

# Measuring plate motion with GPS:

Introducing GPS to study tectonic plates  
as they move, twist, and crumple

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UNAVCO*

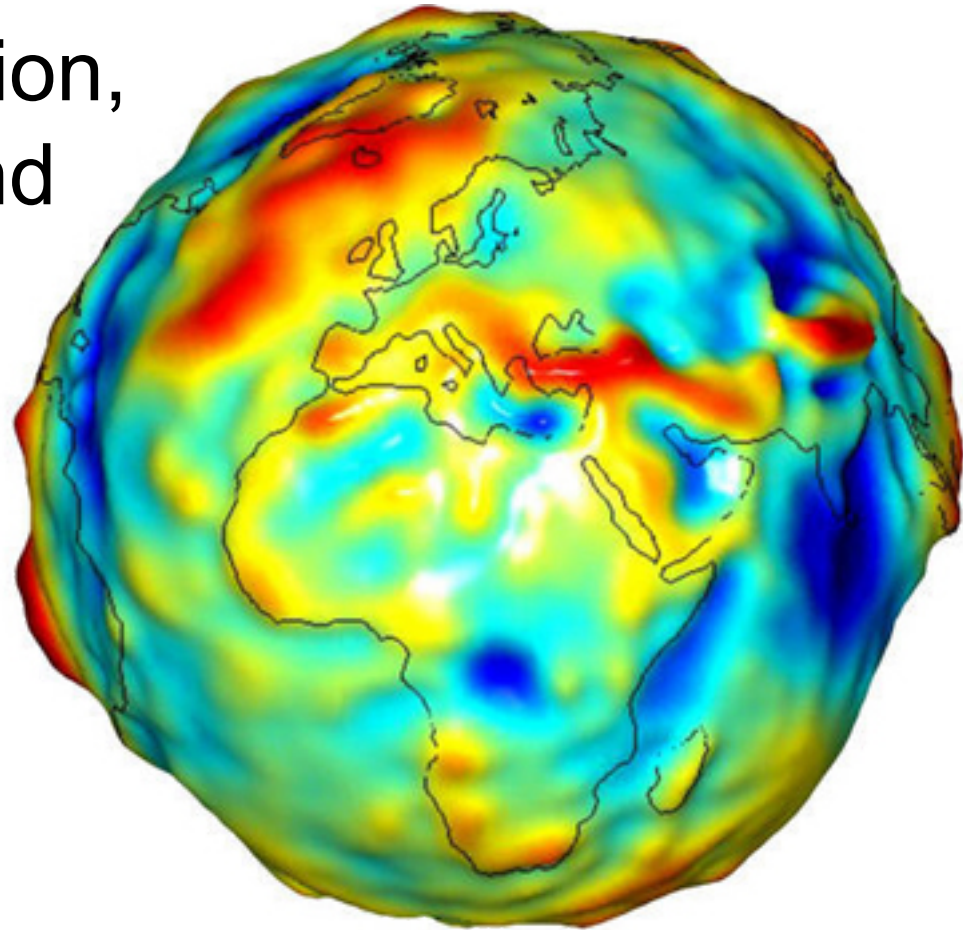
**UNAVCO**

You should be able to:

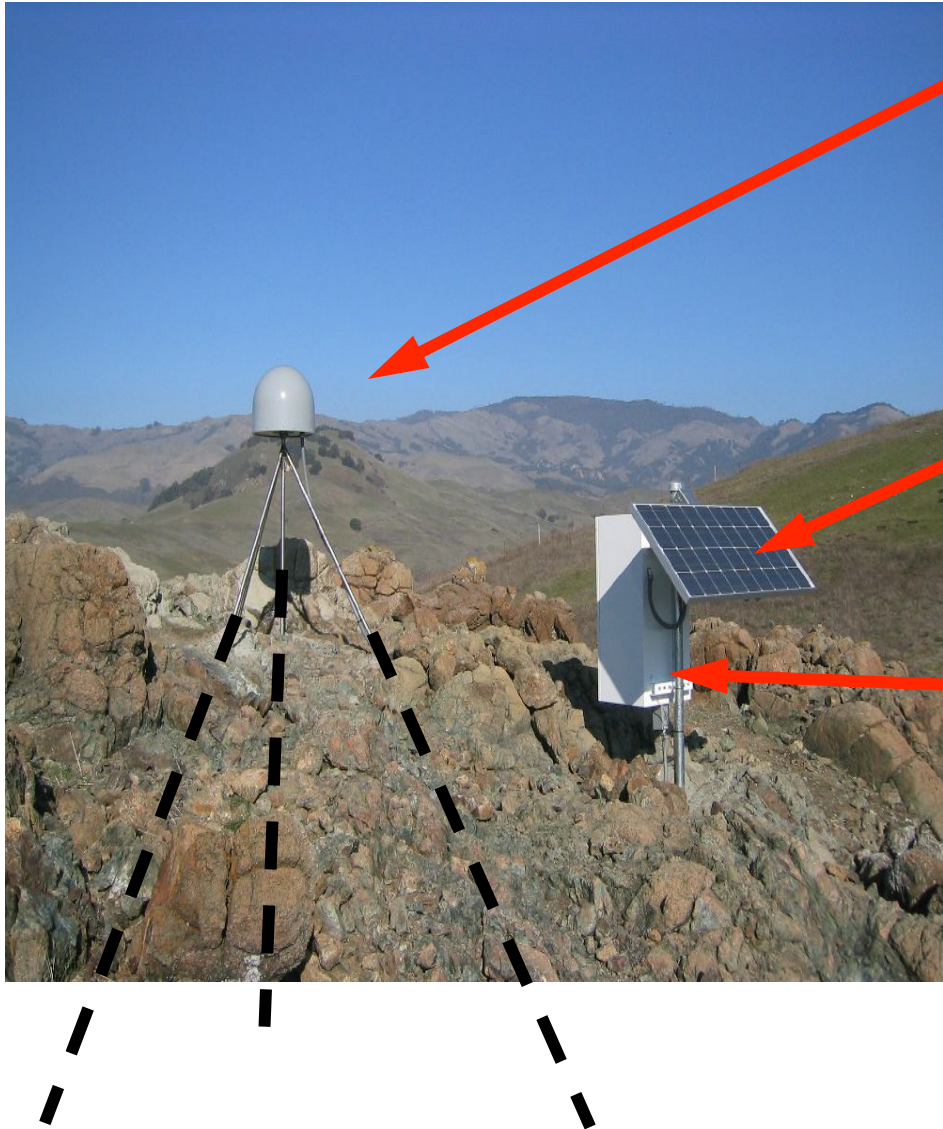
- Describe generally how GPS works;
- Interpret graphs in a GPS time series plot;
- Determine velocity vectors from GPS time series plots;
- Explain relative motions of tectonic plates in Iceland; and
- Explore global GPS data.



Geodesy is the science of ...  
measuring Earth's  
size, shape, orientation,  
gravitational field, and  
variations of these  
with time.



# Anatomy of a GPS station



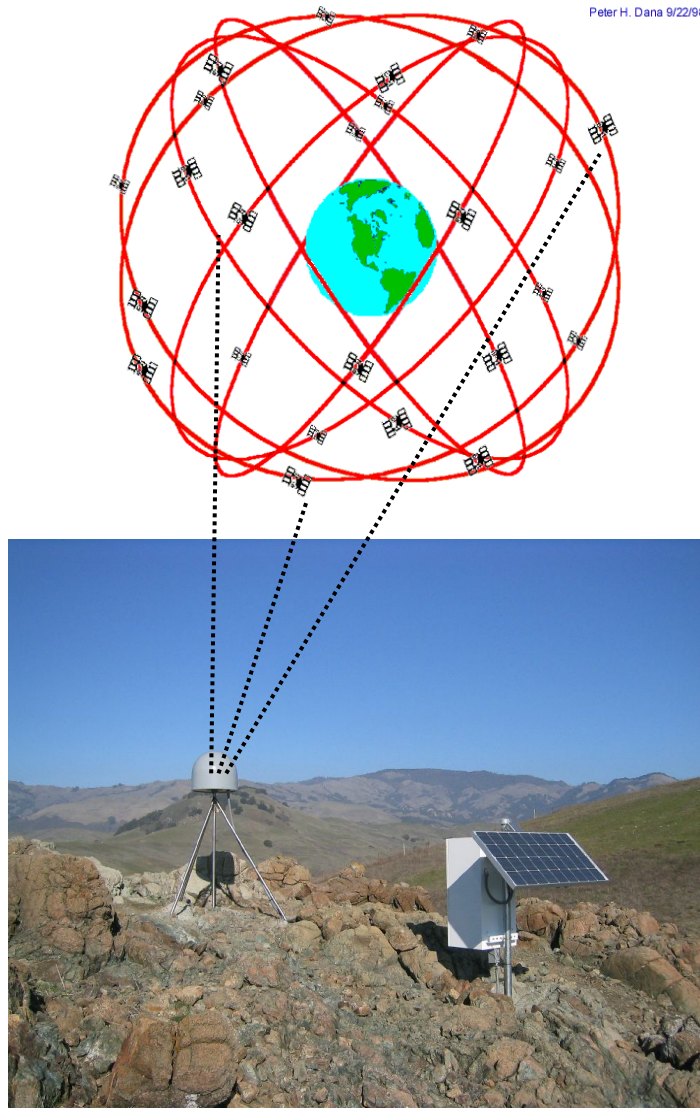
GPS antenna inside the dome is anchored to the ground with braces.

Solar panel for power.

Equipment enclosure includes:

- GPS receiver
- Power/batteries
- Communications
- Data storage

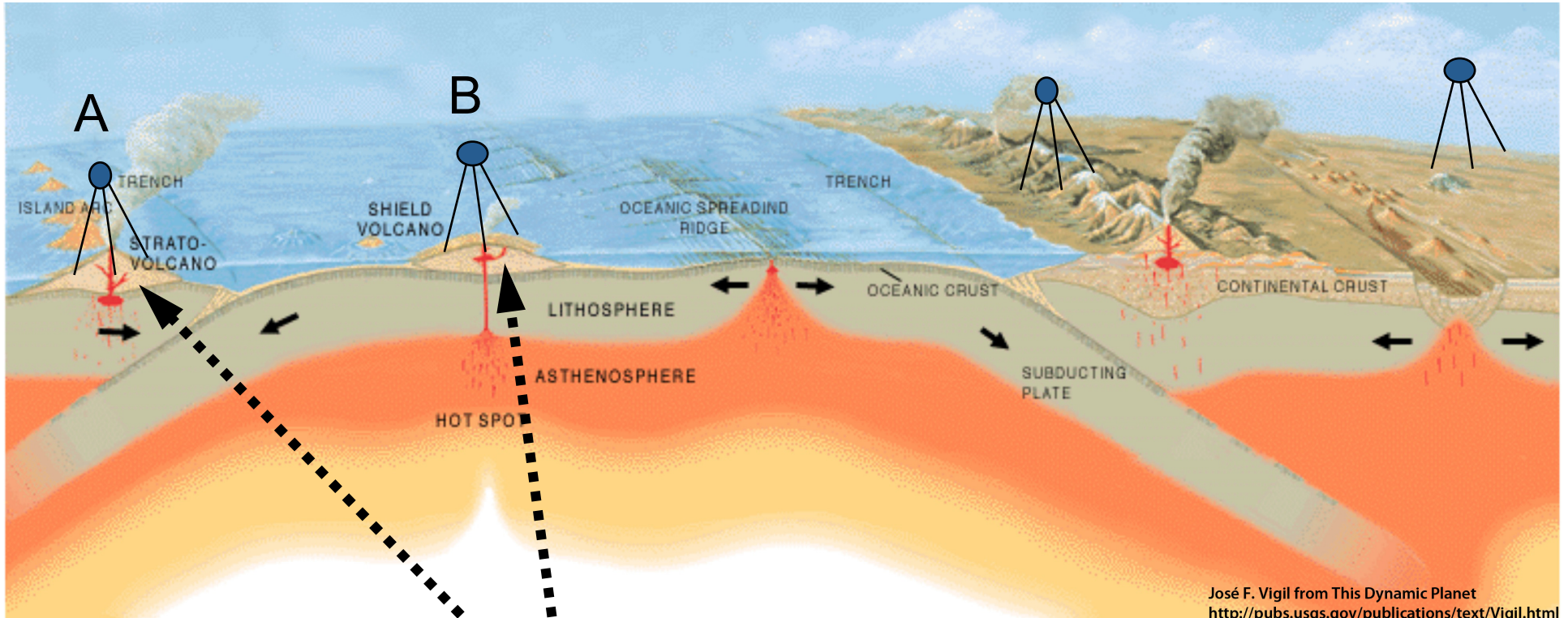




- Three satellite signals locate the receiver in 3D space.
- The fourth satellite is used for time accuracy.
- Position can be located to within less than a centimeter.

# Movement of GPS stations

GPS station positions change as plates move.

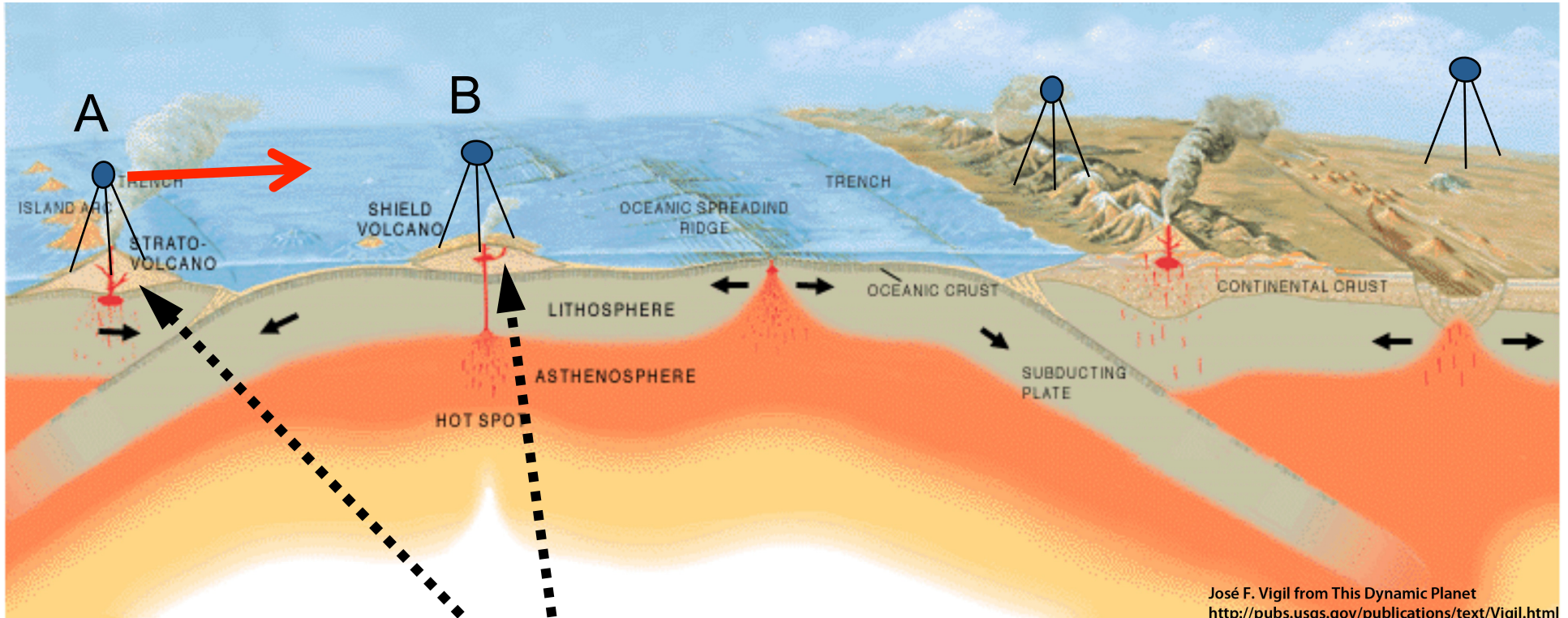


How will Station A move relative to Station B?



# Movement of GPS stations

GPS station positions change as plates move.



GPS Station A is moving toward B.

# Part 1: Modeling GPS

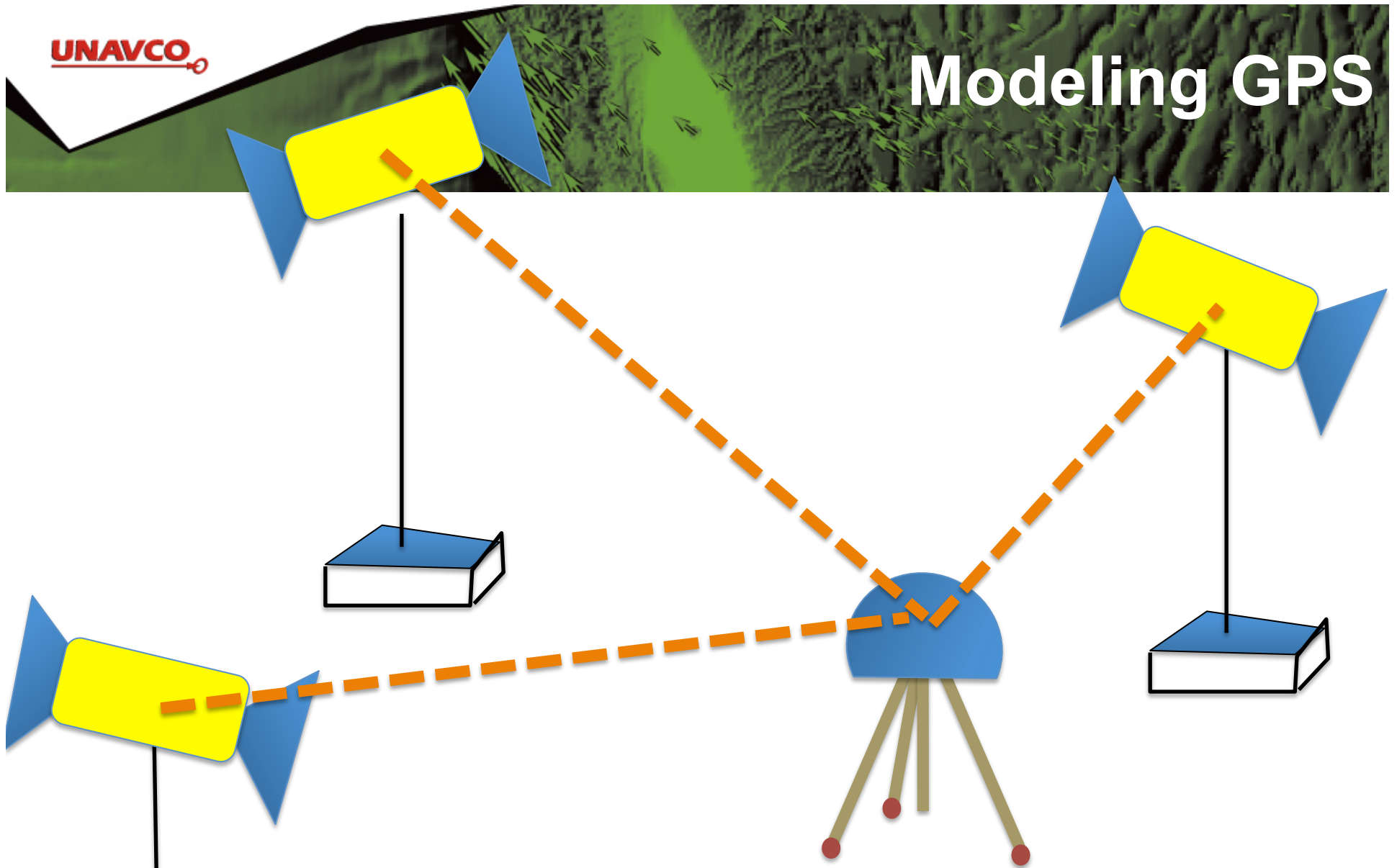
To build a gumbdrop model of a GPS monument:

1. Use one gumbdrop as the receiver (GPS monument).
2. Use toothpicks as three legs and one center post (monument braces).
3. Form feet from three small lumps of clay (concrete).
4. Place on a small piece of transparent paper ("see-through" crust).





# Modeling GPS



Sketch a diagram of the demonstration. Label the components

## SBCC GPS STATION

- Located near Mission Viejo, CA
- Position data collected every 30 seconds
- One position estimate 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



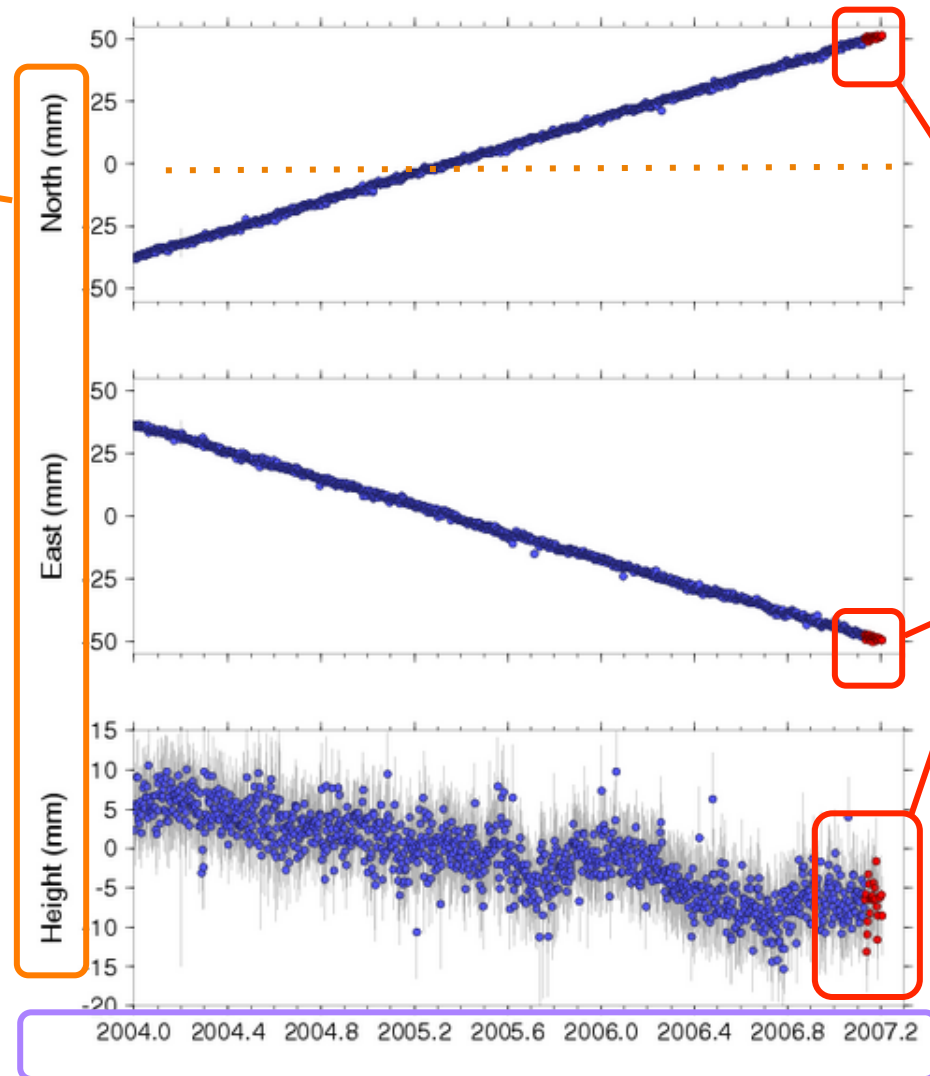
# GPS time series plots

SBCC (SBCC\_SCGN\_CS1999)

3 separate plots  
on y-axis:

- North
- East
- Height  
(Vertical)

Notice that scales  
vary.



Red  
points:  
rapid  
estimates

X-axis: date of the measurement

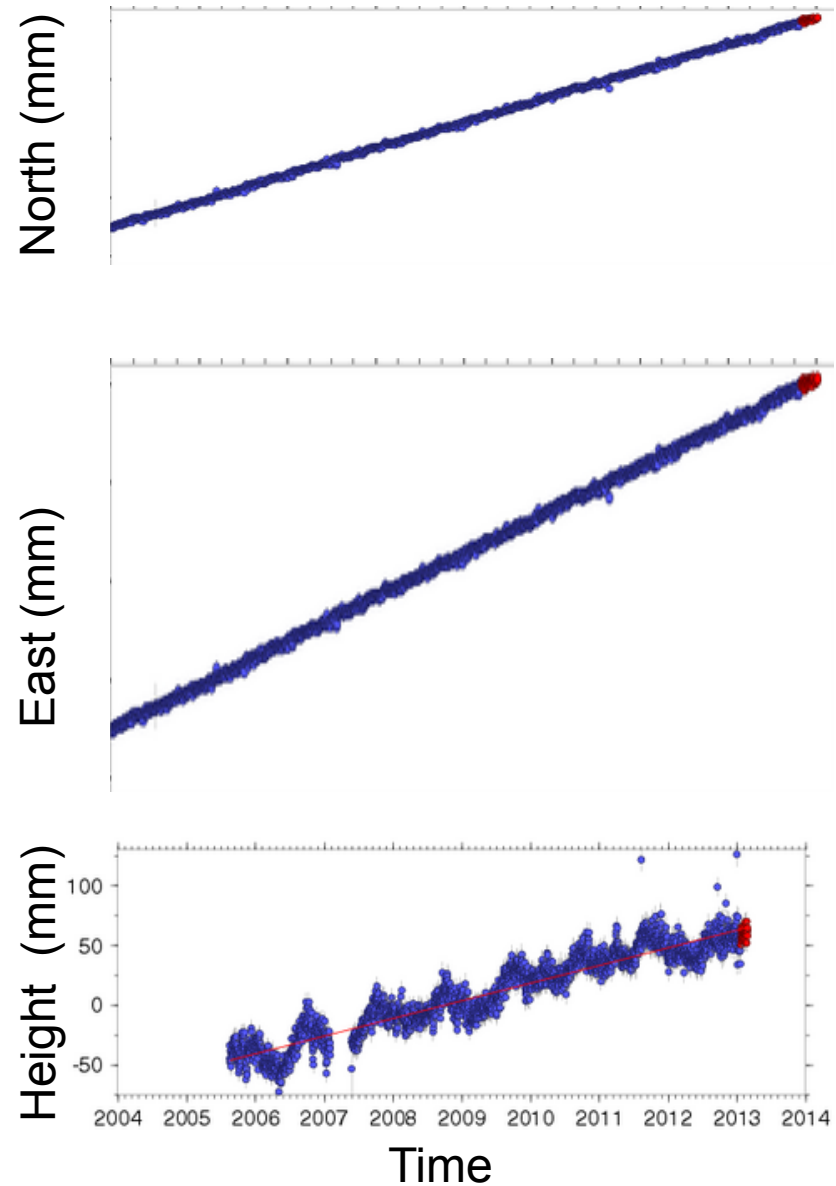
# Which way are we going?

**Is the GPS station  
moving**

north or south?

east or west?

up or down?

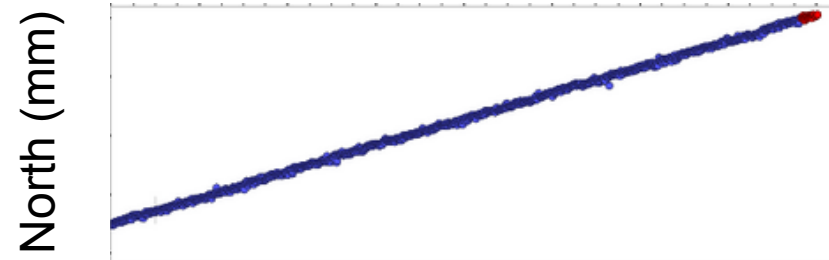




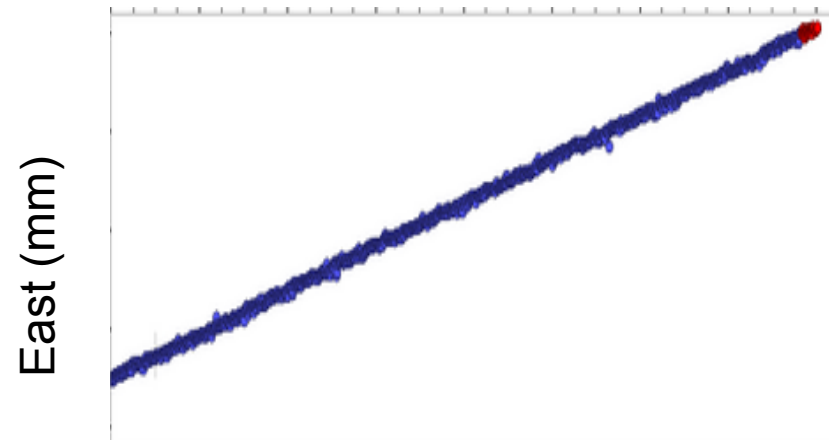
# Which way are we going?

**Positive slope:**

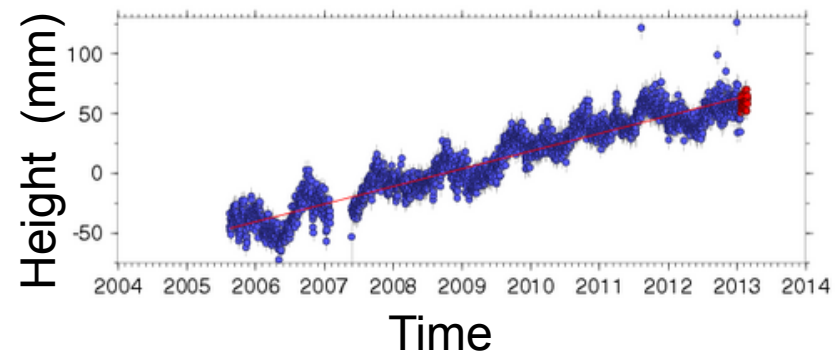
The station is moving  
**north.**



The station is moving  
**east.**

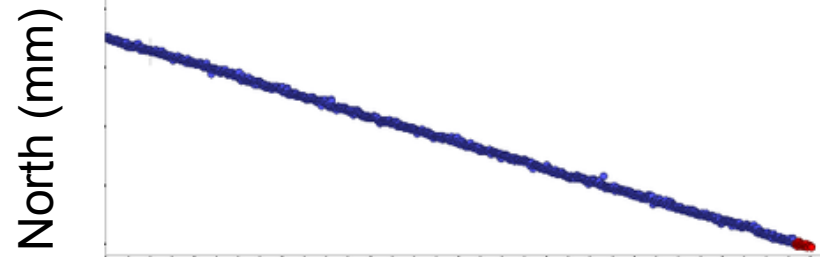


The station is moving  
**up.**

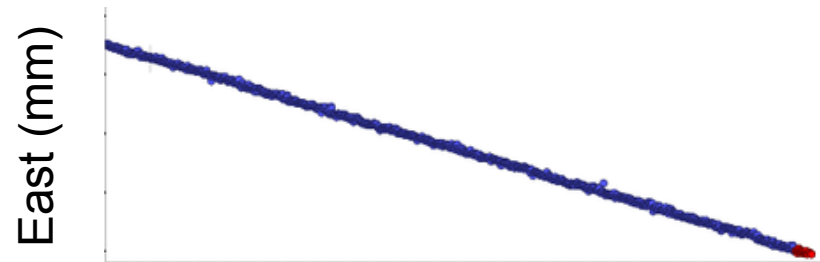


# Which way are we going?

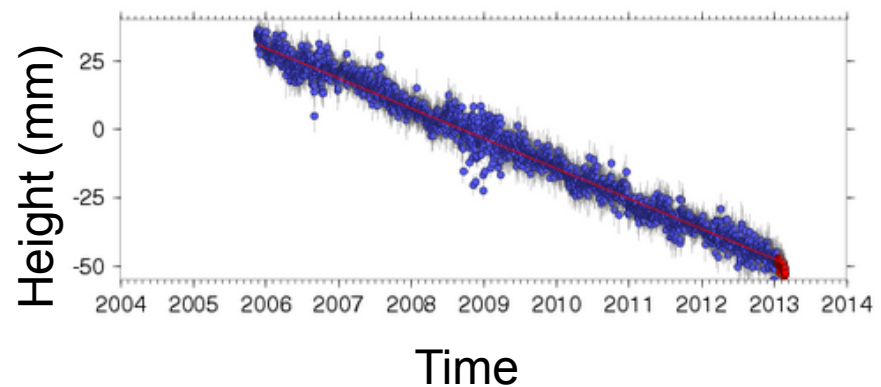
Is the GPS station  
moving  
north or south?



east or west?



up or down?

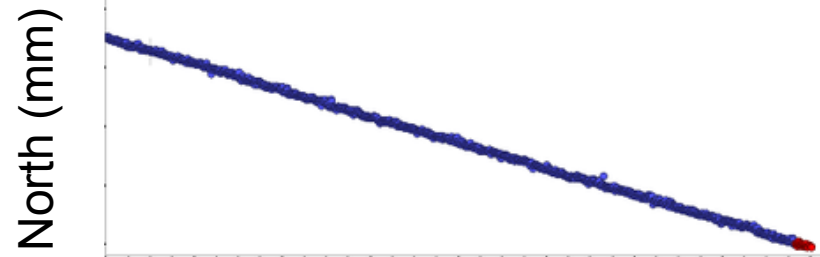




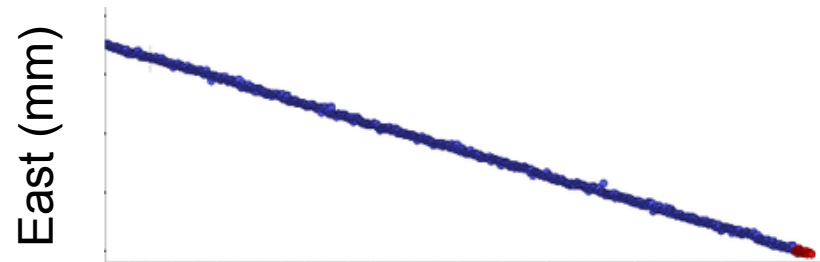
# Which way are we going?

**Negative slope:**

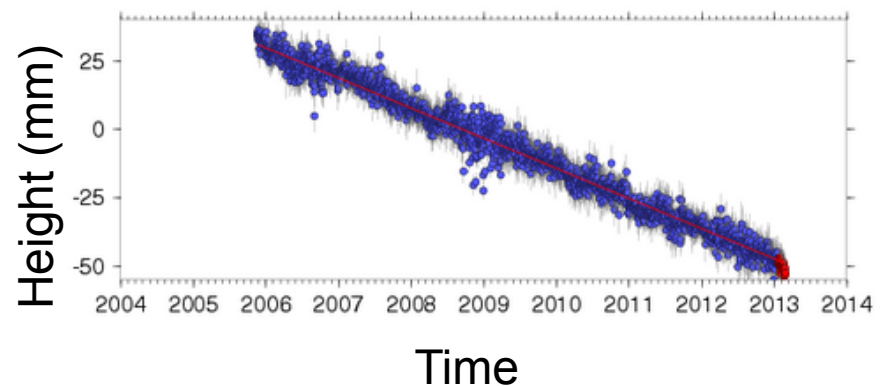
The station is moving  
**south.**



The station is moving  
**west.**

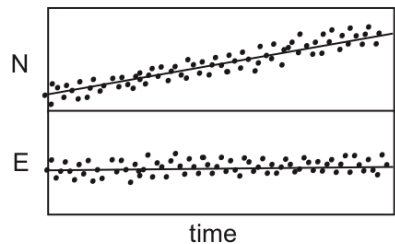


The station is moving  
**down.**



# Time series plots

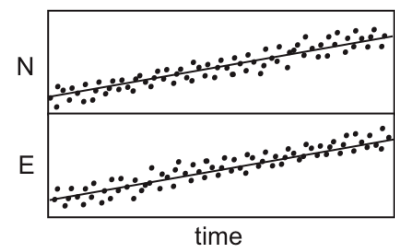
If the GPS Time Series Plots look like:



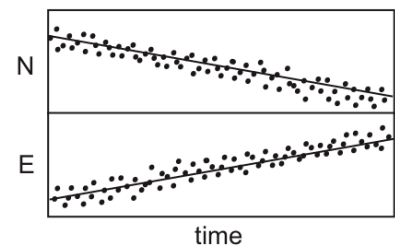
GPS vector looks like:



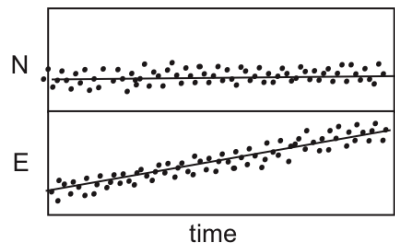
GPS station is moving to the North



GPS station is moving to the Northeast

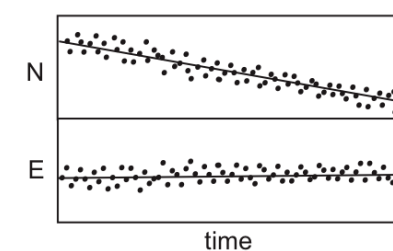


GPS station is moving to the Southeast



GPS station is moving to the East

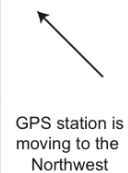
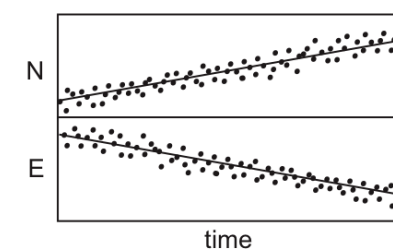
If the GPS Time Series Plots look like:



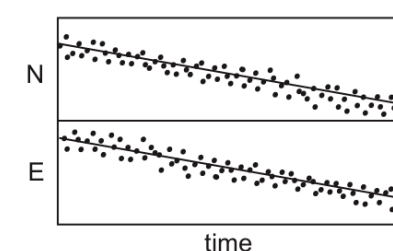
GPS vector looks like:



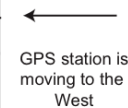
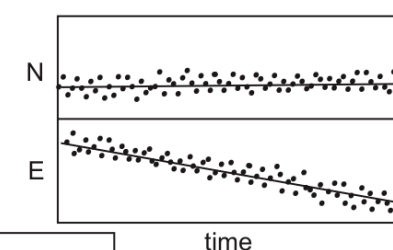
GPS station is moving to the South



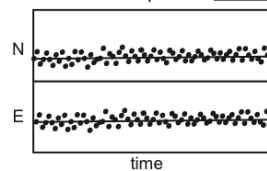
GPS station is moving to the Northwest



GPS station is moving to the Southwest

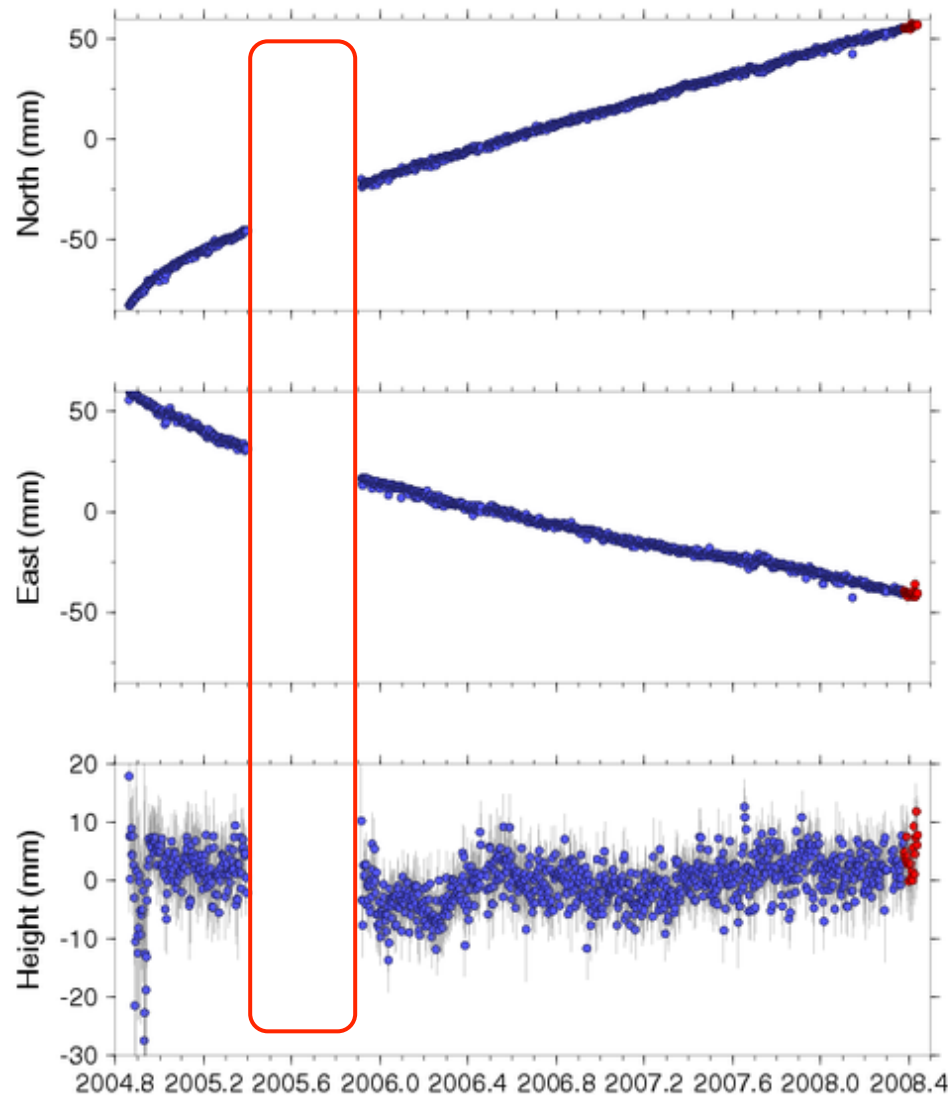


GPS station is moving to the West



GPS station is not moving

P281 (CholameCrkCN2004)

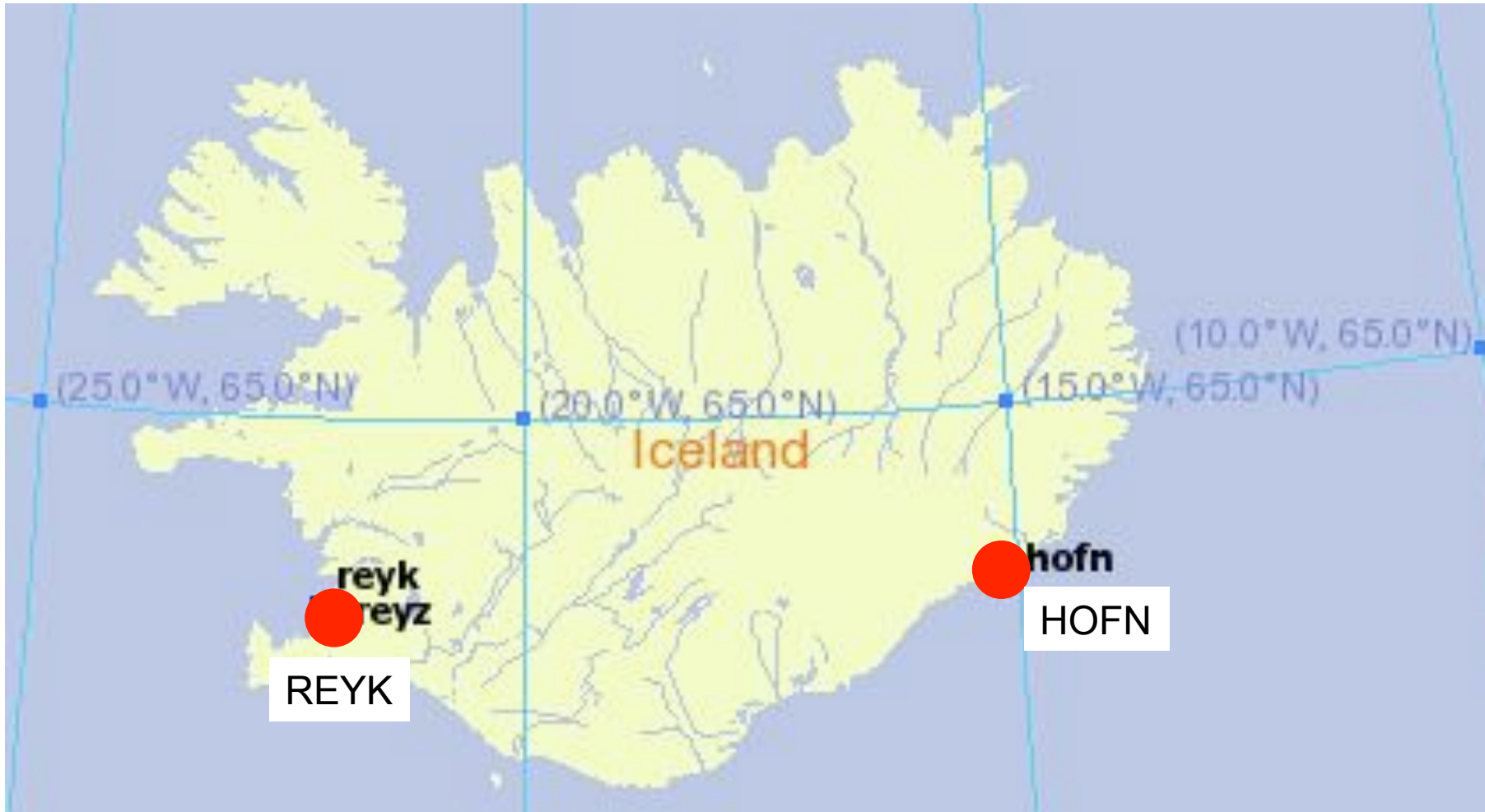


## Causes:

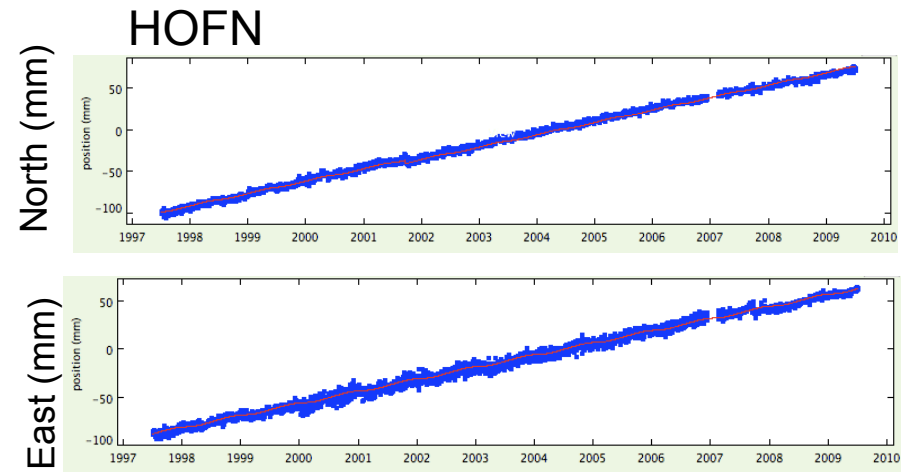
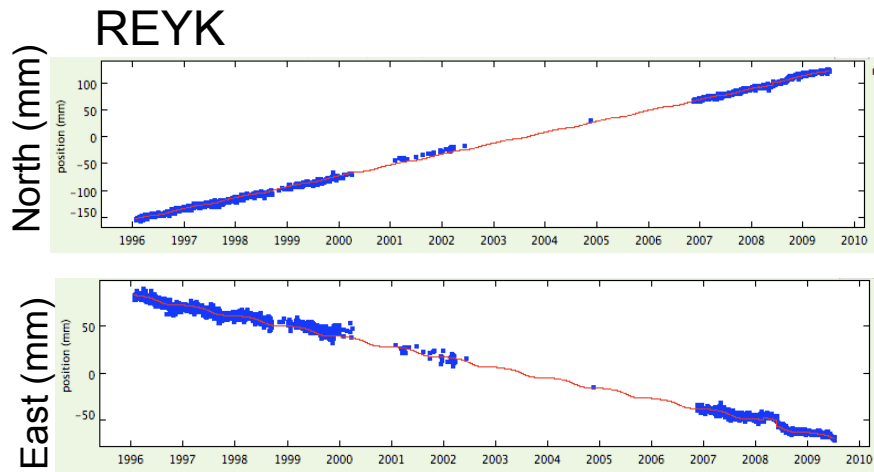
- Power outages
- Snow coverage
- Equipment failure
- Vandalism
- Wildlife
- Etc.





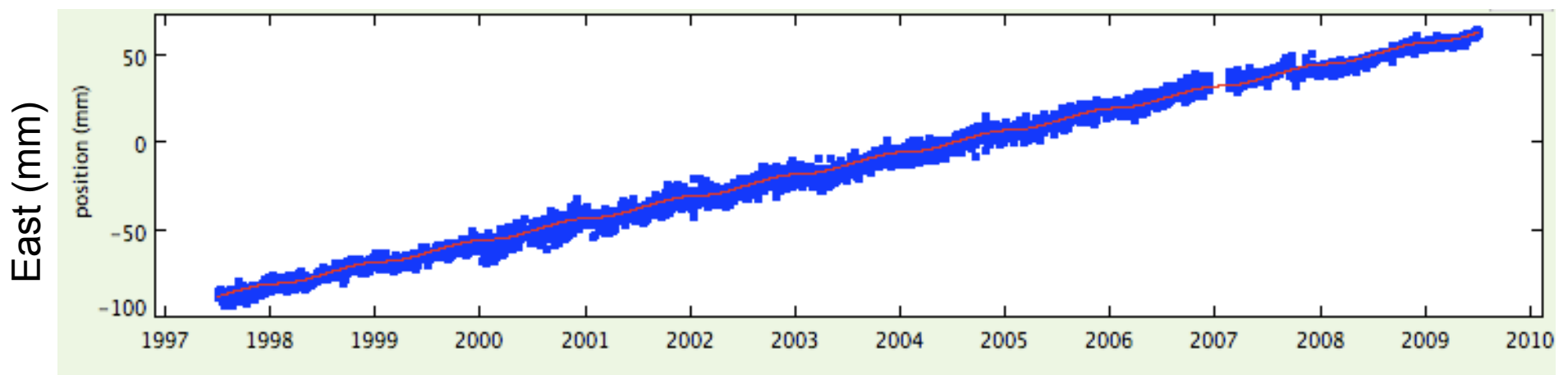
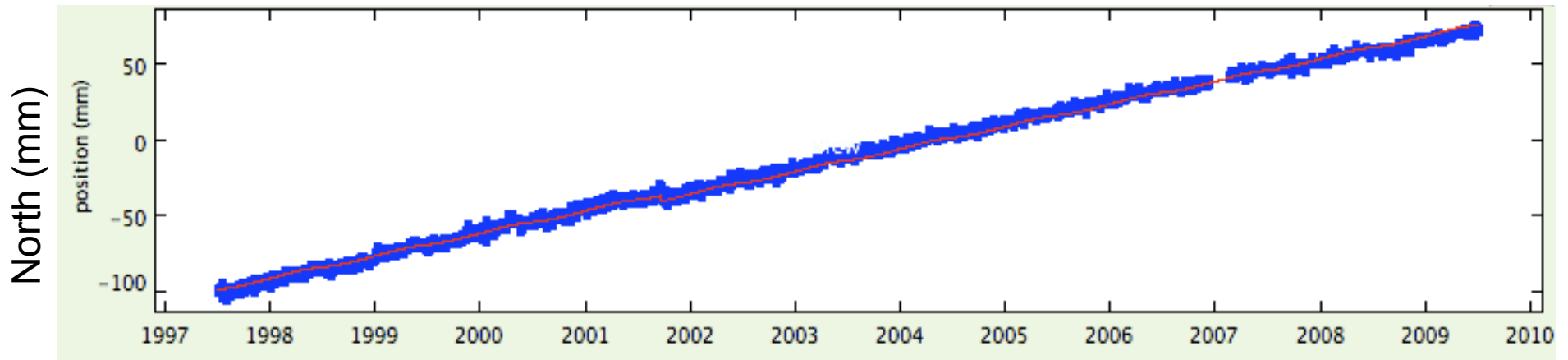




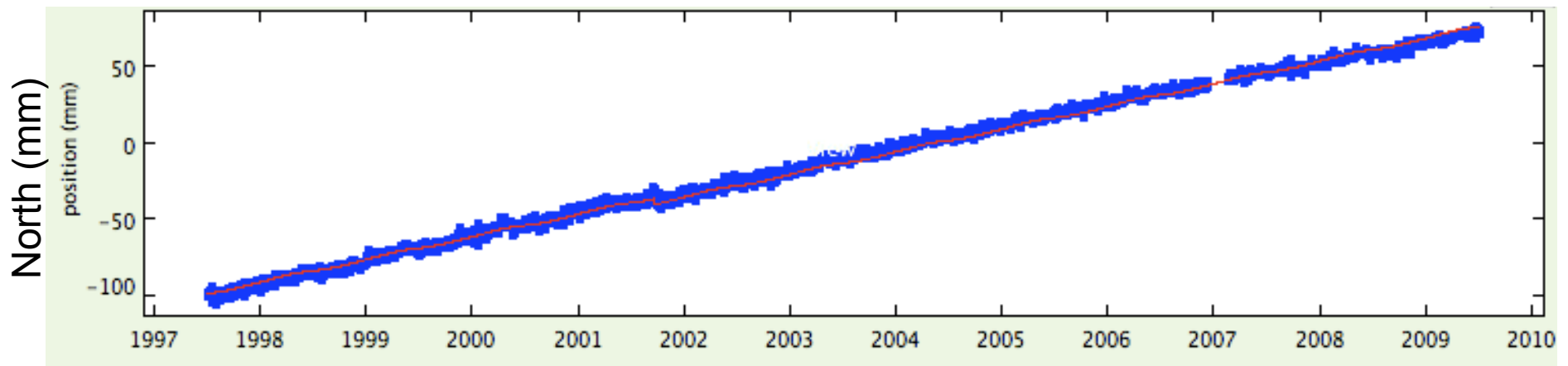




What are the units of measurement for this data?



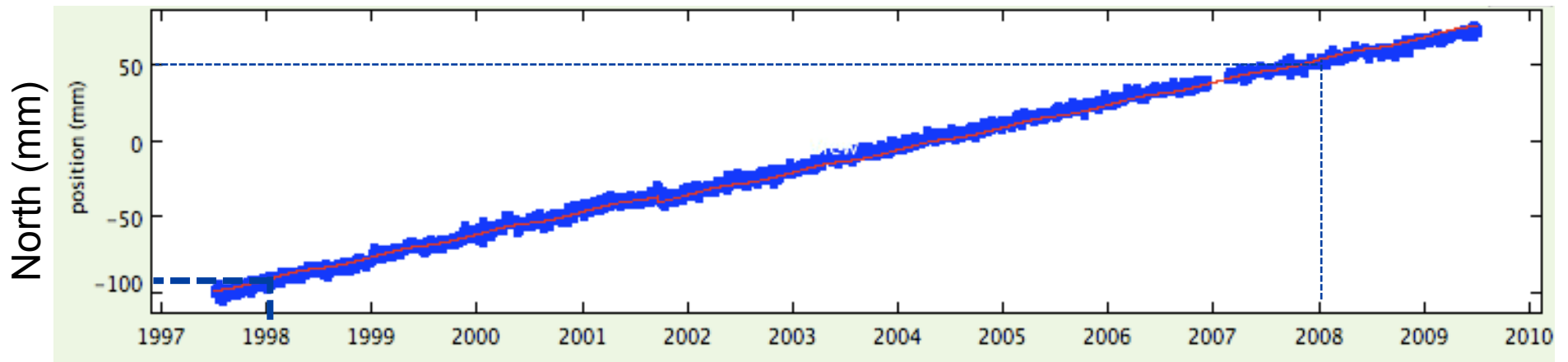
How quickly is HOFN moving in the north - south direction?



Let's look at 1998 and 2008.

Average position on 1/1/2008 = \_\_\_\_\_ mm

Average position on 1/1/1998 = \_\_\_\_\_ mm



Average position on 1/1/2008 = 50 mm

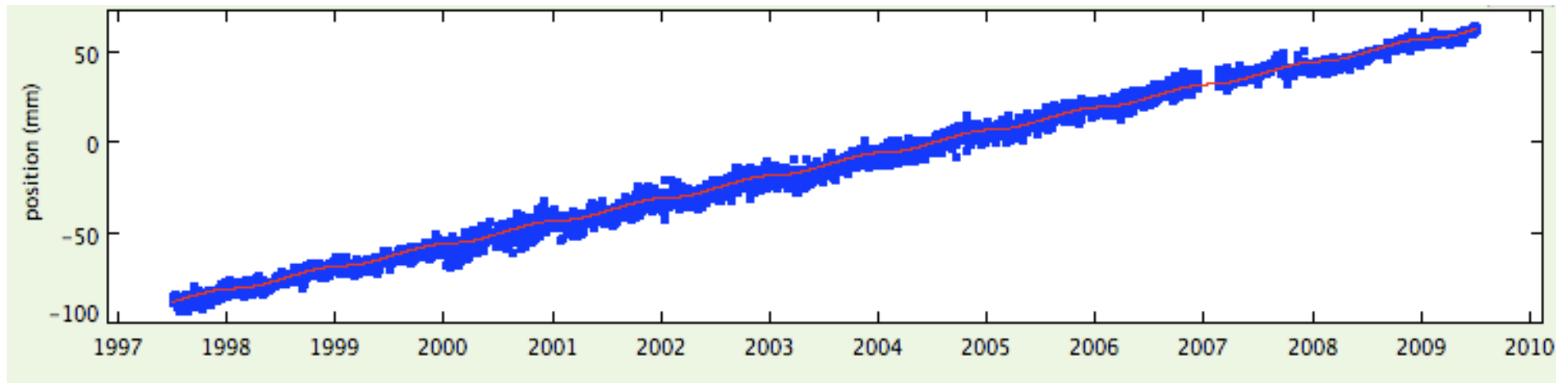
Average position on 1/1/1998 = -98 mm

Change in position =  $50 - (-98) = 148$  mm

Annual speed of HOFN north =  $148 \text{ mm}/10 \text{ years}$   
= 14.8 mm/yr to the north for HOFN



How quickly is HOFN moving in the east - west direction?

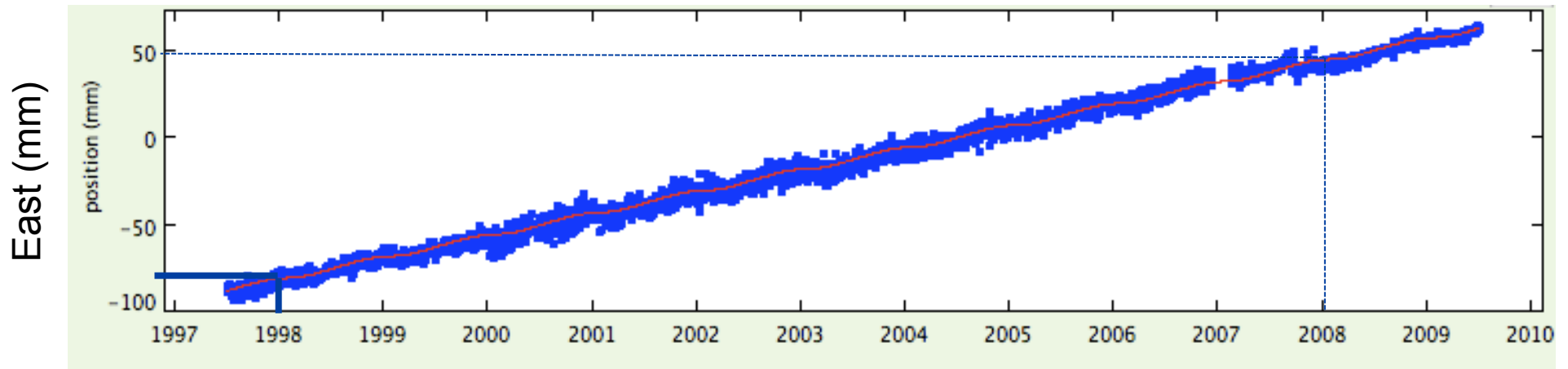


Average position on 1/1/2008 = \_\_\_\_\_ mm

Average position on 1/1/1998 = \_\_\_\_\_ mm

Speed of HOFN east = \_\_\_\_\_ mm/10 years  
= \_\_\_\_\_ /yr to the (east or west)

How quickly is HOFN moving in the east - west direction?



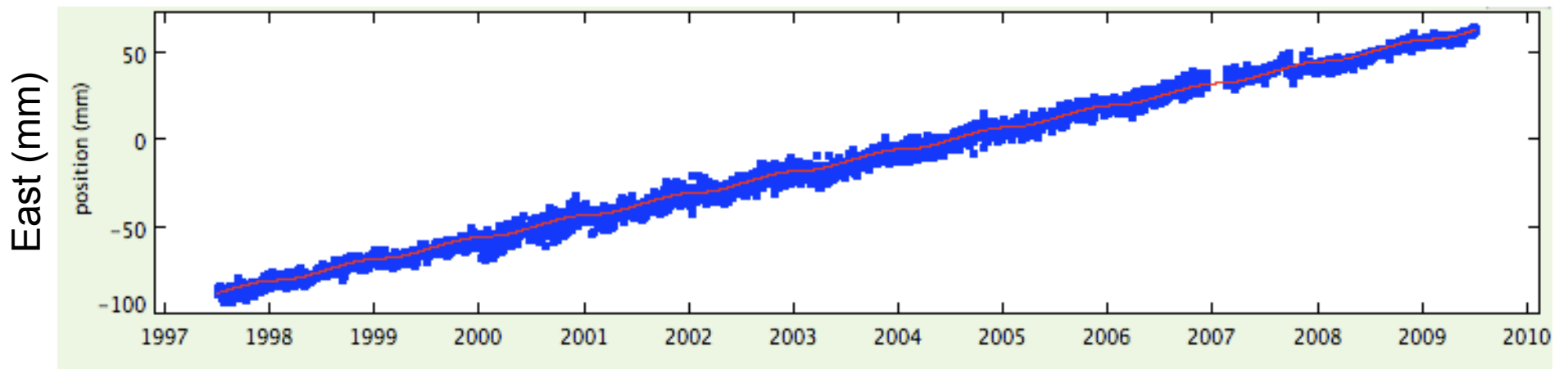
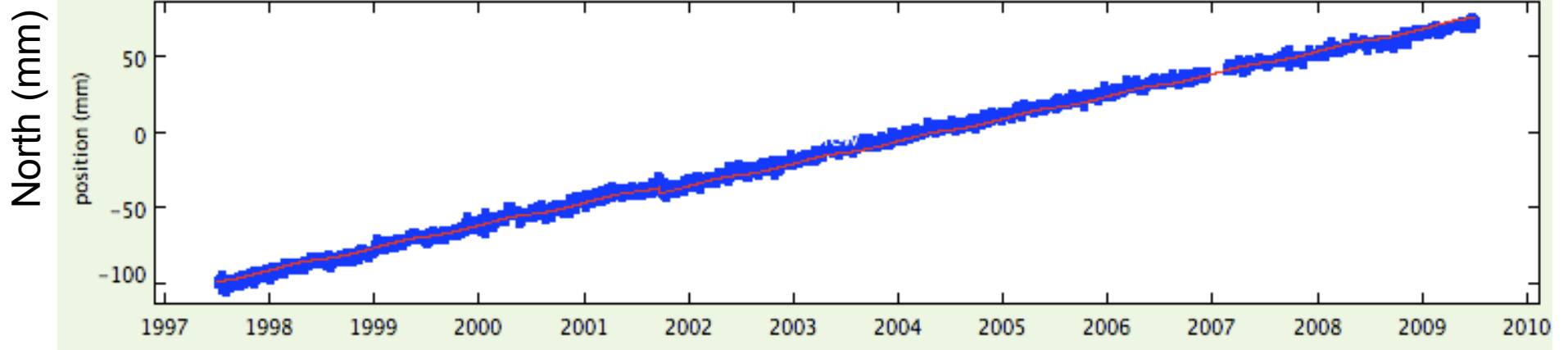
Average position on 1/1/2008 = 50 mm

Average position on 1/1/1998 = -80 mm

Speed of HOFN east = 130 mm/10 years  
= 13 mm/yr to the east for HOFN

What direction is Monument HOFN moving?

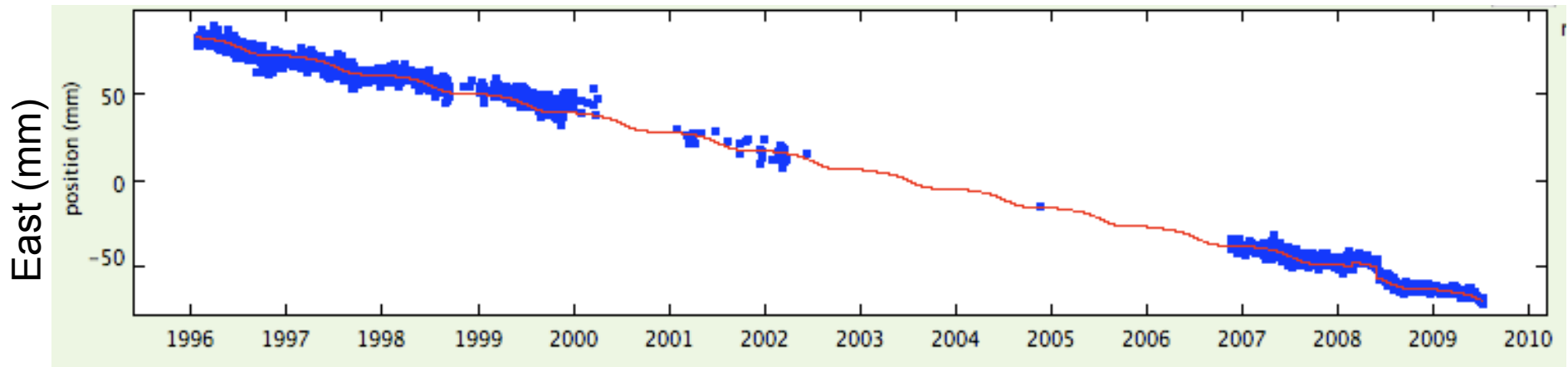
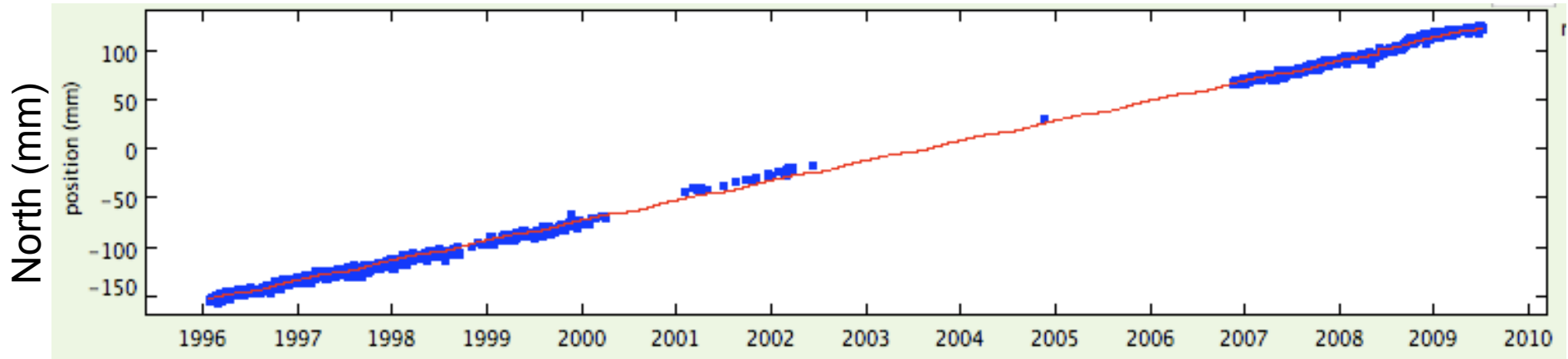
- a) north only
- b) northwest
- c) northeast
- d) southwest



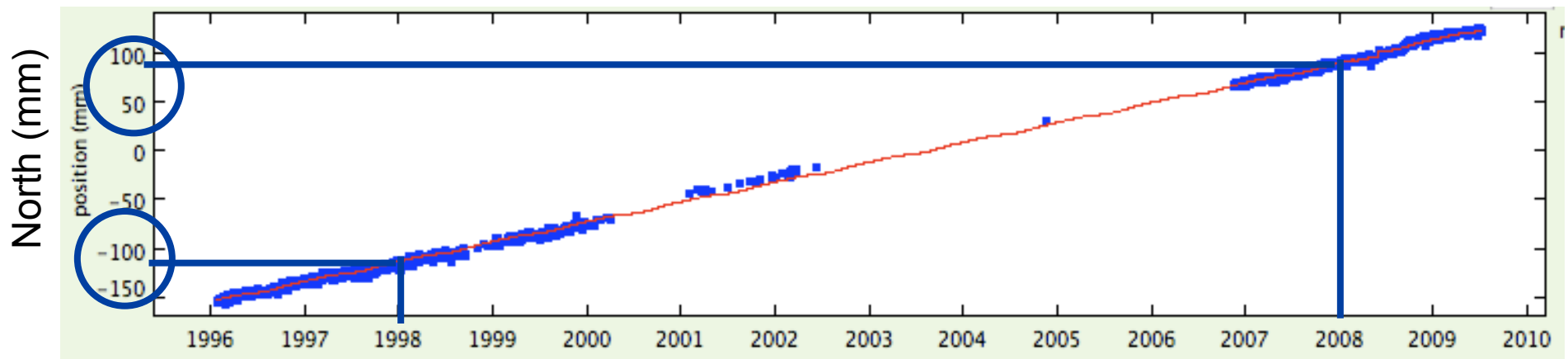


# GPS monument REYK

Think, then discuss with your neighbor: What direction is monument REYK moving? About how fast?



How quickly is REYK moving in the north - south direction?

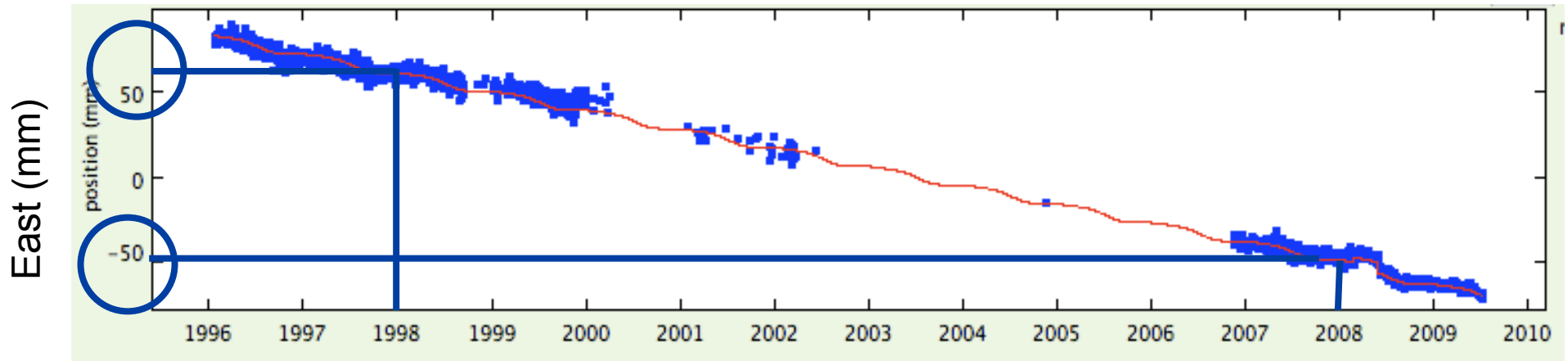


Average position on 1/1/2008 = 90 mm

Average position on 1/1/1998 = -115 mm

Speed of REYK north =  $(90 - -115)$  mm/10 years  
= 205 mm/10 yr  
= 20.5 mm/yr to the north for REYK

How quickly are they moving in the east - west direction?



Average position on 1/1/2008 = -50 mm

Average position on 1/1/1998 = 60 mm

Speed of REYK (east) =  $(-50 - 60)$  mm/10 years

= -110 mm/10 yrs

= 110 mm/10yr to the west

= -11 mm/yr to the west for REYK



# Are REYK and HOFN moving...

...towards each other, away from each other, or in the same direction?



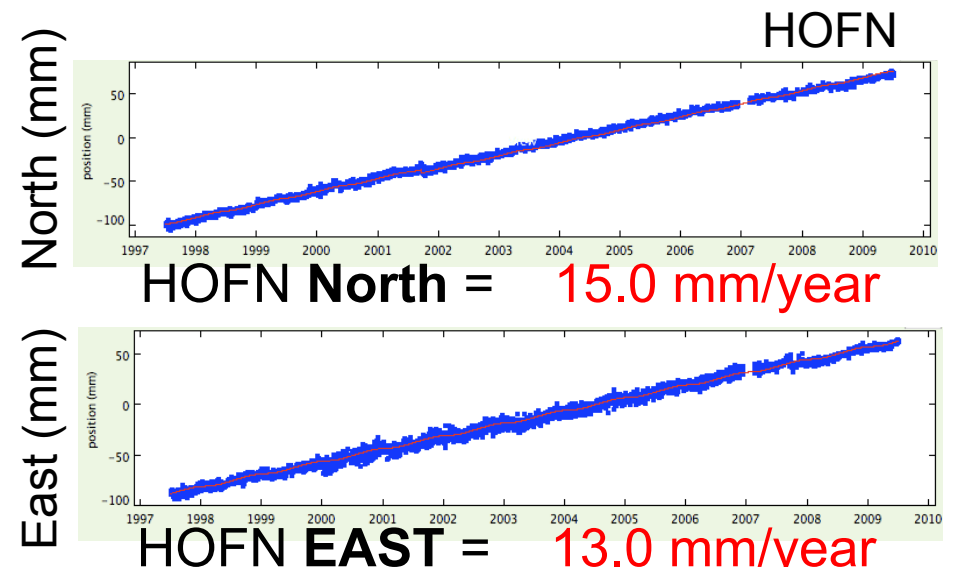
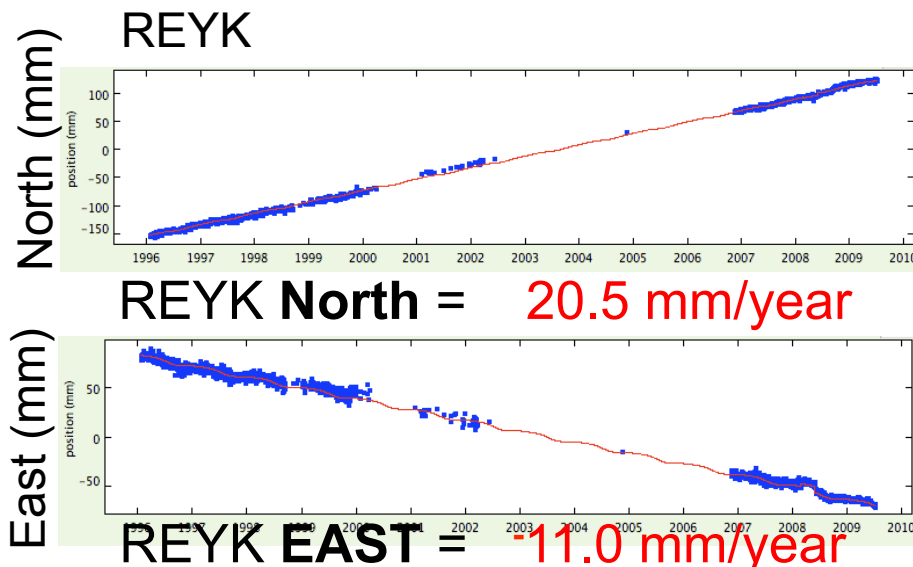
Mimic these motions with your GPS models.

There must be an easier way to show this!



North: 20.5 mm/yr  
East: -11 mm/yr

North: 15 mm/yr  
East: 13 mm/yr

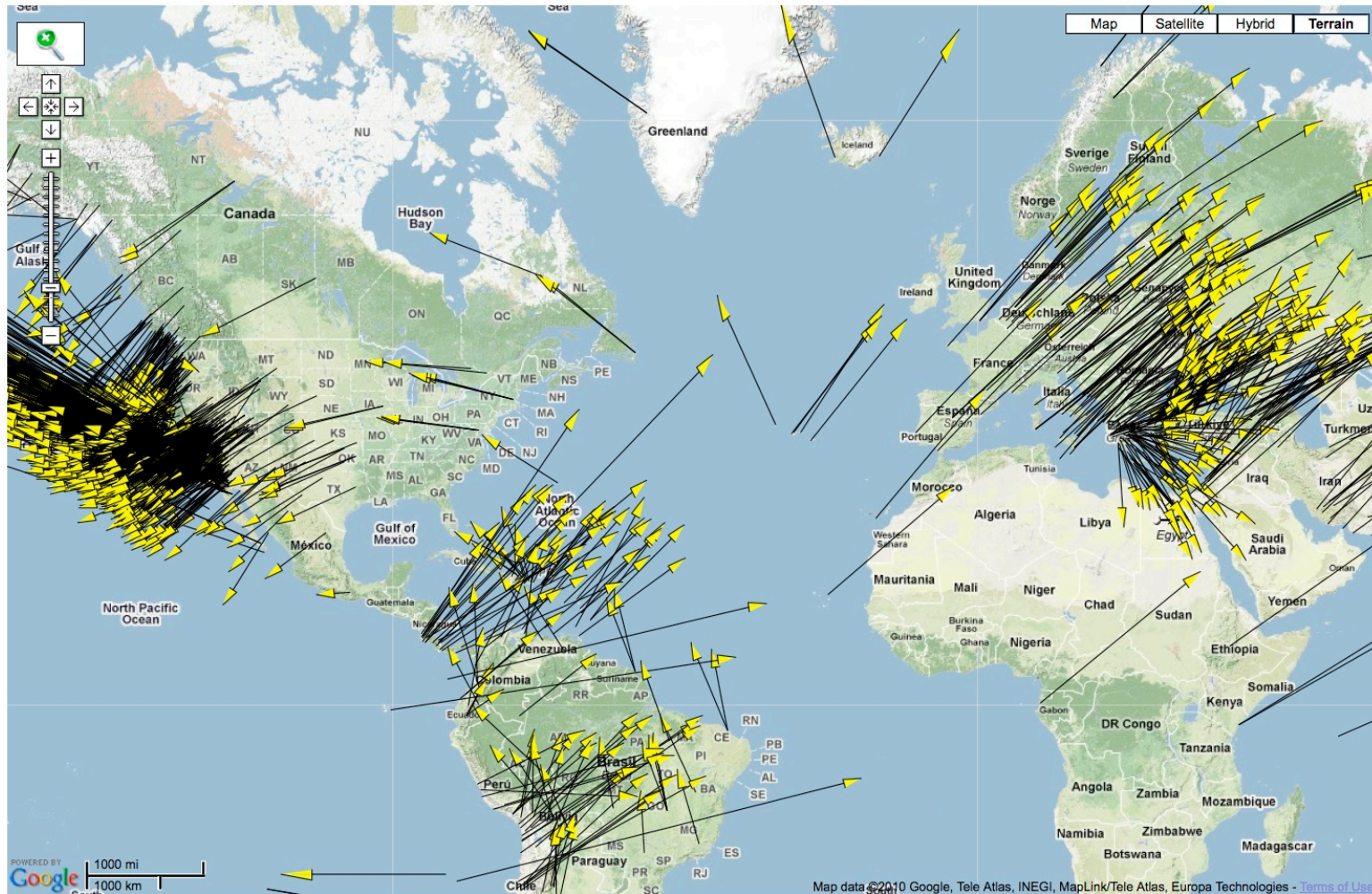




# Mapping plate movement

UNAVCO GPS Velocity Viewer \*

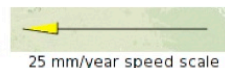
GPS velocity vectors show how the surface of the Earth is moving.



GPS\_vectors\_after\_rotation\_NNR.dat Velocity vectors



Velocity vector  
and error ellipse



25 mm/year speed scale

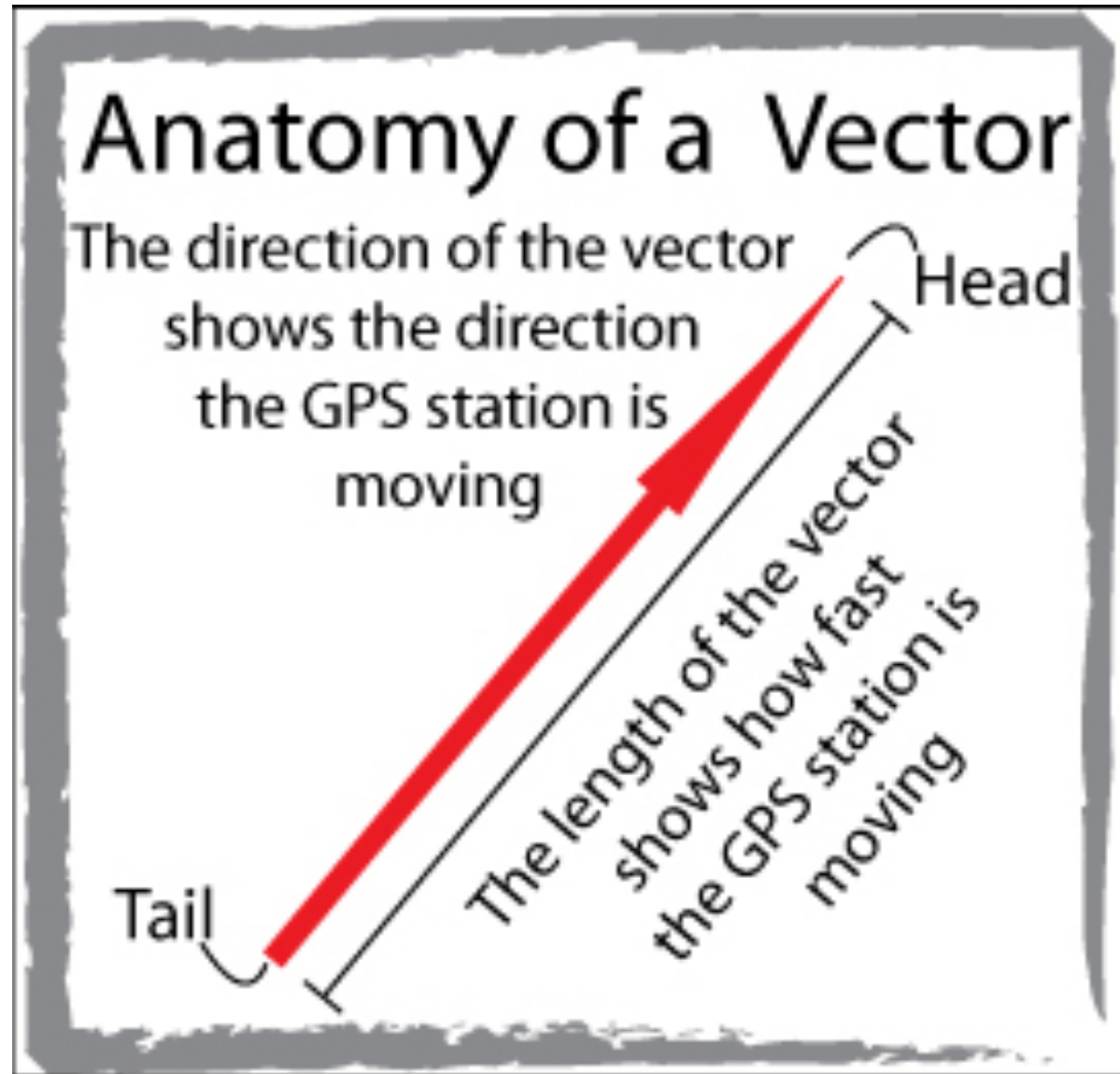


Vertical Speed ( mm/yr )

-20 -10 -5 -2 -1 -0.5 0.5 1 2 3 4 5 10 20  
DOWN UP



A vector shows speed and direction.



# Graph paper as a map

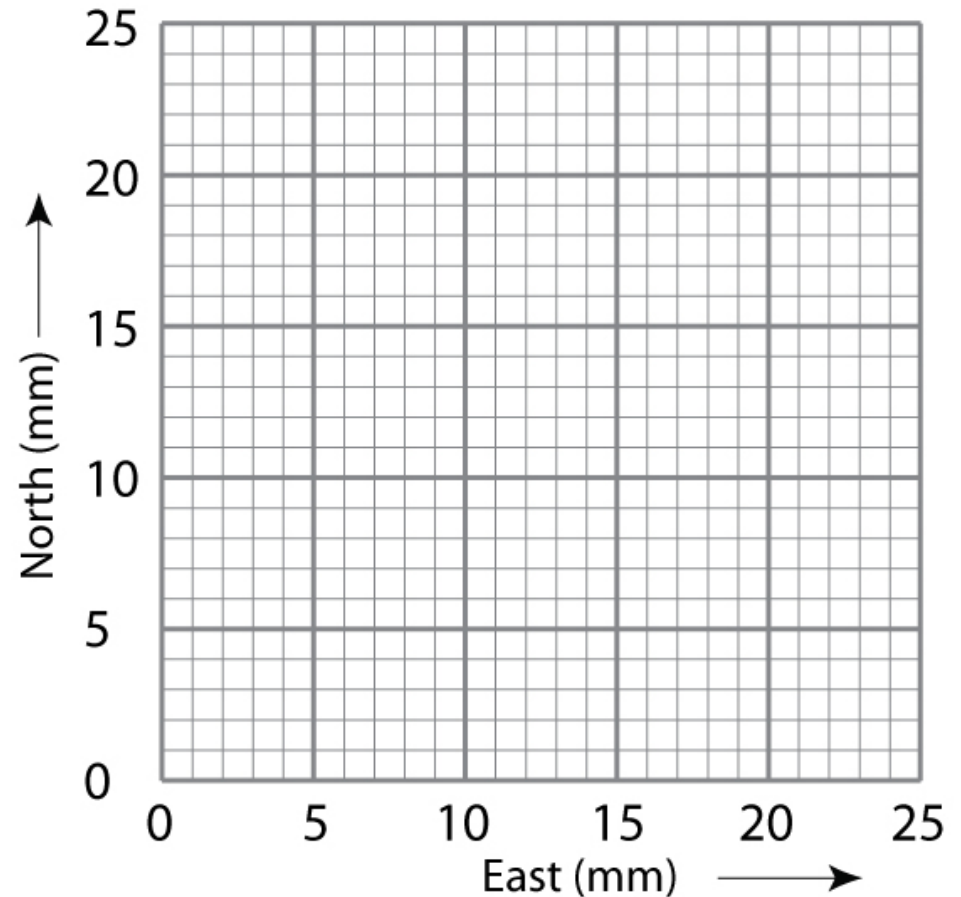
Each axis uses the same scale.

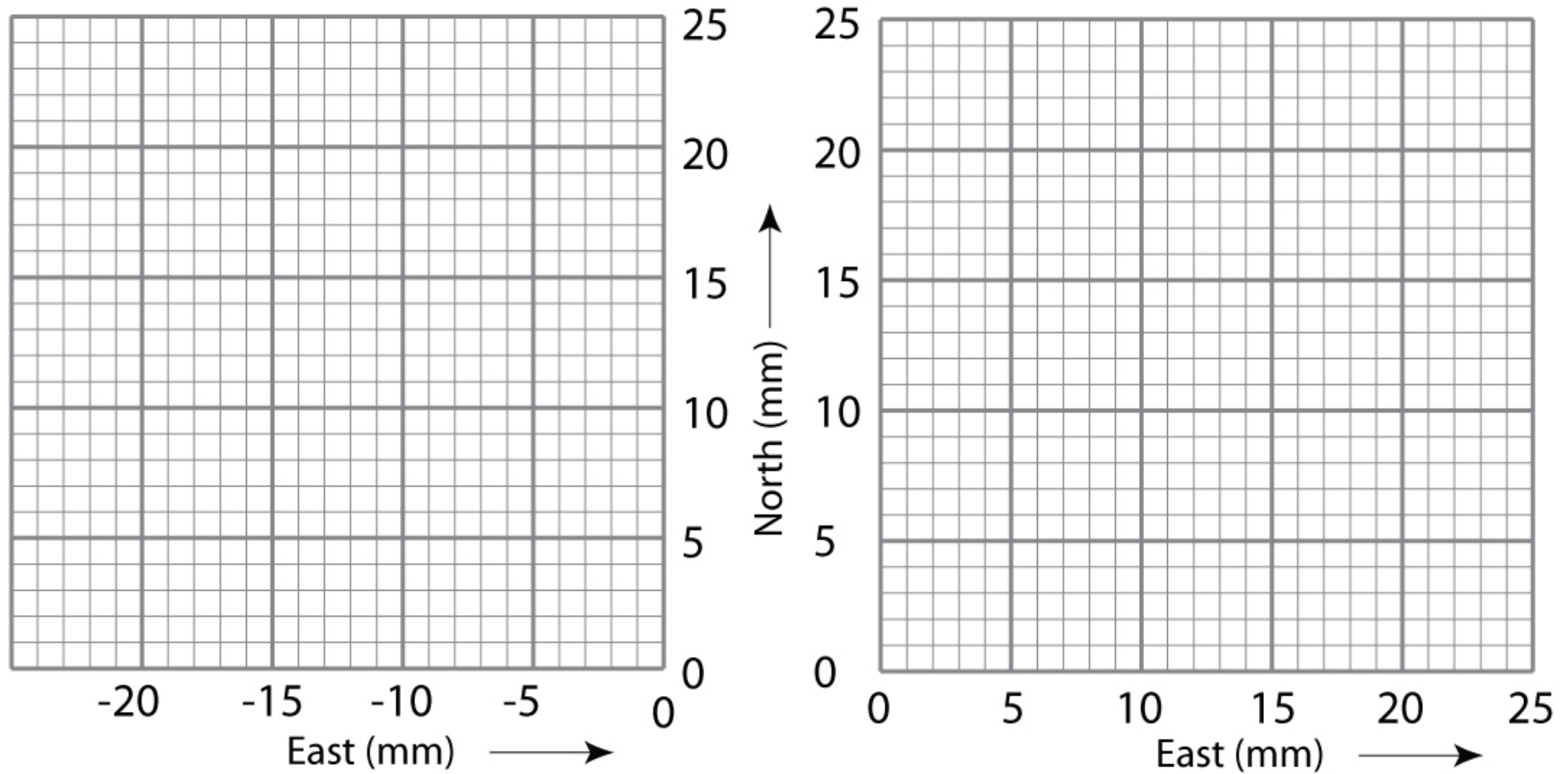
X-axis: east in millimeters

Y-axis: north in millimeters

On your graph paper, each block represents 1 mm.

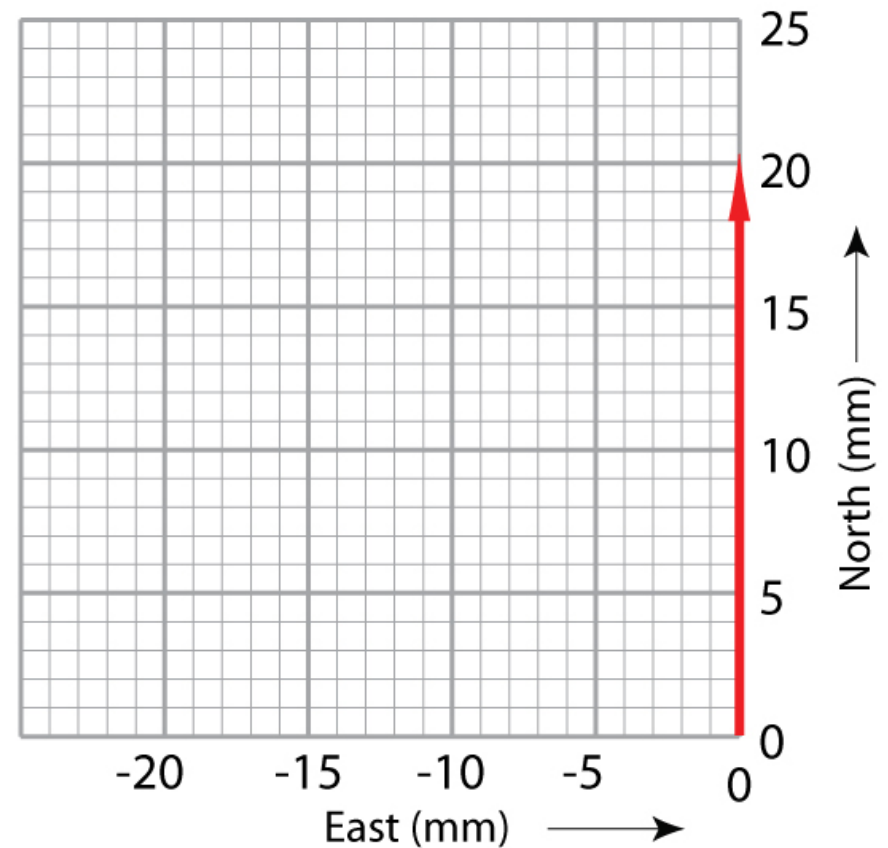
Where is the origin on this graph paper?





# Plotting REYK vectors

- Vector: magnitude and direction
  - Tail is the GPS monument location.
  - Length of arrow is the magnitude.
  - Shows direction on a map.

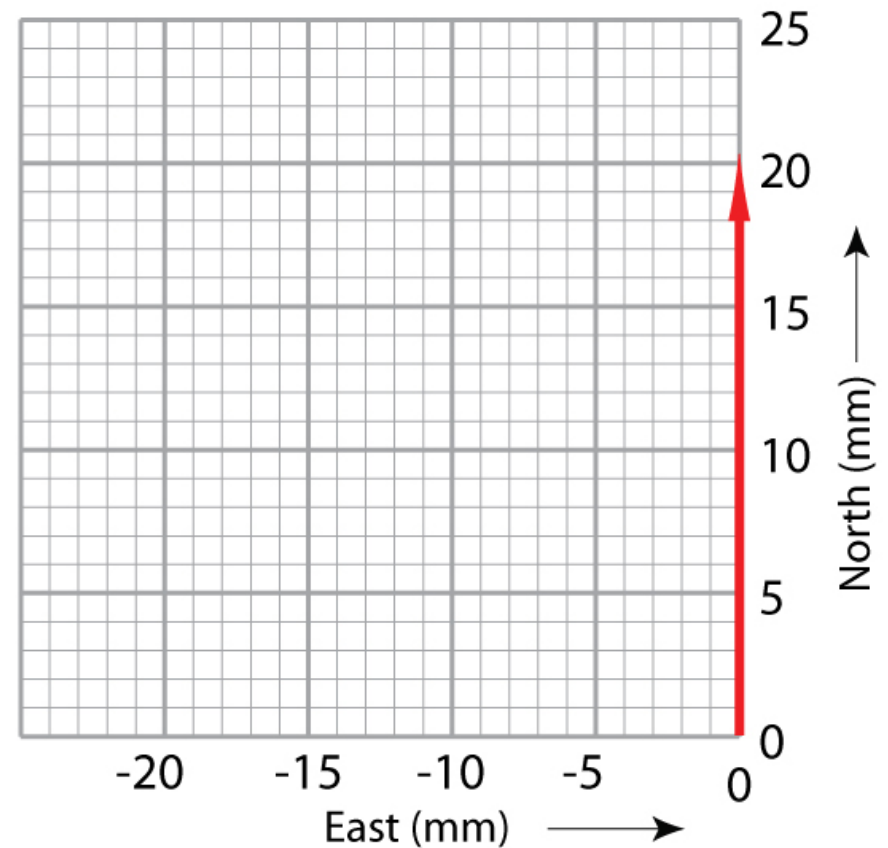




# Plotting REYK vectors

Step 1. Draw the first vector along the north axis with the tail at 0.

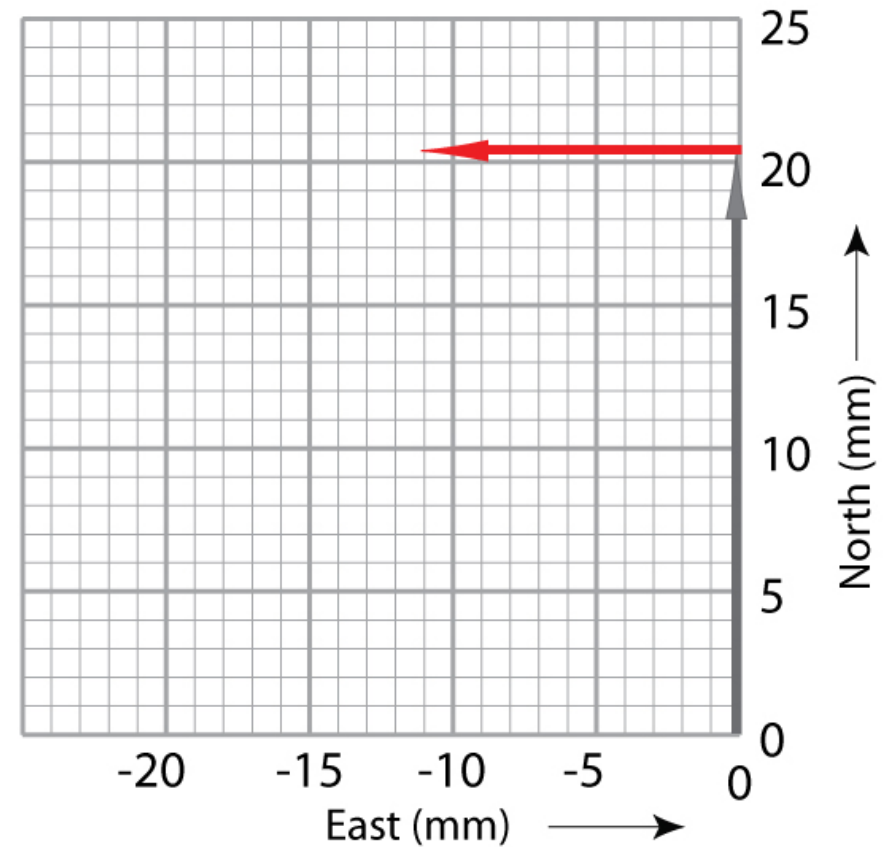
- GPS monument REYK moves 20.5 mm to the north per year
- Draw a vector arrow 20.5 blocks along the north axis.



# Plotting REYK vectors

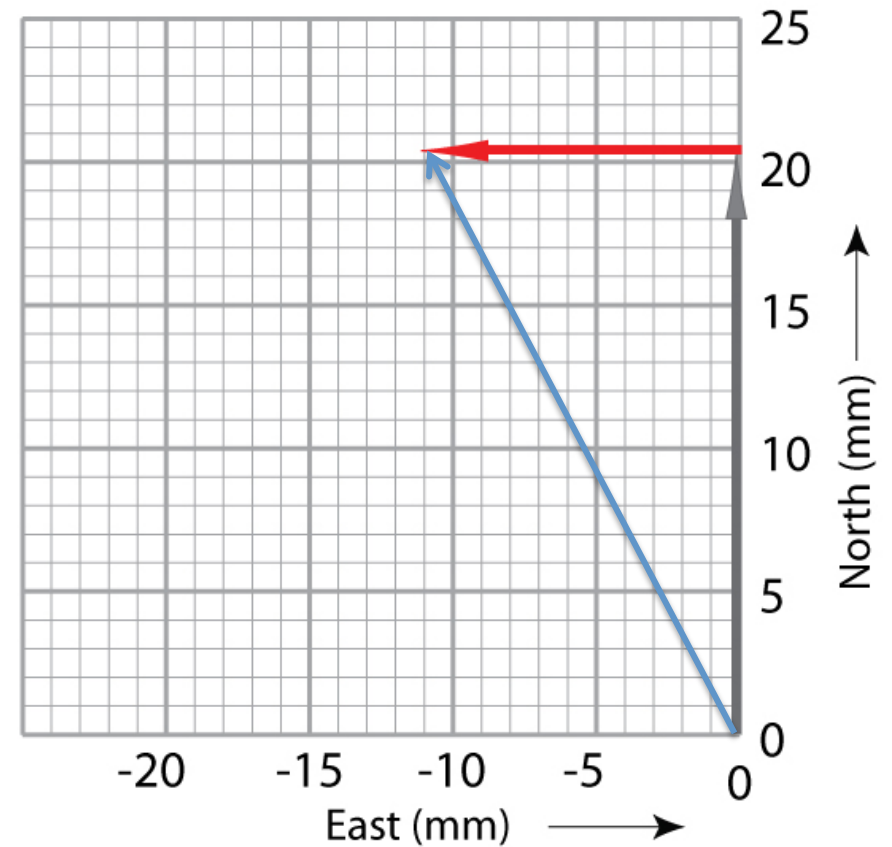
Step 2. Place the tail of the east vector at the head of the north vector.

Draw the vector -11.0 blocks (mm) beginning at the head of the north arrow

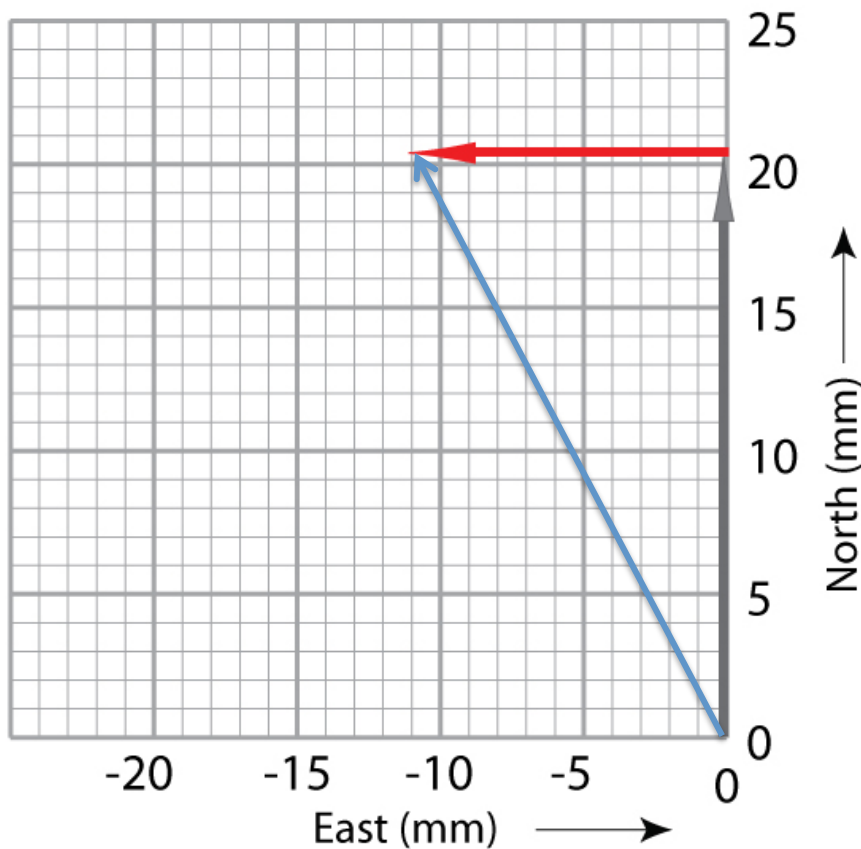


# Adding REYK vectors

Step 3. Draw the total vector from the tail of the north vector to the arrowhead of the east vector. This new vector is the sum of the north and east vectors.







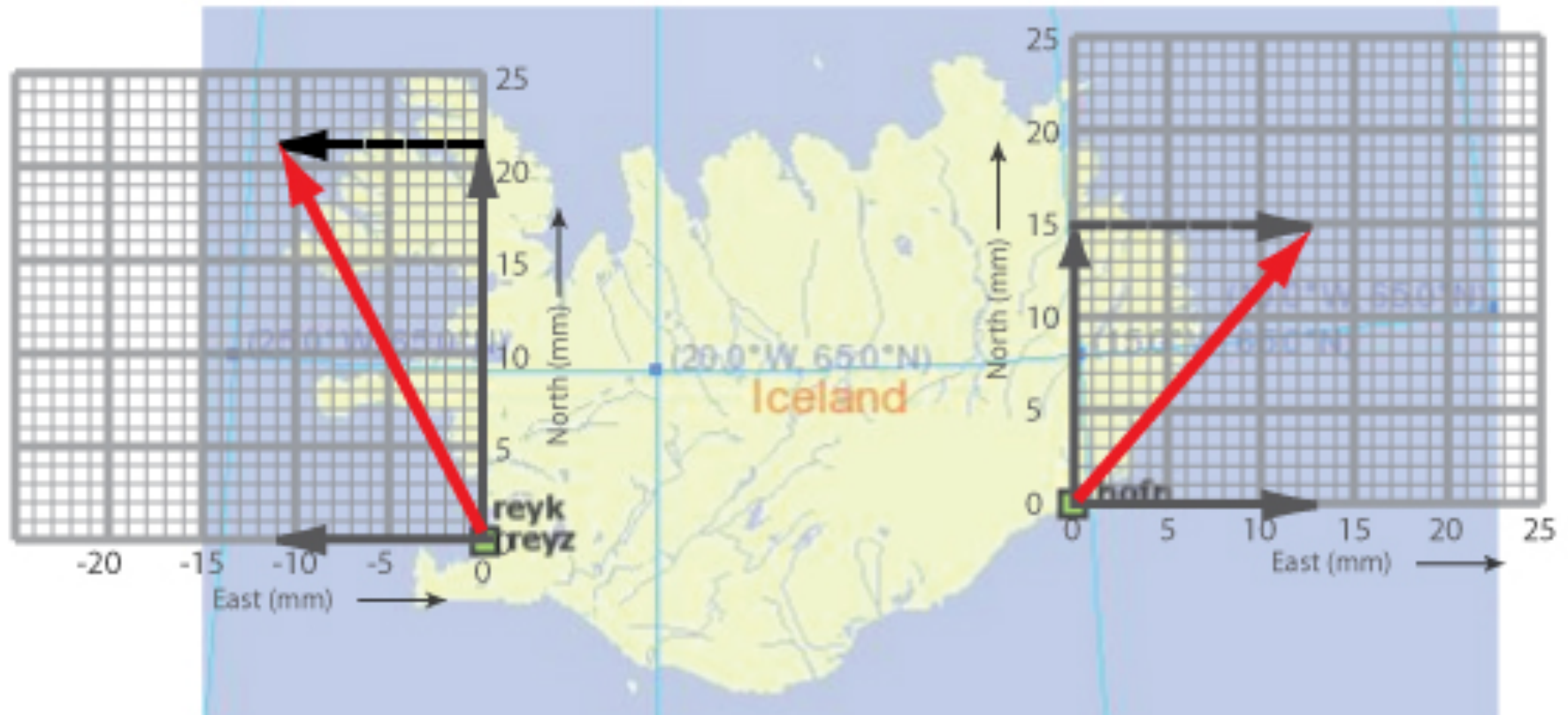
Or, use the Pythagorean theorem to add vectors.

GPS monument moves  
at:  $\sqrt{x^2 + y^2} =$   
\_\_\_\_\_ mm/yr to the \_\_\_\_\_

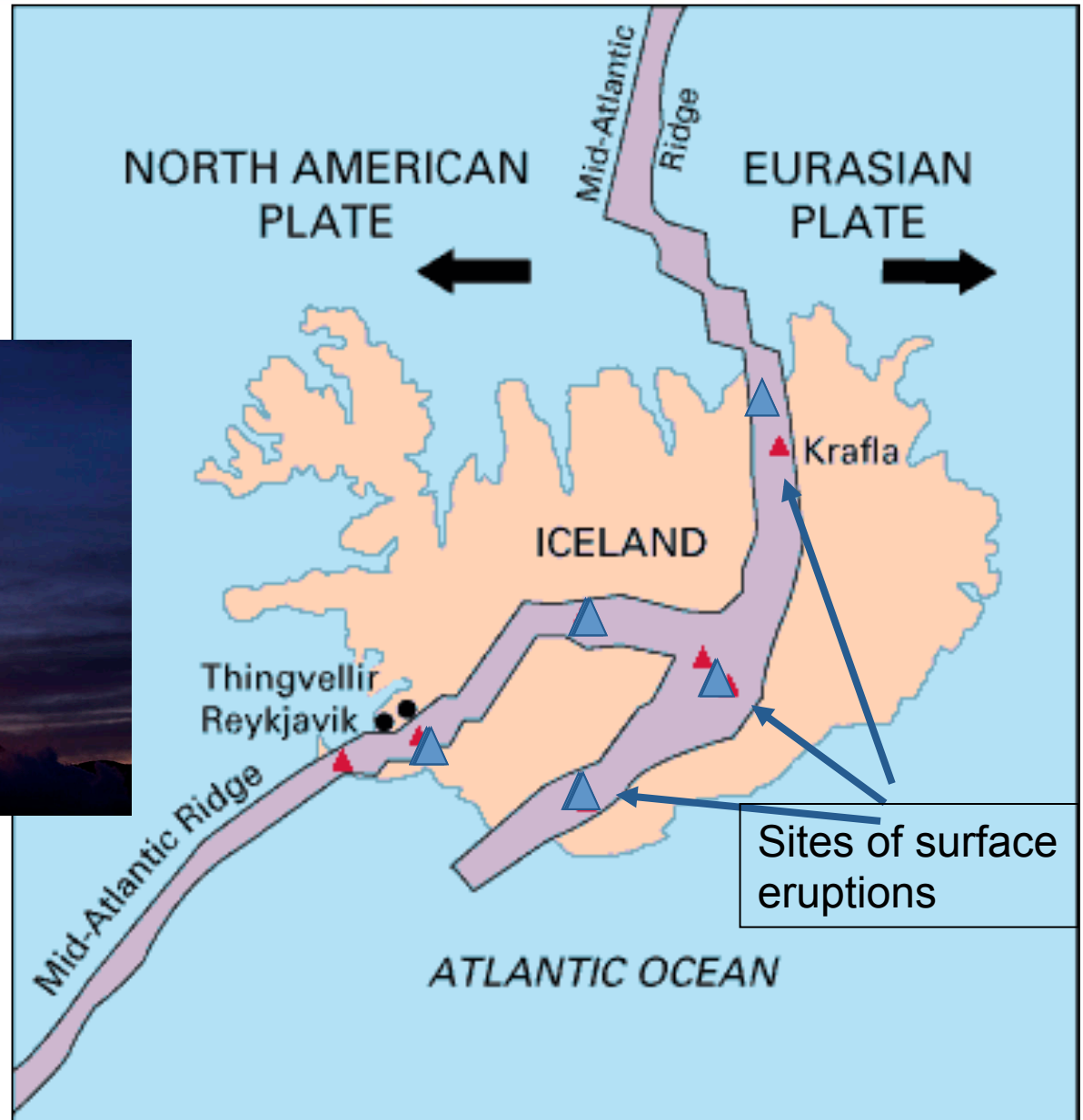


1. Graph the vectors for HOFN and REYK.
2. Answer questions in "Thinking through the data and maps."

# What is happening to Iceland?





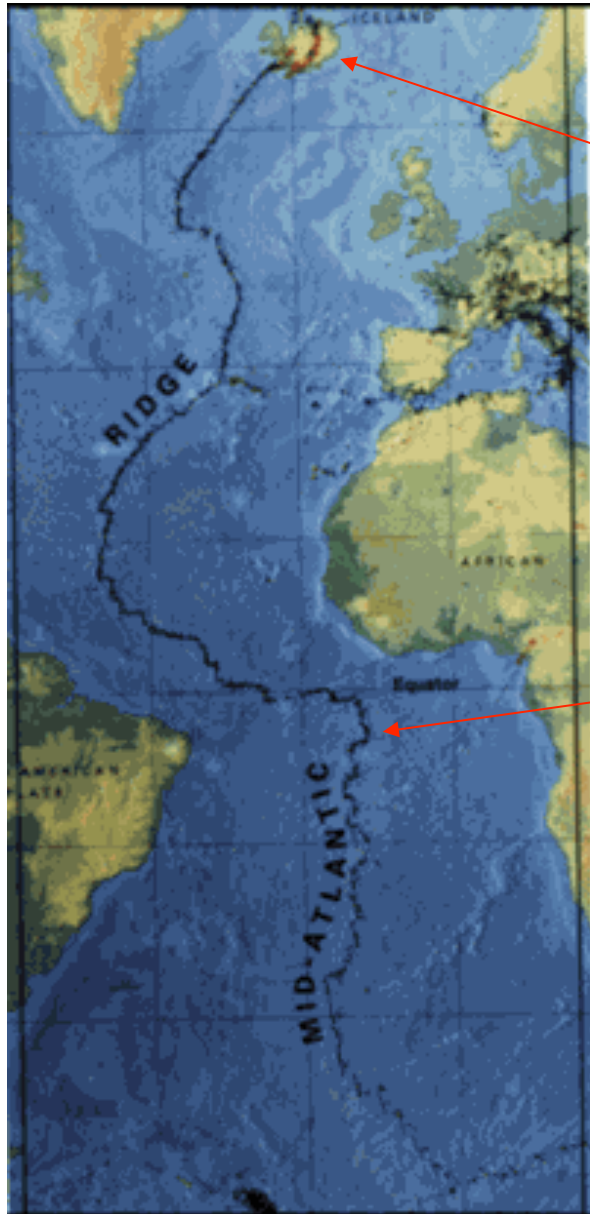








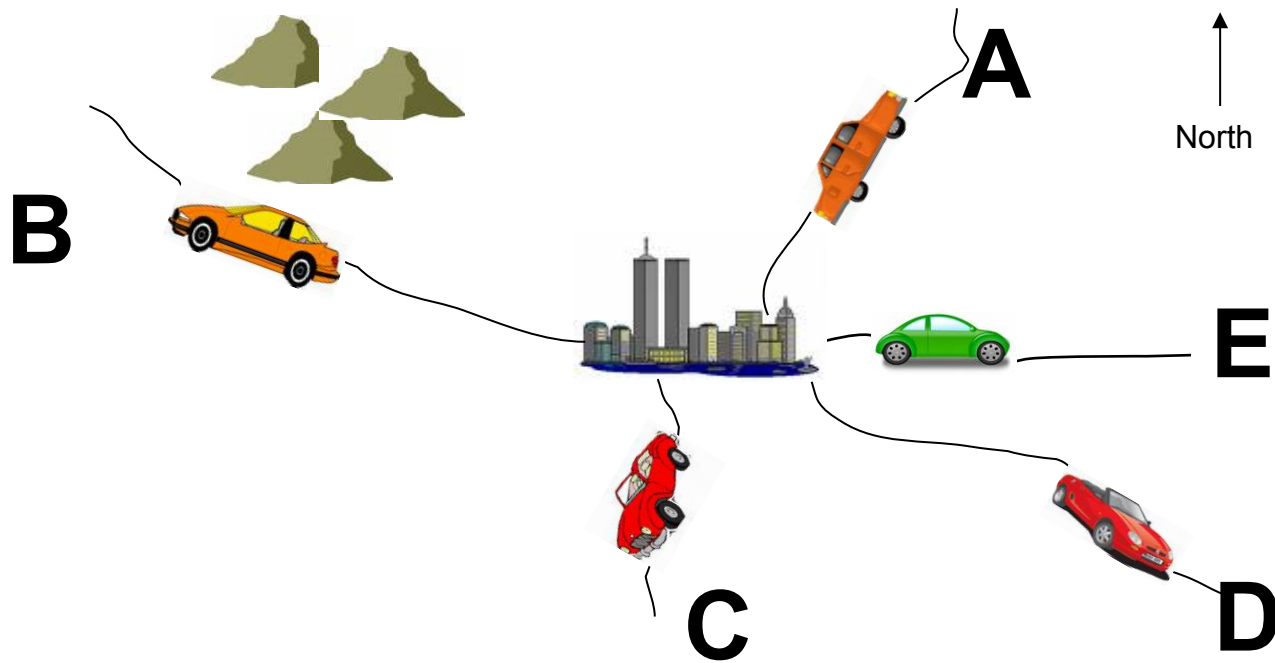
# Mid-Atlantic Ridge



Iceland

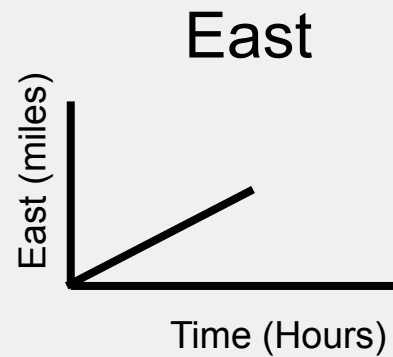
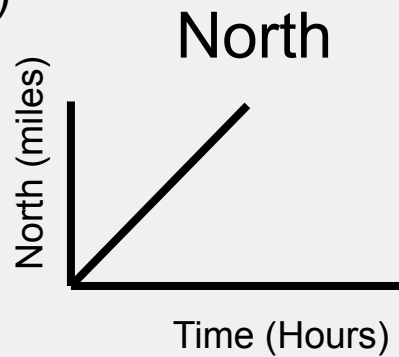
Mid-Atlantic  
Ridge





## Match cars and graphs

i)

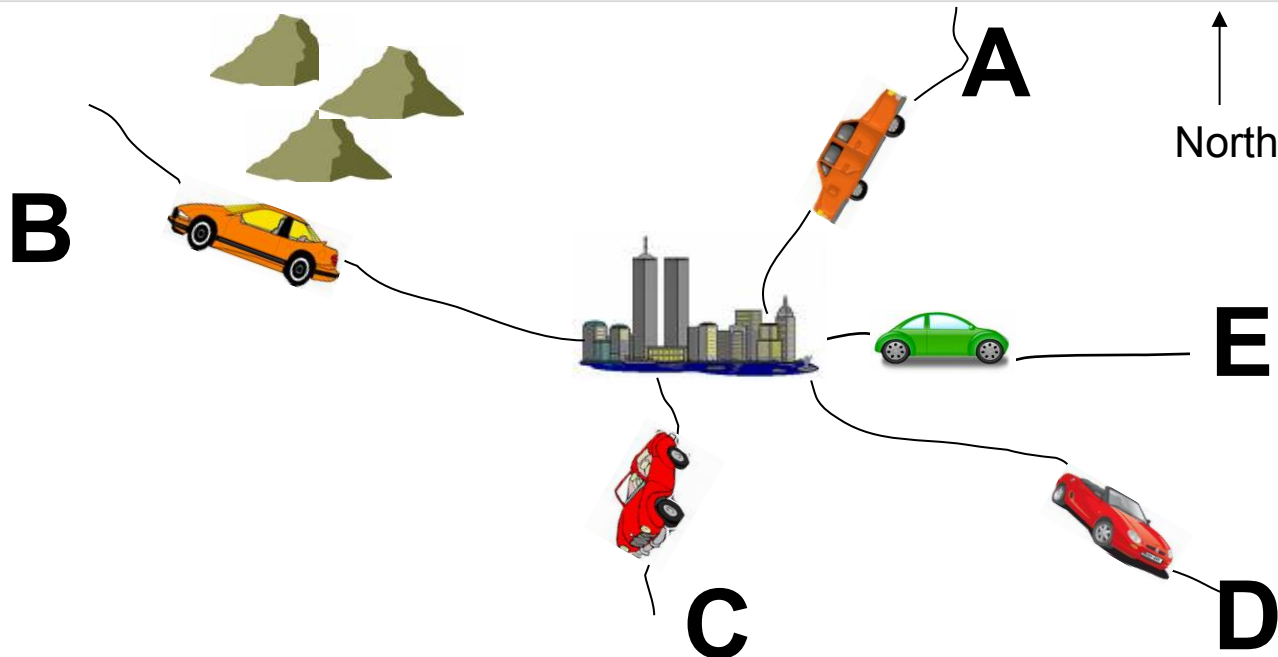


What  
direction?

\_\_\_\_\_

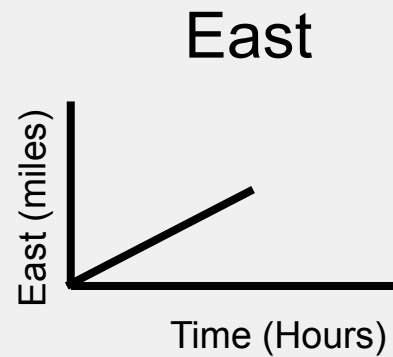
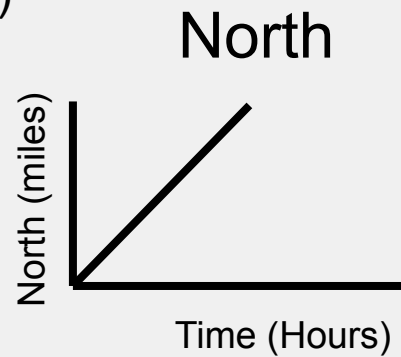
Which car?

\_\_\_\_\_



# Match cars and graphs

i)

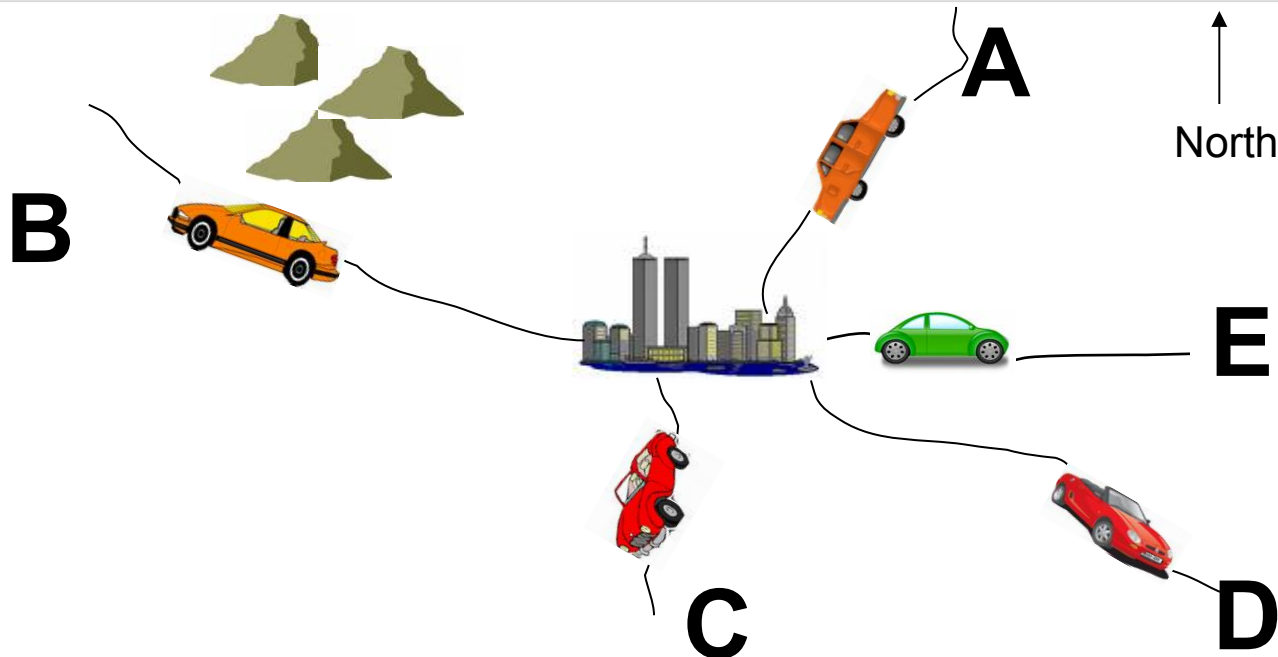


What  
direction?

North-  
Northeast

Which car?

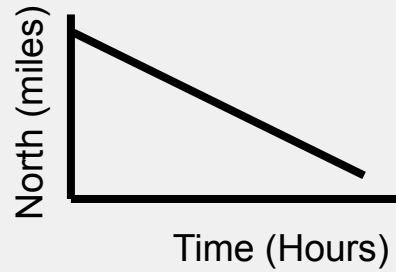
Car A



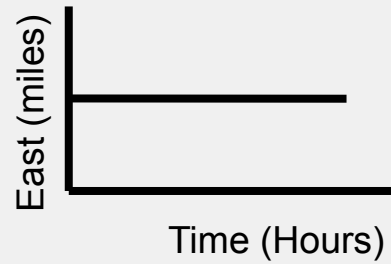
# Match cars and graphs

ii)

North

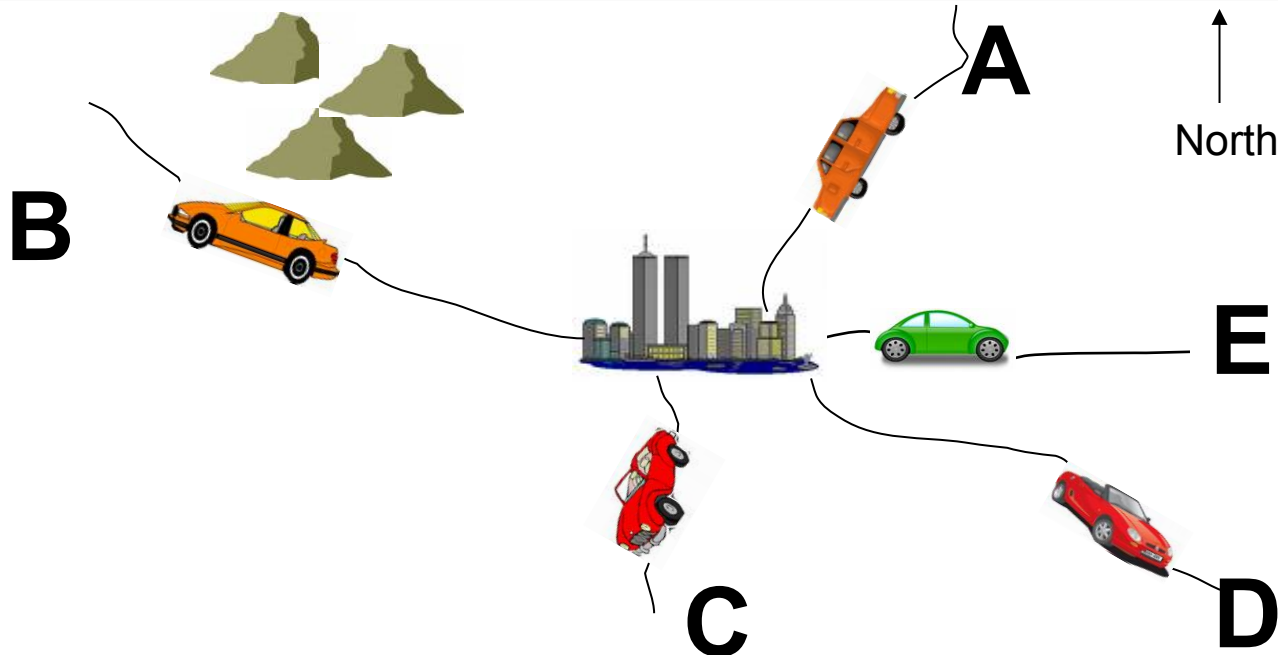


East



What  
direction?

Which car?

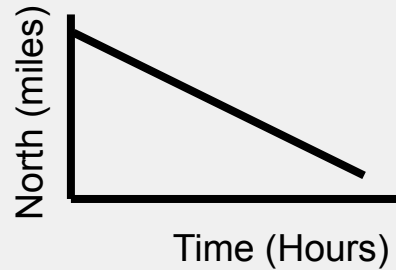




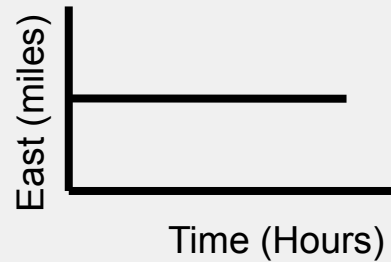
## Match cars and graphs

ii)

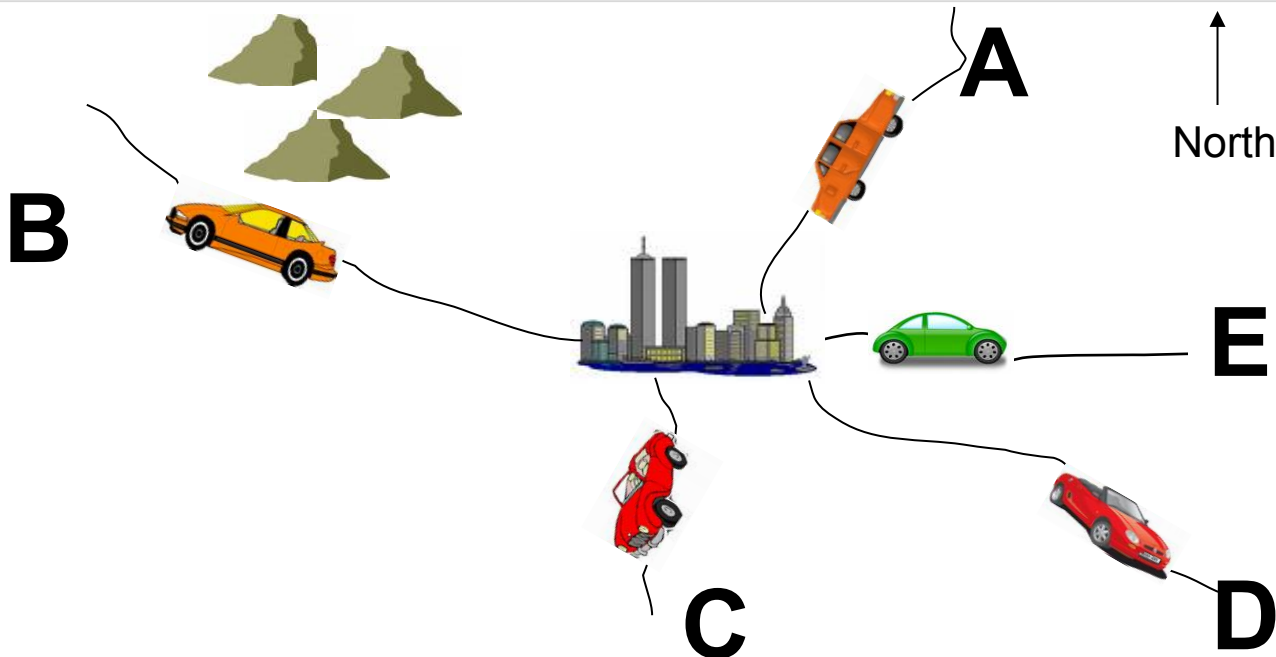
North



East

What  
direction?South

Which car?

Car C

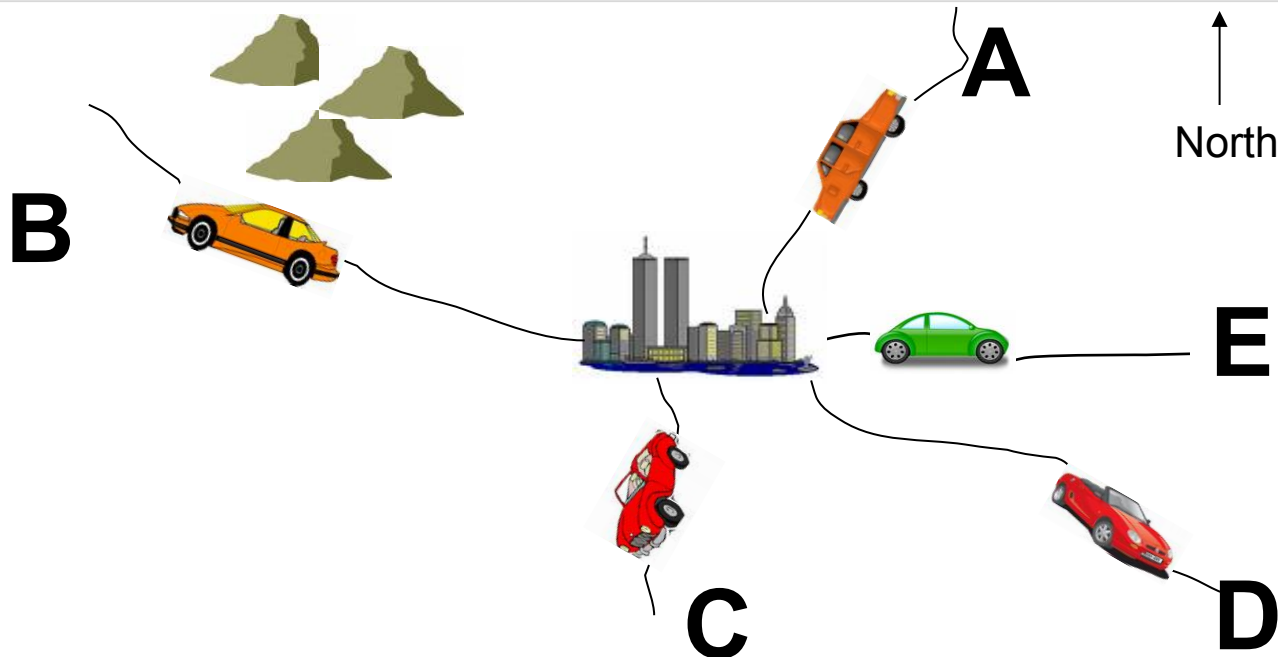
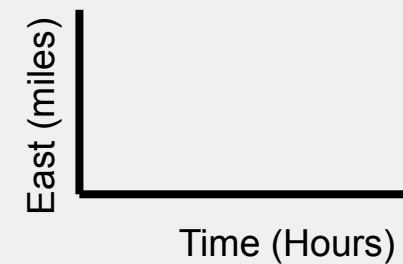
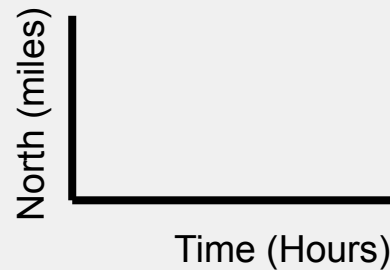
# What direction is car D moving?

v) What direction is Car D moving?

Draw the north and east graphs

North

East



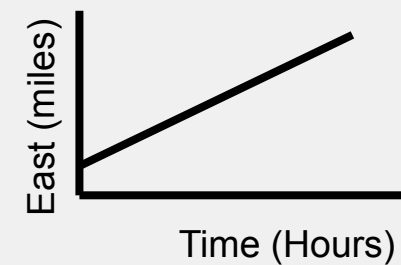
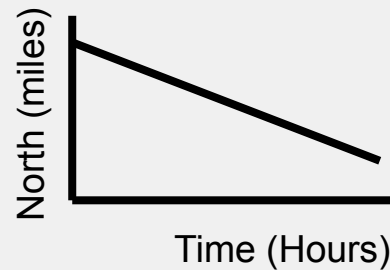
# What direction is car D moving?

v) What direction is Car D moving?

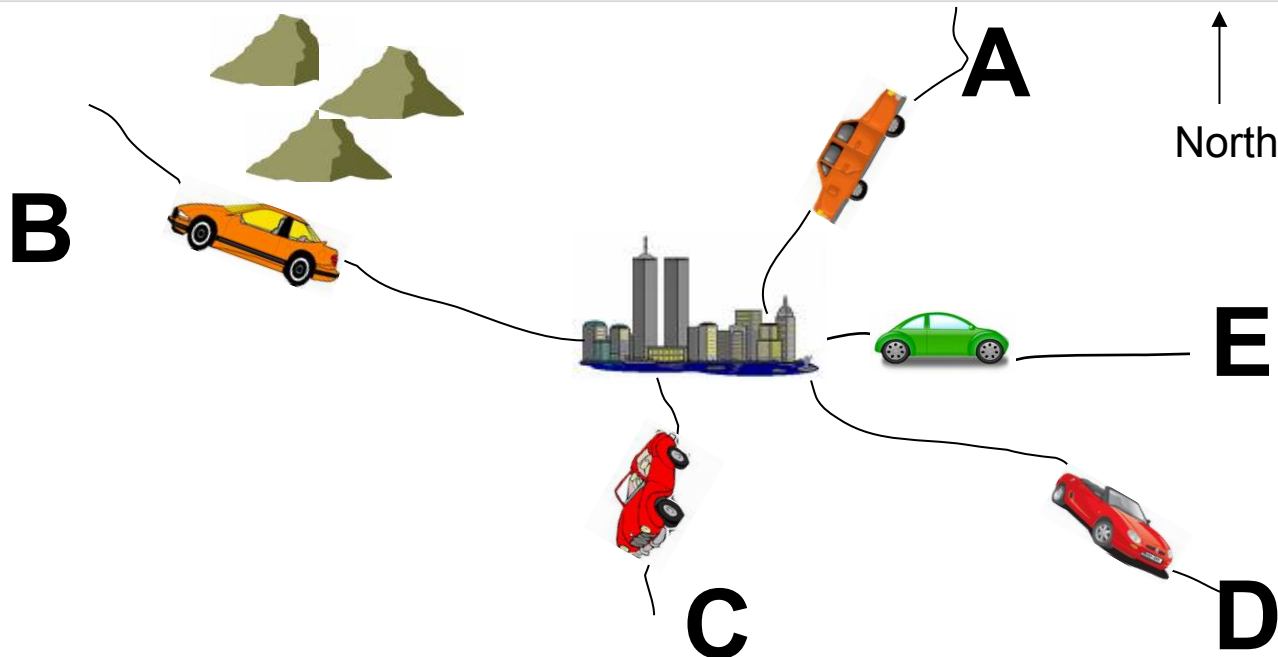
Draw the north and east graphs

North

East



Southeast



- Data for Educators
  - [http://www.unavco.org/edu\\_outreach/data/data.html](http://www.unavco.org/edu_outreach/data/data.html)
- UNAVCO Velocity Viewer
  - <http://facility.unavco.org/data/maps/GPSVelocityViewer/GPSVelocityViewer.html>



You should now be able to:

- Describe how GPS works;
- Interpret graphs in a GPS time series plot;
- Determine velocity vectors from GPS time series plots;
- Explain relative plate motions in Iceland; and
- Explore global GPS data.

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