as its impacts on different sectors, together with a number of sophisticated web-tools

Canadian Climate Data and Scenarios (CCDS-Canada)

www.ccds-dscc.ec.gc.ca/

- Launched in 2002 and regularly updated by Environment Canada
- Presentation and data download from projections and observations
- The National Report on Climate Change (Canada and Environment Canada 2014) is the basis of CCDS-Canada



Climate Change Center Austria (CCCA-Austria)

www.ccca.ac.at

- Launched in 2014 by many different institutions (e.g. Climate Change Center Austria, TU Wien, University of Graz and others)
- CCCA-Austria, so far, consists of a report provided on a website. The website itself does currently not provide any visualizations
- Very comprehensive report (APCC 2014) in IPCC-style; based on a literature review. For the report here, it is not evaluated in terms of content.

DWD Deutscher Klimaatlas (DWD-Germany)

www.dwd.de/DE/klimaumwelt/klimaumwelt_node.html

- Launched in 2010 by the Deutscher Wetterdienst, continuous updates of the platform
- Emphasis on climate change and climate modelling, as well as downloads of observation data

DRIAS Meteofrance (DRIAS-France)

www.drias-climat.fr/

- Launched in 2014 by Meteofrance and ministère de l'Ecologie, du Développement durable et de l'Energie
- Website covers an overview of the causes for climate change, as well as the impacts on different sectors and the possibility to download CORDEX-data
- A report (Ouzeau et al. 2014) on the DRIAS projections is available here

Pictures of the future (KNMI-Netherlands)

www.climatescenarios.nl/

- Launched in 2014 by the Royal Netherlands Meteorological Institute and the Ministry of Infrastructure and the Environment
- KNMI-Netherlands comes as a glossy brochure (KNMI 2015) and a technical report (KNMI 2014)
- Climate data can be downloaded from a different website

Swiss Climate Change Scenarios CH2011 (CH2011-Switzerland)

www.ch2011.ch/

- Launched in 2011 by MeteoSwiss, ETH, the Center for Climate Systems Modelling, NCCR Climate and Organe consultatif sur les changements climatiques
- Consist mainly of a report (CH2011 2011), summaries in different languages and data-download possibilities
- Updates of the scenario products are presented as extension articles

Climate projections for the XXI century en España (CPE-Spain)

www.aemet.es/en/serviciosclimaticos/cambio_climat

- Launched in 2009 by the State Meteorological Agency, Fundacion Investigacion del Clima, Universities of Castilla and Rovira I Virgili
- Online tools are available, as well as possibility to download data
- A technical report (Brunet et al. 2009) can be downloaded here
- Website and report are in Spanish

Impact 2°C (I2C-Germany)

www.atlas.impact2c.eu/

- Launched in late 2015 by the European Union
- IMPACT 2C° was a EU FP7 project from 2011-2015
- Focus on climate impacts to a 2°C warmer climate in Europe

Climat^{HD} (FCHD-France)

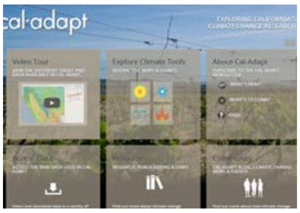
http://www.meteofrance.fr/climat-passe-et-futur/climathd

- Launched in 2015 by Meteofrance
- Offers many interactive tools to present observations and projected climate data
- A technical report (Ouzeau et al. 2014) is also part of Climate^{HD}

State of the Environment Report (MIRA-Belgium)

http://www.milieurapport.be

- Launched in 2015 by the Flanders Environment Agency
- The service is mainly a report (Brouwers et al. 2015), provided on a website



Cal-adapt California (CAL-USA)

http://cal-adapt.org/

- Launched in 2015 by the Cal. Energy Comission, Cal. Natural Resources Ageny, Santa Clara University, UC Berkeley and many more
- Website offers interactive tools to present observations and projected climate data and the possibility to download data
- A report (Cayan et al. 2009) is available here

2.2 Analyzed topics

The 17 analyzed web-platforms differ a lot from each other in terms of presentation and content. Some of them are static and provide only a report or data for download, although the amount of information is high. Other websites provide basic tools with only little supplementary information, while others are in between these cases: they contain tools to display climate data, complemented with additional text to understand the graphics. Also, many websites provide some kind of a technical report on how the data were generated.

The climate scenario platforms serve a variety of user types from expert users, usually from academia, to users in the private sector or the general public. Each type of user has his own specific needs and level of understanding. An expert user might be more interested in questions where to download data and what the data format is. Someone from an engineering office typically has only a few hours' time to analyze the projection data and/or to gather the required information. The success of this analysis might strongly depend on whether some guidance and a quick overview are presented. Hence, the key requirements of a comprehensible website are that data and information is easily accessible, in a commonly applied format and the necessary guidance is granted.

In this review, we cover a wide spectrum of aspects that needs to be considered when building up a new web-platform on climate change. This comprises the content of scenarios of the website (**Chapter 3**), what graphical tools are in use (**Chapter 4**), download possibilities (**Chapter 5**), whether and how guidance is offered (**Chapter 6**), educational aspects (**Chapter 7**) and how the communication with web-users is established (**Chapter 8**).

Each chapter discusses the different approaches implemented in the reviewed web-platforms. These approaches can widely differ among the websites and not all of the 17 websites cover all six categories. Chapters 3 to 8 should therefore not be considered as representative across the 17 websites, but rather discuss the various possibilities in the sense of a toolbox that serves as basis for the development of a new webpage for CH2018. **Chapter 9** is a synthesis of the previous chapters and tries to rate the different climate platforms.

3 Scope of climate scenarios

This section evaluates the content and scope of the provided climate projections on the respective websites and/or in the reports. This encompasses the selection of emission scenarios, climate models and downscaling methods (**Chapter 3.1** and **Chapter 3.2**) and the approach of the KNMI to disseminate climate scenarios (**Chapter 3.3**). In **Chapter 3.4** the extent of treated variables and/or indices is presented, while **Chapter 3.5** discusses the chosen reference and scenario periods.

3.1 Emission scenarios

Not all websites use the same emission scenarios. Some climate services still use the old emission scenarios from the Intergovernmental Panel on Climate Change (IPCC) described in a special report on emission scenarios (“SRES”, Nakicenovic and Swart 2000), while almost half of the analyzed websites cover the more recently published representative concentration pathways (“RCP”, IPCC 2014). In case of CCA-Australia and CCDS-Canada, the user can select either of the two emission scenario types. In each case, this depends on the launch date of the respective website or when the most recent update was made. Almost all websites provide climate information for more than one emission scenario evolution (see **Table 1**). An exception is DWD-Germany with 1 scenario, related to the fact that they provide their projections based on ENSEMBLES data that are only available for one emission scenario.

Table 1 – Emission scenarios used by the different climate scenario platforms. Instead of the B1 scenario and CPE-Spain used the B2 scenario, while CAL-USA used the A1 instead of the A1B emission scenario. X* indicates that projections for this RCPs are planned, but not yet available. KNMI-Netherlands and I2C used another approach.

		NCA	CCA	UKCP	SCS	CGF	CCDS	CCCA	DWD	DRIAS	KNMI	CH2011	CPE	I2C	FCHD	MIRA	CAL
SRES	B1	X	X	X		X	X	X					B2				X
	A1B		X	X	X	X	X	X	X			X		X			A1
	A2	X	X	X		X	X	X				X	X				
RCP	2.6	X	X		X		X			X		X	X		X	X	
	4.5	X	X		X		X		X*	X			X		X	X	
	6.0		X						X*								
	8.5	X	X		X		X		X*	X			X		X	X	

Most websites display three emission scenarios, ranging from a low to a high emission scenario. For the RCP scenarios, RCP2.6, RCP4.5 and RCP8.5 are the most frequent chosen pathways. While there is a considerable number of global circulation model (GCM) simulations available for RCP6.0 within CMIP5, the most recent regional multi-model ensemble project CORDEX does not provide any simulations based on RCP6.0 (e.g. Taylor et al. 2012, Zubler et al. 2015).

Because of the special design of I2C-Germany, studying the effects of a common global temperature increase of 2°C, this approach is largely independent of the emission scenario. For doing this, I2C-Germany used simulations under the A1B scenario and selected the 30-year period, when global temperature reached a warming of 2°C above the reference period (1971-2000). Similarly, also KNMI follow a conceptually different approach and do not disseminate climate change information according to different emission scenarios (see **Chapter 3.3**).

3.2 Local-to-regional projections

For the provision of local-to-regional projections, most scenario platforms use a dynamical downscaling step to bridge the scale discrepancy from coarse GCM grid boxes (see **Table 2**). Those that omit this step are mainly countries with a rather large areal extension (i.e. USA, Australia and Canada). Several scenario platforms have recently switched to the latest generation of climate model runs that have been produced in internationally coordinated frameworks (i.e. CMIP5 for global models and CORDEX for regional models). Five scenario platforms rely on the older multi-model ensemble ENSEMBLES. UKCP-UK follow a different approach: they use a perturbed physics ensemble with 17 versions of their regional climate model HadCM3 in order to get a range of possible climate projections. Interestingly, while CCDS-Canada provide the latest climate projections from CMIP5, the user can also get information on projections according to older CMIP-runs that were used for compiling older assessment reports of IPCC (back to the second assessment report in 1995).

Table 2 – Climate model database that was used by the climate scenario platforms to calculate local-to-regional projections.

	Global Model(s)	Dynamical downscaling	Statistical downscaling / Bias Correction
NCA	CMIP3 / CMIP5		Piecewise quantile regression
CCA	CMIP5	CSIRO's Conformal-Cubic Atmospheric Model	Delta Change
UKCP	HadCM3	HadRM3	Weather generator
SCS	CMIP5	RCA	
CGF	CMIP3		
CCDS	CMIP5 and older CMIP projections		(a) Perfect prognoses with SDSM-software (b) LARS Weather Generator
CCCA	ENSEMBLES	ENSEMBLES	
DWD	ENSEMBLES	ENSEMBLES	
DRIAS	CNRM and IPSL	Aladin and WRF	
KNMI	EC-Earth with uncertainty assessment from CMIP5	RACMO2	Delta change
CH2011	ENSEMBLES	ENSEMBLES	Delta change
CPE	CMIP5	ENSEMBLES	(a) analog-based methods (b) Perfect prognoses with SDSM-software
I2C	ENSEMBLES	ENSEMBLES	
FCHD	CNRM and IPSL	Aladin and WRF	
MIRA	CMIP5	CORDEX + high resolution RCMs	
CAL	PCM1, CCSM3, GFDL, CNRM		(a) bias correction with spatial disaggregation (b) analogue method

Almost all scenario platforms rely on multi-model ensembles for providing uncertainties in climate projections. The French platforms (DRIAS and FCHD), however, show mostly simulations performed with only two models (their own models CNRM-Aladin and IPSL-WRF). Also KNMI-Netherlands rely on just one model chain (EC-EARTH-RACMO2). However, the approach is different: they include the whole uncertainty spread spanned by CMIP5 and different emission scenarios to obtain four plausible storylines (see **Chapter 3.3**), which are then investigated in detail.

What kind of statistical downscaling do the analyzed scenario platforms use to disseminate local-to-regional climate data? On the whole, the approaches are conceptually very diverse and not all of the analyzed platforms provide downscaled data and/or do not provide the information how these were obtained (see **Table 2**). CCA-Australia, KNMI-Netherlands and CH2011-Switzerland use a bias correction in its simplest form. This is a delta-change approach that combines observational data with the change factors derived from climate model output. To disseminate gridded data at a resolution of 5km, CCA-Australia use the spatially interpolated change factors from the CMIP5 suite to combine it with their high-resolution dataset from the Australian Water Availability Project. CH2011-Switzerland apply a spectral representation of the mean annual cycle to derive change factors for each day of the year (Bosshard et al. 2011). KNMI-Netherlands transformed observed time-series in a way that the transformed series match a chosen climate scenario for a selected time horizon (Bakker and Bessembinder 2012).

NCA-USA use a quantile regression approach for downscaling termed "asynchronous regional regression model". This is essentially a bias-correction method that is capable of resolving daily extremes (Stoner et al. 2012). Besides local data for a station network, they also produced high-resolution grids at one-eighth degree resolution (Hayhoe et al. 2013). Disseminated variables provided through this procedure are daily maximum/minimum temperature and daily precipitation.

The statistical downscaling procedure for CAL-USA is documented in Maurer and Hilgado (2008). It first incorporates a bias-correction step at the model grid level by comparison to gridded observations. The downscaling step (i.e. bridging from coarse resolution to a point scale) is accomplished with an analogue approach, thereby sampling from the observed weather record at the station scale based on coarser-resolved predictors. Disseminated variables beyond temperature and precipitation are soil moisture, evapotranspiration, net surface radiation, wind, runoff, and snow water equivalent. The dissemination of these rather specific variables comes with no further reasoning for which kind of users these data are offered.

UKCP-UK provide downscaled data through weather generators. The weather generator is of type Neyman-Scott Rectangular Process Model (Kilsby et al. 2007 in Jones et al. 2009) with which they are able to produce and disseminate gridded data at 5km horizontal resolution. The data comprise temperature, rainfall, humidity and sunshine duration. Results are presented and discussed in a special report and are made available for download (raw data – CSV). The generated series are internally consistent between weather variables. However, the weather generator does not give spatial consistency across grid squares. It also assumes that the observed relationships between weather variables will remain the same in the future (Jones et al. 2009).

In case of CPE-Spain, downscaled data (of minimum and maximum temperature and precipitation) according to two different statistical downscaling methods are provided. One of the approaches is an analogue method similarly as in case of CAL-USA; the other one is based on the freely available Statistical DownScaling Model-software (SDSM) (Wilby et al. 2002). SDSM (available from www.sdsm.org.uk) is a hybrid of a stochastic weather generator and a set of multiple linear regressions between local-scale predictands (e.g. daily precipitation, minimum temperature) and large-scale (circulation-related) predictors. The latter is also followed by CCDS-Canada. However, instead of providing the downscaled data as a product for the users, they simply link to the necessary downscaling tools. So, the downscaling itself is left to the user. For the application of SDSM they provide various predictor fields of atmospheric circulation for download. In addition, they also suggest to use the commonly applied LARS-weather generator (Semenov and Barrow 1997). This is a weather generator that is calibrated through specifying the frequency of dry and wet spell-lengths at the local scale.

3.3 Storyline-Approach

A special case in disseminating national climate change scenarios is provided by KNMI-Netherlands (KNMI 2015). Instead of informing users about climate change according to several emission scenarios with corresponding uncertainties from multiple climate model projections, they select specific scenarios from this two-dimensional uncertainty space. **Figure** shows the four plausible scenarios with relevance to the Netherlands. They are pre-defined and reflect two different levels of global temperature rise (moderate "G" and warm "W") and two levels of change in the air circulation pattern over the region (low value "L" and high value "H"). For each of these scenarios a particular climate model run has to be selected. The selection is done by expert judgement and comparison with other CMIP5-simulations. For each storyline, an EC-EARTH simulation has been further downscaled to roughly 10km x 10km by the KNMI's own regional climate model RACMO2. A detailed description of the method can be found in their scientific report (KNMI 2014). These higher-resolution runs provide the main data basis to tell "stories of a future climate" over the region (e.g. changes in extremes, multi-variate changes, etc.) (Hazeleger et al. 2015). According to the authors, the big advantage of this approach is that the physical consistency in time, space and between variables is conserved, as each case is based on the same climate model simulation. An obvious disadvantage is that no uncertainties can be attached to the storylines and analyzed parameters.

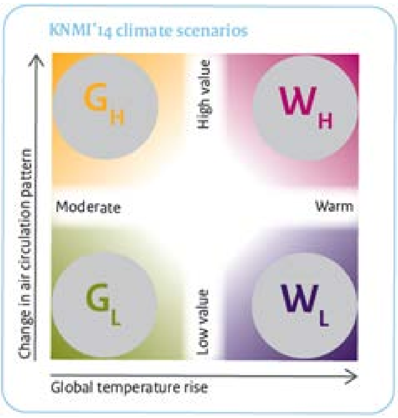


Figure 3: Climate scenarios generated by KNMI-Netherlands.
Their report is based on four different characteristic climate situations over central Europe, with low to high changes in air circulation pattern and moderate to warm global temperature rise (source: KNMI 2015, p. 7).

3.4 Variables and indices

The scope of the information on a changing climate varies widely across the analyzed scenario platforms. This is the case in terms of covered atmospheric variables, but also in terms of provided indices derived from the variables. While for instance all analyzed scenario platforms disseminate information on changes in temperature and precipitation, only a few provide quantitative changes in wind speed.

In the following, more information on the different indices, sorted by variable, is given.

3.4.1 Temperature

Besides changes in the mean, most of the analyzed scenario platforms provide temperature changes in form of absolute and percentile threshold exceedances. These indices are either derived from daily minimum (*TN*), mean (*TG*) or maximum (*TX*) temperature:

Table 3 - Indices for minimum (TN), mean (TG) and maximum (TX) temperature, either defined based on percentiles, absolute thresholds or as return periods. Percentile-based indices are presented in the format "*XX[90]p"* with XX being either TN, TG or TX and the corresponding percentile (in this case 90th percentile). *WSDI (CSDI):* Warm (Cold) spell duration index (a period of at least six consecutive days with TX (TN) above (below) the local 90th percentile of the reference period), The abbreviations for absolute threshold indices are: *SU:* Summer days (TX>25°C), *TR:* Tropical nights (*TR*: TN>20°C), *FD:* Frost days (TN<0°C), *ID:* Ice days (*ID*: TX<0°C). *nZeroCross:* Number of 0°C crossings (frost-thaw days with TX above 0ºC and TN below 0°C). The indices that involve extreme value analysis are the return values of maximum or minimum temperatures occurring once in 20 years. .

	percentile-based threshold indices	absolute threshold indices	extreme value analysis
NCA		●Frost-free season	●1-20yTX ●1-20yTN
CCA	●TX99p ●TN1p		●1-20yTX ●1-20yTN
UKCP	●TX99p ●TX1p ●TN99p ●TN1p		
SCS		●nZeroCross ●Last spring frost date	
DWD		●FD ●TR ●heat day	
DRIAS	●TN90p ●TX90p ●TN10p ●TX10p ●WSDI	●SU ●TR ●FD ●ID	
KNMI	●TG5p ●TX95p ●TX99p ●TN1p	●SU ●TR ●FD ●ID	
CH2011	●WSDI ●TN10p		
I2C	●WSDI ●CSDI	●TR	
FCHD	●WSDI	●SU ●FD	
MIRA		●TG>25°C ●ID	
CAL	●TX98p		

Eight of the analyzed scenario platforms inform on changes in percentile-based indices. These are generally moderate extremes such as the exceedance of the 90th or 95th percentiles in today's climate. With the exceedance above the 98th percentile, CAL-USA provide further information on temperature extremes, as UKCP do with the 99th percentile. Four platforms also provide information on heat and cold waves with the warm and cold spell duration index.

Half of the scenario platforms additionally provide information on absolute threshold exceedances, as they can be designed sector-specific and targeted to specific impact systems. Commonly shown are changes in the number of summer days (SU), tropical nights (TR), frost days (FD), or ice days (ID).

Also, two platforms inform on changes in the return value of extreme temperatures that nowadays occurs once in 20 years. This information is based on the implementation of extreme value statistics applied to current and future temperature time-series (Walsh et al. 2014, p. 39; CSIRO and Bureau of Meteorology 2015, p. 118).

3.4.2 Precipitation

As for temperature, many platforms provide projected changes of daily precipitation with some common indicators (**Table 4**):

Table 4 – Indices for precipitation either defined based on percentiles, absolute thresholds or as return periods. Percentile-based indices are presented in the format "*R[90]p"* with R being daily precipitation and the corresponding percentile (in this case 90th percentile). .Enlisted as absolute threshold indices are: *time in drought:* based on standardized precipitation index (Mackee et al. 1993 in CSIRO and Bureau of Meteorology 2015, p. 122), *CDD:* Maximum number of consecutive dry days, *dry spell>10d:* dry spell that lasts longer than 10 days, *R10mm:* Heavy precipitation days (precipitation > 10 mm) (days), *SDII:* Simple daily intensity index (mm/wet day), *RX5day:* Highest 5-day precipitation amount (mm), *hRd10y:* highest precipitation deficit exceeded once in 10 years and the exceedances of daily sums (e.g. *R20mm:* precipitation > 20 mm). The indices that involves extreme value analysis are the return values that occur only once in a few years (e.g. 1-20yR occurs once in 20 years).

	percentile-based threshold indices	absolute threshold indices	extreme value analysis
NCA	•R99p		•1-20yR
CCA		• time in drought	•1-20yR
UKCP	•R99p	•dry spell>10d	
DRIAS		•R20mm •RR1 •CDD •SDII	
KNMI	•R90p •R99p	•R20mm •RR1 •hRd10y	•1-10yR
CH2011		•CDD •RX5day	
FCHD	•R90p	• CDD	
MIRA		•R10mm	•1 in 1/2/5/10/20/30yR

Four websites provide data that are based on percentile-defined threshold indices, such as days with rain higher than 99th percentile of daily precipitation (*R99p*).. More than two thirds of the websites show fixed-threshold climate indices. Usually those thresholds are daily precipitation sums like R20mm and consecutive days with no rain or days with rain>1mm. Drought indices also belong to this category and are important, especially for agriculture. Commonly provided is the number of consecutive dry days (CDD). Quite a number of platforms also provide quantitative information on extreme precipitation.

3.4.3 Further variables

Many scenario platforms disseminate further information beyond temperature and precipitation. These comprises especially information on mean and extreme wind speed by many platforms (see **Table 5**). Common is also the provision of information on relative humidity changes, while only two inform on changes in solar radiation. Many Scandinavian and Alpine countries consider snow as additional variable, focusing on the maximum daily accumulated amount and the snow duration.

Table 5 – Further variables, listed as variables for wind (FX, FG), relative humidity (*RH*), solar radiation (*SR*), snow and other variables. Abbreviations: *FG:* Daily averaged wind, *FXx:* Maximum value of daily maximum wind gust*, 1-20yFX:* 1-in-20-year wind speed, *CC:* Cloud cover, *SDx:* maximum daily accumulated amount of snow (in kg/m²), *SD1:* snow duration (Average number of days per year with at least 50 % of the ground covered in snow), *T2m dayVegStart5:* Start vegetation period (days of the year where the TG is greater than 5°C. The vegetation period starts on the first day of the first period with at least 4 consecutive days above 5°C), *T2m dayVegEnd5:* End vegetation period (the vegetation period ends on the last day of the last period with at least 4 consecutive days above 5°C.), *T2m dayVegPeriod2:* Duration vegetation period (number of days between start and end of vegetation period), *PET:* Potential evapotranspiration.

	Variables			
NCA	•Hurricanes			•Sea level •Melting ice •Ocean Acidification
CCA	•FG	•RH •SR		•Sea level •Ocean Acidification •Sea surface temperature
UKCP	•1-20yFX	•RH		•CC
SCS	•FXx			•T2m dayVegStart5 •T2m dayVegEnd5 •T2m dayVegPeriod2
EN			•SDx •SD1	
CGF			•SDx	•PET •Runoff •Soil moisture
CCDS				
DWD				•T2m dayVegPeriod2 •Soil temperature •Soil moisture •Forest fire index
DRIAS				
KNMI	•FG •1-20yFX	•RH •SR		•Evaporation •Fog •Sea level •Hail
CH2011				
CPE	•FG	•RH		•CC •Evaporation
I2C			•SD1	•PET
FCHD				
MIRA	•FG •FX99p			•PET
CAL	•FG •FX90p		•SD x	•Sea level •forest free index

The scope of specific additional variables obviously depends on the specific country and its geographic location. Provided variables that could be potentially also relevant for Switzerland are: potential evapotranspiration (PET) and/or evaporation, maps with cloud cover (shown on four websites), vegetation-relevant indices like the start, end and length of the vegetation period, soil moisture, fog, hail and forest fire.

3.5 Reference and scenario periods

Different reference periods have been selected among the various scenario initiatives. Most often an official period proposed by the World Meteorological Organization (WMO) has been chosen. As **Figure 4** shows, five websites still use the 1961-1990 period, whereas two have changed to the more recent period 1981-2010. Five websites use a reference period in-between (1971-2000). As in IPCC, CCA-Australia, CCDS-Canada and MIRA-Belgium only used a 20-year time from 1986-2005. Probably due to constraints from observations at the time of producing the scenarios, slight differences of one or two years exist. So far, only EN-Norway offer the possibility to interactively choose between two reference periods (1961-1990 and 1971-2000) on the website.

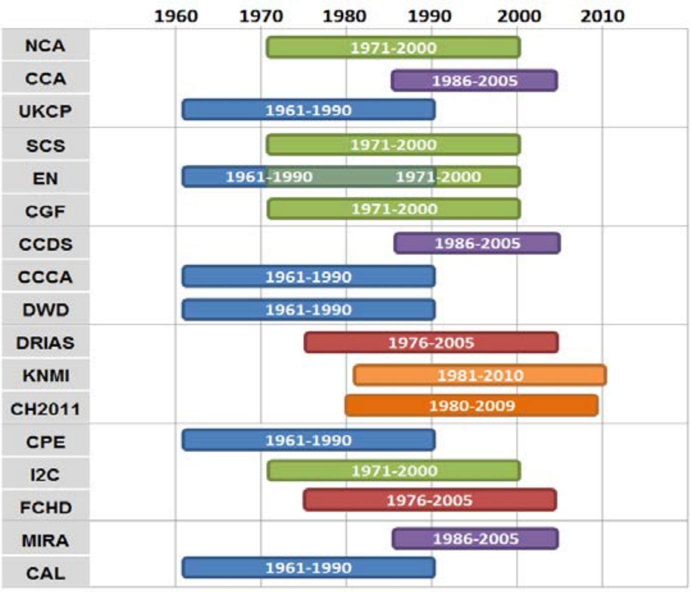


Figure 4: Used reference periods by the different climate services.

How far back are observed data shown? Most scenario platforms provide information on observed changes prior to the chosen reference period (e.g. as time-series plots) and cover the same variables and indicators, as they do for the projections. **Figure 5** shows the start time of observations.

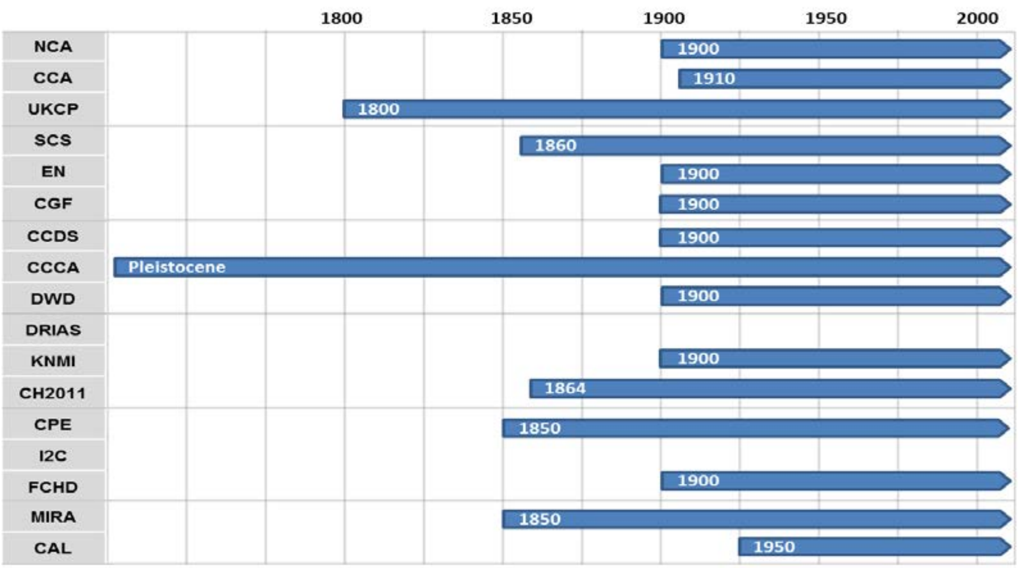


Figure 5: Start time of the observations of the presented data. DRIAS-France and I2C-Germany do not present observational data.

90% of the scenario platforms start within the instrumental measurement period, most of them between 1850 and 1910. CCCA-Austria is an exception as it is mainly a literature review providing proxy-based climate reconstructions back to the Pleistocene and Holocene. CAL-USA data, on the other hand, only reach back to 1950.

As with the reference period, the time intervals to compute and present climatic changes in the 21st century are not uniform among the analyzed scenario platforms. Yet, most of them present projections for three future time-periods covering the century (see **Figure 6**). Most of them used 30yr time intervals. Only CCA-Australia and CCDS-Canada used 20yr time periods. By using only 10yr time periods, CAL-USA are for sure an exception. Usually websites provide an early-, mid- and end-century time period. Eligible (*) indicates that the time period is not predefined and is free of choice on the website. Note, that I2C-Germany chose a different approach and present data from different RCMs at the time, when global temperature reached a rise of 2°C compared to 1971-2000.

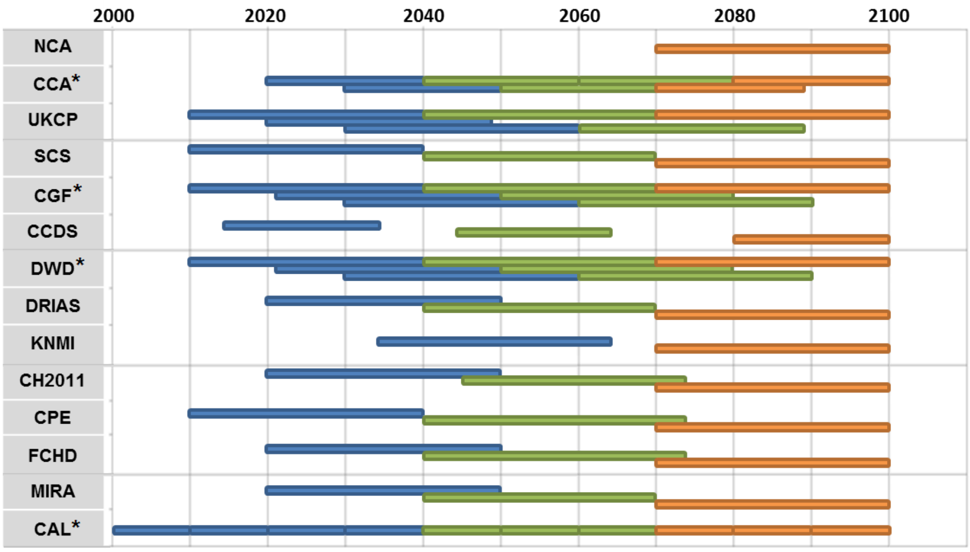


Figure 6: Time intervals that have been used by different climate services.
*indicates that the time period is not predefined and is free of choice. I2C-Germany, EN-Norway and CCCA-Austria are not in the shown graphic. I2C-Germany chose a different approach and present data from different RCMs at the time, when global temperature reached a rise of 2°C compared to 1971-2000.

4 Graphical Tools

In this chapter we discuss the various ways of displaying climate information. The review is a combination of graphical display presented on the web and in written reports. For the web, we further discuss the functionalities of interactive graphical web-tools.

4.1 Displaying direct model output

Most websites and reports provide climate change information in form of graphics that are represented as geographical maps and/or as time-series. However, the complexity of these graphics differs a lot, as well as the way users can interact with the graphics.

4.1.1 Map presentation

All websites and reports contain maps as a graphical element to inform users about climatic changes of a given variable. Obviously, the domain and the content shown differ among the websites. Besides NCA-USA and SCS-Sweden that also present global data, all other climate services provide data for their own county. As I2C are a European project, they also show projections for the entire continent. Most often the maps are presented in a static way (no interaction). However, the users have many options from a browser menu to display the specific content. These options may be: different seasons, models, emission scenarios, variables or specific indices. In Addition, many tools offer setting possibilities. Usually a zoom and navigation cursor is provided, as well as overlays with different regions, roads or rivers. Some of them show the projected changes on a complex map (e.g. EN-Norway or CAL-USA) and offer the option to set the opacity.

Figure 7 shows, as an example, the display of a map from DRIAS-France. It is the output from a single model with no options to display additional climate models.

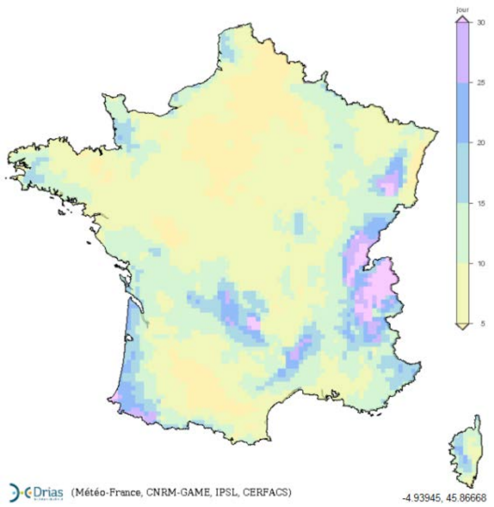


Figure 7: Display of precipitation change in the IPSL-WRF model chain over France.
The map shows changes in daily very heavy precipitation (R20mm) under a high emission scenario (source: DRIAS-France)

The option to display multiple model results is either implemented by showing panel plots with the advantage to visually inter-compare (see e.g. **Figure 8** for the difference between the Aladin/Meteofrance and WRF/IPSL for France) or by allowing the user to select individual model results by a browser menu (e.g. the tool “map explorer” from Australia).

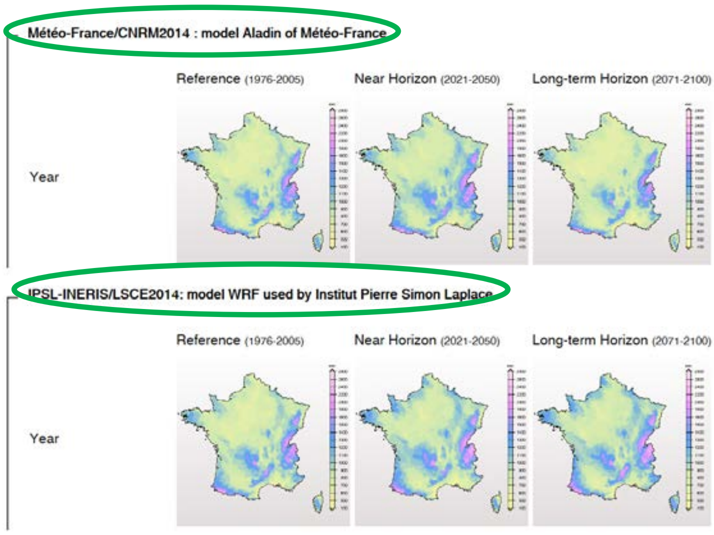


Figure 8: Comparison of two different model-chains over France, displayed on DRIAS-France.
The upper figures show simulations that were done with the CNRM2014-Aladin (GCM-RCM), while the lower figures illustrate LSCE2014-WRF (GCM-RCM) simulations (source: DRIAS-France).

Usually the application of only one climate model causes some risks as model uncertainties and a portion of the natural variability cannot be quantified. Because of that, CCA-Australia label their “Detailed projections” as an expert tool. It offers the option to choose a wide range of climate models. The user can choose from a set of 19 CMIP3-GCMs, 49 CMIP5-GCMs and 28 CMIP5-RCMs by selecting or unselecting them from a list. The tool presents the results as a multi-variance plot (see C**hapter 4.2.1**).

Most of the websites present their climate change information based on the analysis of a multi-model ensemble. Showing the multi-model mean is a common measure to consolidate the information from multiple runs (e.g. CH2011, NCA-US, DWD-Germany and others).

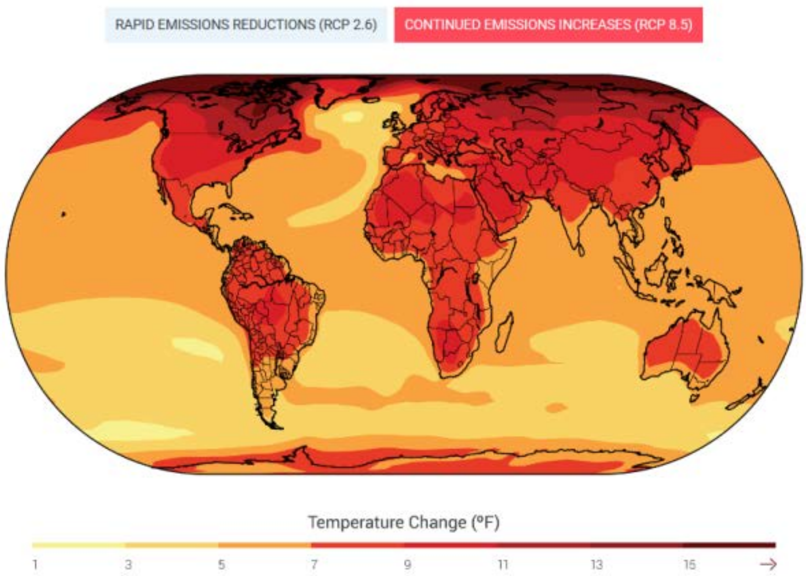


Figure 9: Direct model output for temperature from NCA - USA.
Although they used an ensemble of different GCM, the information content is limited to relative changes. No additional information is shown (e.g. absolute values, percentiles) (source: NCA-USA)

In addition to the mean change, some tools provide possibilities to display percentiles of the multi-model ensemble. Examples thereof are CCDS Canada (**Figure 10**), UKCP-United Kingdom or DWD-Germany.

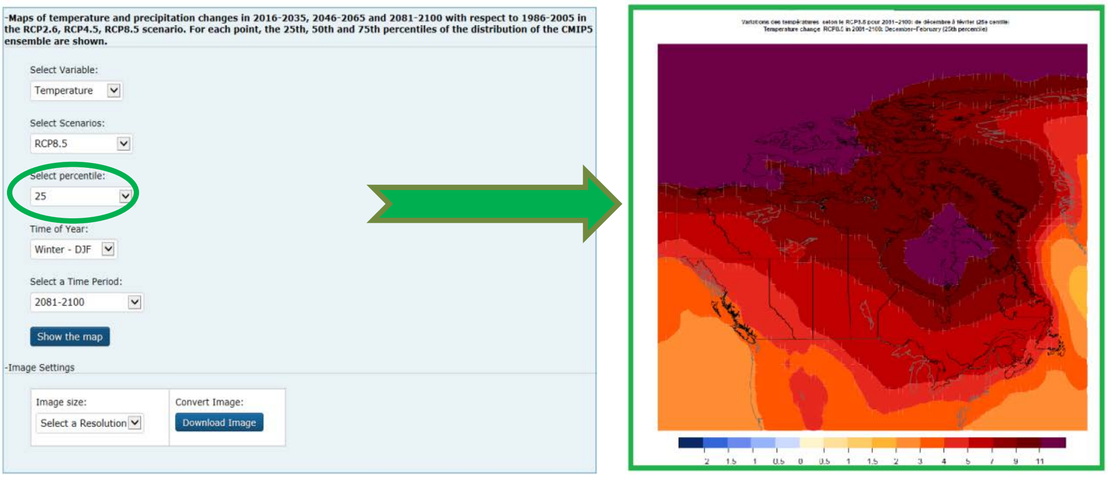


Figure 10: Tool to display percentiles out of a multi-model ensemble. CCDS – Canada allows the 25, 50 and 75 percentiles for display. Additionally, the tool allows to display temperature, precipitation, different emission scenarios, seasons and time-periods (source: CCDS-Canada).

Only a few websites directly link the modeled changes with the observed record. DWD-Germany have such a tool in operation (“Deutscher Klimaatlas”) (**Figure 11**). The maps of multi-model changes (shown are the 15th, 50th and 85th percentiles) are compared to the norm period 1961-1990, which is also shown as a map of Germany (left panel in **Figure 11**). In addition, users can display a particular year for comparison. Default is the actual year (i.e. 2015 in **Figure 11**). The quantities of that particular year can be shown as absolute values, but also as differences with respect to the norm period. The reference to observed conditions allows the user to intuitively assess the projected changes with already experienced conditions. The tool from DWD-Germany comes with further amenities: A broad variety of different climate variables and each month can be selected. Currently, changes according to the A1B emission scenario are available, but will be extended with other emission scenarios in the coming years. The slider in the lower right panel of **Figure 11** allows the selection of a 30-year period in 10-year steps. Note, that in the lower part of the tool from DWD-Germany spatially aggregated climate change information is provided as time series, which will be discussed in **Chapter 4.1.3**.

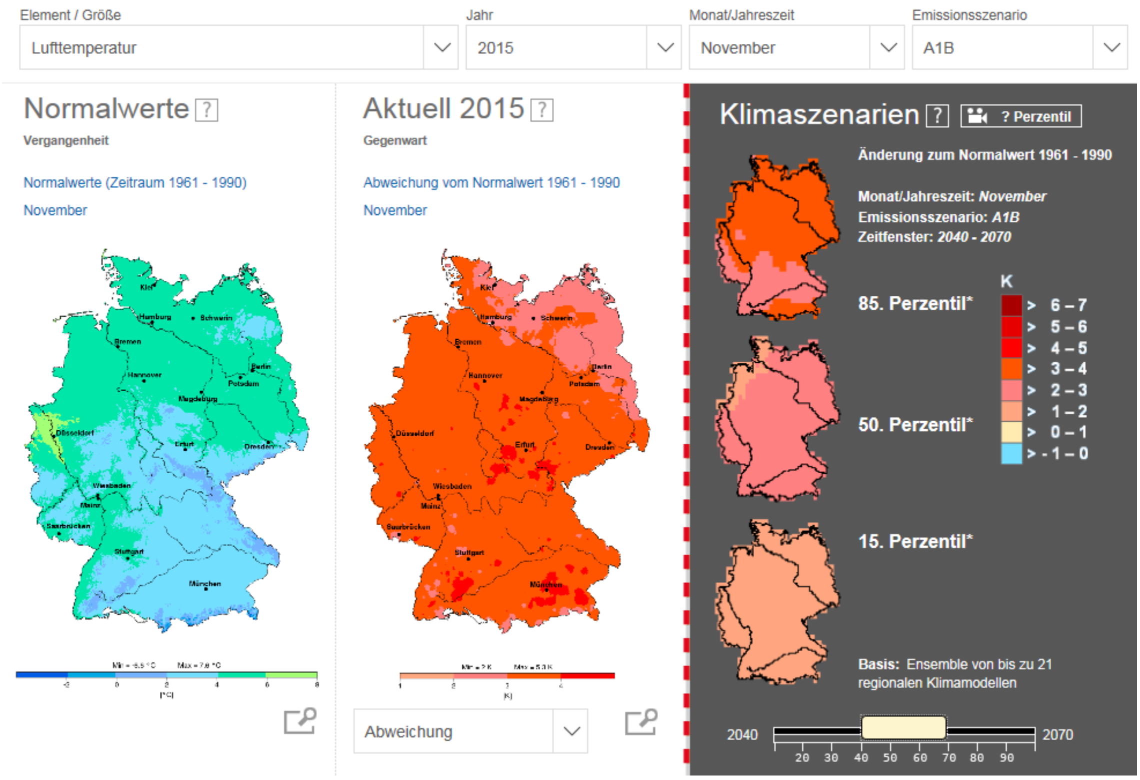


Figure 11: Climate atlas from DWD-Germany. The tool allows the comparison of a certain variable in the reference period (left), a selected year (middle) and projections from a multi-model ensemble from the ENSEMBLE project (source: DWD-Germany).

4.1.2 Bar-plots

Bar-plots are a common way to show the range of spatially aggregated changes over a given region. Unlike time-series, bar-plots do not show continuous data, but for selected time periods (e.g. 2071-2100). CCA-Australia use bar-plots in their "Summary Data Explorer", where they report on seasonal mean changes, but use the same type of graphics for displaying changes in extremes. **Figure 12** shows as an example the maximum temperature change in the "Monsoonal North" for each season. The bar-plot is arranged such that per season four different future 20yr-time-periods are shown and per time-period the effects of the three analyzed emission scenarios are displayed. This way of representing differs slightly from the approach taken by CH2011-Switzerland (**Figure 13**): here, the effect of emission scenarios is displayed on different sub-panels. This has the advantage of visually giving more emphasis on the differences in the seasonal cycle of the change signal.

In case of CCA-Australia (**Figure 12**), a grey bar represents the range of current natural climate variability. This helps to evaluate, whether the modeled changes are still within or outside current natural variability. For CH2011-Switzerland, natural variability is implicitly integrated into the displayed bars. If a bar does not cross the zero line of change, it is interpreted as a significant change.

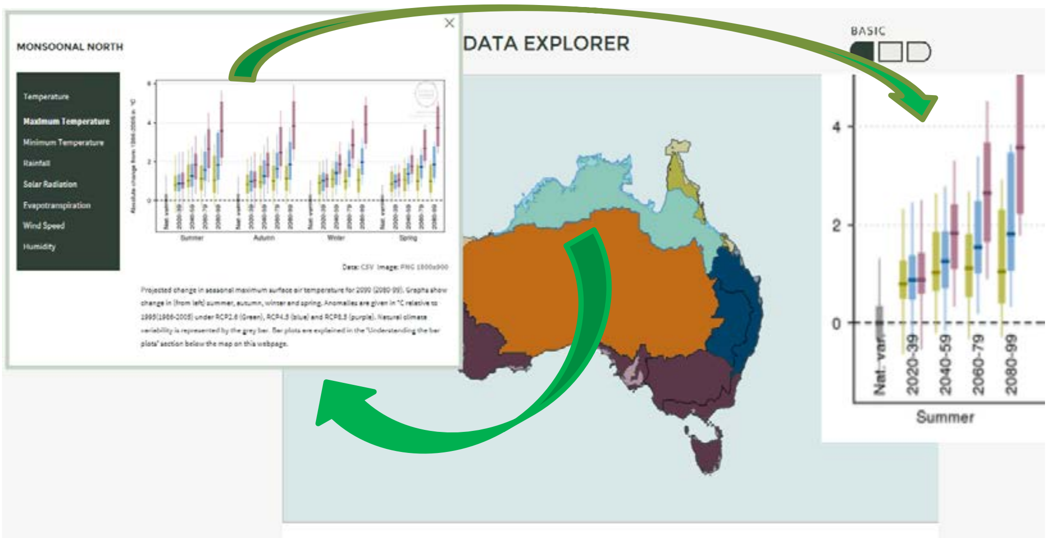


Figure 12: Bar-plots in the Summary Data Explorer from CCA-Australia.
This tool allows to select a desired region, eight different variables and four time periods, CCA-Australia do not only present the likely-ranges of the different emission scenarios (RCP2.6 - green, RCP4.5 - blue and RCP8.5 – purple), but also the natural variability that is shown in gray (source CCA-Australia).

Figure 13 shows the bar plots from CH2011-Switzerland for the three analyzed climate regions. Instead of an extra bar for natural decadal variability, they included this already in the bars that represent the different projections. Decadal variability was also calculated by the analyses of observations.

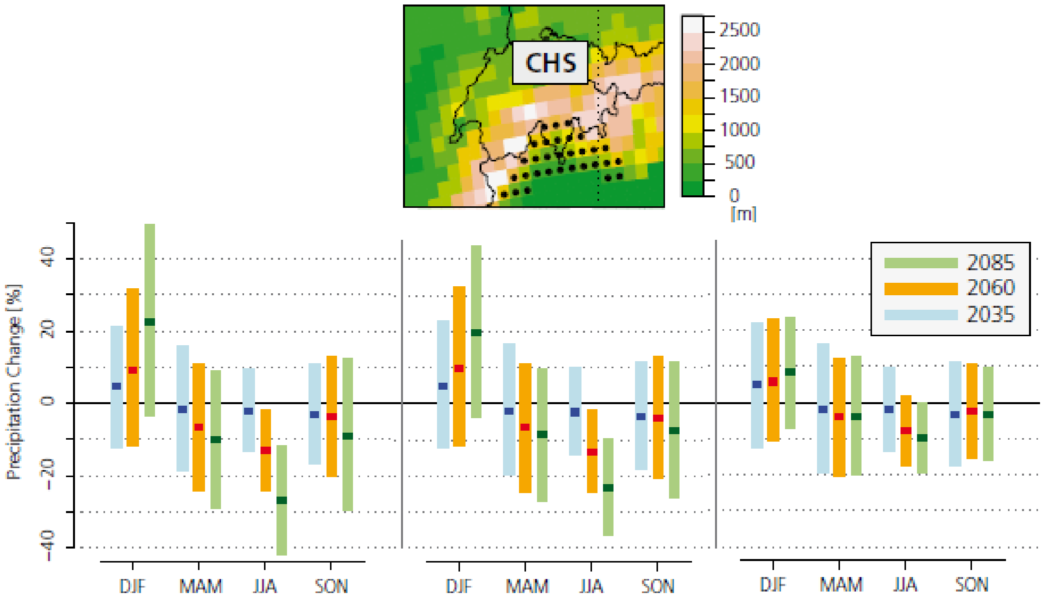


Figure 13: Bar-plots from CH2011-Switzerland in case of Southern Switzerland.
The figure shows the projected changes for different seasons, time periods (blue=2035, orange=2060, green= 2085) and emission scenarios (source: CH2011 2011, p.33).

Bar-plots for the entire country were also disseminated by KNMI-Netherlands for their four self-defined scenarios/storylines (**Figure 14**). To display uncertainty in seasonal mean changes they add historical natural variability, analyzed for 30-year averages (90% confidence interval). This is illustrated with a grey shading, above and below the change according to the respective storyline. The bars are separated according to season and time-period, but the changes according to the four defined scenarios are arranged in the vertical. Thereby, the grey shading of different storylines can overlap. This provides the user a visual impression on the “envelope” uncertainty present in the climate change signals.

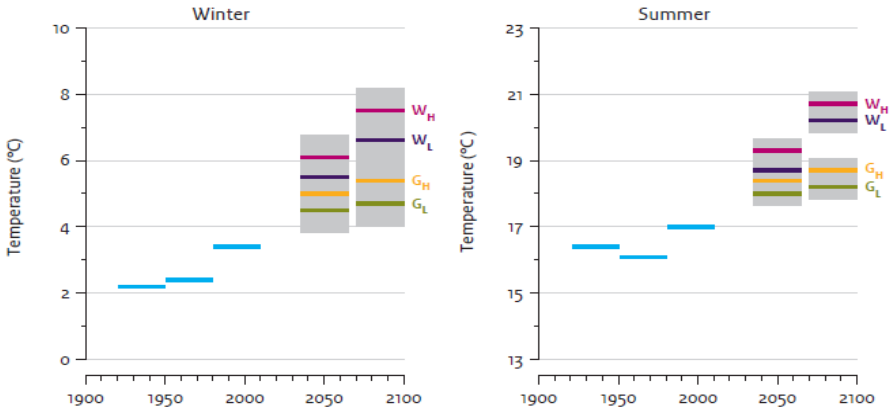


Figure 14: Aggregated bar-plots from KNMI-Netherlands.
The figure shows the observed changes (blue) and projected changes for their four different scenarios/storylines (i.e. WH, WL, GH, GL). The horizontal colored lines represent the modeled changes of the respective scenario. On top of that, natural variability is added to each that is displayed as grey bars (source: KNMI 2015, p. 11).

4.1.3 Time-series

The source of the displayed time-series can vary from measurements to single model runs, and multi-model ensembles that show the probability distribution or different emission scenarios.

Spaghetti-plots of several climate models are a common tool (as shown in **Figure 15** on the left for CH2011-Switzerland). Additionally, the average over all model changes can be displayed too (here as black line).

Figure 15 on the right shows a time-series of a single model in yearly granularity and over the full simulation period. The time-series is shown as anomalies with respect to the reference period 1986-2005. Differently to showing all individual model results, they are jointly assessed to derive an uncertainty range (grey shading) together with the multi-model mean. This is also done for the simulations in the past (“historical simulations”). In the figure here, the 10th – 90th percentiles of CMIP5, as well as the course of the GFDL-ESM2M-model is shown.

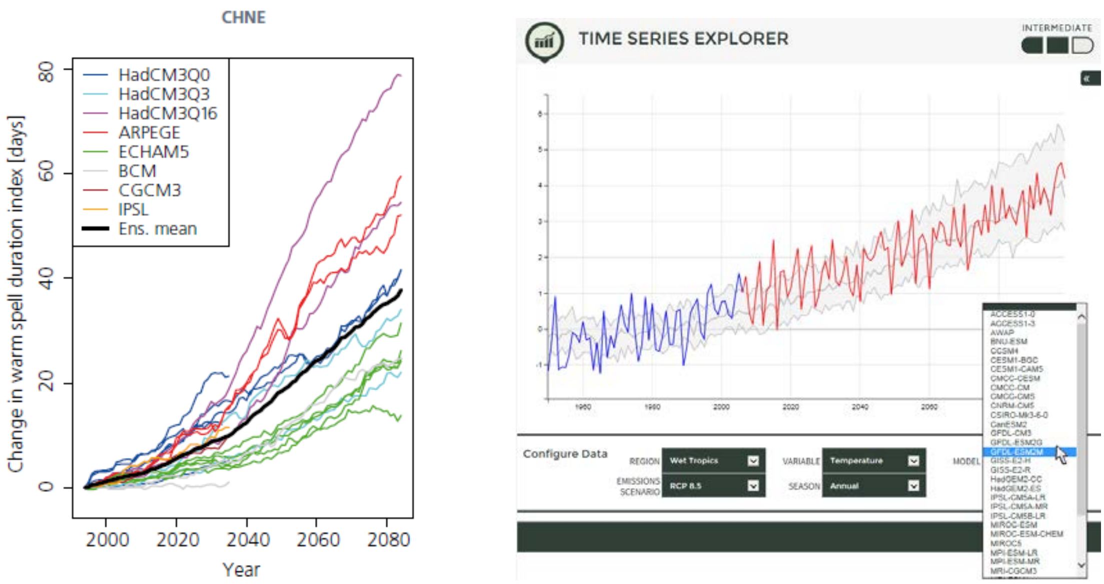


Figure 15: Left: Time-series of individual models (spaghetti-plot) from the CH2011 report (CH2011 – Switzerland). Shown are simulated changes of warm spell duration for northeastern Switzerland. Every colored line represents another model, while the mean is shown in black. (CH2011 2011, p. 50). Right: Time series of the simulation with the GFDL-ESM2M model (CCA-Australia) together with a measure of uncertainty-spread spanned by the full multi-model ensemble. The tool from CCA-Australia allows the user to select a certain model and see the historical and projected course of temperature or precipitation (source: CCA-Australia).

Using the shading as an indicator of model uncertainty, the differing climatic effects according to different multiple emission scenarios can be visualized. This is for instance shown in **Figure 16** on the left side at the example of maximum temperature over the region Andalucía in Spain. On the right-hand side a similar plot is shown, but additionally the observed record is overlaid (thick black line). This figure shows the Arctic sea ice development from 1900 on with projected data starting in 2002 (see colored shading).

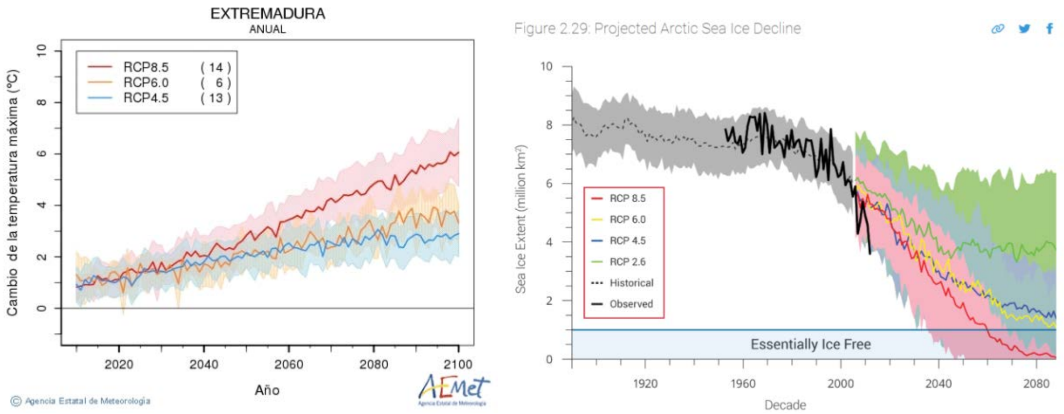


Figure 16: Left: Time-series of maximum temperature from CPE-Spain. The colored lines represent the ensemble mean of the respective emission scenario (source: CPE-Spain). The shading in light color is the uncertainty spread spanned by different climate models. Right: Time-series of the Arctic sea ice extent. The black color indicate measured sea ice in Antarctica. Historic simulation mean is shown in dotted lines, while the future sea ice extent is shown in colors and shaded color lines denote model ranges according to the respective emission scenario (source: NCA-USA, adapted from Stroeve et al. 2012).

Since climate models are prone to systematic biases, the combination of observations and models is usually done by reference to a fixed time-period in the past. Often, both time-series, observed and modeled, are presented as anomalies (see an example of SCS-Sweden, **Figure 17**). The same approach as DWD-Germany is also followed by CGF-Finland (**Figure 19**). However, they additionally include projections according to three emission scenarios, albeit for the multi-model mean only.

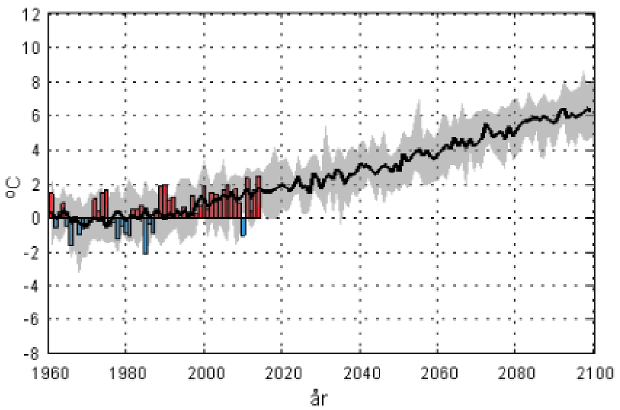


Figure 17: Time-series plot for mean temperature change in Sweden according to the RCP8.5 emission scenario. Observations are shown in colored bars (red are positive anomalies, blue are negative anomalies), while the multi-model mean is shown as thick black line. The grey shading represents the model spread (source: SCS-Sweden).

DWD-Germany, however, shift the model time-series by the average over the reference period (see **Figure 18**) to provide climate information in absolute entities. The RCMs are shown as smoothed averages (Gaussian low-pass filtered) that are referenced to the 1961–1990 period. Common to most time-series plots that combine observations with models is that they show the model results over the full simulation period, hence including historical simulations.

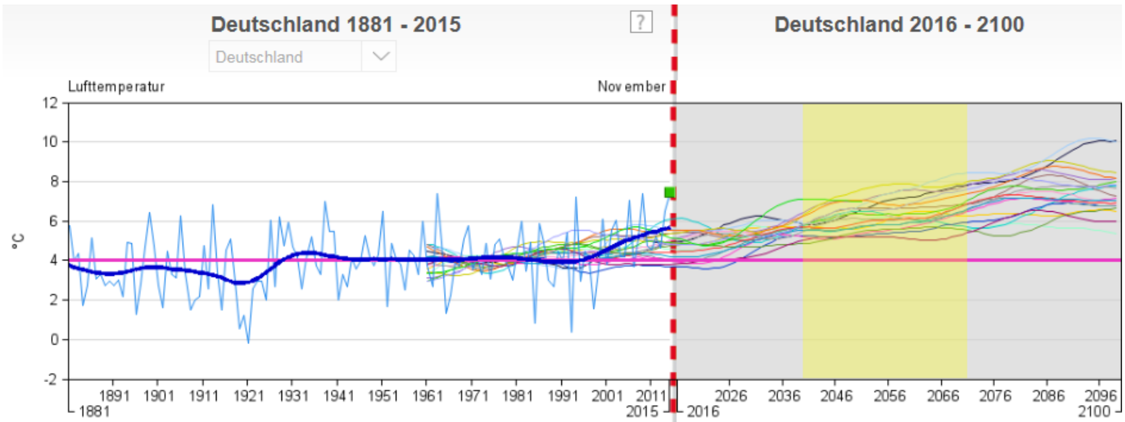


Figure 18: Time-series plot for mean temperature from DWD-Germany.
On the left side of the graph, historical measurements are shown with a thin blue line, while the 30yr mean is represented by the dark blue line. Values of the current year are shown with the green square and the standard value (1961-1990) is marked with the pink line around 4°C. The colored lines on the right side represent different smoothed RCM runs, while their start point lies in the past (source: DWD-Germany).

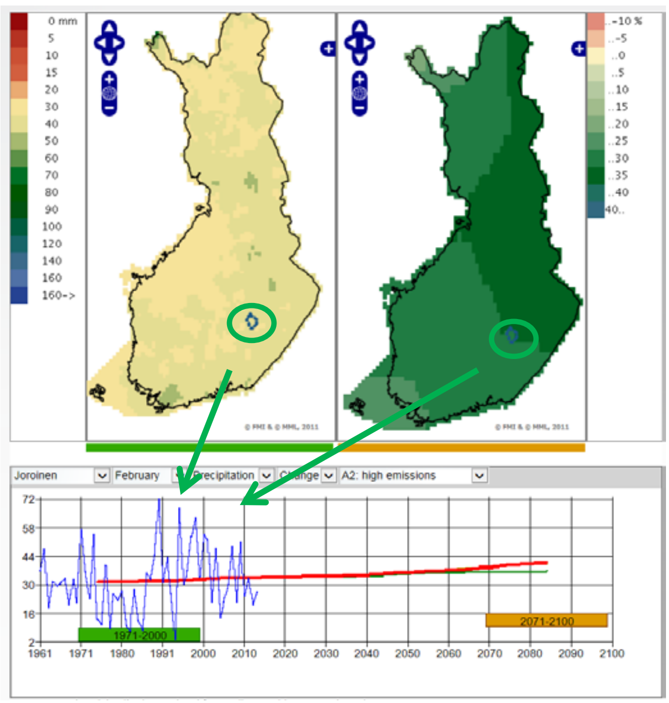


Figure 19: Time-series plot of CGF-Finland (lower panel) with maps (upper panel). The upper left map shows observed values that are spatially gridded over the whole country (1971-2000). The upper right picture shows the projected changes under a high emission scenario (A2) in 2071-2100. These model-based data have been interpolated to a 10km x 10km grid. A time series of measured and projected values is shown in the lower panel. Here, the values for the station Joroinen is shown. The lines in red, dark green and light green are the multi-model mean projections according to three emission scenarios. The user can interact with the graphic by sliding the orange bar of the scenario period, so that a new spatial map in the upper right is shown (source: CGF-Finland).

Also, most of these types of plots provide additional information on the year-to-year variability in observations. The plot from Sweden displays this variability as fine bars with respect to the reference period (**Figure 17**), whereas DWD-Germany and CGF-Finland show it as a line plot (**Figure 18**).

Moreover, information on the model variability can be obtained from the shading, which shows the spread between the highest and lowest value of the members of the multi-model ensemble (**Figure 17**).

The figure from SCS-Sweden is qualitatively very similar to the one of CH2011-Switzerland (**Figure 20**). CH2011-Switzerland also indicate the year-to-year variations of the projections (5th to 95th percentile range of all models) with grey shading. CH2011-Switzerland add another complexity to the time-series: additional climate change information on 30yr-mean changes for three different emission scenarios are added to the plot (colored thick bars).

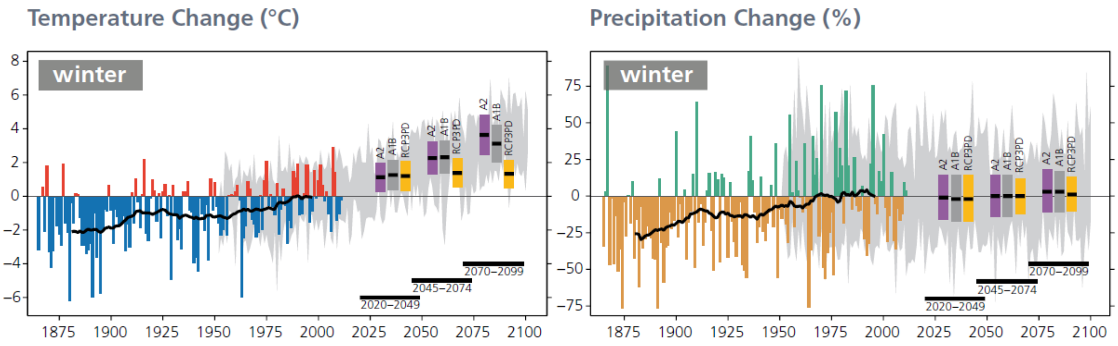


Figure 20: Time-series plots for mean temperature and precipitation rom CH2011-Switzerland.
In the report, time series of observations and projections of mean temperature and precipitation in winter are presented. Observations are shown in colored bars, while the black line corresponds to a smoothed 30-year average. The grey shading represents the year-to-year difference of the projected variable under the A1B scenario (CH2011 2011, p. 7).

A very similar approach as CH2011-Switzerland has been taken up in Austria (CCCA-Austria, **Figure 21**). However, they cover only one emission scenario in 30yr mean changes and two future time-periods (yellow bars).

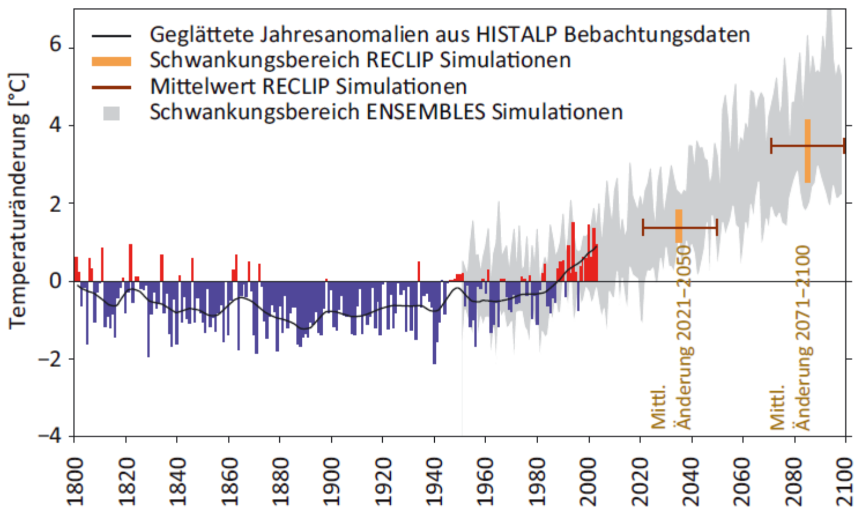


Figure 21: Time-series plot for temperature from CCCA-Austria.
Measurements until the year 2010 are shown in color, model calculations for a moderate emission scenario (A1B) in grey. Color bars are annual averages, while the black line is a 20yr smoothed curve. In addition, two future periods are shown in yellow (APCC 2014, p. 30).

4.1.4 Selection of Regions

Many scenario platforms provide aggregated climate change information for certain sub-regions within a country, be it in form of bar-plots or time-series as shown above. Sometimes, these regions are defined based on climatological arguments. For instance, for CH2011-Switzerland three regions north and south of the Alpine ridge were defined (see **Figure 22** on the left). Apart from climatological characteristics, it was also ensured that roughly the same number of model grid points fall within each of the three regions for statistical robustness. Also CCA-Australia defined their regions across the continent based on past climatic conditions, using a clustering algorithm (see **Figure 22** on the right). Another criterion was that cluster boundaries follow existing boundaries of states (CSIRO and Bureau of Meteorology 2015). In total, they ended up with 15 cluster regions. For some aspects of climate change information they merged these clusters to super-clusters.

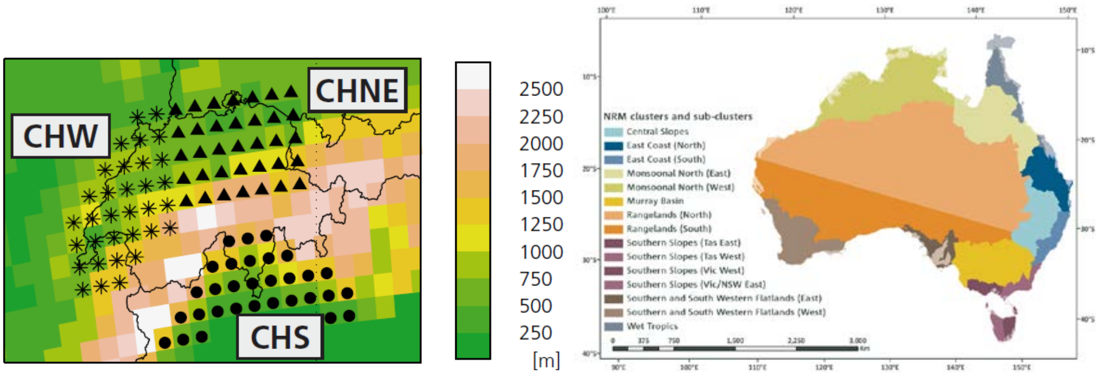


Figure 22: Region selection according to different climate characteristics.
In their report, CH2011-Switzerland used three regions (CHW: Western Switzerland, CHNE: North-eastern Switzerland and CHS: Southern Switzerland). The Western and Eastern Alps followed later in an extension (left) (CH2011 2011, p.15). A similar concept for the regions selection was used by CCA-Australia (right). Because of different climate characteristics, they came up with eight clusters, which can be even more subdivided (CSIRO and Bureau of Meteorology 2015, p. 17).

Besides climatological regions, other descriptions are used. These comprise political borders such as states or provinces targeting directly regional decision makers and politicians. This also makes sense in the light of adaptation strategies that are often determined at a political sub-national level. Another way of defining appropriate regions is impact-driven: aggregating climate change information in a way that it can be directly used for impact studies (e.g. a certain catchment for hydrologists) can ensure that the data receives sub-sequent a wide application.

The tool from SCS-Sweden has the possibility implemented to retrieve different ways of aggregation (political regions and catchments) as **Figure 23** shows. For each of the chosen region, a time-series from the past into the future can be obtained.

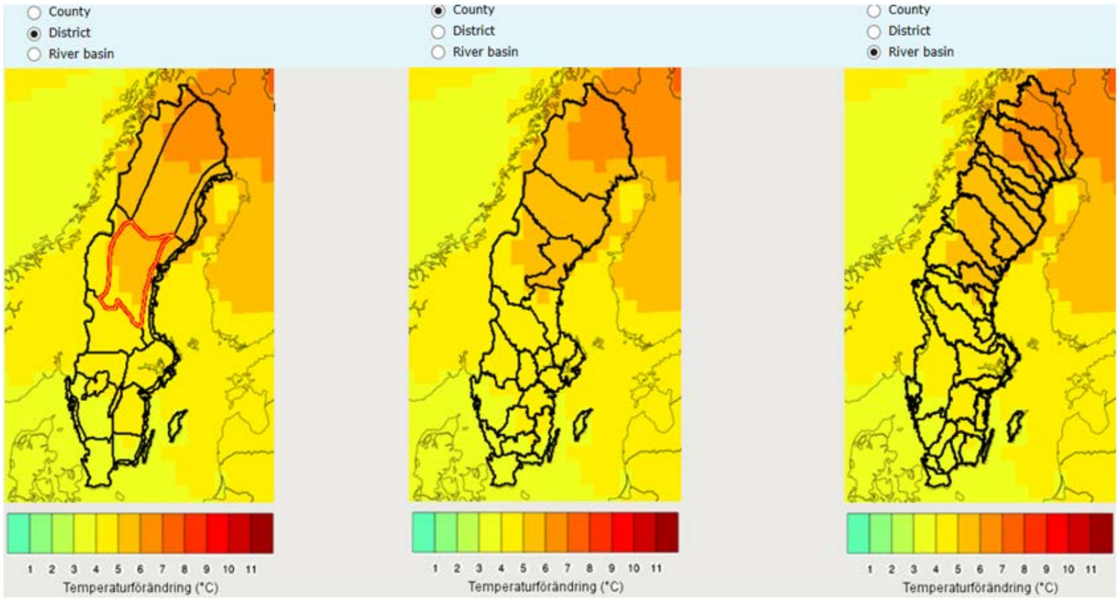


Figure 23: Optional region selection by SCS-Sweden.
The user can choose between a selection according to districts, counties, or river basins. The red marker in the left map shows the selected district, for which a time series will opened up in a new window (source: SCS-Sweden).

Finally, it is worthwhile mentioning that CAL-USA provide a way to select the region of interest interactive on their website. It is either possible to retrieve a rectangle in lat/lon-coordinates, or to select a county (see **Figure 32 and Figure 34**).

4.2 Elaborated graphical tools

Besides these rather basic tools that most websites provide in one form or the other, there are more specialized graphics that target the more experienced users. In the following, we give an overview of these advanced graphical tools.

4.2.1 Multi-variate changes

Often, information on combined changes is key for many impact applications. Only few websites offer the possibility to retrieve information on multi-variate changes. Examples thereof are from CCA-Australia and CGF-Finland. The tool from CGF allows for a basic comparison of precipitation and temperature change (**Figure 24**). After the selection of the time period, the tool shows a multi-variate graphic in the lower left corner. This plot displays the individual bi-variate projections of the multi-model ensemble. In order to generate three different scenarios, the tool selects one model (HadCM3) for a low change scenario (green cross), the multi-model mean for an average change scenario (black cross), as well as a representative model (ECHAM4) for a high change scenario (red cross). Changes of the climate and its impacts are presented for these three scenarios. In addition, the model agreement is indicated too and gives an impression of the uncertainties. This approach resembles the one of KNMI-Netherlands for defining storylines (see C**hapter 3.3**).

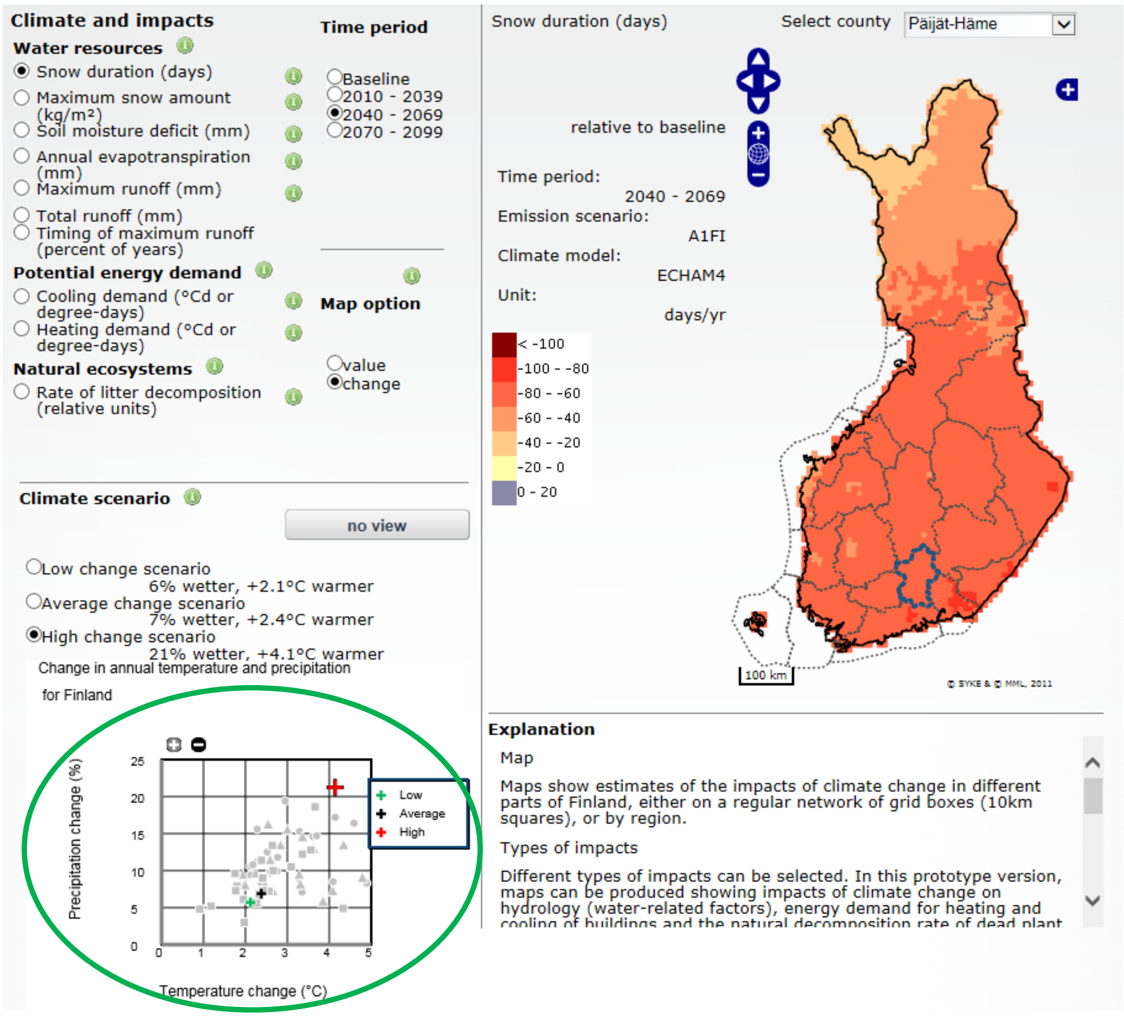


Figure 24: Bi-variate tool from CGF-Finland.
In their tool for impact studies, CGF-Finland shows the changes of precipitation and temperature in a multi-variate change plot (lower left corner). The example above uses a high emission scenario (A1FI) and shows the ECHAM4-model as a representative model for high temperature and large precipitation increases (red cross). In a similar way models are chosen for a "low" (green) and "average" (black) change scenario (source: CGF-Finland).

A very sophisticated multi-variate tool is provided by CCA-Australia. The user can choose from different SRES and RCP emission scenarios and different time periods from 2025 to 2090 in 5-year steps. Changes in 16 climate variables like rainfall, sea level pressure, or maximum daily temperature can be compared against each other to investigate combined changes. **Figure 25** shows the comparison of mean surface temperature and rainfall for the Rangelands. In a further tool, the user can additionally choose the desired models. Because the selection of only a few climate projections has to be interpreted with caution, this tool is also labeled as "Advanced" and is suitable only for experienced users.

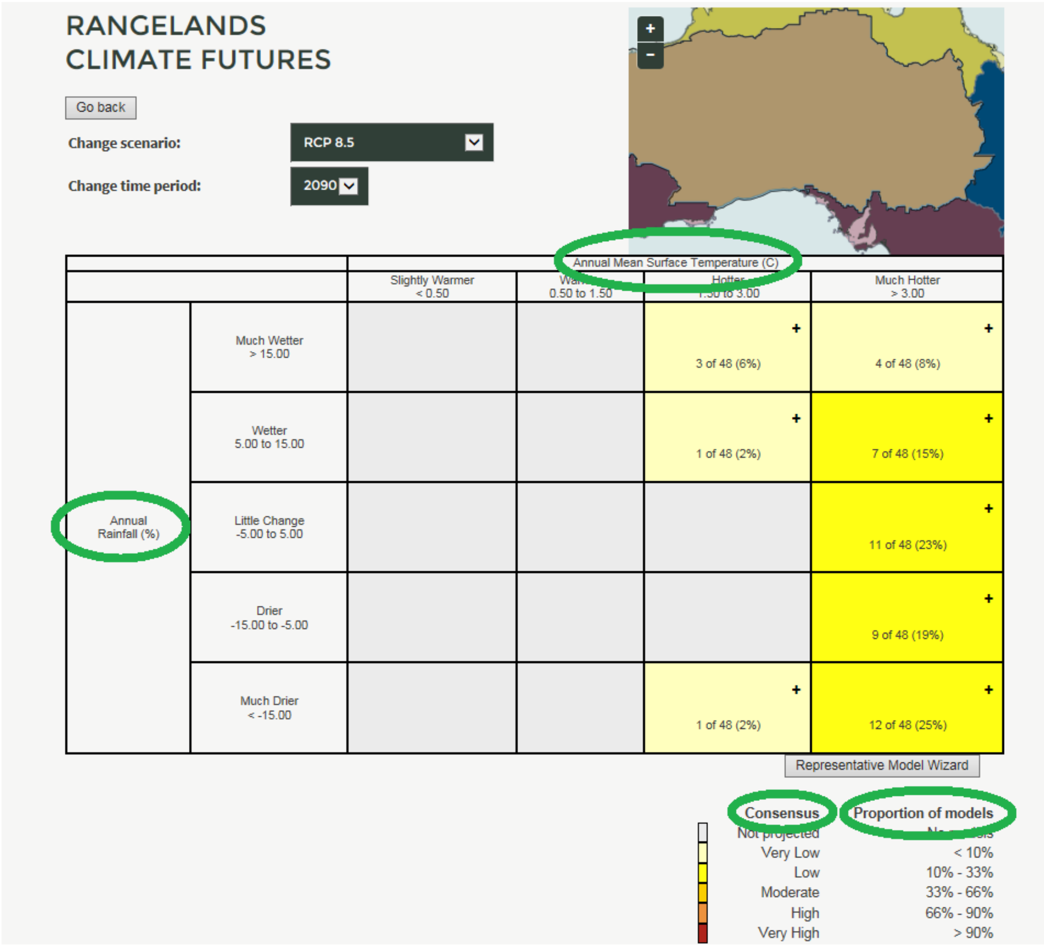


Figure 25: Multi-variance presentation from the Summary Data Explorer tool from CCA-Australia.
This figure shows how well the models agree on changes of temperature and precipitation in the rangelands. The colors indicate the consensus, however, the values are presented as well. A click on the + in the upper right corner will show which models agree on this specific change (source: CCA-Australia).

4.2.2 Displaying analogues of future climate

A comparison to current climate and regions that show already today the climate that is expected in the future is an intuitive mean to convey climate change information. Such information is usually provided through analogue approaches.

For instance, KNMI-Netherlands illustrate the implications of their projections by displaying regions that climatologically match the future expected climate at a given station. In **Figure 26** an example is given that shows the regions (in color), where the current winter climate is similar to Amsterdam's climate around 2050. To search for analogous regions, only temperature and precipitation are considered here. In addition, KNMI-Netherlands provide only one graphic for the time-period around 2050.

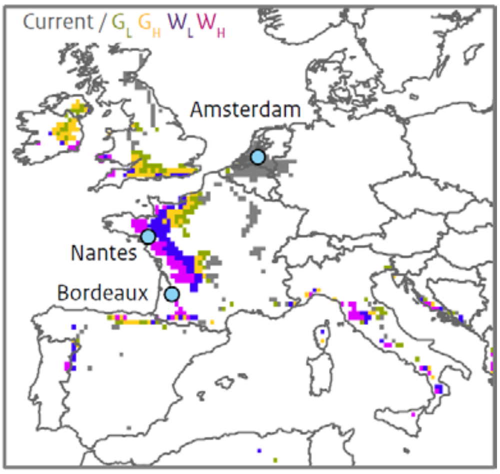


Figure 26: Graphic out from the KNMI'14 climate report that displays climate analogues.

CCA-Australia have a considerably more elaborated and interactive analogues tool. First, the user has to select a region, emission scenario, and time period (2030, 2050 or 2090). Second, the user has the possibility to find analogues for a specific location following three different scenarios (similarly as in CGF-Finland) of combined temperature and precipitation change: (a) maximum consensus (i.e. best estimate of combined change), (b) least hot and wettest and (c) hottest and driest. There is also the option to choose arbitrary temperature and precipitation change combinations. Based on these configurations the analogue tool will then search for the closest analogues (see **Figure 27**).

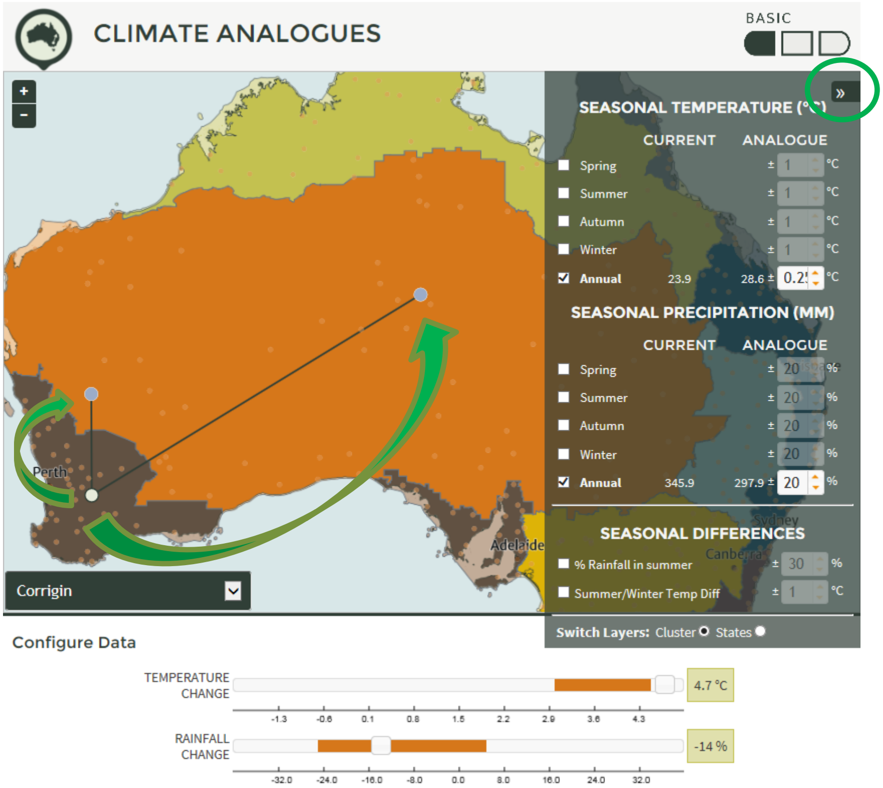


Figure 27: Climate analogue tool from CCA-Australia.
The graphic shows which climate can be expected in Corrigin at the end of the century under the RCP8.5 scenario. It is expected to be much warmer (4.7°C) and also drier (-14% change in rainfall). By clicking on the double angle quotation mark in the upper right corner, an additional window with the selection properties opens up. For this example, annual differences have been selected. Thus, it shows the annual mean temperature of 23.9°C, as well as 345.9mm of rain, as well as the projected changes. By adjusting the thresholds, the tool shows regions that have already today the climate that is projected for Corrigin (source: CCA-Australia).

4.2.3 Climate indicators and thresholds calculator

Many processes in nature, economy and society depend on absolute thresholds: the freezing of a plant, the necessity of heating or cooling a building, the survival of a parasite, etc. In this regard, climate indices (e.g. the number threshold exceedances) are very helpful to provide sector-specific climate information. For instance, the number of frost days is defined as the number of days, when minimum temperature falls below 0°C, which is a key threshold for sectors such as infrastructure, tourism or agriculture. To provide information on such climate indicators, observations have to be combined with the model changes to derive absolute future values.

Figure 28 shows an example of a simple map allowing the user to switch the multi-model plot for tropical nights between the reference period, 2°C period and the resulting change signal.

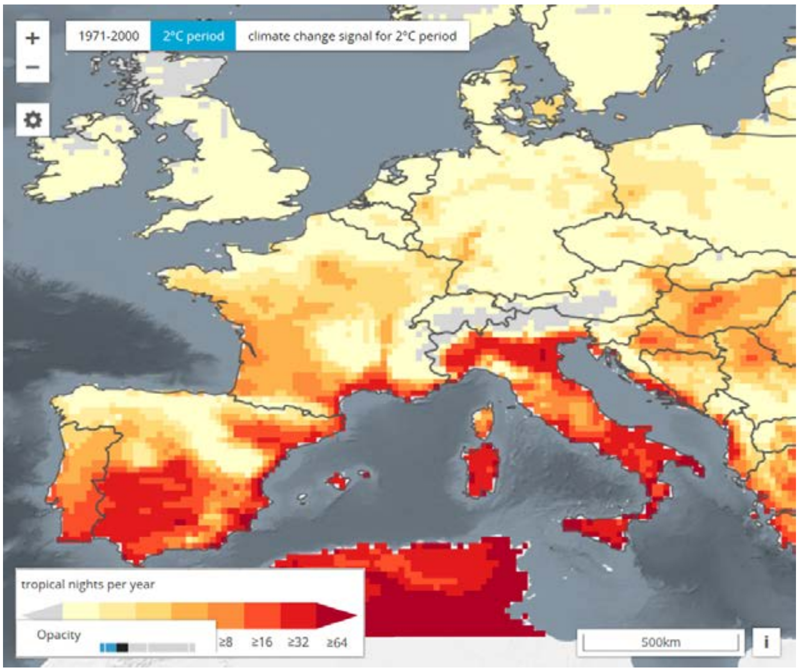


Figure 28: Multi-model plot for tropical nights in the 2°C period.
I2C-Germany presents results from multi-models (source: I2C-Germany).

In case of CCA-Australia users have the possibility to choose their own specific absolute threshold (**Figure 29**). From future minimum and maximum temperature in absolute entities, various levels of absolute thresholds can be selected (i.e. days with maximum temperature greater than 25 up to 29 or days with minimum temperature less than 0 up to 8). This can be displayed for two emission scenarios, different future 20yr-time-periods and for the reference period. The information is available for every single climate model, but not for the whole multi-model ensemble. The model selection can lead to quite big differences: for the example in **Figure 29**, the thresholds for the future vary between 31 days above 25°C (NorESM1-M) to 80 days above 25°C (CanESM2).

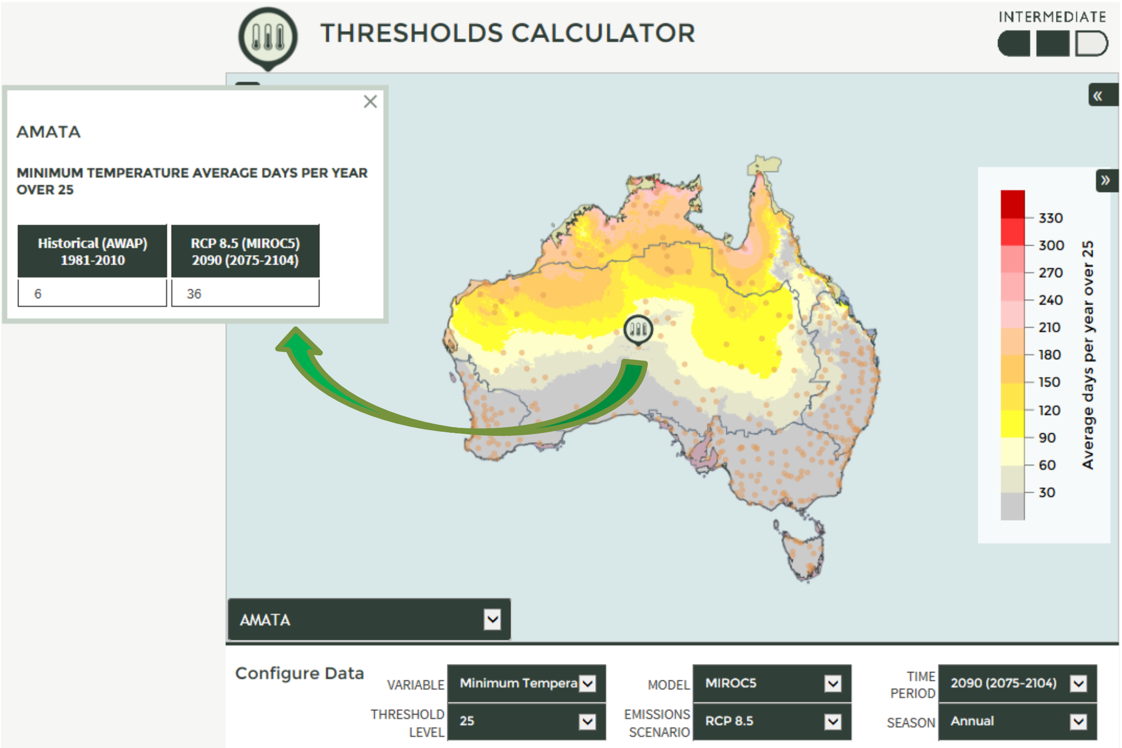


Figure 29: Thresholds calculator tool from CCA-Australia.
After the settings have been made, the map changes its colors according to the threshold properties. Many different stations are available to choose from. A new window opens and shows values for the threshold in the past (reference period, as well as for the future projections (source: CCA-Australia).

4.3 Interactive functionalities

4.3.1 Retrieve more information from the graphics

Some interactive tools offer the option to click on a map to retrieve more information from a particular region. This information can be diverse, ranging from the climatology over a region, to a time-series or decadal averages. It can also be simple by just providing the actual value of a grid box as in case of DRIAS-France. As detailed above, the particular region to select may be climatologically and/or politically defined, but can also be defined according to important impacts. For the map tool of SCS-Sweden (see **Figure 23** and **Figure 30**), the underlying region is highlighted as soon as the cursor is moved over the respective region and the time series of observed and projected aggregated data is displayed. Then, by clicking on the red highlighted region, the user gets more information for the particular selection in a separate box.

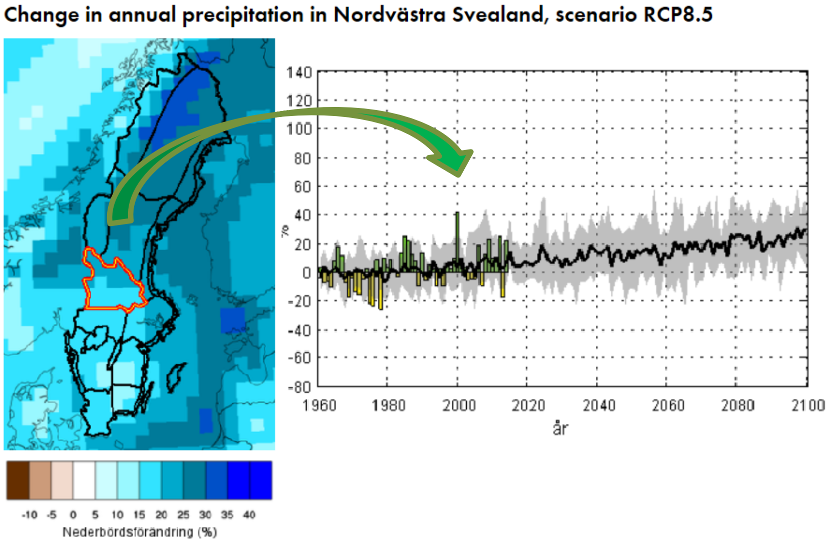


Figure 30: Map and time-series tool from SCS-Sweden.
After clicking on a desired region, the user gets a time-series in addition. The colored bars indicate measured data, while the black line represents the ensemble mean and the grey field shows the range between the highest and the lowest member of the ensemble (source: SCS-Sweden).

In a similar way as SCS-Sweden, by clicking on a particular region, NCA-USA have implemented a functionality that a pop-up window opens that gives more information on the shown map (**Figure 31**). In this case decadal anomalies of precipitation are shown over the 20th century as a time-series for the region Southwest.

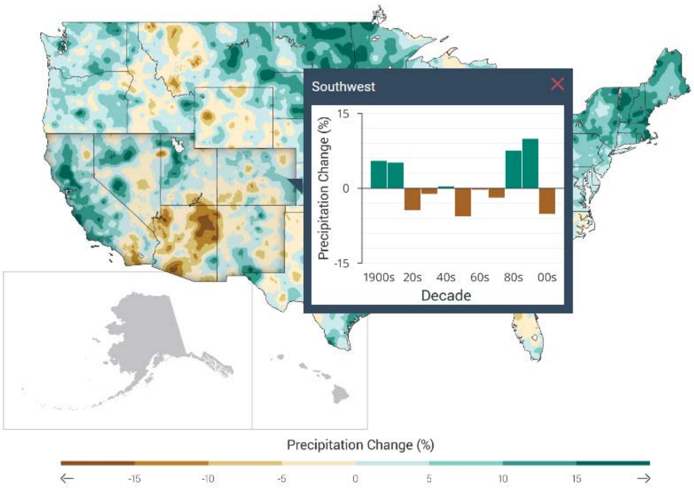


Figure 31: Click on map to get more information NCA-USA, observed RR change.
This figure shows the RR change in the USA in the last 100 years. It is possible to click on a region and get a time-series with values for every decade (source: NCA-USA).

The tools presented by CAL-USA are even more powerful in functionality. First, the user has the possibility to define a squared region or use a pre-defined region of a county (**Figure 32**). From the selected region, the user gets a time-series of a given variable/index covering the past and the future. By moving over the time-series on the right-hand side, a second functionality is implemented that provides the exact quantities as shown in the upper right corner of the figure. In addition, timeline can also be displayed as a table. No direct download is possible.

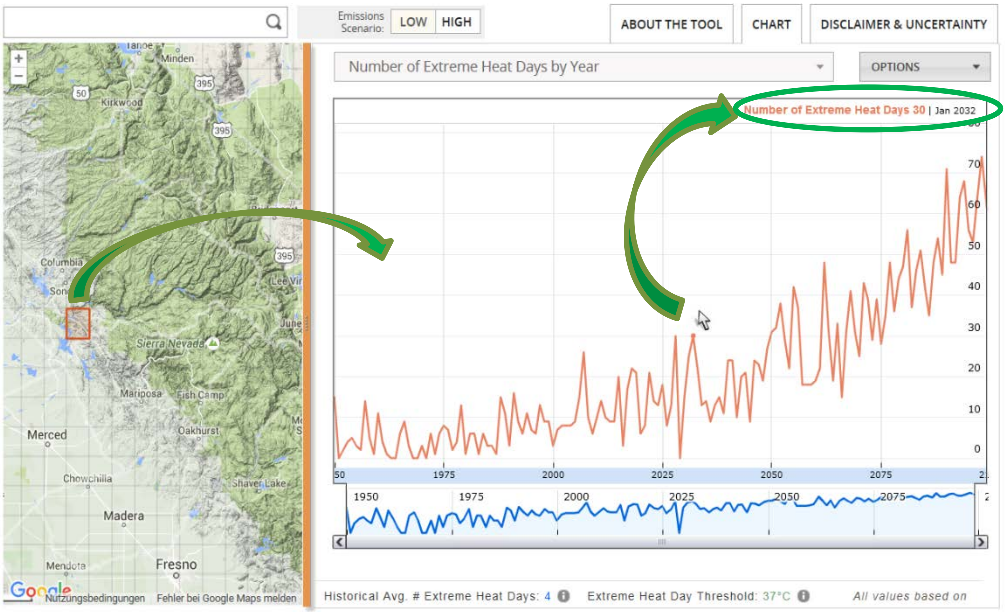


Figure 32: Click on map to get more information CAL-USA, time-series.
By clicking on a desired region, the user gets information on the number of extreme heat days. It is possible to move over the time series an get the exact (projected) number for the particular year. The blue curve bellow represents the same course as the red course above, but allows to zoom in. However, it is possible to select a certain period and get a close up in the record above (source: CAL-USA).

Another format of display is by showing the timing of extreme heat days per year showing the annual pattern of occurrence. **Figure 33** shows in an easy way, that such extreme events will become more frequent and also earlier and later in the year. Again, more information is given by moving the cursor over the dots (year, earliest heat day and latest heat day).

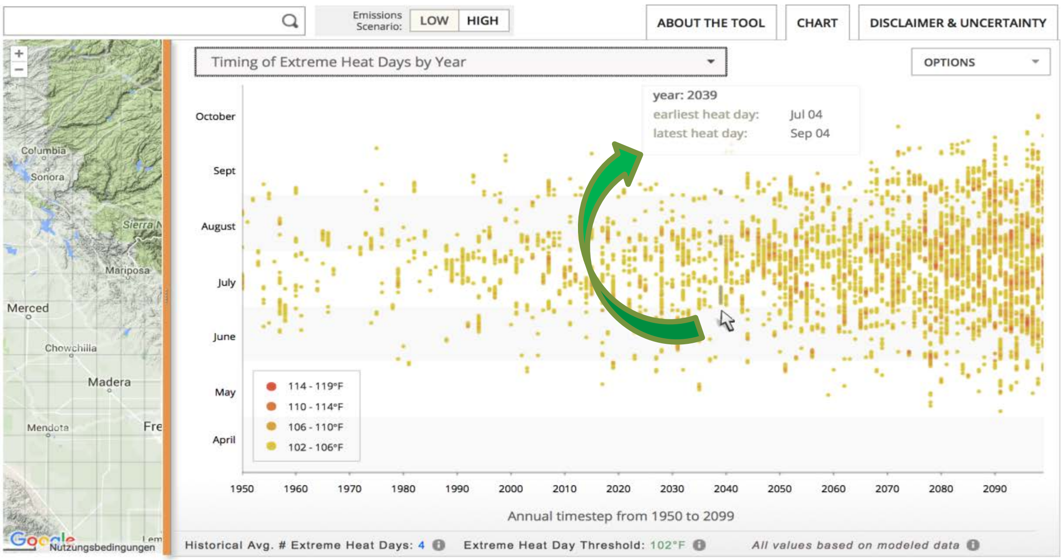


Figure 33: Click on map to get more information CAL-USA, annual pattern change.
This figure shows how often and also when extreme heat days occur during the year (source: CAL-USA).

Further sophisticated functionalities are available at the website of CAL-USA (**Figure 34**). After having chosen a desired region with the respective time-series on the right hand side, the user can add a second time-series for comparison purposes. This might be a different region, or different settings for the same region.

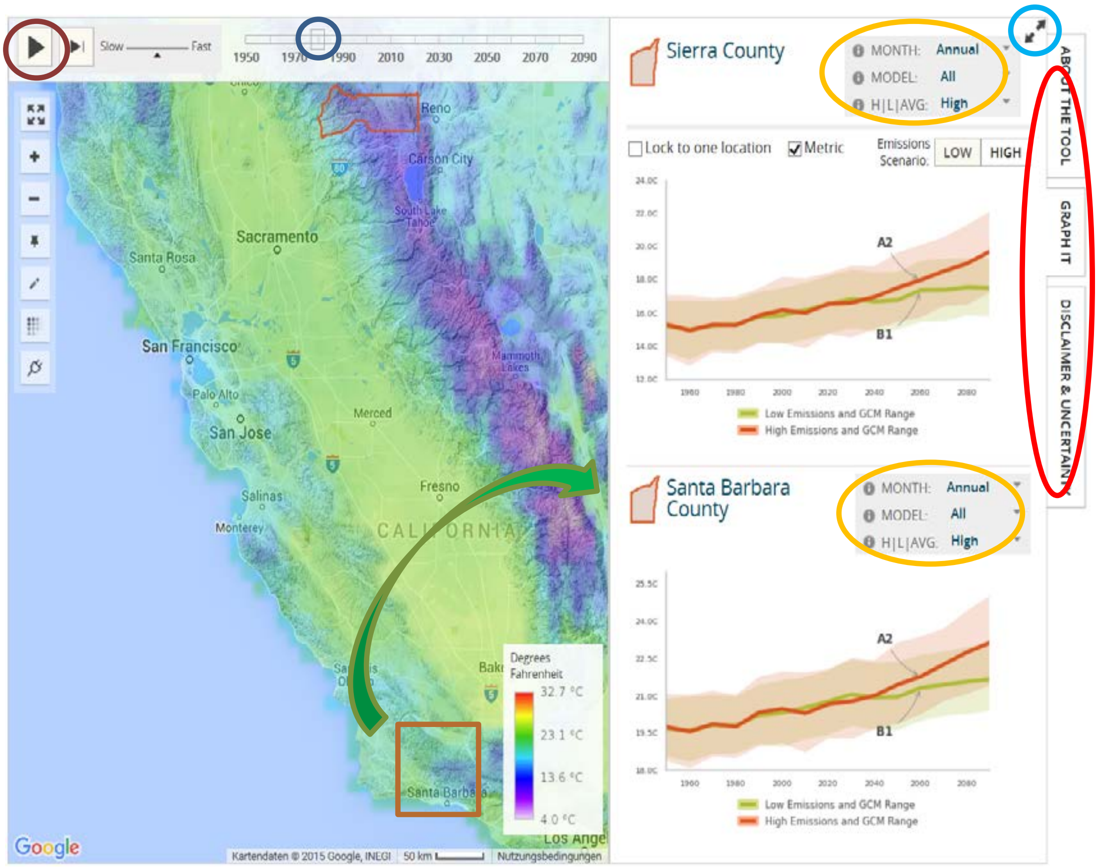


Figure 34: Map and time-series tool for decadal averages from CAL-USA.
Their tool offers a lot of possibilities. Two things can be compared (green arrows), here for Sierra County and Santa Barbara County. The second plot can be another region (example above), different season, model or temperature variable (orange circle). It offers the possibility to play (dark red circle), or move the slider (dark blue). Help is provided for the tool, as well as explanations for uncertainty (red oval). A click on the arrows (light blue circle) expands the graphic over the entire display (source: CAL-USA).

Another sophisticated tool is offered by FCHD-France that allows the interaction with the CSDI and WSDI in the observation period from 1947 to 2015. The x-axis represents the duration of the event, the y-axis the average minimum temperature during the event. The sliding bar indicates the particular time-period that is active in the plot. If a certain event is present in the selected time-period it is displayed in blue, and else in grey. The length of the sliding bar can be widened and narrowed. Through this functionality the user gets a first impression, how CSDI have evolved in the last few decades. Furthermore, the user can click on a certain event and retrieves more information about the exact start date and end date of the respective spell. As for most tools on their website, FCHD-France provide detailed help to interpret the graphics (see **Figure 35**).

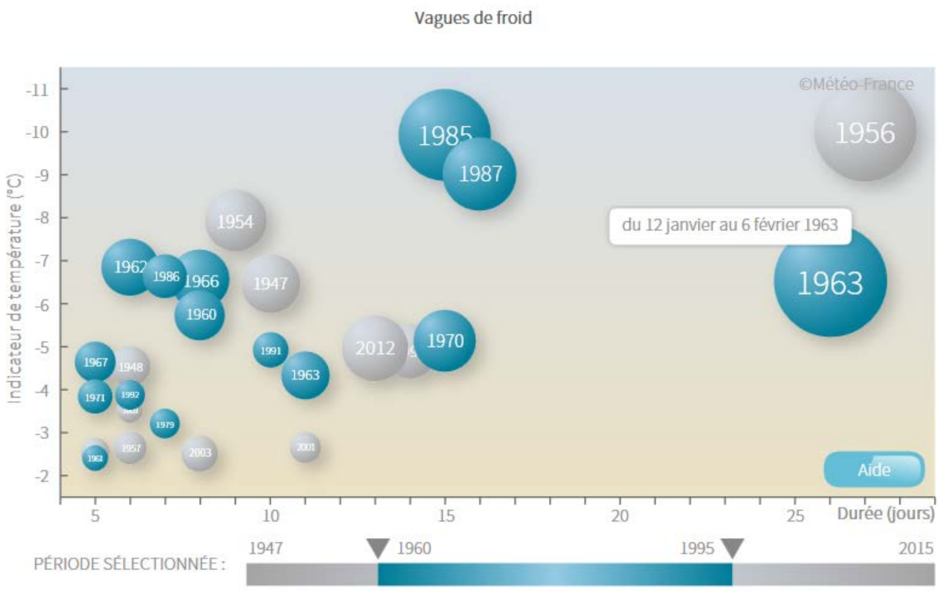


Figure 35: interactive tool for cold spell duration on the website FCHD-France.
By moving the blue bar (Période sélectionnée), cold spell in the particular period appear blue in the graphic above with the respective year. The colder the period was, the bigger is the circle, while longer durations are found on the right side of the graphic. By clicking on "Aide" in the lower right corner, help is provided (source: FCHD-France).

Instead of increasing the functionalities more and more, some scenario platforms go the other way round: their tools allow to reduce complexity from the plot. An example is given in **Figure 36** that shows in black the observed global mean temperature form the late 19th century until today. Overlaid are two different kinds of shading illustrating the simulation of global mean temperature when including natural factors only (green) and when additionally taking into account human factors (blue). By switching off one of the shadings, the complexity of the graphics reduces and helps users to learn the essence of a graphic more efficiently.

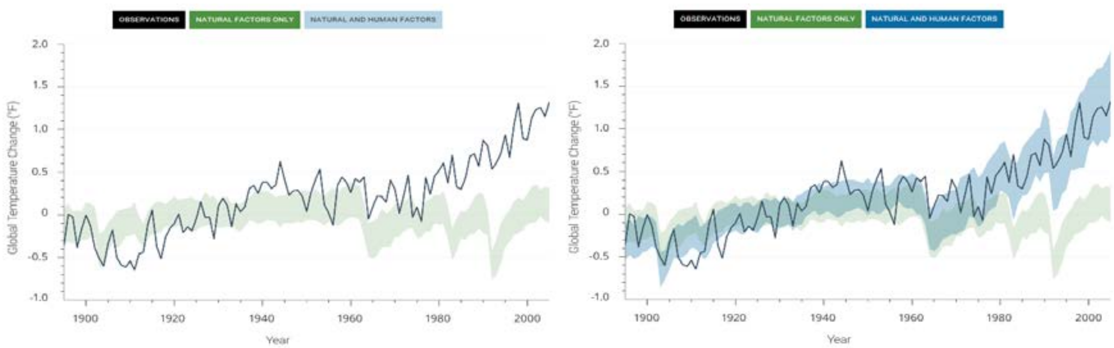


Figure 36: Interactive time-series tool from NCA-USA.
This figure shows the impact of human made climate change on temperature (source: NCA-USA).

4.3.1 Slider as a functionality

Most websites allow the selection of a time-period. This if often accomplished by a drop-down menu. But some of the analyzed websites have a slider incorporated. Just by moving the bar to the left or to the right, the user can switch the selected period. CGF-Finland, DWD, Germany, FCHD-France and CAL-USA offer such functionality (see for instance DWD-Germany in **Figure 37**).

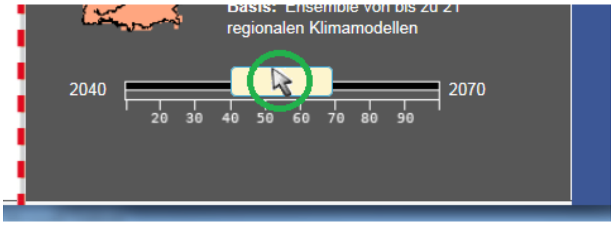


Figure 37: Slider from the “Klimaatlas” (source: DWD-Germany).

In order to highlight the change in glacier extent, NCA-USA provides an interactive tool for illustrative purposes (**Figure 38**). A slider allows to tee one or the other picture by moving the slider to the one side or the other. The pictures have been taken two times from the same vantage point and give a fast impression of the changes of the last 60 years in Alaska.

Figure 38: Interactive graphic for glacier extend from NCA - USA.
If slider is moved to the right, the extent of Muir glacier in August 1941 is shown (left figure). When the slider is moved to the left, the picture from August 2004 is presented (right figure) (source: NCA-USA).

5 Downloads

While some websites only display climate model data, others provide possibilities to download climate data as well. **Chapter 5.1** highlights what kind of climate model data and observational data can be downloaded and in what format they are available on which platform. A couple of platforms additionally offer downloads for high-resolution figures and texts (**Chapter 5.2**). In some cases, the websites provide information on how their climatological data should be acknowledged (**Chapter 5.3**).

5.1 Climatological data

This chapter highlights the different download possibilities for climate model data and observational data. These downloads are not always provided on the same website, but are rather linked to other external data-servers. Together with climate data, a few websites also provide instructions on how to use them and what the limitations are.

5.1.1 Climate model data

Nine platforms offer climate model data for download. As **Table 6** shows, most data are available as gridded data, or aggregated mean over a certain area. Only one third of the websites offer projections for selected stations. The most common formats are specialized formats such as NetCDFs (provided by five websites) or tabular formats (CSV, ASCII, xls or DAT – provided by seven websites). If projections are provided for download, it is offered at least for temperature and precipitation. However, most websites provide more variables and for different temporal resolution (**Table 6**).

Table 6 – Download possibilities for climate model data. Abbreviations: *RR*: precipitation, *CDD*: Maximum number of consecutive dry days (RR < 1mm), *RX1day:* Highest 1-day precipitation amount (mm), *TG*: Mean temperature, *TX*: Maximum temperature, *TN*: Minimum temperature, *SR*: Solar radiation, *FXx*: Maximum value of daily maximum wind gust, *FG*: mean daily wind speed, *RH*: Relative humidity, *PP* – Mean sea level pressure, *PET*: Potential evapotranspiration, *T2m dayVegStart5:* Start vegetation, *T2m dayVegEnd5:* End vegetation period, *T2m dayVegPeriod2:* Duration vegetation period.

	Data	Format	Variables	Temporal resolution				
				Annual	Seasonal	Monthly	Daily	Transient
CCA	station/gridded	NetCDF, CSV, JSON, ASCII	RR, TG, TX, TN, SR, FG, RH, PP, PET	X	X	X		X
UKCP	gridded	NetCDF, CSV, Shapefile	TG, TX, TN, RR, RH, PET, sunshine, CC, PP, longwave and shortwave flux, many more (Ocean)	X	X		X	X
SCS	aggregated	xls	TG, TX, TN, T2m nZeroCross, T2m dayVegStart5, T2m dayVegEnd5, T2m dayVegPeriod2, RR, R10mm,	X				
CCDS	gridded	NetCDF, GeoTIFF	RR, TG				X	
DRIAS	gridded/aggregated	NetCDF, ASCII	TX, TN, TG, RR, FG		X	X	X	X
KNMI	gridded	NetCDF	PET, RR, TX, TN, SR, TG			X		
CH2011	station/aggregated	CSV	RR, TG		X		X	
CPE	station/gridded	DAT	RR, TX, TN, evaporation, PP, soil moisture, runoff			X	X	
CAL	station/gridded	GeoTIFF,ASCII	PET, Baseflow, Fire, soil moisture, RR, TX, TN, RH, Runoff, Snow water equivalent, FXx	X		X	X	

CCA-Australia offer a suite of different variables and for individual models in different granularities. The (downscaled) projections come as change values, hence they are not combined with observational data. In addition, a special tool ("Projections Builder") is provided that mainly targets impact modelers: according to the main vulnerabilities of a particular impact system, the user can define a "best" and "worst" case scenario defined by the future changes of certain atmospheric variables. The tool then searches for three representative models out of the multi-model ensemble that best match the three scenarios (best case, worst case and maximum consensus). The most comprehensive download possibilities are offered by UKCP-UK. Their tool allows to download data from multiple sources: among others these are probabilistic projections of climate change over land and sea, weather generator simulations, projections of trend in storm surges and sea level rise. Depending on the simulation method, several variables (total of 50) can be chosen for different time periods, granularities and for different emission scenarios. Simulations from the weather generator are available on hourly scale and come as a grid at 5km. Quite a few websites offer multi-model output data of different variables. Examples thereof are KNMI-Netherlands, CAL-USA, CPE-Spain or DRIAS-France.

5.1.2 Observational data

Many platforms provide observational data for download. The amount of offered data, however, depends on data policies of the respective country. Four websites offer gridded datasets that are usually available as NetCDF files, while four websites provide station data that usually comes as CSV or xls files (**Table 7**). More than half of the data is homogenized or did undergo quality control.

Table 7 – Download possibilities for observational data. Abbreviations: *RR*: precipitation, *CDD*: Maximum number of consecutive dry days (RR < 1mm), *RX1day:* Highest 1-day precipitation amount (mm), *R10mm:* Heavy precipitation days (precipitation > 10 mm), *1-[XX]yR*: means a 1-in-XX-year daily precipitation (e.g. 1-20yR – means a 1-in-20-year extreme daily precipitation), *TG*: Mean temperature, *TX*: Maximum temperature, *TN*: Minimum temperature, *FD*: Frost days, *SR*: Solar radiation, *FXx*: Maximum value of daily maximum wind gust, *FG*: mean daily wind speed, *dir FXx* – direction maximum wind gusts, *RH*: Relative humidity, *PP* – Mean sea level pressure, *PET*: Potential evapotranspiration, *CC*: Cloud cover.

	Data	Format	Variables	Homogenized
UKCP	gridded	NetCDF, CSV	TG, TX, TN, FD, SR, FX, RR, RX1day, R10mm, PP, RH, CC	
EN	station	CSV	TG, RR, Sow, CC, FX, PP, wave height	Yes for TG
SCS	aggregated	xls	TG, RR	Yes
CGF	station	xls	TG, RR, 1-10yR, 1-20yR, 1-50yR, 1-100yR, 1-500yR	
CCDS	station	CSV	TX,TM, TG, heat deg. Days, RR, snow, dir FXx, FXx	TG, RR, PP, FG
DWD	gridded/station	CSV	FX, CC, RR, TG, TX, and TN	quality controlled
KNMI	gridded	NetCDF	TG, Evaporation, TX, TN, RR	
CAL	gridded	NetCDF, CSV	TG, TX, TN, RR, FXx	quality controlled

The list of providers that offer observational data for download comprises the Nordic countries, Germany, UK and North America. UKCP-UK link to the Met office, that provide datasets on annual, monthly and daily basis that go as far back as 1900. EN-Norway give free access to their climate database. The web portal is sophisticated and allows the download of simple lists of data, or complex analyses. Although it is not possible to get absolute values in a table format, CGF-Finland offer a table with return levels for precipitation for selected stations that have long and reliable time series. Depending on the station, CCDS-Canada provide downloads of raw data, or homogenized data in hourly, daily or monthly granularity for several variables (metadata is included). For each variable, a short explanation on the homogenization method, number of stations and the length of observational record are given. Since the 1st of July 2014, the DWD allows free access to most of their climate data. On their download portal, KNMI-Netherlands do not only provide projections, but also observational data, starting in 1961. CAL-USA link to a website that offers datasets of several variables, starting in 1949.

5.2 Figures and Reports

Besides data, several websites offer the possibility to download figures and maps in high resolution, usually as png. None of the climate services put a copyright sign on their figures. In addition, quite many websites offer written material for download and print. Usually the reports have a professional layout, with high quality graphics. The reports for DRIAS-France, FCHD-France, and CPE-Spain, however, come as simple Word-document. The website of NCA-USA is designed in a way, that the entire content can be downloaded in a printable format. In their technical report, CCA-Australia give explanations on data processing and present regional results in a brochure format. The majority of the providers of national climate change scenarios offer written material in the country-specific language. CCA-Australia is the only website that offers a few scientific papers directly for download. All the others only refer to them or provide the doi-numbers.

5.3 Terms of use and instructions of use

The majority of websites that offer climate data for download, condition the use of these data to the acceptance of the terms of use. Commonly the terms of use rule the restrictions of the data, as well as how data should be acknowledged. Almost all climate services provide the data for free for research (Universities, impact studies, schools) and private use, but prohibit it for commercial use. Additionally, often a login is required. Only CCA-Australia oblige the user to accept their terms of use for every download. The download usually comes with some instructions on how the data should be used and what the limits of these climate data are.

6 Guidance

To reach a broad public and to ensure that scenarios come into practice, guidance is an important leverage. It can also help preventing misuse and misinterpretation of the data. Many scenario platforms provide guidance in some way. In the following, the aspects are discussed where guidance is offered on the scenario platforms.

6.1 Structure of website

First of all, a good overall structure is important to guide the user through the full web-content. This varies a lot from website to website. Many of them structure their site either according to climatic processes / atmospheric variables, climate-affected sectors or geographical regions (see **Table 8).** The majority structure the website according to variables / processes. An example is the report from KNMI-Netherlands that discusses for each relevant variable/process the past and future characteristics, provide a comparison with the preceding report and information on changes in extremes and regional differences.

Table 8 – Structure of the websites.

	NCA	CCA	UKCP	SCS	EN	CGF	CCDS	CCCA	DWD	DRIAS	KNMI	CH2011	CPE	I2C	FCHD	MIRA	CAL
Sectors	X				X	X		X						X			
Regions	X	X															
Variables	X	X	X	X			X		X	X	X	X	X		X	X	X

5 out of 17 platforms structure their suite of climate scenarios according to sectors. The amount of sector-specific information, however, varies a lot among the websites. A structuring according to regions is provided by NCA-USA and CCA-Australia, only. These regions are either geographically outlined as in Australia or come as an aggregation of political states as in the US. Not many websites also offer the possibility to have a flexible structure. In fact, NCA-USA are the only ones that allow for a structure according to sectors, regions, and variables in parallel. Obviously, the structure of a scenario platform depends on its targeted user group and their specific needs.

6.2 Guidance through the website

6.2.1 Website-content at a glance

A common way of guiding through a website is a site-map, that gives a quick overview about the content and the way different sections are inter-linked. From the analyzed websites, NCA-USA, UKCP-UK, CCDS-Canada, CCCA-Austria and CPE-Spain provide such functionality.

CAL-USA provide an overview of the website content at the bottom of every page with links to the covered topics (**Figure 39**).

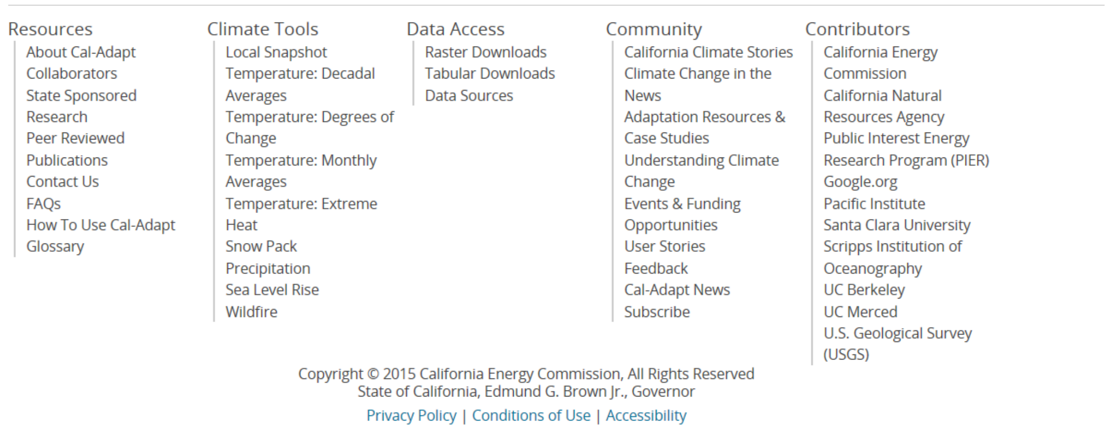


Figure 39: Example of an overview of the website content from CAL-USA (source: CAL-USA).

CCA-Australia provide overview tables about their tools and data availability (see **Table 9**). Each tool is briefly introduced together with a rating on the required knowledge.

Table 9 – Excerpt of an overview table about the tools and data-availability from CCA-Australia (source: CCA-Australia).

Tool	Rating	Description	Variables	View	Download
Regional Climate Change Explorer	Basic	View regional summary information about future climate and key messages	Mean temperature Rainfall Extreme Temperature Extreme Rainfall Drought Marine and Coastal	x	
Climate Analogues	Basic	Find locations whose current climate approximates the future climate at your location.	(Based on changes in temperature and rainfall)	X	
Summary Data Explorer	Basic	View bar plots of multi-model regional-average seasonal changes in eight variables	Mean Temperature	x	x

6.2.2 Decision Trees

Functionally similar, but more sophisticated than simple site-maps are "decisions trees" or "getting started" functions. A decision tree helps the user to find the desired content within a complex website. It guides the user with proposed questions to the desired information. A rather simple example of a decision tree is shown for UKCP-UK in **Figure 40**. The sentences cover a wide spectrum of topics and/or differentiate between different types of users. The flow of questions is structured according to the complexity of user need. While for the first few questions information can be directly offered by graphical and textual material on the website, it is more complex for the later questions: here, detailed instruction on how to use, are might needed when someone downloads climate scenario data.

Getting started

1) I am looking for weather forecasts or warnings for my area
2) I want to get a simple overview of how the climate may change in my area
3) I want to raise awareness of climate change
4) I want to find information on climate change in the marine environment

Understanding climate risk

5) I want to better understand my organisation's exposure to climate risk
6) I want to make the case to others in my organisation of the importance of climate change adaptation
7) I want to conduct a high-level assessment of climate risk

Detailed climate projections and climate adaptation strategies

8) I want detailed information about how the UK climate might change in the future
9) I want to conduct a detailed, quantitative climate impacts or risk assessment

Figure 40: Excerpt of a decision tree from UKCP-Great Britain. In total, eleven questions guide the user to the desired information (source: UKCP-Great Britain).

In a similar way, CCA-Australia provide a more sophisticated decision tree (see Appendix, **Figure 45**).

6.3 Guidance through tools and graphics

To understand the essence of graphics and/or to correctly use the presented tools, an interpretation help is sometimes indispensable. In the following, we summarize the measures taken by the investigated scenario platforms to help the users in this direction.

The easiest and most commonly applied way of helping on graphics is a classical legend to the shown figure. This is commonly provided in text format and resembles figure legends in scientific journals. The legend informs on the shown axes, colors, symbols and other entities that would not be understood by just looking at the figure. The websites from SCS-Sweden or DRIAS-France are good examples of conveying the information in this way.

Another way of guidance through tools is to help in form of a manual. For complex tools this step is rather complex at first sight. For example, CCA-Australia provide help (as text below the tool) for a correct setup (e.g. select emission scenario, season or region), navigate and reading the map (zoom, region selection etc.), how to download the data, methods what were used with links to the technical report, as well as providing information on the main limitations.

Explanations on graphical display are sometimes also provided in an interactive way. For instance, the tools of FCHD-France have a help-button in the lower right part of the plot that provides the user additional explanations on the shown content (see **Figure 41** as an example). The help functionality is implemented as a help menu. This means that the user can click through the menu that walks the user through the plot with various information levels. During the help menu, parts of the plot are fading out again and other parts get highlighted.

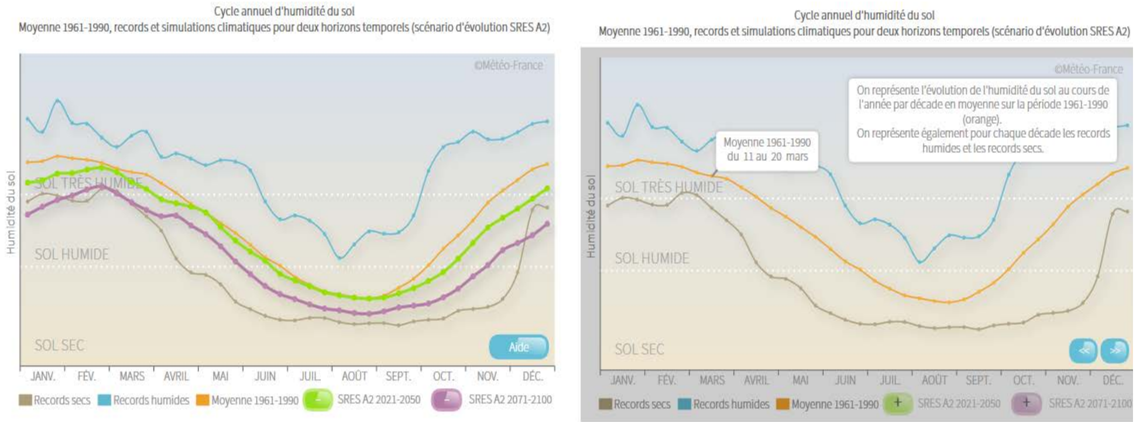


Figure 41: Example of an interactively implemented help. By clicking on the help button ("Aide"), text information on the plot details appears (right panel) (source: FCHD-France).

6.4 Assessment of complexity

A channeling of the website information according to the users' level of knowledge helps to better reach the website users with appropriate information. Only a few websites offer such a complexity assessment of the provided information. DRIAS-France for instance specifically display information on future climate change for beginners and for experts. The beginner's section displays maps of future temperature and precipitation change according to different emission scenarios and different time-periods. The information is shown as panel plots with explanatory texts. All shown changes are based on just one single model (Aladin). The expert's section on the other hand gives the user the possibility to create their "own" map with a multitude of selections such as indices/variables, time horizons, emission scenarios, climate models, percentiles of multi-models etc. It is only in the expert section that they provide information on climate changes based on an ensemble of models (CORDEX).

CCA-Australia provide a complexity rating of their tools they present on their website. The categories reach from beginner to intermediate and to expert. The indication of the specific rating is made for each tool. Below is an overview of all their presented tools ordered by complexity:

Table 10 – Overview of the different tools, offered by CCA-Australia and their corresponding rating. Each tool is linked to the website. The rating is the same that is shown for every tool in the upper right corner.

	BASIC	INTERMEDIATE	ADVANCED
Tools	Summary data explorer Extremes data explorer Climate futures exploration tool Climate analogues	Map explorer Time series explorer Thresholds calculator Projections builder Climate futures comparison tool	Detailed projections

By splitting the climate information into “Highlights” and “Full Report”, NCA-USA also channel the information according to the level of complexity.

6.5 Best practices / limitations

Many websites also provide information on how their climate projections should be used and what the limitations are. The support usually starts with basic information and recommendations on how to use climate projections. UKCP-UK point out the difference between projections and a prediction and that finer modelling resolution does not give greater confidence. Furthermore, difficulties with the provision of uncertainties in climate projections are highlighted. Something very similar is provided by CCA-Australia in their online training. A few words on uncertainty and how climate projections should be used are also given by CAL-USA for their tools in the “Disclaimer and Uncertainty” section.

Some websites make the user aware of the danger when only downloading/using a single model. The strongest warning is issued by CCA-Australia, with a disclaimer in a pop-up window that the user needs to agree with (see **Figure 42**).

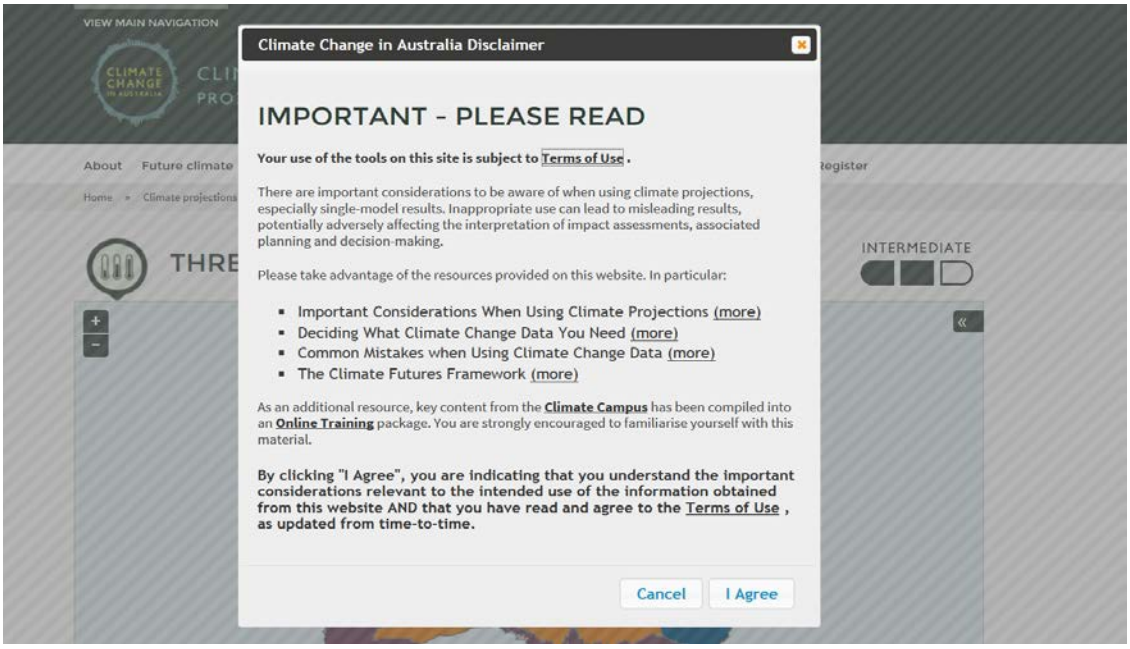


Figure 42: Warning of use of single model data by CCA-Australia.
The use of single model information can pose difficulties, when it comes to interpretation. Because of that, users have to agree to the terms of use, before they can access the tool (source: http://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/).

Only very few climate services link to studies that used their data. CAL-USA and UKCP-UK link to different case studies that used the same projections as they provide. KNMI-Netherlands also present impact studies that are based on KNMI’s projections. With their data, they show how climate change will influence several important sectors.

6.6 Training and User consultancy

Three examined websites provide online trainings as a mean to educate, help and guide users.

CCA-Australia provide an online training that covers the topics of the climate system and climate projections in general. Further topics are how to use the available projections and one tutorial is specifically targeted to a complex tool that attempts to provide the appropriate climate projections for an impact assessment ("climate futures tool"). Each module leads through the different aspects of the respective topic.

An e-learning tool leads through seven different modules at the website of UKCP-UK. Besides educational aspects such as adaptation, mitigation and climate projections, they help on how to consult the User Interface and how to use the UKCP09 Marine Projections. Also CAL-USA provide an online course that mainly focuses on the causes and consequences of climate change, as well as possible solutions to counteract. The training is regularly updated and contains quizzes and exams.

Some websites actively promote users to get in contact and frame their problem. The contact can be done via e-mail or phone to a first contact point. For instance, CH2011-Switzerland provide the contact address info@ch2011.ch, where users can place their specific requests. Other websites such as DRIAS-France provide an online form to get into contact and leave a message. Instead of providing a general contact, for scientific questions CAL-USA ask the users to direct their questions to the different institutes Cal-Adapt is made of.

7 Education

7.1 Content of background information

The websites that have an education section explain Earth's climate in general, its system components and the important role of greenhouse gases. In addition, information on causes for the anthropogenic climate change (greenhouse gases, land use change, aerosols, etc.) is usually provided. An additional common topic is the explanation of the modeling chain down to local climate projections. Although many websites provide information on observed climate, only CGF-Finland, CCCA-Austria and DWD-Germany introduce the readers to how different climate variables are measured and what errors one commonly needs to deal with.

A few websites also touch the causes of uncertainty. CCA-Australia dedicate an entire subchapter to uncertainty sources in regional climate projections. CCA-Australia, KNMI-Netherlands, CH2011-Switzerland and CPE-Spain further disentangle model uncertainty and natural variability. Furthermore, KNMI-Netherlands added a educative graphic of measured variations of coldest and warmest temperature observed at different temporal granularities (see **Figure 43**). This is a promising way to illustrate the concept of natural variability.

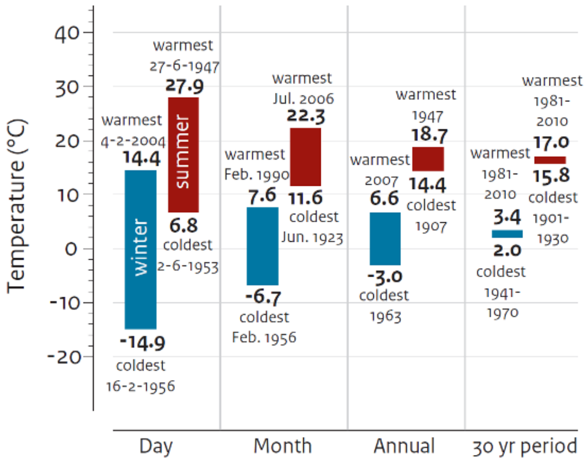


Figure 43: Measured variations of maximum and minimum temperature in the Netherlands (De Bilt).
The longer the time period is, the smaller is the difference between the mean of the measurement period (source: KNMI 2015, p. 9).

9 out of 17 websites give sector-specific climate information. However, the amount of information varies among the reviewed websites. Those that cover this user-relevant topic either provide a number of links to other specialized websites in this field (e.g. CCA-Australia) or they summarize the main expected impacts as a literature review (e.g. CCCA-Austria or NCA-USA). The topics of climate impacts depend on the vulnerability within the specific country. No information on sector-specific impacts of climate change is given on the other websites.

7.2 Format of education

Education is normally provided in the form of text. The most popular formats are glossaries, Frequently asked questions (FAQ)s, but also figures and videos are often used (**Table 11**).

Table 11 – Different formats of education. All investigated climate services provided some kind of educational information (e.g. uncertainty or impact of climate change). Usually the information is provided in texts. In addition to that, some websites also use other formats.

	FAQ	Glossary	Graphics	Videos
NCA	X		X	
CCA	X	X	X	X
UKCP	X and Help			
EN			X	X
CGF				X
DWD			X	
DRIAS	X	X		
I2C		X		
CAL	X	X		

The full list of climate-related FAQs (merged among the analyzed websites) can be found in the appendix together with the corresponding links to the website. Four websites provide a glossary. Besides the definition itself, they additionally provide a link where more information can be obtained. A merged list of terms explained can be found in Appendix. Graphics and videos can also help to illustrate the information that is given in texts. CGF-Finland present around 40 videos of different topics, where researchers present their latest results. Among other topics, the short video clips describe climate change as a phenomenon, the impacts of climate change, as well as mitigation and adaptation to climate change. In 3-6 minutes, researchers describe theirs research topics, applied methods, key findings and what their results imply.

Additional background information often stems from external studies. These studies are not always cited in a scientific way. These websites solely put a literature list at the bottom of the respective text. Some websites do not cite at all, while others provide in-text citations.

8 Communication

8.1 News / Blog / Newsletter

Only a few websites have a newsfeed on their website. CGF-Finland publish news on their start page and inform about current news, such as climate-policy relevant developments (e.g. COP 21) but also about new research findings. A similarly updated news section is provided by CCCA-Austria. Besides CAL-USA, they are the only climate service with a prominent offer for a newsletter. MIRA-Belgium and CAL-USA have a news-section as well, but they are only related to updates of the website/report. DWD-Germany publish news via Twitter.

So far, none of the analyzed websites has a blog functionality integrated. However, CAL-USA encourage users to provide feedback on the climate projections via an online form. In addition, users have the possibility to report on studies they have conducted with the climate data given by CAL-USA. This information will be then used to present case studies for the general public.

8.2 Key messages

Quite a few websites and reports provide results as key messages. These messages generally consist of only 2-3 sentences summarizing the main content of a particular aspect (e.g. NCA-USA). NCA-USA derived these messages from intense discussion among the lead-authors in workshops (NCA-USA 2016). Similar statements can also be found on the websites from EN-Norway, I2C-Germany and in the reports CH2011-Switzerland and KNMI-Netherlands.

Some examples of key messages from these four websites are:

- *“Global climate is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth’s climate is to those emissions.”* – NCA-USA
- *“The nature of extreme events is expected to change, with potentially far-reaching impacts on society, economy and ecosystems.”* – CH2011-Switzerland
- *“There will be more precipitation in Finland in the future.”* – CGF-Finland
- *“The warming results are robust, with 100% model agreement.”* – I2C-Germany

8.3 Online tools for communication purposes

Nice graphical tools can be used for communication purposes to illustrate climate change and to convey a certain message. Usually, these tools are very intuitive for the users and can be regarded as an online-game. CAL-USA link to the educating website http://climatechangecourse.org/ which provides online courses, daily mini-lectures, data visualizations, quizzes and even exams.

CGF-Finland have a tool that calculates the lifetime temperature for a given date of birth (see **Figure 44**). First, it shows the measured temperature from birth to the actual year. Then, the period of the remaining work years are shown, followed by the years of retirement. Then, temperature rise that a today-born child could see in its lifetime is shown, as well as the course of temperature, if greenhouse gas emissions are not reduced. Assumptions are made under the RCP8.5 emission scenario.

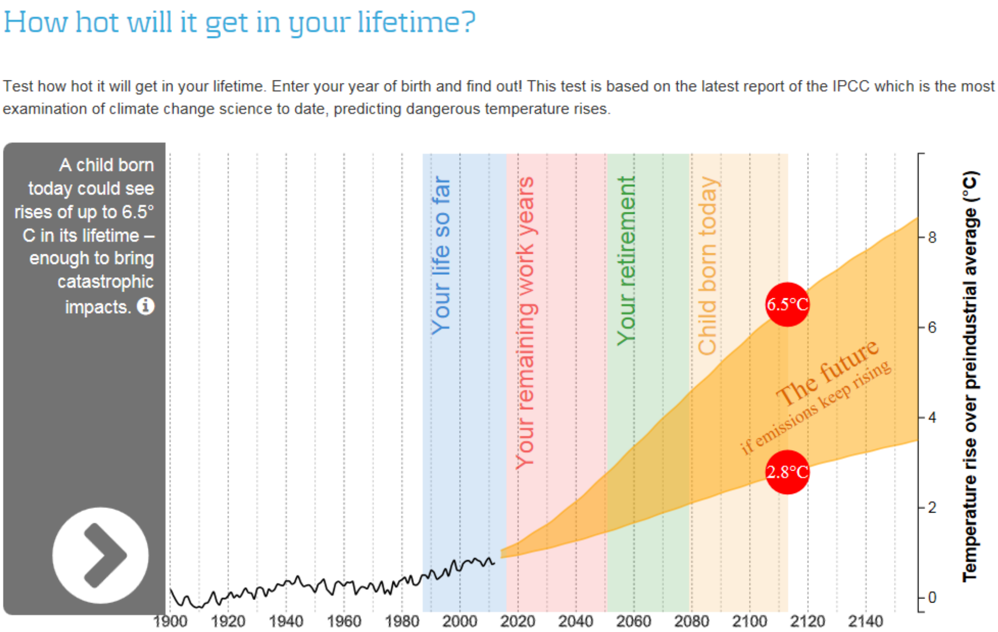


Figure 44: Lifetime temperature calculator.
First, the user has to insert his year of birth. Then for every klick of the user, the tool shows the range of temperature. In the example above, the temperature range for a child that is born today, will be between 2.8 and 6.5°C at the end of his/her lifetime (source: CGF-Finland).

9 Synthesis

Aim of this synthesis is to summarize and rate the examined scenario platforms according to the different topics in chapters 3 to 8. The following grades (number of stars) have been used: ★ very bad, ★★ bad, ★★★ moderate, ★★★★ good and ★★★★★ very good

The rating itself comes as a subjective assessment by the authors of the report. However, emphasis is put on the balanced view of all aspects of the different categories. **Table 12** shows the rating of all platforms according to the respective category. In addition, the accessibility of each website has been evaluated with a simple web search using google. Note that the rating could not be done for all categories and platforms, as some websites lack the respective content. This particularly concerns guidance and graphical tools for quite a few platforms that merely published their report on the website (indicated by “NA” in **Table 12**).

Table 12 – Rating of the different categories of the websites: ★ very bad, ★★ bad, ★★★ moderate, ★★★★ good and ★★★★★ very good. “NA” indicates that the platform does not provide the respective content. The categories correspond to chapters 4-9 of this report. Accessibility describes how easy the platform can be found on the internet.

	Scenarios	Graphics/Tools	Downloads	Guidance	Education	Communication	Accessibility
NCA	★★★	★★★	★★	★★★	★★★★	★★★	★
CCA	★★★★	★★★★★	★★★★	★★★★	★★★★	★★	★★★★★
UKCP	★★★★	★★	★★★★★	★★★★	★★★	★★	★★★★★
SCS	★★★★	★★★	★★★	★★	★★	★★	★★★★★
EN	★★	★★	★★★	★★	★★	★★★	★★★★★
CGF	★★★	★★★	★★	★★	★★★	★★★★	★★★★★
CCDS	★★★	★★★	★★★★	★★	★★	★★	★★★★★
CCCA	NA	★★	★	NA	★★★★★	★★★	★★★
DWD	★★★	★★★	★★★	★	★★★	★★★	★★★
DRIAS	★★★★	★★★	★★★	★★★	★★	★★	★
KNMI	★★★★	★★★	★★★	NA	★★★	★★★	★★★
CH2011	★★★★	★★★	★★★	NA	★★★	★★	★★★
CPE	★★★★	★★	★★	NA	★★★	★★	★★★
I2C	★★★	★★	★	★★★	★	★★★	★
FCHD	★★★	★★★	★	★★	★★	★★	★★★
MIRA	★★★★	★★	★★	NA	★★★	★★★	★★★
CAL	★★★	★★★	★★★★	★★★★	★★	★★★	★★★

In the following, we discuss the ratings of the more sophisticated websites that also have received a high rating through all categories.

On the whole, CCA-Australia receive the highest rank across all categories. They offer a wide range of aspects in climate scenarios, present the most sophisticated graphical tools, many download possibilities, large emphasis on practical guidance and the website can also be found quickly through google. Downsides of the websites are the sparse use of communication means and that only little sector-specific information is given. Although UKCP-UK offer only static and basic graphics, their website is full of relevant climate change information. The excellent download possibilities, a wide scope of the provided climate scenarios, emphasis on good guidance and very good accessibility puts the website on number 2 of the total ranking. CAL-USA come with the most elaborated interactive tools with a number of intuitive functionalities for the user. They also provide relatively good download possibilities and guidance. One downside is the lack of educational background information. In contrast, CGF-Finland cover a broad range of background information about climatic impacts. In addition, the website keeps their user up-to-date with a news section that even includes videos. However, climate projections cannot be downloaded and the website does not offer a site-map / overview or additional guidance. SCS-Sweden present simple but effective maps with CORDEX-simulations. The guidance and communication possibilities are rather basic, but quite instructive. A moderate ranking is presented for DWD-Germany, although their main tool is very nicely done. With its comparison to the norm period and to the actual year, it gives a unique impression on the expected climatic changes. The reason for the lower ranking, though, is a rather low level of guidance, the lacking possibility to download climate data and the absence of sector-specific information. Also NCA-USA receive a moderate ranking. This is because no data download is possible and because the accessibility is very poor. DRIAS-France and FCHD-France do not only present the same data, but are also arranged similarly. Both of them do not (or only sparsely) provide background information. While FCHD do not offer downloads, users can download CORDEX simulations from DRIAS.

In the following, the key ingredients of the ten most elaborated scenario platforms are recapitulated with subjective statements by the authors:

US- National Climate Assessment (NCA-USA)

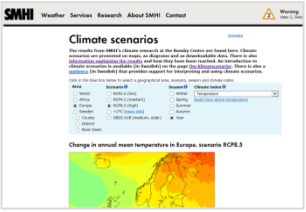
- Very well designed website with floating pictures in the background
- Website obviously puts large emphasis on communication by providing key messages and easy-to-understand figures
- Structure according to variables, sectors or regions
- Nicely made graphics that are particularly attractive for beginners. Some tools provide interaction possibilities
- Download possibilities are restricted to figures and the report

Climate Change Australia (CCA-Australia)

- Very well designed website with a tremendous amount of functionalities implemented
- Structure according to variables; printable material available according to regions (cluster reports) and as technical report
- Comes with the most sophisticated tools of all analyzed websites
- Possibility to download a large number of local projections in different data formats
- A lot of emphasis is put on guiding the users through complex tools and functionalities. Includes also a lot of background information
- A downside of the website is the overall structure. As it is full of information, the user potentially gets lost. Almost no information on impacts available

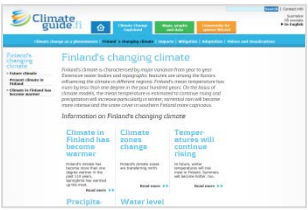
UK Climate Projections (UKCP-UK)

- Come with a large amount of information and graphics
- No interactive tools are provided
- Provide excellent download possibilities for projections, observations and reports
- A user is well guided through this website and gets relevant information to interpret the shown graphics
- Communication with the user is relatively sparse and only an email is provided



SMHI Climate scenarios (SCS-Sweden)

- A rather simple but pragmatic website that provides as main tool a browser to display map output
- Their tool allows the user to interact with the graphic and display time-series for differently defined spatial regions
- Guidance and interpretation of the graphics is provided as text
- Projections can be downloaded as annual and spatial means for Sweden in xls-format
- Background information on climate change related aspects is rather rudimentary
- Contact section provides telephone, email, and fax



Climate guide Finland (CGF-Finland)

- Interactive tool shows basic multi-model output and time series. Functionality to display bi-variate changes
- Guidance through website and tools is generally poor
- Put emphasis on keeping the website up-to-date with news on front page, key messages and a large number of videos

Canadian Climate Data and Scenarios (CCDS-Canada)

- Provide projections in parallel from CMIP3 and from CMIP5
- Basic ensemble output is shown with information on multi-model spread
- Large download section with the possibility to download for every coordinate climate model output for several variables. The data of previous CMIP3 model runs is available, too
- Although a site-map is provided, the website-structure is rather chaotic and not much guidance is provided
- The background information is also rather poor

DWD Deutscher Klimaatlas (DWD-Germany)

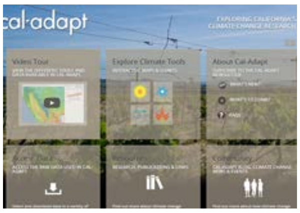
- So far only RCM simulations from ENSEMBLES (A1B emission scenario) are provided
- Nice tool that allows to compare the expected changes with respect to the reference period, and a particular year
- Download possibilities and guidance are rather poor
- Put emphasis on climate modelling as background information
- Enable news via Twitter and regular contact possibilities (telephone, email, fax)
- Also contain news on the front page. Telephone and email to contact

DRIAS Meteofrance (DRIAS-France)

- Structured according to variables
- Display of CORDEX-data for a large number of variables and three time intervals
- Tool shows multi-model output and percentiles. Several maps are shown and allow to compare time periods, emission scenarios or percentiles
- Website offers to download CORDEX simulations for various variables and timescales as NetCDF- and ASCII files
- Front page channels beginners and experts.

Climat^{HD} (FCHD-France)

- Structured according to variables
- Integrates a number of nicely made interactive tools
- No data download is available
- Excellent interpretation help for graphics
- Information on climate modelling and observed changes



Cal-adapt California (CAL-USA)

- Nicely designed website with a huge amount of functionalities
- Tools show basic ensemble output, but with interactive functionalities
- Website offers many download possibilities
- Good guidance and structure of the website
- Educational background information is rather poor and only a few topics are covered
- The website shows news, sends newsletter and provides contacts (Email, contact of researchers)

Abbreviations

CAL-USA	California Adaptation
CCA-Australia	Climate Change in Australia
CCCA-Austria	Climate Change Center Austria
CCDS-Canada	Canadian Climate Data and Scenarios
CDD	Maximum number of consecutive dry days (RR < 1mm) (days)
CGF-Finland	Climate Guide Finland
CH2011-Switzerland	Swiss Climate Change Scenarios CH2011
COP 21	21st Conference of the Parties
CPE-Spain	Climate projections for the XXI century en España
CSDI	Cold spell duration index
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DRIAS-France	DRIAS Meteofrance
DWD-Germany	Deutscher Wetterdienst
EN-Norway	Environment Norway
FAQ	Frequently asked questions
FCHD-France	ClimatHD Meteofrance
FD	Frost days
FG	Daily averaged wind
GCM	Global circulation model
I2C-Germany	Impact2C
ID	Ice days
IPCC	Intergovernmental Panel on Climate Change
KNMI-Netherlands	KNMI’14 climate scenarios for the Netherlands

MIRA-Belgium	Milieurapport Vlaanderen (Belgium)
NCA-USA	National Climate Assesment USA
NCCS	National Center for Climate Services
PET	Potential evapotranspiration
RCM	Regional climate model
RCP	Representative Concentration Pathways
RH	Relative humidity
RR	Precipitation sum
SCS-Sweden	Swedish Climate Scenarios
SDSM	Statistical DownScaling Model
SMHI	Swedish Meteorological and Hydrological Institute
SR	Solar radiation
SRES	Special Report on Emissions Scenarios
SU	Summer days
TG	Mean temperature
TN	Minimum temperature
TR	Tropical nights
TX	Maximum temperature
UKCP-UK	UK Climate Projections
WMO	World Meteorological Organization
WSDI	Warm spell duration index

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Appendix

Decision tree (CCA-Australia)

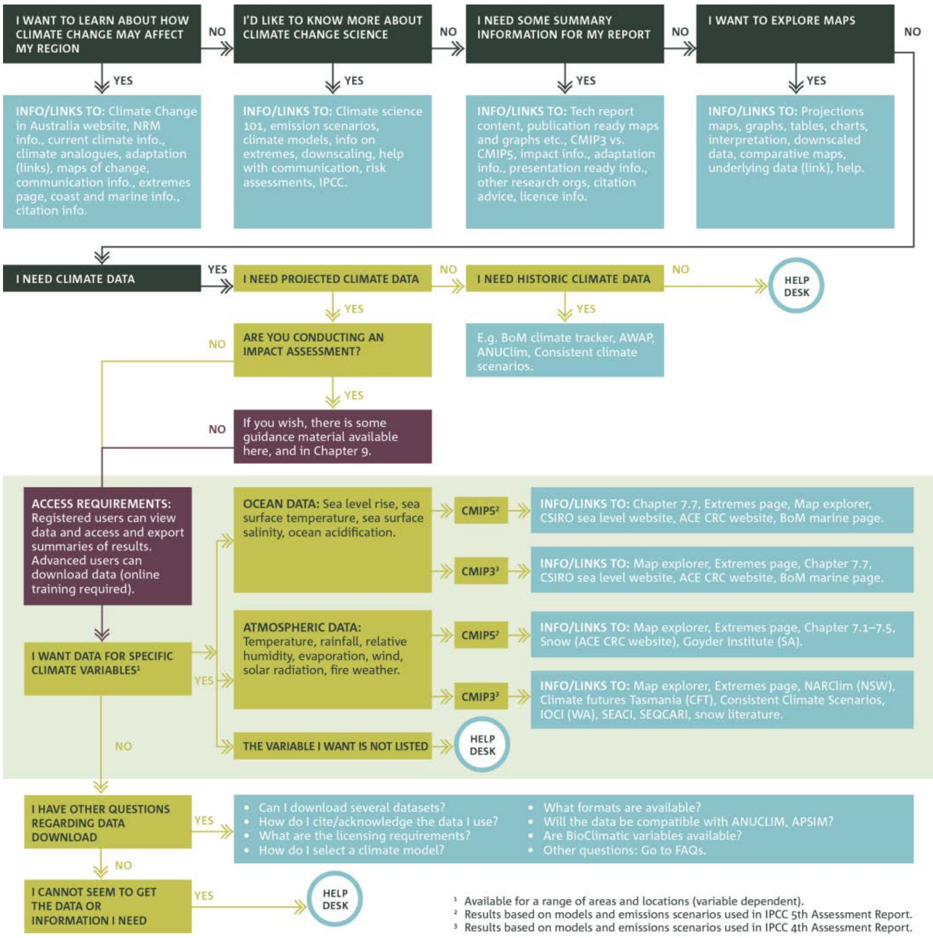

Figure 45: Structure of the decision tree from CCA-Australia. The top questions are marked in black It first tries to direct the user with the help of five top questions to the desired content. The five questions are arranged again in order of complexity of the user need. The most complex pathway is if climate data are needed (fifth question). After having chosen one of the five pathways, a suite of subsequent questions is posed. In case of climate data the next two differentiations are whether the user needs historic or projected data. For the example given, it is then the question whether the user needs the data for an impact assessment. If not, the specific variable of need is evaluated and finally linked. Interestingly, the decision tree gives in any case a link to a "Help Desk", where the request can be placed. (source: CCA-Australia).

Combined Frequently Asked Questions (FAQs)

Comprehensive collection of questions that were asked in the FAQ-section on the websites CCA-Australia, CAL-USA, UKCP-UK and NCA-USA:

Questions on **interpreting future climatic change** with the past or with current climate:

- Climate is always changing. How is recent change different than in the past? – (NCA-USA)
- Is it getting warmer at the same rate everywhere? Will the warming continue? – (NCA-USA)
- How is climate projected to change in the future? – (NCA-USA)

Questions on the **causes of the change**:

- How can the small proportion of carbon dioxide in the atmosphere have such a large effect on our climate? – (NCA-USA)
- Could the sun or other natural factors explain the observed warming of the past 50 years? – (NCA-USA)
- Is the climate changing? How do we know? – (NCA-USA)
- How do we know that human activities are the primary cause of recent climate change? – (NCA-USA)
- What is and is not debated among climate scientists about climate change? – (NCA-USA)
- Are there ways to reduce climate change? – (NCA-USA)
- Are there advantages to acting sooner rather than later? – (NCA-USA)
- Can we reverse global warming? – (NCA-USA)

Questions on **background knowledge**:

- What is a projection? – (CAL-USA)
- What is a Scenario? – (CAL-USA)
- What is uncertainty? – (CAL-USA)
- What is ocean acidification? – (NCA-USA)
- What are Climate Change "Impacts?" – (CAL-USA)
- What does "Vulnerability" mean with respect to Climate Change? – (CAL-USA)
- What does "Adaptation" mean with respect to Climate Change? – (CAL-USA)
- Are there tipping points in the climate system? – (NCA-USA)
- How can I learn more about climate change science? – (CCA-Australia)

Questions on **methodologies** to produce projections:

- How were the models for which application-ready data selected? – (CCA-Australia)
- How are the models used in UKCP09 weighted, and how sensitive are the projections to this weighting? – (UKCP- UK)
- How does UKCP09 model sea level rise? – (UKCP-Great Britain)
- How have Cooling Degree Days (CDD) and Heating Degree Days (HDD) been calculated in UKCP09? – (UKCP- UK)
- Where does Cal-Adapt's data come from? – (CAL-USA)
- What methodology was used to generate Potential Evapotranspiration in the 11-member RCM? – (UKCP- UK)

- Why is the baseline period for the sea level rise projections different from the UKCP09 1961-1990 baseline? – (UKCP- UK)
- Why are the storm surge, sea level waves and multi-level ocean projections not probabilistic? – (UKCP- UK)
- Where can I find out more about how the Climate Data used in the site were developed? – (CAL-USA)

Questions on **climate model parameterization**:

- Are the projections at sea level or are local topographical effects taken into account? – (UKCP- UK)
- Do the projections include intense convective rainfall such as occurs in thunderstorms? – (UKCP- UK)
- Does UKCP09 consider changes to the Gulf Stream (Meridional Overturning Circulation)? – (UKCP- UK)
- How are the estimates of land movement used in the relative sea level projections derived? – (UKCP- UK)
- What atmospheric processes and feedbacks are included in the UKCP09 modelling? – (UKCP- UK)

Questions regarding the **reliability and robustness** of the projections and process understanding:

- What are the key uncertainties about climate change? – (NCA-USA)
- How can we predict what climate will be like in 100 years if we can't even predict the weather next week? – (NCA-USA)
- How reliable are the computer models of the Earth's climate? – (NCA-USA)
- Is the global surface temperature record good enough to determine whether climate is changing? – (NCA-USA)
- What are the sources of uncertainty in the Marine & coastal projections? – (UKCP- UK)
- What uncertainties exist with the sea level rise and storm surge projections? – (UKCP- UK)

Questions on **organizations and climate services**:

- What is the IPCC? – (CAL-USA)
- What does Cal-Adapt do? – (CAL-USA)
- What doesn't Cal-Adapt do? – (CAL-USA)
- Where does Cal-Adapt fit in with other initiatives? – (CAL-USA)
- How was Climate Change in Australia funded? – (CCA-Australia)
- Why did we develop Cal-Adapt? – (CAL-USA)
- What is Climate Change in Australia? – (CCA-Australia)

Questions on **consequences of climate change:**

- Is Antarctica gaining or losing ice? What about Greenland? – (NCA-USA)
- Does climate change affect severe weather? – (NCA-USA)
- How are the oceans affected by climate change? – (NCA-USA)
- How is climate change affecting society? – (NCA-USA)
- Are some people more vulnerable than others? – (NCA-USA)

- What can I use to assess current and near-term vulnerabilities, impacts, risks and adaptation? – (UKCP- UK)
- Are there benefits to warming? – (NCA-USA)
- How will climate change affect my region? – (CCA-Australia)

Questions on **website-content-specific questions**:

- How do I access climate projections data? – (CCA-Australia)
- How can I explore transient future climate and changes throughout the 21st century? – (UKCP-UK)
- What resources and help are available on the use of UKCP09? – (UKCP- UK)
- How can I find out more about new features and data sets that are planned to be added to Cal-Adapt? – (CAL-USA)

Questions on **data format**:

- How do I use NETCDF files in the ARCGIS program? – (CCA-Australia)
- I want to access the NRM regionalisation schemes shapefiles – (CCA-Australia)
- How do I open ".tgz" files downloaded in the raster download tool? – (CAL-USA)
- How can I view Raster data that I download from Cal-Adapt? – (CAL-USA)

Questions on **data application**:

- How do the uncertainties help in decision-making? – (UKCP- UK)
- How do I investigate data for different temporal averaging periods? (e.g. months, seasons, 30-year time periods)? – (UKCP- UK)
- How might the modelling assumptions alter the conclusions reached? – (UKCP- UK)
- Which probability level should I choose? – (UKCP- UK)
- How can I deal with changes in UK since the 1961-1990 baseline period? – (UKCP- UK)
- What does the frequency distribution associated with the sea level projections actually mean? – (UKCP- UK)
- How can Cal-Adapt be used? – (CAL-USA)

Questions on **referencing**:

- How do I cite the website and its resources? – (CCA-Australia)
- How do I acknowledge use of the UKCP09 maps? – (UKCP- UK)
- Can I use images and graphs found on this site? – (CCA-Australia)
- Am I able to reproduce and publish maps and images from the UKCP09 reports and User Interface? – (UKCP- UK)

Questions on **technical issues** with the website:

- The website is appearing incorrectly in my browser, what should I do? – (CCA-Australia)
- How do I load the observed trends gridded data into ArcGIS? – (UKCP- UK)

Combined Glossary

A2 – CAL-USA

Adaptation – CCA-Australia, DRIAS-France, CAL-USA

Adaptive Capacity – I2C-Germany

Aerosols – CCA-Australia

Analogues – DRIAS-France

Anomaly – I2C-Germany

Anticyclones – UKCP-UK

Aragonite saturation state – CCA-Australia

Atmosphere – CCA-Australia

B1 – CAL-USA

Baseline Period – I2C-Germany/ UKCP-UK

Blocking – UKCP-UK

Carbon dioxide – CCA-Australia

CDF data – UKCP-UK

Carbon uptake – I2C-Germany

Climate – CCA-Australia

Climate change – CCA-Australia/ DRIAS-France

Climate data – DRIAS-France

Climate feedback – CCA-Australia/ I2C-Germany

Climate model – DRIAS-France/ I2C-Germany

Climate projection – CCA-Australia/ DRIAS-France/ I2C-Germany/ UKCP-UK

Climate scenario – CCA-Australia/ DRIAS-France

Climate sensitivity – CCA-Australia

Climate service – DRIAS-France

Climate system – I2C-Germany

Climate variable – I2C-Germany

Climate variability – CCA-Australia/ DRIAS-France

Cloud condensation nuclei – CCA-Australia

CMIP3 and CMIP5 – CCA-Australia

Cold spell – I2C-Germany

Coldest day of the season – UKCP-UK

Coldest night of the season– UKCP-UK

Confidence – CCA-Australia/ UKCP-UK

Cryosphere – I2C-Germany

Data sets – I2C-Germany

Decadal variability – CCA-Australia

Detection and attribution – CCA-Australia

Downscaling – CCA-Australia/ DRIAS-France/ UKCP-UK

El Niño Southern Oscillation (ENSO) – CCA-Australia/ UKCP-UK

Emissions scenario – CCA-Australia/ DRIAS-France/ UKCP-UK

Ensemble – I2C-Germany/ UKCP-UK

EURO-CORDEX – I2C-Germany

Evapotranspiration – I2C-Germany
Experiment – DRIAS-France
Extreme weather – CCA-Australia/ UKCP-UK
Fire weather – CCA-Australia
Freeze-thaw days – I2C-Germany
Global Climate Model or General Circulation Model (GCM) – CCA-Australia/ CAL-USA/ UKCP-UK
Gradient – I2C-Germany
Grid – I2C-Germany
Greenhouse gas – CCA-Australia
Gulf stream (Atlantic Ocean Circulation – UKCP-UK
Hadley Cell/Circulation – CCA-Australia
Hail – UKCP-UK
Heat wave – I2C-Germany
High emission scenario – UKCP-UK
Hydrosphere – I2C-Germany
Impacts – CAL-USA
Impact model – DRIAS-France
Indian Ocean Dipole (IOD) – CCA-Australia
Inter-decadal Pacific Oscillation – CCA-Australia
Intergovernmental Panel on Climate Change (IPCC) – I2C-Germany/ CAL-USA/ UKCP-UK
Jet stream – CCA-Australia
Latent heat flux – UKCP-UK
Long-term carbon storage – I2C-Germany
Low emission scenario – UKCP-UK
Madden Julian Oscillation (MJO) – CCA-Australia
Mean daily temperature – UKCP-UK
Medium emission scenario – UKCP-UK
Mitigation – DRIAS-France
Model output – DRIAS-France
Model spread – I2C-Germany
Modelling uncertainty – UKCP-UK
Monsoon – CCA-Australia
Multi model ensemble – I2C-Germany
Natural variability – I2C-Germany
Observed data – UKCP-UK
Parametrization – DRIAS-France
Percentile – CCA-Australia/ I2C-Germany/ UKCP-UK
Precipitation – UKCP-UK
Probabilistic climate projection – UKCP-UK
Projection – DRIAS-France/ I2C-Germany/ CAL-USA
Quantile-quantile correction – DRIAS-France
Radiative forcing – CCA-Australia/ DRIAS-France
Rain – UKCP-UK
Reanalysis – I2C-Germany

Reference Period – I2C-Germany
Regional model – DRIAS-France/ UKCP-UK
Representative Concentration Pathways (RCPs) – CCA-Australia/ I2C-Germany
Resilience – UKCP-UK
Return period – CCA-Australia
Risk – CCA-Australia/ I2C-Germany/ UKCP-UK
Risk assessment – CCA-Australia
Risk management – CCA-Australia
Safran – DRIAS-France
Scenario – DRIAS-France/ CAL-USA
Sea level rise – UKCP-UK
Seasonal – UKCP-UK
Soil moisture – UKCP-UK
Solar radiation – I2C-Germany
Spatial downscaling – DRIAS-France
Stochastic – UKCP-UK
Storms – UKCP-UK
Sub-tropical ridge (STR) – CCA-Australia
Surface energy balance – I2C-Germany
Southern Annular Mode – CCA-Australia
(SAM) – CCA-Australia
SAM index – CCA-Australia
SRES scenarios – CCA-Australia
Temporal average – I2C-Germany/ UKCP-UK
Time period – UKCP-UK
Tipping point – UKCP-UK
Tropical night – I2C-Germany
Uncertainty – CCA-Australia/ DRIAS-France/ UKCP-UK
Urban Heat Island – UKCP-UK
Variable – UKCP-UK
Vulnerability– DRIAS-France/ CAL-USA/ UKCP-UK
Walker Circulation – CCA-Australia
Warmest day of the season – UKCP-UK
Warmest night of the season – UKCP-UK
Waves – UKCP-UK
Weather Generator variables – UKCP-UK
Wettest day of the season – UKCP-UK
Wind or Wind speed – UKCP-UK

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