Atmospheric river activity over the past ~56 million years in an unprecedented set of high-resolution CESM simulations

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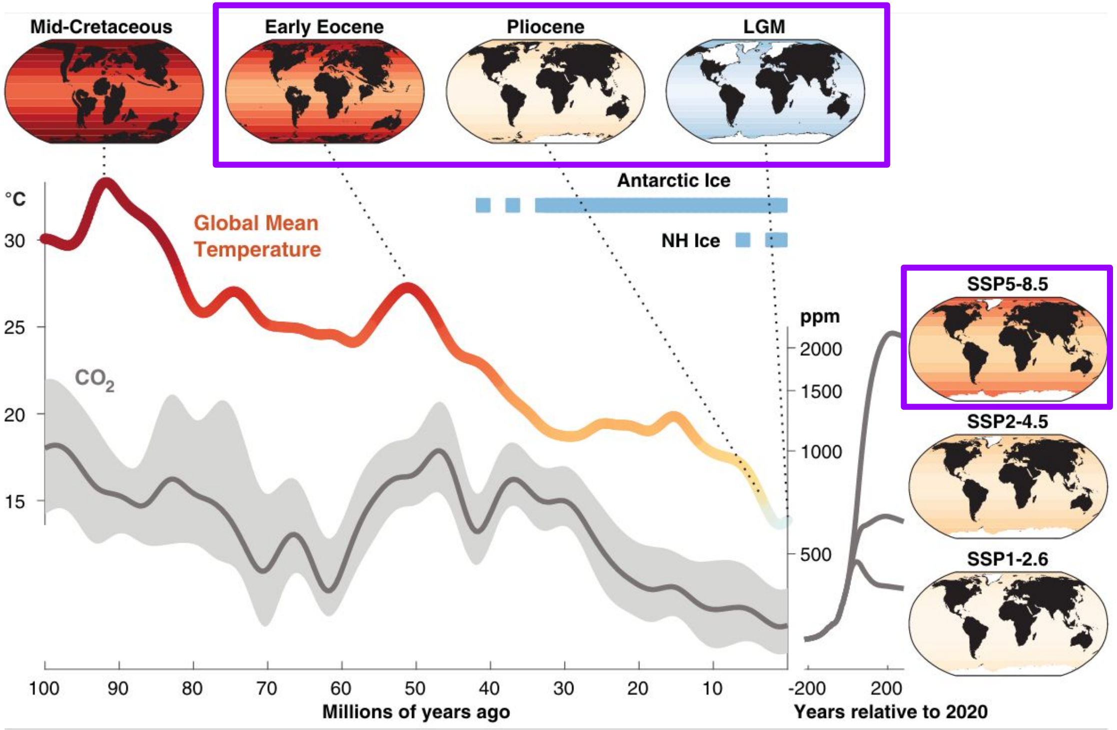
paleoWeather Accelerated Scientific Discovery project

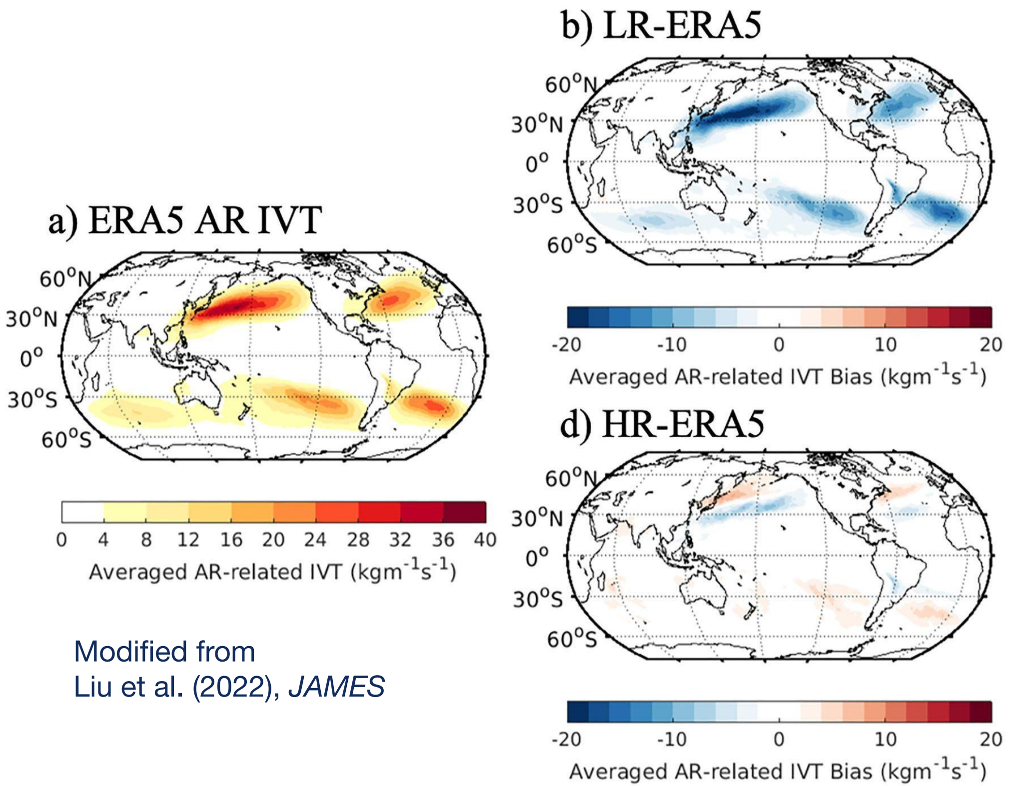


Tierney et al. (2020), *Science*

Hi-res iCESM1.3 (iHESP version)
~0.25 atm/lnd, ~0.1 ocn/ice

- Pre-Industrial
- Last Glacial Maximum
- Pliocene
- Eocene 3x
  - 854 ppmv CO_2
- Eocene 6x
  - 1708 ppmv CO_2
- RCP 8.5
  - 2070-2100

High-resolution CESM provides an exciting opportunity for paleo-atmospheric river activity

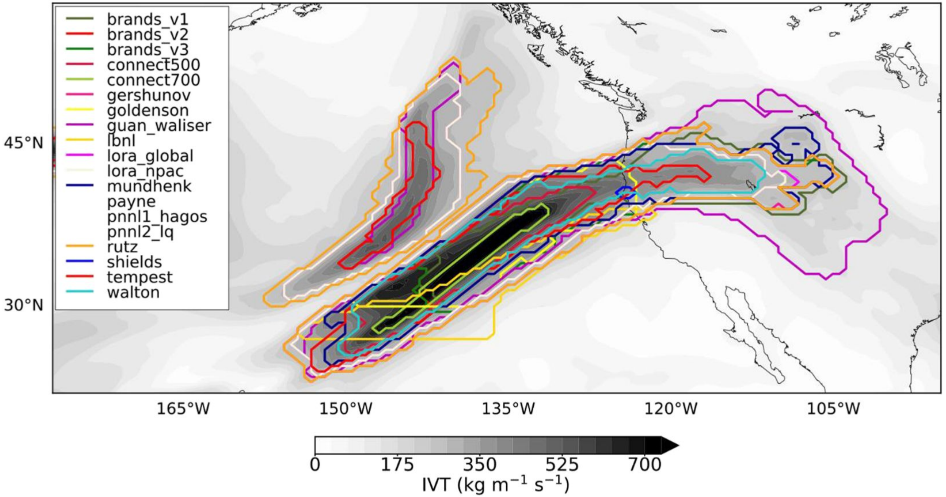


Modified from
Liu et al. (2022), *JAMES*

High vs. low horizontal resolution in CESM…

- Improves atmospheric river (AR) strength and response to large-scale climate modes
- May improve our understanding of the role of ARs in past hydroclimate change
- Potentially resolve proxy-model discrepancies in regional hydroclimate change

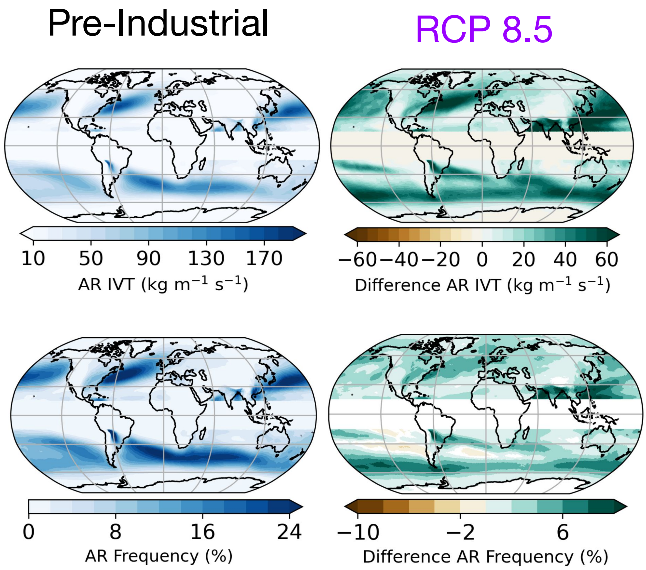
ARs can be defined using many methods for different perspectives



Rutz et al. (2019), *ARTMIP*

- ARs are typically identified using some IVT and shape criteria
- For the same AR, different tracking methods can provide very different AR footprints
- We use TempestExtremes and Lora_v2 methods to provide two different perspectives
    - Same criteria across all time intervals
    - Only TempestExtremes shown today

AR frequency and intensity tends to increase with higher atmospheric CO_2



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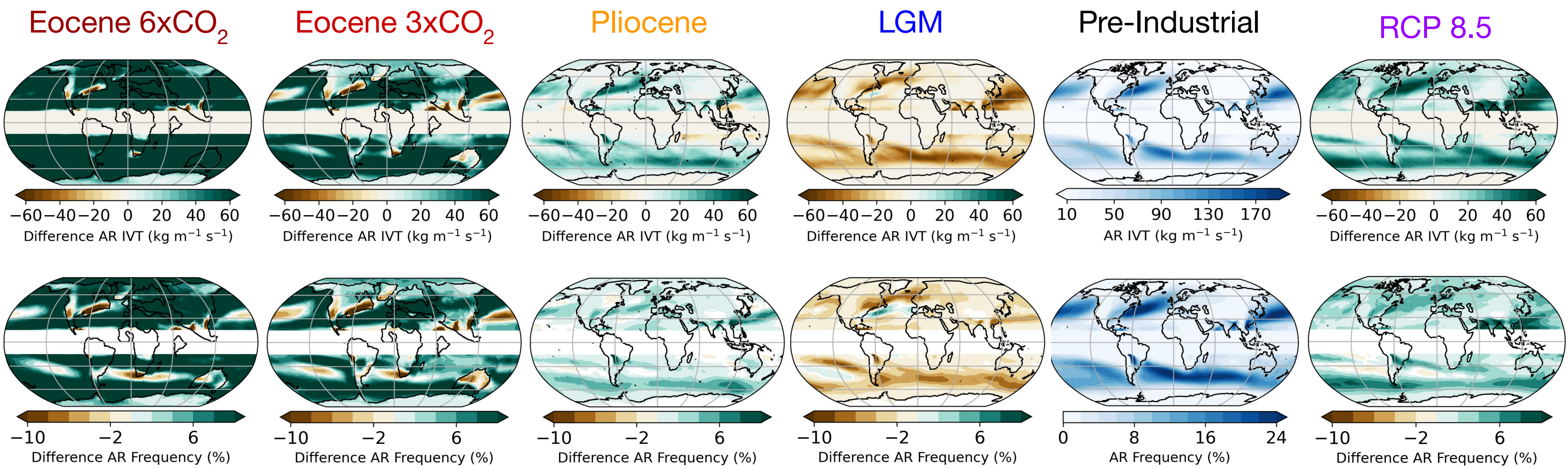
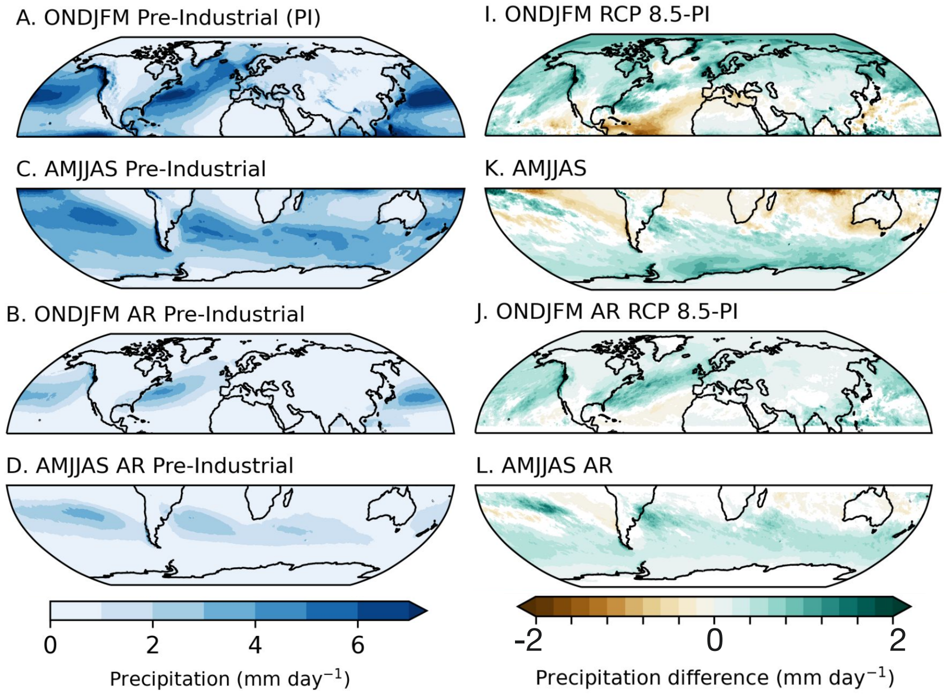


ARs are important drivers of total precipitation change in mid-latitudes



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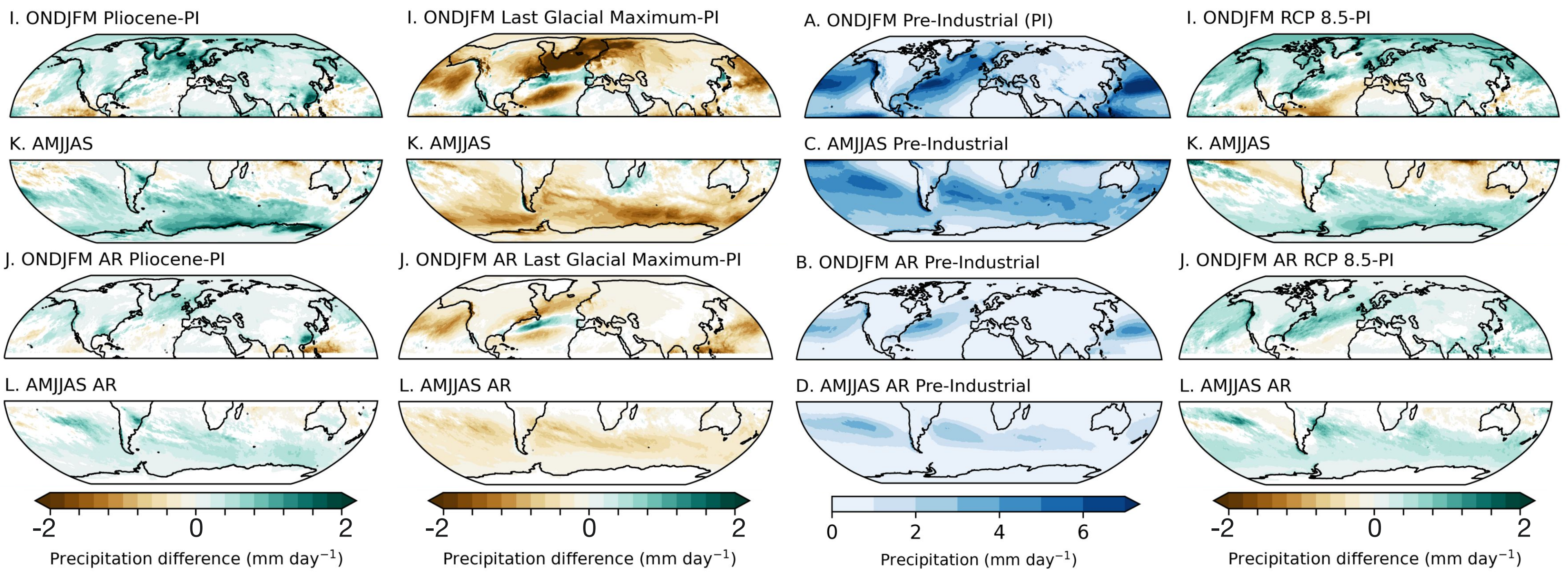

Sophia Macarewich (macarew@ucar.edu)

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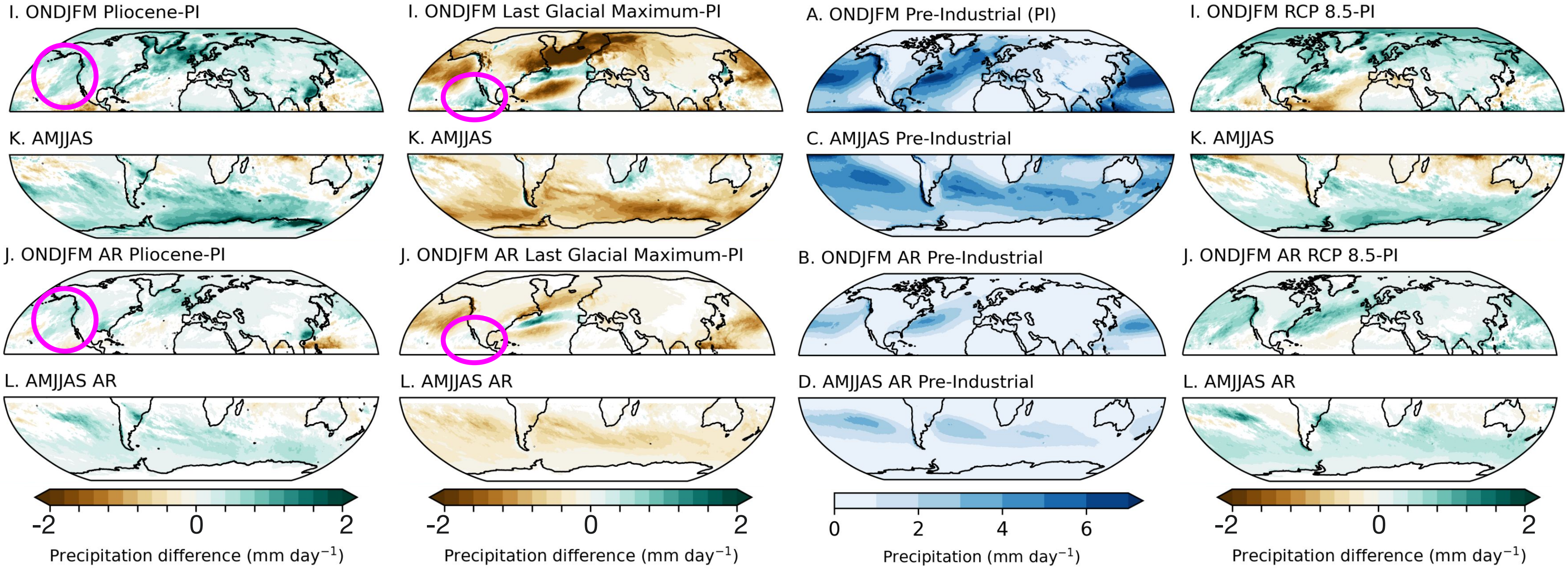


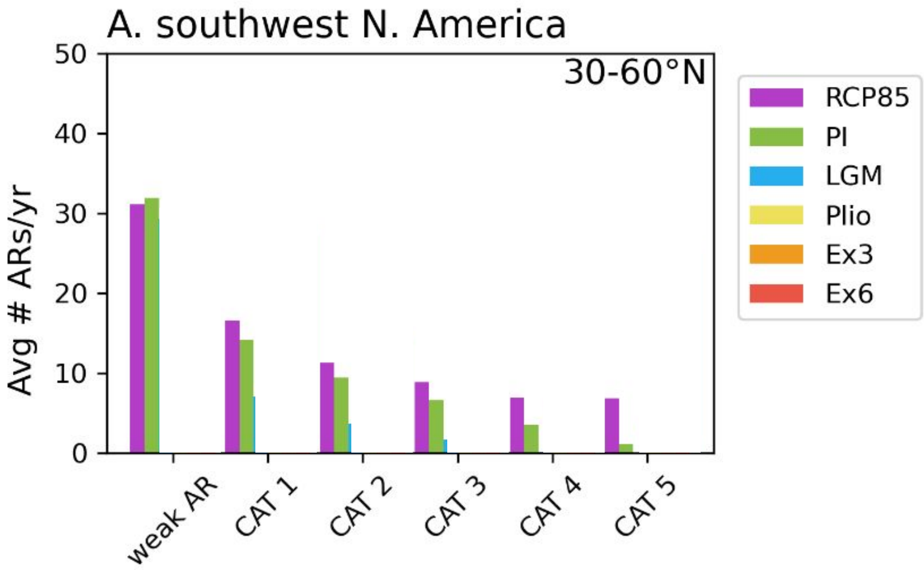
Wetter Pliocene western US
Wetter LGM western US (not due to ARs)

Distribution of landfalling AR intensity changes at higher CO_2

Max IVT (kg m⁻¹ s⁻¹)	Duration of AR conditions (h) ≤24	≥24–48	≥48
≤250	Not an AR	Not an AR	Not an AR
≥250–500	Weak AR	AR Cat 1	AR Cat 2
≥500–750	AR Cat 1	AR Cat 2	AR Cat 3
≥750–1,000	AR Cat 2	AR Cat 3	AR Cat 4
≥1,000–1,250	AR Cat 3	AR Cat 4	AR Cat 5
≥1,250	AR Cat 4	AR Cat 5	AR Cat 5

AR category scale	Assessment of beneficial vs hazardous impacts
AR Cat 1	Primarily beneficial
AR Cat 2	Mostly beneficial, but also hazardous
AR Cat 3	Balance of beneficial and hazardous
AR Cat 4	Mostly hazardous, but also beneficial
AR Cat 5	Primarily hazardous

Modified from
Ralph et al. (2019), *BAMS*



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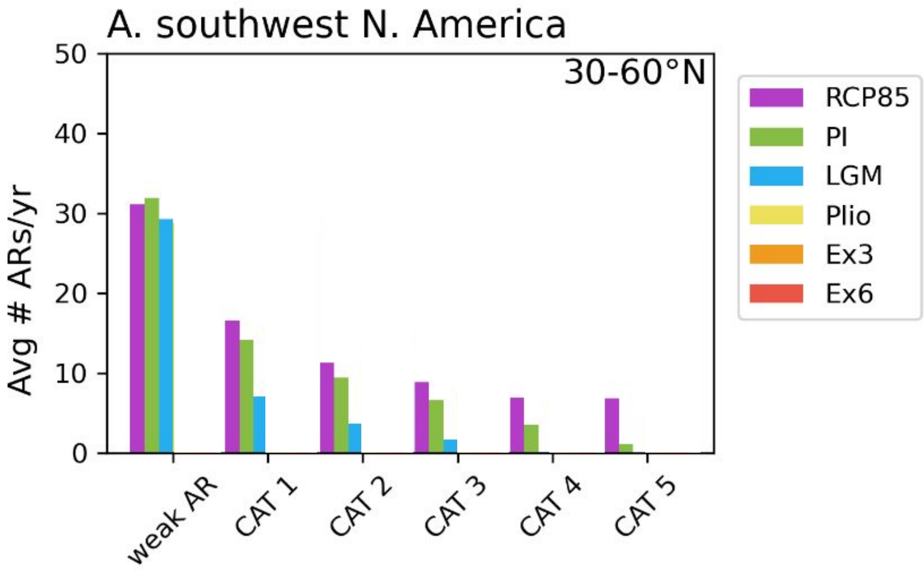

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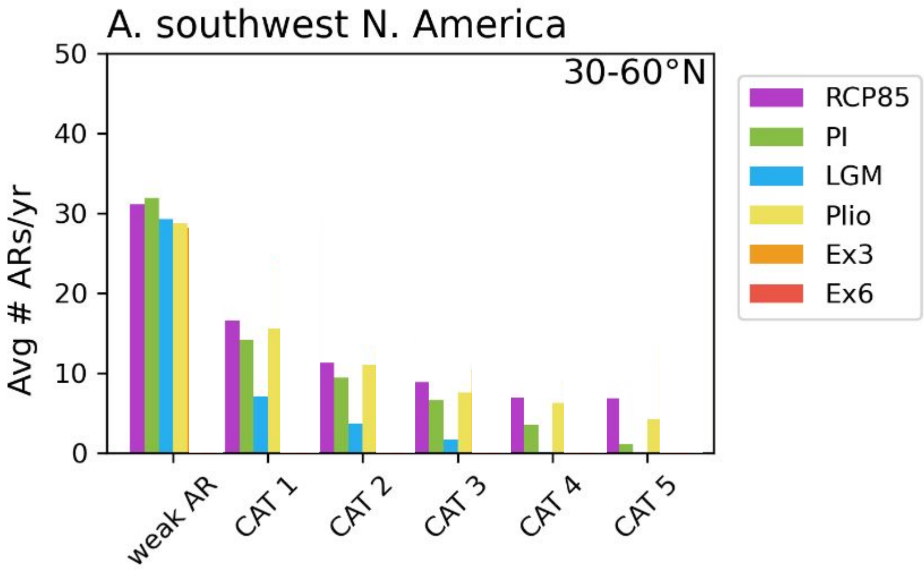

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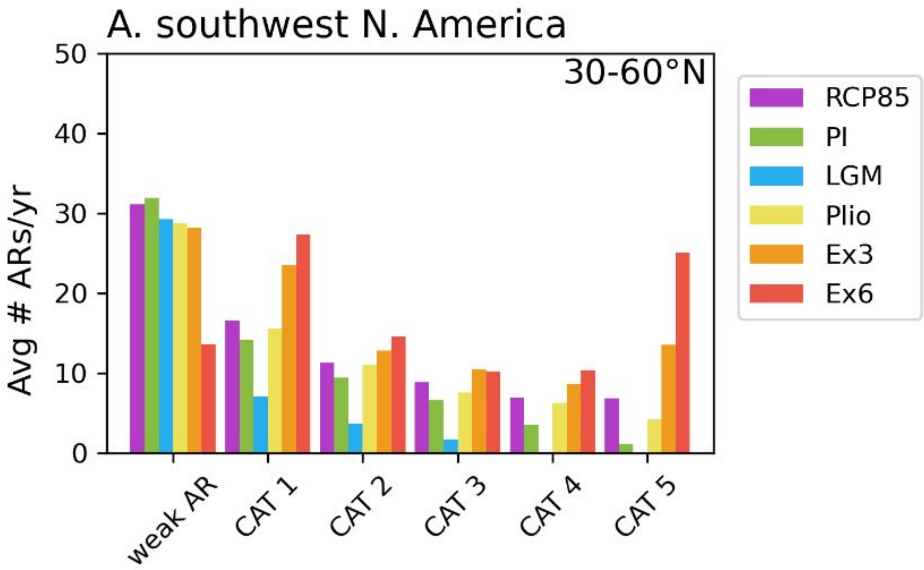
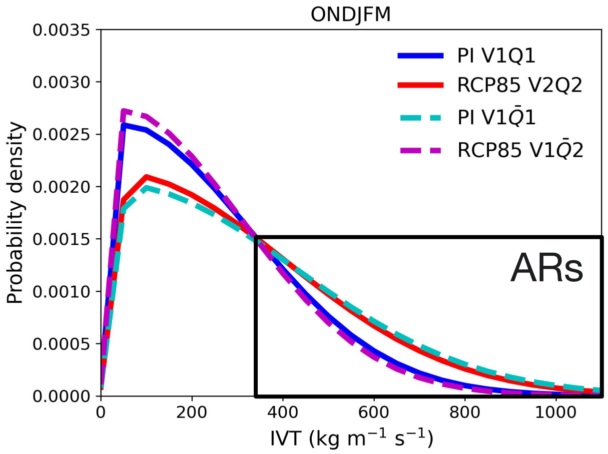


Increased AR activity in NE Pacific driven by moisture at high CO_2

$$\mathrm{IVT} = \sqrt{\left(\frac{1}{\mathrm{g}}\int_{1,000\ \mathrm{hPa}}^{500\ \mathrm{hPa}} qu\ \mathrm{d}p\right)^2 + \left(\frac{1}{\mathrm{g}}\int_{1,000\ \mathrm{hPa}}^{500\ \mathrm{hPa}} qv\ \mathrm{d}p\right)^2}$$

Windy (uv) and *wet (q)* flavors of ARs

Estimate contribution of wind vs. moisture to future AR change by scaling present q by future mean q (Gao et al., 2015, *GRL*)



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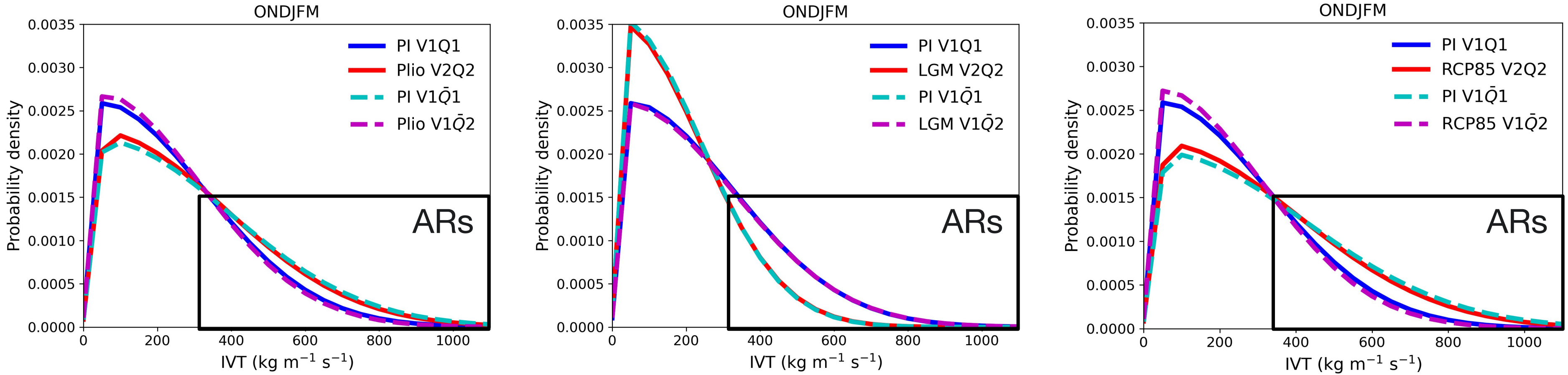

Preliminary Conclusions

- In general, AR frequency and intensity increases with higher CO_2
- In western N. America…
  - Landfalling AR intensity with higher CO_2 increases # damaging ARs
  - Increases in moisture, rather than winds, drive higher ARs under high CO_2
- High-resolution simulations have the potential to resolve some proxy-model discrepancies in reconstructing past hydroclimate change