

The background image shows a group of people walking across a wooden boardwalk in a geothermal area. In the background, there are dark, silhouetted hills and a large plume of white steam or smoke rising from the ground. The foreground shows the wet, reflective surface of the water, with bright sunlight reflecting off it. The overall scene is dramatic and atmospheric.

Exploring Plate Motion and Deformation in California with GPS

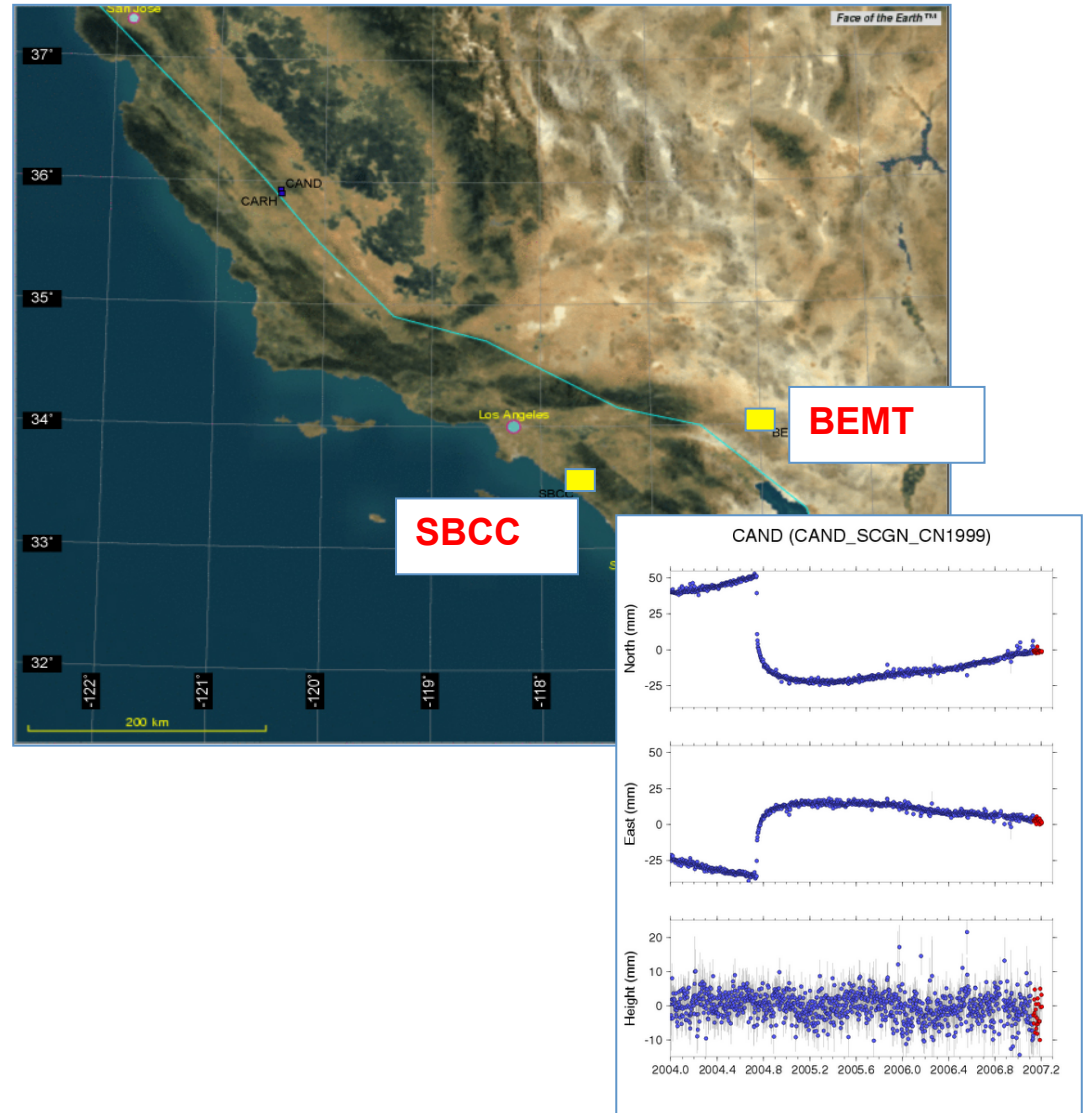
Cate Fox-Lent, UNAVCO Master Teacher; Andy Newman, Georgia Institute of Technology;
Shelley Olds, UNAVCO; revised by Nancy West

UNAVCO

Part 1: Analyze GPS data from two stations to determine tectonic plate motion

Part 2: Investigate deformation of the crust at two stations in California

Extension: explore more GPS data



You should be able to:

- Describe high-precision GPS and its application to plate tectonics;
- Interpret GPS graphs to determine how the GPS station is moving; and
- Describe tectonic plate motions along the San Andreas fault.

SBCC GPS STATION

- Near Mission Viejo, CA.
- Position data is collected every 30 seconds.
- One position reading is developed for each day:
 - North
 - East
 - Vertical

Date	North (mm)	East (mm)	Vertical (mm)
1/1/2004	-37.67	36.57	2.33
1/2/2004	-38.04	35.73	5.63
1/3/2004	-37.16	35.83	4.69
1/4/2004	-37.34	36.34	5.36
1/5/2004	-37.59	36.44	9.11
...
1/1/2005	-9.43	9.63	2.36
1/1/2006	16.48	-18.09	7.35
1/1/2007	45.98	-43.42	-6.43

Position time series plot

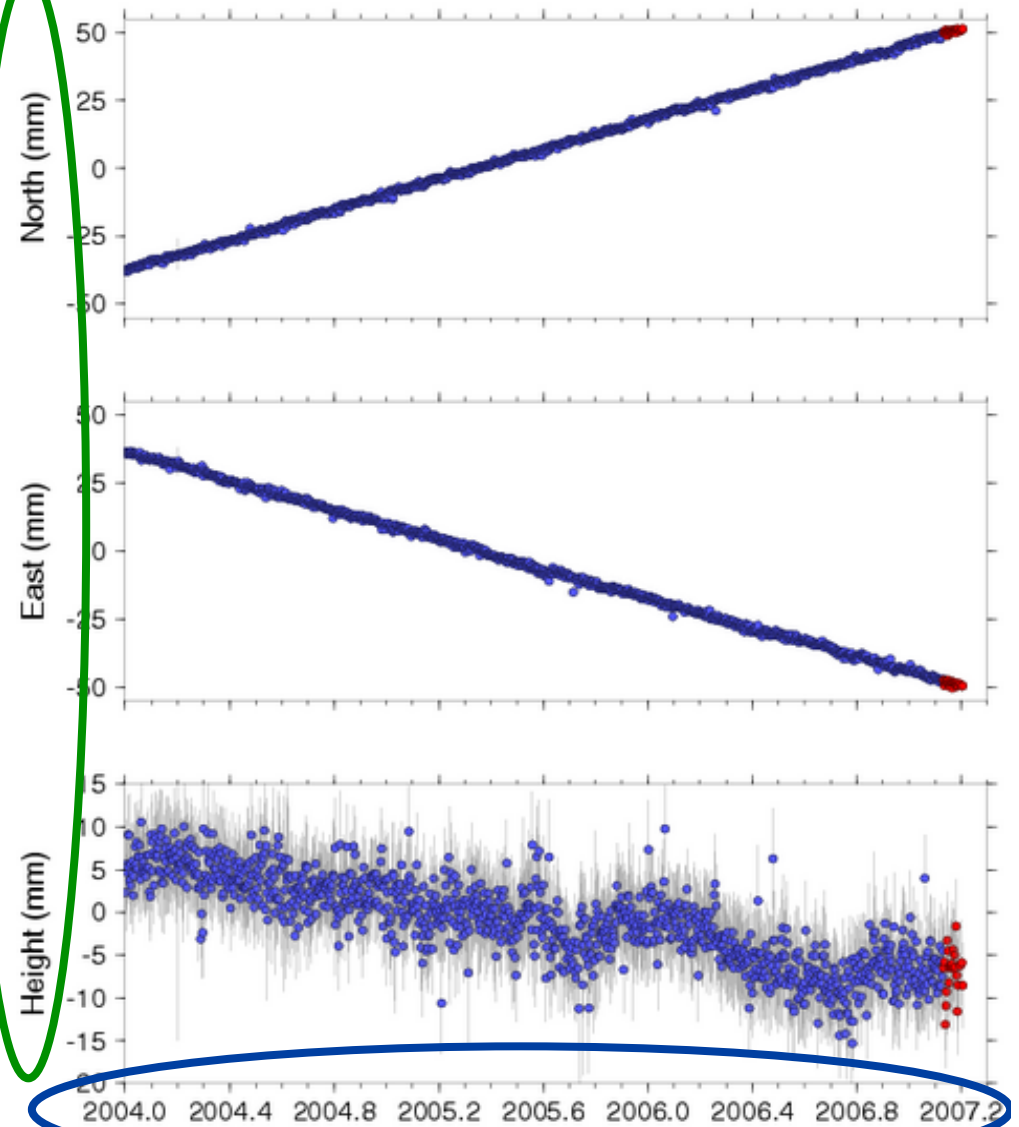
SBCC (SBCC_SCGN_CS1999)

X-axis:

- Date in 10ths of year or months

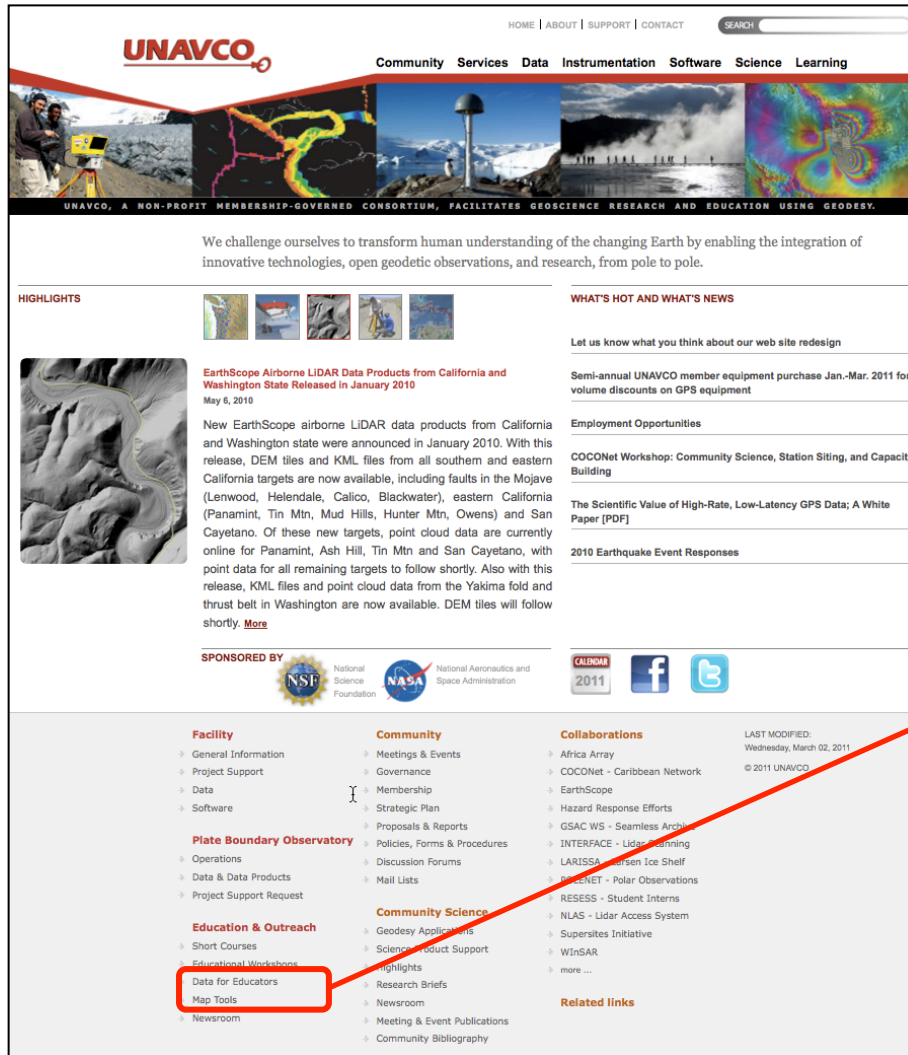
Y-axis:

- North
- East
- Height (or Vertical) in millimeters



X-axis is typically shown as 10ths of a year.

0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec



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Community Services Data Instrumentation Software Science Learning

UNAVCO, A NON-PROFIT MEMBERSHIP-GOVERNED CONSORTIUM, FACILITATES GEOSCIENCE RESEARCH AND EDUCATION USING GEODESY.

We challenge ourselves to transform human understanding of the changing Earth by enabling the integration of innovative technologies, open geodetic observations, and research, from pole to pole.

HIGHLIGHTS

EarthScope Airborne LIDAR Data Products from California and Washington State Released in January 2010
May 6, 2010

New EarthScope airborne LIDAR data products from California and Washington state were announced in January 2010. With this release, DEM tiles and KML files from all southern and eastern California targets are now available, including faults in the Mojave (Lenwood, Helendale, Calico, Blackwater), eastern California (Panamint, Tin Mtn, Mud Hills, Hunter Mtn, Owens) and San Cayetano. Of these new targets, point cloud data are currently online for Panamint, Ash Hill, Tin Mtn and San Cayetano, with point data for all remaining targets to follow shortly. Also with this release, KML files and point cloud data from the Yakima fold and thrust belt in Washington are now available. DEM tiles will follow shortly. [More](#)

SPONSORED BY

NSF National Science Foundation NASA National Aeronautics and Space Administration

WHAT'S HOT AND WHAT'S NEWS

Let us know what you think about our web site redesign

Semi-annual UNAVCO member equipment purchase Jan-Mar. 2011 for volume discounts on GPS equipment

Employment Opportunities

COCONet Workshop: Community Science, Station Siting, and Capacity Building

The Scientific Value of High-Rate, Low-Latency GPS Data; A White Paper [PDF]

2010 Earthquake Event Responses

Facility

- General Information
- Project Support
- Data
- Software

Plate Boundary Observatory

- Operations
- Data & Data Products
- Project Support Request

Education & Outreach

- Short Courses
- Educational Workshops
- Data for Educators**
- Map Tools
- Newsroom

Community

- Meetings & Events
- Governance
- Membership
- Strategic Plan
- Proposals & Reports
- Policies, Forms & Procedures
- Discussion Forums
- Mailing Lists

Community Science

- Geodesy Applications
- Science Product Support
- Highlights
- Research Briefs
- Newsroom
- Meeting & Event Publications
- Community Bibliography

Collaborations

- Africa Array
- COCONet - Caribbean Network
- EarthScope
- Hazard Response Efforts
- GSAC WS - Seamless Archiving
- INTERFACE - Lidar Mapping
- LARISSA - Larsen Ice Shelf
- ICEGENET - Polar Observations
- RESESS - Student Interns
- NLAS - Lidar Access System
- Supersites Initiative
- WinSAR
- more ...

Related links

LAST MODIFIED:
Wednesday, March 02, 2011
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1. Go to

<http://>

www.unavco.org/

Click on “Data for Educators”

home » education & outreach » data

Data For Educators

Looking for interesting data to use in your course? We've worked with educators and scientists to identify GPS stations that illustrate various Earth science processes. The data are the same quality that many scientists use in their research and is in a MS Excel readable format called CVS.

GPS data that show...
... tectonic plates moving and deforming

GPS Data Products

Station Id	Location
ALBH	Albert Head, Victoria, Canada
BEAT	Twenty-nine Palms, CA
NEAH	Neah Bay, WA
SBCC	Mission Viejo, CA
SEAT	Seattle, WA

Educational resources using these stations

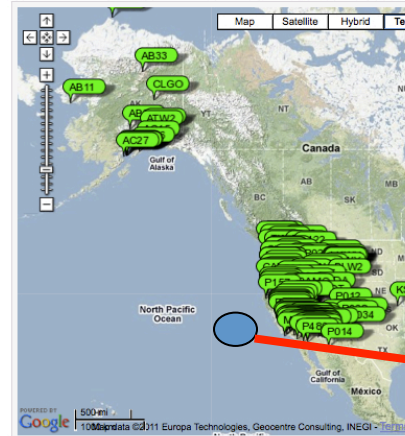
- [Exploring Plate Motion and Deformation in California Using GPS Time Series Plots](#) Analyzing real time-series data of two GPS stations to determine plate tectonic motion
- [Analyzing Plate Motion Using EarthScope GPS Data with the Pacific Northwest as a case study](#) Earth Exploration Toolbook Chapter: Learn how to use GPS to visualize plate tectonics in the Pacific Northwest.
- [Exploring Plate Motion and Deformation in Cascadia Using GPS Data](#) Designed as a large class (50+) exercise
- [Episodic Tremor and Slip in the Pacific Northwest: When is the next big earthquake? \(Mysterious earthquakes, unexpected movements\)](#) Designed for middle school students, grades 6 - 8. Students explore episodic tremor and slip in the Cascadia region by using GPS Time Series Plots.
- [Visualizing Relationships between Earthquakes, Volcanoes, and Plate Boundaries in the Western United States](#) Learners use the web-based data viewing tool, EarthScope Jr., or the included map packet to visualize relationships between earthquakes, volcanoes, and plate boundaries in the western United States.

... movement on different sides of a fault

GPS Data Products

Station Id	Location
------------	----------

Selected GPS Stations

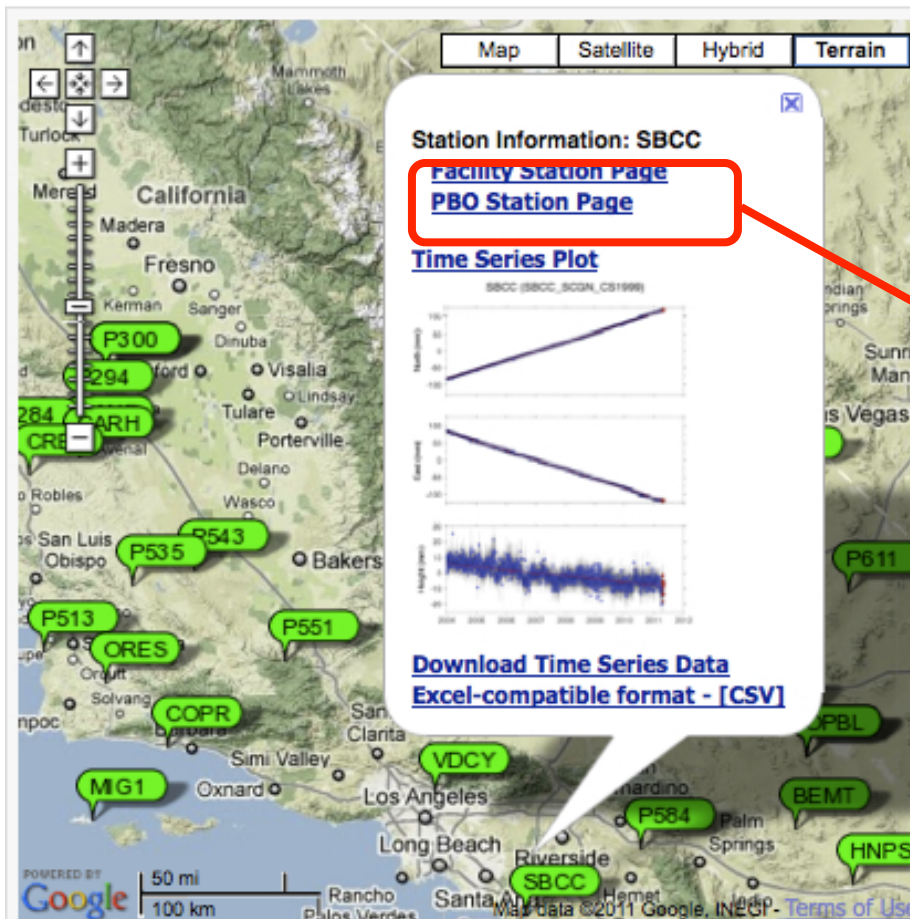


To see these stations on a larger map and discover more GPS stations and data, try the [Archive Interface](#). To explore GPS velocity vectors, try the [UNAVCO Velocity Viewer](#). This is a proof of concept / beta prototype, occasionally has glitches at full-Earth view, and work on older browsers (<Mac OS X 2.9).



2. Zoom in near Southern California.

3. Click on the balloon labeled “SBCC” or “BEMT” near Los Angeles.



Click on the link for
“PBO Station Page.”

Overview

Data Products

Station Health

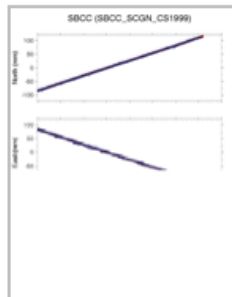
Maintenance

Photos

SBCC Station Overview

[Photo: SBCC Overview](#)
[Photo - \(CLICK TO ENLARGE\)](#)

Station Position



Station Type: GPS

Station Information

Station Status: Installed/Operable
Station ID: SBCC
Station Name: SBCC_SCGN_CS1999
Location (City, State): Mission Viejo, CA
Monument Type: DDBM
Station Install Date: 1999-11-08
Latitude: 33.552999
Longitude: -117.661485
Elevation: 88.695 m / 291 ft

Station Data

IGS Site Log: [Text File](#)
Installation Report: [BIRT Report](#)
Time Series Data: [Excel Compatible \[CSV\]](#)
Time Series Plot Viewer: [Nearby GPS Plots](#)
Realtime Dataflow: Not Available
Meteorologic Plots: Not Available
Station KML: [XML File](#)

Colocated Instruments
None

GPS Monument Coordinates

IGS05 Reference Frame

Nearby Stations Map

Selected Station



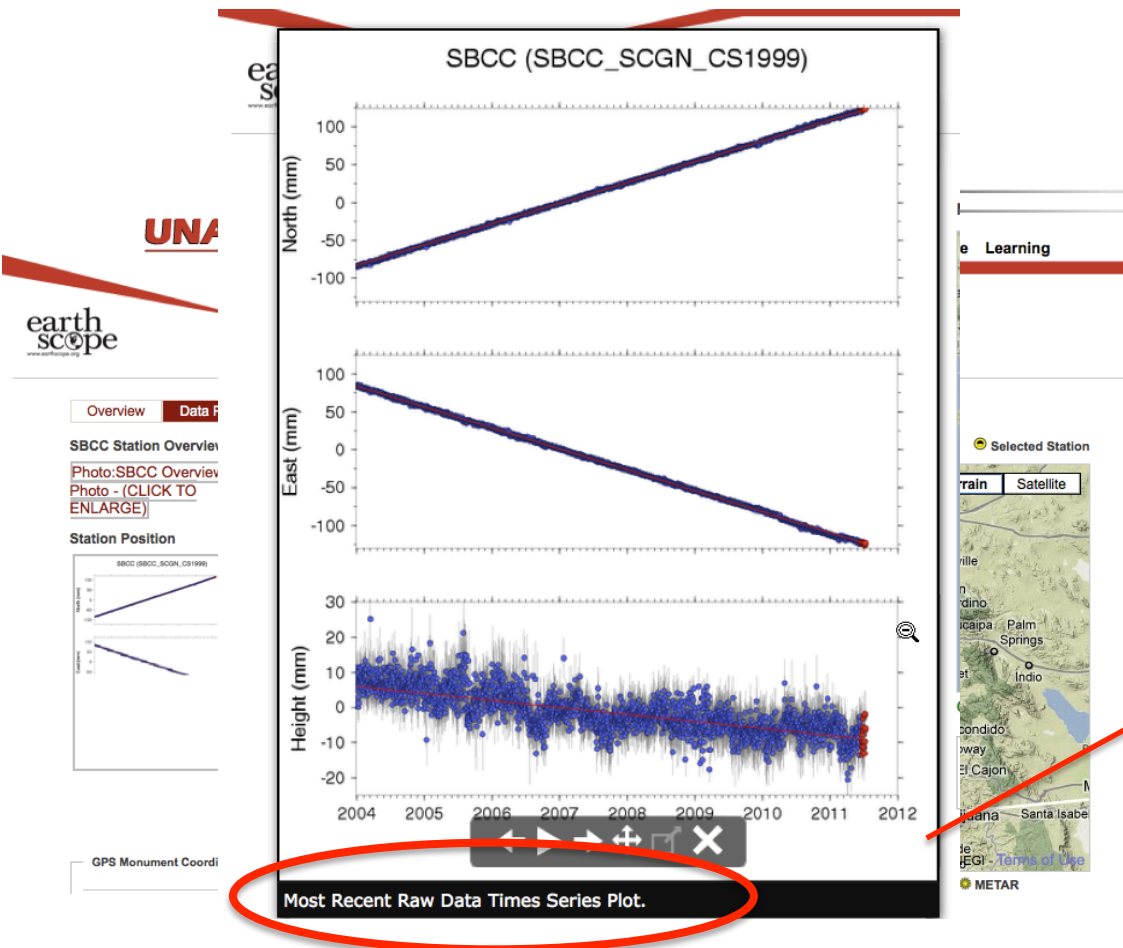
4. Retrieve the station's information and time series plot.

5. Work with a partner to answer questions 4 and 6 about BEMT and SBCC.

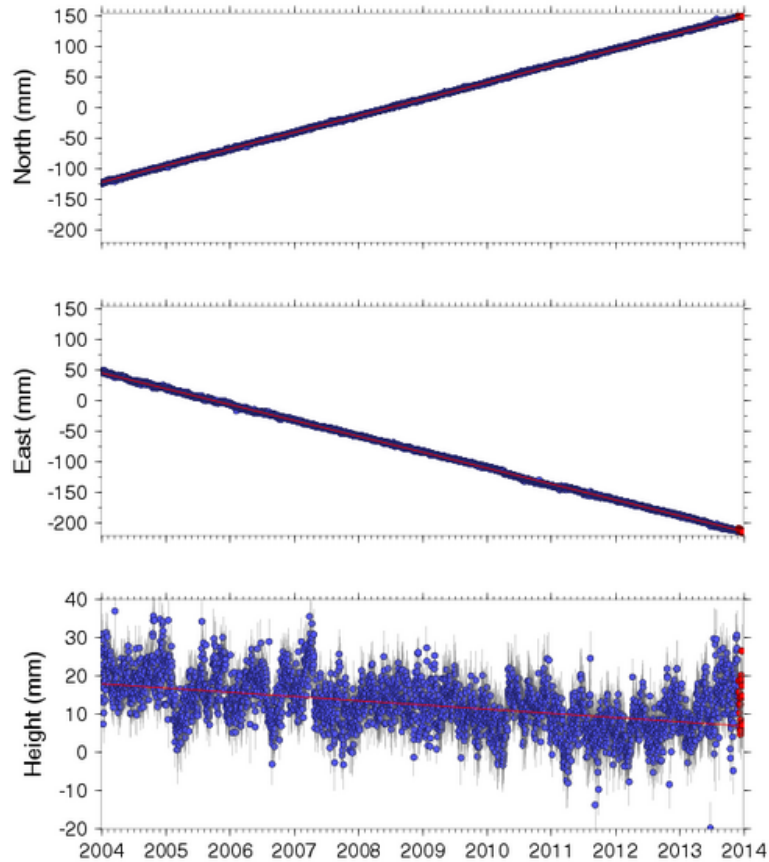
✓ Use the elevation listed under SNARF.

✓ Click on the Station Position graph.

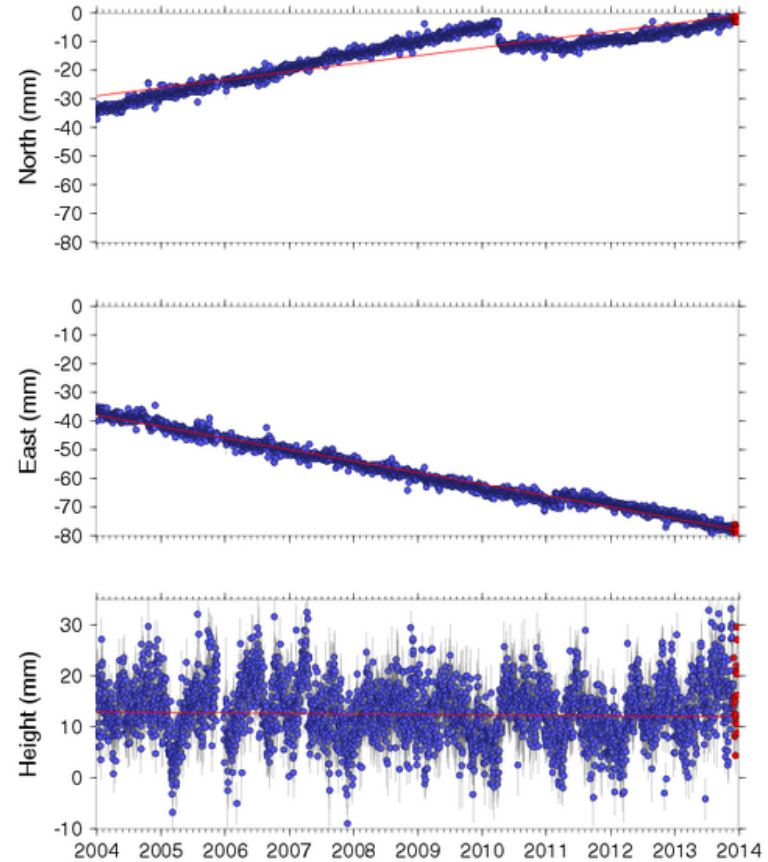
✓ Use the Station Position plot “Most Recent Raw Data Times Series Plot.”



SBCC (SBCC_SCGN_CS1999)

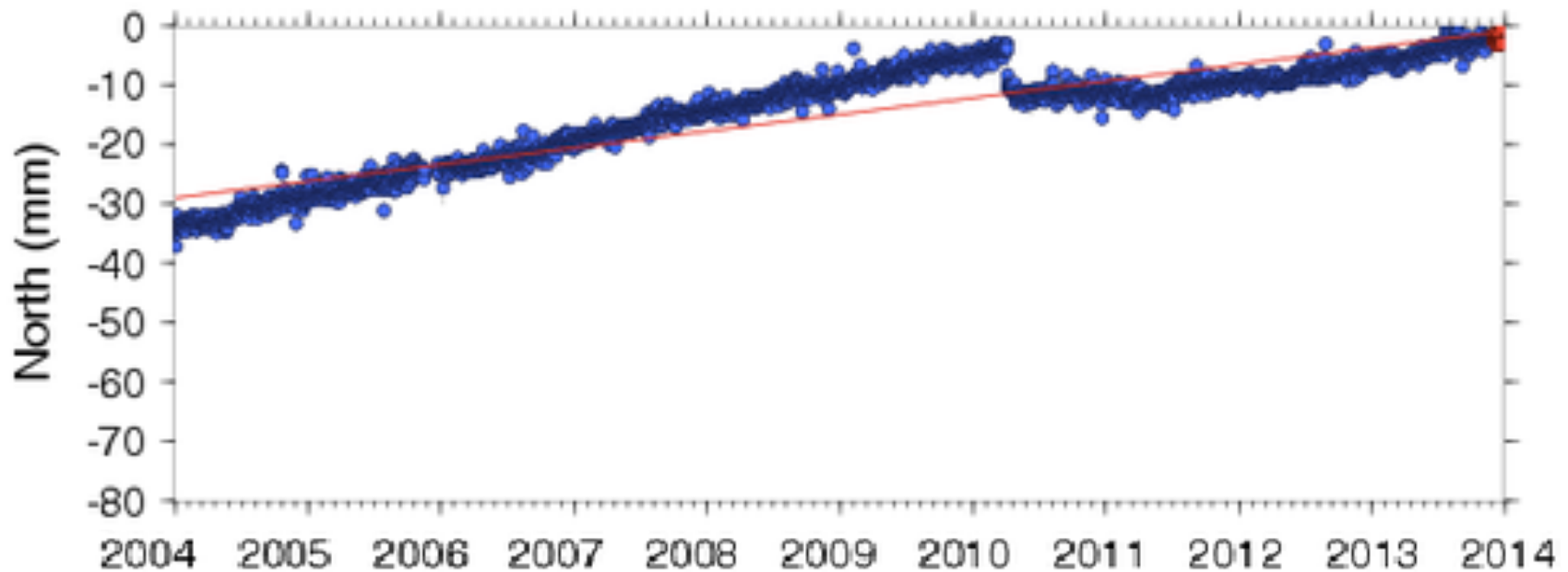


BEMT (BEMT_SCGN_CS2001)



What are the units of measurement for these time series?

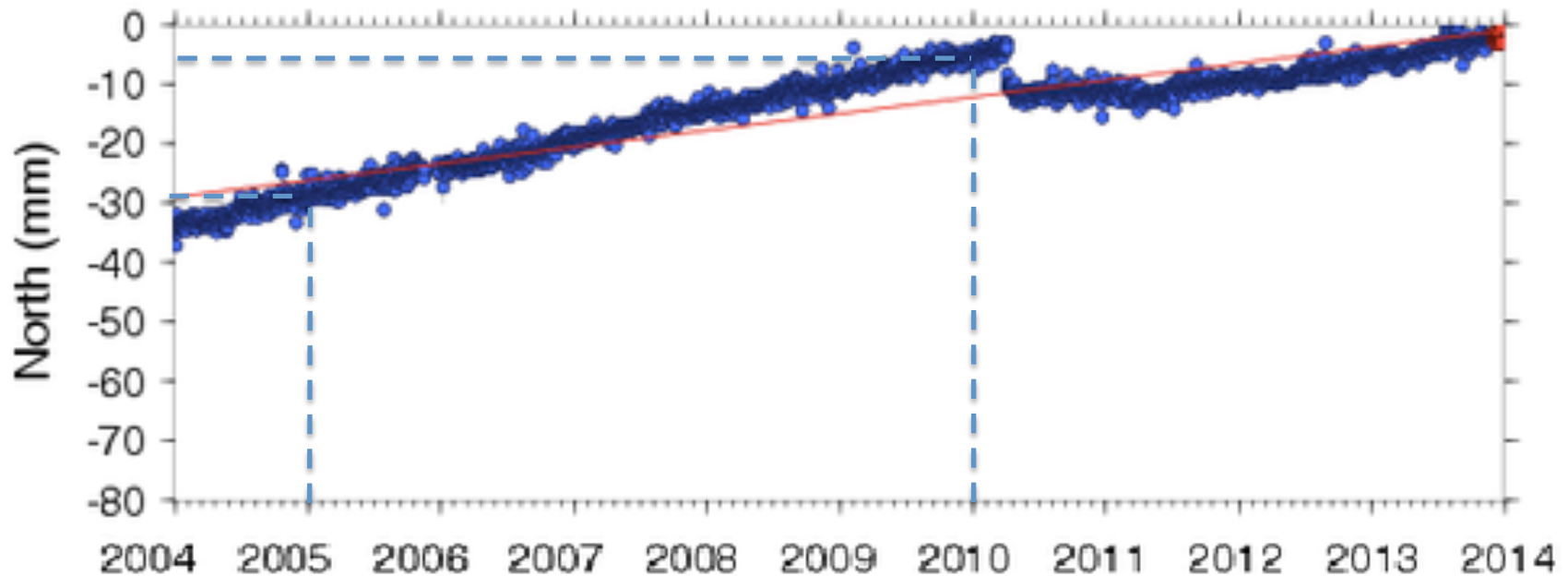
How quickly is BEMT moving north or south?



Average position on 1/1/2010 = _____ mm

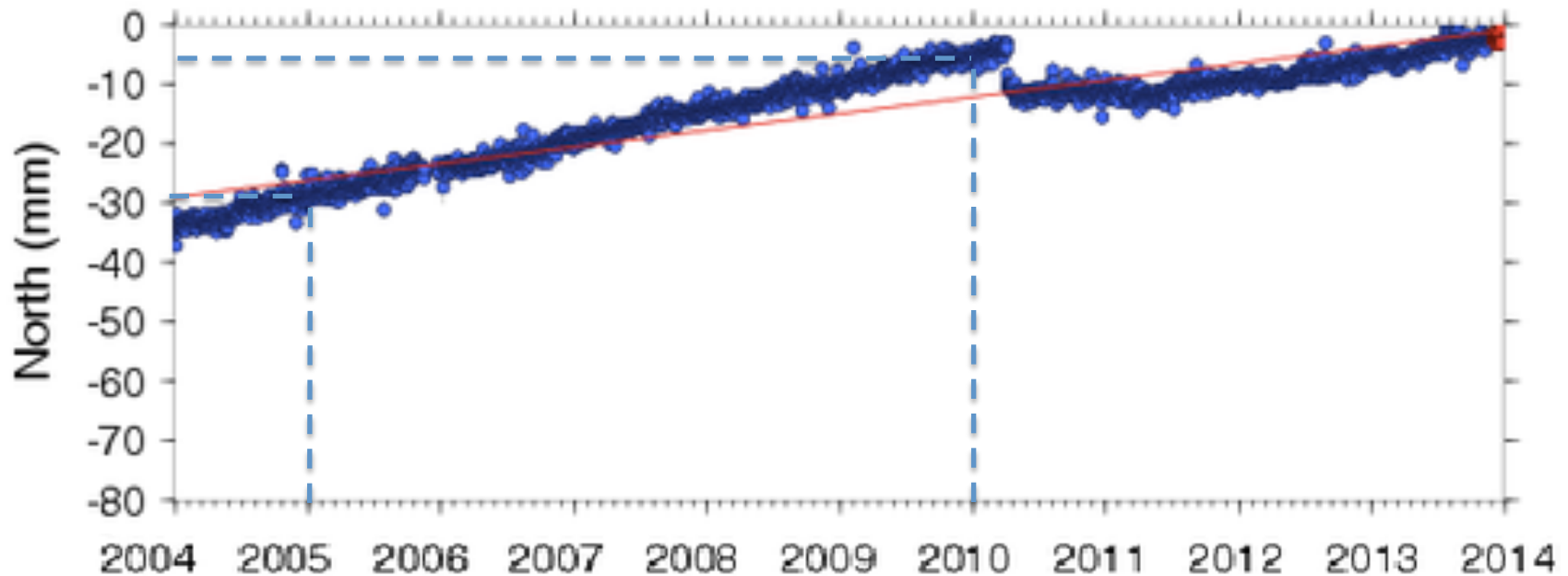
Average position on 1/1/2005 = _____ mm

How quickly is BEMT moving north or south?



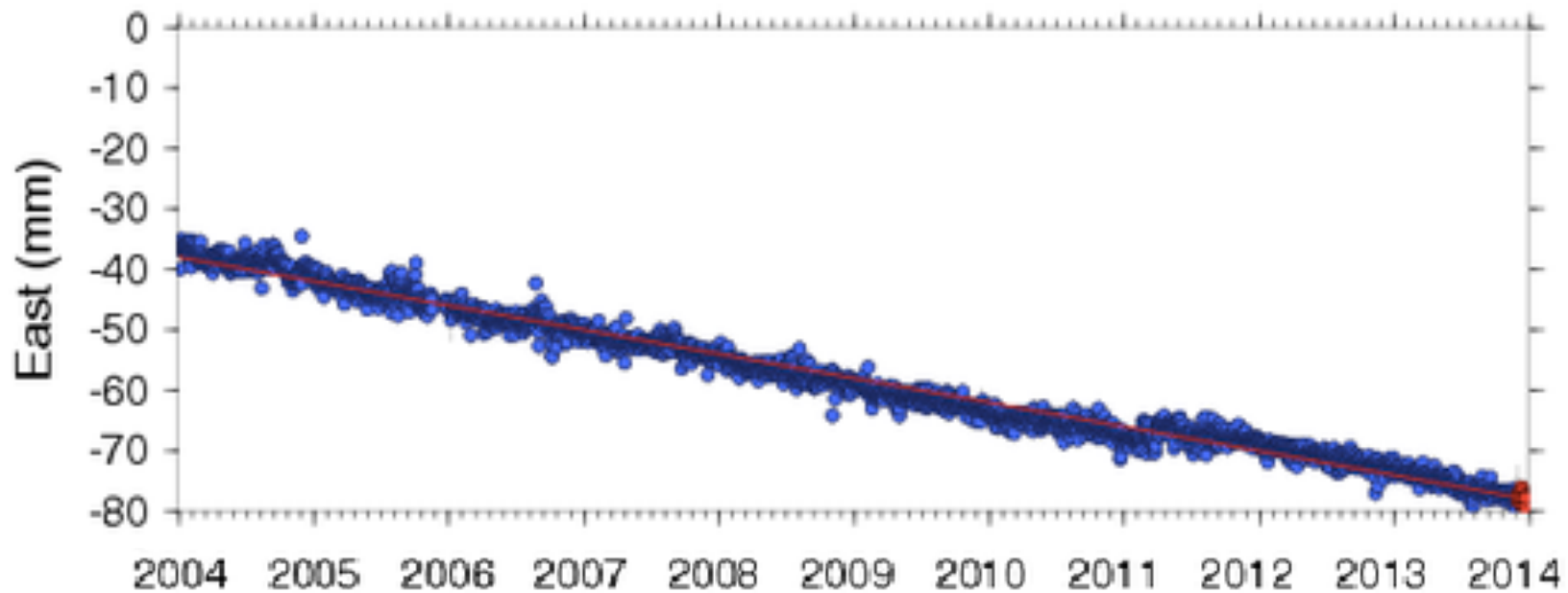
Average position on 1/1/2010 = - 6 mm
Average position on 1/1/2005 = -29 mm

How quickly is BEMT moving north or south?



Annual northward speed of BEMT = $(-6 - -29 \text{ mm})/5$
years
= 23 mm/5yrs
= 4.6 mm/yr to the north for BEMT (+/- 0.2?)

How quickly is BEMT moving east or west?

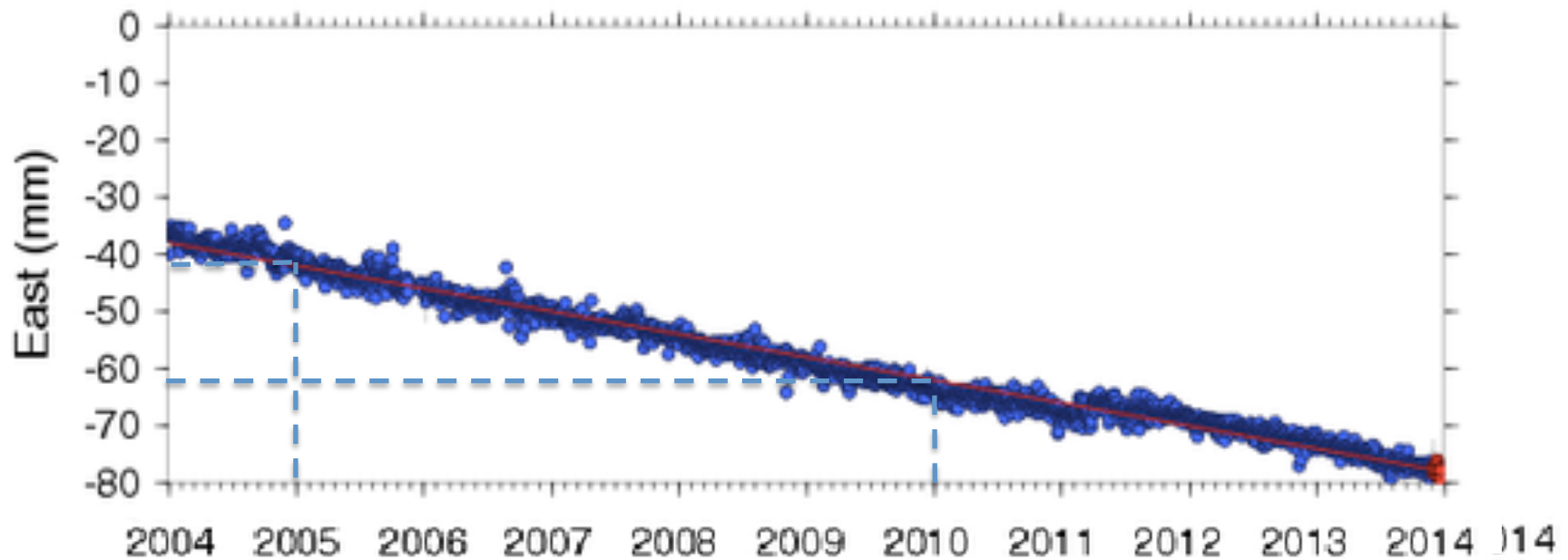


What general direction is BEMT moving?

Average position on 1/1/2010 = _____ mm

Average position on 1/1/2005 = _____ mm

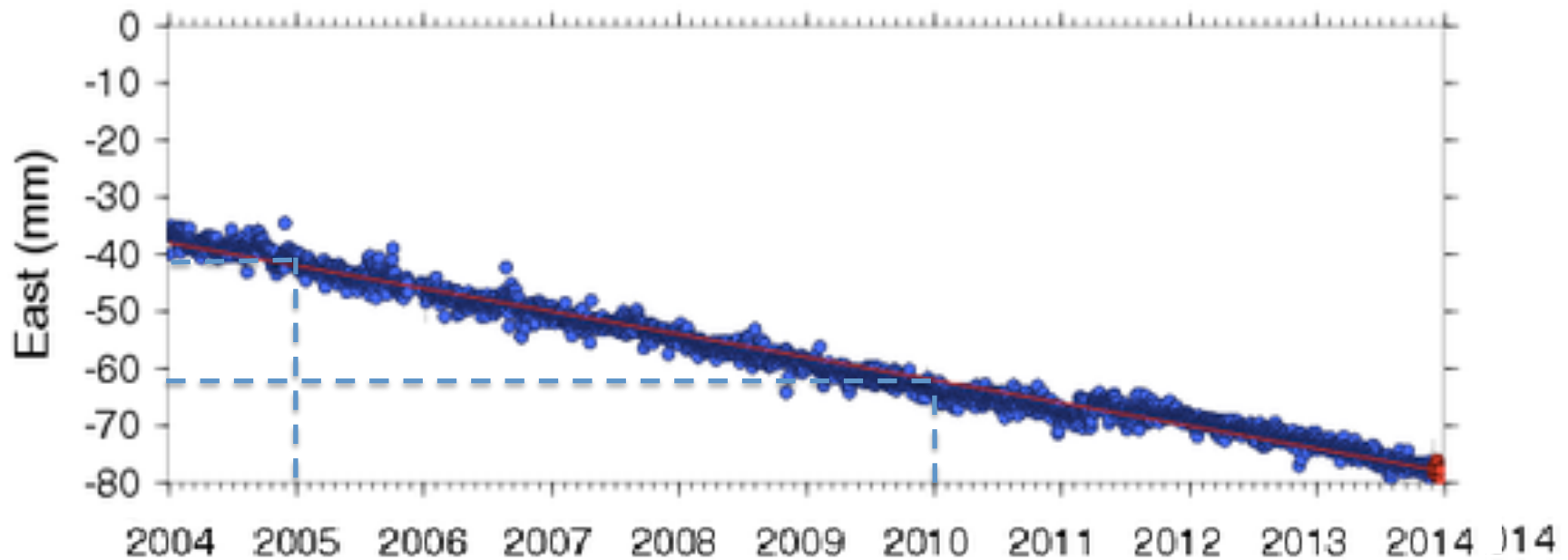
How quickly is BEMT moving east or west?



Average position on 1/1/2010 = -62 mm

Average position on 1/1/2005 = -42 mm

How quickly is BEMT moving east or west?



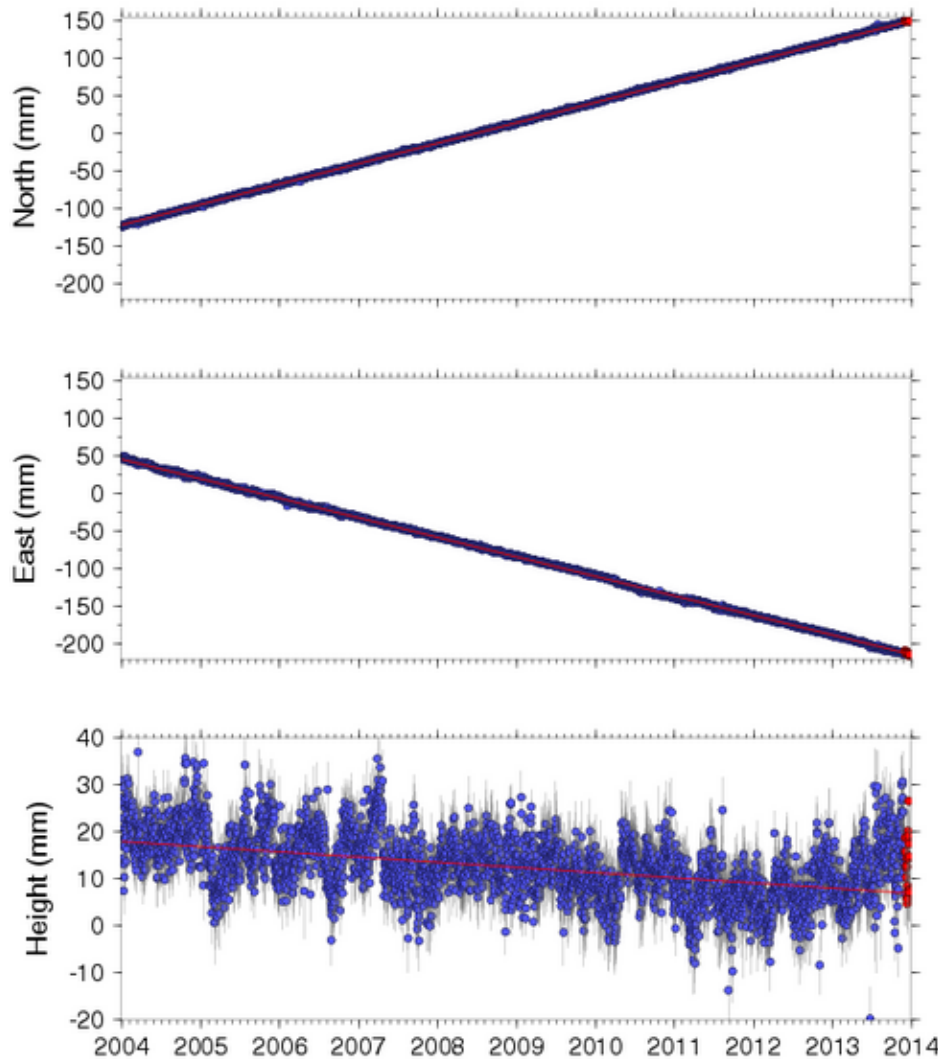
Annual speed of BEMT north = $(-62 - -42 \text{ mm})/5$
years

= -20 mm/5yrs

= -4.0 mm/yr. BEMT is moving westward.

How quickly is SBCC moving?

SBCC (SBCC_SCGN_CS1999)



Now do SBCC.

Speed of SBCC:

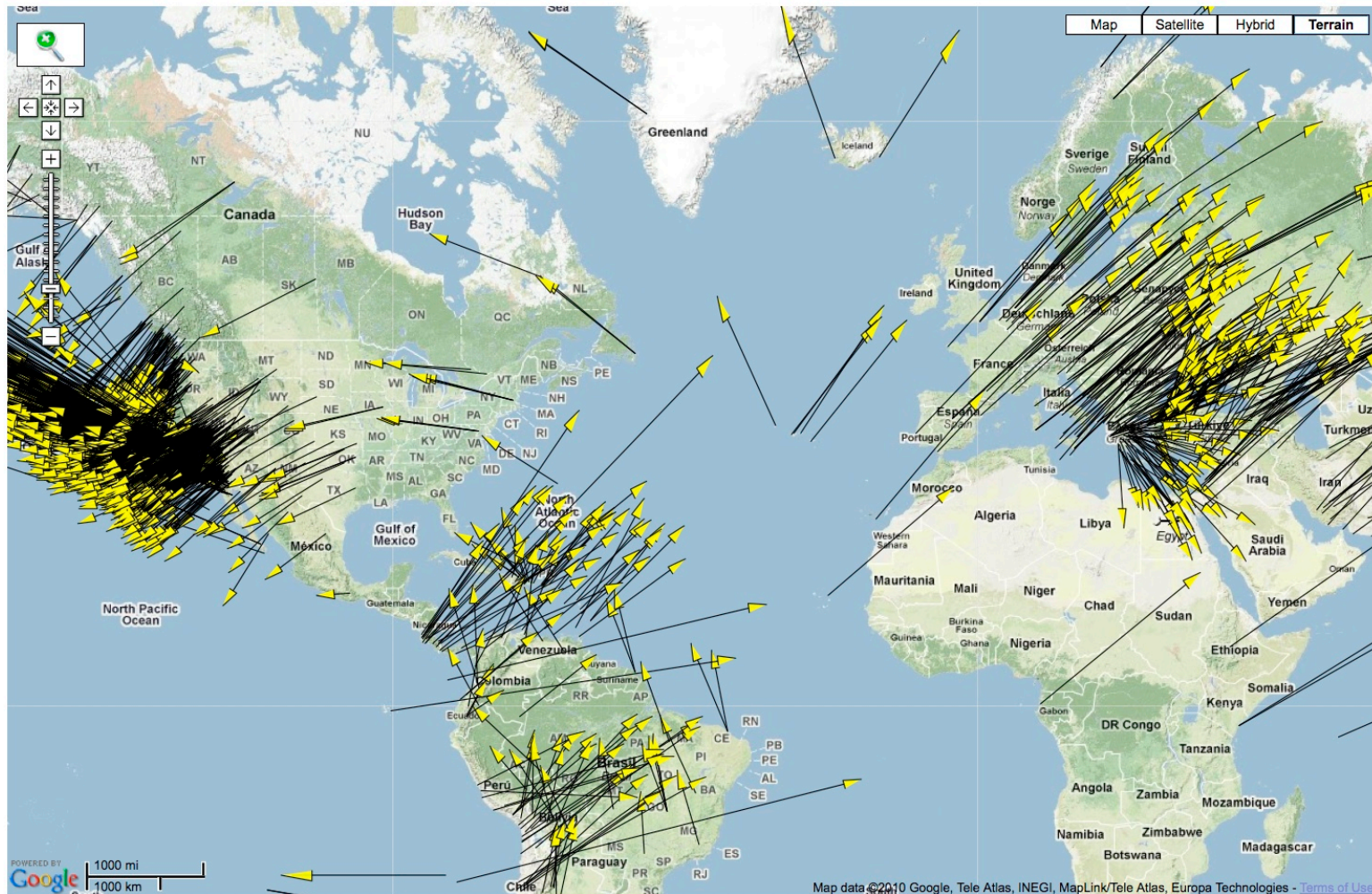
= 27.3 mm/yr to the north

= 26.1 mm/yr to the west

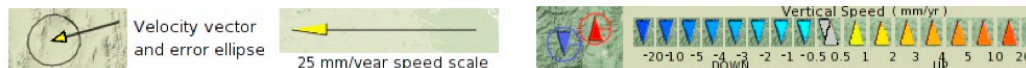
Plate movement via vectors

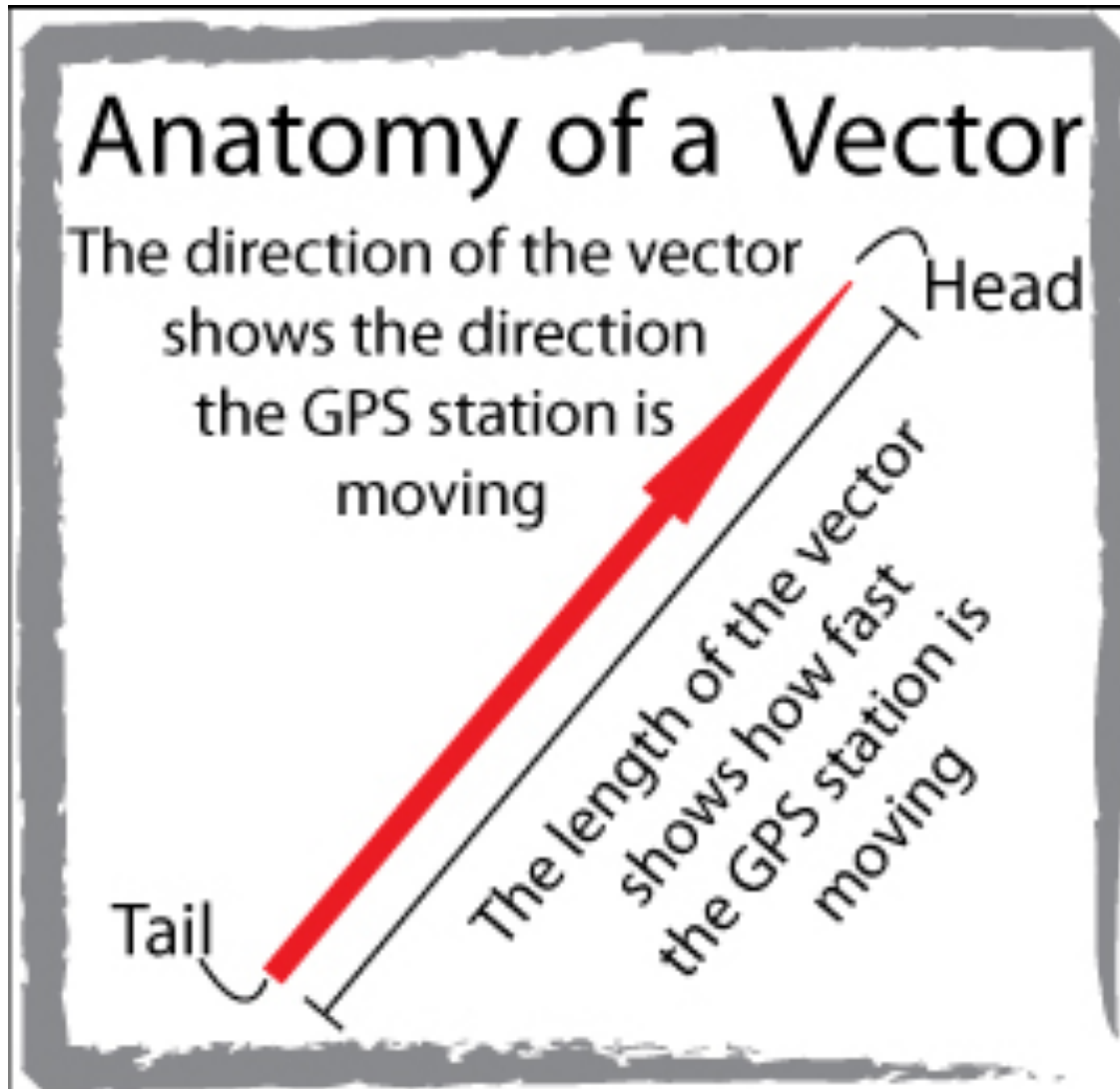
UNAVCO GPS Velocity Viewer *

GPS velocity vectors show how the surface of the Earth is moving.



GPS_vectors_after_rotation_NNR.dat Velocity vectors





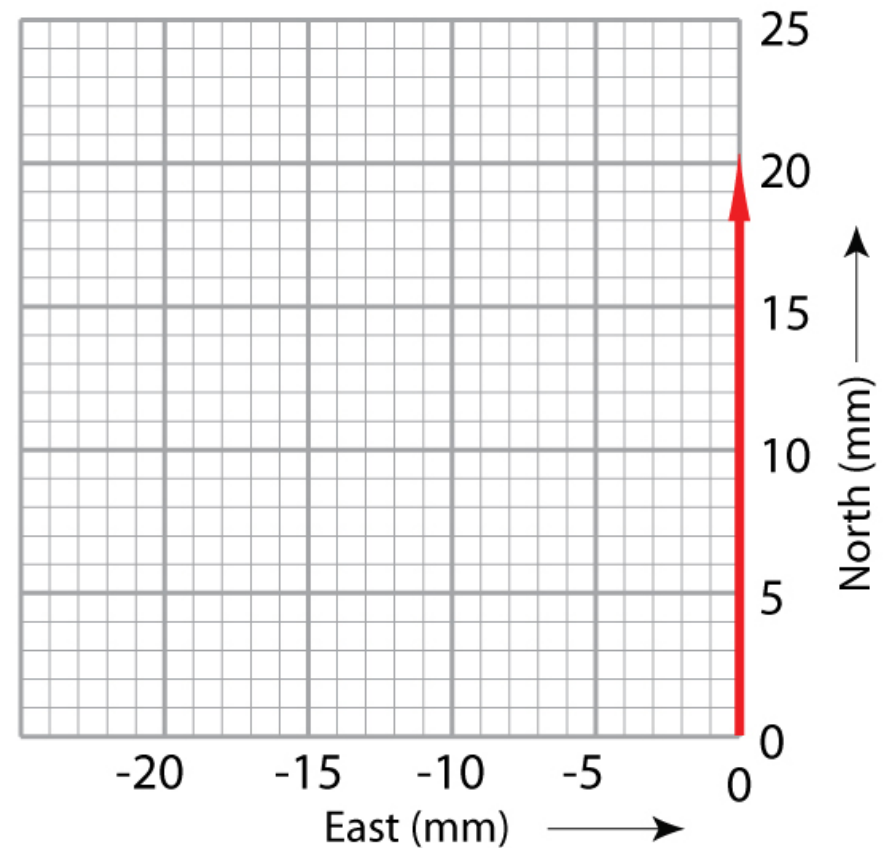
A vector shows speed and direction of motion.

Graph paper as a map

Each axis uses the same scale--millimeters.

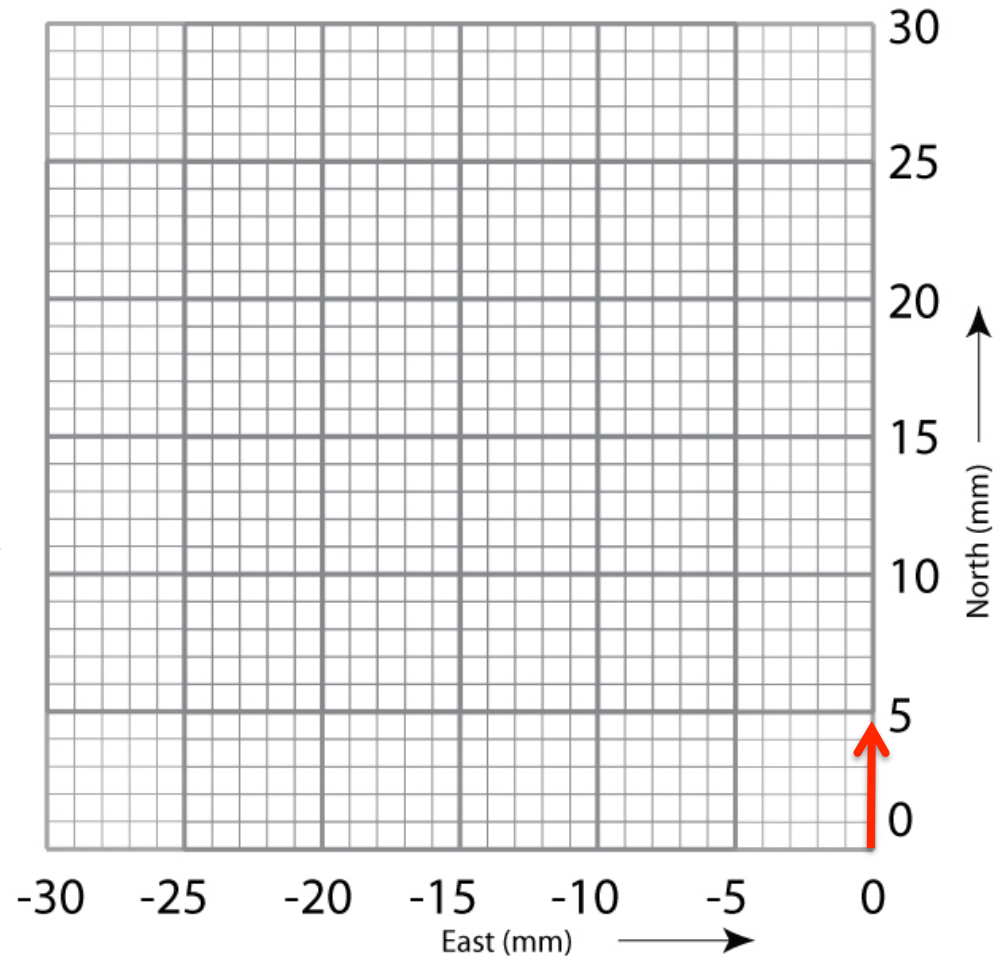
On your graph paper, each block represents 1 mm.

Where is the origin on this graph?



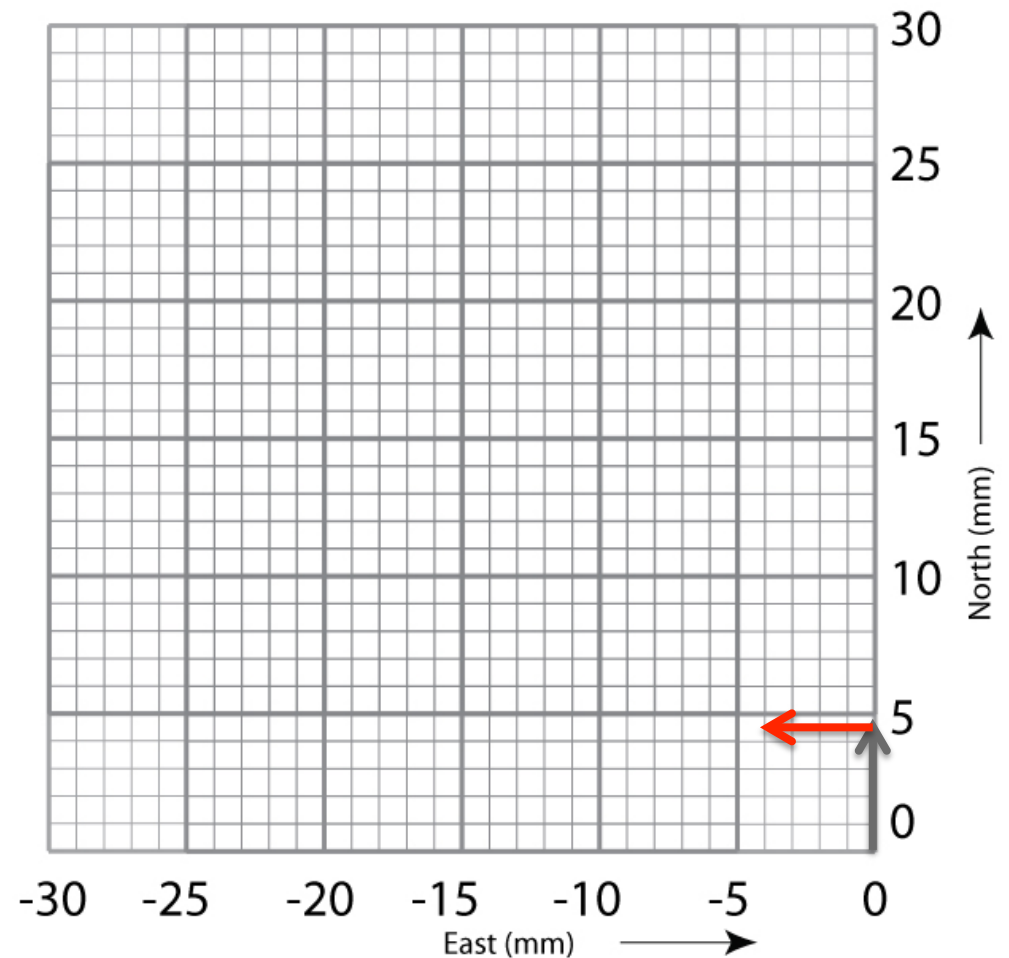
Step 1. Draw the first vector along the North axis with the tail at (0, 0).

To show BEMT moving 4.6 mm to the north every year, draw a vector 4.6 blocks along the north axis.



Step 2. Draw the east vector from the end point of the north vector.

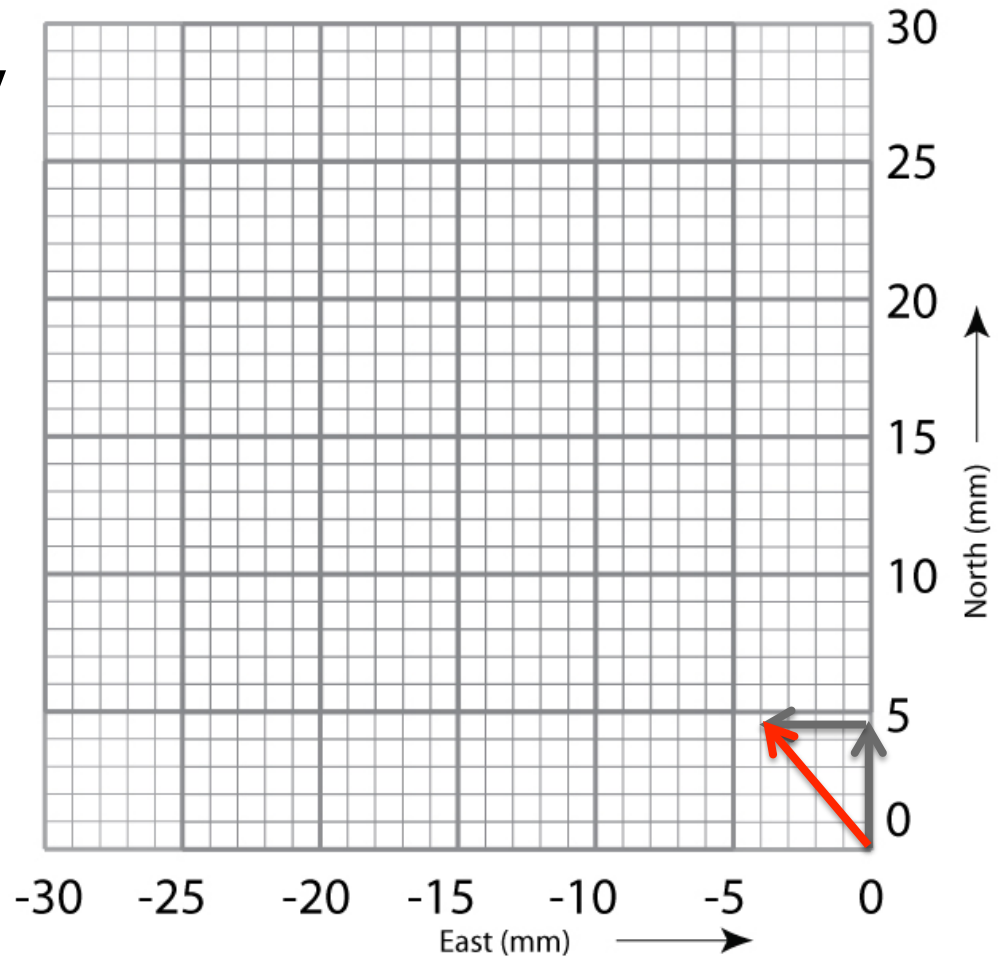
Draw the vector -4.0 blocks (mm).



Adding vectors graphically

Step 3. Add the vectors by drawing a new vector from the origin (0, 0) to the end of the east arrow.

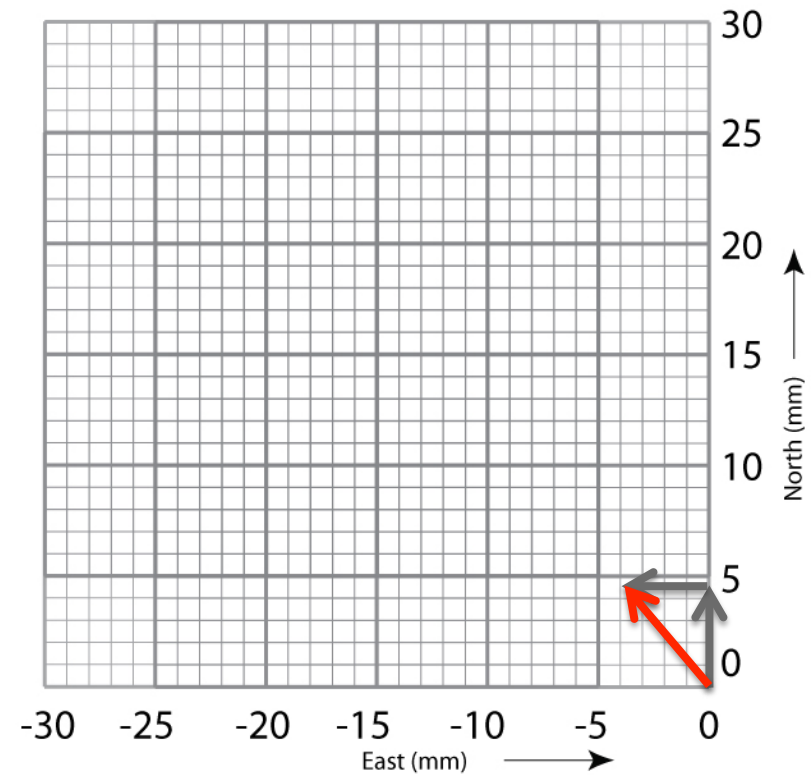
This final vector shows the direction and distance the GPS station and the land beneath it moves each year.



Adding vectors mathematically

Apply the Pythagorean theorem:

$$\begin{aligned}\text{BEMT moves } & \sqrt{x^2 + y^2} \\ &= \sqrt{4.6^2 + 4.0^2} \\ &= 6.1 \text{ mm/yr to the northwest.}\end{aligned}$$



Velocity of tectonic plates



BEMT:

4.6 mm N
-4.0 mm E
= 6.1 mm/yr
to the
northwest

SBCC:

27.3 mm N
-26.1 mm E
= 37.8 mm/yr
to the
northwest

Wait a minute!



The
vectors
point the
same
direction

...

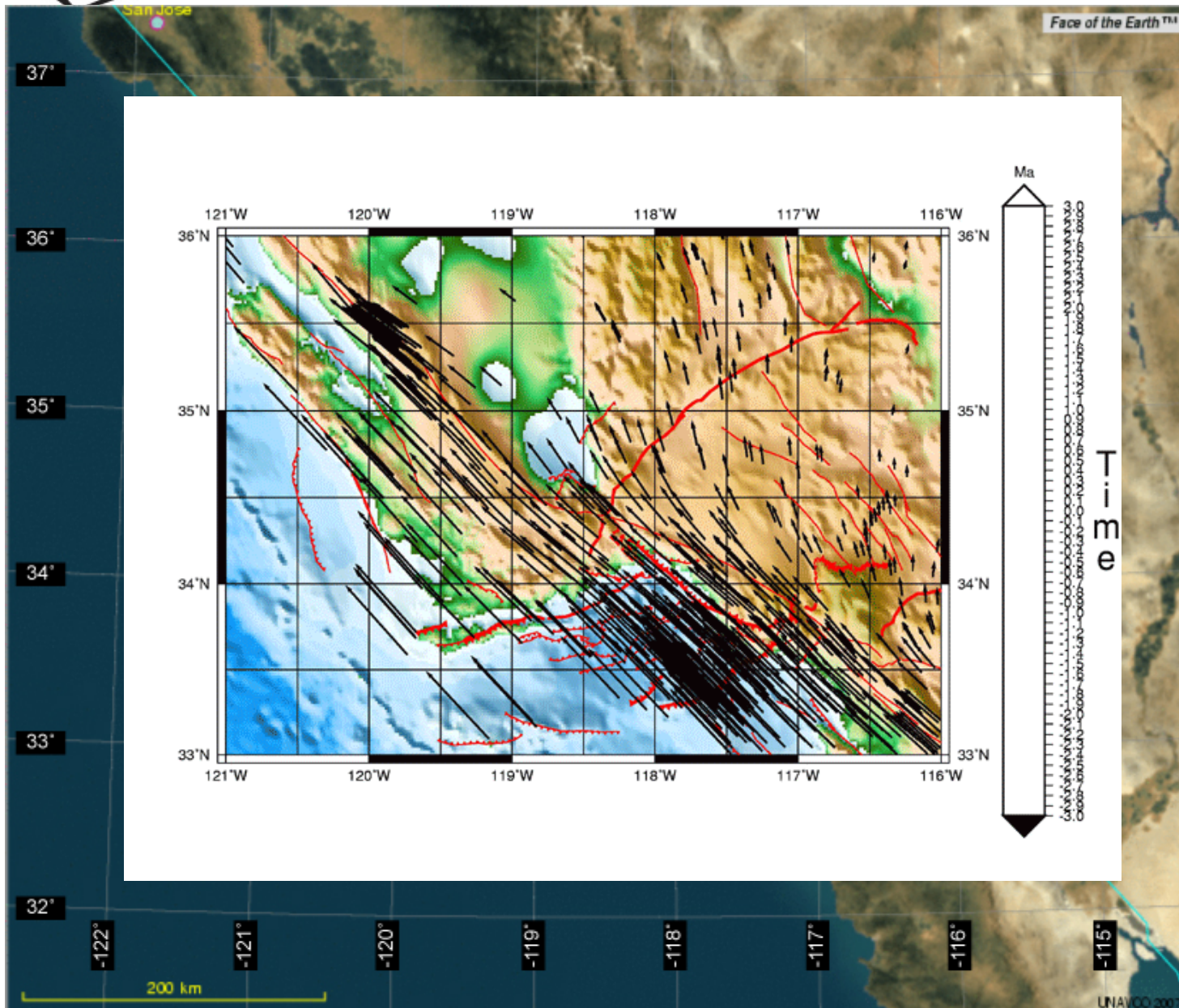
But this is a transform fault!



The velocities are relative to the center of North America.

Imagine you are on a three-lane highway, driving in the middle lane...

Modeling the past and future



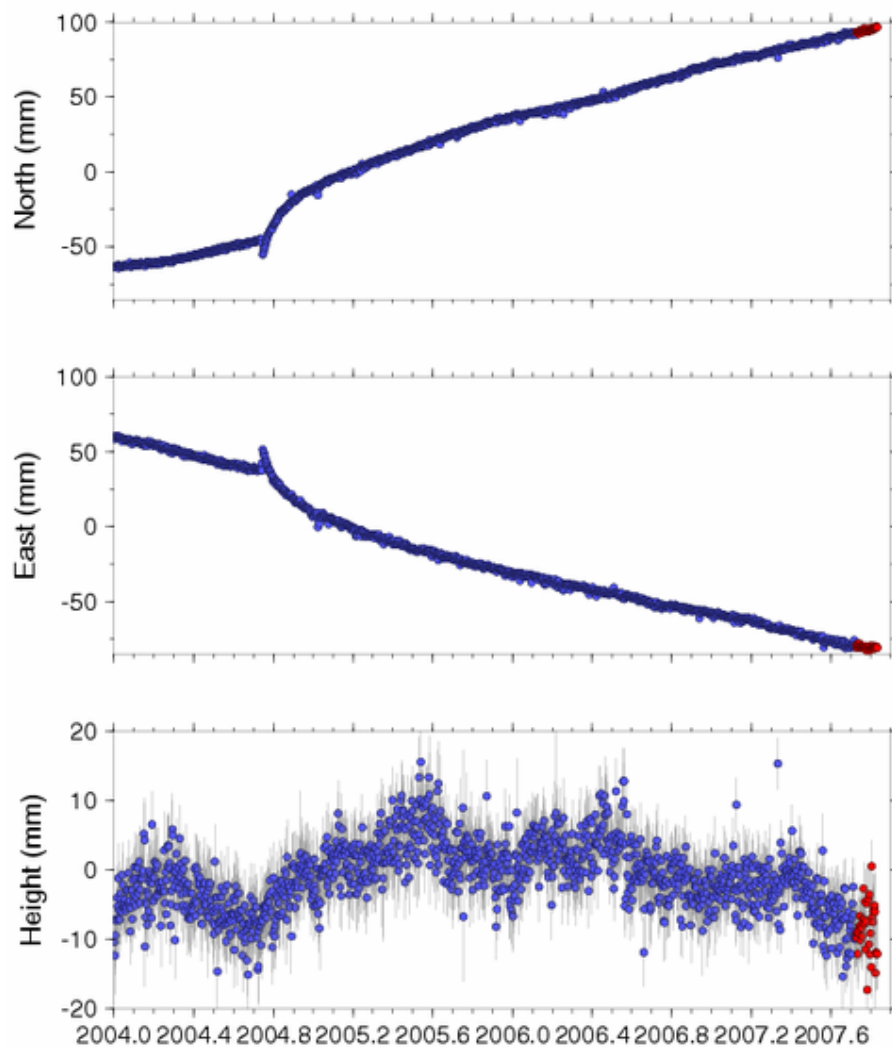
+ 3 million
years

Now

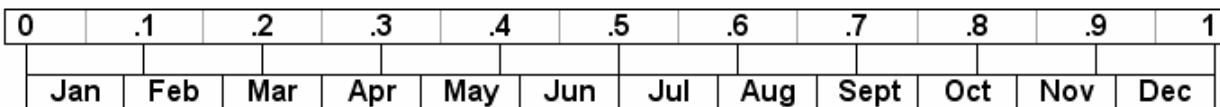
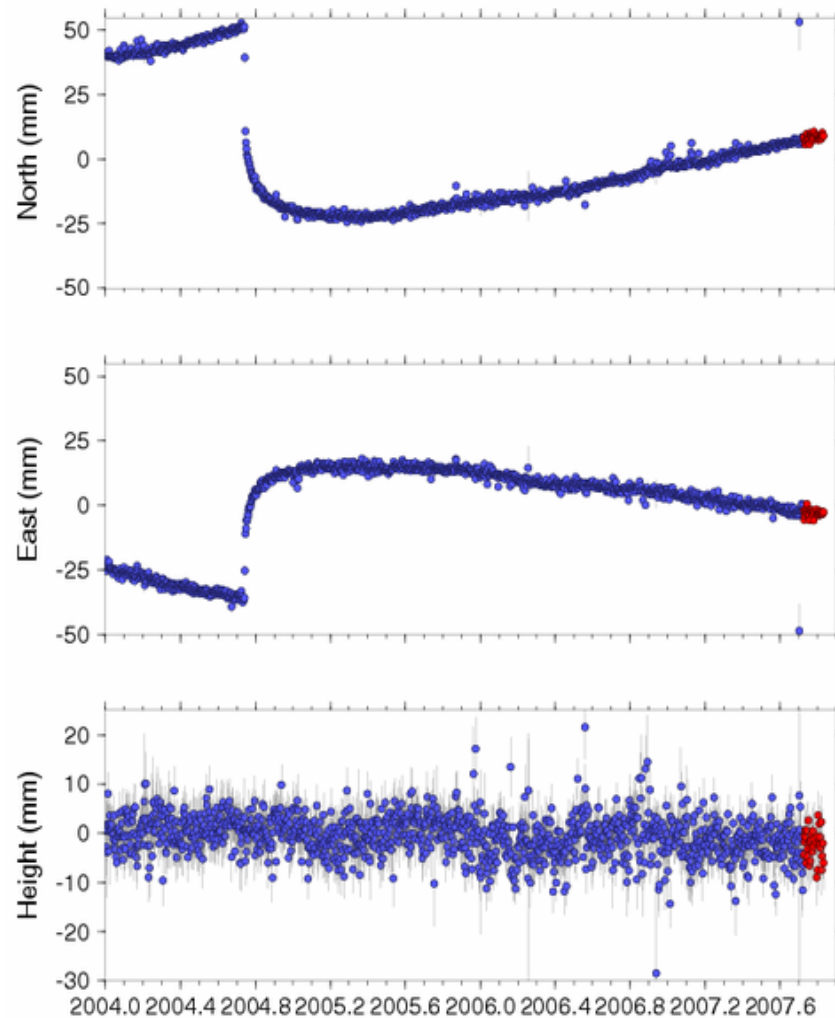
- 3 million
years

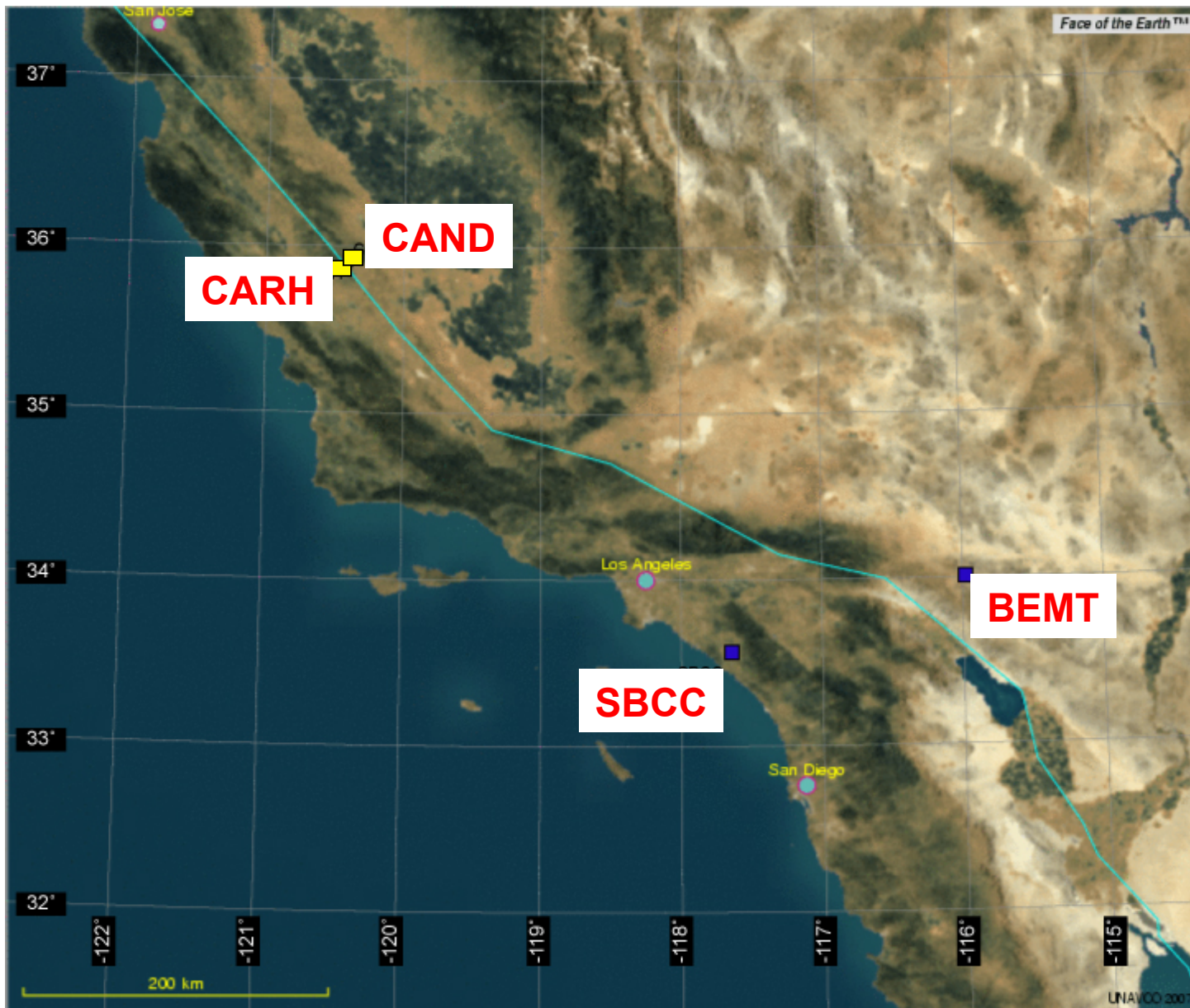
What's happening here?

CARH (CARH_SCGN_CN2001)



CAND (CAND_SCGN_CN1999)





CAND:
Lat: 35.94
Long: -120.43

CARH
Lat: 35.89
Long: -120.43

How much slip on the fault occurred during the event (using the CAND time series plot)?

~ 75 mm south and ~ 60 mm east, resulting in 96 mm combined slip to the southeast.

How did the CAND station's position change-- during the earthquake? It jumped to the SE.

after the earthquake?

It continued to move SE until ~Jan 2005, then resumed its NW movement.

What was the magnitude of the Parkfield earthquake based on the slip that you calculated?

$$M = \frac{\log_{10}(D) + 6.32}{0.9}$$

where M = magnitude

D = average slip in meters

[1000 mm = 1 meter]

$$M = \frac{\log_{10}(.096) + 6.32}{0.9}$$

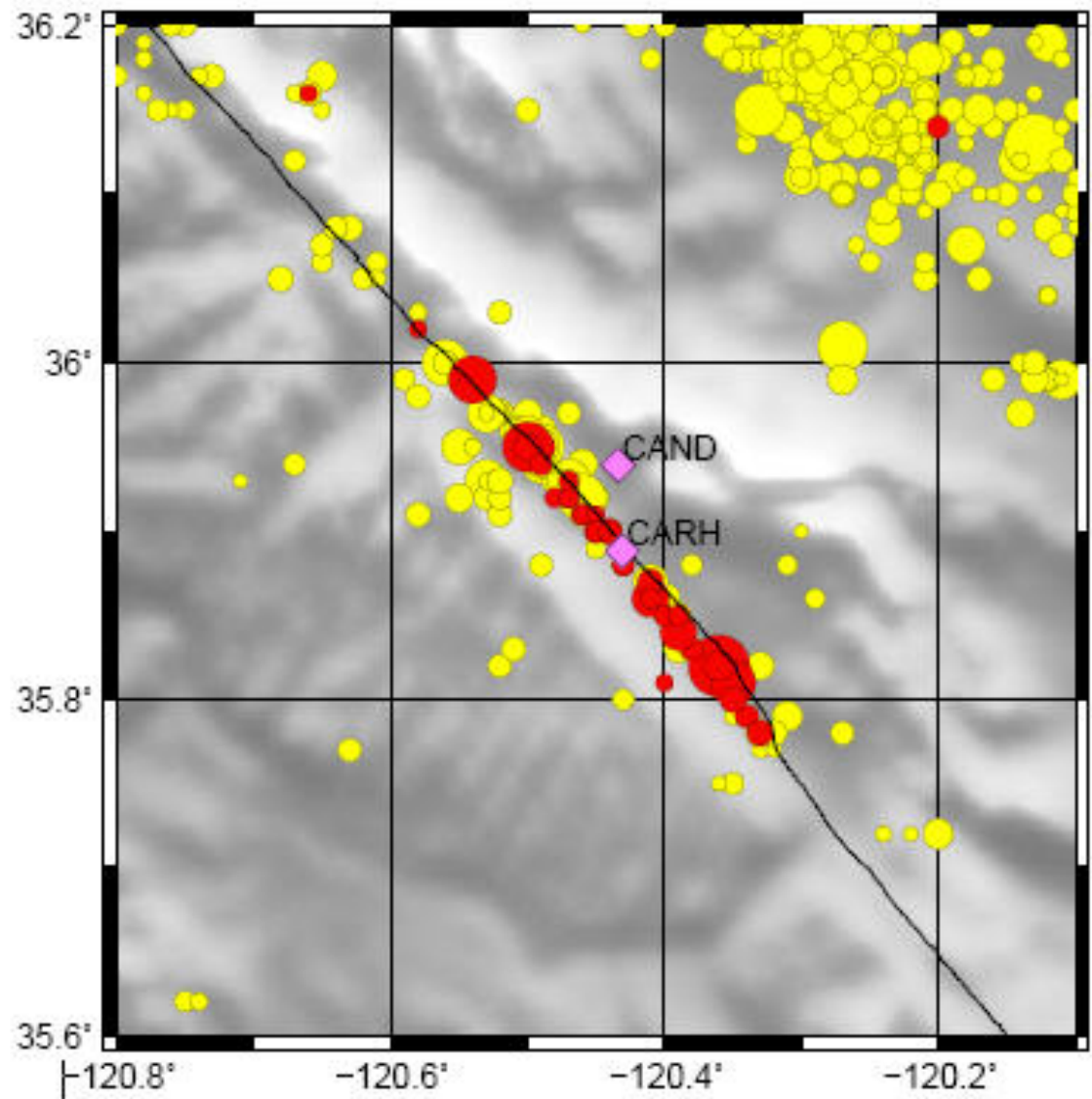
$$M = 5.9$$

(According to the USGS, the Parkfield earthquake was a magnitude 6.0 quake.)

Recurring earthquakes

Red = epicenters
of the main 2004
shock and
aftershocks
within one month
of event

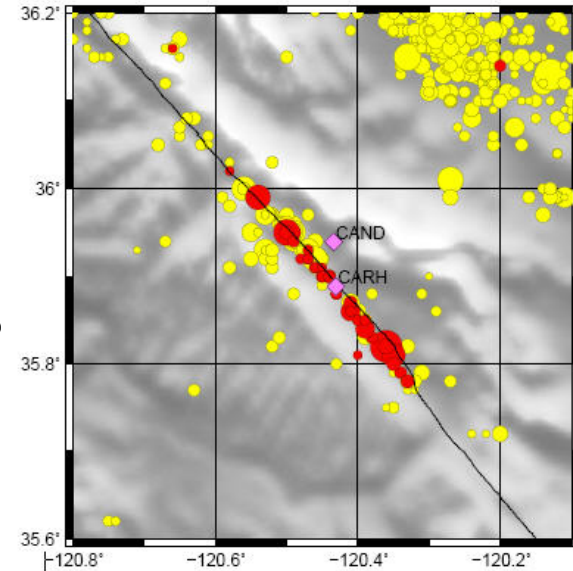
Yellow =
earthquakes
1973–2006



Recurring earthquakes

~96 mm total slip in 2004.

There, the Pacific plate moves past the North American plate
~17mm/yr.



How long should it take to build enough strain to cause an earthquake with a similar magnitude?

$96\text{mm}/17 \text{ mm per year} = \sim 5.6 \text{ years}$

Recurring earthquakes

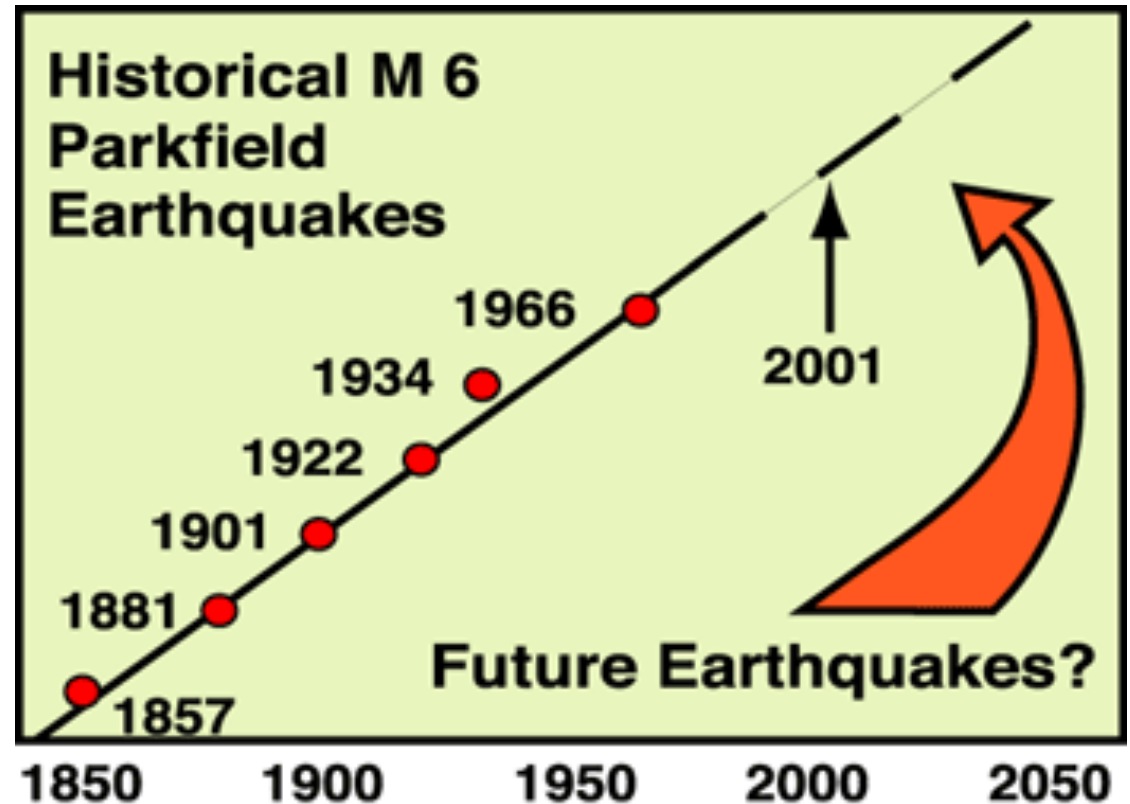
Observed frequency
of M6 earthquakes
during the 20th
century?

~every 20 years

Predicted frequency:

96mm / 17 mm per
year = ~5.6 years

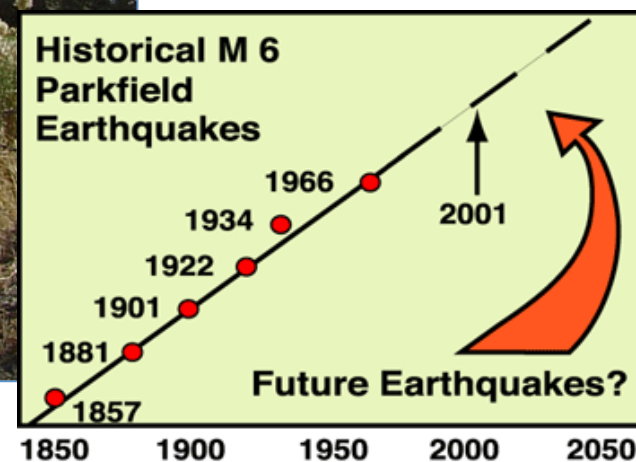
Why are these
numbers different?

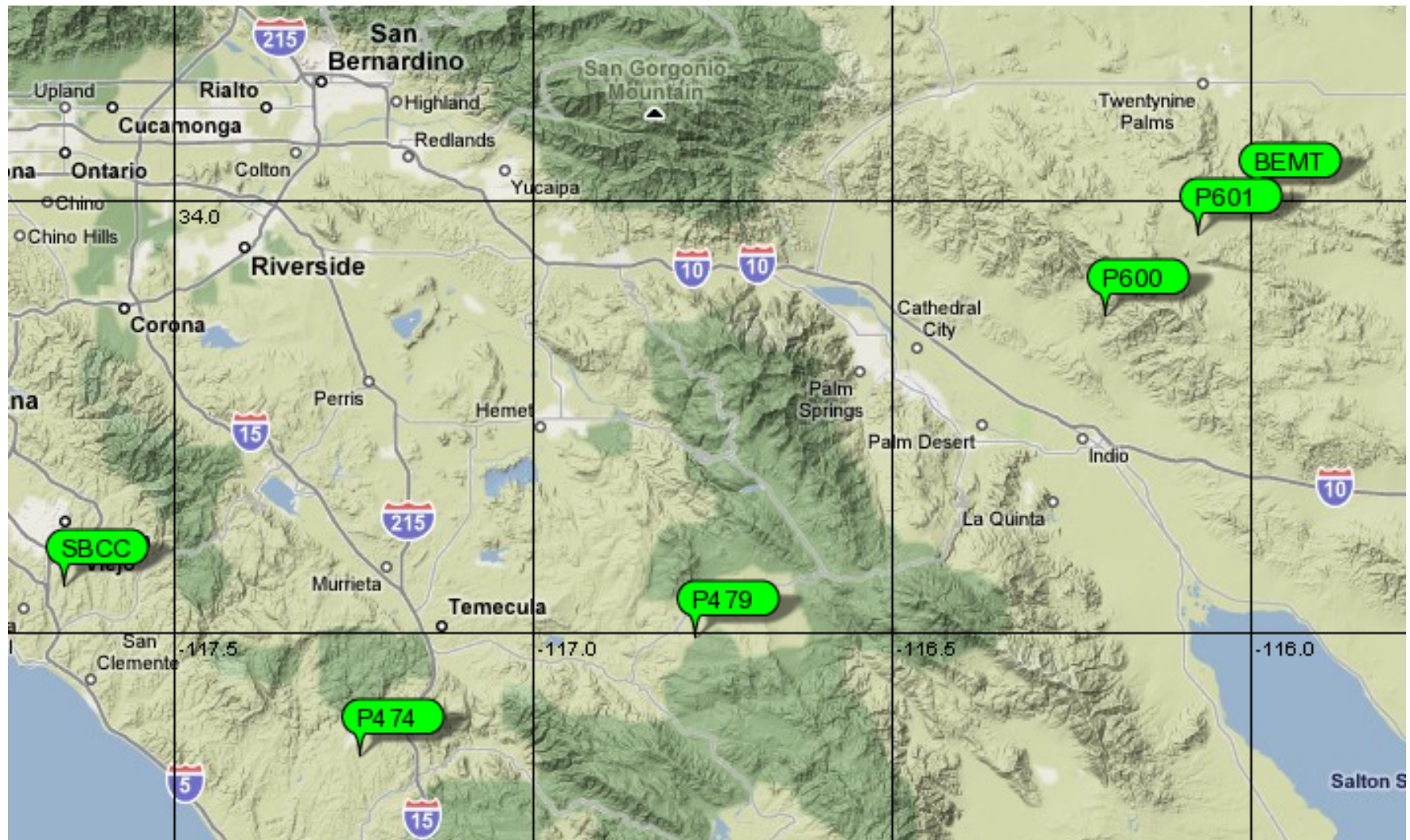


Recurring earthquakes

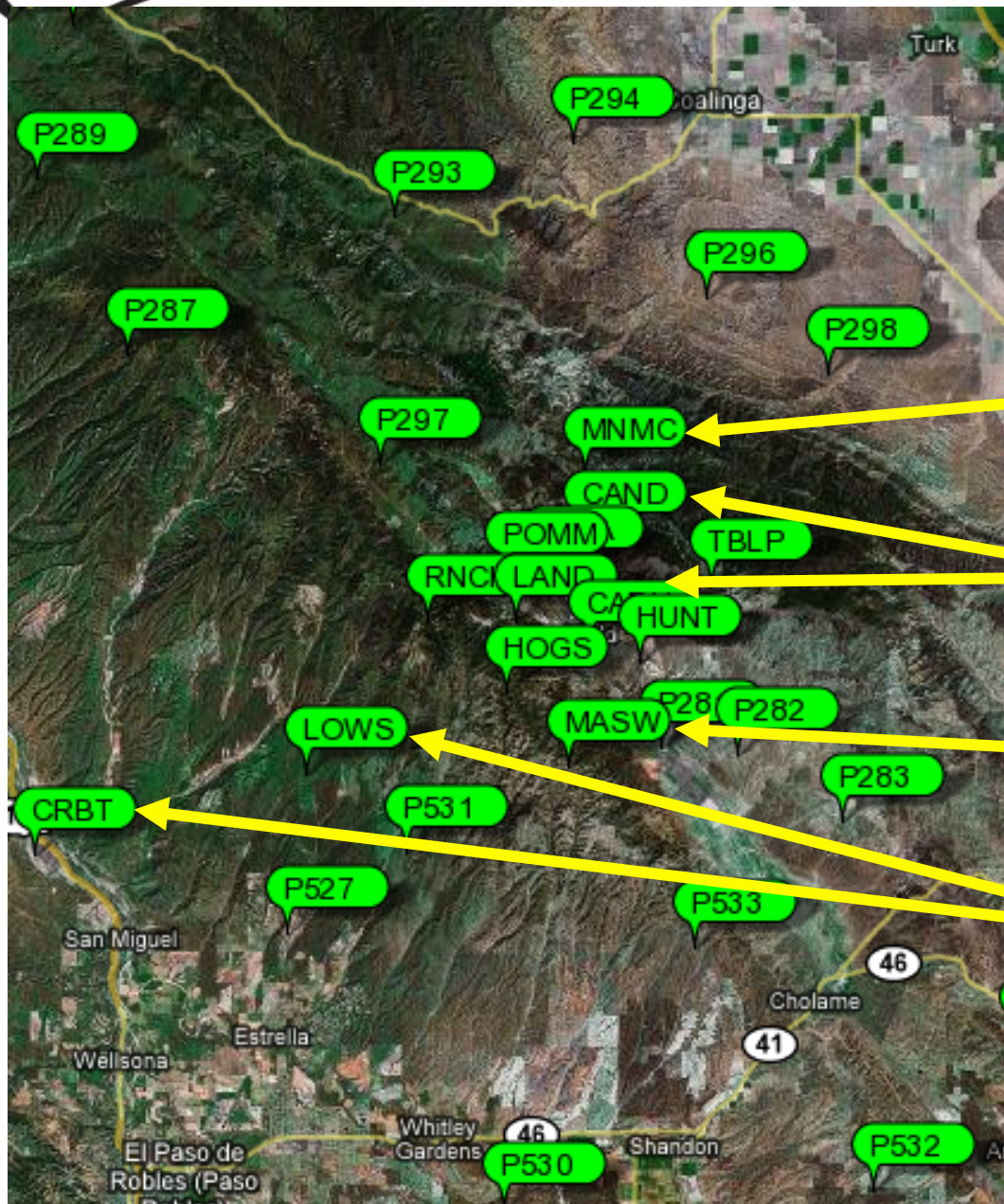


Why are
the
numbers
different?





Station	North	East
P474	26.63	-26.70
P479	22.38	-23.04
P600	7.53	-8.35
P601	3.62	-5.46



Choose sites increasingly far from the epicenter, such as:

MNMC

CAND & CARH

MASW

LOWS & CRBT,
and so on...

Station	North	East
CRBT	32.15	-26.55
LOWS	32.48	-26.05
MASW	33.22	-25.25
MNMC	11.15	-7.63

- How high-precision GPS works and its application to plate tectonics;
- How to find GPS and tectonic plate velocities from GPS time series plots;
- How the Pacific plate moves compared to the North American plate along the San Andreas fault; and
- That motion on faults continues after earthquakes.

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<http://www.unavco.org/>

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