

# ForestClaw: A parallel, adaptive Cartesian grid library for problems in geophysical hazards modeling

## ForestClaw Developers

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## Key features of ForestClaw

ForestClaw is a parallel, multi-block library for solving PDEs on adaptively refined, logically Cartesian meshes.

Some of the features of ForestClaw are :

1. Based on the **highly scalable** grid management library **p4est** ([www.p4est.org](http://www.p4est.org)). Each leaf of the quad-tree or octree contains a fixed size grid (e.g. 16x16 or 32x32) so standard Cartesian grid algorithms can be used.
2. **Multi-block** capabilities extends the usefulness of Cartesian mesh methods to many important domains, including the cubed sphere, and non-square rectangular regions.
3. **Quad-tree** adaptive meshing means that less meta-data is stored on each processor, and nearest-neighbors are easy to find.
4. Cartesian grid layout of each patch and regular neighbor patterns **greatly simplifies the development of novel numerical methods**.
5. **ForestClaw** : See <http://www.forestclaw.org>

## Volcanic ash transport and dispersion

ForestClaw coupling with Ash3d (H. Schwaiger, L. Mastin R. Denlinger (USGS); M. Shih)

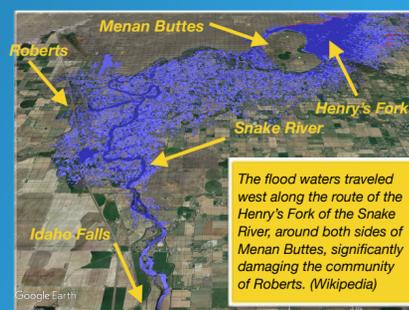
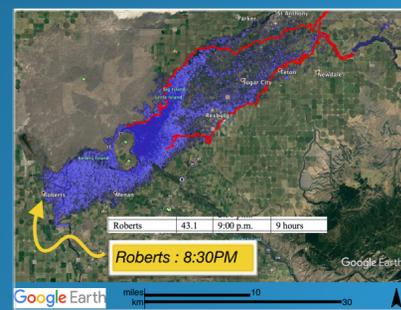
### Ash3d extension of ForestClaw

- **Volcanic eruptions** can cause significant disruptions to civilian airspace. As a result of the 2010 eruption of Eyjafjallajokull in Iceland, zero-ash tolerance restrictions were lifted to allow for air travel within non-zero safety tolerances.
- **Ash3d model** : Developed at the Cascade Volcanic Observatory (Vancouver, WA). Model tracks several grain sizes; advective wind fields interpolated from meteorological data available in several formats.
- **Numerical scheme** : Explicit second order finite volume scheme (wave propagation (CTU, DCU) on 3d regional latitude/longitude grids.
- **Ash3d** is a single grid, serial code developed in **Fortran 90**.
- Using modern F90 features, we were able to run 3d Ash3d code within each ForestClaw quadrant; refinement in horizontal only; 25 vertical levels within each patch.
- **Modified boundary conditions** to handle communication between patches.
- **Excellent agreement** with original Ash3d results

ForestClaw port of Ash3d shows excellent speed-up and efficiency and clearly demonstrates the benefits of including spatial adaptivity and distributed parallelism (see below).

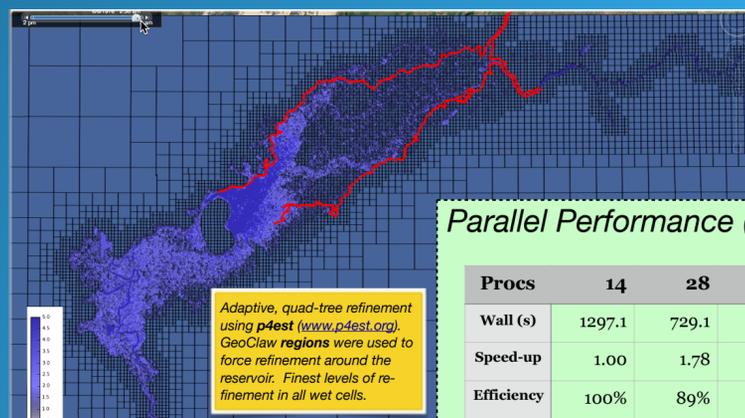
## June 5, 1976 Teton Dam Failure (Eastern Idaho)

ForestClaw coupling with GeoClaw (D. George, R. J. LeVeque; K. Mandli, M. Berger, M. Shih; Steve Prescott (Idaho National Lab); Ram Sampath (Centroid Lab)



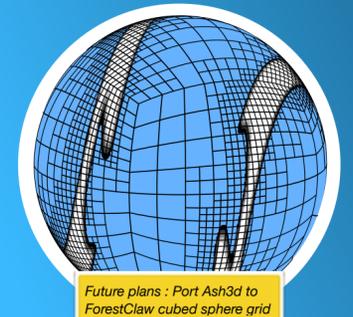
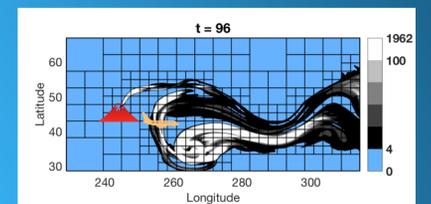
## GeoClaw extension of ForestClaw

- Use **shallow water wave equation** solver in **GeoClaw** for flood simulations
- Excellent agreement with historical **arrival times** (comparison shown)
- **10m** (2048x1024) effective resolution
- **GeoClaw users** can port their applications to ForestClaw with very few changes to underlying code.
- Visualization with **Google Earth** using **VisClaw**
- **GeoClaw** : <http://www.geoclaw.org>

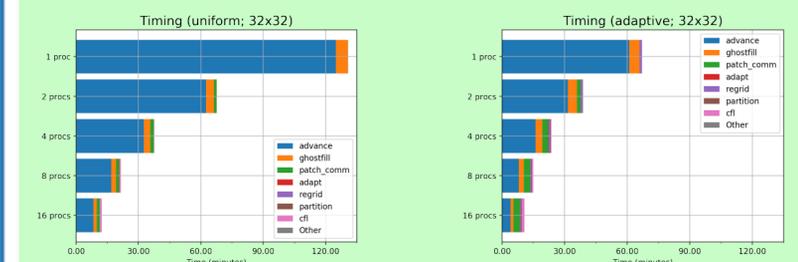


## Parallel Performance (MPI ranks)

Procs	14	28	56	112
Wall (s)	1297.1	729.1	393.2	227.7
Speed-up	1.00	1.78	3.30	5.70
Efficiency	100%	89%	82%	71%



## Parallel Performance (MPI ranks)



D. Calhoun and C. Burstedde, "ForestClaw : A parallel algorithm for patch-based adaptive mesh refinement on a forest of quadtrees", arXiv:1703.03116, (2017).  
H. F. Schwaiger, R. P. Denlinger, and L. G. Mastin, "Ash3d : A finite-volume, conservative, numerical model for ash transport and tephra deposition", J. Geophys. Res., 117 (2012).

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