Summary, Session 1

Physical Processes That May Produce Precursor Signals

Speakers

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A wide range of physical phenomena

Solid state physics, electrochemistry
    P-Holes, “battery” concept

Rock physics, linear and nonlinear
    Small cracks, big cracks, single or many

Multiphase assemblages, rock, water, gas
    Saturated porous medium
    Degassing, radon

Earthquake physics
    From nucleation to rupture propagation
    From brittle failure to stable creep, and ETS events
    From static offset to secular strain

A wide range of observations

Lab EM measurements:
- Conductivity, susceptibility, thermal expansion
- IR, Raman, electron spin resonance spectroscopy

Rheology and rock mechanics
- Elastic constants
- Anelastic and nonlinear properties
- Dilatancy and diffusion
- Acoustic emissions and rupture propagation

Ground-based field observations
- Seismic, geodetic networks
- EM instrument network
- Ground-based ionosphere measurements (ionosonde, GPS)

Remote sensing, including satellite
- Optical, IR, microwave, both passive and active (radar)
- Ionosphere from orbit (Demeter)

A wide range of spatial scales

- Atomic scale (P-holes), dislocations
- Microcracks, individual grains and crystals
- Lab scale to boulder scale
- Small faults (10s of m) to large faults (100s of km)
- Tectonic scales and geological elements
- Outer scale / inner scale ratio is nearly 10 orders of magnitude

A wide range of temporal scales

- Atomic phenomena, dislocations glide/climb
- Dynamic rupture (fractions of sec to minutes)
- Creep, ETS events, tides
- ***Hypothesized precursors***
- Aftershock sequences
- Interseismic phenomena

Different worldviews

- EM precursor researchers
  - Protracted earthquake preparation phase,
  - Spread over large area, commensurable with ultimate rupture dimensions
  - Observable from ground networks and from space.
- Rock researchers and geophysicists (post- ca 1985)
  - Nucleation precursory signals very difficult to detect with surface or even downhole instruments
  - Nucleation taking place in a very localized area O(meters)
  - Tight constraints from field observations
  - Physics must be consistent with clustering
  - Long-range correlations gaining credence
- Seismologists have learned to be careful!

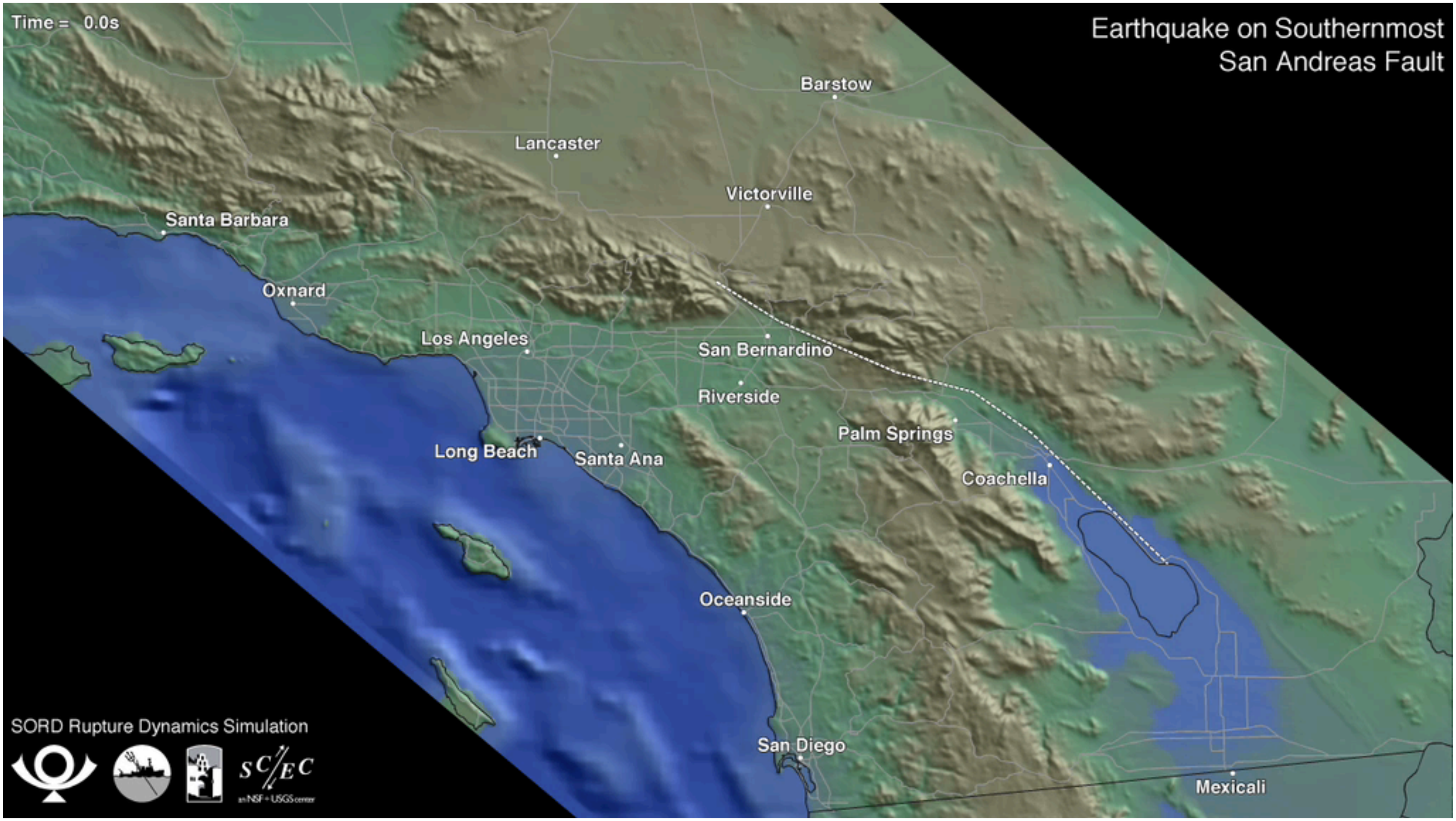
What do we know?

- The Earth is inhomogeneous, perhaps at all scales? Fluids everywhere except very near surface.
- The process of strain (and stress) accumulation is very smooth and well predicted by tectonic models, but the stress state, notably on faults, is evidently very rough
- Deformation is explained (and predicted) extremely well using dislocation source representation in an elastic heterogeneous medium.
    - We know the elastic and anelastic (linear) 3D structure of the Earth very well in certain areas, and so can place upper bounds on mechanical precursors.
- Rupture propagation is not smooth but very complex.
- Co-seismic and post-seismic phenomena are much larger than pre-seismic ones

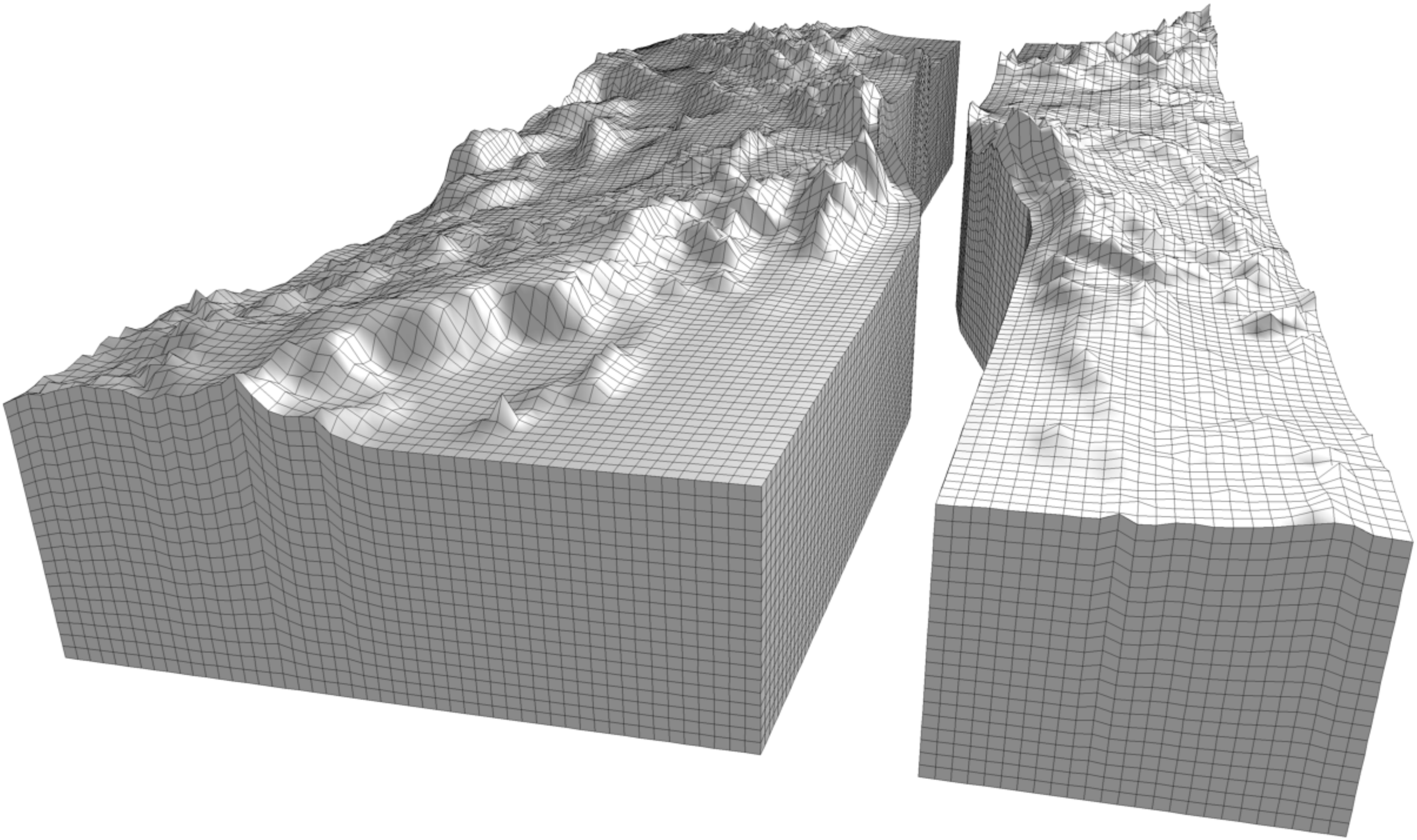
Some vexing issues

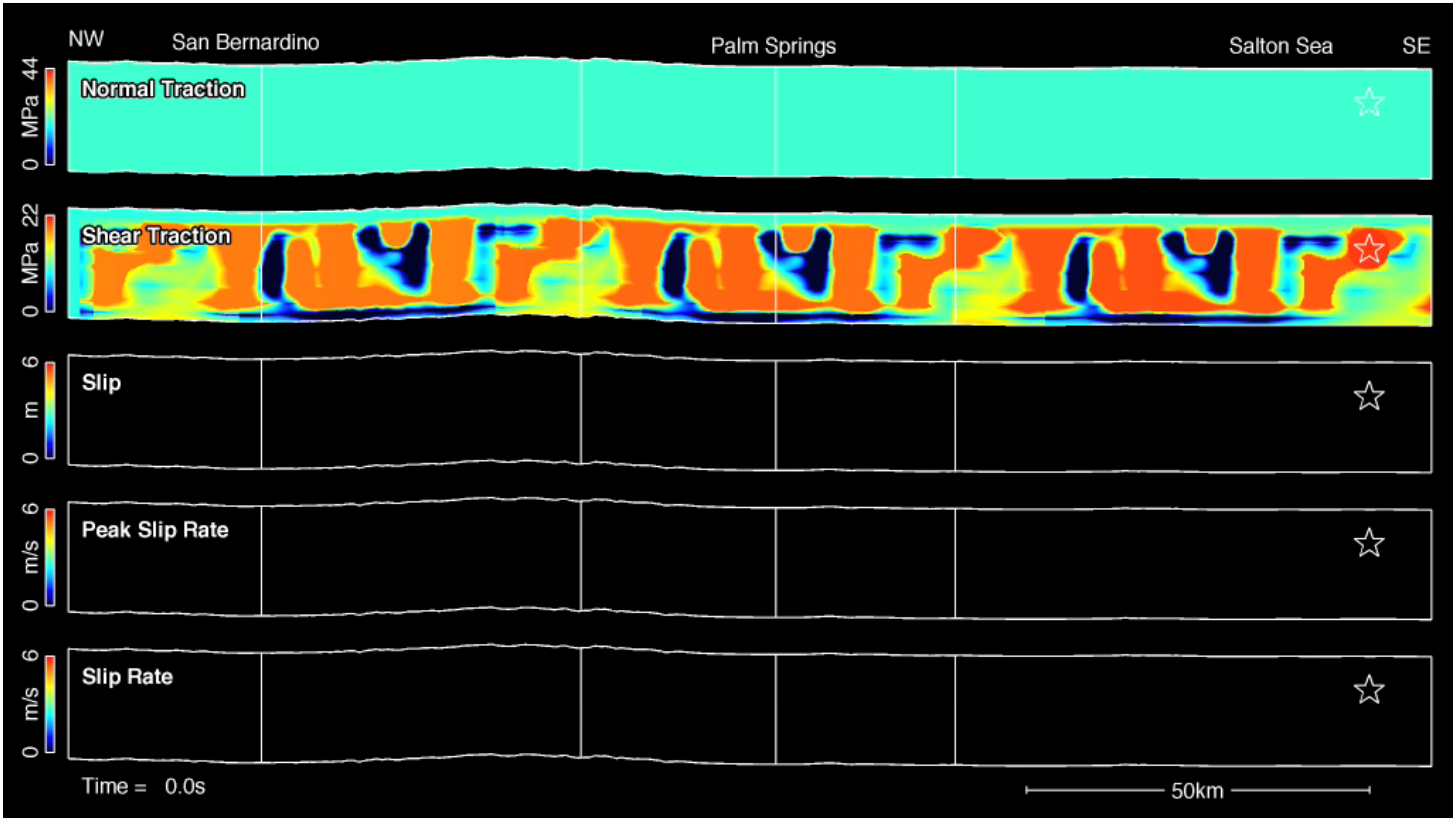
- **Scaling (both geometry and physics!)**
  - From hand samples to boulders
  - From boulders to massifs
  - From massifs to tectonic units
- **Complexity (over what range of scales?)**
  - Modeling physics on a fractal domain
  - Emergent behavior?
  - Time variable spatial correlation lengths
- **How does a baby earthquake grow up to be a big one?**

"Rupture propagation is not smooth but very complex."
Nonplanar, Topography, CVM 4,



TeraShake-class simulations

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San Bernardino
Palm Springs
Salton Sea
SE
0 MPa 44
Normal Traction
0 MPa 22
Shear Traction
0 m 6
Slip
0 m/s 6
Peak Slip Rate
0 m/s 6
Slip Rate
Time = 0.0s
50km

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