Scenarios and models

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Emission and socioeconomic scenarios

When performing studies on climate change impact, adaptation and vulnerability it is in general necessary to have information on how climate, social-, economic development and other environmental factors are anticipated to change in the future. The IPCC Special Report on Emission Scenarios SRES (IPCC, 2000) presented *scenarios* for future greenhouse gas emissions based on development-storylines of society, economy and technology. Global quantification of socio-economic development, greenhouse gas emissions and climate are provided in a coherent way by making use of the SRES emission scenarios (ibid). The SRES scenarios consists of four scenario families; A1, A2, B1 and B2. A very simplistic and general approach of representing the four storylines is shown in Figure 1. Nevertheless, each scenario comprises details concerning the world development, for further information on details see IPCC SRES (2000).

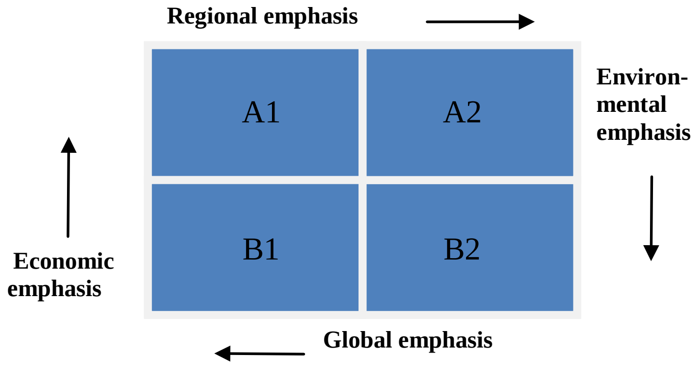

Figure 1: A schematic representation of the four SRES scenario families, adapted from IPCC, 2007a, Figure TS.2

The majority of the studies on climate change impact scenarios reviewed here used storylines derived from the SRES emission scenarios as a basis. However, a few of the reviewed studies modeled the climate change impacts based on other scenarios, for example, pre-SRES emission scenarios and self constructed scenarios.

General Circulation Models

This support material includes the terms *General Circulation Model* (GCM), sometimes simply referred to as global climate models, and *Regional Climate Model* (RCM). GCMs are numerical models of physical processes in the atmosphere, ocean and land surface. The models describe climate using a global three-dimensional grid. The models are used to simulate the global climate response to increased atmospheric concentration of greenhouse gases, by making use of, for example, SRES emission scenarios. Only GSMs, on its own or in combination with RCMs, are capable of providing reliable physical and geographical estimates of regional climate change required for impact analysis (DDC, 2009). However, the resolution of GCMs is rather coarse and most impact assessments require information on a much more local scale than what GCMs provide (ibid).

Regional climate modeling is one solution to the problem with low resolution of GCMs (ClimatePrediction, 2002-2010). Regional climate models usually cover an area of 5 000 km x 5 000 km. The RCM uses the climate data calculated by the GCM as boundary conditions. The reason why RCMs cannot function on its own is that the weather in one part of the world is dependent on the weather in another part of the world. Weather and climate conditions with resolution as fine as 50 to 25 km can be obtained by RCMs by making use of small scale information on, for example, land- use, formation and relief of mountains (ibid).

There are of course uncertainties related to climate models. In GCMs, physical processes on smaller scales, such as processes in clouds, cannot be modeled in a proper manner. Parameterization is used to manage this issue but causes uncertainty in the GCM-based simulations. One other important uncertainty concerns the various feedback mechanisms, for example, clouds coupled to radiation and water vapour coupled to warming. Processes and feedbacks can be modeled in different ways; consequently, diverse GCMs may simulate somewhat various responses to the same forcing (DDC, 2009).

Weather is not random but it could be termed as chaotic since the laws of physics are obeyed and every effect is caused by something, though, there are numerous of possible causes and information about all of them is not known (ClimatePrediction 2002-2010). Even so, it is a necessity to make weather forecasts and climate projections to get an idea of all development possibilities of the atmosphere. Ensembles of GCM runs can be performed to get improved information concerning the likelihood of different development pathways and to limit the uncertainty (ibid). An ensemble could be a collection of GCM runs from the same GCM with slightly different initial conditions (ibid), a collection of runs from different GCMs, or a multi-model ensemble (ENSEMBLES, 2009).

Modeling impacts of climate change

The impacts from the resulting anticipated climate scenarios could be assessed in different ways. One approach, and the focus of this support material, is integrated assessment models. The impacts of climate change can be represented in the integrated assessment models using two different techniques: response functions, and geographically-explicit impact models (Arnell and Osborn, 2006).

The first technique, utilizes impact response functions, also termed damage functions. The impact is by this technique assumed to follow a defined simple relationship with an indicator of climate change, for example, global mean temperature change. GRACE is one example of an integrated assessment model using response functions (Wei and Aaheim, 2010). The second category of integrated assessment models consist of geographically-explicit impact models within the integrated assessment model. One example of an integrated assessment model of this category is the Integrated Model to Assess the Global Environment, termed IMAGE (Bakkenes et al., 2006).

There are pros and cons with both approaches. The first approach, with impact response functions, is computationally much more efficient than the second approach which requires considerable computational resources. On the other hand, the first approach has several drawbacks and challenges. For example, the functions must be constructed or calibrated from empirical evidence, the impacts may not be directly dependent on temperature although temperature is a widely used measure of climate change, lastly, it is very difficult to take into account adaptation explicitly into the impact response functions – only highly generalized assumptions of how adaptation changes the curve of the function could be performed (Arnell and Osborn, 2006).

The second approach is theoretically much more credible and the effects of adaptation can in principle be included. Nevertheless, a spatial explicit impact model for application across the total global sphere is very difficult to construct. Moreover, there is a scale issue associated to the coarse scale climate models and finer-scale impacts models. The process based impact models are usually implemented at finest spatial scale of available input data and operating them at coarser spatial scales would give misleading results since the relationships between driver and response fail (ibid).

References

Arnell and Osborn (2006) Interfacing climate and impacts models in integrated assessment modeling, Tyndall Centre for Climate Change Research, Technical Report 52, Available at: http://www.tyndall.ac.uk/content/interfacing-climate-and-impacts-models-integrated-assessment-modelling (2010-09-06)

Bakkenes, M.; Eickhout, B. and Alkemade, R. (2006) Impacts of different climate stabilisation scenarios on plants species in Europe. *Global Environmental Change* 16: 19–28. Available at: http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6VFV-4HYMY36-1-B&_cdi=6020&_user=650414&_pii=S0959378005000725&_orig=browse&_coverDate=02%2F28%2F2006&_sk=999839998&view=c&wchp=dGLbVlW-zSkWb&md5=80297b68e204ee79de47648bbde2cce0&ie=/sdarticle.pdf (2010-07-14)

ClimatePrediction (2002-2010) 'Regional Climate modeling in Climate Science', Available at: http://climateprediction.net/content/regional-climate-models (2010-09-03)

DDC (2009) Data Distribution Centre of Intergovernmental Panel on Climate Change, 'What is a GCM', Available at: http://www.ipcc-data.org/ddc_gcm_guide.html (2010-09-02)

ENSEMBLES (2009) Climate change and its impacts at seasonal, decadal and centennial timescales. Met Office Hadely Centre. Exeter. Available at: http://ensembles-eu.metoffice.com/ (2010-07-19)

IPCC (2000) Nakicenovic, N., Alcamo, J., Davis, G., and Co-authors: *The Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES)*, Nakicenovic, N. and Swart, R., Eds., Cambridge University Press, Cambridge, UK. Available at: http://www.grida.no/publications/other/ipcc_sr/ (2010-08-27)

IPCC (2007a) Parry, M.L., Canziani, O.F., Palutikof, J.P., and Co-authors: Technical Summary. Climate Change 2007: *Impacts, Adoptaion and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden P.J., and Hanson C.E., Eds., Cambridge University Press, Cambridge, UK, 23-78.

Wei, T. and Aaheim, A. (2010) Impacts of climate change to the global economy in the ENSEMBLES +2 °C scenario E1, CICERO Report 2010:01, available at: http://www.cicero.uio.no/media/8029.pdf (2010-06-28)