Earthquake Location

regional triangulation with real data

Anne M Ortiz
Tammy K Baldwin

Los Alamos Research Park
Los Alamos, NM 87544

http://www.scieds.com/spinet
spinet@scieds.com

Why Triangulation?

There are many methods used for earthquake location. Triangulation is a simple method, but fundamental in identifying the necessary steps in any location procedure: identifying arrivals and estimating the distance to the earthquake source.

What skills will students build?

- Reading graphical information
- Recording scientific data
- Mathematical computation (Subtraction/Multiplication/Estimation)
- Plotting graphical data (including using compass)
- Geographic Map reading (Latitude/Longitude Interpolation)

Materials List

- Master Map with topography - use this map on an overhead projector to lead the class in an example/solution
- Master Map with Location Key
- Student Worksheet (pg 6) - provide a copy to each student
- Station Seismograms (GLA, PCAZ, TUC, WUAZ) - provide copies of **at least three unique seismograms** to each student (group of students)
- Compass - for each student (group of students)

Seismic Location Background

What does *regional triangulation* mean? This is best described by breaking the two words apart. Regional identifies the proximity of the earthquake to the station, specifically within 100 km to 600 km for this exercise. This allows us to use simplifications to determine the distance to an event from wave arrival times, as discussed below. Triangulation is a method of location which uses a minimum of three stations to produce distance circle arcs which intersect at the approximate epicenter of an event.

Why do we use (S-P) x 8 ? In earthquake location the time it takes for a seismic wave to arrive at a given station can be broken into two parts; the time it takes to travel horizontally and the time it takes to travel vertically. By only using earthquakes in close proximity to the station (regional 100-600km) the waves do not penetrate deep into Earth and we can ignore the vertical segment of the travel time and focus on the horizontal segment.

About this Event and the Geologic Setting

This earthquake occurred March 2, 2005 at 11:12:58 GMT (4:12 AM local time) in Northern Arizona approximately 40 km (25 miles) SSW of Winslow, Arizona. It was a shallow event, only 5 km deep, with a magnitude of 5.1 Mw. This event is part of a series of 10 events that began 1/28/2005, of which this is the largest event.

Arizona is located in the Basin and Range Province, an area of tectonic extension characterized by mountains and valleys. This region traverses many western United States including AZ, NV, NM, and UT.

Seismic Stations Featured in this Activity

GLA - Glamis is three component instrument operated as part of the CalTech Regional Seismic Network

PCAZ - Phoenix Country Day School Arizona operates a vertical component AS-1 seismometer in a 5th grade classroom.

TUC - Tucson Arizona is a three component instrument operated by the University of Arizona.

WUAZ - Wupatki Arizona is a three component instrument located on Wupatki National Monument, near Sunset Crater Volcano.

In seismograms from regional events we observe two prominent arrivals, P and S. The separation in time between these arrivals is the basis for the equation (S - P) x 8.

$$(S - P) = D / Vp - D / Vs \qquad (1)$$

where S and P are arrival times, D is the horizontal distance in kilometers to the event and Vp and Vs are seismic velocities for the P-wave and S-wave respectively.

In Earth we often use an approximation that relates Vp and Vs.

$$Vs = Vp / \sqrt{3} \qquad (2)$$

Substituting Equation 2 into Equation 1 and rearranging yields,

$$D = \frac{(S-P) \times Vp}{(\sqrt{3} - 1)}$$

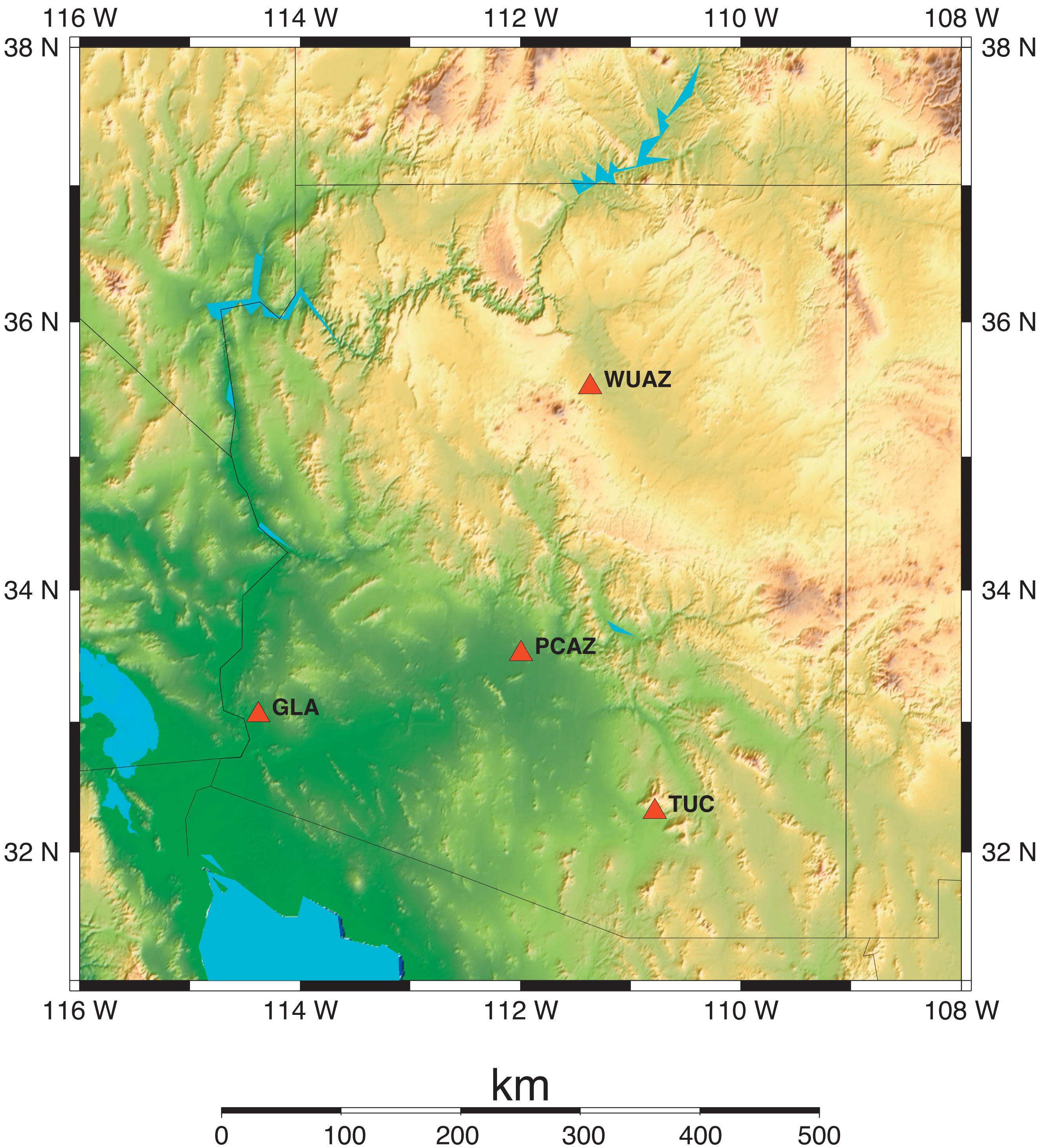
Since our seismic waves do not travel deep they remain in the crust where P-waves travel at a velocity of approximately 5.7-6.0 km/s. Substituting this value for Vp and dividing the ($\sqrt{3}$ -1) reveals

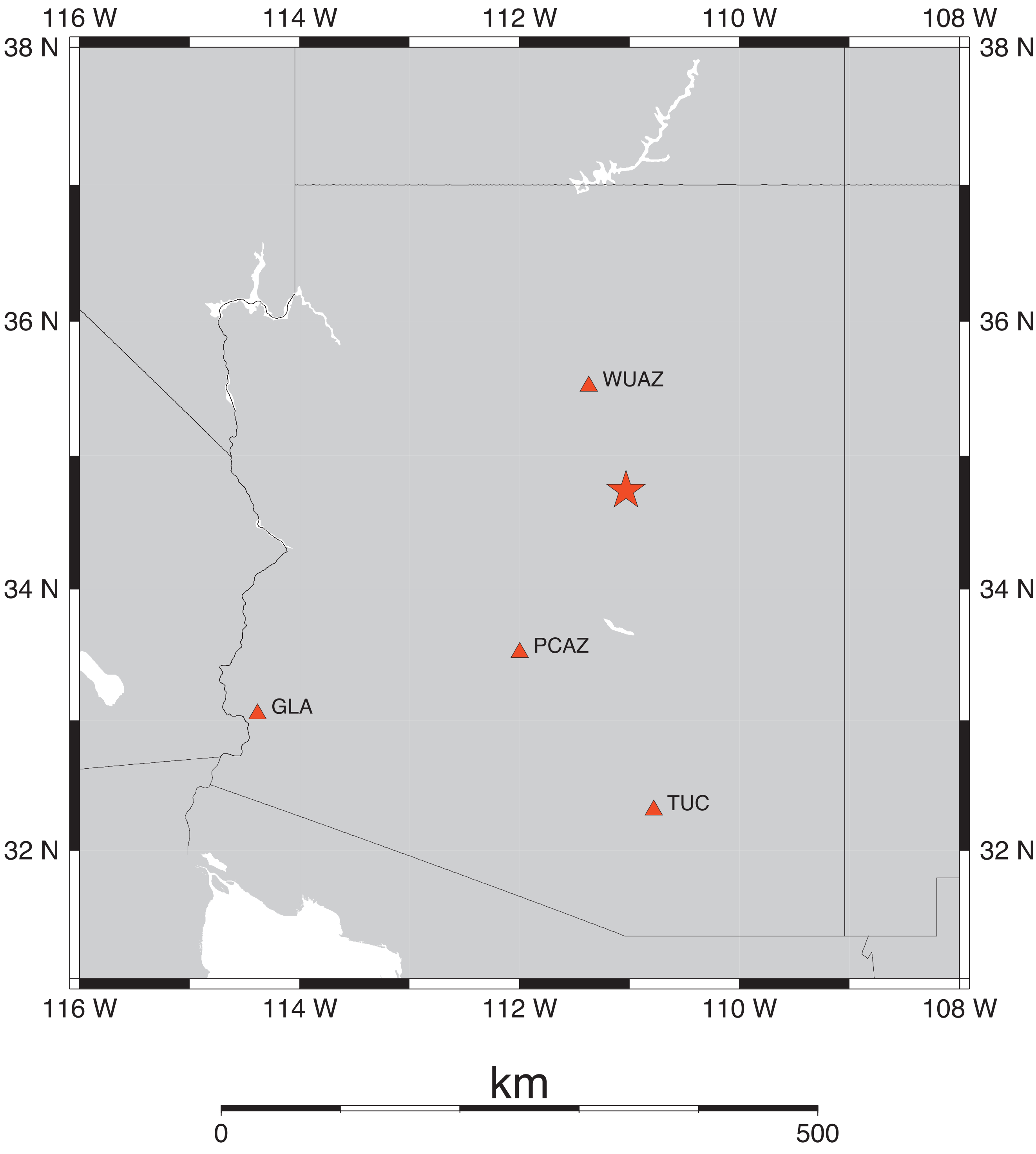
$$D\ (km) = (S - P) \times 8\ km/s$$

Extensions / Assessment

- Test your skills online with the Virtual Earthquake! Complete a triangulation and magnitude determination exercise to receive a certificate of achievement.
  http://www.sciencecourseware.com/VirtualEarthqauke/

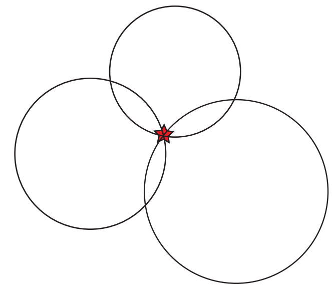
- Use one of the other SpiNet triangulation event classroom sets to evaluate the skills learned in this activity.
  http://www.scieds.com/spinet/activities/triangulation.html


116 W
114 W
112 W
110 W
108 W
38 N
36 N
34 N
32 N
WUAZ
PCAZ
GLA
TUC
km
0
100
200
300
400
500


116 W
114 W
112 W
110 W
108 W
38 N
36 N
34 N
32 N
WUAZ
PCAZ
GLA
TUC
km
0
500

Earthquake Location 101

There are several methods used to locate earthquakes, triangulation is one that uses distance information from 3 or more stations to uniquely locate an earthquake. On a map, circles are drawn around each seismic station. The radius of each circle is scaled to the estimated distance between a station and the earthquake. A minimum of three (3) circles will share one unique intersection that approximates the *epicenter*.



epicenter - is the point on Earth's surface directly above the point where seismic rupture begins

Locate the Quake

Repeat Steps 1-3 for each station/seismogram

Step 1 - Pick the Waves

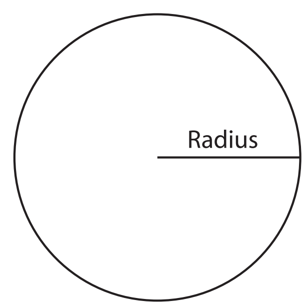
- Record the Station Code (found in the upper right corner of the seismogram) in the **Station Code** column of Table 1.
- Determine the time of the P-wave arrival. Record it in the **P Arrival** column of Table 1.
- Determine the time of the S-wave arrival. Record it in the **S Arrival** column of Table 1.

Step 2 - Go the Distance

- Calculate the **S-P (seconds)** time by subtracting the P Arrival time from the S Arrival time. Record the answer in Table 1.
- Calculate and record the distance (km) from the station to the earthquake by multiplying the **S-P** column value by 8 km/s.

Step 3 - Ring Around the Seismometer

- Locate the scale at the bottom of the worksheet map. Using a compass, set the distance between the point and the pencil to the distance determined for the station. [Setting the compass will require estimating]
- Using the map, place the point of the compass on the matching station triangle.
- **Draw a circle around the station**, the circle has a *radius* equal to the distance to the event. The epicenter of the earthquake is somewhere on the edge of the circle.



radius - is the distance from the center of the circle to its outer edge

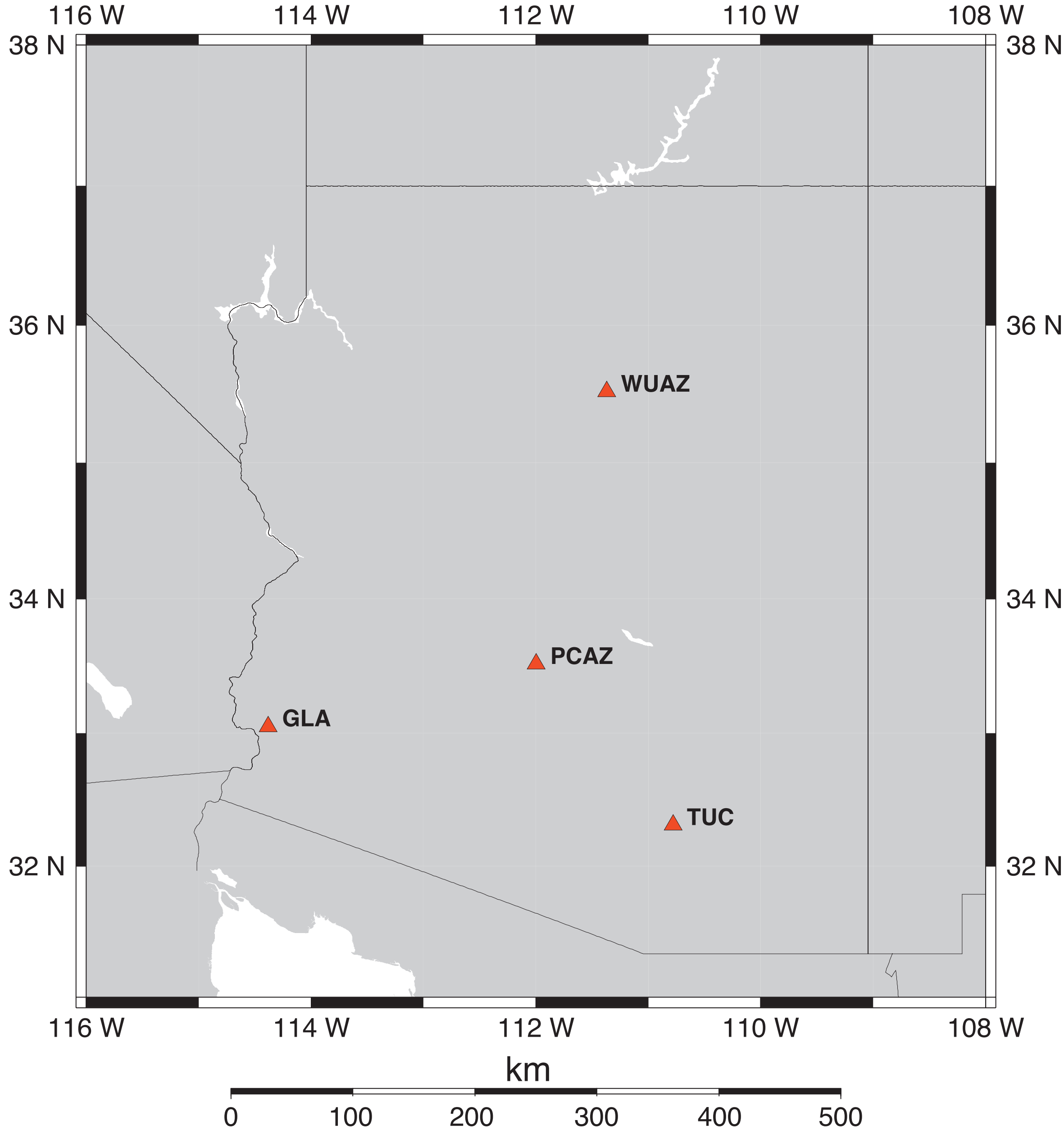
Step 4 - Find the Epicenter *(after repeating Steps 1-3 for each station)*

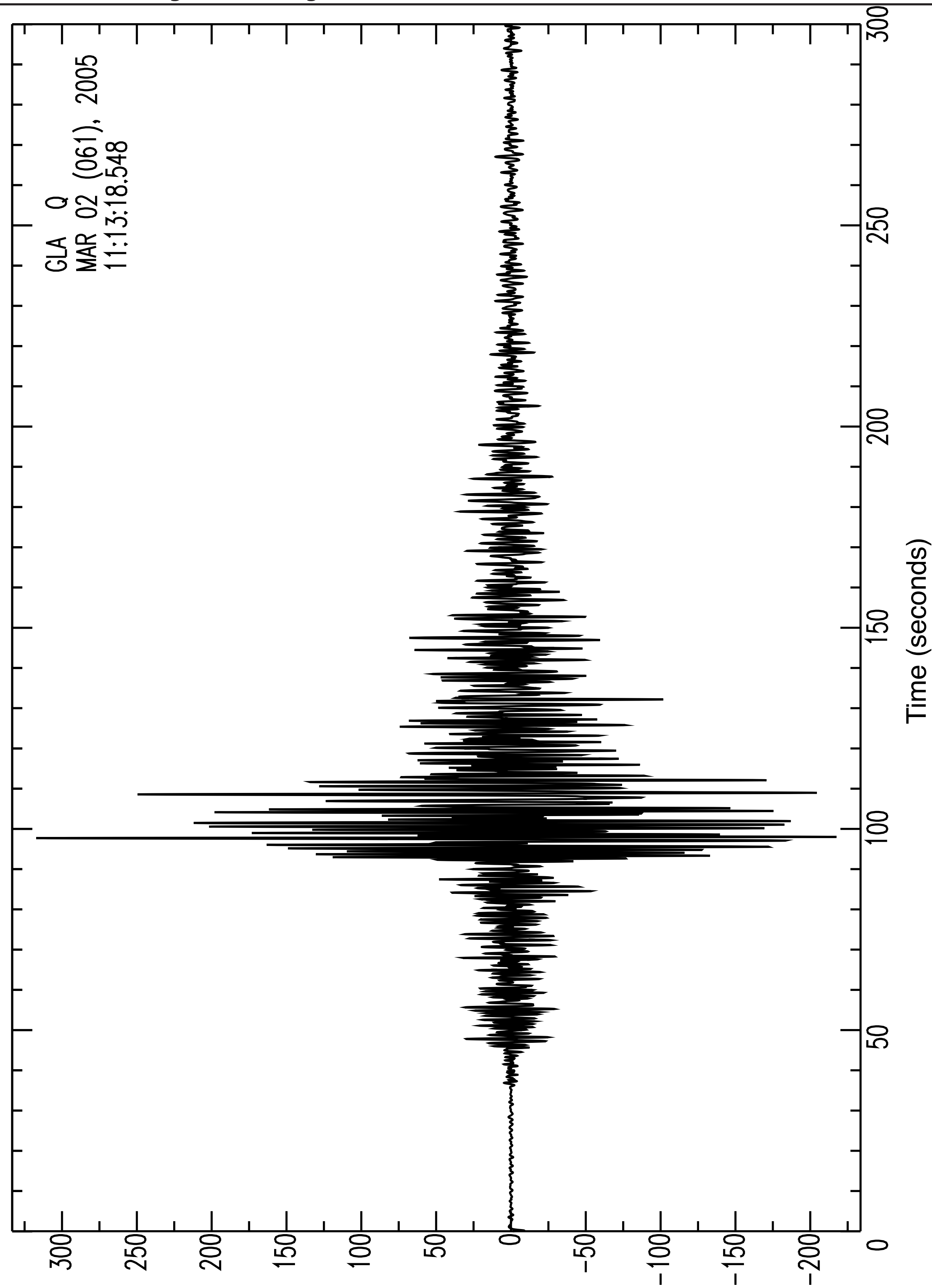
- Your circles should intersect at one point on the map, the epicenter. Using the map, **estimate** the **Latitude** and **Longitude** of the earthquake and record it on the worksheet directly above the map.

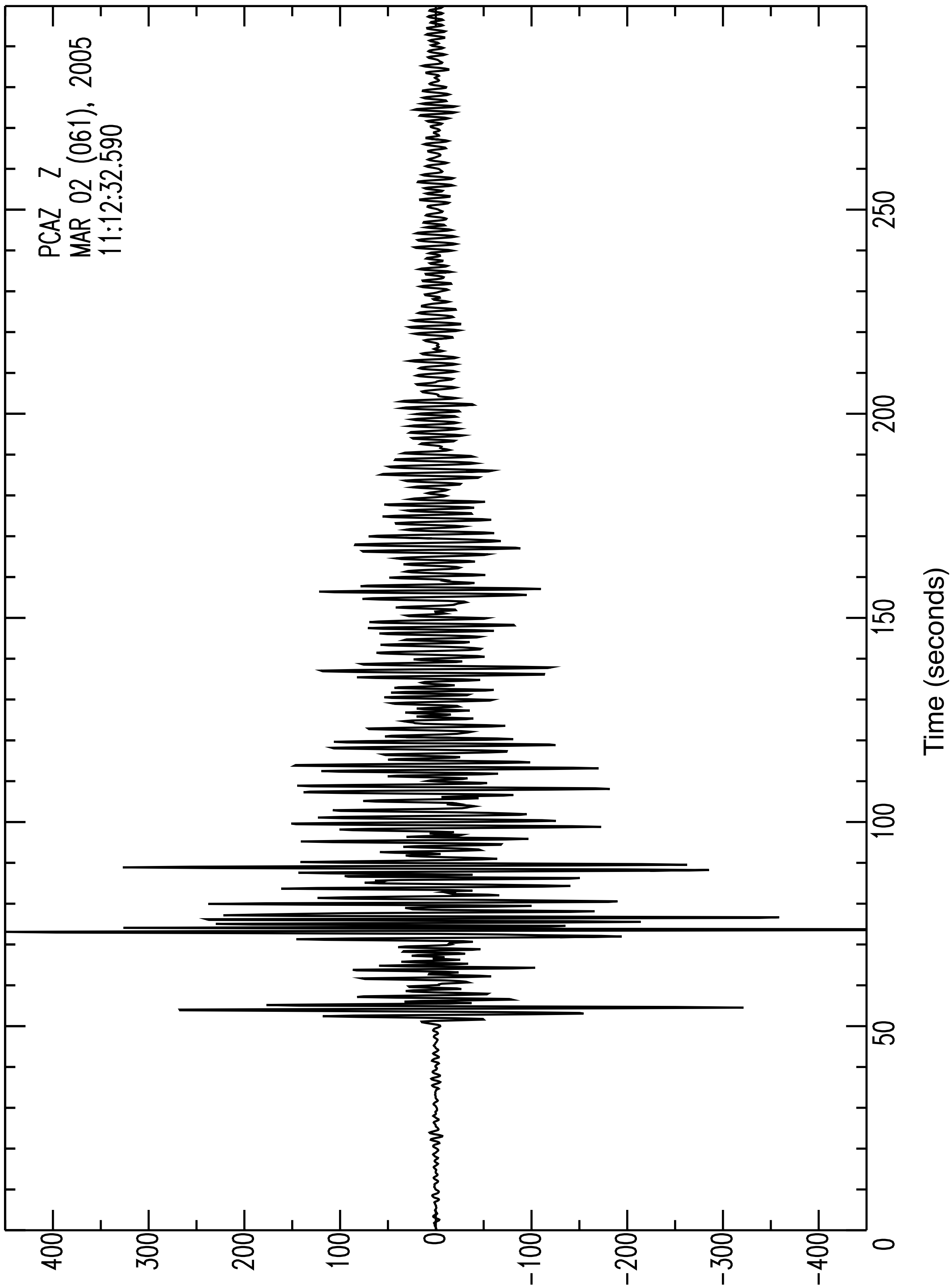
Table 1 - Calculations

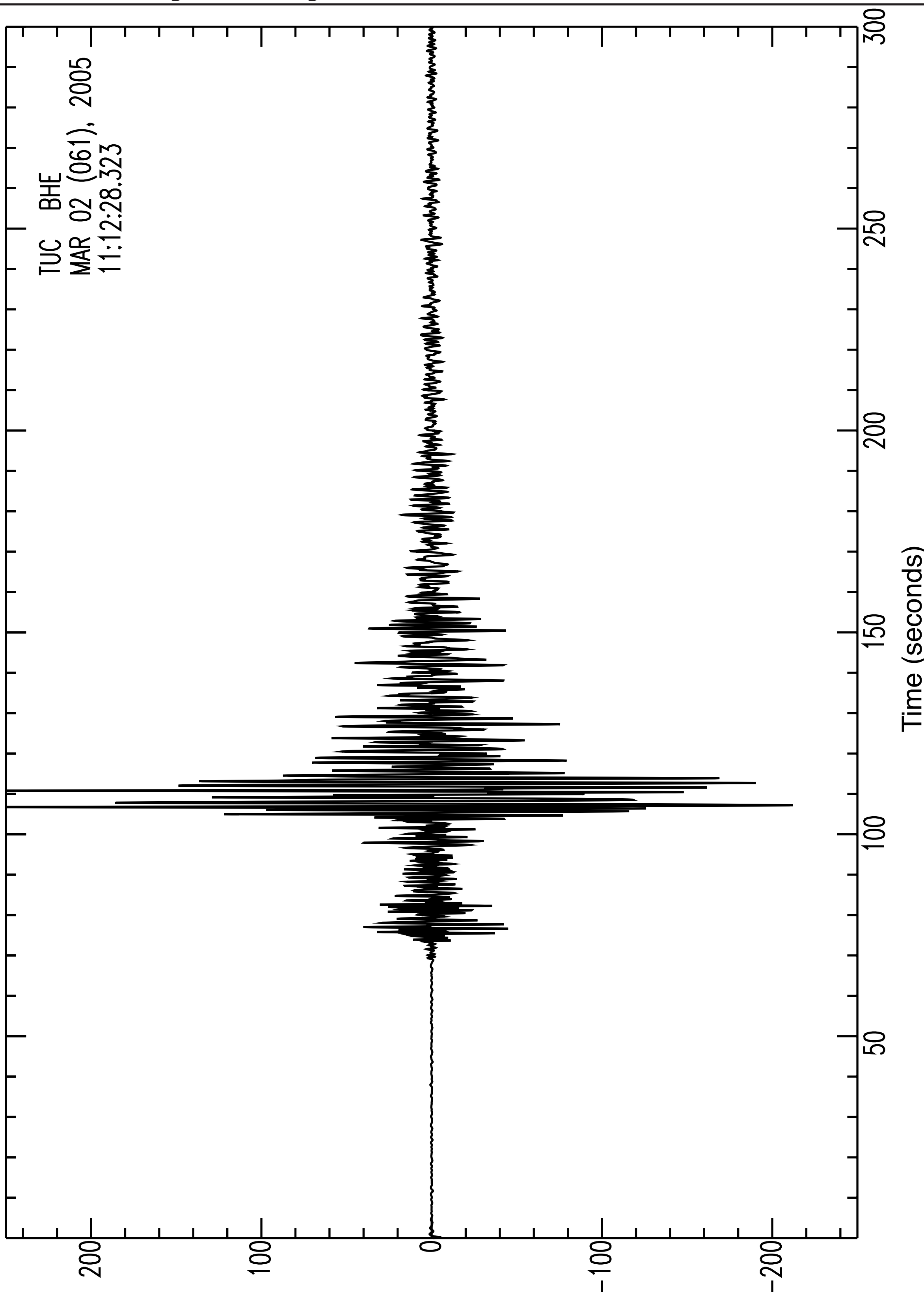
Station Code	P Arrival Time (s)	S Arrival Time (s)	S-P (s)	Distance (km) [(S-P) x 8]

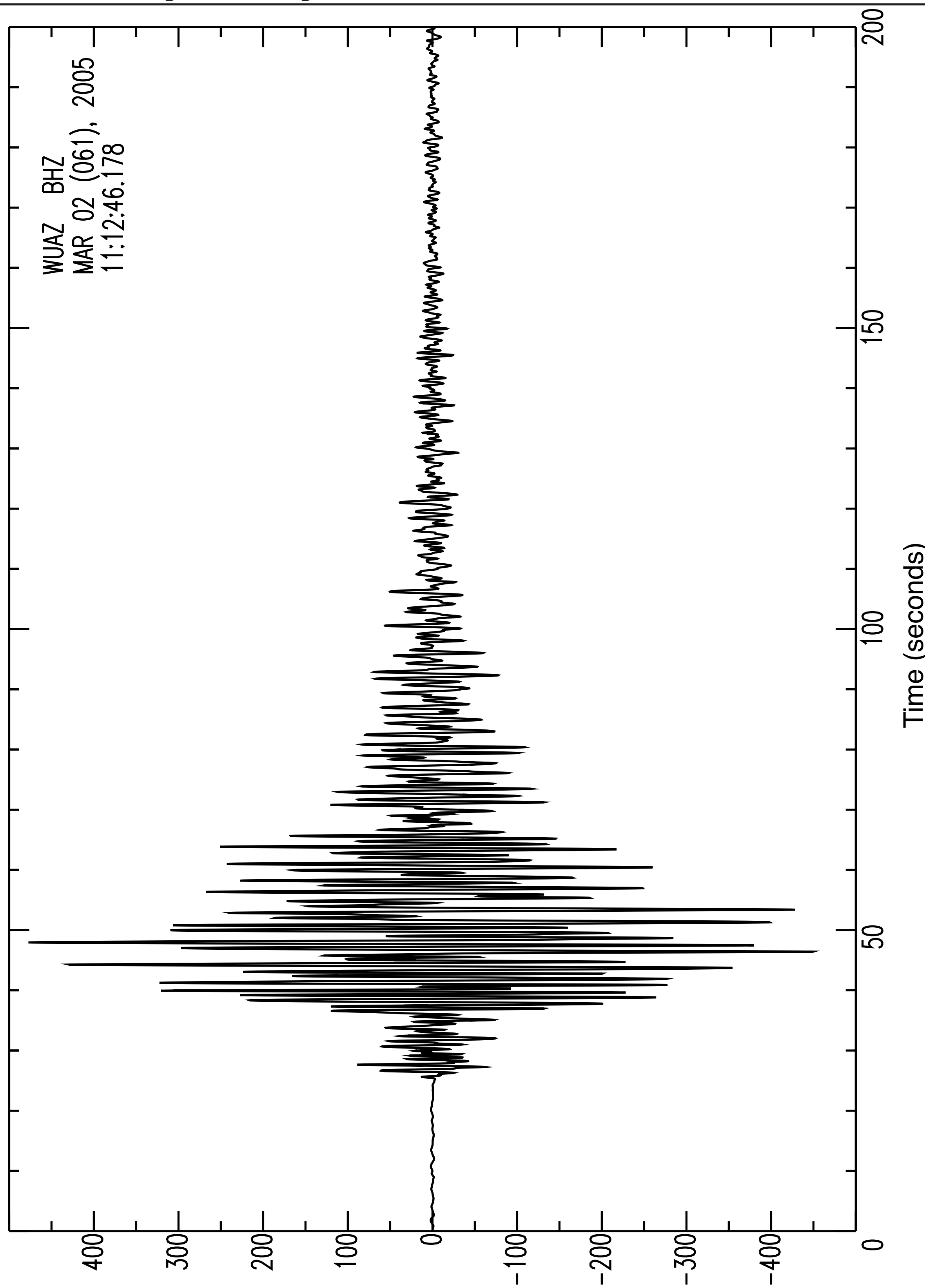
Map 1 - Event Location Latitude ______________ Longitude ______________




GLA Q
MAR 02 (061), 2005
11:13:18.548
Time (seconds)
0
50
100
150
200
250
300
300
250
200
150
100
50
0
-50
-100
-150
-200


PCAZ Z
MAR 02 (061), 2005
11:12:32.590
Time (seconds)
0
50
100
150
200
250
400
300
200
100
0
-100
-200
-300
-400


TUC BHE
MAR 02 (061), 2005
11:12:28.323
Time (seconds)
50
100
150
200
250
300
200
100
0
-100
-200


WUAZ BHZ
MAR 02 (061), 2005
11:12:46.178
400
300
200
100
0
-100
-200
-300
-400
0
50
100
150
200
Time (seconds)