Forecasting and Hindcasting Capabilities in the Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)

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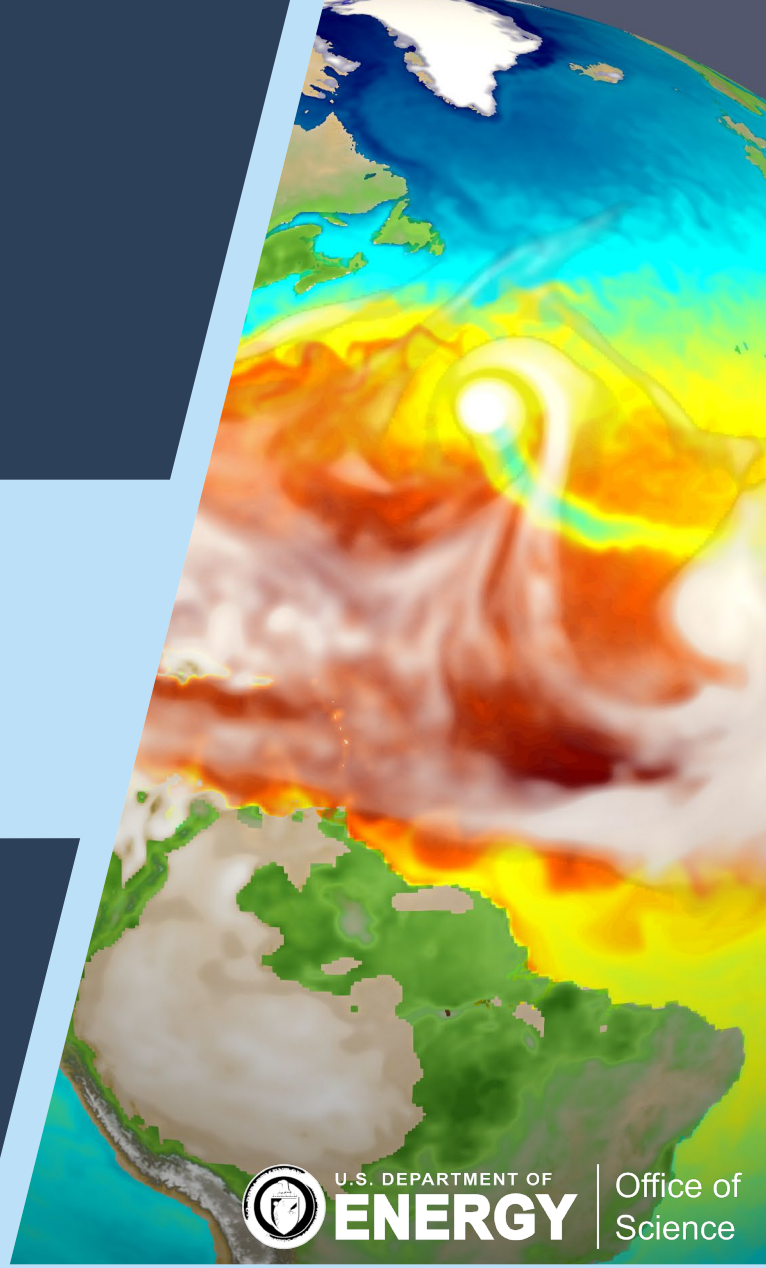

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Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)

Goal: Keep code as simple as possible

- Ensure portability between infrastructures (CPU vs. GPU)
- Higher resolution reduces need for complex parameterizations

Not quite globally cloud-resolving *but makes for a better acronym*

- Typically run at dx = 3.25km, 128 vertical layers with top at 40km
- Has been run down to sub-kilometer scale without issue

As an E3SM component, we can couple to E3SM's land, ocean and sea ice

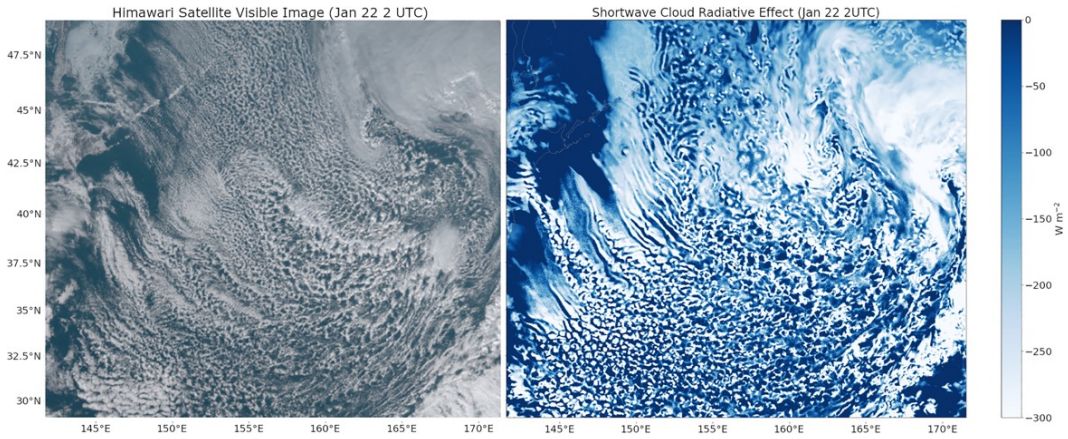


Figure: Cold-air outbreak off Siberia on Jan 22, 2020 at 2Z (~local noon) from a Himawari visible satellite image (left) and shortwave cloud radiative effect from SCREAMv0 (right).

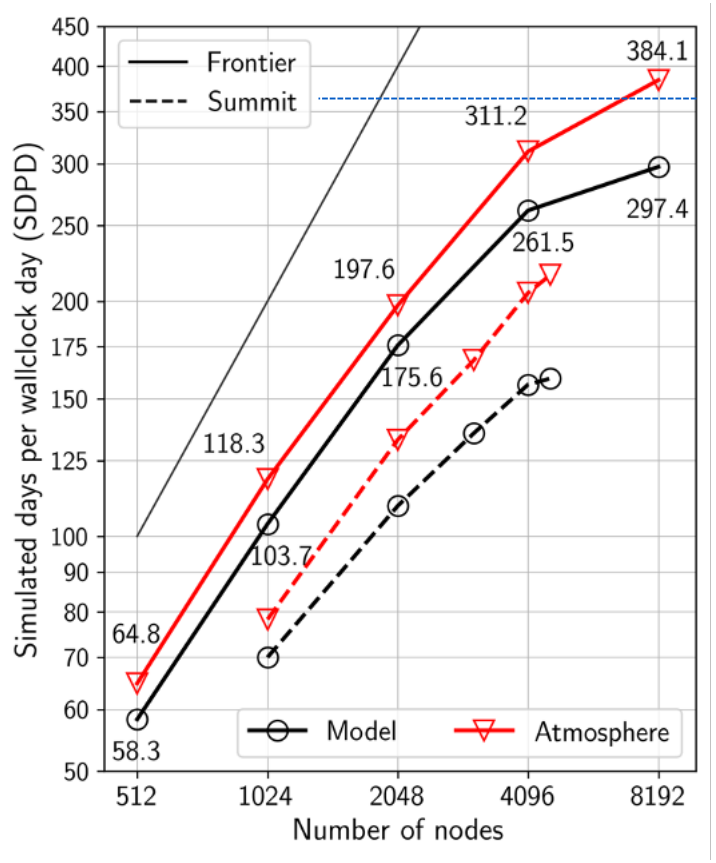
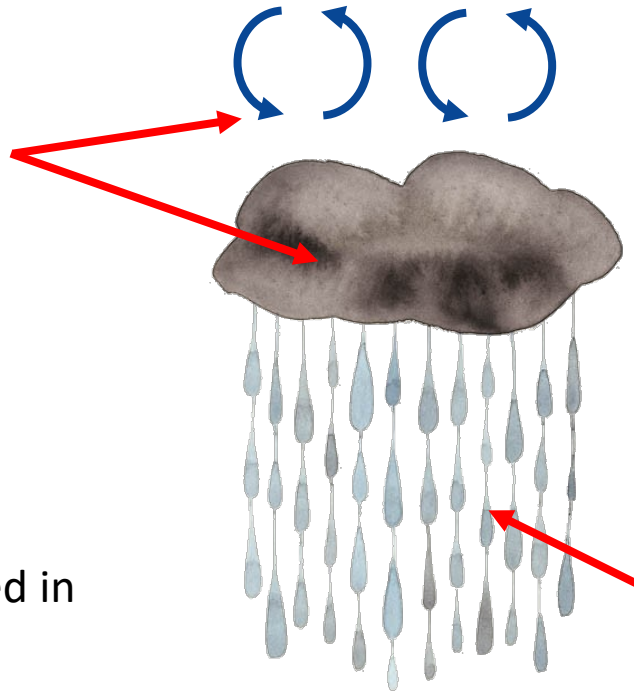


Figure: Model performance on Summit and Frontier supercomputers at ne1024pg2

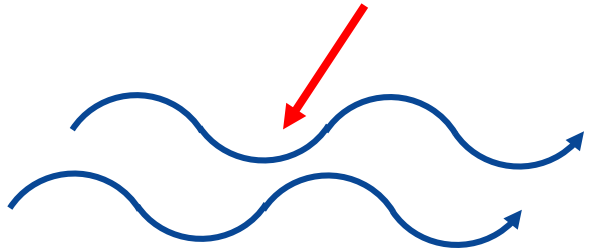
Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)

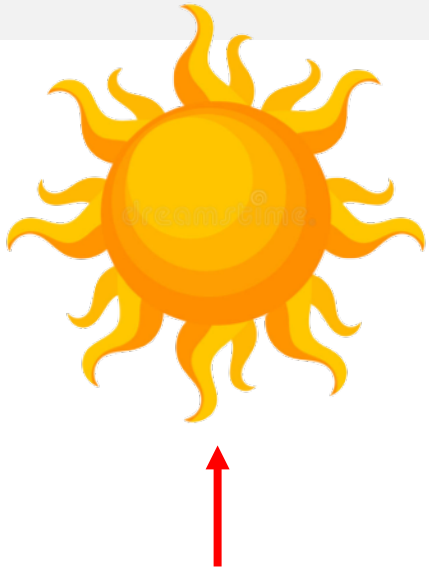
~~parameterized convection~~

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



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





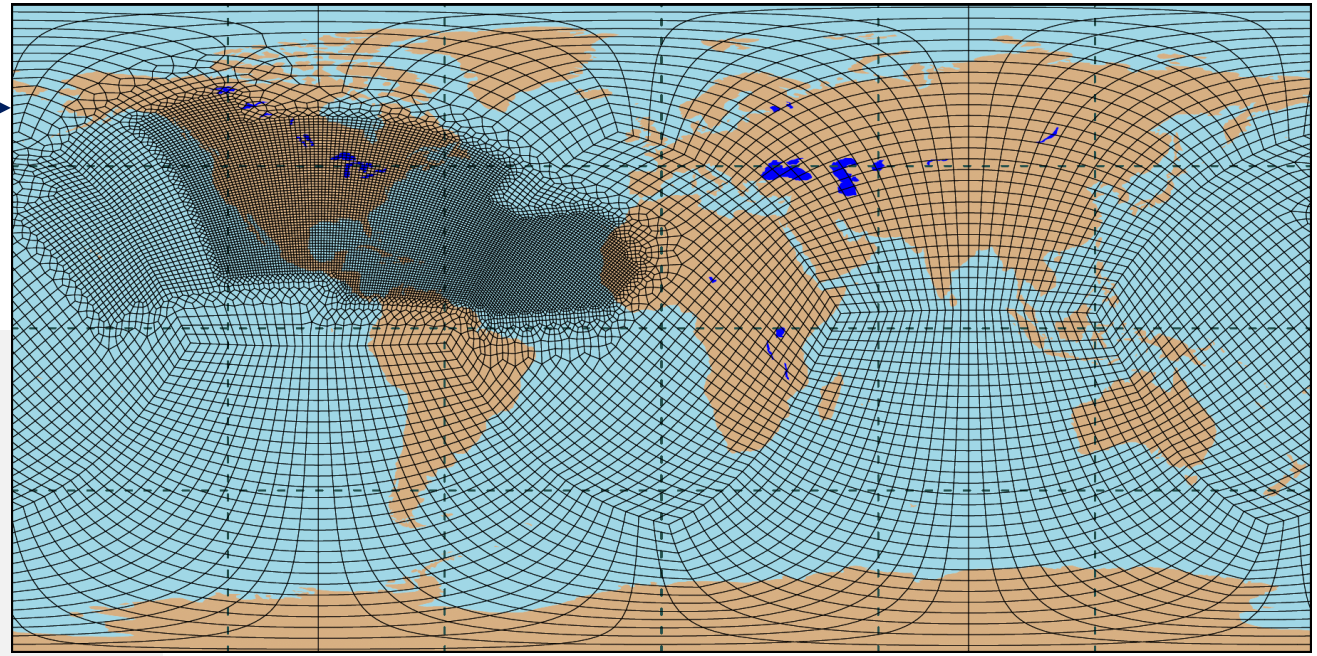
Radiation handled by externally-developed, GPU-ready **RRTMGP** package

Aerosols will be prescribed in initial implementation

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

Regionally Refined Modeling (RRM)

Resolution where you want it



- Reduces computational cost
- Allows resources to be redirected:
  - More ensemble members
  - Greater model complexity (e.g., active chemistry, more tracers)

Figure: The DOE/HyperFACETS contiguous US (CONUS) mesh, with 28km grid spacing over CONUS and in the Atlantic TC genesis region.

Tools Supporting RRM in E3SM

SQuadGen

Flexible grid generation for E3SM with the spherical quadrilateral grid generator.

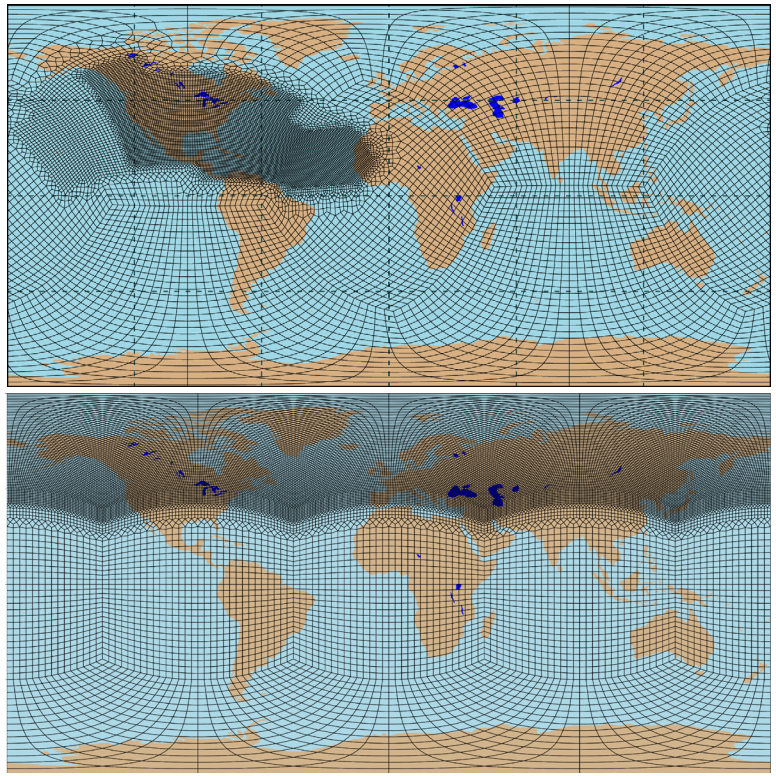


Figure: CONUS and ARCTIC meshes.

Betacast

Rapid initialization of weather forecasts and hindcasts on arbitrary grids.

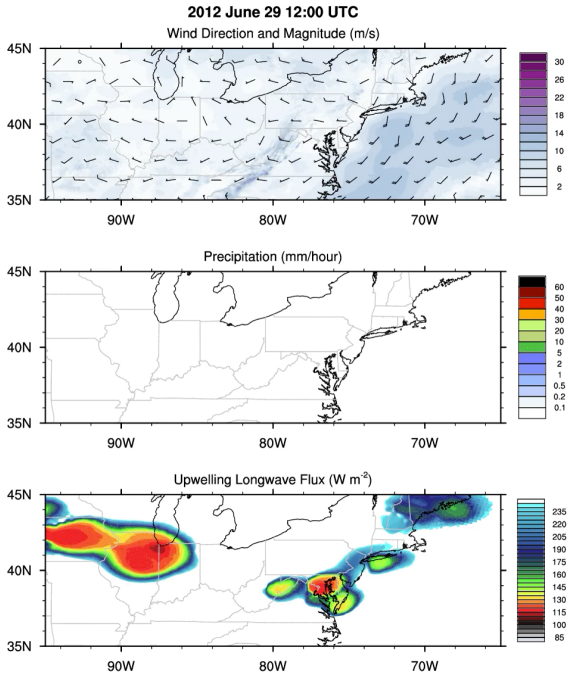
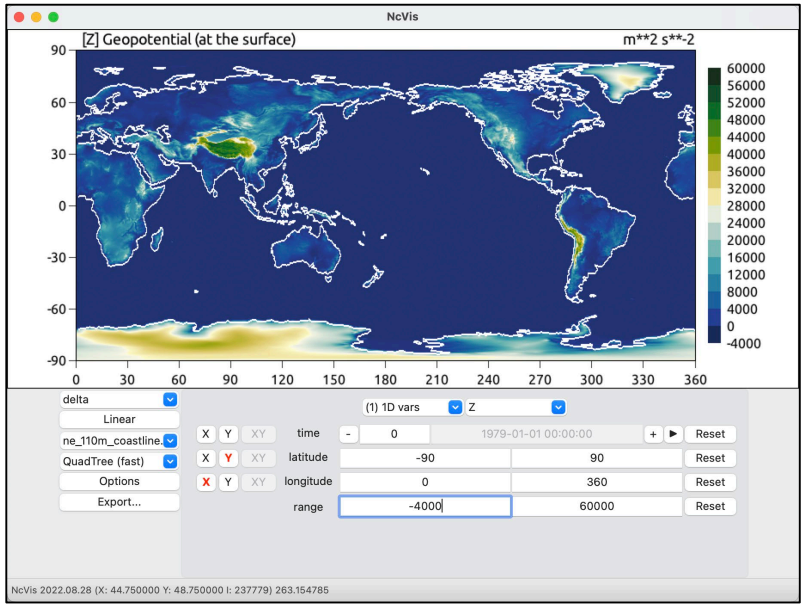


Figure: The 2012 North American Derecho simulated using E3SM/SCREAM at 3.5km grid spacing, initialized via BetaCast.

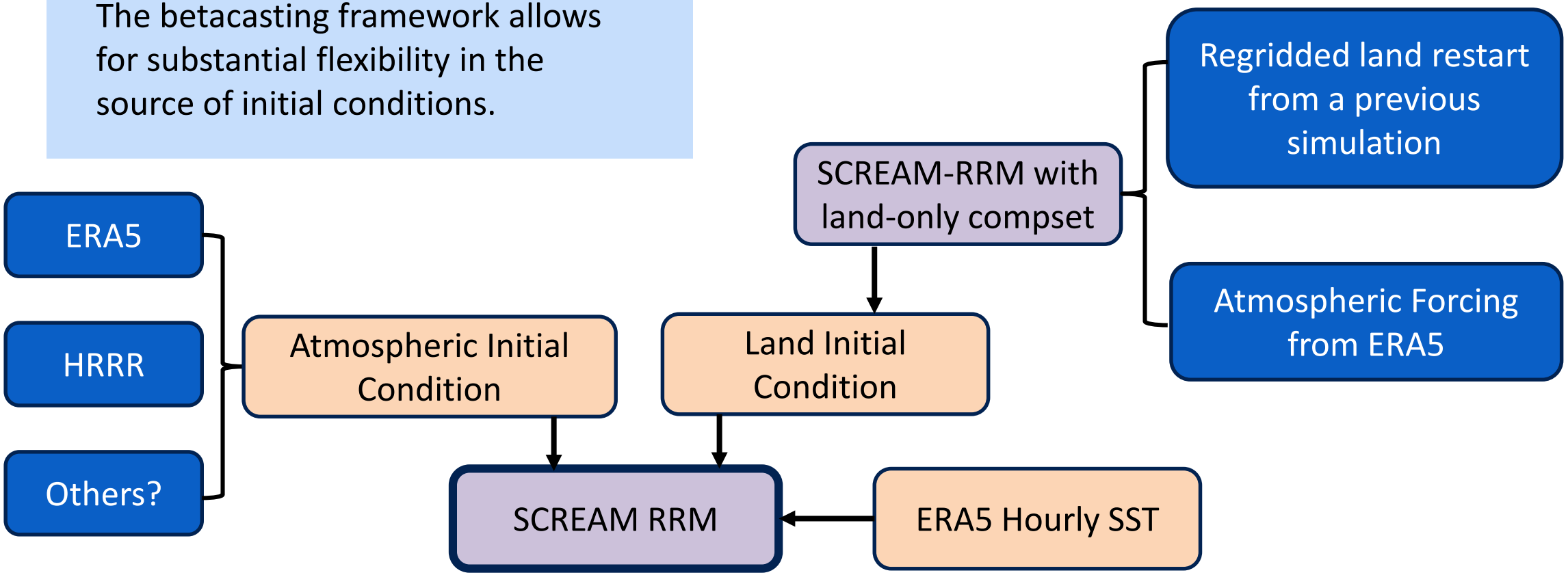
ncvis

A new visualization package for “quick look” examination of structured and unstructured climate and weather data.



Betacasting Framework

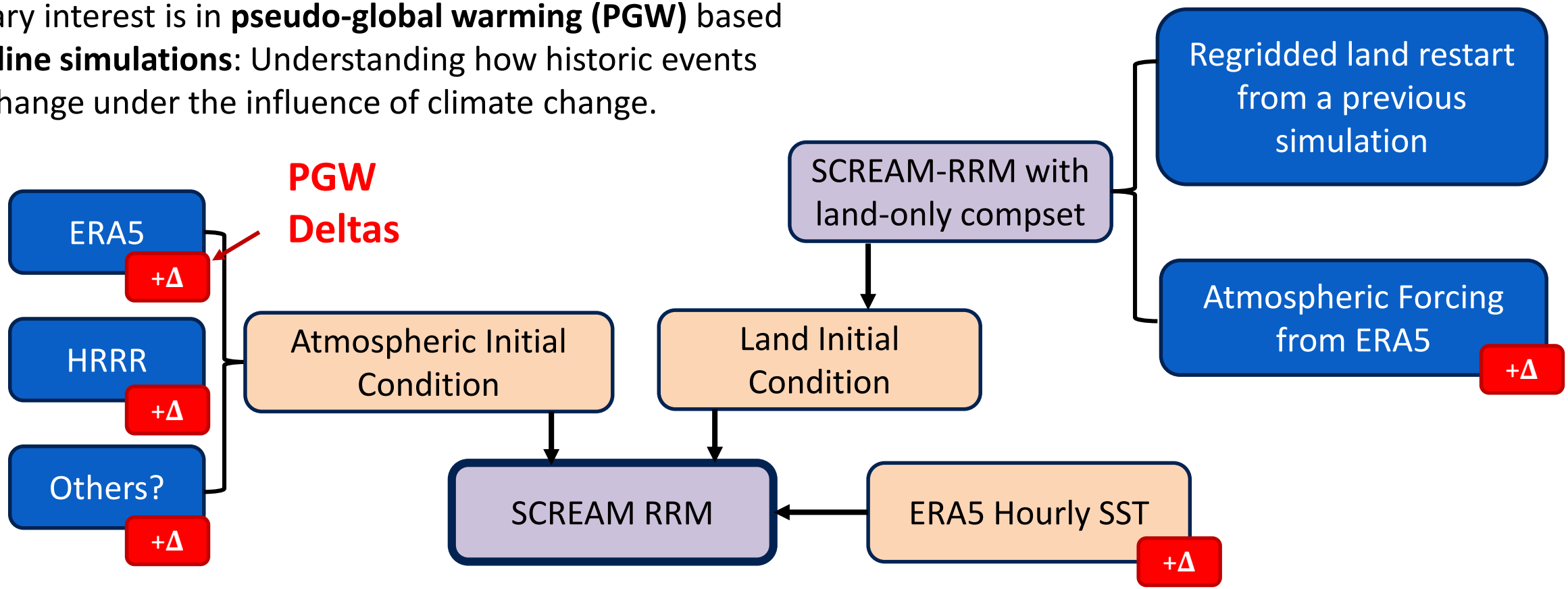
The betacasting framework allows for substantial flexibility in the source of initial conditions.



Why are we interested in ~~hind~~beta casting?

Definitely not because we want to encroach on NOAA's domain

Primary interest is in **pseudo-global warming (PGW)** based **storyline simulations**: Understanding how historic events will change under the influence of climate change.



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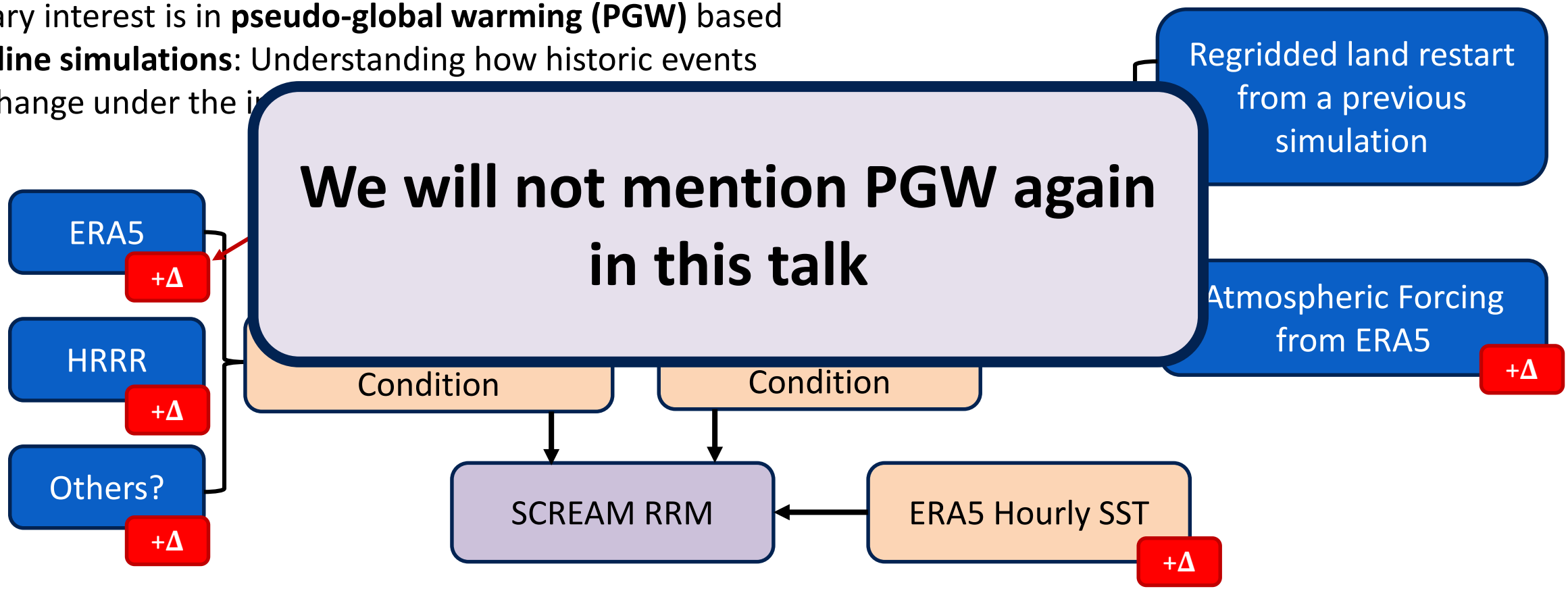
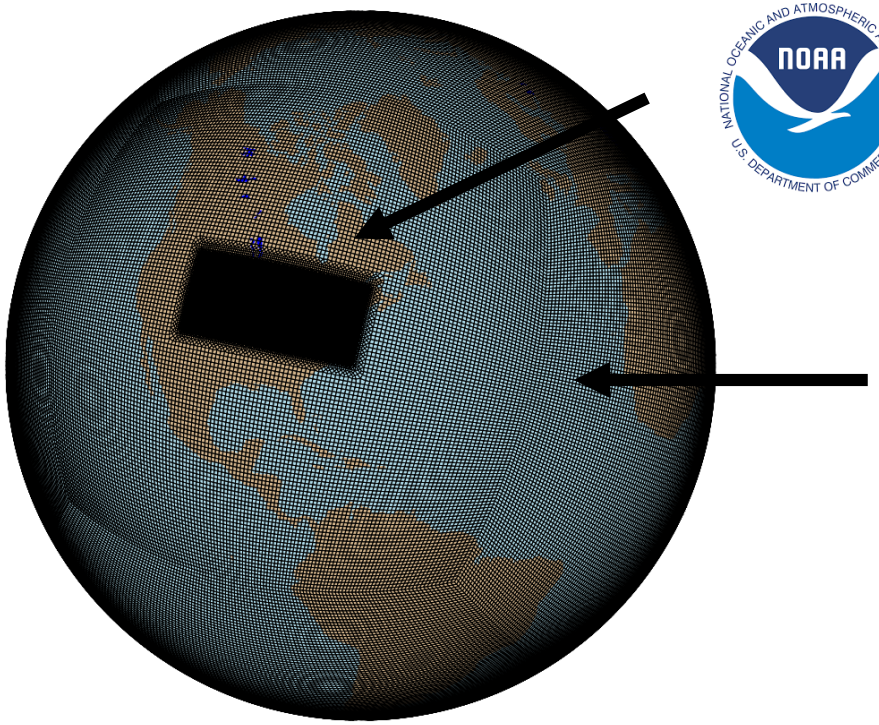


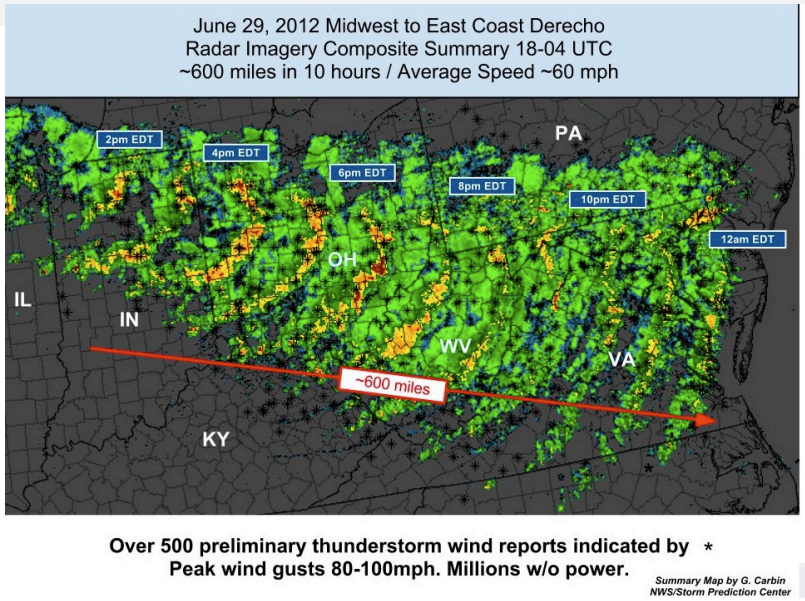
Simulating the 2012 North American Derecho



Rapid Refresh (RAP)

ECMWF

Reanalysis v5 (ERA5)



- **Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)** (Caldwell et al., 2021; Liu et al., 2022)
- Regionally Refined Mesh (RRM) generated using SQuadGen
- Global initial conditions from ECMWF Reanalysis v5 (ERA5)
- North American initial conditions from NOAA Rapid Refresh (RAP)
- Can compare with analogous simulations in WRF

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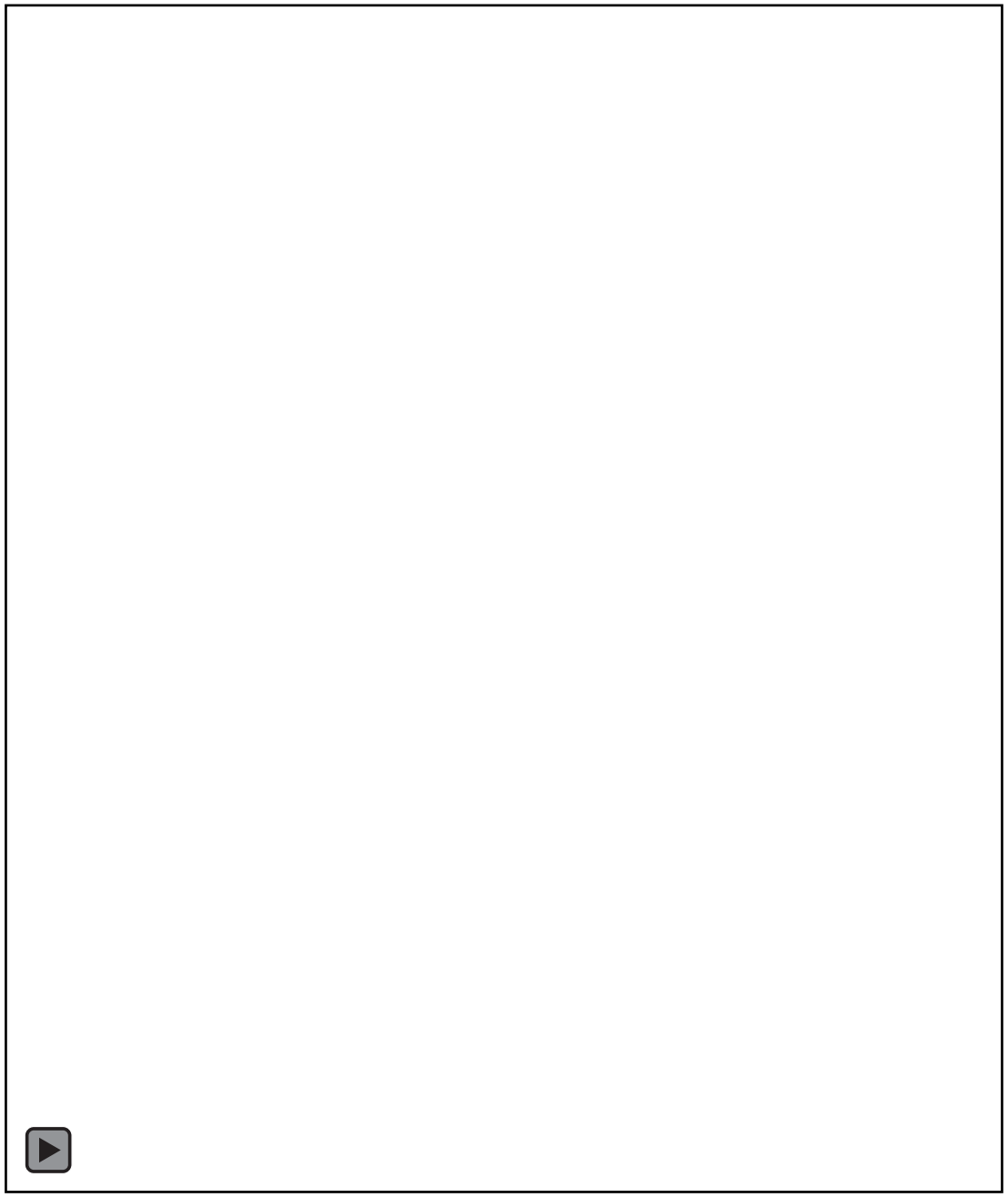
The 2012 NA Derecho

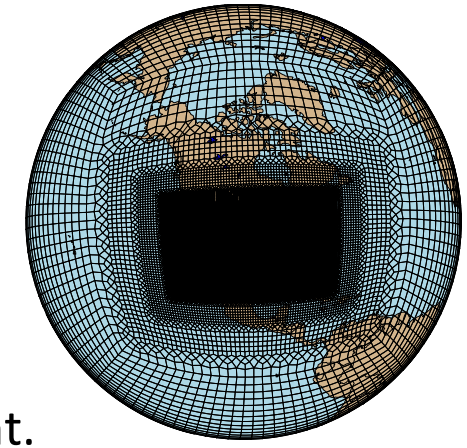
- Hindcast simulation of historic extreme weather events enable targeted evaluation of regional and global climate modeling systems.
- Standardized frameworks (test beds) for evaluation are useful for examining the representation of processes in these models.
- RRM-SCREAM demonstrates similar performance to WRF on the simulation of the historic 2012 North American Derecho (i.e., worse representation of OLR, better representation of precipitation, radar reflectivity and winds).



The 1996 Susquehanna Flood

An example of Rain-on-Snow (RoS) driven flooding

- RoS defined as basin-scale temporal concurrence of rain + runoff + snowmelt.
- There is a lack of agreement between historical reanalyses and statistical or dynamical downscaling of this event. Can we simulate it?
- Evaluation of 1996 Susquehanna flood event shows latent heat flux + longwave radiative fluxes combined with precipitation to enhance runoff: E3SM accurately captures this event.



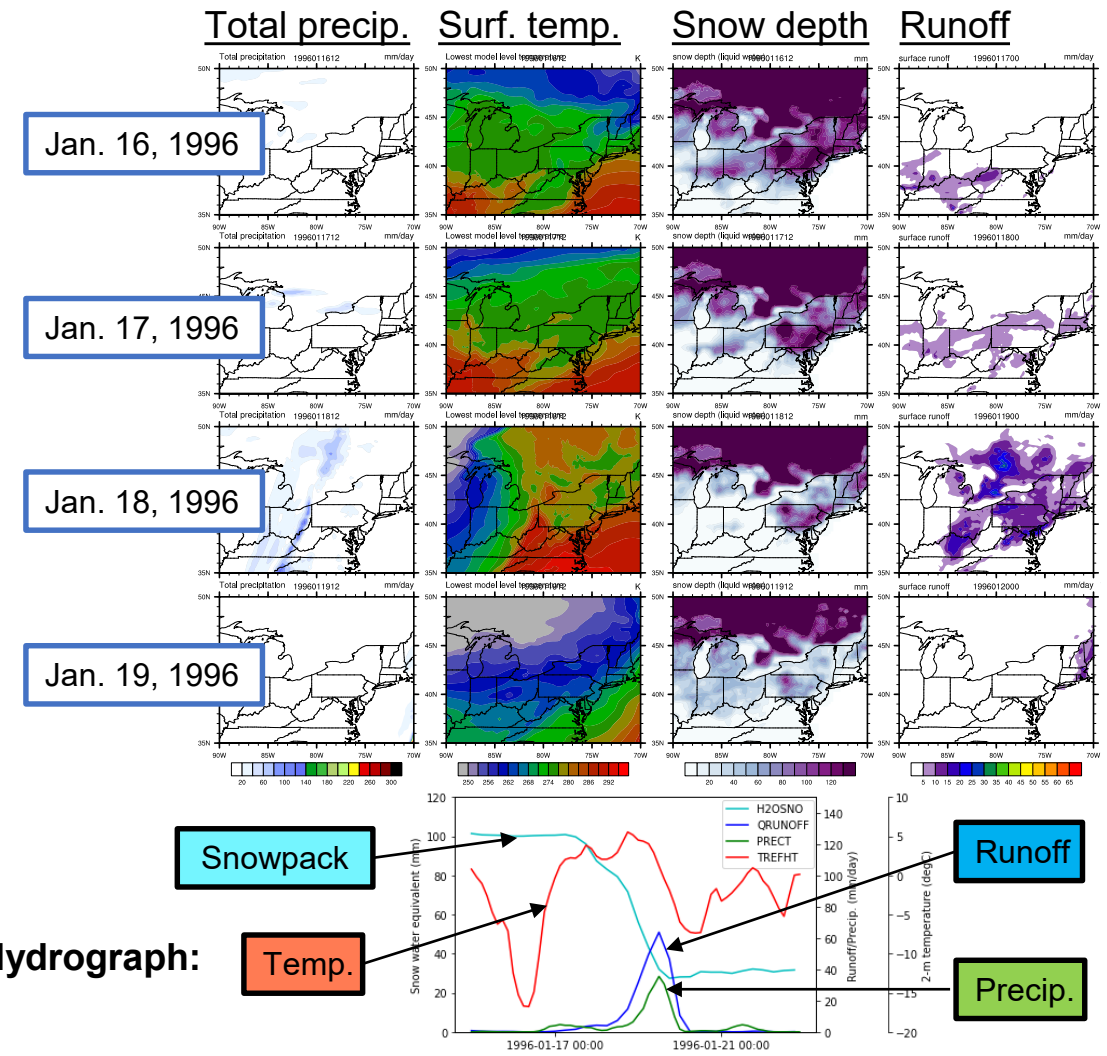


Figure: 14km E3SM hindcast of 1996 Susquehanna flood event. From L to R, precipitation, sfc. temp., SWE, sfc. runoff.

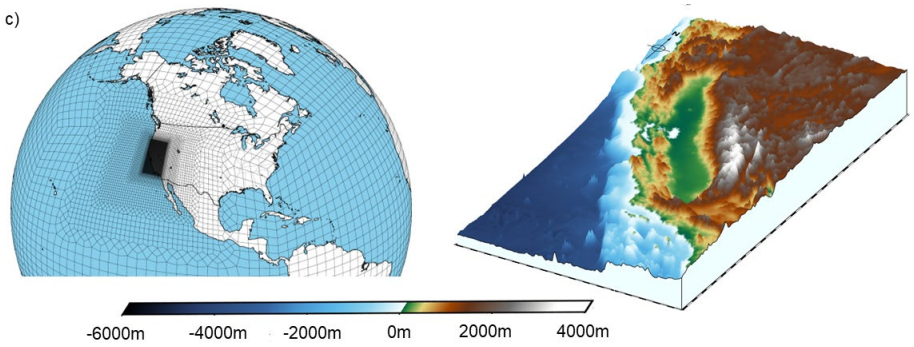
The 1997 New Year's Flood

RRM-E3SM 3.5km meteorology in WEAP correctly captures the high river levels that risk levee breach. These levels are not captured by commonly used high-resolution gridded meteorology data.

The New Year's flood of January 1997 devastated various regions of California, with heavy rain and melting snow causing flooding along the Sacramento River and its tributaries, and widespread damage, evacuations, and disruptions to transportation.

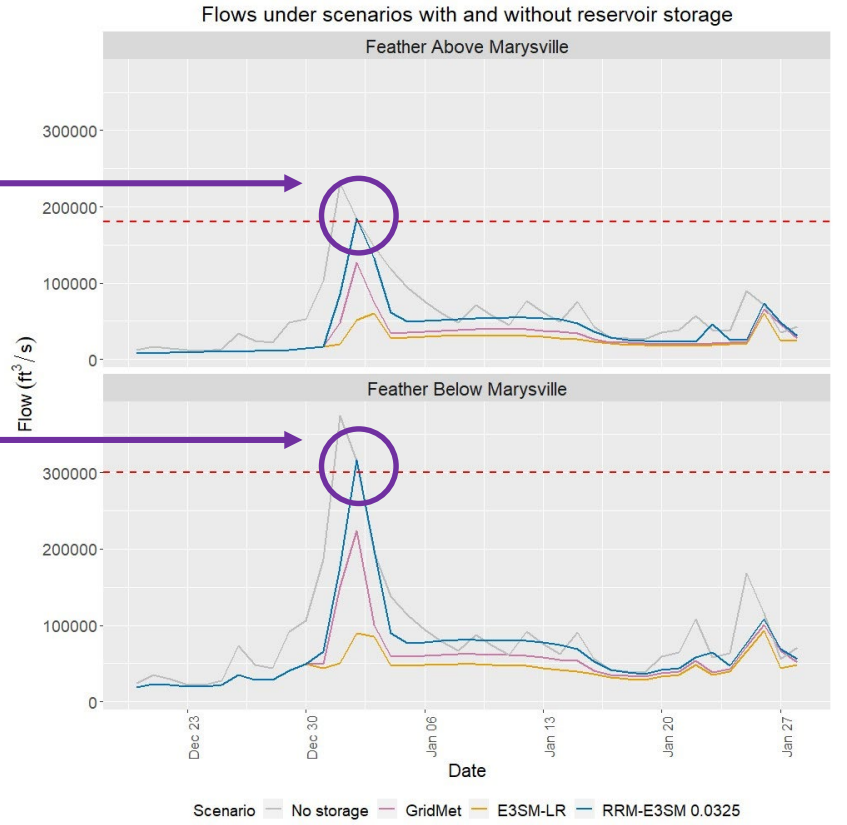
Near Marysville, at the confluence of the Feather and Yuba rivers, three people died and roughly 1,000 homes were destroyed following a levee break.

Simulated in RRM-E3SM at 3.5km local grid spacing



Water Evaluation and Planning (WEAP)

WEAP simulated streamflows near Marysville

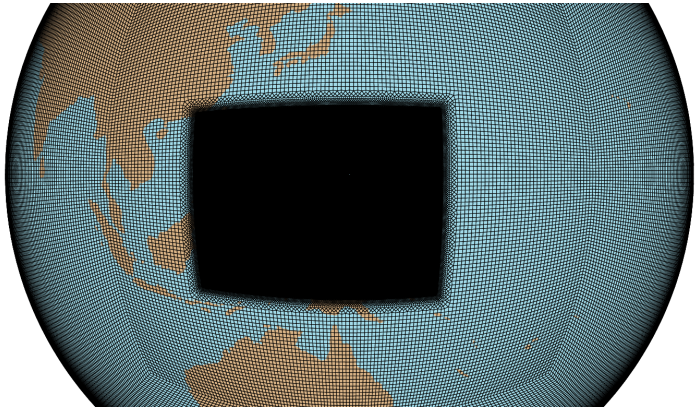


Regulated flow thresholds

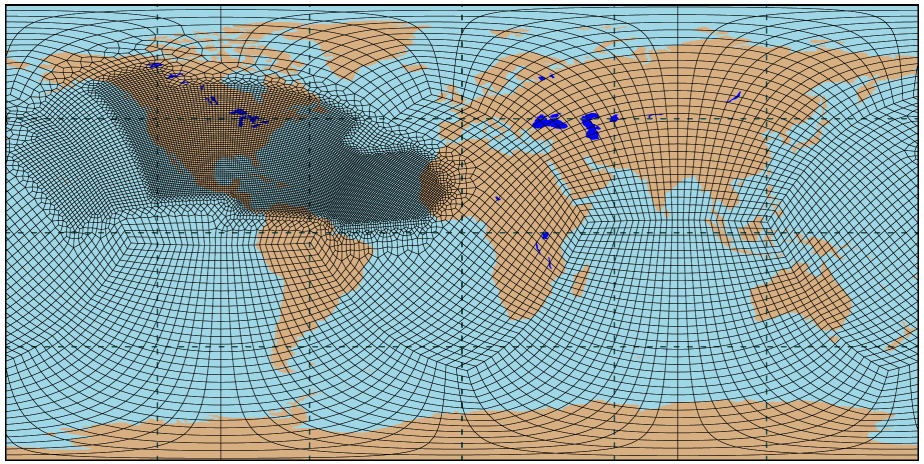
2023 Super Typhoon Mawar

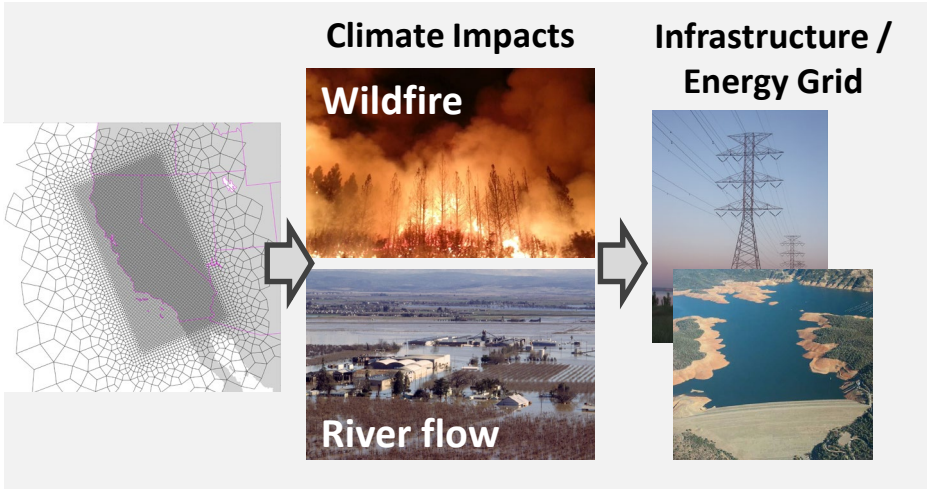
Super Typhoon Mawar was one of the strongest Northern Hemisphere tropical cyclones on record, causing widespread devastation to the territory of Guam.

We hindcast this event using RRM-SCREAM at 3.5km resolution with initialization from ERA5 (globally) and HWRF (over Mawar).



Forward Vision





Large Ensembles: RRM enables the generation of targeted regional large ensembles. These ensembles are particularly useful for generating a large sample of extreme events.

Storylines: RRM allows us to understand model performance for historical extremes, and perform targeted simulations to understand how these extremes are changing in the future.

Climate Impacts: RRM provides the resolutions needed to investigate climate impacts. Linkages with infrastructure and energy grid models allow for systematic exploration of system vulnerabilities.

Thank You!

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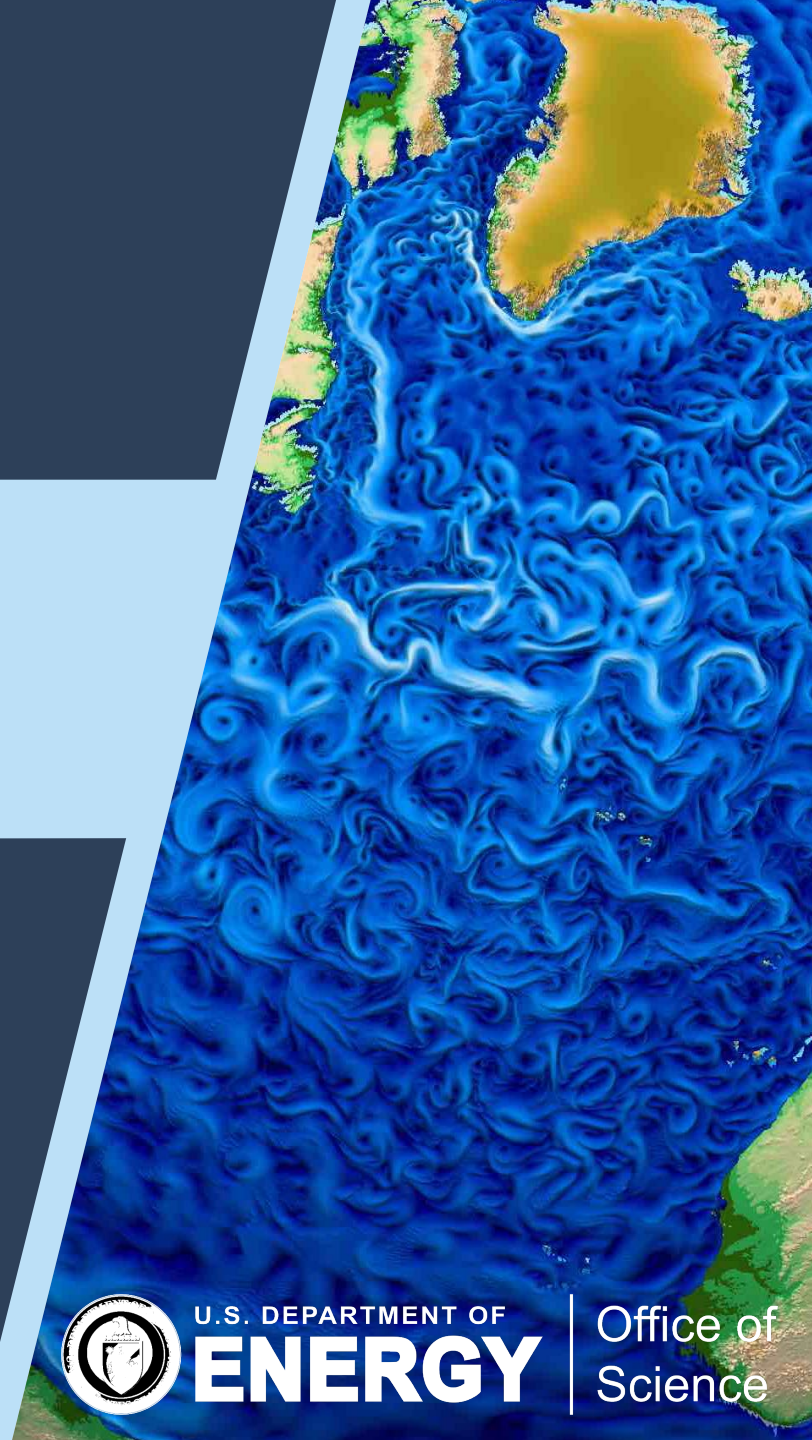

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