Small-scale precipitation objects in the SCREAM global convection permitting model: its characteristics, impacts, and sensitivities to model choice

Christopher Terai[1], Peter Caldwell[1], Hassan Beydoun[1], Peter Bogenschutz[1], Noel Keen[2], Wuyin Lin[3], Benjamin Hillman[4], Weiran Liu[5], Paul Ullrich[5], Hsi-Yen Ma[1], and SCREAM team

contact: terai1@llnl.gov

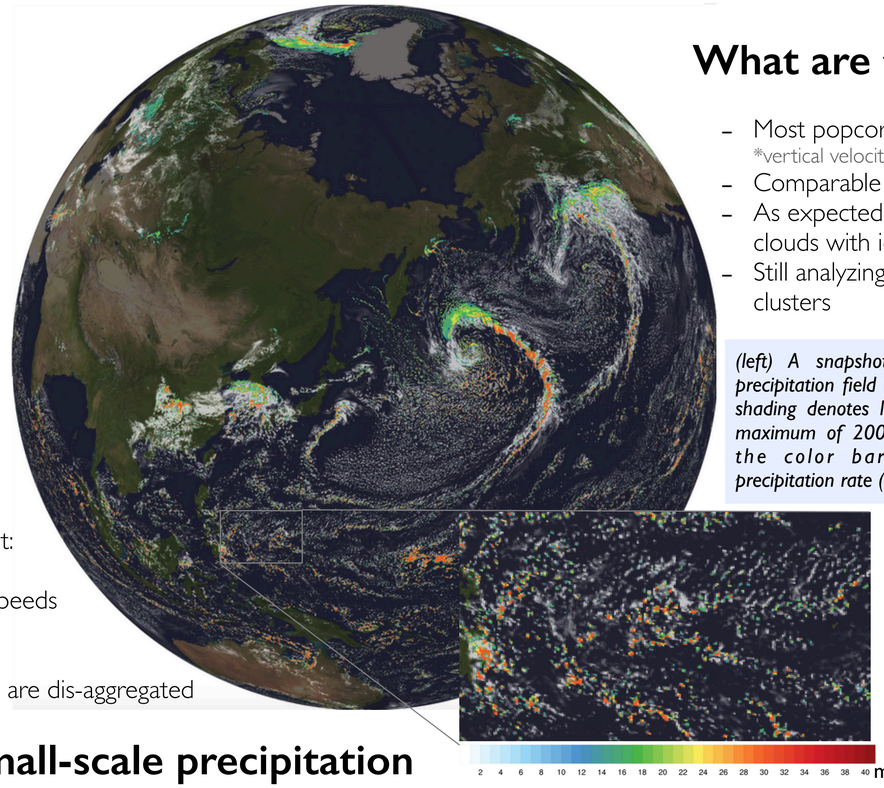
[1]Lawrence Livermore Nat'l Lab [2]Lawrence Berkley Nat'l Lab
[3]Brookhaven Nat'l Lab [4]Sandia Nat'l Lab, 5 UC-Davis

What is SCREAM?

The Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM) is a non-hydrostatic, spectral element atmospheric model that discretizes the globe on a cubed sphere.

- Horiz rez: ~3.25 km; 128 vertical layers with model top at 4km
- Physics: P3 (microphysics), SHOC (turbulence, shallow convection), RRTMGP (radiation),
- v0 is written in F90, v1 is written in C++ Kokkos

*Details in Caldwell et al.. (2021) JAMES**



How well does SCREAM simulate clouds & convection?

Improved simulation of:

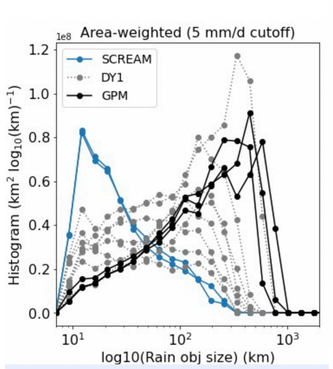
- Realistic stratocumulus
- Diurnal cycle of precipitation
- Marine cold air outbreaks
- Tropical cyclones

Areas for improvement:

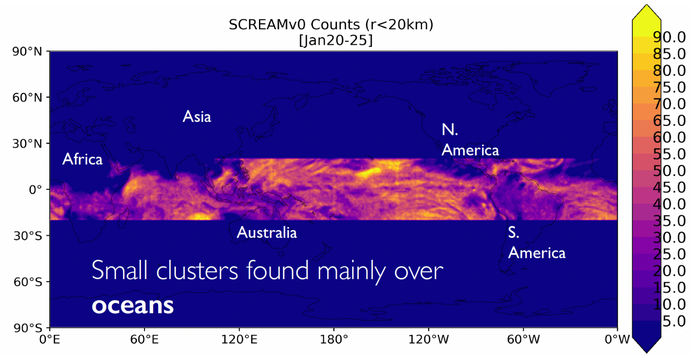
- Overly strong near-surface wind speeds
- Zonal South Pacific Convergence Zone
- Precipitation/clouds are dis-aggregated

How small and frequent are small-scale precipitation objects ('popcorn rain') and are they unique to SCREAM?

- Small-scale rain events have been reported in CPM studies, but rarely quantified
- Rain objects smaller than 25 km in radius occur frequently at the expense of larger rain objects
- Other models in DYAMOND1 had some larger #'s of small rain objects but SCREAMv0 has ~2x the number of other models
- Most found over warm tropical oceans with high precipitable water values, but can be found over wet land (e.g. Amazon)



(above) An area-weighted histogram of precipitating objects over the Tropics in SCREAMv0, DY1 models, and GPM-IMERG (satellite).



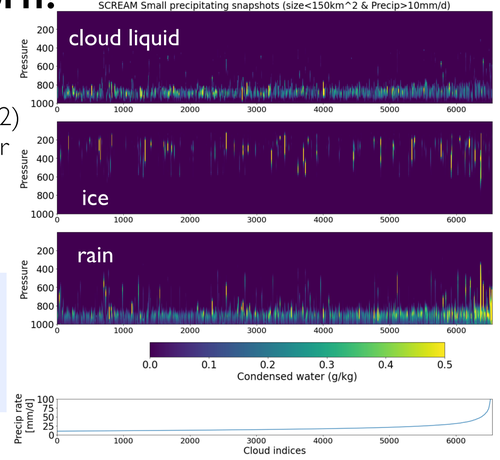
(above) Number of popcorn rain events (r<20km) found over the Tropics in the first 6 days of SCREAMv0's DYAMOND2 simulation.

What are the characteristics of popcorn?

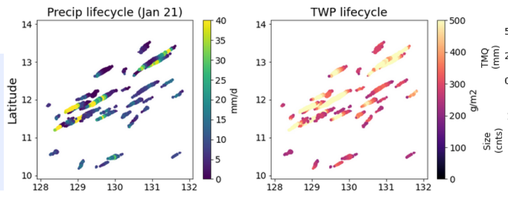
- Most popcorn tend to be shallow (tops lower than 800hPa)
  *vertical velocity profiles show similar result
- Comparable amount of rain and cloud water (both ~ 200 g/m2)
- As expected, higher precipitation rates correspond with deeper clouds with ice
- Still analyzing heating and moistening rates compared to large clusters

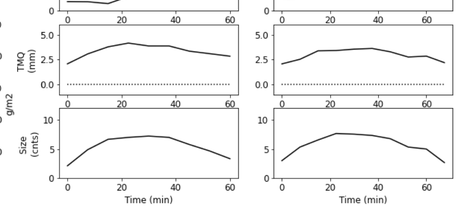
(left) A snapshot of the cloud and precipitation field from SCREAMv0. Gray shading denotes liquid water path with maximum of 200 g/m2. See below for the color bar associated with precipitation rate (mm/d).

(right) Cloud liquid, ice, and rain profiles above the popcorn objects (P >10 mm/d) sorted by precipitation rate. Note that most cloud profiles tend to be shallower than 800 hPa.



- Used higher frequency (every 7.5 min) limited-area output and total water path flag to track lifecycle of popcorn in a small area in Western Pacific
- Lifetimes range from 30 to 50 min (interquartile range)
- Clouds rapidly convert cloud water to rain water





(right) Precipitation and total water path (liq, rain, ice) traces of popcorn events tracked in a 4deg x 4deg box over a 12 hour period.
(far right) Example composite lifecycle of water path, precipitation rate, precipitable water anomaly, and size.

How sensitive are popcorn to various processes / model choice?

We find that popcorn rain also appear in simulations with the doubly-periodic version of SCREAM (DPSCREAM). Some hypothesis tests using DPSCREAM simulations of the deep convective GATE case follow.

Is 3.25 km too coarse to resolve lateral entrainment in cumulus clouds?

- High resolution simulations (500m) also show signs of popcorn
- Also tested an implementation of horizontal turbulent diffusion of humidity and that had minimal effect

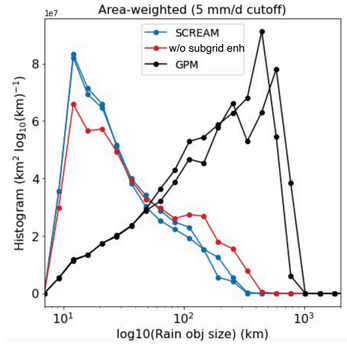
Are updrafts too strong and leading to downdraft shells that cutoff convection?

- Quick analyses of updraft speeds do not appear to be really large (~3 m/s) but looking for observational estimates / case studies to reproduce

Is popcorn a result of too rapid conversion of cloud water into rain?

- The ratio of rain water-to-cloud water is quite high in SCREAMv0
- Turning off rain evaporation dramatically reduced popcorn
- Found that turning off sub grid enhancement of autoconversion and accretion leads to 10-20% improvement in reducing popcorn.

(below) Same histogram as shown on the left, but with SCREAM without the subgrid enhancement of collision-coalescence processes.



Next steps:

- Continuing to explore changes in mixing, microphysics to examine impacts.
- Examining updraft characteristics to see if they are similar to what is observed
- Would you have any ideas of what the cause of popcorn might be?

IM release: LLNL-POSTER-
This work was conducted under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
DYAMOND data management was provided by the DKRZ and supported through the projects ESiWACE and ESiWACE2.

*Caldwell, P. M.,et al. (2021). Convection-permitting simulations with the E3SM global atmosphere model. Journal of Advances in Modeling Earth Systems, 13, e2021MS002544.