2016 CESM WG Meeting: Societal Dimension Working Group

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PATTERN SCALING: A RECENT DEVELOPMENT AND LARGER PLANS

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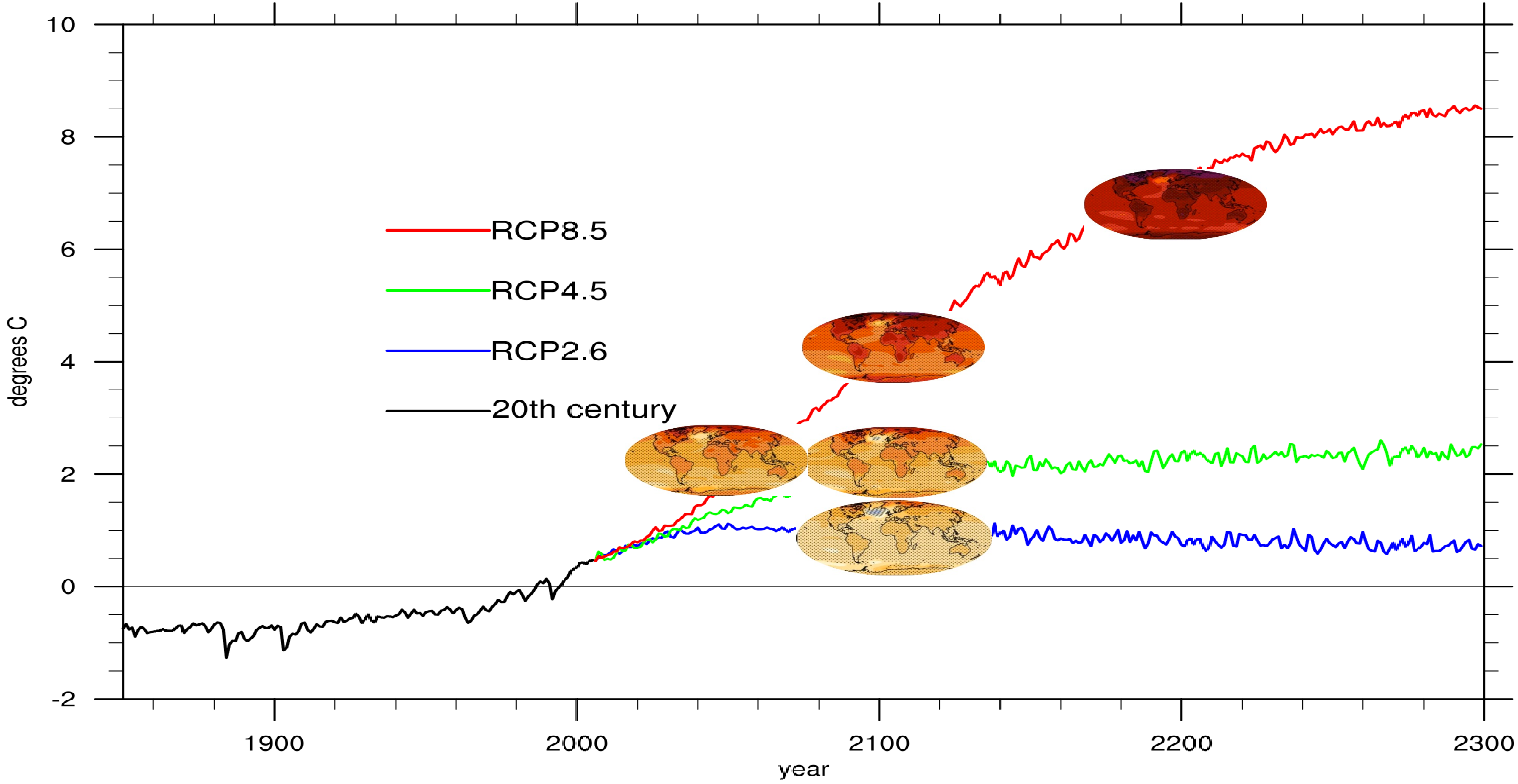
Pattern Scaling

- 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.



Temperature series plot courtesy of G. Strand

Simple Pattern Scaling

$$T_{it}-T_{i0} = \beta_i(g_t-g_0) + \varepsilon_{it}$$

$T_{it}-T_{i0}$ 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.

β_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

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

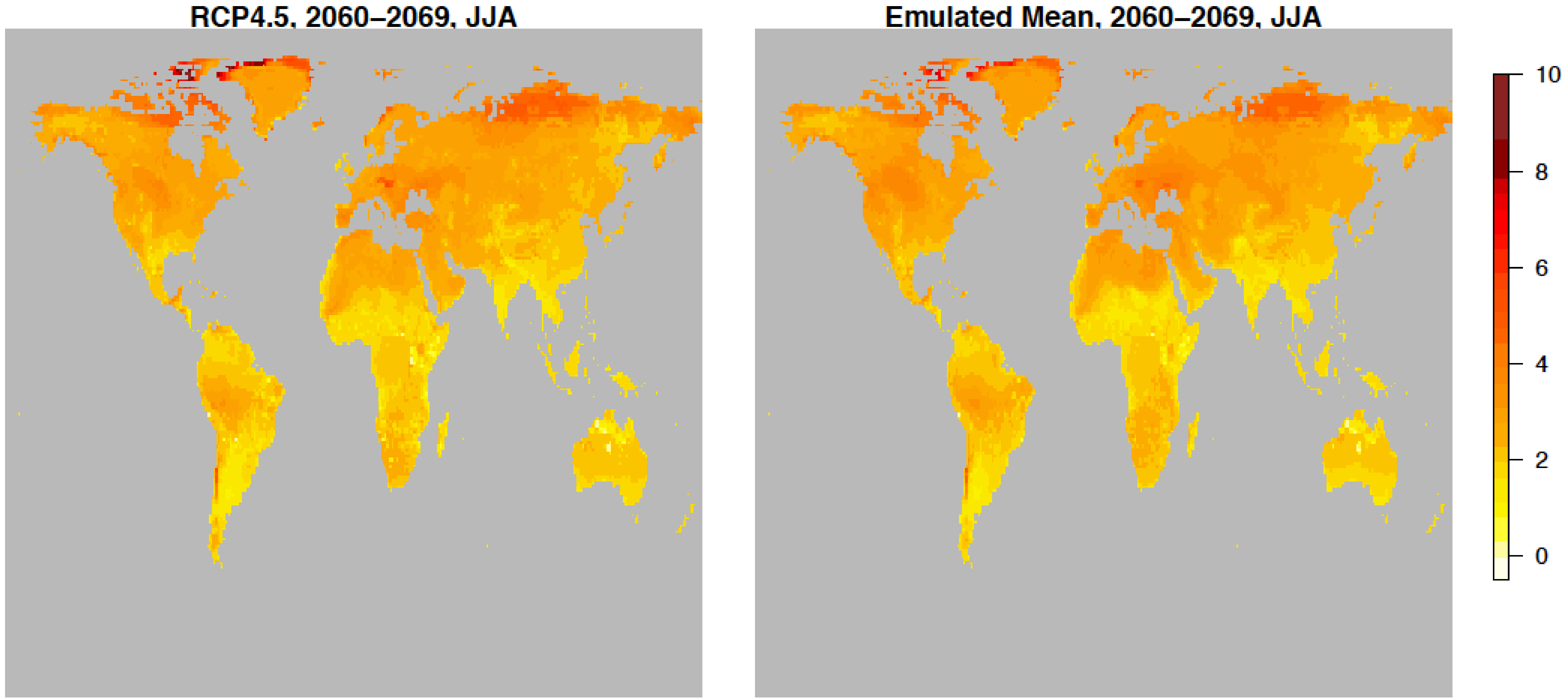
$$\epsilon_{ikt} \sim N(0, \sigma_i^2)$$

where k is the ensemble member

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

Mean Pattern

(As in Simple Pattern Scaling)



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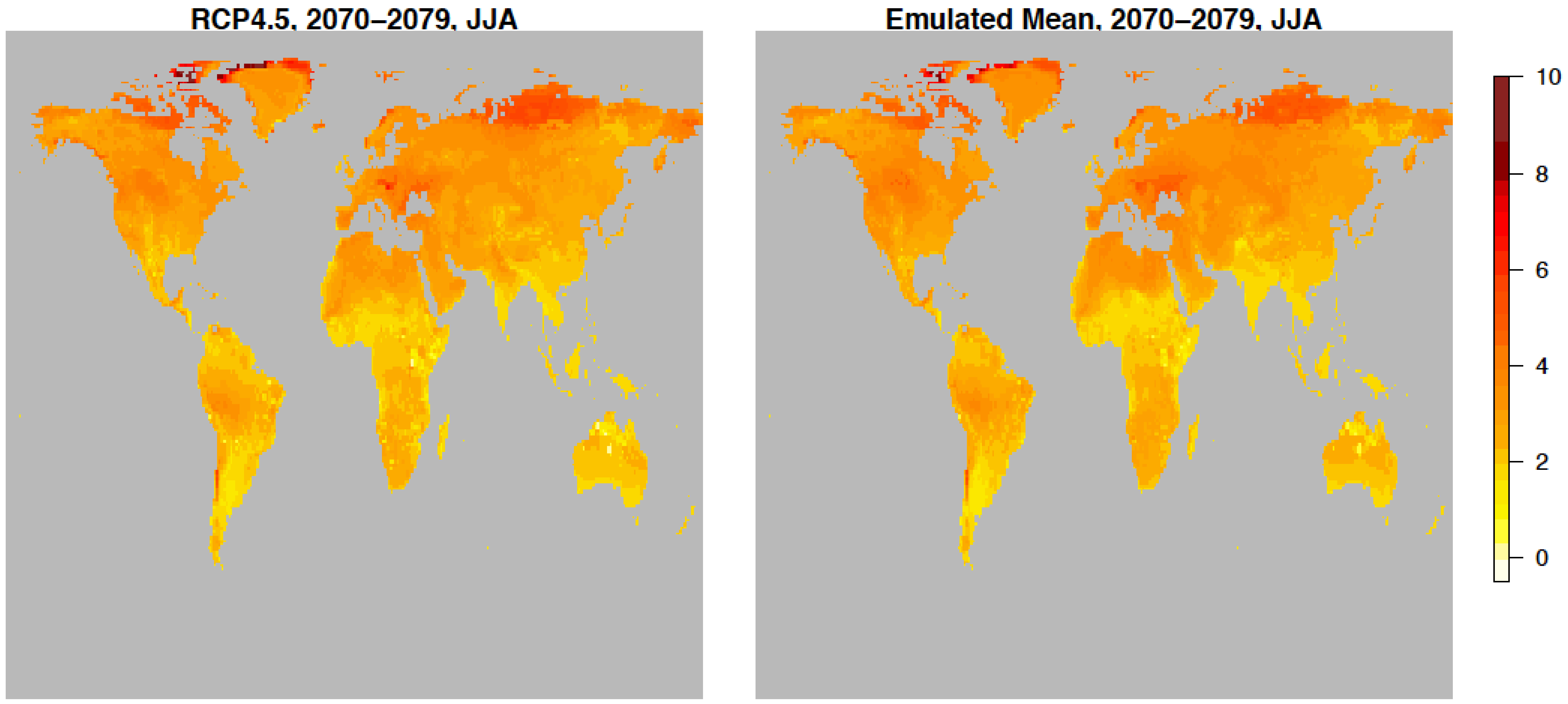

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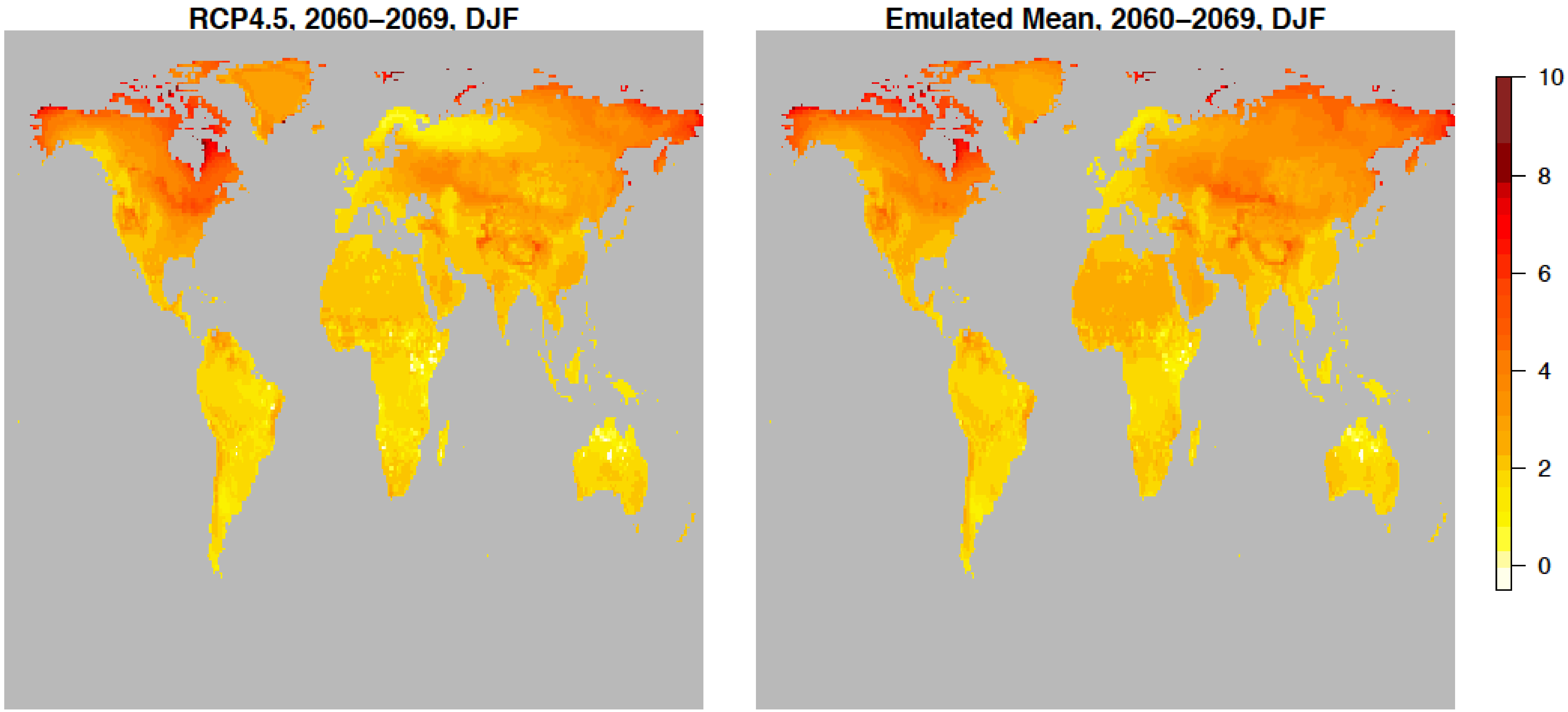

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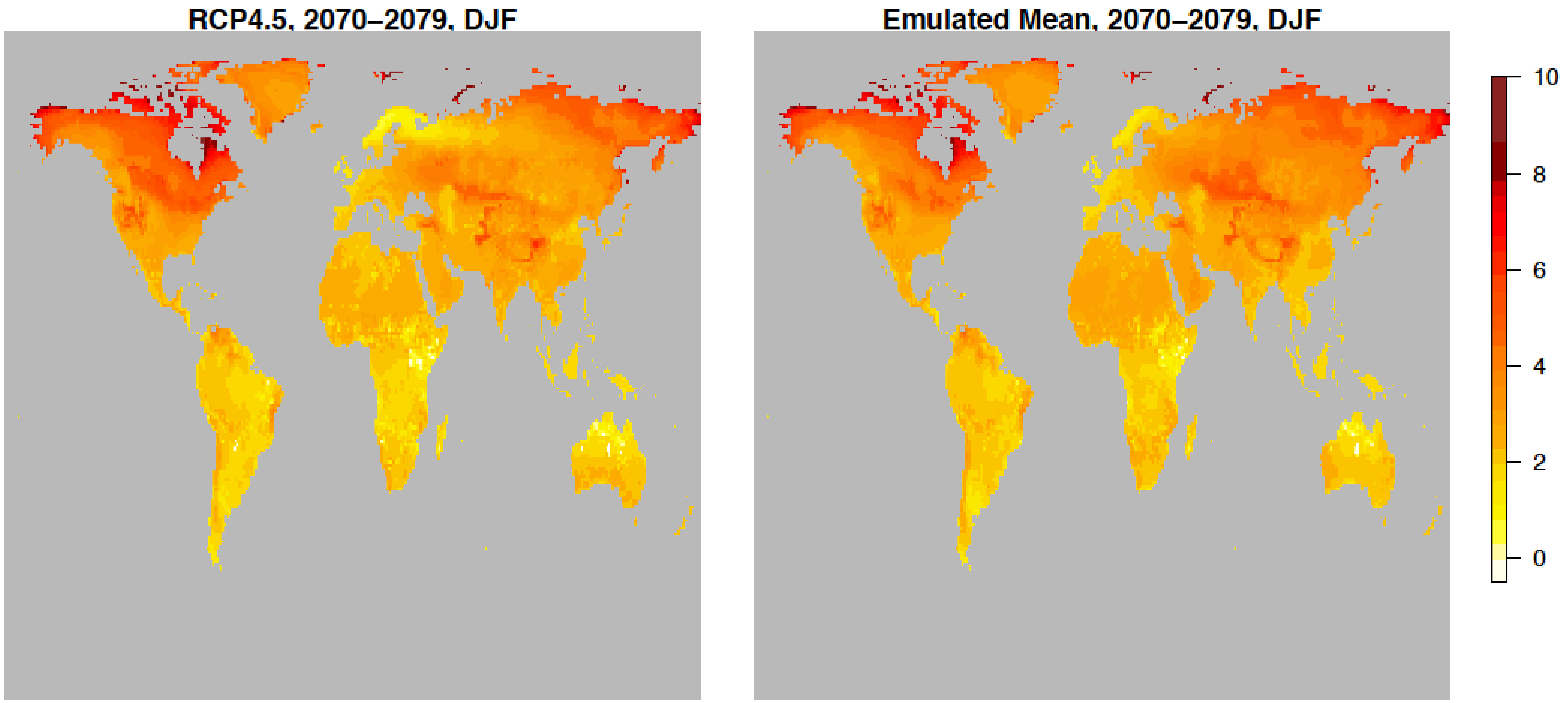

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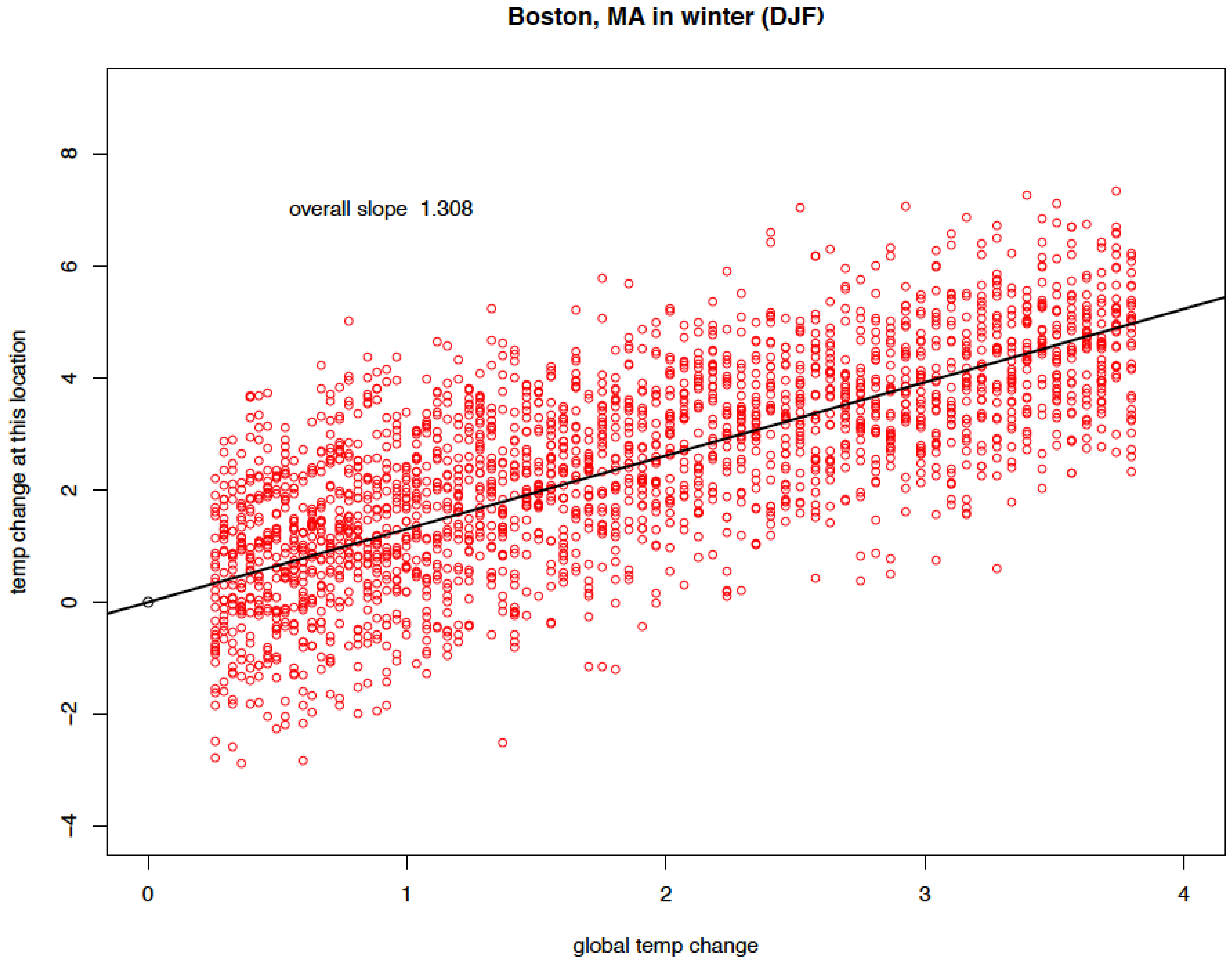
Zooming in on a gridpoint



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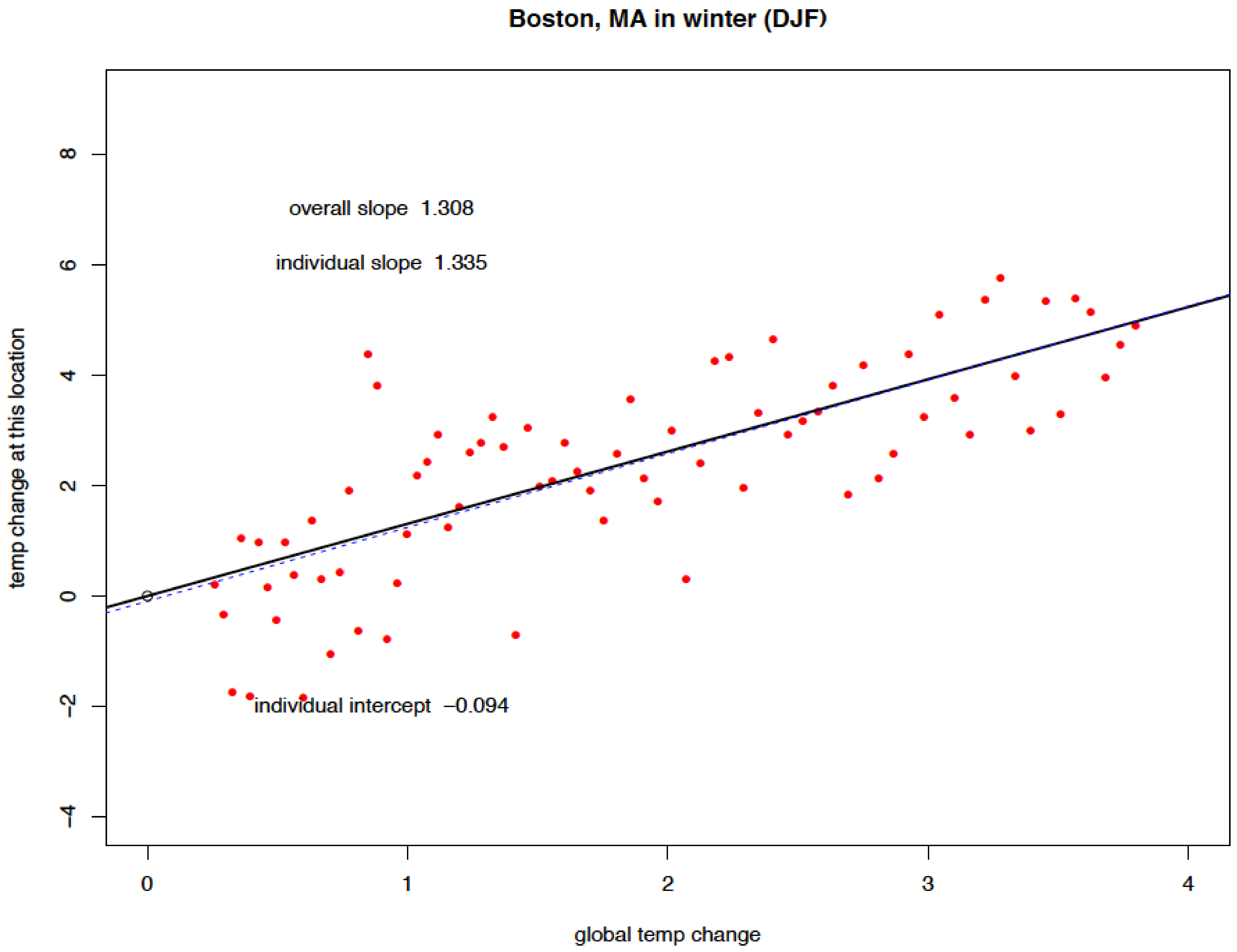

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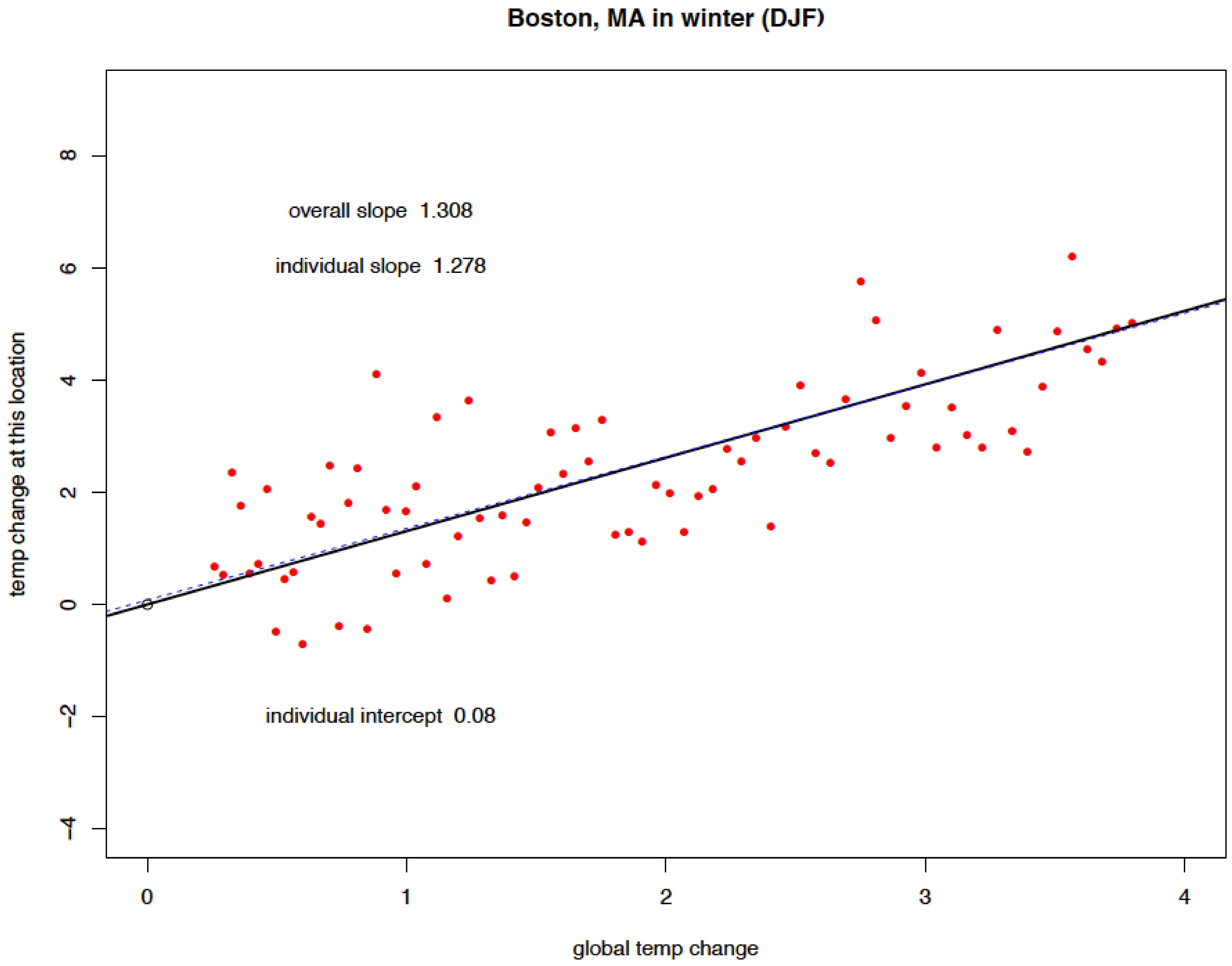


Emulating a different RCP

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

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

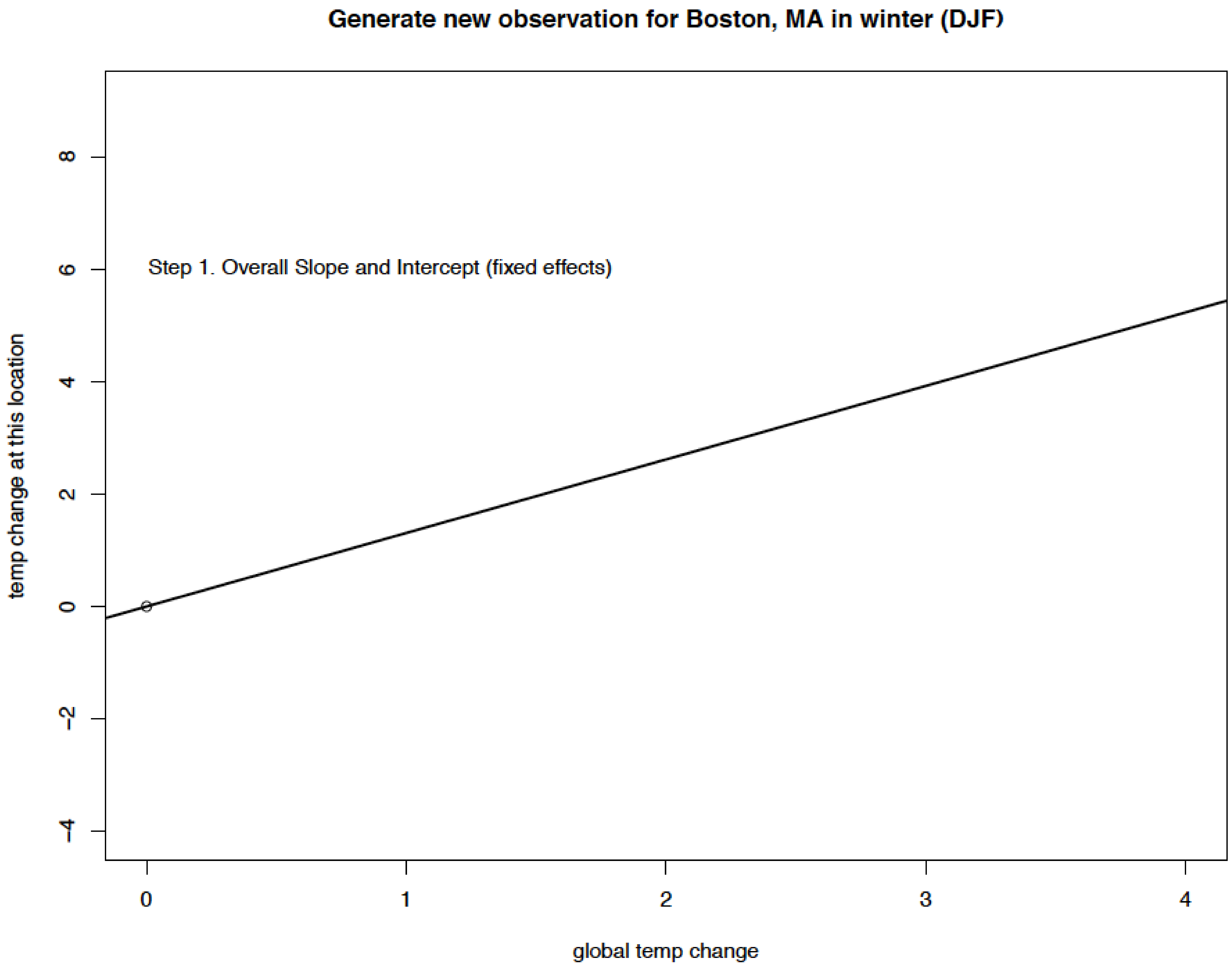
Where g_t is the global average temperature change under the different RCP

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



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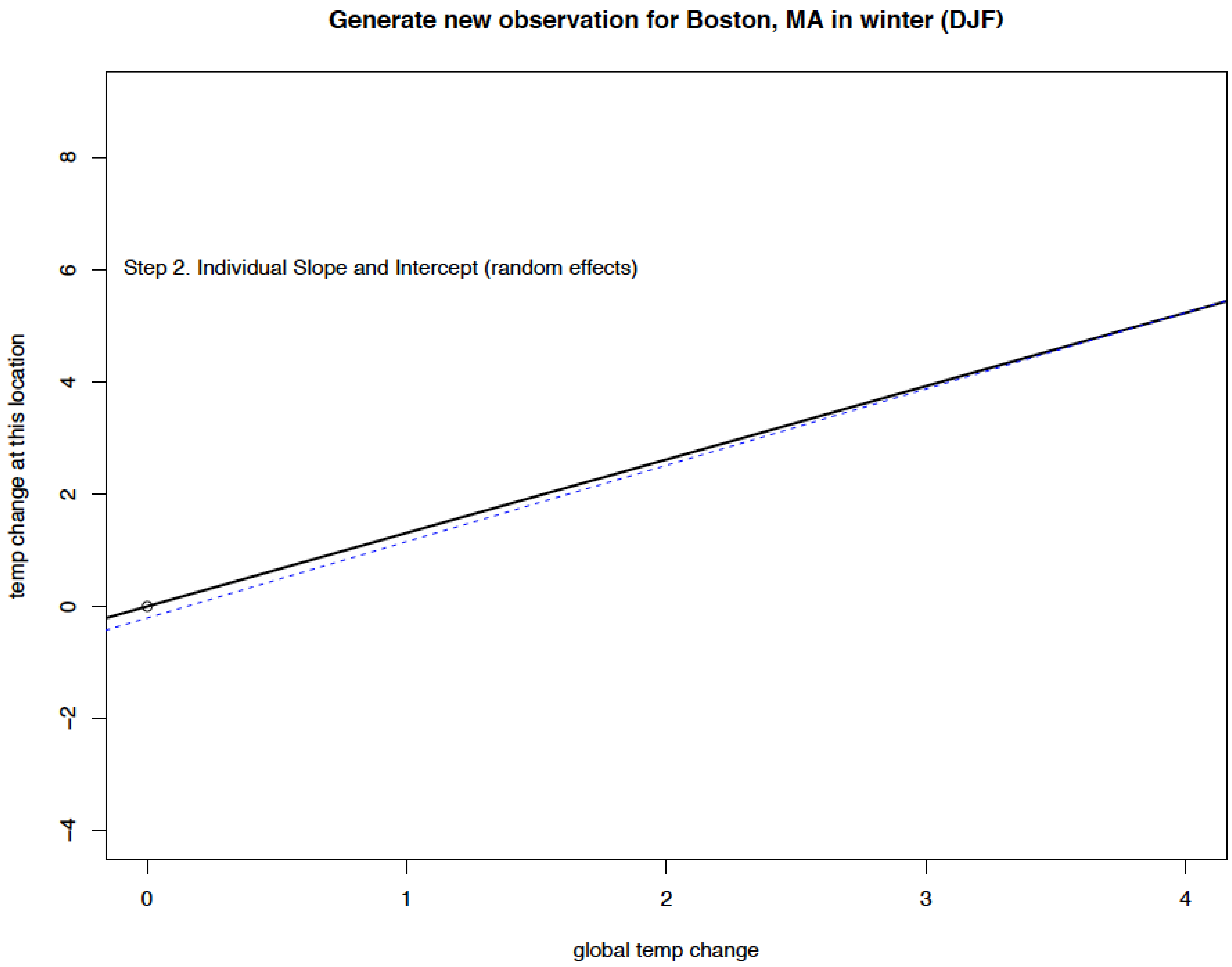

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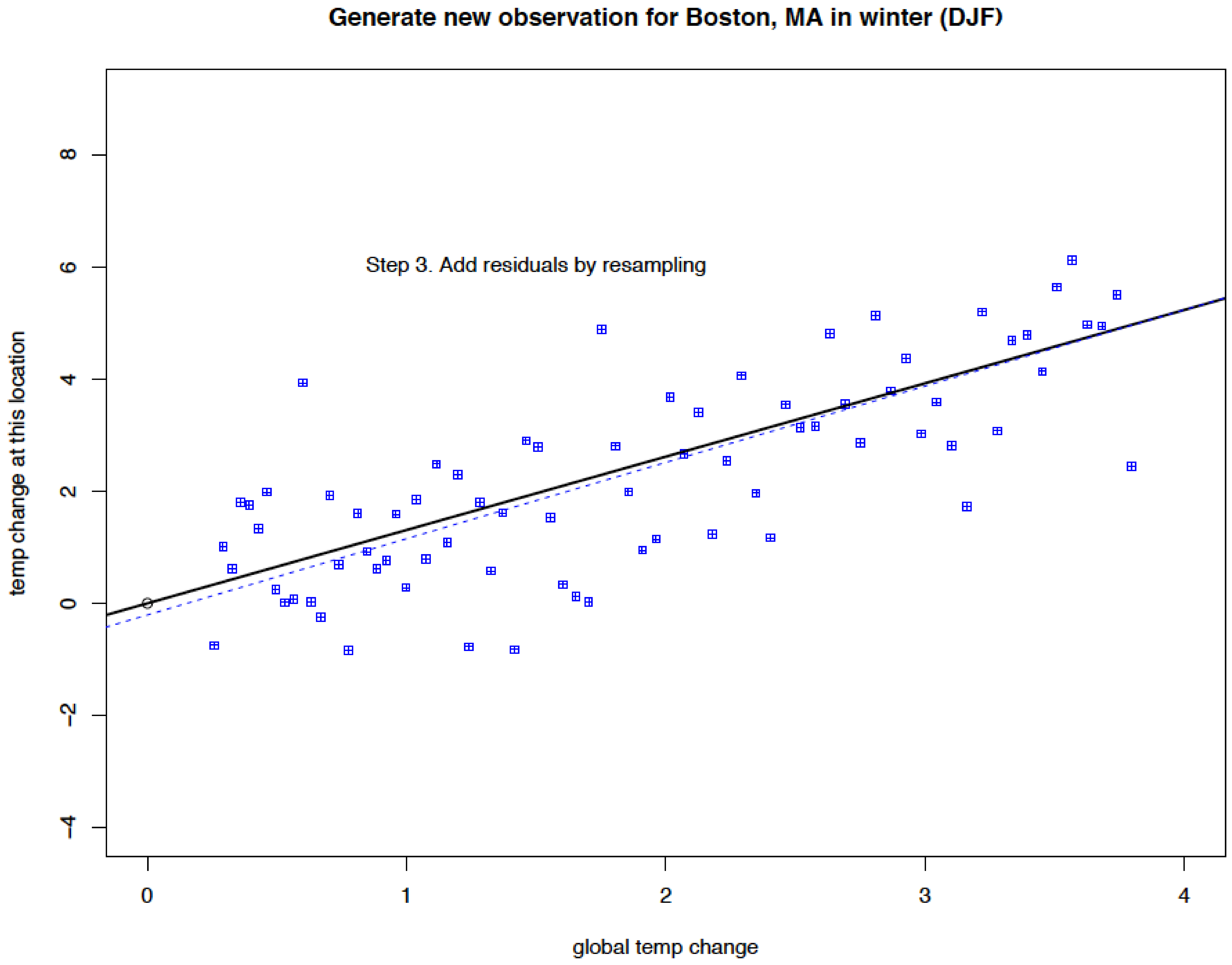

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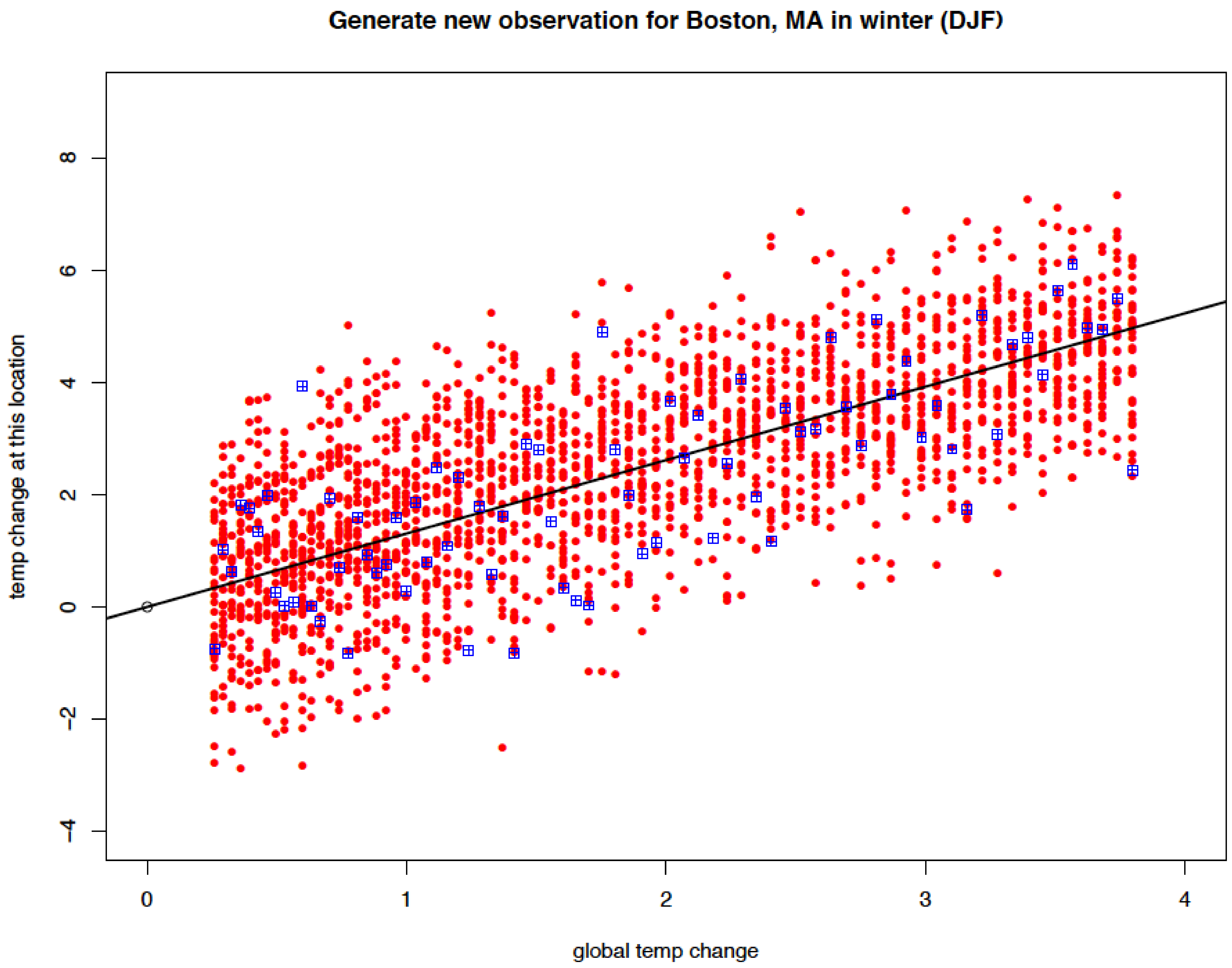


Resampling of the Residuals

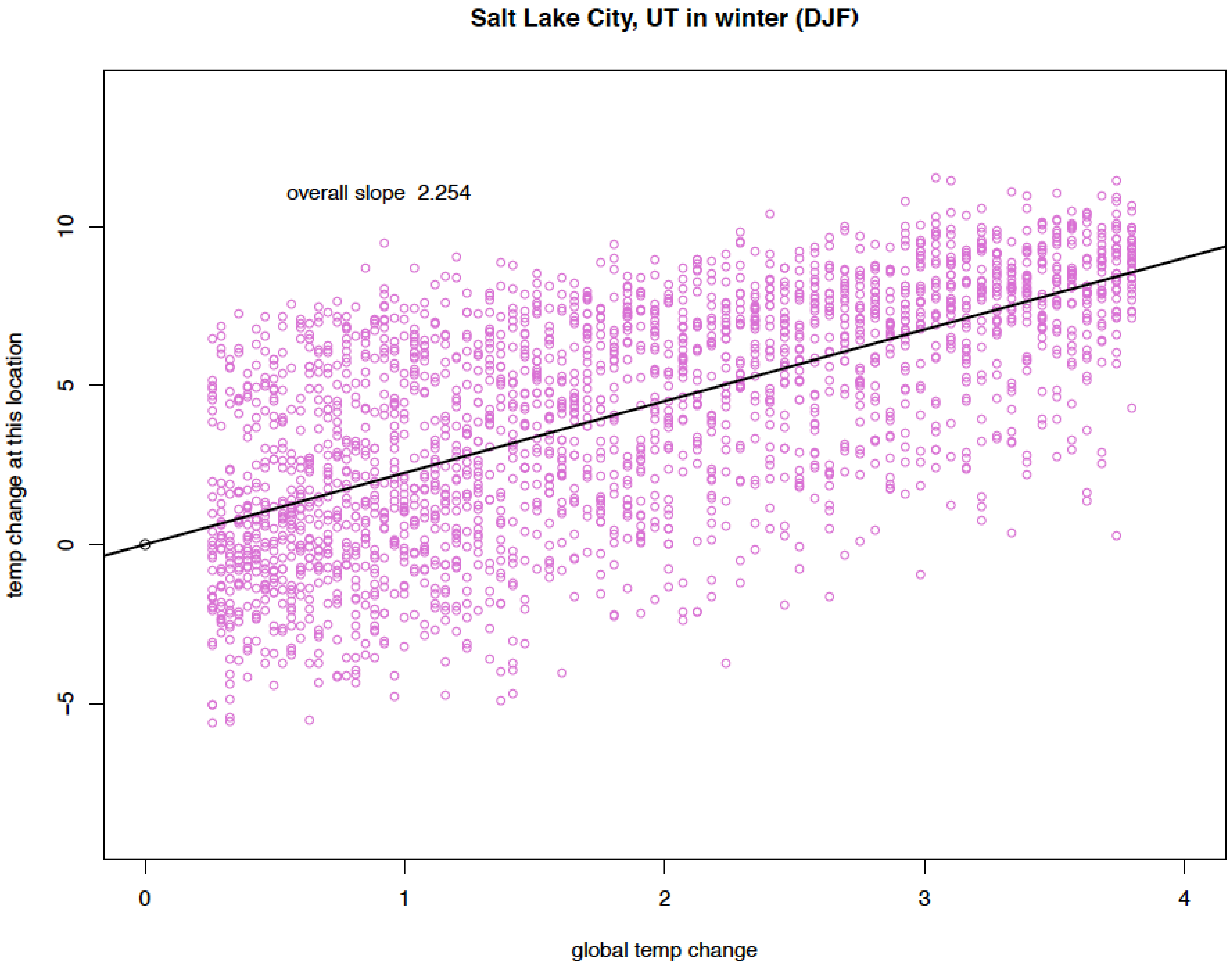
What to consider

- 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



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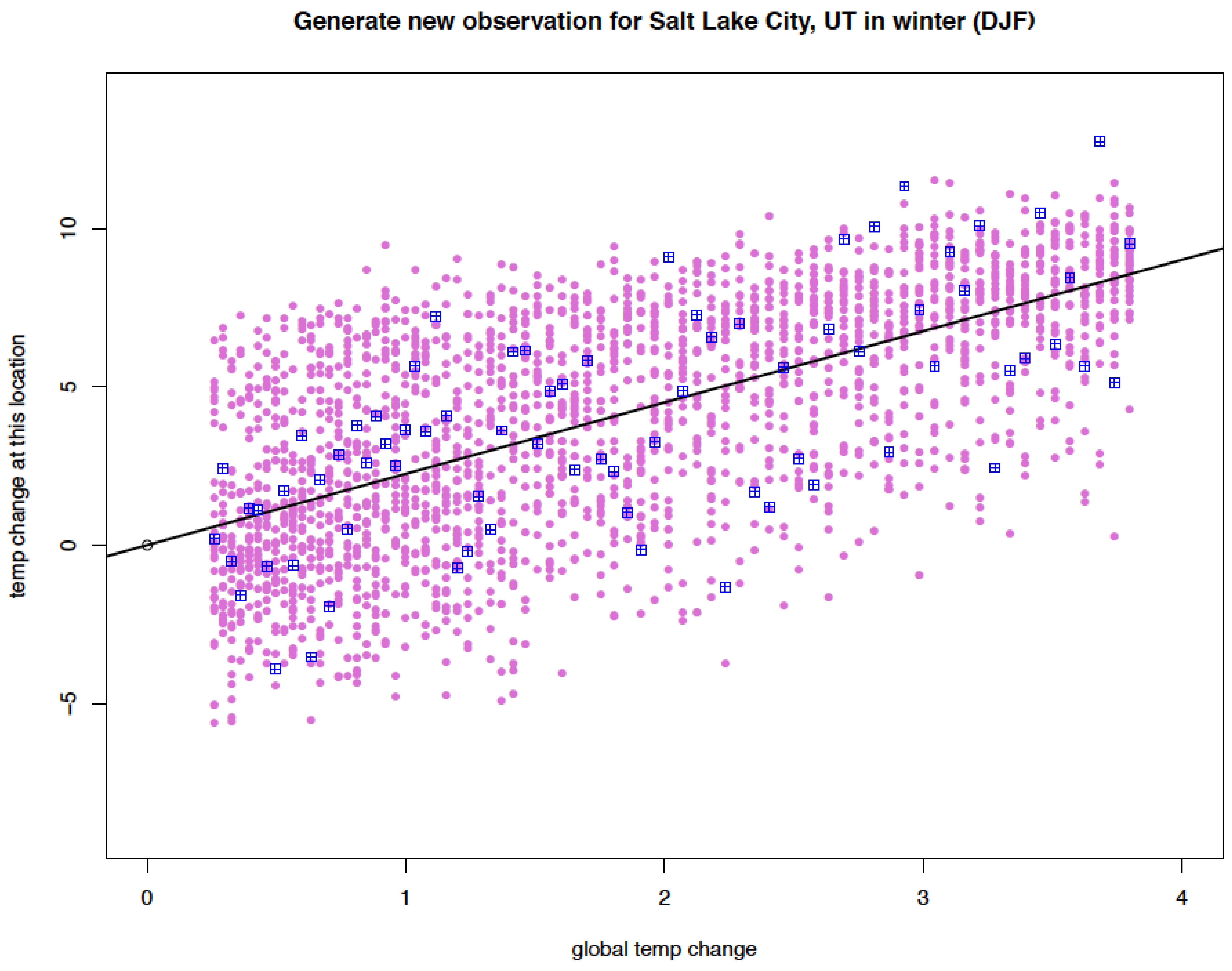

The devil is in the details

- Spatial processes (remember those randome 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