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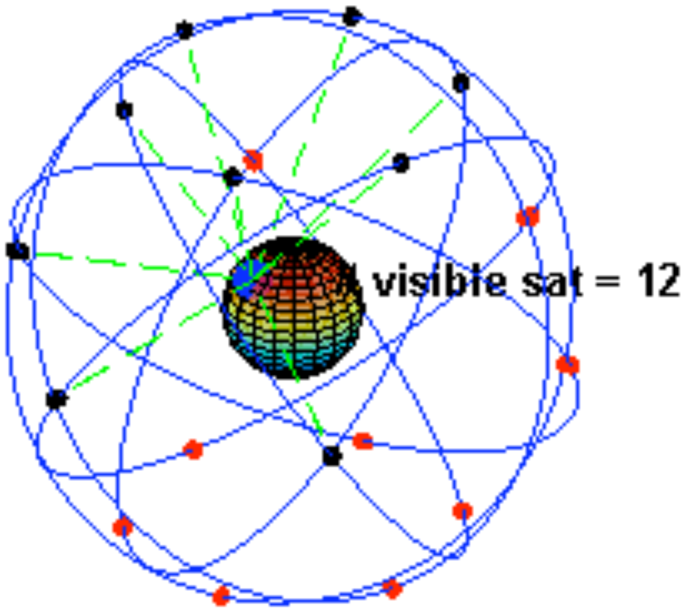
Surface motions and deformation

Peiying Patty Lin, ASU
Edward Garnero, ASU
EarthScopeSeminarClass

Figures and information referenced from various internet sources

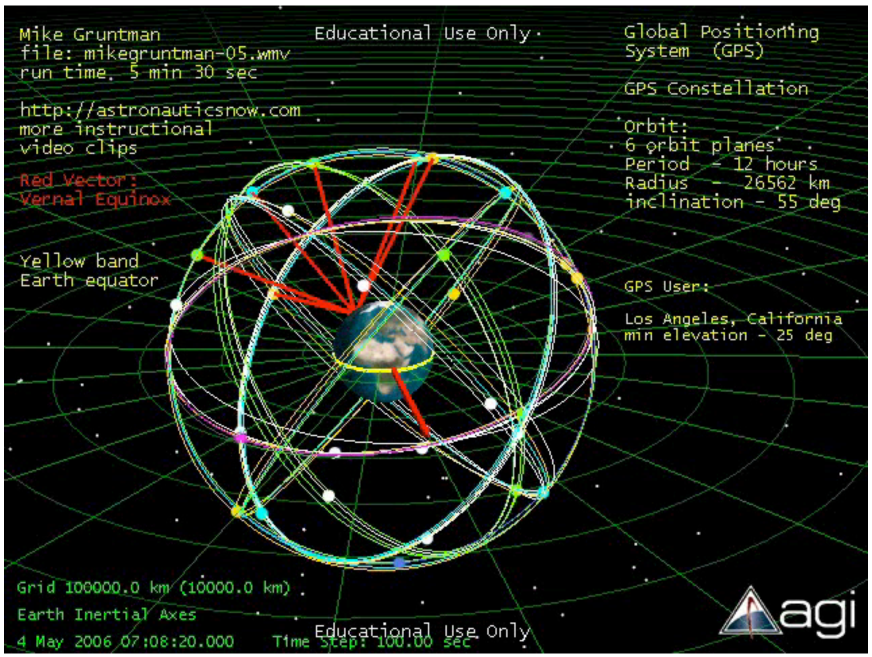
Basic concept of GPS



From wikipedia
(http://en.wikipedia.org/wiki/
Global_Positioning_System)

•Need at least 3 satellite signals to locate the receiver in 3D space
• 4th satellite used for time accuracy

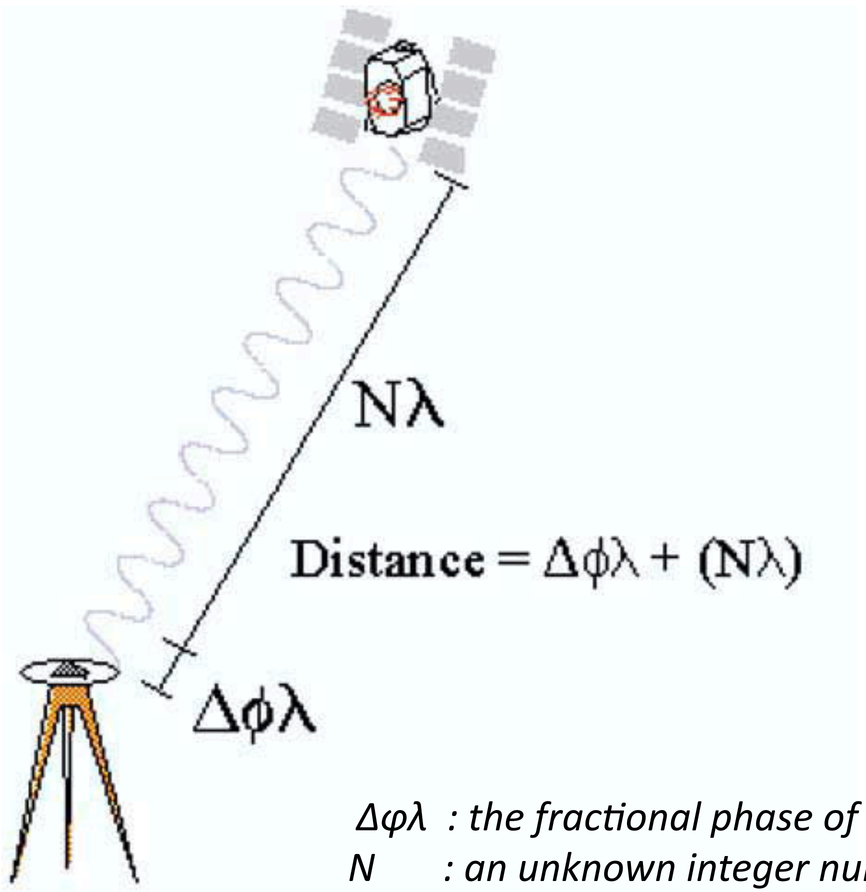
Global Positioning System



From Mike Gruntman's web site
(http://astronauticsnow.com/vp/)

- 24 (+4 spares) satellites
- 20,200 km altitude
- 6 planes with 4 satellites each
- 55 degrees inclination (tilt relative to Earth’s equator)
- 12 hour orbital period

Approximate Distance Range



Satellite vehicles transmit two microwave carrier (carry information) signals

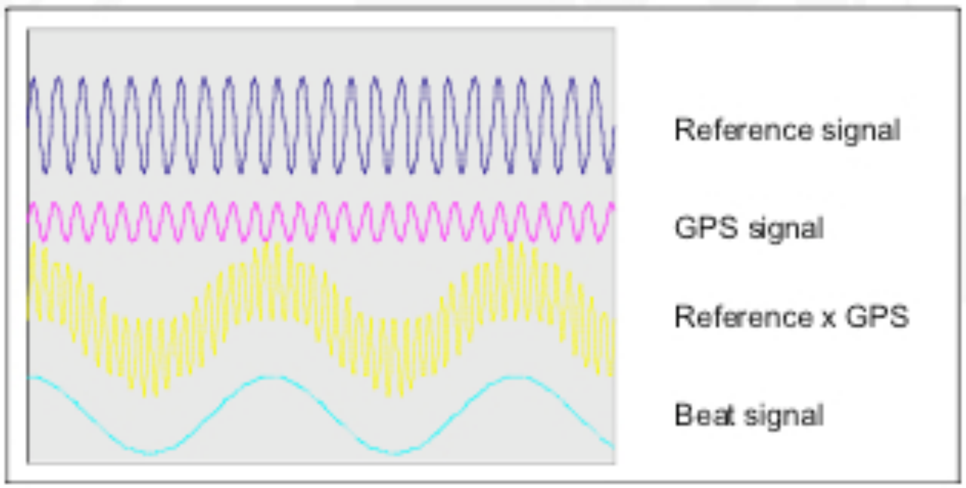
L1 (1575.42 MHz=154*10.23MHZ)
L2 (1227.60 MHz=120*10.23MHZ)

Information is encoded in the form of binary bits on the carrier signals.

Δφλ : the fractional phase of the carrier expressed in terms of distance.
N : an unknown integer number of carrier wavelengths to the satellite.

(Jackson, 2003)

Carrier Phase Signal (concept)



G. Blewitt, 1996

Multiply together 2 signals of similar frequency
Result is sum of high + low frequency signals
Filter out the high frequency, leave low frequency (DECODE)

beat frequency : difference in frequency of two signals
beat phase : difference in phase of two signals

Various error source/ Increase the precision

Some GPS Error Sources:

•Receiver/ satellite clock offsets
•Atmospheric delays: Ionosphere/
Troposphere
•Error in the position of the satellites
•Multipath
•The reflection/refraction of signals from
other interface

Various error source/ Increase the precision

Travel time of the signals is important. (As the same as seismology)
0.1 microsecond difference results in distance error on the order of 30m

Some GPS Error Sources:

- Receiver/ satellite clock offsets
- Atmospheric delays: Ionosphere/ Troposphere
- Error in the position of the satellites
- Multipath
- The reflection/refraction of signals from other interface

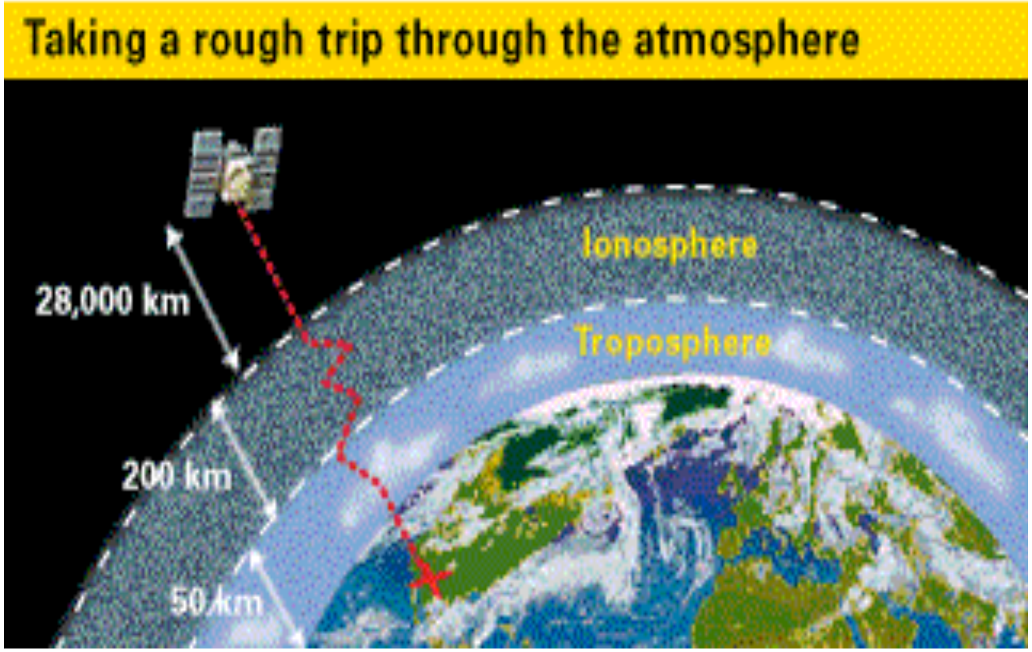
Ways to increase the precision:

- Use the carrier phase
- Dual-frequency receivers (to remove ionosphere)
- High-precision orbital information
- Multiple stations (to remove satellite clock variations)

Dual Frequency Measurement

- The ionosphere delay is frequency dependent.

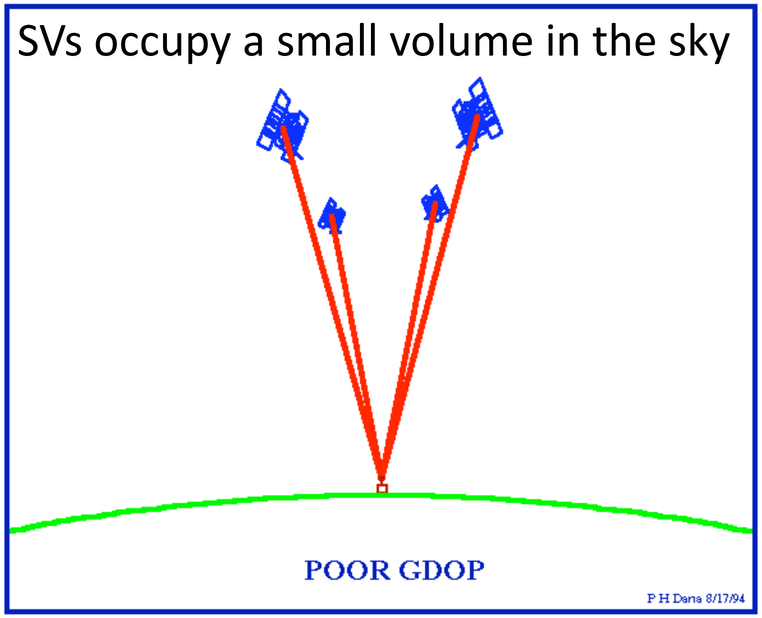
- By comparing the delays of the two different carrier frequencies of the GPS signal, L1 and L2, we can deduce what the medium (i.e. atmosphere) is.

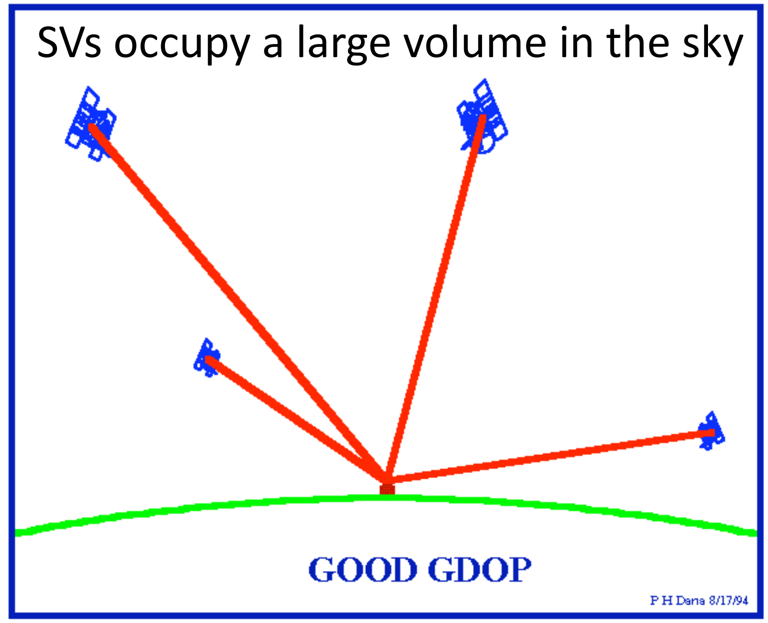


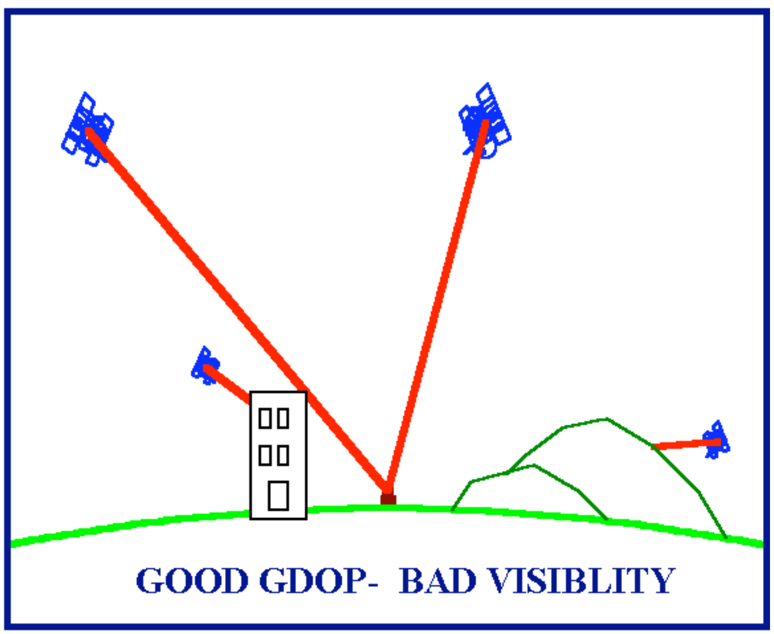
http://www.trimble.com/gps/howgps-error.shtml#3

The troposphere is harder. The correction is usually calculated from model and the data to mitigate delays due to water vapor in troposphere.

Geometric Dilution of Precision (GDOP)



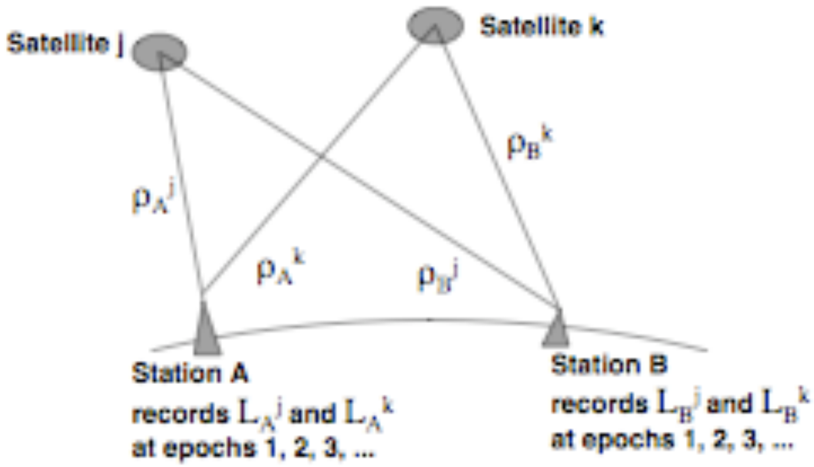




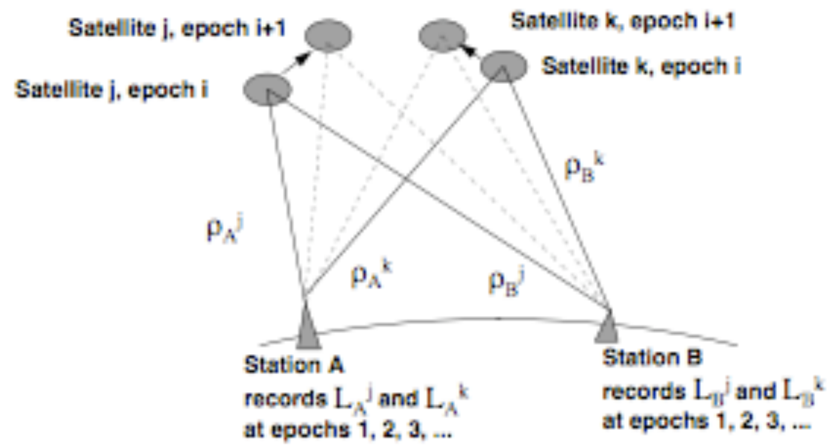
http://comp.uark.edu/~mattioli/geol_4733.html

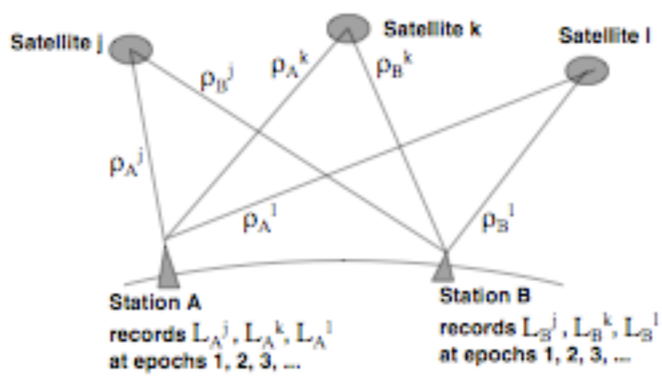
Differencing Techniques to Know Relative Position

Double Differencing



Triple Differencing





G. Blewitt, 1996

Earth Scope- PBO

Plate Boundary Observatory Science Goals

- *What are the forces that drive plate-boundary deformation*?
- *What determines the spatial distribution of plate-boundary deformation*?
- How has plate-boundary deformation evolved?
- What controls the space-time pattern of earthquake occurrence?
- How do earthquakes nucleate?
- What are the dynamics of magma rise, intrusion, and eruption?
- How can we reduce the hazards of earthquakes and volcanic eruptions?

From Earthscope website
(http://earthscope.org/observatories/pbo)

Subcontinental-scale crustal velocity changes along the Pacific-North America plate boundary

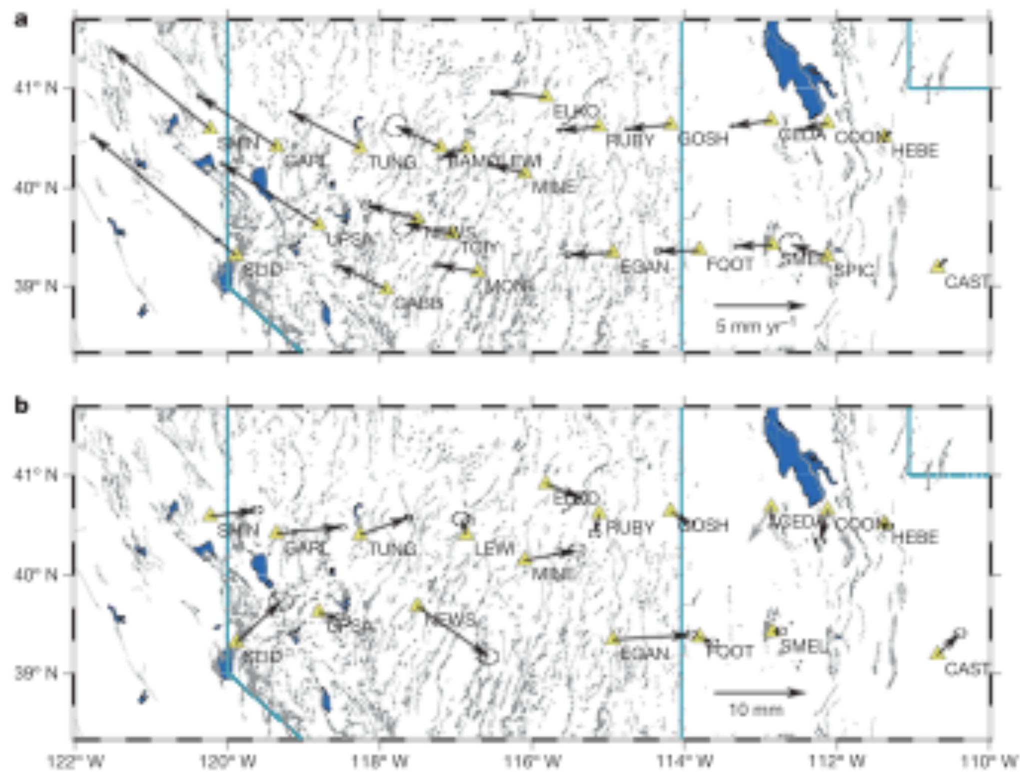
Davis et al. Nature (2006) vol. 441 (7097) pp.1131-1134

DATA:

Continuous GPS data (1996~2005)

RESULT:

A sharp boundary near the centre of the BR oriented parallel to N-NW relative plate motion vector.



(Davis et al., 2006)

Rotation and place locking at the southern Cascadia subduction zone

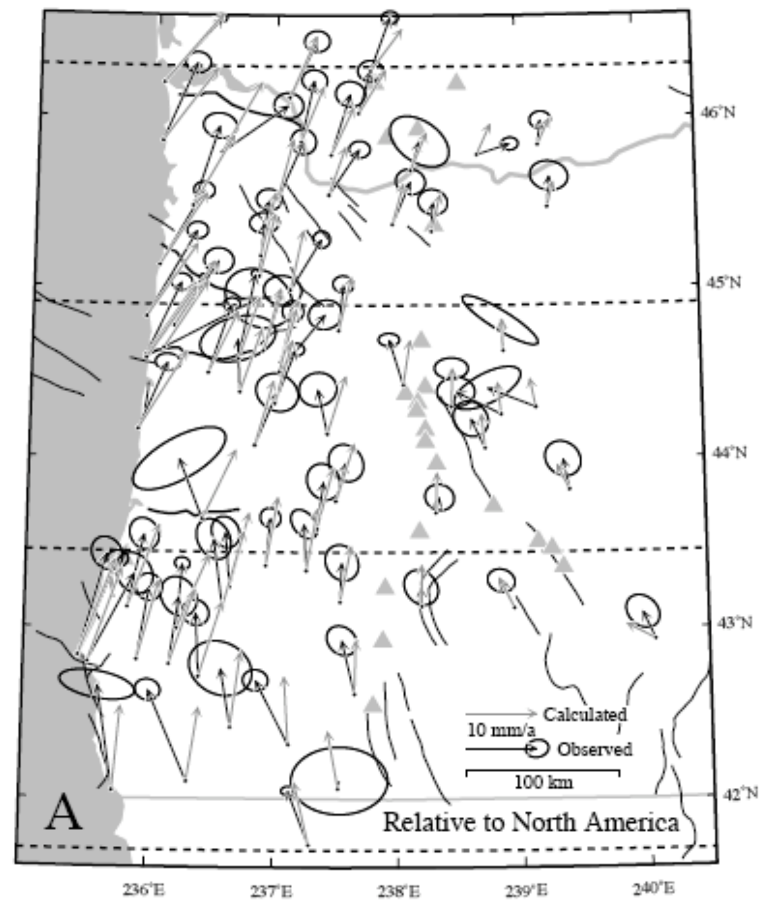
McCaffrey et al. Geophysical Research Letters (2000) vol. 27 (19) pp. 3117-3120

DATA:

GPS vectors and surface tilt rates

RESULT:

Rotation of western Oregon and plate locking on the southern Cascadia subduction thrust fault



(McCaffrey et al., 2000)

Absolute plate motions constrained by shear wave splitting orientations with implications for hot spot motions and mantle flow

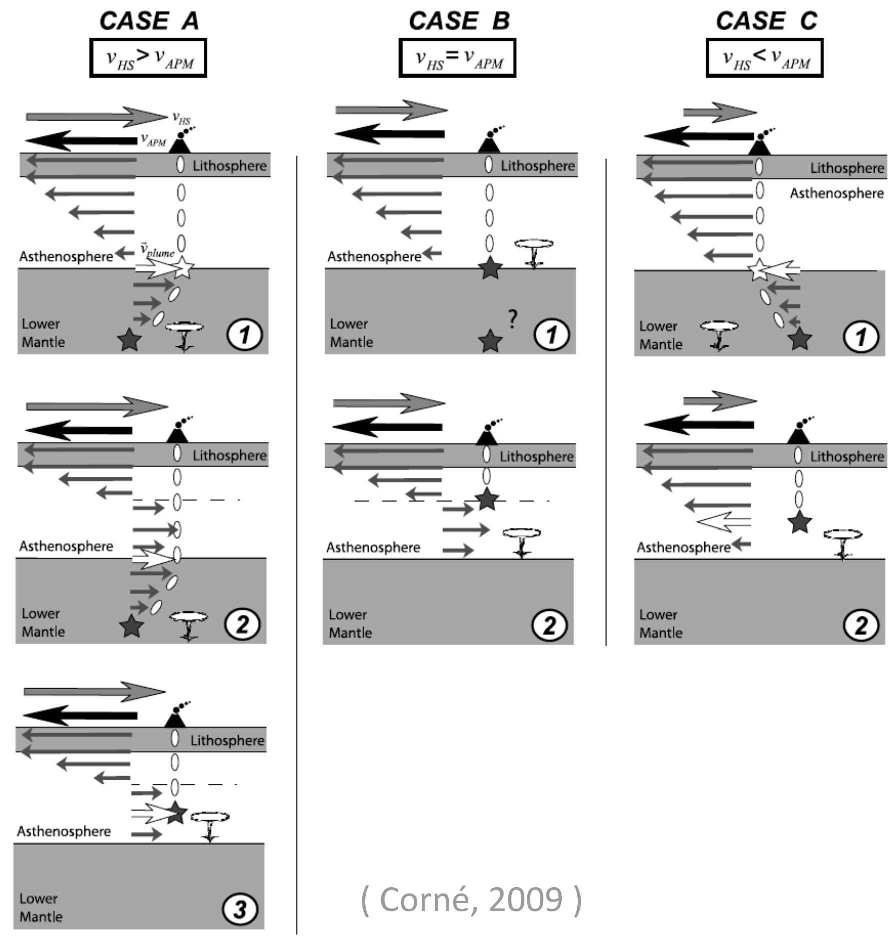
Corné Kreemer JGR, Vol. 114, B10405, 2009

DATA:

shear wave splitting orientations

RESULT:

a new absolute plate motion model of the earth's surface.
Imply for hot spot motions and mantle flow.



(Corné, 2009)

GPS is one of the probes to study Earth

To achieve the science goals:

- GPS can tell us the motions of the surface which are uniquely important.
- Need multidisciplinary effort (seismology/ volcanology/ mineral physics/ geodynamics)