Sandia National Laboratories

E3SM All Hands: Semi-Lagrangian Tracer Transport in the Atmosphere

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COMPOSE: Semi-Lagrangian Tracer Transport for E3SM

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- Problem: Tracer transport is expensive.
- Solution: Semi-Lagrangian (SL) transport. Long time steps; less communication.

- Problem: Transport requires property preservation, and SL makes that harder.
  - (mass conservation, shape preservation, tracer consistency, linear correlation preservation)
- Solution: CEDR: Property preservation in exactly 1 all-to-all reduction equivalent.[1]

- Opportunity: CEDR enables using the fastest, lowest-communication SL method there is: Interpolation SL (ISL) with compact stencil.

- Problem: ISL based on high-order compact stencil (GLL element, $n_p \geq 4$) is unstable.
- Solution: Stabilized ISL.

- Problem: HOMME's deterministic halo exchange is suboptimal for SL.
- Solution: ISL-specific optimal communication pattern.

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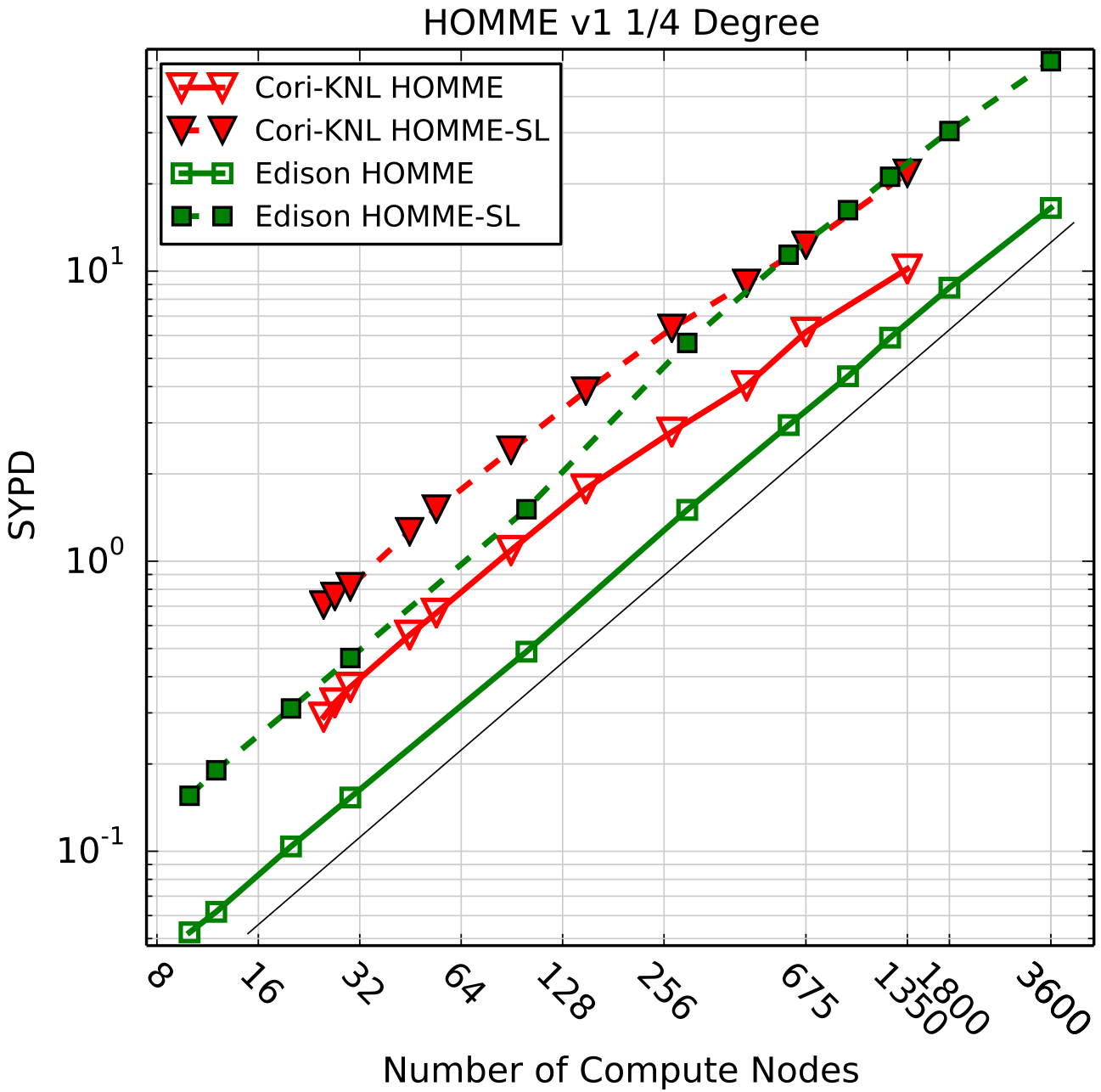
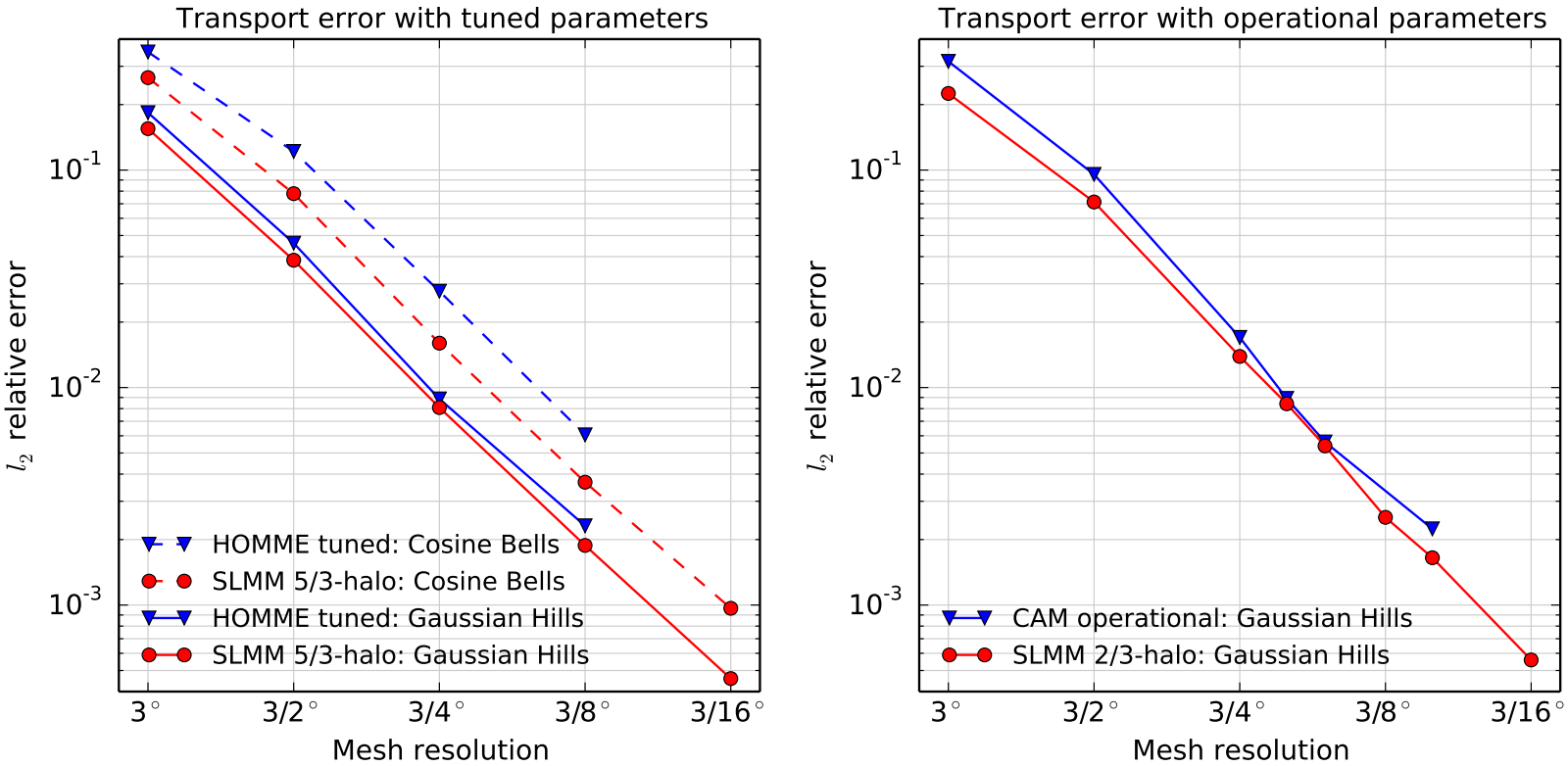
[1] A. M. Bradley, P. A. Bosler, O. Guba, M. A. Taylor, G. A. Barnett, *Communication-efficient property preservation in tracer transport*, to appear in SIAM J. Sci. Comp.
Software: `github.com/E3SM-Project/COMPOSE`

Strong scaling HOMME: Status for 40 tracers



- `preqx` dycore is $>$**2.1**$\times$ faster on KNL at 1350 nodes (strong-scaling limit).
- `preqx` dycore is $>$**3.2**$\times$ faster on Edison at 3600 nodes (strong-scaling limit).

Fidelity study[3]



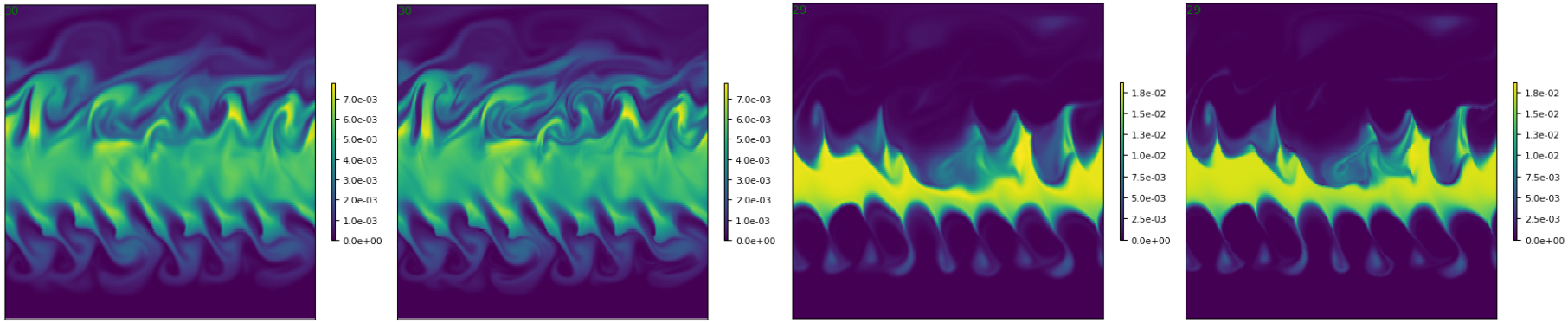
- Nondivergent flow test case.
- Compare (1) tuned parameters and (2) operational parameters, as in previous slide.
- SL transport is uniformly more accurate.
- For climate results, see Nov 2018 DOE Modeling PI Meeting poster[2].

[2] https://acme-climate.atlassian.net/wiki/spaces/CNCL/pages/840073634/E8.1+Semi-Lagrangian+tracer+transport+in+the+E3SM+atmospheric+dycore

[3] "HOMME tuned" data are from O. Guba, et al, *Optimization-based limiters for the spectral element method*, JCP 2014. "CAM operational" data are from P. H. Lauritzen, et al. "Geoscientific Model Development A standard test case suite for two-dimensional linear transport on the sphere: results from a collection of state-of-the-art schemes." GMD 7(1) 2013.

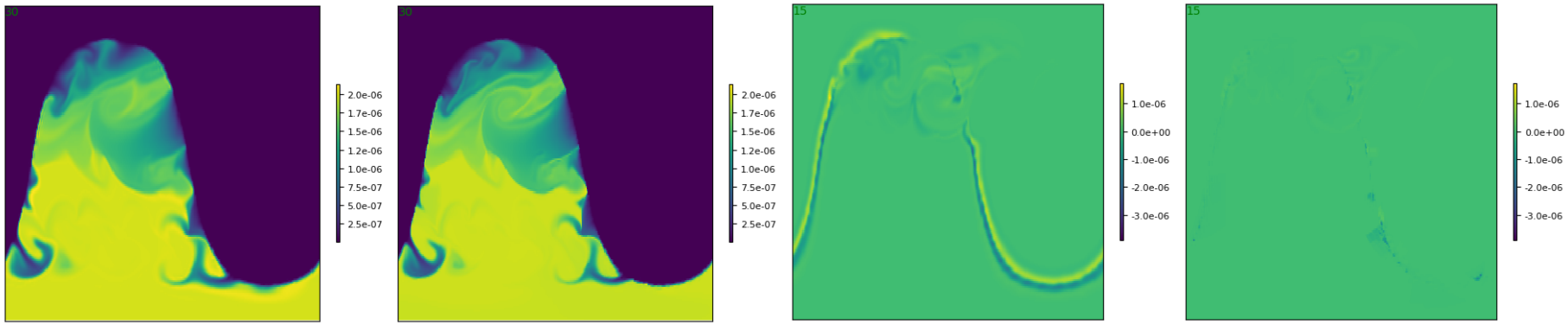
Resolution: DCMIP2016 Baroclinic Instability

- Configuration: `theta-l`, nonhydrostatic mode, moist, `ne` = 30, `tstep` = 300, `rsplit`×`qsplit` = 6
- Eulerian at left; SL at right



(a) q_v, level 20, day 30

(b) q_v, level 30, day 29



(c) Toy chemistry tracer, level 30, day 30

(d) Toy chemistry diagnostic, level 30, day 15