# ForestClaw : Adaptive, multi-block methods on mapped Cartesian grids


## ForestClaw Developers

**Donna Calhoun** (Boise State Univ.)

**Carsten Burstedde** (Univ. of Bonn)

## ForestClaw, Clawpack and GeoClaw Collaborators

D. Ketcheson (Kaust), K. Mandli and Melody Shih (Columbia University), D. George (USGS), R. J. LeVeque (Univ. of WA), M. Berger (NYU); Grady Lemoine (CD-Adaptco) and many others


### Key features of ForestClaw

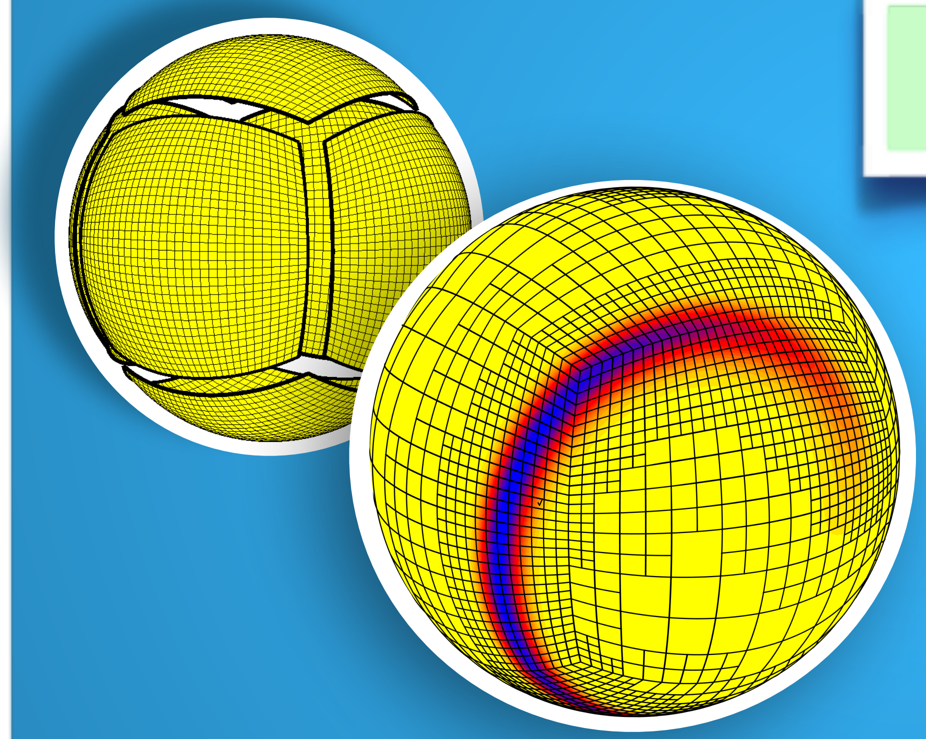
**ForestClaw** is a parallel, multi-block library for solving PDEs on adaptively refined logically Cartesian meshes.

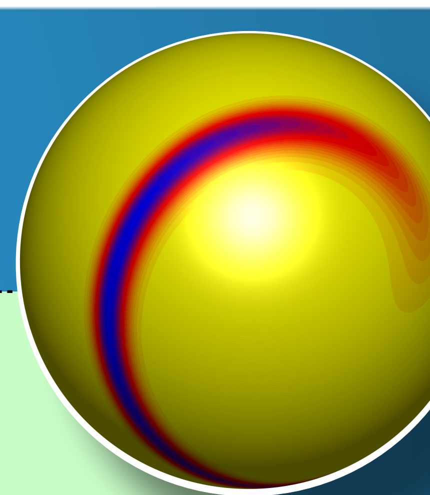
Some of the features of ForestClaw are :

1. Based on the **highly scalable** grid management library p4est (www.p4est.org)
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** has been extended by several popular libraries, such as **Clawpack** and **GeoClaw** (www.clawpack.org).

### *Solving on multiblock domains*

Tracer transport on a cubed sphere





**Handling multiblock boundaries**

- Indices on patch boundaries between coarse grid patches and neighboring coarse or fine grid patches are *transformed* via linear transformation

$$\mathbf{I}_n = A\mathbf{I}_c + \mathbf{F}$$

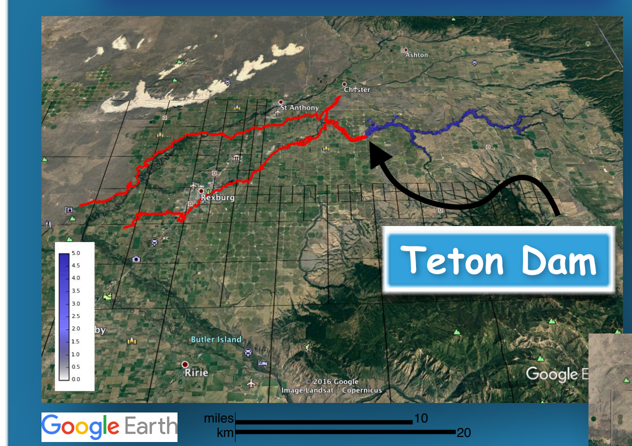
- Patch corners are handled by the Riemann solver sweeps.
- Seams are not treated in any special way, but results remain smooth. Inf-norm accuracy is below 2, however.
- P. H. Lauritzen, P. A. Ullrich, C. Jablonowski, P. A. Bosler, D. Calhoun et al, "A standard test case suite for two-dimensional linear transport on the sphere: results from a collection of state-of-the-art schemes", *Geosci. Model Dev.*, 7 (2014), pp. 105–145.

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

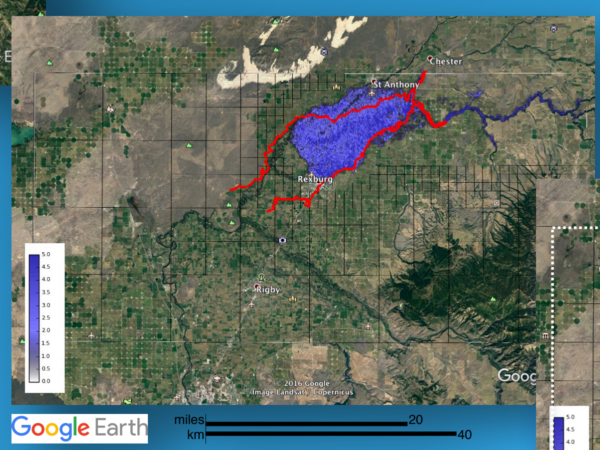
GeoClaw (www.geoclaw.org) extension of ForestClaw; Joint work with Steve Prescott (Idaho National Lab); Ram Sampath (Centroid Lab); Melody Shih (Columbia Univ.); Kyle Mandli (Columbia Univ.)

**Preliminary Results**

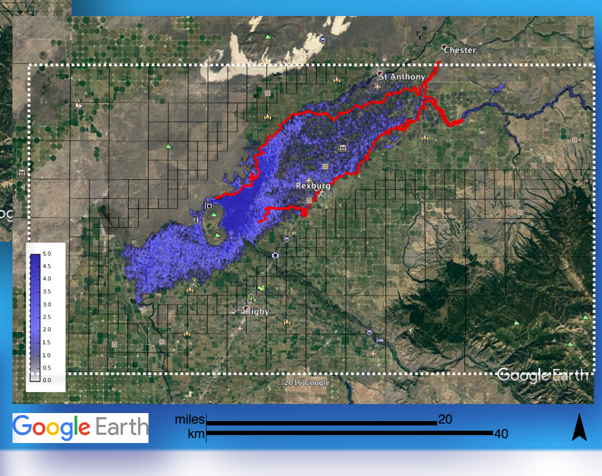
- Excellent agreement with historical survey of flooded area (shown in red)
- 8 hours of simulation time in under half an hour
- Instantaneous dam burst (probably not realistic)
- 2048x1024 effective resolution; 6 levels of refinement; 16x16 patches; global time stepping.




11:55AM 6/5/1976




7:57 PM 6/5/1976




**Parallel Performance**

- 22 node (28 cores/node) BSU R2 cluster; MPI processes only

| 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% |

*For more information, come to*

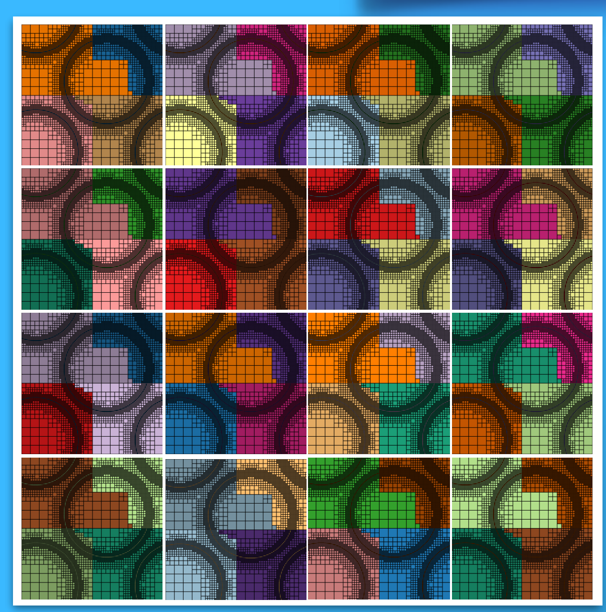
***Flooding the Cores***

- ***MS154*** *(Wed 9:10-10:50)*
- ***MS181*** *(Wed 1:30-3:10)*

*Room 216*

### *Parallel performance results*

Scalar advection on a replicated domain

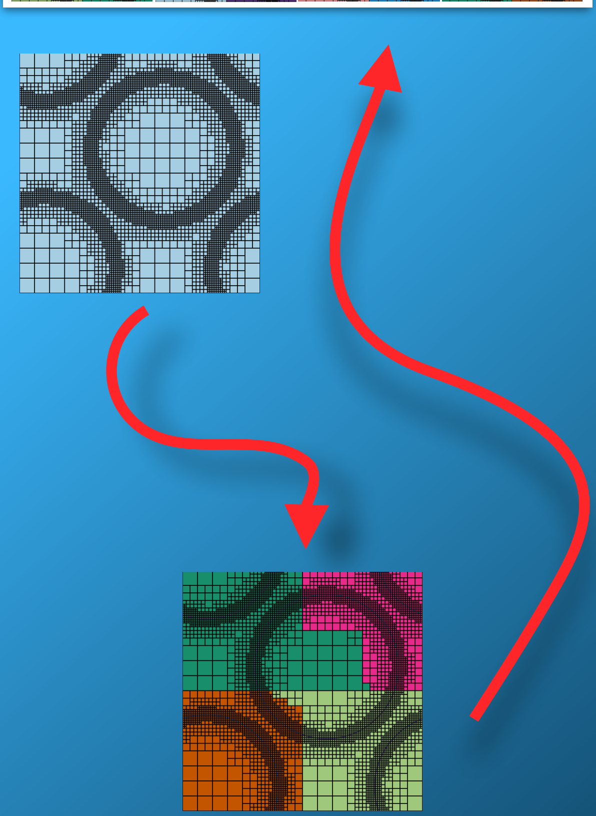


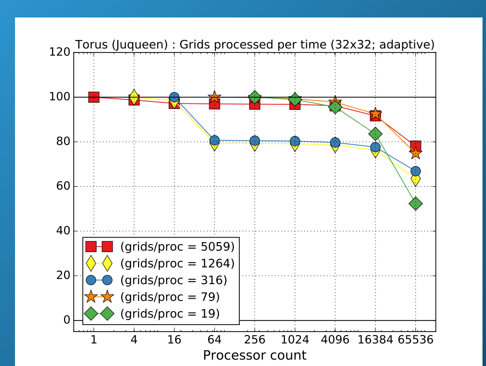
**Parallel setup**

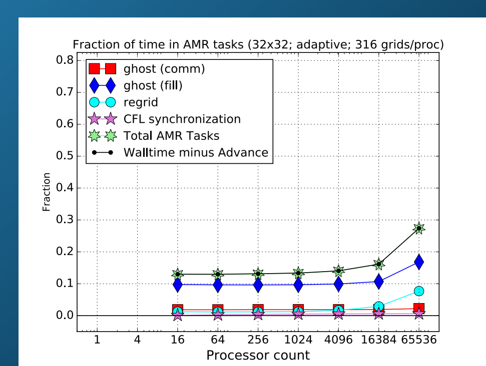
- We use the multi-block features of ForestClaw to replicate a single problem across the domain.
- We studied performance using 8x8, 16x16 and 32x32 grids.
- Runs done on the BlueGene/Q machine JUQUEEN (IBM PowerPC A2 @1.6 GHz and 16GB RAM per node). Used 32 ranks-per-node

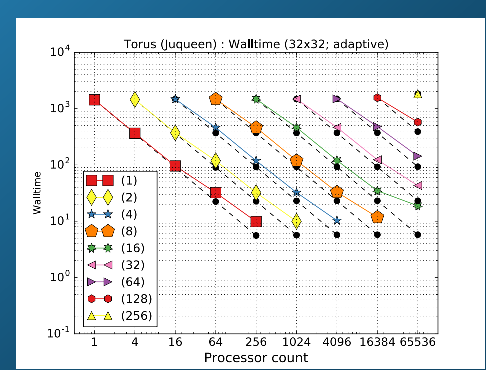
**Results**

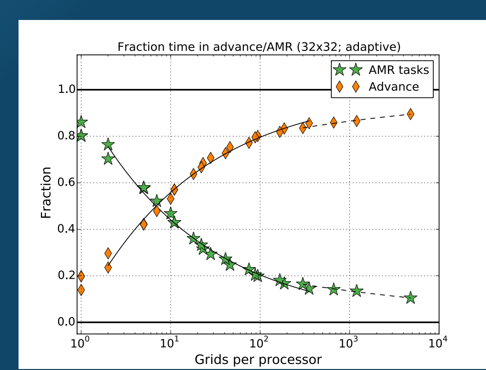
- Weak and strong scaling results over 1 to 65K processors.
- Percentage of time spent in AMR tasks (regridding, ghost filling, load balancing) is strongly dependent on number of grids per processor.
- Dynamic **regridding** times are negligible.






www.forestclaw.org


Donna Calhoun wishes to acknowledge the National Science Foundation (NSF DMS - 1419108) for funding this work.