Model design

A permeable fault channel

We model the ascent of fluid along the permeable fault zone in a **high permeability, 1D channel along the dip of the fault**.

The channel is fed **by a constant fluid flux** q_{in} at its downdip end, from the dehydration of downdip slab segments.

At its updip end, the channel is connected to a highly permeable area (fractured continental crust), and the **pressure is fixed to hydrostatic levels**.

A valve mechanism

Fluid flow in the fault zone carries fine material (silica colloids or material eroded from the permeability walls) [5], that is subject to erosion and deposition processes, in response to the local velocity of the flow.

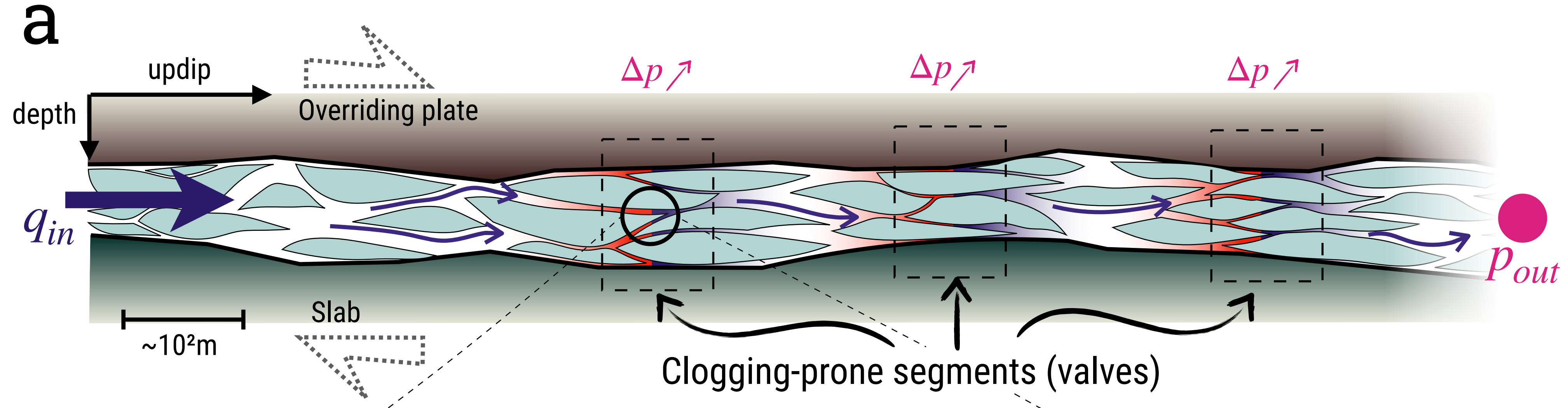
We model this phenomenon as permeability valves. In fixed locations, the permeability can open and close in response to the local pressure gradient: **δp is high, then the valve opens, and δp drops, allowing the valve to close**, with an hysteresis (e).

When a valve opens, it releases a strong fluid pulse because of the local pressure gradient build up while the valve is closed. This strong, rapid, localized pressure gradient can act as **a source of seismic waves** [6], or trigger seismic slip in local asperities.

We therefore consider that each opening is accompanied by an LFE-like seismic event.

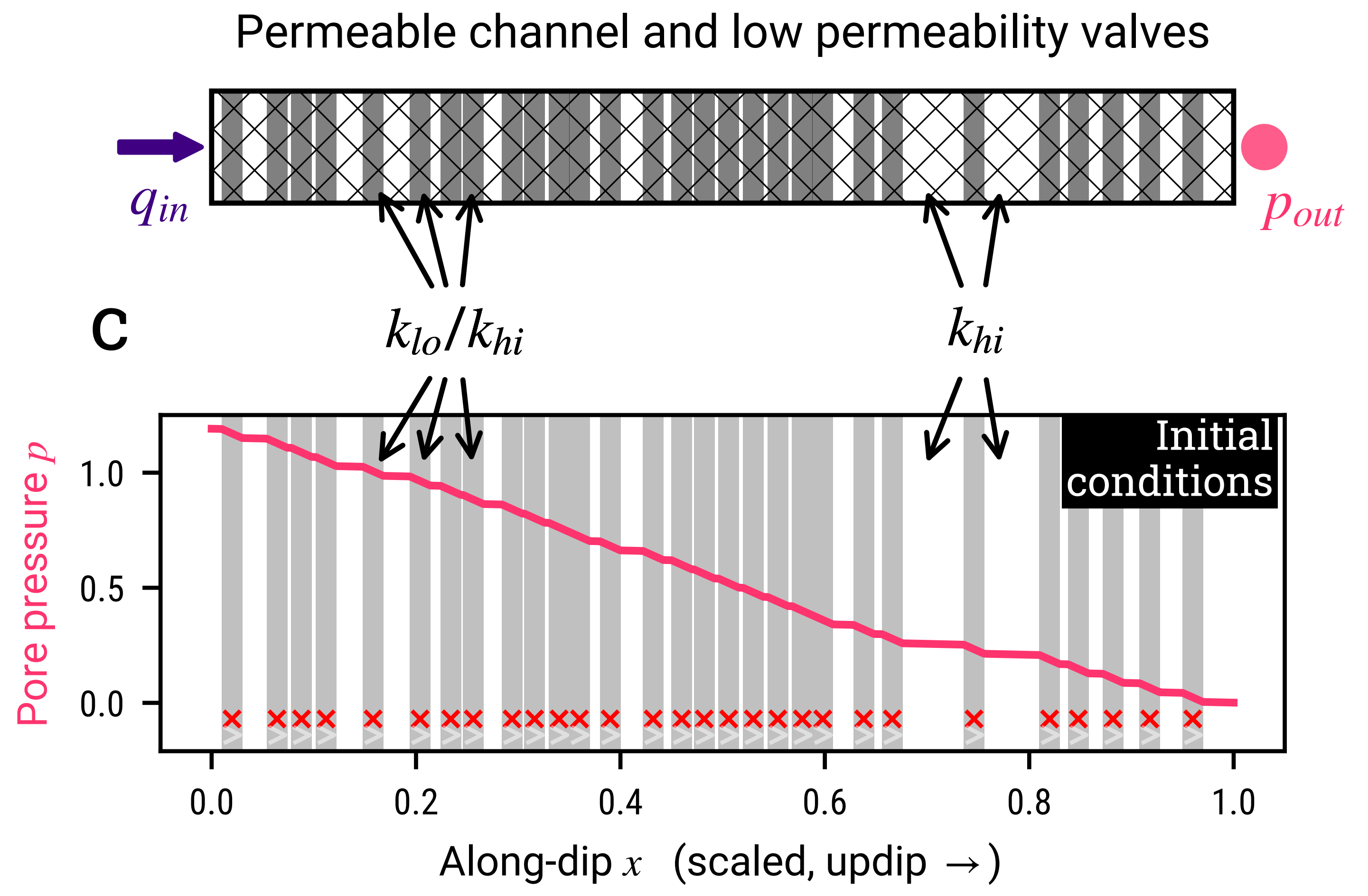
We solve for **fluid pressure diffusion** in a **permeable channel with valves**

a



b

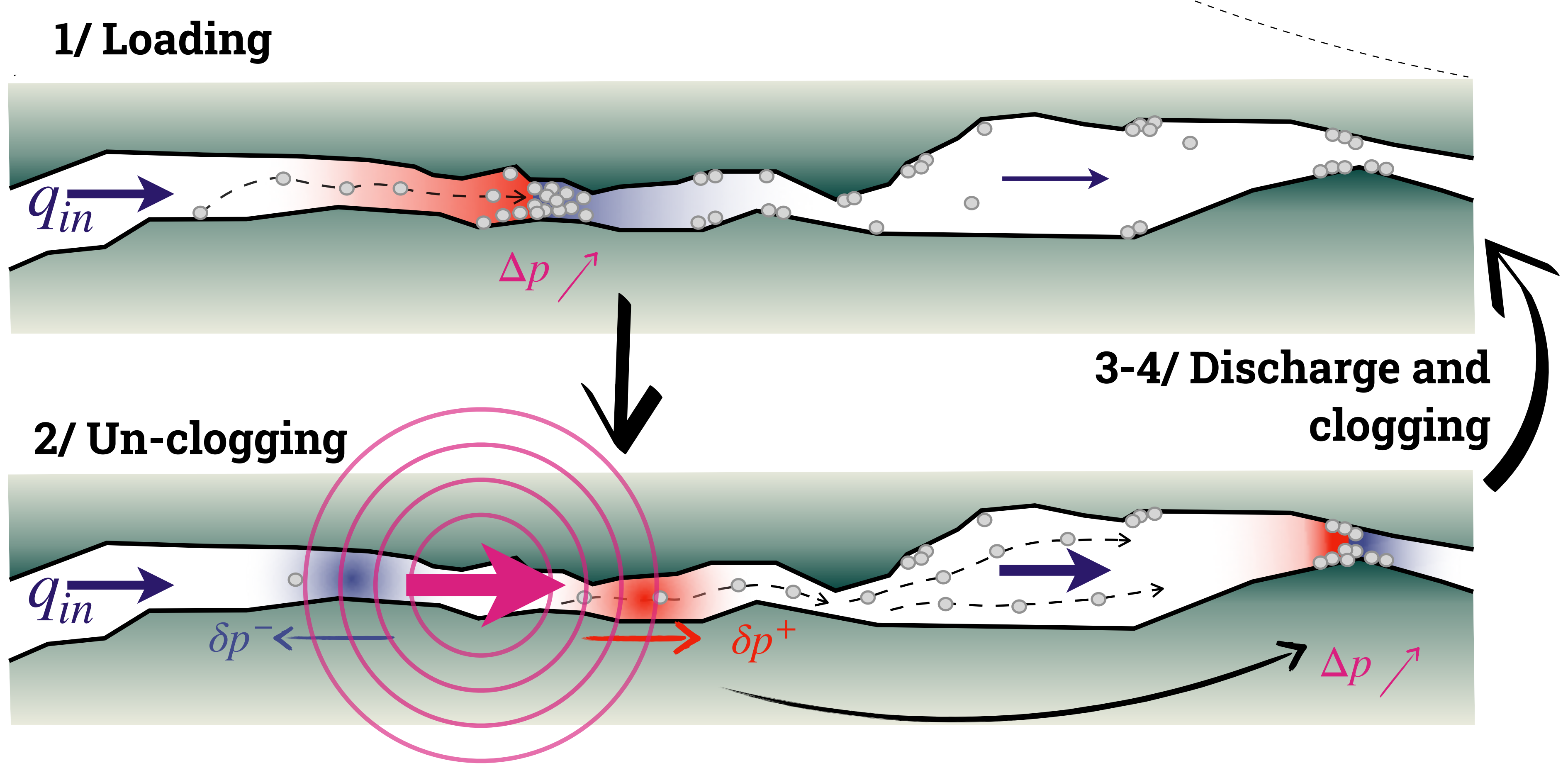
c



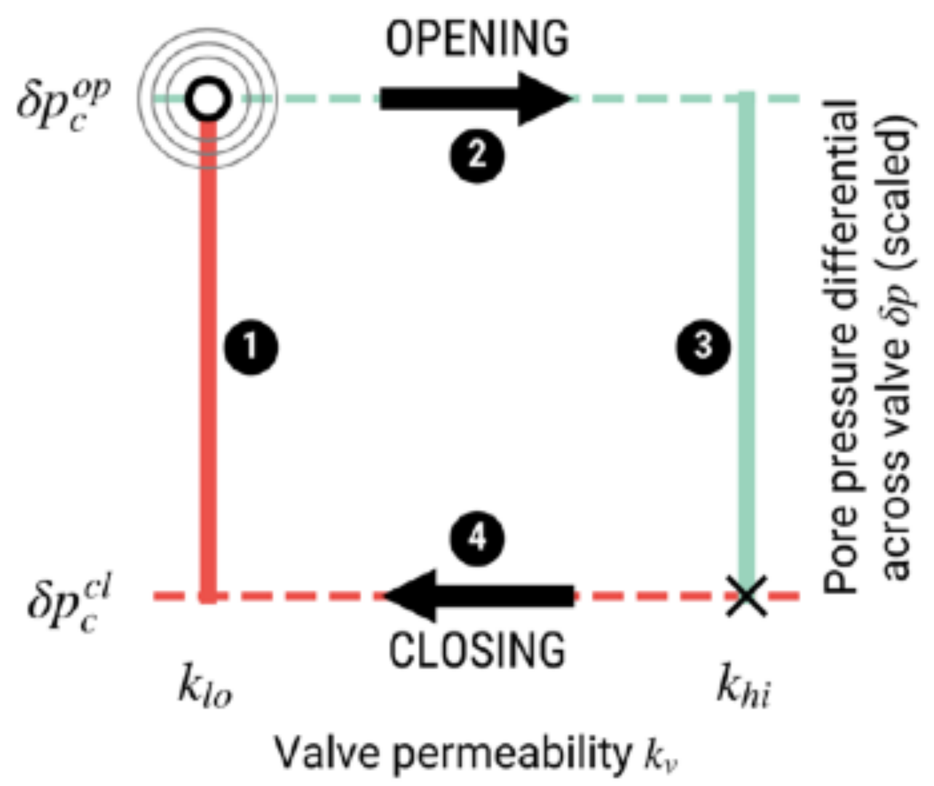
A 1D permeable channel, with valves, along the dip of the fault

Schematic (a) and physical (b) representations of channel and permeability valves. (c) shows the initial fluid pressure conditions in a channel.

d



e



Valves: permeability heterogeneity and variability on an elementary scale

(d) Schematic representations of a valve cycle. (e) shows the hysteretical cycle that valve permeability follows in response to the pressure diff. across the valve.

Results — (i)

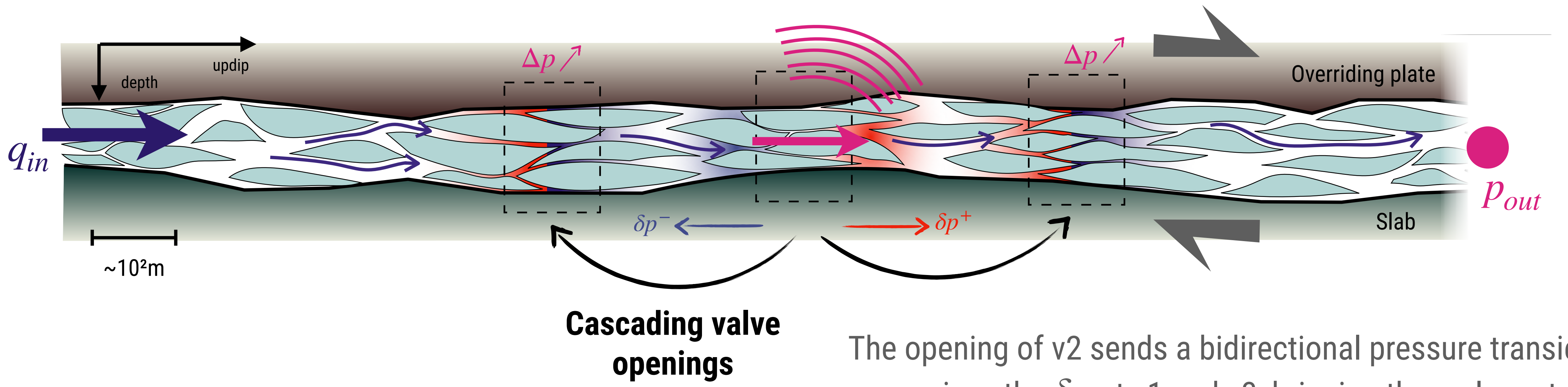
Valve (source) interaction

The opening of a valve generates a strong **pressure transient that diffuses to neighboring valves**. Both updip and downdip valves are brought closer to failures as their δp increases.

This mechanism is the **basis of constructive source interaction** in our model, and generates **fast cascades of valve openings,** and therefore of seismic events.

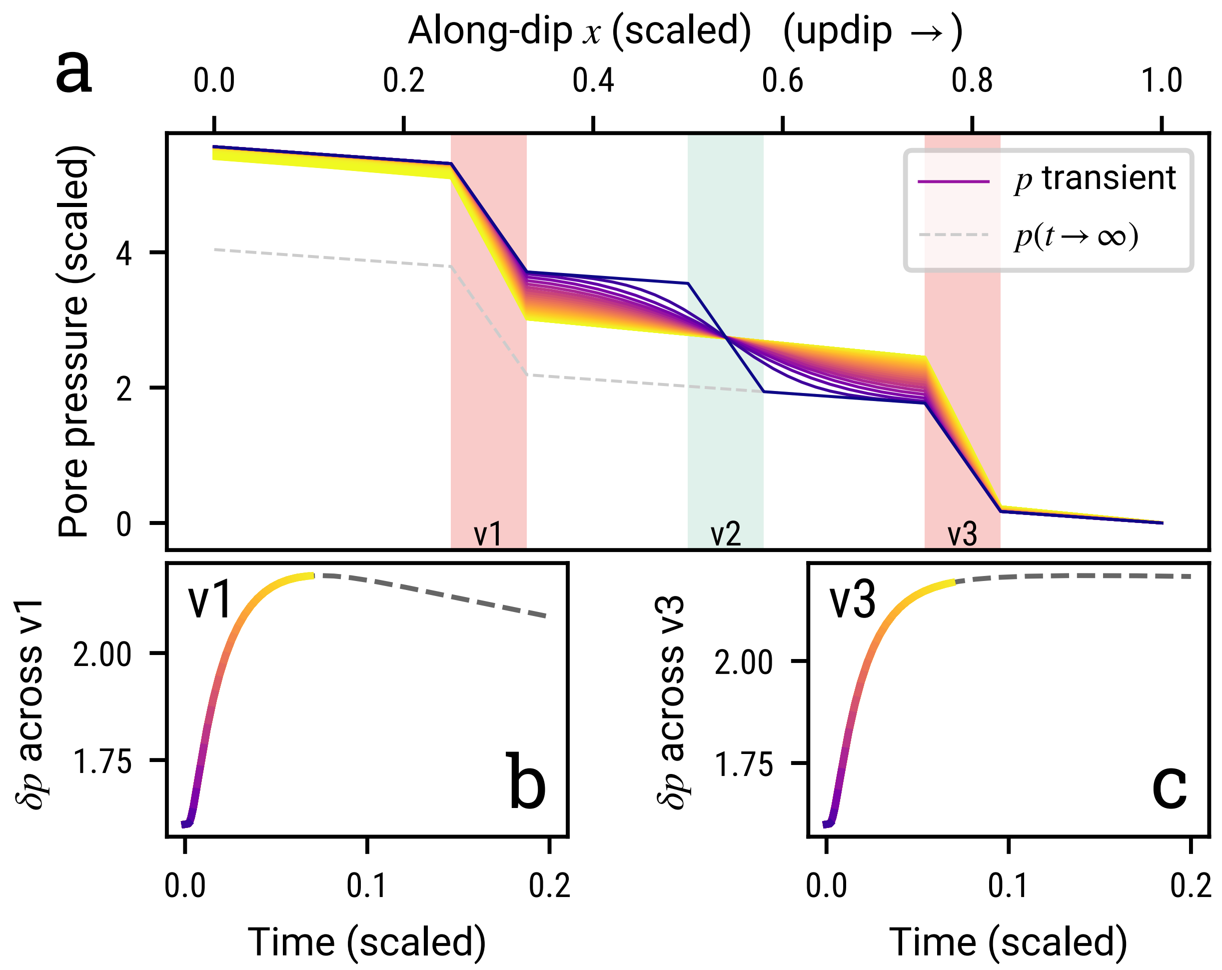
Patterns of clustering and migration

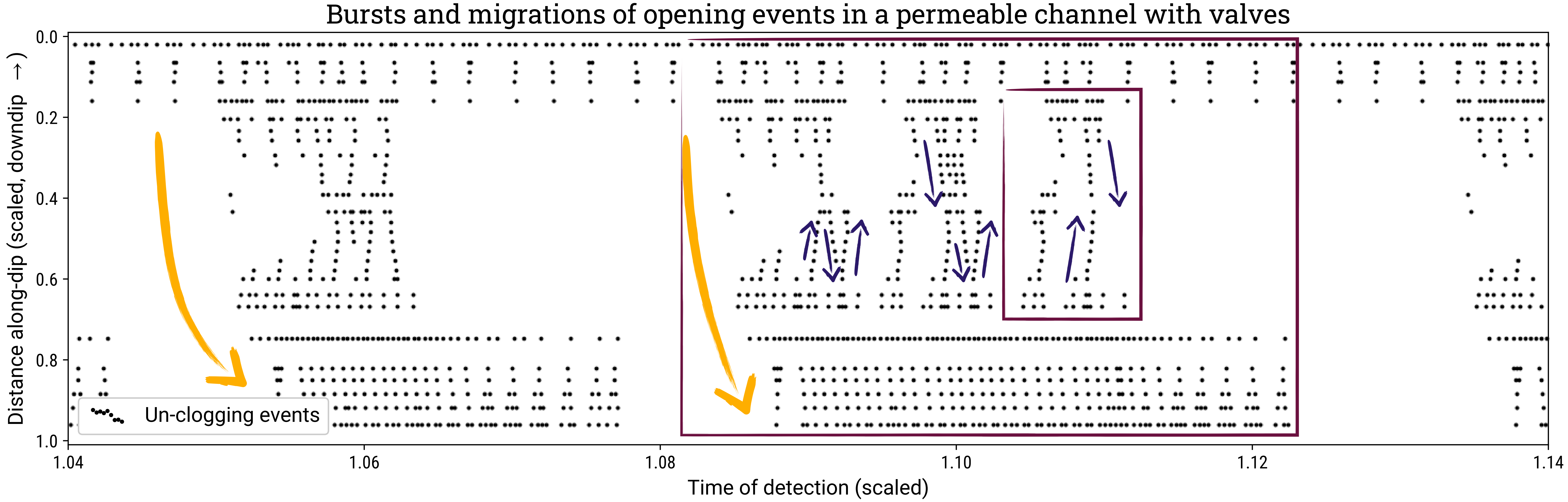
The synthetic seismic activity (opening activity) organizes around those rapid cascades of events. They are the building blocks of larger bursts and migrations, on both short and longer time and space scales.



The opening of v2 sends a bidirectional pressure transient that raises the δp at v1 and v3, bringing them closer to failure

In the model, seismic sources interact with each other through pressure transients





patterns of clustering and migration emerge from these elementary cascades

Background and motivation

Fluid in subduction zones

As it is subducted, the downgoing slab dehydrates, and **free fluid then pushes its way towards the surface, at quasi-lithostatic pressures**.

At 40 km depth, the fluid preferentially follows the fault interface, whose **very anisotropic permeability** is a barrier to the upward flow, but **channels fluid along the fault plane**.

Variations of **fluid pressure** induced by variations in fluid flow within subduction fault zone can **fuel fault-slip** fast and slow slip events [1] and thus be a trigger for the largest earthquakes [2].

Tremor and LFE activity as proxy for fluid transport processes

Tremor migrations move **quickly on short distances**, and **slowly on larger distances**, leading us to think that sources interact through **diffusive interaction** mainly, perhaps through fluid pressure transients.

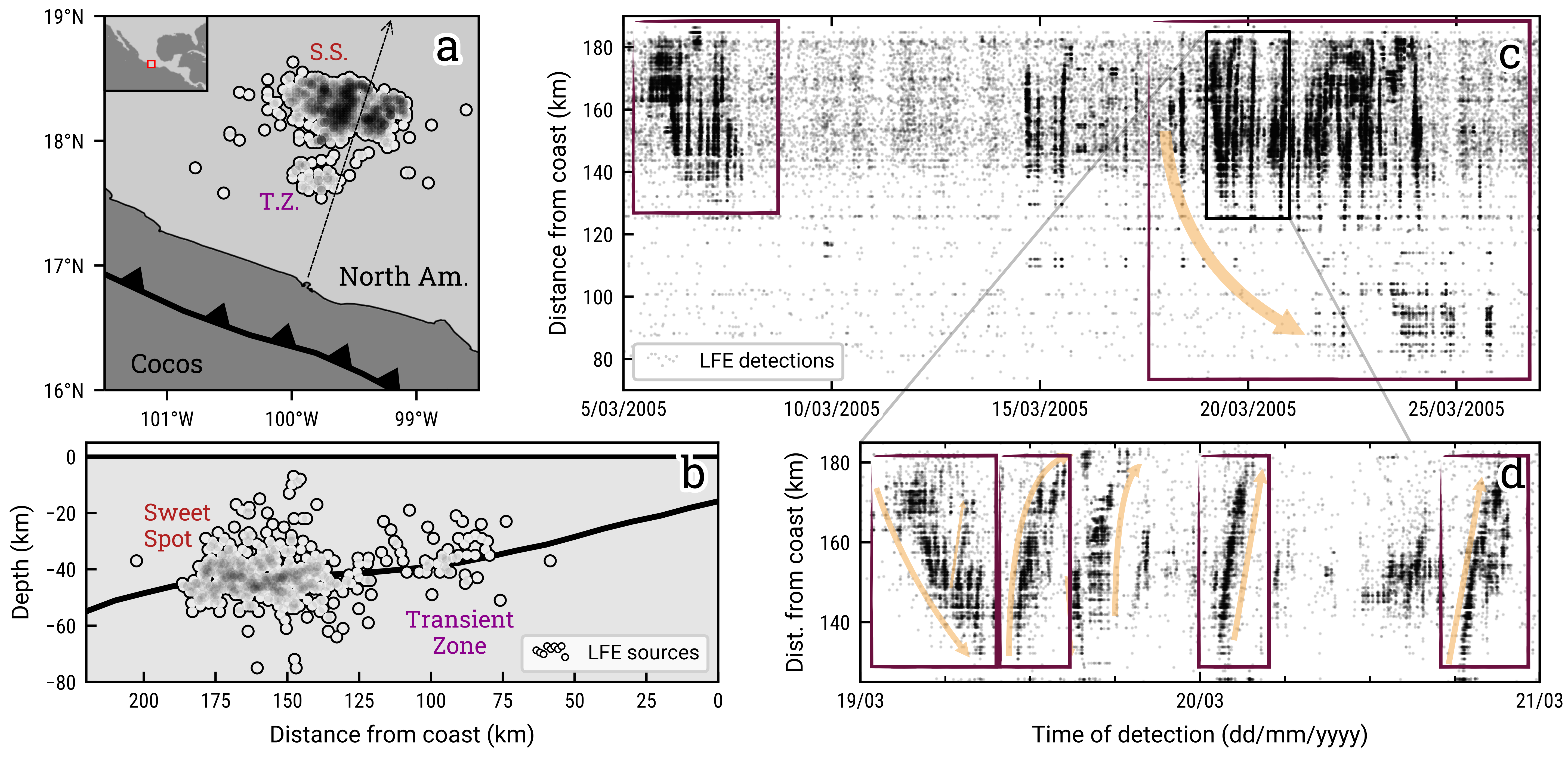
In active subduction zones, the activity of swarms of **low-frequency earthquakes** (LFE)* and **tremor** is often thought to be caused by **pulses of coupled slow fault slip and high fluid pressure** [1, 3, among others] in a mechanism akin to a **fault valve** [1, after 4].

Based on the hypothesis that **tremor activity reflects the dynamics of fluid transport processes in the fault**,

we build a model to explore how the **diffusion of fluid pressure** in a fault with **heterogeneous and variable permeability** could **shape its seismicity**.

* Here we assume that LFEs are elementary tremor sources, and that they are generated by the same underlying processes. "tremor activity" and "low-frequency earthquakes activity" are used as synonyms.

Anatomy of low-frequency earthquakes activity in Guerrero, Mexico



Tremor activity occurs is **intermittent** on **both short and large** time and space **scales**

it occurs in **bursts** and **migrates**

How does fluid transport processes shape these patterns?

Results — (ii)

Input flux controls the activity

In a range of input flux — depending of the valves' sensitivity to the pressure gradient and permeability — **valves can both open when closed and close back when open**. In this flux range, activity is permanent and variable.

Within the domain of flux allowing permanent activity, different regimes can be observed:

- Low flux, valves are mostly closed, and open in bursts: activity is low and time-clustered
- Intermediary flux, valves open and close rapidly, randomly but at a constant rate: activity is high and Poisson-like
- High flux, valves are mostly open, and when they close large bursts occur as they impede the flow: activity is low, and quasi-periodic

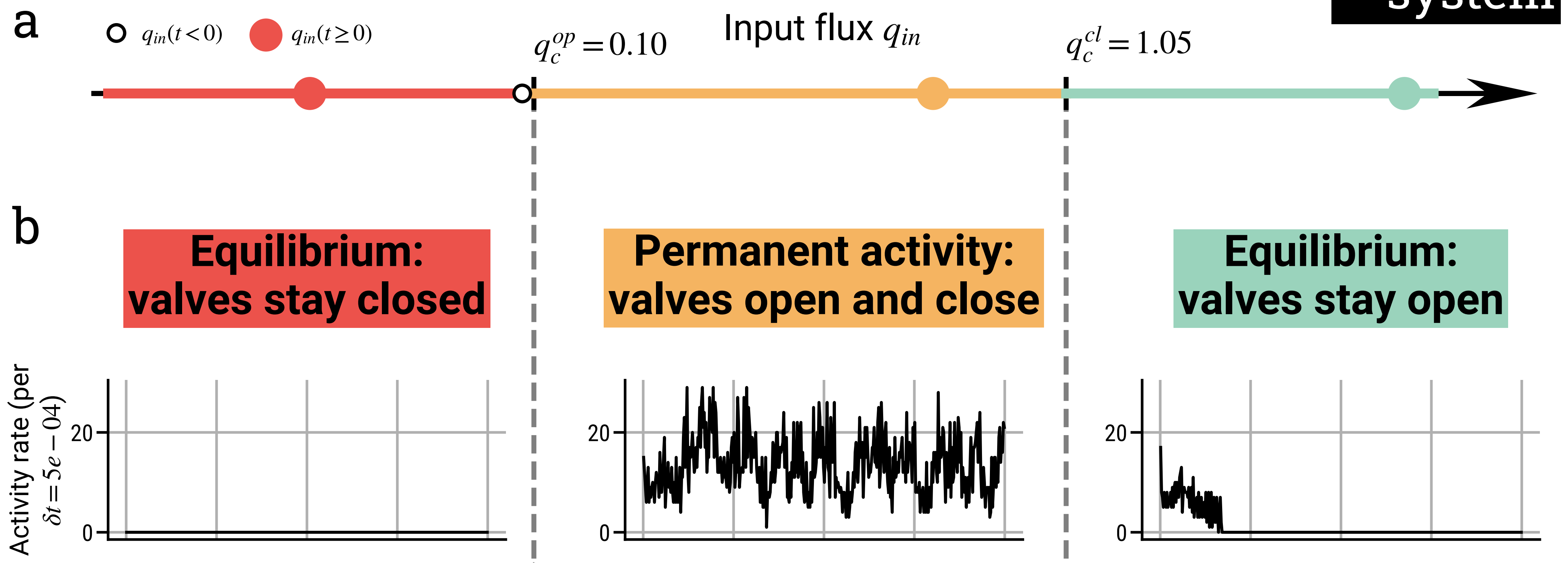
Under a **constant source** of fluid pressure,

the proposed fluid transport processes, **generate** and **sustain**

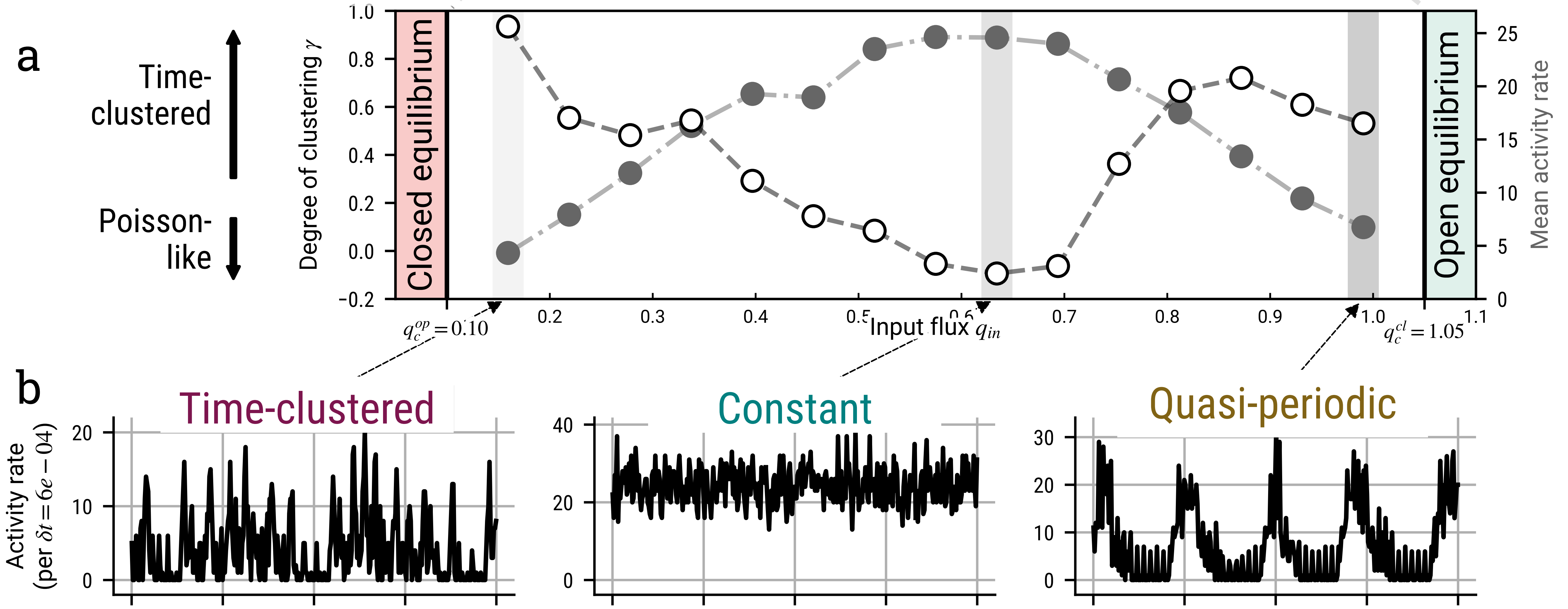
realistic **patterns of intermittence** and **migration** of seismic activity

In a range of input flux q_{in}, **activity is permanent and intermittent**

29 valves system



within this range, q_{in} **governs the activity style**: **time-clustered**, **constant**, or **quasi-periodic**



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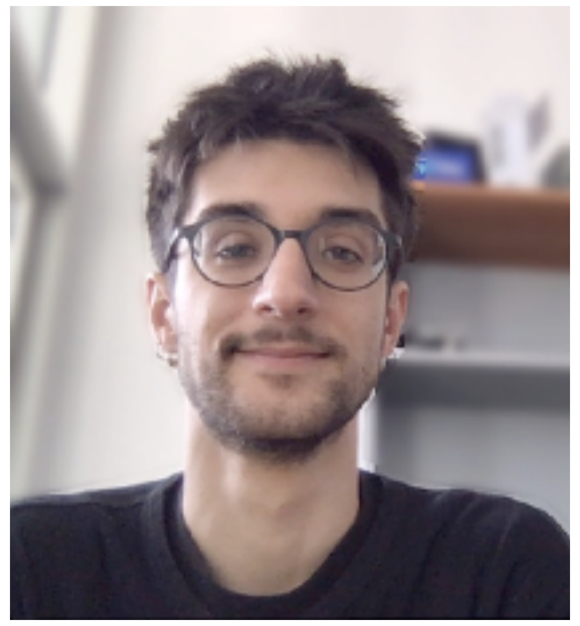

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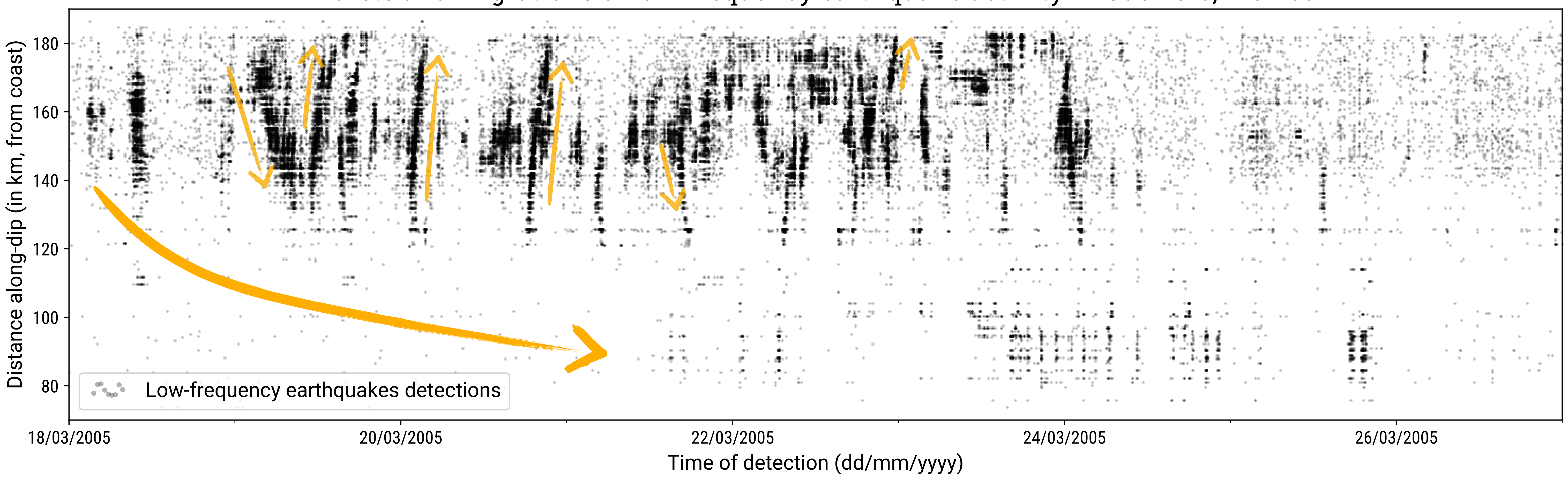
In this model,

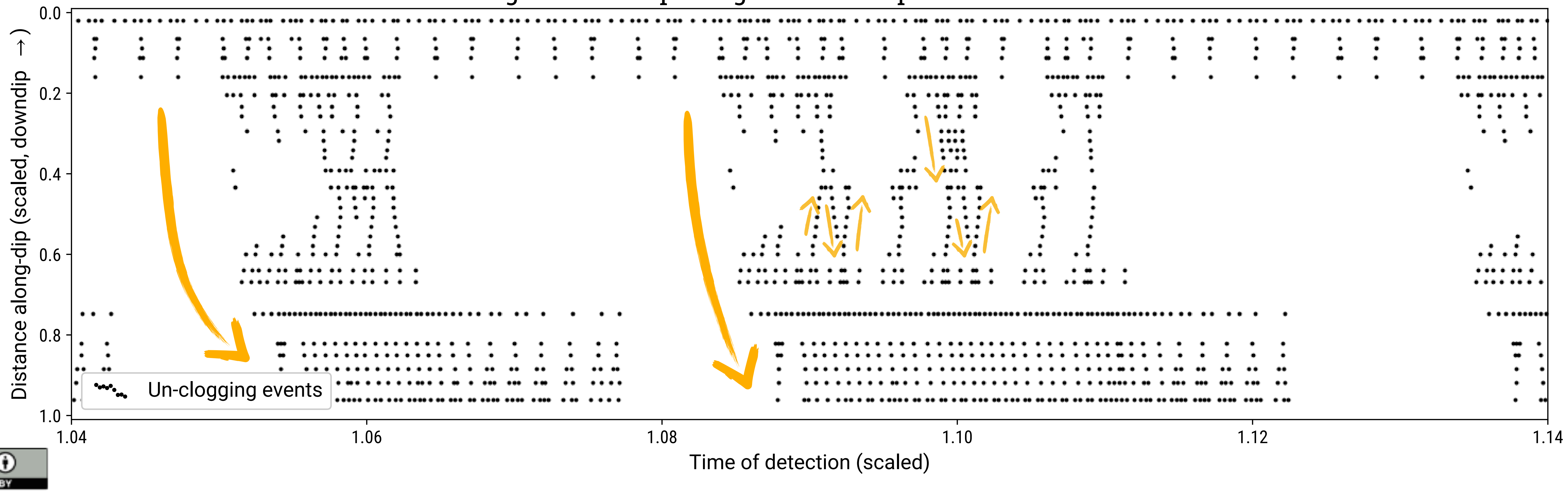
the **intermittence** and **migrations** of tremor activity in subduction faults

Bursts and migrations of low-frequency earthquake activity in Guerrero, Mexico



emerges from **cascades** and **interactions** of **un-clogging and clogging in permeable channels**

Bursts and migrations of opening events in a permeable channel with valves



EGU General Assembly 2021

Clogging and un-clogging of the subduction plumbing system may generate tremor-like patterns

Gaspard Farge, Claude Jaupart, Nikolaï Shapiro

Click where *[+]* for more!

Background and motivation [+]

Variations of **fluid pressure** within subduction fault zones can **fuel fault-slip** events [1] and trigger the largest earthquakes [2].

In active subduction zones, fluid flow can be tracked through the activity of tremor and low-frequency earthquake (LFE) it seems to trigger.

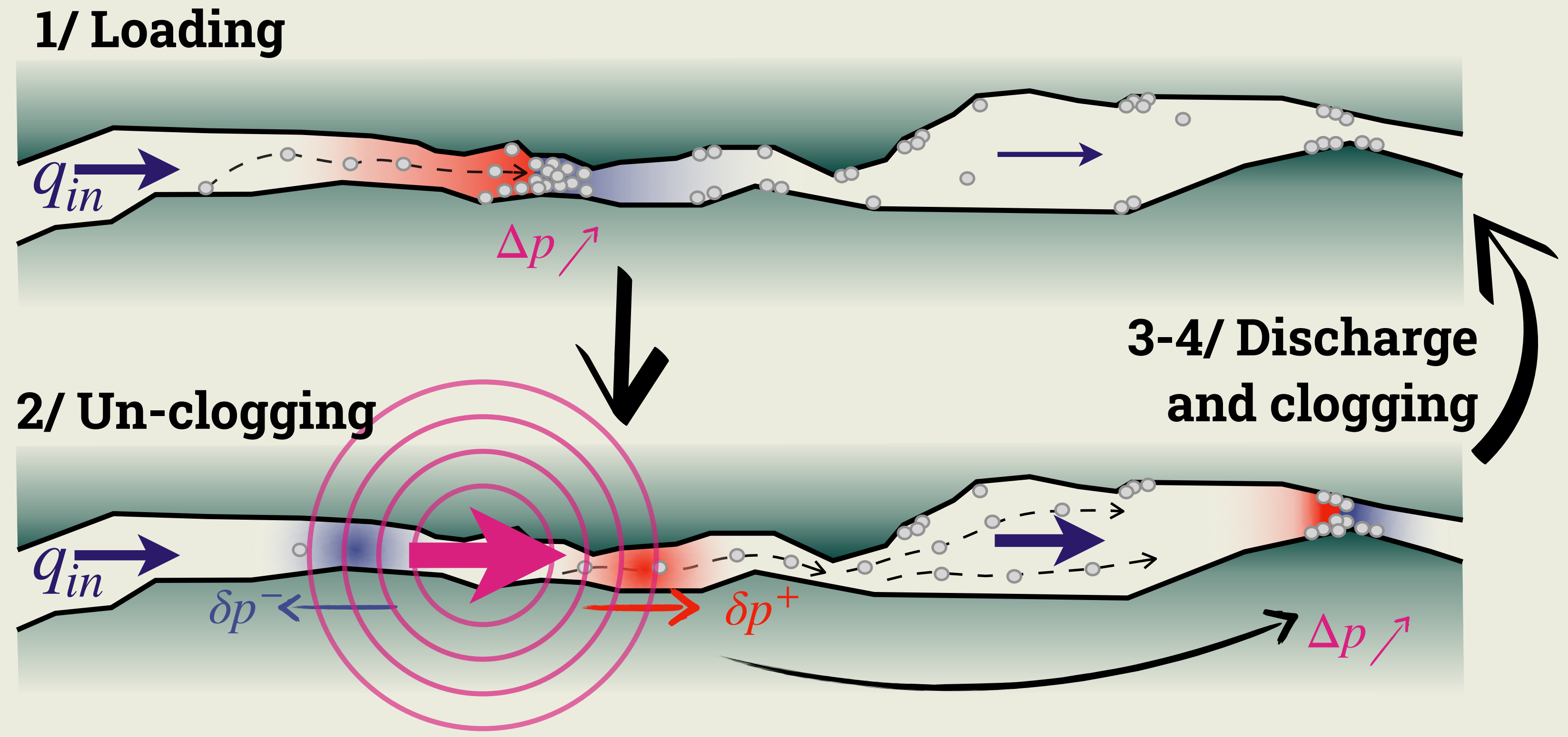
We build a model to **explore how fluid transport in a fault shapes its seismicity**.

Model design [+]

We solve for fluid pressure diffusion in a 1D, **dynamically permeable channel along-dip**.

Locally, several **permeability valves** open/close in response to the pressure gradient.

The strong, rapid pressure transient at **opening can act as** (or trigger) **a seismic source**.



Results [+]

As seismic sources **interact through rapid fluid pressure transients**, events occur in cascades. Activity is **clustered** and **migrates** in the channel. [+]

The input flux in the fault zone controls if activity occurs, and shapes its intermittence. [+]

Conclusions

This simple conceptual model shows how variable and realistic patterns of seismicity can be driven by dynamic permeability in a constantly fed fluid transport system.

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