PATTERN SCALING:
A RECENT DEVELOPMENT AND
LARGER PLANS

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Pattern Scaling

Can provide a simplified, computationally cheap representation of the climate system response to anthropogenic forcings.

Has been developed, tested and applied for more than twenty years now (Santer et al., 1990; MAGICC SCENGEN; many other simple or complex emulation methods)

Relies on the notion that a robust geographic pattern of change is constant through a transient simulation, and the most significant difference as time goes by and GHG atmospheric concentration increase is the intensity of the change, which is to a first approximation proportional to global average temperature increase.
Simple Pattern Scaling

\[ T_{it} - T_{i0} = \beta_i (g_t - g_0) + \epsilon_{it} \]

\( T_{it} - T_{i0} \) is the map of forced change at a given time \( t \) and location \( i \) during the simulation of a specific scenario of interest, using a given model.

\( g_t - g_0 \) is the change in global average temperature under that particular scenario and model.

\( \beta_i \) is the constant (in time) geographic pattern of change per degree of global average warming, independent of scenario and model. Once that is estimated all we need is a simple model able to simulate \( g_t \).
A Better Model

Accounting for variability

At each location $i$, fit a linear mixed-effects model to RCP 8.5 using Large Ensemble

$$T_{ikt} - T_{i,0} = \left( \beta_i \right) \cdot \left( g_t - g_0 \right) + \epsilon_{ikt},$$

$$\epsilon_{ikt} \sim N(0, \sigma_i^2)$$

where $k$ is the ensemble member

(Alexeeff et al., in review – BRACE special issue)
Mean Pattern

(As in Simple Pattern Scaling)
Mean Pattern

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A Better Model

Accounting for variability

At each location \( i \), fit a linear mixed-effects model to RCP 8.5 using Large Ensemble

\[
T_{ikt} - T_{i,0} = (\beta_i) \cdot (g_t - g_0) + \epsilon_{ikt},
\]

\[
\epsilon_{ikt} \sim N(0, \sigma_i^2)
\]

where \( k \) is the ensemble member
Zooming in on a gridpoint

Boston, MA in winter (DJF)

overall slope 1.308

temp change at this location

global temp change
Zooming in on a gridpoint

Boston, MA in winter (DJF)

overall slope 1.308
individual slope 1.335

individual intercept ~0.094
Zooming in on a gridpoint

Boston, MA in winter (DJF)

overall slope 1.308
individual slope 1.278

individual intercept 0.08
Emulating a different RCP

To generate pseudo-ensemble members $\hat{T}_{it}^{(k)}$

$$\hat{T}_{it}^{(k)} = T_{i,0} + (\hat{\alpha}_i + \tilde{a}_i^{(k)}) + (\hat{\beta}_i + \tilde{b}_i^{(k)}) \cdot (g_t - g_0) + \tilde{\epsilon}_{it}^{(k)}$$

Where $g_t$ is the global average temperature change under the different RCP and

- $\tilde{a}_i^{(k)} \sim N(0, \hat{\tau}_{a,i}^2)$, $\tilde{b}_i^{(k)} \sim N(0, \hat{\tau}_{b,i}^2)$
- $\hat{\alpha}_i, \hat{\beta}_i, \hat{\tau}_{a,i}^2, \hat{\tau}_{b,i}^2$ are estimated from the model fit
- $\tilde{\epsilon}_{it}^{(k)}$ we generate by resampling the residuals
Zooming in on a gridpoint

Generate new observation for Boston, MA in winter (DJF)

Step 1. Overall Slope and Intercept (fixed effects)
Zooming in on a gridpoint

Generate new observation for Boston, MA in winter (DJF)

Step 2. Individual Slope and Intercept (random effects)

temp change at this location

global temp change
Zooming in on a gridpoint

Generate new observation for Boston, MA in winter (DJF)

Step 3. Add residuals by resampling
Zooming in on a gridpoint

Generate new observation for Boston, MA in winter (DJF)
Resampling of the Residuals

What to consider

- Spatial correlation for a given ensemble member and year: we preserve them by sampling the entire spatial field of residuals

- Temporal autocorrelation: we preserve it by sampling a – short – time window

- Long-term temporal trends in variance: we preserve it by sampling that window conditionally on the value of global mean temperature
Zooming in on another gridpoint

Salt Lake City, UT in winter (DJF)

Overall slope 2.254
Zooming in on another gridpoint
Zooming in on another gridpoint
The devil is in the details

Spatial processes (remember those random effects?) have to account for:
- non-stationarity and peculiar features (continents vs. oceans, high vs. low latitudes) and need to be estimated over a large (cylindrical) grid (typically T42, ~8000 grid points).
- Simulation should be joint for temperature and precipitation and across seasons to provide not only geographic, but also temporal and climatologic coherence for input to impact models.

Parameters should be valid for multiple models, allowing us to simulate new models and new scenarios.
To Do

- Hyper-parameterization to characterize the CMIP family of GCMs
  Joint Temperature/Precipitation/Other variables? Which ones?
  Seasonally-consistent modeling

- Downscaling to daily time resolution

- Modeling of regional effects from aerosols/land use

- Emulators for extremes
Who is going to do it? NCAR?

Workshop on Pattern Scaling and emulators (Spring 2014)

- Lessons learned: need for cataloguing, systematizing, identifying specific needs (variables/time scales) for a range of impact modeling
- Review papers in preparation

In-house Expertise and Resources

- Climate modeling and Analysis, Integrated Assessment Modeling, Scenarios, Statistics, Computational Power and Methods
- Linkages: TGICA, ICONICS, ScenarioMIP, SAMSI, MetOffice