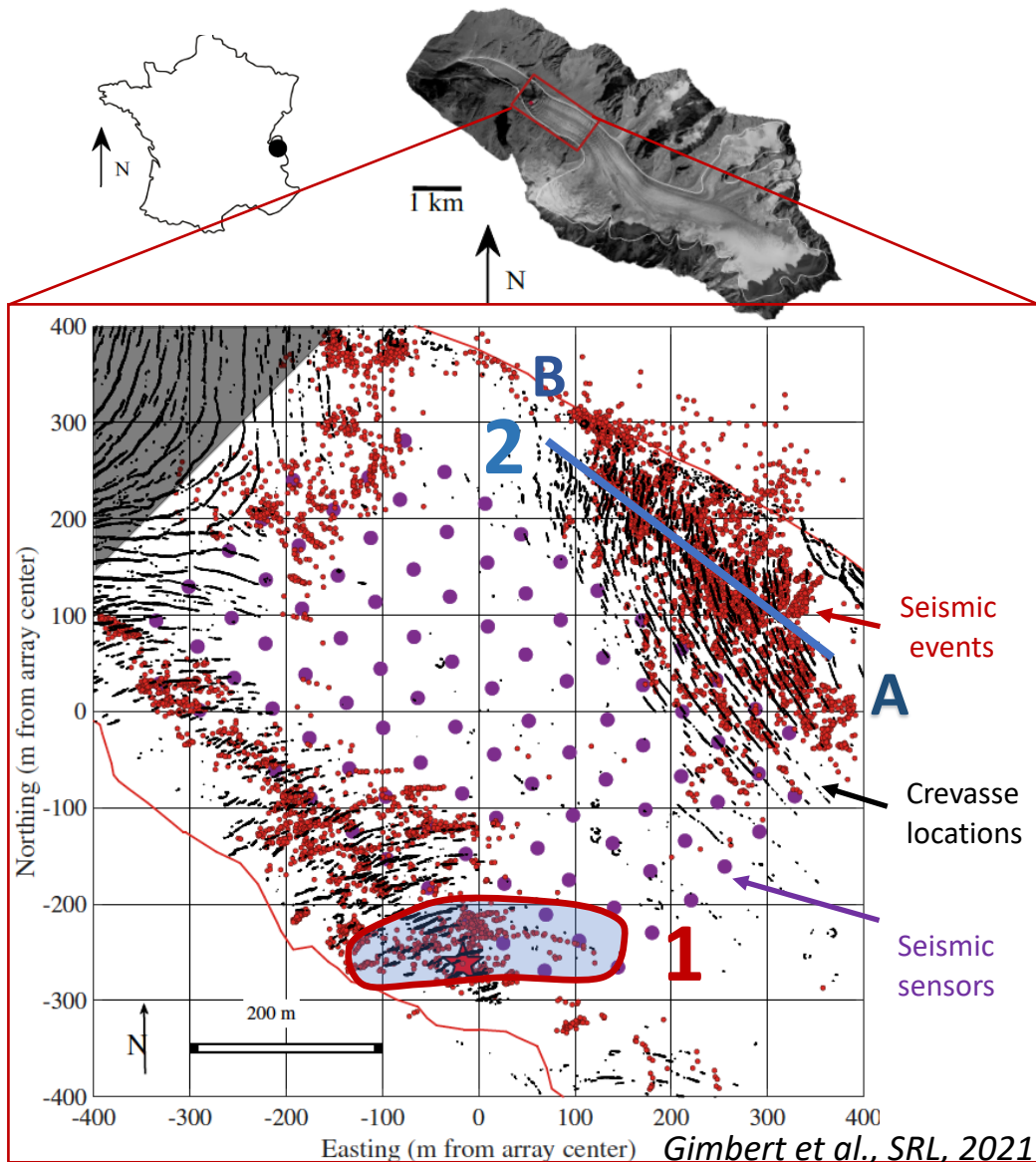
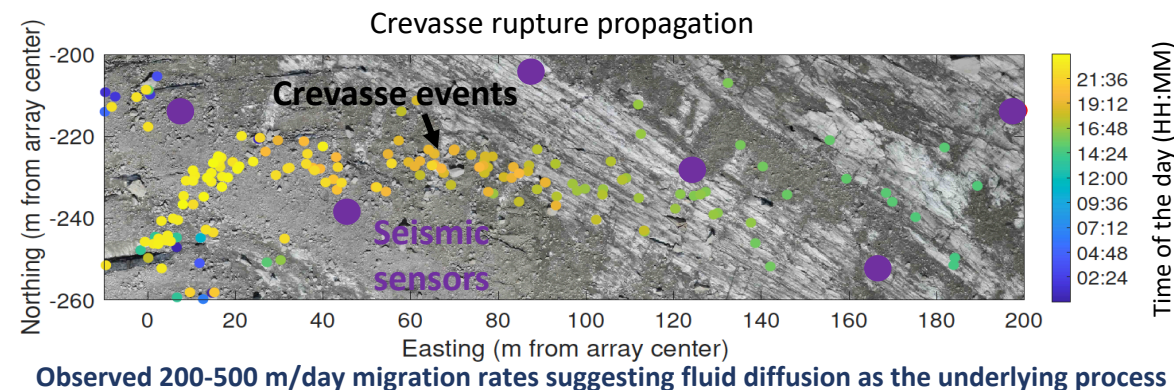


A dense seismic array on the Argentière Glacier, French Alps

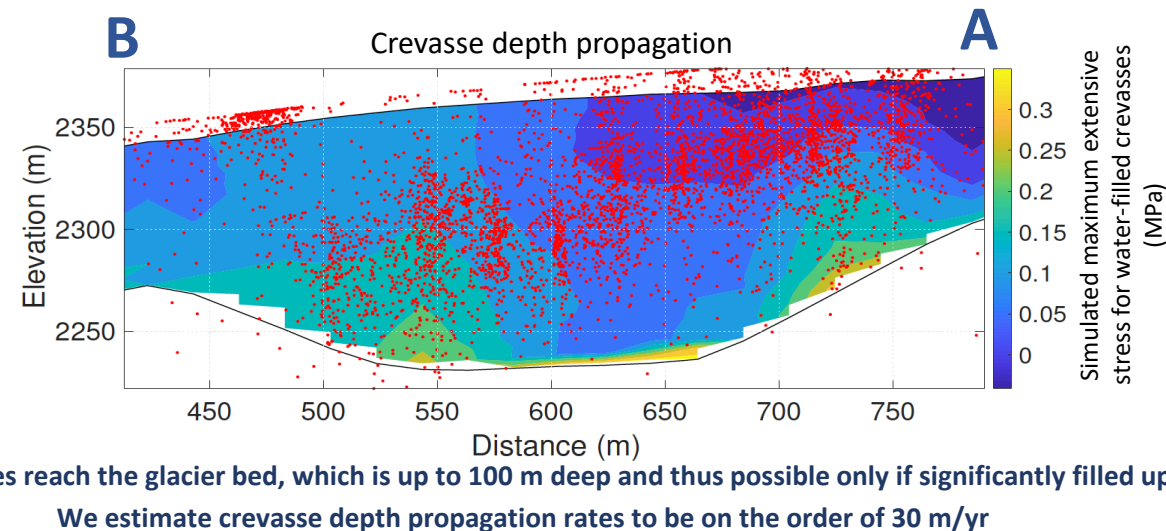


1

How do crevasses grow ?
What are the controlling factors (e.g. water, stress state) ?



2



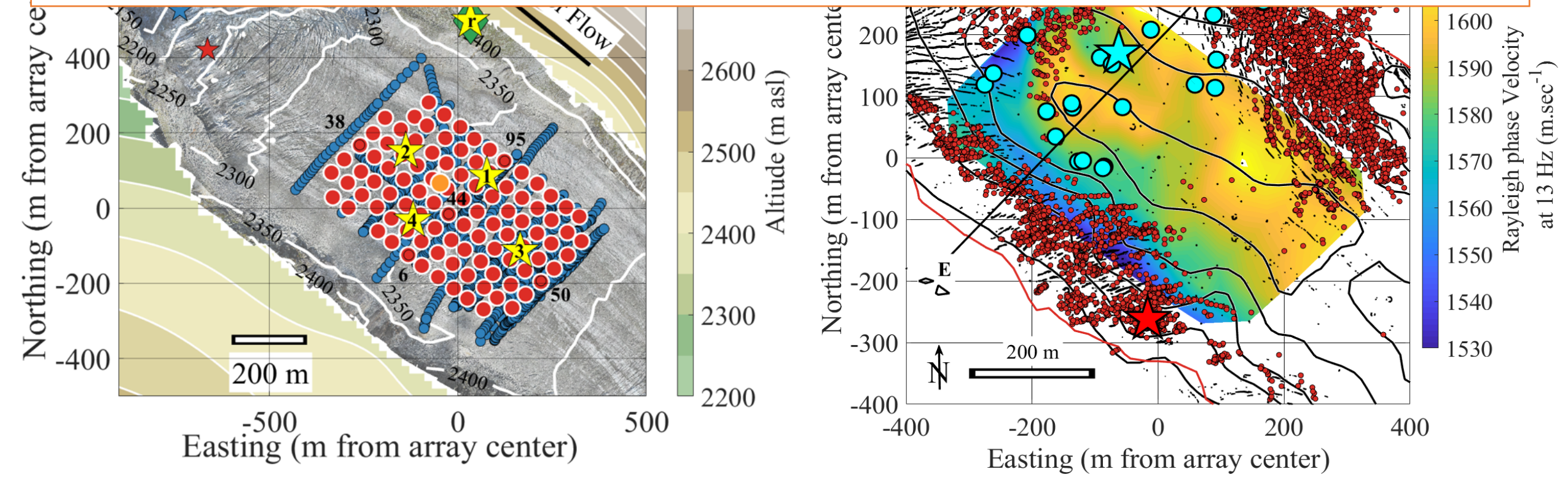
Take away message: Water plays a fundamental role in shaping the geometry and setting the temporal dynamics of crevasses

The RESOLVE project: a multi-physics experiment with a temporary dense seismic array on the Argentière Glacier, French Alps

Gimbert, F.¹, U. Nanni¹, P. Roux², A. Helmstetter², S. Garambois², A. Lecointre², A. Walpersdorf², B. Jourdain¹, M. Langlais², O. Laarman¹, F. Lindner³, A. Sergeant⁴, C. Vincent¹, F. Walter³, *Seismological Research Letters* (2021) 92 (2A): 1185–1201

How do crevasses grow ?

What are the controlling factors (e.g. water, stress state) ?



The RESOLVE project: a multi-physics experiment with a temporary dense seismic array on the Argentière Glacier, French Alps

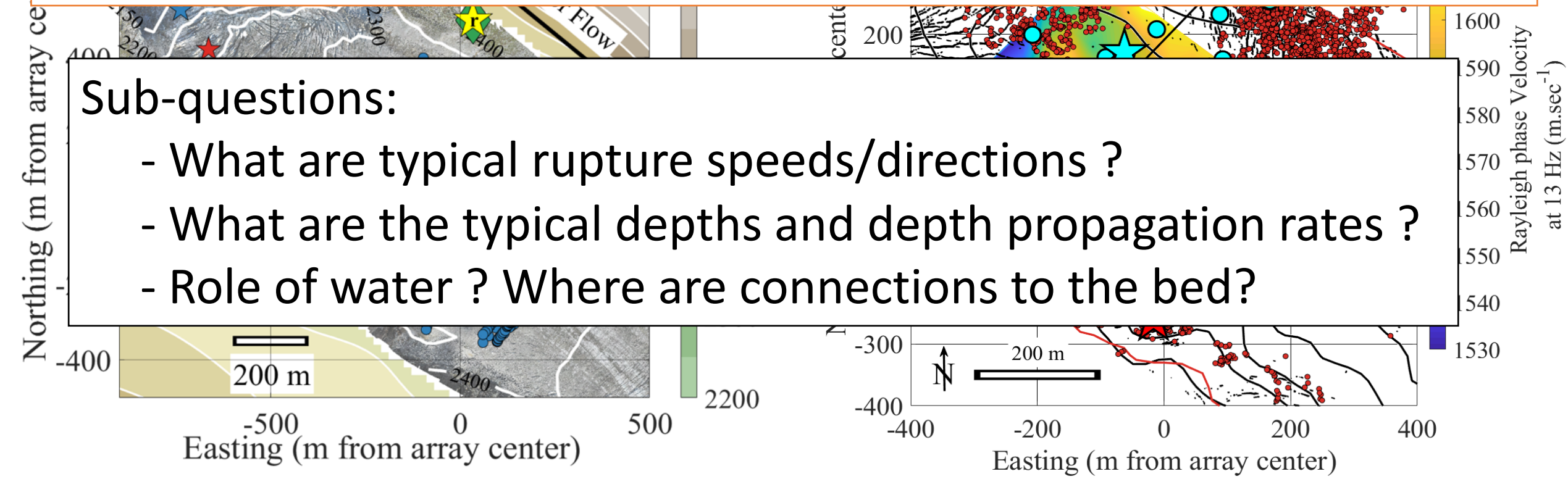
Gimbert, F.¹, U. Nanni¹, P. Roux², A. Helmstetter², S. Garambois², A. Lecointre², A. Walpersdorf², B. Jourdain¹, M. Langlais², O. Laarman¹, F. Lindner³, A. Sergeant⁴, C. Vincent¹, F. Walter³, *under minor revision in Geophysical Research Letters (2021) 92 (2A) 1185–1201*

How do crevasses grow ?

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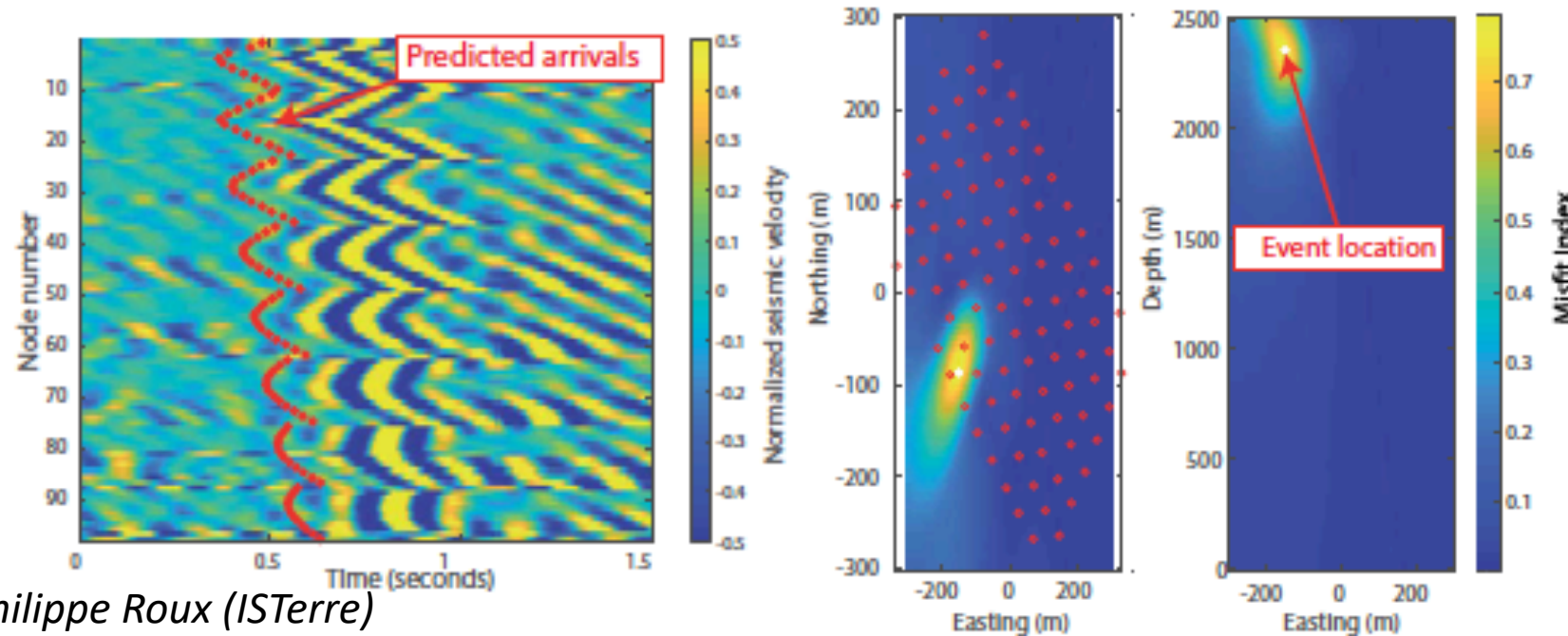
Sub-questions:

- What are typical rupture speeds/directions ?
- What are the typical depths and depth propagation rates ?
- Role of water ? Where are connections to the bed?

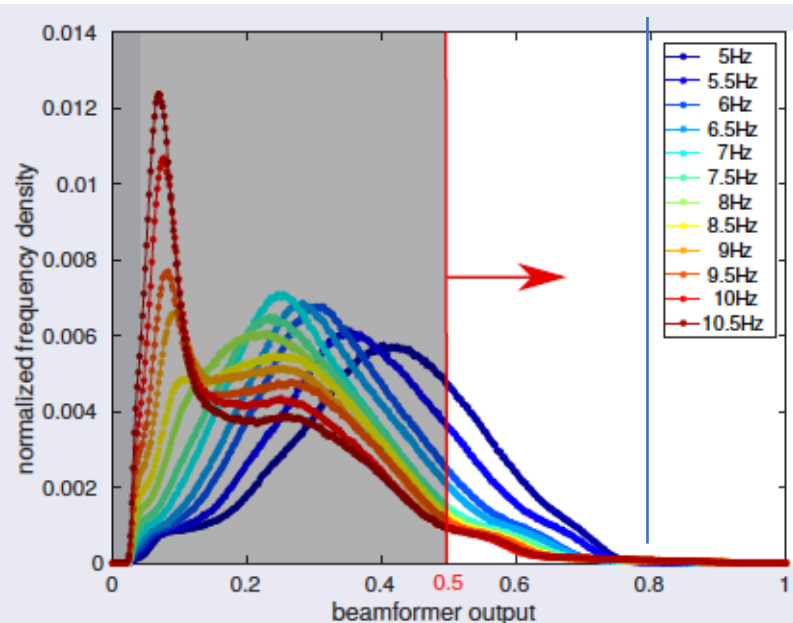


Systematic events detection using Matched-Field-Processing

- 1 → Consider 0.5 seconds-long time windows
- 2 → Assume a punctual source exists over that time window
- 3 → Invert event location (x,y,z) and phase velocity based on phase delay minimization from beamforming analysis
- 4 → Consider as « true » seismic sources that are associated with a beamformer value exceeding a certain threshold



Code developed by Albanne Lecointre and Philippe Roux (ISTerre)



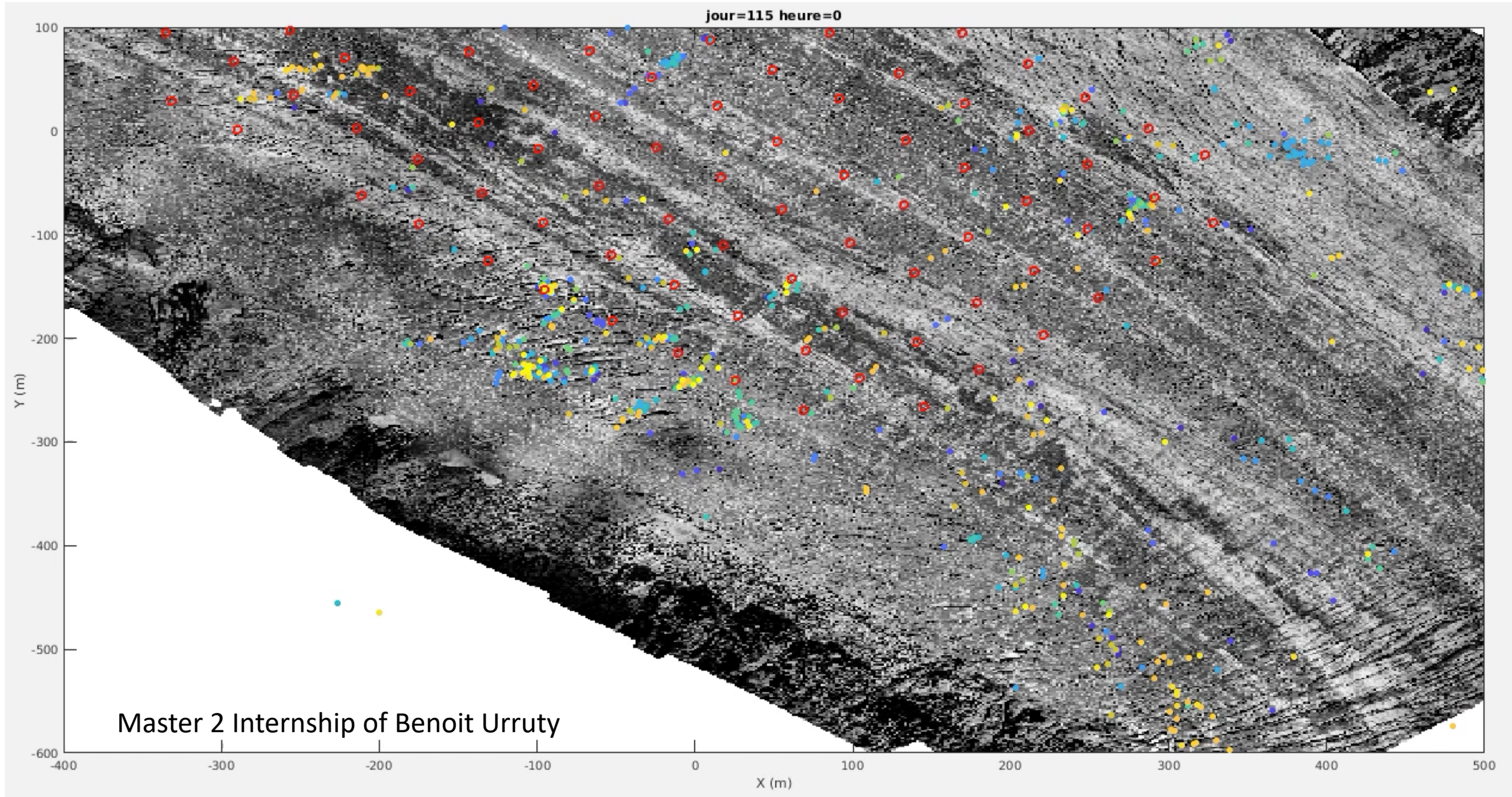
2D investigation

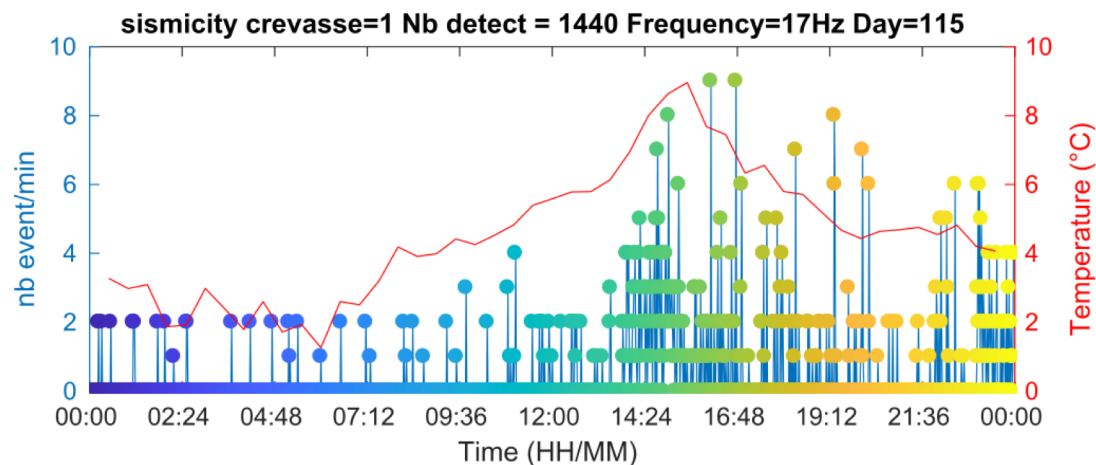
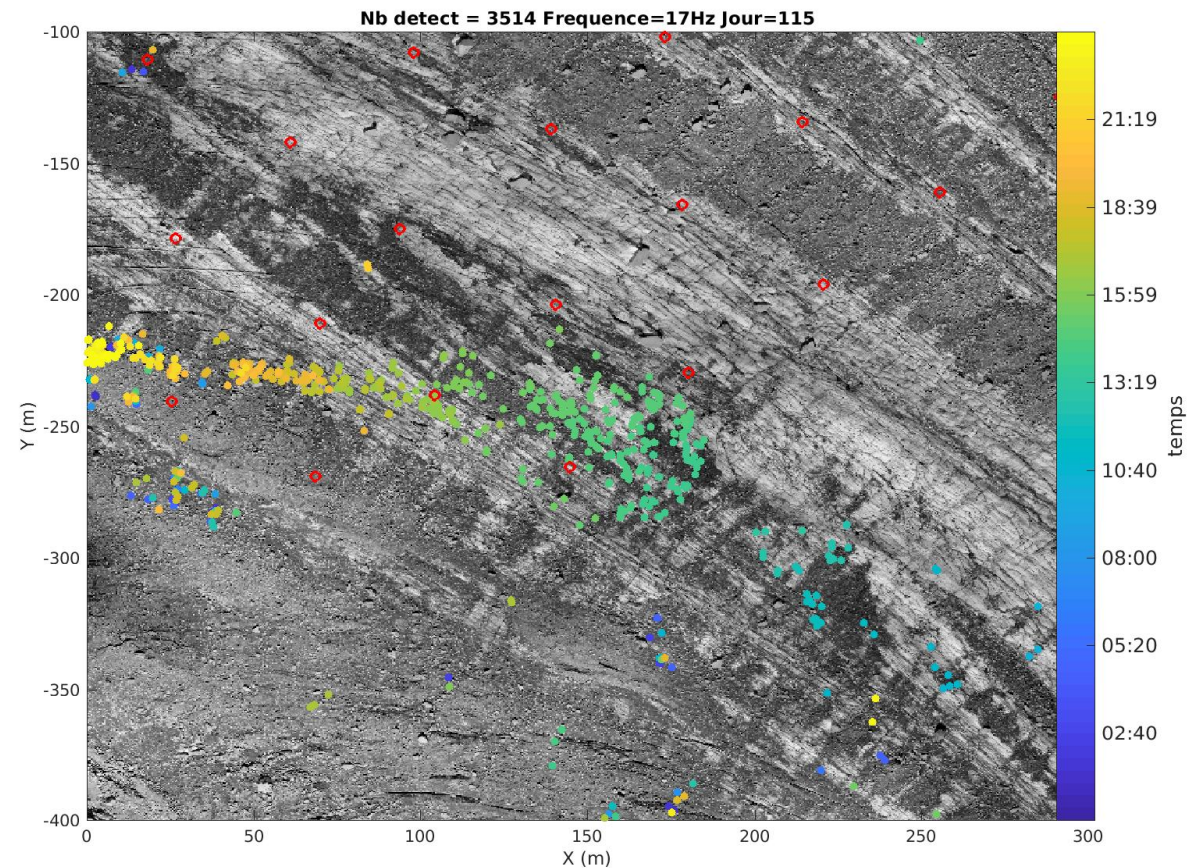
Beam Output >0.5 : many events but questionable event depth resolution

3D investigation

Beam Output >0.8 : fewer events but more robust depth resolution

2D investigation: rupture speeds (SEE SEPARATE UPLOADED VIDEO)





2D investigation: rupture speeds

Average rupture speed : 200 – 500 m/day

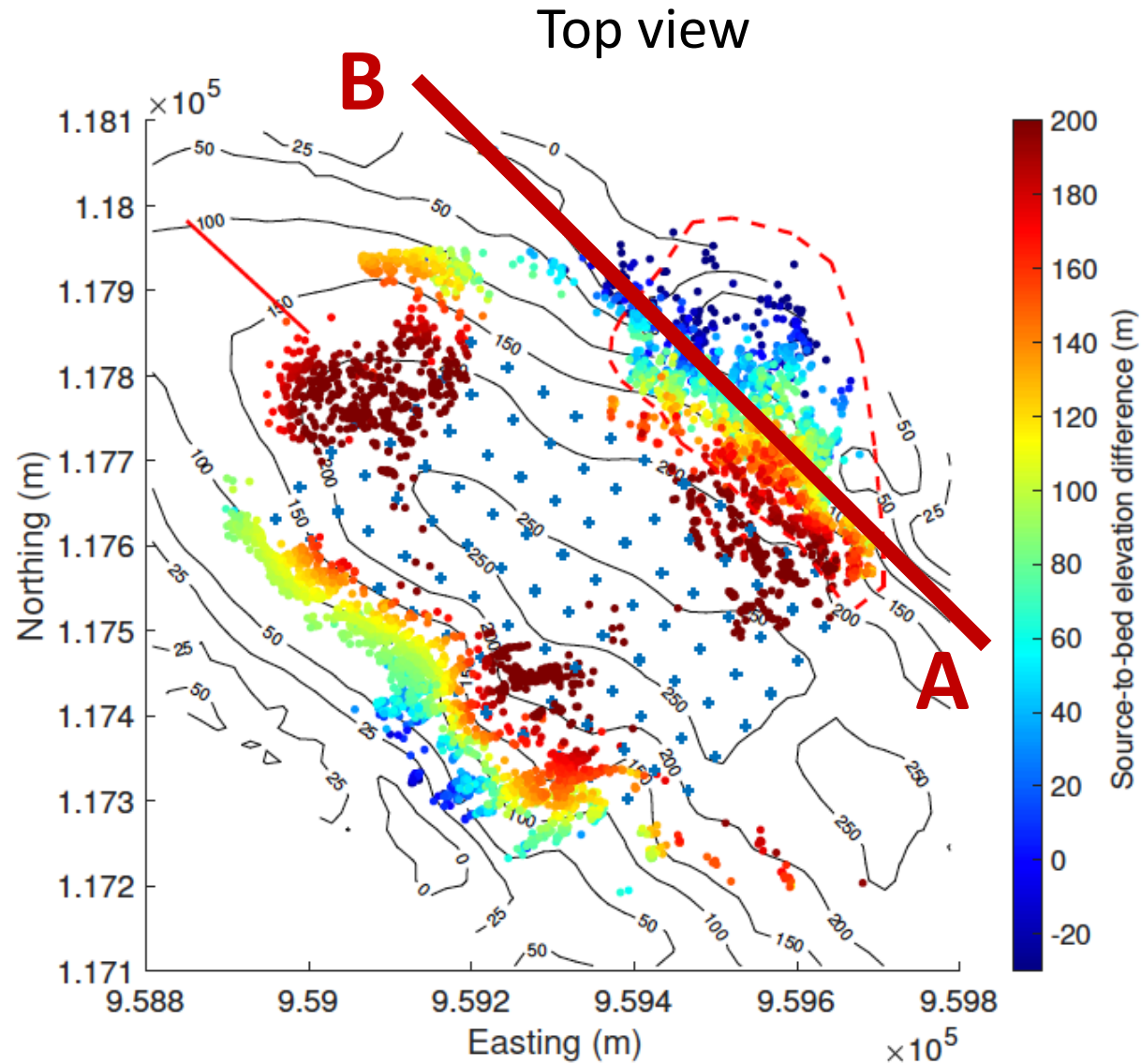
Largely slower than S-wave rupture speeds as observed for many earthquakes (c. 3000 m/s) but largely faster than ice velocities (c. 80 m/yr)

On the order of earthquake swarms migration velocities in subduction zones (e.g. in the Corinth gulf), which velocities have been suggested to be set by fluid diffusion velocities (*DeBarros et al., 2020*).

Potential dependency of seismicity rates and rupture speeds on air temperature

Likely an indirect link. It could rather be due to enhanced melt water input, consistent with the interpretation that water plays a role.

3D investigation: crevasses depths

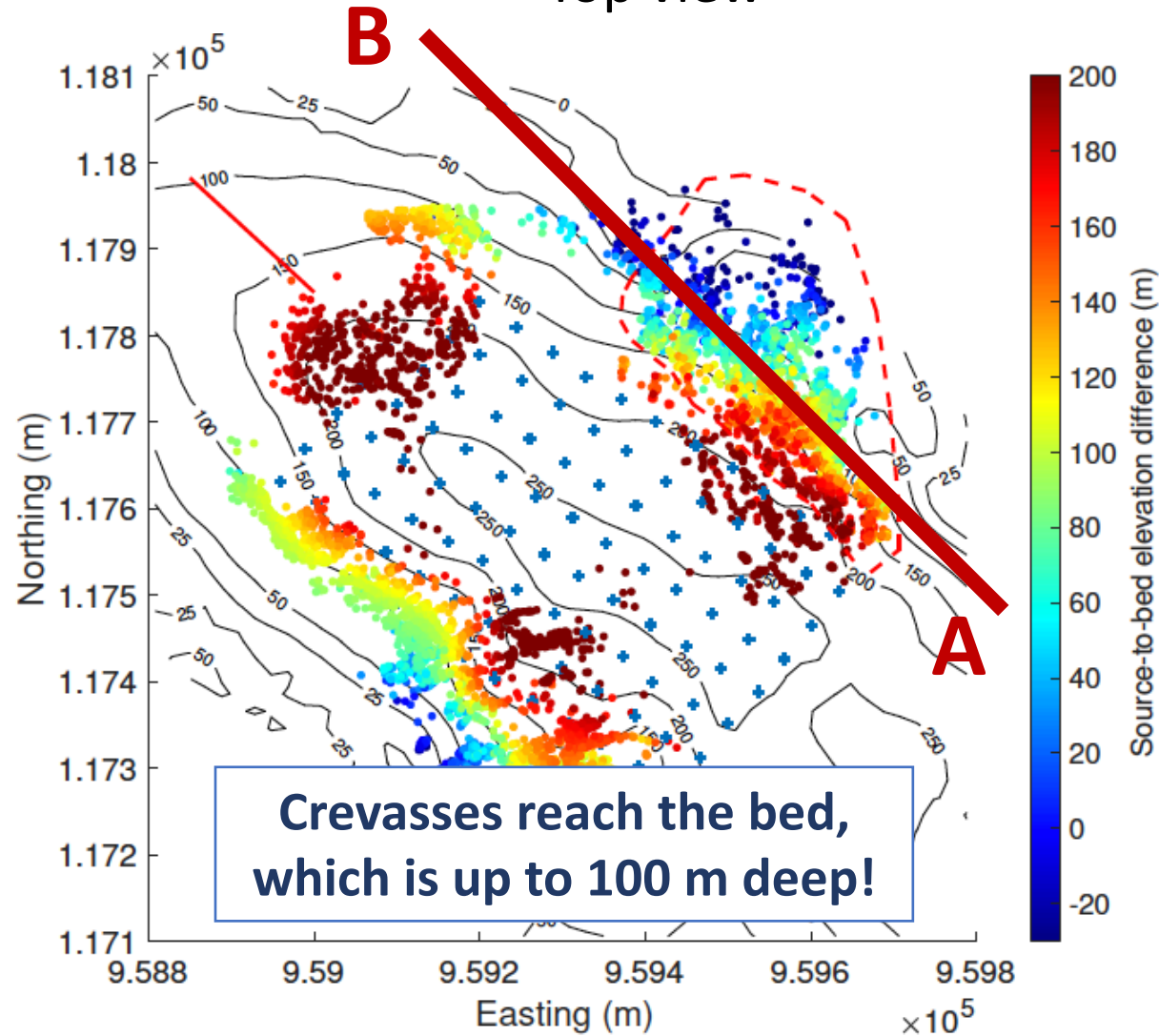


Crevasses reach the bed, which is up to 100 m deep at their locations!

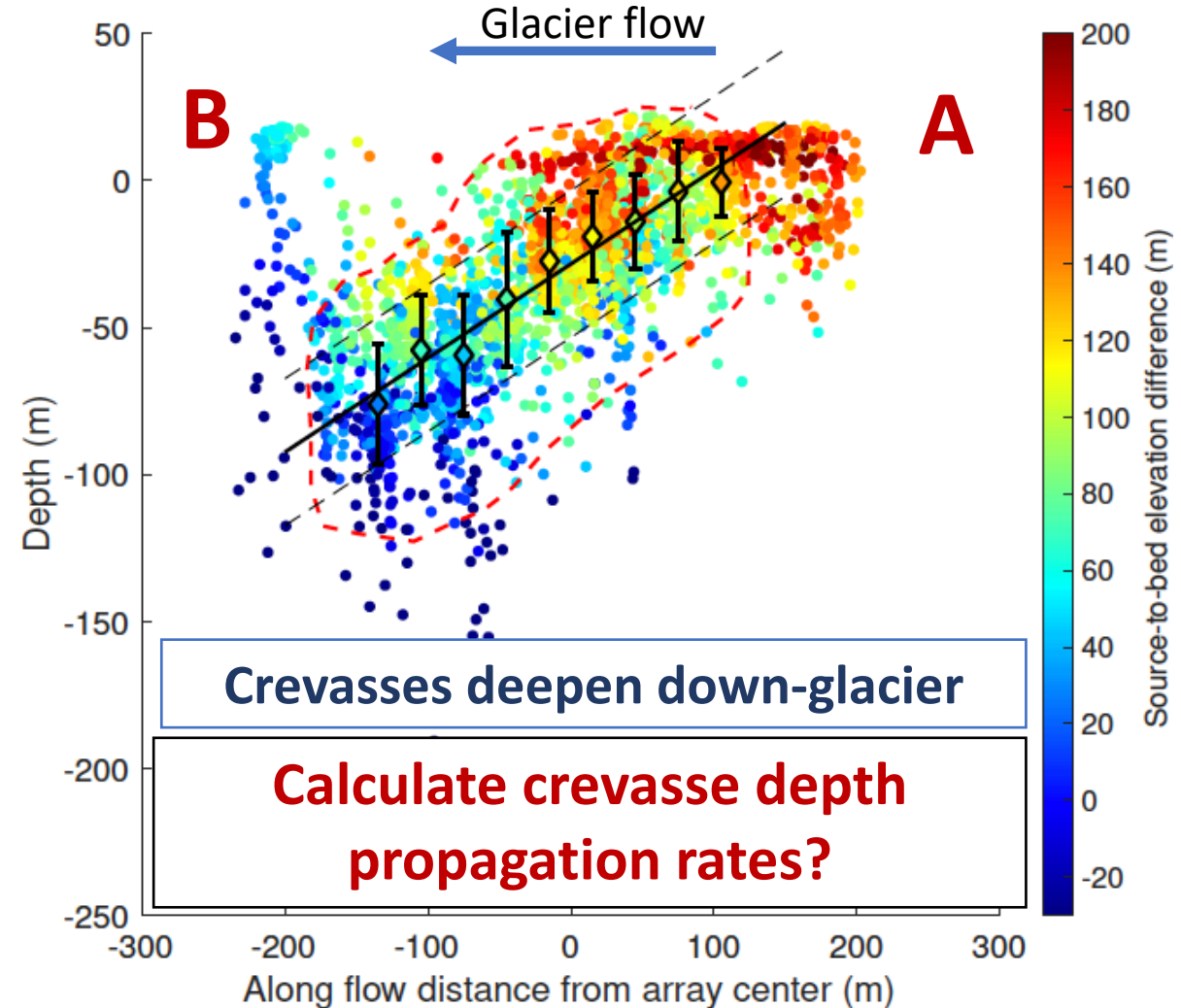
Mechanistically not plausible unless crevasses are water-filled

3D investigation: crevasse depths

Top view

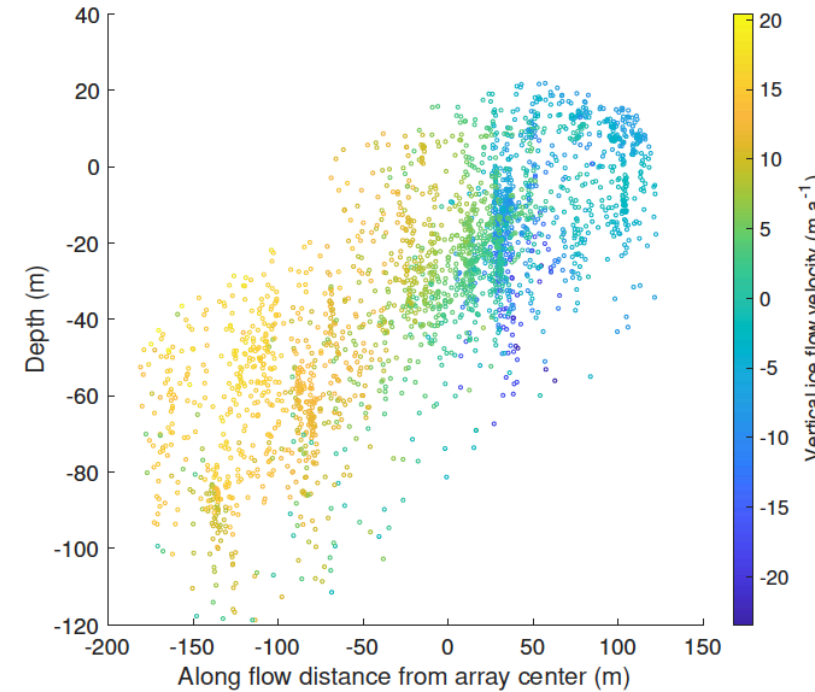
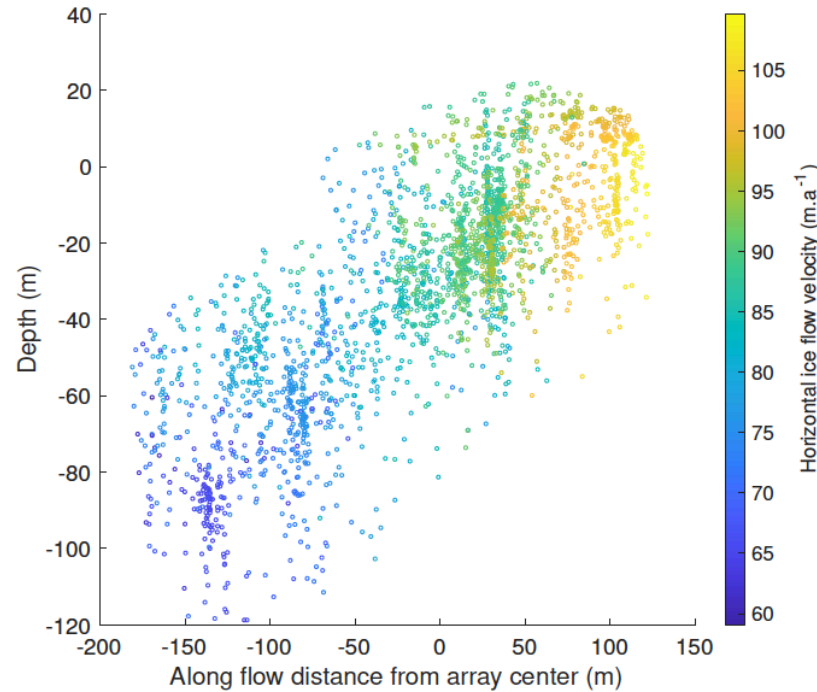
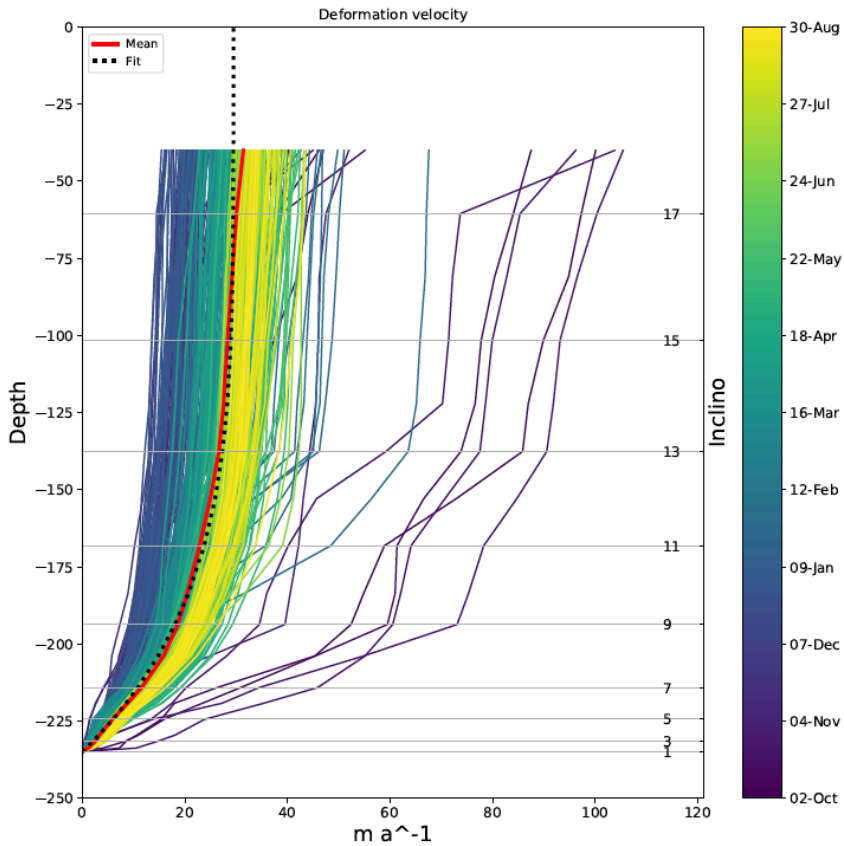


Along-flow cross section

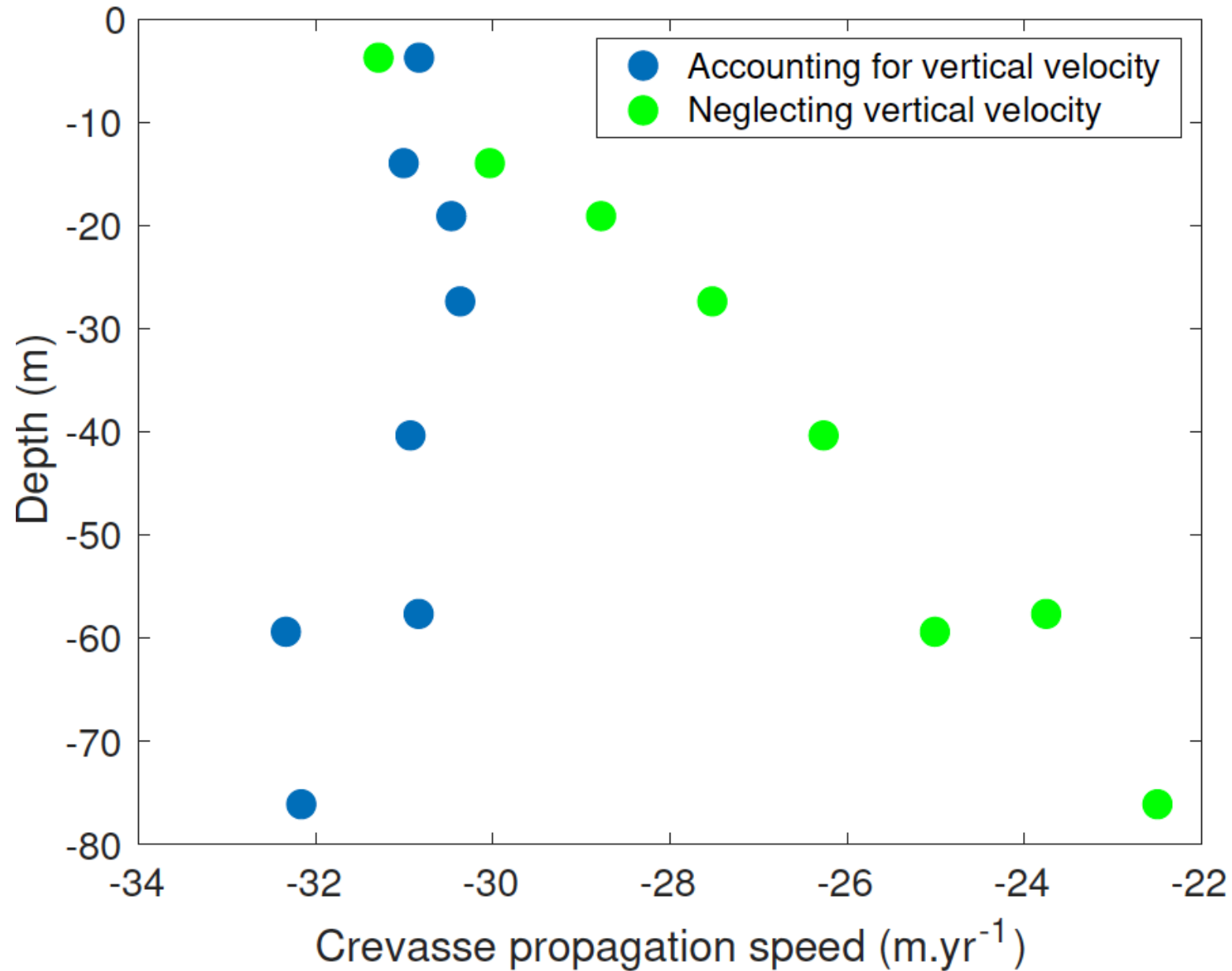


3D investigation: crevasse growth rates

Correction from ice advection as predicted by Adrien using Elmer calibrated from surface velocities, a field-constrained basal friction law and borehole ice deformation measurements

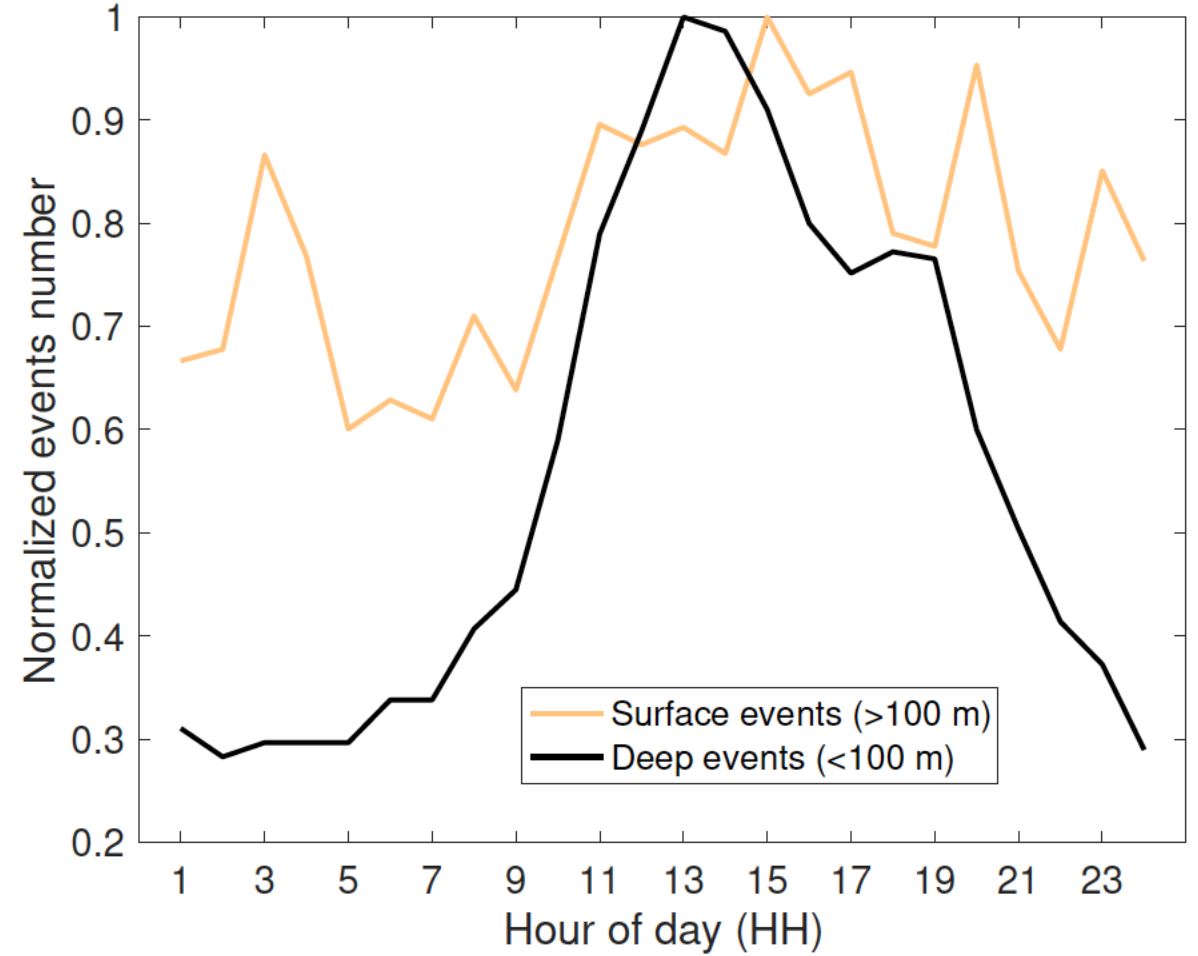
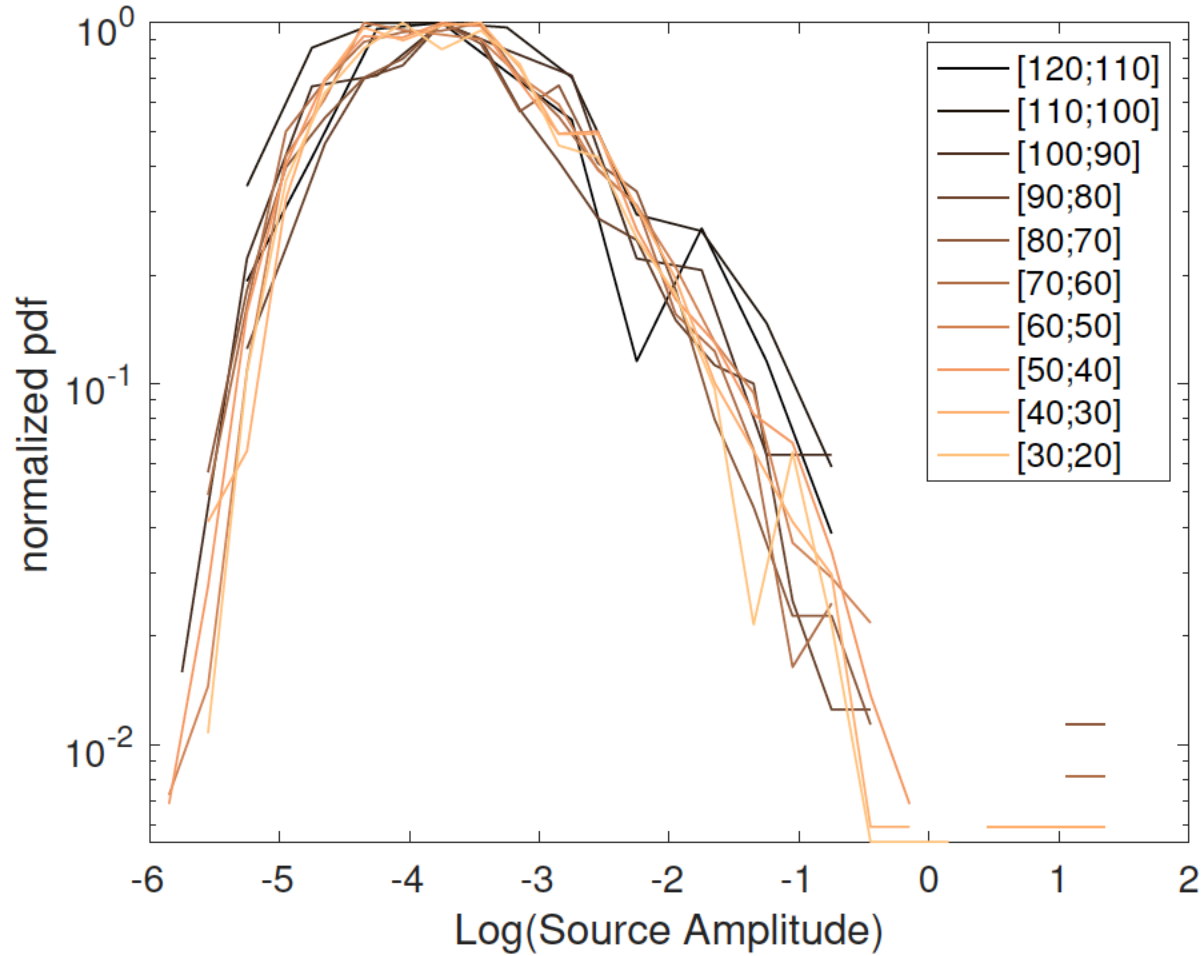


3D investigation: crevasse depth propagation speed



**Crevasses depth
propagation rate is on the
order of 30 m/yr at this site**

Dependency on water input rate and depth



Events have similar amplitude distributions with depth, are all surface melt modulated, although the modulation is stronger for deeper events

CONCLUSION

Results

Crevasse rupturing

Speed : 200 – 500 m/day

Dependency of seismicity rates on melt water input, which is stronger for deeper events

Crevasse depth and depth propagation rate

Crevasses reach the bed, which is up to 100 m deep!

Crevasses depth propagation rates are on the order of 30 m/yr at this site

Perspectives

Gather numerous crevasse rupture events
→ to calculate an average coefficient of diffusion.

→ Understand how much these crevasse depth rates are consistent with theory (Weiss et al., 2004; Van der Veen, 2007)