Name (7 pts):____________________

Classroom Exercise: Tsunami

A great earthquake with a magnitude of 9.0 occurred at 00:58:53 UTC, 26 December 2004 and was located near Sumatra (3.3iN 95.9iE). This earthquake produced a devastating tsunami that was recorded at many worldwide tide gauges.

1. (4 pts) Plot the earthquake location on the map (Fig. 1, page 4) with a (**small!**) dot. Try to be very accurate.

The speed of a tsunami (c) in the ocean is described by the following equation:

c = SQRT (gd) = the square root of (g times d)

where *g = the acceleration due to gravity = 9.8 m/sec^2 and*
d = depth of the ocean in m

2. (8 pts) From the hypsographic curve in the book (Fig 3.4) find the average ocean depth, and use it to compute the average speed of a tsunami.

d=________________ m => c = SQRT(gd) = ________ m/sec

3. (5 pts) Is this speed comparable to that of a (choose the one best answer):

a. car
b. plane
c. bicycle
d. hiker

4. (7 pts) Using the speed you computed in 2., compute the distance traveled by the average tsunami in the following time spans, using: distance = velocity x time. (Hint: first determine how many sec are in an hour and how many m in a km.)

Time (in hours)	Time (in sec)	Distance (in km)
2	_______________	_______________
4		_______________
6		_______________
8		_______________
10		_______________
12		_______________
14		_______________

5. (8 pts) Using the table of distances you produced in 4. and the scale given on the map, plot lines on the map (Fig. 1) to indicate the location of the tsunami at 2, 4, 6, 8, 10, 12 and 14 hours after the earthquake, so 7 lines in total. Remember that tsunami only propagate in water, so do not draw the lines on land. Also label every line (with the number of hours). You should use a compass, or a protractor.

The tsunami that was caused by this earthquake was recorded by many different tide gauges all around the world. These tide gauges do not only measure tides, they measure any kind of change in water level.

6. (6 pts) Mark the locations of the following two tide gauges on the map (Fig. 1) with triangles. Again, try to be very precise:

Hanimaadhoo:	6.46iN	73.10iE
Lamu:	2.16iS	40.54iE

7. (6 pts) Based on the locations of these two tide gauges and the contours you plotted in 5., how much time will it take for the tsunami to travel from the earthquake epicenter to these two locations?

Time to travel to Hanimaadhoo: __________ hours
Time to travel to Lamu: __________ hours

8. (6 pts) Given that the origin time of the earthquake was: 00:58:53 UTC, 26 December 2004 (see above), what would you predict to be the time (in hour:min <u>and date</u>) of the tsunami arrival at these two stations?

Arrival time and date at Hanimaadhoo: _______________ ______________
Arrival time and date at Lamu: _______________ ______________

The horizontal axes of the tide gauge records (Fig. 2a and 2b on page 5) show the days of December 2004, with a tick-mark every hour. On the vertical scale, these records show the water level at the site in cm. To answer the following questions, see Fig. A on page 4 if you need help measuring the amplitude or period of a wave (= the time it takes for one wavelength to pass a fixed point).

9. (5 pts) There is a continuous signal present in this data with a very long period, in addition to a shorter period signal. A grey band in Fig. 2a highlights this long period signal. Measure the period of this continuous signal in Fig. 2a in hours.

Period: _________ hours

As you probably already guessed, this long period signal represents the tide. The shorter period signal superimposed on it (Ôriding onÕ the longer period tidal signal) is mostly due to the arrival of the tsunami.

10. (6 pts) Highlight the tidal signal in Fig. 2b in a similar way as was already done in Fig. 2a, and also measure its period.

Period: _________ hours

11. (6 pts) Measure the maximum amplitude in cm of the <u>tidal</u> signal at both sites from Fig. 2a and 2b. (See Fig. A on page 3 for help, note that amplitude is measured from the peak to the still water level.)

Amplitude at Hanimaadhoo: _____________ cm
Amplitude at Lamu: _____________ cm

Tide gauges measure the water level as a function of time, so in addition to tides, they will show the arrival of tsunami as well.

12. (6 pts) Mark with vertical lines the predicted tsunami arrival times you determined in 8. for the Hanimaadhoo tide gauge on Figure 2a and that for the Lamu record on Figure 2b.

13. (8 pts) Now pick the <u>actual</u> first arrival of the tsunami on the two records, by marking the impulsive first arrival of the shorter period signal (which should be within at least a few hours of your predictionÉ) with lines of a different color (one for each record). Measure the time <u>difference</u> with the predicted times in minutes.

Arrival time difference at Hanimaadhoo: ______________ minutes
Arrival time difference at Lamu: ______________ minutes

The difference in amplitude between the tide gauge measurement and the predicted/guessed tidal signal is mostly due to the tsunami.

14. (8 pts) What is the maximum displacement of the water due to the tsunami? To determine this value, first find the time when the difference in water level between the tidal signal (highlighted band) and the measured tide gauge data (black line) is the greatest and put a marker (arrow) at that time. Then measure what the amplitude difference is.

Maximum tsunami amplitude at Hanimaadhoo: __________ cm
Maximum tsunami amplitude at Lamu: __________ cm

15. (4 pts) For both sites, what is the signal with the largest amplitude: the tsunami or the tide (compare 14. with 11.), circle the correct answer?

Hanimaadhoo: Tsunami / Tide
Lamu: Tsunami / Tide

Extra Credit (5 pts): Speculate and give some possible reasons why your predicted tsunami arrival time was not exactly the same as the actual arrival time.

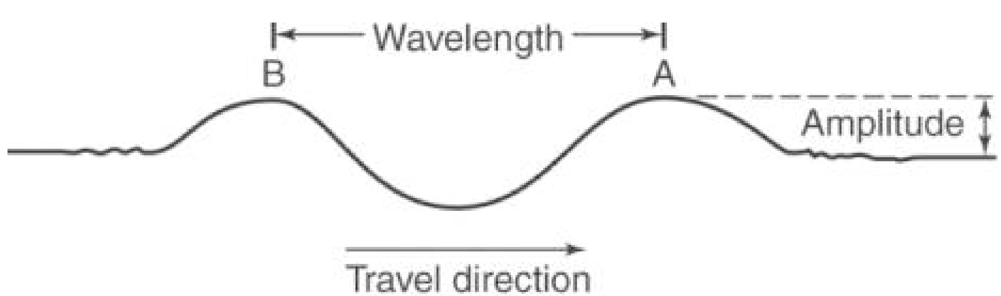


Figure A

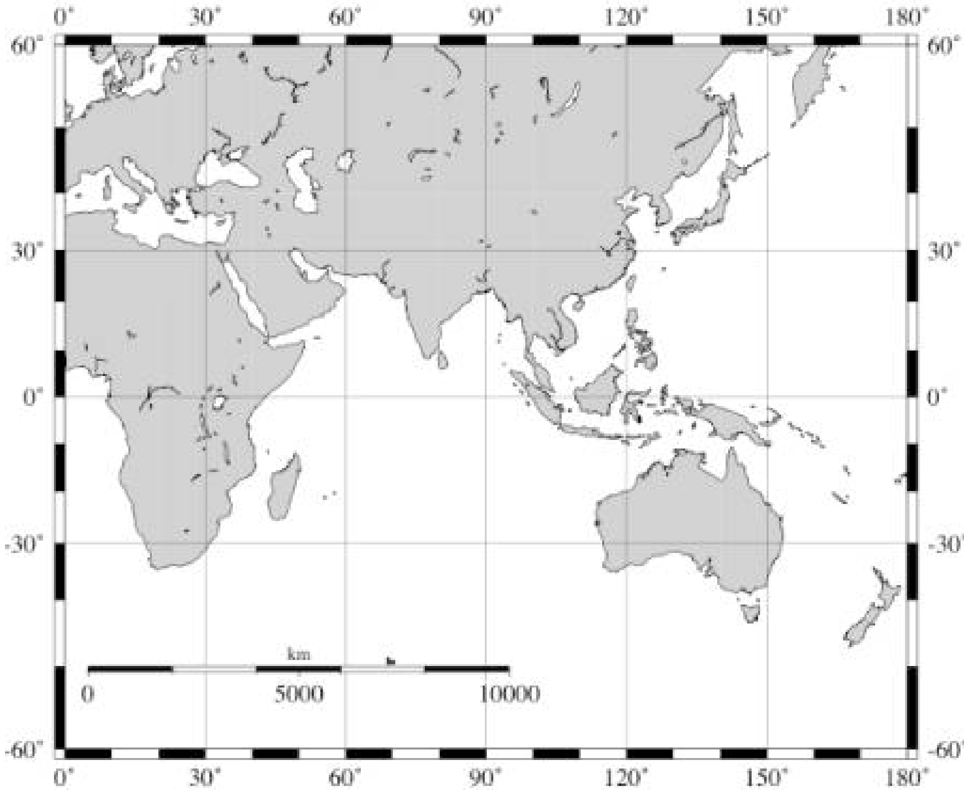


Figure 1

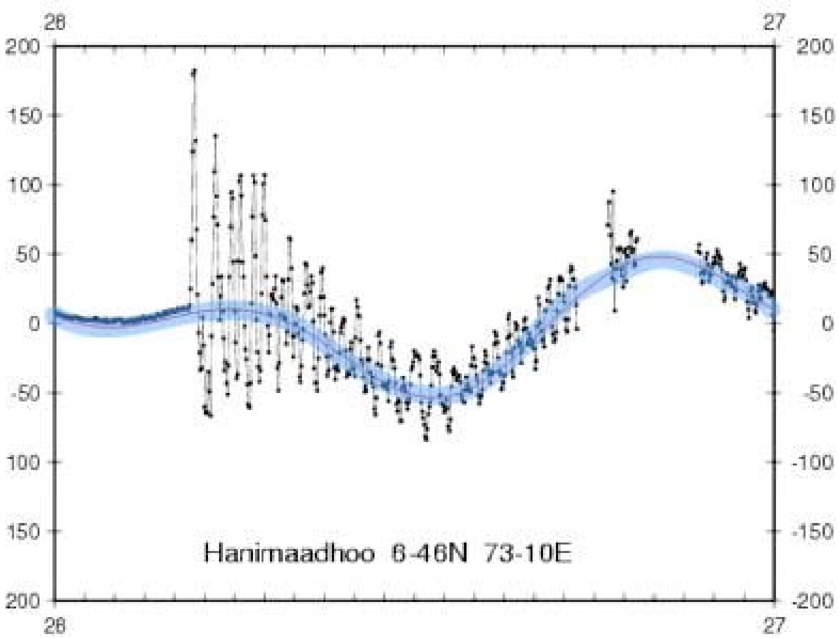


Figure 2a

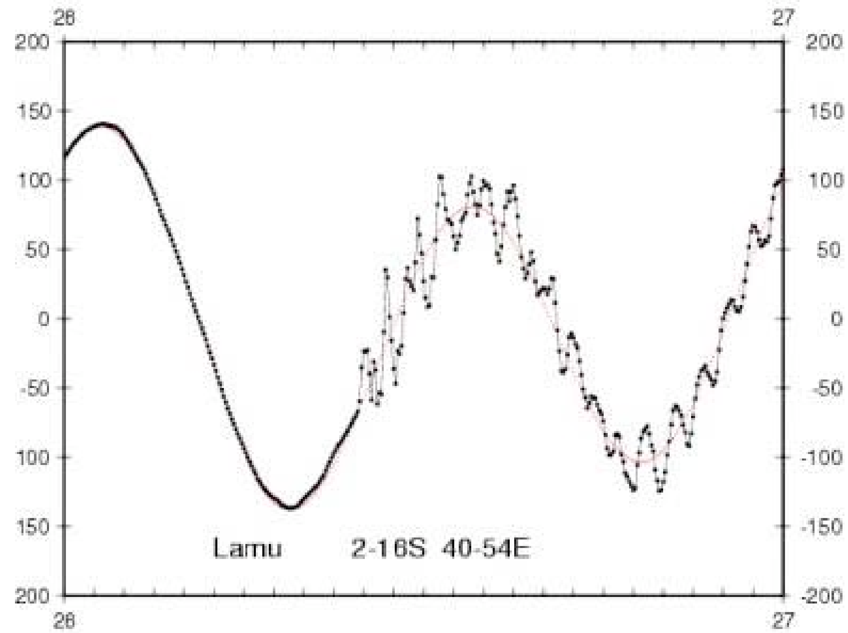


Figure 2b

Name (7 pts):____________________

Classroom Exercise: Tsunami

A great earthquake with a magnitude of 9.0 occurred at 00:58:53 UTC, 26 December 2004 and was located near Sumatra (3.3ïN 95.9ïE). This earthquake produced a devastating tsunami that was recorded at many worldwide tide gauges.

1. (4 pts) Plot the earthquake location on the map (Fig. 1, page 4) with a (**small!**) dot. Try to be very accurate.

The speed of a tsunami (c) in the ocean is described by the following equation:

c = Ã(gd) = the square root of (g times d)

where *g = the acceleration due to gravity = 9.8 m/sec^2 and*
d = depth of the ocean in m

2. (8 pts) From the hypsographic curve in the book (Fig 3.4) find the average ocean depth, and use it to compute the average speed of a tsunami.

d=_3729_ m => c = Ã(gd) = __191__ m/sec

3. (5 pts) Is this speed comparable to that of a (choose the one best answer):

a. car
______**b. plane**
c. bicycle
d. hiker

4. (7 pts) Using the speed you computed in 2., compute the distance traveled by the average tsunami in the following time spans, using: distance = velocity x time. (Hint: first determine how many sec are in an hour = 3600 and how many m in a km = 1000.)

Time (in hours)	Time (in sec)	Distance (in km)
2	____7200_____	____1376_________
4		____2753_________
6		____4129_________
8		____5506_________
10		____6882_________
12		____8258_________
14		____9635_________

5. (8 pts) Using the table of distances you produced in 4. and the scale given on the map, plot lines on the map (Fig. 1) to indicate the location of the tsunami at 2, 4, 6, 8, 10, 12 and 14 hours after the earthquake, so 7 lines in total. Remember that tsunami only propagate in water, so do not draw the lines on land. Also label every line (with the number of hours). You should use a compass, or a protractor.

The tsunami that was caused by this earthquake was recorded by many different tide gauges all around the world. These tide gauges do not only measure tides, they measure any kind of change in water level.

6. (6 pts) Mark the locations of the following two tide gauges on the map (Fig. 1) with triangles. Again, try to be very precise:

Hanimaadhoo:	6.46iN	73.10iE
Lamu:	2.16iS	40.54iE

7. (6 pts) Based on the locations of these two tide gauges and the contours you plotted in 5., how much time will it take for the tsunami to travel from the earthquake epicenter to these two locations?

Time to travel to Hanimaadhoo: _____4______ hours
Time to travel to Lamu: _____9______ hours

8. (6 pts) Given that the origin time of the earthquake was: 00:58:53 UTC, 26 December 2004 (see above), what would you predict to be the time (in hour:min <u>and date</u>) of the tsunami arrival at these two stations?

Arrival time and date at Hanimaadhoo: ____5 am______ ____12/26/05__
Arrival time and date at Lamu: ____10 am_____ ____12/26/05__

The horizontal axes of the tide gauge records (Fig. 2a and 2b on page 5) show the days of December 2004, with a tick-mark every hour. On the vertical scale, these records show the water level at the site in cm. To answer the following questions, see Fig. A on page 4 if you need help measuring the amplitude or period of a wave (= the time it takes for one wavelength to pass a fixed point).

9. (5 pts) There is a continuous signal present in this data with a very long period, in addition to a shorter period signal. A grey band in Fig. 2a highlights this long period signal. Measure the period of this continuous signal in Fig. 2a in hours.

Period: _____14____ hours

As you probably already guessed, this long period signal represents the tide. The shorter period signal superimposed on it (Ôriding onÕ the longer period tidal signal) is mostly due to the arrival of the tsunami.

10. (6 pts) Highlight the tidal signal in Fig. 2b in a similar way as was already done in Fig. 2a, and also measure its period.

Period: ____12_____ hours

11. (6 pts) Measure the maximum amplitude in cm of the <u>tidal</u> signal at both sites from Fig. 2a and 2b. (See Fig. A on page 3 for help, note that amplitude is measured from the peak to the still water level.)

Amplitude at Hanimaadhoo: _____50_____ cm
Amplitude at Lamu: ____140_____ cm

Tide gauges measure the water level as a function of time, so in addition to tides, they will show the arrival of tsunami as well.

12. (6 pts) Mark with vertical lines the predicted tsunami arrival times you determined in 8. for the Hanimaadhoo tide gauge on Figure 2a and that for the Lamu record on Figure 2b.

13. (8 pts) Now pick the actual first arrival of the tsunami on the two records, by marking the impulsive first arrival of the shorter period signal (which should be within at least a few hours of your predictionÉ) with lines of a different color (one for each record). Measure the time difference with the predicted times in minutes.

Arrival time difference at Hanimaadhoo: _____30_____ minutes
Arrival time difference at Lamu: _____10______ minutes

The difference in amplitude between the tide gauge measurement and the predicted/guessed tidal signal is mostly due to the tsunami.

14. (8 pts) What is the maximum displacement of the water due to the tsunami? To determine this value, first find the time when the difference in water level between the tidal signal (highlighted band) and the measured tide gauge data (black line) is the greatest and put a marker (arrow) at that time. Then measure what the amplitude difference is.

Maximum tsunami amplitude at Hanimaadhoo: __170____ cm
Maximum tsunami amplitude at Lamu: __50____ cm

15. (4 pts) For both sites, what is the signal with the largest amplitude: the tsunami or the tide (compare 14. with 11.), circle the correct answer?

Hanimaadhoo: **Tsunami** / Tide
Lamu: Tsunami / **Tide**

Extra Credit (5 pts): Speculate and give some possible reasons why your predicted tsunami arrival time was not exactly the same as the actual arrival time.
Ocean depth not constant or average, earthquake location not perfect, human error.

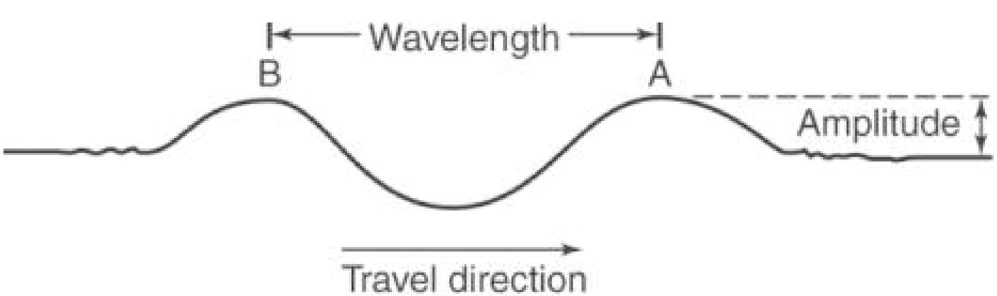


Figure A

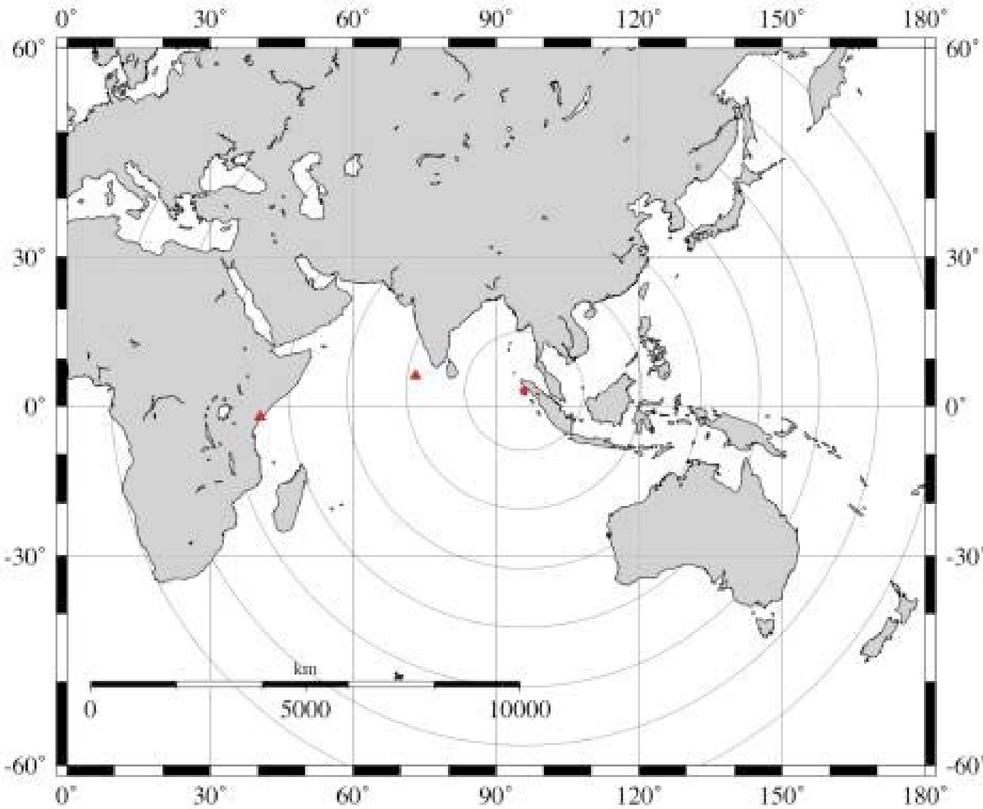
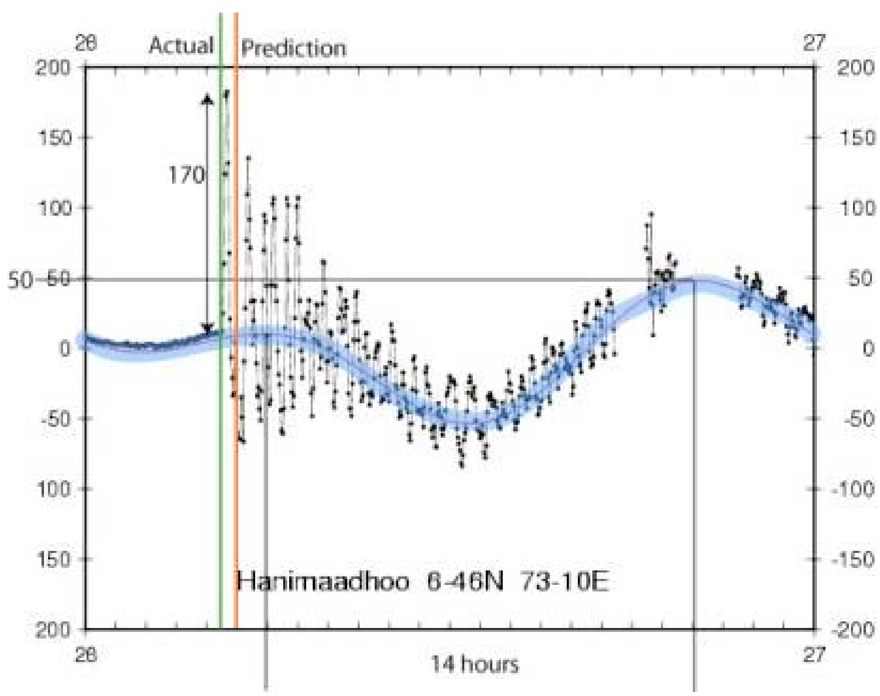

0° 30° 60° 90° 120° 150° 180°
60° 30° 0° -30° -60°
km
0
5000
10000

Figure 1


Actual
Prediction
28
27
170
Hanimaadhoo 6-46N 73-10E
14 hours

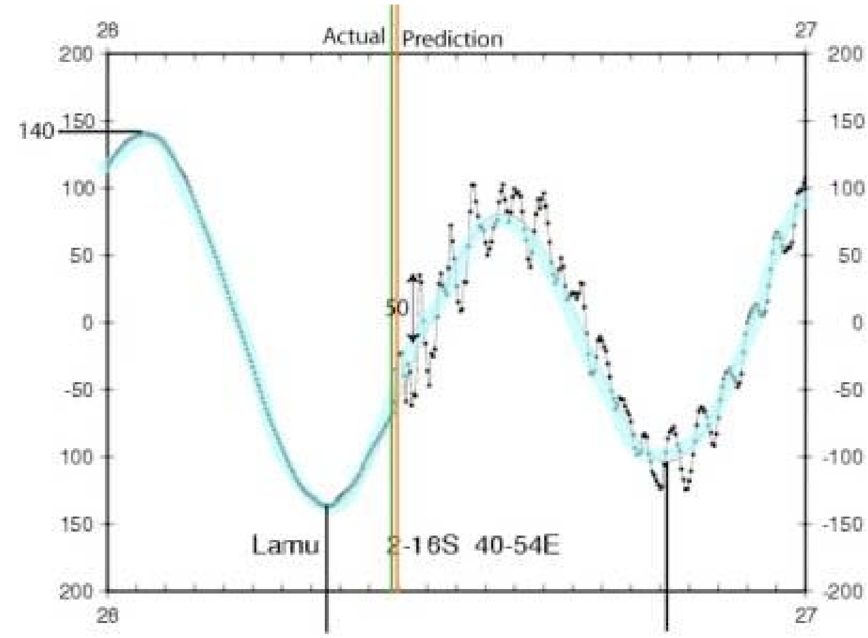


Figure 2a

Figure 2b