Australian Government
Bureau of Meteorology

Event Attribution with S2S systems

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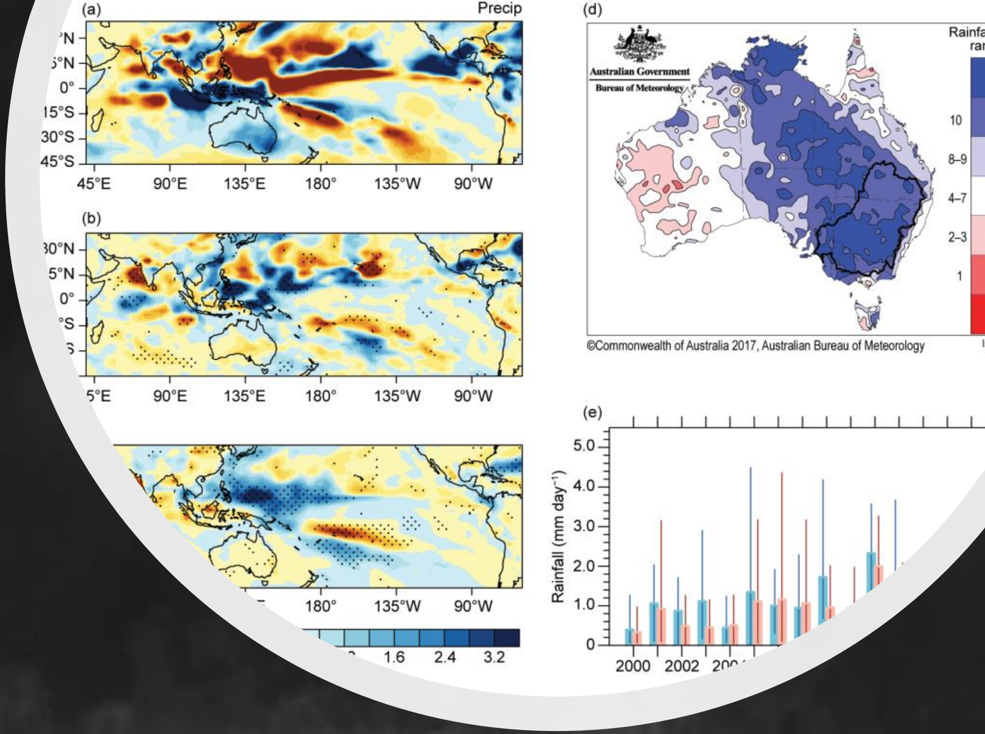
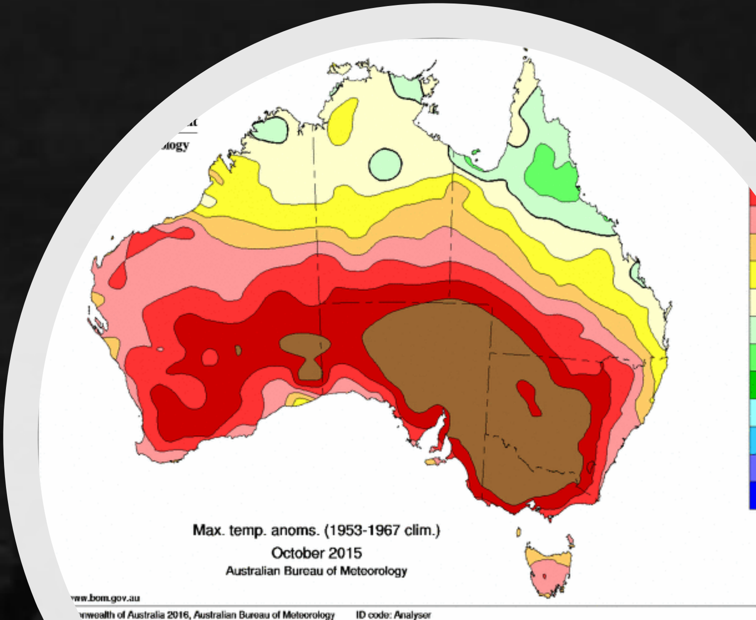
Earth Systems and Climate Change Hub
National Environmental Science Programme

Attributing What to What?

- Attributing **the extremity of a recent multi-week extreme** to **climate change**
- We can analyse the circulation changes also.
- We used the POAMA-S2S-based system to examine extreme heat, rain, dry, frost and fire (BAMS, JSHESS papers).
- Today I want to describe the method in more detail, including the steps to applying the method in ACCESS-S.
- Method paper just published: Wang et al. J. Climate.





Method

Using a sub-seasonal forecasting framework for attributing the extremity of climate extremes to increasing atmospheric CO_2

- Two forecast ensembles of the event:

One forecast under current conditions,

A second forecast with a background climate if CO_2 increase had halted earlier last century:
a 'low CO_2' world

POAMA, ACCESS-S

POAMA

Atmosphere:

Bureau's **A**tmospheric **M**odel v3
(~250km x 250km x 17 vertical levels)

Ocean model:

Australian **C**ommunity **O**cean **M**odel **2**
(200km x 50-150 km x 25 vertical levels)

coupled by **O**cean **A**tmosphere **S**ea **I**ce **S**oil (OASIS, Valcke et al. 2000)

ACCESS-S

Atmosphere:
Unified Model 6.0 N216 (~60 km in the mid-latitudes), Vertical resolution: 85 levels

Ocean 5.0: Nucleus for European Modelling of the Ocean (NEMO ORCA25). ~25km, Vertical resolution: 75 levels.

Coupled by: Ocean Atmosphere Sea Ice Soil coupler (OASIS3)

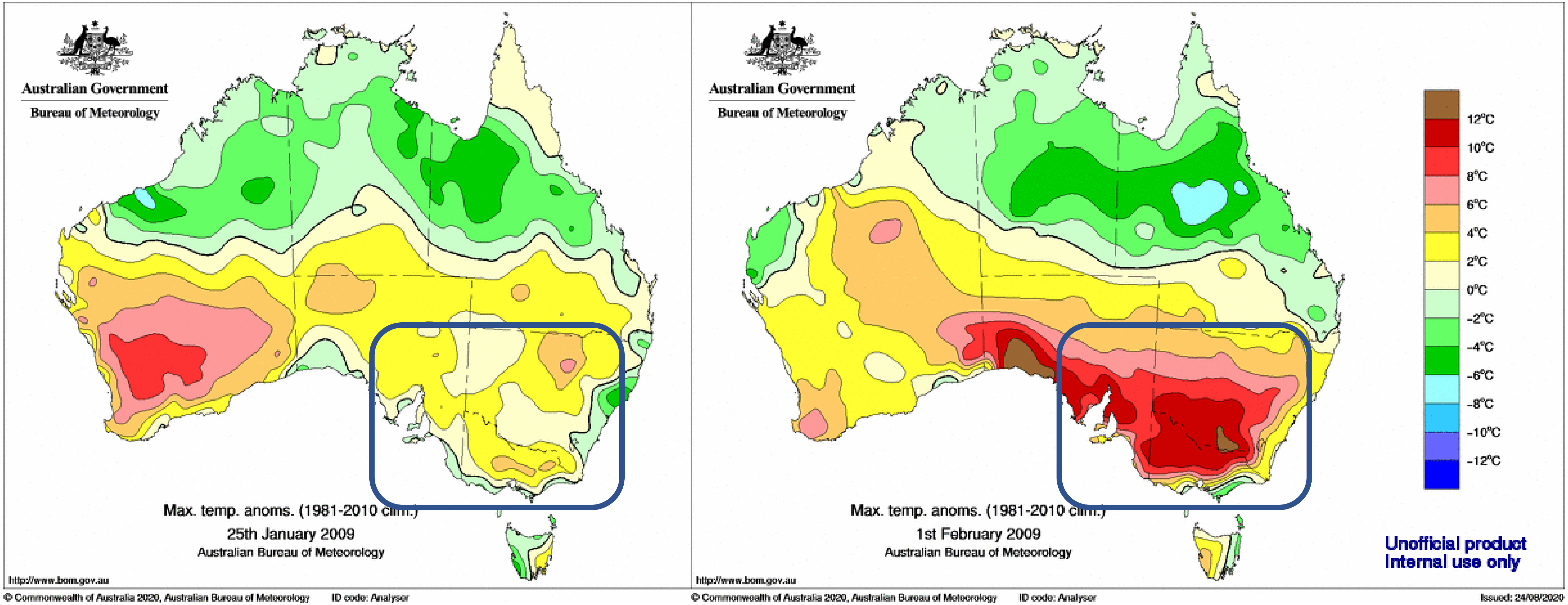
Sea ice model Global Sea Ice 6.0: Los Alamos sea ice model (CICE).

Black Saturday Heatwave Event: 27Jan-8Feb 2009

For details see: http://www.bom.gov.au/climate/current/statements/scs17d.pdf

Combination of two episodes: **28-31Jan** and **6-8 Feb**

Tmax anomalies : end of Jan 2009 (left) and 1st week of Feb 2009 (right)



Reported to have killed 384 people

POAMA Forecast Initialisation – *current climate*

11 member ensemble forecasts initialised on the 23 January 2009 & verified for 28 Jan – 8 Feb 2009

CO_2 concentration was set to **~400ppm** 2009 levels (NOAA Mauna Loa CO_2 data)

Realistic ocean initial conditions generated from PEODAS
(Yin et al. 2011 Mon. Wea. Rev.)

Realistic atmosphere and land initial conditions generated from ALI (Hudson et al. 2010 Clim. Dyn.)

POAMA Attribution Forecast Initialisation: *low CO_2 climate.*

2009 initial conditions, but background climate as it would be if CO_2 increase had halted at 1960.

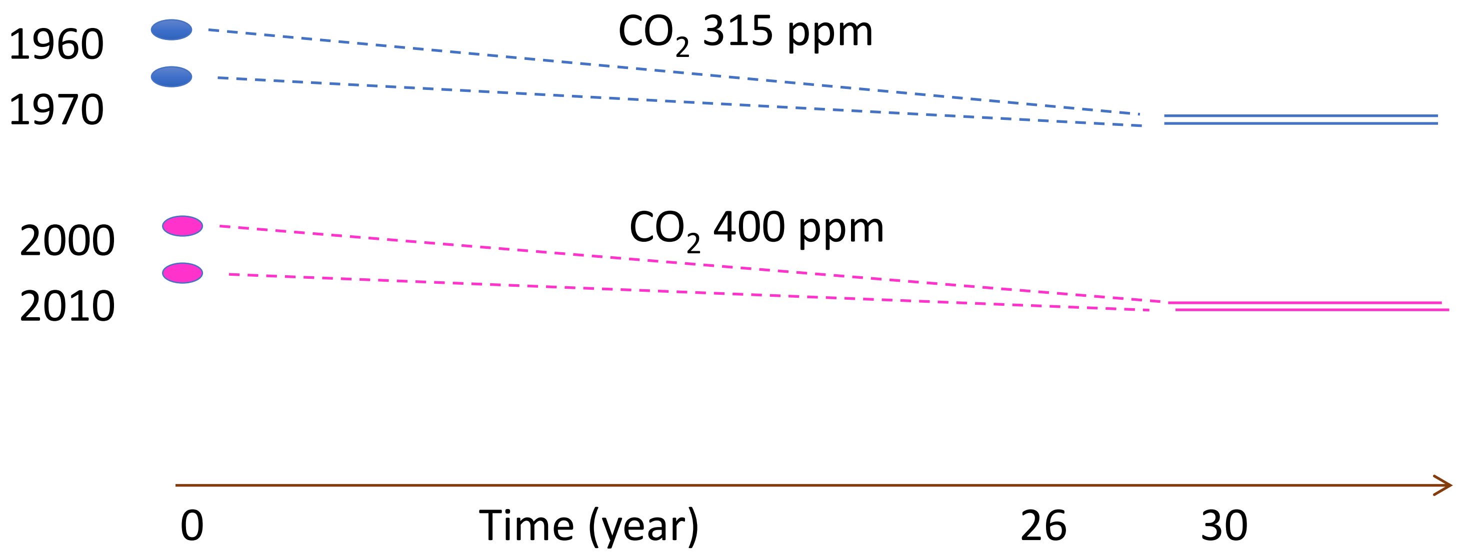
11 member ensemble forecasts initialised on the 23 January 2009 & verified for 28 Jan – 8 Feb 2009

CO_2 concentration was set to **315 ppm** ~ 1960 level (NOAA Mauna Loa CO_2 data)

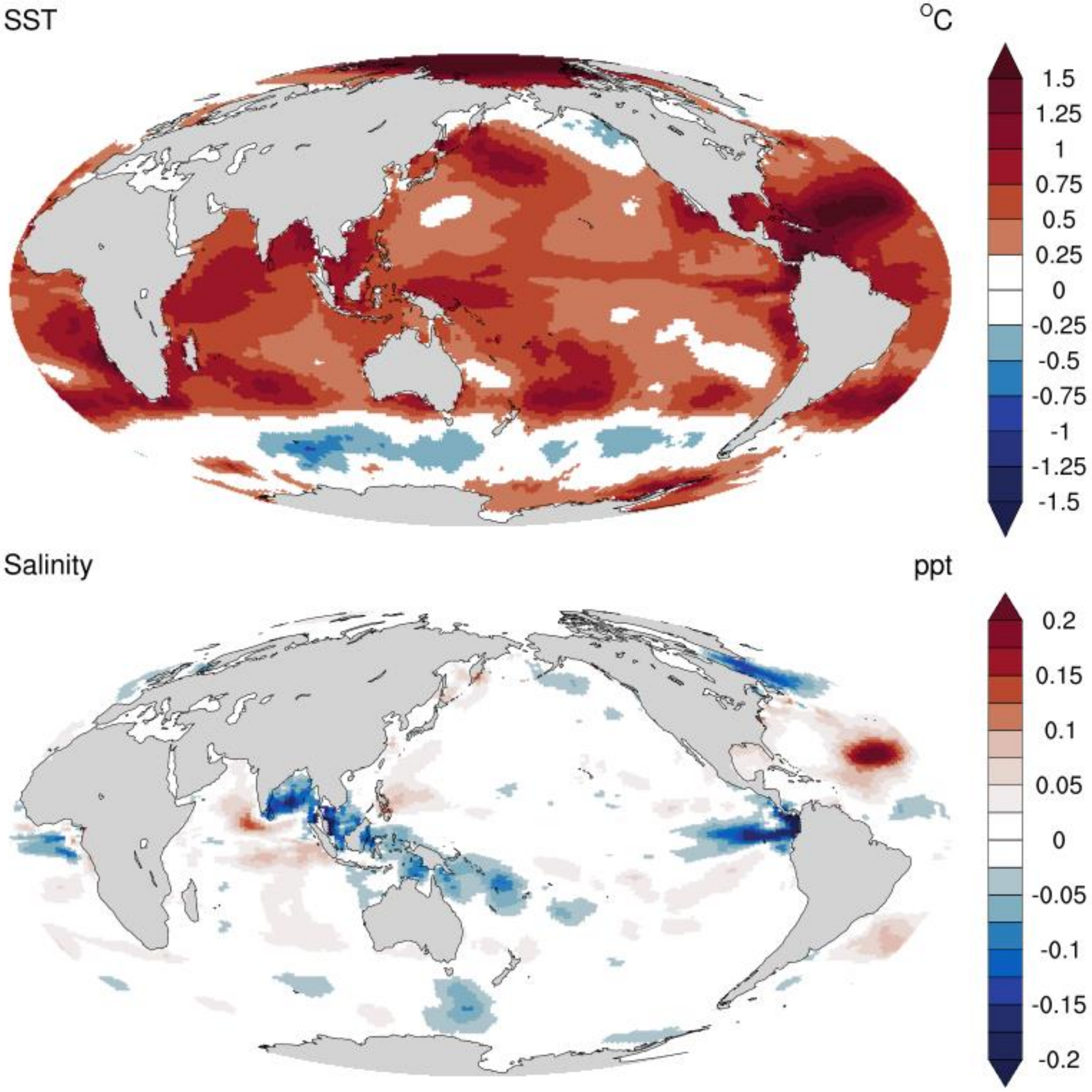
Realistic ocean initial conditions generated from PEODAS ***minus*** an estimate of change due to CO_2 over last 58 years

Realistic atmosphere and land initial conditions ***minus*** an estimate of change due to CO_2 over last 58 years

Estimate ocean change due to CO_2 increase with POAMA long climate runs



Difference of last 5 years of low CO_2 and current: D_{Ocean}.



January Docean for POAMA

Docean = Difference of five years at the end of two 30 year long runs of POAMA with 400 ppm and 315 ppm CO_2

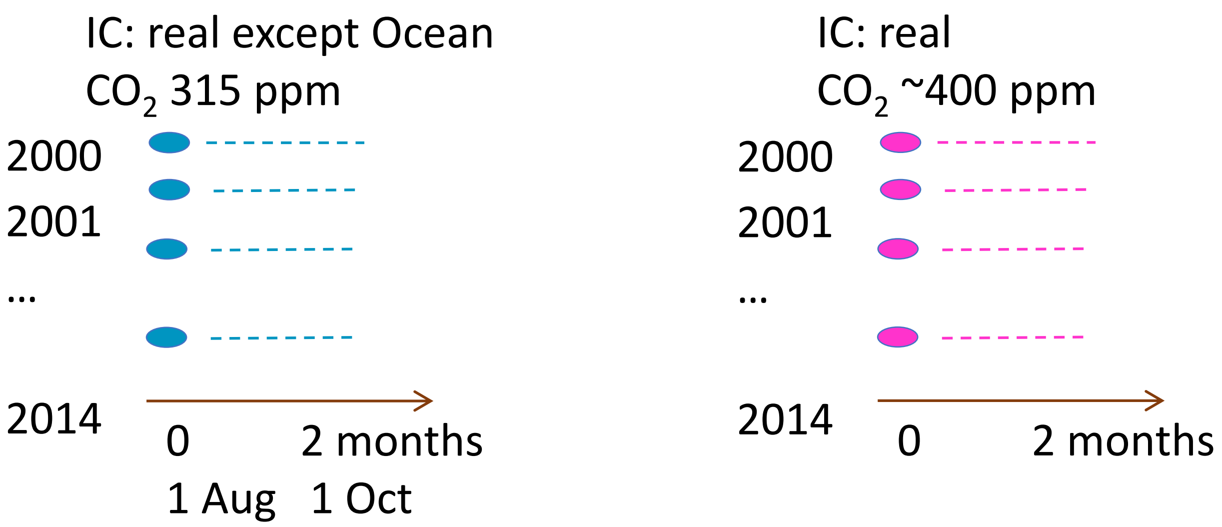
All ocean levels.

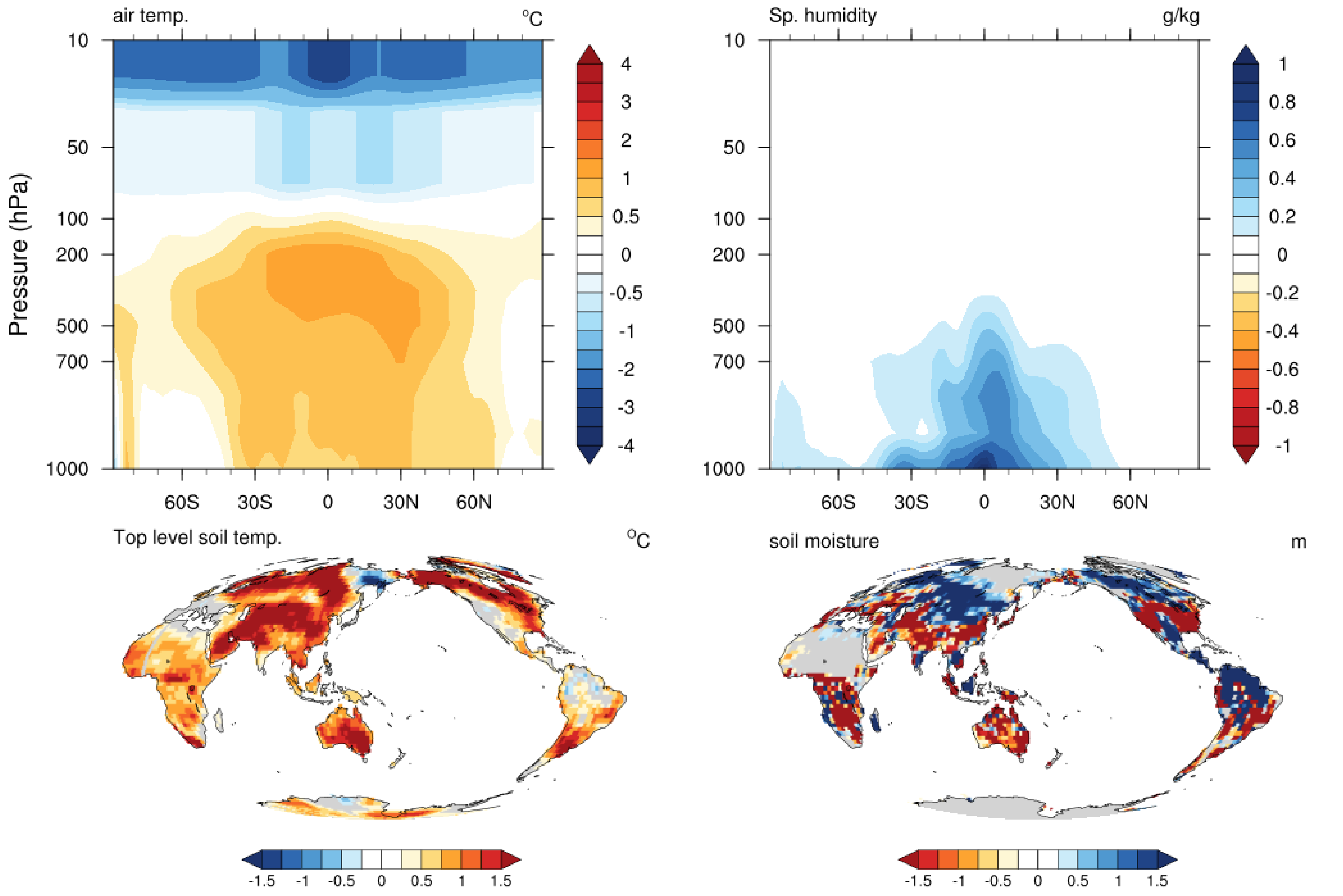
Fixed sea-ice.

Current – lowCO_2

Estimate Land and Atmosphere Changes due to CO_2 increase, with POAMA forecasts

Both land and atmosphere respond to the oceans in ~two months time
Their change due to CO_2 can be estimated by difference between the mean two month lead forecasts over many years. Reducing internal variability and enhancing the signal, reflecting the response to low CO_2 and the lowCO_2 ocean





POAMA January

Datmos

Dland

Current – lowCO2

ACCESS-S1 Forecast Initialisation – *current climate*

11 member ensemble forecasts initialised on the 17 January 2009 & verified for 28 Jan – 8 Feb 2009

CO_2 concentration was set to **~400ppm** 2009 levels (NOAA Mauna Loa CO_2 data)

Met Office Forecast Ocean Assimilation Model (FOAM) which uses the NEMO 3-dimensional variational ocean data assimilation (NEMOVAR)

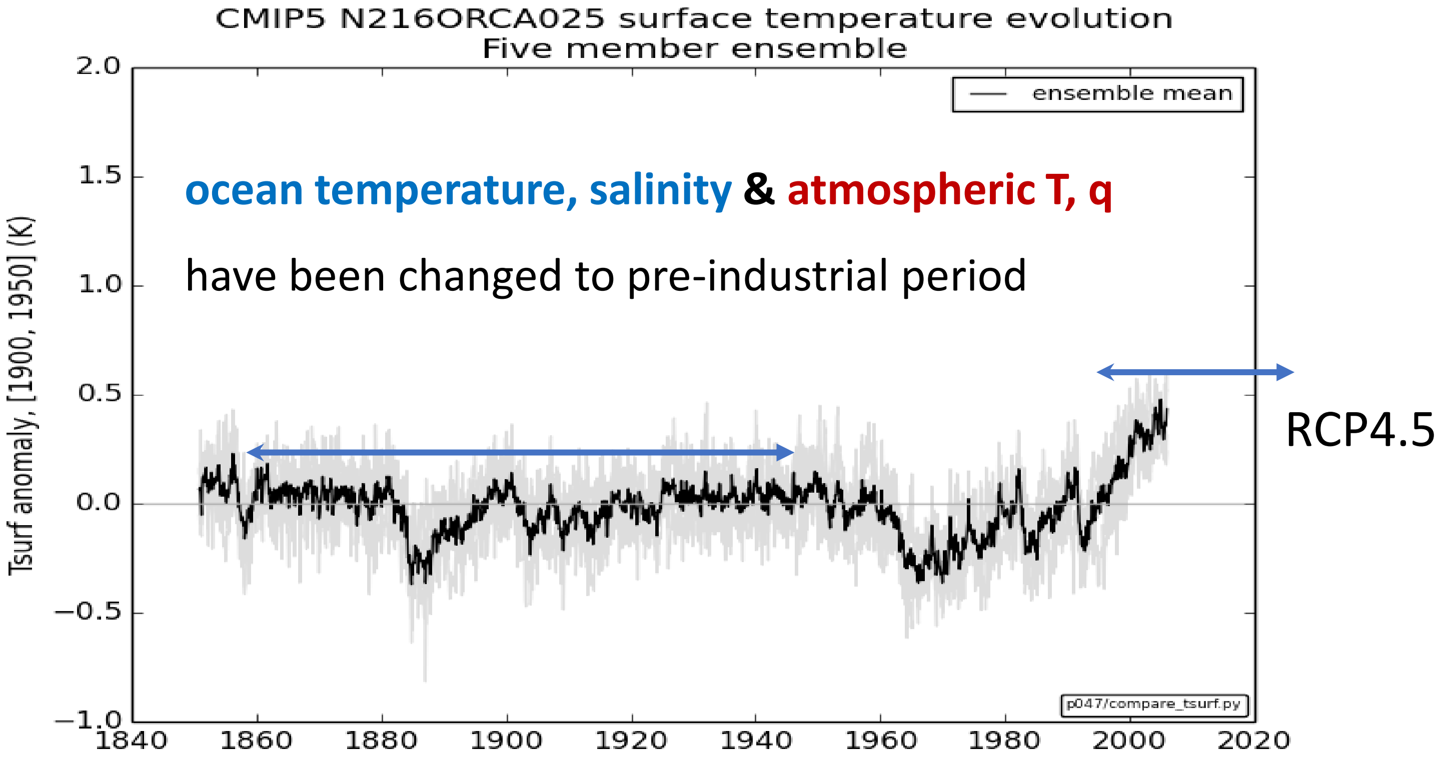
ERA-Interim atmosphere initial conditions (from hindcast set)

ACCESS-S1
Attribution Forecast Initialisation:
low CO_2 climate (EXPT).

2009 initial conditions, but background climate as it would be if CO_2 increase had halted in ~1900.

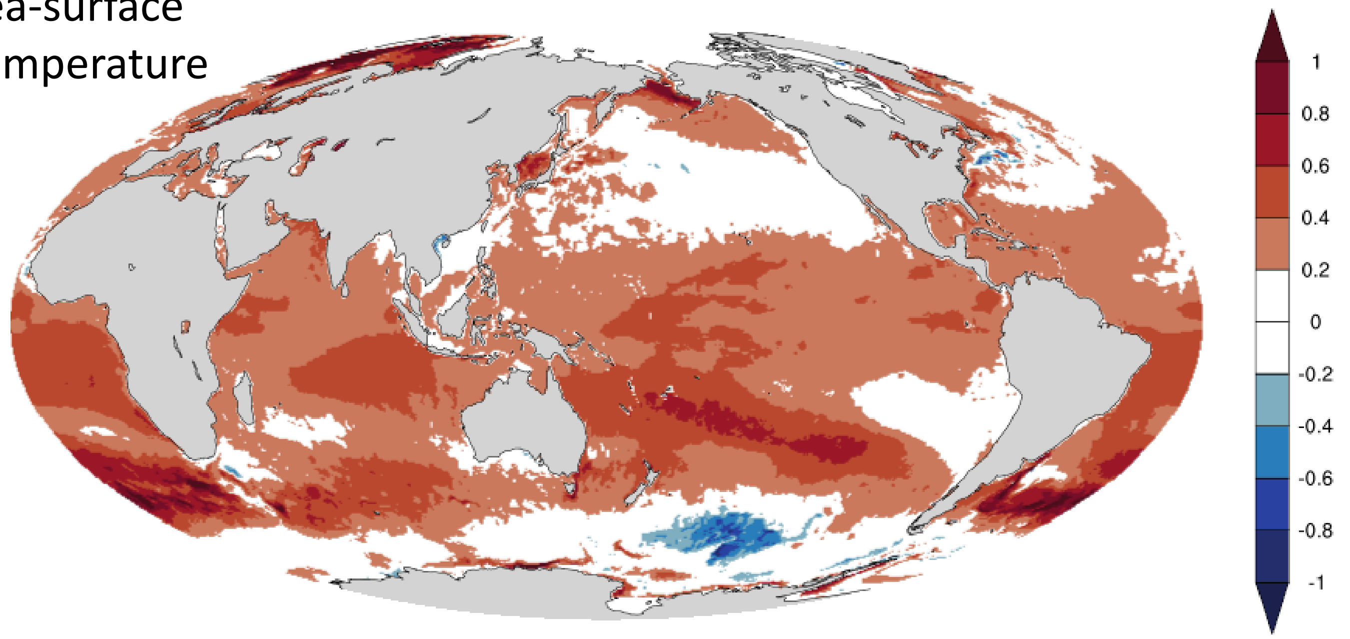
11 member ensemble forecasts initialised on the 17 January 2009 & verified for 28 Jan – 8 Feb 2009

CO_2 concentration was set to **297 ppm** ~ 1905 level (NOAA Mauna Loa CO_2 data)

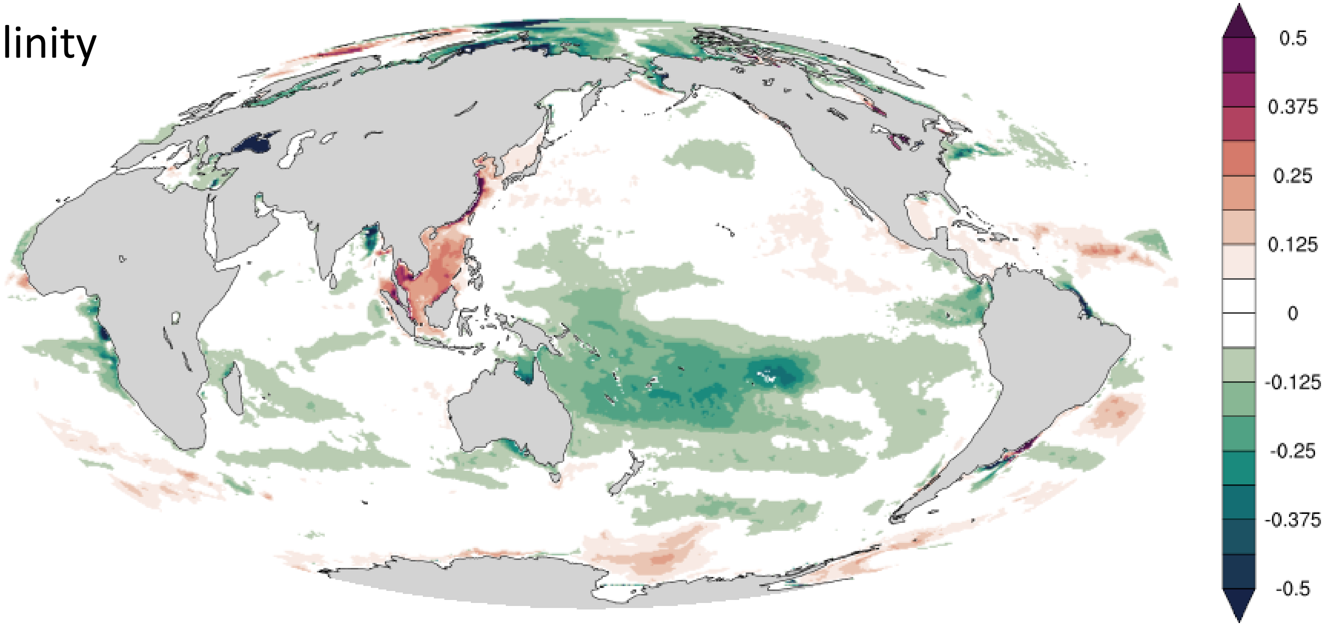


ACCESS-S1 delta

Sea-surface Temperature



Salinity



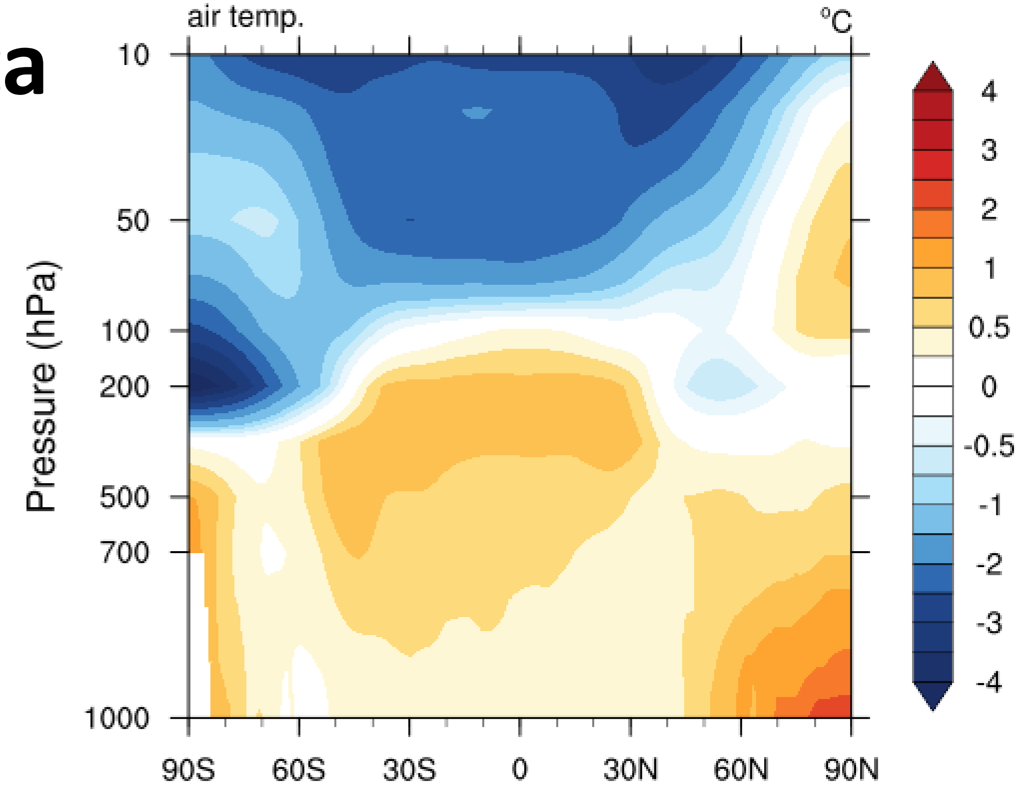
GC2 5-member historical:
SST (°C) and ***surface salinity*** (psu) difference during January between present (2000-20) and pre-industrial (1861-1950) period.

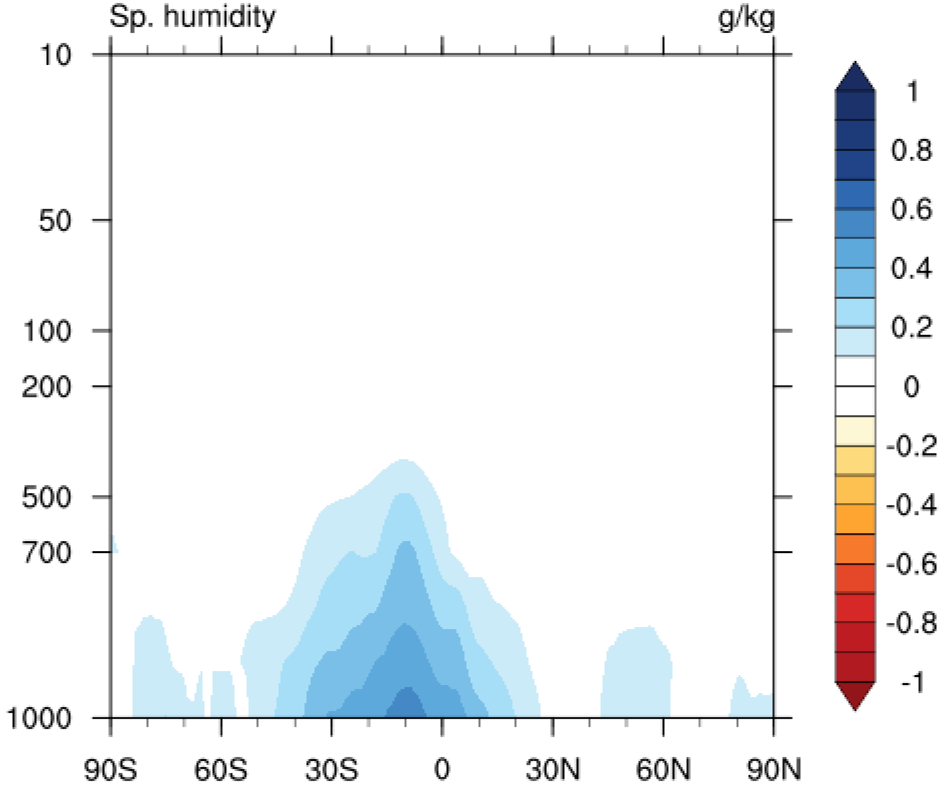
(after 2005: RCP 4.5)

Interactive sea-ice

Weak warming over the global ocean
Cold bias of the model?

ACCESS-S1 delta

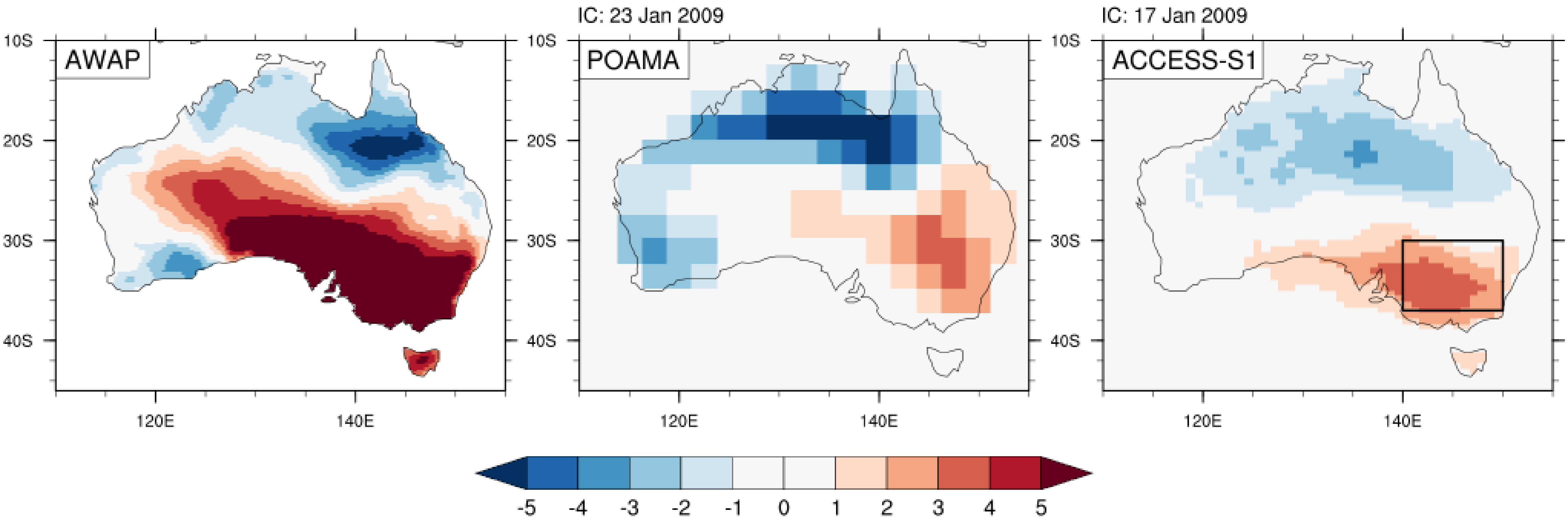




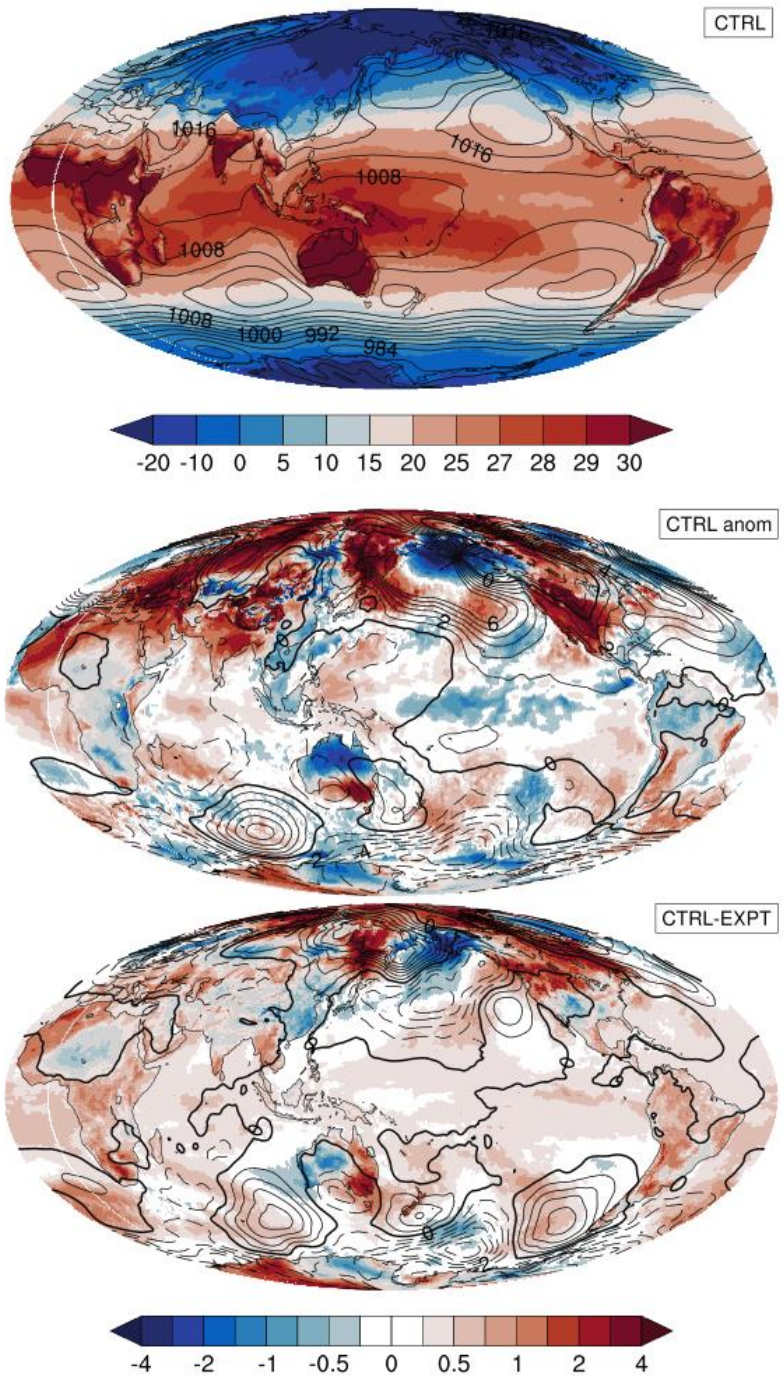
January zonal mean ***air temperature*** and ***specific humidity*** difference between present (2000-20) and pre-industrial (1861-1950) period.

Land is not initialised, and no delta has been applied yet.

Black Saturday Heatawave
Surface Tmax anomalies during 27 Jan – 8 Feb 2009



- Maximum surface temperature occurred over SE Australia.
- Observed Tmax anomalies are much stronger relative to 11-member forecast of **POAMA** & **ACCESS-S1**.



ACCESS-S1 Tmax sfc (shaded) and MSLP (contour) anomalies

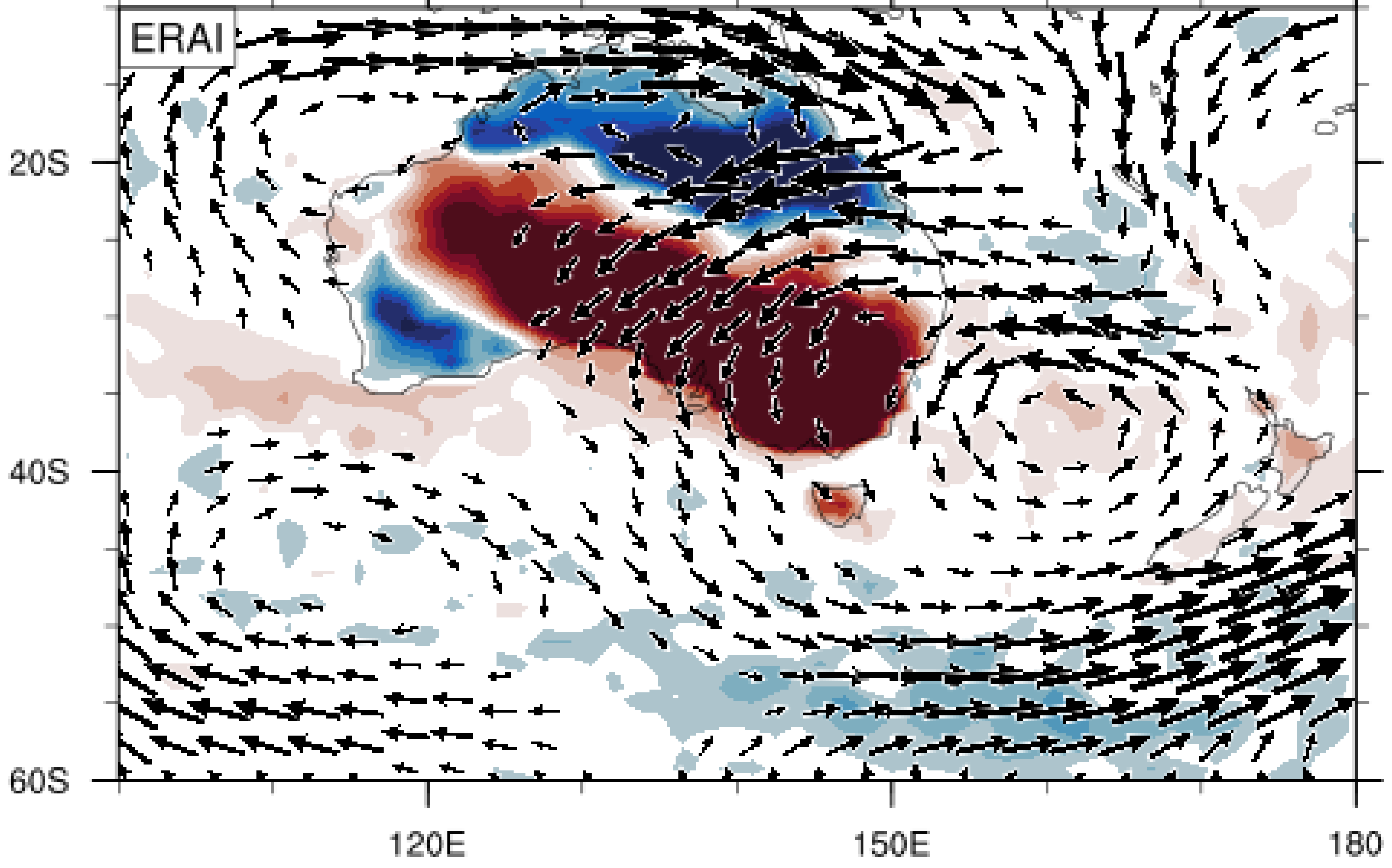
- Mild La Nina over equatorial central Pac in CTRL.
- Blocking over Tasman sea.

Present day compared to low CO2:

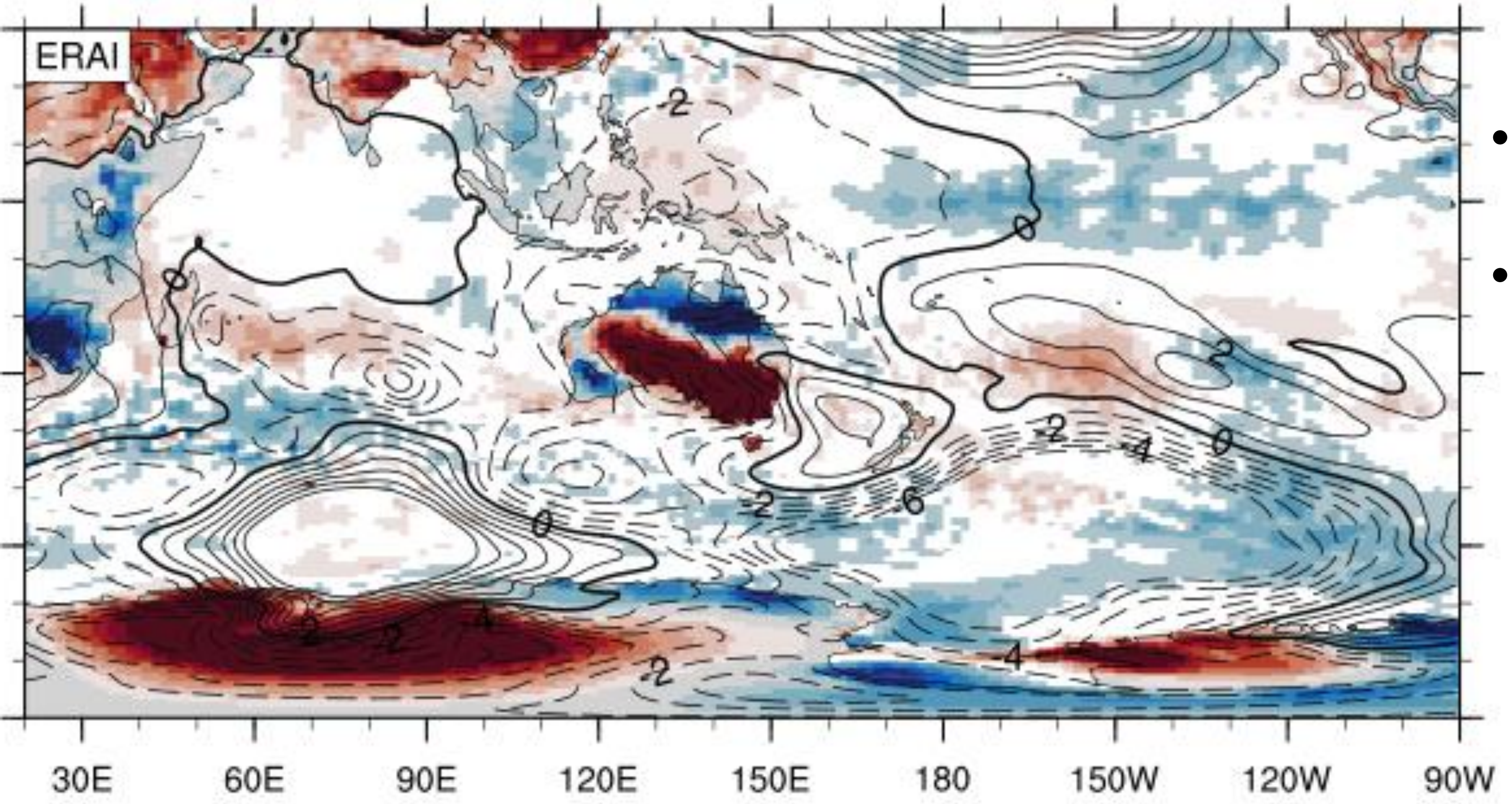
- global mean temperature is 0.4^{O}C warmer
- warming is evident over SE Australia
- High pressure over Tasman sea is higher

Preliminary Results!

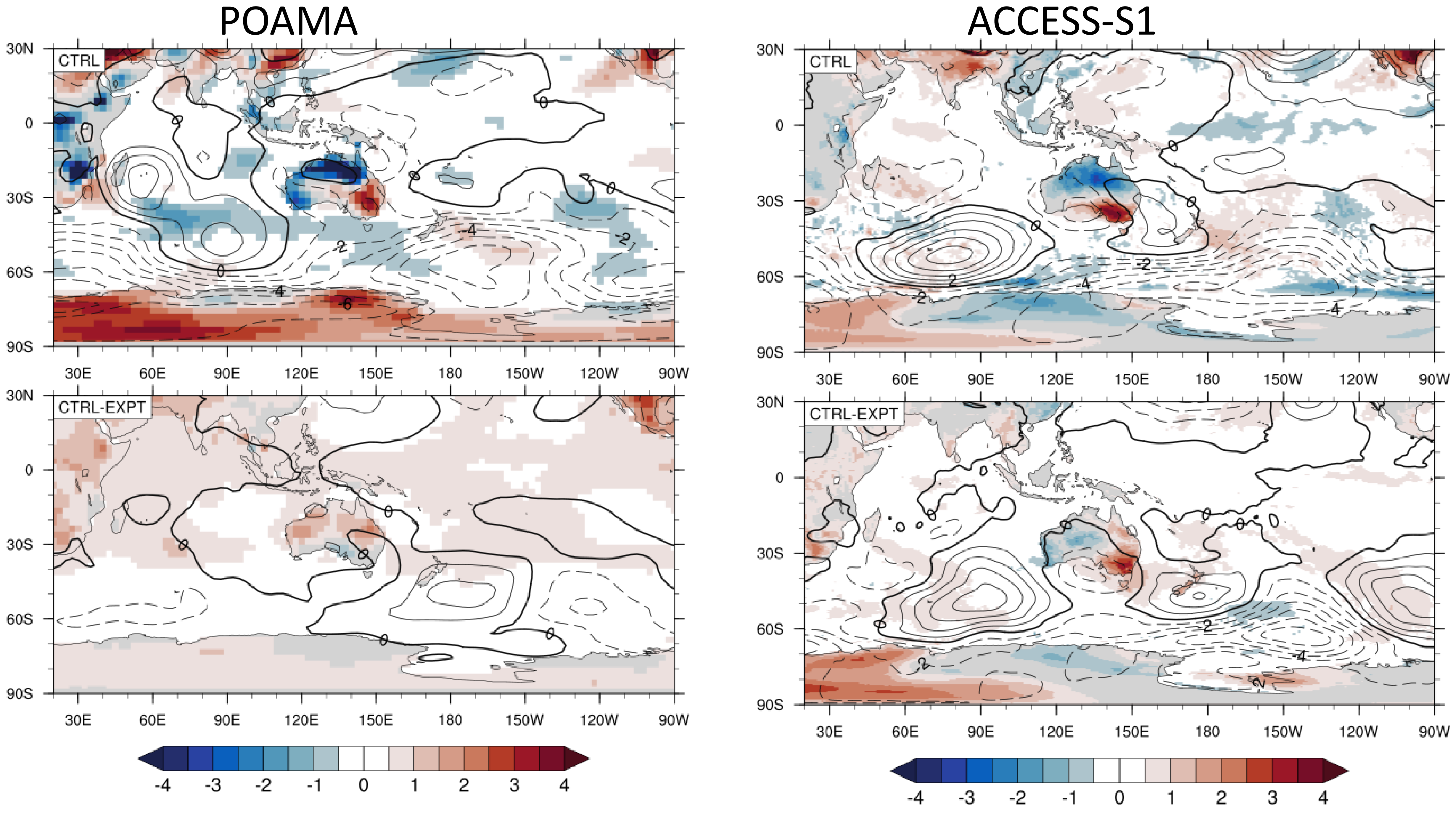
ERA-Interim low-level wind + Surface Tmax anomalies 27 Jan – 8 Feb 2009



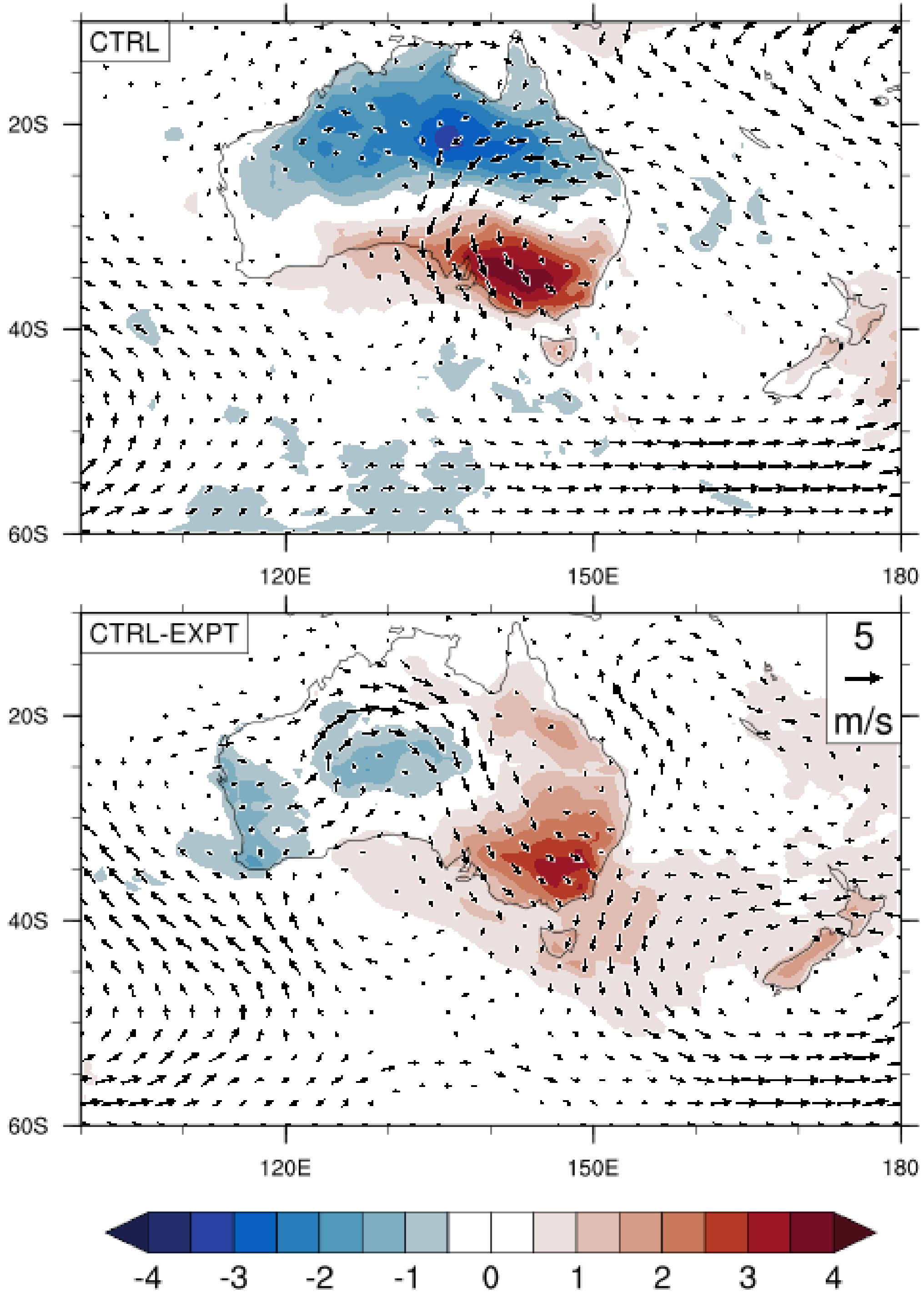
ERA-Interim MSLPressure + Surface Tmax anomalies
27 Jan – 8 Feb 2009



- Mild La Nina over equatorial central Pac in CTRL.
- Blocking over Tasman sea.



POAMA
ACCESS-S1
CTRL
CTRL-EXPT
30N
0
30S
60S
90S
30E
60E
90E
120E
150E
180
150W
120W
90W
-4
-3
-2
-1
0
1
2
3
4



ACCESS-S1 Tmax sfc (shaded) and 850 hPa wind (vector) anomalies

- Northerly wind anomalies induce warming over SE Australia
- S1 forecast captures the wind anomalies, but they are weaker compared to ERAI
- Weaker northerly winds reduce warming in EXPT over SE Australia

How did climate change alter the Black Saturday heatwave in 2009?

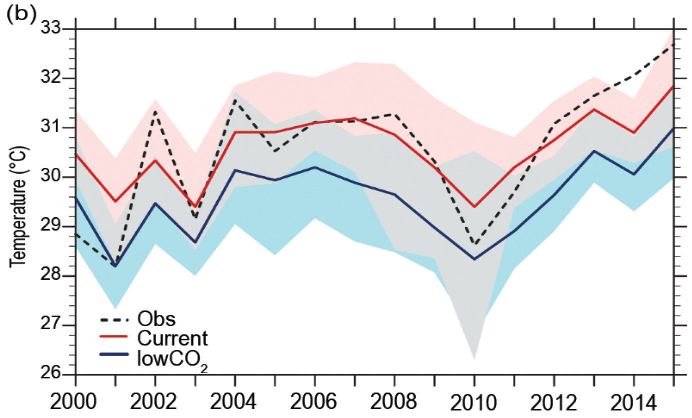
- Spread is large in the forecasts and across the models, indicating that weather variability was important – should we look to shorter lead-time? Assimilation and initialisation techniques?
- CO_2 did enhance the heat across eastern Australia, but shifted northward in POAMA
- Circulation changes were important for the heat
- Land surface conditions might have been important, but we need to further analyse this
- Other approaches can provide information about the change in likelihood or risk

Next Steps for ACCESS-S:

- Develop dSoil – modify soil temperature and moisture
- Develop understanding of the 'trigger' to run this alongside the operational seasonal/subseasonal forecast. i.e. when is an event 'extreme'?
- Develop analysis suite
- Develop messaging about results and disseminate the message.

Further work:

- Making a complete attribution system, including a climatology hindcast set
- Analyse recent climate extremes



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Thank you

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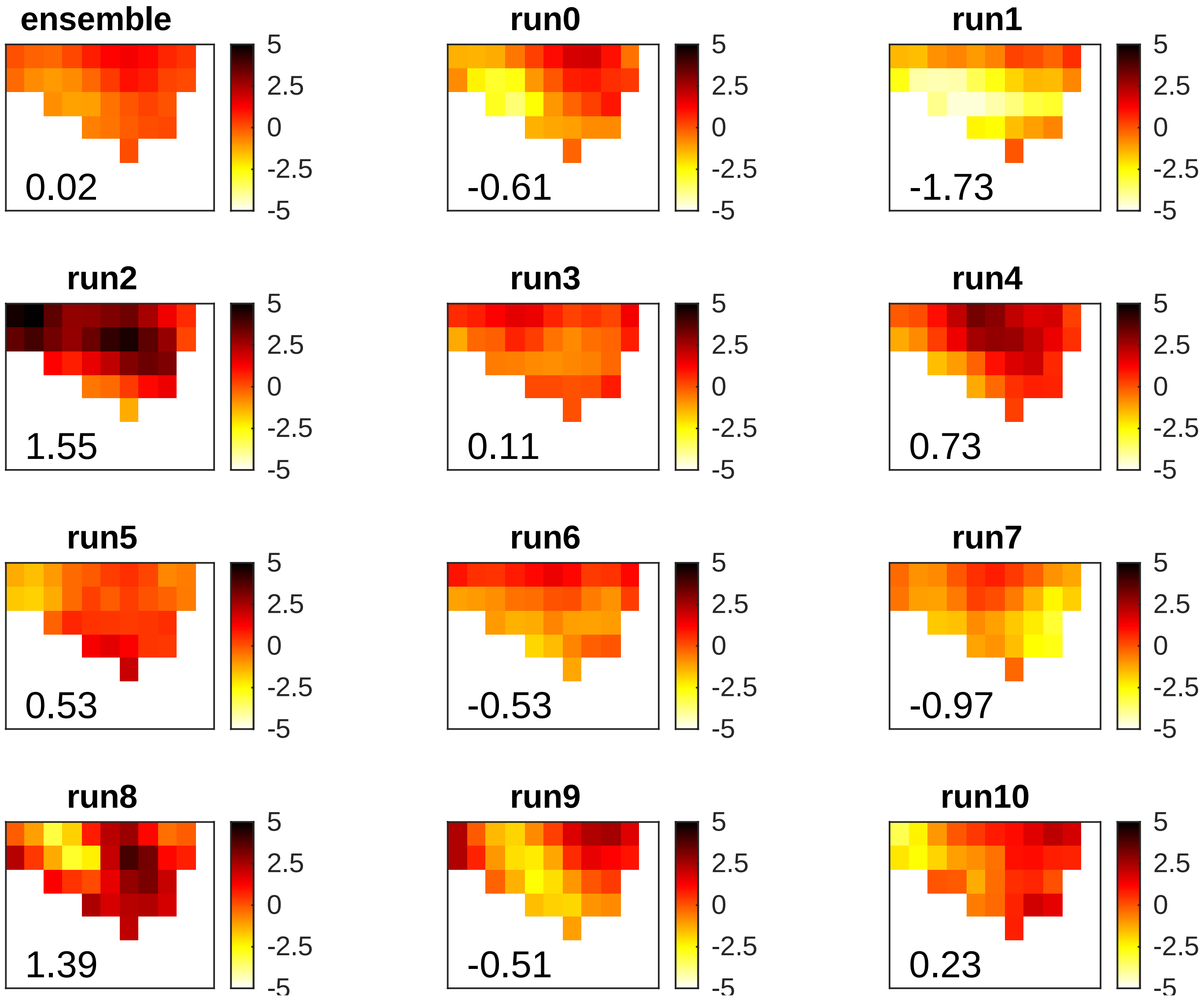
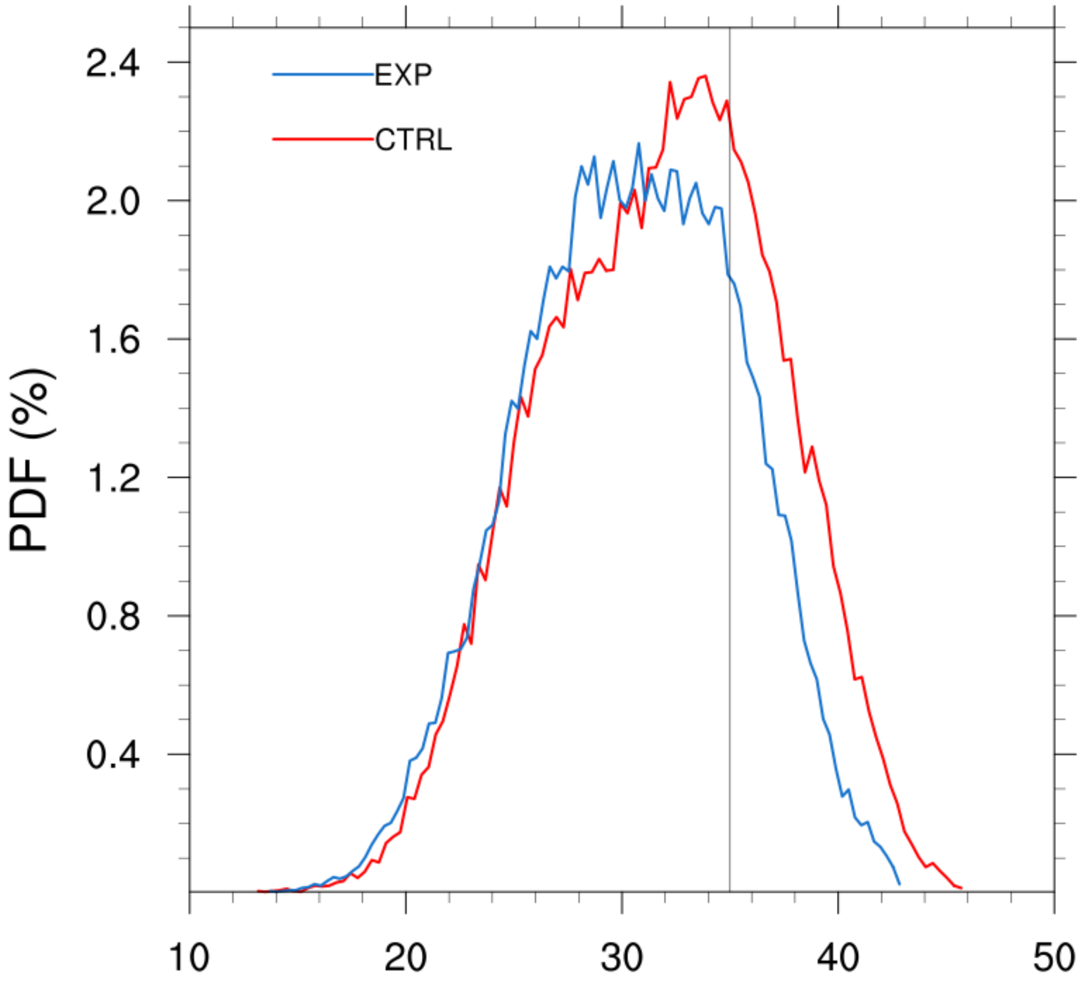
2009 Victorian heatwave

- Heatwave immediately before Black Saturday (27th Jan-8th Feb)
- Reported to have killed 384 people
- 11 POAMA2 runs
  - Daily maximum temperature averaged over 12-day heatwave
  - Low-CO_2 run subtracted from Historical run
  - Lots of variability
  - Ensemble average indicates little change in heatwave *intensity* due to climate change



- Health impact defined by slightly different metric (eg day/s above a threshold such as 95th percentile). This work is still to come.



ACCESS-S1 Probability of 35^{O}C & above
(box over SE Australia, slide 17)**:**

EXP probability (P1): 19.44%

CTRL probability (P2): 29:33%

Fraction of attributable risk

$$FAR = 1 - \frac{P1}{P2} = 1 - 0.66 = 0.34$$