Tides Around the World!

A day of tides, worldwide

Tides are caused by gravitational interactions between the Earth, Sun, and Moon. Both the Sun and Moon influence tides on Earth and result in "bulges" in Earth's oceans that changes depending on the orientation of the Sun and Moon (see figure 1). Since the Moon revolves around the Earth, this orientation changes over the course of the month, causing larger or small tidal bulges. Meanwhile, the Earth is also rotating on its axis, once every 24 hours. Let's see if we can identify and make sense of patterns in tidal data for different locations around the Earth.

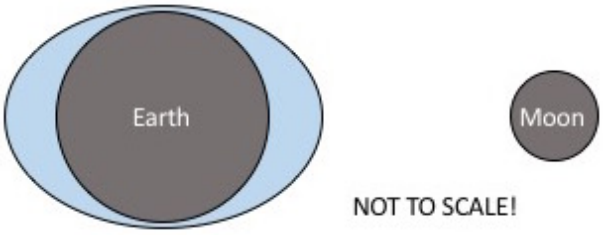

Figure 1. Schematic diagram of (exaggerated) tidal bulges created by the Moon.

A note on timekeeping and time zones

When we say, "It's twelve o'clock noon," we are probably referring to *local time.* Local time is probably most useful to us in our daily lives: maybe we get up at 6 o'clock in the morning, eat lunch at 11:30, get out of school at 3 o'clock or 4 o'clock in the afternoon, and go to bed by nine in the evening. If you've ever traveled far enough east or west from your home, maybe you've entered a different time zone. In different time zones, we shift "local time" so that it makes sense for that place on the planet. If we didn't have different time zones, then "twelve o'clock noon" at one place on the Earth would be light outside, while on the other side of the Earth it would be pitch dark! Instead, we shift the time so that "twelve o'clock noon" means approximately the same thing everywhere on the planet.

The Earth is divided into about twenty-four different "time zones"; each time zone is an hour different from the ones next to it. The United States (including Alaska and Hawaii) spans six time zones, while Russia spans a whopping nine time zones! (When it is morning in Moscow, people on the other side of the country are finishing their day!)

In this activity, we will be using "Coordinated Universal Time," or UTC, based on "Greenwich Mean Time" or GMT. This is different from local time, because local time represents the time at a particular location on the Earth. When it is "12 o'clock noon UTC," that is the case for everywhere on the planet. Each time zone is defined by its difference from GMT (for example,

Pacific Standard Time is UTC minus eight hours). By using UTC, we can compare graphs across the world.

In addition, UTC and local time can be represented by either a "12-hour clock" or a "24-hour clock." The 12-hour clock divides the 24 hours in a day into two 12-hour periods. Time ranging between midnight and noon is denoted with AM (ante meridiem) and the second 12-hour period that ranges from noon to midnight is denoted with PM (post meridiem). The 24-hour clock is a convention that runs from midnight to midnight and is divided into 24 hours indicated by the hours passed since midnight and ranges from 0:00 to 23:59 (11:59 PM). Thus, noon in both the 12- and 24-hour clock is 12:00. However, 1:00 PM using the 12-hour clock would be equivalent to 13:00 using the 24-hour clock.

Graphing the tides (work with your partner)

You will be assigned a dataset for a particular location on the Earth, starting at 00:00 (midnight) UTC December 30, 2015 and ending nearly two days later at 22:00 UTC on Dec. 31. Your location's time zone (as measured from UTC; for example, "UTC –8 hours" for Pacific Standard TIme) will also be listed. **You should determine the local time (using the 24-hour clock) and record it on the data table.**

Plot ocean height on the Y-axis versus time on the X-axis. Note that "ocean height" is a **relative** number (above or below a chosen "zero point"). **Think carefully about the scale and range of your Y-axis before plotting your dataset!** The X-axis is labeled with time in UTC. **You should also add the local time to the x-axis labels.**

Analyzing your data

- What is the time interval between high tides? What is the time interval between low tides?

- Can you predict when the next high tide will occur?

- The *tidal range* for a region is the difference in height between high tide and low tide. What is the tidal range for your location?

Gallery walk

When everybody has finished graphing their dataset, line them all up in order of time zone, and look for patterns. What do you see that is similar between each dataset? What is different? Are they different in systematic ways?

Guiding questions

- Do all regions experience tides at the same time?

- Are there differences between the tides in different locations? What could make the tides different?

- Do all the locations experience about two tidal cycles (low tide, high tide) per day?

Hilo, Hawaii (local time is UTC –10 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		0.266
Dec 30. 2015	02:00		0.405
Dec 30, 2015	04:00		0.478
Dec 30, 2015	06:00		0.429
Dec 30, 2015	08:00		0.239
Dec 30, 2015	10:00		0.198
Dec 30, 2015	12:00		0.363
Dec 30, 2015	14:00		0.622
Dec 30, 2015	16:00		0.820
Dec 30, 2015	18:00		0.794
Dec 30, 2015	20:00		0.561
Dec 30, 2015	22:00		0.332
Dec 31, 2015	00:00		0.232
Dec 31, 2015	02:00		0.341
Dec 31, 2015	04:00		0.475
Dec 31, 2015	06:00		0.485
Dec 31, 2015	08:00		0.367
Dec 31, 2015	10:00		0.276
Dec 31, 2015	12:00		0.326
Dec 31, 2015	14:00		0.501
Dec 31, 2015	16:00		0.694
Dec 31, 2015	18:00		0.676
Dec 31, 2015	22:00		0.291

Woods Hole, Massachusetts (local time is UTC –5 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		0.186
Dec 30. 2015	02:00		0.401
Dec 30, 2015	04:00		0.539
Dec 30, 2015	06:00		0.418
Dec 30, 2015	08:00		0.436
Dec 30, 2015	10:00		0.324
Dec 30, 2015	12:00		0.288
Dec 30, 2015	14:00		0.528
Dec 30, 2015	16:00		0.805
Dec 30, 2015	18:00		0.652
Dec 30, 2015	20:00		0.467
Dec 30, 2015	22:00		0.353
Dec 31, 2015	00:00		0.267
Dec 31, 2015	02:00		0.352
Dec 31, 2015	04:00		0.617
Dec 31, 2015	06:00		0.674
Dec 31, 2015	08:00		0.472
Dec 31, 2015	10:00		0.430
Dec 31, 2015	12:00		0.365
Dec 31, 2015	14:00		0.305
Dec 31, 2015	16:00		0.516
Dec 31, 2015	18:00		0.515
Dec 31, 2015	20:00		0.373
Dec 31, 2015	22:00		0.338

Monterey, California (local time is UTC –8 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		0.771
Dec 30. 2015	02:00		0.176
Dec 30, 2015	04:00		0.015
Dec 30, 2015	06:00		0.422
Dec 30, 2015	08:00		1.008
Dec 30, 2015	10:00		1.378
Dec 30, 2015	12:00		1.319
Dec 30, 2015	14:00		0.994
Dec 30, 2015	16:00		0.834
Dec 30, 2015	18:00		0.987
Dec 30, 2015	20:00		1.248
Dec 30, 2015	22:00		1.286
Dec 31, 2015	00:00		0.957
Dec 31, 2015	02:00		0.445
Dec 31, 2015	04:00		0.144
Dec 31, 2015	06:00		0.366
Dec 31, 2015	08:00		0.871
Dec 31, 2015	10:00		1.325
Dec 31, 2015	12:00		1.396
Dec 31, 2015	14:00		1.137
Dec 31, 2015	16:00		0.850
Dec 31, 2015	18:00		0.808
Dec 31, 2015	20:00		1.015
Dec 31, 2015	22:00		1.187

Sitka, Alaska (local time is UTC –9 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		2.856
Dec 30. 2015	02:00		2.208
Dec 30, 2015	04:00		0.810
Dec 30, 2015	06:00		-0.107
Dec 30, 2015	08:00		0.176
Dec 30, 2015	10:00		1.454
Dec 30, 2015	12:00		2.571
Dec 30, 2015	14:00		2.644
Dec 30, 2015	16:00		1.837
Dec 30, 2015	18:00		0.974
Dec 30, 2015	20:00		0.995
Dec 30, 2015	22:00		1.792
Dec 31, 2015	00:00		2.517
Dec 31, 2015	02:00		2.376
Dec 31, 2015	04:00		1.331
Dec 31, 2015	06:00		0.365
Dec 31, 2015	08:00		0.267
Dec 31, 2015	10:00		1.205
Dec 31, 2015	12:00		2.343
Dec 31, 2015	14:00		2.814
Dec 31, 2015	16:00		2.310
Dec 31, 2015	18:00		1.481
Dec 31, 2015	20:00		1.127
Dec 31, 2015	22:00		1.549

Kwajalein, Marshall Islands (local time is UTC +12 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		-0.024
Dec 30. 2015	02:00		0.081
Dec 30, 2015	04:00		0.567
Dec 30, 2015	06:00		0.994
Dec 30, 2015	08:00		1.029
Dec 30, 2015	10:00		0.543
Dec 30, 2015	12:00		0.002
Dec 30, 2015	14:00		-0.051
Dec 30, 2015	16:00		0.275
Dec 30, 2015	18:00		0.672
Dec 30, 2015	20:00		0.822
Dec 30, 2015	22:00		0.516
Dec 31, 2015	00:00		0.157
Dec 31, 2015	02:00		0.090
Dec 31, 2015	04:00		0.380
Dec 31, 2015	06:00		0.837
Dec 31, 2015	08:00		0.953
Dec 31, 2015	10:00		0.630
Dec 31, 2015	12:00		0.200
Dec 31, 2015	14:00		-0.006
Dec 31, 2015	16:00		0.179
Dec 31, 2015	18:00		0.547
Dec 31, 2015	20:00		0.743
Dec 31, 2015	22:00		0.654

Saint John, Canada (local time is UTC –4 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		1.3
Dec 30. 2015	02:00		1.6
Dec 30, 2015	04:00		4.4
Dec 30, 2015	06:00		7.2
Dec 30, 2015	08:00		7.1
Dec 30, 2015	10:00		4.8
Dec 30, 2015	12:00		2.0
Dec 30, 2015	14:00		1.7
Dec 30, 2015	16:00		4.1
Dec 30, 2015	18:00		7.0
Dec 30, 2015	20:00		7.4
Dec 30, 2015	22:00		5.2
Dec 31, 2015	00:00		2.2
Dec 31, 2015	02:00		1.3
Dec 31, 2015	04:00		3.3
Dec 31, 2015	06:00		6.2
Dec 31, 2015	08:00		7.4
Dec 31, 2015	10:00		5.8
Dec 31, 2015	12:00		3.0
Dec 31, 2015	14:00		1.6
Dec 31, 2015	16:00		3.0
Dec 31, 2015	18:00		5.8
Dec 31, 2015	20:00		7.3
Dec 31, 2015	22:00		6.1

Cairns, Australia (local time is UTC +10 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		1.95
Dec 30. 2015	02:00		2.34
Dec 30, 2015	04:00		2.35
Dec 30, 2015	06:00		2.06
Dec 30, 2015	08:00		1.66
Dec 30, 2015	10:00		1.47
Dec 30, 2015	12:00		1.47
Dec 30, 2015	14:00		1.57
Dec 30, 2015	16:00		1.63
Dec 30, 2015	18:00		1.58
Dec 30, 2015	20:00		1.48
Dec 30, 2015	22:00		1.50
Dec 31, 2015	00:00		1.76
Dec 31, 2015	02:00		2.08
Dec 31, 2015	04:00		2.26
Dec 31, 2015	06:00		2.17
Dec 31, 2015	08:00		1.85
Dec 31, 2015	10:00		1.51
Dec 31, 2015	12:00		1.36
Dec 31, 2015	14:00		1.44
Dec 31, 2015	16:00		1.59
Dec 31, 2015	18:00		1.72
Dec 31, 2015	20:00		1.71
Dec 31, 2015	22:00		1.64

London Bridge, England (local time is UTC +0 hours)

Date	Time (hh:mm, UTC)	Local Time (hh:mm)	Water Level (m, relative)
Dec 30, 2015	00:00		2.01
Dec 30. 2015	02:00		4.71
Dec 30, 2015	04:00		6.41
Dec 30, 2015	06:00		5.64
Dec 30, 2015	08:00		3.25
Dec 30, 2015	10:00		1.28
Dec 30, 2015	12:00		1.02
Dec 30, 2015	14:00		3.69
Dec 30, 2015	16:00		6.05
Dec 30, 2015	18:00		6.10
Dec 30, 2015	20:00		3.50
Dec 30, 2015	22:00		1.66
Dec 31, 2015	00:00		1.56
Dec 31, 2015	02:00		4.12
Dec 31, 2015	04:00		5.84
Dec 31, 2015	06:00		6.11
Dec 31, 2015	08:00		3.77
Dec 31, 2015	10:00		1.82
Dec 31, 2015	12:00		0.90
Dec 31, 2015	14:00		2.91
Dec 31, 2015	16:00		5.26
Dec 31, 2015	18:00		6.39
Dec 31, 2015	20:00		4.11
Dec 31, 2015	22:00		2.20

Pago Pago, American Samoa (local time is UTC –11 hours)

Date	Time (hh:mm, UTC)		Water Level (m, relative)
Dec 30, 2015	00:00		0.746
Dec 30. 2015	02:00		0.499
Dec 30, 2015	04:00		0.438
Dec 30, 2015	06:00		0.661
Dec 30, 2015	08:00		0.924
Dec 30, 2015	10:00		1.076
Dec 30, 2015	12:00		0.884
Dec 30, 2015	14:00		0.57
Dec 30, 2015	16:00		0.374
Dec 30, 2015	18:00		0.51
Dec 30, 2015	20:00		0.752
Dec 30, 2015	22:00		0.946
Dec 31, 2015	00:00		0.863
Dec 31, 2015	02:00		0.623
Dec 31, 2015	04:00		0.423
Dec 31, 2015	06:00		0.521
Dec 31, 2015	08:00		0.791
Dec 31, 2015	10:00		0.974
Dec 31, 2015	12:00		0.941
Dec 31, 2015	14:00		0.658
Dec 31, 2015	16:00		0.448
Dec 31, 2015	18:00		0.447
Dec 31, 2015	20:00		0.652
Dec 31, 2015	22:00		0.867