

## ISS orbit projected onto a map

<b>Subject/Grade Level:</b>	Space and the Solar System / Middle School (Grades 6-8)
<b>Lesson Objective(s):</b>	To understand orbital motions of satellites using the International Space Station.
<b>Materials:</b>	<ul style="list-style-type: none"> <li>• ISS Above (set-up and ready to go)</li> <li>• Sharpies, black and red</li> <li>• Sticky tape</li> <li>• Scissors</li> <li>• 10 oranges, elastic bands, knife and kitchen roll/hand wipes (messy)! OR</li> <li>• Aluminum soft drink cans with scaled world map printout OR</li> <li>• World map (provided for printing out)</li> </ul>
<b>NGSS Essential Standards and Clarifying Objectives:</b>	<p><b>NGSS Essential Standards and Clarifying Objectives:</b></p> <p><u>MS-ESS1-2:</u> Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.</p> <p><b>Science and Engineering Practices:</b></p> <ul style="list-style-type: none"> <li>• Developing and Using Models Modeling in G6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena.</li> </ul> <p><b>Disciplinary Core Ideas:</b></p> <ul style="list-style-type: none"> <li>• <u>ESS1.A:</u> The Universe and Its Stars Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.</li> <li>• <u>ESS1.B:</u> Earth and the Solar System The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.</li> </ul> <p><b>Crosscutting Concepts</b></p> <ul style="list-style-type: none"> <li>• Systems and System Models <ul style="list-style-type: none"> <li>✓ Models can be used to represent systems and their interactions.</li> </ul> </li> <li>• Connections to Nature of Science <ul style="list-style-type: none"> <li>✓ Scientific Knowledge Assumes an Order and Consistency in Natural Systems Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.</li> </ul> </li> </ul>
<b>Differentiation strategies to meet diverse learner needs:</b>	<ul style="list-style-type: none"> <li>• <u>Think-pair-share</u>, for students that learn best when engaging with classmates.</li> <li>• <u>Multisensory learning</u>, to accommodate students that are auditory learners and visual learners, as well as encourage students to engage their senses in the learning process.</li> <li>• <u>Awareness of social and cultural backgrounds</u> of students to reinforce the real-life application of what they are learning.</li> </ul>
<b>Student Worksheet</b>	Worksheets for Option A and Options C. Option B available online.

## ENGAGEMENT

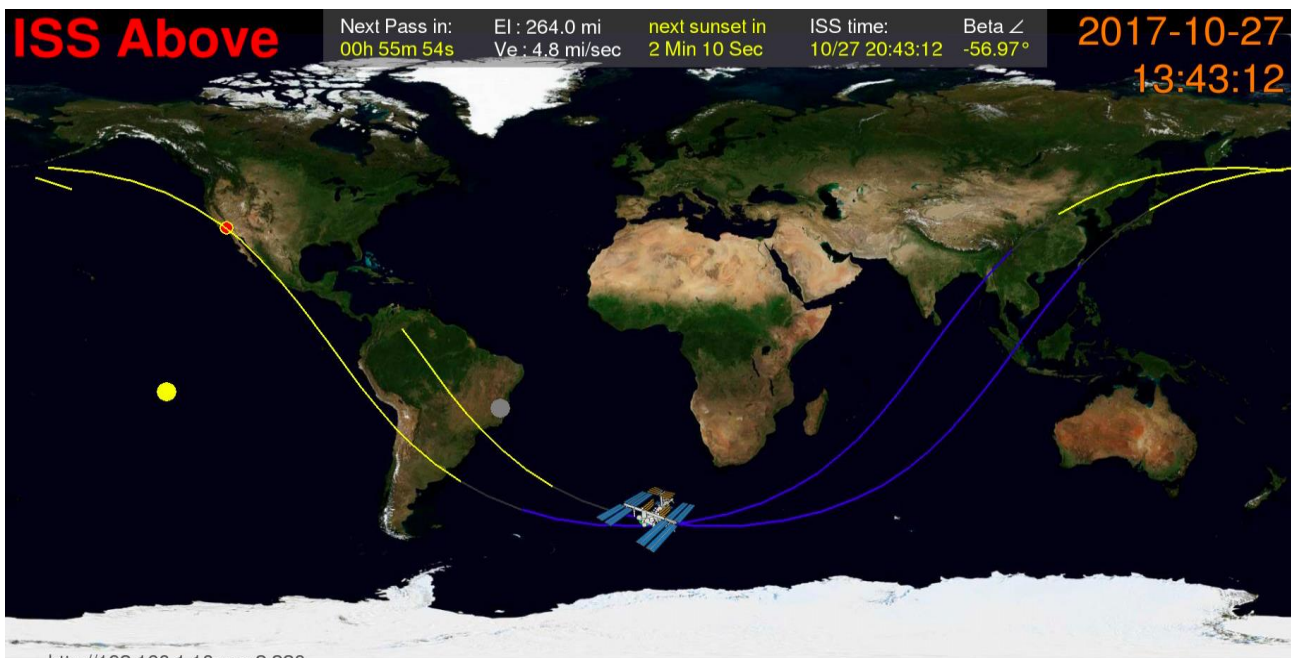
To engage students in this lesson, first make sure that the ISS Above is properly installed and ready-to-go in the classroom.

Have students look at the world map/orbital screen from the ISS Above (see screenshot below). Note: pressing "3" on your remote will set the screen to display this.

## Questions

1. What do students notice?
2. What patterns do students observe in the movement of the ISS around the planet Earth?
3. Do they notice the ISS icon moving?
4. How would students describe the shape of the orbit path taken by the ISS? Is this how the ISS moves around the Earth?

## ISS-ABOVE orbit on a Mercator Map



## EXPLORATION

### The ISS Orbit on a Mercator Map

Have students do one of the following exercises (see Student Worksheet) to get acquainted with the orbital path the ISS follows around Earth and how it is illustrated on a Mercator map. Students will draw a circle around a spherical object (e.g. an orange) or a cylindrical map (such as a map wrapped round a can) or plot the ISS wave track as shown on the ISS-ABOVE.

1. Option A: Use an orange to draw a circular orbit, then peel the fruit to create a Mercator Map (see example below). Team of 3-4 recommended. They can each eat part of the orange.



Fig 1 – Orange with Equator and GMT / 180° circle



Fig 2 – Orange with Equator and my location dot



Fig 3 – Orange with black circle (ISS orbit)



Fig 4 – Orange Mercator map showing wave orbit

2. Option B: Take a Mercator Map (basically a flattened map) of the Earth and create a print-out of it to wrap around a can (see links provided courtesy of Sally Ride EarthKAM).
3. Option C: Use the full-page printout of the world map to draw the orbit as shown on the ISS-ABOVE world map/orbit screen, then rolled into a cylinder (see Supporting Materials for the map).

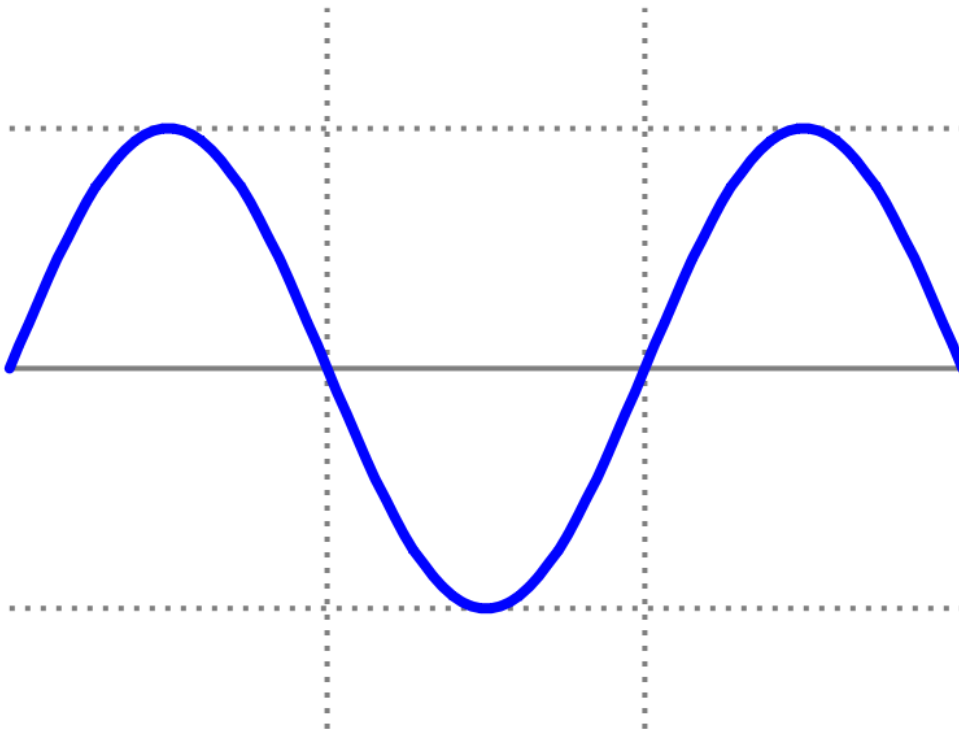
## EXPLANATION

Explain to students that the reason why the ISS orbit looks like a *wave* is because an orbit is three-dimensional and moves around the Earth or any spherical object in a **circular** orbit, but when it's projected onto a two-dimensional (Mercator) map of the world, it flattens and looks like a sinusoidal wave.

OPTIONAL: Use the video <https://www.youtube.com/watch?v=8-mKLs2b3MM> to show that the ISS orbit really is a circle. Note: each orbit takes around 92 minutes, approx. 16 orbits per 24 hours.

OPTIONAL: Show this very short 8 second (blink and you'll miss it) video which animates a circular orbit into a Mercator map. <https://www.youtube.com/watch?v=ITILmcrrU0A>

The ISS orbit projected onto a Mercator map can be predicted in mathematics using a *sinusoidal* wave described by the function  $\sin(x)$ . A sinusoidal wave looks like this:



What other situations show up as a sine wave or an approximation to one? (Ripples on a pond, tuning forks, AC electricity.)

## EVALUATION

Choose from 2 videos:

1. A full explanation of how the 3D Earth and ISS orbit maps to a 2D Mercator map. Potential use for students who need additional support in understanding the 3D to 2D problem or as a wrap up. NOTE: The green circle around the ISS is the area of the Earth that the astronauts can see from ~250 miles up.

<https://www.youtube.com/watch?v=JyfEffMrgII> Video 5:30min

OR

2. Astronaut Don Pettit from Expedition 30 describes the orbital trajectory around Earth and how that projects onto a map. Play time 6 minutes.

<https://www.youtube.com/watch?v=hO9-WqSK5HM> Video 6 min

## Questions

1. Why does the ISS-ABOVE screen show a sine-wave orbit even though the real orbit is circular?
2. How would you demonstrate that the orbit is circular using a 2D map of the world?

## Student Worksheets

**OPTION A:** Oranges worksheet – see attached

**OPTION B:** Aluminum can map/exercise

Use the Teacher document below (courtesy of Sally Ride EarthKAM for a printout of a map that fits a soft drink can.

[https://www.earthkam.org/dls/8\\_EarthKAM%20activities/EK\\_GroundTracks\\_Teacher.pdf](https://www.earthkam.org/dls/8_EarthKAM%20activities/EK_GroundTracks_Teacher.pdf)

Student work sheet is below:

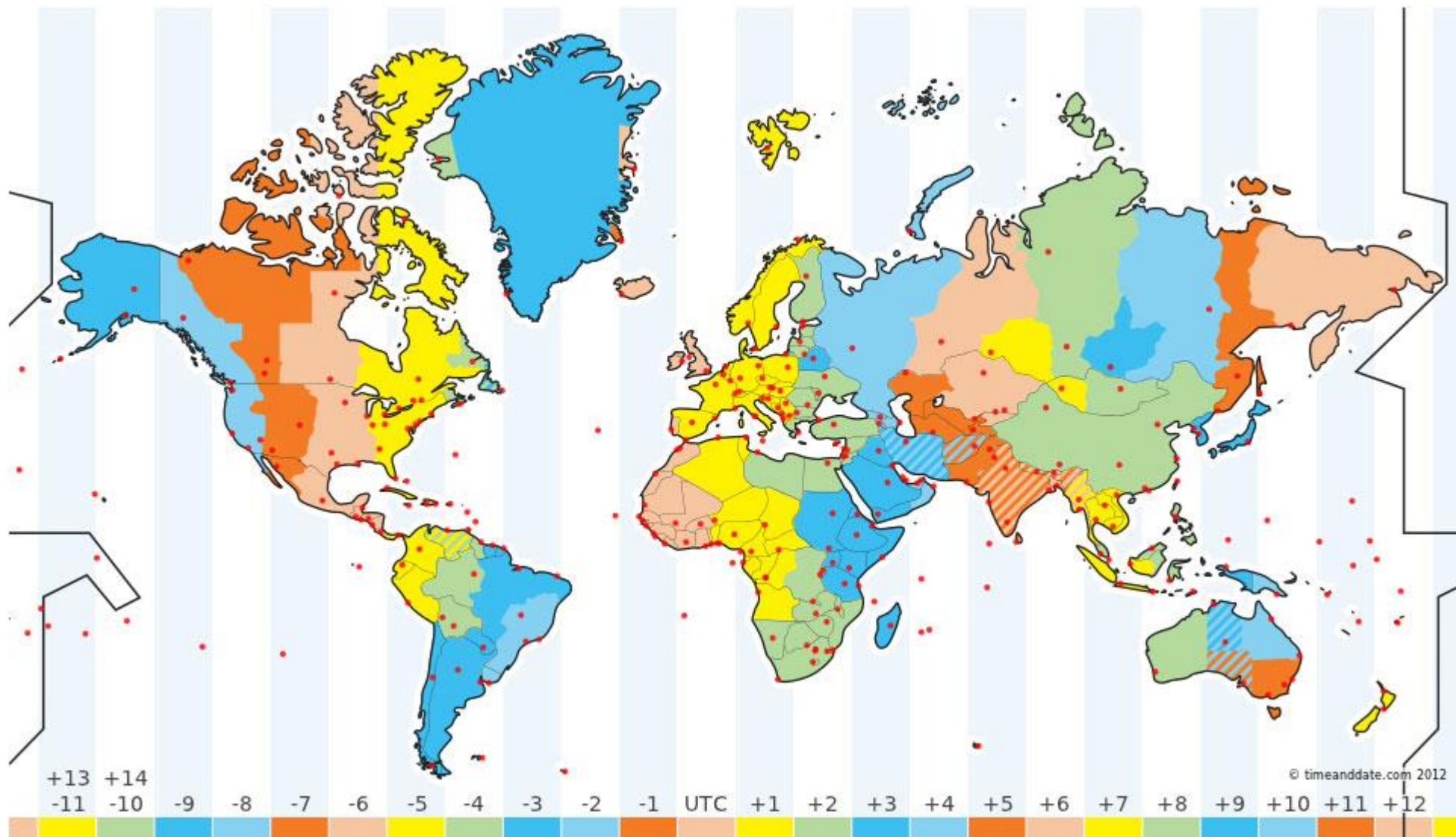
[https://www.earthkam.org/dls/8\\_EarthKAM%20activities/EK\\_GroundTracks\\_Student.pdf](https://www.earthkam.org/dls/8_EarthKAM%20activities/EK_GroundTracks_Student.pdf)

**OPTION C:** World map for 8.5"x11" paper (see next page)

The world map (courtesy of timeanddate.com) prints well in grayscale using black ink only. FYI, the dots are major cities and the colors indicate that the time zones are distorted for practical purposes. Unit 4 does more work on time zones.

Additional materials: A sheet on latitude/longitude is provided in the Additional Resources section.





By kind permission of timeanddate.com

## Student Worksheet – OPTION A: The Orange Mercator Map

This experiment allows your team of 3-4 to convert a spherical orange with a circular orbit into a Mercator map with a sine-wave orbit. Each team member does one step.

**STEP 1:** Take an elastic band and put it around the 'waist' of your orange. Using a red Sharpie, draw an equator around your orange using the elastic band as a guide. Now move the elastic band and put it around the 'poles' of your orange. Draw a circle at 90° to your equator. This is your GMT line (0° longitude on one side and 180° longitude on the other side). See Figure 1 below.

**STEP 2:** Using a red Sharpie again, mark the position of your school relative to the equator and the GMT circle. See Figure 2 - the example is Los Angeles, CA.

**STEP 3:** Take your elastic band and place it around the orange to represent the orbit of the ISS (you can use the ISS-ABOVE world map/orbit screen to see where the current orbit is). Using a black Sharpie, draw a circle to show the position of the orbit. See Figure 3.

**STEP 4:** Ask your teacher to cut your orange into four (from the north pole to the south, then each half from the pole to pole again). You will have four quarters as in Figure 4. Without touching the lines you've drawn, each student eats away the orange flesh, leaving the skin intact. Lay the four pieces together and you should see the sine-wave shape of the orbit on your orange Mercator map!

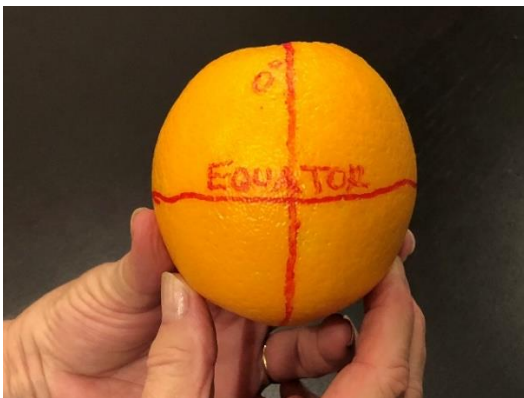


Fig 1 – Orange with Equator and GMT / 180° circle

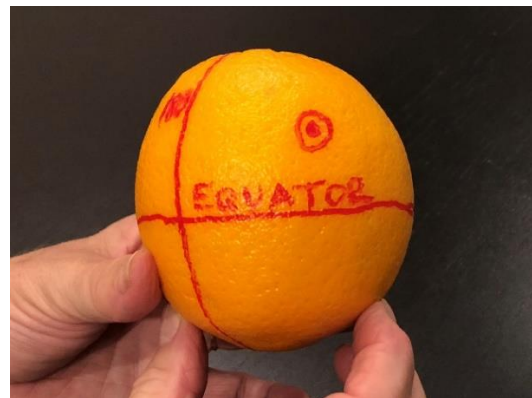


Fig 2 – Orange with Equator and my location dot



Fig 3 – Orange with black circle (ISS orbit)

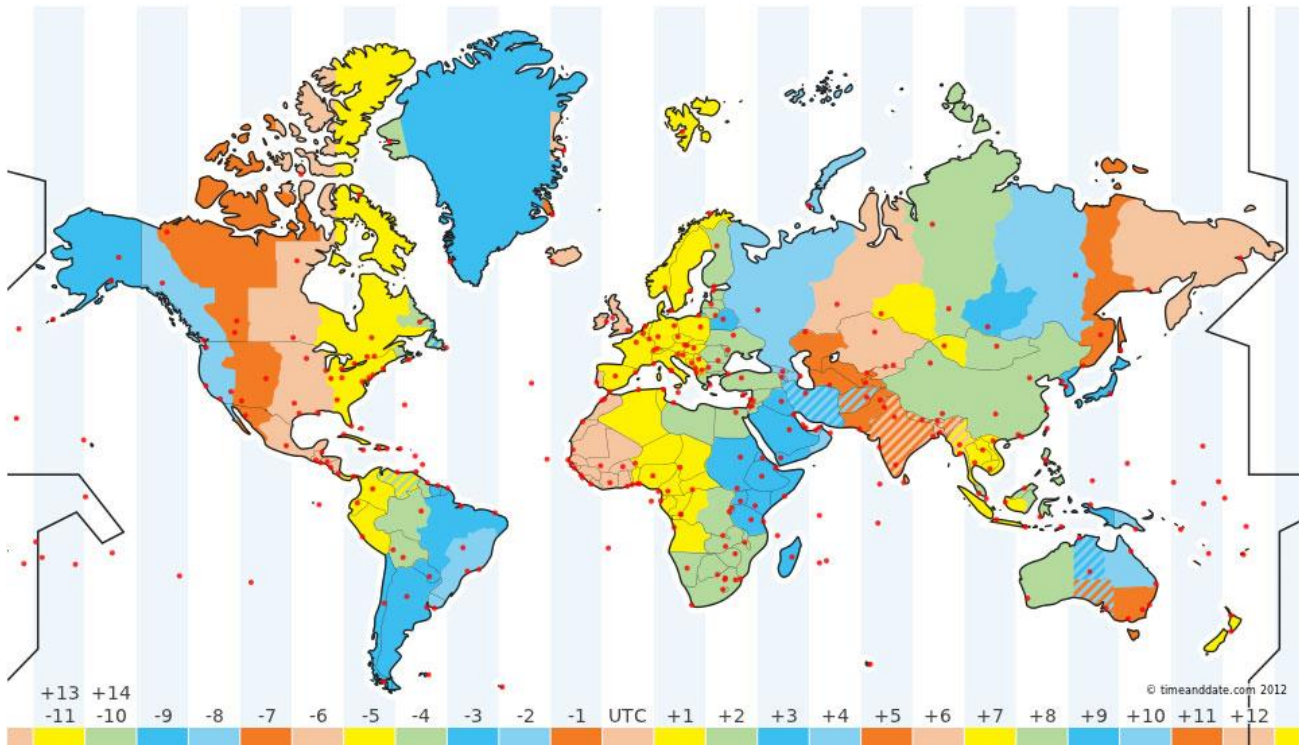


Fig 4 – Orange Mercator map showing wave orbit

## Student Worksheet – OPTION C: The World Map Orbit

This experiment allows your team of 3-4 to plot the ISS orbital path shown on the world map/orbit screen of the ISS-ABOVE onto a world map and then roll the map up to show that the orbit is a circle.

Your teacher will give you a copy of a map that looks like the one below:



Students do one step each:

**STEP 1:** Mark the position of your school on the map with a red Sharpie.

**STEP 2:** Copy the orbit path from the ISS-ABOVE screen onto your world map using a black Sharpie.

**STEP 3:** Cut along the black line on the right-hand side of your map.

**STEP 4:** Roll your map into a cylinder shape and match the shaped right-hand edge to fit the black lines on the left-hand side.

Look at the shape of the orbital path on the rolled-up map. It should be a circle.