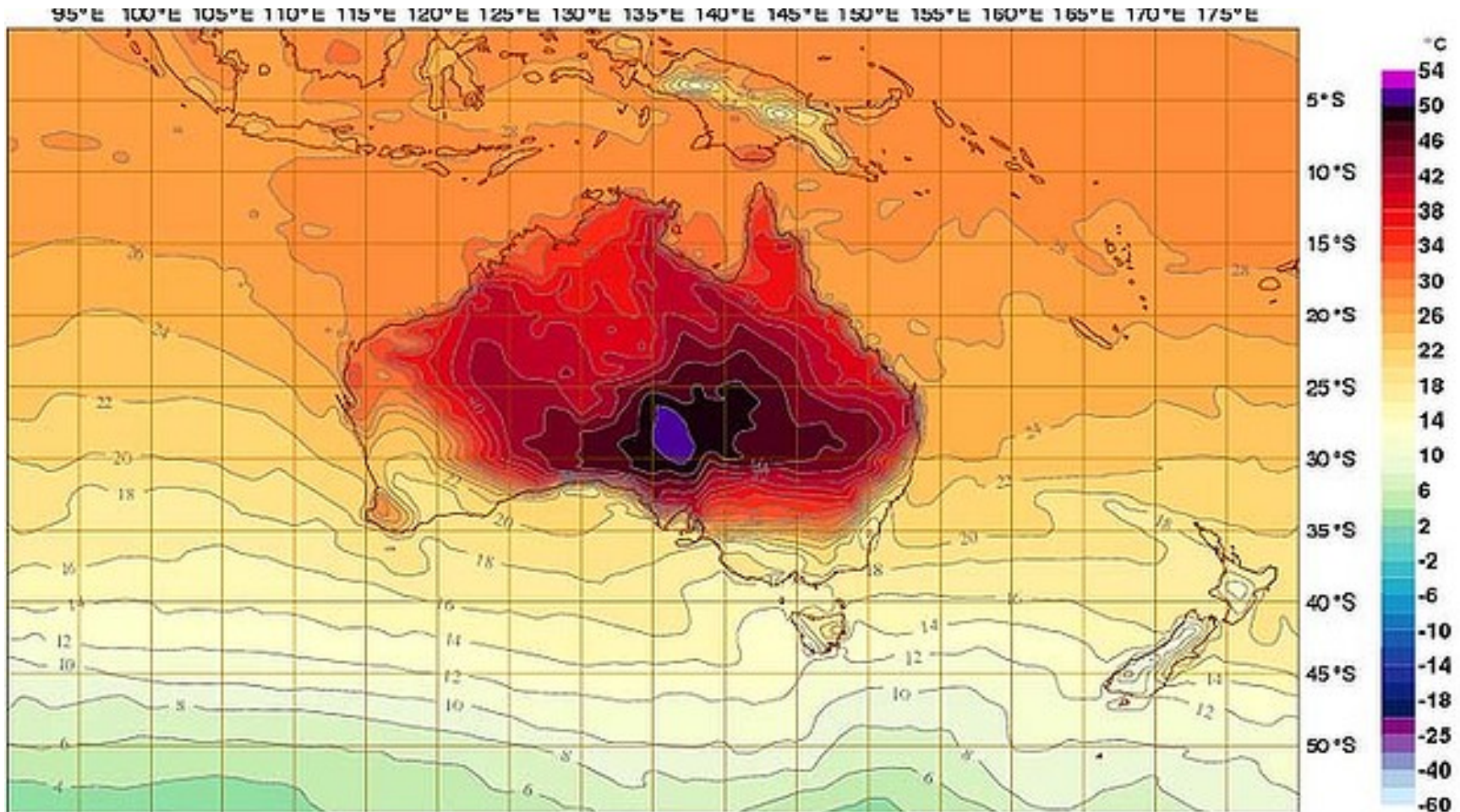


# Projections of Heatwaves over Australia using the CESM model

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# Why study Heat Waves?



# Why study Heatwaves?

- IPCC AR5 concluded it is *likely* that heat waves have increased in frequency over Australia (and Europe)
- Impacts of European/Russian/Black Saturday events spread across many sectors, including massive losses of human life
- Human contribution to the occurrence of the hottest Australian summer on record (2012/2013) has been quantified
- Need projections from climate models to inform us of likely future conditions
- Are they any good at simulating heatwaves?

# Heatwave definition: EHF (excess heat factor)

- Derived by John Nairn (BoM, Adelaide)
- Considers daily Tmax AND Tmin:

$$T = (T_{max} + T_{min}) / 2$$

- Includes an acclimatization factor (monthly):

$$EHI(accl.) = (T_i + T_{i-1} + T_{i-2}) / 3 - (T_{i-3} + \dots + T_{i-32}) / 30$$

- And a significance factor:

$$EHI(sig.) = (T_i + T_{i-1} + T_{i-2}) / 3 - T_{90(cal)}$$

- Which are combined:

$$EHF = \max[1, EHI(accl.) \times EHI(sig.)]$$

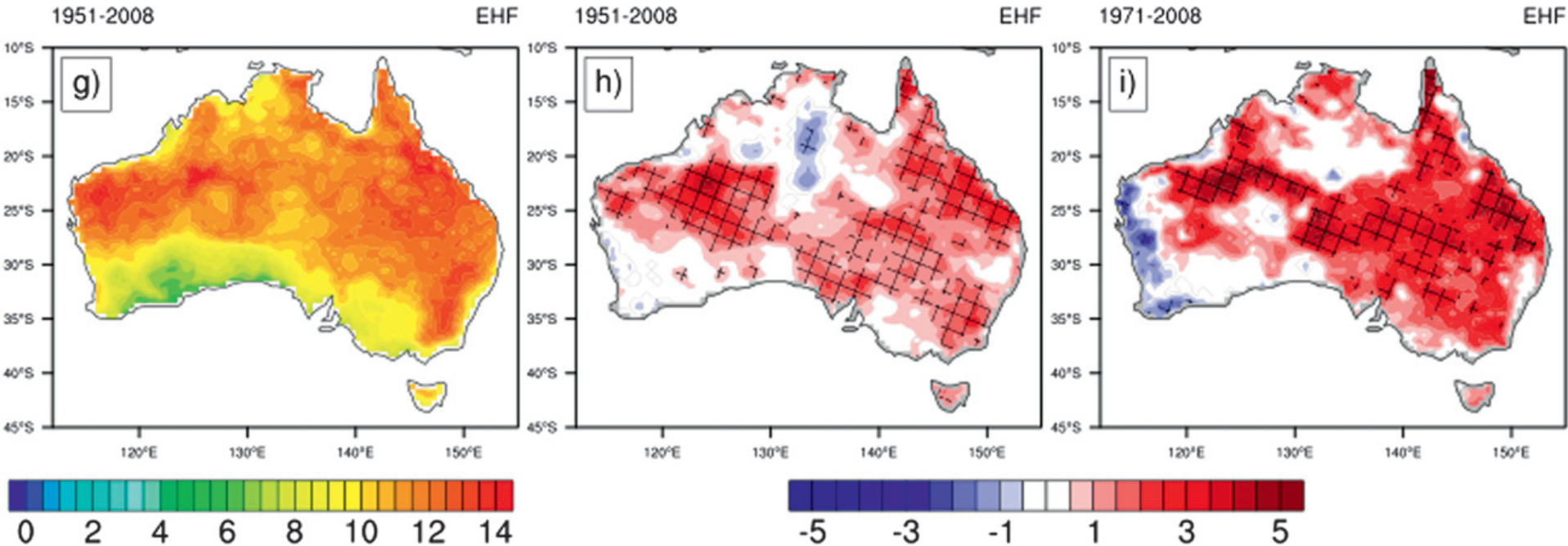
- Interested in POSITIVE EHF values only

# A heatwave occurs when the EHF is positive conditions for AT LEAST 3 consecutive days

What other information do we require?

- HWF - sum of days participating in an event
- HWN – frequency of events
- HWD – length of longest event
- HWA – Hottest day of hottest event (anomaly against seasonal mean)
- HWM – average magnitude of all events (anomaly against seasonal mean)
- HWT – day number of first heat wave for the season
- HWE – spatial extent of an event

# Observed changes in heatwaves



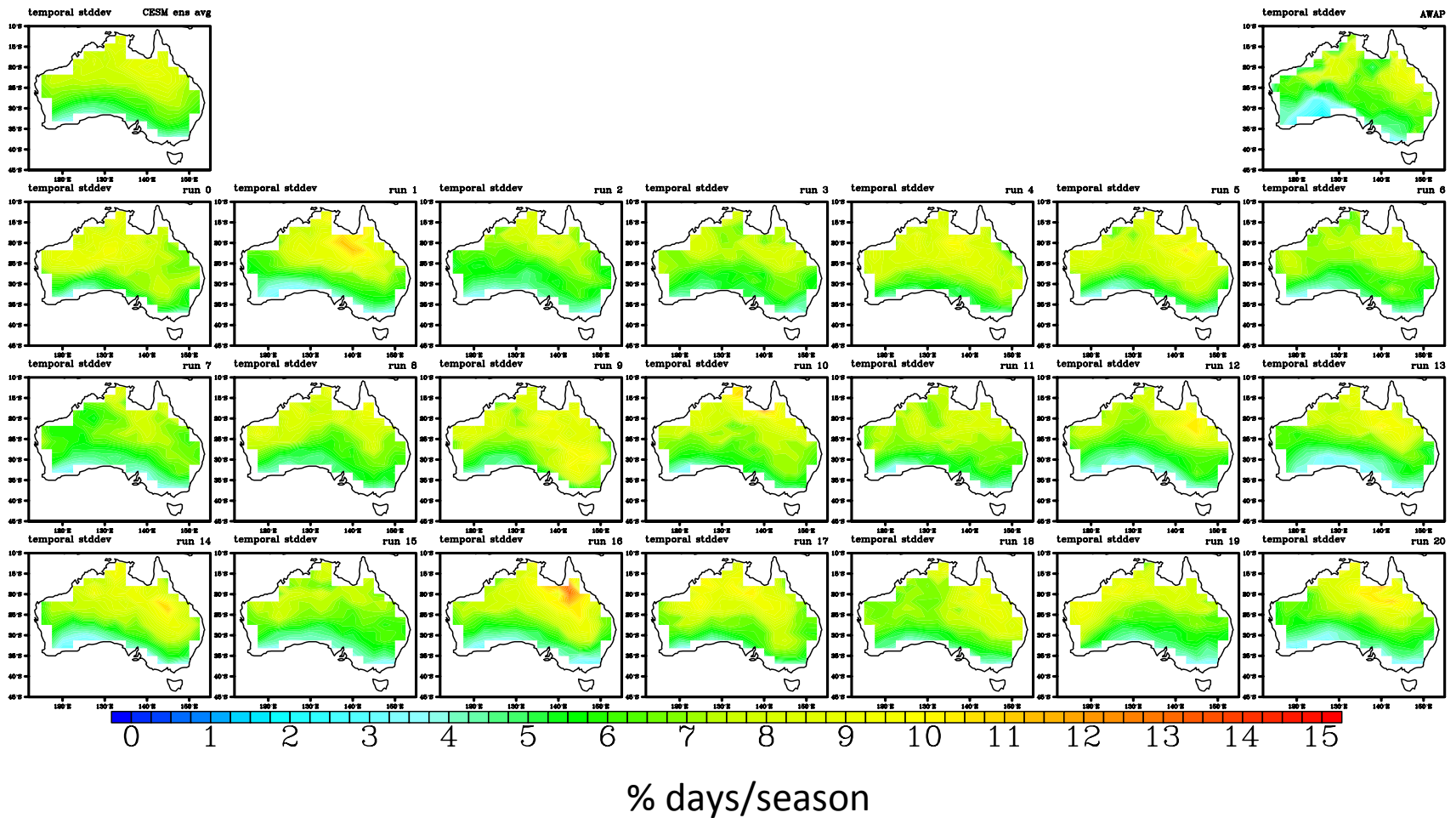
*Perkins and Alexander, Journal of Climate, 2013*

# So, what do climate models say?

- Starting off with just one model, and how well it simulates observed heatwaves (move on to CMIP5 later).
- CESM Global Climate model, 2°x2°, historical simulation
- Compared to AWAP, 1950-2005 for EHF definition, and HWF characteristic
- 21 members, differing only in their initial atmospheric perturbation by  $10^{-13}$
- Everything else is the same – model version, all other initial conditions, prescribed historical anthropogenic forcings
- Aid in determining the role/uncertainty of natural/internal variability on heatwaves
- *Perkins and Fischer (Geophys. Res. Lett., 2013, accepted)*

# ...what do we get?

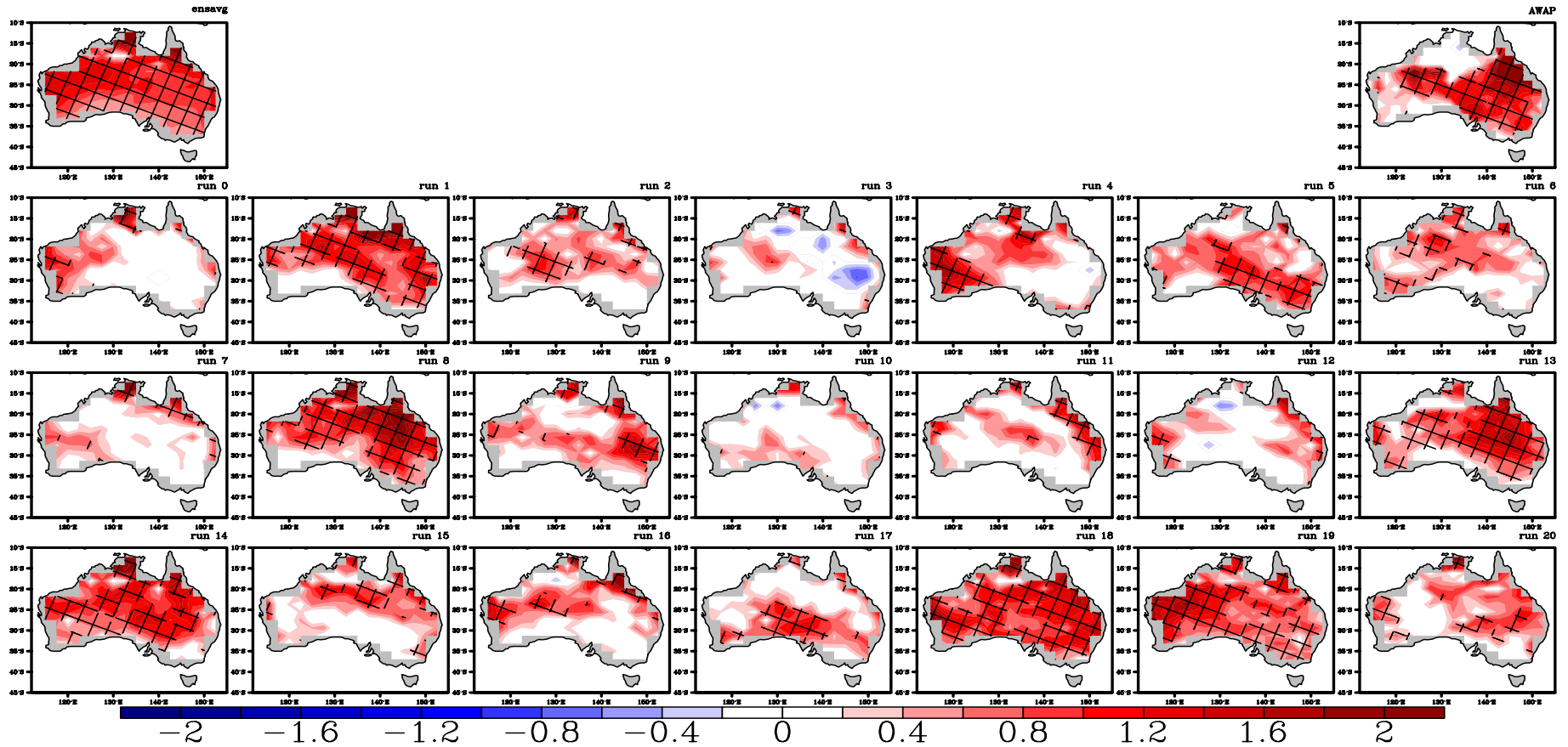
CESM climatology HWF 1950–2005





# ...but the trends!

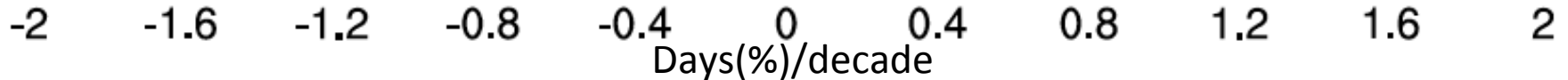
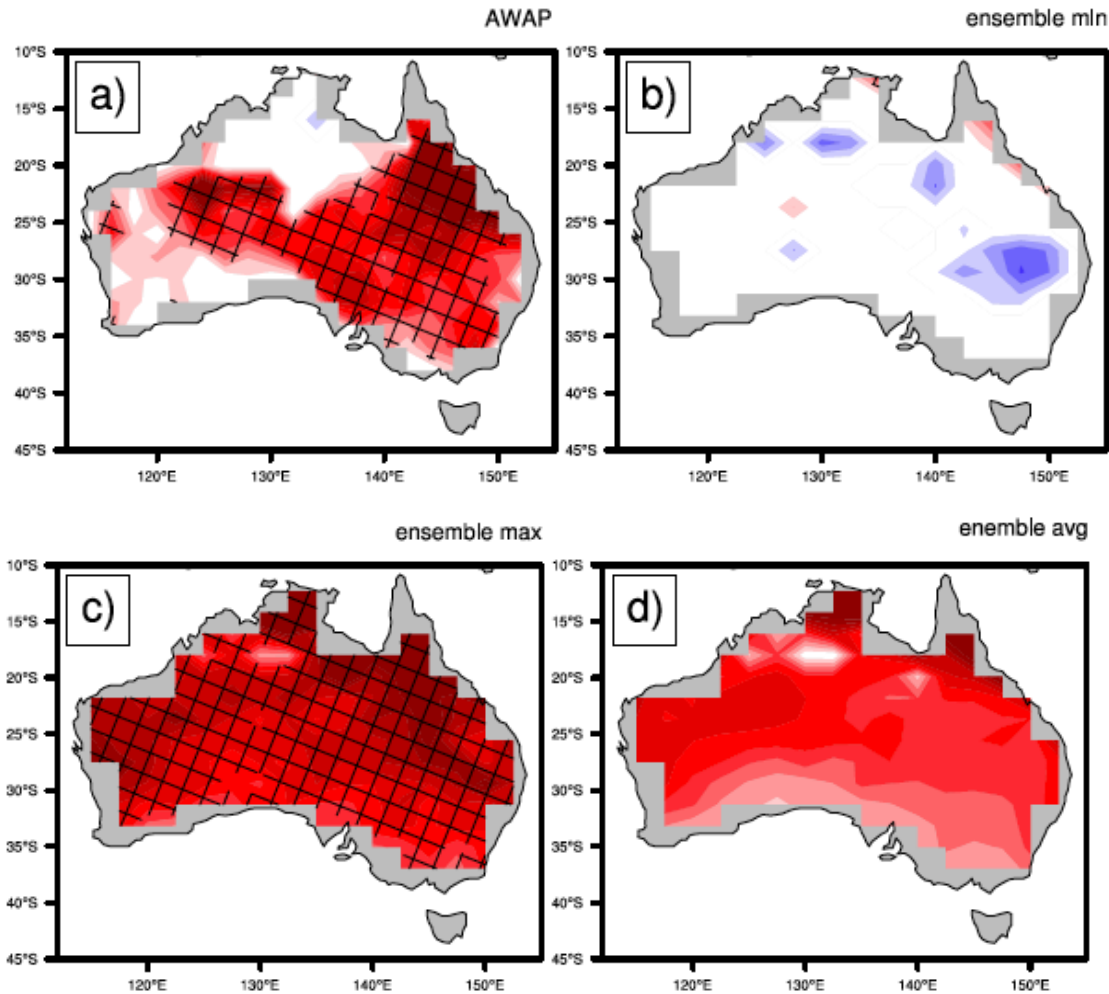
CESM Sen's slope (MK) trend HWF 1950–2005



Days(/decade

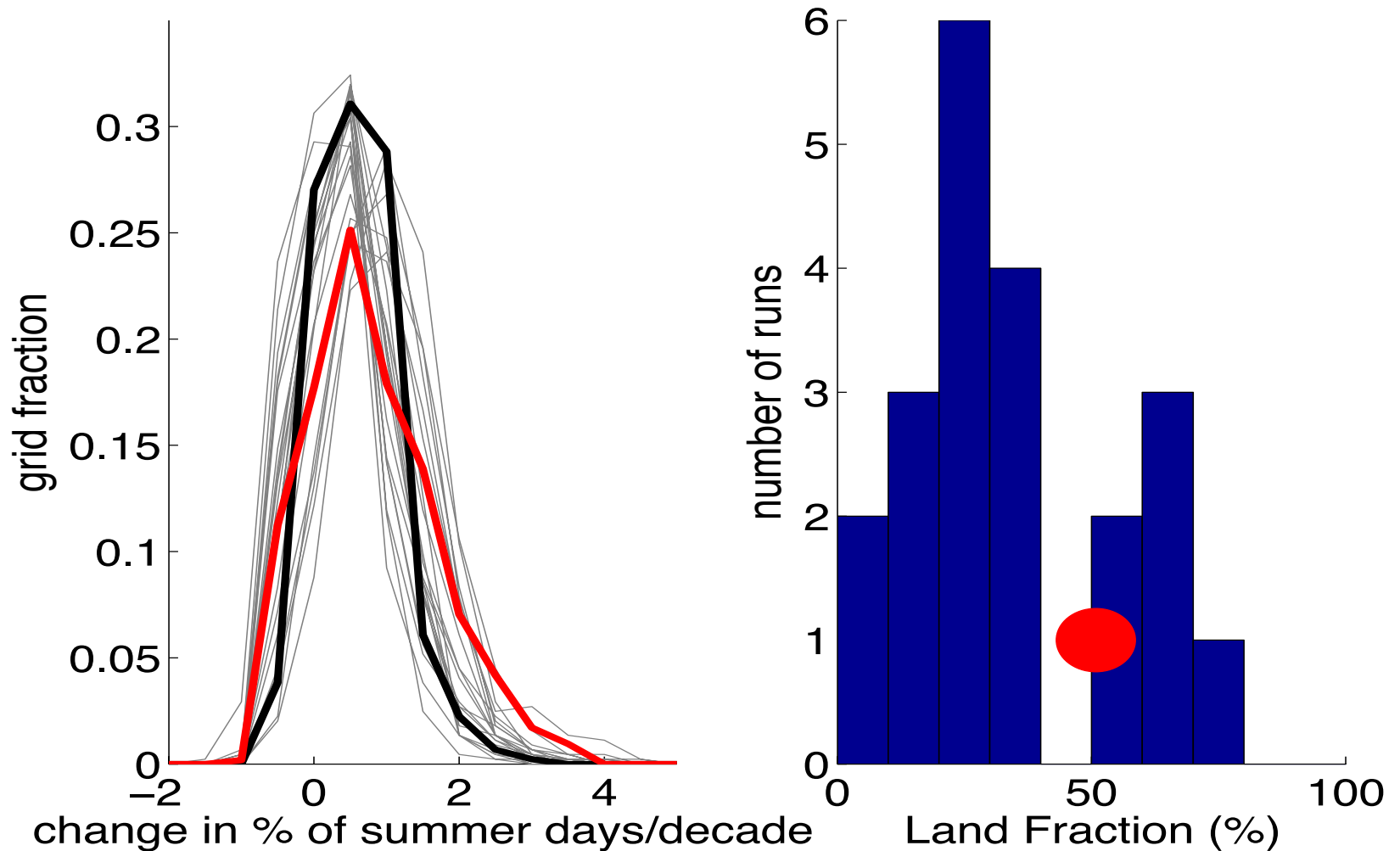
Hatching = significance @ 5% level

# Ensemble vs observations

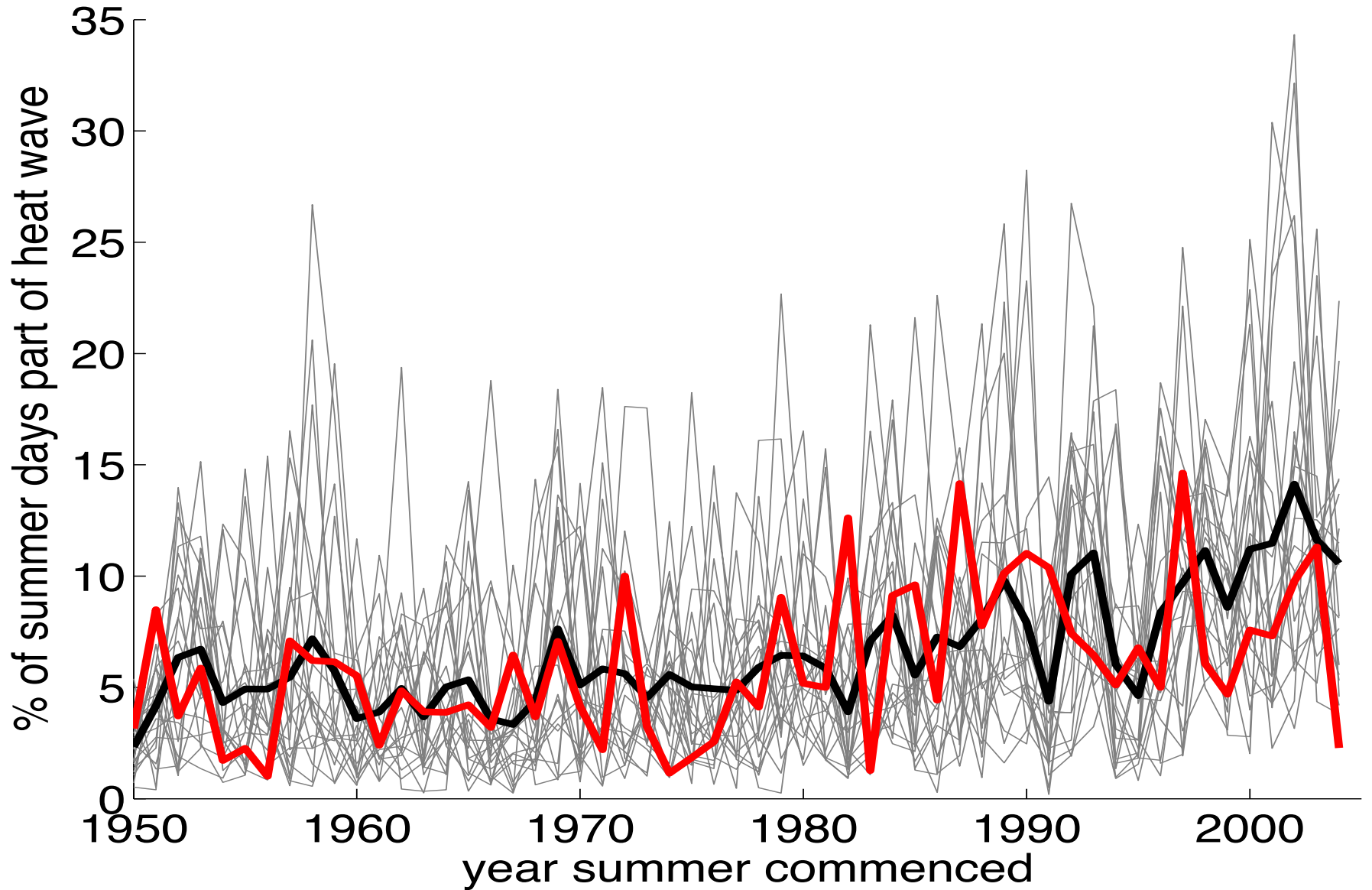


Hatching = significance @ 5% level

# Trend magnitude and significance



# Continentially averaged time series



# What can be learned from this?

- One simulation of a model is not enough! (Pros and cons....)
- Model particulars:
  - overestimation of the number of heatwave days
  - large yearly fluctuations - higher interannual variability than observed?
  - narrow PDFs - overconfidence in estimation of local trends; and not enough spatial variability.

But....

- Spatial pattern, magnitude and significance of trends in CESM are reasonable since AWAP trends lies *within* the ensemble range = a sound representation of heatwave days.
- marked trend towards increasing HWF values in all simulations (and observations) from 1975 onwards

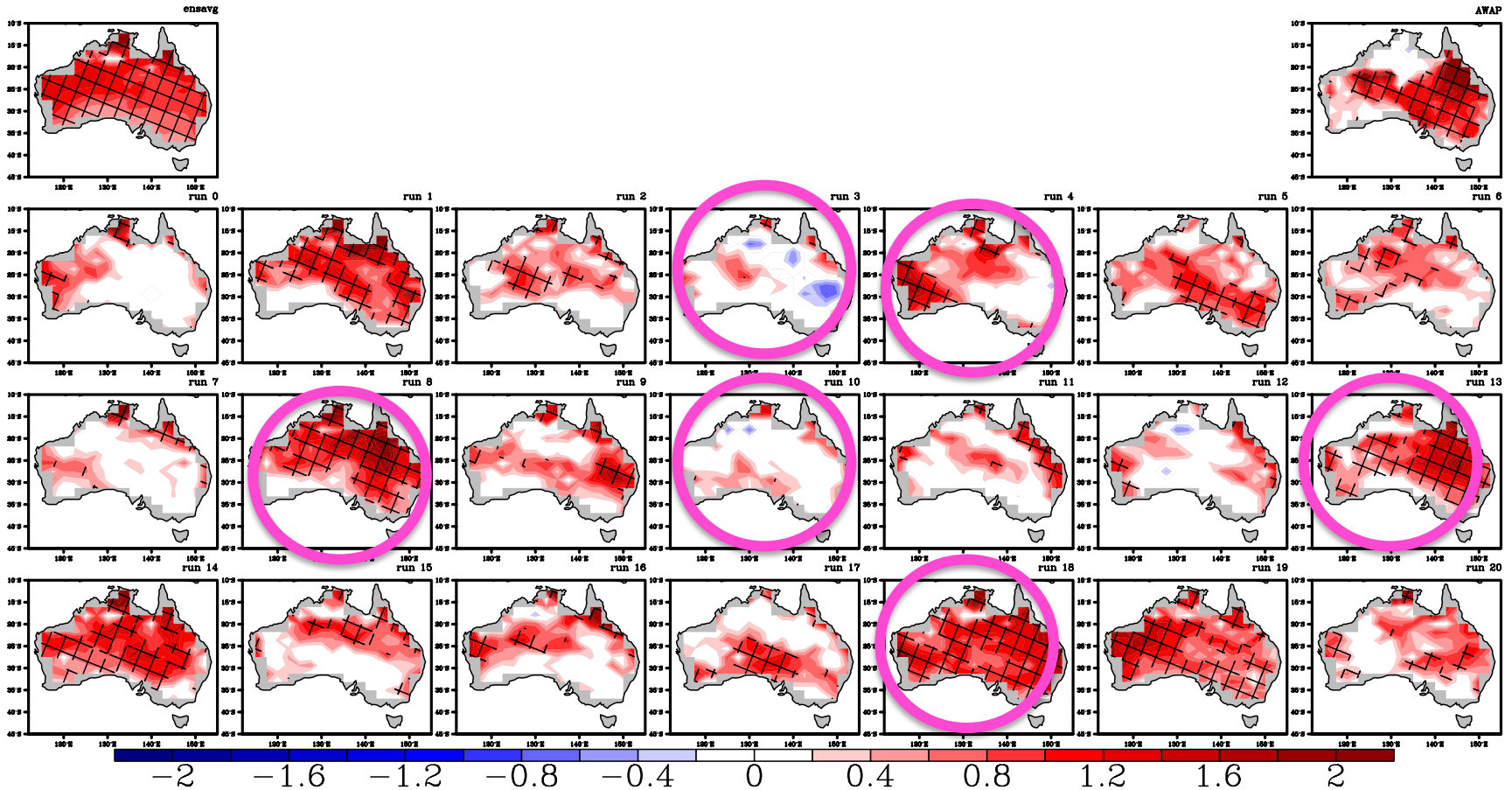
**Evidence that climate models (or, at least CESM) provide realistic & plausible simulations of heat waves – implications for future projections**

Can the historical runs provide us with more information?

# Historical trends HWF (EHF)

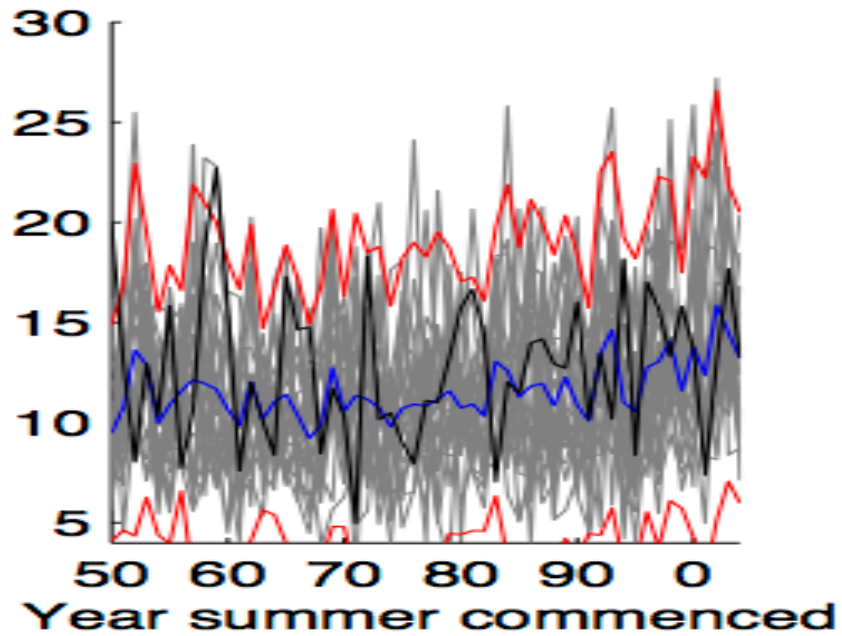
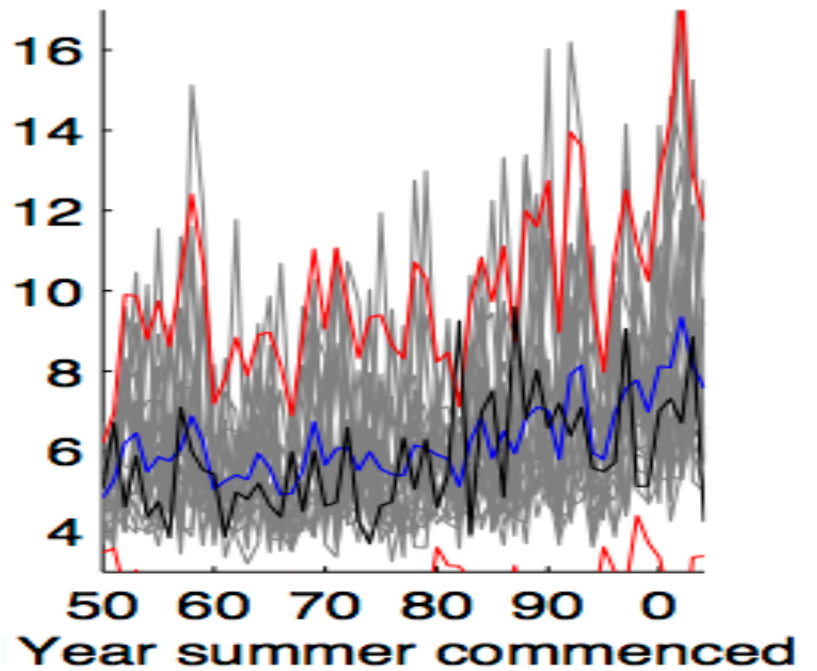
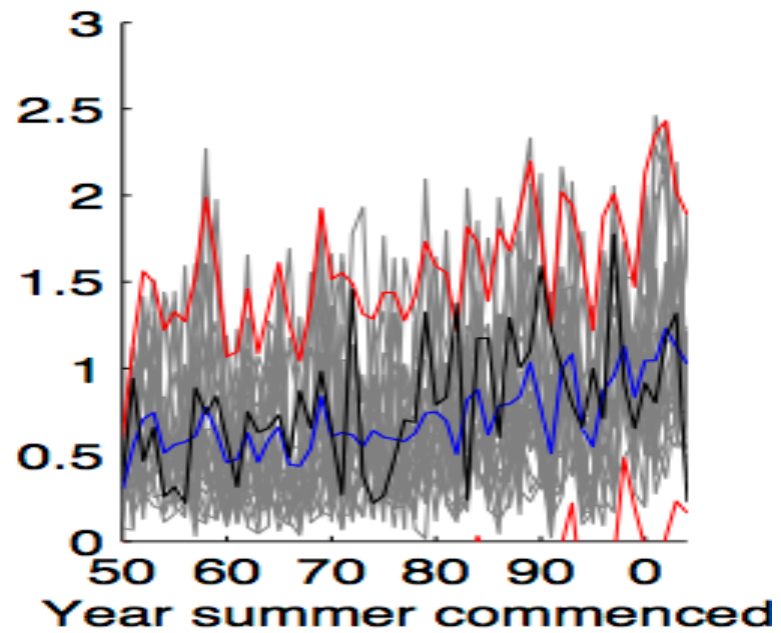
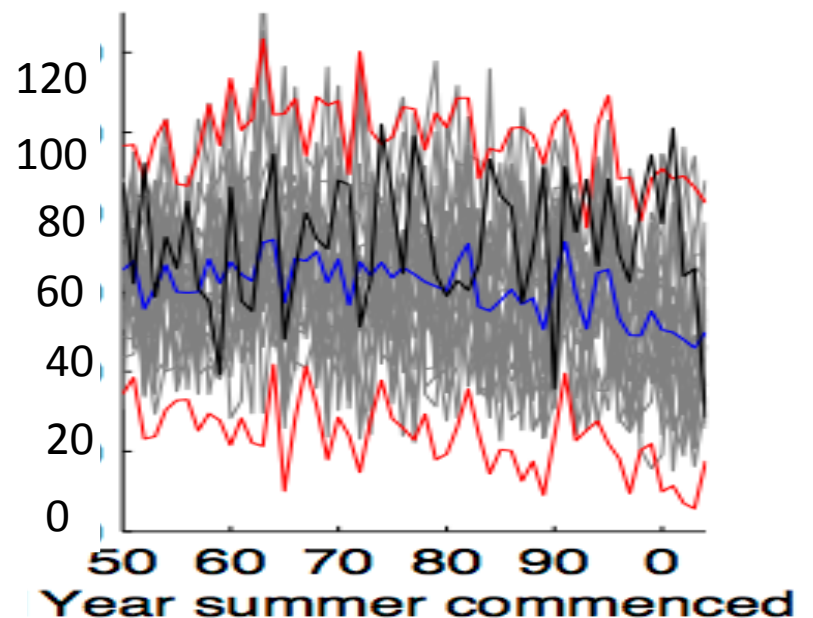
Ensemble average

Observed (AWAP)



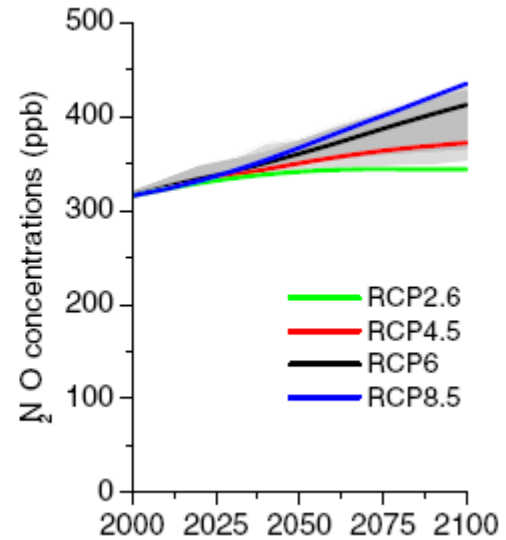
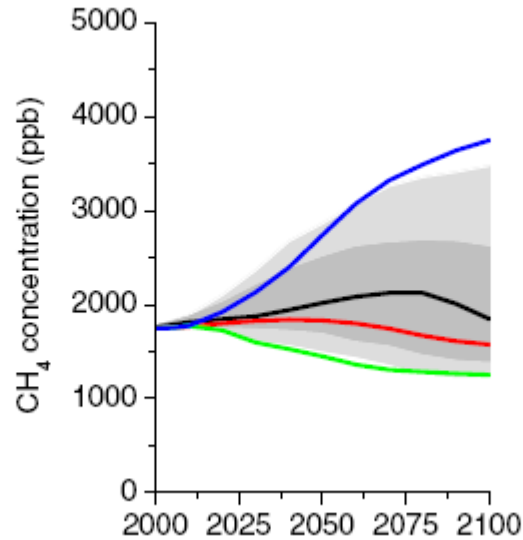
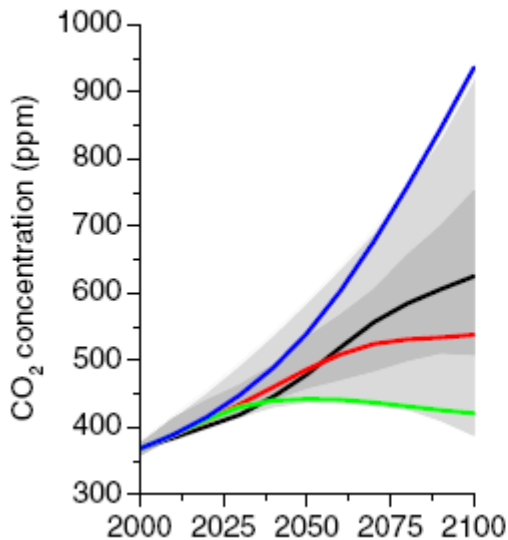
Days(%)/decade

Hatching = significance @ 5% level

**HWA****HWD****HWN****HWT**

# And the future?

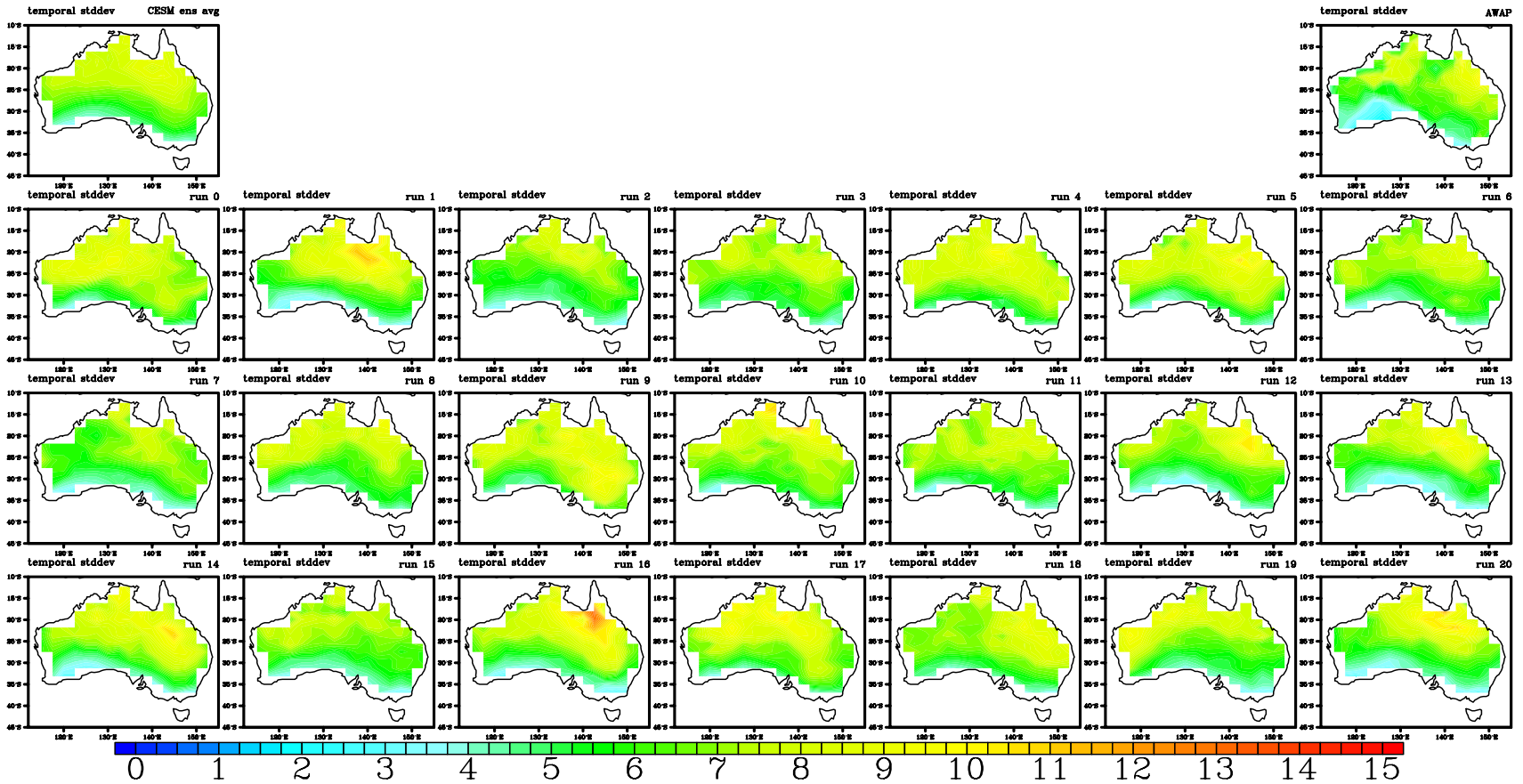
- Same model, projections for the 'RCP8.5' scenario, 2006-2100
- Global average temperature rise of 3.4-5.2°C
- PRELIMINARY results





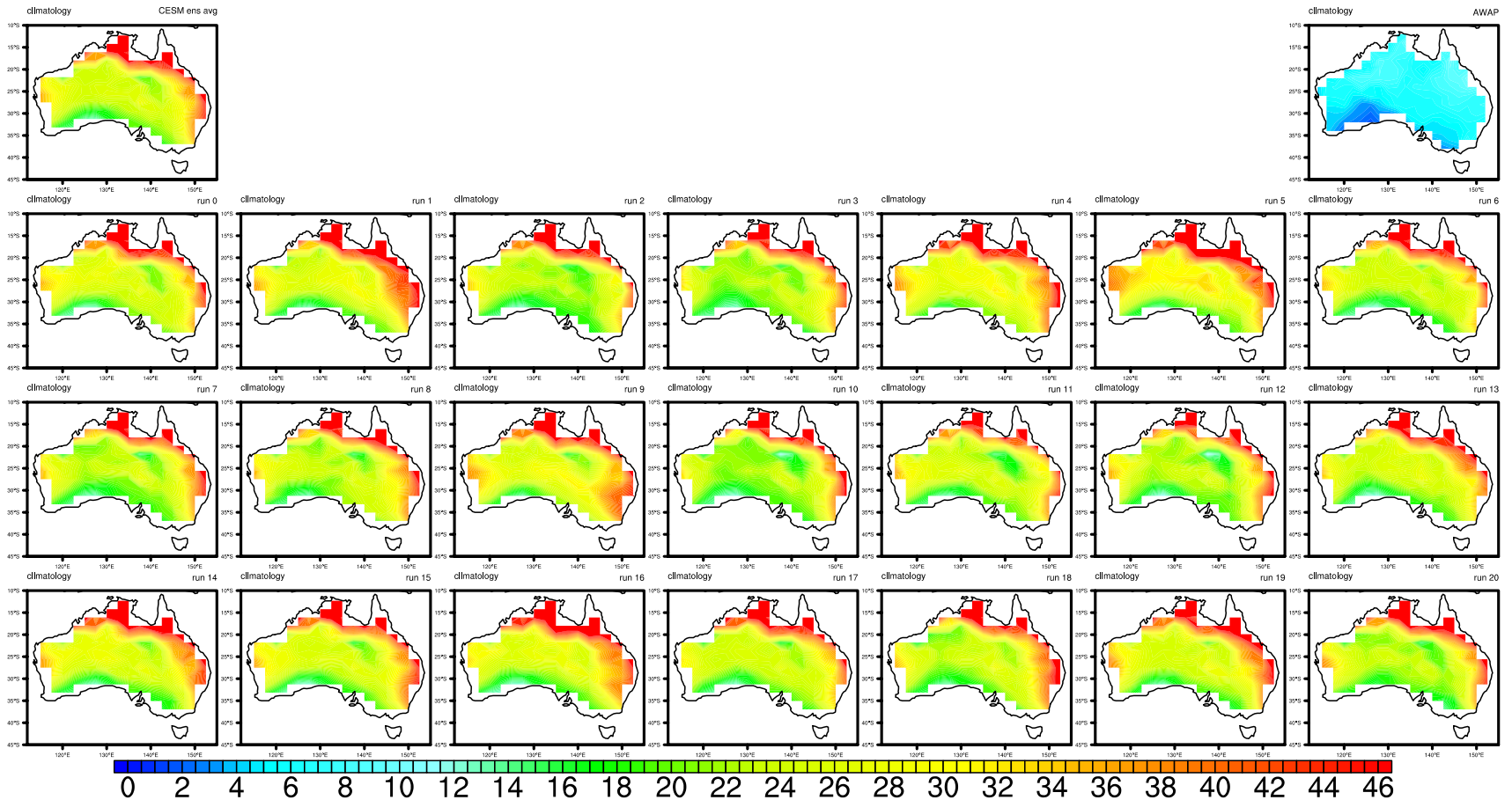
# ...the past...

CESM climatology HWF 1950–2005



# ...and future

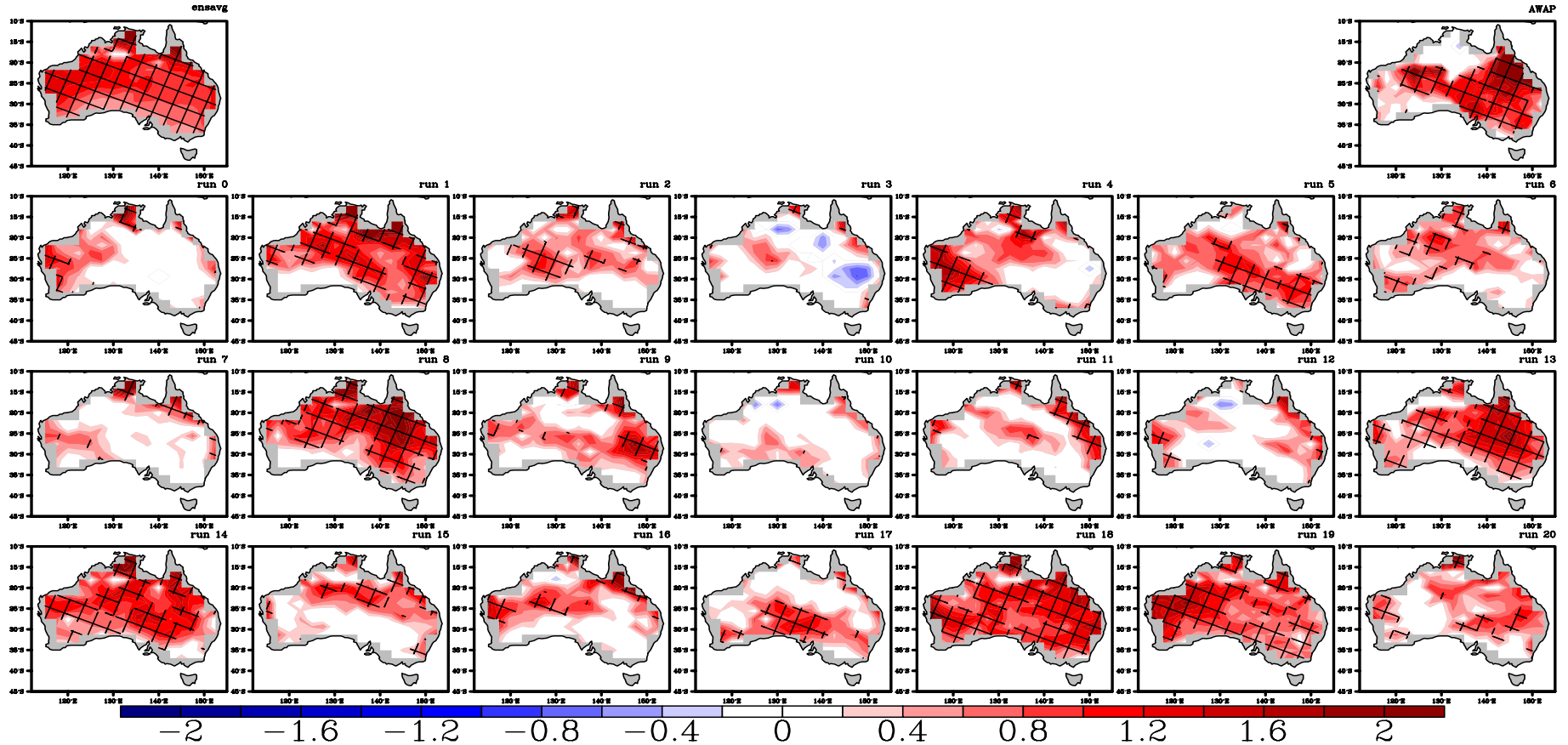
CESM climatology HWF 2006-2100



% days per season

# ...and the trends...

CESM Sen's slope (MK) trend HWF 1950–2005

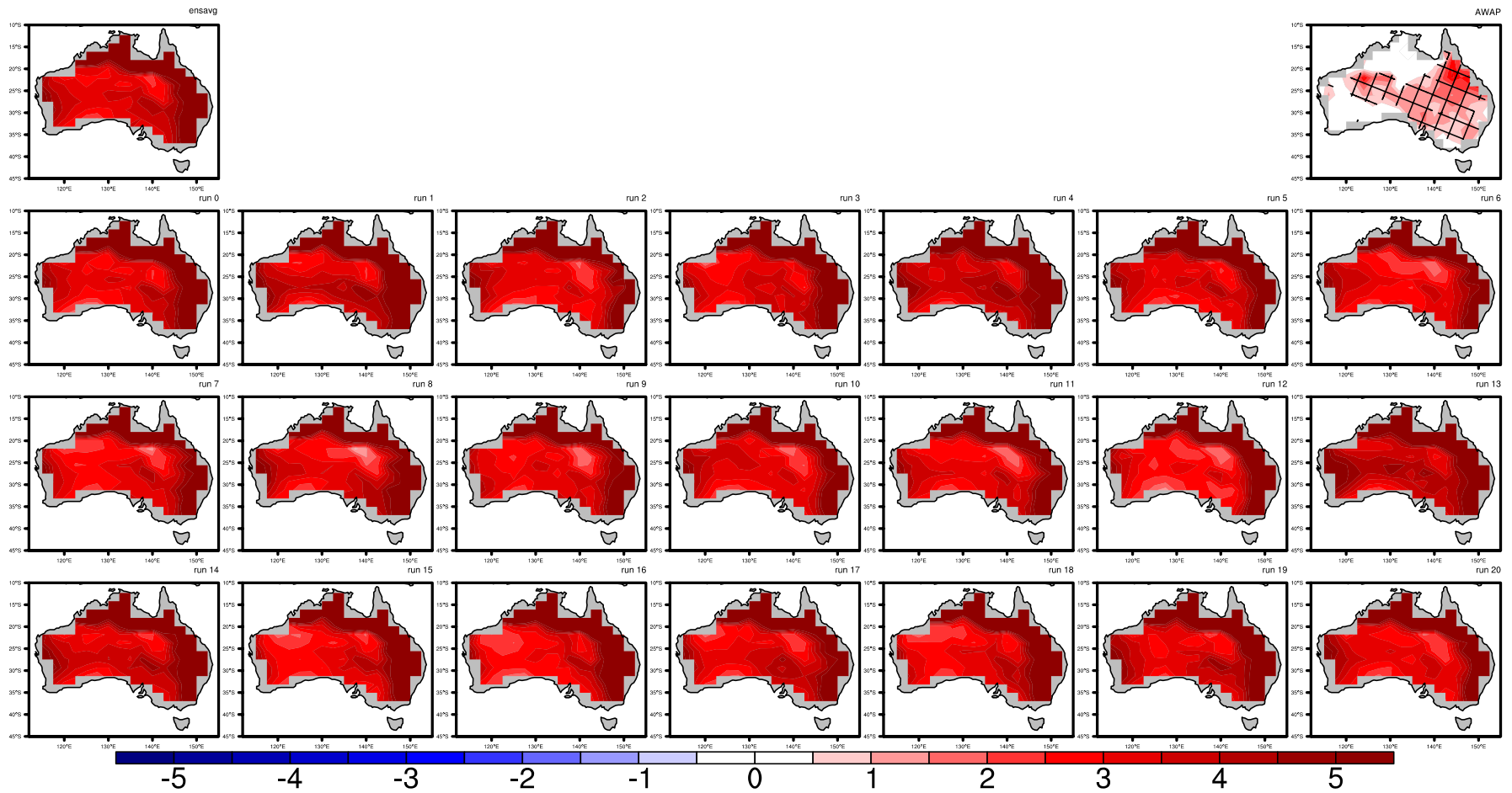


Days(/decade

Hatching = significance @ 5% level

# Yikes!

CESM Sen's slope (MK) trend HWF 2006-2100

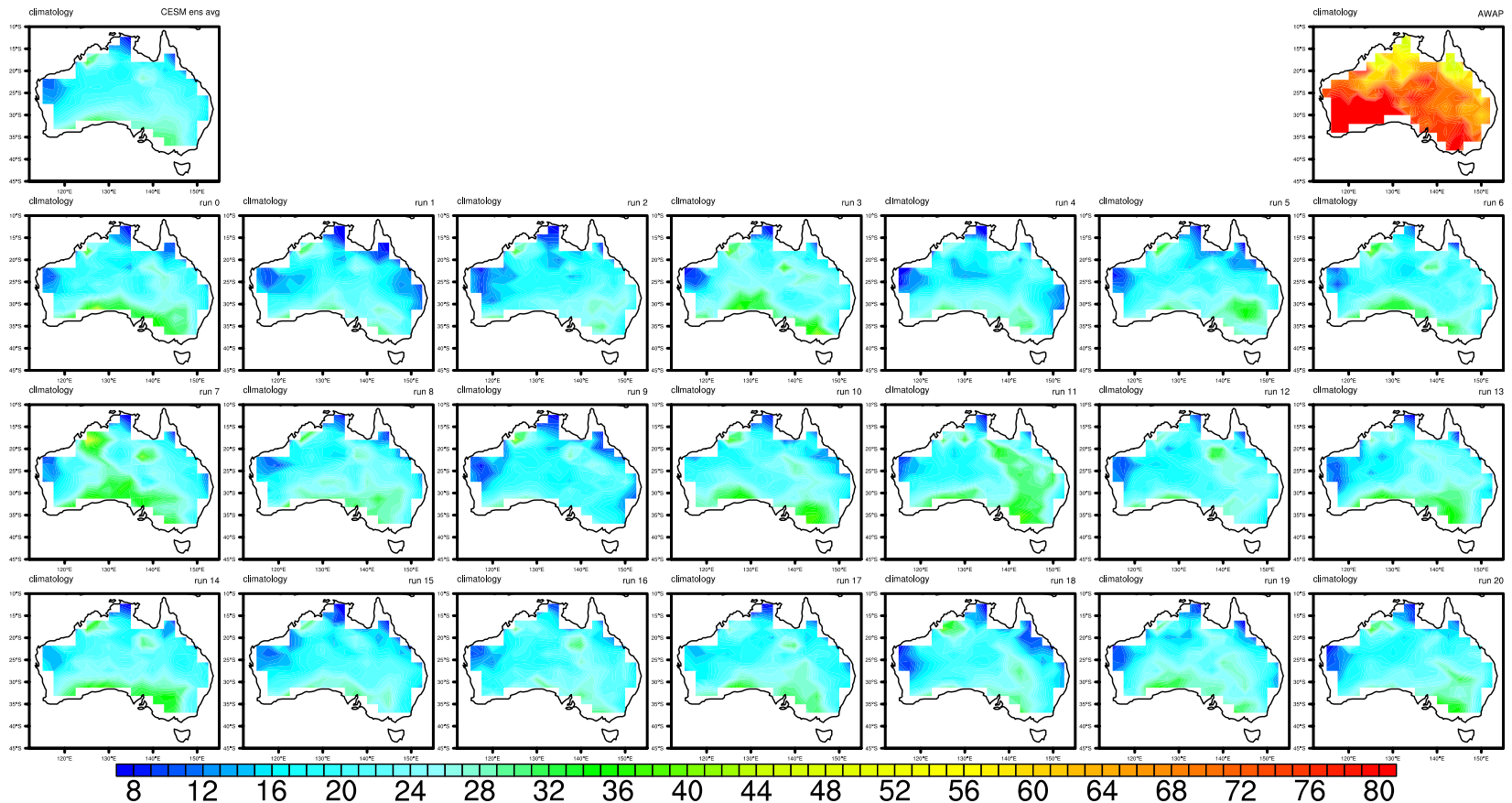


Days(%)/decade

Hatching = significance @ 5% level

# Heatwaves are going to occur earlier...

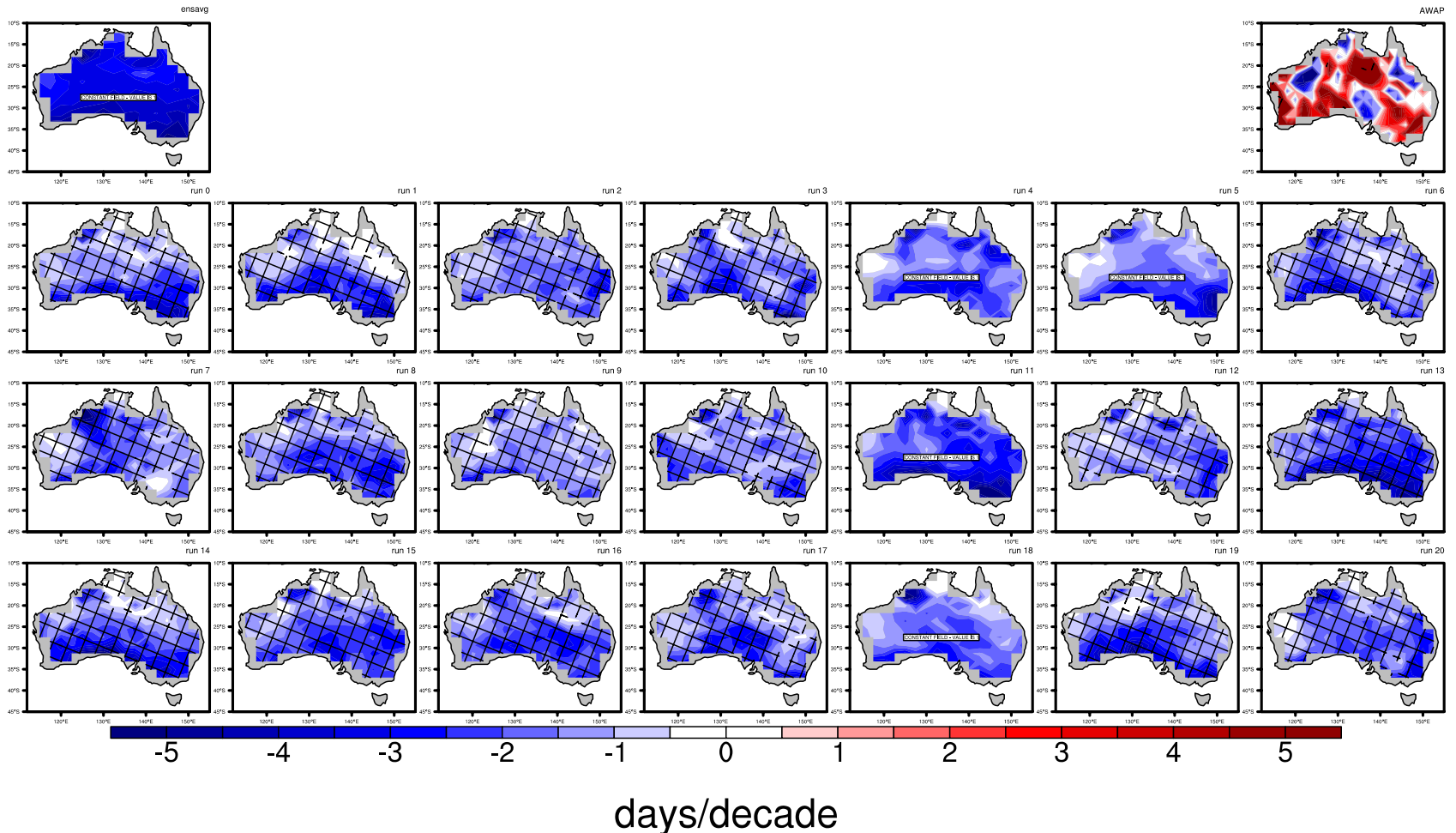
CESM climatology HWT 2006-2100



day number of 1st event (from Nov 1st)

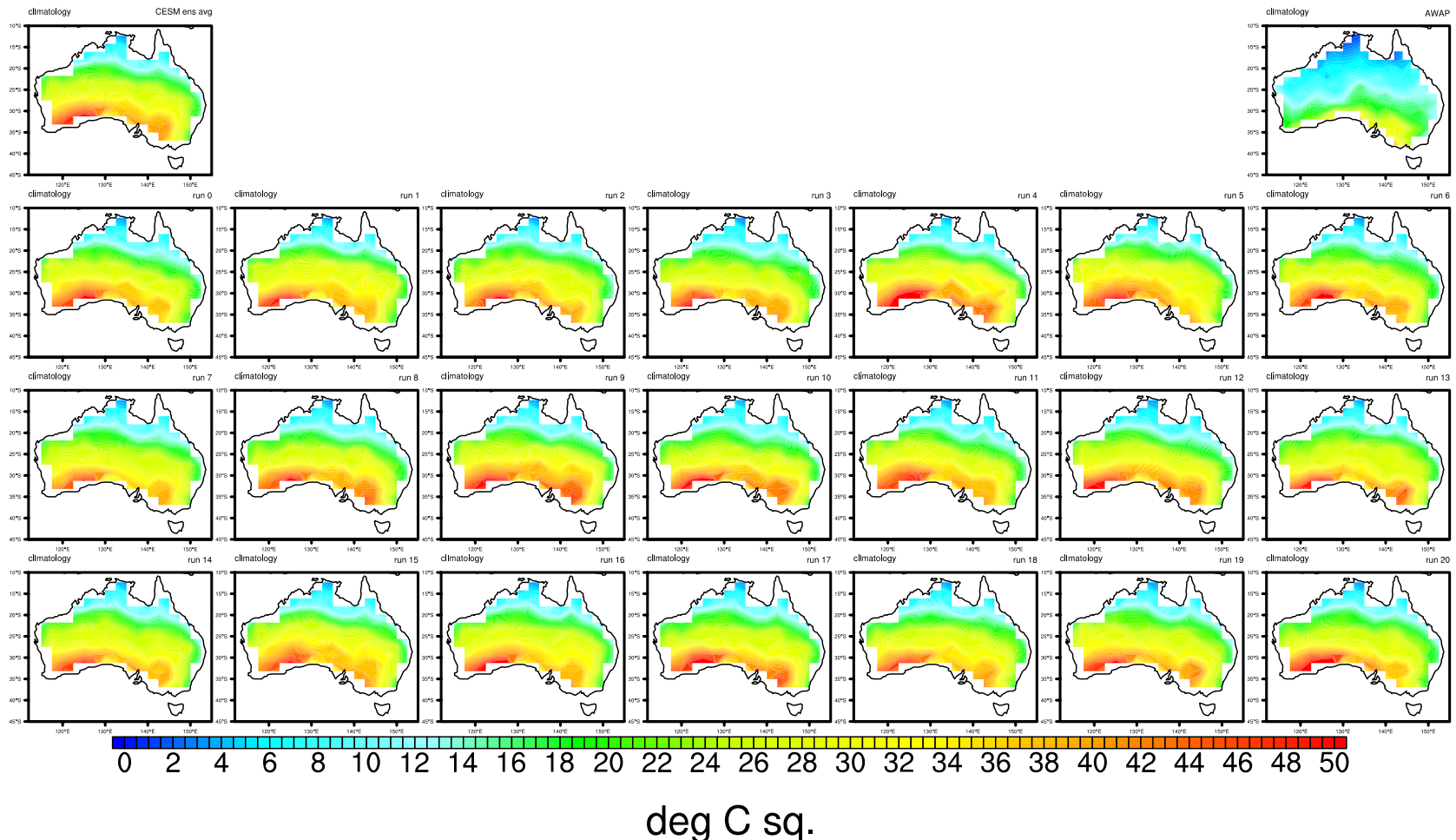
# Heatwaves are going to occur earlier...

CESM Sen's slope (MK) trend HWT 2006-2100



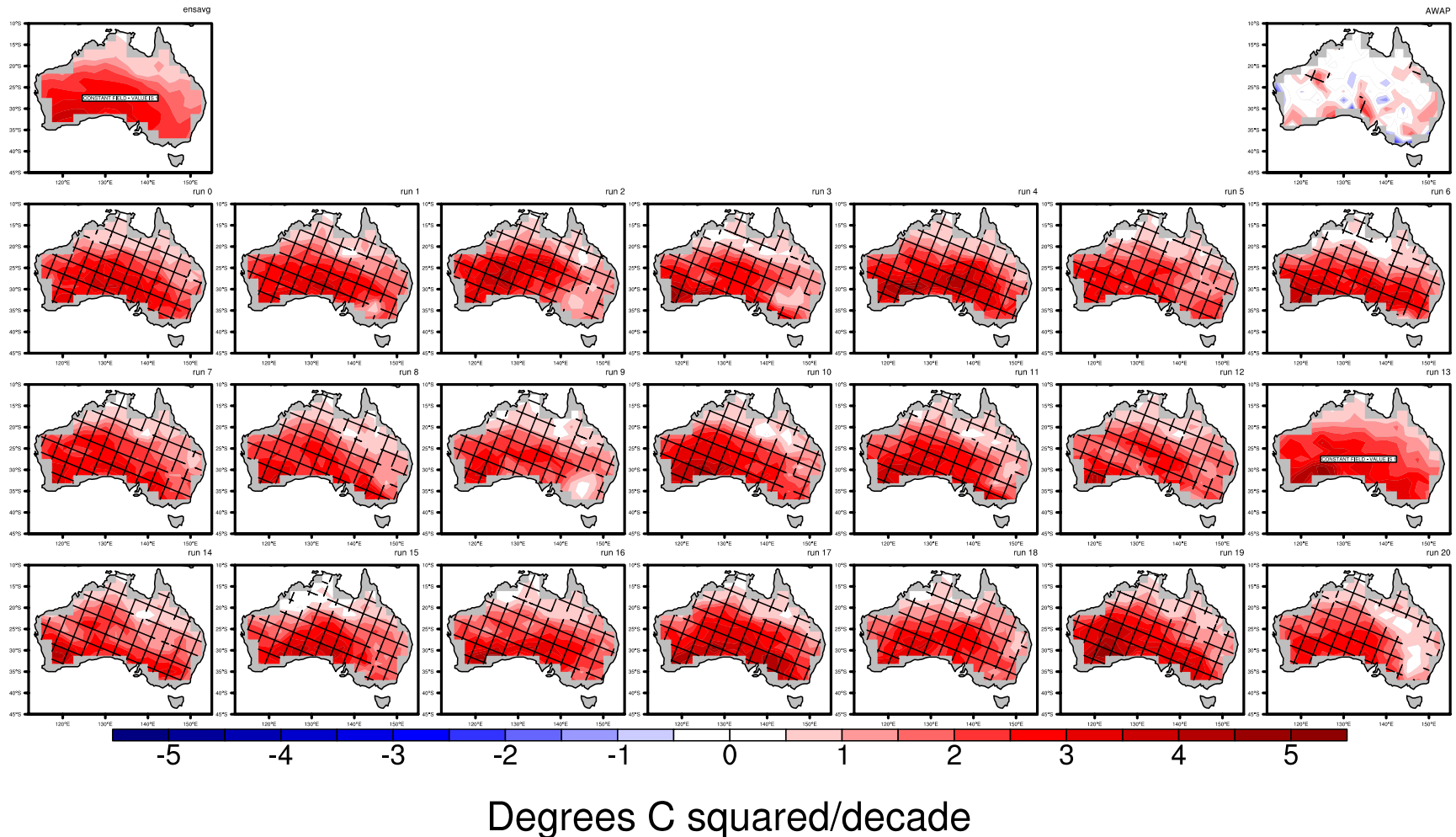
# ...and are going to be more intense

## CESM climatology HWA 2006-2100



# ...and are going to be more intense

## CESM Sen's slope (MK) trend HWA 2006-2100





# Summary and next steps

- The CESM model can realistically simulate historical heatwaves over Australia
- Future projections indicate more heatwaves, that are more intense and occur earlier
- The model is not perfect – indications of too much variability
- But the number, and difference among realizations provides a unique resource
  - Natural drivers
  - Interactions with human-induced climate change
  - Physical interactions
  - FAR studies

Thanks for your time!

Questions?

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