Near and Far-Field Seismo-Acoustic Analysis of Mb 4.9 Mine-Quake Nearby Kiruna, Sweden

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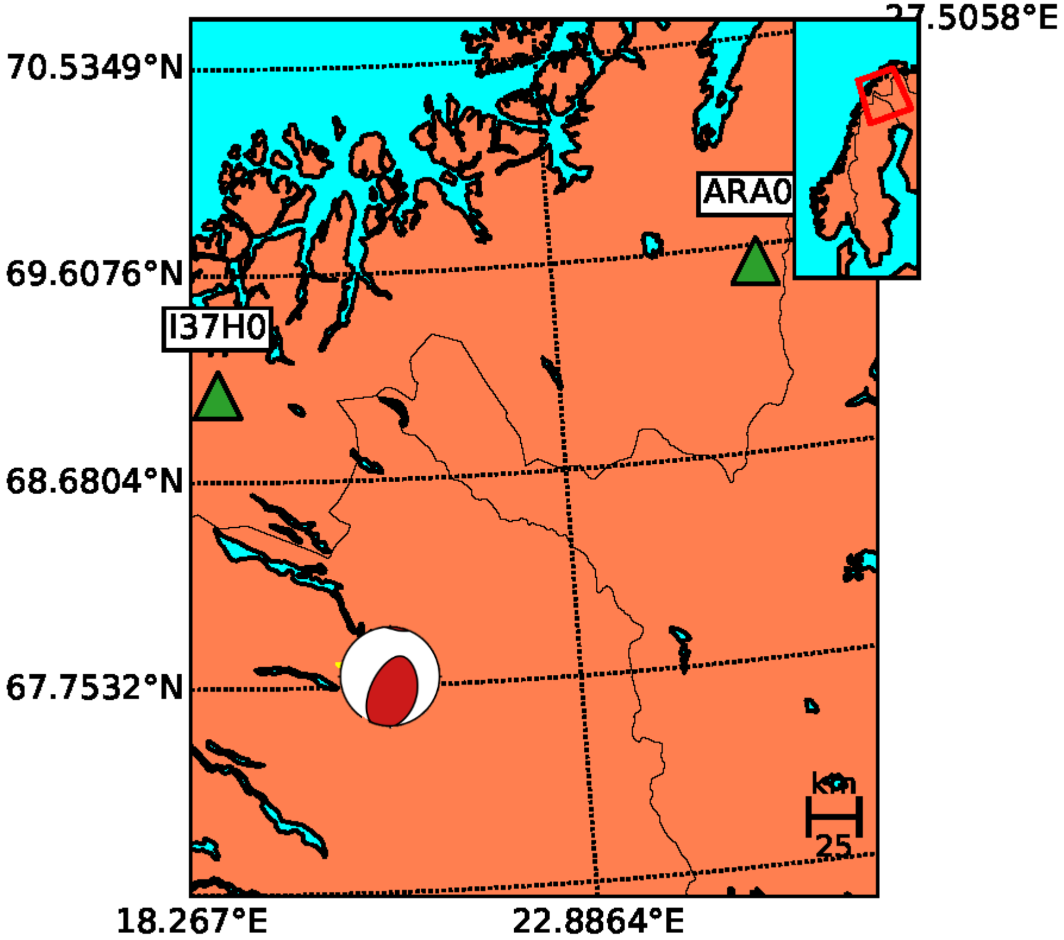
Records from Kiruna minequake
(NORSAR,CEA)

A shallow (depth = 1km) mine quake of magnitude mb 4.9 occurred in Kiruna, Sweden on May 18th 1:11:56 UTC

Focal mechanism derived from regional seismic data shows that the signature is different than a conventional mine collapse. The first analyses indicate there might be multiple quasi-simultaneous events.



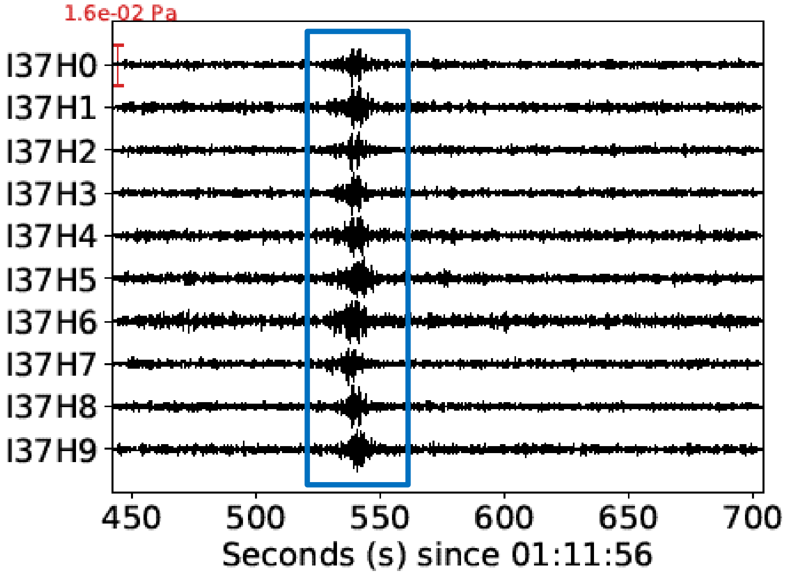
Infrasound phases were detected at IS37NO and ARCI arrays.

Infrasound arrivals after Kiruna minequake - Far-field

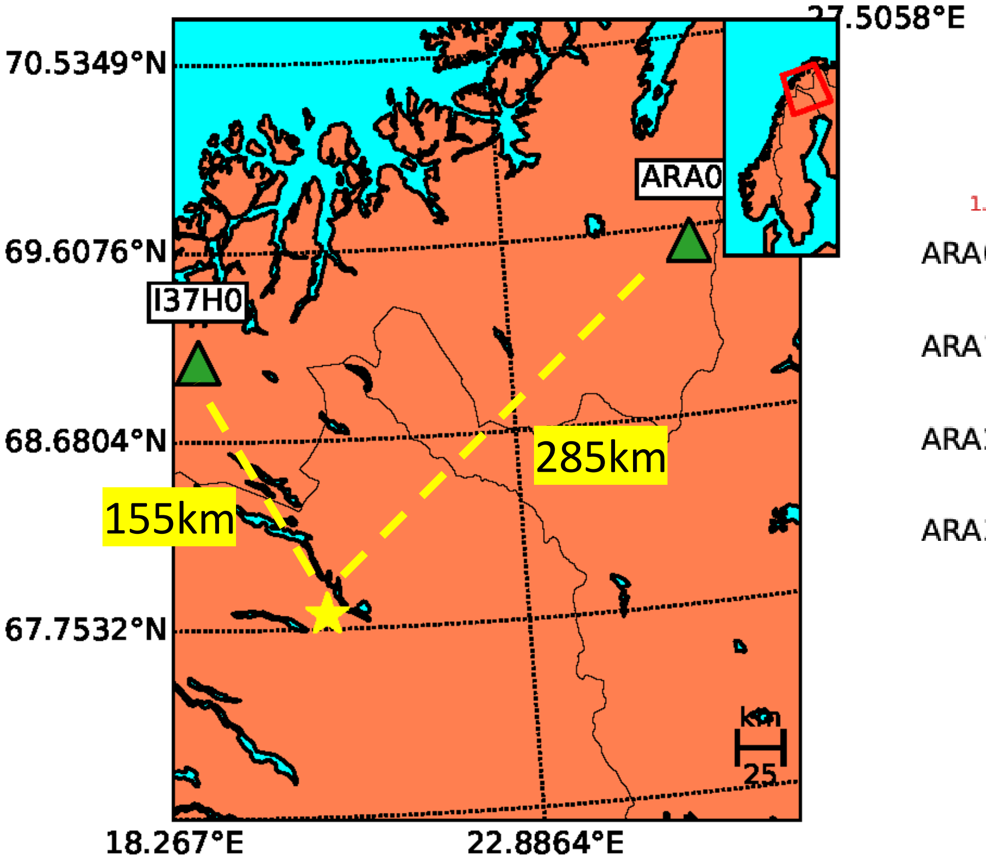
Infrasound signals (1 – 5Hz) show clear stratospheric arrivals at IS37 and ARCI

Signals peak around 1-2Hz

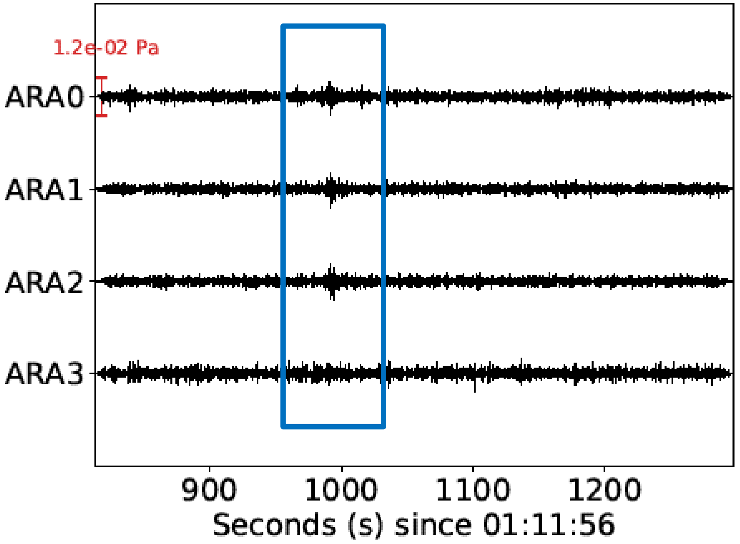
IS37 Array



Celerity= 282.8 m/s

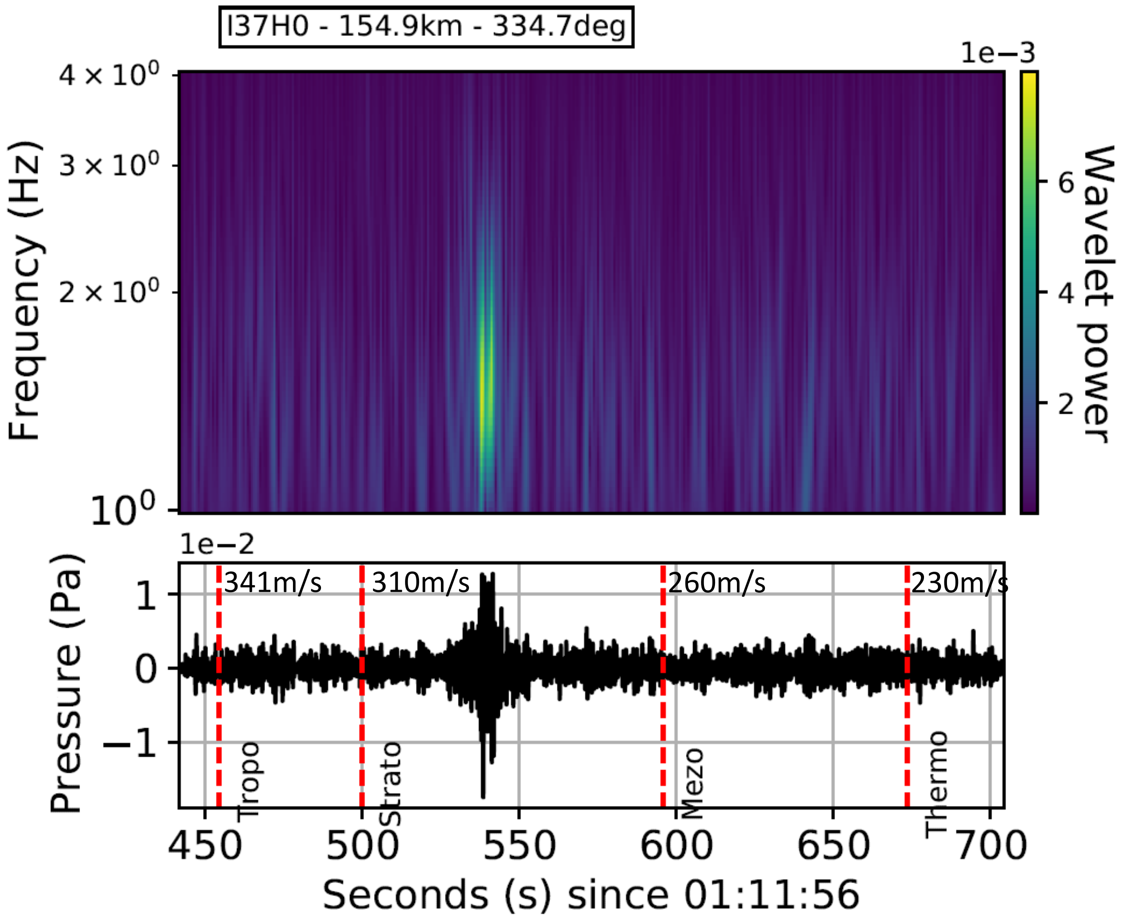


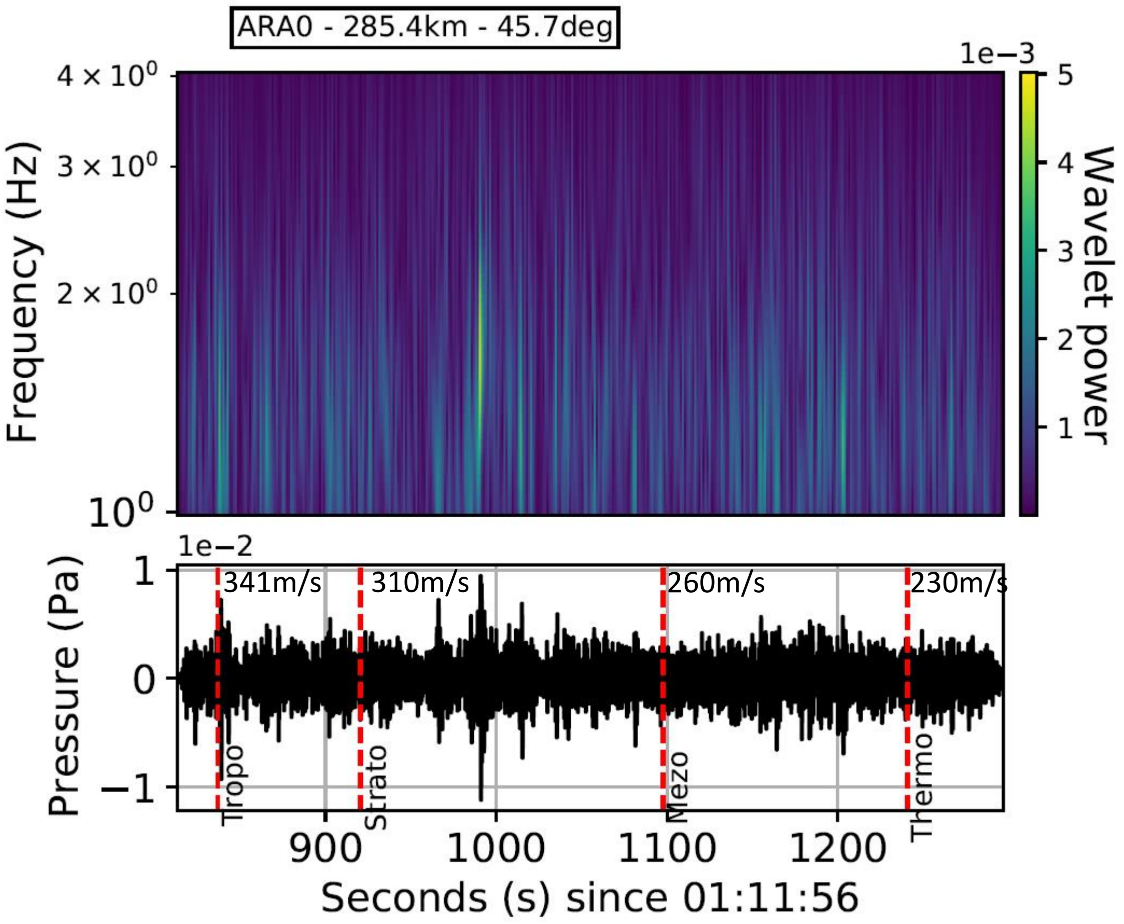
ARCI Array



Celerity= 281.7 m/s

Frequency content of infrasound arrivals - Far-field

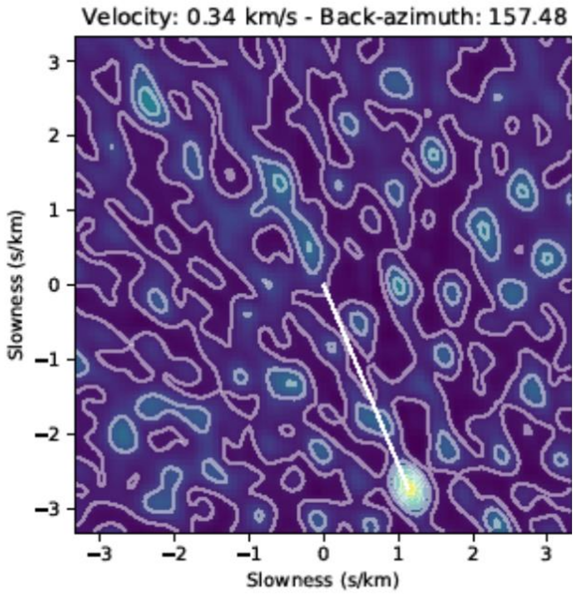




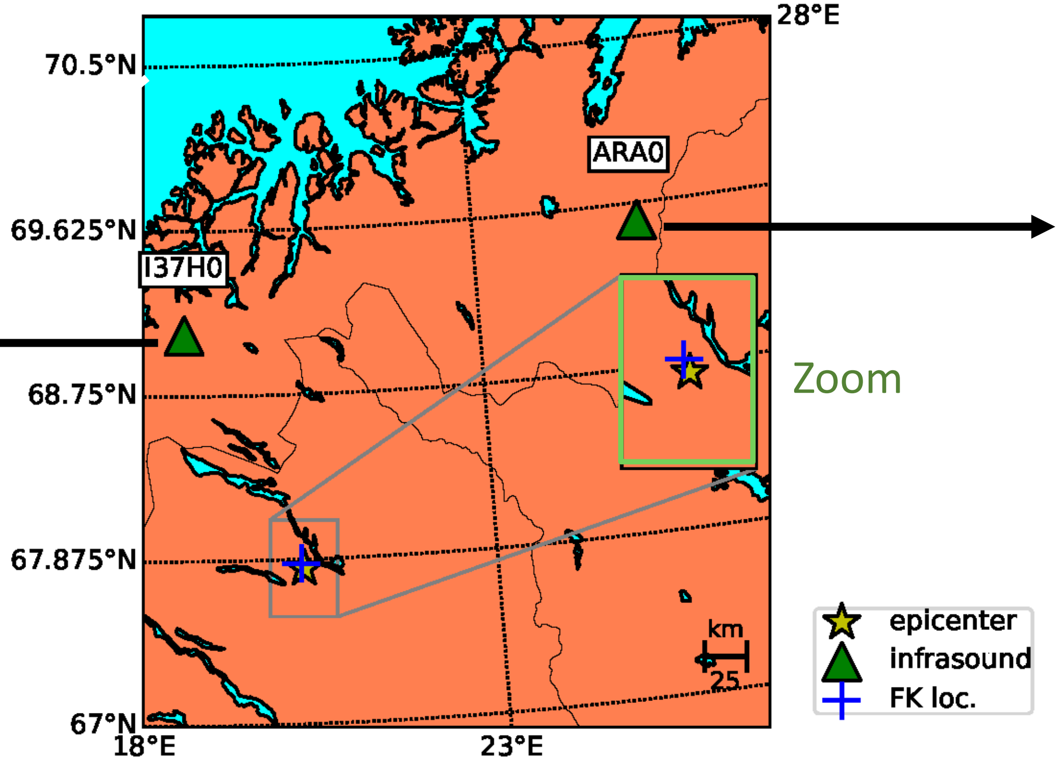
FK analyses - Far-field

Infrasound back-azimuth at IS37 and ARCI arrays indicate a location <1km from Kiruna mine pit

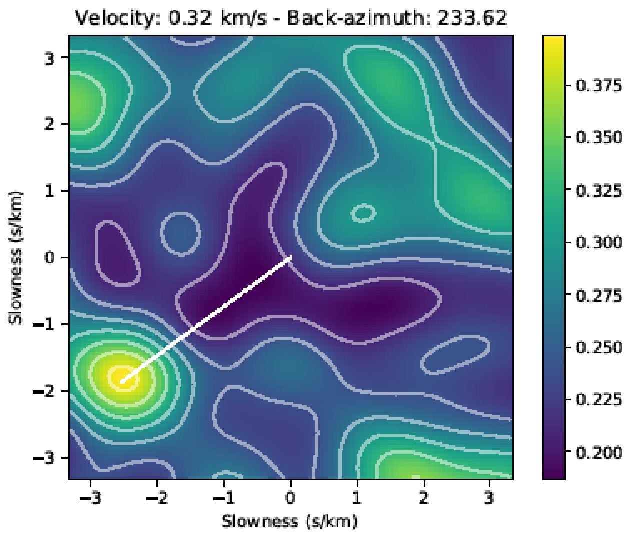
IS37 Array



True azimuth: 153.2°
Av. cross wind vel.: -8.15 m/s

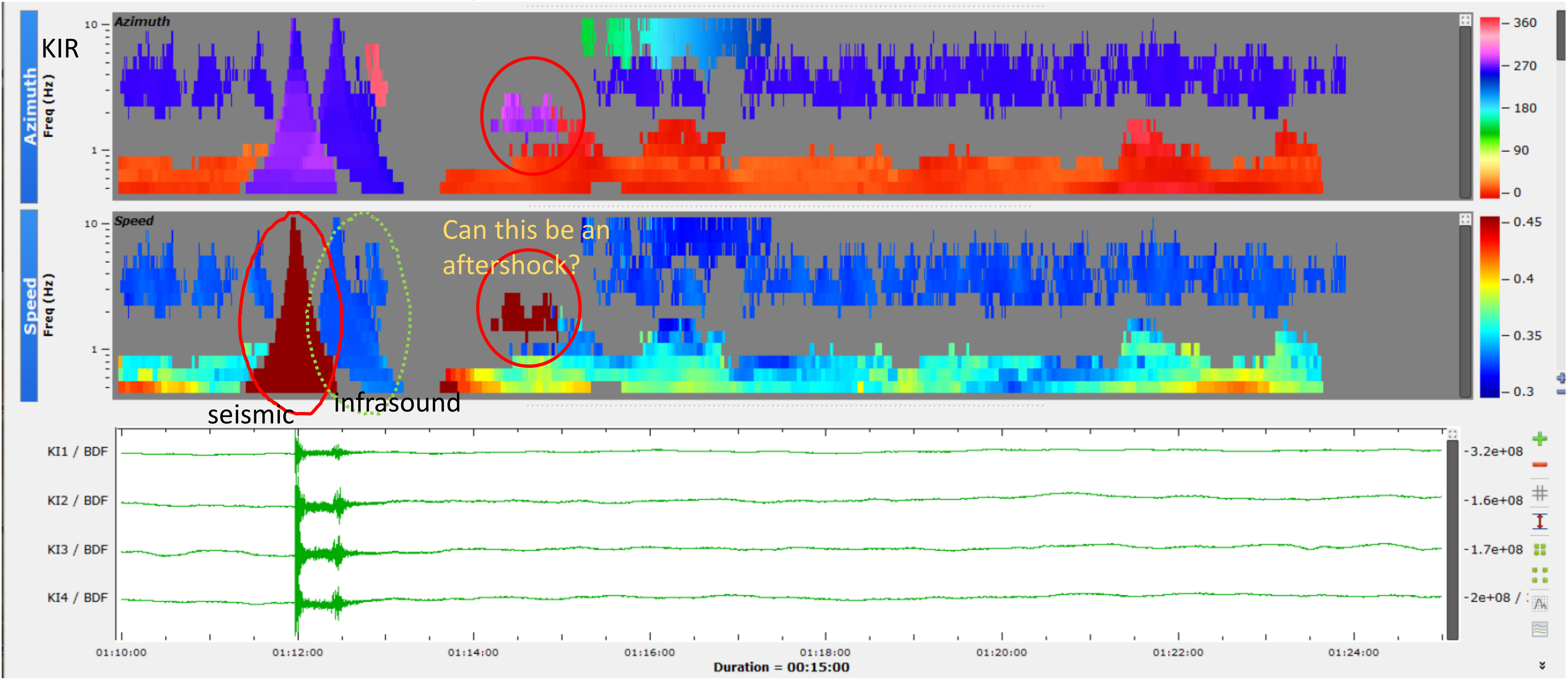


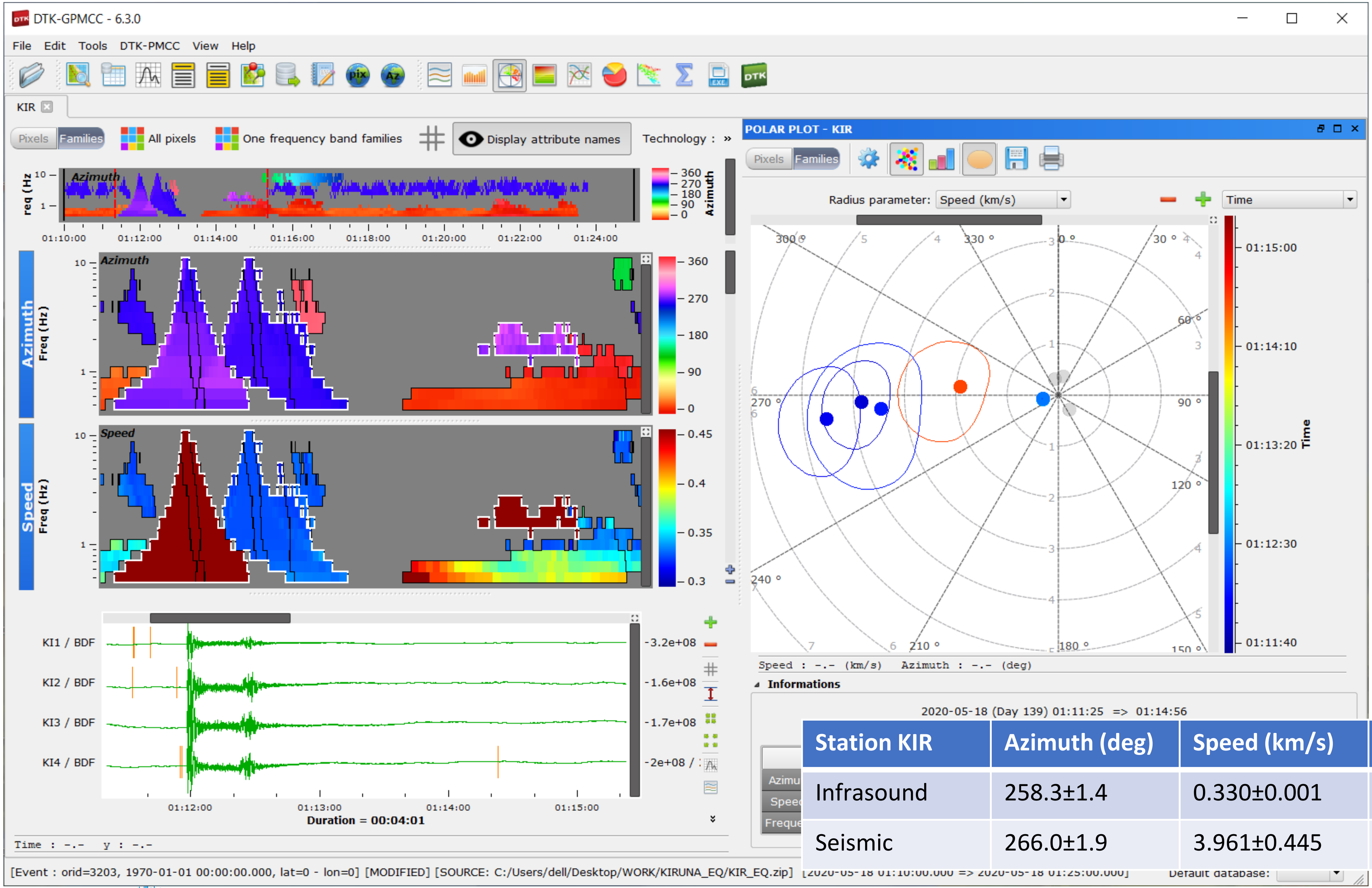
ARCI Array



True azimuth: 230.5°
Av. cross wind vel.: -10.6 m/s

Near-field analysis via PMCC software





Station KIR	Azimuth (deg)	Speed (km/s)	Mean Frq(Hz)
Infrasound	258.3±1.4	0.330±0.001	3.59±1.47
Seismic	266.0±1.9	3.961±0.445	3.59±1.51

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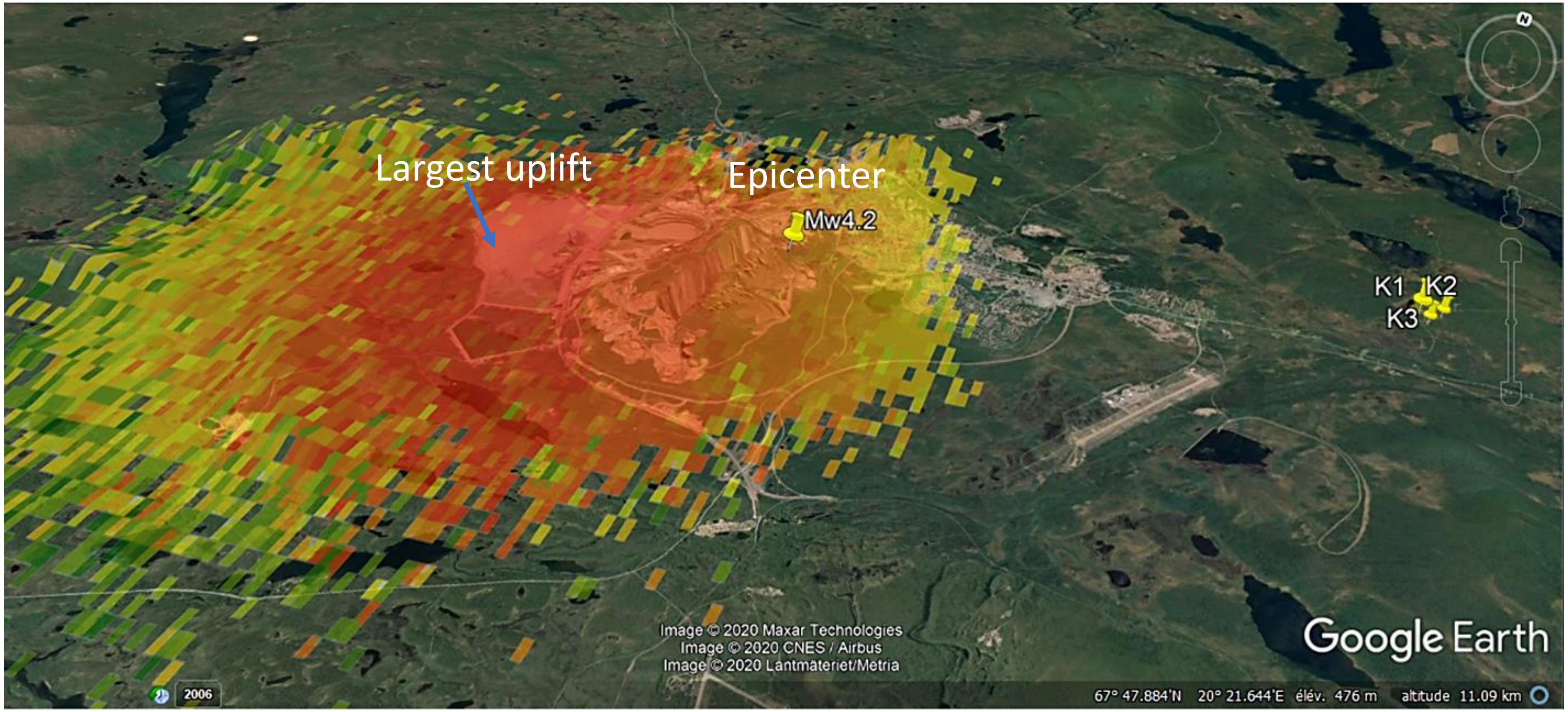
Sound Pressure Level (SPL) backprojected from KIR

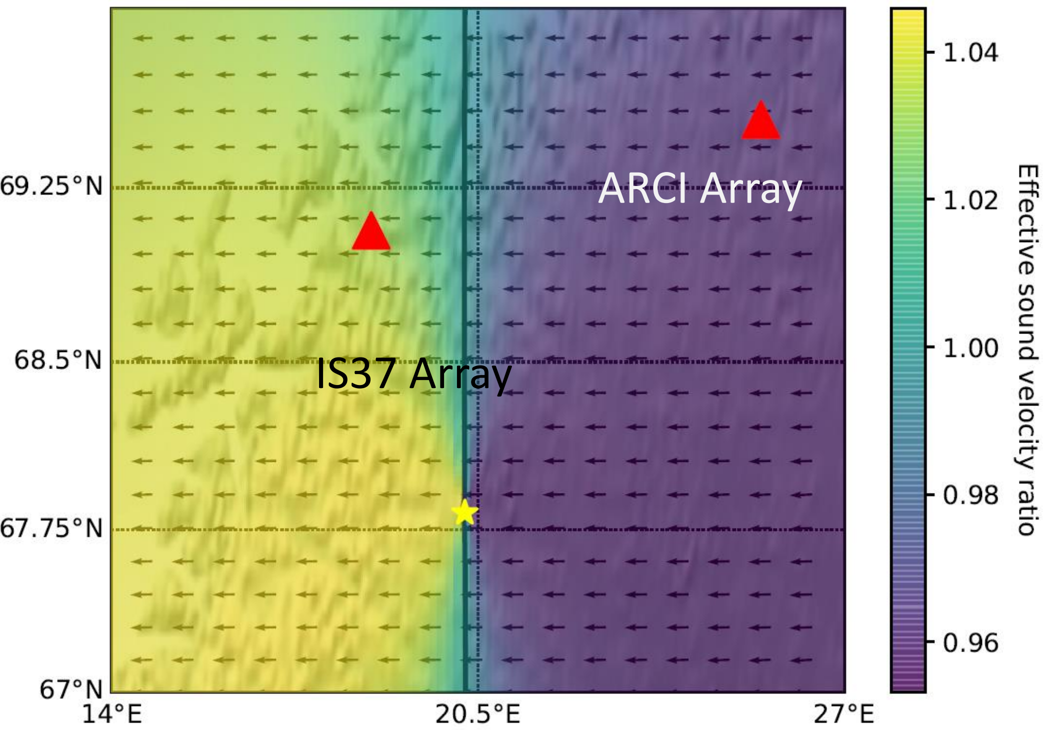
Near-field

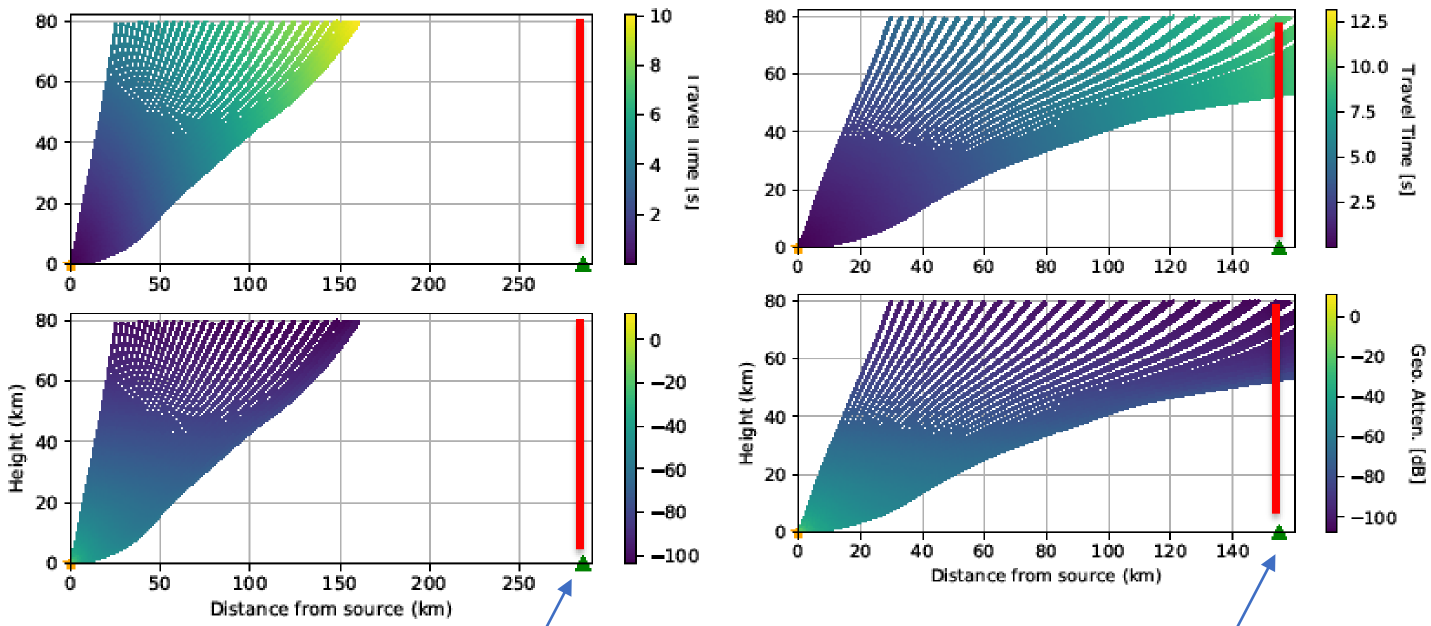


dB SPL @1 km

- 100.4 - 101.9
- 101.9 - 103.4
- 103.4 - 104.8
- 104.8 - 106.3
- 106.3 - 107.7
- 107.7 - 109.2
- 109.2 - 110.6
- 110.6 - 112.1
- 112.1 - 113.6
- 113.6 - 115.0
- 115.0 - 116.5
- 116.5 - 117.9
- 117.9 - 119.4
- 119.4 - 120.8
- 120.8 - 122.3

Infrasound wave propagation - Far-field





ARCI Array Location

IS37 Array Location

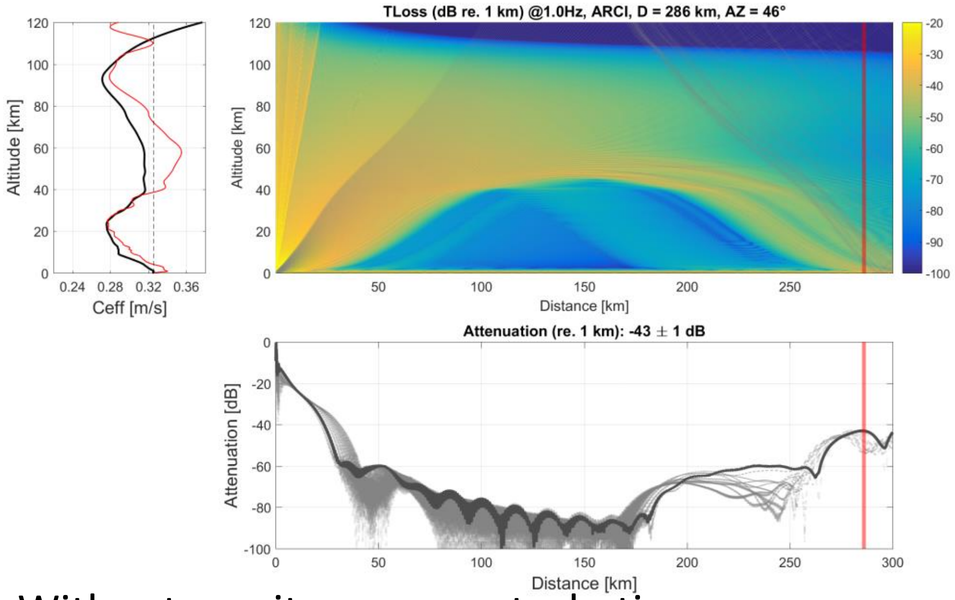
Effective velocity map show the impact of wind and temperature on the wave.
Eff. Vel > 1 -> expected refraction to surface

Ray-tracing indicates that we do not observe any stratospheric arrival at the stations.
Atmospheric models are not sufficient to explain.
Wind perturbations due to gravity waves can enable refracting.

Waveform simulations – ARCI Far-field

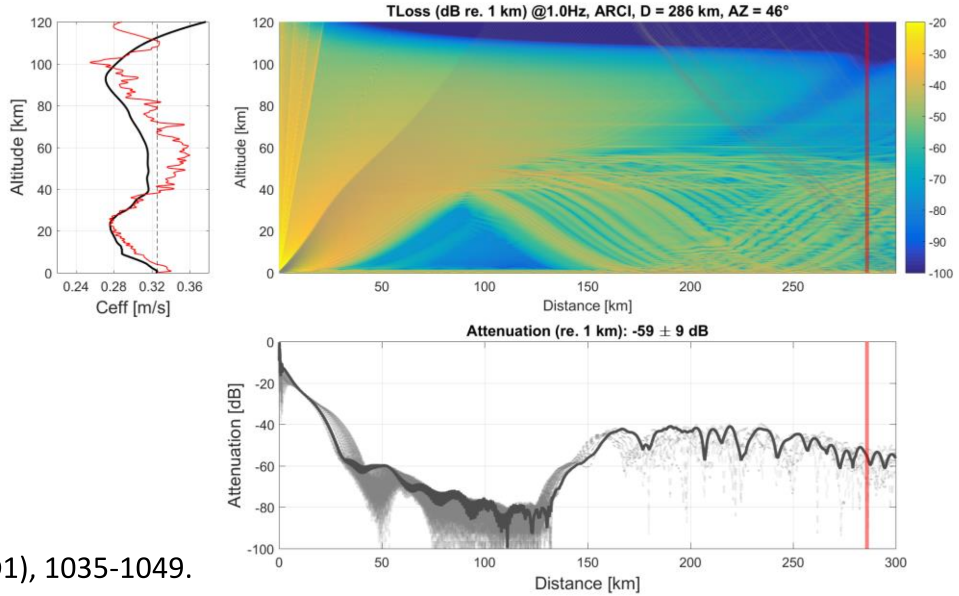
ARCI Station full-waveform simulations with parabolic equation at 1Hz. Then, we include gravity wave perturbations as indicated in Gardner et al. 1993 to simulated waveform propagations.

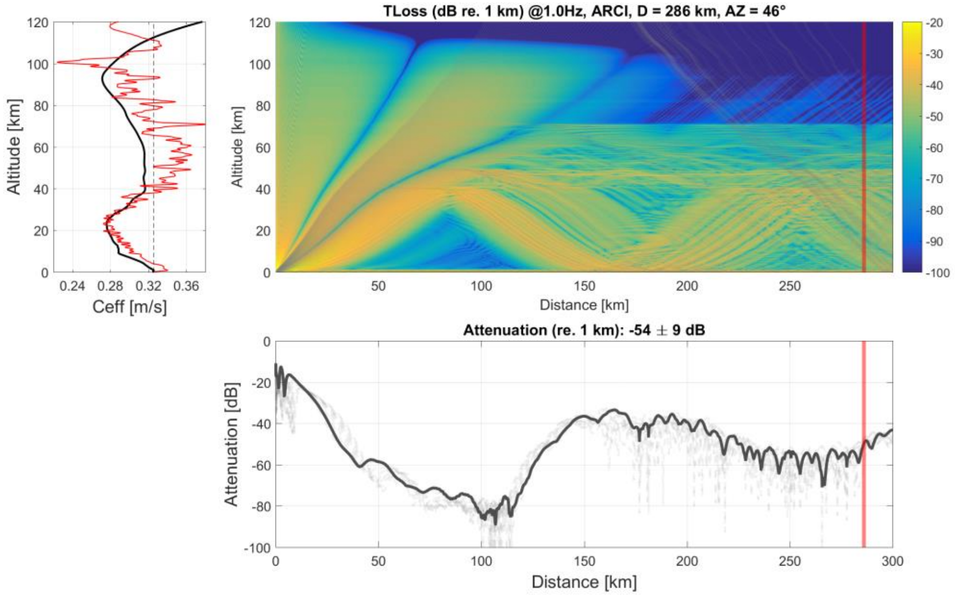
The red line shows the source – receiver distance.



Without gravity wave perturbations

With gravity wave perturbations



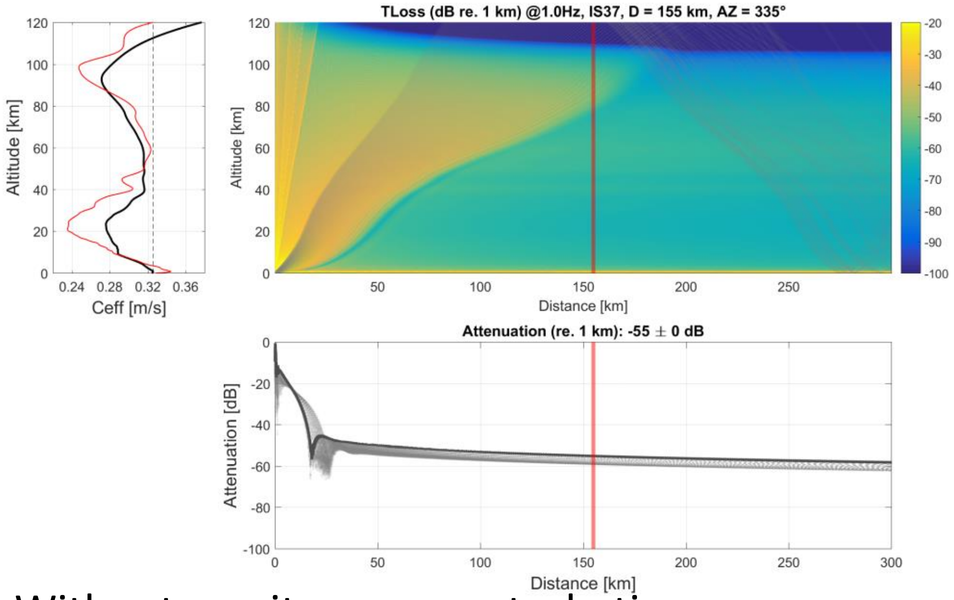


Gardner, C. S. et al. (1993).*JGR: Atmos*, *98*(D1), 1035-1049.

Waveform simulations – IS37 Far-field

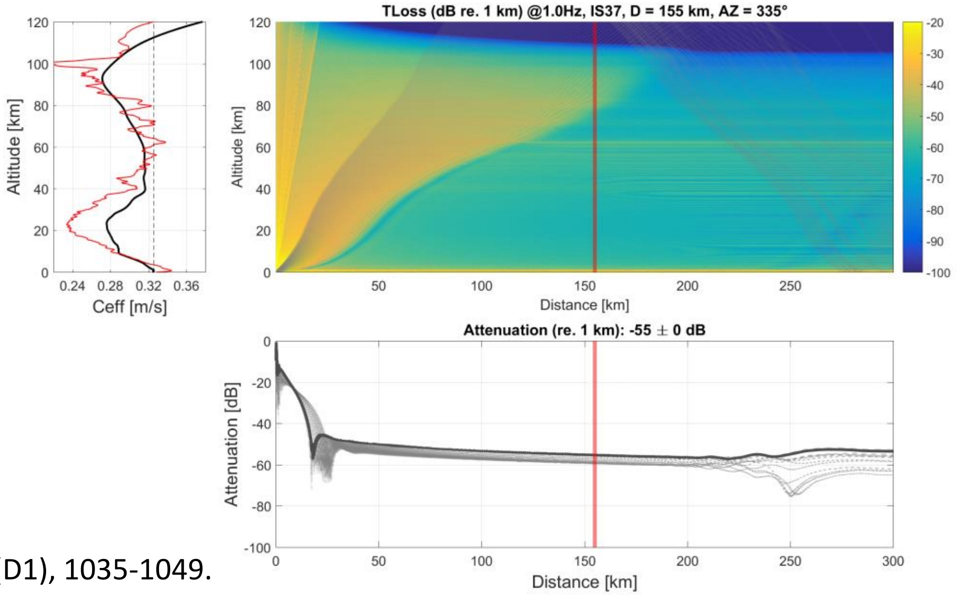
IS37 Station full-waveform simulations with parabolic equation at 1Hz. We include gravity wave perturbations as indicated in Gardner et al. 1993 to simulated waveform propagations.
Gravity wave perturbation helps to model to get better on explaining the infrasound arrival to IS37 however this is not enough.

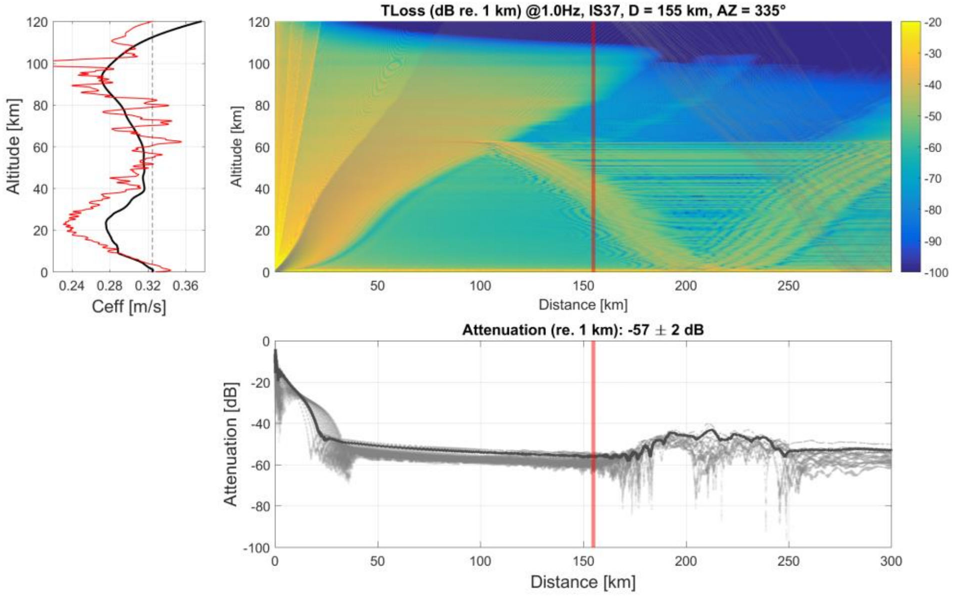
The red line shows the source – receiver distance.



Without gravity wave perturbations

With gravity wave perturbations



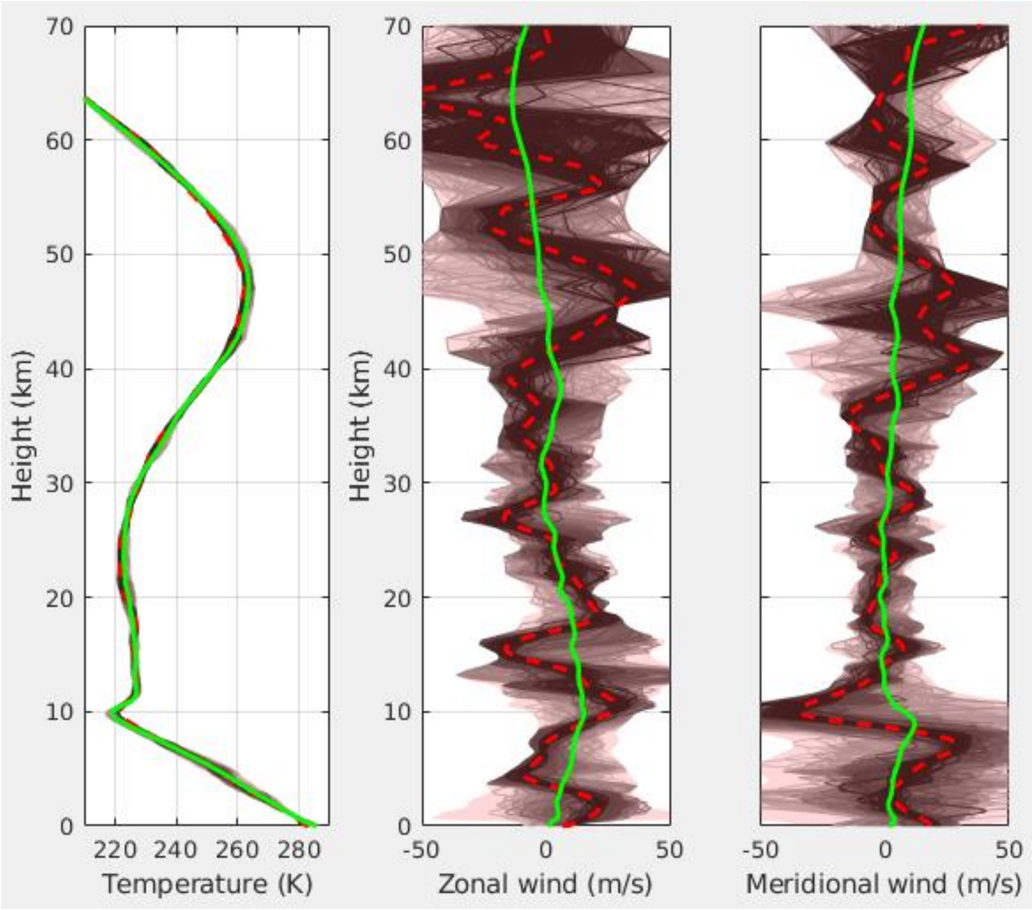


Gardner, C. S. et al. (1993).*JGR: Atmos*, *98*(D1), 1035-1049.

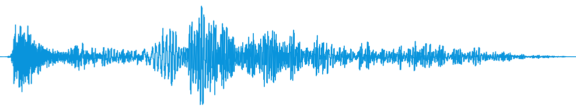
Current research: updating the atmospheric model

From the observed back-azimuth, arrival time and apparent velocity **we can build an atmospheric model that explains the detection using ray-tracing** (V. Rodriguez, 2020)

The example here shows the atmospheric model for an explosion at Hukkakero, Finland in 2019. To explain the arrivals from that explosion the initial model (- green) has been perturbed to obtain an optimized model (-- red) that recovers an unresolved southern tropospheric jet and an Eastern stratospheric flow



Note: “mine-quake events” not necessarily are the best cases for atmospheric model inversion since it’s <u>not a sequence of events</u> but we are currently running to build an atmospheric model for Kiruna



V. Rodriguez, I. et al, 2020

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Conclusions

- Kiruna minequake was strong enough to couple to the atmosphere and propagate to large distances.
- Moment tensor studies show that the source mecanism is more complex than ordinary mine collapse.
- Having a coupled study with seismic recordings we can obtain information about the cross-wind velocity, atmospheric conditions.
- Backpropagation of near-field infrasound data provided a map of seismo-acoustic coupling over the mine.
- More study about the aftershock and source mechanisms will follow. Stay tuned!

THANK YOU

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Swedish Institute of Space Physics