

# Seismological instrumentation: scientific aims and practical use - GIPP presentation and visit



Christian Haberland, GFZ



# GFZ - Telegrafenberg



1832 Station of optical telegraf line  
1870 Royal Prussian Geodetic Institute  
1890 Geomagnetic observatory  
...  
1969 Zentralinstitut für Physik der Erde  
1992 GeoForschungsZentrum Potsdam

Einstein tower(built 1919-22)



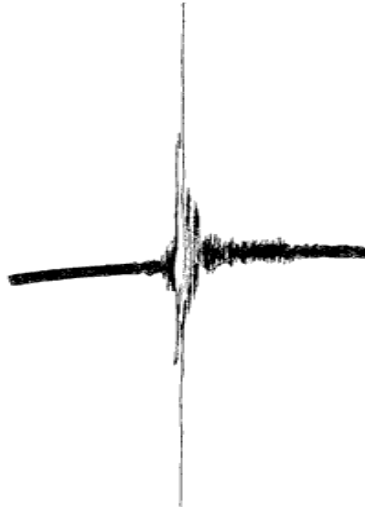
- National research center for the solid Earth Sciences
- ~1300 employees (2021)
- Yearly budget 66 Mio. € inst. funds + 30 Mio. € 3<sup>rd</sup> party (2021)
- German Federal Ministry of Education & Research and Fed. State of Brandenburg

# First recording of teleseismic earthquake in Potsdam



*E. von Rebeur-Paschwitz 1899*

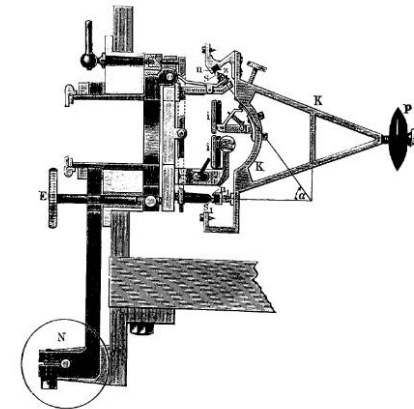
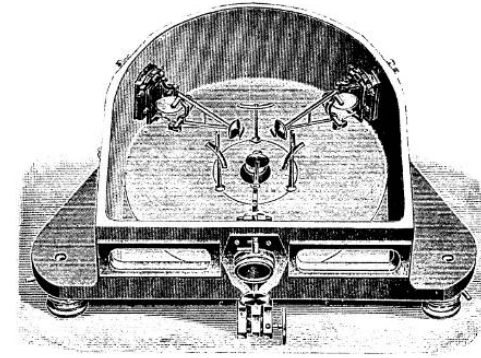
wikipedia.org



## Ernst v. Rebeur-Paschwitz (1861-95)

- A focus of his work was the **improvement of a horizontal pendulum** used in gravity/geodesy
- actually designed to measure **changes in plumb direction** (gravity direction) caused by movements of the earth's crust under the influence of astronomical bodies or local mass anomalies
- **2 instruments (Potsdam & Wilhelmshaven)**
- Seismological phenomena influencing the variation of vertical axis
- **First recording of teleseismic event 17.4.1889** (*Nature* article 1889)
- Regarded as **beginning of modern, systematic, global seismological observations**
- In 1885 proposal for homogeneous global station network

## Horizontal pendulum



From: Eschenhagen (1985) (<http://bib.gfz-potsdam.de/pub/digi/seismograms.pdf>)



# Historical seismometers

## Milne horizontal pendulum seismometer

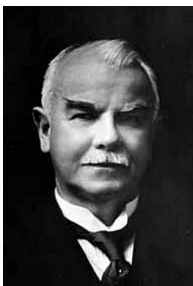


first seismogram 3.11.1880

By Momotarou2012 - Own work, CC BY-SA 3.0,  
<https://commons.wikimedia.org/w/index.php?curid=23356547>



John Milne

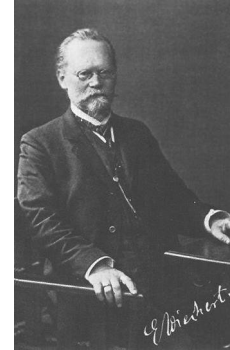


James Alfred Ewing

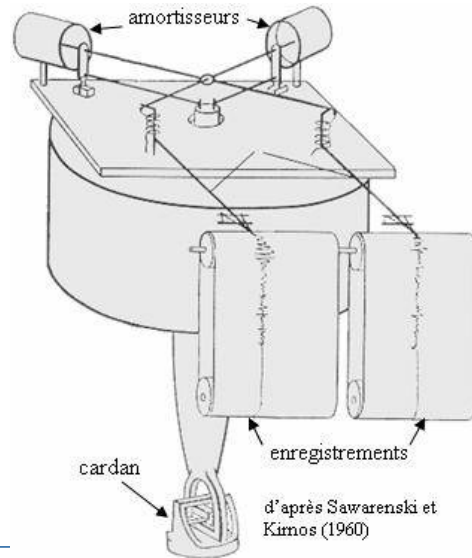
+ Thomas Lomar Gray

wikipedia.org

## Wiechert Seismograph



Emil Wiechert



1906

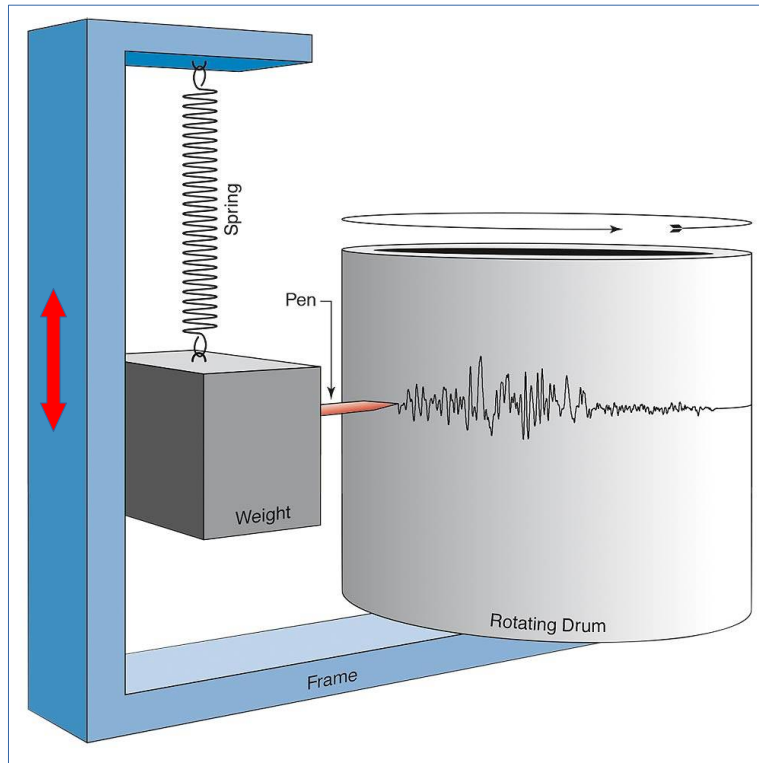


GFZ Potsdam, Albert-Einstein-Strasse!

Mass: 1000 kg  
 Period: 8 s

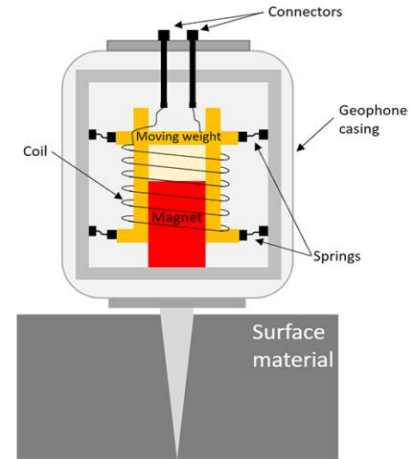
# Some physics...

## Seismometer principle



...add damping

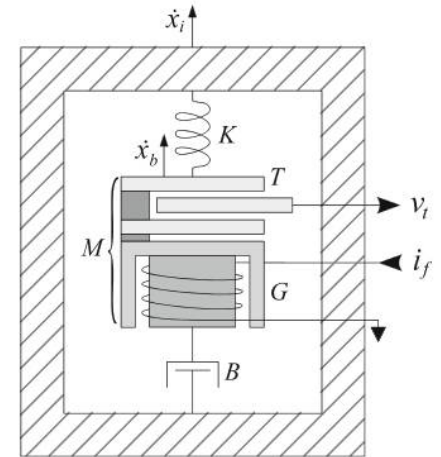
www.faulhaber.com



www.guidelinegeo.com

Passive inertial sensor

Active inertial sensor (force feedback)



Ackerly (2014)

...add A/D converter and recording system (data logger) with proper timing

# Modern seismograph designs

## Broadband seismometers (active, 240s - 100Hz)



Streckeisen STS-2



Nanometrics Trillium 120



Güralp CMG-3ESP



Trillium compact



... posthole



Nanometrics Horizon



Kinometrics MBB-2

## Geophones (passive, $\geq 1\text{Hz}$ )



Mark 1Hz



Geophone 4.5Hz 3-C



Geophone 4.5Hz vertical



Geophone string

## Accelerometer (passive)



Kinometrics Episensor

# Modern seismograph designs

Broadband seismometers  
(active, 240s - 100Hz)



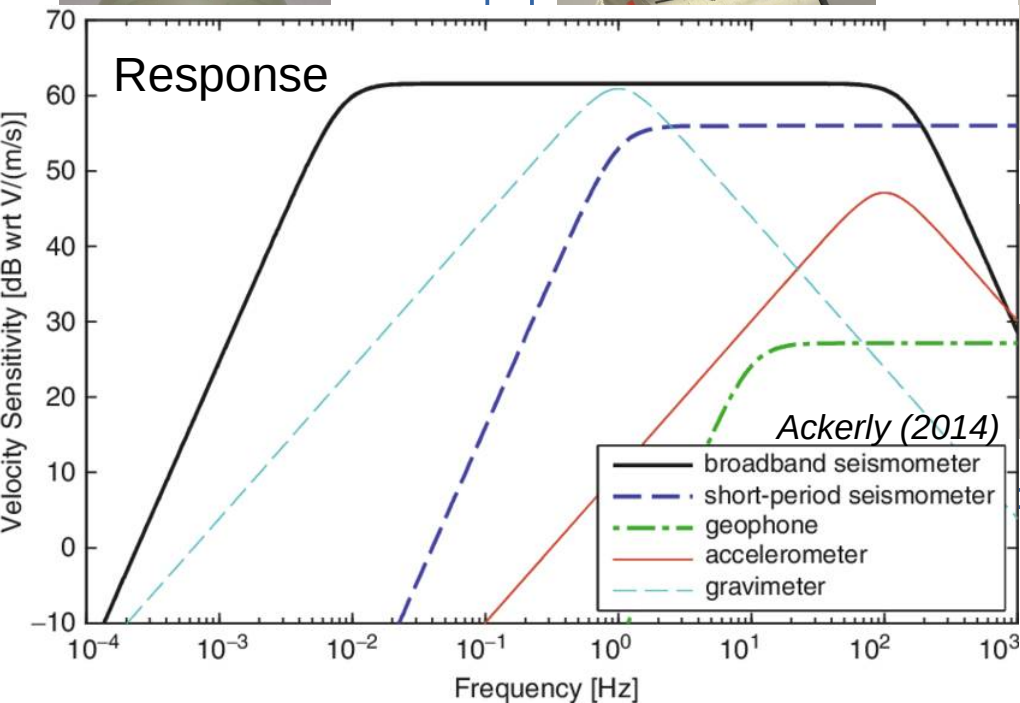
Streckeisen STS-2



Güralp CMG-3ESP



Nanometrics Horizon

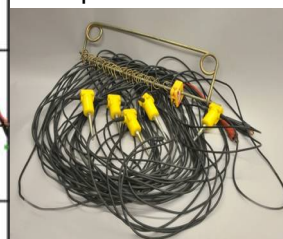


Kinematics MBB-2

Geophones (passive,  $\geq 1$ Hz)



Geophone 4.5Hz 3-C



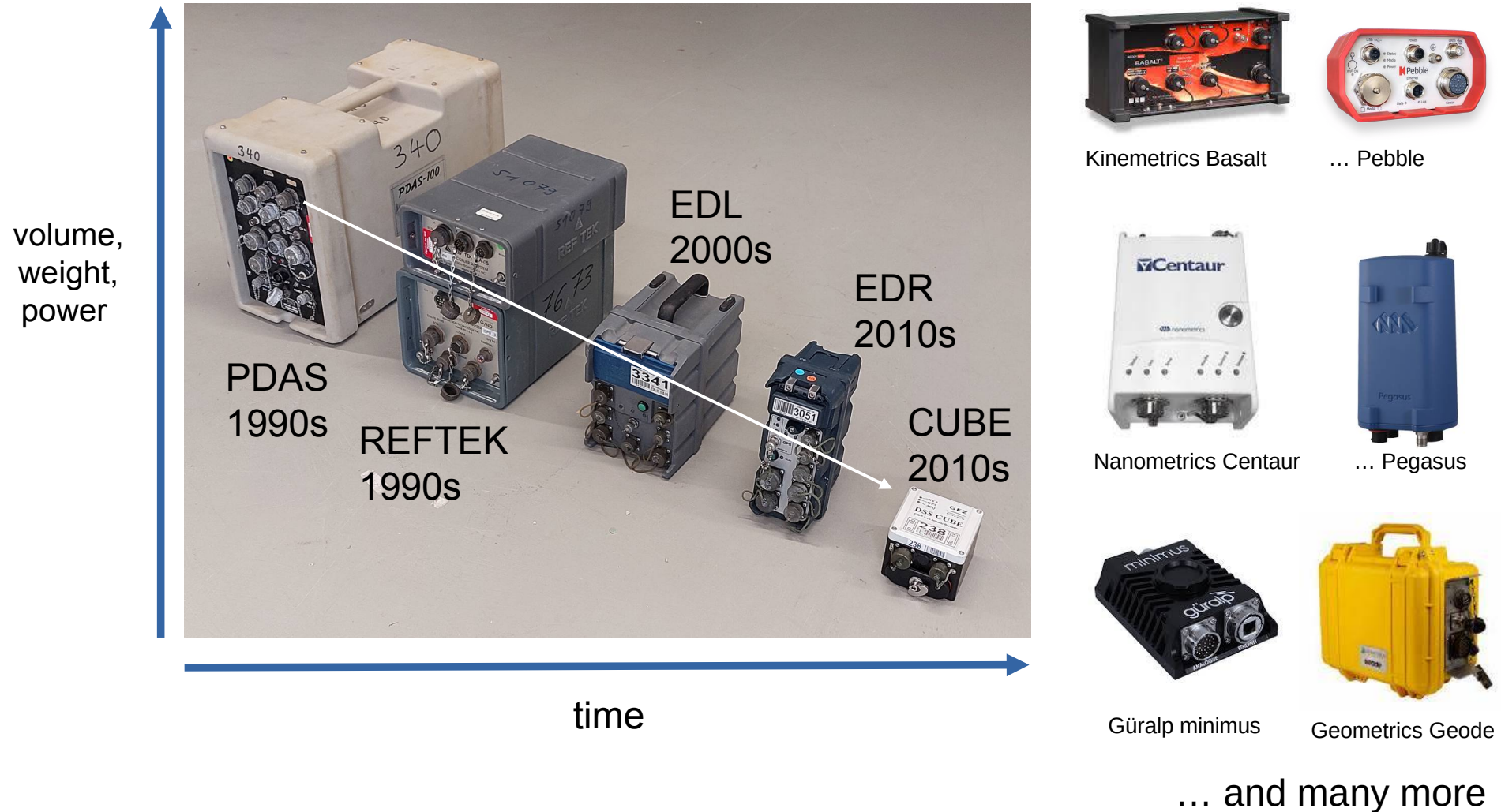
Geophone string



Kinematics Episensor



# (Autonomous) Recorders

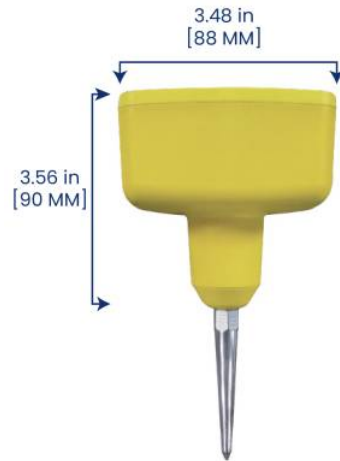




# Compact autonomous recorders (nodes)



GE-ANT-3C



Geospace GS-5



NuSeis NRU



Cube



Inova Quantum



SmartSolo



Stryde



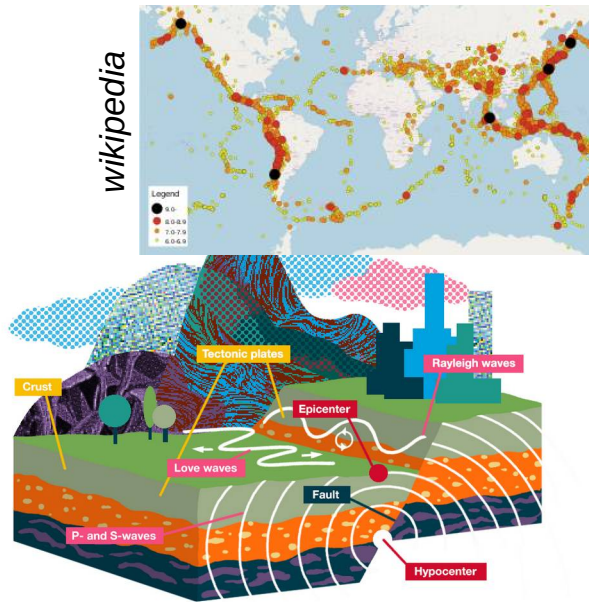
Fairfield  
ZLand



SmartPoint

# Sources/signals

## Natural (impulsive) sources (earthquakes)



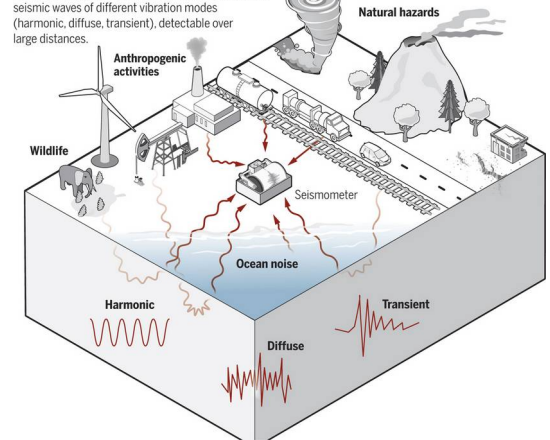
## Controlled sources (hammer, vibro, blast)



## Ambient noise

### Humans and nature excite seismic waves

Seismometers record vibrations from everything, not only earthquakes. Shown are sources that induce seismic waves of different vibration modes (harmonic, diffuse, transient), detectable over large distances.



[x.com/ScienceMagazine](https://www.x.com/ScienceMagazine)

- EQ location/study
- Monitoring
- Imaging

- Imaging
- (monitoring)

- Imaging
- monitoring

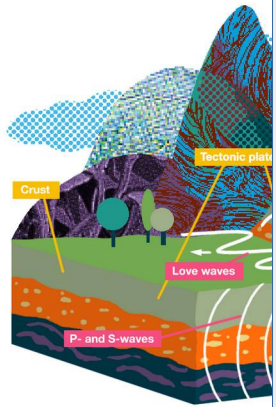


# Sources/signals

## Natural (impulsive) sources (earthquakes)

## Controlled sources (hammer, vibro, blast)

## Ambient noise



### Applications (selection):

- Earth structure (meterscale to global)
- Geodynamic processes: active/passive continental margins, orogenes, shear zones, volcanoes...
- Seismicity
- Resources, exploration
- Use of subsurface (geothermal, storage)
- Hazard (EQ, volcanoes, tsunamis)
- climate (permafrost, glaciers, ice)
- Soil, engineering
- ...

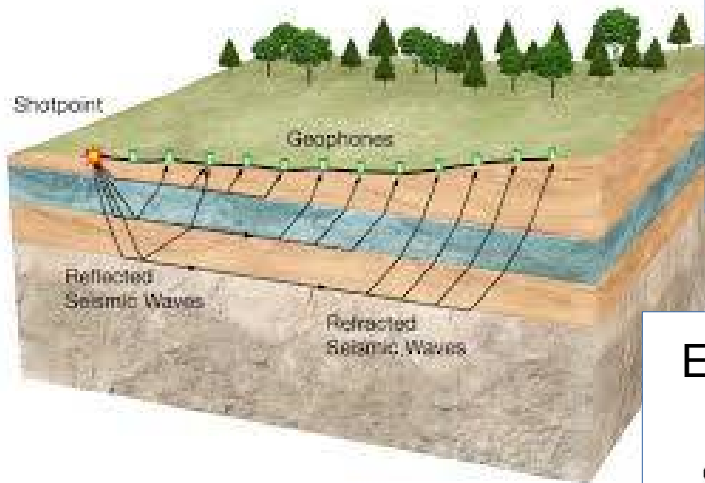
- EQ location/study
- Monitoring
- Imaging

- Imaging
- (monitoring)

- Imaging
- monitoring

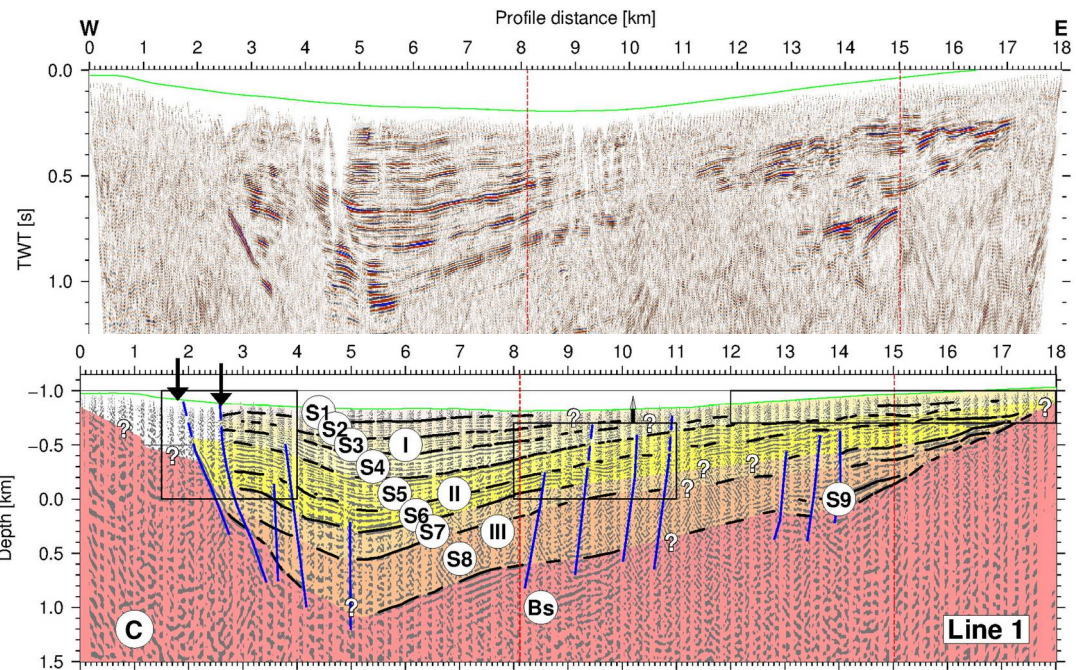
# Controlled source seismics

petrosine.com

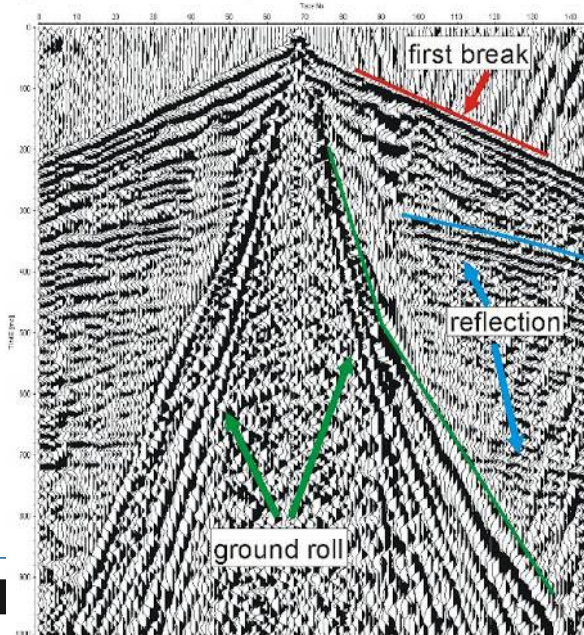


Reflection and refraction seismics, tomography

Example: Imaging of sedimentary basin structure



Haberland et al., 2017, Tectonophysics



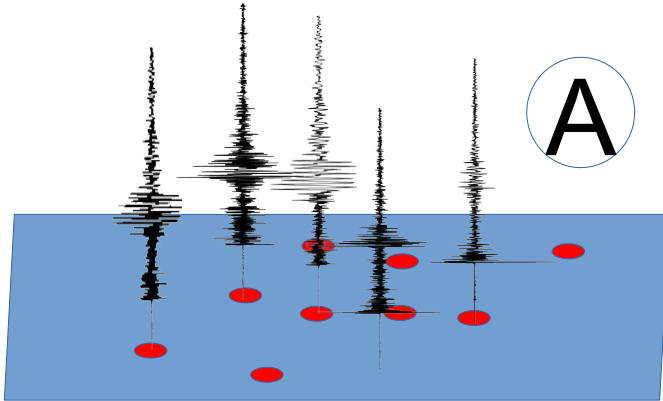
GI

Helmholtz-Zentrum  
POTSDAM

HELMHOLTZ



# Typical seismological observation designs

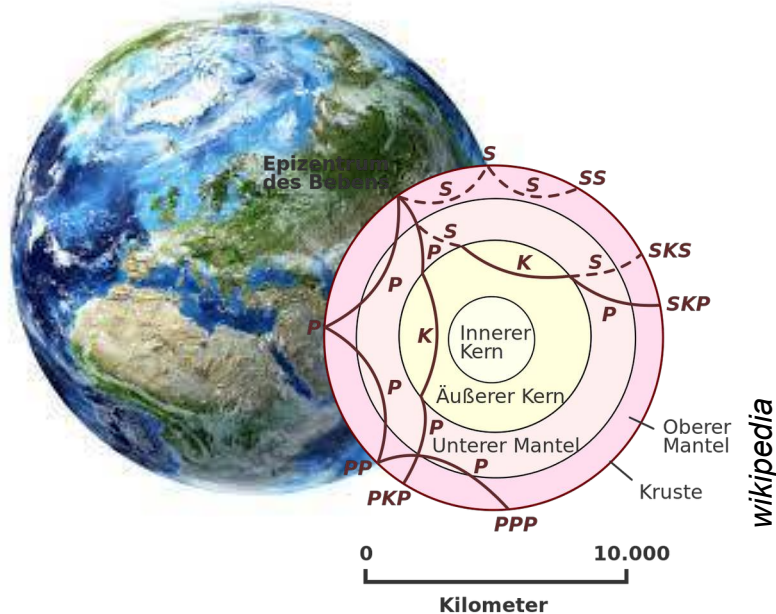


## “Conventional” network

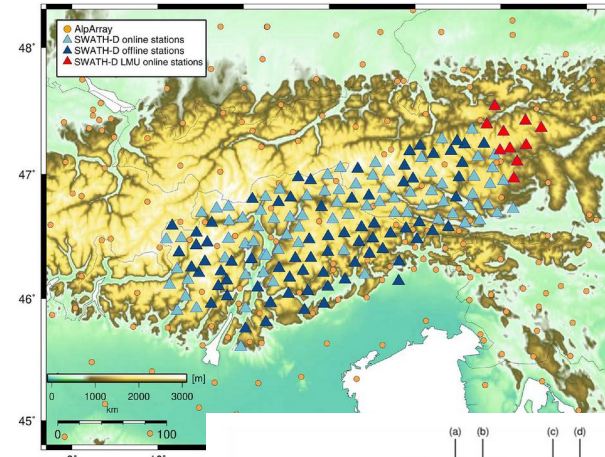
- Interstation distances “large”
- Coherent waveforms only for “low” frequencies (limiting spatial resolution)
- Use e.g. of arrival times (tomography) and/or (individual) waveforms

# Typical Studies A

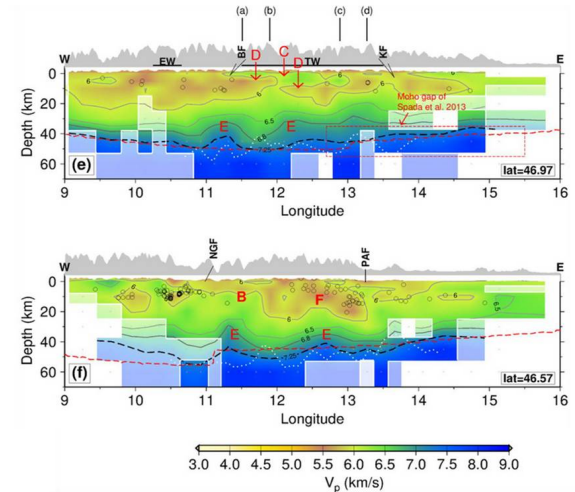
## Permanent networks - Global/regional studies



## Temporary seismic networks: SPP 4D-MB: SWATH-D



Heit et al., SRL, 2021



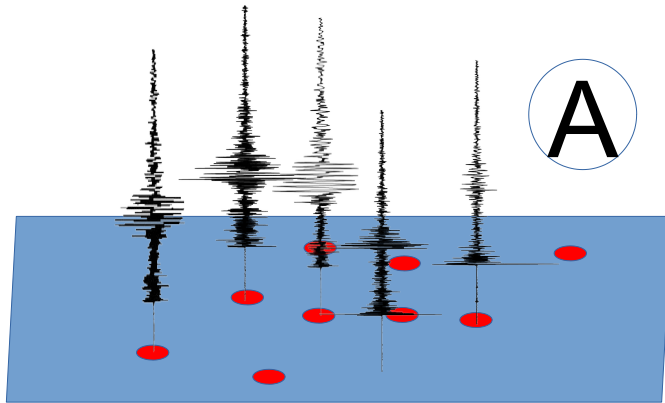
Jozi Najafabadi et al, JGR, 2022



PROVE School #4 GPZ 26-31 May 2024

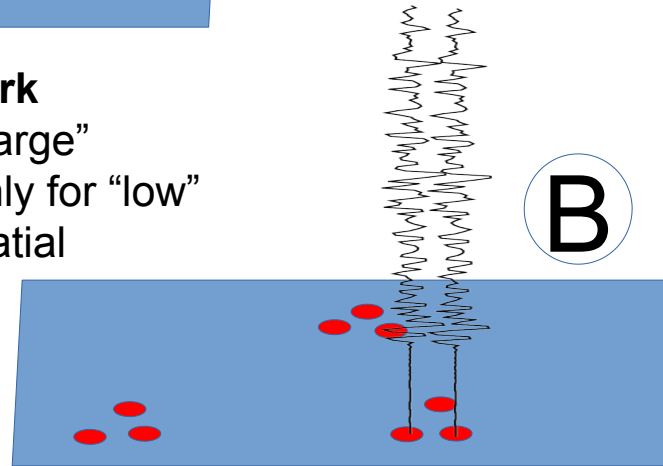


# Typical seismological observation designs



## “Conventional” network

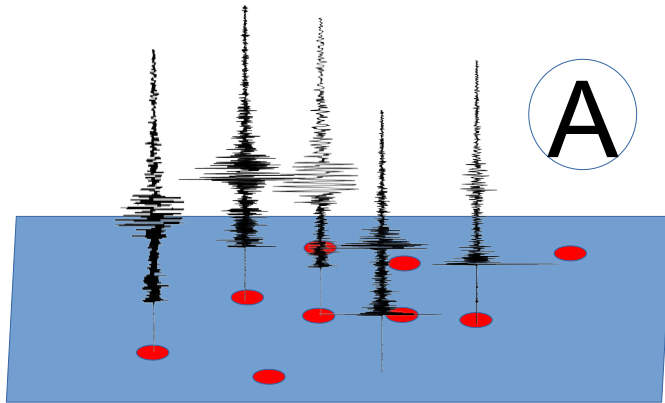
- Interstation distances “large”
- Coherent waveforms only for “low” frequencies (limiting spatial resolution)
- Use e.g. of arrival times (tomography) and/or
- (individual) waveforms



## “Array” approach

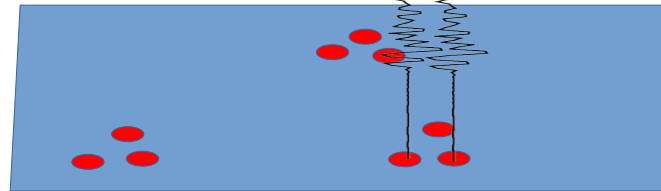
- Interstation distances within array “small”
- Coherent waveforms within array even for “high” frequencies
- Locally use of wavefield (e.g. beamforming)

# Typical seismological observation designs



## “Conventional” network

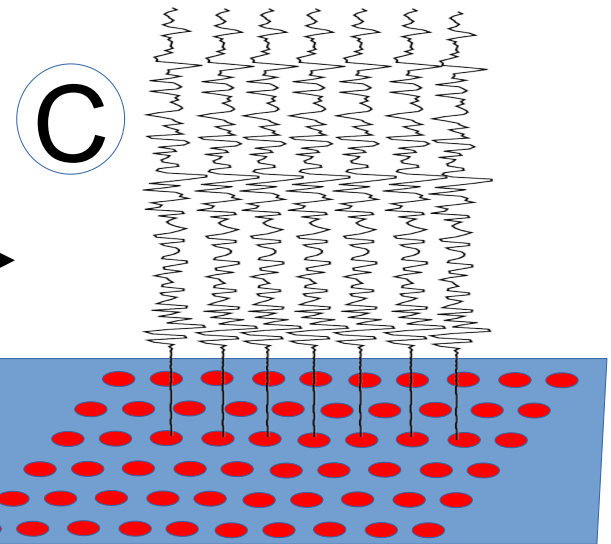
- Interstation distances “large”
- Coherent waveforms only for “low” frequencies (limiting spatial resolution)
- Use e.g. of arrival times (tomography) and/or (individual) waveforms



## “Array” approach

- Interstation distances within array “small”
- Coherent waveforms within array even for “high” frequencies
- Locally use of wavefield (e.g. beamforming)

← frequency/  
wavelength →

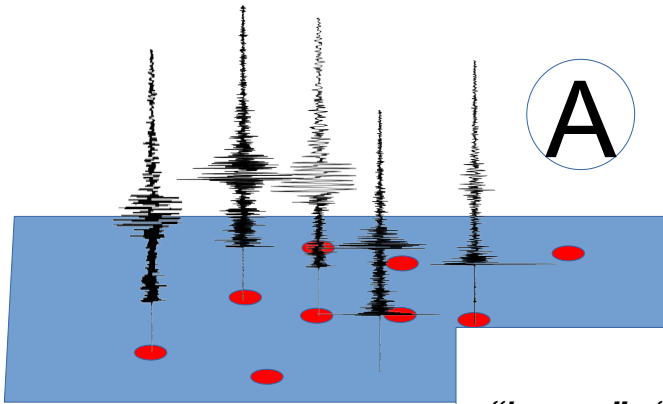


## “Dense” network

- Interstation distances “small”
- **Full wavefield**/coherent waveforms even for “high” frequencies
- **Higher spatial resolution**
- Stacking, migration, imaging, time-reversal, Helmholtz-tomography, waveform/-field inversion...

# Typical seismological observation designs

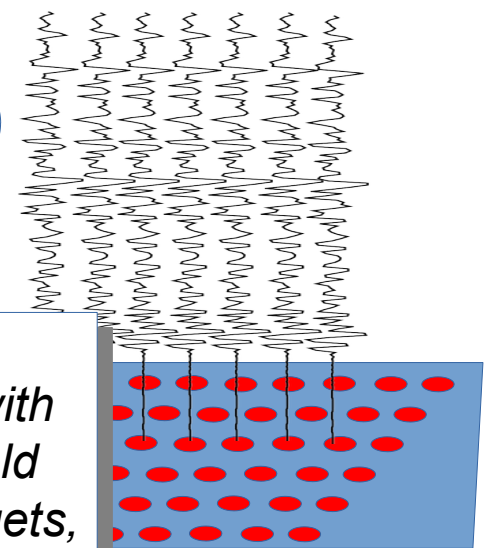
A



## “Conventional” network

- Interstation distances “large”
- Coherent waveforms only at low frequencies (limiting spatial resolution)
- Use e.g. of arrival times (tomography) and/or (individual) waveforms

C

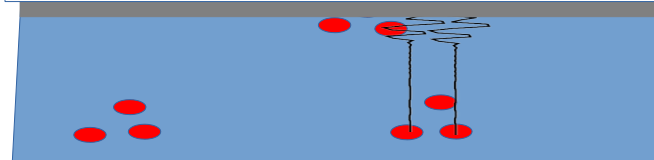


## Full wavefield/coherent network

- Interstation distances “small”
- **Full wavefield/coherent** waveforms even for “high” frequencies
- **Higher spatial resolution**
- Stacking, migration, imaging, time-reversal, Helmholtz-tomography, waveform/-field inversion...

frequency/  
wavelength

*“large”, “dense”, “high” ... in context with coherent spatial sampling of wavefield (depending on signal frequencies, targets, scale)*



## “Array” approach

- Interstation distances within array “small”
- Coherent waveforms within array even for “high” frequencies
- Locally use of wavefield (e.g. beamforming)

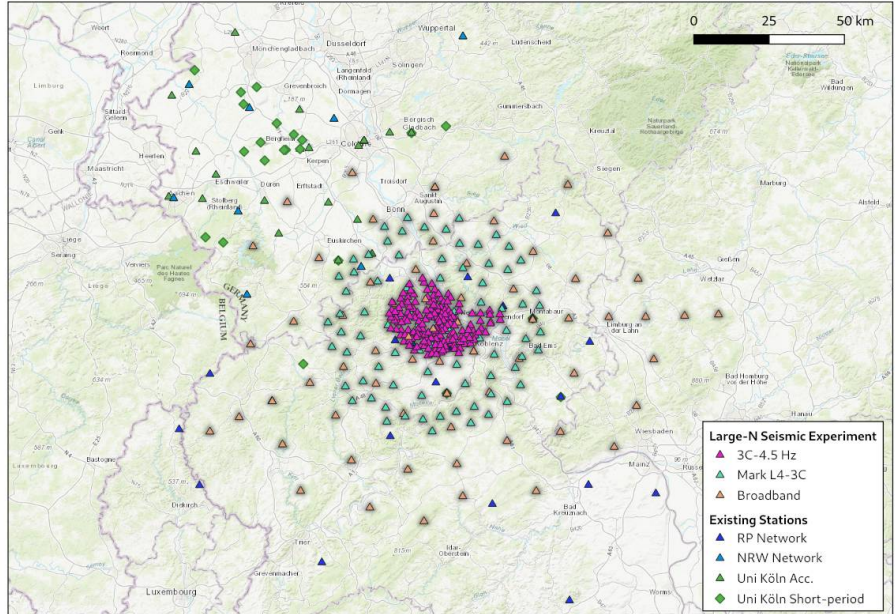


# Typical Studies

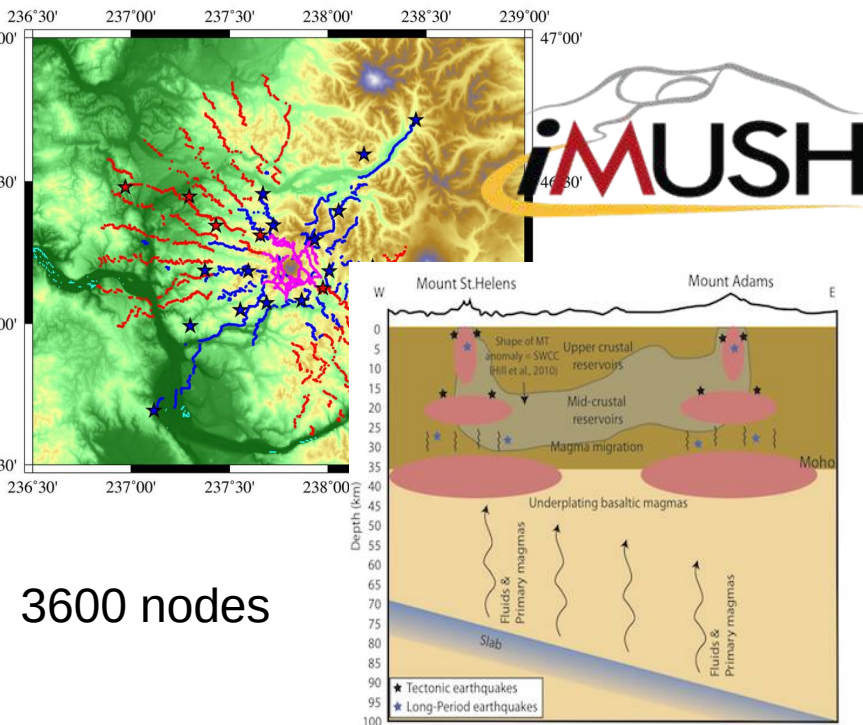
„Large-N“



## EIFEL-LARGE-N (310 SP/BB stations)



Dahm et al., 2022  
([www.gfz-potsdam.de](http://www.gfz-potsdam.de))



<http://imush.org/>

# Geophysical Instrument Pool Potsdam (GIPP)

*Christian Haberland, GFZ*



## Mission:

The „Geophysical Instrument Pool Potsdam“ GIPP of the GFZ provides seismic and magnetotelluric instruments for temporary field experiments.

- Scientific infrastructure since 1993
- Operated by Section 2.2 „Geophysical Imaging“
- For „academic“ research, GFZ + inter-/national loans
- Financed by GFZ
- 6+ staff (scientific + technical)
- Transparent procedures, terms of use, external steering board
- **Next application submission 1. October 202**

# Responsibilities & duties

## **GIPP responsibilities/duties:**

- Supply of seismological/seismic and electromagnetic field equipment
- Packing, preparation
- Maintenance of equipment
- Market/product analysis; purchases
- Guidance/training of users, assistance
- archiving of data (partly with GEOFON)
- Hard- and software-development, company spin-off

**[www.gfz-potsdam.de/gipp](http://www.gfz-potsdam.de/gipp)**



## **User's responsibilities/duties:**

- Field operation
- Transport/shipping/customs
- Permits
- Consumables
- Fully liable (insurance!)
- Data delivery



# GIPP seismic & EM/MT instruments

## Seismic recorders (>1200)



## Land-MT-recorders & sensoren (magnetometers, electrodes; ~80)



## Seismic sensors/ geophones (>1300)



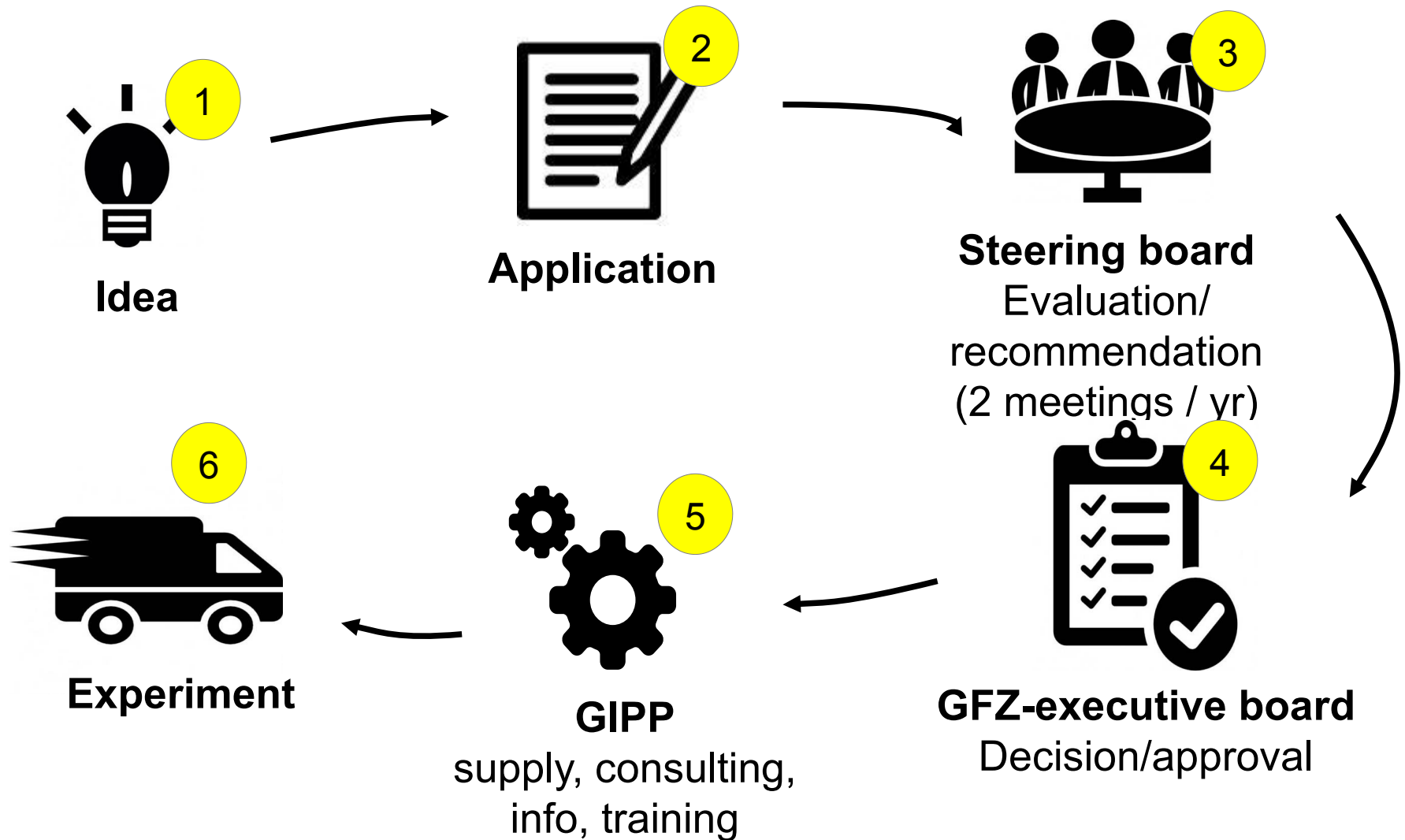
## Seismic-multichannel (>288ch) & sources



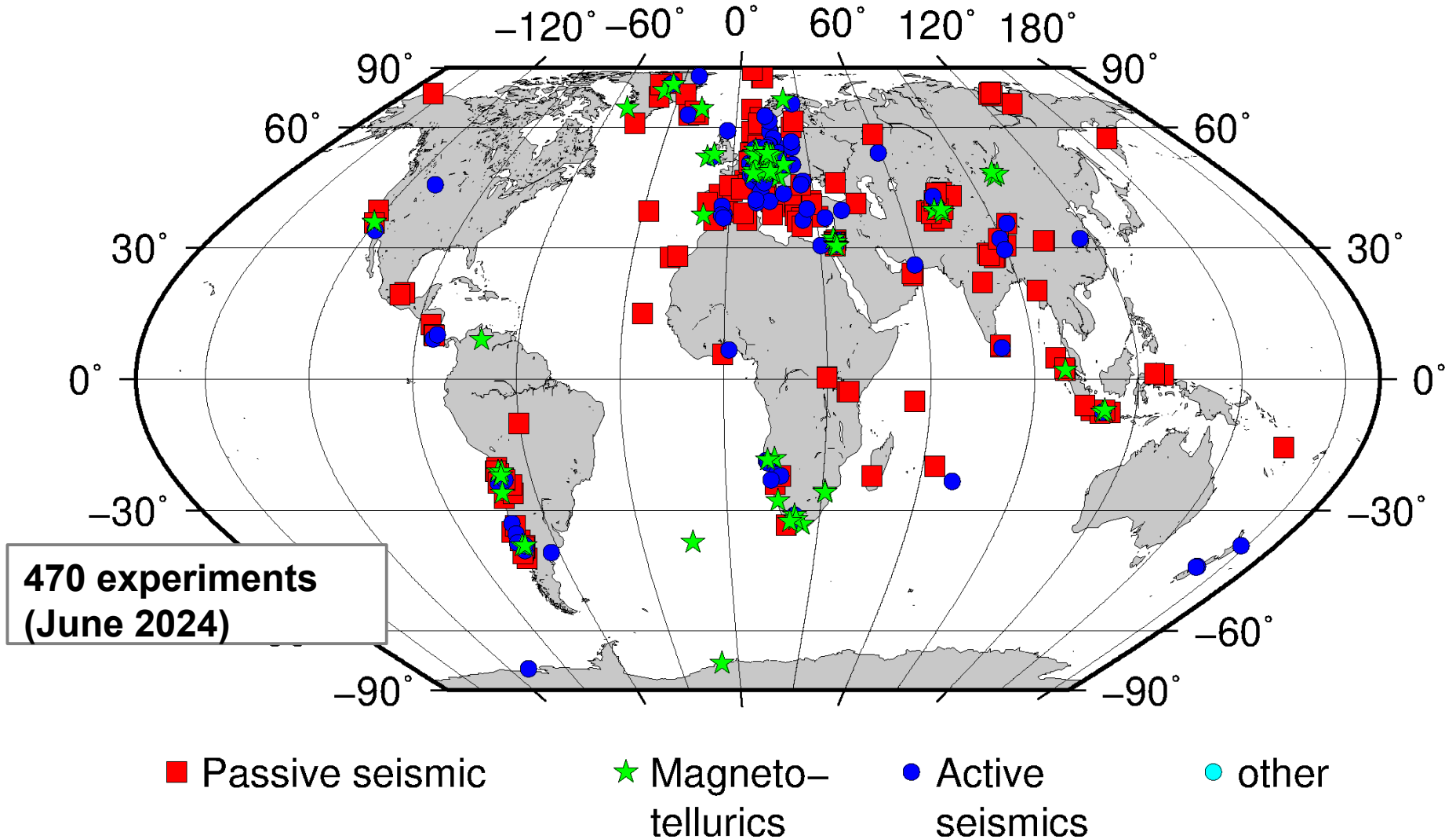
managed by GFZ

[www.gfz-potsdam.de/gipp](http://www.gfz-potsdam.de/gipp)

# Application & supply procedure



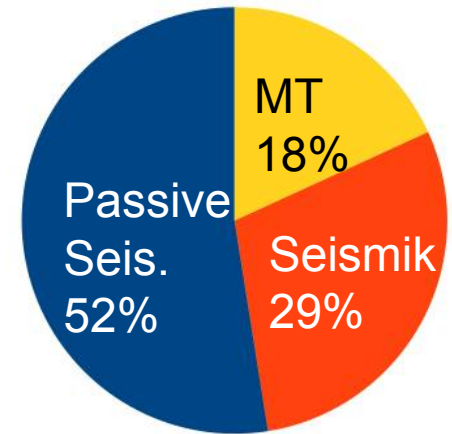
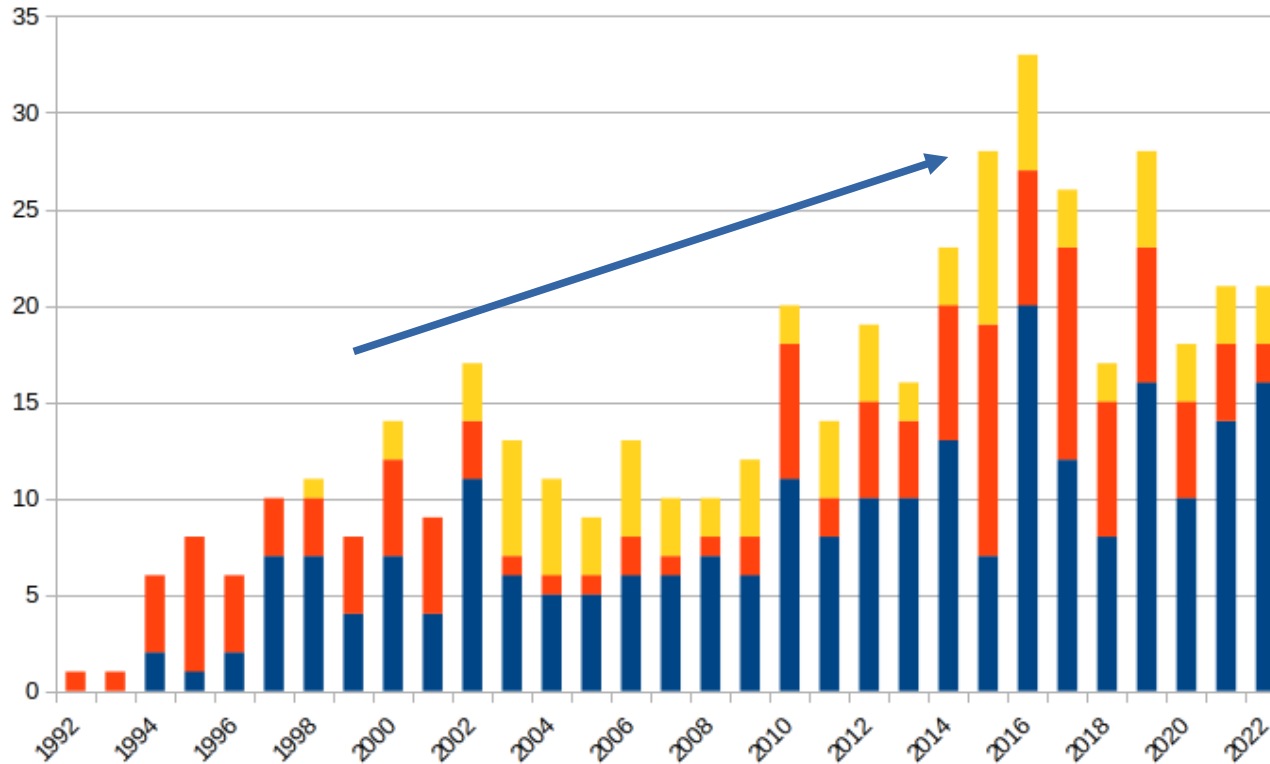
# GIPP-deployments



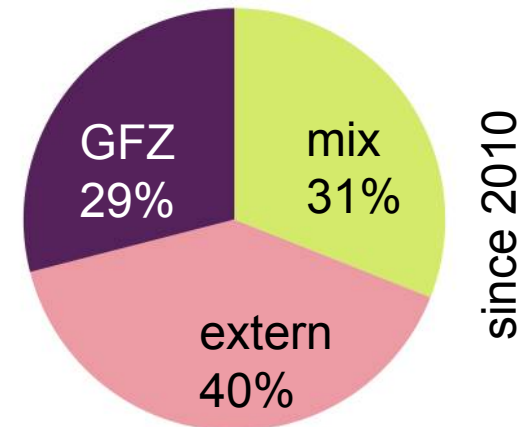


# Usage

New experimente / year



■ MT  
■ Act. Seis.  
■ Pass. Seis.



# Data & Publications

HEIMHOLTZ-ZENTRUM  
POTSDAM

Geophysik / Geophysical Deep Sounding / Infrastructure / Geophysics

GIPP Experiment Database

HEIMHOLTZ-ZENTRUM POTSDAM  
DEUTSCHES  
GEOFORSCHUNGSZENTRUM

Grand Number

Experiment Name

find in Abstract

Experiment type


Program

Person

Institute

Time Range  -

Has Data? ☐



Leaflet/Map data © OpenStreetMap contributors, Imagery © OpenStreetMap contributors

Experiment type:

☐ passive seismology

☐ controlled source seismology

☐ magnetotelluric / electromagnetic

Data:

☐ Data with DOI

☐ Data without DOI

Number of Results: 407

[Previous](#)
[1](#)
[2](#)
[3](#)
[4](#)
[5](#)
[6](#)
[7](#)
[8](#)
[9](#)
[Next](#)

Mark L4C-3D 1Hz Geophone 3-C

Instrument category: Seismic sensors Short period sensors (1-20s) Mark L4C-3D 1Hz Geophone 3-C

Code	HS-3006
Inventory	0224
Serial	3006
Location	FRG
Status	OK
Delivery date	2003-12-17
Type	3CH-1Hz
Condition	
Calibration	
Owner	GDG
Instrument category	Mark L4C-3D 1Hz Geophone 3-C
Manufacturer	Sennelager
Customization	
Drushine	no
Mount	no

20° Cube3

5° cube3 extern

22° Mark L4C

35° EDL

87° 70kN Compant

60° EDL

Related Projects

201605 - SIOA

2016-04-01 - 2018-12-31

By: Wilhelm Gaiser, Frank Krüger, Christen

201401 - LOFS

2014-02-20 - 2015-07-31

By: Steffen Langer, Axel Carlsbauer

201224 - SanCort

2010-10-09 - 2018-05-09

By: Joanna Morgan, Kai Wümmers, Feride Hocht, Costas Papageorgiou, Mike Warner

Instrument-  
database

- 🎬 Data policy
- 🎬 Archivierung bei GEOFON oder GIPP

File Edit View History Bookmarks Tools Help ... Publikationen - Cswsweat

Startseite ... Telegraf... .. Nutzung... .. Dokumente... .. Dokumente... .. Publikation... .. Publikati...

gfzpublic.gfz-potsdam.de/gfzpublic/years/docs/Query-ecidoc-any.org Google

Most Visited ... Getting Started ... Latest Headlines ... Search result as f...

Publikationen  
Helmholtz-Zentrum Potsdam  
Deutsches GeoForschungsZentrum - GFZ

[Zeitschriftenmarkt (SCS/Scopus Zeitschriften) [24] | Zeitschriftenmarkt (Gestaltung Zeitschriften) [56] | Buchkapitel [25] | Konferenzbeitrag [10] | Bericht [9] | ...]

**Leiterschienenmarkt (SCS/Scopus Zeitschriften)**

2014-06-13

- Brauer, B., Asch, G., Hofstetter, P., Haberland, C., Jaser, D., El-Kenali, R., Weber, M. (2014 online): Detailed seismicity analysis revealing the dynamics of the southern Dead Sea area - *Journal of Seismology* [GFZpublic | <http://dx.doi.org/10.1007/s10959-014-9441-4>] [U]

2014

- Graves, A., Streich, P., Ritter, O. (2014): 3D inversion and resolution analysis of land-based CSEM data from the Katin storage form' *Geophysics*, 79, 2, p. E101-E114. [GFZpublic | <http://dx.doi.org/10.1199/gsg2013-0184-1>] [U]
- Moreno, M., Haberland, C., Oncken, O., Rietbrock, A., Angbauts, S., Heidbach, O. (2014): Locking of the Chile subdu' by fluid pressure before the 2010 earth-quake - *Nature Geoscience*, 7, p. 292-296. [GFZpublic | <http://dx.doi.org/10.1038/ngeo1588>] [U]
- Sak, P., Ritter, O., Patschschaler, L., Tynpel, J., Matukov, V. E., Pybom, A. K., Batalev, V. Y. (2014): Resis' and Southern Tian Shan - *Geophysical Journal International*, 198, p. 564-579. [GFZpublic | <http://dx.doi.org/10.1093/gjg/ggu141>] [U]

2013

- Bohm, M., Haberland, C., Asch, G. (2013): Imaging fluid-related subduction processes' using seismic attenuation tomography. *Technophysicon*, 506, p. 175-188. [GFZpublic | <http://dx.doi.org/10.1016/j.tech.2013.05.021>] [U]
- Elkin, T., Timmer, F., Machie, J., Zhao, W., Kind, R., Su, H., Xue, G. J' *Geophysical Journal International*, 192, p. 1021-1031. [GFZpublic | <http://dx.doi.org/10.1093/gjg/ggt20130054>] [U]
- Karipis, M. S., Klemessov, S. L., Lawrence, J. F., Zha' north Tectonics limits geological tectonic signature to' *Geophysical Research Letters*, 40, 5, p. 808-813. [GFZpublic | <http://dx.doi.org/10.1029/2012GL052022>] [U]
- Kawliani, A., Hofstetter, R., Pümpker, G. networks of broadband stations' *Geophysical Research Letters*, 40, 5, p. 3476-3491. [GFZpublic | <http://dx.doi.org/10.1029/2012GL052022>] [U]
- Machie, J., Kind, R. G' *Geophysical Journal International*, 192, p. 1021-1031. [GFZpublic | <http://dx.doi.org/10.1093/gjg/ggt20130054>] [U]
- Machie, J., Ben-A, Arabian plate and s' *Geophysical Journal International*, 192, p. 1415-1431. [GFZpublic | <http://dx.doi.org/10.1093/gjg/ggt20130054>] [U]
- Moghe, H., Ritter, O., DESPER Group (2013): A magnetotelluric transect across the Dead Sea Basin: electrical properties of geological and hydrological units of the upper crust - *Geophysical Journal International*, 193, 3, p. 1415-1431. [GFZpublic | <http://dx.doi.org/10.1093/gjg/ggt20130054>] [U]

2565 GIPP-PUBLICATIONS

[gipp.gfz-potsdam.de](http://gipp.gfz-potsdam.de)  
[www.gfz-potsdam.de/gipp](http://www.gfz-potsdam.de/gipp)

[illegible]

# Conclusions

- Seismological equipment (sensors & recorders) powerful instruments for seismological experiments
- Seismological experiments most powerful for imaging Earth's structure and processes
- Wide range of different instruments (from broadband to geophone) for different purposes
- Necessary for passive seismological observations (eq, ambient noise) and controlled source seismology
- Geophysical instrument pool provides instruments for temporary experiments

**[www.gfz-potsdam.de/gipp](http://www.gfz-potsdam.de/gipp)**