A Support-Operator Method for Rupture Modeling

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Discretization Method

On a curvilinear mesh, form operators that obey a discrete analog of the adjoint relation between gradient and divergence. Based on the the Support Operator method of Shaskov.

Derivation

$$f(\xi) = \sum_{\alpha,\beta,\gamma=0}^{n} N_{\alpha\beta\gamma}(\xi) F_{\alpha\beta\gamma}$$

$$\nabla f = \frac{\partial f}{\partial \xi} \cdot \mathrm{J}^{-1}$$

$$(\mathrm{D}_i F)_{jkl} \approx \partial_i f(\xi = 0)$$ **One-point quadrature**

or

$$(\mathrm{D}_i F)_{jkl} \approx \frac{1}{V_{jkl}} \int_V \partial_i f \, dV$$ **Mean stress**

Adjoint Relation

$$\int_V f\partial_i w_i \, dV + \int_V w_i \partial_i f \, dV = \int_S f w_i \, dS_i$$

$$\sum_{j,k,l=1}^{m,n,p} F_{jkl}(\mathcal{D}_i W_i)_{jkl} = \sum_{j,k,l=1}^{m-1,n-1,p-1} -(\mathrm{D}_i F)_{jkl}(W_i)_{jkl}$$

PML Absorbing Boundaries

$$\dot{g}_{ij} + d_j g_{ij} = \partial_j v_i$$

$$w_{ij} = \lambda \delta_{ij} \sum_k g_{kk} + \mu (g_{ij} + g_{ji})$$

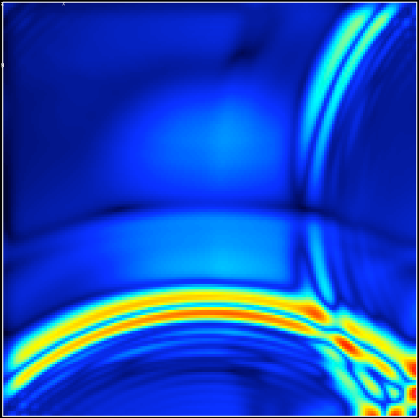
$$\dot{p}_{ij} + d_j p_{ij} = \partial_j w_{ij}$$

$$f_j = \sum_i \dot{p}_{ij}$$

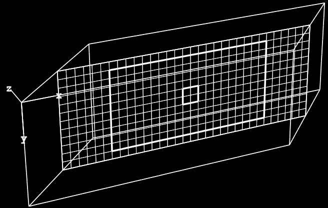
$$\dot{v}_i = \frac{f_i}{m}$$

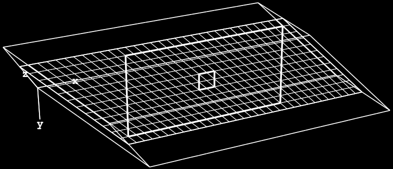
note: summation convention not used here.

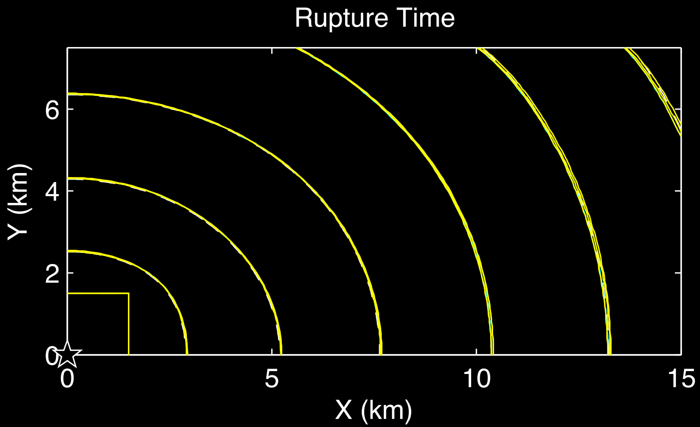
Point Source



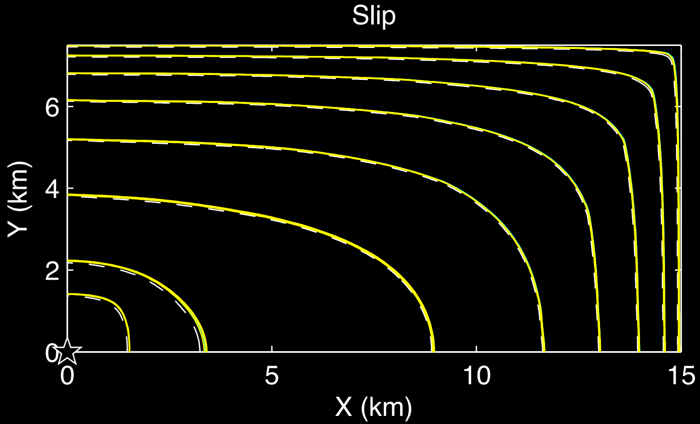
SCEC Rupture Validation Workshop Problem ver. 3







white: 50m rectangular, blue: 100m rectangular, yellow: 100m sheared



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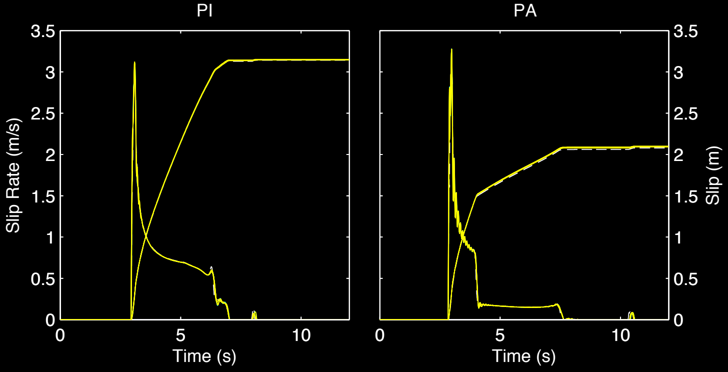
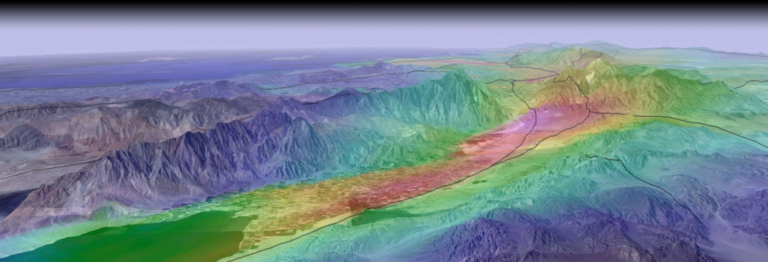


white: 50m rectangular, blue: 100m rectangular, yellow: 100m sheared
PI: mode II point, PA: mode III point

Challenges for large problems

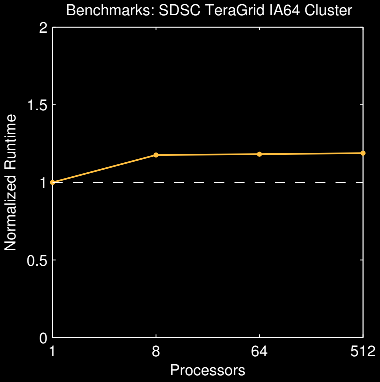
- Large propagation distances
- Non-planar faults
- Topography
- Spatial resolution for rupture dynamics
- Frequency resolution for seismic hazard



Portability

- Linux: Intel, GNU Fortran 95, MPICH2
- Solaris: Sun Workshop Fortran 95
- SDSC DataStar: IBM Power4+, XL Fortran
- SDSC Teragrid: IA64, Intel Fortran 95, MPICH-GM
- SDSU Babieca Cluster: Intel Xeon, PGI Fortran 95, MPICH-GM

Scalability



Weak scaling where problem size is proportional to number of processors, and perfect scaling is a horizontal line.

Summary of Capabilities

- Support-Operator method on curvilinear meshes
- Rupture Dynamics on non-planar faults
- PML absorbing boundary
- Portable and scalable

Future work

- Attenuation