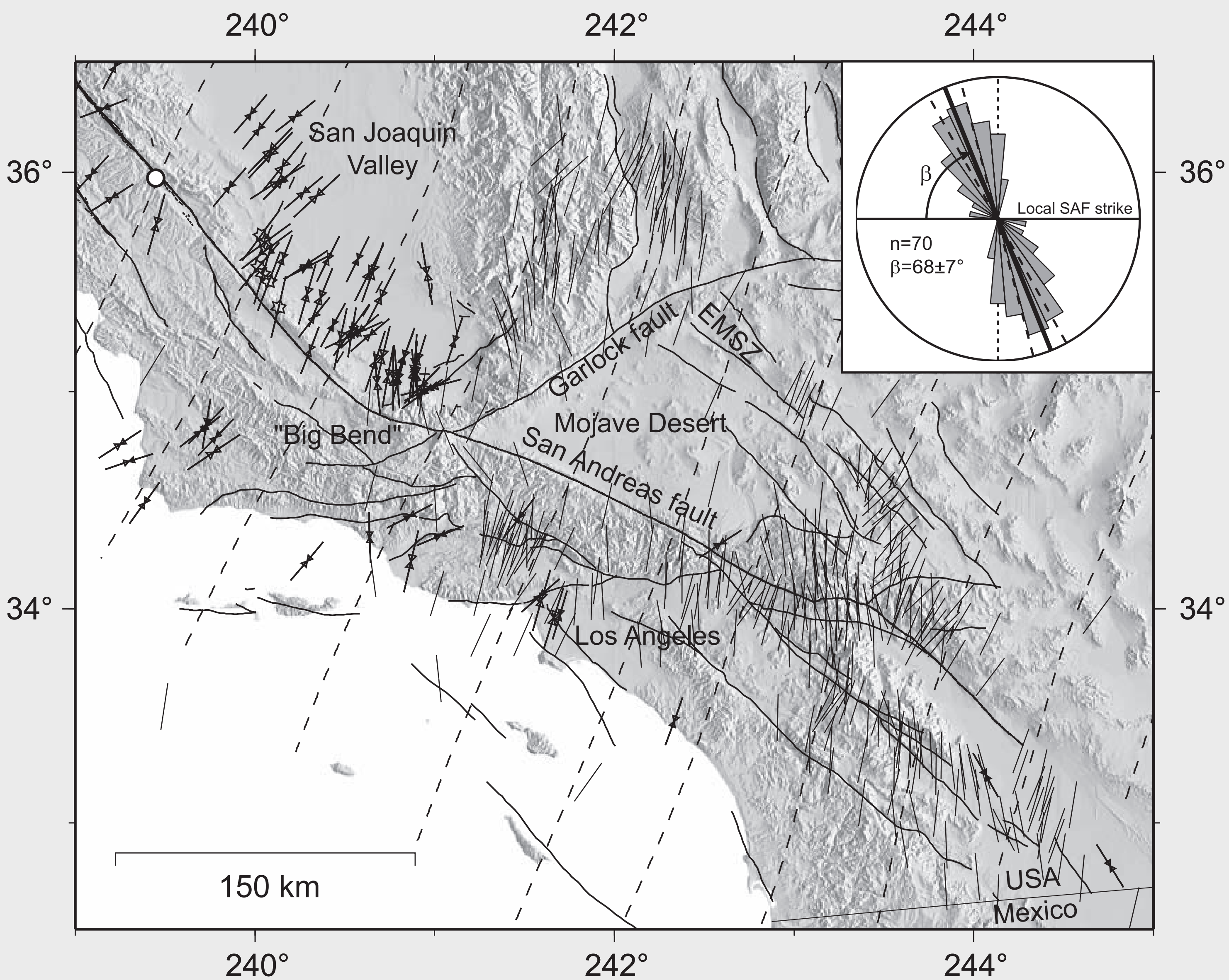
Dynamic Rupture Along the San Gorgonio Pass Section of the San Andreas Fault:

The effects of fault geometry and stress/traction input

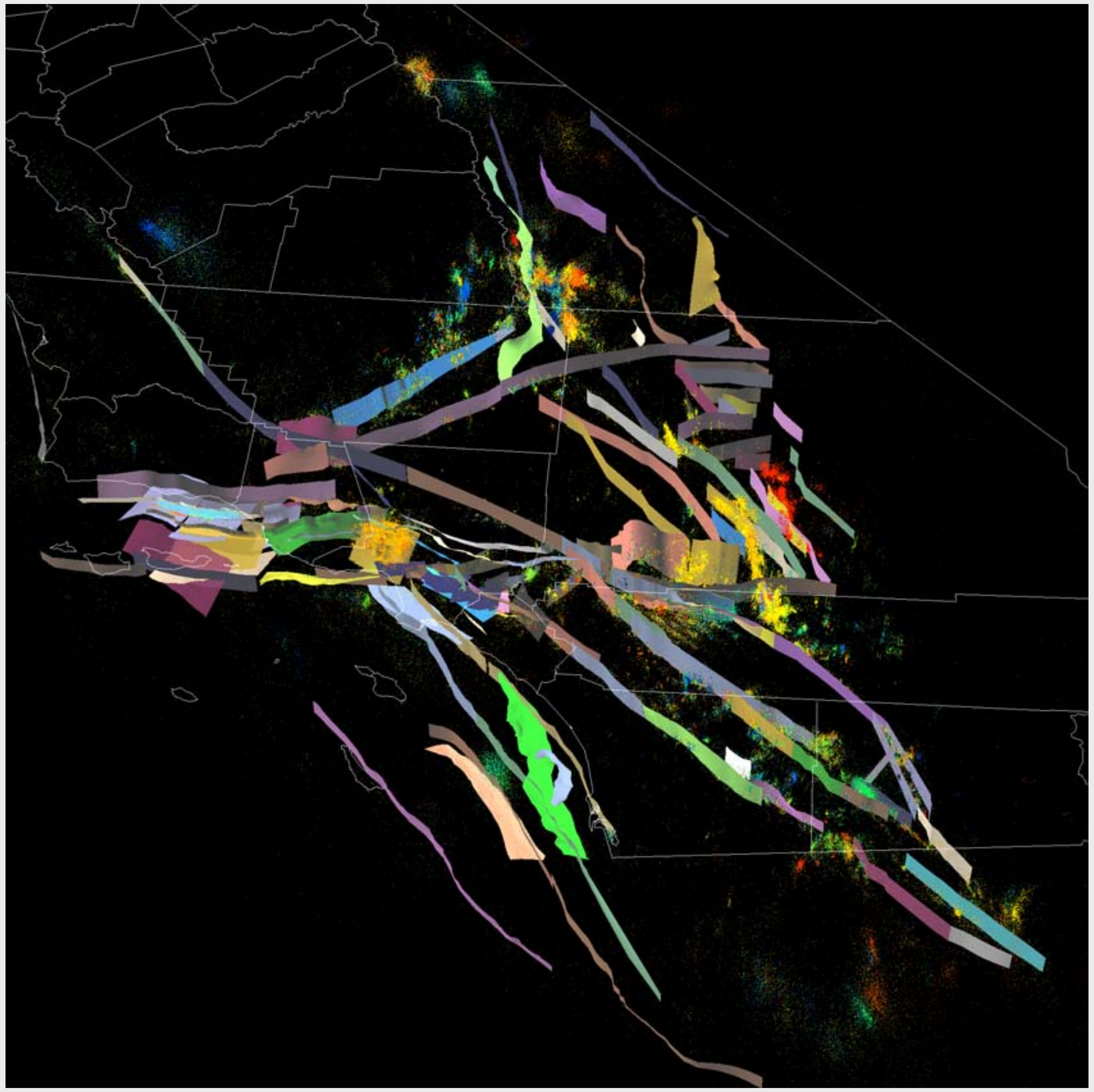
[1]Zheqiang Shi, [1]Shuo Ma, [1]Steven M. Day and [2]Geoffrey P. Ely

[1]Department of Geological Sciences, San Diego State University
[2]Argonne National Laboratory

Observations of Stress Orientation



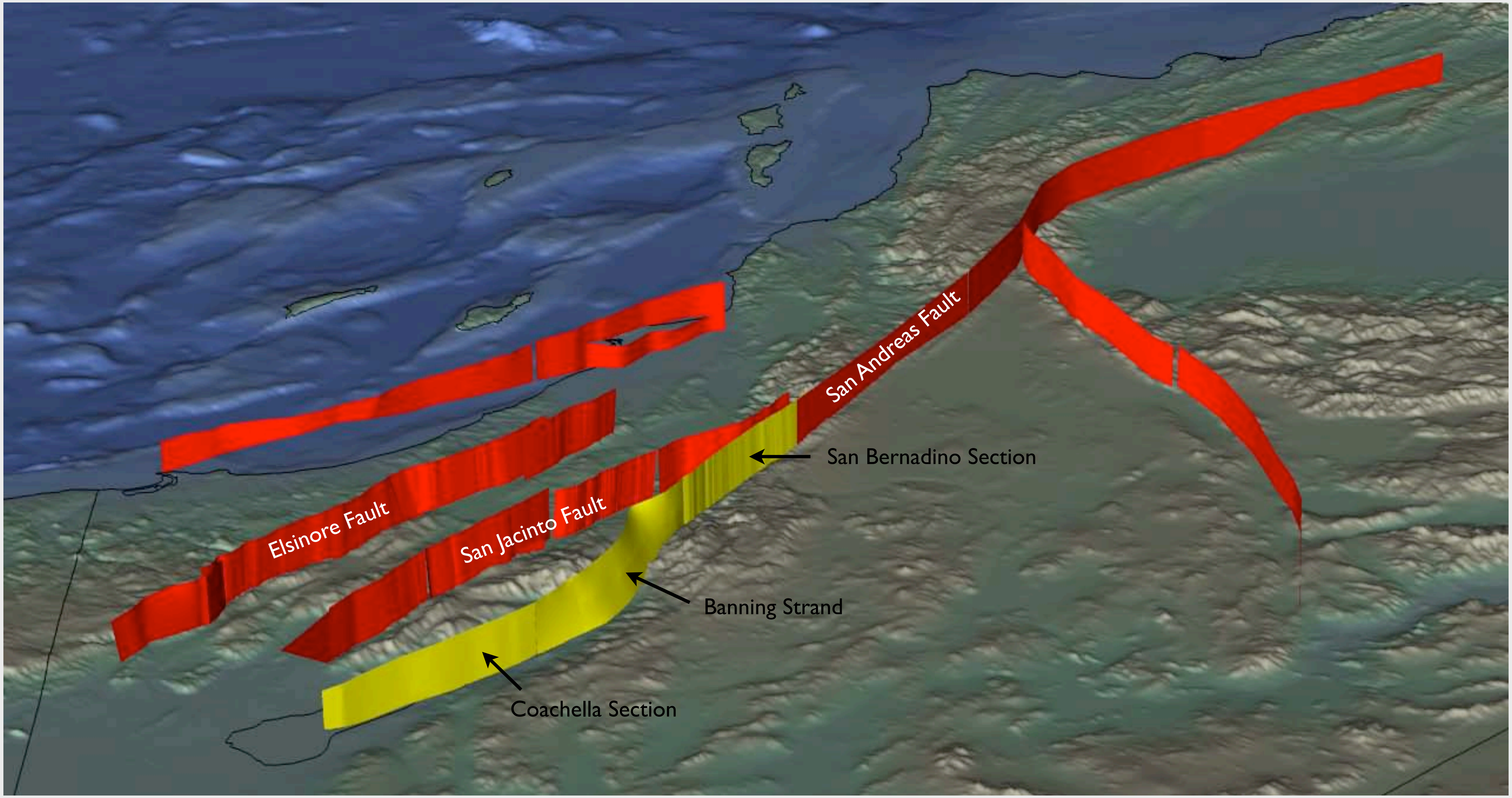
Townend and Zoback (2004)



SCEC CFM Version 4.0

S_{Hmax} determined from borehole breakouts, hydraulic fracturing experiments, focal mechanism inversions

Fault Geometry at the San Gorgonio Pass



3D Numerical Modeling of Dynamic Rupture

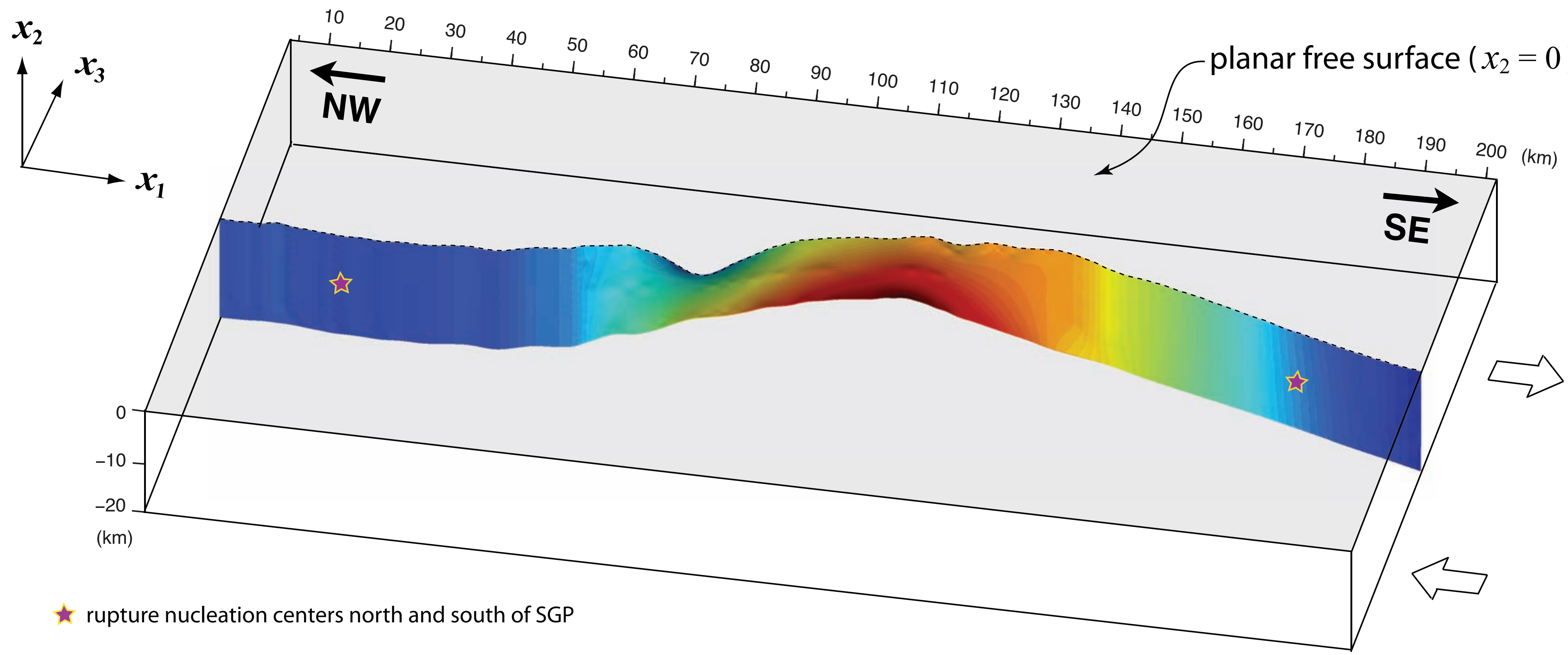


Table 1. Model parameters.

Parameter	Value
Material Properties	
Density ρ	3000 kg/m^3
P-wave speed c_d	6000 m/s
S-wave speed c_s	3464 m/s
Slip-weakening Friction	
Static friction coef.	0.4
Dynamic friction coef.	0.15
Characteristic slip distance L	0.1 m
Numerical Computation	
Grid size	100 m
Time step size	0.008 sec

One simulation of 60-sec rupture propagation takes ~32 mins using 5,120 processors on TeraGrid Kraken.

Hexahedral mesh ~750 million cells SORD (Ely et al., 2008, 2009, 2010)

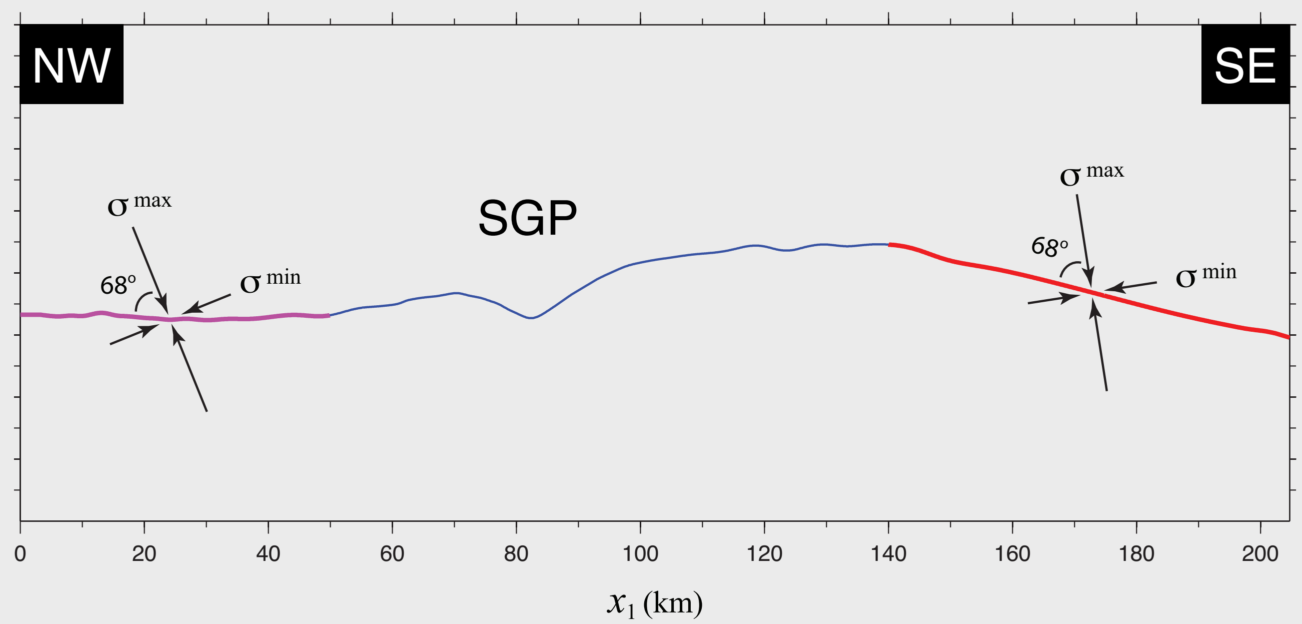
Two end-member sets of calculations:*

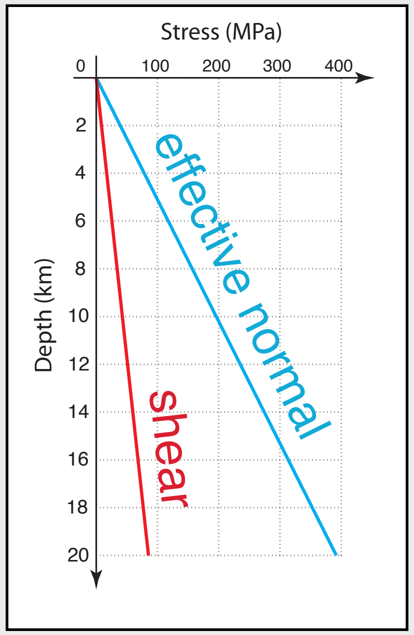
(1) Homogeneous volumetric stress with Drucker-Prager plasticity ("Set Stress")

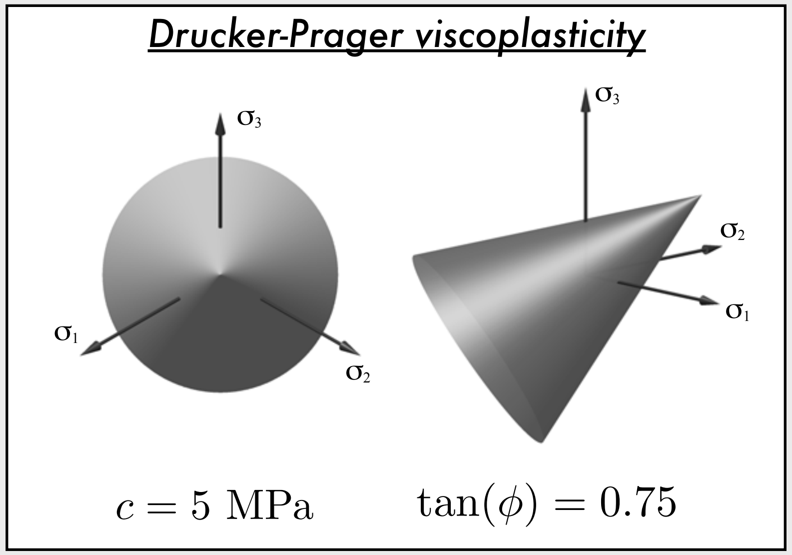
(2) Heterogeneous fault traction with pure elasticity ("Set Traction")

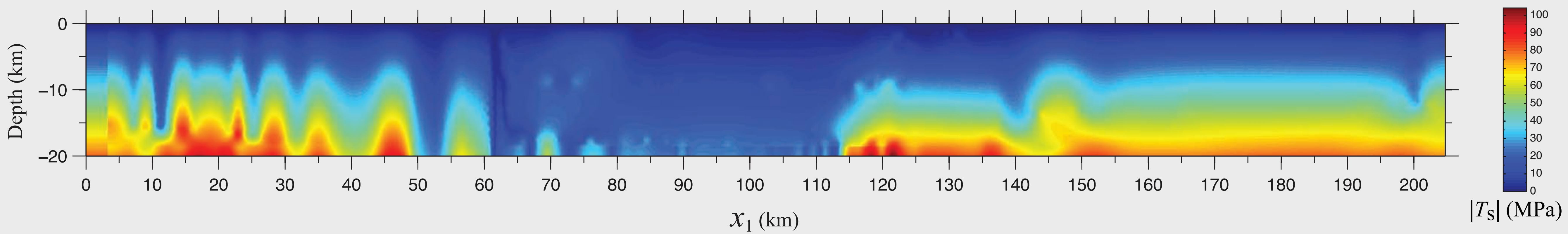
(* in terms of the influence of fault geometry on rupture dynamics)

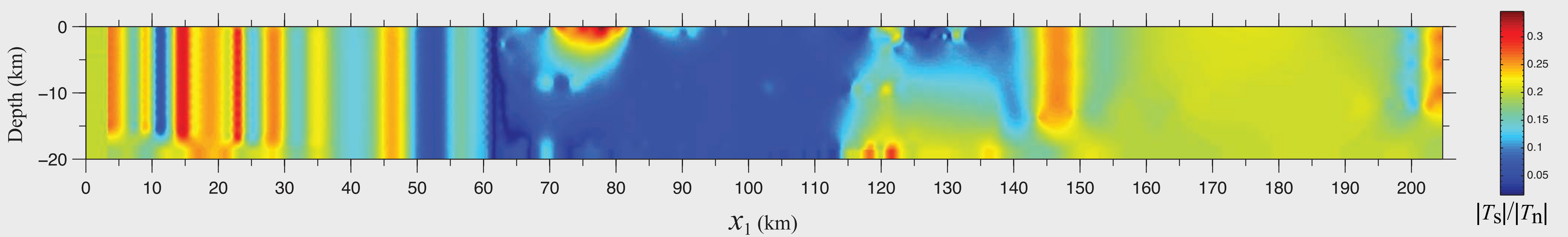
Simulation "Set Stress"





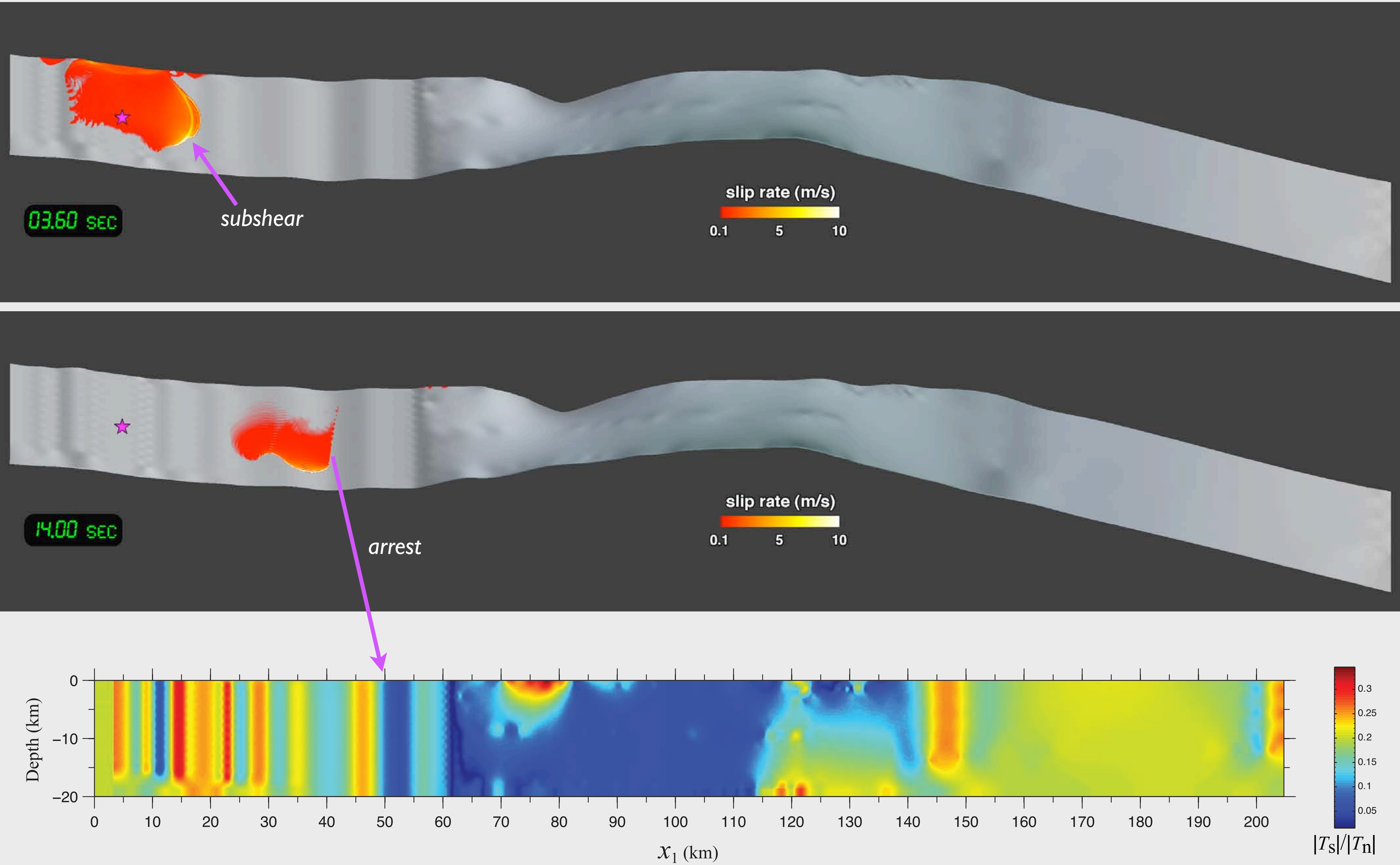






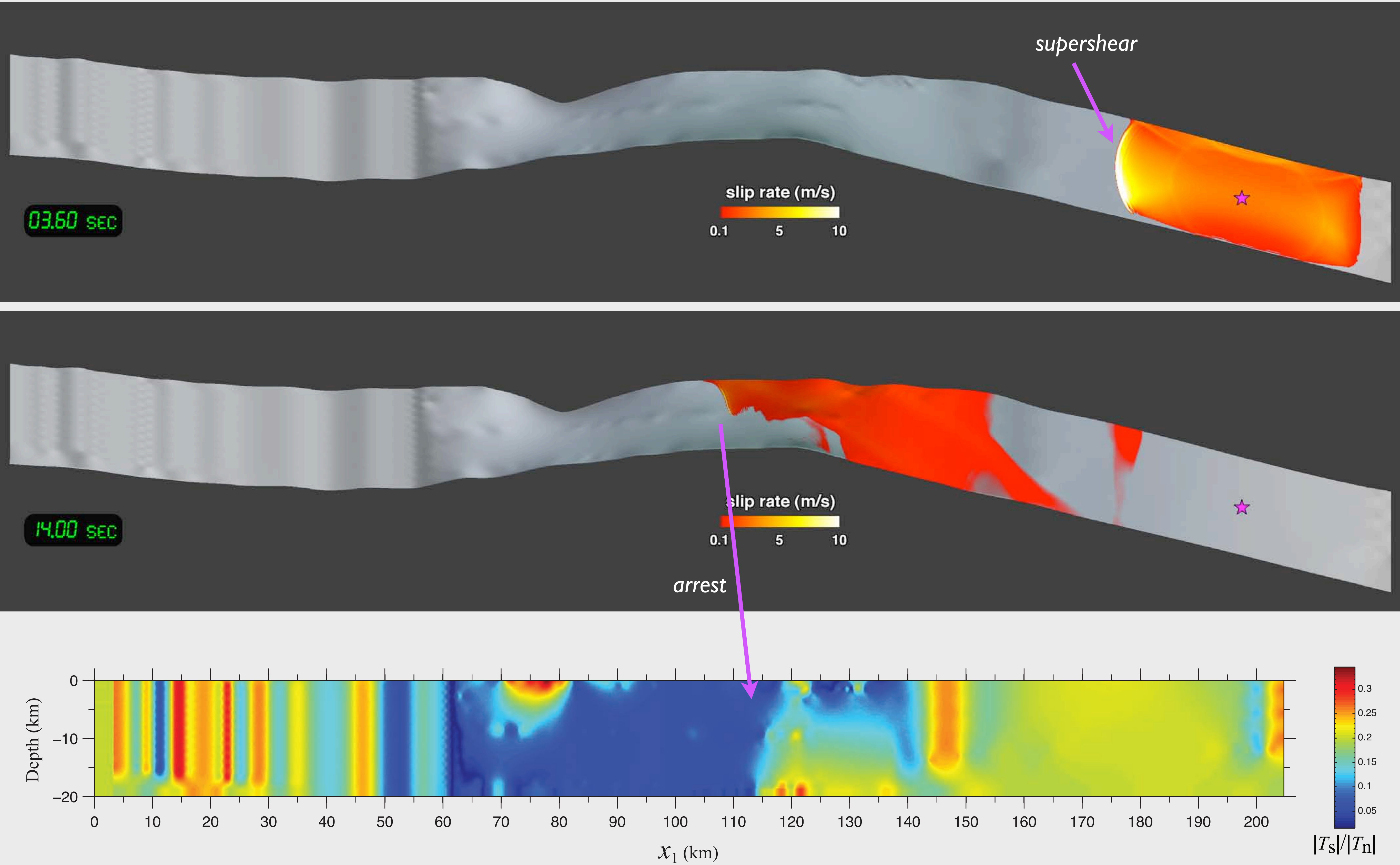
Simulation "Set Stress"

Propagation from north of SGP



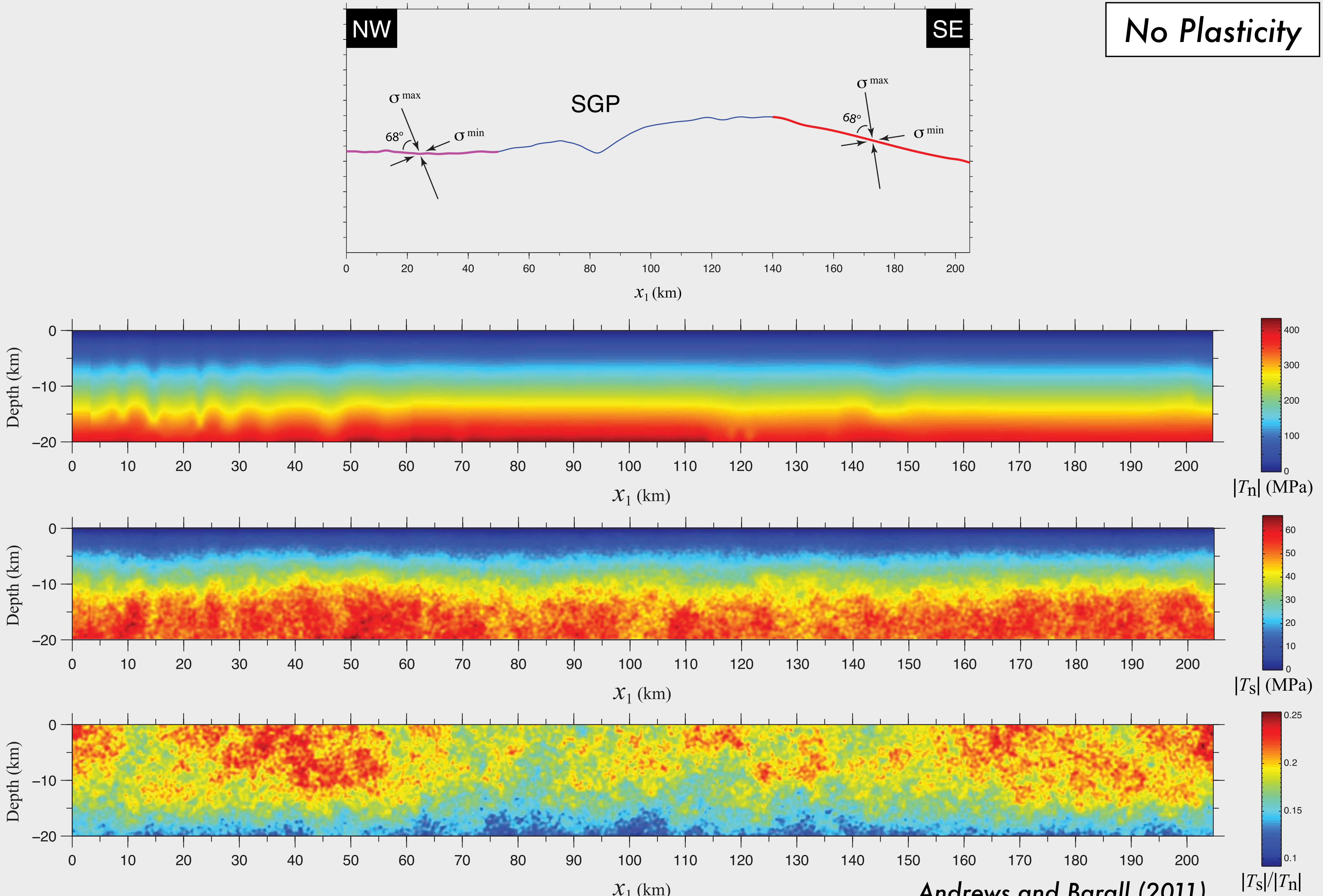
Simulation "Set Stress"

Propagation from south of SGP



Simulation "Set Traction"

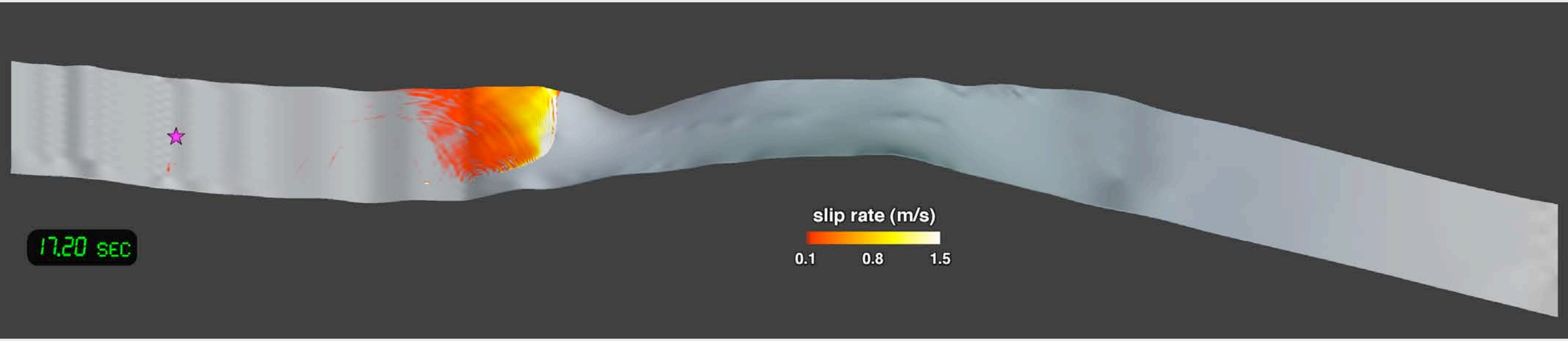
No Plasticity

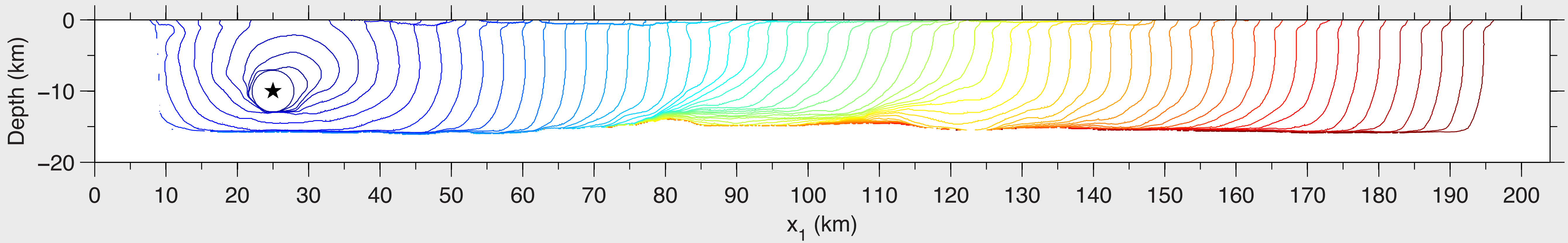


Andrews and Barall (2011)

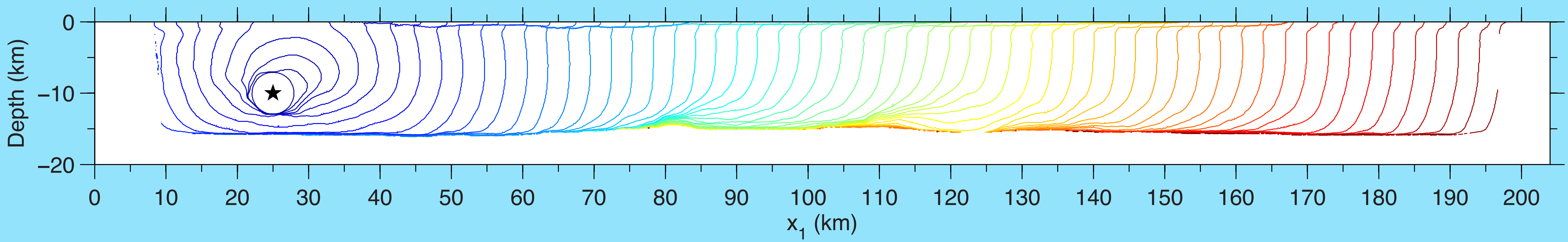
Simulation "Set Traction"

Propagation from north of SGP



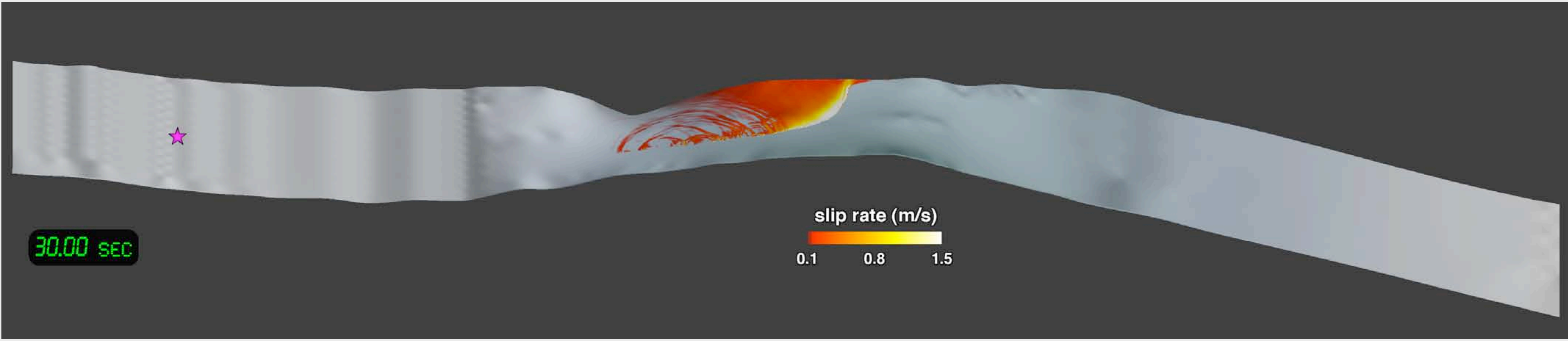


Planar fault

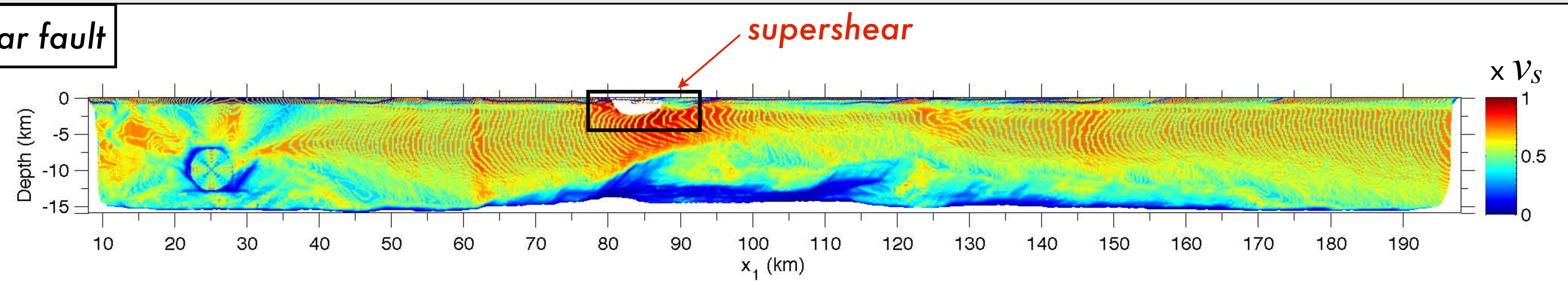


Simulation "Set Traction"

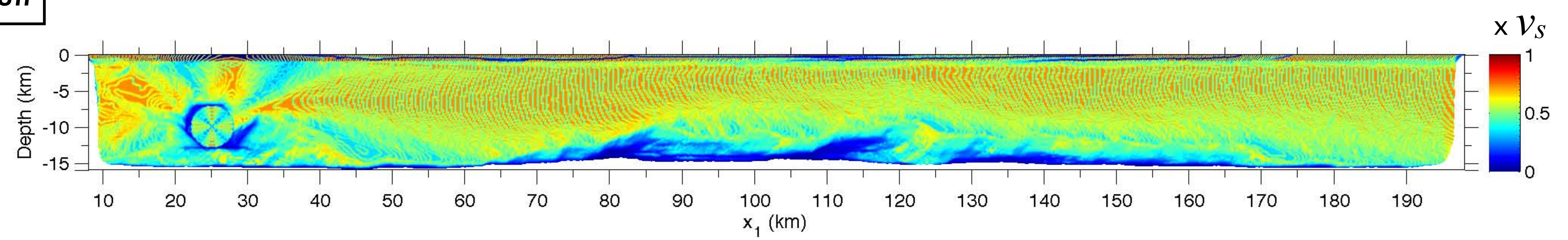
Propagation from north of SGP



Non-planar fault

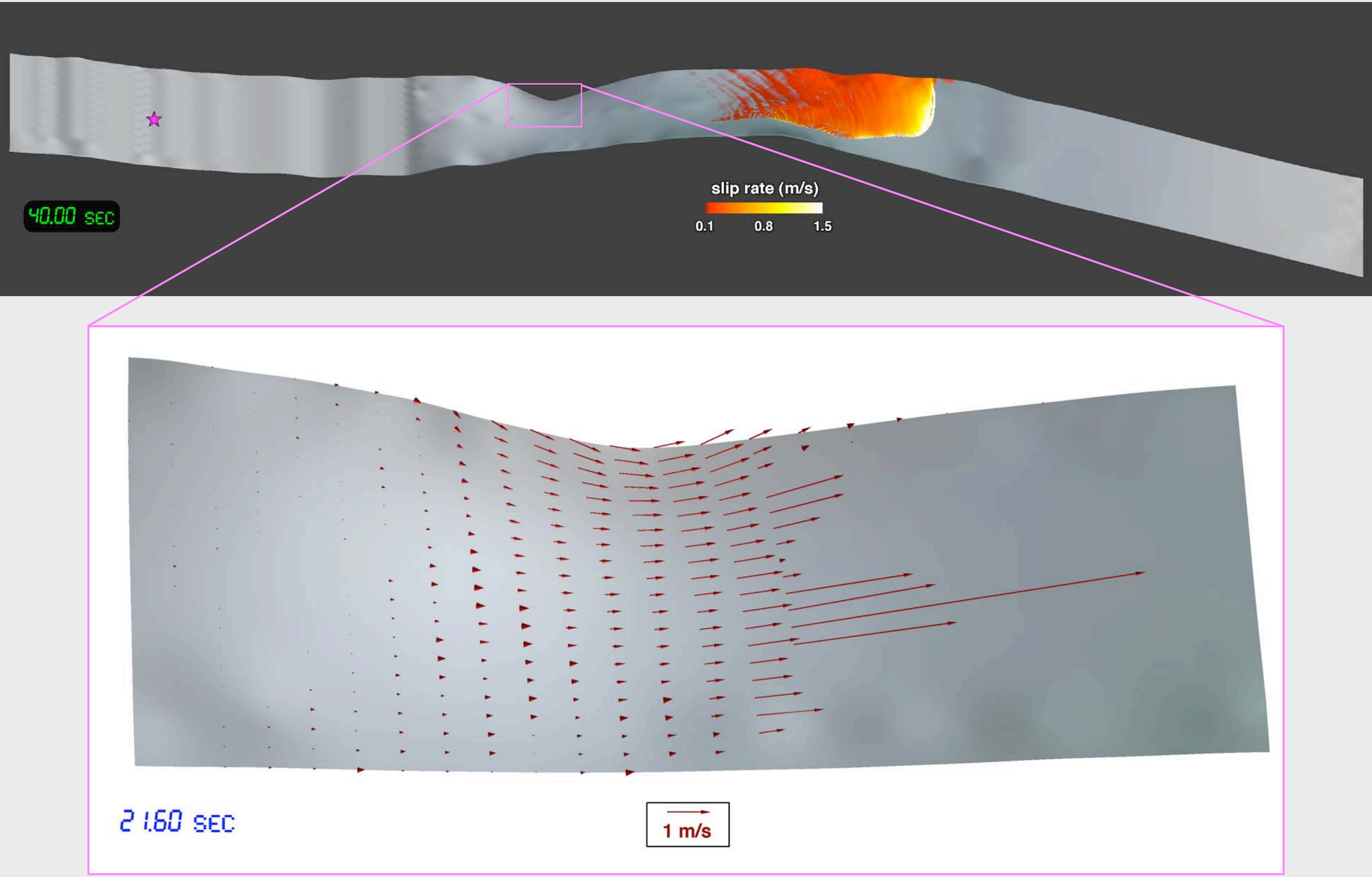


Planar fault

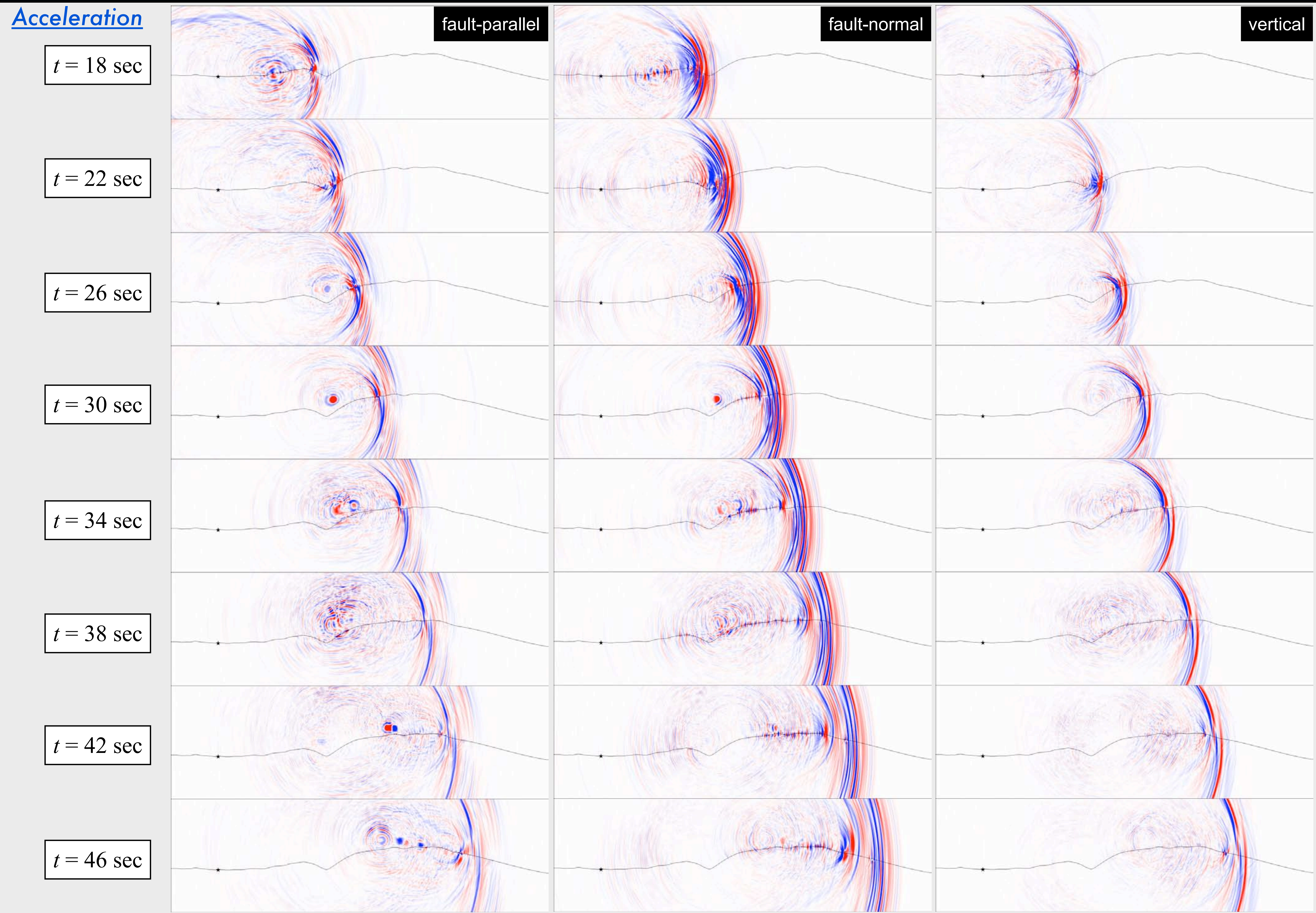


Simulation “Set Traction”

Propagation from north of SGP

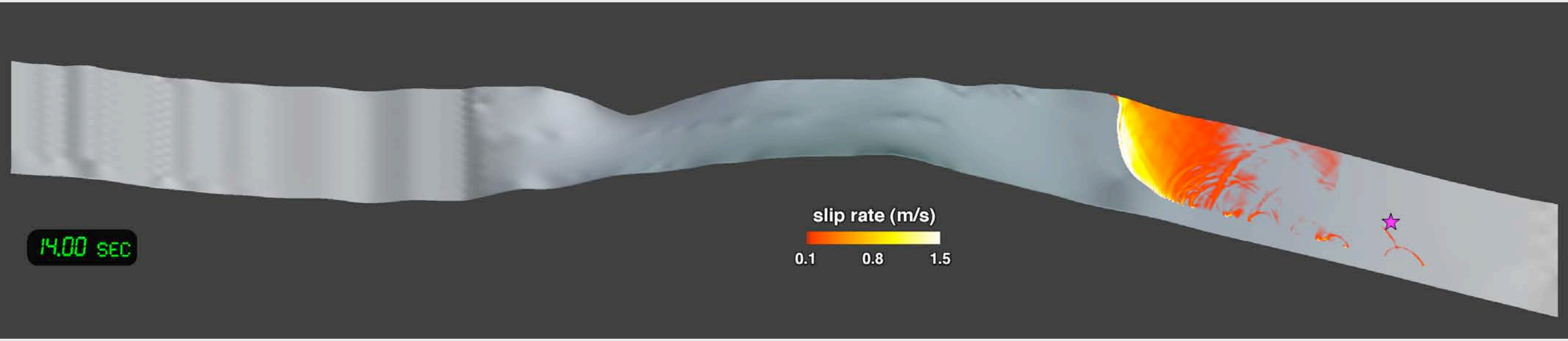


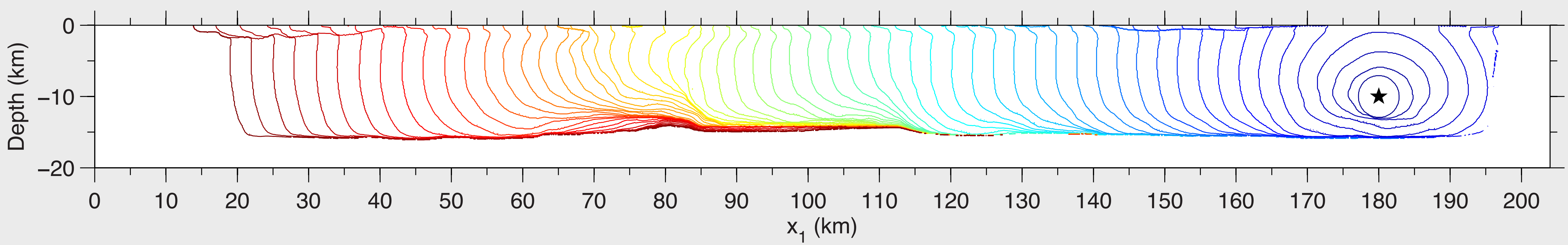
Simulation "Set Traction"



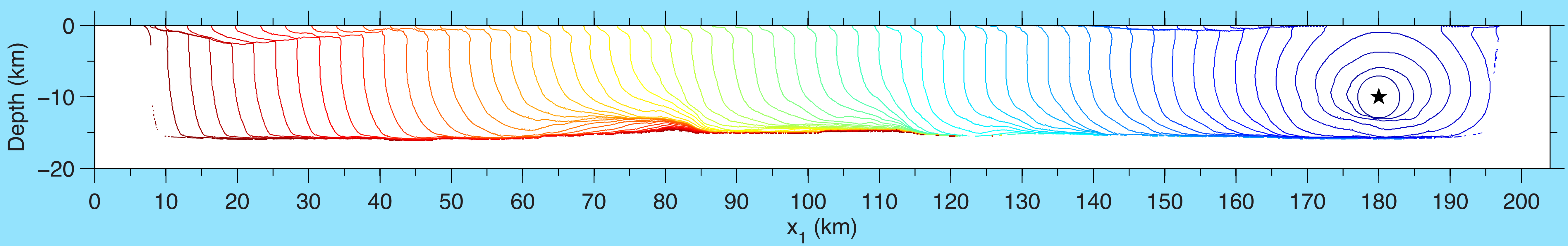
Simulation “Set Traction”

Propagation from south of SGP



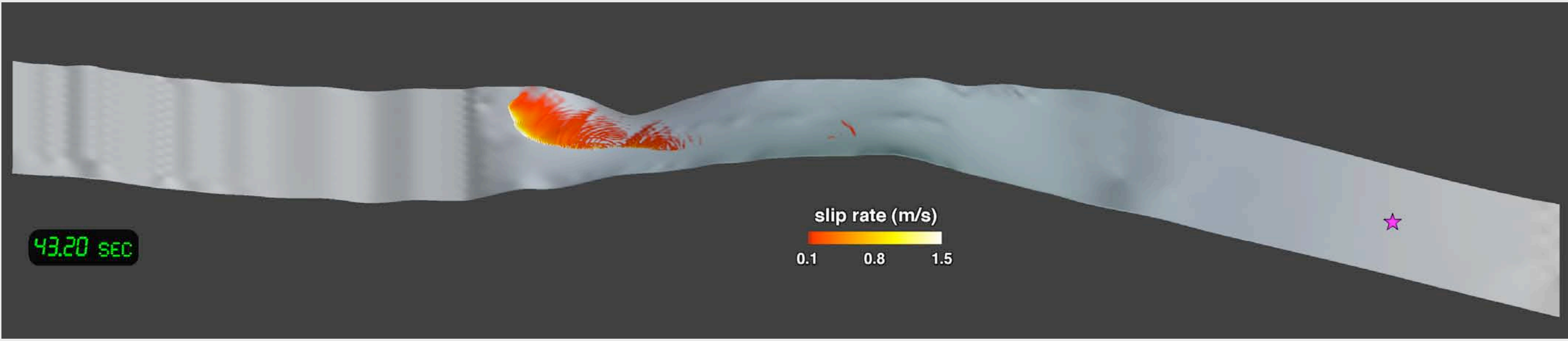


Planar fault

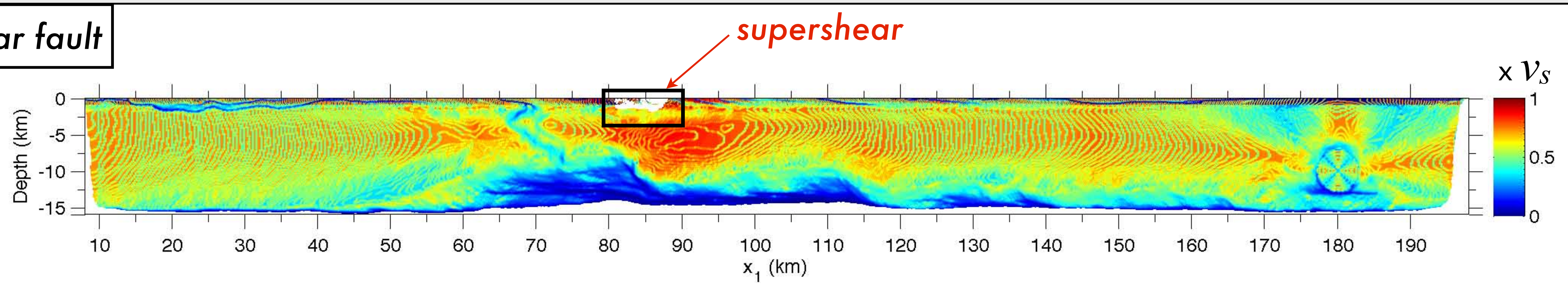


Simulation "Set Traction"

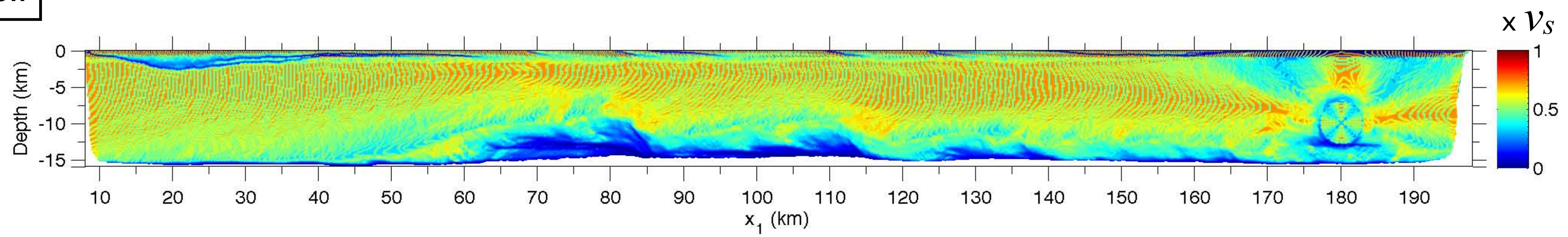
Propagation from south of SGP



Non-planar fault



Planar fault



Discussions

- We performed ***two end-member sets*** of 3D simulations of dynamic rupture along the non-planar SGP section of the San Andreas fault using:
  ❶ Homogeneous volumetric stress with Drucker-Prager viscoplasticity
  ➔ Rupture fails to run through SGP regardless of propagation direction and speed (Fault geometry has major effects on prestress on fault and ensuing rupture dynamics)
  ❷ Heterogeneous fault tractions with pure elasticity
  ➔ Rupture properties do not seem to be affected much by the relatively-large-scale geometric irregularities present in the current SCEC CFM (small-scale features?) (Fault geometry has minor effects on rupture dynamics)

- Observational studies suggest a nonhomogeneous volumetric stress field around the SAF in southern California including the SGP region. The preferred approach of simulating most physically reasonable rupture scenario is to use the nonhomogeneous volumetric stress field as input and take into account of the generation of plastic deformation in the presence of geometric irregularities of the fault.

A challenging problem for numerical modelers:
How to generate a nonhomogeneous volumetric stress field with self-consistency that mimics observational data?