P 2.3 PRECLIM
Probabilistic climate change scenarios for mean and extremes in the Alpine region

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1. Three research questions of the project

- How can the uncertainty of expected seasonal temperature and precipitation changes in Switzerland be quantified using a multi-model ensemble approach?
- How can end-users make optimal use of the full multi-model information and how can statistical downscaling help them to obtain information in a high temporal and spatial resolution?
- How will extreme weather events change in Switzerland and Europe? Can we use the multi-model approach to reliably quantify expected changes and uncertainty in extremes? How can the characteristics of changes in extremes be preserved in downscaling? To what degree can patterns be scaled to other scenarios?

2. Research Summary

Climate change is projected to have major impacts on various aspects of our society. In order to plan the future effectively, reliable information on the expected changes are needed that can be communicated and applied in end-user models. Such models typically require information on very local spatial and temporal scales. Several national climate change assessments (e.g. CH, NL, UK) made first attempts to make available such information by providing expected changes in mean quantities mainly derived from time slice experiments. Although today's climate models (as e.g., developed in P2.1 Schär/Wild) do have comparably high resolution, there is still a substantial gap to the end-user needs. E.g. the current climate change scenarios for Switzerland (OcCC 2007, Frei 2004) only consider seasonal averages for Northern and Southern Switzerland, thus limiting their applicability from a user perspective. This gap is even wider if climate extremes are considered, which are more difficult to predict because the relevant processes are often not adequately incorporated in today's climate models, and because the events are poorly sampled. Yet it is precisely those events that are probably most important to society.

P2.3 aims to fill this gap. P2.3 develops and applies statistical techniques to generate climate change scenarios with high temporal and spatial resolution while at the same time quantifying the underlying uncertainties. This involves the construction of calibrated multi-models from transient scenarios (e.g. Scherrer et al., 2005, Tebaldi and Knutti, 2007, Weigel et al., 2008, 2009) as well as the development and application of statistical downscaling methods to station level (e.g. Schmidli et al. 2007, Kilsby et al. 2007). Thereby, not only climate mean variables are considered, but also changes in climate extremes.

3.Data and methods

The recent OcCC (2007) climate change scenarios for Switzerland are based on model runs from the international PRUDENCE project which do not represent the state-of-the-art any more. The new scenarios to be developed in P2.3, on the other hand, will be based on the output of a new generation of Global Climate Models (GCMs) and Regional Climate Models (RCMs) as provided by P2.1 and particularly by the EU FP6 ENSEMBLES project. The ENSEMBLES model runs (Jacob et al. 2008) consist of 22 GCM-driven transient RCM simulations (1950-2050; A1B scenario), which will be available by the beginning of the 3rd phase of the NCCR Climate. They are based on various combinations of 6 GCMs and 14 RCMs, thus allowing for a probabilistic multi-model approach and a quantification of model uncertainties.

A methodological key question with respect to the construction of multi-model scenarios is whether or not all participating single models shall be considered, and whether or not weights shall be assigned to them (e.g. by applying the method of Buser et al. 2008). This requires an assessment of model performance with observational data, considering appropriate skill metrics (Weigel et al. 2007), such as model bias and the reproduction of observed climate characteristics (e.g. Liniger et al. 2007, Scherrer et al. 2006, 2008). For this task, the ENSEMBLES gridded high-resolution observational datasets of daily temperature and precipitation (Haylock et al. 2008) can be used, as well as homogenized observational data of MeteoSwiss. These data will also be the basis for the development and assessment of an appropriate statistical downscaling method.

The downscaled probabilistic multi-model scenarios will not only quantify changes in climate mean but will also estimate changes in extremes over Switzerland and Europe. In this context, more fundamental questions regarding the characteristics of extreme events in climate models will be additionally considered. For example, while changes in many variables can often be assumed to scale linearly with temperature, this may not be true for extreme events. Tebaldi et al 2006 have shown that even the globally averaged changes in dry days (defined as the annual maximum number of consecutive dry days) aggregated over several models show some change-points where the trends change or reverse abruptly, for example in the A2 scenario. Moreover, the B1 scenario indicates no significant trends despite substantial warming. Global models available from the CMIP3 multi-model archive will be used to test how spatial patterns of changes in extremes vary over time and across scenarios.

4. Milestones and deliverables

After 18 months:

- Scenarios for seasonal mean temperature and precipitation in regional resolution for Switzerland and (if possible) the Alps, based on multi-model transient climate scenarios (A1B scenario, time range until 2050);
- A set of statistical methods to robustly extract extreme statistics from climate model simulations.

After 36 months:

- A method to combine a statistical downscaling technique with a probabilistic multi-model approach to generate highly localized time series of temperature and precipitation on seasonal to daily time scales for Switzerland (A1B scenario, time range until 2050);
- An assessment of projected changes in extreme events in central Europe, with a focus on robustness, methods on how to combine models, the validity of pattern scaling and the consistency of the downscaled results.

5. Contribution to the WP2 and collaboration with other NCCR projects and 3rd parties

P2.3 will be strongly interlinked within WP2, as well as with WP1 and WP3. The dynamical global and regional climate model runs from P2.1 and P2.2 (as soon as available) together with model runs from international projects (PRUDENCE, ENSEMBLES) are the basis for our multi-model calibration effort. Historical model simulations and reconstructions from P1.1 MONALISA-3, P1.2 PALVAREX-3 and P1.3. DETREE will provide the historical context. Transient scenarios for end-user modellers (WP3, P4.2) are provided after 18 months (regional seasonal mean temperature and precipitation) and after 3 years (downscaled to daily time scales). Swiss scenarios are of prime interest to many other governmental bodies (e.g. BAFU, OcCC) and economic sectors (e.g. infrastructure as SIA, energy).

References

Buser, C. M., H. R. Künsch, D. Lüthi, M. Wild, and C. Schär, 2008: Estimating uncertainties in predicting climate distributions: A Bayesian ensemble method. *Clim. Dyn.* (submitted)

Frei, C, 2004: Die Klimazukunft der Schweiz – Eine probabilistische Projektion. (www.occc.ch/Products/CH2050/CH2050-Scenarien.pdf)

Haylock, M. R., N. Hofstra, A. M. G. Klein Tank, E. J. Klok, P. D. Jones, M. New, 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation for 1950-2006. *J. Geophys. Res.* (in press)

Jacob, D., O. B. Christensen, F. J. Doblas-Reyes, C. Goodess, A. Klein Tank, P. Lorenz, and E. Roeckner, 2008: Information on observations, global and regional modeling data availability and statistical downscaling. *ENSEMBLES Technical Report,* **4**, 10 pp.

Kilsby, C. G., P. D. Jones, A. Burton, A. C. Ford, H. J. Fowler, C. Harpham, P. James, A. Smith, and R. L. Wilby, 2007: A daily weather generator for use in climate change studies. *Env. Model. Softw.,* **22**, 1705-1719

Liniger, M. A., H. Mathis, C. Appenzeller, and F. J. Doblas-Reyes, 2007: Realistic greenhouse gas forcing and seasonal forecasts. *Geophys. Res. Lett.*, **34**, L04705

OcCC, 2007: *Klimaänderung und die Schweiz 2050 – Erwartete Auswirkungen auf Umwelt, Gesellschaft und Wirtschaft.* ISBN 978-3-907630-26-6, OcCC and ProClim, Bern, Switzerland. 172 pp.

Scherrer, S. C., C. Appenzeller, M. A. Liniger, and C. Schär, 2005: European temperature distribution changes in observations and climate change scenarios. *Geophys. Res. Lett.*, **32**, L19705, doi:10.1029/2005GL024108.

Scherrer, S. C., C. Appenzeller, and M. A. Liniger, 2006: Temperature trends in Switzerland and Europe: Implications for climate normals. *Int. J. Climatol.,* **26**, 565-580

Scherrer, S. C., M. A. Liniger, and C. Appenzeller, 2008: Distribution changes of seasonal mean temperature in observations and climate change scenarios. In: Climate Variability and Extremes during the Past 100 Years, S. Brönnimann et al. (eds), Springer Netherlands, *251-267*

Schmidli, J., C. M. Goodess, C. Frei, M. R. Haylock, Y. Hundecha, J. Ribalaygua and T. Schmith, 2007: Statistical and dynamical downscaling of precipitation: An evaluation and comparison of scenarios for the European Alps. *J. Geophys. Res.,* **112**, D04105

Tebaldi, C., K. Hayhoe , J.M. Arblaster, and G.A. Meehl, 2006: Going to the extremes: An intercomparison of model-simulated historical and future changes in extreme events. *Climatic Change*, **82**, 233–234

Tebaldi, C. and R. Knutti, 2007: The use of the multi-model ensemble in probabilistic climate projections. *Phil. Trans. Roy. Soc.* A, **365**, 2053-2075.

Weigel, A.P., M. A. Liniger and C. Appenzeller, 2007: The discrete Brier and ranked probability skill scores. *Mon. Wea. Rev.,* **135**, 118–124.

Weigel, A.P., M. A. Liniger and C. Appenzeller, 2008: Can multi-model combination really enhance the prediction skill of probabilistic ensemble forecasts ? *Q. J. R. Meteorol. Soc.*, **134**, 241-260

Weigel, A.P., M. A. Liniger and C. Appenzeller, 2009: Seasonal ensemble forecasts: Are recalibrated single models better than multi-models? *Mon. Wea. Rev.* (in press)