Future changes in extreme precipitation, rainfall erosivity and hillslope erosion in southeast Australia

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Outline

- NARCliM
- Extreme precipitation
- Rainfall erosivity & hillslope erosion

NARCliM

NSW / ACT Regional Climate Modelling project

NARCliM is a collaboration with state governments to produce a climate projection ensemble that can be used across government departments to include future climate change in planning processes in a systematic and consistent way.

NARCliM Modeling

- A2 scenario
- 4 GCMs + 3 RCMs = 12 member ensemble
- 2 domains: AUS44 (CORDEX 50km), NSW/ACT (10km)
- Control period: NCEP re-analysis 1950-2010
- 3 GCM time-windows: 1990-2010, 2040-2060, 2060-2080
- Create an ensemble best estimate with uncertainty for most common variables

Evans, J. P., F. Ji, C. Lee, P. Smith, D. Argüeso, and L. Fita (2014), Design of a regional climate modelling projection ensemble experiment – NARCliM, Geosci. Model Dev., 7(2), 621–629, doi:10.5194/gmd-7-621-2014.

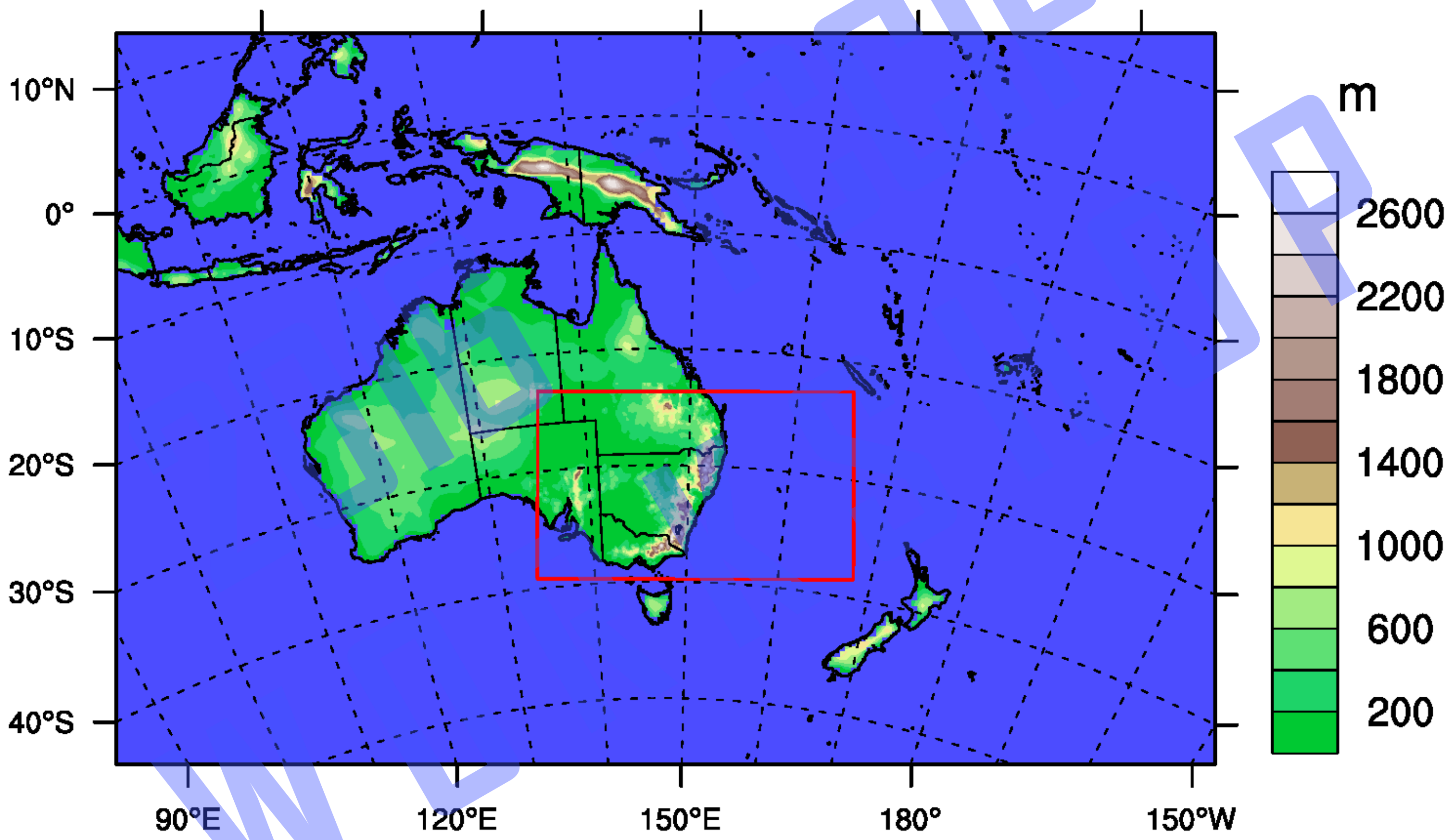
Criteria for choosing RCMs & GCMs

1. The chosen models perform adequately for the recent past compared to observations.
2. The chosen models do not exhibit the same strengths and weaknesses in their representation of the climate (i.e. they are independent).

And for the GCMs

3. The chosen models span the plausible future change space.

RCM domains

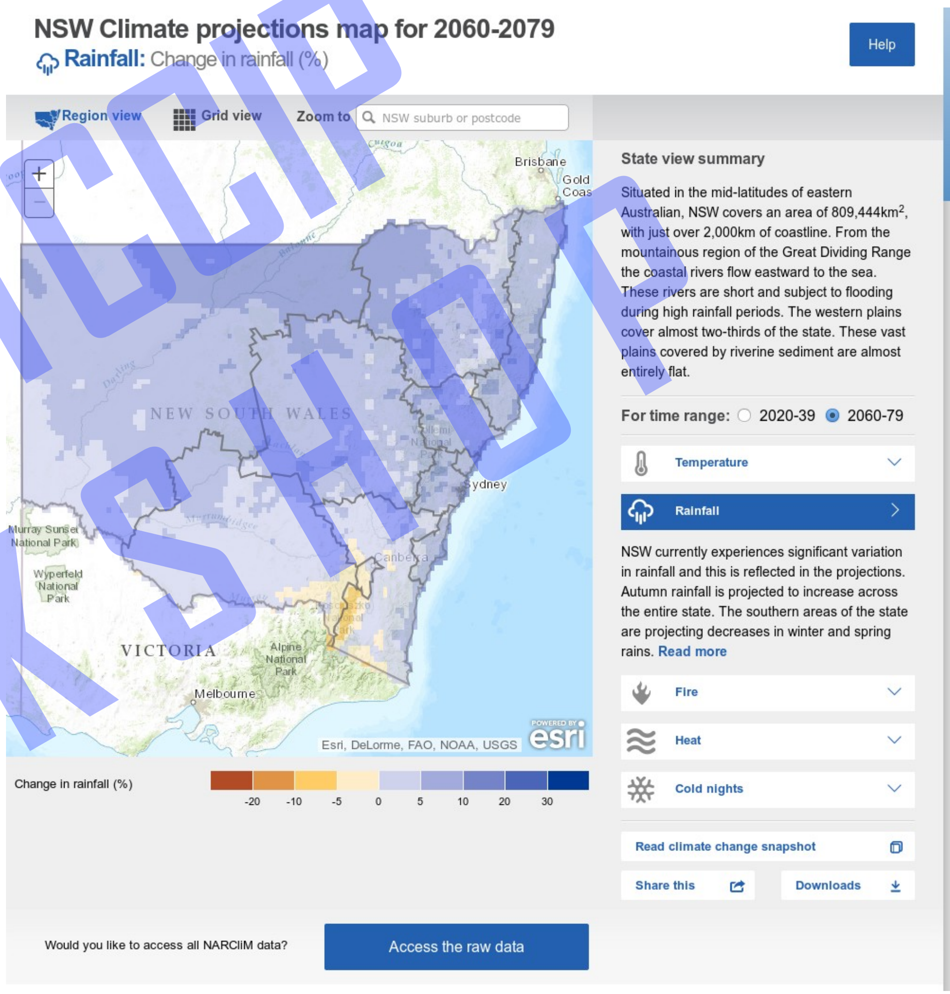


10°N
0°
10°S
20°S
30°S
40°S
90°E
120°E
150°E
180°
150°W
m
2600
2200
1800
1400
1000
600
200

NARCliM data

NARCliM data underpins the AdaptNSW website

http://www.climatechange.environment.nsw.gov.au/



Extreme Precipitation

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Evaluation of NARCliM
Annual maximum 1-day precipitation

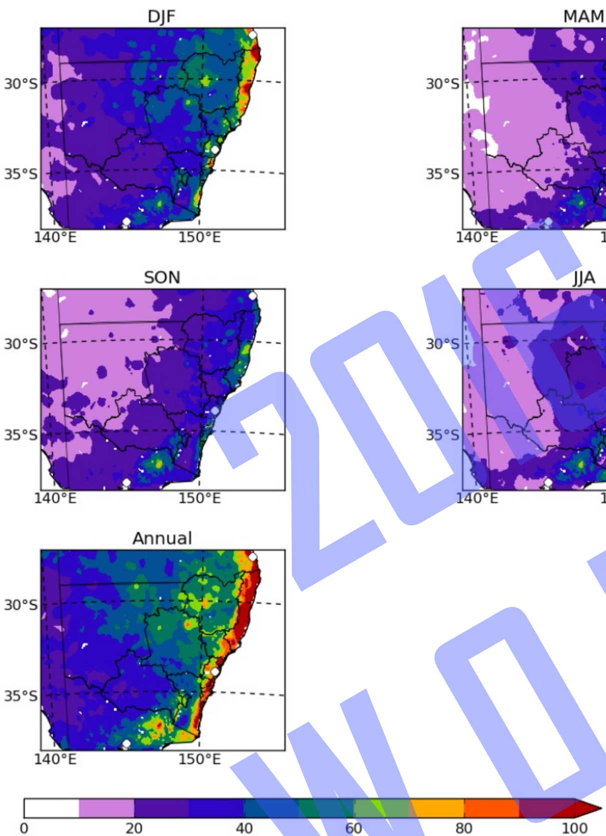


Figure 3.1: Present day (1990-2009) average seasonal and annual maximums of AWAP maximum 1-day preciptation (Rx1day) [mm]. White circles (top to bottom): Brisbane, Sydney, Melbourne.

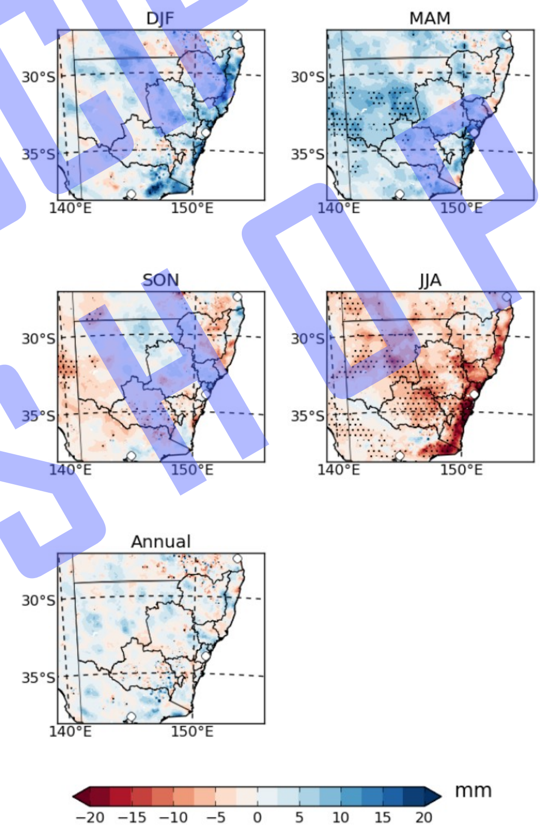


Figure 4.13: Present-day (1990-2009) multi-model average seasonal and annual maximum maximum 1-day precipitation (Rx1day) minus corresponding AWAP observations [mm]. Stipling indicates the bias is significant at the 5% level. White circles (top to bottom): Brisbane, Sydney, Melbourne.

Observed past trends (1911-2014)

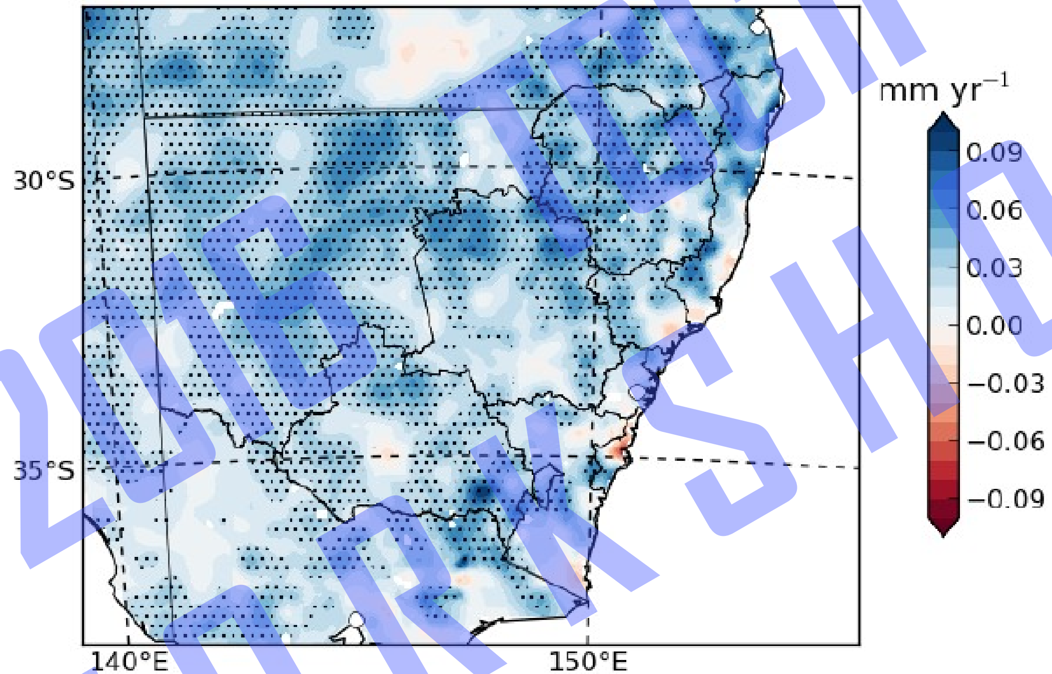
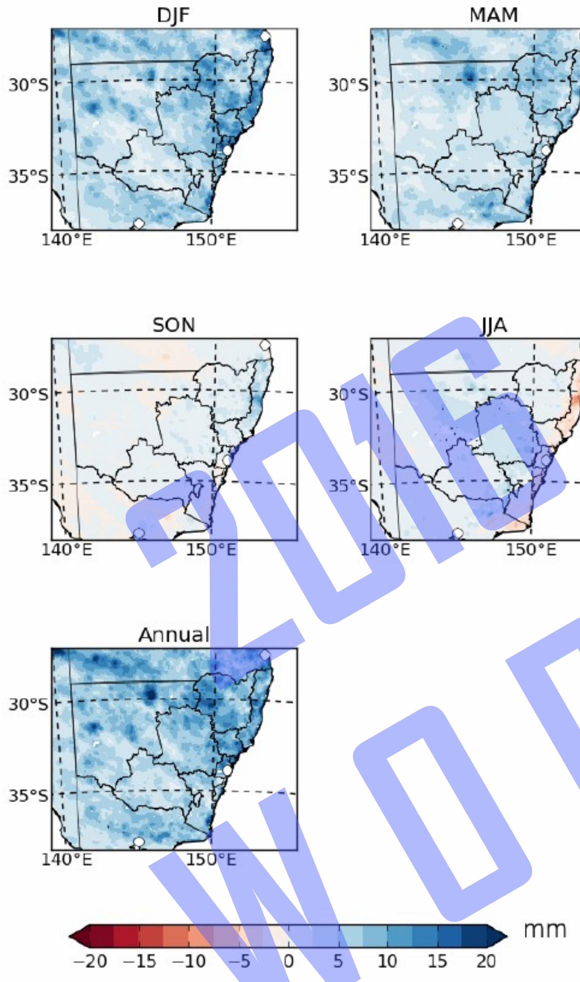


Figure 3.17: Trends from 1911 to 2014 in annual maximum 1-day preciptiation (Rx1day) [mm yr^{-1}]. Stippling indicates the trend is significant at the 5% level. White circles (top to bottom): Brisbane, Sydney, Melbourne.

Far Future Changes (2070-2000)



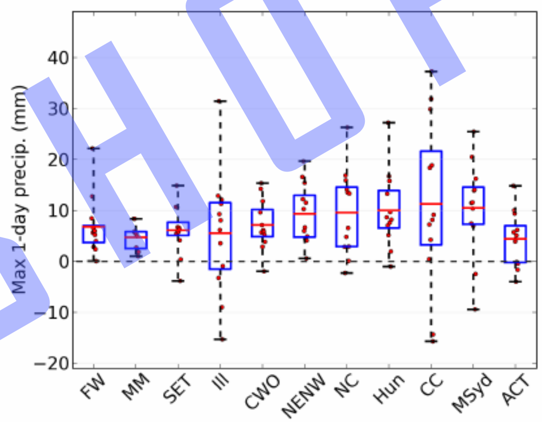


Figure 6.25: Boxplots of monthly maximum 1-day precipitation (Rx1day) for NSW state planning regions (years 2060-2079). Red line indicates ensemble mean, box extends from the 25th to the 75th percentile, whiskers extend to the ensemble range. Red dots indicate individual RCMs, black squares indicate the AWAP estimate.

Rainfall erosivity & hillslope erosion

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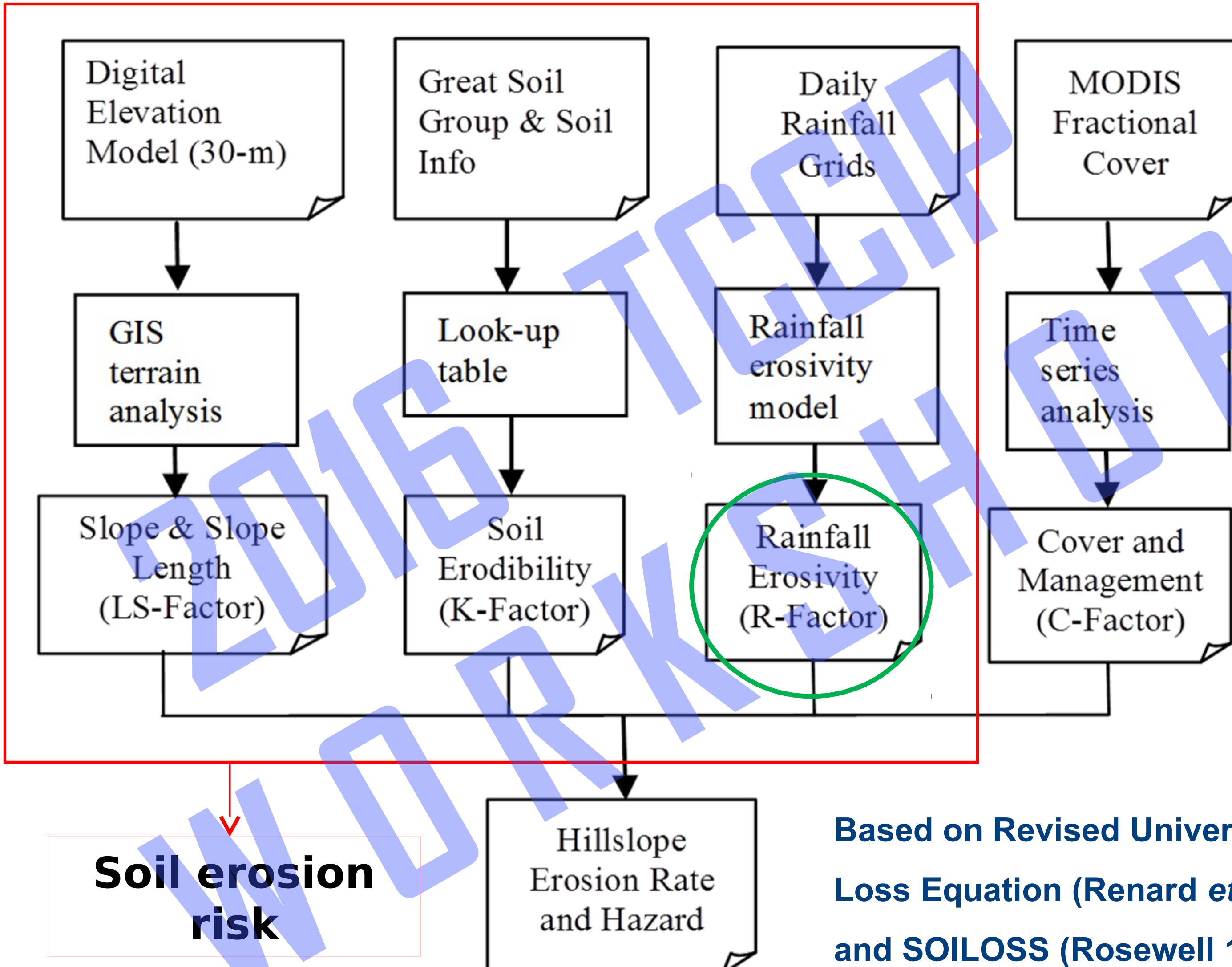
Background & data sets

Soil erosion rates are expected to change in response to changes in the erosive power of rainfall or **rainfall erosivity**.

Data

- NARCliM projected daily rainfall with bias correction:
  - Four GCMs: CGCM 3.1, CSIRO mk3.0, ECHAM5, MIROC-medres 3.2
  - Three RCMs: R1, R2, R3
  - Three time slides: 1990–2009, 2020–2039, 2060–2079
- Gridded Daily Rainfall (BoM): 1910–2013, 1961–1990, 1990–2009
- 1-second (about 30 m) hydrologically corrected Digital Elevation Model (DEM-H).
- Fractional vegetation cover (MODIS, Landsat)
- Great Soil Groups (GSG) map and Soil and Land Information System (SALIS).

RUSLE modelling



Based on Revised Universal Soil Loss Equation (Renard *et al*. 1997) and SOILOSS (Rosewell 1993).

The Rainfall Erosivity Model

$$\hat{E}_j = \alpha[1 + \eta \cos(2\pi f j - \omega)] \sum_{d=1}^{N} R_d^{\beta}$$

$$\beta = 1.02 - 0.0209L$$

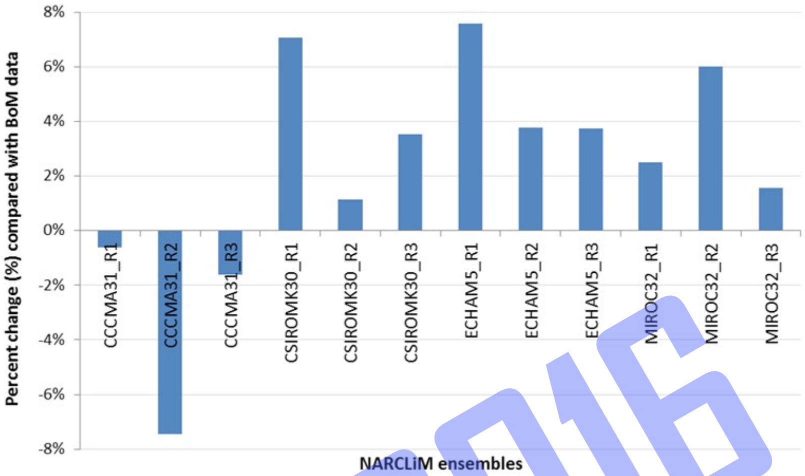
$$\alpha_0 = 1.05 \times 10^{(2.08-1.58\beta)}$$

$$\frac{\alpha}{\alpha_0} = 2.349 + 0.04040L - 0.0002684E$$

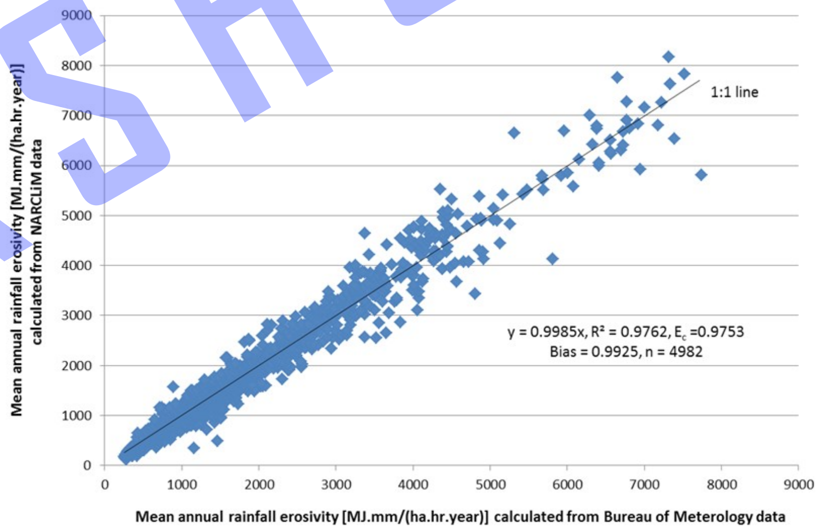
where R_d is the **daily rainfall amount**, *N* is the number of rain days in the month, and *α*, *β*, *η*, and *ω* are model parameters. *L* is the **latitude** in decimal degrees and *E* is the **elevation** above the sea level in meters.

Yang, X. and Yu B.F. (2015). Modelling and mapping rainfall erosivity in New South Wales, Australia. ***Soil Research* 53**, 178-189.

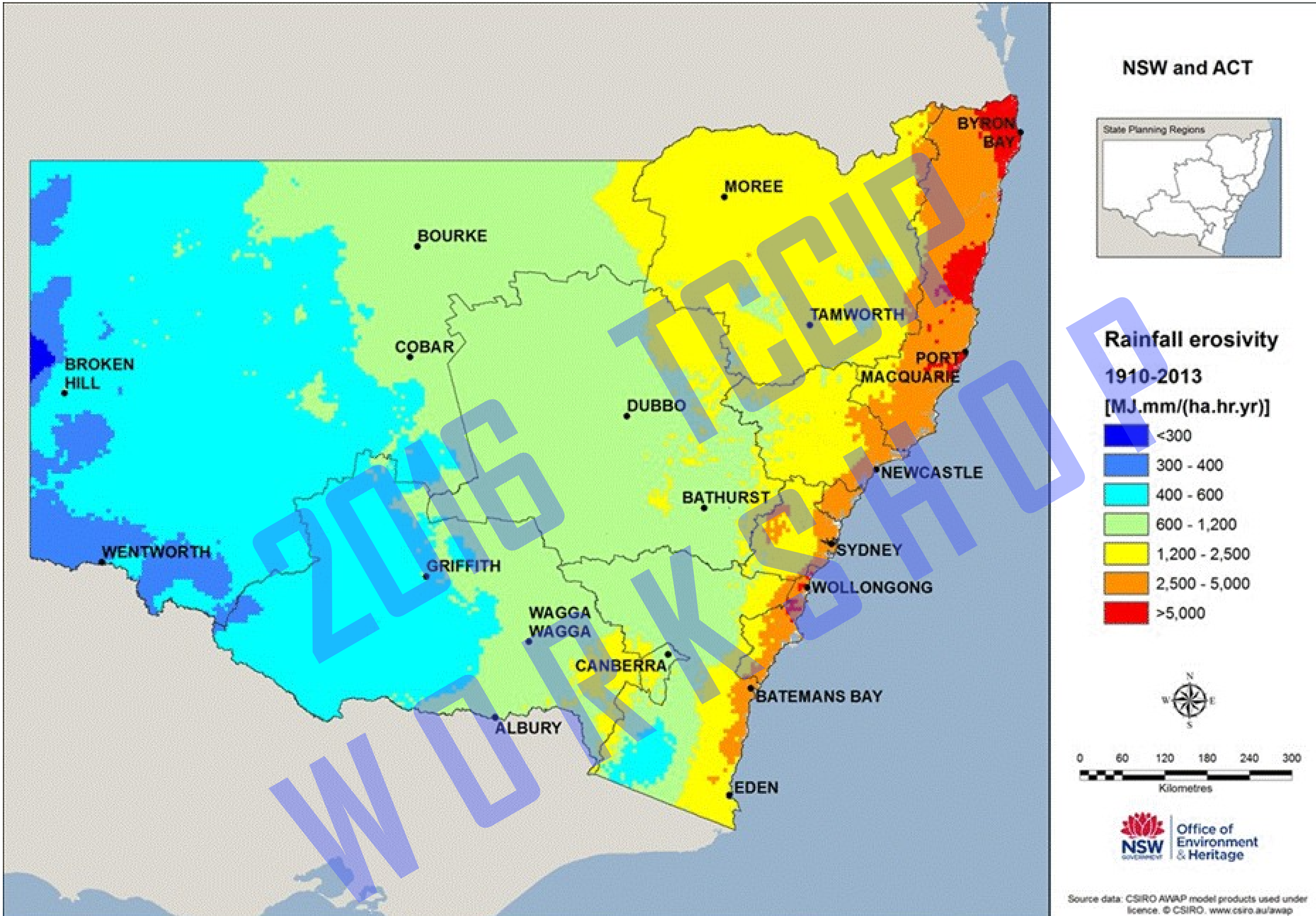
Rainfall Erosivity Evaluation



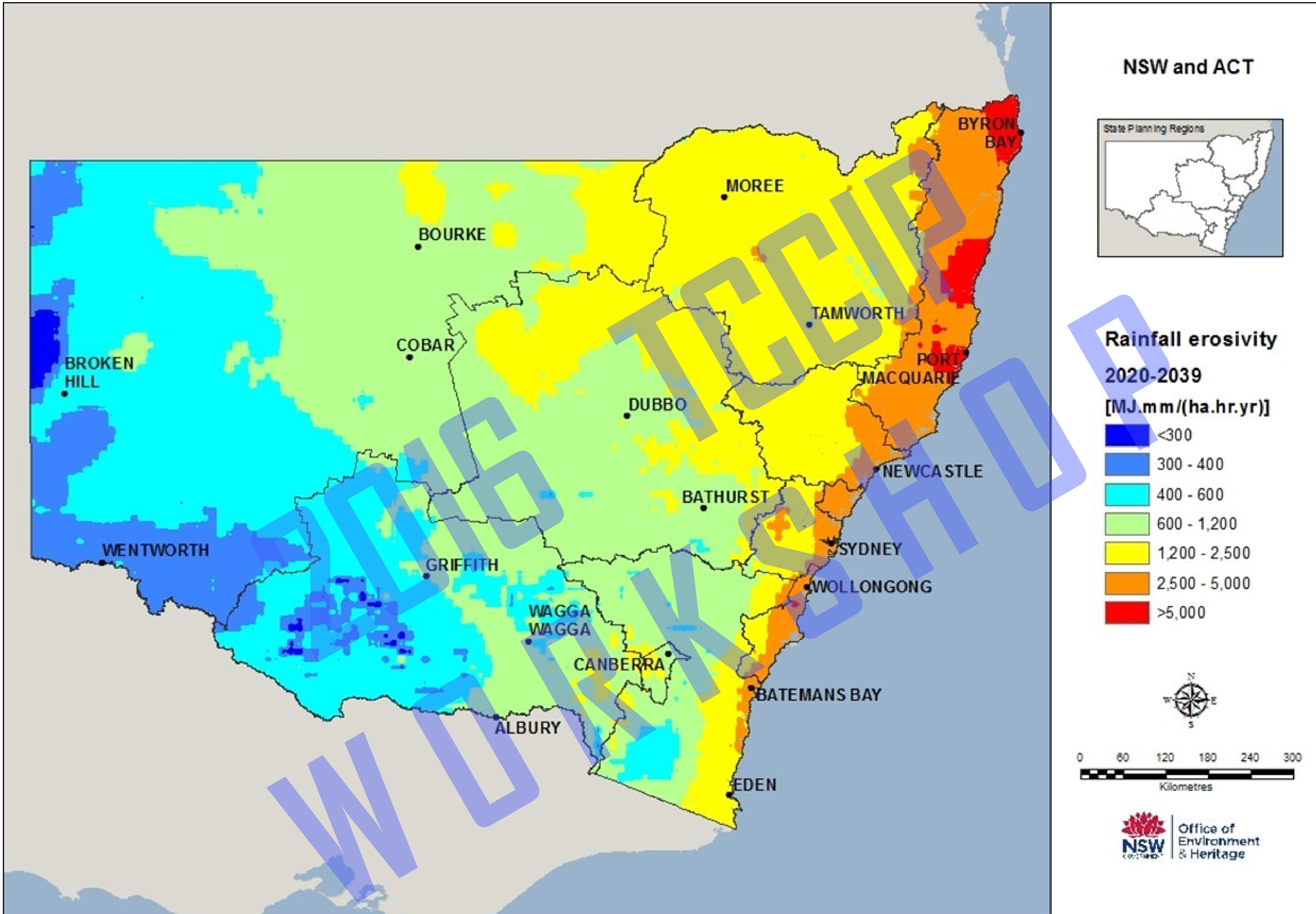
The relative error (%) of mean annual rainfall erosivity calculated from 12 NARCliM ensemble members compared with observations



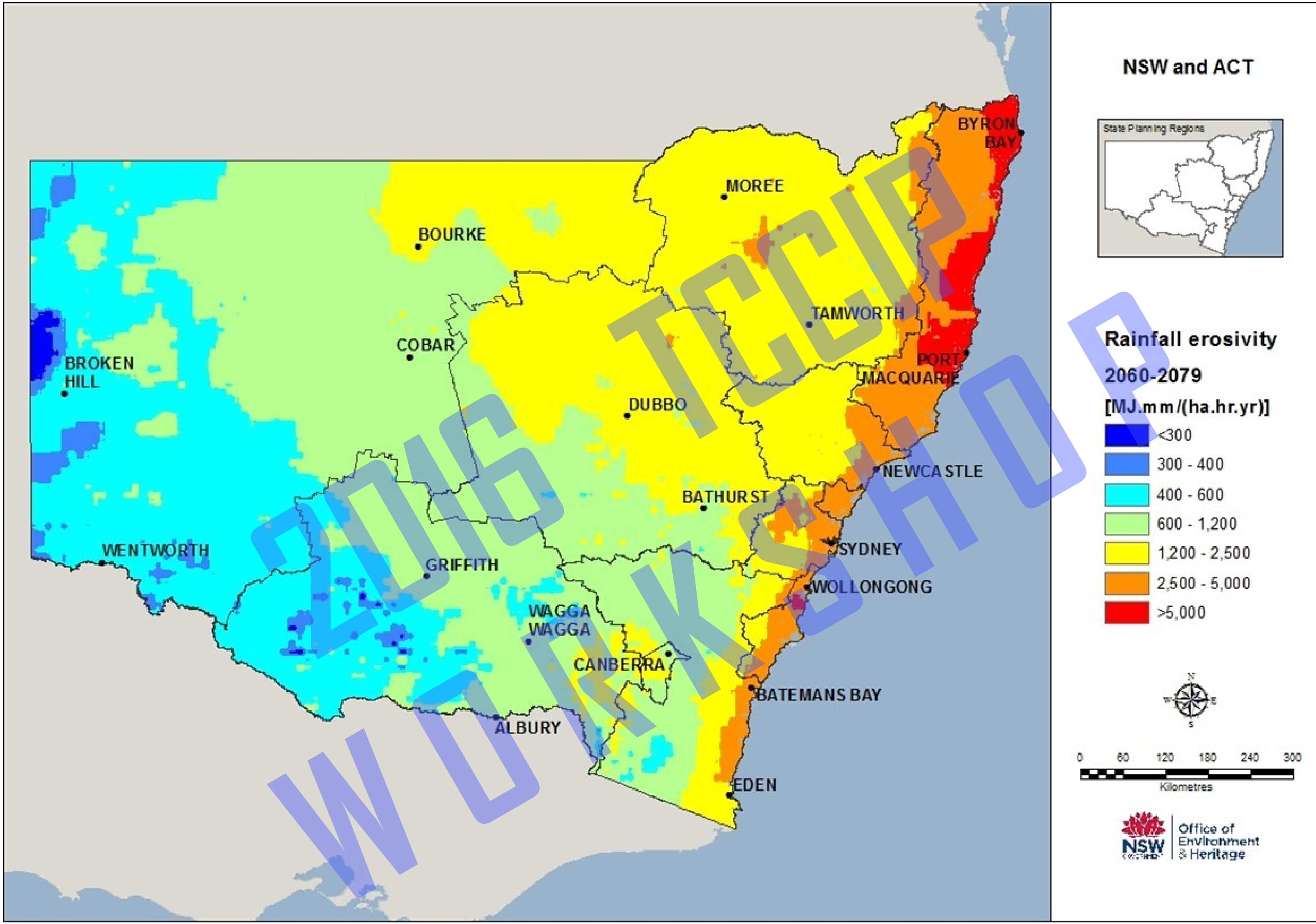
Comparison of mean annual rainfall erosivity calculated from NARCliM ensemble and observations



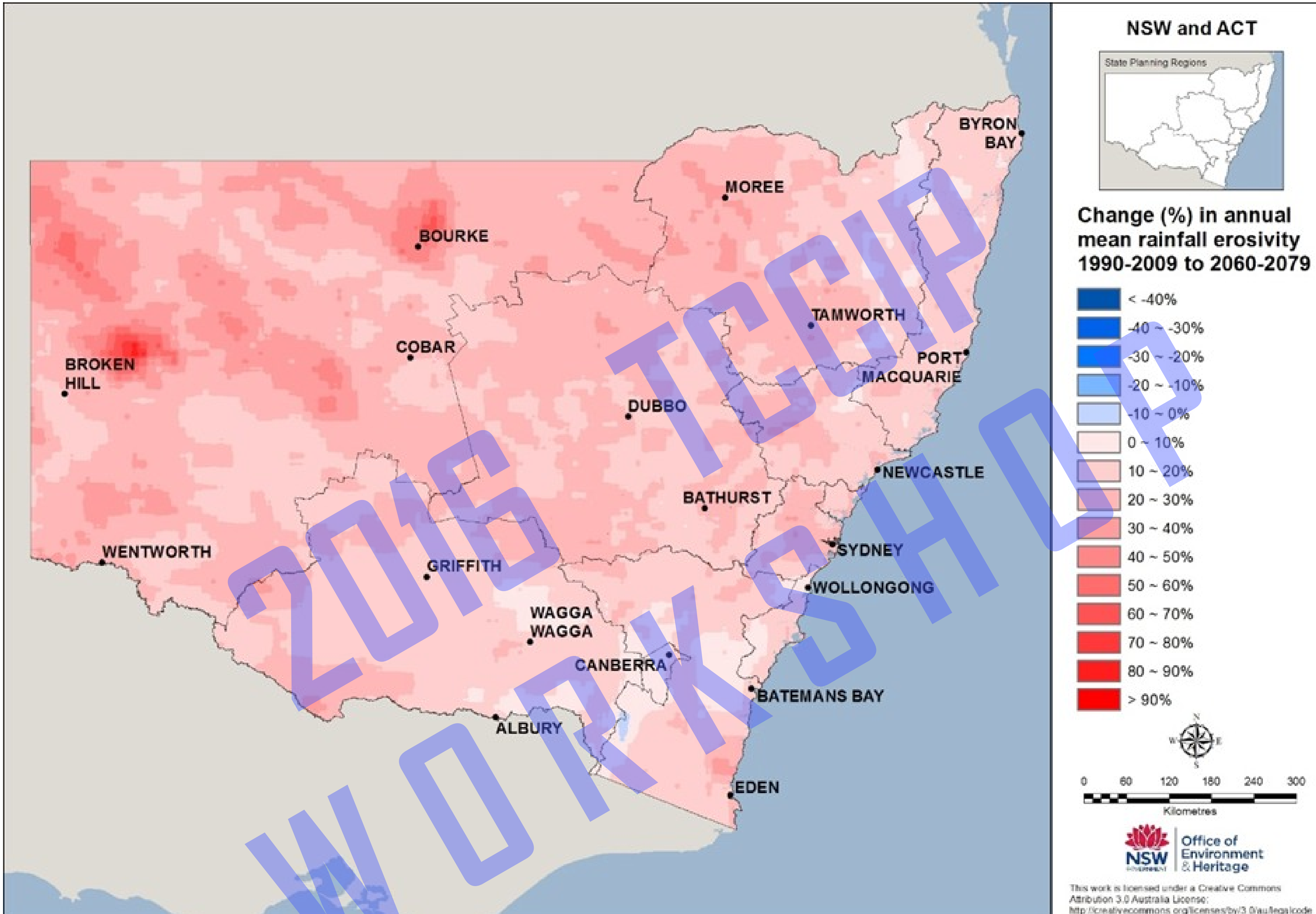
Mean annual rainfall erosivity (Baseline)



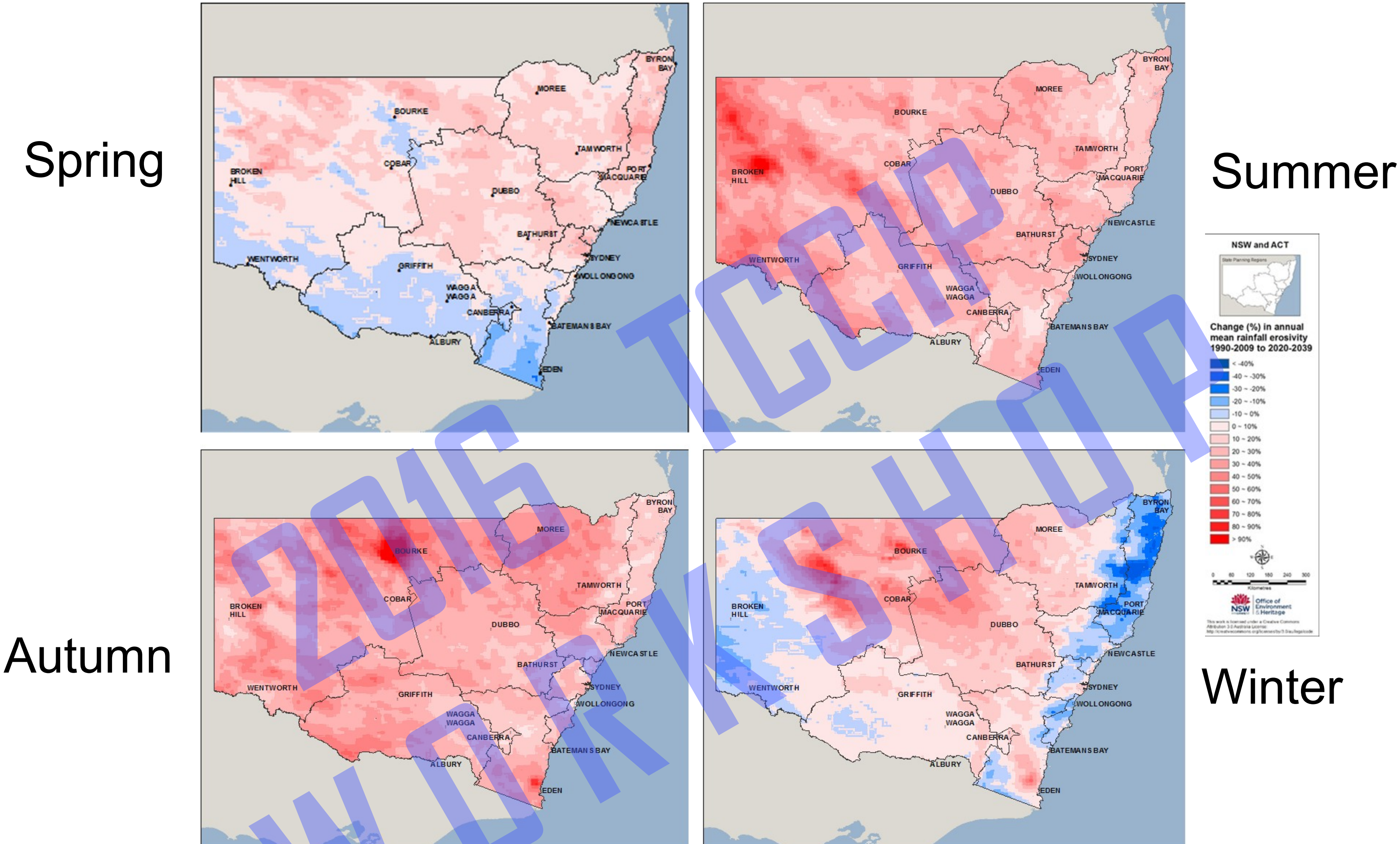
Mean annual rainfall erosivity (Near future)



Mean annual rainfall erosivity (Far future)

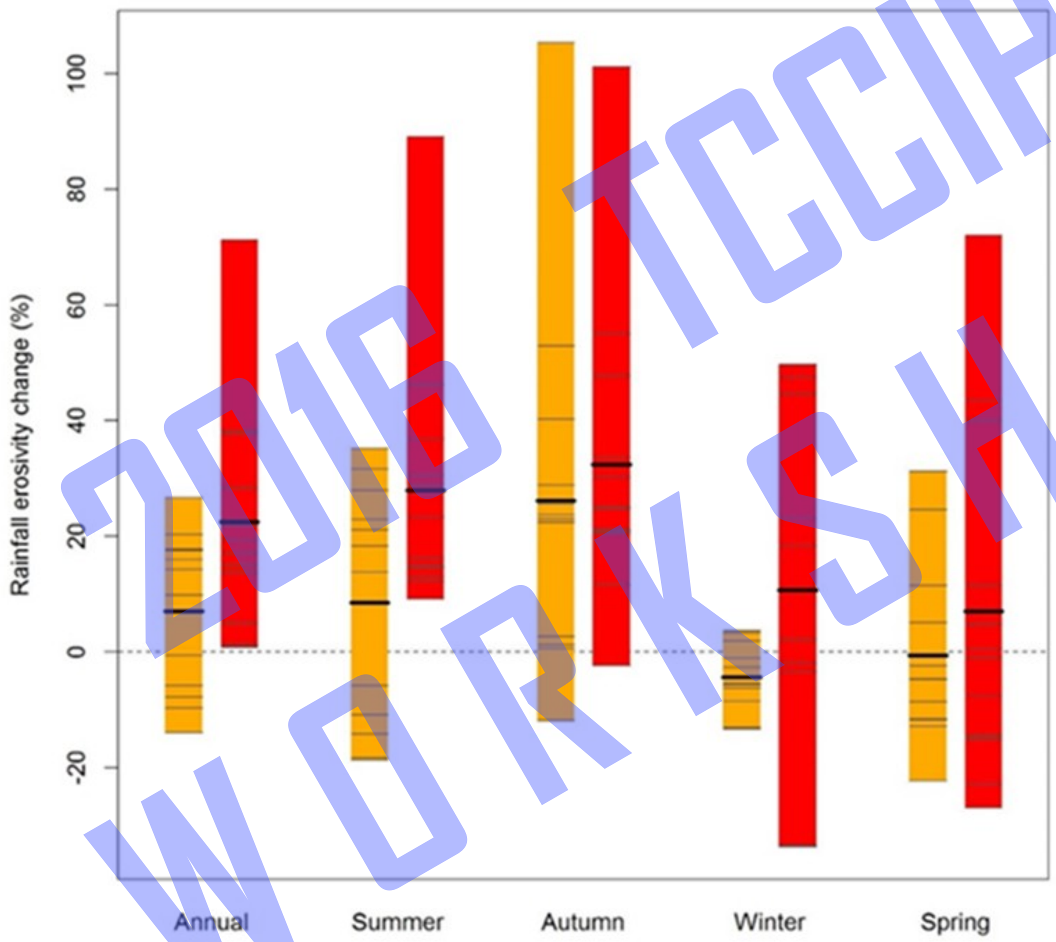


The percent change of in rainfall erosivity in the far-future period (2060–2079) compared with the baseline period (1990–2009).



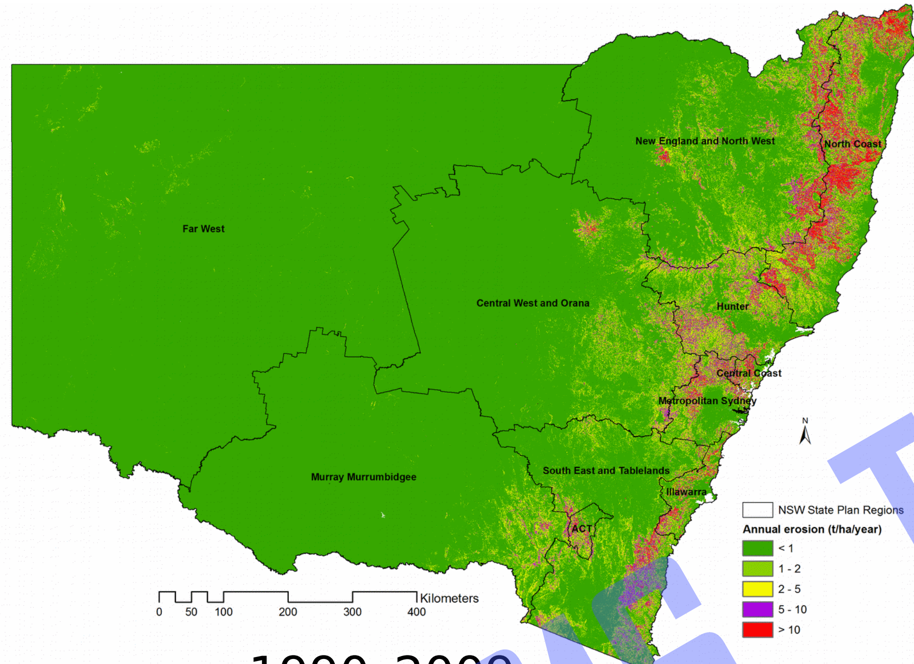
The seasonal changes (%) of in rainfall erosivity in the far-future period (2060–2079) compared with the baseline period (1990–2009)

Future Change in Rainfall Erosivity

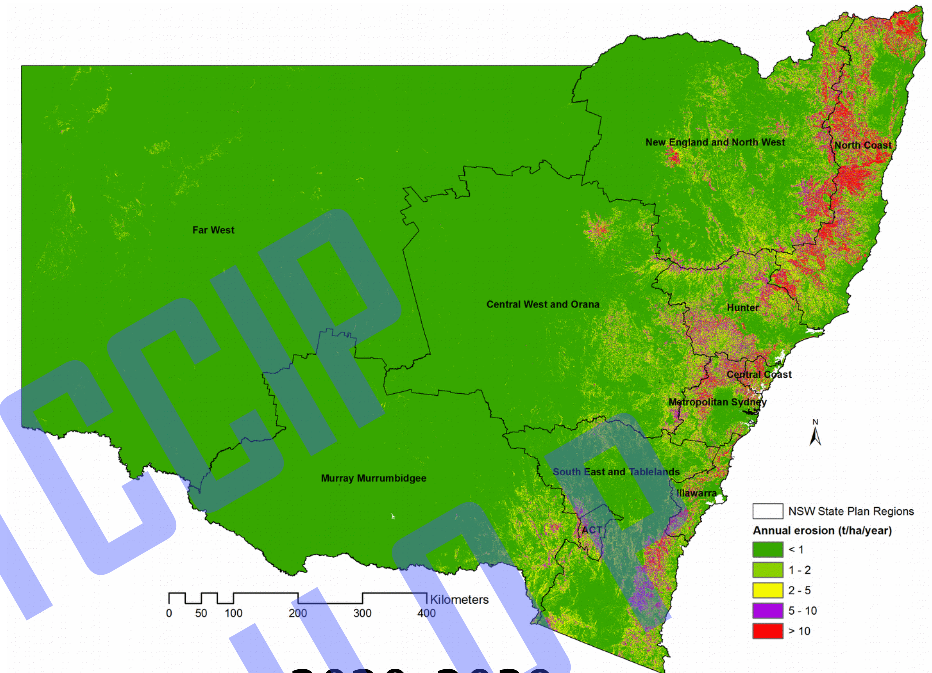


Yellow bars represent near future scenarios (2020–2039)

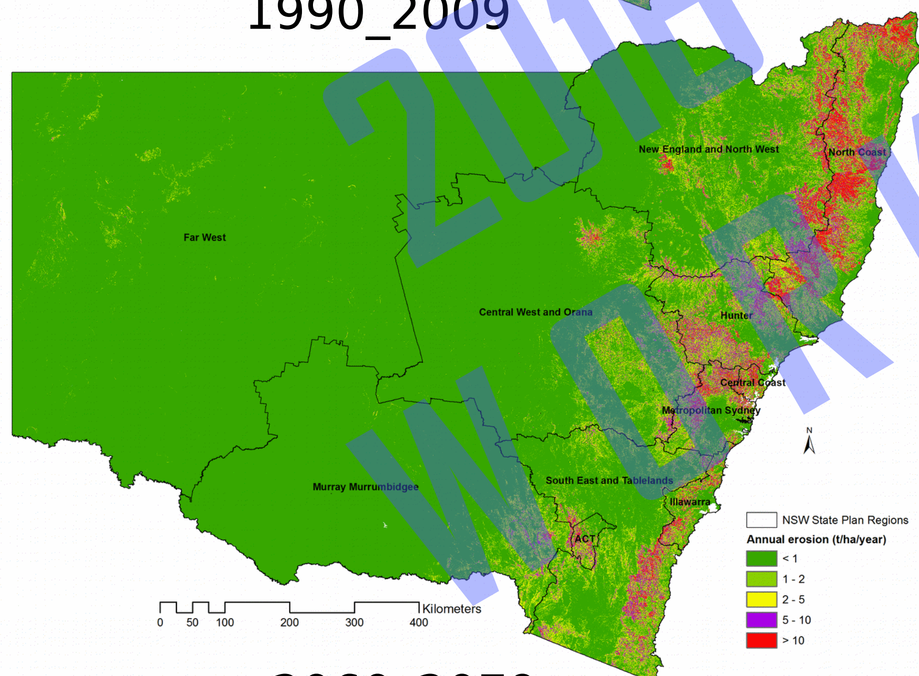
Red bars represent far future scenarios (2060–2079)



1990_2009



2020_2039

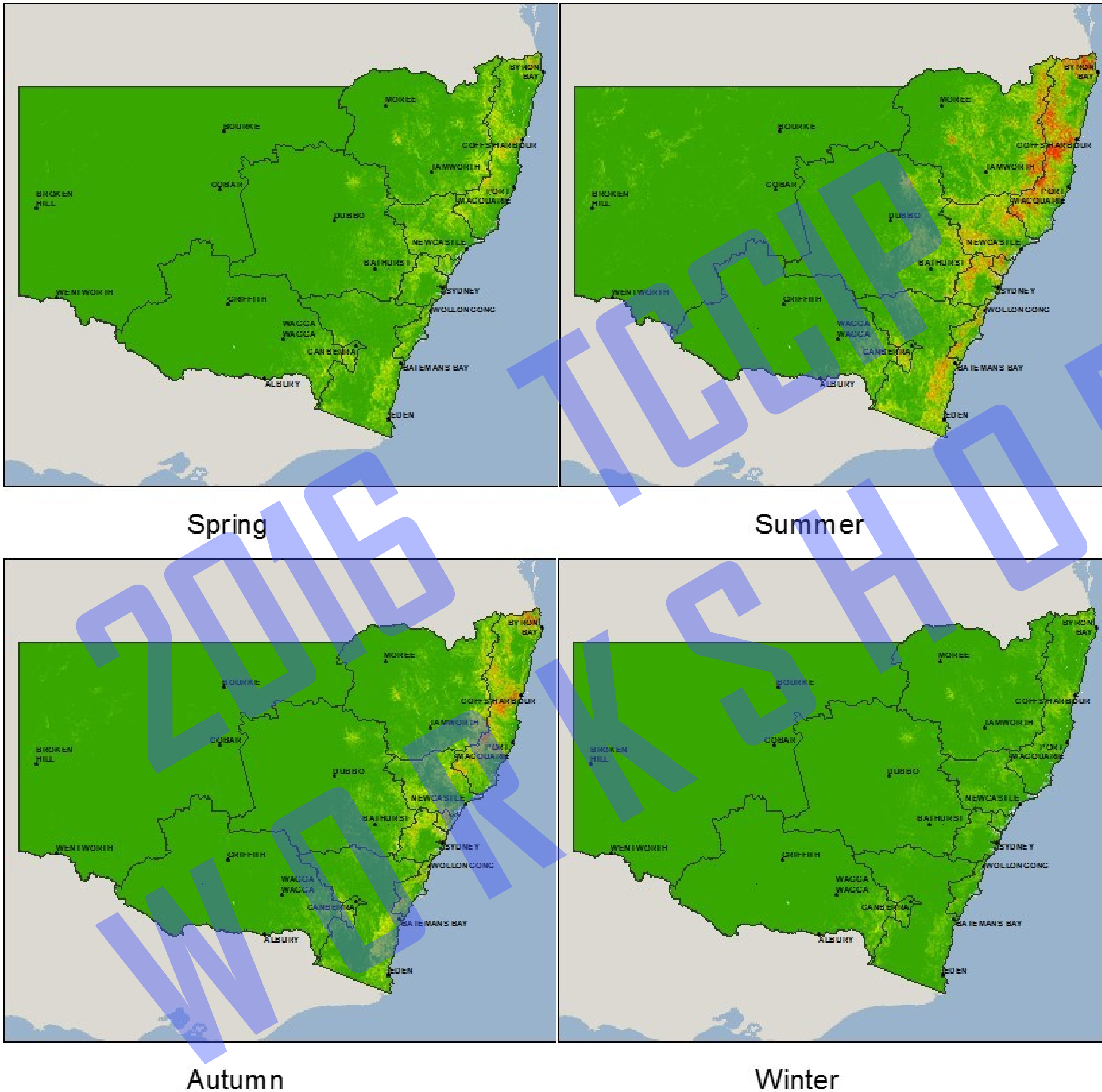


2060_2079

Predicted future soil erosion risk (t/ha/year) with current ground cover

1990_2009: 0.69 t/ha/year
2020_2039: 0.73 t/ha/year
2060_2079: 0.82 t/ha/year

Erosion change	2020_39	2060_79
Without cover	7%	22%
With cover	6%	19%



Far future change in hillslope erosion (t/ha/season) < 0.1 | 0.1 - 0.5 | 0.5 - 1.0 | 1.0 - 2.0 | > 2.0

Mean annual hillslope erosion values ($t.ha^{-1}.year^{-1}$) and their changes across NSW in the future

State planning region	Baseline	Near future	Far future	Near future change		Far future change	
	(t/ha/year)	(t/ha/year)	(t/ha/year)	(t/ha/year)	(%)	(t/ha/year)	(%)
Far West	0.1116	0.1238	0.1441	0.0122	10.92	0.0325	29.10
Murray Murrumbidgee	0.1725	0.1749	0.1960	0.0024	1.40	0.0235	13.63
South East and Tablelands	1.0519	1.0627	1.2041	0.0107	1.02	0.1522	14.46
Illawarra	2.2276	2.3080	2.4894	0.0804	3.61	0.2618	11.75
Central West and Orana	0.4662	0.4877	0.5593	0.0215	4.62	0.0931	19.97
New England and North West	0.9082	0.9475	1.0663	0.0393	4.32	0.1581	17.41
North Coast	4.0393	4.2359	4.6319	0.1966	4.87	0.5926	14.67
Hunter	3.7431	4.1678	4.5011	0.4247	11.35	0.7581	20.25
Central Coast	4.4057	5.0379	5.2851	0.6323	14.35	0.8794	19.96
Metropolitan Sydney	3.0596	3.3887	3.7087	0.3290	10.75	0.6491	21.21
New South Wales	**2.0186**	**2.1935**	**2.3786**	**0.1749**	**6.7**	**0.3600**	**18.2**
ACT	**2.2684**	**2.2225**	**2.4562**	**-0.0459**	**-2.03**	**0.1877**	**8.28**

Summary

- Extreme precipitation is projected to increase particularly in summer & autumn (though not significant compared to current inter-annual variability)
- Rainfall erosivity and hillslope erosion are projected to increase by about 7-19% by 2070
- The change is highly uneven in space and time; the high erosion risk areas are predicted to be the Central Coast, North Coast and Hunter regions, particularly in summer time.

Caveats

This work focused on daily precipitation rates

- Need to incorporate sub-daily precipitation rates
- Need to know how much confidence can be assigned to changes at these time scales….

Thank you for your attention

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