



# Сейсмичность Арктического региона

Скоркина Анна Александровна,  
к.ф.-м.н., старший научный сотрудник  
ГЦ РАН, ИТПЗ РАН

8 июня 2022 г.

# План выступления

## I. Введение

- Тектоническая обстановка
- Источники сейсмологических данных

## II. Сейсмичность Арктики

- Особенности региональной сейсмичности
- Сильные землетрясения

# Тектоническая карта Арктики

## Древние платформы

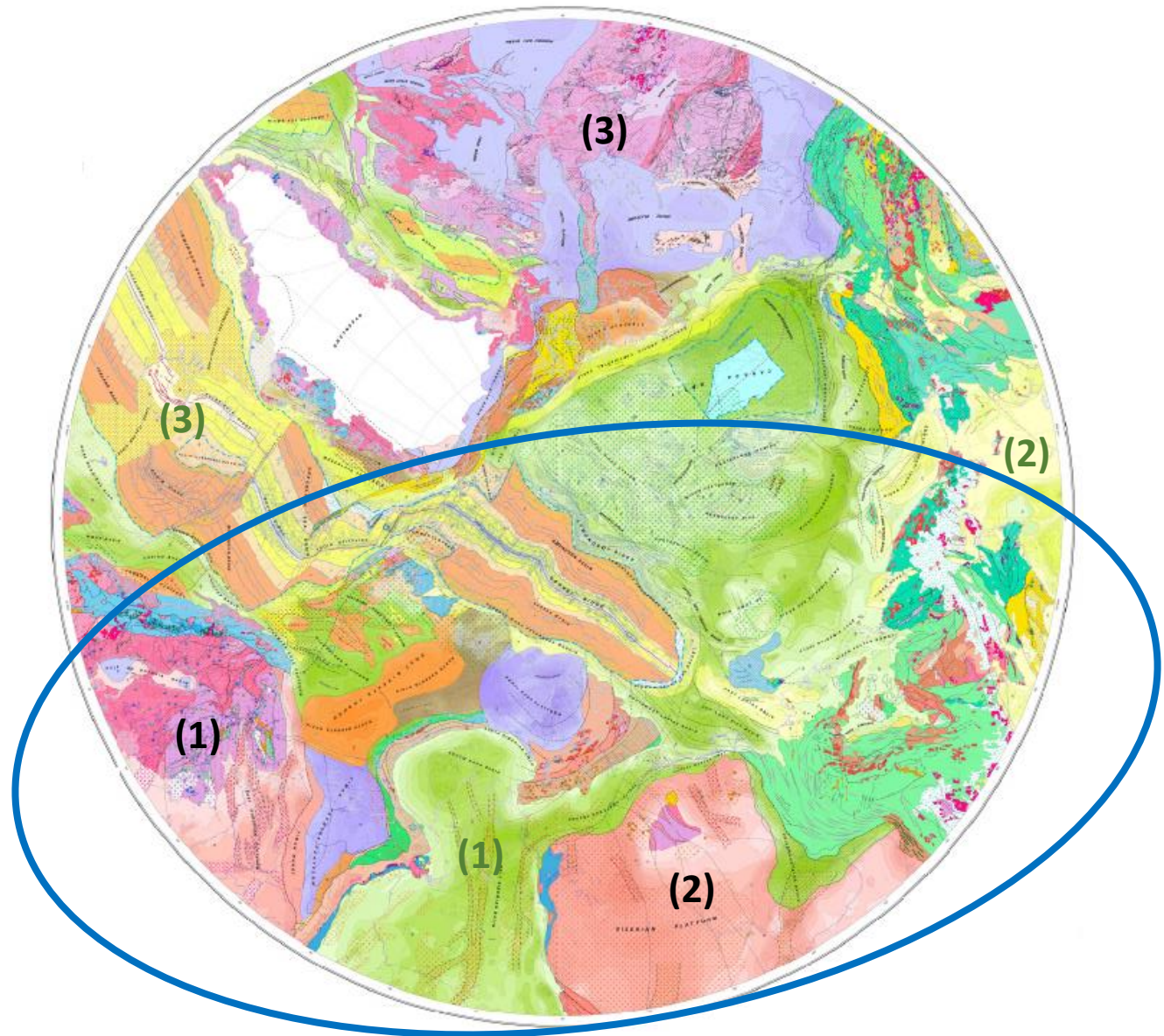
(преимущественно, протерозой, 2500-500 млн лет назад):

- (1) Восточно-Европейская
- (2) Сибирская
- (3) Северо-Американская

## Подвижные пояса

(разновозрастные складчатые системы)

- (1) Урало-Охотский
- (2) Тихоокеанский
- (3) Северо-Атлантический



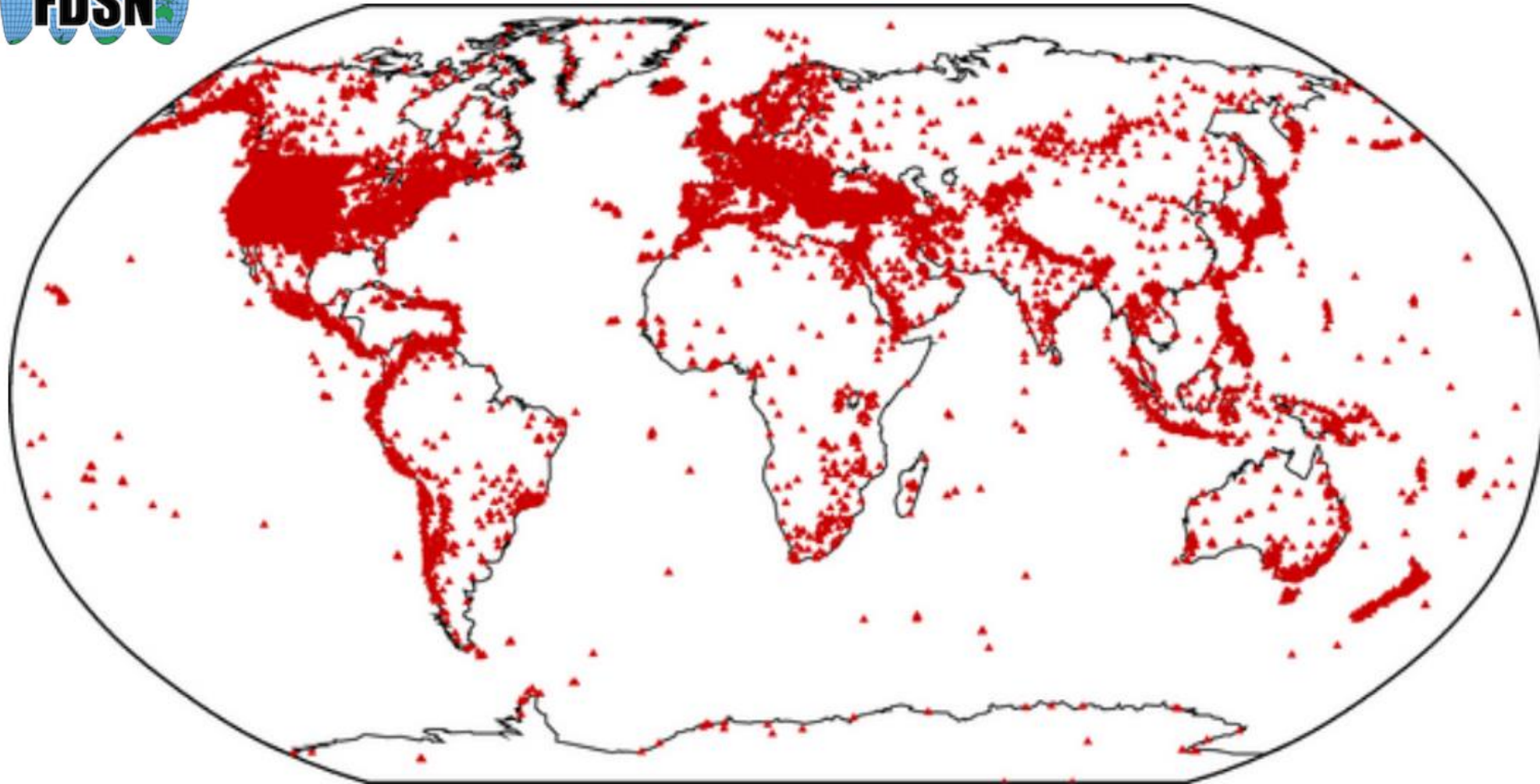
# Источники сейсмологических каталогов и бюллетеней

## I. Глобальные:

- Международный сейсмологический центр (**ISC**, Великобритания)
- Global Centroid Moment Tensor Project (**GCMT**, США)
- Source Time Functions Database (**SCARDEC**, Франция)
- Earthquake Source Model Database (**SCRMOD**, США)

## II. Региональные.

# International Federation of Digital Seismograph Networks



# International Federation of Digital Seismograph Networks

**88.8°** Assured Arctic Awareness (AAA), **University of Washington**, 2013 (T-phases)

**85.7°** Mid Ocean Volcanoes & Earthquakes (MOVE/AGAVE), **Alfred Wegener Institute**, 2007

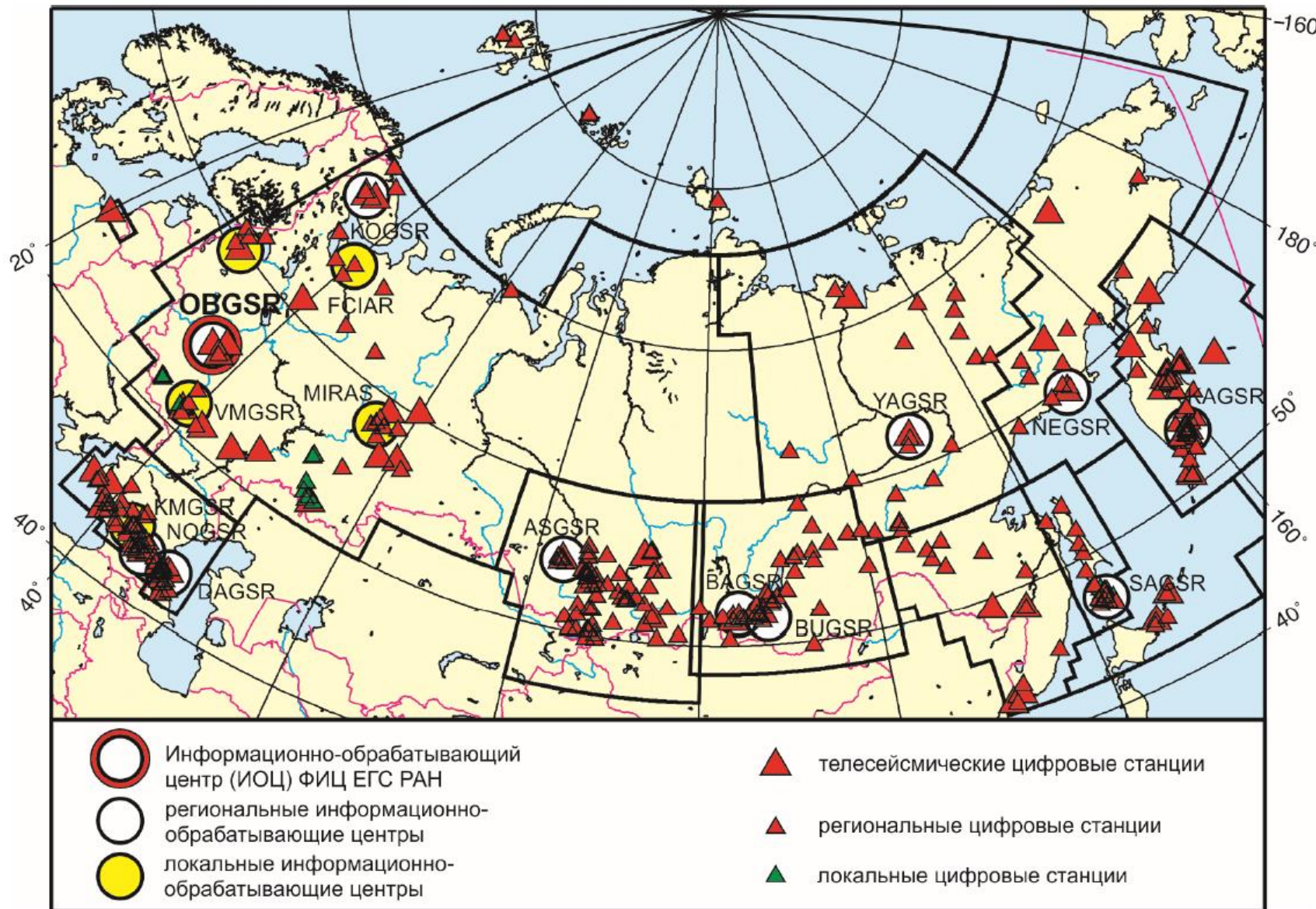
**79°** INTAROS temporary Ocean Bottom Seismometers (OBS) on northern Mid Atlantic Ridge (INTOBS), **University of Bergen**, 2018-2020

**78°** **NORSAR**, c 1971

**77.9°** Svalbard – Vallunden, **Universite Joseph Fourier – Grenoble**, 2019

**72.6°** Laptev Sea Rift Seismological Network (SIOLA), **Alfred Wegener Institute**, 2016-2027

# Единая геофизическая служба (ФИЦ ЕГС РАН)



## KOGSR:

«Баренцбург А,  
Баренцбург Б»  
(с 01.01.2001)

«Пирамида»  
(с 25.06.2015)

## FCIAR:

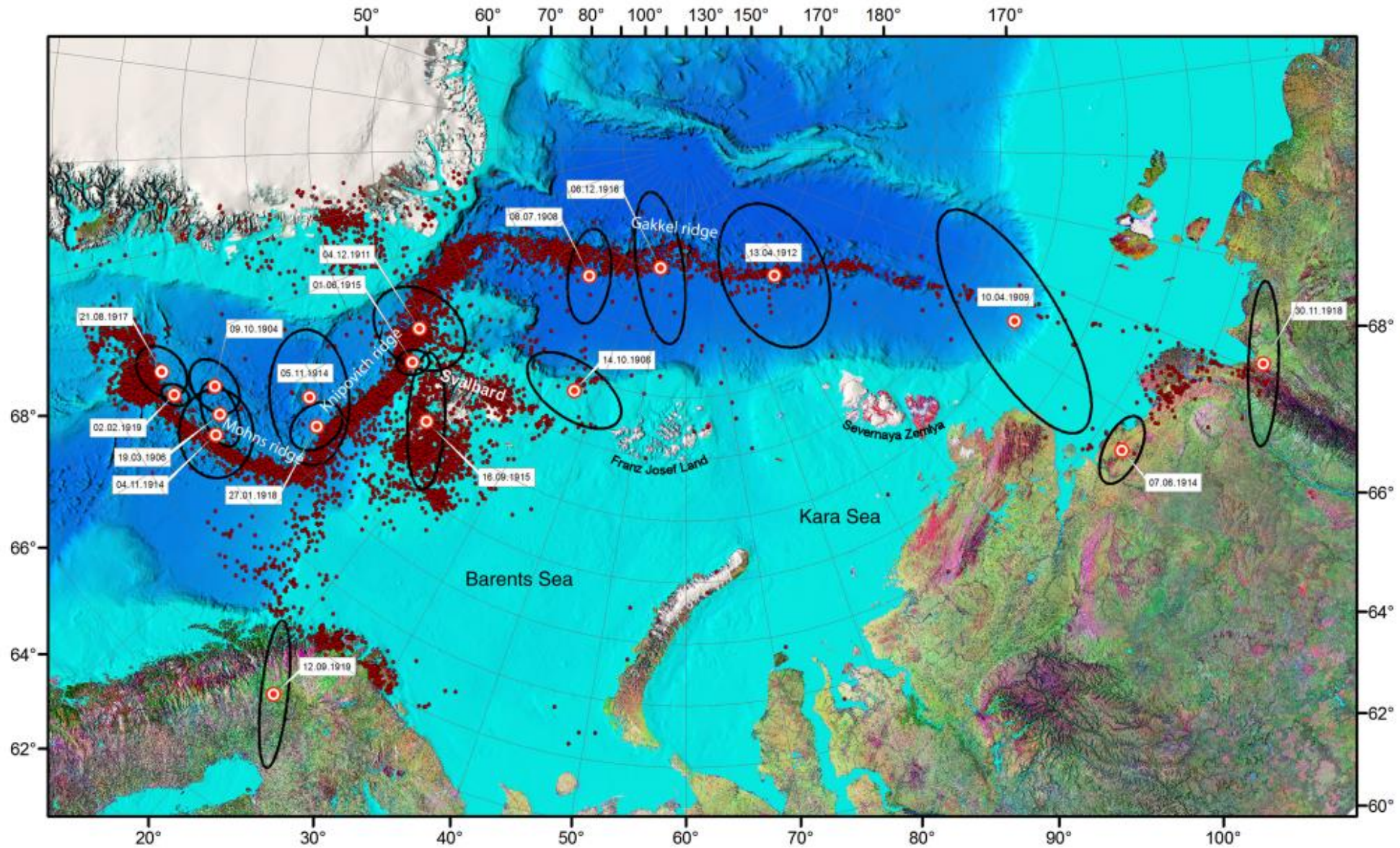
«Земля Франца-Иосифа»  
(80.809 47.655,  
с 22.09.2011)

«Омега»  
(80.784 47.732,  
с 25.08.2015)

«Северная Земля»  
(79.276 101.657,  
с 21.11.2016)

# Seismicity of the Arctic in the Early Twentieth Century: Relocation of the 1904–1920 Earthquakes

[Morozov et al., 2019]





# Международный сейсмологический центр (ISC)



[f](#) [t](#) [Home](#) [About ISC](#) [Staff](#) [Contact us](#) [Site Map](#)

[About ISC](#)

[ISC Products](#)

[ISC Bulletin](#)

[ISC-GEM Catalogue](#)

[ISC-EHB Bulletin](#)

[Int. Station Registry](#)

[IASPEI GT](#)

[Event Bibliography](#)

[Dataset Repository](#)

[Seismological Contacts](#)

## ISC News



International  
Seismological Centre

Centre Séismologique  
International

Международный  
Сейсмологический Центр

国際地震センター

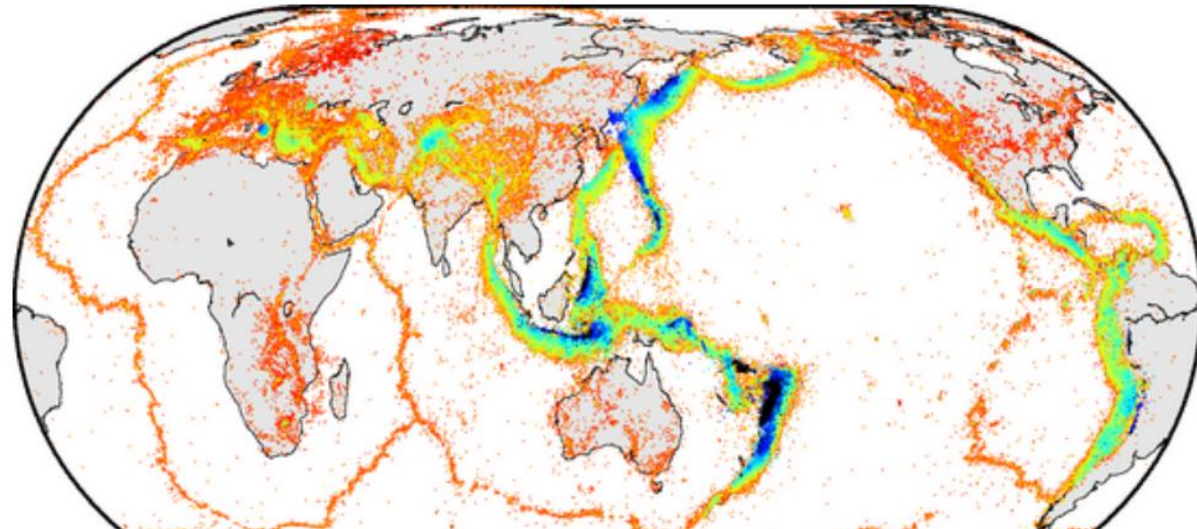
国际地震中心

Internationales  
Seismologisches Zentrum

المركز الدولي لبحوث الزلازل

Centro Internacional  
de Sismología

## ISC locations: 1964 to present



**2019-07-09**

[Seismological Dataset Repository is live](#)

**2019-07-08**

[Rebuilt ISC Bulletin \(1964-1990\) is available](#)

**2019-06-10**

[1964-2016 ISC-EHB Released](#)

**2019-05-01**

[The ISC Bulletin as earthquake mechanism source paper is out](#)

**2019-03-07**

[ISC-GEM Version 6 released](#)

[Past news](#)

News feed from data contributors

# Международный сейсмологический центр (ISC)

Database: **Reviewed ISC Bulletin**

Search type: **Flinn-Engdahl region**

Seismic region: **40 (Arctic Zone)**

Start date: **1970-01-01 00:00:00**

End date: **2020-06-01 00:00:00**

Events found: **14 854**

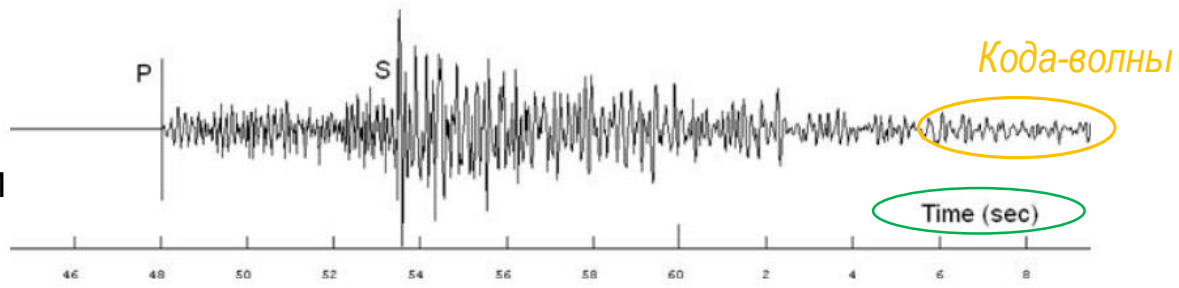
Agencies whose data contributed towards the results of this search:

**79 agencies from 35 countries**

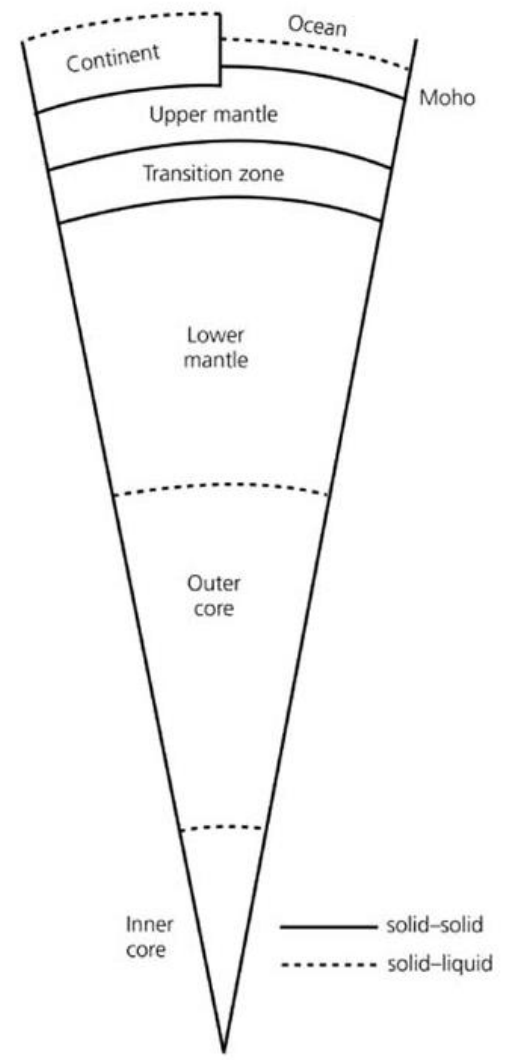
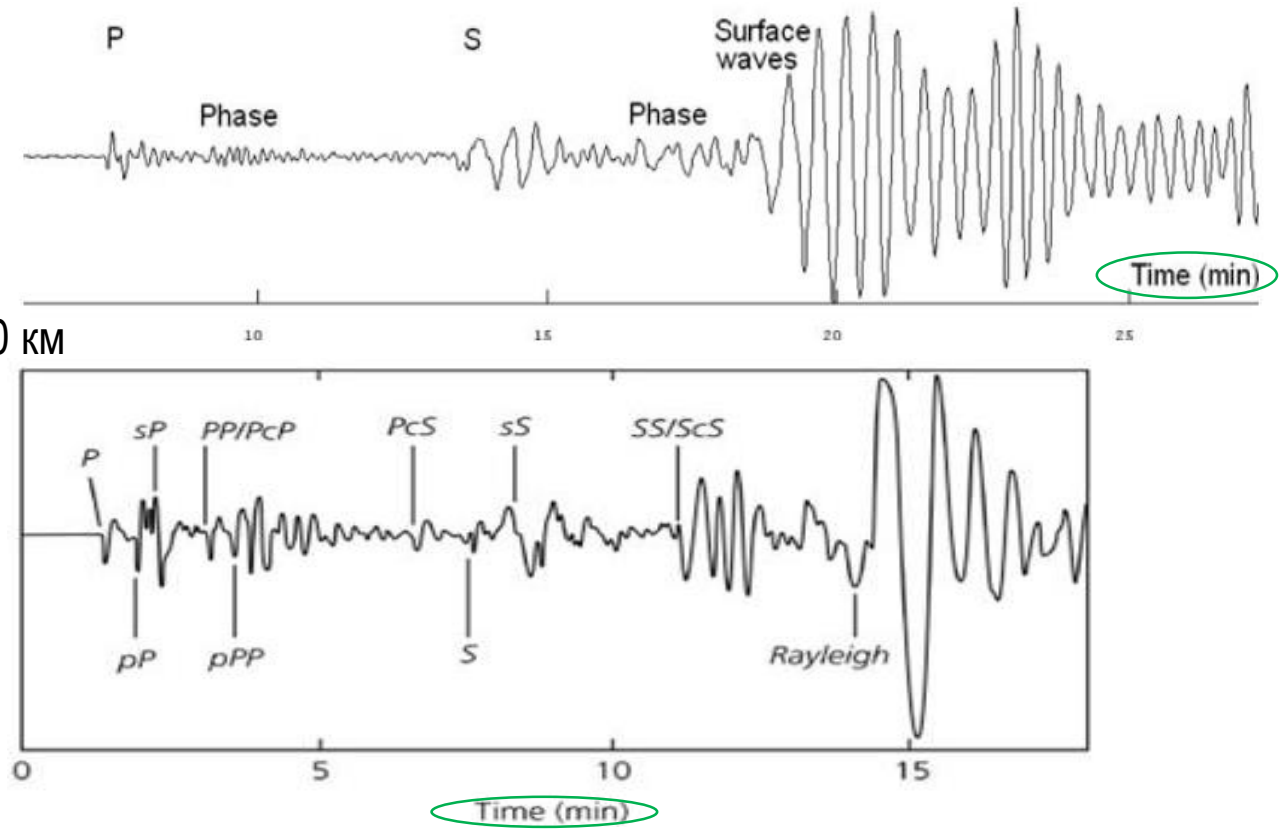
ASL, ATH, BCIS, BER, BGR, BGS, BJI, BYKL, CANSK, CASC, CENT, CLL, CNRM, CRAAG, CSEM, DHMR, DJA, DNK, EHB, EIDC, EPSI, EUROP, EVBIB, FCIAR, GCMT, GFZ, GUC, HEL, HFS, HFS1, HFS2, IASPEI, IDC, IEPN, IGS, INMG, IPGP, IRIS, ISC, ISC-EHB, ISC-PPSM, ISK, JMA, JSO, KLM, KOLA, KRSC, LAO, LDG, LVSN, MED\_RCMT, MEX, MOS, MSUGS, NAO, NEIC, NEIS, NIED, NNC, ORF, OTT, PEK, PGC, PJWWP, REY, RSNC, SCB, SEA, SJA, SKHL, STR, THE, UCR, UPP, USAEC, USCGS, WAR, YARS, ZUR

Algeria, Argentina, Austria, Bolivia, Canada, Chile, China, Colombia, Costa Rica, Denmark, Finland, France, Germany, Greece, Iceland, Indonesia, Italy, Japan, Jordan, Kazakhstan, Latvia, Malaysia, Mexico, Morocco, Netherlands, Norway, Poland, Portugal, Russia, Sweden, Switzerland, Turkey, U.S.A., United Kingdom, Yemen

~100 KM



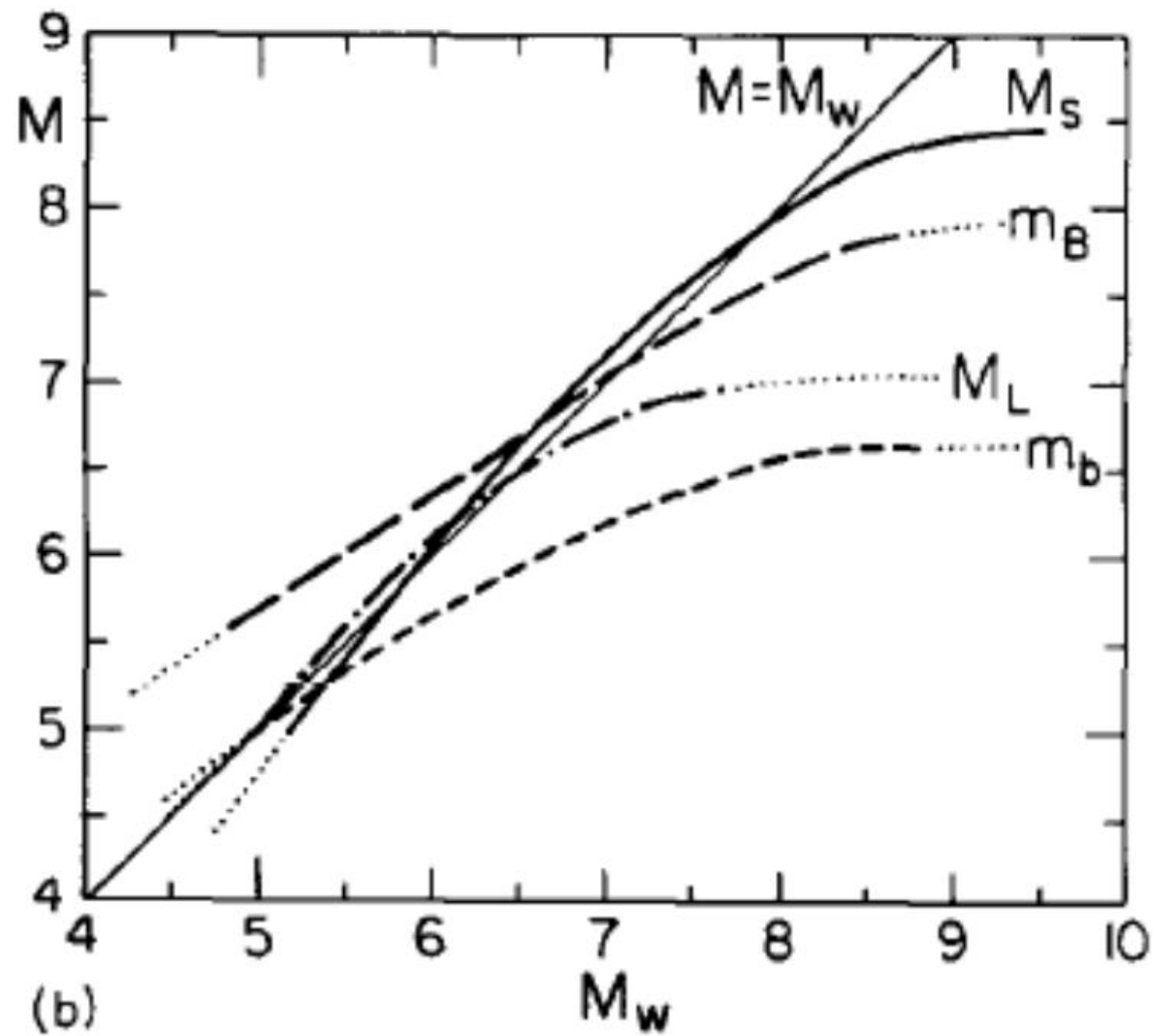
>3 000 KM



# Наименование магнитуд

This report	BSSA editorial style	NMSOP generic	NMSOP specific	USGS Search	USGS EDR	ISC
ML	$M_L$	Ml	MH(WA;CF), MV(WA;CF)	ML	ML	$M_L$
Ms_20	$M_S(20)$	Ms	MLV(B)	Ms	MSZ	Ms
Ms_BB	$M_S(BB)$	Ms	MLV(D)	--	--	Ms
mb	$m_b$	mb	MPV(A)	mb	MB	Mb
mB_BB	$m_B(BB)$	mB	MPV(D)	--	--	mB
mb_Lg	$m_b(L_g)$	mbLg	MLgV(A;Author)	Lg	LG	MN

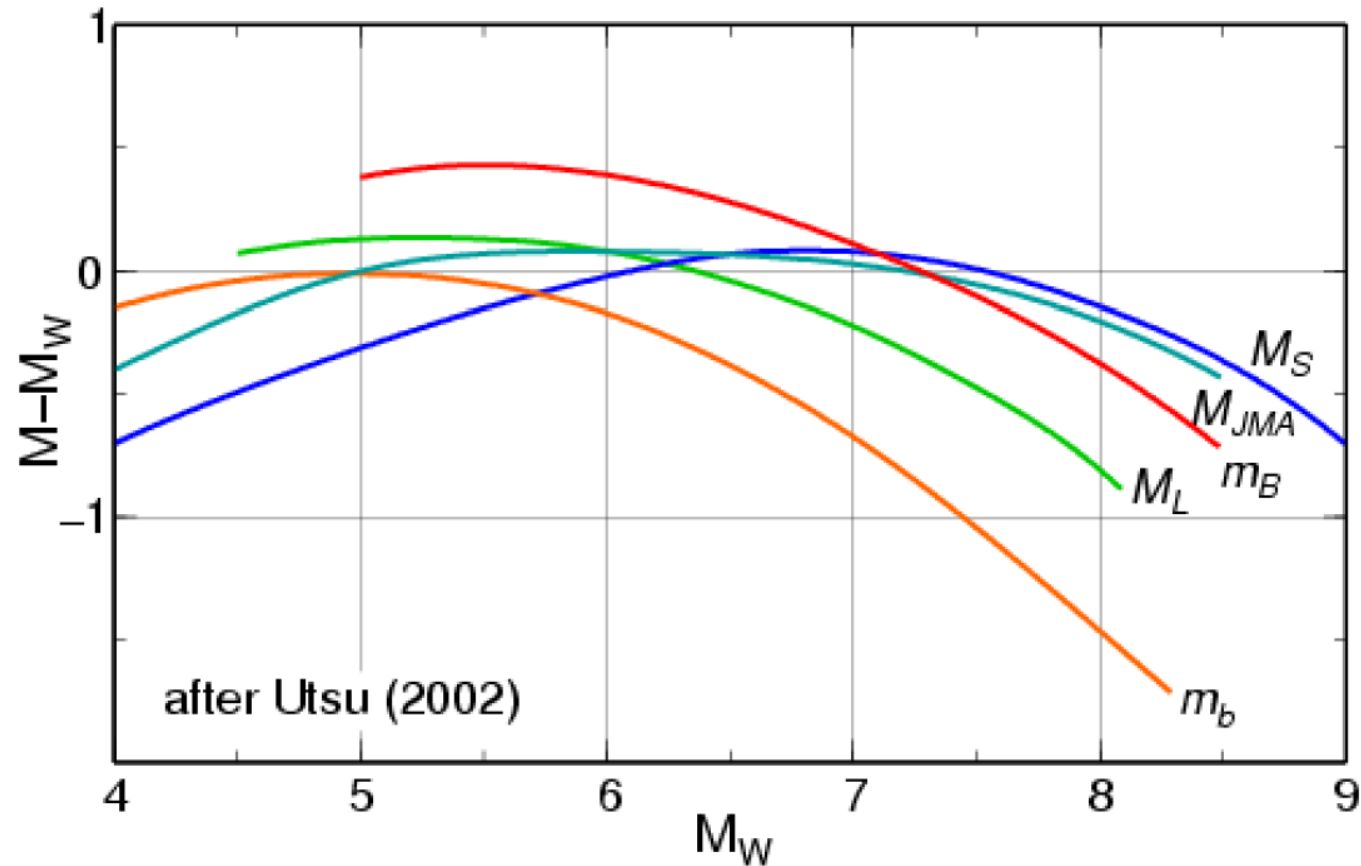
# Соотношение магнитуд



# Моментная магнитуда $M_w$

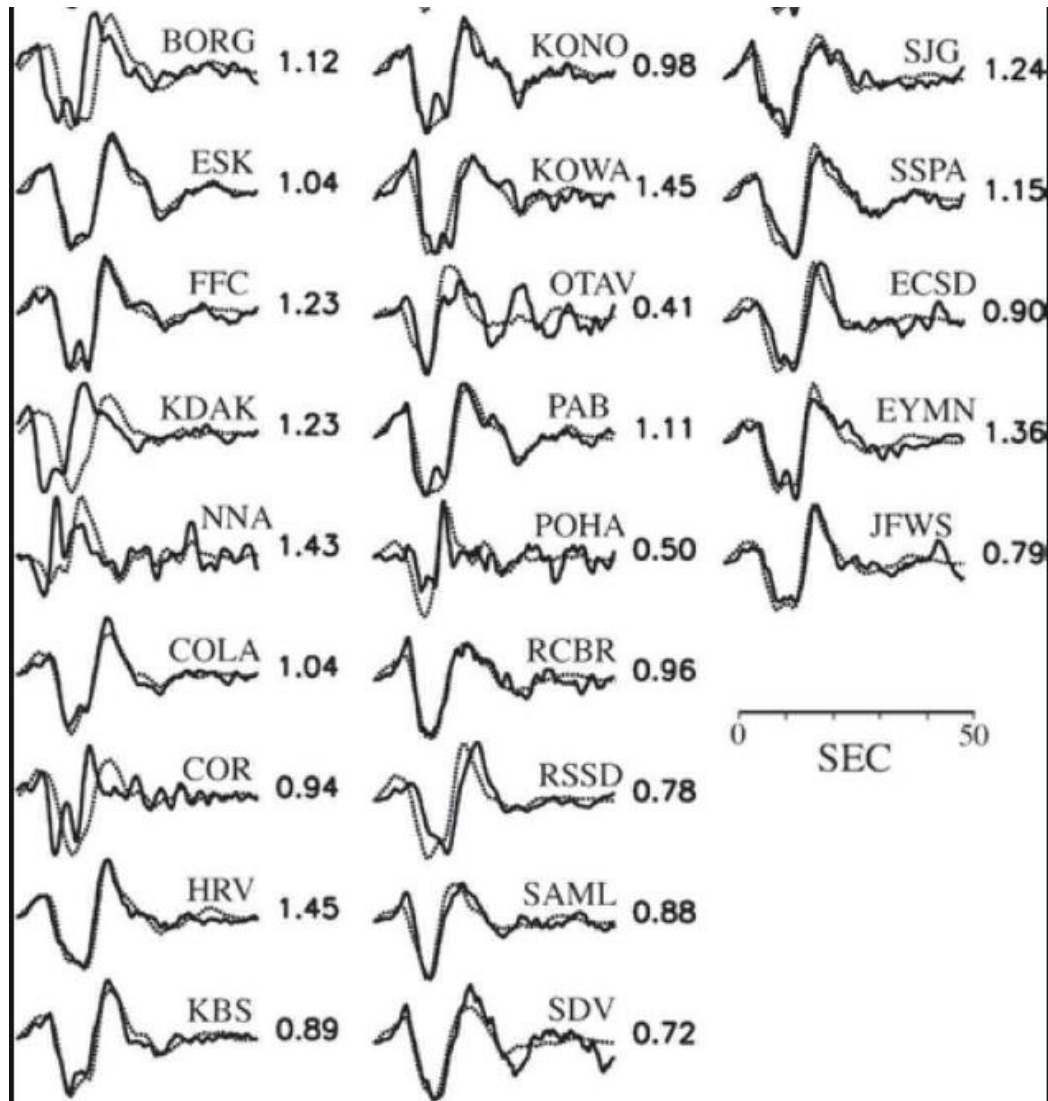
$$M_w = (2 / 3) \cdot (\log M_0 \text{ [Ньютон·метр]} - 9.1)$$

$$M_w = (2 / 3) \cdot (\log M_0 \text{ [дин·см]} - 16.1)$$



**Все традиционные шкалы** (не  $M_w$ ) испытывают **«насыщение»** :  
при больших  $M$  они **занижают** вклад очага в упругие волны и геологическую деформацию

# Моментная магнитуда $M_W$ №1 (GCMT)



Global CMT Catalog

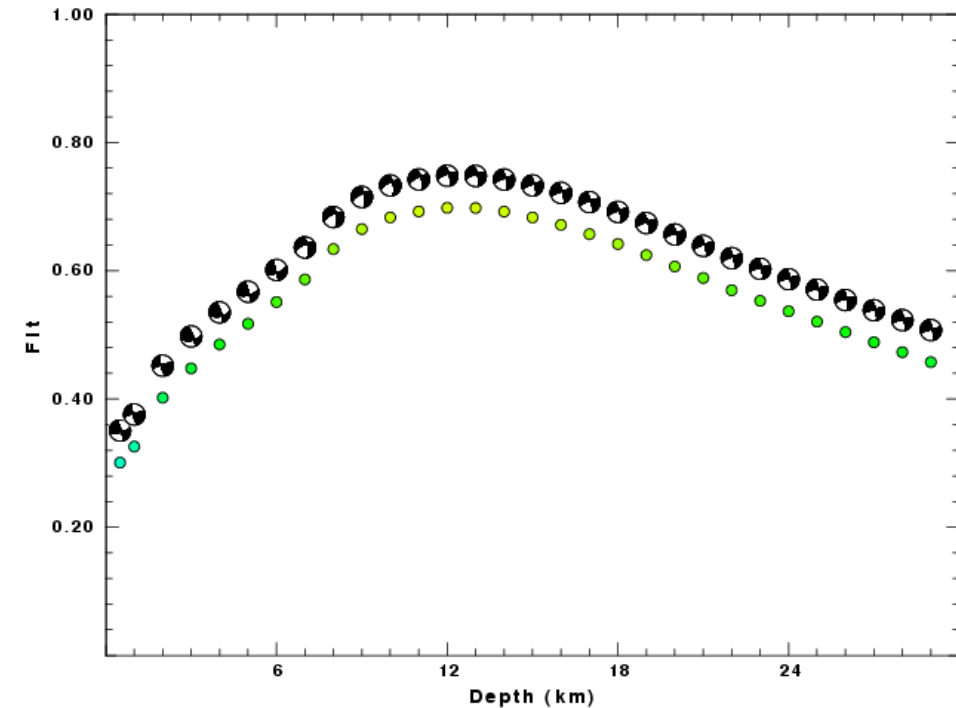
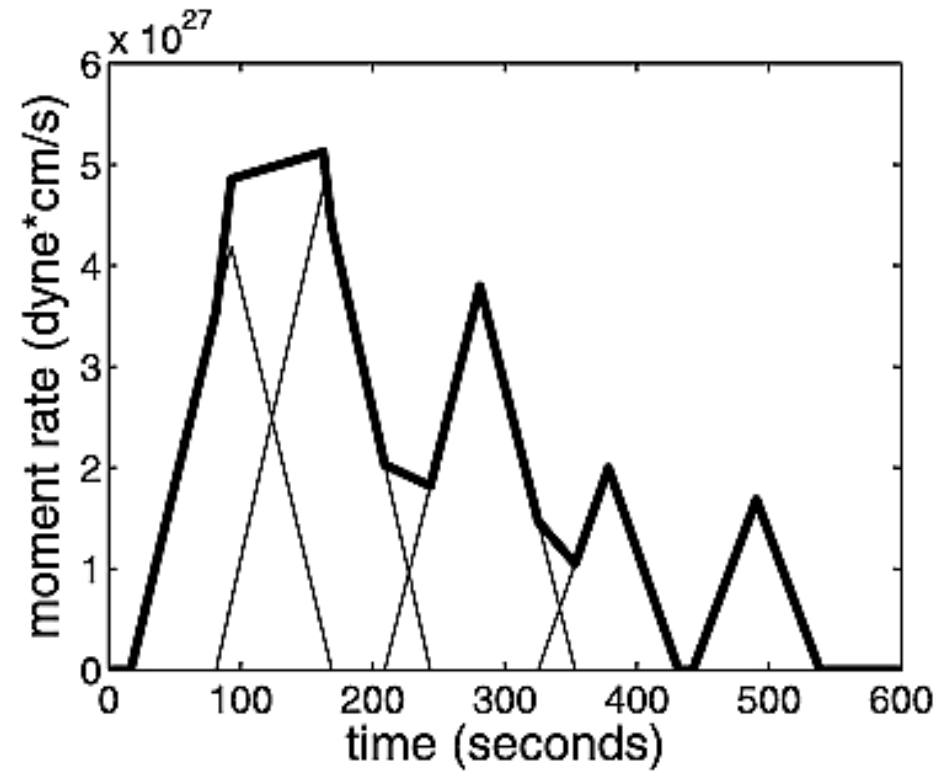
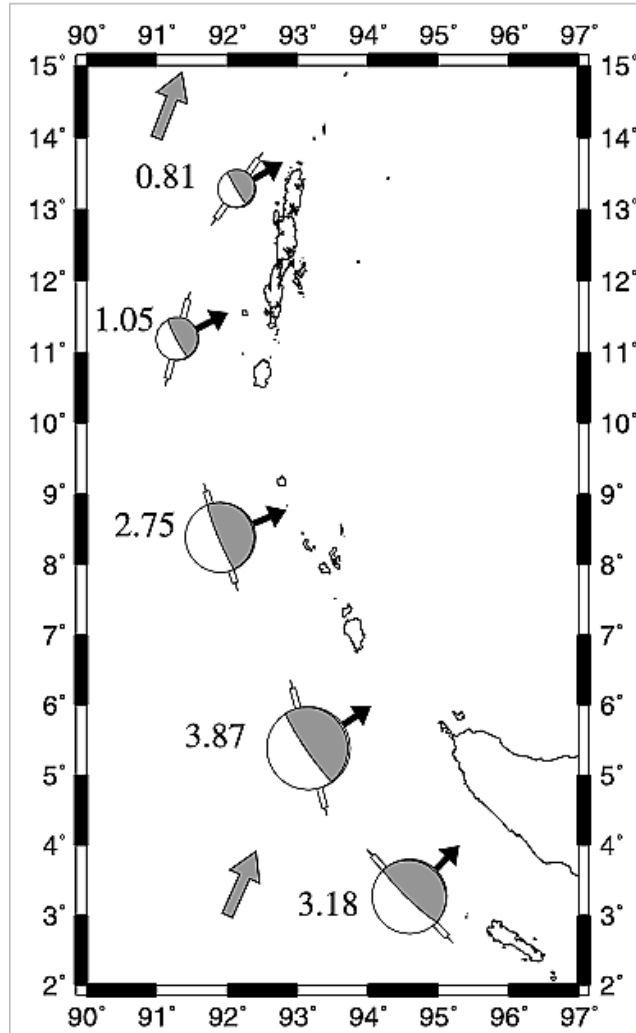


Figure 2. Depth sensitivity for waveform mechanism

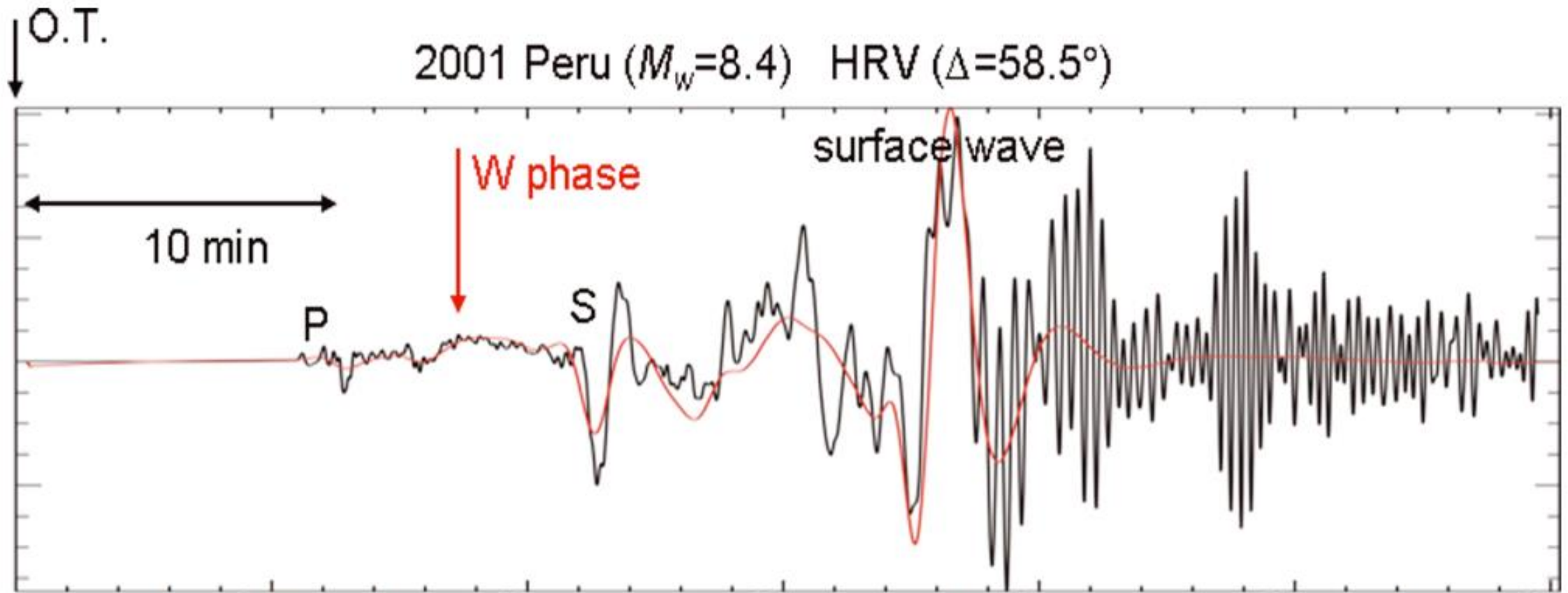
# Моментная магнитуда $M_W$ №1.1 (разновидность GСMT)



[Tsai et al., 2005]

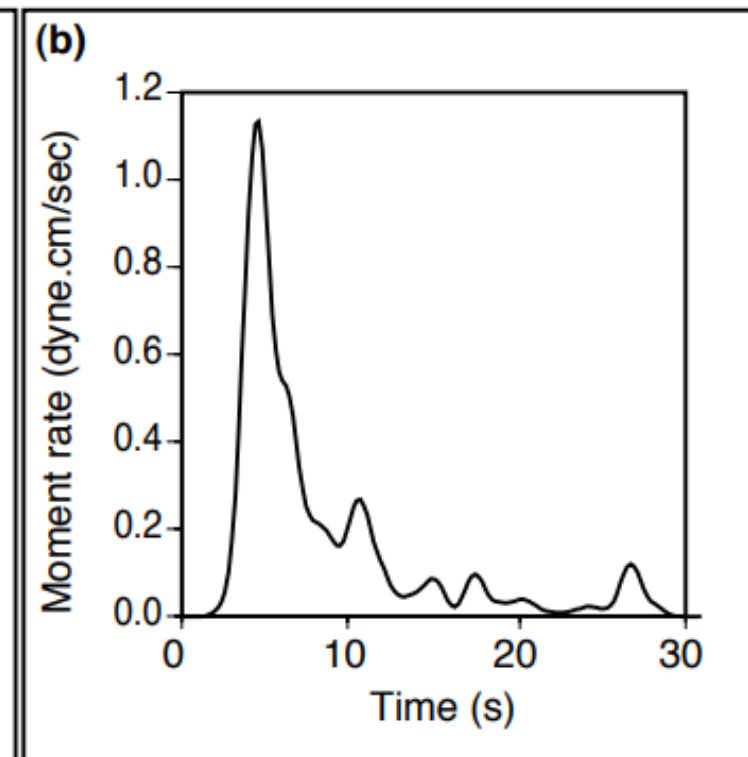
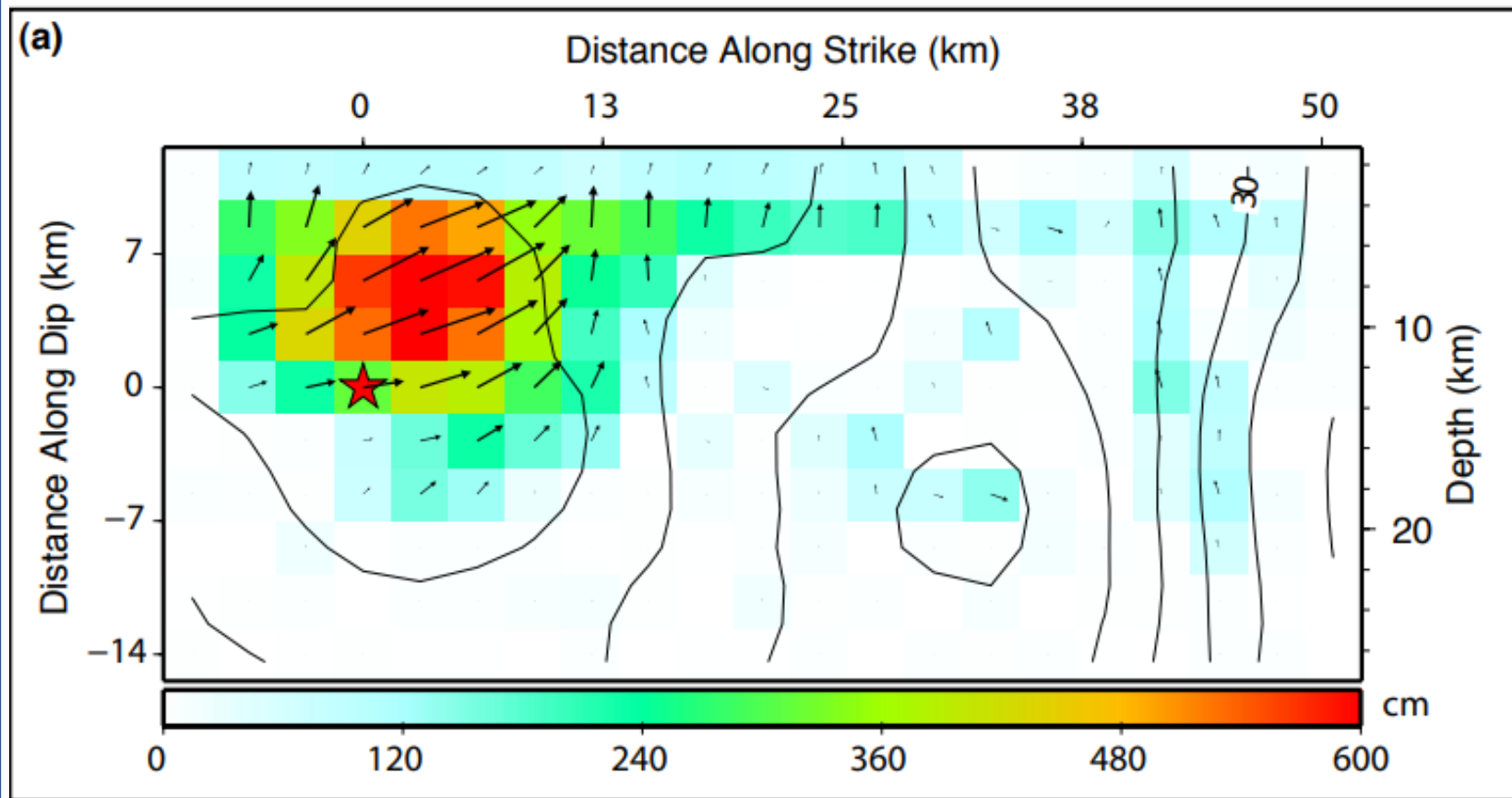


# Моментная магнитуда №2 ( $M_{WW}$ ) [Duputel et al., 2011]

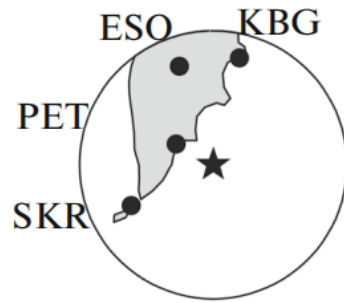


*W phase from the 2001 Peruvian earthquake ( $M_w = 8.4$ ) recorded at HRV, and the synthetic W phase computed by mode summation using the Global CMT solution.*

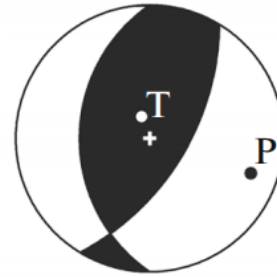
# Моментные магнитуды №3 (результат инверсии со сложной моделью очага)



# Моментная магнитуда №4 ( $M_w^{RSMT}$ ) [Абубакиров и др., 2018]

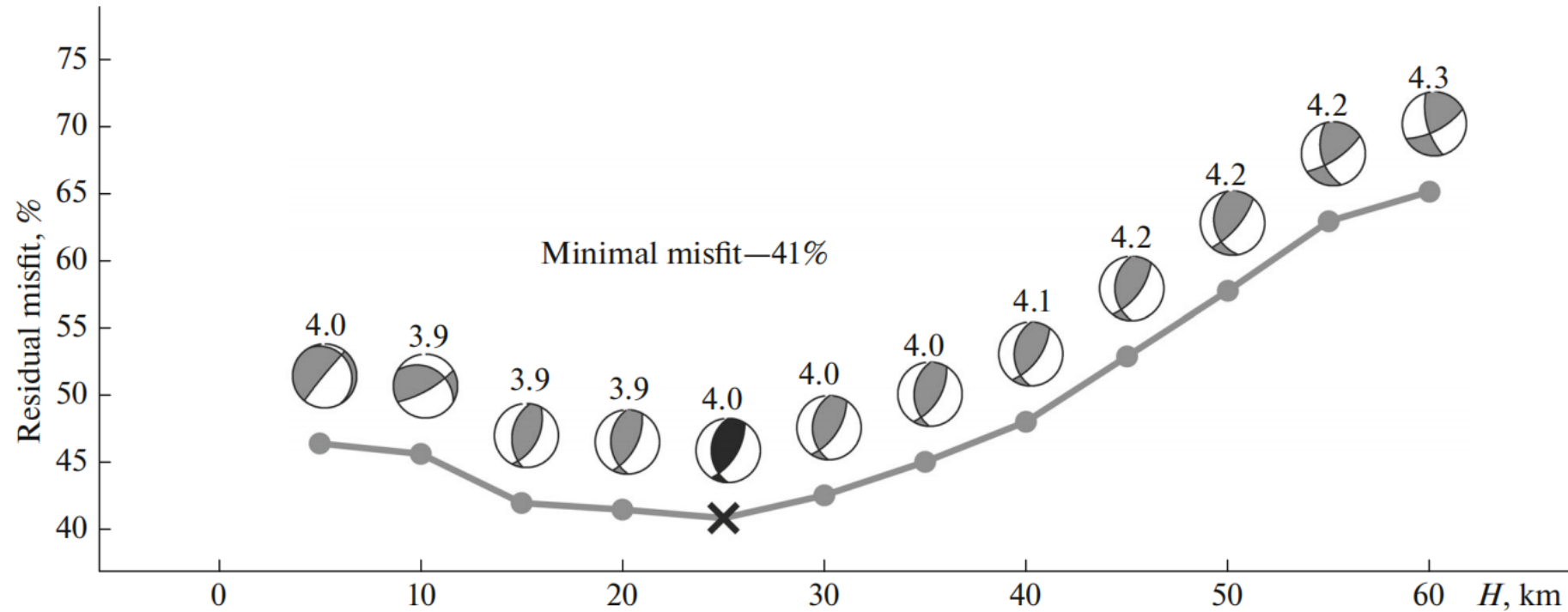


$M_L^{KB} = 4.5$   
 $K_S^{KB} = 10.5$   
 $H^{KB} = 41 \text{ km}$   
 $M_0^{RSMT} = 1.08e + 0.15 H \cdot m$

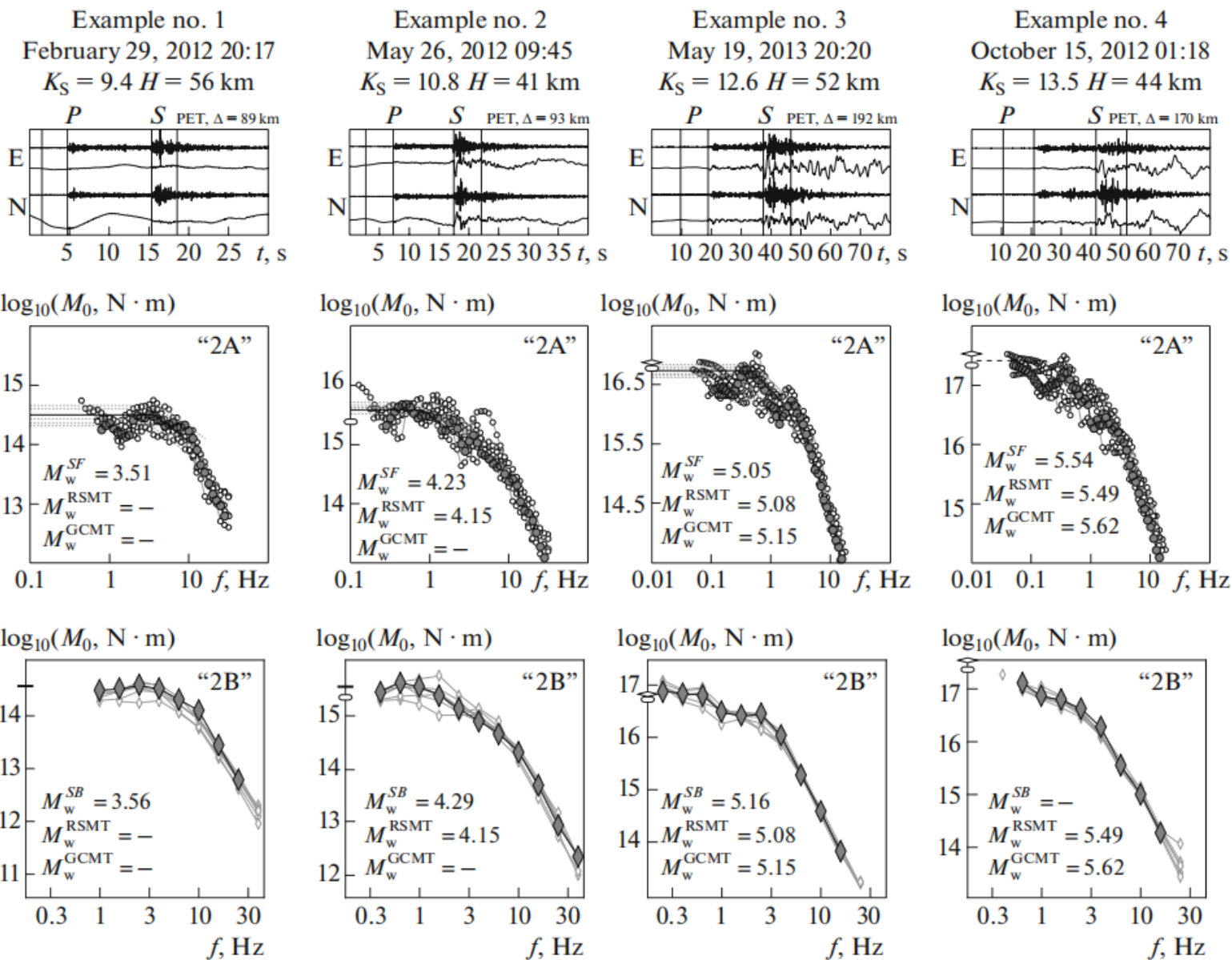


$M_w^{RSMT} = 3.95$   
 $H^{RSMT} = 25 \text{ km}$   
 $\tau = 2 \text{ s}$   
 $NDC = 6\%$

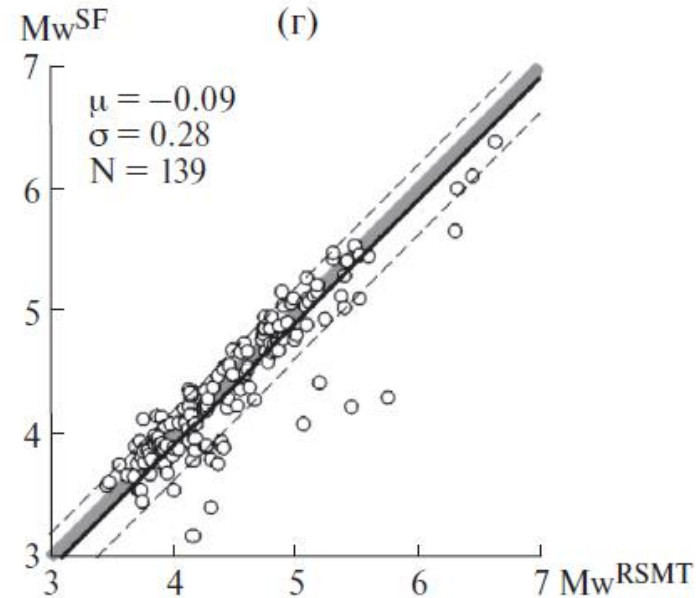
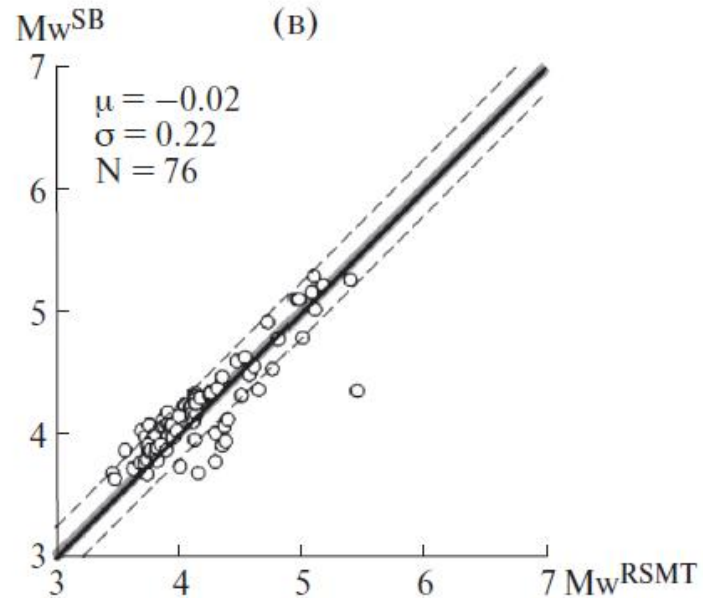
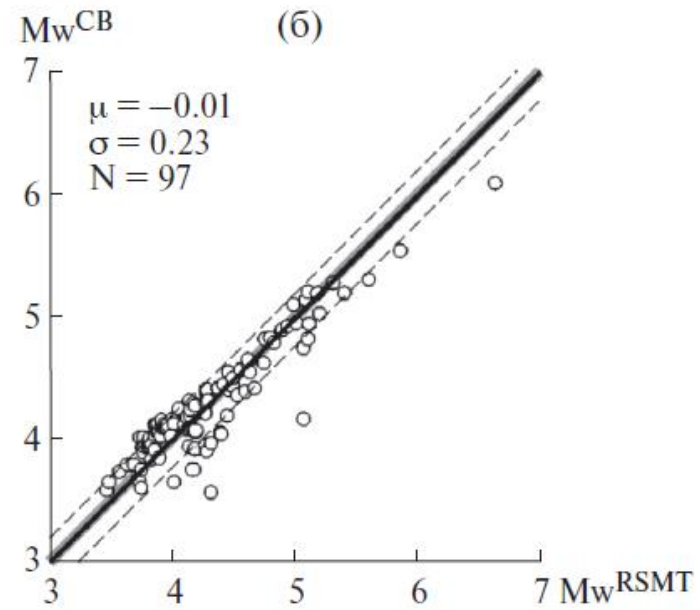
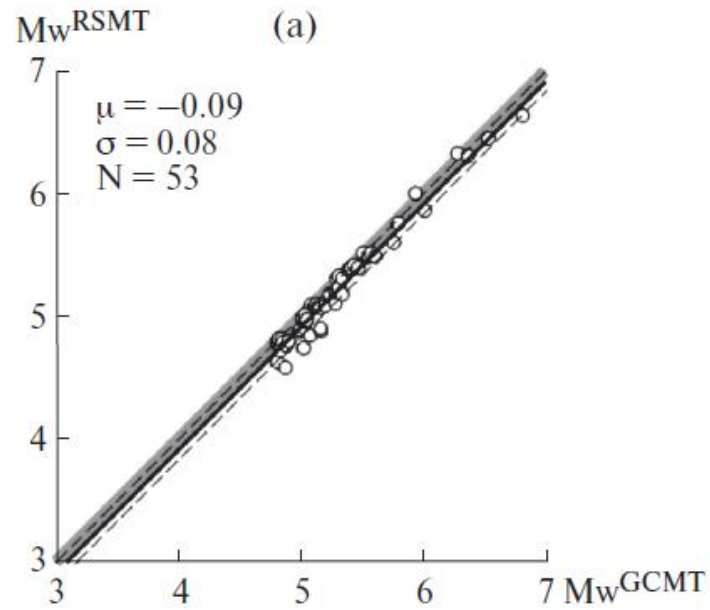
	NP1	NP2
$\phi$ :	$180^\circ$	$031^\circ$
$\delta$ :	$035^\circ$	$059^\circ$
$\lambda$ :	$063^\circ$	$107^\circ$



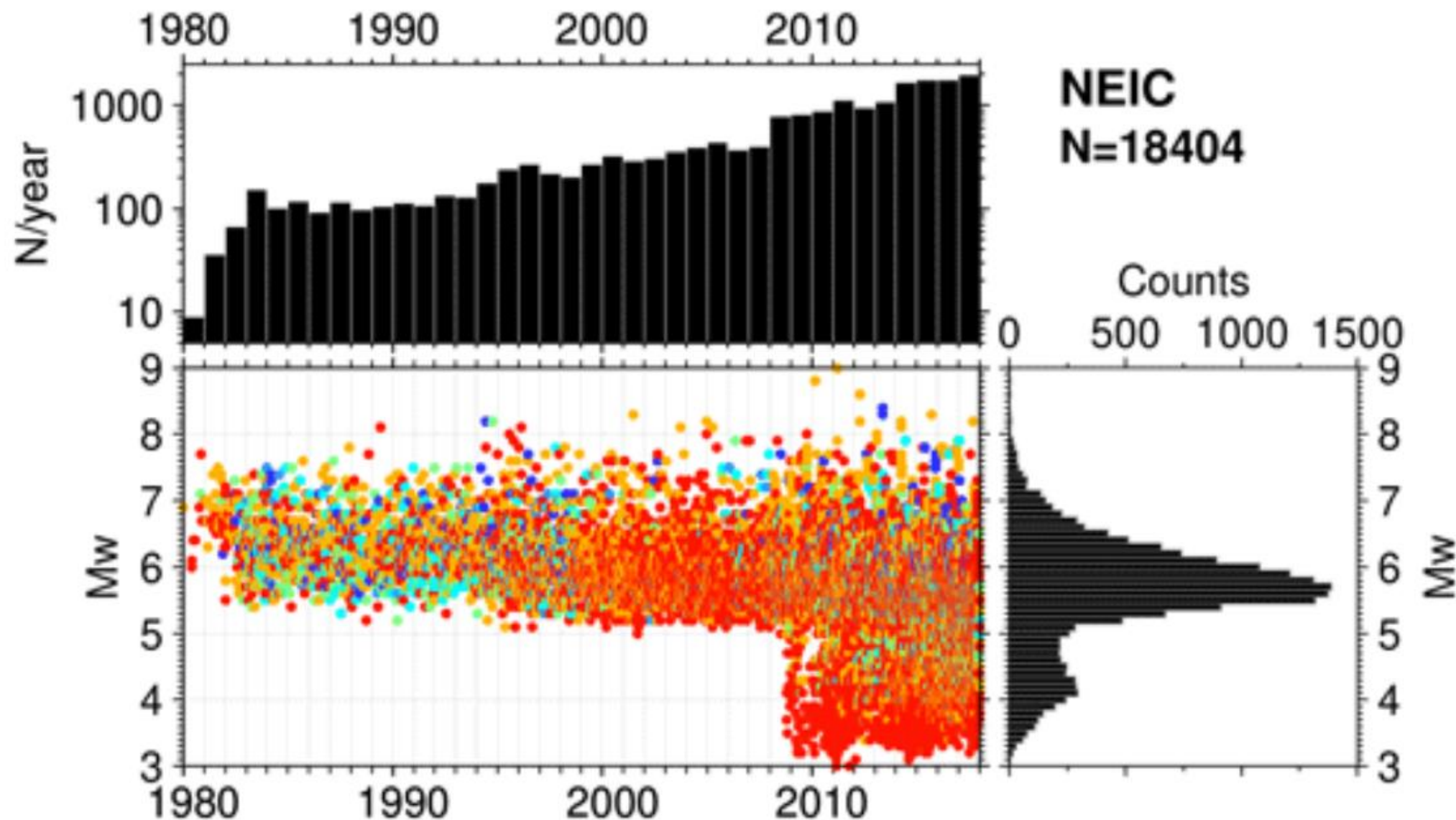
# Моментные магнитуды №5 ( $M_w^{CB}$ , $M_w^{ES}$ , $M_w^{CS}$ , и др.) [Абубакиров и др., 2018]



# Моментные магнитуды №5 ( $M_w^{CB}$ , $M_w^{ES}$ , $M_w^{CS}$ , и др.)

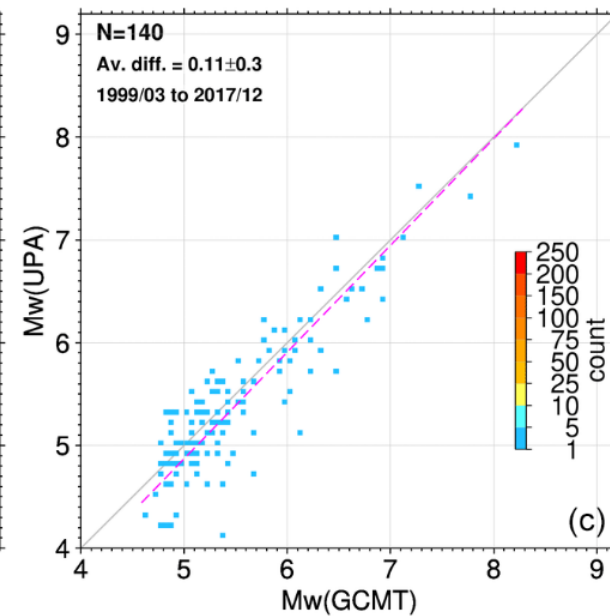
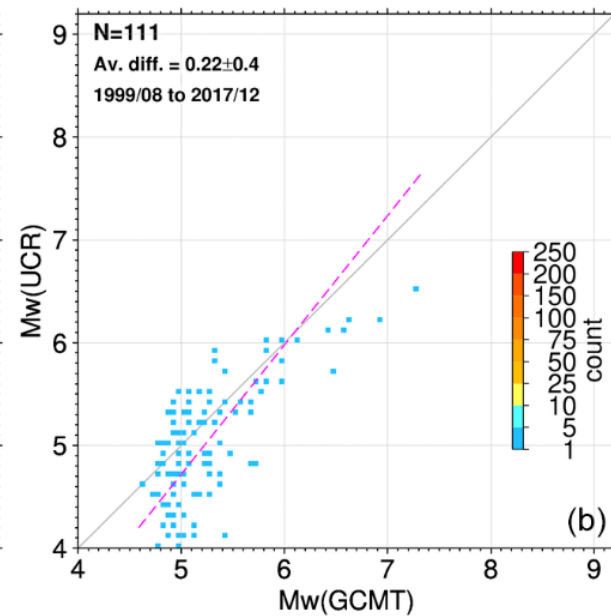
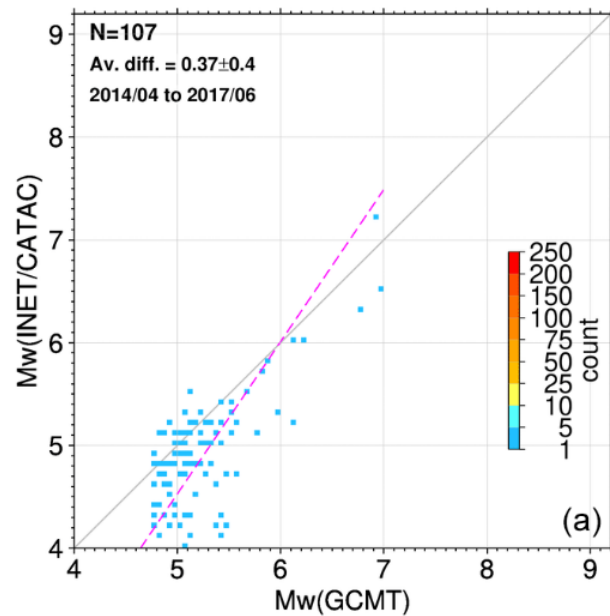
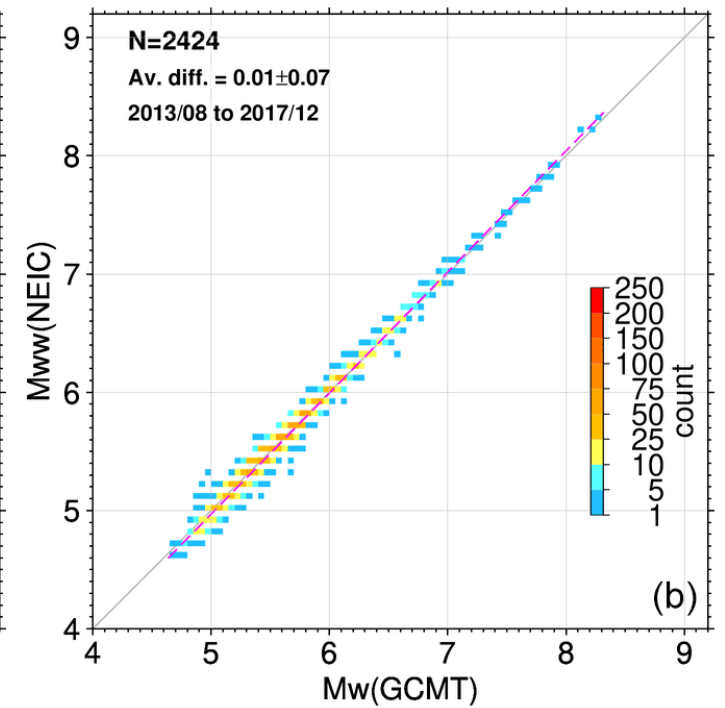
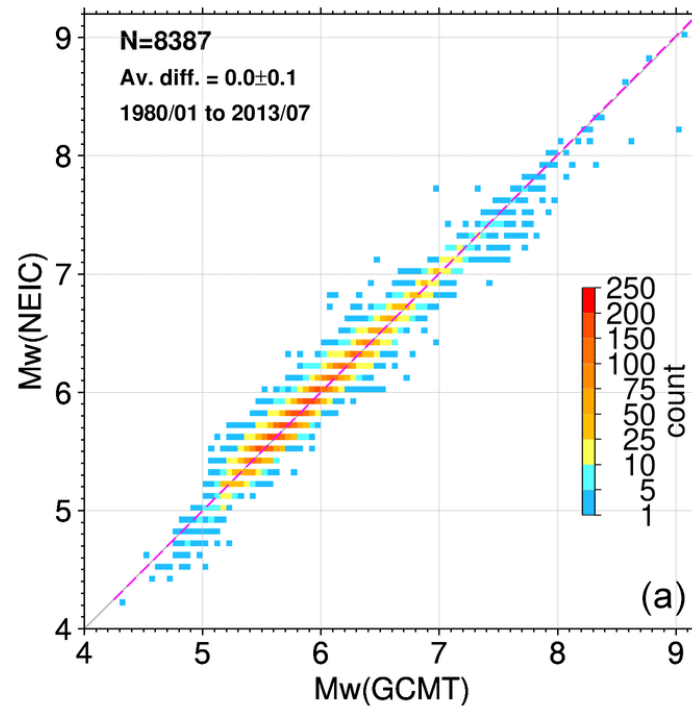


# Моментные магнитуды [Di Giacomo et al., 2021]

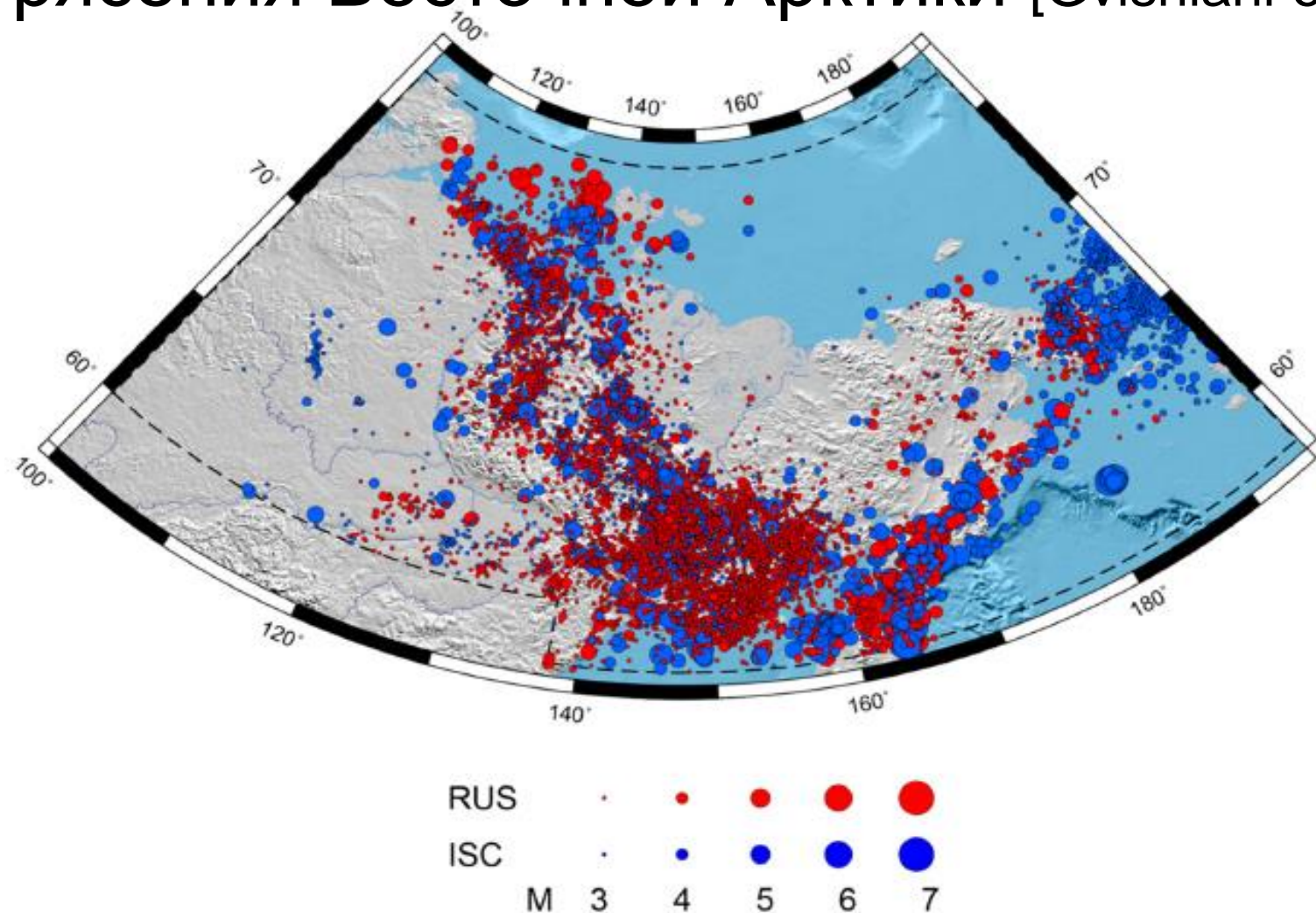


# Моментные магнитуды

[Di Giacomo et al., 2021]






# Землетрясения Восточной Арктики [Gvishiani et al., 2022]



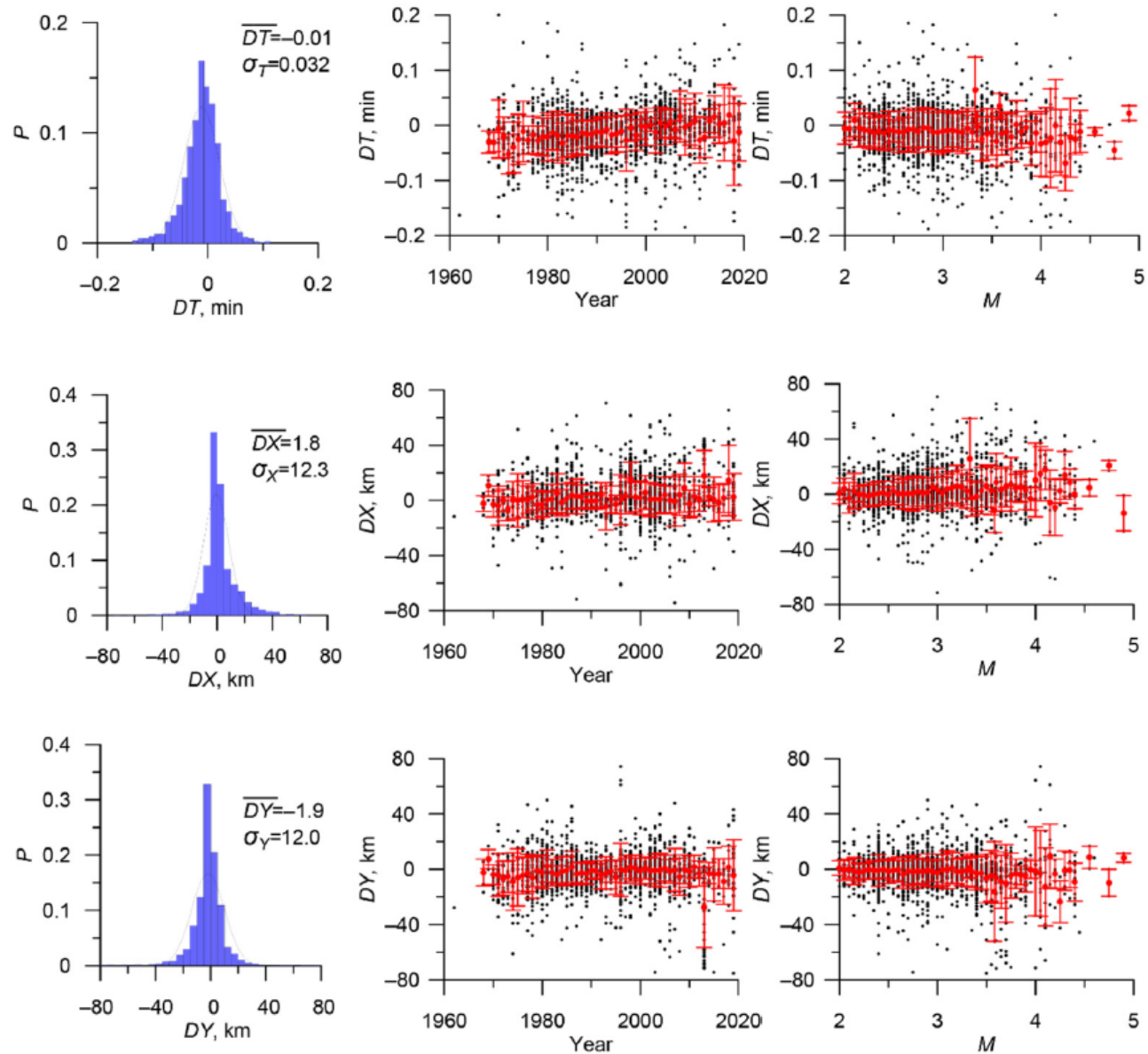
*Article*

## Integrated Earthquake Catalog of the Eastern Sector of the Russian Arctic

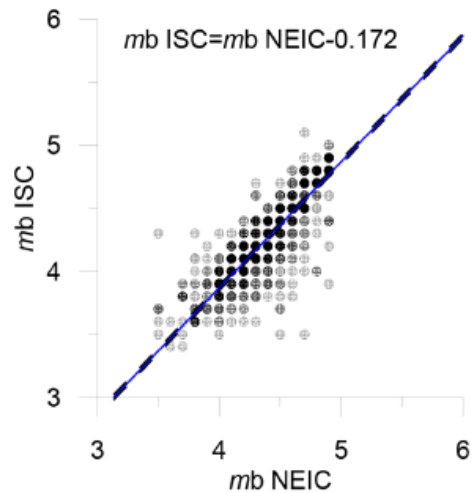
Alexei D. Gvishiani <sup>1,2</sup>, Inessa A. Vorobieva <sup>1,3</sup>, Peter N. Shebalin <sup>1,3</sup> , Boris A. Dzeboev <sup>1,\*</sup> ,  
Boris V. Dzeranov <sup>1</sup>  and Anna A. Skorkina <sup>1,2,3</sup>



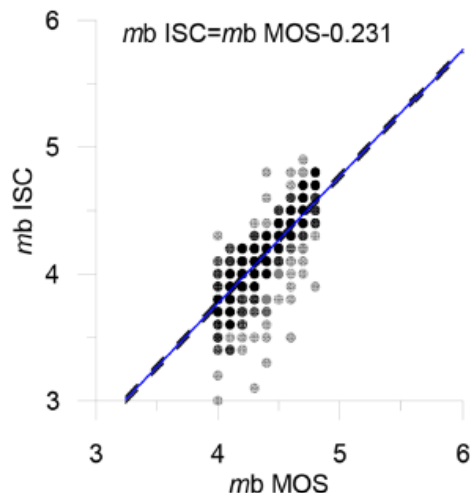
# Поиск дублей в парах каталогов



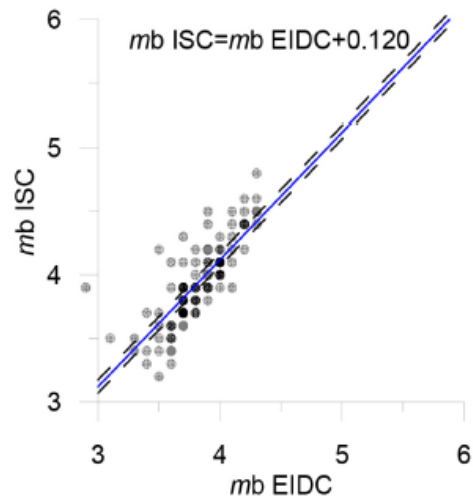
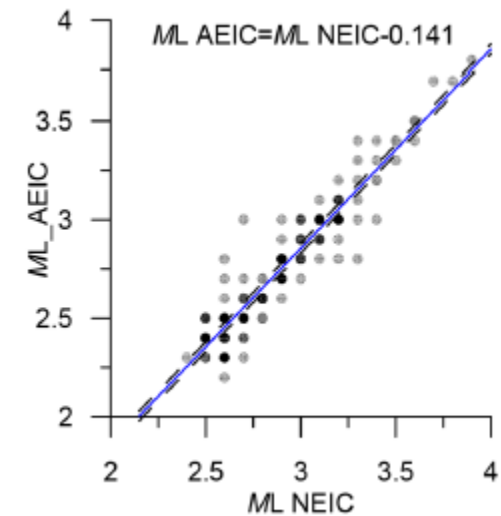
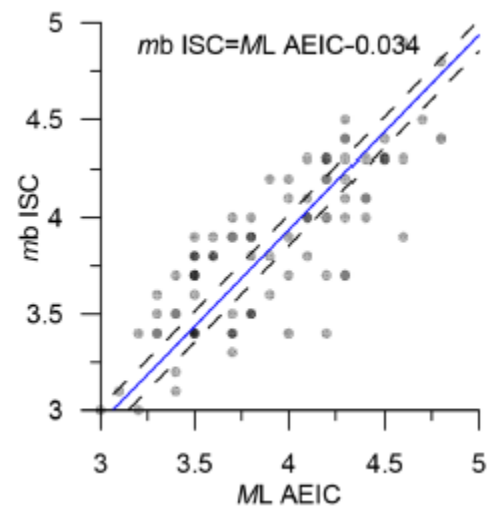
# Изучение соотношений между магнитудами



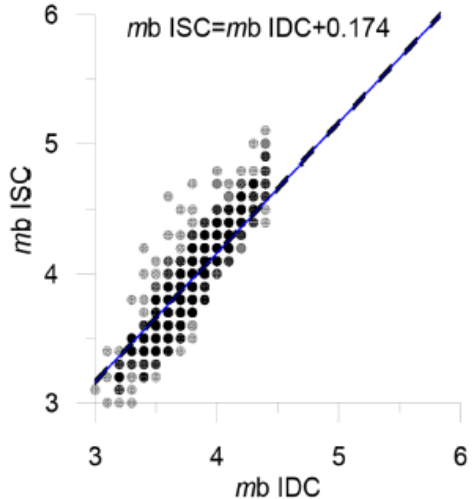
(a)



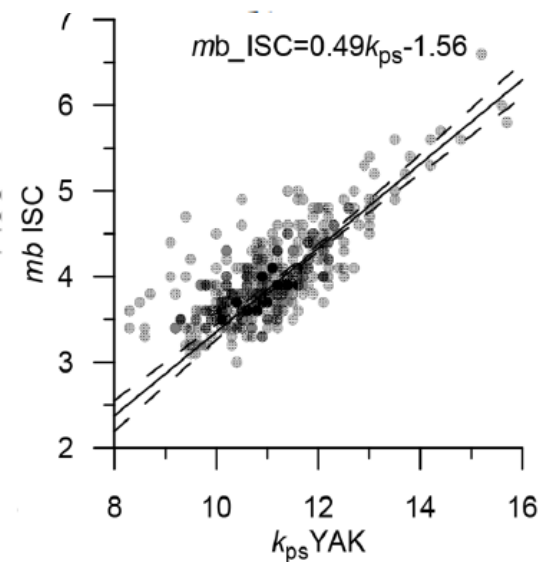
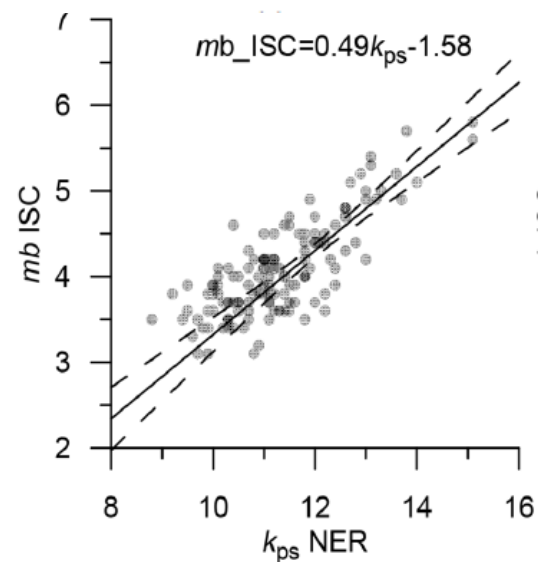
(b)



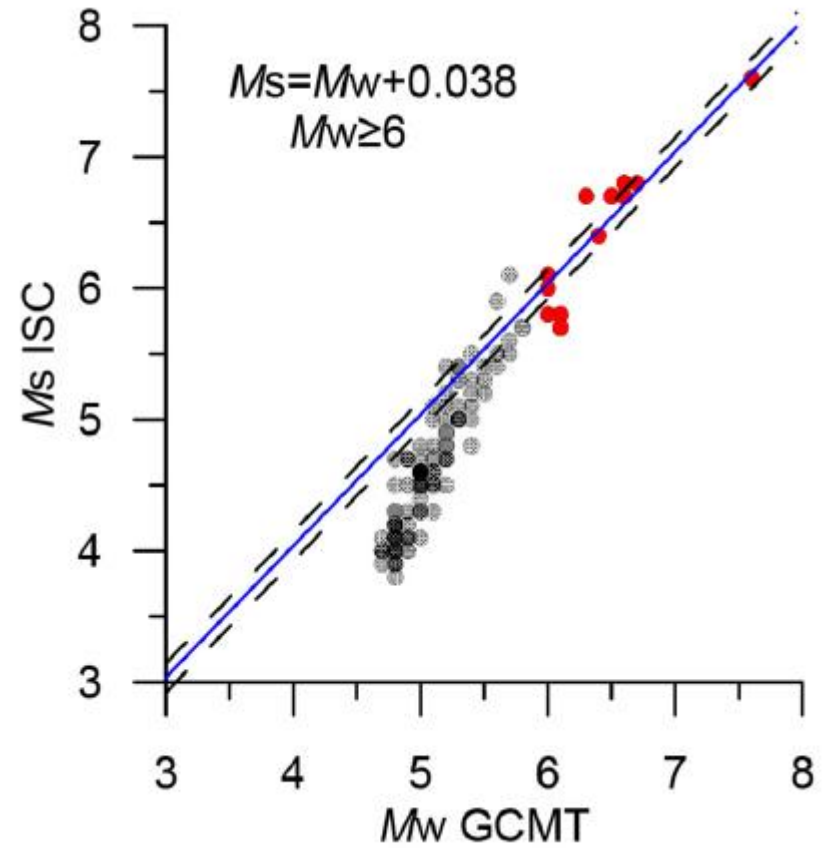
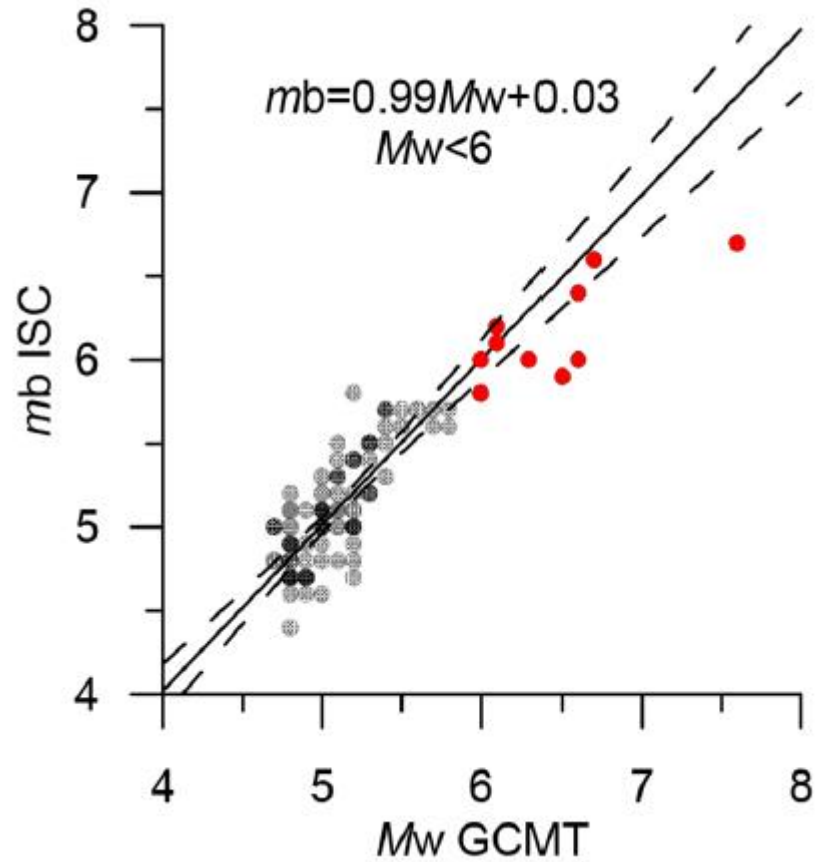
(c)



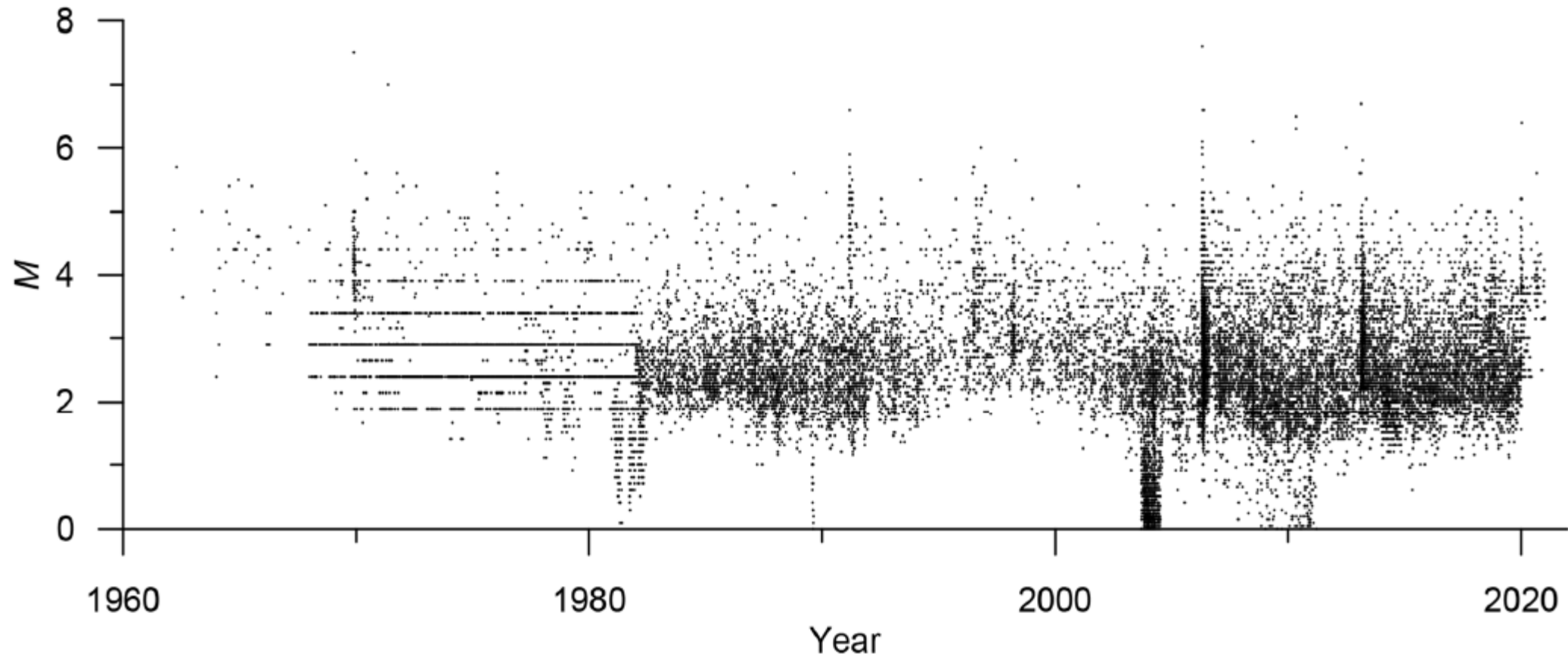
(d)



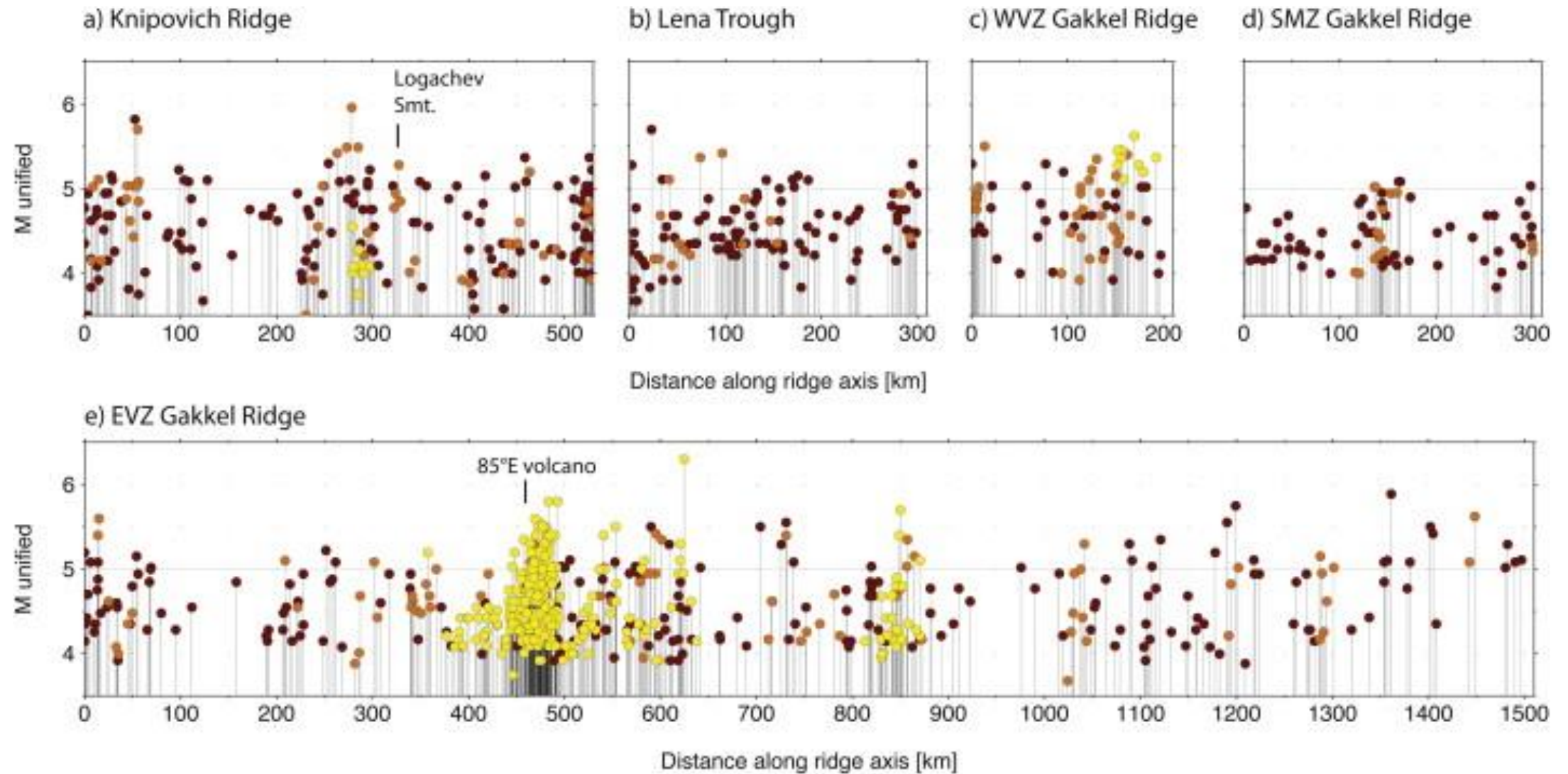
# Соотношение магнитуд



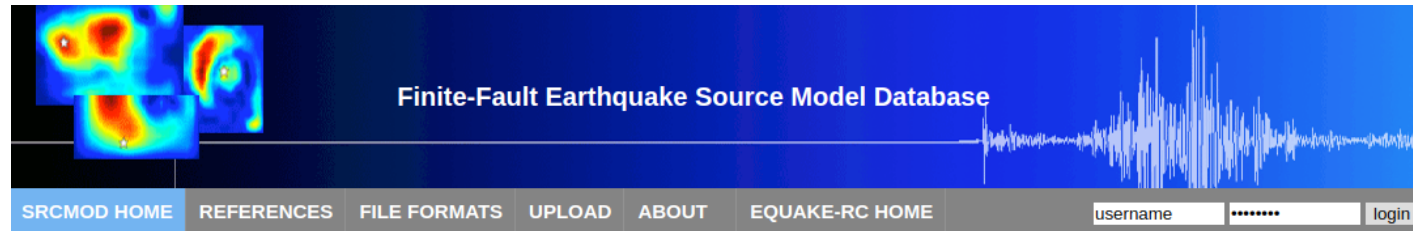
# Распределение магнитуд для Арктики [Gvishiani et al., 2022]



# Распределение магнитуд для Арктики [\[Schlindwein, 2015\]](#)



# База данных моделей очага (SRCMOD)



Welcome to SRCMOD - an online database of finite-fault rupture models of past earthquakes!

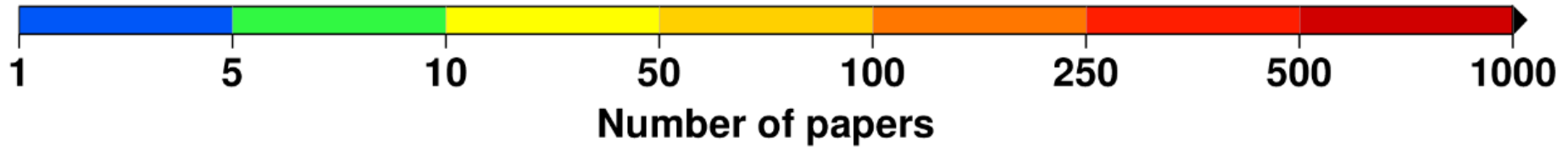
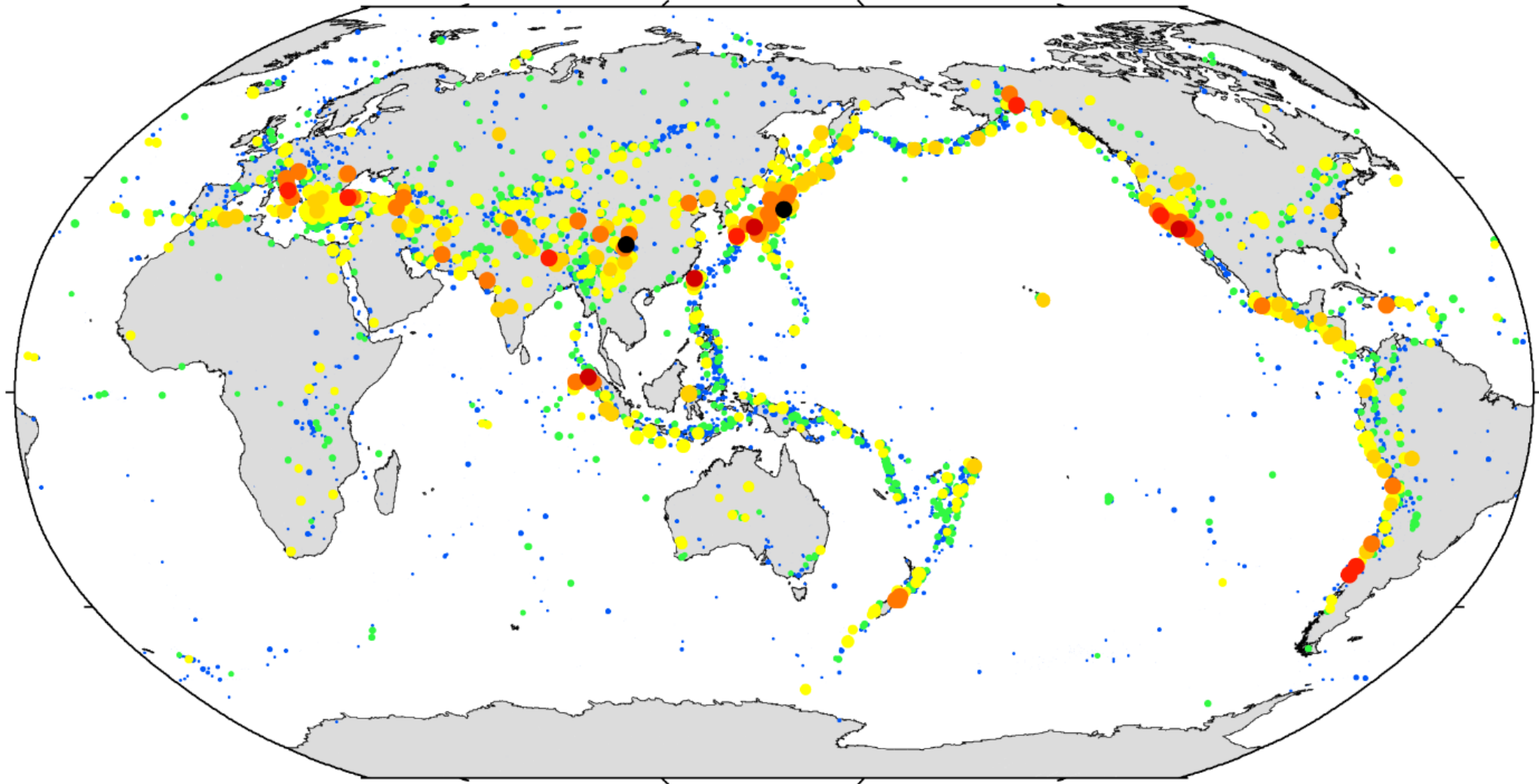
- > Join us in our efforts to collect and disseminate earthquake rupture models by using this database for your research, contributing your rupture models that you obtain(ed) in your research, and sending us comments and suggestions.
- > You can access the models, by searching based on meta information or browse [all the models](#).
- > In the list of the models, link to the page for each source model is provided under the **author** field.
- > The page for each source model provide the fundamental parameters, image of slip on the fault, and download links.
- > See [File Formats](#) page for details on the conventions used for MATLAB-binaries and ASCII-file formatting.
- > **Your contributions to this database are highly appreciated!** We hope that the number of source models will increase as researchers send us their inversion/modeling results, not only for recent, but also for past earthquakes.
- > We encourage contributors to prepare their source models in **\*mat-format**.
- > **You can download all the models (.zip files).**
- > Currently; the database has **353 models from 182 earthquakes, last updated: Sept. 24, 2019.**
- > You can upload the data directly by using [Upload](#) tool.
- > Please send us your [inquiries and suggestions](#). If you discover inconsistency or error, please inform us immediately.
- > **Check out the 2014 paper in the Seismological Research Letters (including an erratum).**



List all models or use the form to search

Date range (yyyy-mm-dd)	
From <input type="text" value="1906-04-18"/>	To <input type="text" value="2019-09-26"/>
Magnitude range	
<input type="text" value="0.0"/> ≤ Mw ≤ <input type="text" value="10.0"/>	
Location	
Latitude (°N): <input type="text" value="-90.0"/>	To <input type="text" value="90.0"/>
Longitude (°E): <input type="text" value="-180"/>	To <input type="text" value="180"/>
Depth range (km)	
From <input type="text" value="0.0"/>	To <input type="text" value="1000.0"/>
<input type="button" value="Submit"/>	

# Самые «изученные» землетрясения (по данным ISC)



# База данных очаговых функций (SCARDEC)



## SCARDEC Source Time Functions Database

### 🏠 Presentation

This page is the web tool associated with the article : Vallée, M. and V. Douet, [A new database of Source Time Functions \(STFs\) extracted from the SCARDEC method, Phys. Earth Planet. Int., 257, 149-157, 2016](#). Besides technical aspects, the reader will find in this article how this database should and should not be used. Please refer to it if publicly using the information provided by the STF database. More information on the SCARDEC method, and on an exhaustive application can be found [here](#).  
STFs provided here have been revised and are therefore provided with a delay. The automatic real-time STFs since 2014 can be visualized on the [GEOSCOPE website](#).  
You can find additional Source Time functions (from surface waves) on [the IRIS Source Time Function Product webpage](#)

### 📄 Notice

According to the constraints filled in the section "Searching events" and after validation with the button "SEARCH DATABASE", the corresponding events are listed with their SCARDEC-determined parameters. Each Source Time Function (STF) can be visualized online and a group of STFs can be downloaded after selecting them. The number of earthquake STFs that can be downloaded is limited to 500. If more earthquakes are selected, please split your request or download the full database (see below). See also the [format](#) of the STFs files.  
[Download the whole STF database](#) (Most recent earthquake present in the database : 2017/12/31 - Last update of the database : 2018/11/01)

### 🔍 Searching events

📅 Date constraints: From  to

📏 Magnitude constraints (Mw): From  to

📏 Depth constraints (kms): From  to

📏 Focal mechanism constraints:

- Strike (°): From  to

- Dip (°): From  to

- Rake (°): From  to

📍 Location constraints:

Hold down the **Shift** key while dragging a box or use the visual control below.

For development purposes only

Latitude max

Longitude min   Longitude max

Latitude min

Google Изображения ©2019 NASA 1000 км Условия использования

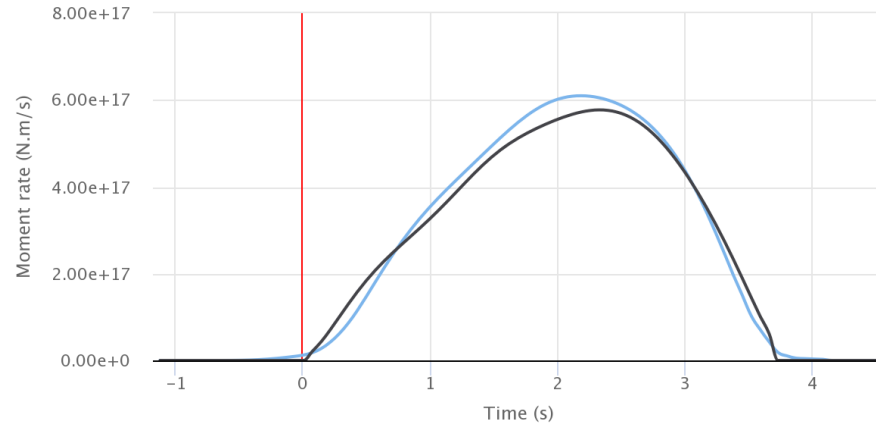
### 📅 Selecting events



# База данных очаговых функций (SCARDEC)

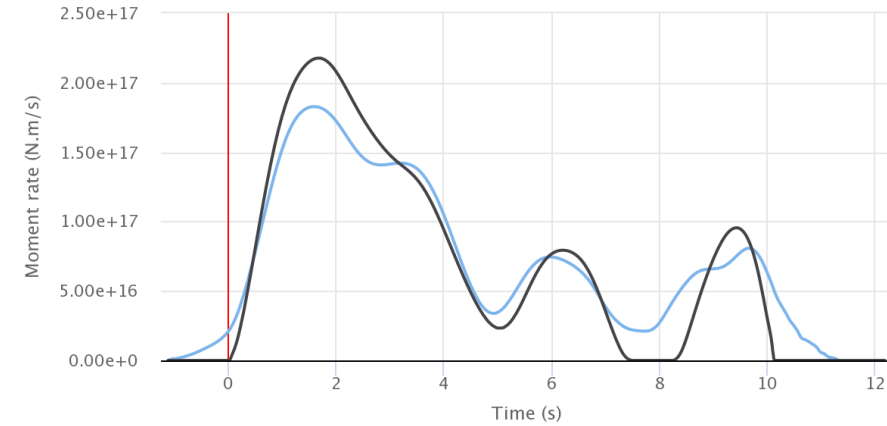
SOURCE TIME FUNCTION

EASTERN SIBERIA RUSSIA , 2006-04-21 11:14:15, Mw=6.0, Depth=12km



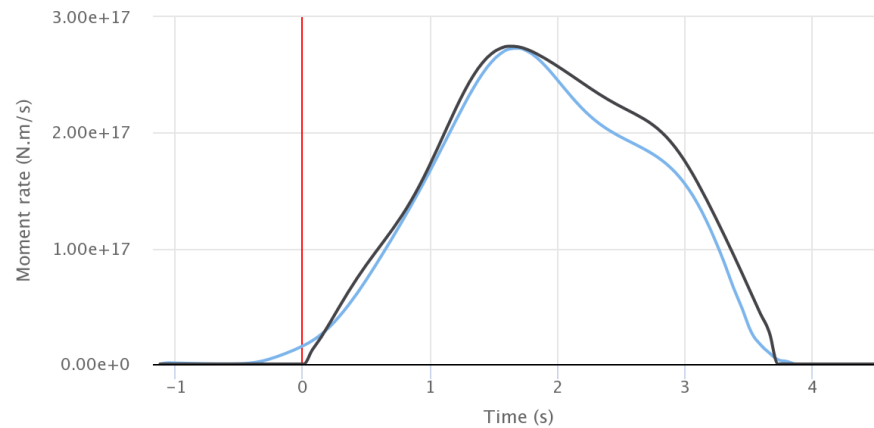
SOURCE TIME FUNCTION

EAST OF SEVERNAYA ZEMLYA , 2009-10-07 20:52:13, Mw=5.9, Depth=7km



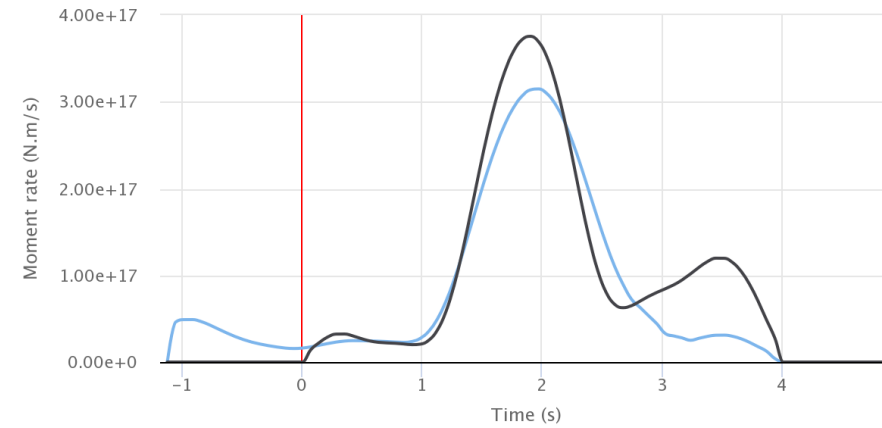
SOURCE TIME FUNCTION

EASTERN SIBERIA RUSSIA , 2013-03-13 03:12:53, Mw=5.8, Depth=9km



SOURCE TIME FUNCTION

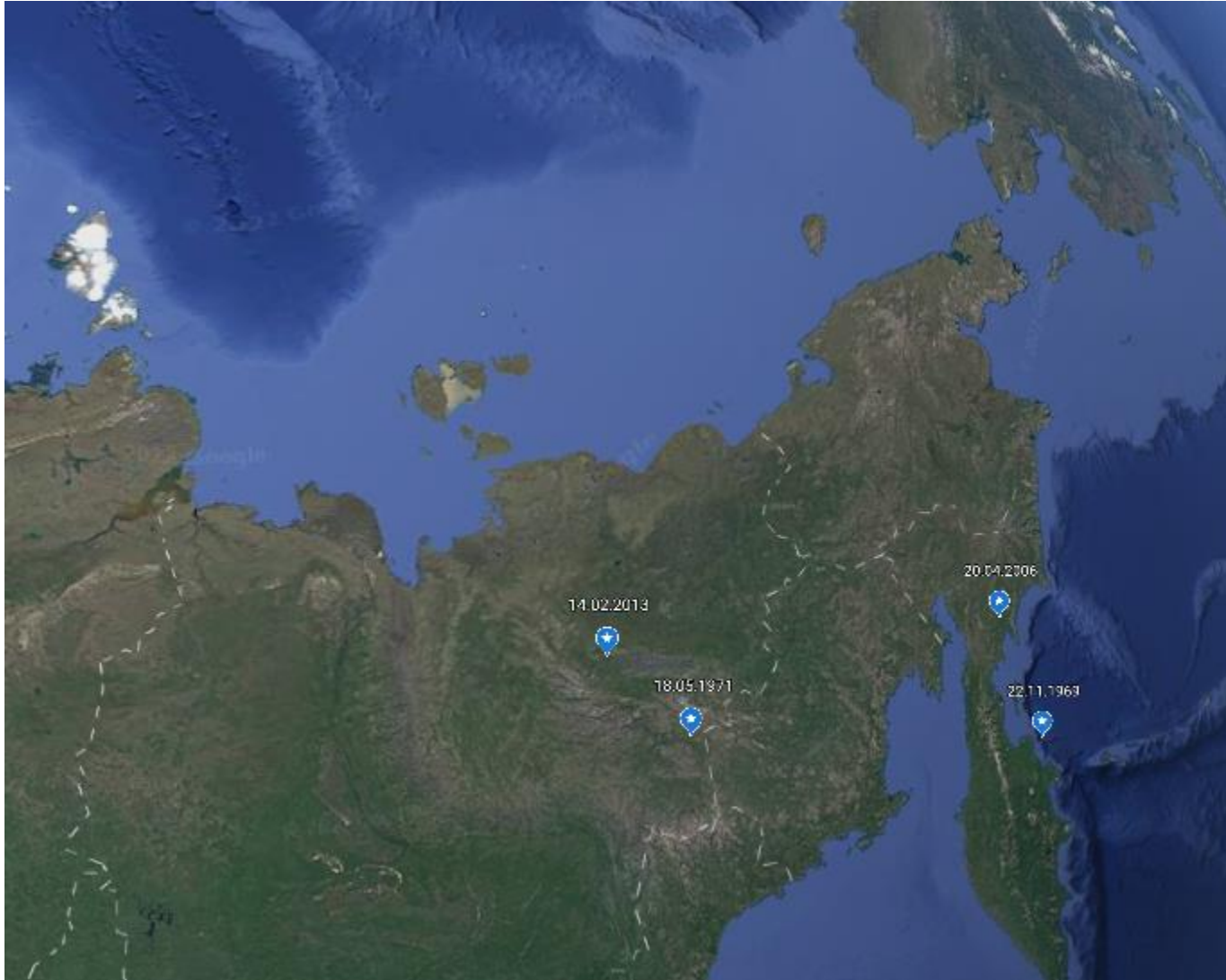
EASTERN SIBERIA RUSSIA , 2006-05-09 11:02:21, Mw=5.7, Depth=7km



— Average Source Time Function — "Optimal" Source Time Function

— Average Source Time Function — "Optimal" Source Time Function

# Сильные землетрясения



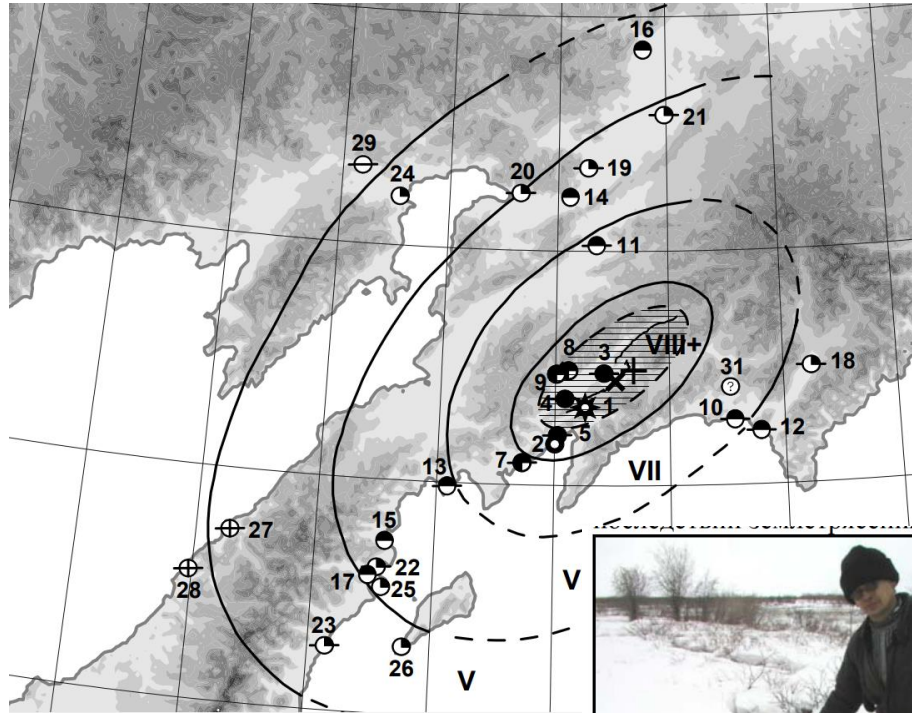
21.04.2006 (M = 7.6)

22.11.1969 (M = 7.5)

19.05.1971 (M = 6.7)

14.02.2013 (M = 6.9)

# Олюторское землетрясение 21.04.2006 (M = 7.6)

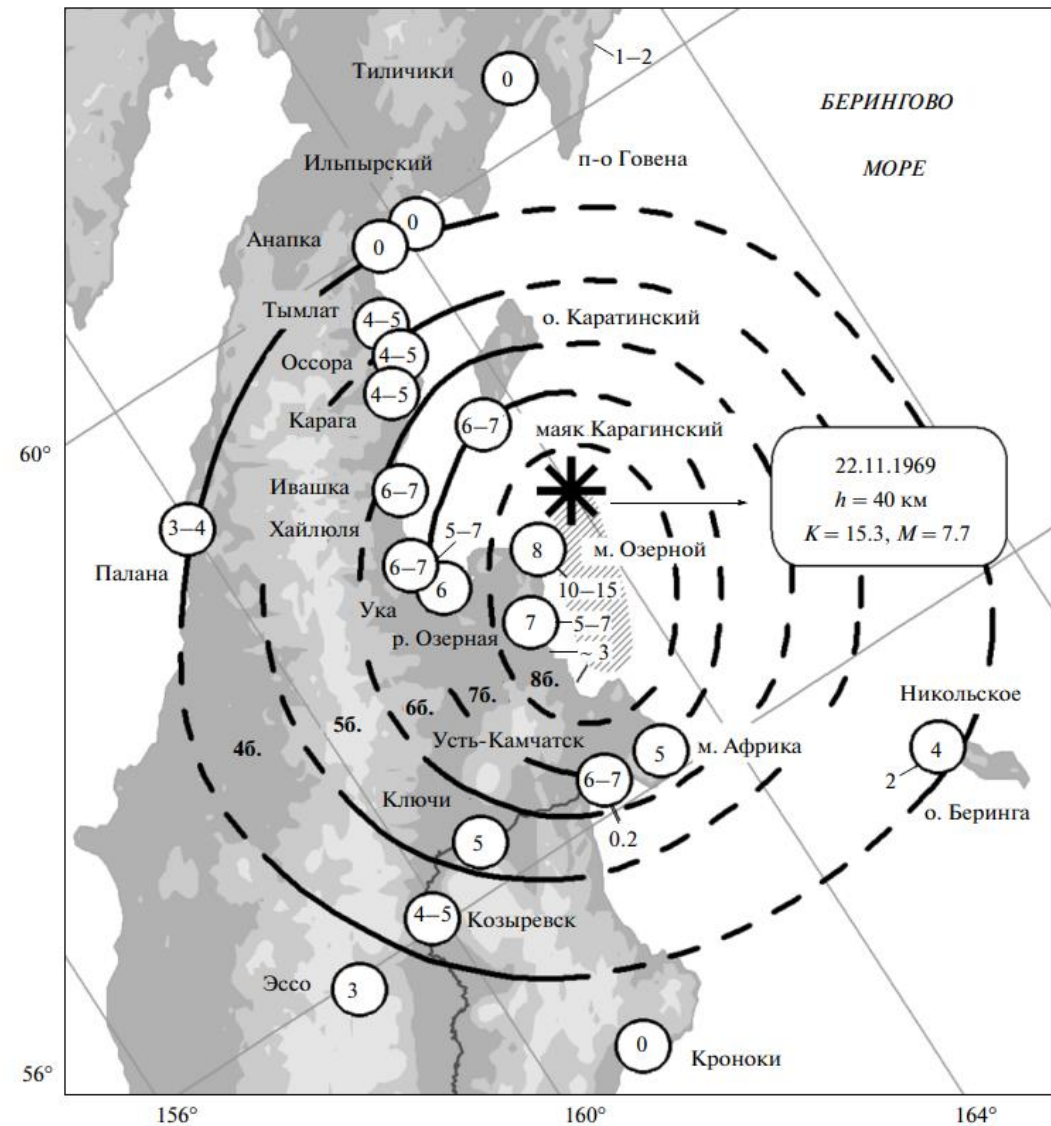


Землетрясение на р. Авьянваям. Разрушения внутри домика. (Фото Т.П.)

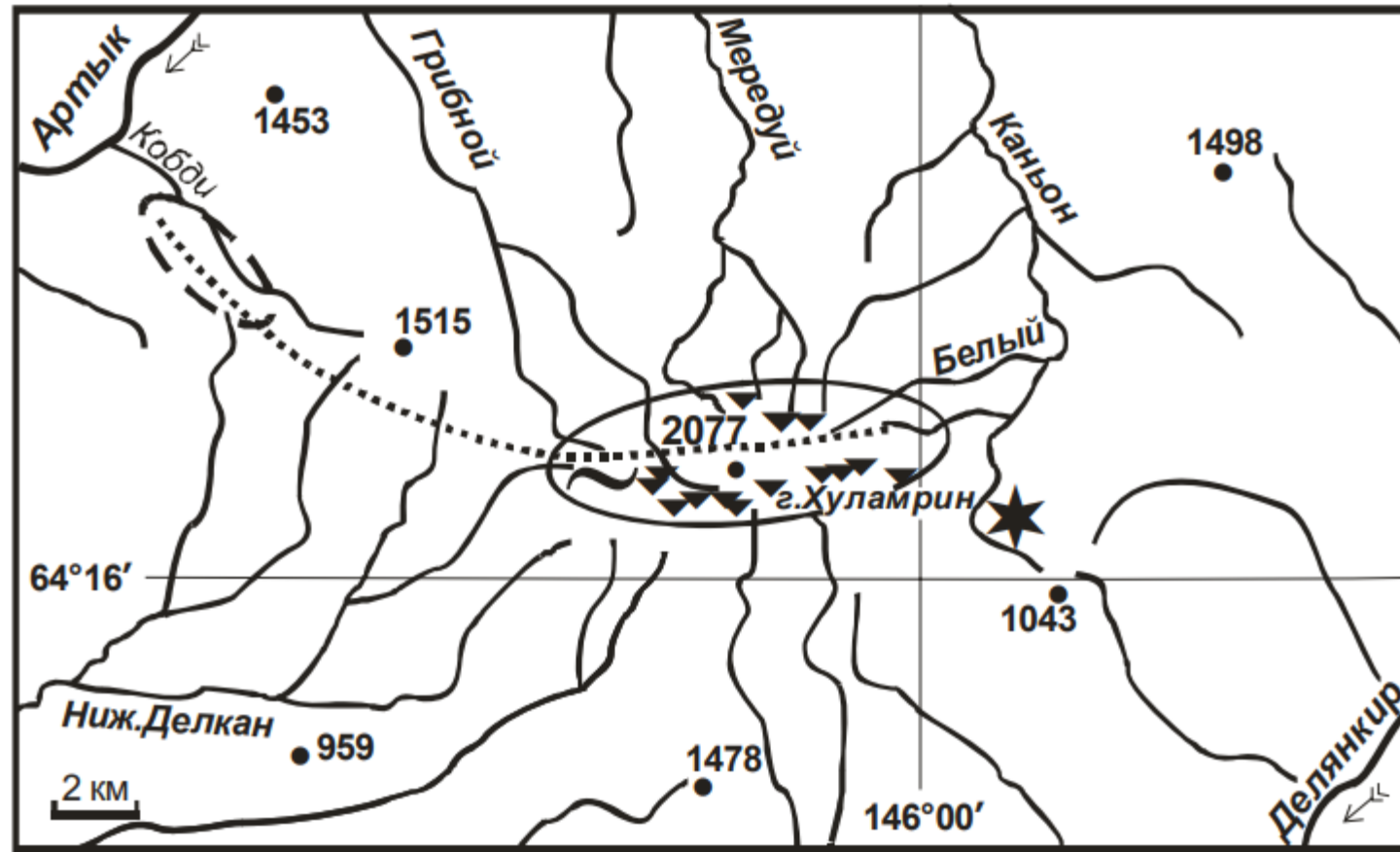


# Землетрясение в Озерновском заливе

22.11.1969 ( $M = 7.5$ ) [В.Н. Чебров и др., 2012]

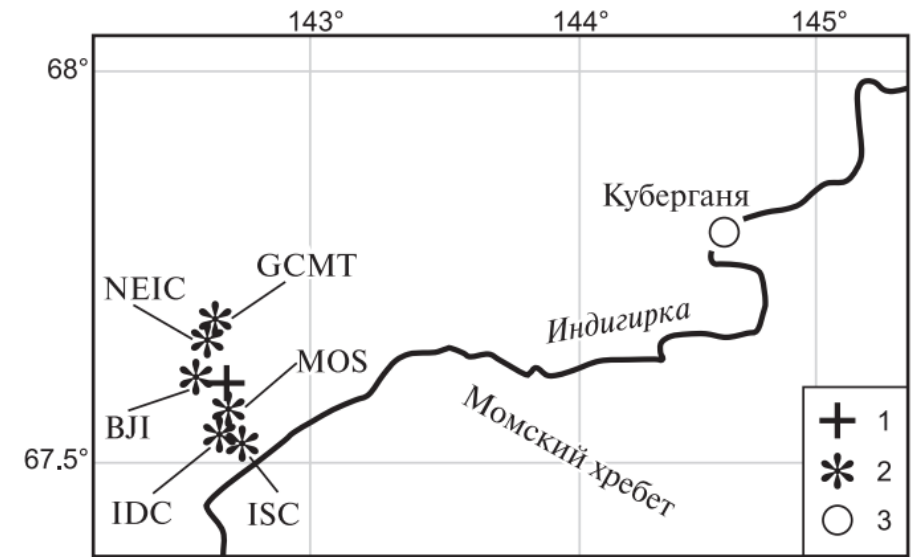
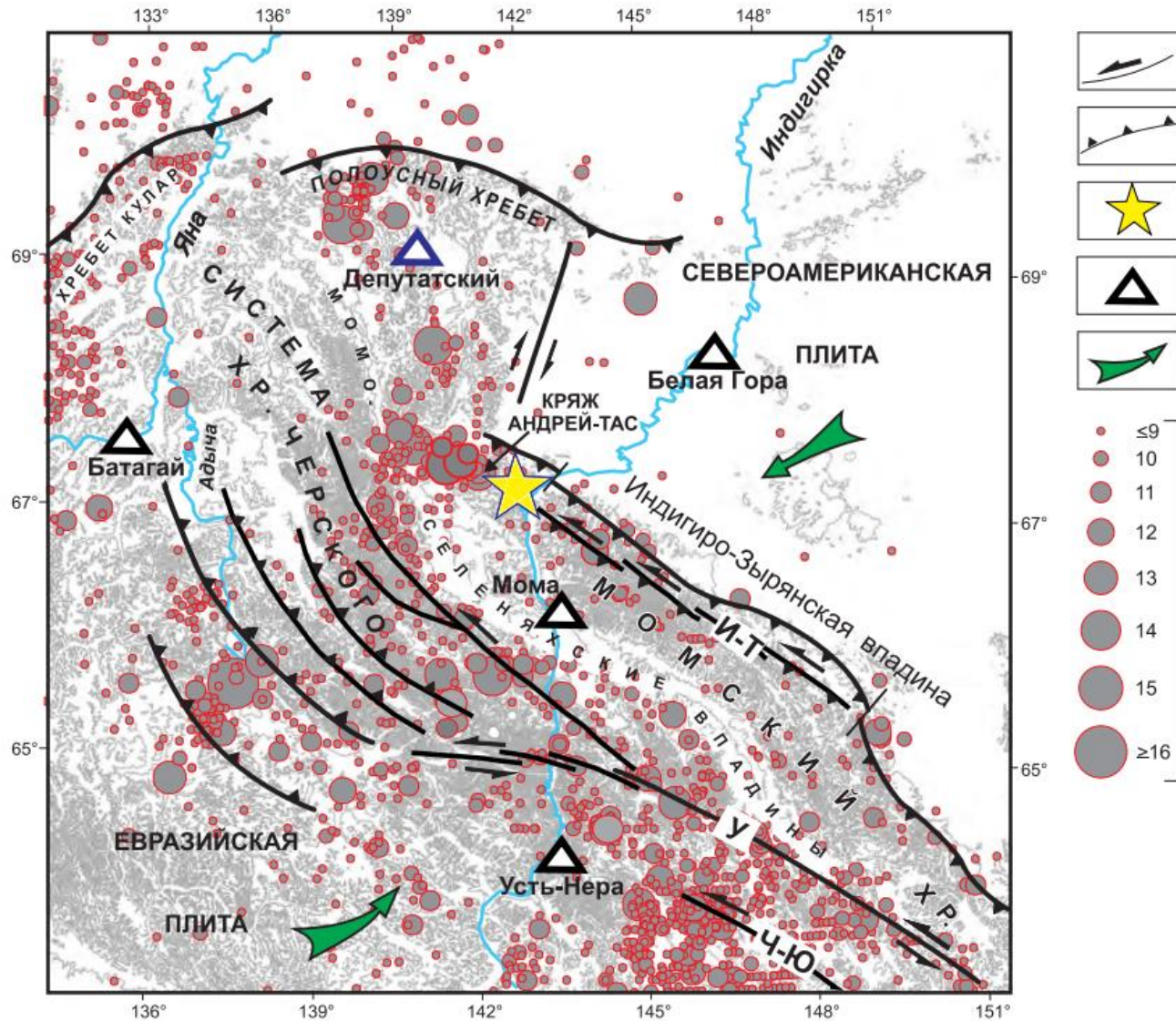


# Артыкское землетрясение 19.05.1971 (M = 6.7) [Важенин, 2012]



# Иллин-Тасское землетрясение

## 14.02.2013 (M = 6.9)



Благодарю за внимание!



**Скоркина Анна Александровна**

Кандидат физико-математических наук

Старший научный сотрудник Геофизического центра РАН

Старший научный сотрудник Института теории прогноза землетрясений и математической геофизики РАН

[anna@mitp.ru](mailto:anna@mitp.ru)