INSTITUTE OF GEOLOGY, EARTHQUAKE ENGINEERING AND SEISMOLOGY
OF THE ACADEMY SCIENCES OF THE REPUBLIC TAJIKISTAN

TAJIK SEISMOLOGICAL NETWORKS

DATA COLLECTION, ANALYSIS AND APPLICATIONS IN HAZARD ASSESSMENT

WORKSHOP ON TRAINING IN NETWORK MANAGEMENT SYSTEMS AND ANALYTICAL TOOLS FOR SEISMIC
BAKU, AZERBAIJAN
23-27 OCTOBER 2017

Head Researcher Associate
FARHAD HAKIMOV

IGEES

Institute of Geology, Earthquake Engineering and Seismology Academy of Sciences of the Republic of Tajikistan, was formed 04-02-2011 by decision of Government of the Republic of Tajikistan on the basis of the Institute of Geology TAS (1941) and the Institute of Earthquake Engineering and Seismology TAS(1951) .

PURPOSE OF THE INSTITUTE

– The main purpose of the Institute is to study the solution of scientific problems in the field of geology, seismology and earthquake engineering of the Republic of Tajikistan.

THE STRUCTURE OF INSTITUTE

The Institute consists of the following laboratories:

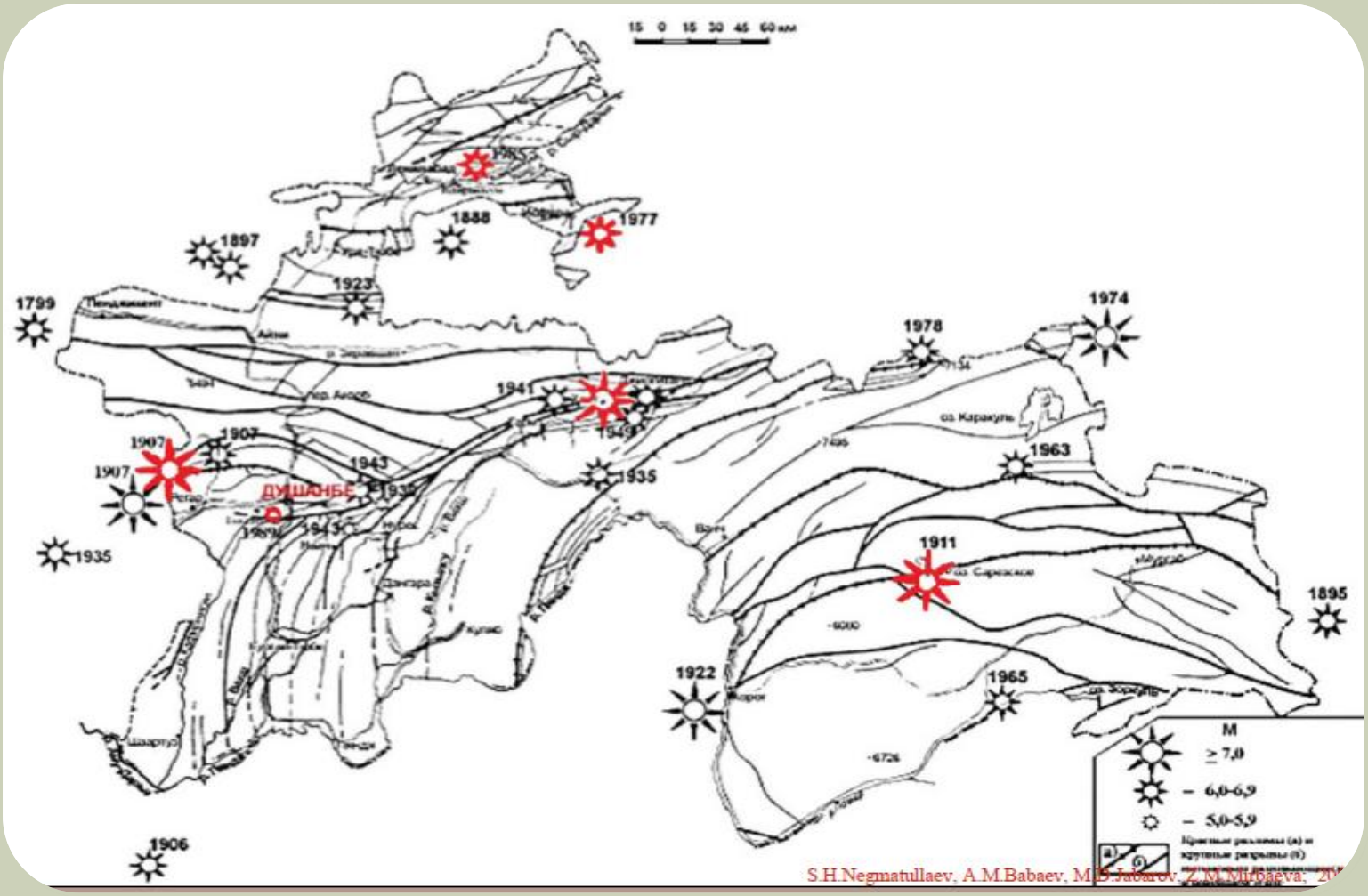
- paleontology and stratigraphy;
- petrology and geochemistry;
- regional geology and geodynamics;
- minerals resources;
- seismic hazard assessment and geoecology;
- complex geophysical studies;
- regional seismology;
- seismic stability of buildings;
- seismic stability hydraulic engineering constructions;
- theory of seismic stability and modeling
- and four scientific and industrial departments - the service of the seismic monitoring, group of physico-chemical methods of research, group of GIS and Geological Museum.

EARTHQUAKES

As a result of earthquakes over the past nearly 100 years in Tajikistan, have killed more than 45,000 people:

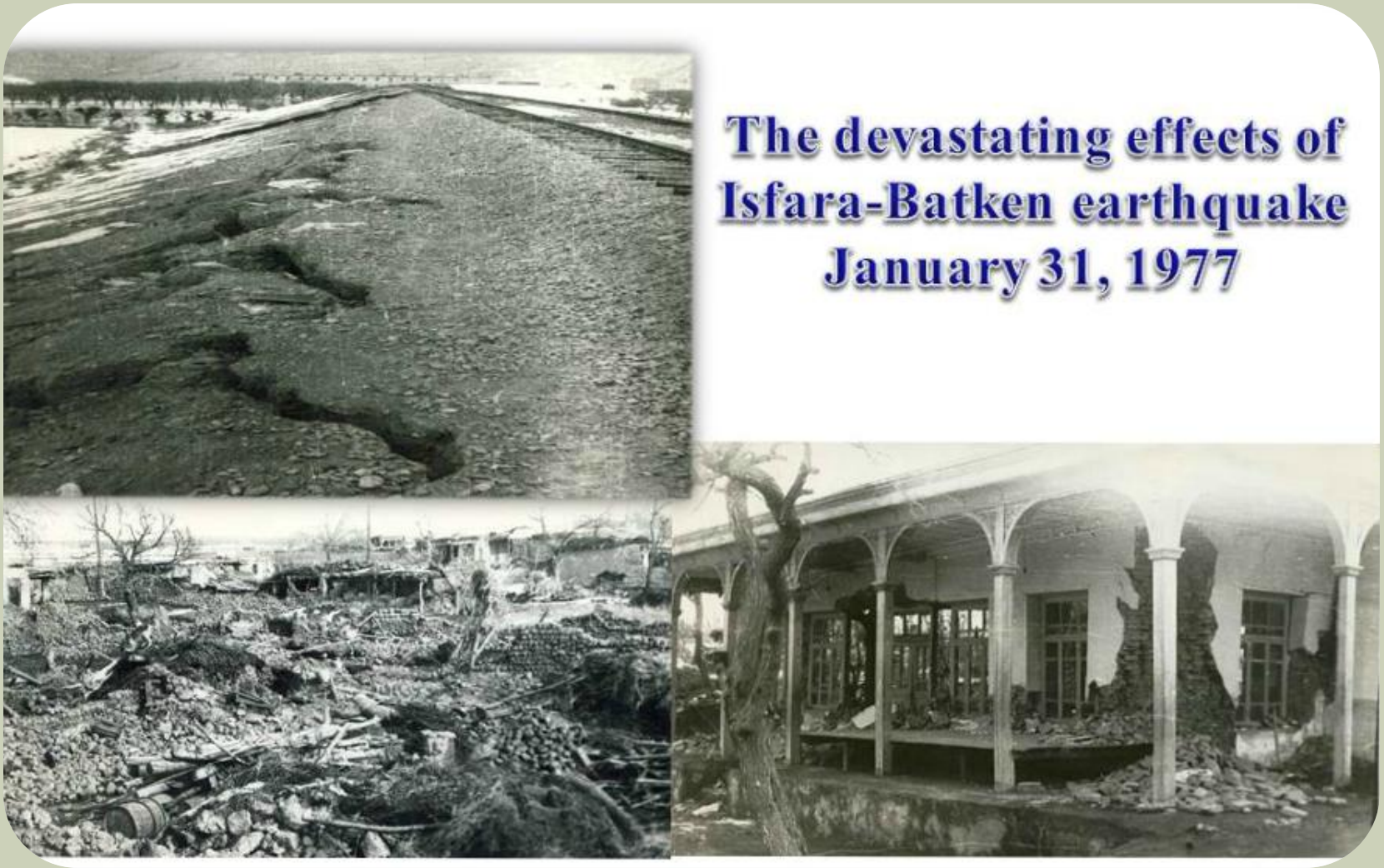
Karatag, 1907 - about 15000,
Sarez, 1911. - A few hundred,
Chait, 1949. - 30000,
Kairakkum, 1985. - A few tens
Hissar, 1989. - 300 people.

THE STRONG AND DESTRUCTIVE EARTHQUAKES OF TAJIKISTAN

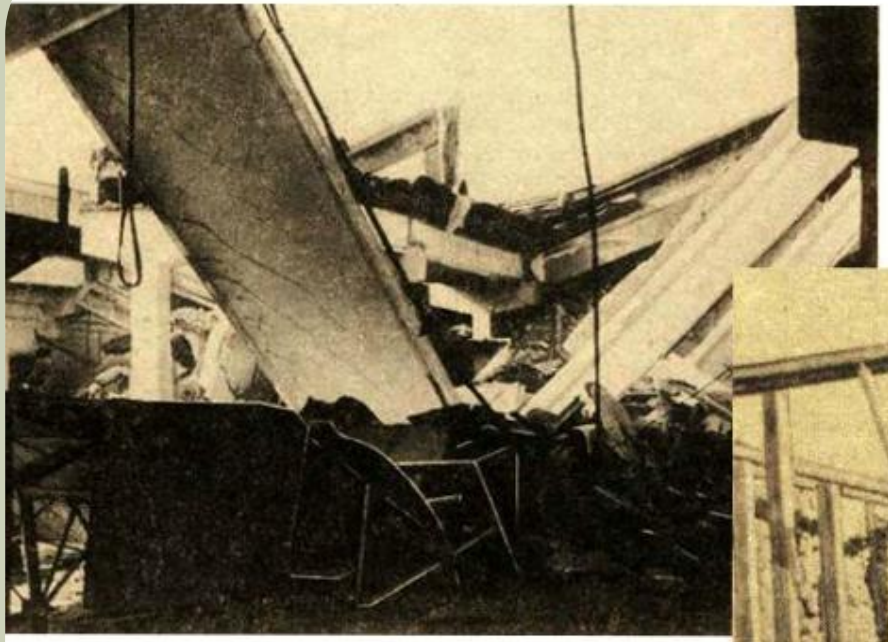


HAIT EARTHQUAKE

ISFARA-BATKENT EARTHQUAKE



KAIRAKKUM EARTHQUAKE



Kairakkum earthquake

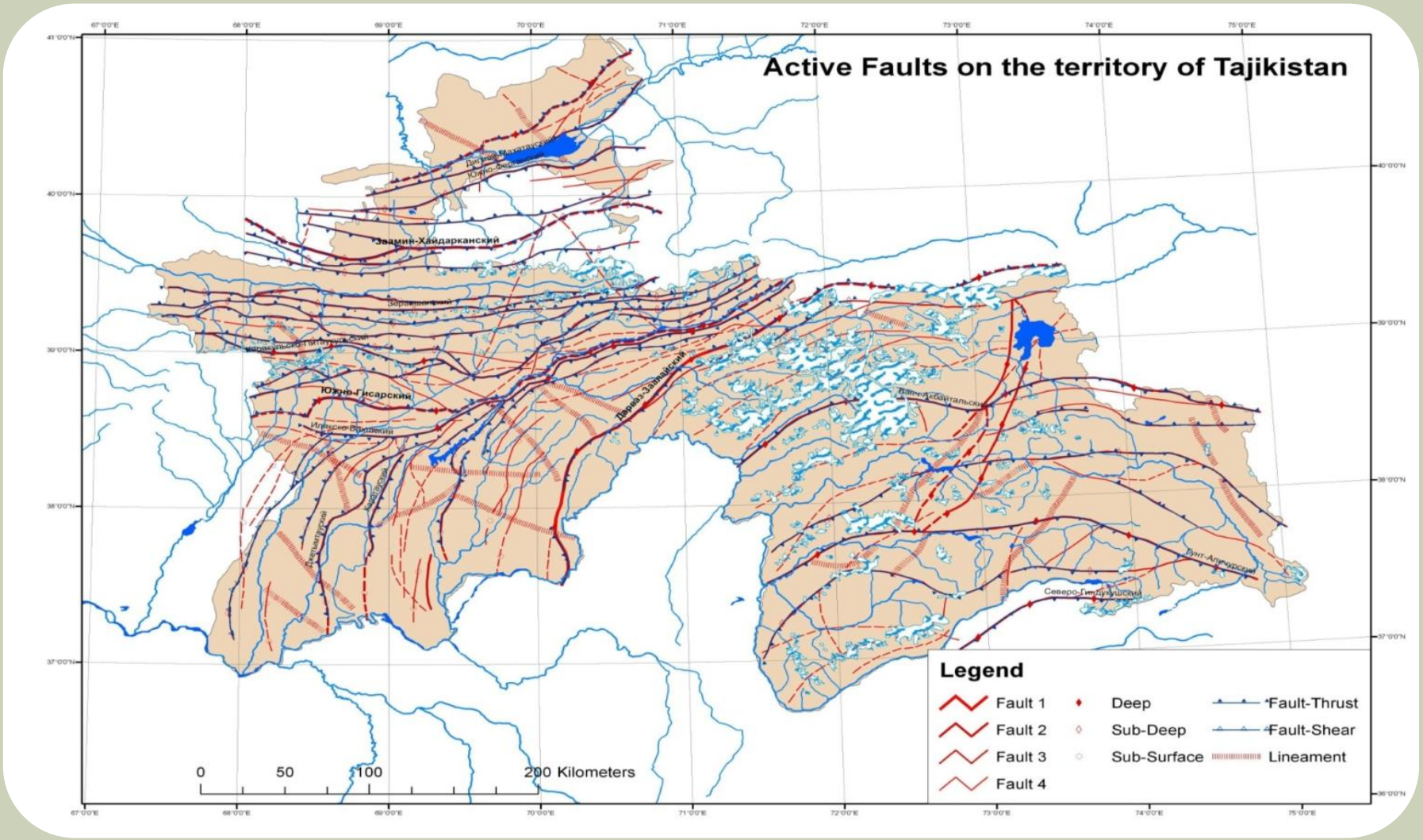
13.10.1985 year

HISSAR EARTHQUAKE

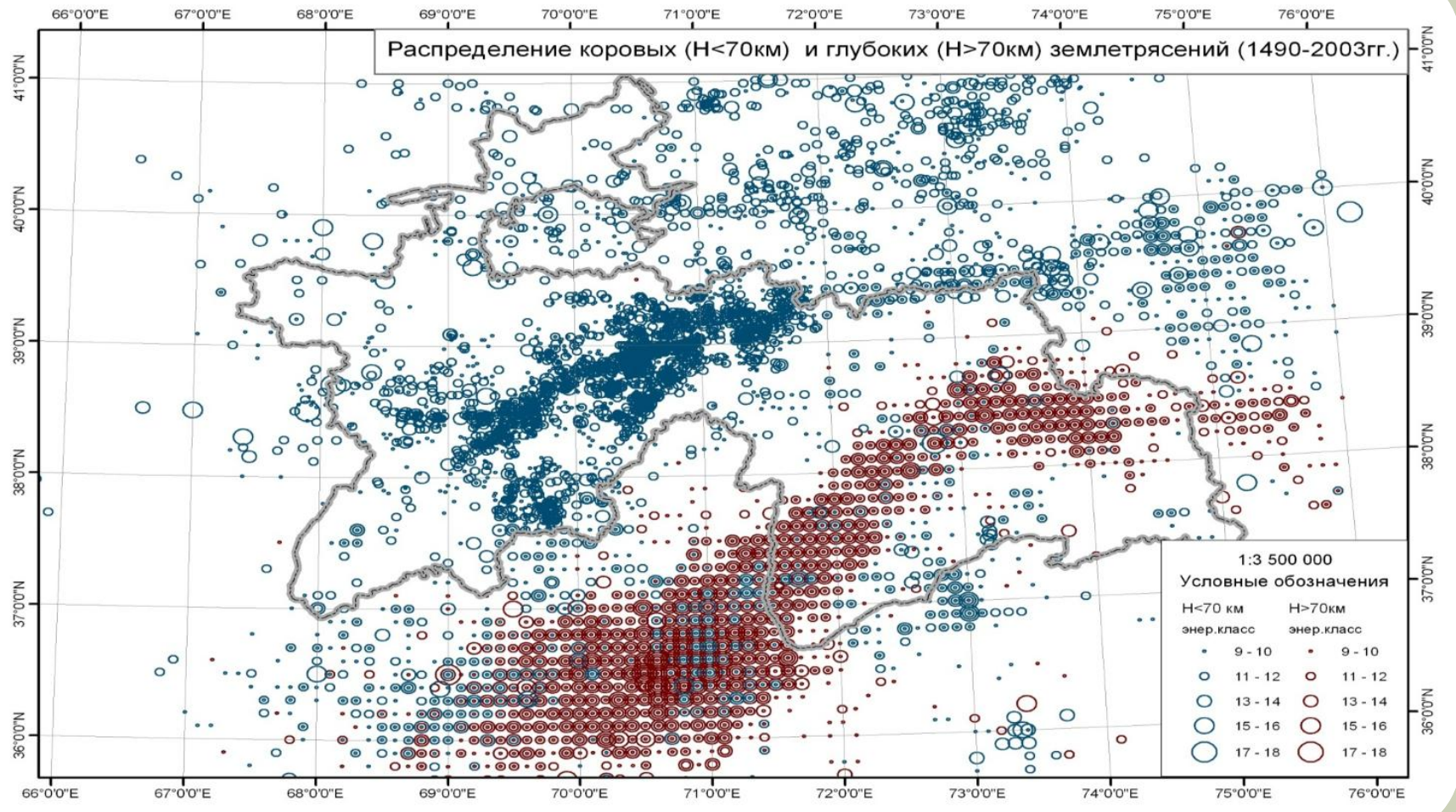
Houses, flooded by a landslide after Hissar earthquake 23/01/1989

SAREZ EARTHQUAKE

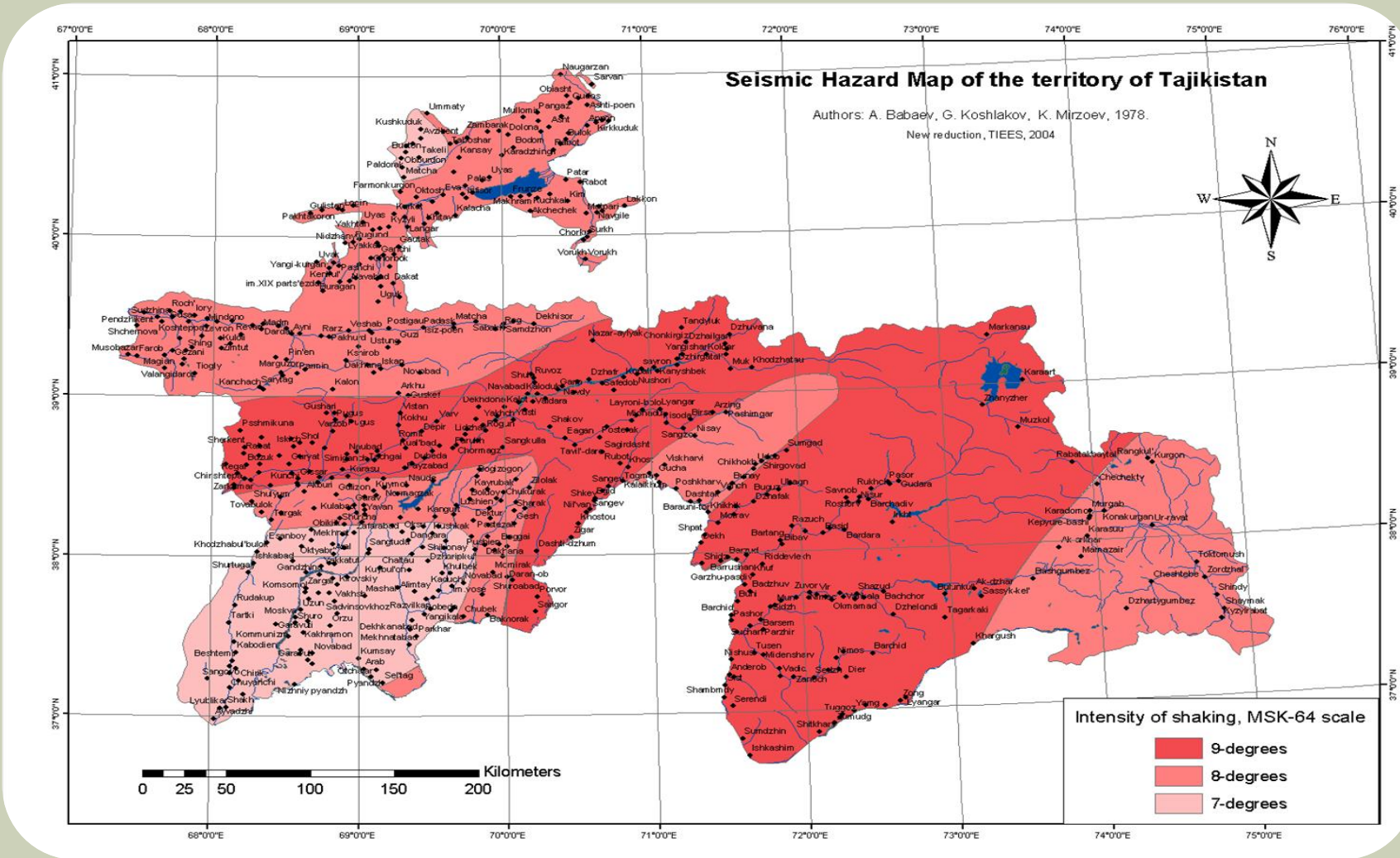
ACTIVE FAULTS



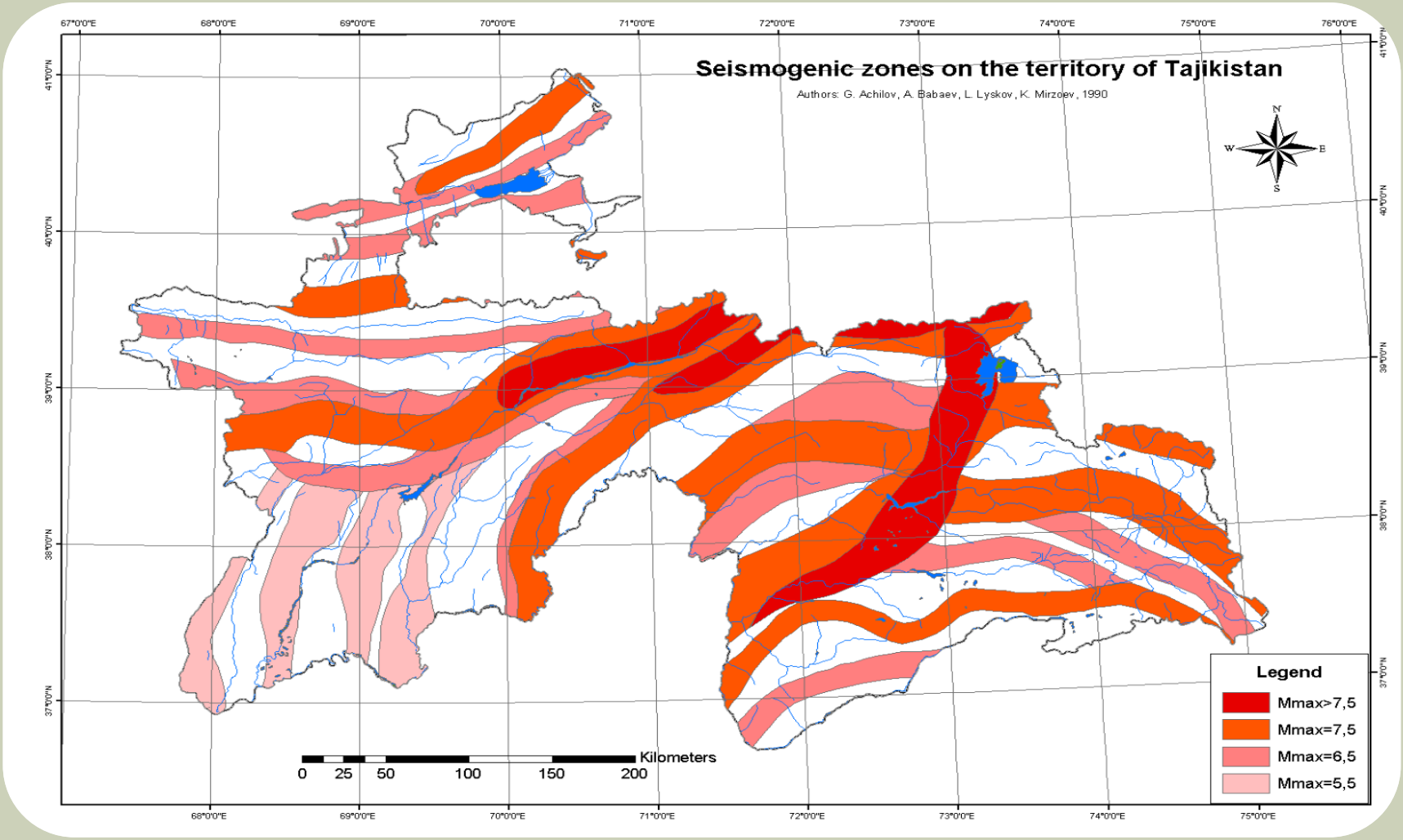
EARTHQUAKES



SEISMIC HAZARD MAP

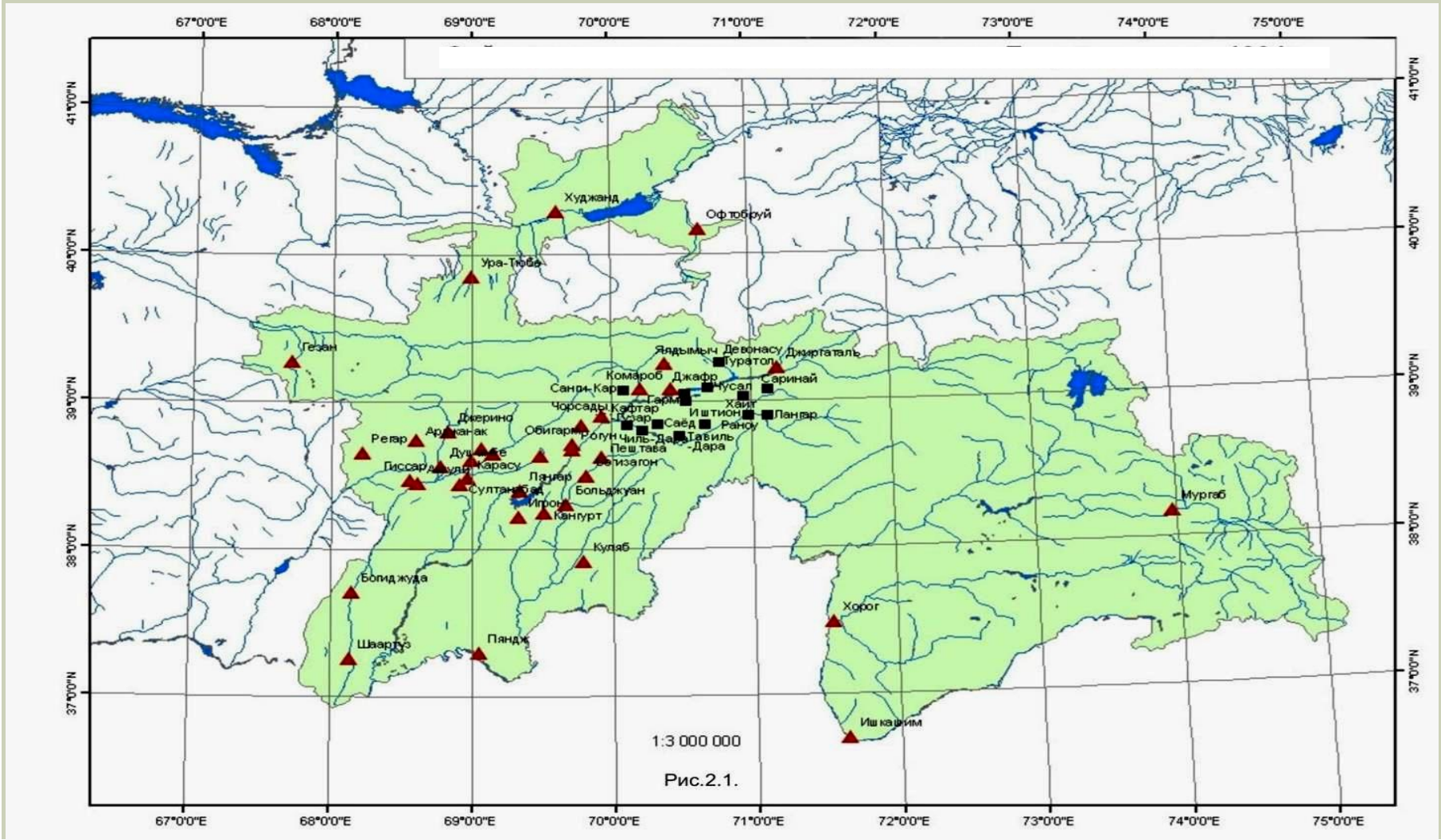


SESMOGENIC ZONES

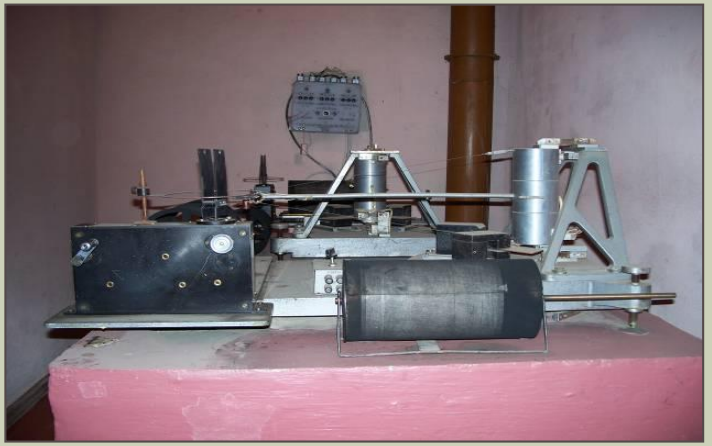


- TJ Networks

SEISMIC STATIONS IN TAJIKISTAN



ANALOGY SOVIET UNION STATIONS



Remote control of analog seismic station

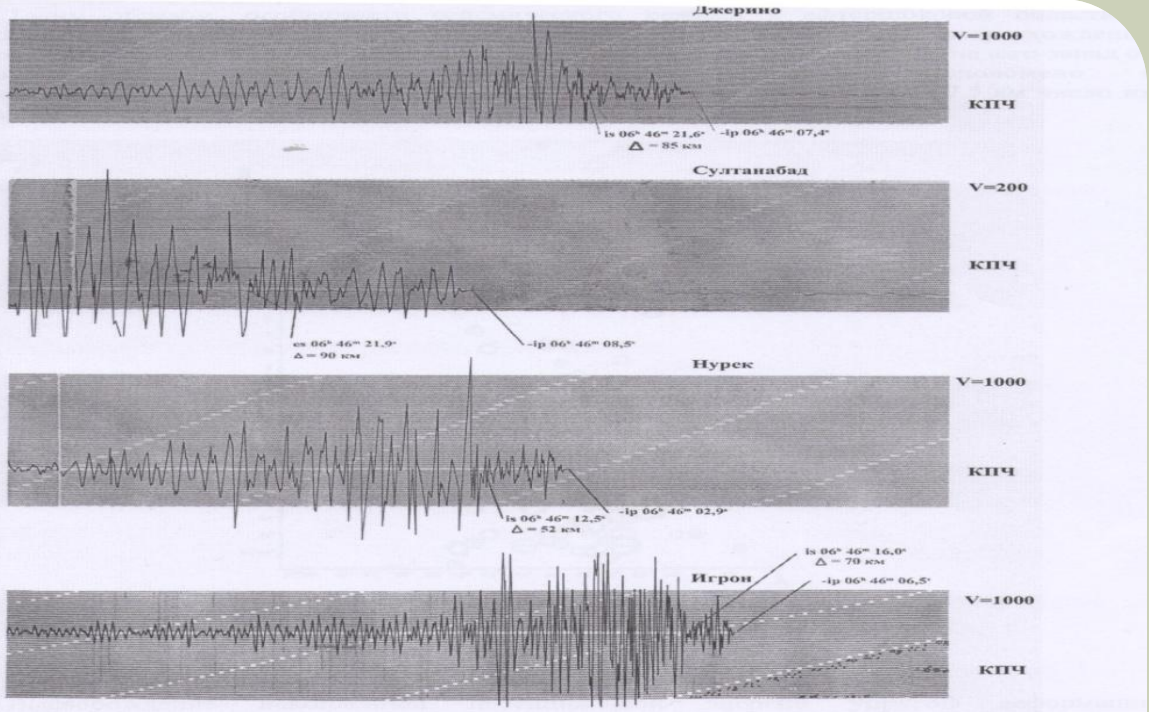


Рис.6. Записи Рогунского землетрясения 09 января 2002 года.

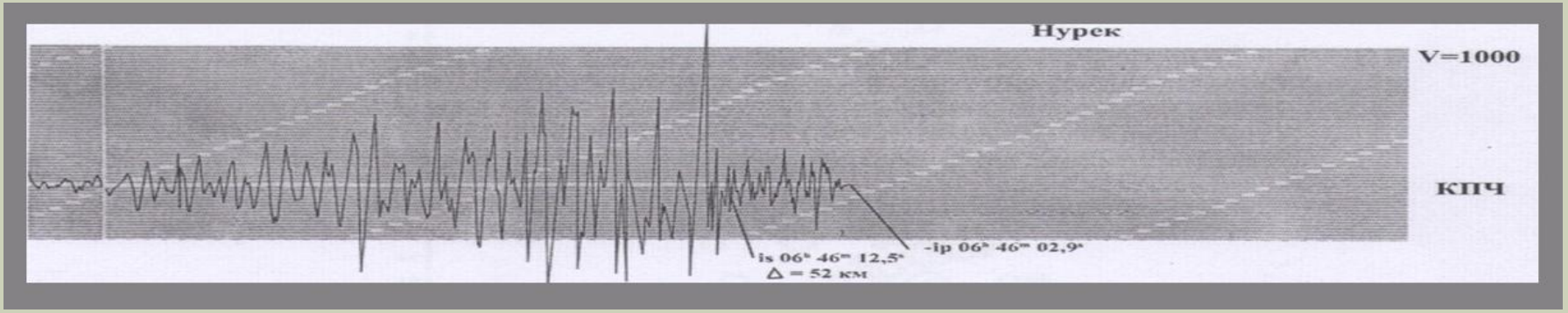
Таблица 2.

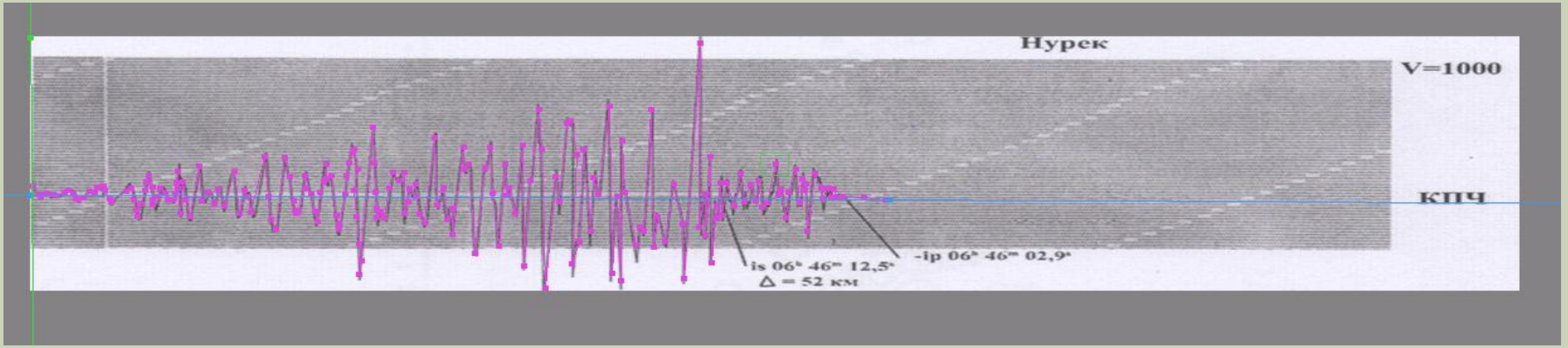
Энергетический класс	5	6	7	8	9	10	11	12
Число афтершоков	4	19	11	10	4	4	-	2

При рассмотрении обстановки в эпицентральной зоне основного события выбрана территория, ограниченная координатами:

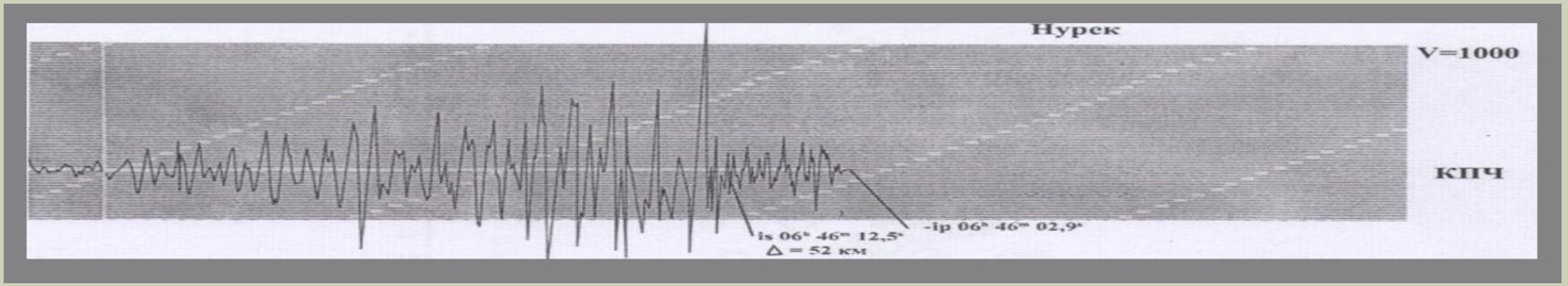
38°39.5′ - 38°49.5′

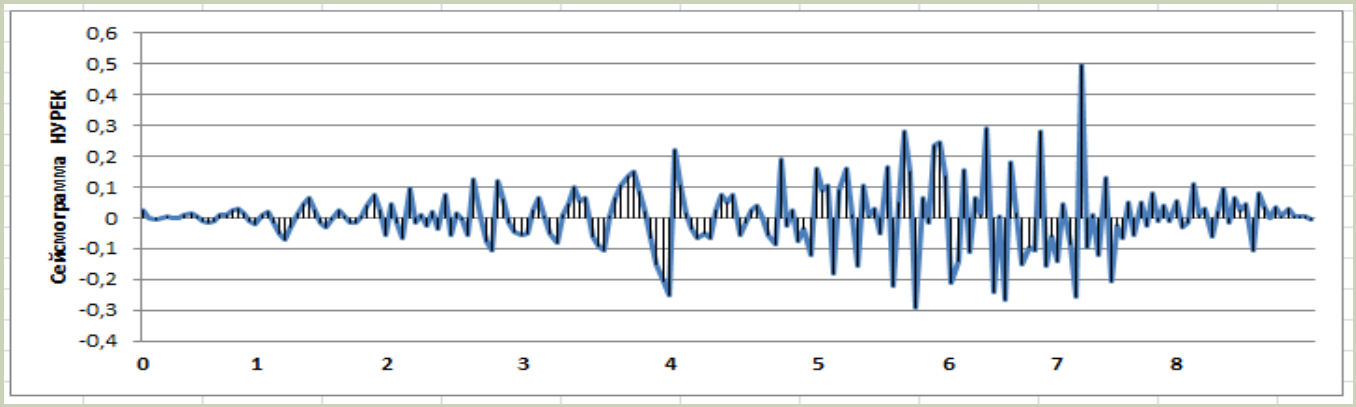
69°42.0′-69°55.0′


Нурек
V=1000
КПЧ
is 06ʰ 46ᵐ 12,5ˢ
Δ = 52 км
-ip 06ʰ 46ᵐ 02,9ˢ


Нурек
V=1000
КПЧ
is 06ʰ 46ᵐ 12,5ˢ
Δ = 52 км
-ip 06ʰ 46ᵐ 02,9ˢ

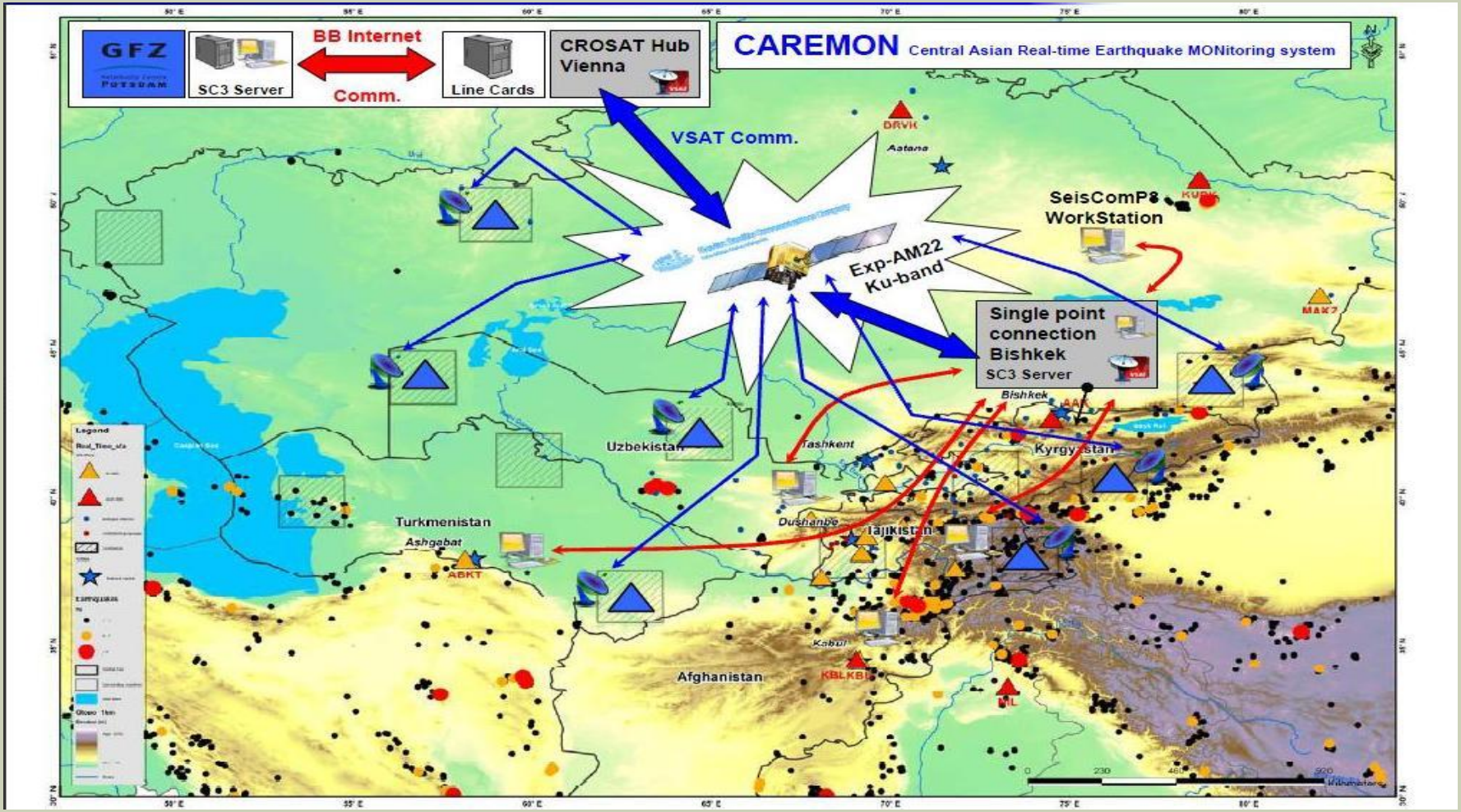
Digitize analogy waveform



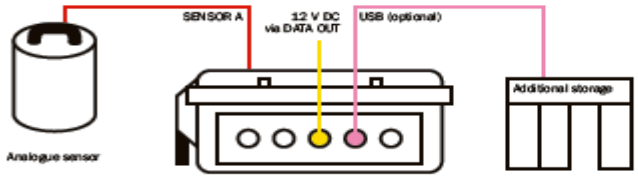


N.△	X	Y
0	0.0268664	0.0151062
1	9.841164e-005	0.0440392
2	-0.0065739	0.0586041
3	1.968233e-004	0.0806975
4	0.00359202	0.0954101
5	3.345996e-004	0.132019
6	-0.00298187	0.146633
7	0.00722341	0.198103
8	0.0139941	0.220196
9	0.00400535	0.249375
10	-0.0127345	0.263792
11	-0.0160509	0.278407
12	-0.00926053	0.307832
13	0.0109729	0.344785
14	0.00769579	0.374063
15	0.0245143	0.388972

CAREMON NETWORK IN DJERINO STATIONS (DUSHANBE)

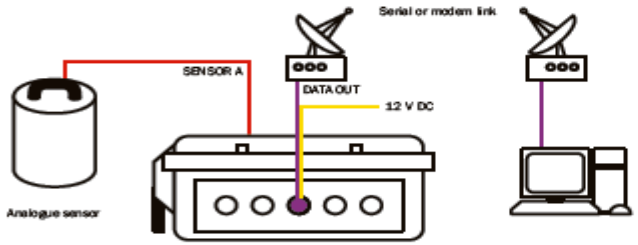


DJERINO STATION



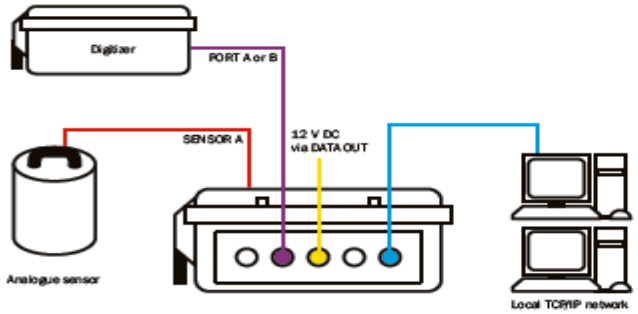
Autonomous data storage

The DM24S3DCM uses a standard USB hard drive, replaceable in the field with 100% data surety.. Self-contained, low power installations can have over 40 Gb of storage space, ideal for long-term experiments in remote locations.



Long-range telemetry

The DM24S3DCM can digitize signals from an analogue instrument and transmit the data directly over a serial modem or VSAT link. Alternatively, PPP and SLIP capabilities allow you to use a modem link as an extension of your local network.



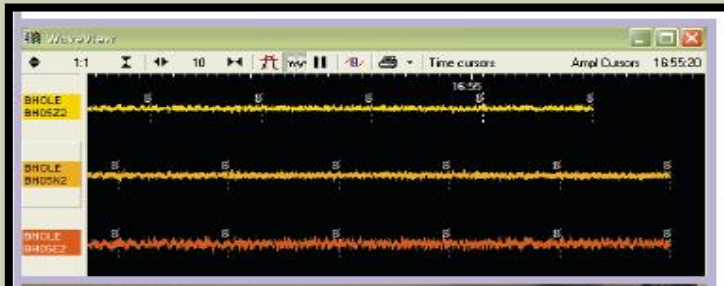
Fully networked installations

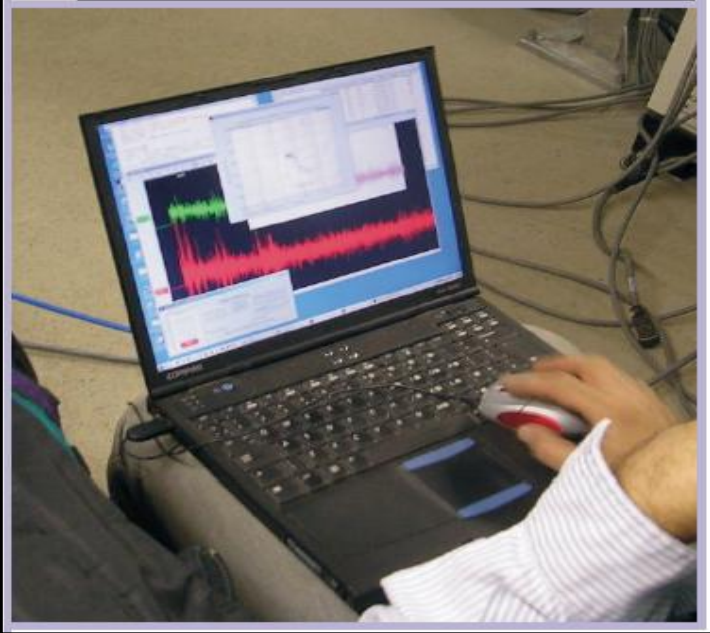
The DM24S3DCM runs a fully configurable and scriptable Linux operating system.

In addition to the on-board digitizer, its two digital inputs allow it to collate data from additional digital instruments.

All received data can be saved to the hard disk and transmitted to a data centre as normal.

DJERINO STATION





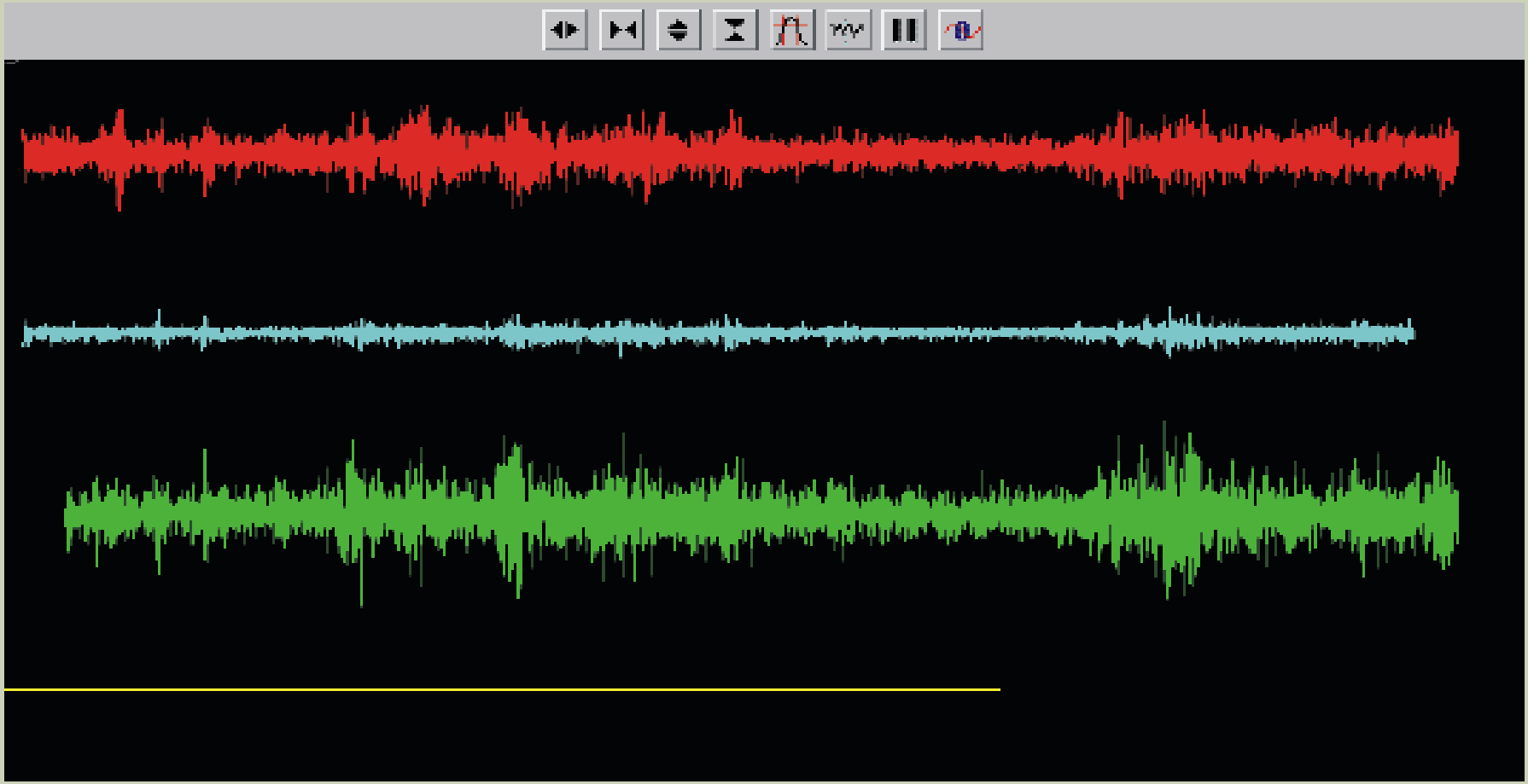
The Güralp CMG-DM24 is a high-quality 3-channel digitizer with full 24-bit resolution, designed for data quality and durability.

The component housed inside the DM24S3DCM is a full-featured DM24 unit with direct output to the DCM component.

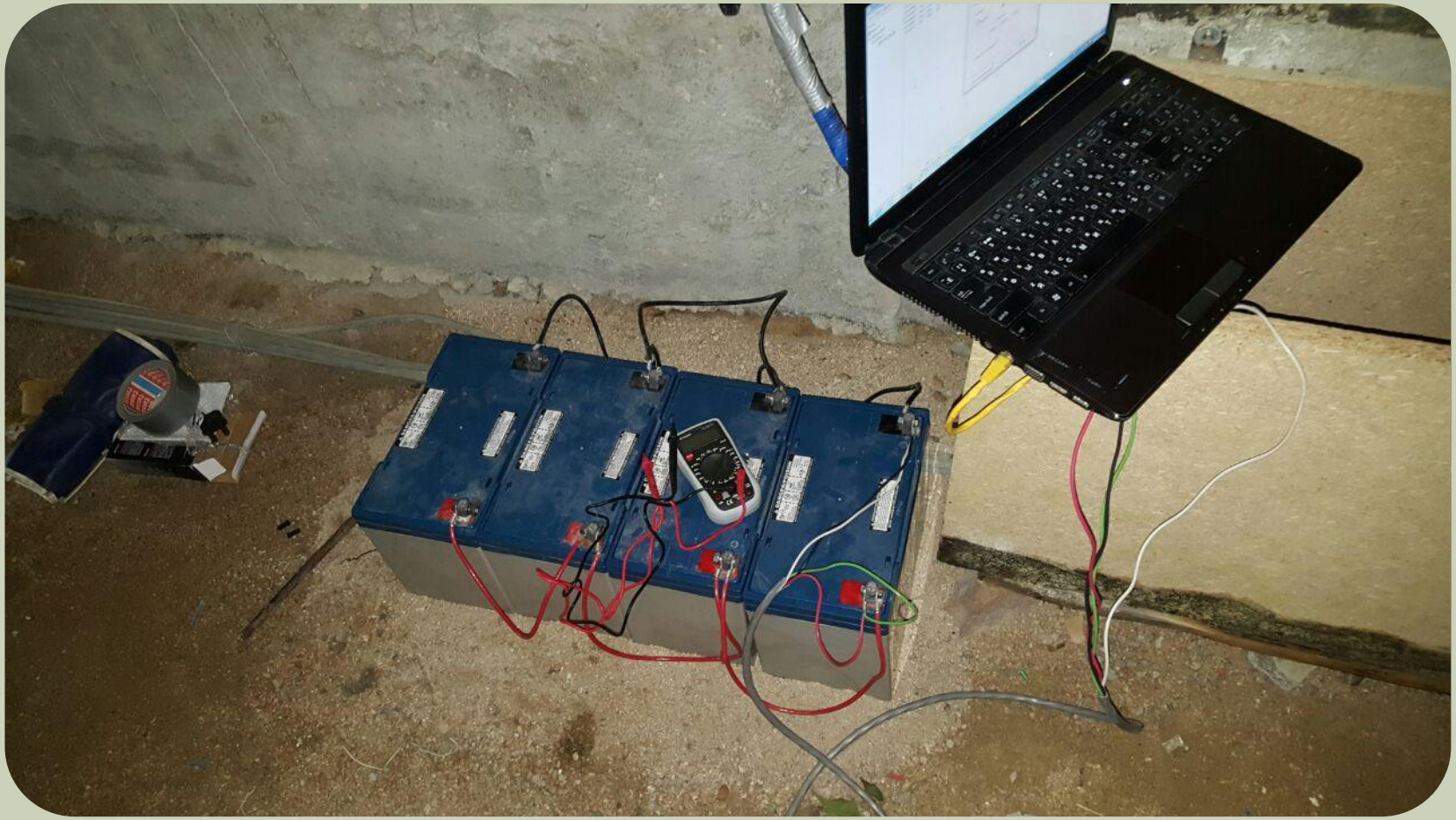
Features

- 4 low noise 24-bit channels (3 primary, 1 auxiliary)
- 12-channel digitizer options available
- Auxiliary channel for user signals and calibration
- Multiple concurrent data rates up to 1000 samples/s
- 8 environmental channels with 20-bit resolution (3 × mass position, 5 user)
- Optional further 8 environmental channels
- Low power 32-bit DSP and ARM processor
- System power consumption < 1 W (for 4 channels recording at 100 samples/s)

DJERINO STATION



DJERINO STATION



DJERINO STATION

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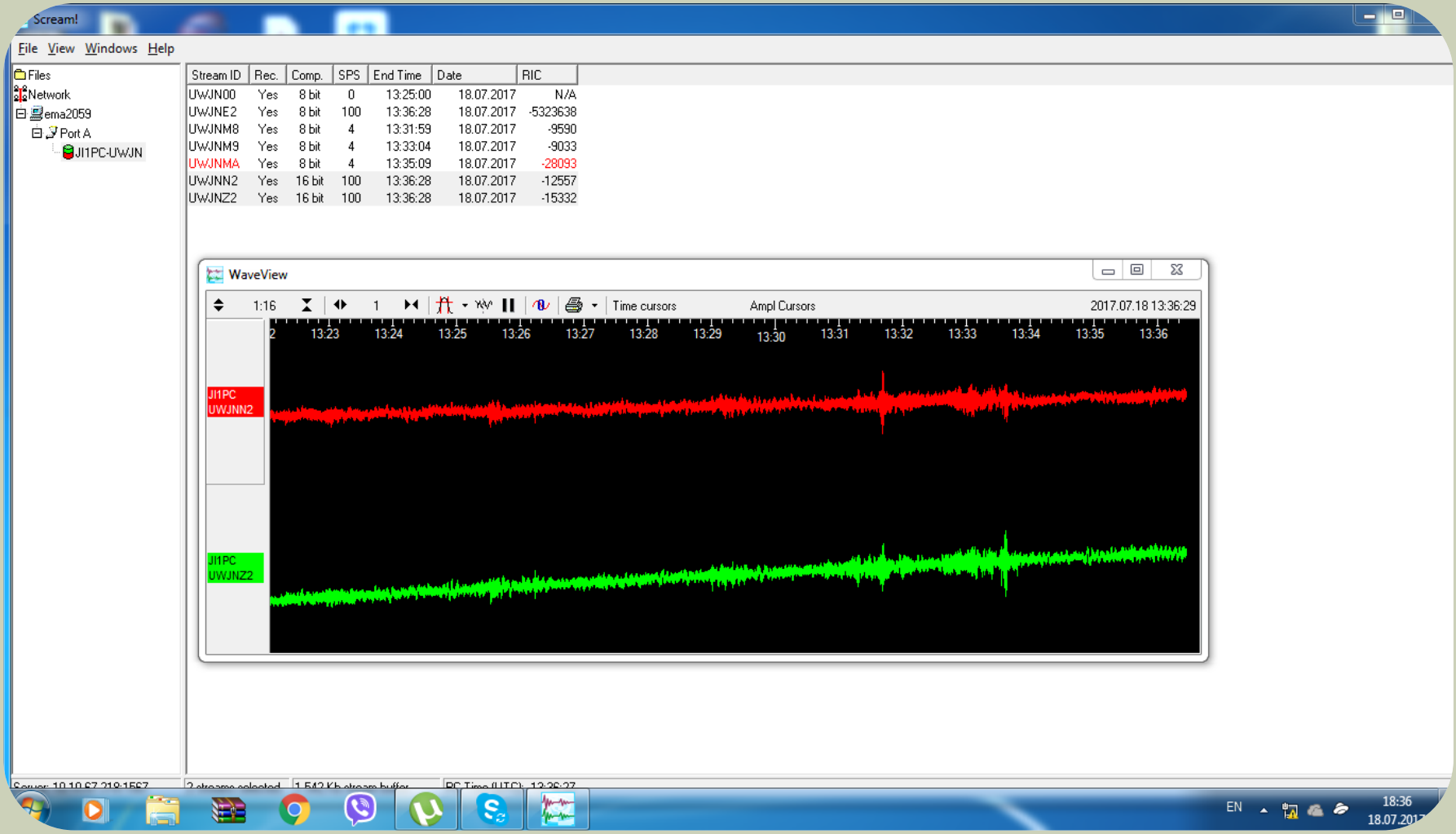
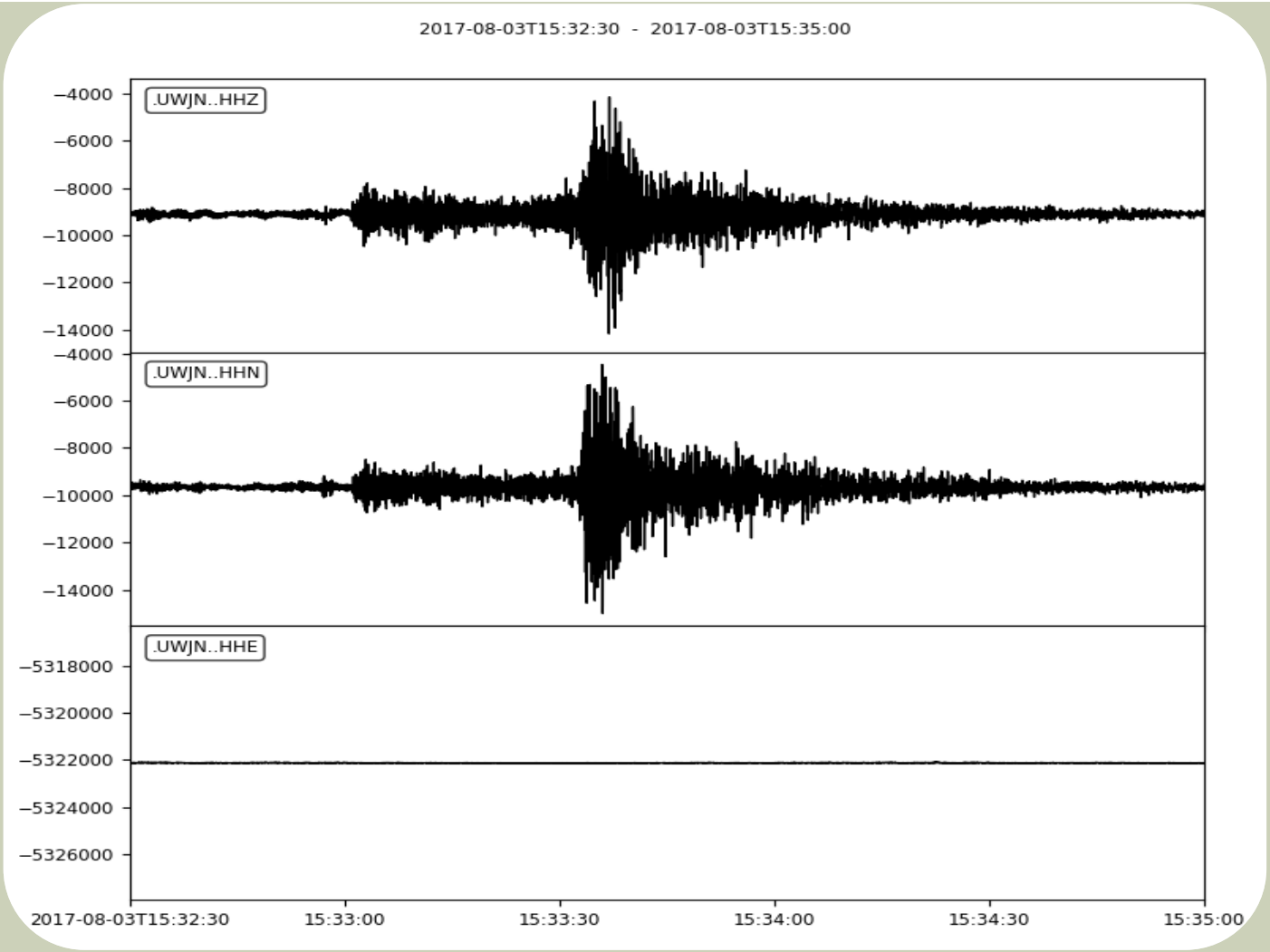
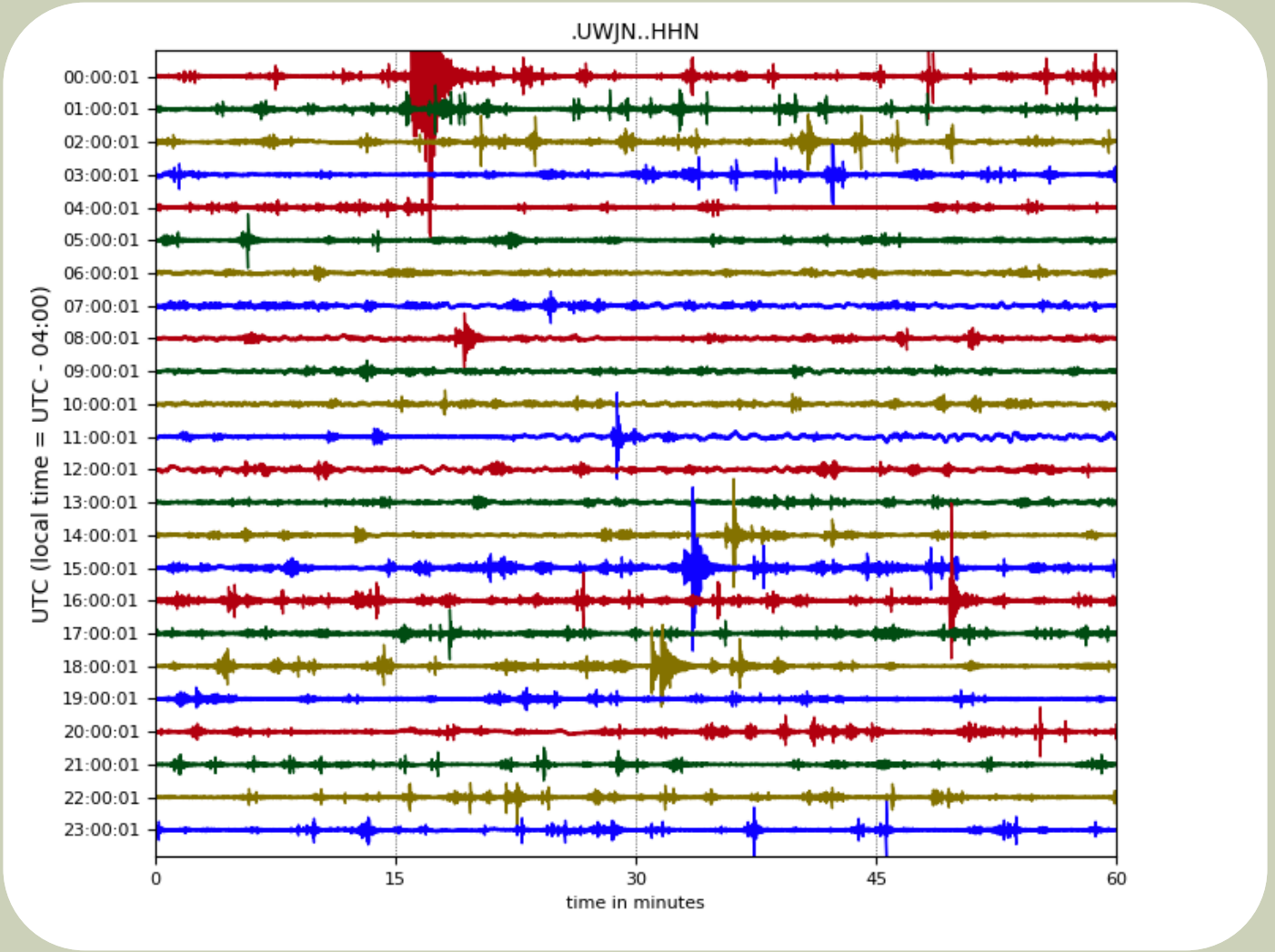


DJERINO STATION



DJERINO STATION



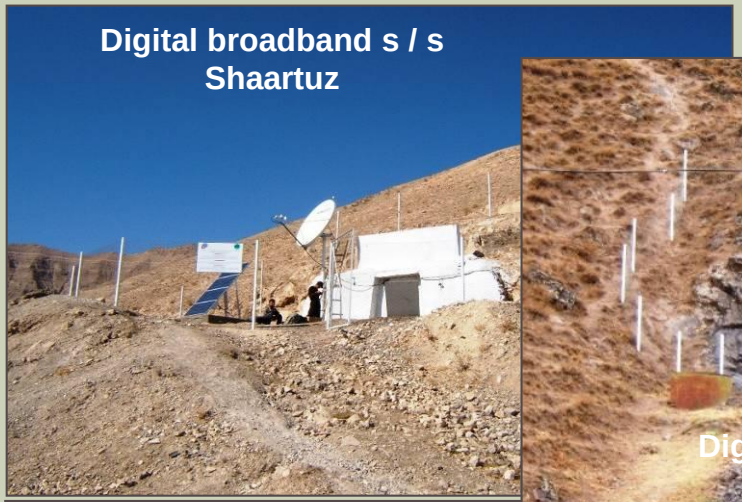
THE NETWORK OF DIGITAL BROADBAND SEISMIC STATION IN TAJIKISTAN

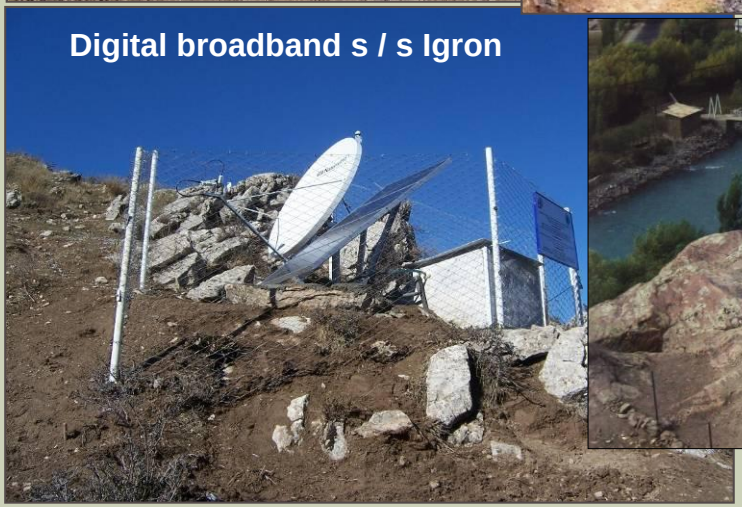
CENTRAL SEISMIC STATION "DUSHANBE"

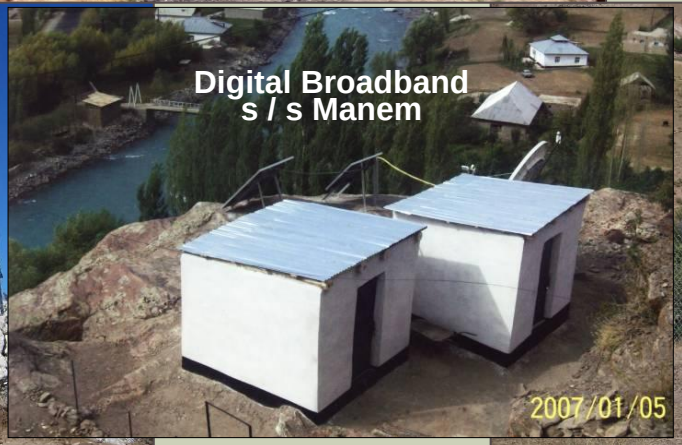
Data collection, processing and analysis center

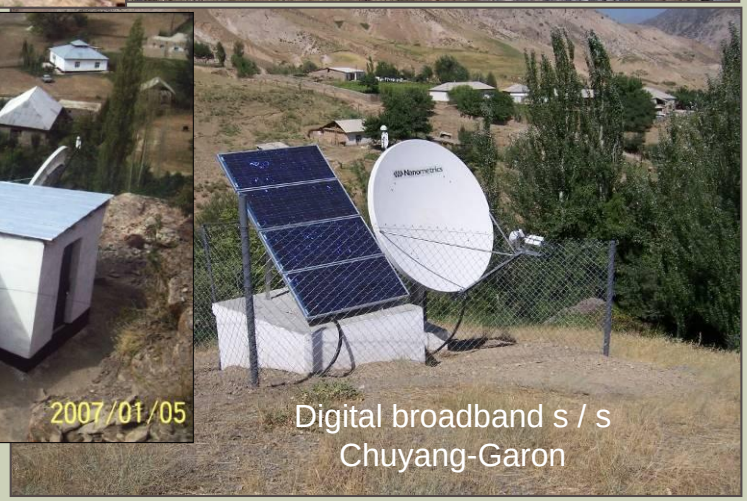
THE CENTRAL SEISMIC STATION "DUSHANBE" AT THE TIME OF INSTALLATION

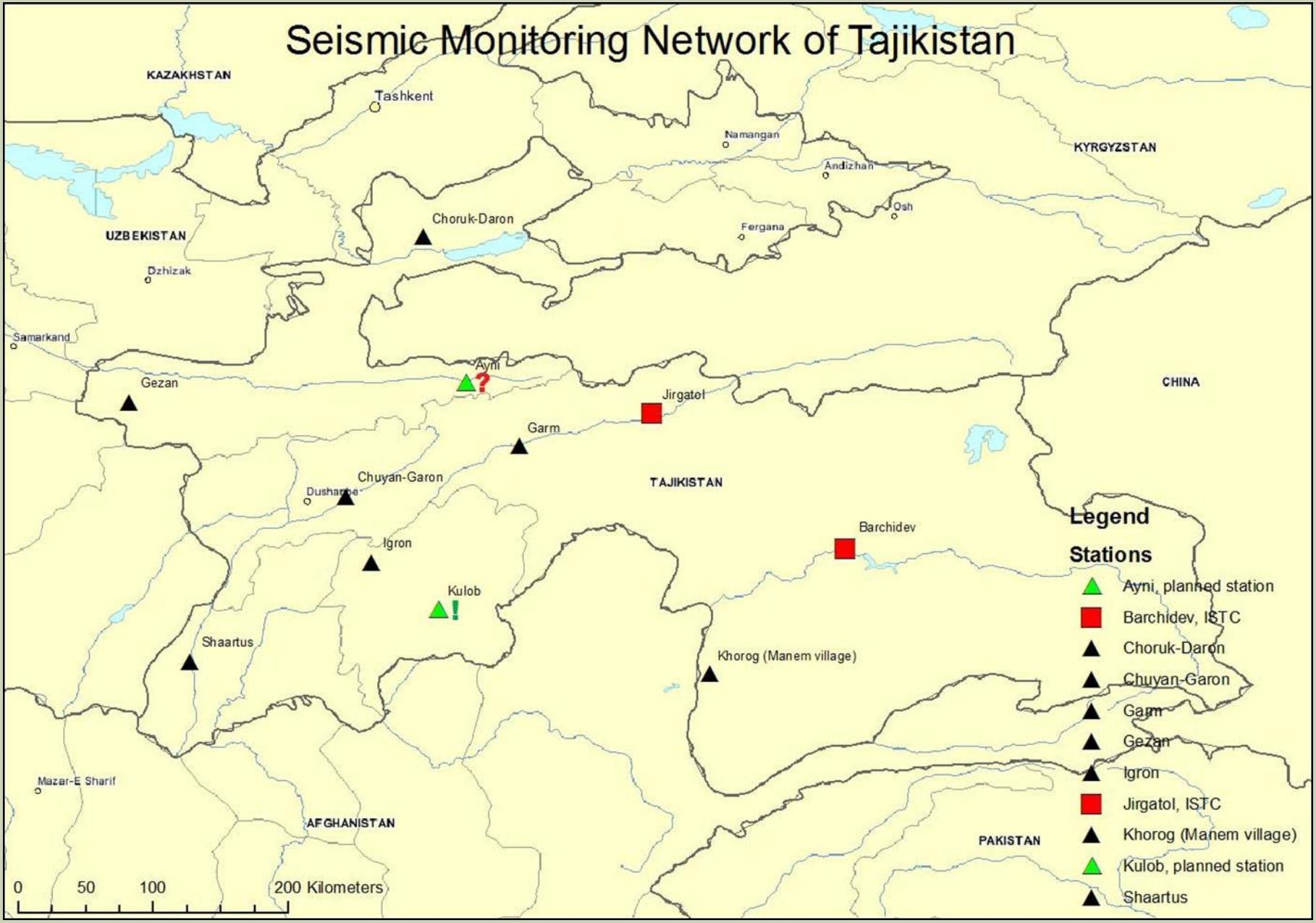
SEISMIC STATIONS







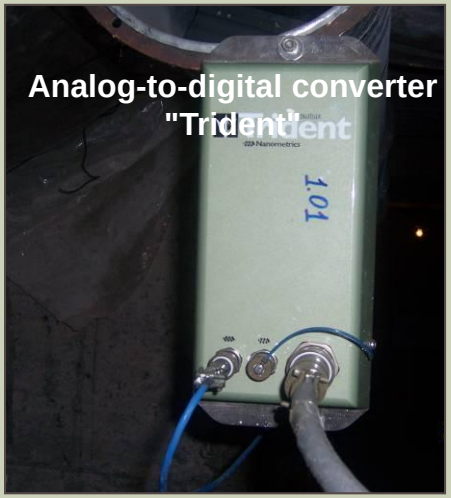



Seismic Monitoring Network of Tajikistan
KAZAKHSTAN
Tashkent
Namangan
KYRGYZSTAN
Andizhan
Osh
Choruk-Daron
Fergana
UZBEKISTAN
Dzhizak
Samarkand
Ayni
Gezan
Jirgatol
CHINA
Garm
Chuyan-Garon
Dushanbe
TAJIKISTAN
Barchidev
Igron
Kulob
Shaartus
Khorog (Manem village)
Mazar-E Sharif
AFGHANISTAN
PAKISTAN
0
50
100
200 Kilometers
Legend
Stations
Ayni, planned station
Barchidev, ISTC
Choruk-Daron
Chuyan-Garon
Garm
Gezan
Igron
Jirgatol, ISTC
Khorog (Manem village)
Kulob, planned station
Shaartus

SEISMIC STATION EQUIPMENT: ANALOG AND DIGITAL


Remote Control

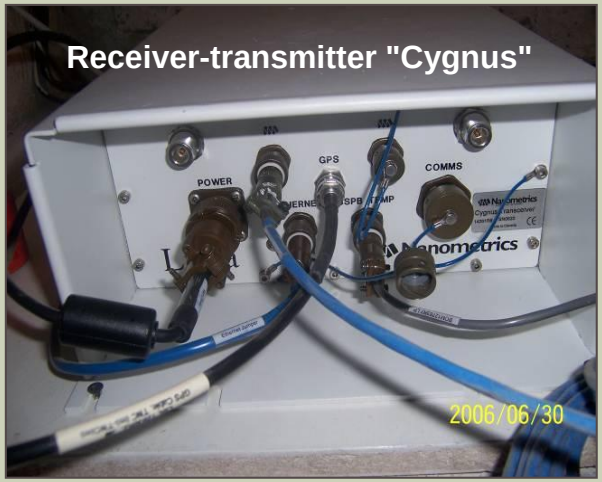

Mechanical registration of SMR-P



Analog-to-digital converter "Trident"

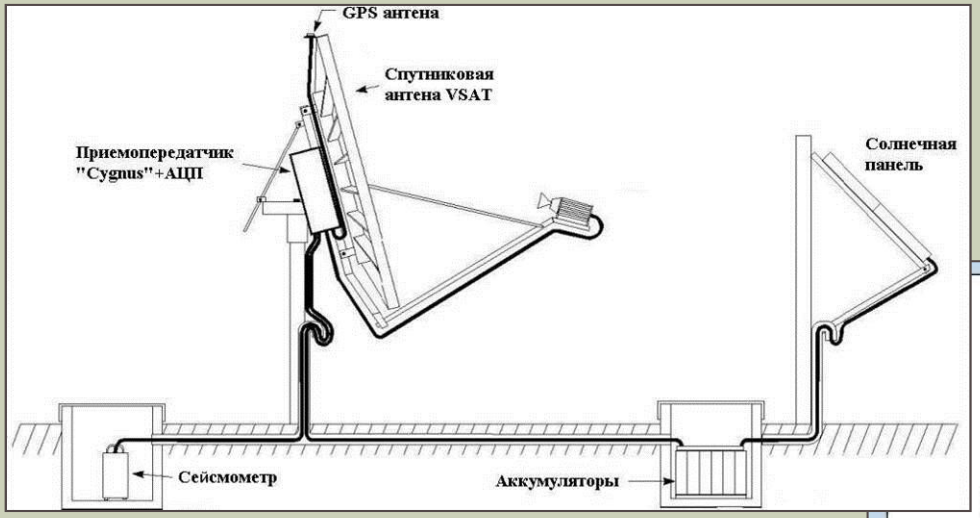
Seismographs of the Kernos system

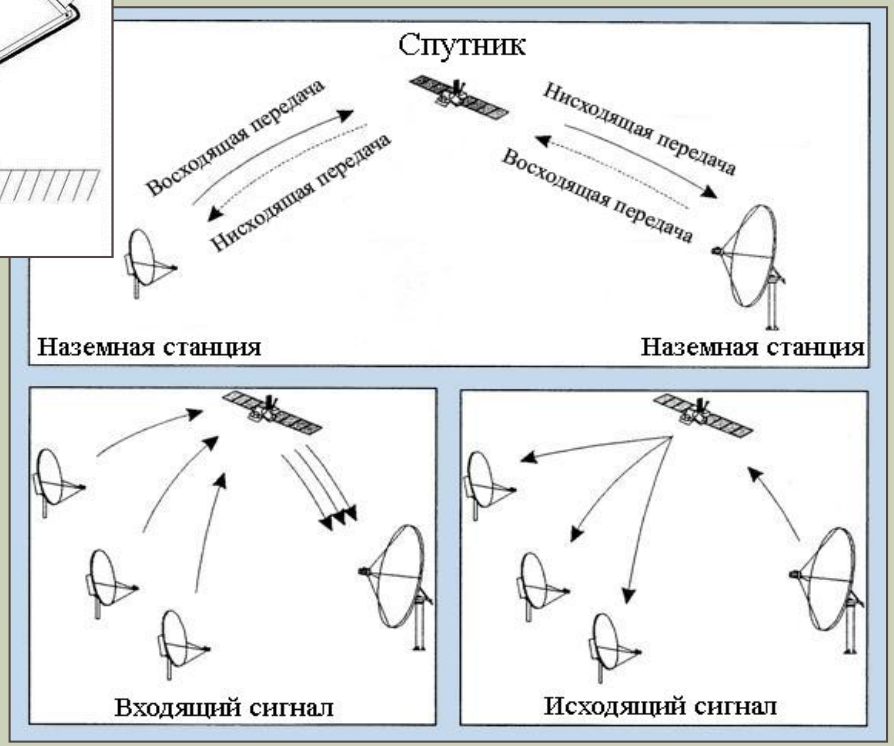
3-component seismometer "Trillium-40"



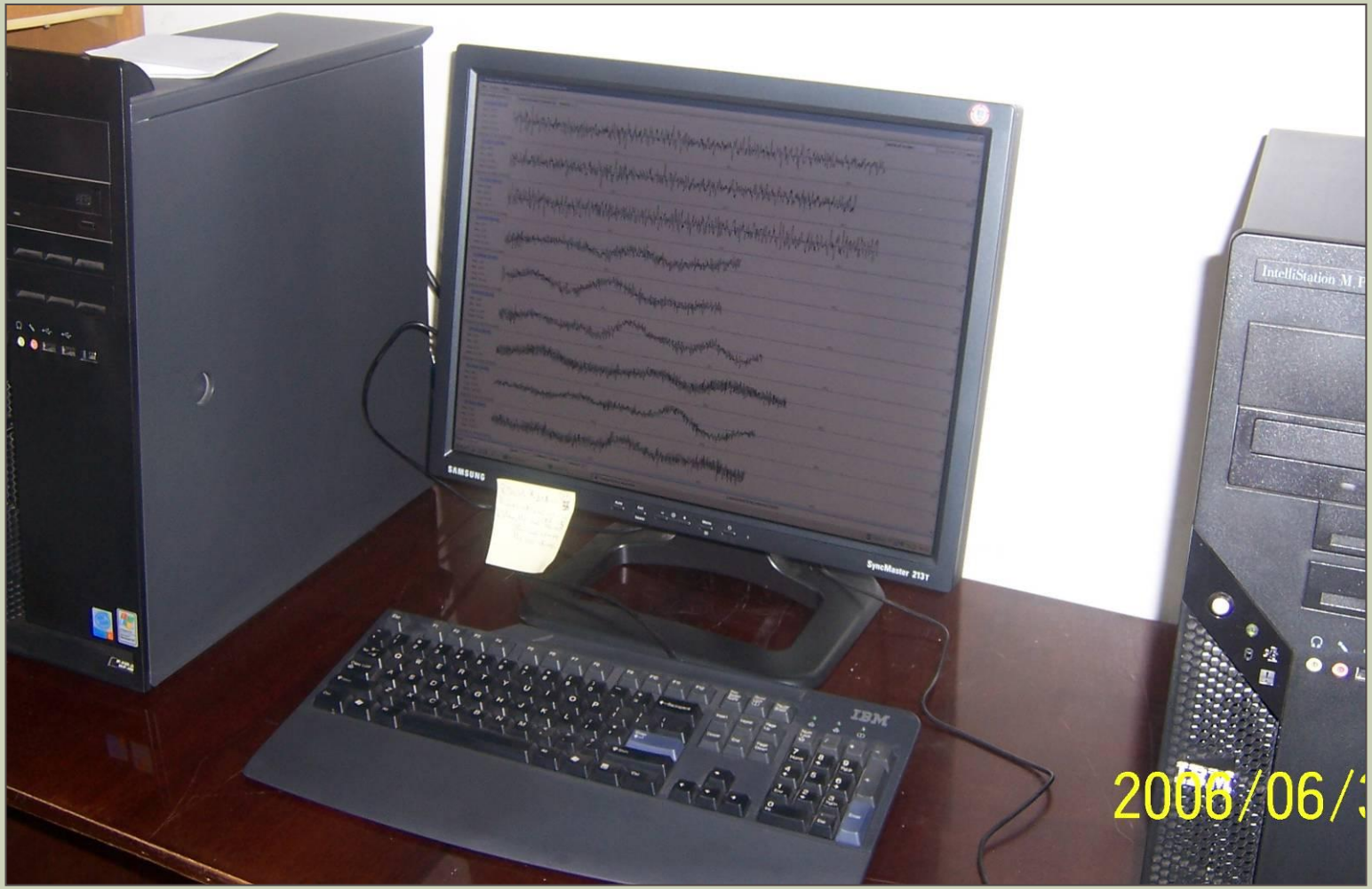
Receiver-transmitter "Cygnus"

PRINCIPLE OF OPERATION OF DIGITAL BROADBAND SEISMIC STATIONS

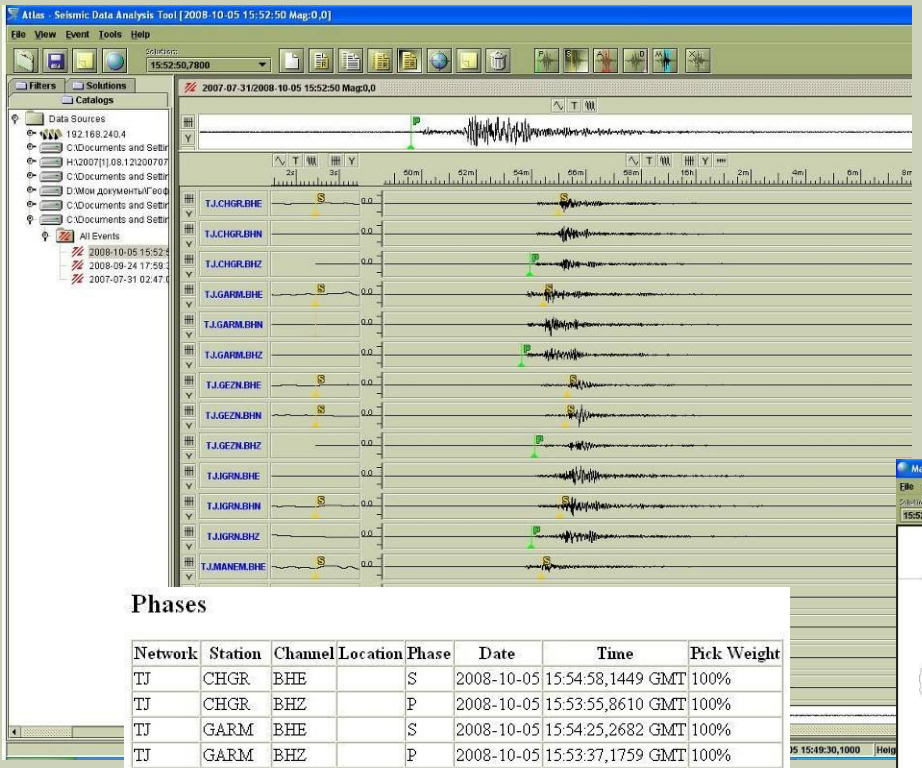




REAL-TIME DATA

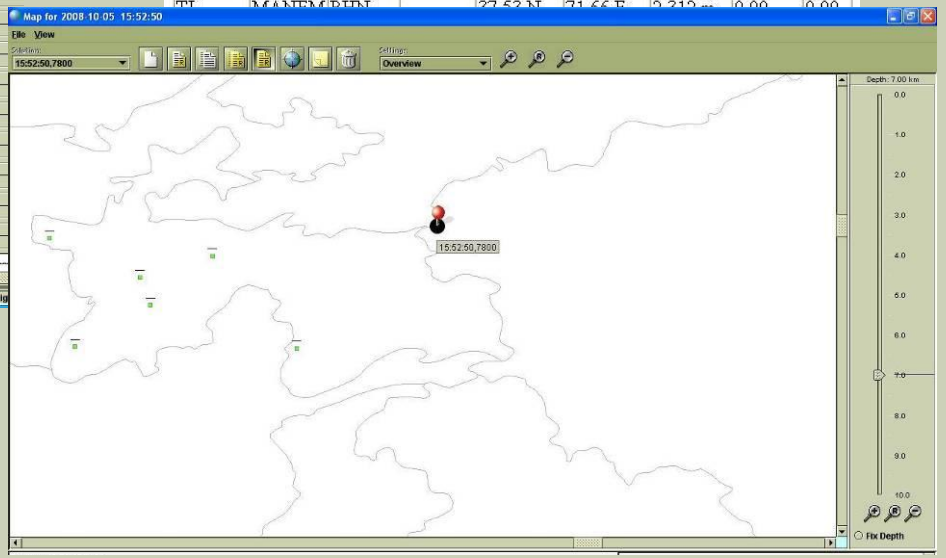


THE BULLETIN OF THE KYRGYZ EARTHQUAKE, 2008-10-05 15:52:50 (GMT)



Channels

Network	Station	Channel	Location	Latitude	Longitude	Elevation	Azimuth	Dip
TJ	CHGR	BHE		38,6569 N	69,1582 E	1 049 m	90,00	0,00
TJ	CHGR	BHN		38,6569 N	69,1582 E	1 049 m	0,00	0,00
TJ	CHGR	BHZ		38,6569 N	69,1582 E	1 049 m	0,00	90,00
TJ	GARM	BHE		39 N	70,316 E	1 305 m	90,00	0,00
TJ	GARM	BHN		39 N	70,316 E	1 305 m	0,00	0,00
TJ	GARM	BHZ		39 N	70,316 E	1 305 m	0,00	90,00
TJ	GEZN	BHE		39,2833 N	67,7154 E	1 485 m	90,00	0,00
TJ	GEZN	BHN		39,2833 N	67,7154 E	1 485 m	0,00	0,00
TJ	GEZN	BHZ		39,2833 N	67,7154 E	1 485 m	0,00	90,00
TJ	IGRN	BHE		38,2203 N	69,3266 E	1 284 m	90,00	0,00
TJ	IGRN	BHN		38,2203 N	69,3266 E	1 284 m	0,00	0,00
TJ	IGRN	BHZ		38,2203 N	69,3266 E	1 284 m	0,00	90,00
TJ	MANEM	BHE		37,53 N	71,66 E	2 312 m	90,00	0,00

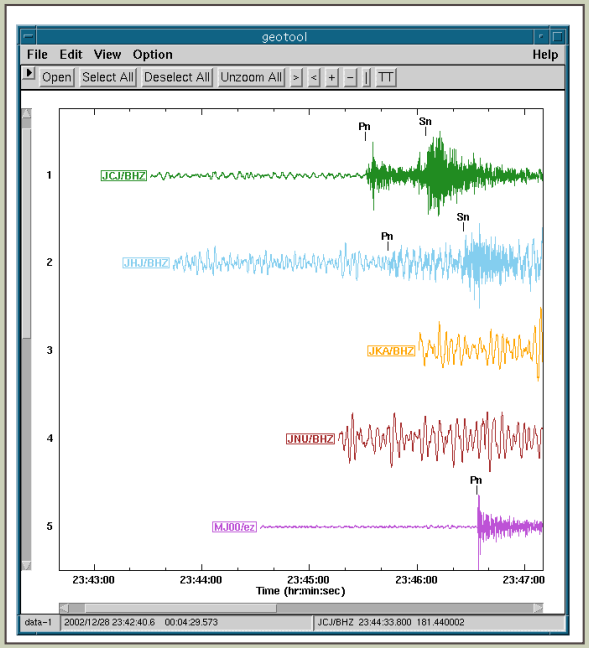


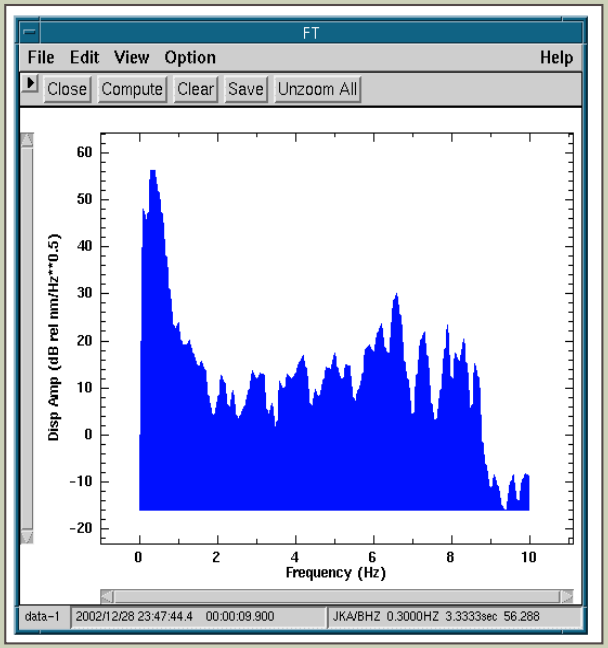
Phases

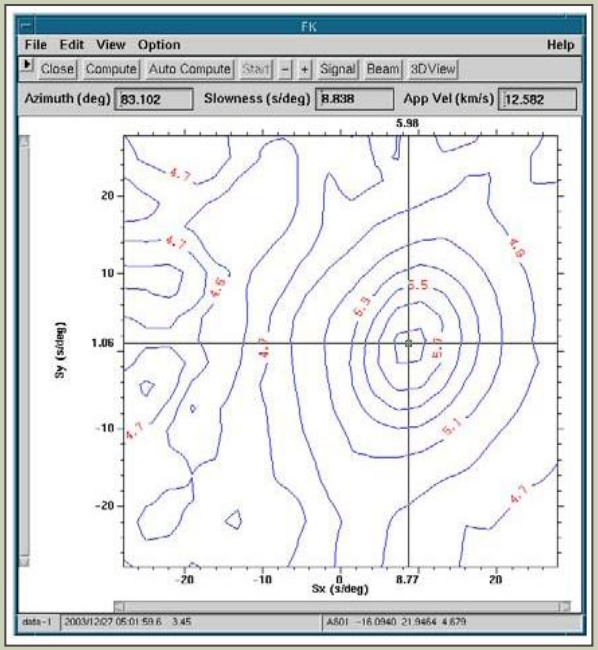
Network	Station	Channel	Location	Phase	Date	Time	Pick Weight
TJ	CHGR	BHE		S	2008-10-05	15:54:58,1449 GMT	100%
TJ	CHGR	BHZ		P	2008-10-05	15:53:55,8610 GMT	100%
TJ	GARM	BHE		S	2008-10-05	15:54:25,2682 GMT	100%
TJ	GARM	BHZ		P	2008-10-05	15:53:37,1759 GMT	100%
TJ	GEZN	BHE		S	2008-10-05	15:55:17,5636 GMT	100%
TJ	GEZN	BHN		S	2008-10-05	15:55:13,6067 GMT	100%
TJ	GEZN	BHZ		P	2008-10-05	15:54:05,0833 GMT	100%
TJ	IGRN	BHN		S	2008-10-05	15:55:01,6483 GMT	100%
TJ	IGRN	BHZ		P	2008-10-05	15:53:59,5676 GMT	100%
TJ	MANEM	BHE		S	2008-10-05	15:54:21,0739 GMT	100%
TJ	MANEM	BHZ		P	2008-10-05	15:53:36,3609 GMT	100%
TJ	SHAA	BHE		S	2008-10-05	15:55:28,0446 GMT	100%
TJ	SHAA	BHZ		P	2008-10-05	15:54:14,3260 GMT	100%

EARTHQUAKE SPECTRA

NDC-in-a-box is a set of utilities and programs that allow processing and analyzing seismic data and data of nuclear explosions, as well as constructing spectra of events, a strong earthquake, etc.

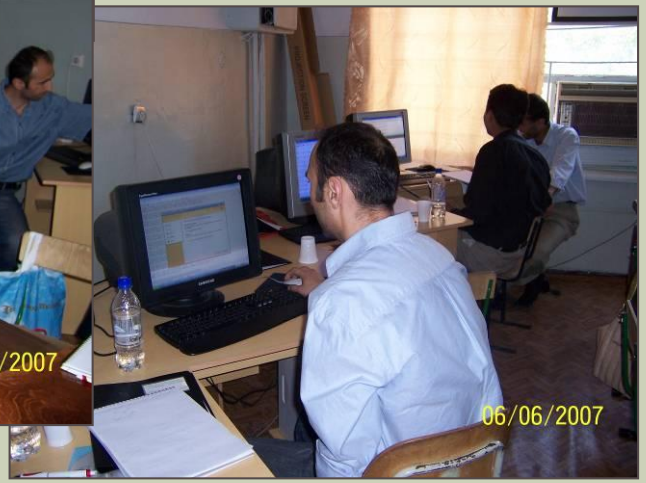




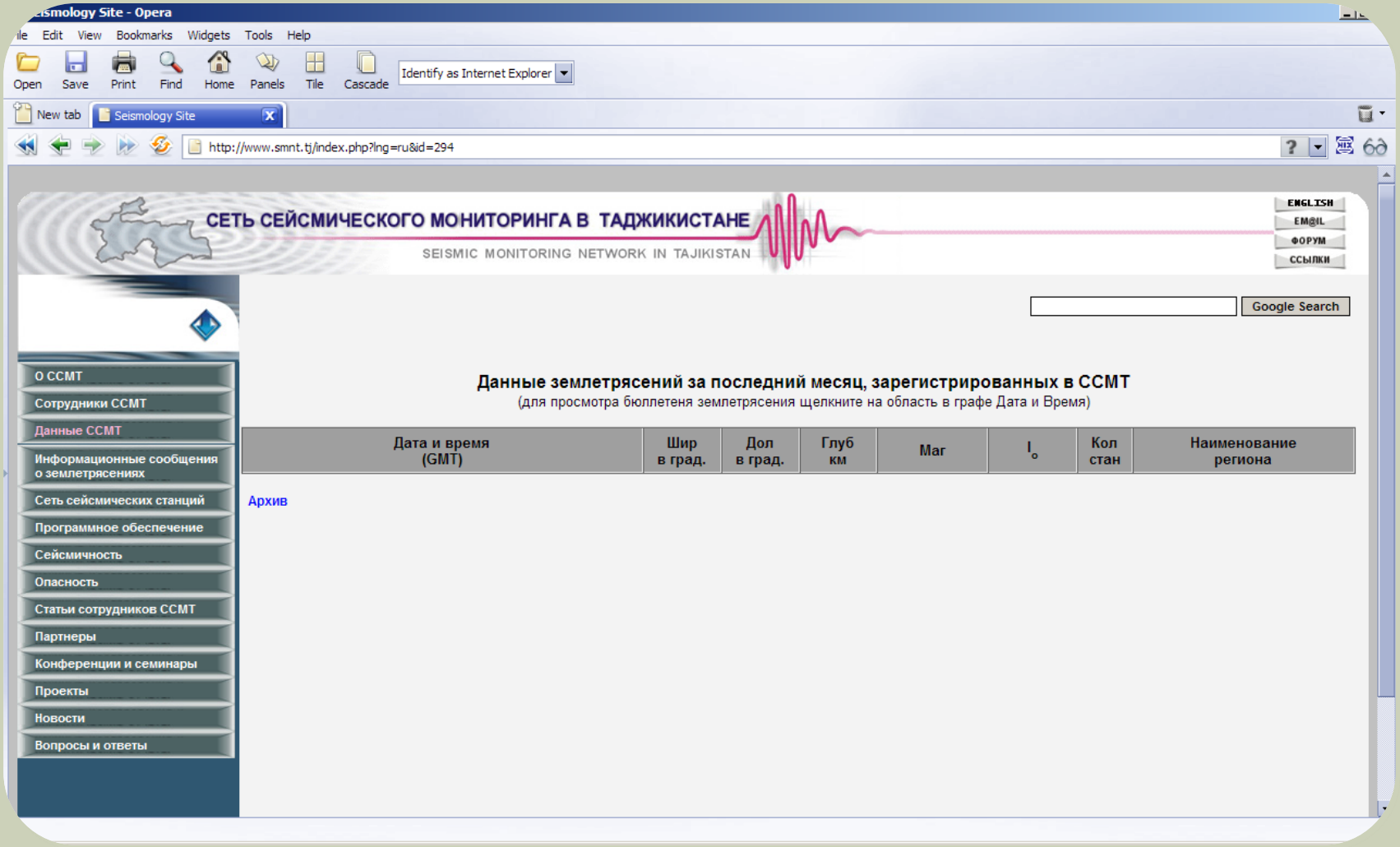


Geotool - program for processing events and plotting earthquake spectra

TRAINING COURSE ON SEISMOLOGY AND SEISMIC TOMOGRAPHY, DUSHANBE



WEB-SITE (WWW.SMNT.TJ)



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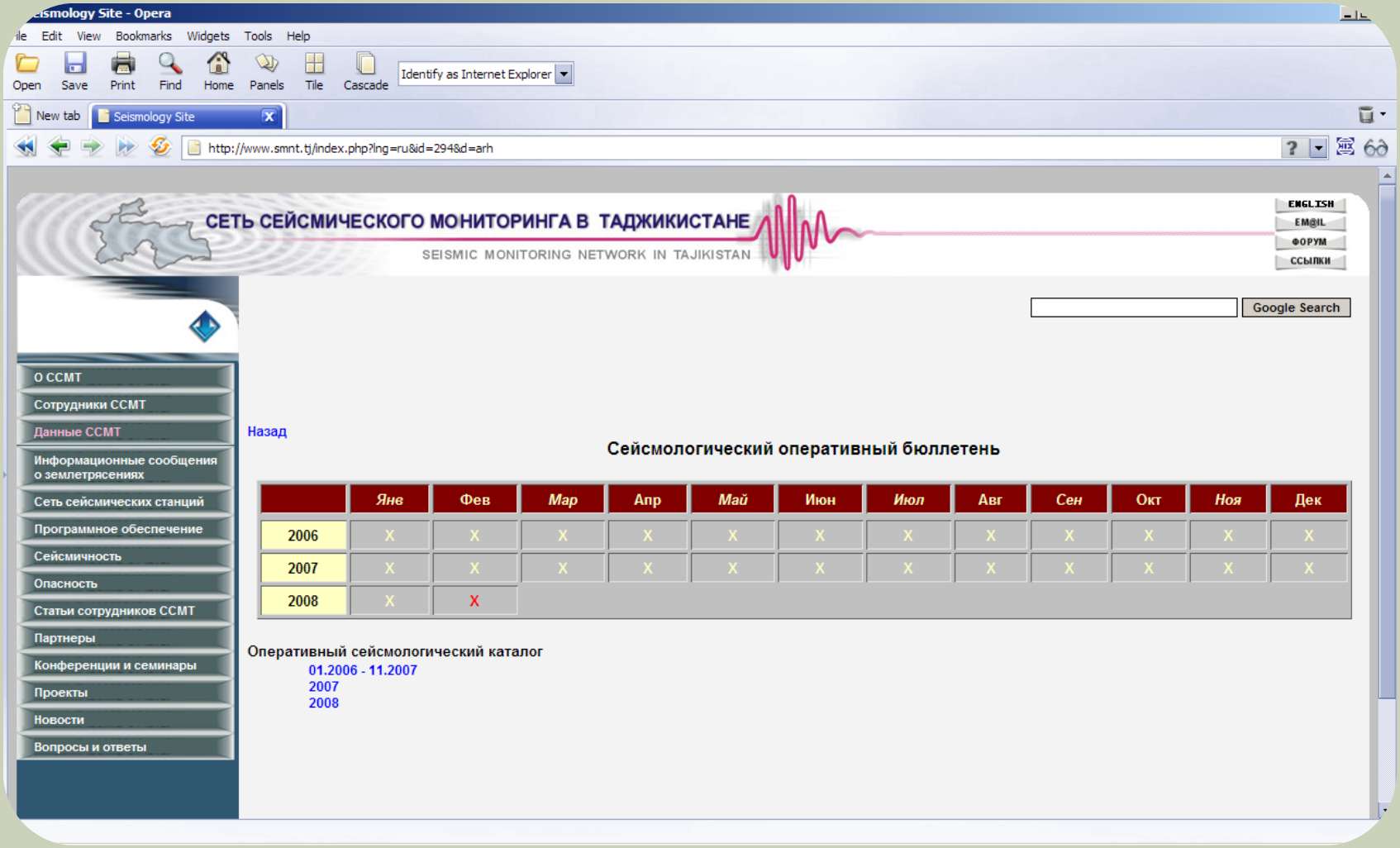

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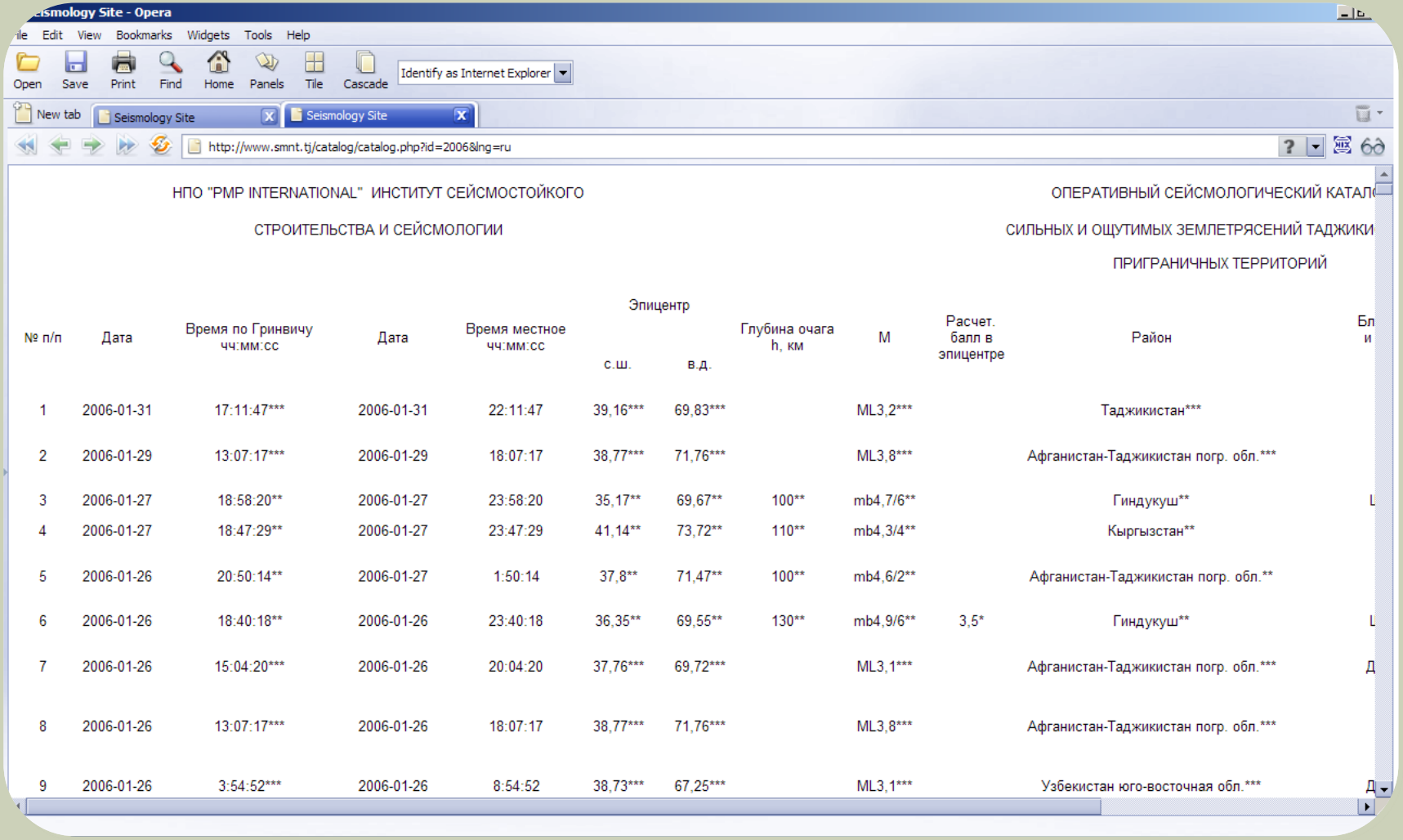
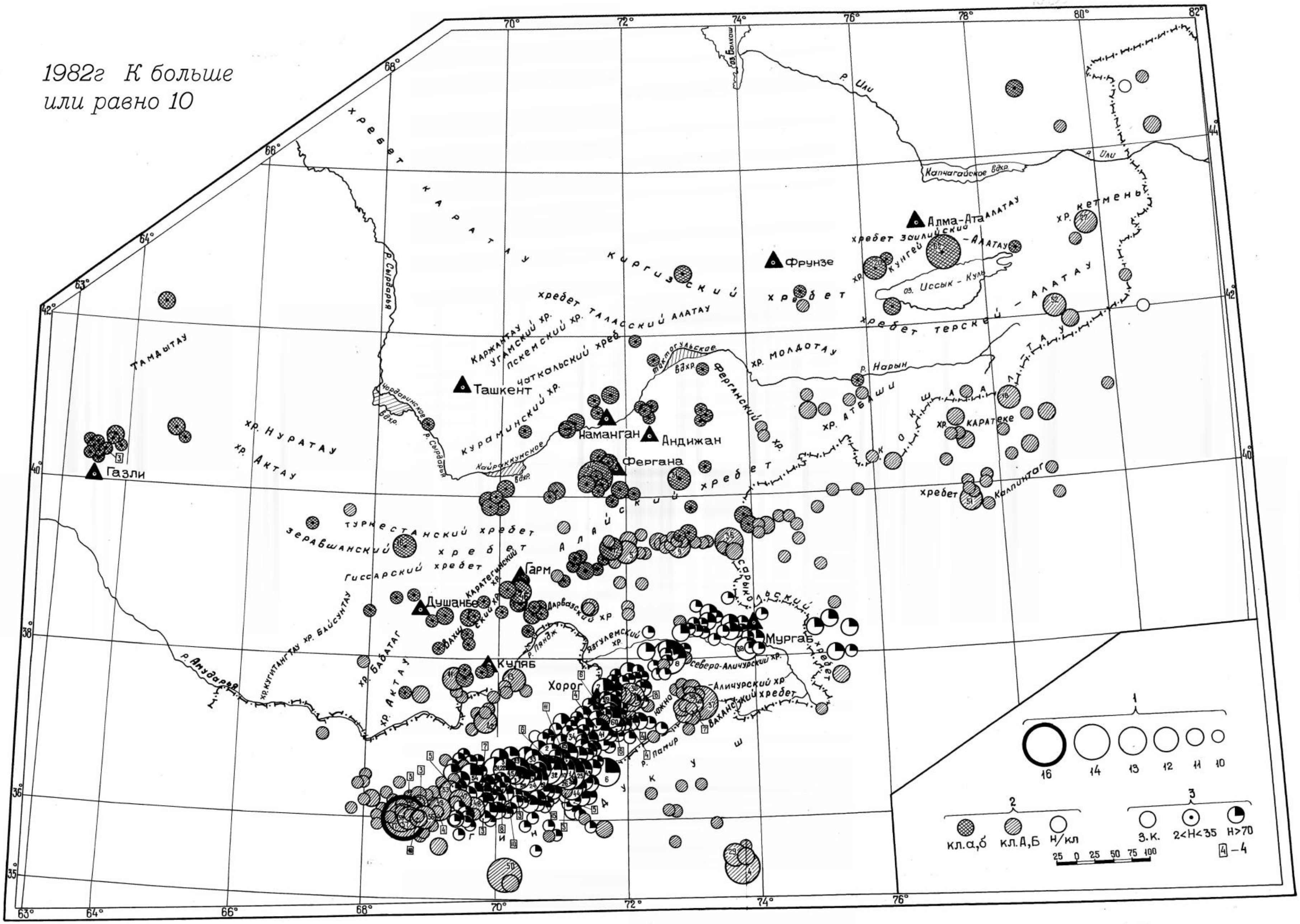


НПО "PMP INTERNATIONAL" ИНСТИТУТ СЕЙСМОСТОЙКОГО СТРОИТЕЛЬСТВА И СЕЙСМОЛОГИИ

ОПЕРАТИВНЫЙ СЕЙСМОЛОГИЧЕСКИЙ КАТАЛ
СИЛЬНЫХ И ОЩУТИМЫХ ЗЕМЛЕТРЯСЕНИЙ ТАДЖИКИ
ПРИГРАНИЧНЫХ ТЕРРИТОРИЙ

№ п/п	Дата	Время по Гринвичу чч:мм:сс	Дата	Время местное чч:мм:сс	Эпицентр с.ш.	Эпицентр в.д.	Глубина очага h, км	M	Расчет. балл в эпицентре	Район	Бл и
1	2006-01-31	17:11:47***	2006-01-31	22:11:47	39,16***	69,83***		ML3,2***		Таджикистан***	
2	2006-01-29	13:07:17***	2006-01-29	18:07:17	38,77***	71,76***		ML3,8***		Афганистан-Таджикистан погр. обл.***	
3	2006-01-27	18:58:20**	2006-01-27	23:58:20	35,17**	69,67**	100**	mb4,7/6**		Гиндукуш**	L
4	2006-01-27	18:47:29**	2006-01-27	23:47:29	41,14**	73,72**	110**	mb4,3/4**		Кыргызстан**	
5	2006-01-26	20:50:14**	2006-01-27	1:50:14	37,8**	71,47**	100**	mb4,6/2**		Афганистан-Таджикистан погр. обл.**	
6	2006-01-26	18:40:18**	2006-01-26	23:40:18	36,35**	69,55**	130**	mb4,9/6**	3,5*	Гиндукуш**	L
7	2006-01-26	15:04:20***	2006-01-26	20:04:20	37,76***	69,72***		ML3,1***		Афганистан-Таджикистан погр. обл.***	Д
8	2006-01-26	13:07:17***	2006-01-26	18:07:17	38,77***	71,76***		ML3,8***		Афганистан-Таджикистан погр. обл.***	
9	2006-01-26	3:54:52***	2006-01-26	8:54:52	38,73***	67,25***		ML3,1***		Узбекистан юго-восточная обл.***	Д

1982г К больше или равно 10



DIGITAL NETWORK CHARACTERISTICS

- Hardware
  - Station components
    - Vault, Seismometer, accelerometer
    - Digitizer, Timing
    - Communications, Data Storage
  - Response
    - Sensor, station
    - Amplitude, phase
  - Noise
    - Sources
    - Signal to Noise
- Data
  - Data structure
    - SEED format
      - Header information
      - Data structure and data types
    - Mini-SEED, Dataless SEED
    - Data volumes

TJ – TAJIK NATIONAL NETWORK

Network Code	TJ	
Stations	GARM	Garm
	CHGR	Chuyangaron
	IGRN	Igron
	SHAA	Shaartuz
	MANEM	Manem
	GEZN	Gezan
	CHRDR	Chorukh Dayron
Components	HHZ	Vertical
	HHN	North-South
	HHE	East-West

TAJIK NETWORK – DATA FLOW

TAJIK NATIONAL NETWORK (TJ)

Geophysical Service

Real time analysis and event location

Real Time Reporting and National Earthquake Catalog

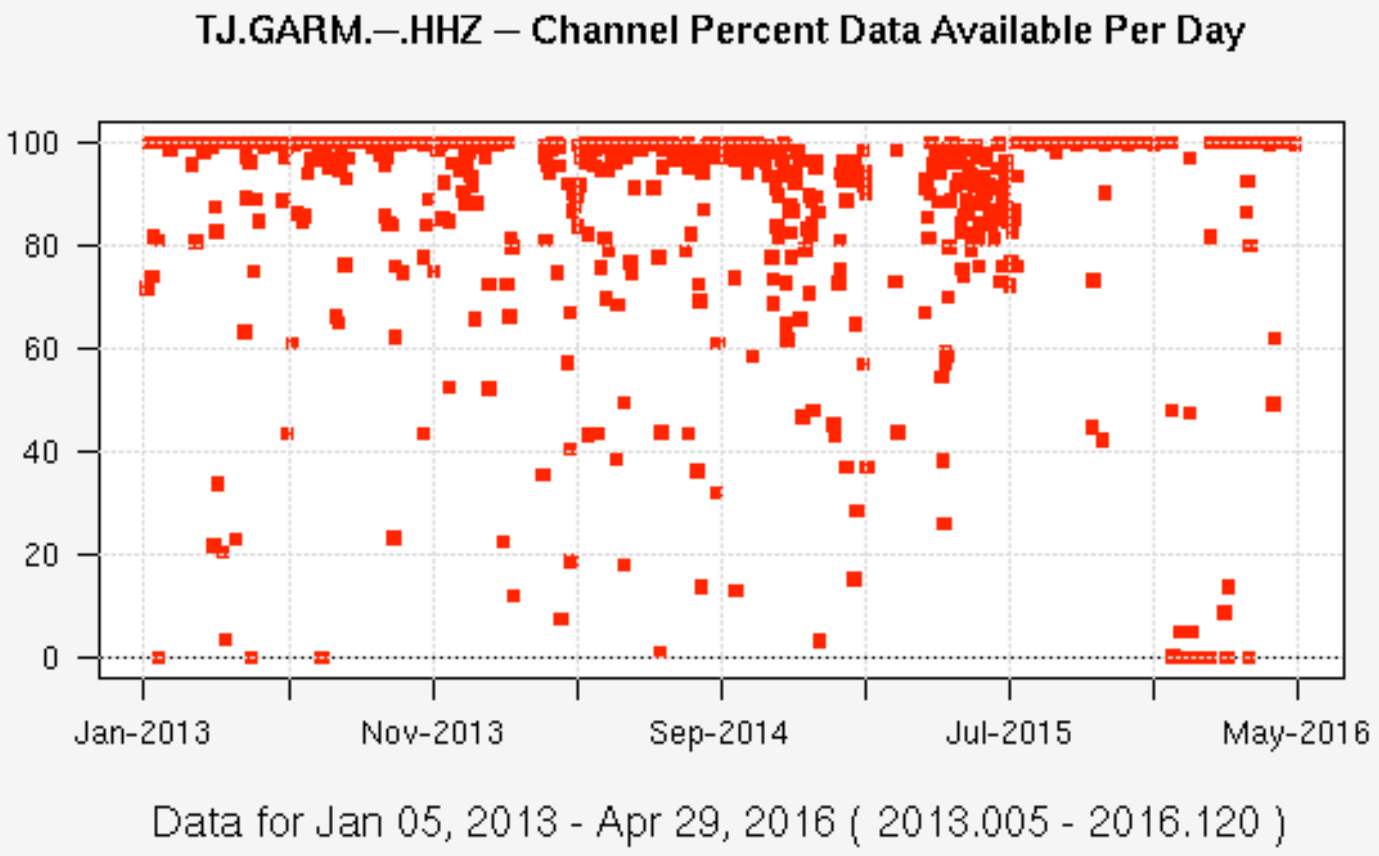
IRIS Data Management Center

USGS NEIC Global Catalog

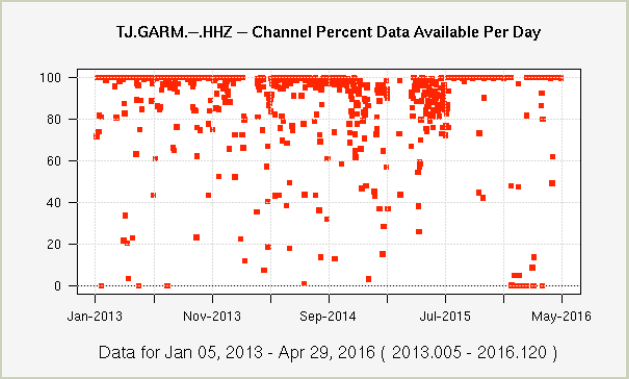
Search and request tools Waveform and Metadata

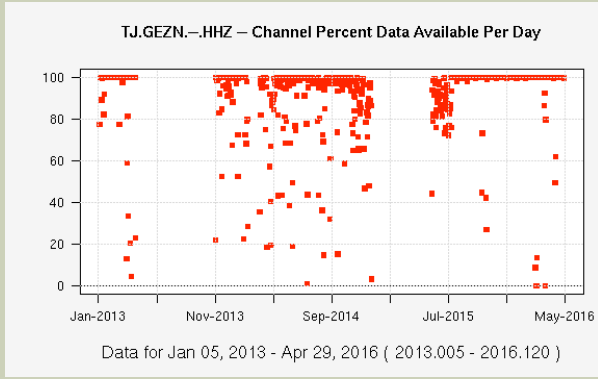
Users and Agencies
eg IGEES and university researchers

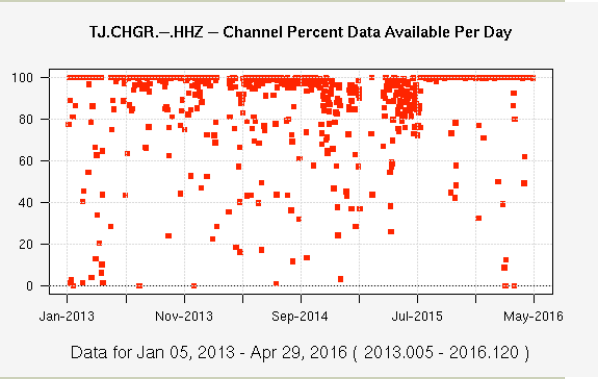
DATA AVAILABILITY

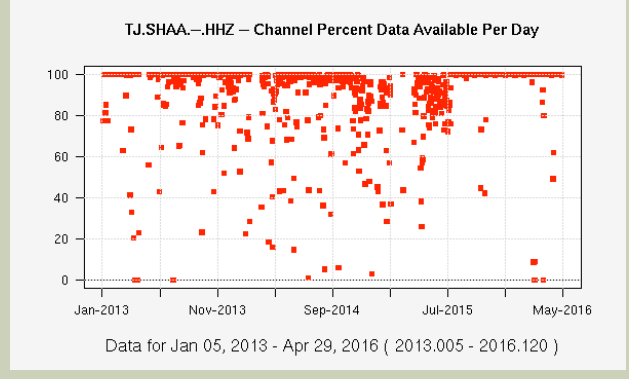


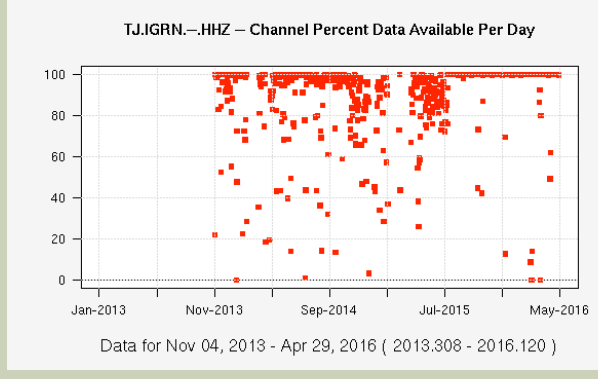
TJ – Station data return -- 1/1/2013 to 5/1/2016

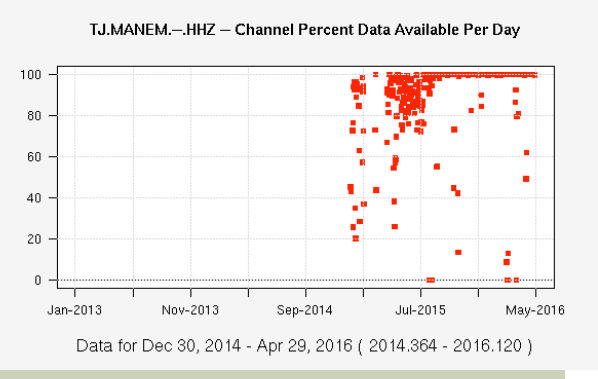


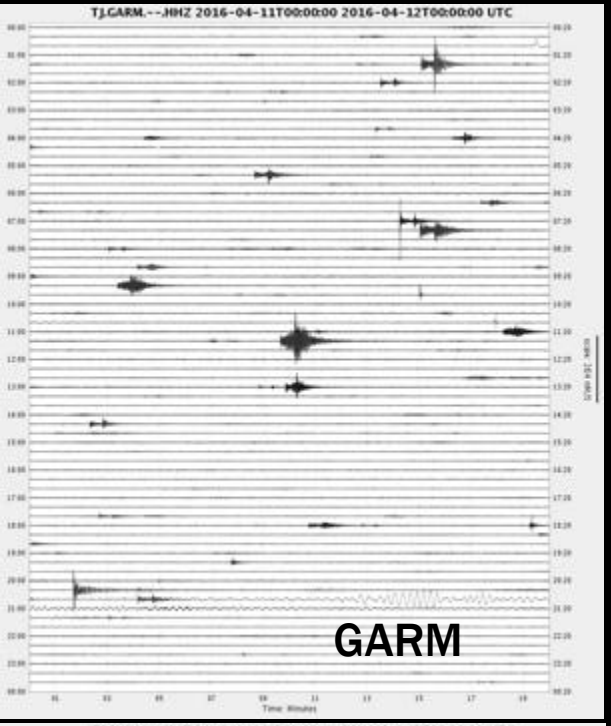








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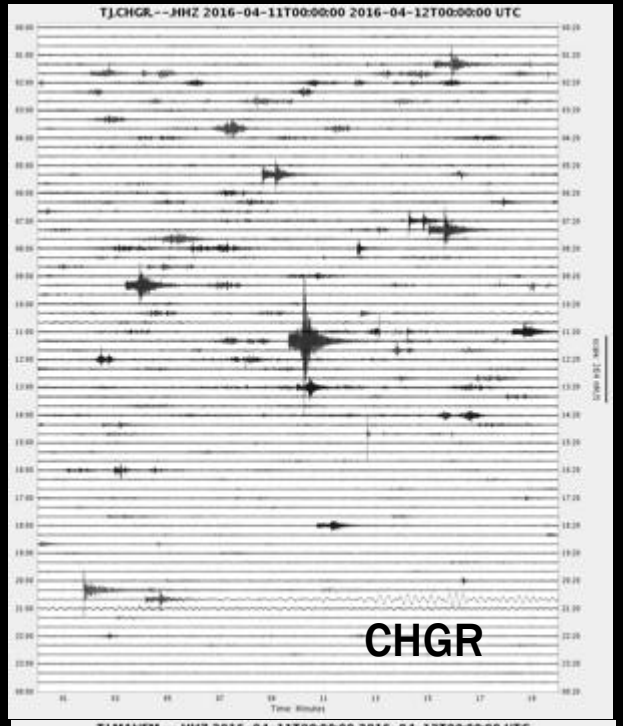
GARM


TJ.GEZN.--.HHZ 2016-04-11T00:00:00 2016-04-12T00:00:00 UTC
GEZN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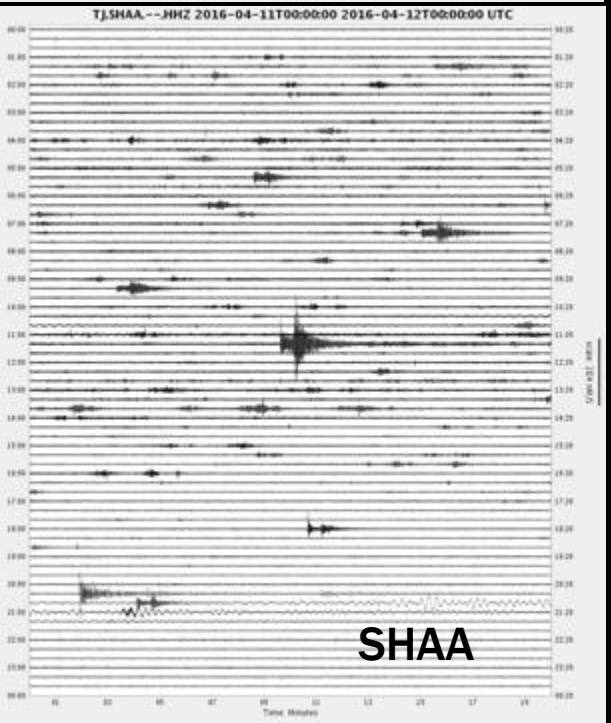
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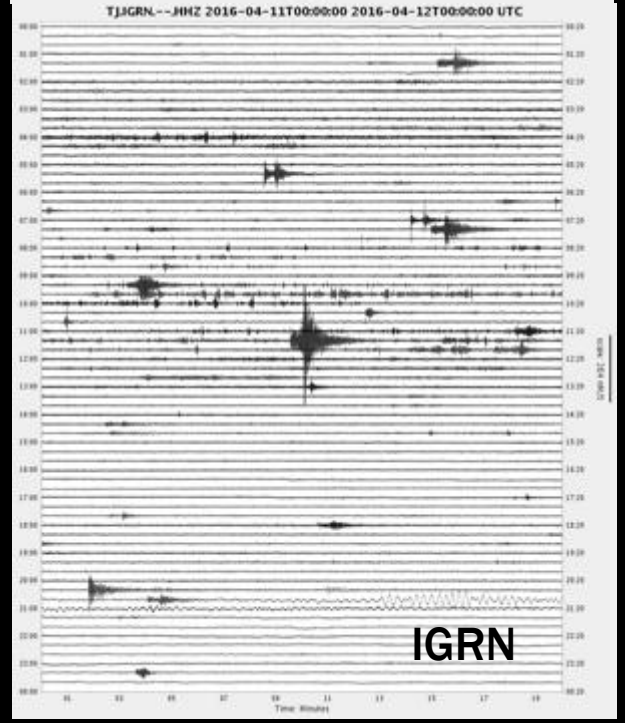
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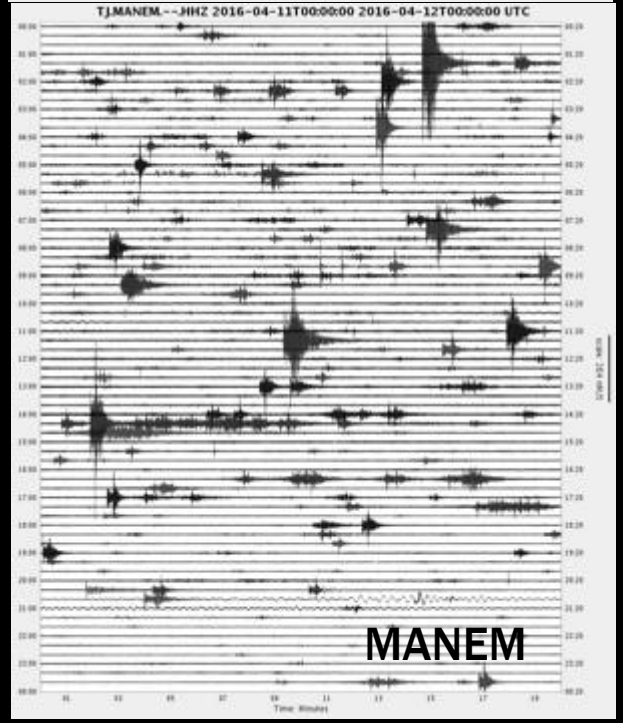
IGRN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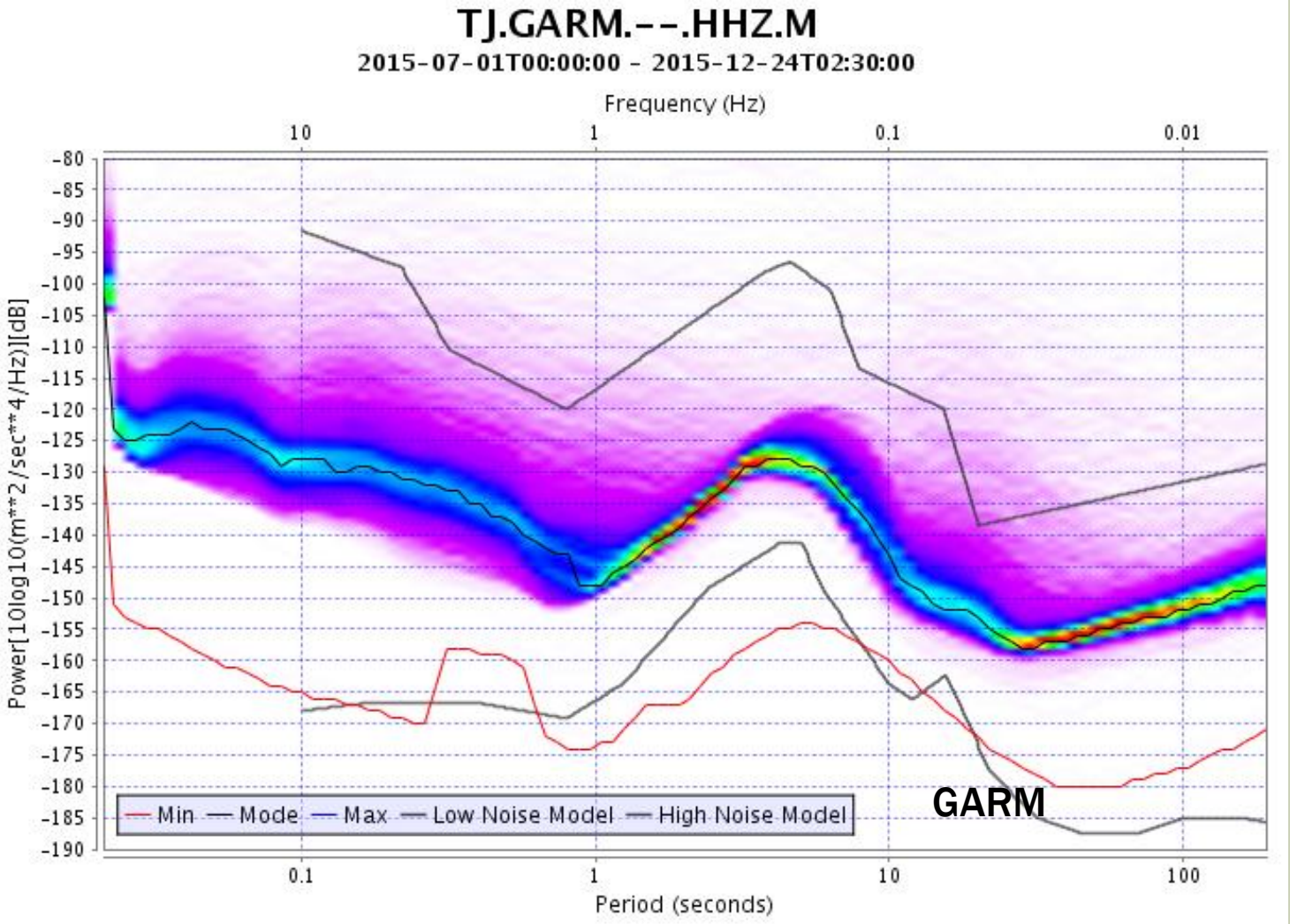
MANEM

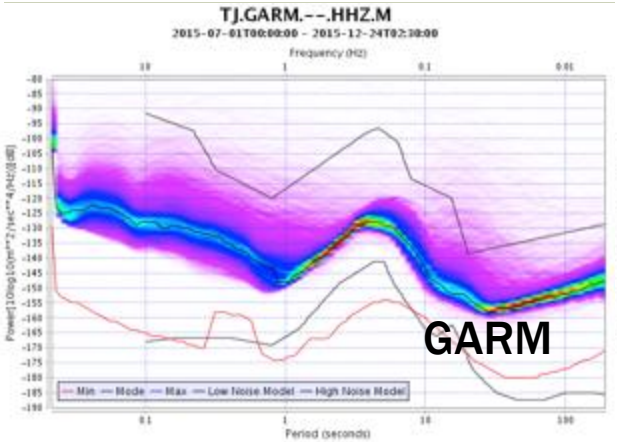
TJ - NOISE SPECTRA - PSD

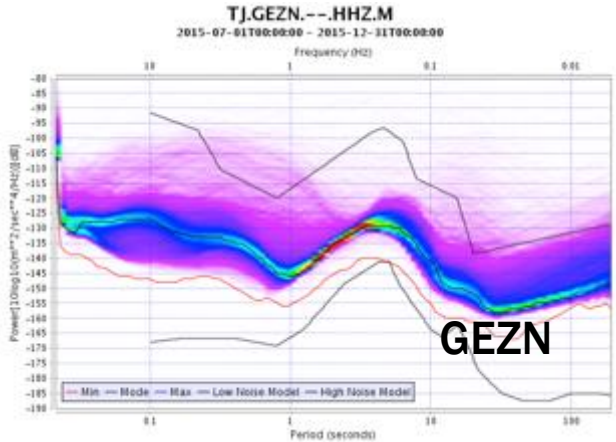


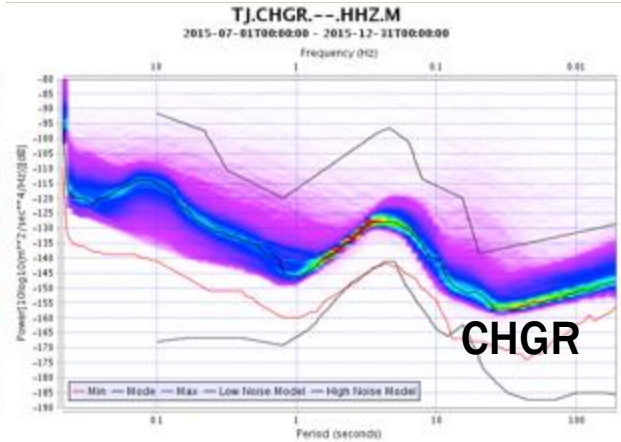
Noise Spectra

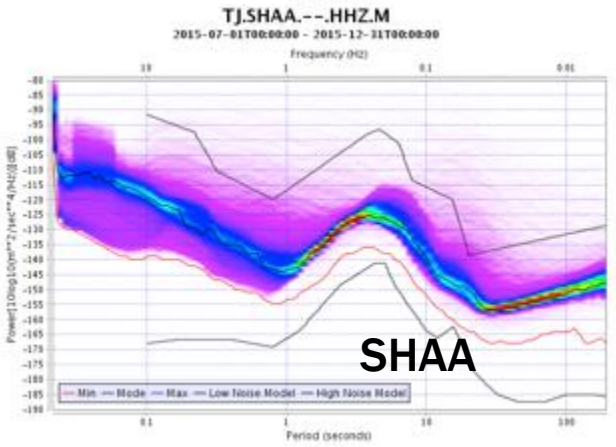
GARM

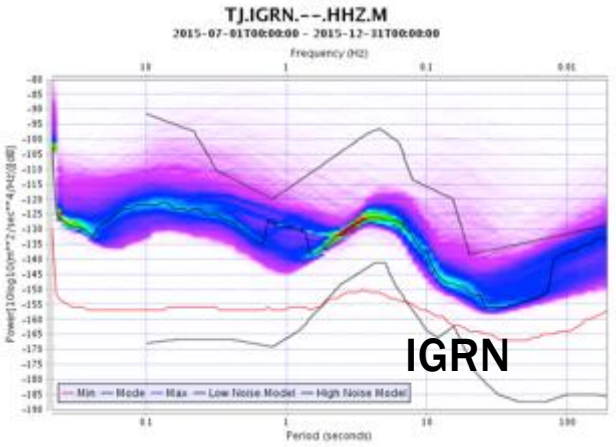
TJ - NOISE SPECTRA - PSD

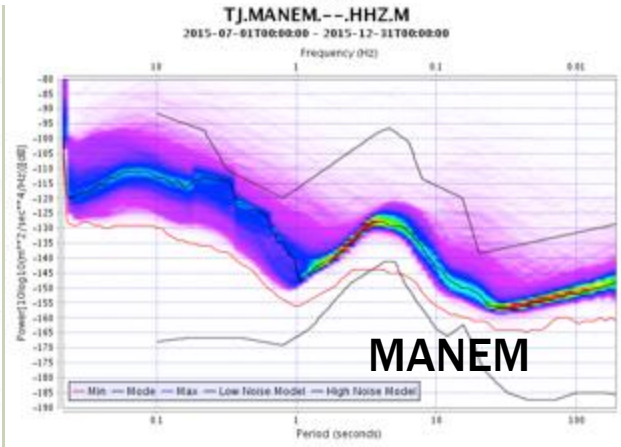




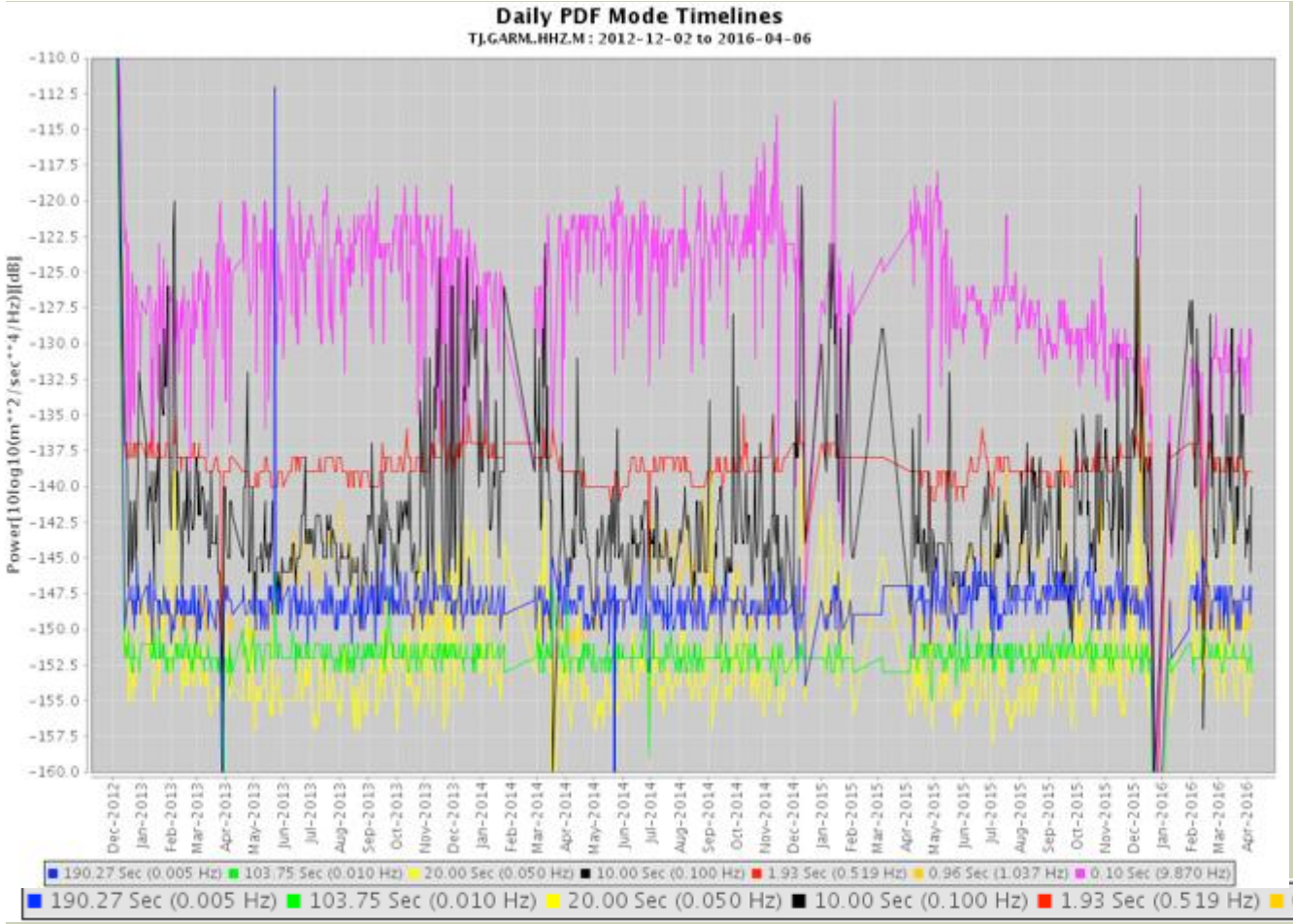








TIME VARIATION IN NOISE



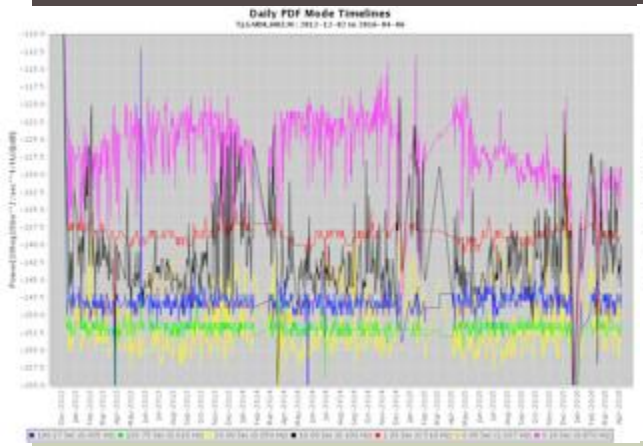
Noise levels by time

GARM

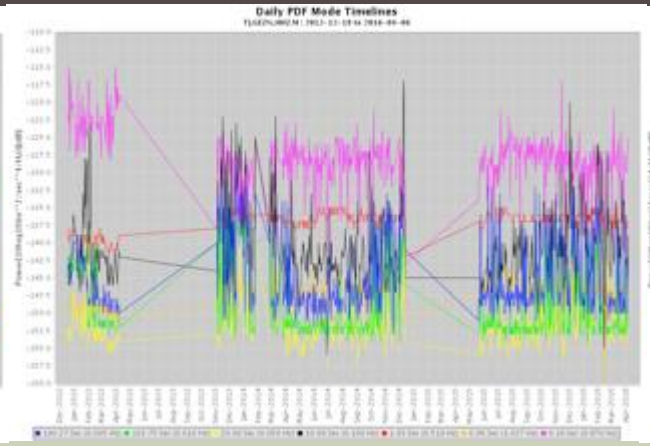
Dec 2012 – Apr 2016

.005 Hz	0.01 Hz	.05 Hz	0.1 Hz	0.5 Hz	1.0 Hz	10 Hz
200 Sec	100 Sec	20 Sec	10.0 Sec	2.0 Sec	1.0 Sec	0.1 Sec

TIME VARIATION IN NOISE



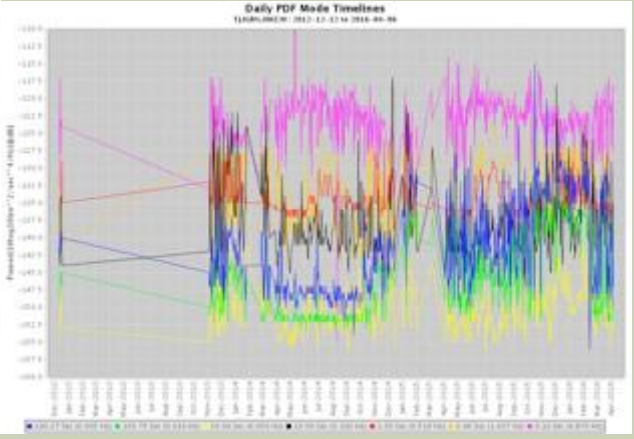
GARM



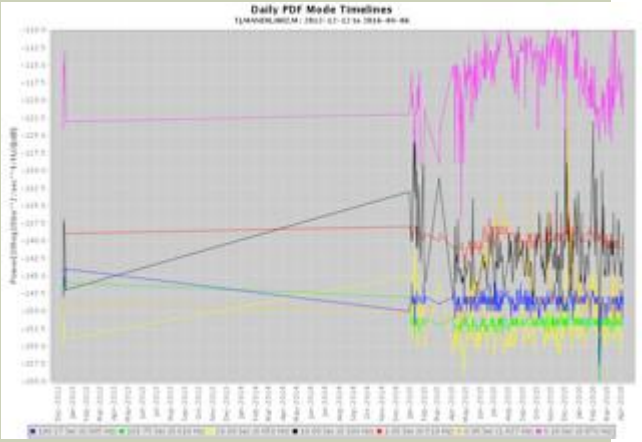
GEZN

CHGR

SHAA



IGRN



MANEM

■ 190.27 Sec (0.005 Hz) ■ 103.75 Sec (0.010 Hz) ■ 20.00 Sec (0.050 Hz) ■ 10.00 Sec (0.100 Hz) ■ 1.93 Sec (0.519 Hz) ■ 0.96 Sec (1.037 Hz) ■ 0.10 Sec (9.870 Hz)

.005 Hz	0.01 Hz	.05 Hz	0.1 Hz	0.5 Hz	1.0 Hz	10 Hz
200 Sec	100 Sec	20 Sec	10.0 Sec	2.0 Sec	1.0 Sec	0.1 Sec

STATION SIMI, SIMIGANJ, TAJIKISTAN

Station Overview

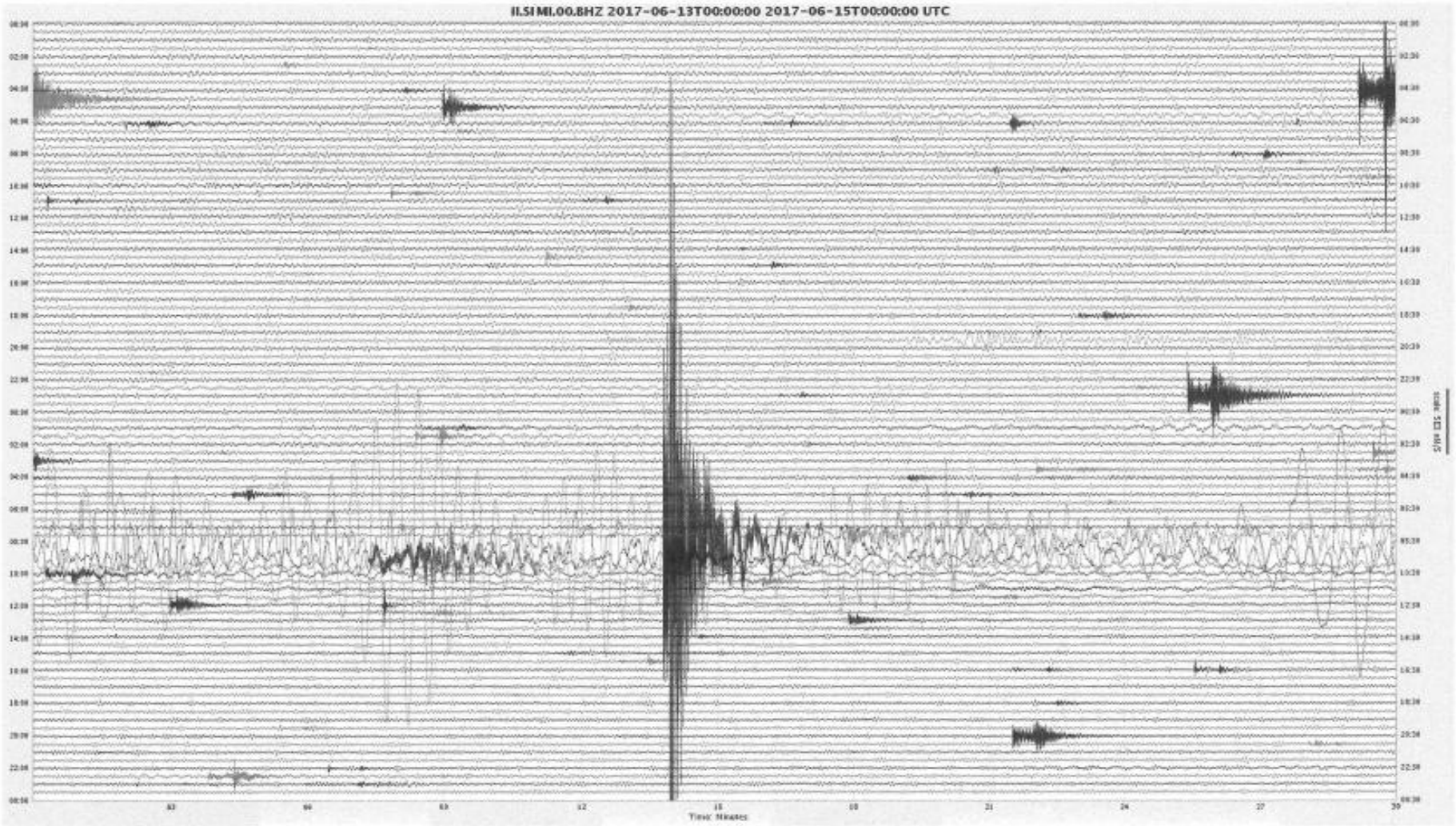
Coordinates: Latitude: 38.3951
Longitude: 69.0053

4:15 PM
Tue, Oct 24, 2017

GSN


LVZ
BORG
ESK
BFO
CMLA
Station SIMI, Simiganj, Tajikistan
SIMI
ECM
RAYN
UOSS
SACV
PALK
KWJN
MBAR
MSEY
DGAR
KAPI
ASCN
SHEL
COCO
ABPO
WRAB
MSVF
SUR
TAU
EFI
HOPE
Leaflet | Tiles © Esri
LEGEND: Up Down Problems Other GSN Stations

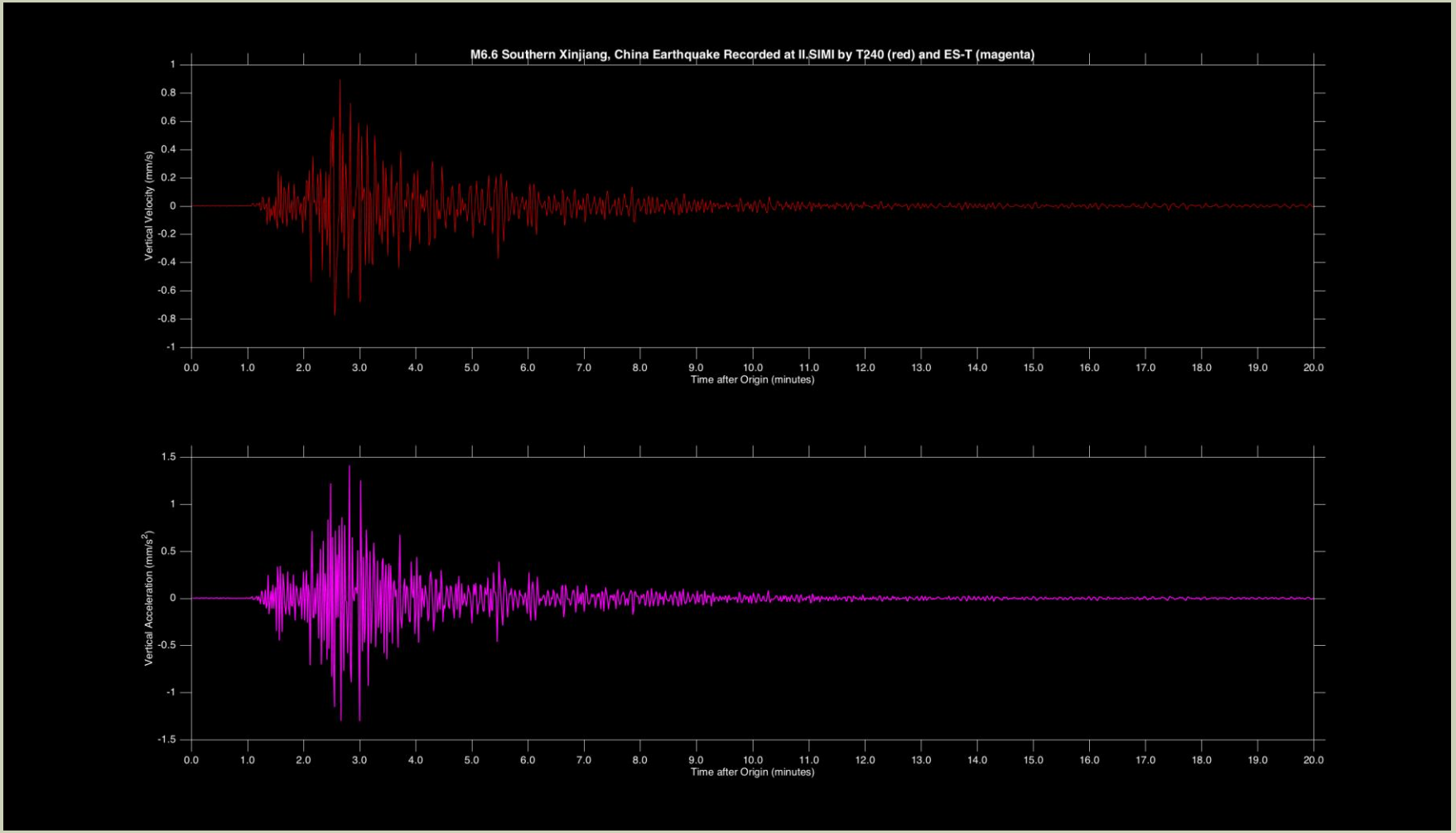
II.SIMI.00.BHZ 2017-06-13T00:00:00 2017-06-15T00:00:00 UTC



MEASURE THE ORIENTATION OF THE SEISMOMETER

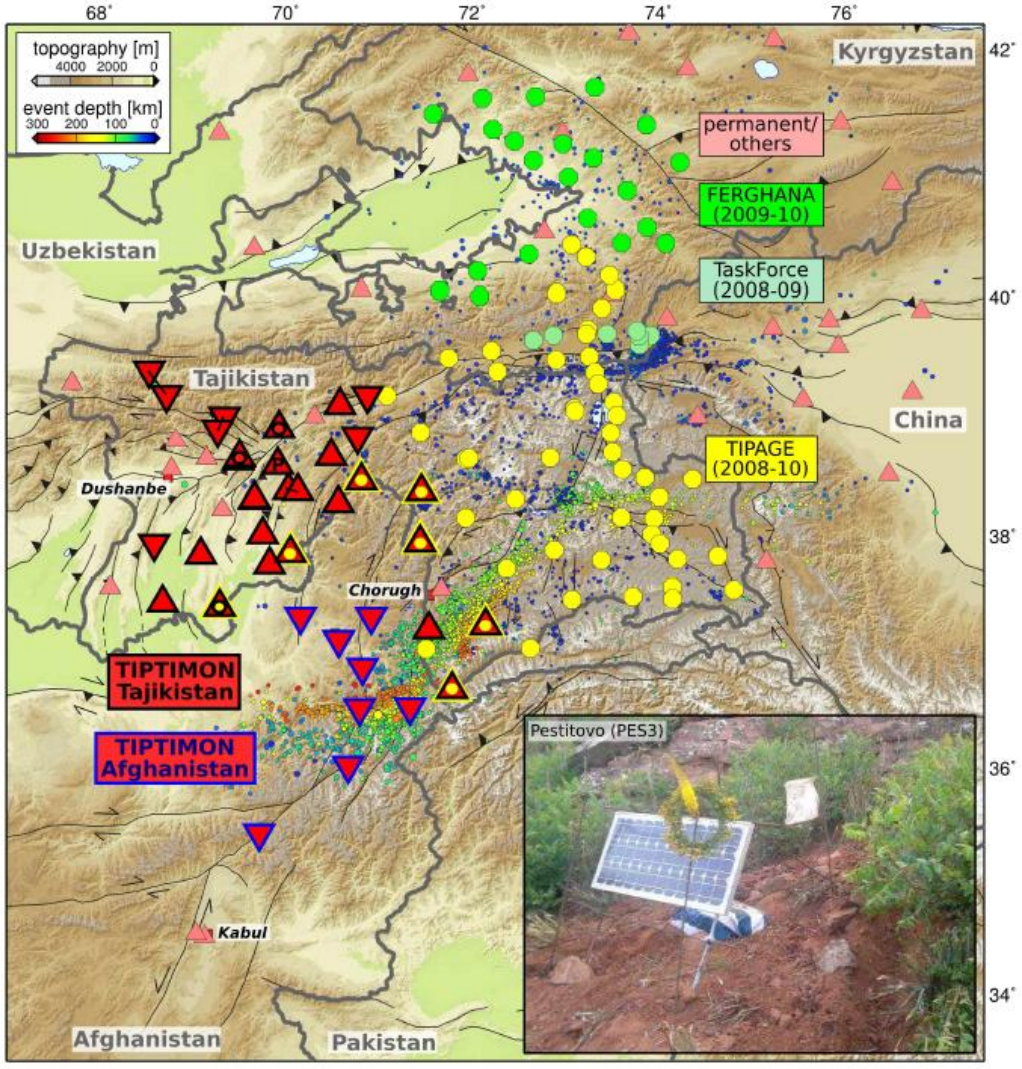
EQUIPMENT INSTALLED IN TUNNEL. THE FOAM COVERED BOX IS INSULATING THE TRILLIUM 240 SEISMOMETER.

SEISMOGRAM FROM THE MAGNITUDE 6.6 EARTHQUAKE THAT OCCURRED IN SOUTHERN XINJIANG, CHINA ON NOVEMBER 25, 2016, AT SEISMIC STATION II.SIMI. TOP (RED): RECORDED BY THE T240 BROADBAND SEISMOMETER. BOTTON (MAGENTA): RECORDED BY THE ES-T STRONG MOTION SEISMOMETER. CLICK TO SEE LARGER IMAGE



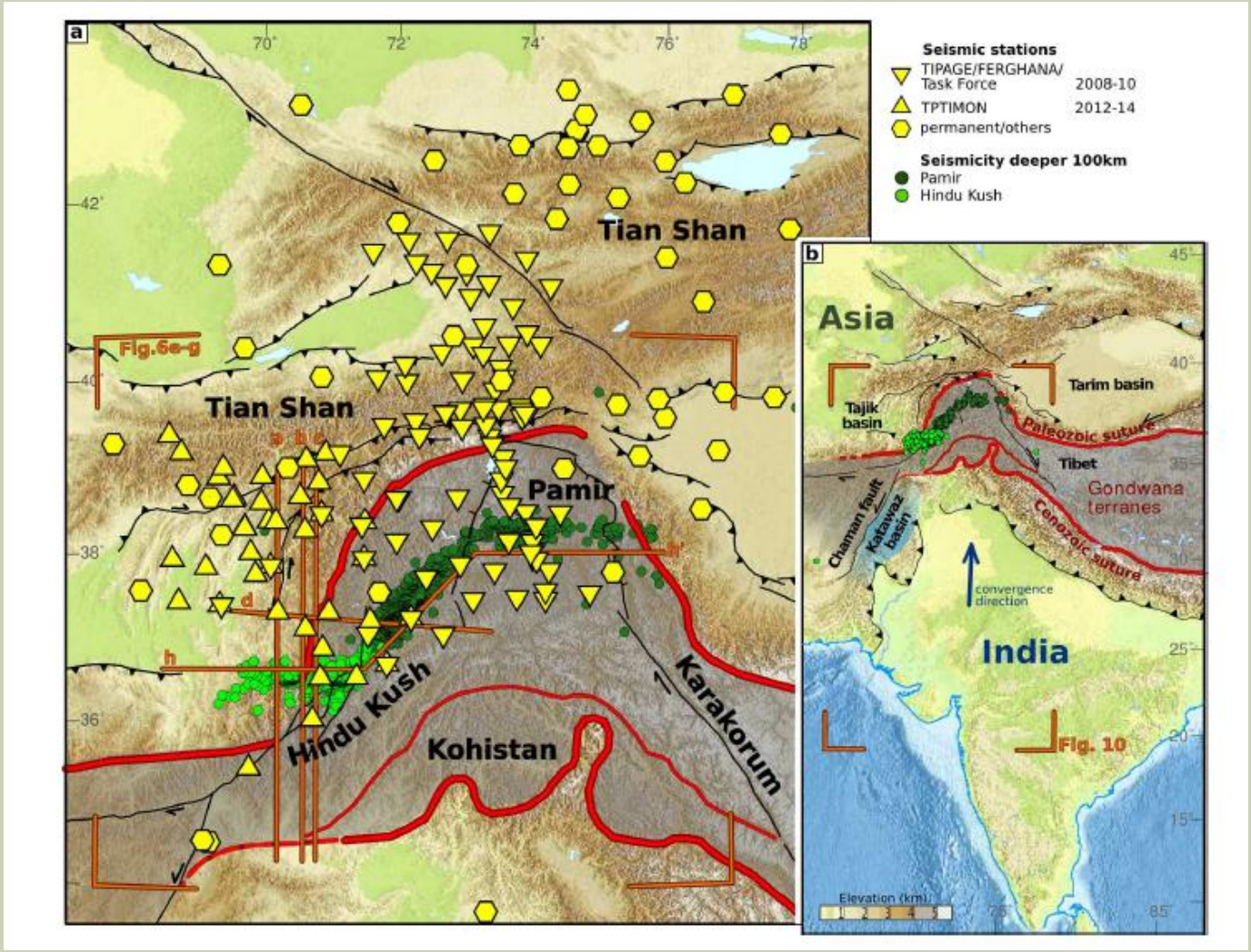
- Temporary seismic networks

TIPTIMON NETWORK

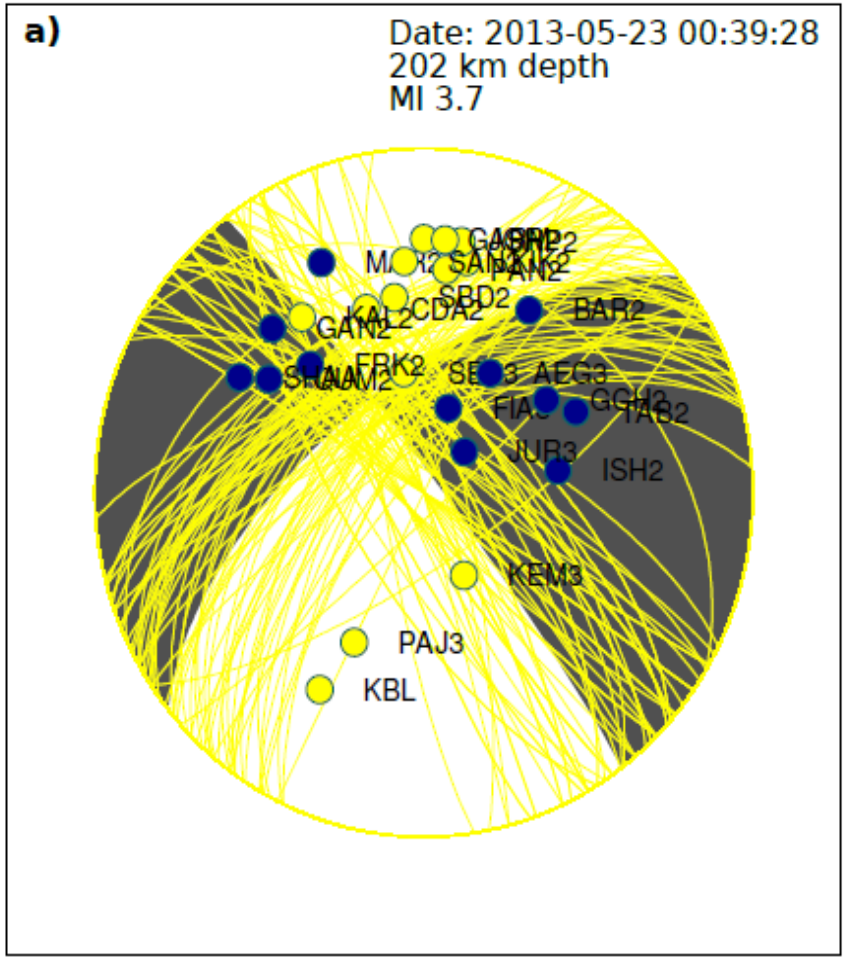


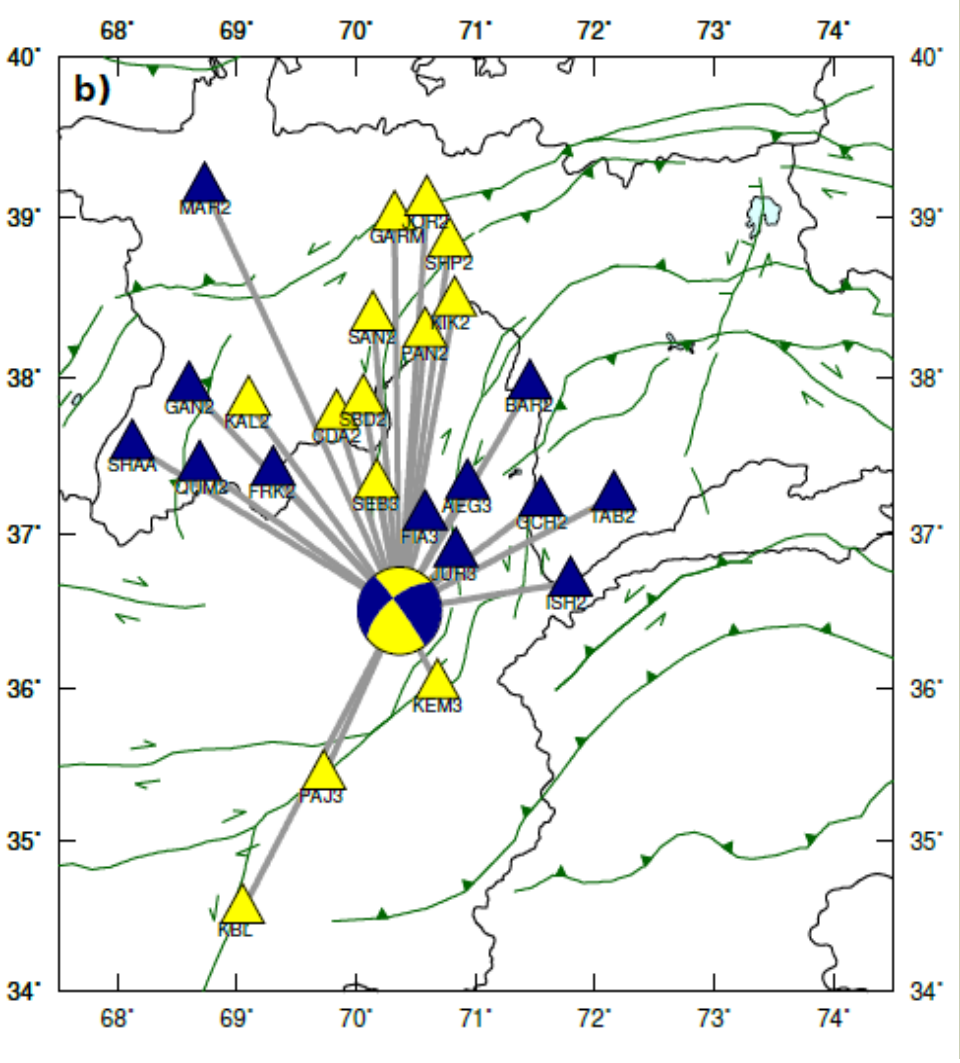
Map showing the seismic stations used in this study and political boundaries (gray) together with the seismicity from Sippl et al. (2013b) and local tectonic features (black) from Schurr et al. (2014). TIPTIMON stations (red triangles) were deployed between 2012-14 and 2013-14 in Tajikistan and Afghanistan, respectively. Triangles represent Guralp CMG- 3ESP seismometers, inverted triangles Nanometrics Trillium-120 and MARK L-4C-3D seismometers on the Tajik and Afghan side, respectively. Stations marked with a yellow dot are redeployed TIPAGE sites. The three stations with a black circle temporarily lost their GPS antenna. Stations connected with a black line were moved during the deployment accordingly. The label P marks the Pestitovo station, which is shown in the map inset as an
example for our setup. The other labeled networks were deployed prior to TIPTIMON, but also used in this study (see Sippl, 2013, for a detailed description of these stations). Most of the other/permanent stations (light red), which I included in my work operated during both deployment periods (see Supplementary Section A.1 for more detailed information regarding the TIPTIMON network and the permanent stations).

TIPTIMON NETWORK

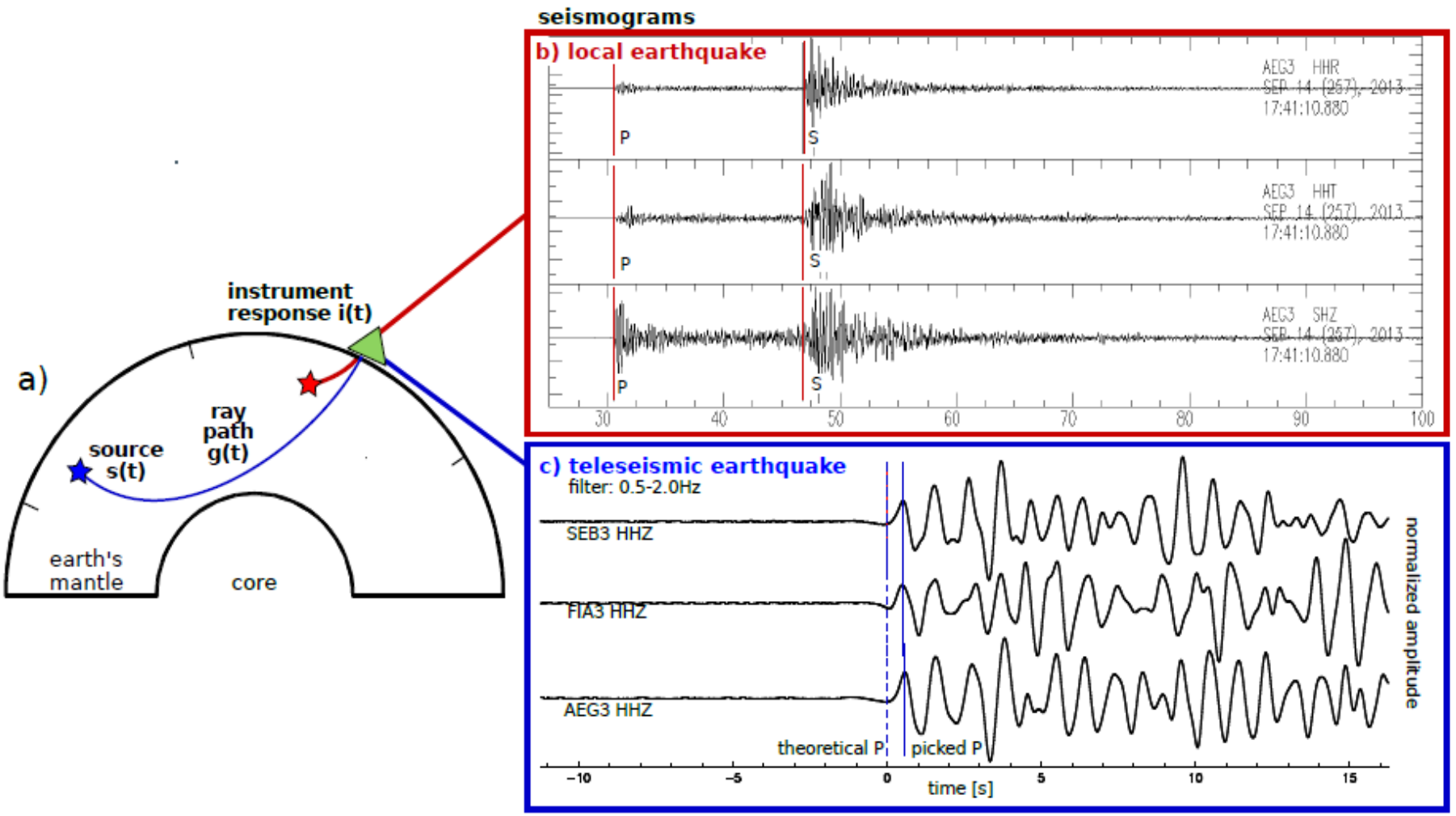


TIPTIMON NETWORK



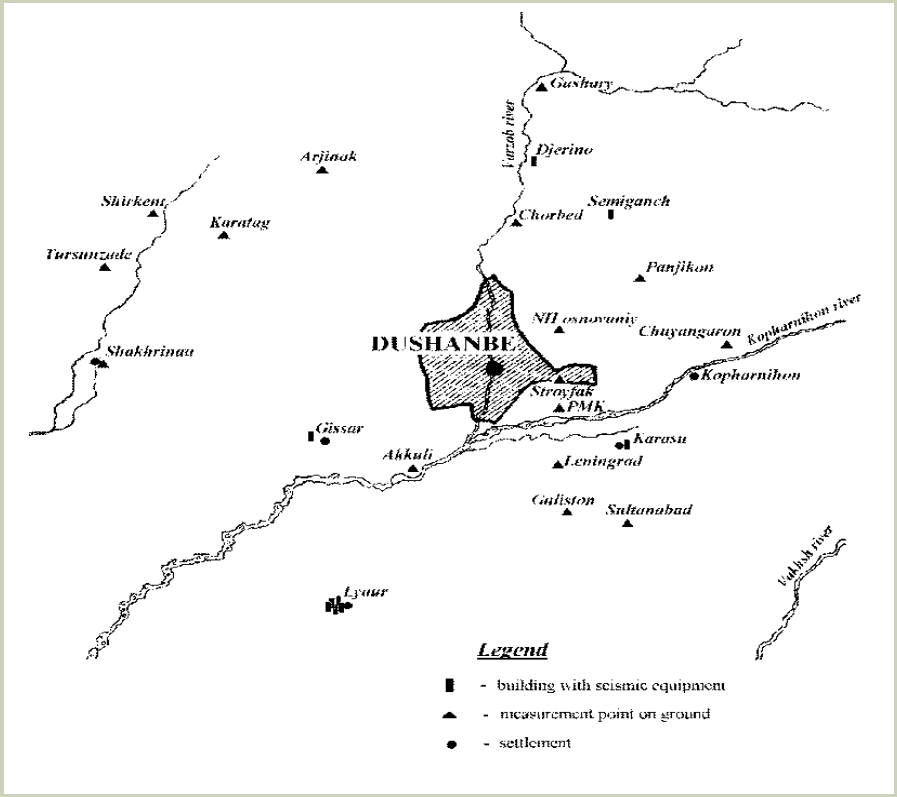


TIPTIMON NETWORK

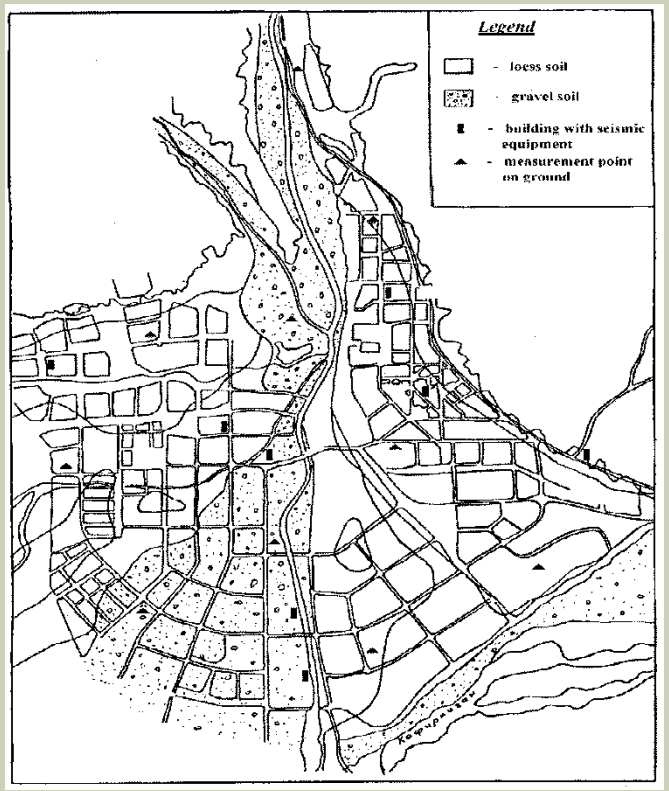


STRONG MOTION NETWORK

Strong motion network
for Dushanbe area.



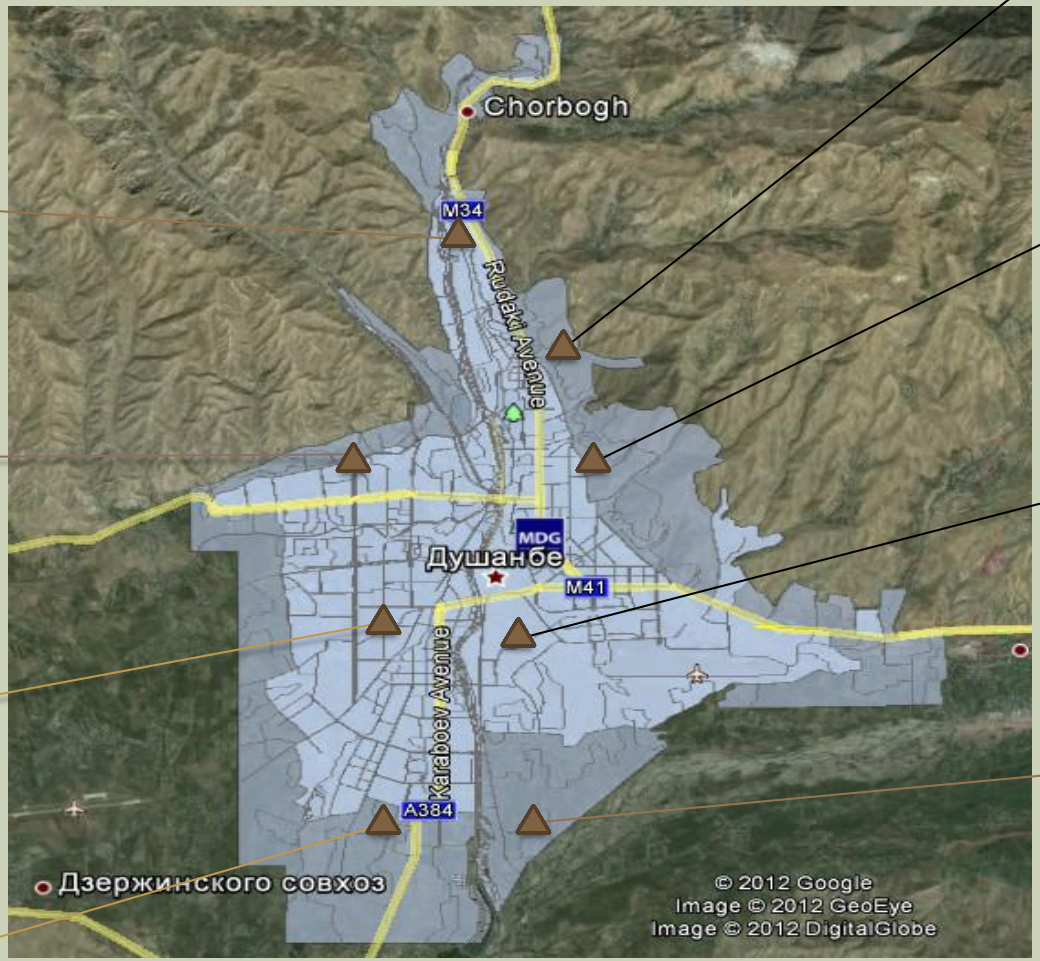
Strong motion network
in the Dushanbe
(on the buildings and on the ground).



TEMPORARY SEISMIC NETWORK INSTALLATION (EMCA PROJECT)

- Starting from 22 March 2012 a dense temporary seismic network was installed in Dushanbe. The network consisted of 45 EDL 24bit acquisition systems equipped with short-period Mark-L4-C-3D sensors. To increase the number of monitored sites in the inhabitated area 27 stations were moved beginning of July 2012. For 9 stations the sites were not changed and 9 stations were removed completely. All stations operated in continuous mode at a sampling rate of 100 samples per second until the removal of the entire network during the last days of October 2012.

TEMPORARY SEISMIC NETWORK INSTALLATION (EMCA PROJECT)



SEISMIC TOOLS

Seismometer / MARK L-4C-3D

Mechanical Parameters

Sensor 3 orthogonal geophones

Seismometer, 210 units:

210 Units: 3 components, 1 Hz, 5500 Ohms coil resistance

Signal Output

Generator Constant	270 Vs/m
Output	180 Vs/m
Response	Ground velocity from 1 Hz to >100 Hz
Damping	set to 0.7 by built-in resistor

Physical Parameters

Weight	13 kg (incl. adjusting plate)
Operating Temperatures	-20 to + 60 °C

RECORDER / EARTHDATA PR6-24

Recorder, 240 units

200 Units	3 Channels (138 Units with USB connector)
40 Units	6 Channels (30 Units with USB connector)

Hard Disk, 372 units

45 Units	10.0 GByte
4 Units	20.0 GByte
33 Units	30.0 GByte
340 Units	40.0 GByte

Digital Signal

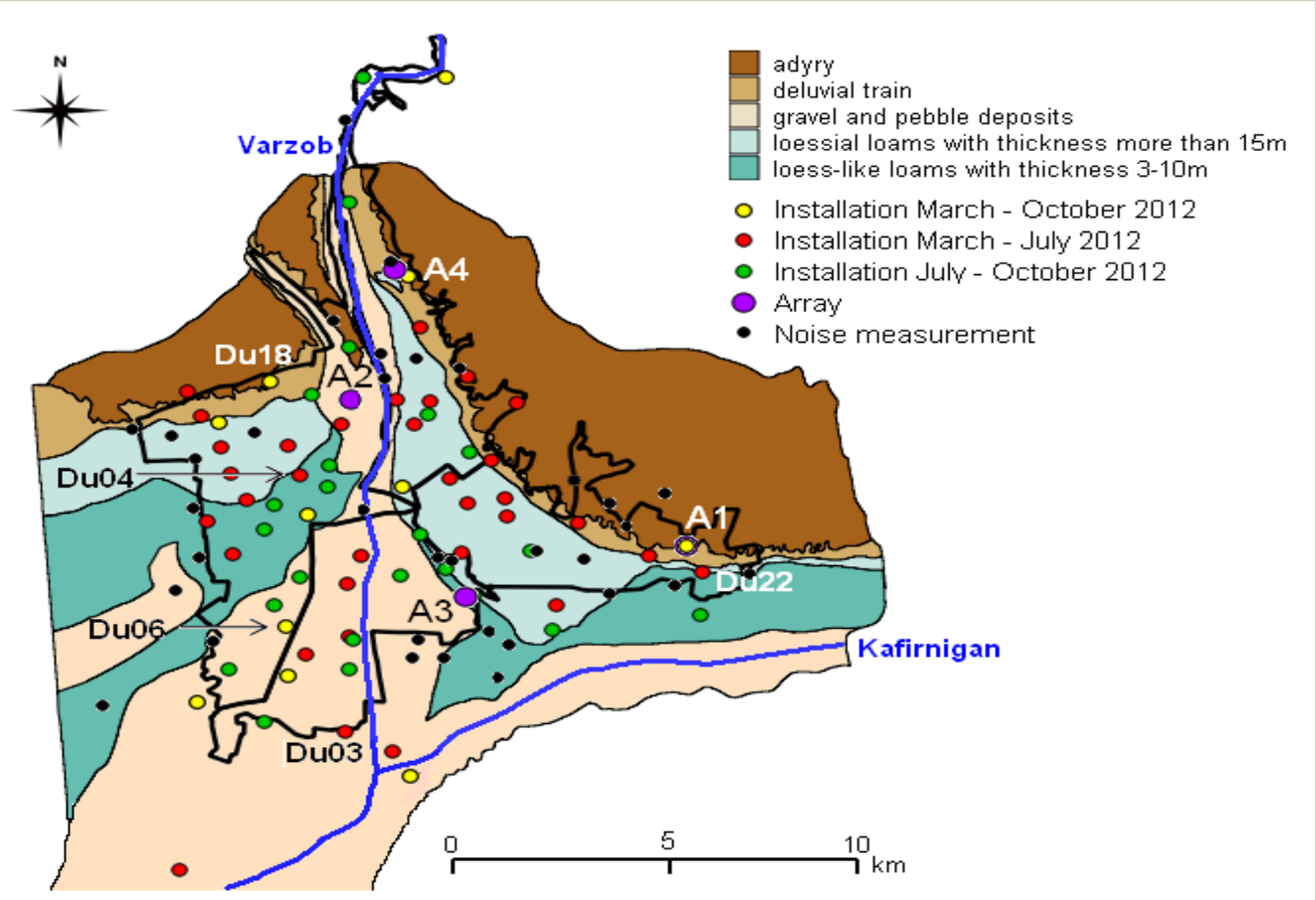
Sampling Rate	1; 2; 4; 5; 10; 20; 25; 40; 50; 75; 100, 120; 125; 150; 200; 250; 300; 375; 500; 600; 750; 1000 sps; 3000 sps (reduced dynamic range);
Resolution	MiniSEED, ASCII: 1 microVolt/digit (@ PreAmp = 1) digitiser output: 3.9 nanoVolt/digit
Dynamic Range	140 dB @ 100 sps 145 dB @ 25 sps (4 Byte digitiser output 150 dB) 96 dB @ 3000 sps (upper 2 Bytes only)

Parameters - Input Signal

Channels	3 or 6, plus 4 auxiliary
Preamplification	1; 10 ; 0.4 (85 units only)
Clipping	Signal Channels: 16.77 Vpp @ PreAmp = 1 Auxiliary Channels: 20 Vpp

ARRAY MEASUREMENTS

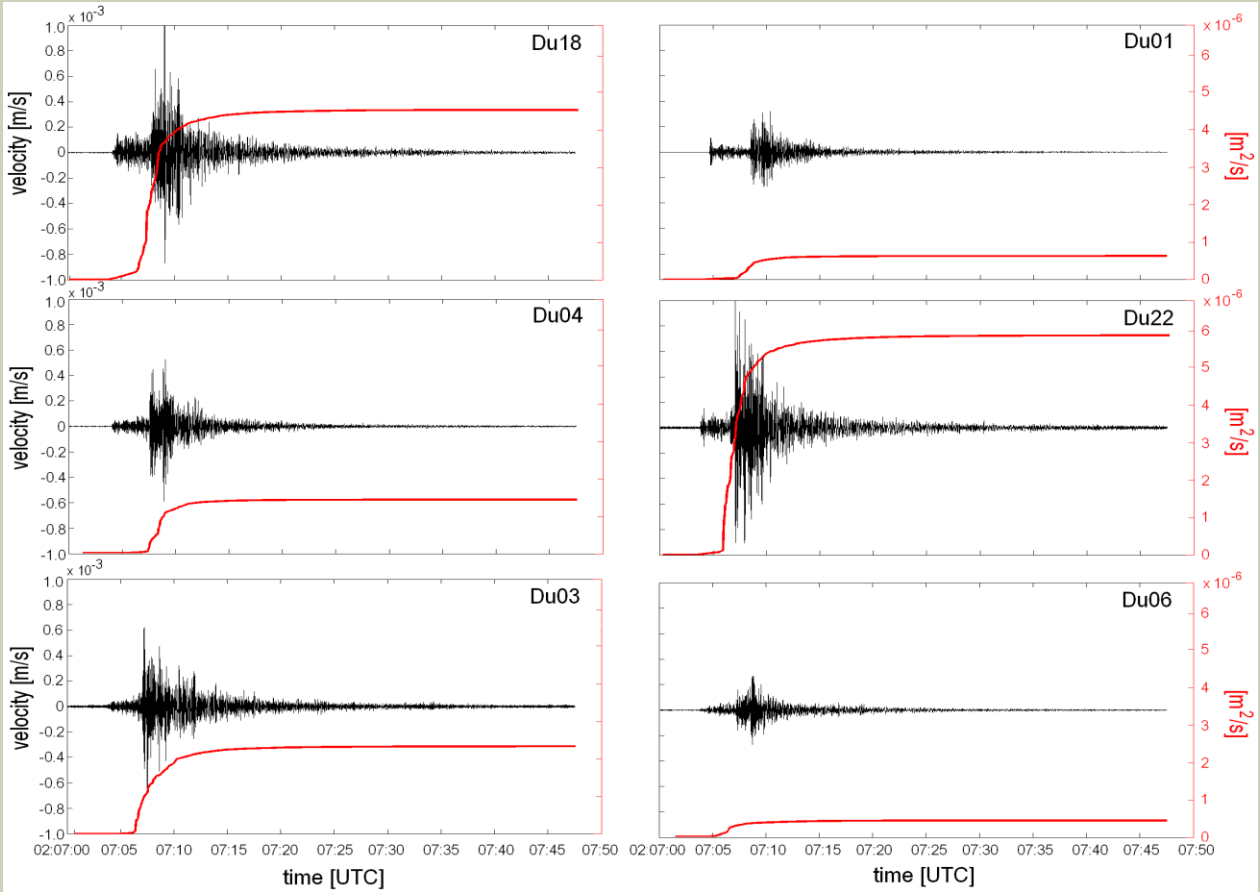
TEMPORARY SEISMIC NETWORK INSTALLATION (EMCA PROJECT)



Surface soils (Zodotarow et al., undated). Colored dots represent installation sites of the temporary seismic network. Purple dots represent array measurement sites and black dots noise measurement sites. Network installation sites and sites of array measurements mentioned in the text are labeled. Thick black lines are administrative borders of the city.

Pilz, et al. (2013)

TEMPORARY SEISMIC NETWORK INSTALLATION (EMCA PROJECT)



As an example shows the recordings at different sites in the city of a Mw = 4.6 earthquake that occurred 150 km far away from the city. Note the clear differences of the waveforms depending on the position of the station. Not only the amplitude ratio can differ by more than a factor of two compared with reference station Du01, but there are also significant differences of the cumulative energy function due to longer shaking on soft soil sites.

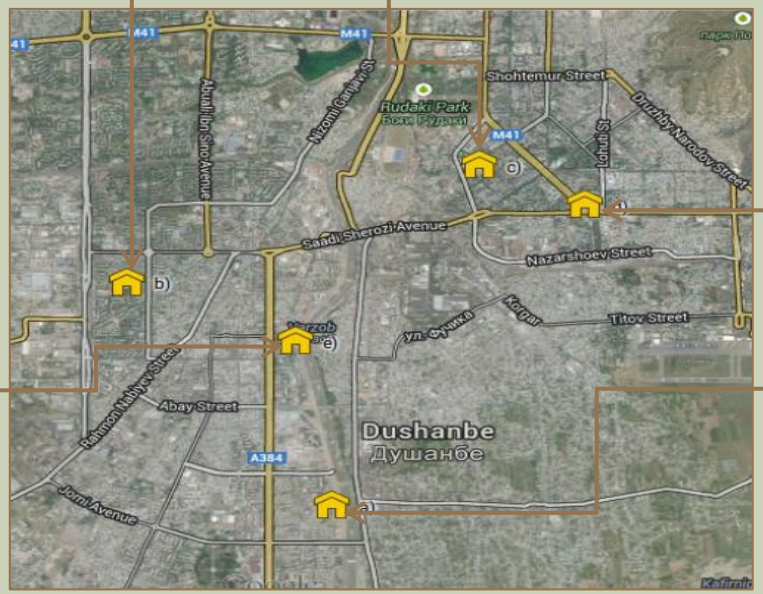
Recordings at six different stations of the 29 June 2012 (Mw = 4.6) earthquake. The panels are ordered corresponding to their geographic distribution. The red line indicates the cumulative velocity square integral.

Pilz, et al. (2013)

BUILDING MONITORING IN DUSHANBE BY USING AMBIENT VIBRATION ANALYSIS

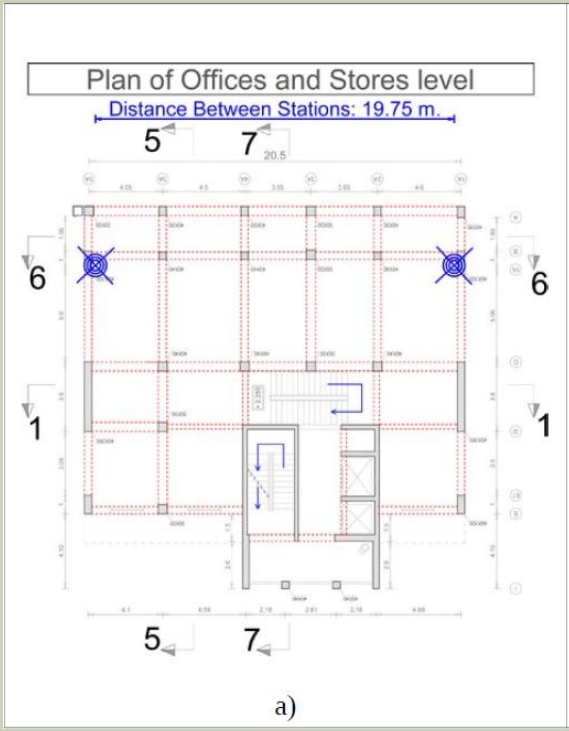
- In Dushanbe one masonry and four reinforced concrete (RC) buildings were investigated. The selected buildings are representative of the constructions in Central Asia in different periods.

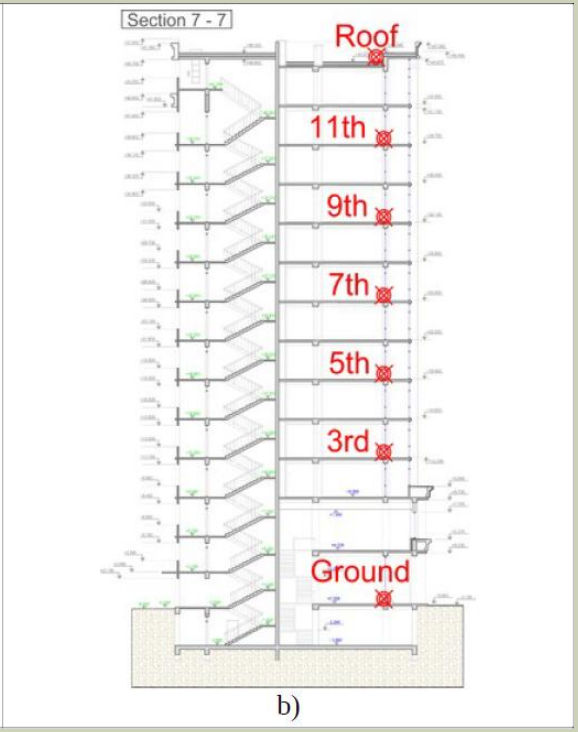
BUILDING MONITORING IN DUSHANBE BY USING AMBIENT VIBRATION ANALYSIS



Map with the locations of the monitored buildings in Dushanbe

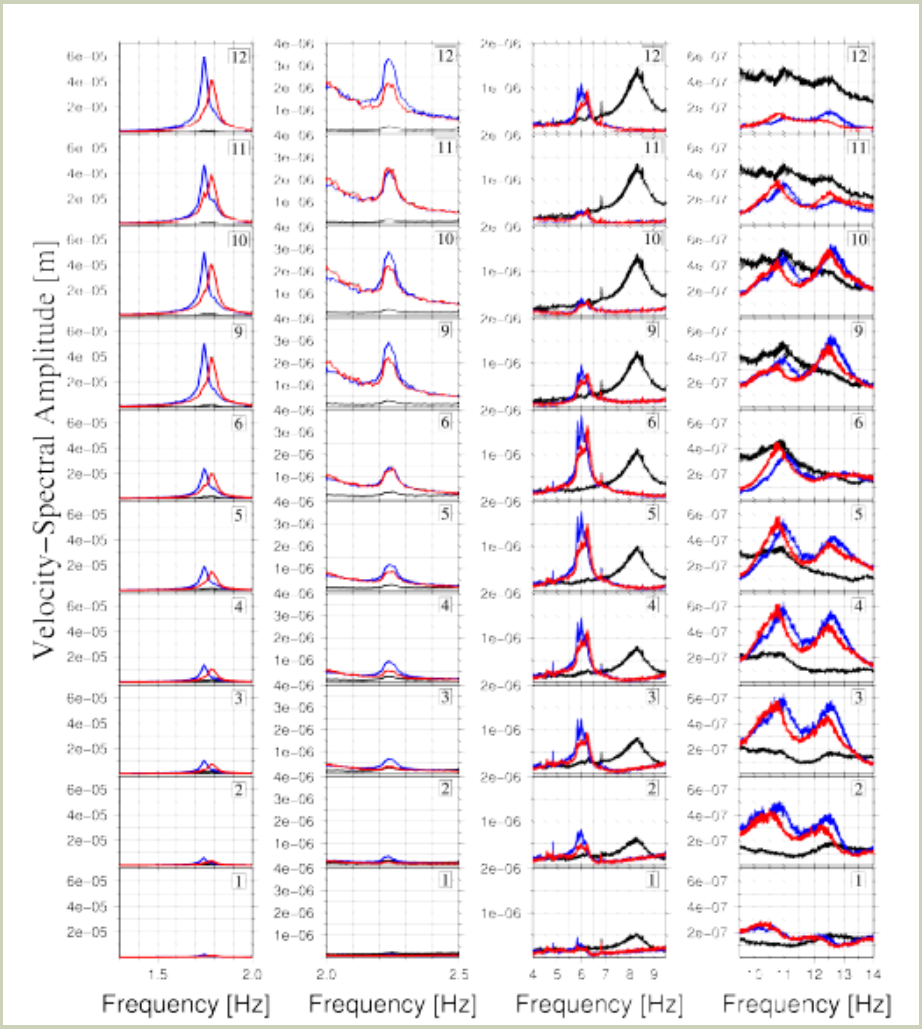
BUILDING MONITORING IN DUSHANBE BY USING AMBIENT VIBRATION ANALYSIS



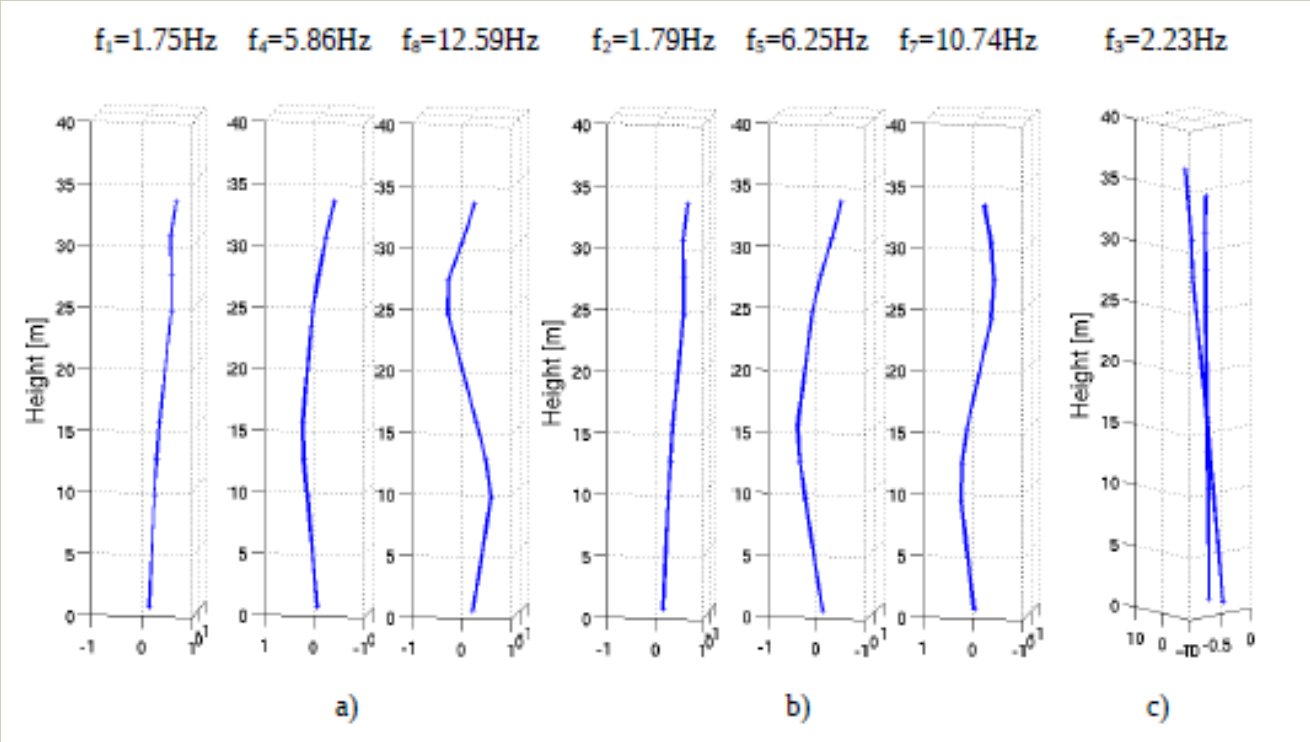


Building floor plan and cross-section of the building under construction. The locations of the stations are marked with blue and red symbols, respectively.

SPECTRAL ANALYSIS



OPERATIONAL MODAL ANALYSIS

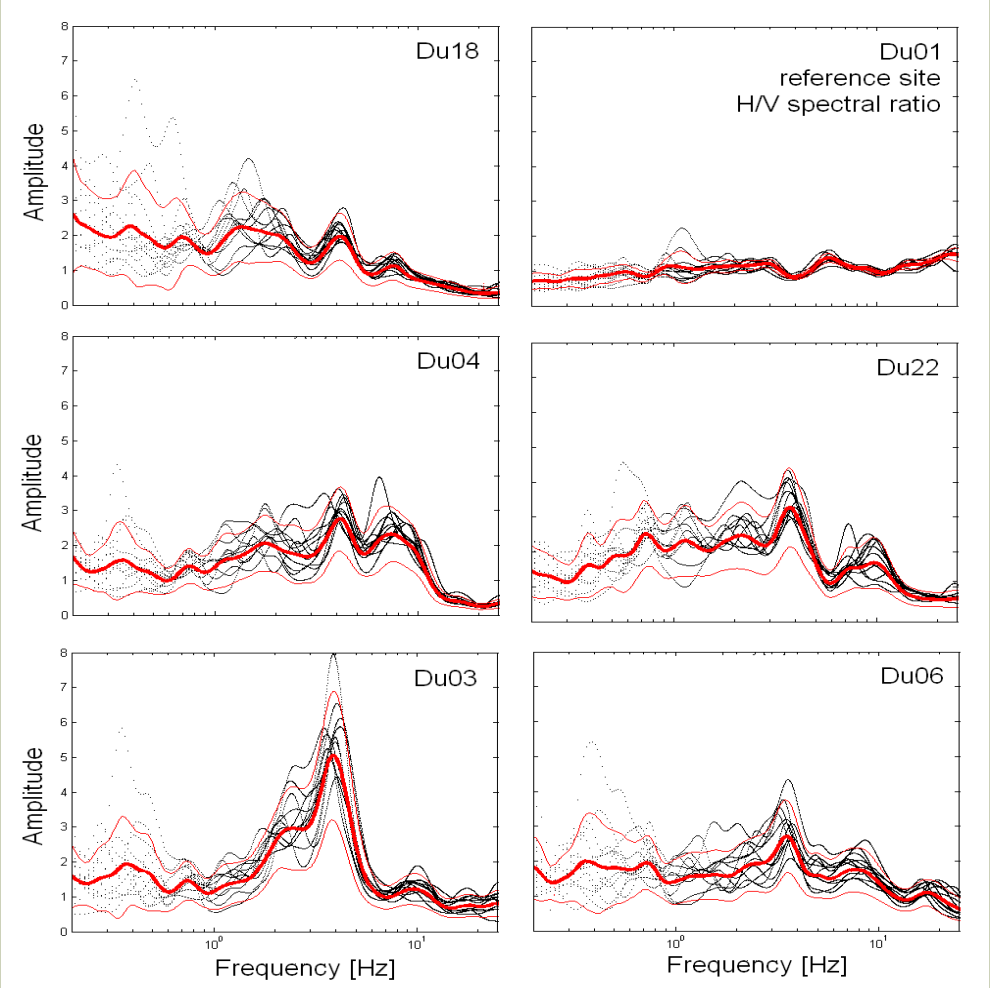


Eigenvectors corresponding to the first three bending modes for a) longitudinal
b)transverse direction.
c) first rotational mode.

DATA ACQUISITION

- Recordings were carried out at 45 points using the sensor MARK L-4C-3D
- The points of measurements are spaced at about 1000-2000m
- Sampling rate of 100 samples per second

HVSR



SSR calculated for the S-wave window for the North-South component at each station and the corresponding spectrum at the station Du01. For Du01 the nearly flat response for the H/V spectral ratio is shown, indicating that Du01 is a suitable reference site. The black dots represent spectral ratios computed at frequencies where the signal to noise ratio is greater than 3, while the red curves represent the mean ratio plus/minus one standard deviation.

THANK YOU

شكرا لكم على اهتمامكم

СПАСИБО ЗА ВНИМАНИЕ

THANK YOU FOR YOUR ATTENTION

感谢您的关注

GRACIAS POR SU ATENCIÓN

TERIMA KASIH UNTUK PERHATIAN ANDA

आपल्या लक्ष धन्यवाद

MERCI POUR VOTRE ATTENTION

DANKIE VIR JOU AANDAG