SCREAM Model description for TRACER-MIP

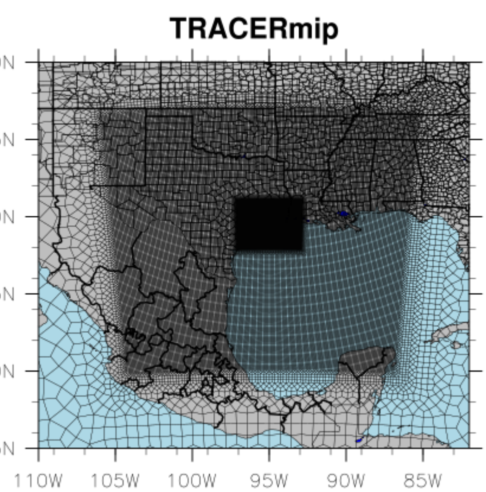
Hsi-Yen Ma (ma21@llnl.gov), Hassan Beydoun, Peter Bogenshutz, Jishi Zhang, and Yunyan Zhang

Tying in High Resolution E3SM with ARM Data (THREAD) project

Lawrence Livermore National Laboratory

Model:

The US DOE SCREAM (Simple Cloud Resolving E3SM Atmosphere Model) version1 is a new GSRM written in C++ and employing the Kokkos C++ Performance Portability Ecosystem (Trott et al., 2022) to enable it to run efficiently on a variety of hardware architectures, including conventional CPU-based systems and emerging GPU-based systems. SCREAMv1 is the non-hydrostatic version of the High Order Method Modeling Environment (HOMME) dynamical core used in all E3SM model releases (Taylor et al., 2020), which was written in C++ for SCREAMv1 (Bertagna et al., 2020). Turbulence, condensation, and liquid cloud fraction is handled by the Simplified Higher Order Closure (SHOC) scheme (Bogenschutz & Krueger, 2013). All-or-nothing ice cloud fraction is assumed with an ice mixing ratio threshold of 10^{-14} kg kg^{-1}. The single-category Predicted Particle Properties (P3) of Morrison and Milbrandt (2015) is used for microphysics. As described in Caldwell et al. (2021), liquid supersaturation was removed from P3 to enable consistency with SHOC's liquid saturation adjustment assumption. Prescribed aerosol effects are included as described in Donahue et al. (2024). Radiation is handled by a C++ version of the RTE + RRTMGP radiative transfer package originally written in Fortran (Pincus et al., 2019; Donahue et al., 2024). The simulations were conducted with a regionally-refined model configuration of SCREAM (RRM-SCREAM). The following figure shows the meshes for the experiments. The horizontal resolution of the most inner domain is ~ 400 m around the Houston area. The resolution for the middle layer is around 3.25 km and the resolution of outer domain is ~100 km. There 128 vertical levels for the model.



References:

Bertagna, L., Guba, O., Taylor, M. A., Foucar, J. G., Larkin, J., Bradley, A. M., . . . Salinger, A. G. (2020). A performance-portable nonhydrostatic atmospheric dycore for the energy exascale earth system model running at cloud-resolving resolutions. In Sc20: International conference for high performance computing, networking, storage and analysis (p. 1-14). doi: 10.1109/SC41405.2020.00096.

Bogenschutz, P. A., & Krueger, S. K. (2013, June). A simplified PDF parameterization of subgrid-scale clouds and turbulence for cloud-resolving models. Journal of Advances in Modeling Earth Systems, 5 (2), 195–211.

Donahue, A. S., Caldwell, P. M., Bertagna, L., Beydoun, H., Bogenschutz, P. A., Bradley, A. M., . . . Zhang, Y. (2024, July). To Exascale and Beyond—The Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM), a Performance Portable Global Atmosphere Model for Cloud-Resolving Scales. Journal of Advances in Modeling Earth Systems, 16 (7), e2024MS004314.

Morrison, H., & Milbrandt, J. A. (2015). Parameterization of cloud microphysics based on the prediction of bulk ice particle properties. part i: Scheme description and idealized tests. Journal of the Atmospheric Sciences, 72 (1), 287 - 311.

Pincus, R., Mlawer, E. J., & Delamere, J. S. (2019). Balancing accuracy, efficiency, and flexibility in radiation calculations for dynamical models. Journal of Advances in Modeling Earth Systems, 11 (10), 3074-3089.

Taylor, M. A., Guba, O., Steyer, A., Ullrich, P. A., Hall, D. M., & Eldrid, C. (2020). An energy consistent discretization of the nonhydrostatic equations in primitive variables. J. Adv. Model Earth Syst., 12 (1).

Trott, C. R., Lebrun-Grandie, D., Arndt, D., Ciesko, J., Dang, V., Ellingwood, N., . . . Wilke, J. (2022). Kokkos 3: Programming model extensions for the exascale era. IEEE Transactions on Parallel and Distributed Systems, 33 (4), 805-817. doi: 10.1109/TPDS.2021.3097283

Variable information:

Atmospheric State (3D)		
Variable	**Variable Long Name**	**Unit**
p_mid	Pressure	(Pa)
T_mid	Temperature	(K)
geopotential_mid	Height	(m)
pseudo_density	Air density	(kg/m3)
U	U-wind	(m/s)
V	V-wind	(m/s)
omega	W-wind	(Pa/s)

Water Variables (3D)		
Variable	**Variable Long Name**	**Unit**
qv	Water vapor mixing ratio	(kg/kg)
qc	Cloud water mixing ratio	(kg/kg)
nc	Cloud water droplet number concentration	(1/kg)
qi	Cloud ice mixing ratio	(kg/kg)
ni	Cloud ice number concentration	(1/kg)
qr	Rain water mixing ratio	(kg/kg)
nr	Raindrop number concentration	(1/kg)
qm	Rime mass mixing ratio	(kg/kg)
bm	Rime volume mixing ratio	(1/kg)

2D Variables		
Variable	**Long Name**	**Unit**
topo	Topography (m)	(m)
precip_total_surf_mass_flux	Instantaneous surface precipitation rate (mm/sec)	(m/s)
SeaLevelPressure	Sea-level pressure (Pa or hPa)	(Pa)
surf_sens_flux	Surface sensible heat fluxes	(W/m2)
surf_evap	Surface latent heat fluxes	(kg/m2/s)
T_2m	2-m temperature and if available.	(k)
wind_speed_10m	10-m wind speed	(m/s)
SW_flux_up_at_model_bot	Surface upward SW radiative fluxes	(W/m2)
SW_flux_dn_at_model_bot	Surface downward SW radiative fluxes	(W/m2)
LW_flux_up_at_model_bot	Surface upward LW radiative fluxes	(W/m2)
LW_flux_dn_at_model_bot	Surface downward LW radiative fluxes	(W/m2)
SW_flux_up_at_model_top	TOA upward SW radiative fluxes	(W/m2)
SW_flux_dn_at_model_top	TOA downward SW radiative fluxes	(W/m2)
LW_flux_up_at_model_top	TOA upward LW radiative fluxes	(W/m2)

Microphysical Process Rates (3D)		
Variable	**Variable Long Name**	**Unit**
heating	Latent heating	(K/s)
cooling	Latent cooling	(K/s)
shoc_cond	Liquid condensation	(kg/kg/s)
evap	Liquid evaporation	(kg/kg/s)
qv2qi_vapdep	Ice deposition	(kg/kg/s)
qi2qv_sublim	Ice sublimation	(kg/kg/s)
qi2qr_melt	Melting	(kg/kg/s)
freeze	Freezing	(kg/kg/s)
qc2qi_collect	Riming of cloud droplets	(kg/kg/s)
qr2qi_collect	Riming of rain drops	(kg/kg/s)
qc2qr_autoconv	Autoconversion	(kg/kg/s)
qc2qr_accret	Accretion	(kg/kg/s)