Sourcing and using climate information for economic assessments of adaptation

Key Messages

- Sourcing and using climate information is something that should be taken collaboratively between climate experts and adaptation economists. Building relationships, trust and understanding between these different communities is essential. It should also not be seen as a one way process, from climate information providers, but as an iterative and integrated process, in which information and discussion will flow back and forth.
- Recent developments in climate services have focused more on the impacts community and end users rather than on the needs of the adaptation community.
- Climate model data and standard packages of outputs are not sufficient for developing 'adaptation services'. The needs of the latter are very diverse, encompassing both quantitative and qualitative information at various different spatial and temporal scales, as well as guidance and advice, support and (importantly) interpretation. Climate experts working with the adaptation community need to be flexible particularly in response to ad hoc requests and bespoke applications.
- The adaptation community has different needs to the impact community. There is a much greater focus on the current climate (including observations and recent trends) and also on capturing uncertainty of future climate projections: the latter includes a move beyond multi-model ensembles to include more comprehensive scenario and climate uncertainty (including deep uncertainty) as well as specific metrics to allow the application of decision making under uncertainty methods.
- Climate information should be credible, legitimate, salient and timely. There is a tendency for the physical climate science community to focus on the first two criteria, whereas the last two are particularly important for stakeholders and policy makers focused on adaptation.

Context

Adaptation to climate change requires knowledge of the climate to which one is adapting – normally both to present-day climate variability and anticipated future change. Traditionally the adaptation community has looked to the physical climate science community to provide this information and it has done so following the sequential, top-down, science-first approach typically used by the climate impacts community. These studies tend to have a long-term perspective, typically assessing impacts and adaptation around mid-century, when the climate signal more strongly emerges. Thus the focus has been on the development of emission scenario based climate projections for the coming decades generally delivered in the form of numerical data (i.e., climate model output). While this approach may be appropriate for experts running physical impact models (such as crop models or hydrological models), it has a number of shortcomings for economic-based assessments of adaptation, particularly where a policy-led framework is adopted.

There are a number of problems associated with the impact driven approaches when considering adaptation. The long-term focus does not align to immediate policy needs, namely what adaptation is needed over the next decade. Furthermore, these impact studies are quite stylized and omit wider (non-climatic) drivers, existing policy and the socio-institutional context and goverance (more information here).

As a consequence, there has been a move towards a policy-orientated approach, in which the primary objective of the analysis is framed towards implementing adaptation. In this context, the starting point for the analysis is to understand the adaptation context and objectives, rather than starting with the future projections. This puts a much greater emphasis on other factors (than just climate alone). This is illustrated here. In such a framework, the input on future climate projections comes later in the decision process, and is an input to an existing assessment: this contrasts with the science (I-A) driven approach, which starts with the climate models.

There has also been a shift to look the phasing and timing of adaptation, advancing an iterative climate risk management (ICRM) approach, as recommended in the IPCC Fifth Assessment Report (IPCC, 2014). This centres on the fact that practical adaptation involves a broad set of response types, addressing different problems. This approach starts with current climate variability and then assesses future climate change, considering uncertainty. It then uses new techniques to consider decisions under this uncertainty. As well as iterative pathways (adaptive management) this can include specific techniques such as robust decision making, real options analysis, rule-based decision making or portfolio analysis.

There are two rather important consequences from these changes. First, there is a much greater need for information on current climate variability and extremes, thus information on observations and recent trends are a priority. Second, there is a much greater focus on the uncertainty associated with future climate change, moving beyond individual projections or mean/median estimates of multi-model ensembles, to capture a wider information set for analysis in decision making under uncertainty.

The science-first approach tends to focus on the data alone, although there is growing recognition particularly by the emerging climate services community that what is really required is knowledge and information rather than just data. Quantitative and numerical climate data clearly have a valuable role as input to impact and economic models, but in some cases a more qualitative approach may be more appropriate, e.g., based on narratives or story lines. Whether a quantitative or more qualitative approach is taken, it is important for the providers of climate data and information to also provide expert guidance and advice and to develop a good understanding of user needs including the decision-making or policy context and how the information will be used.

Policy and methodological developments

The main building blocks for the development of climate projections (see the Box for definition) are global climate models (GCMs). These represent the physical processes driving weather and climate at the grid-box level using numerical equations and parameterisations in a similar way to the numerical weather prediction models from which they have evolved. The current generation of GCMs (e.g., the CMIP5 multi-model ensemble – see the table below) has a typical grid-box resolution at mid-latitudes of a few hundred kilometers (e.g., 2.5 degrees latitude by 3.75 degrees longitude) though a few modelling centres now have the capacity to perform shorter runs at resolutions of 20-50 kilometers.

Some definitions from the climate science community **Climate services:** Climate information provided in a way that assists decision making by individuals and organizations. Requires appropriate engagement along with an effective access mechanism and must respond to user needs. *Global Framework for Climate Services (WMO)* **Projection:** A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized. *IPCC Fifth Assessment Report, Working Group 1, Glossary* **Uncertainty:** A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts of terminology, or uncertain projections of human behavior. *IPCC Fifth Assessment Report, Working Group 1, Glossary*

When run in climate projection mode, GCMs are forced by greenhouse gas emission or concentration scenarios which reflect different assumptions about future socioeconomic and technological developments. The CMIP5 ensemble, for example, uses four different Representative Concentration Pathways (RCPs): RCP2.6, RCP4.5, RCP6.0 and RCP8.5, where the numbers indicate the radiative forcing achieved by 2100 in W/m^2. Thus RCP8.5 can be viewed as a high ‘business-a--usual’ scenario, while RCP2.6 represents a world with more ambitious and effective mitigation interventions.

For many applications, particularly where the effects of extreme weather events may be important, the relatively coarse spatial scale of GCMs is considered inadequate and thus two main approaches to downscaling to finer resolutions have been developed. The first is a dynamical approach in which Regional Climate Models (RCMs) are run at higher resolution (typically 25-50 km, or even 8-12 km) over a smaller domain (e.g., Europe, the Mediterranean) using boundary conditions or forcing taken from GCMs. The second is a statistical approach (ESD: Empirical Statistical Downscaling) based on empirical relationships between the climate variable(s) required (e.g., surface temperature) and predictor variables (e.g., large-scale circulation patterns). ESD has the potential to provide information at the point or weather station scale.

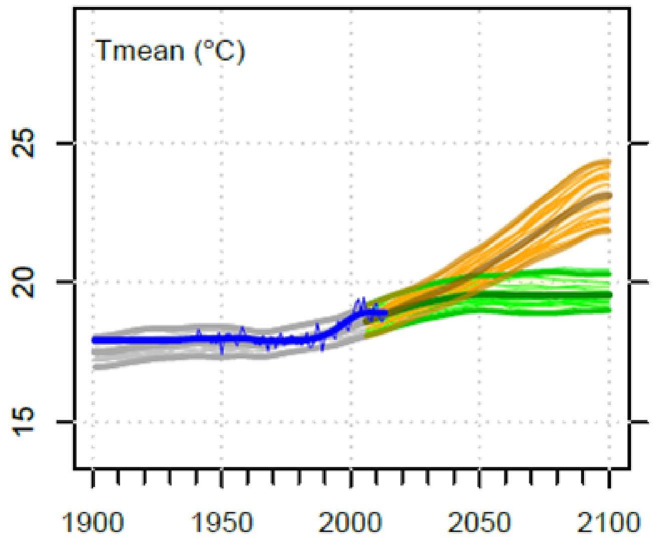
The specific advantages and disadvantages of these different modelling approaches or tools are summarized in the Table below. Nonetheless it can be difficult for a potential user of climate information to know which is the most appropriate ‘tool for the job’. This is where a climate expert can provide valuable guidance – based on the requirements and capacity of the user, but also taking into account consideration of model performance and modelling uncertainties. The latter arise because models are imperfect and are sensitive to the variety of different structures and parameterisations that are used. In order to take some account of this uncertainty, it is recommended good practice to take an ensemble approach – most commonly a multi-model ensemble approach (i.e., to use a number of different models from different modelling centres). The choice is, however, complicated by the trade-off between ensemble size and spatial resolution. Higher-resolution simulations are more computationally expensive to run so there needs to be clear added value in terms of the reliability of the model output to justify running at higher resolution. Higher resolution does not necessarily imply ‘better quality’.

Climate model performance or reliability is assessed by comparing model outputs with historical observed climate data. On climate change timescales, however, good reproduction of observations is only a ‘necessary but not sufficient’ guide to the reliability of future projections. The latter cannot be verified in the same way as a weather forecast or seasonal prediction.

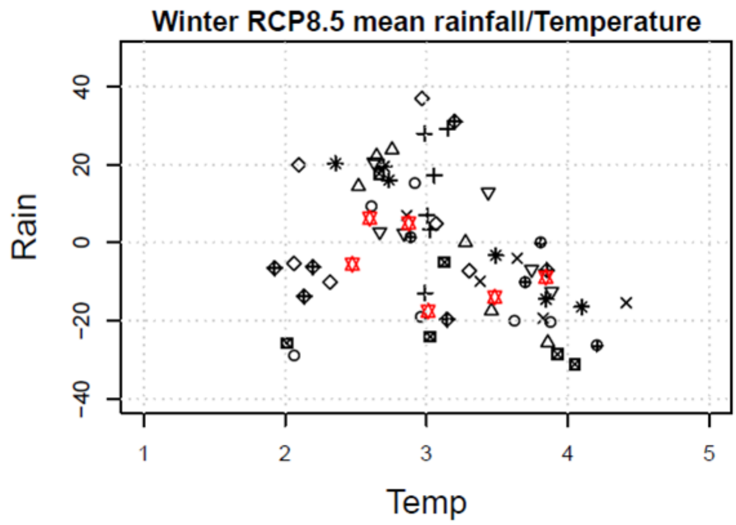
It is also important to remember that climate projections do not represent predictions for specific future calendar years (thus they are different in nature to decadal predictions which are initialized or conditioned on present-day conditions). For this reason projections are typically presented as statistics of 20-30 year present-day and future scenario periods (e.g., 1971-2000, 2021-2050, 2071-2100). This is more robust than looking at differences between individual years because it takes some account of natural internal year-to-year variability in climate. Some indication of the level of this variability, including the occurrence of extreme events, is potentially very important for adaptation. This applies as much, if not more so, for present-day observed variability and extreme events as for the future. Unfortunately access to observed climate data, particularly for variables other than temperature and rainfall and at daily or higher temporal resolutions, remains problematic in many parts of the world, including both Europe and Africa.

Examples

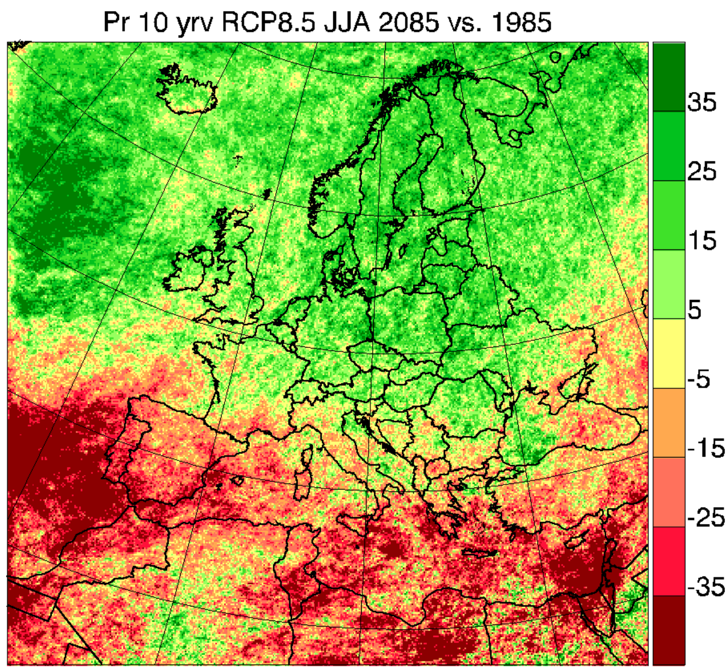
The following example of GCM-based climate projections shows mean annual temperature for Rwanda. The projected changes are averaged over 18 CMIP5 GCMs (thick lines) for RCP8.5 (orange) and RCP2.6 (green). The figure also shows each model individually as well as the 90% model range (shaded). The observed record (based on gridded station data) is shown in blue.



This example of RCM-based climate projections shows projected changes for 2071-2100 minus 1971-2000 in mean monthly temperature (horizontal axis – degrees C) and rainfall (vertical axis – mm) for Bilbao for the winter half of the year (October to March) for RCP8.5. Data are from 11 EURO-CORDEX models with the model selected as the most representative of the ensemble highlighted in red.



An example of a plot of noisy data, which is made more robust through looking at an ensemble. Percentage change in the 10-year return value of daily precipitation between the periods 1961-1990 and 2071-2100 following the RCP8.5 emission scenario. The median between results from 15 different simulations in 12 km resolution.



Overview on modelling approaches

Modelling approach	Advantages	Disadvantages	Selected resources
Global Climate Models (GCMs)	Physically-based, consistent for multiple variables. Large ensembles (~20+ members). Better sampling of RCPs (RCP2.6, RCP4.5, RCP8.5)	Coarse spatial resolution (e.g., 2.5° x 3.75° lat/long). Potentially large data volumes (in NetCDF format).	CMIP5 http://esgf.llnl.gov and http://www.ipcc-data.org/docs/factsheets/TGICA_Fact_Sheet_CMIP5_data_provided_at_the_IPCC_DDC_Ver_1_2016.pdf
Regional Climate Models (RCMs)	Physically-based, consistent for multiple variables. Higher spatial resolution (~12 km for Europe). Growing availability of bias-adjusted runs.	Smaller (10-20 member) ensembles. Fewer RCPs (RCP4.5 & RCP8.5). Potentially large data volumes (in NetCDF format)	CORDEX http://www.cordex.org
Empirical Statistical Downscaling (ESD)	Potential to provide information at point (station) locations. Not restricted to standard climate variables.	Rather ad hoc availability. No large ensembles. Need to assume statistical relationships hold into the future.	ESD projections for Africa from the CSAG Climate Information Platform: http://cip.csag.uct.ac.za/webclient2/app/ R software for ESD - downscaleR: https://github.com/SantanderMetGroup/downscaleR/wiki One of a number of online tools for ESD: http://co-public.lboro.ac.uk/cocwd/SDSM/index.html

Main implications and recommendations

The climate information needs for adaptation and adaptation economic assessments are different to those for climate impact assessments. Furthermore there are differences in terms of the stage in the assessment cycle at which it is appropriate for climate information providers to seek to identify and meet these needs. These processes often happen at a later stage, particularly in a policy-led rather than a science-first framework. This does not, however, negate the importance of climate information providers and adaptation experts developing relationships and building trust from an early stage.

A responsible and responsive climate information provider will not just ask a potential user technical questions about the climate variables they require and at what spatial and temporal resolutions, but will seek to build an understanding of how and why the information is to be used, including the policy and decision-making context.

It also needs to be recognized that ‘one size does not fit all’ and standard climate products may not be appropriate, particularly as they tend to focus on mean temperature and rainfall rather than other aspects of climate such as extreme events, sea level rise and tropical cyclones which may be critical from the adaptation and economic perspective. Provision of a one-off, literature review written in non-technical language assessing, for example, the scientific evidence for a change in the risk from tropical cyclones over Zanzibar would not normally be considered part of a generic climate service, but in the context of a country-specific adaptation assessment could complement very well more conventional climate projection information on changes in mean temperature and precipitation.

Climate information should be credible, legitimate, salient and timely. In terms of climate projections, such information might come from GCMs, RCMs or ESD or from a combination of these modelling tools. Regardless of source, however, some form of validation or evaluation of the model output should be undertaken – recognizing that agreement with observations for the present-day does not guarantee a reliable or robust projection and nor does greater spatial resolution guarantee better ‘skill’. There is perhaps a tendency in the climate services community to assume that the user always wants and needs information at high spatial and temporal resolutions. While this may be the case for assessing engineering-based adaptations to changes in flood risk for example, information about mean annual temperature at the country scale may be sufficient for input to a macroeconomic model.

When considering credibility and legitimacy, consideration also needs to be given to the treatment of uncertainty. There are several aspects here. First, in an adaptation context, it is necessary to include other sources of uncertainty, not just climate change. Second, when considering climate modelling uncertainty, there is a greater focus on capturing and considering uncertainty in the decision making process, indeed the focus is now on decision-making under uncertainty. There is also an issue of the diversity of users: some will want simple information, especially when aligned to policy decisions, while others will be running complex uncertainty assessments which actually increase the demand for multi-model data and more complex metrics and outputs.

While climate experts recommend the use of large multi-model ensembles, in practice the ability to use them may be limited by the capacity of users to run an impacts or economic model multiple times, particularly where the latter model is complex and computationally demanding. In such circumstances, the climate expert can provide guidance about how to select a smaller number of model runs which are somehow representative of the larger ensemble range. Information can also be provided, for example in the form of scatter plots, as to where the selected climate model run(s) fall within the ensemble. There is also a role for the climate experts to communicate why ignoring uncertainty might adversely affect adaption assessments and decisions. This is particularly important for variables such as precipitation and wind where the uncertainties relating to both the magnitude and direction of change tend to be much higher than for temperature. In cases where more complex methods are used (e.g. real options, robust decision making, portfolio analysis), the demands on climate modellers will actually increase, as these tools seek to capture as much information on uncertainty as possible, usually combining with other non-climatic uncertainty. These techniques may require different information.

The capacity to use climate information is also very relevant in considering the saliency and timeliness of such information. Output from GCMs and RCMs is typically archived and distributed in NetCDF format – a format which is not widely used outside the climate modelling community. Thus at least, help may be needed in identifying, downloading and re-formatting climate data from the large international data archives.

Adaptation economic assessments not only require climate information, but also socioeconomic information. For climate projections based on RCPs, this information comes from Shared

Socioeconomic Pathways (SSPs) which were initially developed in a parallel process to the RCPs. Five SSPs have been defined spanning the space of different degrees of challenge for mitigation and adaption. SSP2, for example, represents moderate challenges for both mitigation and adaption and is considered to be consistent with RCP4.5. Consistency with and availability of socioeconomic information should be considered in identifying appropriate sources of climate information for adaptation assessments.

Recent decades have seen the emergence of climate services in a process which has been more supply-led than demand-led, particularly with respect to adaptation and economic applications. As part of this process, international activities such as the Global Framework for Climate Services and the Climate Services Partnership have been established, along with regional activities such as the Copernicus Climate Change Service in Europe, together with the establishment of many national climate services either in conjunction with or complementary to national meteorological and hydrological services (NMHS). At the same time boundary organisations such as UKCIP and OURANOS have continued their activities in this area. In terms of research-focused activities, NMHS as well as academic institutions have developed relevant expertise and methodological approaches in projects such as EUPORIAS (focused on seasonal forecasts) and ECONADAPT. In this complex landscape of purveyors and providers it can be difficult to know where to go for climate information. In the short term at least, however, there is a need for further research as well as closer dialogue and engagement between the climate science and economic adaptation communities in order to develop and disseminate good practice building on the experiences of ECONADAPT.

Bibliography

Brasseur, G.P., Gallardo, L. (2016), Climate services: Lessons learned and future prospects. Earth's Future, 4, 79-89.

Dosio, A. (2016), Projections of climate change indices of temperature and precipitation from an ensemble of bias-adjusted high-resolution EURO-CORDEX regional climate models. Journal of Geophysical Research Atmospheres, 121, *http://dx.doi.org/10.1002/2015JD024411*.

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.-L., Fichefet, T., Friedlingstein, P., Gao, X., Gutowski, W. J., Johns, T., Krinner, G., Shongwe, M., Tebaldi, C., Weaver, A.J., Wehner, M. (2013), Long-term Climate Change: Projections, Commitments and Irreversibility. In: Climate Change (2013), The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, *http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter12_FINAL.pdf*.

Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S.C., Collins, W., Cox, P., Driouech, F., Emori, S., Eyring, V., Forest, C., Gleckler, P., Guilyardi, E., Jakob, C., Kattsov, V., Reason, C., Rummukainen, M. (2013), Evaluation of Climate Models. In: Climate Change (2013), The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, *http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf*

IPCC (2014), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp., http://ipcc-wg2.gov/AR5/report/

Jacob, D. et al. (2013), EURO-CORDEX: new high-resolution climate change projections for European impact research. Regional and Environmental Change, *http://dx.doi.org/10.1007/s10113-013-0499-2*.

Maraun, D., Wetterhall, F., Ireson, A.M., Chandler, R.E., Kendon, E.J., Widmann, M., Brienen, S., Rust, H.W., Sauter, T., Themeßl, M., Venema, V.K.C., Chun, K.P., Goodess, C.M., Jones, R.G., Onof, C., Vrac, M., Thiele-Eich, I. (2010), Precipitation downscaling under climate change: recent developments to bridge the gap between dynamical models and the end user. Reviews of Geophysics, 48, *http://dx.doi.org/10.1029/2009RG000314*.

McSweeney, C.F., Jones, R.G. (2016), How representative is the spread of climate projections from the 5 CMIP5 GCMs used in ISI-MIP? Climate Services, 1, 24-29.

O’Neill, B.C., Kriegler, E., Riahi, K., Ebi, K.L., Hallegatte, S., Carter, T.R., Mathur, R., van Vurren, D.P. (2014), A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change, 122, 387-400, *http://dx.doi.org/10.1007/s10584-013-0905-2*.

O’Neill, B.C., Tebaldi, C., van Vuuren, D., Eyring, V., Fridelingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J-F., Lowe, J., Meehl, J., Moss, R., Riahi, K., Sanderson, B.M. (2016), The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. Geoscientific Model Development, *http://dx.doi.org/10.5194/gmd-2016-84*.

Rummukainen, M. (2016), Added value in regional climate modelling. WIREs Climate Change, 7, 145-159.

Further Information

Documentation of the climate scenarios and data developed and used in the case study WPs

Contact

Clare Goodess

Partner

University of East Anglia (UEA)

Danish Meteorological Institute (DMI)

Paul Watkiss Associates