Visualizing the surface of the Earth

Abstract

In this paper we implemented two methods to visualise the height of the surface of the Earth: by warping it and by using isolines with 1000 meters increments. These isolines were wrapped into tubes for better visualisation. Two scales were provided to change the scale of the warp and to adjust the radius of the tubes. We found that while both approaches have various pros and cons, the best visual outcome was achieved by combining them.

1 Introduction

The motivation behind this study was to compare and investigate the advantages and disadvantages of two height representation (by warping and by isocontours) of the Earth's surface using an interactive visualisation tool called VTK. The Earth's texture, bathymetry and topography data were provided by NASA. To run the program, after making sure VTK library is installed, navigate to the directory of the program file in command line and run the *earth.py* python file as follows:

python3 earth.py heights.vtp texture.jpg

where the *heights.vtp* is the elevation data and the *texture.jpg* is the image of the Earth's surface.

2 Height maps by warping

By warping the Earth's surface (sphere) with VTK warp filter according to the elevation data provided by NASA, we could make use of the 3rd dimension and hence represent heights and depths on the sphere. The elevation scale was designed to be adjusted interactively in the range of 0 to 200. Figure 1 shows some examples of the Earth using the warp filter with various elevation scale. On the right side of the Earth one can clearly see the elevations caused by the warp. To study this warp effect on close-up visuals, we obtained images of Europe as seen on Figure 2. Since we used more moderate scale values (10.5, 28.6 and 60.5) than before, the elevation is not as exaggerated as in Figure 1, however one can clearly spot the difference in heights and depths by comparing the images. The elevation of the Alps to the North of Italy is clearly apparent, furthermore the changes in depths of the Mediterranean sea are also evident.

Investigating the highest point on Earth in our model seemed to be an interesting idea, thus on Figure 3 we show the Himalaya mountain range. It is unmistakable how it suddenly drops in height on the north part of India and Nepal.

Overall we found that an optimal, pleasant-to-eye scale value should be somewhere between 25 and 55, moreover that higher scale values produce not just unrealistic results (relative too big elevations or decreases), but also huge spikes in heights and depths due to the provided dataset not being dense enough. If we had a denser dataset, one derive a smooth surface even for higher scale values, however it could still remain unrealistic.

3 Hight maps by isocontours

Another way of visualising elevations is by using isolines and colormaps. In our study we created isolines every 1000 meters starting from -10000 up to 8000 meters. However, just by doing this without any indication would not yet produce useful information, since we would only see a clutter of lines of the same color blending into the texture of the Earth. What one could do, which is a common technique, is to display the value of the given isoline on the line itself. Still, this would work only if the underlying background is clearly different to that of

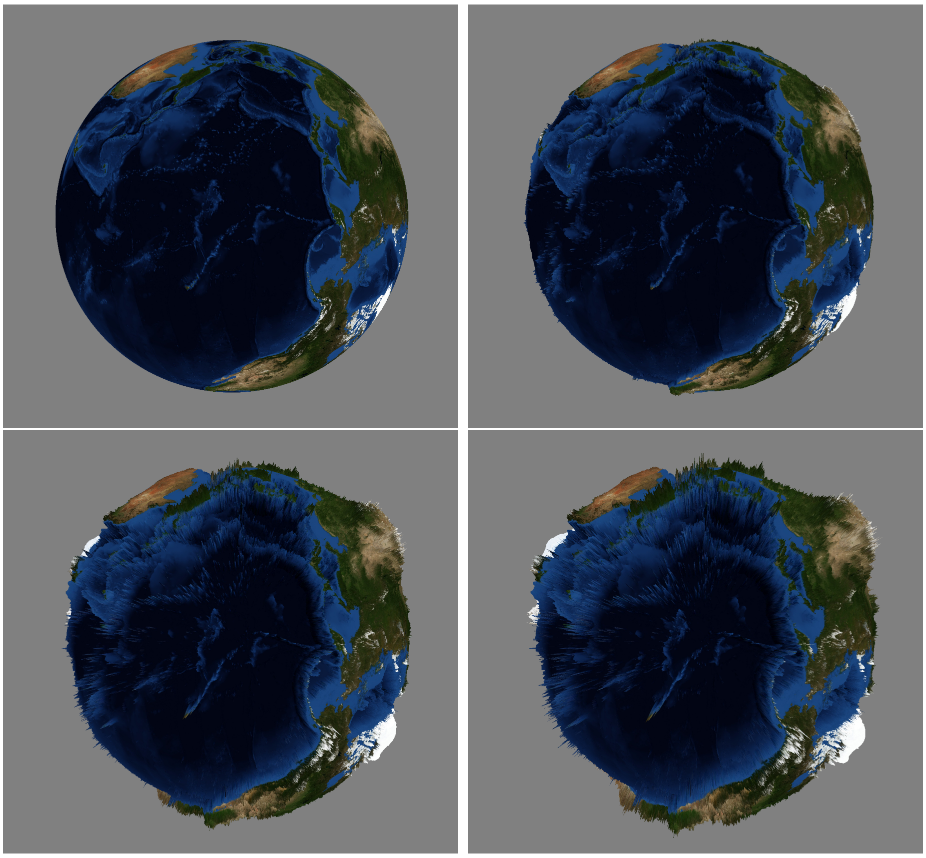

Figure 1: Representing the depths/heights of the Earth using the warp filter from VTK with various elevation scales: top-left scale: 0, top-right scale: 52.3, bottom-left scale: 137, bottom-right scale: 200.

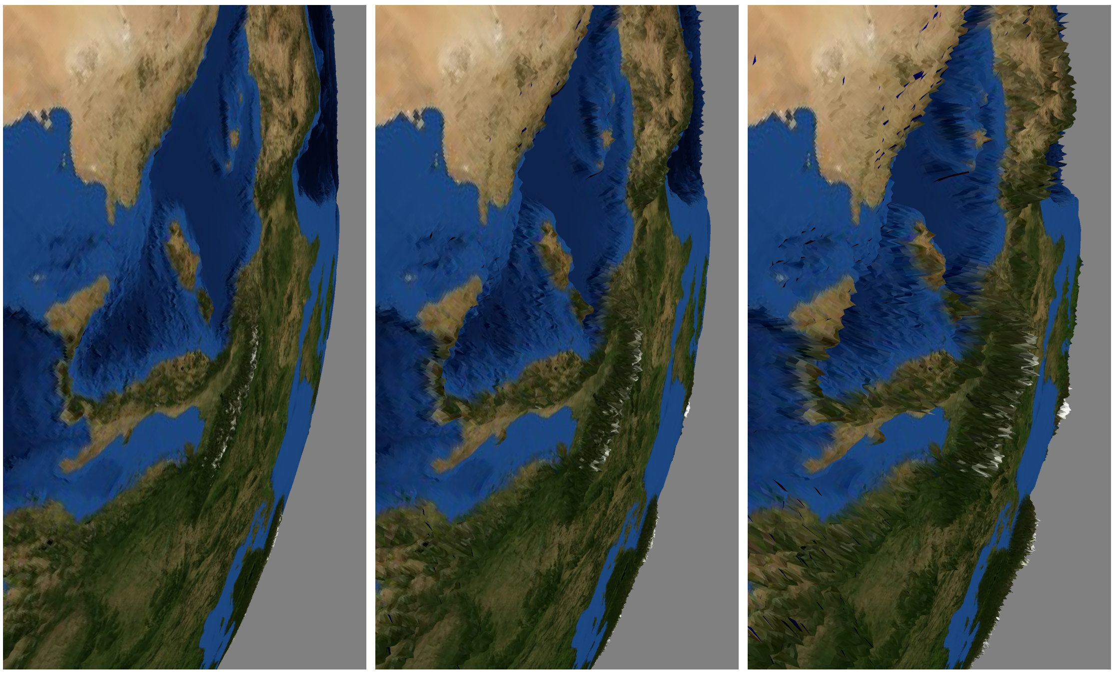

Figure 2: Representing the depths/heights Europe using the warp filter from VTK with various elevation scales: left scale: 10.5, middle scale: 28.6, right scale: 60.5.

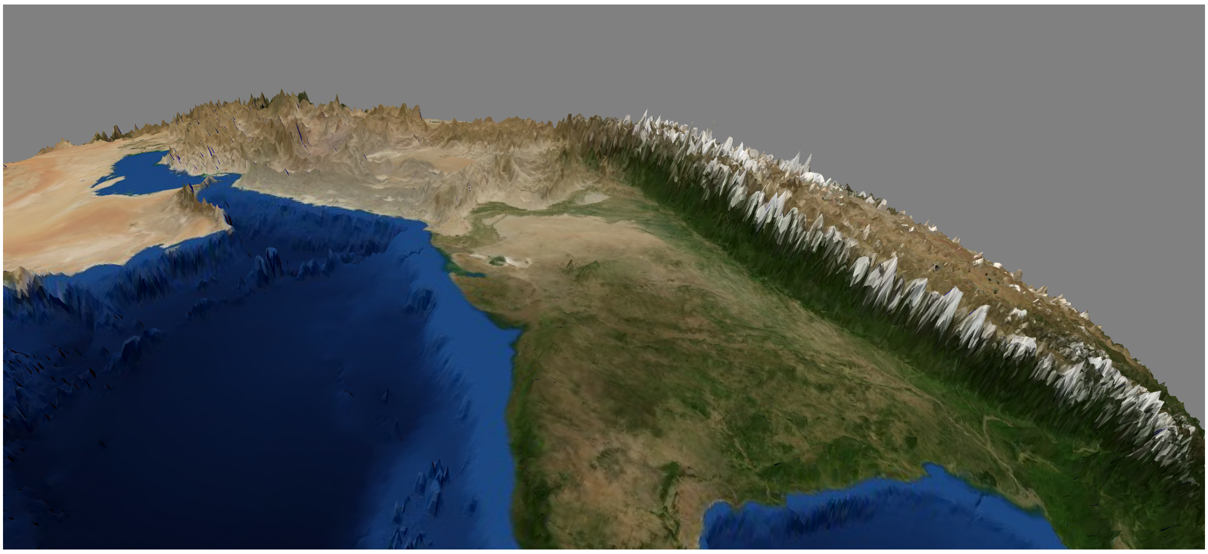

Figure 3: The Himalaya, the highest mountain range on Earth using the height maps by warping the surface. The elevation scale is 49.1.

the isoline. Another way to make this distinction between isolines and the background texture without having to display values is by using a colormap which represents the isovalues. The downside of this method is that the corresponding values would not be immediately available on the map itself (less precise), but would need to be looked up (e.g. through a legend), still, it gives a better visualisation of the overall height map of a region (or the entire planet).

Hence we colored our isolines, by interpolating between blue (at -10000 meters) and yellow (at 8000 meters). In addition, to indicate the sea-level, we used red color for isolines of height 0. At this point the isolines were correctly representing the elevation data, yet due to them being thin, they were not always visible. Moreover, their thickness remained the same thin lines, relative to the window, as we zoomed in, making them unpleasant for the eye to focus on. Therefore, we wrapped these isolines into tubes using a tube filter from VTK, turning the isolines into "isotubes", whose radii could be adjusted interactively, making them thicker (and more visible) or thinner. Figure 4 demonstrate our "isotubes" with various radii. Even though on the left image the tubes have non-zero radii, the contours are almost invisible. On Figure 5 we looked at a close up image of Japan to study at how varying the radius of tubes would affect visibility.

Interestingly, while for the long shot Earth image the tubes with large radii (relative to our max radius size) proved to be clearer and more visible for the eye, we found that for close up images, like the one of Japan, a small to medium (relative to our max radius size) radius size gave better results than the greater ones. This is due to the powerful property of the tubes that they do not change in size as we zoom in or out of the Earth, they remain the same, relative to the surface, as opposed to the simple isolines earlier. That is, if in a long shot image the tubes with large radii gave satisfying results, as we zoom in to the close up image we find that we zoom in the tubes as well (as opposed to earlier). Hence a medium sized tube in a long shot image became larger in the close up image as we zoomed in. An example of this is shown on Figure 6: by zooming into the left-most image we obtained the middle-left close-up image, where the tubes were overlapping/blocking one another and in some parts making it hard to see what was happening. Then we reduced the radii sizes to derive a more pleasant image (middle-right), but when we zoomed back out to the long shot Earth (right-most), these smaller radii tubes almost vanished in comparison to the left-most Earth image.

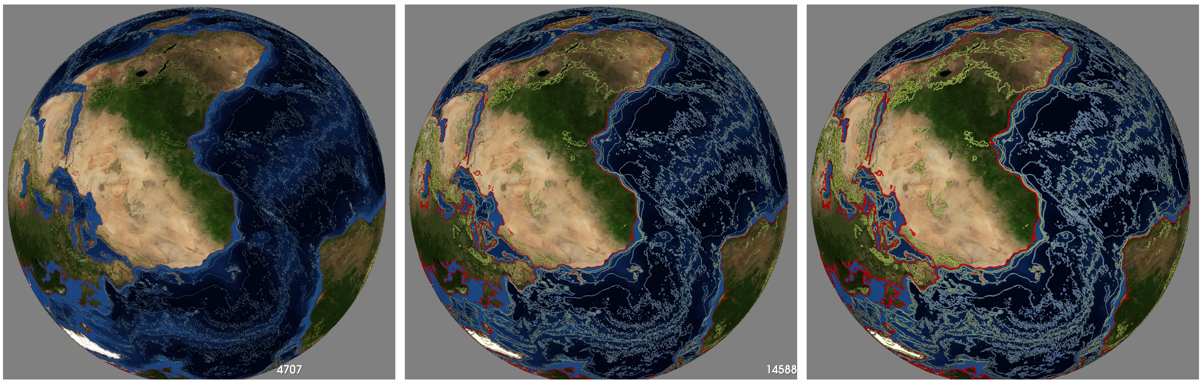

Figure 4: Earth surface elevation represented using isolines wrapped into tubes with varying radii: left: 4707, middle: 14588, right: 26054.

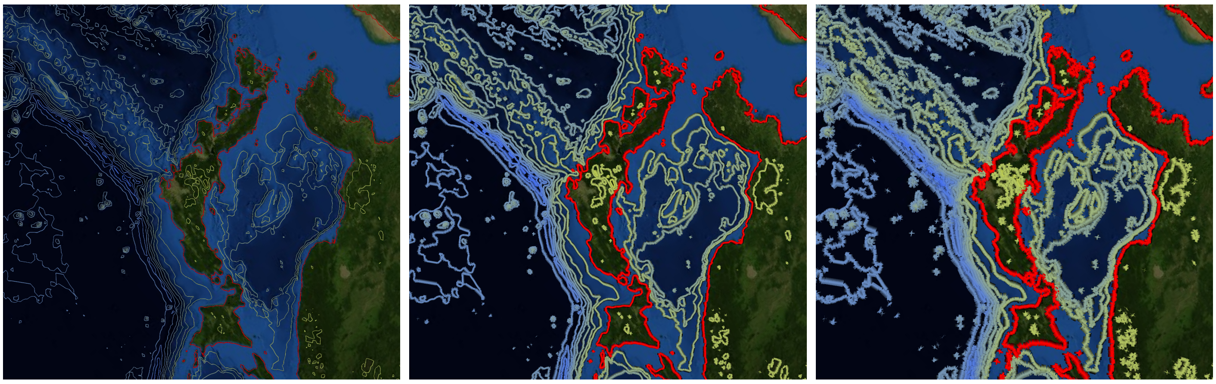

Figure 5: "Isotubes" with varying radii showing the height map of the area of Japan in a close up image: left: 2553, middle: 13068, right: 24628.

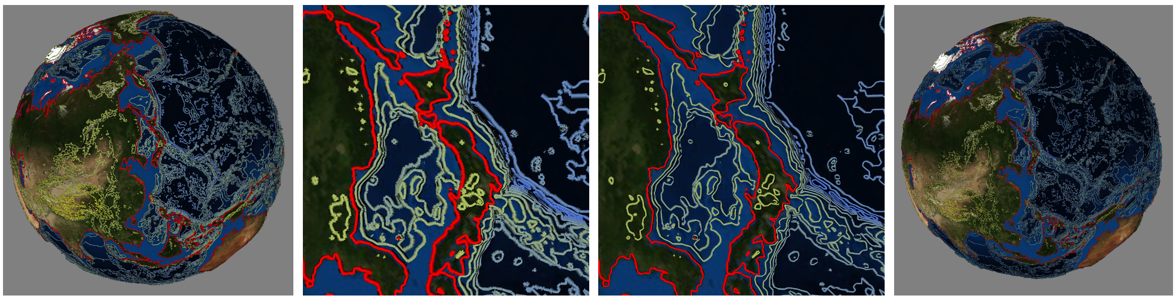

Figure 6: Comparing the visualisation of long shot and close up images using fixed sized tube radius: left-most and left: 23595, right-most and right: 13068.

4 Further investigation: combining height map with isocontours

Our design was built in such a way that allowed us to use both the warping method and the colored "isotubes" together. Note that both the warp scale slider and tube radius slider could be adjusted simultaneously in the user interface. To turn either one off, one could simply set the slider to 0.

Based on our observations we deduced that once we found a realistic and pleasant-to-eye (smooth) warp scale (independent of the camera distance) and an optimal radius for the tubes (dependent of the camera distance) independently, we could simply combine them without further readjustments to obtain even more informative outcomes. An example of this is shown on

Figure 7. This combination was useful since on the left image one could not easily distinguish between the various depths of the ocean due to the texture on it being mainly the same shade of blue, however with the help of isolines this became much clearer (right image). On the other hand, observing the mountain range in North America on the middle image, one could see a clutter of yellow tubes, which again made it difficult for the eye to see the explicit topography. Nevertheless, the combined approach on the right image again clearly clarifies this, therefore the elevation of the mountain range becomes much more evident. To see an example of the long shot Earth image using this combined approach, take a look at Figure 8.

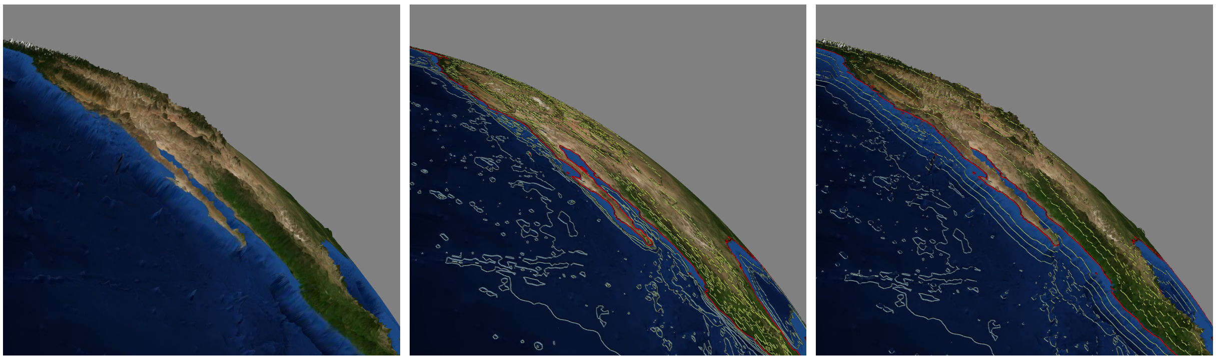

Figure 7: Combining the height map with the colored isocontours. Left: realistic warp scale of 42.4, middle: optimal radius for the given distance: 6400, right: combination of warp and "isotubes" from the other two images.

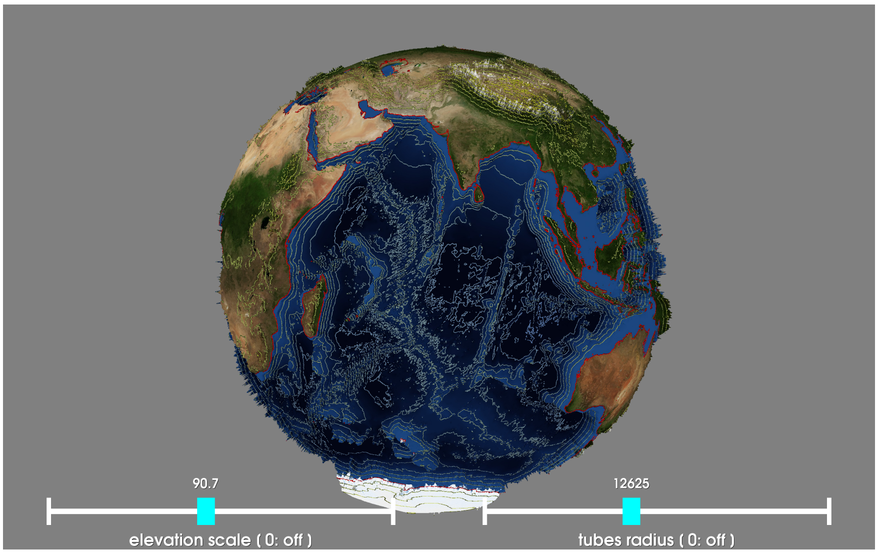

Figure 8: Observing the Earth using the combined approach to visualise topography and bathymetry of the surface.Warp scale set to 90.7, while the radius scale to 12625.

5 Conclusion

Overall, we concluded that both techniques were successfully implemented, although they both had their advantages and disadvantages. Nonetheless using their combination constructed the finest visual effects of the Earth's surface, since they completed/mitigated each other's deficiencies to some extent. Perhaps the most surprising discovery we made during this project was realizing the height of the ice sheets: Greenland and Antarctica.