Adaptive Mesh Refinement

Gauges

Benchmarks

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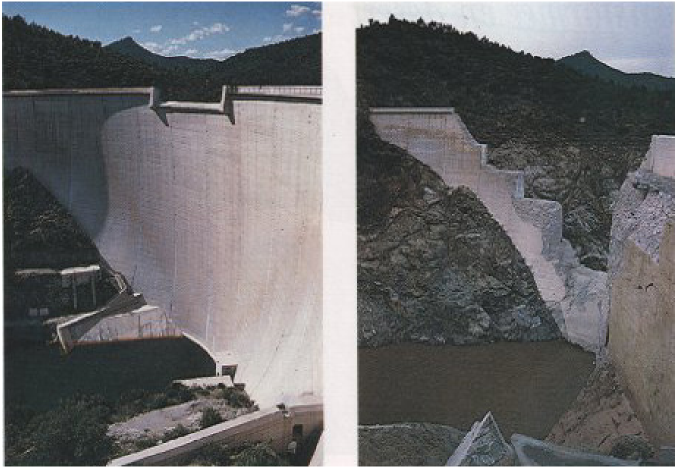
Malpasset Dam Failure

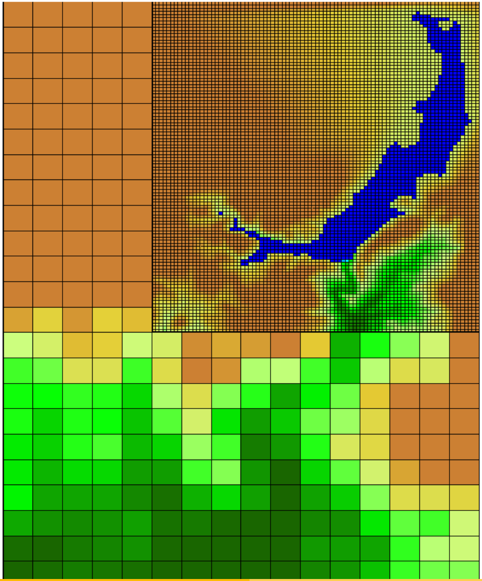
Catastrophic failure in 1959



Malpasset Dam Failure

Modeling work by David George, using GeoClaw

Coarse: 400m cell side,   Level 2: 50m,   Level 3: 12m,   Level 4: 3m



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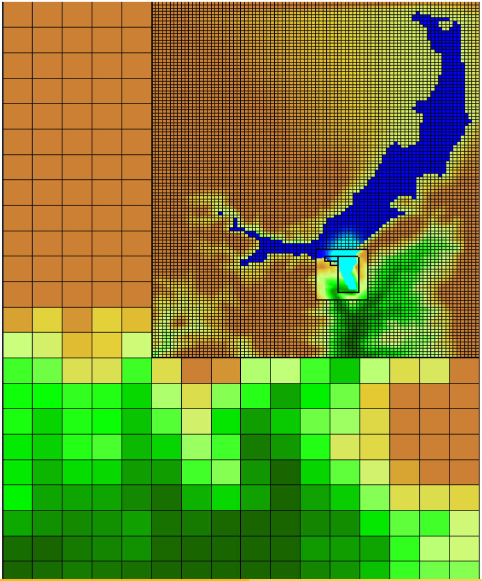

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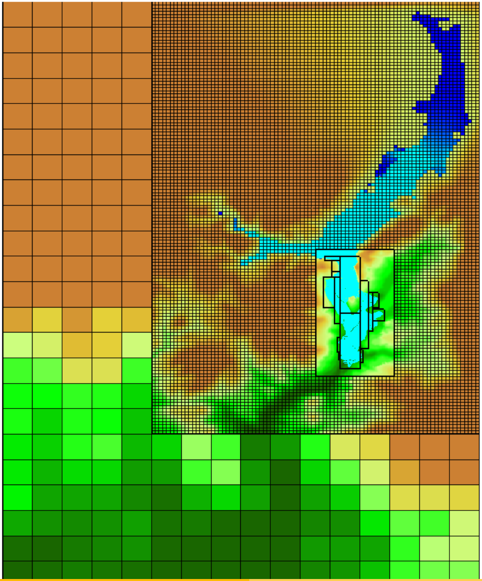

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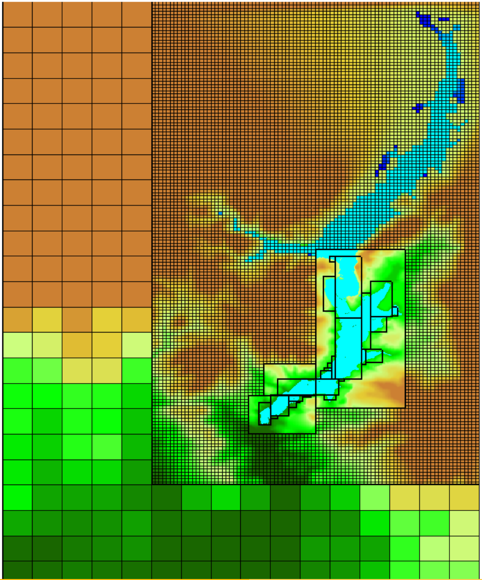

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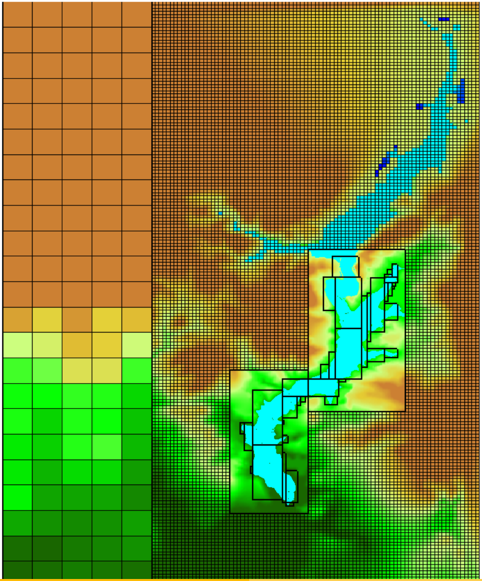

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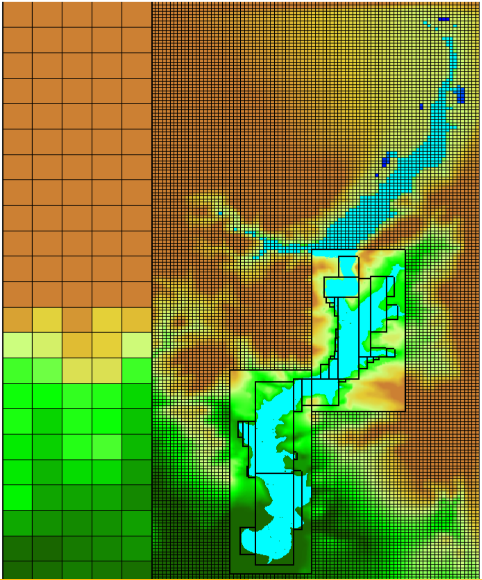

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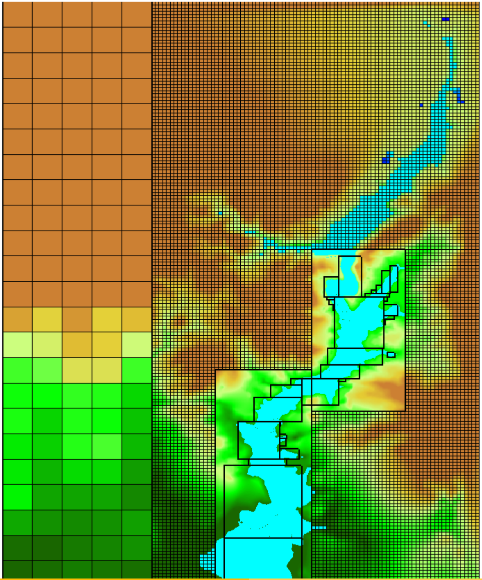
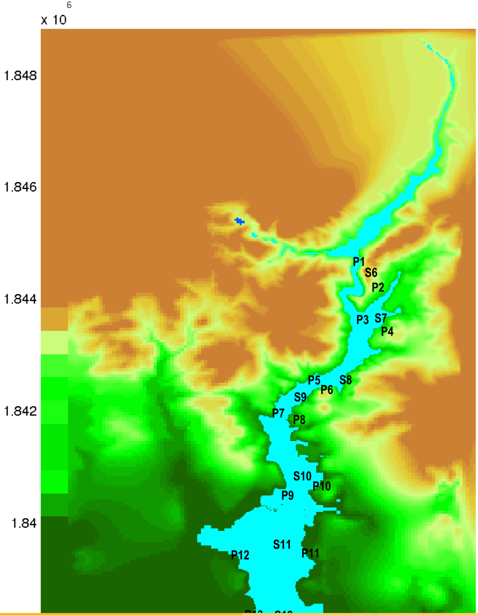


Malpasset survey locations



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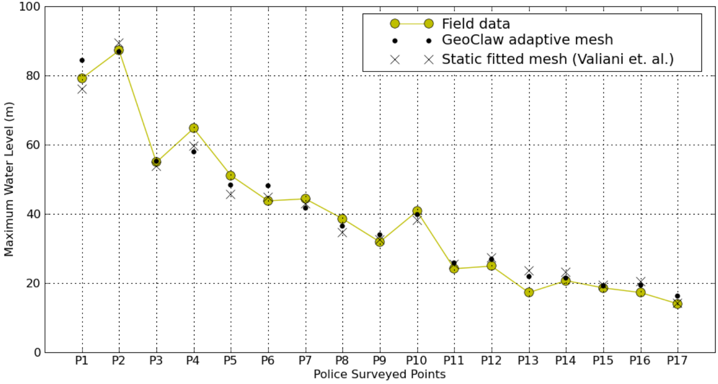
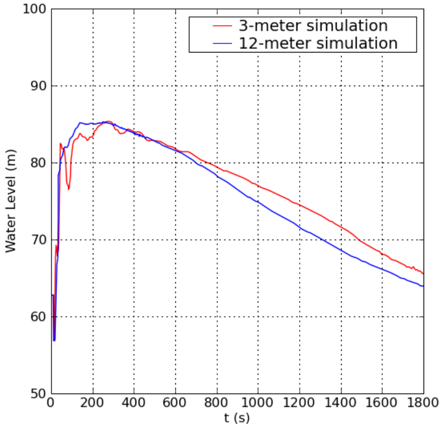


Grid convergence study

Water depth gauge at location P2 computed with two different resolutions (using 4 levels or only 3):



Adaptive Mesh Refinement (AMR)

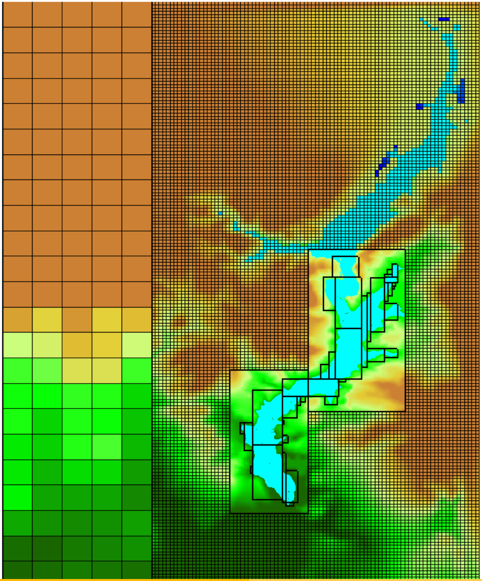
- Cluster grid points where needed
- Automatically adapt to solution
- Refined region moves in time-dependent problem

Basic approaches:

- Cell-by-cell refinement
  Quad-tree or Oct-tree data structure
  Structured or unstructured grid
- Refinement on "rectangular" patches
  Berger-Colella-Oliger style
  (AMRCLAW and CHOMBO-CLAW)

Nested AMR grids

Coarse: 400m cell side, Level 2: 50m, Level 3: 12m, Level 4: 3m

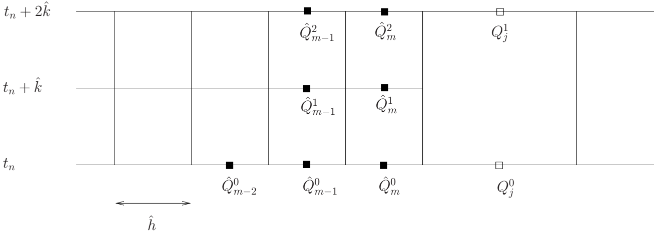


AMR Issues

- Refinement in time as well as space
- Conservation at grid interfaces
- Accuracy at interfaces, Spurious reflections?
- Refinement strategy, error estimation
- Clustering flagged points into rectangular patches

Time stepping algorithm for AMR

- Take 1 time step of length k on coarse grid with spacing h.
- Use space-time interpolation to set ghost cell values on fine grid near interface.
- Take L time steps on fine grid.
  $L =$ refinement ratio, $\hat{h} = h/L$, $\hat{k} = k/L$.
- Replace coarse grid value by average of fine grid values on regions of overlap — better approximation and consistent representations.
- Conservative fix-up near edges.



Flagging Cells for Refinement

Every `kcheck` time-steps at each level (except finest), check all grid cells and flag those needing refinement.

Use one or more of the following flagging criteria:

- Richardson estimation of truncation error.
  Compare result after last two time steps on this grid with one time step on a coarsened grid.
- Estimate spatial gradient of one or more components of solution.
- Check for regions where refinement is user-forced to some level.
- Problem-specific, e.g. near shore for tsunami simulation.
- Other user-supplied criterion set in `flag2refine.f`.

Clustering Flagged Cells for Refinement

Use Berger-Rigoutsos algorithm
[IEEE Trans. Sys. Man & Cyber.] 21(1991), p. 1278]

Clusters flagged points into a set of rectangular patches.

Tradeoff between:

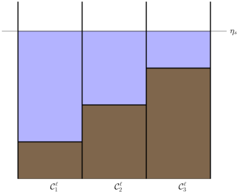
- Many small patches cover flagged points with minimal refinement of unflagged points.
- But.... increases overhead associated with each patch, e.g. boundary values: ghost cell values set by copying or interpolation from other grids,

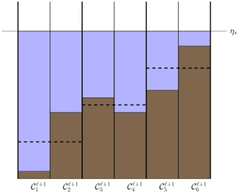
B-G algorithm has cut-off paramter: require that this fraction of refined cells be flagged (usually set to 0.7).

Refinement of topography

Topography should be consistent between different levels.

$$B_1^\ell = \frac{1}{2}(B_1^{\ell+1} + B_2^{\ell+1})$$





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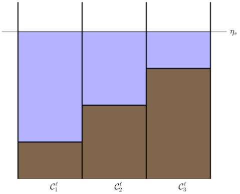
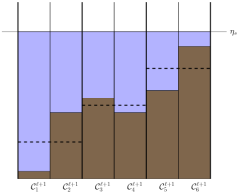
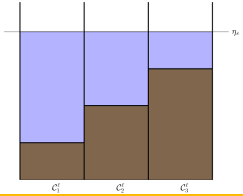
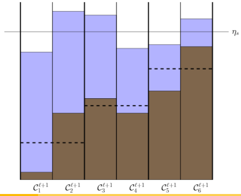




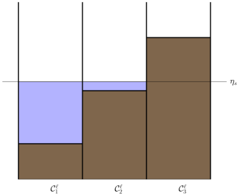
Important to interpolate surface, not depth, as in...

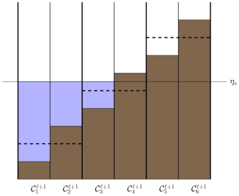




Refinement of topography near shore

Again need to maintain flat surface before wave arrives:





Mass cannot always be conserved!

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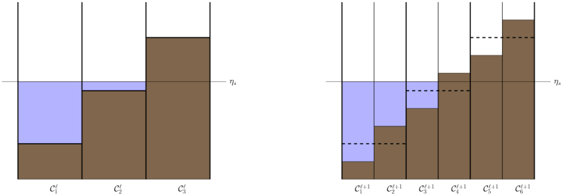

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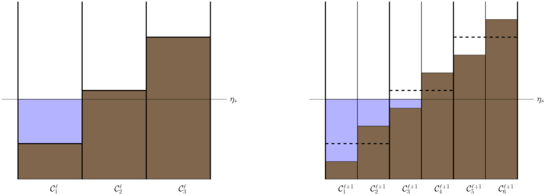
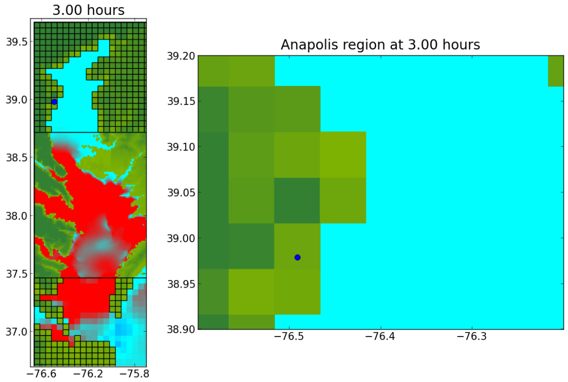


Chesapeake Bay and Anapolis

Cannot conserve mass when refining near shore!



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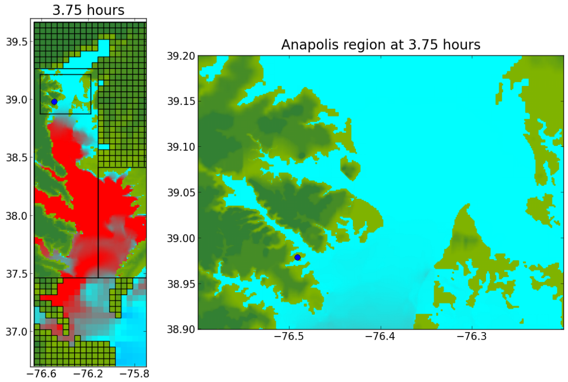

Gauges in GeoClaw

Set gauge locations in `setrun.py`, e.g. DART location:

```
# == setgauges.data values ==
geodata.gauges = []
# for gauges append lines of the form
#   [gaugeno, x, y, t1, t2]
geodata.gauges.append([32412, \
   -86.392, -17.975, 0., 1.e10])
```

Can add additional lines of this form.

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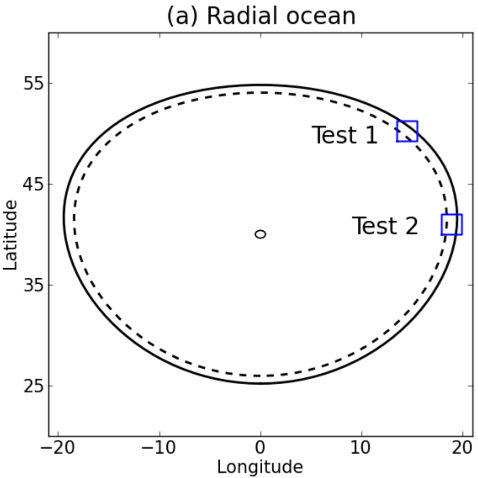
Useful for comparison with observations or lab measurements.

Also useful for quantitatively comparing different grid resolutions, parameter choices, etc.

Radial ocean verification study



From: Berger, George, RJL, Mandli, *Adv. Water Res.* 2011,
www.clawpack.org/links/awr11/

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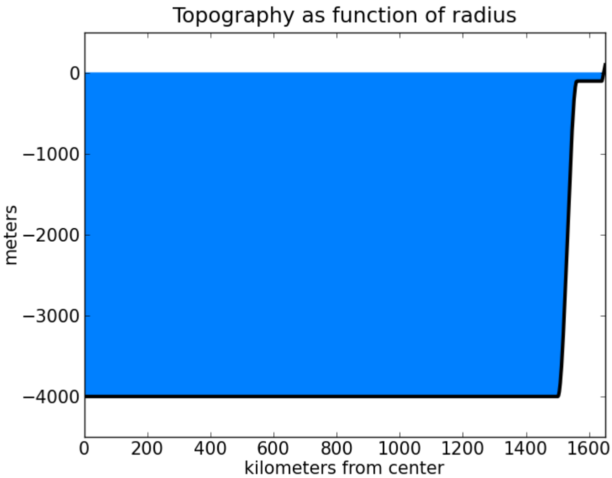

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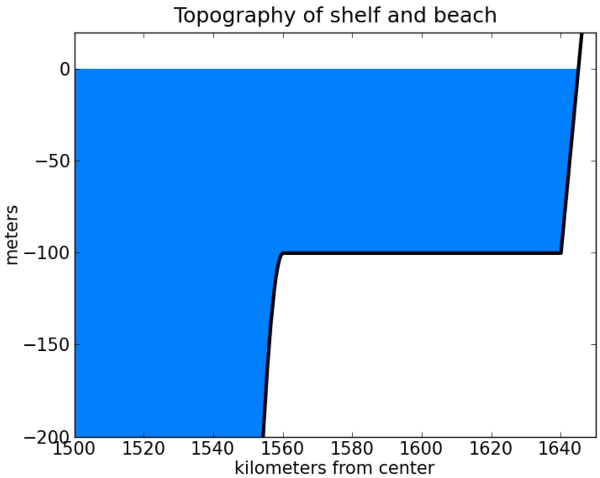

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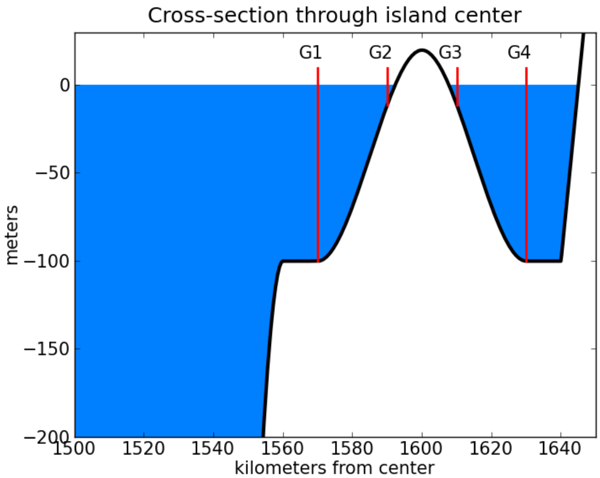

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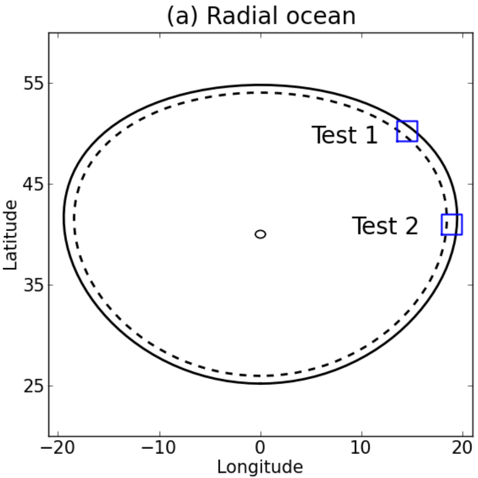

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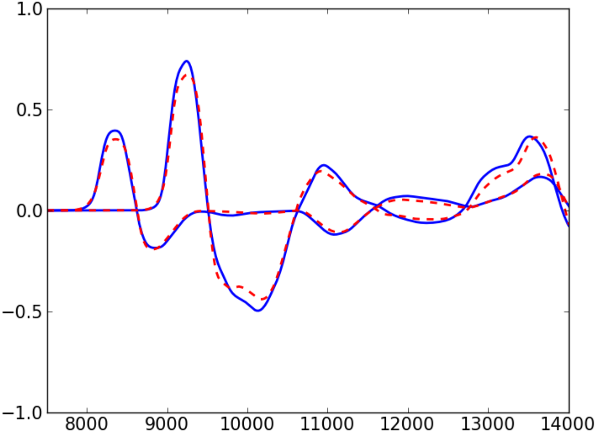
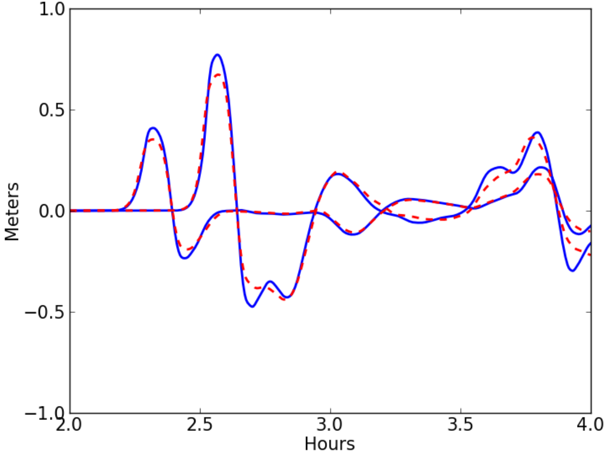
Radial ocean verification study

Comparison of Gauges 1 and 2 from Test 1 and 2:



Radial ocean verification study

Comparison of Gauges 1 and 2 with more refined grids (Test 1):



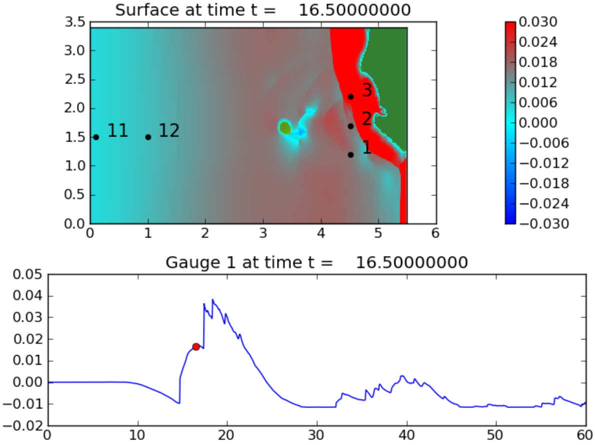
Benchmarking project

National Tsunami Hazard Mitigation Program
set of 9 benchmark problems.

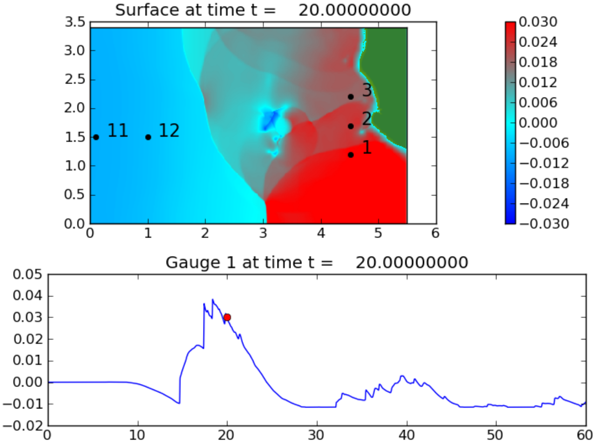
- One-dimensional waves on beach: analytic and wavetanks
- Waves around conical island (wave tank)
- Okushiri Island tsunami of 1993
- Wave tank model of Monai Valley
- Wave tank experiments of submarine landslides

Recently solved by several teams and comparisons soon to appear.

Our results available at
www.clawpack.org/links/nthmp-benchmarks/


Surface at time t =   16.50000000
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
11
12
3
2
1
0.030
0.024
0.018
0.012
0.006
0.000
−0.006
−0.012
−0.018
−0.024
−0.030
Gauge 1 at time t =   16.50000000
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
0
10
20
30
40
50
60

Monai Valley wave tank experiment



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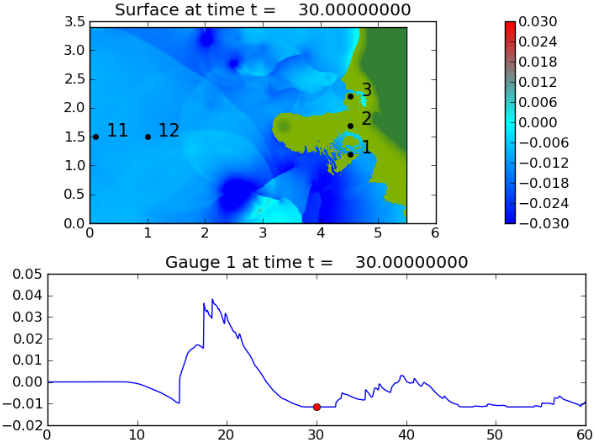

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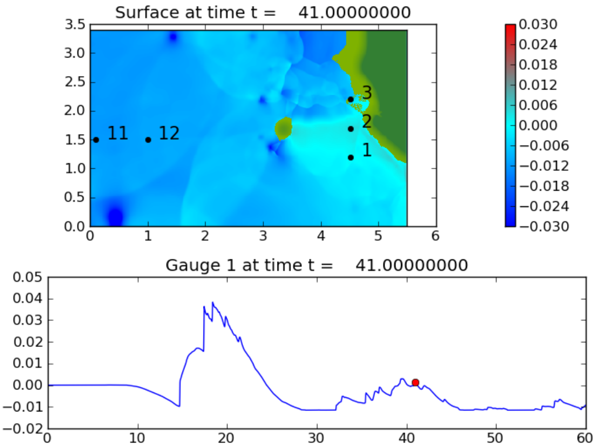

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