

Identifying icequakes at ice-covered volcanoes in Southern Chile

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1: Highest risk volcanoes in Chile

- Villarrica and Llaima are two of most active volcanoes in Chile
- High priority targets for OVDAS, the national volcano observatory
- At least 14 km² of glacial ice present on each volcano

Problem:

- Icequakes may be mistaken for low-frequency volcanic earthquakes, and vice-versa

- Risk of false alarms or missed warnings from misidentification

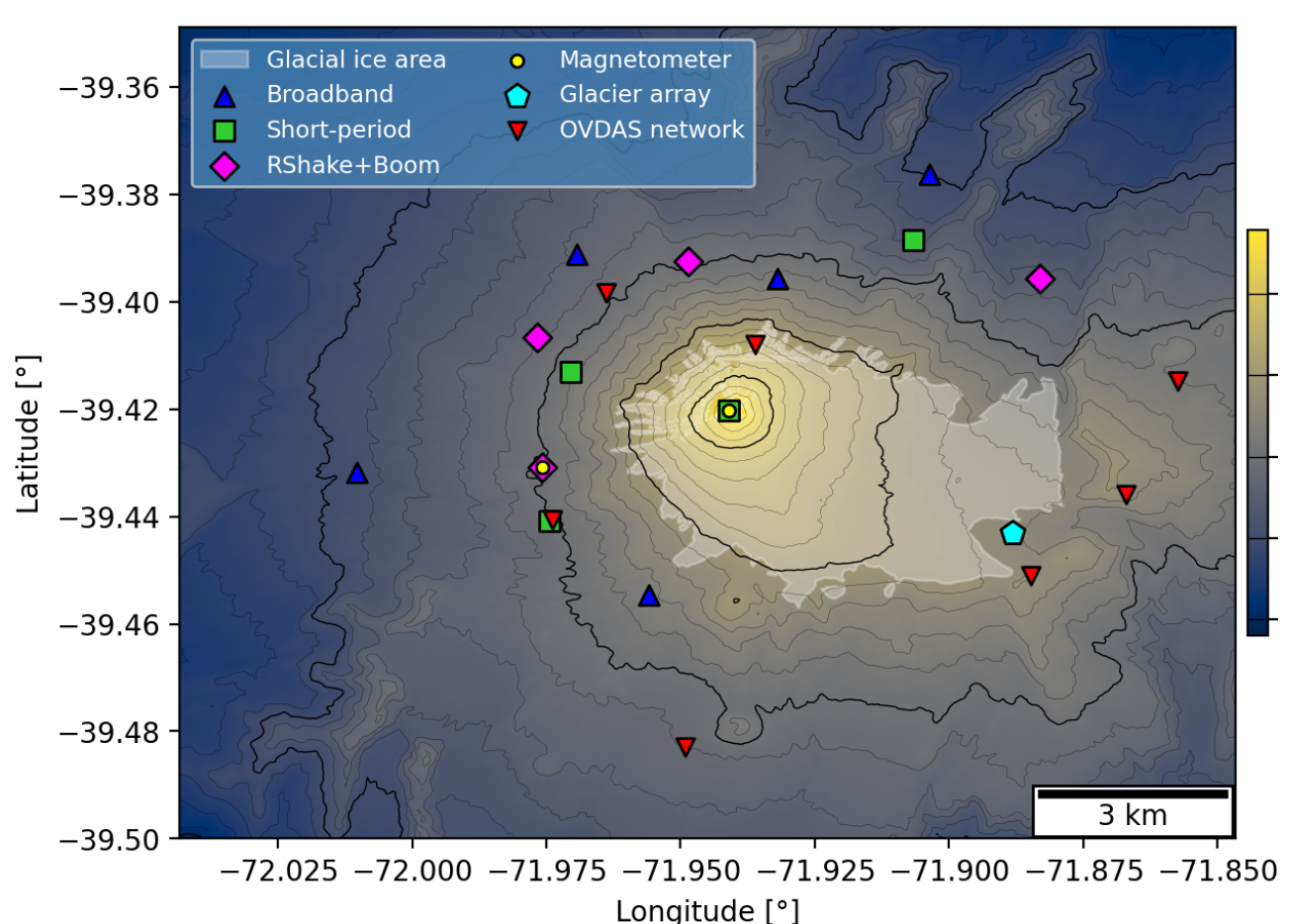
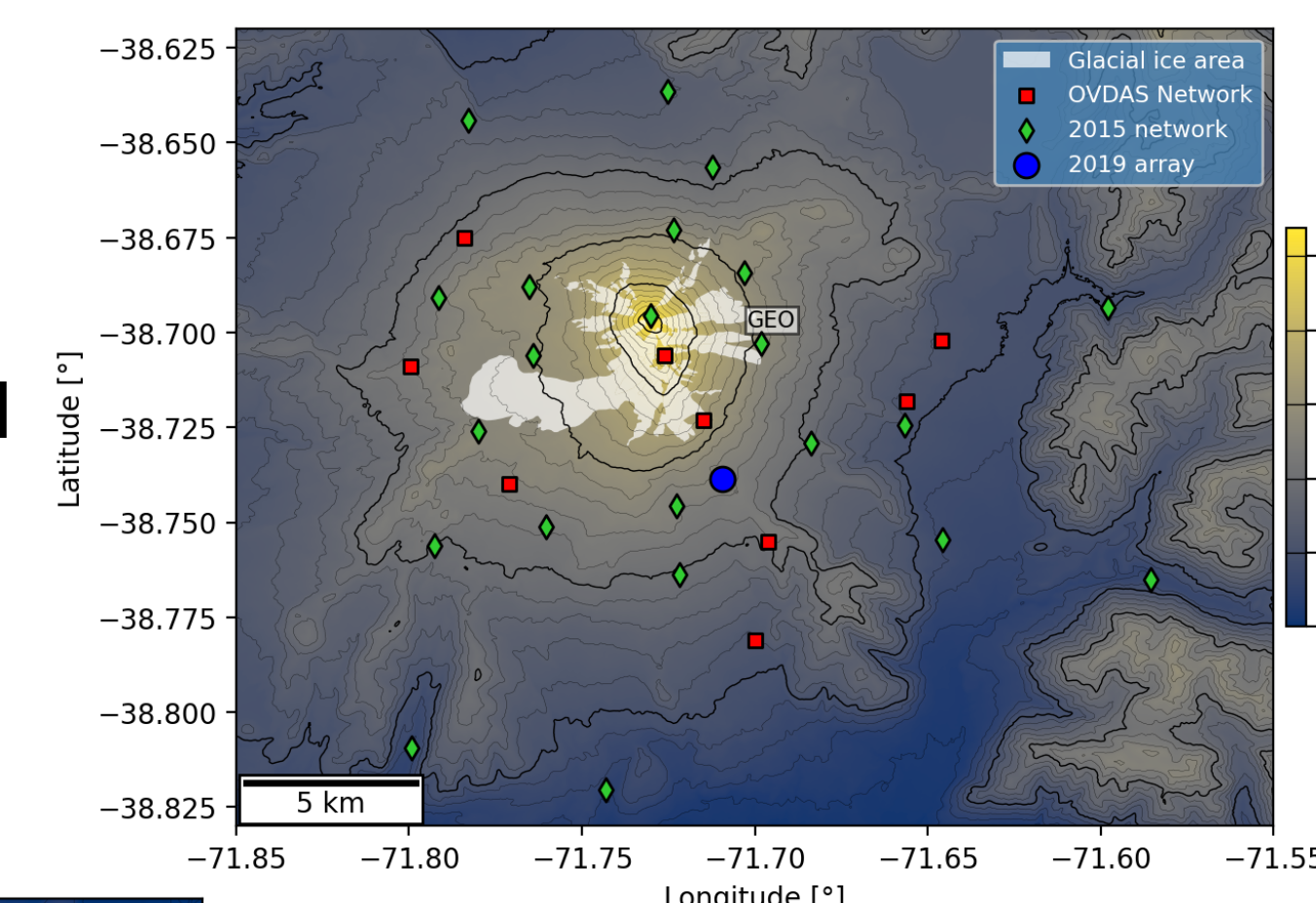
Project goals:

- Estimate the quantity and location of icequakes at Llaima and Villarrica
- Characterize the source mechanism(s)
- Develop criteria for efficiently identifying icequakes

2: Data collection

Llaima volcano (right)

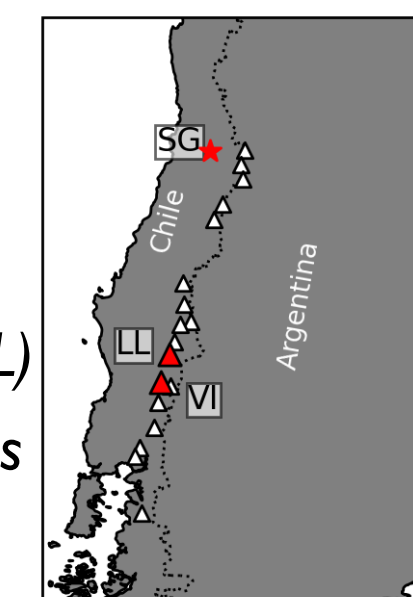
- Feb. - Mar. 2015: Seismic deployment around volcano
- Feb. - Apr. 2019: Seismic and acoustic array on southern flank



Villarrica volcano (left)

- Network of instruments deployed in Jan. 2020

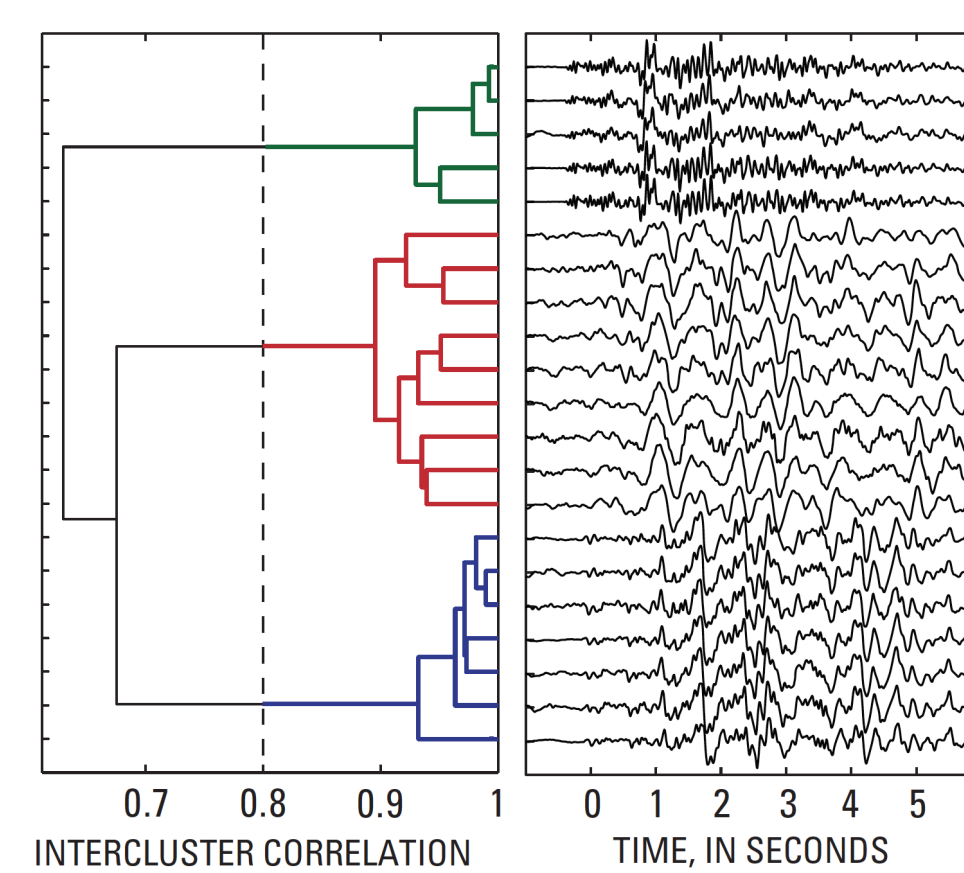
Location map of Llaima (LL) and Villarrica (VI) volcanoes in Southern Chile.



3: Methods

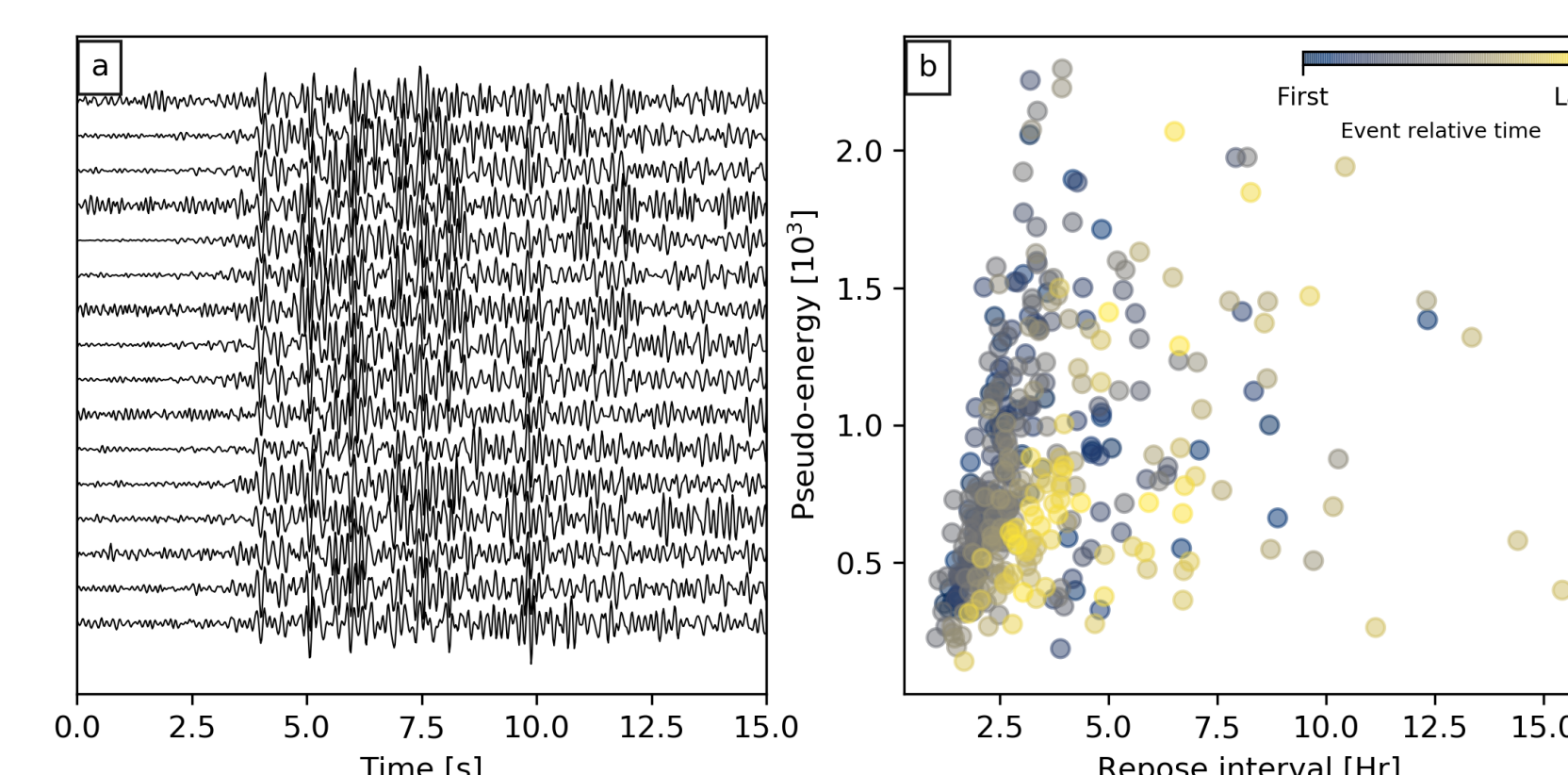
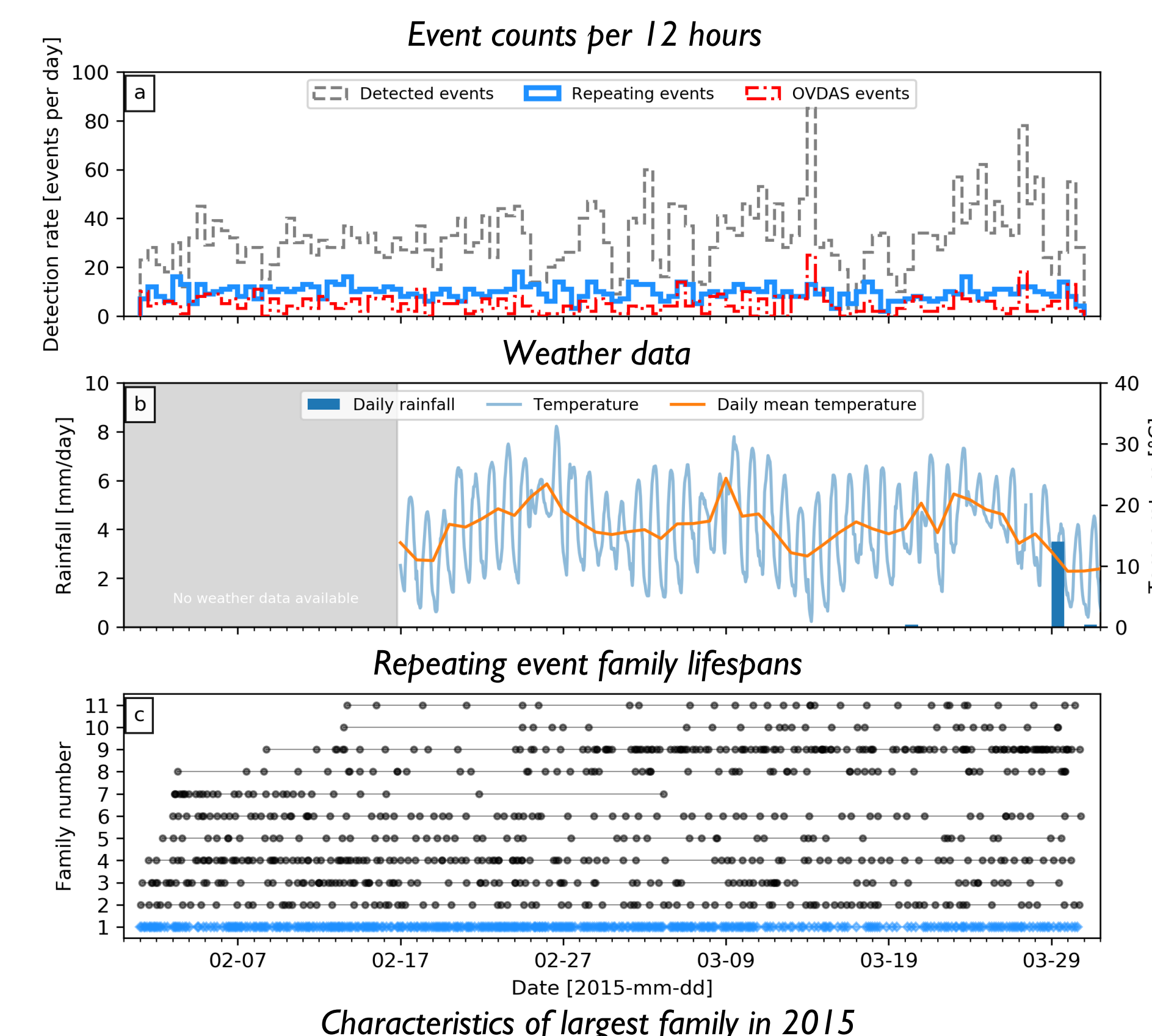
To detect potential icequakes:

- Apply multi-station STA/LTA detection algorithm
- Match events by similarity using cross-correlation
- Organise into families using hierarchical clustering



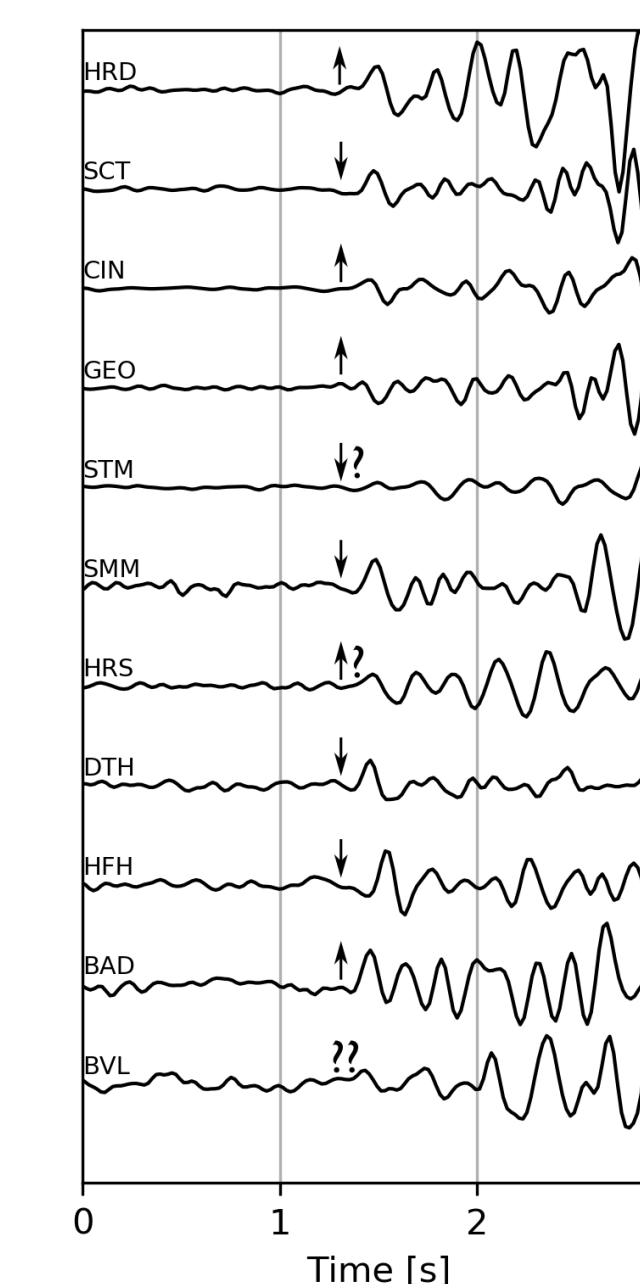
Example of hierarchical clustering (adapted from Buurman and West, 2010)

4: Llaima micro-seismic activity - 2015



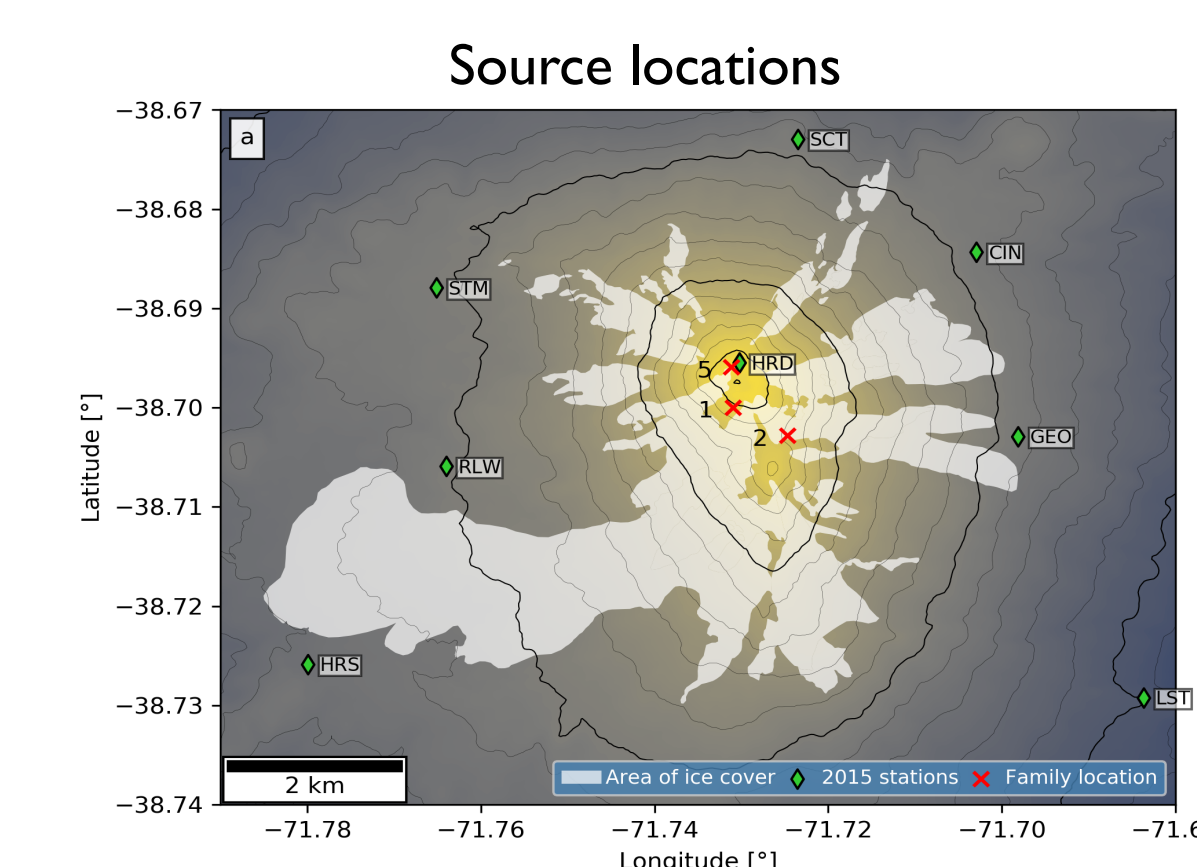
- 4,894 micro-seismic events detected in 2 months
- 1,134 repeating events across 11 families
- Largest family contains 397 events
- Characteristics of largest family indicate shear motion at source

First motions of stacked waves (see section below)

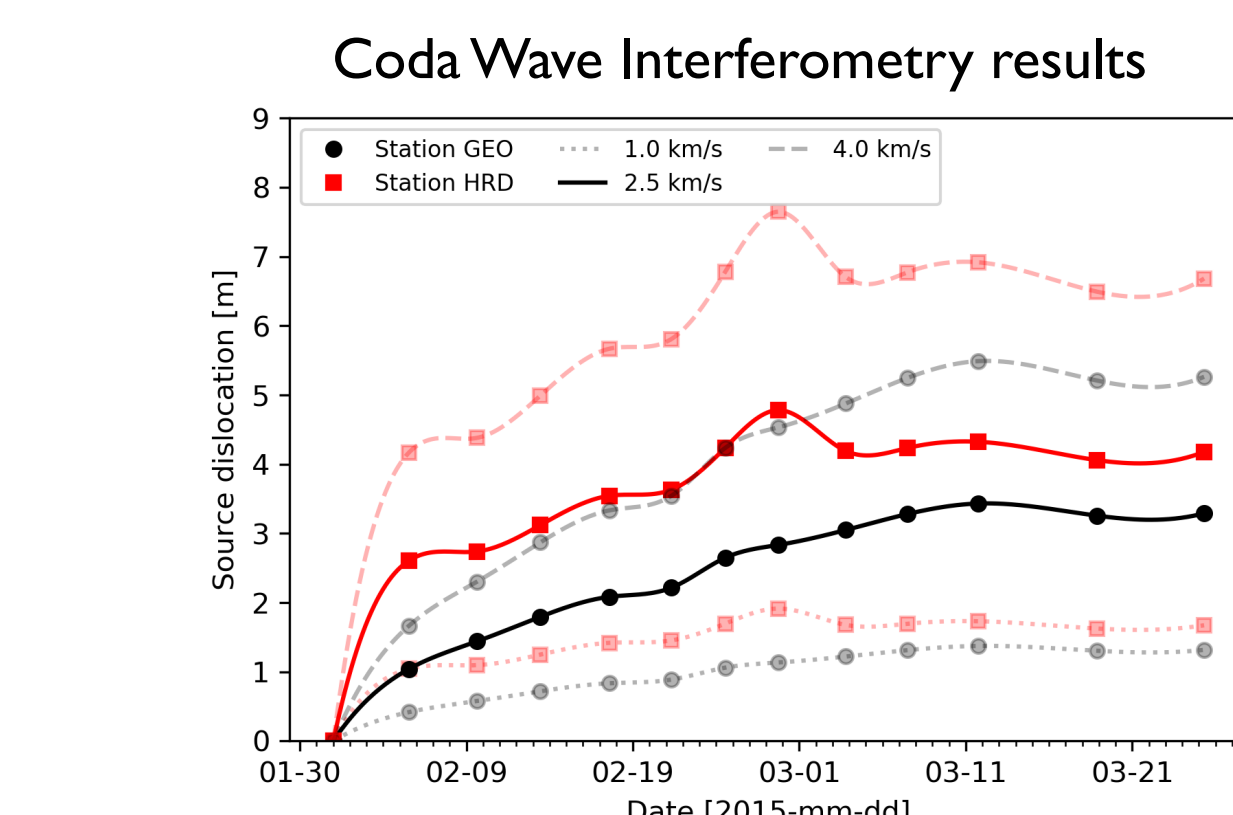
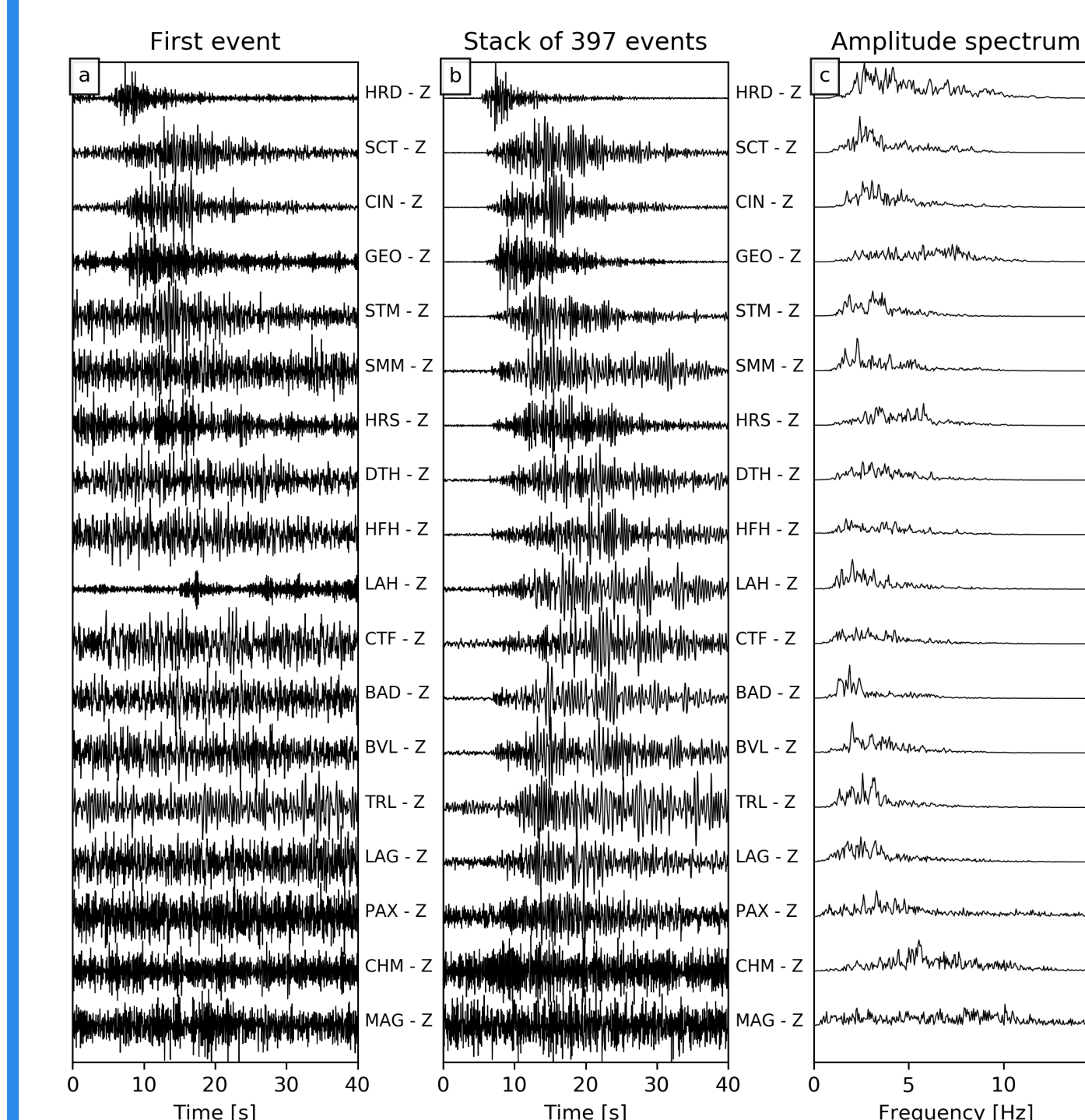


5: Llaima icequake locations - 2015

- Original waves have very low SNR
- Stacking reduces SNR enough to get clear first arrivals to use for locations
- 3D grid search used to locate sources



- Largest families placed near summit, beneath or close to glaciers



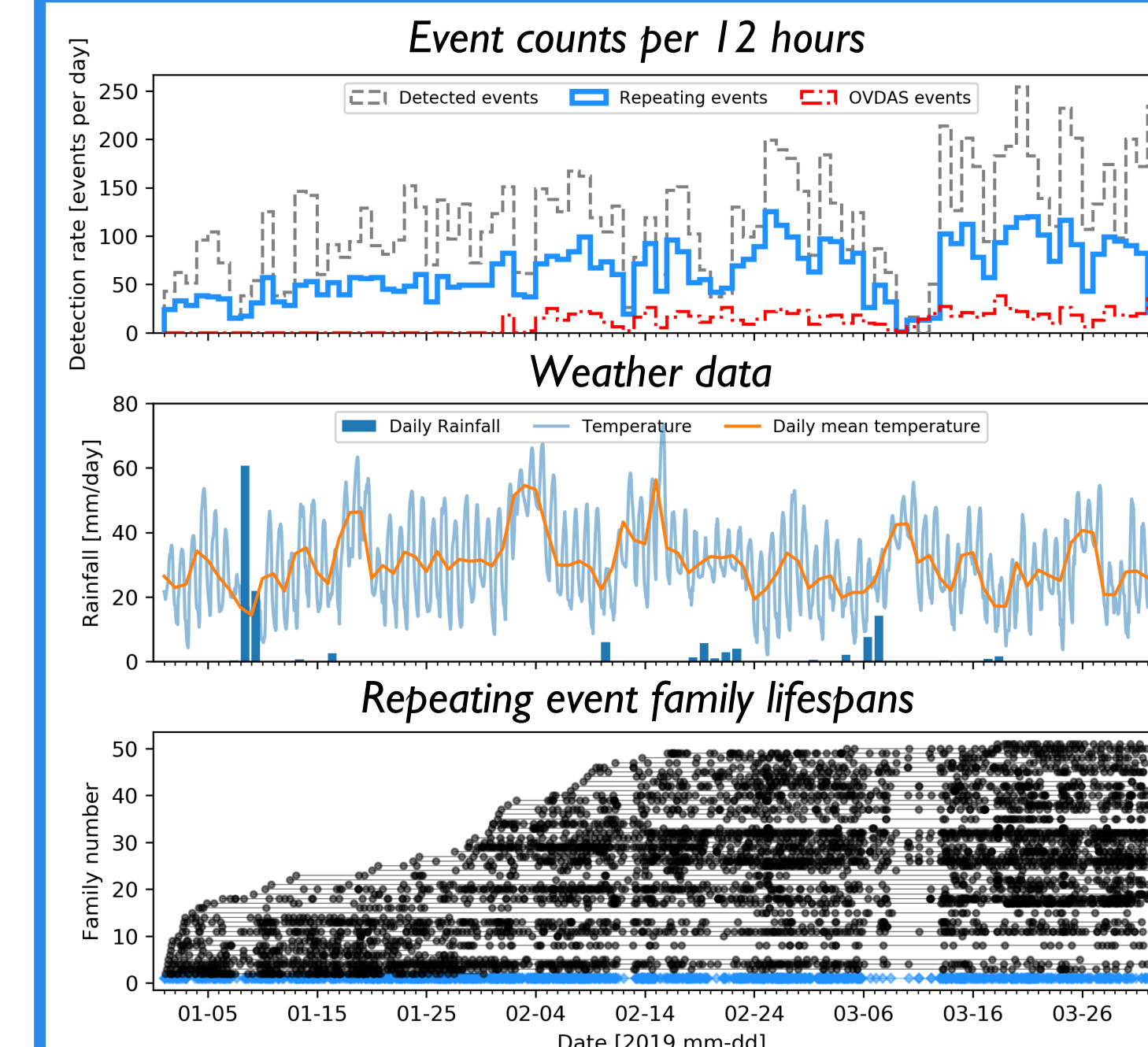
- Coda wave interferometry indicates little or no source location motion

Want to read more? Download our open-access article with full analysis on the 2015 data from Volcanica at the address below:

<https://www.jvolcanica.org/ojs/index.php/volcanica/article/view/56>

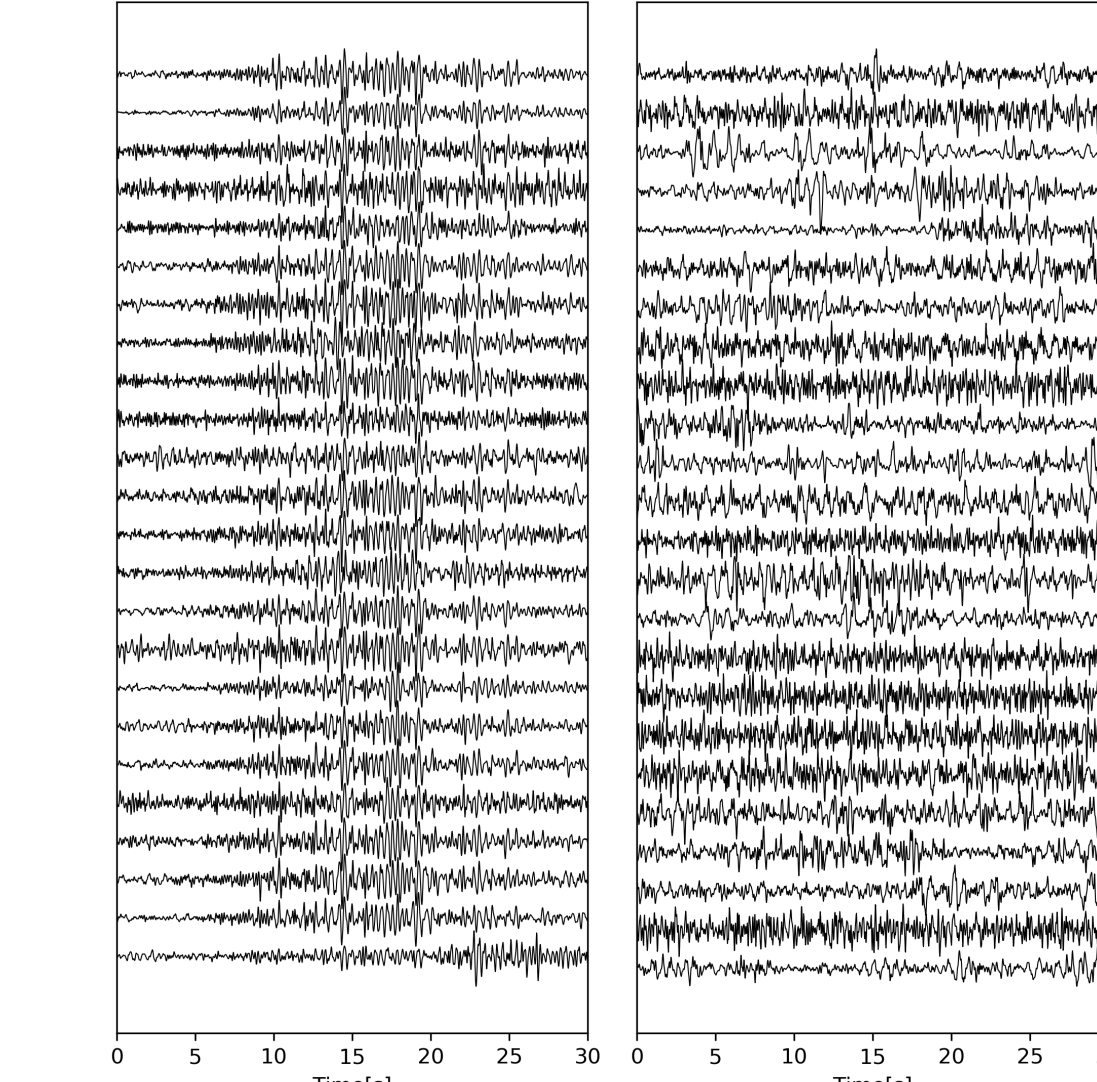


6: Llaima micro-seismic activity - 2019

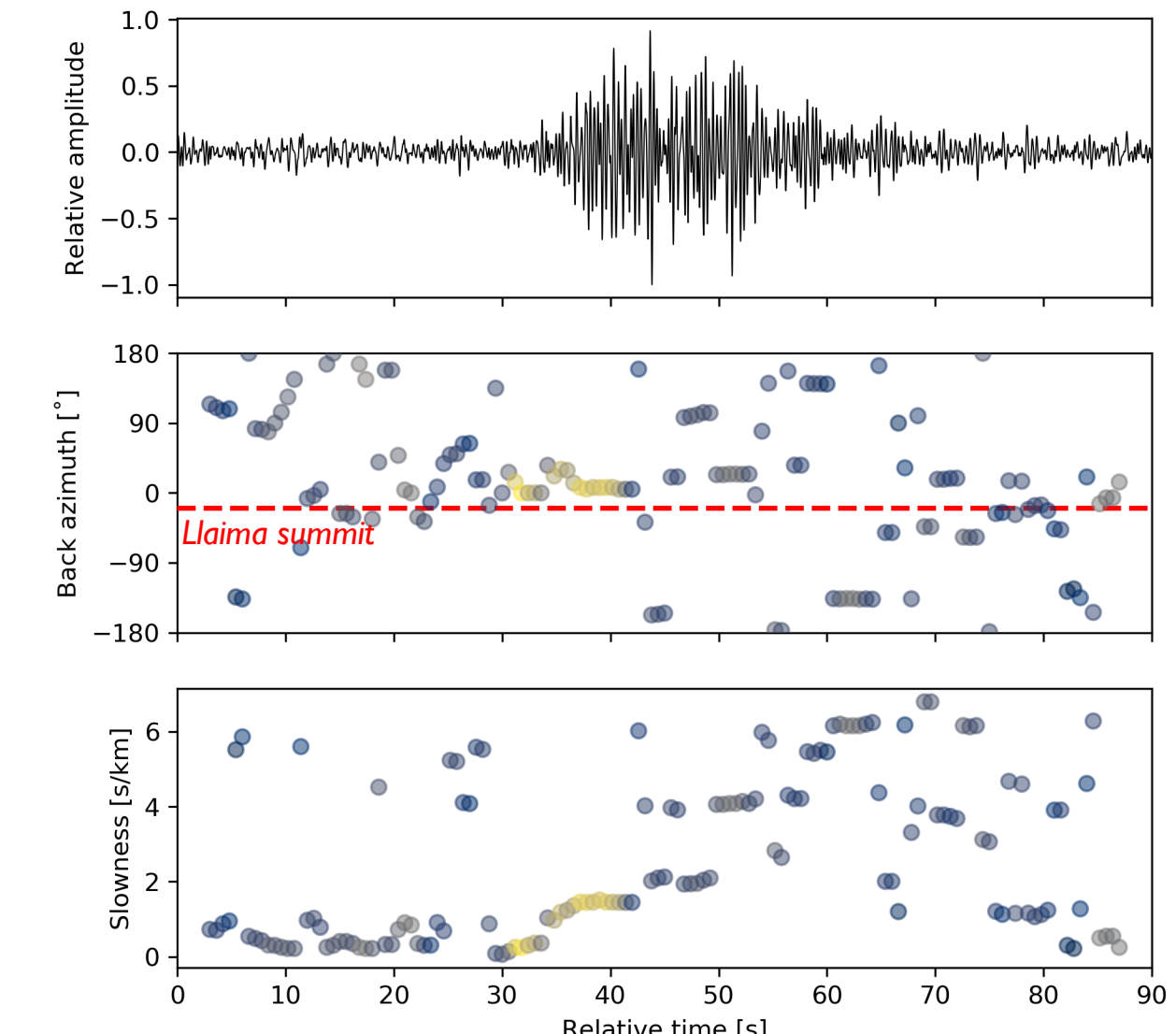


- 10,508 micro-seismic events over 3 months
- 5,674 repeating events across 51 families
- Largest family contains 1,054 events
- No co-seismic acoustics recorded
- Preliminary back-azimuth suggests location on eastern flank.

Repeating waves as recorded at array Station



F-K analysis for one potential icequake



7: Preliminary results from Villarrica

- This is the section in which I would have presented first results from instrument deployment, but recovery has been delayed by COVID-19.
- We expect a challenge in distinguishing icequakes from seismicity generated by summit activity and shallow long-period seismicity within and near conduit.

8: Key findings and future directions

- Thousands of micro-seismic events found at Llaima volcano
- Many events can be sorted into persistent families
- Likely related to persistent shear failure at ice-rock interface on base of glaciers on volcano
- Scan OVDAS seismic data archive for Llaima, Villarrica, and other ice-covered volcanoes
- Expand research to other ice-covered volcanoes in Chile, Alaska, and Iceland



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