13km to 3km: Where the E3SM Atmosphere Model Exhibits Resolution Sensitivities

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Motivating Question

Running multi-year simulations and tuning at 3 km (SCREAM) remain expensive. E3SMv4's atmosphere resolution will therefore target 13 km.

What aspects of the atmosphere are retained at 13 km, and what requires 3 km?

Main Takeaways and Implications

Mean state and geographic distribution of MCSs and tropical cyclones barely change with resolution…

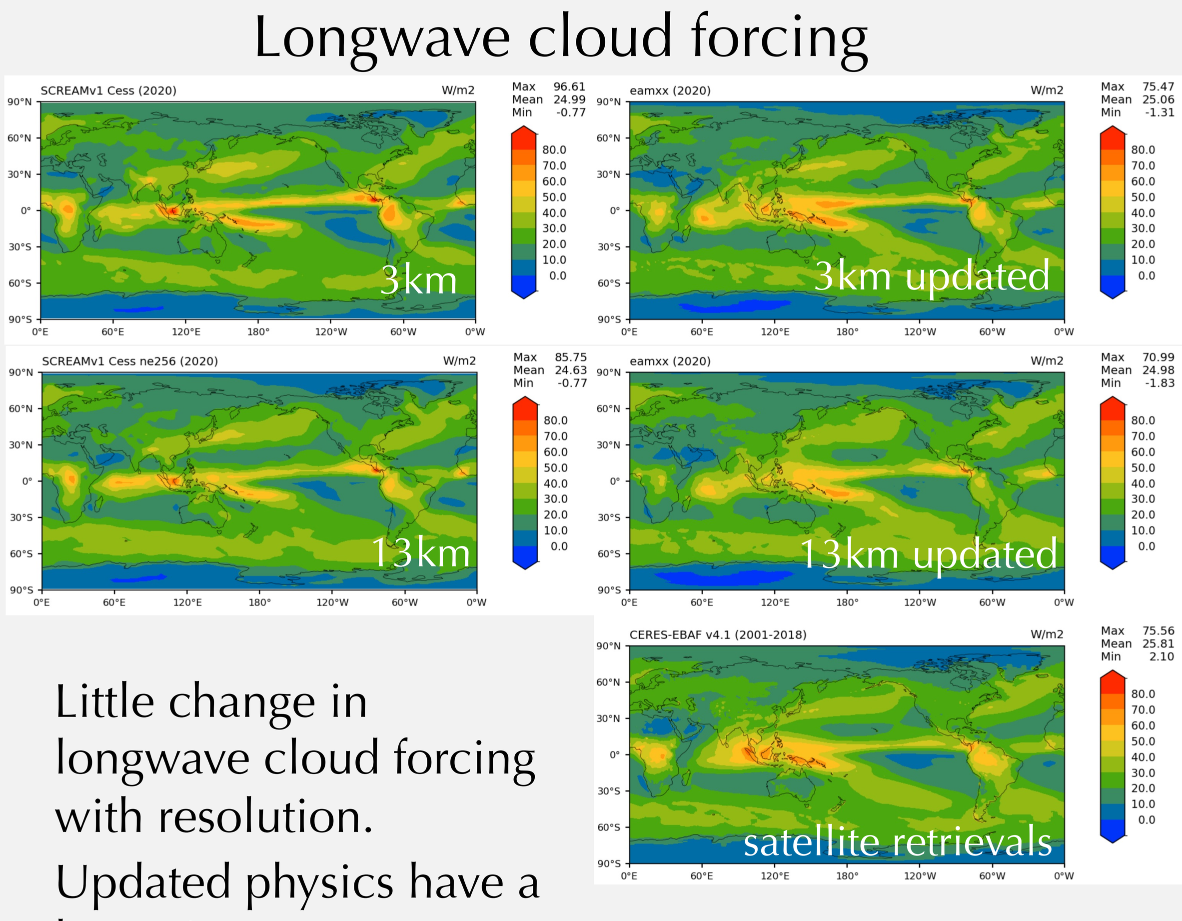
…but low-clouds and their response to warming, cloud-feedbacks, and storm intensity and precipitation extremes are sensitive to resolution.

Tuning and physics exploration can be done at 13 km, with 3 km focused on targeted simulations of storms/feedbacks.

What other scientific questions and applications require a global 3km model?

Mean State

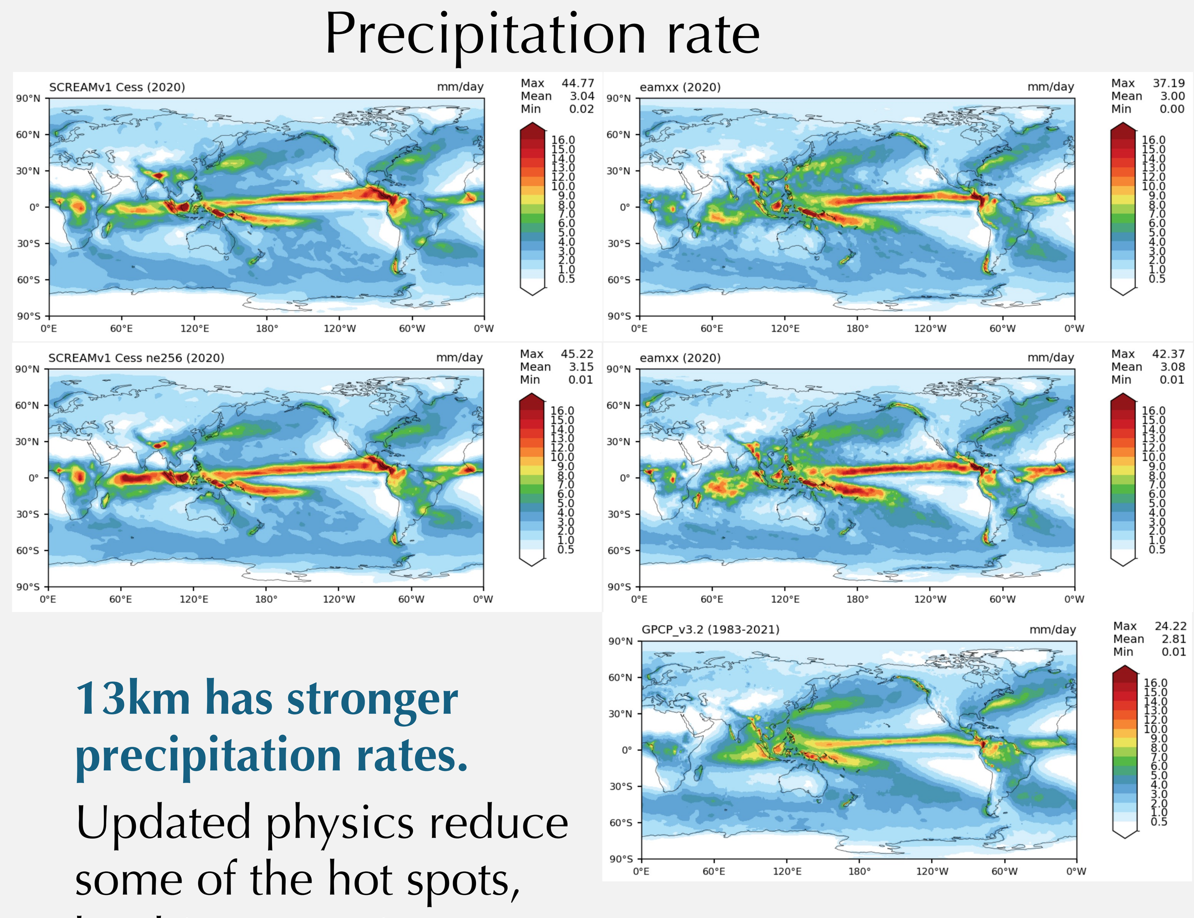
Longwave cloud forcing



Little change in longwave cloud forcing with resolution.

Updated physics have a larger impact on longwave cloud forcings.

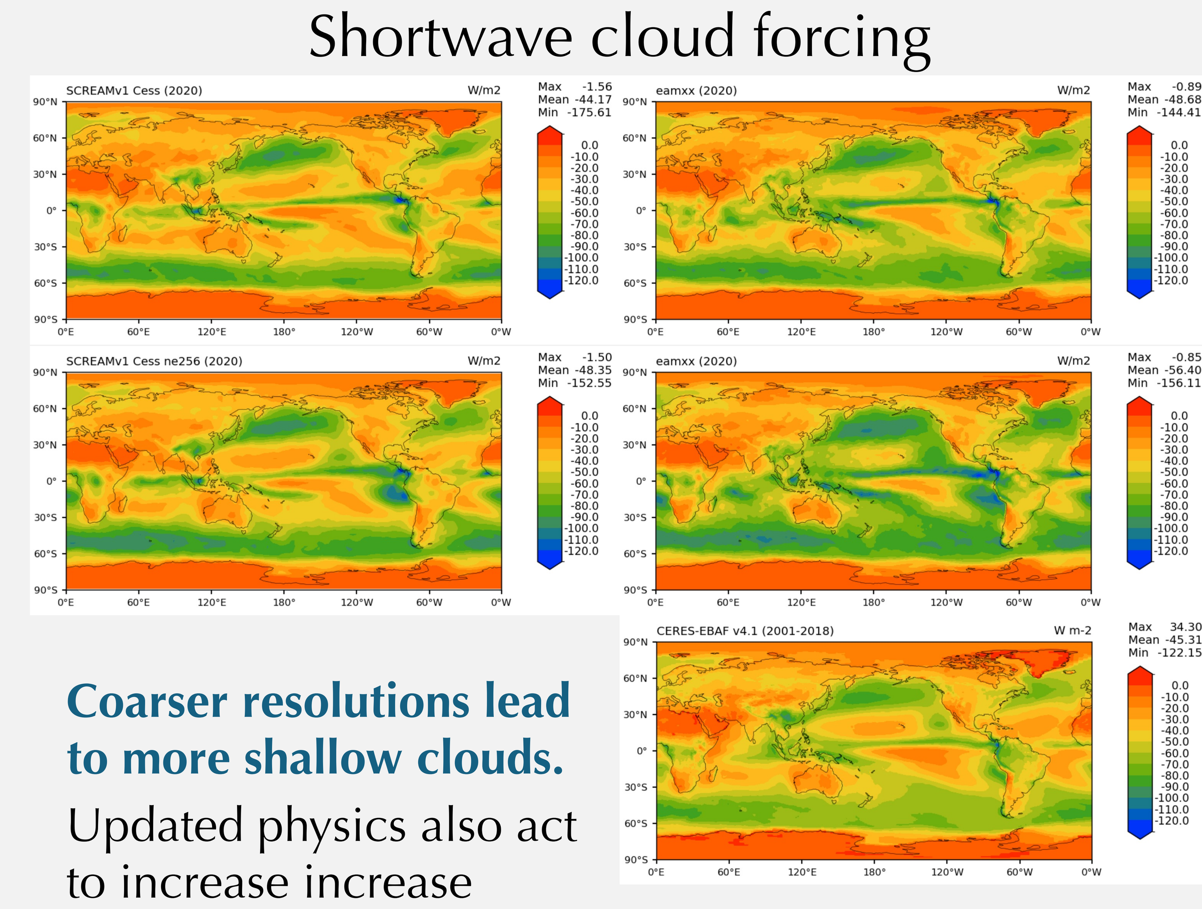
Precipitation rate



13km has stronger precipitation rates.

Updated physics reduce some of the hot spots, but biases persist.

Shortwave cloud forcing

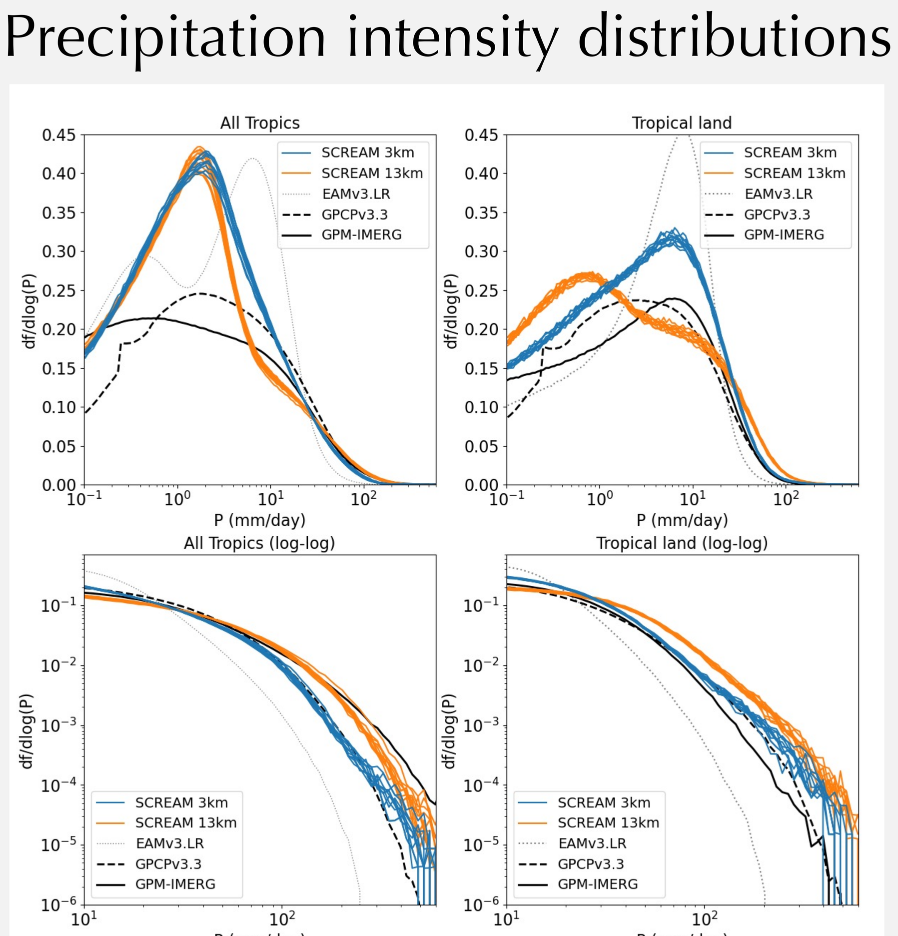


Coarser resolutions lead to more shallow clouds.

Updated physics also act to increase increase cloud cover.

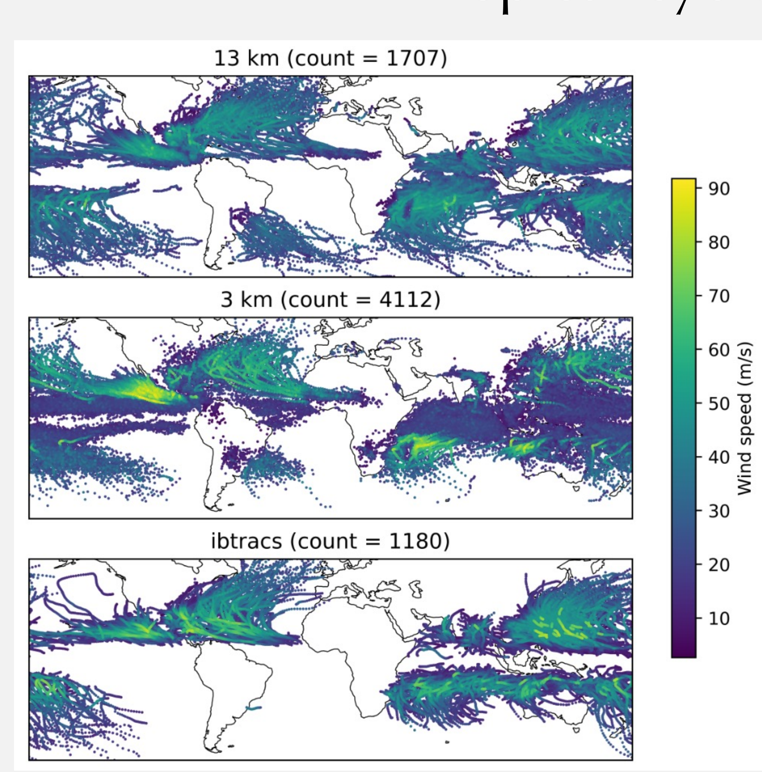
Storms and Extremes

Precipitation intensity distributions

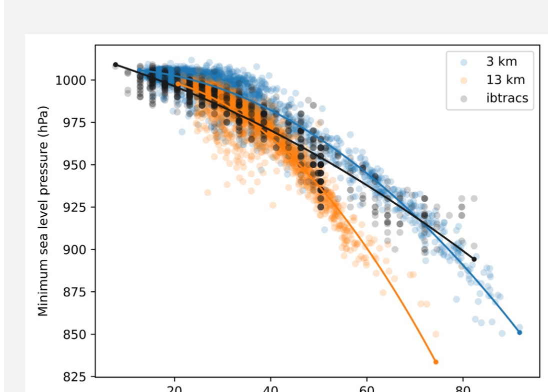


Consistent with the spatial maps, 13 km increases the frequency of heavier precipitation rates.

Tropical cyclones

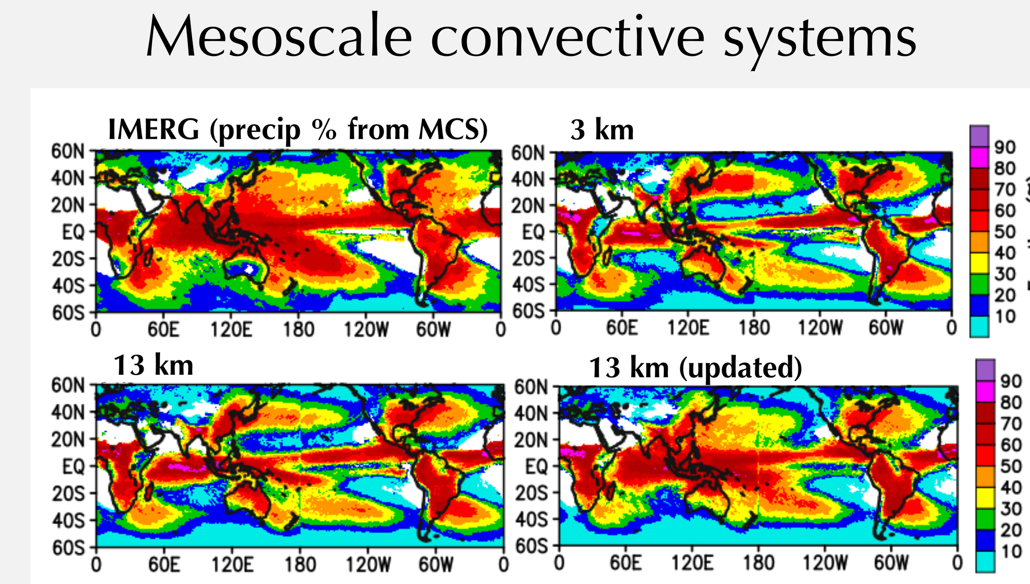


Spatial distribution of tropical cyclones are largely consistent between 3 km and 13 km.



Storm intensities, based on minimum sea level pressure and max wind, are reduced at coarser resolutions.

Mesoscale convective systems



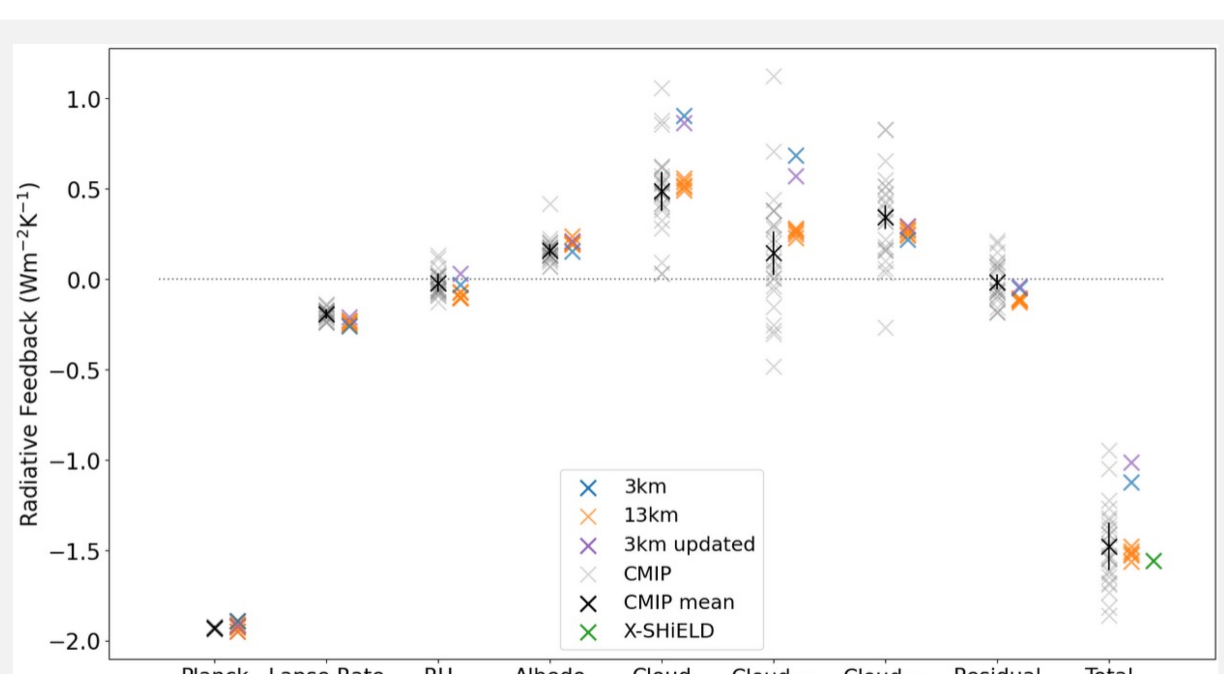
Spatial distribution of mesoscale convective systems (MCSs) are quite consistent between 3 km and 13 km.

Updated physics significantly improve the spatial distribution of MCSs.

Radiative Feedbacks

SCREAM exhibits a strong resolution sensitivity in cloud feedbacks (Terai et al., 2025), coming from differences in the low-cloud sensitivity to estimated inversion strength (Chao et al., 2026).

Tunings have a smaller impact on radiative feedback and on non-cloud feedbacks.



Simulations Behind the Results

Simulation	Duration	References
Cess-Potter I	13 mo (Aug 2019–Aug 2020)	Terai et al., 2025
Decadal	11+ yr (Oct 1994 – Dec 2005)	Hillman et al., in prep
Cess-Potter II / DYAMOND3	19 mo (Aug 2019 – Feb 2021)	Beydoun et al., in review

Each experiment includes 3 and 13 km configurations*.

Relevant papers (see also simulation table)

Chao, L., and Coauthors, 2026: Examining Cloud Feedback Components in the Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM). J. Climate, 39, 2563–2578, https://doi.org/10.1175/JCLI-D-25-0656.1.

Merlis, T. M., Cheng, K.-Y., Guendelman, I., Harris, L., Bretherton, C. S., Bolot, M., et al. (2024). Climate sensitivity and relative humidity changes in global storm-resolving model simulations of climate change. Science Advances, 10(26), eadn5217. https://doi.org/10.1126/sciadv.adn5217

Terai, C. R., Keen, N. D., Caldwell, P. M., Beydoun, H., Bogenschutz, P. A., Chao, L.-W., et al. (2025). Radiative, hydrologic, and circulation responses to warming in Cess-Potter simulations using the global 3.25-km SCREAM. Journal of Advances in Modeling Earth Systems, 17, e2024MS004930. https://doi.org/10.1029/2024MS004930

Acknowledgments

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E3SM Energy Exascale Earth System Model