Course Announcement
GEOL 730 ADVANCED GEOLOGY OF NEVADA AND THE BASIN AND RANGE. 3 credits.
Instructor: Wesnousky

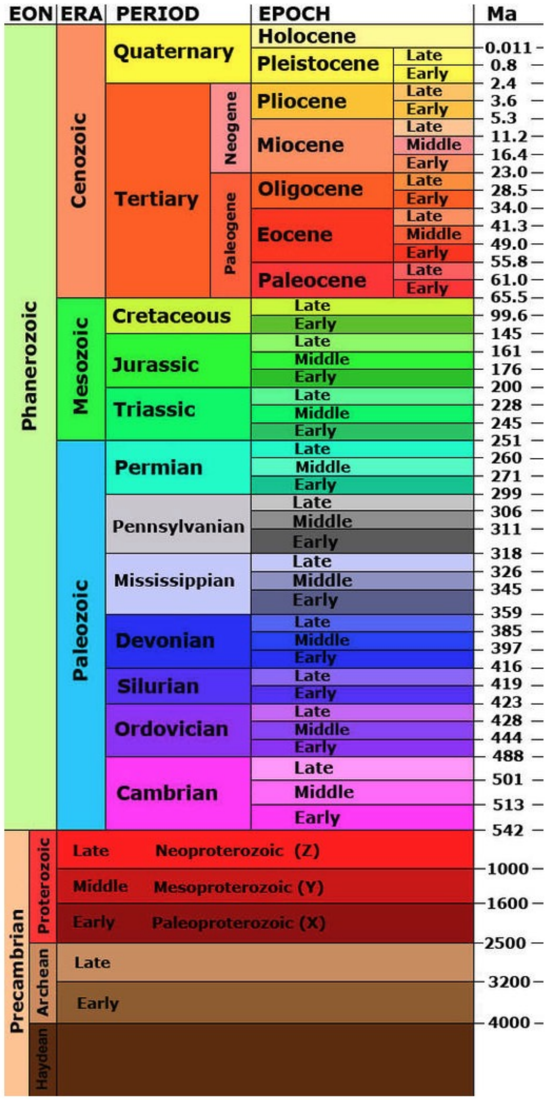
The course will be combined lecture and greater part seminar and designed 1) to guide the participants to understanding the investigators, investigations and attendant observations that are the basis for current understanding of the tectonic evolution of the Basin and Range, from PreCambrian to present, 2) provide experience of extracting critical observations from professional literature, 3) and experience in orally providing presentations like those that will be needed in presenting results of thesis research. At the end, the participant should have a firm understanding of the spatial and temporal development of events that have led to the current tectonics of the Basin and Range.

Course will be taught if enrollment is >=8.

GEOL 730 ADVANCED GEOLOGY OF NEVADA AND THE BASIN AND RANGE. 3 credits.
Instructor: Wesnousky (aka Steve)

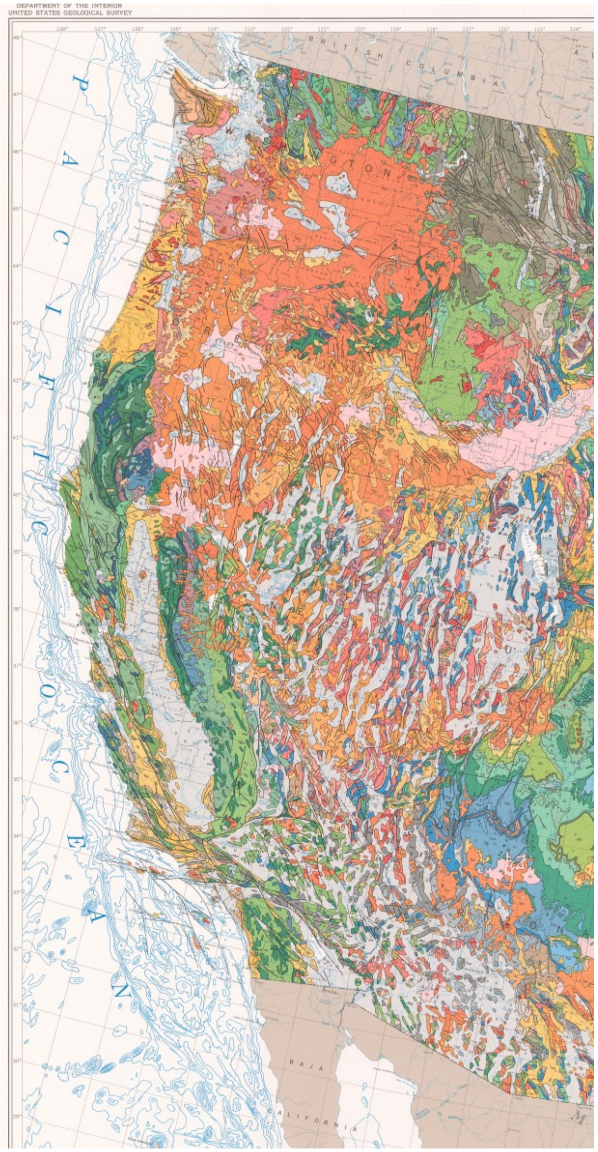
Topics to be covered – approximately in this order…

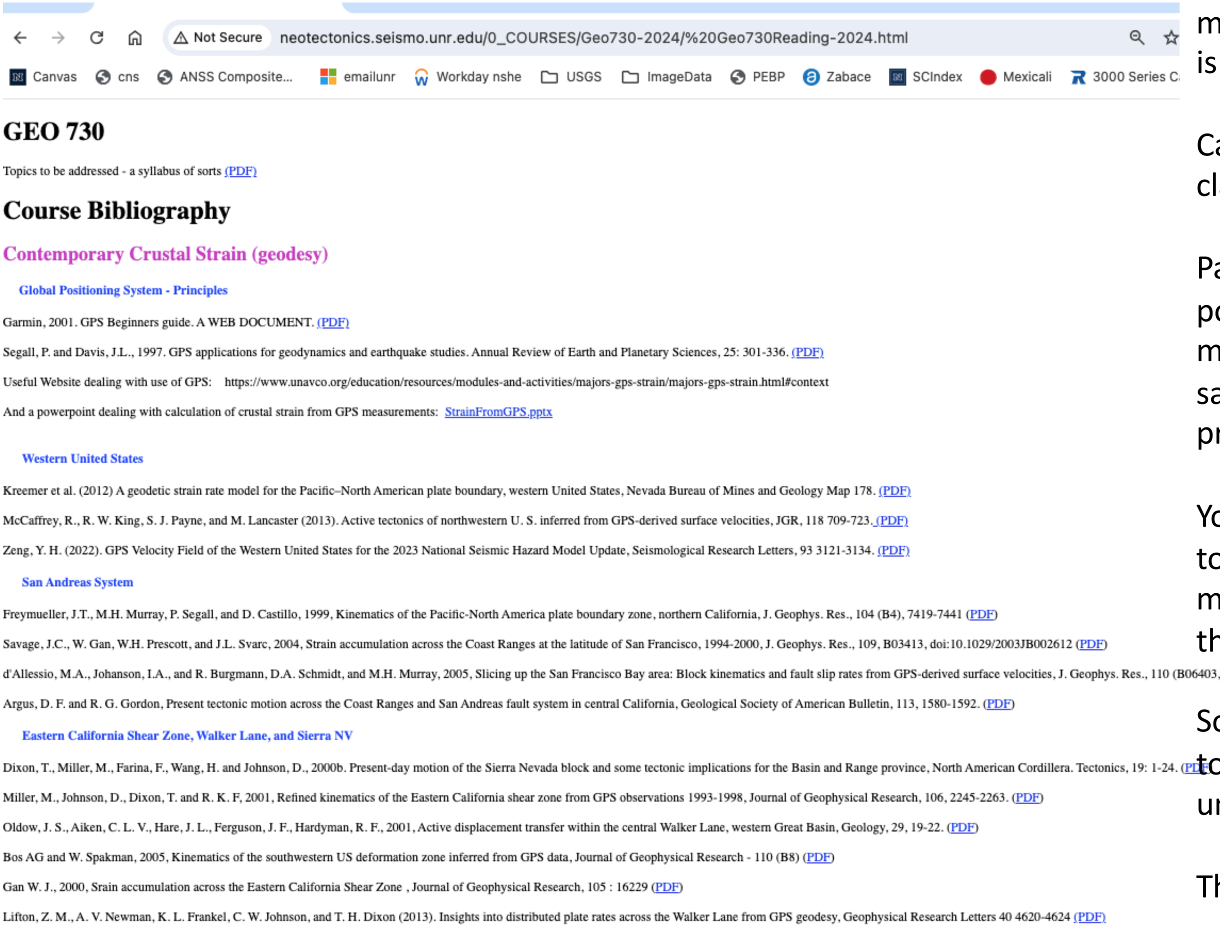
- Contemporary Strain
    - San Andreas System
    - Eastern California Shear Zone, Walker Lane, and Sierra NV
    - Basin and Range and Wasatch
- Contemporary Seismicity
- Glacial and Pluvial History
    - Oxygen-Isotope Record
    - Basin and Range Glaciation
    - Sierran Glaciation
    - Ruby-East Humboldts
    - Pluvial Lake History
- PActive Faults and Recent Quakes
- Mojave
- Southern Walker Lane
    - Death Valley and Fish Lake Valley fault zones
    - Panamint Valley, Hunter Mountain,and Saline Valley
    - Owens Valley and Mono Basin
- Central Walker Lane
- Northern Walker Lane
- Basin and Range
- Wasatch
- Late Cenozoic Deformation: Inception and Offset
    - Mojave/Eastern California Shear Zone
    - Southern Sierra
    - Southern Walker Lane
    - Death Valley
    - White Mountains
    - Panamint-Saline Valley
    - Central Walker Lane
    - Northern Walker Lane
    - Basin and Range
    - Appearance of fault controlled basins
- Lack of relief prior to basin and range faulting (ash flow sheets and stratigraphy)
- Geologic constraints on amount of extension/displacement
- Other Characteristics
- Cenozoic Volcanism
- Plate Tectonic Models
- Core Complexes and Early Cenozoic Extension
- Mesozoic: Sevier Orogeny
- Paleozoic: The Antler and Sonoma Orogenys (Roberts Mtn and Golconda Allochthons)
- Sonoma Orogeny and Golconda Allocthon (latest Permian)
- Antler Orogeny and Roberts Mtn Allocthon(Mississippian)
- PreCambrian Continental Margin and Evolution



EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.011
				Pleistocene	Late	0.8
					Early	2.4
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	23.0
			Paleogene	Oligocene	Late	28.5
					Early	34.0
				Eocene	Late	41.3
					Middle	49.0
					Early	55.8
				Paleocene	Late	61.0
					Early	65.5
	Mesozoic	Cretaceous		Late		99.6
				Early		145
		Jurassic		Late		161
				Middle		176
				Early		200
		Triassic		Late		228
				Middle		245
				Early		251
	Paleozoic	Permian		Late		260
				Middle		271
				Early		299
		Pennsylvanian		Late		306
				Middle		311
				Early		318
		Mississippian		Late		326
				Middle		345
				Early		359
		Devonian		Late		385
				Middle		397
				Early		416
		Silurian		Late		419
				Early		423
		Ordovician		Late		428
				Middle		444
				Early		488
		Cambrian		Late		501
				Middle		513
				Early		542
Precambrian	Proterozoic	Late		Neoproterozoic (Z)		1000
		Middle		Mesoproterozoic (Y)		1600
		Early		Paleoproterozoic (X)		2500
	Archean	Late				3200
		Early				4000
	Haydean					

The Geologic Time Scale in all its glory. Image: USGS





GEO 730

Topics to be addressed - a syllabus of sorts (PDF)

Course Bibliography

Contemporary Crustal Strain (geodesy)

Global Positioning System - Principles

Garmin, 2001. GPS Beginners guide. A WEB DOCUMENT. (PDF)

Segall, P. and Davis, J.L., 1997. GPS applications for geodynamics and earthquake studies. Annual Review of Earth and Planetary Sciences, 25: 301-336. (PDF)

Useful Website dealing with use of GPS: https://www.unavco.org/education/resources/modules-and-activities/majors-gps-strain/majors-gps-strain.html#context

And a powerpoint dealing with calculation of crustal strain from GPS measurements: StrainFromGPS.pptx

Western United States

Joe Kreemer et al. (2012) A geodetic strain rate model for the Pacific–North American plate boundary, western United States, Nevada Bureau of Mines and Geology Map 178. (PDF)

McCaffrey, R., R. W. King, S. J. Payne, and M. Lancaster (2013). Active tectonics of northwestern U. S. inferred from GPS-derived surface velocities, JGR, 118 709-723. (PDF)

Zeng, Y. H. (2022). GPS Velocity Field of the Western United States for the 2023 National Seismic Hazard Model Update, Seismological Research Letters, 93 3121-3134. (PDF)

San Andreas System

Susy Freymueller, J.T., M.H. Murray, P. Segall, and D. Castillo, 1999, Kinematics of the Pacific-North America plate boundary zone, northern California, J. Geophys. Res., 104 (B4), 7419-7441 (PDF)

Savage, J.C., W. Gan, W.H. Prescott, and J.L. Svarc, 2004, Strain accumulation across the Coast Ranges at the latitude of San Francisco, 1994-2000, J. Geophys. Res., 109, B03413, doi:10.1029/2003JB002612 (PDF)

d'Allessio, M.A., Johanson, I.A., and R. Burgmann, D.A. Schmidt, and M.H. Murray, 2005, Slicing up the San Francisco Bay area: Block kinematics and fault slip rates from GPS-derived surface velocities, J. Geophys. Res., 110 (B06403, doi:10.1029/2004JB003496) (PDF).

Argus, D. F. and R. G. Gordon, Present tectonic motion across the Coast Ranges and San Andreas fault system in central California, Geological Society of American Bulletin, 113, 1580-1592. (PDF)

Eastern California Shear Zone, Walker Lane, and Sierra NV

Fred Dixon, T., Miller, M., Farina, F., Wang, H. and Johnson, D., 2000b. Present-day motion of the Sierra Nevada block and some tectonic implications for the Basin and Range province, North American Cordillera. Tectonics, 19: 1-24. (PD

Miller, M., Johnson, D., Dixon, T. and R. K. F, 2001, Refined kinematics of the Eastern California shear zone from GPS observations 1993-1998, Journal of Geophysical Research, 106, 2245-2263. (PDF)

Oldow, J. S., Aiken, C. L. V., Hare, J. L., Ferguson, J. F., Hardyman, R. F., 2001, Active displacement transfer within the central Walker Lane, western Great Basin, Geology, 29, 19-22. (PDF)

Bos AG and W. Spakman, 2005, Kinematics of the southwestern US deformation zone inferred from GPS data, Journal of Geophysical Research - 110 (B8) (PDF)

Camillia Gan W. J., 2000, Srain accumulation across the Eastern California Shear Zone , Journal of Geophysical Research, 105 : 16229 (PDF)

Lifton, Z. M., A. V. Newman, K. L. Frankel, C. W. Johnson, and T. H. Dixon (2013). Insights into distributed plate rates across the Walker Lane from GPS geodesy, Geophysical Research Letters 40 4620-4624 (PDF)

Website with papers to be covered – actually many more papers on listthan we'll actually address – so task is not daunting.

Can expect to cover ~8 papers per week – 4 - 5 per class – history shows its generally 4…

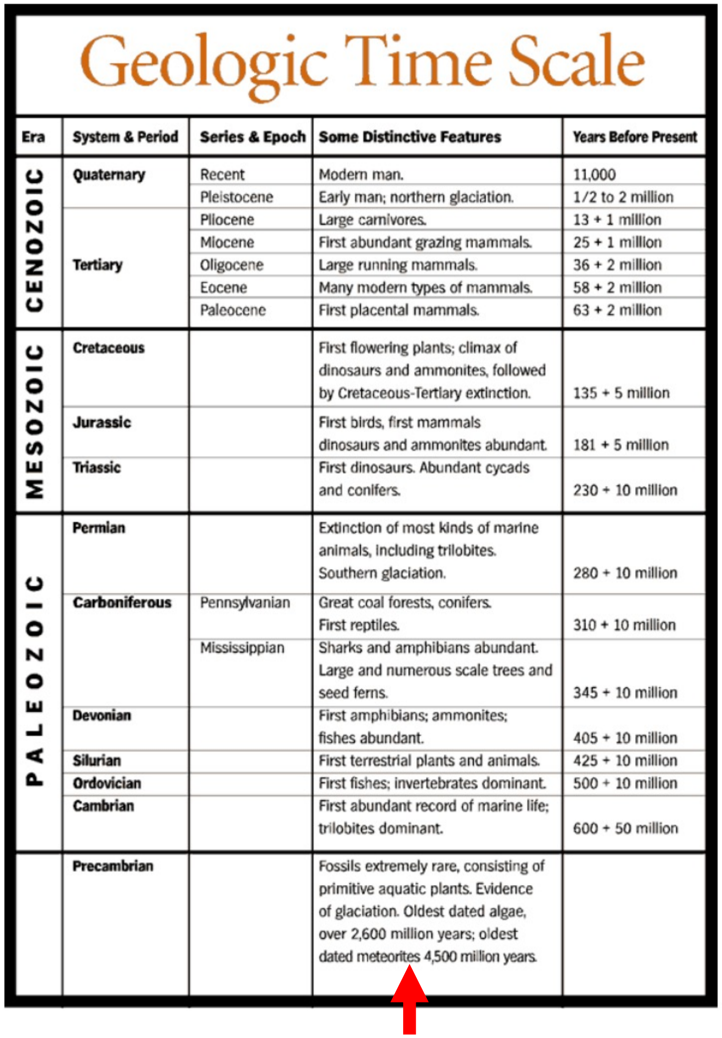
Participants will on rotational basis construct powerpoint synopsis of papers to be presented in 10 minutes to class, plus 5 minutes of discussion – in the same manner and time generally allotted for presentation of a paper at a professional meeting.

Your assignment with each of these papers to present to you classmates the motivation of the paper, the methods employed by the paper, the main findings of the paper.

So in effect we're crowdsourcing our efforts to piece together the observations and studies on which our understanding of geologic history is built.

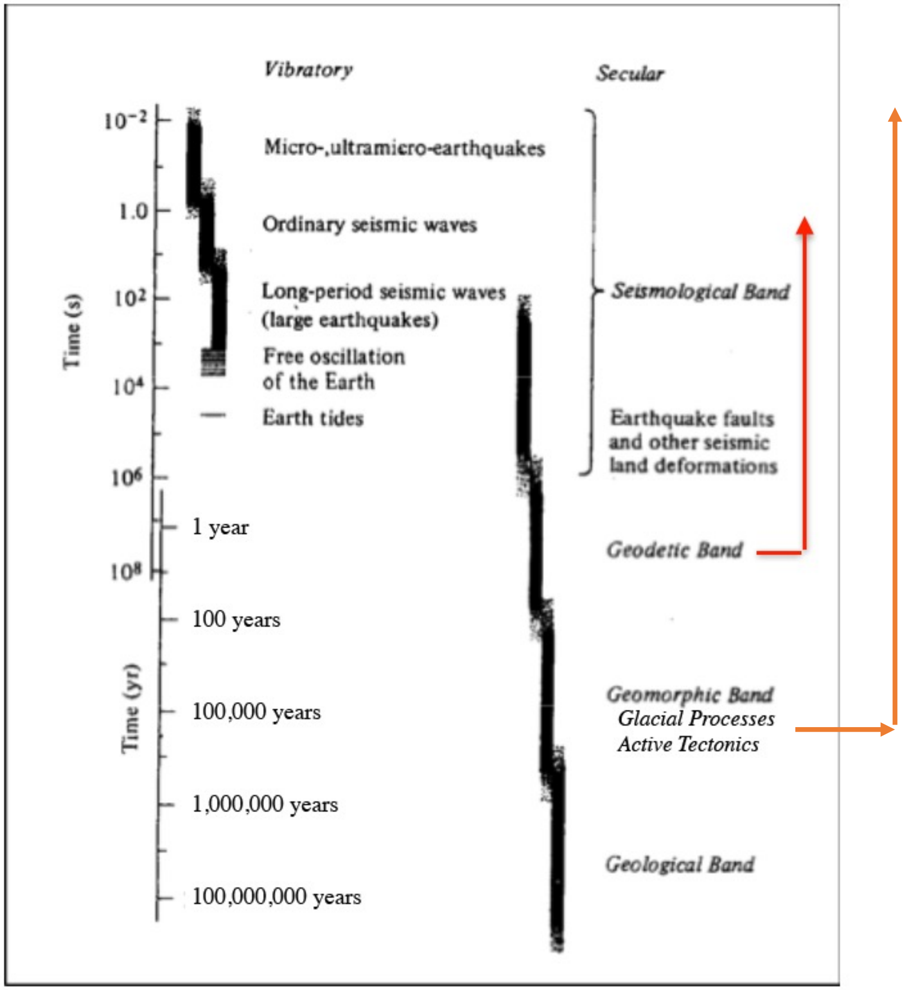
There are to be no other assignments or exams.

Powerpoints emailed to me by midnight preceding day of presentation

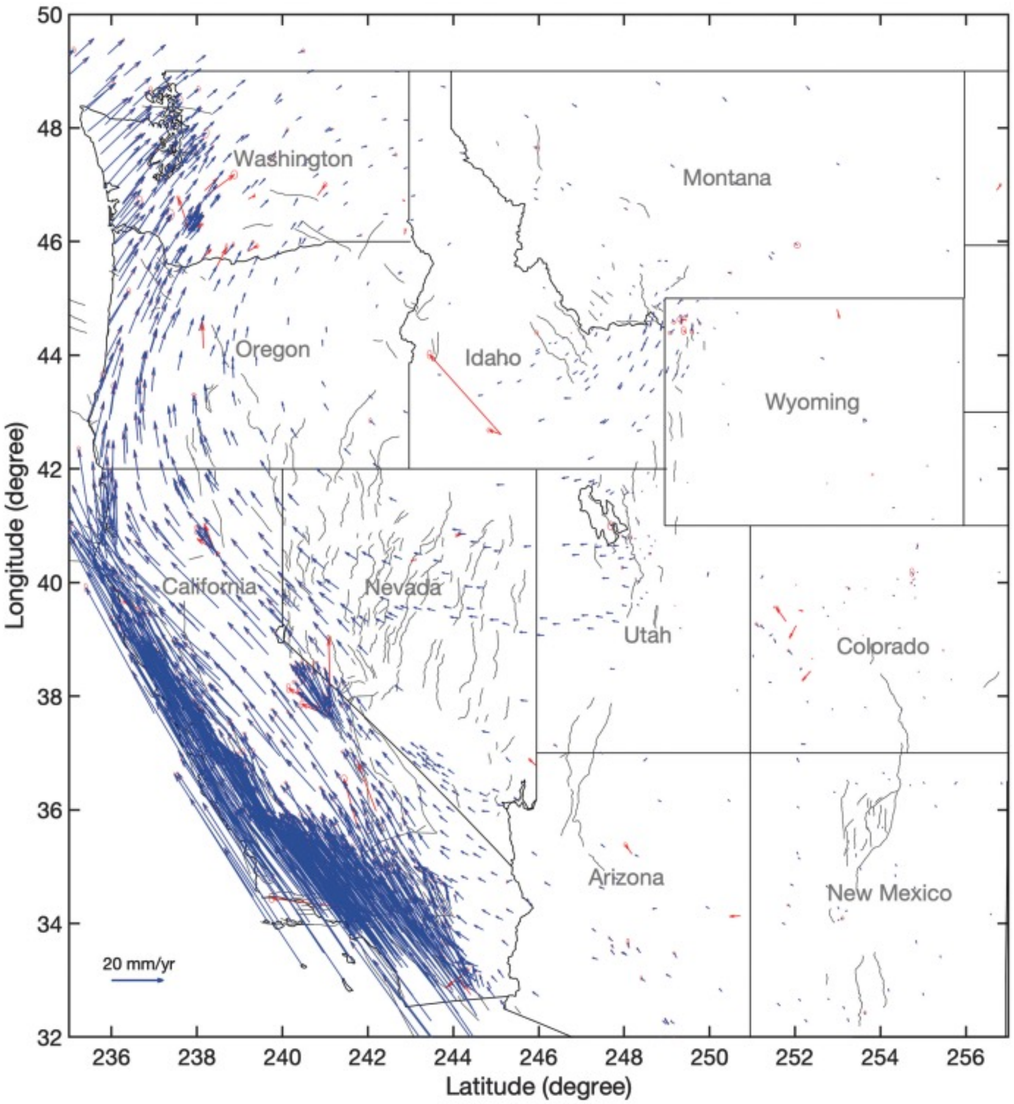


Geologic Time Scale

Era	System & Period	Series & Epoch	Some Distinctive Features	Years Before Present
CENOZOIC	Quaternary	Recent	Modern man.	11,000
		Pleistocene	Early man; northern glaciation.	1/2 to 2 million
	Tertiary	Pliocene	Large carnivores.	13 + 1 million
		Miocene	First abundant grazing mammals.	25 + 1 million
		Oligocene	Large running mammals.	36 + 2 million
		Eocene	Many modern types of mammals.	58 + 2 million
		Paleocene	First placental mammals.	63 + 2 million
MESOZOIC	Cretaceous		First flowering plants; climax of dinosaurs and ammonites, followed by Cretaceous-Tertiary extinction.	135 + 5 million
	Jurassic		First birds, first mammals dinosaurs and ammonites abundant.	181 + 5 million
	Triassic		First dinosaurs. Abundant cycads and conifers.	230 + 10 million
PALEOZOIC	Permian		Extinction of most kinds of marine animals, including trilobites. Southern glaciation.	280 + 10 million
	Carboniferous	Pennsylvanian	Great coal forests, conifers. First reptiles.	310 + 10 million
		Mississippian	Sharks and amphibians abundant. Large and numerous scale trees and seed ferns.	345 + 10 million
	Devonian		First amphibians; ammonites; fishes abundant.	405 + 10 million
	Silurian		First terrestrial plants and animals.	425 + 10 million
	Ordovician		First fishes; invertebrates dominant.	500 + 10 million
	Cambrian		First abundant record of marine life; trilobites dominant.	600 + 50 million
	Precambrian		Fossils extremely rare, consisting of primitive aquatic plants. Evidence of glaciation. Oldest dated algae, over 2,600 million years; oldest dated meteorites 4,500 million years.	



For us – it will be tectonic events – not life



Zeng 2003

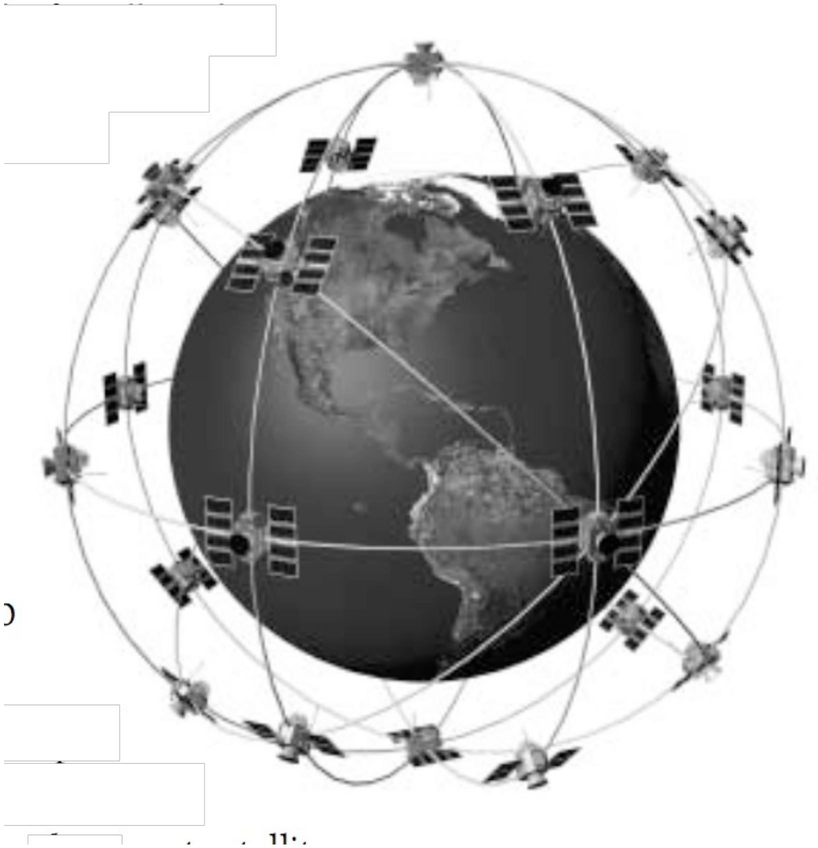
Figure 1. Map of Plate Boundary Observatory (PBO) Global Positioning System (GPS) velocity field for the western United States (WUS) references to the North America Reference Frame NAM14. Red velocity vectors are outliers removed from the solution after rigorous data editing. The color version of this figure is available only in the electronic edition.

GPS – global positioning system

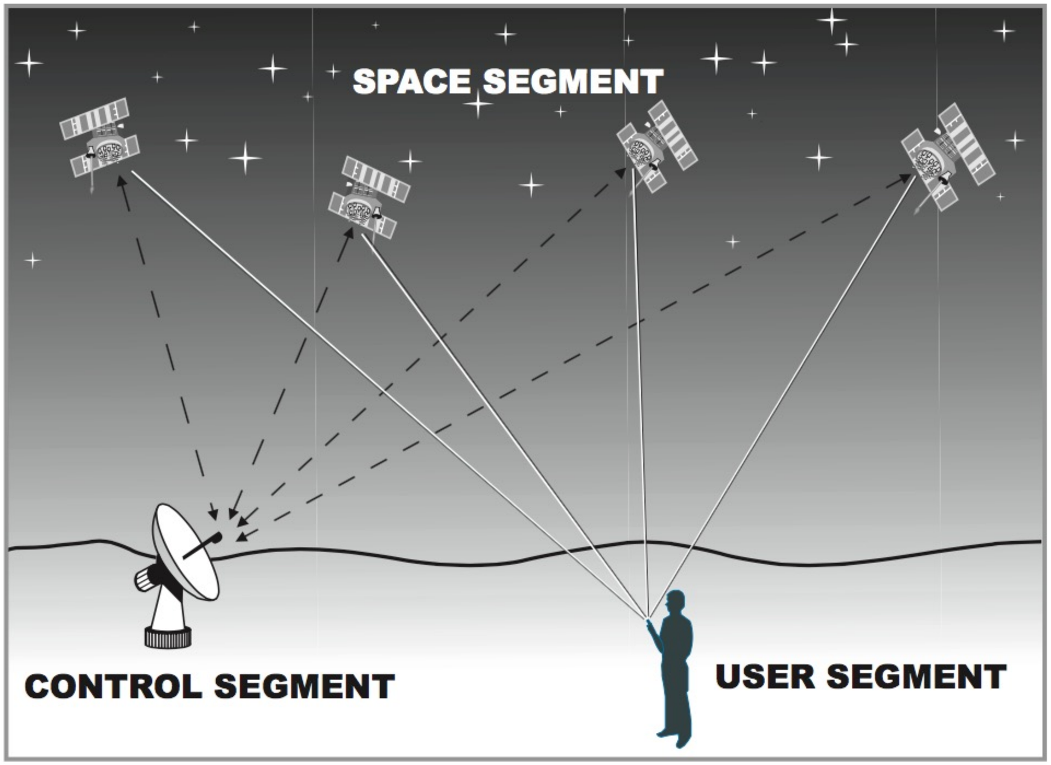
Based on constellation of Department of Defense Satellites

NAVSTAR –

“Navigation Satellite Timing and Ranging’ – official DoD name for the thing.



3 parts to it.



Space 'Segment'

- 24 Satellites (21 active, 3 spare)
- 12,000 miles above Earth surface
- Each making full orbit each 12 hours
- Powered by Solar, expected life 10 years
- Arranged so 4 visible
- Each Transmits low power radio signals at several (L1, L2,..) frequencies (L1 is 1575 MHz)
- Each broadcasts two pseudoradom signals – a protected (P) code and a Coarse/Acquistion (C/A) code

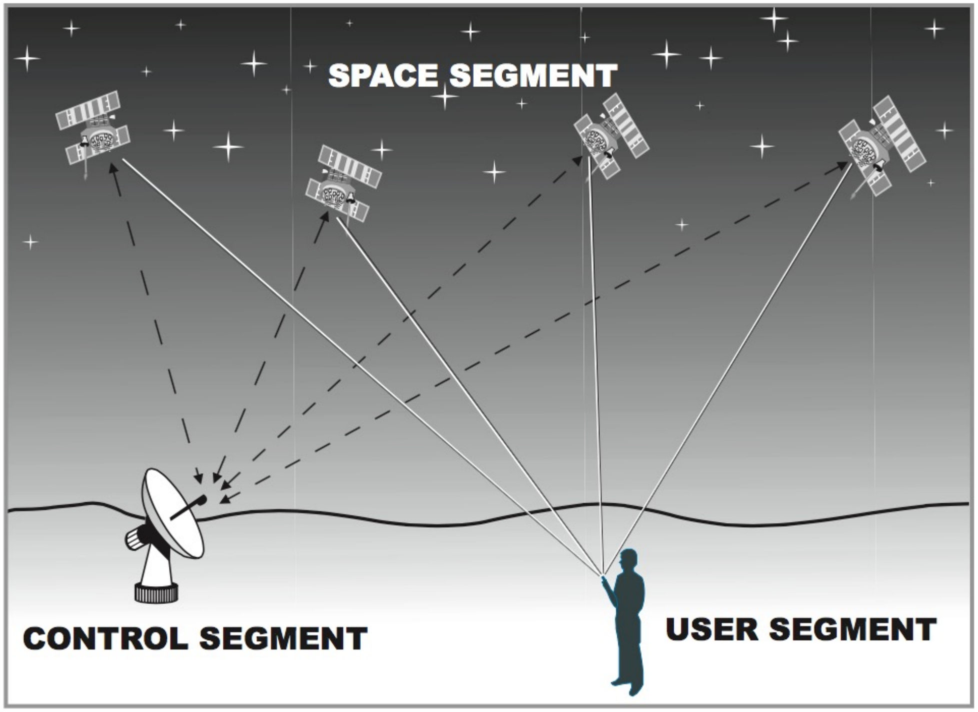
Control ‘Segment’

‘Controls’ GPS satellites by tracking them and providing orbital and clock(time) information.

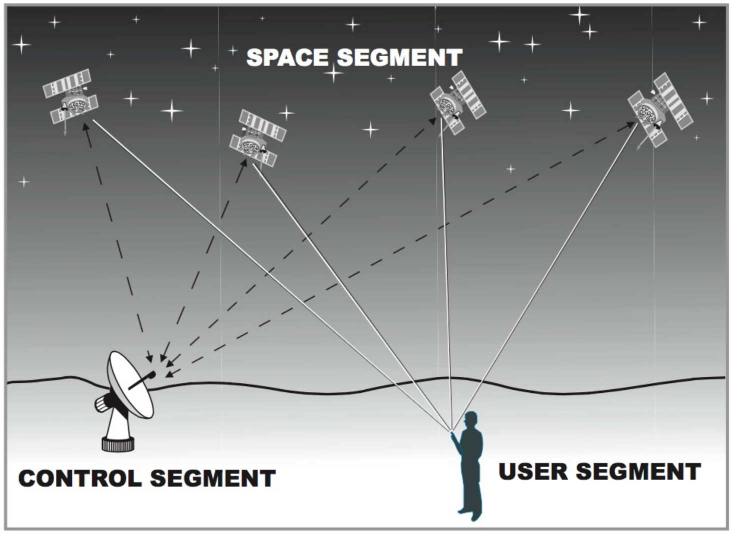
There are five control ‘receiving’ stations – 4 unmanned plus the ‘BOSS station’

The 4 unmanned constantly receive info from satellites and send it to the ‘BOSS station’

The ‘BOSS station’ then ‘corrects’ the data and returns info to the satellites – ultimately allowing the location of each satellite.



‘Correcting the Data’ - How it works – in principle



GPS receiver needs to know where exactly is each satellite – To do this, receiver picks up two types of data.

Type 1: Almanac data (contains approx position of the satellites) is transmitted continuously and stored in memory of receiver.

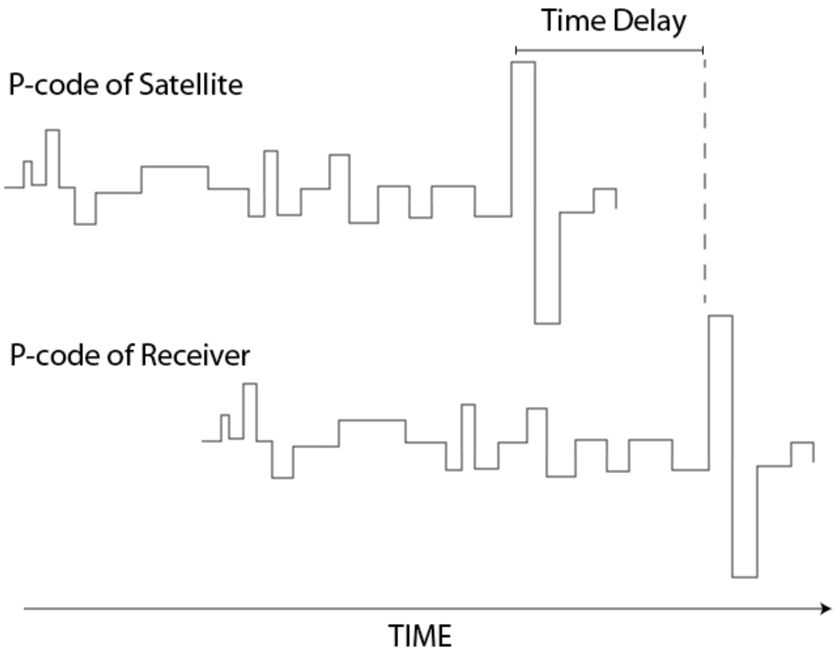
Type 2: Ephemiris data. Satellite orbits may deviate, so ground monitoring station continuously trace the altitude, location, and speed of each satellite. The ground stations send this data to the ‘master’, and then the master sends the corrected data up to the satellites and this corrected data is in turn sent to the receiver. The corrected data is called the ‘ephemeris’ and is valid for ~4 to 6 hours.

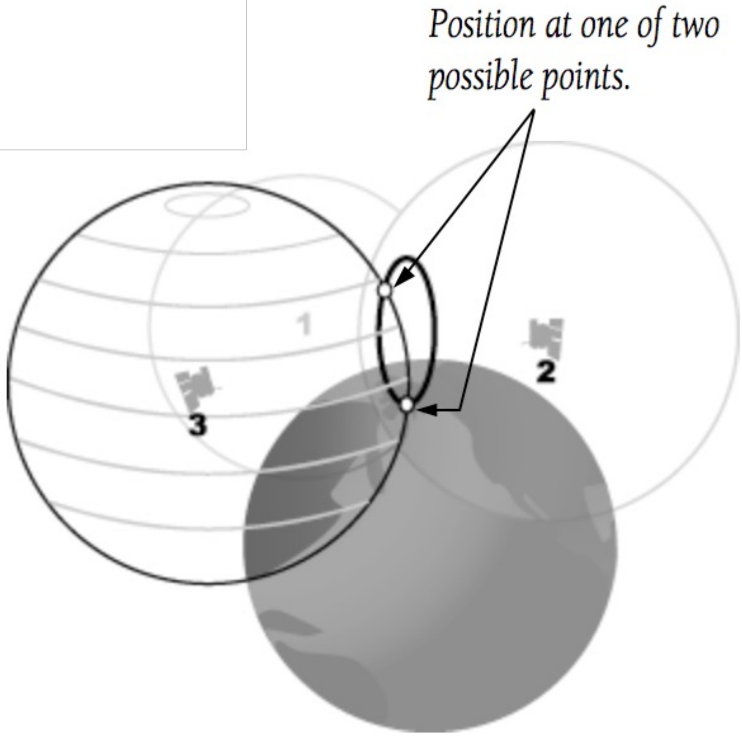
With above – the location of all satellites is known at all times - and the distance of a receiver from from given satellite is = Velocity of Light by Time it takes for radio wave to travel from the satellite to the receiver.

The trick in determining the distance is with the P-code…

The trick is that each the respective satellite and receiver are generating the ‘pseudo-random’ P-code at the same time.

The Receiver than determines the amount of time it needs to shift the P-codes to match each other – and that is the time delay.




Position at one of two possible points.

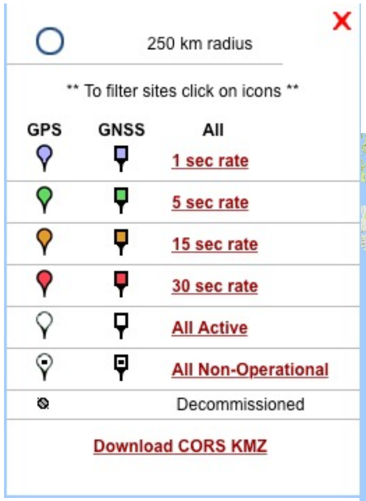
Speed of light x time delay is distance of a satelite to any

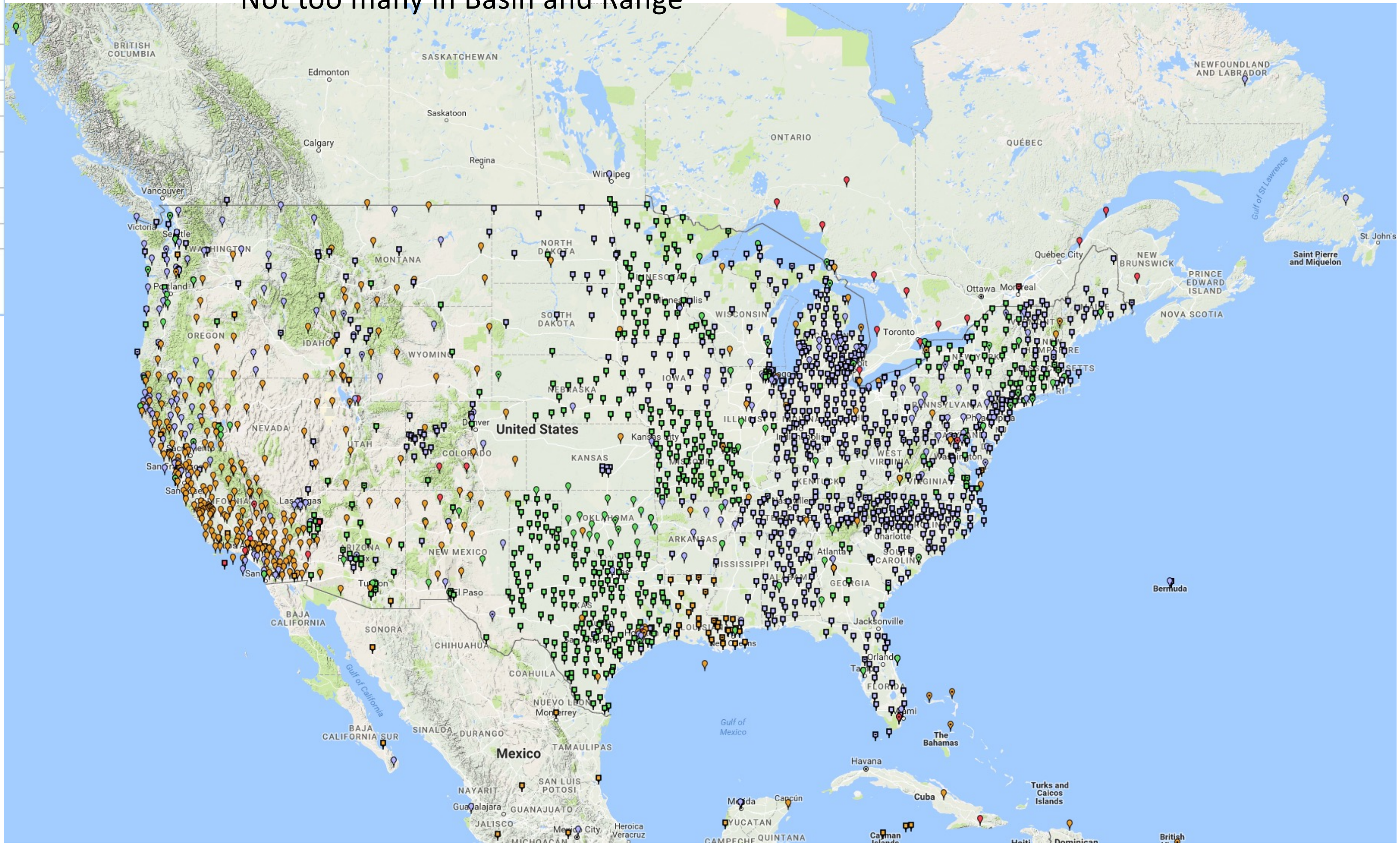
UNAVCO Universties

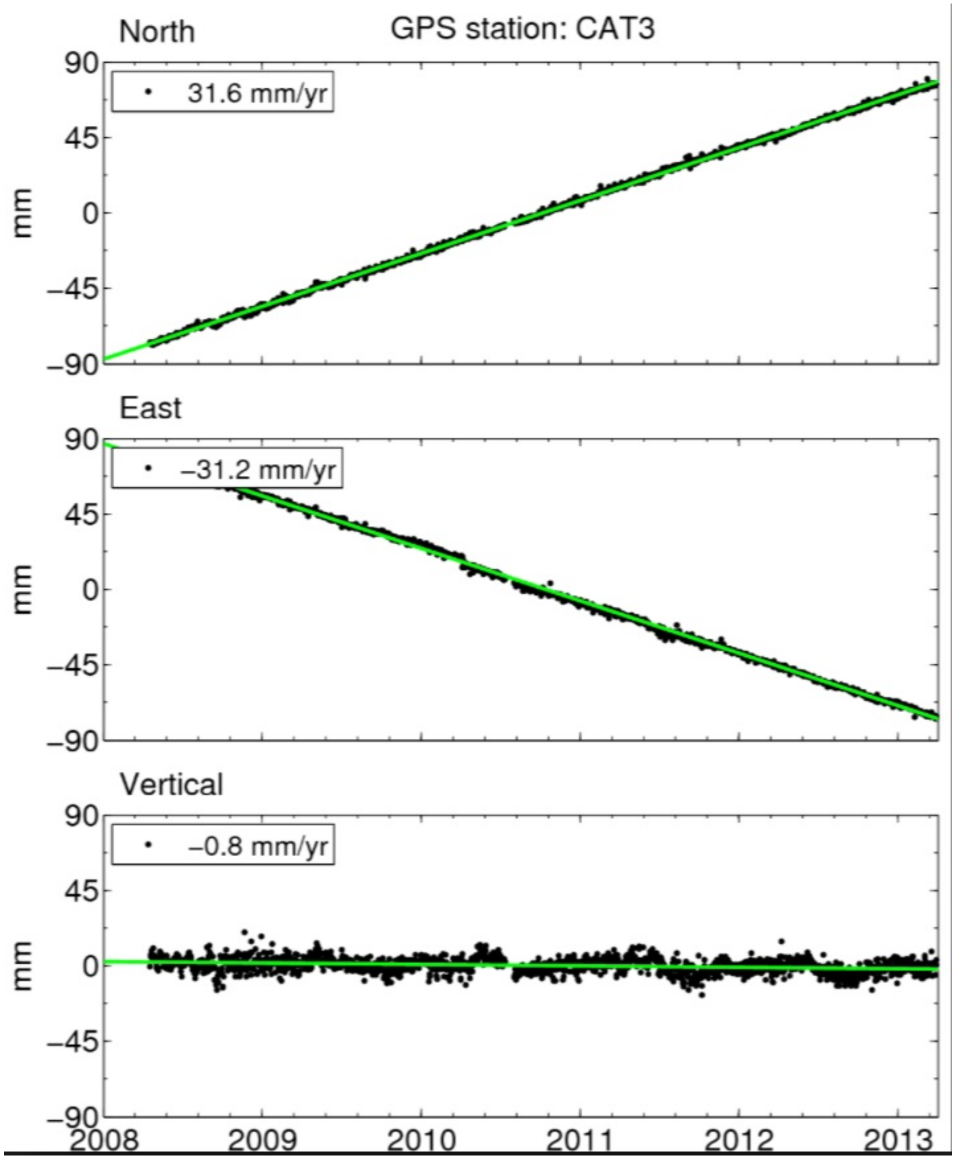
Permanent Plate Boundary Observatory GPS Receiver
UNAVCO – Univeristy NAVstar COnsortium

Continuously Recording GPS Stations in United States

Not too many in Basin and Range







Typical GPS Time Series from a continuously operating GPS station.

3 – components

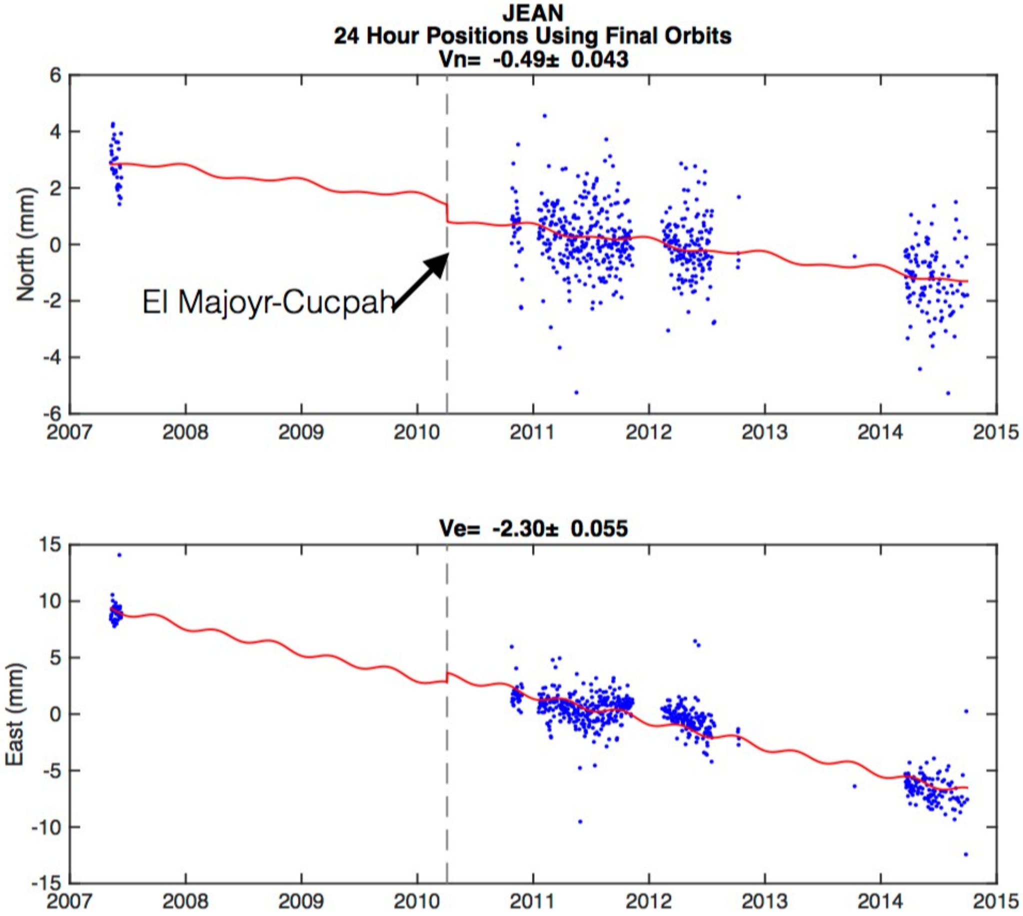
There is scatter associated with each measurment.

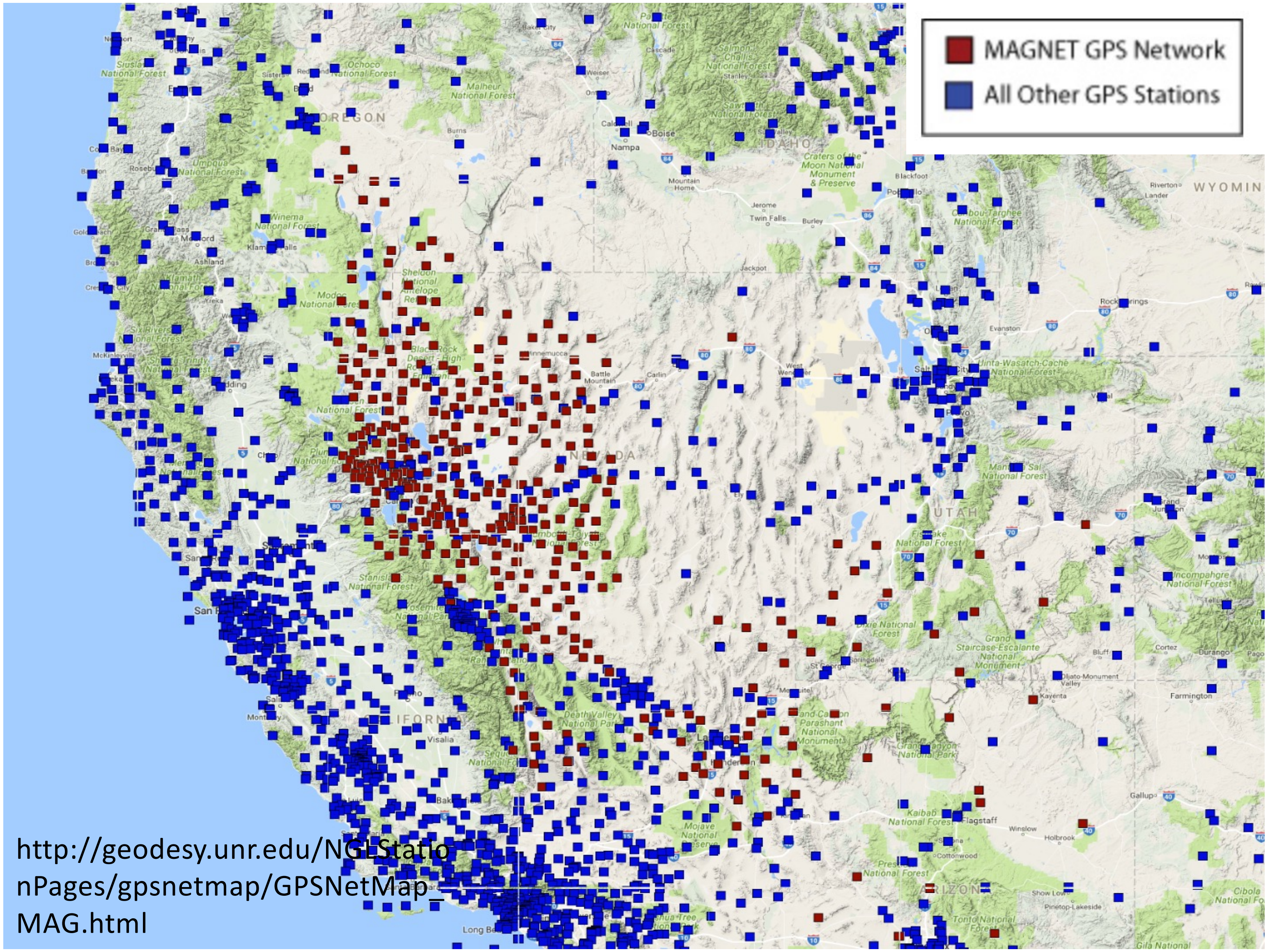
Resolution increased by time averaging/line fitting

But these cost a good bit to install and maintain. So other games are played to fill in the areas that have no permanent stations.

One of NBMG’s Magnet Array Temporary Stations
Mobile Array of GPS for Nevada Transtension

With MAGNET and other temporary occupations – The long-term signal is found by piecing together time-series of reoccupations of the same receiver site. Not quite as accurate as real time, but close when concerned with trends over half-dozen years or so…

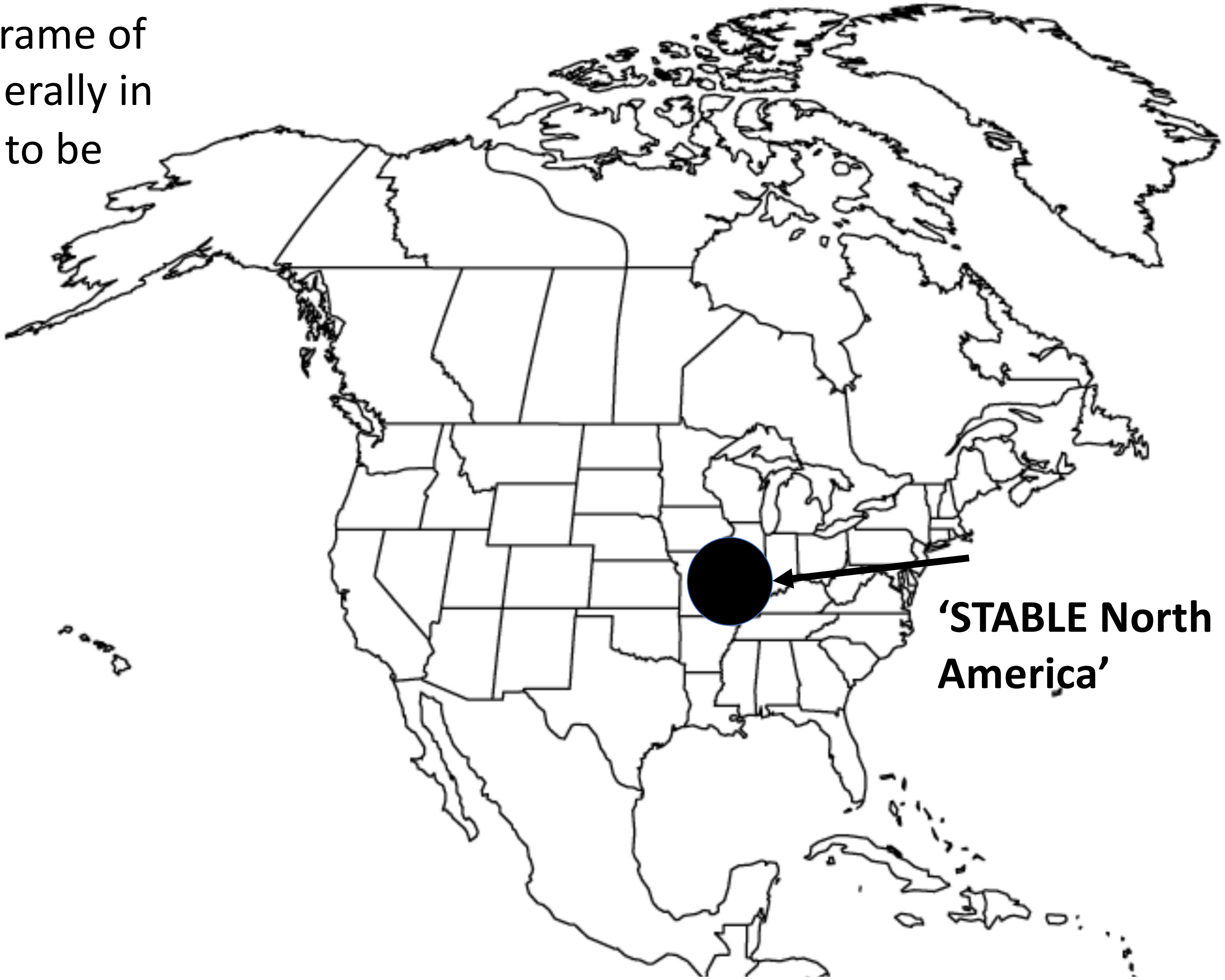


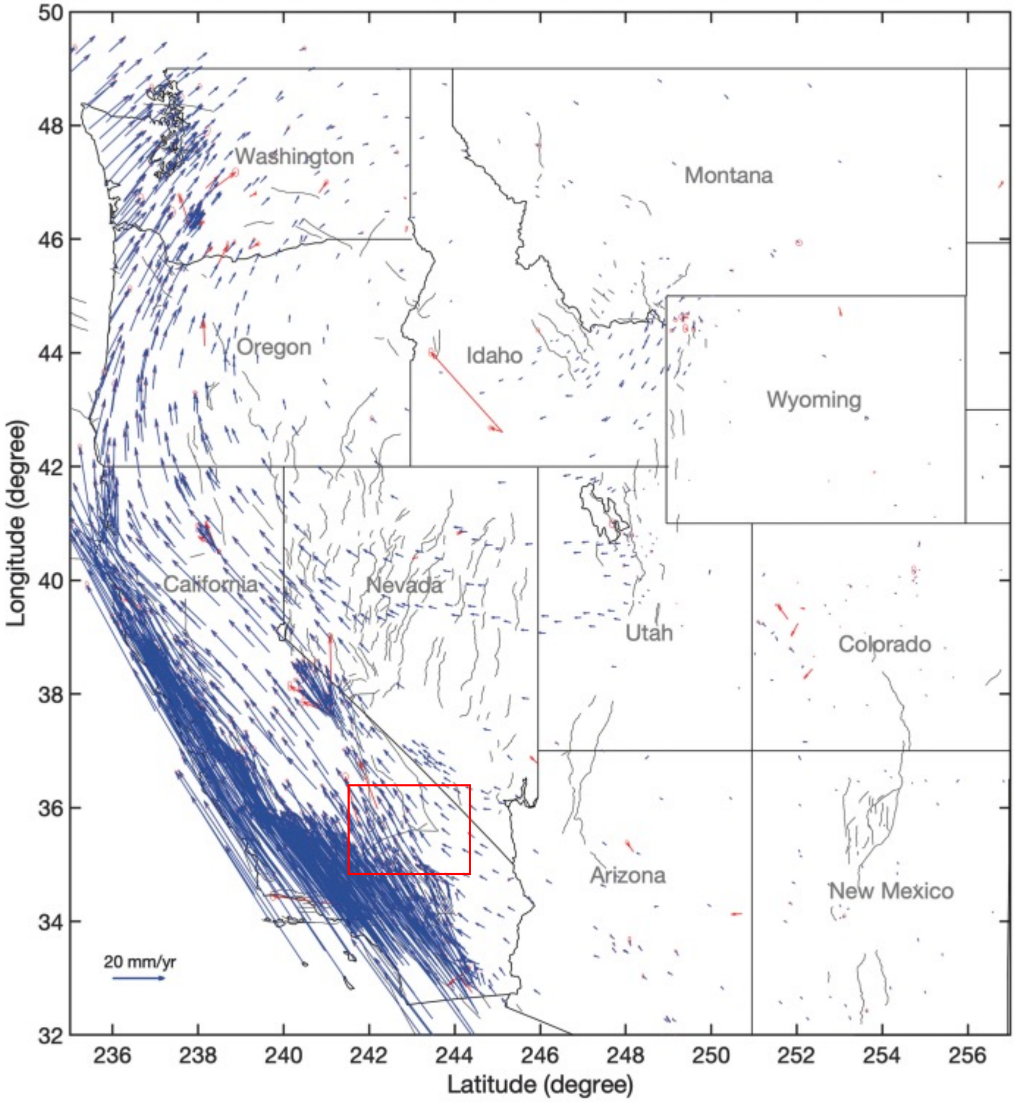


http://geodesy.unr.edu/NGLStationPages/gpsnetmap/GPSNetMap_MAG.html

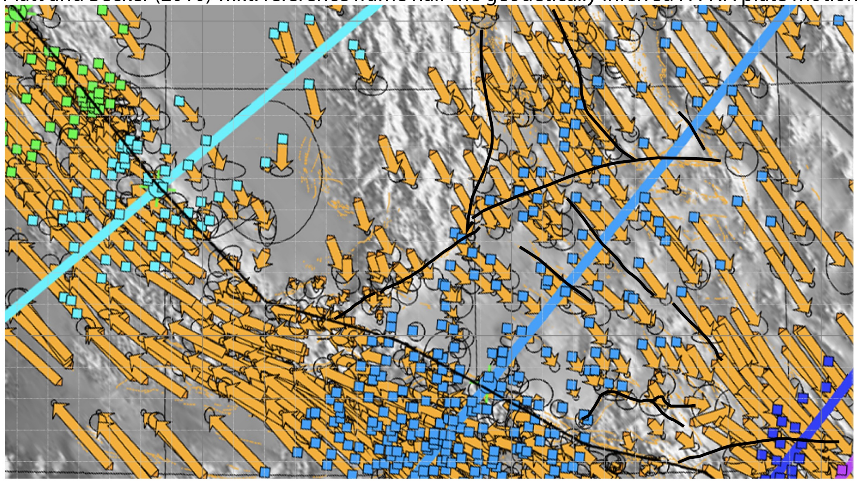
All Maps of Crustal Movements Determined by GPS Require a Frame of Reference be Established – Generally in place/region that is considered to be 'Stable'

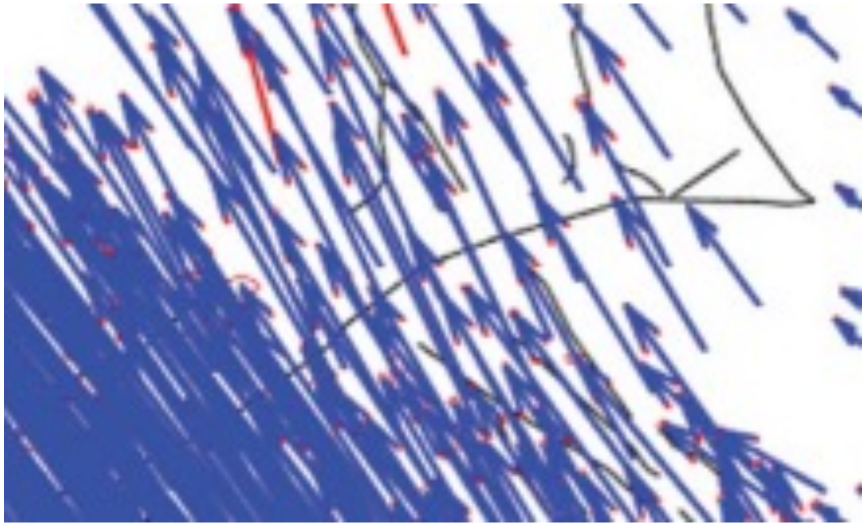
In US – most of time that is 'stable North America –
But not always





Platt and Becker (2010) w.r.t. reference frame half the geodetically inferred PA-NA plate motion





Always pay attention to reference frame

With GPS, there was of course a race among geodecists to determine the pattern of crustal deformation across the U.S. The race was slower across the Basin and Range because of the few stations – and thus temporary campaigns were used.

Thatcher (Science, 1999) won the race

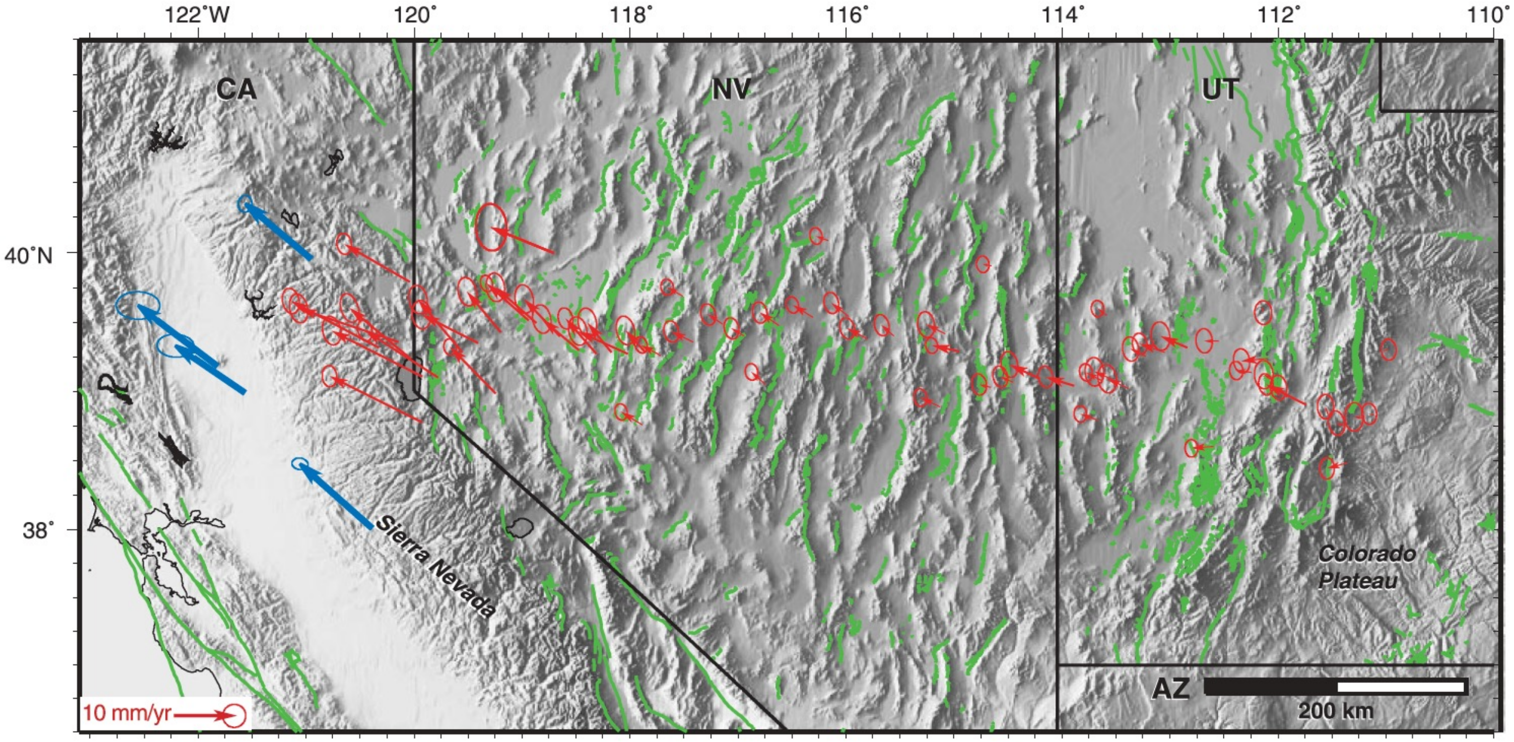


Fig. 1. GPS station velocities relative to other stations on the stable North American plate lying to the east of the network shown here. One standard deviation error ellipses are shown for each vector (*27*). The base map is shaded topography derived from data from the U.S. Geological Survey digital elevation model. State boundaries (CA, California; NV, Nevada; UT, Utah; AZ, Arizona) and stable blocks of the Sierra Nevada and Colorado Plateau are shown for reference. Active faults (*3*, *4*) are shown by solid green lines. The velocities of four stations on the stable Sierra Nevada block are shown with blue arrows. Velocities of Basin and Range stations are shown with red arrows.

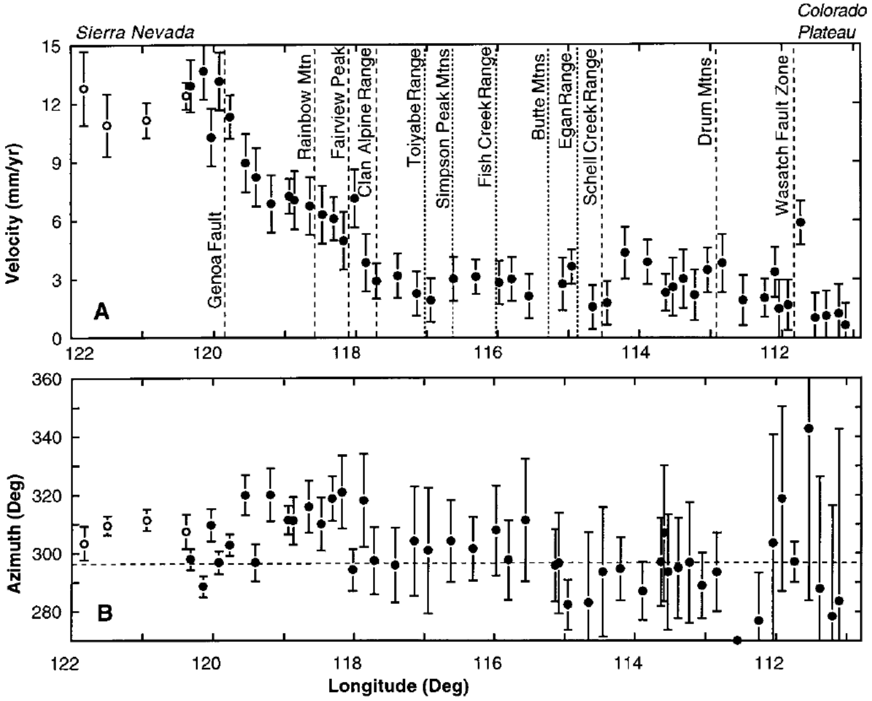
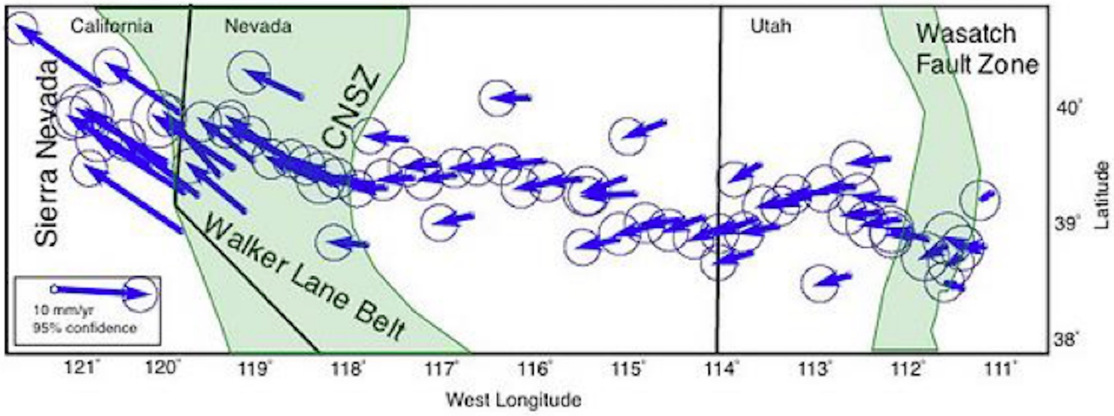


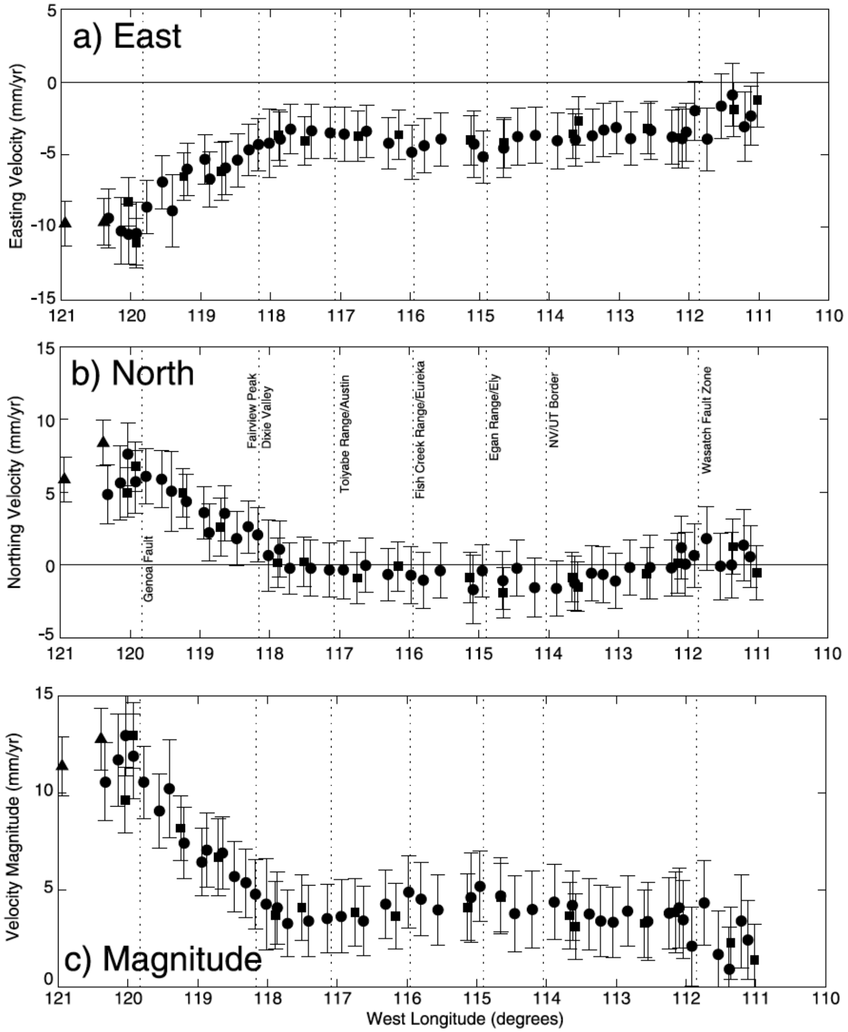
Fig. 2. Velocity magnitude (**A**) and azimuth measured clockwise from north (**B**) plotted versus longitude. Only the GPS stations along U.S. Highway 50 shown in Fig. 1 are plotted. However, the velocities of four additional continuously recording GPS stations (open circles) that lie within the stable Sierra Nevada block are shown for comparison. Error bars indicate 1 SD. Major range-bounding faults with Holocene slip (long-dashed lines) and Quaternary slip (short-dashed lines) are shown in (A), and the 308° azimuth of North America–Sierra Nevada relative motion (*13*) is shown by the horizontal dashed line in (B).

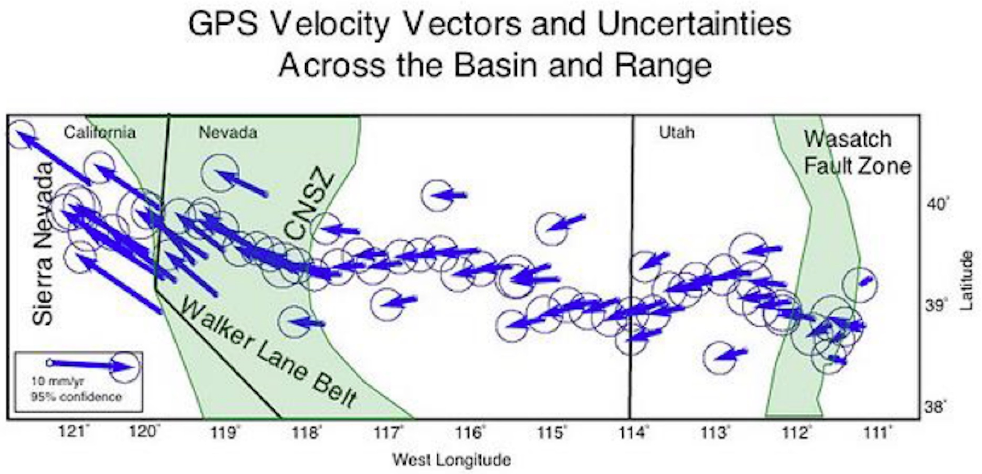
GPS Velocity Vectors and Uncertainties
Across the Basin and Range



Velocity with respect to
'Stable North America'

Azimuth with respect to
'Stable North America'



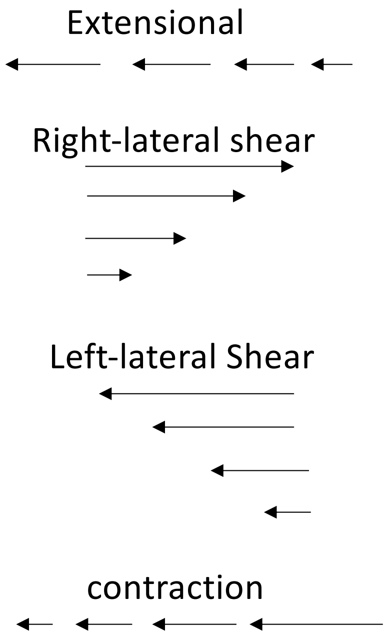

GPS Velocity Vectors and Uncertainties Across the Basin and Range

The east component is stable then begins marked decrease in Central Nevada seismic belt (CNSB)

The north component is stable then begins marked decrease in Central Nevada seismic belt (CNSB)

From observed differences in velocities over spatial distances
The strain accumulating in the crust may be calculated.

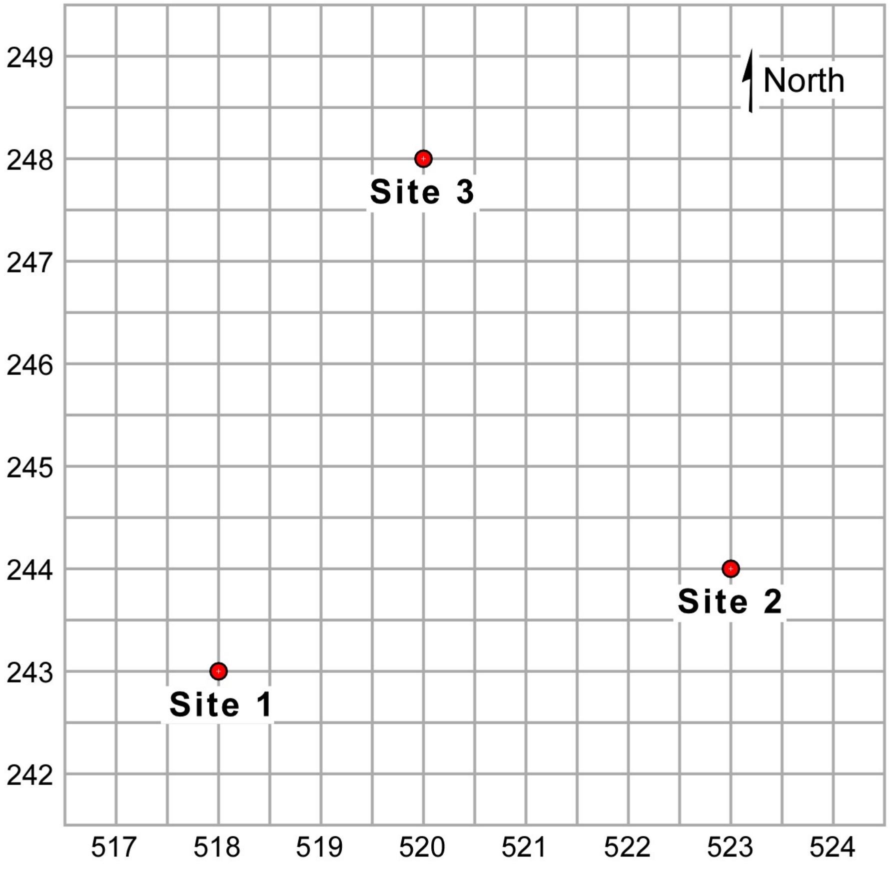
Motions (velocities) that cannot be explained by block motions indicate strain of crust is occurring

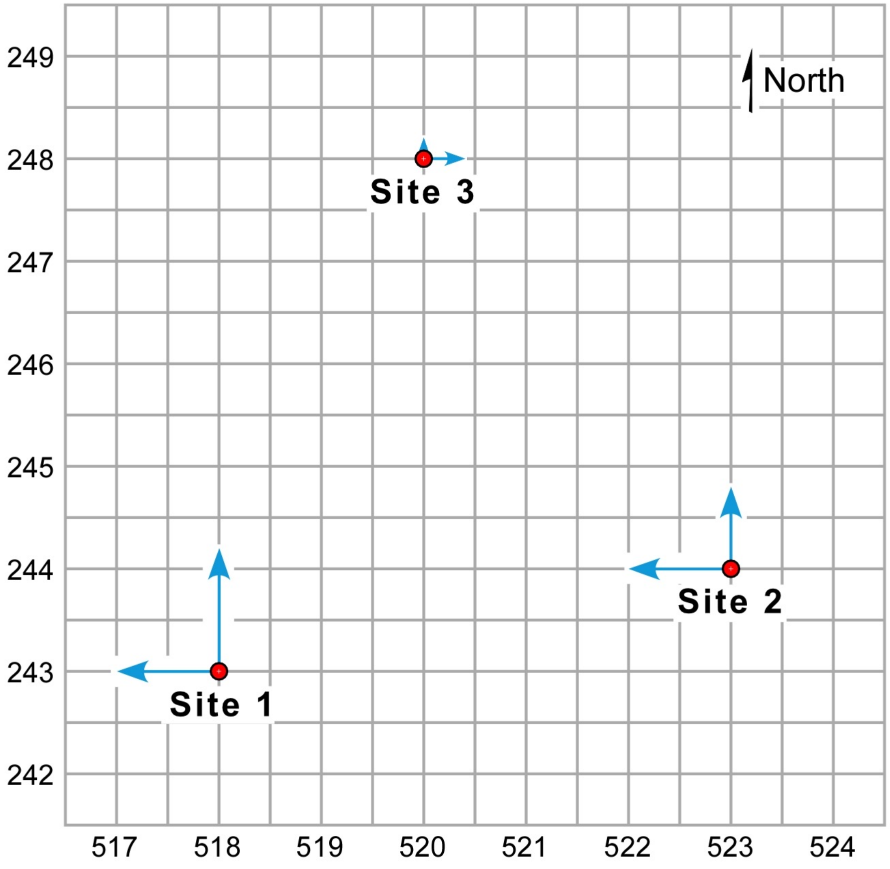

Extensional

Right-lateral shear

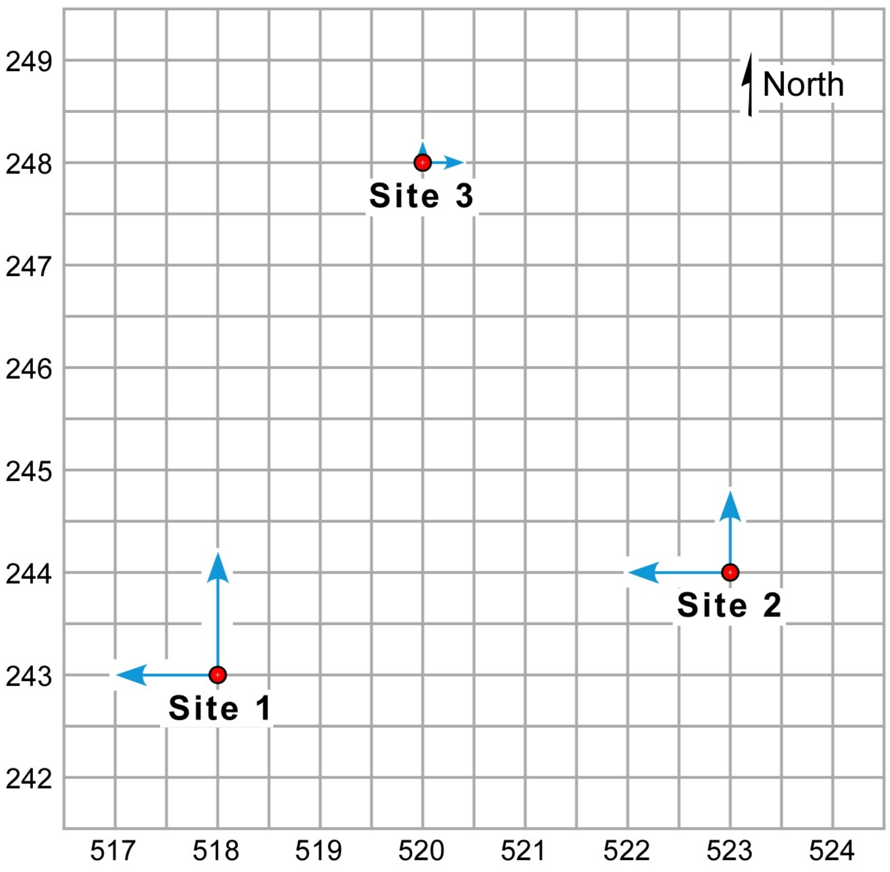
Left-lateral Shear

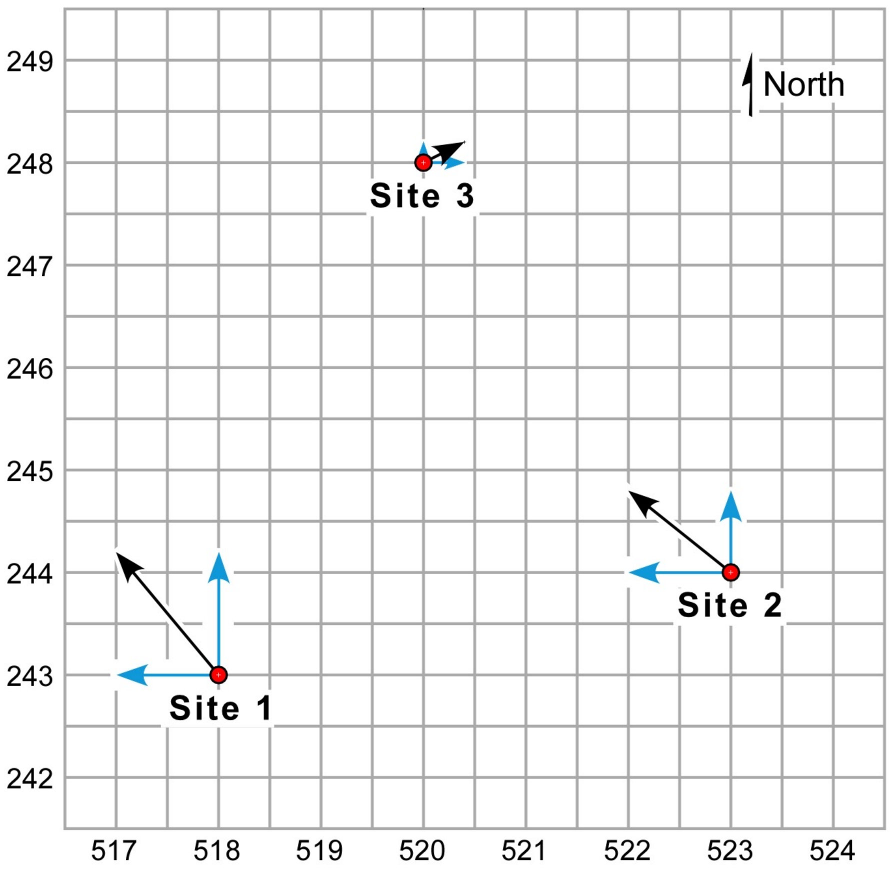
contraction



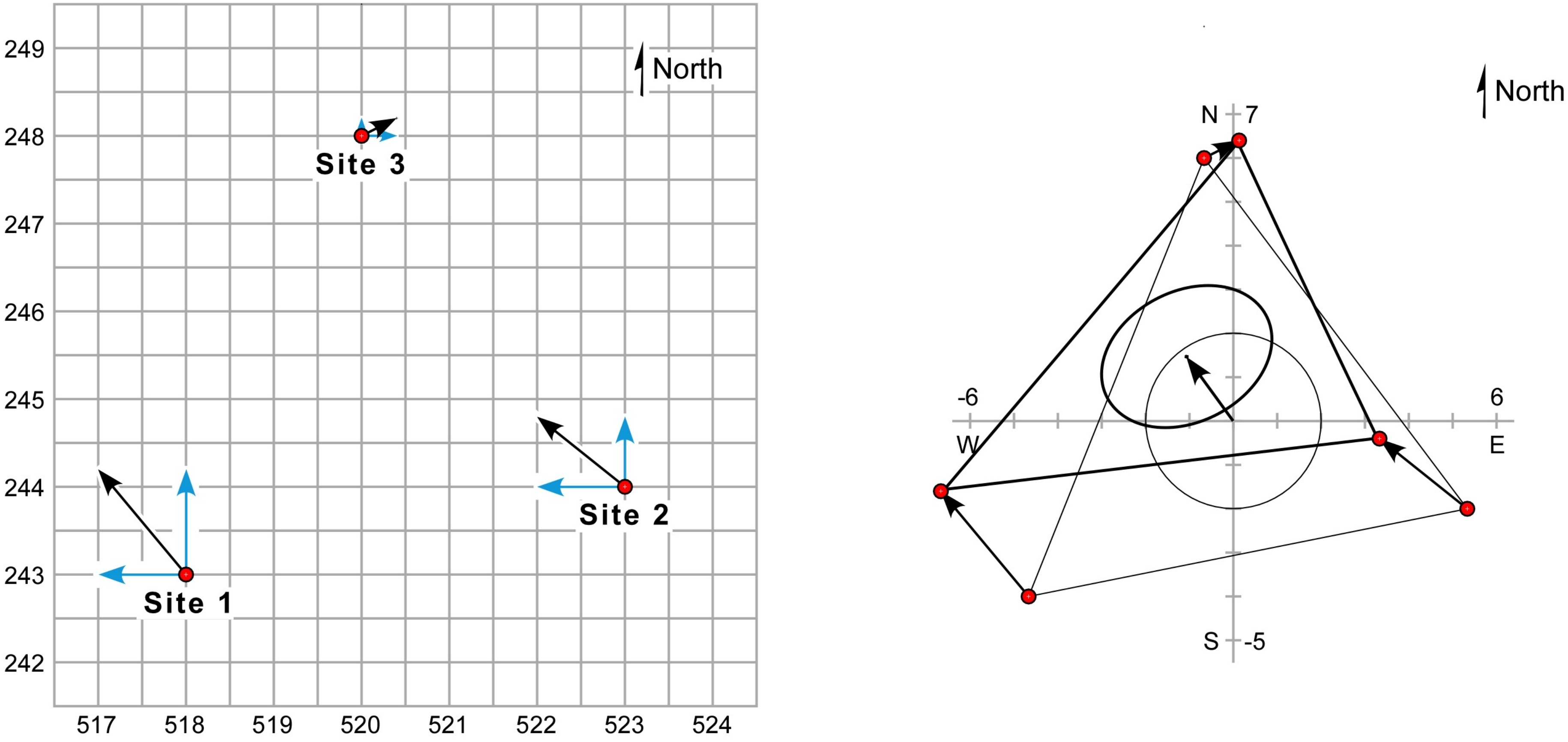


Following slides from a UNAVCO power point provided in reading list

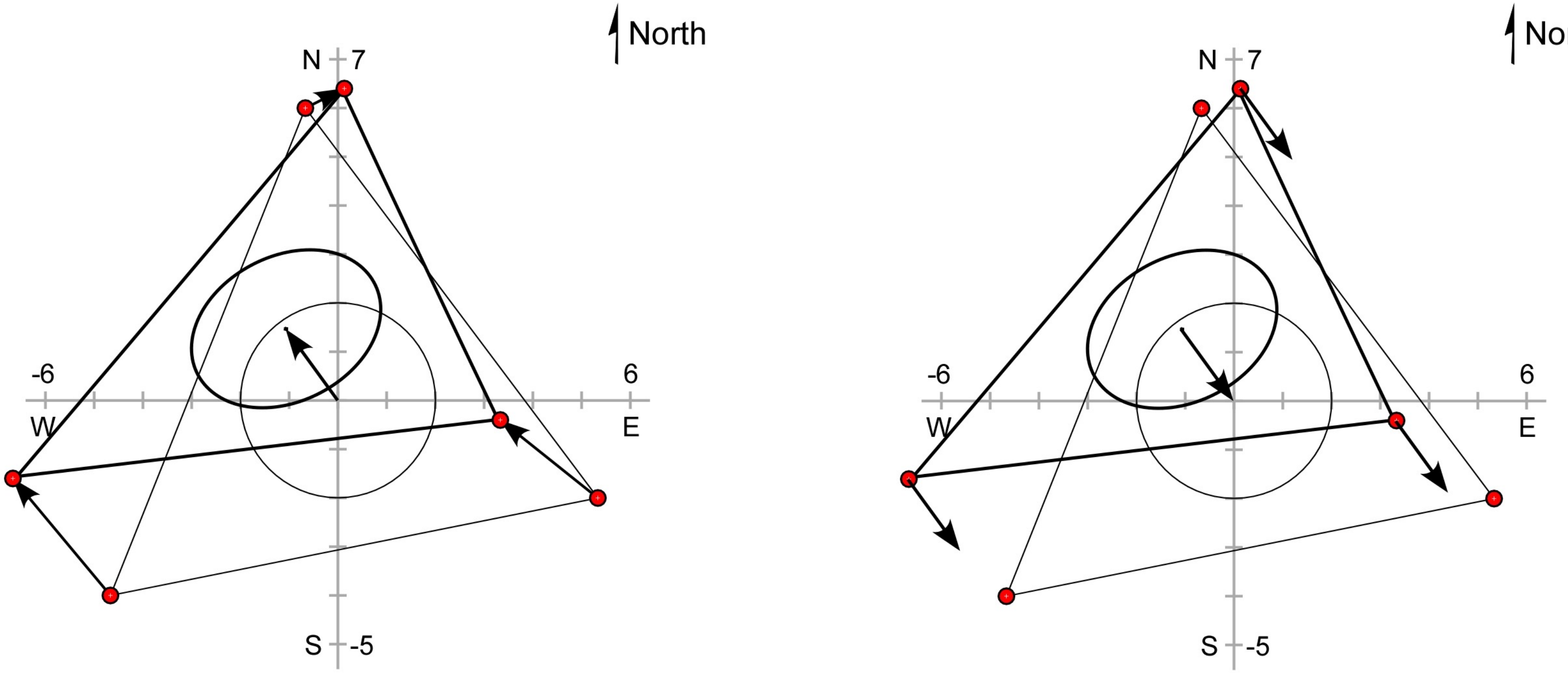




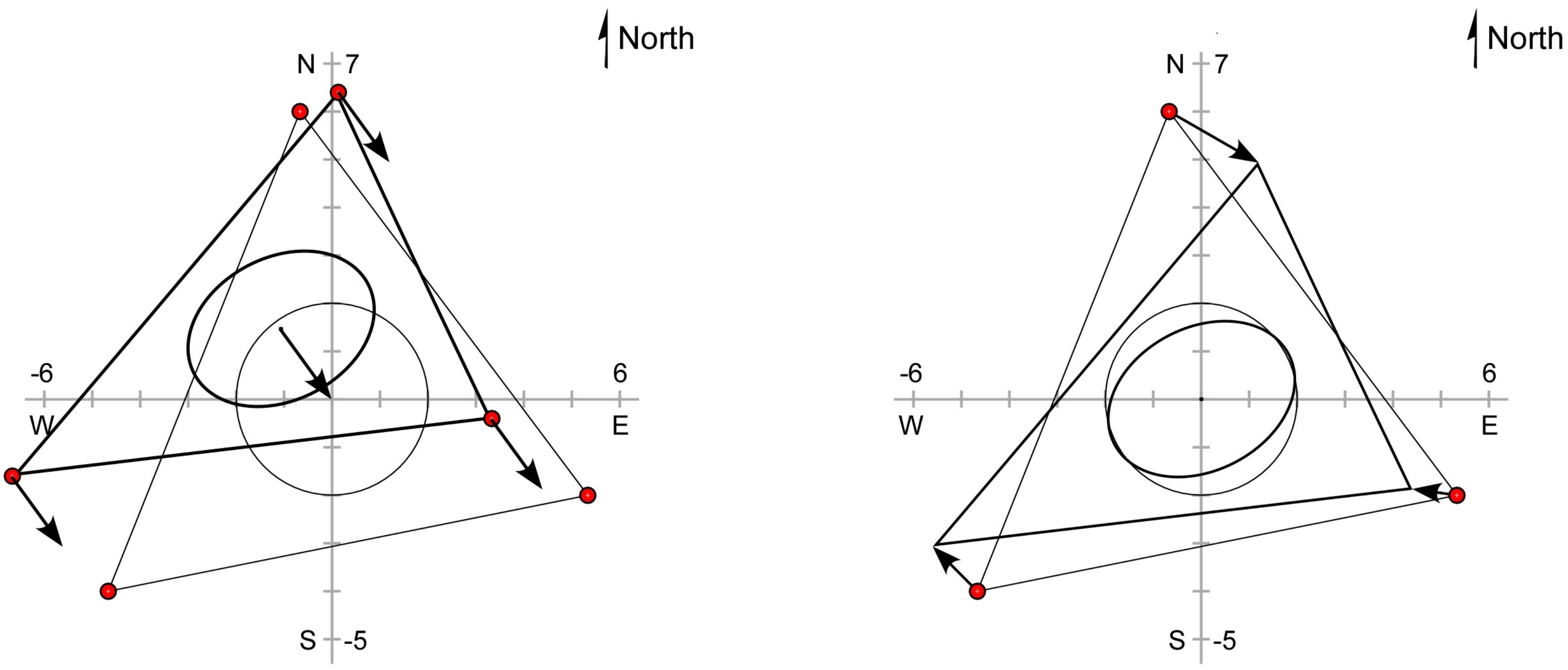
E-W + N-S components = total horizontal velocity of site



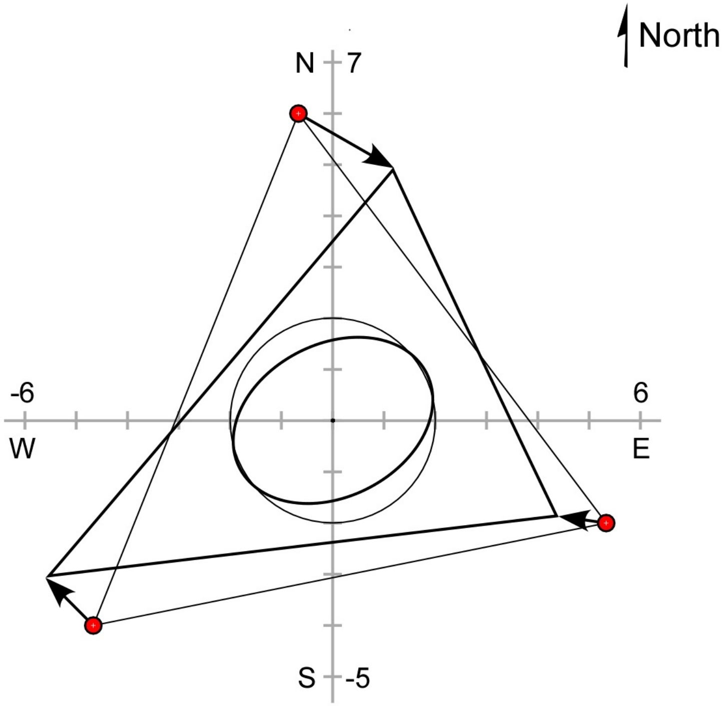
The triangle deforms as each of the sites moves. The vector from the centroid of the undeformed triangle to the centroid of the deformed triangle is the the horizontal translation vector.

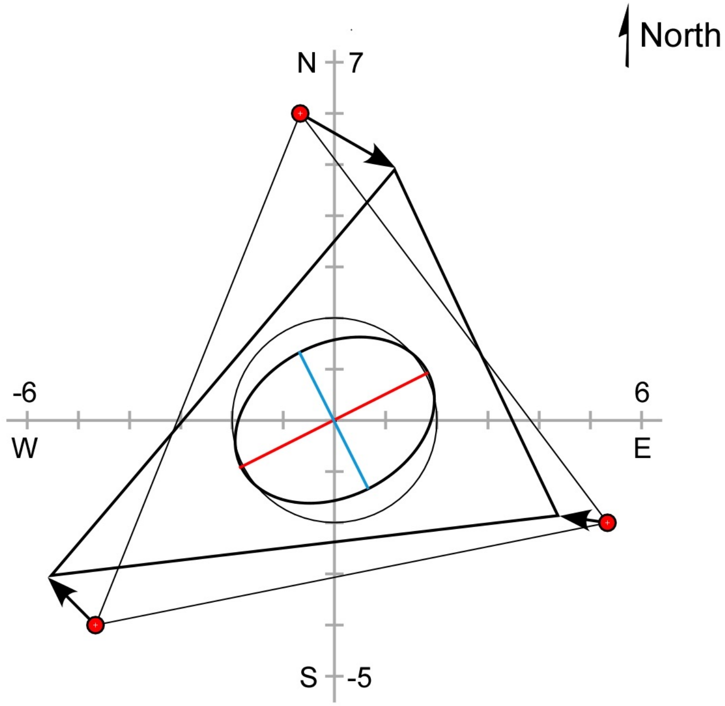


Subtracting the translation vector from the site velocities brings the two triangle (original and deformed) centroids together.

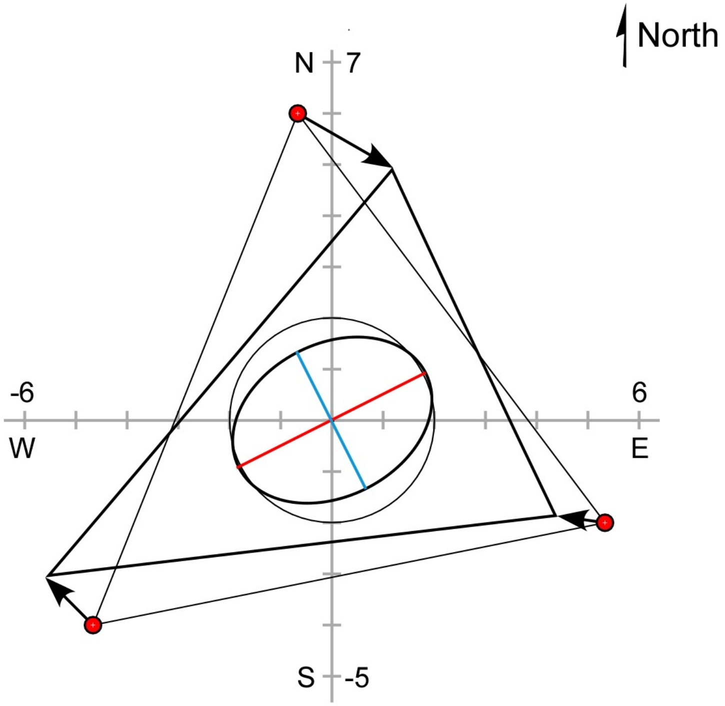


The total site velocities minus the translation vector yields the site vectors associated with the change in shape of the triangle.





And from this the principal (max and min) of the horizontal crustal strain (rate) between the stations can be calculated



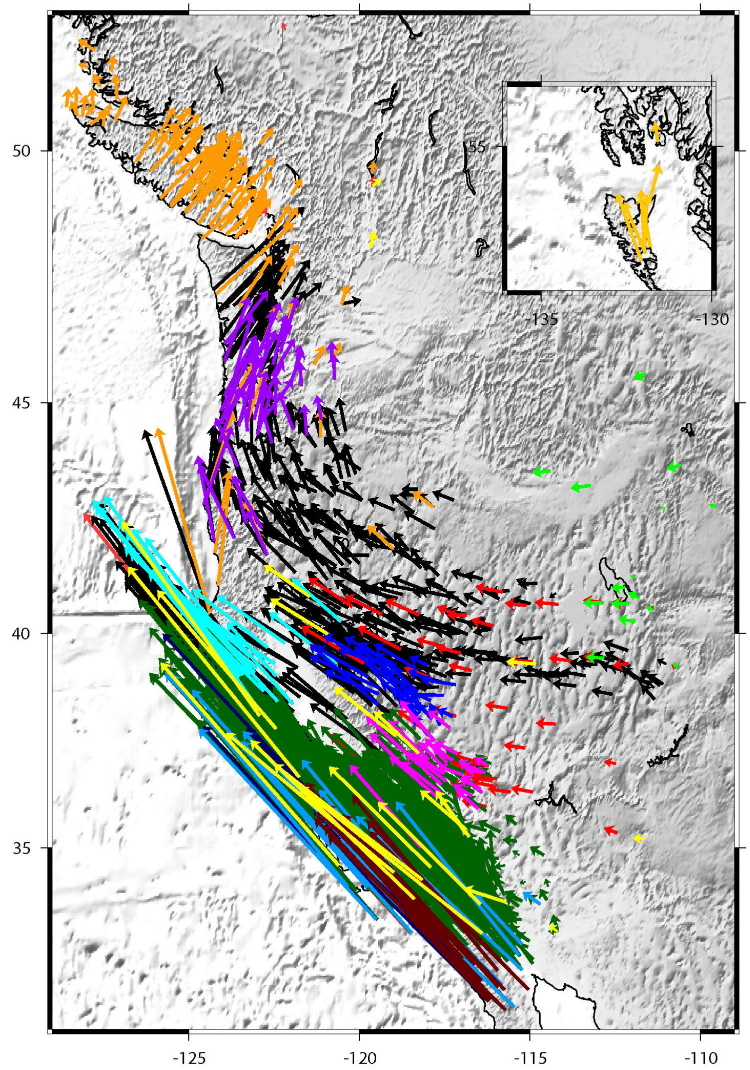
σ_1. is max horizontal strain axis

σ_2. is min horizontal strain axis

2nd Invariant of strain

$\sim \sigma_1^2 + \sigma_2^2$

Which is a measure of the magnitude of shear stress



And over to San Andreas.

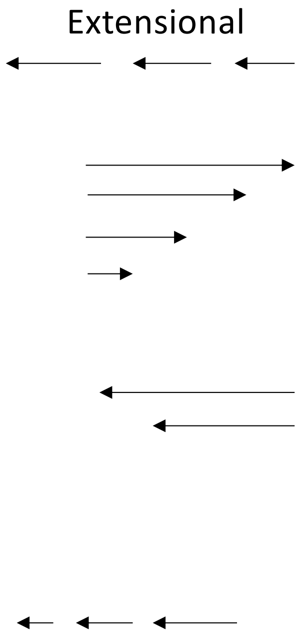
Total NW directed slip w.r.t stable North America is ~5 cm/yr

Geodetic Data

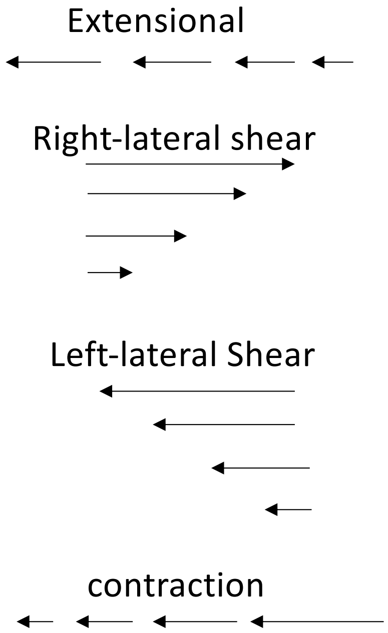
- **IGS**
- **USGS (incl. Svarc et al. ’02a,’02b; Savage et al. ’04; Hammond and Thatcher, ’04)**
- **BARGEN (R. Bennett, ’03)**
- **SCEC v.3.0**
- **EBRY (R. Smith, ’03)**
- **PANGA (Mazzotti et al., ‘02)**
- **Mazzotti et al. (‘03)**
- **McCaffrey et al. (‘00)**
- **Freymueller et al. (‘99)**
- **Oldow et al. (‘01)**
- **McClusky et al. (‘01)**
- **Dixon et al. (‘00)**
- **Dixon et al. (‘02)**
- **Gonzales-Garcia et al. (’03)**
- **Ma et al. (’98) VLBI**

Corne Kreemer slide…

Motions define regions of extension,
Contraction,
Shear (right and left lateral)



Motions (velocities) that cannot be explained by block motions indicate strain of crust is occurring

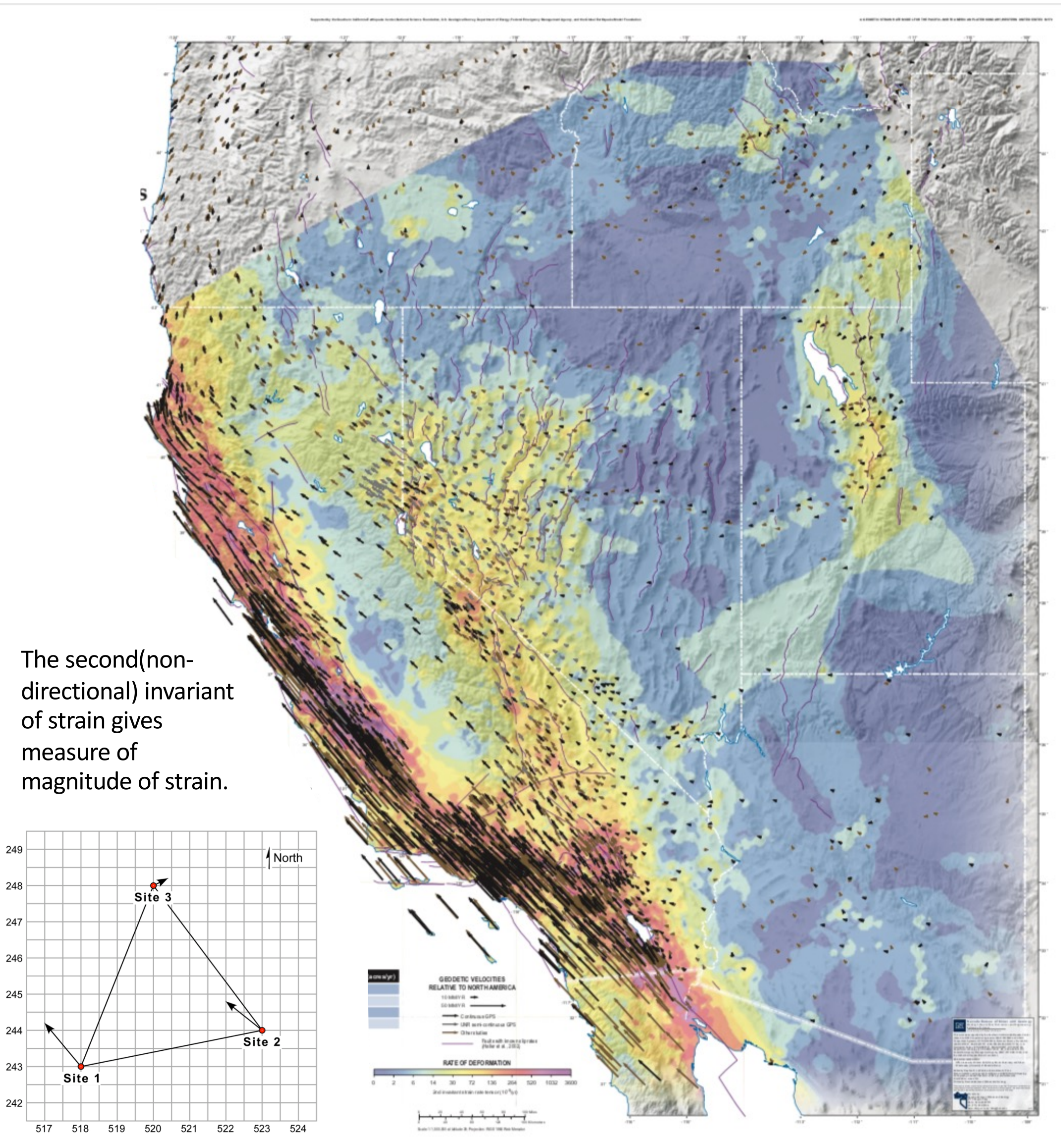


Extensional

Right-lateral shear

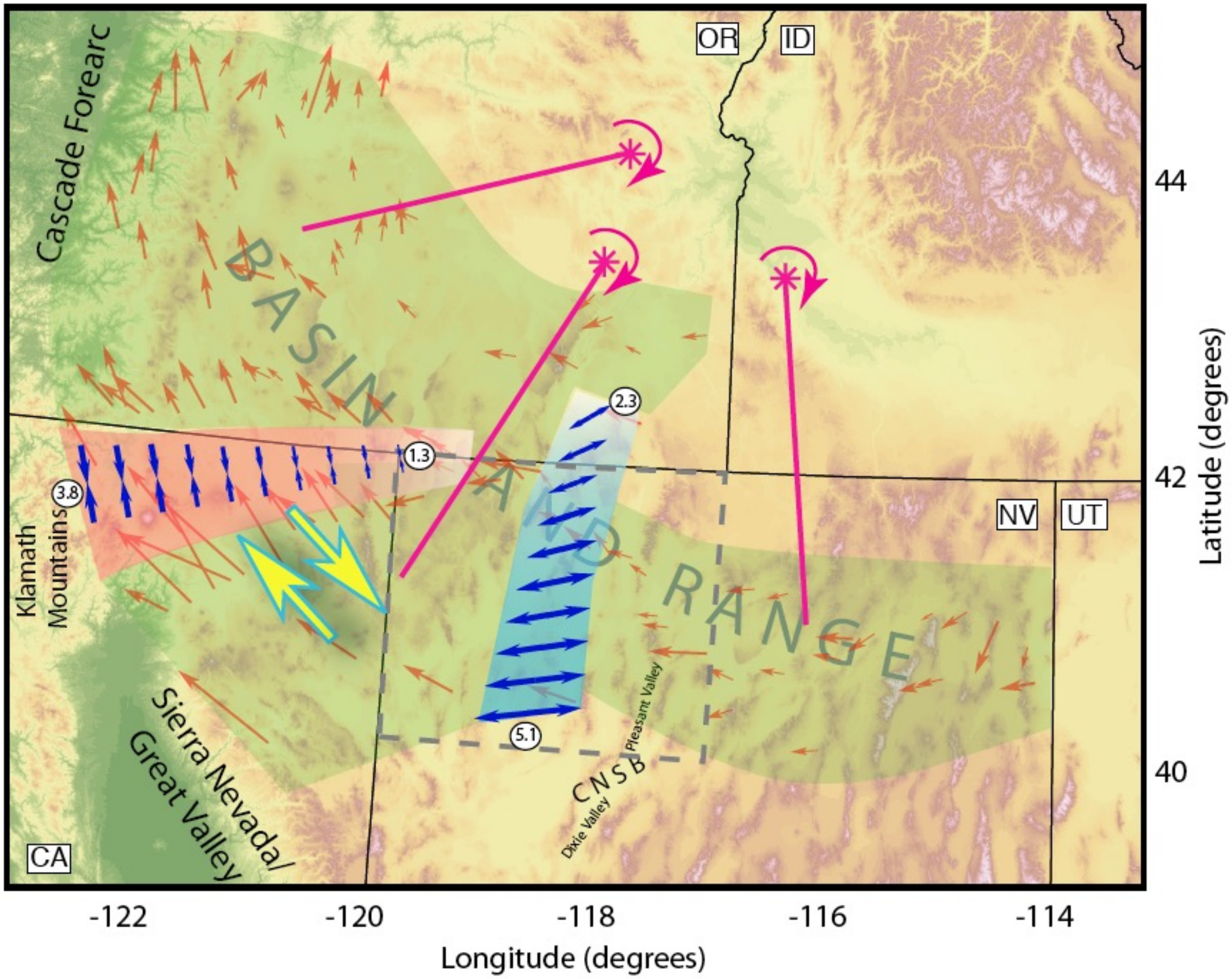
Left-lateral Shear

contraction



The second(non-directional) invariant of strain gives measure of magnitude of strain.

Blocks of crust can move (about poles of rotation) and produce large velocities but little/no strain



A Geodetic Strain Rate Model for the Pacific–North American Plate Boundary, Western United States

Corné Kreemer[1]
William C. Hammond[1]
Geoffrey Blewitt[1]
Austin A. Holland[2]
Richard A. Bennett[2]

[1]Nevada Bureau of Mines and Geology,
University of Nevada Reno
[2]Department of Geological Sciences,
University of Arizona

2012

SUMMARY

[illegible]

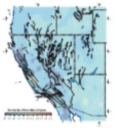
[illegible]

GPS DATA

[illegible]

MODELING DETAILS

[illegible]



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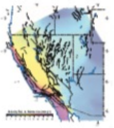

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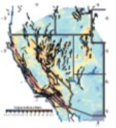

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BIBLIOGRAPHY

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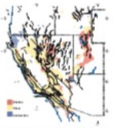
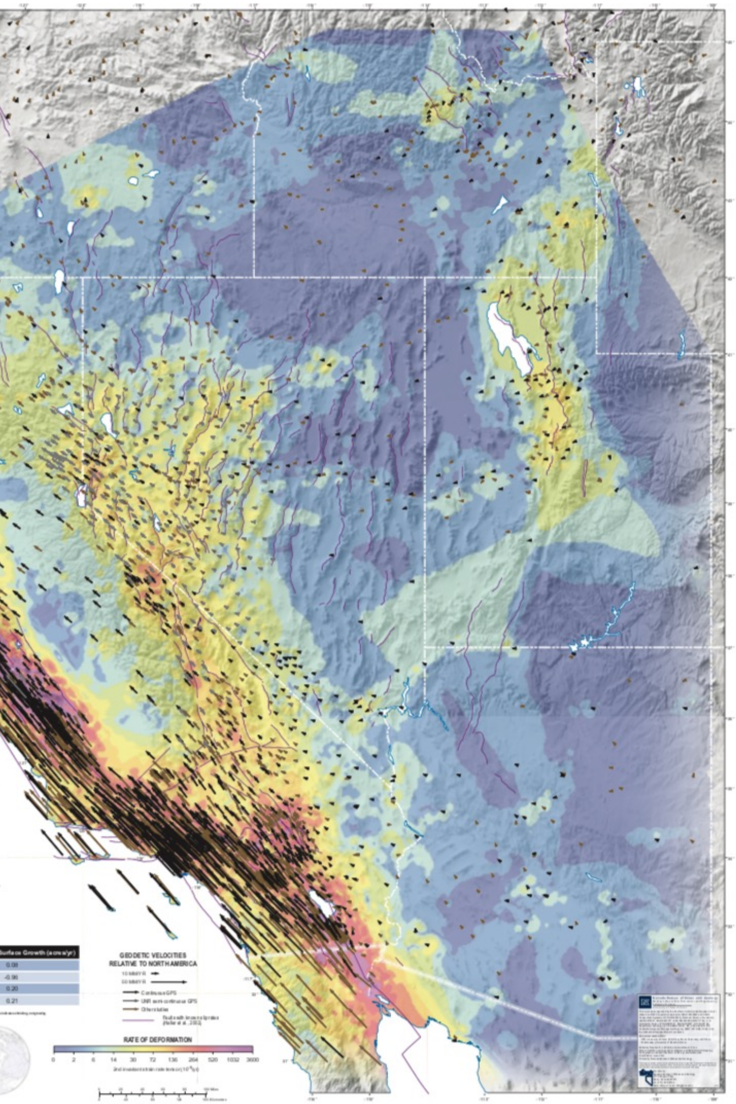


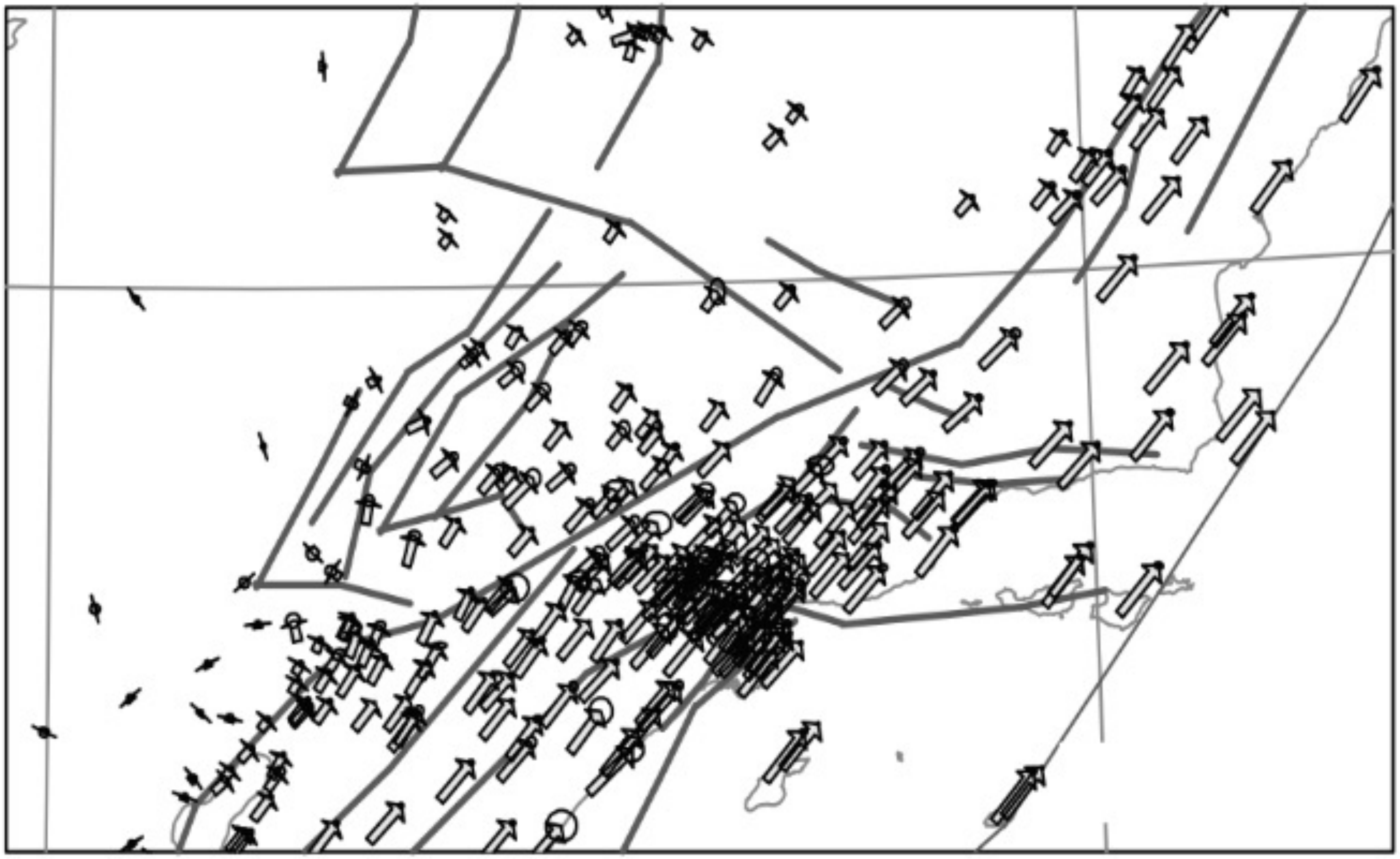
[illegible]



State	Surface Growth (acres/yr)
AZ	0.08
CA	-0.96
NV	0.20
UT	0.21

[illegible]

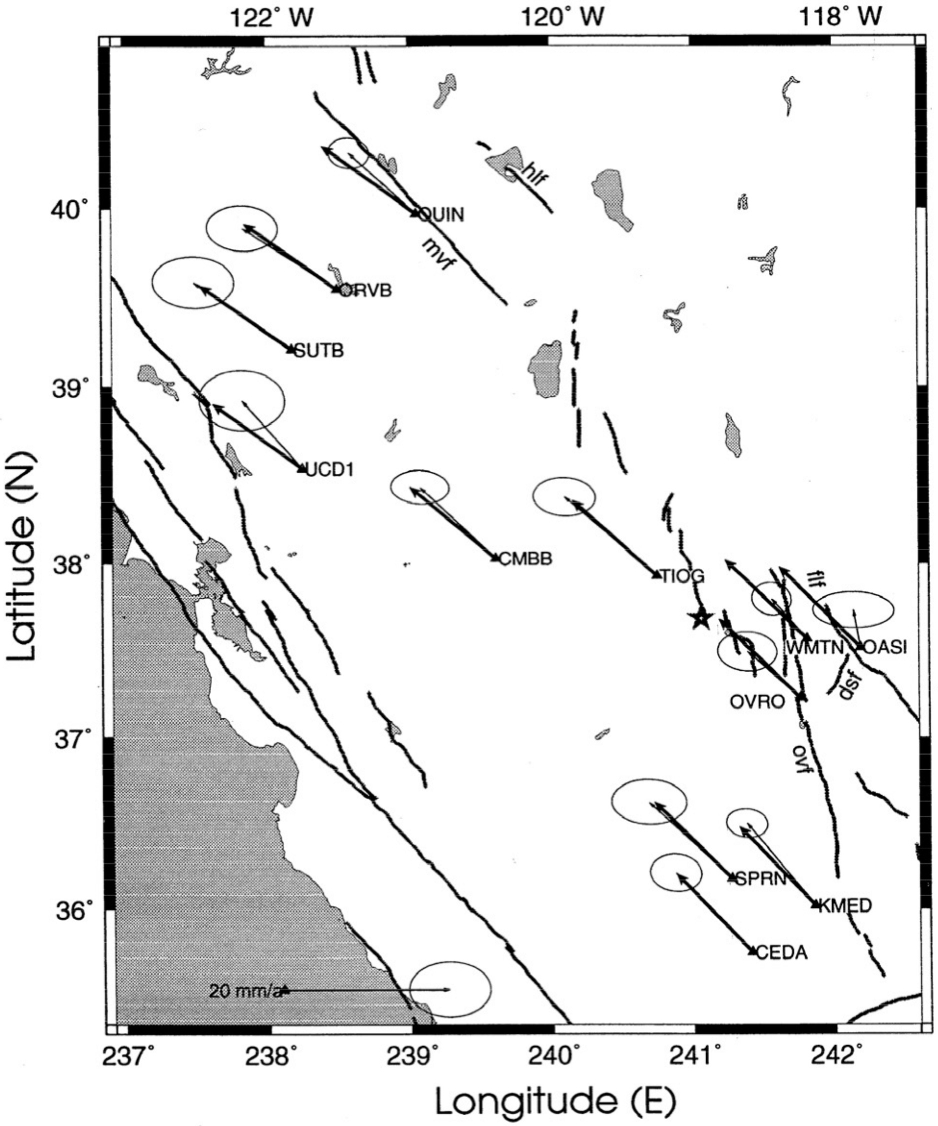
GEODETIC VELOCITIES
RELATIVE TO NORTH AMERICA



What kind of fault is this????

Present-day motion of the Sierra Nevada block and some tectonic implications for the Basin and Range province, North American Cordillera

Timothy H. Dixon,[1] Meghan Miller,[2] Frederic Farina,[1] Hongzhi Wang[1] and Daniel Johnson[2]



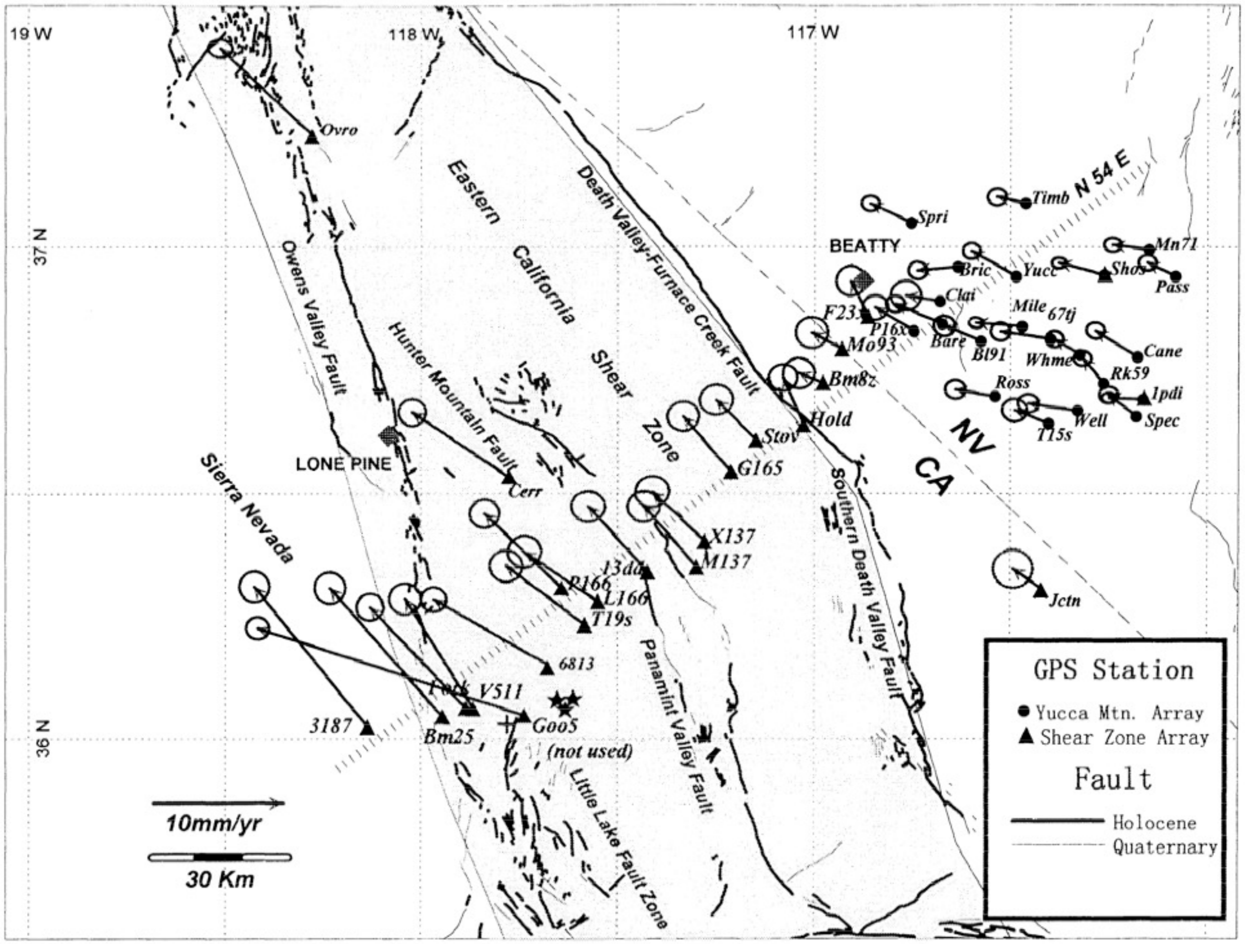
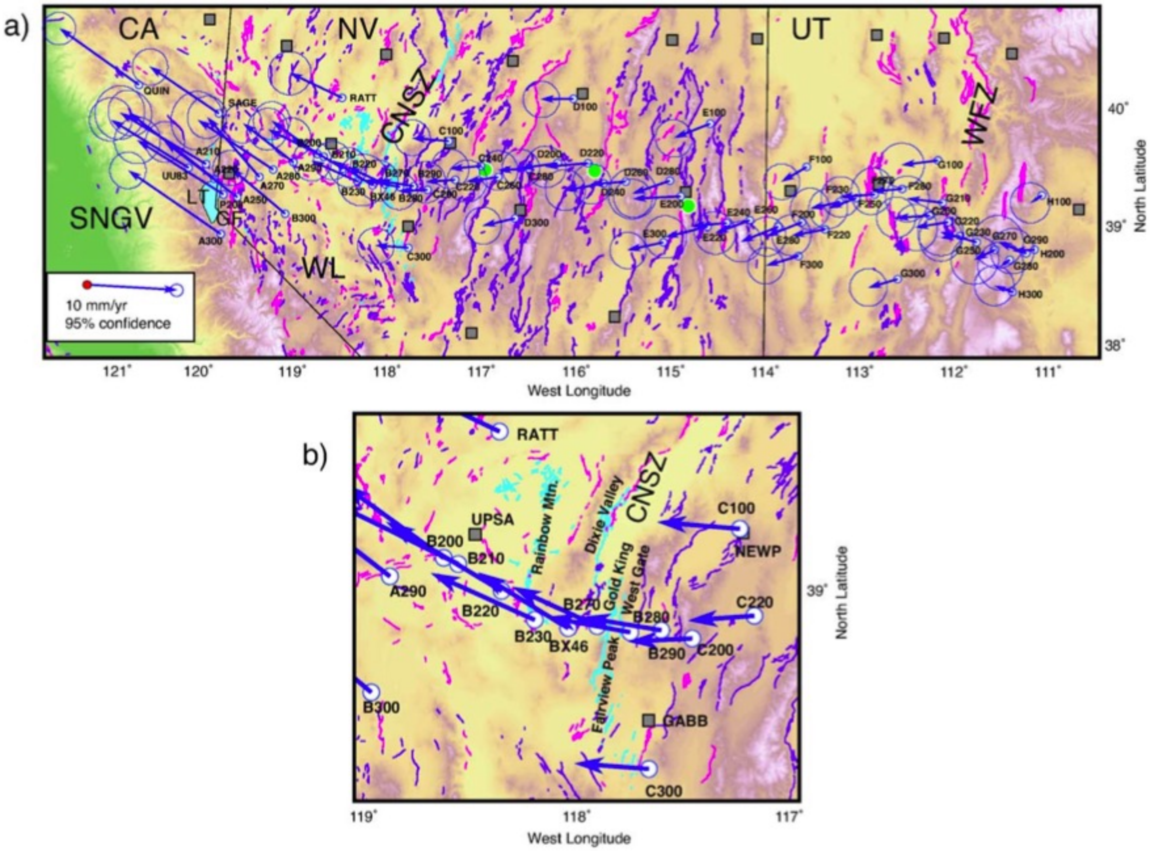


Figure 2. Map of the GPS arrays across the Eastern California Shear Zone (solid triangles) and around Yucca



a)
CA
NV
UT
CNSZ
WFZ
SNGV
LT
GF
WL
QUIN
SAGE
RATT
UU83
A210
A250
A270
A280
A290
A300
B200
B210
B220
B230
BX46
B270
B280
B290
B300
C100
C140
C200
C220
C260
C300
D100
D200
D220
D240
D260
D280
D300
E100
E200
E220
E240
E260
E280
E300
F100
F200
F220
F230
F260
F280
F300
G100
G200
G210
G220
G230
G250
G270
G280
G290
G300
H100
H200
H300
10 mm/yr
95% confidence
121°
120°
119°
118°
117°
116°
115°
114°
113°
112°
111°
West Longitude
40°
39°
38°
North Latitude
b)
RATT
UPSA
C100
NEWP
CNSZ
Dixie Valley
Rainbow Mtn.
Gold King
West Gate
Fairview Peak
B200
B210
A290
B220
B230
BX46
B270
B280
B290
C200
C220
B300
GABB
C300
119°
118°
117°
West Longitude
39°
North Latitude

Figure 1

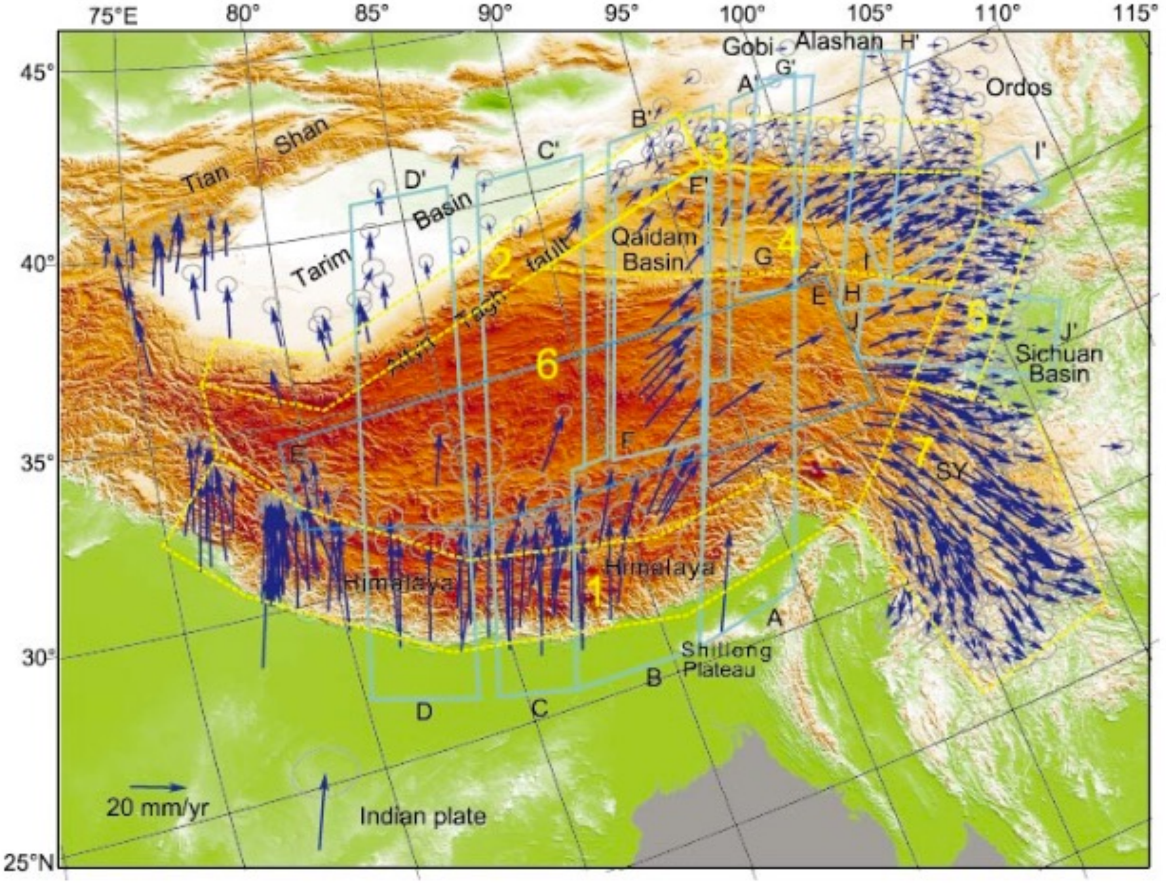


Figure 1. Global positioning system (GPS) velocities (mm/yr) in and around Tibetan Plateau with respect to stable Eurasia, plotted on shaded relief map using oblique Mercator projection. Ellipses denote 1σ errors. Blue polygons show locations of GPS velocity profiles in Figures 3 and DR1 (see footnote 1). Dashed yellow polygons show regions that we used to calculate dilatational strain rates. Yellow numbers 1–7 represent regions of Himalaya, Altyn Tagh, Qilian Shan, Qaidam Basin, Longmen Shan, Tibet, and Sichuan and Yunnan, respectively.