Exploring spatial patterns of GCM projection bias via model-based geostatistics

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1 Introduction

General Circulation Models (GCMs) are numerical models developed to represent physical processes in the atmosphere, ocean, cryosphere and land surface. They constitute the most advanced tool currently available for simulating future climate scenarios as a response to increasing greenhouse gas concentrations. GCMs, possibly in conjunction with nested regional climate models (RCMs), have the potential to provide consistent estimates of regional climate change which are required in climate impact assessments (IPCC, 2011).

The characterization of model bias in terms of magnitude and spatial patterns is part of the process of evaluating the model performance via hindcast skill analysis, an important preliminary step in climate change impact assessments. In this paper, we discuss how Model Based Geostatistics can be applied for exploring bias patterns, key information for performing bias correction of GCM or RCM projections in future time slices. As example, we present an assessment of annual rainfall projection bias for three GCMs across the Northeast Brazil.

2 Material and Methods

We assessed spatial patterns of annual rainfall bias for three General Circulation Models - GCMs - (IPCC AR4, IPCC, 2007) across Northeastern Brazil (NEB) using gridded data obtained from the Climate Research Unit (CRU, Mitchell & Jones 2005) and GCM hindcasts. To assess GCM performance via hindcast skill we used 1961 – 1990 period as baseline climatology and compared retrospective projections to corresponding hindcasts from the three GCMs: CCSM3 (National Center for Atmospheric Research, USA), ECHAM5 (Max Planck Institute for Meteorology, Germany) and UKMO-HadCM3 (Hadley Center for Climate Prediction and Research/Met Office, UK).

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For each pixel (5º x 5º), we calculated the difference (row bias) between model hindcast for the total annual rainfall and the corresponding CRU value. Bias spatial patterns were explored by using model-based geostatistics (MBG, Diggle et al, 2003). Spatial models including quadratic trends along longitude and latitude and a spatial dependence structure represented by the Mátern model (Mátern, 1960) were fit by using GeoR package (Ribeiro and Diggle, 2001) of the R free software environment for statistical computing and graphics (R Development Core Team, 2006).

3 Results and discussion

We observed consistent spatial patterns for all the evaluated models: i) a gradient from positive bias in the semi-arid interior zone (driest sub-region) to negative bias for the higher rainfall zones near the western and eastern borders of NEB and ii) occurrence of negative bias in the Northern (North Maranhão) and Southern extremes (South Bahia) of the region, corresponding to zones of positive spatial rainfall anomalies (**Figures 1 and 4**).

Relative bias for all models evaluated was high, ranging from: -60 to 143% (CCSM3), -65 to 147% (ECHAM5) and -71 to 71%(HADCM3). All evaluated models showed a higher frequency of positive bias corresponding to large areas with rainfall overestimation in the central backland (**Figure 3**).

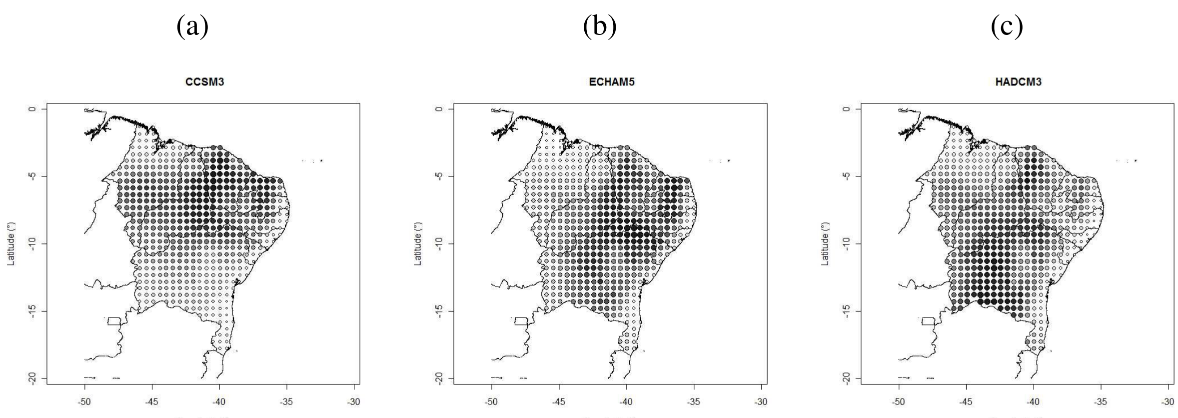

Figure 1. Observed absolute annual rainfall bias for the general circulation models CCSM3 (a), ECHAM5 (b) and HADCM3 (c) across North-Eastern Brazil. Dot size and grey intensity proportional to data values.

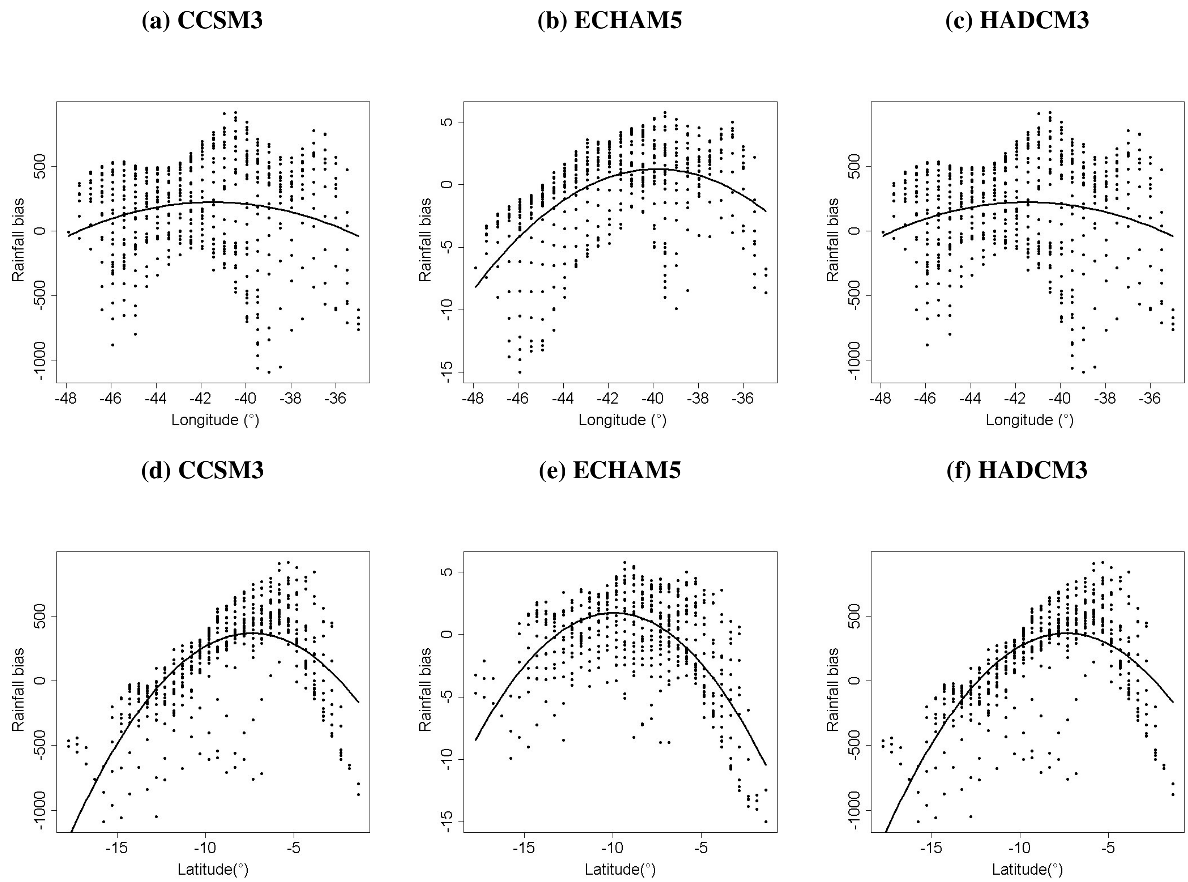

Figure 2. Trend patterns of annual rainfall bias along longitude (a-c) and latitude (d-f) across North – Eastern Brazil for the general circulation models CCSM3, ECHAM5 and HADCM3.

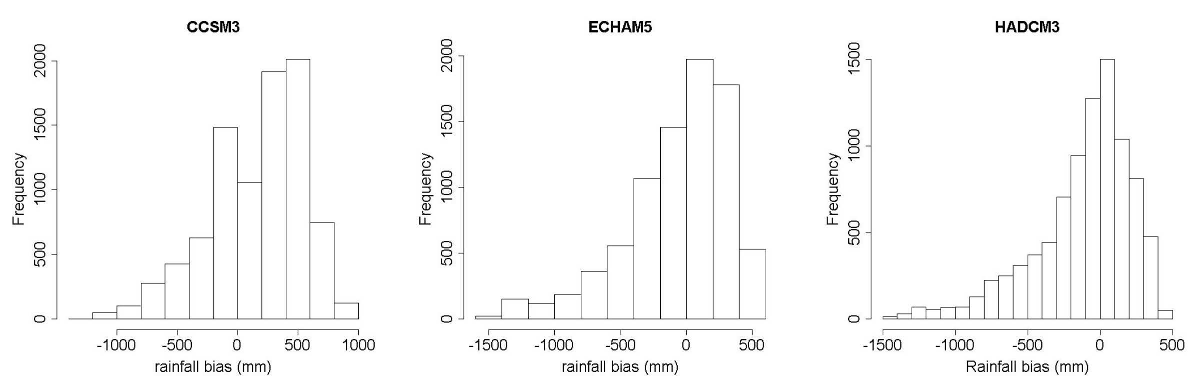

Figure 3. Histograms of smoothed absolute annual rainfall bias for the general circulation models CCSM3, ECHAM5 and HADCM3 across North-eastern Brazil.

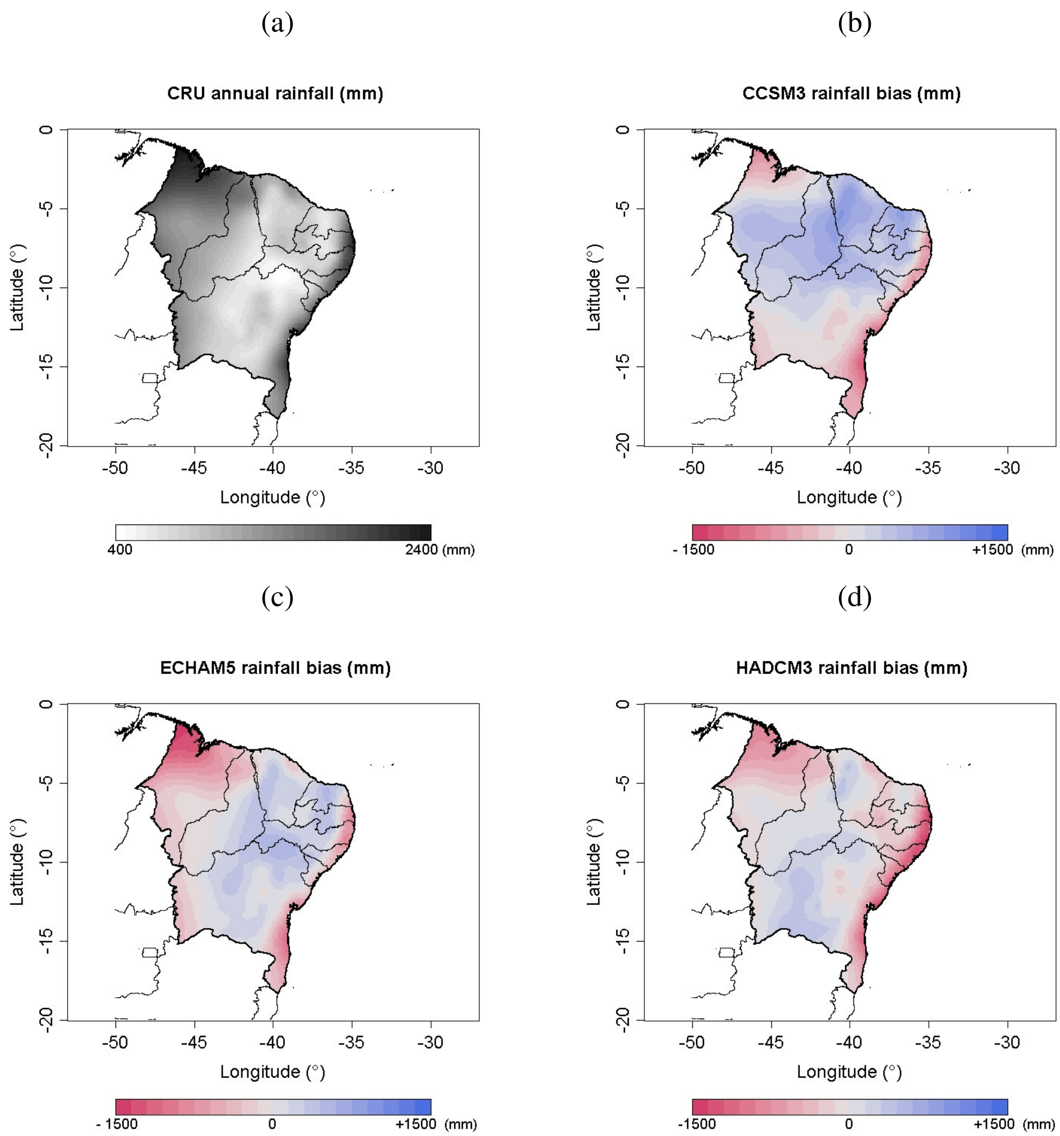

Figure 4. Spatial patterns of average annual rainfall (CRU data, 1961-1990) and smoothed absolute biases for CCSM3, ECHAM5 and HadCM3 models across North-eastern Brazil.

The MBG approach allows, via likelihood-based methods, the test of statistical hypotheses related to patterns of bias, such as presence of spatial trends. We propose the use of the smoothed bias surfaces derived form fitted models for bias correction of climate projections for future time slices.

4 Conclusions

Model based geostatistics provide an inferential framework to estimate bias surfaces including their associated uncertainties derived from the spatial modelling. When applied to data with adequate temporal and spatial resolution, this constitutes essential information for guiding bias-correction as a preliminary step for global or regional climate impact assessments.

Smoothed bias surfaces arising from spatial models can capture important geographic related bias patterns which constitutes an advance in relation to the use of crude bias calculated as simple difference between CRU and corresponding model hindcast values for each pixel.

5 References

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