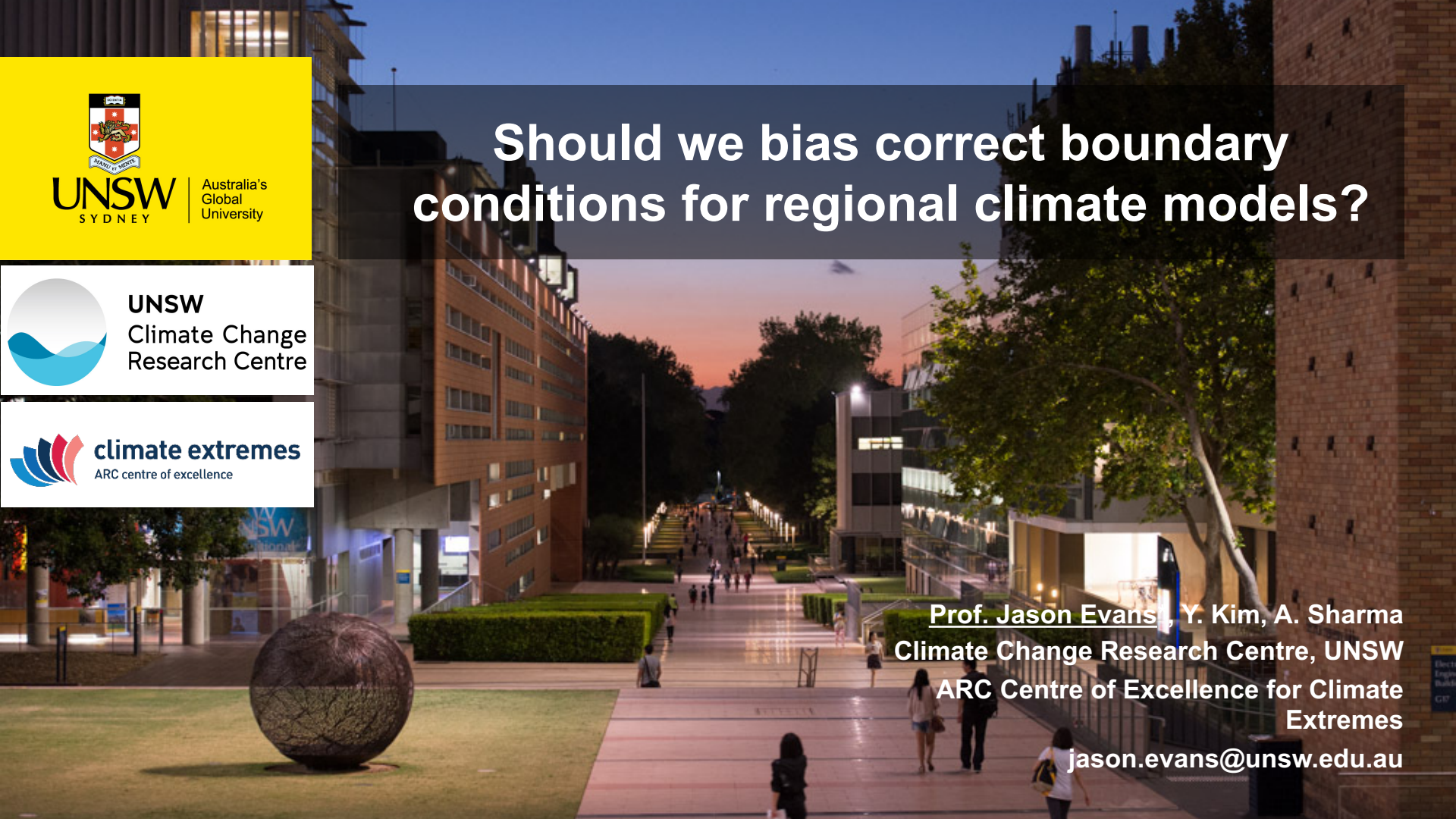


Should we bias correct boundary conditions for regional climate models?

Prof. Jason Evans, Y. Kim, A. Sharma

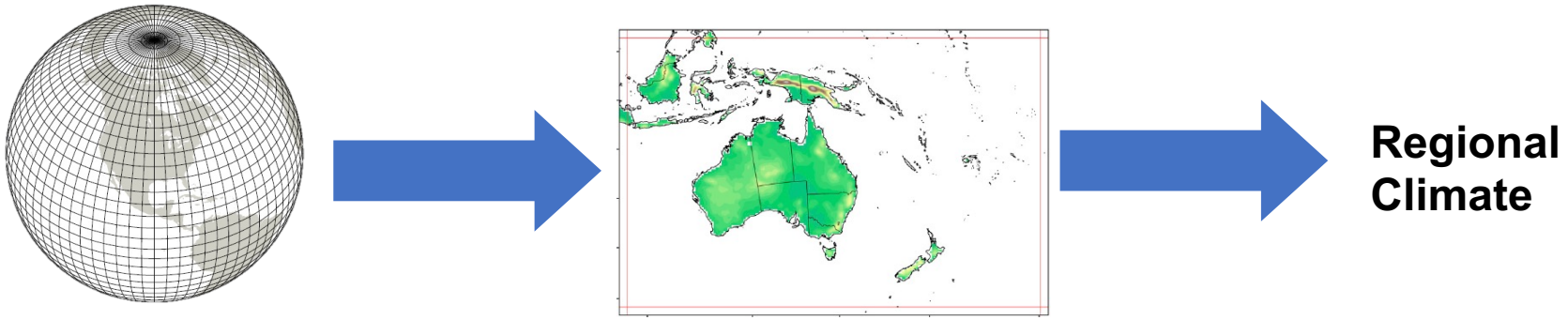
Climate Change Research Centre, UNSW

ARC Centre of Excellence for Climate Extremes

jason.evans@unsw.edu.au

Garbage in – garbage out

If GCM derived boundary conditions are garbage, then the RCM simulated climate will be garbage.



Giorgi, F., and L. O. Mearns, 1999: Introduction to special section: Regional Climate Modeling Revisited. Journal of Geophysical Research: Atmospheres, 104, 6335–6352, https://doi.org/10.1029/98JD02072.

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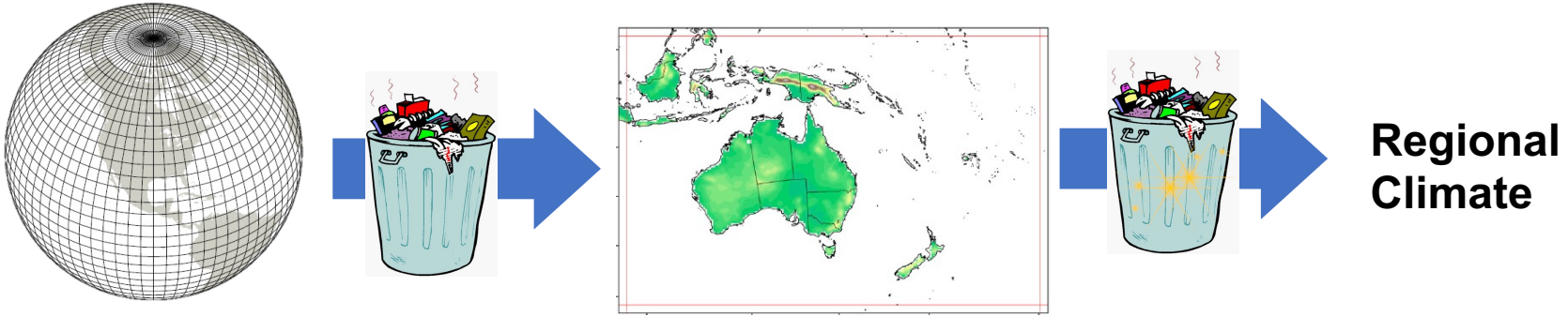

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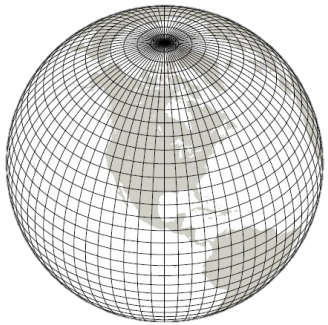
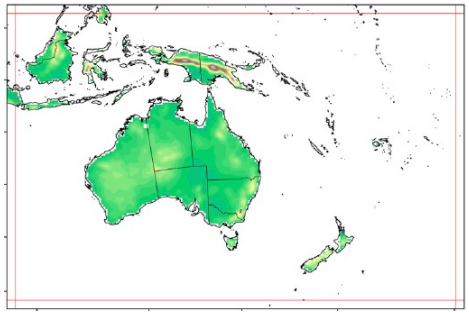


GCM

ε_{GCM}



RCM

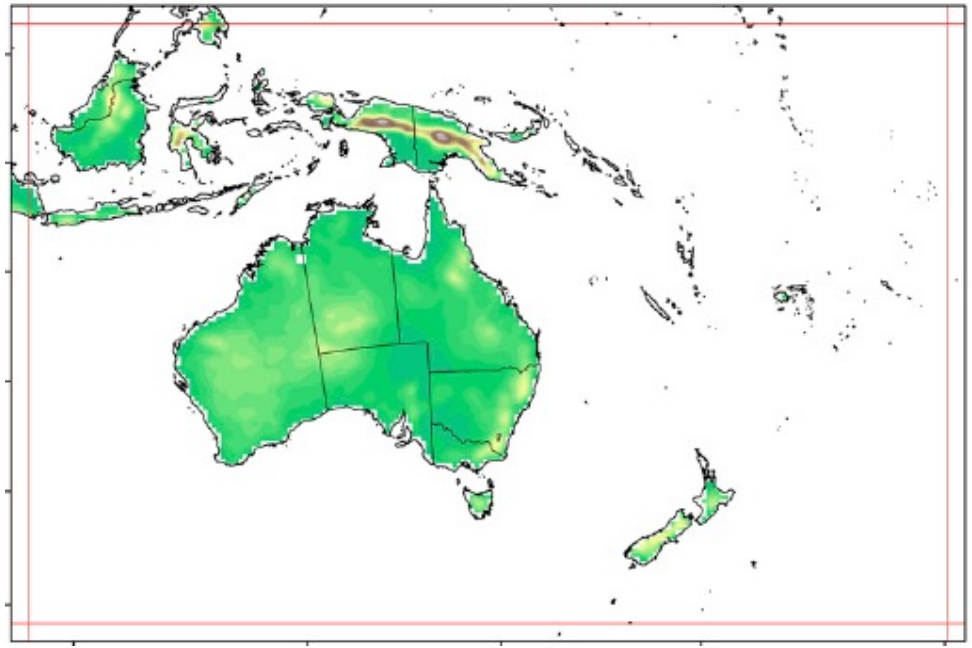
$f(\varepsilon_{GCM}, \varepsilon_{RCM})$

Regional Climate

Giorgi, F., and L. O. Mearns, 1999: Introduction to special section: Regional Climate Modeling Revisited. Journal of Geophysical Research: Atmospheres, 104, 6335–6352, https://doi.org/10.1029/98JD02072.

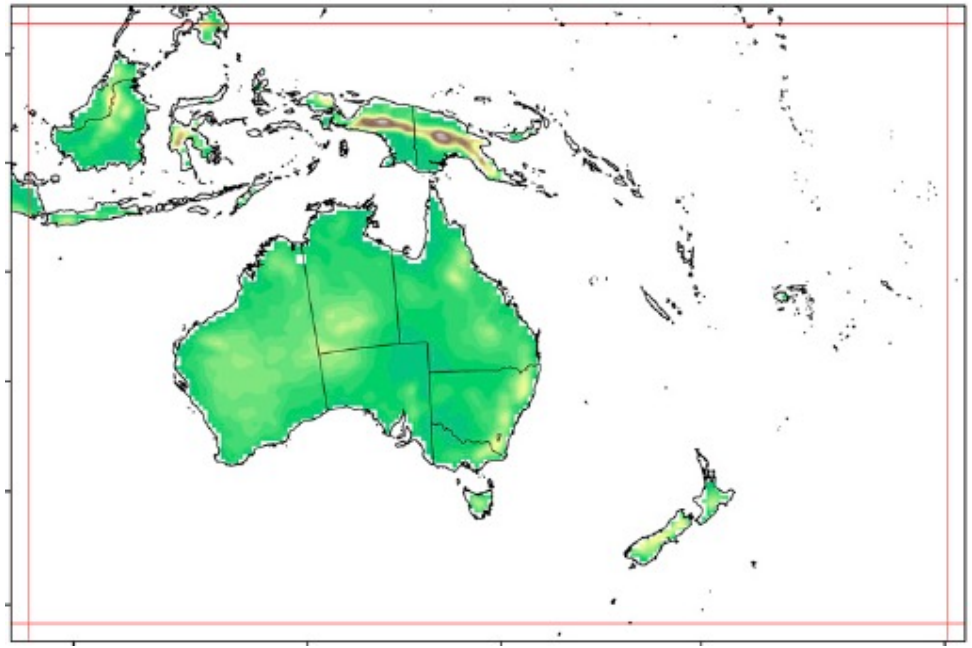
Our Experiment

- CORDEX-Australasia domain
- CMIP3 (CSIRO-Mk3.5) and CMIP6 (ACCESS1.5) GCMs
- RCM – Weather Research and Forecasting (WRF) model
- “Perfect” boundary conditions coming from ERA-Interim and ERA5
  - ERA-WRF produces the regional climate with no boundary condition error
- We test WRF driven with different boundary conditions against ERA-WRF to understand the errors from the boundary conditions.



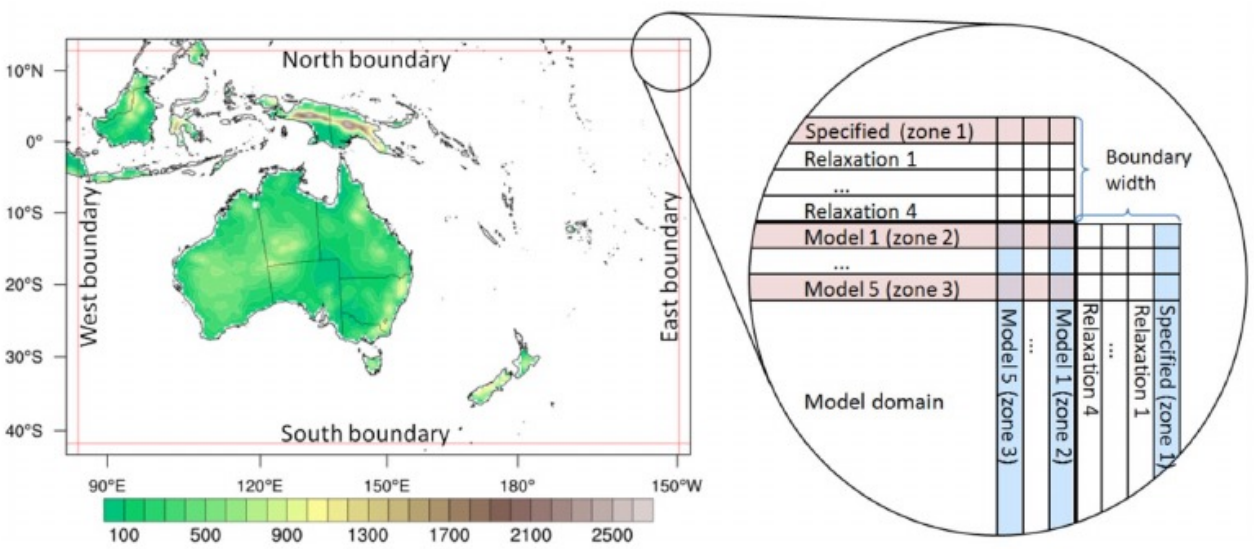
Our Experiment – Bias Corrections

- Correct atmospheric temperature, water vapour, winds, pressure, and SSTs
- Bias corrections tested
  - Mean (M)
  - Mean + standard deviation (MSD)
  - Nested Bias Correction (NBC)
    - MSD + lag 1 autocorrelation at monthly, seasonal & annual time scales.
  - Multivariate nested bias correction (MBC)
    - NBC + cross-correlations between variables



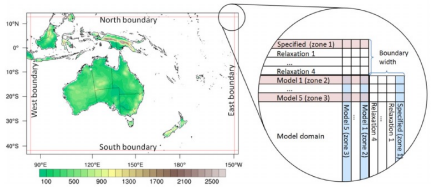
Effect of the relaxation zone

How much information makes it through the relaxation zone?



Rocheta, E., J. P. Evans, and A. Sharma, 2020: Correcting lateral boundary biases in regional climate modelling: the effect of the relaxation zone. Clim Dyn, 55, 2511–2521, https://doi.org/10.1007/s00382-020-05393-1.

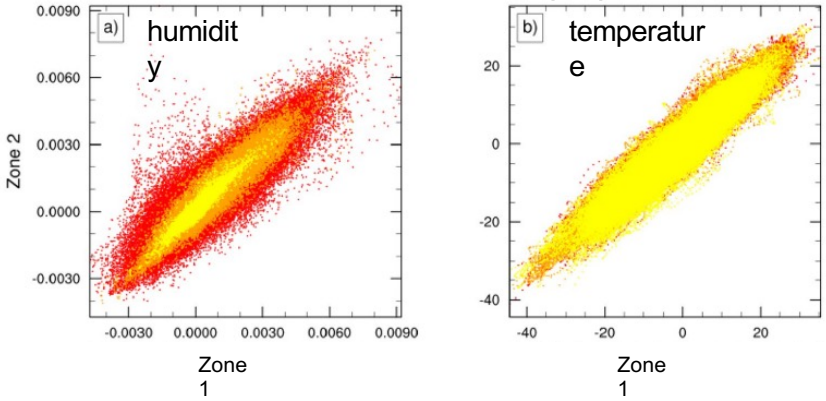
Effect of the relaxation zone



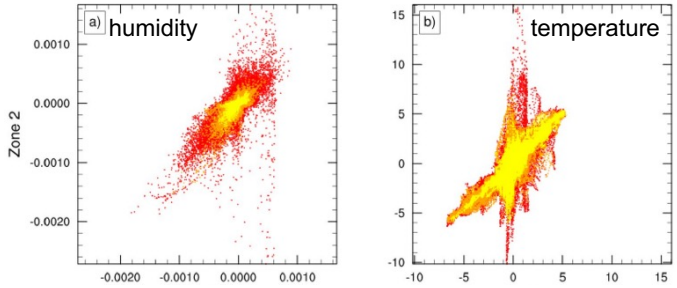
For inflow points on the boundary:

Does the correction in zone 1 make it to zone 2?

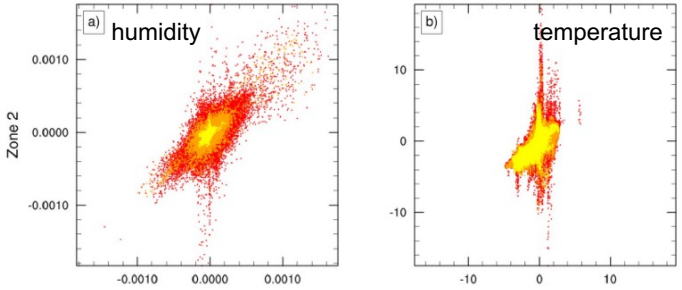
GCM - GCM(M)



GCM(M) - GCM(MSD)



GCM(MSD) - GCM(NBC)



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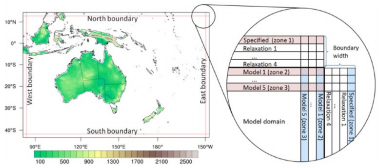


Does interpolation and bias correction mean boundary conditions are not physically consistent?

Are correlations between variables maintained?

Table 1
Percentage of the Cells That Show a Significant Difference in the Correlation Between the Model and RCM(ERA-I) at the 5% Significance Level at Specified Zone (1st) and After Passing Through the Relaxation Zone (6th) From the Western Boundary

		Significantly different % of cells				Significantly different % of cells	
Variable pair	Model	1st	6th	Variable pair	Model	1st	6th
uv	RCM(CSIRO)	92.9	93.9	vT	RCM(CSIRO)	93.7	90.6
	RCM(M)	92.9	90.4		RCM(M)	88.3	89.5
	RCM(NBC)	90.7	90.1		RCM(NBC)	88.0	88.1
uT	RCM(CSIRO)	93.1	91.3	vq	RCM(CSIRO)	91.9	92.3
	RCM(M)	90.9	87.9		RCM(M)	85.4	89.0
	RCM(NBC)	89.8	88.4		RCM(NBC)	85.5	89.7
uq	RCM(CSIRO)	92.8	92.0	Tq	RCM(CSIRO)	95.1	93.8
	RCM(M)	92.1	87.8		RCM(M)	95.0	84.5
	RCM(NBC)	92.4	87.5		RCM(NBC)	95.1	82.9

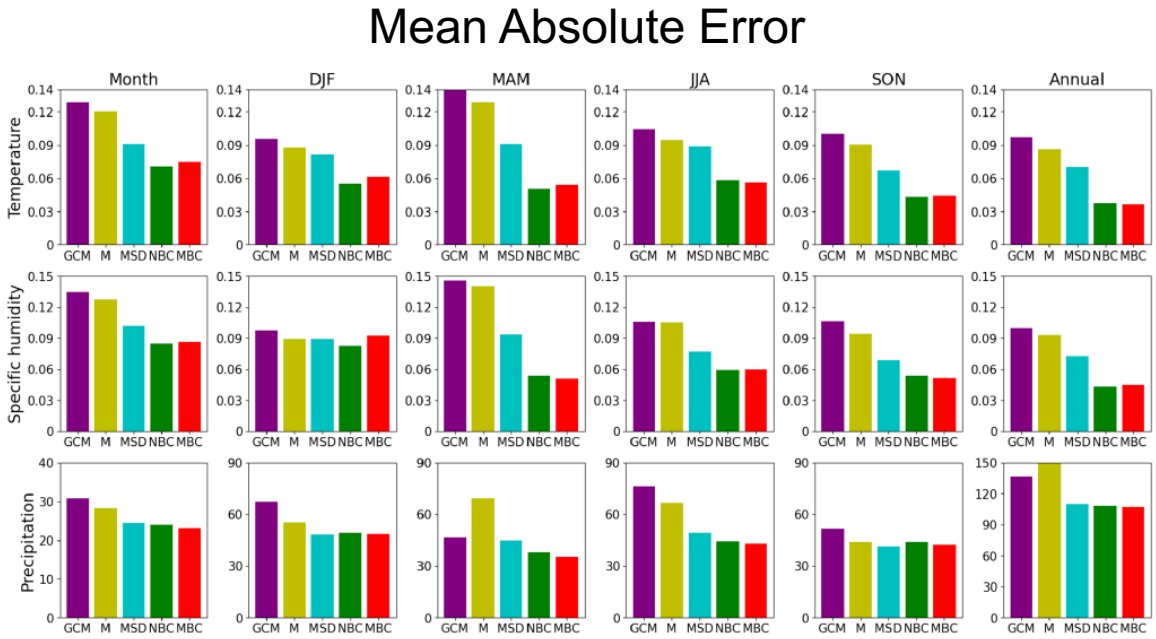
Kim, Y., J. P. Evans, A. Sharma, and E. Rocheta, 2021: Spatial, Temporal, and Multivariate Bias in Regional Climate Model Simulations. Geophysical Research Letters, 48, e2020GL092058, https://doi.org/10.1029/2020GL092058.

Multivariate bias correction

Bias correcting boundary conditions tends to improve temperature, humidity and rainfall simulation.

Bias correcting more aspects of the distributions tends to improve rainfall simulation more.

Adding multivariate correction does not show a clear improvement.



Kim, Y., J. P. Evans, and A. Sharma, 2023: Multivariate bias correction of regional climate model boundary conditions. Clim Dyn, 61, 3253–3269, https://doi.org/10.1007/s00382-023-06718-6.

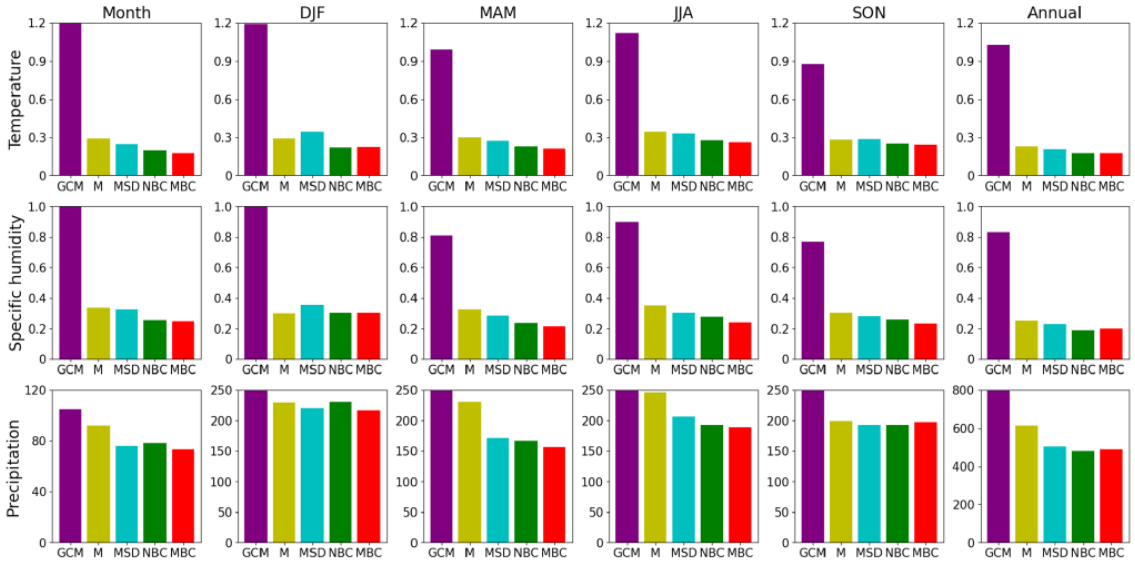
Multivariate bias correction

Bias correcting boundary conditions tends to improve temperature, humidity and rainfall simulation.

Bias correcting more aspects of the distributions tends to improve rainfall simulation more.

Adding multivariate correction provides consistent improvement to simulation of extremes.

Mean Absolute Error



99th percentiles

Kim, Y., J. P. Evans, and A. Sharma, 2023: Multivariate bias correction of regional climate model boundary conditions. Clim Dyn, 61, 3253–3269, https://doi.org/10.1007/s00382-023-06718-6.

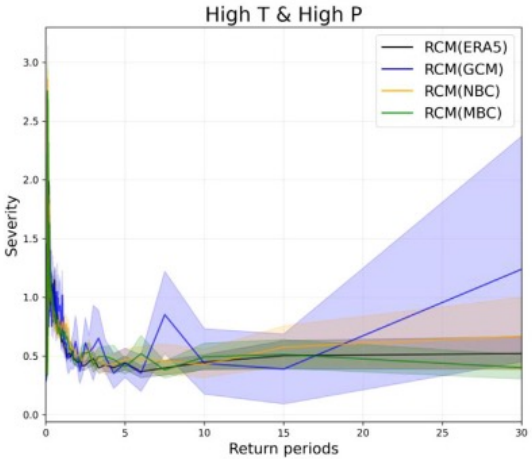
Impact on compound events

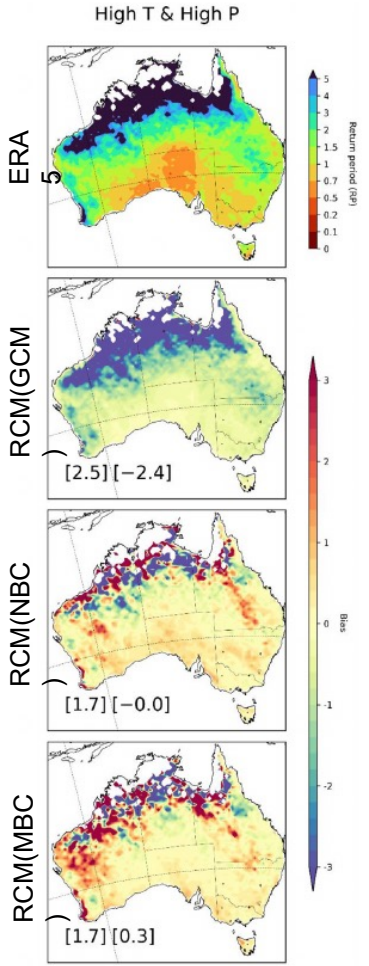
High T & High P – temperature and precipitation jointly exceeding 95th percentile

MBC simulates consistent improvements in severity of compound event at different return periods

MBC simulates consistent reductions in bias spatially of the compound event threshold return period.

MBC shows similar improvements for other compound events.





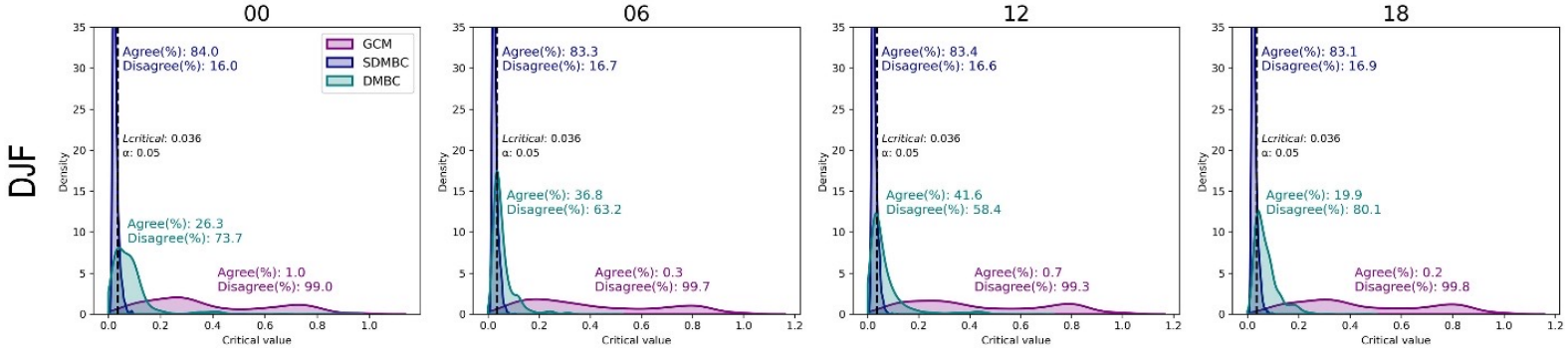
Kim, Y., J. P. Evans, and A. Sharma, 2023: Correcting biases in regional climate model boundary variables for improved simulation of high-impact compound events. iScience, 26, 107696, https://doi.org/10.1016/j.isci.2023.107696.

Sub-daily bias correction

So far bias corrections have been performed at daily time-scale.

What does this mean for different times of day?

Here Sub-daily correction has been added to MBC (SDMBC)

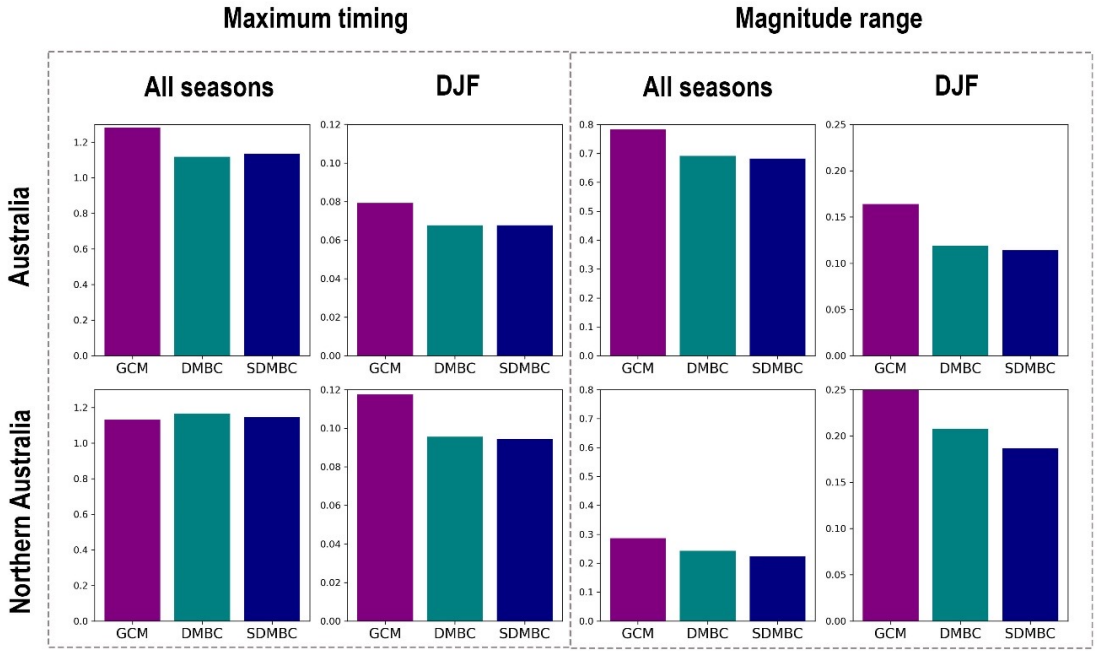


Kim, Y., J. P. Evans, and A. Sharma, 2023: Can sub-daily multivariate bias correction of regional climate model boundary conditions improve simulation of the diurnal precipitation cycle?. Geophysical Research Letters, accepted.

Sub-daily bias correction

Sub-daily MBC produces similar timing of maximum precipitation to daily MBC.

Sub-daily MBC improves the daily range in precipitation magnitude (intensity).



Kim, Y., J. P. Evans, and A. Sharma, 2023: Can sub-daily multivariate bias correction of regional climate model boundary conditions improve simulation of the diurnal precipitation cycle?. Geophysical Research Letters, accepted.

Software to perform bias correction of boundary conditions

Software based on code developed at UNSW.

Name of the software: SDMBC (Sub-Daily Multivariate Bias Correction).

Developer: Youngil Kim.

Contact information: youngil.kim@unsw.edu.au.

Program language: Python and Fortran.

Cost: free.

Software availability: https://pypi.org/project/sdmbc/

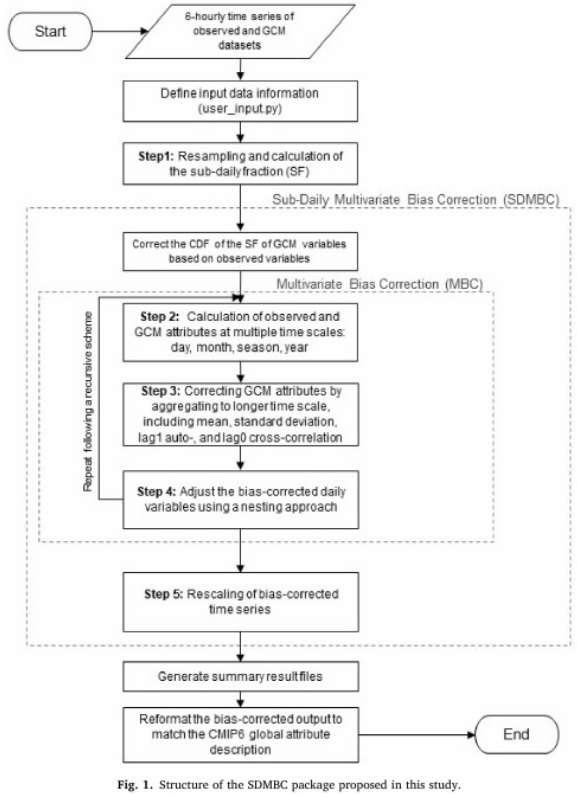


Fig. 1. Structure of the SDMBC package proposed in this study.

Kim, ... and V. Sharma, 2023: A software for correcting systematic biases in RCM input boundary conditions. Environmental Modelling & Software, 168, 105799, https://doi.org/10.1016/j.envsoft.2023.105799.

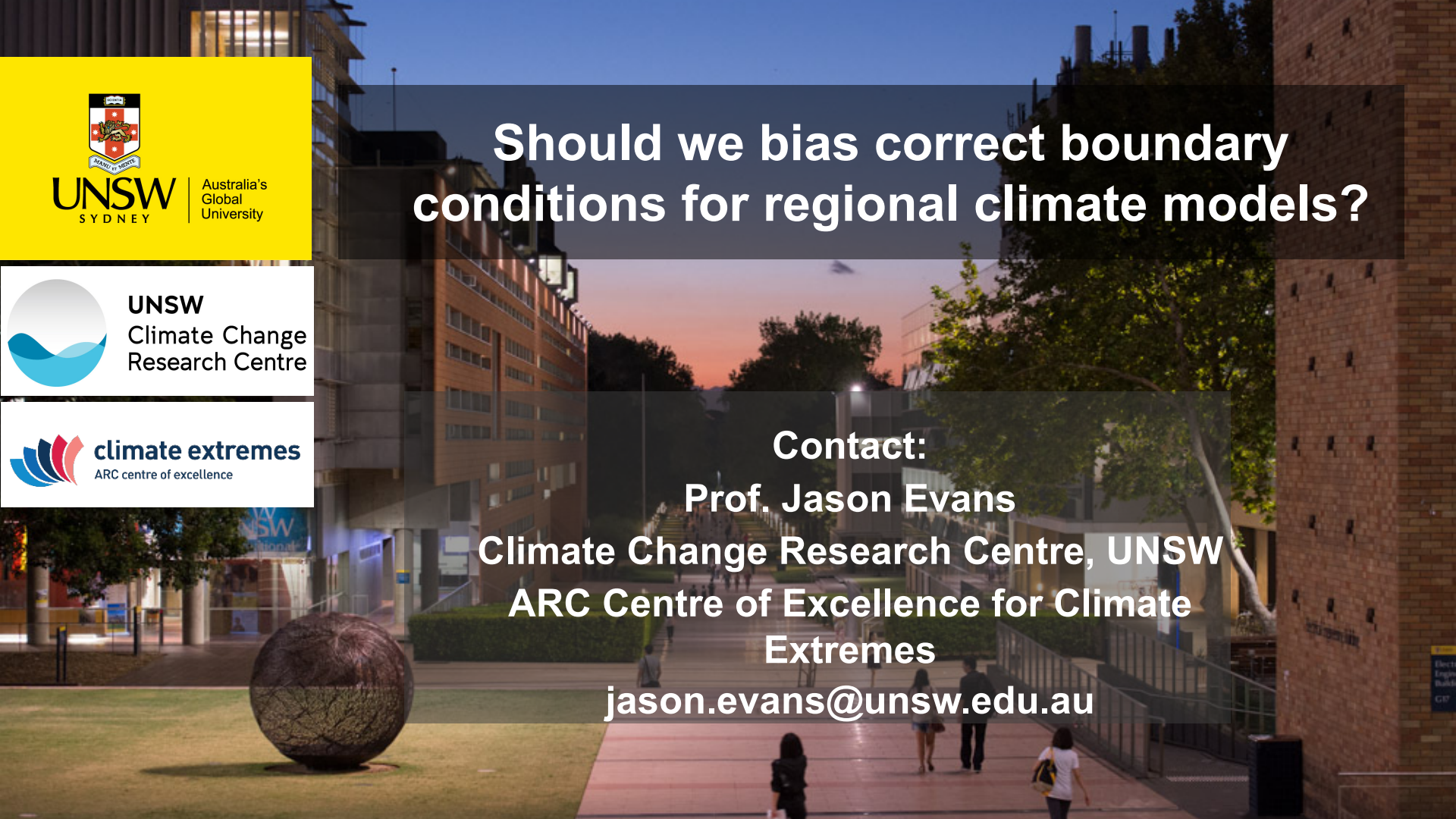
Conclusions

Bias correction of RCM boundary conditions improves the simulated climate by reducing the GCM error impact on the RCM simulation.

The bias correction method should be multivariate (physically consistent).

Sub-daily correction needs to be included explicitly.

We have created a software package if you're interested in trying it



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