Approach to study the seismicity in the Perunika Glacier, Livingston Island, Antarctica

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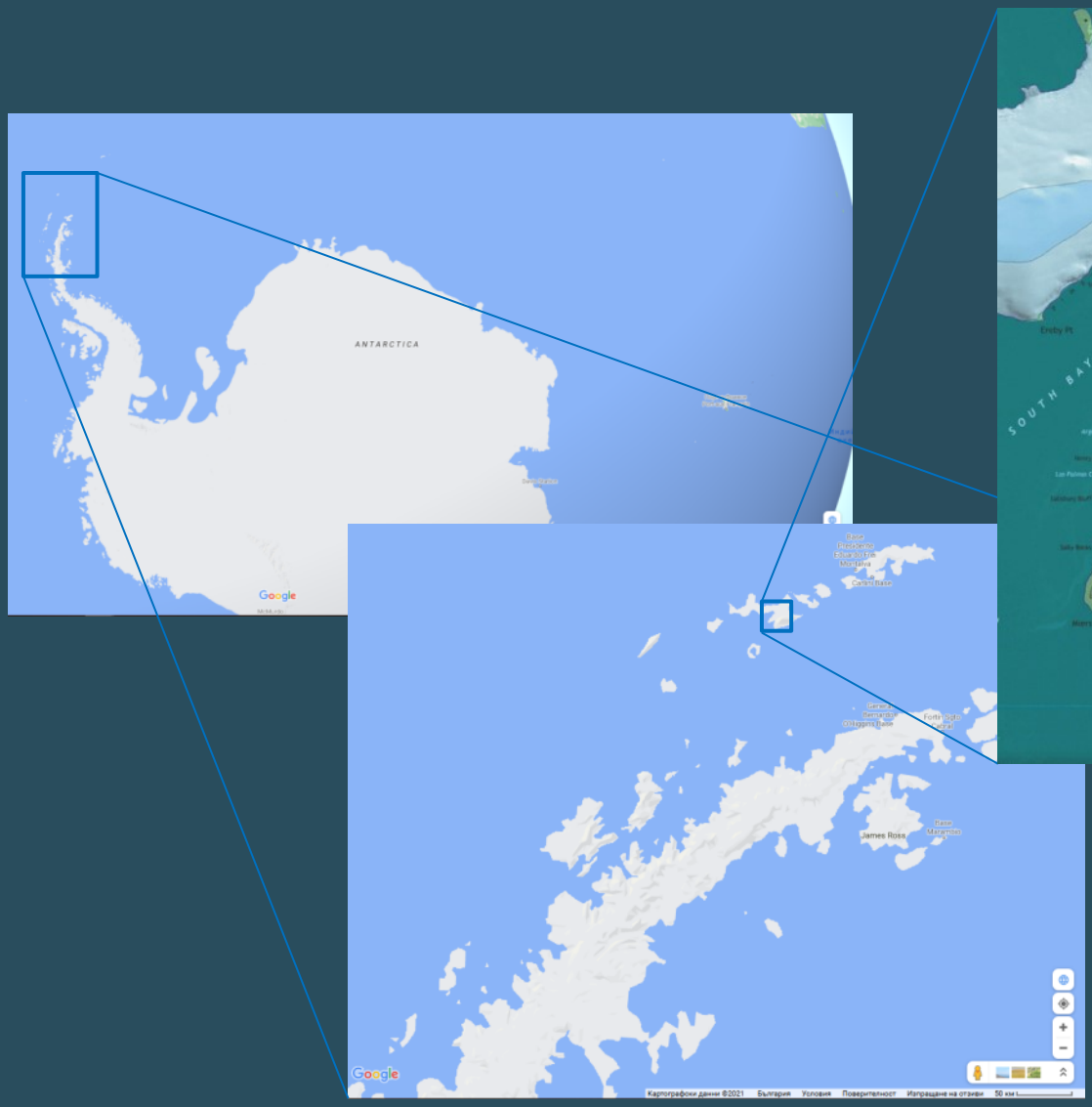
Location of the glacier and seismic station



Perunika glacier is situated near Bulgarian Antarctic Base "Sv. Kliment Ohridski"(yellow on the map) on Livingston Island, Antarctica. Seismic station is 1 km far from the Base – red star on the map.

Seismic station

Station LIVV is situated on Livingston Island close to the calving zone of Perunika glacier and 1 km away from Bulgarian Antarctic Base „Sv. Kliment Ohridski". The seismological equipment comprised of a broad band (BB) and a short period (SP) seismometers and a 24 bit Digital Acquisition System (DAS) with GPS timing and two 4GB internal memory cards. Both seismometers were installed on a concrete pillar previously constructed on an outcrop. Seismometers were oriented according to the geographic North – a correction was made for the declination of 12°. Isolation cover was mounted over the sensors which ensured stable environment during the deployment period. Data were recorded continuously at 100 Hz sample rate on the memory cards.

Seismic station

From 2015 until 2018 the station was seasonal and was located on a hill with coordinates 62° 38′ 11″ S, 60° 20′ 89″ W . Seismic equipment was installed on a concrete pillar previously constructed on the outcrop. This location was selected because it was one of the few free from snow in December 2015 and the closest suitable place to the glacier .

In 2020 due to the strong wind in the winter a new place (with coordinates 62° 38′ 9″ S 60° 20′ 45″ W) for seismic station was found. It is closer to the glacier and on the lee. The seismometer was placed directly on the rock and the isolation cover was mounted again. The seismic station was left in recording status for the winter.

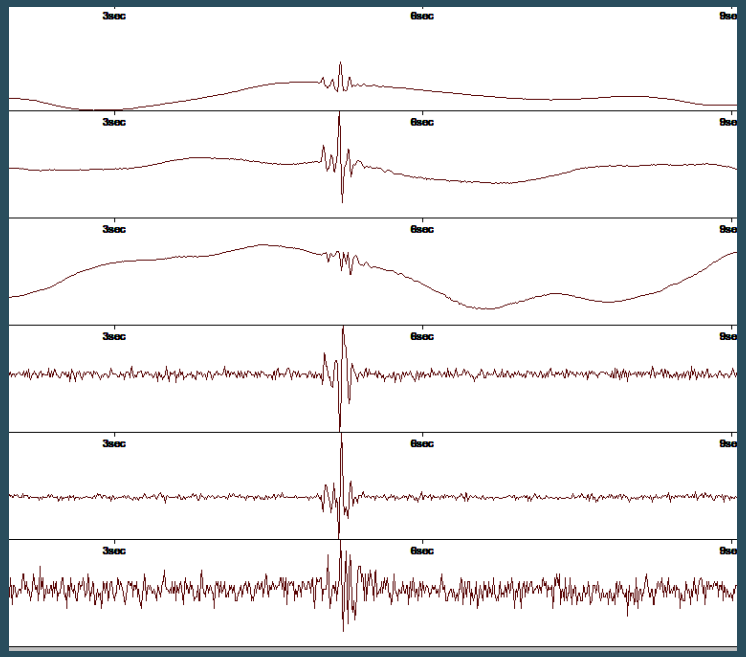
Location of SS LIVV until 2018

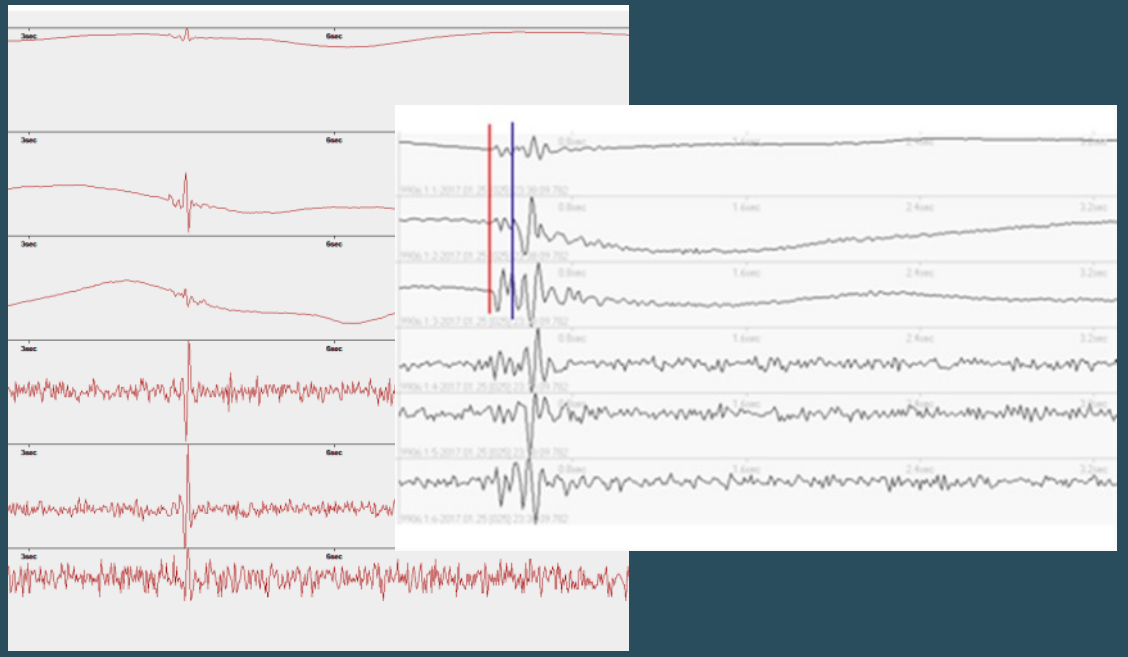
Location of SS LIVV in 2020 and now

Registered events

During the operational time of seismic station more than 16000 icequakes were recorded. Its duration varies between less than a second and more than a minute. A few events are several minutes long.

Some of the recorded events with duration between 1 and 3 s were localized. The coordinated of events epicenters were computed using a code for earthquakes single station localization developed by the project team. The code was developed for localization of recorded earthquakes.





Single station location

This method developed by Golitsyn is based on analysis of the seismic signals recorded at one three-component seismic station. Distance to the earthquake's epicenter is computed from the difference between arrival times of P- and S-waves and travel-time tables. Velocity model for the Back arc region of South Shetland Islands limited up to 70 km depth was used to compute the travel time table.

The back azimuth of the epicenter is computed by formula:

$tg\alpha = Ae/An$

where Ae is the amplitude of P phase, registered on E-W component of the seismogram, An is P phase amplitude from N-S component and α is the back azimuth (BAZ) of the earthquake. Both amplitudes are measured positive or negative. The sign of P phase from vertical component estimates the real back.

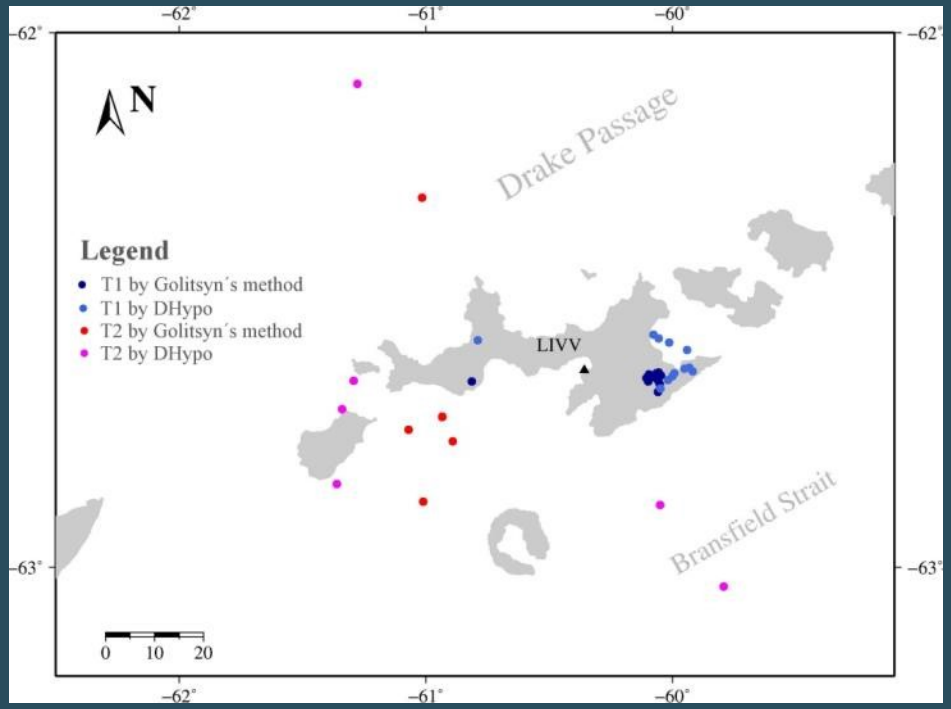
After the BAZ and distance of each event are computed Vincenty direct equation is used to compute the geographic coordinates of the epicenter.

For automatic localization of events a software code based both on Golitsyn's method and Vincenty formulae was developed.

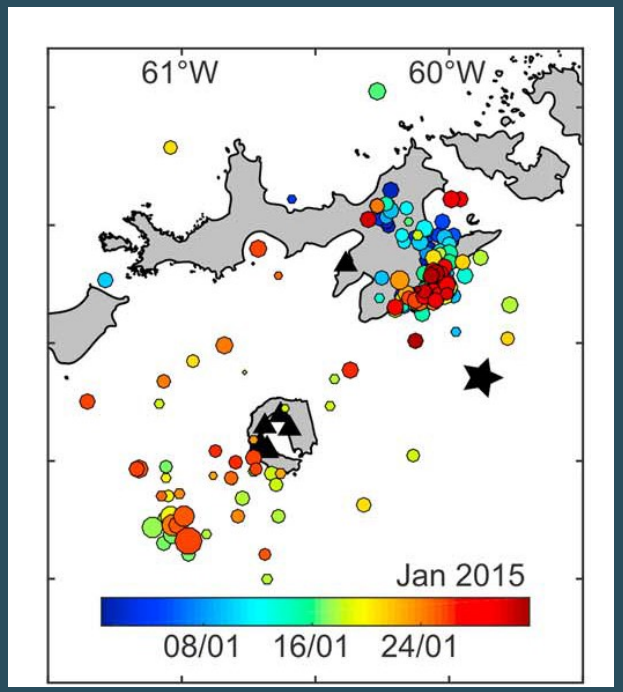
Code is published in *L. Dimitrova, G. Georgieva, P. Raykova, V. Protopopova, I. Aleksandrova, M. Popova, D. Dimitrov, V. Gourev, R. Raykova, D. Solakov. SEISMIC ACTIVITY OF SOUTH SHETLAND ISLANDS: RESULTS FROM FIRST BULGARIAN BROAD BAND SEISMIC STATION IN ANTARCTICA, Jubilee Edition of the Annual of Sofia University 130 years Sofia University and 55th anniversary of Faculty of Physics , 35-53*

Single station location

The developed code was applied successfully for localization of earthquakes from 2015 near Livingston island. Left in blue are epicenters estimated using single station localization (dark blue) and standard minimization procedure and data from 3 or more stations (light blue). Right epicenters estimated in parallel study.



Dimitrova et al., 2019



Almendros et al., 2018 (from fig.2c)

Velocity model construction

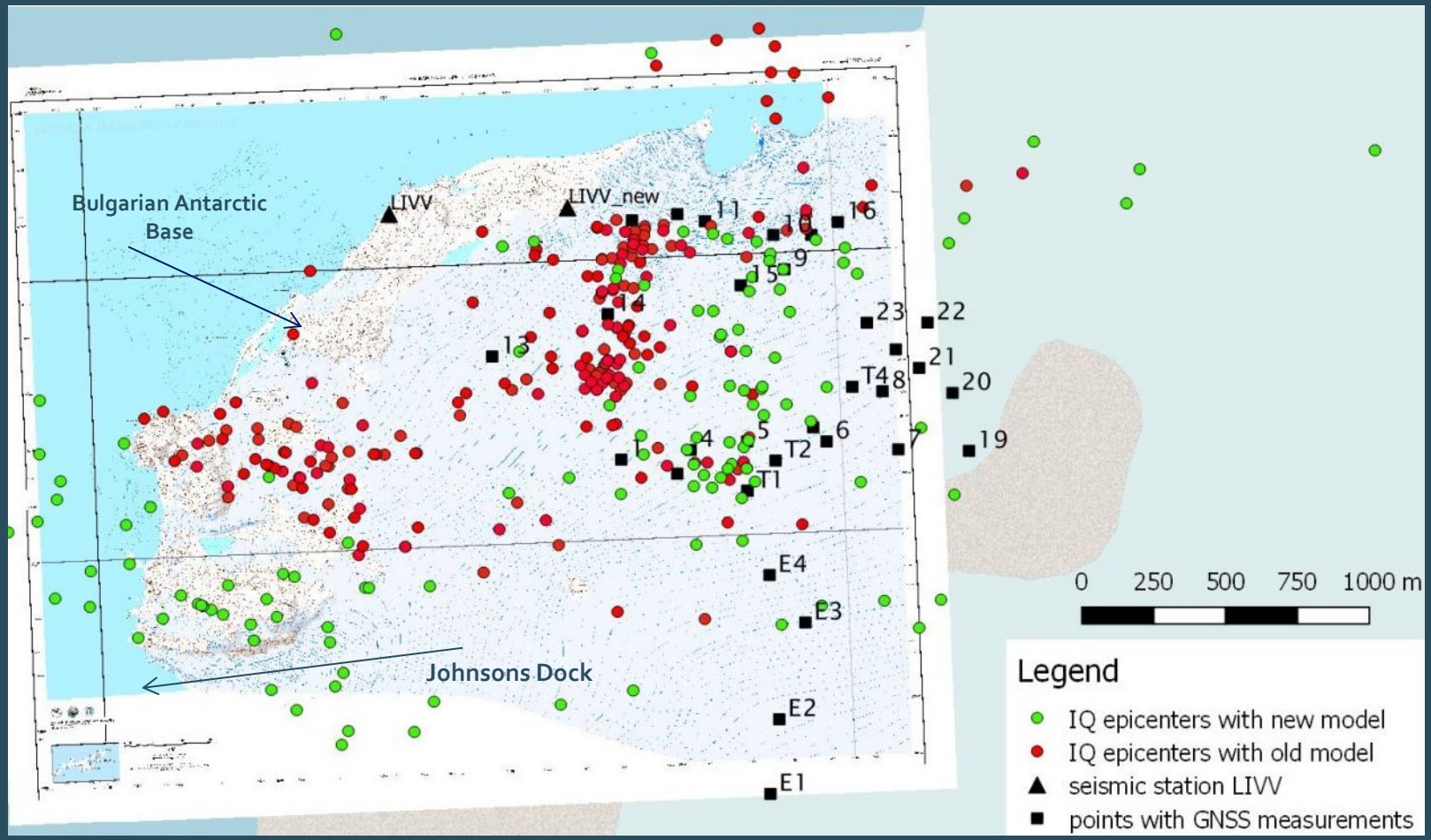
For localization of the glacial events a first travel time table was computed based on the mean seismic velocity (S) of 3000 m/s. A sample of the rock were the seismic station is installed was taken in 2020 and Vp and Vs were measured in Geophysics Laboratory of University of Mining and Geology. Results are presented in table:

A new travel time table was computed.

Name	Vp	Vs	Poisson's ratio
A	5260	3079	0,239
B	5136	3424	0,100
C	6778	3187	0,358

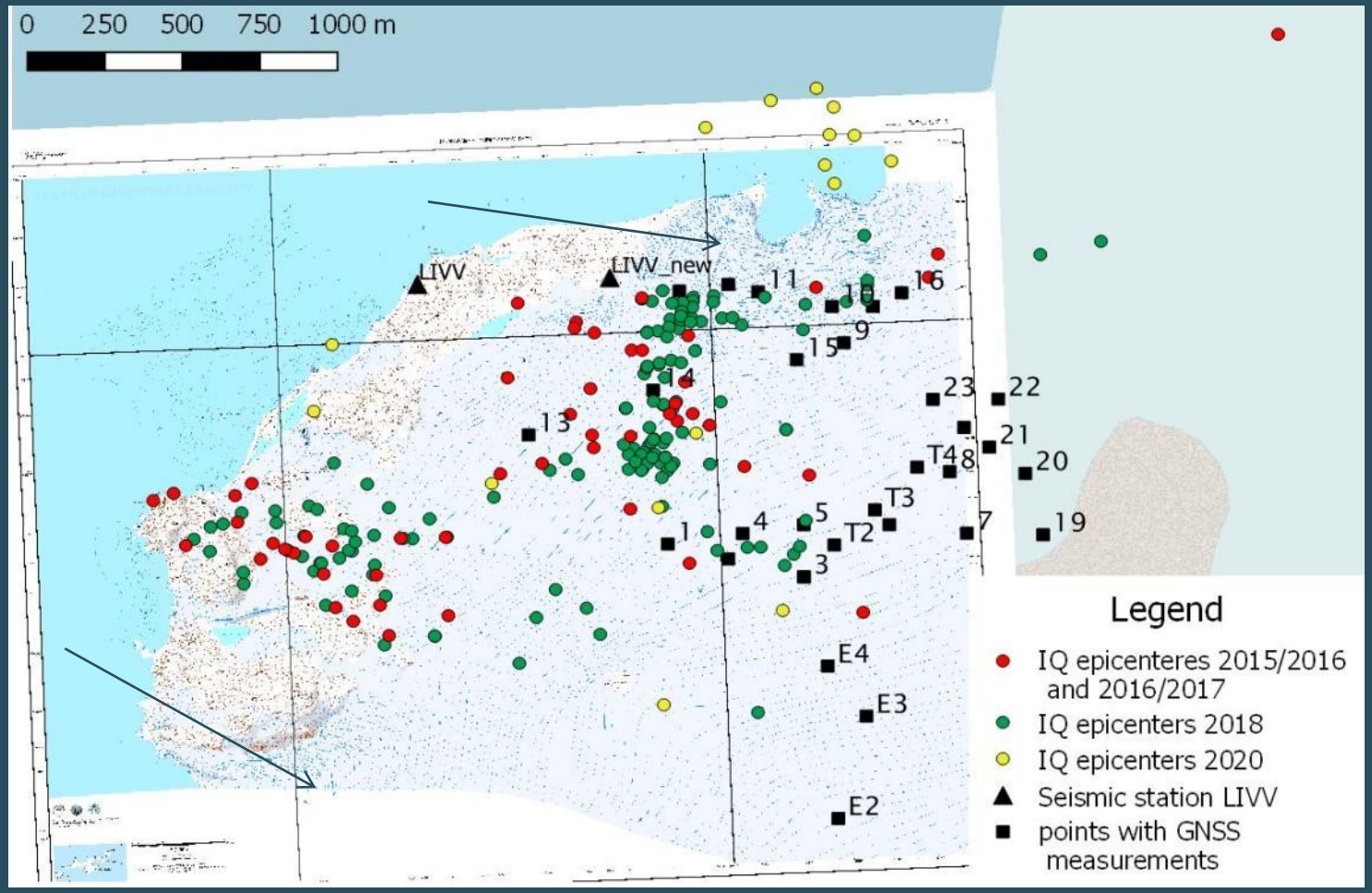
Single station location

Epicenters of icequakes with short duration were estimated with both travel time tables. As seen on the map three clusters are formed. With the new model (green) the clusters move to the more active parts of the glacier as was estimated from GNSS measurements (black). The sources of the cluster situated south of the Bulgarian Antarctic Base probably are in the part of the glacier flowing to the Johnsons Dock.

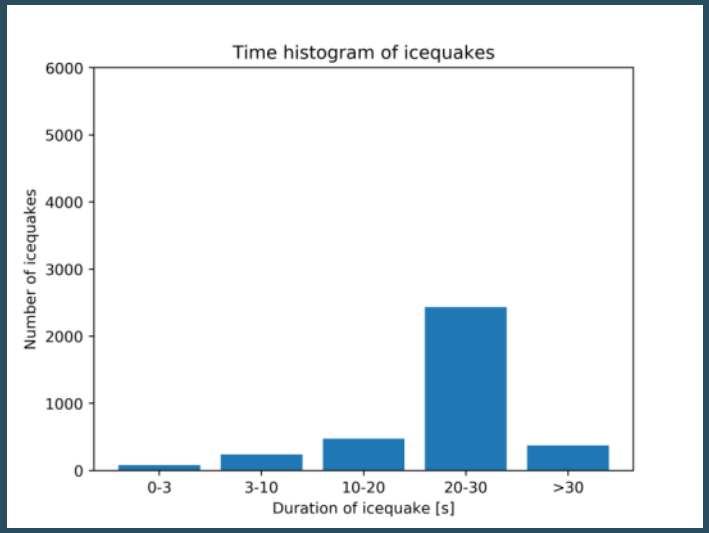


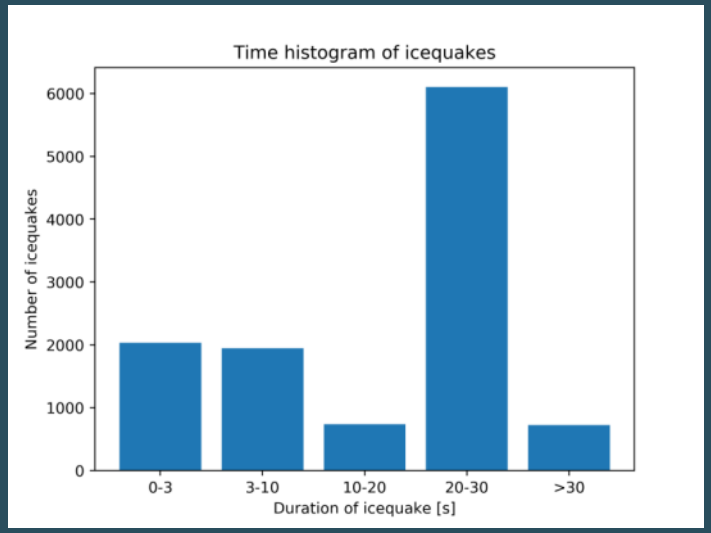
Single station location

Epicenters of the short duration icequakes plotted according to the season, when they were registered. As seen on the map most events from 2018. Epicenters from 2020 form a new cluster north-east from the station. In this part of the glacier we have observed many calvings in 2020. It should e noted that many events were not localized because of very small amplitudes on E-W or N-S component. We can see from the map (arrows) that the both very active parts of the glacier are situated in the East and in the South of seismic station.



Looking at the distribution of the icequakes according to its duration one can see that the number of events with short duration increases in 2020. It is well ween also that in first three seasons most events continue between 20 and 30 s and in 2020 most events are with duration up to 20 s. Generally every season the number of icequakes increase compared to previous which is better seen from the spectrograms on the next slide.





2016-2017

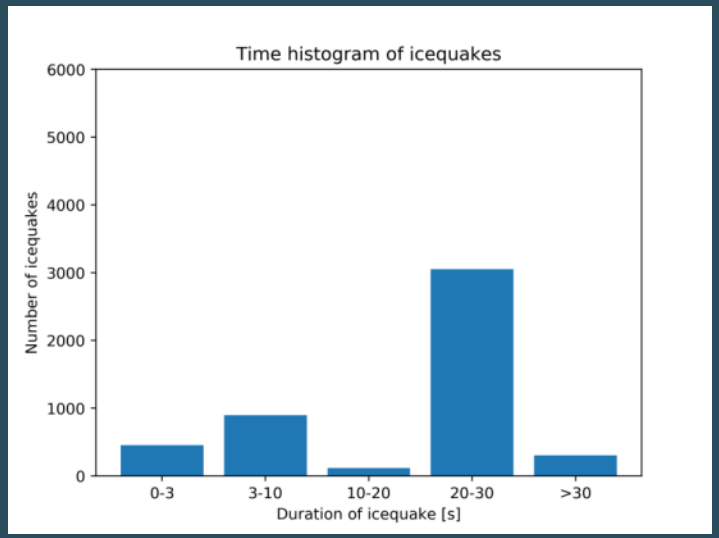
(4 months)

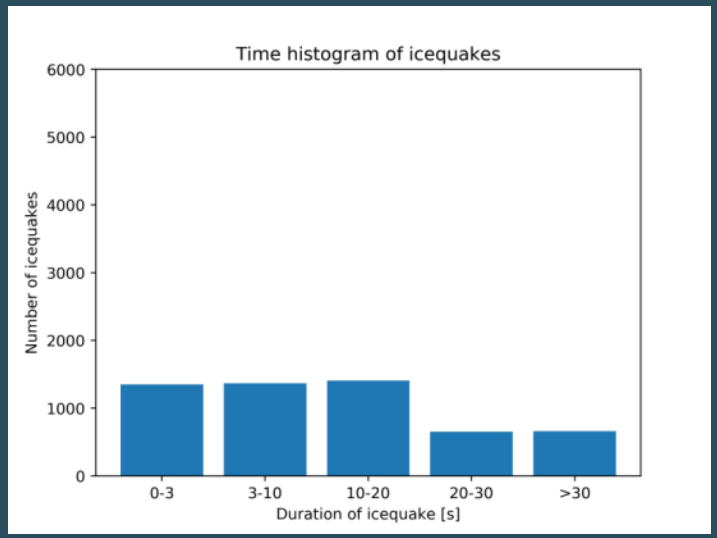
2020

(20 days)

2015-2016

(3 months)



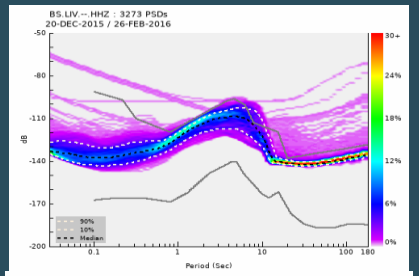


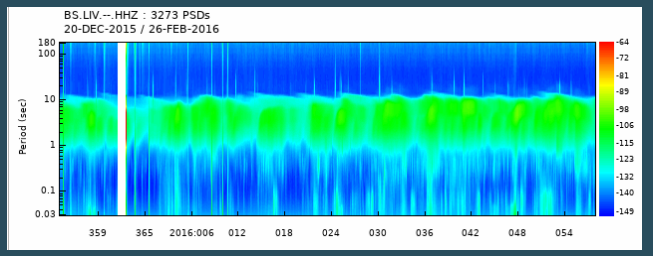
2018

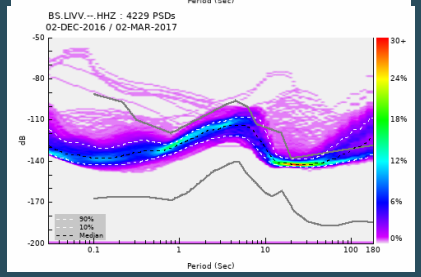
(2,5 months)

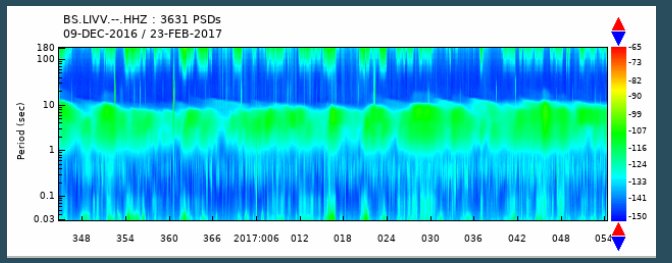
Ambient seismic noise

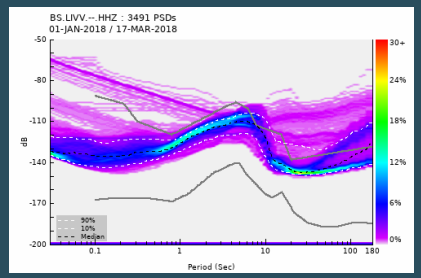
Frequency distribution of the ambient noise recorded by Z component of the LIVV station for the four deploying periods. The left panel presents the PSD PDFs and the right panel presents spectra of the noise. The short-period seismic noise between 1 and 0,1 s links to the calving activity of the Perunika glacier. Analyzing the recorded data and the distribution of PSD PDFs of the noise, it is determined that the calving at the terminus of the glacier generates energy in the 0.2 to 0.6 s period bands.

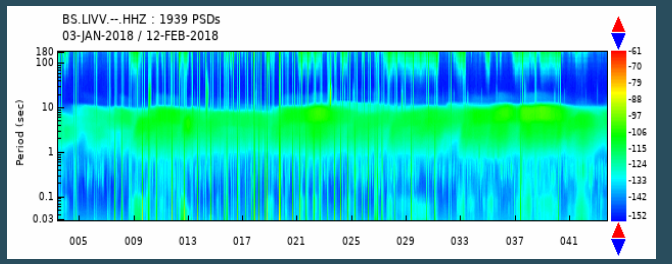


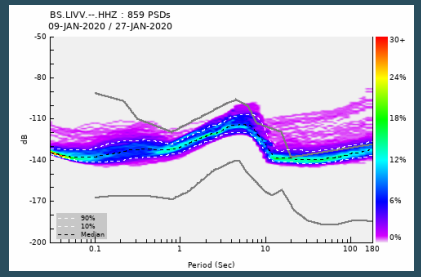


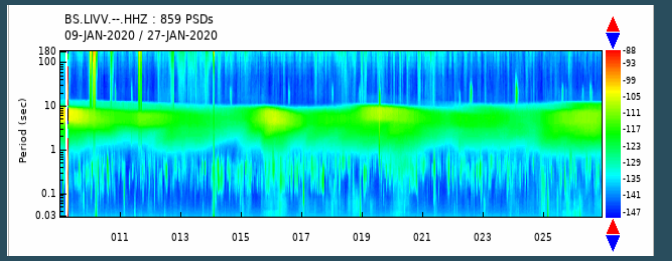












Dimitrova, L,. SEISMIC NOISE AT BULGARIAN ANTARCTIC SEISMIC STATION AND INFLUENCE FROM SITE SELECTION, International Multidisciplinary Scientific GeoConference : SGEM; Sofia, Vol. 20, Iss. 1.2, (2020), DOI:10.5593/sgem2020/1.2/s05.079

Conclusions

An approach was made to study the seismicity of the Perunika Glacier. For the recording period of four seasons between 2015 and 2020 more than 16000 glacial seismic events were registered. An increase of the number of events is observed and decrease of its duration.

Single station localization code was applied for estimating of epicenters of very short glacial seismic events (with duration up to 3 s). The epicenters are grouped in three areas from the glacier.