Ecological risks from rapid cooling with stratospheric aerosol injection

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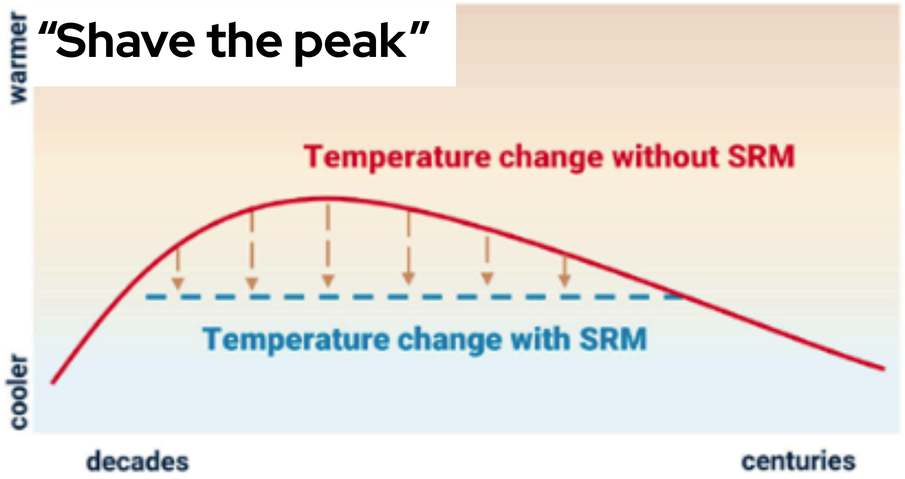
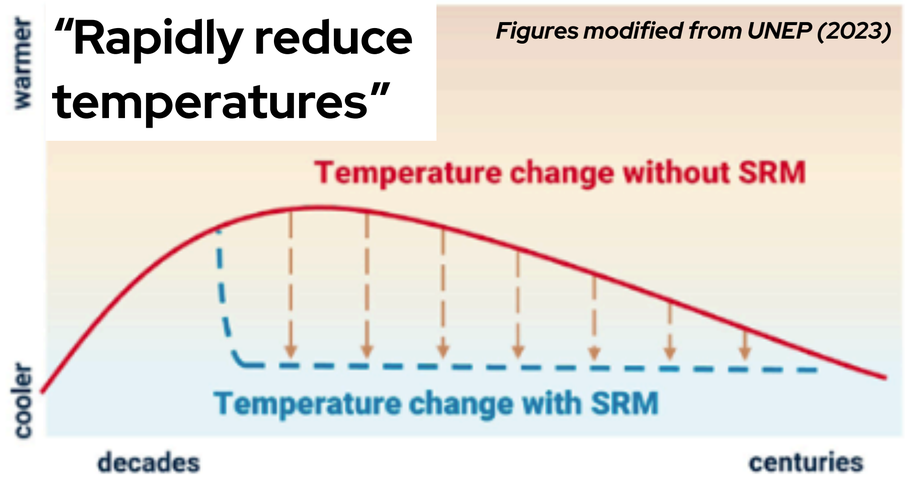
What is stratospheric aerosol injection (SAI)?

- **SAI is a proposed climate intervention method to cool the planet by adding reflective particles to the stratosphere**
- Inspired by processes occurring naturally after volcanic eruptions and extreme wildfires
- **SAI is not a substitute for decarbonization**— but could complement its goals





Figures modified from UNEP (2023)

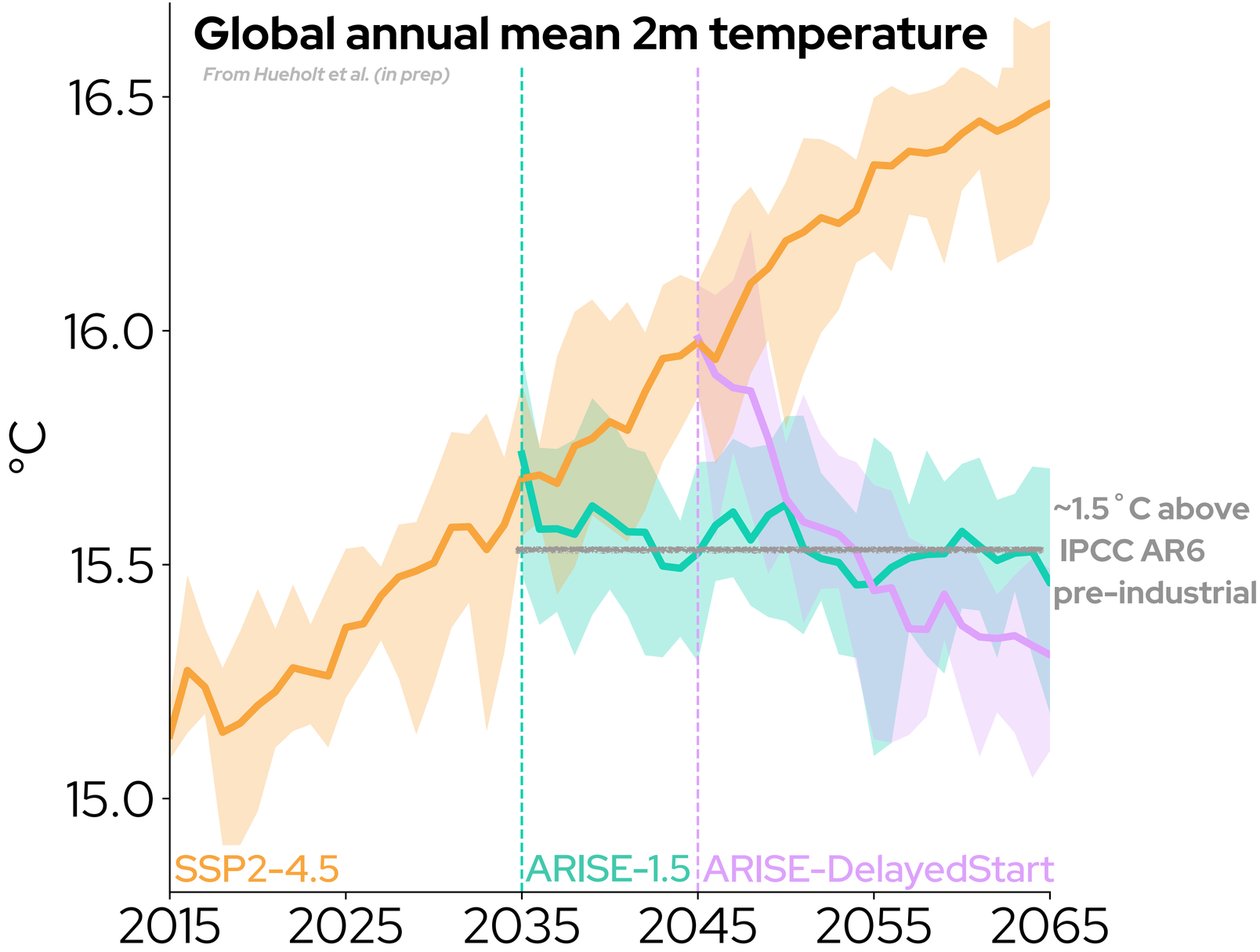
ARISE-SAI[1]: Inject aerosol at four locations to obtain global temperature, pole-to-pole, and pole-to-equator gradient targets against SSP2-4.5 forcing

SSP2-4.5 (no-SAI)
Moderate mitigation of GHG emissions with slow deployment of negative emissions technologies

ARISE-SAI-1.5
Starting in 2035, maintain global mean temperature at ~1.5 ˚C in CESM2(WACCM6)

ARISE-SAI-DelayedStart
Starting in 2045, return global mean temperature to 1.37 ˚C in CESM2(WACCM6)

Each experiment is a 10-member ensemble



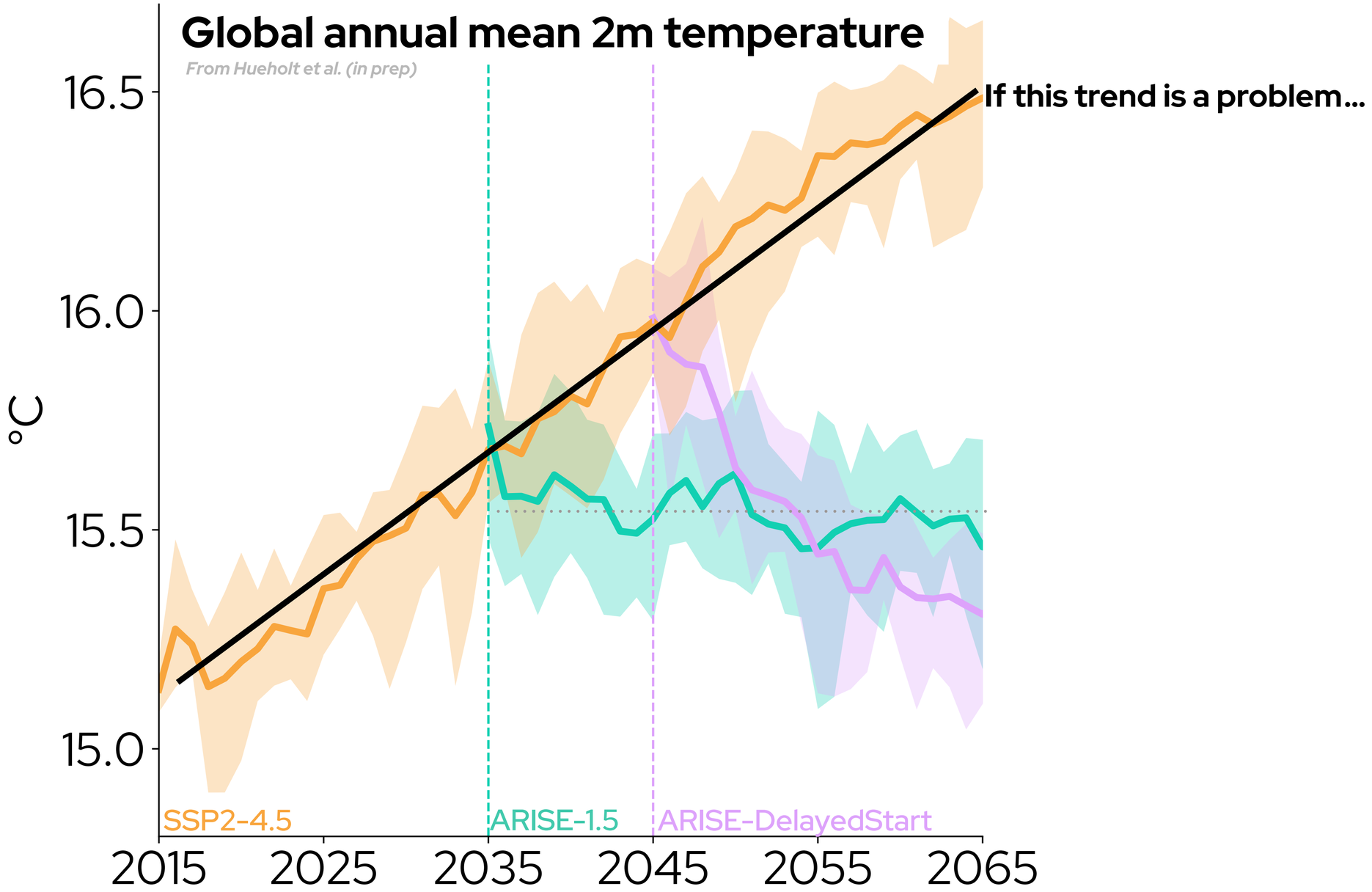
One climate risk to ecosystems is the “movement” of environmental conditions driven by changes in temperature

- **C*limate speed of 2m temperature*: the speed necessary to stay in the same starting isotherm**[2]
- The temporal gradient in temperature divided by the spatial gradient of temperature
- **Climate speeds >1–2 km/yr are a problem**[2,3,4,5,6,7]; **greater than ~10 km/yr are a *big* problem**[4,7,8]
- Climate speed has limitations, but provides actionable information about the degree of forcing experienced by bulk ecosystems[2,9,10,11]

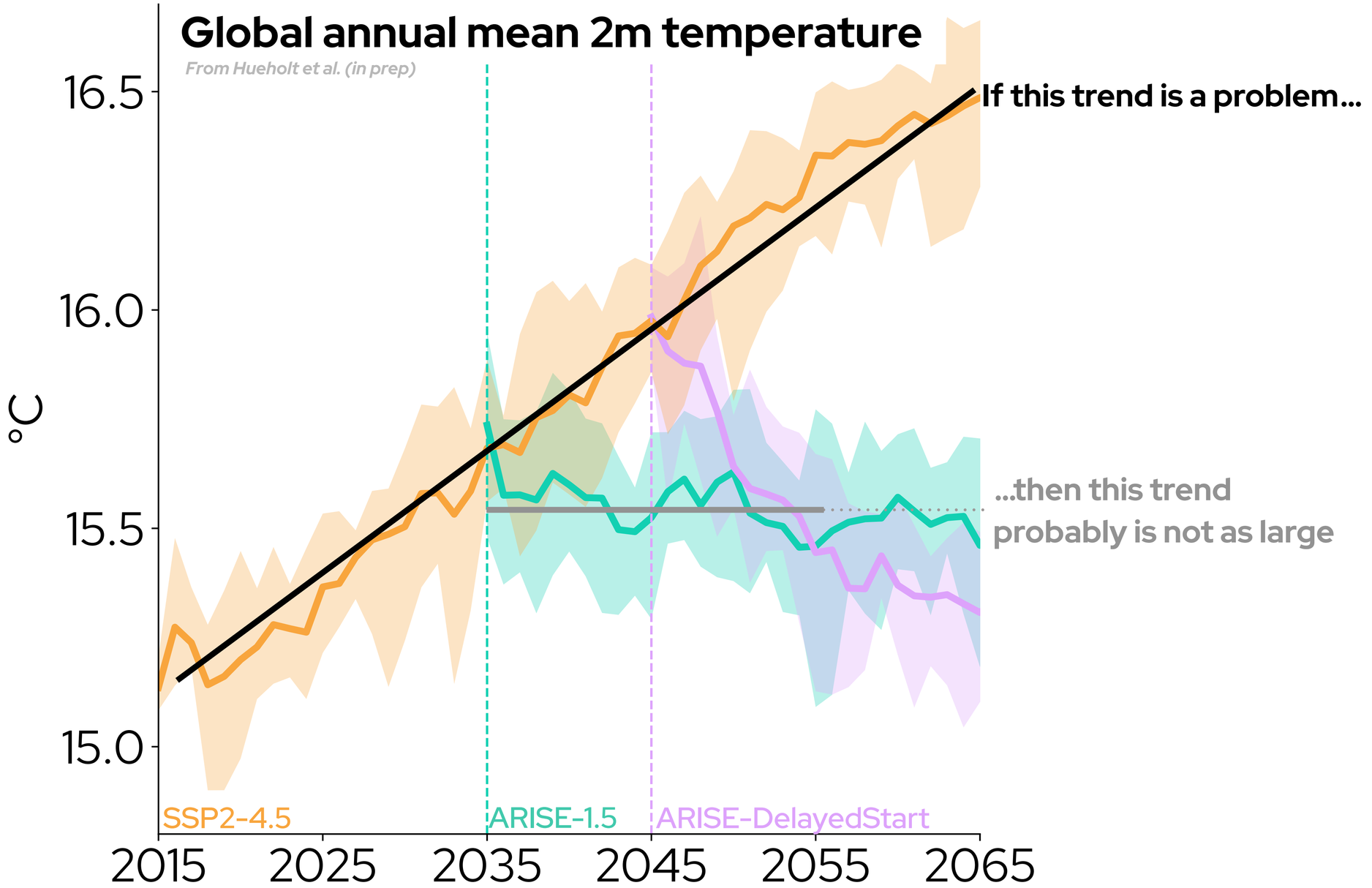
$$\frac{\frac{^{\circ}C}{\text{time}}}{\frac{^{\circ}C}{\text{space}}} = \frac{\text{space}}{\text{time}} \text{ (e.g., km/yr)}$$

Yields a vector (“climate velocity”); we analyze the magnitude (“climate speed”)

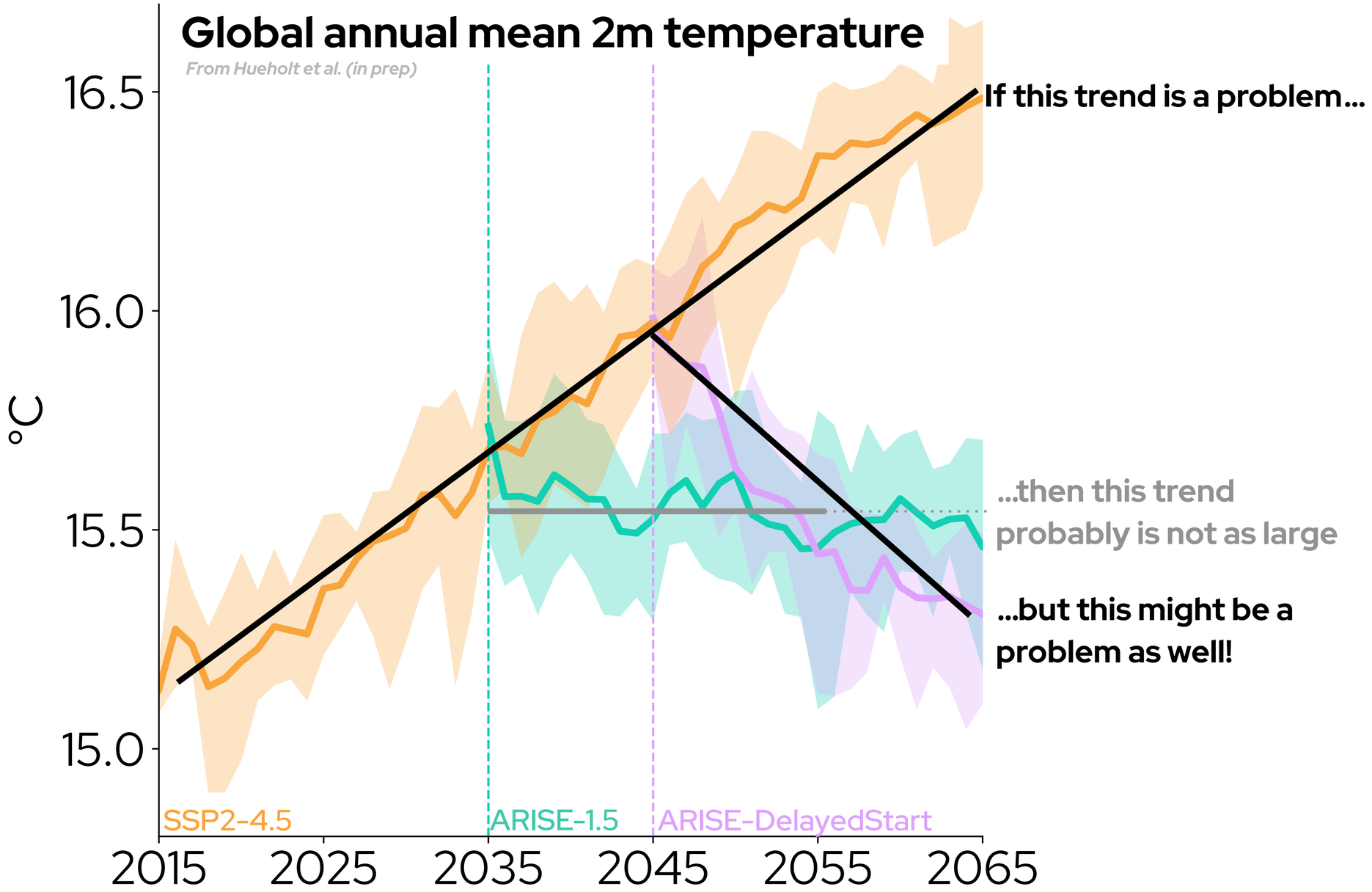
Climate speed scales with the rate of change in temperature



In ARISE-1.5, global mean temperatures are held nearly constant

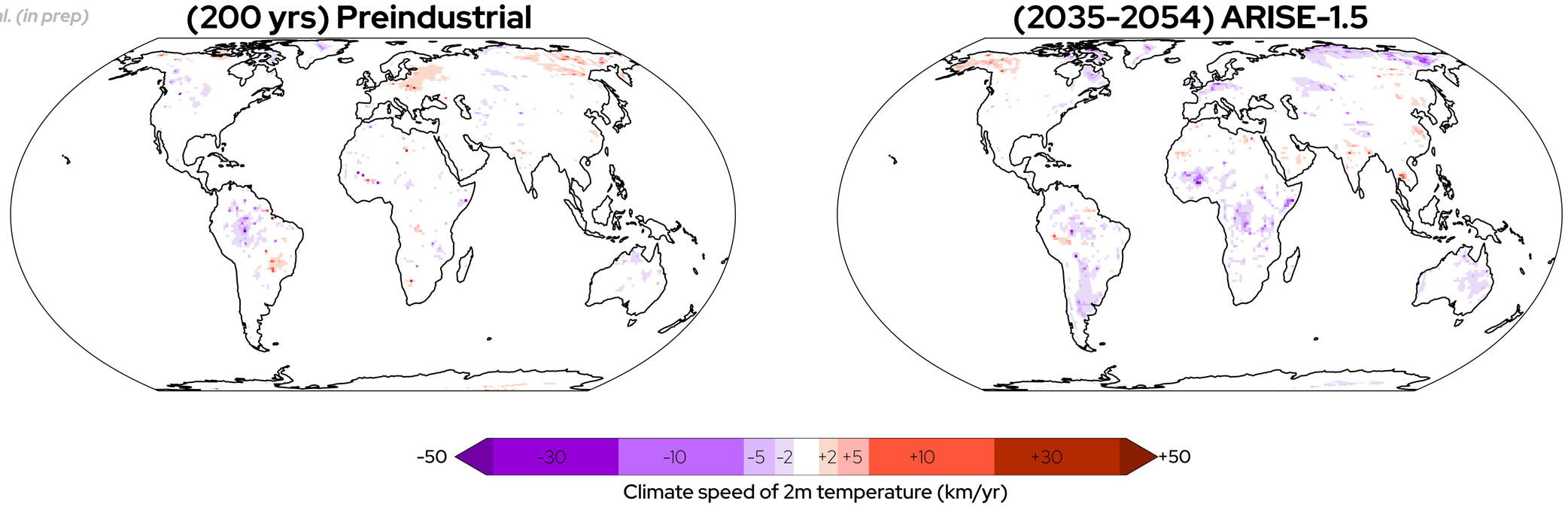


But what happens if we wait 10 years?



Climate speeds over land under ARISE-1.5 are similar to preindustrial

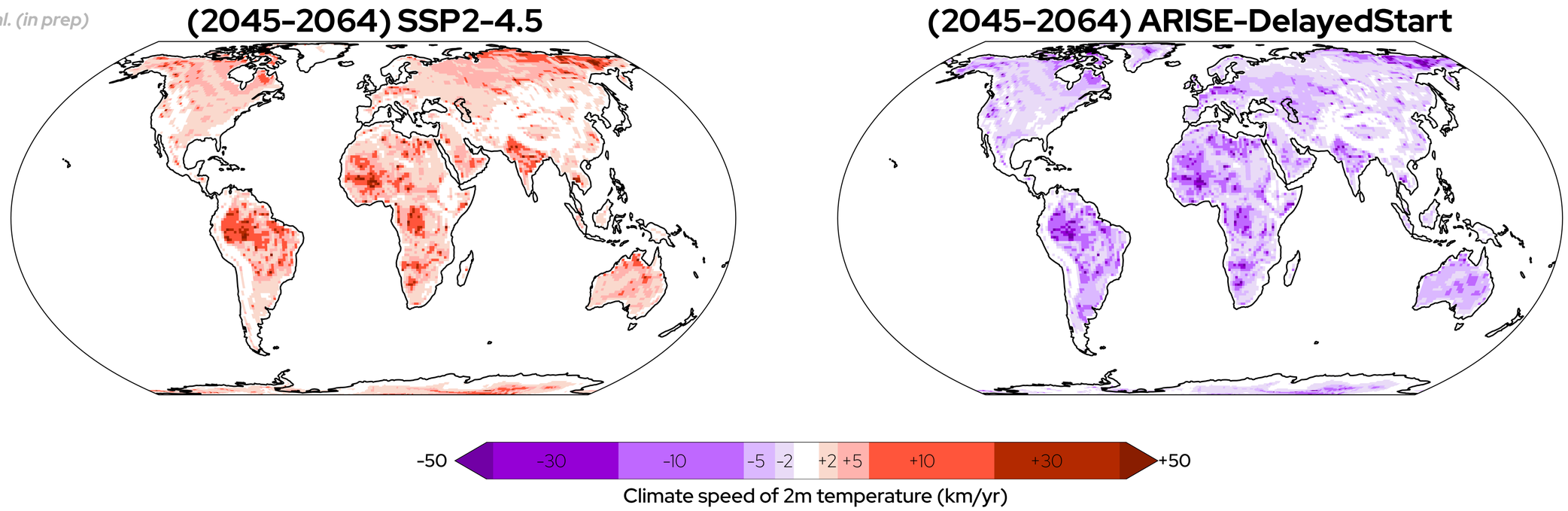
From Hueholt et al. (in prep)



- **Patchy climate speeds consistent with stochastic internal variability**
- **Sign indicates whether climate speed is associated with "warming" or "cooling" trend**
- Ocean data masked out in these figures for visual simplicity

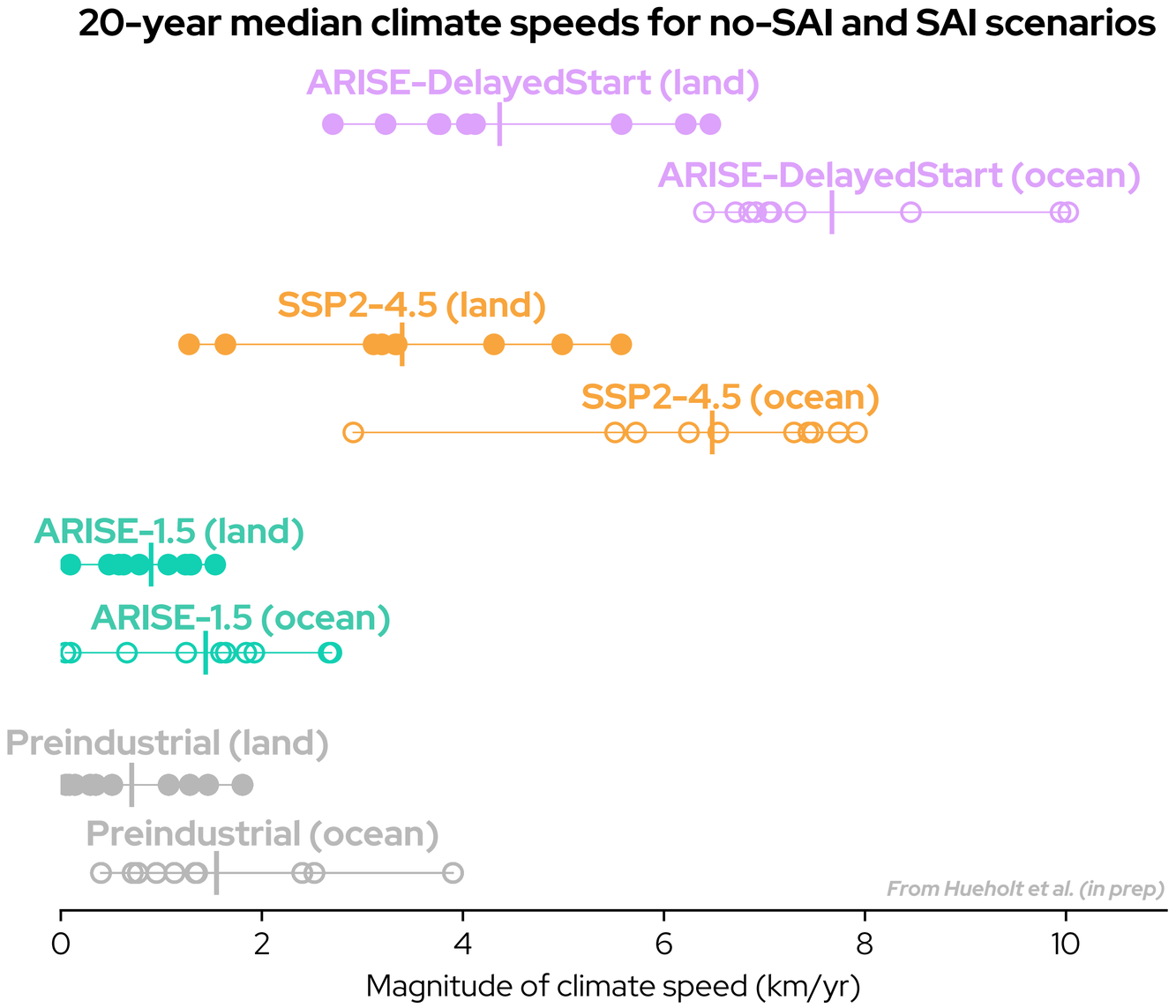
Climate speeds under ARISE-DelayedStart are greater than or equal to SSP2-4.5

From Hueholt et al. (in prep)

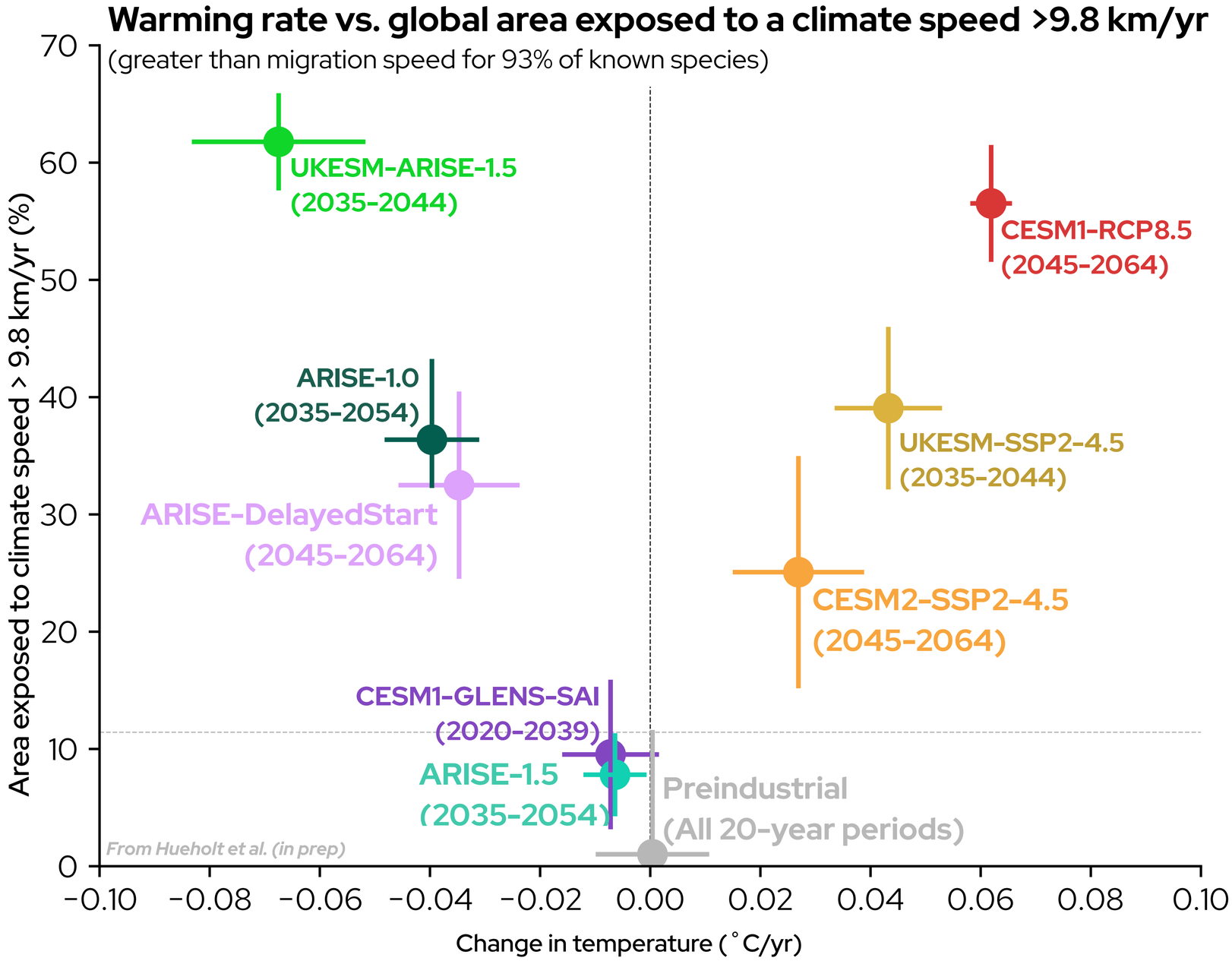


- **Large climate speeds forced by warming in no-SAI SSP2-4.5 and cooling in ARISE-DelayedStart**
- **Climate speeds generally greatest in tropical regions with small spatial gradients**
- Anywhere there is color indicates substantial forcing to terrestrial ecosystems

ARISE-1.5 climate speeds are indistinguishable from pre-industrial variability, but ARISE-DelayedStart climate speeds are greater than SSP2-4.5



Climate speeds provide one way to think about relative risk between scenarios



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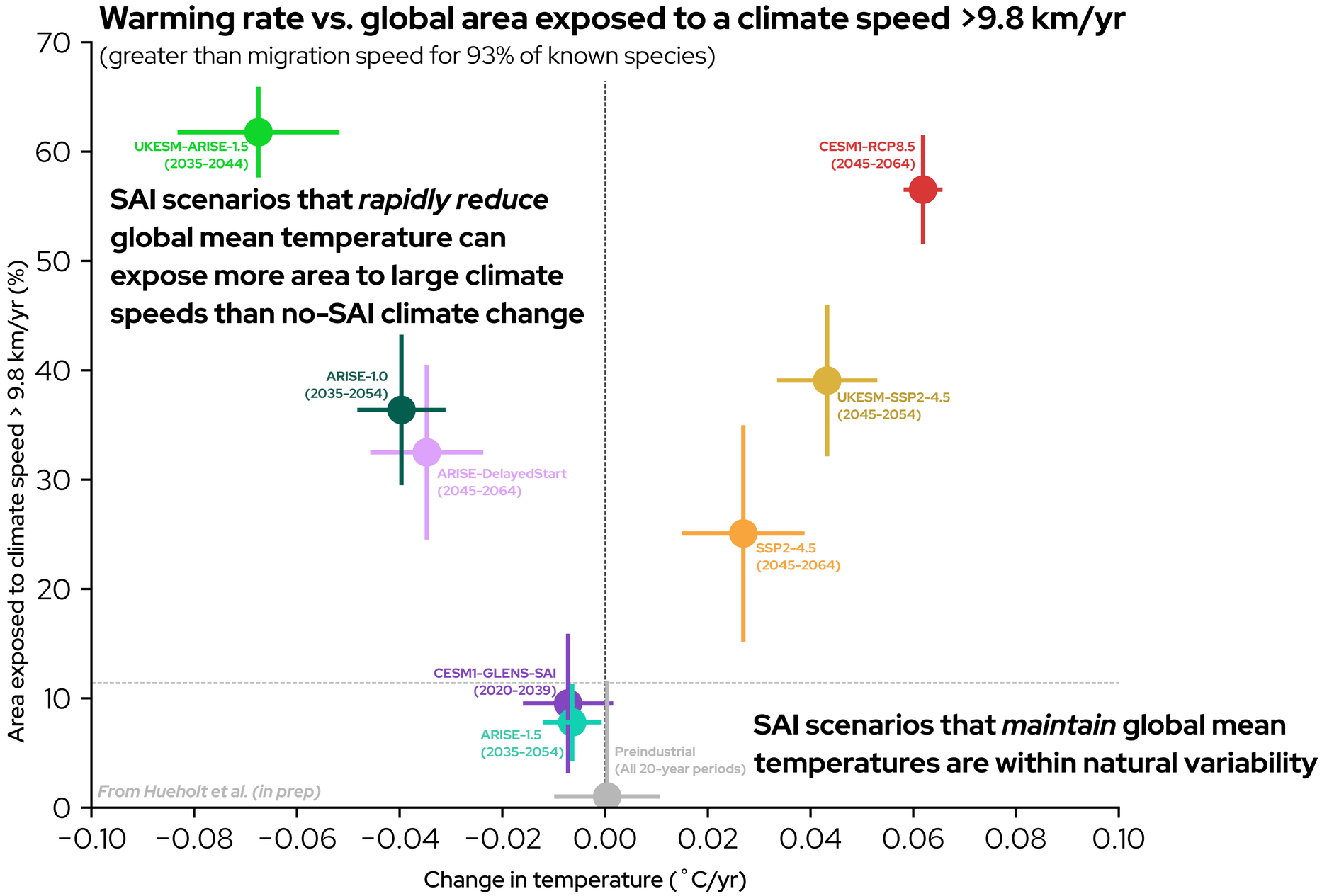
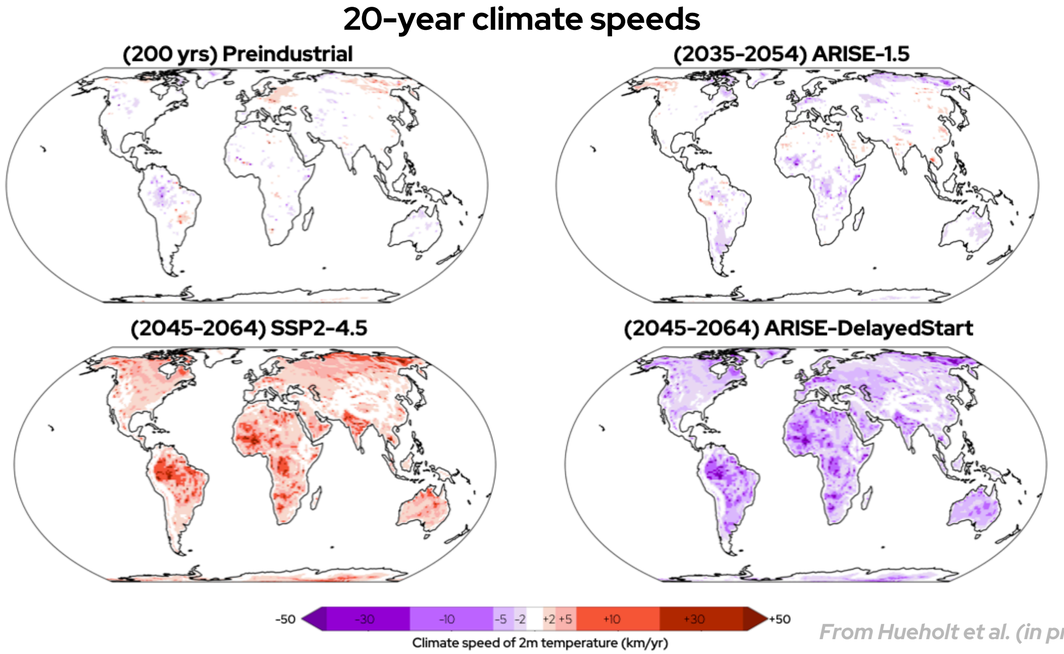


Summary

- Climate speeds when global mean temperature is maintained with SAI (ARISE-1.5) are similar to those experienced in a preindustrial climate
- A similar SAI strategy but with deployment delayed by 10 years (ARISE-DelayedStart) yields large planetary-scale climate speeds
- The climate speeds experienced during a delayed deployment are far beyond natural variability, and greater than what would be experienced under climate change without SAI



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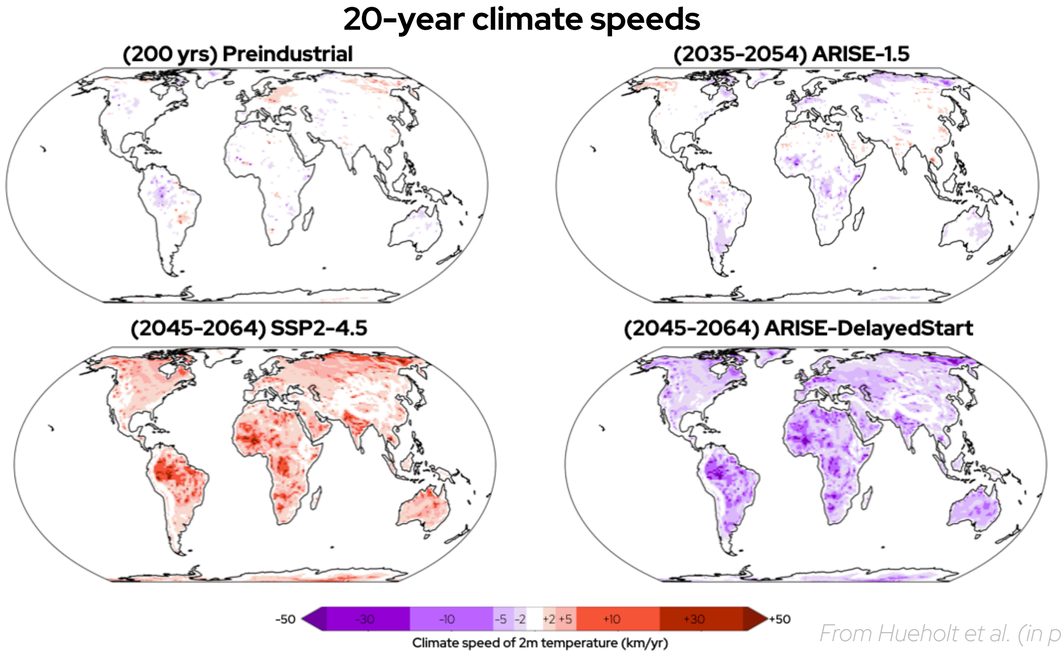

From Hueholt et al. (in prep)

Thank you for listening! Questions?

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Footnotes

1. Richter et al. 2022 "Assessing Responses and Impacts of Solar climate intervention on the Earth system with stratospheric aerosol injection (ARISE-SAI): protocol and initial results from the first simulations"
2. Loarie et al. 2009 "The velocity of climate change"
3. Burrows et al. 2011 "The pace of shifting climate in marine and terrestrial ecosystems"
4. Trisos et al. 2018 "Potentially dangerous consequences for biodiversity of solar geoengineering implementation and termination"
5. Parmesan and Yohe 2003 "A globally coherent fingerprint of climate change impacts across natural systems"
6. Chen et al. 2011 "Rapid Range Shifts of Species Associated with High Levels of Climate Warming"
7. Lenoir et al. 2020 "Species better track climate warming in the oceans than on land"
8. Poloczanska et al. 2013 "Global imprint of climate change on marine life"
9. Sunday et al. 2015 "Species traits and climate velocity explain geographic range shifts in an ocean-warming hotspot"
10. Brito-Morales et al. 2018 "Climate Velocity can Inform Conservation in a Warming World"
11. Sachan et al. 2022 "Contemporary climate change velocity for near-surface temperatures over India"

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Brian Dobbins and Alicia Karspeck (ARISE-DelayedStart, ARISE-1.0), Matthew Henry and Jim Haywood (UKESM-ARISE)
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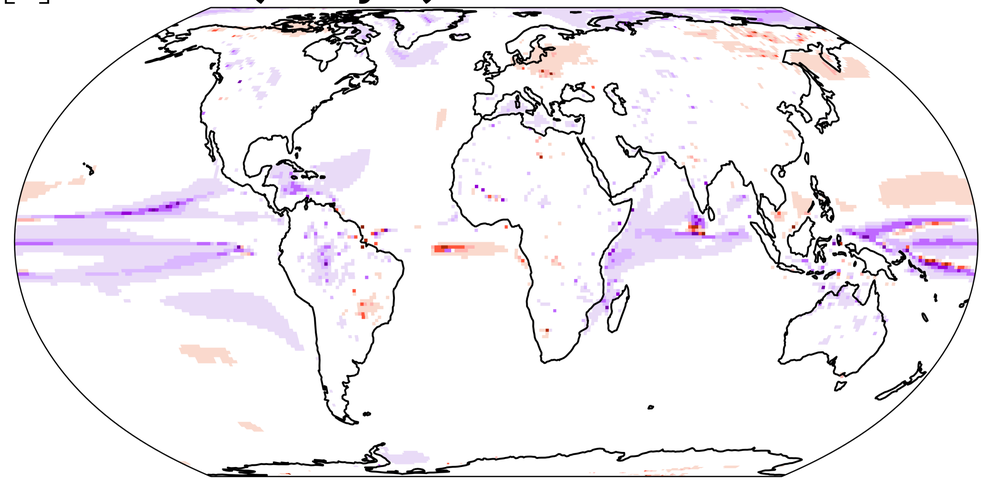
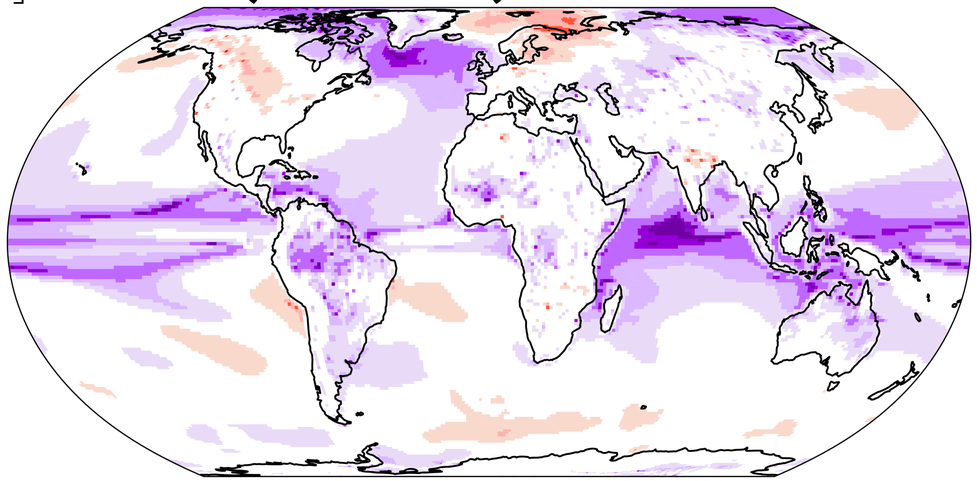
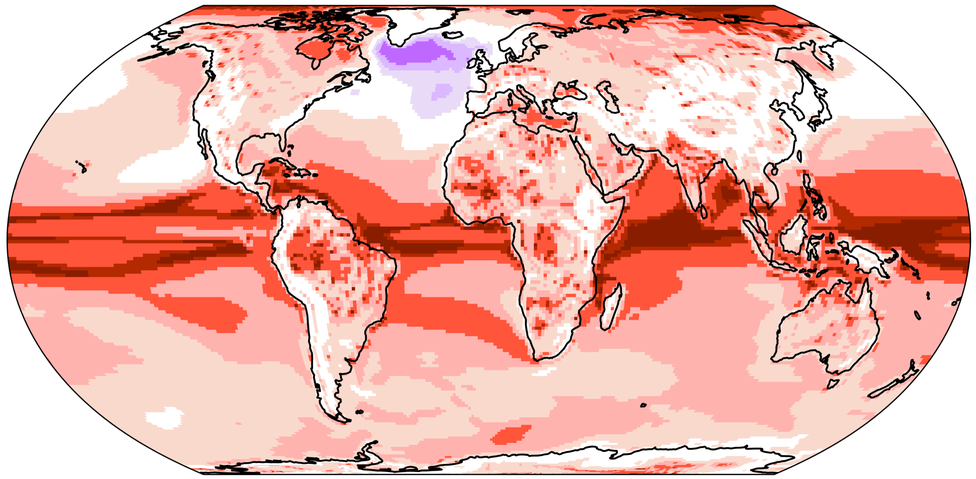
[a] (200 yrs) Preindustrial



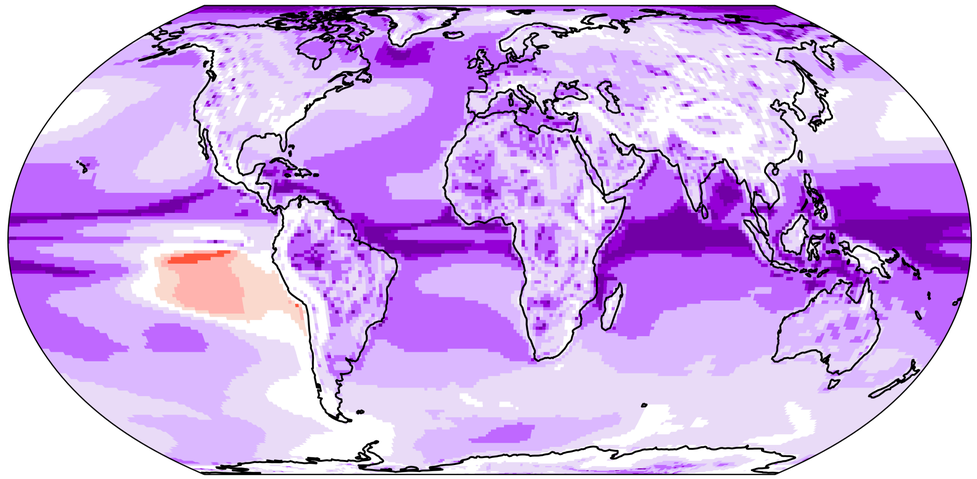
[b] (2035-2054) ARISE-1.5



[c] (2045-2064) SSP2-4.5



[d] (2045-2064) ARISE-DelayedStart



Climate speed of 2m temperature (km/yr)