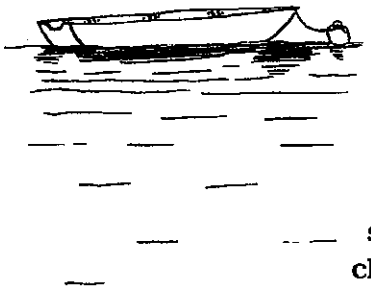
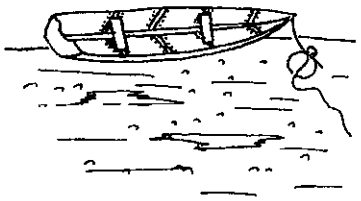
Name _____

WHAT CAUSES THE TIDES?



Anyone who has spent a day at the beach knows that the level of the sea rises and falls over a period of several hours. A boat might be floating high in the water at 9:00 in the morning, and sitting on mud at the very same spot at 3:00 in the afternoon. These regular changes in water level are called tides.



What causes the tides? While a study of everything involved would be very complicated, the basic force that causes the tides is called gravity. Until Isaac Newton (1642-1727) described the laws of gravity, tides were not fully understood.

Gravity tends to pull any two objects in the universe together. The size of the force depends on two factors:

1. The **mass** of the objects.
2. The **distance** between them.

What happens to a ball if you hold it in your hand and let it go? Why doesn't the earth rise to the ball if there is a force between them?

Only two bodies in the solar system are close enough and massive enough to affect the earth significantly. Can you guess which they are?

The gravitational pull of the moon and of the sun causes tides on the earth.

Sometimes building a model of how a thing works can help explain it better. You are going to build a model of the tides.

Materials

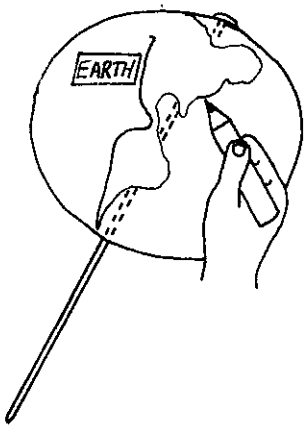
You will need to collect these things:

- ☐ 1 knitting needle (or piece of stiff wire)
- ☐ 1 clear plastic bag
- ☐ 1 wire tie
- ☐ 1 foam ball

You will also need to use tape, a marking pen, pencil, scissors, and sticky labels.

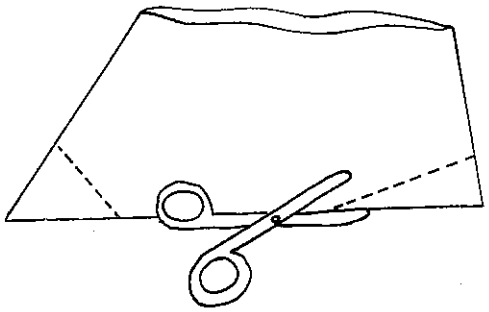
Building the Model

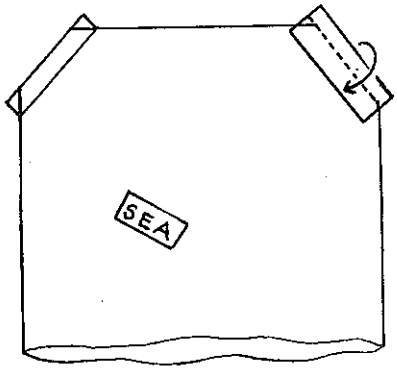
The foam ball will represent the earth. Draw some land on it with the pen. Write the word **"earth"** on a label and stick it to the ball.



Stick the knitting needle right through the ball so the head is just showing, as in the picture here.

Put the plastic bag on the table with the opening away from you. Cut off the two corners nearest to you, like this:

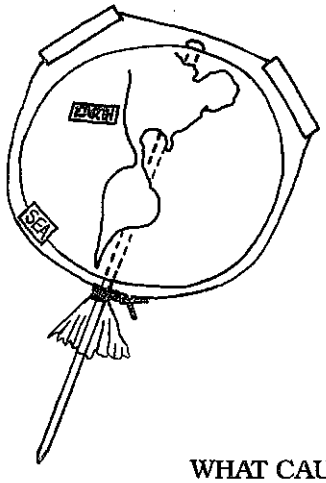




Cut off a piece of Scotch tape the same length as the edge of a corner. Stick it along the edge about half way across. Turn the bag over and stick the other half of the tape on that side. Do the same with the other cut corner.

The plastic bag represents the sea. Write the word **"sea"** on a label and stick it to the bag.

Put the ball into the bag. The knitting needle should stick through the open end. Blow up the bag — carefully! Seal it with the wire tie. Your model should look like this:

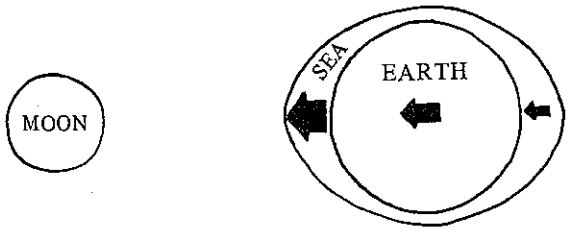


The Pull of the Moon

As you work with the model, write down your answers to the questions so that you remember what you found out.

The gravitational force between the earth and the moon and between the earth and the sun affects both land and sea. It affects the sea more because it is a liquid and can flow. The moon's gravity causes the sea to bulge towards it, making a high tide.

Take a sticky label. Write **"pull of the moon"** on it and stick it onto your thumb. Grasp one flap of the plastic bag with your thumb and finger. Pull gently. **What happens?**



⬅ REPRESENTS THE PULL OF THE MOON

The moon also causes another bulge in the sea on the other side of the earth. This is because the moon pulls the earth more strongly than the water which is further away on the other side of the earth.

Move the ball towards your thumb like the moon pulls the earth. This should create another bulge — another high tide — of about the same size in the sea on the opposite side of the earth.

Low tides occur where the sea doesn't bulge so much.

With the hand holding the knitting needle, spin the earth around once. Carefully watch a shoreline of one of the land masses you drew on the model earth.

In one turn of the earth how many high tides pass that shoreline?

How many low tides?

In one day, how many high tides will there be along that shore?

The Pull of the Sun

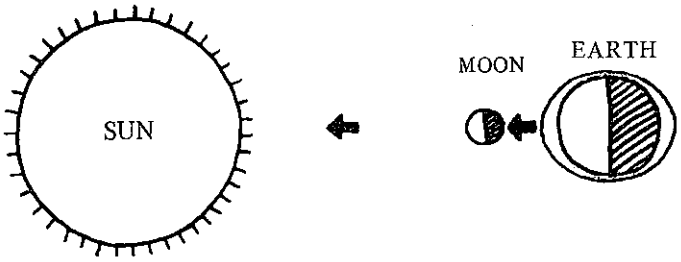
The moon and the earth spin around the sun. The sun also affects the tides but because it is so far away its effect is only about half as much as the moon's.

Get a partner to be the sun. Write **"pull of the sun"** on a label and stick it onto your partner's thumb. Hold the model by the knitting needle.

What happens to the high tide when you both pull together on the flap?

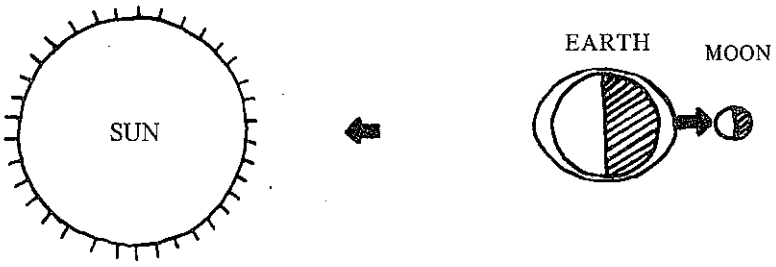
The same effect also occurs in the second bulge on the opposite side of the earth.

The sun and moon pull together on the earth when all three bodies are in line. This happens during a new moon, when we can't see the side of the moon lit up by the sun.



NEW MOON

The earth, moon, and sun are also in line when there is a full moon. At this time we see the entire circle of the moon fully lit up by the sun.



FULL MOON

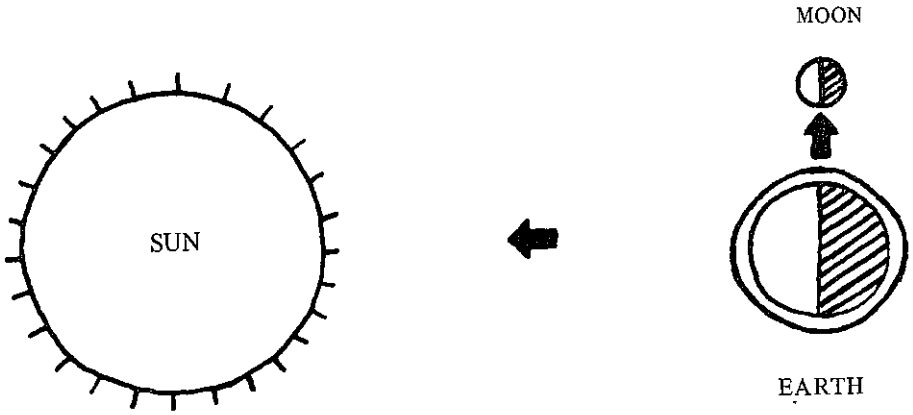
The combined pull of the sun and the moon produces very high tides when there is a new or full moon. These are called spring tides.

Are low tides higher or lower than usual at times of spring tides?

Sometimes the sun is at right angles to the line between the earth and moon. When this happens we see half the circle of the moon in the sky. Have your partner pull the bag at right angles to your pull.

What happens to the high tide when the sun and moon are pulling in different directions?

What happens to the low tides?



Tides that occur when the sun and moon pull at right angles to one another are called neap tides.

You have made a model of the tides. Models help us to understand complicated things but they are not necessarily like the real world.

How is the model different from what really happens?

Name _____

READING THE TIDE TABLES

Whether you are the captain of a Hudson River sloop like the Clearwater, a naturalist studying the animals in the Hudson estuary, or an angler planning a fishing trip on the River, you need to be able to use tide tables. They really aren't hard to read. Let's start by looking at a simple one.

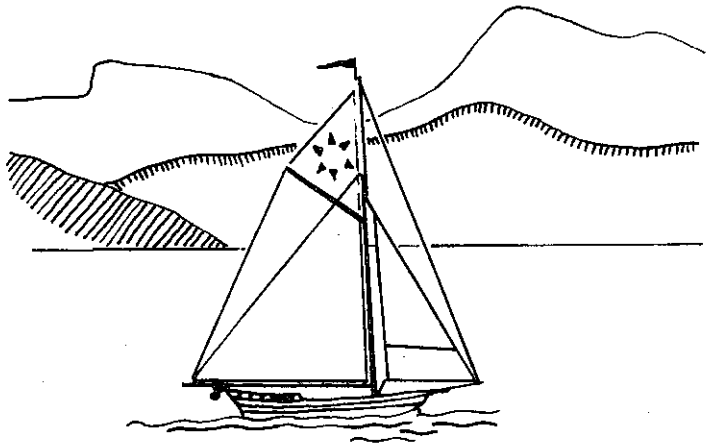


Table 1 — Tides at the Battery, New York Harbor

	high	*low*	*high*	*low*
November 25	0224	0850	1423	2123
November 26	0316	0951	1522	2209
November 27	0412	1042	1626	2254

1. The times in this tide table are given using a 24 hour clock. That means that instead of starting over at 1:00 in the afternoon, you continue numbering the hours up from 1200 until you get to 2400. For example, 1:00 PM is written as 1300 hours, 12:00 midnight as 2400 hours. Notice that the colon (the punctuation mark :) is left out of these times. Don't let that bother you; the first two numbers give the hours and the second two the minutes, just like the usual method of writing times.

   Write the following 24 hour clock times in the more usual way times are written. Be sure to indicate a.m. or p.m.

   1400 **1530**

   2015 **0015**

2. **How many low tides are there in each 24 hour period?**

3. **How many high tides?**

4. **When is low tide in the evening of November 26?**

5. **When is low tide on the evening of November 27?**

6. **Is the evening low tide on November 27 later or earlier than the evening low tide on November 26? How much later or earlier (in minutes)?**

7. **At what times are the morning low tides on November 25 and 26? How much later or earlier is that tide on the 26th (in minutes)?**

8. From these examples you can see that a given tide at a certain spot does not occur exactly 24 hours later from one day to the next. On average, it will be about 50 minutes later.

   When is high tide during the morning of November 27? When would you predict high tide should occur on the morning of November 28?

9. **Looking at the table, can you estimate about how many hours there are between one low tide and the next high tide?**

10. **Why do the tides happen later from one day to the next?** (Clue: think about what causes the high tide and its relationship with the earth).

Adjusting tide predictions for different sites

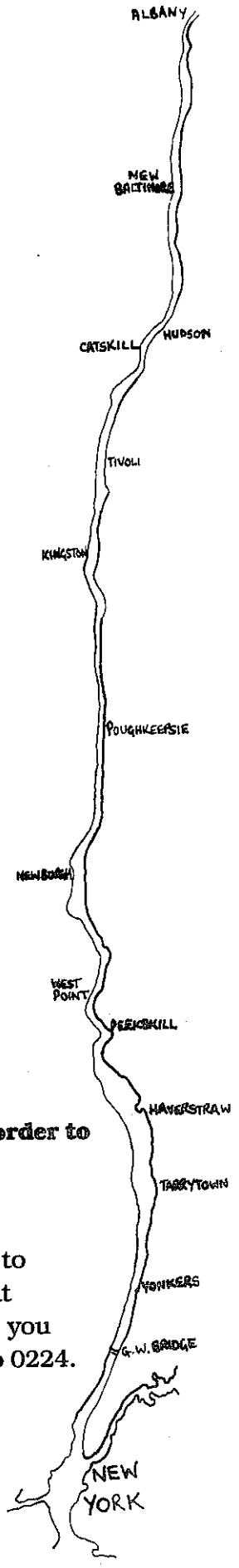
In many cases the times in tide tables need to be corrected depending on one's exact location. On the Hudson, for example, it takes awhile for the tidal water to flow upstream. A high tide occurring at a given hour in New York City will reach Albany roughly nine to ten hours later.

Table 2 gives the differences between times of high and low tide at New York and at various spots on the Hudson. The time differences are given in hours and minutes.

Table 2 — Tidal Differences

Place	*High water hrs./mins.*	*Low water hrs./mins.*
Weehawken, NJ	+0 28	+0 26
George Washington Bridge	+0 50	+0 46
Yonkers	+1 13	+1 13
Tarrytown	+1 49	+1 57
Haverstraw	+2 03	+2 28
Peekskill	+2 28	+3 03
West Point	+3 20	+3 40
Newburgh	+3 46	+4 03
Poughkeepsie	+4 34	+4 46
Kingston Point	+5 20	+5 34
Tivoli	+5 50	+6 04
Catskill	+6 41	+6 58
Hudson	+6 58	+7 12
New Baltimore	+8 30(*)	+8 30(*)
Albany	+9 00(*)	+9 00(*)

(*) approximations



11. Which of the listed places is closest to where you live?

12. How much time should you add to the high tide time in New York in order to get the high tide time at this place?

Adding times can be a little tricky. Let's try a few examples. Looking back to Table 1, you can see that the first high tide in New York on November 25 is at 0224, or 2:24 a.m. To figure out when that high tide would reach West Point, you would consult the table to see that you must add 3 hours and 20 minutes to 0224.

13. When adding times, it's easiest to add the minutes first. **What is this sum?**

24 minutes
+20 minutes

14. Now add the hours.

2 hours
+3 hours

15. Putting hours and minutes together, at what time would that high tide reach West Point?

That was pretty simple, right? Let's try a more complicated example. Suppose you wanted to know the time when that November 25 high tide would reach Tivoli. To do this, the table tells us you must add 5 hours and 50 minutes to 0224.

16. Again, add the minutes first.

24 minutes
+50 minutes

17. Notice that your answer is greater than 60, which is the number of minutes in one hour. When this is the case, we must carry 60 of those minutes over to the hours column. To do this, start by subtracting 60 from your answer. **How many minutes are left over?**

18. Now add the hours. Don't forget to add the extra hour carried over from the minutes column.

2 hours
5 hours
+1 hour (carried over)

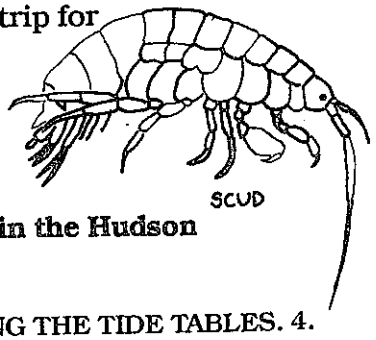
19. Putting together the hours and the leftover minutes, what time will high tide occur at Tivoli?

20. Now try it yourself. **At what time would the first low tide of November 25 reach the listed location nearest to you?**

21. At what time would the first high tide of November 27 reach the listed location nearest to you?

22. A naturalist wants to study scuds in the Hudson River near the city of Hudson. When the tide goes out these tiny creatures can be found by turning over rocks left uncovered by the falling tide. The naturalist has planned a field trip for November 27 and will arrive on the shore at 11:00 a.m.

Will this person be able to work?



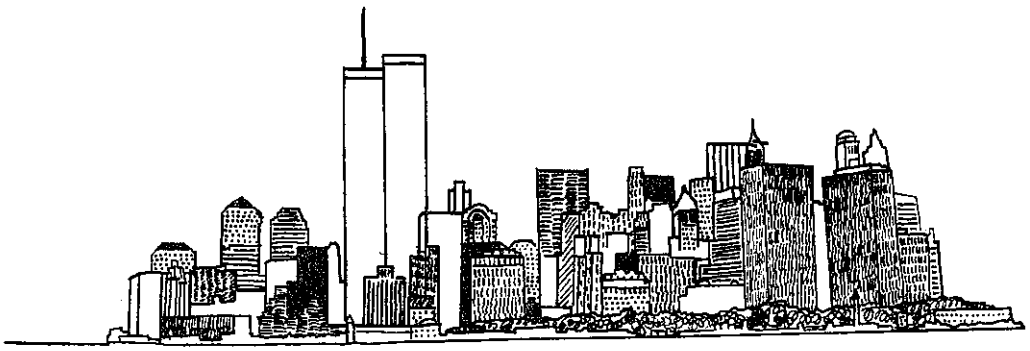
SCUD

At what time do you think the naturalist should go to look for scuds in the Hudson on that day?

Name _____

GRAPHING THE TIDES

Tide tables tell you the times of high and low tides. They also tell you what height the water will reach. This height changes with the phases of the moon. You are going to use a tide table for New York Harbor to see how the moon affects the tides.



NEW YORK HARBOR

Look at the tide table for October, 1986. There is a lot of information on the page, and it's set up differently from the table you might have used in the lesson "Reading the Tide Tables". However, this table really isn't any more difficult to read. You can tell whether the tide is high or low by looking at the "height" column. The lowest height(s) for each date are the low tides. Tide heights are given in both feet (ft) and meters (m). Times are given using a 24 hour clock.

1. **What information is given for each date?**

2. **How many low tides are there for most 24 hour periods? How many high tides?**

3. **Are the heights of the low tides always the same? Are the heights of the high tides?**

4. Look at the bottom of the page. It says "Heights are referred to mean low water". **What does this mean? (Hint: The word "mean" here has the same definition as the word "average".)**

5. **About how many hours does it take to go from one high tide to the next low tide?**

6. **At what times are the low tides on October 12th?**

7. **What is the height of the tide (in feet) on October 3rd at 2:02 p.m.? Is it a high or a low tide? Why is the number negative?**

8. **For the entire month of October, what is the height of the lowest low tide (in feet)? What height is the highest high tide?**

9. The height difference between a high and a low tide is called a tidal range. **What is the range between the highest high tide and the lowest low tide on October 5th?**

Drawing the graph

Often information contained in a table can be more easily understood if it's presented in the form of a graph. You are now going to plot a graph of the tides for October 1986.

Along the top margin of the graph paper write the title of the graph you will make — "Tidal Cycles at the Battery, New York — October, 1986."

Draw a vertical (Y) axis. It will have to have a scale from the lowest low tide to the highest high tide. Label the axis "height in feet". The horizontal (X) axis should be labelled "days in October", numbered from 1 to 31.

Plot the height of the highest high tide on the 1st of October, then for the 2nd of October (remember how much later the high tide gets each day) and so on until the 8th of October. What happens then? Why is there only one high tide? It is because the second high tide of that day's cycle doesn't occur until just after midnight on October 9th. Continue plotting the highest daily tide through October 31st.

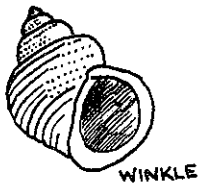
On the same axes plot the corresponding lowest low tides for October. Note that on October 14 the second low tide of the 24 hour cycle occurs after midnight, and therefore on October 15.

Now use the graph to answer the following questions.

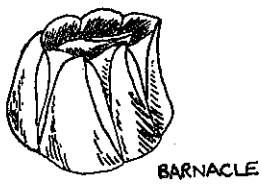
10. **On what dates do spring tides occur? What is the tidal range on each of those dates?**

11. **On what dates do neap tides occur? What is the tidal range on each of those dates?**

12. Imagine you are a winkle (a type of snail) living on the shore 5.3 feet above the mean low water level. **On how many days in October would you be wetted by a high tide?**



13. **If you were a barnacle living 4.1 feet above the mean low water level, then on how many days in October would you not be covered by water?**



NEW YORK (The Battery), N.Y., 1986

Times and Heights of High and Low Waters

OCTOBER

Day	Time	Height		Day	Time	Height		Day	Time	Height		Day	Time	Height	
	h m	ft	m		h m	ft	m		h m	ft	m		h m	ft	m
1	0022	0.2	0.1	9	0010	4.1	1.2	16	0054	-0.3	-0.1	24	0026	3.4	1.0
W	0627	4.6	1.4	Th	0546	0.5	0.2	Th	0709	5.3	1.6	F	0522	1.2	0.4
	1235	0.4	0.1		1237	5.1	1.6		1320	-0.2	-0.1		1229	4.2	1.3
	1840	5.0	1.5		1911	0.5	0.2		1926	5.0	1.5		1913	1.1	0.3
2	0101	0.0	0.0	10	0118	3.9	1.2	17	0136	-0.3	-0.1	25	0119	3.3	1.0
Th	0704	4.9	1.5	F	0710	0.8	0.2	F	0749	5.4	1.6	Sa	0613	1.5	0.5
	1319	0.1	0.0		1343	5.0	1.5		1404	-0.2	-0.1		1324	4.1	1.2
	1917	5.2	1.6		2028	0.5	0.2		2006	4.9	1.5		2026	1.1	0.3
3	0140	-0.2	-0.1	11	0225	3.9	1.2	18	0215	-0.3	-0.1	26	0216	3.3	1.0
F	0740	5.3	1.6	Sa	0840	0.9	0.3	Sa	0827	5.4	1.6	Su	0828	1.5	0.5
	1402	-0.2	-0.1		1450	4.8	1.5		1447	-0.2	-0.1		1420	4.0	1.2
	1955	5.2	1.6		2137	0.4	0.1		2045	4.6	1.4		2125	0.9	0.3
4	0217	-0.3	-0.1	12	0336	4.0	1.2	19	0253	-0.1	0.0	27	0315	3.5	1.1
Sa	0818	5.5	1.7	Su	0951	0.7	0.2	Su	0904	5.2	1.6	M	0937	1.3	0.4
	1445	-0.3	-0.1		1559	4.8	1.5		1525	0.0	0.0		1522	4.1	1.2
	2035	5.1	1.6		2233	0.2	0.1		2122	4.4	1.3		2215	0.6	0.2
5	0254	-0.4	-0.1	13	0441	4.3	1.3	20	0328	0.1	0.0	28	0412	3.8	1.2
Su	0857	5.6	1.7	M	1050	0.4	0.1	M	0941	5.0	1.5	Tu	1030	0.9	0.3
	1526	-0.3	-0.1		1702	4.9	1.5		1603	0.2	0.1		1621	4.2	1.3
	2117	4.9	1.5		2323	-0.1	0.0		2203	4.1	1.2		2257	0.4	0.1
6	0331	-0.3	-0.1	14	0539	4.7	1.4	21	0358	0.4	0.1	29	0501	4.2	1.3
M	0942	5.6	1.7	Tu	1145	0.1	0.0	Tu	1020	4.8	1.5	W	1118	0.5	0.2
	1611	-0.2	-0.1		1756	5.0	1.5		1639	0.4	0.1		1715	4.4	1.3
	2208	4.6	1.4						2245	3.8	1.2		2339	0.1	0.0
7	0410	-0.1	0.0	15	0011	-0.2	-0.1	22	0427	0.7	0.2	30	0547	4.7	1.4
Tu	1035	5.5	1.7	W	0626	5.0	1.5	W	1059	4.6	1.4	Th	1206	0.2	0.1
	1659	0.0	0.0		1233	-0.1	0.0		1719	0.7	0.2		1802	4.6	1.4
	2304	4.3	1.3		1844	5.1	1.6		2335	3.6	1.1				
8	0452	0.2	0.1					23	0451	1.0	0.3	31	0019	-0.2	-0.1
W	1133	5.3	1.6					Th	1144	4.3	1.3	F	0629	5.1	1.6
	1756	0.3	0.1						1805	0.9	0.3		1251	-0.2	-0.1
													1845	4.8	1.5