Accuracy of Google Earth

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Introduction

This is part two, of a multi part paper. Part one introduced the topic of Early Islamic Qiblas and then examined over 60 early mosques and their Qibla directions. From this data I drew a number of conclusions:

1. There are no existing mosques from the first century AH that point to Mecca in Saudi Arabia. All of the mosques that have not been rebuilt point to Petra in Jordan.
2. During the second century of Islam, there was a time of confusion, with six new mosques pointing between the two cities, and six new mosques pointing parallel, and four new mosques pointing to Mecca.
3. Once the Abbasids took control, their mosques all pointed to Mecca in Saudi Arabia.

In this paper I will begin to address several questions that my readers have raised. First are the questions raised about the accuracy of Google Earth, from which I extracted images to illustrate the first paper.

As always, any mistakes and errors are mine. It is inevitable that when dealing with such a wide breath of information drawn from a life-long study that covers many different countries, over many centuries, errors and omissions will creep in. While I have done my best to eliminate these, I do invite anyone with comments to email me at: research@canbooks.ca.

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Accuracy of Google Earth Ruler

I have been fortunate to be able to live or visit in the Middle East for much of the last thirty years. During this time I have been able to visit a good number of the mosques listed in the first paper. For some the mosques which I could not visit, I have been able to access measurements and GPS readings of other scholars, and for a few I have had personal friends who have been able to visit and take GPS readings. There are a few mosques however, that are located in areas where it has been unsafe to travel because of wars and internal conflicts. For those mosques, which have no published archeological research, I have had to resort to taking measurements using online tools like Google Earth and Earthdata's ASTER. However, at the beginning, let me emphasize, that although I use Goggle Earth images to illustrate my research, I only used online data for a small number of mosques, and only as a last resort.

When I first started using Google Earth I wondered about the accuracy of using such a tool. First, there is Google Earth' own disclaimer about accuracy:

Google makes no claims as to the accuracy of the coordinates in Google Earth. These are provided for entertainment only and should not be used for any navigational or other purpose requiring any accuracy whatsoever. Our imagery varies from sub-meter resolution in major cities to 15 meter resolution for most of the earth's surface, with a global base resolution of 1KM. Since our database is constantly being updated, we cannot state a specific resolution for any geographic region. Google acquires imagery from many different sources with many different file formats, projections and spectral characteristics. All imagery sources are fused into a single global database with a proprietary format that has been developed for the specific purpose of streaming to our client software.

There are several things here that we should take note of. First, Google distances themselves from accuracy claims, obviously so that they do not end up in court battles. Imagine two land owners measuring their property using Google Earth, each deciding where the boundary should be between them. Google Earth must publish such disclaimers, so that they are not involved in such legal disputes. However, at the same time, Google Earth does strive for accuracy, which they are constantly improving.

When considering the issue of accuracy, there are a number of issues that must be dealt with. First, Google Earth's ruler has several uses. It can be used to measure the distance between two points. However, since Google's globe is made up of many square satellite photos mounted on a circular globe, they struggle with a host of problems.

Let's start by considering how accurate a measurement on an image can be. If the resolution of a satellite image pixel is 1 square meter on the ground, and if you are zoomed in far enough to see individual pixels (original, not re-sampled for display purposes), you can measure to within +/- 1 meter. Now let's get that into GIS, which requires both orthorectification and georeferencing. Both can introduce small errors. On top of which, you're looking at errors introduced by (re)projection onto your computer screen.

Now you must put this one image into Google Earth and mix it thousands of other images, all of which may vary in their original resolution and quality. Google then mashes them together to make what appears to be a seamless interface. This is one reason why Google has a disclaimer about accuracy.

All of that is just for the accuracy of the imagery you're measuring from. Then add in the user interface:
- How far out are you zoomed when you do your measurements?
- Far enough in to see those individual original pixels, if they're even available to you?
- Or out far enough to see the entire mosque? or the mosque and its surroundings?
- What display resolution is your computer running?
- how accurate/precise is your hand with the cursor as you mark Qiblas and their direction?

What distortions are introduced by the projection(s) Google Earth uses may change depending on where you are looking and how far out you are zoomed. The best you can do is find something of known distance near your mosque and see what it measures at to estimate the error in that area. This is why visiting a mosque and taking measurements is so important. You can later compare you "on the ground" measurements with the satellite images.

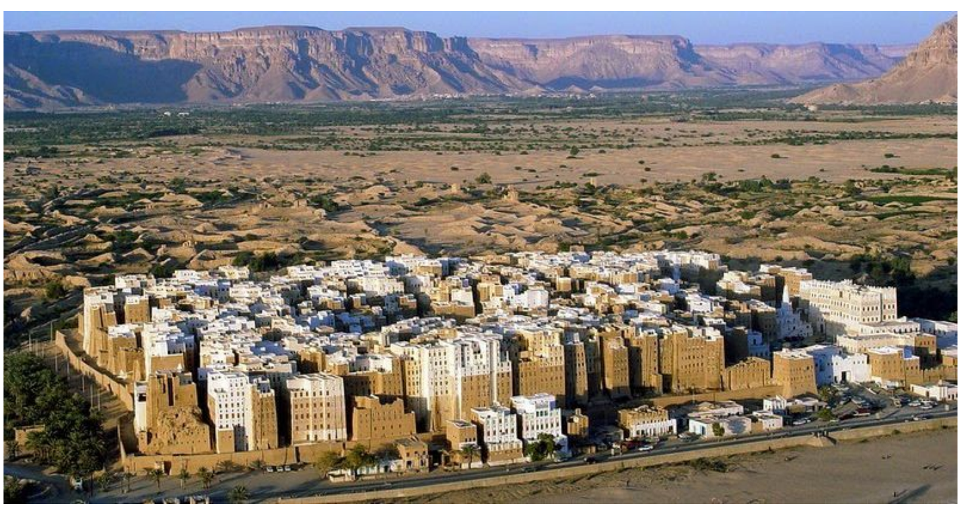
To test this, one user measured the area of an individual farm using the Google Ruler and compared it to the legally defined area of his property contained on the title deeds (2334,6Ha) at the highest resolution possible on GEP (2299.7Ha). He discovered that the "accuracy" in this instance was 98.51%; ie ~1,5% error. That is for measuring with straight lines.

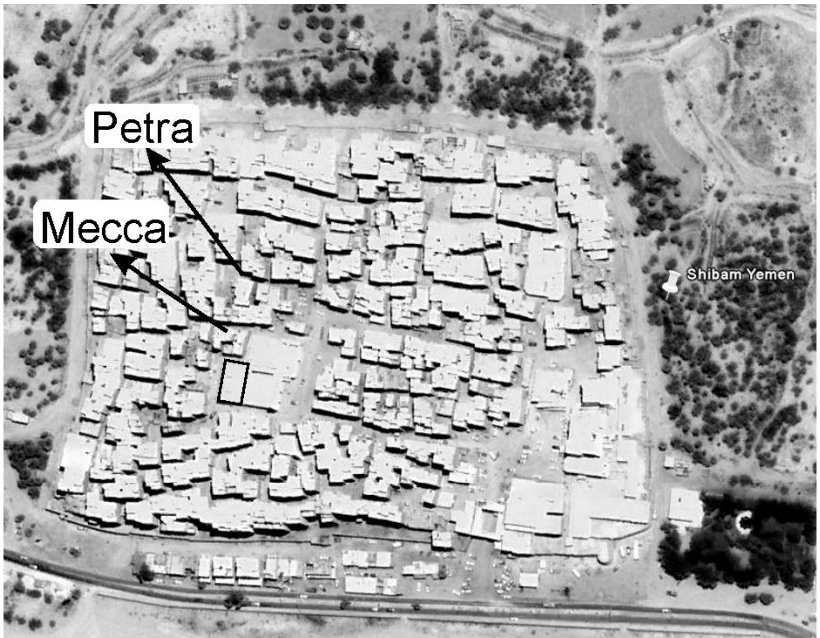
Now comes a tricky part. When you are looking at Google Earth, you are not actually looking at a single satellite photo. For instance, when I am zoomed out at 700 miles and look down on the city of Vancouver, the image is dated from December 1969, and is labeled Data LDECO-Columbia, NSF-NOAA, Image Landsat, Data SIO NOAA, US Navy, NGA, GEBCO.

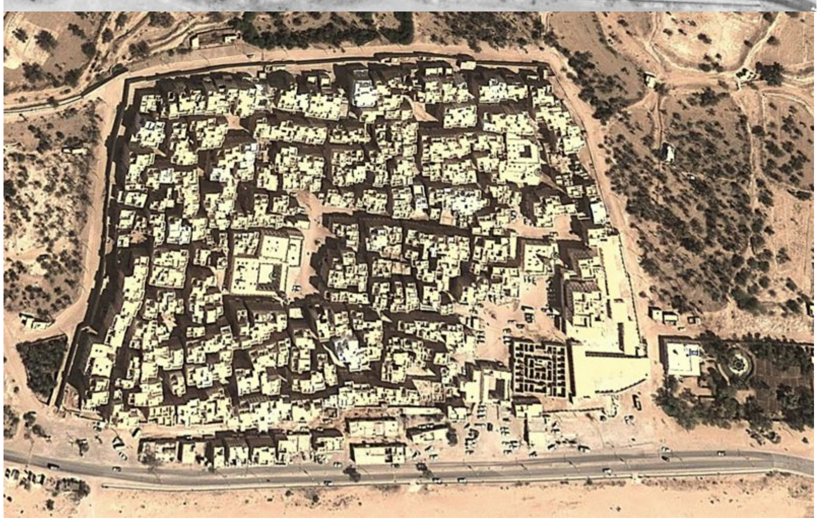
However, as I zoom in to about 50 miles, I am suddenly looking at an image dated December 2015. However, if I move a bit over and look down on Mount Baker, the image changes to 2013. So there are not just multiple images, but also multiple images on different layers from different dates.

As I move over the globe at a given altitude, say 37 thousand feet I can discover the edge of some of the images, because the date changes. Since Google Earth has customers who pay for specific data, the images over some cities are far more numerous and complex than the images over wilderness or desert.

Now, on top of this, I have noticed that some of the images I captured seven years ago have been removed and replaced by more modern images. And to make it even more complex, in some of the images, the angle of the satellite looking down from space is different. Consider the two images in the next page. The first image is from Google Earth over the walled city of Shibam in Yemen in 2009. The second image came from Google Earth in 2016. There are differences. As you check out the photos, remember that many of these mud buildings are 8 and 9 stories tall.

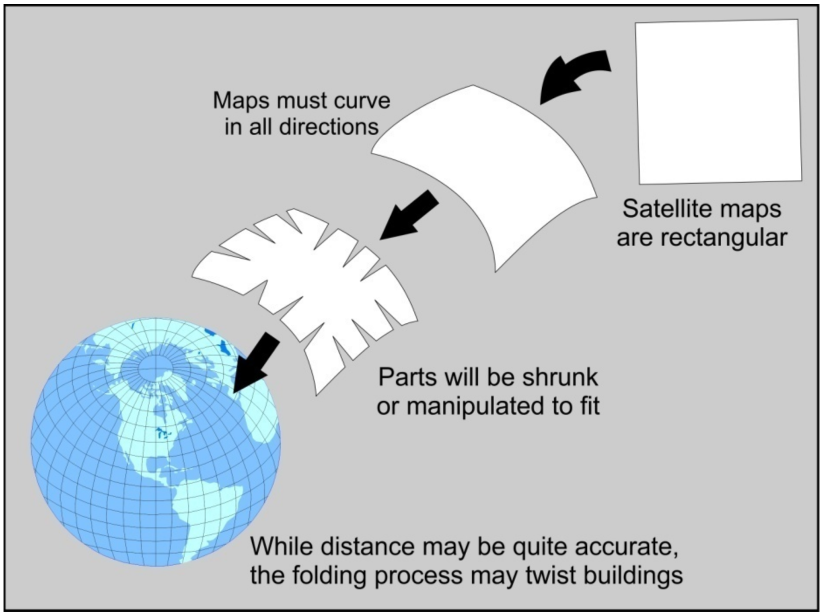




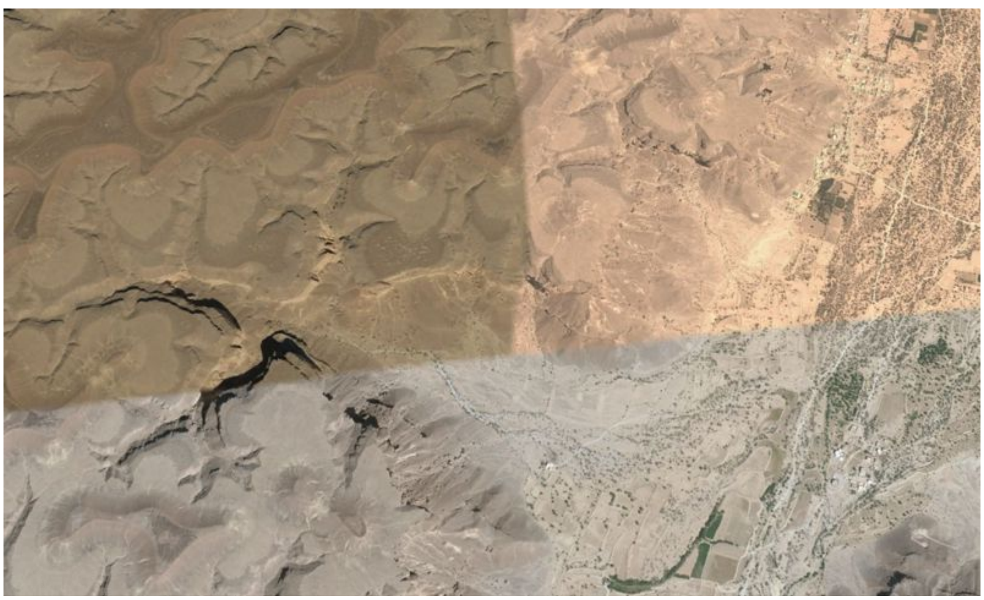


Note some of the changes. The second image is from a different perspective. The 2009 image was taken from almost directly above, but in the 2016 image, the satellite is positioned differently allowing you to see the sides of the buildings. While the newer image has higher resolution, the angles of the buildings are different so that we cannot look directly down. This is very important for when measuring mosque qibla angles.

While Google has not revealed how its images are placed and welded together, the issue of placing a square image onto a convex surface also requires that the image be manipulated. Google is not saying how this manipulation is being done, but it is obvious that it can affect accuracy at the edges of the image.



The image below is taken from Google Earth, showing the borders where different satellite photos are brought together.



It is fascinating to see how images of different resolutions and different angles are brought together to make the Google world appear to be seamless. However, the seams are sometimes blurred as Google tries and bring similar objects together. Given the thousands of maps involved, I would imagine that this is done by computers and complex algorithms.

In 2016 I approached Google and asked them about the issues being raised concerning the accuracy of using Googel earth to plotting qilbas. They explained to me that Google Earth internally uses the WGS84 datum. That means its model of the planet is a spheroid. That's better than just a sphere, but still only an approximation of the actual shape of the planet. Complicating things further, there are variables like continental drift adding effects that change over time.

On the question of accuracy they said that in most places, the imagery in Google Earth is located to within 100 - 200 meters of what you'd get with a GPS. In some remote places or places where there's not a good tie-point (eg. islands) it can be worse, but generally the misplacement is under 20 meters. In Mecca some features have a displacement of ~15 meters between the imagery they had in 2004 and the imagery now in 2016.

When I asked them what model the ruler tool uses, and what it mean to "face" a direction on a spheroid they replied: *The ruler uses a geodesic line. That means a line that follows the great circle distance (shortest path) between two points. On a sphere, this can be very counter-intuitive. For instance, the shortest-distance path from San Francisco to Mecca is nearly due north (9 degrees), up and over the north pole (and that's 9 degrees from the sphere's center of rotation, not magnetic north, which also moves around and varies from location to location).*

They suggested that instead of trying to measure "direction" on a sphere, people instead should use "direction preserving" projections.
See http://www.progonos.com/furuti/MapProj/Normal/CartProp/Rhumb/rhumb.html.
But, they added, as points get farther and farther apart, it becomes less and less clear what "direction" means.

Having said all this, several things seem apparent:

1. Google Earth provides us with an excellent overview of places and situations that is readily available to the public. In locations where Google Earth has done in-depth research the accuracy is higher, as there are more higher resolution images available, and more good good tie-points with actual GPS readings. I have found this to be true. When measuring the distance from point A to point B in the Middle East, Google Earth is very accurate. Even over very long distances, they can be accurate to within ~200 meters. My son who at this writing is in the Middle East made measurements with his GPS, and communicated with me in my office in Canada. He would measure short distances and various way-points on the ground,

and we discovered that these favorably compared to the measurements on Google Earth Professional.

2. When using Google Earth's ruler, measuring the accuracy of the "heading" tool is more difficult. So much depends on how the tool is used. For instance, when zoomed in close to a structure, the tool provides a line that is one pixel wide. The accuracy of this pixel depends on the resolution of the map. When one zooms out and then heads for another location, the width of the yellow line varies according to the resolutions of the images it is passing through. So in short, the best way to measure the axis of a mosque is to visit the site, and use a dedicated GPS unit rather than Google Earth.

3. Google Earth, however, is an excellent tool for making illustrations. In my research I have used Google Earth images to illustrate the direction of Qiblas. When I first started collecting data, I did careful study of mosques, visiting them and taking GPS readings. After I realized that the majority of them were facing Petra in Jordan, I began to also include a line from Mecca and Petra back to mosques to see if Petra could be where they were pointing. So in my paper "Early Islamic Qiblas" when illustrating mosques, I have sometimes begun in Mecca or Petra and have brought the lines back to the mosque under examination, to demonstrate the Qibla direction of these places. Not surprisingly these Google Earth images are very close to the data we found when examining the mosque on the ground.

4. While Google Earth is an easy solution for making illustrations, better tools are available for measuring. For online measuring I prefer to use Earthdata's ASTER. This is the Japanese Advanced Thermal Emission and Reflection Radiometer, or ASTER. It is an instrument on board NASA's *Terra* spacecraft. NASA launched the *Earth Observing System's* flagship satellite "*Terra*," named for Earth, on December 18, 1999. Terra has been photographing the earth since then. Terra carries five state-of-the-art sensors that have been studying the interactions among the Earth's atmosphere, lands, oceans, and radiant energy. The map it produces is called a global digital elevation model and the satellite images the entire Earth every 1 to 2 days

Because ASTER uses images taken from a single high quality camera on one satellite, at one elevation, it does not have the problem of multiple images at multiple elevations. Second, because ASTER takes long seamless images around the earth, it has fewer issues with overlapping or connecting images. ASTER also provides high-resolution images of planet

Earth in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The resolution of images ranges between 15 and 90 meters.

An update to the ASTER data adds 260,000 images to the already-expansive map, and improves basically every measurement—spatial recognition, horizontal and vertical accuracy, and recognition of bodies of water. The map covers 99 percent of Earth's landmass, and its measurement points are just 98 feet apart.

The ASTER data has been validated by NASA, METI, Japan's Earth Remote Sensing Data Analysis Center (ERSDAC), and the U.S. Geological Survey, and the U.S. National Geospatial-Intelligence Agency, but users are still warned that there will be a few "anomalies and artifacts" that limit its use for certain projects.

Therefore, for research purposes I applied for permission to use ASTER data, and only use Google Maps for illustrations. But for the best measurements, noting tops visiting the mosque and checking it with a good GPS unit, before checking the same points on Google Maps.

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