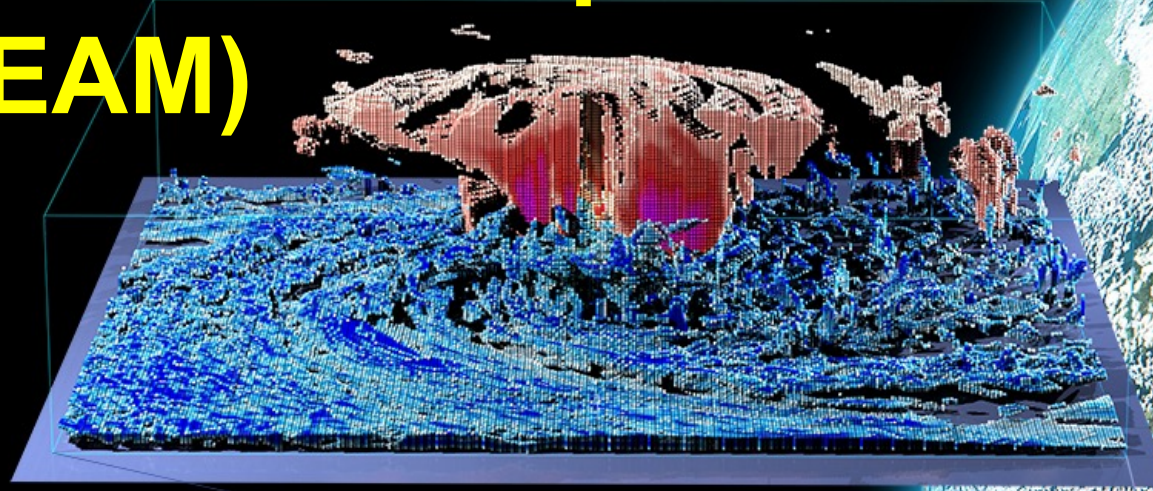


# Progress with the Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)



Peter Caldwell, Andy Salinger, Luca Bertagna, Hassan Beydoun, Peter Bogenschutz, Andrew Bradley, Aaron Donahue, Chris Eldred, Jim Foucar, Chris Golaz, Oksana Guba, Ben Hillman, Rob Jacob, Jeff Johnson, Noel Keen, Jayesh Krishna, Wuyin Lin, Weiran Liu, Balwinder Singh, Andrew Steyer, Mark Taylor, Chris Terai, Paul Ullrich, Danqing Wu, Xingqiu Yuan, Charlie Zender

Pan-GASS Meeting, July 29, 2022

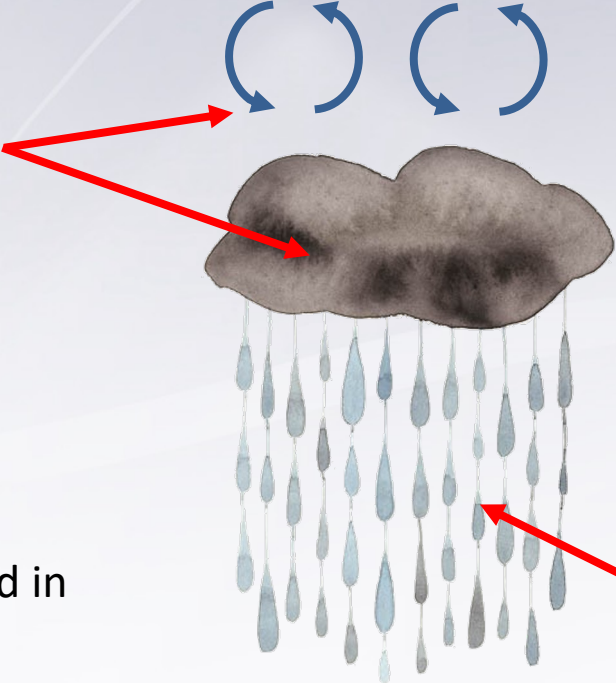
*Fig: Zoom into a SCREAMv0-simulated hurricane with liquid (blue) and ice (red) mass. From JAMES, Nov 2021 cover*



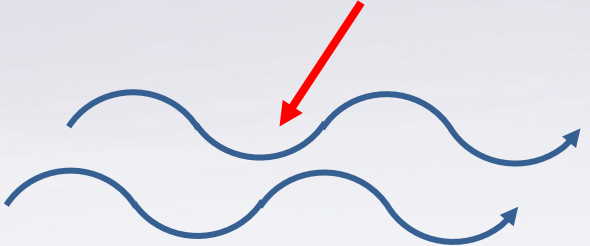
~~parameterized convection~~

# What is in SCREAM?

**Turbulence and cloud formation** handled by Simplified Higher-Order Closure (**SHOC**)



Resolved-scale **fluid dynamics** treated by a non-hydrostatic Spectral Element (**SE**) approach



**Aerosols** will be prescribed in initial implementation

**Microphysical processes** handled by Predicted Particle Properties (**P3**) scheme



**Radiation** handled by externally-developed, GPU-ready **RRTMGP** package

\* Using coarser grid for physics parameterizations (PG2) \*

# SCREAM Novelties:

- Written in C++/Kokkos: Excellent GPU performance + performance portability
- SHOC is a more sophisticated cloud/turbulence parameterization (see fig)
- Focus on unit tests yields a more trustworthy model
- Access to eddying ocean/ice enables coupled runs

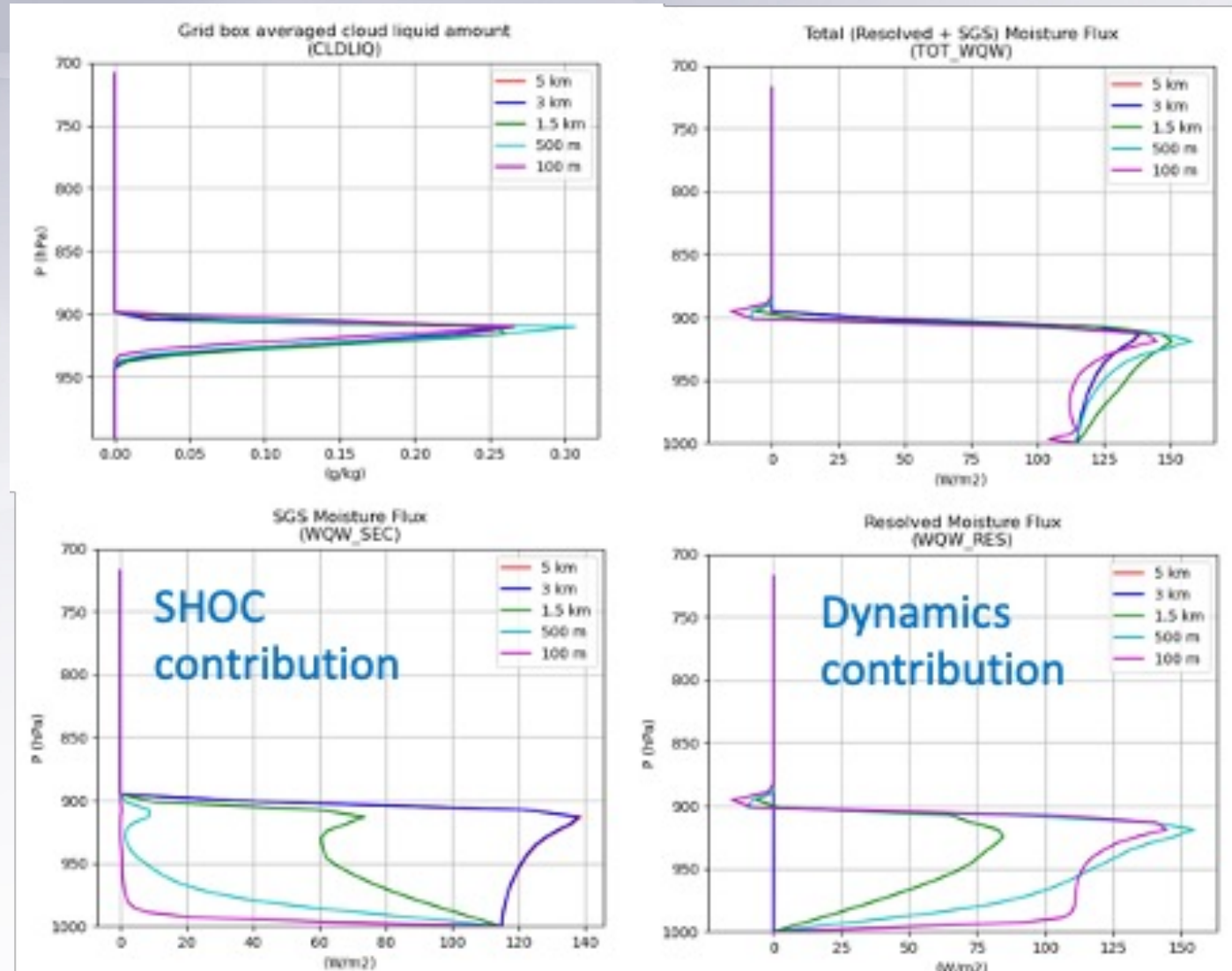


Fig: Doubly periodic SCREAM simulations of marine stratocumulus (DYCOMS-RF01) at a variety of horizontal resolutions

# SCREAM Performance

**Audience question:** how fast does a Global Storm Resolving Model (GSRM) need to be to be useful?

How fast can we run?

- Expect 0.7 SYPD using all of Summit
- Should get 1.2 SYPD using all of Frontier
  - Kokkos allows us to run on Frontier very soon
  - Lots of opportunities for further improvement

How many years can we run?

- A typical INCITE allocation  $\cong$  8 simulated years

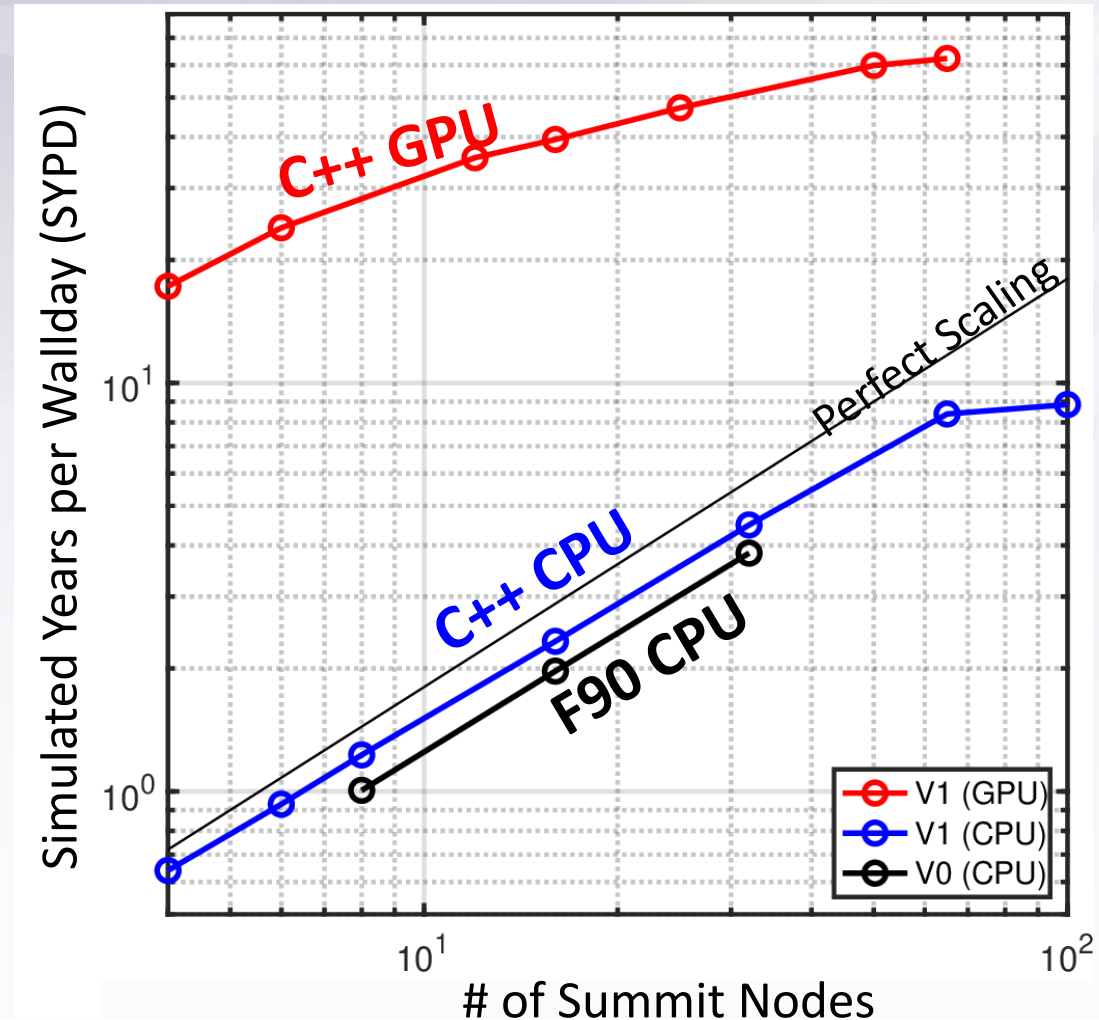
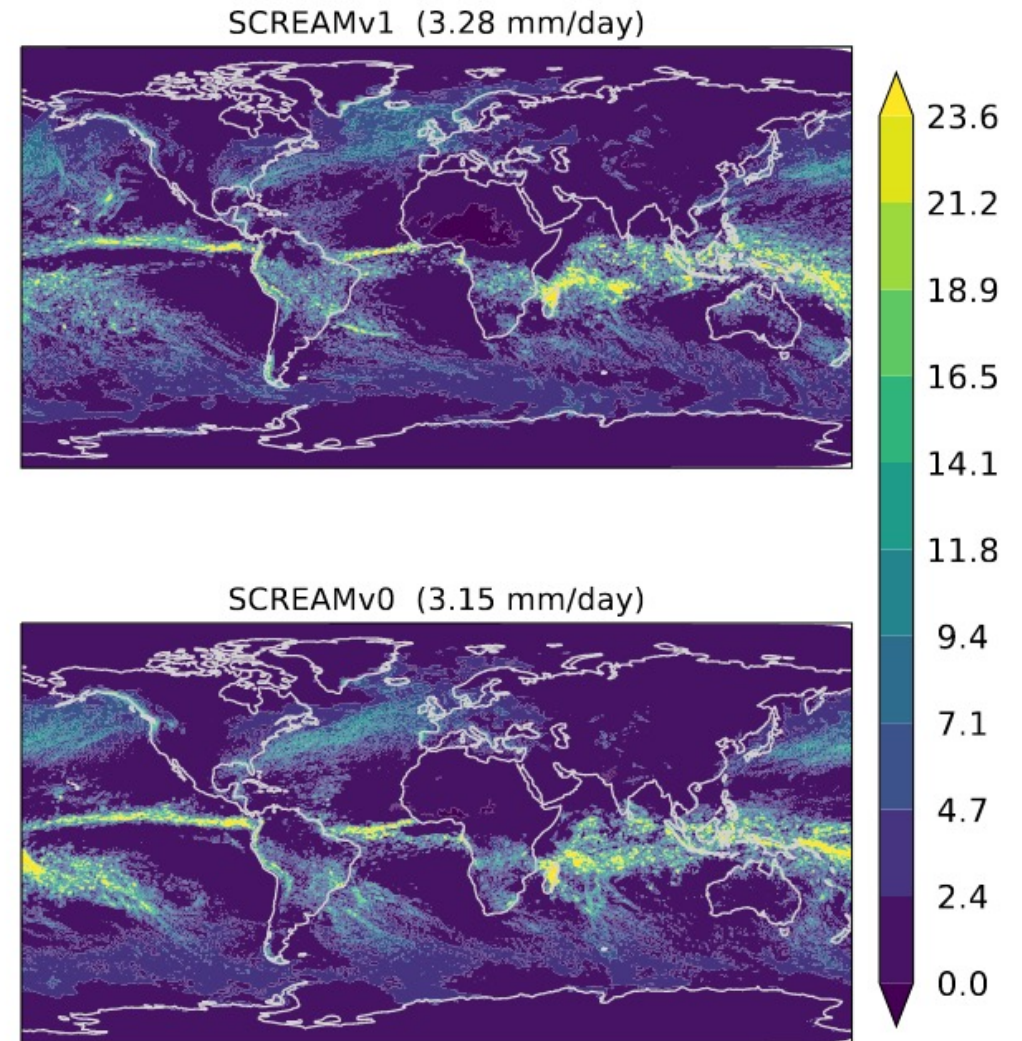


Fig: Model performance as a function of processors used. All runs used 72 vertical levels and  $dx=100$  km.



# SCREAM Skill

- While building v1 (our C++ model), we explored model climate with a F90 prototype (called v0)
- v0 and v1 are ~identical (see Fig), so we will use v0 to assess SCREAM skill

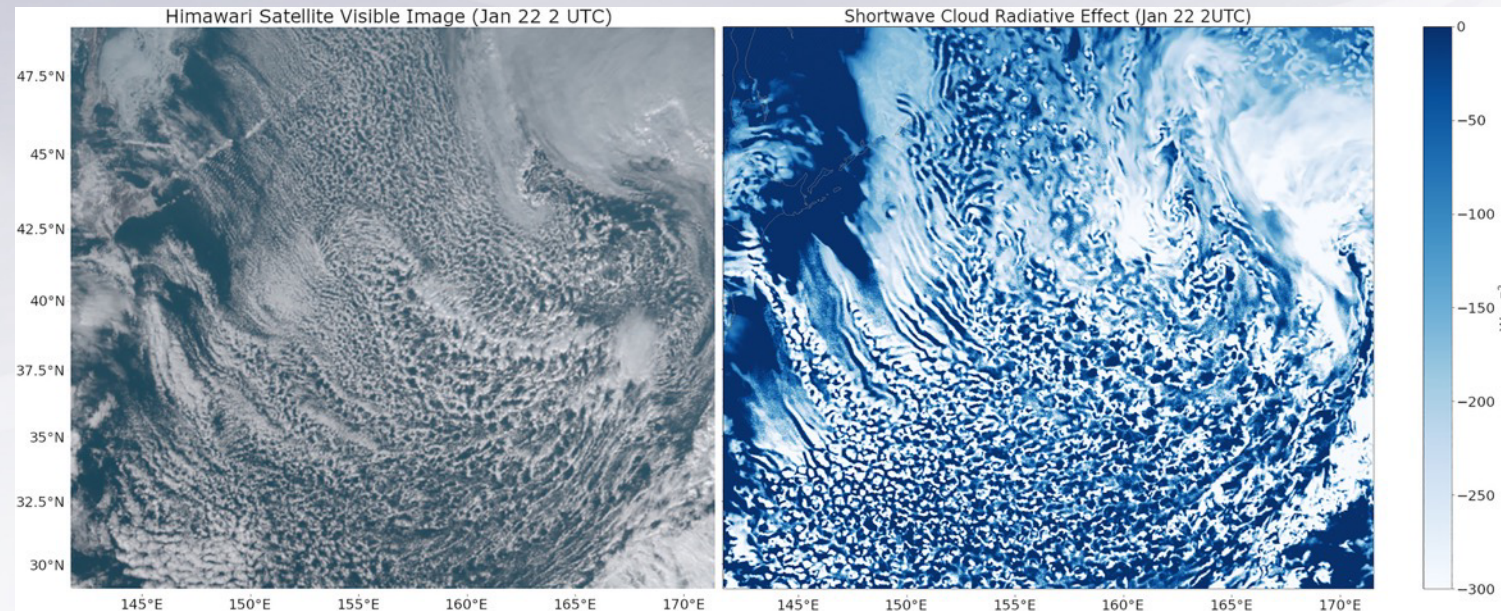


*Fig: Precipitation averaged over the last 30 days of a 40 day SCREAMv1 (C++) simulation (top) and SCREAMv0 (F90) simulation (bottom). Both simulations use  $dx=28$  km.*

# SCREAM Skill

*See Caldwell et al (JAMES, 2021) and DYAMOND2 archive for details*

- Even without significant tuning, the fidelity of clouds and precipitation in SCREAM is impressive (see Fig)
- Resolution solves many long-standing issues in climate modeling like:
  - precipitation intensity and timing
  - vertical structure of convection
  - Amazon rainfall



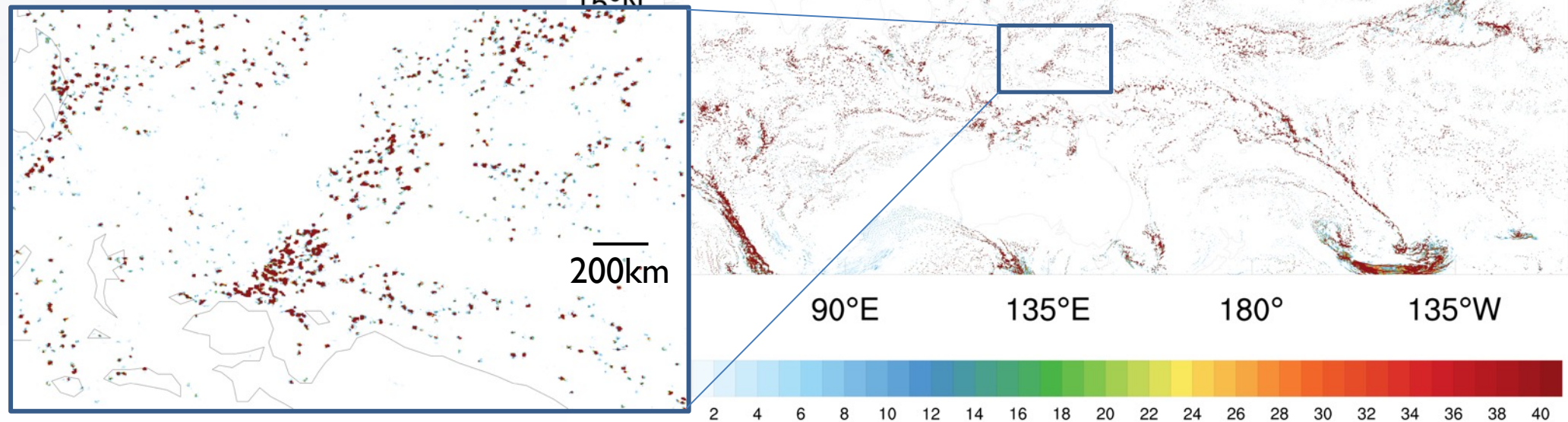
*Fig: Cold-air outbreak off Siberia on January 22, 2020 at 2:00:00 UTC (~local noon) from a Himawari visible satellite image (left) and shortwave cloud radiative effect from SCREAMv0 (right). Visualization is over a region bounded by 29°–49°N and 141.5° to 171.5°E.*



# SCREAM Challenges

- SCREAM struggles to aggregate tropical convection (see Fig)
  - Chris Terai presented a poster about this on Tues
- Convective anvils are too small
- Double ITCZ and misplaced Warm-Pool precipitation max remains

*Fig: Snapshot of precipitation on Jan 21 2020 at 0 UTC from GPM obs (top) and EAMxx (bottom)*

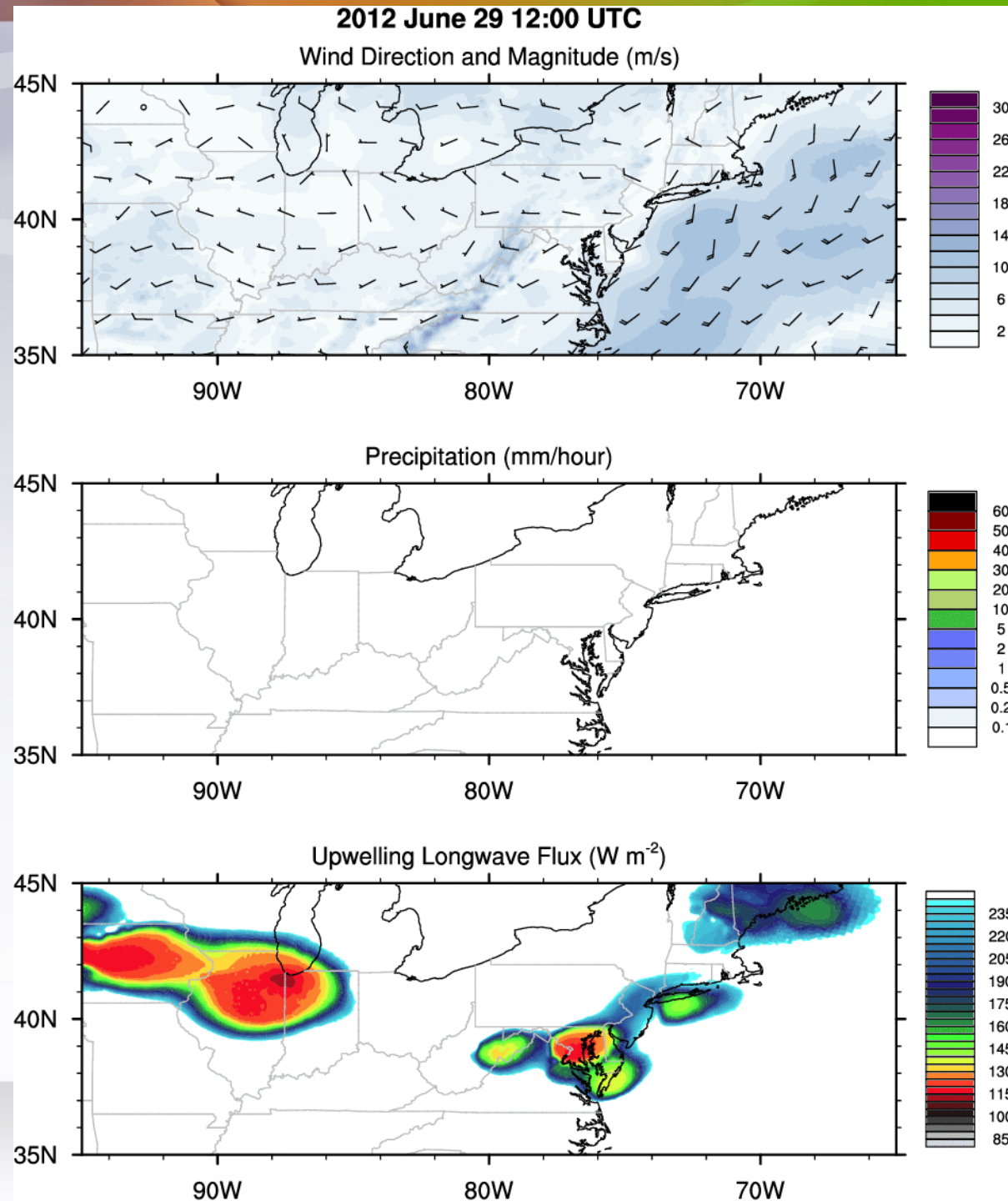


# Midlatitude Storms

- Popcorn is a *tropical* problem
- SCREAMv0 did an excellent job at reproducing the 2012 North American Derecho at 3 km and 1.5 km dx

Liu, Ullrich, Zarzycki, & Caldwell (in review @ JAMES, available from ESSOAR) “Simulating the 2012 North American Derecho in the Regionally-Refined Simple Cloud-Resolving E3SM Atmosphere Model”

Fig: June 29<sup>th</sup> 2012 derecho over the Midwest/Mid-Atlantic US as simulated by SCREAM at 3 km





# F90 Results - Radiation

See Caldwell et al (JAMES, 2021) for details

- Not enough clouds over the Southern Ocean
- Not enough tropical anvil clouds
- We have a double ITCZ (not shown)

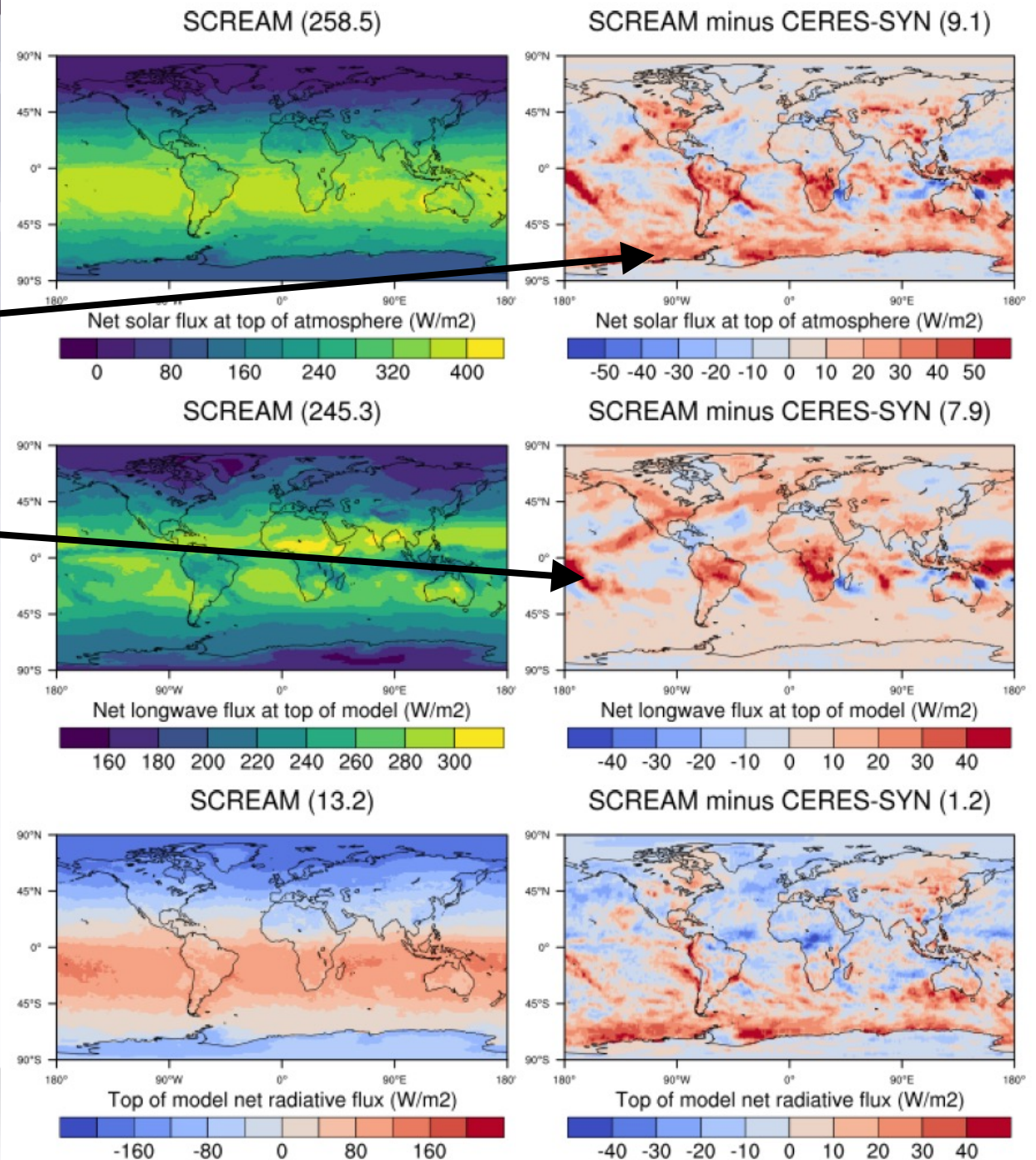


Fig: Top-of-Atmosphere SW (top), LW (middle), and total (bottom) net radiation for last 30 days of DYAMOND2 period. From SCREAM on left and bias relative to CERES-SYN (right)

# Summary, Plans, and Opportunities

- SCREAMv1 is *just* about ready for science. We are planning:
  - 3 yr 2010 control, uniform +4K SST, and historical-pattern +4K SST runs for later this year
  - coupled simulations should start in 2024(?)
  - all output should be freely available... somehow
- Over the next 2 yrs we will extend SCREAM to also work at 100 km dx
- Interesting challenges:
  - How do we get rid of popcorn?
  - How do you tune a 3 km model?
  - What output do you save for multi-year, km-scale simulations? How do you share it?