CLIMATE CHANGE IMPACTS ON RAINFALL INTENSITY

Dr Tom Remenyi

Climate Science Translator,
Director, Acclimatised

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WHAT WE’LL COVER

Climate change scenarios

- The change of language: SRES vs RCP vs SSP-RCP

The most likely path forward

- What is the most likely scenario

Certainty & uncertainty

- What do we know about rainfall changes
- What don’t we know about rainfall changes

The history of projected rainfall in Tasmania

- Climate Futures for Tasmania (CMIP3), 2010
- ARR interim guidance (2018)
- ARR Guidance (2024)
- ARR tools

Key gaps in ARR (2024)

CLIMATE CHANGE SCENARIOS

HOW THE LANGUAGE HAS CHANGED

HOW DO CMIP6 SCENARIOS COMPARE TO CMIP5 (AND CMIP3)

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CLIMATE CHANGE SCENARIOS

What are climate change scenarios?

Climate change scenarios aim to:

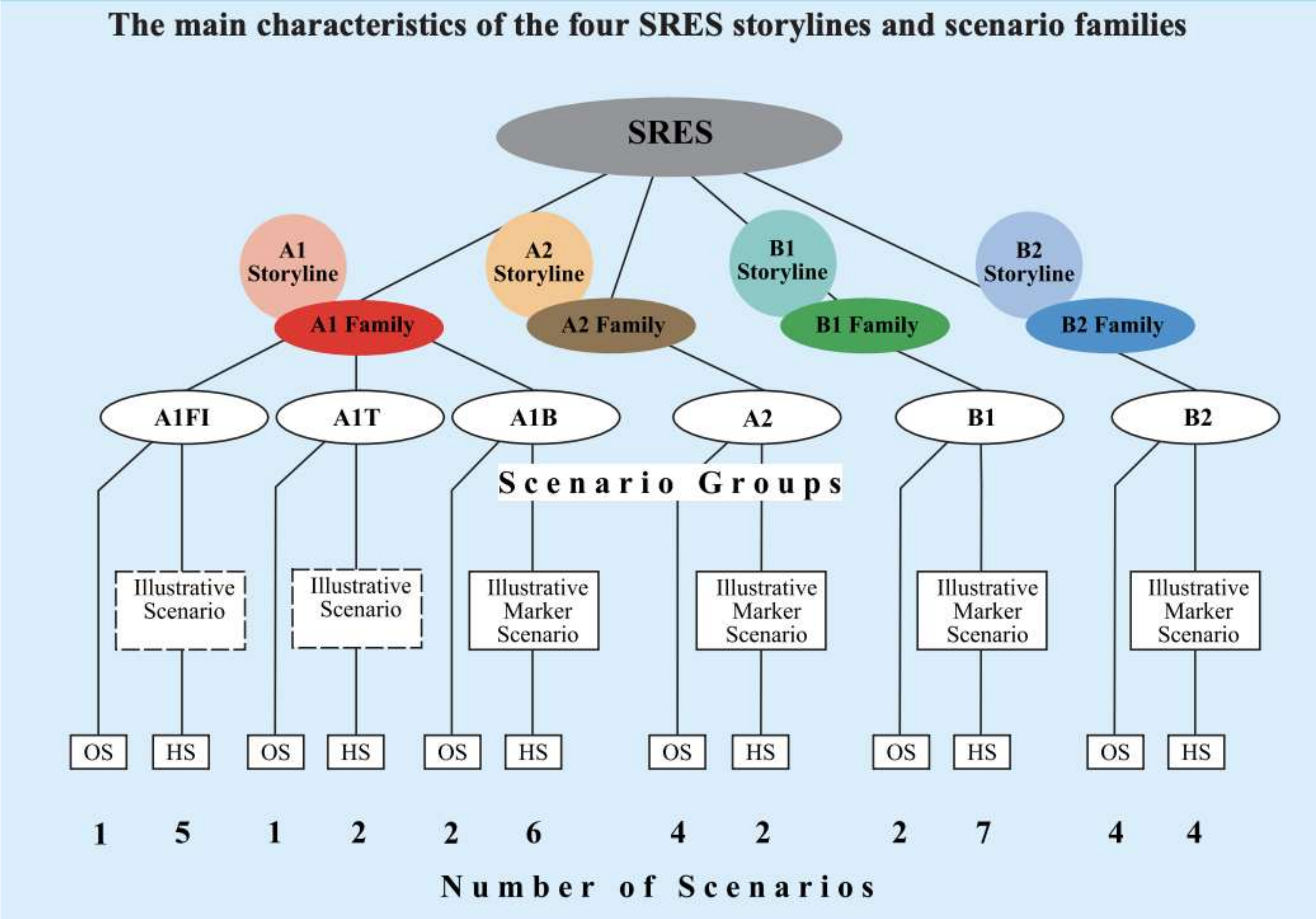
(i) capture the uncertainty related to the range of plausible future environmental and societal pathways and their induced GHG emissions; and

(ii) demonstrate how the Earth system will respond to these GHG-induced radiative forcings

van Vuuren, D.P., Carter, T.R. Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. Climatic Change 122, 415–429 (2014). https://doi.org/10.1007/s10584-013-0974-2

CLIMATE CHANGE SCENARIOS

CMIP3 scenarios (1990-2005)



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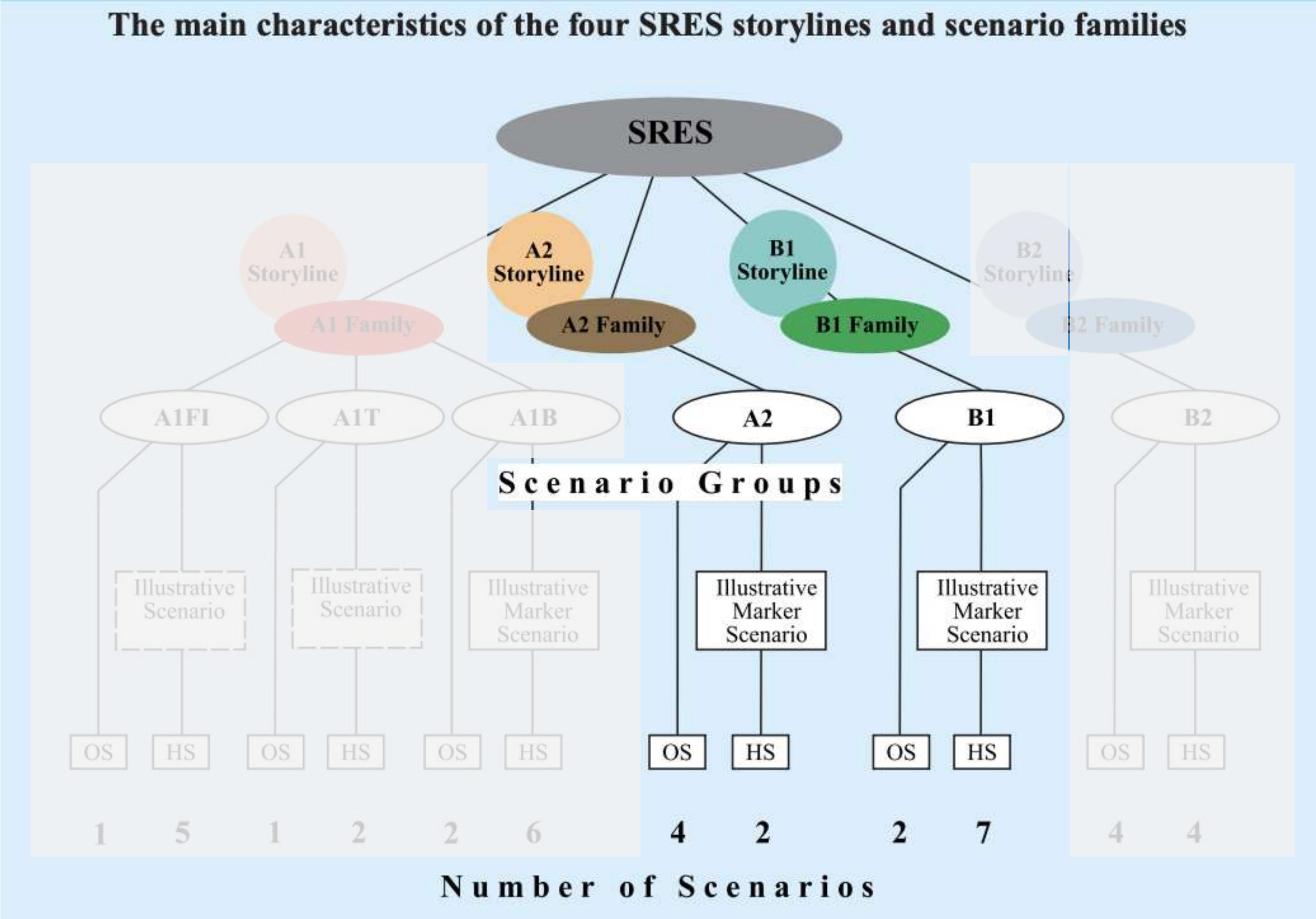
CLIMATE CHANGE SCENARIOS

CMIP3 scenarios
used by the Climate Futures for Tasmanian project (2010)



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CLIMATE CHANGE SCENARIOS

CMIP5 scenarios (2006-2017)

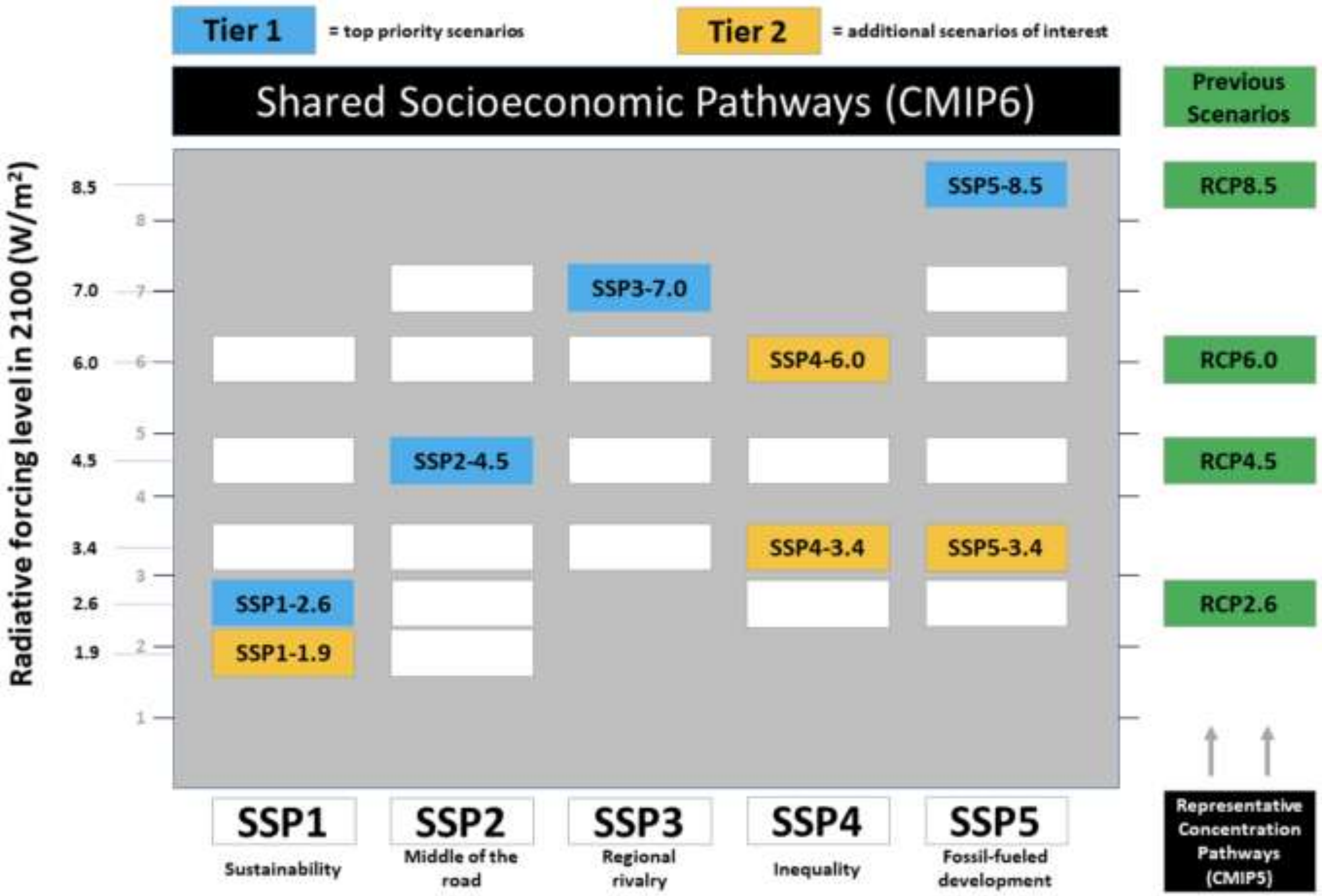
RCP 1.9	Additional heat capturing capacity of the atmosphere of 1.9 W/m squared. Limits global warming to <1.5°C.
RCP 2.6	Additional heat capturing capacity of the atmosphere of 2.6 W/m squared. Limits global warming to <2.0°C.
RCP 3.4	Additional heat capturing capacity of the atmosphere of 3.4 W/m squared. Limits global warming to <2.5°C.
RCP 4.5	Additional heat capturing capacity of the atmosphere of 4.5 W/m squared. Limits global warming to <3.0°C.
RCP 6.0	Additional heat capturing capacity of the atmosphere of 6.0 W/m squared. Limits global warming to <4.0°C.
RCP 7.0	Additional heat capturing capacity of the atmosphere of 7.0 W/m squared. No limit to global warming, expected to be <5.0°C.
RCP 8.5	Additional heat capturing capacity of the atmosphere of 8.5 W/m squared. Actively trying to warm planet. Global warming expected to be <6.0°C.

CMIP5 scenarios (2006-2017)

SSP1	Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)
SSP2	Middle of the Road (Medium challenges to mitigation and adaptation)
SSP3	Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation)
SSP4	Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation)
SSP5	Fossil-fuelled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)

CLIMATE CHANGE SCENARIOS

CMIP6 scenarios (2018-present)



Government of Canada website: https://climate-scenarios.canada.ca/?page=cmip6-overview-notes

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WHAT IS THE MOST LIKELY FUTURE SCENARIO?

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Which scenarios are most likely?

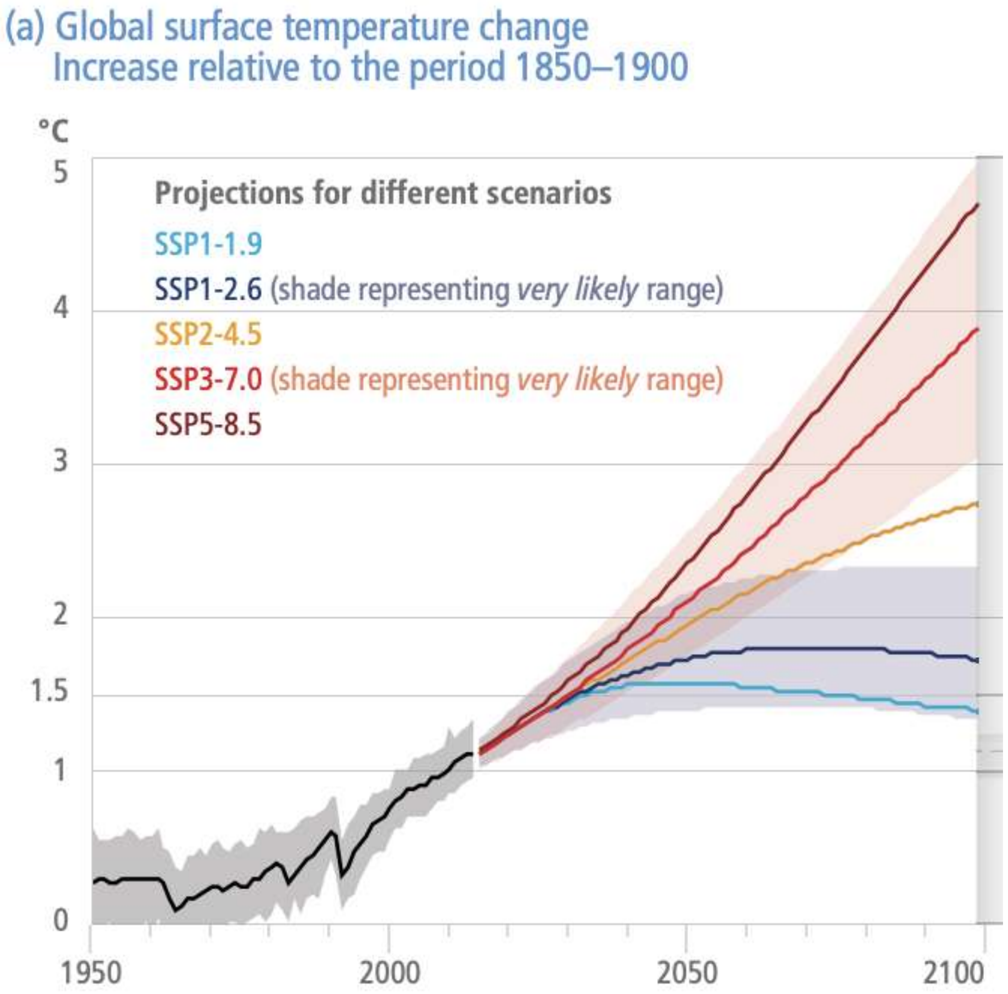
"The global warming projected by all CMIPs and future climate scenarios project a global warming slightly lower than the observed one."

*"The observed warming is closer to the upper level of the projected ones, revealing that CMIPs future climate scenarios with **higher GHG emissions appear to be the most realistic ones**."*

Carvalho, D., Rafael, S., Monteiro, A. et al. How well have CMIP3, CMIP5 and CMIP6 future climate projections portrayed the recently observed warming. Sci Rep 12, 11983 (2022). https://doi.org/10.1038/s41598-022-16264-6

CLIMATE CHANGE SCENARIOS

Which scenarios are most likely?



+3.5°C Highly likely

+2.7°C Hopefully likely

+2.0°C Unavoidable

IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001.

CERTAINTY & UNCERTAINTY

WHAT DO WE KNOW ABOUT RAINFALL CHANGES

WHAT DON'T WE KNOW ABOUT RAINFALL CHANGES

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Rainfall patterns are changing due to climate change

- The Sub-Tropical Ridge (STR) is spending more time further south. This:
  - decreases Westerly Frontal Systems, and
  - increases East Coast Lows
  - Sea Surface Temperature (SST) is increasing, providing more energy to coastal rain-bearing systems
  - Warming atmosphere carries more water, so when it rains, it rains heavier.

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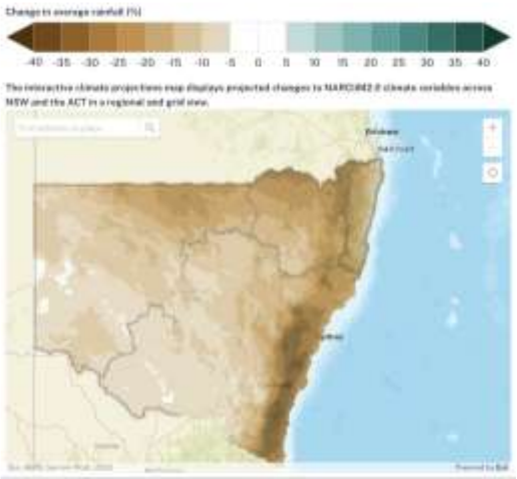
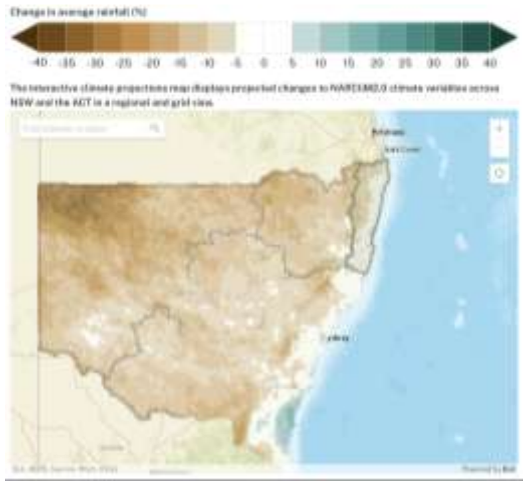
Rainfall patterns are changing due to climate change

Winter



Autumn



Summer

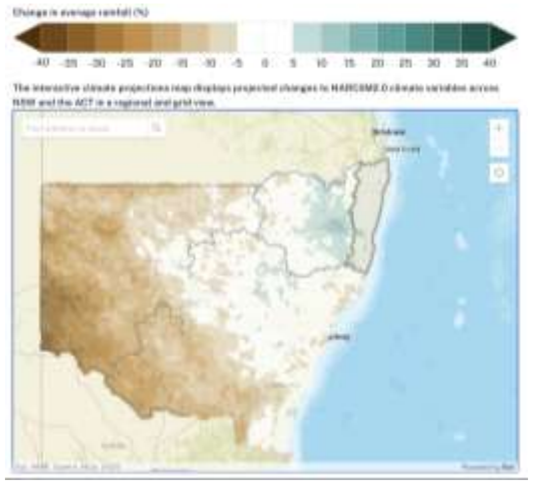
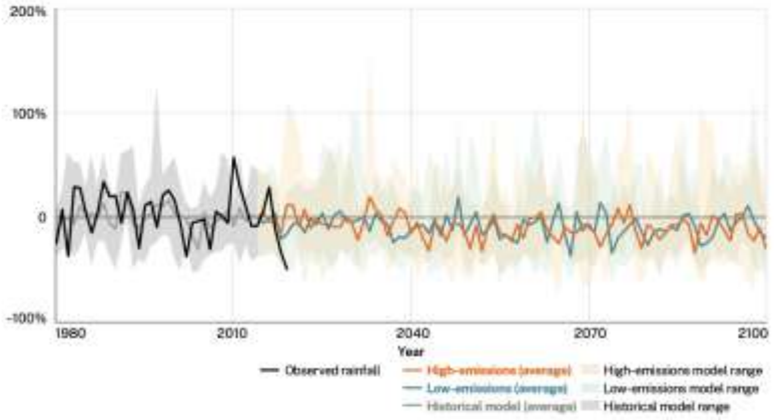


Figure 10. Historical and projected change to average rainfall – NSW



AdaptNSW - NARCLIM2.0 outputs soruced from: https://www.climatechange.environment.nsw.gov.au/projections-map

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What are we certain about with future rainfall intensity?

- Daily rainfall increases with temperature at a rate of approximately *7% per °C* according to the Clausius-Clapeyron water-holding capacity relationship between temperature and vapour pressure

- Rainfall intensity is projected to increase.
- Rainfall intensity is increasing

- Subhourly rainfall intensity is increasing more than Clausius-Clapeyron

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What studies have been done?

- The Climate Futures for Tasmania found some *rainfall intensities increasing by >50% by 2100* [CMIP3]
- *3-hourly rainfall intensity increased by 15% per °C* according to Mantegna et al. (2017) [CMIP3]
- Recent rainfall observations and flash-flooding impacts align with these levels of change.

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What studies have been done?

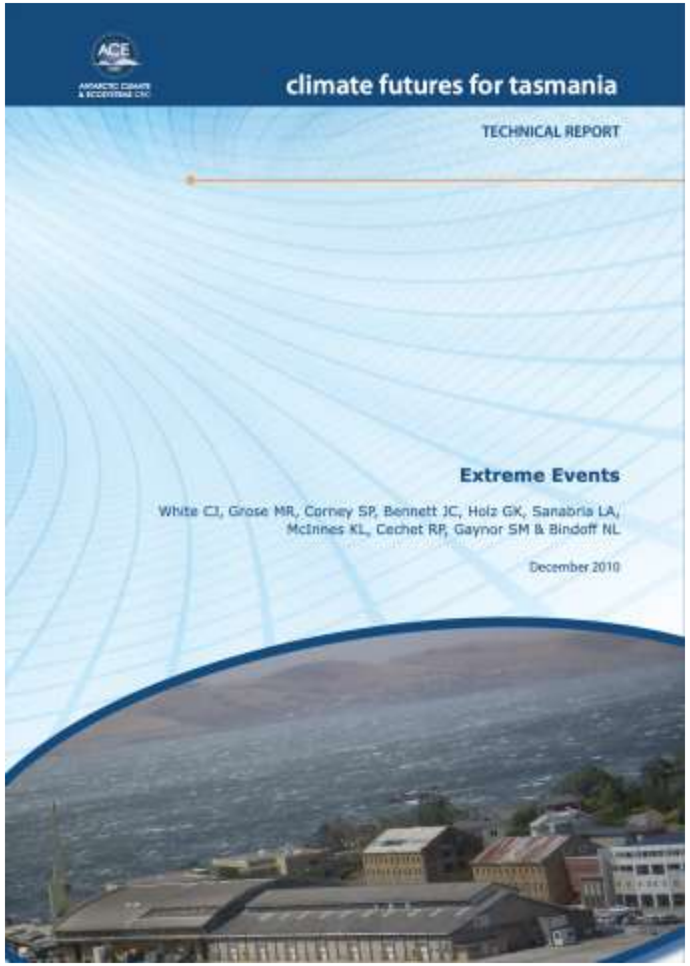

Table 7.3 Magnitudes of 24-hour duration ARI-200 (years) for 1961-1990 estimated from AWAP gridded observations (5th/95th CIs in brackets), with projected multi-GCM ensemble change for 2010-2039, 2040-2069 and 2070-2099, at eight representative locations across Tasmania. ARIs estimated using a generalized Pareto distribution. Multi-GCM ensemble ARIs estimated using the six downscaled-GCMs for the A2 emissions scenario. ARIs are expressed in mm. Delta ARI-200 values are expressed in millimetres and as a percentage change (in square brackets []), relative to the AWAP 1961-1990 baseline. Location of sites is shown in Appendix A

	ARI–200 (mm)	Delta ARI–200 (mm)		
Location	AWAP (1961–1990)	Multi–GCM ensemble (2010–2039)	Multi–GCM ensemble (2040–2069)	Multi–GCM ensemble (2070–2099)
Hobart	100 (76/128)	31 [31%]	40 [40%]	30 [30%]
Swansea	122 (91/162)	16 [13%]	14 [11%]	112 [92%]
St Helens	145 (107/210)	10 [7%]	40 [27%]	68 [47%]
Launceston	66 (51/85)	3 [4%]	34 [51%]	34 [52%]
Devonport	97 (76/131)	4 [4%]	23 [24%]	36 [37%]
Strahan	68 (65/73)	6 [9%]	8 [12%]	18 [26%]
Strathgordon	97 (93/105)	21 [21%]	30 [31%]	36 [37%]
Miena/Liawenee	98 (78/134)	50 [51%]	30 [30%]	5 [5%]

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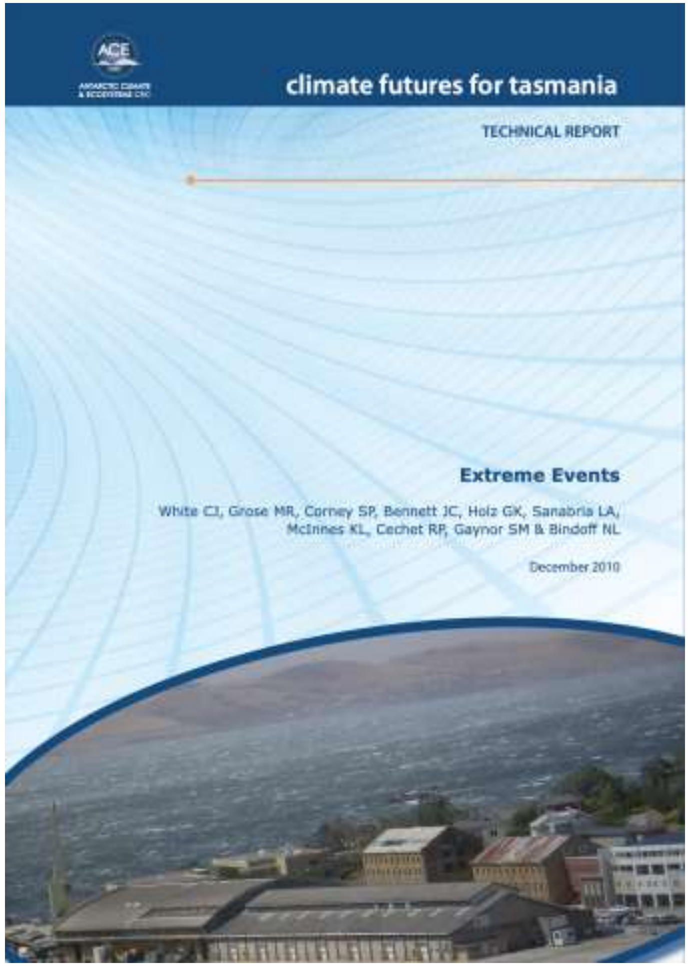
What studies have been done?



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What studies have been done?

Journal of Hydrology 554 (2017) 277–291

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Simulating sub-daily Intensity-Frequency-Duration curves in Australia using a dynamical high-resolution regional climate model

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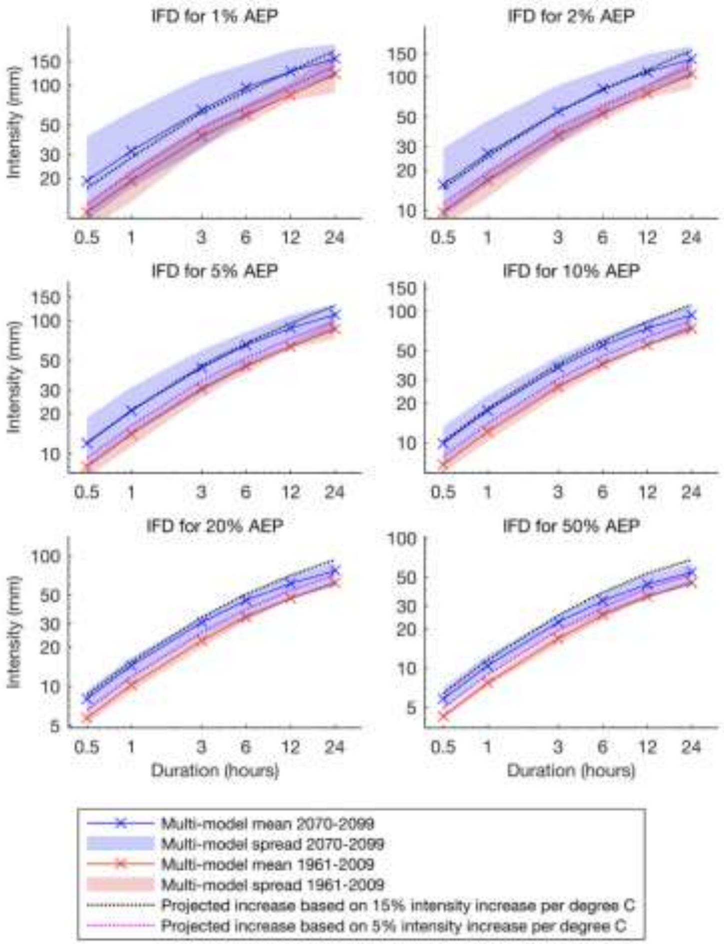
ARTICLE INFO

Article history:
Received 3 April 2017
Received in revised form 6 August 2017
Accepted 13 September 2017
Available online 18 September 2017
This manuscript was handled by K. Georgakakos, Editor-in-Chief, with the assistance of Jianzhong Wang, Associate Editors

Keywords:
Sub-daily rainfall
Extremes
Intensity-Frequency-Duration
Depth-Duration-Frequency
Flood
RCM

ABSTRACT

Climate change has the potential to significantly alter the characteristics of high-intensity, short-duration rainfall events, potentially leading to more severe and more frequent flash floods. Research has shown that future changes to such events could far exceed expectations based on temperature scaling and basic physical principles alone, but that computationally expensive convection-permitting models are required to accurately simulate sub-daily extreme rainfall events. It is therefore crucial to be able to model future changes to sub-daily duration extreme rainfall events as cost effectively as possible, especially in Australia where such information is scarce. In this study, we seek to determine what the shortest duration of extreme rainfall is that can be simulated by a less computationally expensive convection-parametrizing Regional Climate Model (RCM). We examine the ability of the Conformal Cubic Atmospheric Model (CCAM), a ~10 km high-resolution convection-parametrizing RCM, to reproduce sub-daily Intensity-Frequency-Duration (IFD) curves corresponding to two long-term observational stations in the Australian island state of Tasmania, and examine the future model projections. We find that CCAM simulates observed extreme rainfall statistics well for 3-h durations and longer, challenging the current understanding that convection-permitting models are needed to accurately model sub-daily extreme rainfall events. Further, future projections from CCAM for the end of this Century show that extreme sub-daily rainfall intensities could increase by more than 15% per °C, far exceeding the 7% scaling estimate predicted by the Clausius-Clapeyron vapour pressure relationship and the 5% scaling estimate recommended by the Australian Rainfall and Runoff guide.



Gabriel A. Mantegna, Christopher J. White, Tomas A. Remenyi, Stuart P. Corney, Paul Fox-Hughes, *Simulating sub-daily Intensity-Frequency-Duration curves in Australia using a dynamical high-resolution regional climate model,* Journal of Hydrology, Volume 554, 2017, Pages 277-291, ISSN 0022-1694, https://doi.org/10.1016/j.jhydrol.2017.09.025.

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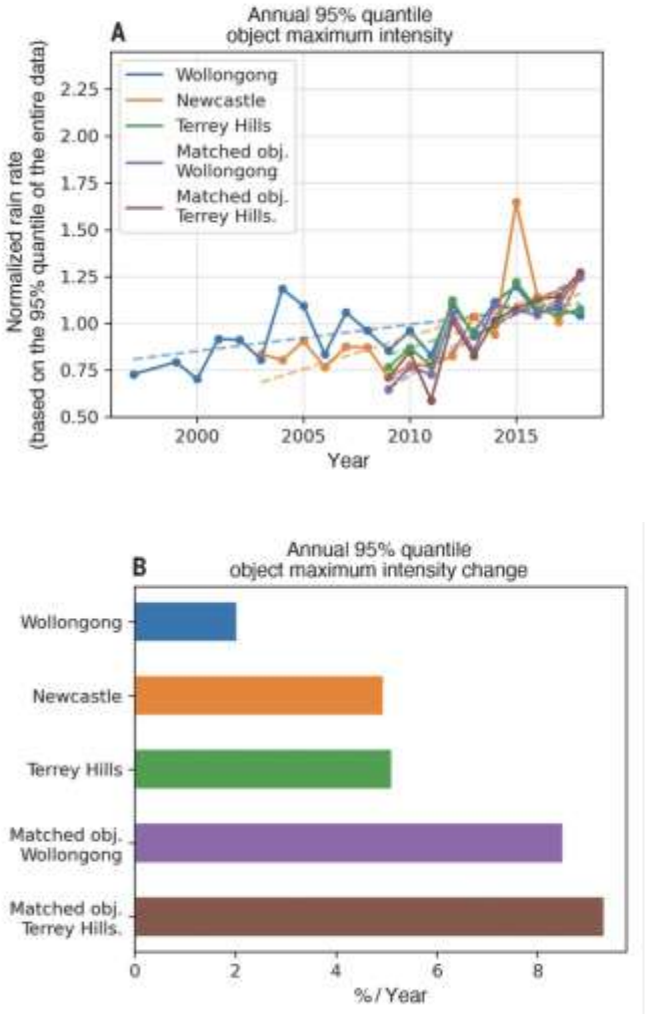
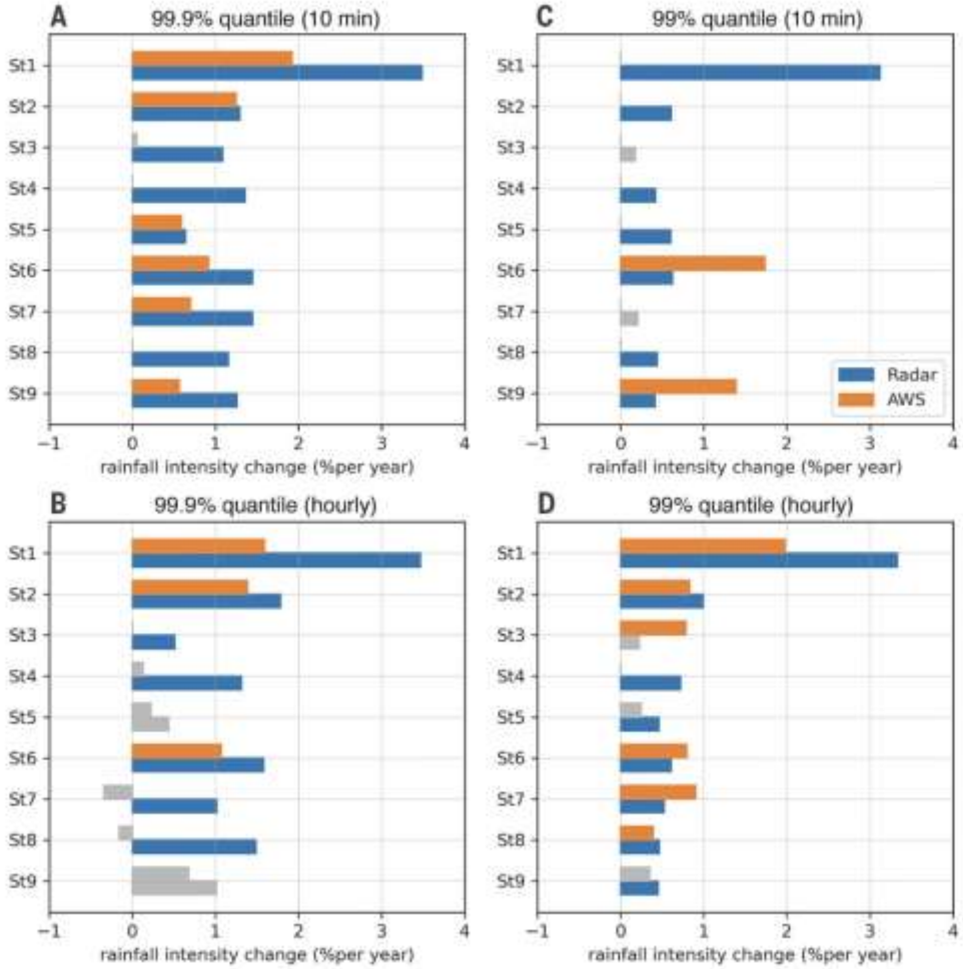
Rainfall patterns are changing due to climate change





Hooman Ayat Jason P. Evans, Steven C. Sherwood, and Joshua Soderholm, Intensification of subhourly heavy rainfall. Science, 378, 655-659 (2022). DOI:10.1126/science.abn8657

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What is the official guidance from the BoM?

- Australian Rainfall and Runoff 2019 – interim guidance
  - *Increase rainfall intensity by 5% per °C*
- **Australian Rainfall and Runoff 2024**
  - *“Because our climate is changing, unadjusted historical observations are no longer a suitable basis for design flood estimation: they must be adjusted to reflect the impacts of rising global temperatures.”*
  - The evidence is quite strong that short-duration rainfalls intensify more than longer duration rainfall
  - For every degree of warming, the new guidance estimates:
    - *1-hour rainfall events will increase 15% per °C*
    - *24-hour rainfall events will increase by 8% per °C*

Climate Systems
National Environmental Science Program
ENGINEERS AUSTRALIA
Australian Government
Department of Climate Change, Energy, the Environment and Water

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$$I_p = I \times \left(1 + \frac{\alpha}{100}\right)^{\Delta T}$$

where

- I_p the projected (current or future) design rainfall depth or intensity
- α is the rate of change from Table 1.6.1
- I is the historical design rainfall depth or intensity (e.g. from the 2016 IFD portal or historical PMP estimates)
- ΔT is the most up-to-date estimate of global (land and ocean) temperature projection for the design period of interest and selected climate scenario relative to a baseline time period. When used in conjunction with the 2016 IFD curves the baseline is recommended to be the 1961-1990 period (see Table 1.6.2 and text below).

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Table 1.6.1. Recommended rates of change (α) and associated uncertainty derived in Wasko et al. (2024), presented per degree global temperature change (%/°C). The factors in this table are applicable for exceedance probabilities from 1EY up to and including the PMP and are designed for application across mainland Australia and Tasmania.

	≤ 1 hr	> 1 hr and < 24 hr	≥ 24 hr
Central (median) estimate (%/°C)	15	Interpolation zone (see Table 1.6.5)	8
'Likely' range (corresponding to ~66%[a] range) (%/°C)	7-28		2-15

[a]Consistent with terminology used by the IPCC the 66% range corresponds to an uncertainty range of +/- 33%.

Table 1.6.2. Global mean surface temperature projections (ΔT) for four socio-economic pathways relative to 1961-1990. The 90% uncertainty interval is provided in parentheses[a]

Climate Scenario	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Current and near-term (2021-2040) (°C)	1.2 (0.9-1.5)	1.2 (0.9-1.5)	1.2 (0.9-1.5)	1.3 (1.0-1.6)
Medium-term (2041-2060) (°C)	1.4 (1.0-1.9)	1.7 (1.3-2.2)	1.8 (1.4-2.3)	2.1 (1.6-2.7)
Long-term (2081-2100) (°C)	1.5 (1.0-2.1)	2.4 (1.8-3.2)	3.3 (2.5-4.3)	4.1 (3.0-5.4)

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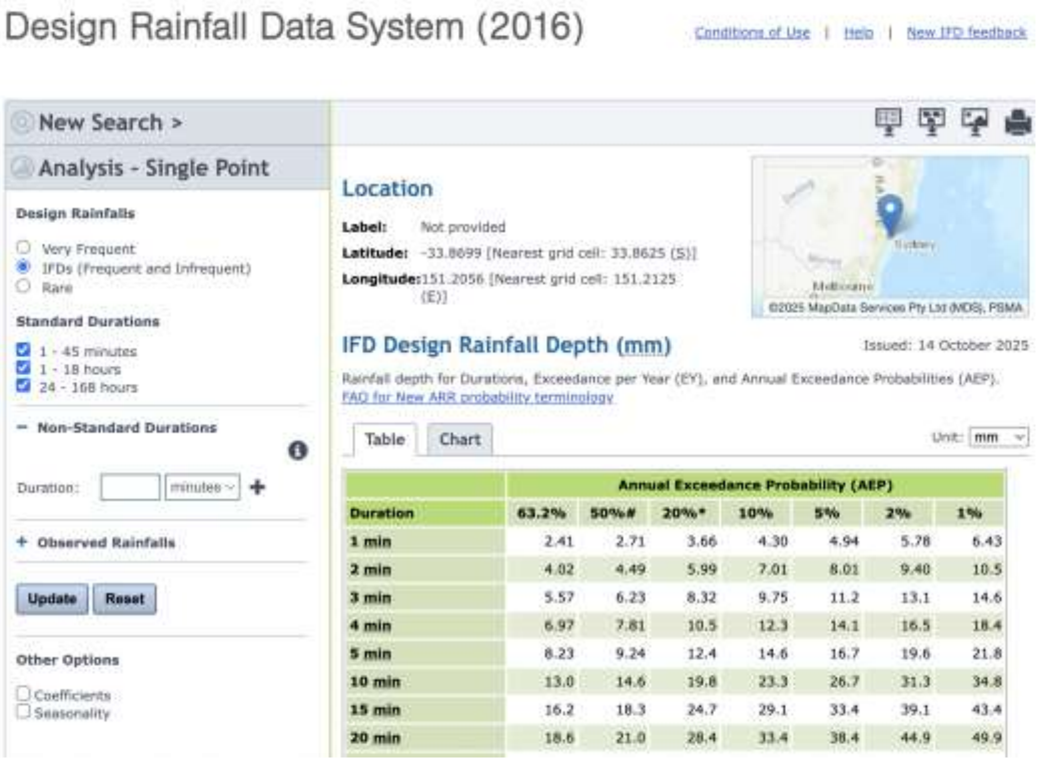

Design Rainfall Data System (2016)

Conditions of Use | Help | New IFD feedback

New Search >

Analysis - Single Point

Design Rainfalls

- Very Frequent
- IFDs (Frequent and Infrequent)
- Rare

Standard Durations

- 1 - 45 minutes
- 1 - 18 hours
- 24 - 168 hours

Non-Standard Durations

Duration: minutes

Observed Rainfalls

Update Reset

Other Options

- Coefficients
- Seasonality

Location

Label: Not provided
Latitude: -33.8699 [Nearest grid cell: 33.8625 (S)]
Longitude: 151.2056 [Nearest grid cell: 151.2125 (E)]

©2025 MapData Services Pty Ltd (MDS), PSMA

IFD Design Rainfall Depth (mm)

Issued: 14 October 2025

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table Chart Unit: mm

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	2.41	2.71	3.66	4.30	4.94	5.78	6.43
2 min	4.02	4.49	5.99	7.01	8.01	9.40	10.5
3 min	5.57	6.23	8.32	9.75	11.2	13.1	14.6
4 min	6.97	7.81	10.5	12.3	14.1	16.5	18.4
5 min	8.23	9.24	12.4	14.6	16.7	19.6	21.8
10 min	13.0	14.6	19.8	23.3	26.7	31.3	34.8
15 min	16.2	18.3	24.7	29.1	33.4	39.1	43.4
20 min	18.6	21.0	28.4	33.4	38.4	44.9	49.9

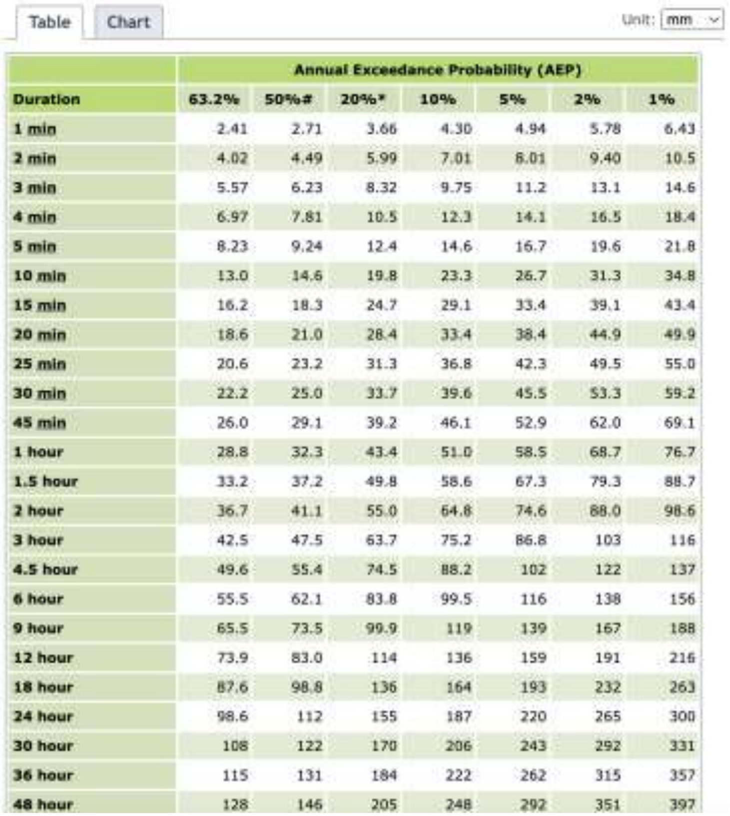

Table Chart Unit: mm

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1 min	2.41	2.71	3.66	4.30	4.94	5.78	6.43
2 min	4.02	4.49	5.99	7.01	8.01	9.40	10.5
3 min	5.57	6.23	8.32	9.75	11.2	13.1	14.6
4 min	6.97	7.81	10.5	12.3	14.1	16.5	18.4
5 min	8.23	9.24	12.4	14.6	16.7	19.6	21.8
10 min	13.0	14.6	19.8	23.3	26.7	31.3	34.8
15 min	16.2	18.3	24.7	29.1	33.4	39.1	43.4
20 min	18.6	21.0	28.4	33.4	38.4	44.9	49.9
25 min	20.6	23.2	31.3	36.8	42.3	49.5	55.0
30 min	22.2	25.0	33.7	39.6	45.5	53.3	59.2
45 min	26.0	29.1	39.2	46.1	52.9	62.0	69.1
1 hour	28.8	32.3	43.4	51.0	58.5	68.7	76.7
1.5 hour	33.2	37.2	49.8	58.6	67.3	79.3	88.7
2 hour	36.7	41.1	55.0	64.8	74.6	88.0	98.6
3 hour	42.5	47.5	63.7	75.2	86.8	103	116
4.5 hour	49.6	55.4	74.5	88.2	102	122	137
6 hour	55.5	62.1	83.8	99.5	116	138	156
9 hour	65.5	73.5	99.9	119	139	167	188
12 hour	73.9	83.0	114	136	159	191	216
18 hour	87.6	98.8	136	164	193	232	263
24 hour	98.6	112	155	187	220	265	300
30 hour	108	122	170	206	243	292	331
36 hour	115	131	184	222	262	315	357
48 hour	128	146	205	248	292	351	397

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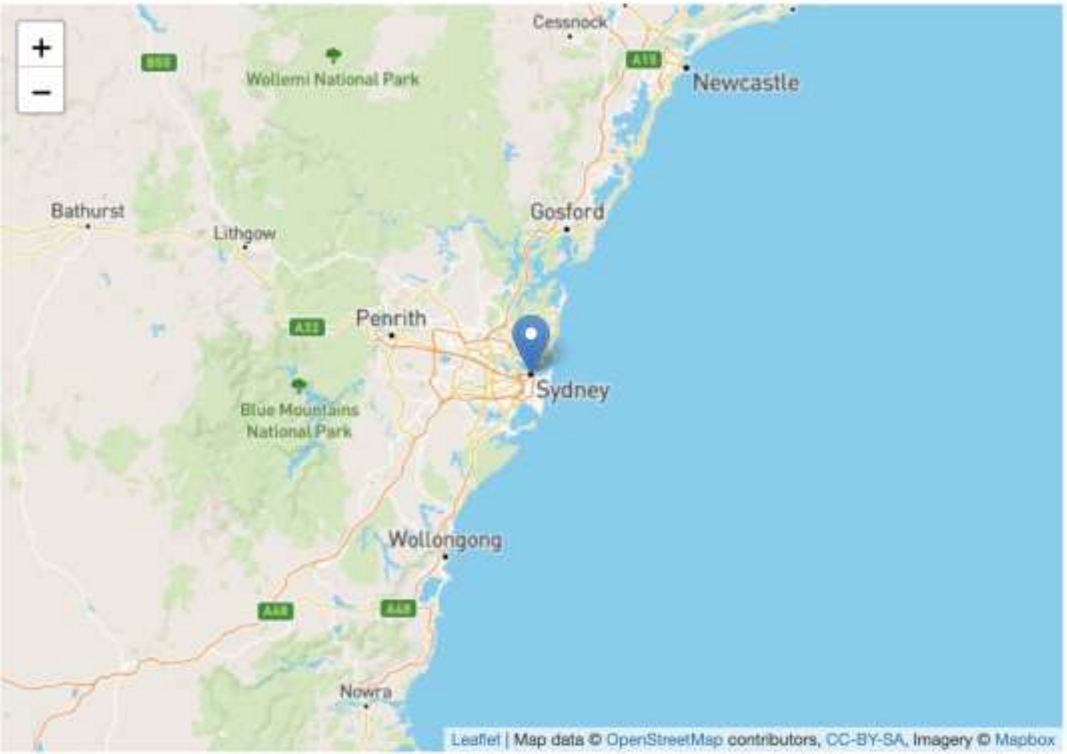
What is the official guidance from the BoM? ARR 2024

Home About Limitations Changelog Publications Jurisdiction Specifics ▾ Project reports ARR

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	151.206
Latitude	-33.87
Selected Regions (clear)	
BOM IFDs	show
Climate Change Factors	show
Probability Neutral Burst Initial Loss	show



Data

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Australian Rainfall & Runoff Data Hub - Results

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BOM IFDs

Click here to obtain the IFD depths for catchment centroid from the BoM website

Climate Change Factors

Rainfall Factors

SSP1-2.6

Data

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	1.22	1.2	1.18	1.17	1.15	1.15	1.14	1.13	1.12	1.11
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

Layer Info

Time Accessed	14 October 2025 01:05PM

Layer Info

Time Accessed	14 October 2025 01:05PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

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What is the official guidance from the BoM? ARR 2024

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	1.22	1.2	1.18	1.17	1.15	1.15	1.14	1.13	1.12	1.11
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.2	1.18	1.17	1.16	1.14	1.13	1.13	1.12	1.11	1.11
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	1.34	1.31	1.29	1.26	1.24	1.23	1.21	1.2	1.18	1.18
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	1.77	1.69	1.64	1.58	1.52	1.49	1.45	1.42	1.39	1.37
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

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What is the official guidance from the BoM? ARR 2024

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

CERTAINTY & UNCERTAINTY

What is the official guidance from the BoM? ARR 2024

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

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What is the official guidance from the BoM? ARR 2024

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

2050
1hour 1%AEP = 76mm
SSP2-4.5 (x1.27) = 97mm
SSP3-7.0 (x1.29) = 98mm

2050
48hour 1%AEP = 397mm
SSP2-4.5 (x1.14) = 452mm
SSP3-7.0 (x1.15) = 456mm

2100
1hour 1%AEP = 76mm
SSP2-4.5 (x1.41) = 107mm
SSP3-7.0 (x1.66) = 126mm

2100
48hour 1%AEP = 397mm
SSP2-4.5 (x1.21) = 480mm
SSP3-7.0 (x1.32) = 524mm

KEY GAPS

Key gaps in climate change guidance

- Regional scale modeling to improve climate change impact estimates
  - Higher-resolution modeling (sub-hourly and sub-1km) over important regions to improve flash-flooding estimates
    - Catchment scale?
    - City scale?
    - Which population centers across Australia?
- What kinds of collaborations?
  - Governance
    - What should the update cycles for ARR be?
    - Document risk-appetite vs financial-costs for your regions
      - What are rate-payers willing to buy!
  - Science
    - Which areas/event-types have the lowest confidence?
  - Guidance
    - Communities of practice that document useful climate change guidance and tools, how to use them, and what is working

THANK YOU

Dr Tom Remenyi | tom@acclimatised.com.au

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What is the official guidance from the BoM? ARR 2024

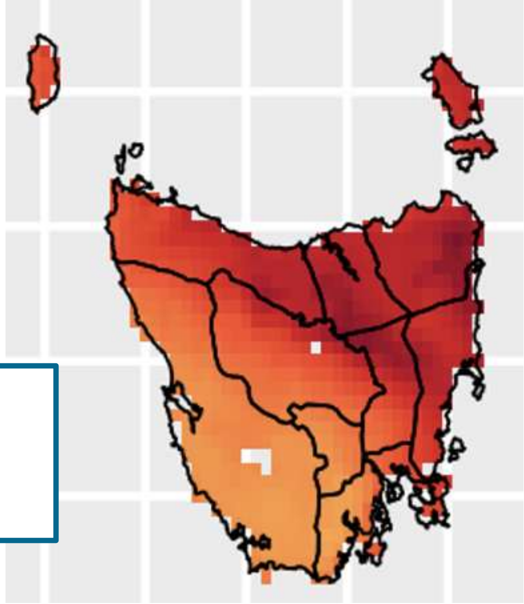
Table 1.6.1. Recommended rates of change (α) and associated uncertainty derived in Wasko et al. (2024), presented per degree global temperature change (%/°C). The factors in this table are applicable for exceedance probabilities from 1EY up to and including the PMP and are designed for application across mainland Australia and Tasmania.

	≤ 1 hr	> 1 hr and < 24 hr	≥ 24 hr
Central (median) estimate (%/°C)	15	Interpolation zone (see Table 1.6.5)	8
'Likely' range (corresponding to ~66%[a] range) (%/°C)	7-28		2-15

[a]Consistent with terminology used by the IPCC the 66% range corresponds to an uncertainty range of +/- 33%.

Table 1.6.2. Global mean surface temperature projections (ΔT) for four socio-economic pathways relative to 1961-1990. The 90% uncertainty interval is provided in parentheses[a]

Climate Scenario	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (°C)	[illegible]	[illegible]	[illegible]	[illegible]



- *Temperature change varies across the country.*
- *We have the data, we should use it.*

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ANNUAL RAINFALL CHANGES

WHAT DO WE KNOW ABOUT RAINFALL CHANGES

WHAT DON’T WE KNOW ABOUT RAINFALL CHANGES

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FUTURE CLIMATE CHANGE

RAINFALL

Figure 1: Observed mean Growing Season Rainfall

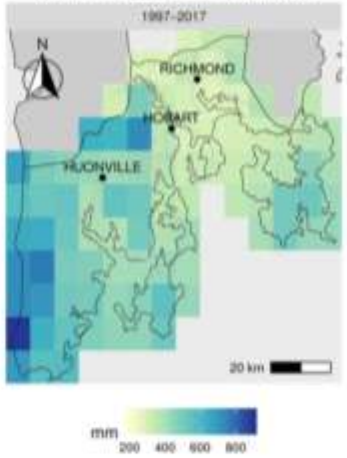


Figure 2: Observed change in mean Growing Season Rainfall

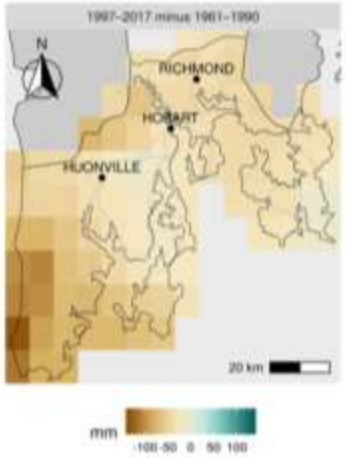


Figure 3: Projected mean Growing Season Rainfall

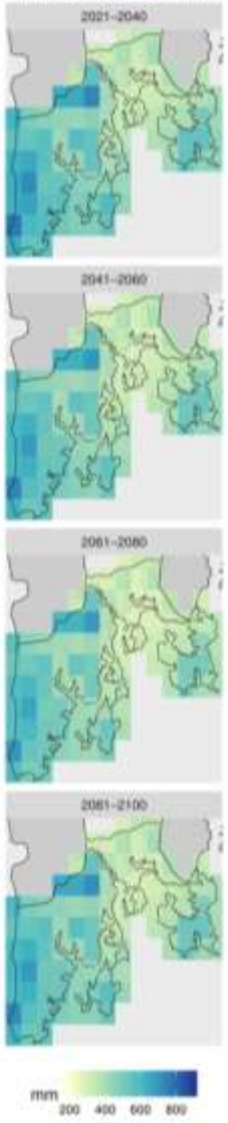


Figure 4: Projected Growing Season Rainfall (October to April)

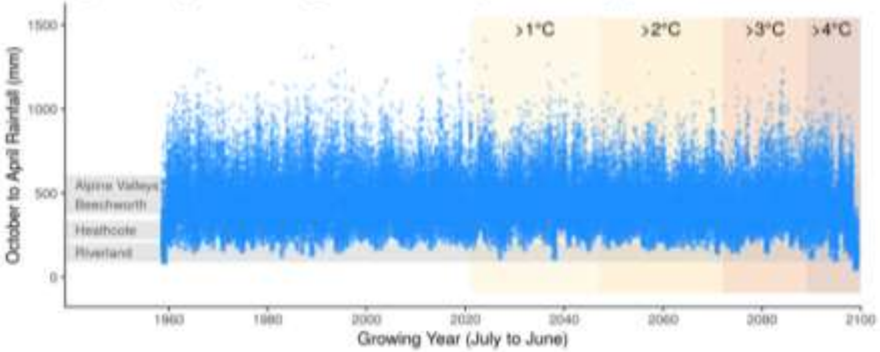
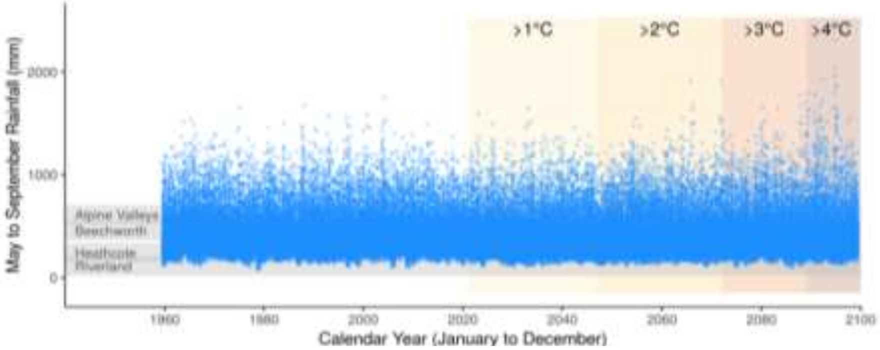


Figure 5: Projected Non-Growing Season Rainfall (May to September)



Warmer months

- A bit more rain
- In more intense storms

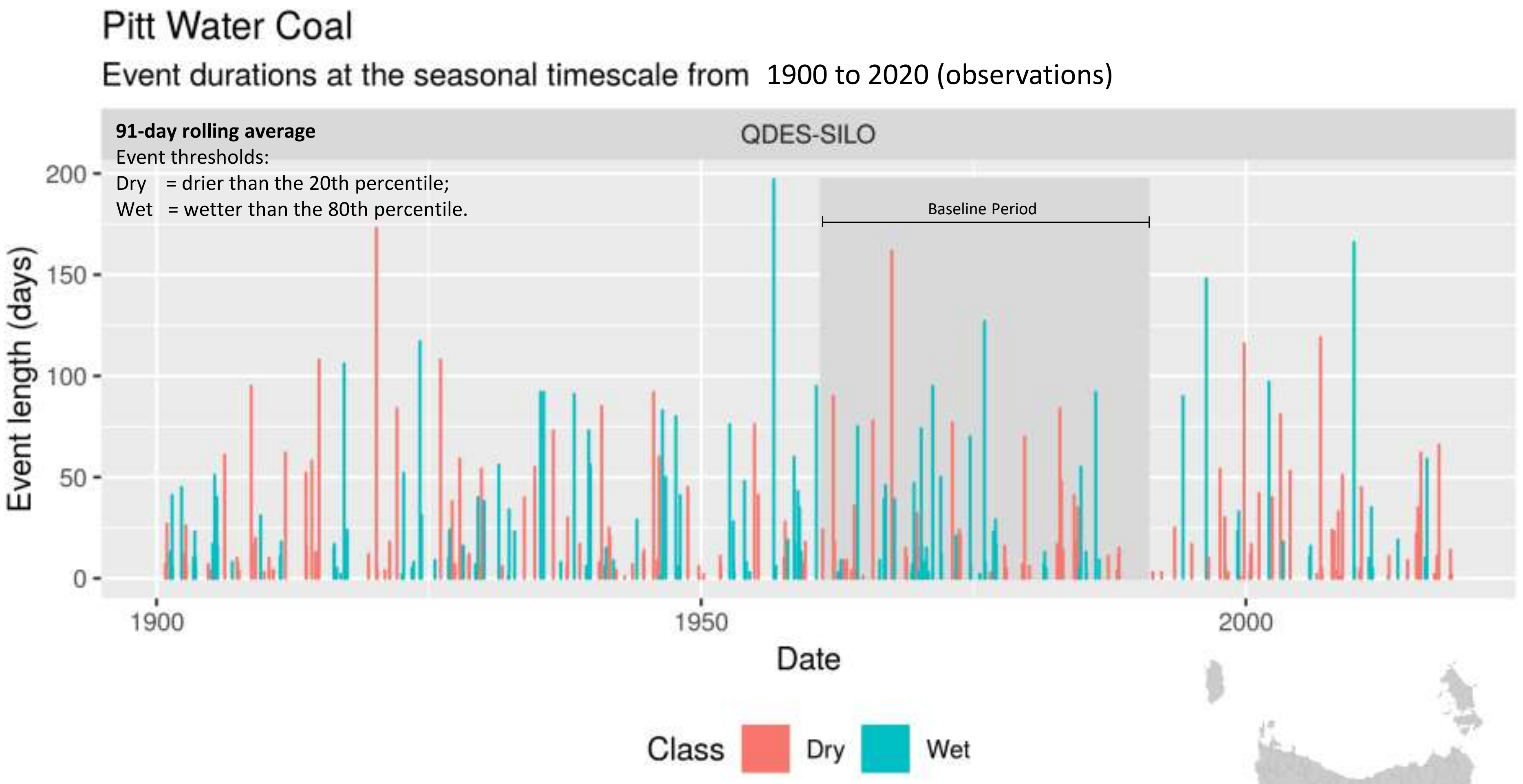
Cooler months

- Less rain
- Slightly drier

Annual rainfall is not expected to change much.

FUTURE CLIMATE CHANGE

DROUGHT



Before 1950 : More longer wet periods

After 1990 : More dry periods

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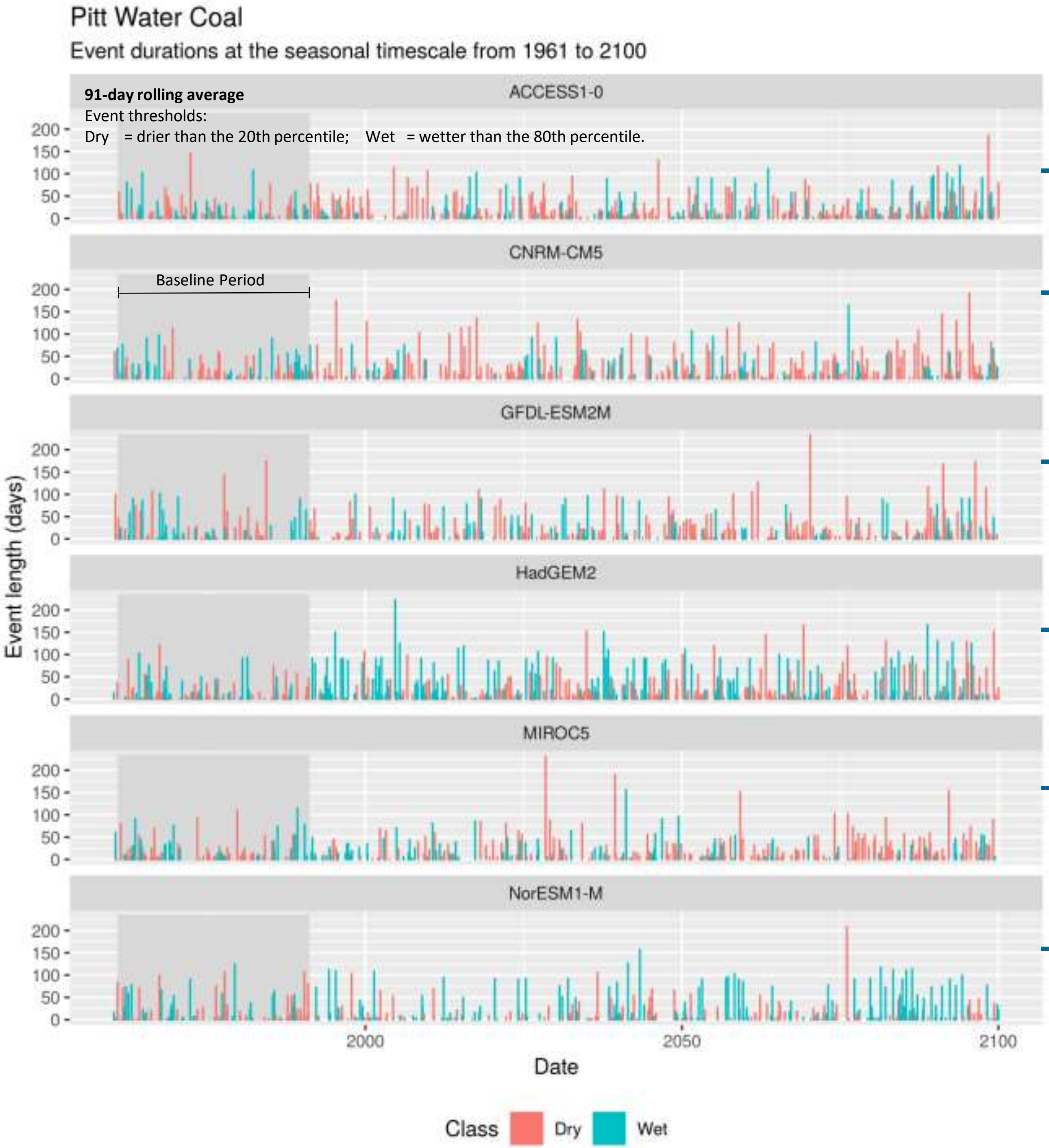
FUTURE CLIMATE CHANGE

DROUGHT



All 6 models show long dry periods will be common.

Indicates longer more intense droughts.

However, long wet periods will also be common.

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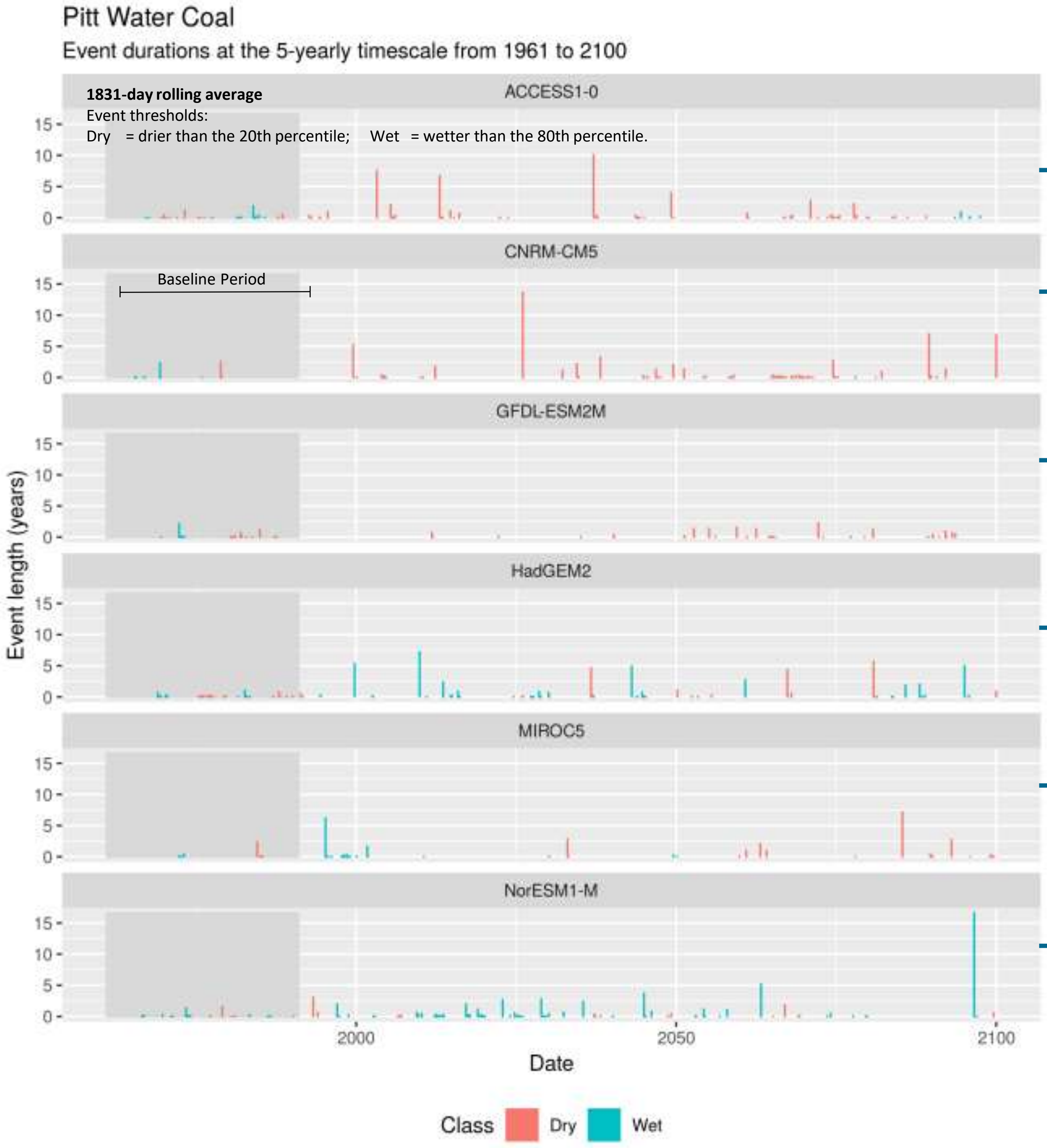
FUTURE CLIMATE CHANGE

DROUGHT



All 6 models show long dry periods will be common.

Indicates longer more intense droughts.

However, long wet periods will also be common.

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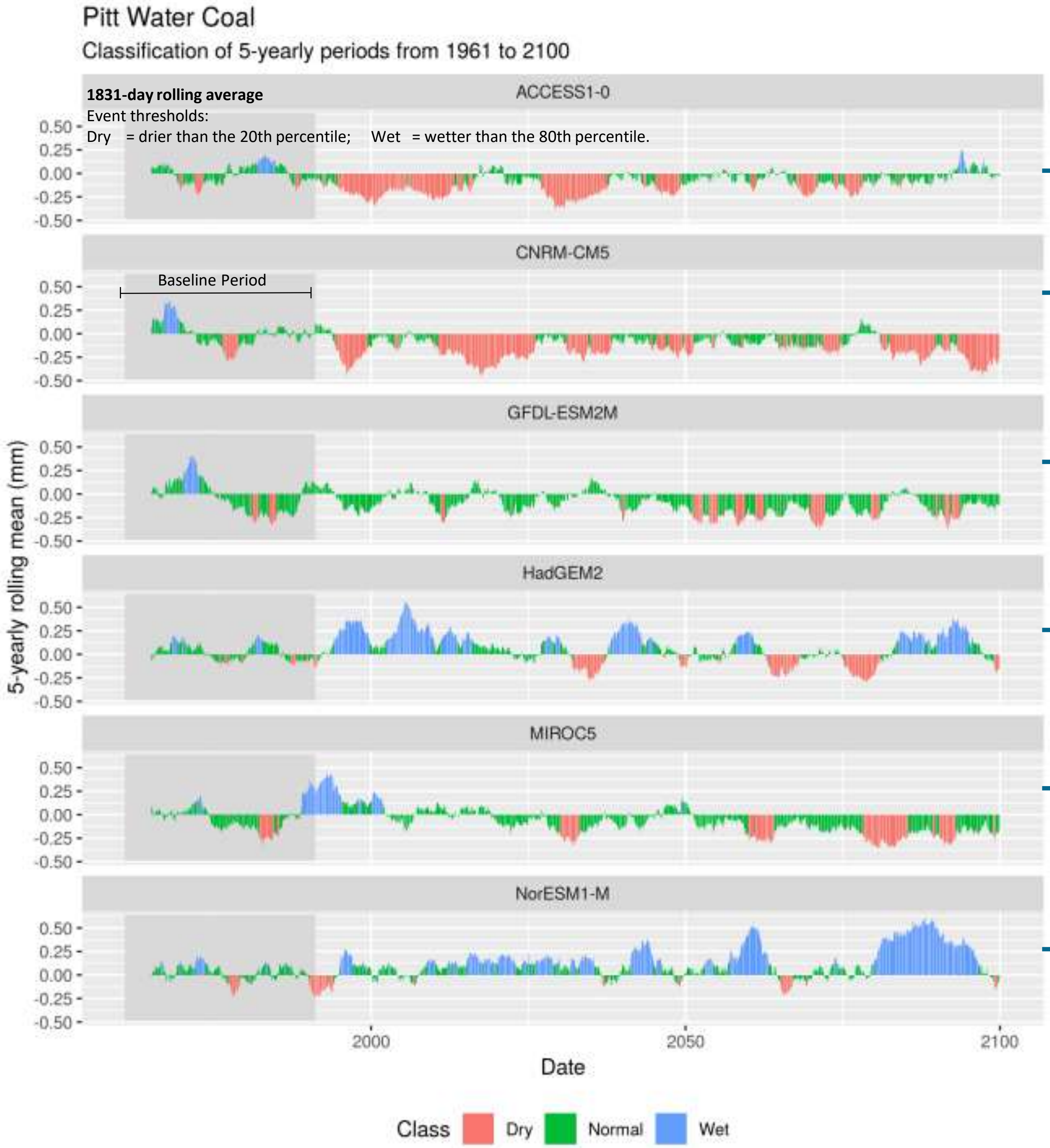
FUTURE CLIMATE CHANGE

DRY (DROUGHT)
VS
WET (FLOOD)



All 6 ensemble members show long dry periods will be common.

Indicates longer more intense droughts.

However, long wet periods will also be common.

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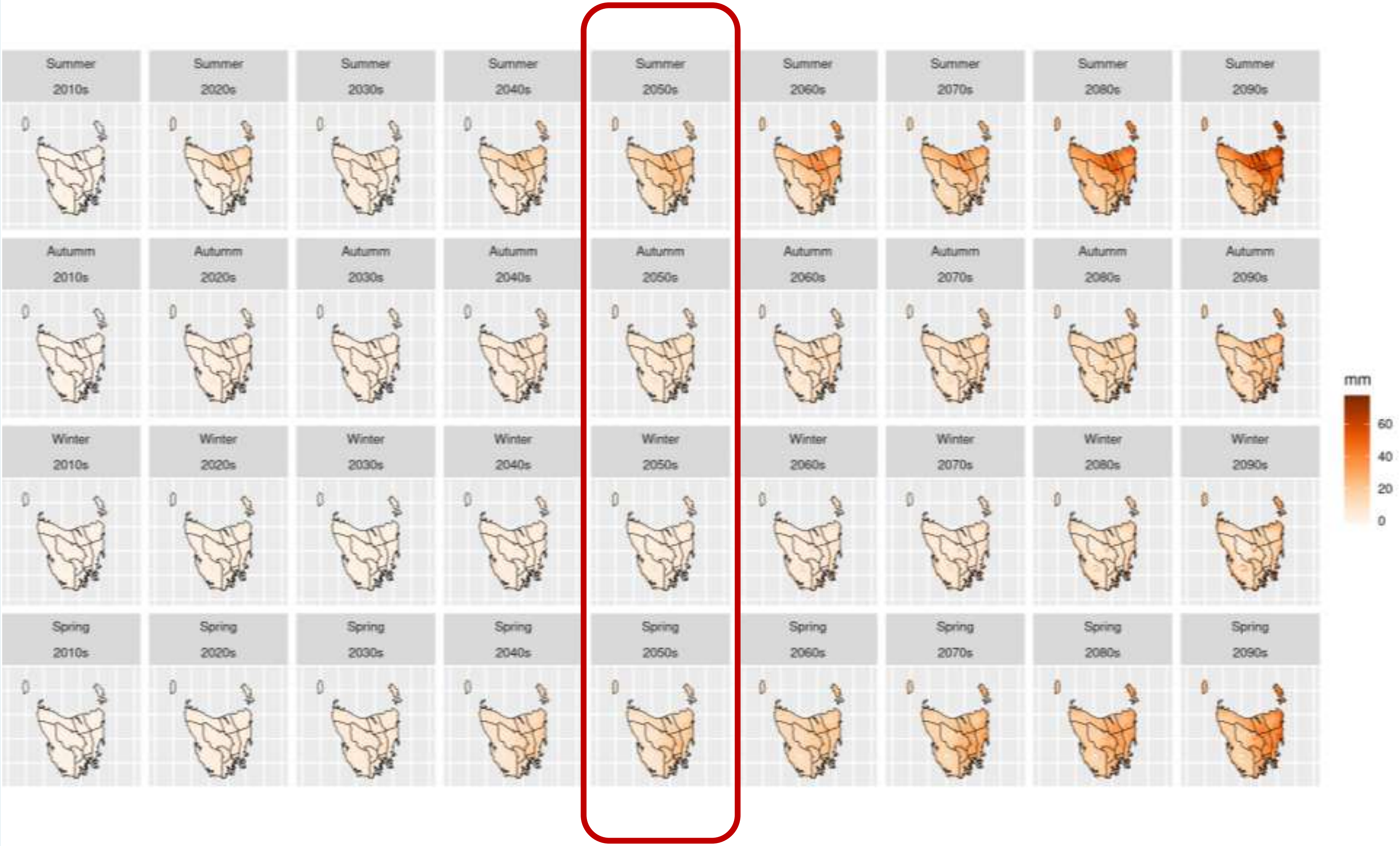
FUTURE CLIMATE CHANGE

EVAPORATION



WHY TRUST CLIMATE SCIENCE

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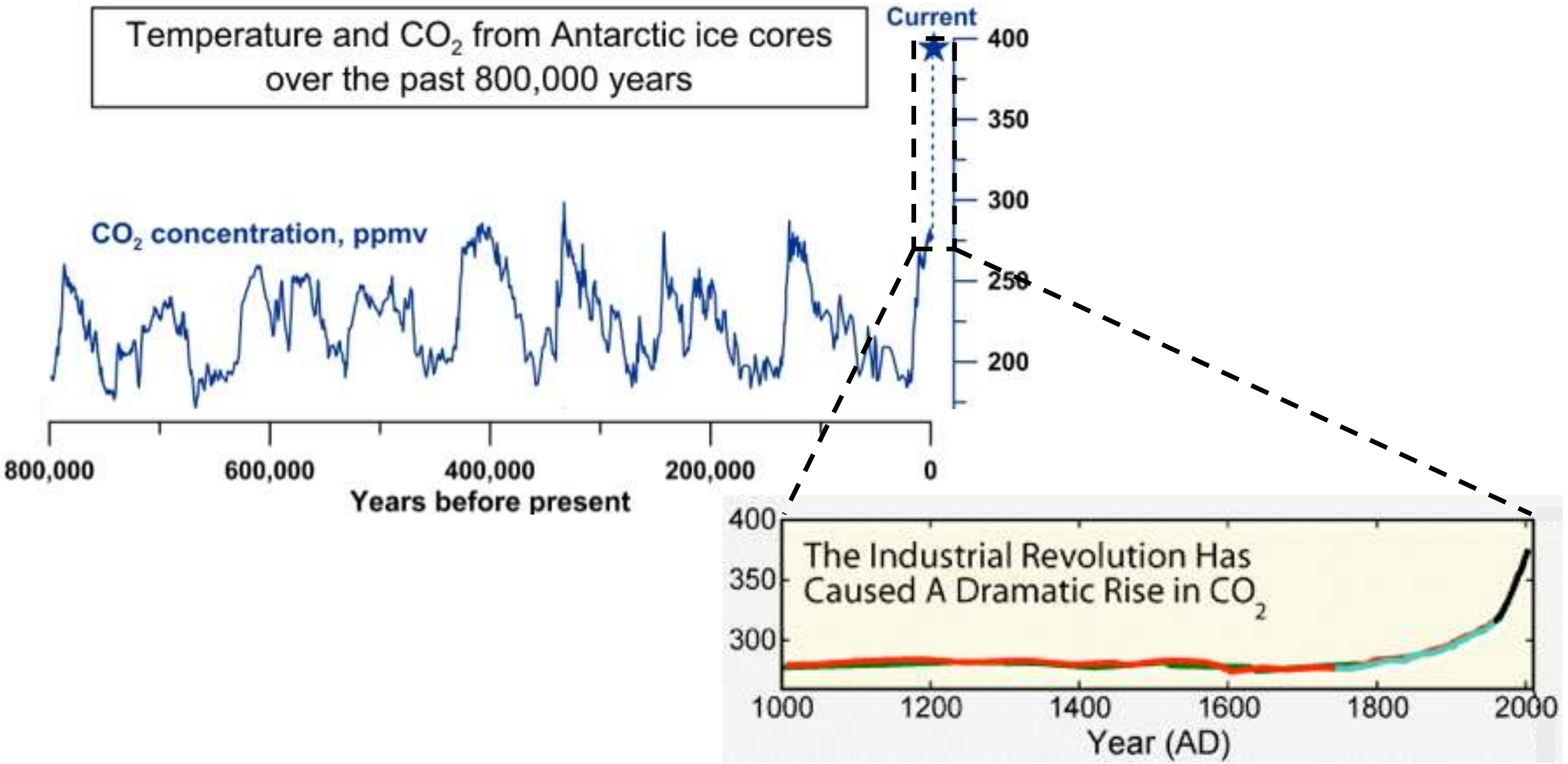
PALEO-CLIMATE

Carbon dioxide

- Can change naturally
- Humans have increased it much more and much faster than natural processes

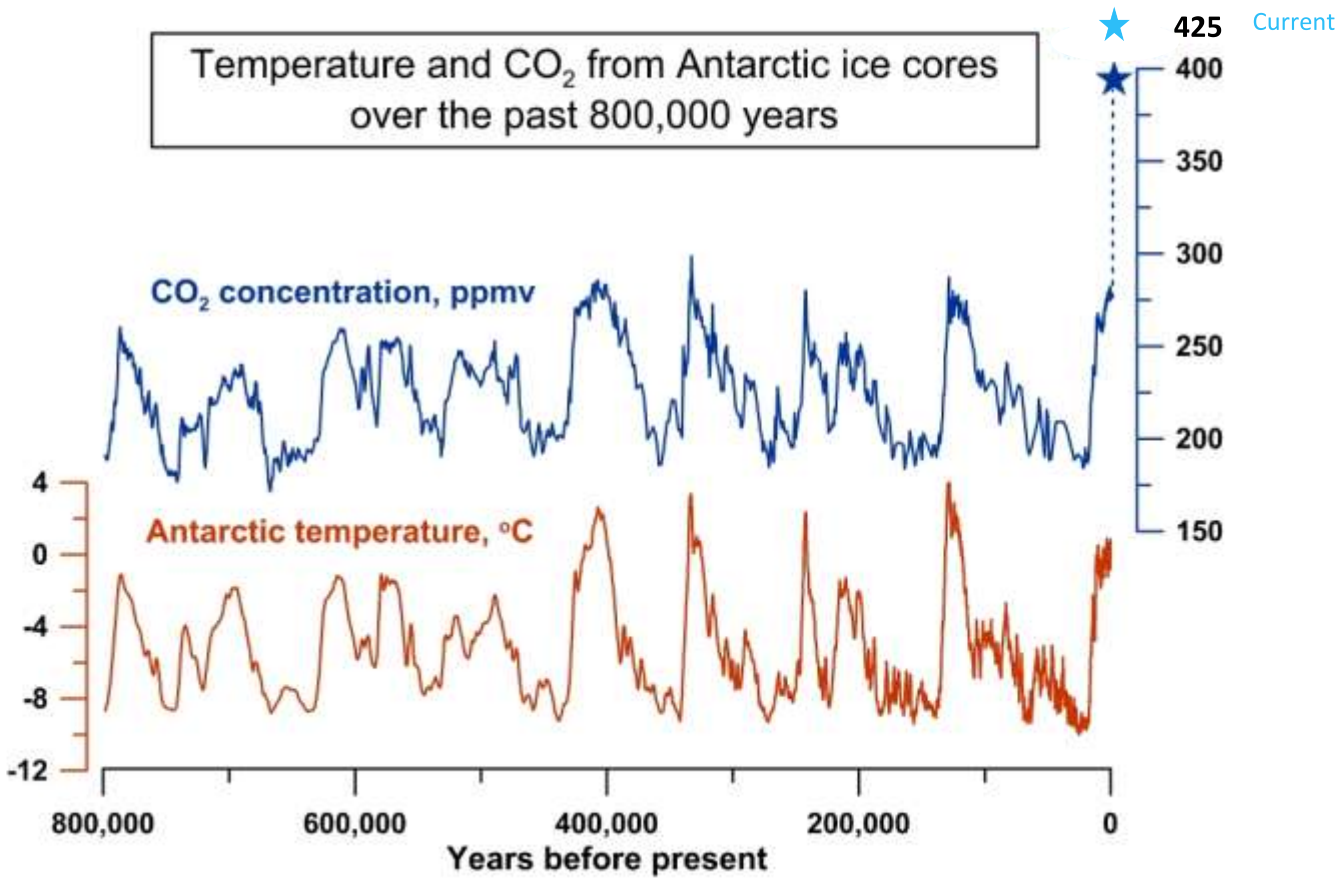


- Why does this matter?

PALEO-CLIMATE

Carbon dioxide (CO_2)

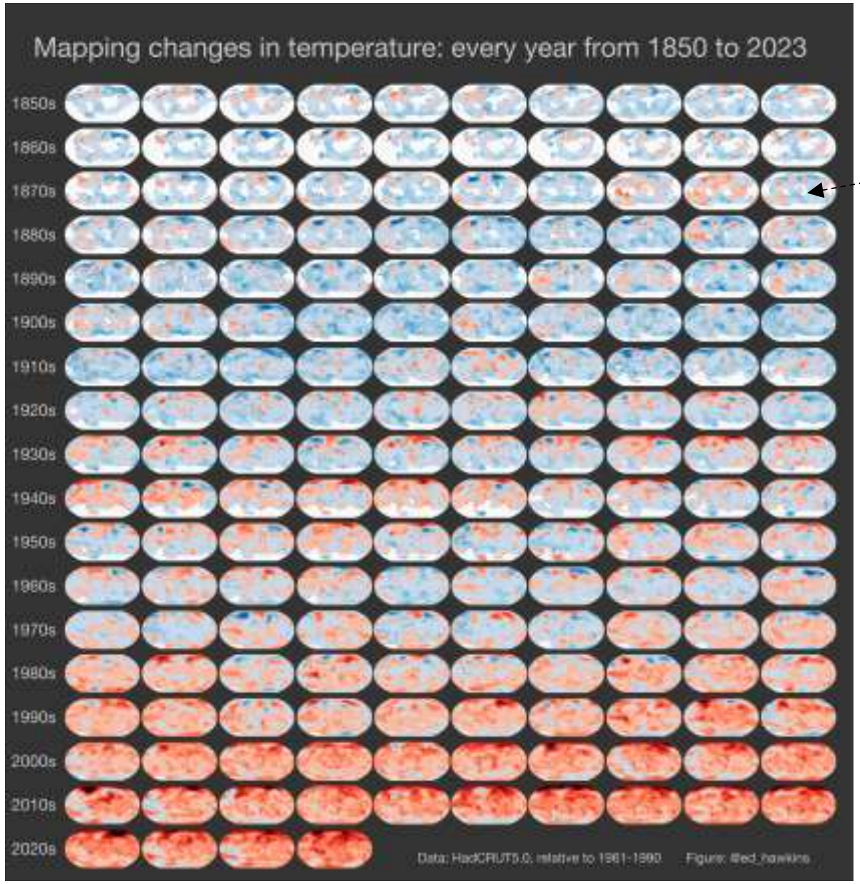
- Strong relationship with temperature
- CO_2 is very high, so planet will warm a lot



HISTORICAL-CLIMATE (OBSERVED)

Temperature

- Is the planet warming?
  - YES
- Records from 1850 to present show warming trend everywhere on earth.
- Rate of warming is increasing

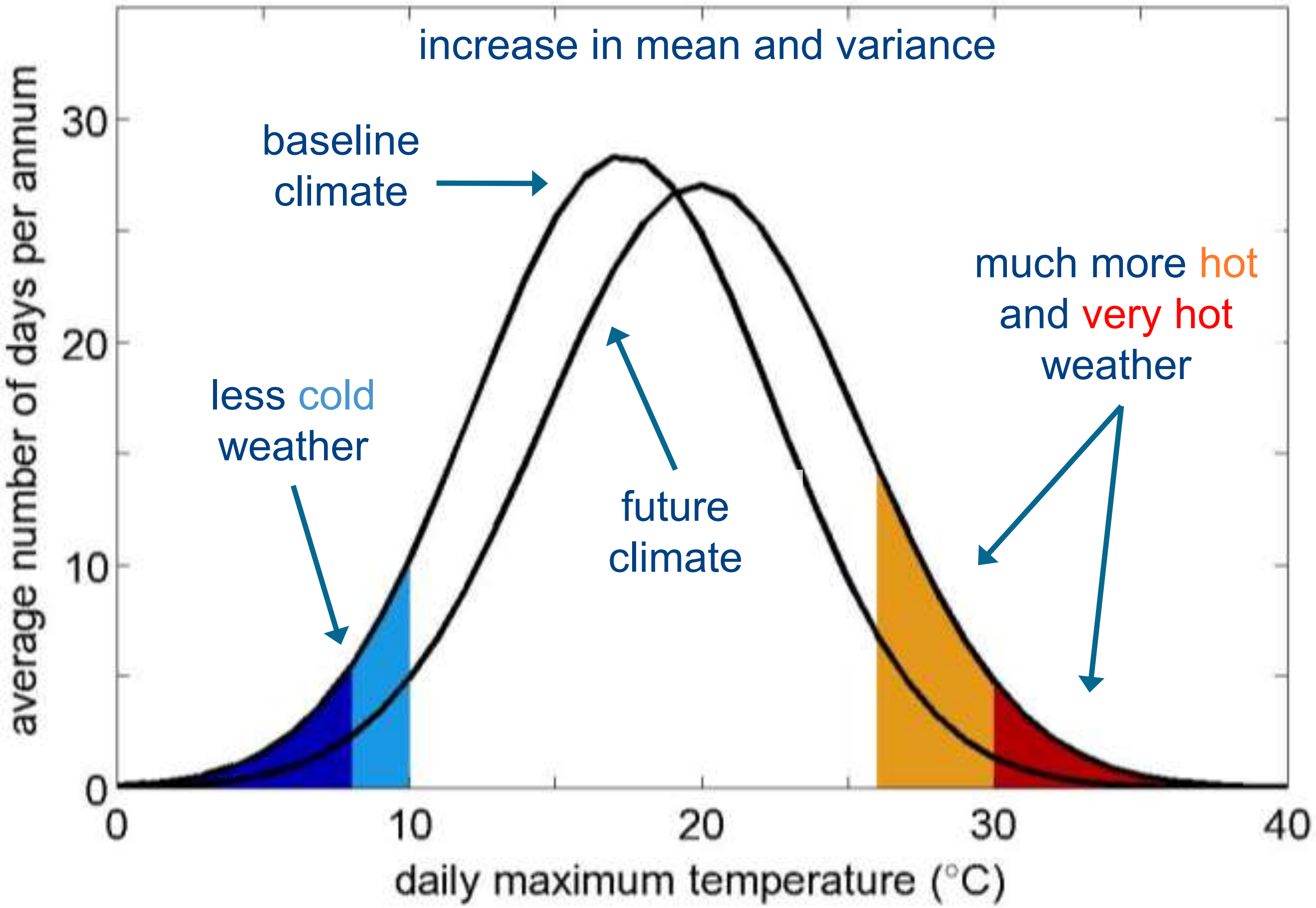


Each oval is a map of the Earth, showing the annual average temperature for each year

WHAT IS A CLIMATIC CHANGE

Some cold conditions go extinct

- Snow lines go uphill
- Alpine areas become subalpine



Unprecedented hot conditions

- Max daily temperatures
- Heatwaves

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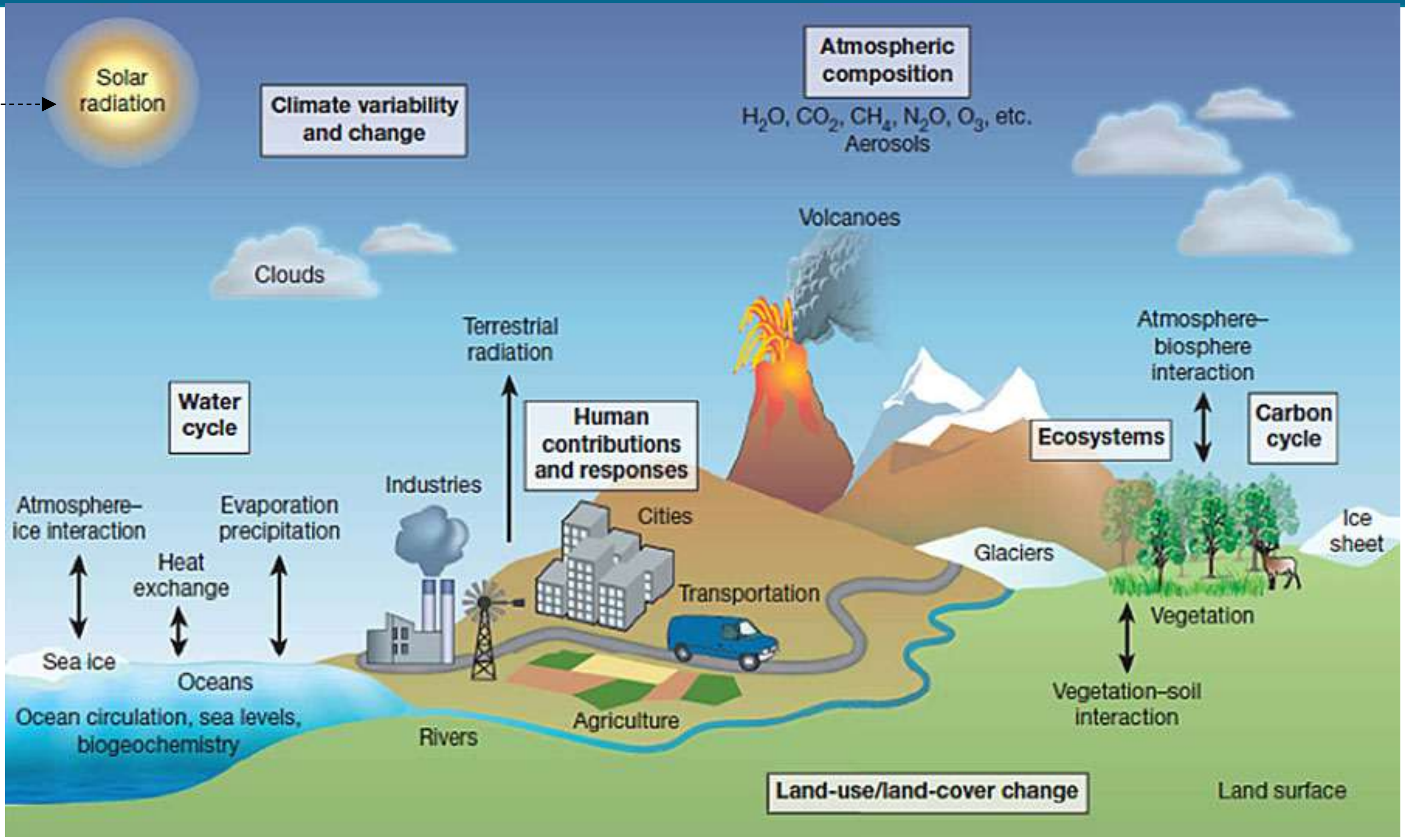
HOW CLIMATE MODELS WORK

Each term in this cartoon represents 10s to 100s of equations



With simulations you can test what happens when:

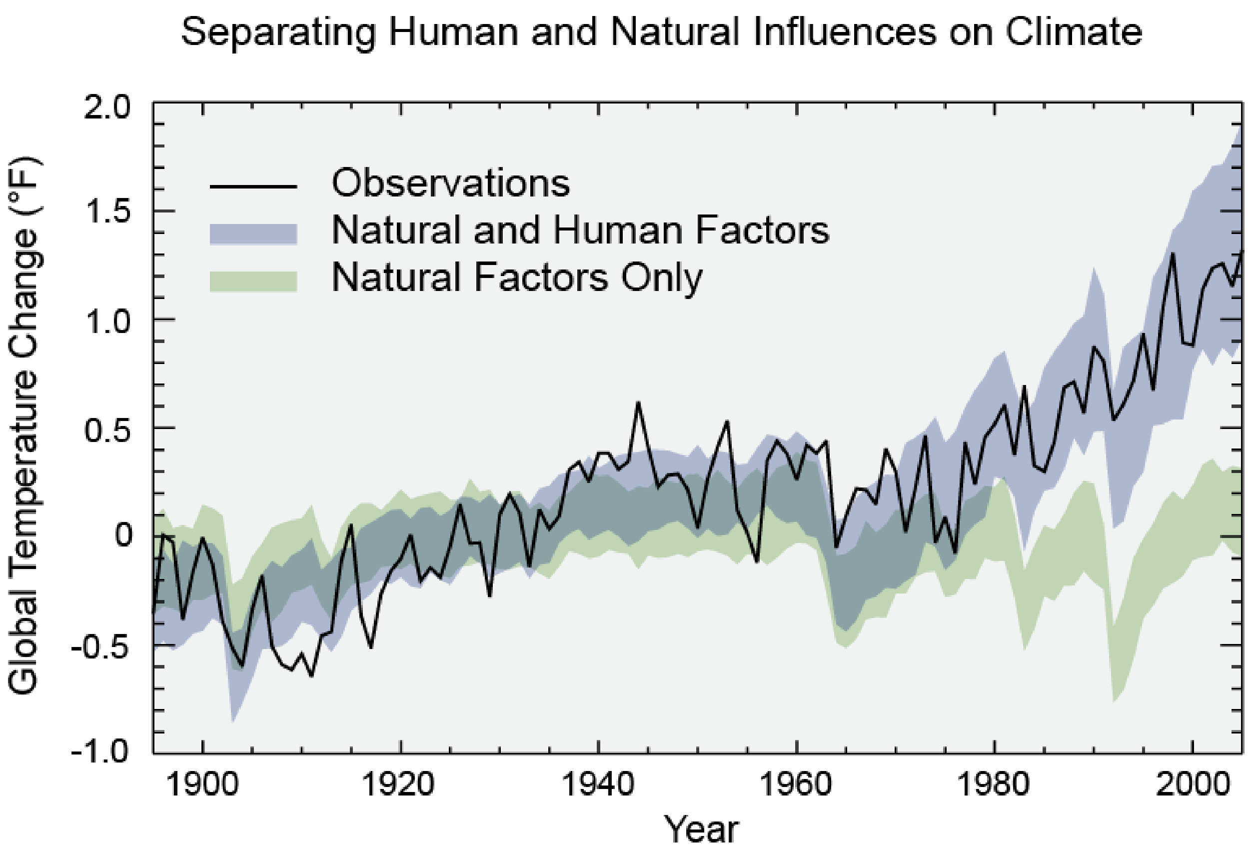
- we switch off the sun?
- we have 100x more volcanoes?
- we remove all vegetation?
- ozone (O3) changes?
- carbon dioxide (CO2) changes?

HOW CLIMATE MODELS WORK

Science has tested lots of things.

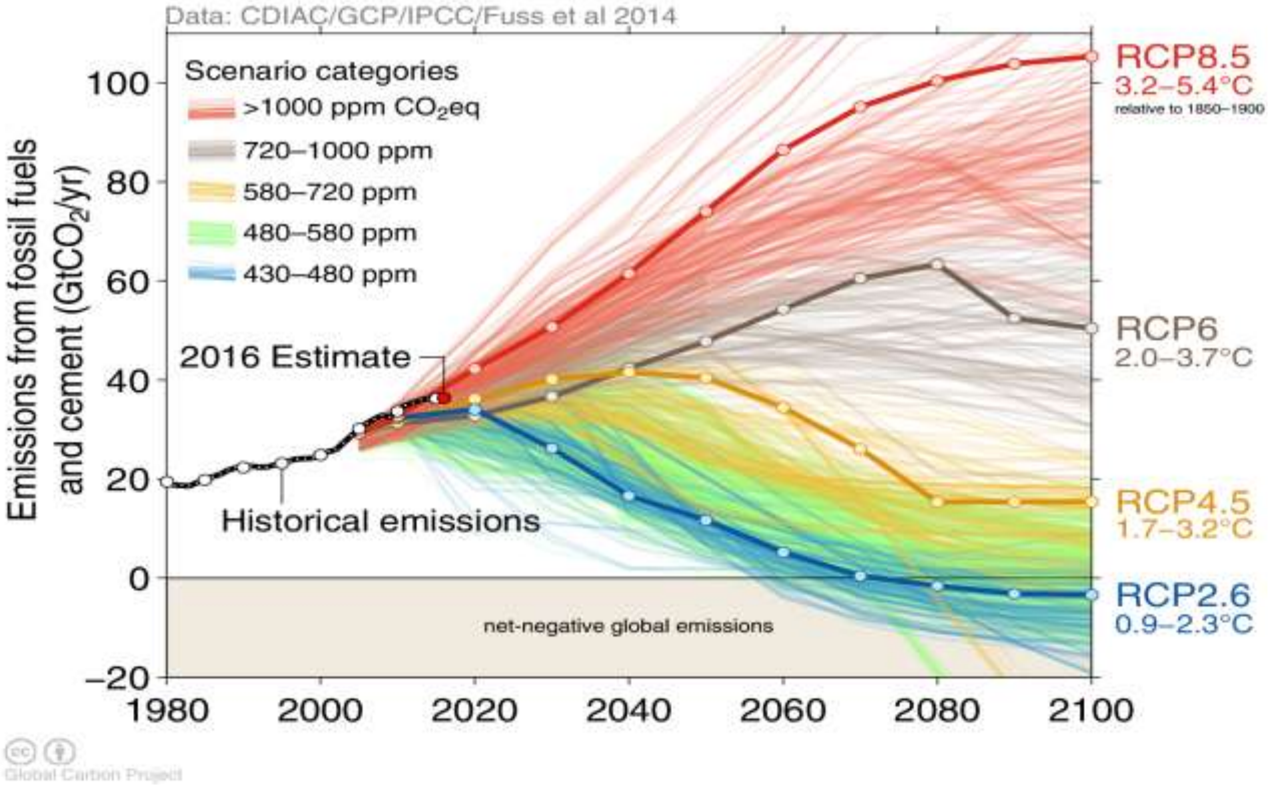
We know what happens when:

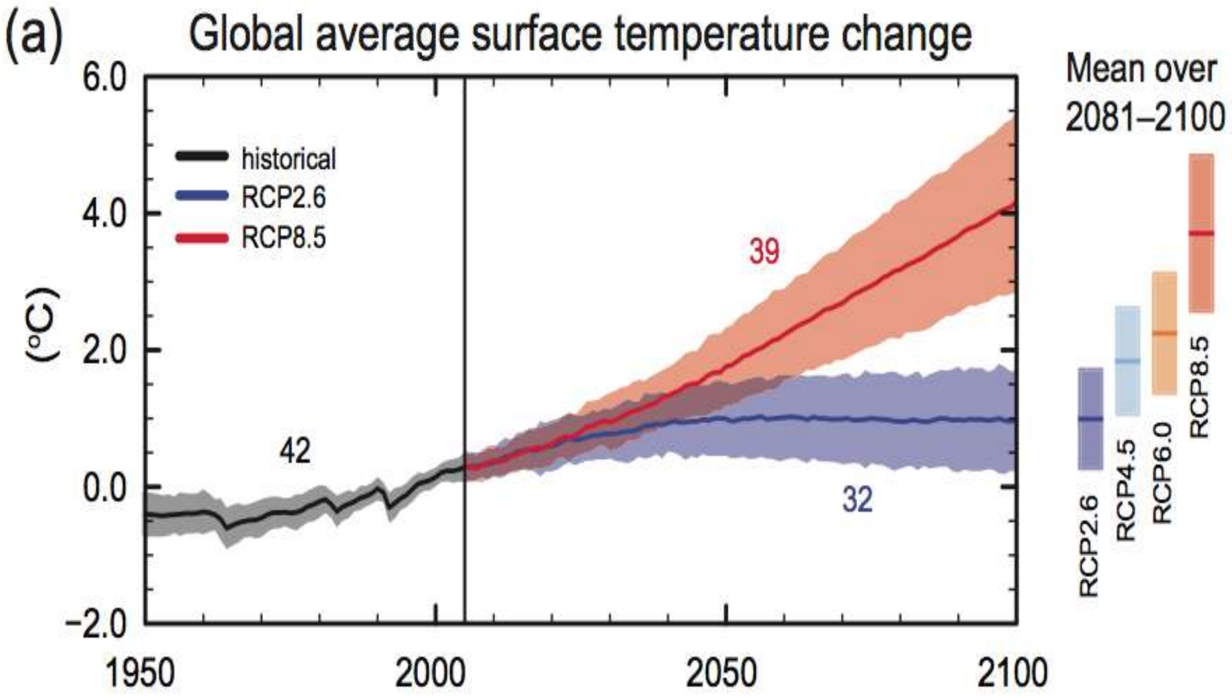
- Humans **DON'T** change greenhouse gases
  - The climate stays does not change
  - Does not match observations
- Humans **DO** change greenhouse gases
  - We start warming the planet
  - This matches observations



CLIMATE CHANGE IS REAL.

ITS CAUSED BY HUMANS BURNING FOSSIL FUELS.





WHAT ARE THE INVESTORS SAYING?

Acclimatised

WHAT ARE THE INVESTORS AND INSURERS SAYING?

2007-2009
Global Financial Crisis

2009-2011
Financial Stability Board (FSB) Established

Identifies key risks:
- Poor Lending Practices
- **Climate Change**

2011-2014
FSB recommendations for improved lending practices (successful)

Lobbies national governments to implement climate change policies (unsuccessful)

2014-2017
FSB established the Taskforce on Climate-related Financial Disclosures (TCFD)

Follow the money
Decide to influence where investors are putting their money

2017-2023
TCFD recommendations to investors (successful)

Investors start considering climate change risk
Start changing the types of enterprises they support

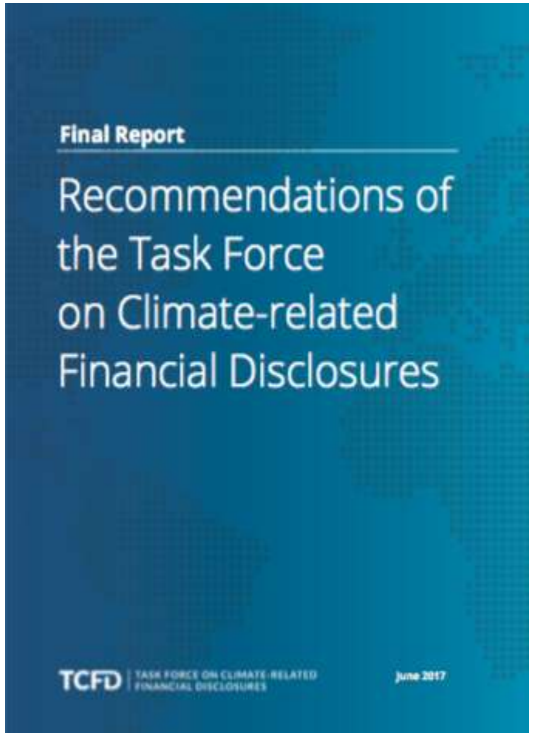
WHAT ARE THE INVESTORS AND INSURERS SAYING?

"The **market believes** climate change is real and that humans are causing it by burning fossil fuels."

TCFD, June 2017

Climate deniers' opinions are no longer relevant

In fact, they become destructive to business success



Michael Bloomberg (Bloomberg)

Mark Carney (Bank of England)

WHAT ARE THE INVESTORS AND INSURERS SAYING?

"…company directors who fail to properly consider and disclose **foreseeable** climate-related risks to their business could be held **personally liable**…"

Geoff Summerhayes, APRA, 2017

Executive level (directors, C-suite) now can be sued personally for not understanding and telling investors about climate related risk.