# A Brief Overview of Computational Modeling for Multi-Hazards

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# Computational Modeling

CIG COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

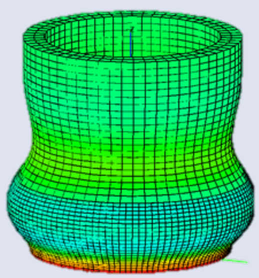
- Computational Modeling and Simulation
  - What is it?
  - Why do we use it?
- Computational Seismology
- Virtual California
- Computational Infrastructure for Geodynamics

# What is Computational Modeling?

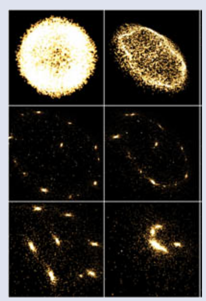
- Approximating the behavior of a system on a computer using a set of well defined rules
- The rules are often based on physics equations governing gravity, temperature, stress, pressure, magnetism, etc.
- Model details are specified through parameters, such as gravity
- Where we don't know exact rules we use probabilistic rules and run many simulations
- We can try using different rules, different parameters, to quickly experiment with the system

# What is Computational Modeling?

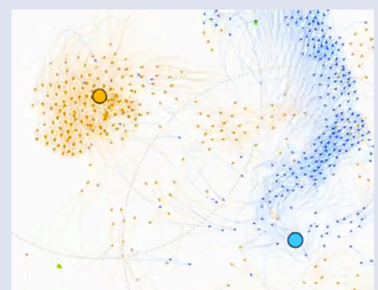
| | Finite Element | N-body | Agent | Cellular Automata |
|---|---|---|---|---|
| Connection | Nearby | None | None | Nearby |
| Interaction | Nearby | All | Nearby/ Environment | Nearby |
| Example Uses | Car engineering, seismology | Drug discovery, astrophysics | Social and economic simulation | Chemical/ biological patterns |



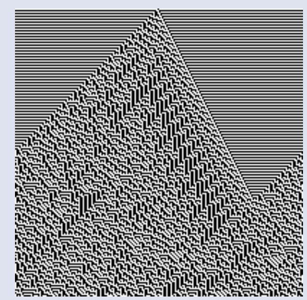
FE model of crushed cylinder (courtesy deal.II)



N-body simulation (courtesy nVidia)

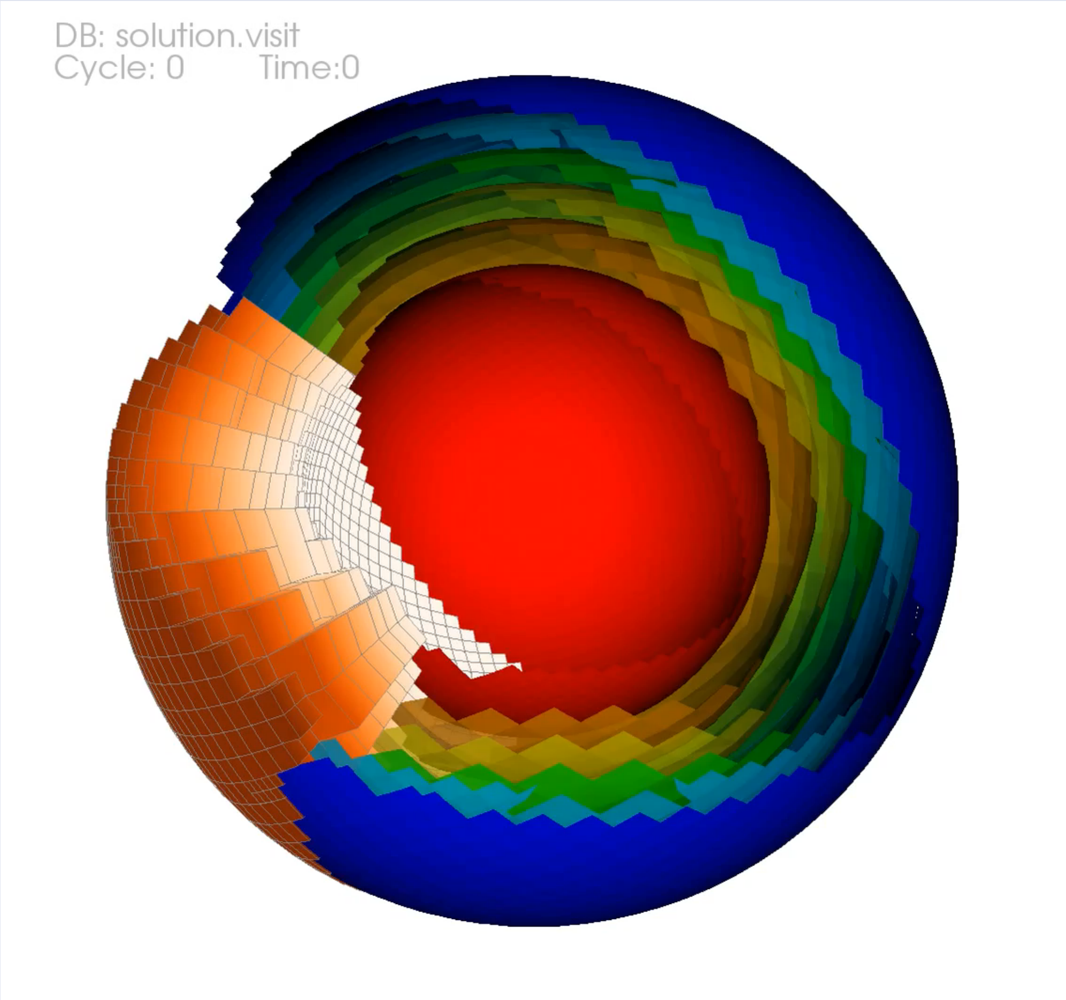


Swarming Simulation (courtesy Nils Seifert)



“Rule 89” cellular automata (courtesy Stanford Encyclopedia of Philosophy)

# Example: Finite Element

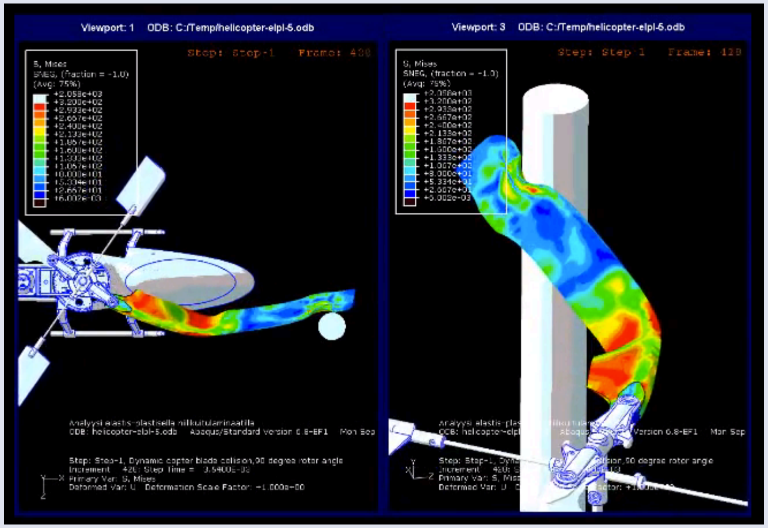



Finite element simulation of long term material flow in the Earth's mantle driven by temperature differences, modeled by ASPECT (Advanced Solver for Problems in Earth's ConvecTion)

(courtesy Wolfgang Bangerth)

# Why Computational Modeling?

- Many phenomenon occur too slowly/quickly to see, or occur on spaces too large/small
  – The Earth changes over thousands to millions of years, we can't wait to see what happens
- It can be too expensive or dangerous to perform real experiments
  – If you want to test a new airplane, you can't crash a few to see what happens
- There may be too many parameters to test with real world experiments



Helicopter collision stress analysis
Courtesy Matti Hyötyniemi

# Why Computational Modeling?

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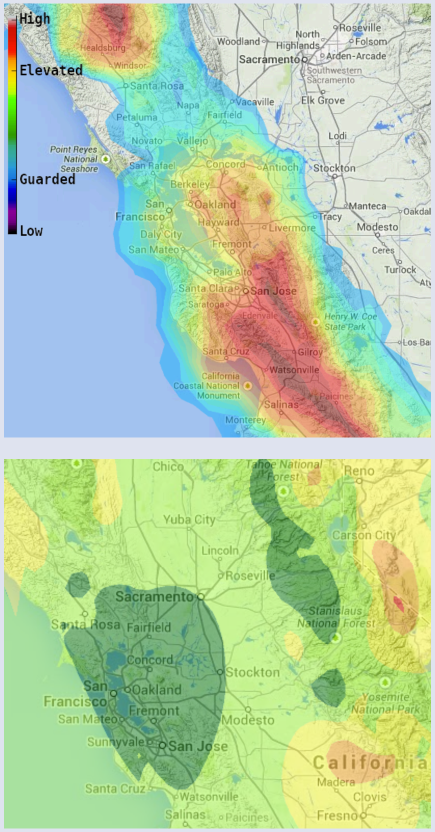
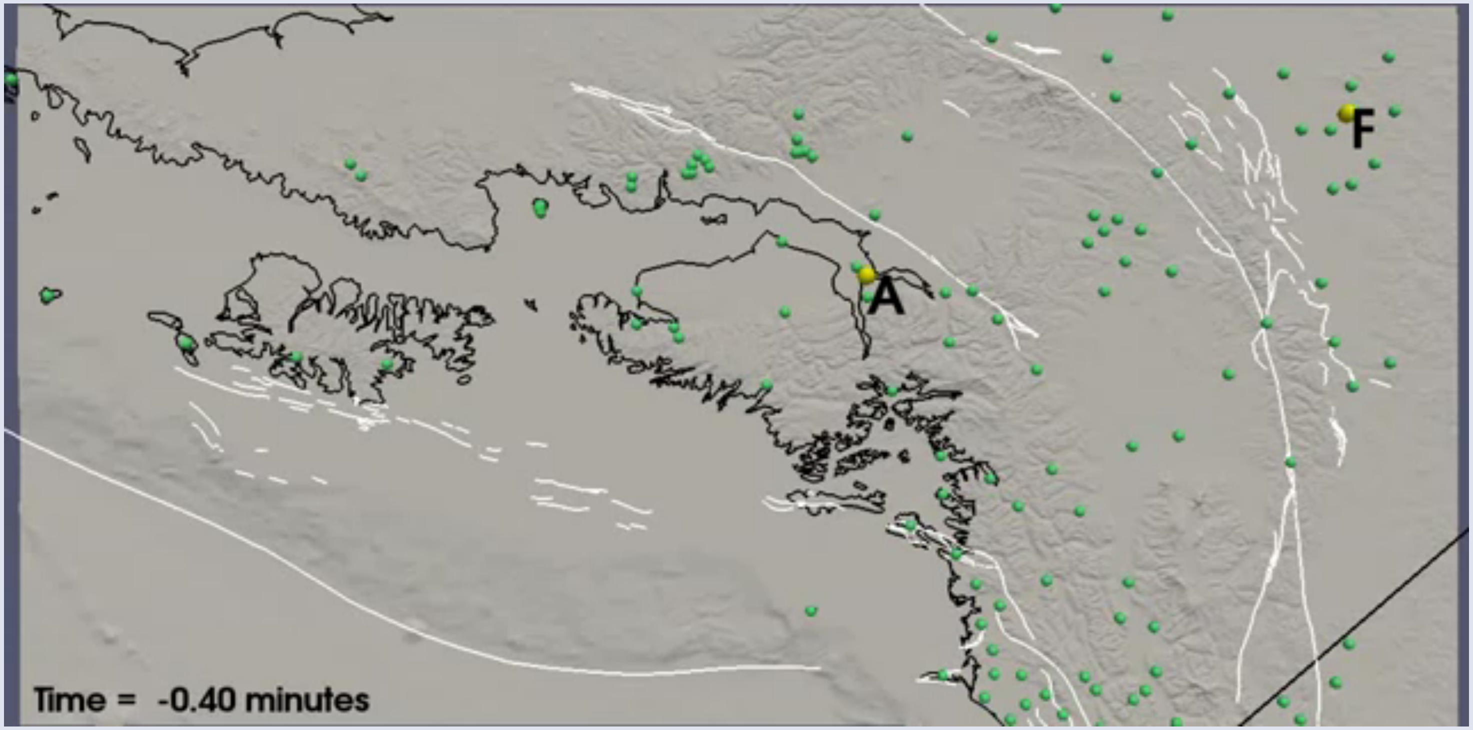
- In regards to multi-hazards
  - Expected earthquake shaking affects the building codes
  - Insurance rates are set based on expected damage
  - Simulations help predict the damage of a given earthquake/ tsunami/landslide, can help inform the response mechanisms



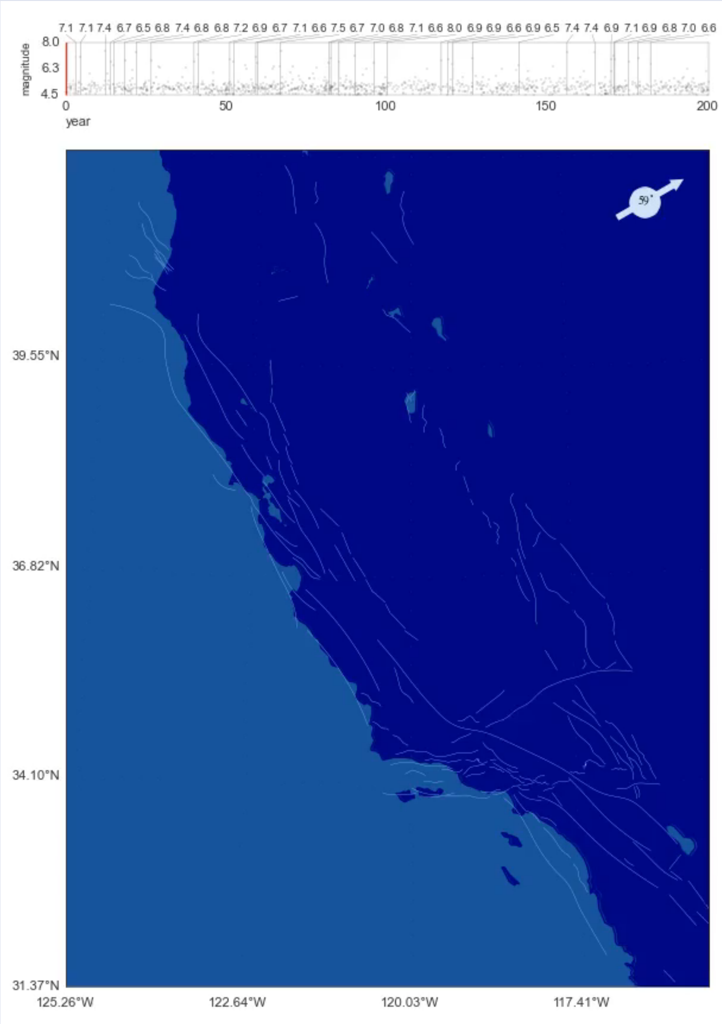

Earthquake and Wildfire Hazard Maps for CA (courtesy OpenHazards.com)

# Computational Seismology




This is a 1200 km by 600 km oblique view of southern Alaska; Anchorage (A) and Fairbanks (F) are labeled for reference. This simulation shows a surface view of earthquake wave propagation of the 1964 Alaska M9.2 earthquake. The 3D wave propagation code is called SPECFEM3D. Science credits: Carl Tape, Ulrika Cahayani, Emanuele Casarotti.

# Computational Seismology




InSAR and earthquake visualization from Virtual California. Simulation uses all major faults in California and runs for 200 year time period. Fault ruptures are shown as highlighted faults. Large ruptures are also visualized as InSAR interferogram fringe patterns. Lower left shows the cumulative magnitude-frequency distribution.

(courtesy Michael Sachs)

# VC

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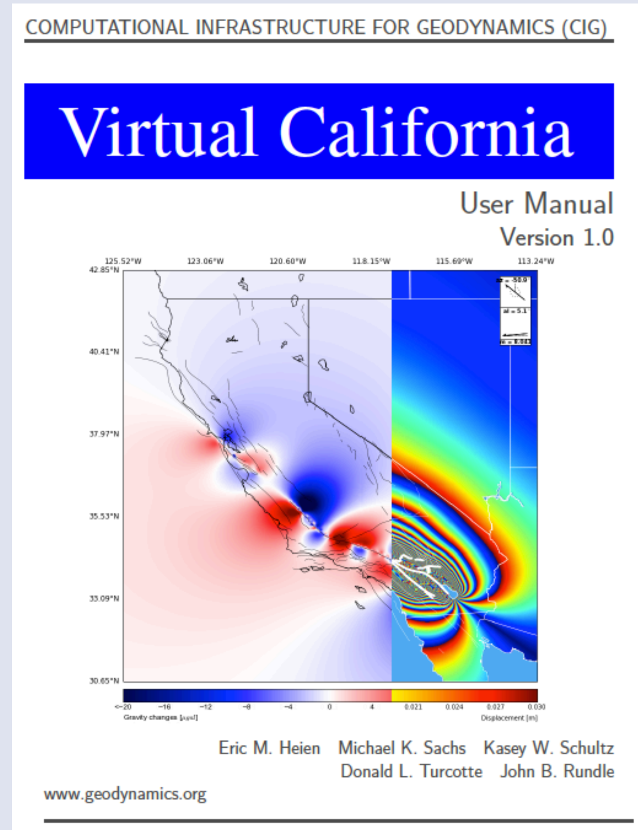
- Virtual California is an earthquake simulation program developed by Heien, Sachs, Rundle
- It combines an N-body simulation and cellular automata style simulation
  - Over long time periods, all pieces interact with each other
  - During earthquakes, only nearby pieces interact
  - Helps study long term earthquake cycle statistics and behavior




Now available at [http://geodynamics.org/cig/software/vc/](http://geodynamics.org/cig/software/vc/)

# CIG

- Computational Infrastructure for Geodynamics (CIG)
  - Based in Davis, CA, funded by NSF (National Science Foundation)
  - http://geodynamics.org/
- Many researchers write computer programs to study earthquakes, tsunami, landslides, other phenomenon
- CIG gathers and maintain these programs for reuse by other researchers
  - Avoid reinventing the wheel
  - Help researchers use cutting edge techniques
- CIG provides infrastructure, documentation, support for users and developers

Thank you

Any questions?