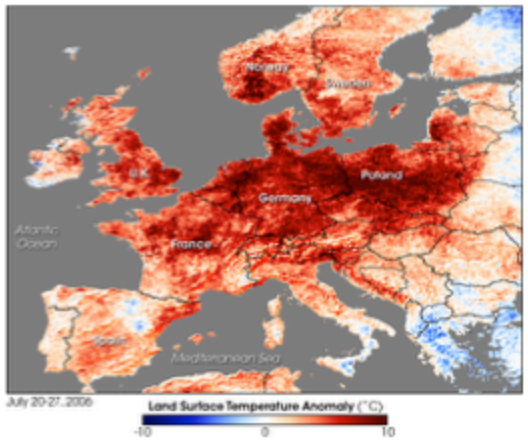

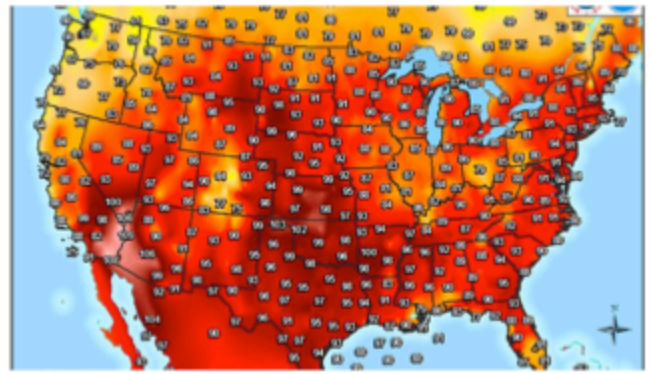

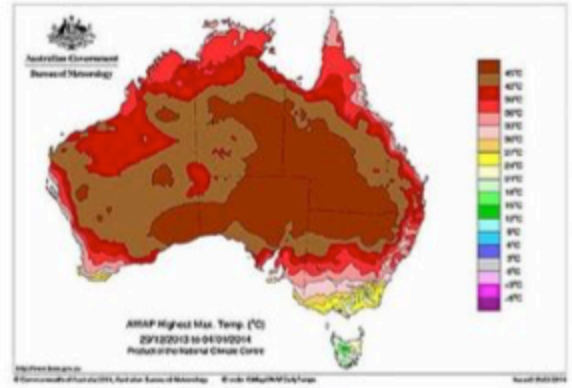

Changes in regional heatwave characteristics as a function of average warming

GEWEX, Canmore, 7th May 2018

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Motivation

- Paris agreement calls for global warming to be limited to “well below” 2°C
- Evidence that daily maximum temperatures warm faster than global average (Seneviratne et al. 2016)
- Heatwaves are more than just single daily temperatures
- Warming of heatwave characteristics past 2°C
- Influence of internal variability at different warming thresholds

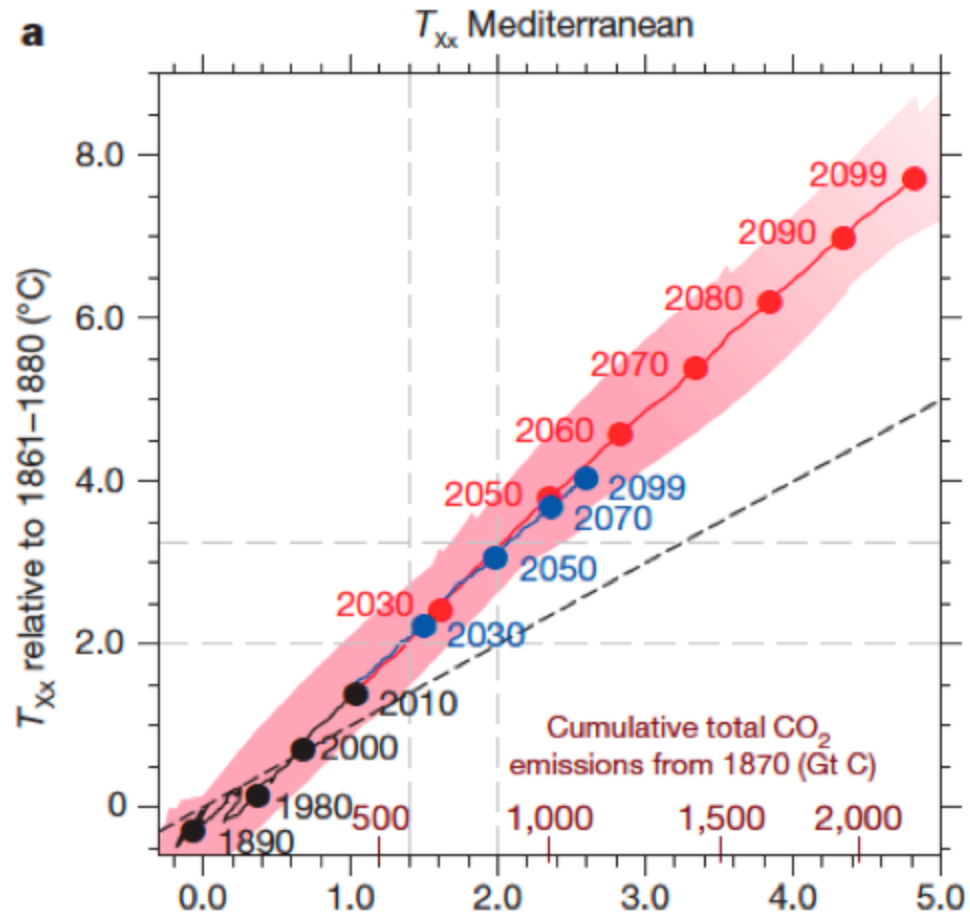
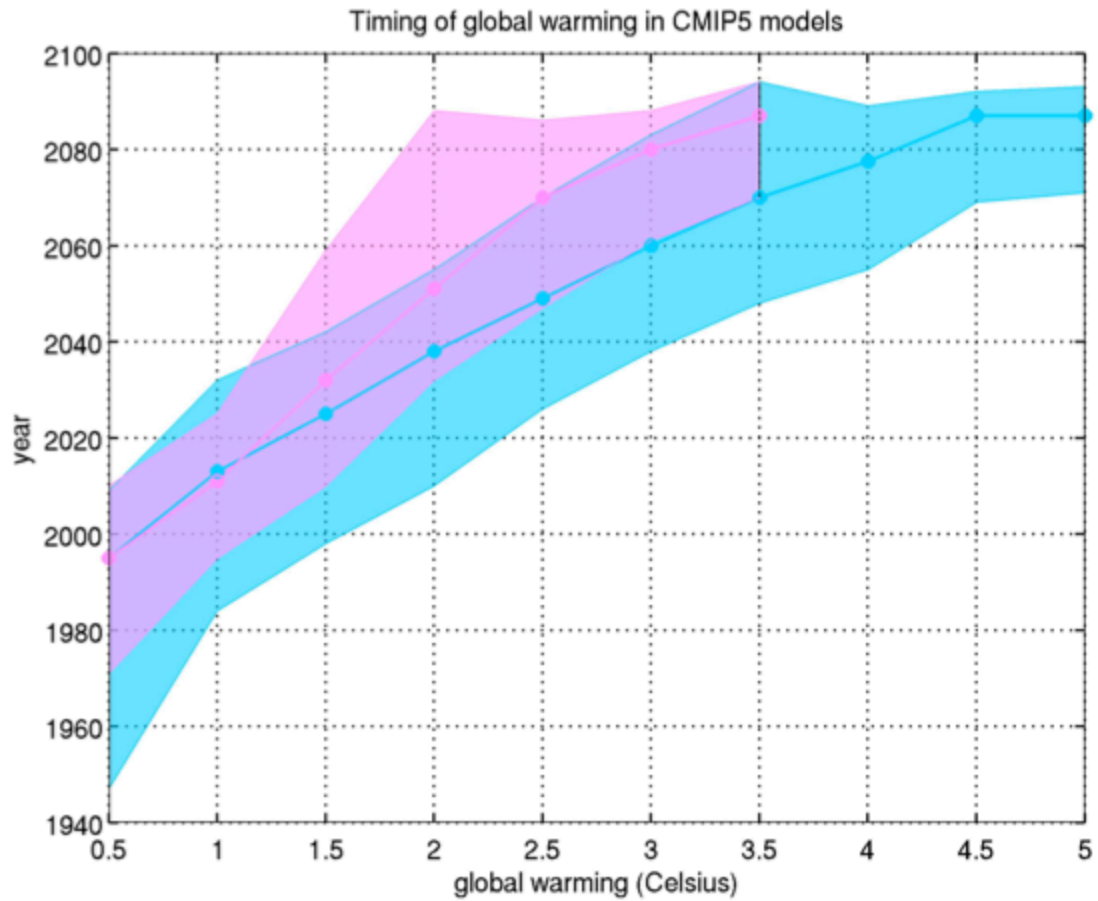


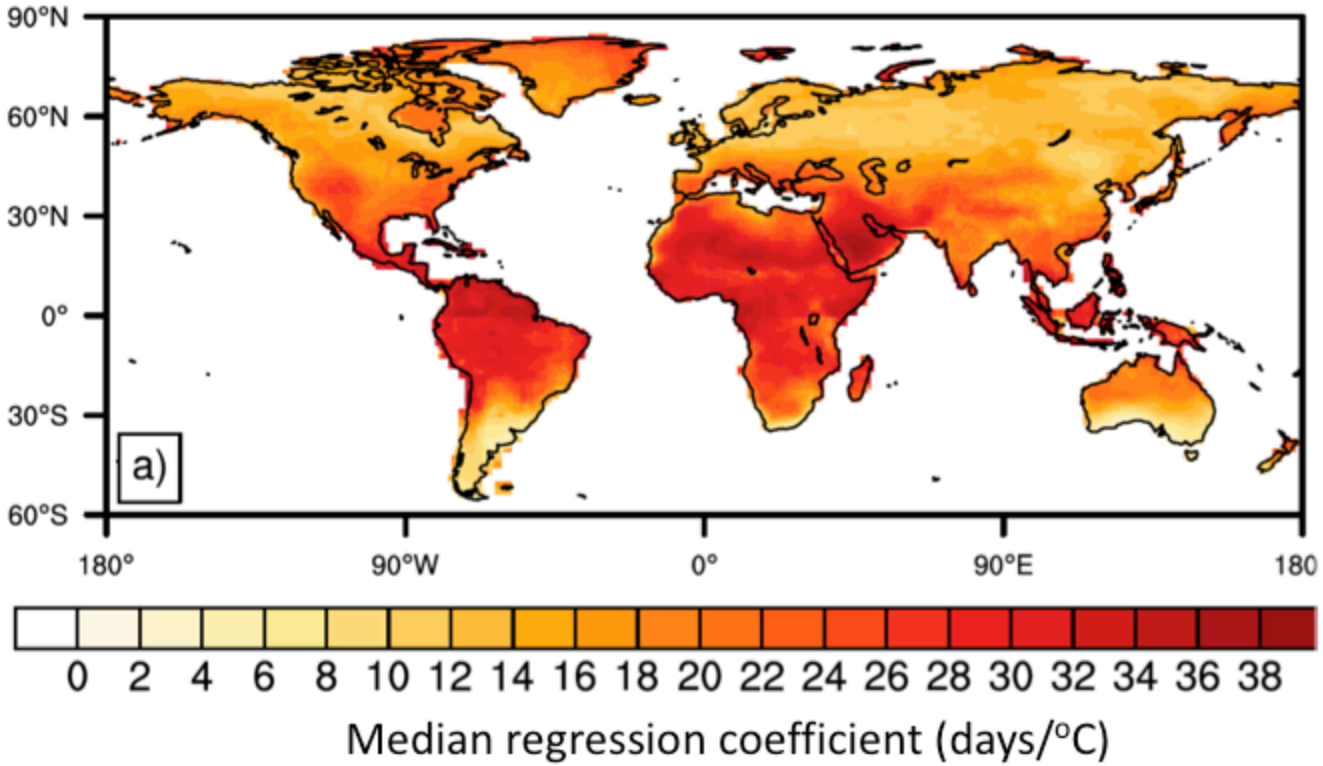
Figure 3a from Seneviratne et al. 2016, *Nature*

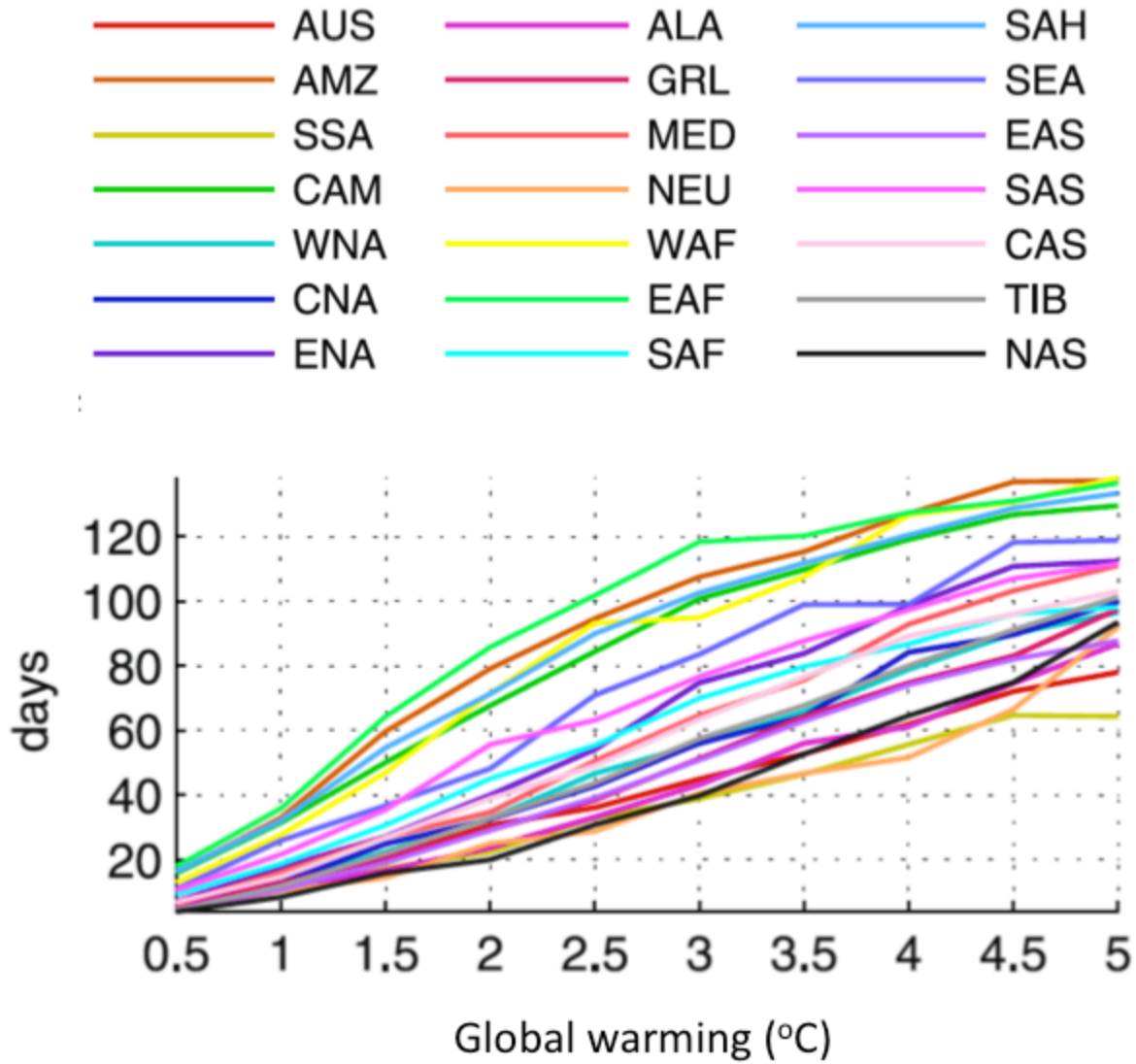
Methods

- CMIP5 ensemble (27 models); 21-member CESM ensemble
- 21 “Giorgi” regions
- Heatwaves & global warming relative to 1861-1890/control simulation
- Definition based on maximum temperature
  - 3+ consecutive days
  - Calendar day 90th percentile threshold
  - 5-month summer
  - Heatwave days; peak intensity; longest duration; number of events
- RCP4.5 & RCP 8.5 demonstrated similar relationships



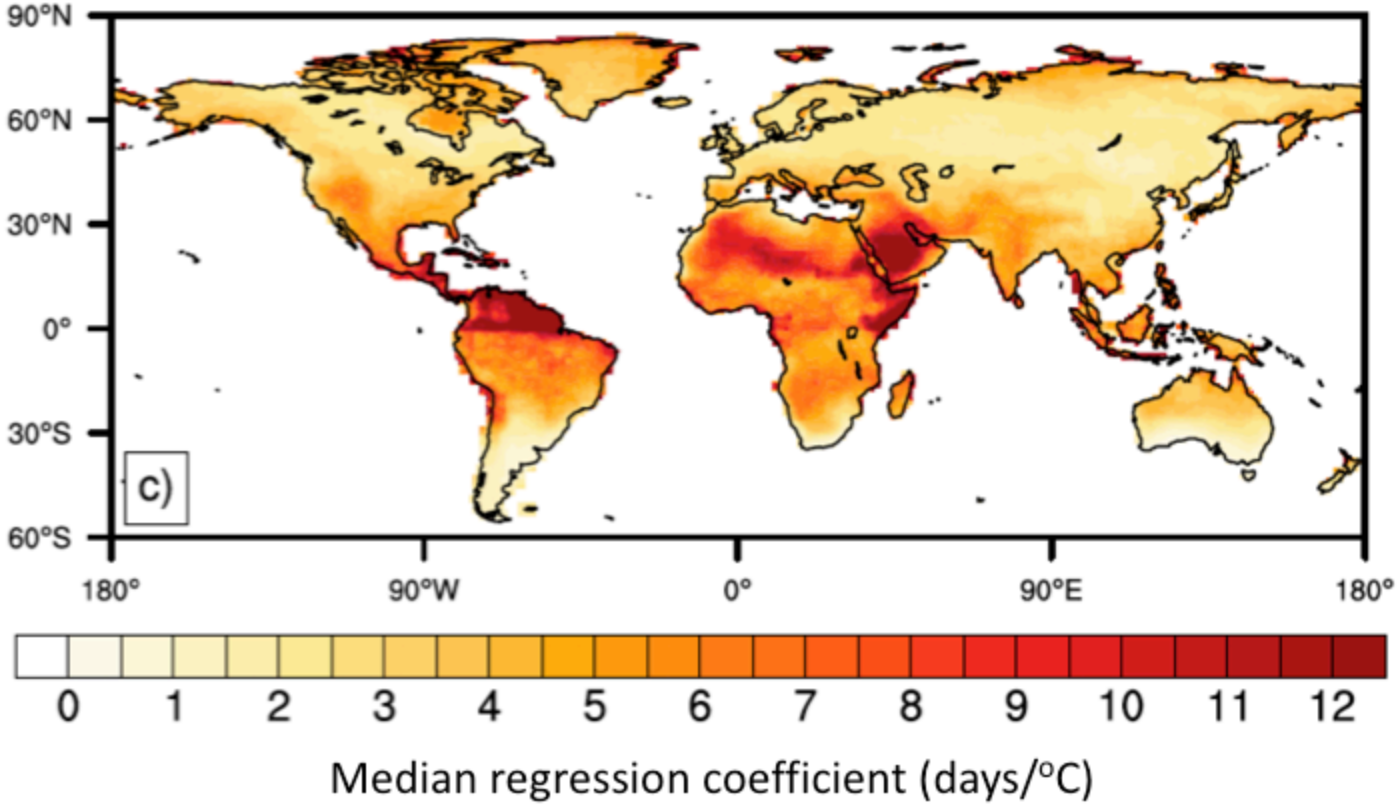
Heatwave days (CMIP5)

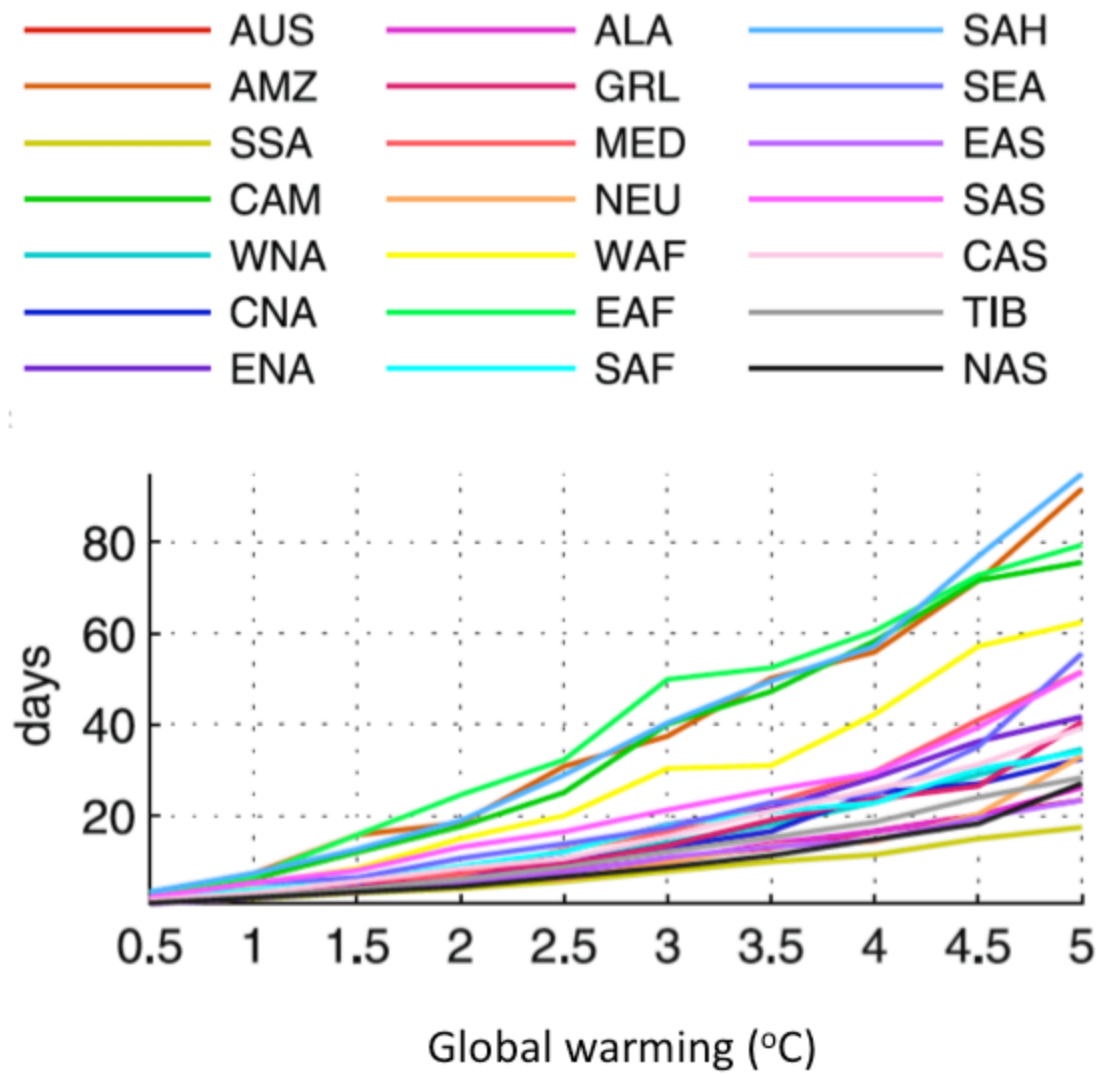




Most dramatic change of all heatwave characteristics

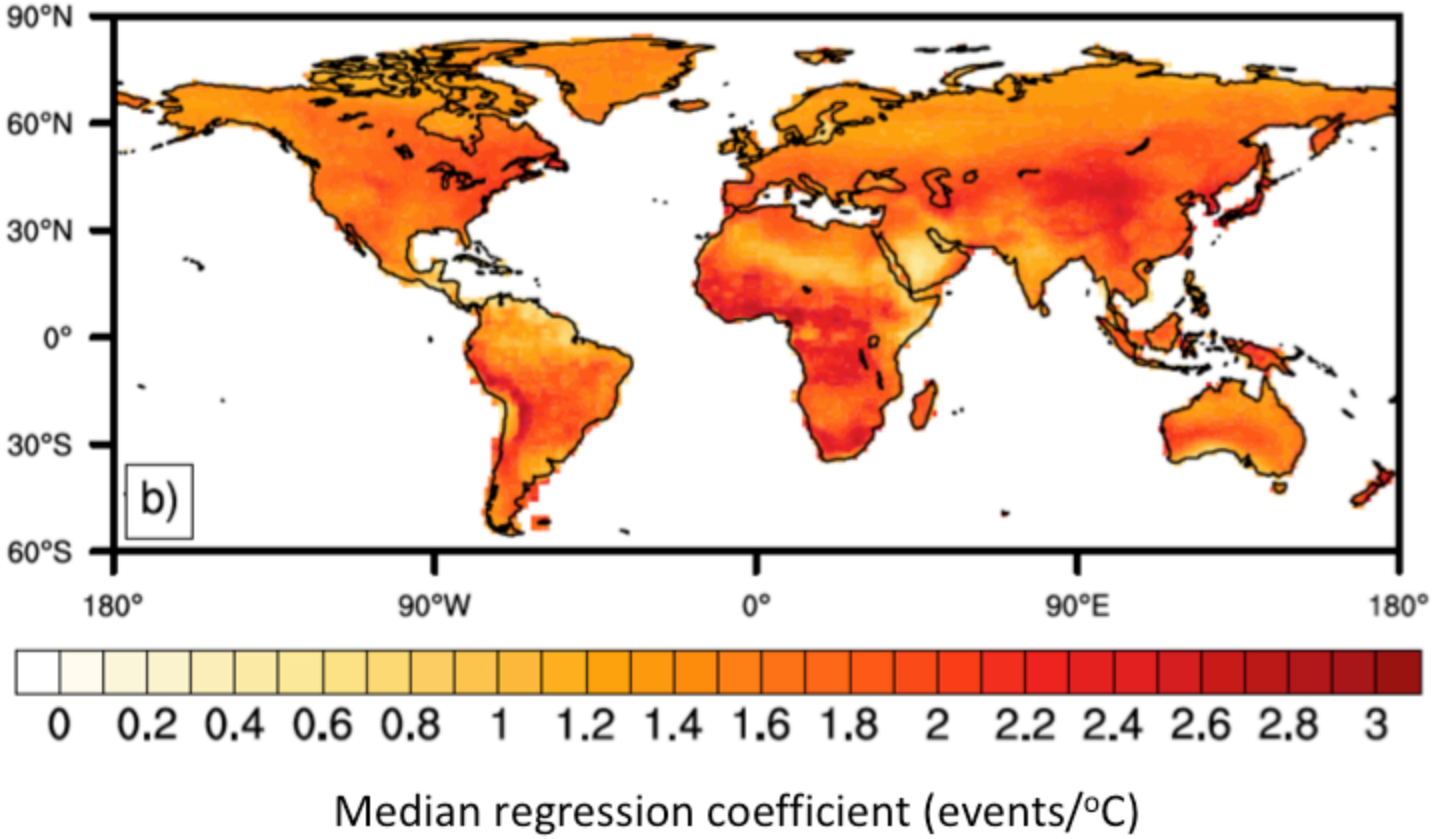
Heatwave duration (CMIP5)

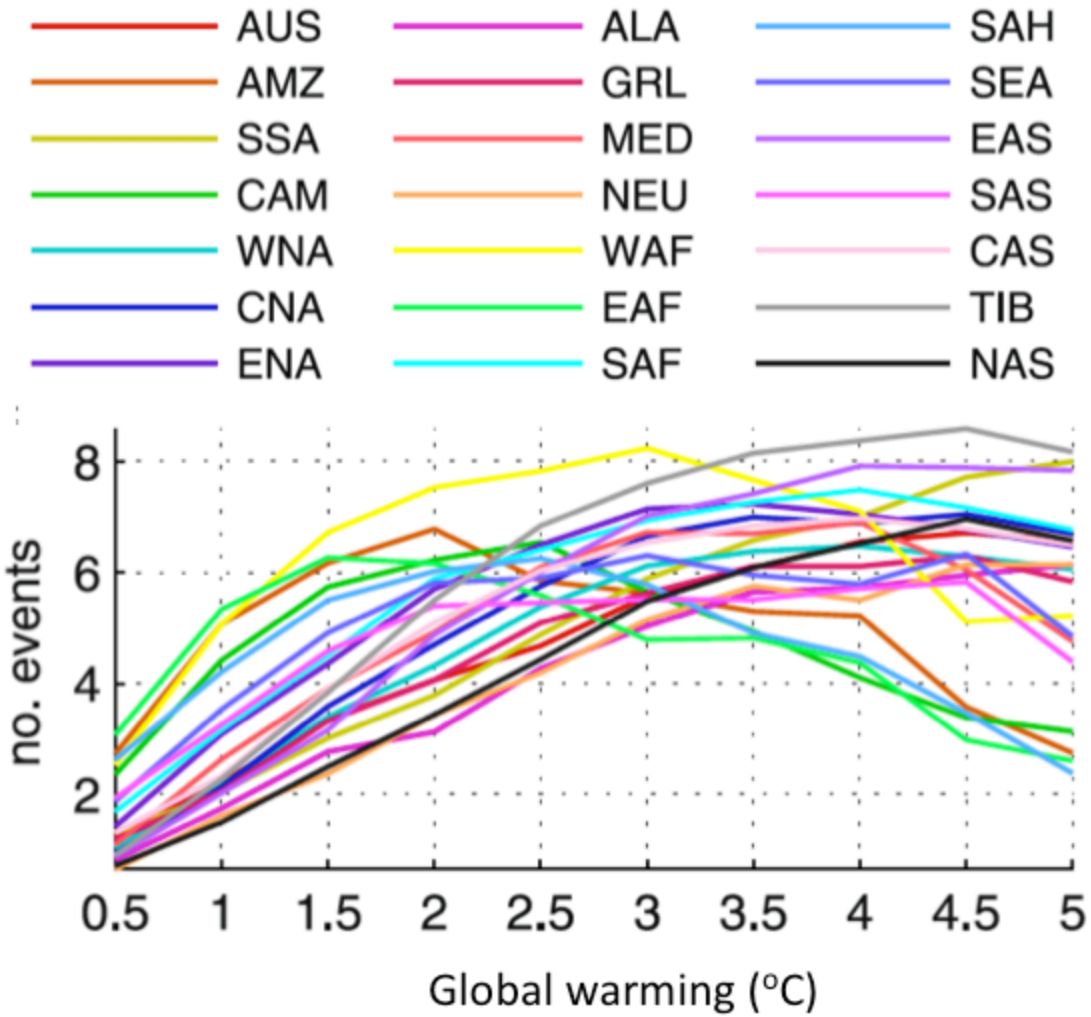




Changes in the *Longest* event per season, not across all heatwaves

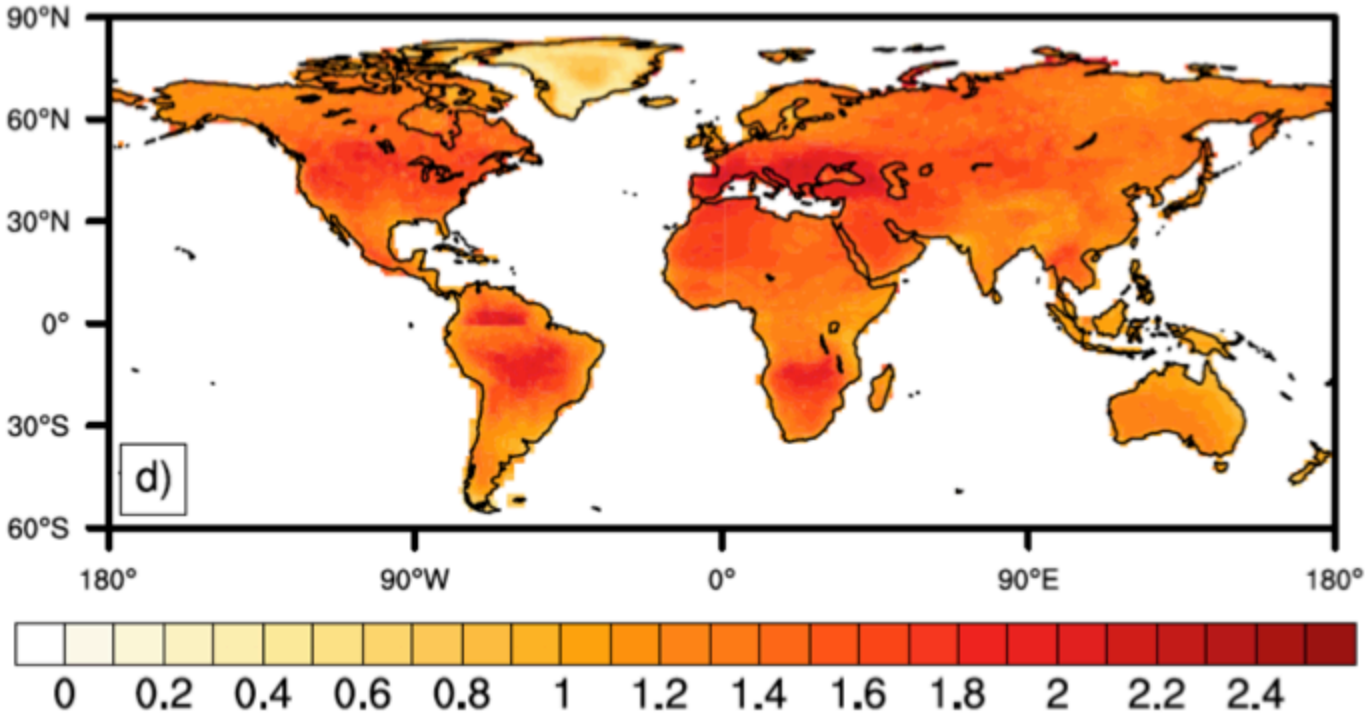
Number of heatwaves (CMIP5)

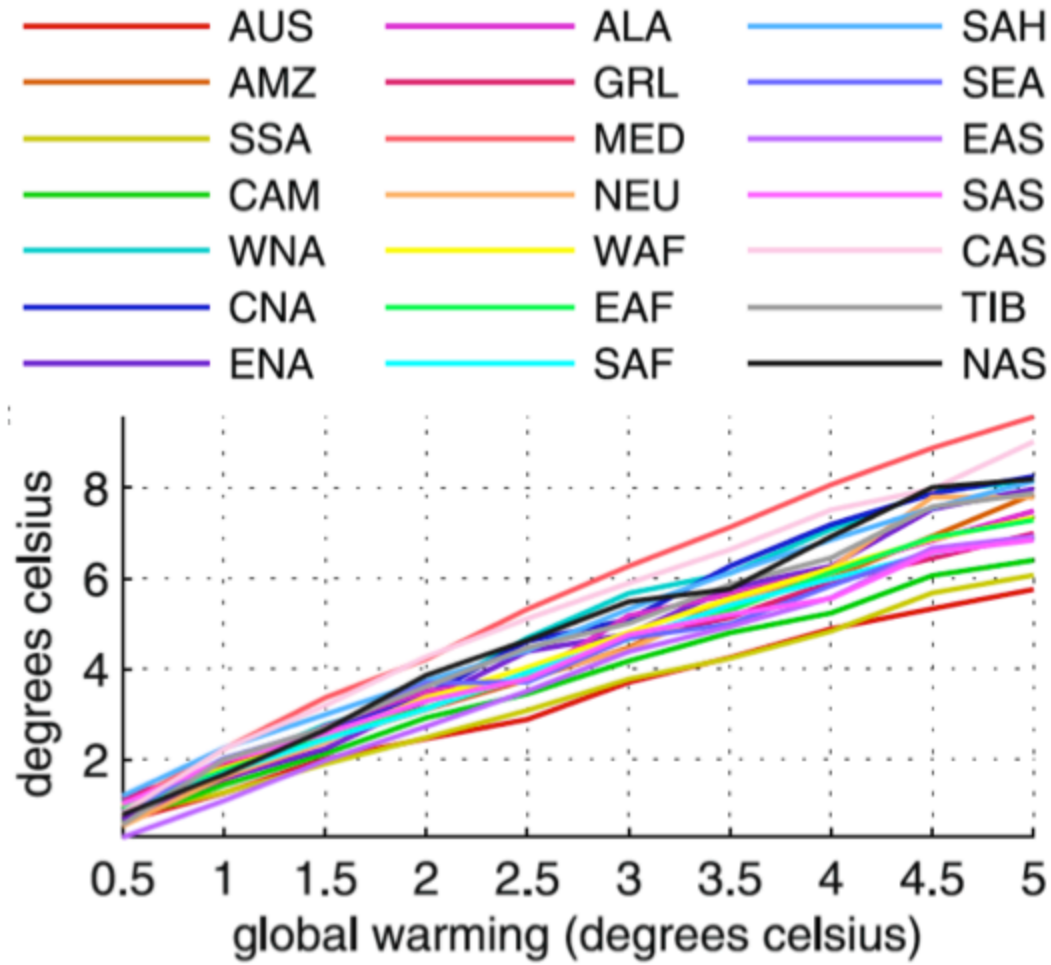




NOT a linear relationship – perpetual heatwaves from 2°C-4°C

Peak intensity (CMIP5)



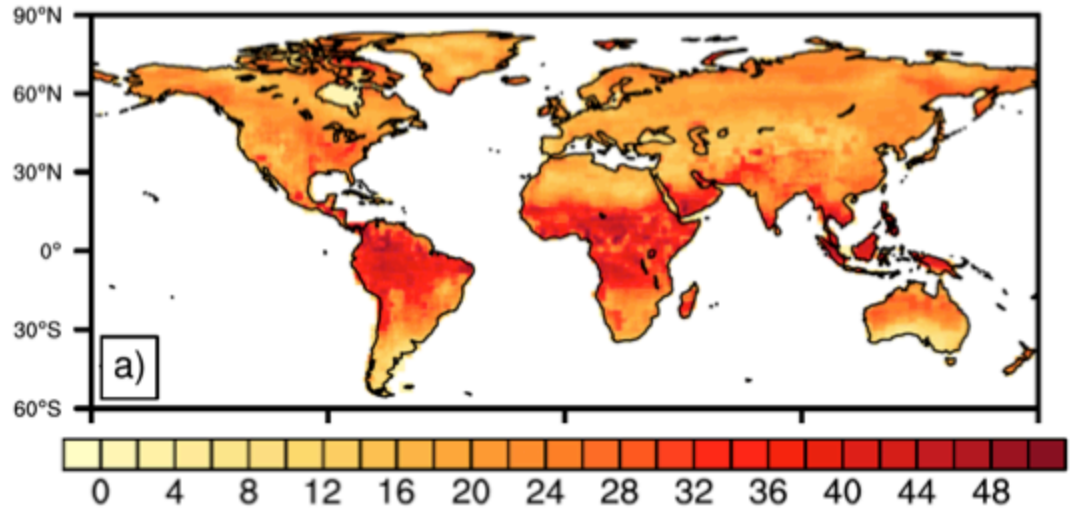


Similar to TXx, though not identical

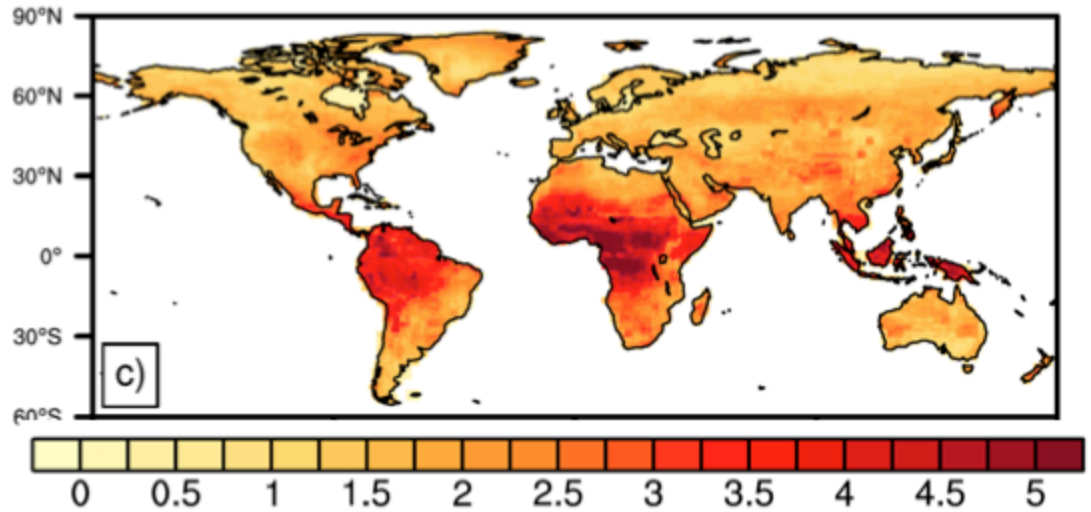
Global warming (°C)

A note on CMIP5 ensemble spread….

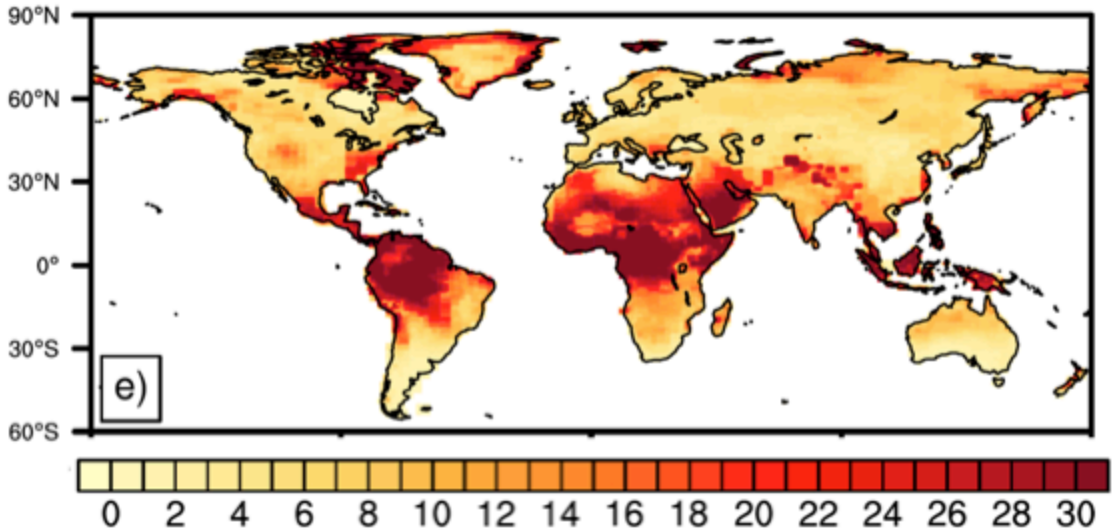
Heatwave days



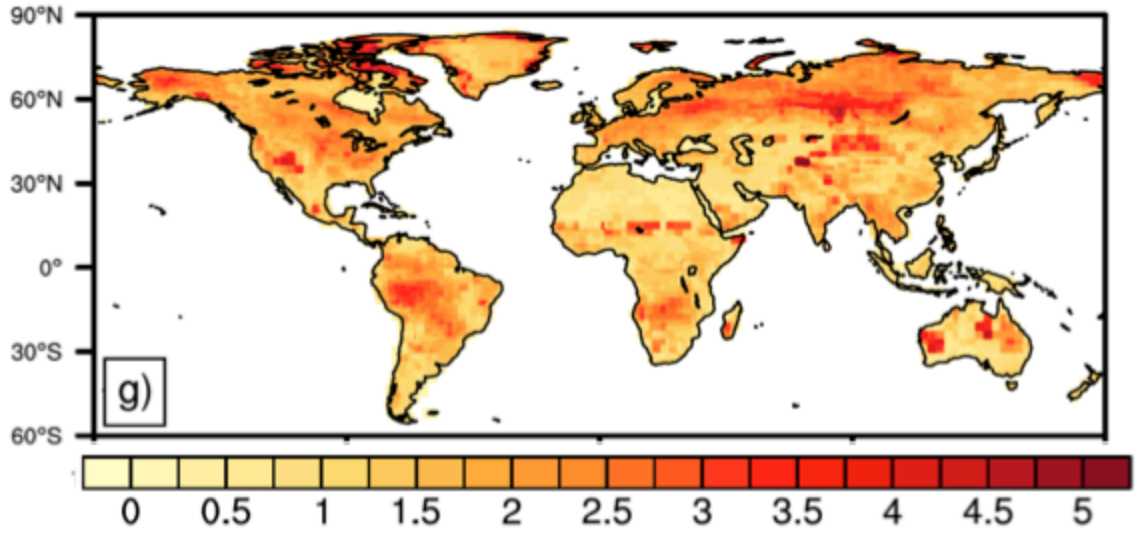
Number of events



Longest event



Peak intensity

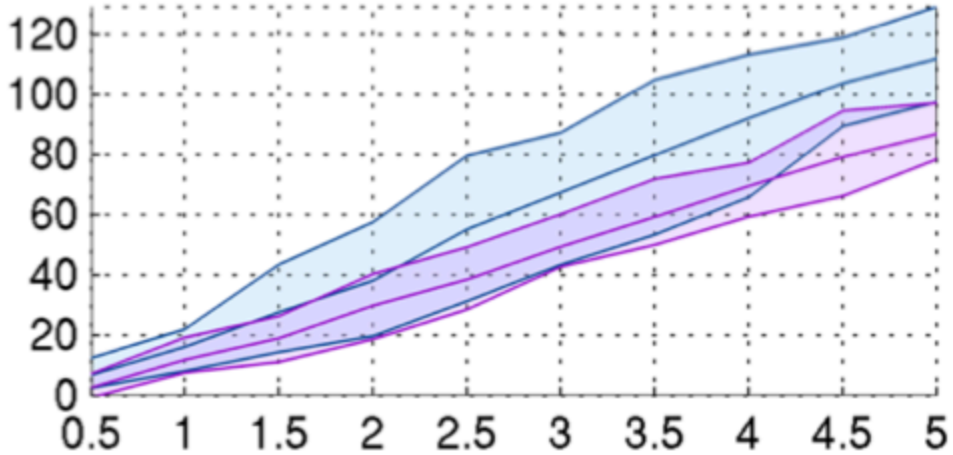


Return levels of 1-in-20 year peak intensity (CMIP5)

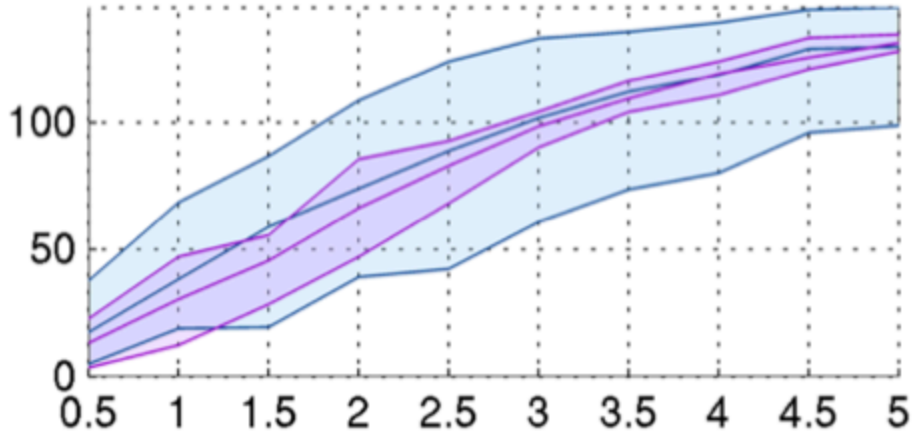
	1°C	2°C	3°C	4°C	5°C
Alaska	15	4.6	2.5	1.4	1.1
Mediterranean	3.75	1.25	1	1	1
Australia	5	1.9	1.2	1	1
Amazon	4	1.25	1	1	1
Canada	10	4.3	1.3	1	1
W. North America	7.5	1.4	1.1	1	1
South East Asia	6.7	2.7	1.7	1.2	1
Northern Europe	15	5	1.7	1.1	1

Influence of internal variability (heatwave days)

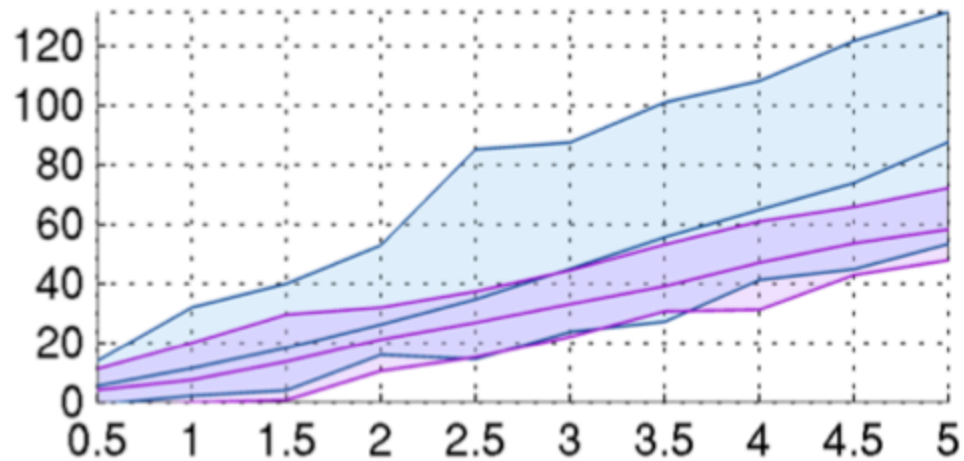
Mediterranean



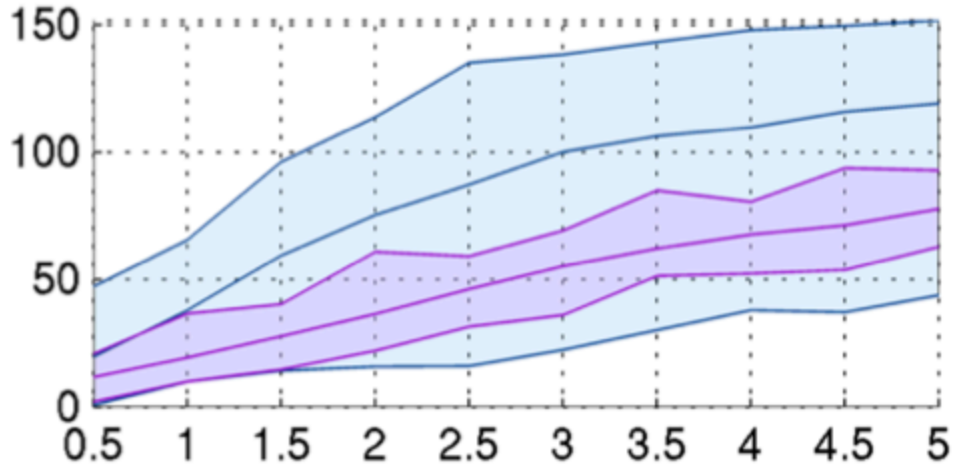
Amazon



Alaska



Africa



Internal variability accounts for 20-50% of spread in increase of heatwaves per degree global warming

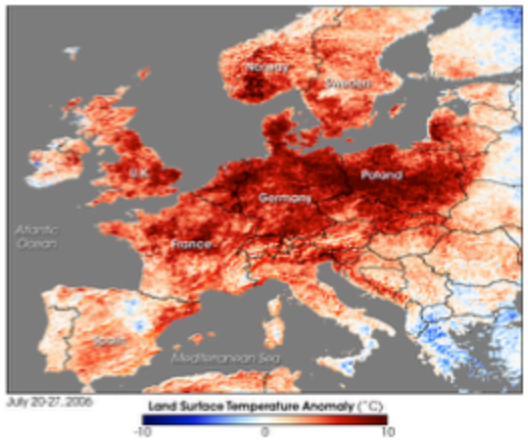
Influence diminishes over some regions when perpetual heatwave conditions are reached

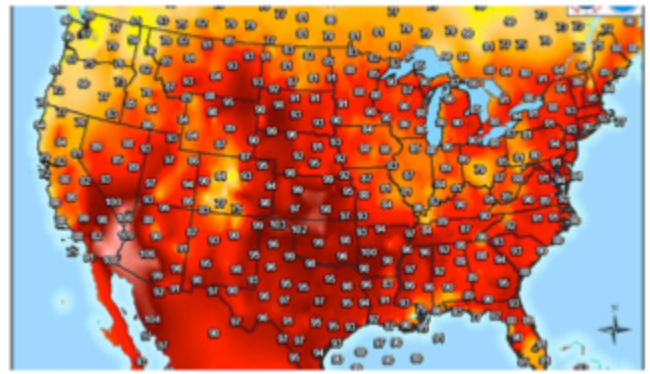
Regional estimate of % change due internal variability

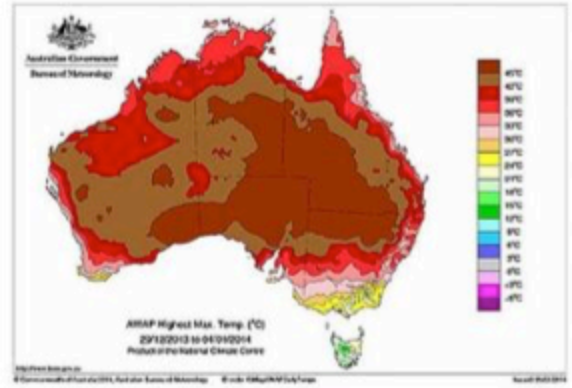
Region	Heatwave days	Number of events	Longest event	Peak intensity
Alaska	39	70	25	90
Mediterranean	54	61	35	67
Australia	36	50	34	47
Amazon	28	21	17	35
Canada	53	78	44	68
W. North America	41	55	37	46
South east Asia	25	28	12	51
Northern Europe	46	59	33	54

Summary

- Largest signal in heatwave days; over Tropical regions
- Perpetual heatwave conditions may start to emerge from 2^{o}C
- Very intense heatwaves become commonplace by 4^{o}C-5^{o}C (sometimes earlier)
- Peak heatwave intensity warms faster than global mean over most regions, though not identical to TXx
- For most regions and characteristics, influence of internal variability is reasonably constant
- Even *IF* global warming is capped below 2^{o}C, heatwaves will change adversely – no “safe” warming for heatwaves







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