NTHMP Currents Benchmarking Workshop
GeoClaw Team

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http://www.geoclaw.org

Benchmark results
http://www.geoclaw.org/benchmarks/nthmp_currents_2015

GitHub repository
https://github.com/rjleveque/tsunami_benchmarks

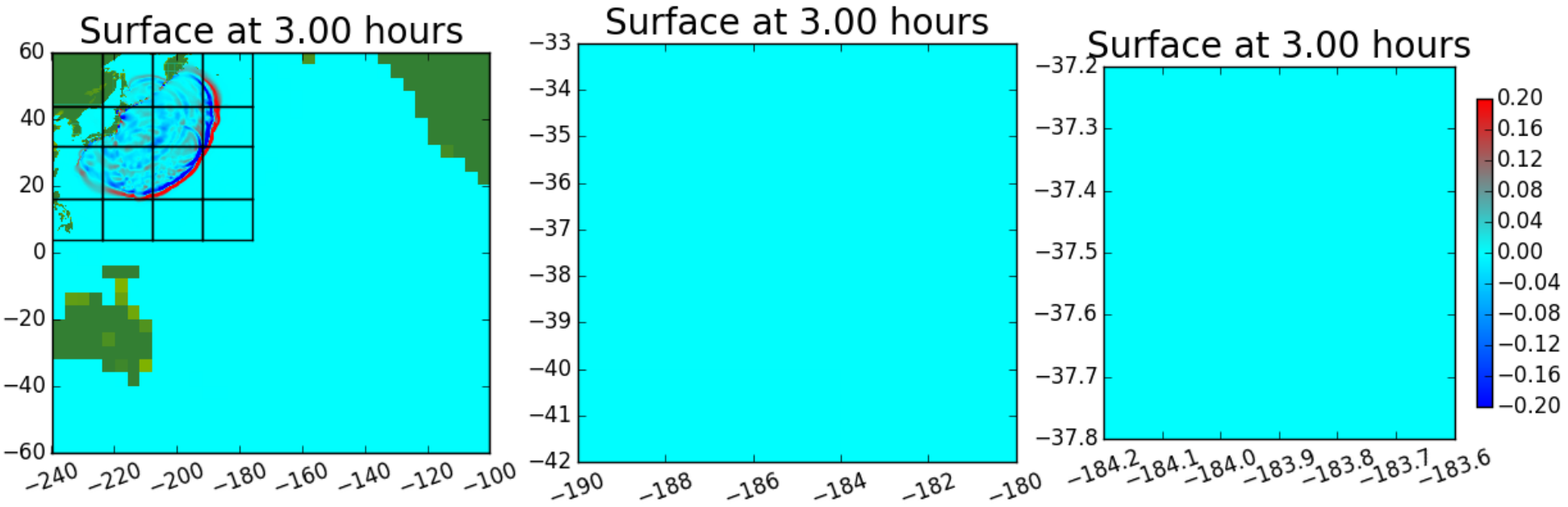
Shallow water equations with bathymetry $B(x, y)$

$$
\begin{aligned}
h_t + (hu)_x + (hv)_y &= 0 \\
(hu)_t + \left(hu^2 + \frac{1}{2}gh^2\right)_x + (huv)_y &= -ghB_x(x, y) \\
(hv)_t + (huv)_x + \left(hv^2 + \frac{1}{2}gh^2\right)_y &= -ghB_y(x, y)
\end{aligned}
$$

Some issues:

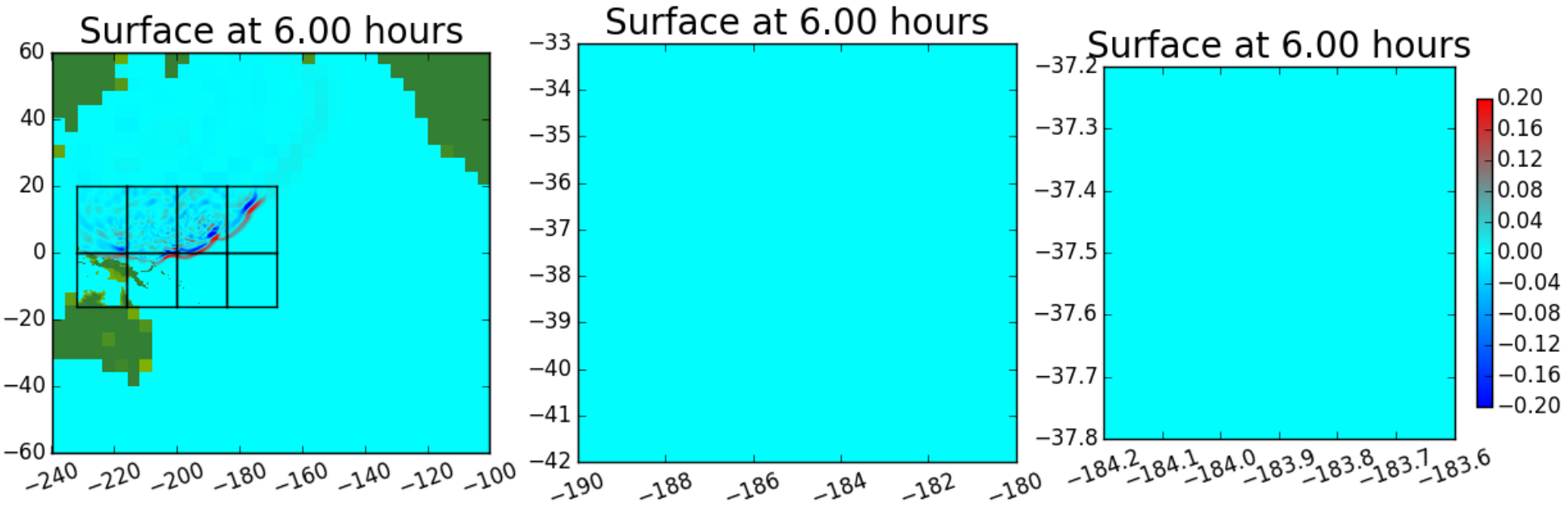
- Delicate balance between flux divergence and bathymetry:
  h varies on order of 4000m, rapid variations in ocean
  Waves have magnitude 1m or less.
- Cartesian grid used, with $h = 0$ in dry cells:
  Cells become wet/dry as wave advances on shore
  Robust Riemann solvers needed.
- Adaptive mesh refinement crucial
  Interaction of AMR with source terms, dry states

Tohoku to Tauranga Harbor, NZ with AMR



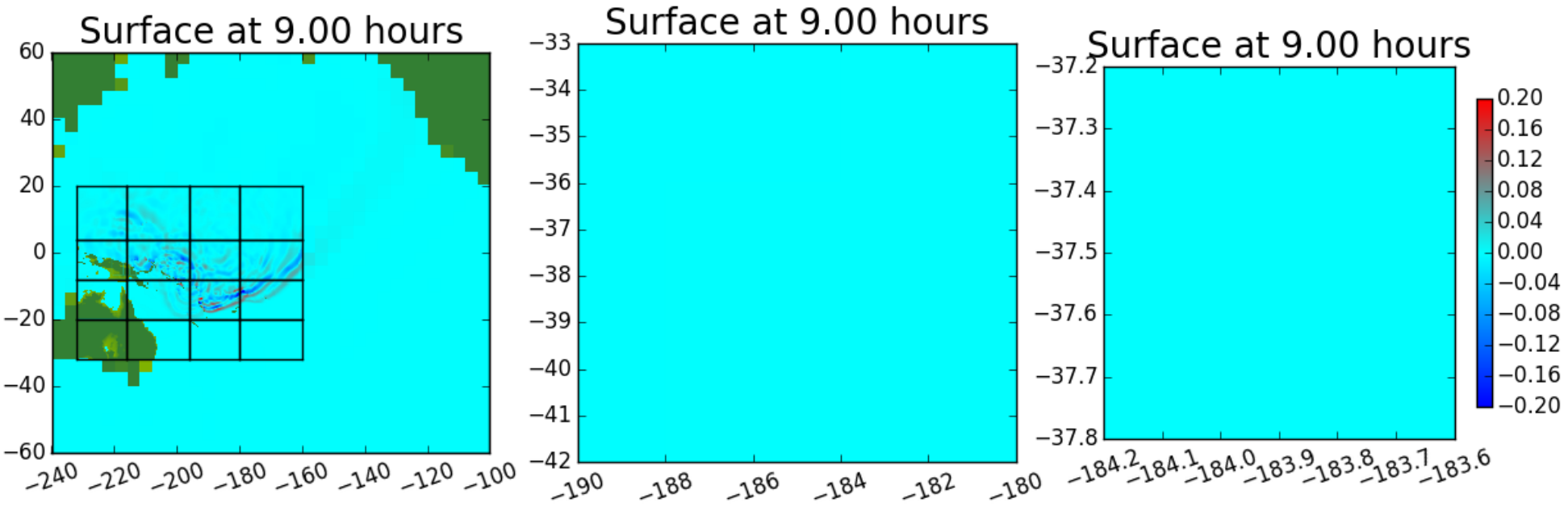
Elapsed time on quad-core MacBook: < 1 minute

Tohoku to Tauranga Harbor, NZ with AMR



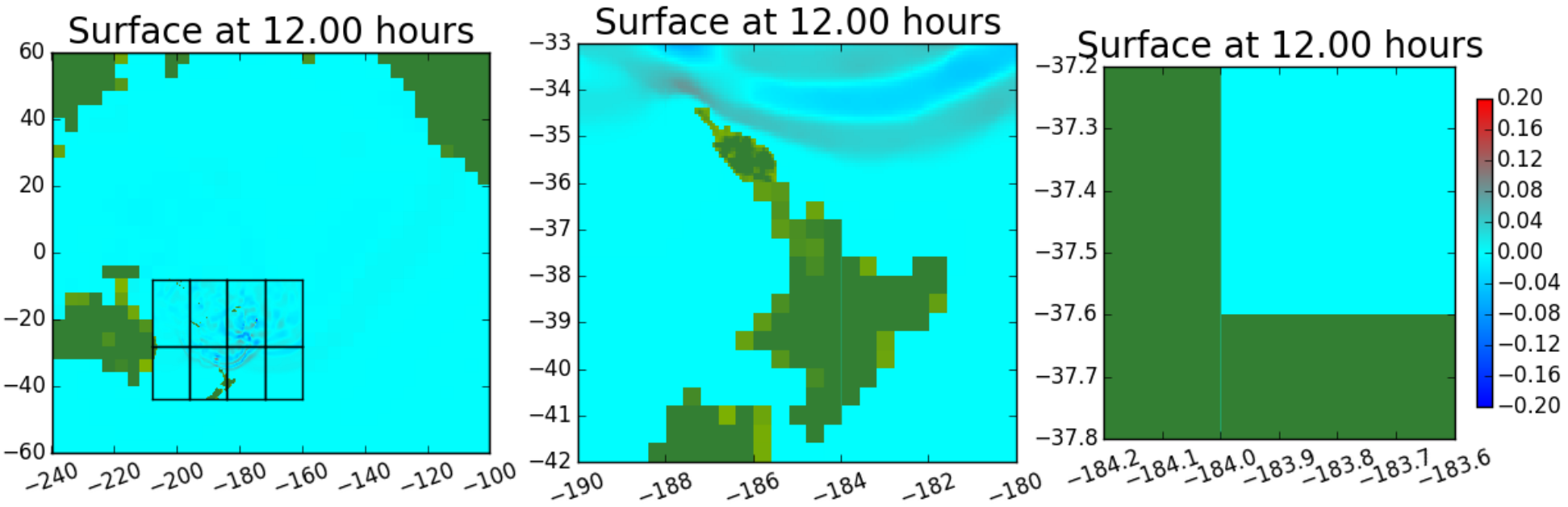
Elapsed time on quad-core MacBook: < 2 minutes

Tohoku to Tauranga Harbor, NZ with AMR



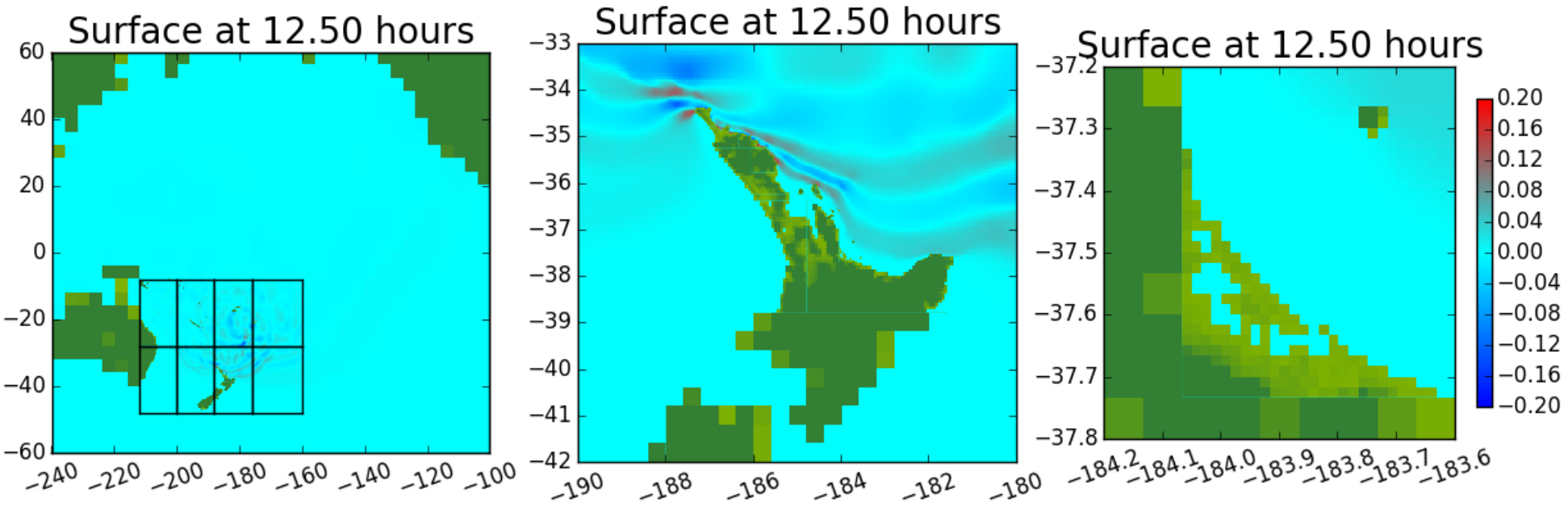
Elapsed time on quad-core MacBook: 3 minutes

Tohoku to Tauranga Harbor, NZ with AMR



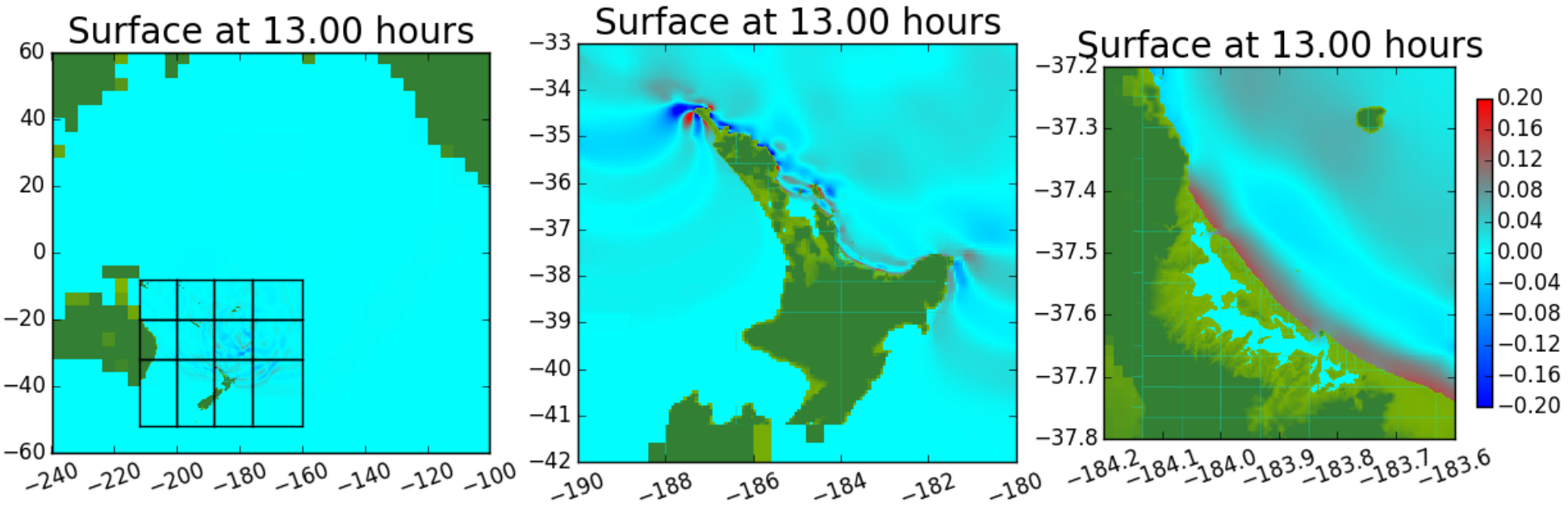
Elapsed time on quad-core MacBook: 5 minutes

Tohoku to Tauranga Harbor, NZ with AMR



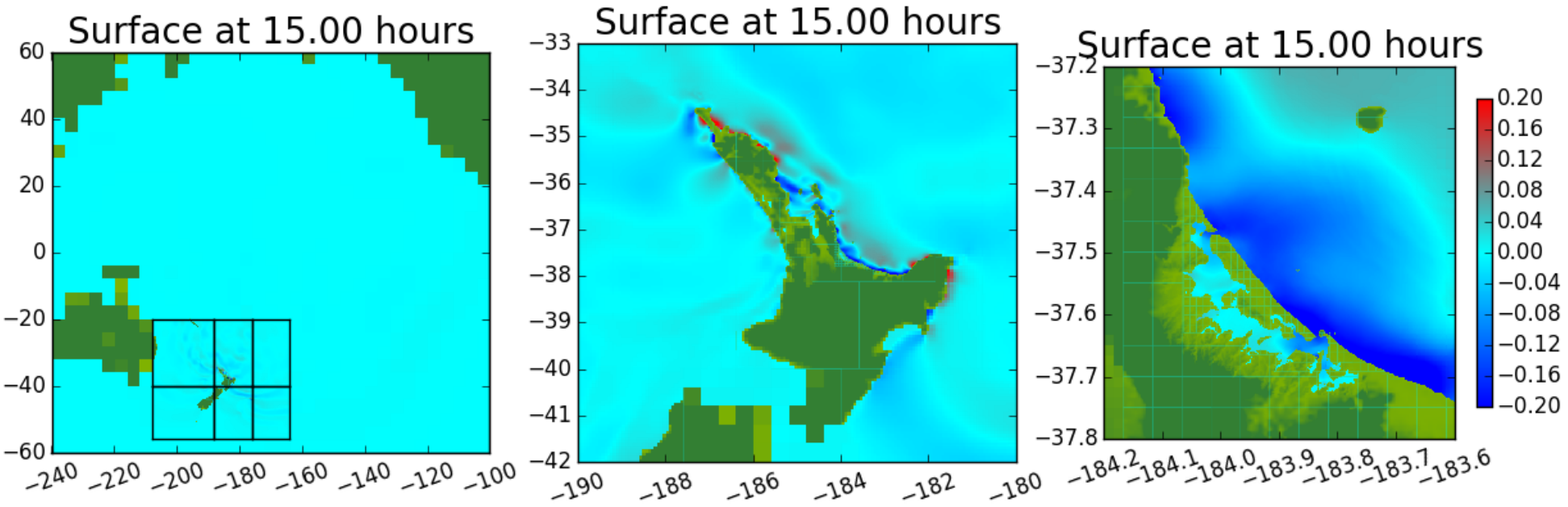
Elapsed time on quad-core MacBook: 6 minutes

Tohoku to Tauranga Harbor, NZ with AMR



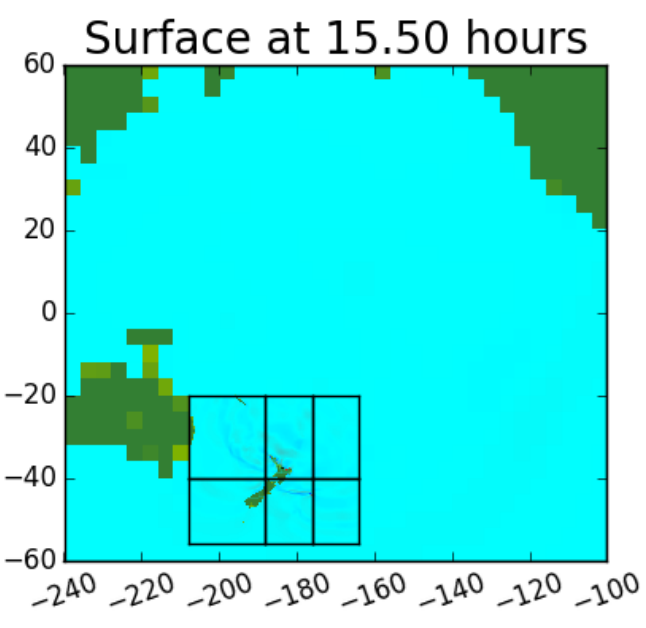
Elapsed time on quad-core MacBook: 19 minutes

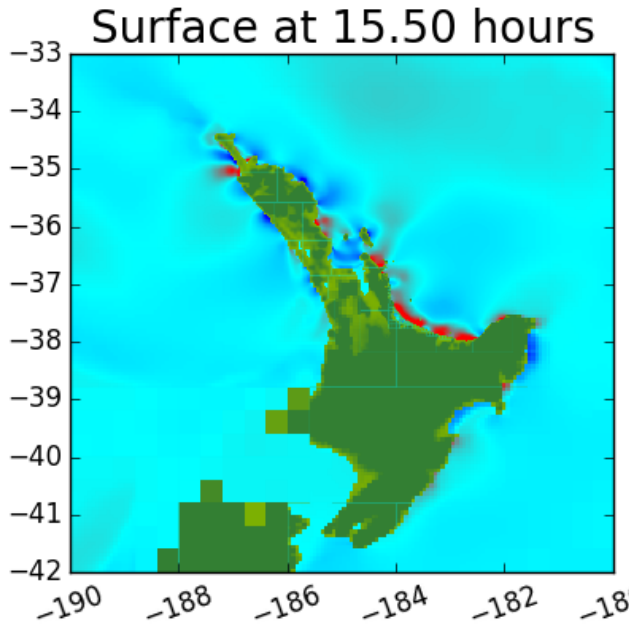
Tohoku to Tauranga Harbor, NZ with AMR

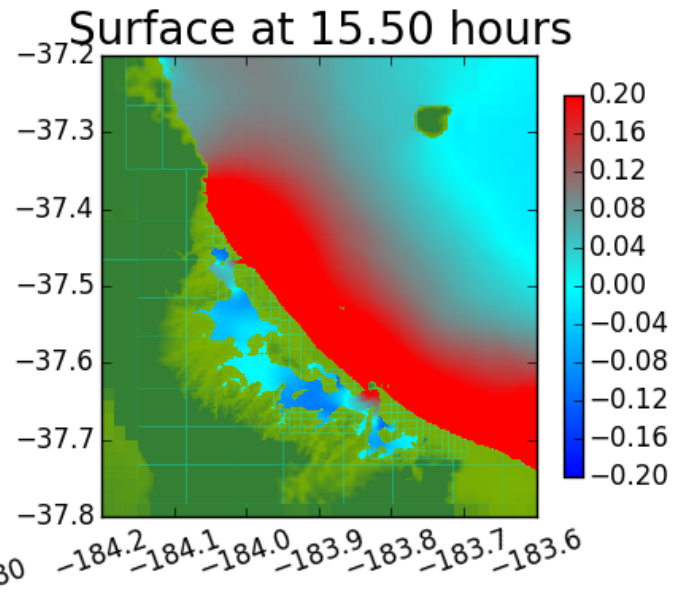


Elapsed time on quad-core MacBook: 3 hours

Tohoku to Tauranga Harbor, NZ with AMR

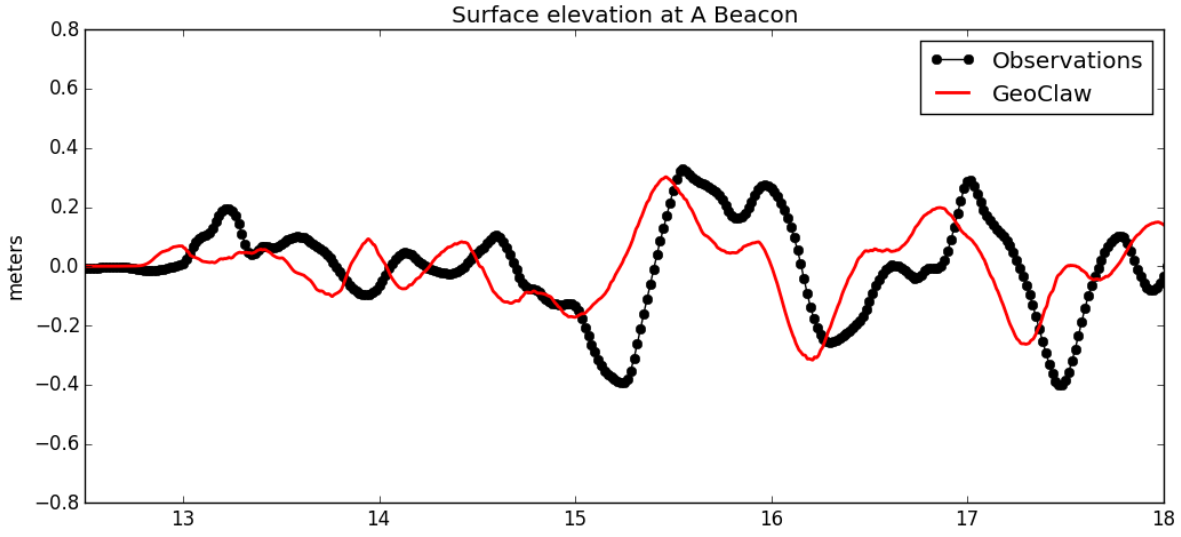


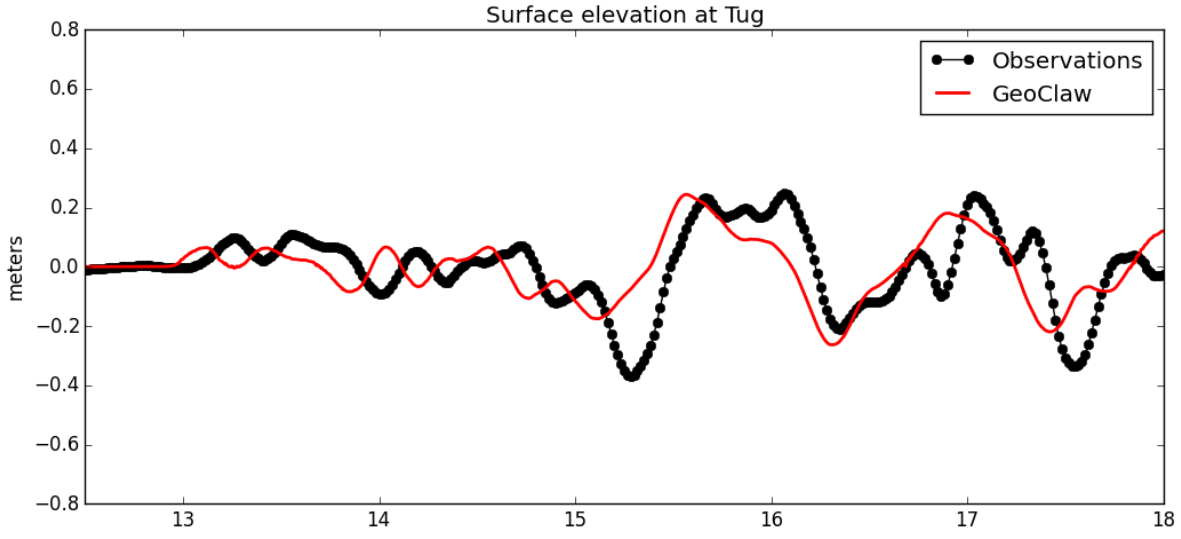




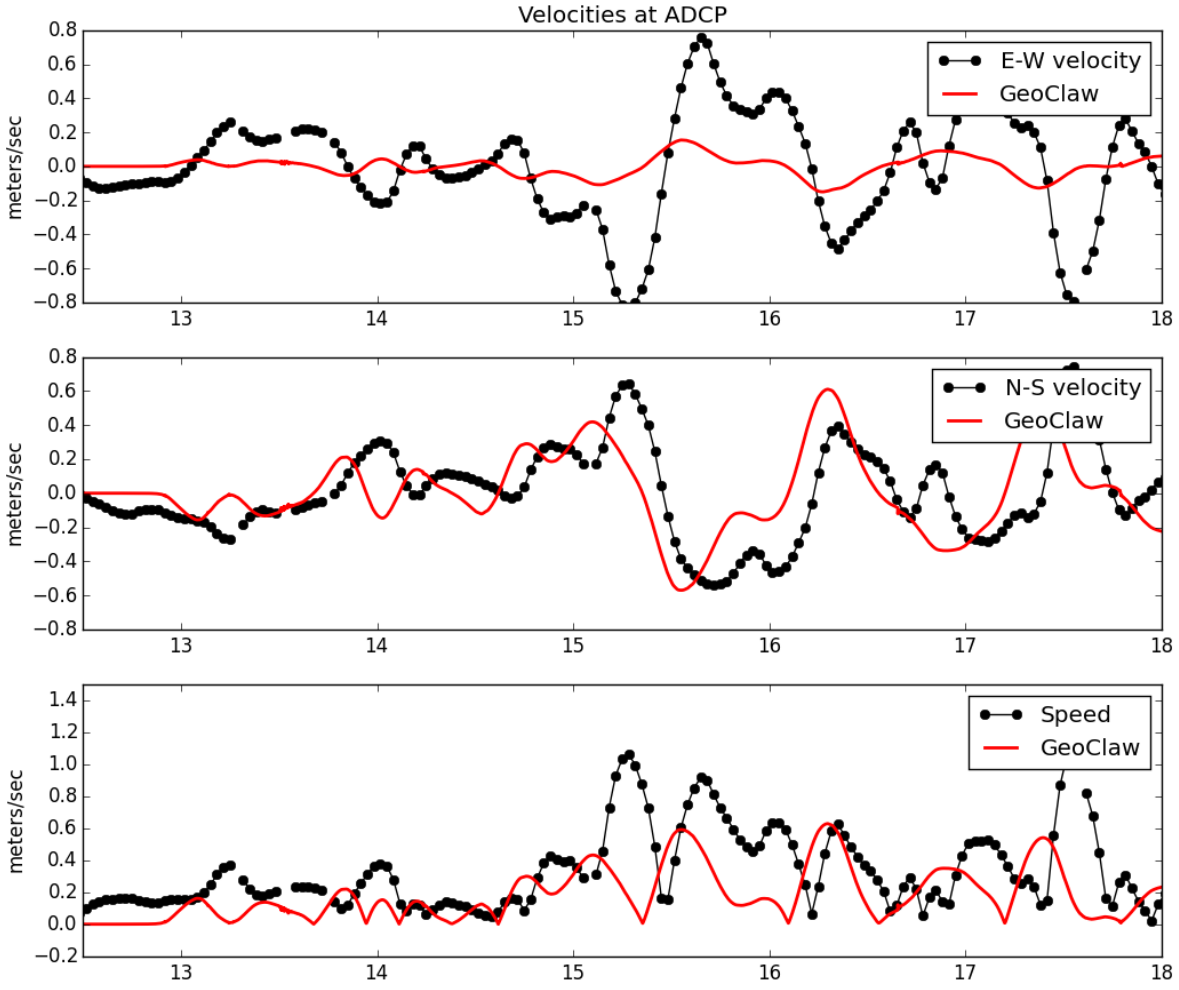
Elapsed time on quad-core MacBook: 3.5 hours

Tauranga Harbor gauges (First attempt!)

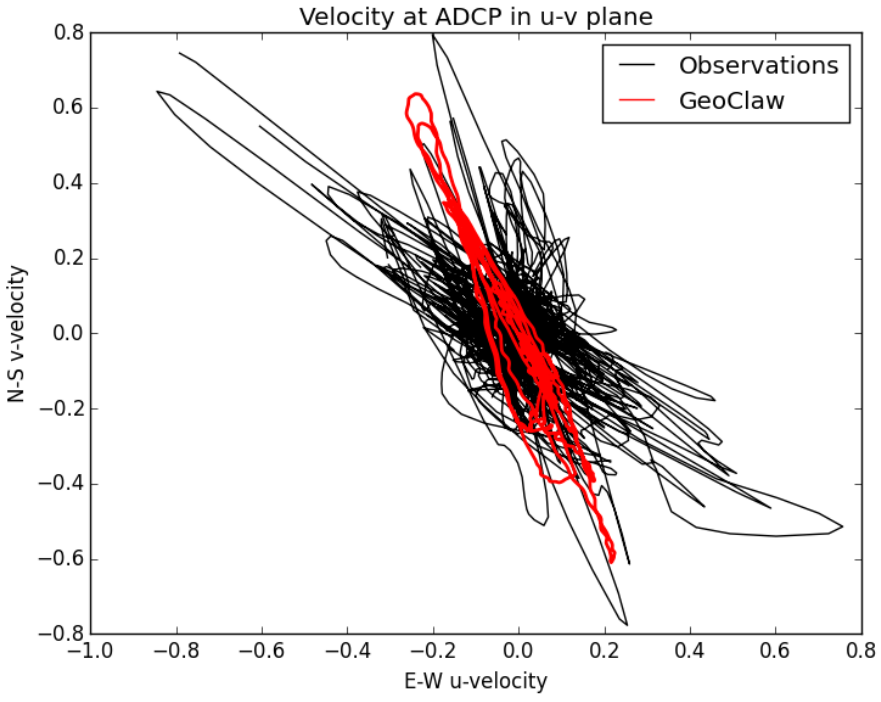




Tauranga Harbor gauges (First attempt!)



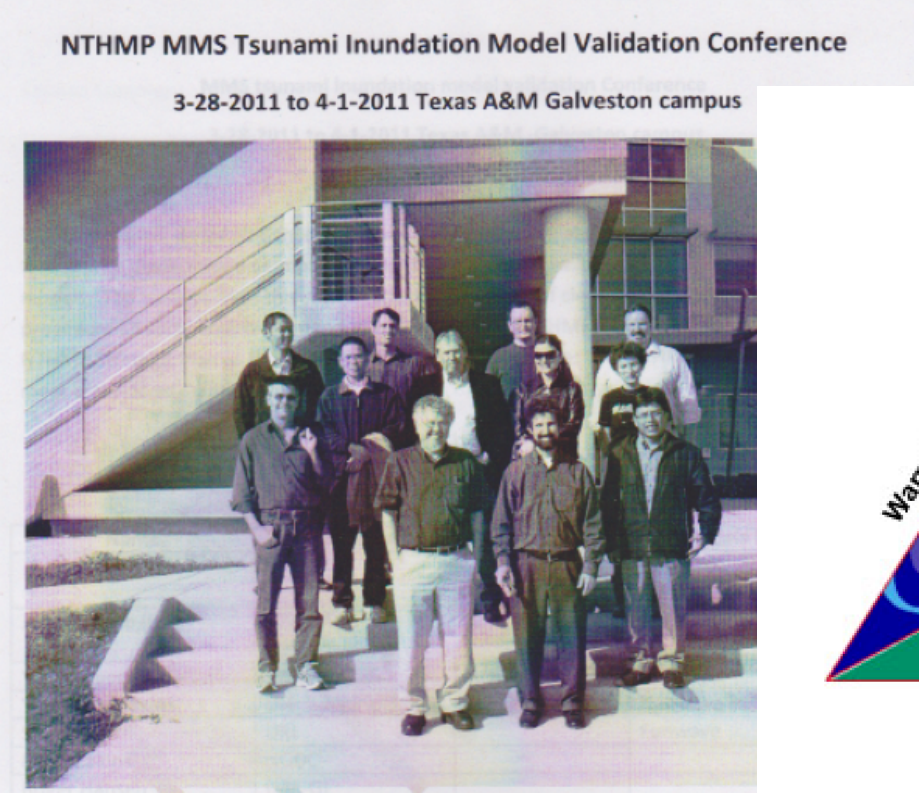
Velocities in u–v plane at ADCP

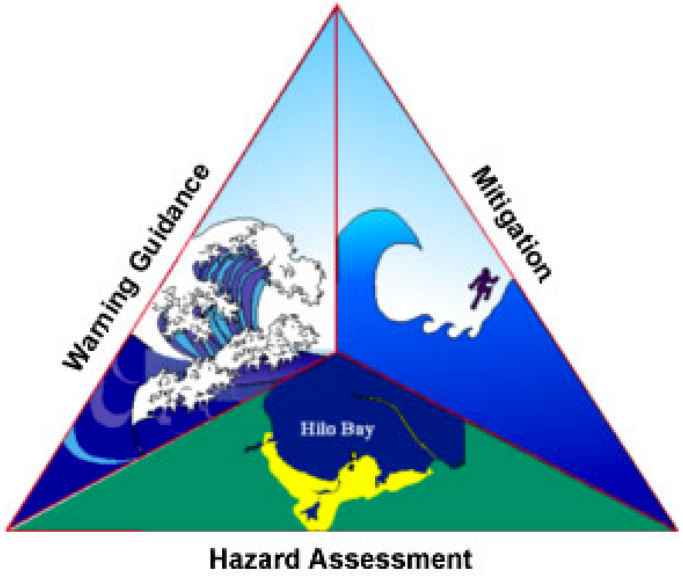


Preliminary GeoClaw simulation used $1''$ (30m) finest level.

More resolved simulations will be posted when available, see
http://www.geoclaw.org/benchmarks/nthmp_currents_2015

National Tsunami Hazard Mitigation Program





Benchmark data can now be found at
github.com/rjleveque/nthmp-benchmark-problems

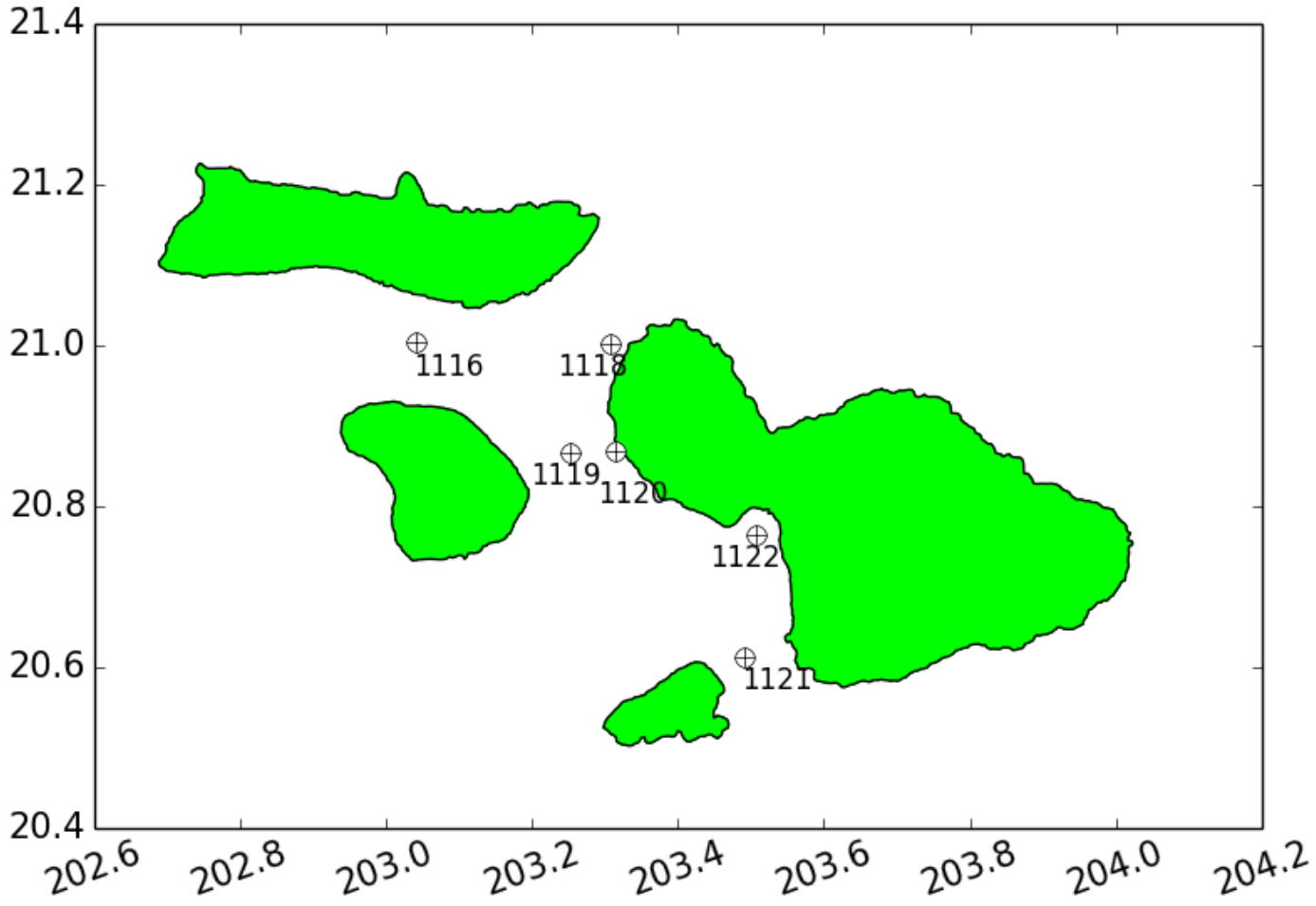
Paper:

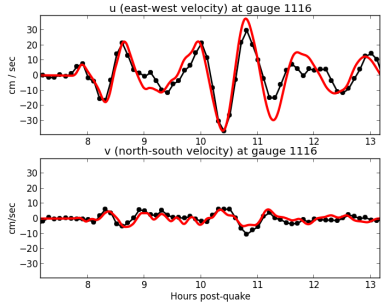
M.E.M. Arcos & RJL, *Validating Velocities in the GeoClaw Tsunami Model using Observations Near Hawaii from the 2011 Tohoku Tsunami*, PAGEOPH Special Issue, 2015,
http://dx.doi.org/10.1007/s00024-014-0980-y

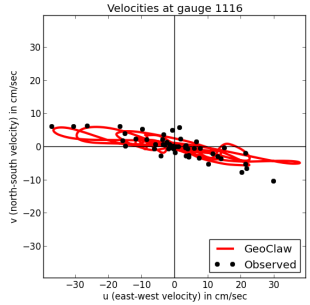
Code and data:

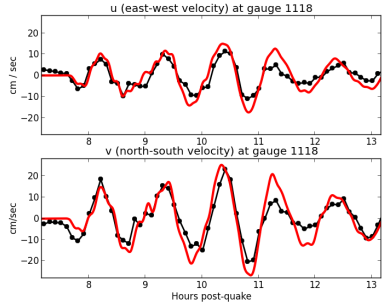
- Available on Github:
  https://github.com/rjleveque/tohoku2011-paper2
- Published on Zenodo with DOI **10.5281/zenodo.12185**

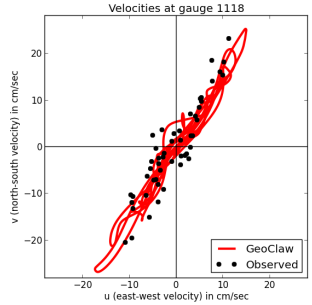
Current meters in channels

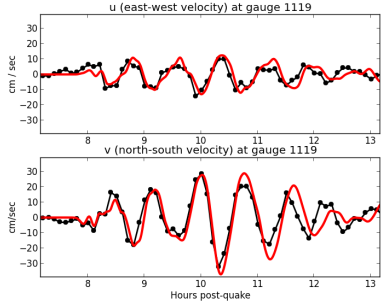


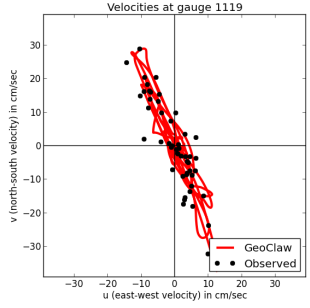

u (east-west velocity) at gauge 1116
cm / sec
v (north-south velocity) at gauge 1116
cm/sec
Hours post-quake

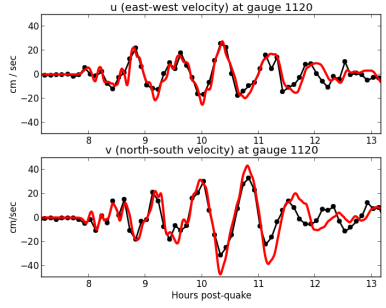

Velocities at gauge 1116
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed

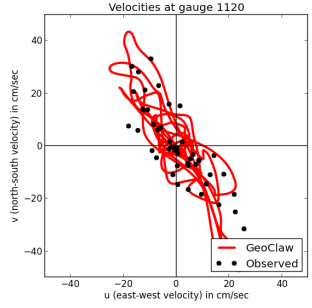

u (east-west velocity) at gauge 1118
cm / sec
v (north-south velocity) at gauge 1118
cm/sec
Hours post-quake

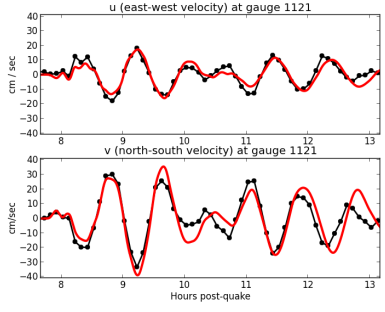

Velocities at gauge 1118
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed

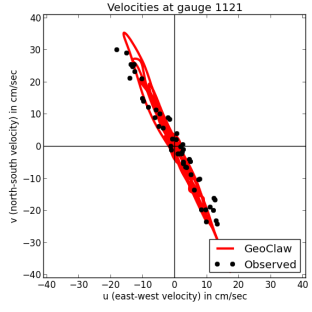

u (east-west velocity) at gauge 1119
cm / sec
v (north-south velocity) at gauge 1119
cm/sec
Hours post-quake

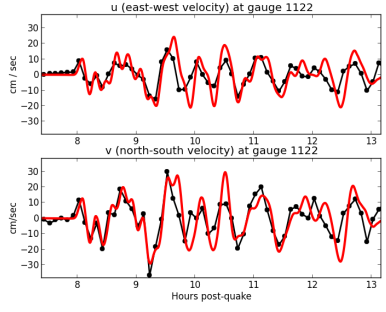

Velocities at gauge 1119
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed

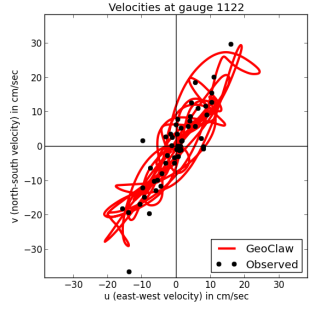

u (east-west velocity) at gauge 1120
cm / sec
v (north-south velocity) at gauge 1120
cm/sec
Hours post-quake


Velocities at gauge 1120
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed


u (east-west velocity) at gauge 1121
cm / sec
v (north-south velocity) at gauge 1121
cm/sec
Hours post-quake


Velocities at gauge 1121
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed

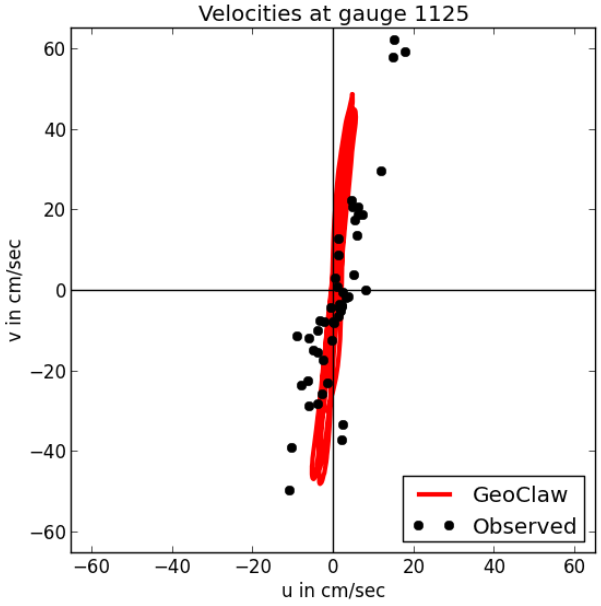

u (east-west velocity) at gauge 1122
cm / sec
v (north-south velocity) at gauge 1122
cm/sec
Hours post-quake

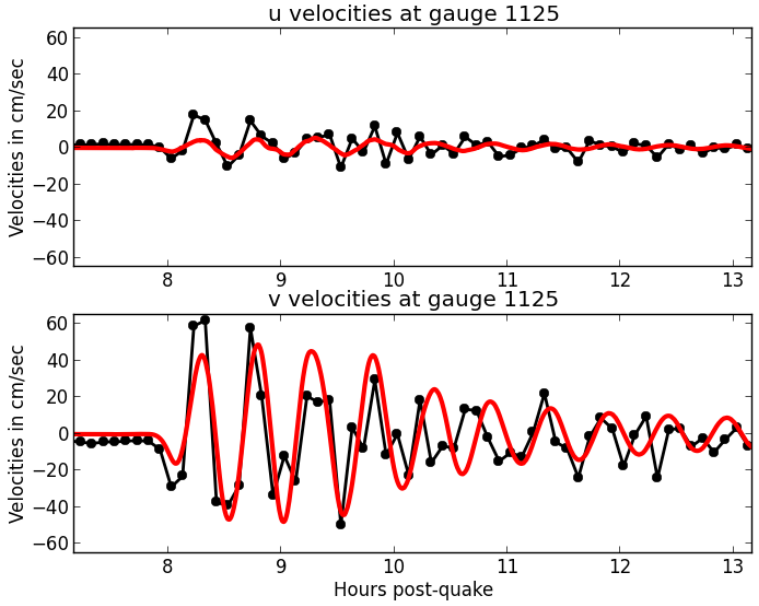

Velocities at gauge 1122
v (north-south velocity) in cm/sec
u (east-west velocity) in cm/sec
GeoClaw
Observed

Hilo Harbor Approach

19.29 m depth, 15 sensors from 2.59 to 16.58 m.

Currents are N/S in approach to harbor





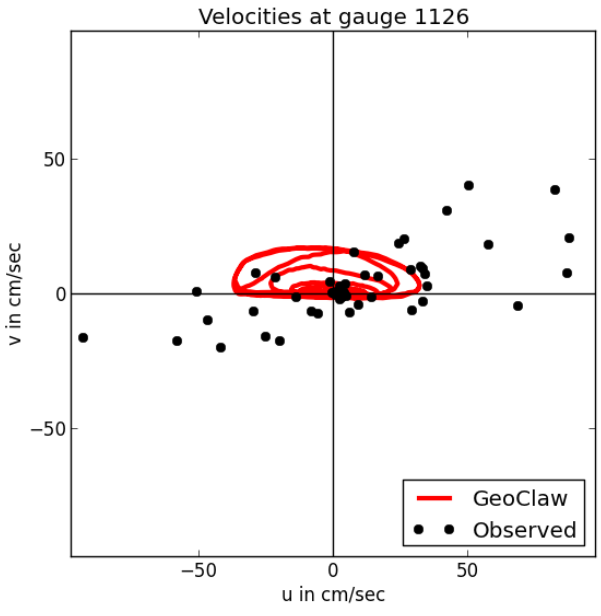
Hilo Harbor gauge near seawall

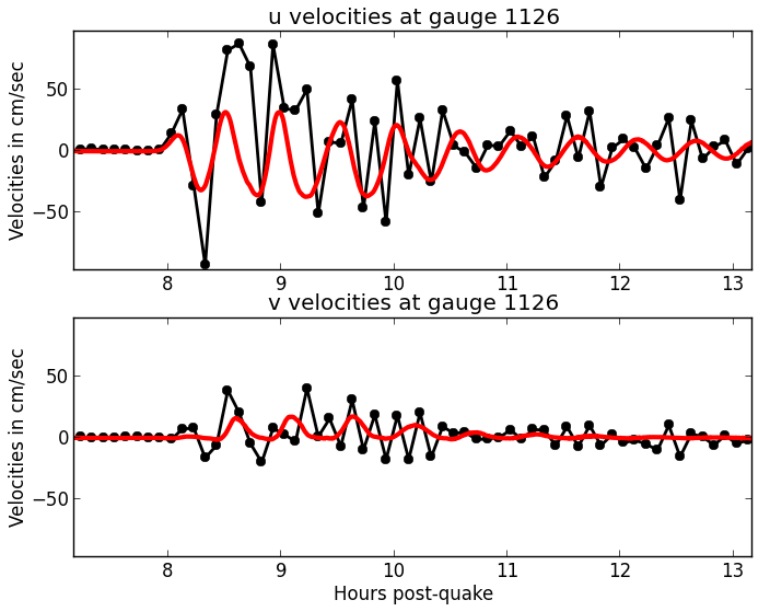
12.5 m depth, 9 sensors from 1.74 to 9.75 m.

Currents are roughly E/W.

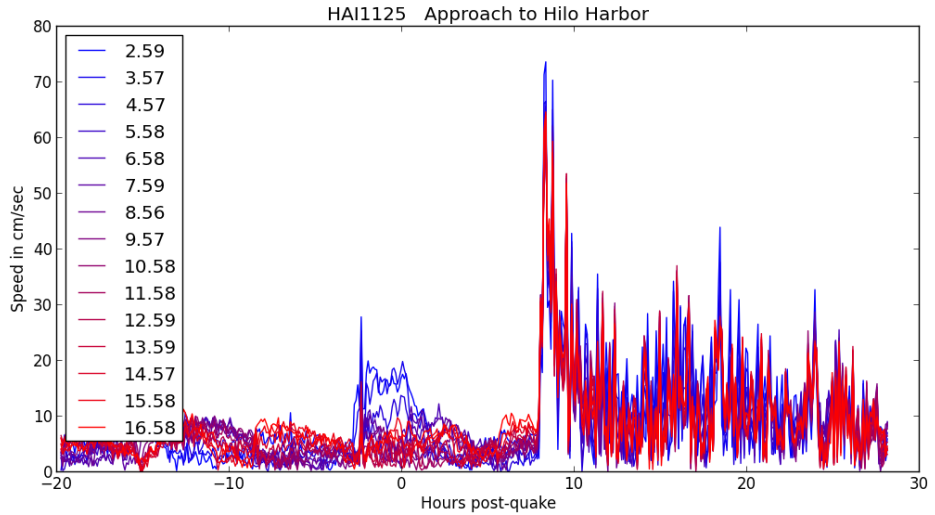
Station in shallow water and close to sea wall.

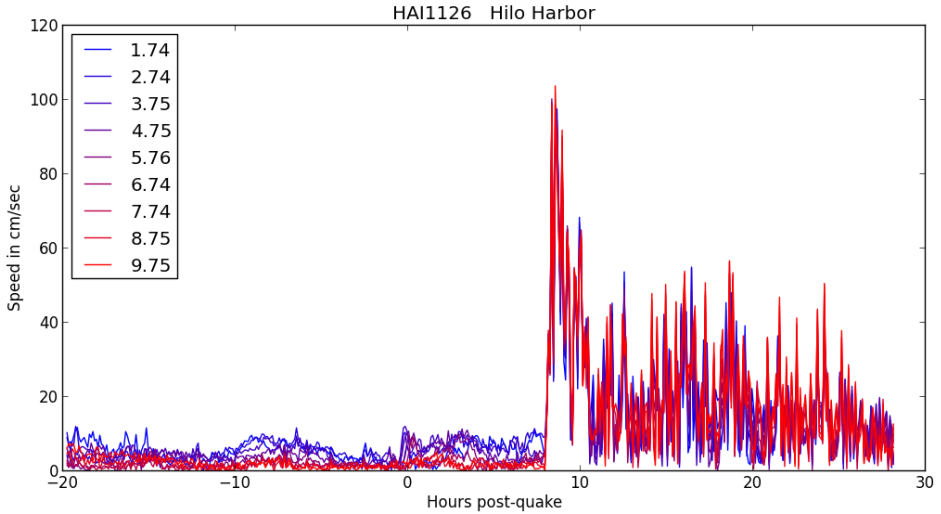
May be very sensitive to local bathymetry, currents, friction.





Raw ADCP data (before depth-averaging, de-tiding)





Raw data and more plots:

http://faculty.washington.edu/rjl/pubs/tohoku2/

Summary of Benchmark results

Problem 1 (Vortex shedding)

Manning $n = 0.015$ better than 0.01. (friction only on cone)

Problem 2 (Hilo Harbor)

Reasonable numerical convergence

Comparison to ADCP results questionable

Problem 3 (Tauranga Harbour)

Very preliminary, full Pacific, too coarse, no tides

Problem 4 (Seaside Model)

No parameter study done

3D OpenFOAM model — Mike Motley, UW CEE

Problem 5: Not done.

For more results, see...

http://www.geoclaw.org/benchmarks/nthmp_currents_2015