Applications of pattern scaling for probabilistic assessment of regional climate impacts

Katja Frieler[1], Ben Poulter[2], Nadine Braun[3], Bill Hare[1,4], Malte Meinshausen[1]

[1] Potsdam Institute for Climate Impact Research, Potsdam, Germany
[2] Swiss Federal Research Institute (WSL), Zurich, Switzerland
[3]Department of Environment Engineering, TU Berlin, Berlin, Germany
[4] Climate Analytics, Potsdam Germany

Contact: katja.frieler@pik-potsdam.de

Background: (AO)GCMs show a relatively linear relationship between global mean temperature change ΔT_{global} and regional changes in temperature and precipitation[1,2,3]. While scaling coefficients are nearly independent from emissions scenarios they may differ from model to model. Here, we use this information to develop regional climate projections that depend on global mean temperature change. Inter-model, inter-scenario, and inter-run variations of scaling coefficients are translated into uncertainty distributions that provide the input for impact functions allowing probabilistic impact assessment.

Data base

AR4 AOGCM simulations: 22 models, 6 scenarios, up to 5 runs per scenario

Modelling assumptions

1. Regional changes in temperature and precipitation depend linearly on ΔT_{global}.
2. Scaling coefficients vary from model to model (and to a much lesser degree from scenario to scenario or from run to run).
3. Model specific deviations from mean scaling coefficients for temperature and precipitation may be correlated, i.e. models showing a high temperature scaling coefficient may also show a high precipitation scaling coefficient or vice versa.

Linear mixed effects model for regional climate projections

$$\begin{pmatrix} \Delta T_{regional} \\ \Delta \log(P_{regional}) \end{pmatrix}_{i,j,k} = \begin{pmatrix} c + r_i^{mod} + r_{i,j}^{scen} + r_{i,j,k}^{run} \\ \tilde{c} + \tilde{r}_i^{mod} + \tilde{r}_{i,j}^{scen} + \tilde{r}_{i,j,k}^{run} \end{pmatrix} * \Delta T_{global} + \begin{pmatrix} \varepsilon_{i,j,k} \\ \tilde{\varepsilon}_{i,j,k} \end{pmatrix}$$

$\begin{pmatrix} r^{mod} \\ \tilde{r}^{mod} \end{pmatrix} \sim N((0,0), C_{mod})$ inter-model variability

$\begin{pmatrix} r^{scen} \\ \tilde{r}^{scen} \end{pmatrix} \sim N((0,0), C_{scen})$ inter-scenario variability

$\begin{pmatrix} r^{run} \\ \tilde{r}^{run} \end{pmatrix} \sim N((0,0), C_{run})$ inter-run variability

$i = \text{model}, \quad j = \text{scenario}, \quad k = \text{run}$

Model is fit by R-routine „lme", Pinheiro and Bates, 2001

Greenland

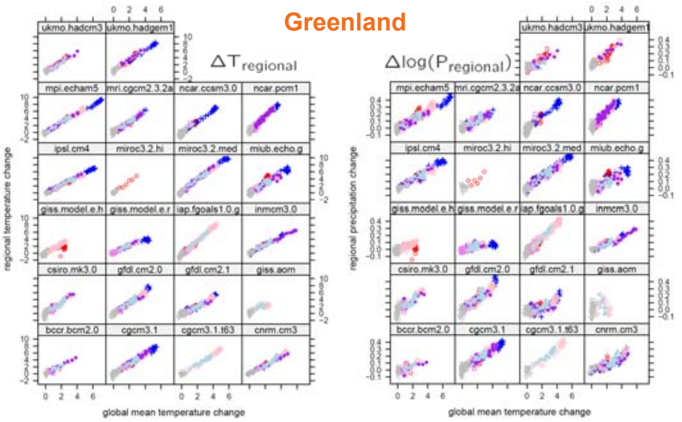

Figure 1: Ten year averages of regional temp and log(prec) changes (with respect to the associated control runs) plotted against ΔT_{global}. ○ **1pctto2x**, **+ 1pctto4x**, ▽ **20c3m**, □ **commit**, ● **sresa2**, ▲ **sresb1**, ◊ **sresa1b**.

Results provided by the statistical model

	Scaling coeff.	Std.error	σ_{model}	$\sigma_{scenario}$	σ_{run}
temp	1.44	0.061	0.280	0.118	0.026
prec	0.06	0.005	0.025	0.009	NA
Corr.		0.873	0.877	0.885	NA

Impact: Sea level rise (SLR)

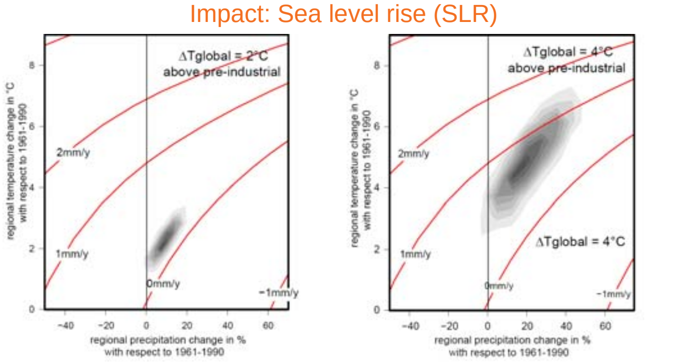

Figure 2: Uncertainty distribution of *median* temp and prec. changes over Greenland under 2 °C and 4 °C global warming. Red isolines: *Changes* in sea level rise due to changes in Greenland's surface mass balance (SMB), purely diagnostic model (Gregory and Huybrechts, 2006).

	Exceedance prob 2 °C	Exceedance prob 4 °C
1.00 mm/yr	0%	~20%
0.62 mm/yr	0%	~70%

Greenland's SMB becomes negative (Gregory and Huybrechts, 2006).

Estimation of SLR does not account for dynamical losses of the ice sheet that might add considerably to the values given here[4].

Amazon

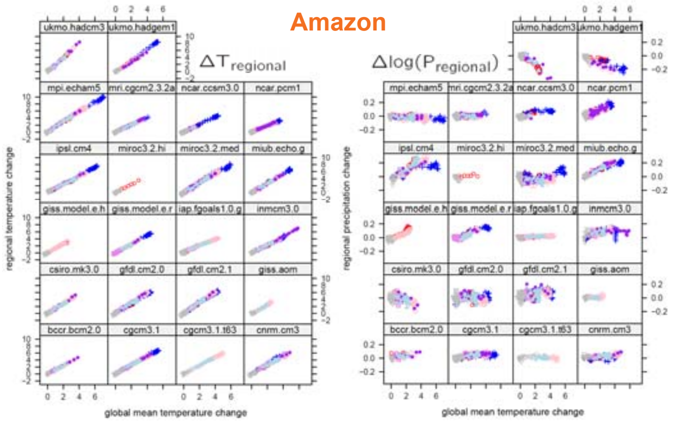

Figure 3: Ten year averages of regional temp and log(prec) changes (with respect to the associated control runs) plotted against ΔT_{global}. ○ **1pctto2x**, **+ 1pctto4x**, ▽ **20c3m**, □ **commit**, ● **sresa2**, ▲ **sresb1**, ◊ **sresa1b**.

Results provided by the statistical model

	Scaling coeff.	Std.error	σ_{model}	$\sigma_{scenario}$	σ_{run}
temp	1.29	0.046	0.214	0.050	0.009
Prec	0.01	0.006	0.030	0.010	NA
Corr.		-0.639	-0.651	-0.084	NA

Climate change in the Amazon Basin

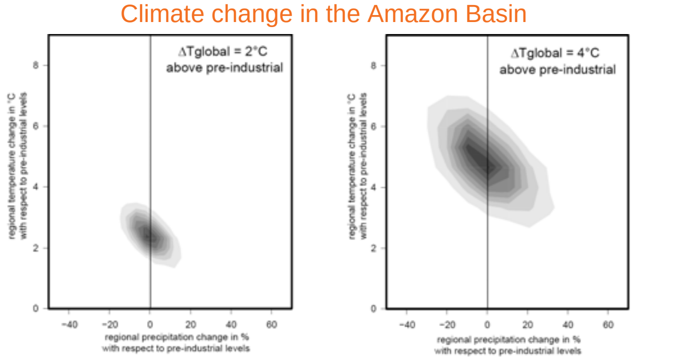

Figure 4: *Median* projected climate changes analogously to Figure 2.

Outlook

We work on an extension of this linear scaling approach taking into account further variables (e.g. aerosol temperatures).

We plan to implement a new scaling methodology for 0-1 processes (e.g. occurrence of coral bleaching, droughts, and floods).

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Literature: [1]Mitchell et al., Climate Change, 41 (1999); [2]Mitchell, Climatic Change, 60 (2003); [3]Giorgi et al., Journal of Climate, 21 (2008); [4]Pachauri, R.K. and Reisinger, A. (Eds.), Climate Change 2007: Synthesis Report.