Exploring drivers of modeled mid-latitude precipitation change

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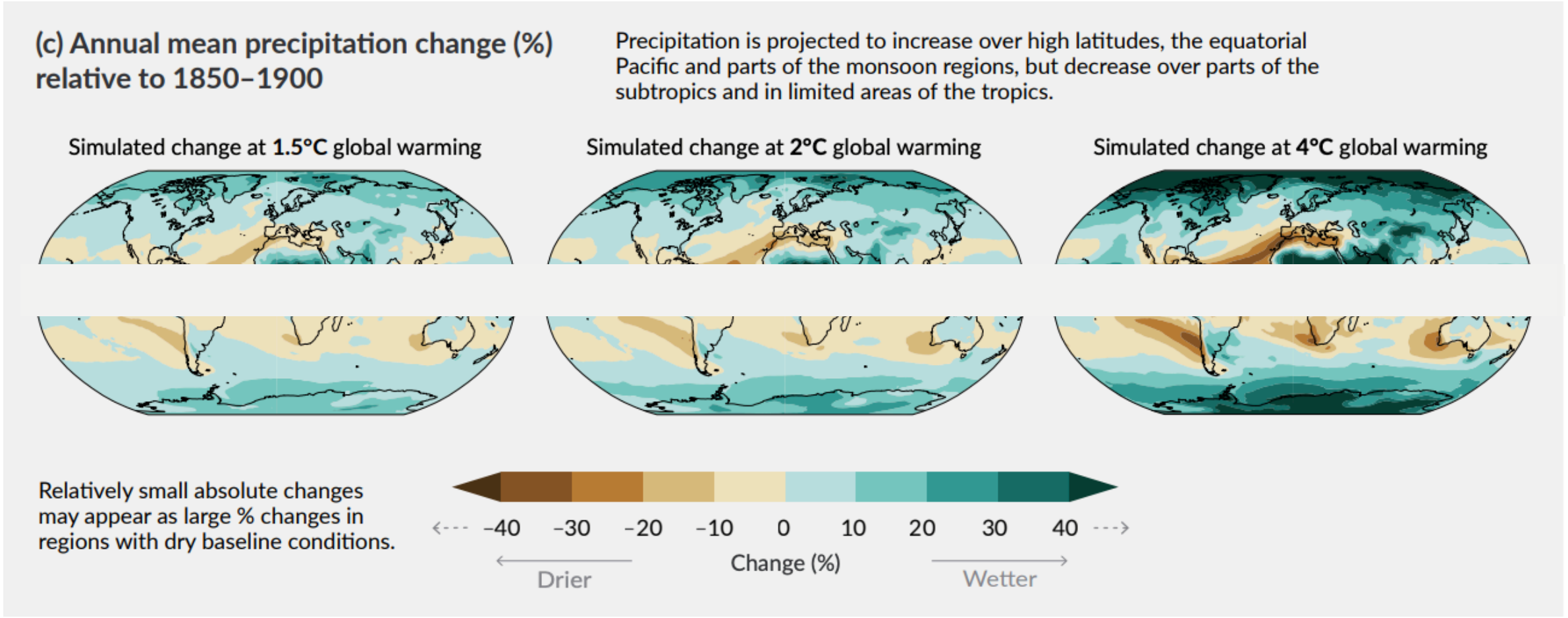
CIRES

What mechanisms drive future precipitation change?



IPCC Figure SPM.5

What are the relative contributions of dynamics vs. thermodynamics to mid-latitude precipitation trends?

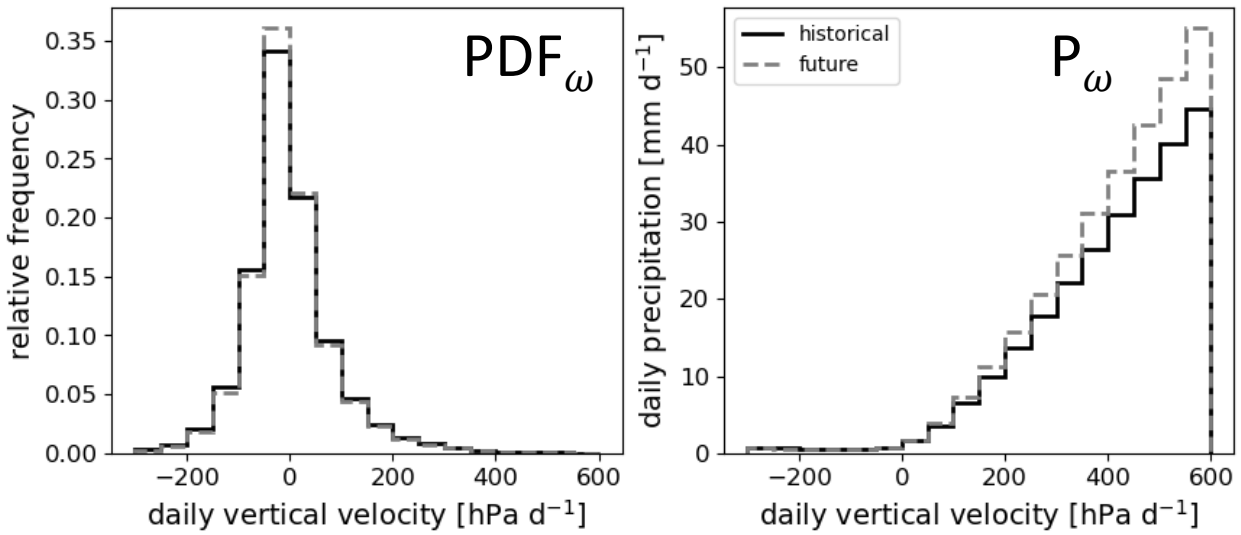
Dynamic vs. thermodynamic contributions to precipitation change

Daily 500 hPa vertical velocity (ω) is used as a proxy for the strength of a 'dynamic disturbance'

1. Obtain the PDF of ω (PDF_{ω}) for a historical (1981-2000) and future period (2081-2100)
2. Composite daily precipitation for each ω bin for both periods (P_{ω})

Bony et al. 2004, *Clim. Dyn.*Emori and Brown 2005, *GRL*

Can find these distributions and calculate the thermodynamic change and the dynamic change at each grid point



Following EB2005 methodology, what are we doing different?

EB2005

1. Considered **6** different models
2. Considered **one** run from each model
3. Considered **annual** precipitation

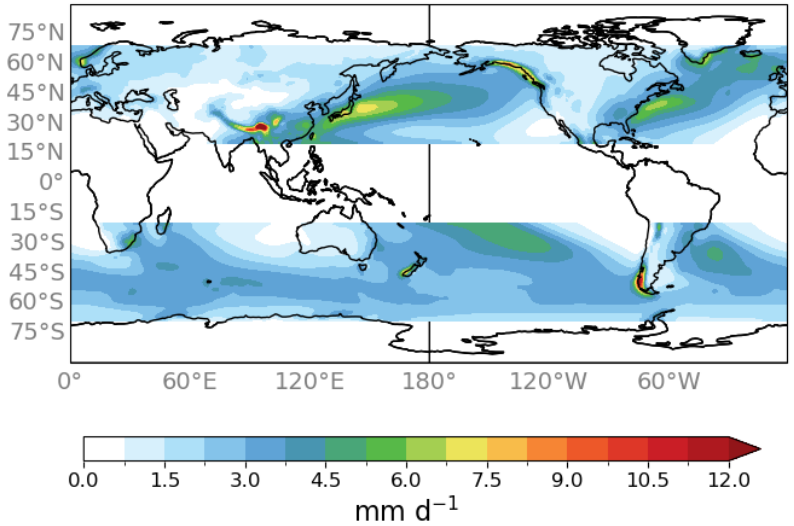
Our ongoing work

1. Considering **one** model: CESM2
2. Considering **50** (soon to be 100) runs from the model
3. Will consider **all seasons** (mostly focusing on winter vs. summer)

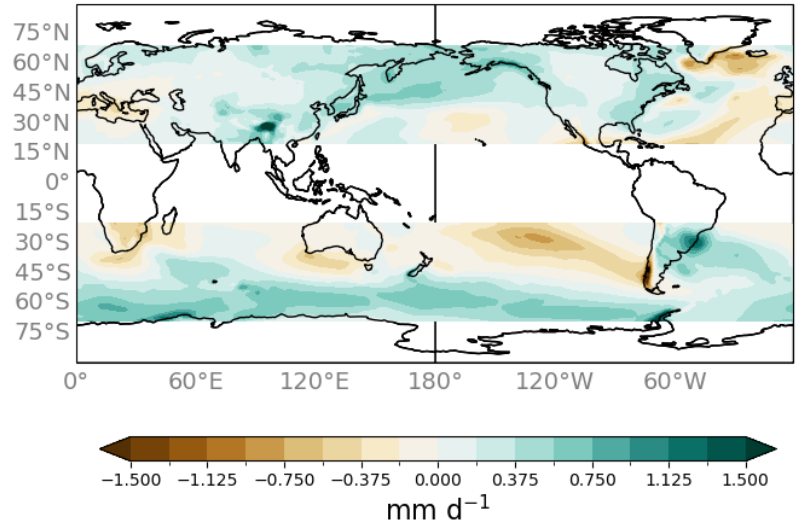
(1) and (2) afford us the opportunity to better quantify the forced response *and* explore the ensemble spread
Different seasons are driven by different physical mechanism (e.g., large-scale vs. convective)

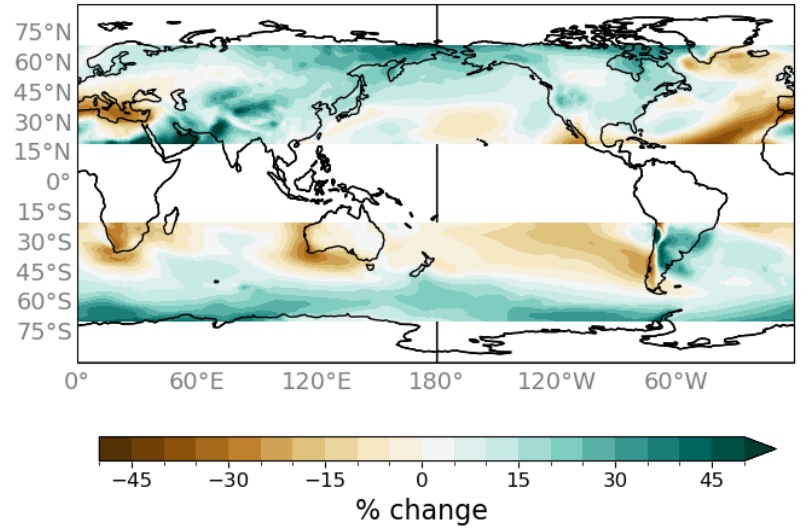
Annual mean precipitation and forced response

Annual precipitation climatology



ΔP (2081-2100 minus 1981-2000)

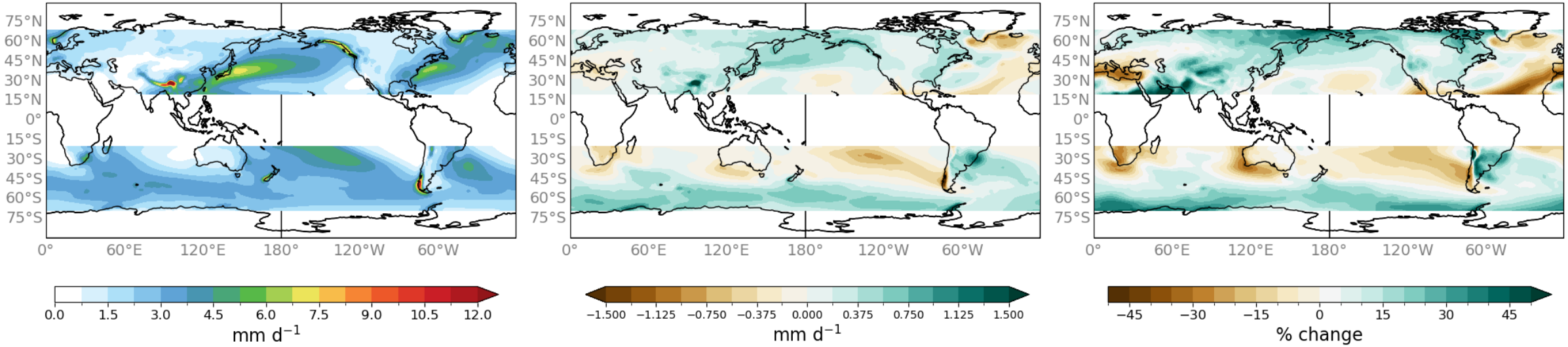




Annual mean precipitation and forced response

Annual precipitation climatology

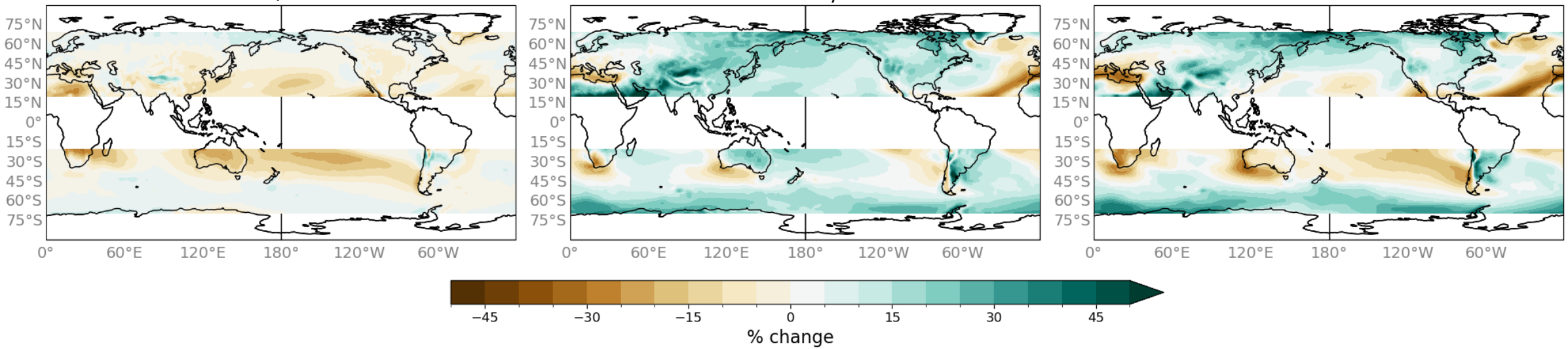
ΔP (2081-2100 minus 1981-2000)



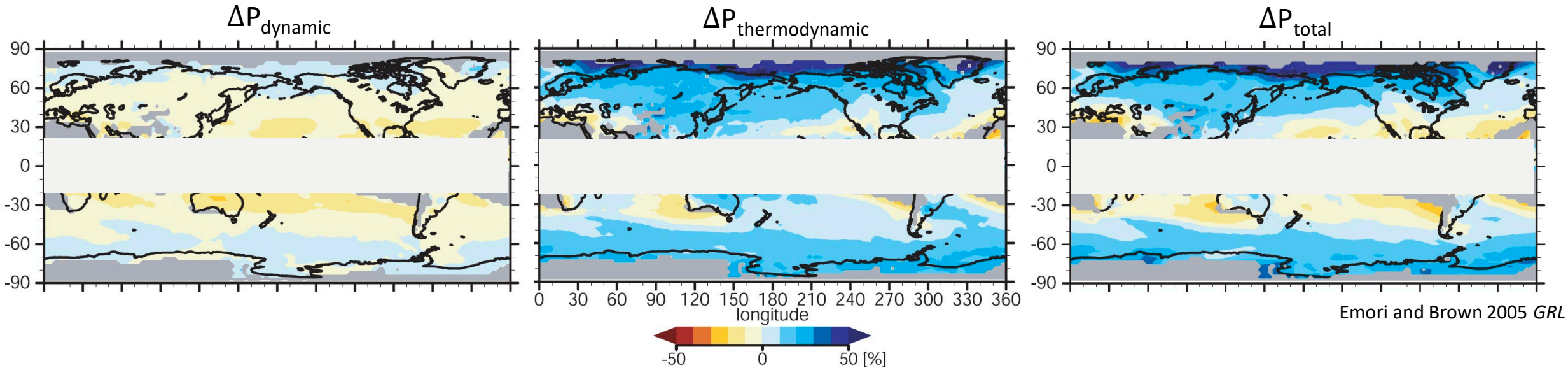
$\Delta P_{dynamic}$

$\Delta P_{thermodynamic}$

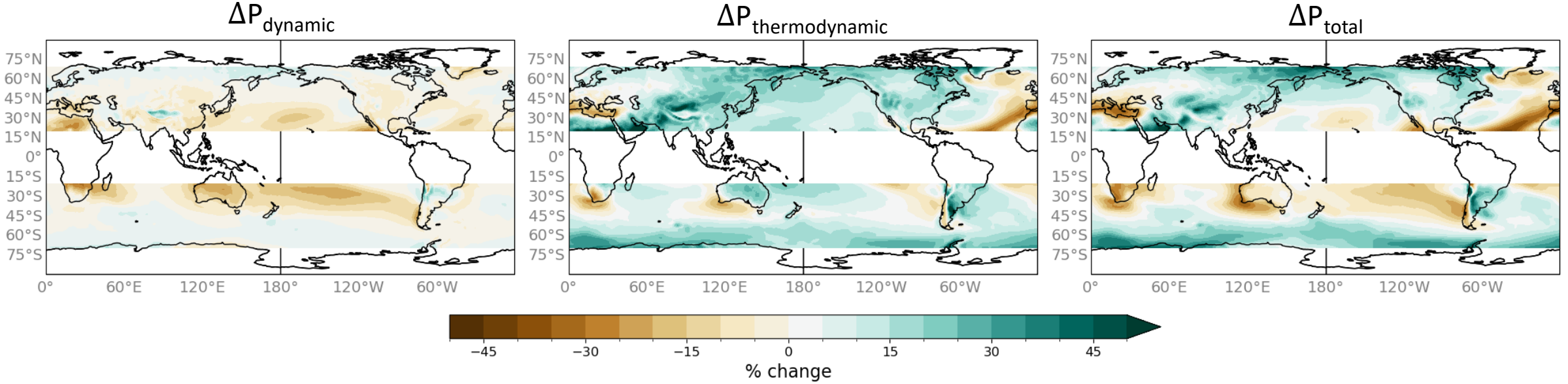
ΔP_{total}



Annual mean precipitation and forced response

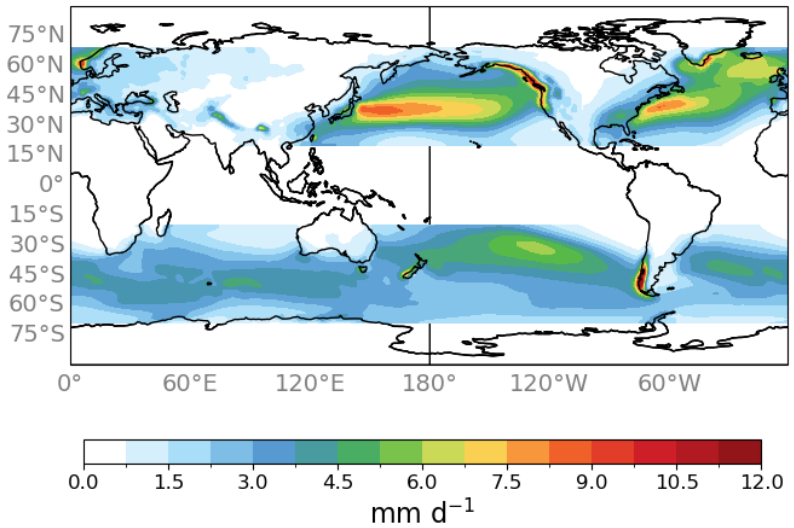


Emori and Brown 2005 *GRL*

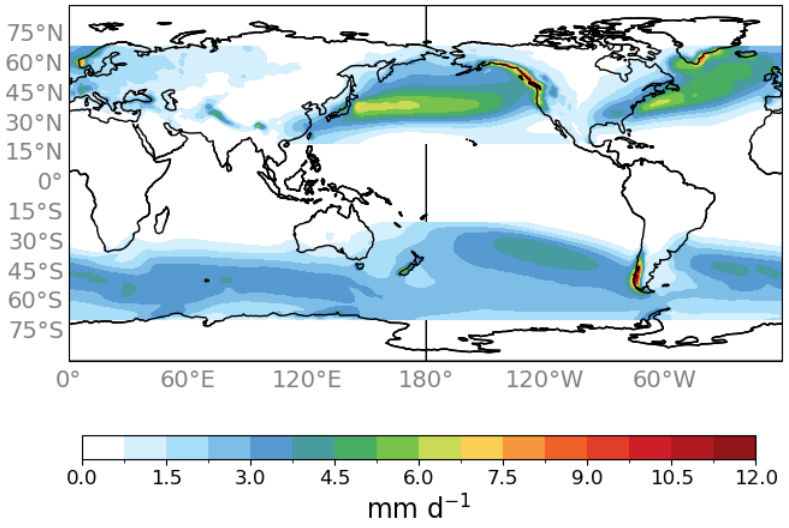


Let’s consider winter vs. summer precipitation

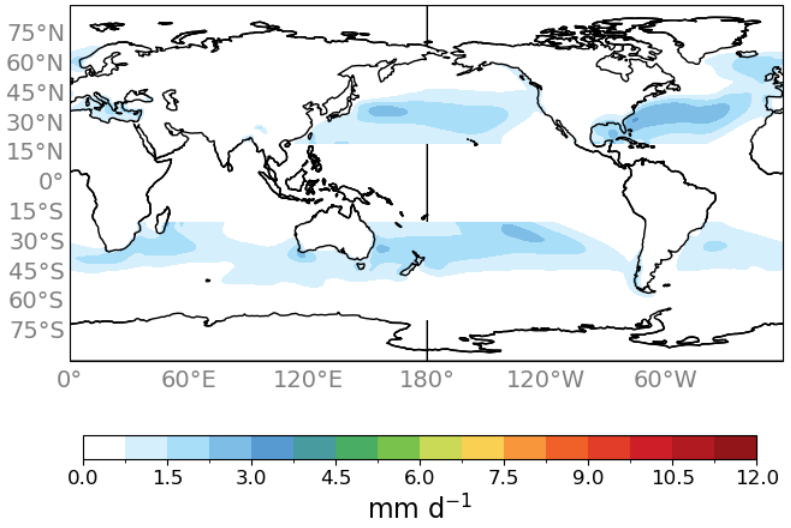
Winter precipitation climatology



Large-scale precipitation



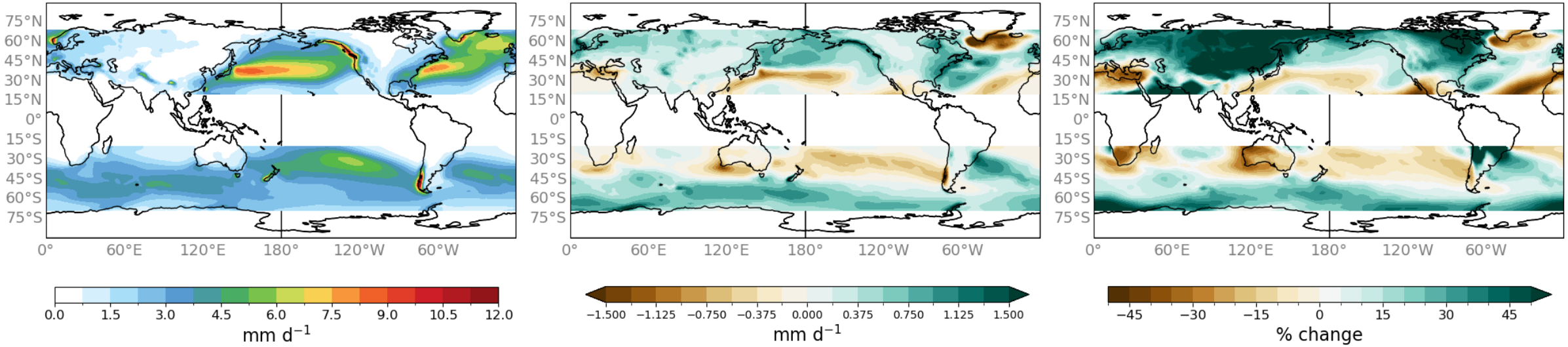
Convective precipitation



Winter mean precipitation and forced response

Winter precipitation climatology

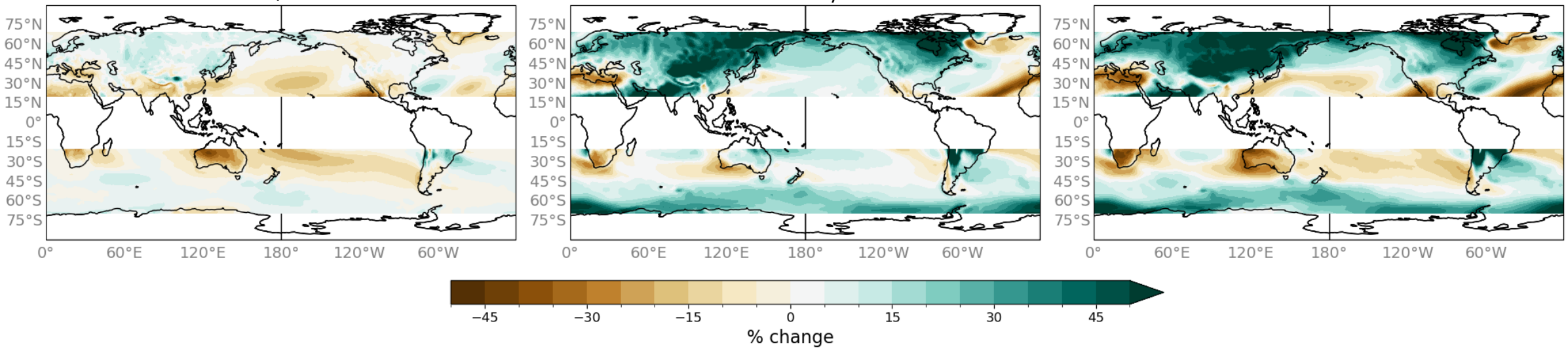
ΔP (2081-2100 minus 1981-2000)



$\Delta P_{dynamic}$

$\Delta P_{thermodynamic}$

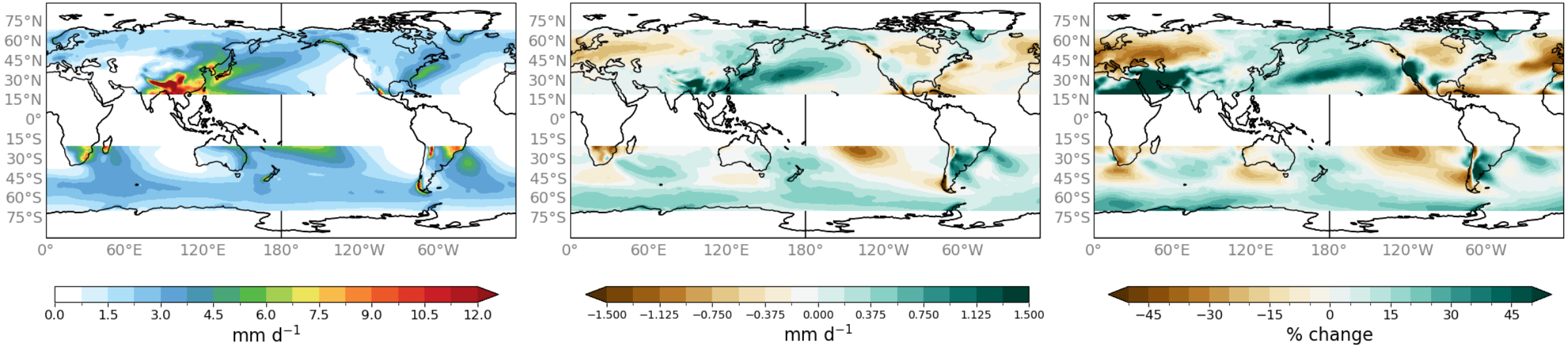
ΔP_{total}



Summer mean precipitation and forced response

Summer precipitation climatology

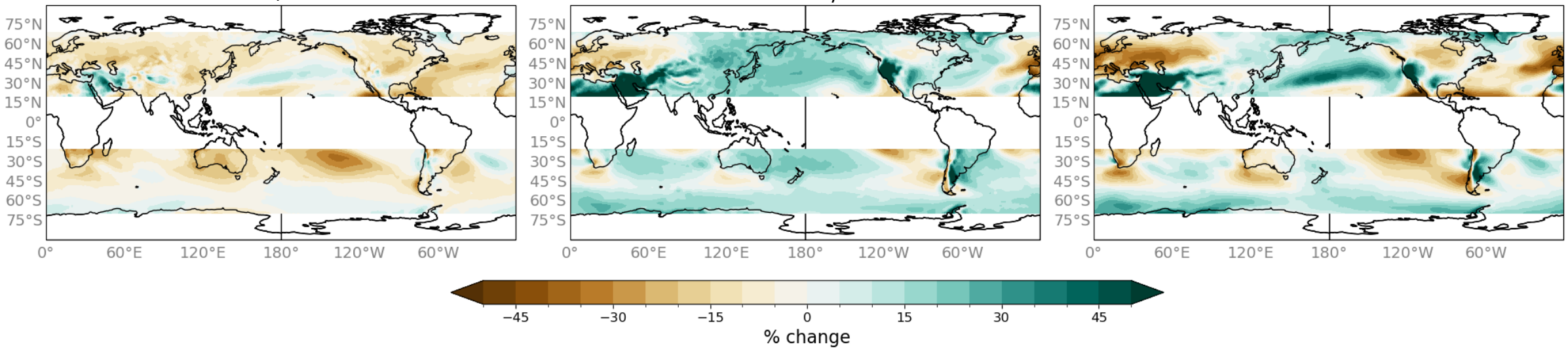
ΔP (2081-2100 minus 1981-2000)



$\Delta P_{dynamic}$

$\Delta P_{thermodynamic}$

ΔP_{total}



Next steps

- Investigate the different thermodynamic and dynamic contributions across ensemble members
  - In Australia the dynamic precipitation change outweighs the thermodynamic precipitation change – *why*?
- How do the thermodynamic and dynamic contributions evolve through time (ΔT = 2K, 3K, 4K, etc.)
  - Everything here has just compared 1981-2000 and 2081-2100
- Using a vertically integrated moisture budget vs. this single-level decomposition
- Idealized simulations - **wind nudging**?

References

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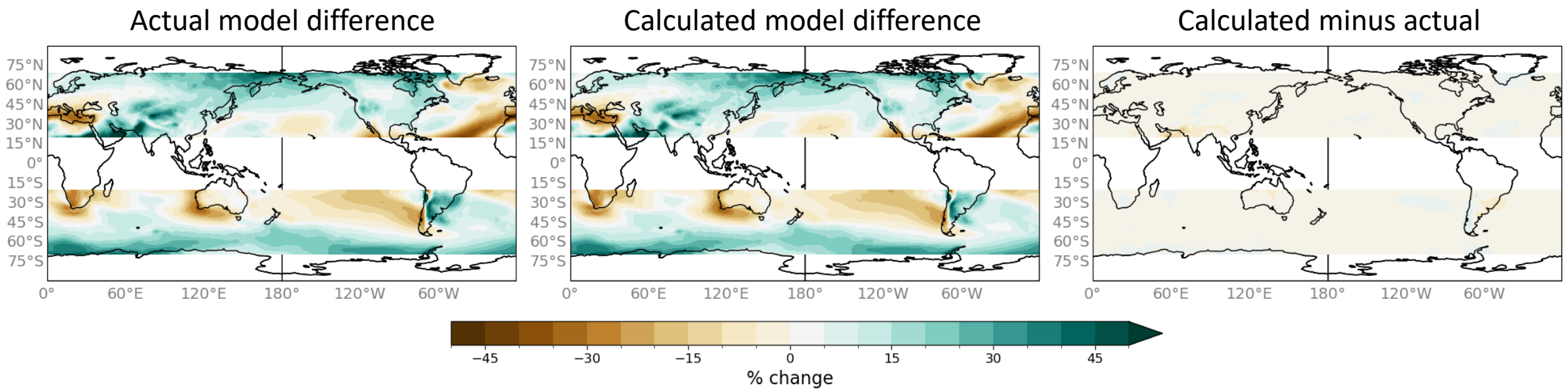
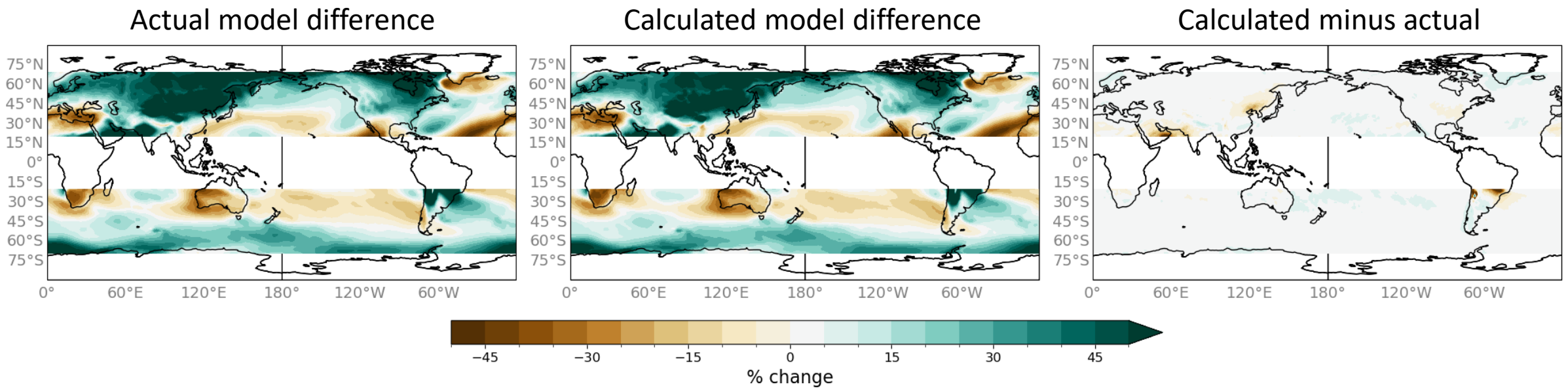
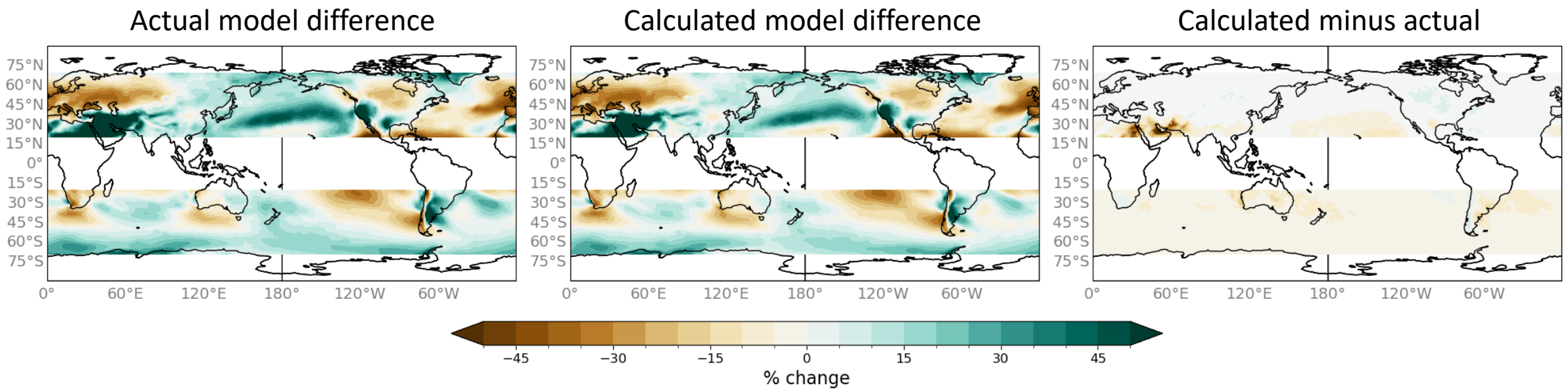
Annual precipitation change (2081-2100 minus 1981-2000)

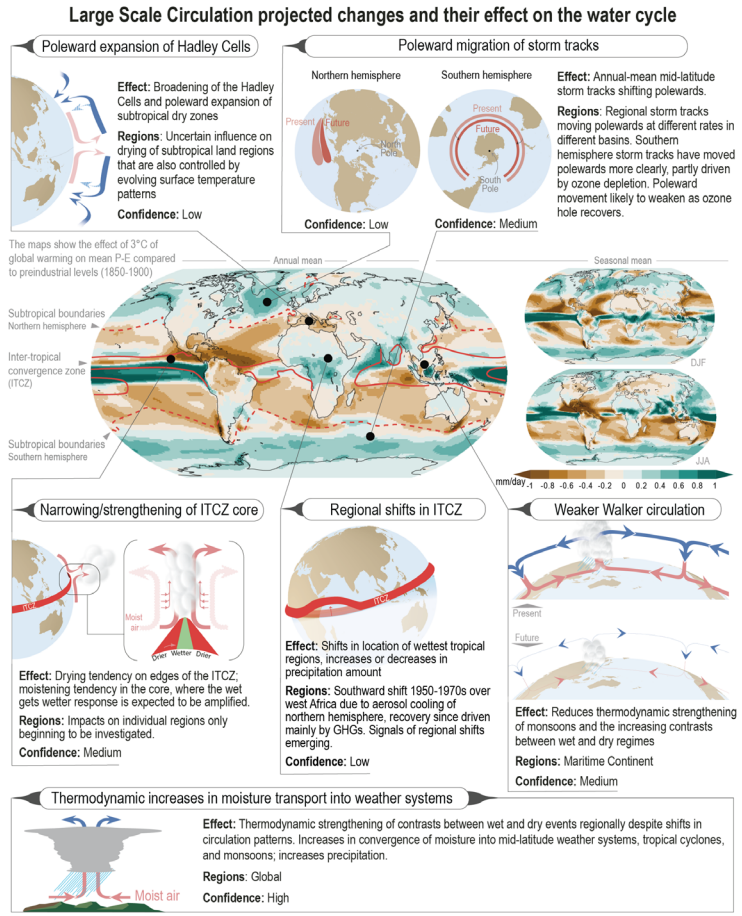


Winter precipitation change (2081-2100 minus 1981-2000)

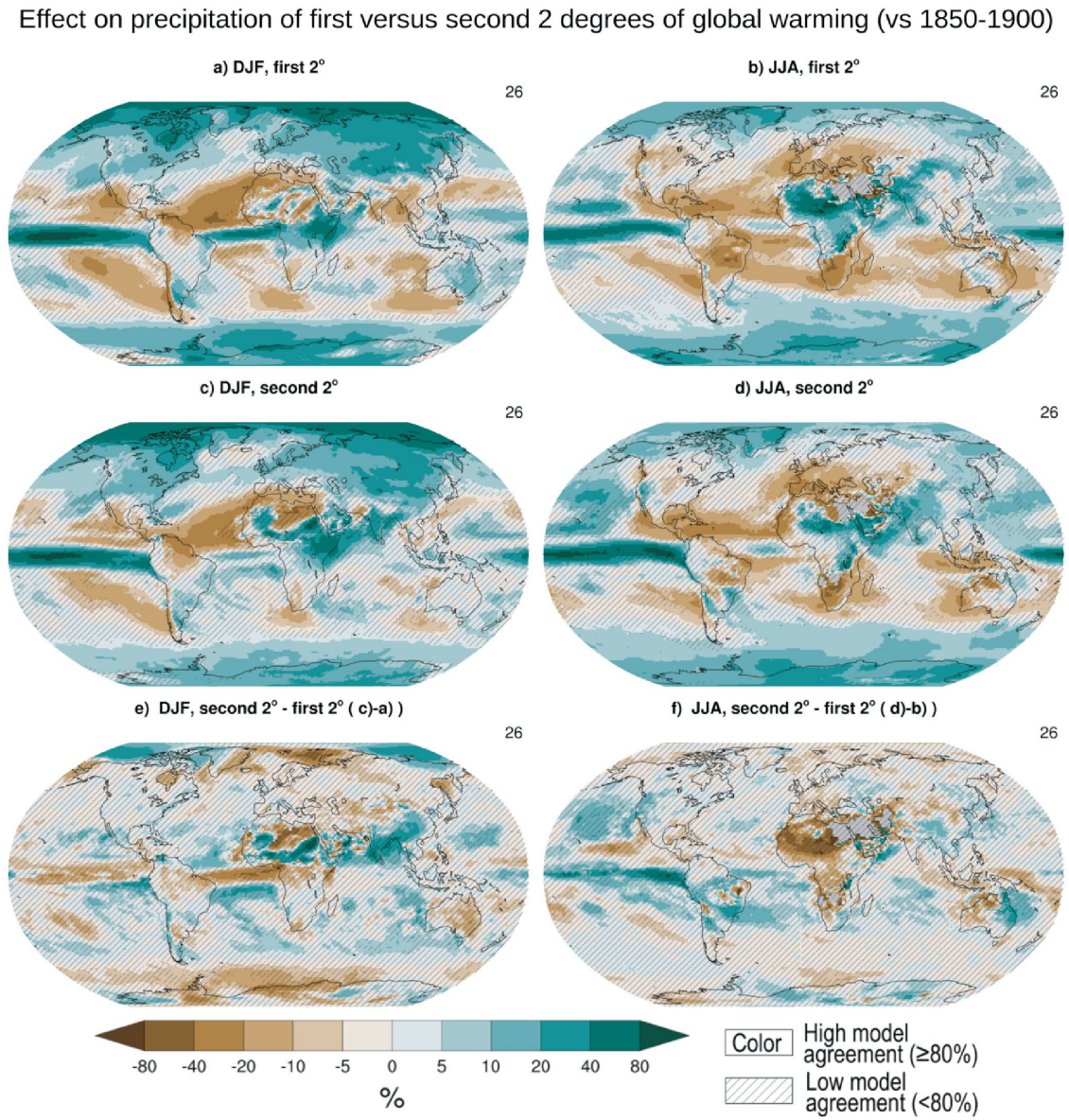


Summer precipitation change (2081-2100 minus 1981-2000)





IPCC Figure 8.21



IPCC Figure 8.25

Introduce methods

$$\bar{P} = \int_{-\infty}^{\infty} P_\omega \, \mathrm{Pr}_\omega d\omega$$

$$\overline{\delta P} = \int_{-\infty}^{\infty} P_\omega \, \delta \mathrm{Pr}_\omega d\omega + \int_{-\infty}^{\infty} \delta P_\omega \, \mathrm{Pr}_\omega d\omega \int_{-\infty}^{\infty} \delta P_\omega \, \delta \mathrm{Pr}_\omega d\omega$$

The jury is out on the drivers of the trend…

2010

The wetting trend is driven by **natural atmosphere-ocean variability** *
Seager et al. (2010)

2014

Stratospheric ozone depletion drives trend post-1960*
Gonzalez et al. (2014)

2016

GFDL models simulate a wetting trend in response to **GHG forcing** *
Zhang et al. (2016)

2018-2023

My goal is to reconcile the previous literature, namely the assessment of the weak trend in models…

*Each paper notes that climate models underestimate the precipitation trend

Can we use climate models as a tool to better understand and diagnose the drivers of the SESA precipitation trend?

Gross Discrepancies between Observed and Simulated Twentieth-to-Twenty-First-Century Precipitation Trends in Southeastern South America

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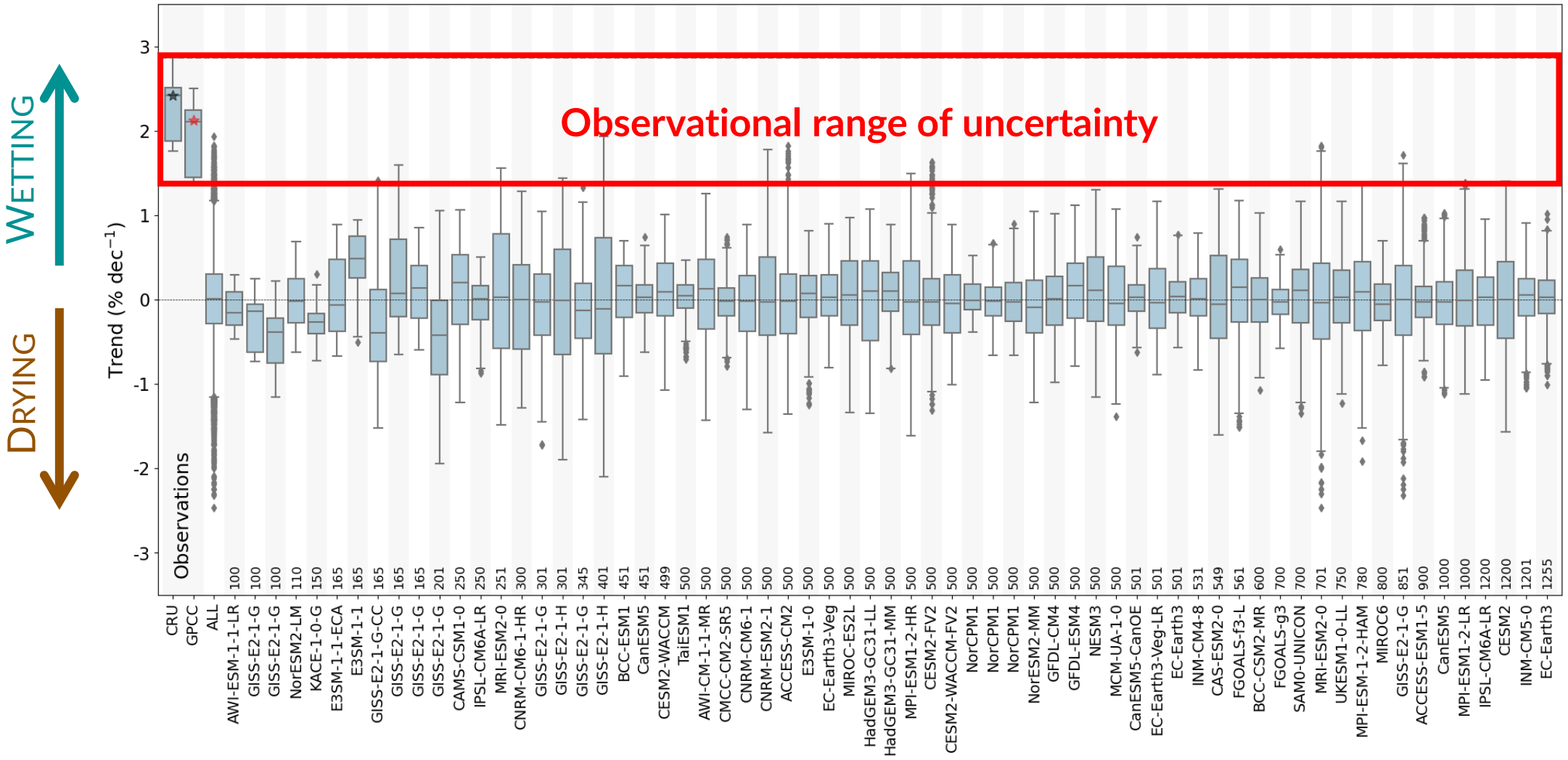
What do precipitation trends look like without any forcing?

65 total runs



Varuolo-Clarke et al. (2021), J. Clim.