Wegener Center for Climate and Global Change (WEGC),
Institute for Geopühsysics, Strophysics and Meteorology
Institute for Physics (IGAM/IP),
Karl-Franzens-University Graz (UniGraz)

Data demands of the climate impact community

Taken from chapter 6 of the PhD thesis of Matthias Themeßl "Empirical-statistical downscaling and error correction of temperature, precipitation and derived extremes in Europe" (http://www.uni-graz.at/igam7www-report_45_mtheme_1_june11.pdf) from 2011 and based on the WEGC Report to the ACRP Nr. 01/2011 "Concept for an Austrian Climate Data Centre (KlimDatZ)" by Matthias Themeßl, Andreas Gobiet and Heimo Truhetz in 2011.

April 2012

6. Data demands of the climate impact community

Having described techniques to generate fine scale climate information in the previous chapters, these downscaled data may not be an end itself, but, e.g., function as input for further assessments of the sensitivity of various sectors on climate conditions.

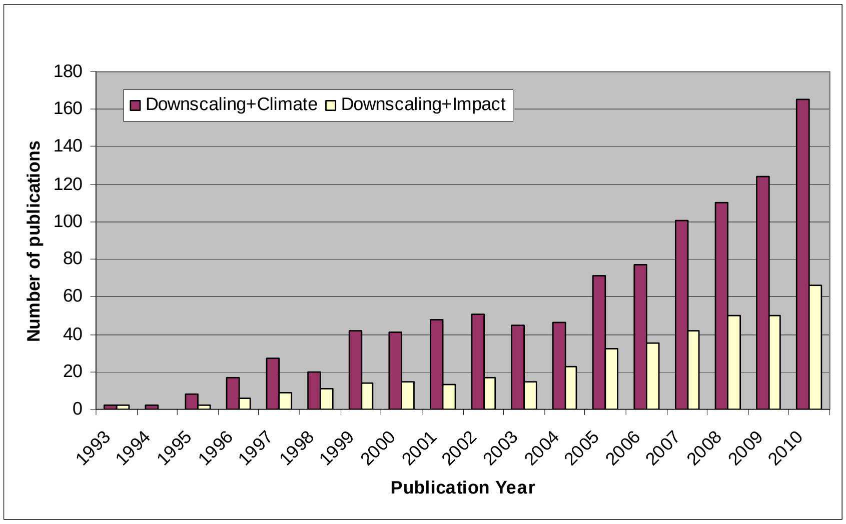

Figure 6.1 Number of scientific publications per year since 1993 in the field of "downscaling" (purple) and "downscaling and impact" (yellow). The data is taken from the ISI Web of Knowledge.

However, regarding Figure 6.1, the ISI Web of knowledge reveals that while the number of publications focusing on pure downscaling issues still strongly increases (search criterion "Downscaling and Climate") only between a third and a half of downscaled data enter further impact assessments (search criterion "Downscaling and Impact"). These numbers underline Cramer et al. (2000) who state "*climate change scenarios for impact assessments are usually an offspring rather than an intended result*". The question thus remains why only such a limited number of downscaling studies go beyond the pure downscaling. Referring to a questionnaire presented at the Infrastructure for the European Network for Earth System Modelling (IS-ENES) workshop 2011 in Copenhagen entitled "Bridging Climate Research Data and the Needs of the Impact Community" 2011 in Copenhagen (Swart, 2011), impact scientists from different disciplines listed 5 broad categories of problems of available climate data:

1) data format
2) user-friendly data access to data
3) required spatial and temporal resolution
4) reliability and uncertainty
5) specific local needs.

Following this listing, problems are obviously either related to different data management policies and habits in different disciplines (point 1 and 2), which leads to technical difficulties in data exchange or missing communication between producers and user (point 3 to 5), which leads to the problem of unsuitable available data.

6.1 Useful data for climate impact studies

Facing the problems of available climate data, the following sections aim at providing a general description of useful data, concepts to produce them, as well as concrete data requirements of different user groups and sectors.

6.1.1 General definition of useful data

McNie (2007) defines useful data in science by salience, credibility, and legitimacy. Salient information represents data that is context-sensitive and tailored to the users demand. I.e., an urban administration is interested in very high resolved precipitation data, temporally as well as spatially, e.g., in order to assess possible discharges for planning canal systems. For such users, monthly climate scenarios from GCMs are obviously insufficient for making appropriate decisions.

Secondly, data users should trust the data they are working with. Credibility in the data may be achieved by various pathways ranging from scientific most rated peer review processes, via strong communication between producers and users to the inclusion of users in the data production process. Jacobs et al. (2005) stated the ease of interpretation, the clear communication of accuracy, or the possibility to assess the accuracy of the provided data by themselves, e.g., by hands on trainings, to be essential. Furthermore, clear communications about the made assumptions, methodological shortcomings, validation methods as well as statements about uncertainties are important points towards more credibility concerning the applied data (Maraun et al., 2010).

Legitimacy, finally, defines that the provided data are generated free from political suasion or bias and that the interests of the users have been encountered in the generation process (McNie, 2007). Useful data will account for these three points in a balanced way.

6.1.2 Generation and evaluation of useful data

Jacobs et al. (2005) describes 6 phases in the direction of useful data generation. Firstly, if, e.g., climate modelers want their data to be implemented in further applications they have to learn what information is needed (intelligence phase). Here for example, workshops are helpful to get the right insights. Then, the data producers enter the promotion phase, where they have to communicate their results, thus make them understandable for further user, but also scientifically sound for peer review processes. This phase is followed by the prescription, implementation and application phase, where data users decide which data to apply. Finally, the termination phase decides if data is no longer useful and the evaluation phase determines if the implemented data was useful in meeting the needs of the users. The lessons learned should then enter via a feedback in the intelligence phase of consequent projects.

The general usefulness of data may be judged in various ways. Possible measurements may be peer-reviewed results in science, or even already measurable reduced losses from climate related impacts such as floods due to adaptation measurements. Furthermore, such measurements could include new and sustainable contacts between research institutions, an open and participatory process, better scientific understanding or increased demand for information (Jacob et al., 2005 and references therein).

Relating to the promotion phase, the problem of scientific boundaries is often visible in interdisciplinary projects. In this context Callahan et al. (1999) and Jacobs et al. (2005) define science integrators as important intermediaries or translators at the boundaries between producers and user. They represent the interface between different science disciplines but also between science and stakeholders, know and understand both sides and thus ensure that science and its results meet the needs of the users and are understood correctly. Jacobs et al. (2005) define such integrators to have: outside-the-box mentality; interdisciplinary background and willingness to bridge disciplinary gaps; credibility in the science community and knowledge how to translate complex information; expertise in a specific sector; understanding of the institutions and cultures of the partner in the project and the ability to facilitate and to build science-practice networks.

6.1.3 Definition of user groups and user sectors

Beyond the former given general definition of useful data, useful data in practice will vary depending on who is using the data and where it is applied. Thus, in the following likely user groups of climate data as well as application sectors are defined. Along with the definition of user sectors, also those there specifically requested meteorological variables are given in order to concretize useful data for climate change impact research and decision making. These definitions are primarily based on a working paper of Themeßl et al. (2011) which was prepared for an Austrian Climate Data Centre as well as on Swart (2011). In general, these sections will only focus on meteorological data, and do not include, e.g., socio-economic or demographic data needs, which are of course equally essential in any integrated assessment (compare IPCC-TGICA, 2007).

Overall, five groups of data users are defined as follows:

1) climate and climate impact researchers
2) experts in environmental and conservation organizations, or in NGOs
3) experts from private sector (consultants, spatial planners, architects,..)
4) people in federal institutions
5) politicians and policy makers.

The order of the user groups is chosen to range from 1) specialist users who need detailed data but little guidance to 5) non-specialist users who mostly need guidance (compare Swart and Pagé, 2010).

Sector	**Required parameters**	**Temporal Resolution**	**Spatial Resolution**	**Periods**
Research	Temperature (mean, min, max), precipitation, humidity, wind (speed, direction), pressure, surface radiation budget, extreme indices	Sub-daily, Daily, Monthly, Seasonal, Annual, Decadal	Point, Grid (50 km─1 km and below)	1900─2100; Ensemble of scenario periods
Education	Temperature (mean, min, max), precipitation, wind speed, wind direction, snow (depth cover), indices as frost days, tropical nights	Daily, Monthly, Seasonal, Annual	Point, Grid (50 km), municipality	Climatological normal period (1971─2000); Exemplary scenario period (2021─2050)
Hydrology and Water management	Temperature (mean, min, max), precipitation, humidity, river discharge, surface runoff, water vapor, global radiation, evapotranspiration, indices of extremes	Sub-daily, Daily, Monthly, Seasonal, Annual	Point, Grid (50 km─1 km and below)	1900─2011; Ensemble of scenario periods (2021─2050)
Energy	Temperature (mean, min, max), precipitation, wind (speed direction), global radiation, indices such as heating/cooling degree days	Sub-daily, Daily, Monthly, Seasonal, Annual	Point, Grid (50 km─1 km)	1961─2011; Ensemble of scenario periods (2021─2050)
Tourism	Temperature (mean, min, max), precipitation, sunshine duration, snow (depth, cover)	Daily, Monthly, Seasonal, Annual	Point, Grid (25 km), municipality, NUTS regions	1961─2011; Ensemble of scenario periods (2021─2050)

Table 6.1 Definition of user sectors in climate change impact research and those there requested data according to the temporal and spatial resolution as well as the needed time span.

According to their diverging working field, Table 6.1 list 10 sectors, which are dependent on or interested in climate data. The listed data requirements should be regarded as an overview and are based on the 50 Essential Climate Variables (ECVs) defined by the Global Climate Observing

System (GCOS), as well as on experiences and questionnaires, e.g., from IPCC-TGICA (2007), Swart (2011), the Climate Impacts Group, Center for Science in the Earth System at the University of Washington (Lee and Whitely Binder, 2010), the EU FP6 Climate Change and Variability: Impact on Central and Eastern Europe (CLAVIER) project (www.clavier-eu.org), the EU FP7 Assessing Climatic Change and Impacts on the Quality and Quantity of Water (ACQWA) project (http://www.acqwa.ch/) as well as Themeßl et al. (2011). For further details, interested readers should consider the mentioned references.

Sector	**Required parameters**	**Temporal Resolution**	**Spatial Resolution**	**Periods**
Agriculture-Forestry-Ecosystems	Temperature (mean, min, max), precipitation, global radiation, wind (speed), snow (depth), humidity, indices as frost, heat waves, drought indices	Daily, Monthly, Seasonal, Annual	Point, Grid (50 km—1 km)	1900—2011; Ensemble of scenario periods (2021—2050)
Health	Temperature (mean, min, max), precipitation, humidity, derived indices as human comfort index, heat waves, tropical nights summer days	Daily, Monthly, Seasonal, Annual	Point, Grid (25 km)	1961—2011; Ensemble of scenario periods (2021—2050)
Infrastructure-spatial planning-transport	Temperature (mean, min, max), precipitation, snow, wind, river discharges, extremes as maximum one day precipitation, frost days	Sub-daily, Daily, Monthly, Seasonal, Annual	Point, Grid (50 km—1 km and below)	1961—2011; Ensemble of scenario periods (2021—2050)
Insurance and finances	Temperature (mean, min, max), precipitation, snow, wind, hail, derived extremes as frost days, heat waves, drought indices, extreme precipitation, wind storms	Sub-daily, Daily, Monthly, Seasonal, Annual (also required frequency or return periods instead of transient time series)	Point, Grid (50 km—1 km), NUTS regions	1900—2011; Ensemble of scenario periods (2021—2050)
Civil protection	Temperature (mean, min, max), precipitation, snow, wind, hail, derived extremes as frost days, heat waves, drought indices, extreme precipitation, wind storms	Sub-daily, Daily, Monthly, Seasonal, Annual	Point, Grid (50 km—1 km and below)	1961—2011; Ensemble of scenario periods (2021—2050)

Table 6.1 Definition of user sectors in climate change impact research and those there requested data according to the temporal and spatial resolution as well as the needed time spans (continued).

Table 6.1 only contains surface parameters and does not include, e.g., 3 dimensional atmospheric fields, which would be needed as boundary conditions for modeling purposes in the research sector.

In summary, the main meteorological data such as temperature, precipitation, wind, humidity, and radiation as well as derived indices such as extremes, which are in more detail listed in Table

6.2, are required by climate impact researchers and decision makers. Concerning the respective scales, variables are in fact needed on all temporal scales (ranging from sub-daily to annual) and on spatial scales between points of interest to grids (between 50 km and 1 km resolution). Experiences however show that spatially the Europe-wide state-of-the-art ~25 km grid is sufficient for most climate change impact assessments.

Concerning the requested time periods, usually historical data as well as future scenarios are required. Historical records are chosen in this context to represent some kind of base line, which is representative of the present day or recent climate average (e.g., from 1971 to 2000) and also sufficient long to encompass a range of climatic variation (IPCC-TGICA, 2007). For example hydrologists use 100 year time series to estimate a realistic variability for their hydrological models (Salathé et al., 2007). Future scenarios in most cases cover the period until 2050 or until the end of the 21st century. Transient data is demanded if effects such as trends are to be assessed or if the data is needed to initialize subsequent impact models. Often, however, impact modeling is undertaken with equilibrium modeling approaches where impact models are run once for the current climate and then for a future climate. Then, future climates are defined as mean states of time slices extracted from transient runs (Cramer et al., 2000). If climate impacts are assessed until the end of the 21st century, the range of the available scenarios becomes more and more important as from the mid of the century on the scenarios start to diverge (compare IPCC, 2007). In practice, usually not all scenarios are implemented for assessments due to computational limitation. Thus, the spread of differing climate scenarios is then taken into account by applying, e.g., 3 scenarios representing low, mid and high climate changes which are considered to lead to the best, medium, and worst impacts for the focused sector.

Beyond the data requirements of the different user sectors concerning spatial and temporal characteristics, climate impact researchers often also define useful data via attributes such as spatial coherence, temporal persistence or physical consistency (e.g., Kilsby, 2000; Maraun et al., 2010).

6.1.4 Categories of useful data

Concluding the definition of useful data, this section introduces 5 categories of useful data. These categories mainly describe the data's origin and can be classified into

1) metadata
2) observational data
3) direct model output
4) downscaled and error corrected data
5) derived indices.

Metadata represent background information on and descriptions of the data set, i.e., its data sources, its producer, its provided variables, its assumptions and its consequent limitations and uncertainties or other information about its reliability or performance skill. Such meta information is essential for the correct application of the dataset and increases the credibility of the data set (Lee and Whitely Binder, 2010).

Observational data represent the basis of any climate and climate impact study. Observational data enables to assess historic conditions and trends or to calibrate and evaluate models. Besides point-scale time series from federal meteorological services or, e.g., the European Climate Assessment & Dataset (ECA&D) project (http://eca.knmi.nl/) for entire Europe, gridded observational data is, e.g., available globally on monthly basis for temperature, diurnal temperature range, precipitation amount, vapor pressure and cloud cover from 1901─2000 at a spatial resolution of 0.5 degrees (Mitchell et al., 2004). For Europe, the most recent gridded observational dataset ─ E-OBS ─ contains minimum, maximum and mean temperature, as well as precipitation amount and sea level pressure and is available on daily basis between 1961 and 2010 on a 25 km grid (Haylock et al., 2008; van den Besselaar et al., 2011). For precipitation amount a similarly resolved gridded data set on daily basis is available for the Greater Alpine region from 1971─1990 (Frei et al., 2006). For Austria a gridded dataset for mean temperature and precipitation amount at 1 km resolution is also available from 1961─2009 (Beck et al., 2009).

Gridded observational data is important for climate model validation purposes as it does not represent point scale but area average information and thus has the same statistical properties such as climate model output (e.g., Goodess et al., 2003 and references therein; Déqué, 2007).

Direct model output, especially from RCMs has recently become available for Europe and the USA along with various regional climate modeling projects such as ENSEMBLES or NARCCAP (http://www.narccap.ucar.edu/). Due to their fine resolution between 50 km and 25 km and their strengths listed in Appendix B, such data is often used in complex impact models.

Downscaled and error corrected data represent an important data category for climate change impact studies. Such post-processed data increase the reliability of impact assessments by reducing sources of errors in the modeling chain. In its simplest form an error corrected climate scenario can be obtained via the so called delta approach where the difference between a future period and a reference period from a climate simulation is added as a climate change delta on reference observations (Déqué, 2007; Graham et al., 2007). By this means, it is expected that systematic errors are cancelling out. However, this approach also features shortcomings such as unchanged future variance characteristics. Besides, more sophisticated techniques can be found in literature and are applied and described in Chapter 4 and Chapter 5. Because all DECMs are dependent on observational data, already published studies on downscaled and error corrected data are yet limited on the one hand side to the main meteorological parameters temperature, precipitation, humidity, pressure, wind speed and global radiation (compare Chapter 4 and Chapter 5; Fuchs, 2011; Wilcke et al., 2011) and on the other hand side to industrialized countries with long-term observational networks.

Derived indices are useful information for various sectors, as they describe either sector-relevant thresholds or non-linear sector-relevant effects by combining different variables. Table 6.2 lists commonly demanded indices and provides respective definitions. Some indices are also exemplarily included in the analyses presented in Chapter 4 and Chapter 5.

Derived indices	Short description or reference
Temperature related indices	
90th percentile of maximum temperature	90th percentile of daily maximum temperature
10th percentile of minimum temperature	10th percentile of daily minimum temperature
Heating degree day	Prettenthaler et al. (2008)
Cooling degree days	Prettenthaler et al. (2008)
Summer days	No. of days with maximum temperature > 25°C
Tropical nights	No. of days with minimum temperature > 20°C
Frost days	No. of days with minimum temperature < 0°C
Growing season length	Nr. of days between first occurrence of at least 6 consecutive day with > 5°C and the first occurrence after 1st July of at least 6 consecutive days with < 5°C
Start of growing season	Date due to definition of growing season length
Precipitation related indices	
Precipitation intensity	mean daily precipitation sum on wet days (days where pr_24h exceeds 1 mm/day)
Precipitation frequency	No. of wet days
90th percentile of rain days	90th percentile of daily precipitation sums on wet days
Greatest 1-day rainfall	maximum precipitation sum in one day
Greatest 5-day rainfall	maximum precipitation sum in 5 consecutive days
Intense precipitation	No. of days with precipitation > 10 mm/day
Heavy rainfall days	Nr. of events > long-term 90th percentile of wet days
Snow related indices	
Snow days	No. of days with snow height ≥ 1 cm
Heavy snow days	No. of days with snow height ≥ 30 cm
Wind related indices	
Strong wind days	No. of days with maximum wind speed > 15 m/s
Storm days	No. of days with maximum wind speed > 30 m/s
Aridity indices	
Palmer Drought Severity Index	Heinrich and Gobiet (2011)
Standardized Precipitation Index	Heinrich and Gobiet (2011)
Aridity Index	Heinrich and Gobiet (2011)
Others	
Potential evapotranspiration	Thornthwaite (1948)
Hail frequency	No. of days of hail per hail season
Hail intensity	Energy per hail event per area

Table 6.2 Derived indices for the climate impact research community. The indices are based on STARDEX, CLAVIER and ACQWA project as well as via the ECA&D dictionary of indices (http://eca.knmi.nl/indicesextremes/indicesdictionary.php).