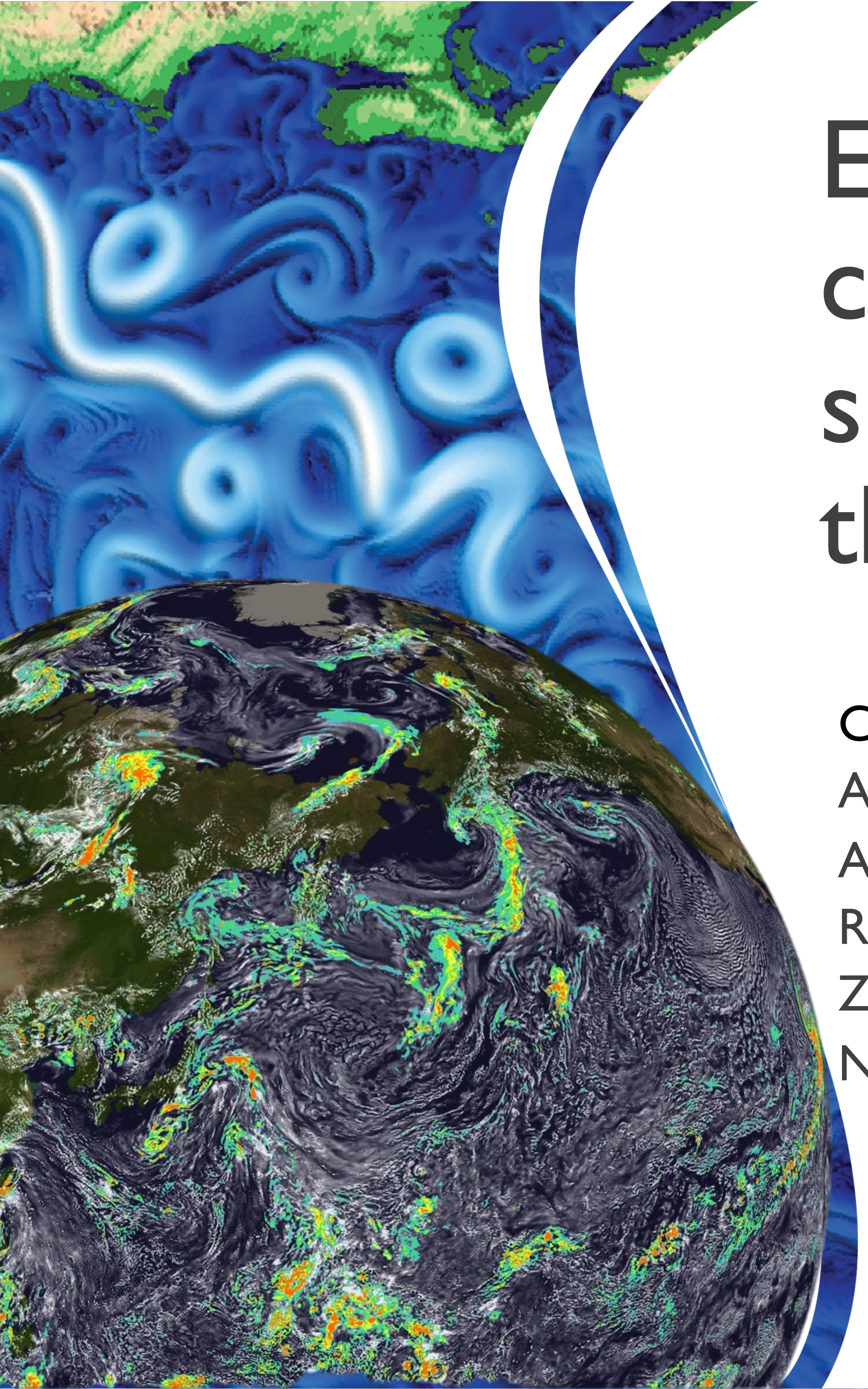

Evaluating SCREAM's climate sensitivity and skill in representing the present-day 'climate'

Christopher Terai, Peter Caldwell, Ben Hillman, Hassan Beydoun, Aaron Donahue, Noel Keen, Wuyin Lin, Luca Bertagna, Peter Bogenschutz, Andrew Bradley, Chris Eldred, Jim Foucar, Chris Golaz, Oksana Guba, Rob Jacob, Jeff Johnson, Andy Salinger, Xingqiu Yuan, Walter Hannah, Yunyan Zhang, Balwinder Singh, Paul Ullrich, Charlie Zender, Susannah Burrows, Naser Mahfouz, Yi Qin, Mark Zelinka, Li-Wei Chao, Jingjing Tian

E3SM All-Hands Webinar
February 29, 2024

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The biggest challenge with running and evaluating SCREAM

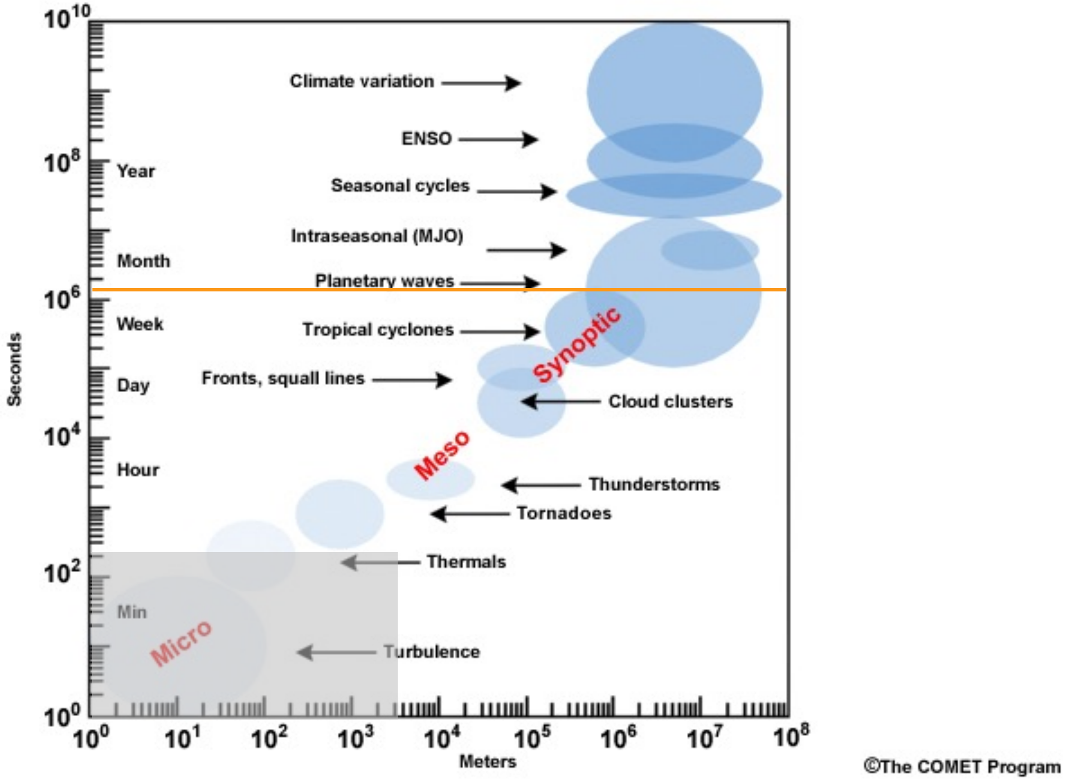
Computational cost

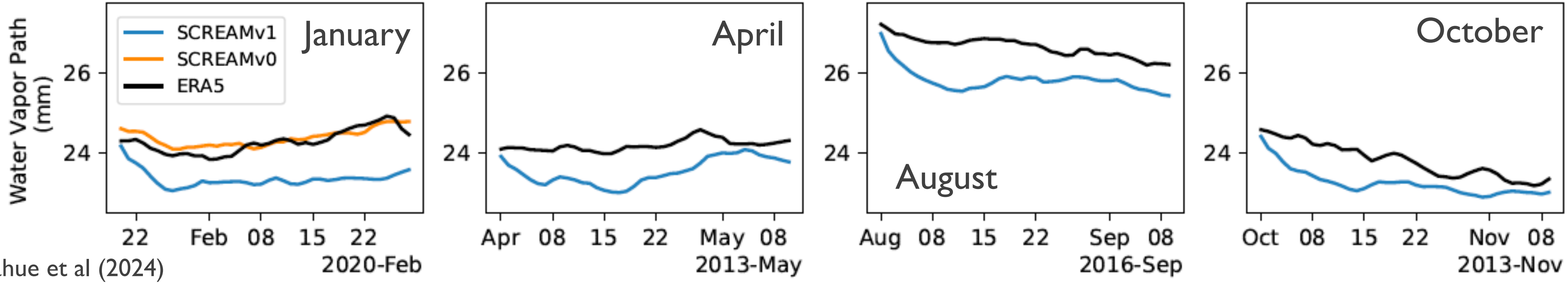
A main constraint driving our simulation strategy, but we have been rapidly expanding our simulation length.

- 40 days — DYAMOND2 simulation with v0 (2021)
- 4 x 40 days — Four Seasons simulation with v1 (2022)
- 13 months — Cess-Potter simulations (2023) (+ aerosol simulations 2024)
- 10+ years — Decadal simulations (2024)

Fortunately, many atmospheric processes occur on time-scales of days

- Previous studies have reported that model errors in climatology manifest themselves in the first few days (Phillips et al, 2004; Ma et al., 2015)

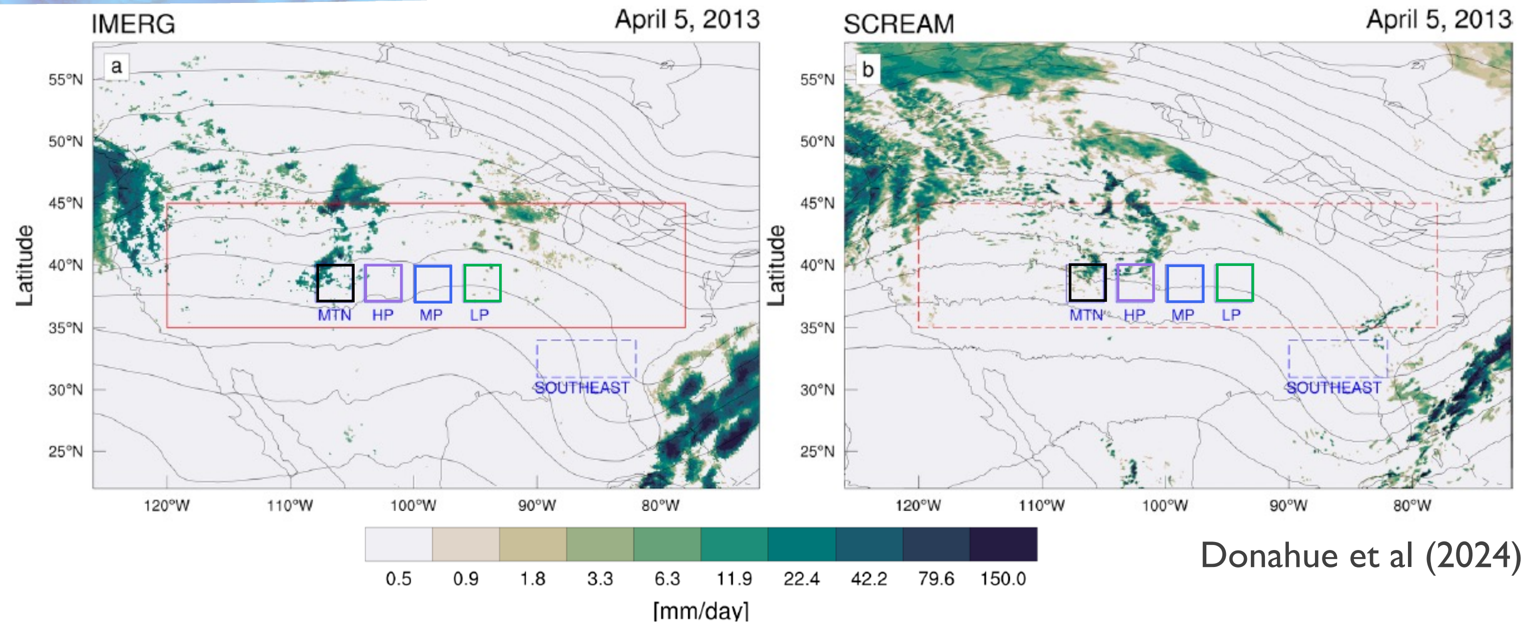




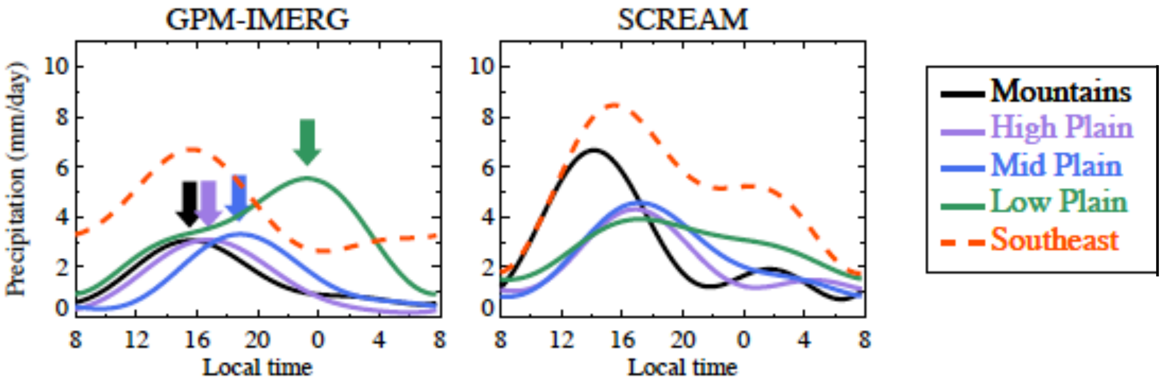
Donahue et al (2024)

Phenomena that SCREAM represents well (those that we expected)

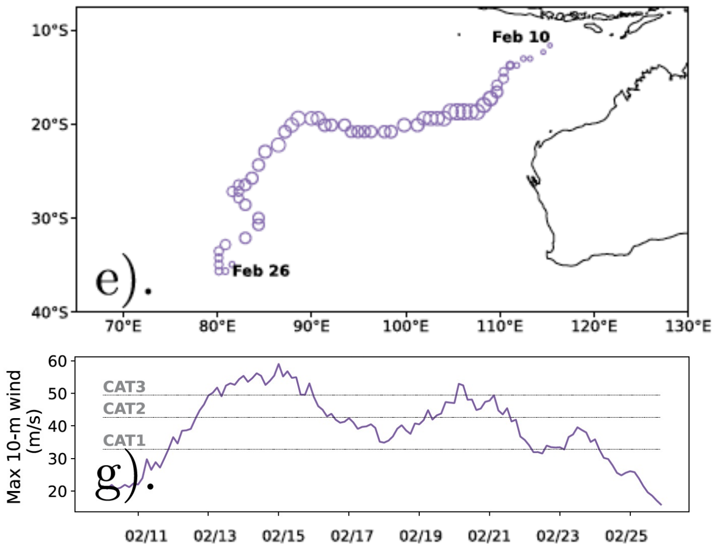
- Representing qualitative aspects mesoscale organization
  - Tropical cyclones
- Diurnal cycle of precipitation

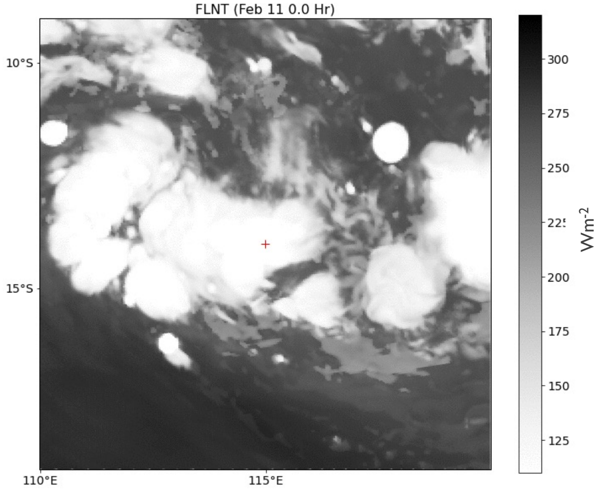


Donahue et al (2024)



Donahue et al (2024)

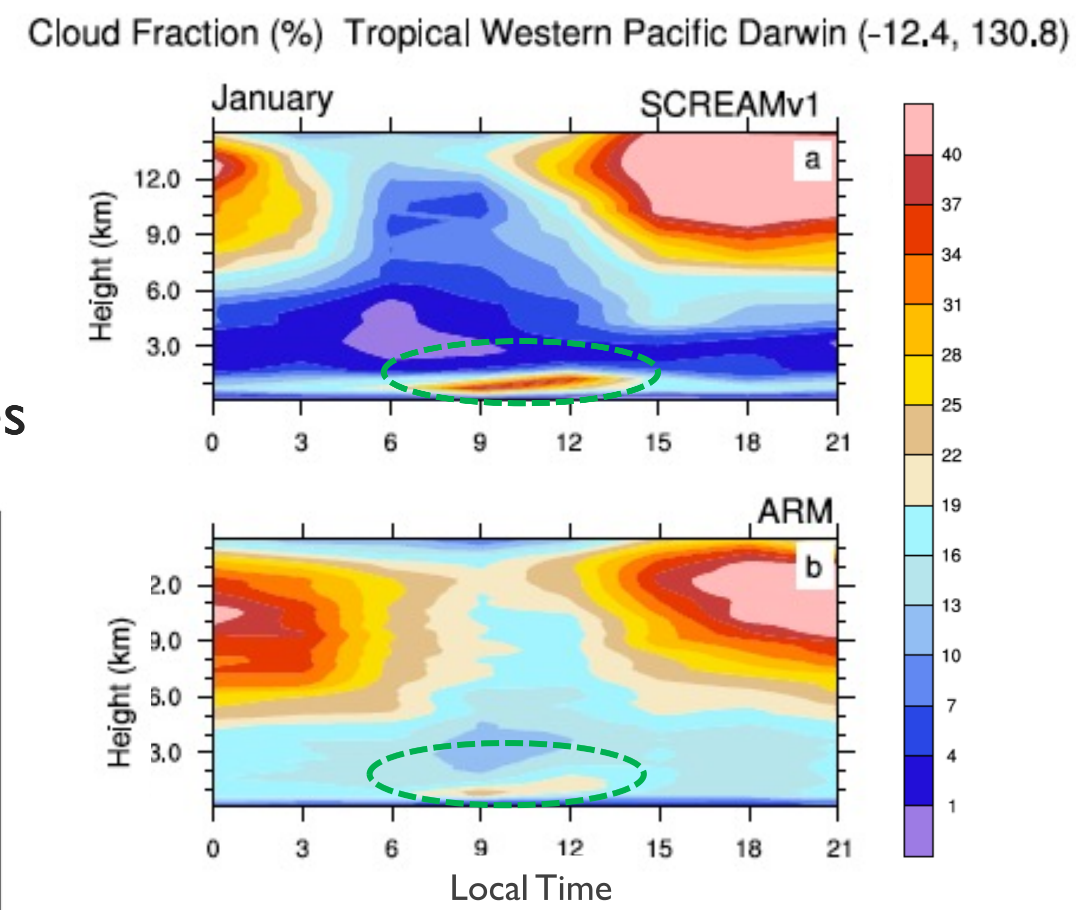




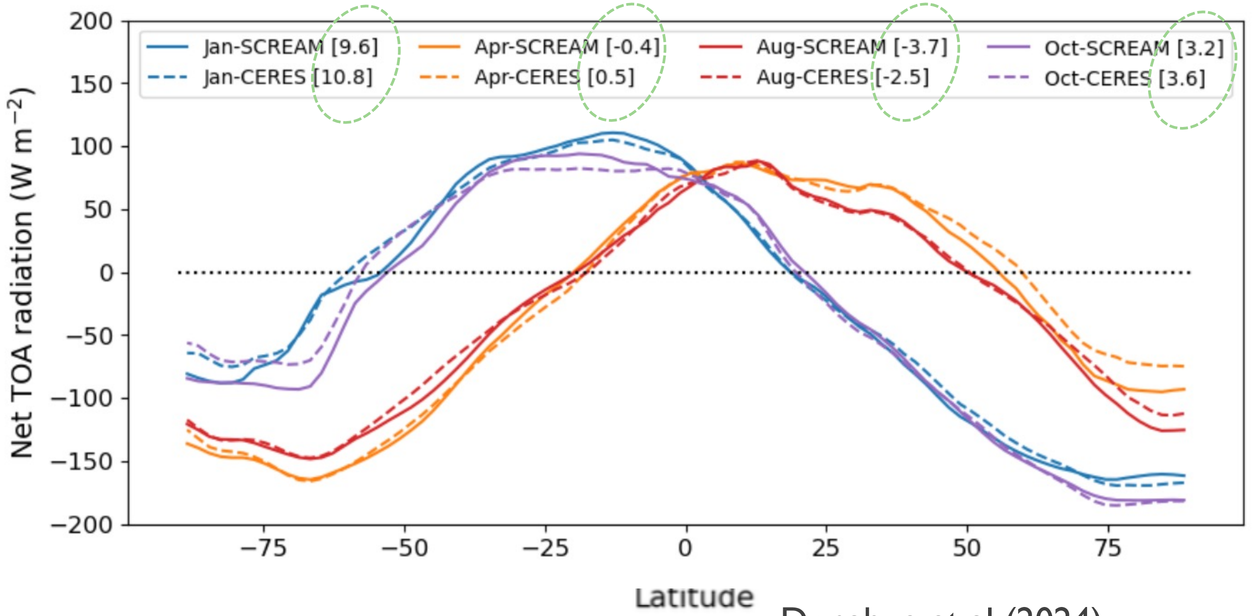
Caldwell et al (2021)

Unexpected features that SCREAM captures well

- Diurnal cycle of boundary layer clouds
- Atmospheric Rivers (not shown)
- Global-mean top of atmosphere radiative fluxes



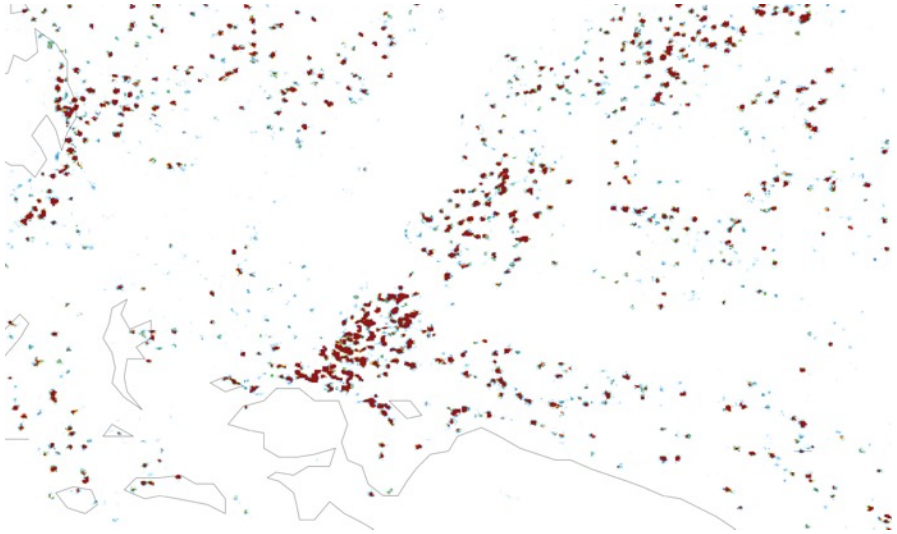
Donahue et al (2024)



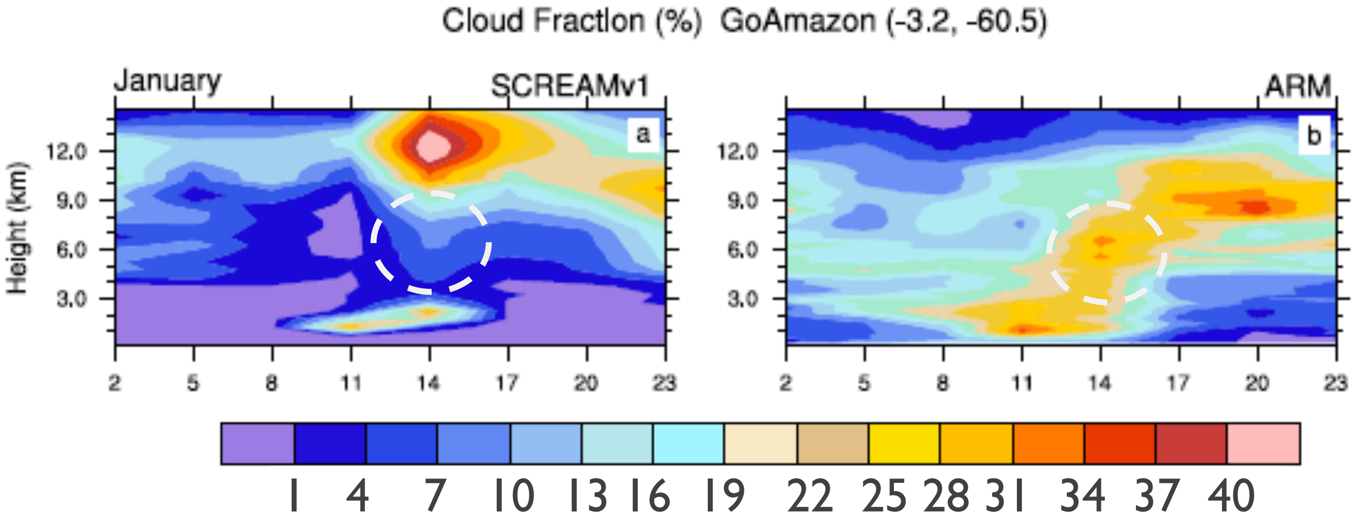
Donahue et al (2024)

Features that SCREAM struggles with

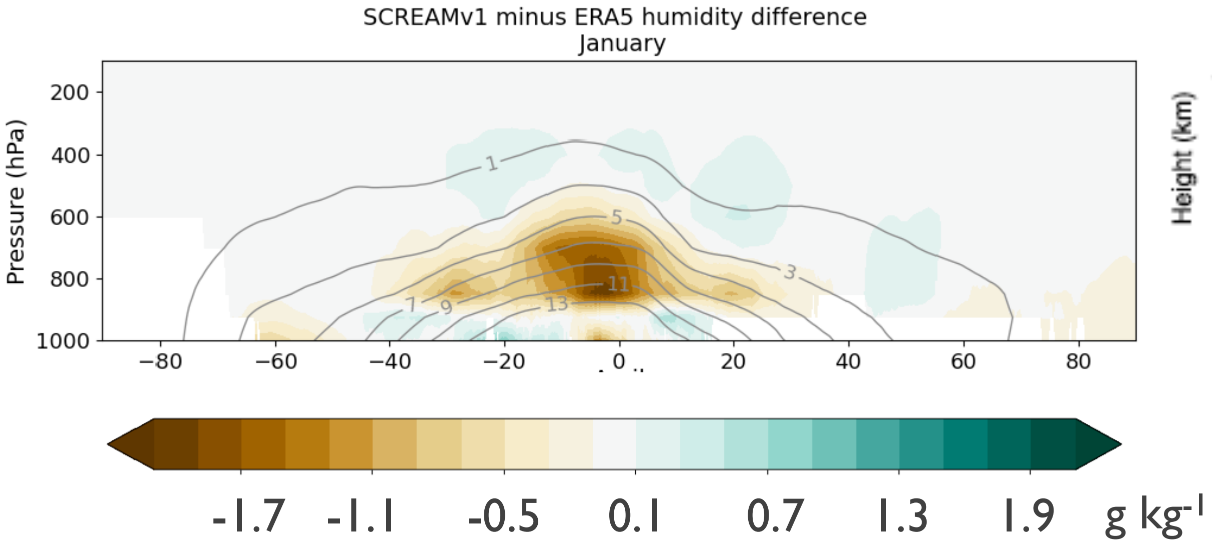
- Popcorn convection
- Lack of mid-level clouds and humidity
- Warmer near-surface land temperatures (not shown)



Snapshot of precipitation rate over the Tropical West Pacific (Jan 22, 2020)



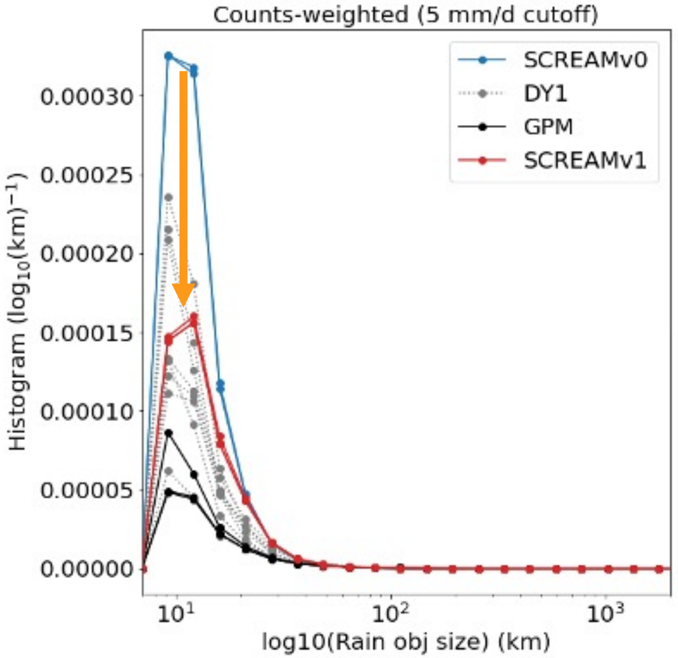
Donahue et al (2024)



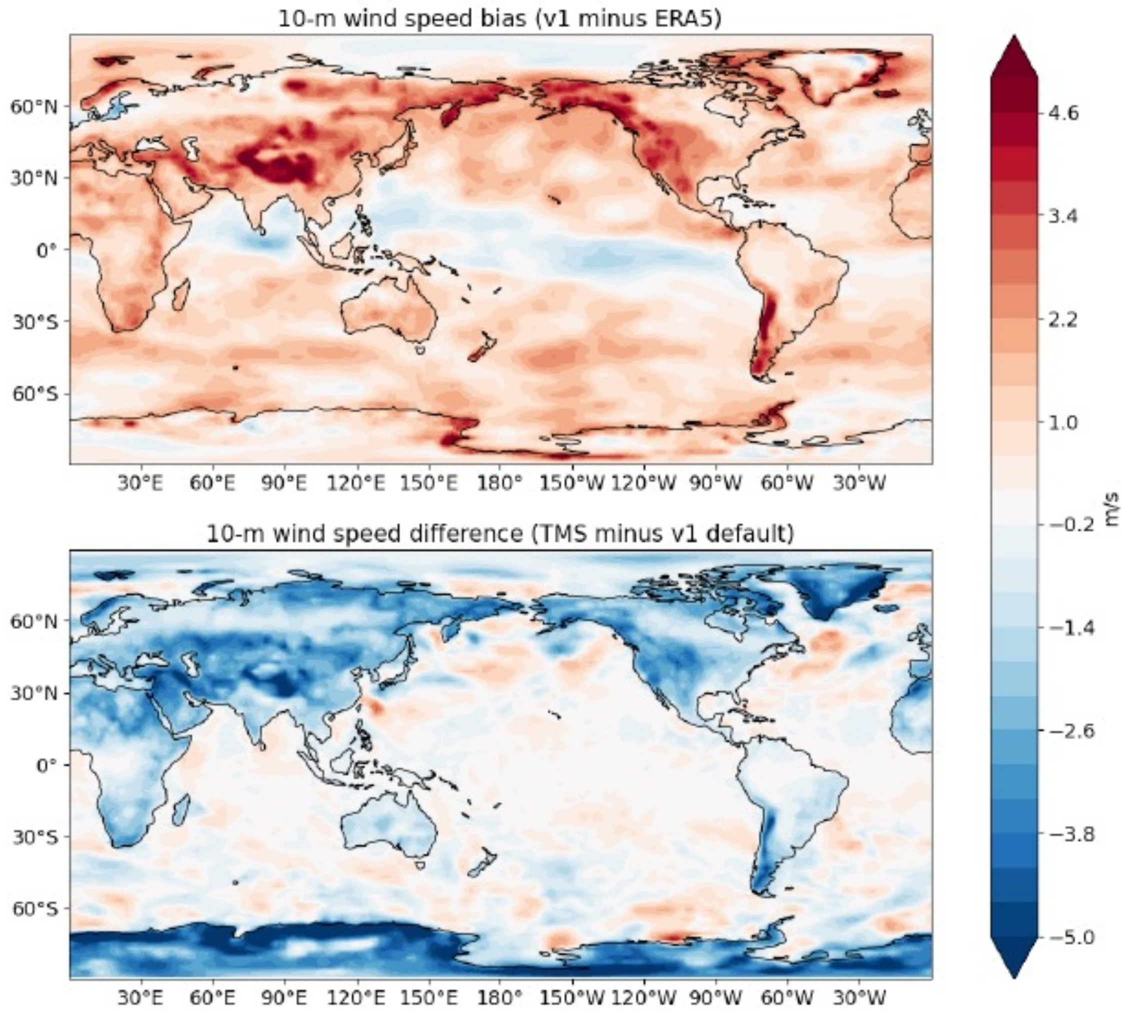
Lessons learned along the way

- We still need turbulent mountain stress scheme even at 3km

- Removing subgrid variability of microphysical tendencies help reduce popcorn bias



Frequency of convective events as a function of their size (x axis). Note SCREAMv0 (F90) from DYAMOND2 (winter), SCREAMv1 (C++) is from DY2 and Oct 2013, and other lines are from DYAMOND1 (summer) model runs.



Donahue et al (2024)

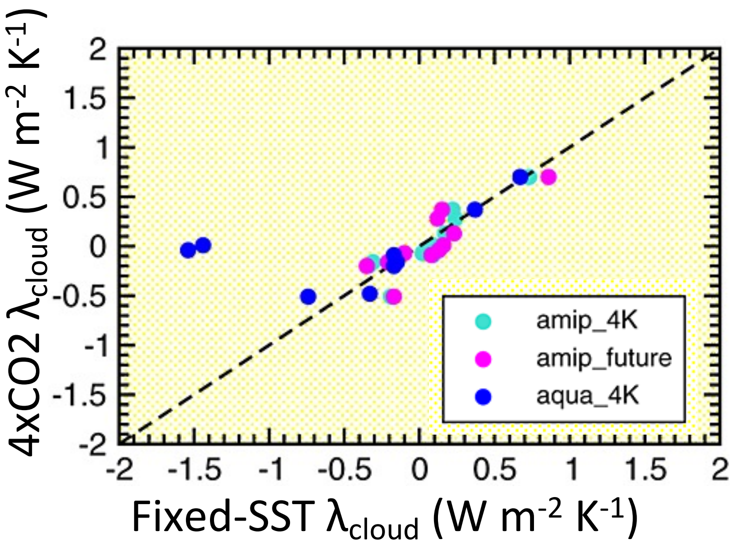
What can we learn from a 1-year simulation? - Climate feedbacks

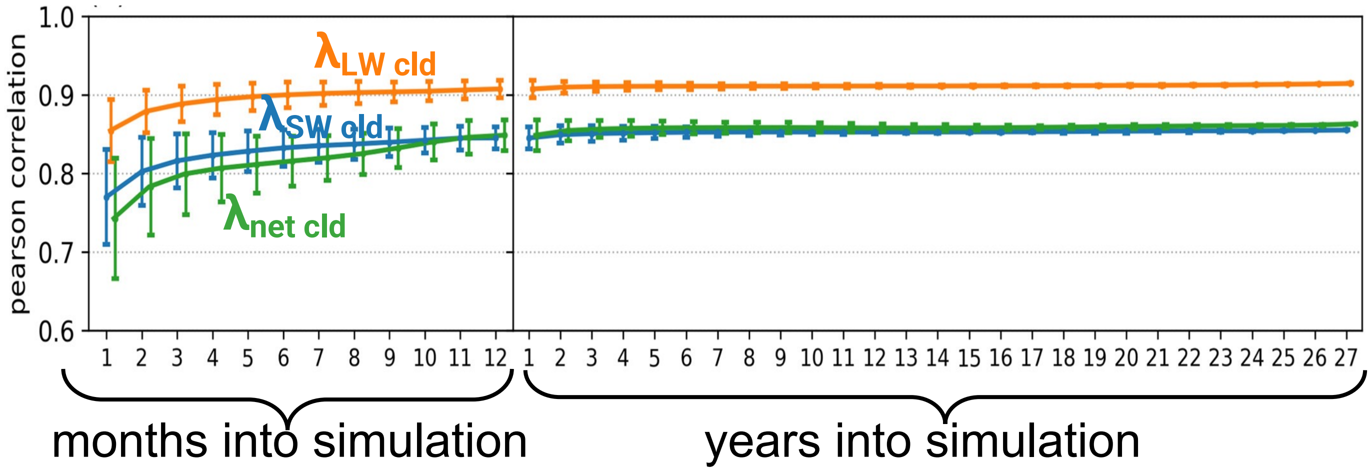
Radiative forcing ΔF causes equilibrium temperature response ΔT proportional to the net feedback λ:

$$\Delta F = \lambda \Delta T$$

- Cess et al., (JGR, 1990), Ringer et al., (GRL, 2014), and others noted that λ can be cheaply and reasonably computed by prescribing ΔSST and reading the resulting ΔF
- Qin et al., (JGR-A, 2022) find that this can be done credibly using a single year of data (see figure)
  - Best results come from ENSO-neutral years

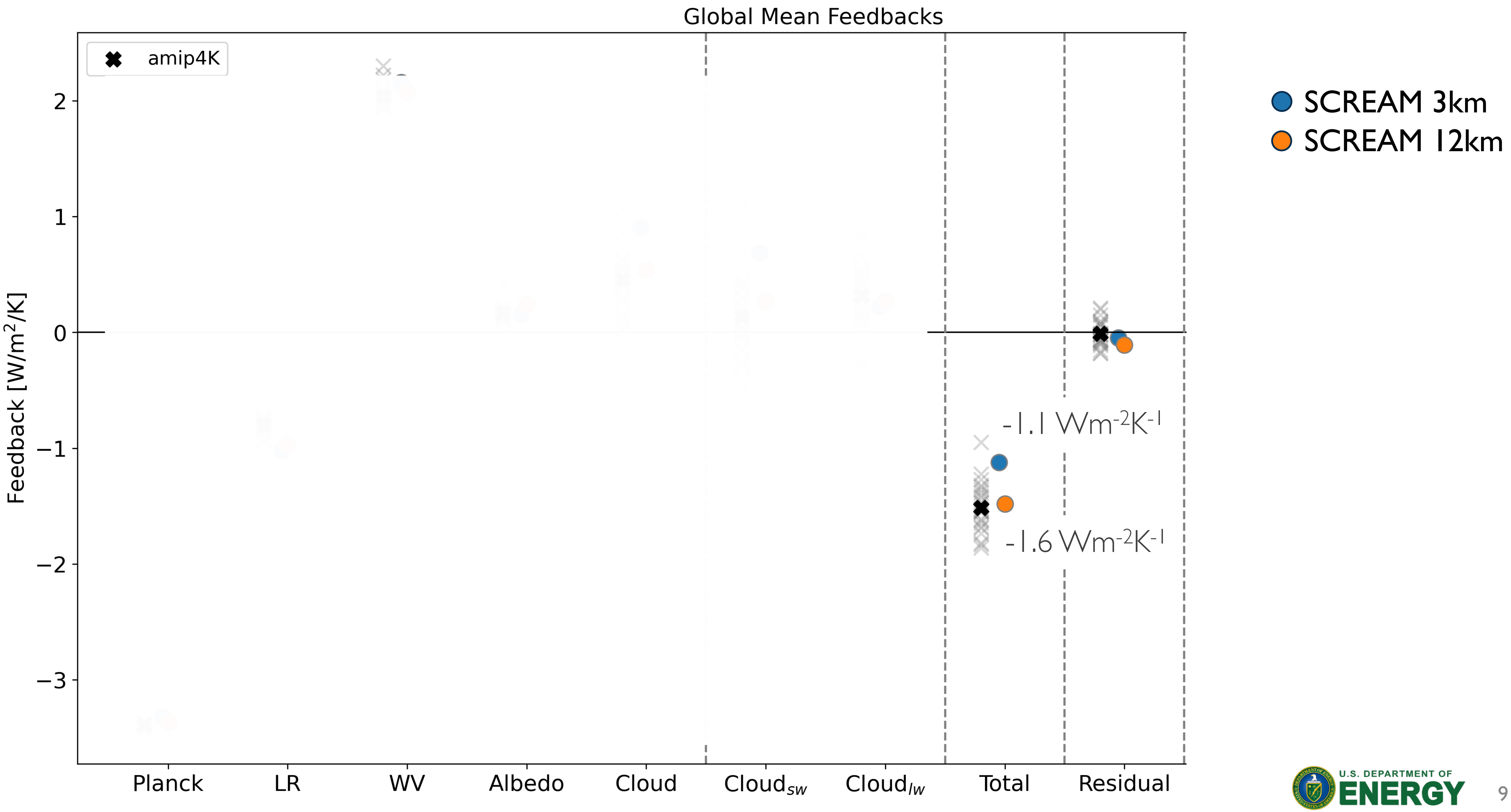
Cloud feedback from full-complexity (y-axis) versus fixed SST simulations in CMIP5. Adapted from Ringer et al, (2014 GRL).



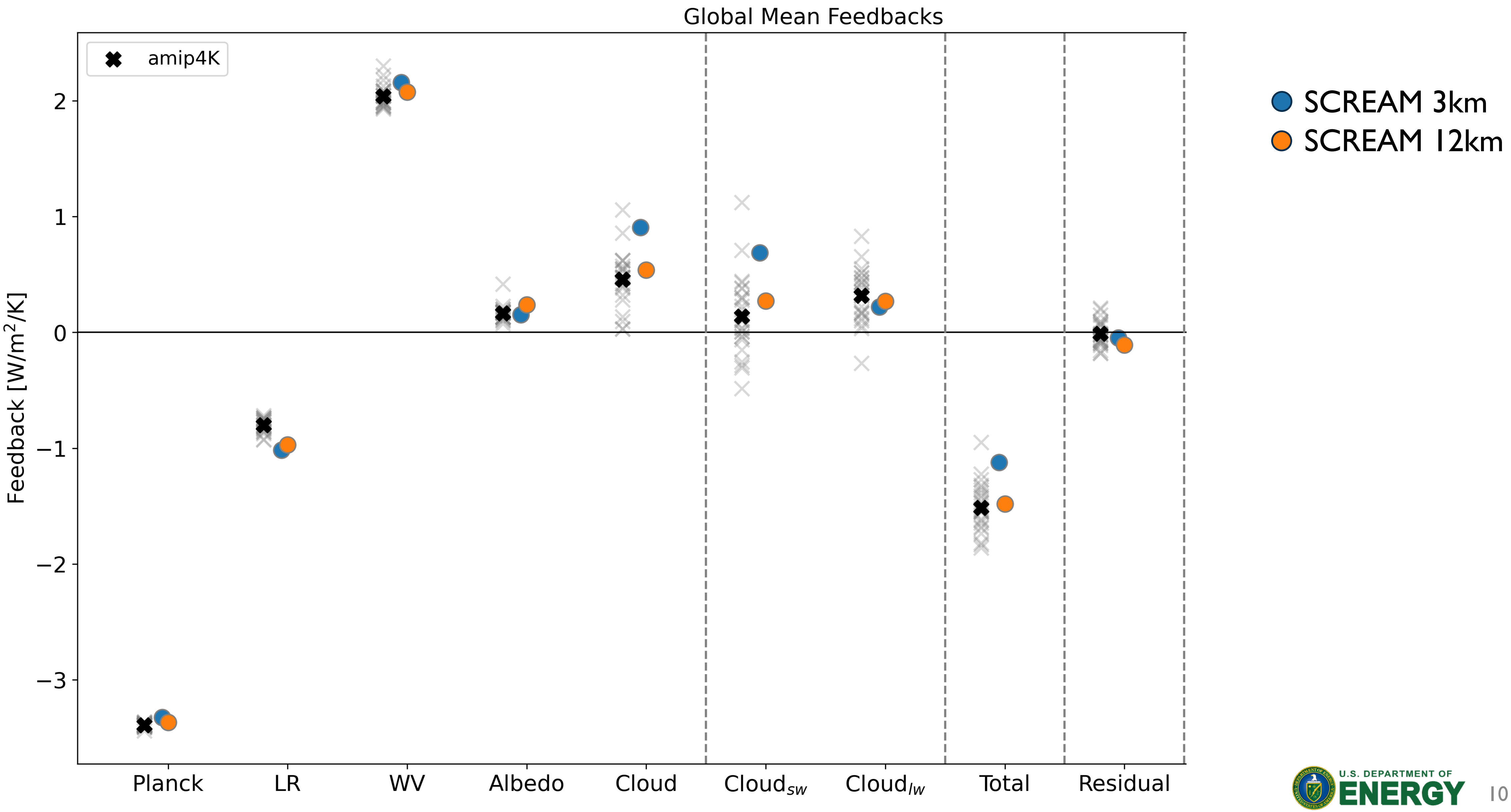


CMIP6 inter-model correlation between feedbacks computed using AMIP +4K versus Abrupt $4xCO_2$ simulations. Error bars are standard deviations due to variation in selected time slices. From Qin et al., (JGR-A, 2022)

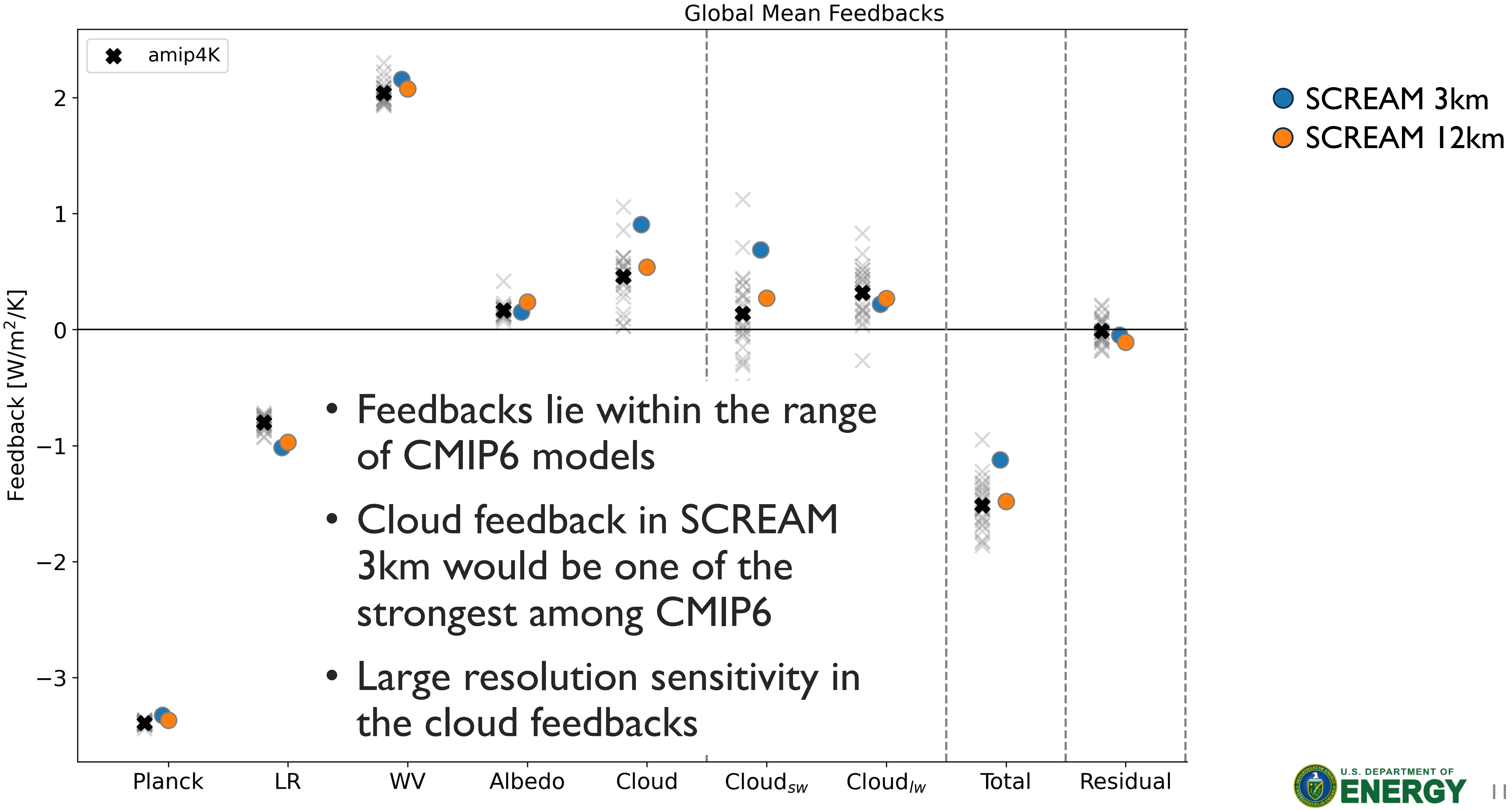
Climate feedbacks



Climate feedbacks



Climate feedbacks



- Feedbacks lie within the range of CMIP6 models
- Cloud feedback in SCREAM 3km would be one of the strongest among CMIP6
- Large resolution sensitivity in the cloud feedbacks

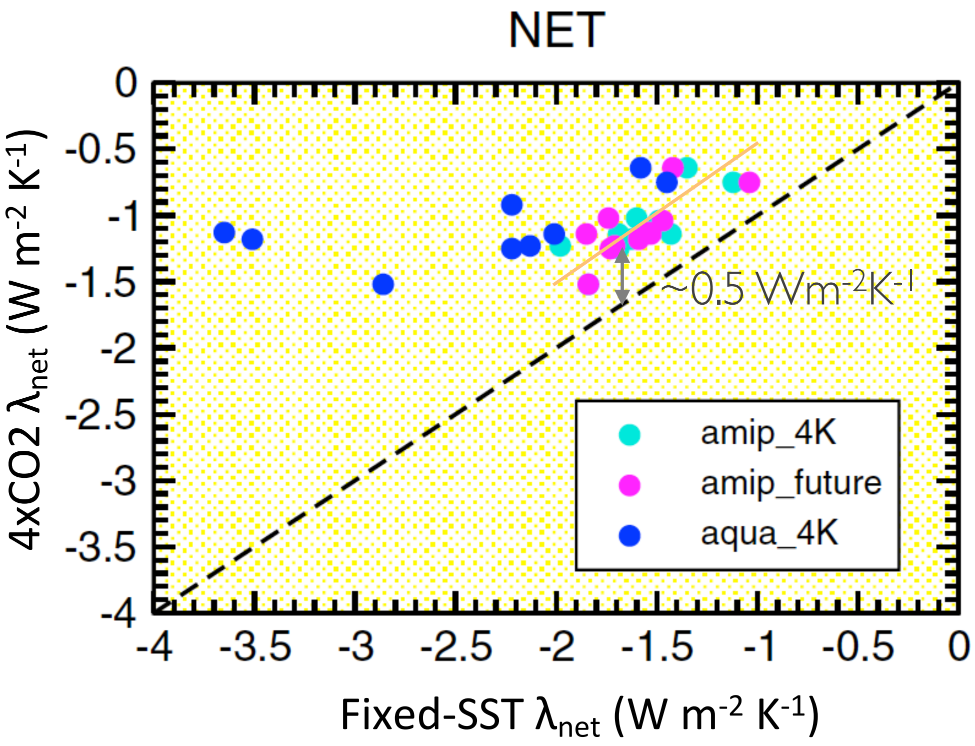
~~Equilibrium~~ Estimated Climate Sensitivity

- Total radiative feedback (-1.1 $Wm^{-2}K^{-1}$ for 3km model and -1.6 $Wm^{-2}K^{-1}$ for 12km model)
- Adjusting for difference between atmosphere-only and coupled simulation net feedback, estimate ~-0.6 $Wm^{-2}K^{-1}$

$$\Delta F = \lambda \Delta T$$

where ΔF ~ 3.7 Wm^{-2} (2xCO2)

- SCREAM 3km has an ECS of 6.2K (E3SMv1 and 2 had ECS of 5.3K and 4.0K)
  - SCREAM 12km has an ECS of 3.7K



Net radiative feedback from full-complexity (y-axis) versus fixed SST simulations in CMIP5. Adapted from Ringer et al, (2014 GRL).

Un-answered questions and next steps

- How much confidence can we ascribe to the climate feedbacks?
- To what extent would Doubly-Periodic SCREAM or RRM configurations have informed us about the strength of cloud feedbacks?
- How does SCREAM do with variability and extremes?
- How can we best improve some of the largest biases in the model?
- What is the best scientific use of the 3km global SCREAM?

Summary

- SCREAM is very computationally expensive, but we are quickly scaling up our simulation length from days to years to decade+
- Previously un-resolved features are now resolved everywhere on the globe, but large-scale biases exist and need improving
- Our first year-long simulation campaign reveals a strong cloud feedback (and suggest a very high ECS) in SCREAM 3km
- Ongoing decadal simulation will inform SCREAM's ability to capture variability and extremes

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