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CONSISTENCY OF REGIONAL CLIMATE PROJECTIONS WITH THE GLOBAL CONDITIONS THAT STIMULATED THEM

ABSTRACT

Policy decisions related to climate impacts would benefit from robust regional projections if such information was reliable. Regional climate models can be used to add local detail to projections of global climate models. The regional models are usually driven by a global model in a one way fashion: no information from the regional model feeds back into the evolution of the global model which drives it.

This research contrasts regional climate variables from a regional climate model with projections for the same region made by the global model driving it. Simulations from the North American Regional Climate Change Assessment Program (NARCCAP) provide a valuable test bed for this type of study.

The wider aim of this research is to assess the quality and reliability of climate simulations and the effectiveness of various downscaling methods, in order to better understand the relationship between climate model output, downscaled output, and the climate system itself. It is hoped that improving our understanding of these relationships will (i) allow a more informed measure of fidelity of climate model simulations, (ii) assist in the development of more accurate models, and (iii) aid scientific support for decision-making and policy. Here we show significant divergence between RCM and GCM estimates of surface radiation, and consider the implications for the reliability of such models.

1. AIMS OF CLIMATE SIMULATION DOWNSCALING

North American Regional Climate Change Assessment Program (NARCCAP) is an initiative of National Centre of Atmospheric research (NCAR) in the USA. NARCCAP provides a multi-model high resolution climate simulations over a domain covering most of North America for current (1971-2000) and future period (2040-2070).

The fundamental scientific motivation of NARCCAP is to explore the separate and combined uncertainties in regional climate change simulations that result from the use of different atmosphere–ocean general circulation models (AOGCMs) to provide boundary conditions for different regional climate models (RCMs) (Mearns et al., 2012). The program has additional aims: to explore of some remaining uncertainties in regional climate modelling; to generate climate change scenarios for use in impacts research and to enhance collaboration between US, Canadian and the European climate modelling groups.

Global Circulation Models (GCMs) are widely applied to understand climate change. However, their usefulness is limited for the officials and the public, because they provide the climate projections at the large scale - hundreds of kilometers. RCMs have been developed to produce high resolution climate information by downscaling GCMs simulations. Regional Climate Models act like a magnifying glass of their driving models for a certain geographical area. They can provide high resolution simulations, are capable of describing climate feedback mechanisms at the regional scale and resolve a process that the low-resolution models are parametrising. RCMs are not independent tools, they take boundary conditions from GCMs within which they are nested but do not feed back to the global model.

2. HOW CONSISTENT ARE REGIONAL CLIMATE PROJECTIONS WITH THE GLOBAL CONDITIONS THAT STIMULATED THEM?

This research contrasts long term and short term averages of regional and global scale of atmospheric variable -surface radiation upward, compares outputs from regional and global climate models using NARCCAP project database. Analyses have been carried out based on a range of RCM/GCM pairs over the same area of North America (USA area). The Climate of the United States varies significantly due to its range of geographic features, this is why the study focuses on a land area which show different climate characteristics: South-East (SE) and North-West (NW) of the USA.

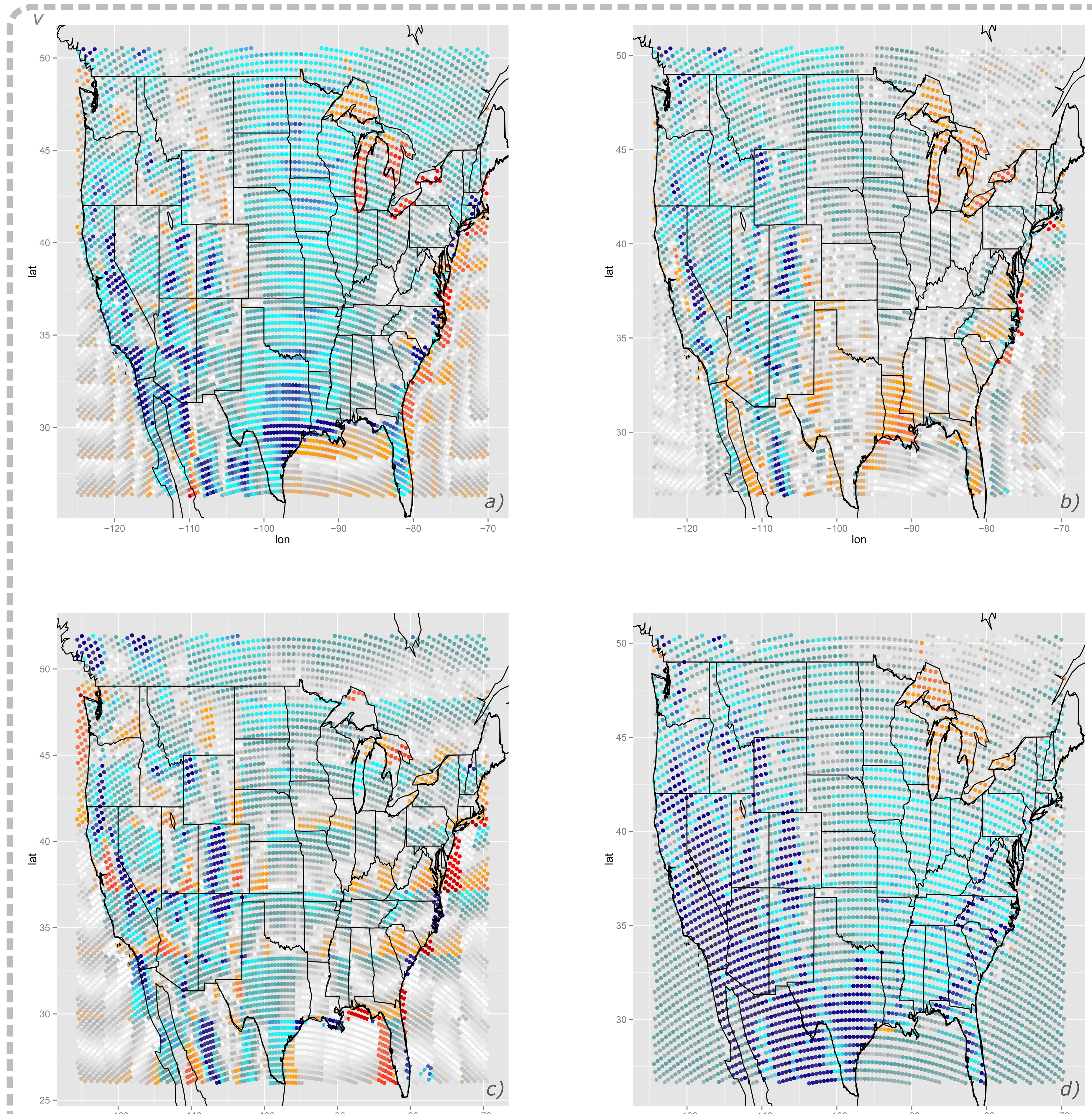
To evaluate the significance of the adjustments generated by RCM downscaling, we consider the difference in radiation upward between regional model projections and the corresponding (forcing) global model projections and compare it with the radiative forcing of 3.7 W/m^2 associated with doubled CO_2. Although local changes greater than this amount are to be expected due to local topography, if the regional or continental average adjustments exceed this magnitude then we would expect significant errors in ongoing forcing conditions due to the neglected feedback effects.

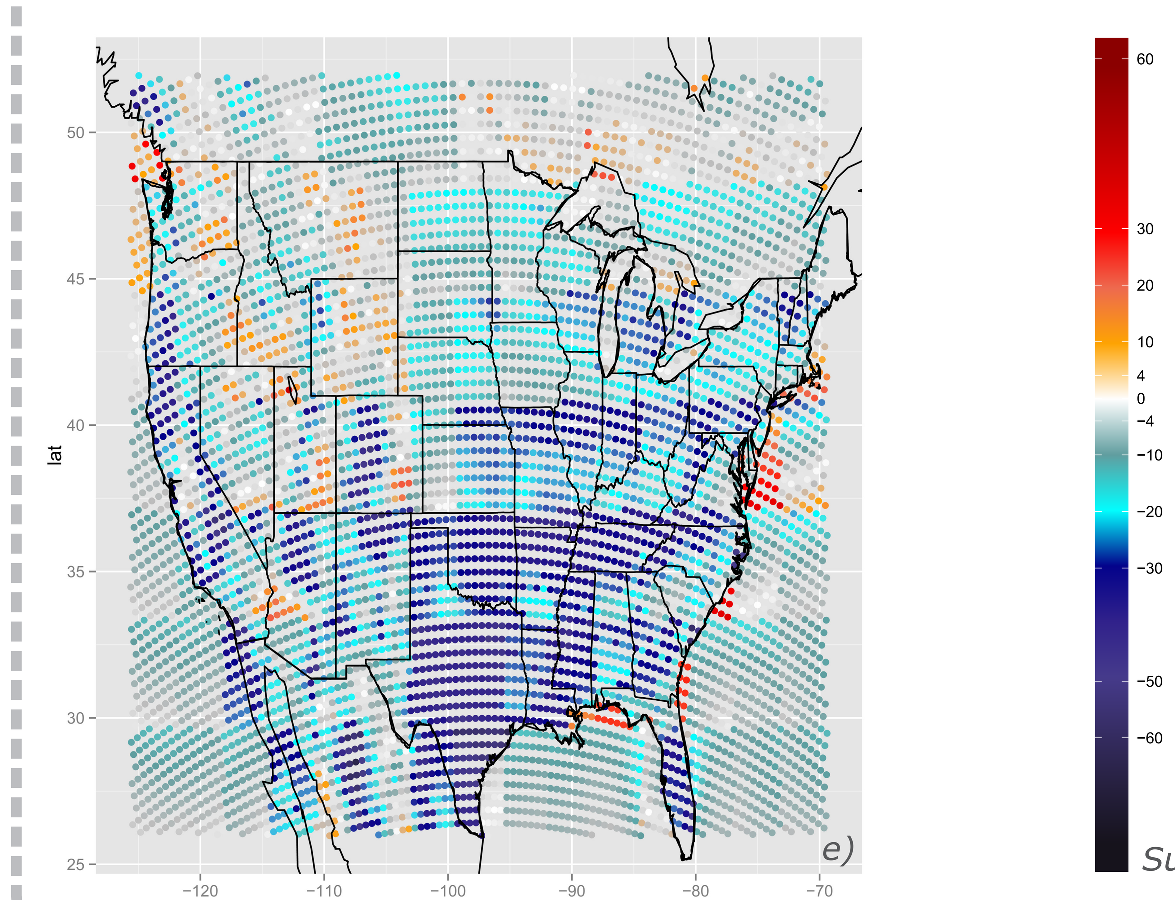
Conclusions:

*In general **all RCMs have lower radiation comparing to GCMs** (this is expressed by blue coloristics on each map). Average difference in long term averages of surface radiation upward between RCM and its parent GCM for the USA area are: a) -8 W/m^2; b) -3 W/m^2; c) -4 W/m^2; d) -16 W/m^2 and e) -14 W/m^2.*

*Area of research contain many climate zones and as expected, **results vary by the region**. For example for a,d and e model combinations, RCM averages differ from those of the parent GCMs over area of **Texas** even by **30-40 W/m^2**.*

*The difference between regional and global model types, is positive for pairs a, b and d over area of **lakes** on the North East of the USA. This may indicate that RCMs can be useful tools for capturing physical features of the territory.*





Surface Radiation Upward (W/m^2)

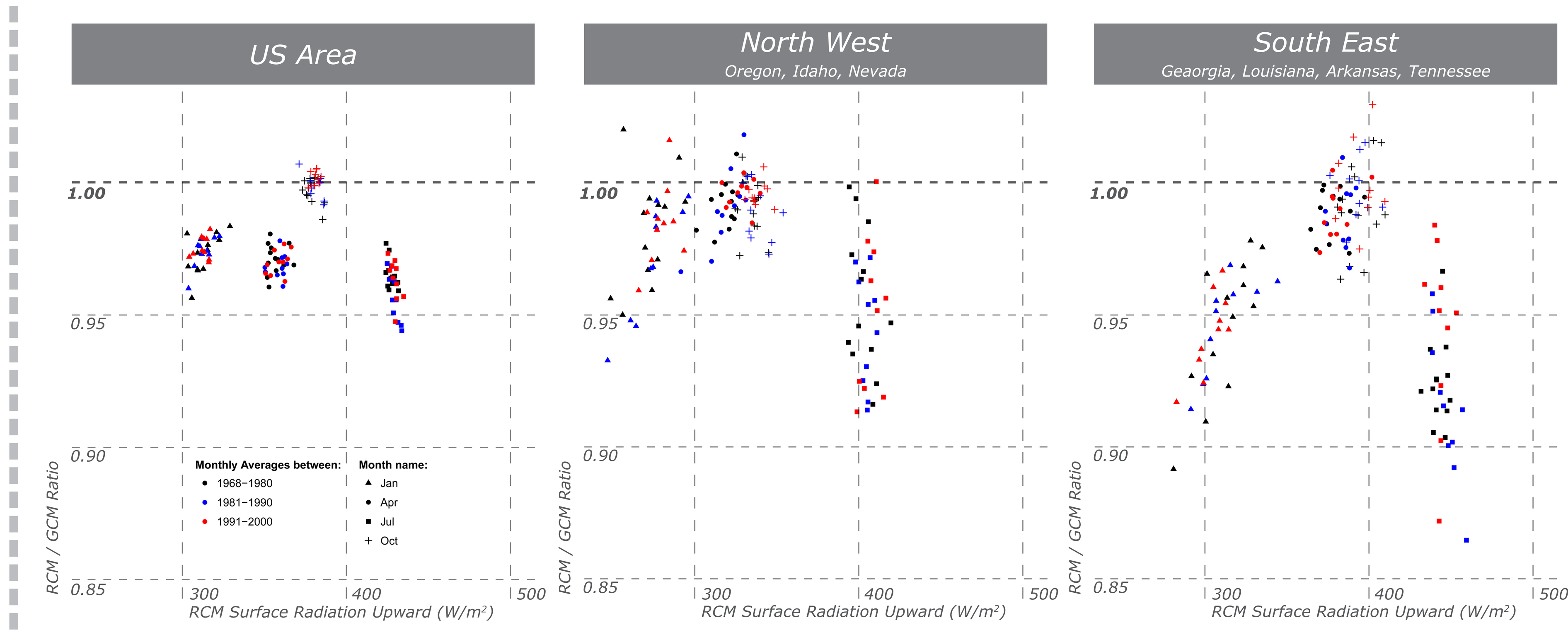
2.1 Analysis of long term averages

***Fig.1** Maps illustrate difference in long term averages (over 1991-2000) of surface radiation upward between RCM output and its driving data by the grid point. The results concern the following NARCCAP RCM-GCM pairings (from the top left corner): a) ECP2-gfdl, b) CRCM-ccsm, c) CRCM-cgcm3, d) MM5I-ccsm, e) WRFG-cgcm3.*

For comparison, the net radiative forcing due to a doubling of CO_2 is 3.7 W/m^2.

2.2 Analysis of short term averages

***Fig.2** Each point in this diagram represents **monthly average**, is coloured by the interval of simulation it fall into (beginning: 1968-1980 -black, middle: 1981-1990 -blue, end: 1991-2000 -red), its shape depends on month name. X axis show RCM surface radiation upward value, Y axis RCM/GCM ratio. Data Source: ECP2-gfdl, NARCCAP.*



Conclusions:

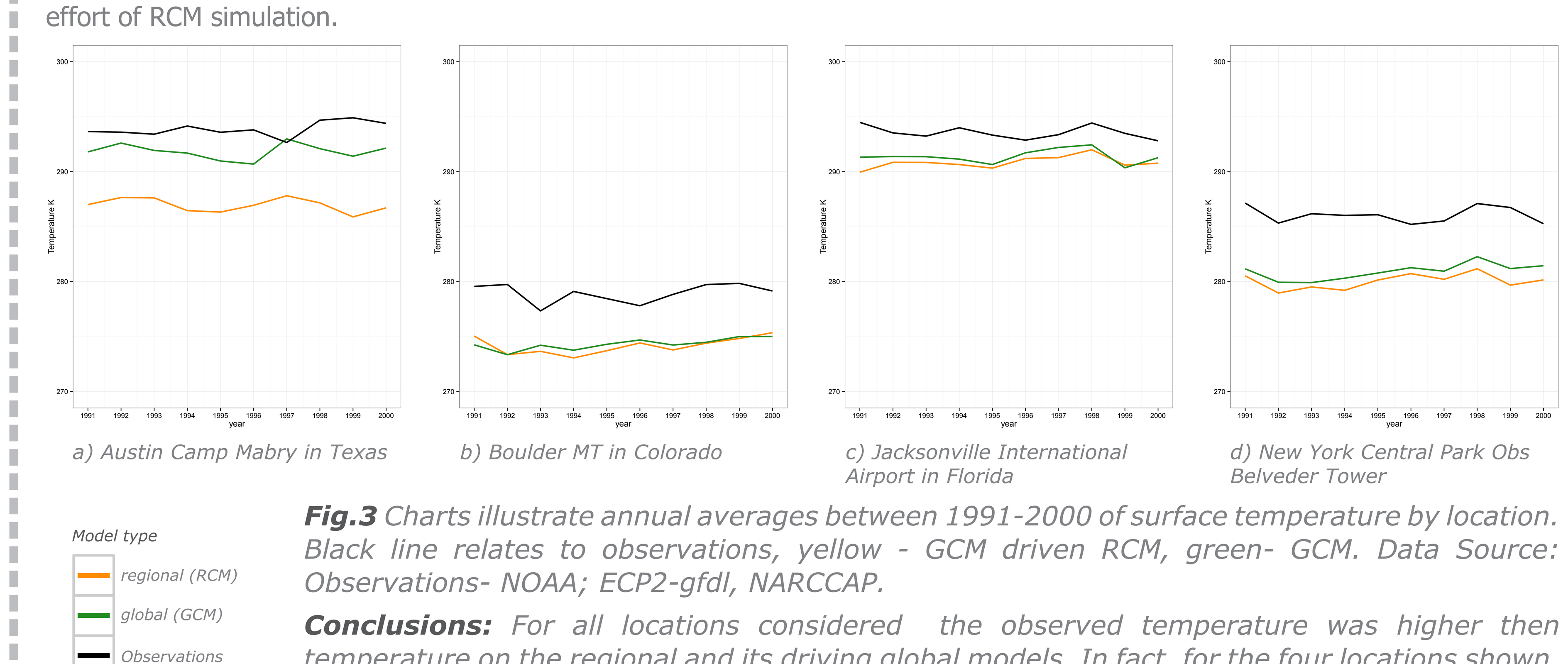
*Looking at monthly averages, the same pattern is observed of **systematically lower radiation in the RCM** than the parent GCM, since the majority of points lie below the line of equality.*

*Diagrams at **region level** (NW, SE) show **bigger variation** of results then output at country level. This can be explained by the fact that USA area has heterogeneous climate.*

***The biggest discrepancies** between models are during the **summer months** when the surface radiation is the highest. Further analysis of the July time series shows that the downscaled RCM adjustments to the GCM values are around **50-60 W/m^2 in SE**, an order of magnitude greater than the effect of doubling CO_2.*

3. ADDED VALUE IN TEMPERATURE SIMULATED BY HIGH RESOLUTION NESTED RCM

Regional model output and its driving data is compared with the observed temperature in order to justify the additional computational effort of RCM simulation.



a) Austin Camp Mabry in Texas

b) Boulder MT in Colorado

c) Jacksonville International Airport in Florida

d) New York Central Park Obs Belveder Tower

***Fig.3** Charts illustrate annual averages between 1991-2000 of surface temperature by location. Black line relates to observations, yellow - GCM driven RCM, green- GCM. Data Source: Observations- NOAA; ECP2-gfdl, NARCCAP.*

Conclusions:** For all locations considered the observed temperature was higher then temperature on the regional and its driving global models. In fact, for the four locations shown, **the RCM data are actually further from observations than were the GCM boundary conditions.

4. FINAL CONCLUSIONS

The RCM and GCM data deviate to such an extent that the physical basis of the forcing assumption must be questioned. An average discrepancy over the whole US of -8 W/m^2 seems likely to result in significant feedbacks if the RCM and GCM were coupled rather than using the GCM only as a boundary condition. The physical interpretation of output from either model should be approached with caution, given the large sensitivity of the average output to the use of an alternative model. Of course, this applies also at the smaller scale where the RCM has better representation of topography, but is still subject to an uncertainty in average conditions similar to the range between the GCM and RCM values, which is many times larger than the range generated by doubling CO_2.

References:

1. Ewelina A Sienkiewicz, Erica L Thompson, Leonard A Smith: Consistency of regional climate projections with the global conditions that stimulated them (in preparation).
2. Mearns, Linda O., and Coauthors, 2012: The North American Regional Climate Change Assessment Program: Overview of Phase I Results. Bull. Amer. Meteor. Soc., 93, 1337–1362.
3. NARCCAP website: http://www.narccap.ucar.edu/contrib/presentations.html