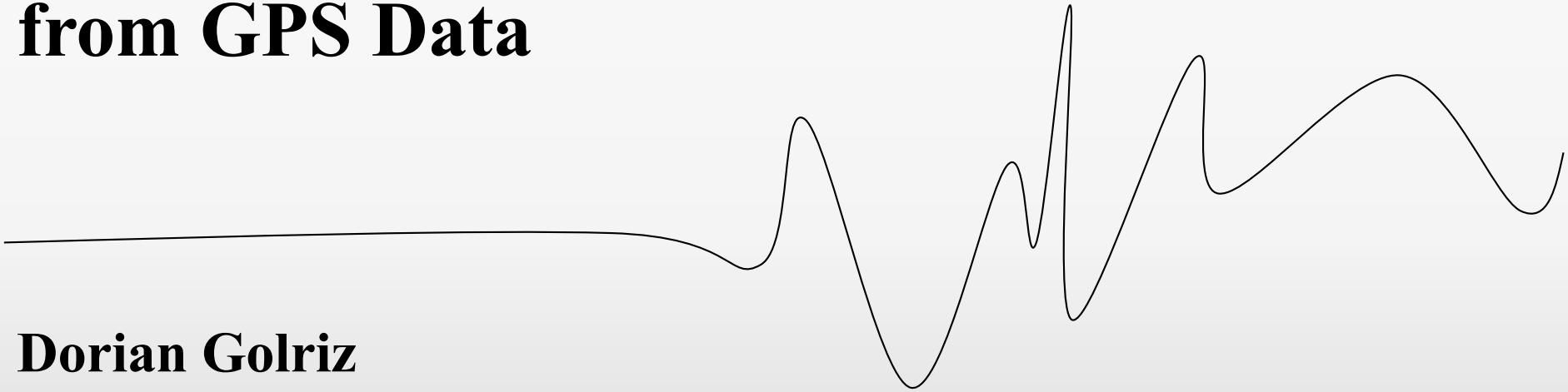
Active Tectonics and Earthquake Source from GPS Data



Dorian Golriz

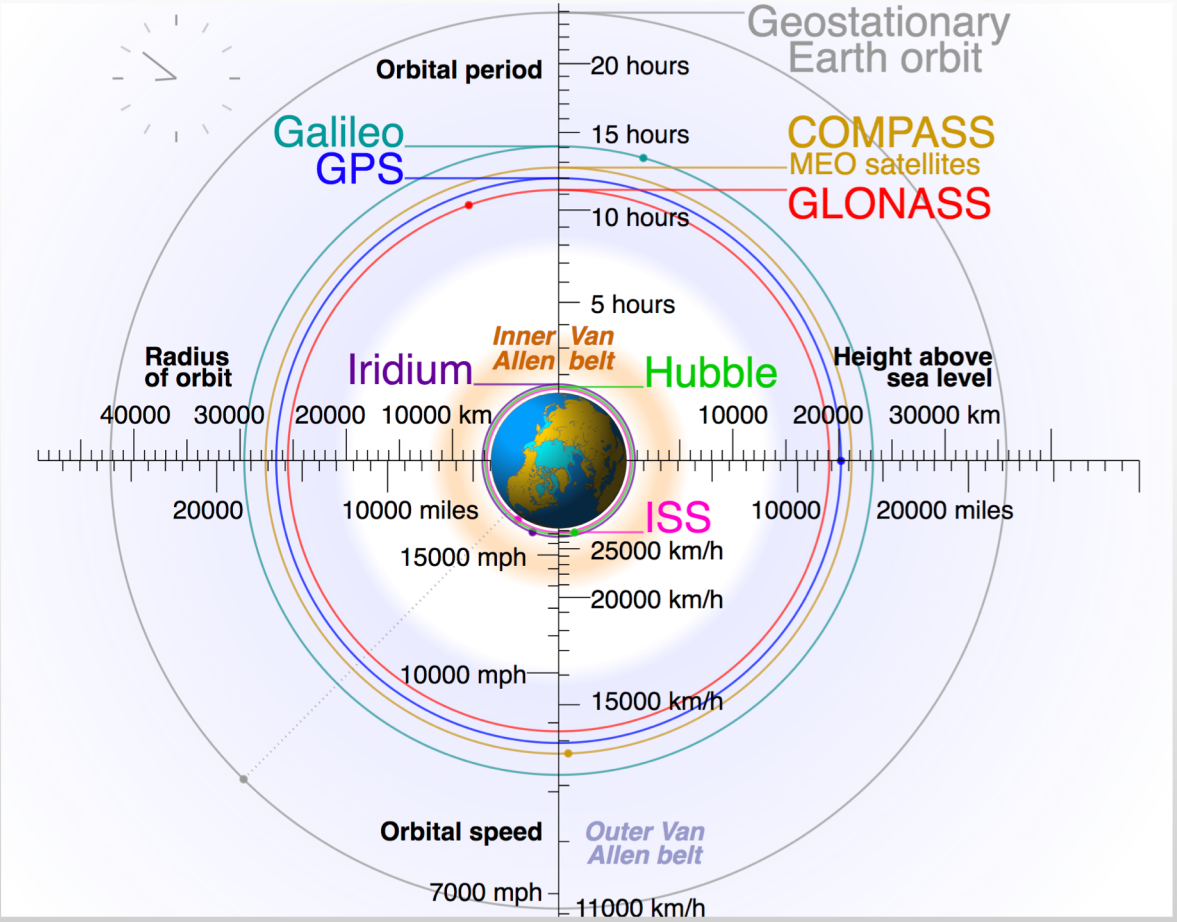
Global Positioning System (GPS)

Global Navigation Satellite Systems (GNSS):

- GPS (United States of America)
- Galileo (European Union)
- GLONASS (Russia)
- COMPASS (China)

Medium Earth Orbit (MEO)

Altitude of ~ 20,000 Km



"Satellite Navigation", in Wikipedia: The Free Encyclopedia

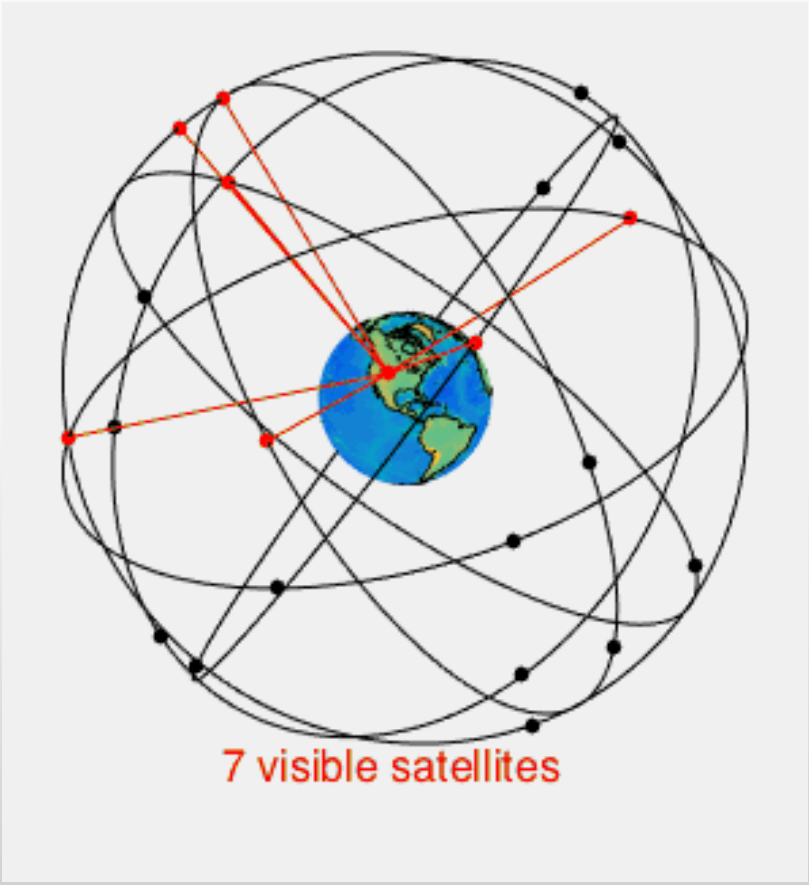
Global Positioning System (GPS)

Global Navigation Satellite Systems (GNSS):

- **GPS (United States of America)**
- Galileo (European Union)
- GLONASS (Russia)
- COMPASS (China)

More Than 30 Satellites

~12 Hours Period (One-Half A Sidereal Day)



"GPS", in Wikipedia: The Free Encyclopedia

The Positioning Problem

$$Fundamental\ Frequency - 10.23\ MHz$$

$$10.23 * 154 = 1575.42\ MHz\ (L1\ band)$$
$$10.23 * 120 = 1226.60\ MHz\ (L2\ band)$$
$$\dots$$

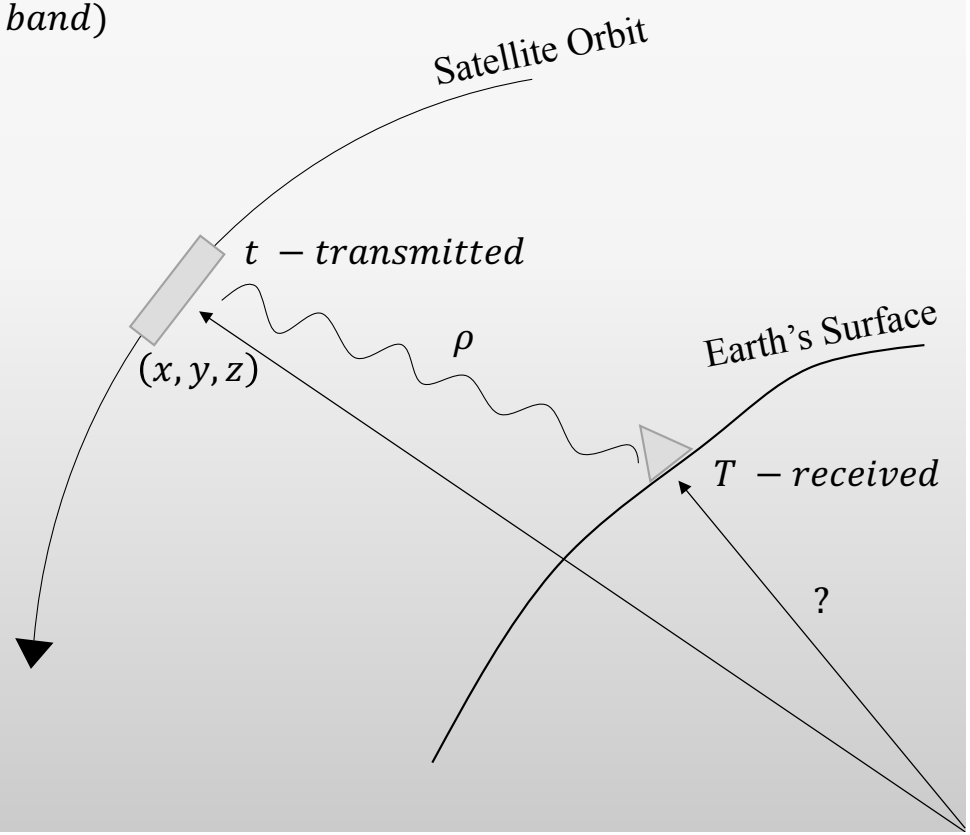
Pseudorange $\rho = c(t - T)$

$$1\ nanosec\ error = 30\ cm\ error$$

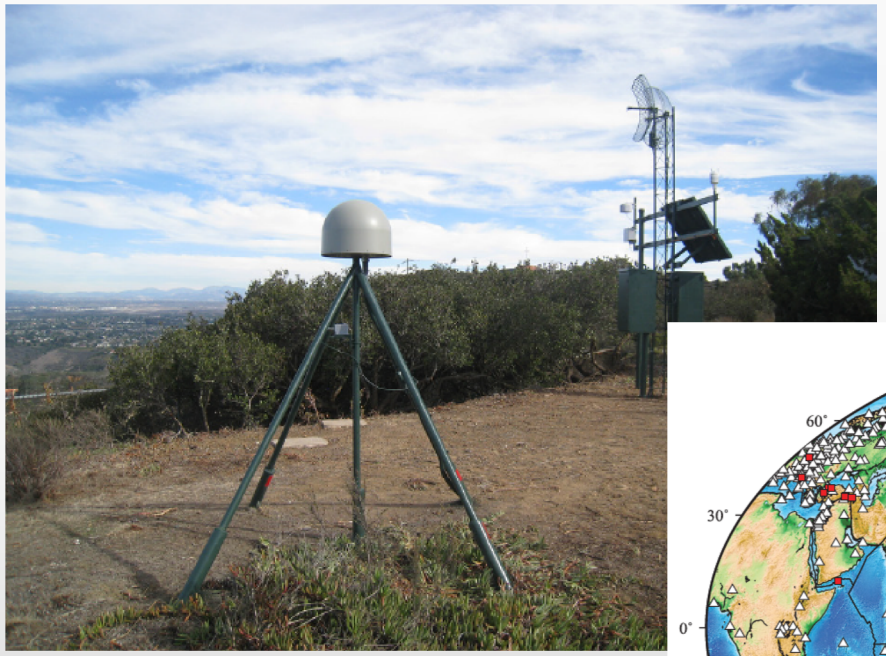
1m precision

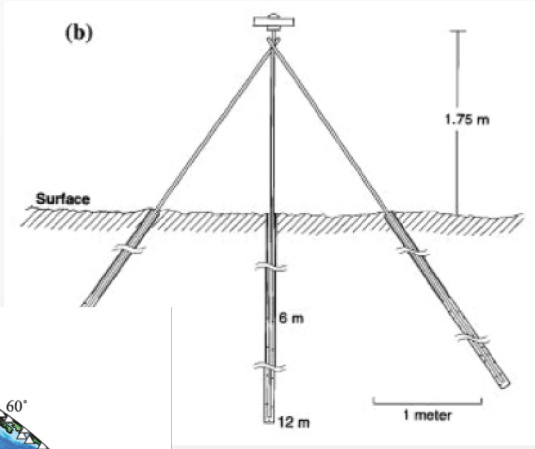
Pseudorange + Phase

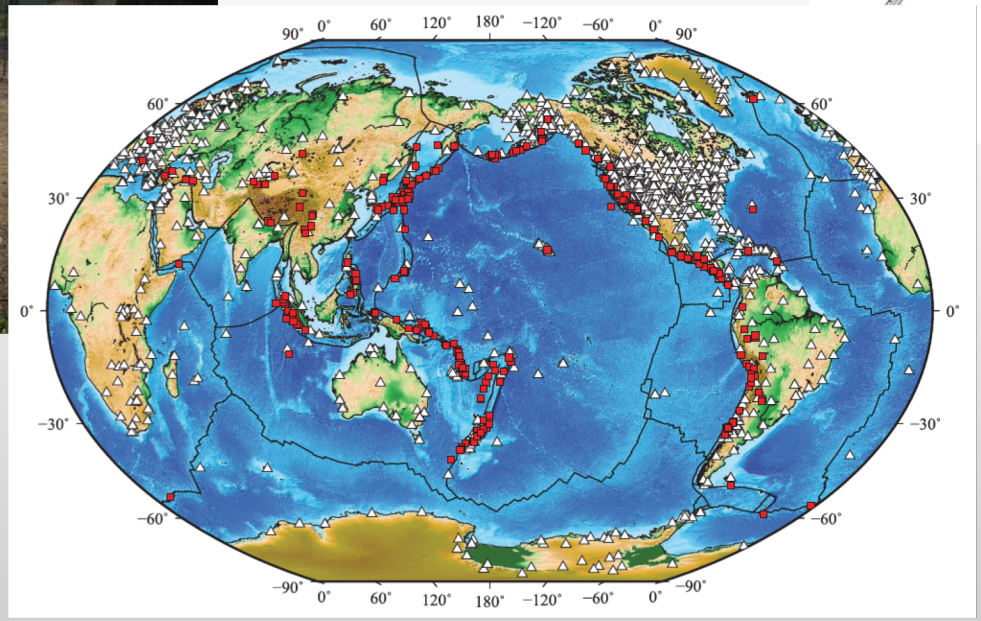
0.001m precision



Continuous Global Positioning System (cGPS)

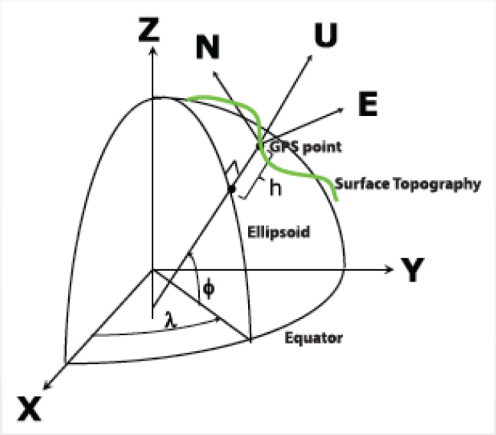






Bock Y. and Melgar D. (2016)

GPS Time-Series

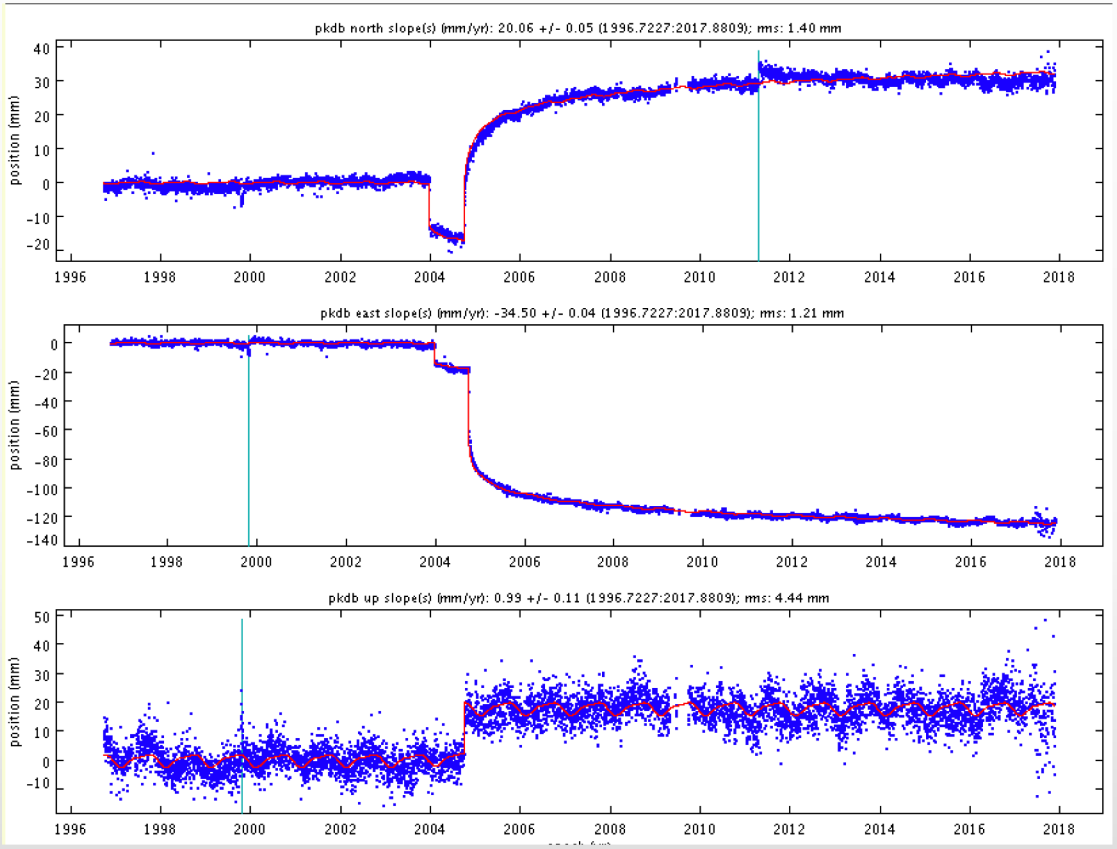


Bock Y. and Melgar D. (2016)

East

North

Up



Linear trend

Annual (or semi-annual) variation

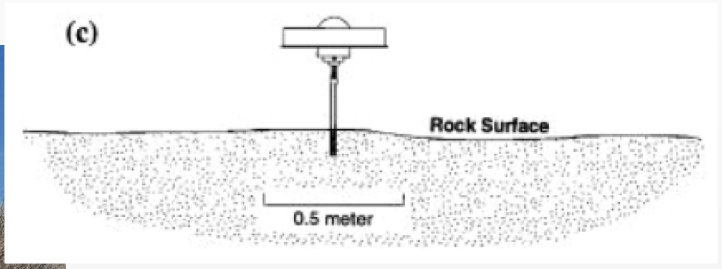
Co-seismic offset

Post-seismic relaxation

$$y(t) = a + bt + \mathrm{c}\sin(2\pi t) + d\cos(2\pi t) + \sum_i e_i H(t - T_i) + \sum_i f_i \log\left(1 + \frac{t - T_i}{\tau_i}\right) H(t - T_i)$$

Survey Global Positioning System (sGPS)

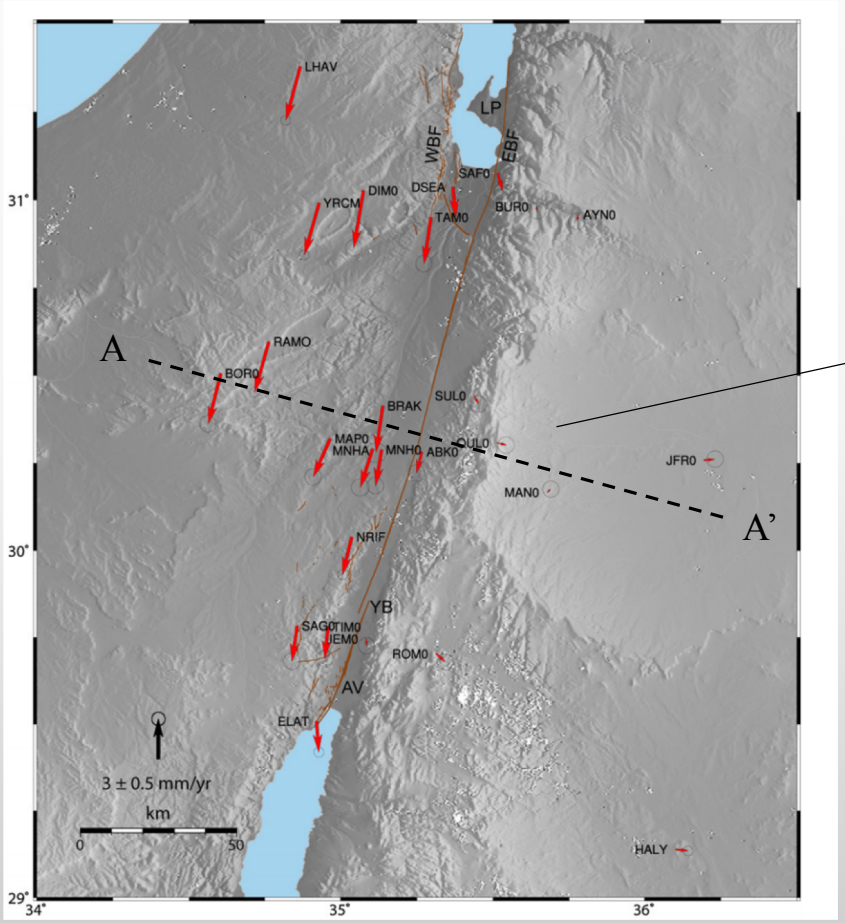
Painted Canyon Campaign GPS, January 2018



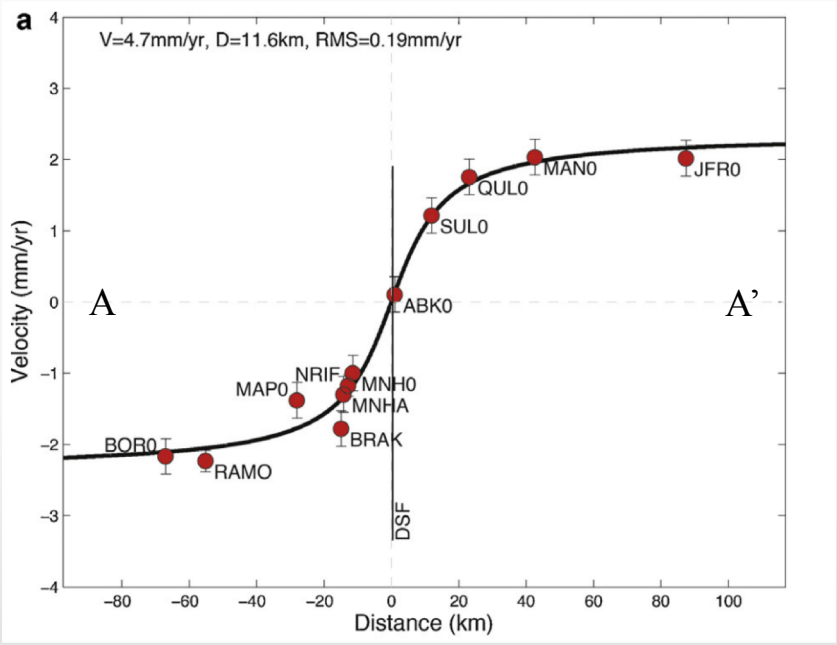
Bock Y. and Melgar D. (2016)

Geological Survey of Israel

Survey Global Positioning System (sGPS)



Masson F. et-al (2014)



$$v(x) = \frac{v_0}{\pi} \arctan\left(\frac{x}{D}\right)$$

v_0 $-$ *Interseismic Slip rate*

D $-$ Locking Depth

Earthquake Source Determination

Moment Tensor:

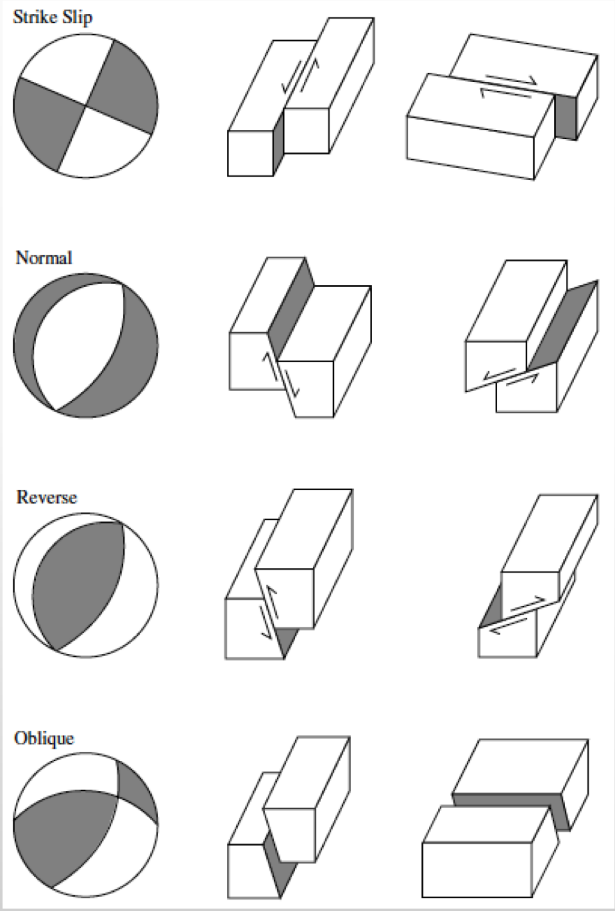
$$M = \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

$$u_i^k = G_{ij}^k \; m_j$$

- u_i^k: Co-Seismic Displacements
- G_{ij}^k: Green's functions (by Wang et-al, 2003)
- m_j: Moment tensor components

Seismic Moment:

$$m_0 = \frac{1}{\sqrt{2}} \sqrt{\sum_{ij} {M_{ij}}^2}$$



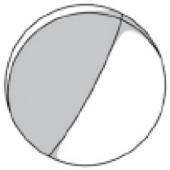
Shearer P., Introduction to Seismology

Earthquake Source Determination

a)

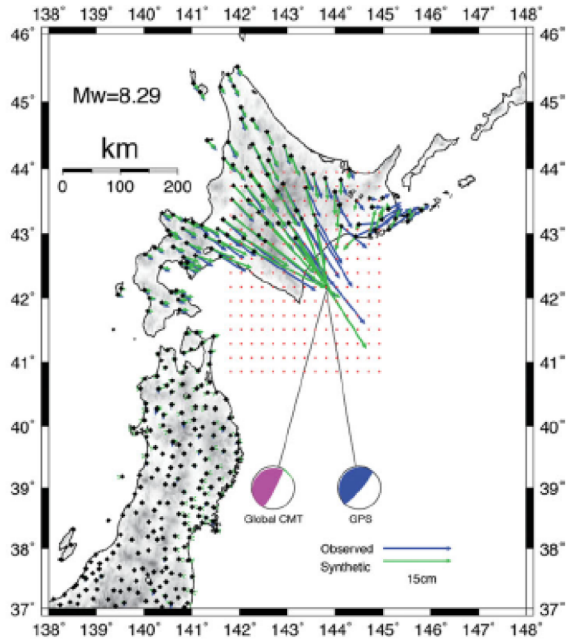
fastCMT Event Report			
Event ID: 2003 Tokachi–oki			
Lat = 42.20	Lon = 144.00	Depth = 48 km	
Final Solution Time: 19:53:15		Mw = 8.2	
Moment Tensor (Scale 1x10^21 Nm)			
Mrr = 1.001	Mtt = -0.463	Mpp = –0.539	
Mrt = 1.353	Mrp = 1.871	Mtp = –0.518	
Prinicpal Axes			
Axis	Value	Plunge	Azimuth
T P B	2.518 –2.523 –0.005	57 33 3	303 129 37
Best Double Couple (Mo = 2.932e+21 Nm)			
Plane	Strike	Dip	Rake
NP1 NP2	229 36	12 78	103 87
Inversion Summary			
#Stations = 151		Var. Red. = 79.76%	
%DC = 99.60	%CLVD = 0.40	%ISO = (null)	

b)



Global CMT Solution			
Event ID: 2003 Tokachi–oki			
Lat = 42.21	Lon = 143.84	Depth = 28.2 km	
Final Solution Time: N/A		Mw = 8.3	
Moment Tensor (Scale 1x10^21 Nm)			
Mrr = 0.777	Mtt = –0.411	Mpp = –0.366	
Mrt = 1.320	Mrp = 2.590	Mtp = –0.662	
Prinicpal Axes			
Axis	Value	Plunge	Azimuth
T P B	2.980 –3.130 0.150	53 36 7	289 124 29
Best Double Couple (Mo = 3.050e+21 Nm)			
Plane	Strike	Dip	Rake
NP1 NP2	250 28	11 82	132 83
Inversion Summary			
#Stations = N/A		Var. Red. = N/A	
%DC = 90.42	%CLVD = 9.58	%ISO = (null)	

c)



Melgar D. et-al (2011)