Exploring complex normal faulting systems through physics-based dynamic rupture modeling

10-12 min talk!

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ANR EQTIME Project

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Outline

Motivation

Settings

Results

Conclusions & discussion

Motivation

Seismic Hazard in Central Italy

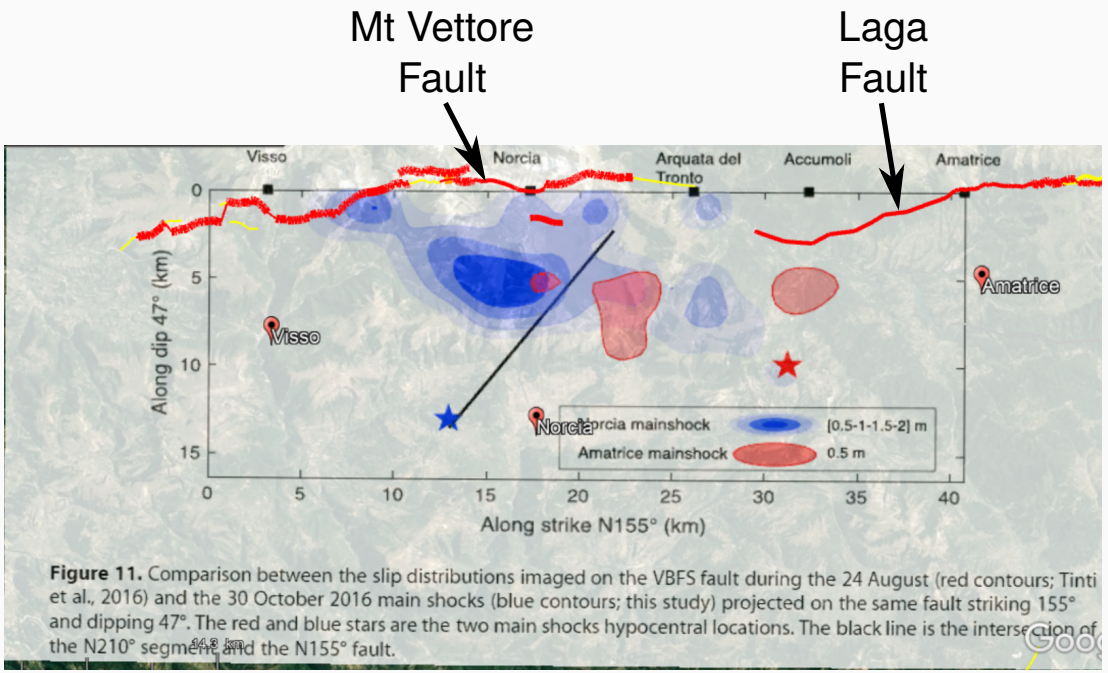

Figure 11. Comparison between the slip distributions imaged on the VBFS fault during the 24 August (red contours; Tinti et al., 2016) and the 30 October 2016 main shocks (blue contours; this study) projected on the same fault striking 155° and dipping 47°. The red and blue stars are the two main shocks hypocentral locations. The black line is the intersection of the N210° segment and the N155° fault.

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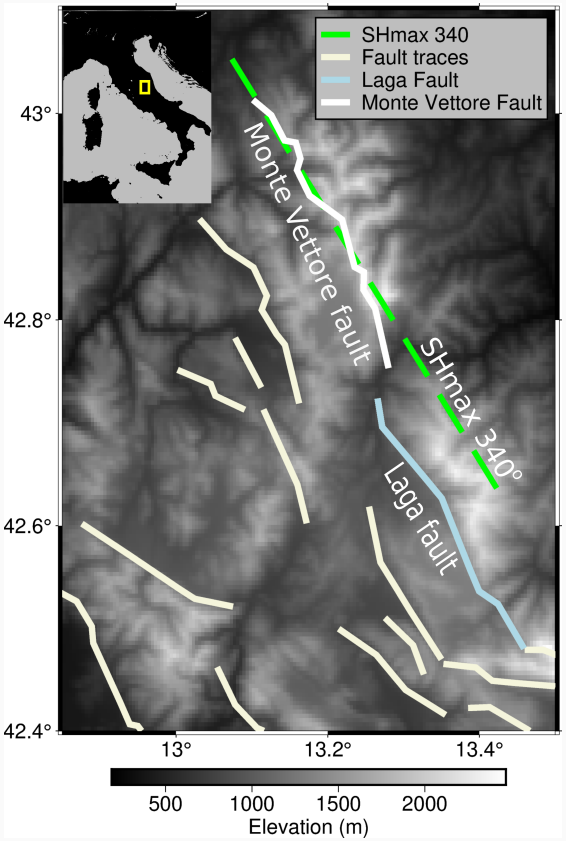

Map based on Walker et al. (2021)

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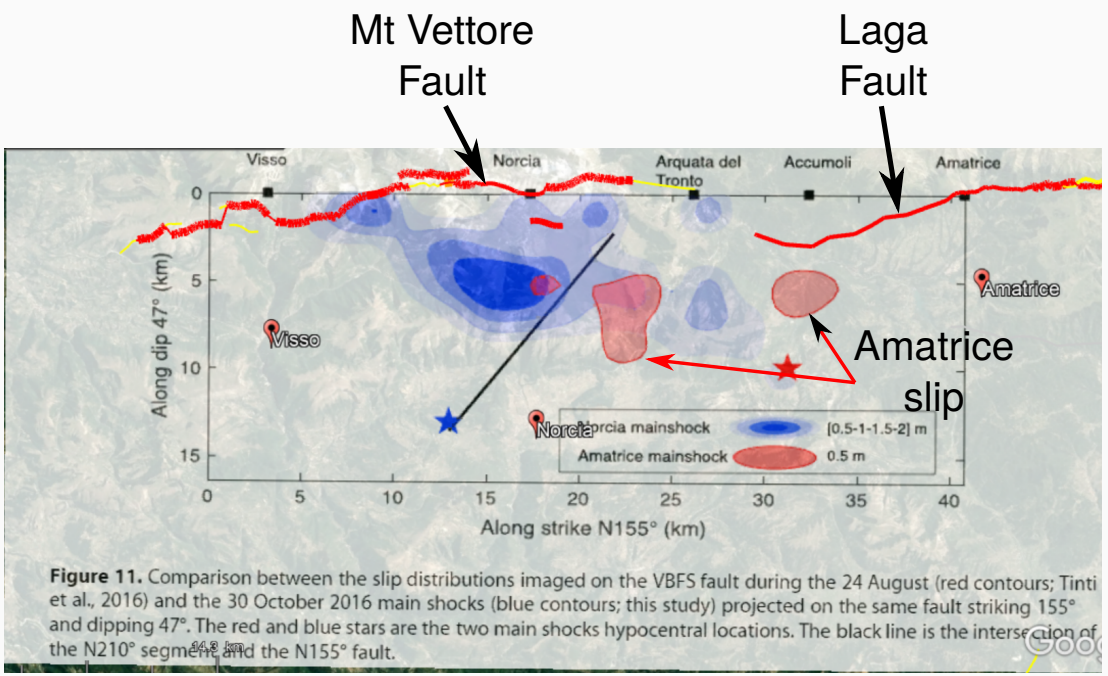

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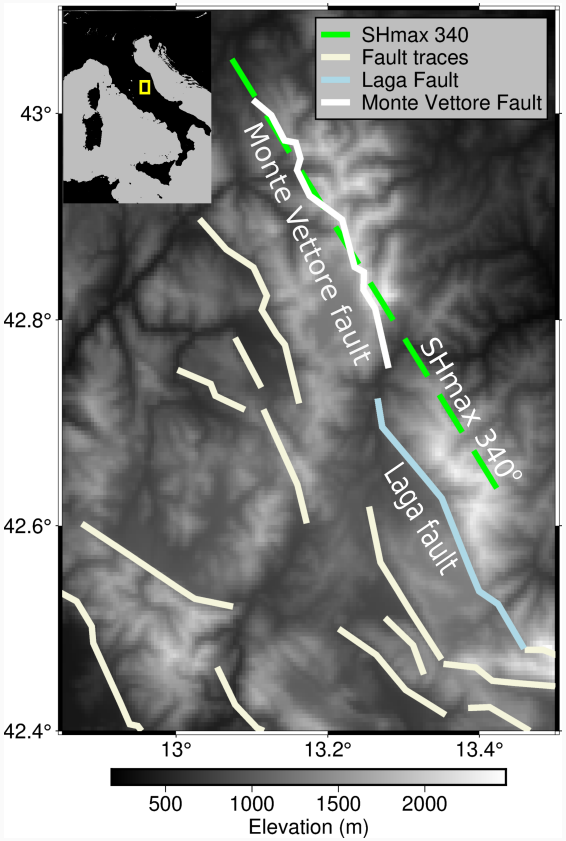

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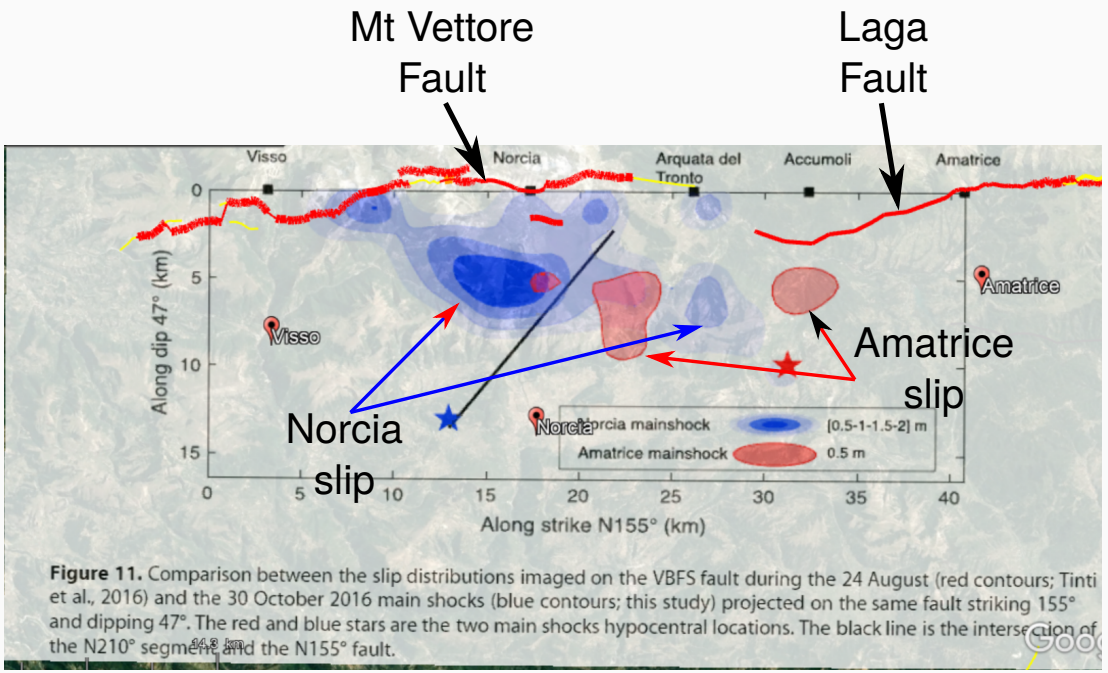

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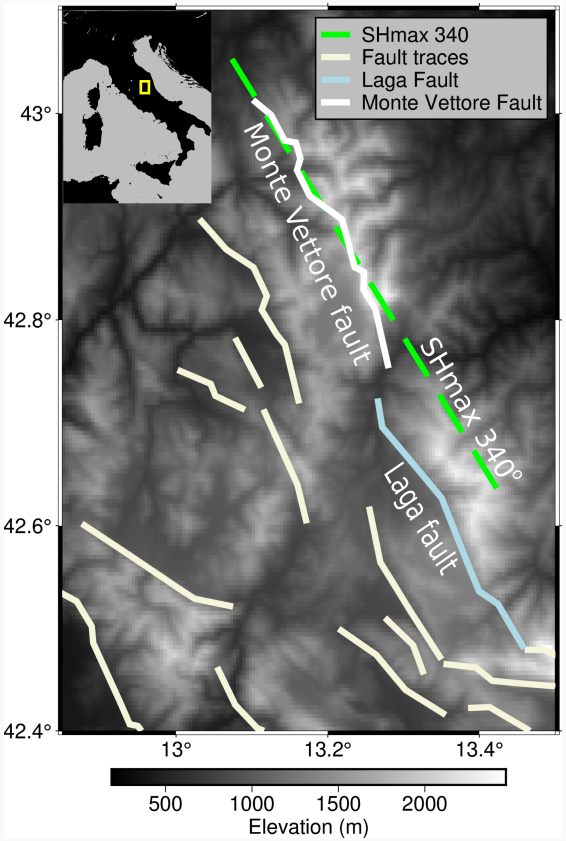

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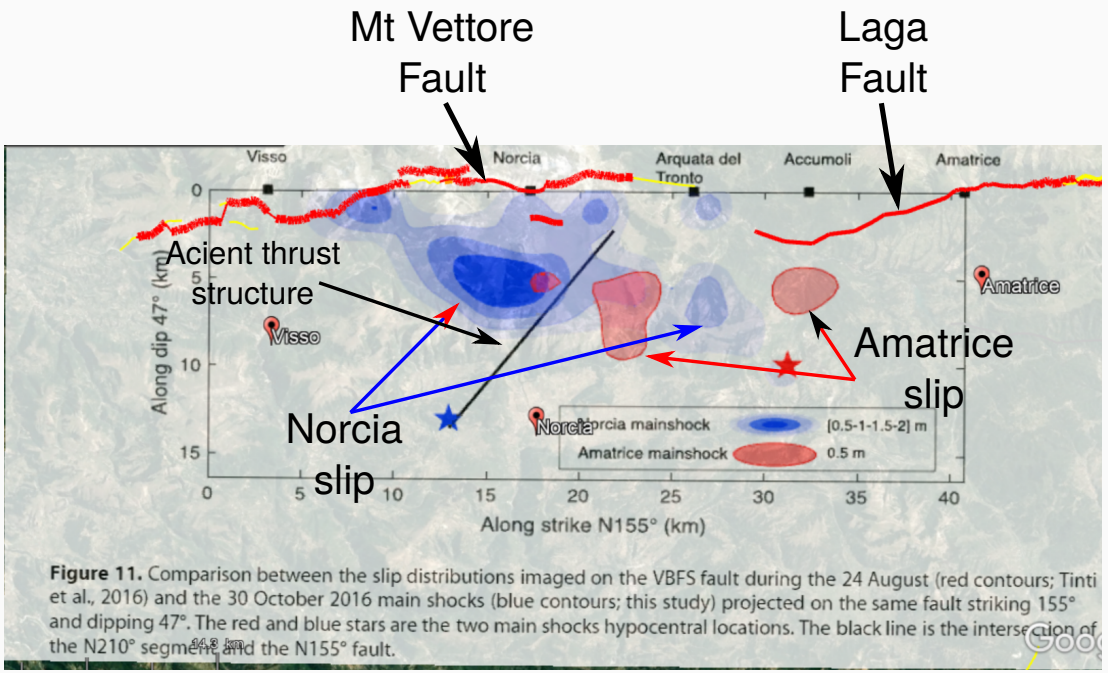

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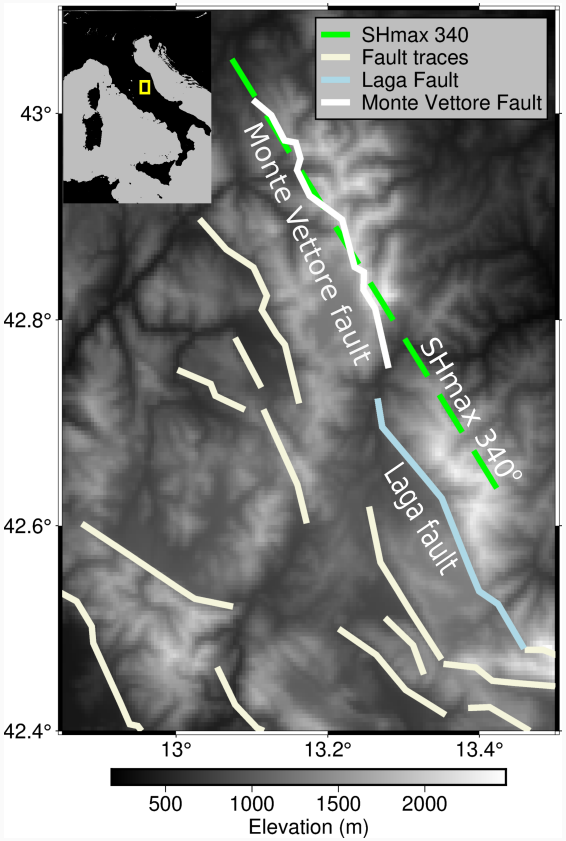

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Rupture jumps across step-overs

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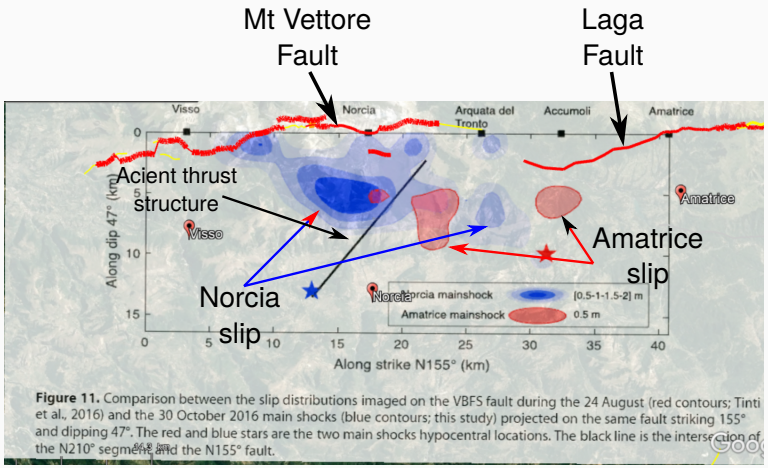

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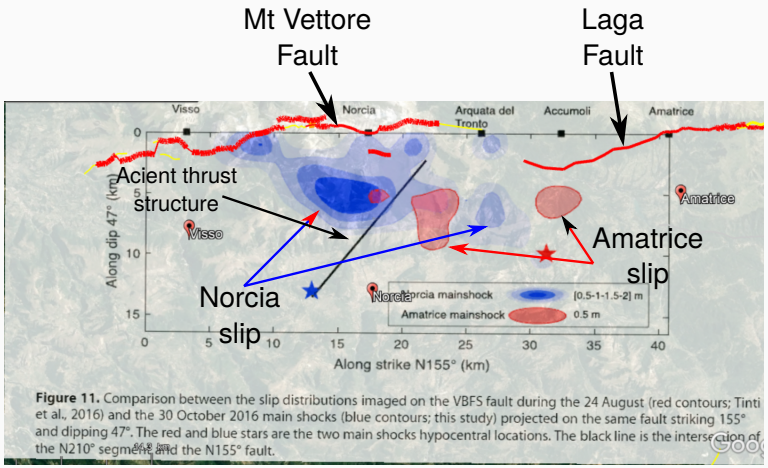

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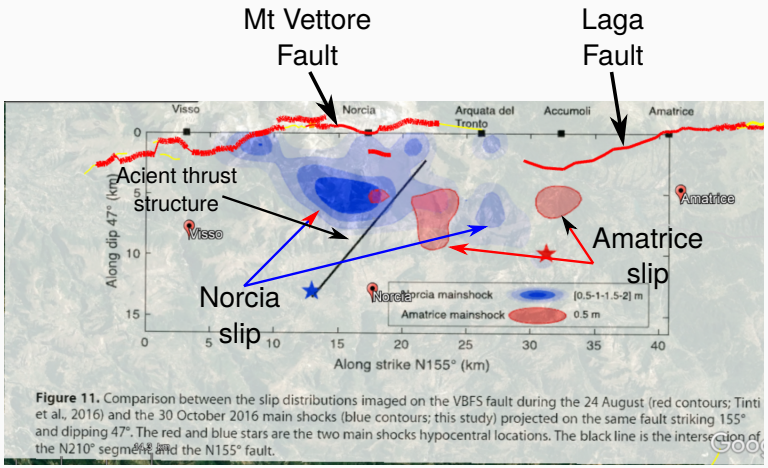

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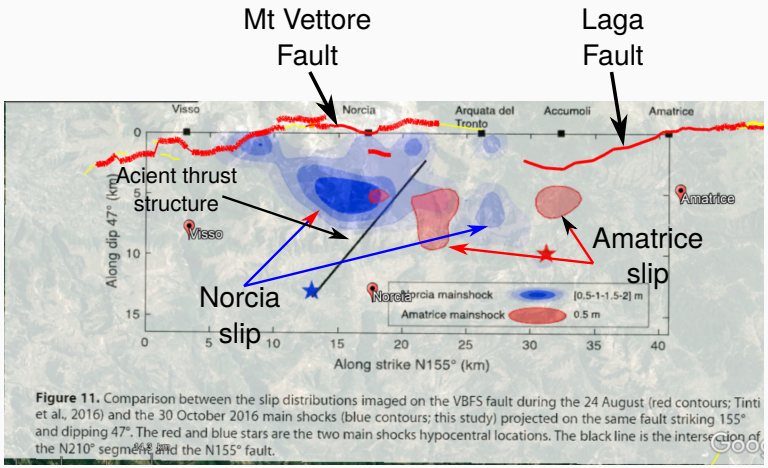

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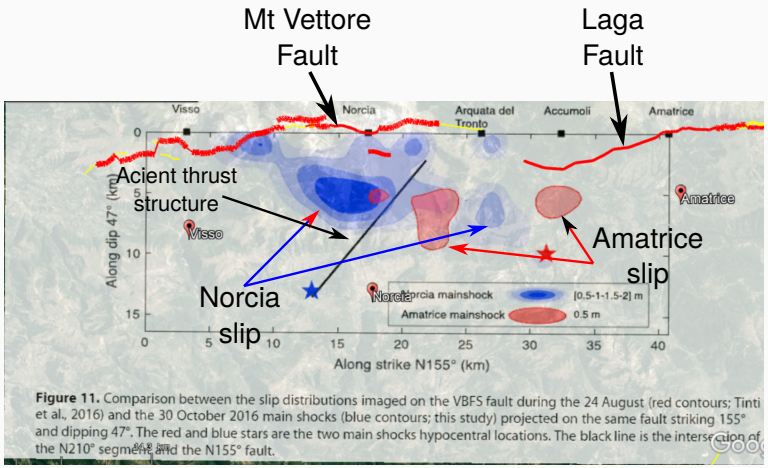

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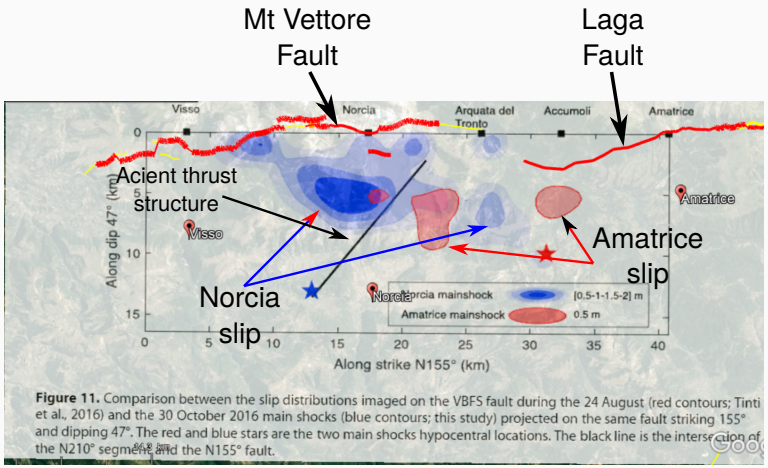

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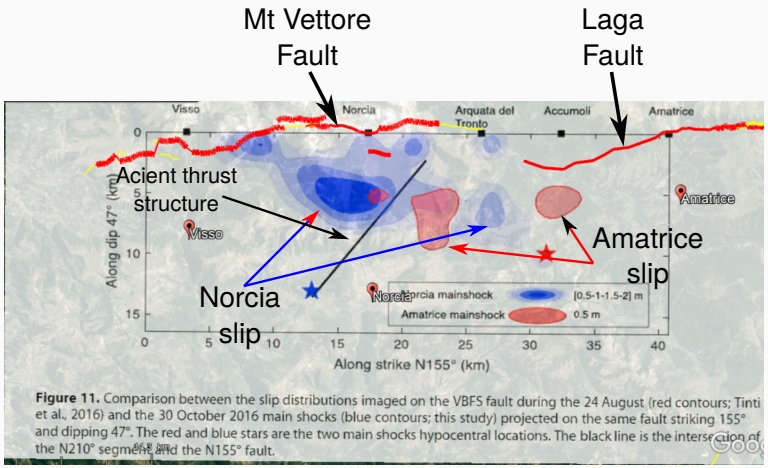

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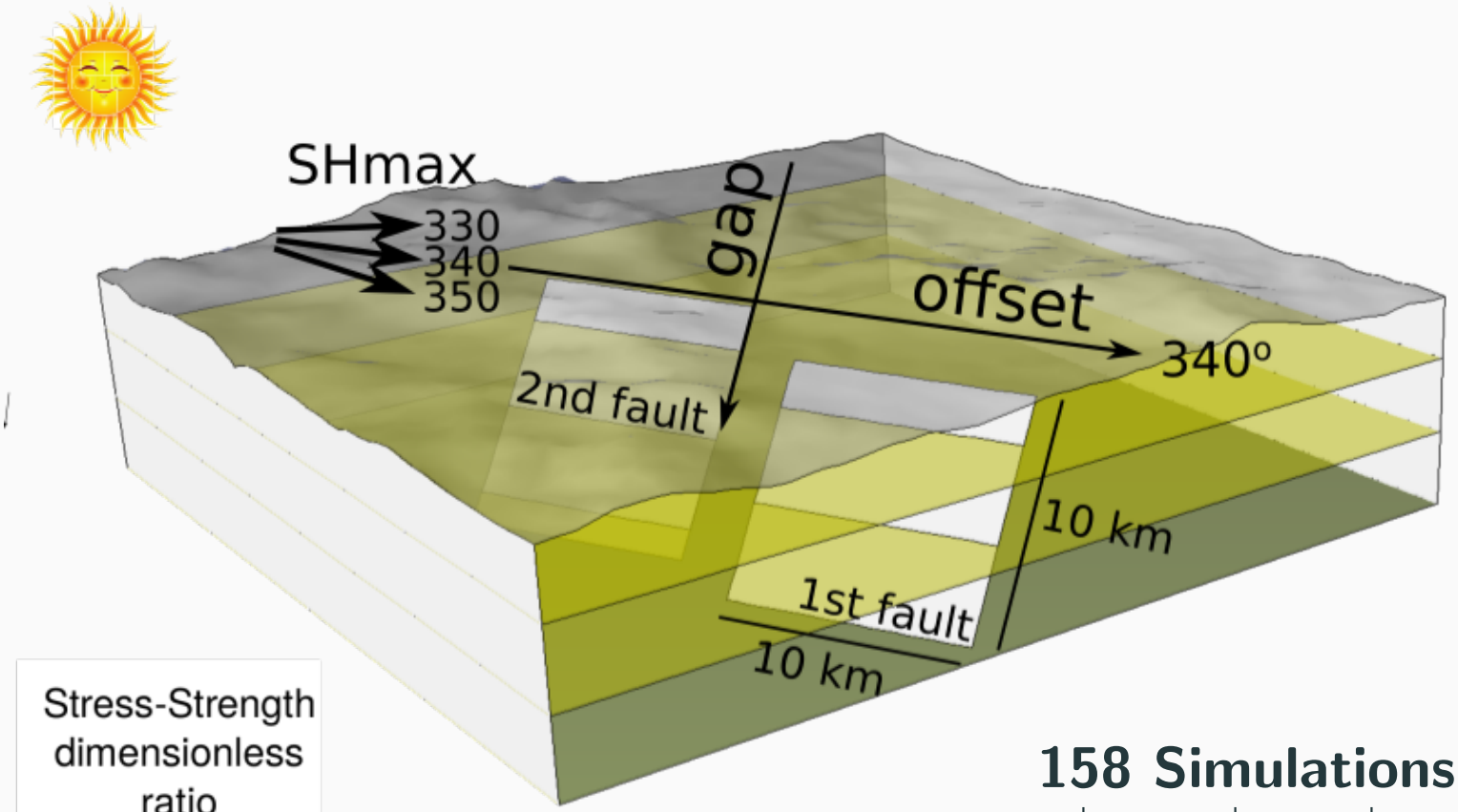
Investigate the physical conditons promoting rupture jumps across step overs regarding normal fault systems

Settings

Geometry and parameters explored



Stress-Strength dimensionless ratio

$$S = \frac{\tau_p - \tau_0}{\tau_0 - \tau_r}$$

158 Simulations

Parameter	min	Δ	max

Simulations using: www.seissol.org

linear slip weakening law

(e.g., Wollherr et al., 2018; Ulrich et al., 2019)

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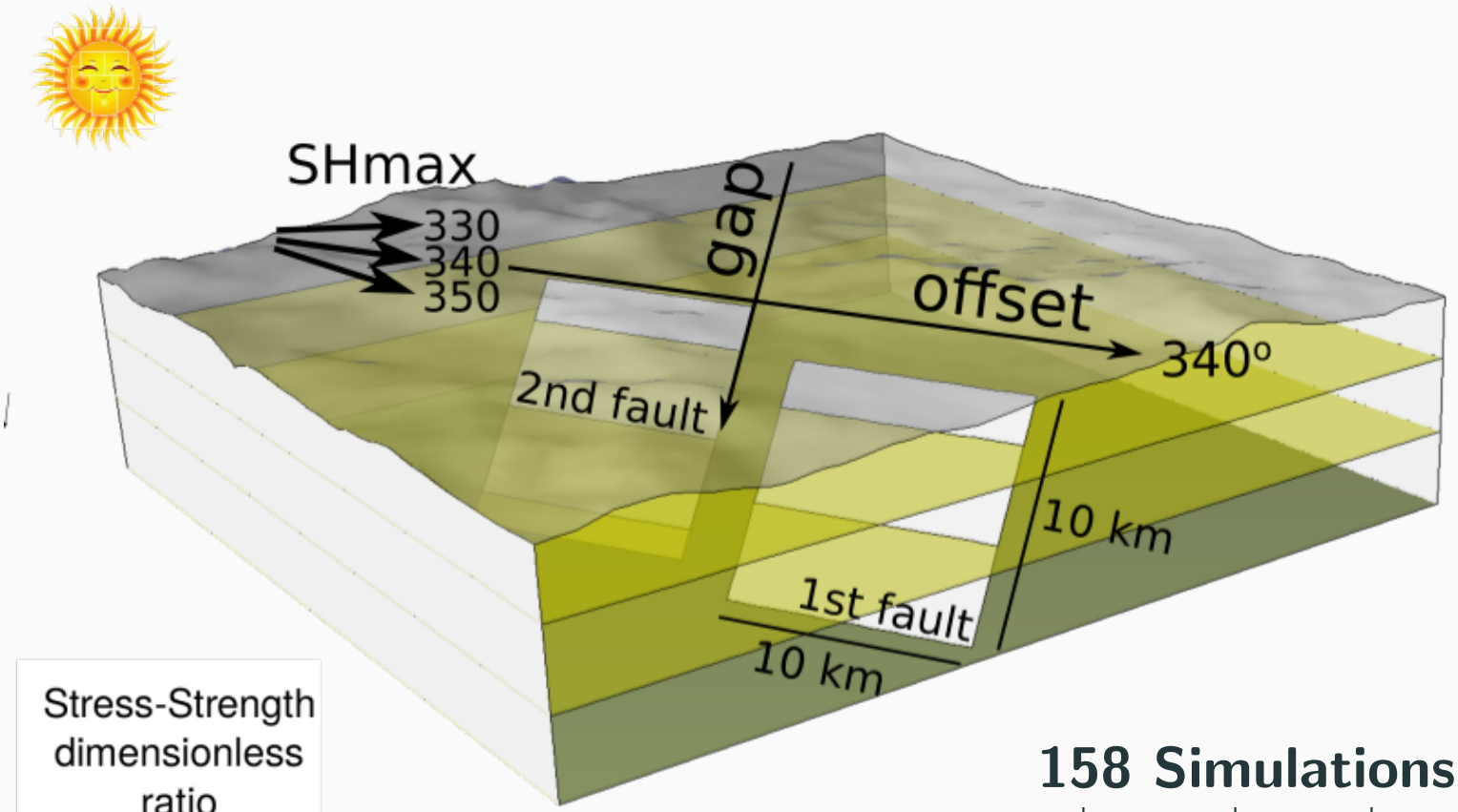

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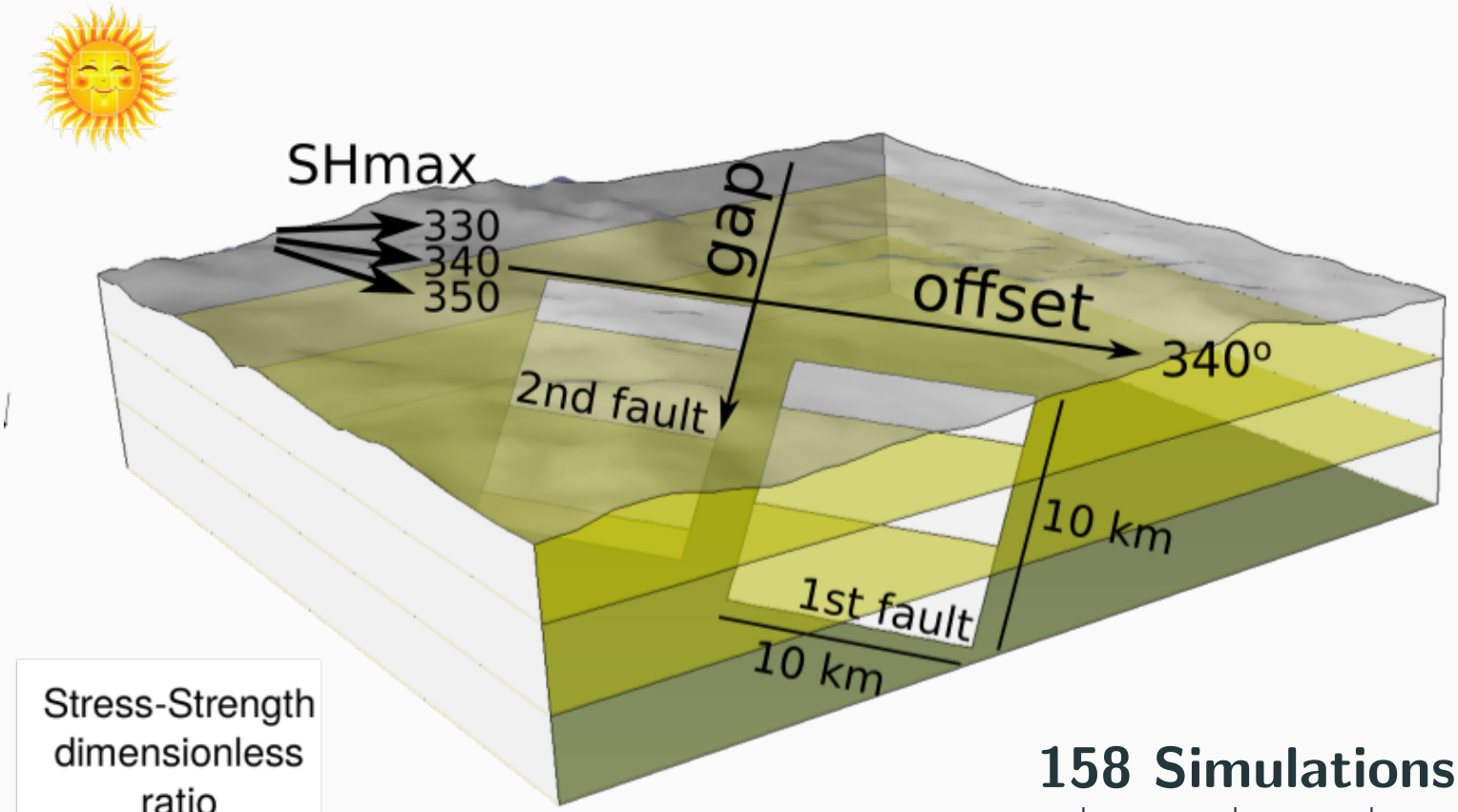

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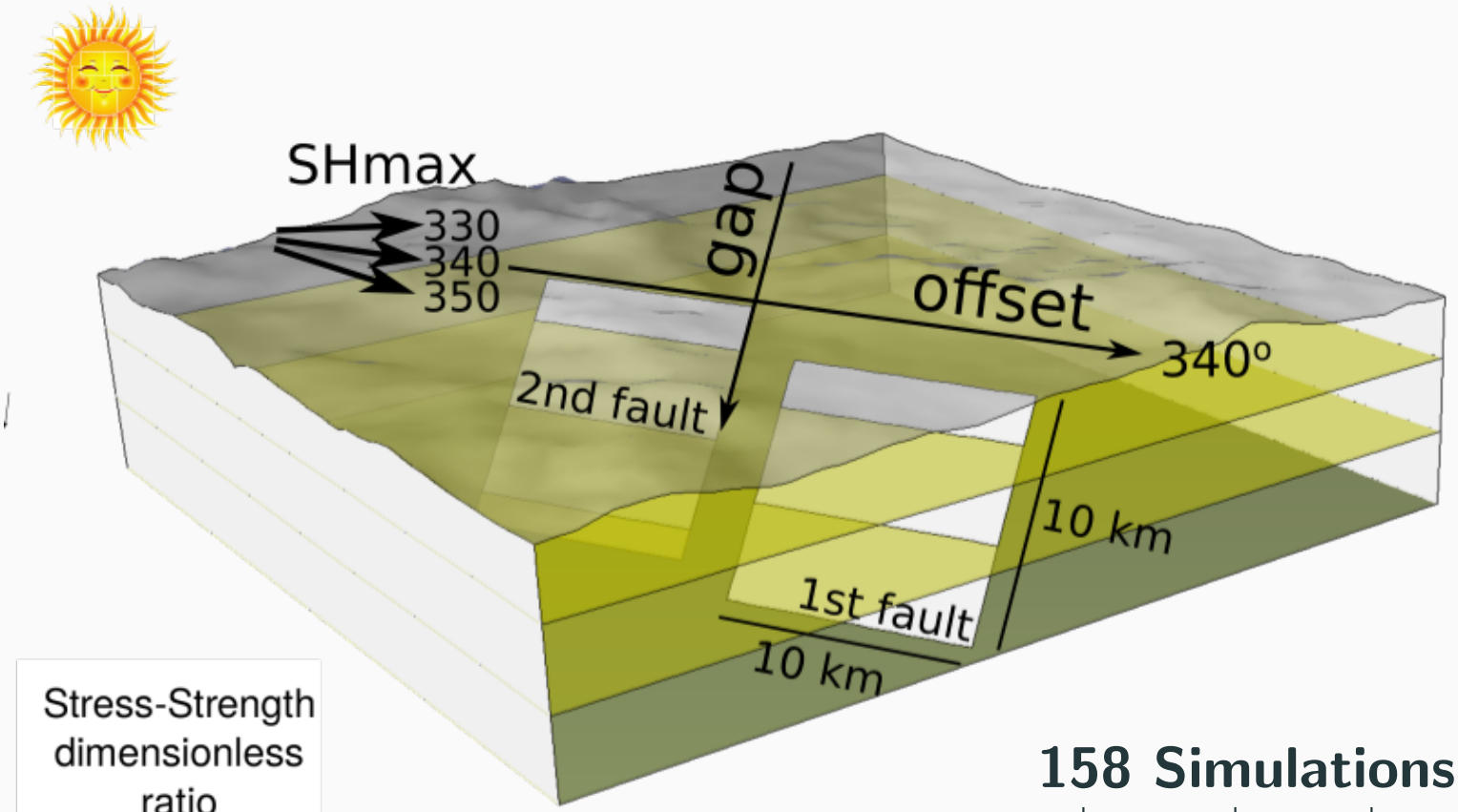

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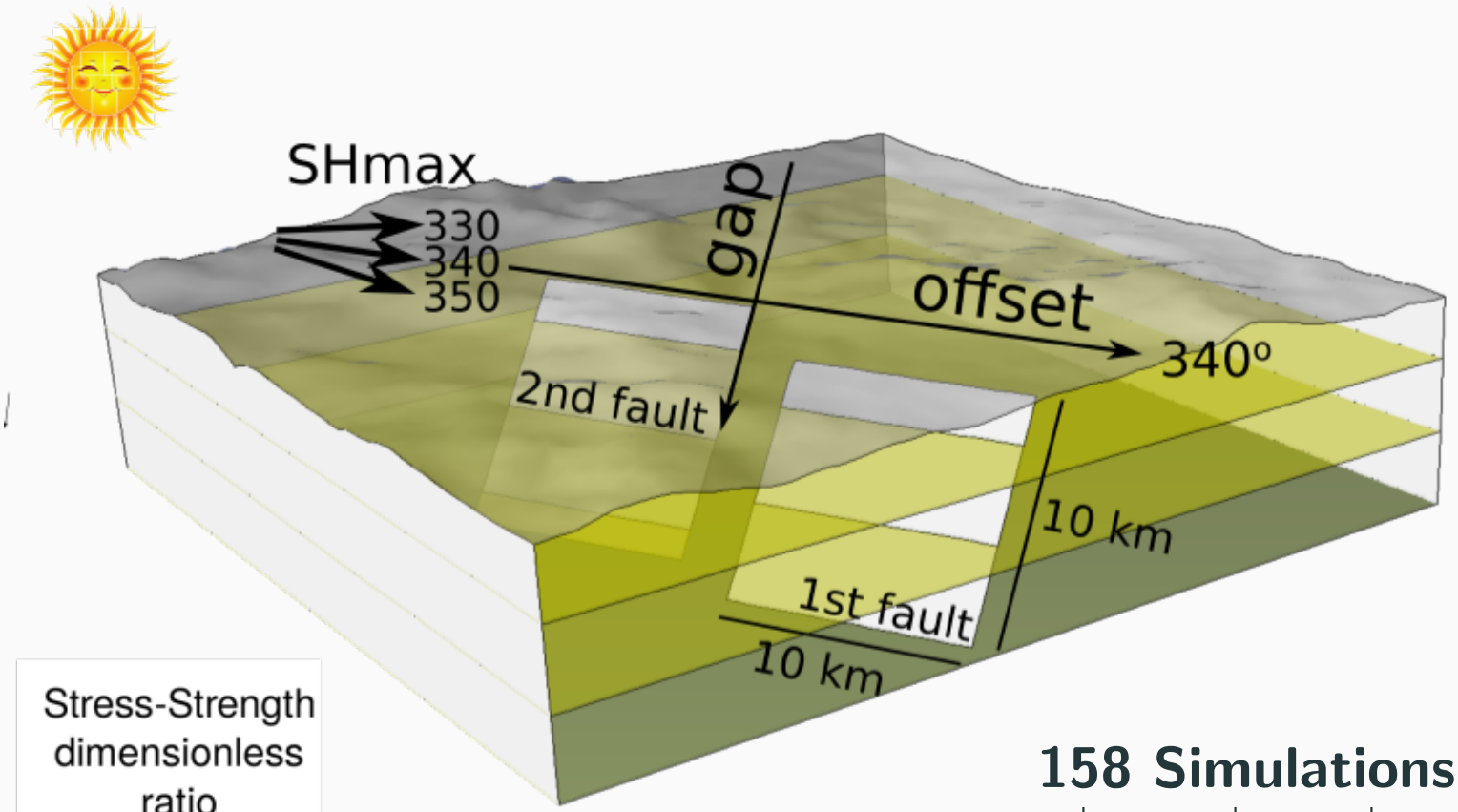

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SH_{max} (^{o})	330	10	350

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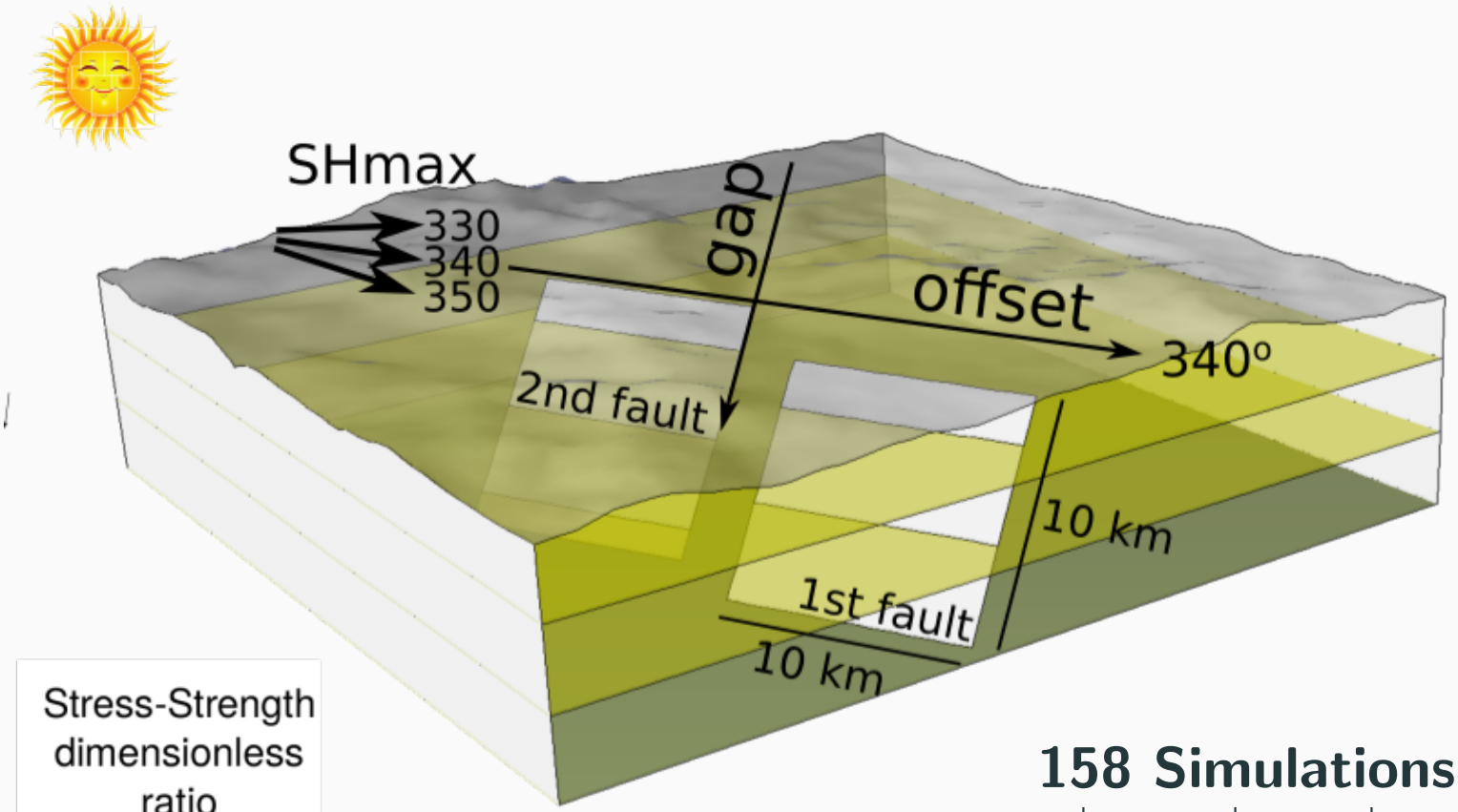

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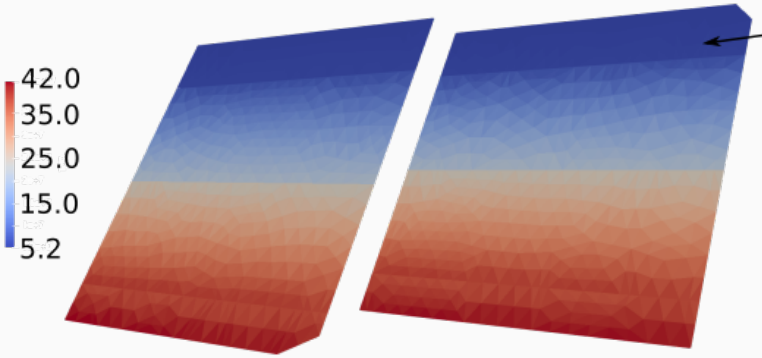
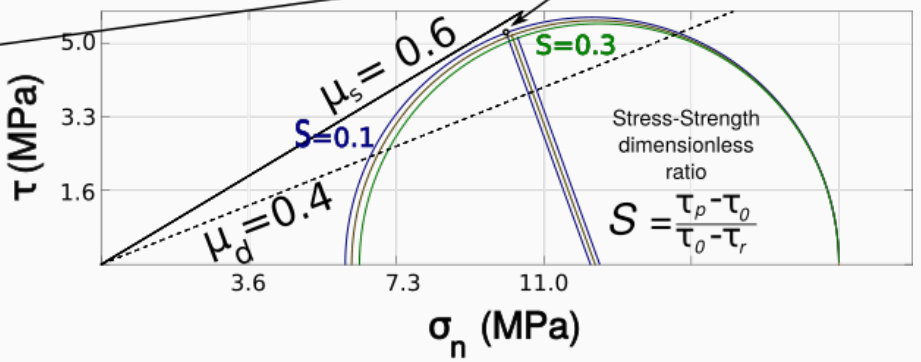
Initial stress & medium velocity model

Initial stress state



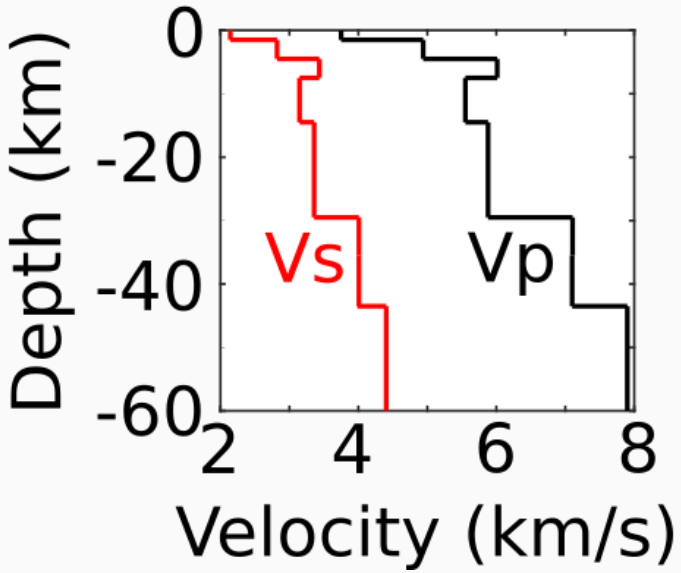
τ_{dip}=10.7 MPa ,
P_n =5.6 MPa



On the faults:

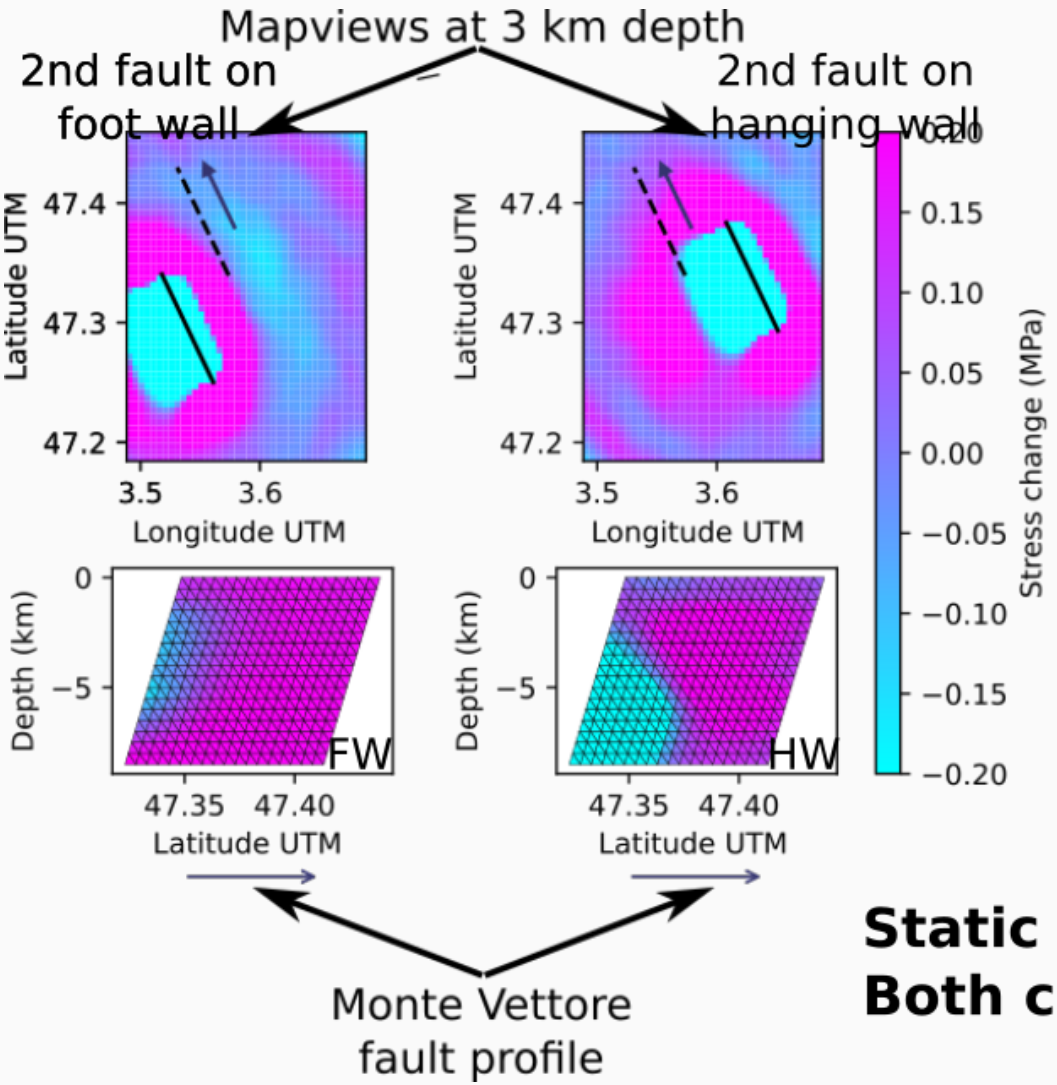
μ_s=0.6

μ_d=0.4



Velocity structure from Herrmann et al. (2011).

Static analysis ... jump? break-away?



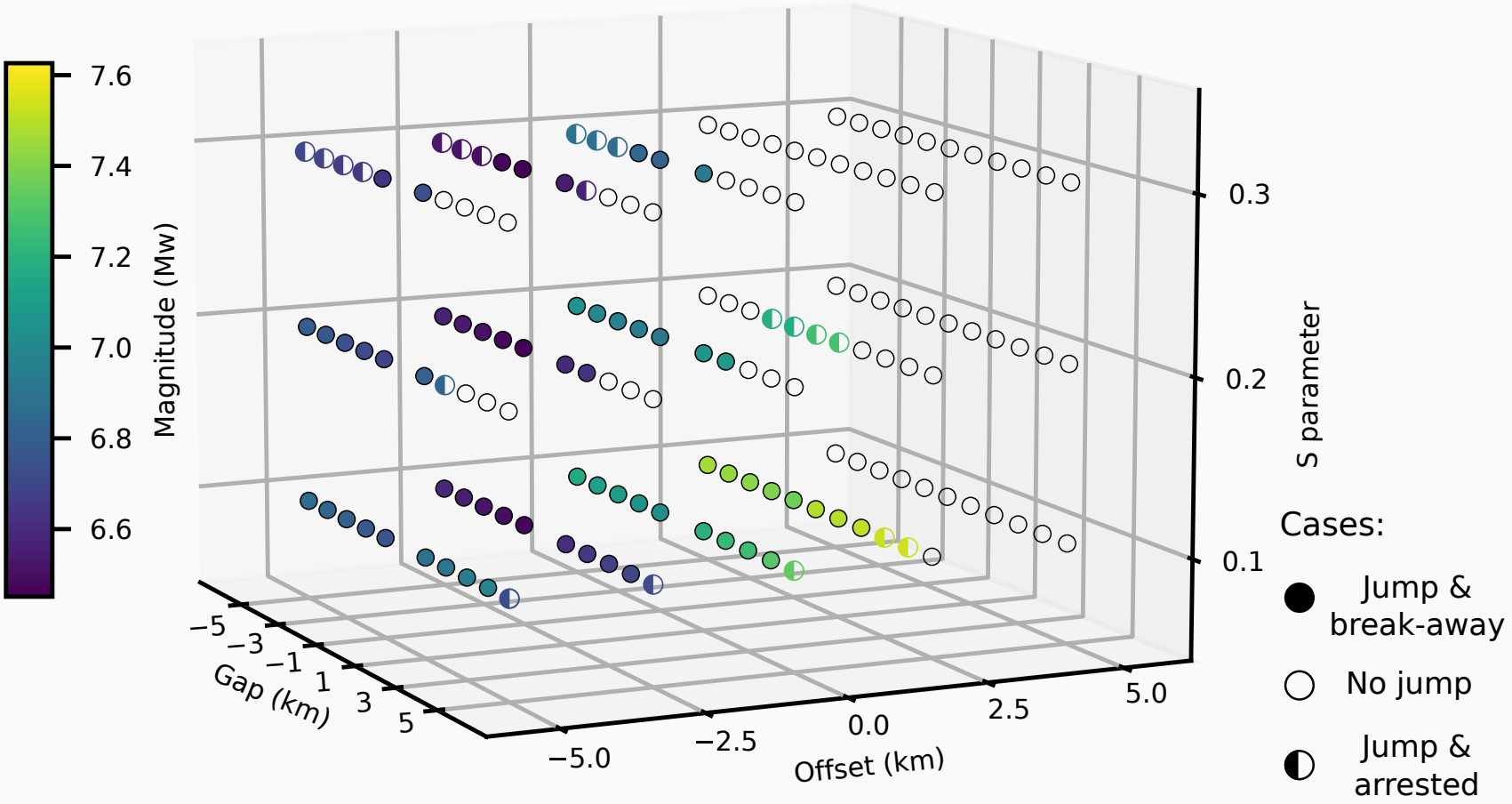
Are jumps and breakaway behavior prone to happen in both cases?

Is a static analysis enough to determine such behaviors?

Static analysis:
Both cases might break!

Results

Results ... summary from 158 simulations



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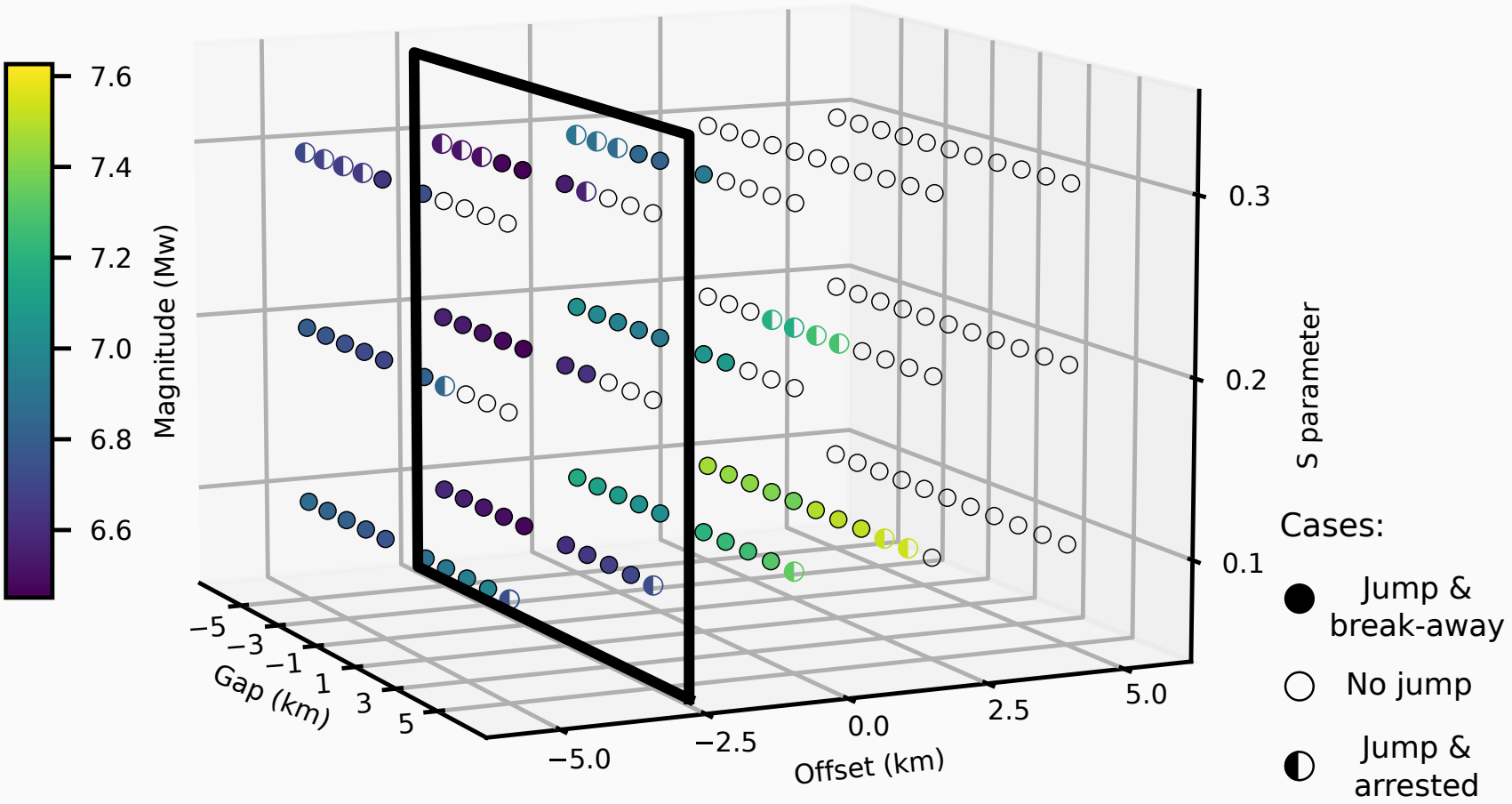
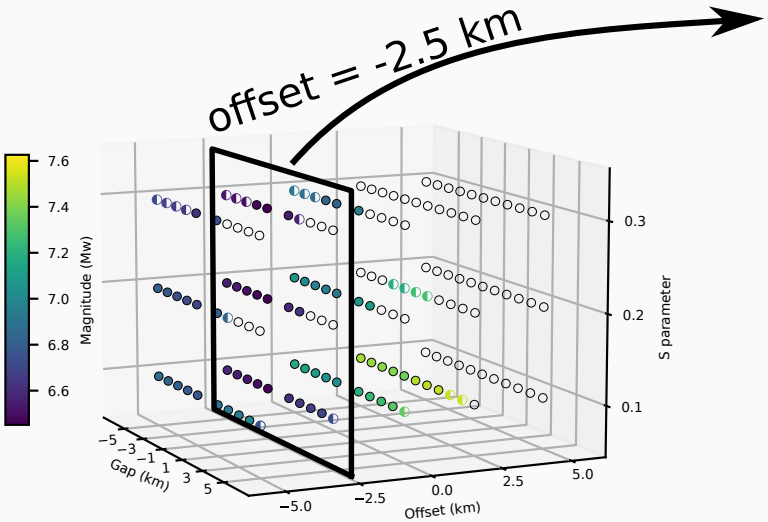


Let's see in detail some results at

a given offset ... at offset $= -2.5$ km ($\frac{1}{4}$ overlapped)

Results: Hanging/foot wall Asymmetric behavior



Cases:

● jump & break-away

○ jump & arrested

◐ no jump

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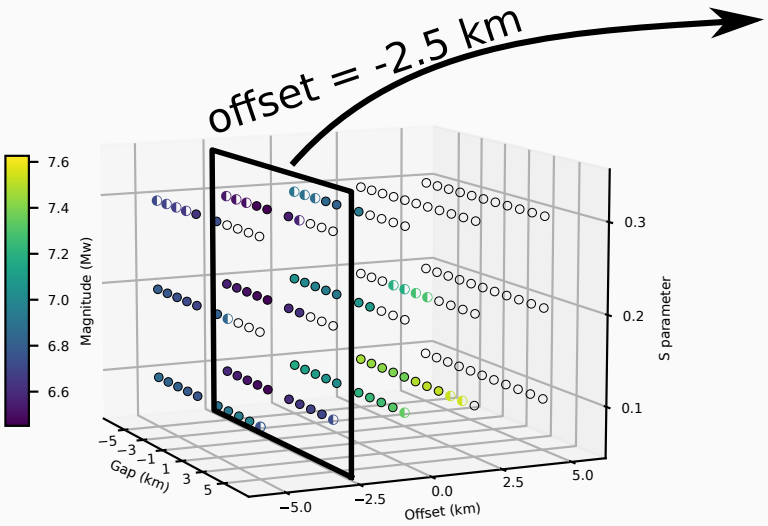

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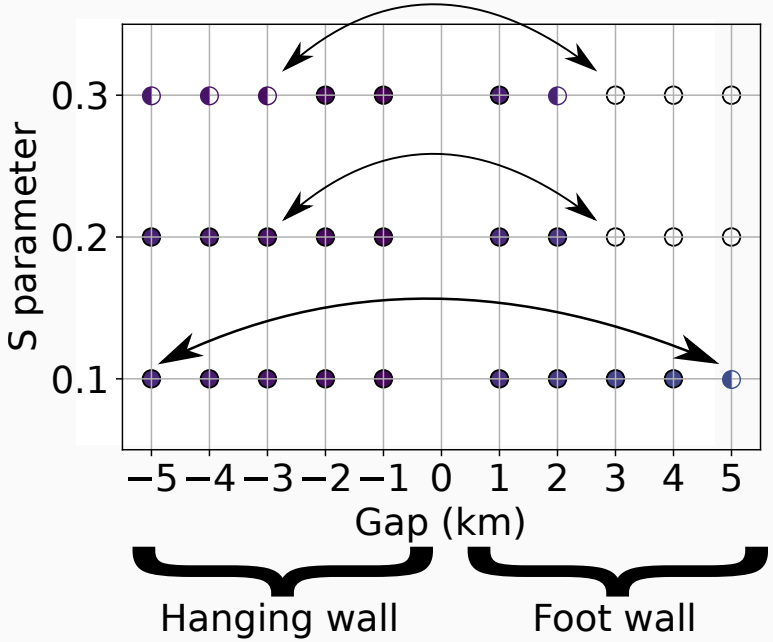

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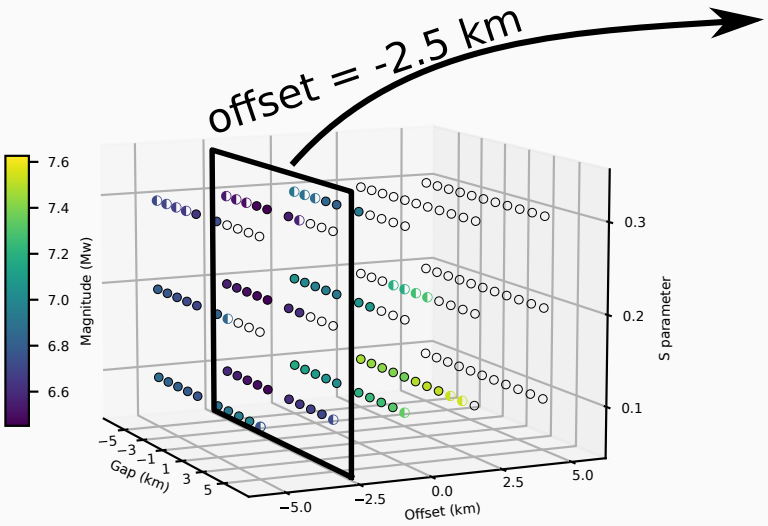

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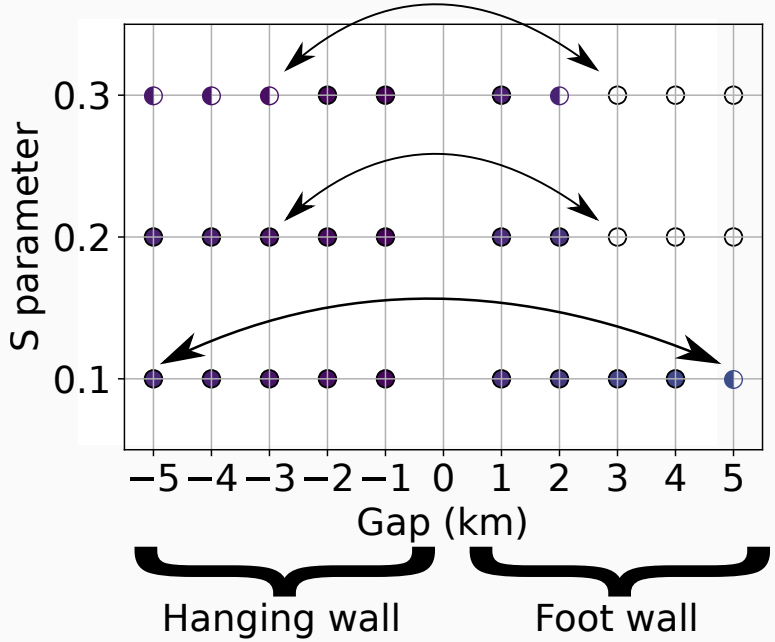
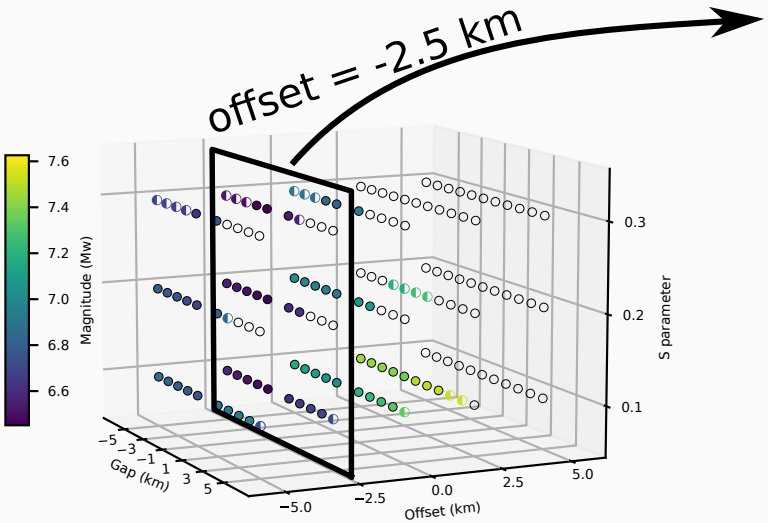


☞ **Hanging/foot wall asymmetry:**

When the 2nd fault is on the hanging wall (Gap < 0), the rupture is more likely to

- be triggered
- be sustained

Results: Stress shadow ☞ expected magnitudes



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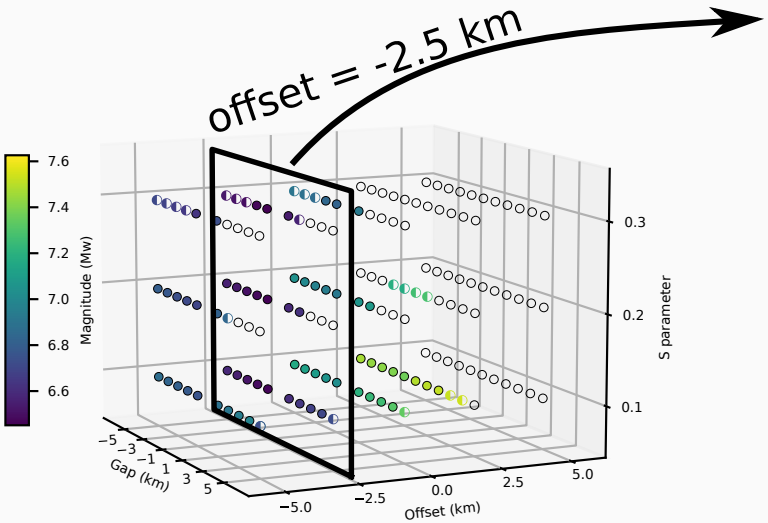

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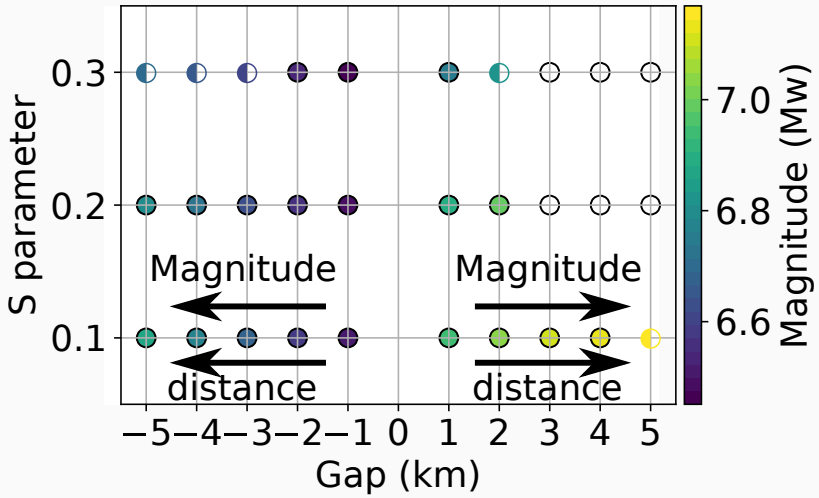

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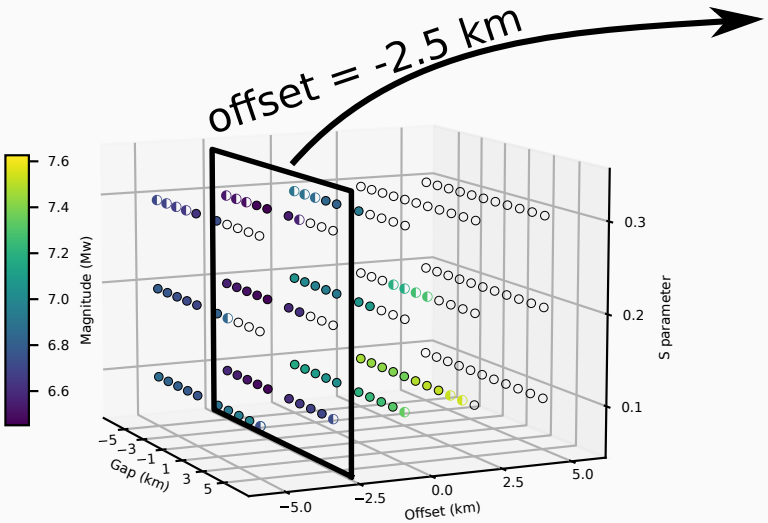

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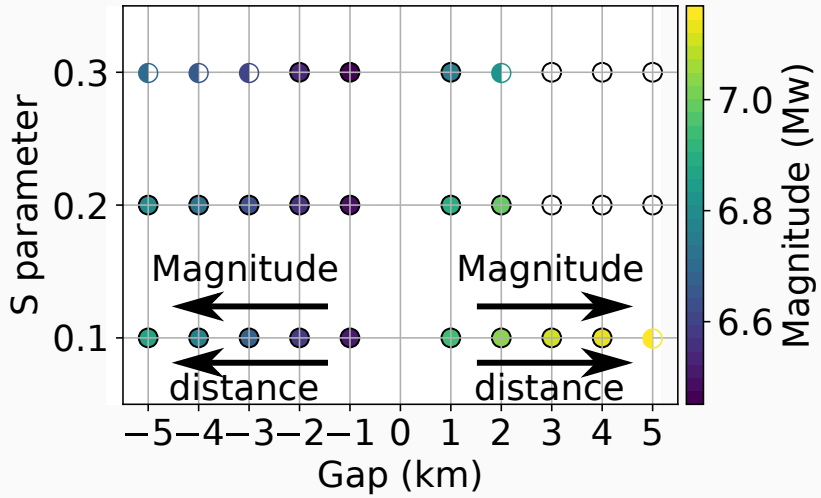
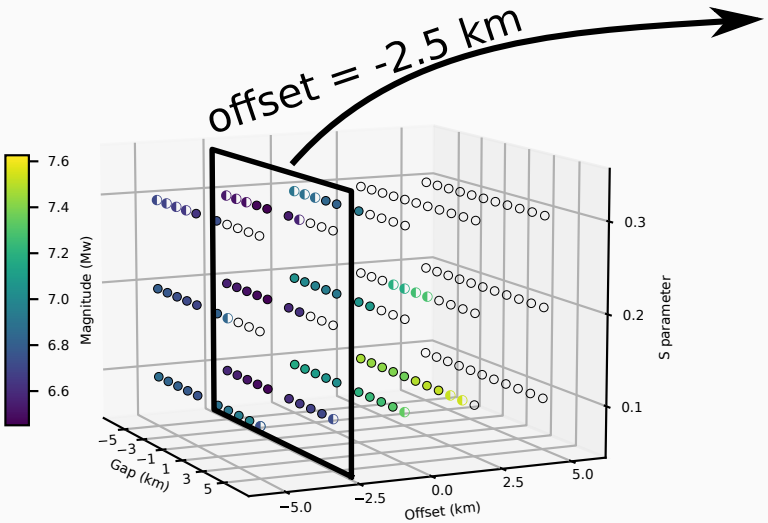


☞ **Stress shadow:**

The final energy released (M_w proxy) increases/decreases according to the distance between faults.

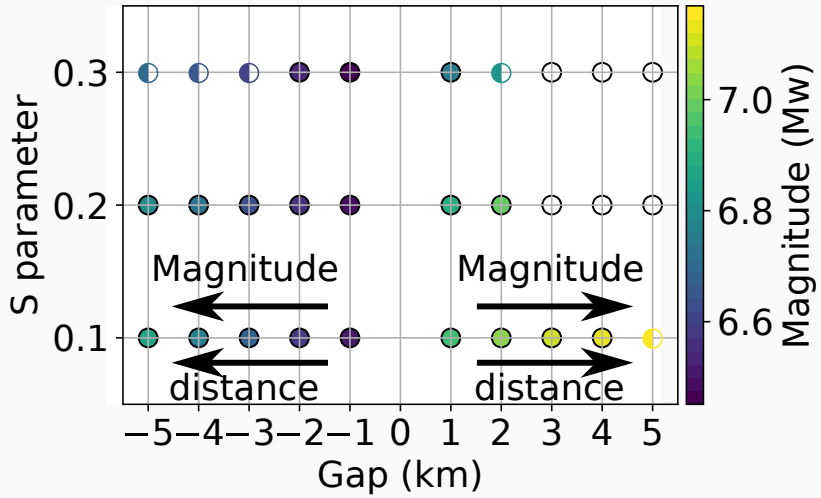
Results: Stress shadow ☞ expected magnitudes



Cases:

- ● jump & break-away
- ○ jump & arrested
- ◐ no jump

Proximity VS magnitude



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The final energy released (M_w proxy) increases/decreases according to the distance between faults.

The closer $\longrightarrow$ rupture jump

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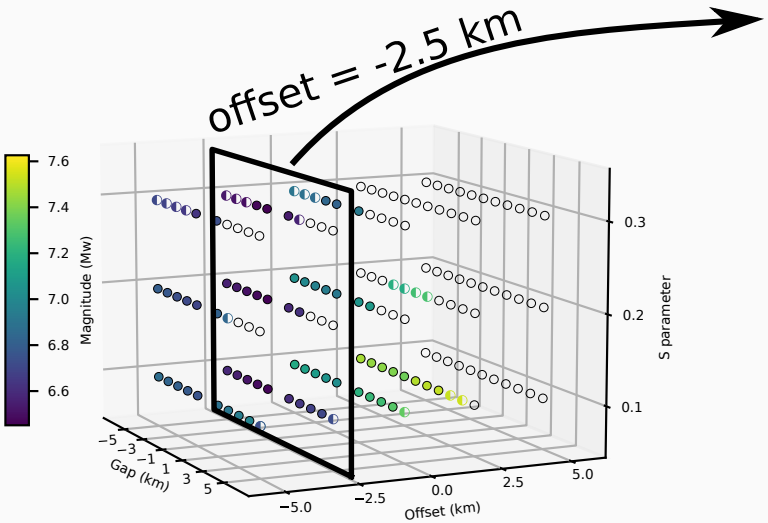

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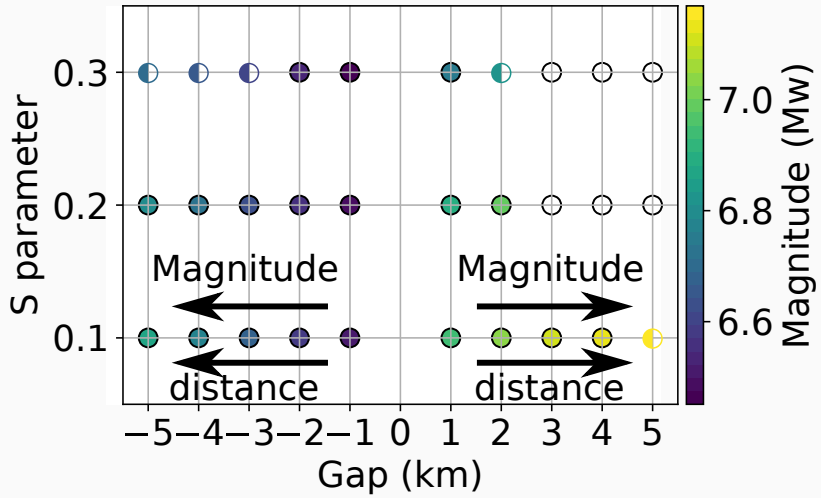


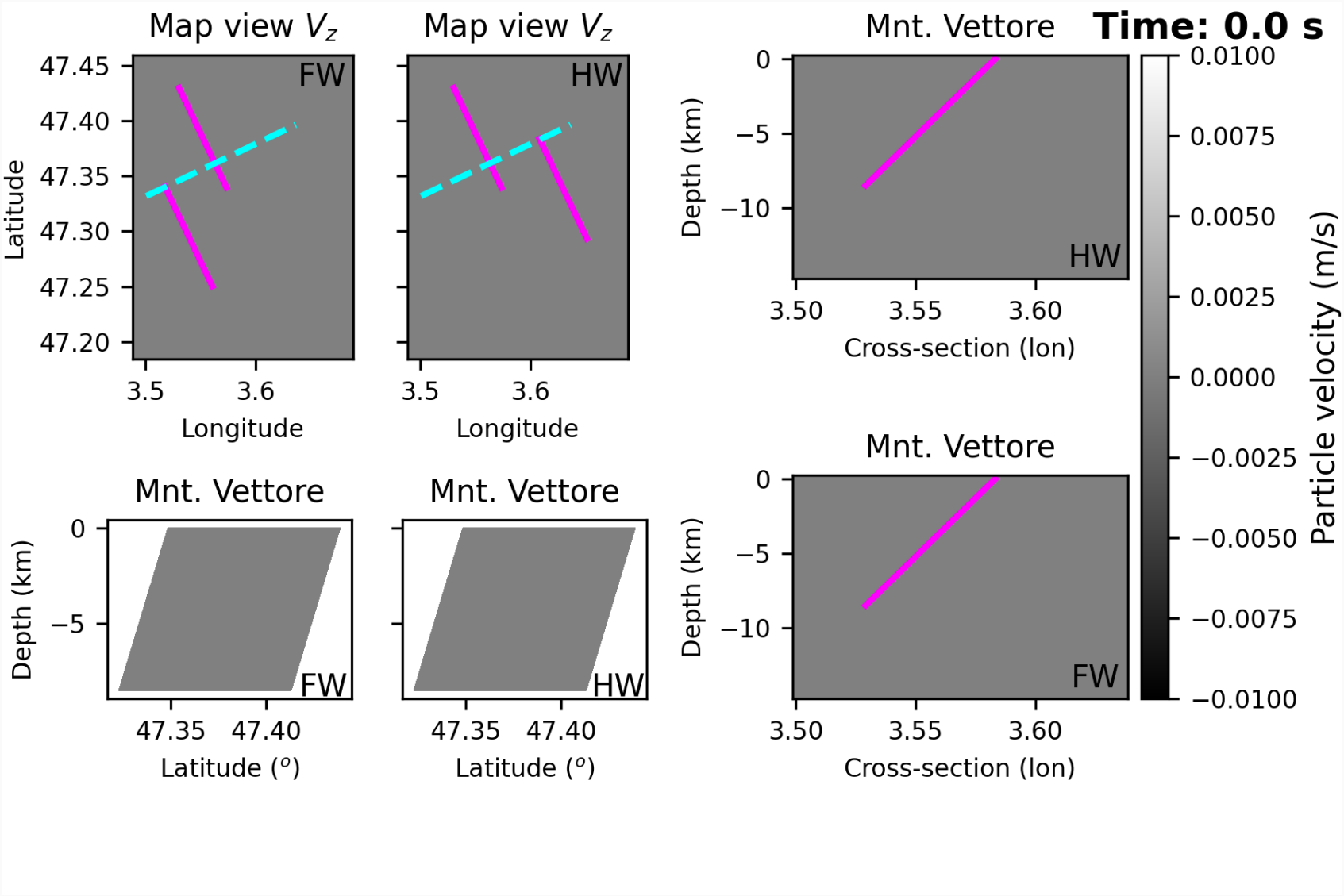
☞ **Stress shadow:**

The final energy released (M_w proxy) increases/decreases according to the distance between faults.

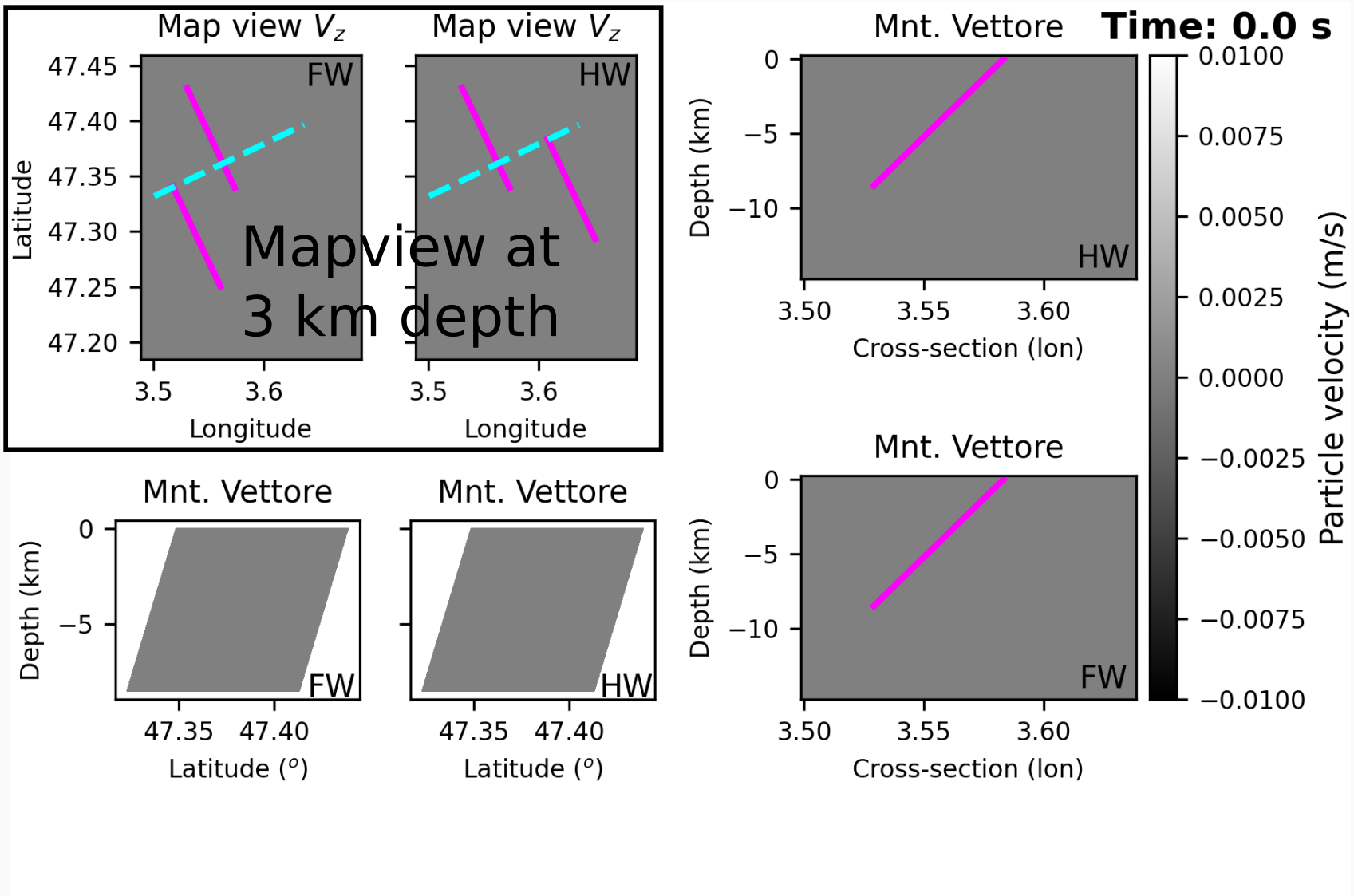
The closer $\longrightarrow$ rupture jump

The closer $\longrightarrow$ less magnitude

Special case: offset −2.5 km, gap ±5.0 km



Special case: offset -2.5 km, gap ± 5.0 km



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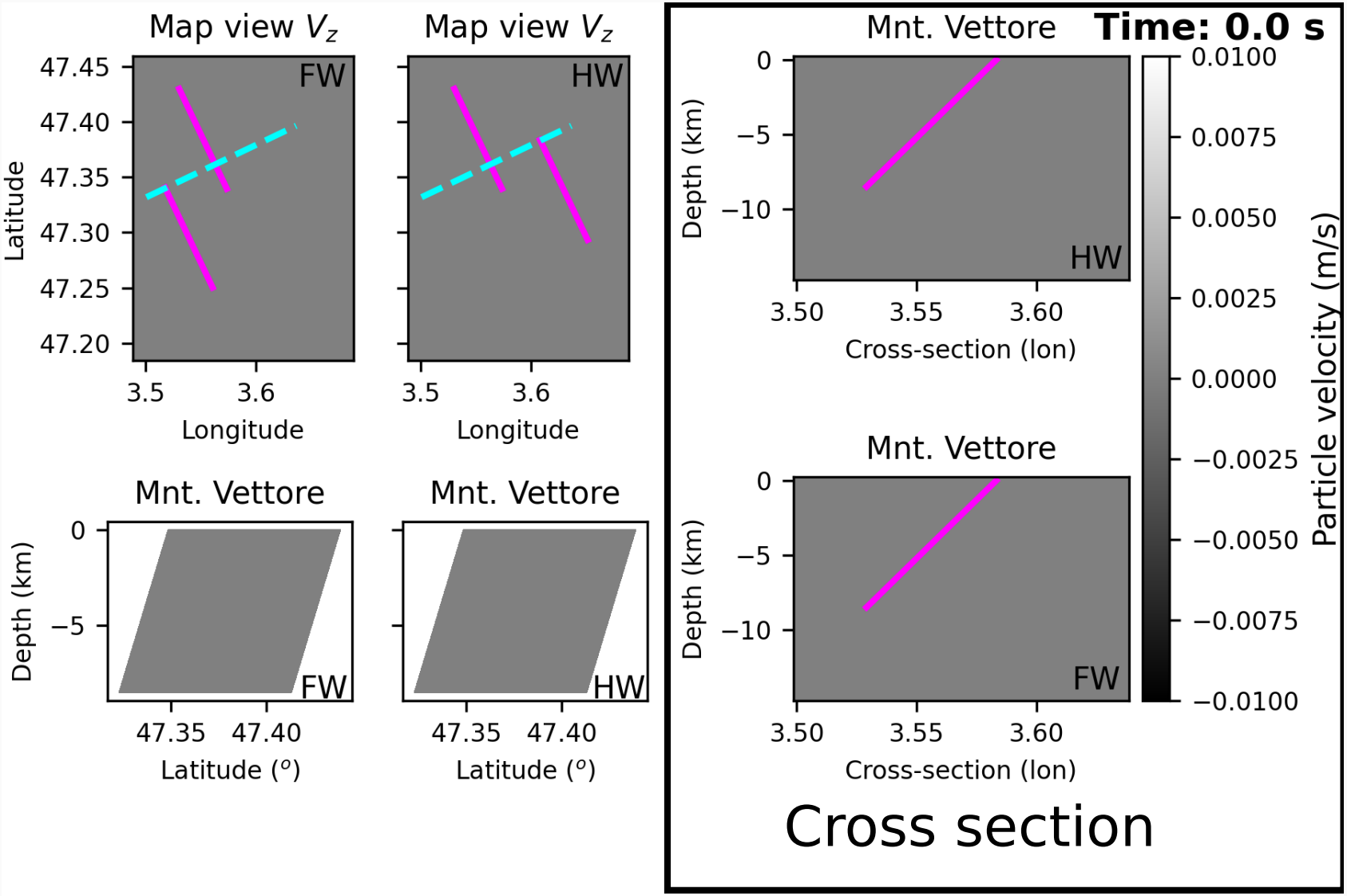

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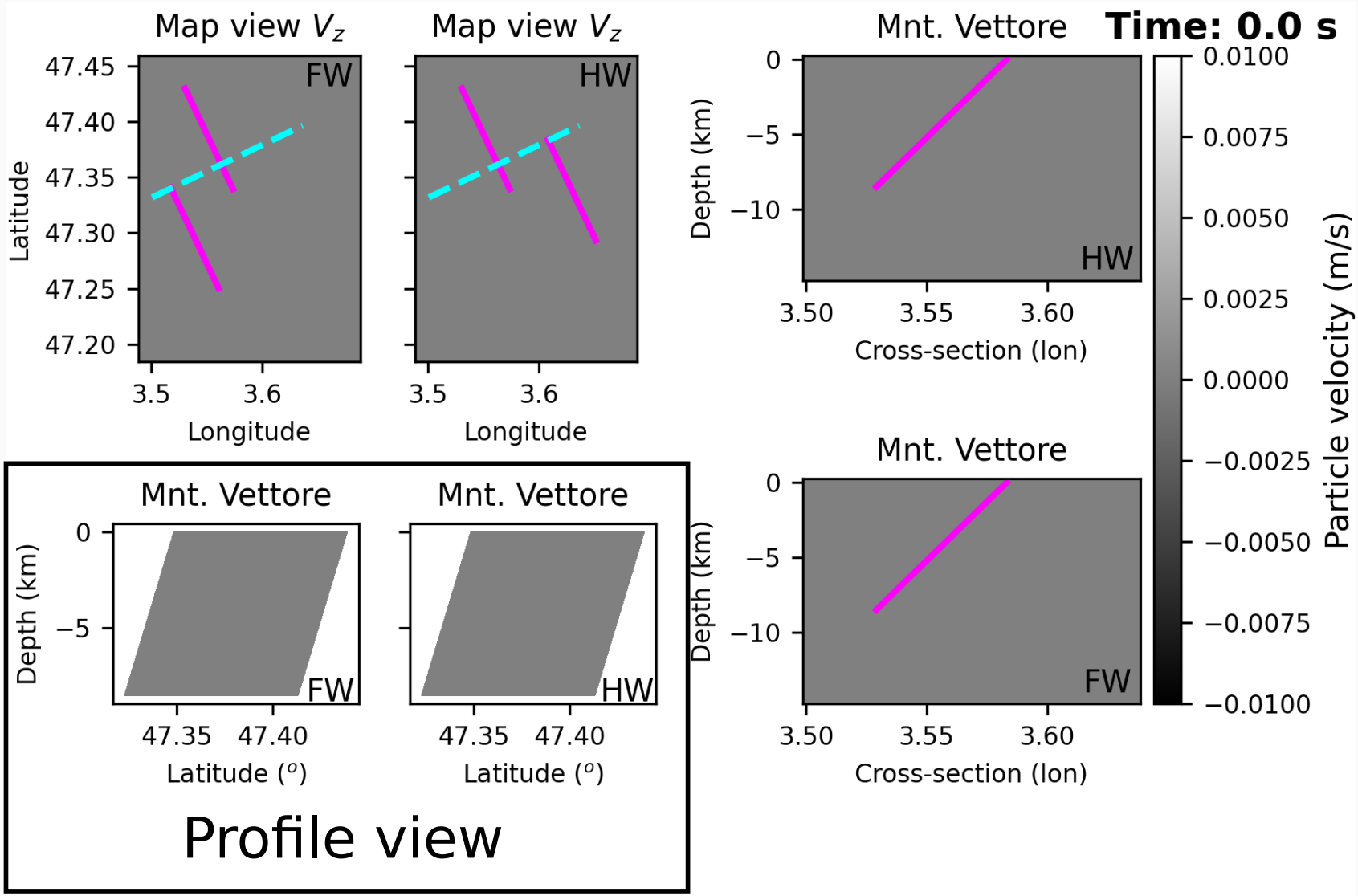

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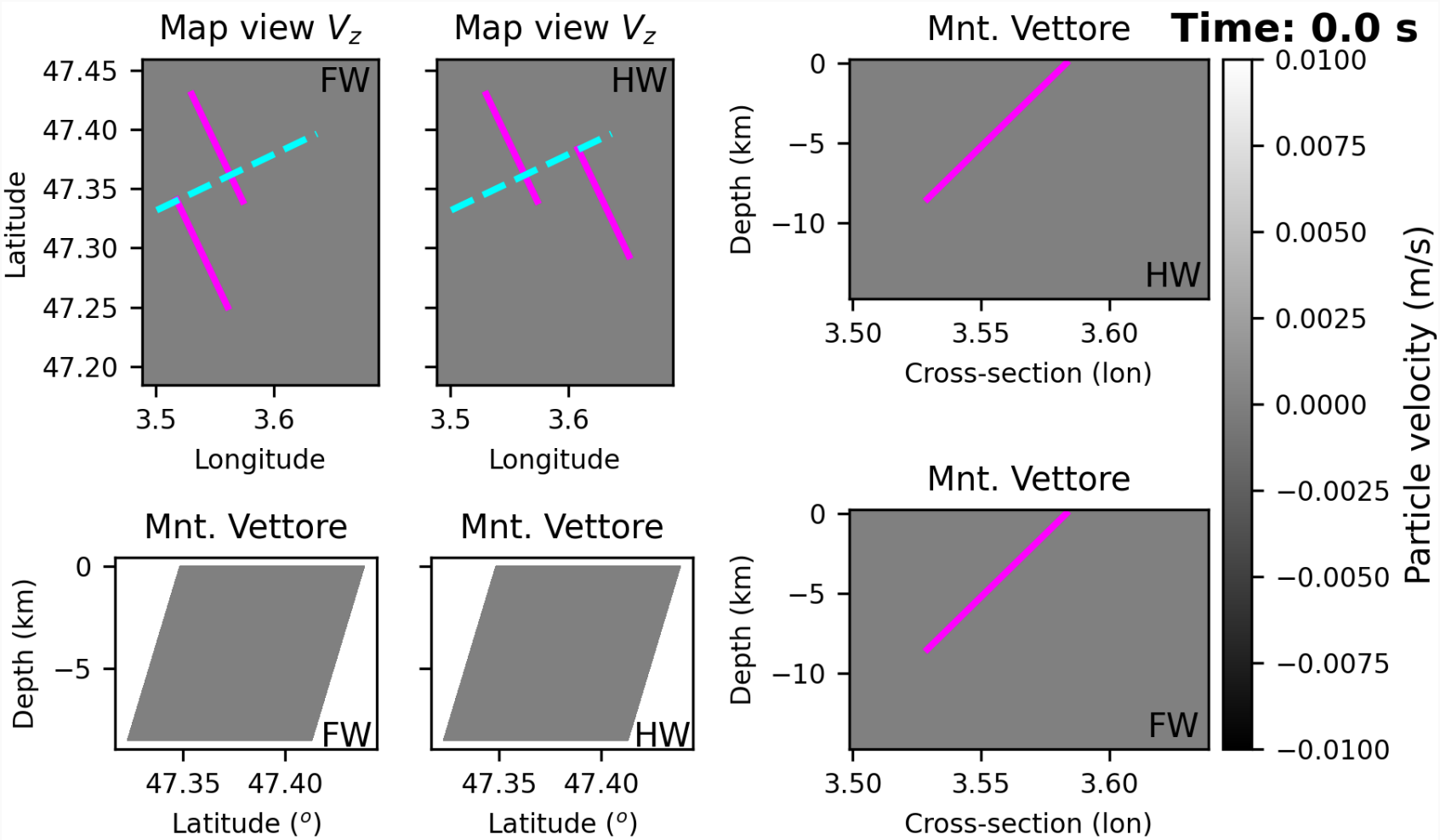
Video of the simulation



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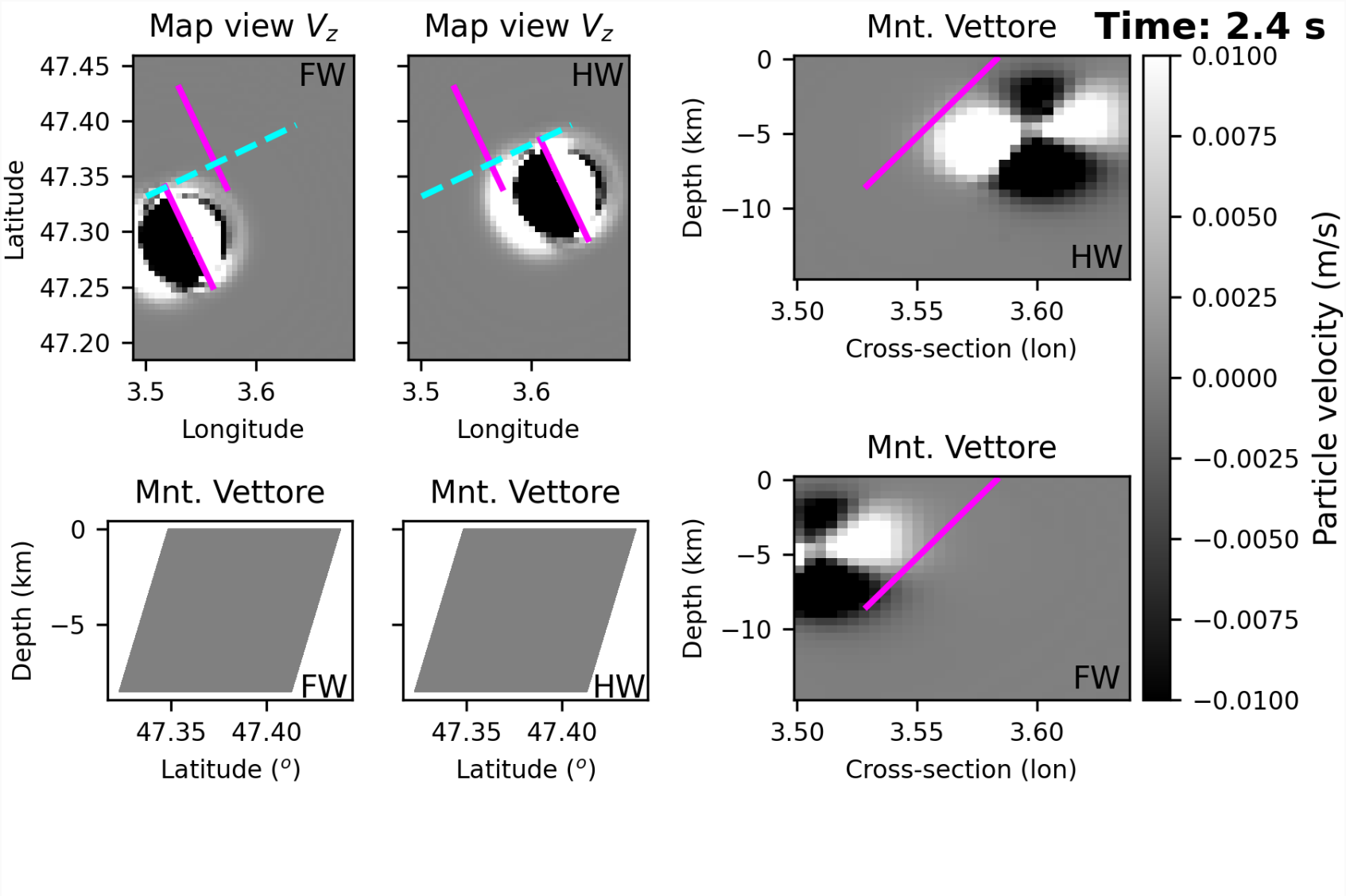

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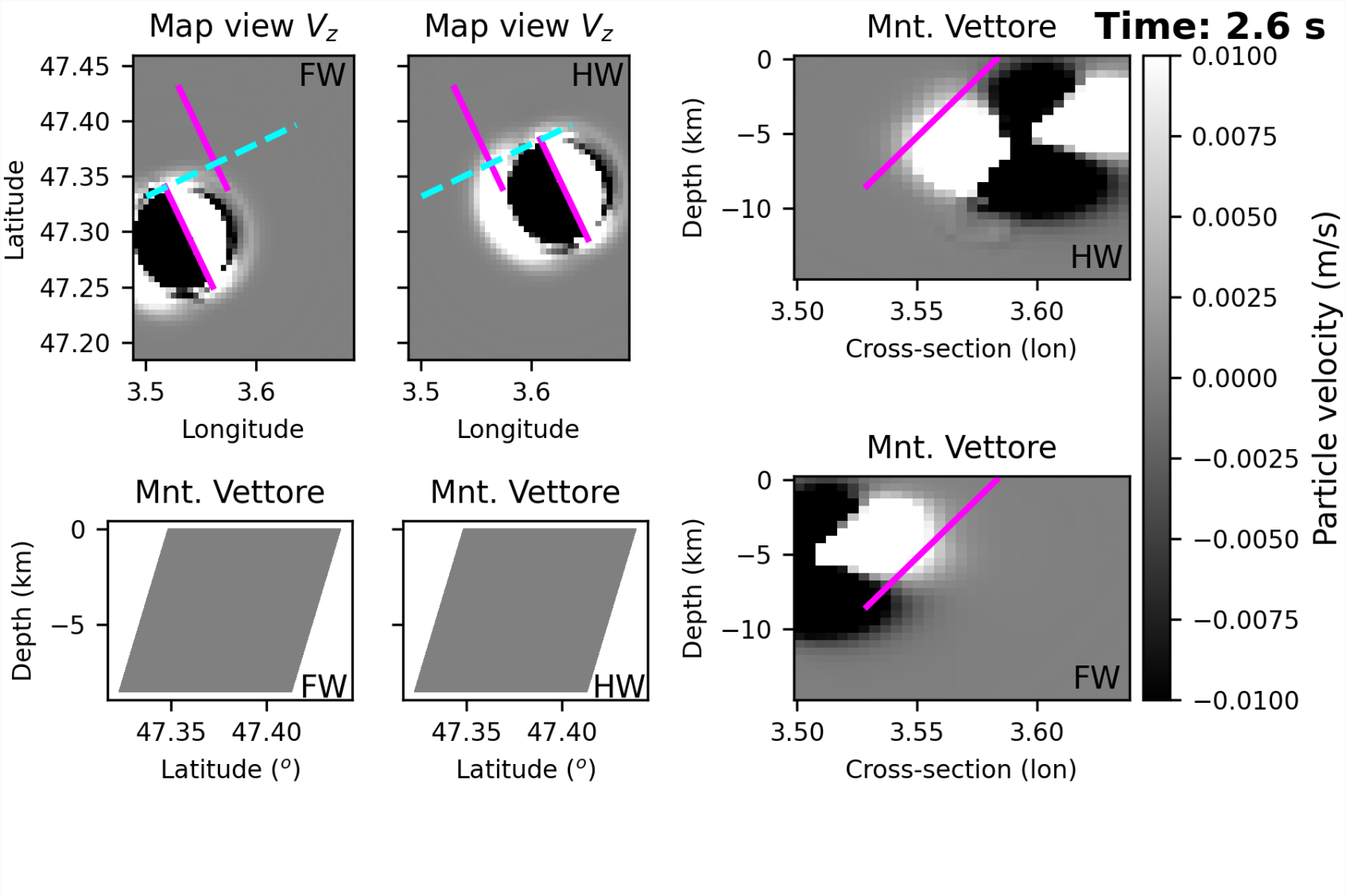

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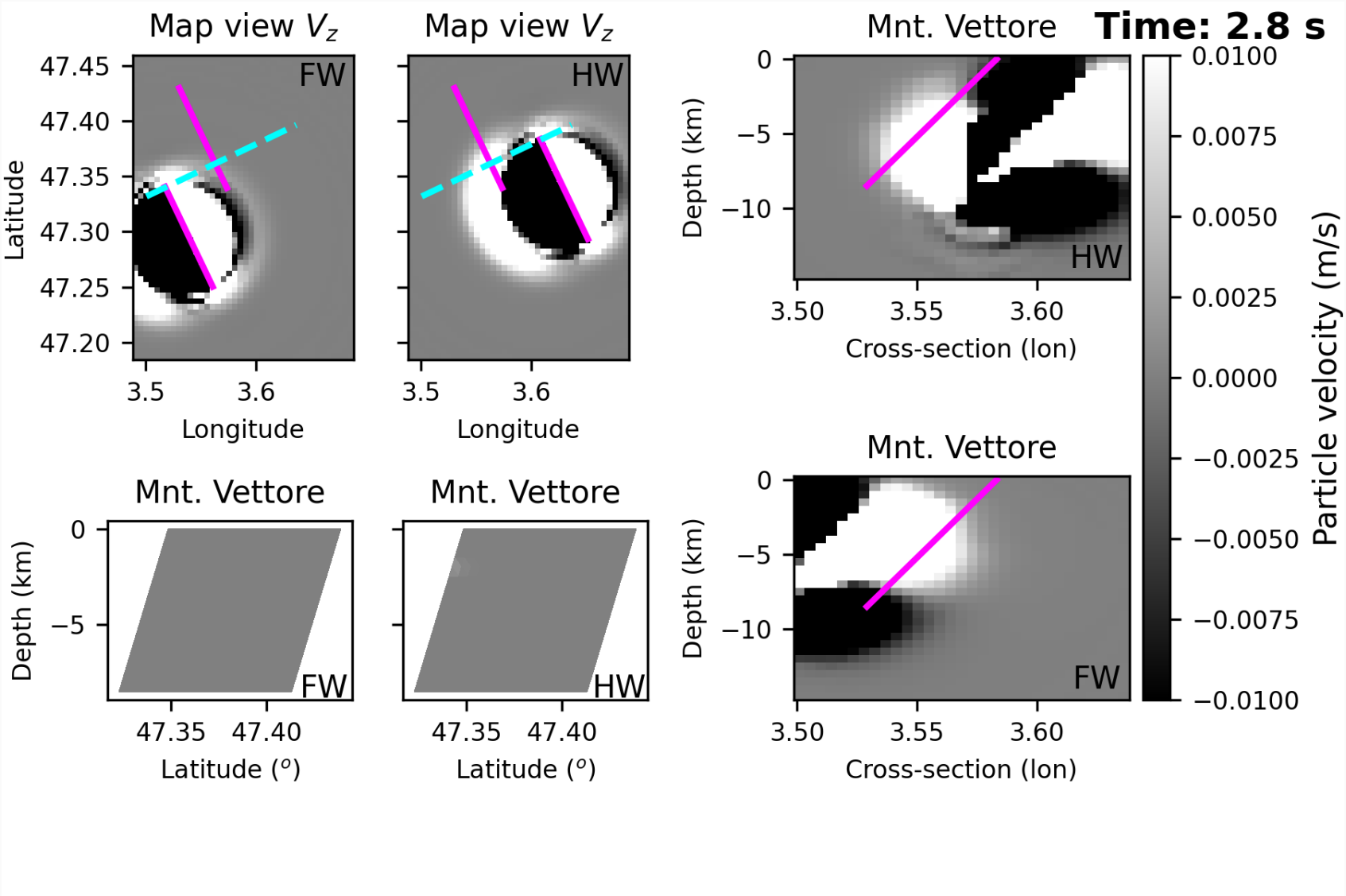

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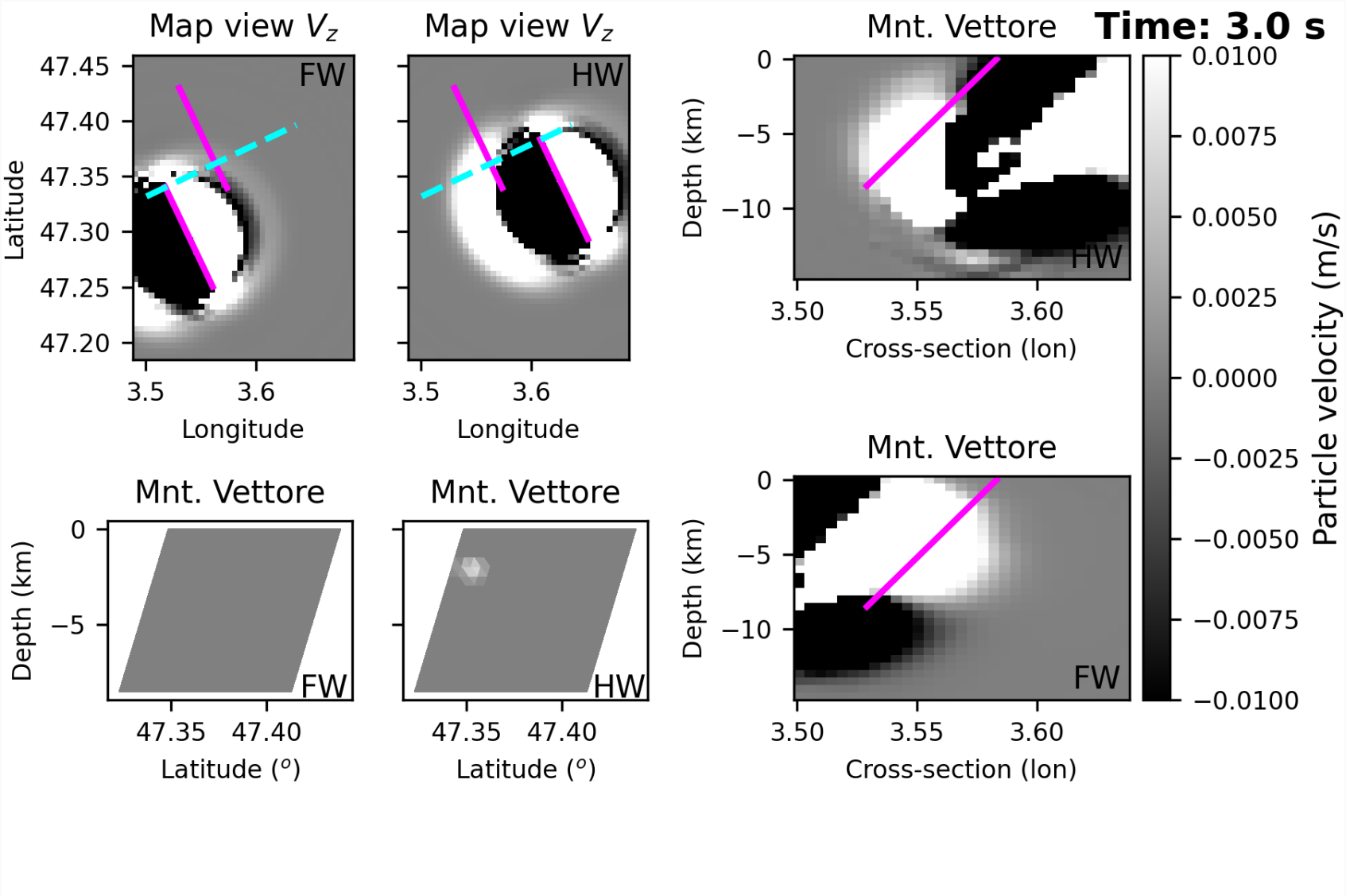
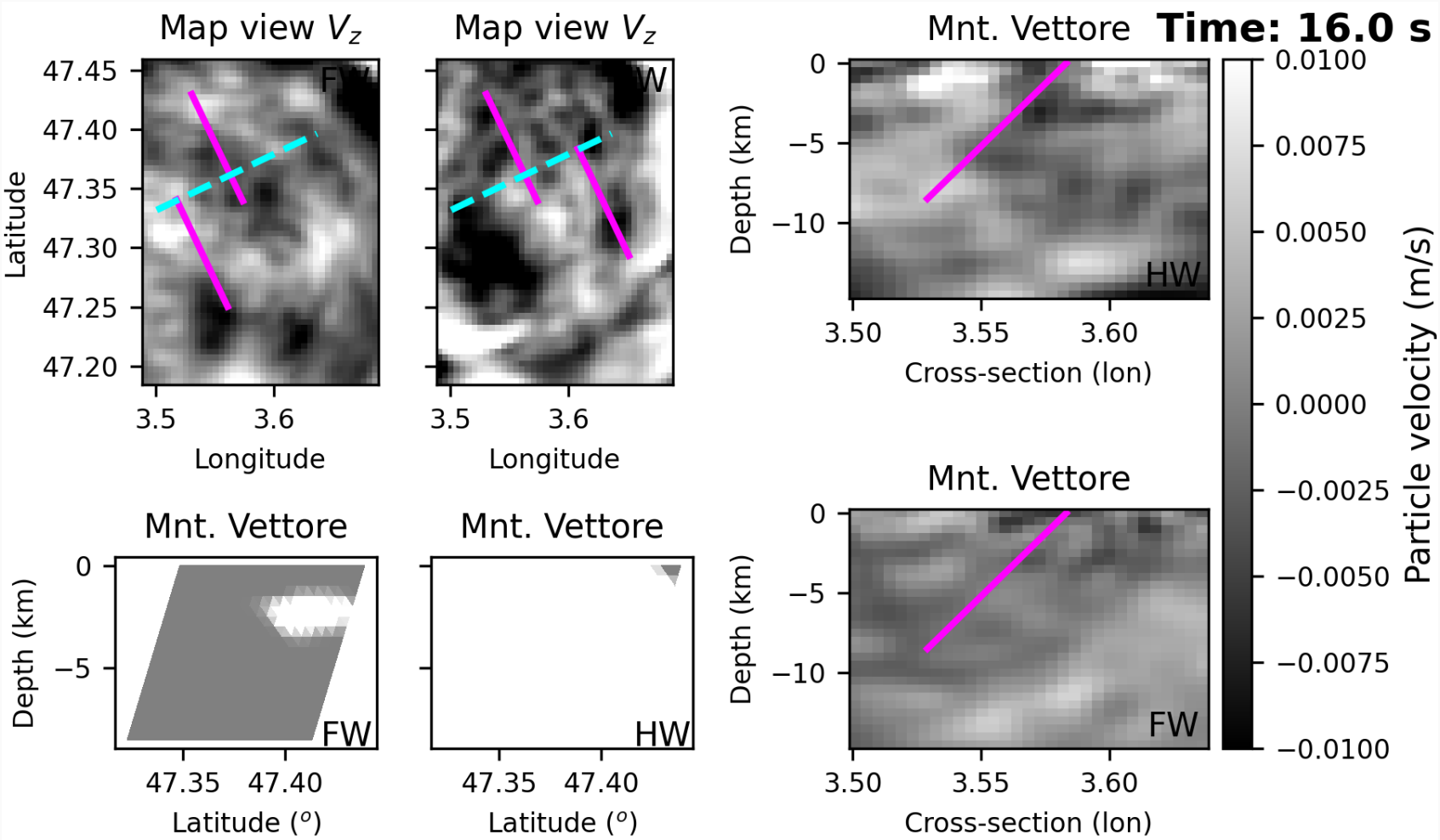


Special case: offset -2.5 km, gap ± 5.0 km

Last snapshot: Rupture occurred for both cases,
but with different behaviors



Conclusions & discussion

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To sum up:

- ☞ Static analyses seem to be insufficient to precisely determine a rupture jump and beak-away behaviors.
- ☞ It is necessary to have an enough large area where ΔCFF$>$0 to ensure a sustained rupture after it jumped across the step-over.
- ☞ Behaviors such as “stress shadow” and ”asymmetric response” were observed as for strike-slip faults.

To sum up:

- ☞ Static analyses seem to be insufficient to precisely determine a rupture jump and beak-away behaviors.
- ☞ It is necessary to have an enough large area where ΔCFF$>$0 to ensure a sustained rupture after it jumped across the step-over.
- ☞ Behaviors such as “stress shadow” and ”asymmetric response” were observed as for strike-slip faults.
- ☞ The 2nd fault rupture seems to be dynamically triggered by the strong stopping phase arriving from behind.

To sum up:

- ☞ Static analyses seem to be insufficient to precisely determine a rupture jump and beak-away behaviors.
- ☞ It is necessary to have an enough large area where ΔCFF$>$0 to ensure a sustained rupture after it jumped across the step-over.
- ☞ Behaviors such as "stress shadow" and "asymmetric response" were observed as for strike-slip faults.
- ☞ The 2nd fault rupture seems to be dynamically triggered by the strong stopping phase arriving from behind.
- ☞ Using this configuration, 5 km seems to be the largest distance that the rupture can jump, considering very high stress levels and favorable physical conditions.

Thank you for listening!

Questions?

References

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