International Conference on the 120th Anniversary of the Bulnay Earthquake: Advances in Astronomy and Geophysics
Ulaanbaatar, Mongolia,
August 11-17th 2025

# DEBRIS FLOW MONITORING AND EMERGENCY WARNING SYSTEM

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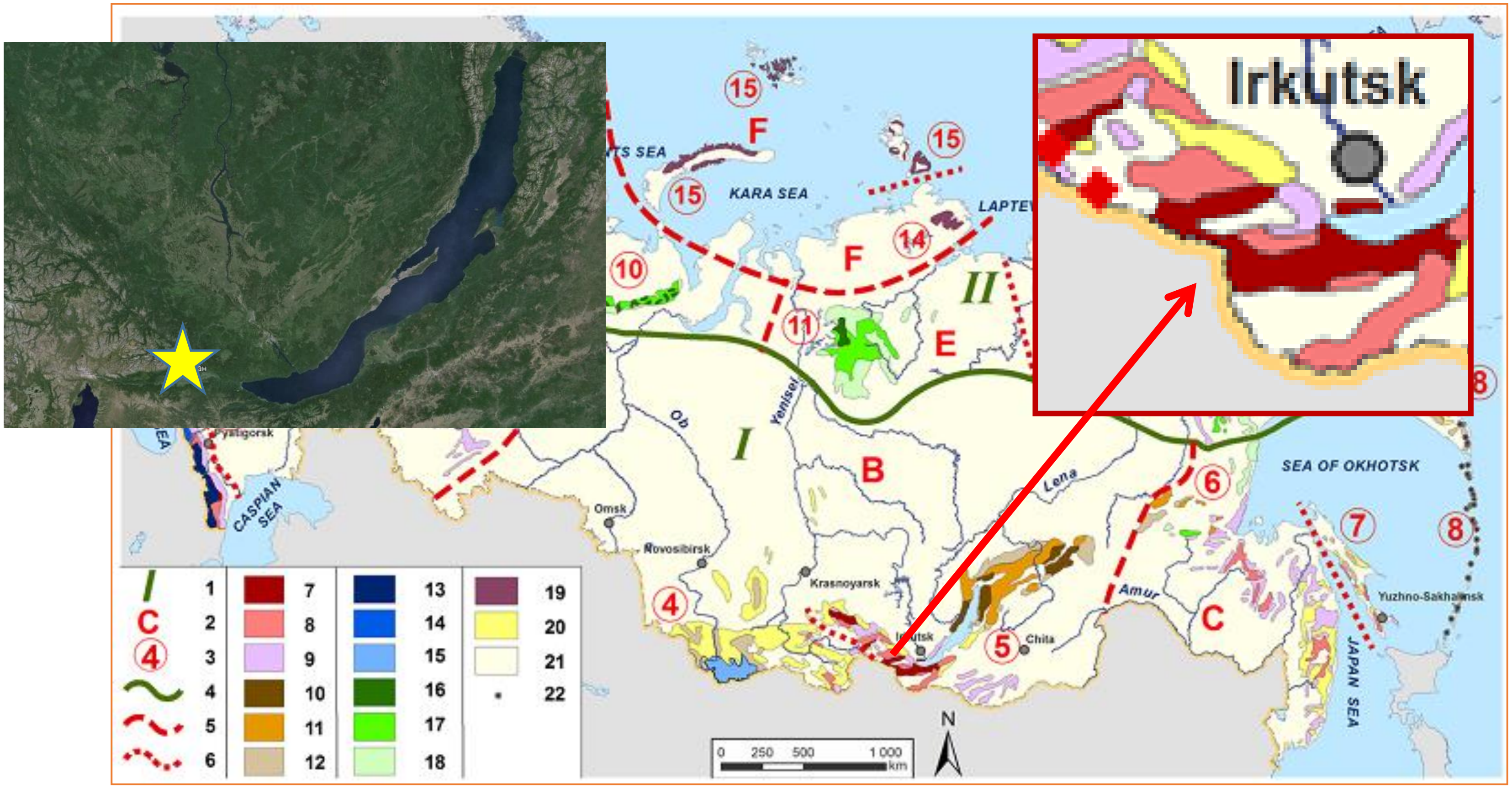
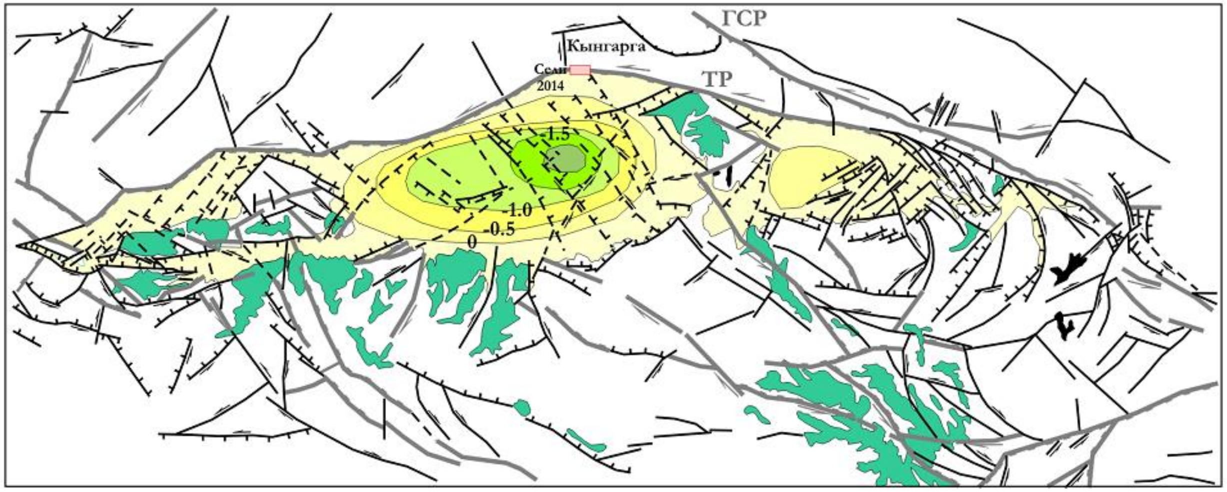
# Debris flow hazard map

[Perov et al., 2017]

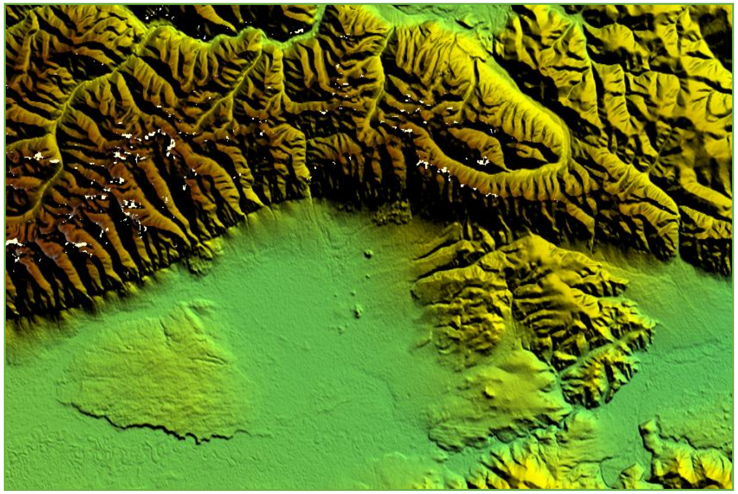


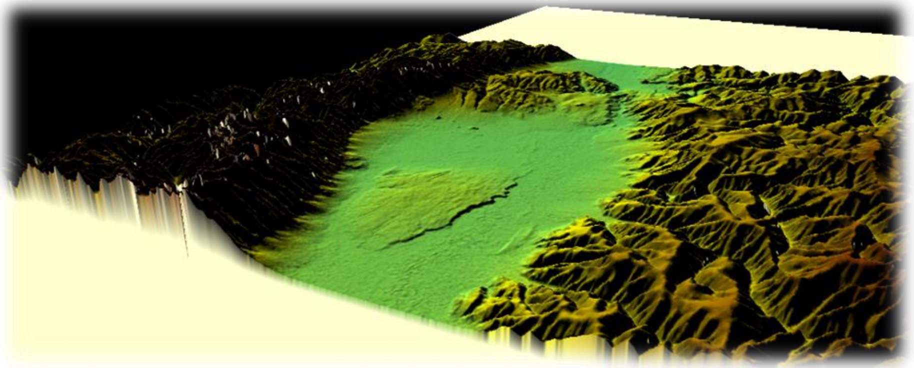

Types of debris flows and degree of debris flow activity: **rain-induced debris flows (7-high,** 8-medium, 9-low activity); rain-induced debris flows (predominant) and slush flows (10-high, 11-medium, 12-low activity); rain-induced (predominant) and glacial debris flows (13-high, 14-medium, 15-low activity); slush flows and rain-induced debris flows (16-high, 17-medium, 18-low activity); 19-slush flows; 20-territories with potential debris flow activity; 21- territories without debris flows

# Study region: Tunka basin




Geologic map *[Laperdin et al., 2014]*

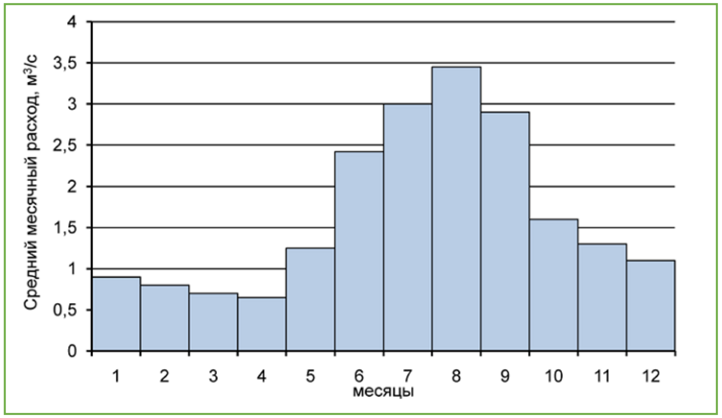




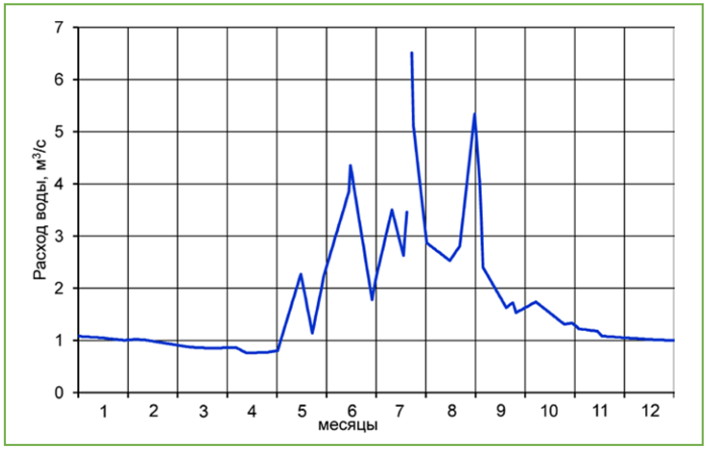
Tunka rift depression
elevation difference ~1000 m

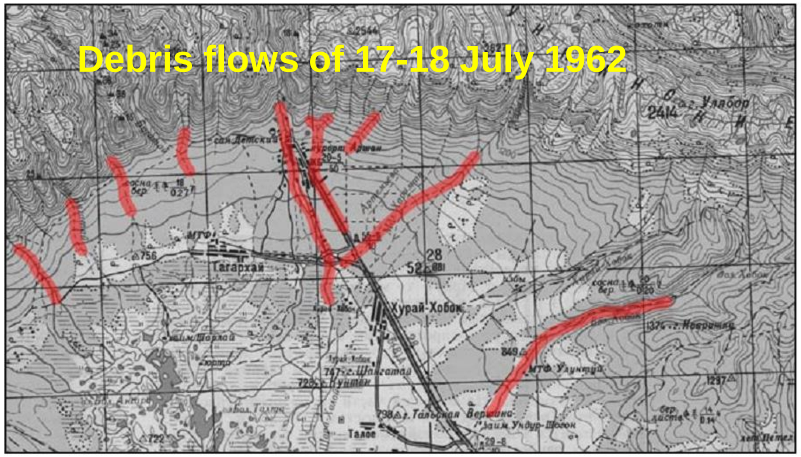
# Kyngarga river: debris flows

**Annual distribution of runoff r. Kyngarga (s. Arshan)**




**Hydrograph of the r. Kyngarga (settlement Arshan), 1984**



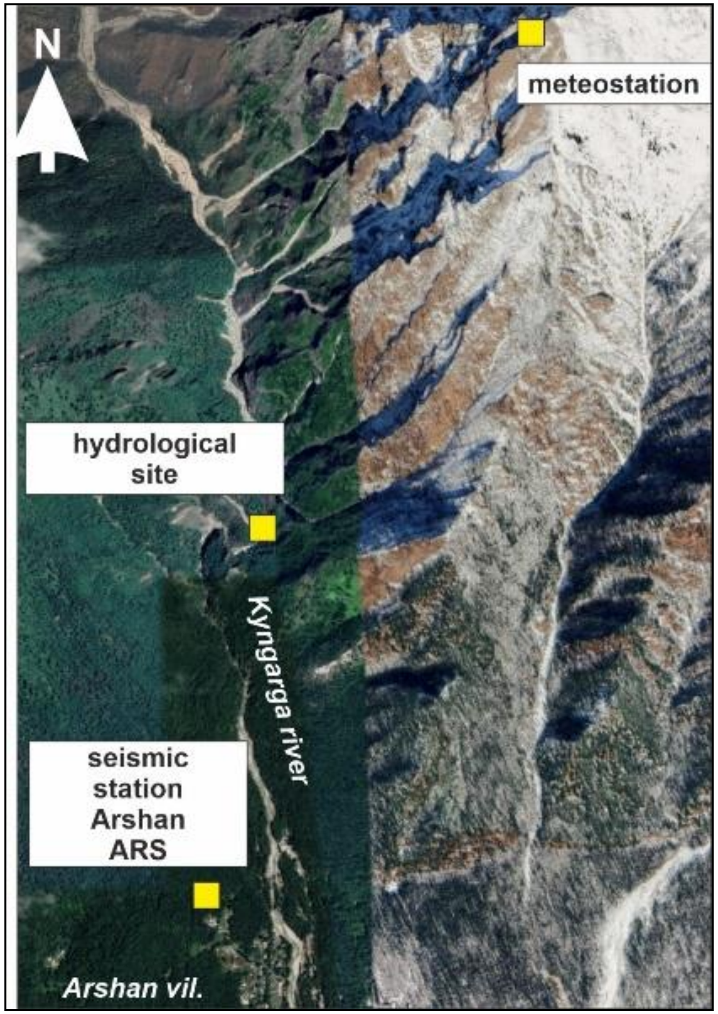



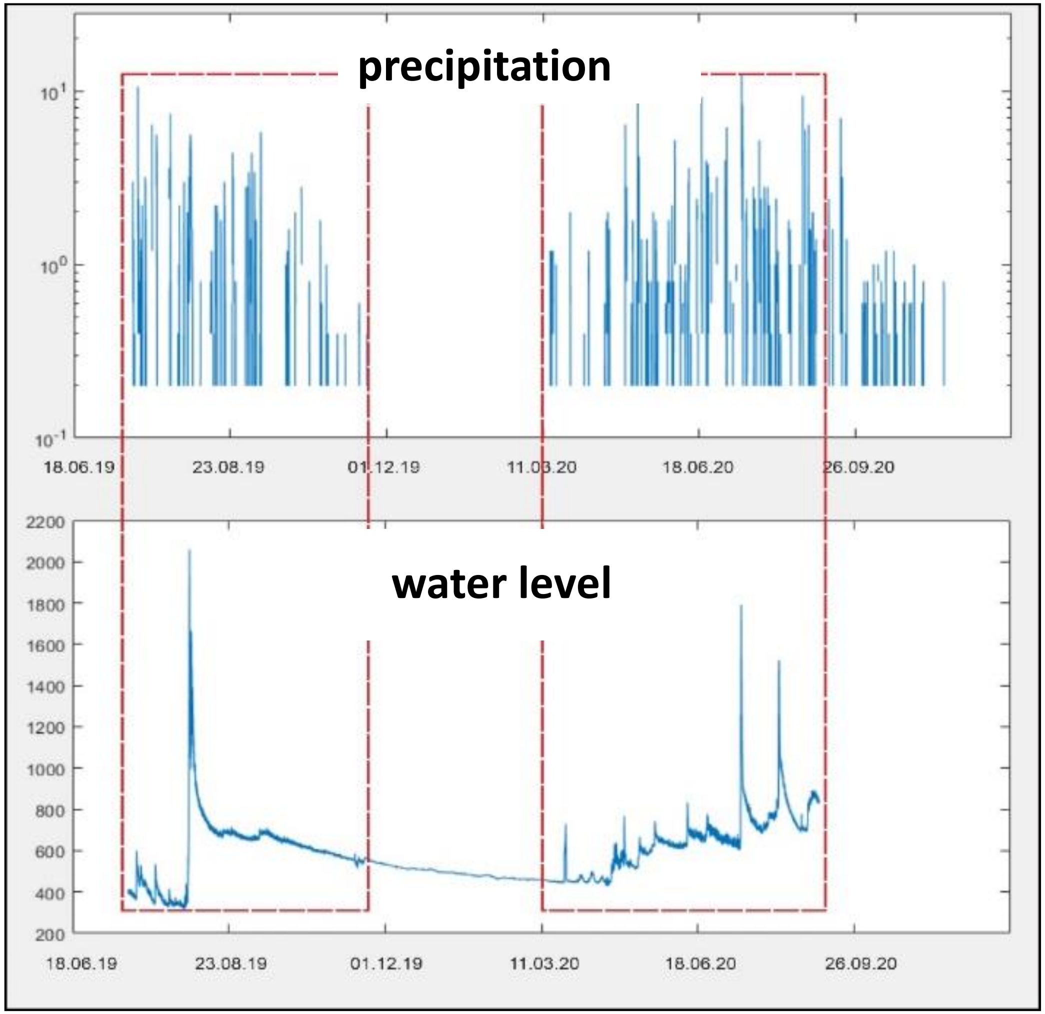

*[Makarov et al., 2014]*


*[Laperdin et al., 2014]*

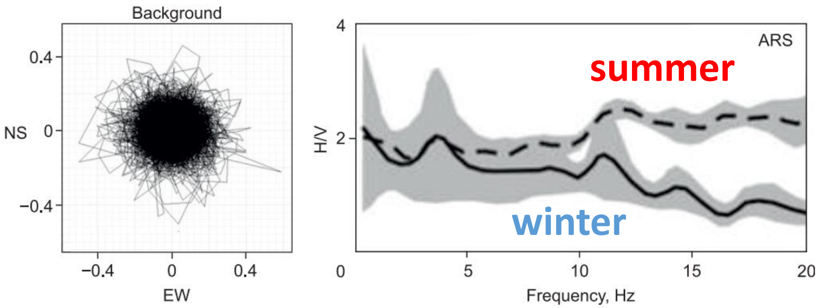
# Kyngarga river: location of instrumented sites

**Rain gauge at Peak of Love (Tunkinskie Goltsy)**: 51°56'44" C, 102°26'24" B, elevation 2100 meters)
**Hydrological post (Kyngarga river)**: 51°55'53.75"C, 102°25'29.50"B, elevation 1044 meters)
**Seismic station Arshan (village Arshan**:  51°55'12.15"C, 102°25'18.51"B, elevation 931 meters)

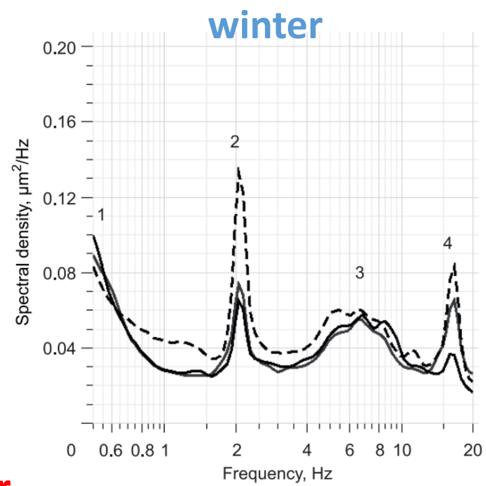


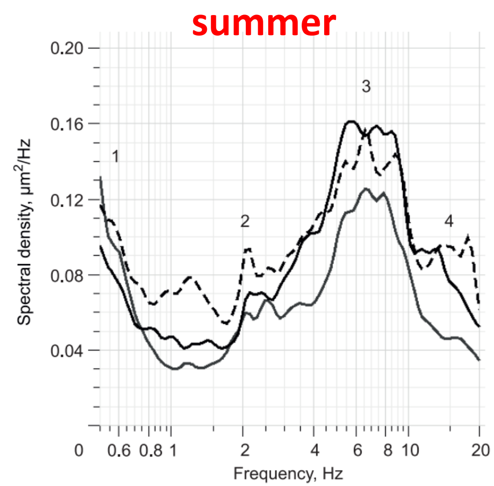



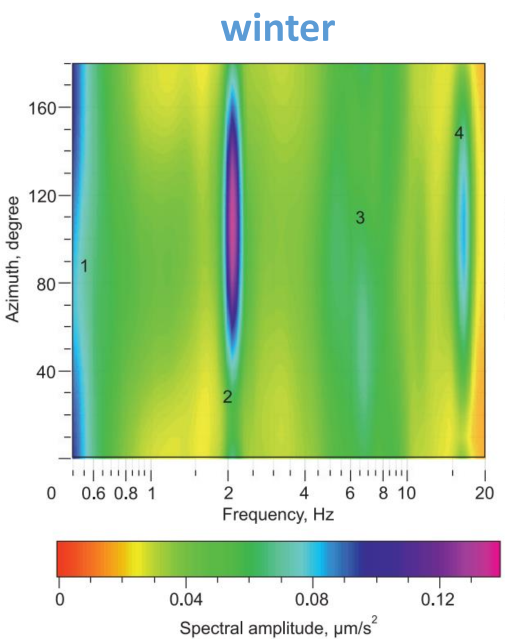
# Seismic ambient noises: stable situation

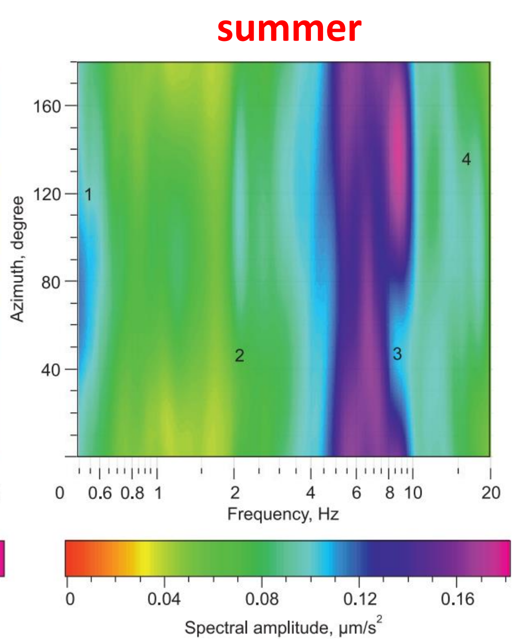



[Chechelnitsky et al., 2017; Dobrynina et al., 2018]



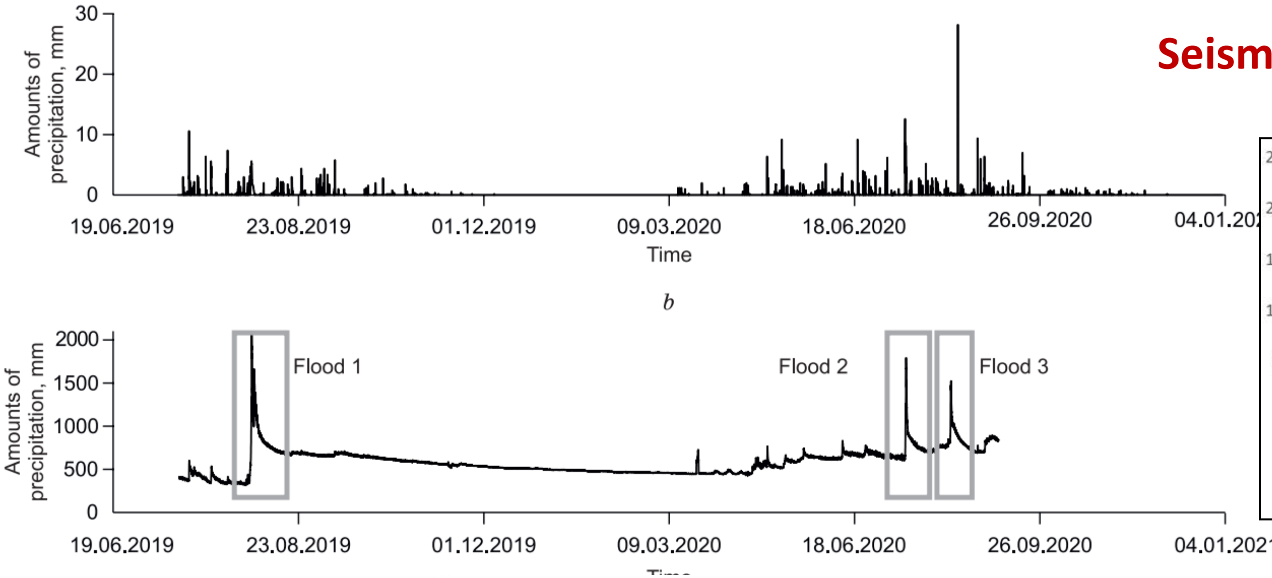



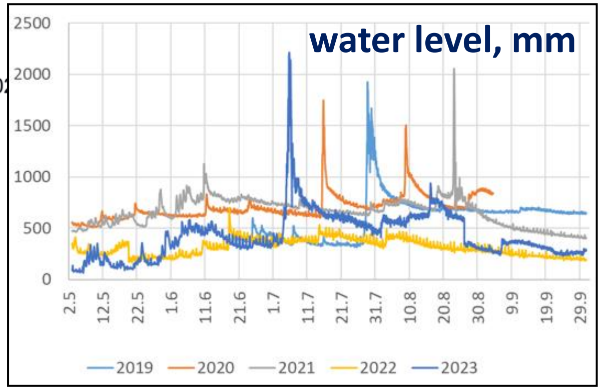



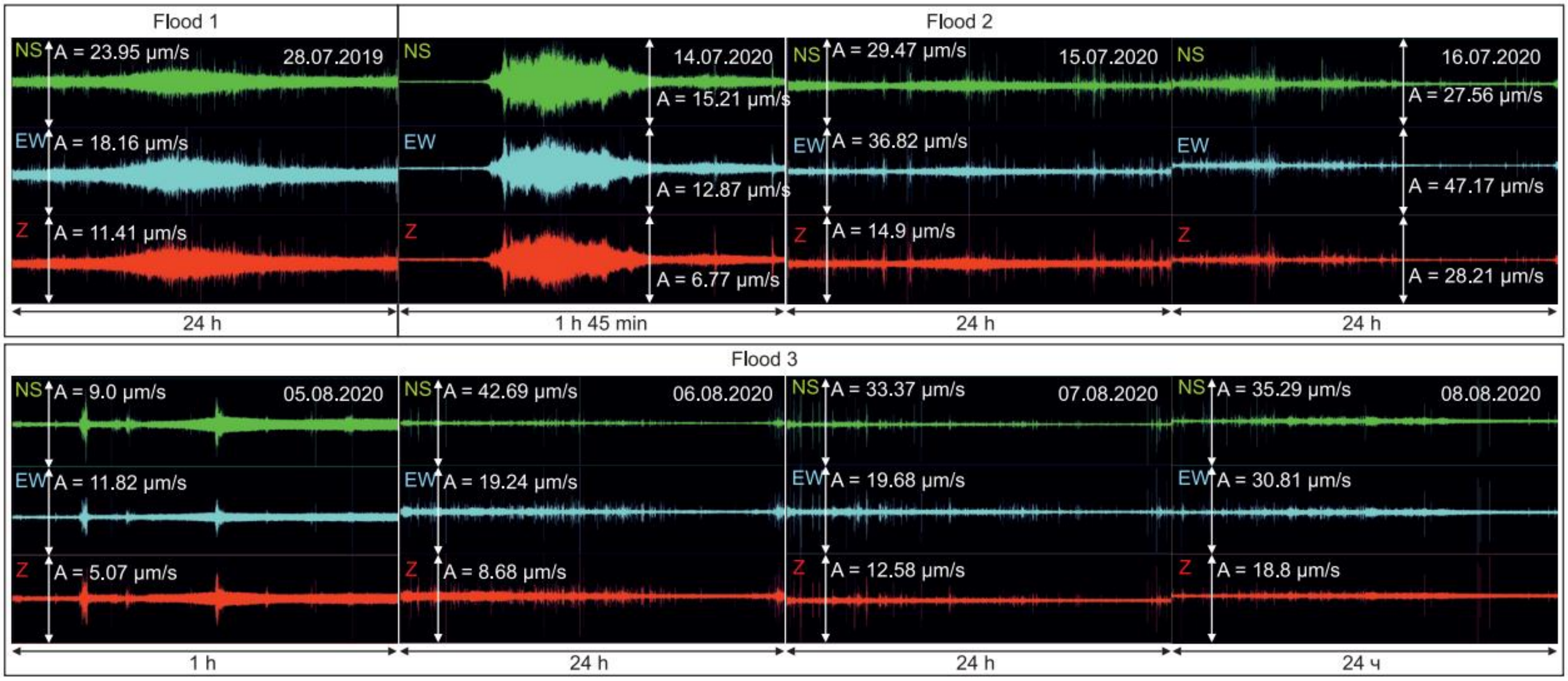




Background fluctuations of ambient noise at the Arshan station are a superposition of low-frequency fluctuations (up to 1 Hz) associated with microseisms of Lake Baikal, constant fluctuations with frequencies of 2 and 16 Hz, polarized in the east-west direction (peak No. 2 with azimuths of oscillations of 50 ÷ 170 ° + π and peak No. 4 with azimuths of 80 ÷ 130 ° + π), and oscillations in the frequency range of 4–10 Hz associated with the flow of water along the bed of the Kyngarga River

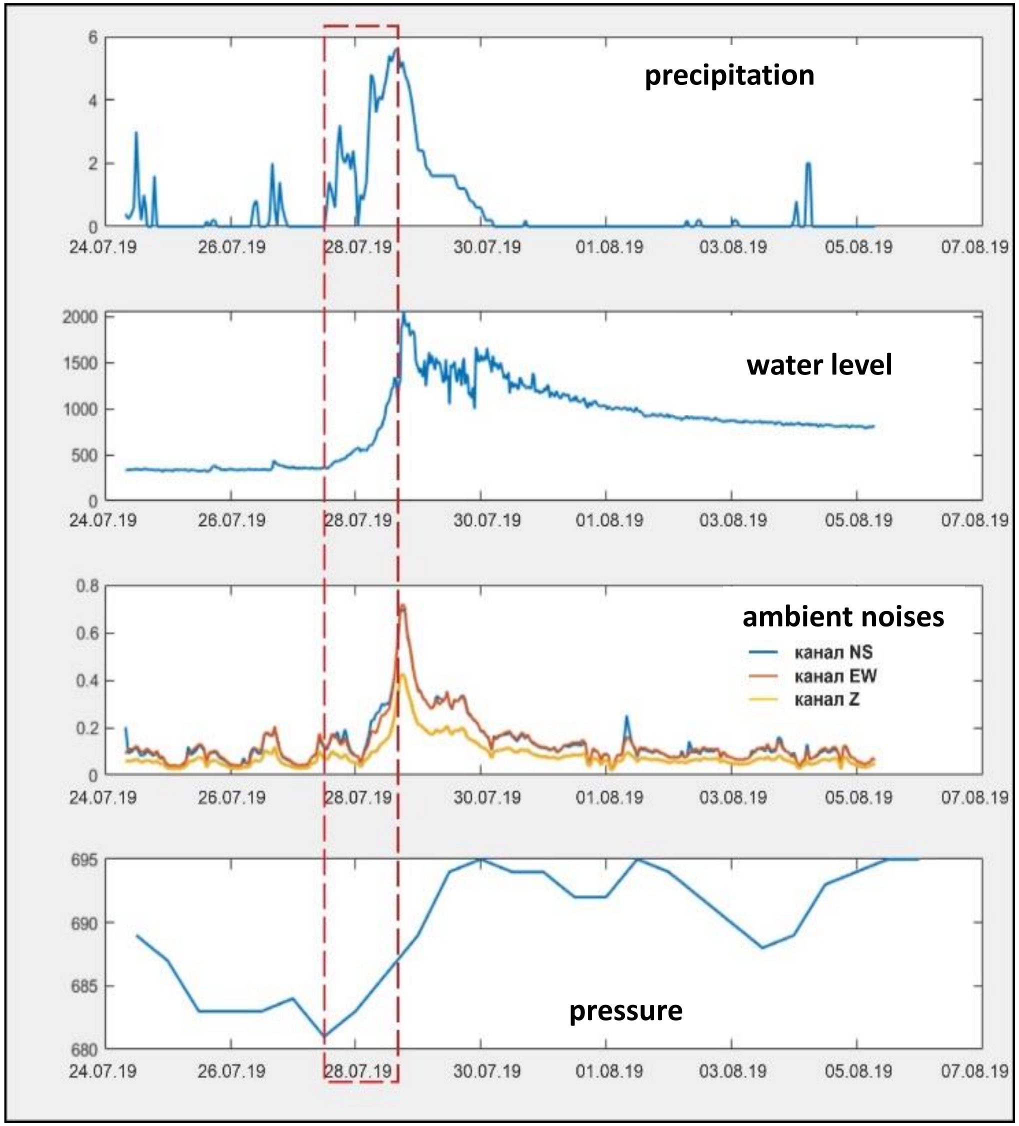
# Seismic ambient noises: floods



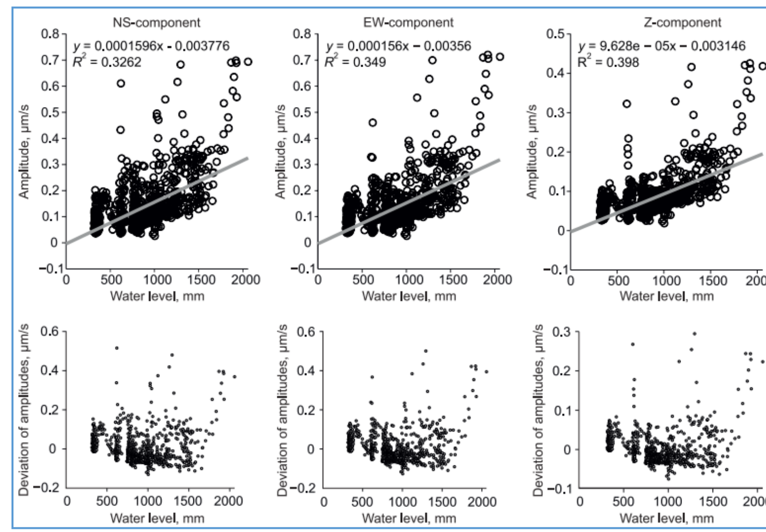



# Seismic ambient noises: floods




Dependence of ambient noise amplitudes on the water level in the Kyngarga River for three channels. For each channel, the regression dependence and determination coefficient are shown, and at the bottom is the deviation of the observed values from the straight regression

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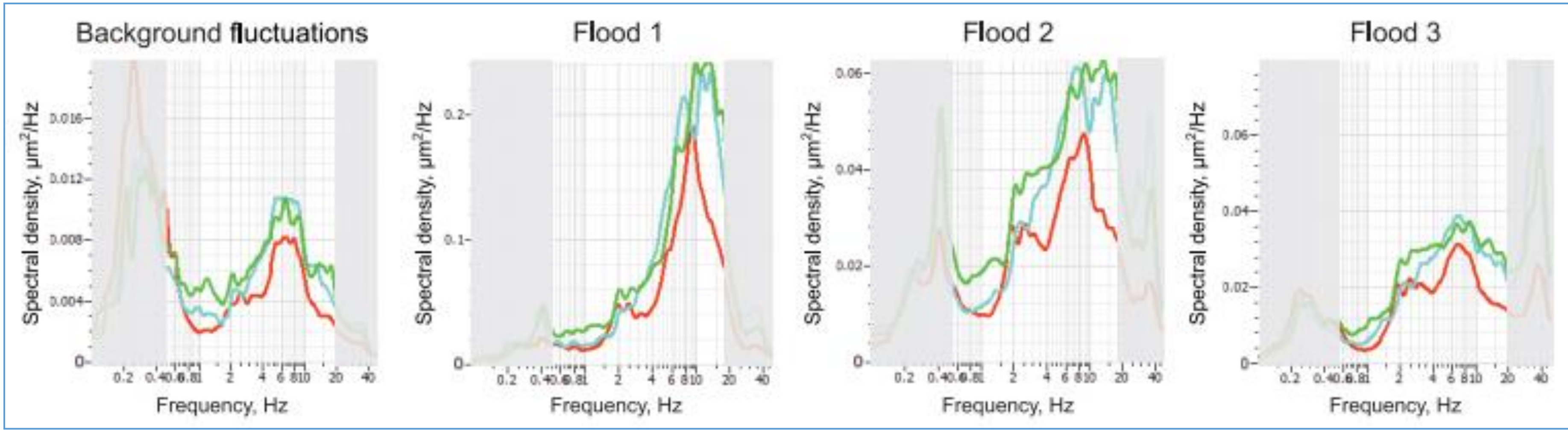
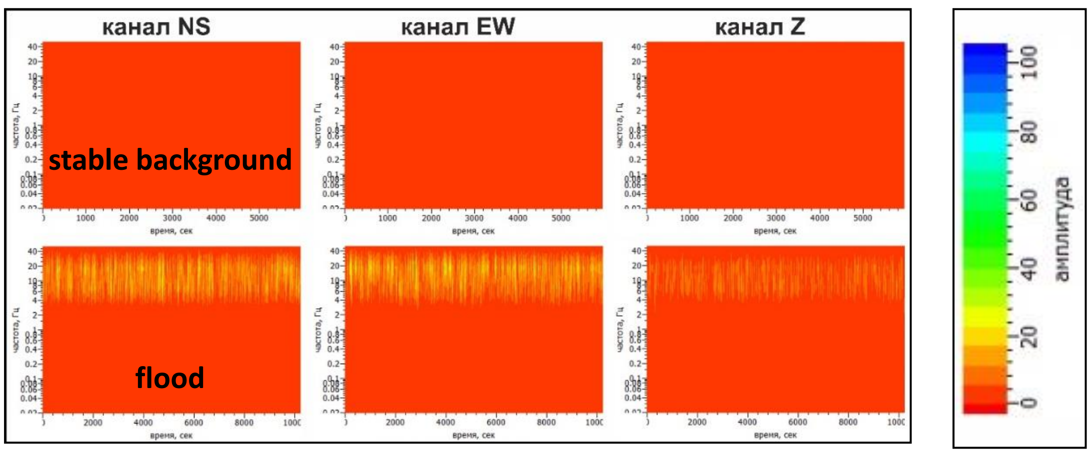
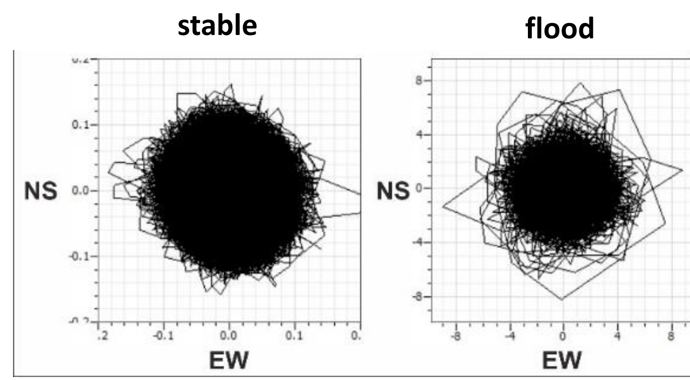
# Seismic ambient noises: floods



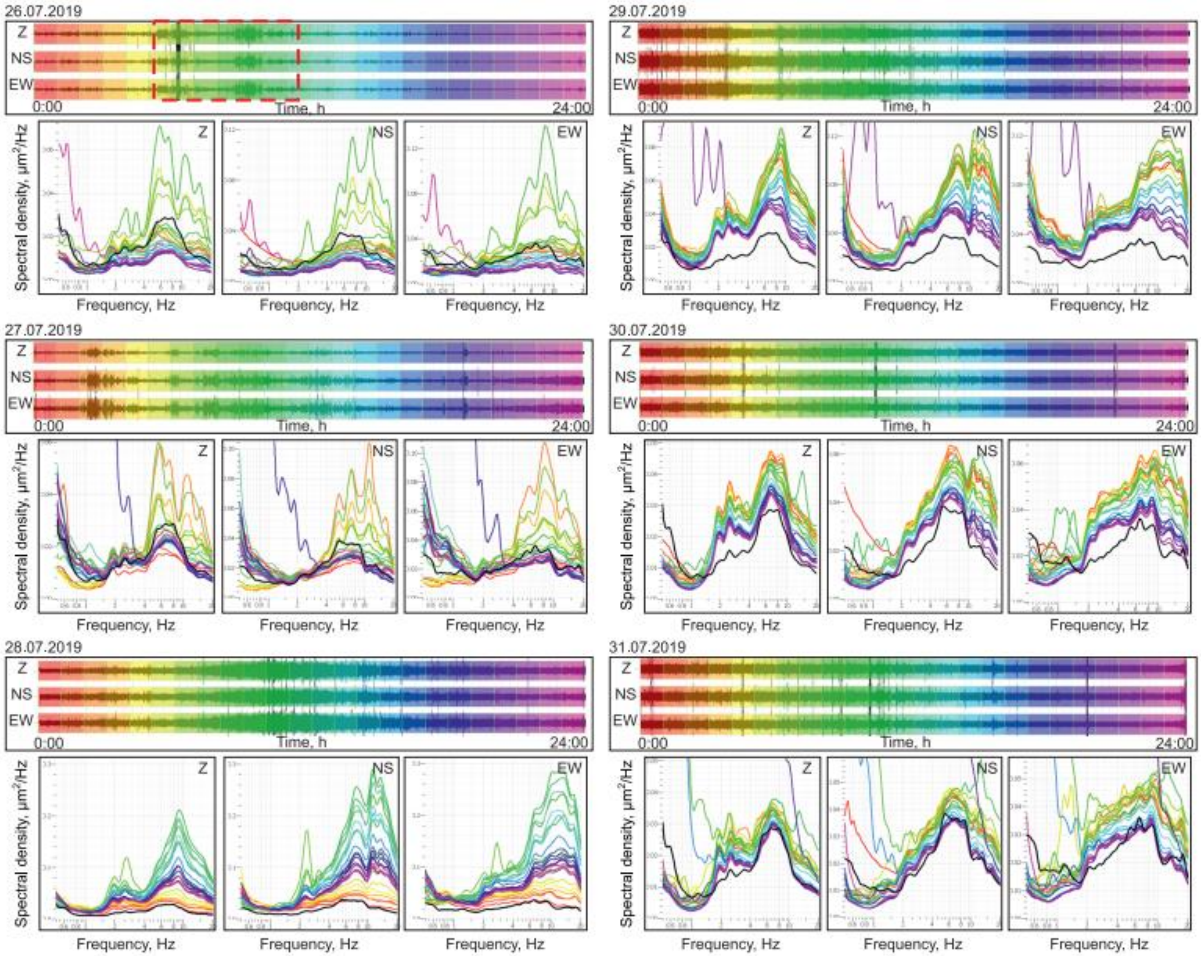

When a large volume of water passes through (during floods), the high-frequency component of ambient noise increases significantly. The peak at low frequencies (up to 1 Hz) is also preserved, but its amplitude, although increasing, becomes significantly less than the amplitude of the high-frequency peak.



# Seismic ambient noises: floods

Dynamics of ambient noise variations before, during and after flood 1: period from 26 to 31 July 2019. The maximum radiation for background oscillations is in the range of 4–10 Hz, while for radiation during the period of water rise it shifts to the high-frequency region – up to 20 Hz and is a wide band from 4 to 20 Hz with a maximum on the horizontal components



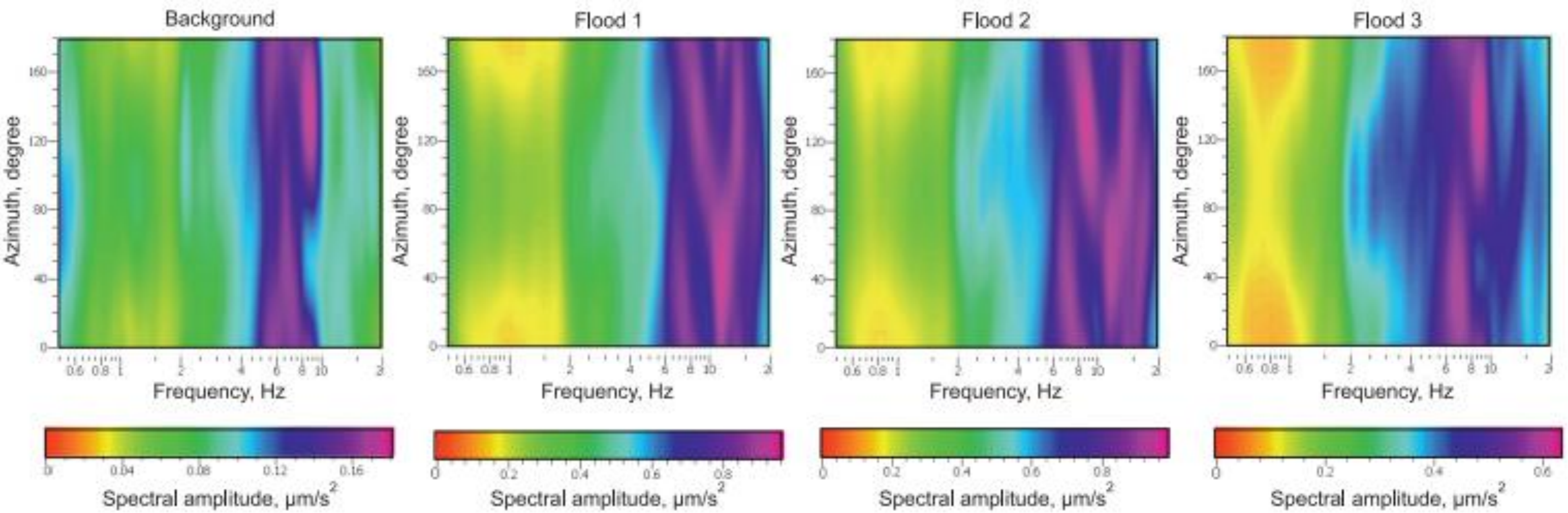

black curve – stable conditions

# Seismic ambient noises: floods

The diagrams of particle motion in the medium during the passage of seismic waves during a flood do not show a specific, clearly expressed orientation of the oscillations.

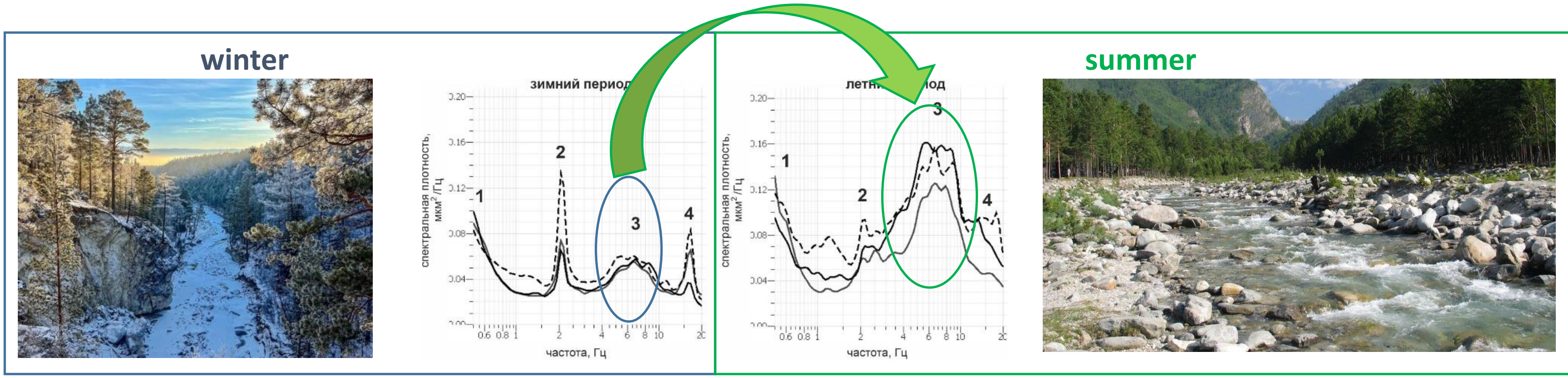
The chaotic nature of the oscillations indicates that their source is not strictly localized in space, although individual fluctuations in the radiation intensity maxima by frequency are observed.

In the background mode, the maximum emission of seismic waves falls in the range from 4–5 to 10 Hz, while for floods it shifts to the high-frequency region – from 6 to 18 Hz, and for different floods the distribution of emission by frequency is different.



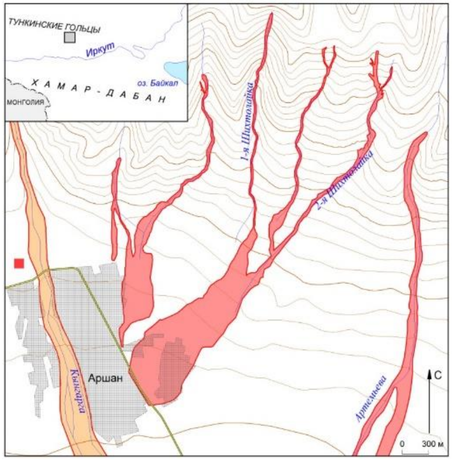
# Seismic ambient noises

Water flow + physical obstacles (bottom and sides, boulders, large stones) = generation of seismic waves due to **turbulence**

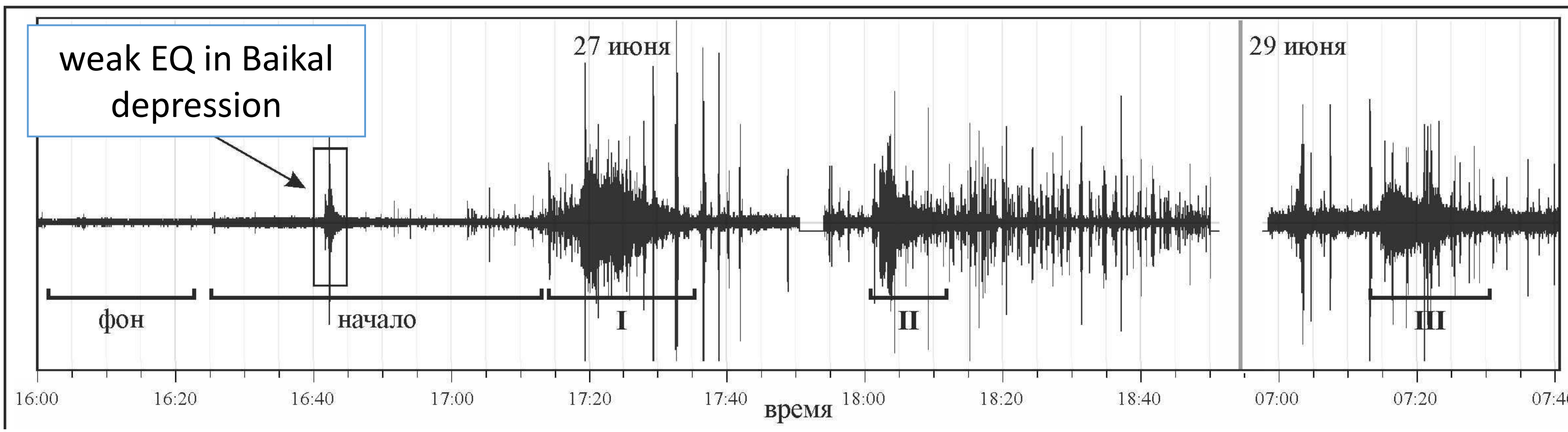



When large volumes of water pass through ⇒ the flow speed and the number of obstacles increase ⇒ increased turbulence ⇒ increased amplitudes and a change in the prevailing frequencies of oscillations

# Water-stone debris flow on the Kyngarga river, 2014





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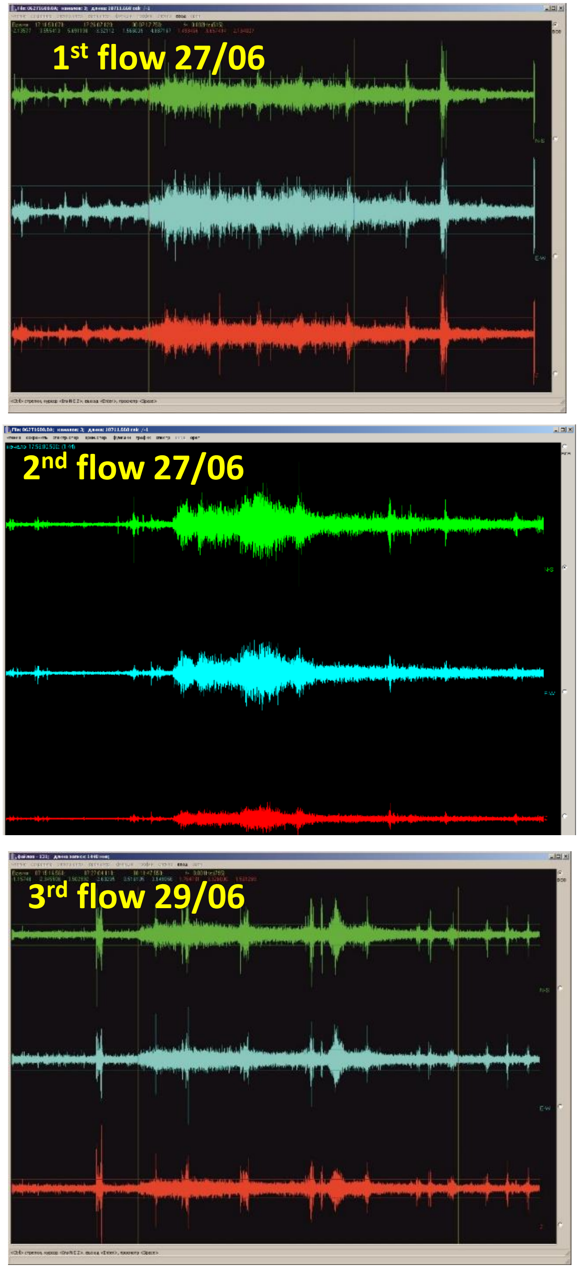


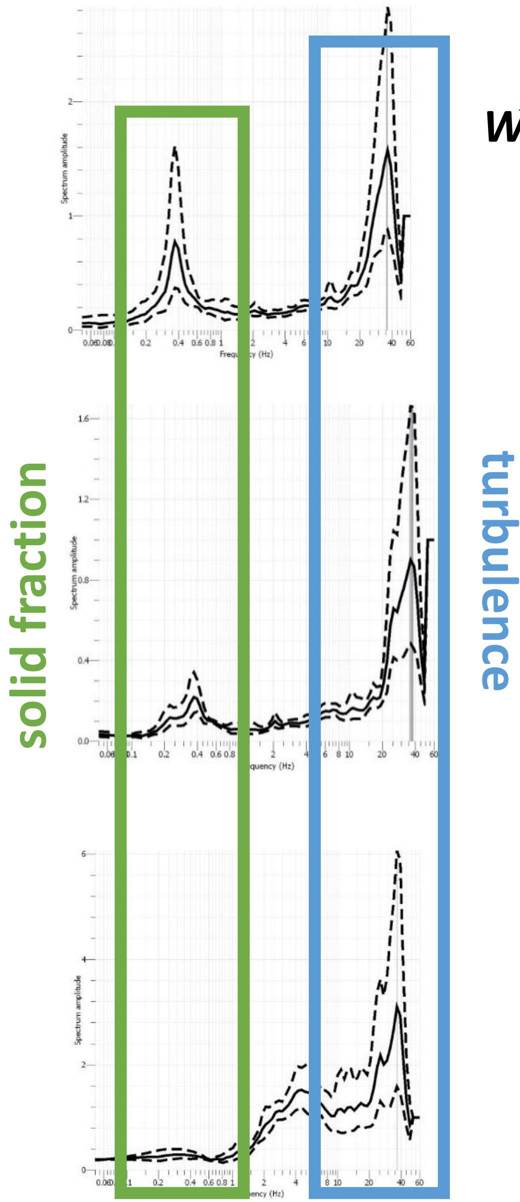


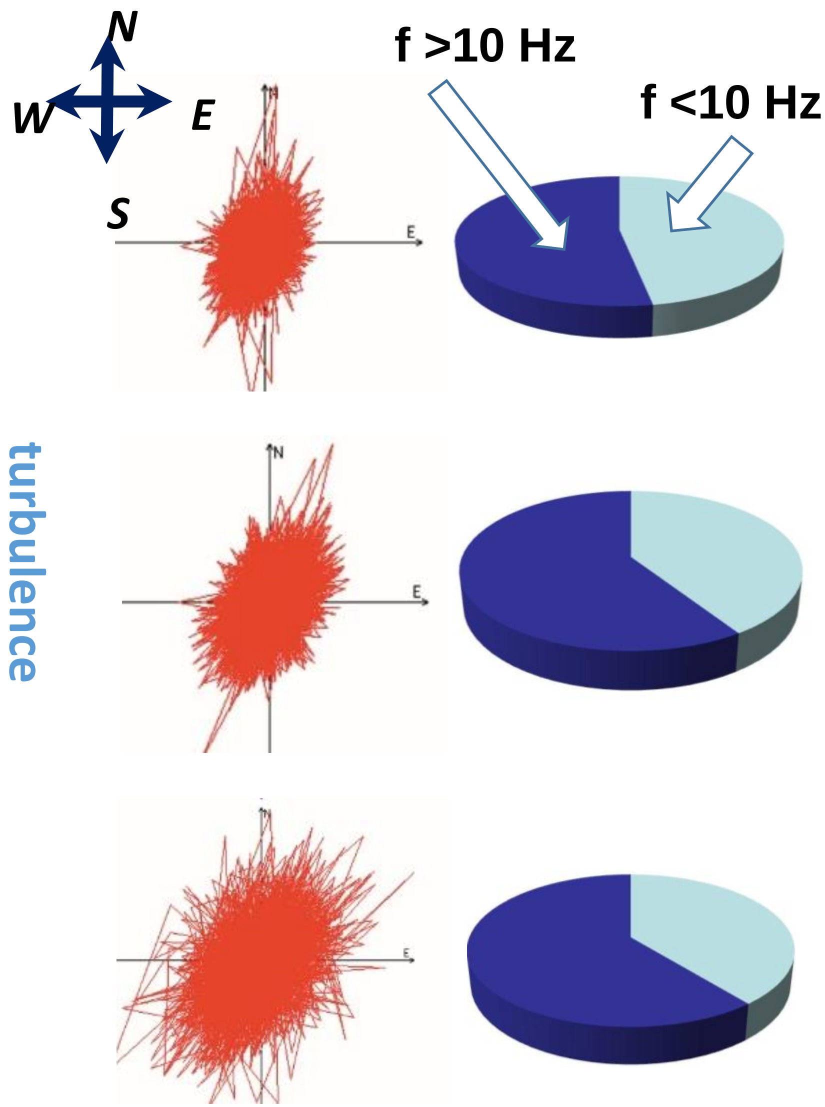

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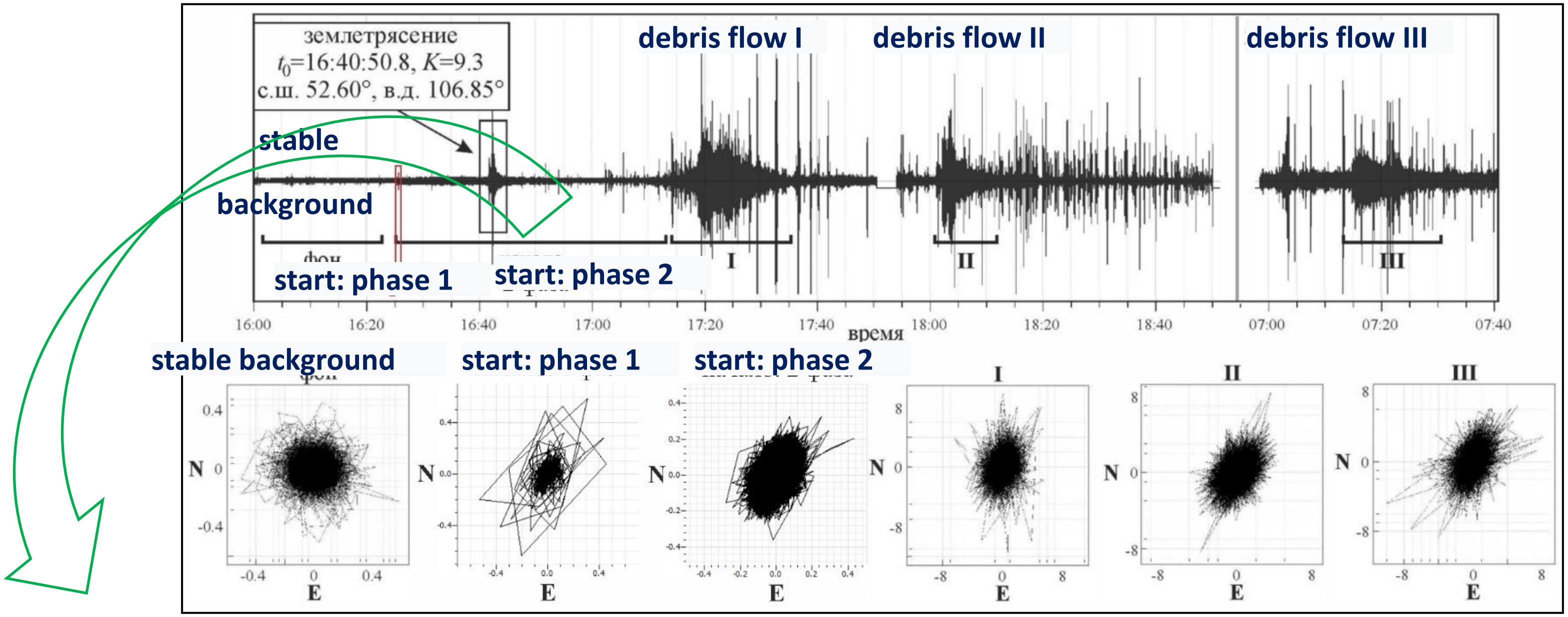
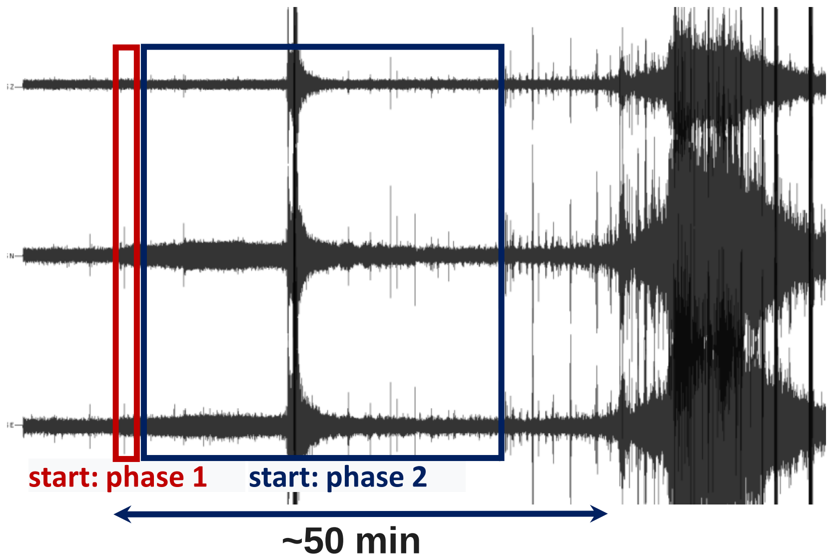
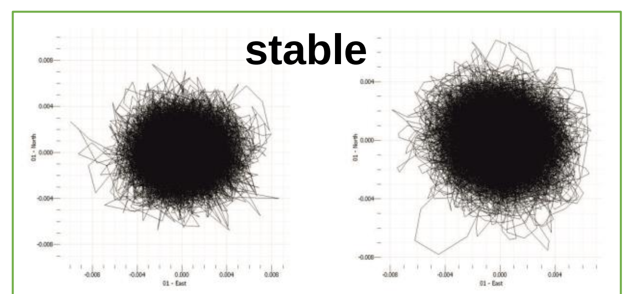


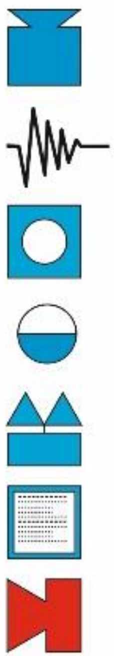




An increase in amplitude and a change in the orientation of oscillations were noted 50 minutes before the debris flow passed through the village of Arshan.

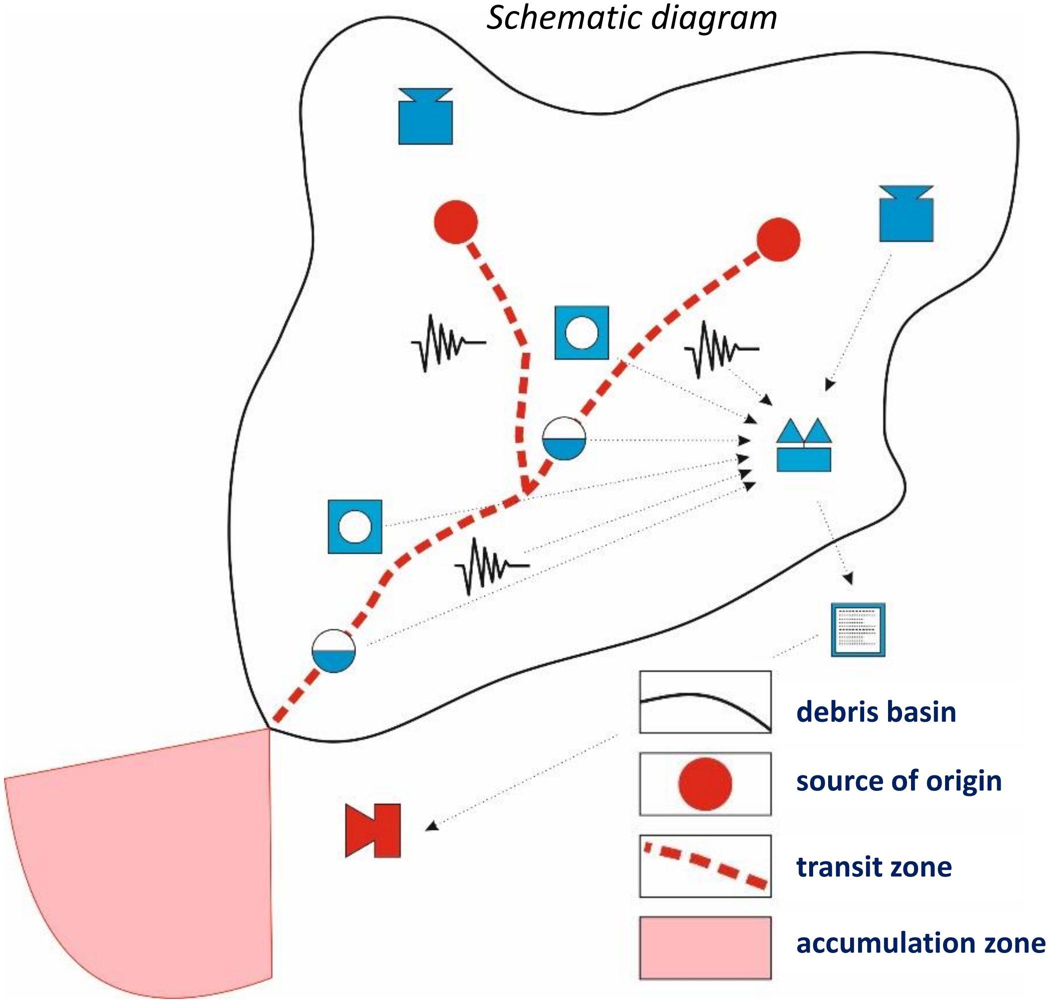


# THE MONITORING AND EMERGENCY WARNING SYSTEM

## EQUIPMENT:



- Weather station
- Seismic or acoustic station
- Camera traps
- Hydrograph
- Telemetry station for real-time data transmission
- Computing station
- Warning system




РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2656123

СПОСОБ ОПРЕДЕЛЕНИЯ ПРИБЛИЖЕНИЯ СЕЛЯ

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Приоритет изобретения 17 мая 2017 г.
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*Руководитель Федеральной службы по интеллектуальной собственности*

*Г.П. Ивлиев*

The effectiveness of the emergency warning system is based on the velocity differences:

- debris flow velocity ~ 5-10 m/s
- speed of sound ~ 300 m/s
- seismic wave velocity ~ 3,500 m/s

# SUMMARY

- The level of ambient seismic noise from the flow of water in the Kyngarga riverbed at Arshan station directly correlates with the amount of precipitation and the increase in water level; there is no dependence on variations in atmospheric pressure.

- In a stable state, the response of the water flow is manifested at frequencies from 4 to 20 Hz. When the water level rises (flood), a significant increase in the amplitudes of ambient seismic noise is recorded (up to 20 times relative to the background) in the entire frequency range with a maximum of 4–20 Hz.

- The noise spectrum during the passage of a debris flow is represented by the sum of high-frequency (22–48 Hz) and low-frequency (<0.45 Hz) peaks. The separation of the spectrum is explained by the superposition of two processes – the flow of water masses with the formation of turbulent flows and the impact of the solid fraction of the debris flow on the bottom and walls of the channel.

- Polarization analysis of seismic records during the mudflow (movement of mudflow masses, individual pulse events and microseismic background) showed the predominance of NE or NNE orientation of oscillations with weak expression of oscillations in the Z plane.

- A comparative polarization analysis of the characteristics of the seismic background during quiet times, during rising waters (floods) and during a mudflow showed a sharp change in the polarization properties of seismic waves during the passage of a mudflow, which can be used in mudflow monitoring.

- A concept for a system for monitoring and emergency notification of flood/debris flow movement is proposed.

# THANK FOR YOUR ATTENTION