Dynamic Issues That May Pertain to the San Gorgonio Pass Region

David Oglesby
UC Riverside

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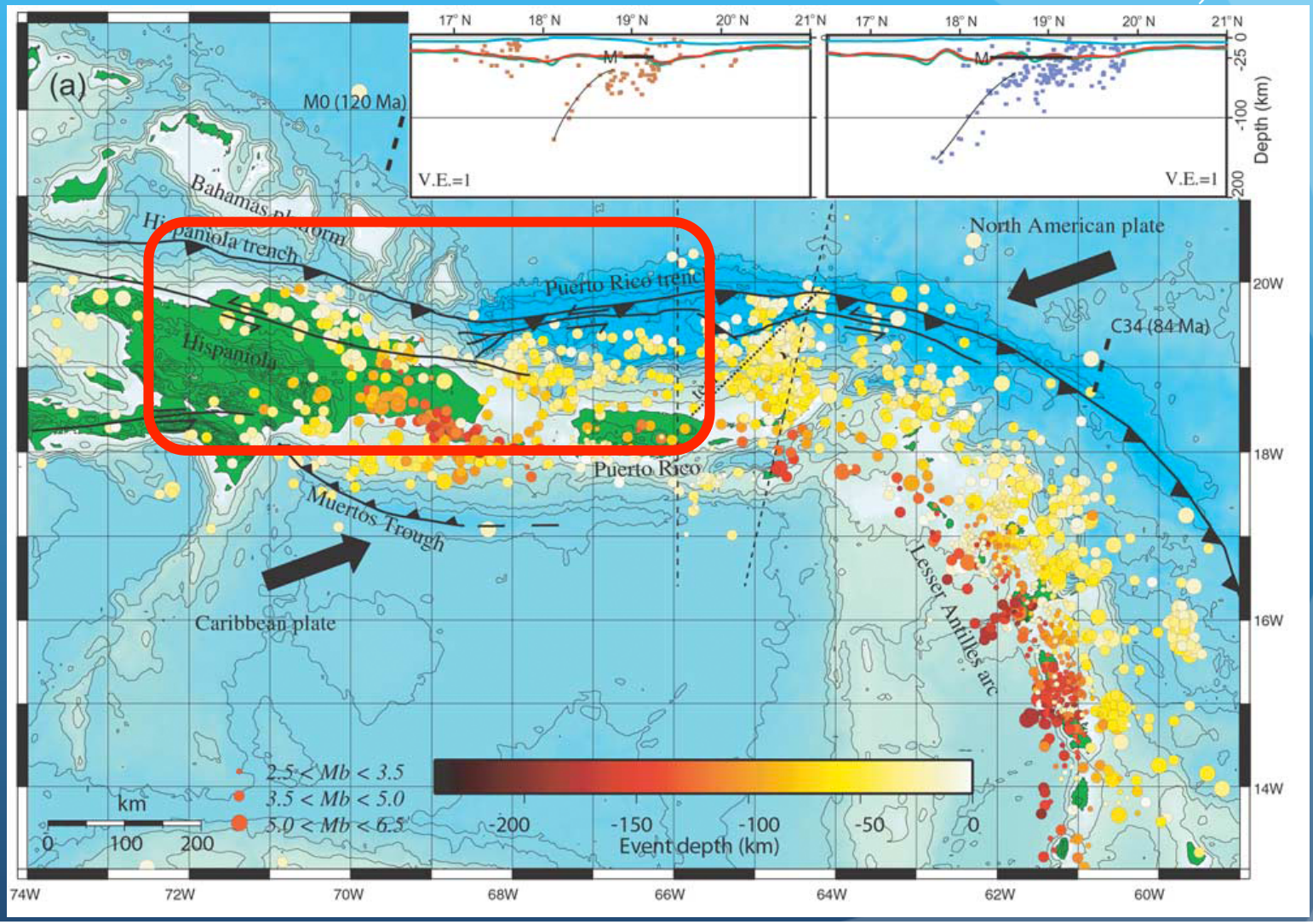
Outline

- Dynamic interactions between thrust and strike-slip faults
  - Eric Geist
  - Uri ten-Brink
- Effect of small-scale fault geometry on through-going rupture and ground motion
  - Julian Lozos
  - Kim Olsen
  - Jim Brune
- How does fault connectivity at depth affect surface slip?

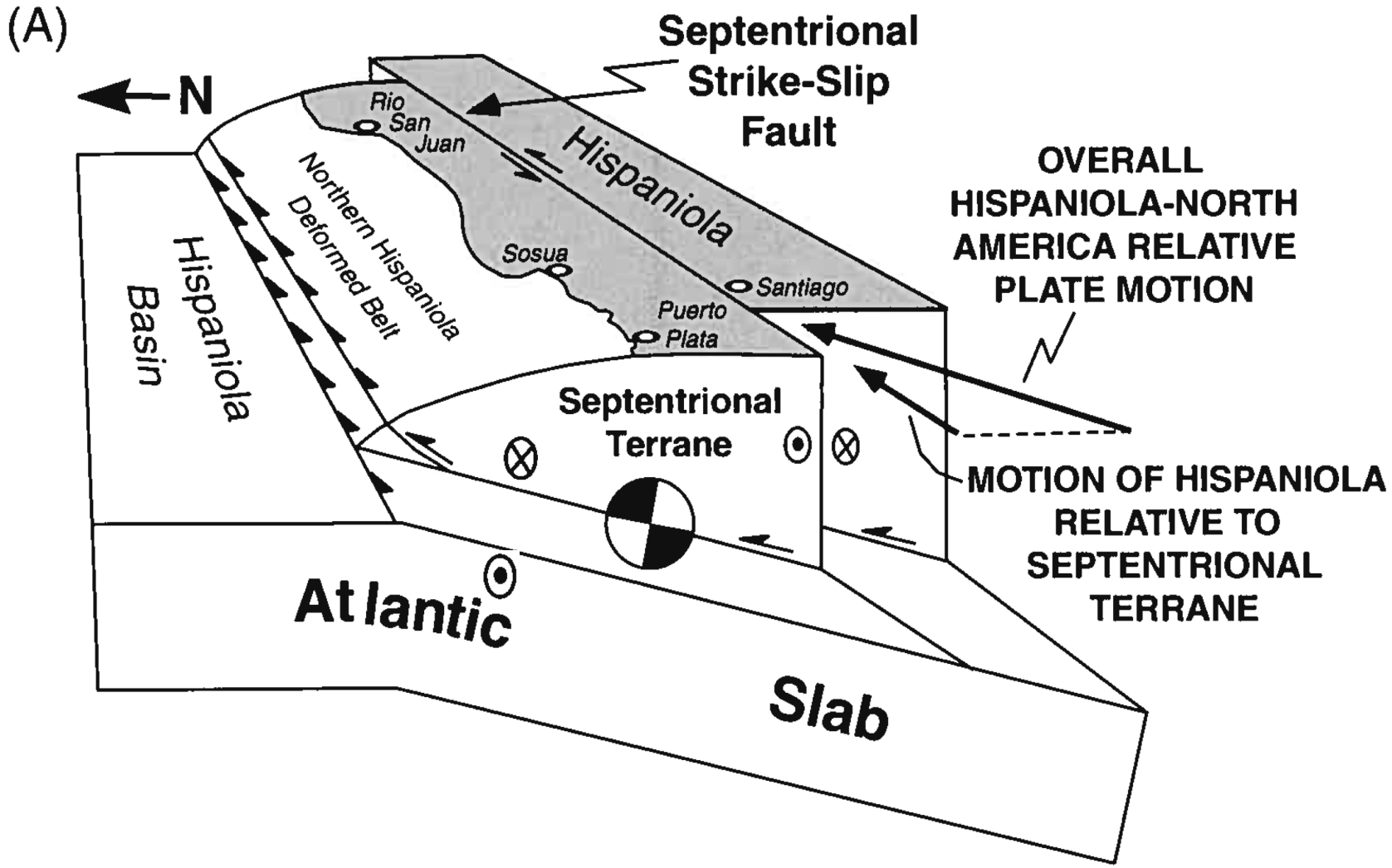
Dynamic interactions between thrust and strike-slip faults

Ten Brink, 2005

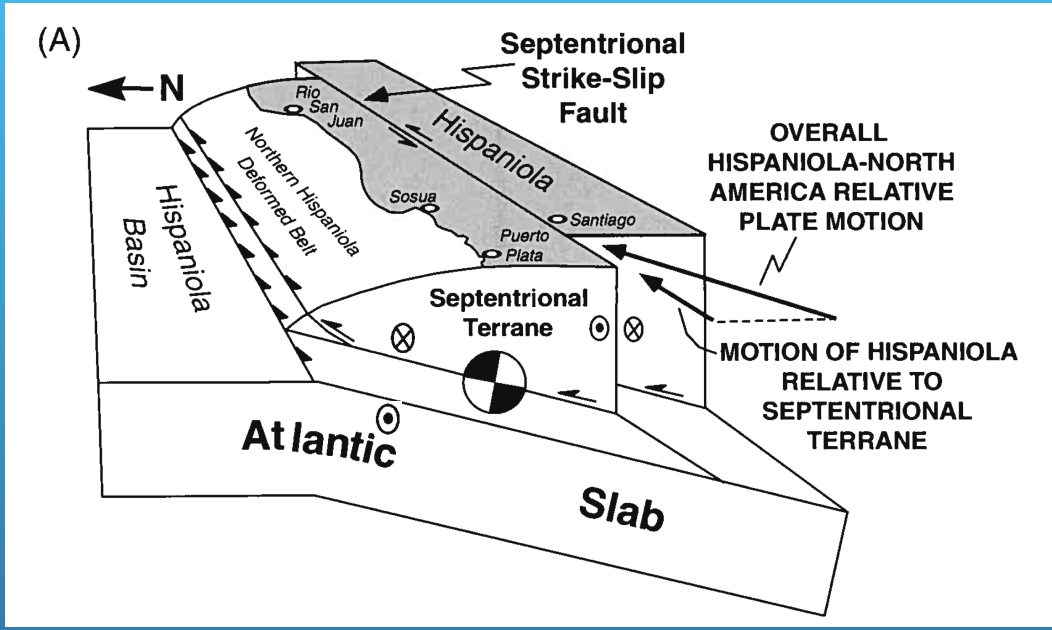


Tectonic Background

Dolan and Bowman, 2005



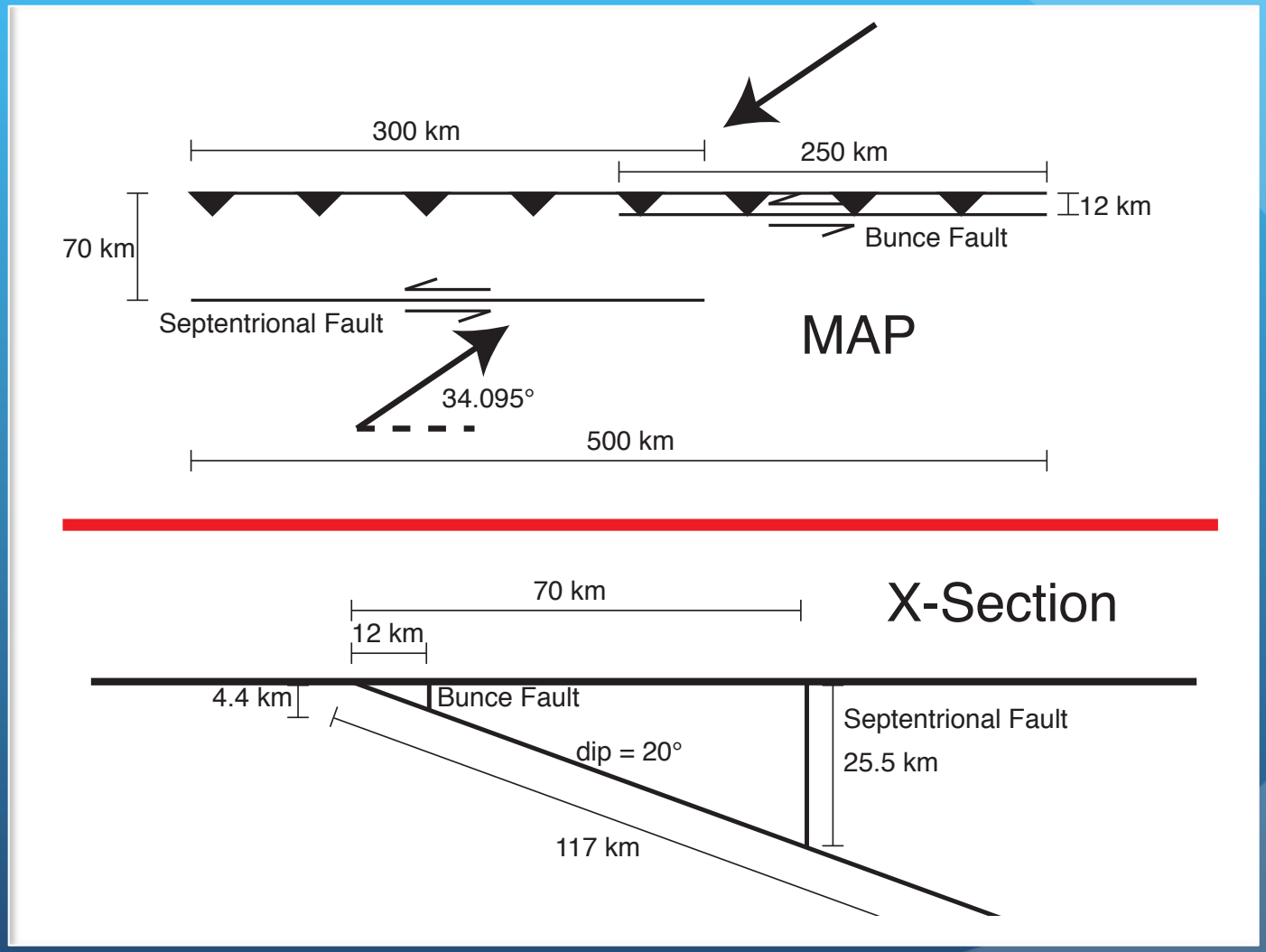
Theoretical Background



Dolan and Bowman, 2005

- Stress Field is 3D, with different mix of strike-slip and dip-slip stress on each fault.
- For large events, rupture is primarily along-strike (parallel to fault intersection).
- 2D rules of thumb may not apply.

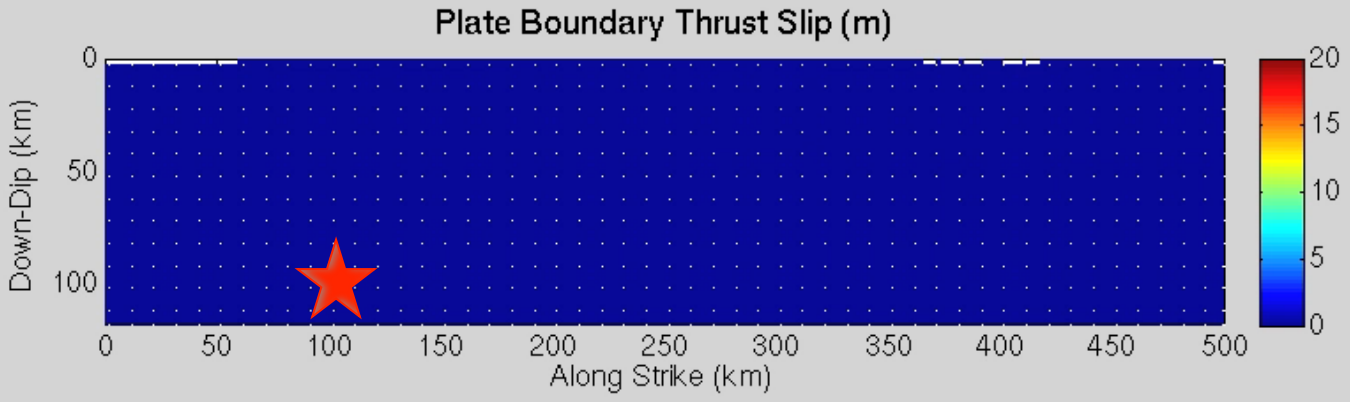
Method

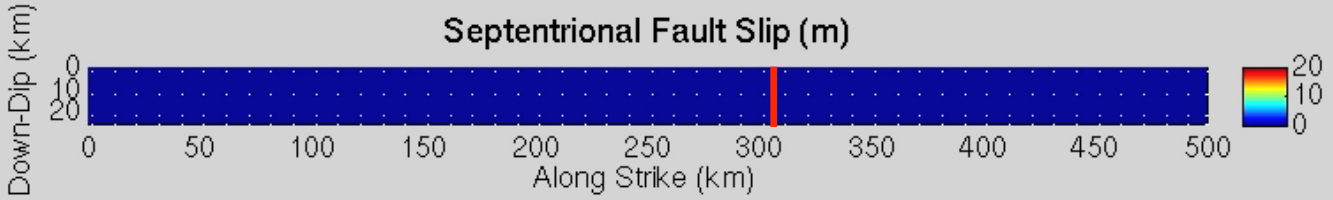

300 km
250 km
12 km
70 km
Bunce Fault
Septentrional Fault
MAP
34.095°
500 km
70 km
X-Section
12 km
4.4 km
Bunce Fault
Septentrional Fault
dip = 20°
25.5 km
117 km

Numerical Results

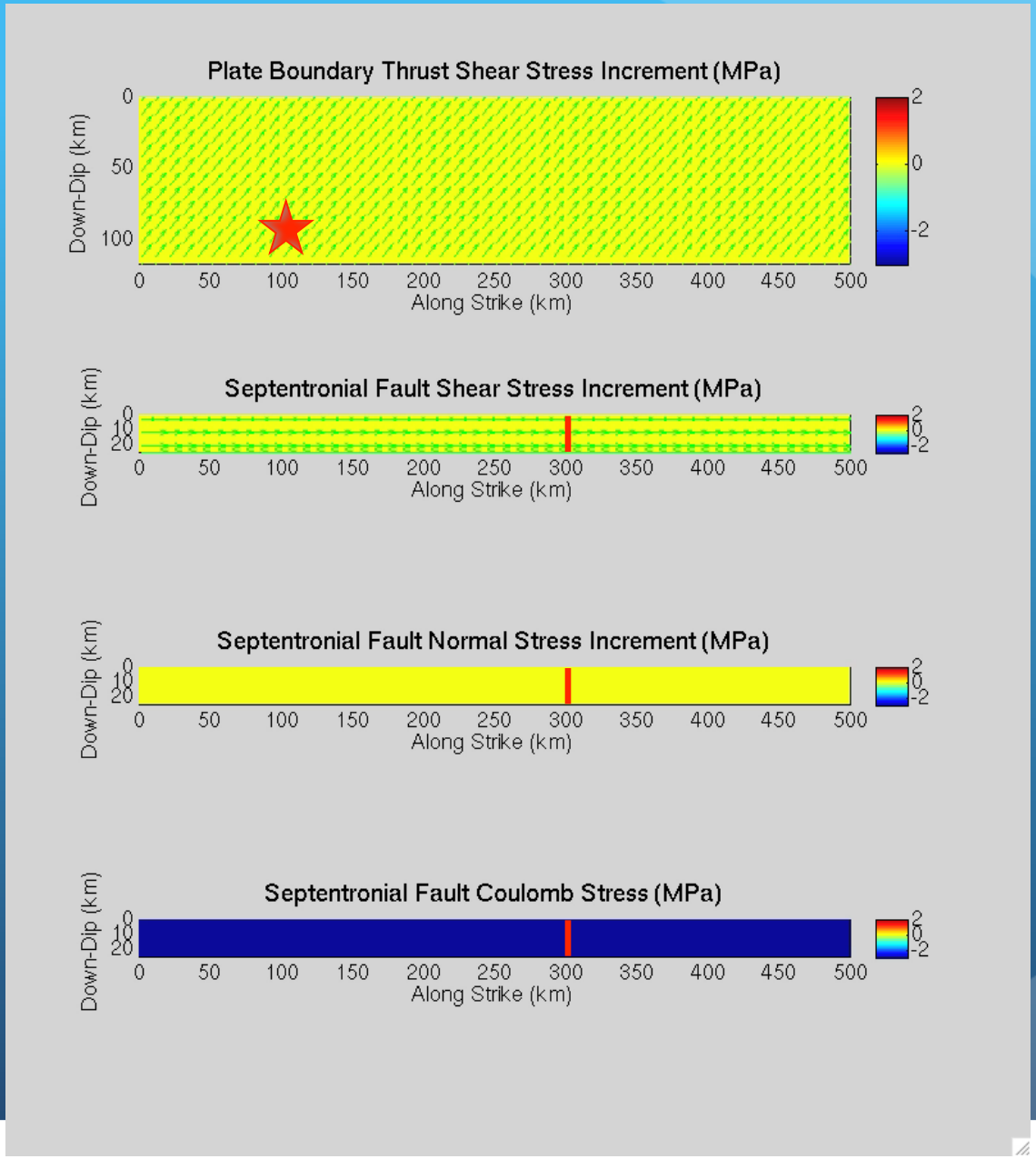
- Can rupture propagate from fault to fault, and why?

Nucleation on Western PBT

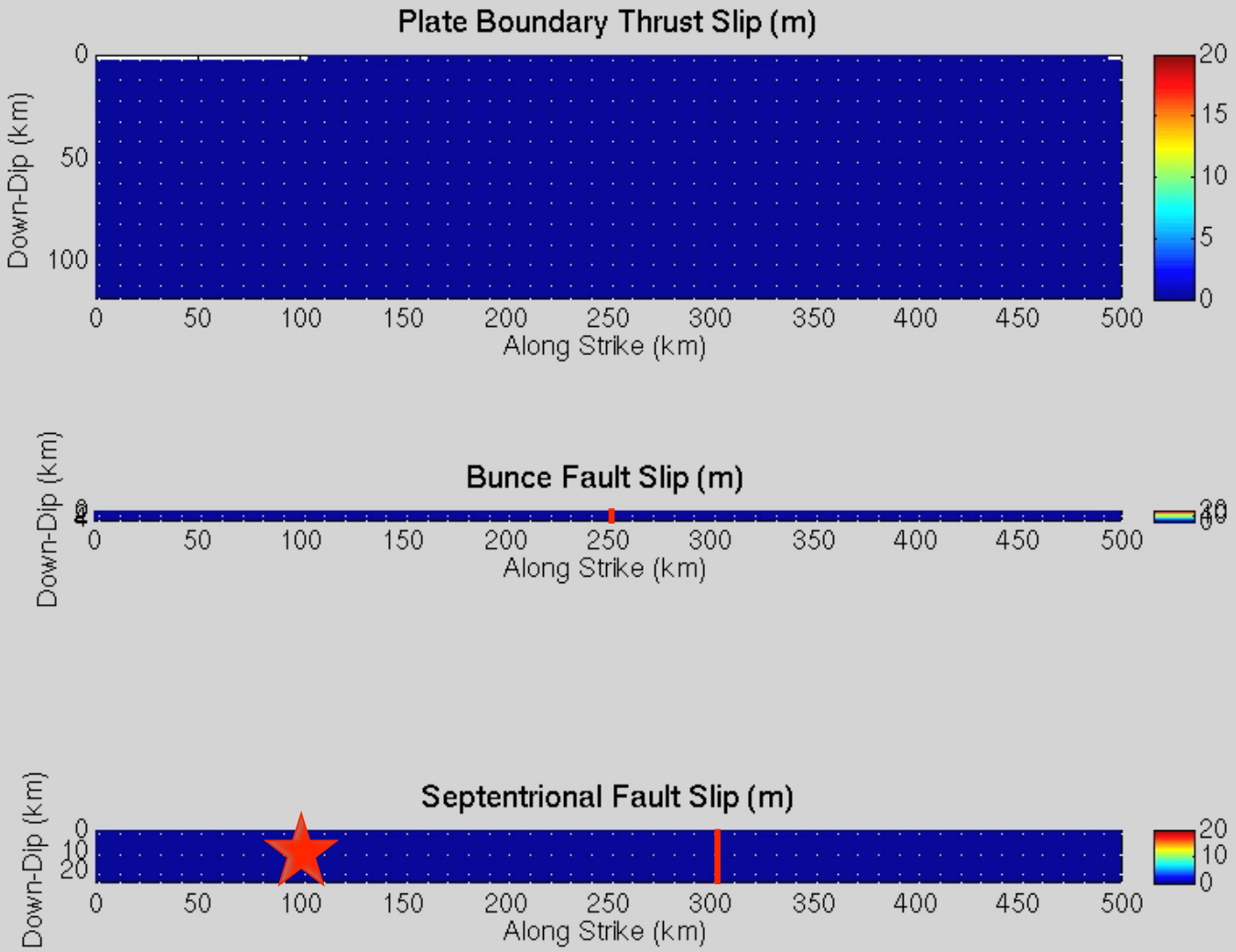




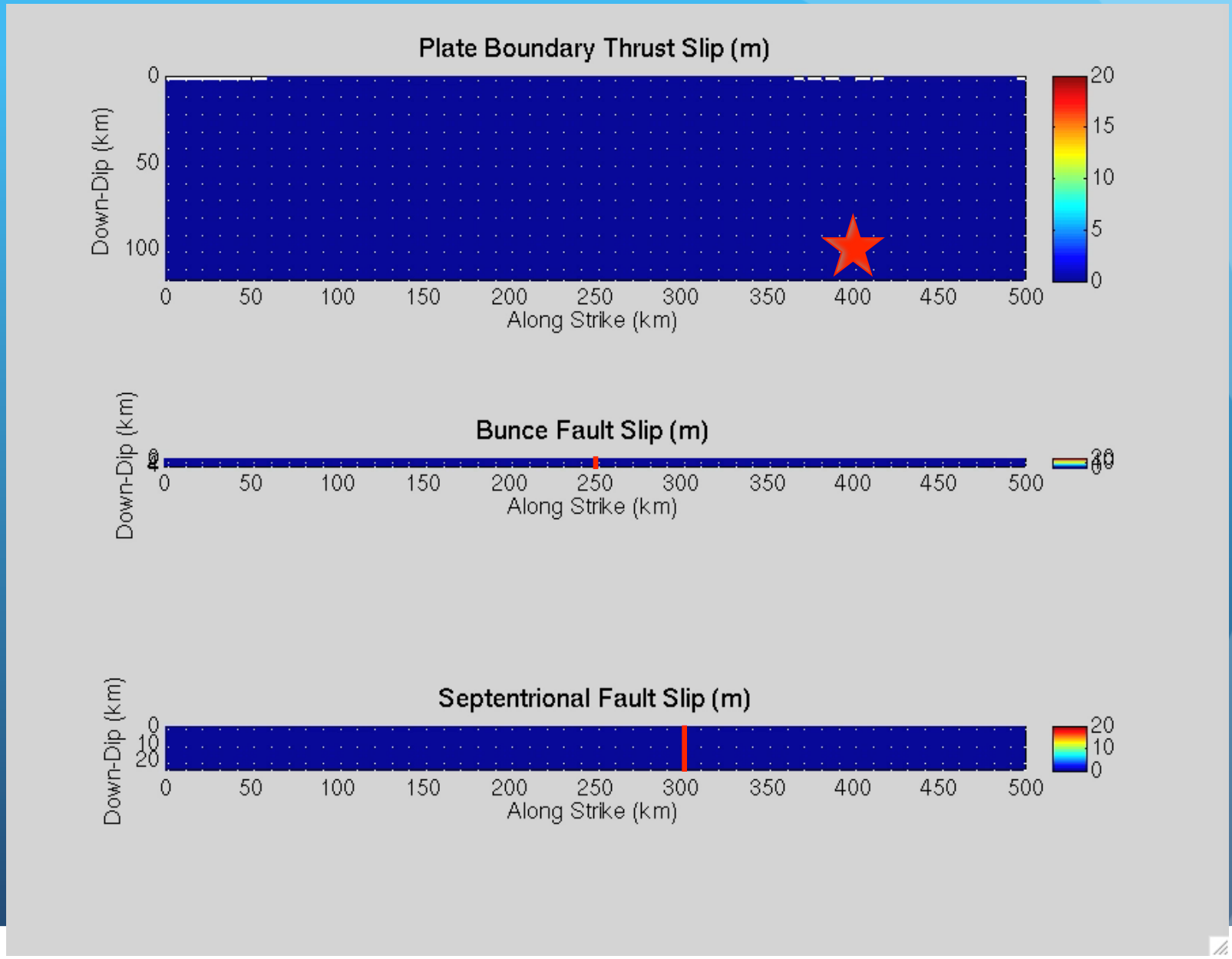
Time-Dependent vs. Static (Final) Coulomb Stress



Nucleation on Western SEP

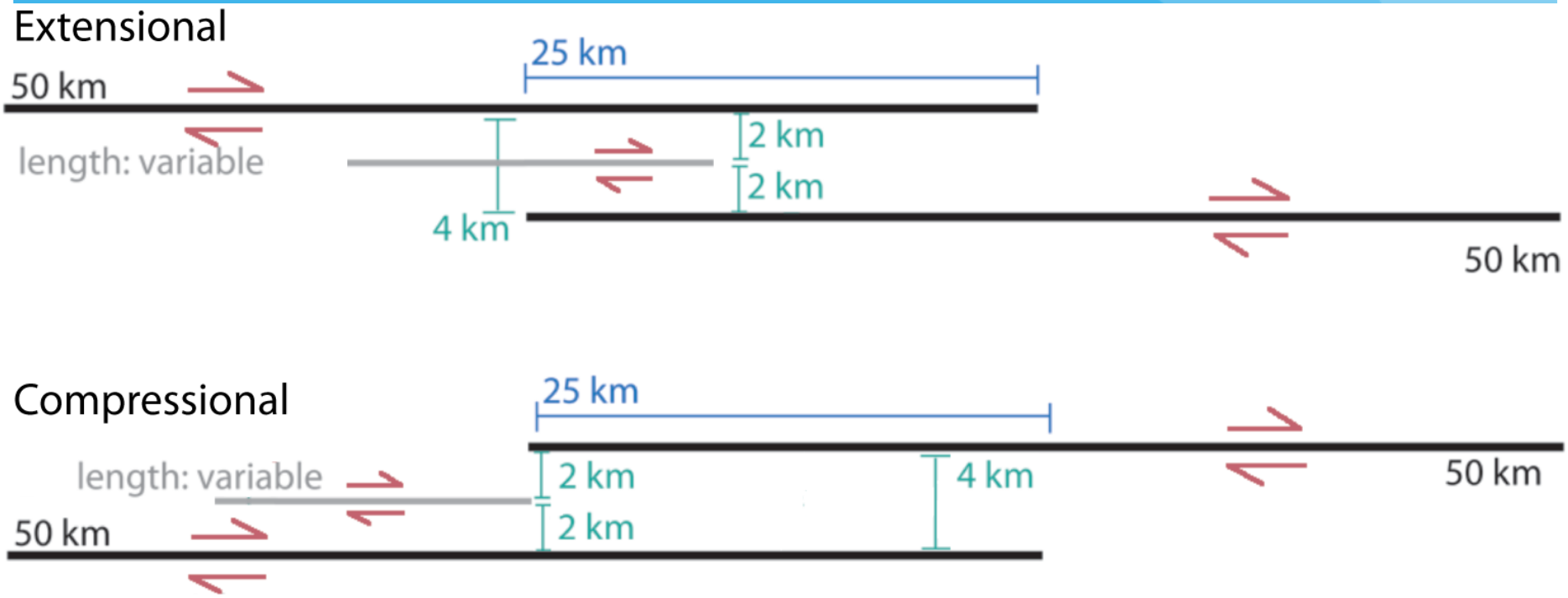


Nucleation on Eastern PBT



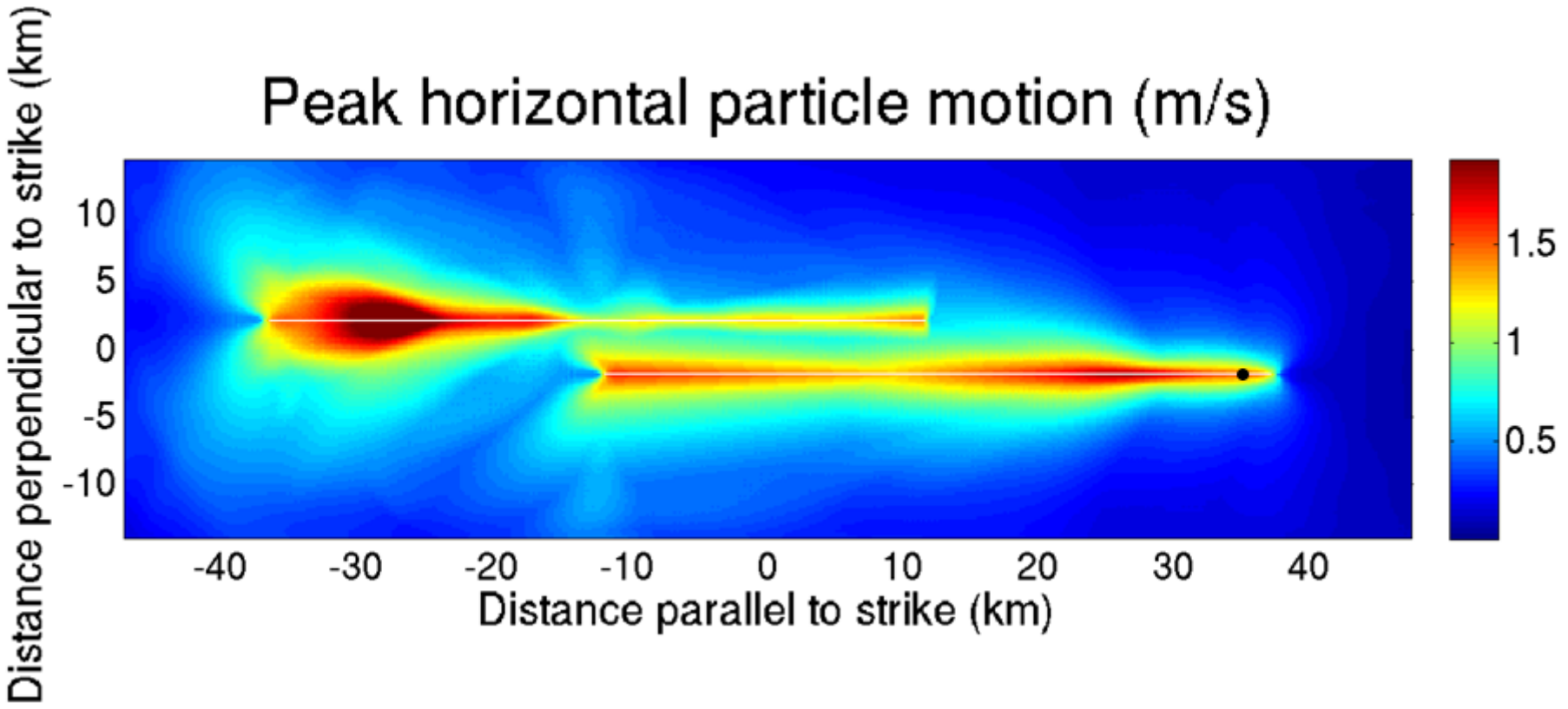
Effect of an Intermediate Fault on Rupture at Stepovers

Cartoon of Geometry

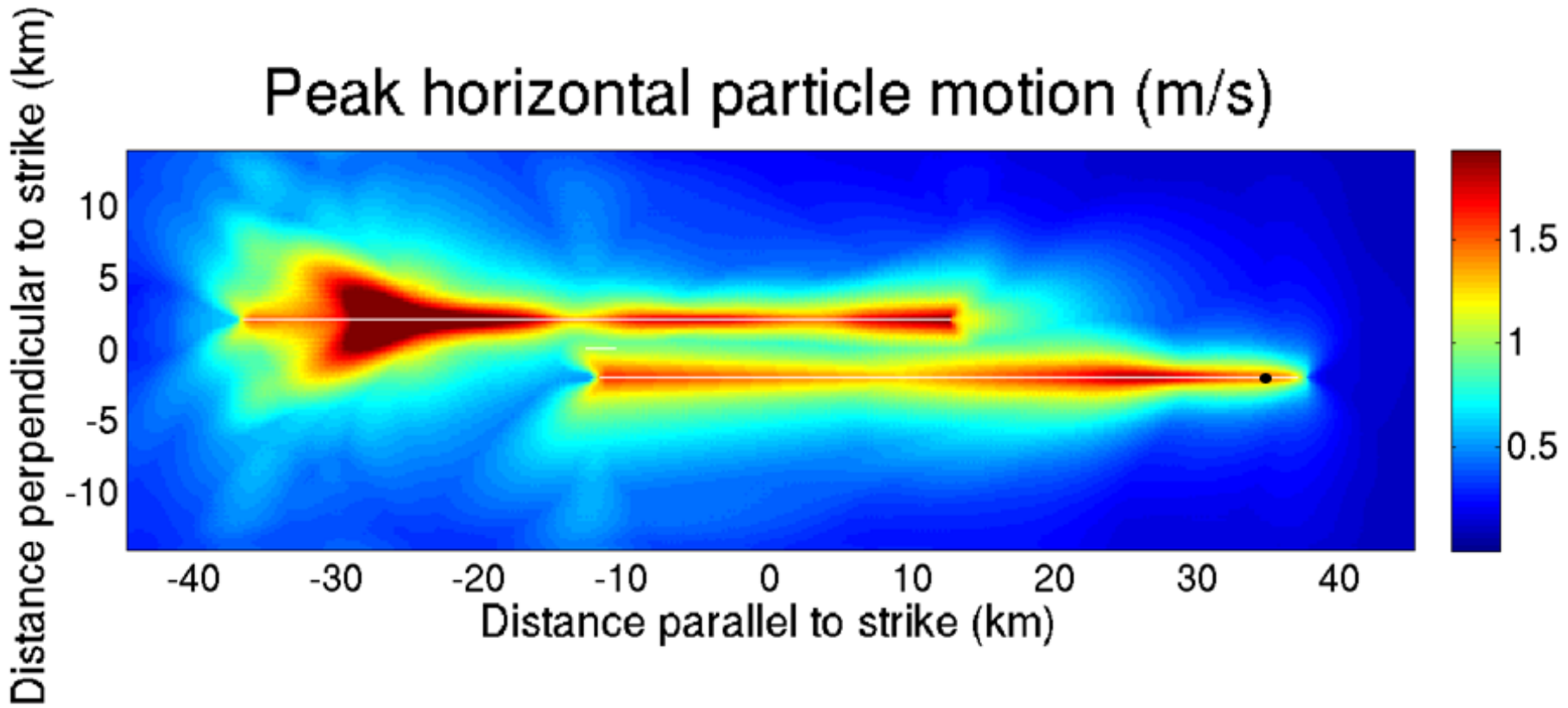


Faults extend to depth of 16 km.

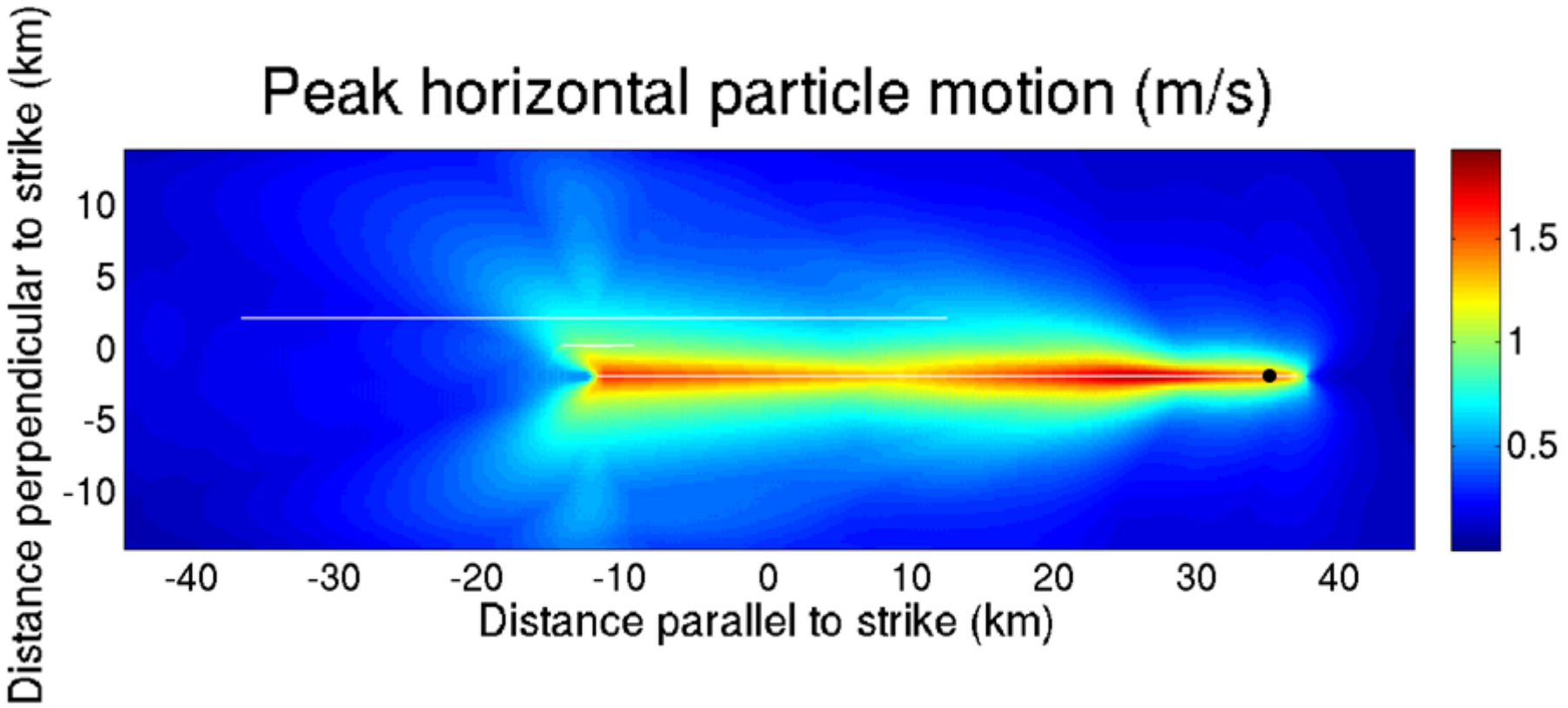
No intermediate segment



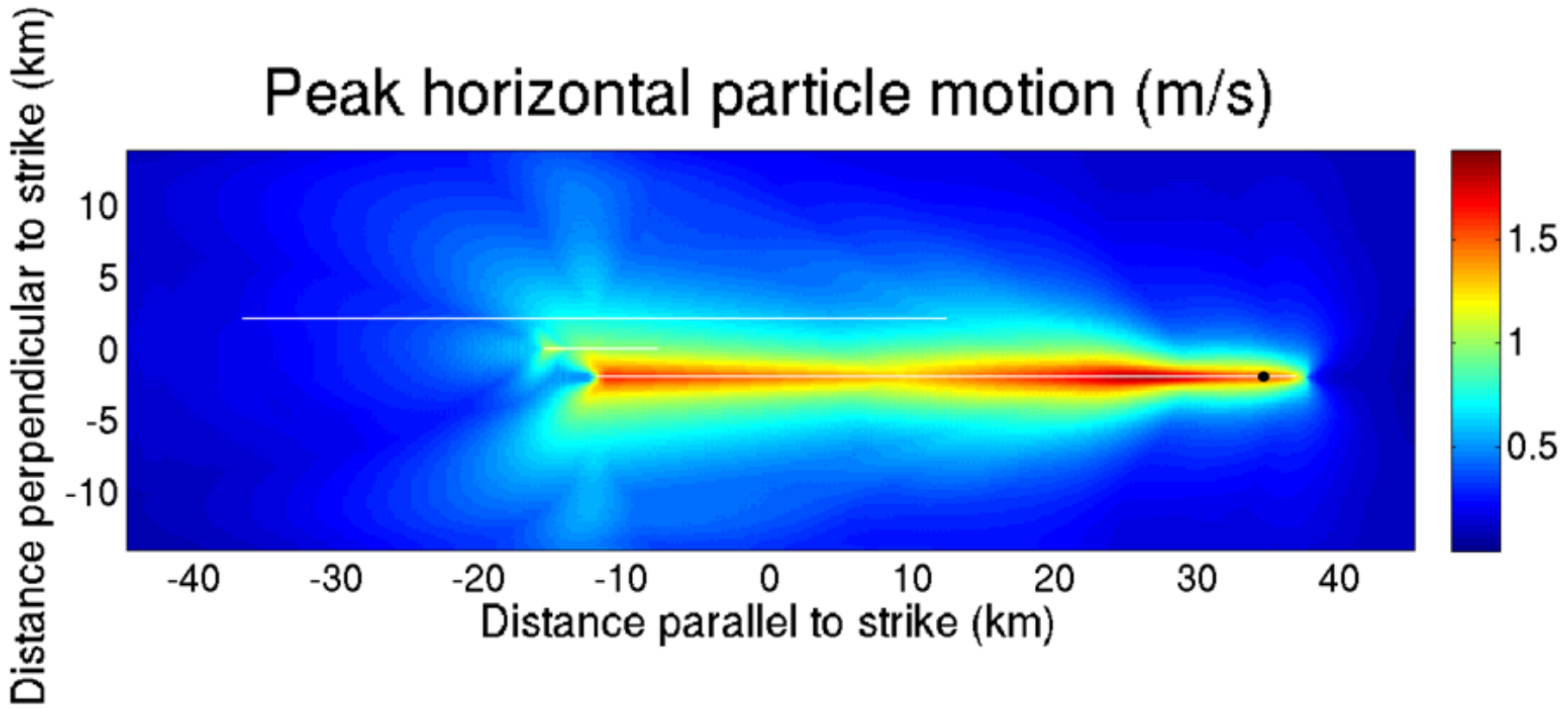
3 km intermediate segment



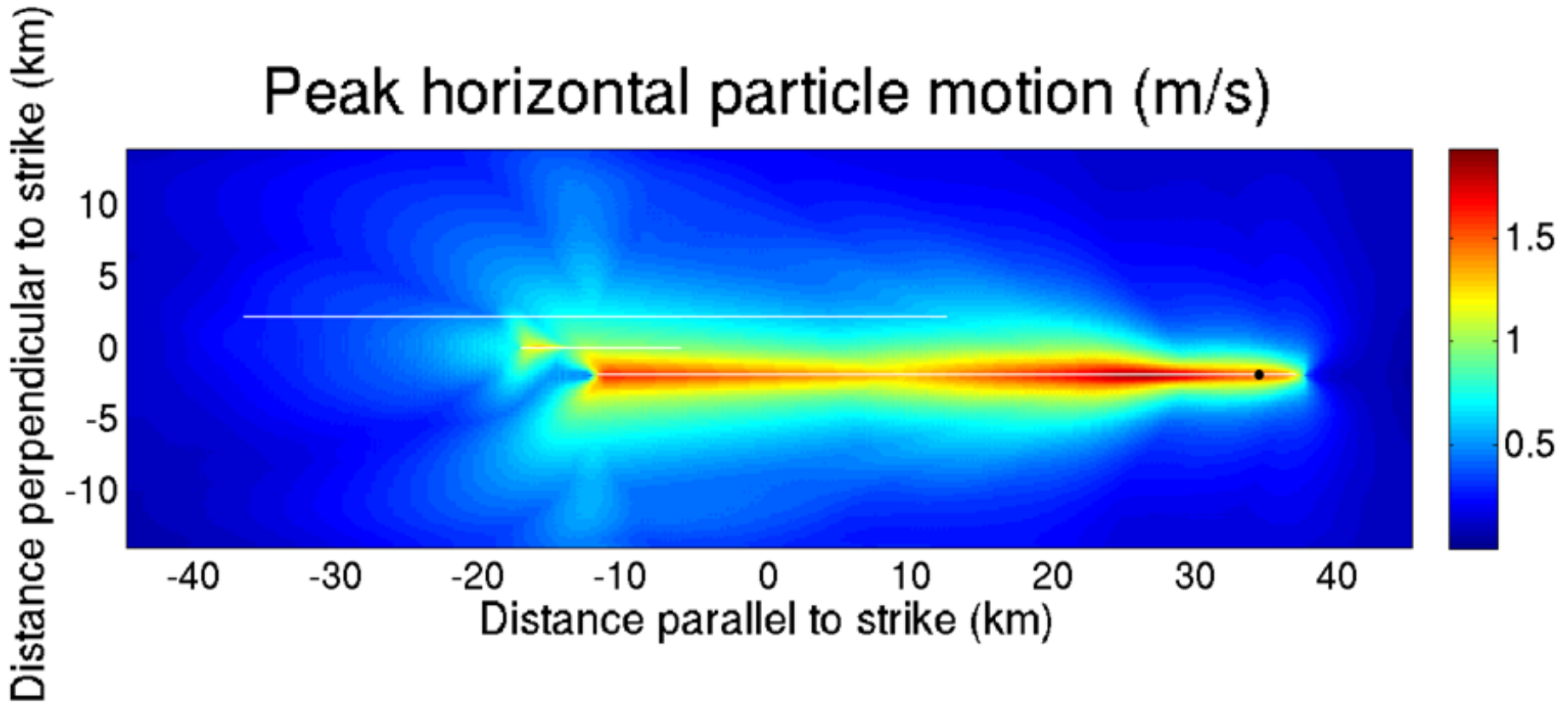
5 km intermediate segment



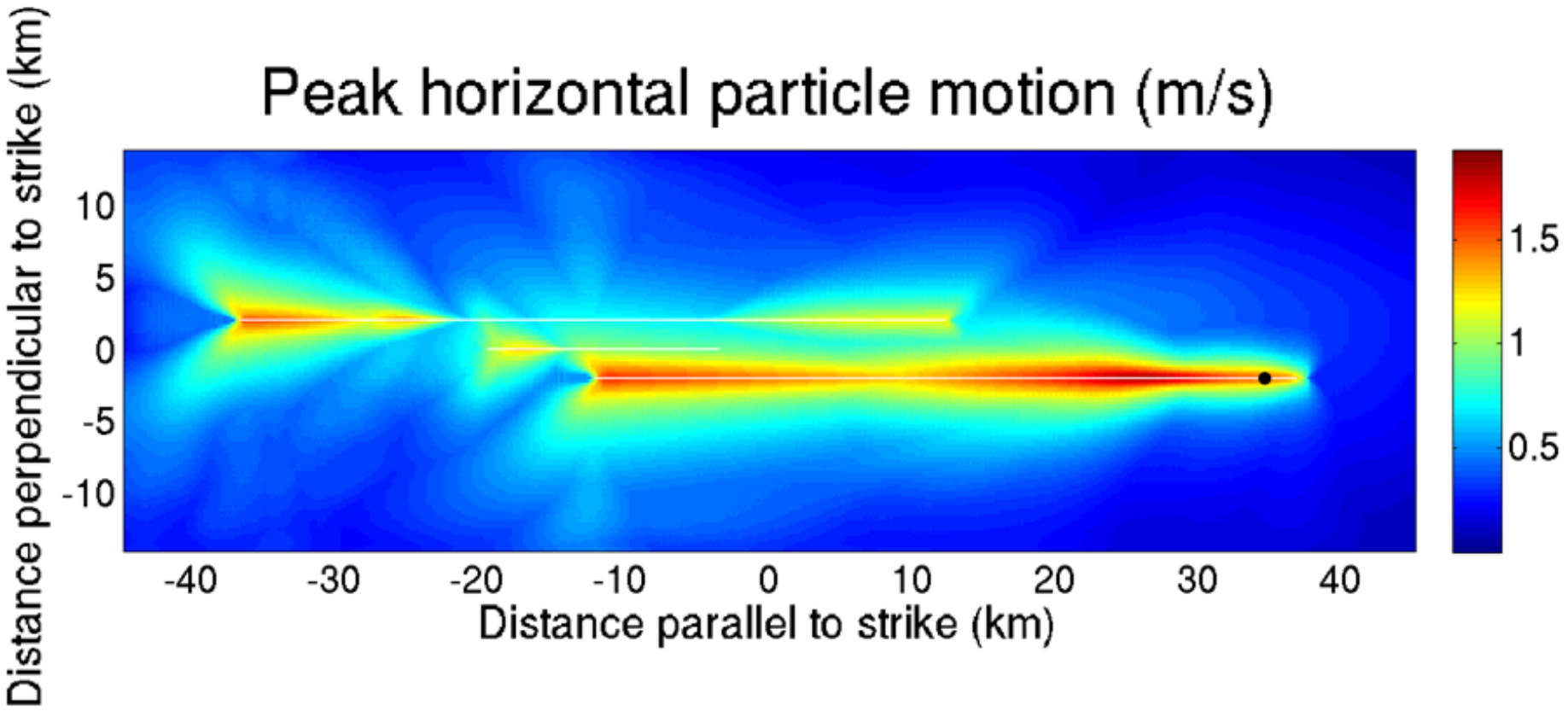
7 km intermediate segment



10 km intermediate segment



15 km intermediate segment



Effect of Segment Basal Depth

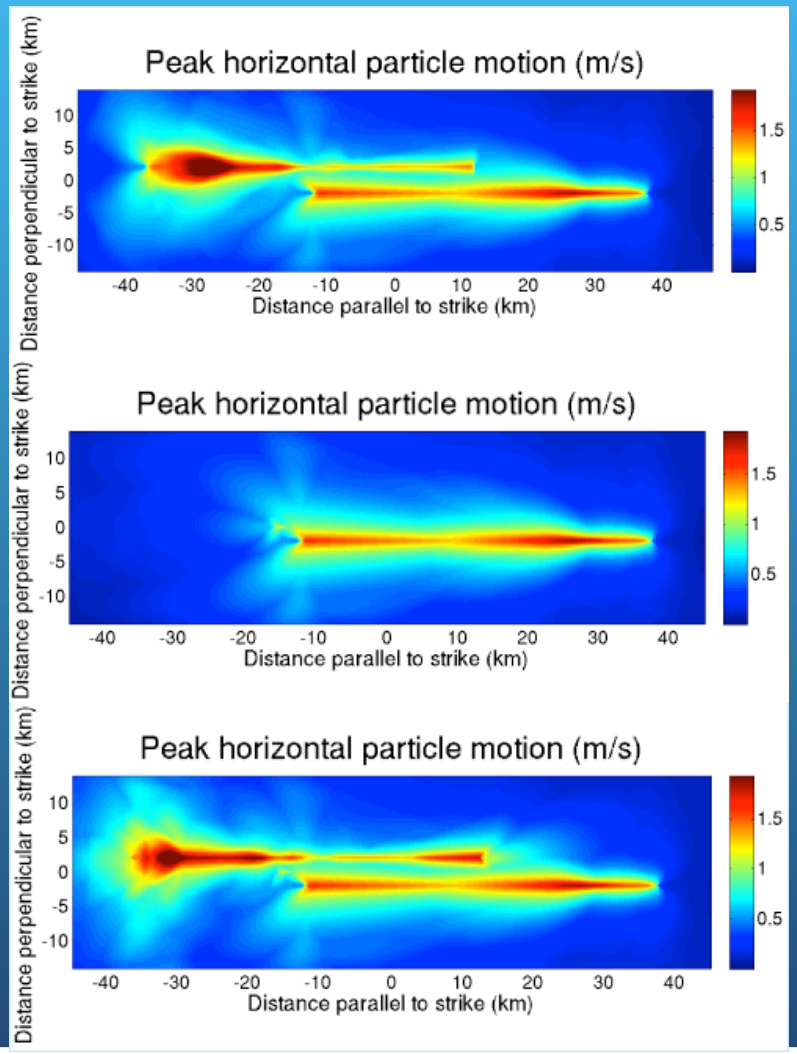
Jumps without segment

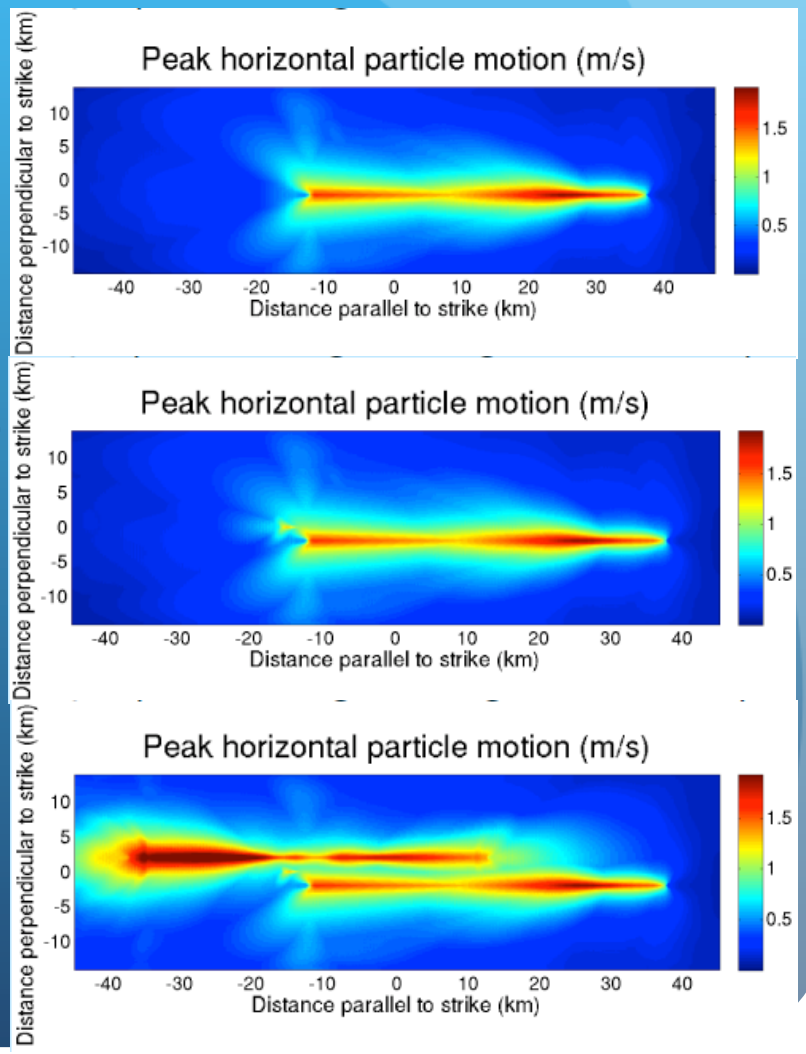
No jump without segment

No segment

16 km deep

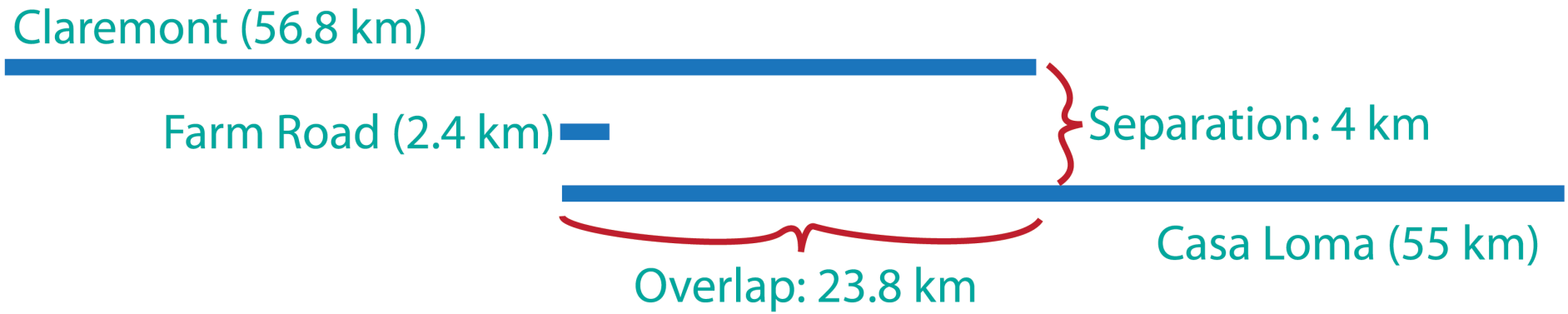
8 km deep





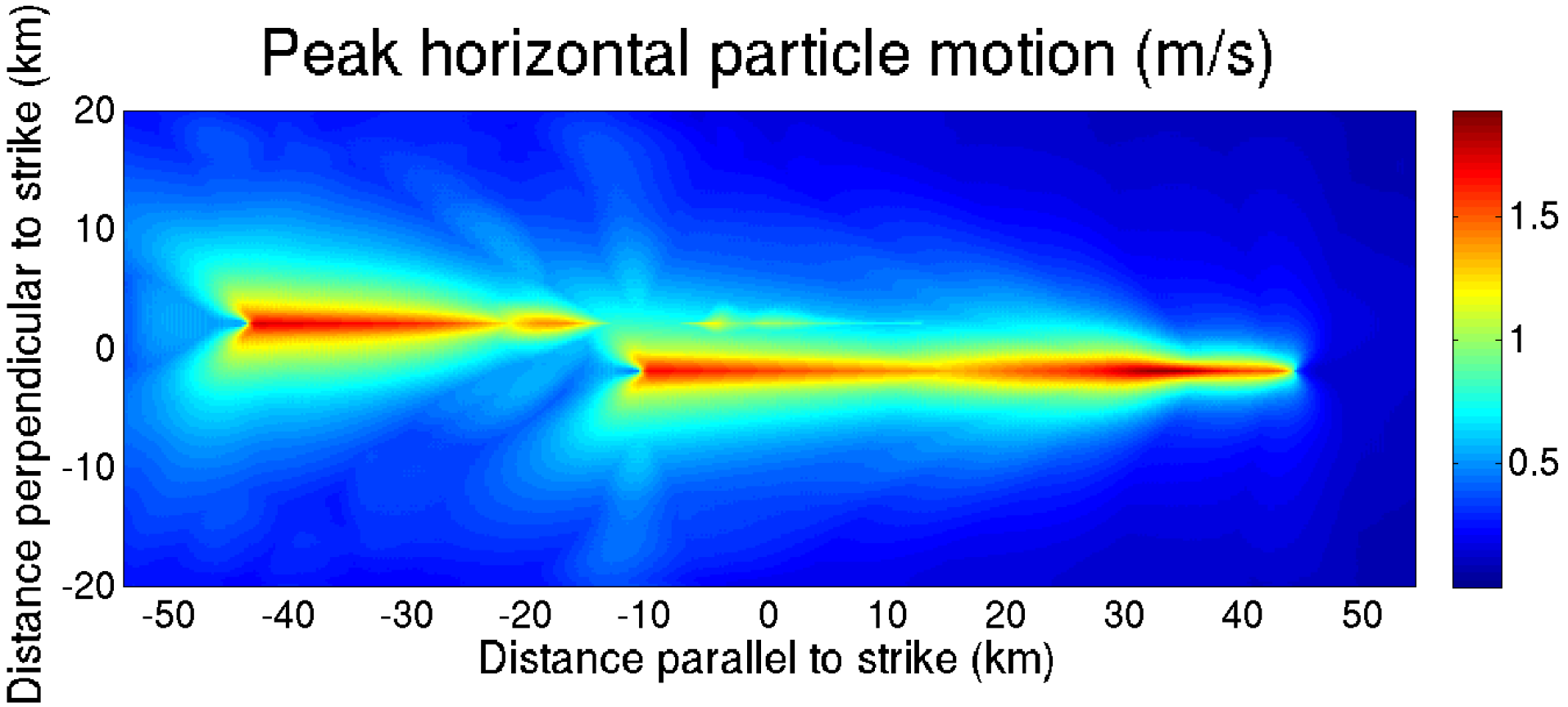
Effect of fine-scale fault geometry on ground motion

Planar Geometry

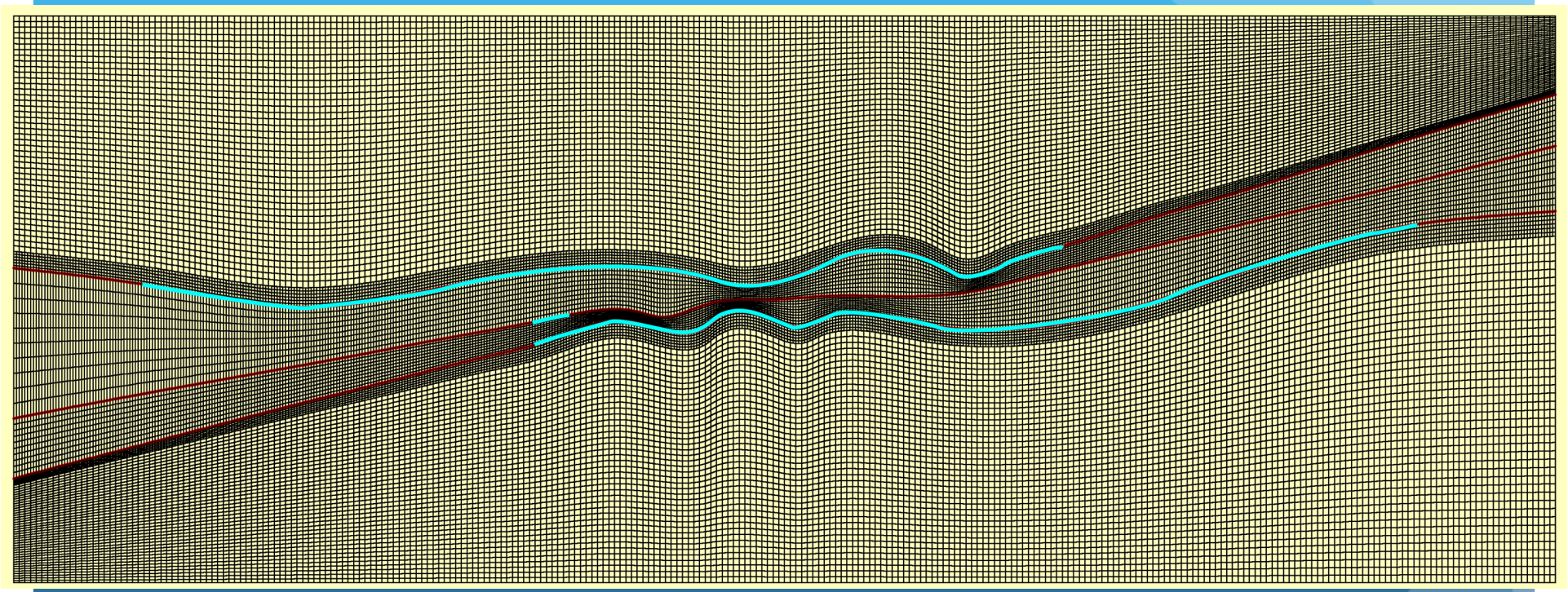


Fault basal depth: 16 km
Nucleation: 3 km from right end of Casa Loma strand, 8 km deep

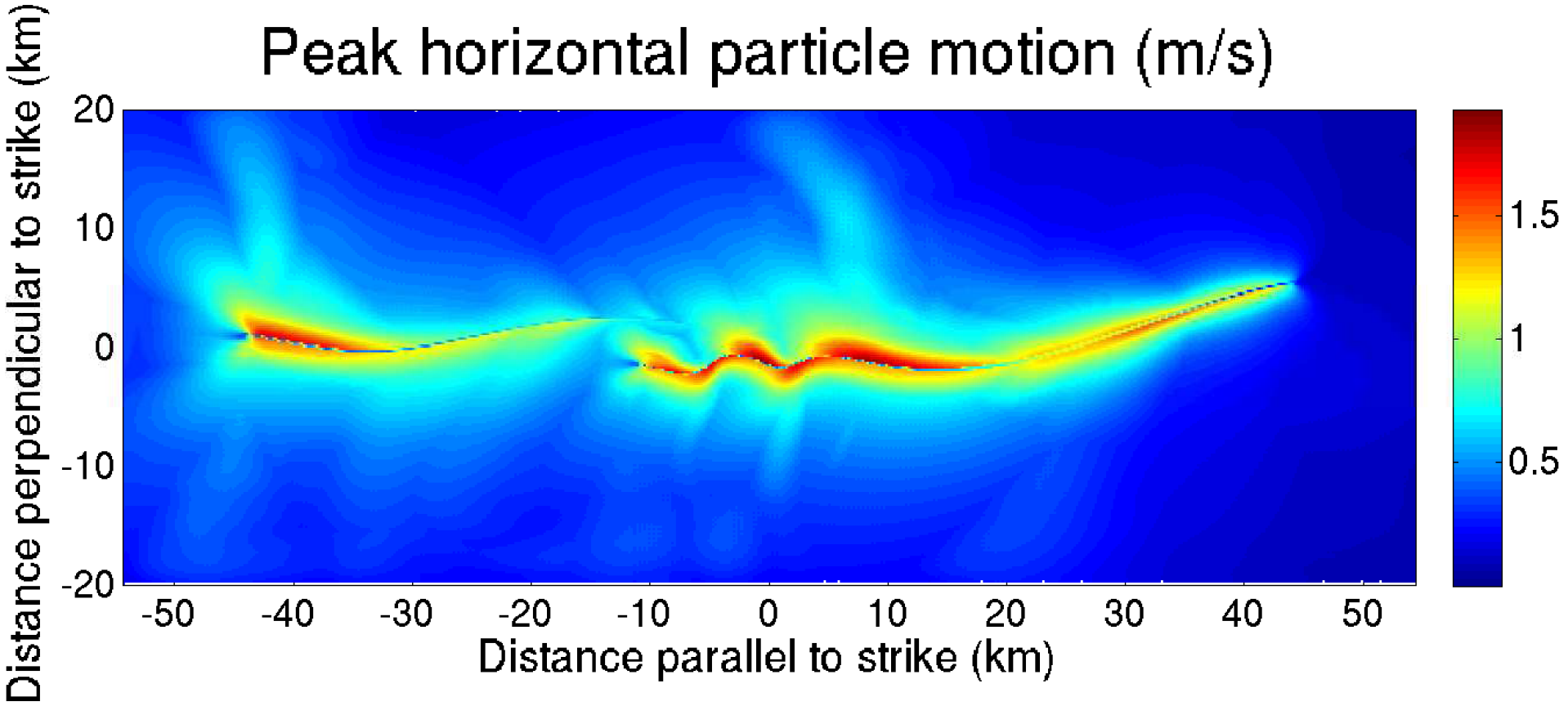
Planar Geometry



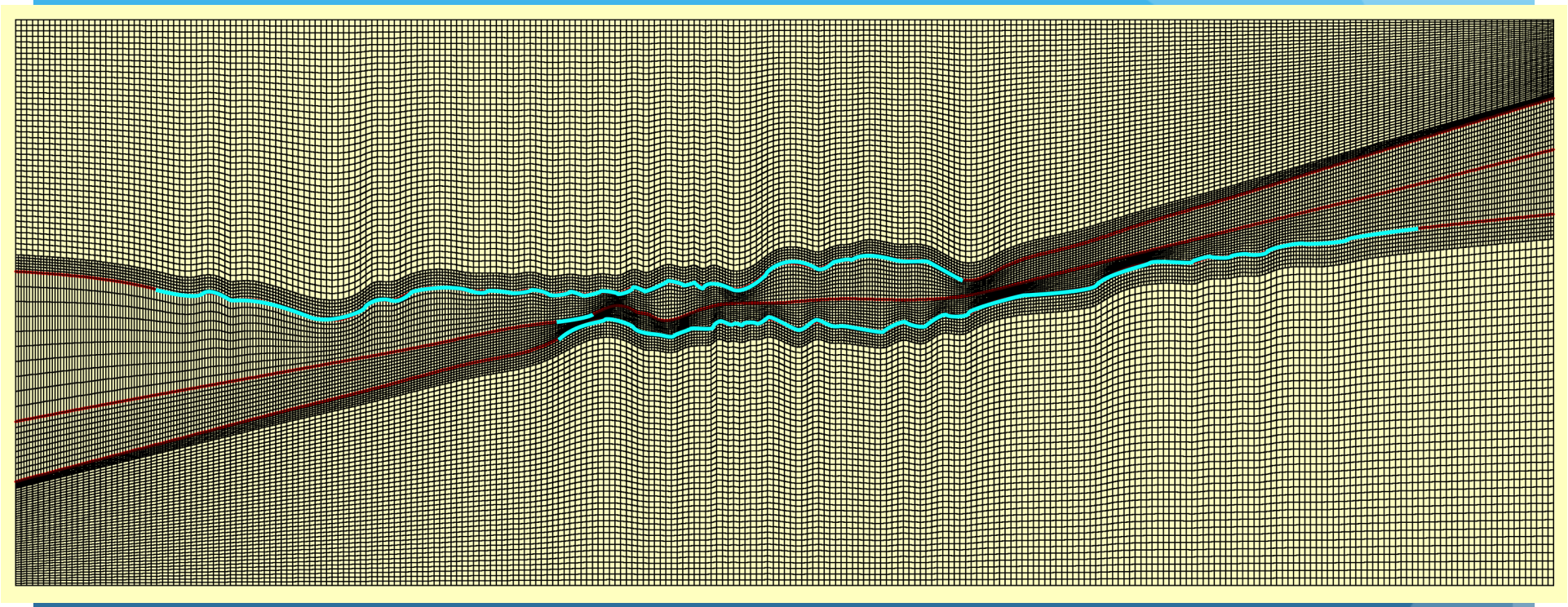
Bends Within Segments - Mesh



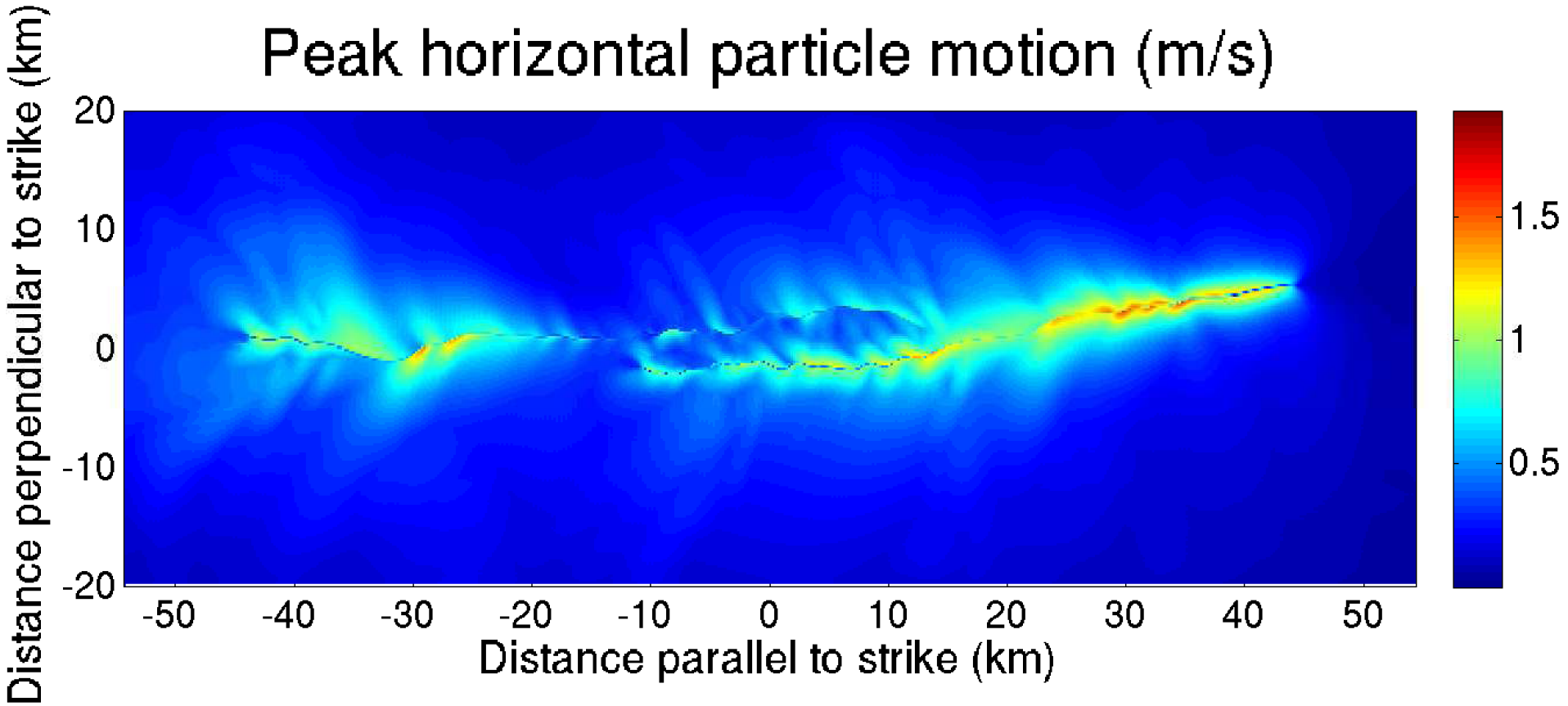
Bends Within Segments - Result



Detailed Bend Segmentation - Mesh

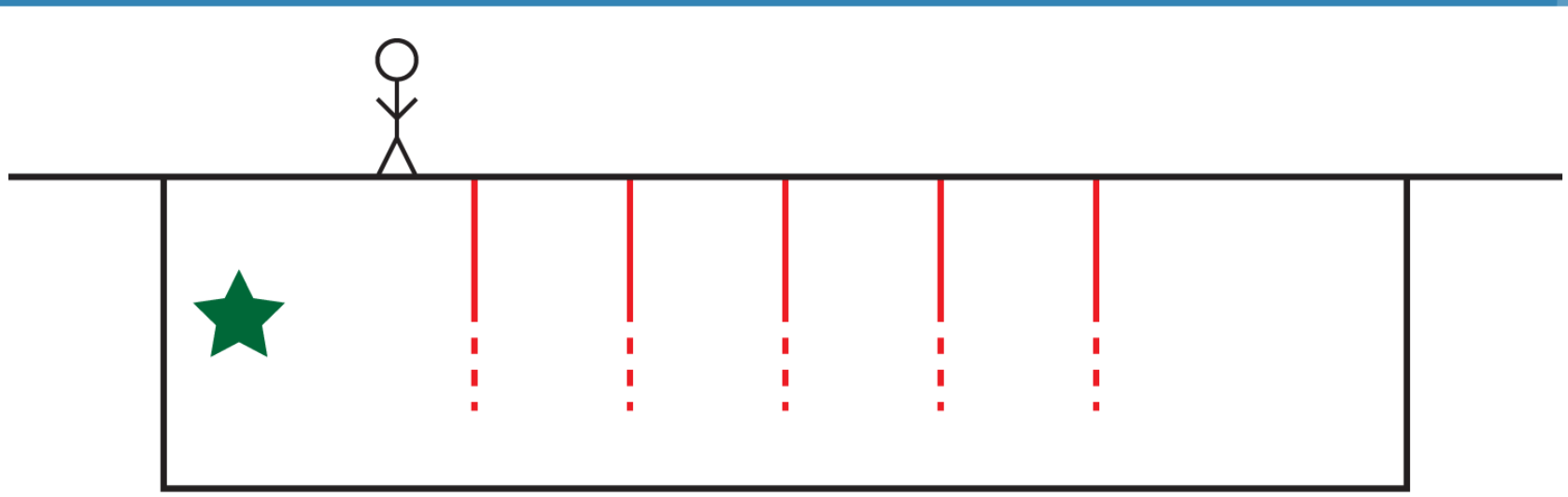


Detailed Bent Segmentation - Result

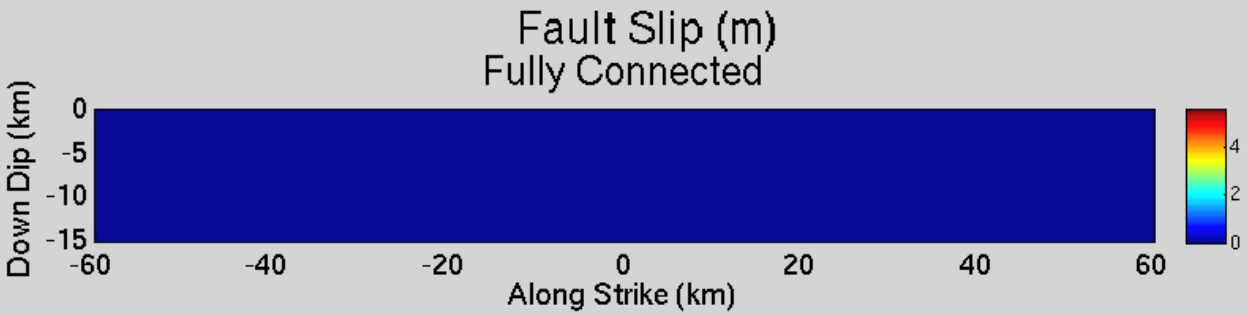


Does fault connectivity at depth strongly influence surface slip?

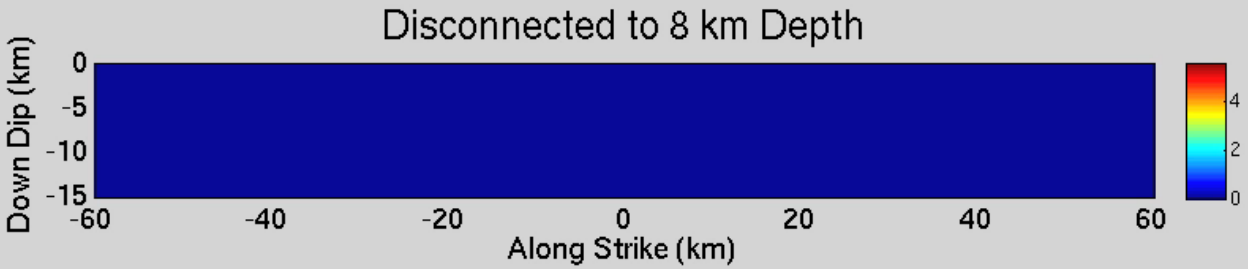
- Planar fault broken into coplanar segments by thin zones of artificially high friction coefficient (600 m wide) along strike
- 3D Finite Element Method (FaultMod, Michael Barall)
- Slip-weakening friction (slip-strengthening in top 1 km)



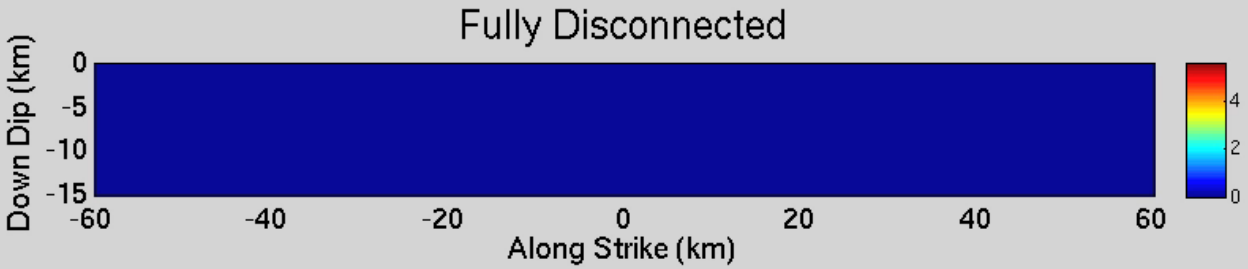
Sample Fault Slip Comparison



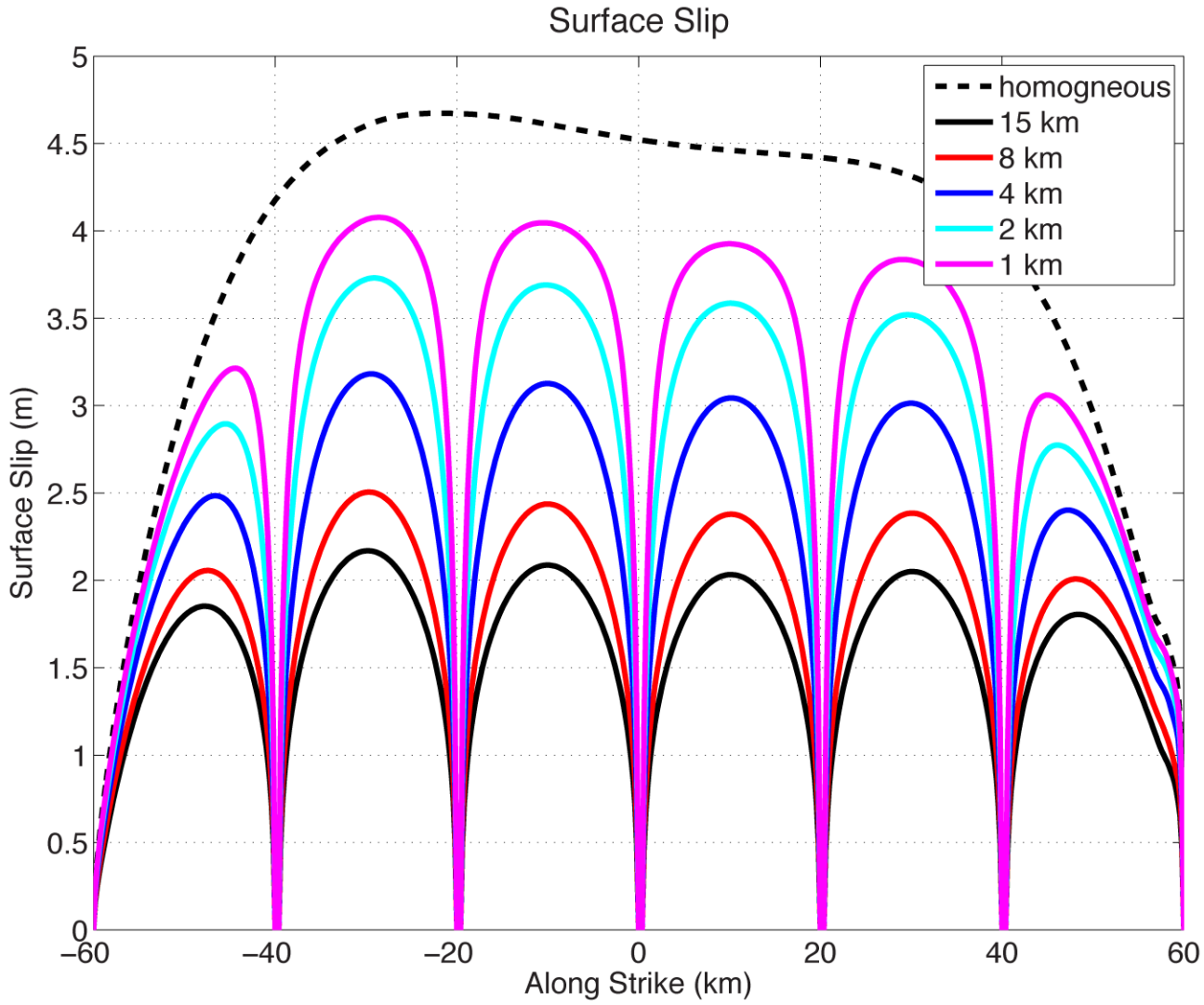
Peak Slip: 5.7 m

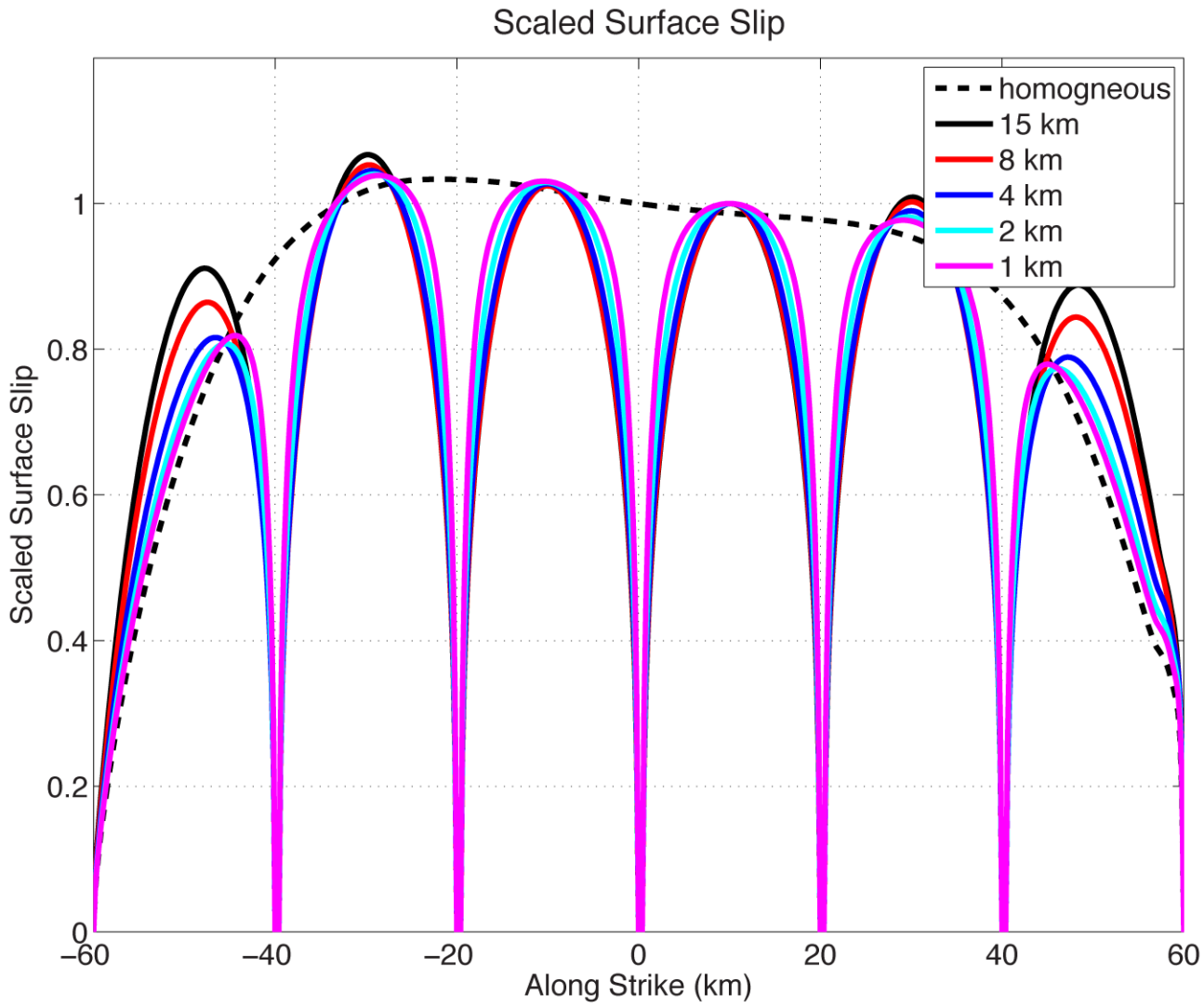


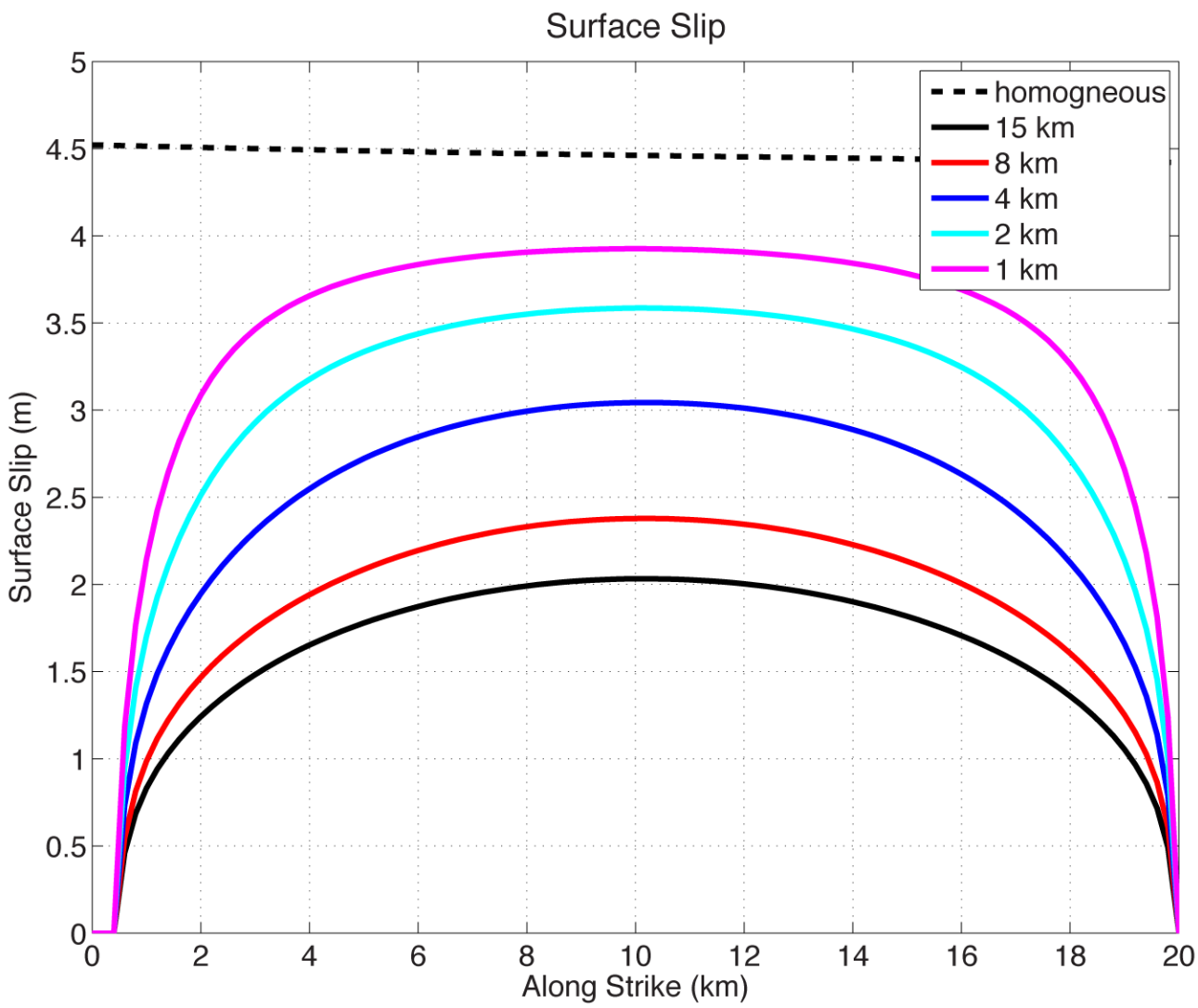
Peak Slip: 3.7 m

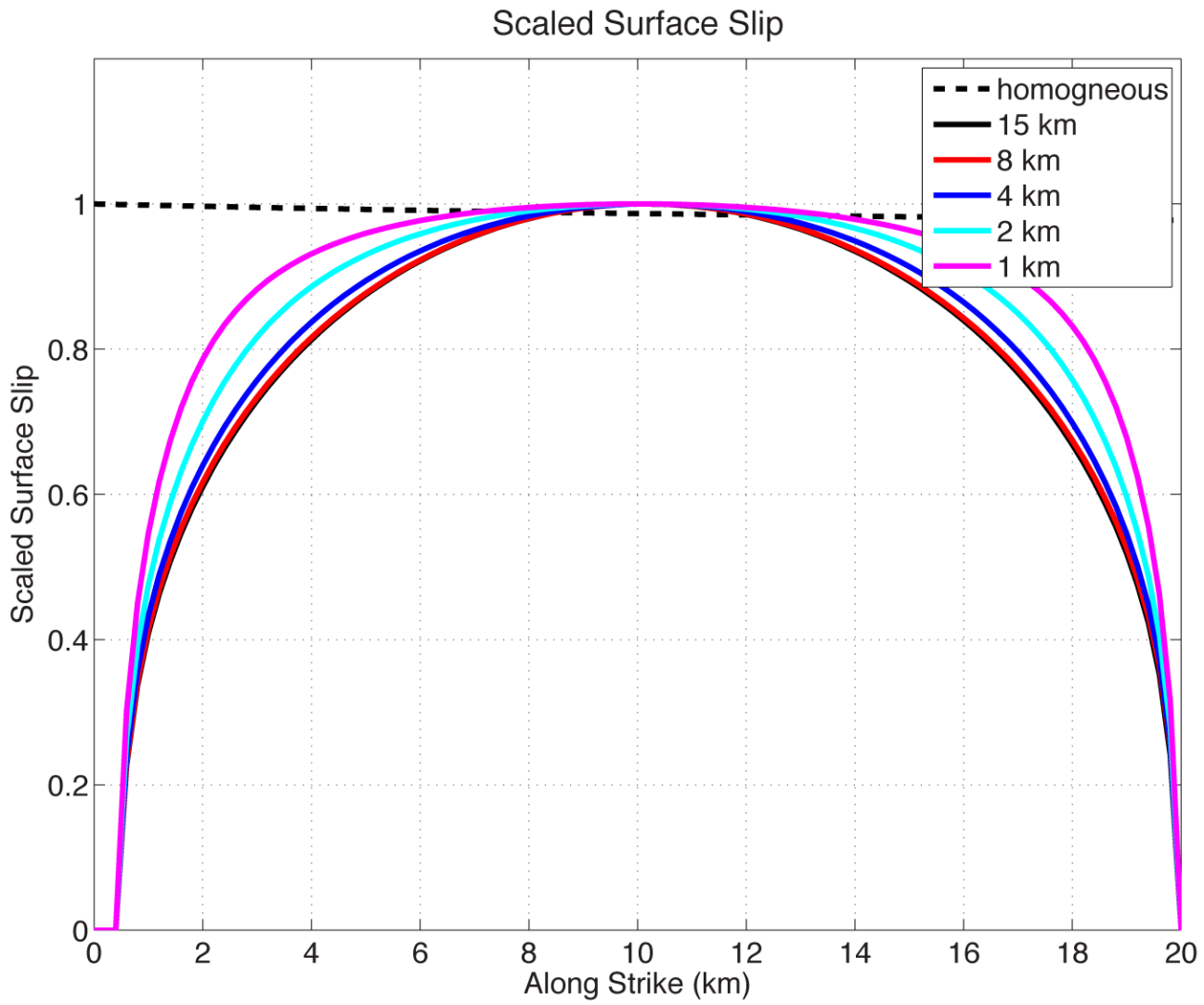


Peak Slip: 3.4 m


Surface Slip
homogneous
15 km
8 km
4 km
2 km
1 km
Surface Slip (m)
Along Strike (km)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
–60
–40
–20
0
20
40
60


Scaled Surface Slip
homogneous
15 km
8 km
4 km
2 km
1 km
Scaled Surface Slip
0
0.2
0.4
0.6
0.8
1
−60
−40
−20
0
20
40
60
Along Strike (km)


Surface Slip
homogneous
15 km
8 km
4 km
2 km
1 km
Surface Slip (m)
Along Strike (km)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10
12
14
16
18
20


Scaled Surface Slip
homogneous
15 km
8 km
4 km
2 km
1 km
Scaled Surface Slip
Along Strike (km)
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
12
14
16
18
20

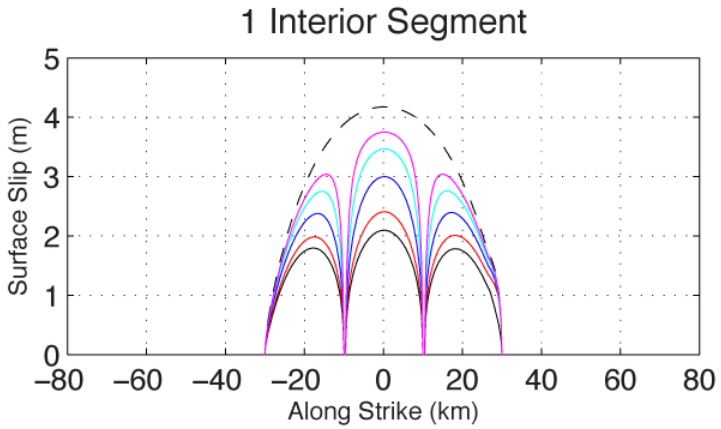
Discussion

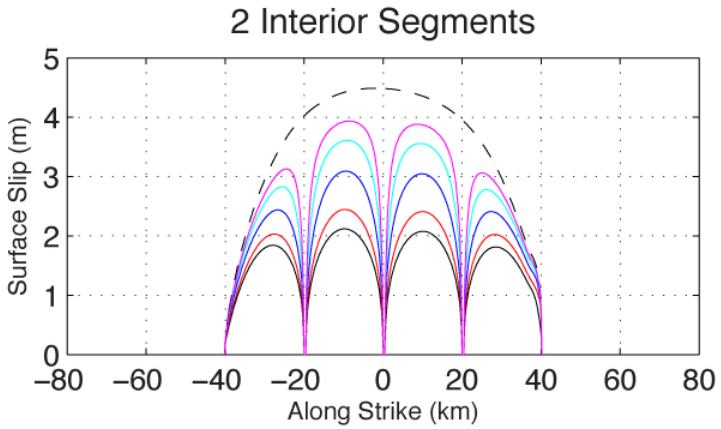
- Surface slip distribution might not be very helpful in determining the connectivity of a fault at depth.
  - High slip gradient near segment edges is clear only for:
    - wide fault segments
    - Segments with shallow (1-2 km deep or so) connection
- Caveat: model very simple!
  - But I suspect more realistic geometry might further mask gradient.

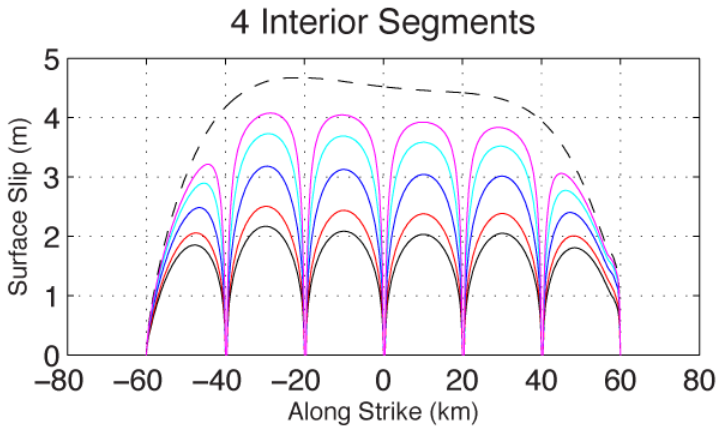
Overall Conclusions

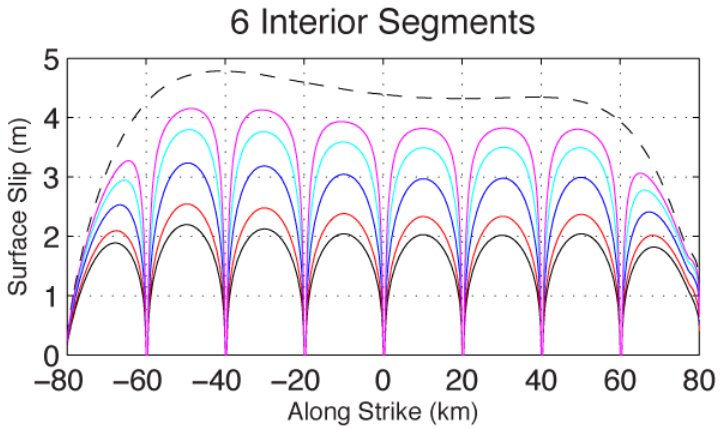
- Propagation between thrust and strike-slip faults should be considered (stress interactions very complex)
  - Denali Fault 2002
  - Dynamic Models
- Fine details of the geometry may make a crucial difference in the likelihood of through-going rupture.
- Fine details of fault geometry may strongly affect slip amplitude, pattern, and ground motion.
- Better knowledge of fault structures is needed!

How Do Results Scale With Fault Length?

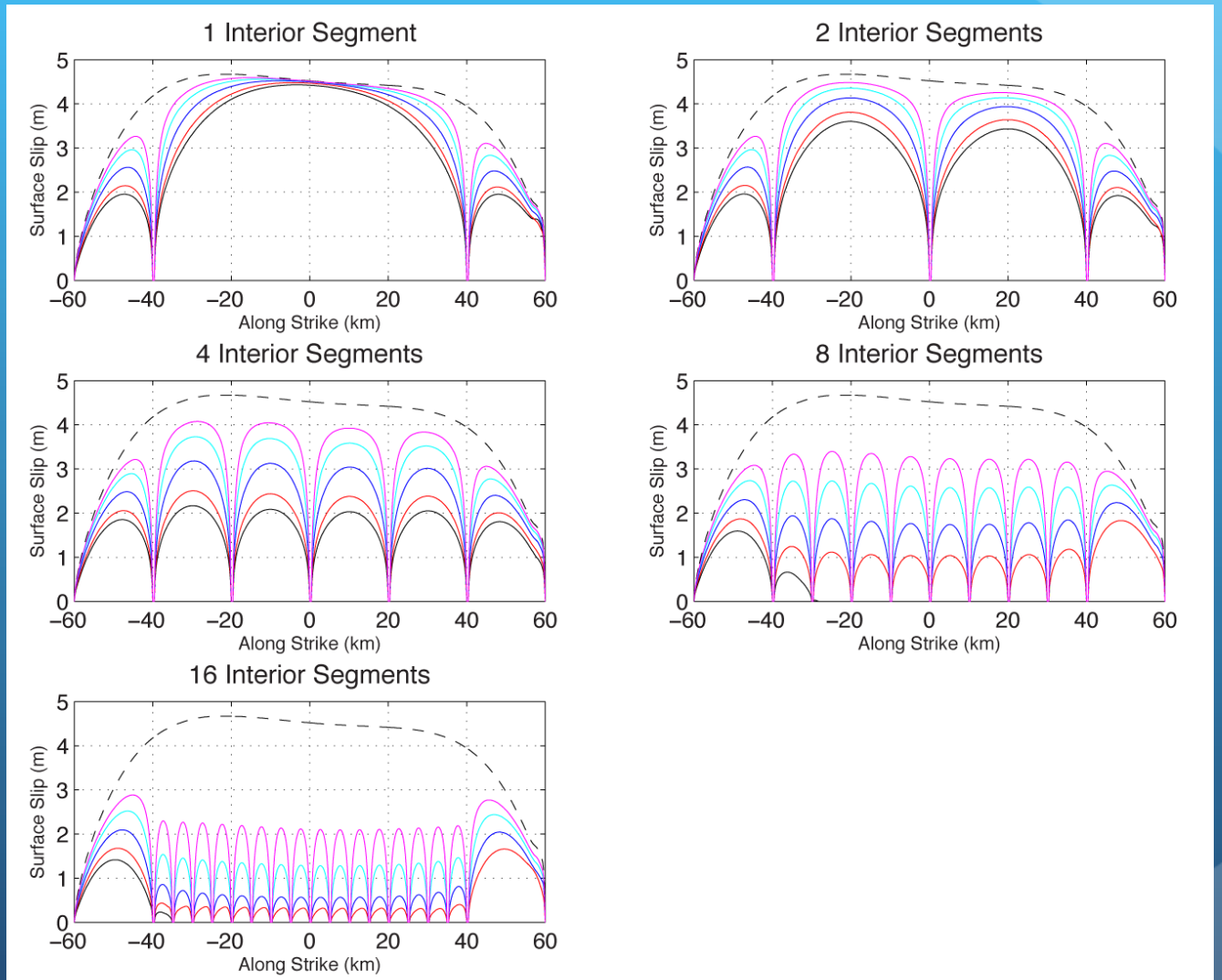




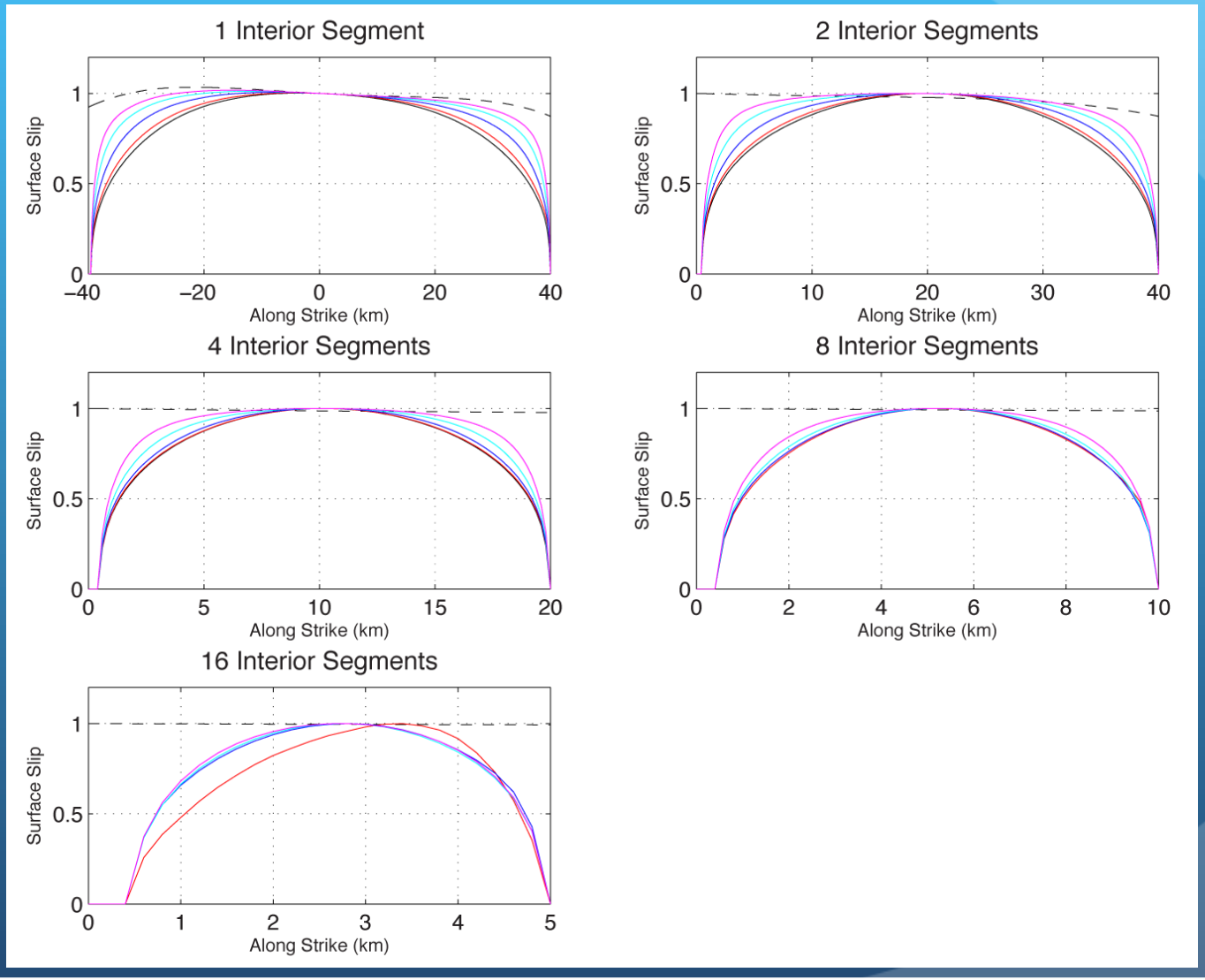




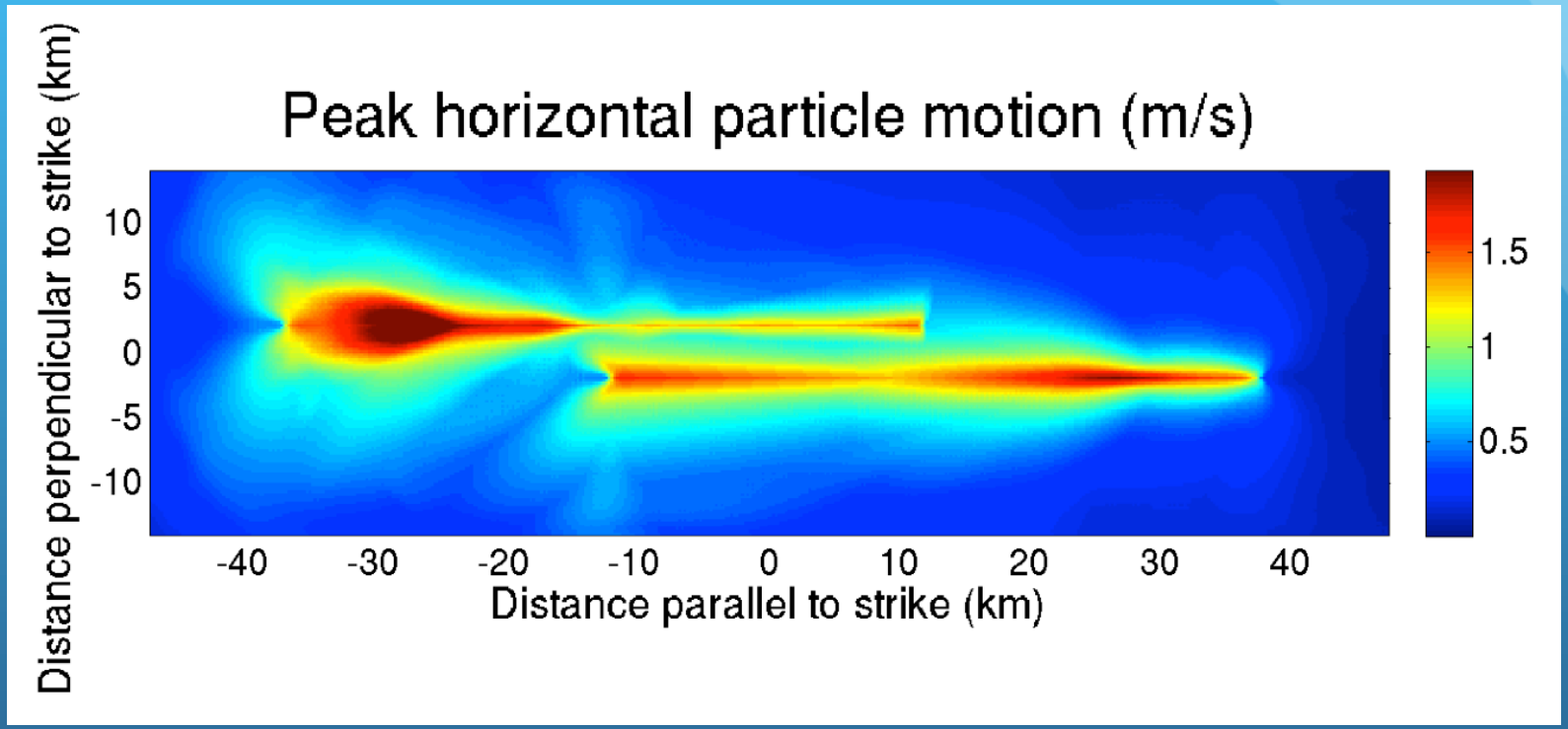
How Do Results Scale With Number/Size of Segments?



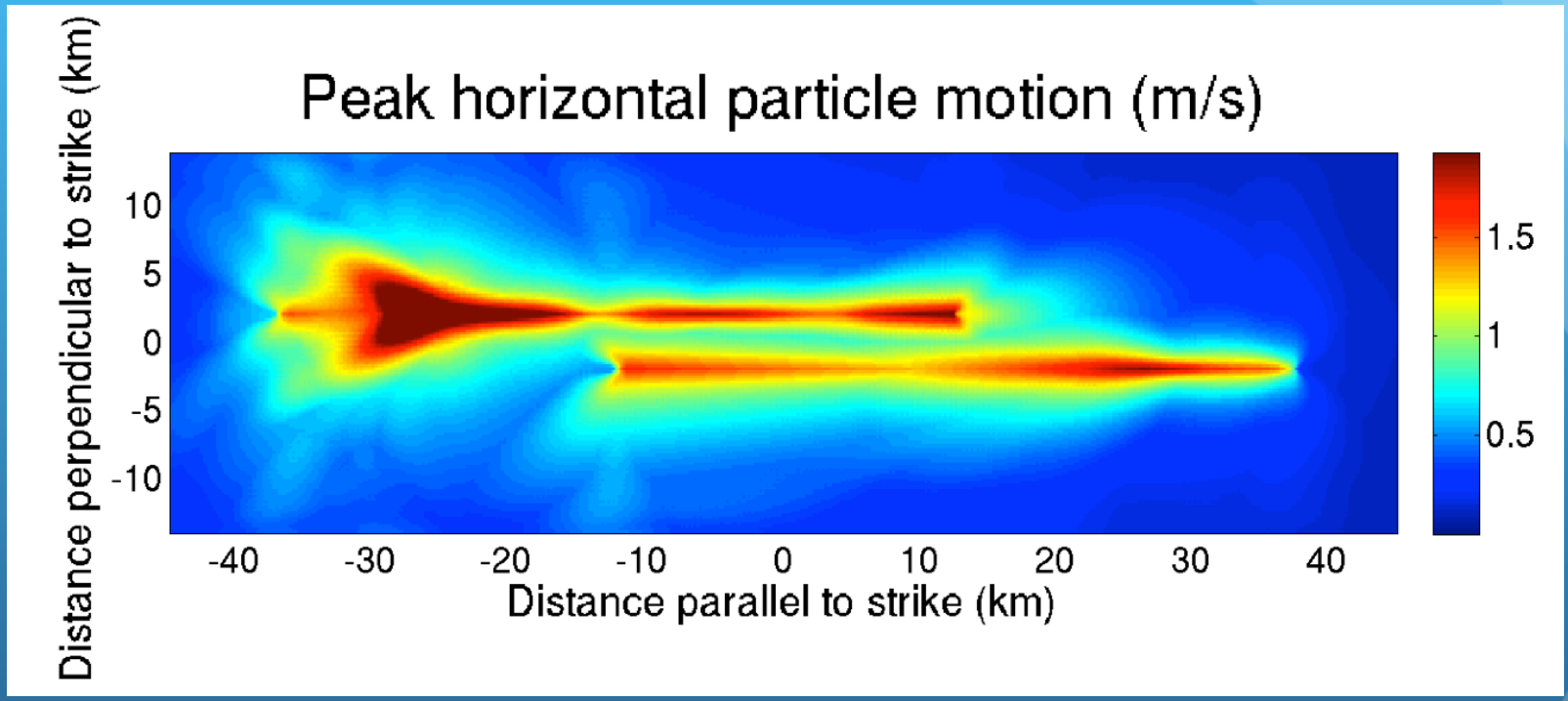
How Do Results Scale With Number/Size of Segments?



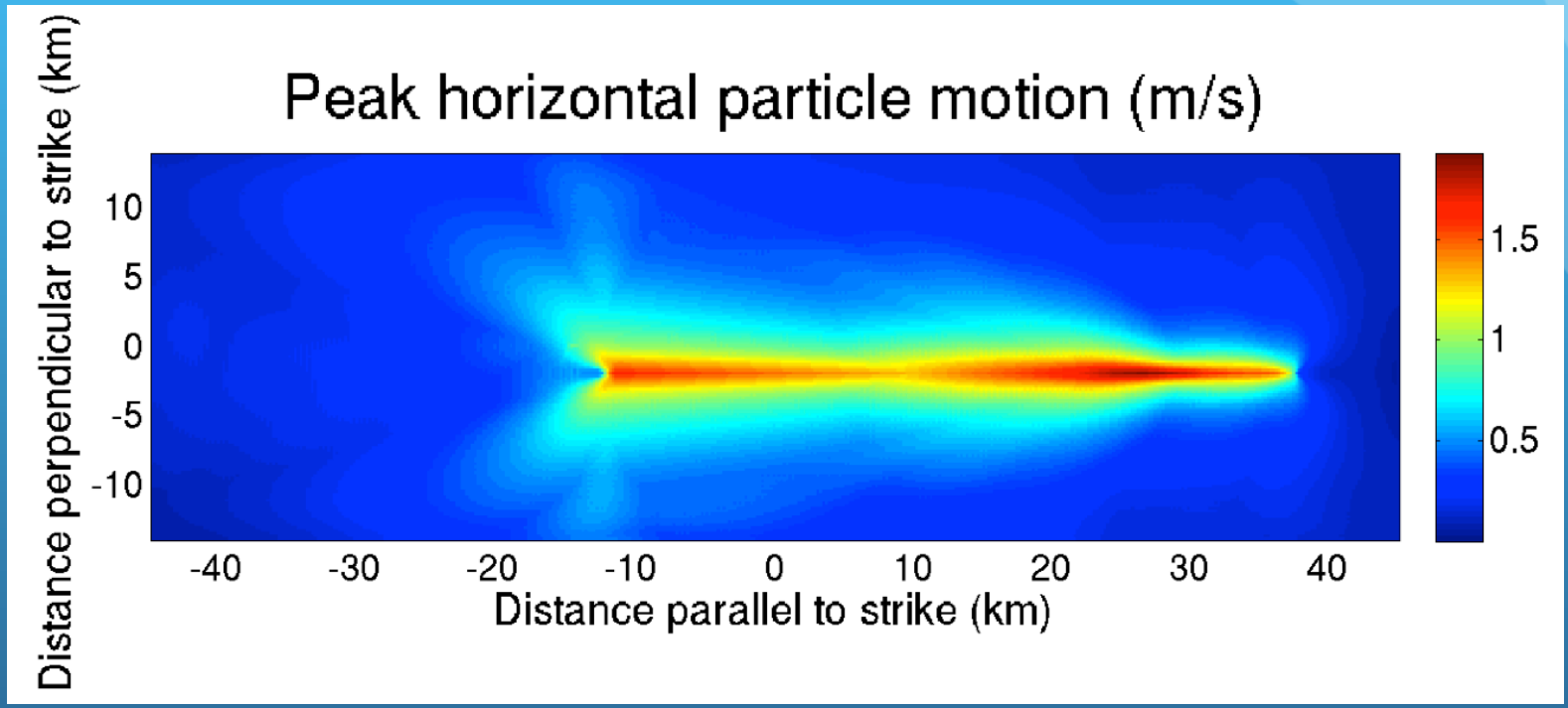
ExenNo intermediate fault



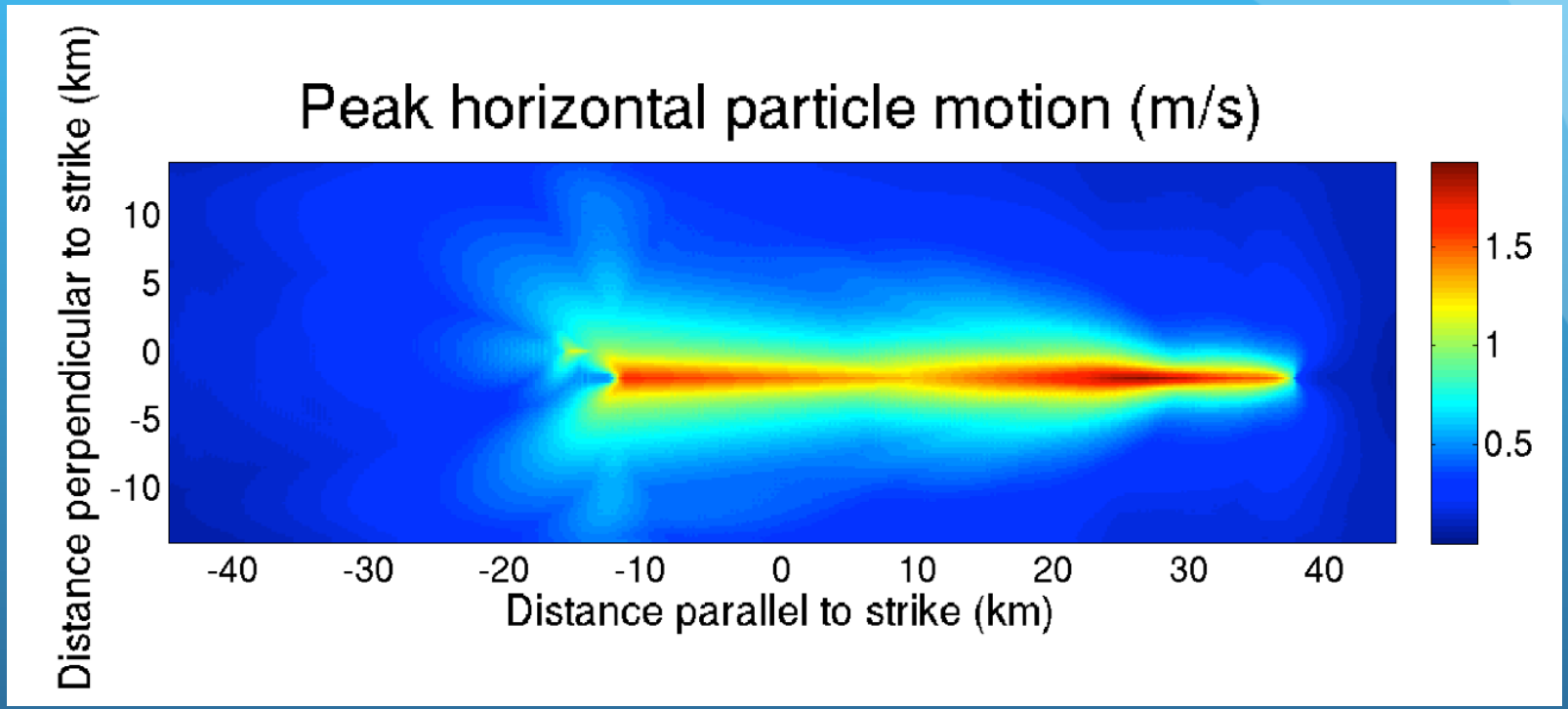
3 km long intermediate fault



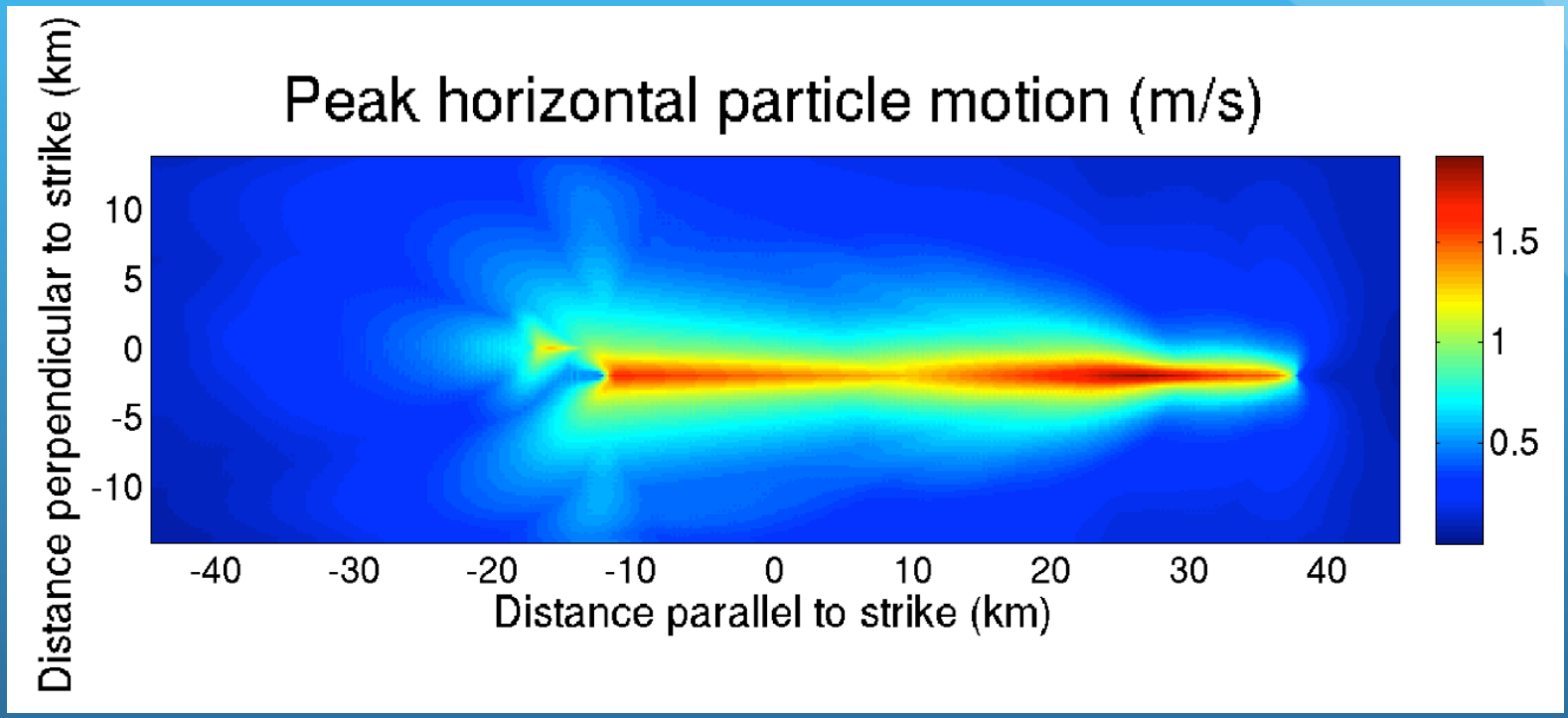
5 km long intermediate fault



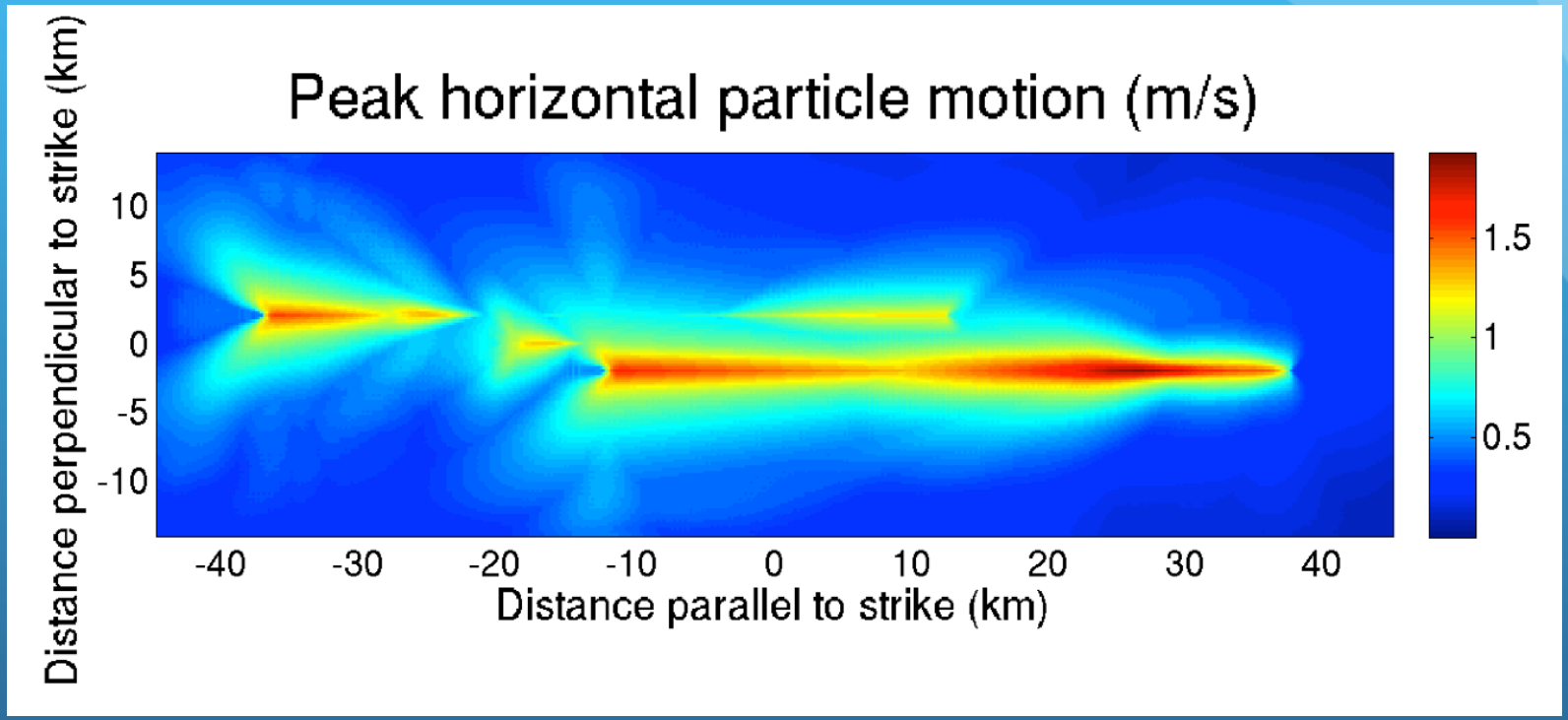
7 km long intermediate fault



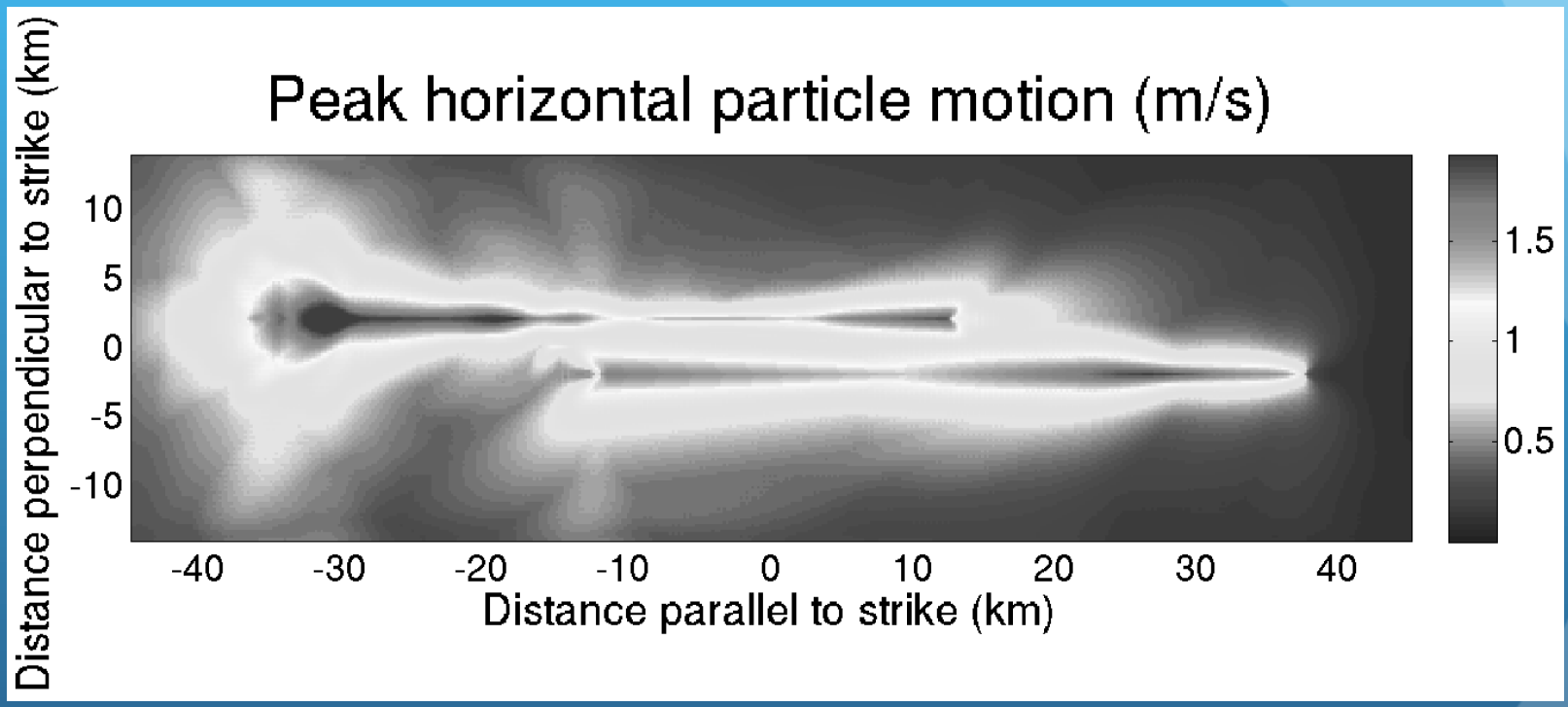
10 km long intermediate fault



15 km long intermediate fault

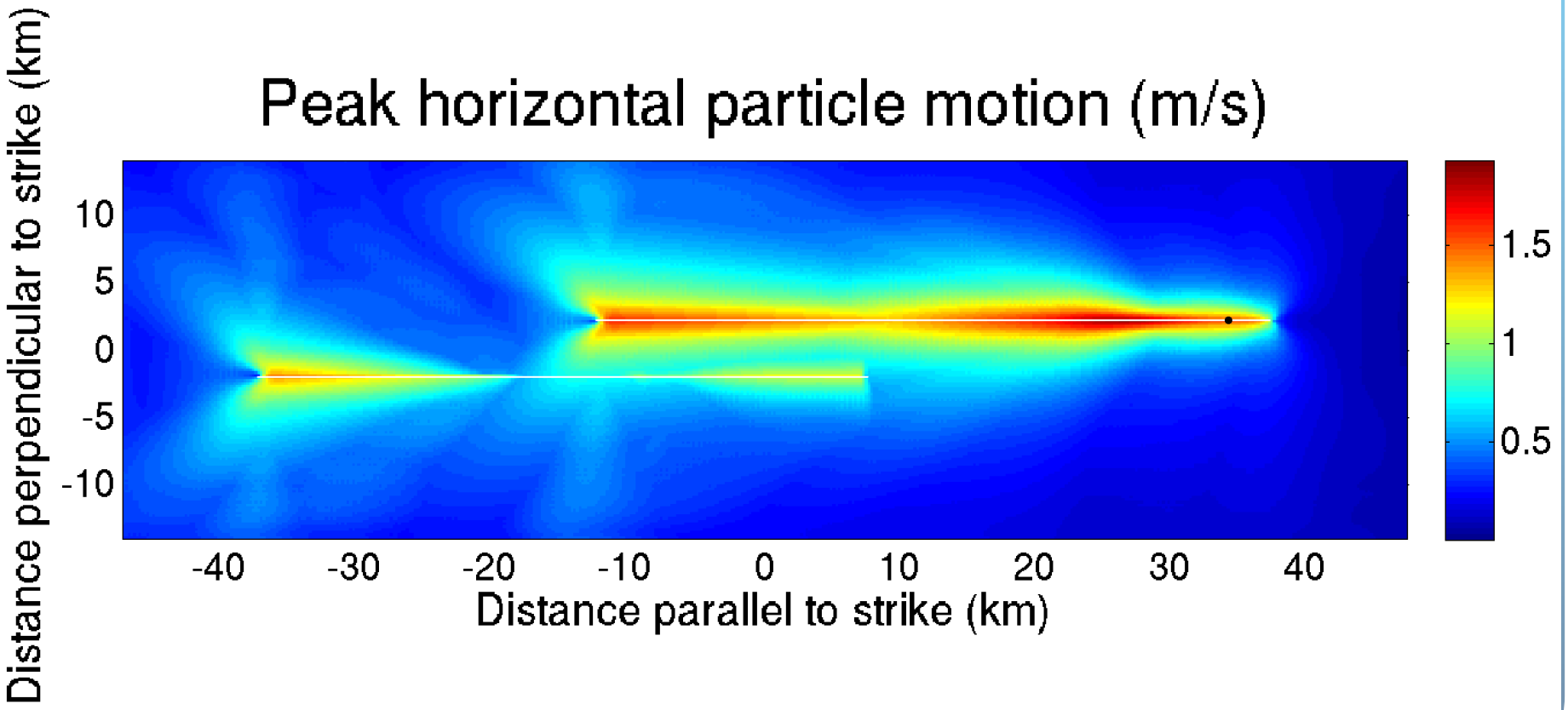


7 km long intermediate fault extending only to 8 km depth



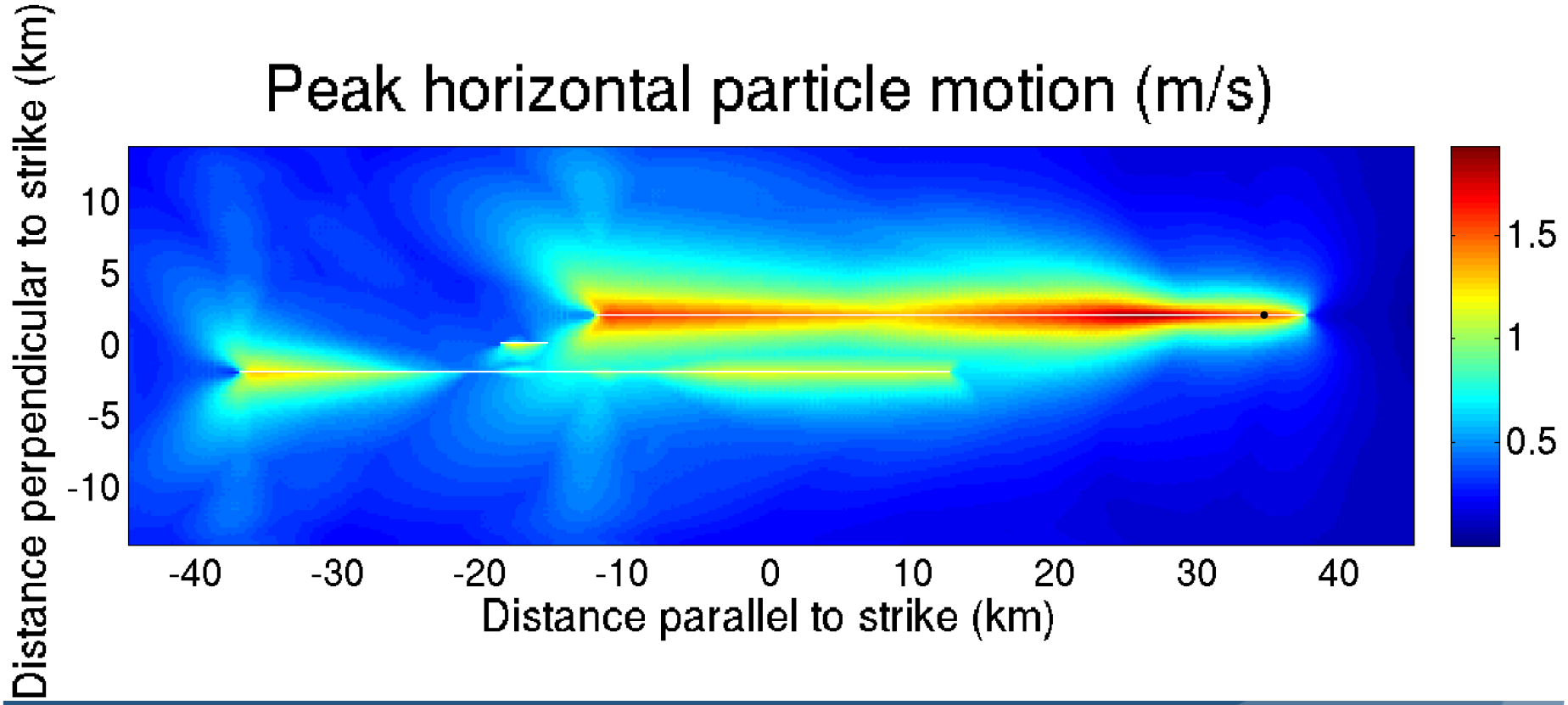
Compressional: Jumps Without Segment

No intermediate segment



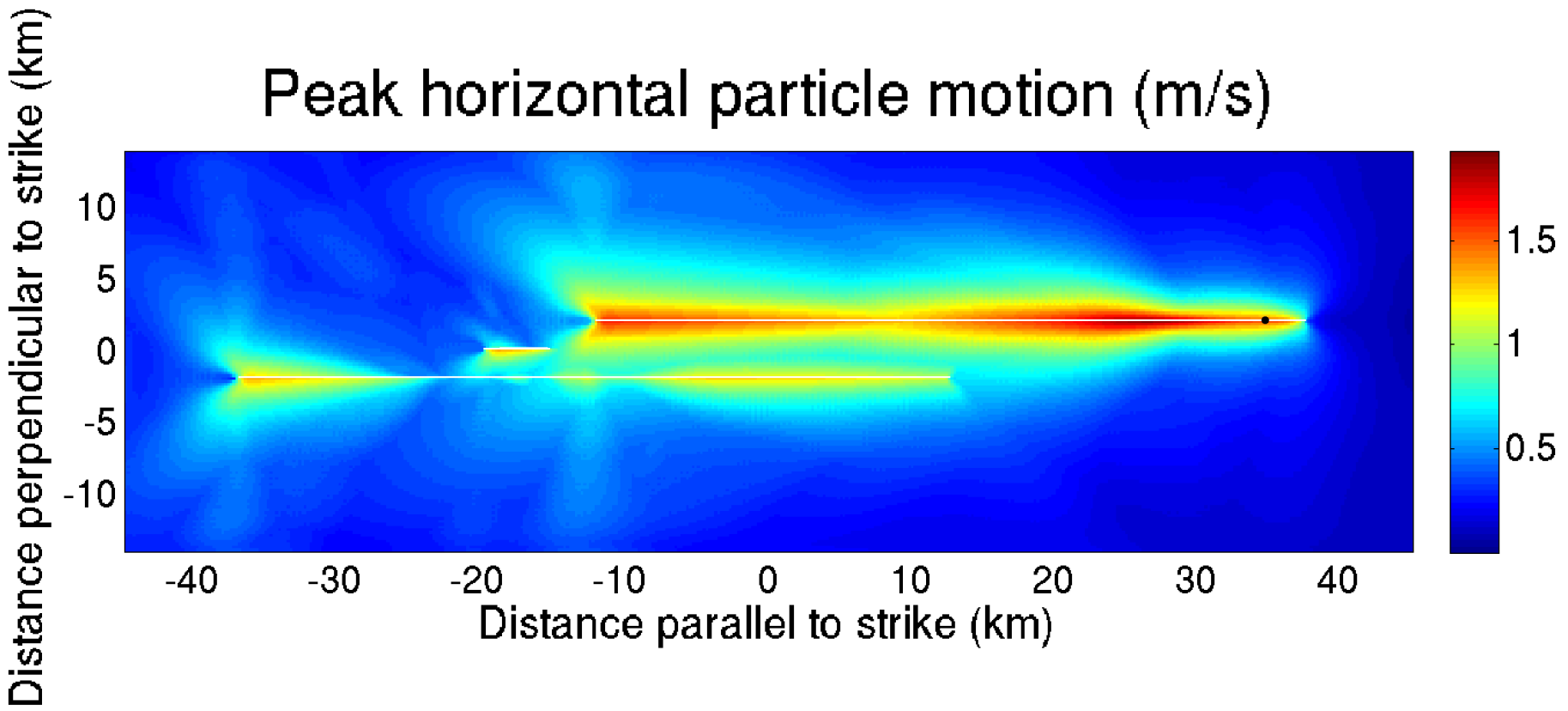
Compressional: Jumps Without Segment

3 km intermediate segment



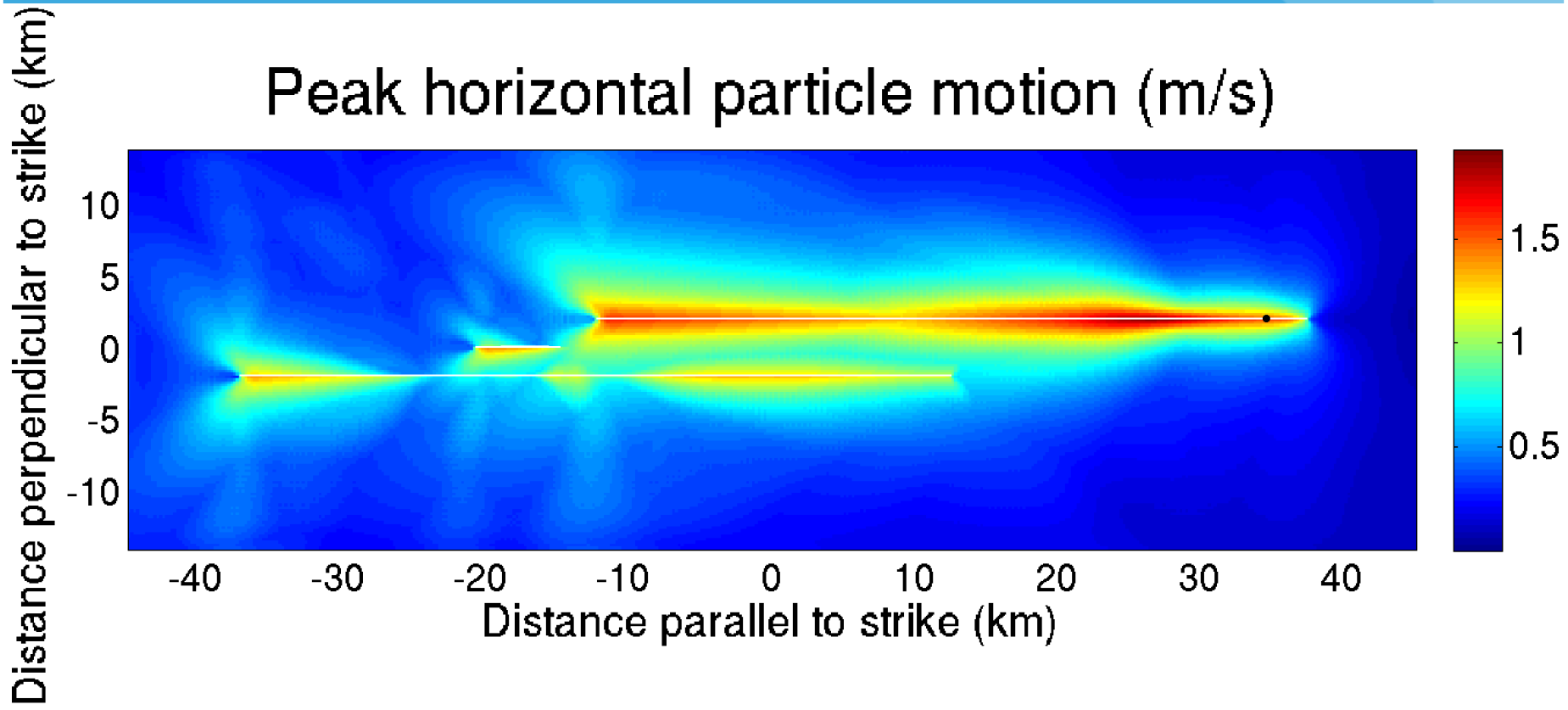
Compressional: Jumps Without Segment

5 km intermediate segment



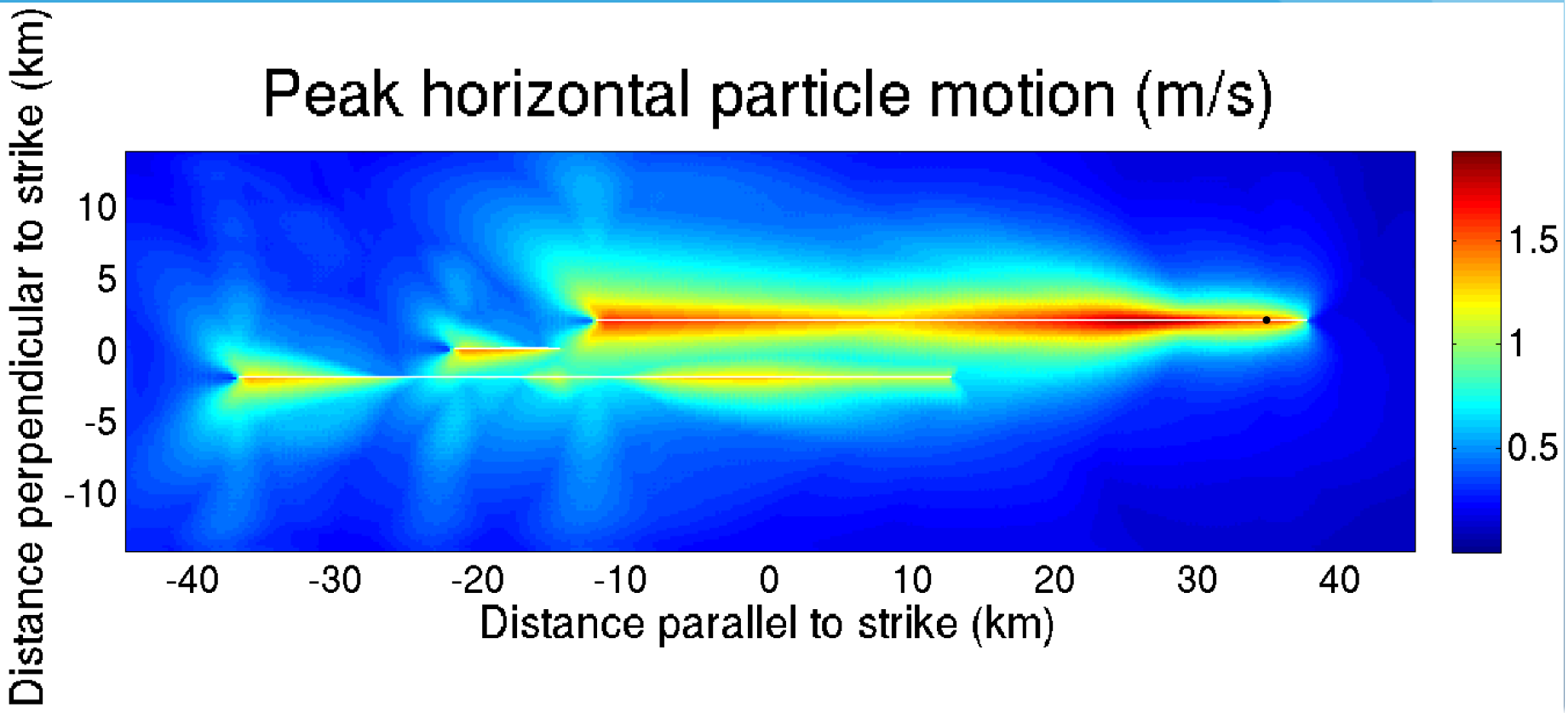
Compressional: Jumps Without Segment

7 km intermediate segment



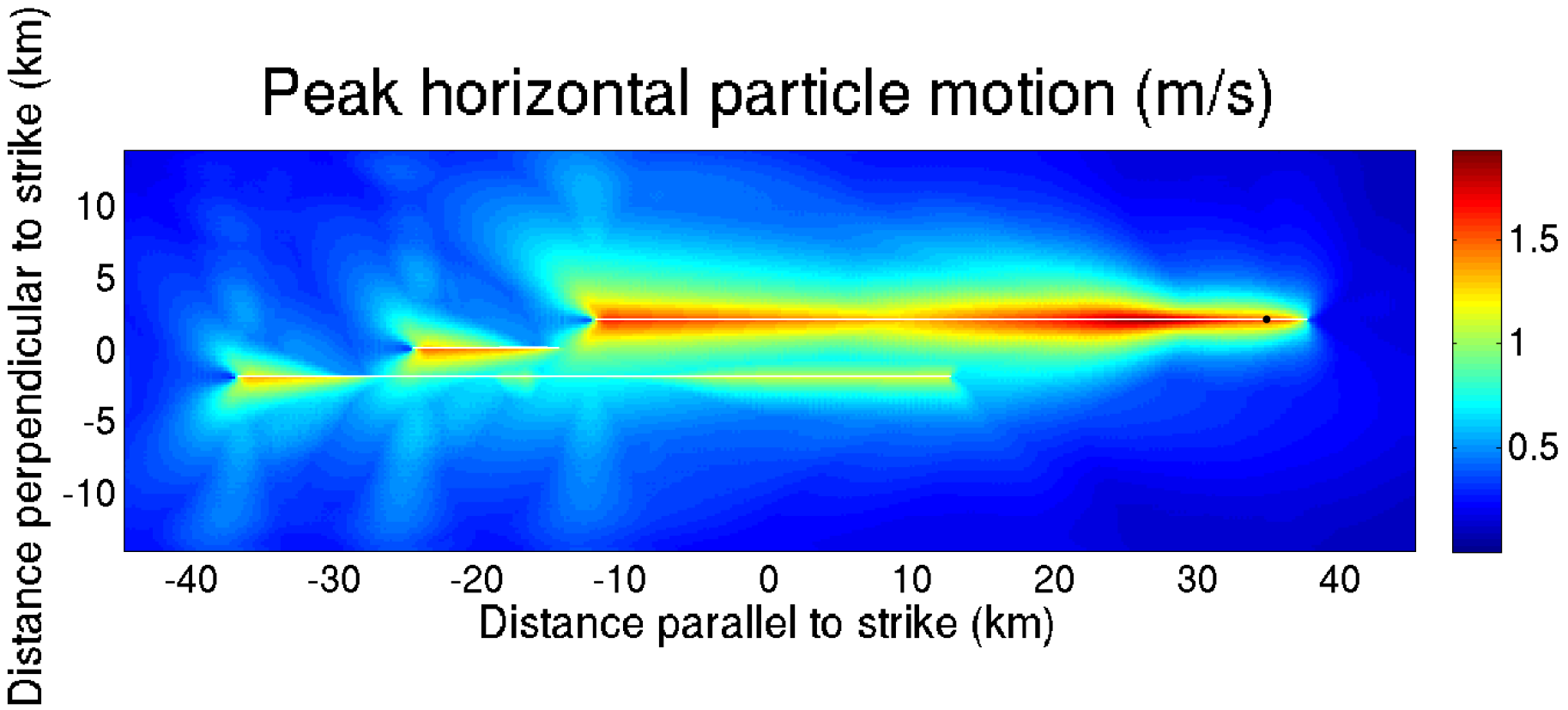
Compressional: Jumps Without Segment

10 km intermediate segment

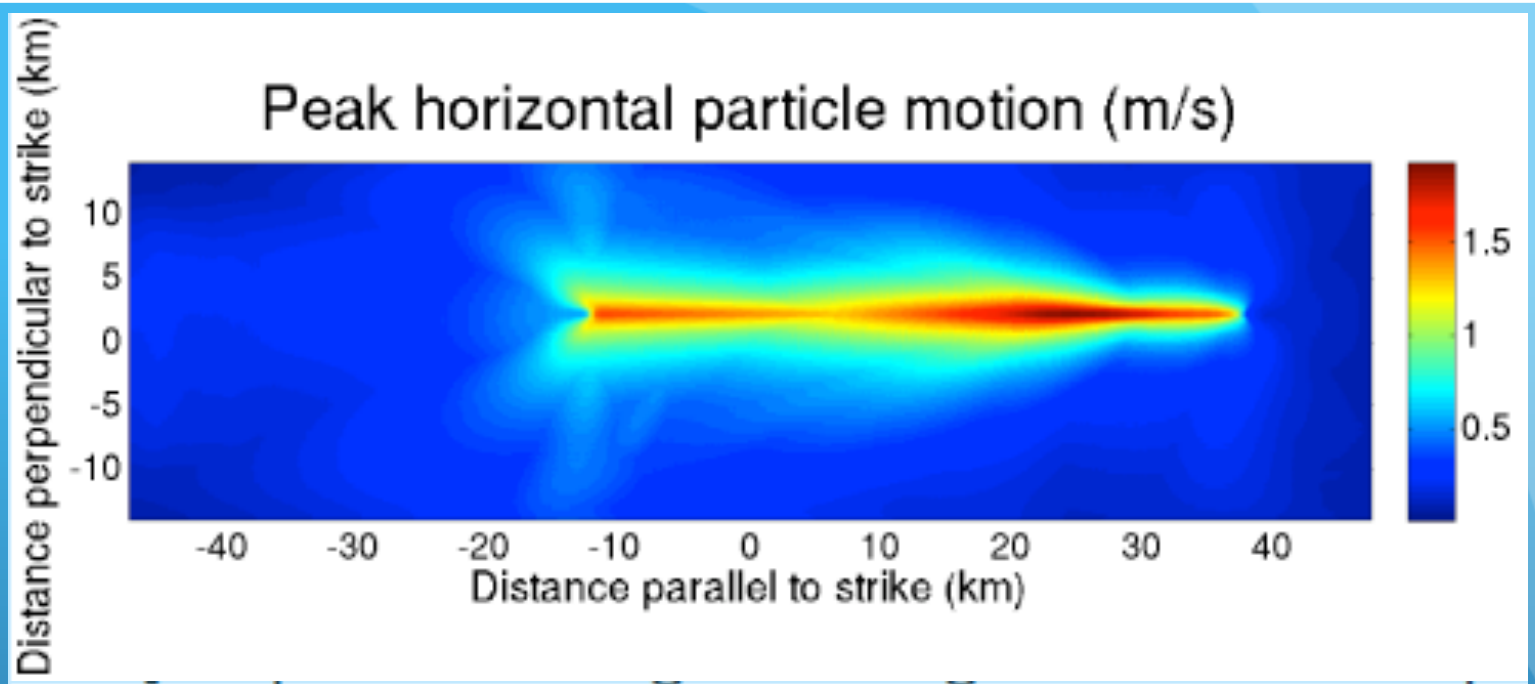


Compressional: Jumps Without Segment

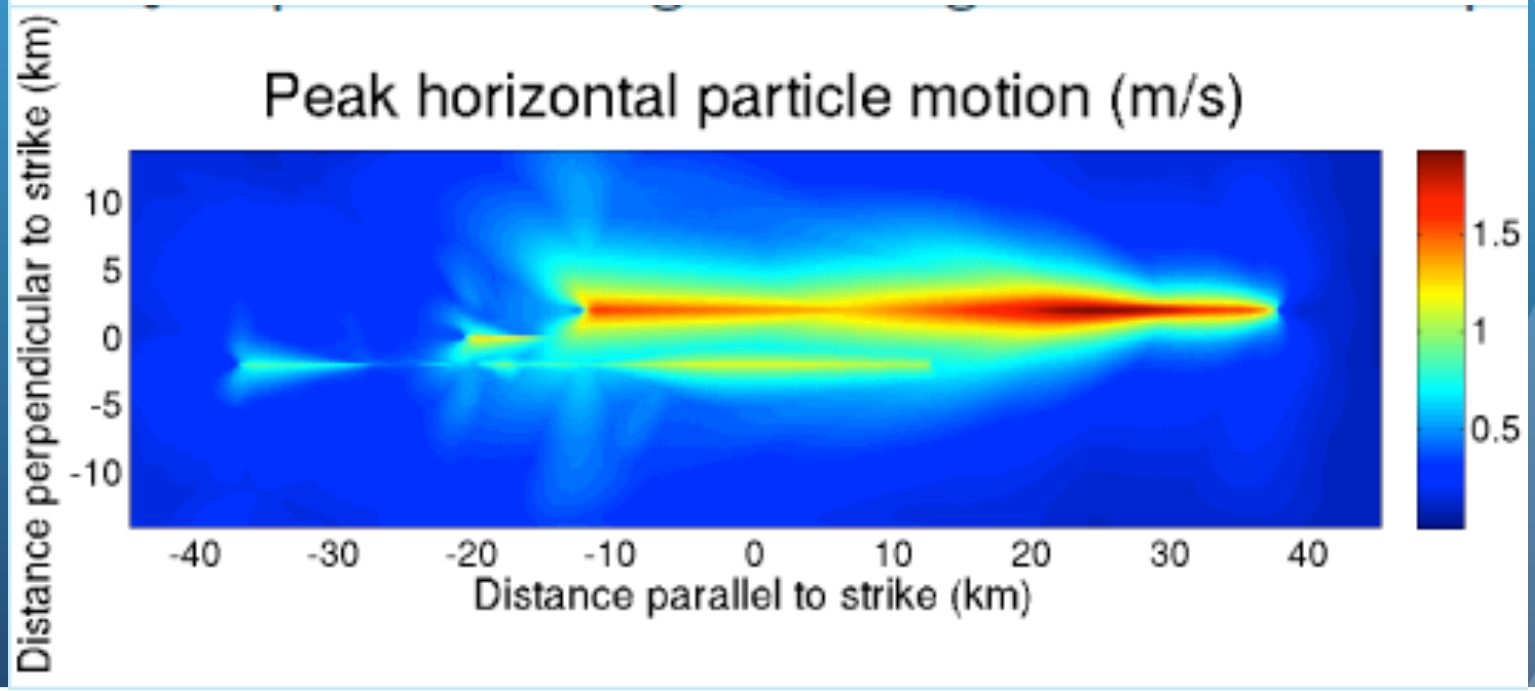
15 km intermediate segment



No segment

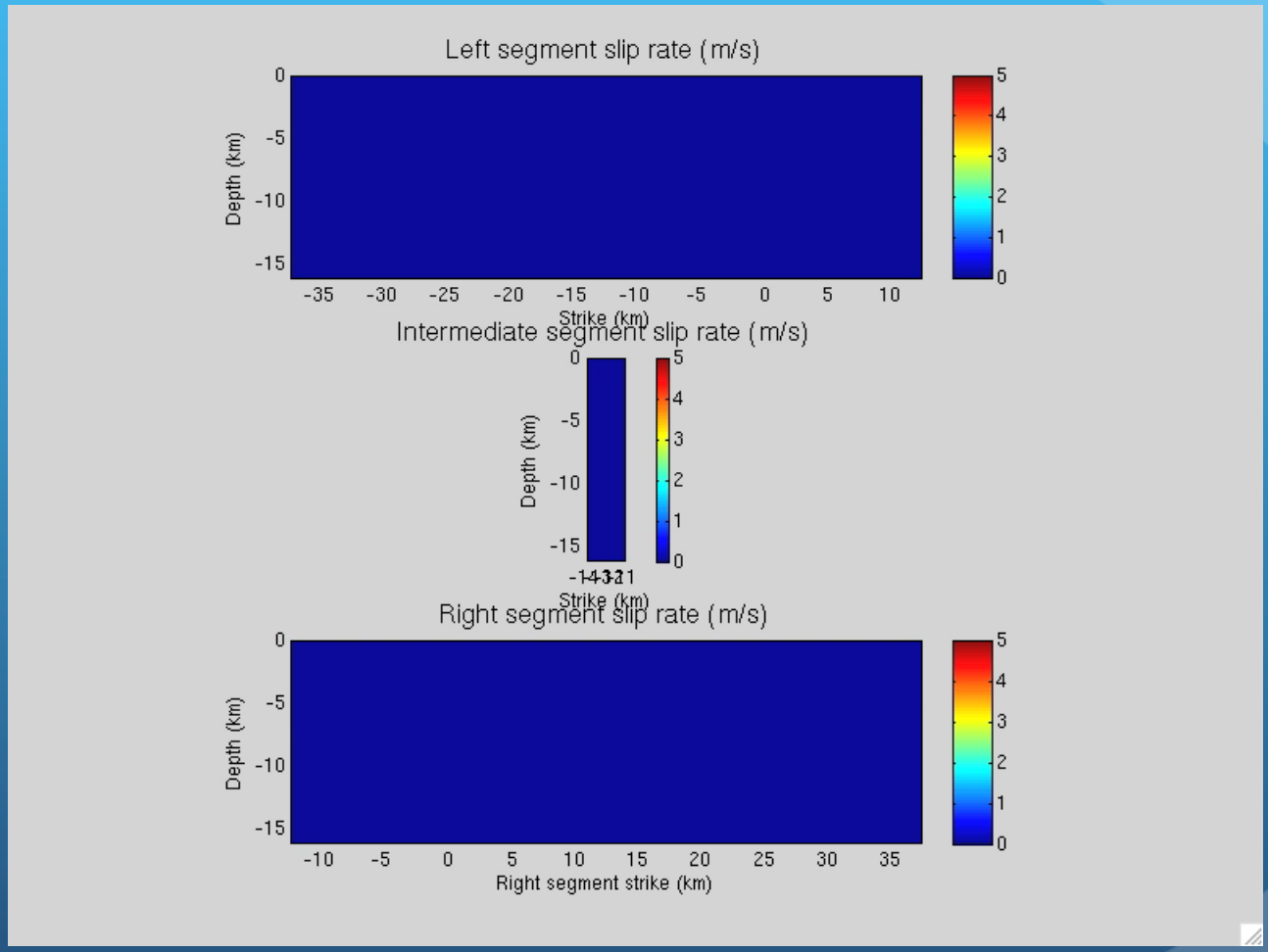


7 km Segment

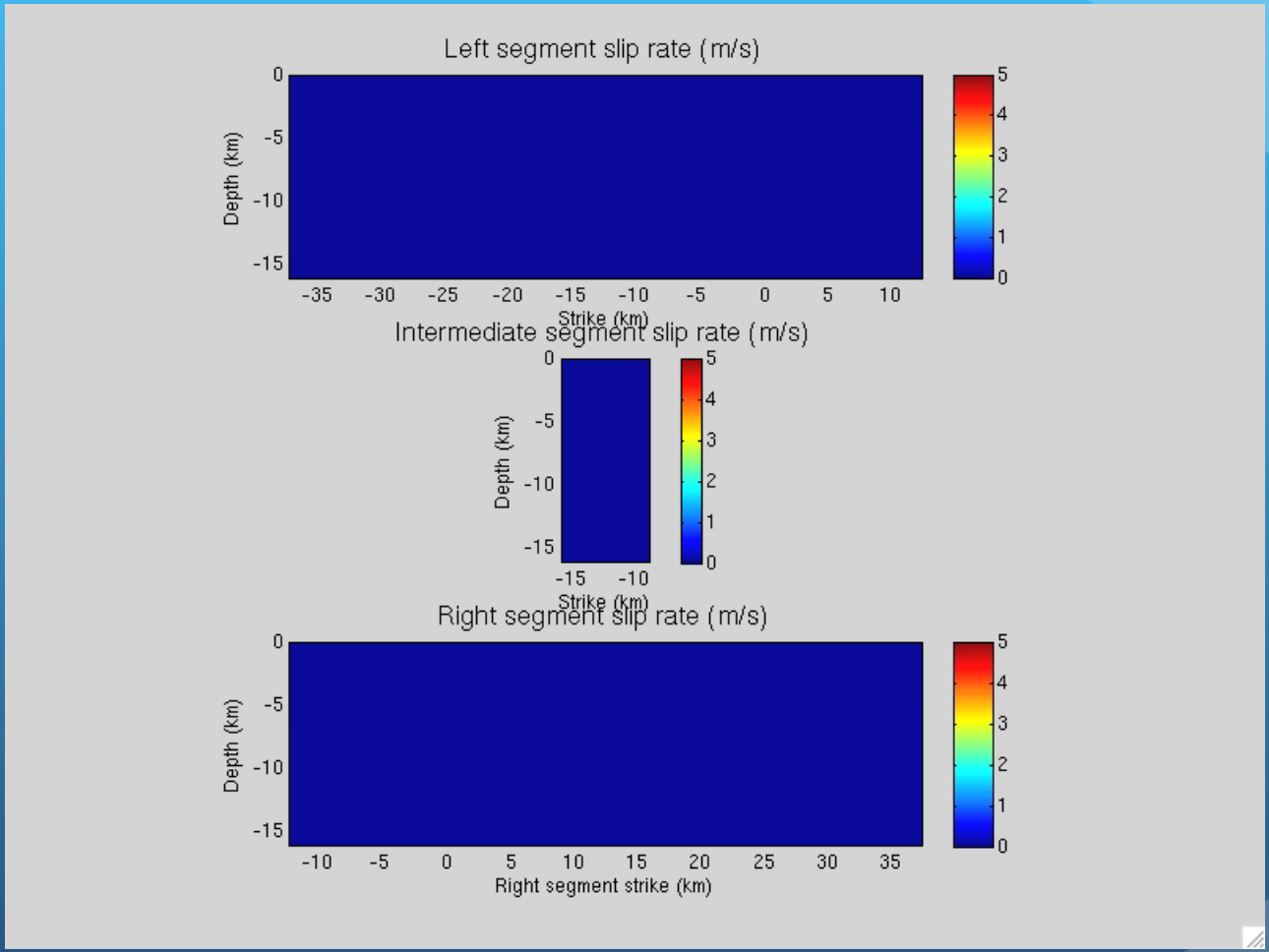


Animations of Fault Slip

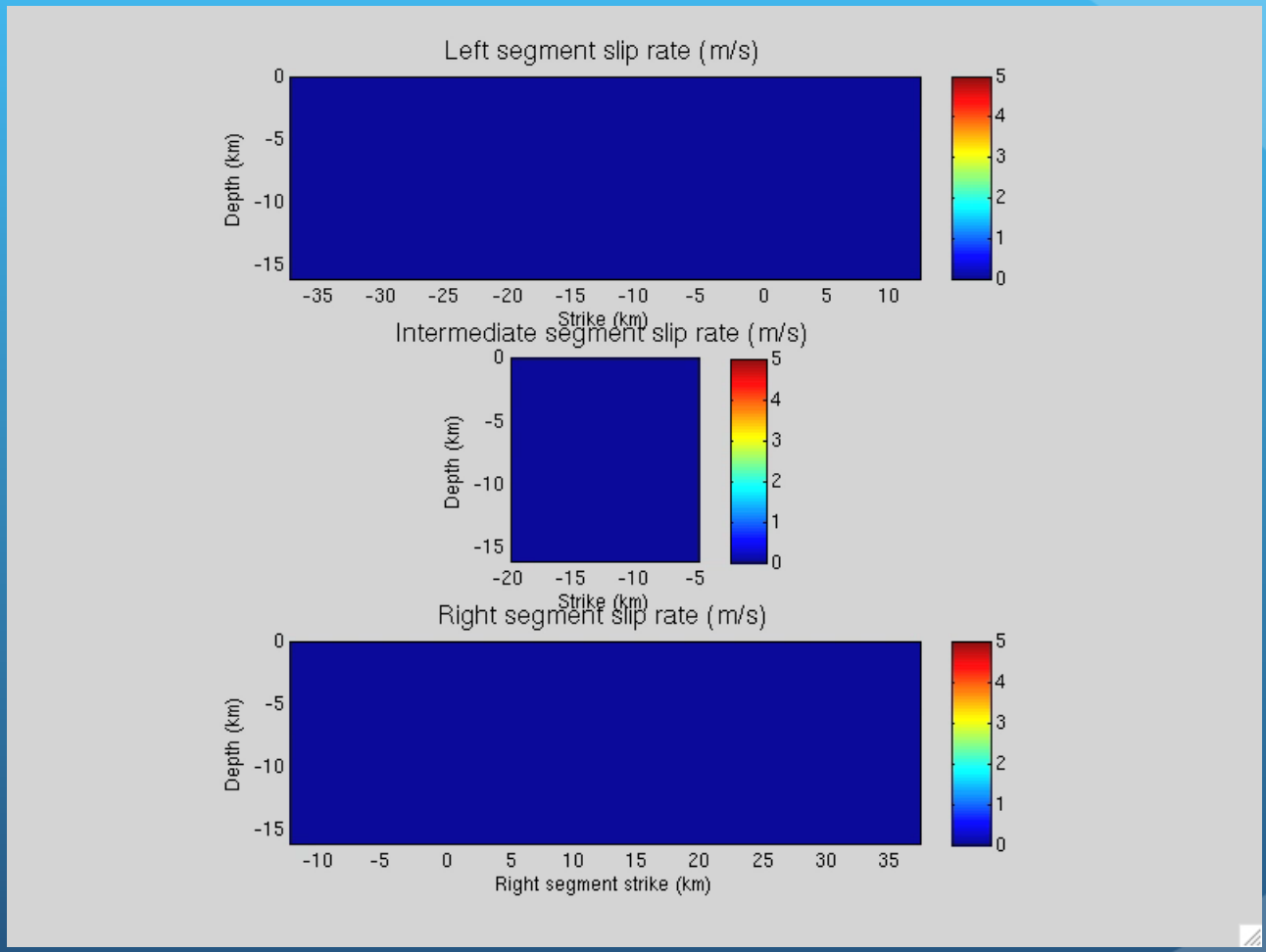
3 km long intermediate segment



7 km long intermediate segment



15 km long intermediate segment



Method

Plate Boundary Thrust	$\sigma_{strike-slip}$	3.54 MPa
	σ_{thrust}	4.41 MPa
	σ_{normal}	12.60 MPa
Septentronial Fault	$\sigma_{strike-slip}$	10.35 MPa
	σ_{thrust}	0
	σ_{normal}	24.71 MPa
Bunce Fault	$\sigma_{strike-slip}$	10.35 MPa
	σ_{thrust}	0
	σ_{normal}	24.71 MPa
	μ_{static}	0.6
	$\mu_{sliding}$	0.3
	Slip-weakening distance	0.4 m
	V_P	5.48 km/s
	V_S	3.16 km/s
	Average grid size	2 km

- 3D Finite Element Method
- Slip-Weakening Friction

Physical and Numerical Parameters

P-wave velocity	5000 m/s
S-wave velocity	3100 m/s
Density	2675 kg/m^3
Static frictional coefficient	0.75
Dynamic frictional coefficient	0.3
Slip weakening parameter	0.4
Element size	200 m
Forced nucleation radius	3000 m

Normal Stress	Shear Stress	S
16.65 MPa	10 MPa	0.49

Physical and Computational Parameters

P-wave velocity	5100 m/s
S-wave velocity	3100 m/s
Density	2675 kg/m^3
Regional shear stress	100 bars
Regional normal stress	166.5 bars
Static frictional coefficient	0.75
Dynamic frictional coefficient	0.3
Slip-weakening parameter	0.4
Element size	200 m
Forced nucleation radius	3000 m

3D finite element code FaultMod (Michael Barall, Invisible Software)

Method

Shear Stress	8.4 MPa
Normal Stress	24 MPa
Static Friction	0.6
Sliding Friction	0.1
Slip-Weakening Parameter	0.4 m
Cell size	200 m