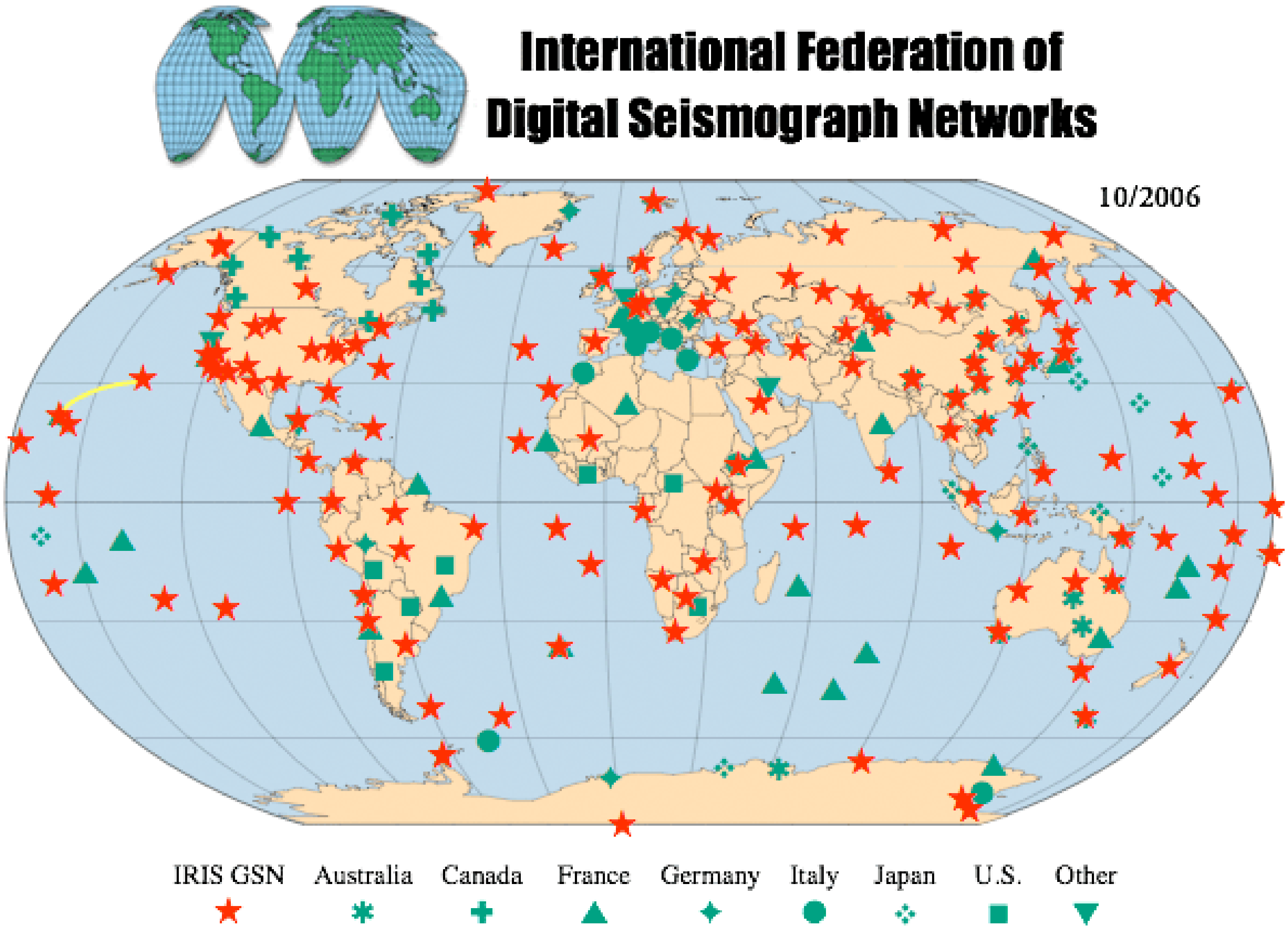
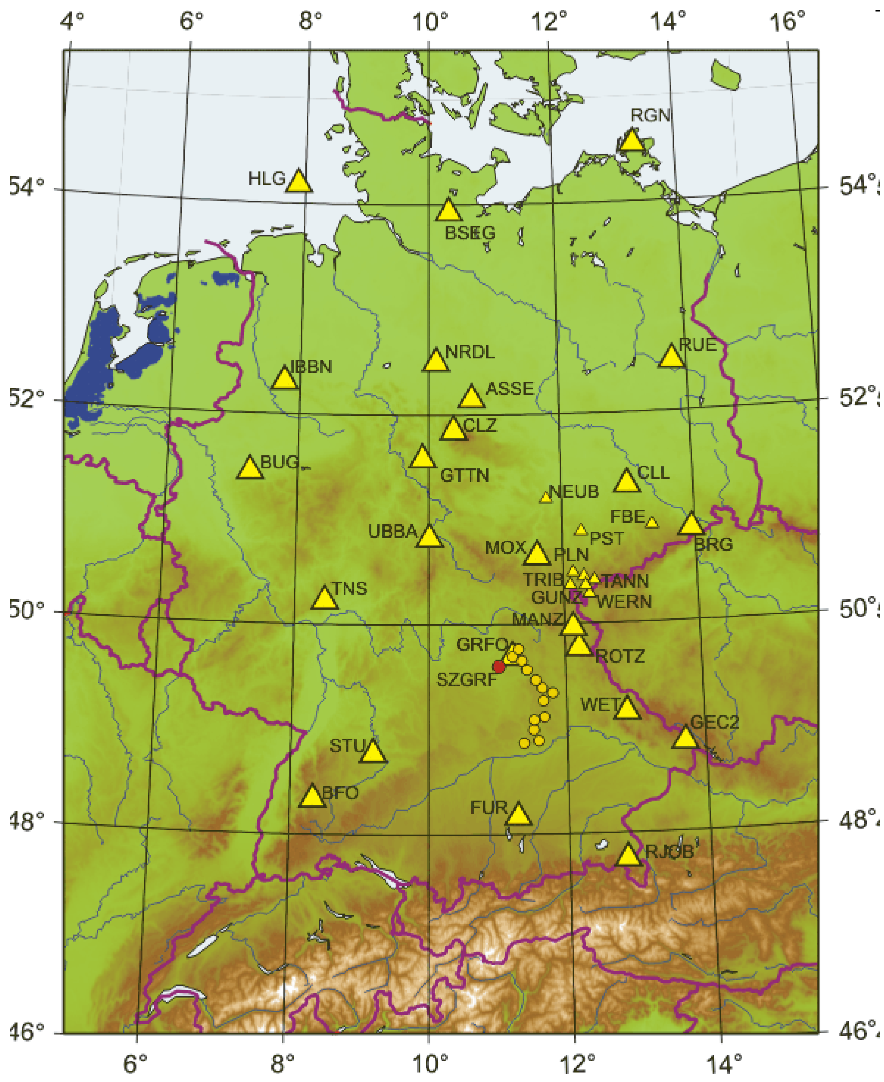
Data in seismology: networks, instruments, current problems

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

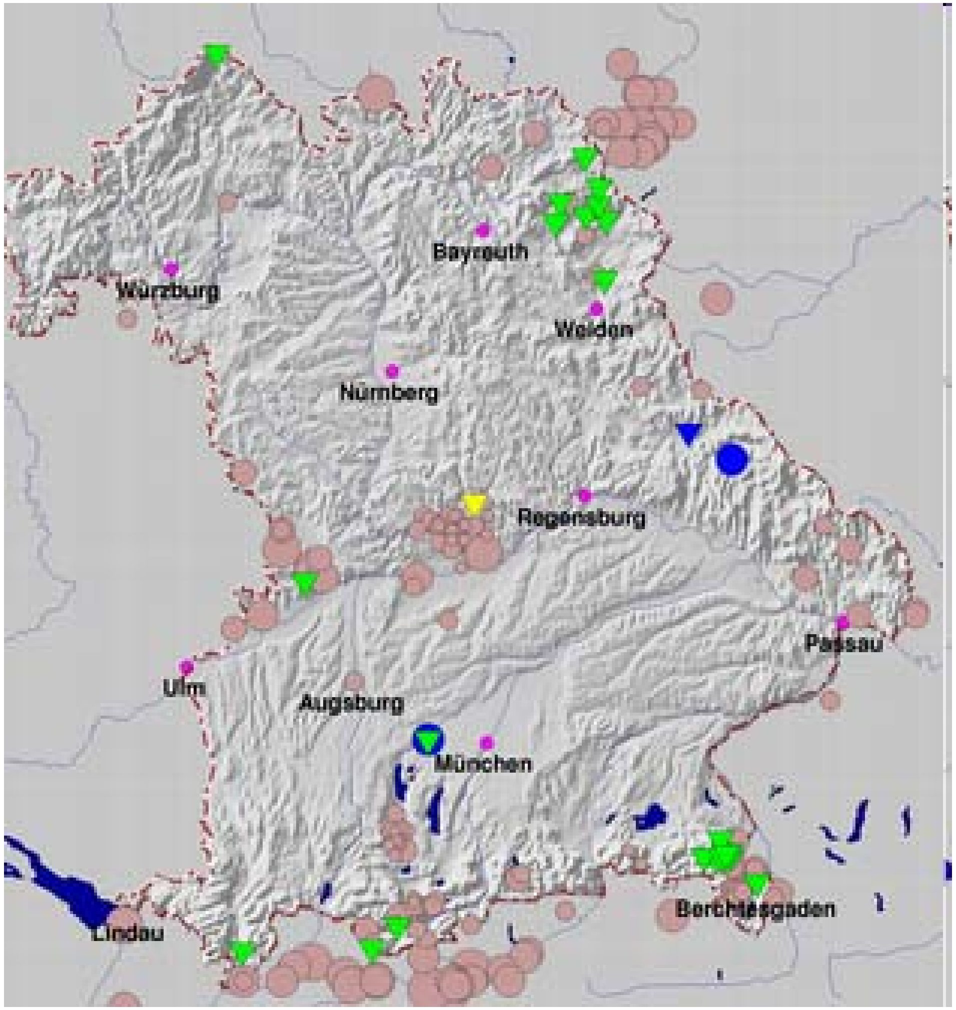
Global seismic networks



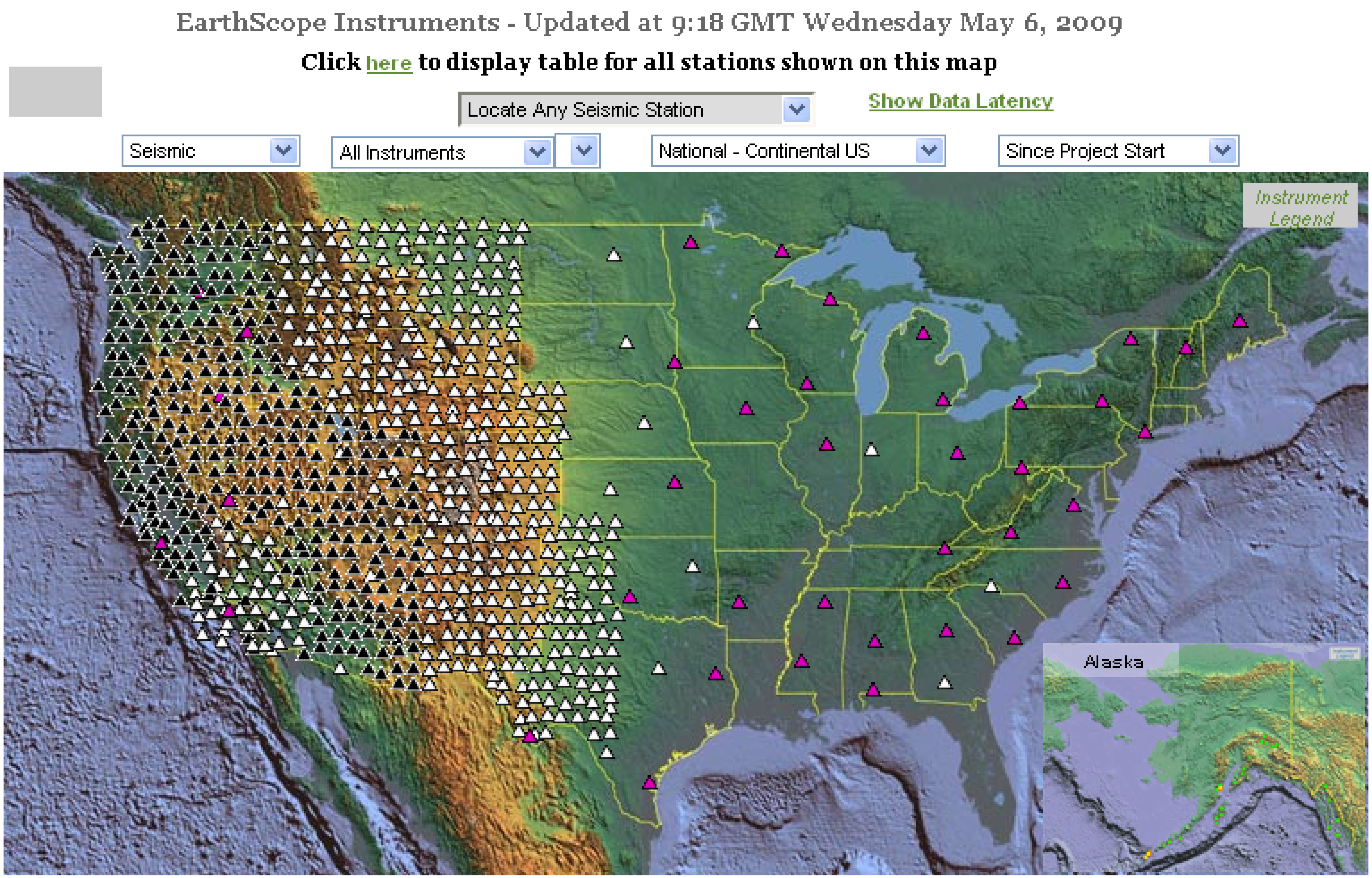
Regional seismic networks



Local seismic networks



Temporary (campaign) networks



Arrays

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

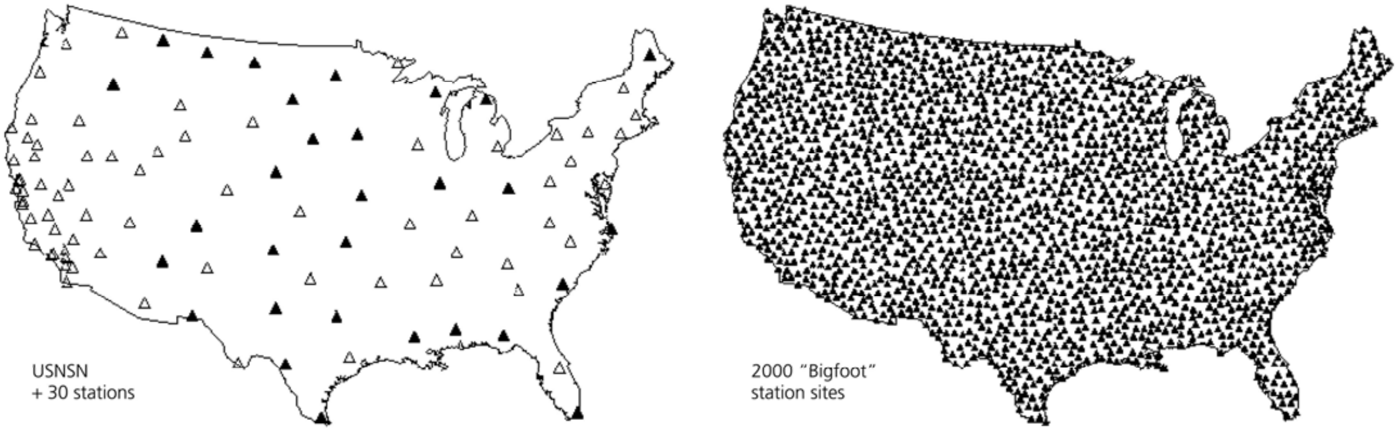
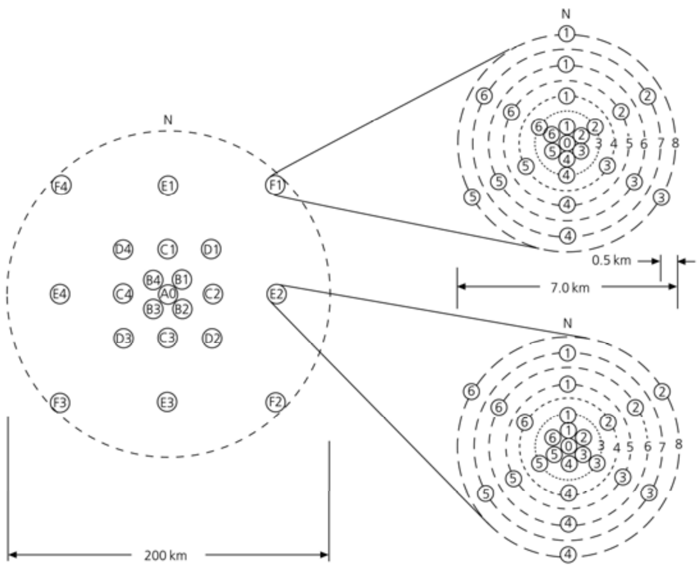
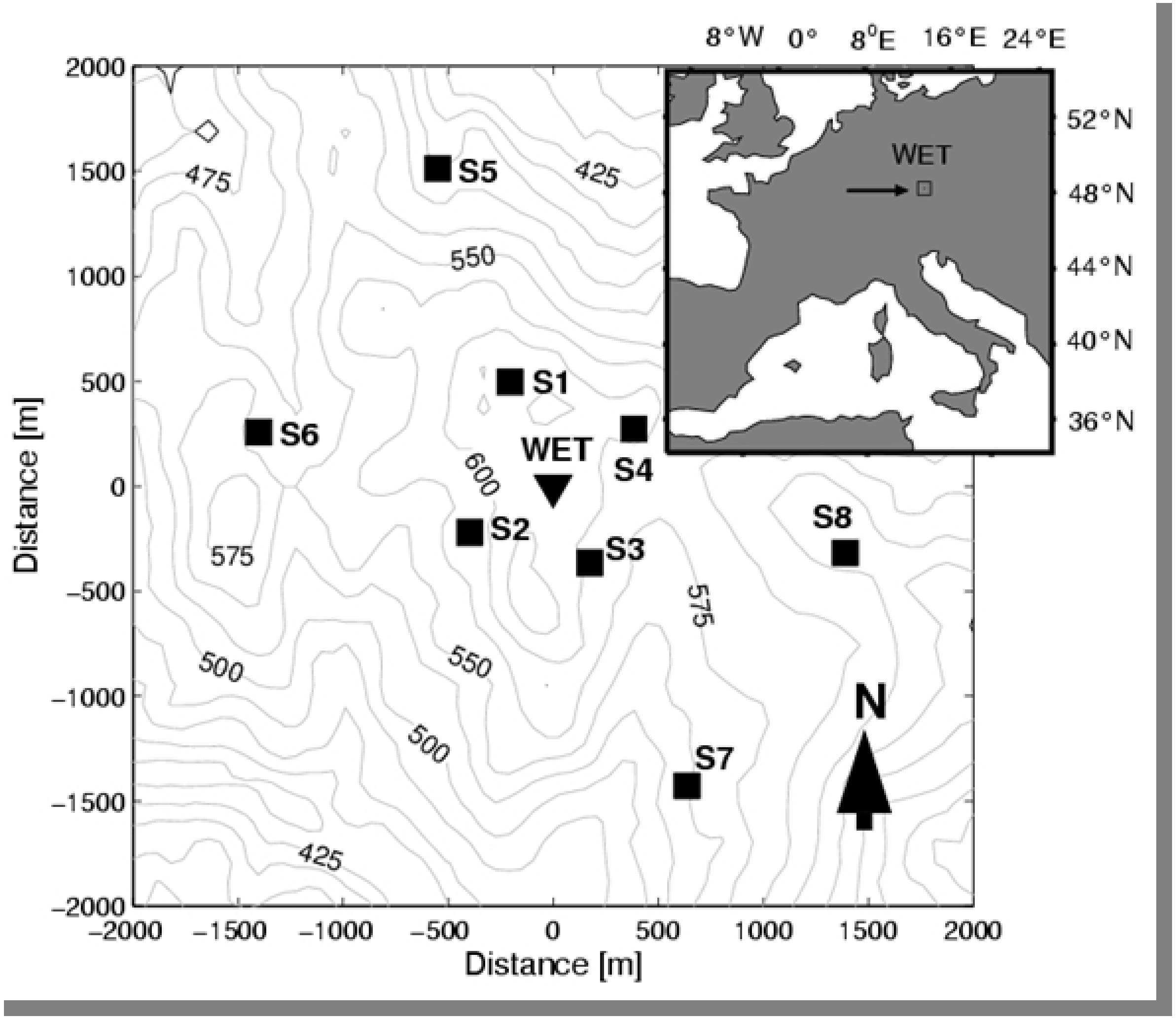


Figure 6.6-17: Station geometry of the Large Aperture Seismic Array (LASA).

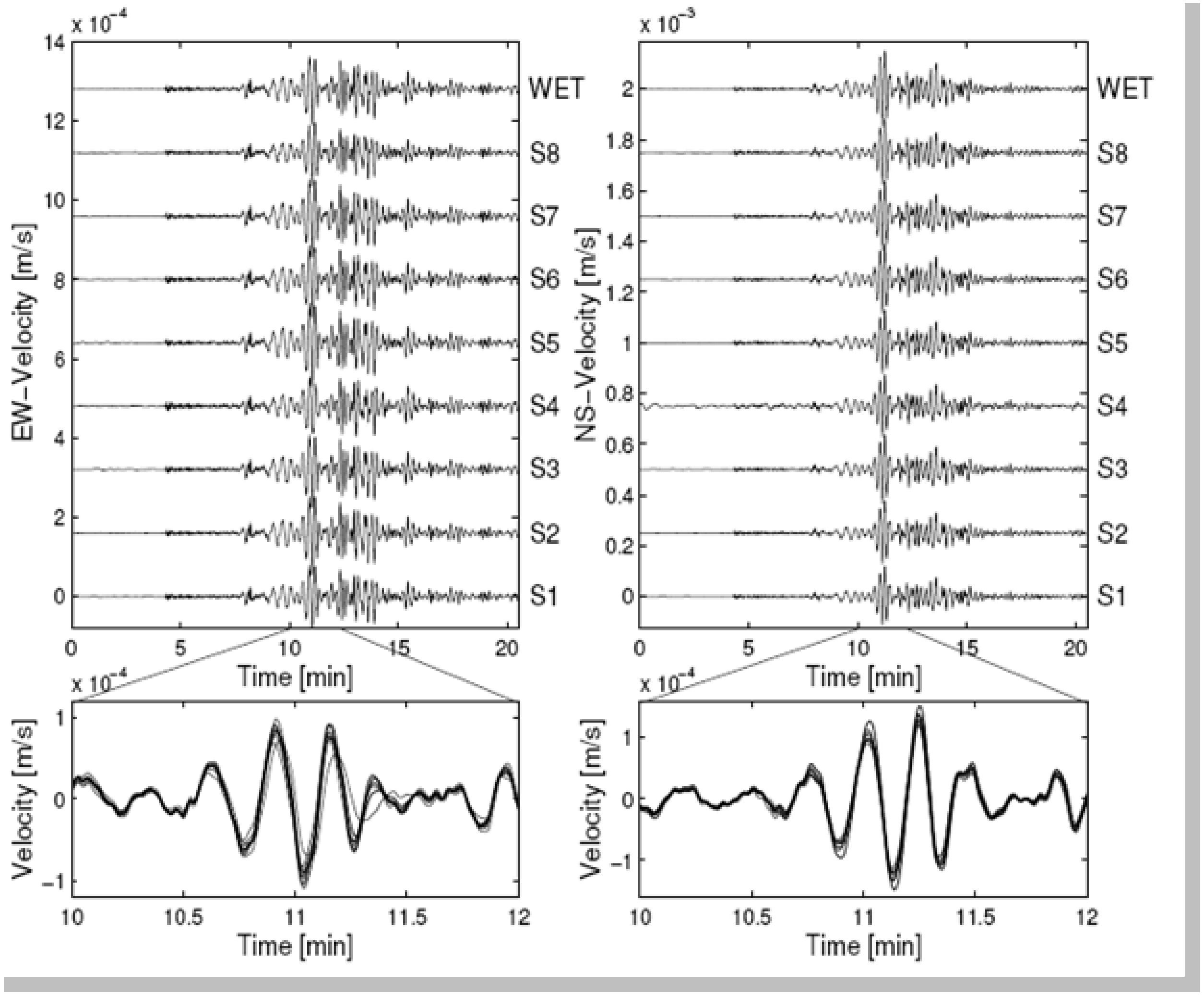


What could be the advantages of array recordings?

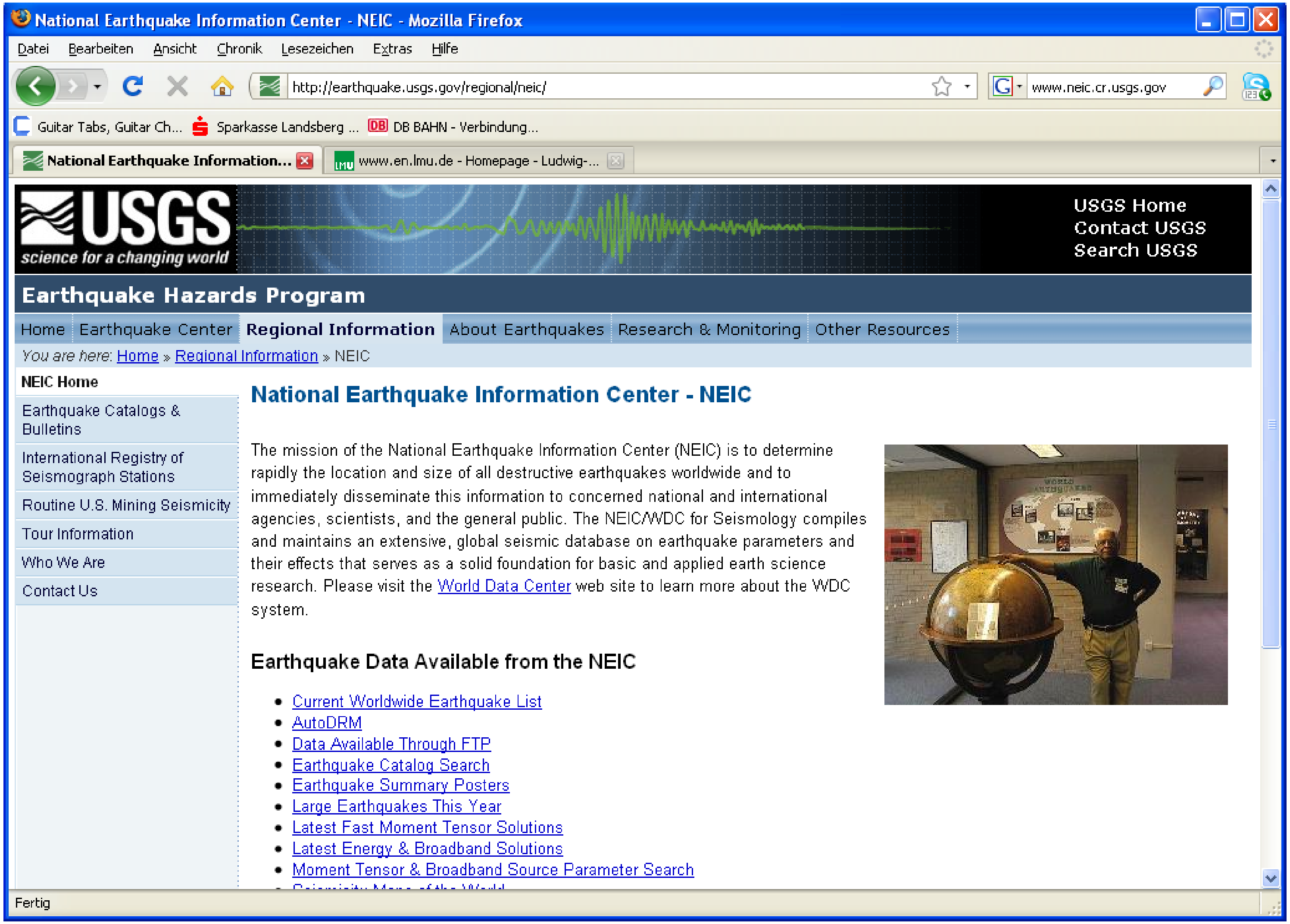
Seismic arrays



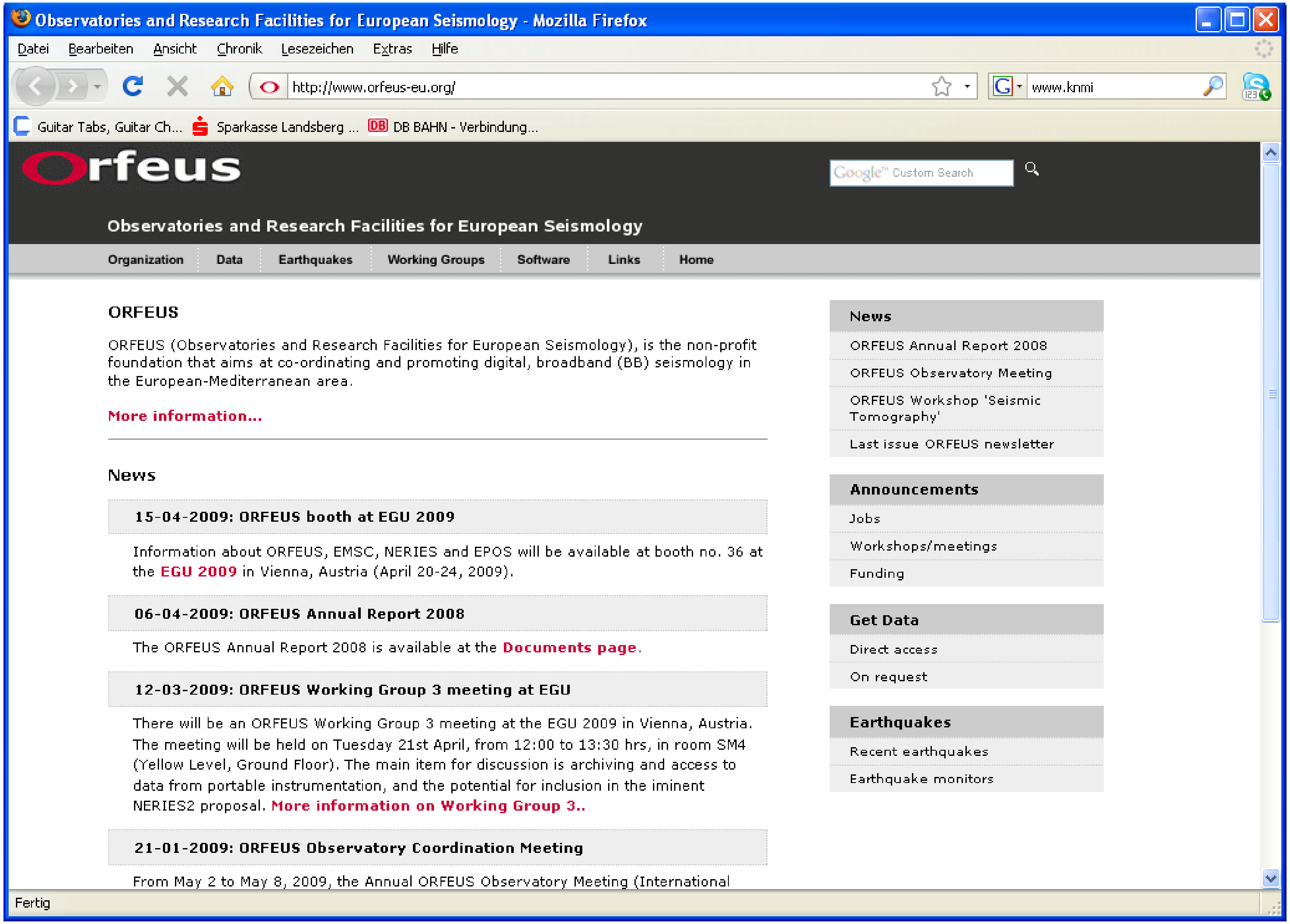
Seismic arrays



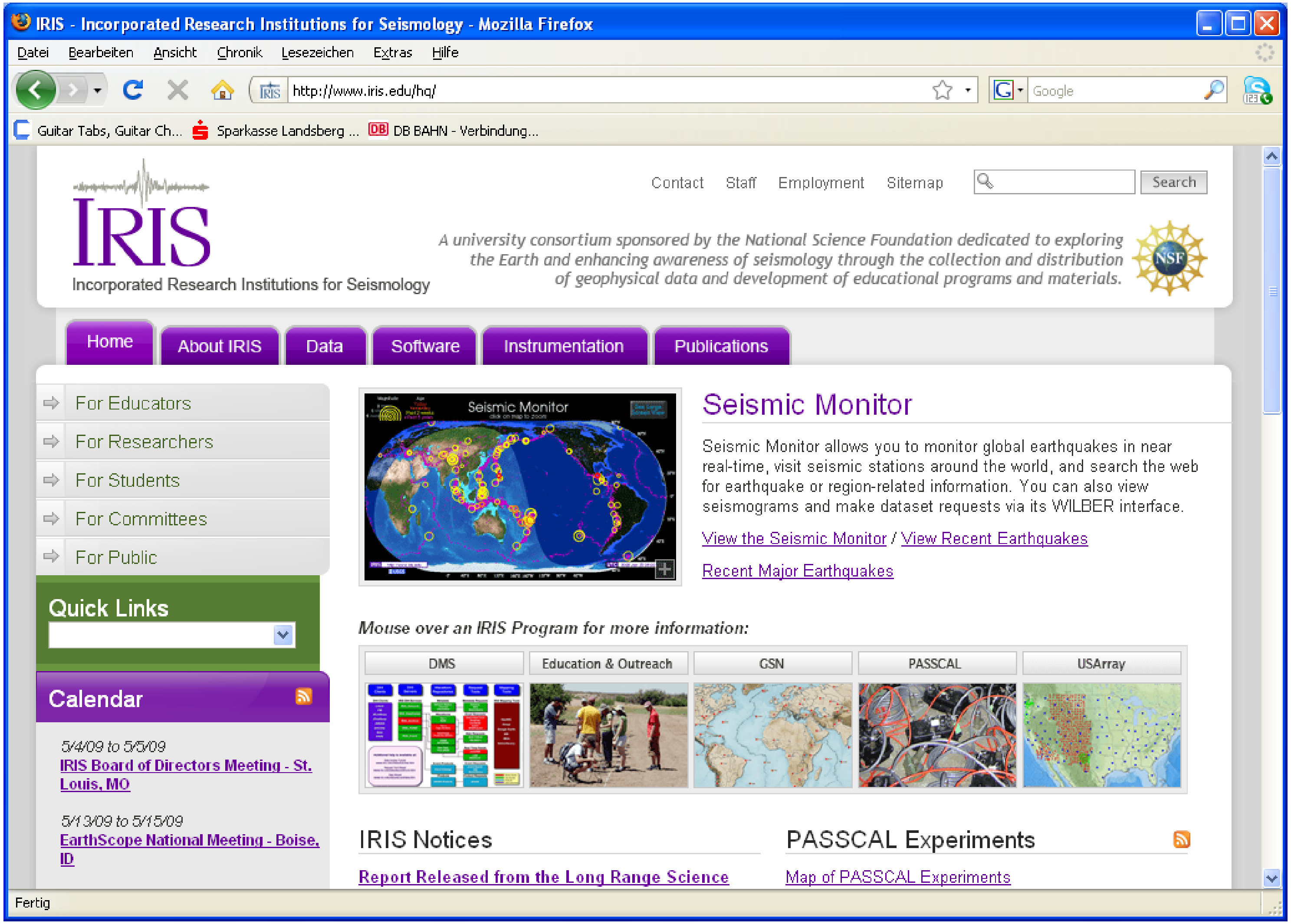
Seismic data centres: NEIC



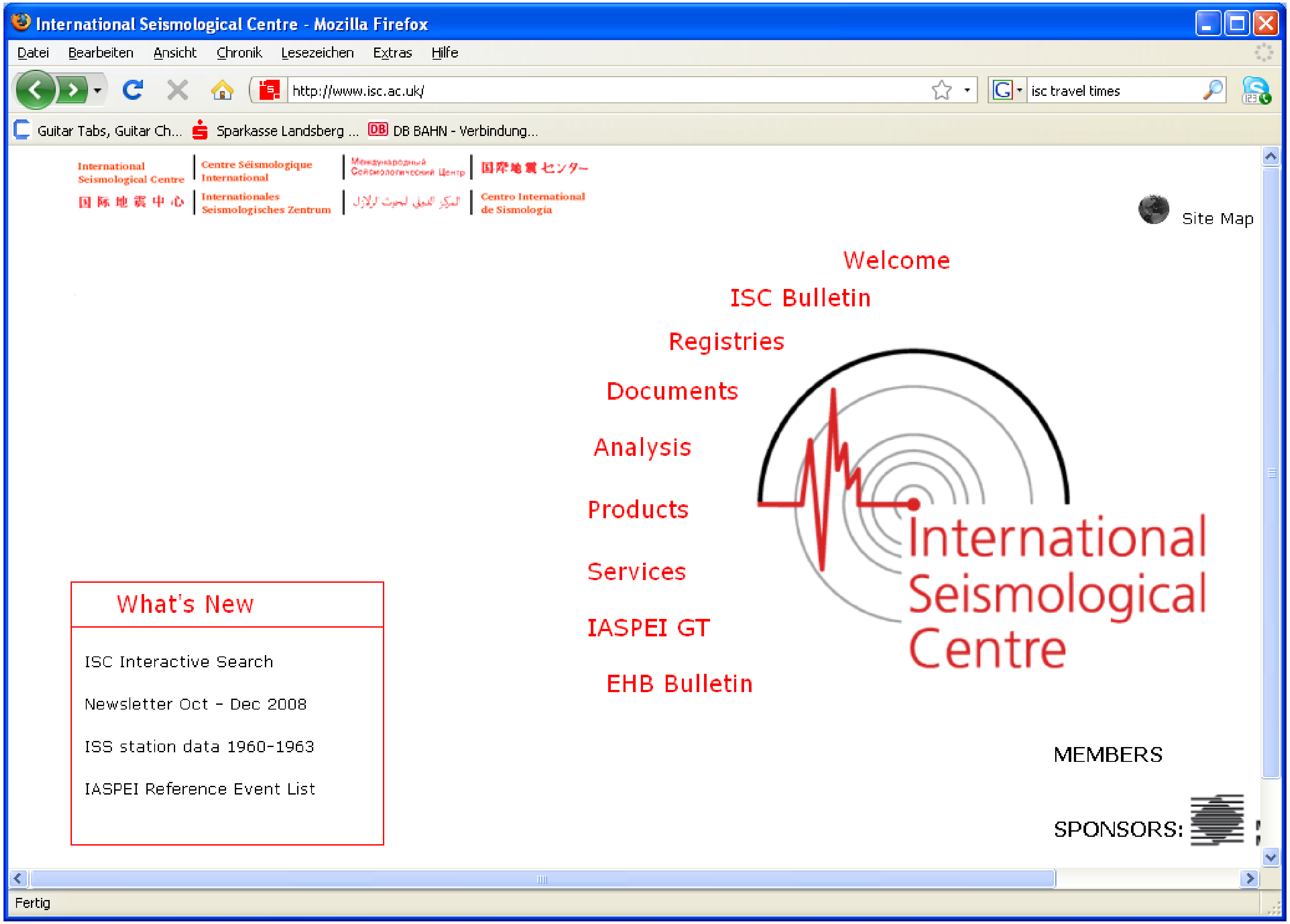
Seismic data centres: ORFEUS



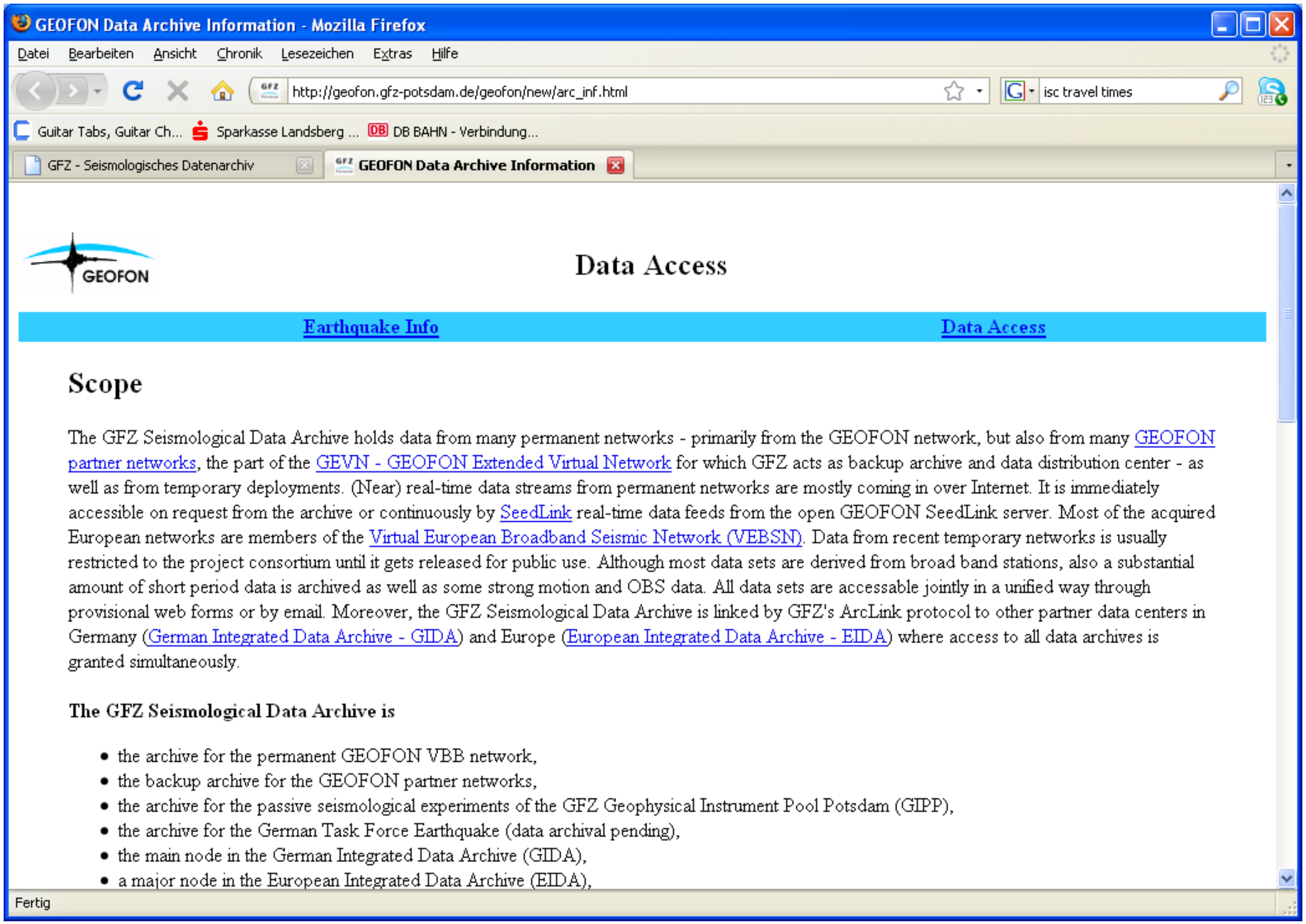
Seismic data centres: IRIS



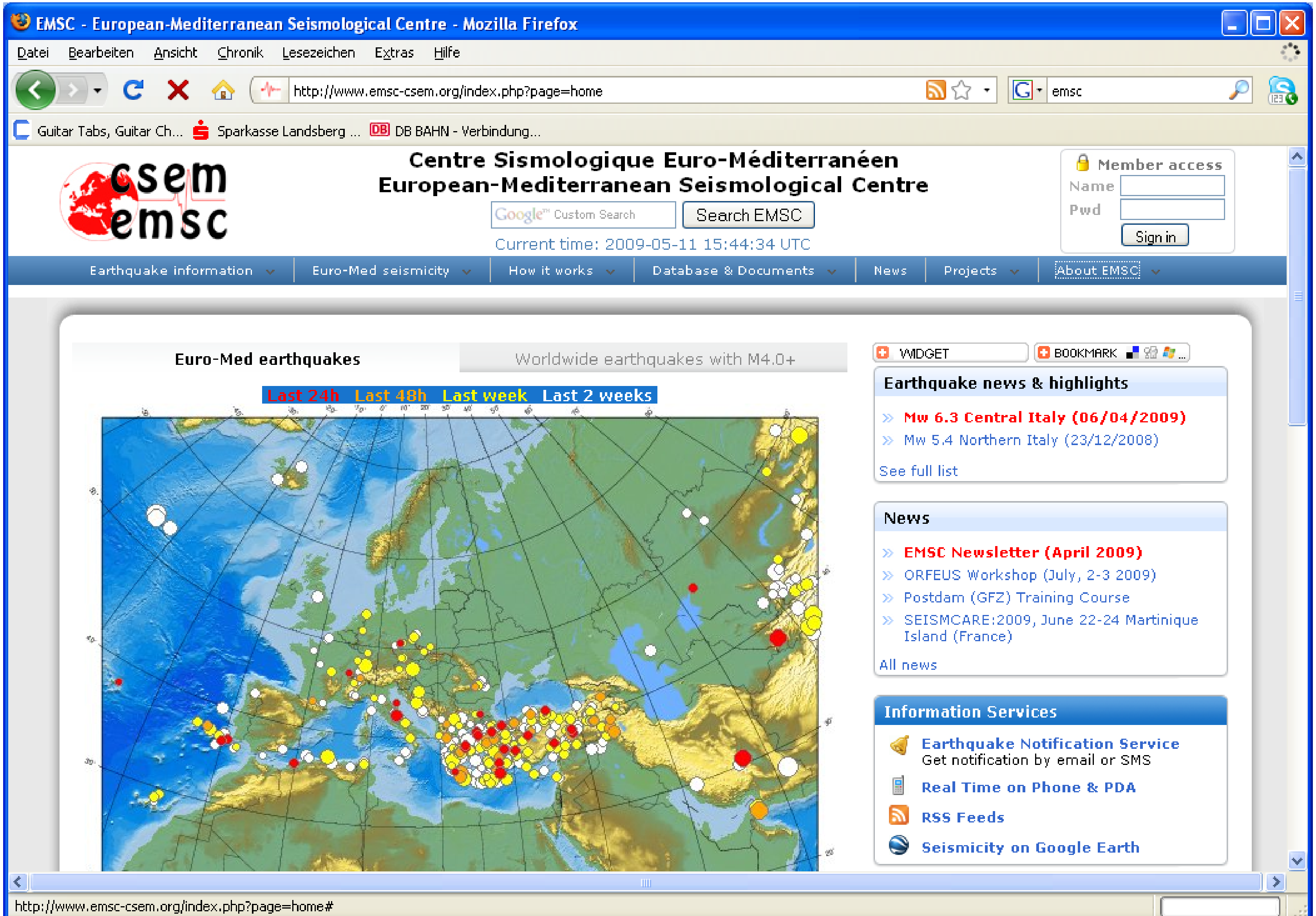
Seismic data centres: ISC



Seismic data centres: GEOFON



EMSC


EMSC - European-Mediterranean Seismological Centre - Mozilla Firefox
Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe
http://www.emsc-csem.org/index.php?page=home
emsc
Guitar Tabs, Guitar Ch... Sparkasse Landsberg ... DB BAHN - Verbindung...
csem emsc
Centre Sismologique Euro-Méditerranéen
European-Mediterranean Seismological Centre
Custom Search
Search EMSC
Current time: 2009-05-11 15:44:34 UTC
Member access
Name
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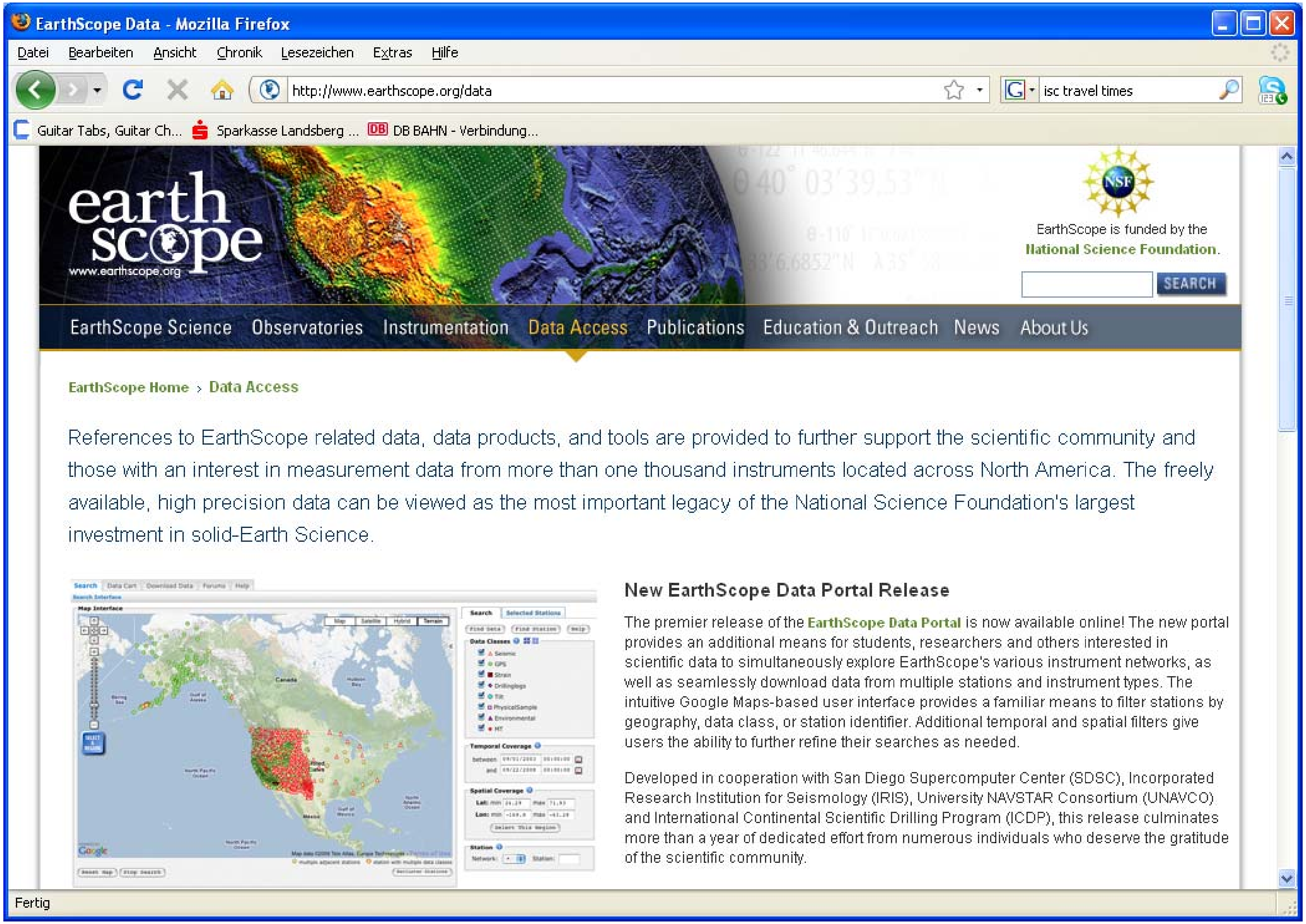
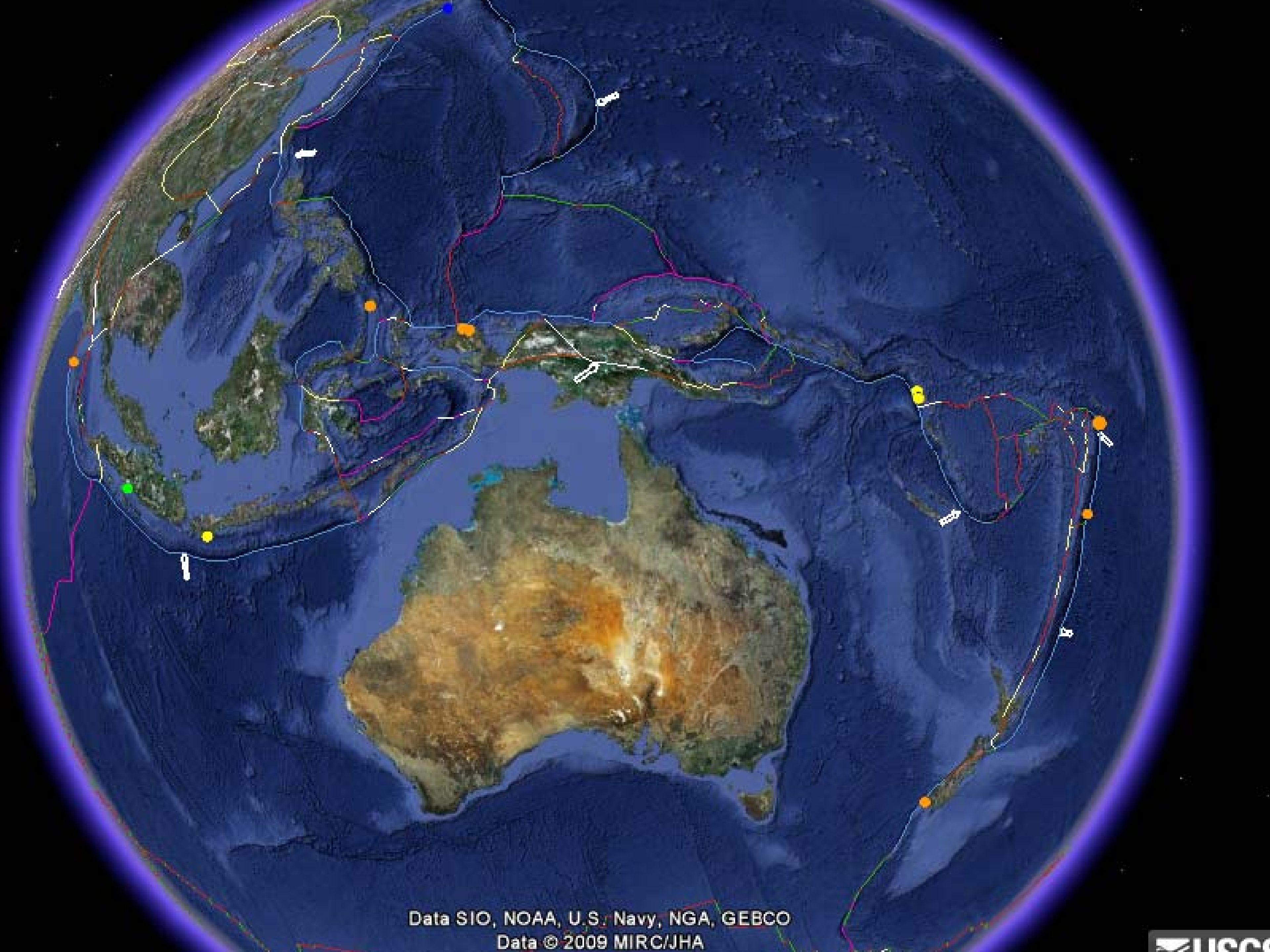
Earthquake Notification Service
Get notification by email or SMS
Real Time on Phone & PDA
RSS Feeds
Seismicity on Google Earth
http://www.emsc-csem.org/index.php?page=home#

Seismic data centres: EarthScope




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

Seismic observables: Period ranges (order of magnitudes)

- 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

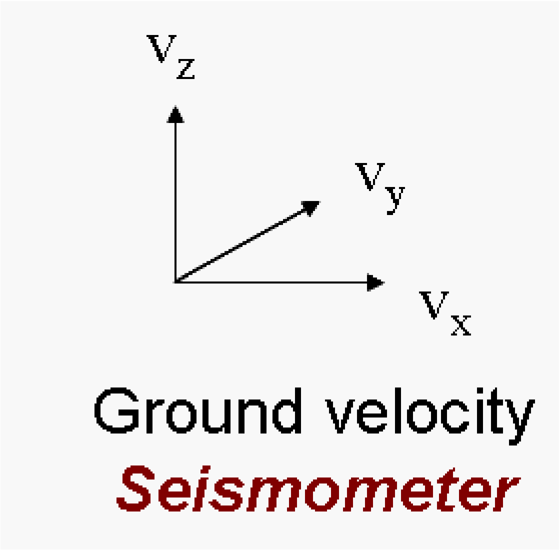
-> What are the consequences for sampling intervals, data volumes, etc.?

Seismic observables: *translations*

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.

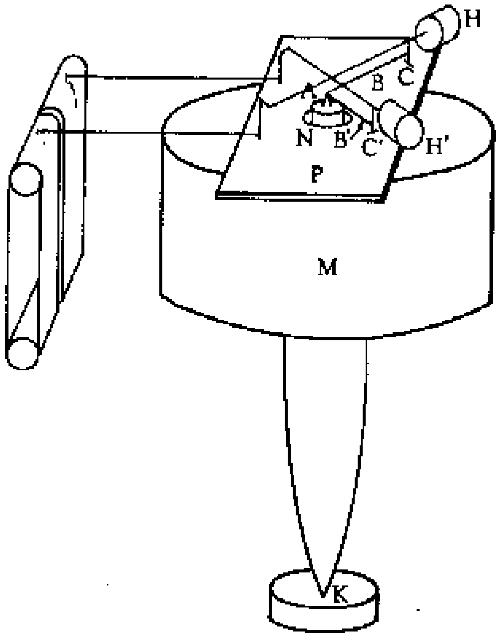
The use of these three variations of the same motion type will be explained below.



Seismic observables: *translations - displacements*

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).

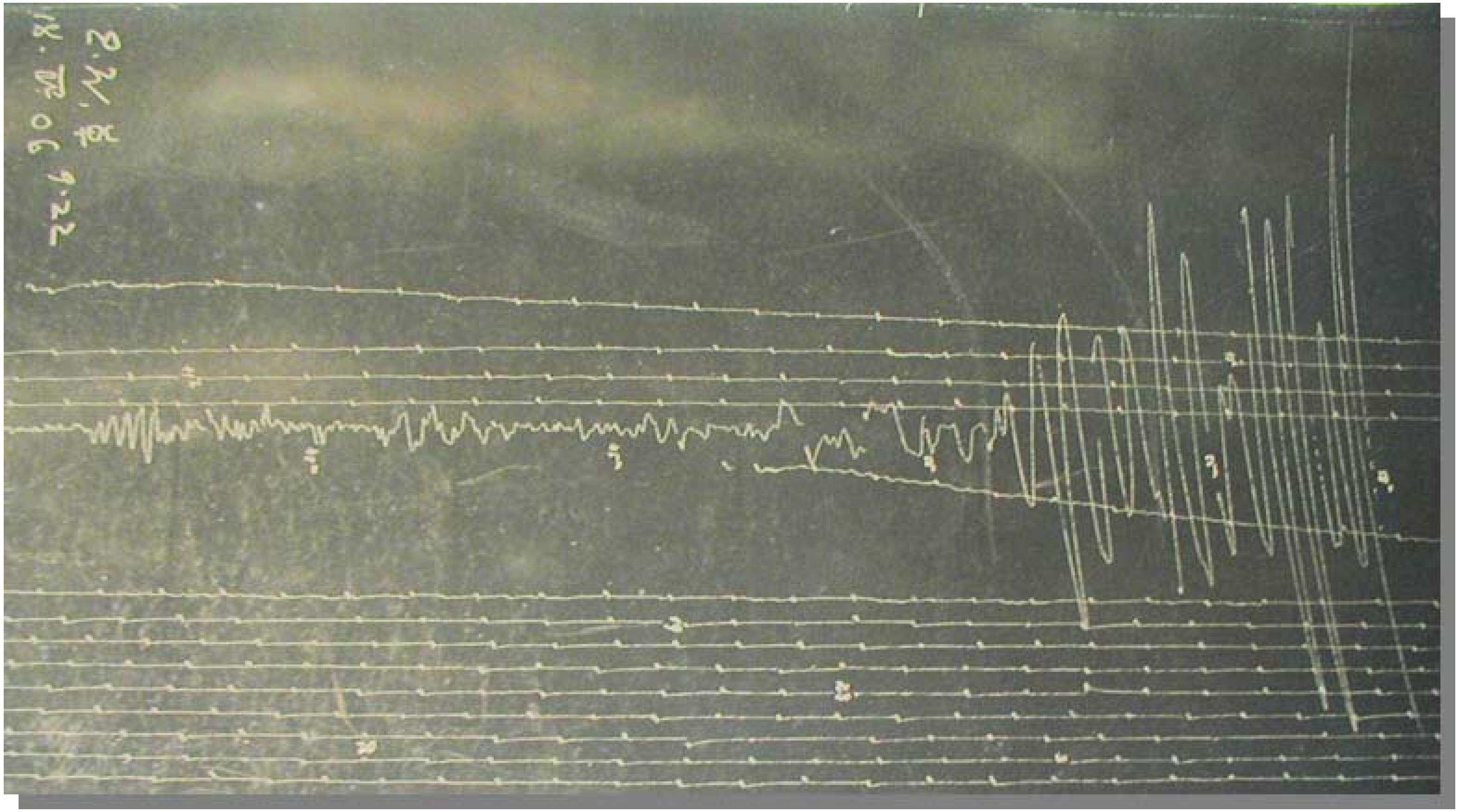
Horiztonal displacement sensor (ca. 1905). Amplitude of ground deformation is mechanically amplified by a factor of 200.



Today displacements are measured using GPS sensors.

Seismic observables: *translations - displacements*

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



Seismic observables: *translations - velocities*

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.

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

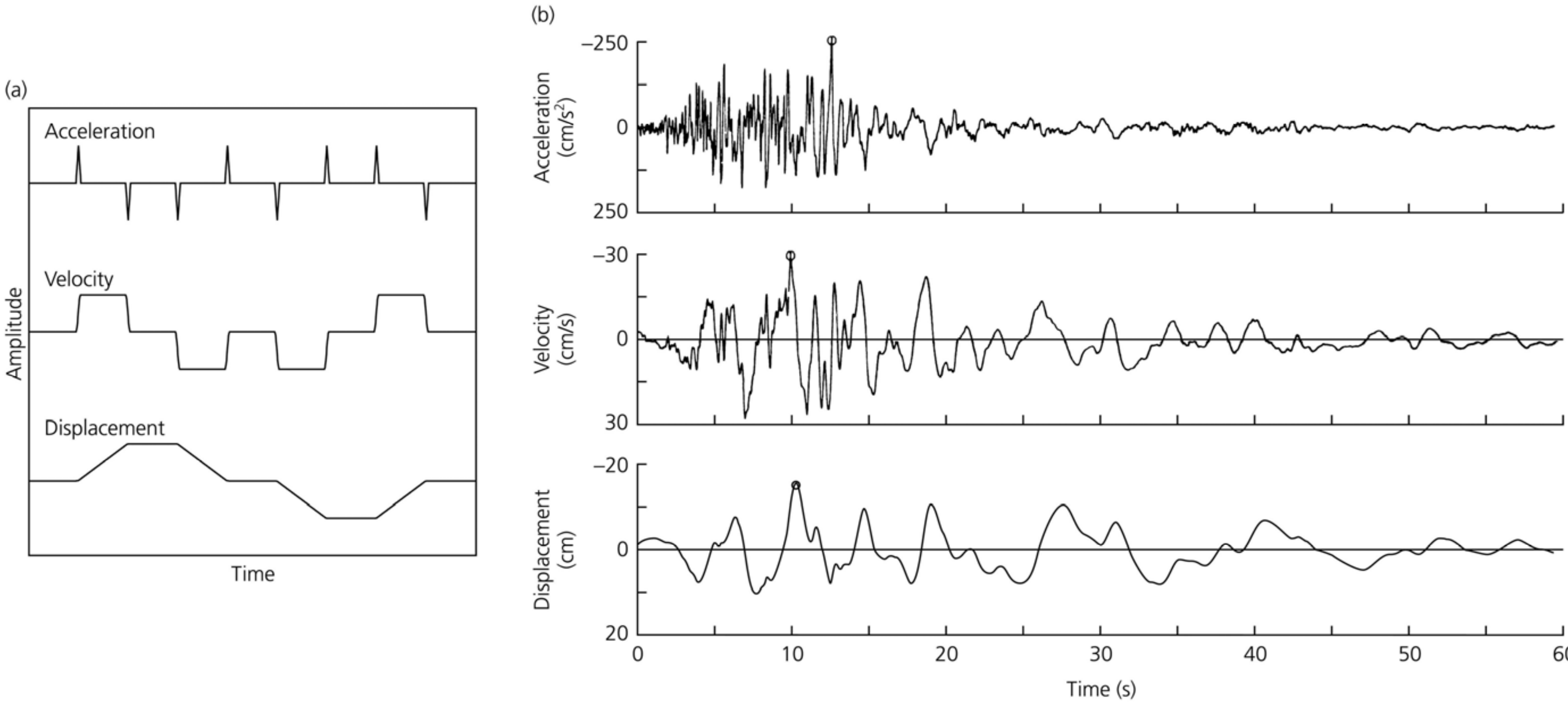
Seismic observables: *translations - accelerations*

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^2 (four times gravity, see *Science* 31 October 2008: Vol. 322. no. 5902, pp. 727 – 730)

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

Displacement, Velocity, Acceleration

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



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.

$$\boxed{\varepsilon_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)}$$

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

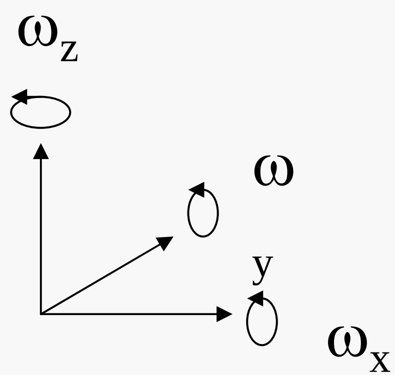
What is the meaning of the various elements of the strain tensor?

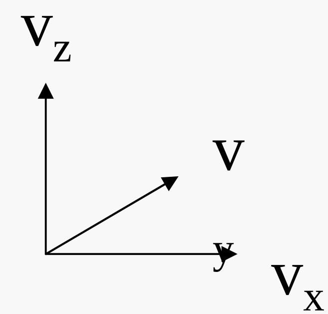
Strain components (2-D)

$$\varepsilon_{ij} = \begin{bmatrix} \dfrac{\partial u_x}{\partial x} & \dfrac{1}{2}\left(\dfrac{\partial u_x}{\partial y} + \dfrac{\partial u_y}{\partial x}\right) \\ \dfrac{1}{2}\left(\dfrac{\partial u_x}{\partial y} + \dfrac{\partial u_y}{\partial x}\right) & \dfrac{\partial u_y}{\partial y} \end{bmatrix}$$

Seismic observables: *rotations*

$$\begin{pmatrix} \omega_x \\ \omega_y \\ \omega_z \end{pmatrix} = \frac{1}{2} \nabla \times \underline{\mathbf{v}} = \frac{1}{2} \begin{pmatrix} \partial_y v_z - \partial_z v_y \\ \partial_z v_x - \partial_x v_z \\ \partial_x v_y - \partial_y v_x \end{pmatrix}$$





Rotation rate

Rotation sensor

Ground velocity

Seismometer

Seismic observables: *rotations*

- 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 $10^{-9} – 10^{-3}$ rad/s
- Rotations are only now being recorded
- Rotations are likely to contribute to structural damage

Seismic observables: *tilt*

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.

$$\boxed{\Theta(x,t) = \partial_x u_z}$$

Other causes of tilt:

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

Summary: Observables

- 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)