- Seismic networks, data centres, instruments
- Seismic Observables and their interrelations
- Seismic data acquisition parameters (sampling rates, dynamic range)

# Global seismic networks



### Regional seismic networks



Data centres and observables

# Local seismic networks



# Temporary (campaign) networks

EarthScope Instruments - Updated at 9:18 GMT Wednesday May 6, 2009

Click <u>here</u> to display table for all stations shown on this map



### Arrays



### Figure 6.6-20: Hypothetical seismometer locations for the proposed USArray.

Figure 6.6-17: Station geometry of the Large Aperture Seismic Array (LASA).



What could be the advantages of array recordings?

Data centres and observables

### Seismic arrays



# Seismic arrays





Data centres and observables

### Seismic data centres: NEIC

😻 National Earthquake Inforr	rmation Center - NEIC - Mozilla Firefox			
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International Registry of Seismograph Stations	The mission of the National Earthquake Information Center (NEIC) is to determine rapidly the location and size of all destructive earthquakes worldwide and to			
Routine U.S. Mining Seismicity	y immediately disseminate this information to concerned national and international	47.64		
Tour Information	and maintains an extensive, global seismic database on earthquake parameters and			
Who We Are	their effects that serves as a solid foundation for basic and applied earth science			
Contact Us	research. Please visit the World Data Center web site to learn more about the WDC			
	system.			
	Earthquake Data Available from the NEIC			
	<u>Current Worldwide Earthquake List</u>			
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### Seismic data centres: ORFEUS



### Seismic data centres: IRIS

![](_page_10_Picture_1.jpeg)

#### Data centres and observables

# Seismic data centres: ISC

![](_page_11_Picture_1.jpeg)

## Seismic data centres: GEOFON

🕲 GEOFON Data Archive Information - Mozilla Firefox			
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Scope The GFZ Seismological Data Archive holds data from many permanent networks - primarily from the GEOFO partner networks, the part of the <u>GEVN - GEOFON Extended Virtual Network</u> for which GFZ acts as back well as from temporary deployments. (Near) real-time data streams from permanent networks are mostly com accessible on request from the archive or continuously by <u>SeedLink</u> real-time data feeds from the open GEOF European networks are members of the <u>Virtual European Broadband Seismic Network</u> (VEBSN). Data from restricted to the project consortium until it gets released for public use. Although most data sets are derived fro amount of short period data is archived as well as some strong motion and OBS data. All data sets are access provisional web forms or by email. Moreover, the GFZ Seismological Data Archive is linked by GFZ's ArcLin Germany (German Integrated Data Archive - GIDA) and Europe (European Integrated Data Archive - EIDA granted simultaneously.	DN network, but also from many GEOF up archive and data distribution center - ning in over Internet. It is immediately FON SeedLink server. Most of the acqu a recent temporary networks is usually om broad band stations, also a substantia sable jointly in a unified way through nk protocol to other partner data centers ) where access to all data archives is	ON as ired 1 in	
The GFZ Seismological Data Archive is			
<ul> <li>the archive for the permanent GEOFON VBB network,</li> <li>the backup archive for the GEOFON partner networks,</li> <li>the archive for the passive seismological experiments of the GFZ Geophysical Instrument Pool Potsdam</li> <li>the archive for the German Task Force Earthquake (data archival pending),</li> <li>the main node in the German Integrated Data Archive (GIDA),</li> </ul>	a (GIPP),		
• a major node in the European Integrated Data Archive (EIDA),		×	

### EMSC

![](_page_13_Picture_1.jpeg)

Data centres and observables

### Seismic data centres: EarthScope

![](_page_14_Picture_1.jpeg)

Data centres and observables

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Data © 2009 MIRC/JHA

![](_page_15_Picture_1.jpeg)

- Sound 0.001 0.01 s
- Earthquakes 0.01 100 s (surface waves, body waves)
- Eigenmodes of the Earth 1000 s
- Coseismic deformation 1 s 1000 s
- Postseismic deformation +10000s
- Seismic exploration 0.001 0.1 s
- Laboratory signals 0.001 s 0.000001 s
- -> What are the consequences for sampling intervals, data volumes, etc.?

**Translational motions** are deformations in the direction of three orthogonal axes. Deformations are usually denoted by **u** with the appropriate connection to the strain tensor (explained below).

Each of the orthogonal motion components can be measured as displacement u, velocity v, or acceleration a.

The use of these three variations of the same motion type will be explained below.

![](_page_17_Figure_4.jpeg)

Displacements are measured as "differential" motion around a reference point (e.g., a pendulum). The first seismometers were pure (mostly horizontal) displacement sensors. Measureable *co-seismic* displacements range from *microns to dozens of meters* (e.g.,Great Andaman earthquake).

Horiztonal displacement sensor (ca. 1905). Amplitude of ground deformation is mechanically amplified by a factor of 200.

Today displacements are measured using GPS sensors.

![](_page_18_Figure_4.jpeg)

### Seismic observables: translations - displacements

### Data example: the San Francisco earthquake 1906, recorded in Munich

![](_page_19_Figure_2.jpeg)

Most seismometers today record *ground velocity*. The reason is that seismometers are based on an electro-mechanic principle. An electric current is generated when a coil moves in a magetic field. The electric current is proportional to ground velocity v.

Velocity is the time derivative of displacement. They are in the range of µm/s to m/s.

$$v(x,t) = \partial_t u(x,t) = \dot{u}(x,t)$$

![](_page_20_Picture_4.jpeg)

Strong motions (those getting close to or exceeding Earth's gravitational acceleration) can only be measured with accelerometers. Accelerometers are used in earthquake engineering, near earthquake studies, airplanes, laptops, ipods, etc. The largest acceleration ever measured for an earthquake induced ground motion was 40 m/s<sup>2</sup> (four times gravity, see *Science* 31 October 2008: Vol. 322. no. 5902, pp. 727 – 730)

$$a(x,t) = \partial_t^2 u(x,t) = \ddot{u}(x,t)$$

![](_page_21_Picture_3.jpeg)

Data centres and observables

### Displacement, Velocity, Acceleration

# Figure 6.6-14: Relation between displacement, velocity, and acceleration in the time domain.

![](_page_22_Figure_2.jpeg)

### Seismic observables: strain

Strain is a tensor that contains 6 independent linear combinations of the spatial derivatives of the displacement field. Strain is a purely geometrical quantity and has no dimensions.

![](_page_23_Figure_2.jpeg)

Measurement of differential deformations involves a spatial scale (the length of the measurement tube).

What is the meaning of the various elements of the strain tensor?

Strain components (2-D)

![](_page_24_Figure_2.jpeg)

### Seismic observables: rotations

![](_page_25_Figure_1.jpeg)

- Rotation is a vectorial quantity with three independent components
- At the Earth's surface rotation and tilt are the same
- Rotational motion amplitudes are expected in the range of 10<sup>-9</sup> – 10<sup>-3</sup> rad/s
- Rotations are only now being recorded
- Rotations are likely to contribute to structural damage

![](_page_26_Picture_6.jpeg)

Tilt is the angle of the surface normal to the local vertical. In other words, it is rotation around two horizontal axes. Any P, SV or Rayleigh wave type in layered isotropic media leads to tilt at the Earth's free surface. In 3-D anisotropic media all parts of the seismic wave field may produce tilts.

Other causes of tilt:

- Earth tides
- Atmospheric pressure changes
- Soil deformation (water content)
- Temperature effects
- Mass movements (lawn mower, trucks, land slides)

$$\Theta(x,t) = \partial_x u_z$$

- Translations are the most fundamental and most widely observed quantity (standard seismometers)
- Translation sensors are sensitive to rotations!
- Tilt measurements are sensitive to translations!
- Really we should be measuring all 12 quantities at each point (cool things can be done with collocated observations of translation, strains and rotations)