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Regional Climate Projections, NARCliM, and small spatial/temporal scale extremes

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Outline

- Why downscale?
- What about extremes?
- How do you create a regional climate model ensemble?
- NARCliM project
  - Project plan
  - Choosing RCMs & GCMs
  - How does the model perform?
- Small scale precipitation extremes

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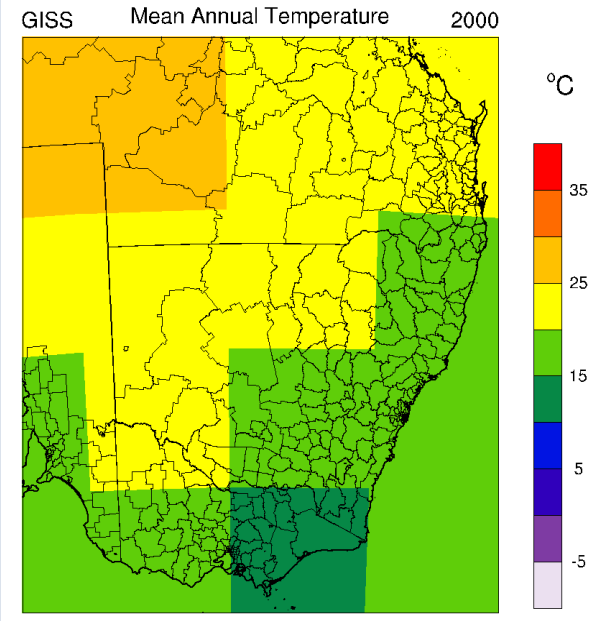
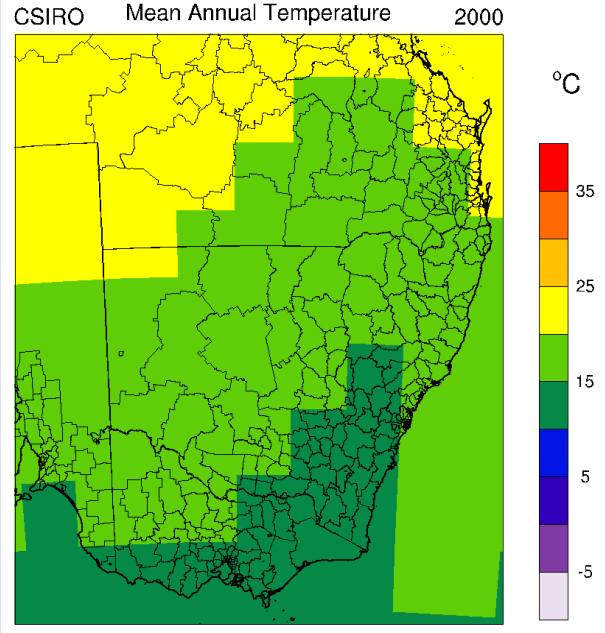
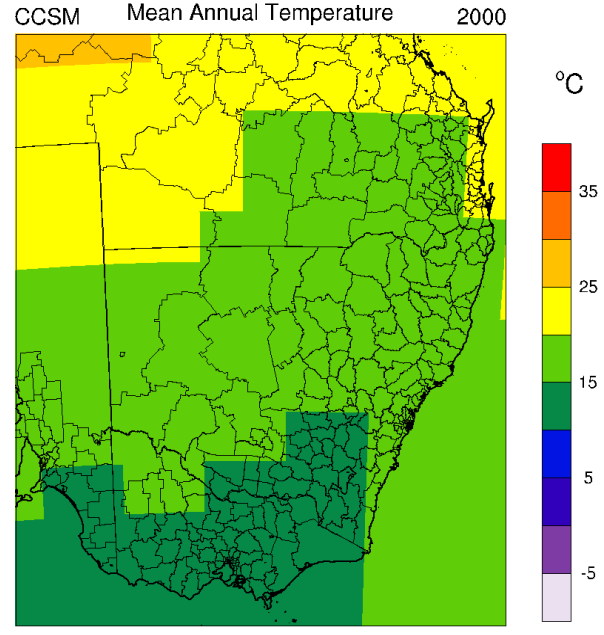
Why downscale?

Global to regional scales

GCM Simulations







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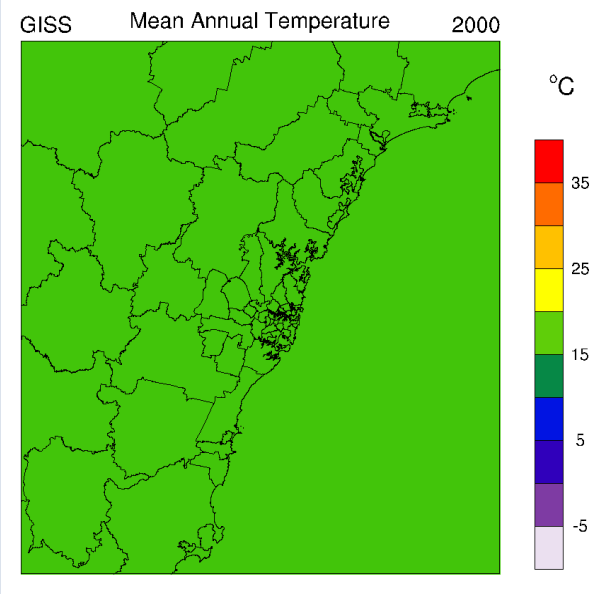
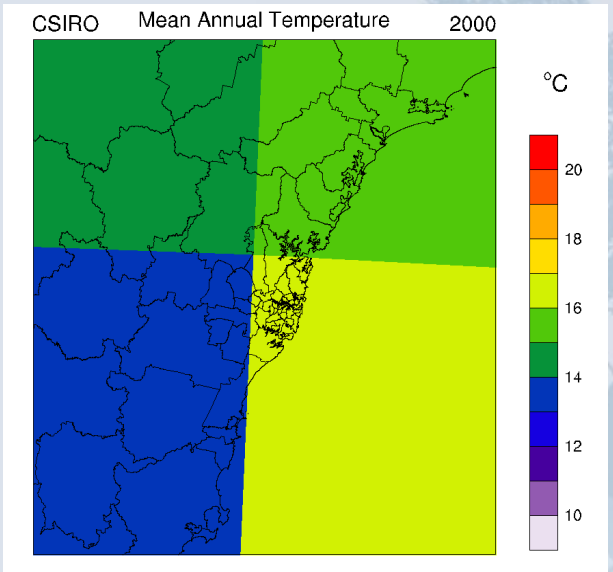
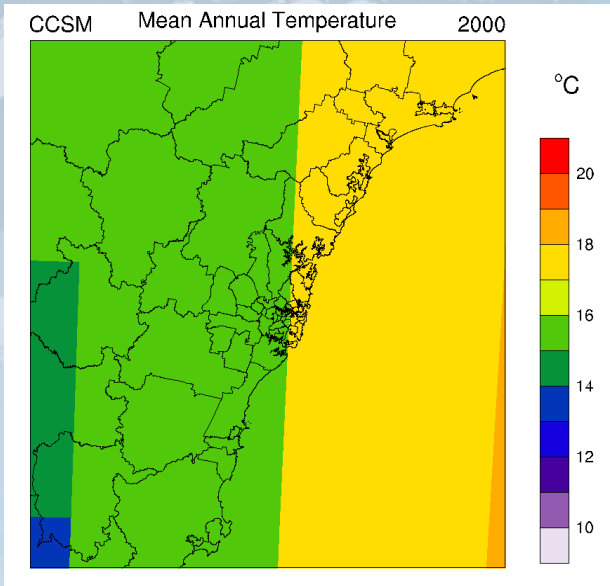
GCM Simulations







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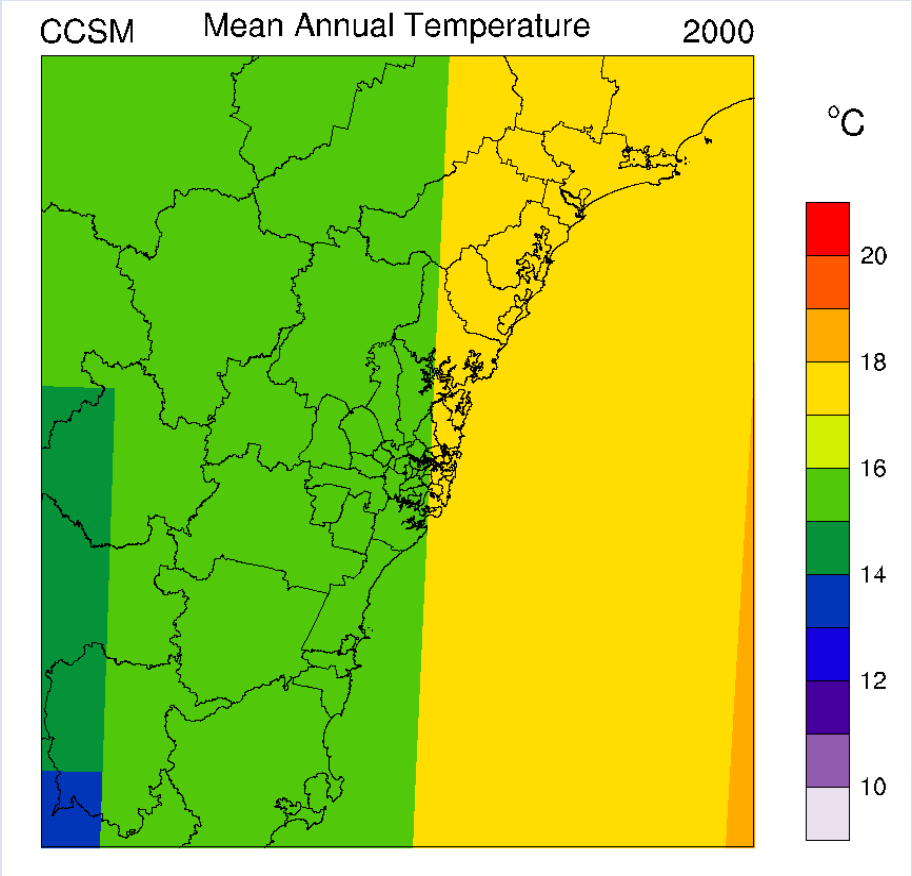
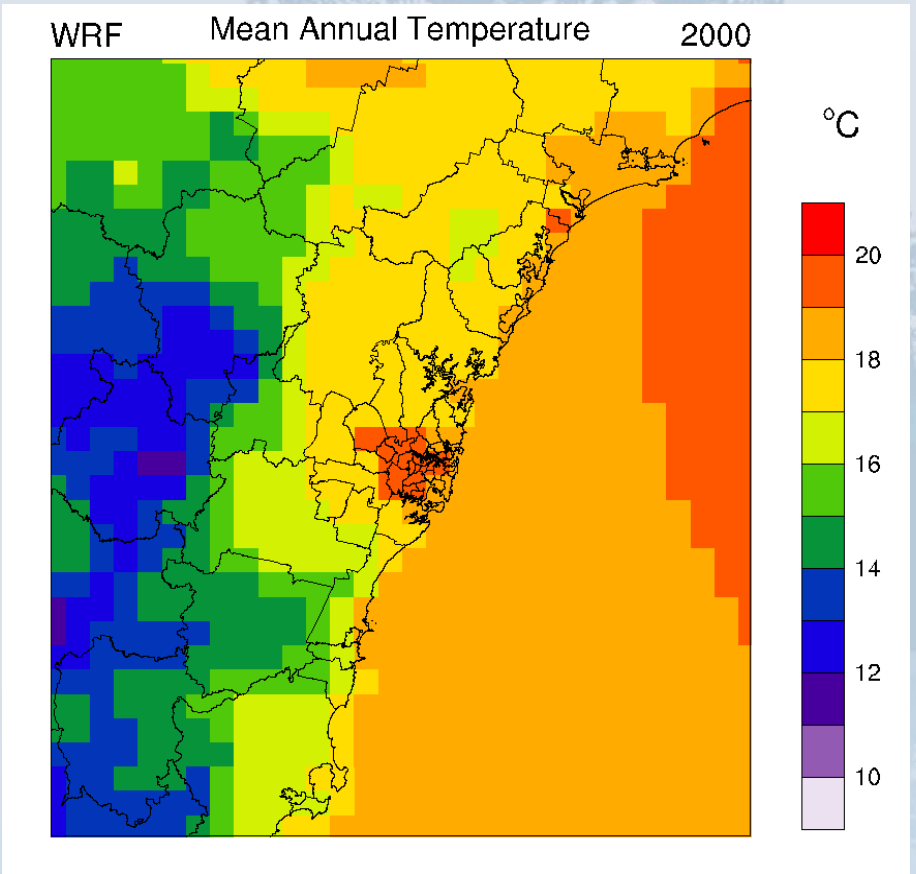
Global to Regional





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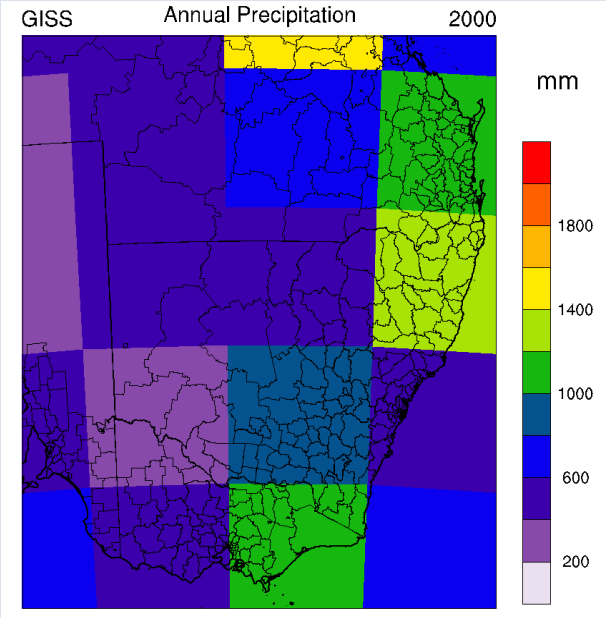
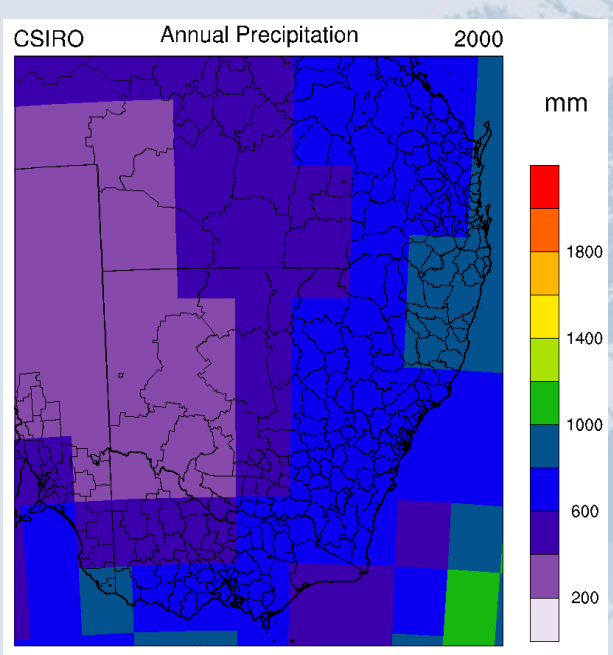
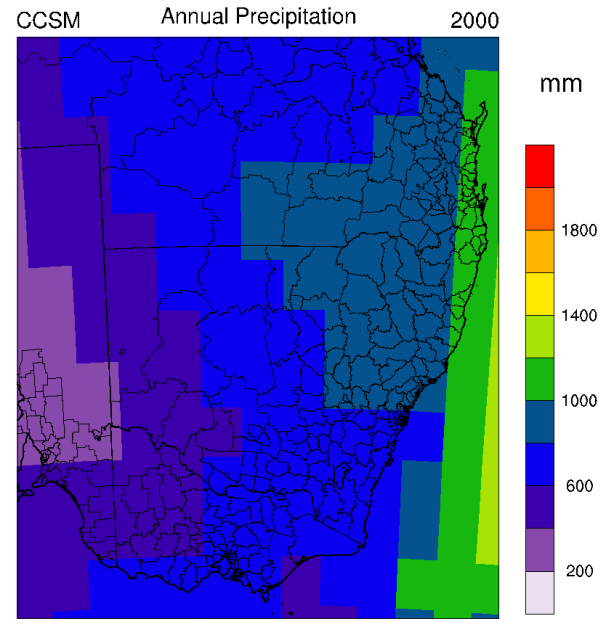
GCM Simulations







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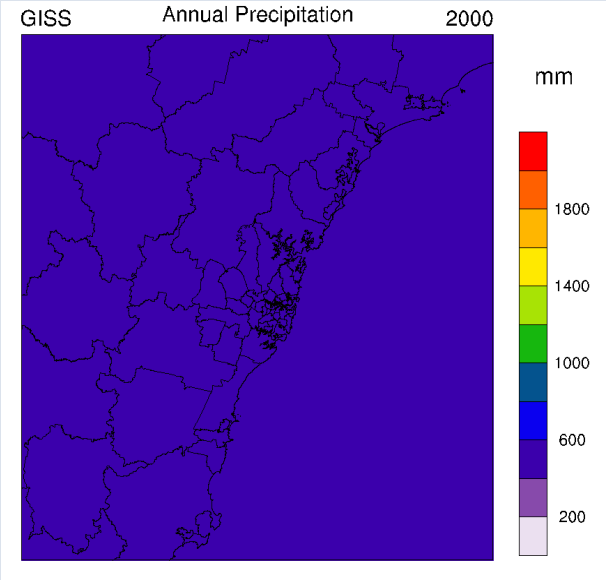

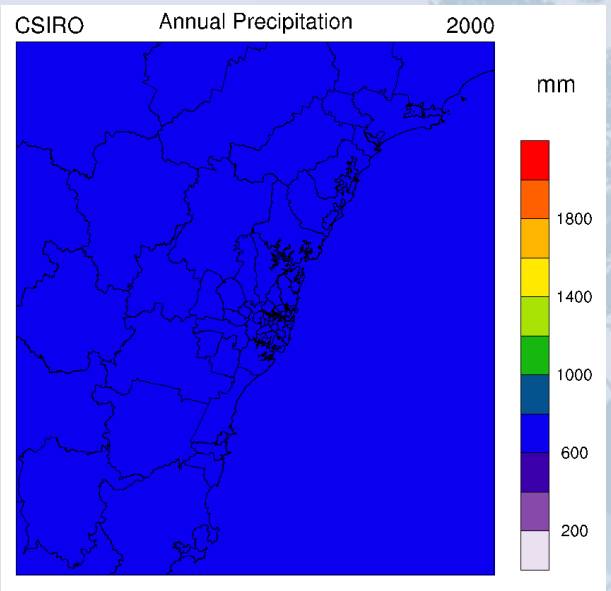

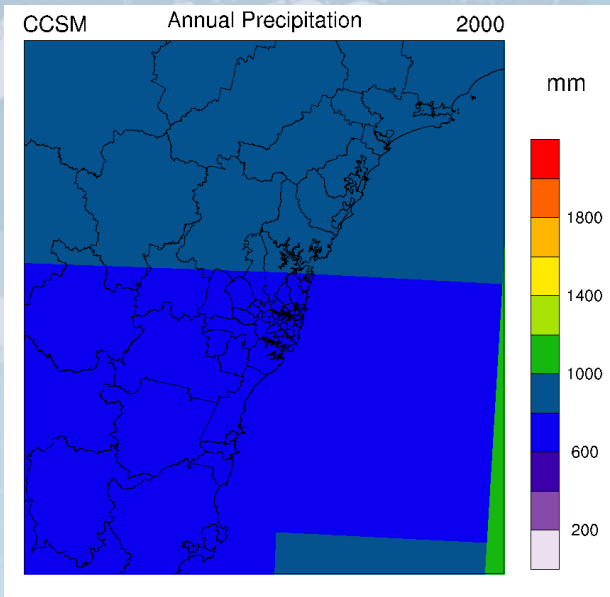

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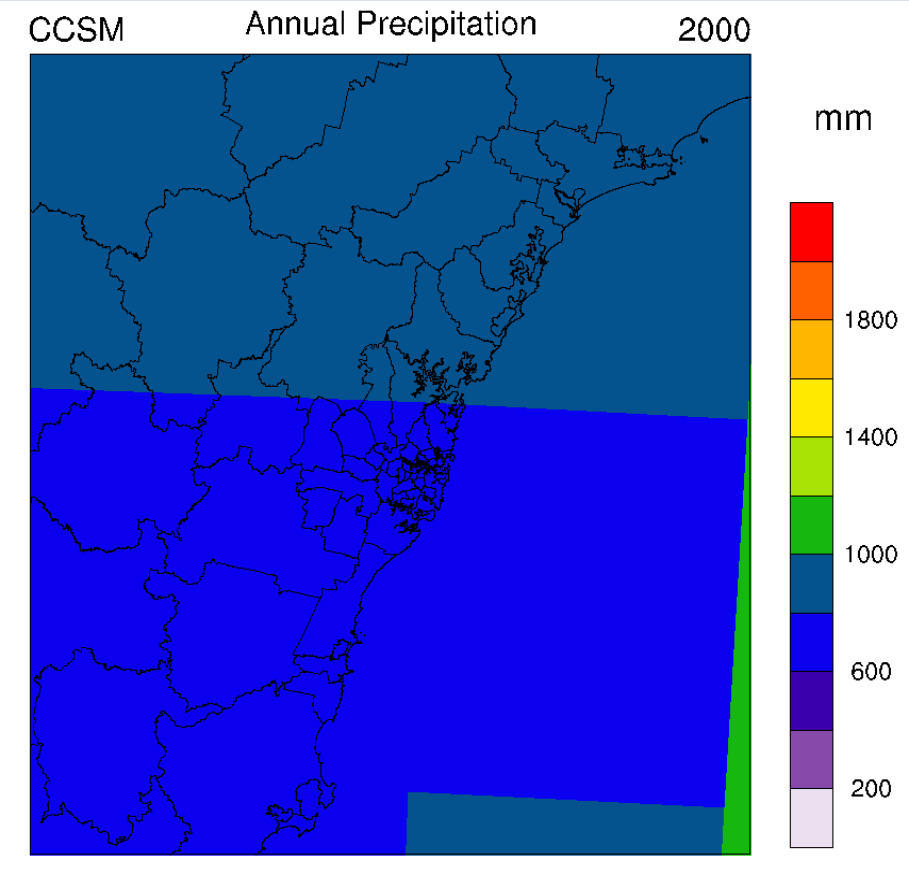
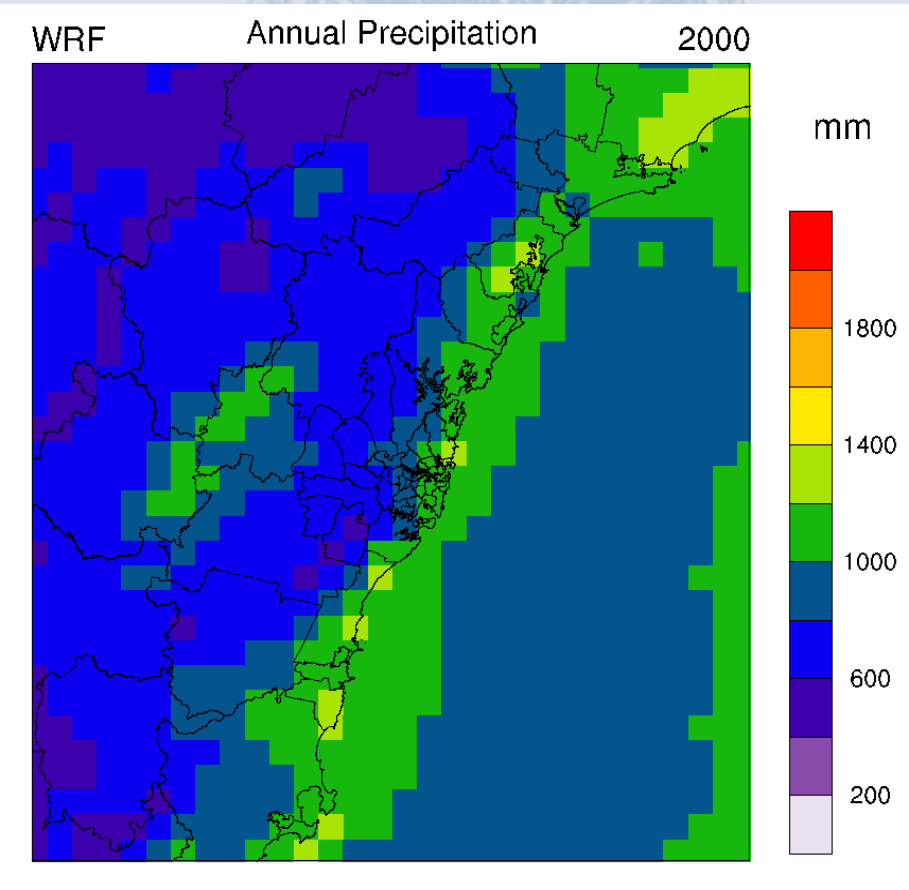
Global to Regional





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What about Extremes?

Spatial & temporal scales of extremes

- Most extremes are local to regional in nature

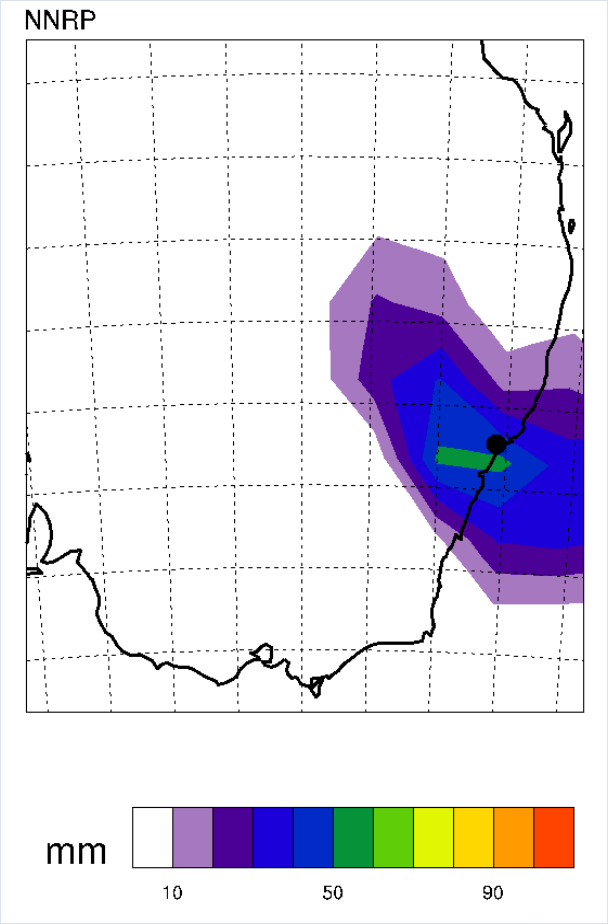
  Scales of 1 to 100s of kms

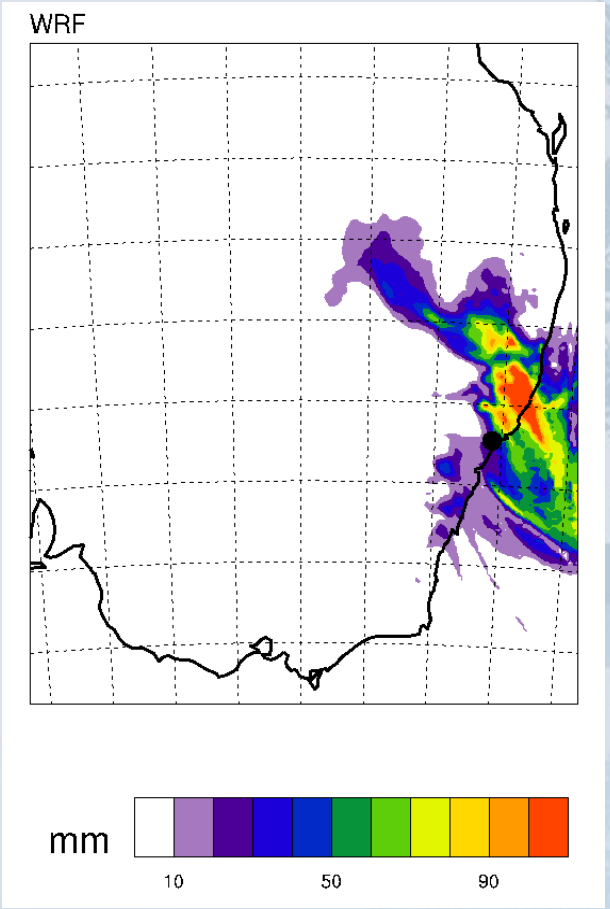
- Most extreme events are of short duration

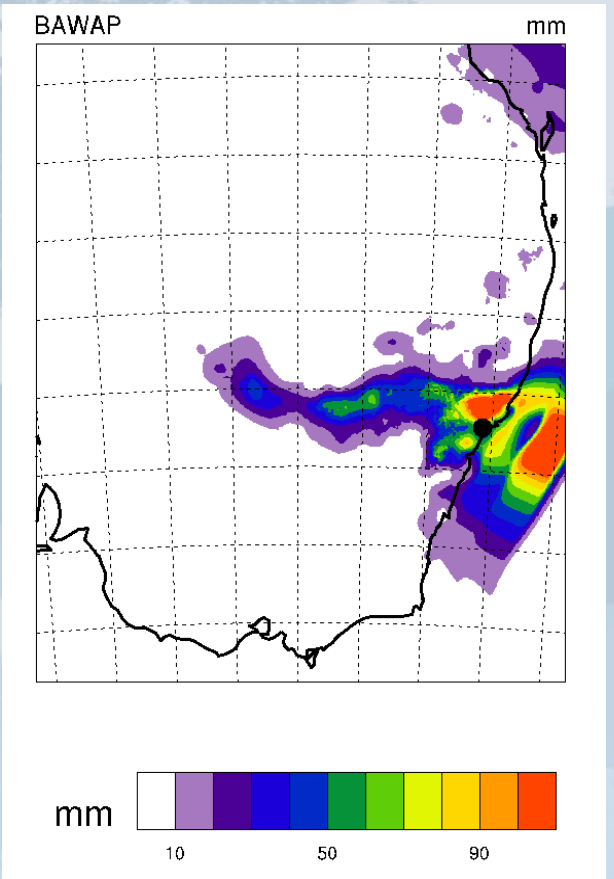
  Hours to days

- Large scale extreme events have small scale variability that is important
  - Lockyer valley during recent Queensland floods
  - Kinglake during 2009 Victorian fires

8 June 2007 – Newcastle Storm







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Regional climate model ensemble

- How do you choose the RCMs to downscale with?
- How do you choose the GCMs to downscale?
- How do you produce the optimum ensemble mean?
- What output variables should be saved?

NARCliM

(NSW/ACT Regional Climate Modelling project)

- 4 GCMs
- 3 RCMs
- 12 member ensemble
- ~10km grid over NSW
- 60 year "real" historical simulation to assess RCM performance
- SRES A2 emission scenario
- Three 20 year periods: 1990-2010, 2020-2040, 2060-2080
- Create an ensemble best estimate and uncertainty for most common variables
- Requires ~6 million CPU hours on super computer & ~ 3 Petabytes of data storage
- Data to be made available through a online portal.
- The development of tools to simplify access and use of the data, aimed at specific industries/impacts, is an important part of NARCliM
- High resolution (2km) experimental simulations over greater Sydney

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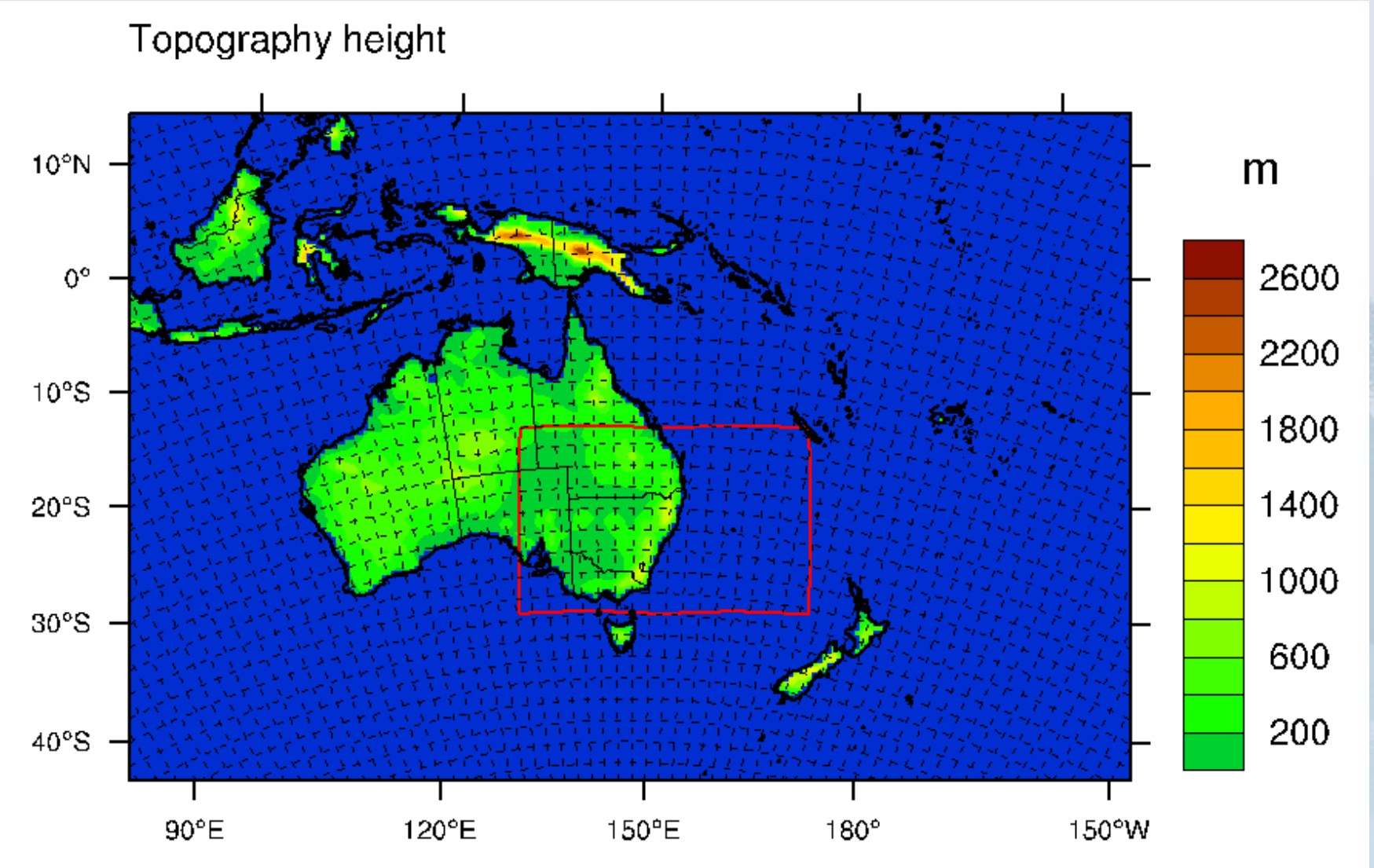
The RCM domain



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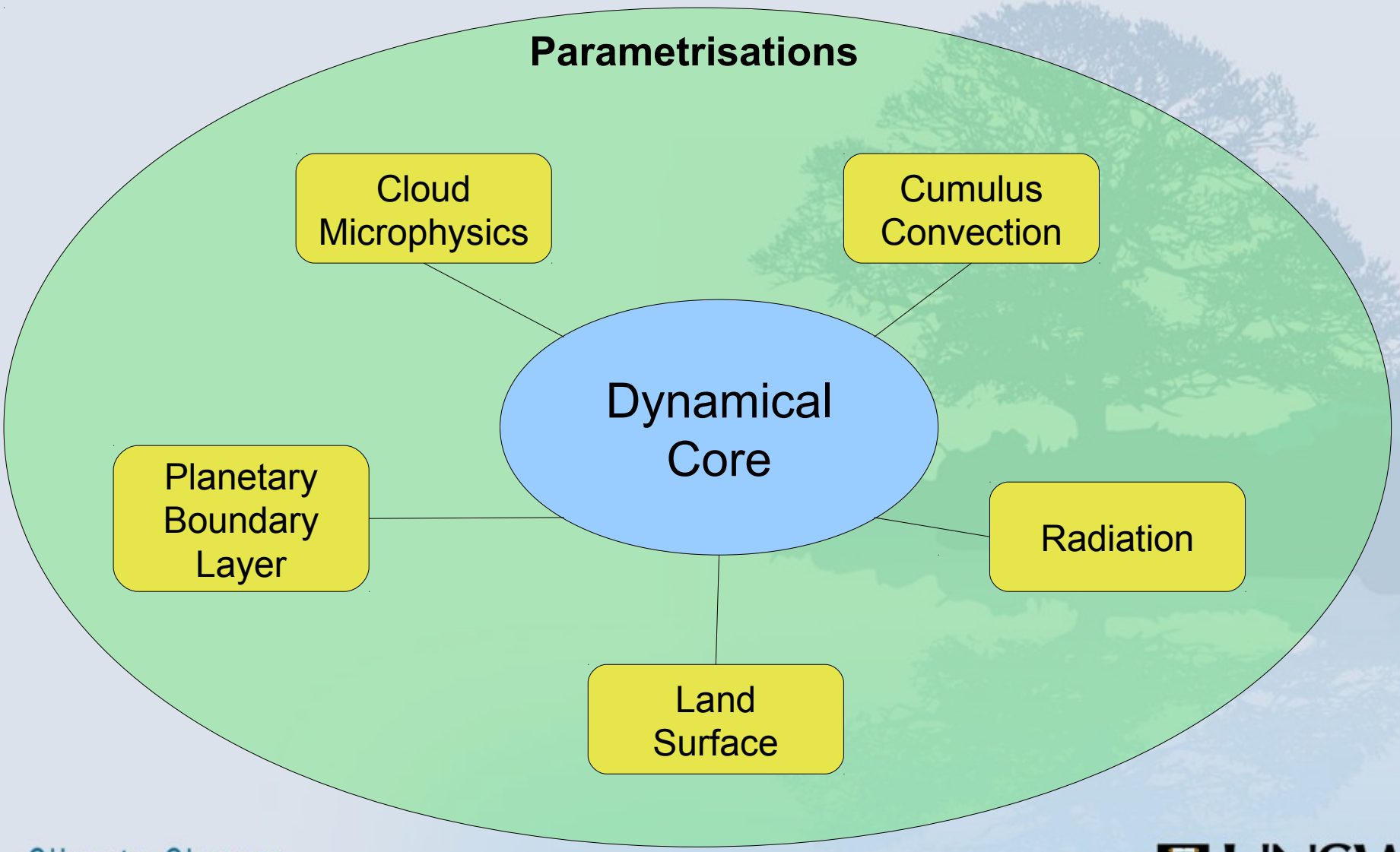
Choosing the RCMs

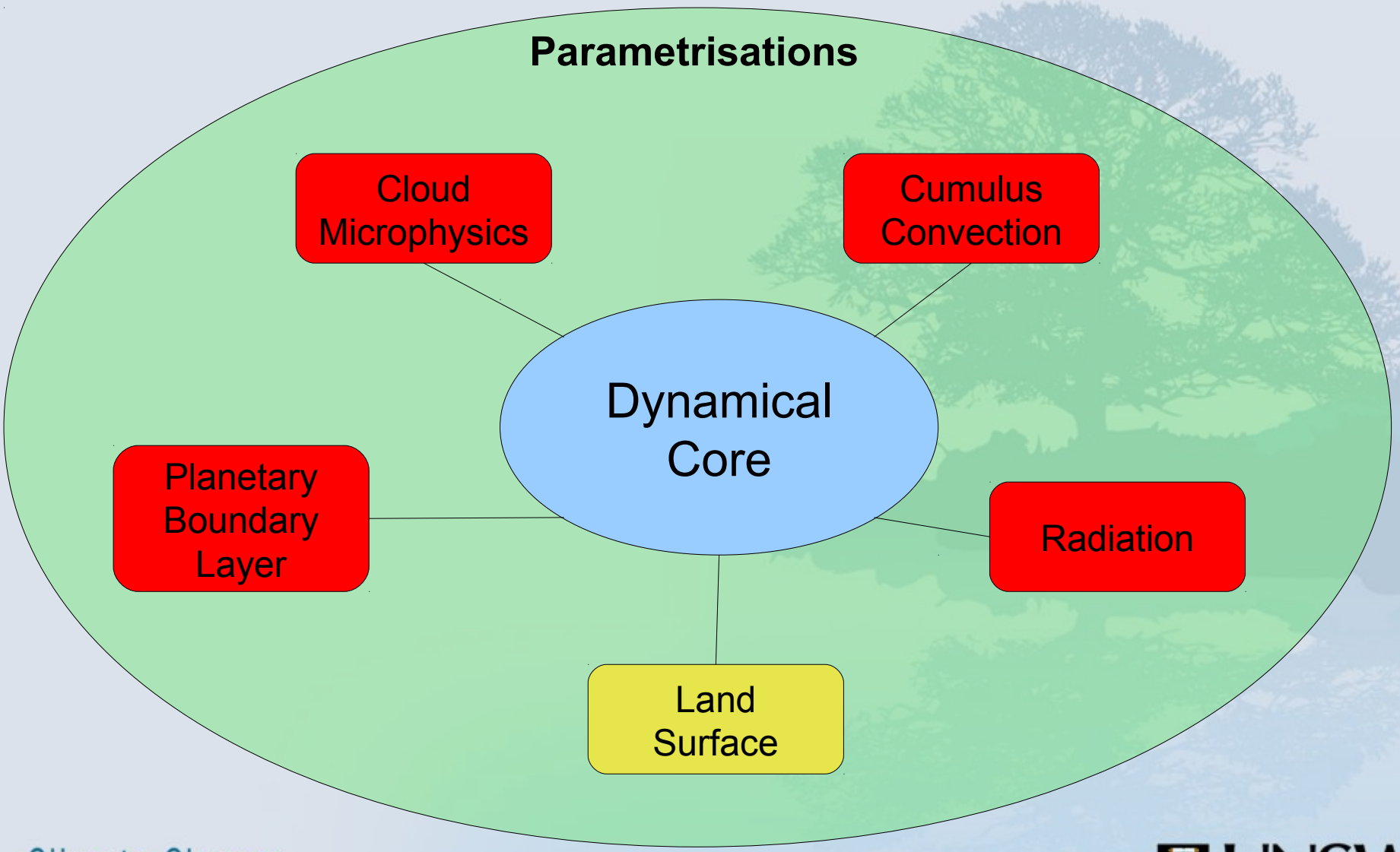
RCMs based on the Weather Research and Forecasting (WRF) system.

1. Evaluate the performance of 36 RCMs for a series of important precipitation events for NSW. Remove the worst performing RCMs.
2. Determine RCM independence using Bishop & Abramowitz (2010)
3. Choose the most independent RCMs while spanning the 36 member ensemble variance

Components of RCMs

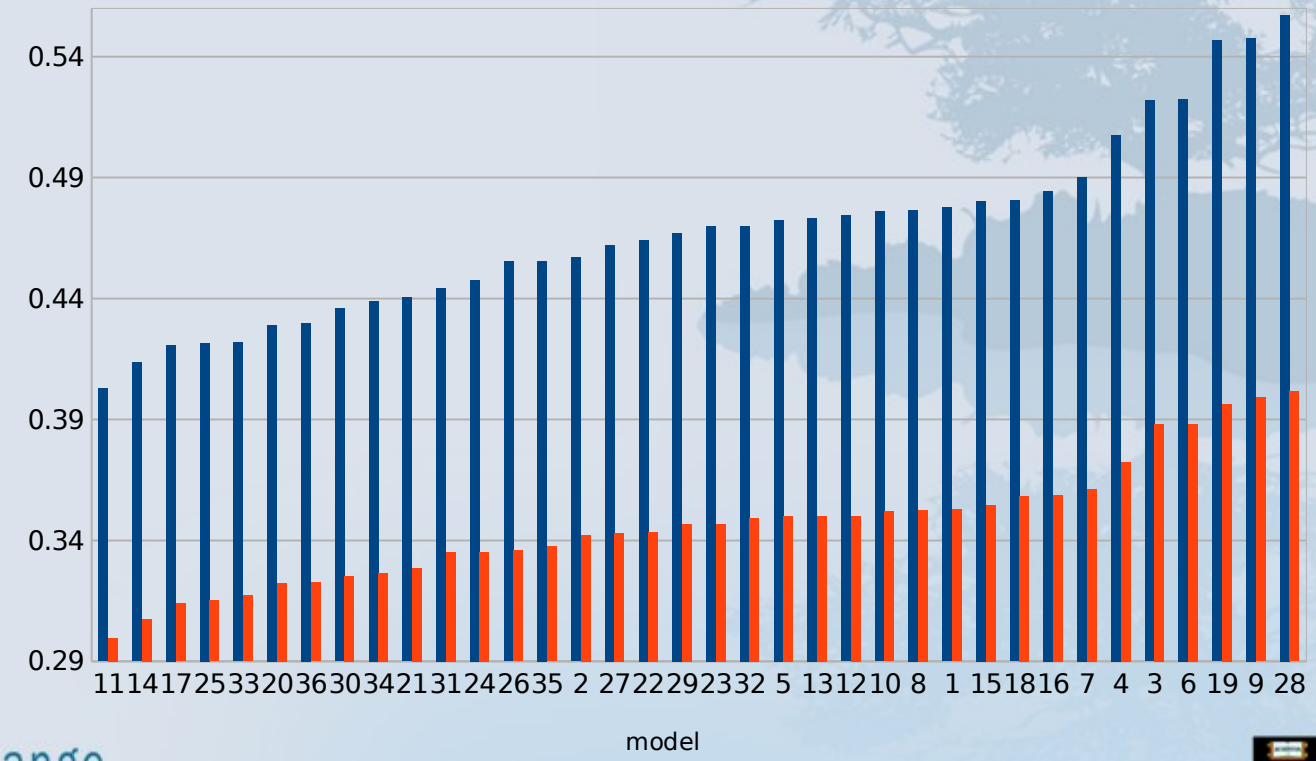


Components of RCMs



RCM performance

Statistics for temperature, precipitation, wind and sea level pressure are combined into an overall model performance metric. Low score is better.



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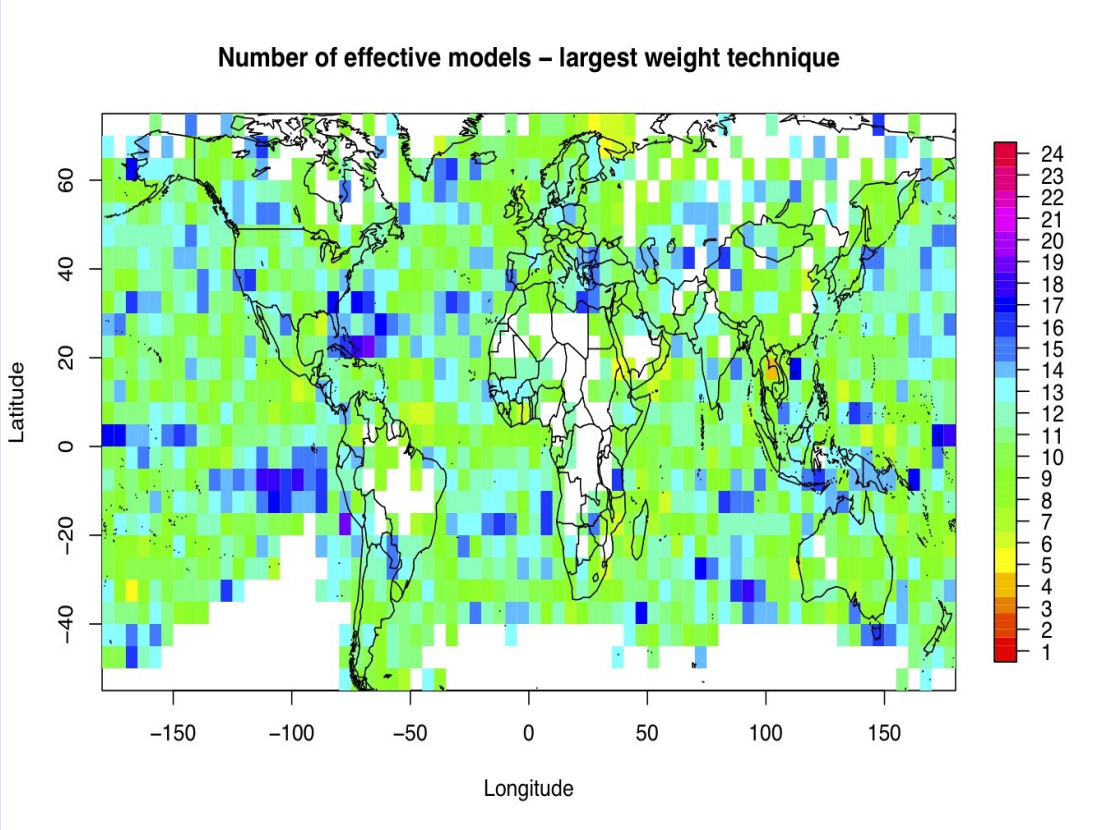
GCM Independence

From Bishop & Abramowitz (2010)

- A measure of model independence based on the correlation of model errors.
- After some fancy maths we obtain an estimate of the independence of each model and hence a number of effective models.



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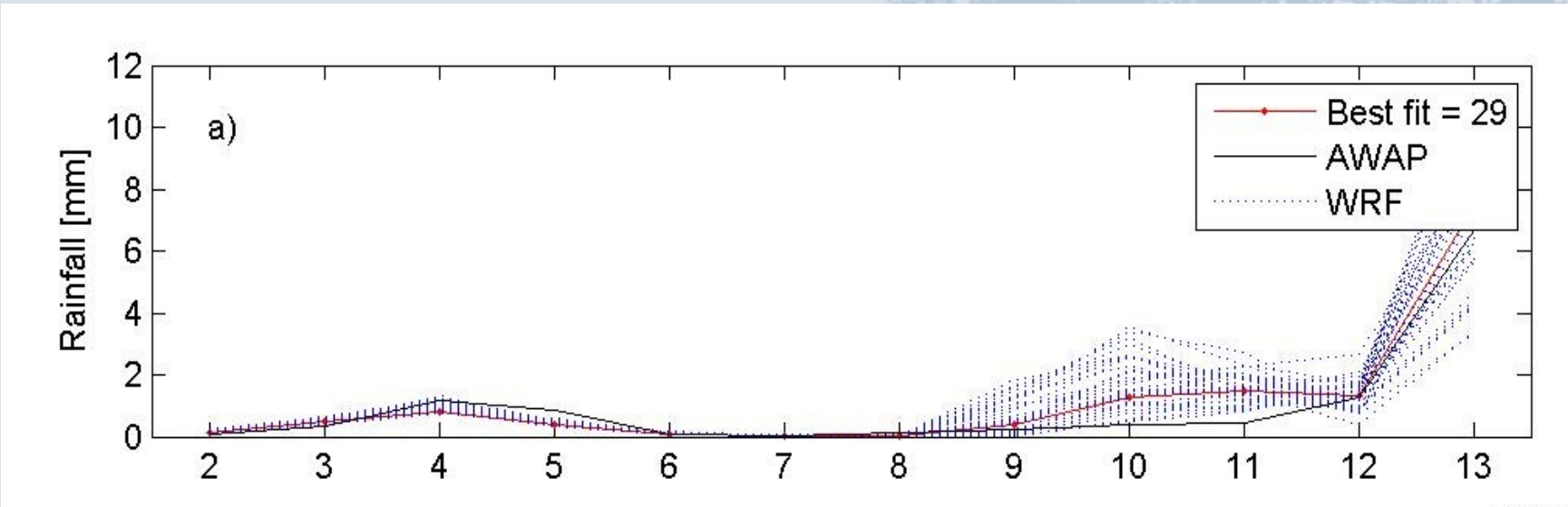
Evaluate the RCMs performance

36 RCMs rainfall for 23 Aug 2008 event



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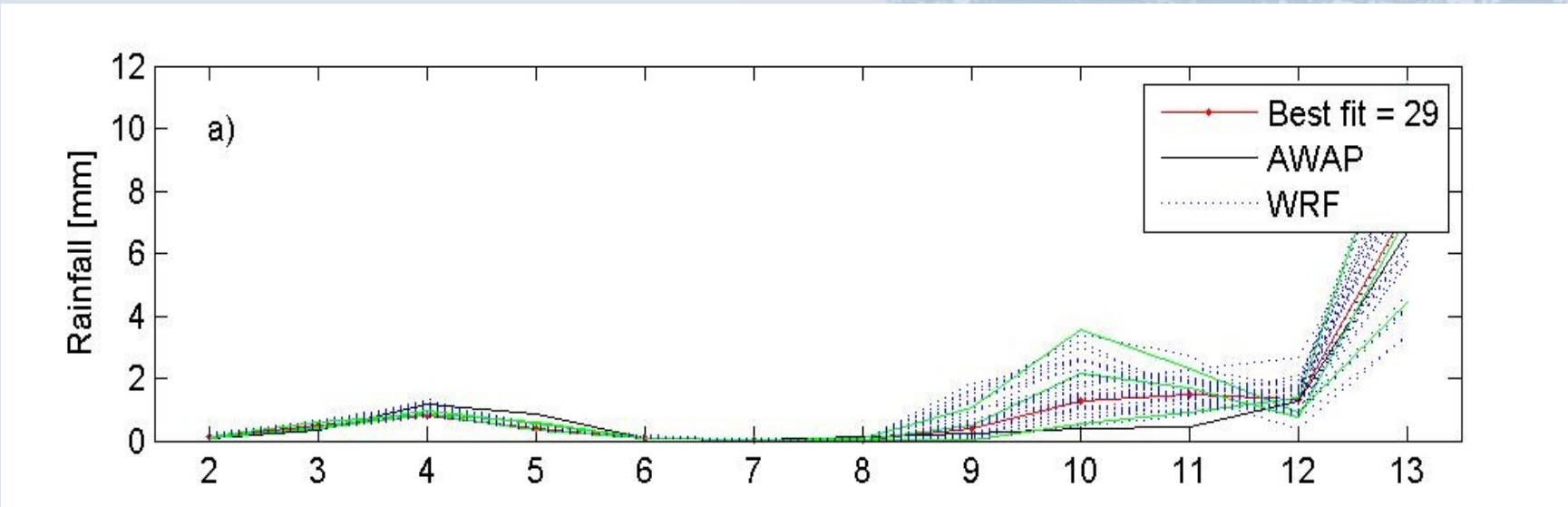
Top 3 RCMs by Independence

36 RCMs rainfall for 23 Aug 2008 event



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Choosing the GCMs

1. Use the published GCM evaluations over Australia (particularly NSW) to identify and remove the worst performing models
2. Determine GCM independence using Bishop & Abramowitz (2010)
3. Choose the most independent GCMs while covering the potential future climate change

GCM Evaluation

Table 2 Summary of model assessments

Assessment region	Model no	Aus					MDB		GLOBE
		A	B	C	D	E	F	G	H
GFDL-CM2.0	2	0	Yes	2	671	Yes	No	Yes	Yes
ECHAM5/MPI	4	0	Yes	1	700	Yes	No	No	Yes
UKMO-HadCM3	11	0	Yes	6	608				Yes
MIROC3.2(hires)	14	0	Yes	7	608		Yes		Yes
GFDL-CM2.1	16	0	Yes	2	672	Yes	No	Yes	Yes
CCSM3	9	0	No	2	677	No	No		Yes
CNRM-CM3	19	0	No	4	542			No	No
UKMO-HadGEM1	21	0	No	2	674				Yes
GISS-ER	5	0	No	8	515	Yes	No	No	No
ECHO-G	8	0	No	4	632	Yes	Yes	No	
CSIRO-Mk3	1	1	No	7	601	Yes	Yes	No	No
MRI-CGCM2.3.2	3	1	No	3	601	No	Yes	Yes	Yes
GISS-AOM	10	1	No	8	564	No	Yes		No
CGCM3.1(T63)	17	1		10	478		No		Yes
INM-CM3.0	13	1	No	7	627			Yes	No
CGCM3.1(T47)	15	1	No	8	518	No	Yes	No	Yes
FGOALS-G1.0	6	2	No	2	639	No	Yes		No
MIROC3.2(medres)	7	2	Yes	7	608	Yes	Yes	No	Yes
GISS-EH	12	5	No	14	304				No
BCCR-BCM2.0	18	5		5	590	Yes	No		No
IPSL-CM4	20	2	No	14	505	No	Yes		No
PCM	22	3	No	11	506				No

A number of rainfall criteria failed (this study), *B* satisfied ENSO criteria (Min et al. 2005; van Oldenborgh et al. 2005), *C* demerit points based on criteria for rainfall, temperature and MSLP (Suppiah et al. 2007), *D* M-statistic representing goodness of fit at simulating rainfall, temperature and MSLP over Australia (Watterson 2008), *E* satisfied criteria for daily rainfall over Australia (Perkins et al. 2007), *F* satisfied criteria for daily rainfall over MDB region (Maximo et al. 2007), *G* satisfied criteria for MSLP over MDB region (Charles et al. 2007), *H* below median errors for 14 variables (Reichler and Kim 2008)

Smith & Chandler (2010) +

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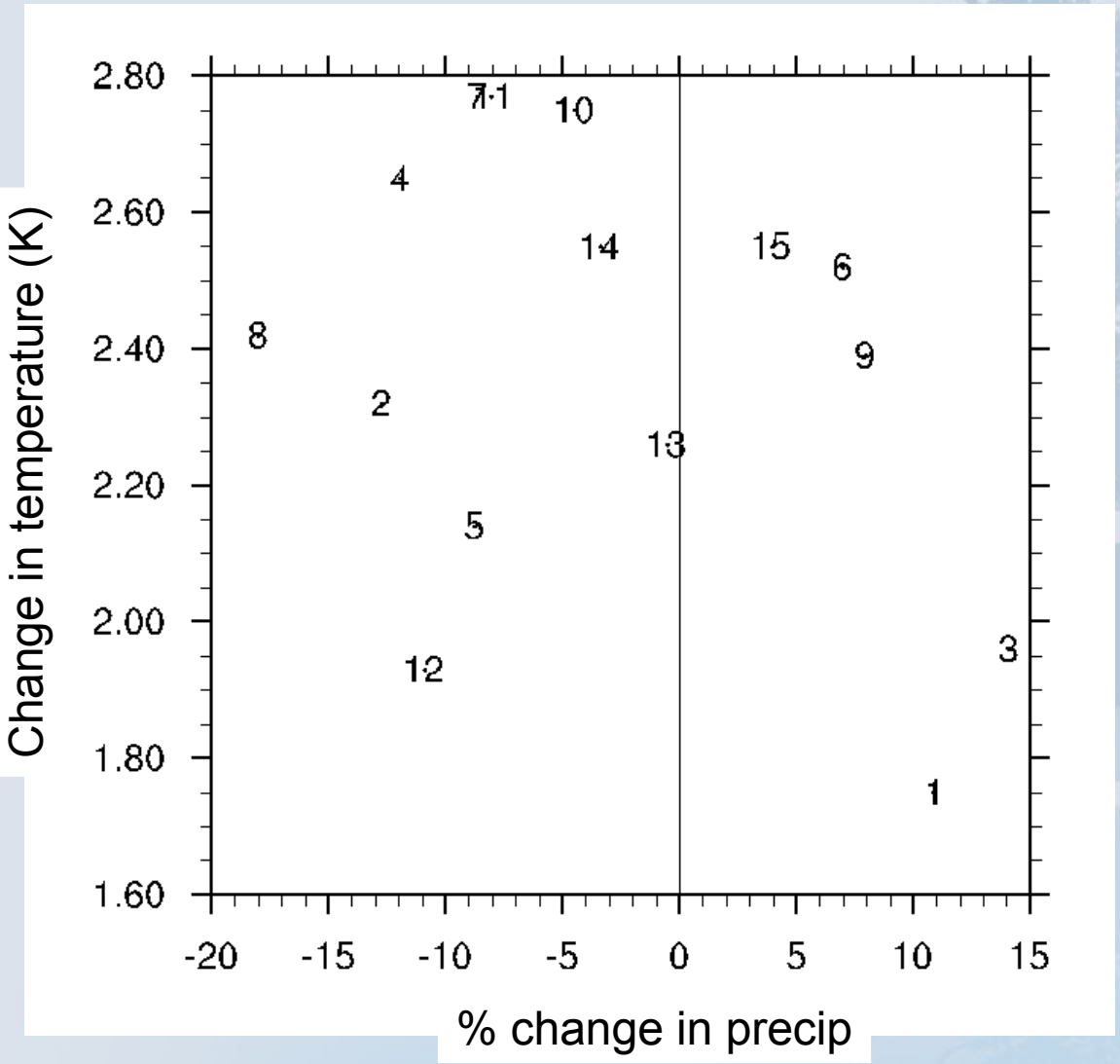
GCM Independence

models	abs(tas)	abs(pr)	average	rank
miroc3_2_medres	0.3524954	0.03638067	0.38887607	1
ukmo_hadgem1	0.1360727	0.06942903	0.20550173	2
inmcm3_0	0.16053	0.04361571	0.20414571	3
gfdl_cm2_0	0.07290747	0.1077916	0.18069907	4
mpi_echam5	0.07039613	0.09215108	0.16254721	5
mri_cgcm2_3_2a	0.06236396	0.084668	0.14703196	6
miub_echo_g	0.08682907	0.0413819	0.12821097	7
gfdl_cm2_1	0.02902377	0.0799438	0.10896757	8
cccma_cgcm3_1	0.02332552	0.07327753	0.09660305	9
ukmo_hadcm3	0.03306758	0.06017381	0.09324139	10
csiro_mk3_5	0.005901015	0.08603905	0.091940065	11
csiro_mk3_0	0.03983158	0.0502712	0.09010278	12
ncar_ccsm3_0	0.00908887	0.07265306	0.08174193	13
ingv_echam4	0.02170008	0.05087526	0.07257534	14
cnrm_cm3	0.006109701	0.05134836	0.057458061	15

Choose independent GCMs sampling the potential Future Changes



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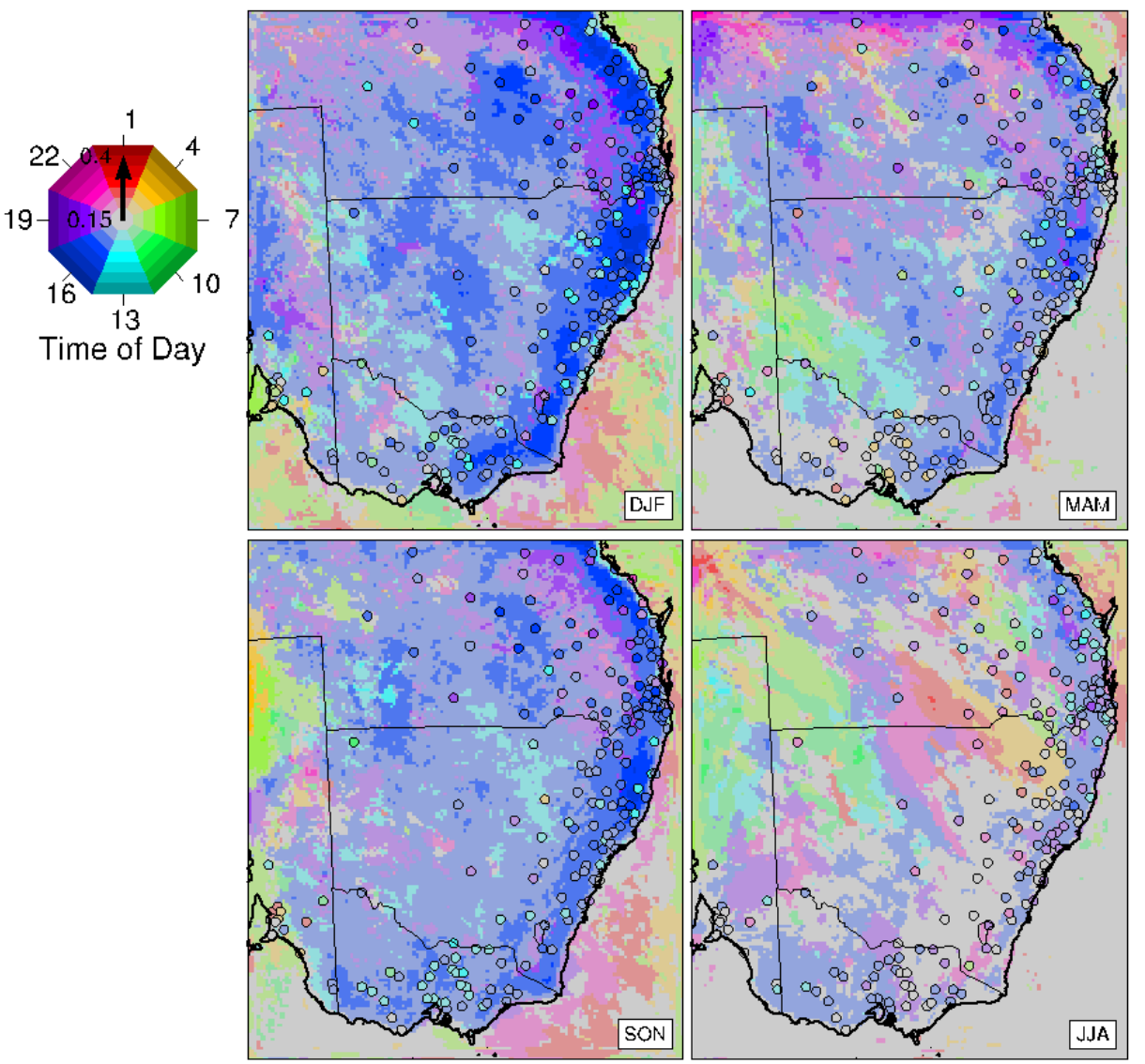
Small space/time scale extreme precipitation

Model evaluation: Diurnal cycle of precipitation



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Small scale precipitation extremes

Standard Engineering practice to look at peak rainfall events at different time scales

- 5 minute
- 10 minute
- 20 minute
- 30 minute
- 1 hour
- 3 hour
- Day +

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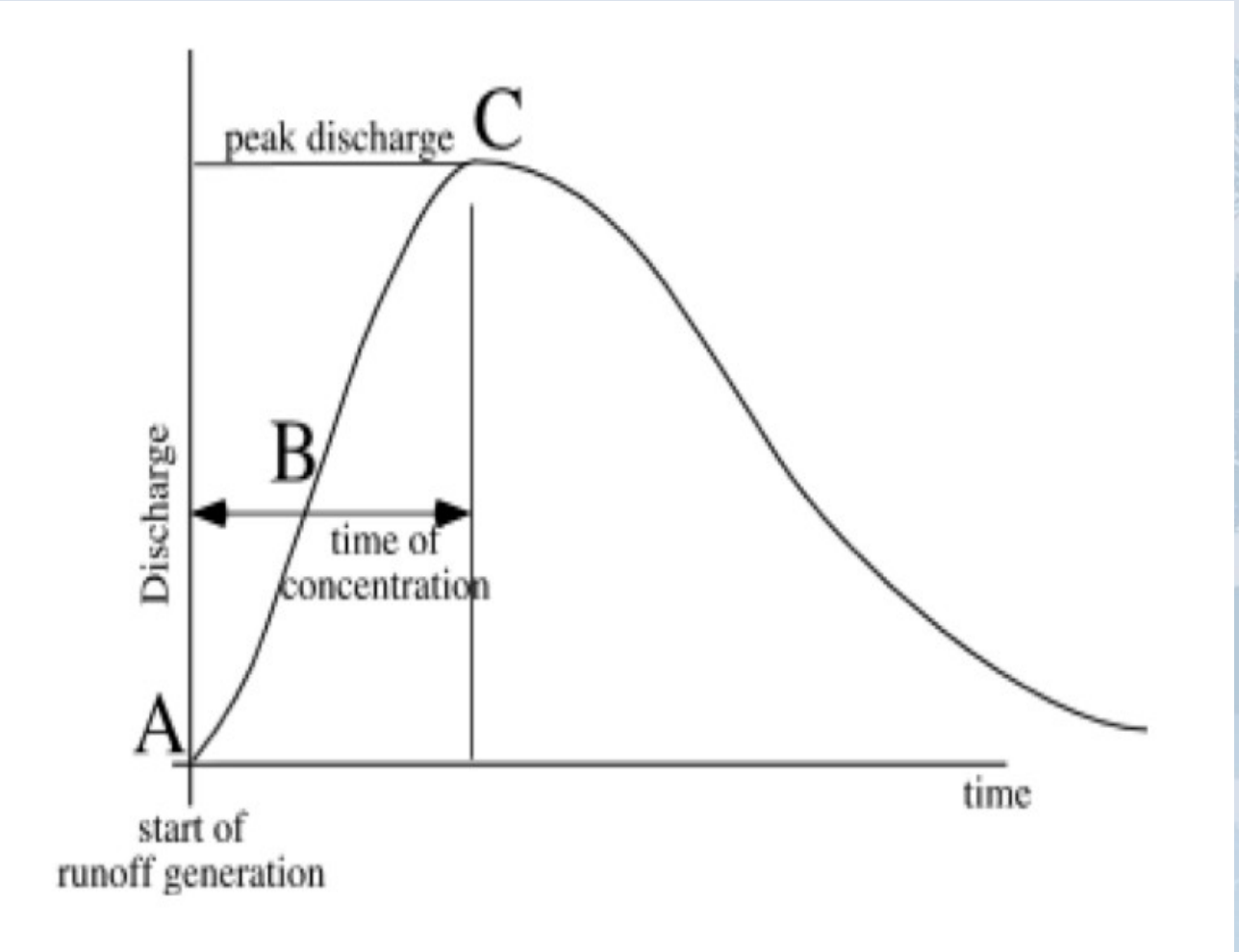
Time of concentration



AR&R: time of concentration t_c (in hours) for NSW catchments

$$t_c = 0.76\mathrm{A}^{0.38}$$

In order to resolve the hydrograph we would need

$$t_{resolved} = 0.38\mathrm{A}^{0.38}$$

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Engineering for Flooding Australian Rainfall and Runoff

Standard Engineering practice to look at peak rainfall events at different time scales

- 5 minute = 0.018km^2 ~ 1.8ha
- 10 minute = 0.11km^2 ~ 11ha
- 20 minute = 0.7km^2
- 30 minute = 2km^2
- 1 hour = 13km^2
- 3 hour = 230km^2
- Day = 55,000km^2

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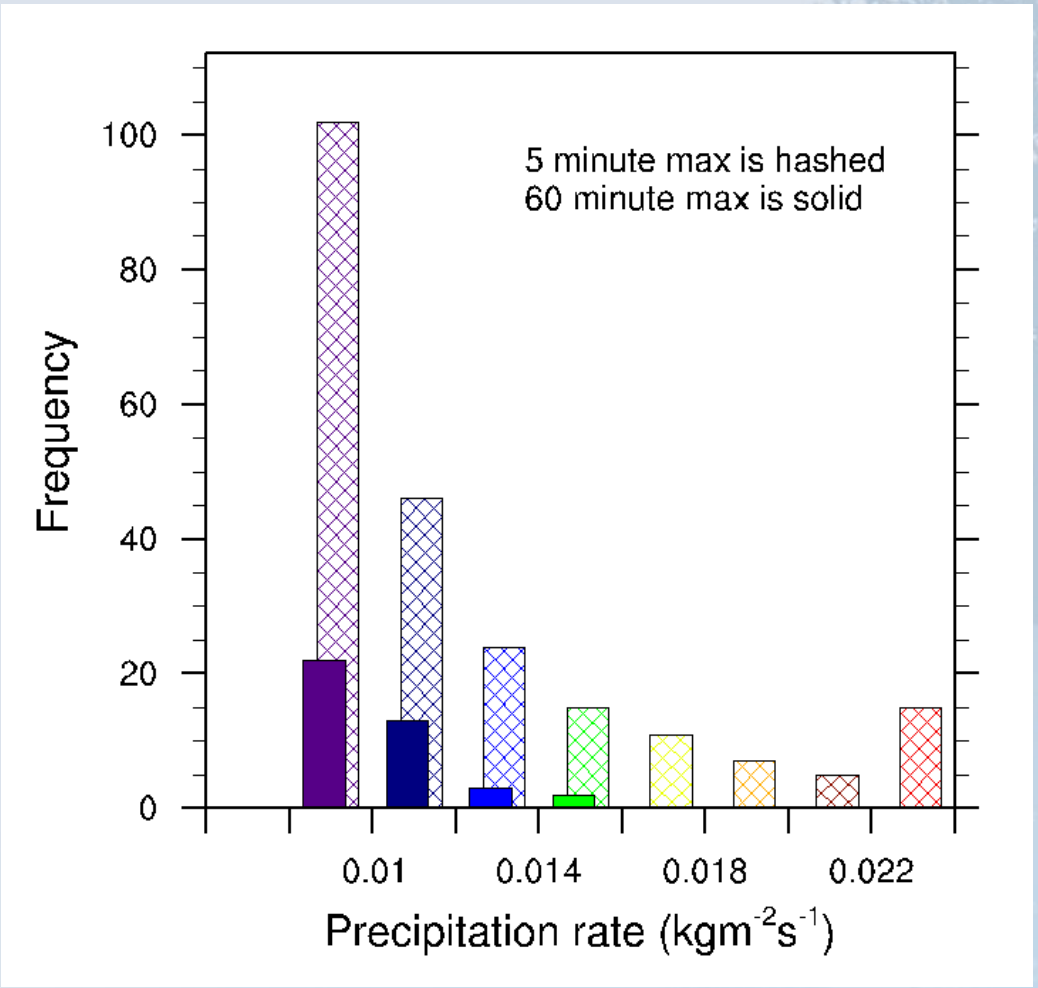
Preliminary peak precipitation distributions



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Summary

- Impacts and adaptation research requires downscaled climate projections – particularly if extremes are of interest.
- Regional climate model ensembles should be created considering:
  - Model evaluation (to remove worst performers)
  - Model independence (to produce “optimum” ensemble mean)
  - Potential future climates
- Spatial scales <10s km are needed to address sub-daily precipitation extremes.

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Some statistics

	Temperature (K)		Precipitation (mm)	
	Murray	Darling	Murray	Darling
Bias	0.72	1.05	-4.27	0.04
RMSE	0.98	1.22	9.02	3.98
Pattern Correlation	0.94	0.94	0.75	0.66
Anomaly Correlation	0.26	0.32	0.42	0.43