Geophysical Data Analysis

L01: Data, Observables & Instruments - An Introduction

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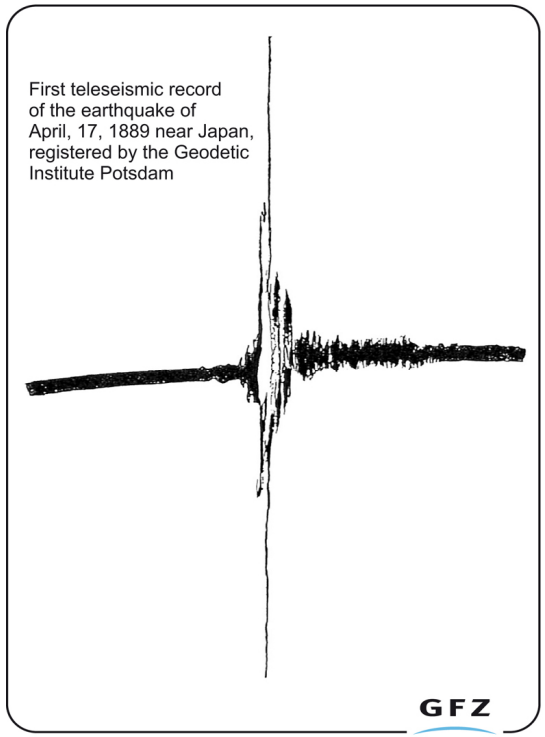

Literature

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- Scherbaum, F. (2013). Of poles and zeros: Fundamentals of digital seismology (Vol. 15). Springer Science & Business Media.
- Kanasewich, E. R. (1981). Time sequence analysis in geophysics. University of Alberta.

Why bother?

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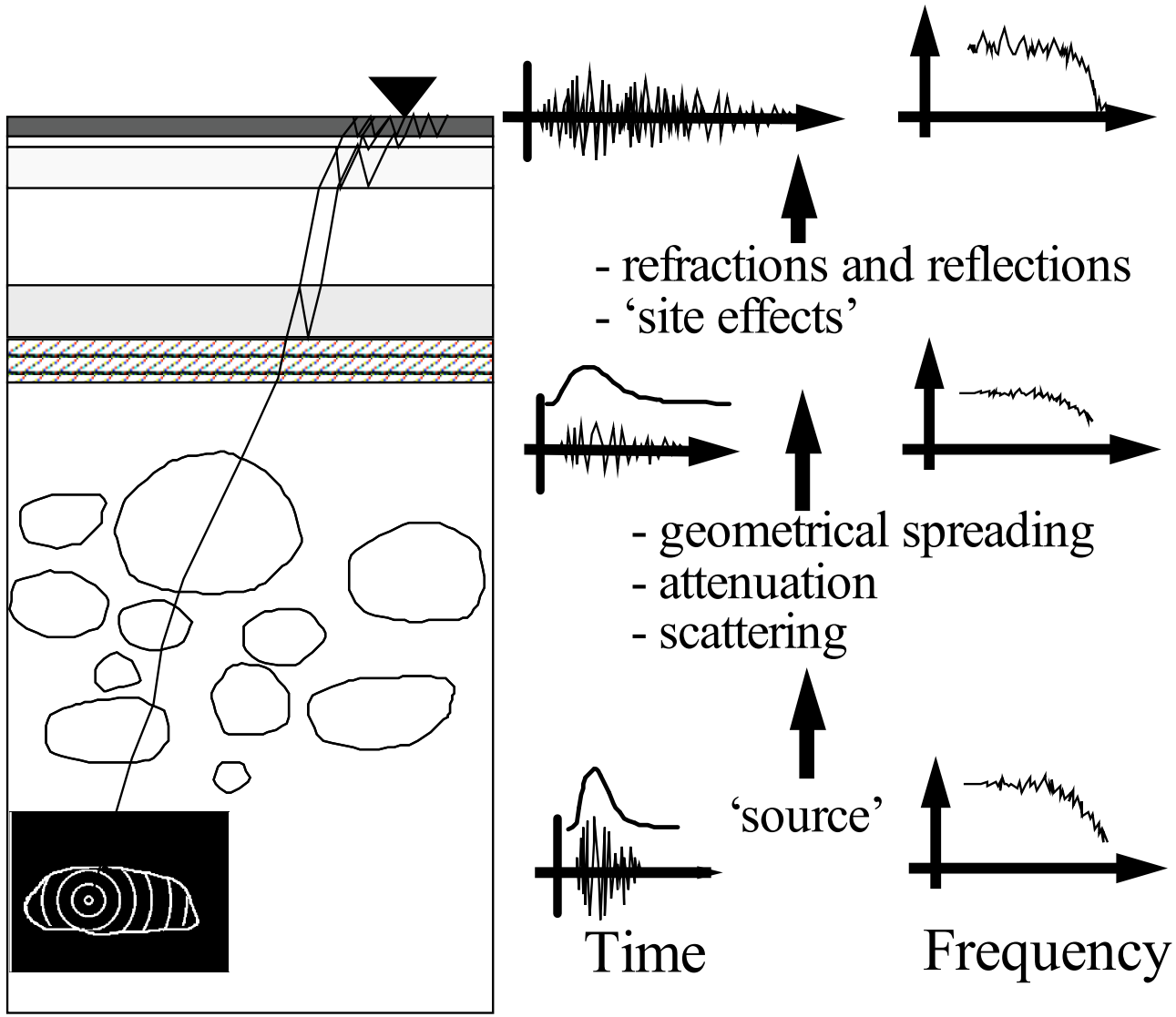

Scherbaum, F. (2013)

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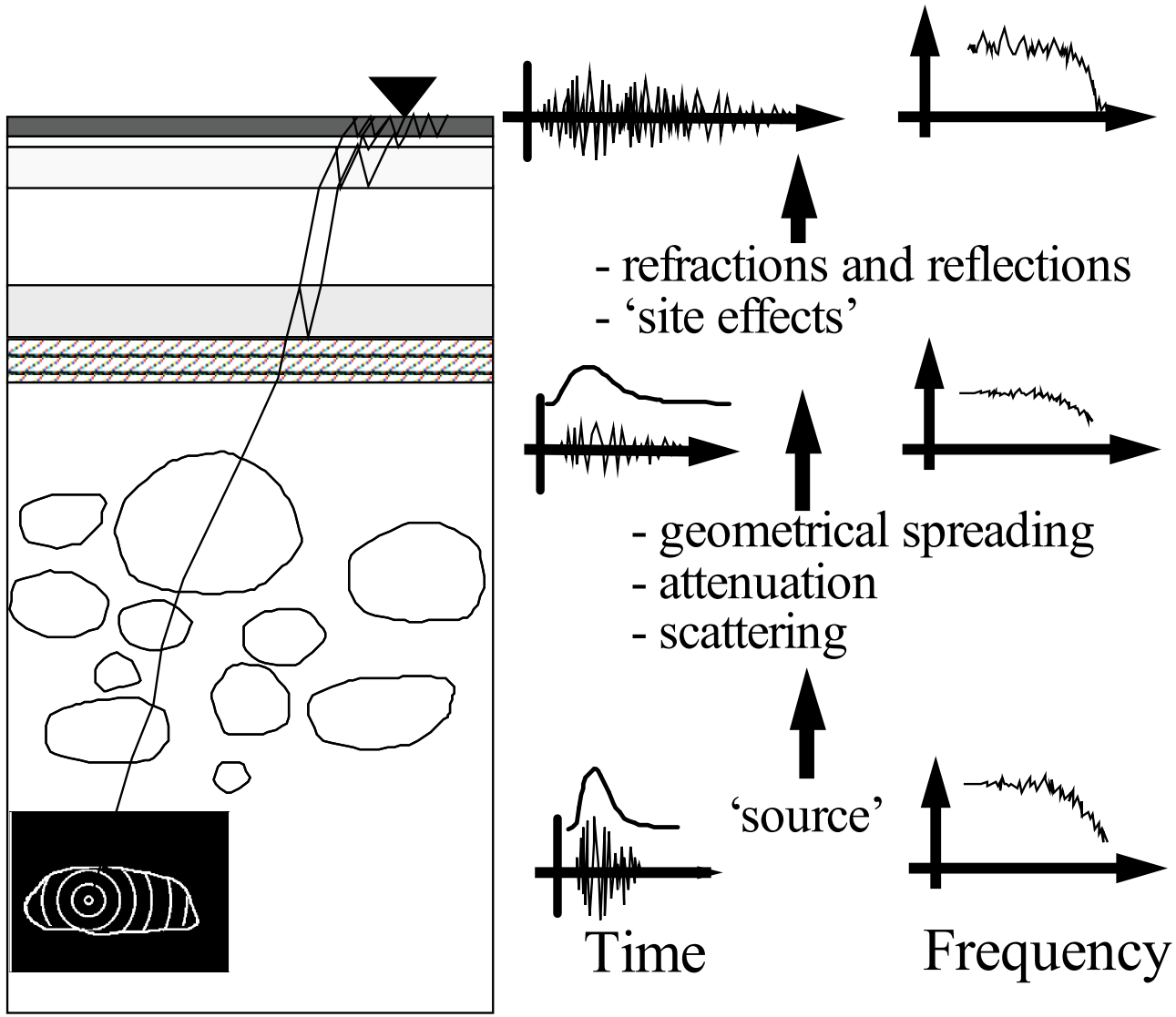
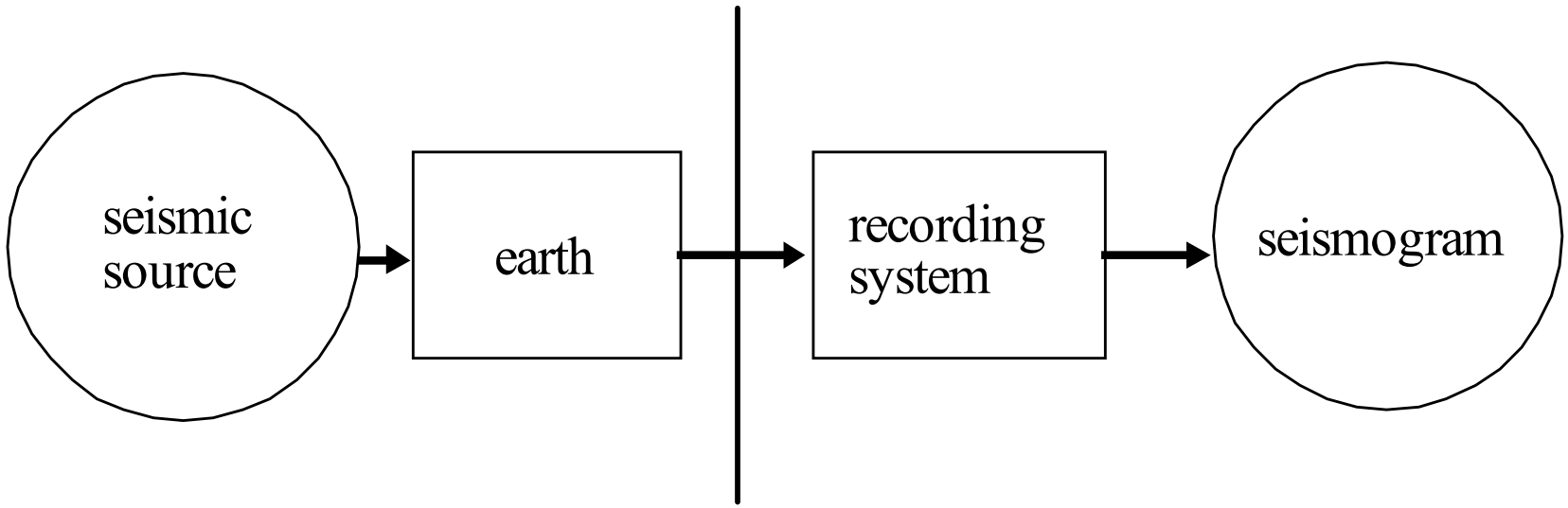


… depending on what is desired, we have to separate source from path effects using signal processing

Scherbaum, F. (2013)

But first: the instrument!



Work-Flow in Geophysics

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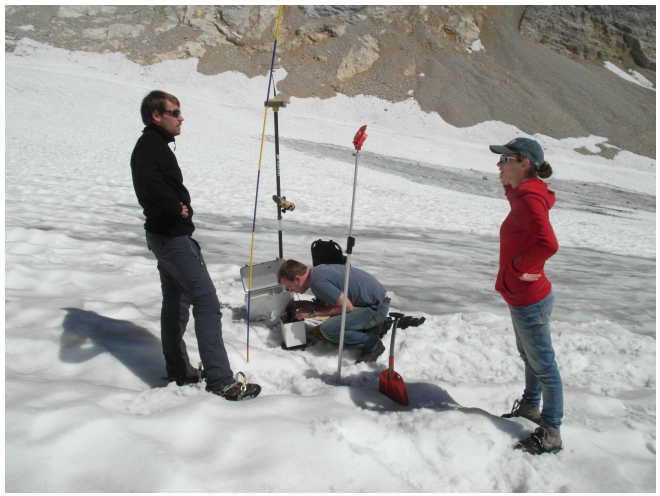

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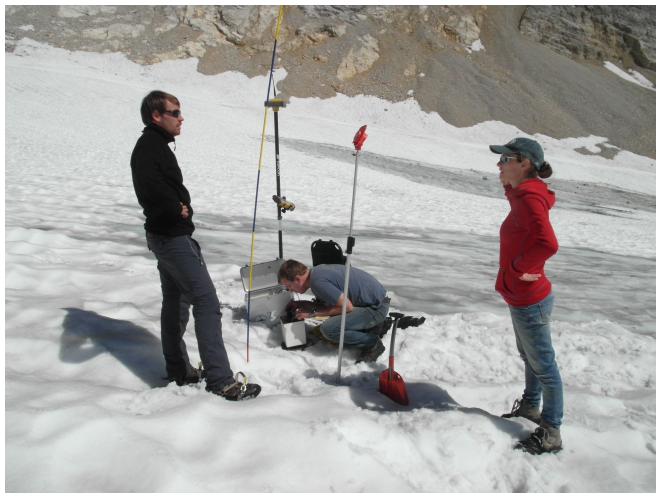

2: Pre-Processing

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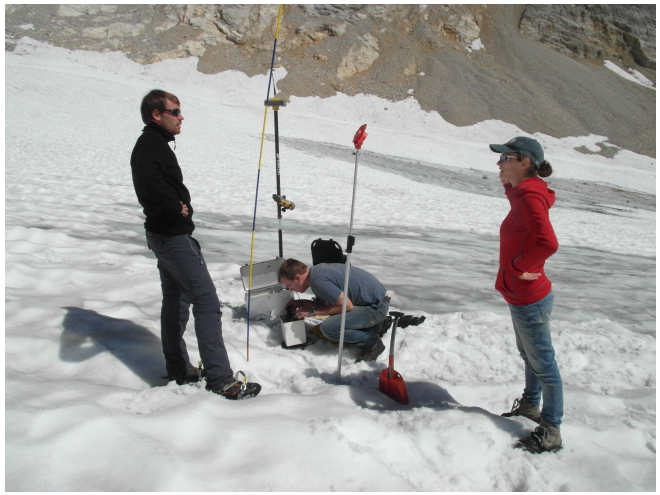

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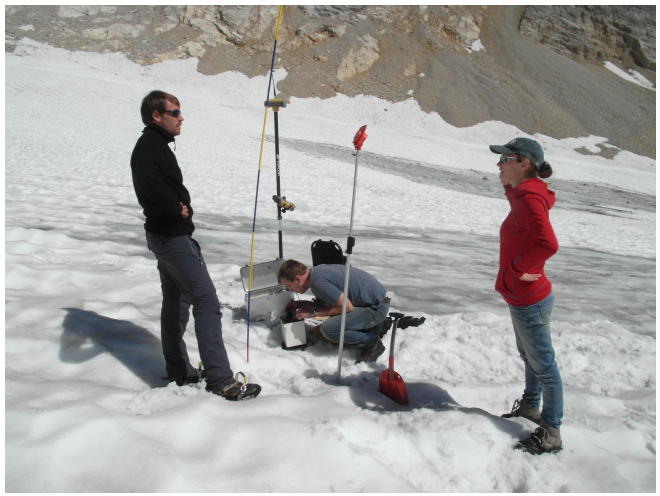

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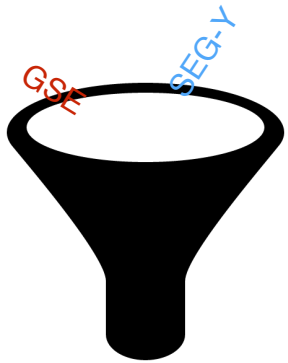

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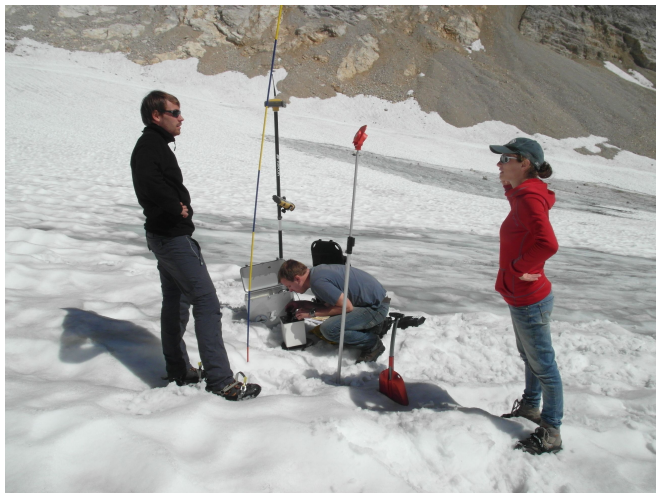

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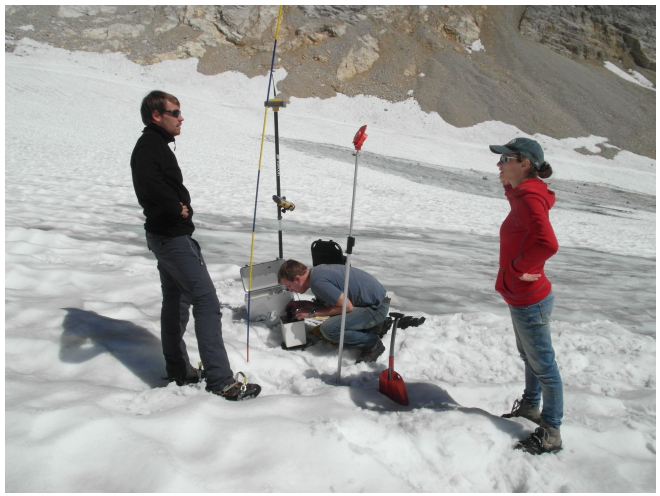

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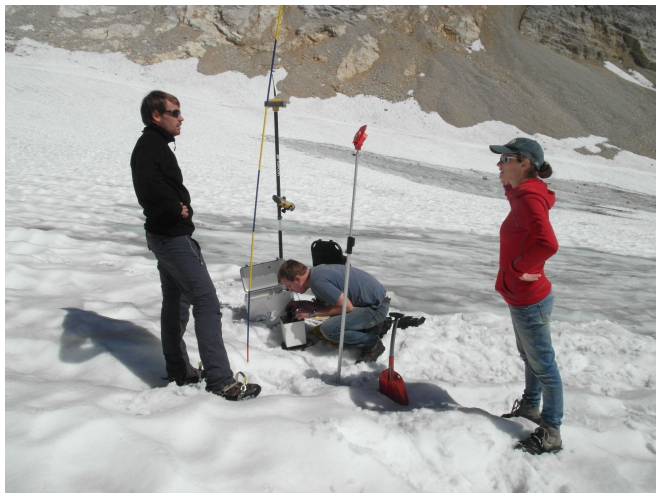

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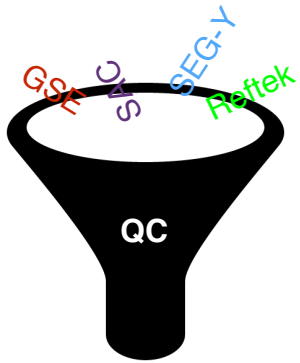

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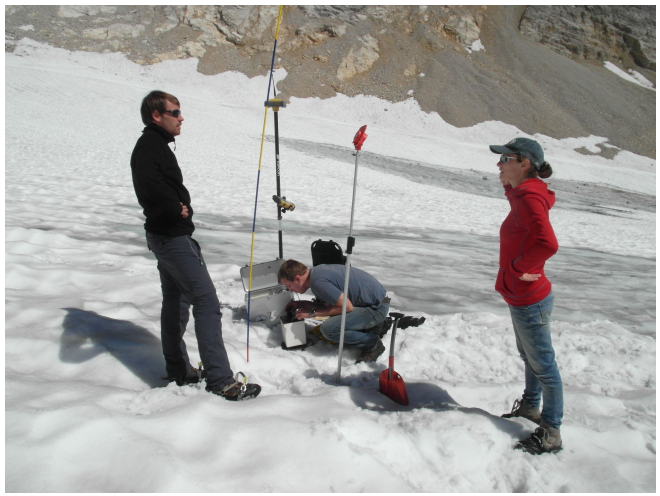

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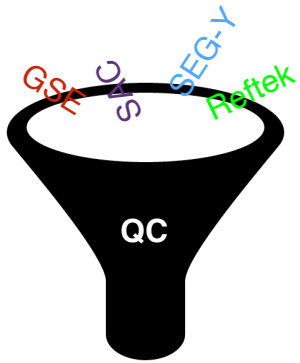

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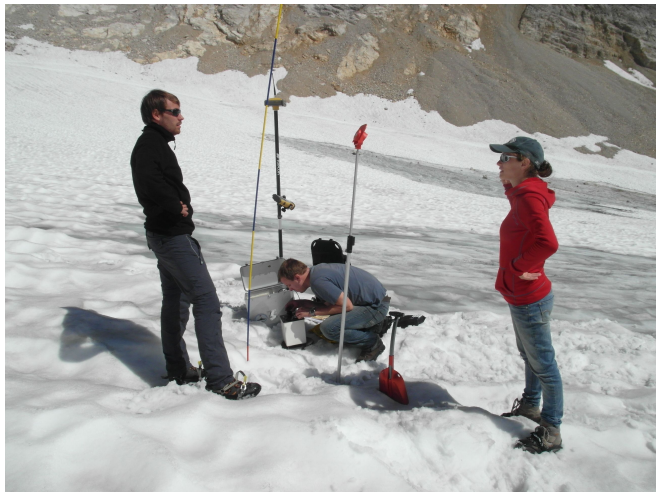

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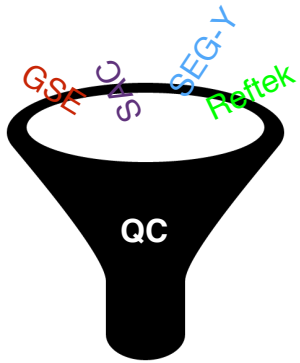

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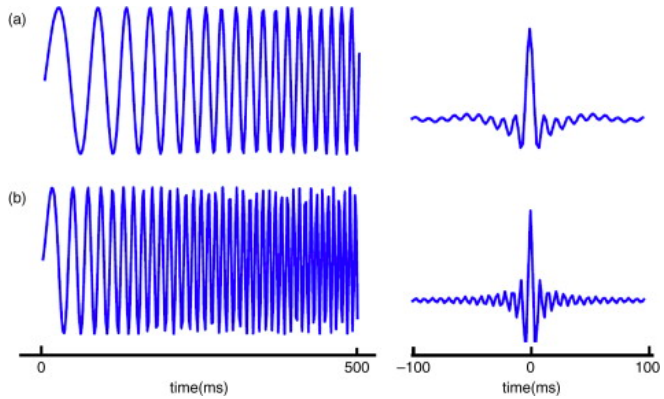
3: Processing



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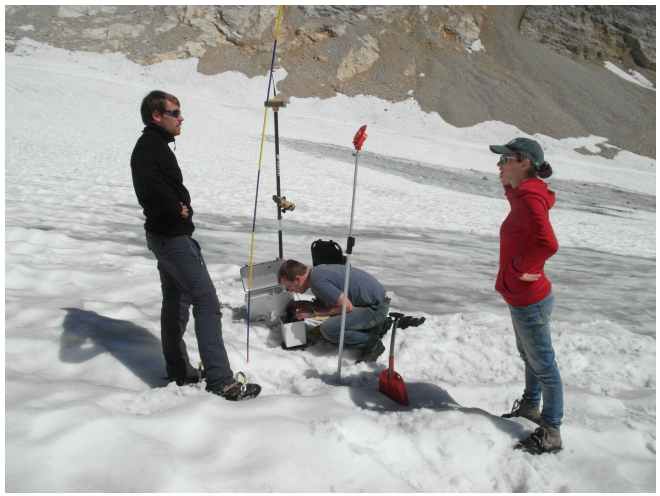
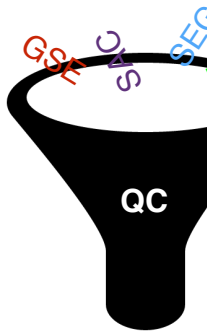


2: Pre-Proces



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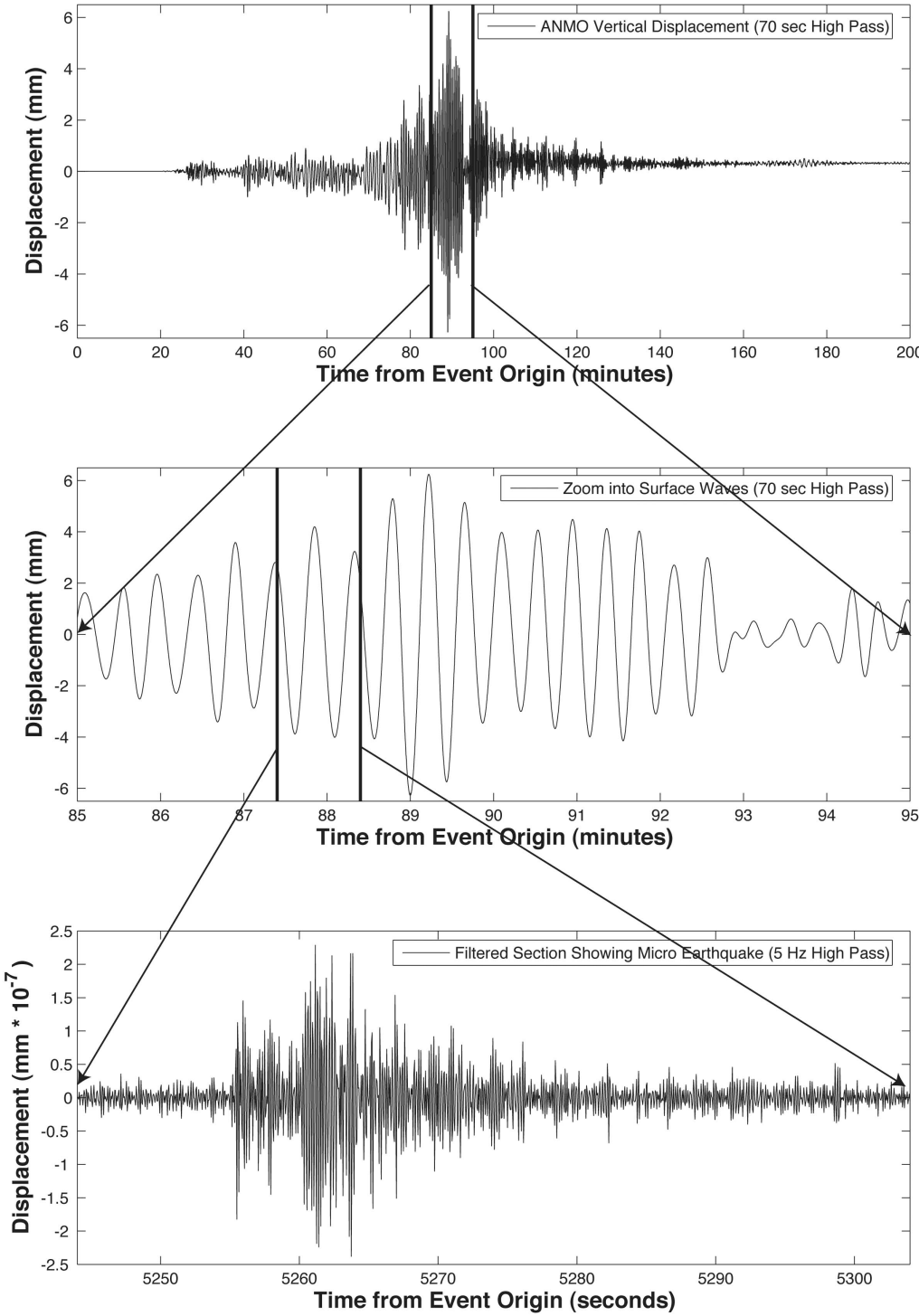

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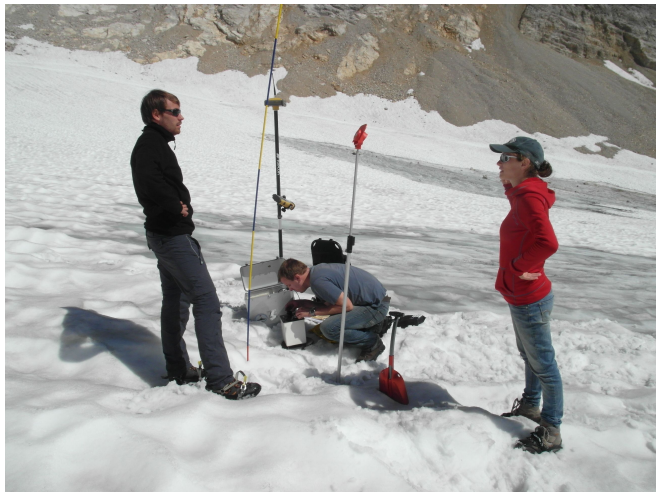

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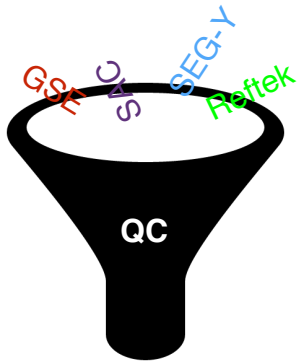

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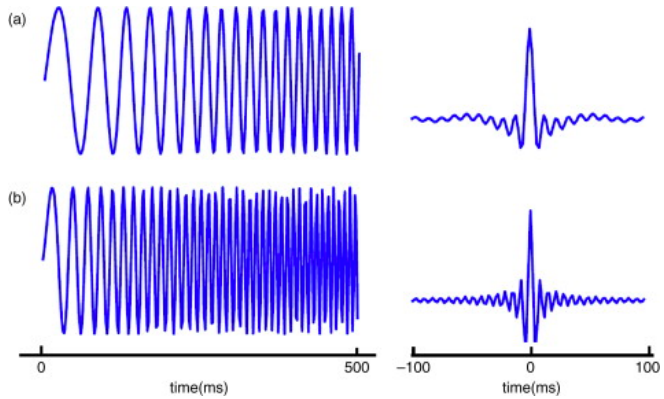

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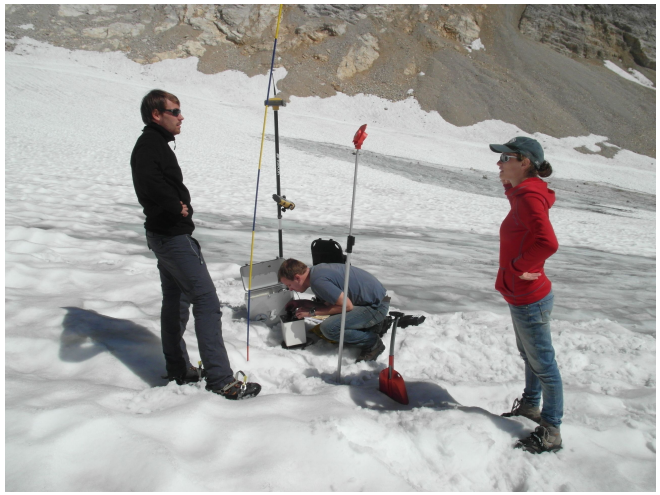

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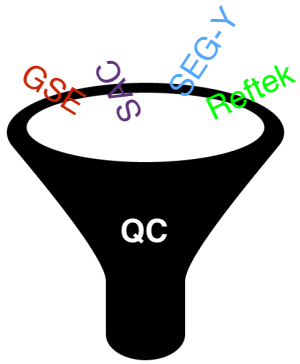

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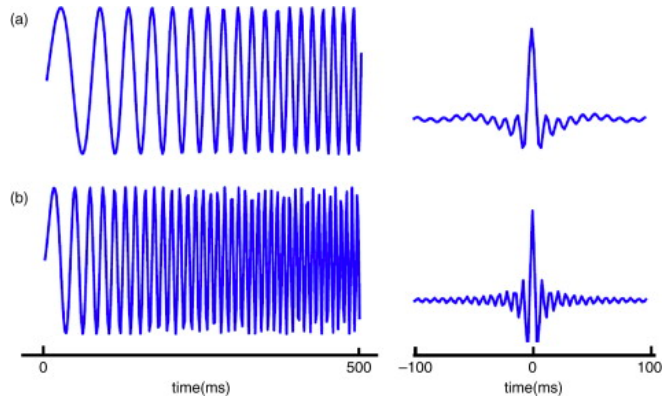
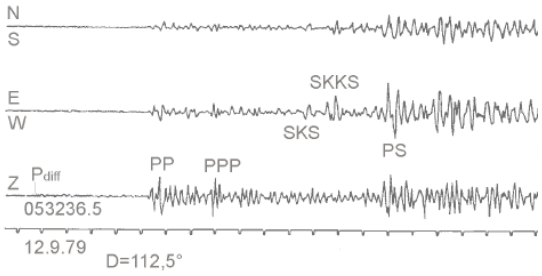


4: Analysis/Inversion



$\mathbf{m} = \mathbf{F}^{-1}(\mathbf{d})$

Inversion

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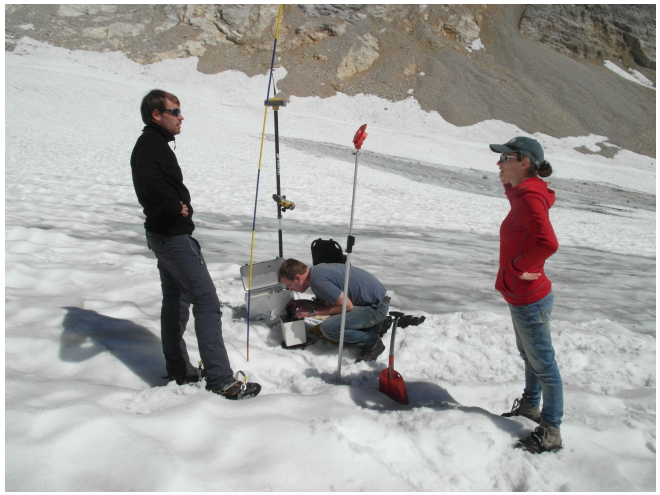

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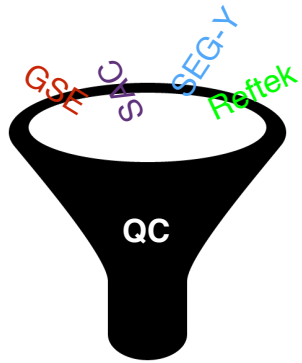

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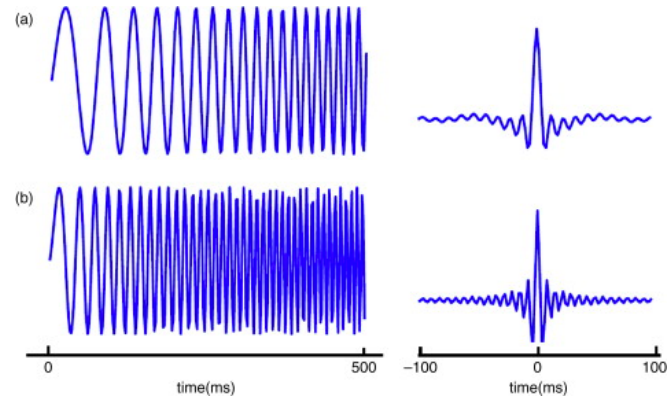

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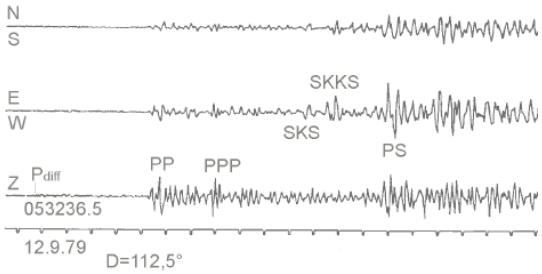

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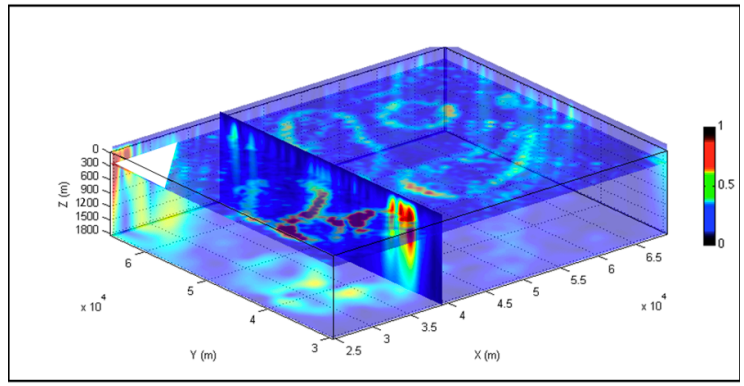
5: Visualisation



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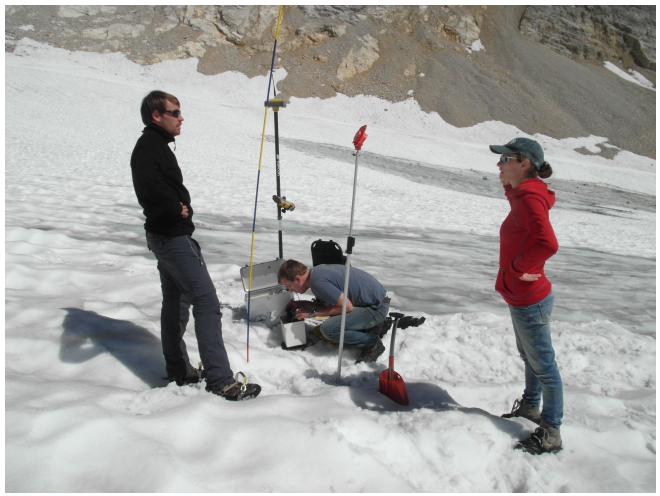

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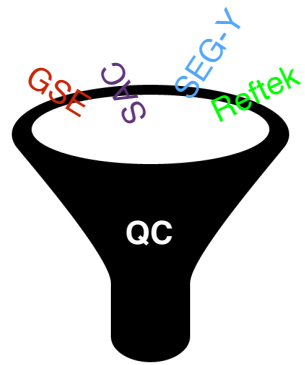

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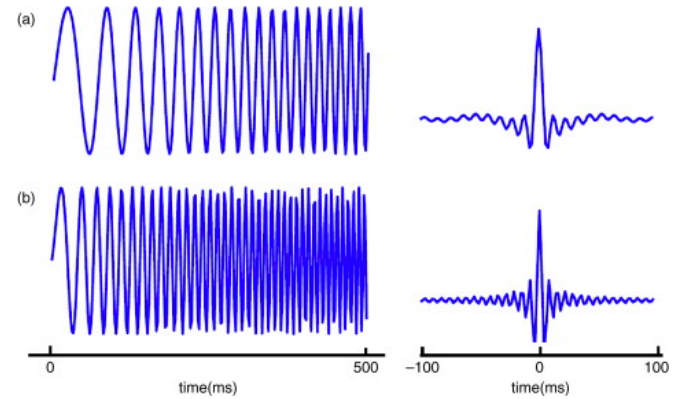

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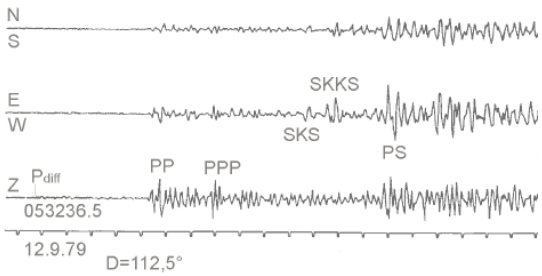

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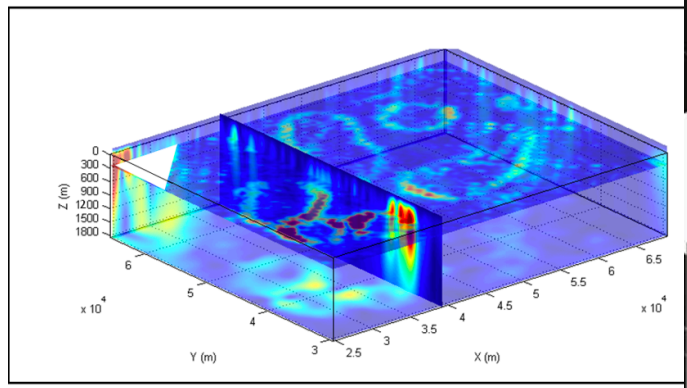
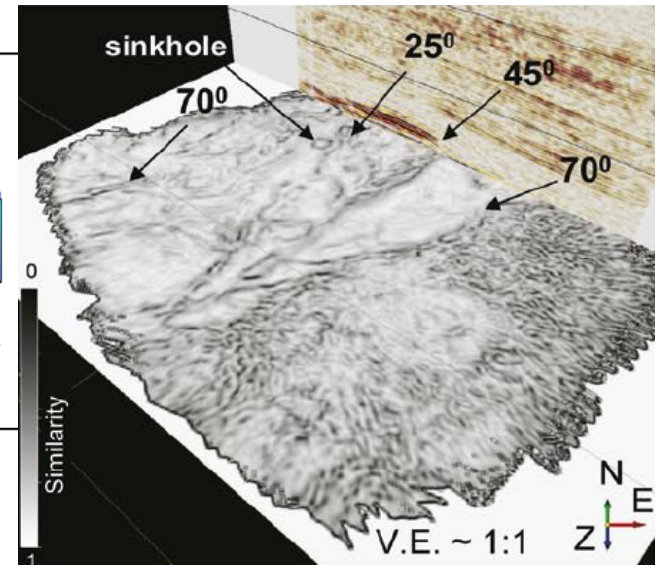


6: Interpretation



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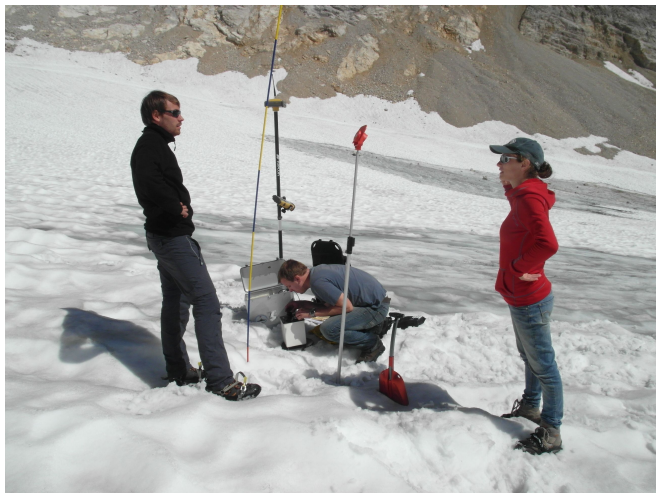

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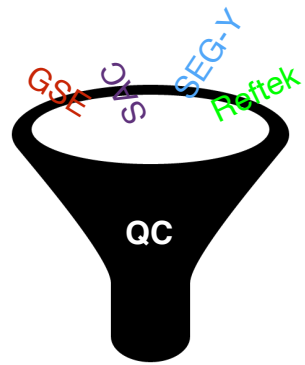

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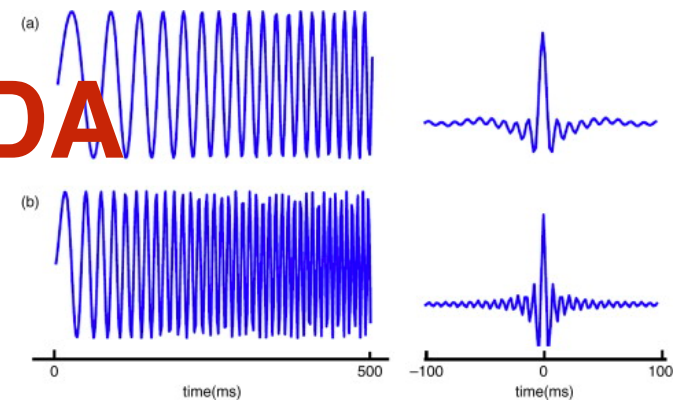
3: Processing

GDA



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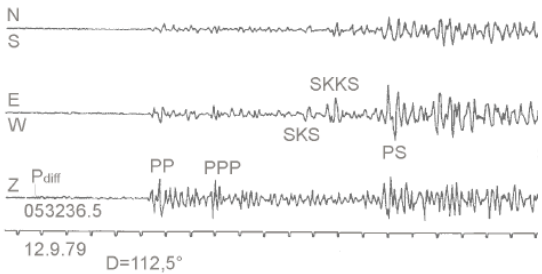

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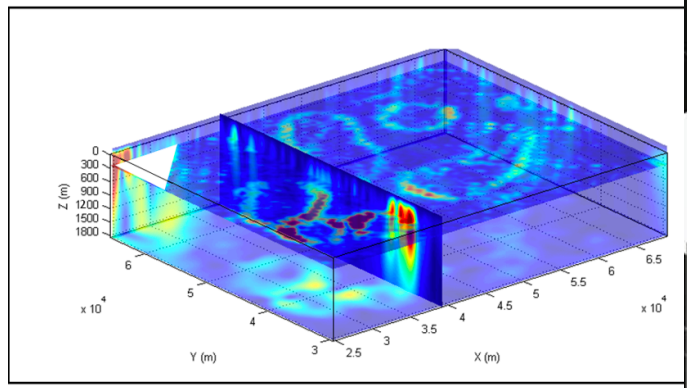

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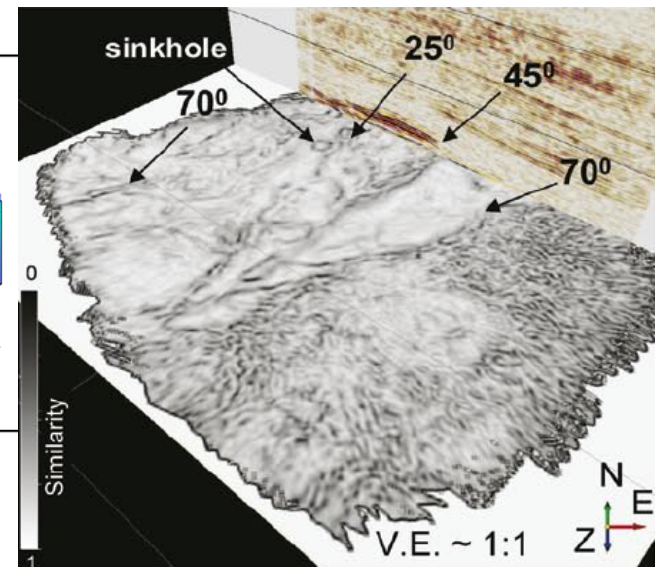

Be Aware:

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- Every manipulation of data (analog/digital) will change its (their) content, behaviour etc
- some of which are irreversible
- always work on **copies** of data – never change the **raw data**!!!

What is Data?

“Data is defined as facts or figures, or information (that’s stored in or used by a computer)”

https://www.yourdictionary.com/data (Apr 29, 2022)

What is Geophysical Data?

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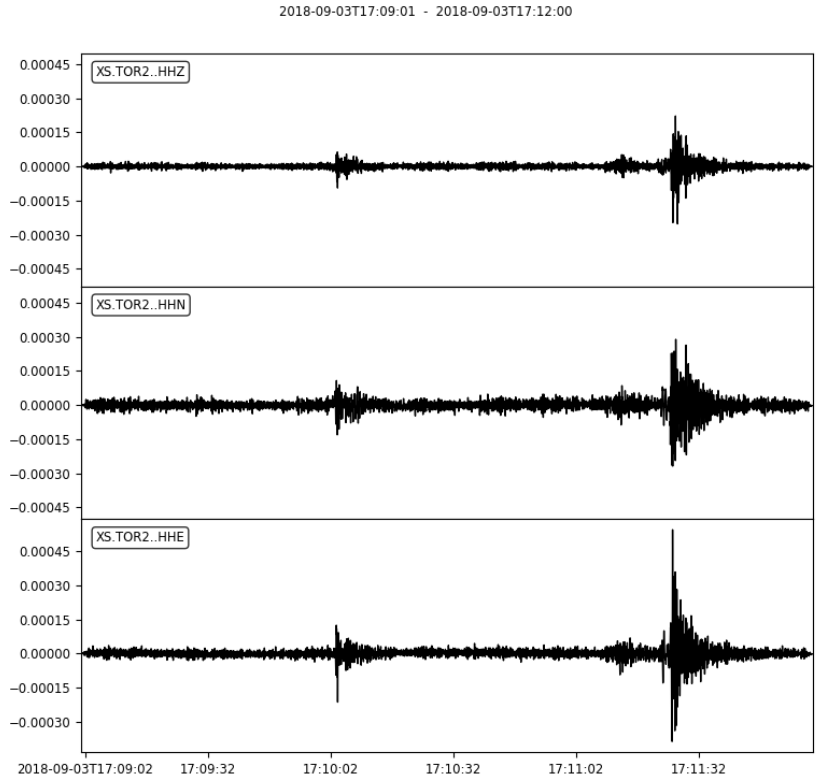

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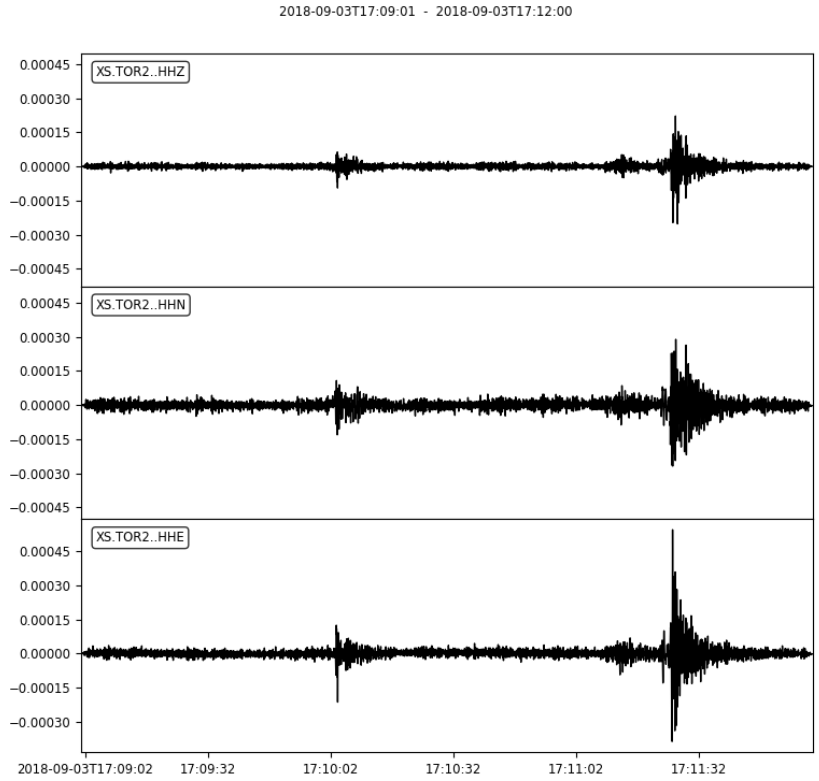
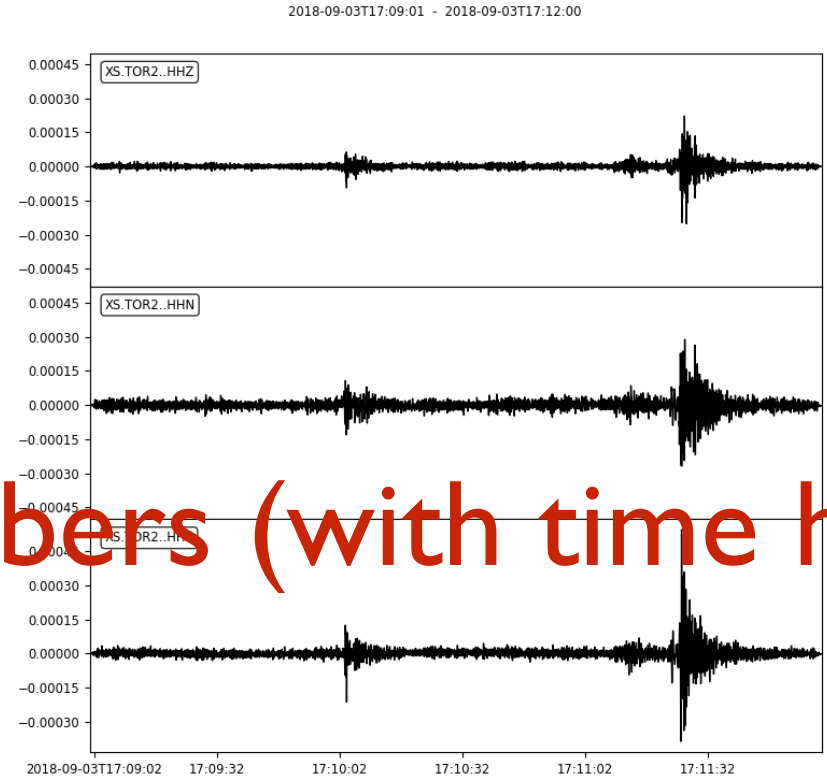



```
[5]: print(st[0].data)
[0.00000000e+00   1.63912466e-10
6.93998203e-10 ...,  -2.33506887e-06
 -2.33414802e-06  -2.33337034e-06 ]
```

What is Geophysical Data?

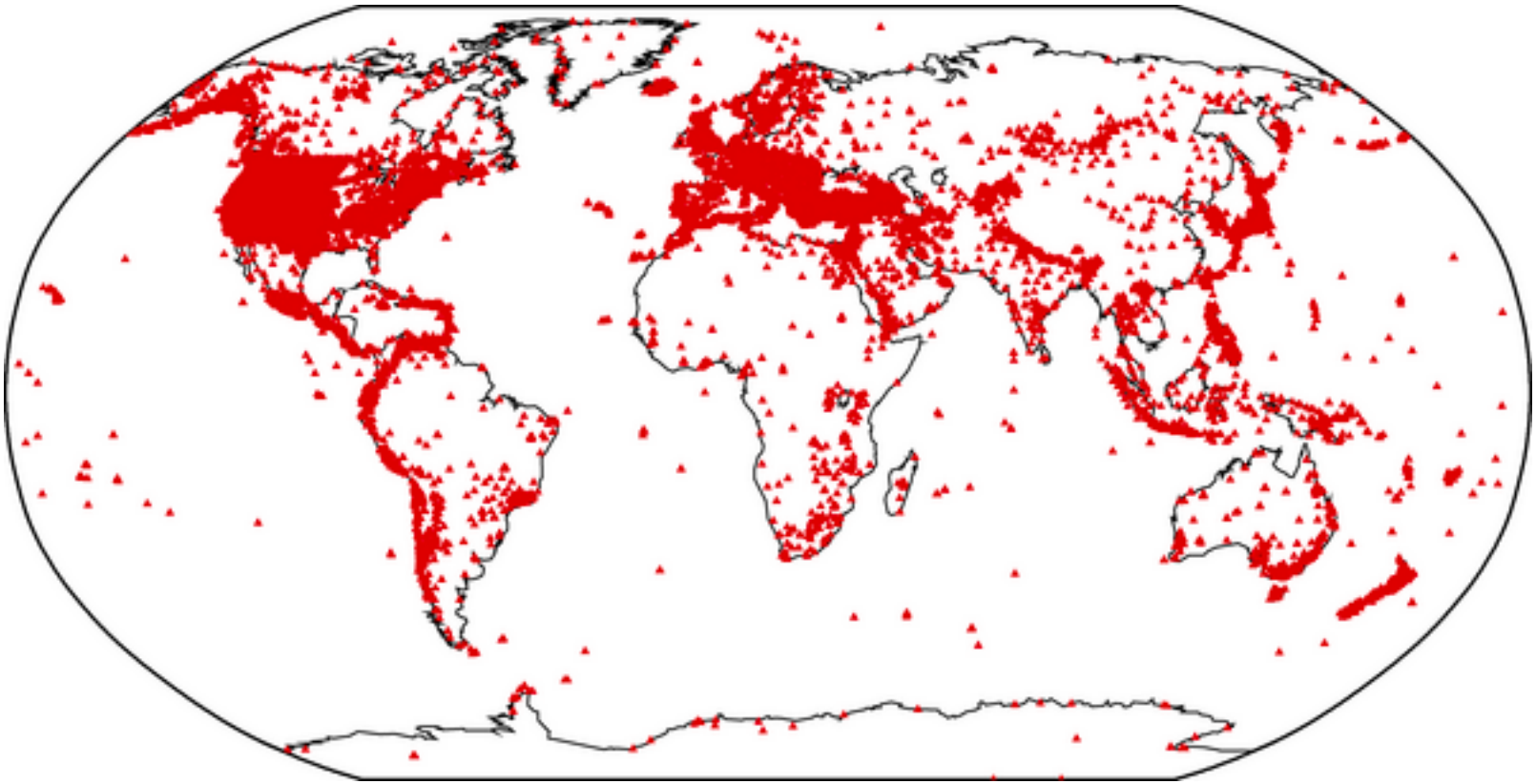


Numbers (with time history)

```
[5]: print(st[0].data)
[0.00000000e+00  1.63912466e-10
6.93998203e-10 ...,  -2.33506887e-06
 -2.33414802e-06  -2.33337034e-06 ]
```

Prominent Data Resources

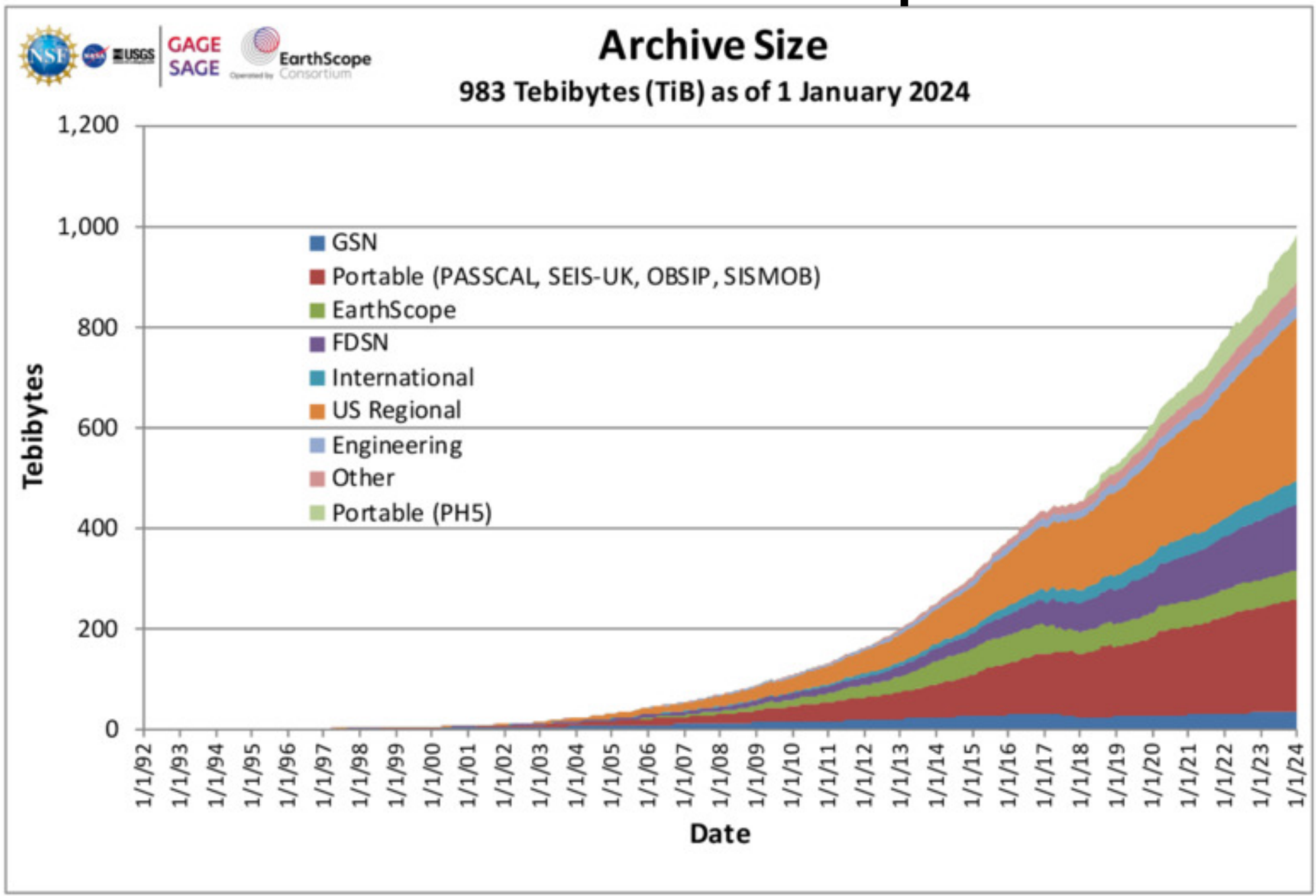
Seismic Stations



http://www.isc.ac.uk/registries/

>26000 station (registered) in 2023

Data Volume Transported



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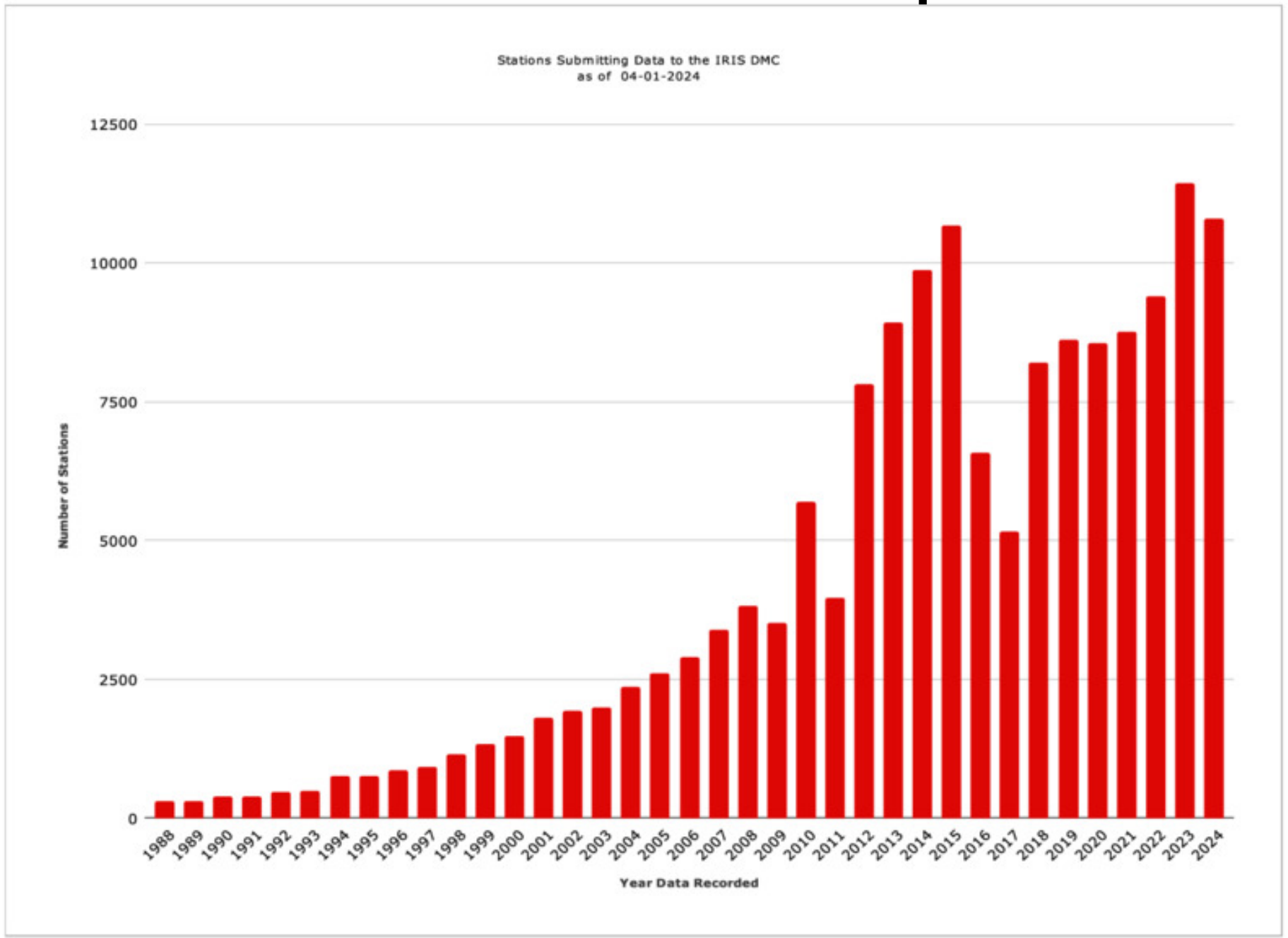
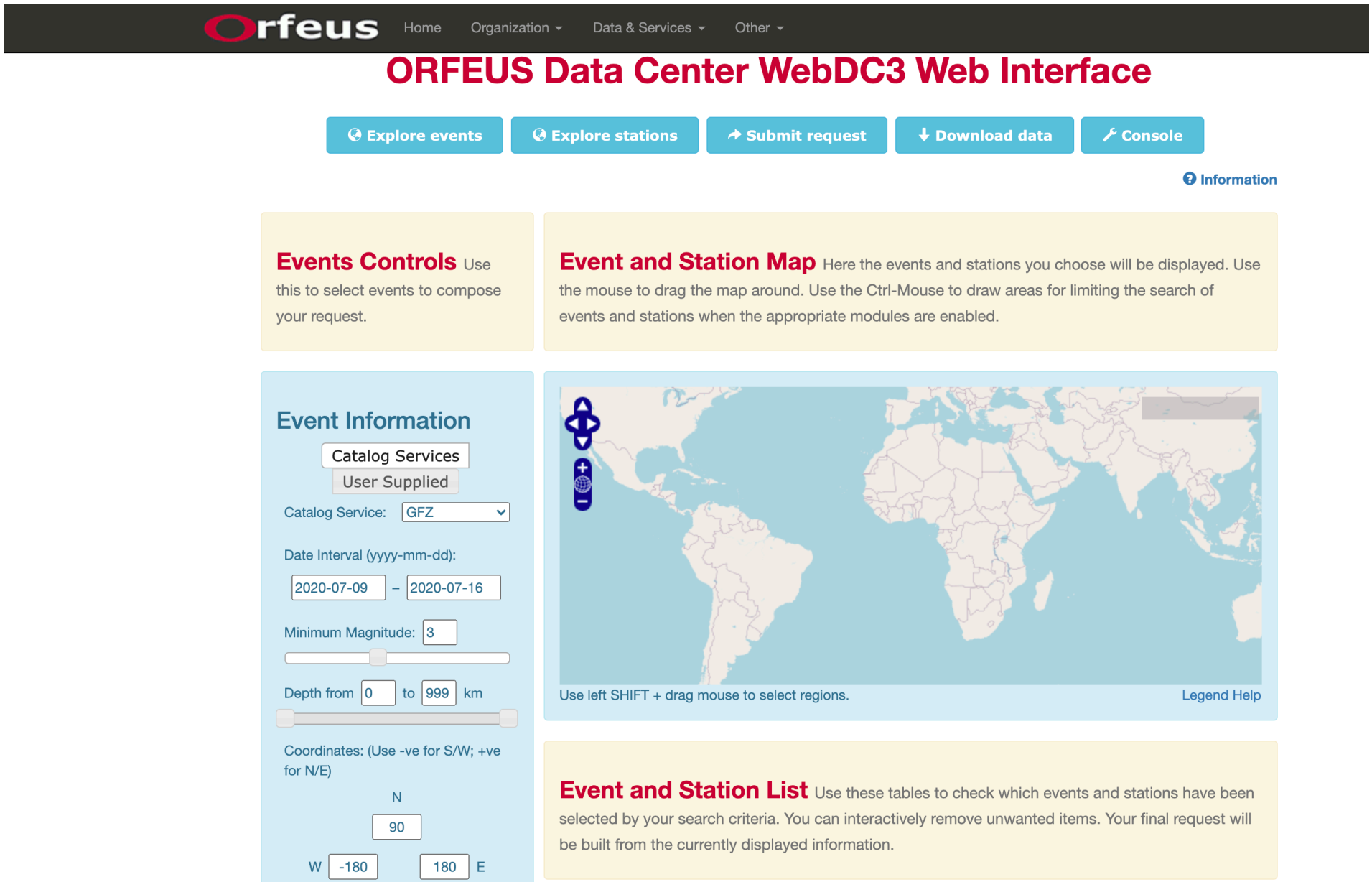
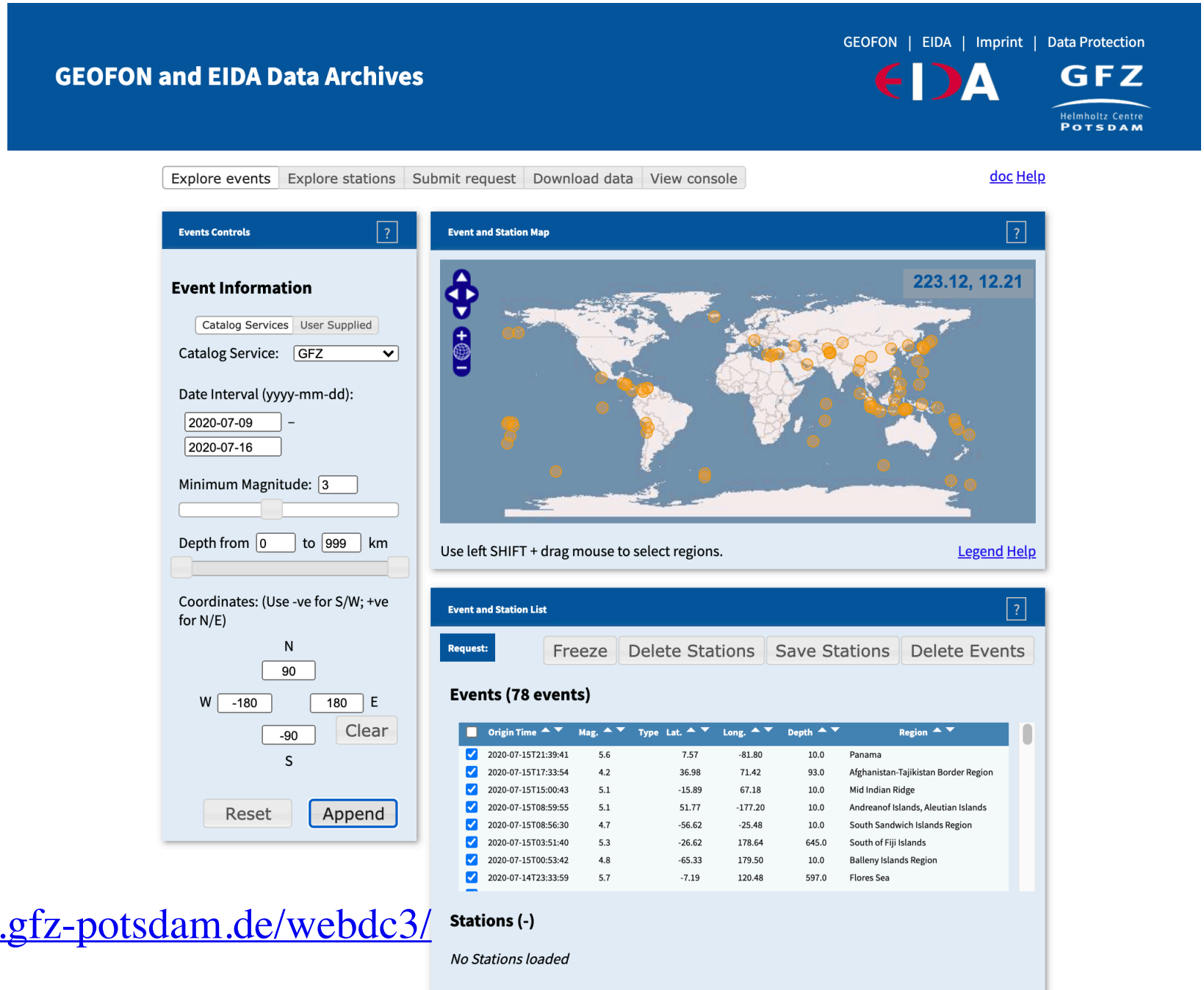


Important Landing Pages

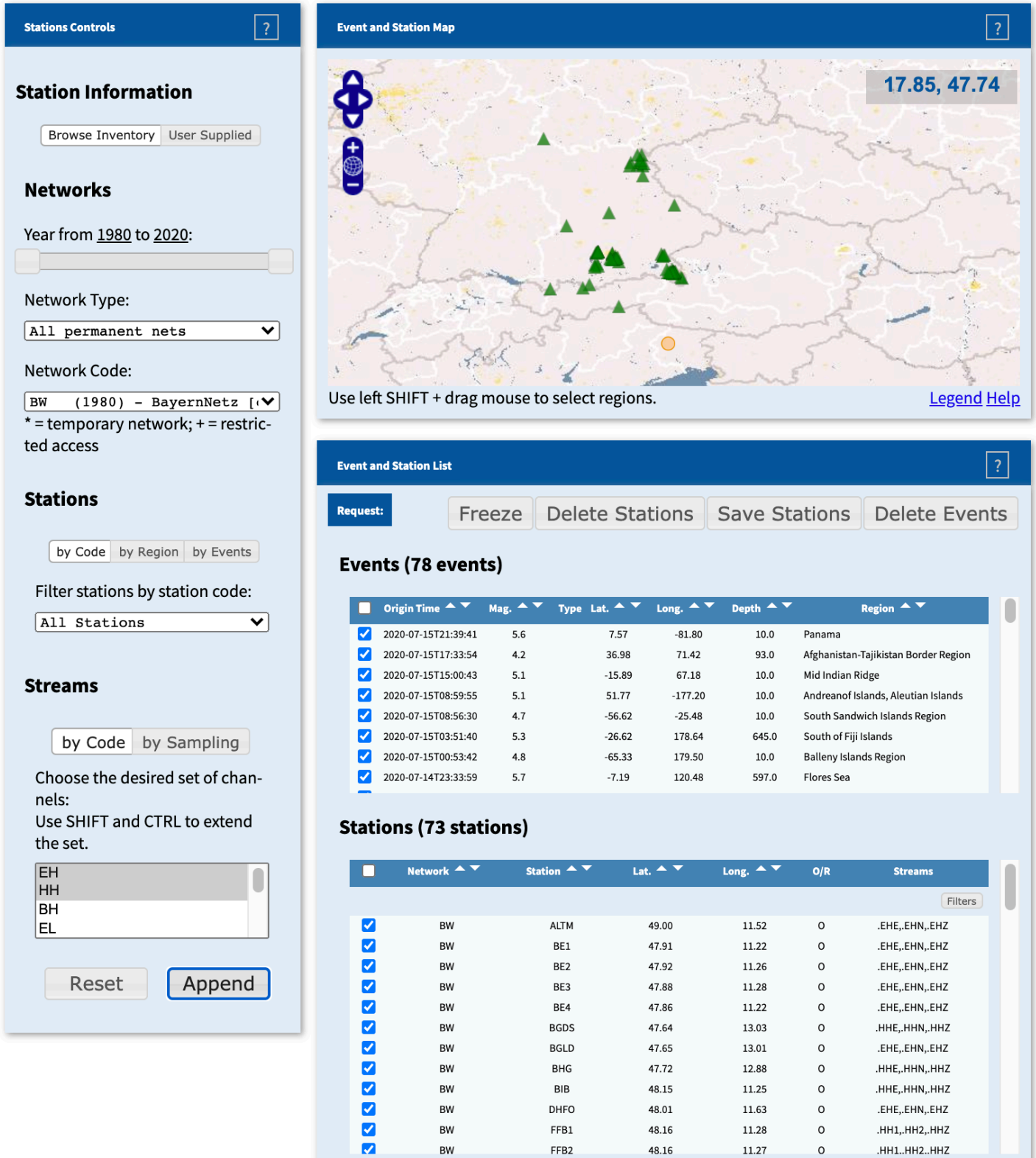


http://orfeus-eu.org/webdc3/

Important Landing Pages



http://eida.gfz-potsdam.de/webdc3/


Stations Controls
Station Information
Browse Inventory
User Supplied
Networks
Year from 1980 to 2020:
Network Type:
All permanent nets
Network Code:
BW (1980) - BayernNetz [
* = temporary network; + = restricted access
Stations
by Code
by Region
by Events
Filter stations by station code:
All Stations
Streams
by Code
by Sampling
Choose the desired set of channels:
Use SHIFT and CTRL to extend the set.
EH
HH
BH
EL
Reset
Append
Event and Station Map
17.85, 47.74
Use left SHIFT + drag mouse to select regions.
Legend
Help
Event and Station List
Request:
Freeze
Delete Stations
Save Stations
Delete Events
Events (78 events)
Origin Time
Mag.
Type
Lat.
Long.
Depth
Region
2020-07-15T21:39:41 5.6 7.57 -81.80 10.0 Panama
2020-07-15T17:33:54 4.2 36.98 71.42 93.0 Afghanistan-Tajikistan Border Region
2020-07-15T15:00:43 5.1 -15.89 67.18 10.0 Mid Indian Ridge
2020-07-15T08:59:55 5.1 51.77 -177.20 10.0 Andreanof Islands, Aleutian Islands
2020-07-15T08:56:30 4.7 -56.62 -25.48 10.0 South Sandwich Islands Region
2020-07-15T03:51:40 5.3 -26.62 178.64 645.0 South of Fiji Islands
2020-07-15T00:53:42 4.8 -65.33 179.50 10.0 Balleny Islands Region
2020-07-14T23:33:59 5.7 -7.19 120.48 597.0 Flores Sea
Stations (73 stations)
Network
Station
Lat.
Long.
O/R
Streams
Filters
BW ALTM 49.00 11.52 O .EHE,.EHN,.EHZ
BW BE1 47.91 11.22 O .EHE,.EHN,.EHZ
BW BE2 47.92 11.26 O .EHE,.EHN,.EHZ
BW BE3 47.88 11.28 O .EHE,.EHN,.EHZ
BW BE4 47.86 11.22 O .EHE,.EHN,.EHZ
BW BGDS 47.64 13.03 O .HHE,.HHN,.HHZ
BW BGLD 47.65 13.01 O .EHE,.EHN,.EHZ
BW BHG 47.72 12.88 O .HHE,.HHN,.HHZ
BW BIB 48.15 11.25 O .HHE,.HHN,.HHZ
BW DHFO 48.01 11.63 O .EHE,.EHN,.EHZ
BW FFB1 48.16 11.28 O .HH1,.HH2,.HHZ
BW FFB2 48.16 11.27 O .HH1..HH2..HHZ

GEOFON and EIDA Data Archives

Explore events | Explore stations | Submit request | Download data | View console

doc Help

Make Request

Time Window selection:

Relative Mode | Absolute Mode

Use an absolute time window.

Start

2020-07-16

End

2020-07-16

00:00:00

23:59:59

Request Type:

- (●) Waveform (Mini-SEED)
- ( ) Metadata (StationXML)
- ( ) Metadata (Text)

Authentication:

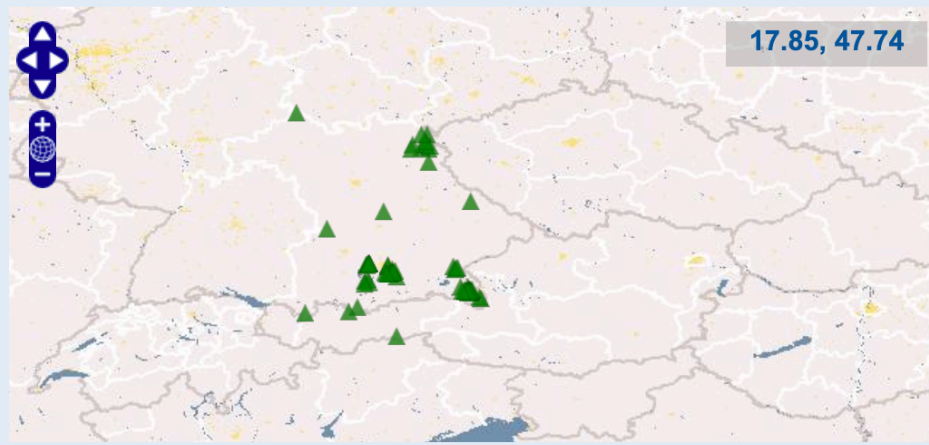
Current ID: Anonymous
Valid until: N/A

Load Token | Remove Toke

Reset

Review | Submit

Event and Station Map



Use left SHIFT + drag mouse to select regions. Legend Help

Event and Station List

Request: | Freeze | Delete Stations | Save Stations | Delete Events

Events (-)

No Events loaded

Stations (73 stations)

Filters

Network	Station	Lat.	Long.	O/R	Streams
BW	ALTM	49.00	11.52	O	.EHE,.EHN,.EHZ
BW	BE1	47.91	11.22	O	.EHE,.EHN,.EHZ
BW	BE2	47.92	11.26	O	.EHE,.EHN,.EHZ
BW	BE3	47.88	11.28	O	.EHE,.EHN,.EHZ
BW	BE4	47.86	11.22	O	.EHE,.EHN,.EHZ
BW	BGDS	47.64	13.03	O	.HHE,.HHN,.HHZ
BW	BGLD	47.65	13.01	O	.EHE,.EHN,.EHZ
BW	BHG	47.72	12.88	O	.HHE,.HHN,.HHZ
BW	BIB	48.15	11.25	O	.HHE,.HHN,.HHZ
BW	DHFO	48.01	11.63	O	.EHE,.EHN,.EHZ
BW	FFB1	48.16	11.28	O	.HH1,.HH2,.HHZ
BW	FFB2	48.16	11.27	O	.HH1..HH2..HHZ

GEOFON and EIDA Data Archives

Explore events | Explore stations | Submit request | Download data | View console

doc Help

Make Request

Time Window selection:

Relative Mode | Absolute Mode

Use an absolute time window.

Start

2020-07-16

End

2020-07-16

00:00:00

23:59:59

Request Type:

- (•) Waveform (Mini-SEED)
- ( ) Metadata (StationXML)
- ( ) Metadata (Text)

Authentication:

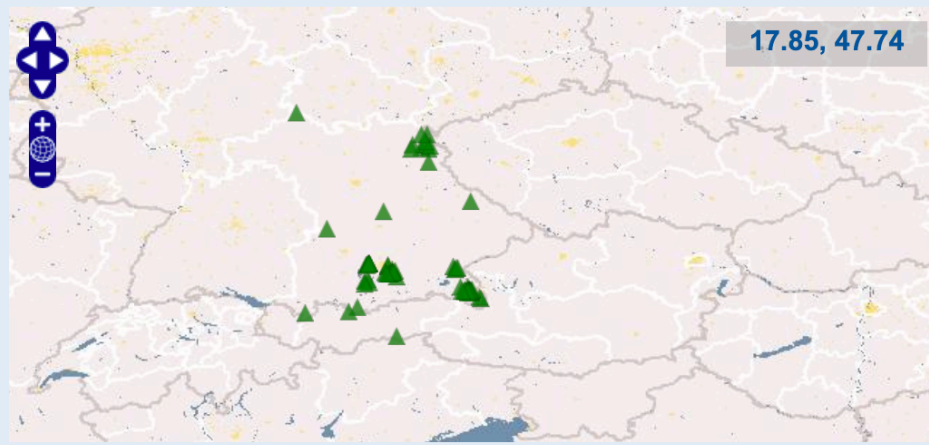
Current ID: Anonymous
Valid until: N/A

Load Token | Remove Toke

Reset

Review | Submit

Event and Station Map



Use left SHIFT + drag mouse to select regions.

Legend Help

Event and Station List

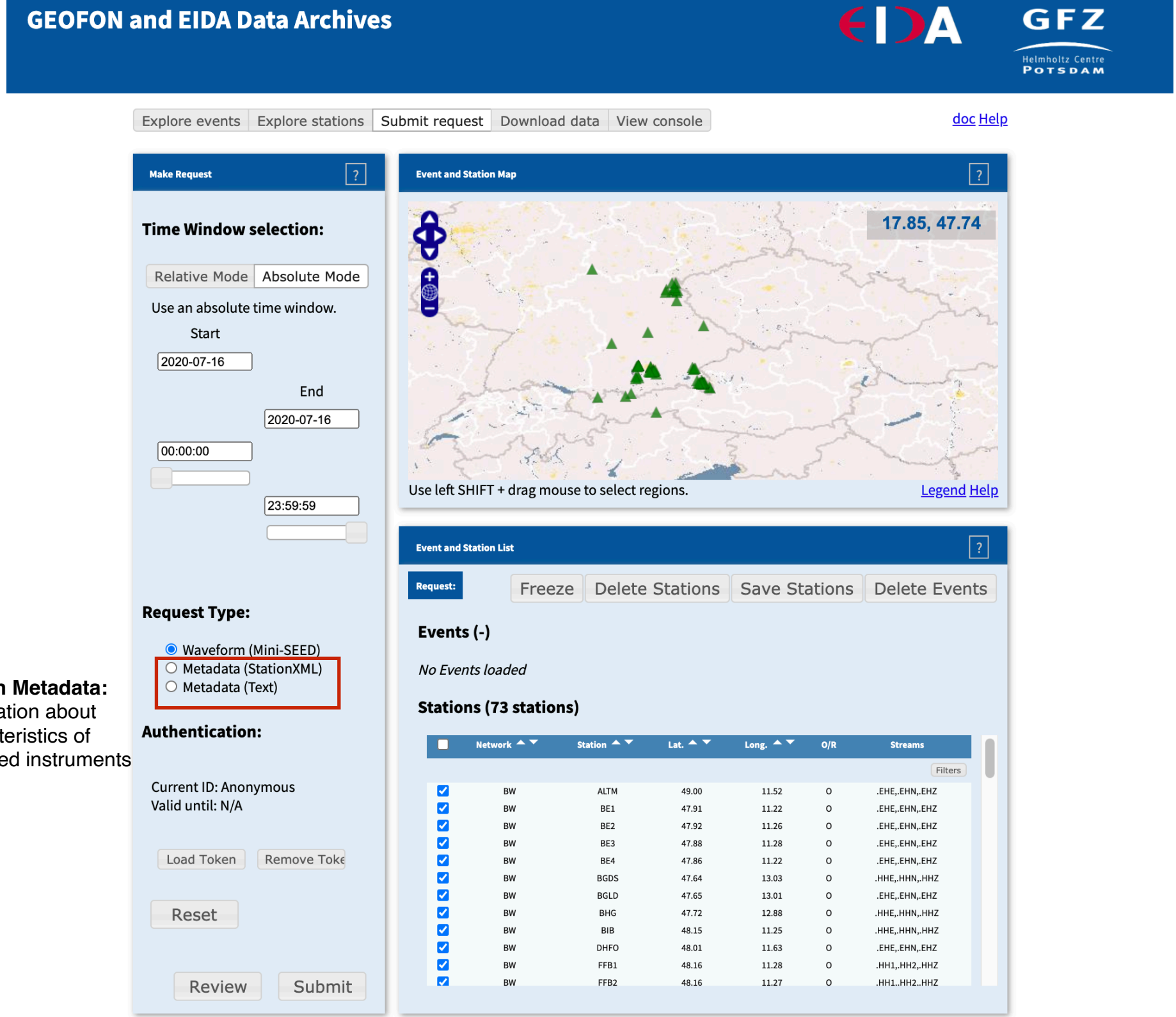
Request: | Freeze | Delete Stations | Save Stations | Delete Events

Events (-)

No Events loaded

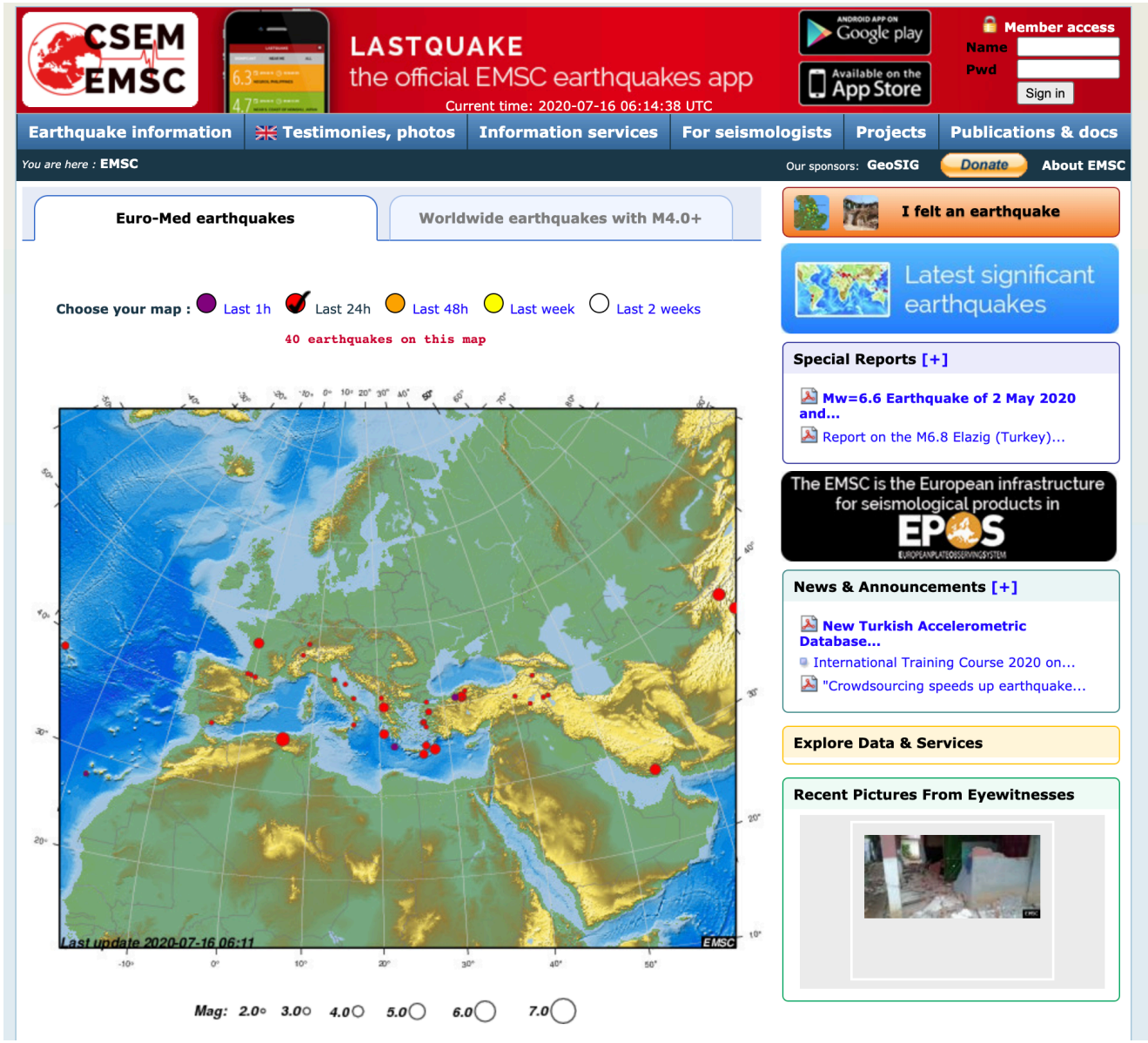
Stations (73 stations)

Network	Station	Lat.	Long.	O/R	Streams
					Filters
BW	ALTM	49.00	11.52	O	.EHE,.EHN,.EHZ
BW	BE1	47.91	11.22	O	.EHE,.EHN,.EHZ
BW	BE2	47.92	11.26	O	.EHE,.EHN,.EHZ
BW	BE3	47.88	11.28	O	.EHE,.EHN,.EHZ
BW	BE4	47.86	11.22	O	.EHE,.EHN,.EHZ
BW	BGDS	47.64	13.03	O	.HHE,.HHN,.HHZ
BW	BGLD	47.65	13.01	O	.EHE,.EHN,.EHZ
BW	BHG	47.72	12.88	O	.HHE,.HHN,.HHZ
BW	BIB	48.15	11.25	O	.HHE,.HHN,.HHZ
BW	DHFO	48.01	11.63	O	.EHE,.EHN,.EHZ
BW	FFB1	48.16	11.28	O	.HH1,.HH2,.HHZ
BW	FFB2	48.16	11.27	O	.HH1..HH2..HHZ



Station Metadata: Information about characteristics of deployed instruments

Important Landing Pages



https://www.emsc-csem.org/#2

Important Landing Pages

M 3.7 - FRANCE - 2020-07-16 03:19:44 UTC

I felt this earthquake

Summary | Maps | Testimonies | Pictures | List of data providers | Scientific data

You felt this earthquake. Tell us!

- Magnitude **ML 3.7**
- Region **FRANCE**
- Date time **2020-07-16 03:19:44.5 UTC**
- Location **46.82 N ; 0.33 W**
- Depth **2 km**
- Distances 295 km SE of Saint Helier, Jersey / pop: 28,000 / local time: 04:19:44.5 2020-07-16
  57 km NW of Poitiers, France / pop: 86,000 / local time: 05:19:44.5 2020-07-16
  3 km NE of Chiché, France / pop: 1,500 / local time: 05:19:44.5 2020-07-16

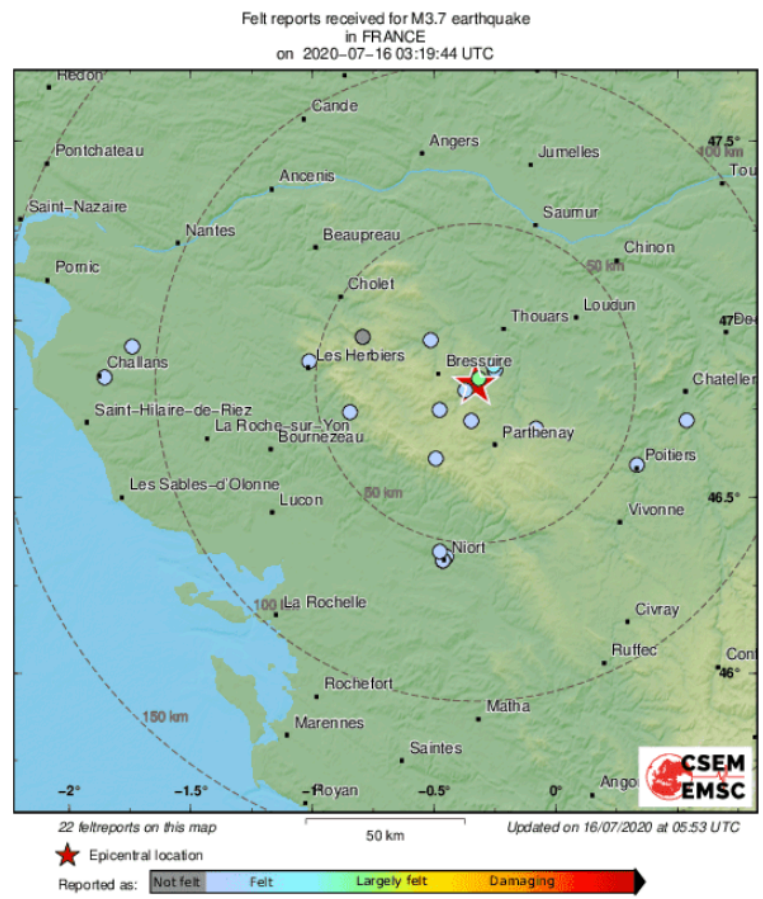
Source parameters reviewed by a seismologist

More information at:

- Laboratoire de Détection et de Géophysique Bruyères-le-Châtel, France
- Réseau National de Surveillance Sismique Strasbourg, France
- Bureau Central Sismologique Francais (BCSF) Strasbourg, France
- Plan Séisme (*Information sur les bons gestes à appliquer en cas de séisme*)
- Bureau de Recherches Géologiques et Minières, France

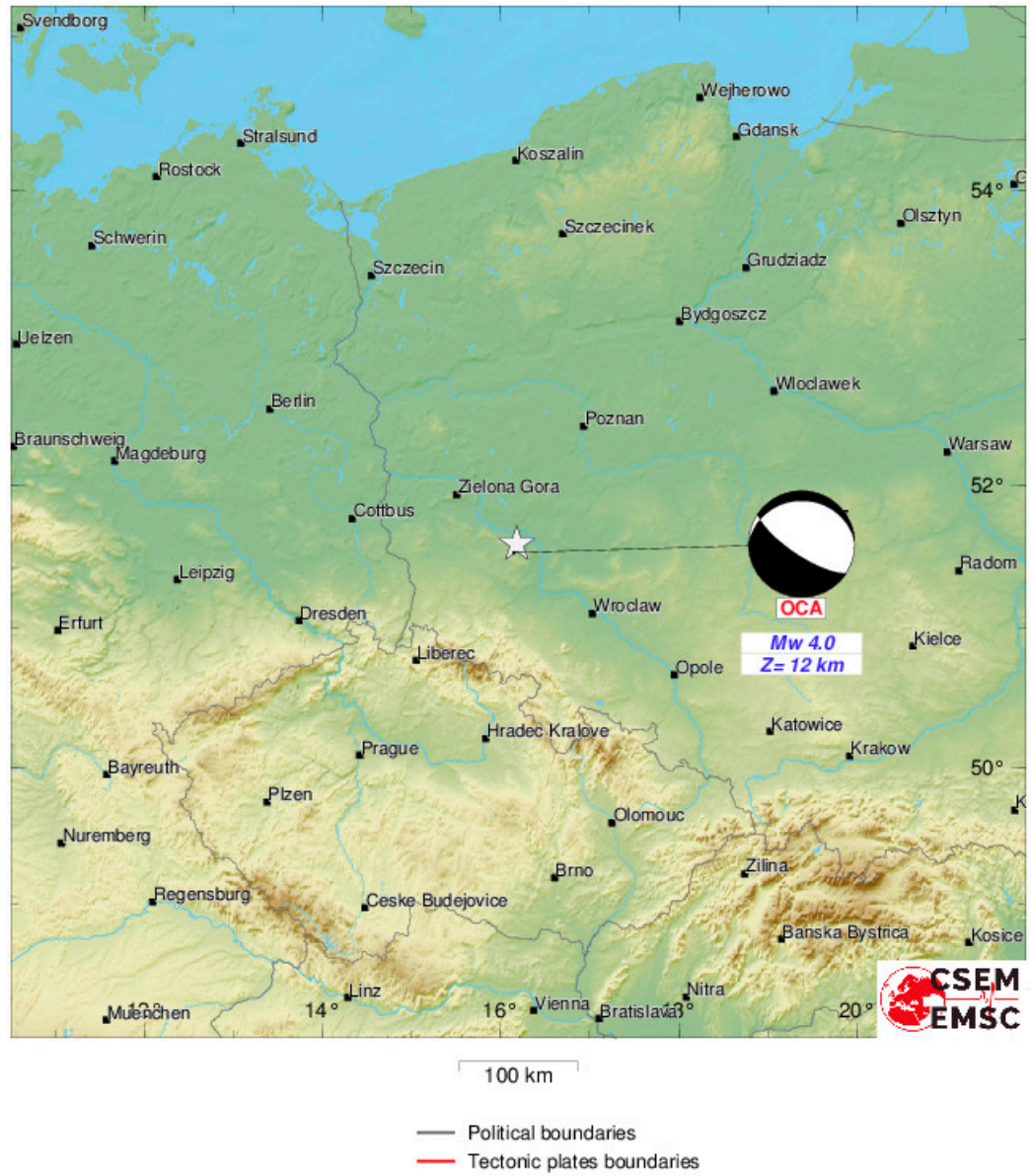
Important Landing Pages

Map **Graphs**



Map created with the testimonies provided by the eyewitnesses (click to enlarge).

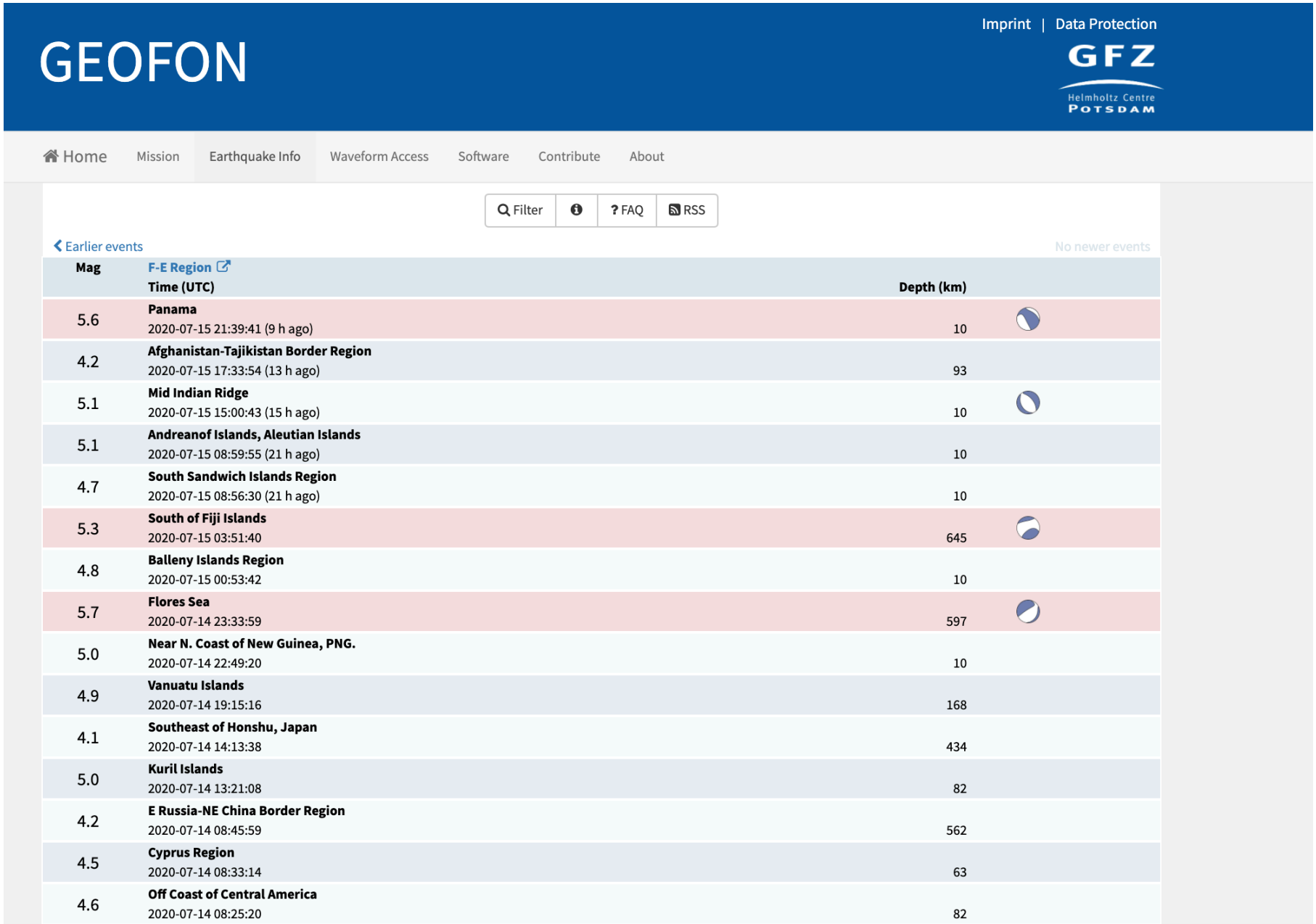
Important Landing Pages



Important Landing Pages

https://geofon.gfz-potsdam.de/

Important Landing Pages



GEOFON

Imprint | Data Protection

GFZ Helmholtz Centre Potsdam

Home | Mission | Earthquake Info | Waveform Access | Software | Contribute | About

Filter | FAQ | RSS

Earlier events — No newer events

Mag	F-E Region Time (UTC)	Depth (km)
5.6	**Panama** 2020-07-15 21:39:41 (9 h ago)	10
4.2	**Afghanistan-Tajikistan Border Region** 2020-07-15 17:33:54 (13 h ago)	93
5.1	**Mid Indian Ridge** 2020-07-15 15:00:43 (15 h ago)	10
5.1	**Andreanof Islands, Aleutian Islands** 2020-07-15 08:59:55 (21 h ago)	10
4.7	**South Sandwich Islands Region** 2020-07-15 08:56:30 (21 h ago)	10
5.3	**South of Fiji Islands** 2020-07-15 03:51:40	645
4.8	**Balleny Islands Region** 2020-07-15 00:53:42	10
5.7	**Flores Sea** 2020-07-14 23:33:59	597
5.0	**Near N. Coast of New Guinea, PNG.** 2020-07-14 22:49:20	10
4.9	**Vanuatu Islands** 2020-07-14 19:15:16	168
4.1	**Southeast of Honshu, Japan** 2020-07-14 14:13:38	434
5.0	**Kuril Islands** 2020-07-14 13:21:08	82
4.2	**E Russia-NE China Border Region** 2020-07-14 08:45:59	562
4.5	**Cyprus Region** 2020-07-14 08:33:14	63
4.6	**Off Coast of Central America** 2020-07-14 08:25:20	82

Important Landing Pages

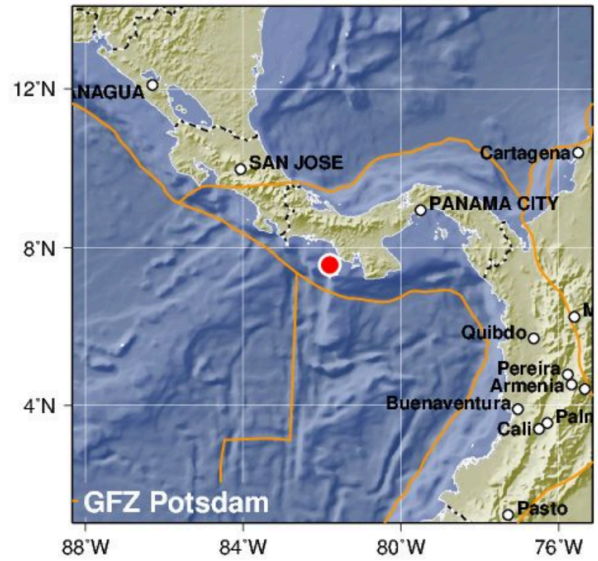
GEOFON

Imprint | Data Protection

GFZ Helmholtz Centre Potsdam

Home | Mission | Earthquake Info | Waveform Access | Software | Contribute | About

F-E Region Panama
Time 2020-07-15 21:39:41.9 UTC
Magnitude 5.6 (Mw)
Epicenter 81.80°W 7.57°N
Depth 10 km
Status M - manually revised



Moment tensor solutions

GEOFON standard[1]

Time 2020-07-15 21:39:41
Magnitude 5.6
Latitude 7.59°N
Longitude 81.77°W
Depth 11 km

Nodal planes

Strike	Dip	Rake
159°	70°	116°
283°	32°	38°

1. GEOFON standard inversion using body and surface waves. [Details].

Important Landing Pages

International Seismological Centre

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

2020-07-10
Newsletter 2020 Apr-Jun

2020-04-09
ISC-GEM Catalogue Ver 7.0 Released

2020-02-05
Rebuilt ISC Bulletin (1964-2010) is available

2020-01-20
ISC-EHB 1964-2016 paper published in ESS

2019-11-21
New Paper released: The (Mythical) M 8.2 Off Coast of Peru Earthquake of 12 December 1908, Seism. Res. Lett.

2019-07-09
Seismological Dataset Repository is live

Past news

News for / from data contributors

SRL Call for Papers: Focus Section on Monitoring During Crisis

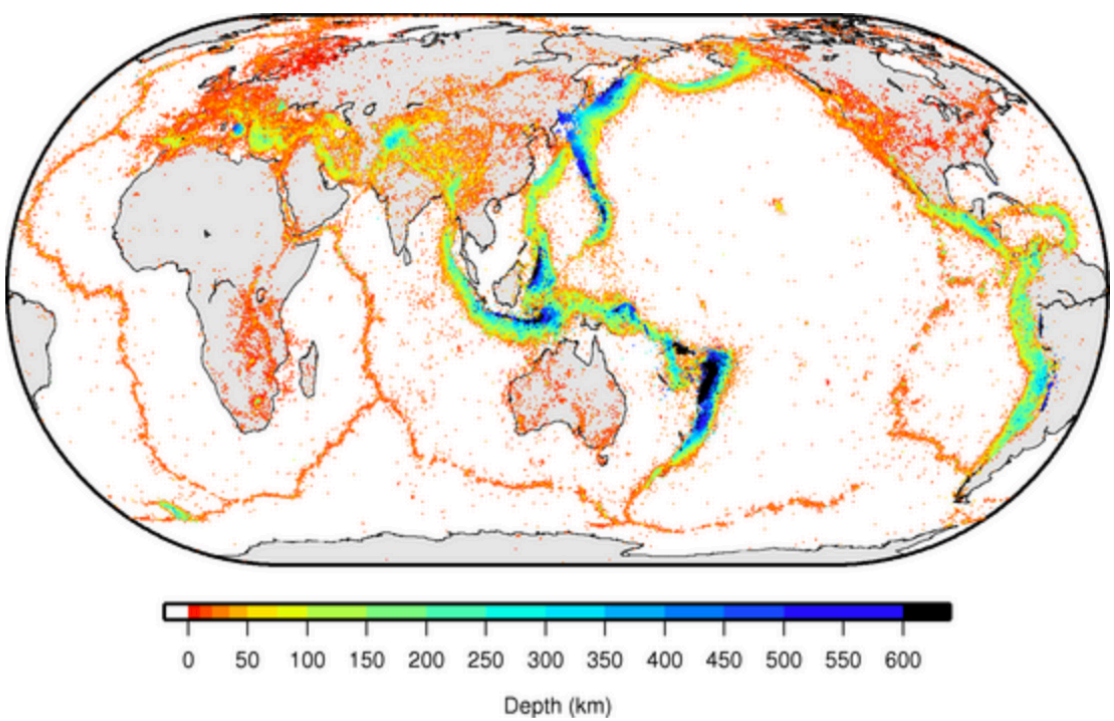
Seismic Monitoring at the Turkish National Seismic Network (TNSN)

Operating procedures of the Servicio Sismológico Nacional, Mexico

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



Important Landing Pages

Home About ISC Staff Contact us Site Map

Catalogue ISC-EHB Bulletin

Dataset Repository Seismological Contacts

What we do

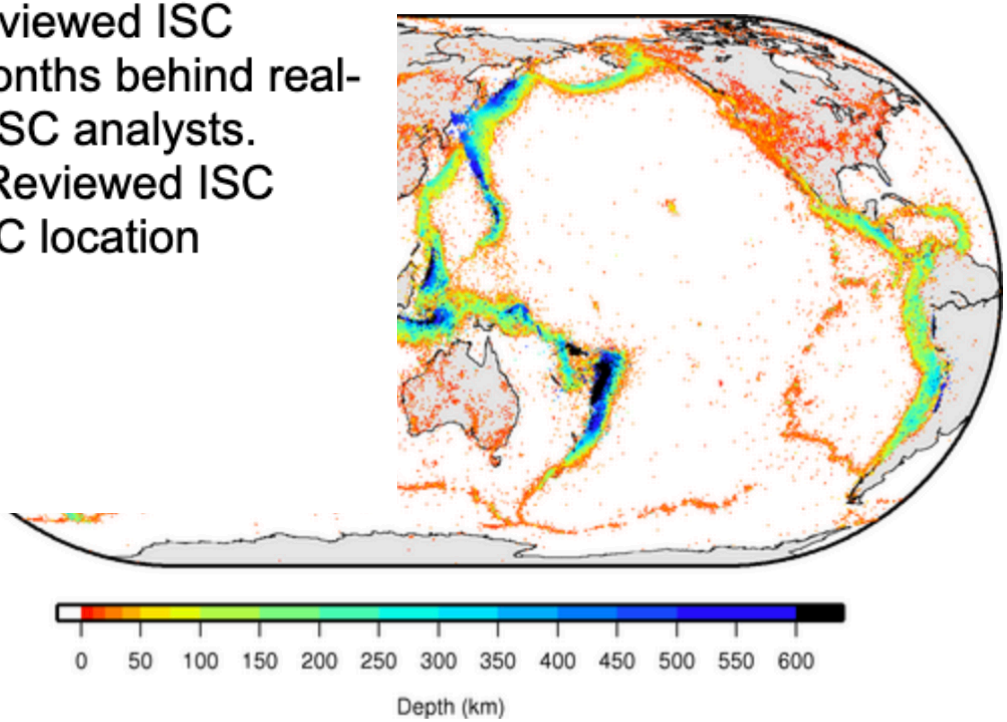
The main purpose of the ISC is to compile the ISC Bulletin, regarded as the definitive record of the Earth's seismicity. Data is collected from over 130 agencies worldwide and is available online soon after being received. The Reviewed ISC Bulletin is typically available 24 months behind real-time and is manually checked by ISC analysts. With sufficient data events in the Reviewed ISC Bulletin are relocated using the ISC location algorithm (ISCloc).

more information

ue | Международный Сейсмологический Центр | 国際地震センター

um | المركز الدولي لبحوث الزلازل | Centro Internacional de Sismología

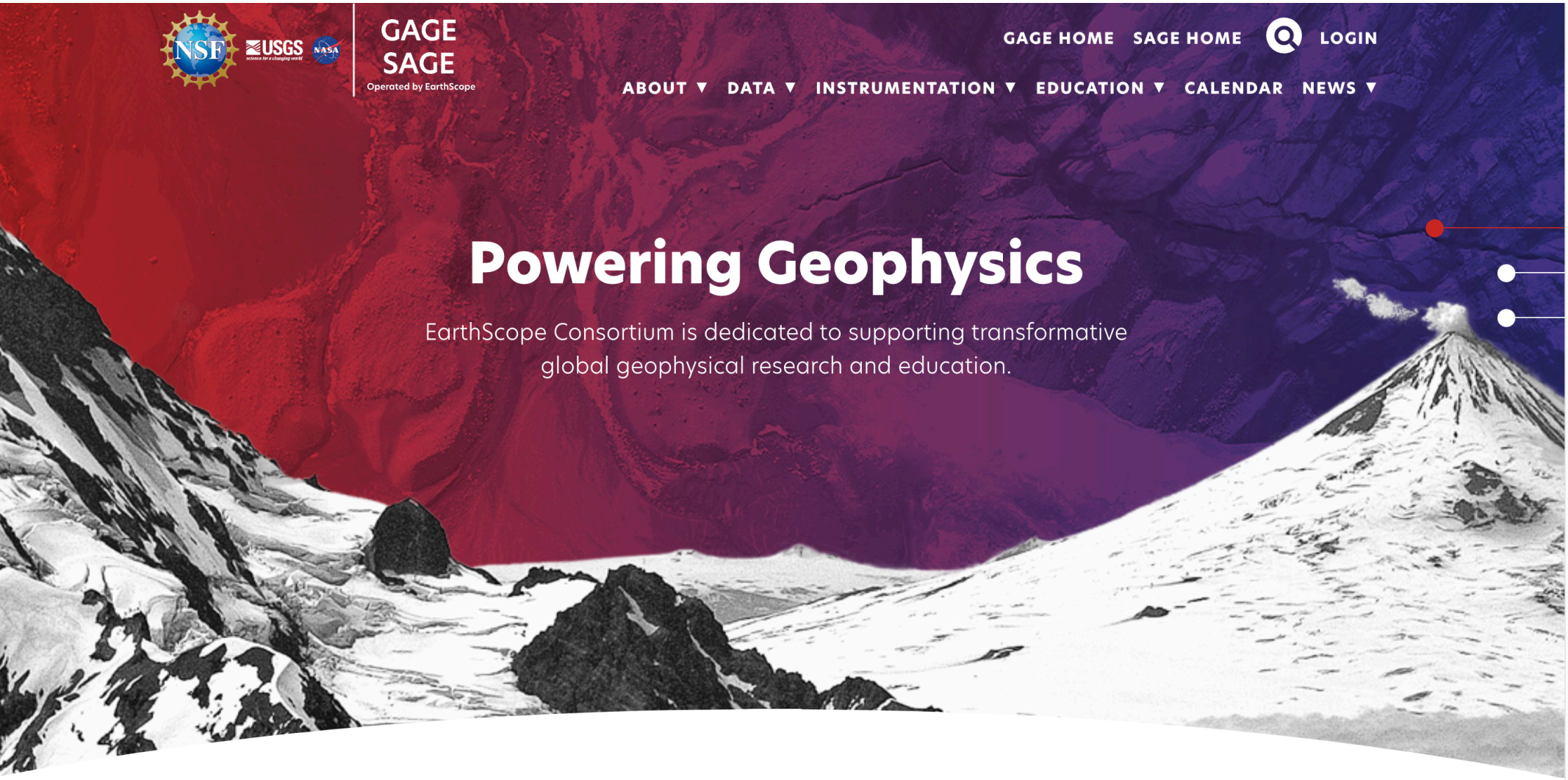
tions: 1964 to present



Seismic Monitoring at the Turkish National Seismic Network (TNSN)

Operating procedures of the Servicio Sismológico Nacional, Mexico

Important Landing Pages



http://earthscope.org

Our Science Support

Important Landing Pages

https://www.iris.edu/hq/

Important Landing Pages

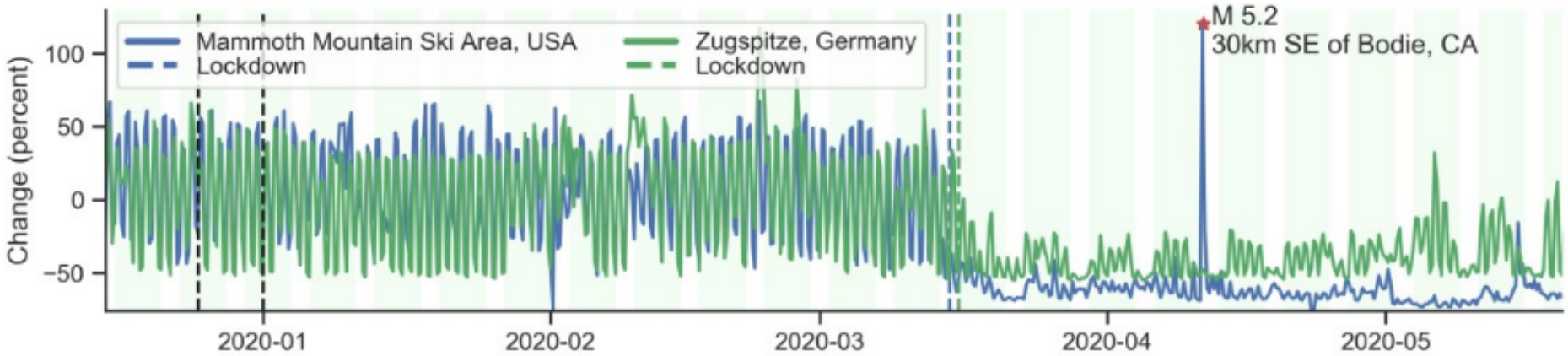
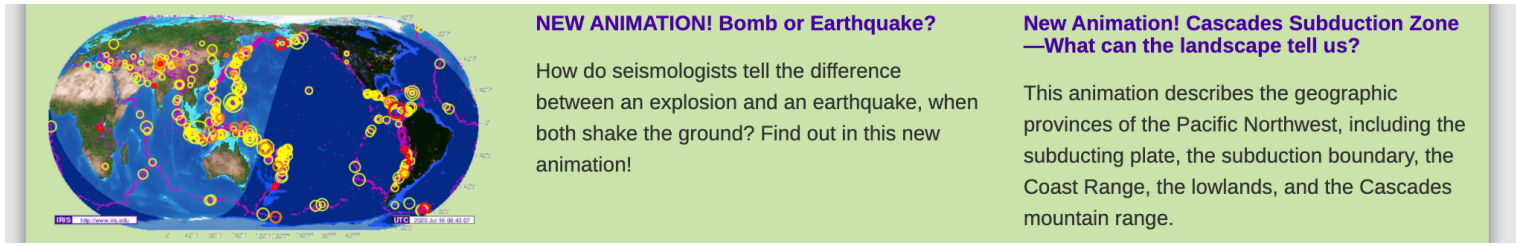


Fig. S5. Lockdown effects on seismic noise in touristic ski resort areas.

Temporal changes of hiFSAN at two touristic ski resort areas: Mammoth Mountain (USA - station NC.MCY) and Zugspitze (Germany, station BW.ZUGS), showing the effect of the complete stop of the resorts' lifts or cog-wheel railway

https://www.iris.edu/hq/



Important Landing Pages

Data at IRIS

Data Types

Time Series data
Continuous seismic instrument recordings from thousands of stations worldwide. This is the primary IRIS archive.

Metadata
Includes information such as recording instrument characteristics and data quality; this is generally used to determine the waveform data to request.

Event data
Catalog of 4 million+ events, this is useful in determining the timeframe for retrieving useful data.

Assembled data
Discrete collections of waveform data, generally recorded over a period of weeks or months. Assembled data are often active source, meaning that they include artificial seismic events such as explosive blasts intended to seismically map a given region.

Data products
Calculated datasets providing a higher-level view of the raw data. For example, the GMV product is an animated map showing ground movement across hundreds of stations during an earthquake.

Historical data
Scanned seismograms and other information from pre-digital sources.

Important Landing Pages

Data Delivery

Web Services

This is the base delivery mechanism for most IRIS data. It can be accessed directly, but a variety of convenient wrappers are available.

Application Programming Interfaces

APIs are available via Java, Matlab, and Python libraries, as well as command line fetch scripts.

Web Tools

Downloadable Software

Other Data Centers

How to Cite Data Sources

Time Series Data

Web and Email-based Tools

BREQ_FAST takes requests via email and delivers data via FTP/HTTP.

SeismiQuery provides low-level access to IRIS data via web forms.

Wilber3 offers a rich UI for acquiring data related to a given seismic event.

See our full set of web tools.

Downloadable Software

SAC (Seismic Analysis Code) is a general purpose interactive program designed for the study of sequential signals, especially time series data.

JWEED is a Java program for requesting data related to events.

SEEDLink is a protocol for streaming real-time data.

See our full set of software tools.

Important Landing Pages

Data Delivery

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Time Series Data

Web and Email-based T

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See our full set of web

Downloadable Software

SAC (Seismic Analysis study of sequential sign

JWEED is a Java progr

SEEDLink is a protocol

See our full set of softw

Metadata

Web Tools

Metadata Aggregator (MDA) provides a browsable list of all networks and stations archived at the DMC.

GMap displays networks on an interactive map.

BUD provides information on near real-time holdings.

New Data added recently to the DMC archive.

Other Data Types

Assembled Data

Request assembled data

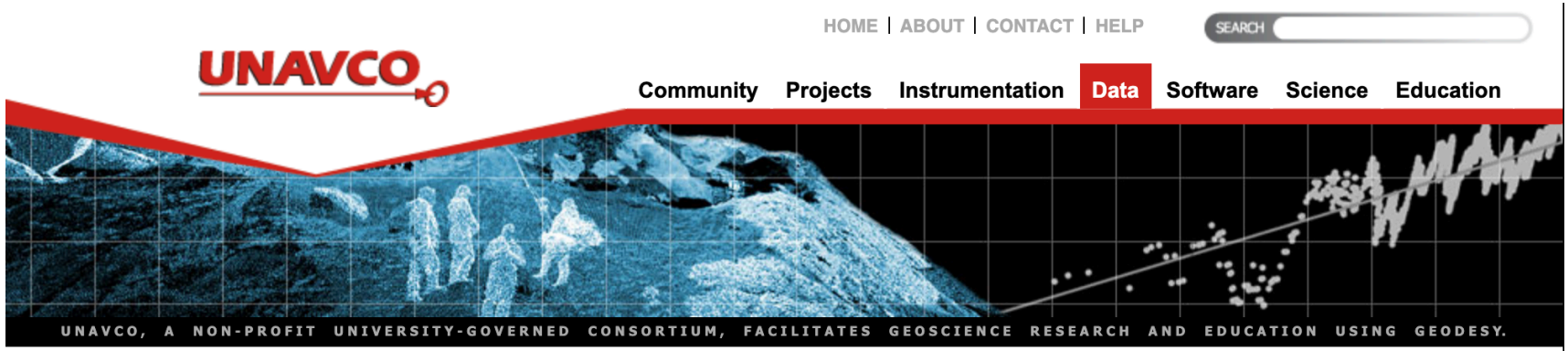
Assembled request status

Event Data

Interactive Earthquake Browser (IEB) shows recent earthquakes on an interactive map.

Important Landing Pages

https://www.unavco.org/data/data.html



Index

- Data Attribution
- GPS/GNSS
- Synthetic Aperture Radar (SAR)
- Lidar/SfM
- Strain & Seismic
- Tropospheric
- Web Services

Data

UNAVCO promotes research by providing access to data that our community of geodetic scientists uses for quantifying the motions of rock, ice and water that are monitored by a variety of sensor types at or near the Earth's surface. After processing, these data enable millimeter-scale surface motion detection and monitoring at discrete points, and high-resolution strain imagery over areas of tens of square meters to hundreds of square kilometers. The data types include **GPS/GNSS**, **SAR** and **Lidar/SfM**, **strain and seismic borehole data**, and **Tropospheric data**. Most of these can be accessed via **web services**. In addition, GPS/GNSS data sets, TLS data sets, and InSAR products are assigned digital object identifiers. See our About Data page for more information. See our data **help** page to request support or custom data acquistion.

ICSU WORLD DATA SYSTEM **ICSU WDS Regular Member certification since 2015**

Data Attribution

The UNAVCO GAGE Facility archives datasets and derived data products collected by community investigators funded by a variety of sources.

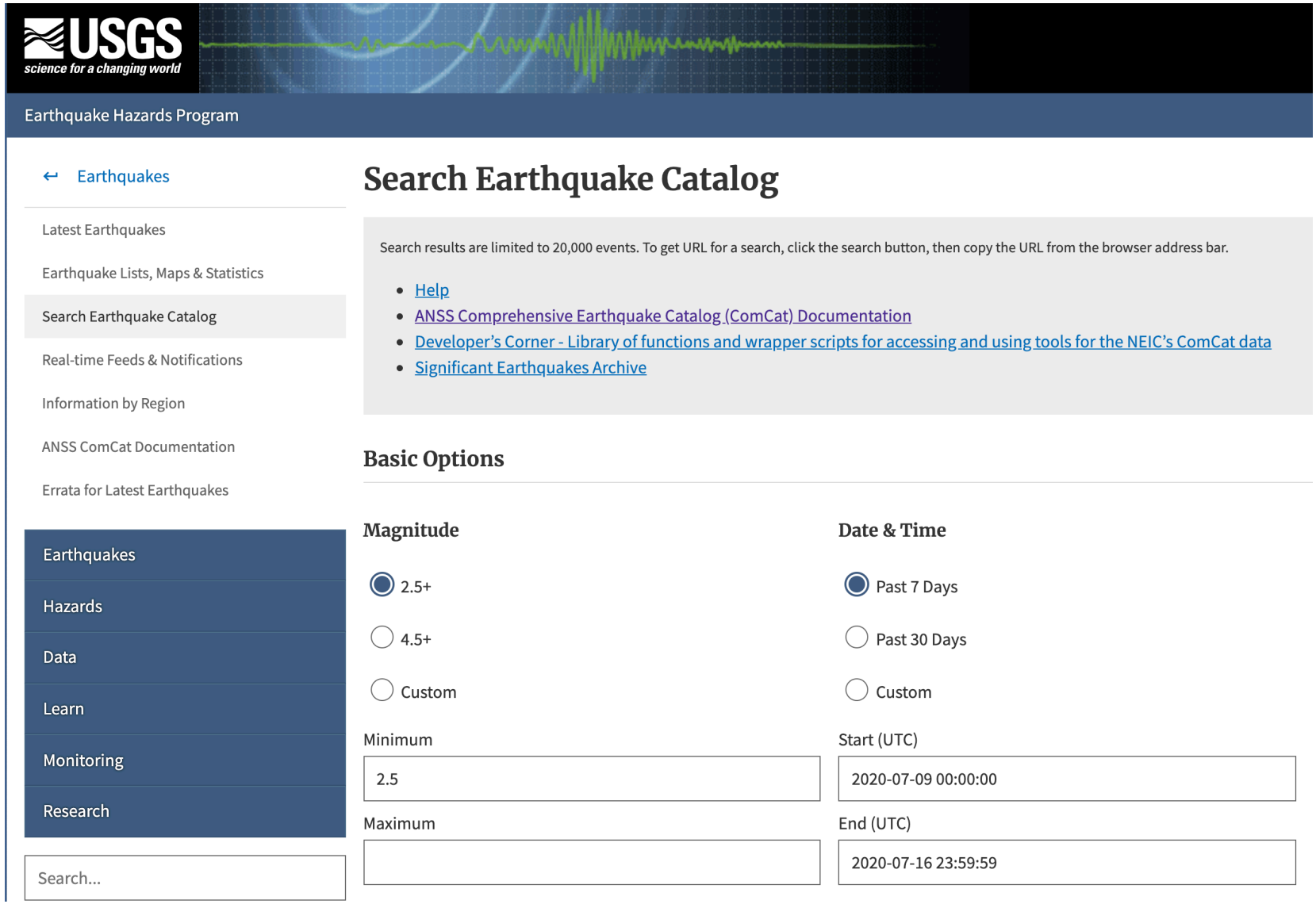
The data user bears sole responsibility for

Acknowledgment of GAGE Support

Data Citation Guidance

Search GPS/GNSS Dataset DOIs

Important Landing Pages



https://earthquake.usgs.gov/earthquakes/search/

Important Landing Pages

All Based on:

FDSNWS:
Federation of Digital Seismic Networks - WebServices

Important Landing Pages

- About FDSN
- Mailing Lists
- Meetings
- Membership
- Networks
- Publications
- Services
- Structure
- Terms of Reference
- Working Groups
- Search FDSN
- Contact Us

Home / About the FDSN Sign in

About the FDSN

The International Federation of Digital Seismograph Networks (FDSN) is a global organization. Its membership is comprised of groups responsible for the installation and maintenance of seismographs either within their geographic borders or globally. Membership in the FDSN is open to all organizations that operate more than one broadband station. Members agree to coordinate station siting and provide free and open access to their data. This cooperation helps scientists all over the world to further the advancement of earth science and particularly the study of global seismic activity. The FDSN also holds commission status within IASPEI.

The FDSN goals related to station siting and instrumentation are to provide stations with good geographic distribution, recording data with 24 bits of resolution in continuous time series with at least a 20 sample per second sampling rate. The FDSN was also instrumental in development of a universal standard for distribution of broadband waveform data and related parametric information. The Standard for Exchange of Earthquake Data (SEED) format is the result of that effort.

Network Codes

Network codes are also assigned by the FDSN in order to provide uniqueness to seismological data streams. Network operators request these unique codes for both permanent and temporary networks. Network Code request forms are here.

FDSN historical information

International Federation of Digital Seismograph Networks

07:36:22

Important Landing Pages

All Based on:

FDSNWS:
Federation of Digital Seismic Networks - WebServices

http://erde.geophysik.uni-muenchen.de/fdsnws/dataselect/1/query?net=BW&sta=RJOB&cha=EHZ&start=2010-02-27T06:30:00.000&end=2010-02-27T10:30:00.000

Important Landing Pages

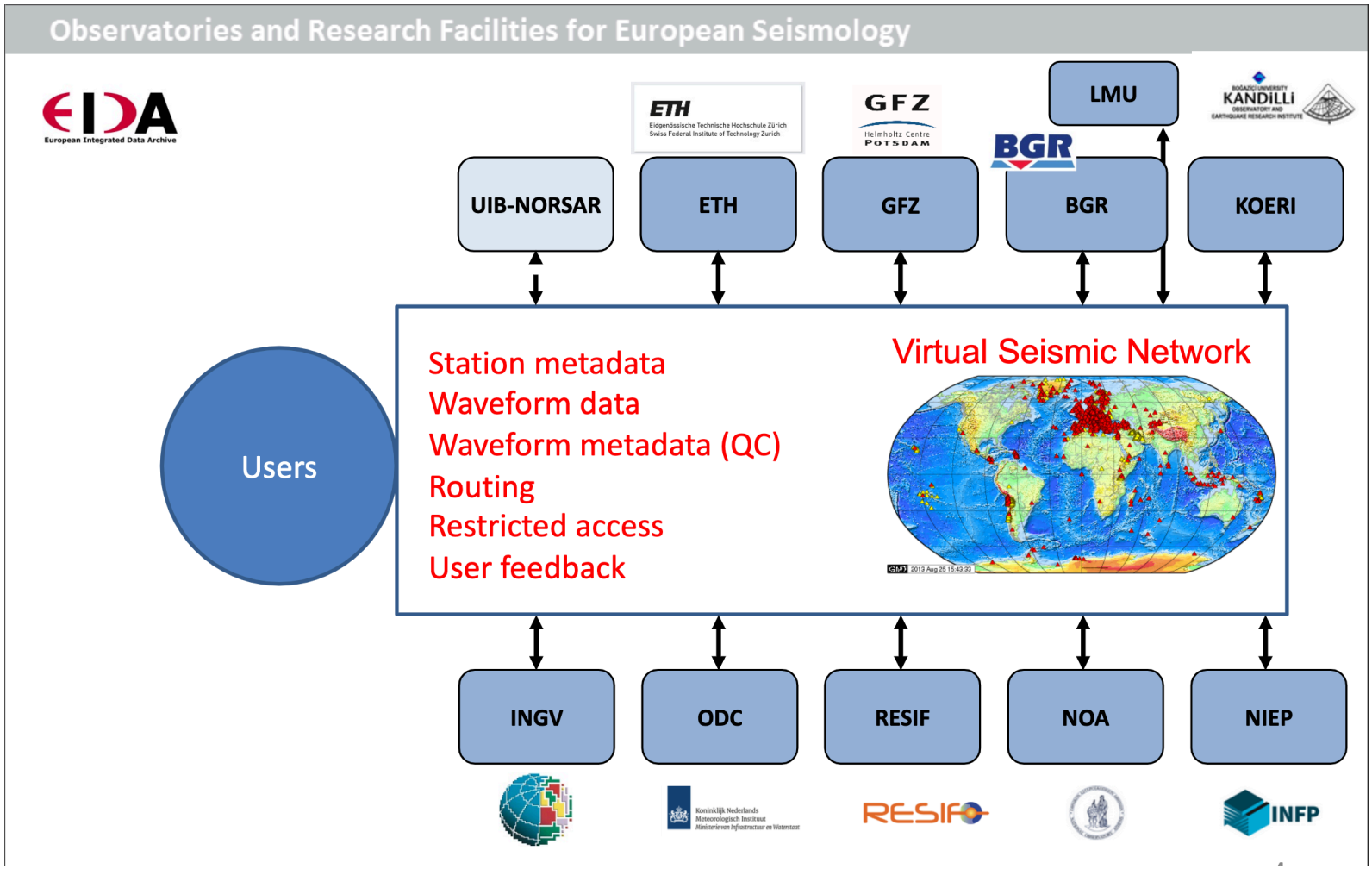
All Based on:

FDSNWS:
Federation of Digital Seismic Networks - WebServices

http://erde.geophysik.uni-muenchen.de/fdsnws/dataselect/1/query?net=BW&sta=RJOB&cha=EHZ&start=2010-02-27T06:30:00.000&end=2010-02-27T10:30:00.000

In this course, we will learn more convenient mechanisms to access the data centers

Important Services



Important Services

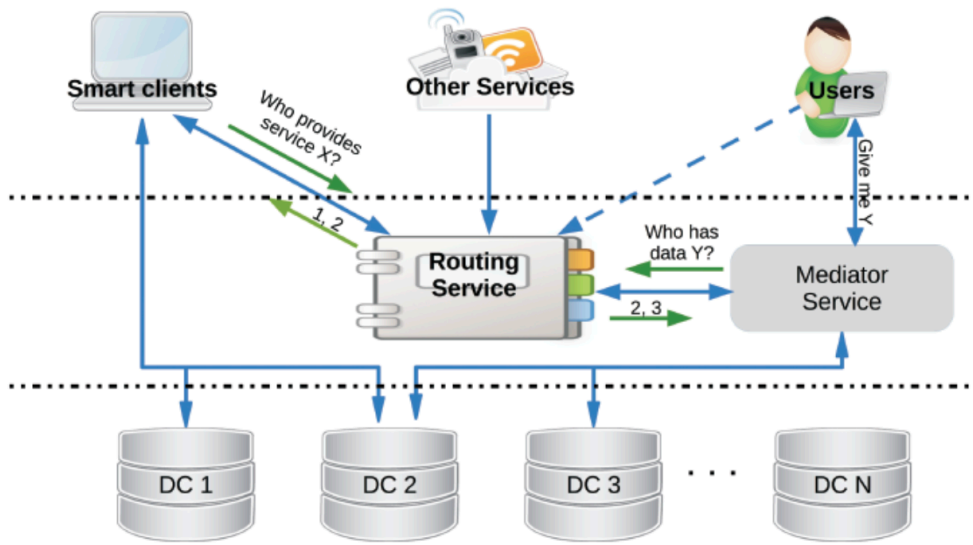
Orfeus EIDA European Integrated Data Archive EOSC-hub EPOS

Observatories and Research Facilities for European Seismology

The EIDA routing service

What does a routing service?

- Provides routing to data (streams)
- Routing to services
- Routing priorities
- Station discovery by geographical location



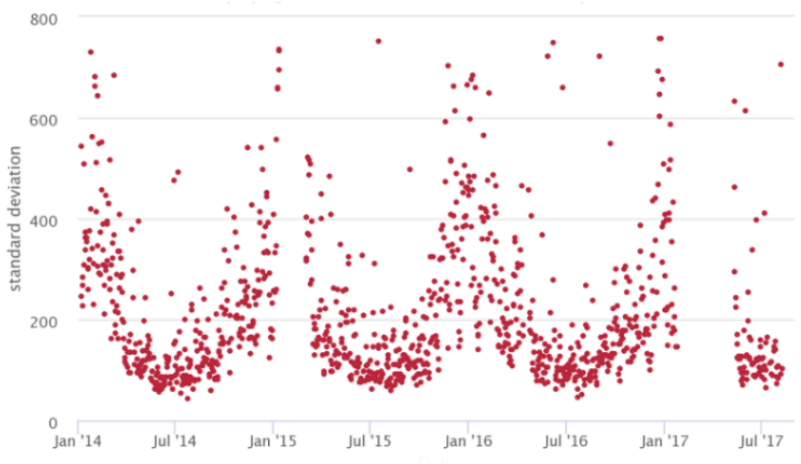
Can also be deployed as a standalone router to run on the client side to create virtual DCs

Important Services

WFCatalog

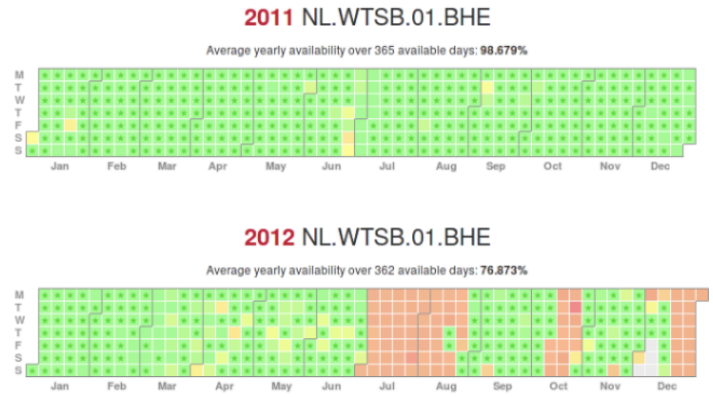
Sample Metric Options				
max_gap	0	Maximum gap length in seconds		Float
max_overlap	0	Maximum overlap length in seconds		Float
num_gaps	0	Number of gaps		Integer
num_overlaps	0	Number of overlaps		Integer
num_samples	86400	Number of samples		Integer
percent_availability	100	Percentage of available data		Percentage
sample_max	100	Maximum sample value		Integer
sample_min	-100	Minimum sample value		Integer
sample_mean	0	Mean sample value		Integer
sample_rms	0	Quadratic mean of samples		Float
sample_stdev	0	Standard deviation of samples		Float
sample_lower_quartile	0	25th percentile of samples		Float
sample_median	0	50th percentile of samples		Float
sample_upper_quartile	0	75th percentile of samples		Float
sum_gaps	0	Sum of data gaps in seconds		Float
sum_overlaps	0	Sum of data overlaps in seconds		Float

WFCatalog



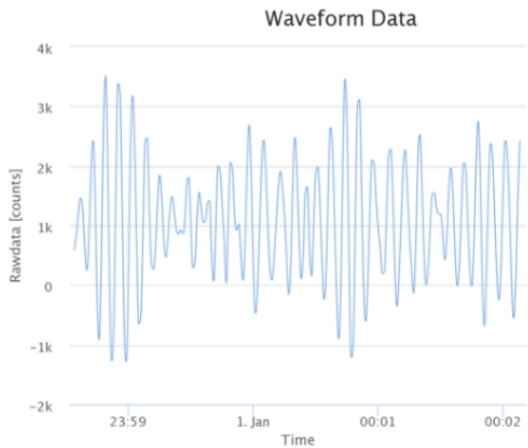
Data Metrics

Graphical interface showing daily waveform metrics.



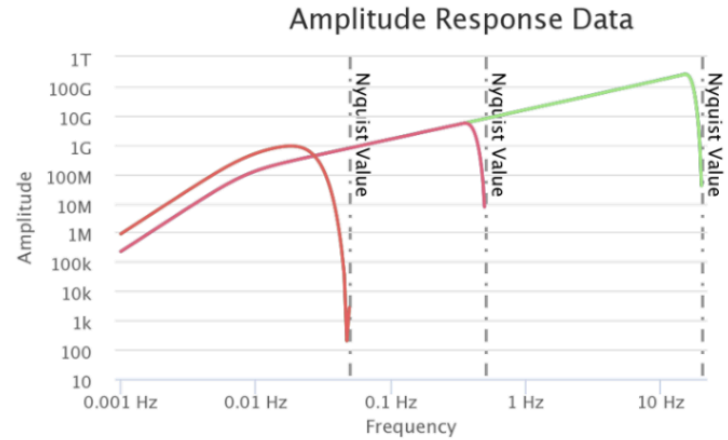
Data Availability

Graphical interface showing daily data availability.



Waveform Viewer

Graphical interface showing for viewing waveform data.

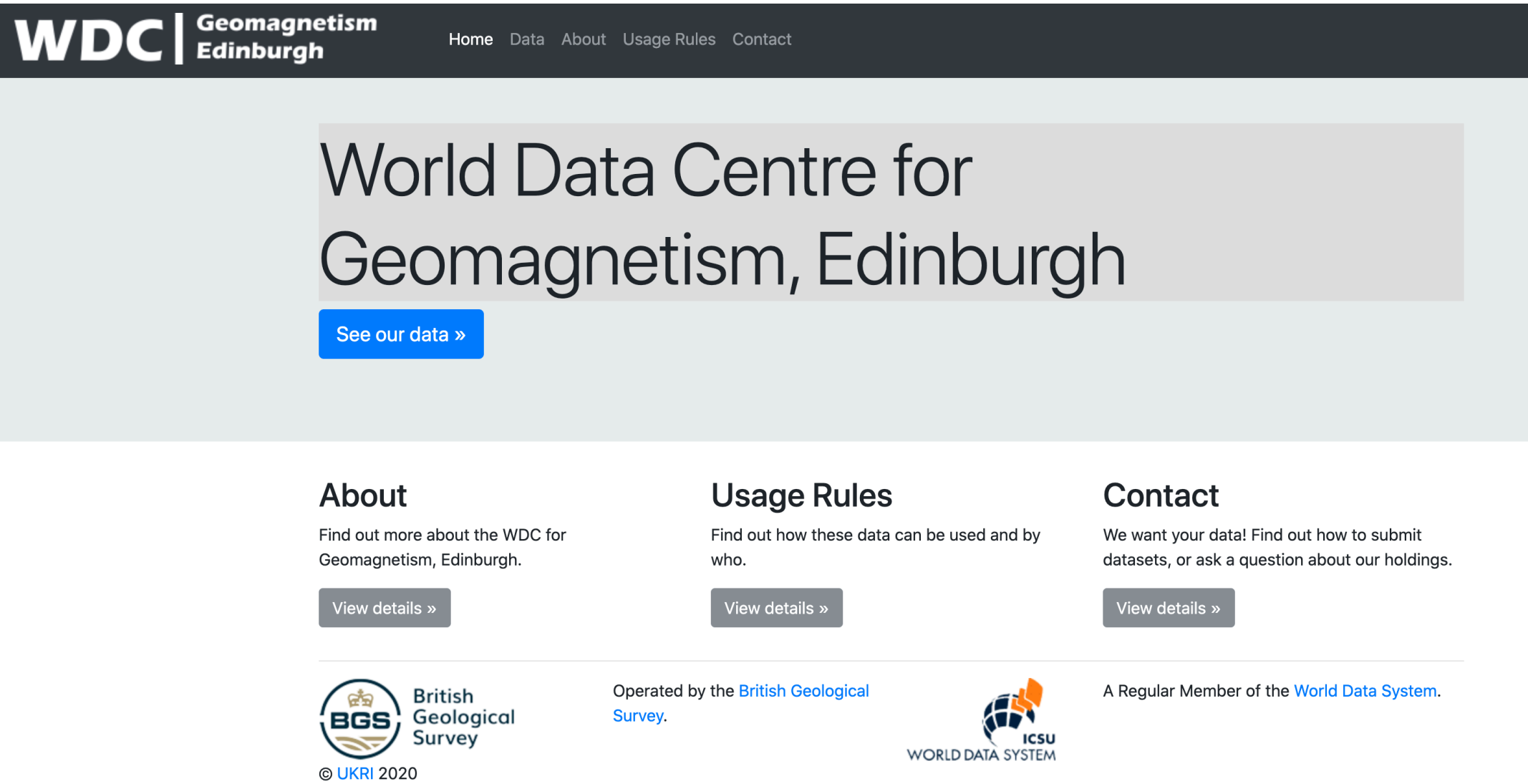


Instrument Response

Interface showing instrument response characteristics.

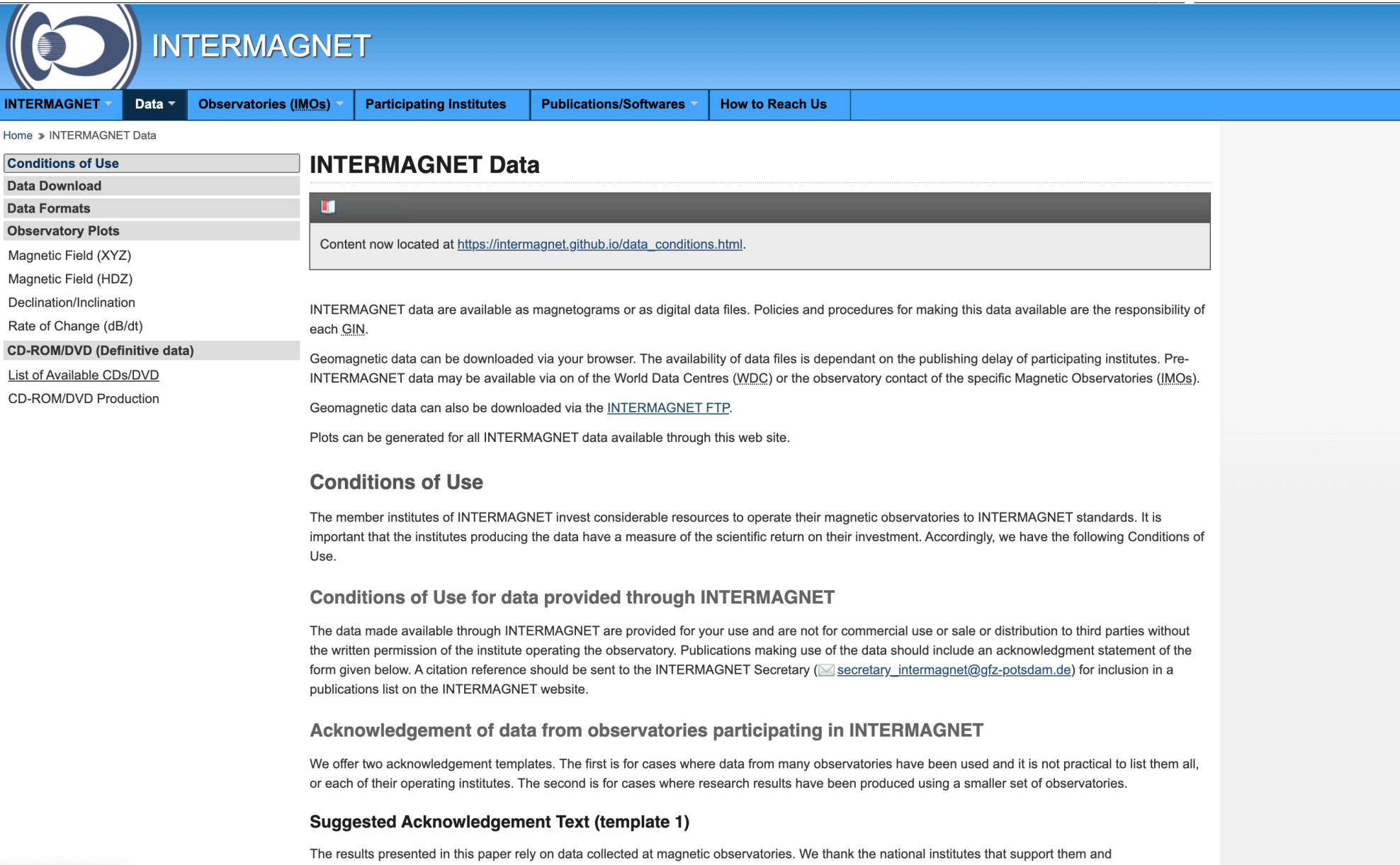
Important Landing Pages

http://www.wdc.bgs.ac.uk/



Important Landing Pages

https://www.intermagnet.org/index-eng.php



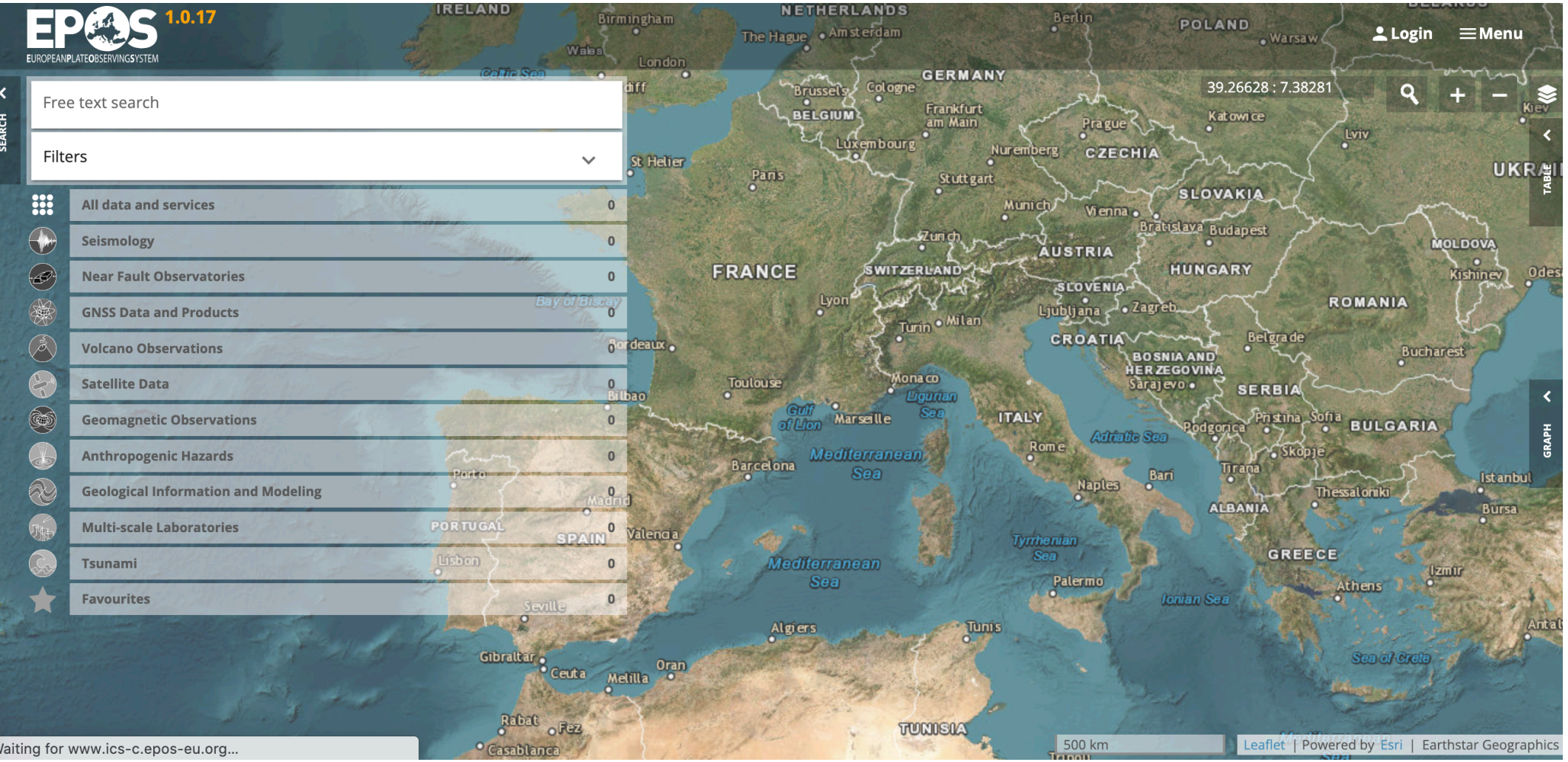
The Future!

http://www.epos-eu.org

Integrated Data Portals

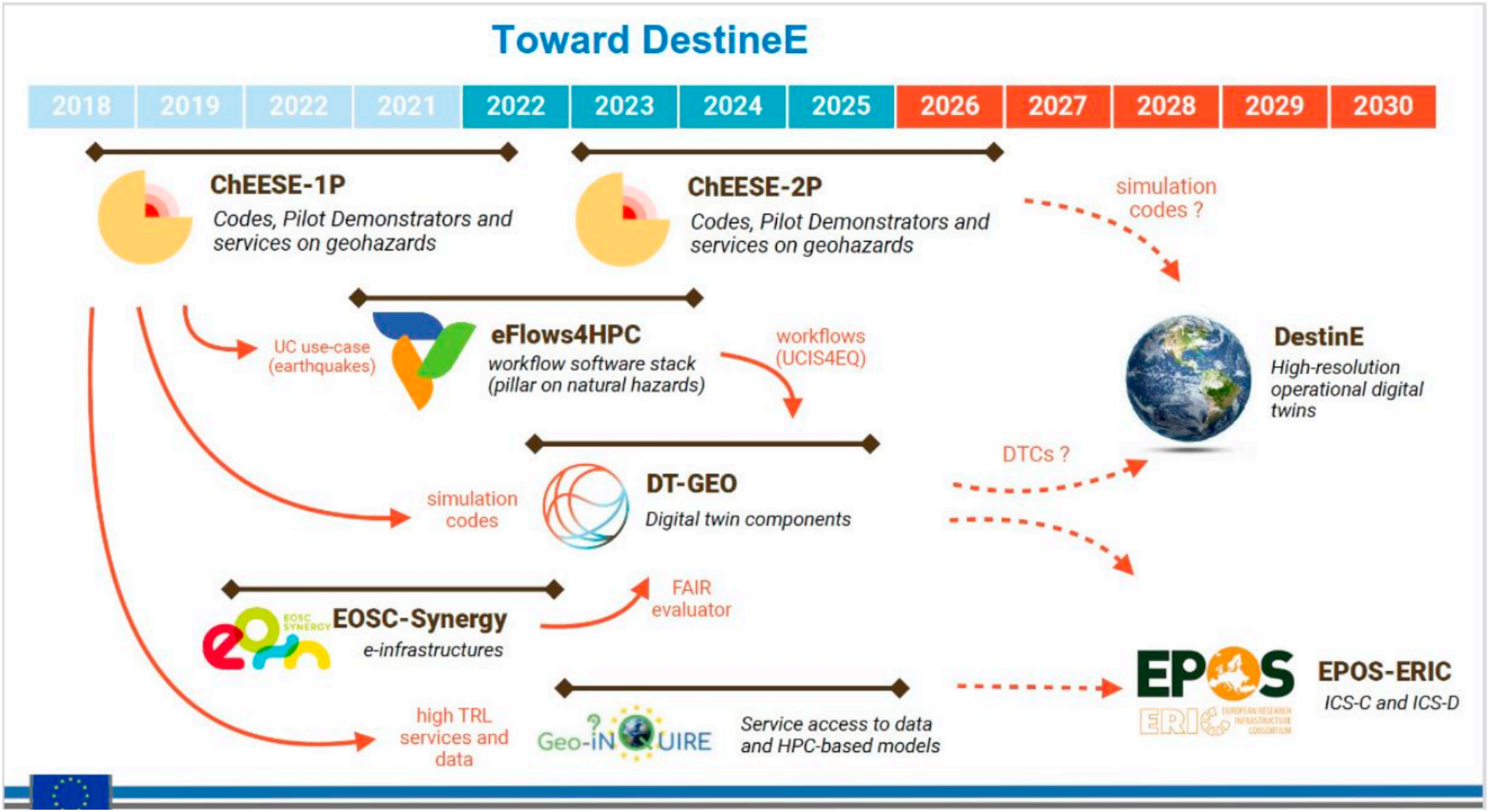
The Future!

http://www.epos-eu.org



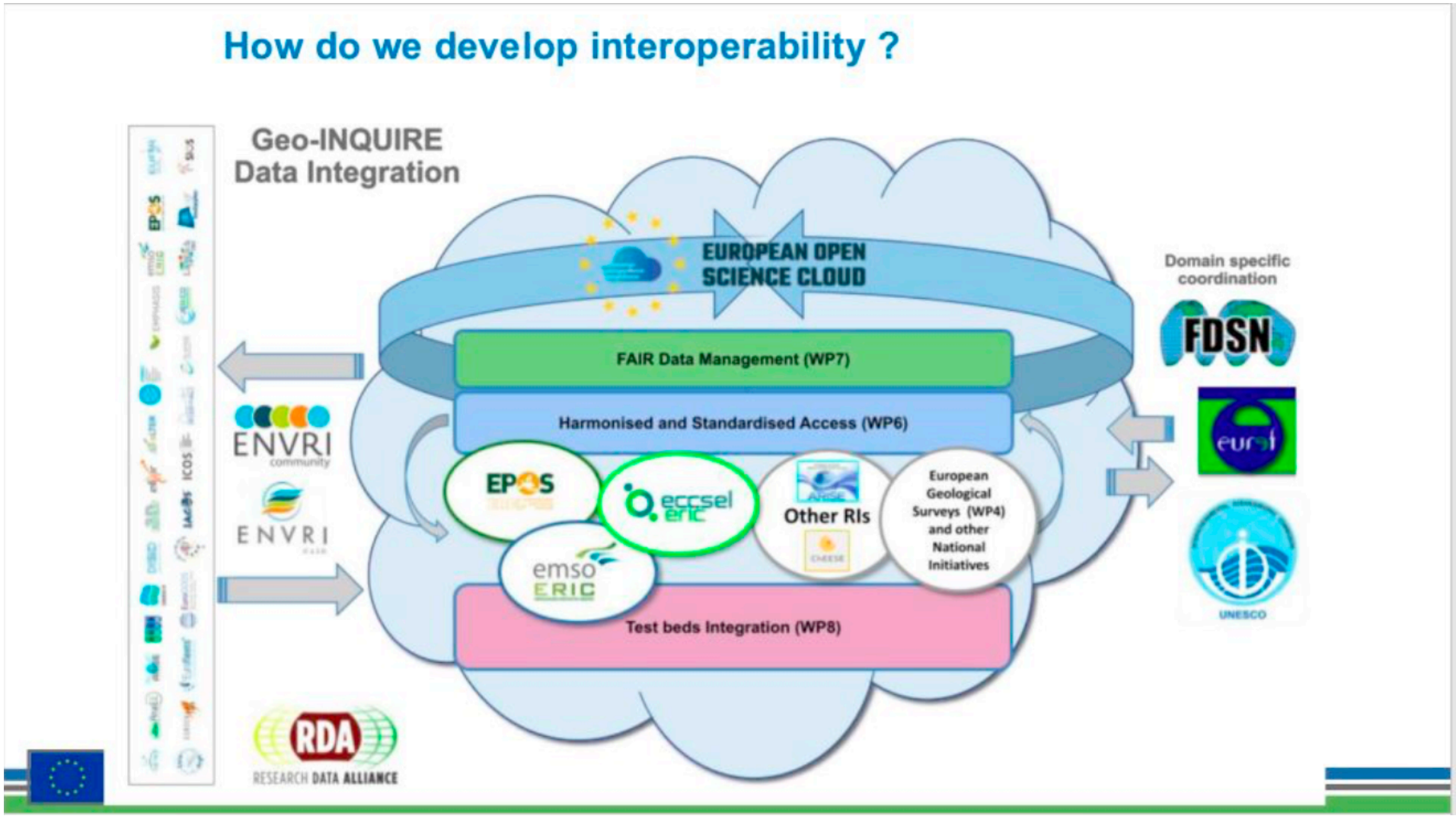
Integrated Data Portals

The Future!



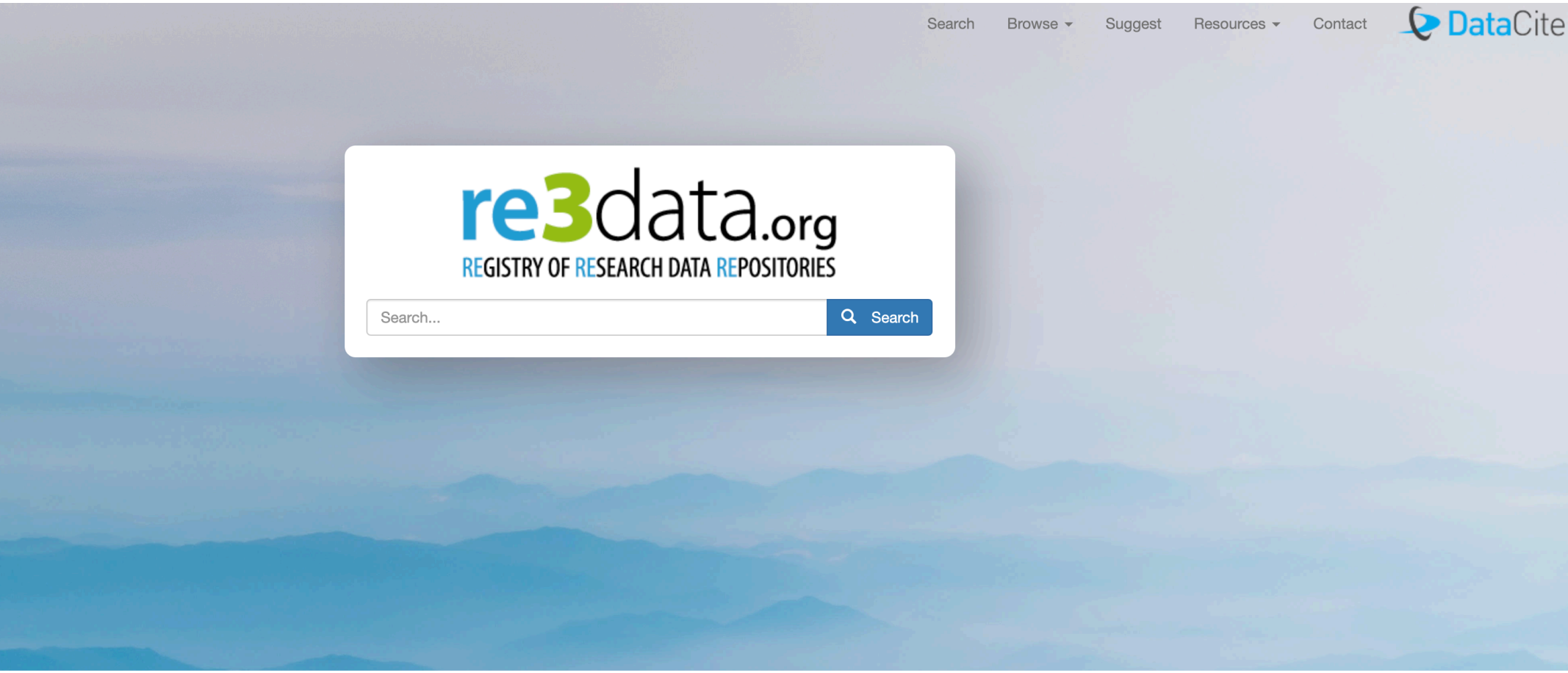
Simulation Environment

The Future!



Integrated Cloud Services

The Future!



It is now mandatory for many journals that you publish also your data at a freely accessible data repository

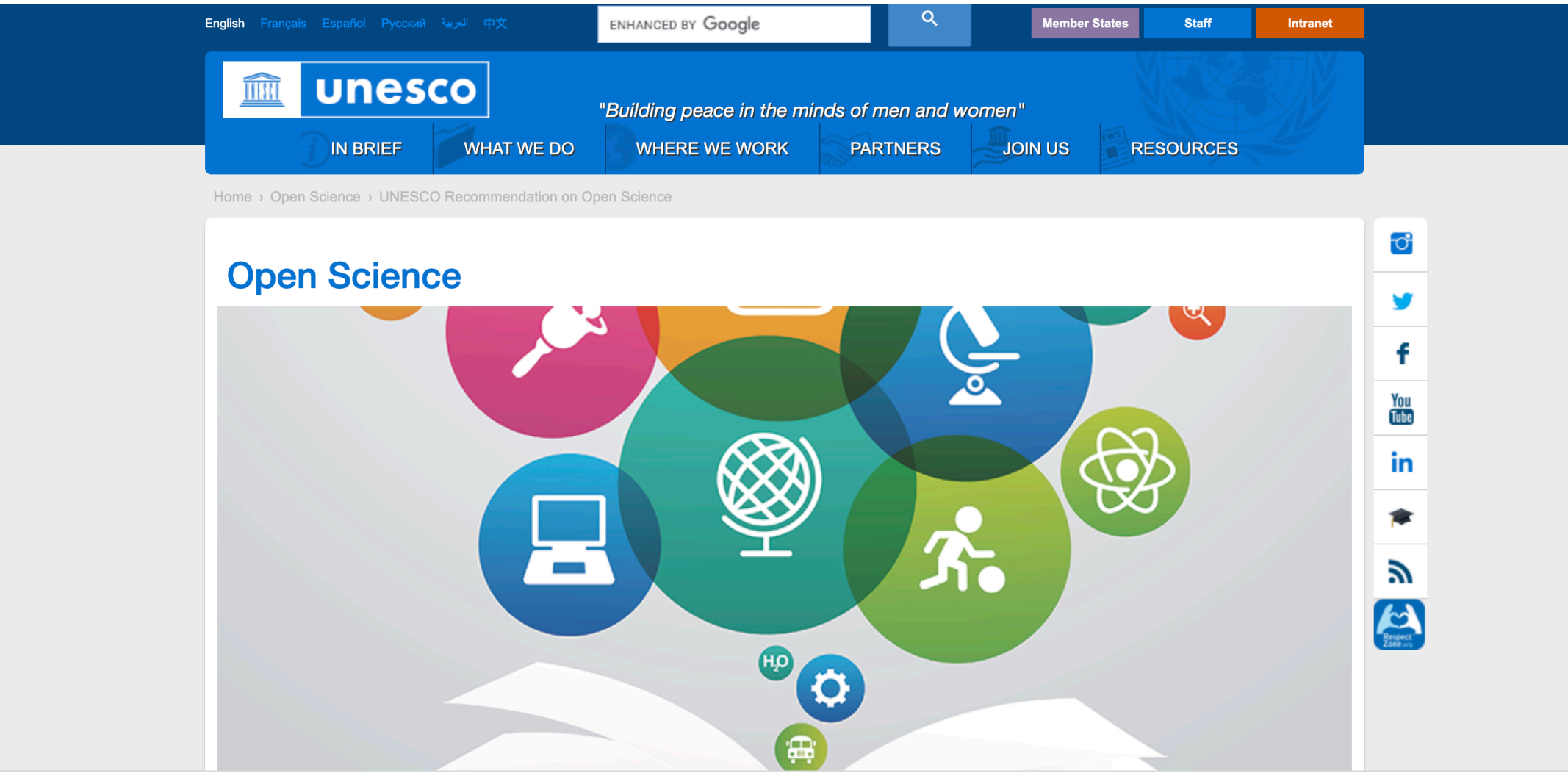
The Future!

The output of research is not only journal articles but also **data sets, model code, samples, etc**. Only the entire network of interconnected information can guarantee integrity, transparency, reuse, and reproducibility of scientific findings. Moreover, all of these resources provide great additional value in their own right.

Hence, it is particularly important that data and other information underpinning the research findings are "**findable, accessible, interoperable, and reusable**" (FAIR) not only for **humans** but also for **machines**.

The Future!

https://en.unesco.org/science-sustainable-future/open-science/recommendation



Important for the Network Operator

Orfeus

Observatories and Research Facilities for European Seismology

How to cite seismic data

Citing is based on network code.
If the network has a DOI: Refer to the data as you would to a normal scientific manuscript, and include the reference in the normal list of references.

Network, citation and DOI information can be found at http://www.fdsn.org/networks/
If many networks are used: most journals accept a 'Data Section'

Example:
'We used data from GEOSCOPE (Institut De Physique Du Globe De Paris (IPGP) and Ecole Et Observatoire Des Sciences De La Terre De Strasbourg (EOST), 1982) and GEOFON (Geofon Data Centre, 1993).'

References:

GEOFON Data Centre, 1993. GEOFON Seismic Network. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.14470/tr560404

Institut De Physique Du Globe De Paris (IPGP), & Ecole Et Observatoire Des Sciences De La Terre De Strasbourg (EOST), 1982. GEOSCOPE, French Global Network of broad band seismic stations. Institut de Physique du Globe de Paris (IPGP). https://doi.org/10.18715/geoscope.g

Data - Formats?

... for recording

- e.g. Guralp gcf, reftek, ...

... for exchange

- contain additional information in header, e.g. instrument characteristic
- e.g. gse, seed, mseed & stationXML, quakeML, …

... for processing

- almost every code has its own working format
- e.g. Q, sac, seisan, obspy ...

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Again more about this later ….

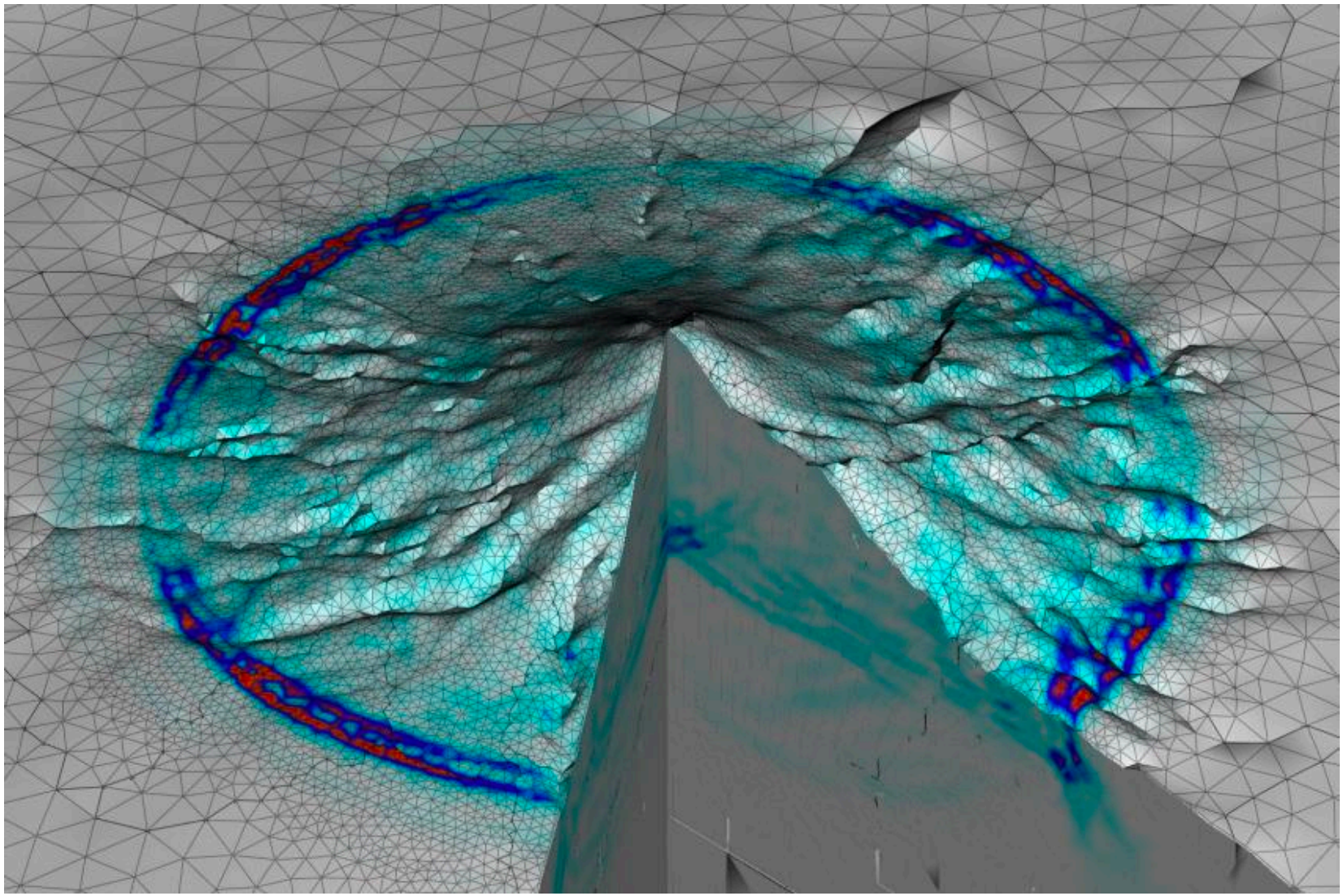
Data - Formats?

... few more words on format:

- simple, machine and human readable formats are getting more and more important
- XML, JSON are widely used
- format should support automatic up- and download with “on-the-fly” validation check
- RESTful (REpresentational State Transfer) services are most common to put and get data from (-> FDSNWS)

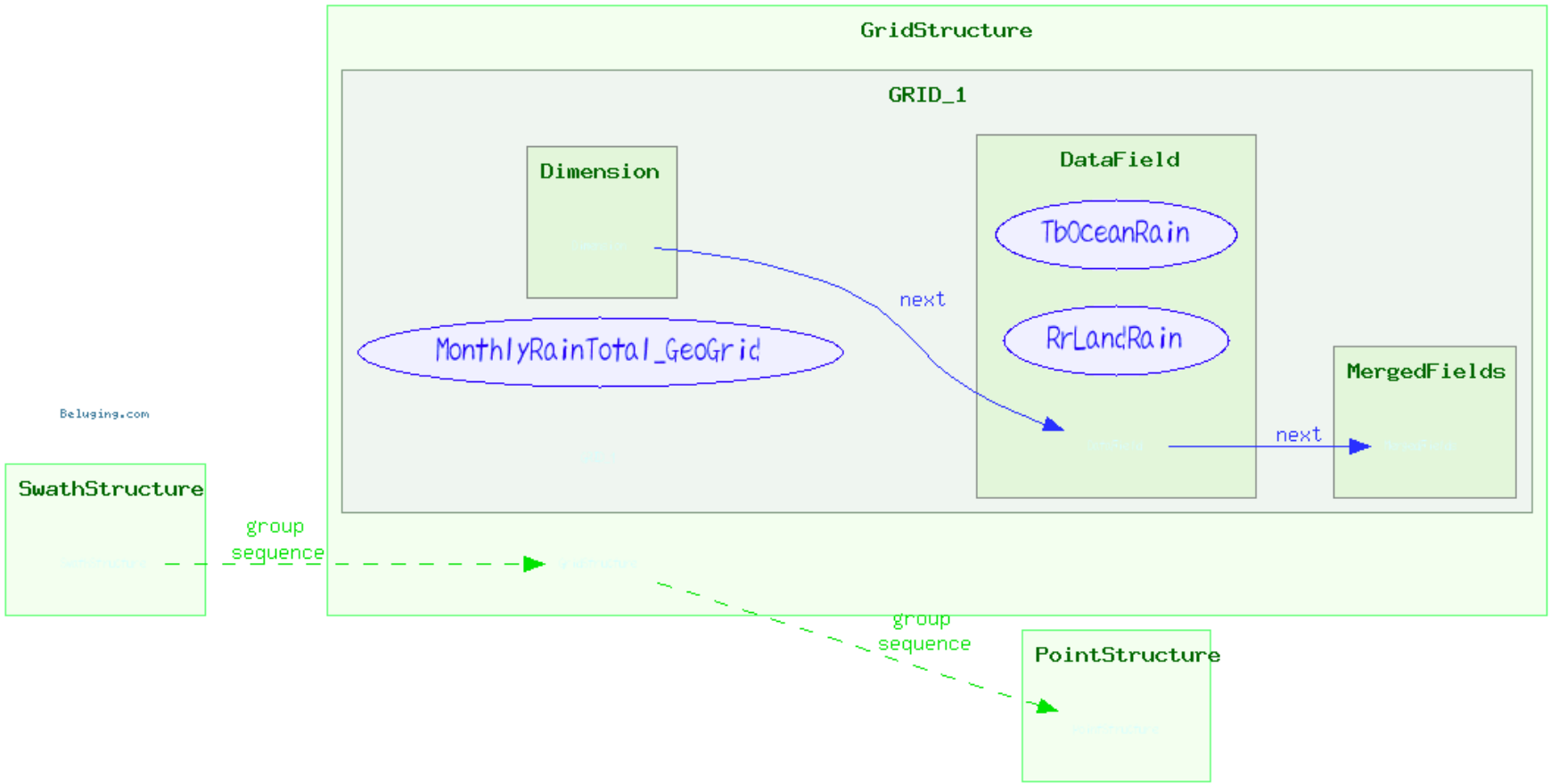
Data - Formats?

New: 3D-Volume + Time Data



Data - Formats?

HDF-5

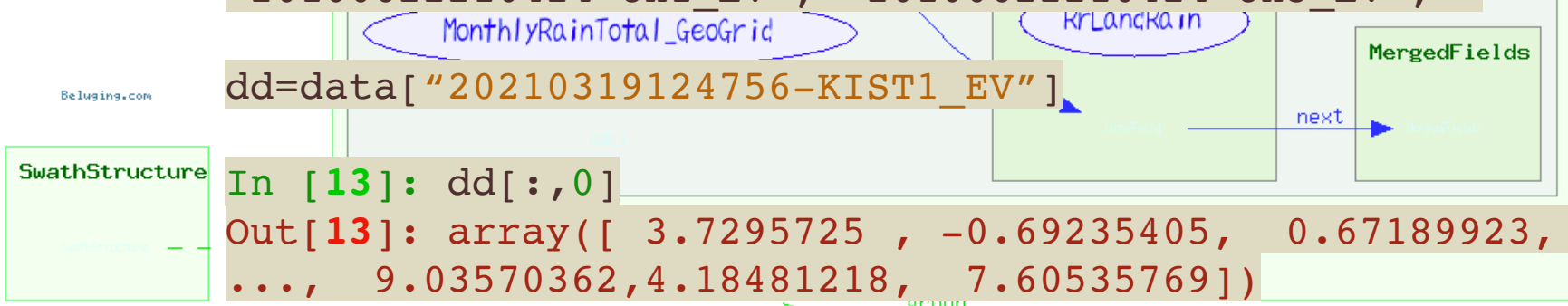


Eg. STEAD (STanford EArthquake Dataset)

Formats?

```
In [4]: merge.keys()
Out[4]: <KeysViewHDF5 ['data']>
data = merge['data']
```

```
In [6]: data.keys()
Out[6]: <KeysViewHDF5 ['20100622205905-UH1_EV',
'20100622205905-UH2_EV', '20100622205905-UH3_EV',
'20100622205905-UH4_EV', '20100622210059-NORI_EV',
'20100622210059-RJOB_EV', '20100622210059-RTBE_EV',
'20100622210059-UH1_EV', '20100622210059-UH2_EV',
'20100622210059-UH3_EV', '20100622210059-UH4_EV',
'20100622210243-UH1_EV', '20100622210243-UH2_EV',
'20100622210243-UH3_EV', '20100622210243-UH4_EV',
'20100622210424-UH1_EV', '20100622210424-UH3_EV', '
```




```
dd=data["20210319124756-KIST1_EV"]
```

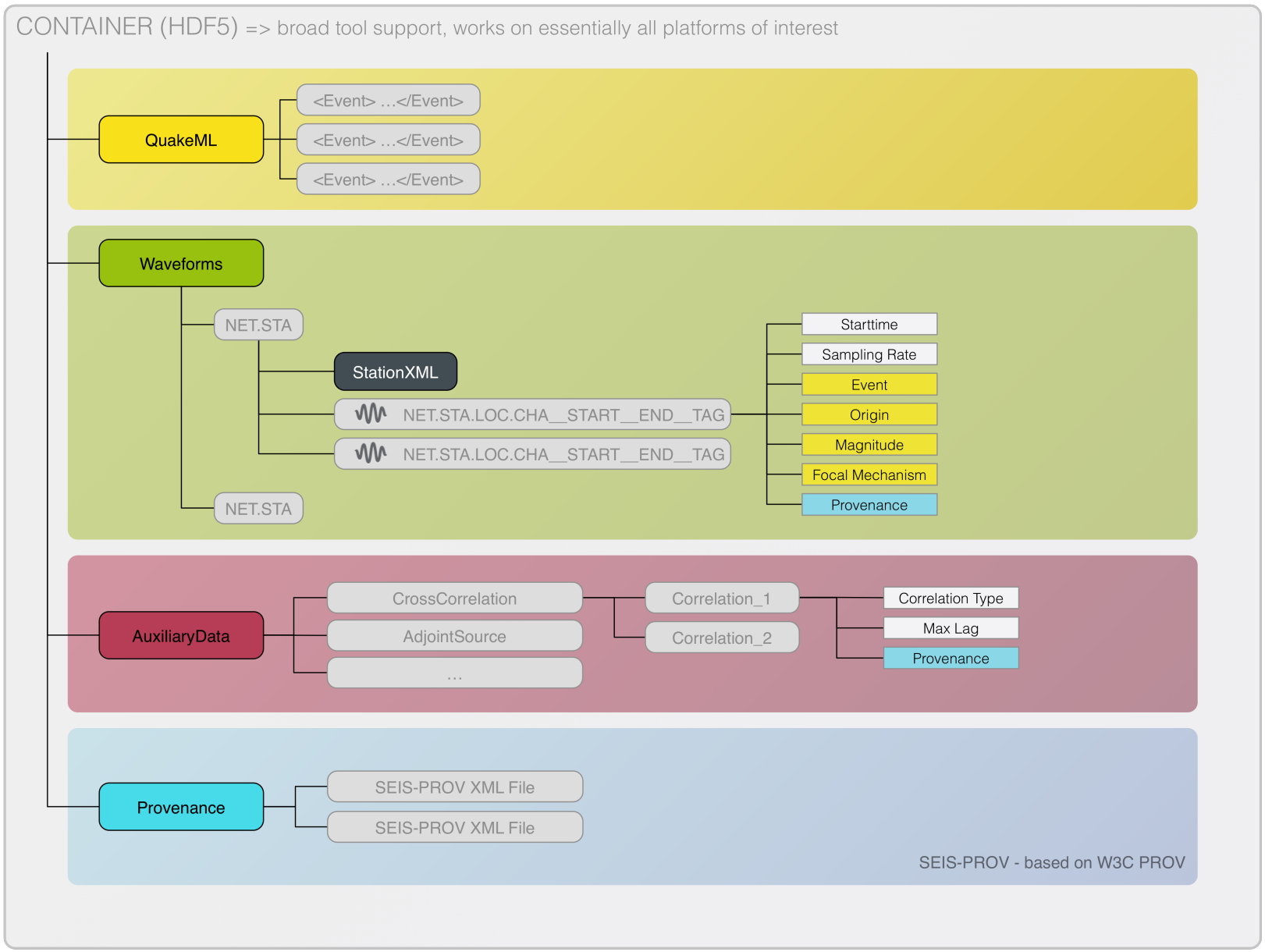
```
In [13]: dd[:,0]
Out[13]: array([ 3.7295725 , -0.69235405,  0.67189923,
...,  9.03570362,4.18481218,  7.60535769])
```

```
In [15]: dd.attrs.keys()
Out[15]: <KeysViewHDF5 ['back_azimuth',
'coda_end_sample', 'network_code', 'p_arrival_sample',
'p_status', 'p_travel_sec', 'p_weight',
'receiver_code', 'receiver_elevation',
'receiver_latitude', 'receiver_longitude',
'receiver_type', 's_arrival_sample', 's_status', '
```

Eg. STE

Data - Formats?

Adaptable **S**eismic **D**ata **F**ormat



Naming of Your Data

We still stick to the SEED naming (pretty complete)

BW.RJOB..HHZ

Naming of Your Data

We still stick to the SEED naming (pretty complete)

BW.RJOB..HHZ

Network Code
(to be registered at FDSN)

Naming of Your Data

We still stick to the SEED naming (pretty complete)

Station Code
(to be registered at ISC)

BW.RJOB..HHZ

Network Code
(to be registered at FDSN)

Naming of Your Data

We still stick to the SEED naming (pretty complete)

Station Code
(to be registered at ISC)

BW.RJOB..HHZ

Network Code
(to be registered at FDSN)

Location Code
(numeric: e.g. 00)

Naming of Your Data

We still stick to the SEED naming (pretty complete)

Channel Code
(following SEED)

Station Code
(to be registered at ISC)

Network Code
(to be registered at FDSN)

Location Code
(numeric: e.g. 00)

Naming of Your Data

Band Code

The first letter specifies the general sampling rate and the response band of the instrument. (The "A" code is reserved for administrative functions such as miscellaneous state of health.)

Band code	Band type	Sample rate (Hz)	Corner period (sec)
F	...	≥ 1000 to < 5000	≥ 10 sec
G	...	≥ 1000 to < 5000	< 10 sec
D	...	≥ 250 to < 1000	< 10 sec
C	...	≥ 250 to < 1000	≥ 10 sec
E	Extremely Short Period	≥ 80 to < 250	< 10 sec
S	Short Period	≥ 10 to < 80	< 10 sec
H	High Broad Band	≥ 80 to < 250	≥ 10 sec
B	Broad Band	≥ 10 to < 80	≥ 10 sec
M	Mid Period	> 1 to < 10	
L	Long Period	≈ 1	
V	Very Long Period	≈ 0.1	
U	Ultra Long Period	≈ 0.01	
R	Extremely Long Period	≥ 0.0001 to < 0.001	
P	On the order of 0.1 to 1 day[1]	≥ 0.00001 to < 0.0001	
T	On the order of 1 to 10 days[1]	≥ 0.000001 to < 0.00001	
Q	Greater than 10 days[1]	< 0.000001	
A	Administrative Instrument Channel	variable	NA
O	Opaque Instrument Channel	variable	NA

1. These are approximate values. The sample rate should be used for the correct Band Code.

Instrument Code and Orientation Code

The second letter specifies the family to which the sensor belongs. In essence, this identifies what is being measured. Each of these instrument types are detailed in this section.

The third letter in the channel name is the Orientation Code, which provides a way to indicate the directionality of the sensor measurement. This code is sometimes used for a purpose other than direction, which is instrument-specific. When orthogonal directions are used, there are traditional orientations of North (N), East (E), and Vertical (Z), as well as other orientations that can readily be converted to traditional ones. These options are detailed with each instrument type. Use N or E for the orientation when it is within 5 degrees of north or east. Use 1 or 2 when orientations are more than 5 degrees from north or east. Put the actual orientation of the sensor in the dip and azimuth fields of blockette 52.

Seismometer: Measures displacement/velocity/acceleration along a line defined by the dip and azimuth.

Instrument Code	
H	High Gain Seismometer
L	Low Gain Seismometer
G	Gravimeter
M	Mass Position Seismometer
N*	Accelerometer
	* historically some channels from accelerometers have used instrumentation codes of L and G. The use of N is the FDSN convention as defined in August 2000.
Orientation Code	
Z N E	Traditional (Vertical, North-South, East-West) (see 5 degree convention above)
A B C	Triaxial (Along the edges of a cube turned up on a corner)
T R	For formed beams (Transverse, Radial)
1 2 3	Orthogonal components but non traditional orientations (see 5 degree convention above)
U V W	Optional components
Dip/Azimuth:	Ground motion vector (reverse dip/azimuth if signal polarity incorrect)
Signal Units:	M, M/S, M/S**2, (for G & M) M/S**2 (usually)
Channel Flags:	G

Tilt Meter: Measures tilt from the horizontal plane. Azimuth is typically N/S or E/W.

Instrument Code

A

Orientation Code

N E	Traditional
Dip/Azimuth:	Ground motion vector (reverse dip/azimuth if signal polarity incorrect)
Signal Units:	Radians
Channel Flags:	G

Creep Meter: Measures the absolute movement between two sides of a fault by means of fixing a metal beam on one side of the fault and measuring its position on the other side. This is also done with light beams.

The orientation and therefore the dip and azimuth would be perpendicular to the measuring beam (light or metal), which would be along the average travel vector for the fault. Positive/Negative travel would be arbitrary, but would be noted in the dip/azimuth. Another type of Creep Meter involves using a wire that is stretched across the fault. Changes in wire length are triangulated to form movement vector.

Instrument Code

B

Orientation Code

Unknown

Dip/Azimuth:	Along the fault or wire vector
Signal Units:	M
Channel Flags:	G

Magnetometer: Measures the magnetic field where the instrument is sitting. They measure the part of the field vector that is aligned with the measurement coil. Many magnetometers are three axis. The instrument will typically be oriented to local magnetic north. The dip and azimuth should describe this in terms of the geographic north.

Example: Local magnetic north is 13 degrees east of north in Albuquerque. So if the magnetometer is pointed to magnetic north, the azimuth would be + 103 for the E channel. Some magnetometers do not record any vector quantity associated with the signal, but record the total intensity. So, these would not have any dip/azimuth.

Instrument Code

F

Orientation Code

Z N E	Magnetic
Signal Units:	T — Teslas
Channel Flags:	G

Humidity: Absolute/Relative measurements of the humidity. Temperature recordings may also be essential for meaningful results.

Instrument Code

I

Orientation Code

O	Outside Environment
I	Inside Building
D	Down Hole
1 2 3 4	Cabinet Sources

All other letters available for mnemonic source types.

Dip/Azimuth:	Not applicable — Should be zero.
Signal Units:	%
Channel Flags:	W

Common Observables

Common Observables

- Acceleration/Velocity/Displacement/Strain/Rotations

Common Observables

- Acceleration/Velocity/Displacement/Strain/Rotations
- Geomagnetic field

Common Observables

- Acceleration/Velocity/Displacement/Strain/Rotations
- Geomagnetic field
- Gravitimetric field

Common Observables

- Acceleration/Velocity/Displacement/Strain/Rotations
- Geomagnetic field
- Gravitimetric field
- Temperature (heat flow)

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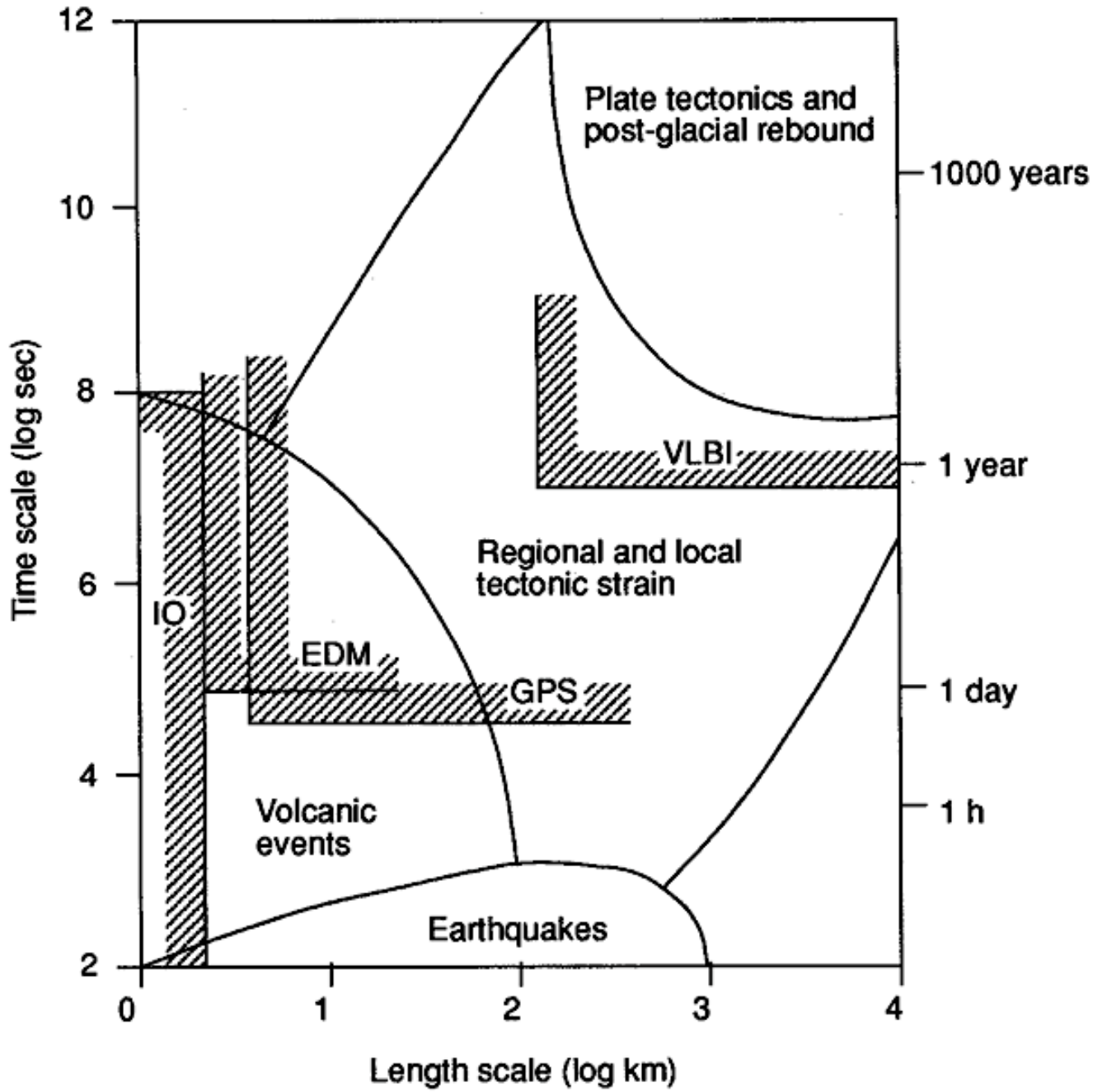
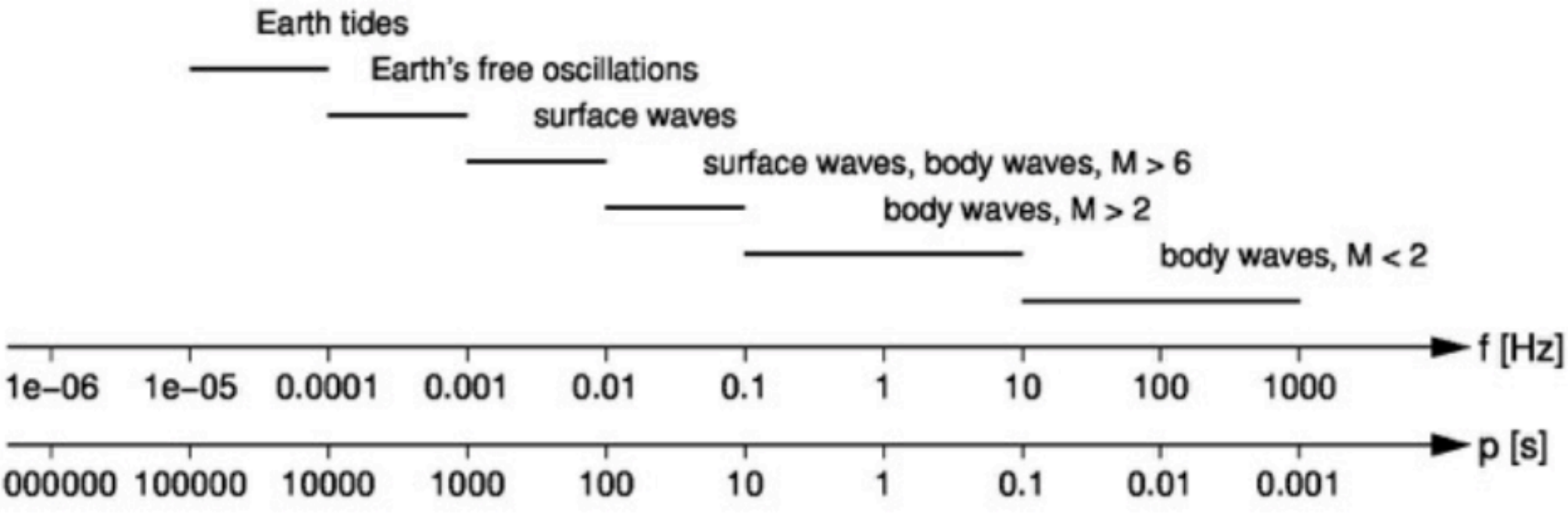
Time Length Scales



Time Scales in Seismology

- Laboratory signals 0.000001 – 0.001s
- Seismic exploration 0.001 – 0.1s
- Earthquakes 0.01 – 100s
- Coseismic deformation 1 – 1000s
- Eigenmodes of the Earth (Normal Modes) 1000s
- Postseismic deformation > 10000s



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Different Types of Sensors needed!!