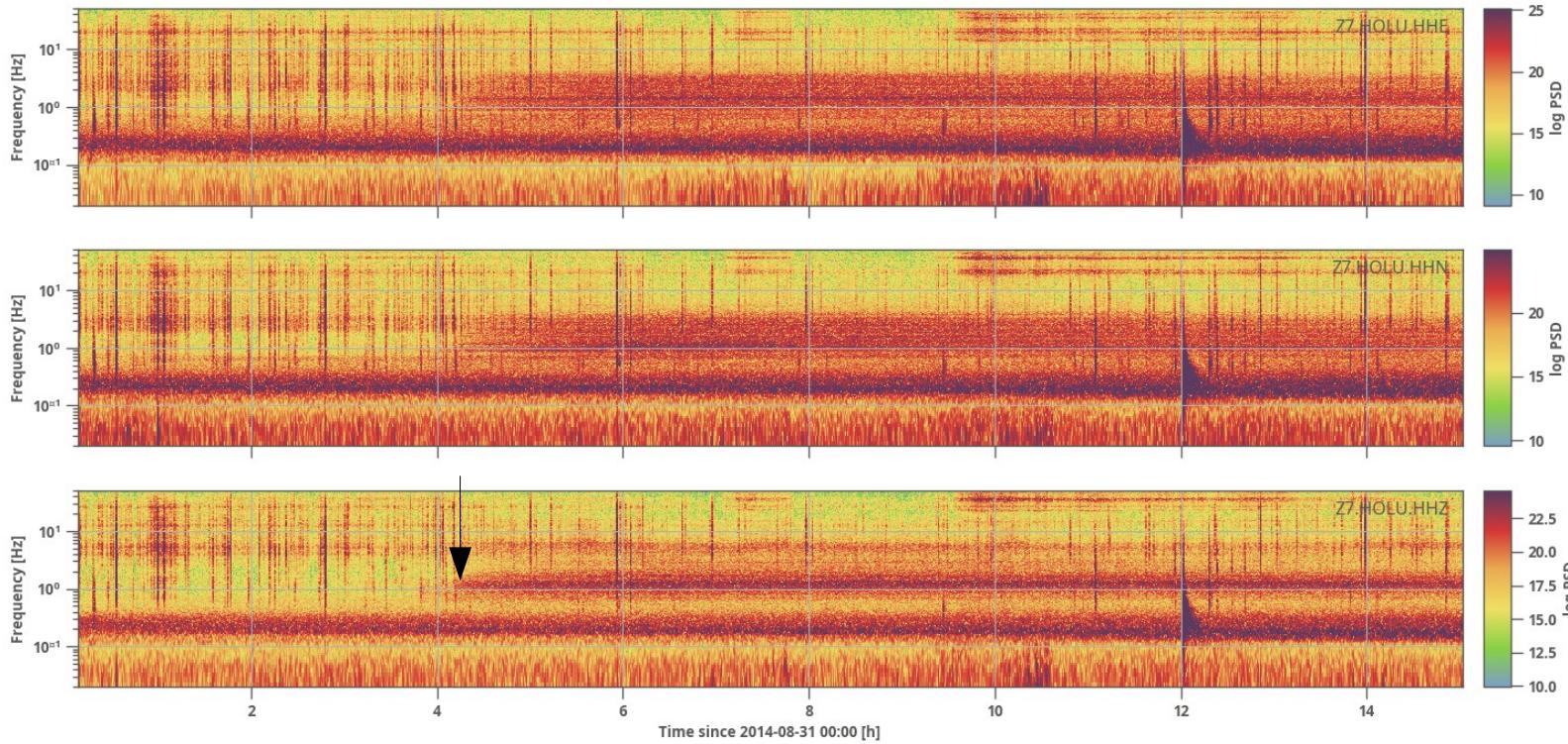


Analyzing the tremor of the Holuhraun eruption 2014-2015 using tremor modelling

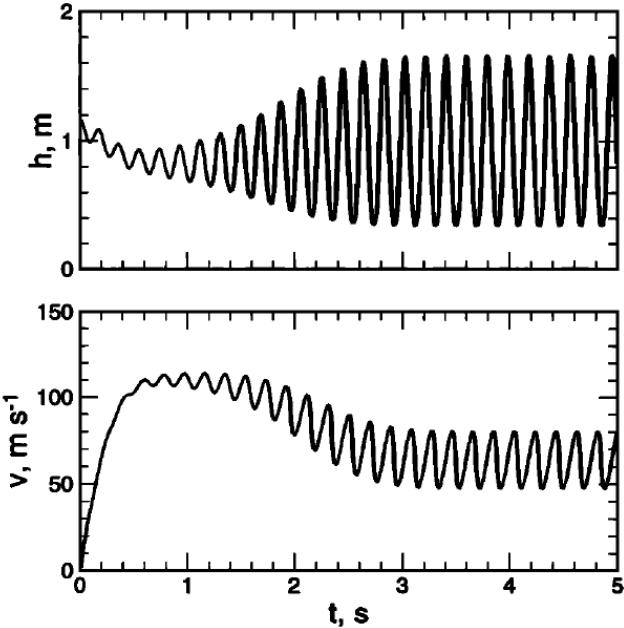
Tremor, 31st of August, 2014



Tremor
onset at
4am,
1Hz

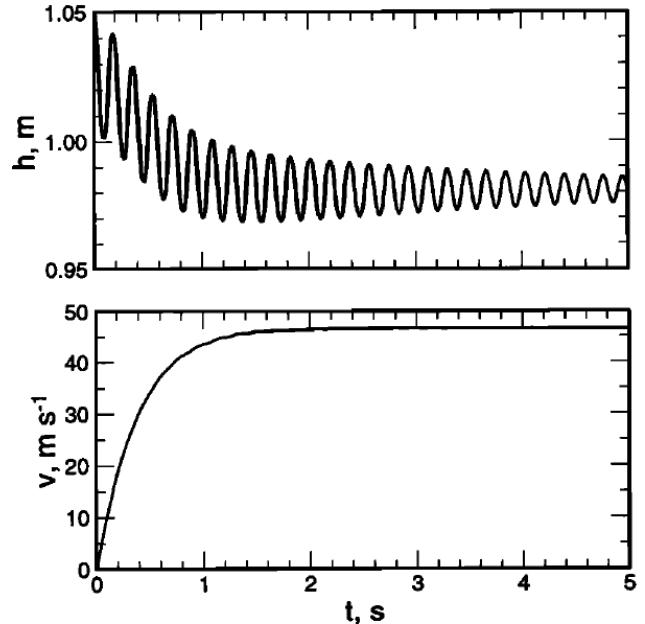
Heimann et al,(2017): Pyrocko - An open-source seismology toolbox and library. V. 0.3. GFZ Data Services. <https://doi.org/10.5880/GFZ.2.1.2017.001>

Original solutions of B. Julian (1994)



Left: Tremor
emerging

Right: Tremor starts
and approaches
steady solution



Images taken from: B. Julian (1994) – Volcanic tremor: Nonlinear excitation by fluid flow

Parameter comparison

B. Julian (1994) parameters
(for emerging tremor)

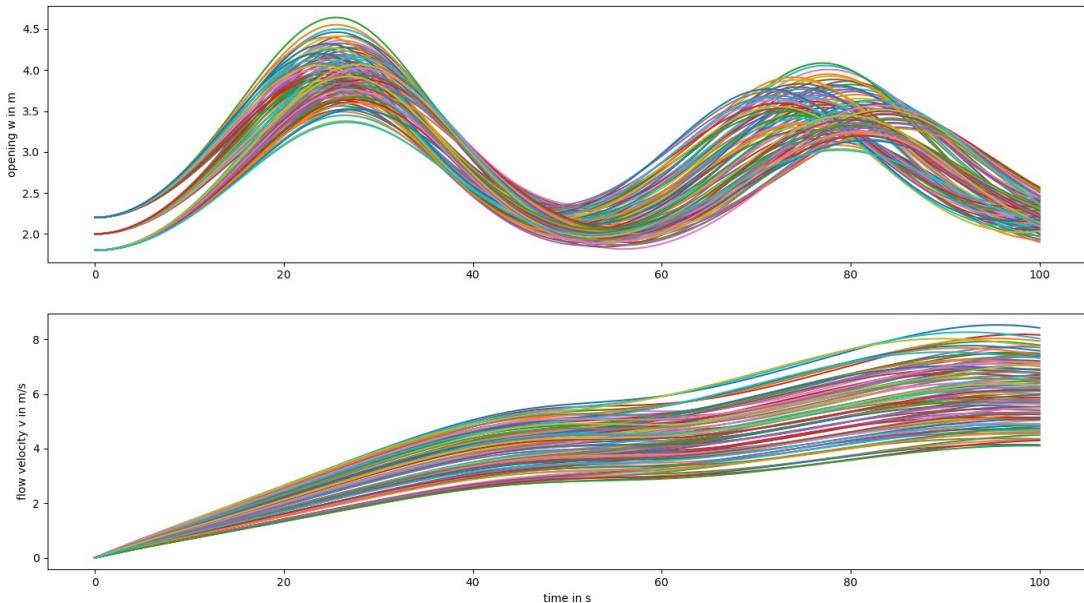
```
L = 10.0,          # (vertical) Length in m
w = 1.0,          # width in m
d = 2500.0,        # density in kg/m³
nu = 500.0,        # viscosity in Pa*s
pin = 10.0*1e6,   # incoming pressure in Pa
pout = 1.0*1e5,   # outgoing pressure in Pa
k = 600.0 * 1e6,  # stiffness in Pa
A= 0              # geometry factor
```

Holuhraun parameters
(from field measurements/literature)

```
L = 400.0,         # (vertical) Length in m
w = 2.0,           # width in m
d = 2750.0,        # density in kg/m³
nu = 22.0,          # viscosity in Pa*s
pin = 0.20e6,      # incoming pressure in Pa
pout = 0.10e6,     # outgoing pressure in Pa
k = 0.05 * 1e9,    # stiffness in Pa
A= 0               # geometry factor
```

Parameters differ in magnitudes! → Not necessary the same behaviour

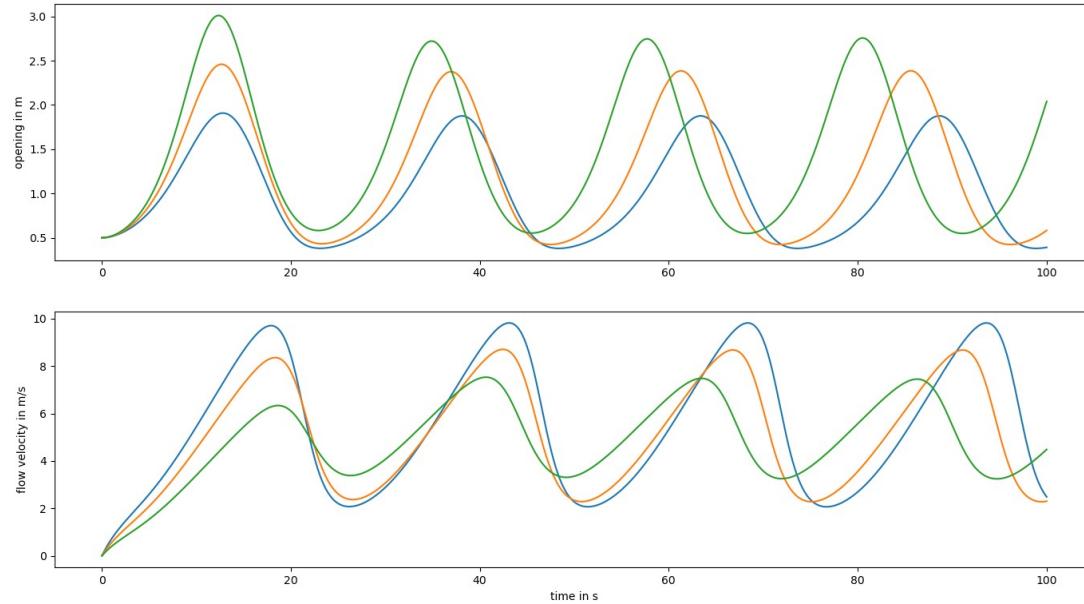
Tremor behaviour: Holuhraun parameters



Variation of input
parameters $\pm 10\%$

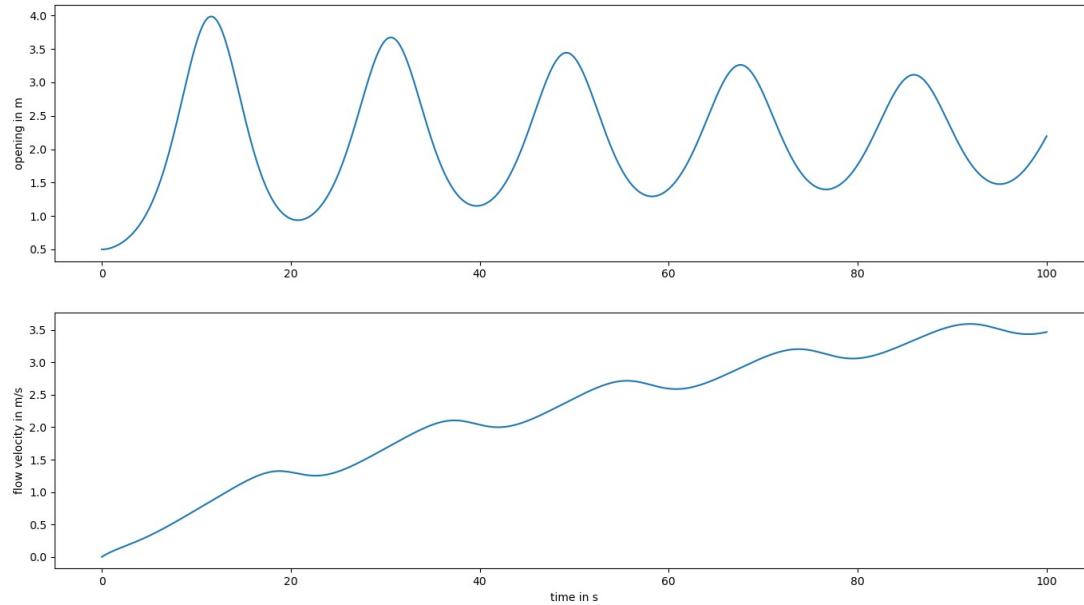
→ Still no real tremor!
→ Let's have a look at
possible behaviours

Tremor behaviour I



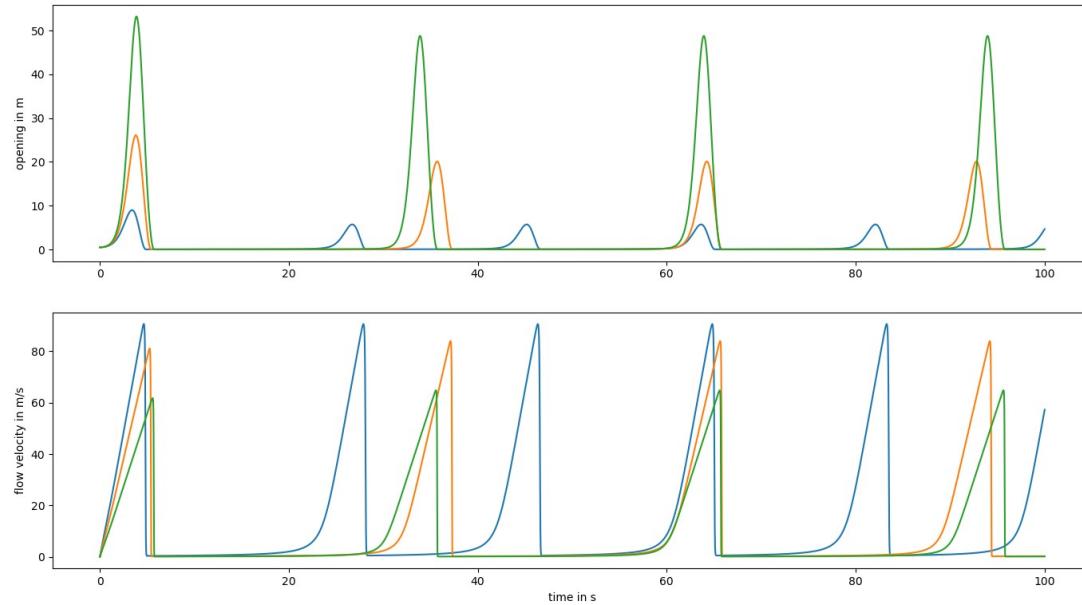
Harmonic behaviour,
Oscillations maybe a bit big,
frequency low (<0.1 Hz),
But realistic values for opening
width (w) and flow velocity (v)
 p_{in} : 0.2 MPa,
 $p_{out}/p_{in} \leq 0.5$
 $k=10\text{ MPa}$

Tremor behaviour II



Harmonic behaviour,
Approaching a steady state,
 $p_{in} : 0.2 \text{ MPa}$,
 $p_{out}/p_{in} = 0.9$
 $k=10\text{MPa}$
→ most similar to synthetic
solutions with field measurements

Tremor behaviour III



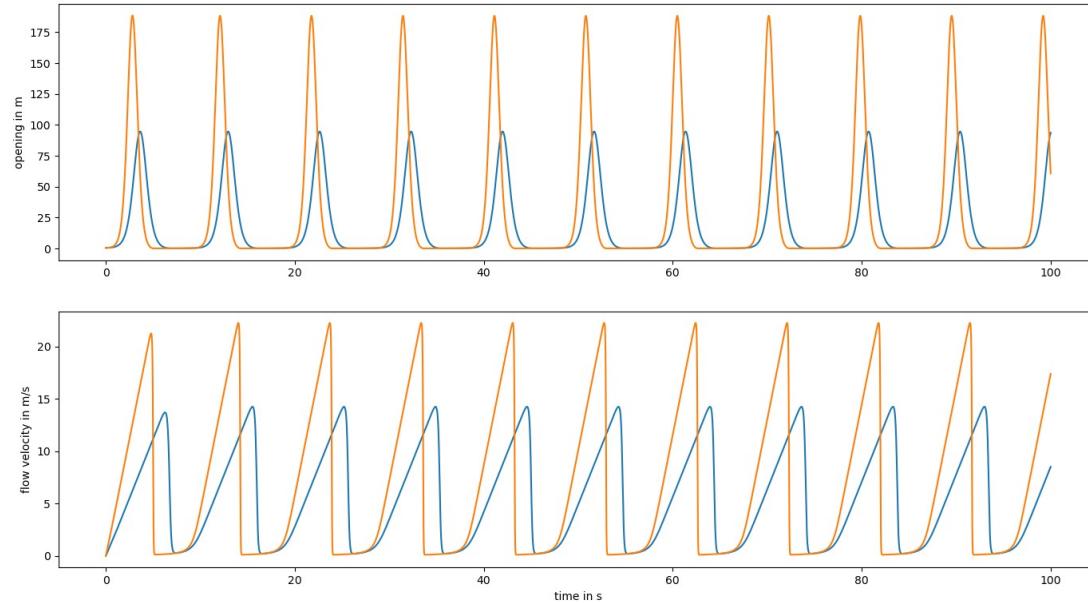
Periodic behaviour,
Unreasonable extremes (both
high and low) for w and v,

$$P_{in} = 5 \text{ MPa or } 10 \text{ MPa}$$

$$p_{out}/p_{in} \leq 0.5$$

$$k=10 \text{ MPa}$$

Tremor behaviour IV



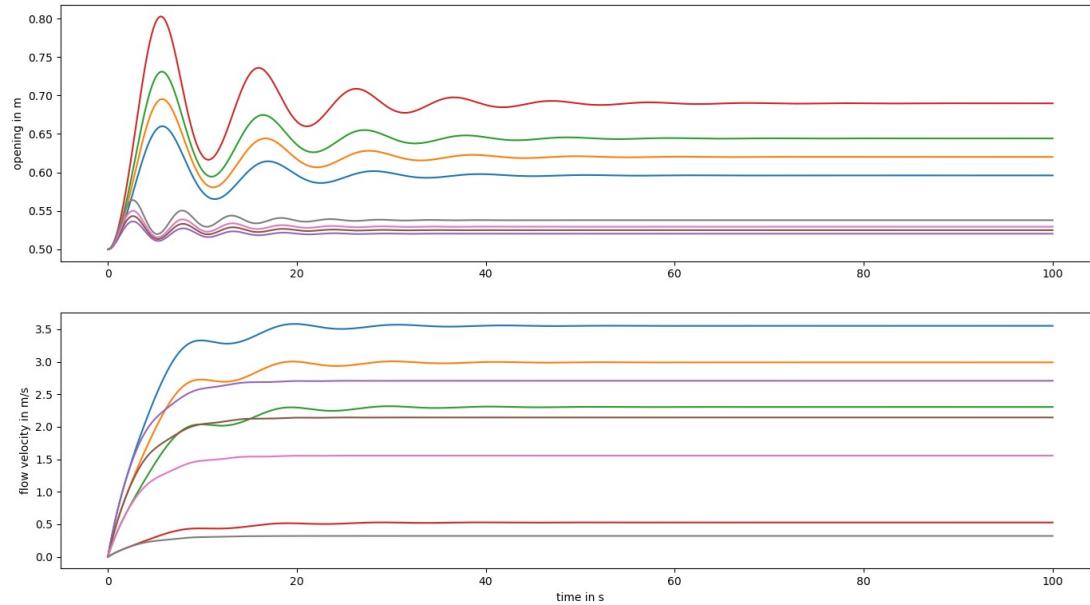
Periodic behaviour,
Unreasonable extremes (both
high and low) for v ad w,

$P_{in} = 5 \text{ MPa or } 10 \text{ MPa}$

$p_{out}/p_{in} = 0.9$

$k=10 \text{ MPa}$

Tremor behaviour V



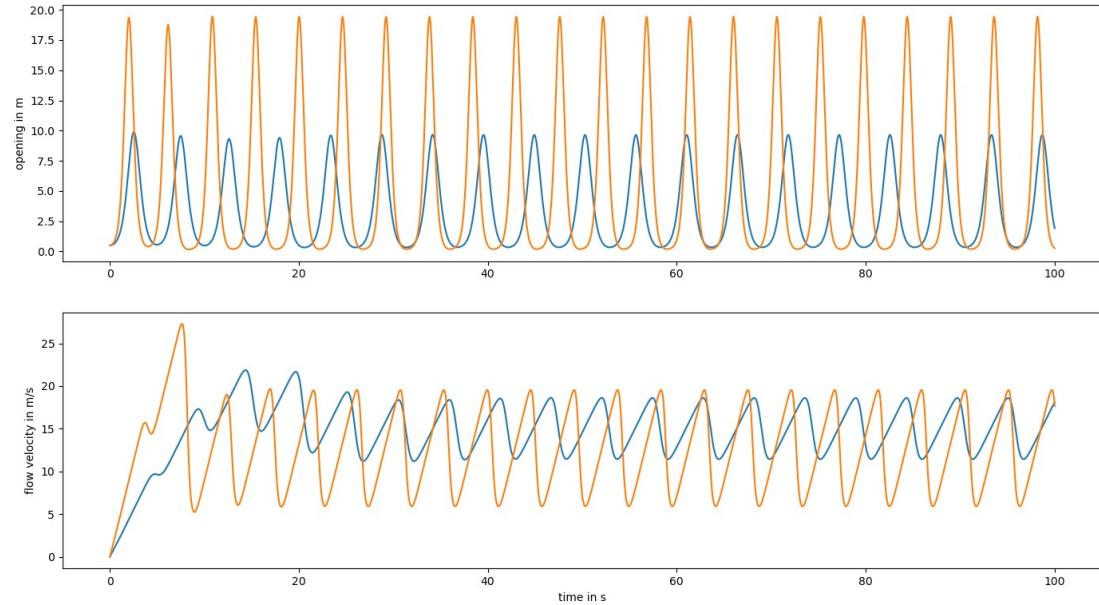
Fast approaching of a
steady state, few
oscillations.

$P_{in} = 5\text{ MPa}$ or 10 MPa

$p_{out}/p_{in} = 0.9$

$k=100\text{ MPa}$

Tremor behaviour VI



Periodic behaviour,

„Big“ openings $\geq 10\text{m}$,

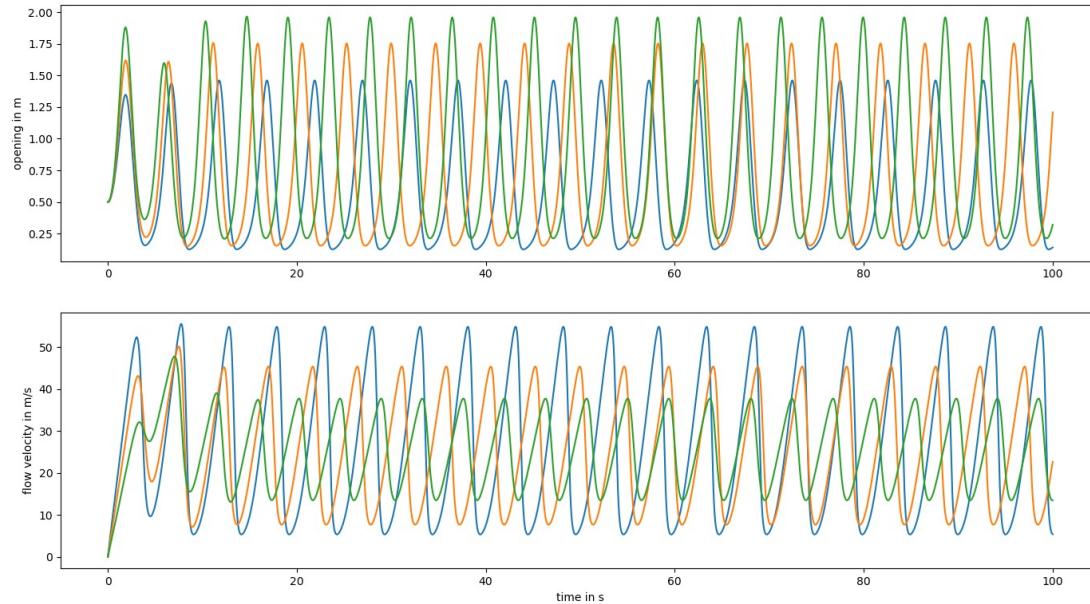
Then back to almost 0m

$$P_{in} = 50\text{ MPa}$$

$$p_{out}/p_{in} = 0.9$$

$$k=100\text{ MPa}$$

Tremor behaviour VIa



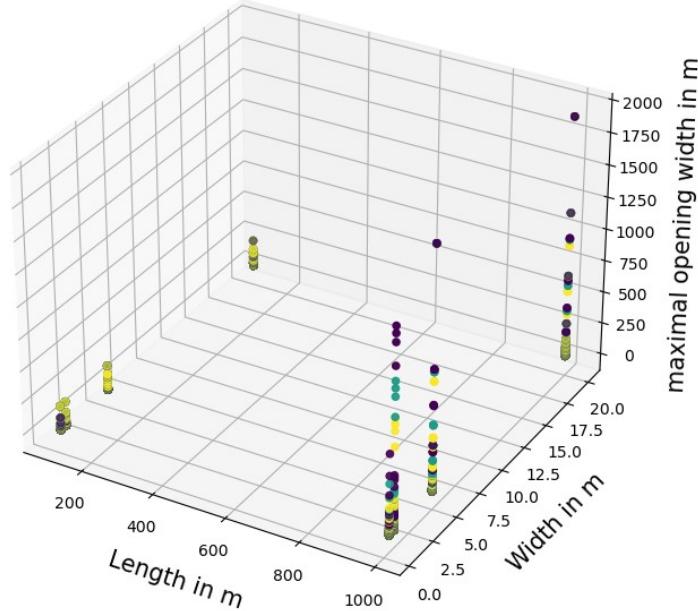
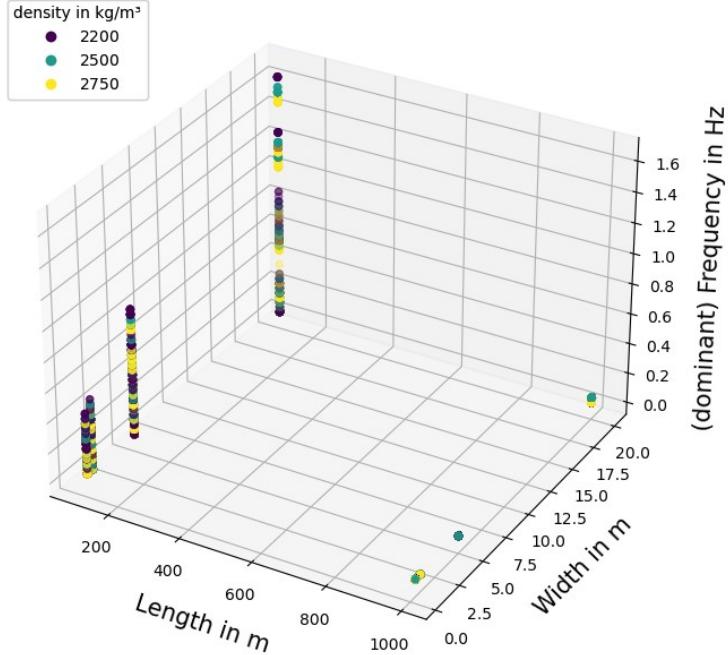
Periodic behaviour,
Max. opening width reasonable but
comes to almost closure;
Flow velocity peaks quite high (but
within possible ranges)

$$P_{in} = 50 \text{ MPa}$$

$$p_{out}/p_{in} \leq 0.5$$

$$k=500 \text{ MPa}$$

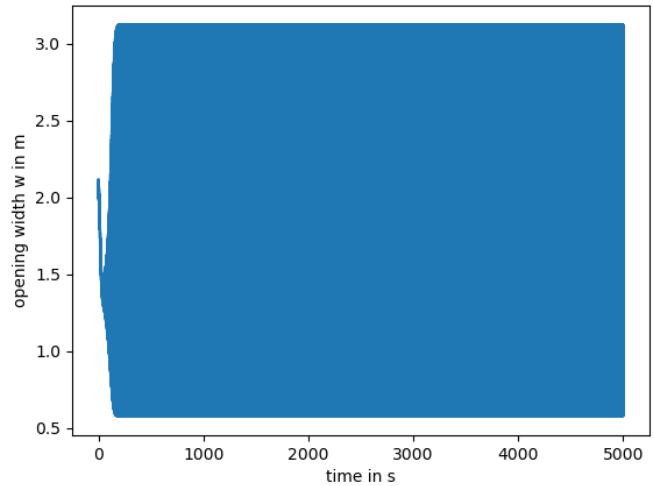
Broad grid search



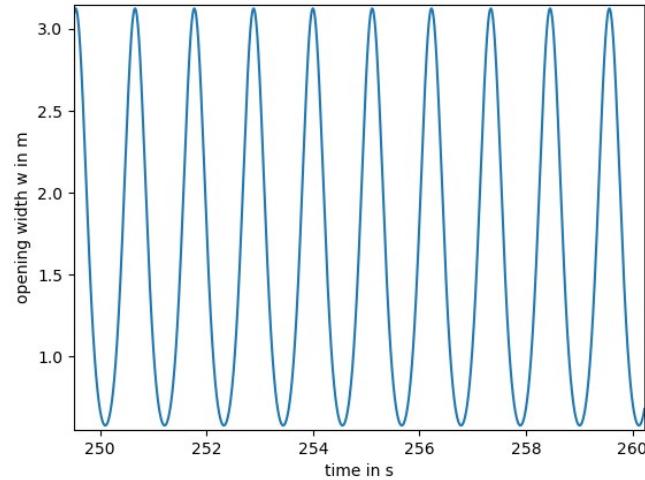
Frequency depends on many different parameters
→ shorter & wider conduits favor higher frequencies,
so does lower pressure

Assuming a really short conduit $L = 20\text{m}$
(And Holuhraun field measured parameters)

Tremor emerges, stays.



Harmonic oscillations of the dike walls



With a really short conduit* of 20m, the tremor emerges for 100s and then stays with a frequency at around 0.9 Hz.

*Dike propagation depth was at 4-6km depth.

Conclusions

The Julian model is sensitive to parameter changes.

With the initial given parameters from field measurements, the tremor cannot easily be explained; yet there are simulated behaviours that approach the observed tremor's spectrum well.

The biggest variability in pressure and vertical conduit length could solve the problem, but fine tuning is still needed while avoiding pitfalls of explaining observed frequencies with absurdly high/low flow velocities/opening widths.

How you can help

- Send code for other models to tdietric@uni-potsdam.de
- Suggestions on how to grid search/ classify behaviours
- Update parameter estimations

Thank you!

