The regionally refined model of E3SM: overview and extremes applications

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[1]LLNL, [2]LANL, [3]UCI
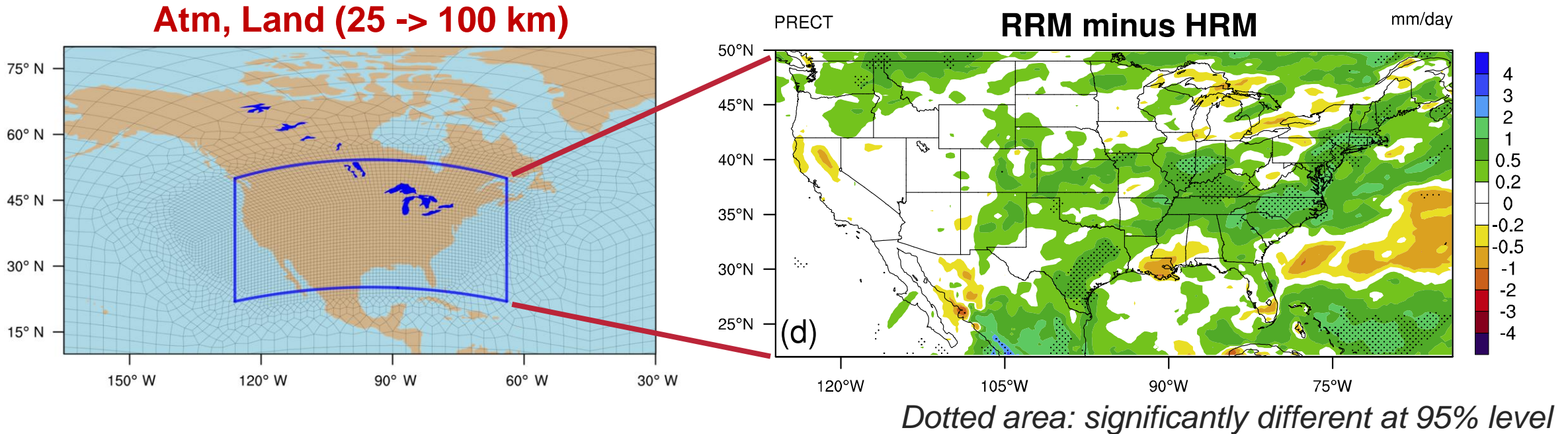
EESM PI meeting, Washington D.C.

August 6-9, 2024

- Higer resolution simulation is a long-time goal of climate model development.

- Increasing interests in key regions and ensemble simulations

- RRM is a computationally efficient solution.
  - ~10-20% of uniform high-res model

Simulation	Configuration	Effective angular resolution	Number of elements	Speed (SYPD)	Number of nodes	Cost (core-hours per year)
Low-resolution model (LRM)	Default	1°	5400	6	81	22 000
High-resolution model (HRM)	Default	0.25°	86 400	2	675	551 000
Regionally refined model (RRM)	HRM default	1 to 0.25°	9905	1.7	88	84 000
RRM_LR	LRM default	1 to 0.25°	9905	1.9	88	75 000

costs of EAMv1 atmosphere-only cases (Tang et al., 2019)

- We developed RRM in other components in E3SMv2.
  - Ocean – eddy activity; Ice – ice streams; Land – surface types
 - All major components (atmosphere, land, ocean, sea ice) can do RRM.

An EAMv1 RRM example

- Use the EAMv1 HR parameters and only focus on the high-res CONUS domain.

Atm, Land (25 -> 100 km)

PRECT   **RRM minus HRM**   mm/day

(d)

*Dotted area: significantly different at 95% level*

- June-July-August precipitation
- RRM generally reproduces high-res precipitation patterns over the refined domain.

- A first-of-its-kind application of RRM in all major components, accomplished CMIP6 climate simulation campaign

- Key achievements
  - Improved climate at refined mesh without degrading the fidelity over low-res (LR) mesh

  - Novel hybrid timestep strategy in EAM

    - dt = high-res dycore + LR physics

    - Avoids recalibration beyond v2.LR

    - Large time-truncation errors at 25 km

  - Efficient throughput (12 SYPD on Chrysalis)

Atm, Land (25 -> 100 km)

Ocean, Sea ice (14 -> 60 km)

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Global results
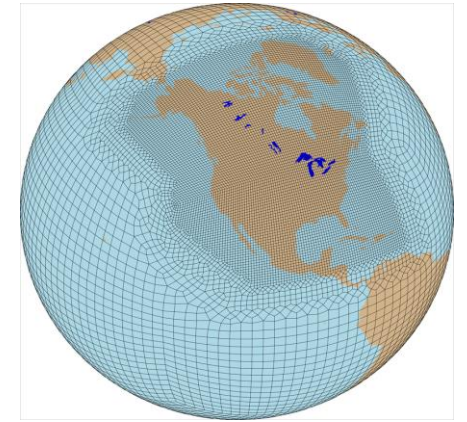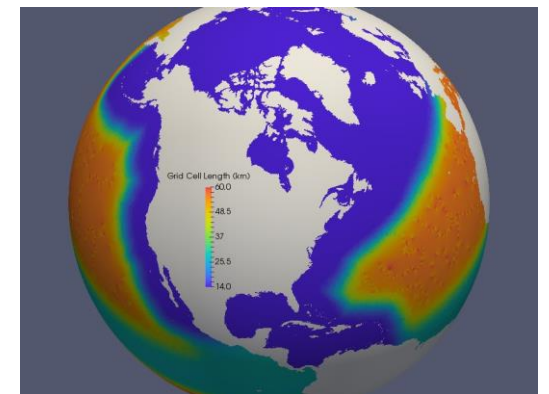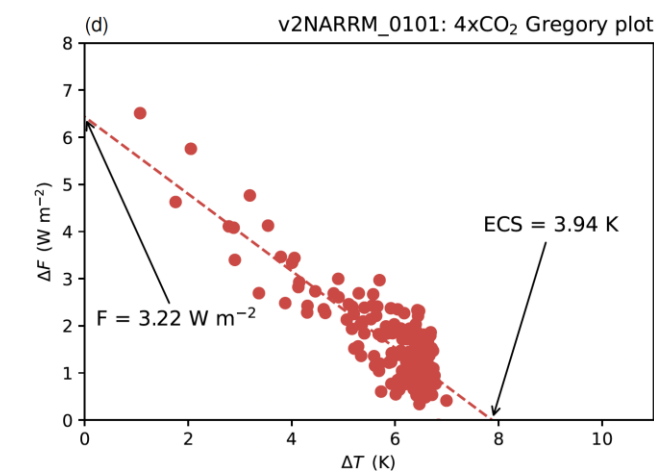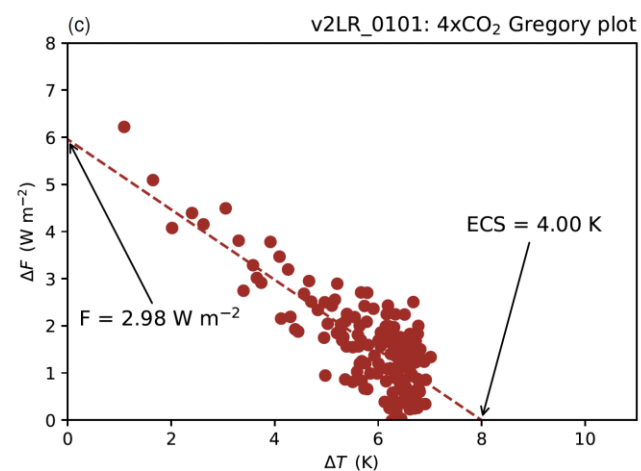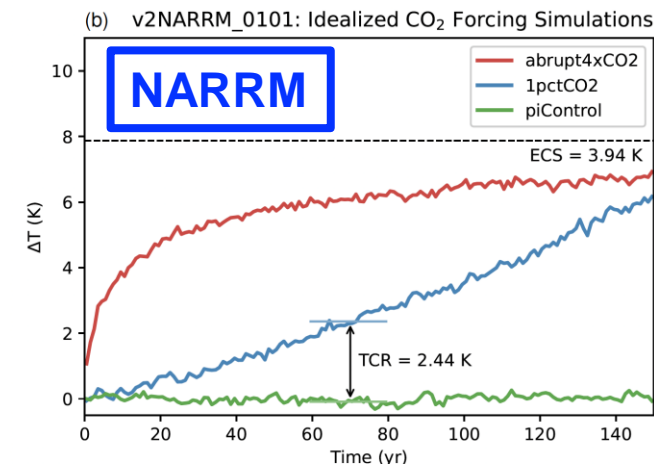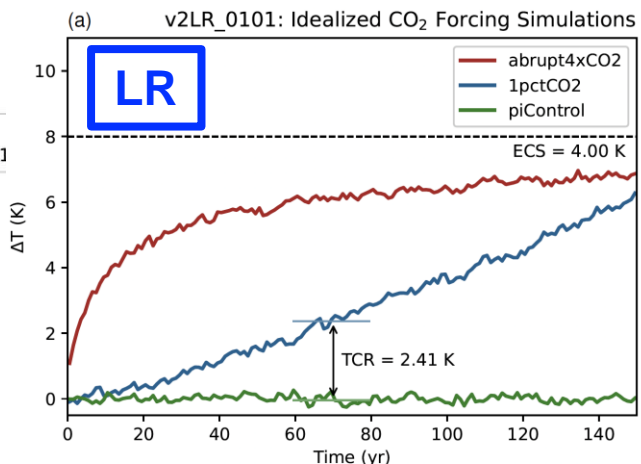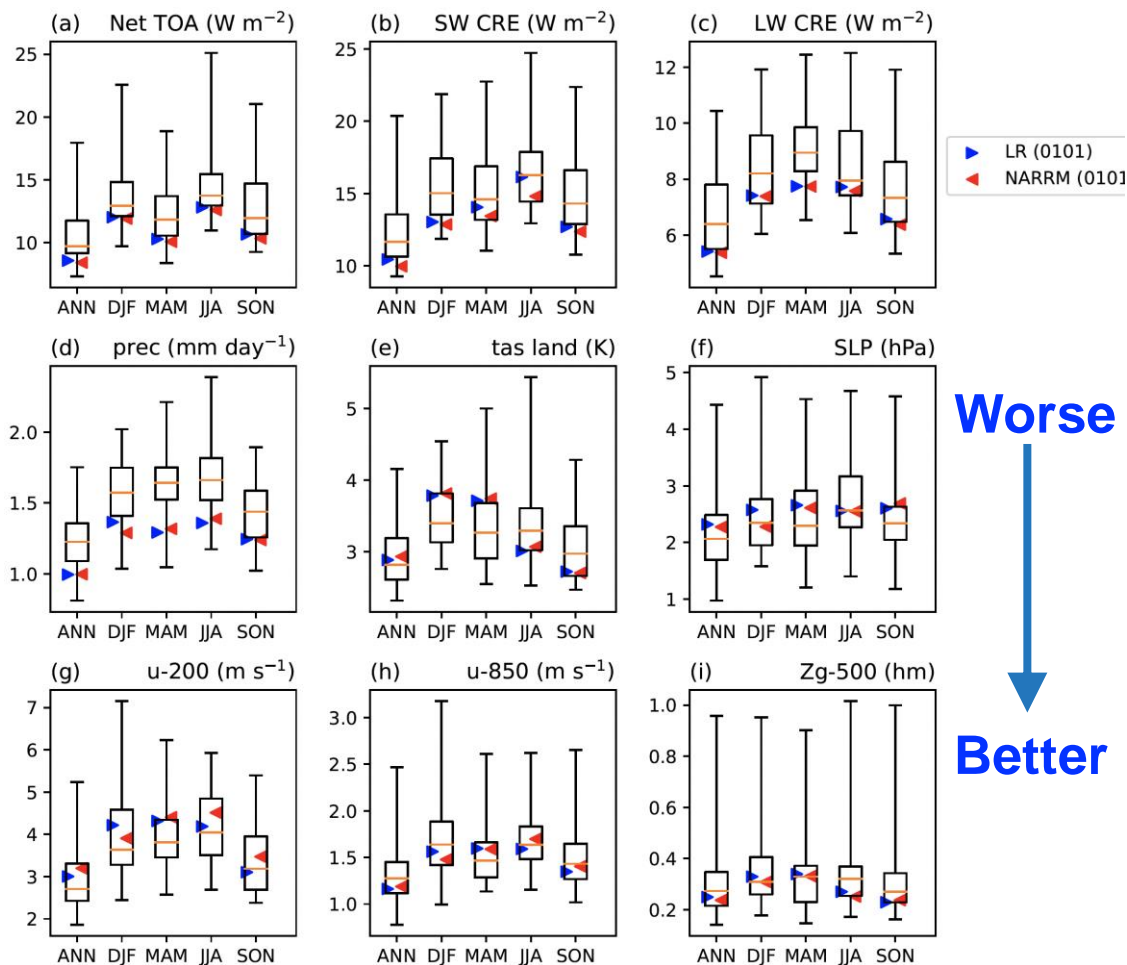


- Left: global NARRM climatology is the same as or slightly better than its low-resolution (LR) counterpart compared to observations and CMIP6 models.

- Right: NARRM and LR have similar climate sensitivities and feedbacks.
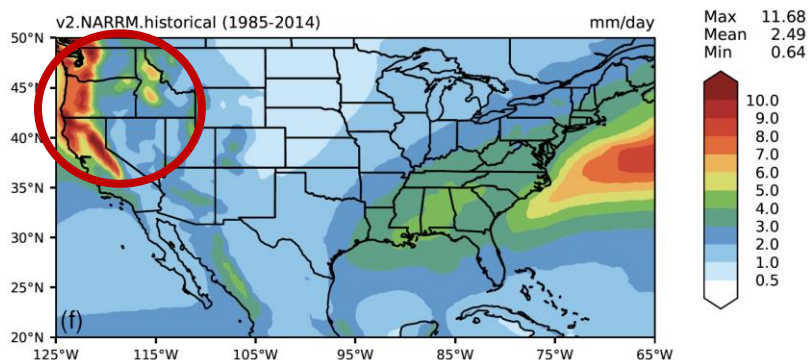
Precipitation

Obs

LR

NARRM

- NARRM simulates better precip (left) related to the finer topography.

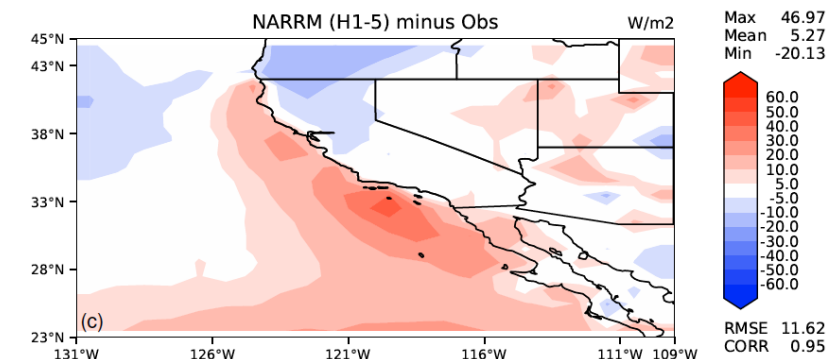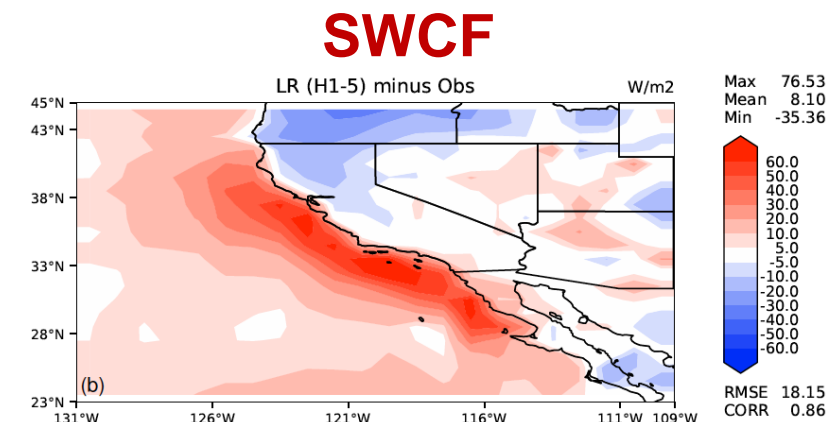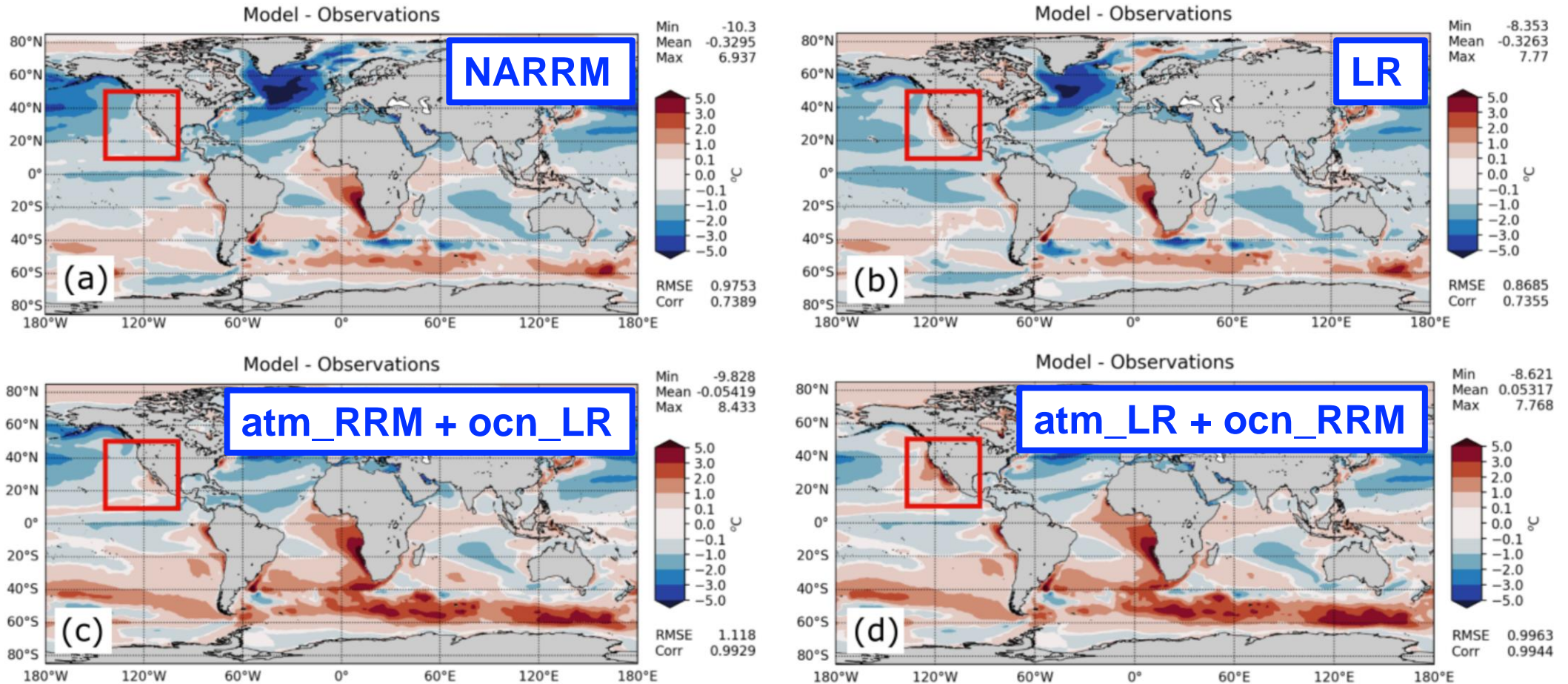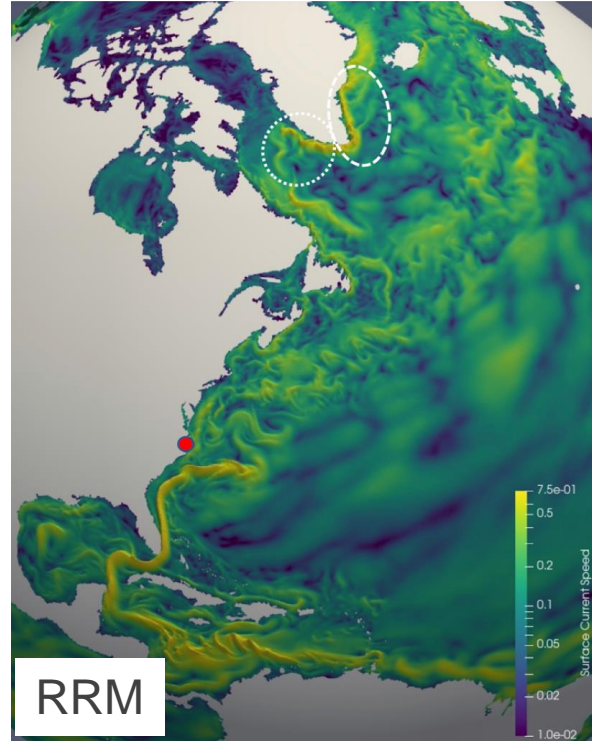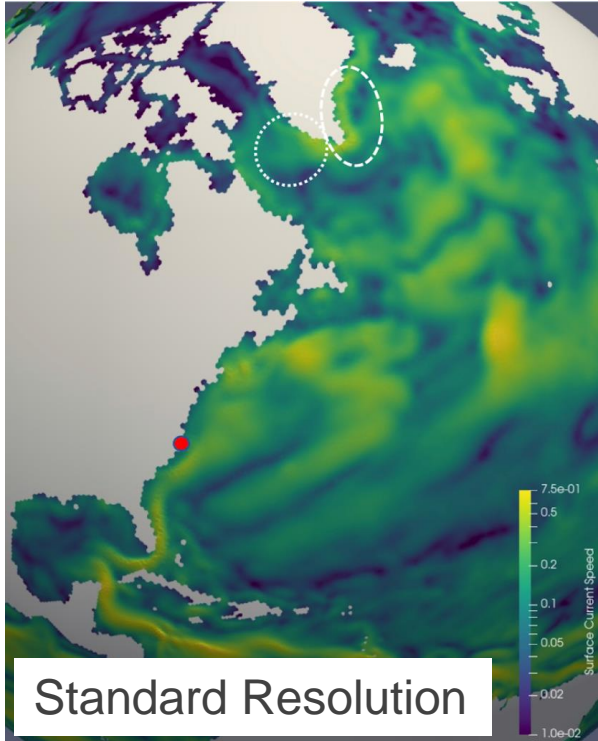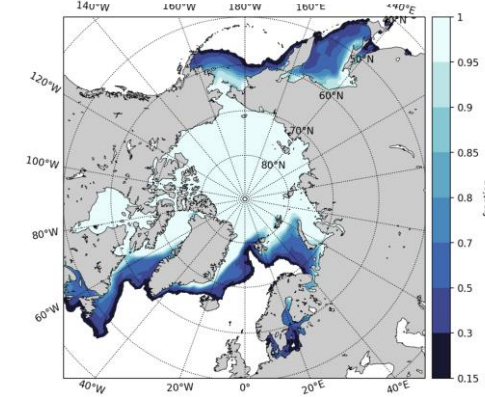- Reduces the biases in marine stratocumulus clouds off the California coast (right).

SWCF
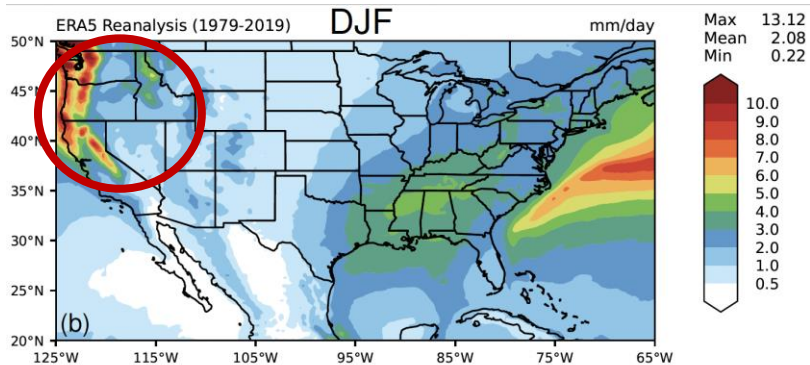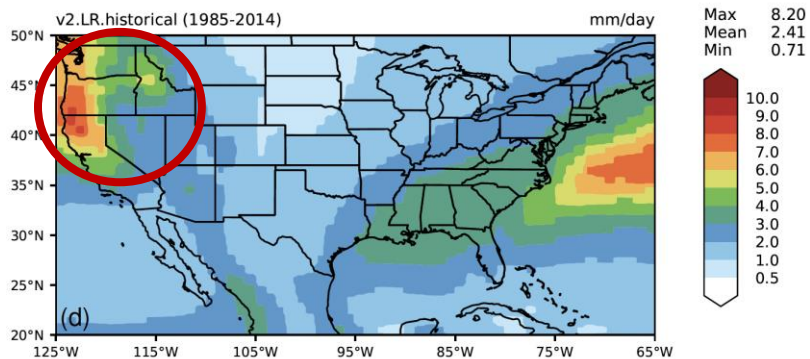
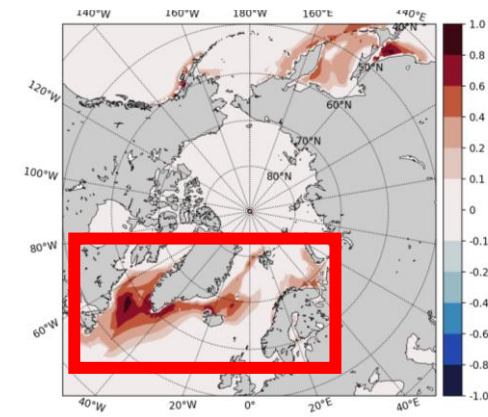# SST bias (model – obs) with four configurations
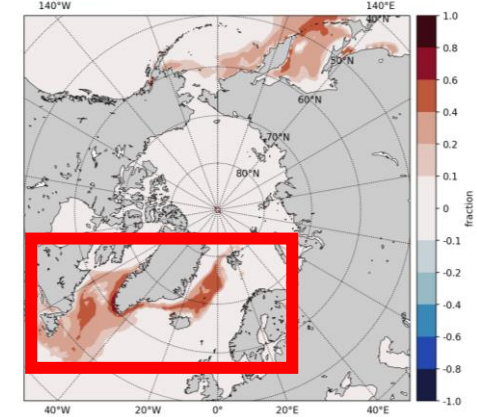
Standard Resolution

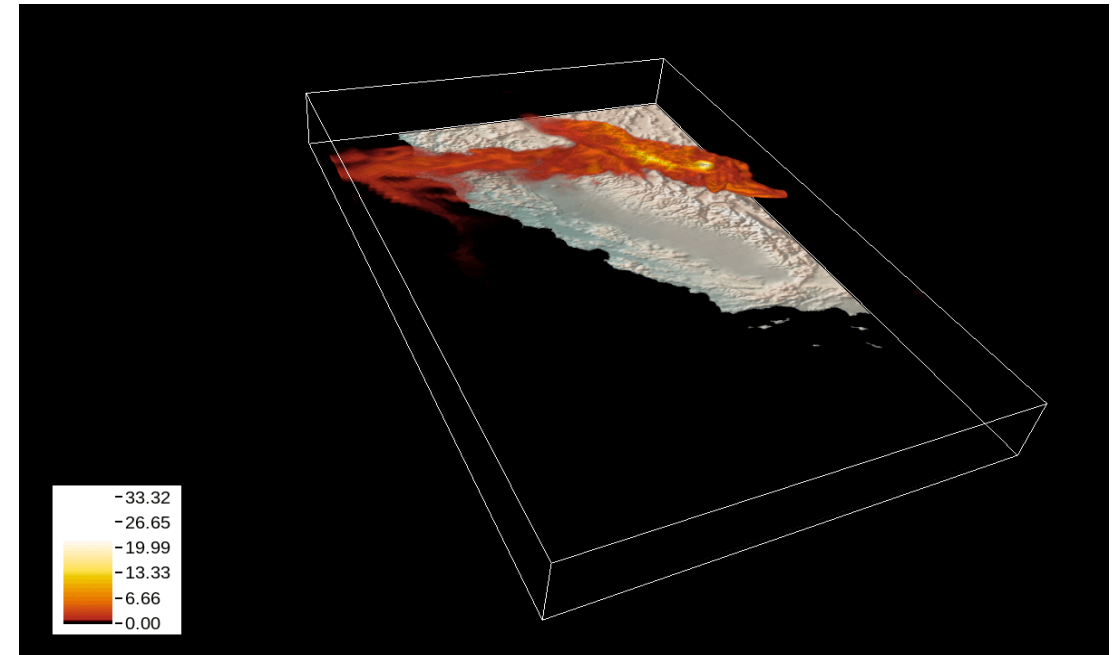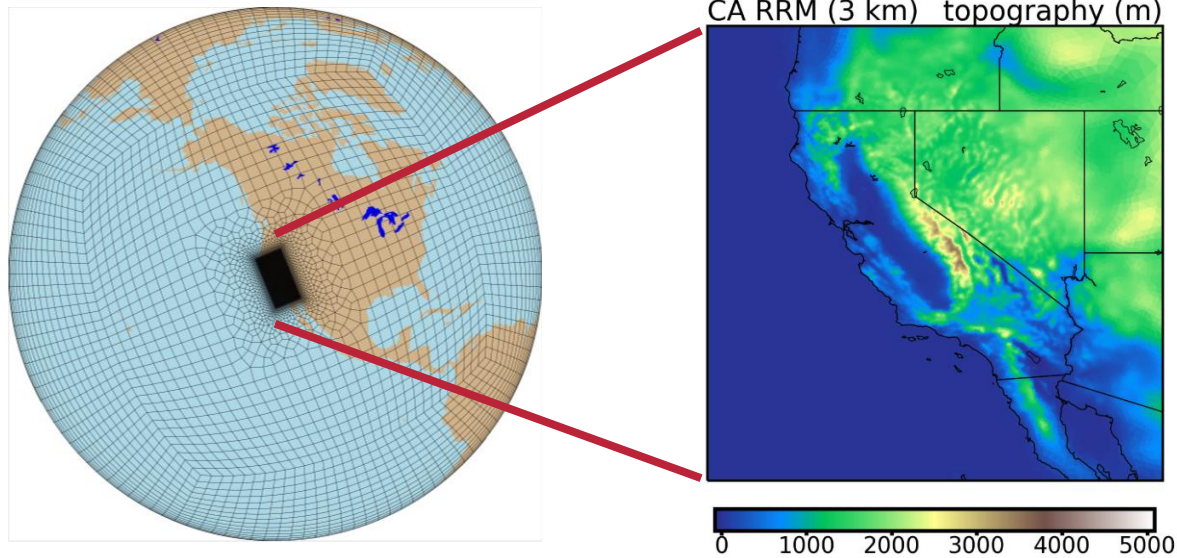

RRM

Observations

Standard Res. Bias

RRM Bias

- Above: surface current speed shows significant eddy activity in RRM, including improved Irminger and Labrador currents

- Right: Sea ice concentration improved in Labrador sea

Opportunities

- RRM opportunities with E3SMv3 and SCREAM/EAMxx capabilities.
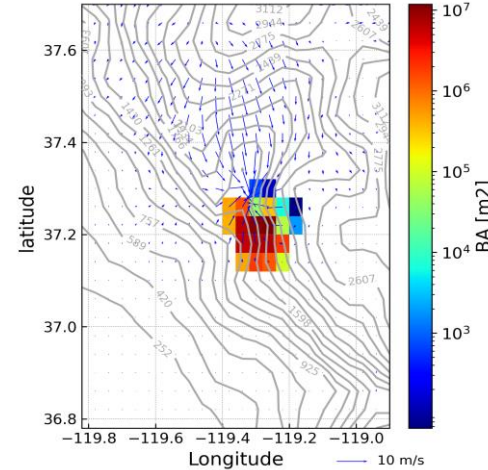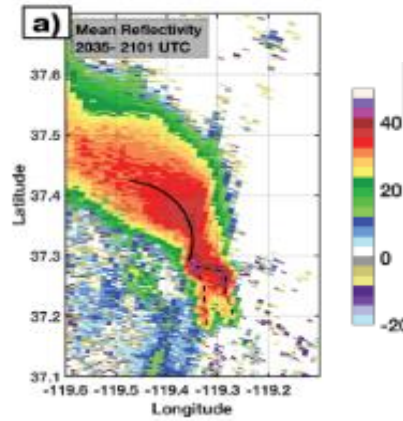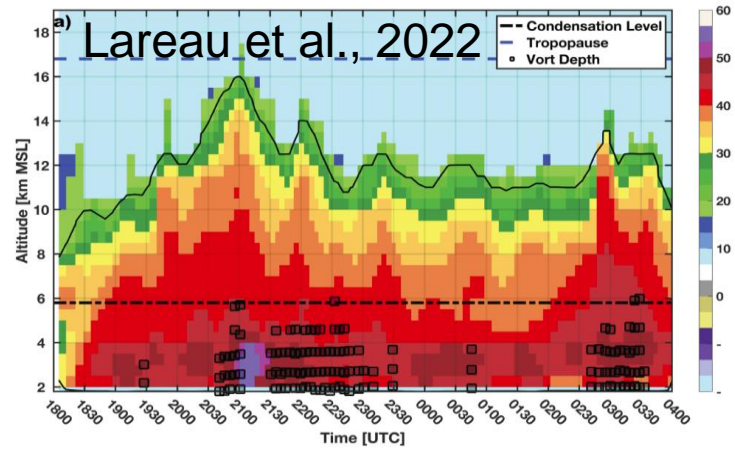 - Advanced physics + non-hydrostatic dynamics

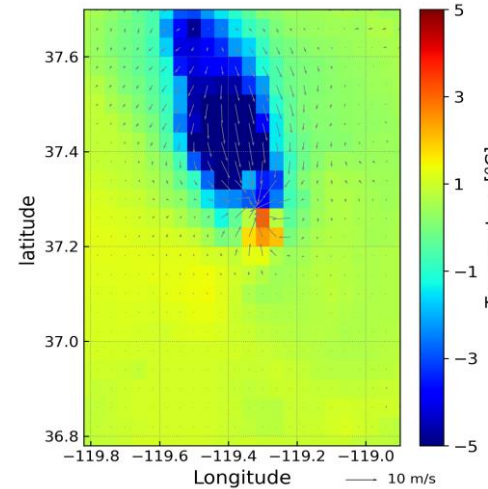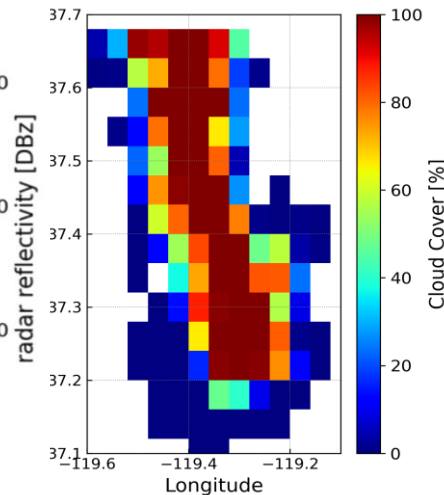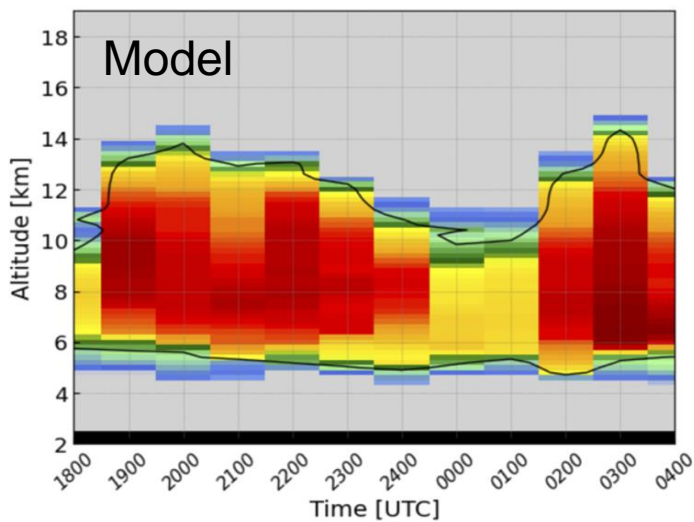**CARRM (3 km -> 100 km)**

Courtesy of Hsiang-He Lee

- Creek fire (2020) simulation of hourly black carbon (BC, ug/kg)
- 2020/09/07 00z to 2020/09/10 23z

- Pyrocumulonimbus is reasonably represented by E3SM-CARRM.

Lareau et al., 2022

Simulated Radar Reflectivity (CF >0)

Model

More in Ziming Ke's talk in Extremes at 2:45 PM Wednesday

Geoscientific
Model Development

Leveraging regional mesh refinement to simulate future climate projections for California using the Simplified Convection-Permitting E3SM Atmosphere Model Version 0

**Jishi Zhang, Peter Bogenschutz, Qi Tang, Philip Cameron-smith, and Chengzhu Zhang**

Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

EGUsphere
Preprint repository

Atmospheric River Induced Precipitation in California as Simulated by the Regionally Refined Simple Convective Resolving E3SM Atmosphere Model (SCREAM) Version 0

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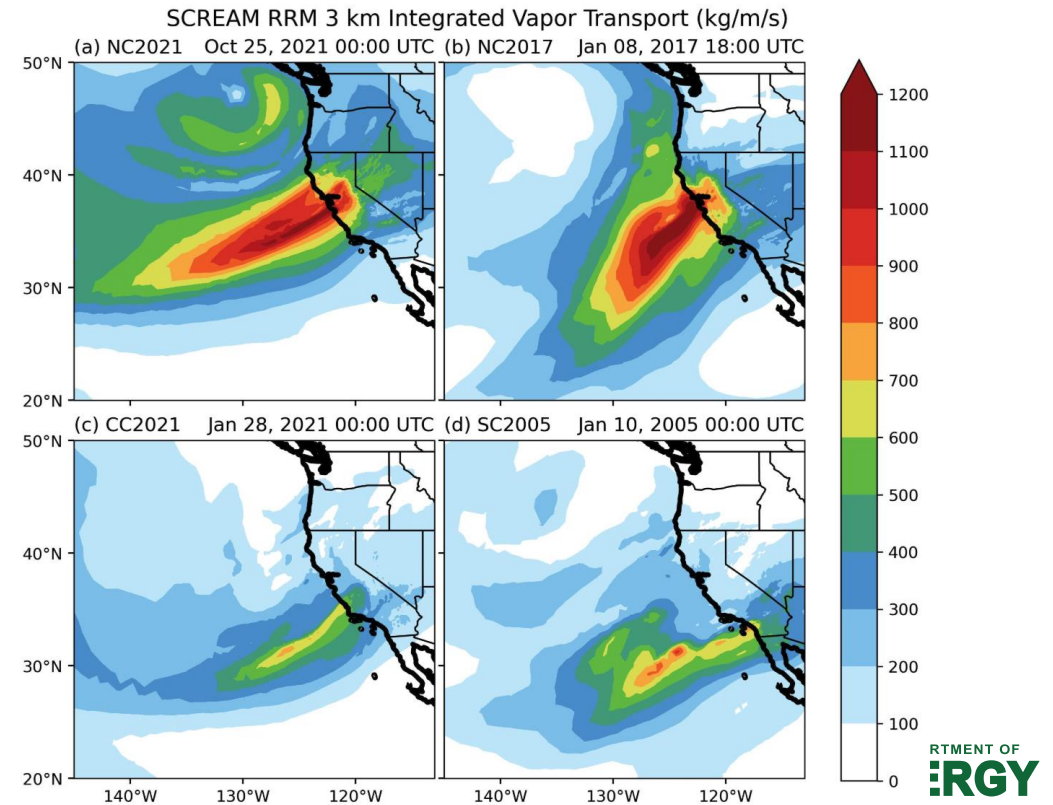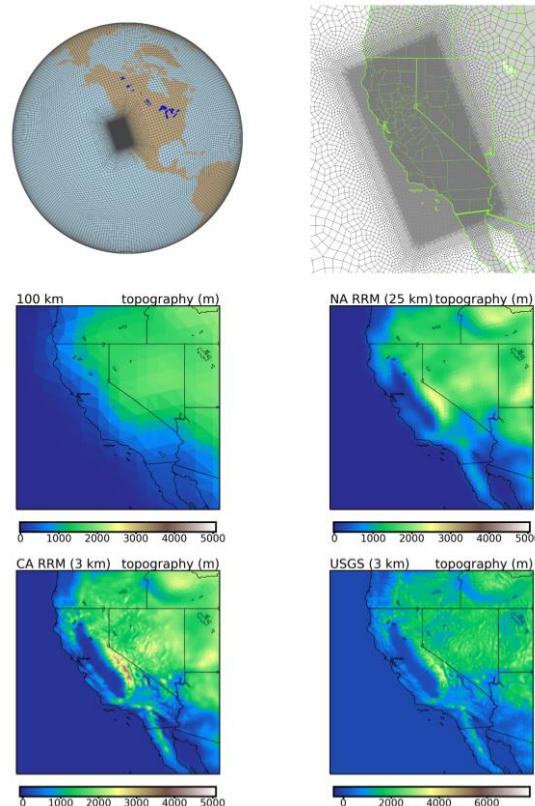
SCREAM RRM 3 km Integrated Vapor Transport (kg/m/s)

- Cross-scale parameterization
  - Some physical parameters are spatial & temporal resolution specific.

- Lack of benchmark observations to evaluate and help understand extreme simulations
  - E.g., wild-fire related pyrocumulonimbus…