Simulation of Shallow Water Flows Using HPX

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2019 DOE CSGF Annual Program Review
Arlington, VA
July 15, 2019

The University of Texas at Austin
Oden Institute for Computational
Engineering and Sciences

Figure: The four horsemen of the apocalypse; Starvation, Latency, Overheads, and Waiting on contention resolution. (Peter von Cornelius, 1845).

STELLAR HPX

The Runtime Solution

- Managing less synchronized parallelism very burdensome.
- Users should rely on a level of middle-ware to ensure efficient compute utilization.
- Other runtimes: Legion, Charm++, ParSec, X10, Habanero, Darma, Unitah, (Crest) HPX

Stellar HPX

- Large international group of developers (LSU, FAU, CSCS)
- Written in modern C++ (350k LOC)
- Has scaled to full Cori runs with 96.8% parallel efficiency.

Case Study: Hurricanes

Simulation of Hurricane Storm Surge

Motivation

- Hurricane simulation plays a key role in coordinating evacuation efforts.
- The STORM project aims to port this application to a task-based programming model (HPX).
- Collaborators include: UT Austin, LSU, Notre Dame, UNC Chapel Hill, Sea Horse Coastal Consulting and others.

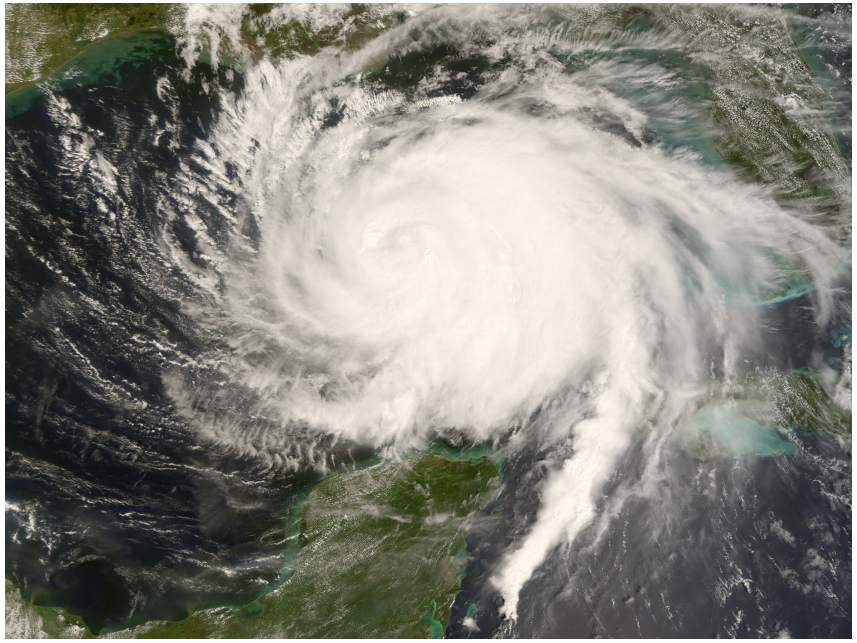


Figure: NASA image created by Jesse Allen, using data provided courtesy of the MODIS Rapid Response team.

Simulation of Hurricane Storm Surge

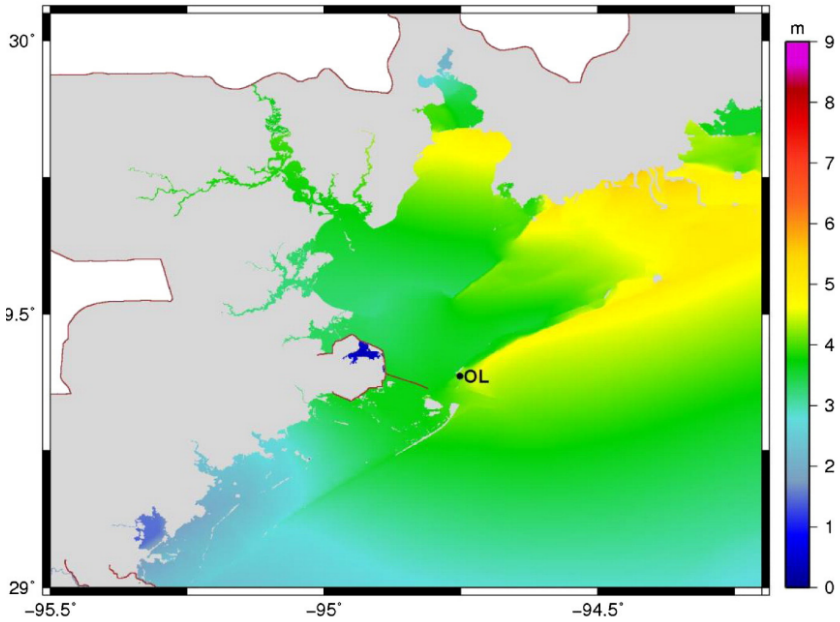


Figure: Surge profile generated by ADCIRC+SWAN for Hurricane Ike [Sebastian et al., 2014].

Computational kernel

- Simulate the ocean surface using the shallow water equations.
- Using a discontinuous Galerkin discretization; can be thought of as an explicit stencil kernel.
- The key source of irregularity is the computational difference between the simulation of wet and dry regions of the mesh.

The Algorithm – [Baggag et al. 1999]

```
function SUBMESH_UPDATE_A(n, j)
    require: SUBMESH_UPDATE_B(n − 1, j) has returned
    Fill all send buffers.
    Post Receives.
    Post Sends.
    for all elements ∈ Submesh j do
        Evaluate volume kernels
    end for
    for all internal interfaces ∈ Submesh j do
        Evaluate interface kernels
    end for
    Wait for all sends and receives to complete.
    return
end function
```

The Algorithm – Continued

```
function SUBMESH_UPDATE_B(n, j)
    require: SUBMESH_UPDATE_A(n, j) has returned.
    for all shared interfaces ∈ Submesh j do
        Evaluate interface kernels
    end for
    for all elements ∈ Submesh j do
        Evaluate Runge-Kutta updates
    end for
    return
end function
```

Performance Comparison with MPI

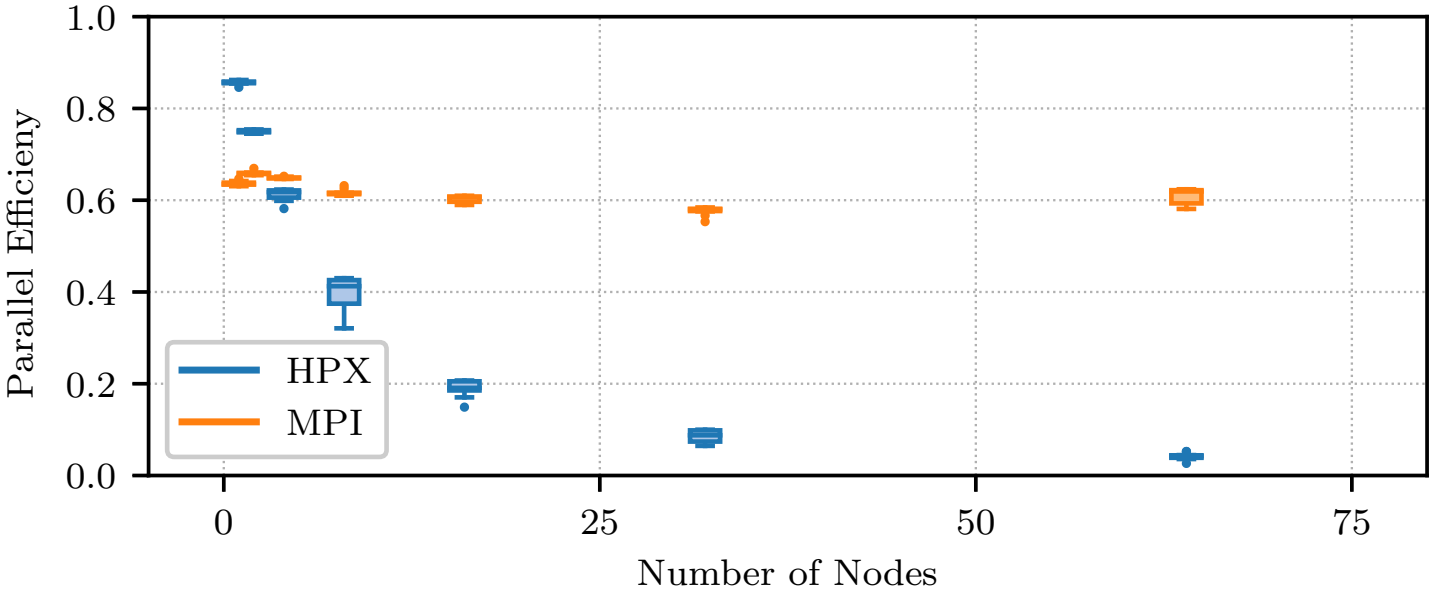


Figure: Strong scaling results comparing the performance of HPX to MPI for up to 64 KNL nodes on Stampede2. For each configuration, the simulation was run 10 times with no data being excluded.

Task Overheads

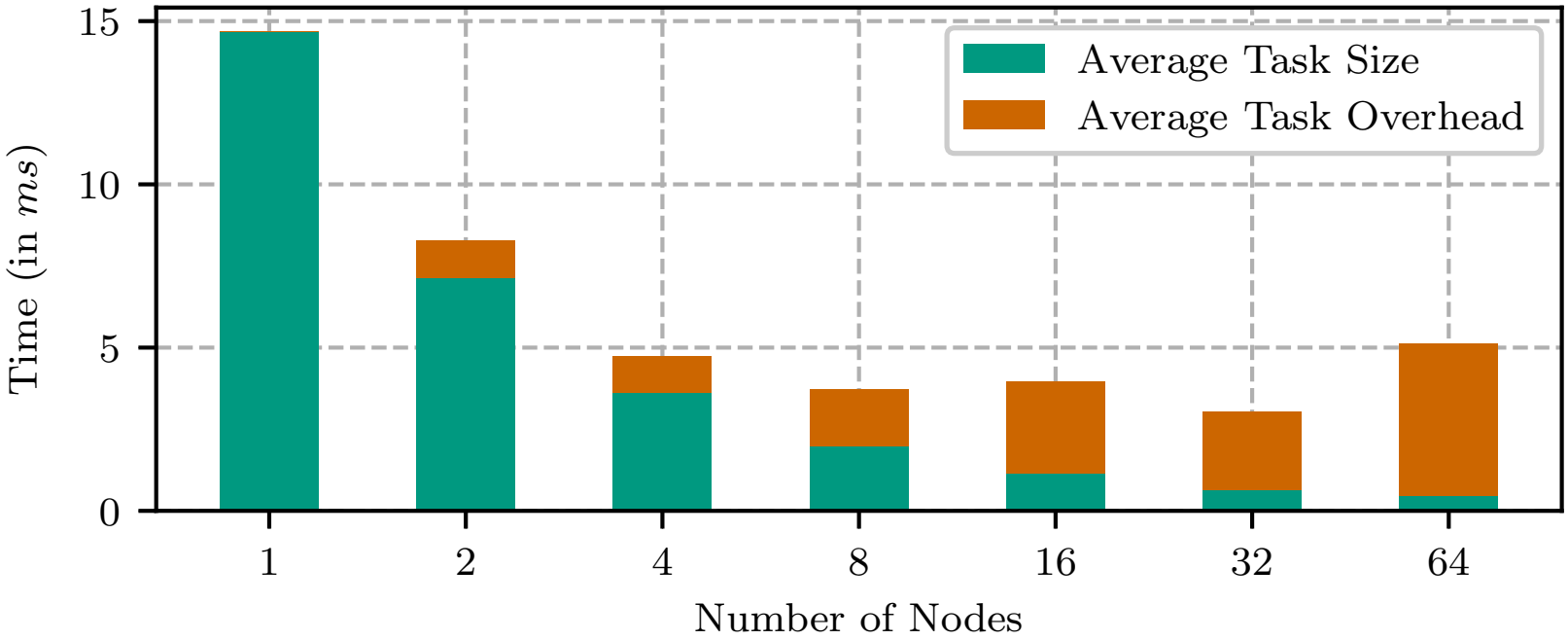
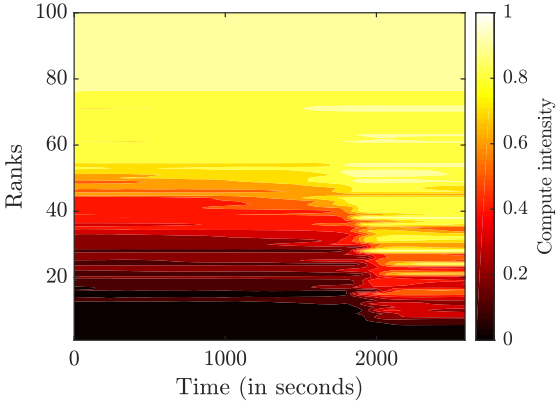
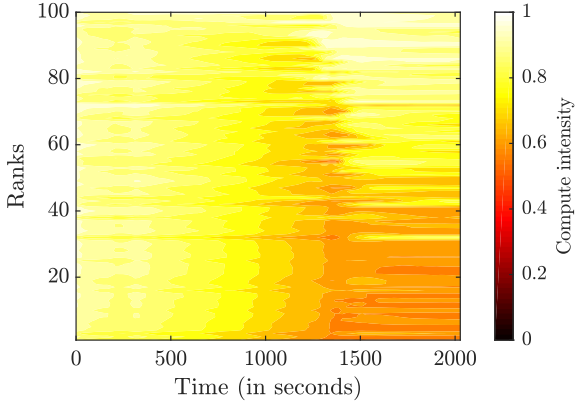


Figure: Task composition on Stampede2's KNL partition. Task overheads remain reasonable as long as tasks are on the order of milliseconds.

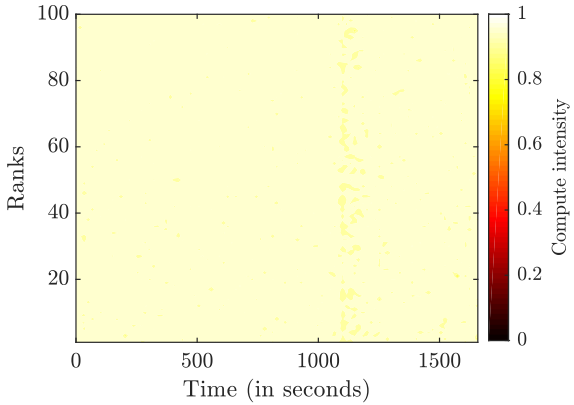
Compute Intensities due to Wetting and Drying



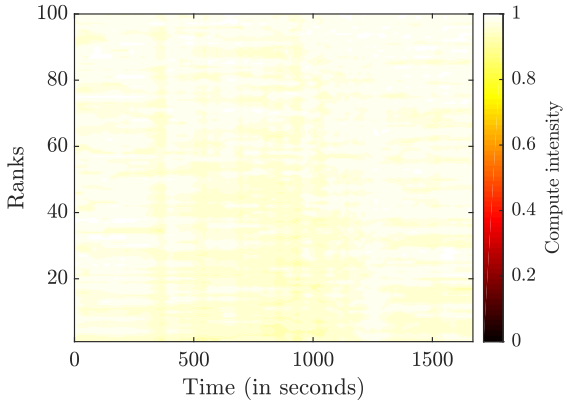
(a) Static



(b) Multi-constraint Static



(c) Semi-Static



(d) Asynchronous Diffusion

Adaptive Local Timestepping

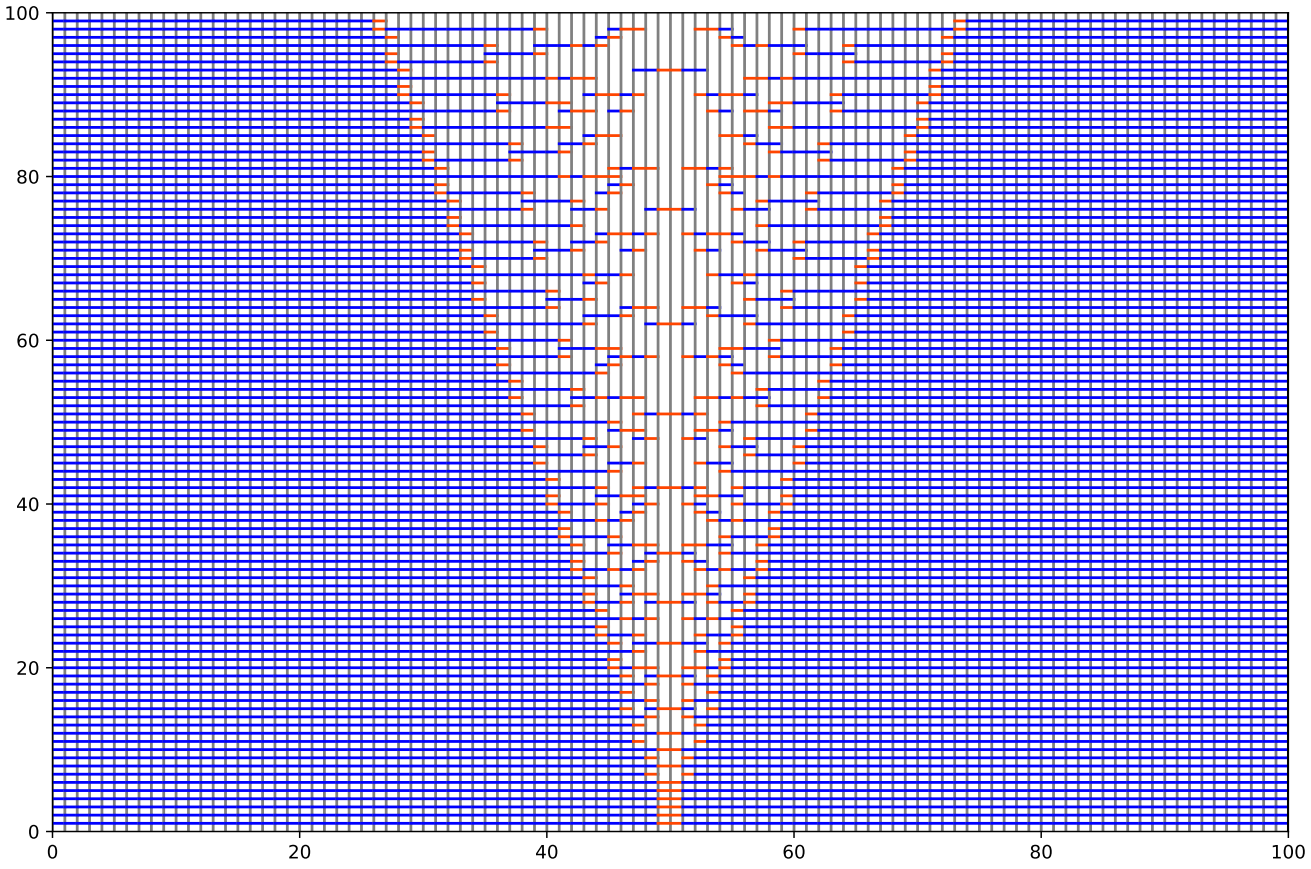


Figure: Space-time plot of cell updates for Burgers' equation undergoing a rarefaction.

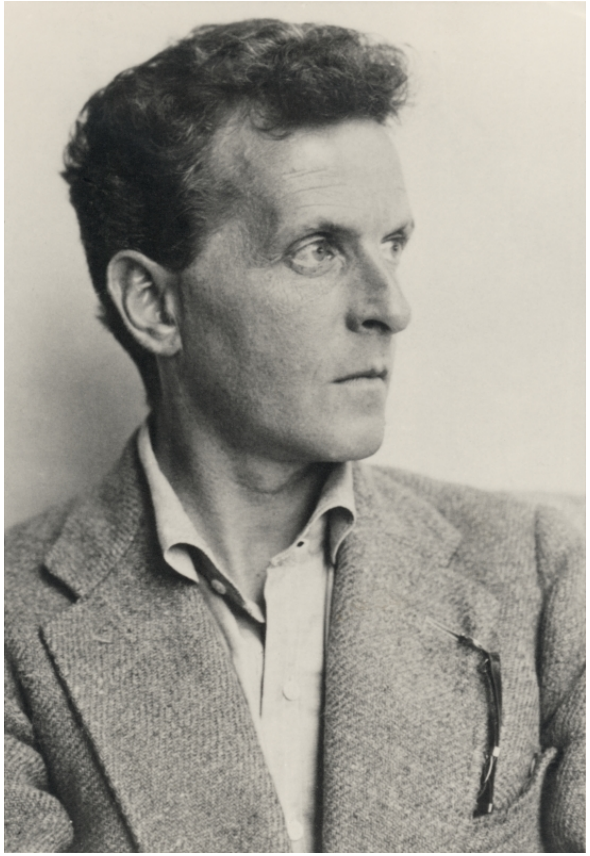
Conclusions

Take-aways

- Working with HPX is very comfortable, and feels like the right level of abstraction.
- The Stellar group is very accommodating and willing to support features that you need.
- Code can be found at `https://github.com/UT-CHG/dgswemv2`.

If you want to port to a task-based runtime...

- Profile the code, and come up with performance estimates for task-based runtimes.
- Do not under estimate software engineering effort (although you should probably refactor your code anyway).
- Find opportunities to take advantage of adaptivity.



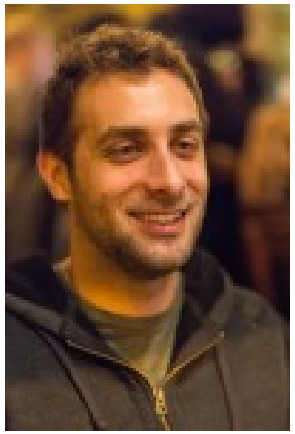
"The limits of my language mean the limits of my world" ∼Ludwig Wittgenstein

Thank you!

Clint Dawson

Hartmut Kaiser

Cy Chan



John Bachan

Thank you!

Acknowledgements

This work was supported by the National Science Foundation under Grants ACI-1339801 and ACI-1339782 and the U.S. Department of Energy through the Computational Science Graduate Fellowship, Grant DE-FG02-97ER25308. Furthermore, this research used resources of the National Energy Research Scientific Computing Center (NERSC), a U.S. Department of Energy Office of Science User Facility operated under Contract No. DE-AC02-05CH11231.