Comparison of Adaptive and Uniform 2D Galerkin Simulations

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overview

- Motivation
- Results: what do we gain by using AMR?
- Next steps

NUMA

Non-hydrostatic Unified Model of the Atmosphere

- **dynamical core** inside the Navy's next generation weather prediction system NEPTUNE
- **unified across numerics** (contains Continuous and Discontinuous Galerkin methods)
- **unified across applications** (regional and global modeling)
- 3D, DG, MPI: **strong scaling** for explicit time integration (tested up to 32000 CPUs)
- 2D, serial: allows **dynamic AMR**

NUMA
Collaborators

Numerical Methods and Moisture
Francis X. Giraldo, Applied Math, NPS
Michal Kopera, Applied Math, NPS
Andreas Müller, Applied Math, NPS
Simone Marras, Applied Math, NPS

Physical Parameterization and Databases
Jim Doyle, NRL-Monterey
Saša Gaberšek, NRL-Monterey
Kevin Viner, NRL-Monterey
Alex Reinecke, NRL-Monterey
Eric Hendricks, NRL-Monterey

Time-Integrators and PETSc Interface
Emil Constantinescu, ANL
Debo Ghosh, ANL

Preconditioners and Iterative Solvers
Carlos Borges, Applied Math, NPS
Les Carr, Applied Math, NPS

Riemann Solvers and Limiters
Dale Durran, University of Washington
Maria Lukacova, University of Mainz

Many-Core Implementation
Andreas Klöckner, Computer Science, UIUC
Lucas Wilcox, Applied Math, NPS
Tim Warburton, CAAM, Rice University
Dave Norton, NVIDIA
Daniel Abdi (soon to be) Applied Math, NPS

ESMF Interface
Tim Campbell, NRL-Stennis
Tim Whitcomb, NRL-Monterey

Data Structures Optimization
Michael Bader, Computer Science, TUM
Kaveh Rahnema, Computer Science, TUM
Alex Breuer, Computer Science, TUM

Goal

methods

- dynamic AMR, uniform meshes
- high order, low order

applications

- cloud simulations
- Hurricane simulations

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- high order, low order

applications

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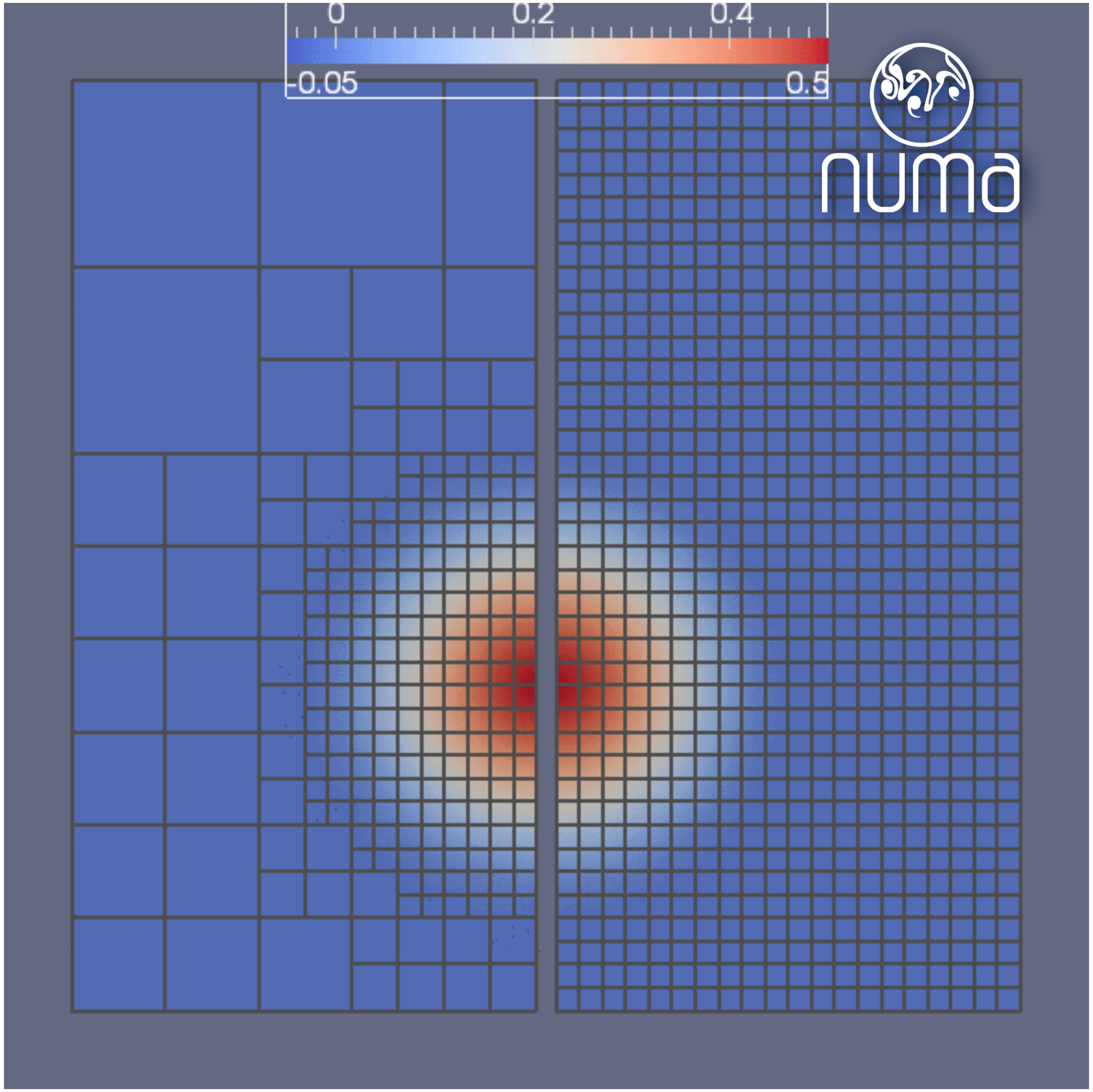
For which of these applications should we use these methods and how should we use them?

Motivation

Warm air bubble test case with $\mu = 0.1 m^2/s$



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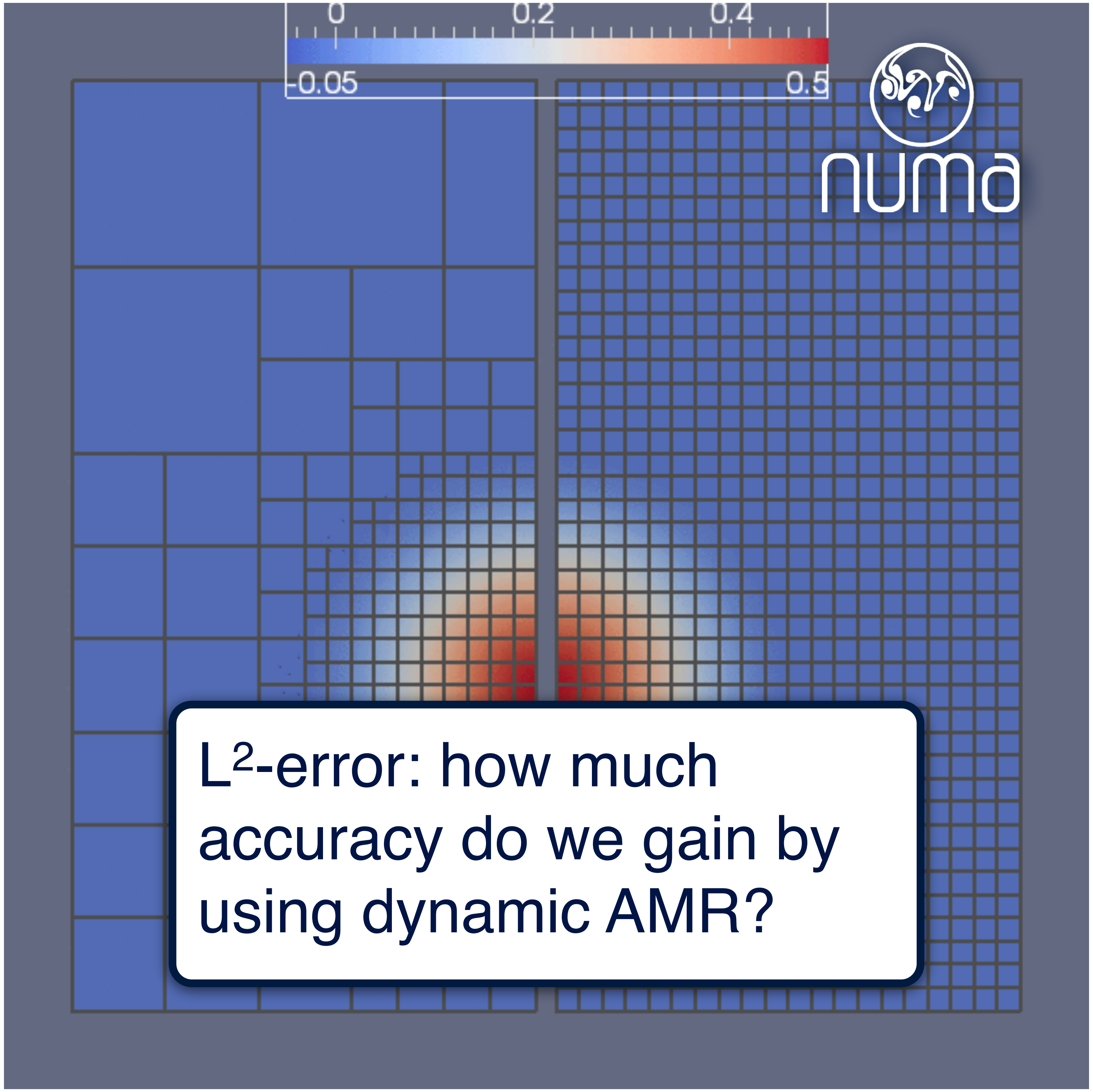

L²-error: how much accuracy do we gain by using dynamic AMR?

Questions for Today

Warm air bubble test case with $\mu = 0.1 m^2/s$ at $t = 700s$

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L^2-error: how much accuracy do we gain by using dynamic AMR?

Results:

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1. L^2-error: how much accuracy do we gain by using dynamic AMR?

2. How does the benefit of AMR depend on the initial condition?

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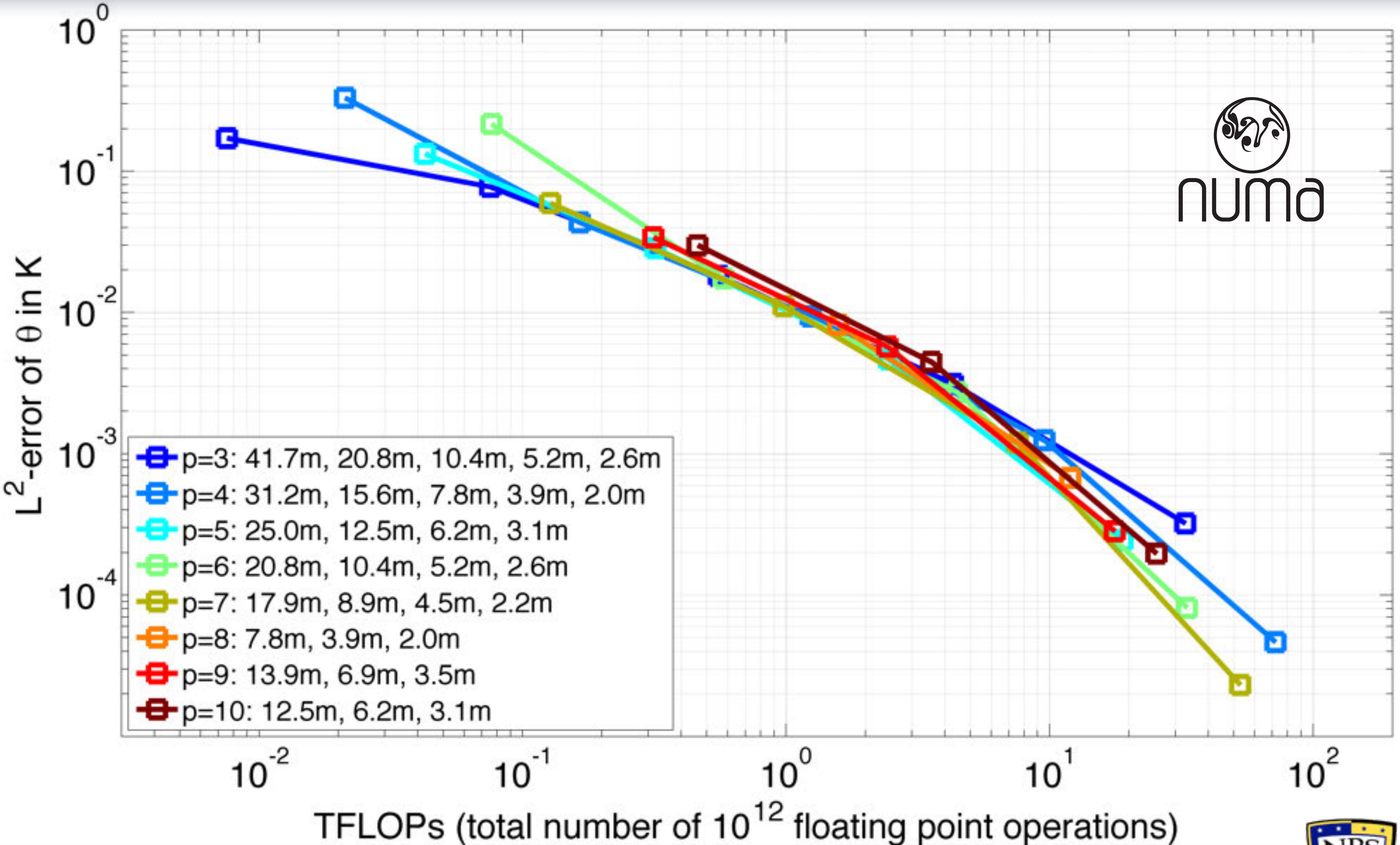
3. What is the benefit for the error of max(θ)?

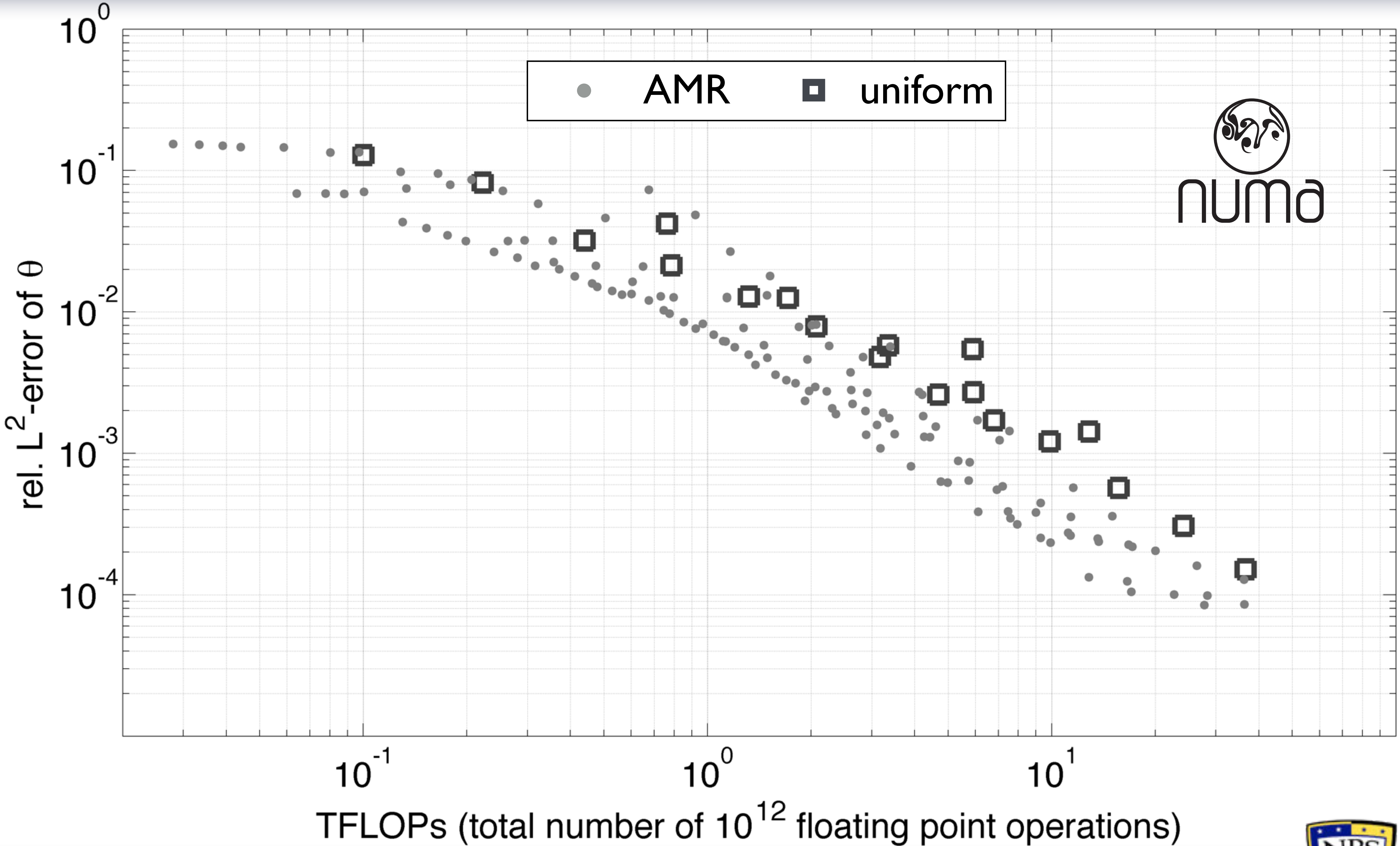
L^2-error of uniform simulations

as a function of number of floating point operations



L^2-error of AMR simulations

as a function of number of floating point operations



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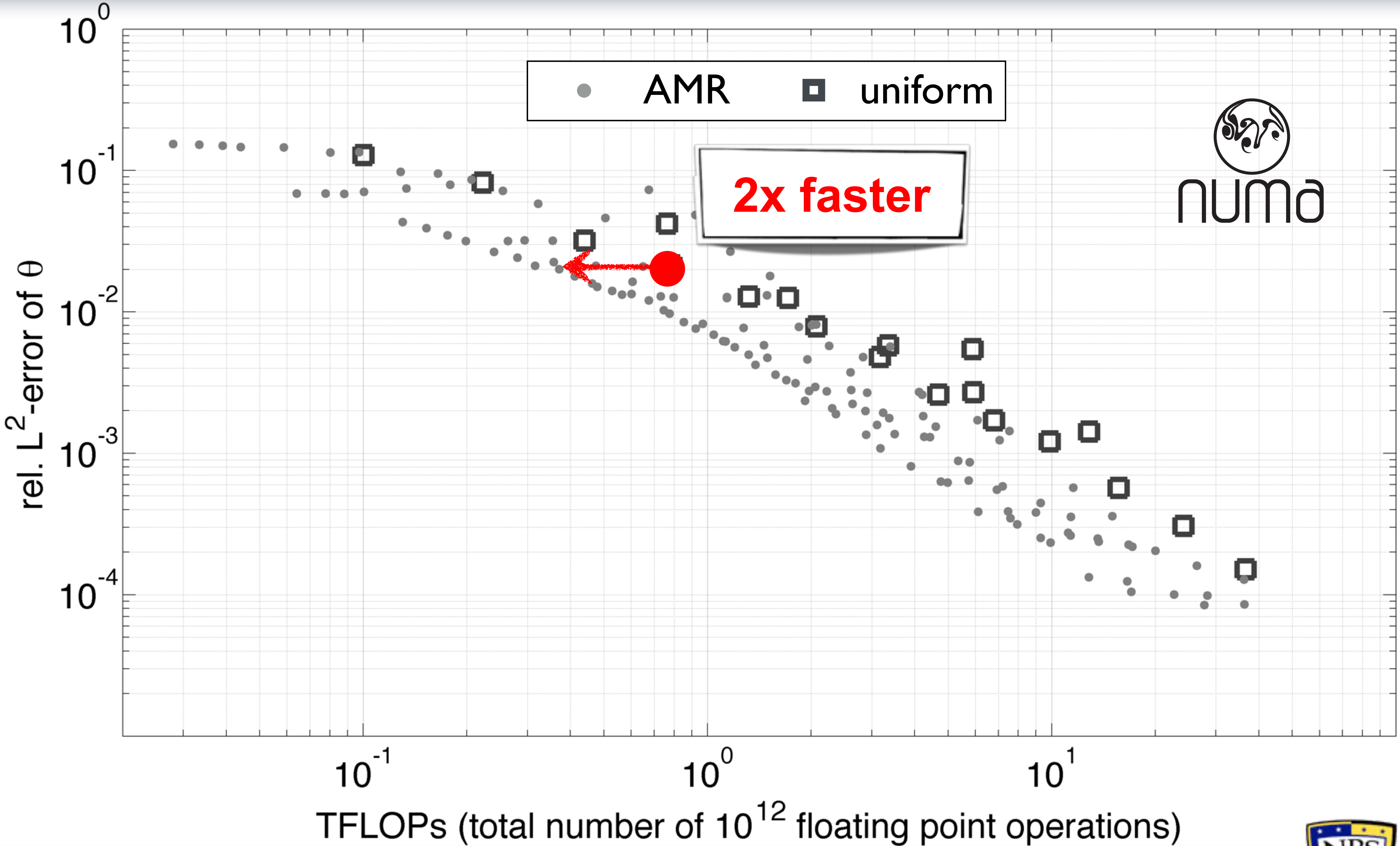
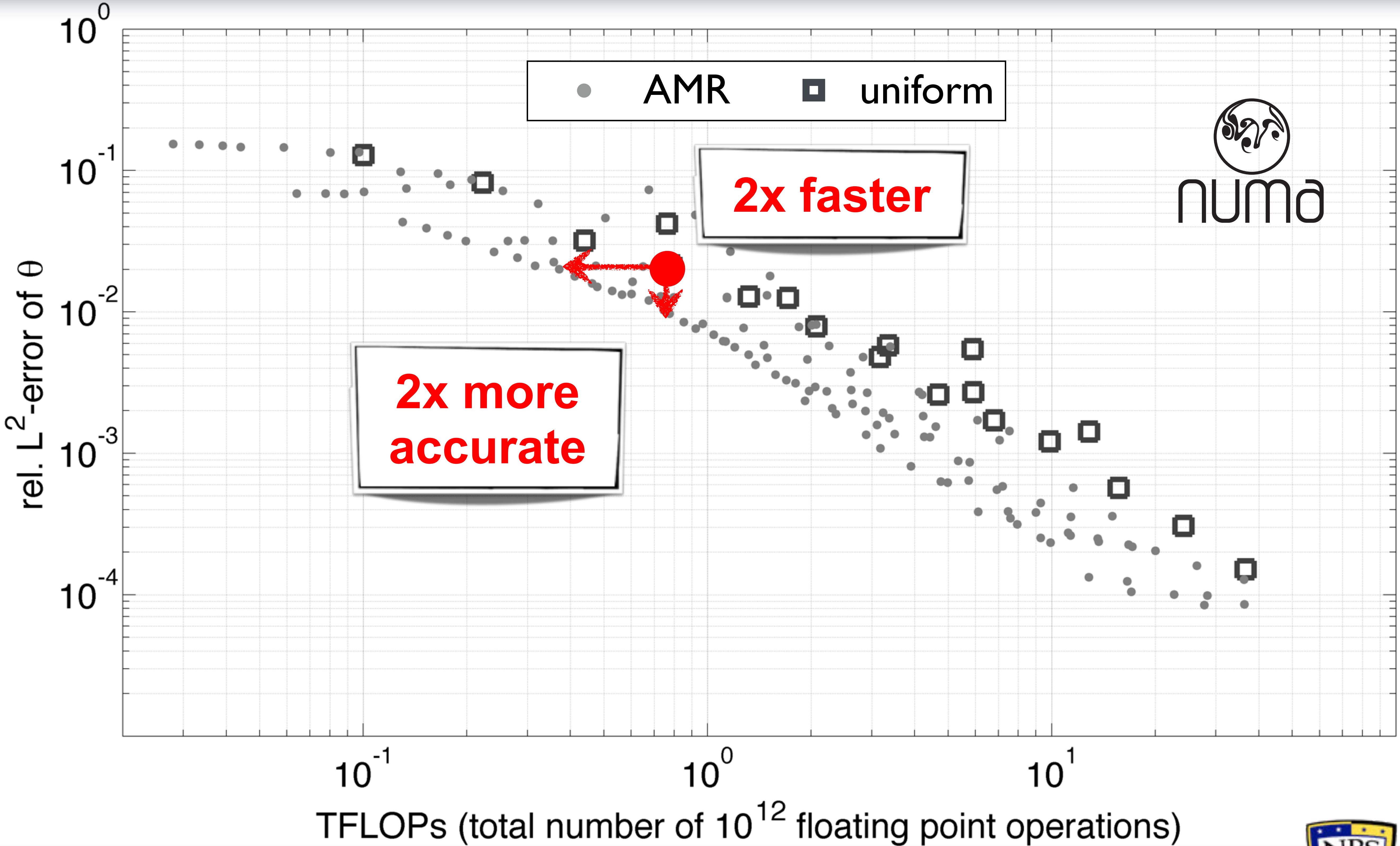


L^2-error of AMR simulations

as a function of number of floating point operations



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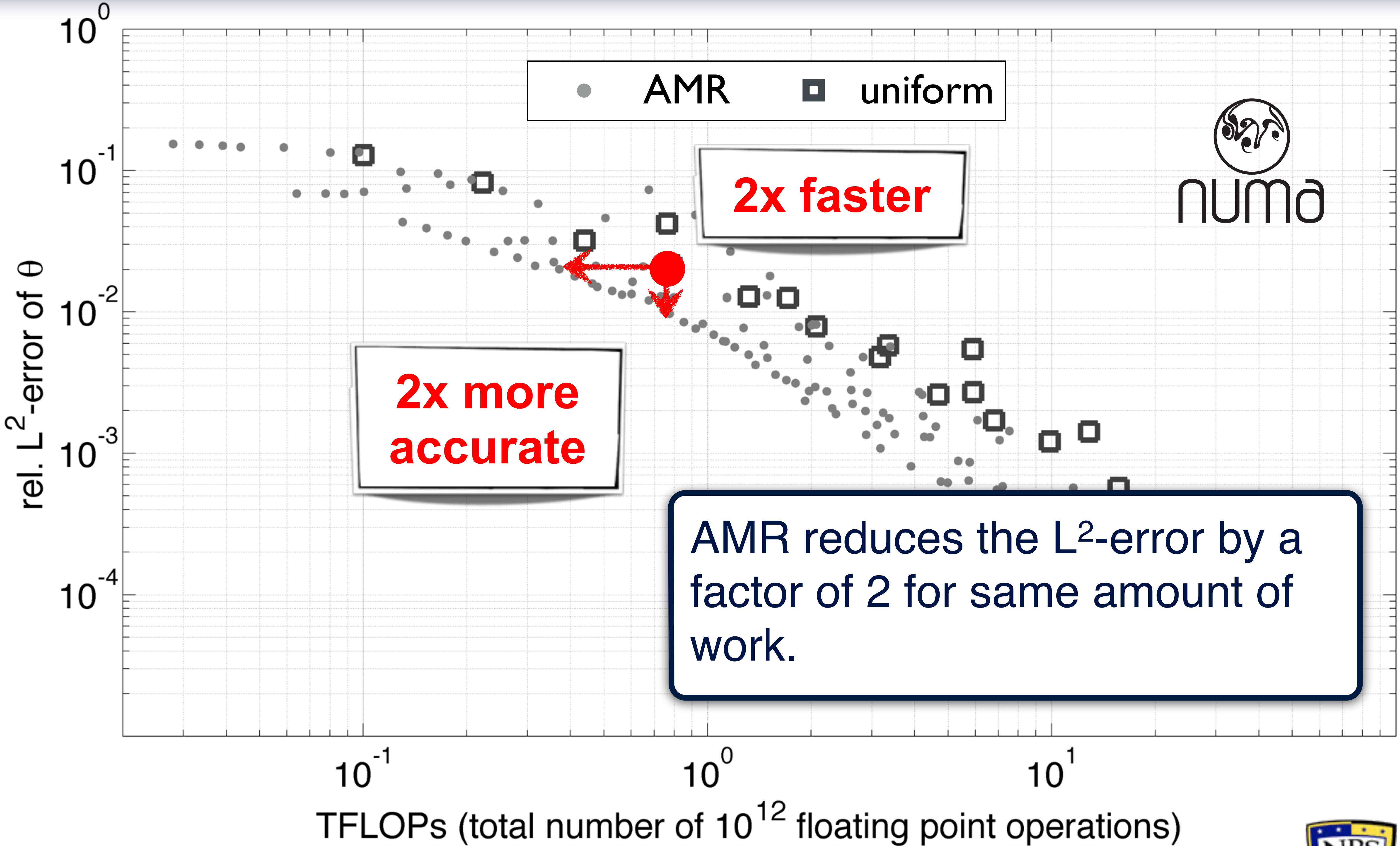

AMR reduces the L^2-error by a factor of 2 for same amount of work.

Questions for Today

Warm air bubble test case with $\mu = 0.1 m^2/s$ at $t = 700s$

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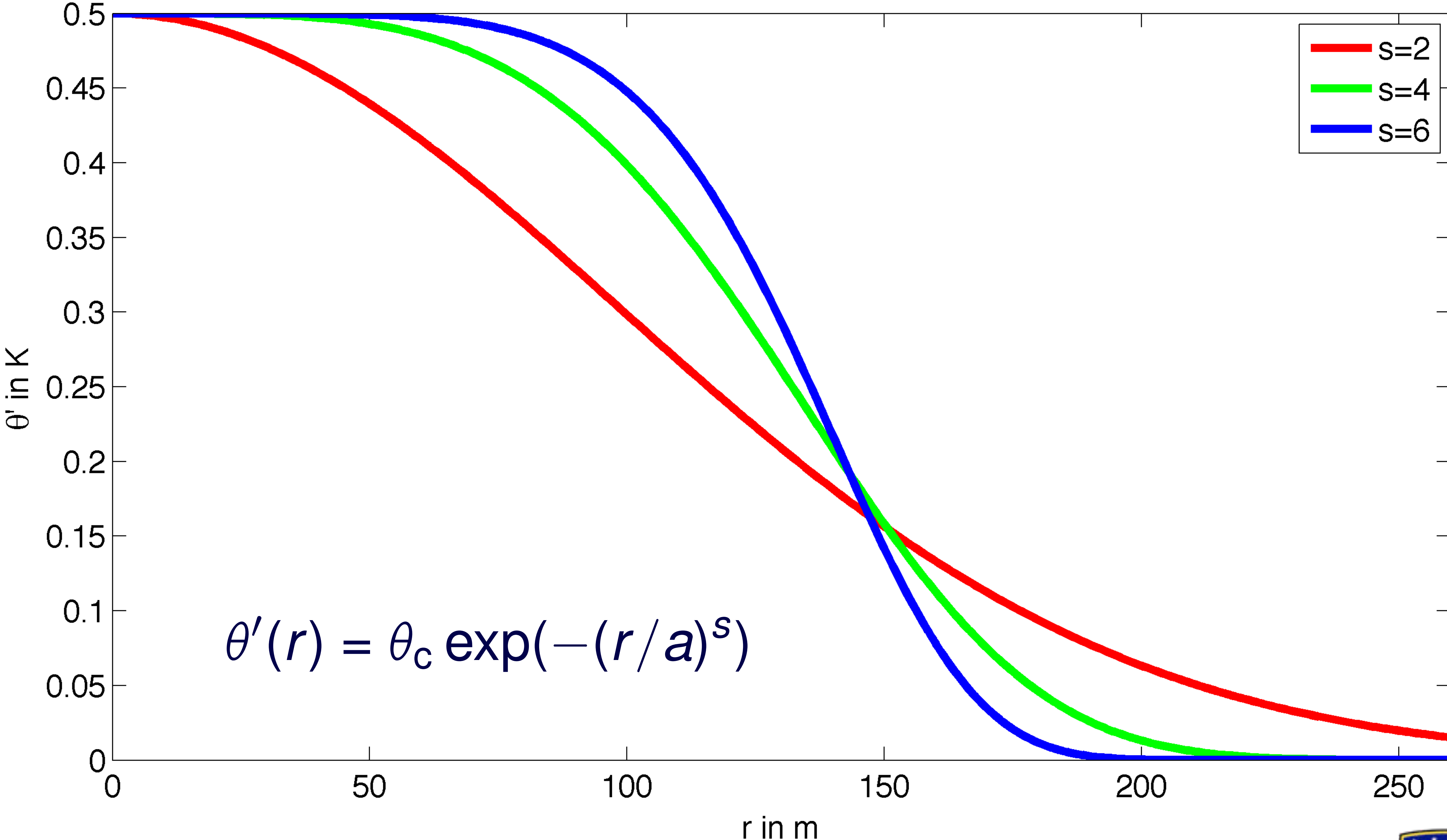
Three different initial profiles for θ'

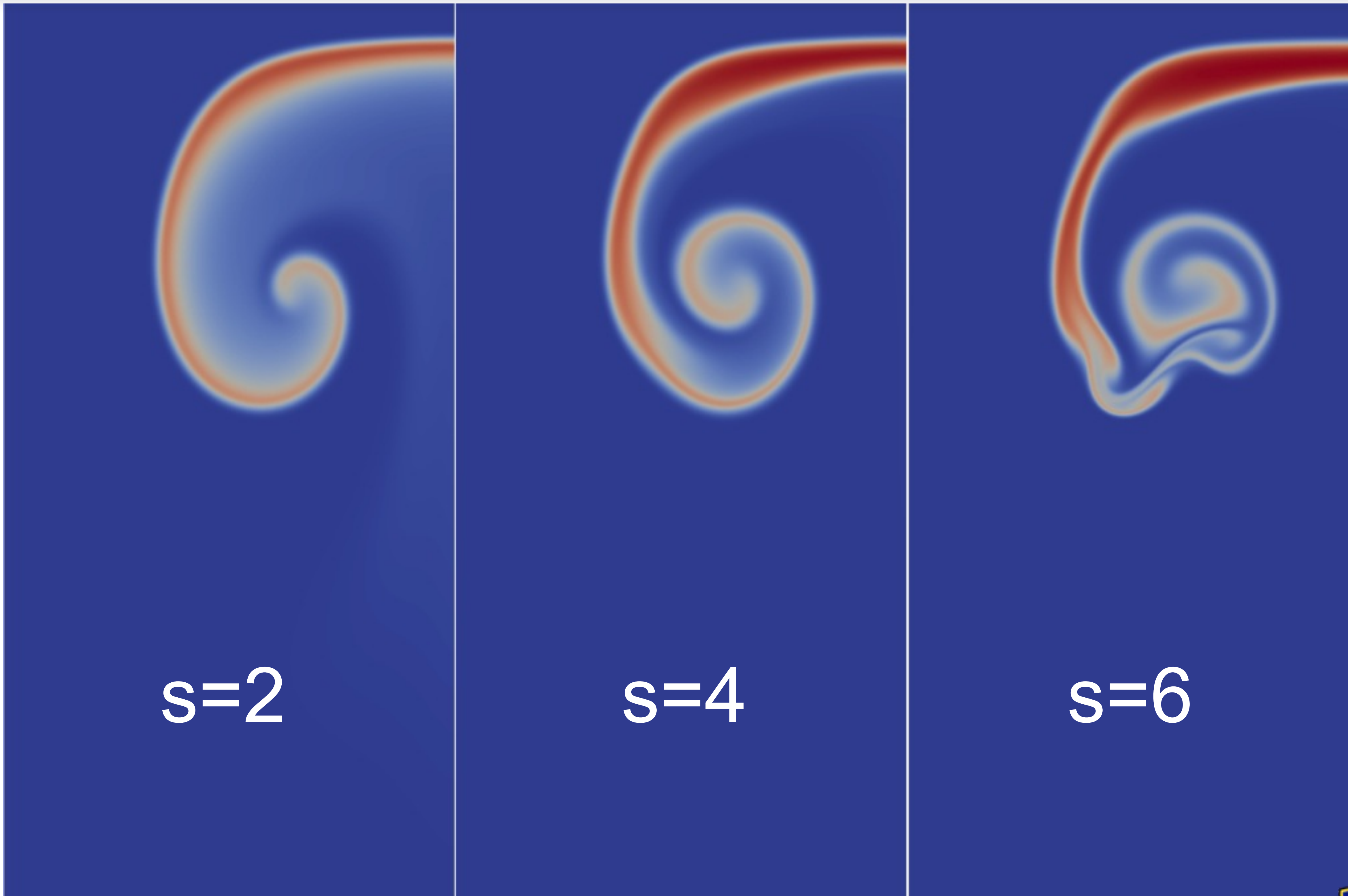
as a function of distance from the center of the bubble *r*



$$\theta'(r) = \theta_c \exp(-(r/a)^s)$$

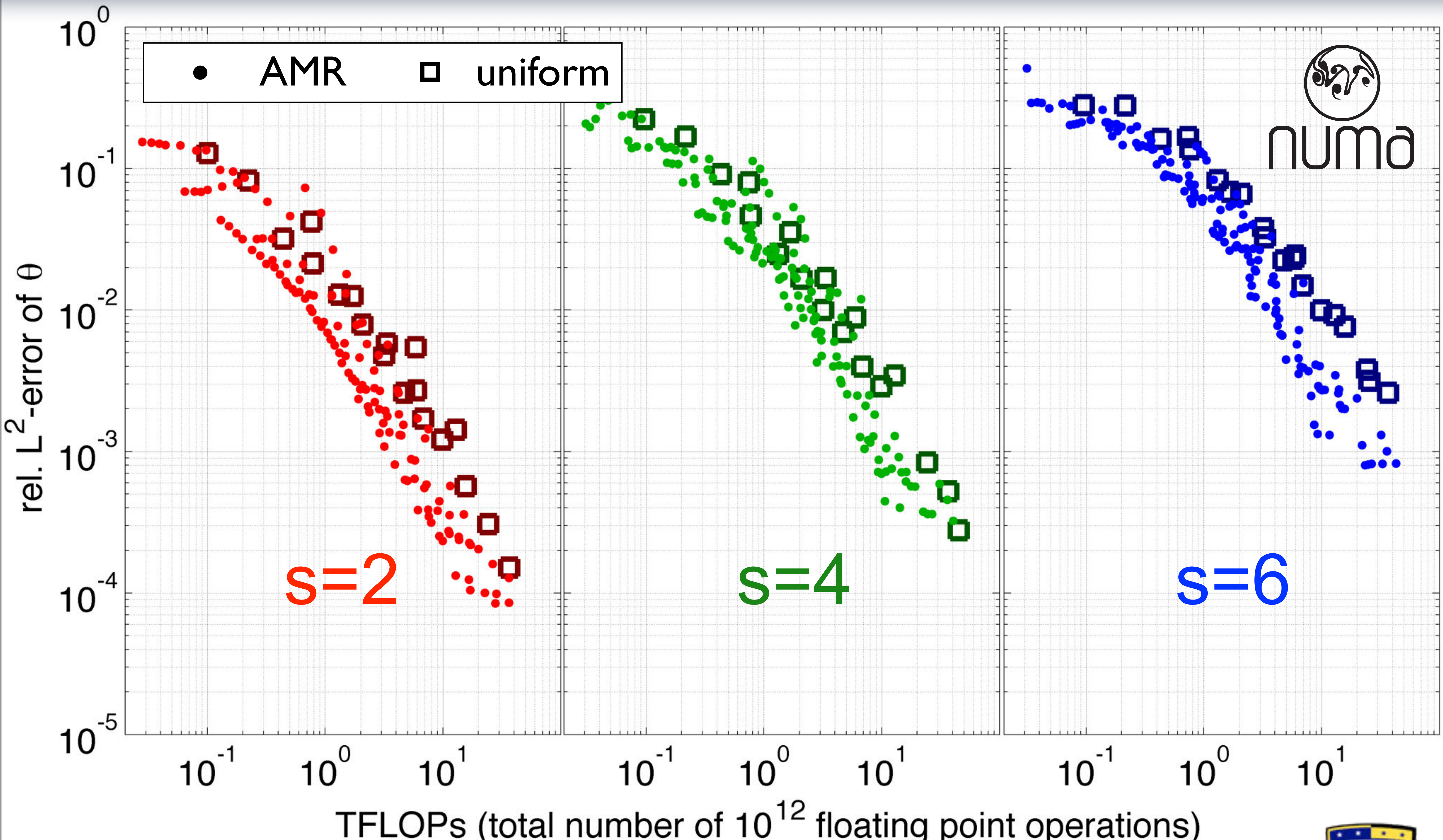
Reference result for modified bubbles

resolution *Δx* = 40cm, time t=700s



L^2-error for 3 different initial conditions

viscosity: μ=0.1m²/s



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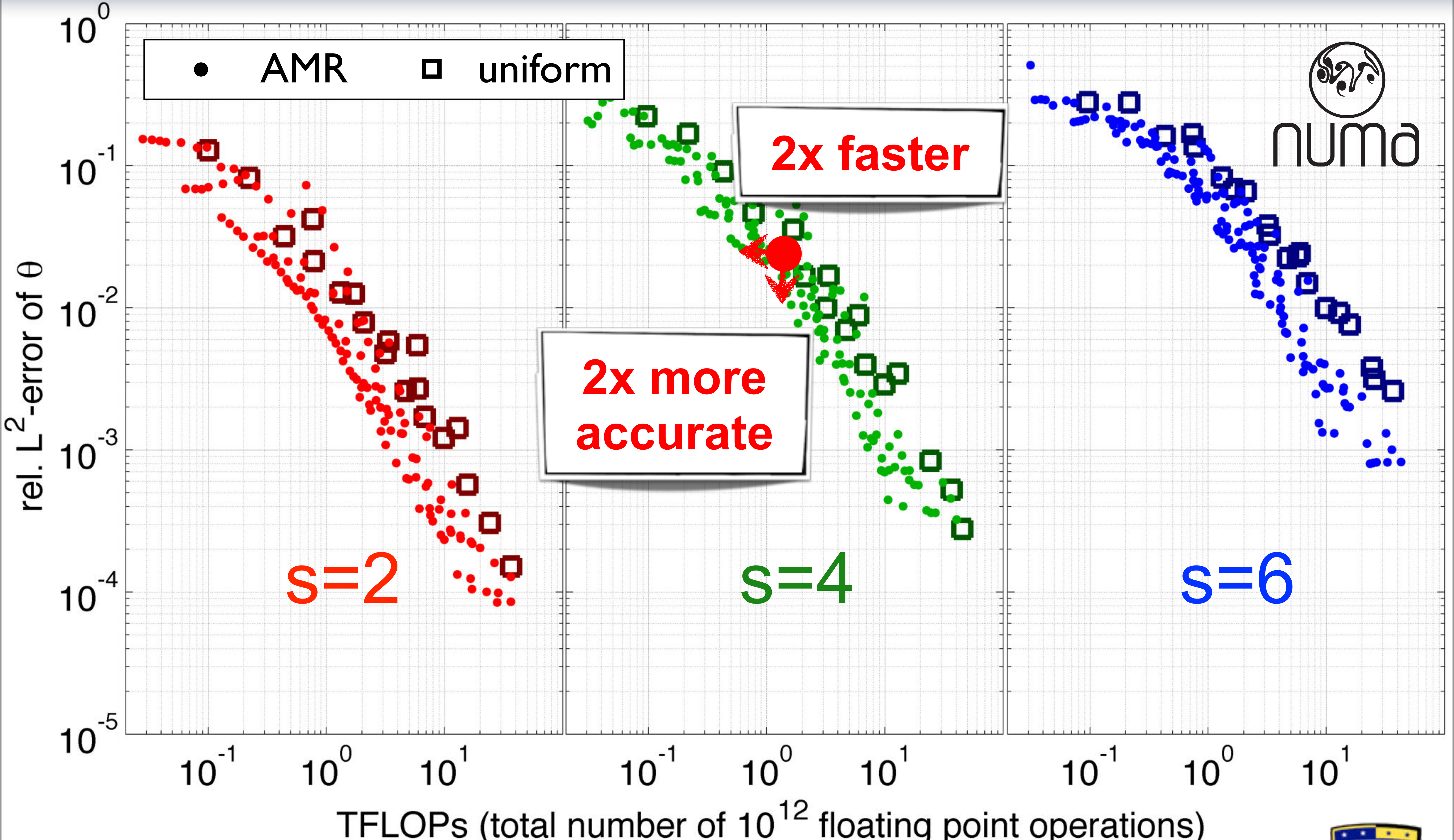

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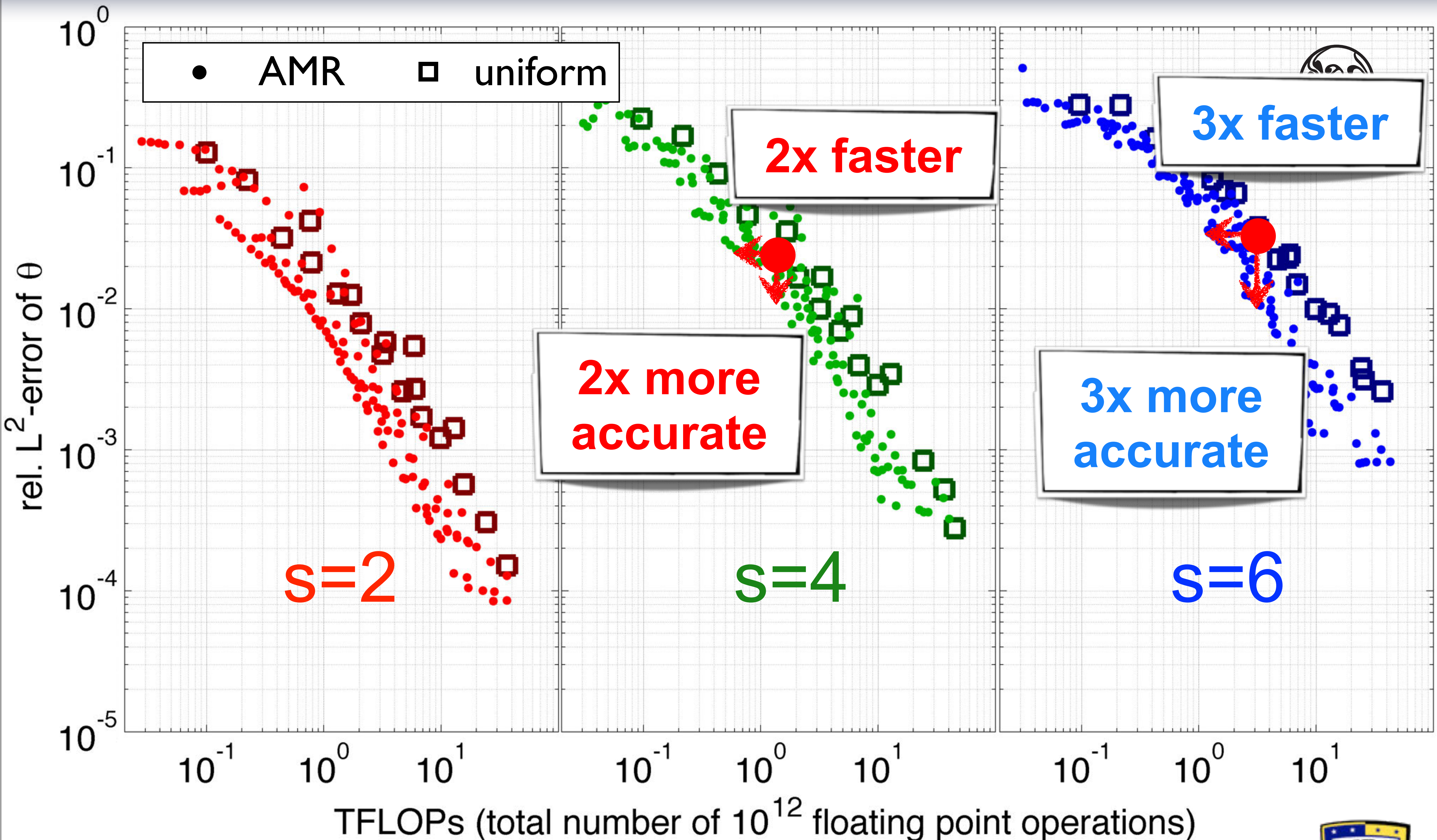

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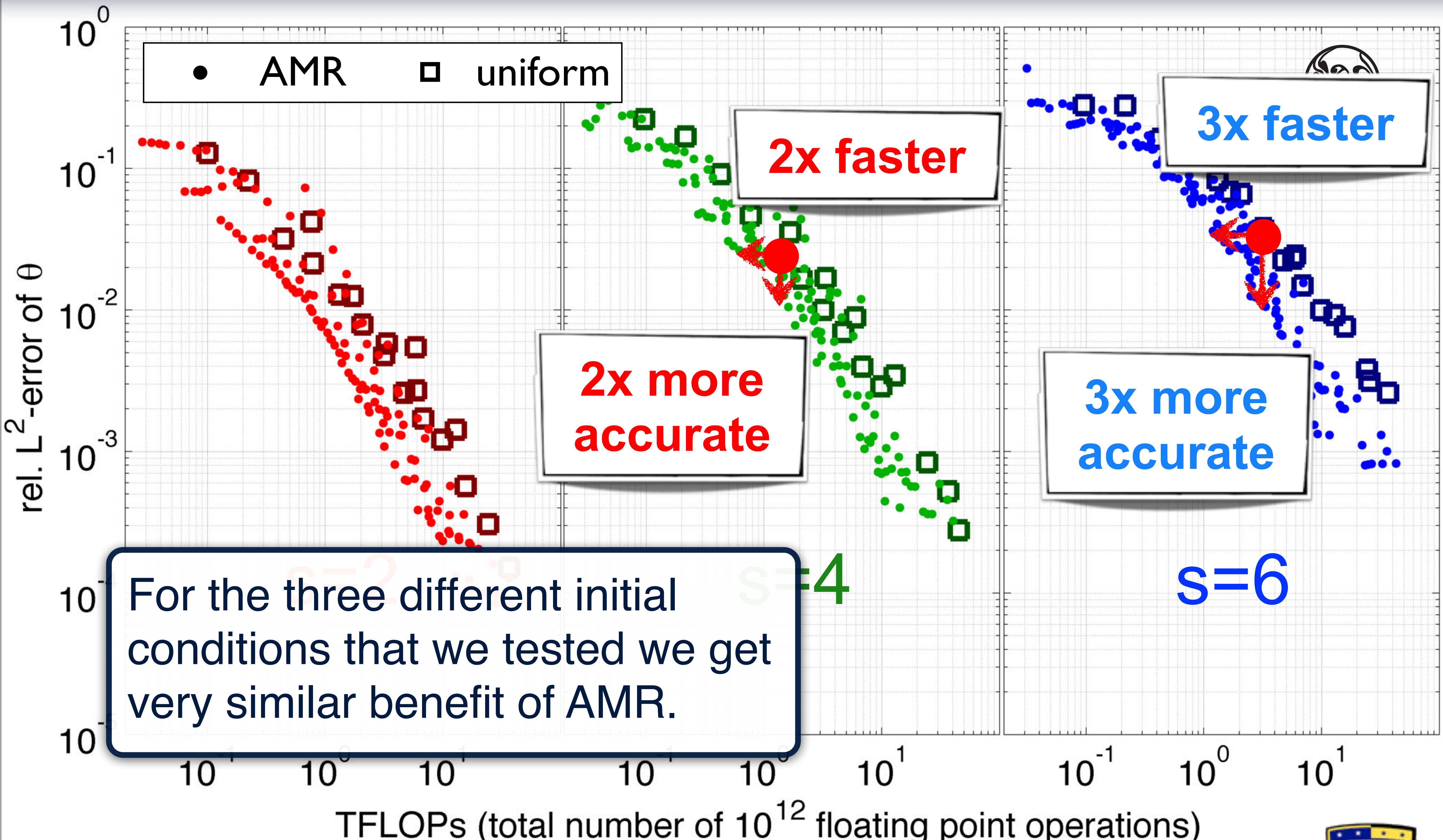


For the three different initial conditions that we tested we get very similar benefit of AMR.

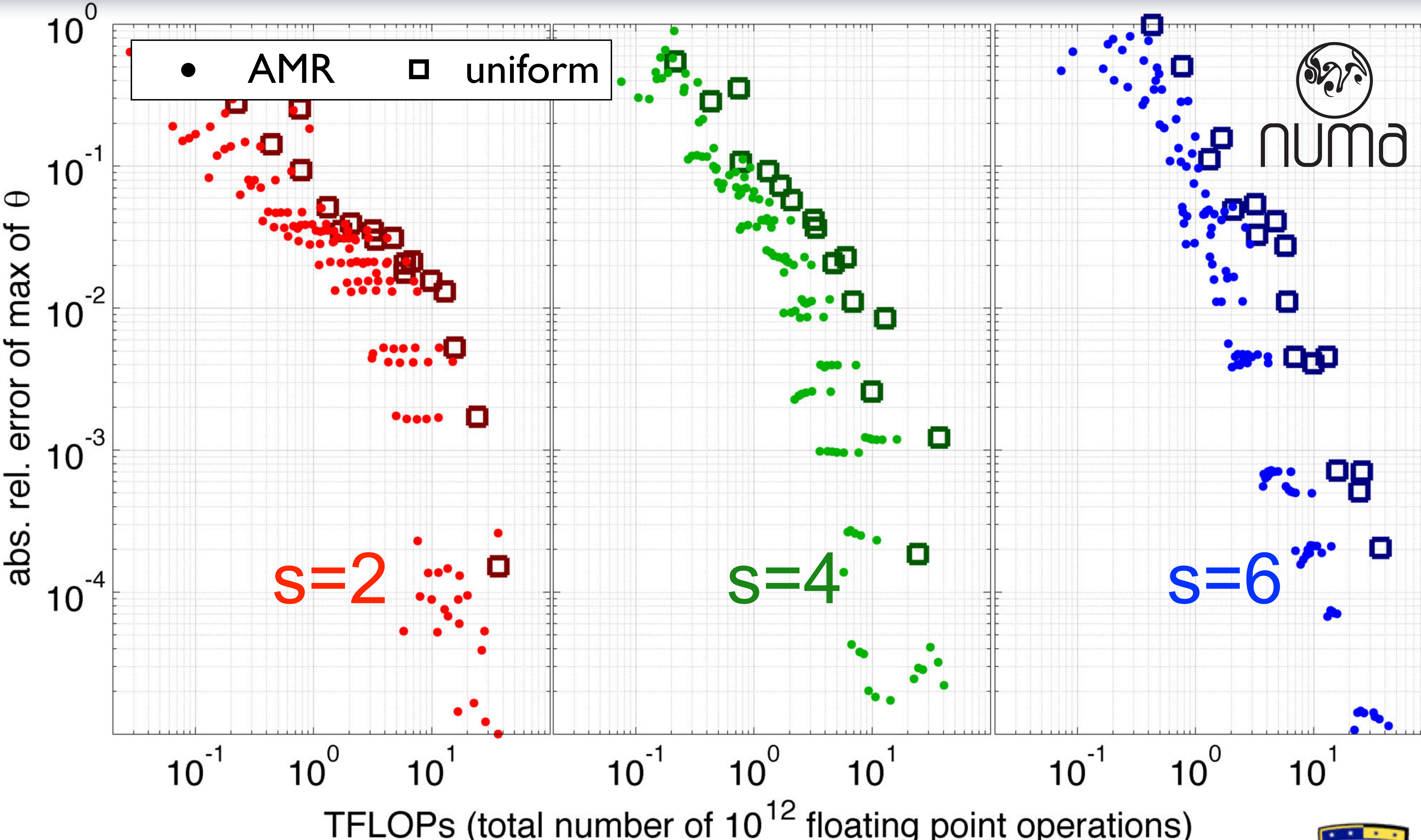
Questions for Today

Warm air bubble test case with $\mu = 0.1 m^2/s$ at $t = 700s$

Questions:	**Results**:
1. L^2-error: how much accuracy do we gain by using dynamic AMR?	AMR reduces the L^2-error by a factor of 2 for same amount of work.
2. How does the benefit of AMR depend on the initial condition?	For the three different initial conditions that we tested we get very similar benefit of AMR.
3. What is the benefit for the error of max(θ)?	

absolute relative error of max(θ)

viscosity: μ=0.1m^2/s



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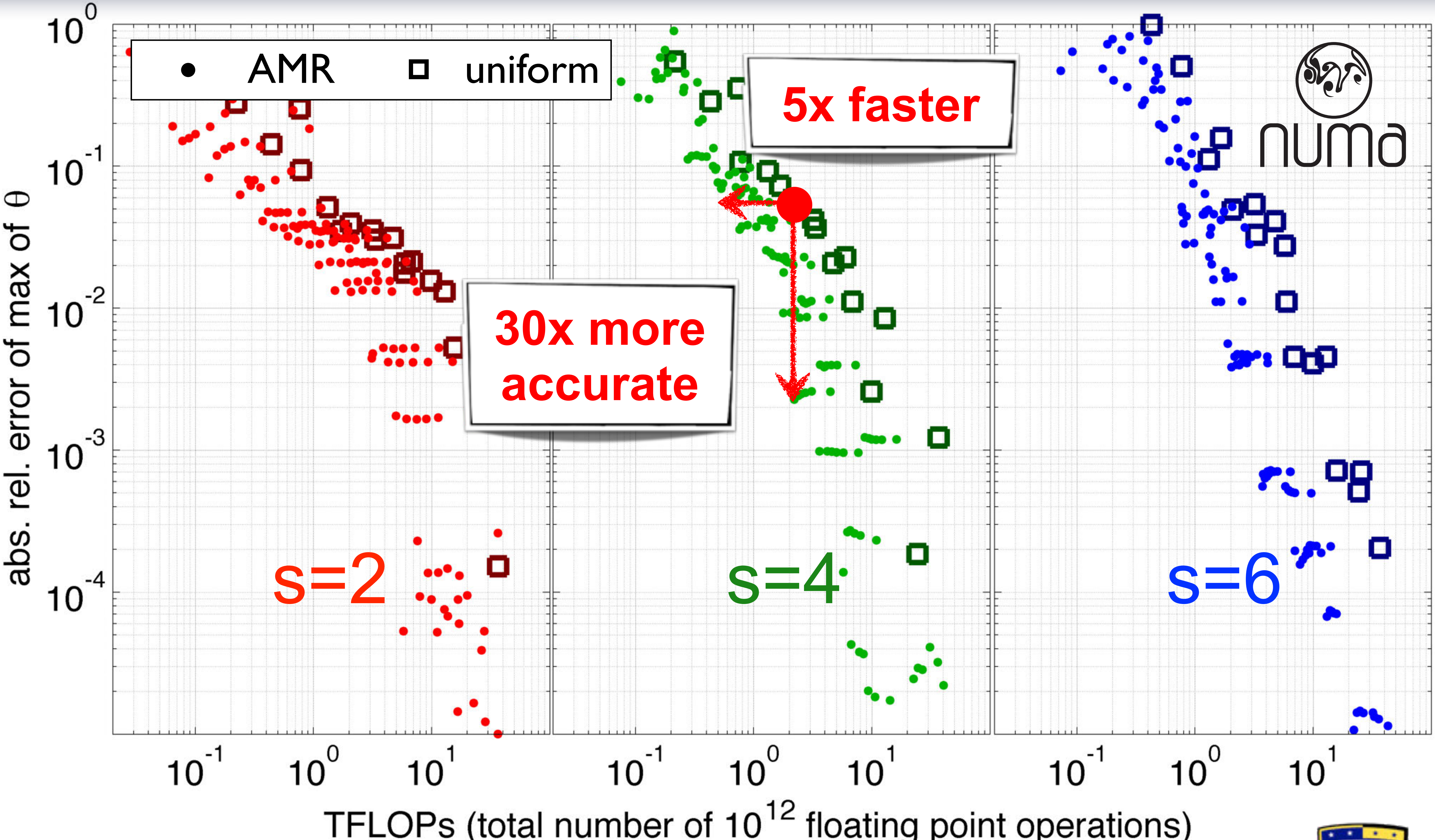

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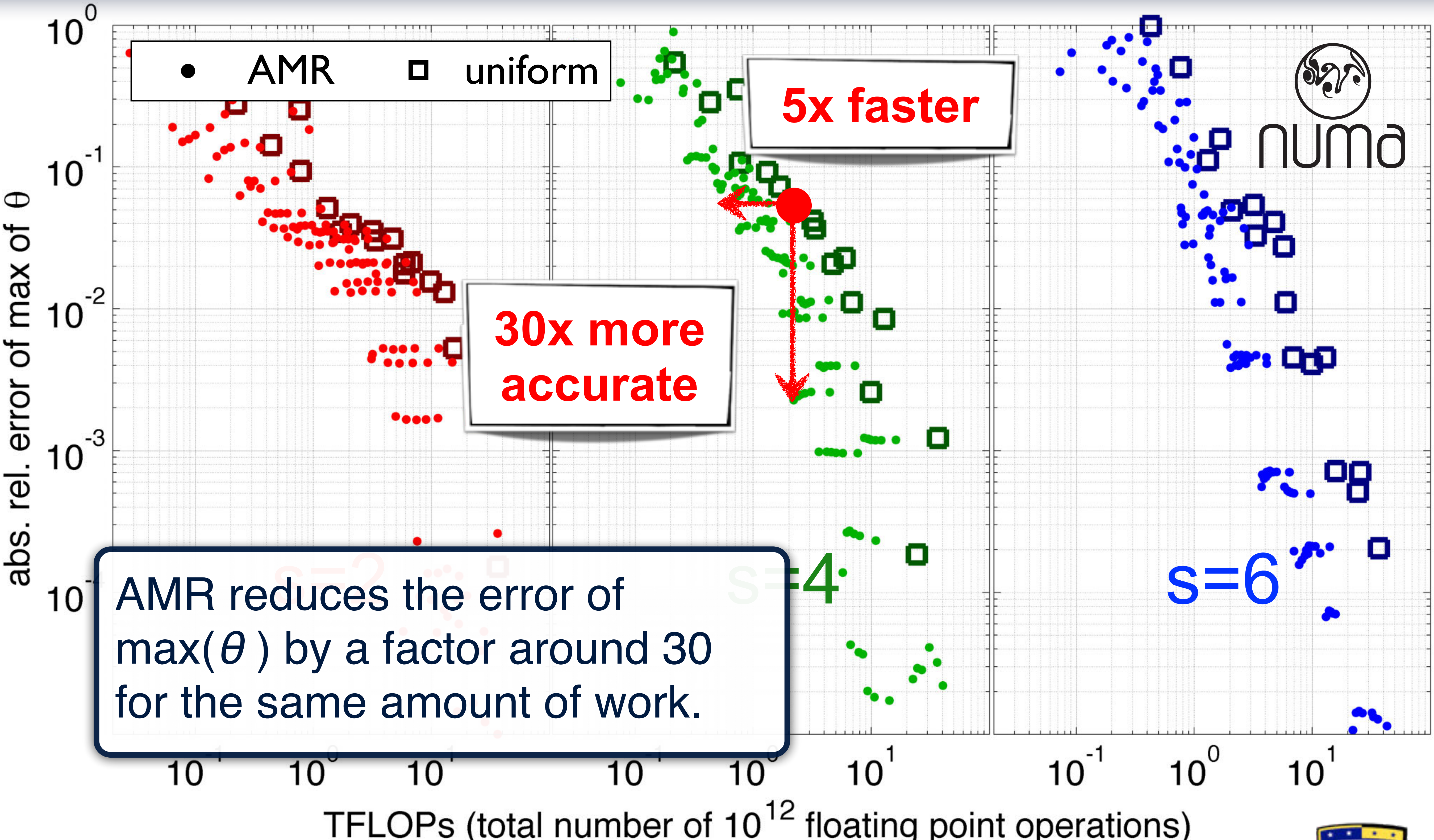

AMR reduces the error of max(θ) by a factor around 30 for the same amount of work.

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Next steps: 1. different refinement criteria (gradient, ...), 2. include moisture, 3. run comparison in 3D

NPS
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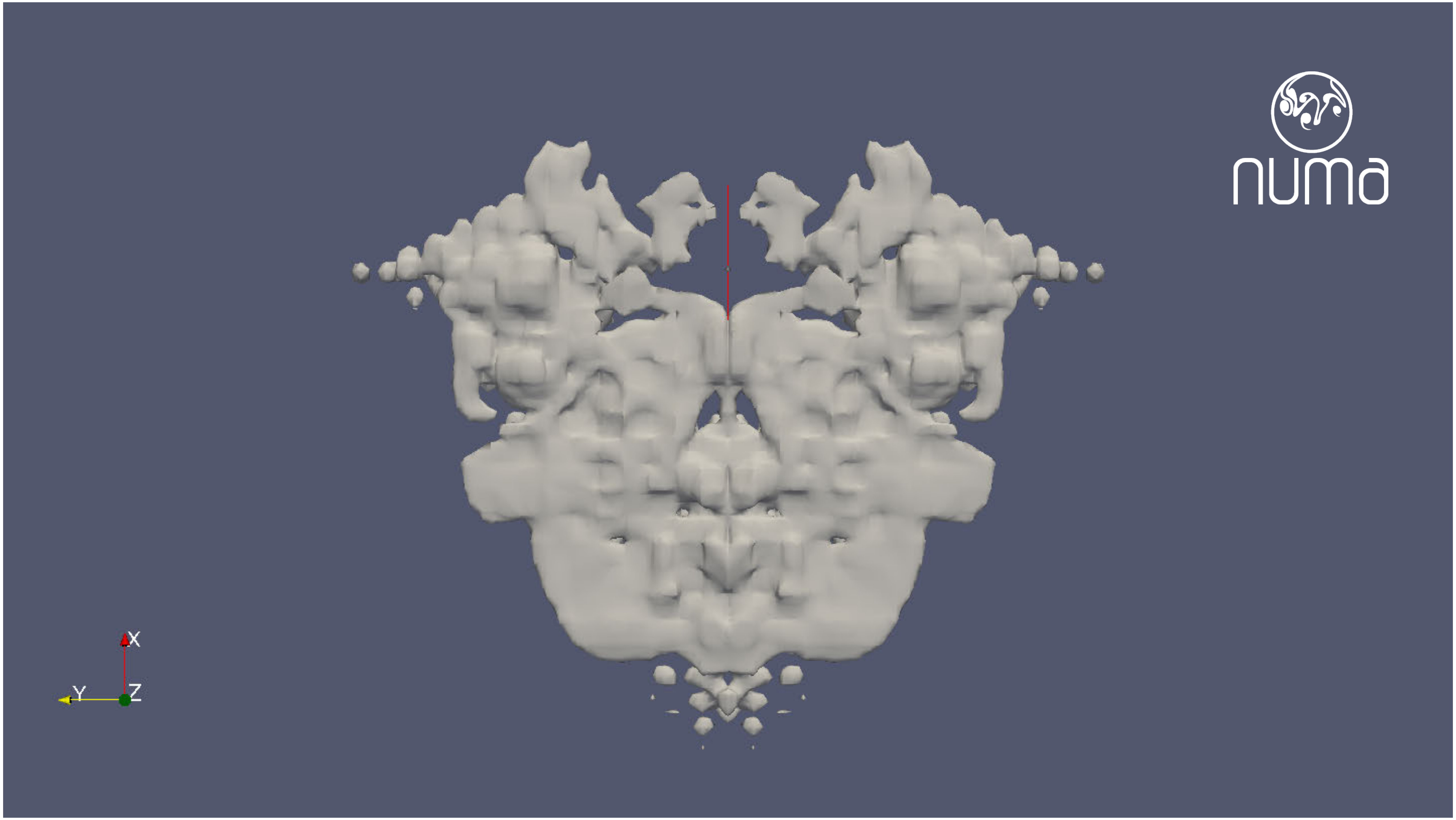
Squall line simulation with NUMA

isosurface of cloud water content q_c=0.0035 at t=7500s



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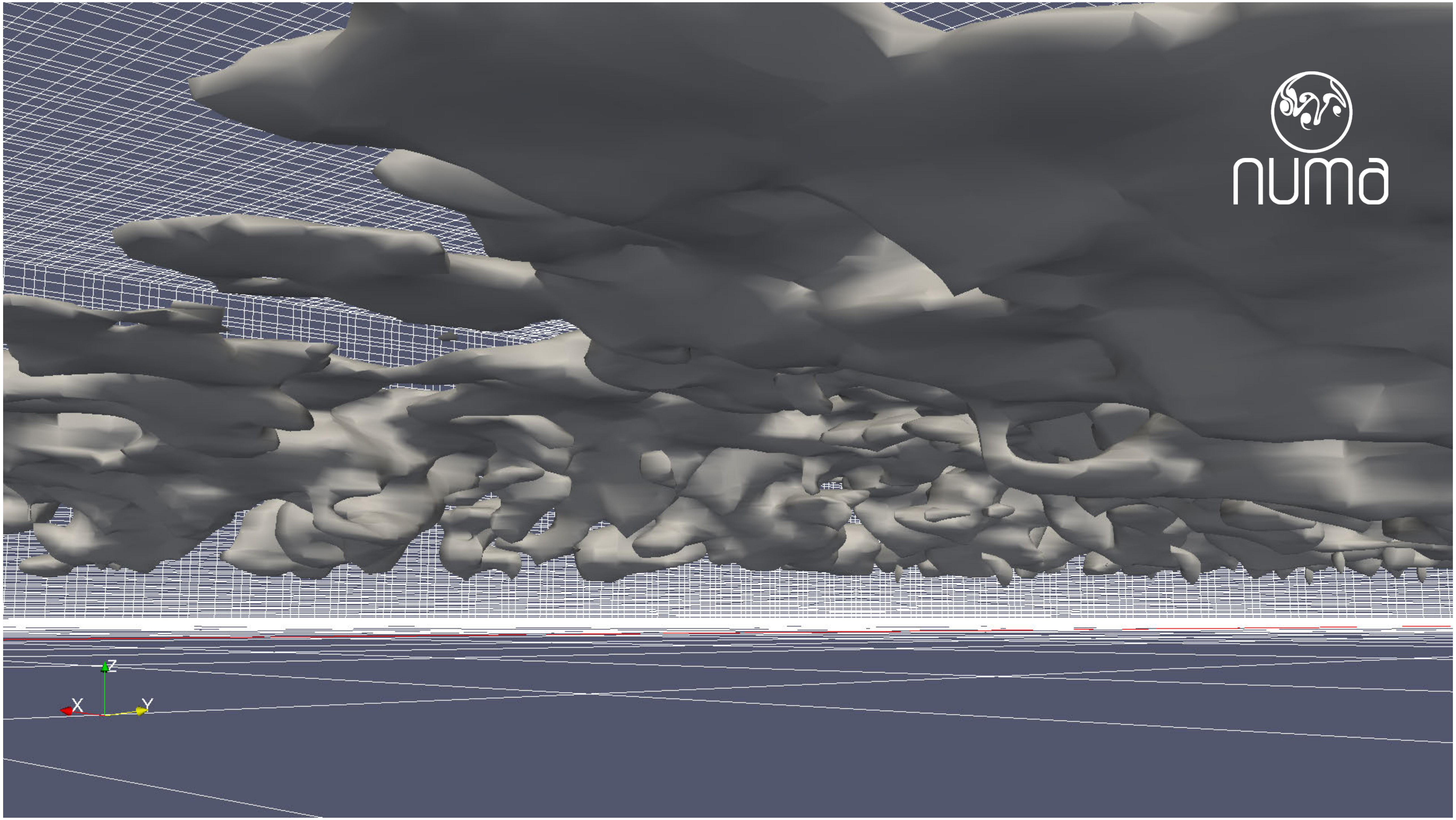

Squall line simulation with NUMA

visualization with Maya® (see http://anmr.de for instructions)

Thank you for your attention!