Overview of Benchmarks for 2014

TPV29-30 — Rough Fault with Viscoplasticity
TPV31-32 — Planar Fault with 1D Velocity Model

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Benchmarks for 2014

Vertical strike-slip fault with stochastic roughness:

TPV29 – Linear elastic material properties.

TPV30 – Drucker-Prager viscoplastic material properties.

Planar strike-slip fault in a 1D velocity structure:

TPV31 – Discontinuous 1D velocity structure, minimum V_S = 2250 m/s.

TPV32 – Continuous 1D velocity structure, minimum V_S = 1050 m/s.

Recent Kinds of Benchmarks

Recent benchmarks have tended to fall into two categories, which are exemplified by this year's benchmarks:

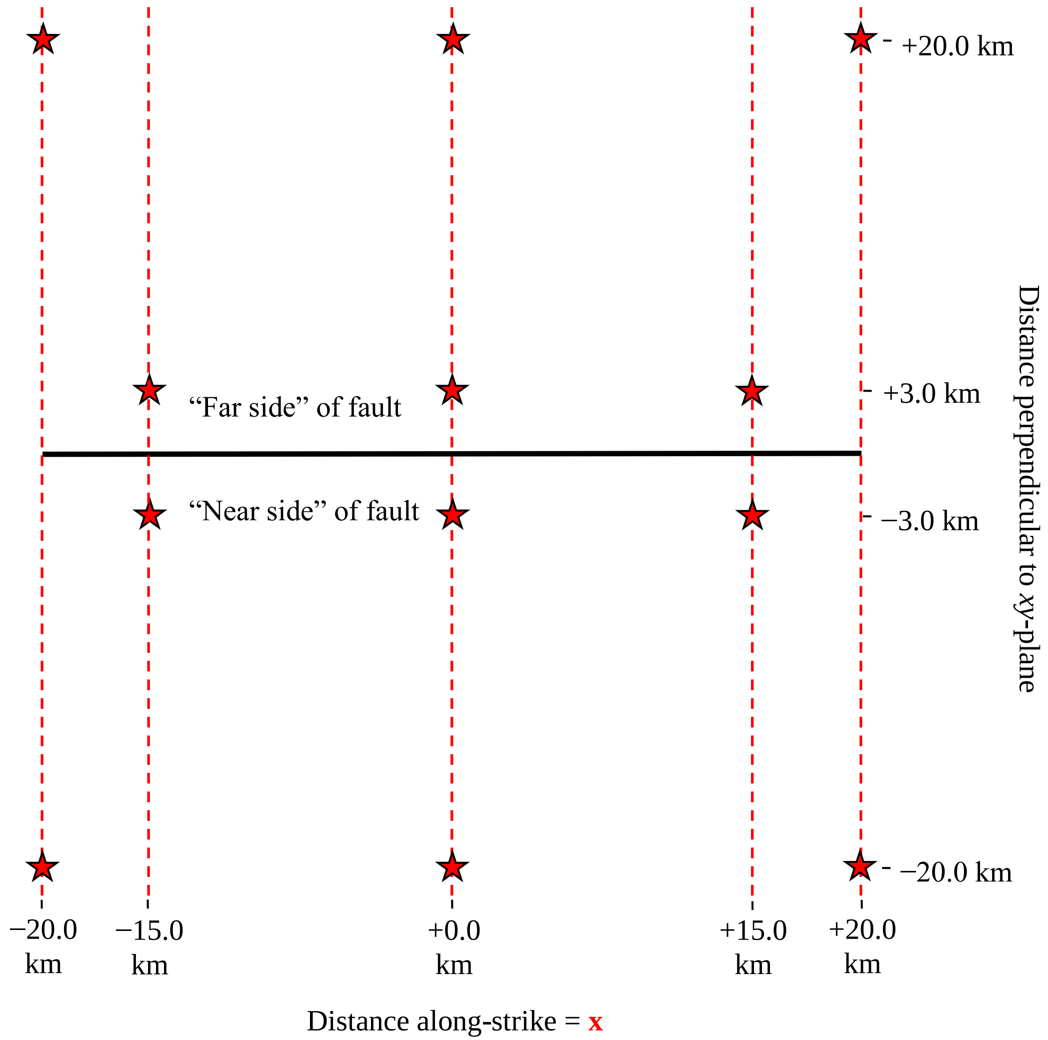
1. Linear elastic benchmarks (*e.g.,* TPV31-32):

- Depth-independent initial stress (initial strain for TPV31-32).
- May or may not give initial stress tensor throughout model volume.
- No gravity.
- Nucleation by overstress in a nucleation zone.
- High friction coefficient (μ_s = 0.58 for TPV31-32).

2. Viscoplastic benchmarks (*e.g.*, TPV29-30):

- Initial stress increases with depth.
- Initial stress tensor specified throughout model volume.
- Gravity is included.
- Nucleation by time-weakening and forced rupture in a nucleation zone.
- Extremely low friction coefficient (μ_s = 0.18 for TPV29-30).

New Feature – Distant Off-Fault Stations



For the first time, we include off-fault stations far away from the fault (20 km for TPV29-30, 15 km for TPV31-32). This gives a first look at how codes model ground motions at some distance from the fault, which is needed for a long-term goal of comparing modeling results to real-world data.

Overview of Metrics

Barall, M., and R.A. Harris (2015), Metrics for Comparing Dynamic Earthquake Rupture Simulations, *Seismological Research Letters*, vol. 86, no. 1, pages 223-235, doi: 10.1785/0220140122.

Data Supplied by Modelers

1. On-fault time series (synthetic seismograms):

- H and V slip $\Longrightarrow$ 2D slip
- H and V slip rate $\Longrightarrow$ 2D slip rate
- H and V shear stress $\Longrightarrow$ 2D shear stress
- Normal stress

2. Off-fault time series (synthetic seismograms):

- H, N, and V displacement $\Longrightarrow$ 3D displacement
- H, N, and V velocity $\Longrightarrow$ 3D velocity

3. Rupture time (contour plot) data.

- Time at which rupture occurs, for each point on the fault surface.

When computing time-series metrics, individual components are combined to form a vector-valued time series. A 5 Hz low-pass filter is applied so velocity, slip rate, shear stress, and normal stress.

Metric Formula for Time Series

We use a normalized root-mean-square difference, with a time shift, expressed as a percentage.

For a function of time $f(t)$, which may be vector-valued, define the L^2 norm:

$$\|f(t)\|_2 \equiv \left[\int |f(t)|^2 \, dt \right]^{1/2}$$

Our main misfit metric is a normalized RMS difference. Given two functions $f(t)$ and $g(t)$, and a time shift t_s, the metric value is:

$$Q \equiv \frac{\|f(t) - g(t - t_s)\|_2}{\|f(t)\|_2 + \|g(t - t_s)\|_2}$$

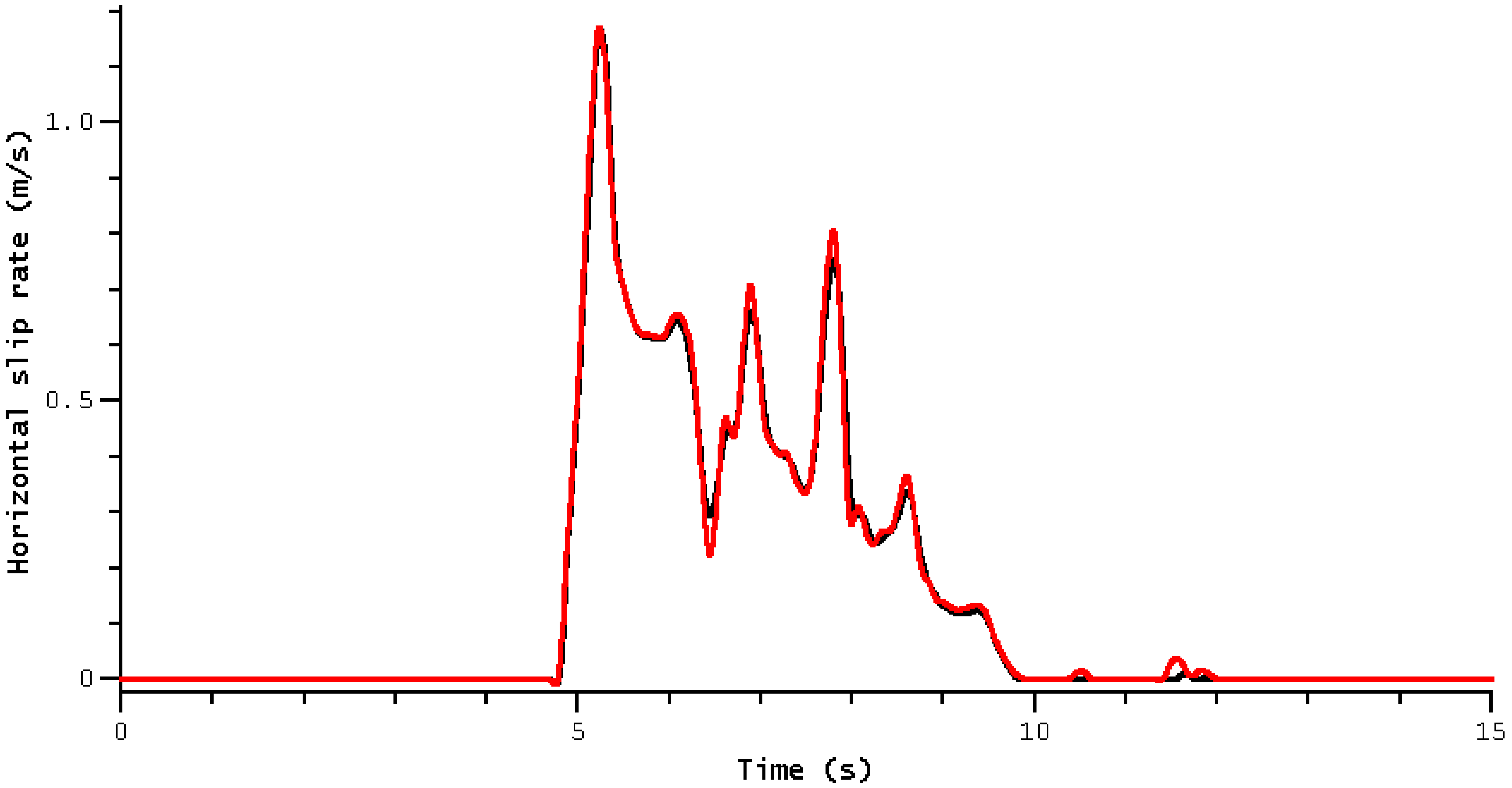
The integrals are computed over the range of times t where both $f(t)$ and $g(t - t_s)$ are defined. The time shift t_s is chosen to minimize Q.

It can be proved that

$$0 \leq Q \leq 1$$

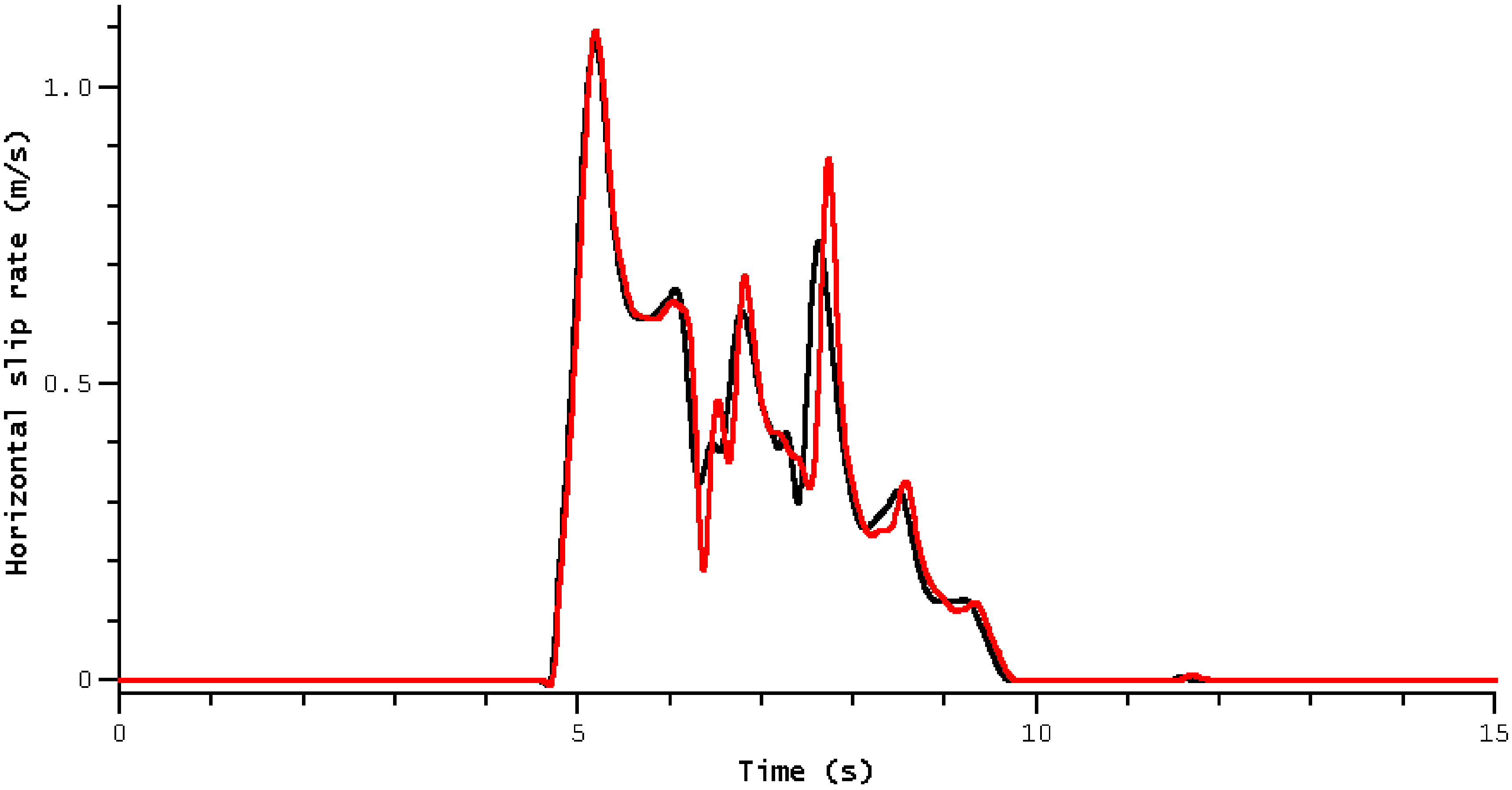
The value $Q = 0$ indicates a perfect match. To convert Q into a percentage, we multiply by 200. Generally, $Q \lesssim 10\%$ indicates reasonably good agreement.

Time Series Metric Examples



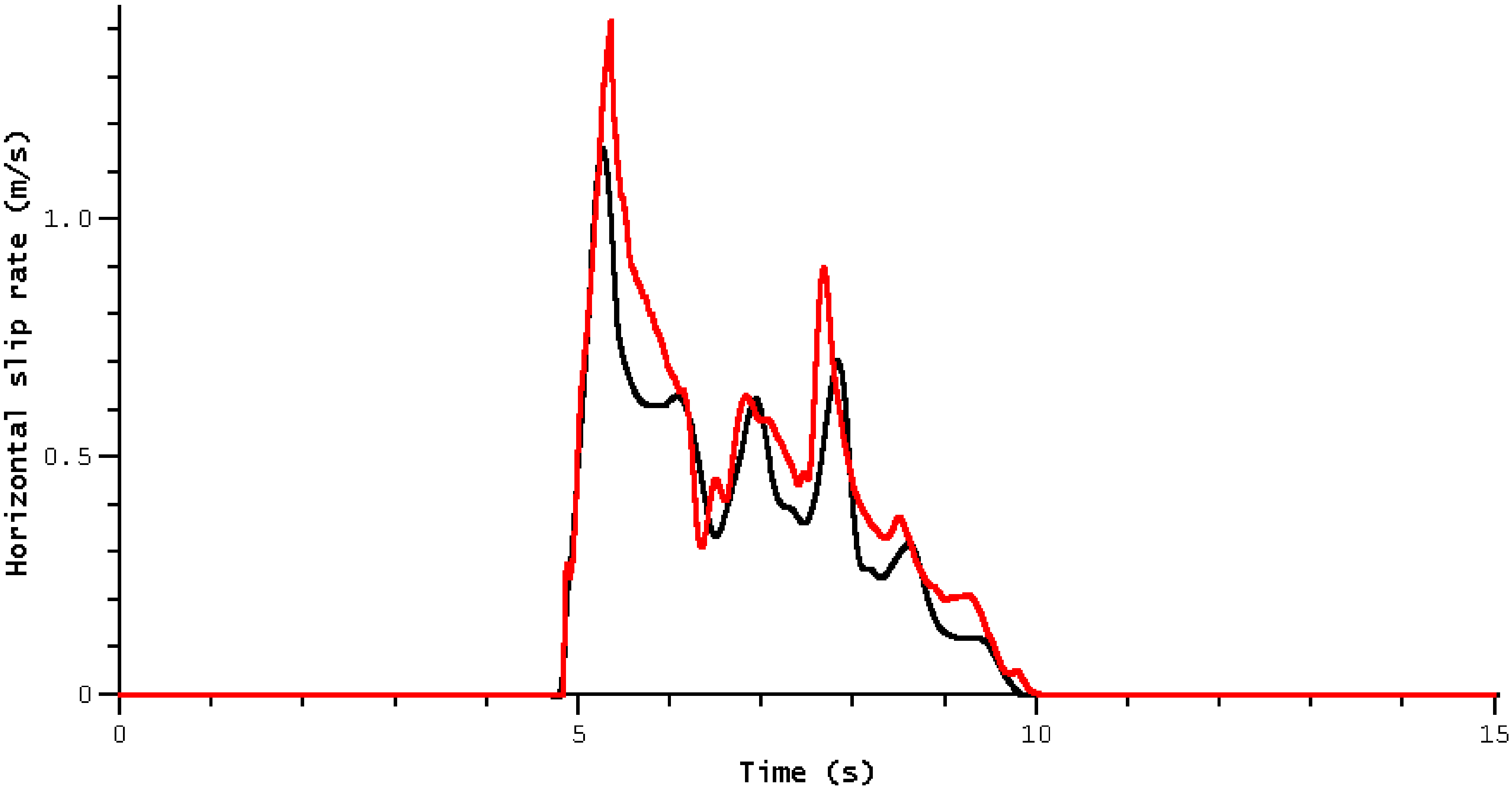
Q = 4.0 percent

Time Series Metric Examples



Q = 10.7 percent

Time Series Metric Examples



Q = 24.1 percent

Metric Formula for Contour Plot

We use the root-mean-square difference in rupture time, expressed in milliseconds.

Let (x, y) be position on the fault plane. The contour plot data gives the rupture time as a function of x and y.

For a function of position $f(x, y)$, , define the L^2 norm:

$$\|f(x,y)\|_2 \equiv \left[\int |f(x,y)|^2 \, dx \, dy \right]^{1/2}$$

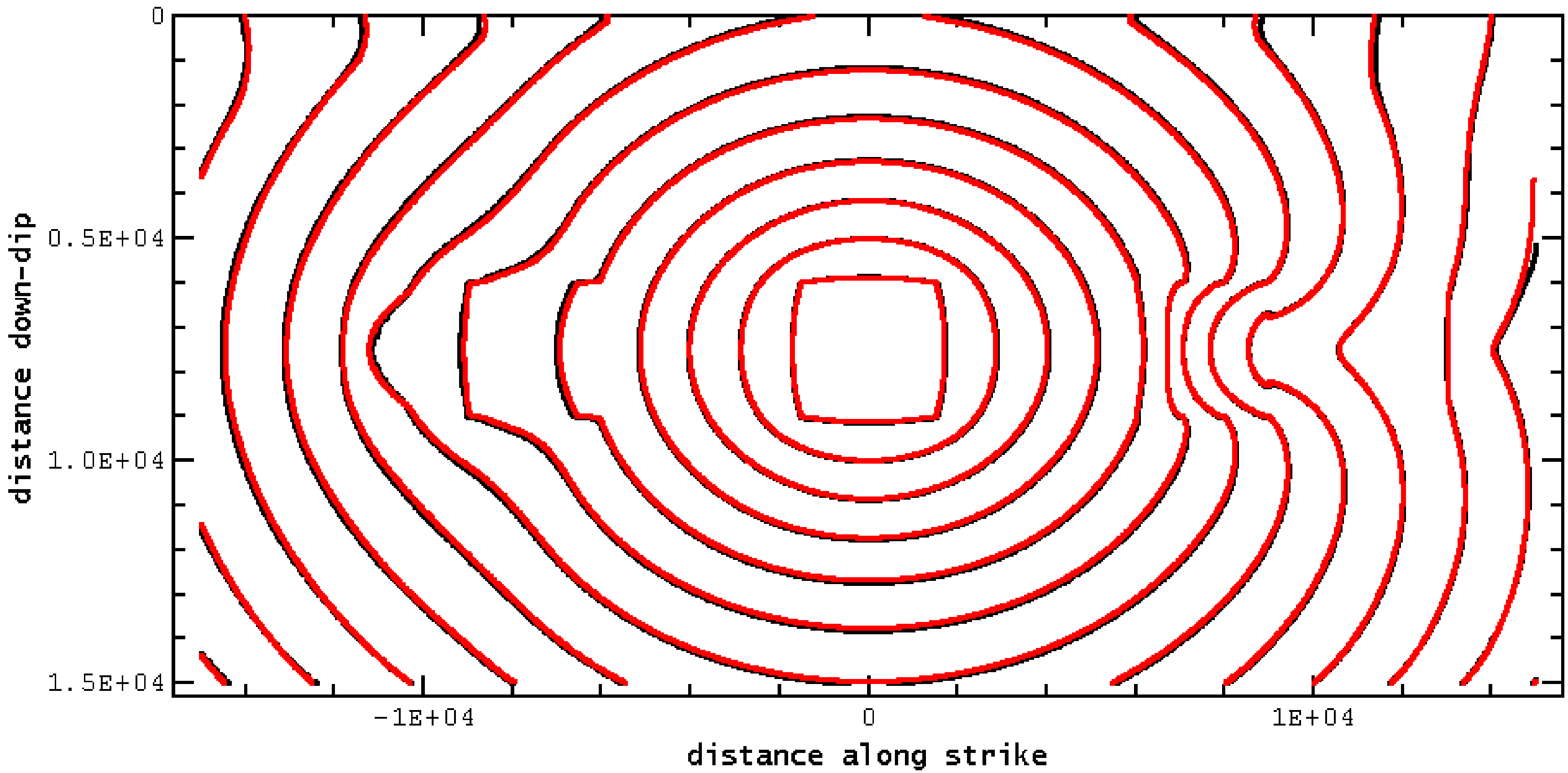
Our main misfit metric is the RMS difference. If $f(x, y)$ and $g(x, y)$ are two rupture time functions, the metric value is:

$$T \equiv \frac{1}{\sqrt{A}} \|f(x,y) - g(x,y)\|_2$$

The integral runs over the part of the fault surface where both $f(x, y)$ and $g(x, y)$ are defined, and A is the area of that part of the fault surface.

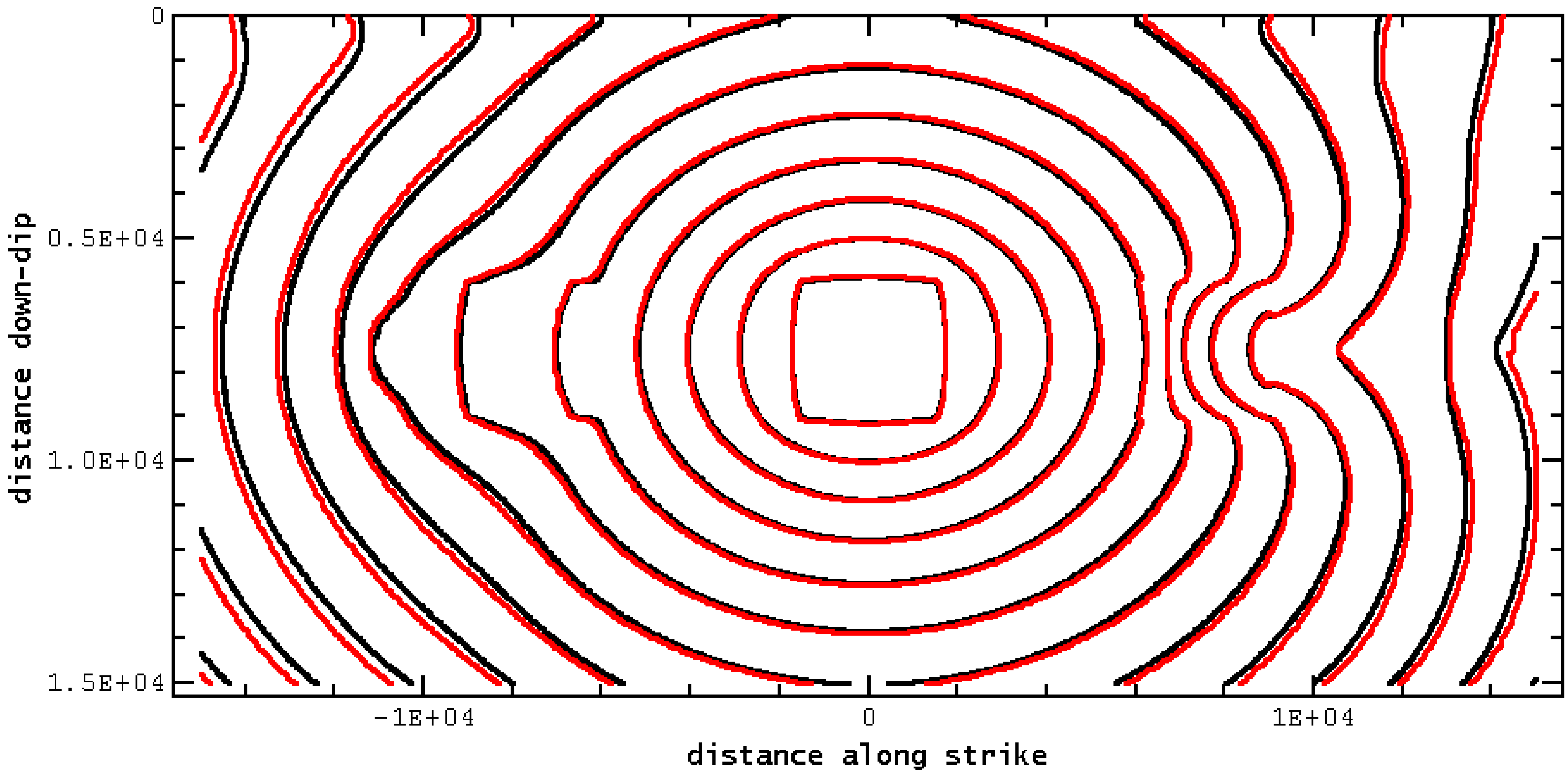
Generally, $T \lesssim 50 \text{ milliseconds}$ indicates reasonably good agreement.

Contour Plot Metric Examples



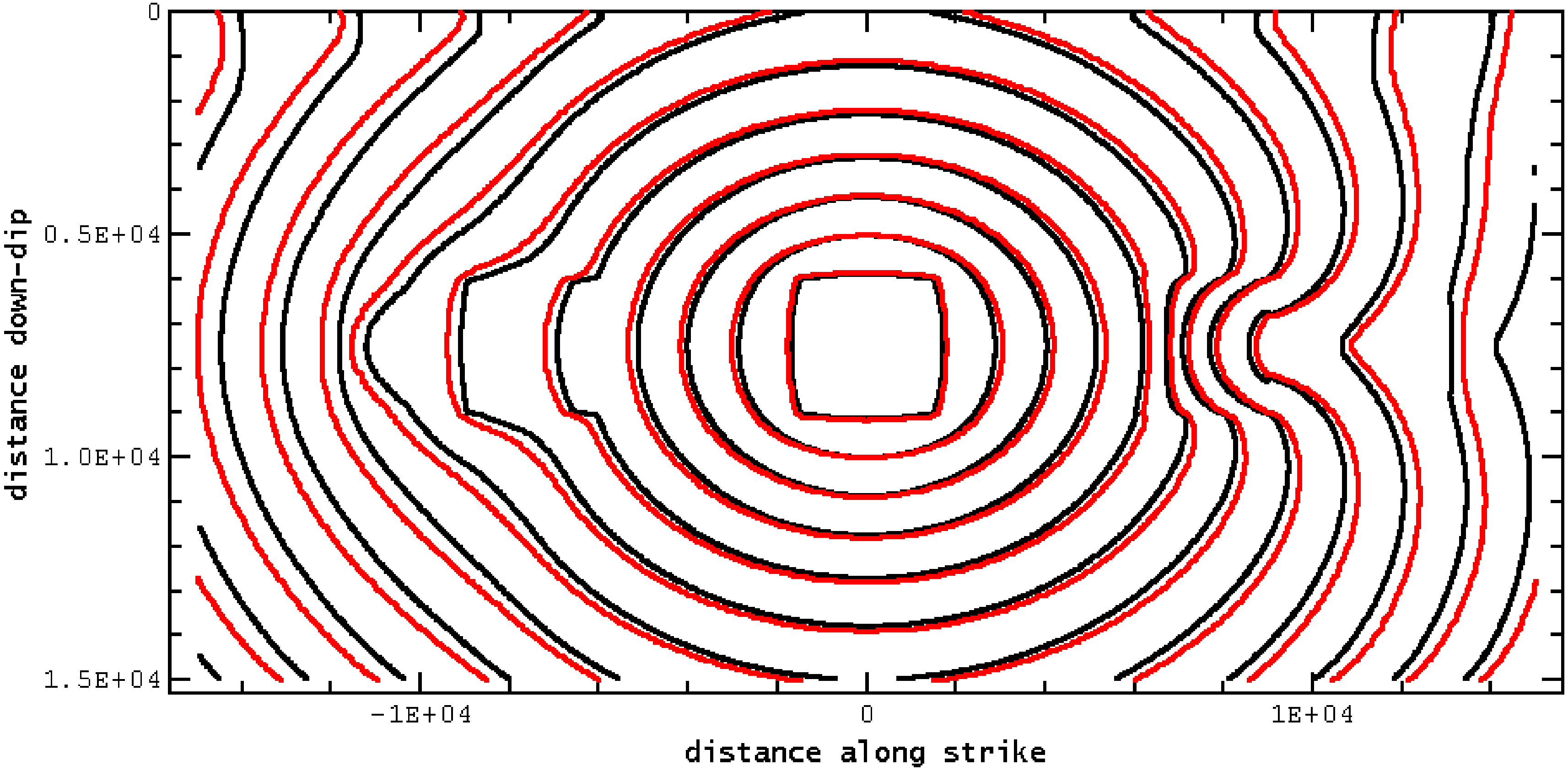
T = 18.8 milliseconds

Contour Plot Metric Examples



T = 47.8 milliseconds

Contour Plot Metric Examples



T = 106.0 milliseconds