CO-099

# GEOMETRIC DESIGN ALTERNATIVES FOR TOPOGRAPHIC 3D MAPS INSPIRED BY HAND-PAINTED PANORAMAS

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## ABSTRACT

When creating digital topographic 3D maps, mapmakers encounter a number of challenges related to occlusion, foreshortening and viewpoint selection. In this paper, we present methods to geometrically deform 2.5D digital elevation models to mitigate such problems. Our methods are inspired by manual techniques of panorama painters. Our algorithms allow the cartographer to interactively apply global progressive and local deformation to a digital terrain model. To demonstrate our methods, we present a series of digital 3D maps that imitate a hand-painted panorama.

## INTRODUCTION

With strong resemblance to the way we perceive and mentally picture space, the 3D map harbors great potential to become a very effective and entertaining medium to clarify spatial circumstances. Yet, cartographers struggle with a number of problems when digitally creating and designing 3D maps. Such challenges include for example occlusion of important landscape elements or reduction of essential map objects due to perspective foreshortening. We hope to help establish and promote this promising type of cartographic representation by improving its geometric design and production process with unconventional solutions. Our approach to finding these solutions is to deduce them from the techniques used in hand-painted panoramas. Panorama painters often apply geometric distortions when designing skiing and hiking maps. In digital 3D maps created with standard 3D rendering and modeling software, such geometric deformations are largely absent. Such software packages do not sufficiently support the specialized deformation and rendering functionalities needed by cartographers.

In this contribution, we identify the challenges encountered by digital 3D mapmakers that can be solved by applying geometric terrain distortion. Our digital deformation methods are inspired by analyzing the techniques of panorama painters and bringing them to the digital realm. The resulting prototype software Terrain Bender is especially targeted at deforming 2.5D digital elevation models and allows the cartographer to interactively apply global and local surface bending. The user can also add horizon bending and generate bent cylindrical projections. Our methods can be applied to arbitrary regions, perform at interactive speed and do not require artistic talent or knowledge on rendering systems.

## TYPICAL 3D MAP MAKING CHALLENGES AND MANUAL SOLUTIONS

In the following section, we have a closer look at typical problems encountered by authors of oblique cartographic representations. Such challenges occur when creating panoramas manually as well as digitally. To find inspiration for geometric deformation algorithms, we observe how panorama painters master these challenges in their hand-painted works.

An often-encountered problem is that the perfect point of view for displaying a landscape is difficult to select and often cannot be found at all. In an oblique view, some important landscape objects are usually partly or totally occluded by others. Due to perspective foreshortening, they are also sometimes reduced beyond recognition or are not shown from their publicly renowned side.

As Patterson (2000) and Premoze (2002) point out, panorama painters like H.C. Berann creatively remodel the terrain to mitigate these problems: they enlarge important and shrink unimportant landscape elements; they move and reshape lakes to better portray them; they rotate famous mountains to depict them from their familiar side; they push valley shoulders apart to make rivers and valley floors visible; and they distort the terrain to give the painting artistic focus.

Apart from the aforementioned techniques that mitigate local challenges concerning specific landscape elements, panorama painters like H.C. Berann, Max Bieder (Maggetti, 2000), and Hal Shelton (Tait, 2008) also gradually apply deformation to the entire landscape along the viewing direction. The landscape is deformed globally so that the foreground is represented in a close to orthogonal view and gradually changes into a perspective view towards the panorama background. Patterson (2000) compares this sometimes called ‘progressive projection’ to the experience of observing a landscape from an airplane - with a steep viewing angle when looking directly on the ground and a flatter viewing angle when gradually looking towards the horizon (Figure 1 D). When applying a global progressive deformation, foreground objects are less occluded and are depicted on more image space compared to a standard perspective view. Towards the background, the characteristic shape of the landscape is well discernable, as it appears three-dimensional. Also, a better horizon impression is created with a flat compared to a steep background-viewing angle. On medium to small scale maps, entire countries or continents can be depicted with 3D appearance using progressive projection.

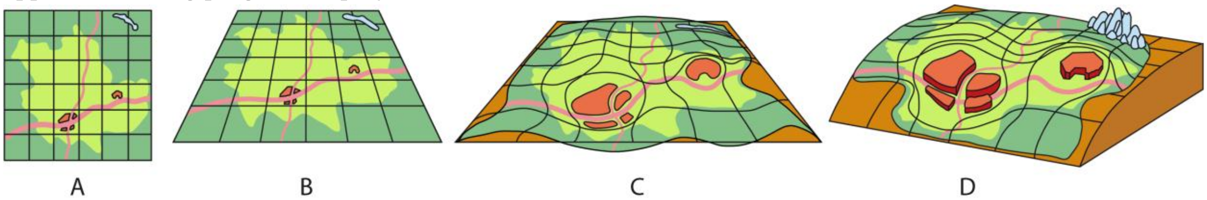


*Figure 1 Combination of local deformation and progressive bending in manual panorama creation: landscape in orthogonal view (A), in central perspective projection (B), with local deformations (C), with local deformations and progressive bending (D) (after Ribas Vilas and Nuñez Guirado, 1990, simplified, colors adapted)*

As contemporary panorama painter Juan Nuñez Guirado (Ribas Vilas and Nuñez Guirado, 1990) explains, panorama painters often combine local and global progressive deformation (Figure 1). We suggest that when working with digital elevation models, these manual techniques can be translated into algorithms that apply geometric transformations globally and locally to selected regions to solve the aforementioned challenges of 3D map creation.

## TERRAIN BENDER SOFTWARE AND TERRAIN DEFORMATION METHODS

Terrain Bender is an implementation of our deformation algorithms. It was written in Java and uses JOGL, a Java implementation of OpenGL, to render 2D and 3D graphics. The user can select a 2.5D digital elevation model to be loaded and rendered in the Terrain Bender preview window. Georeferenced, regular 2.5D terrain models are common data structures in cartography and GISciences as they are easy to process and to combine with other raster data. In contrast to full 3D models, 2.5D terrain models store only one altitude value per grid cell. Landscape forms that require more than one altitude value, e.g. arcs, thus cannot be represented using 2.5D models.

To apply global progressive deformation, the user can deform a curve graph representing the terrain base profile in the viewing direction (Figure 2 right). The left end (labeled ‘Front’) of the curve controls the deformation applied to the altitudes of the grid cell closest to the viewer; the right end (labeled ‘Back') steers the elevation deformation of the grid cell farthest away from the viewer.

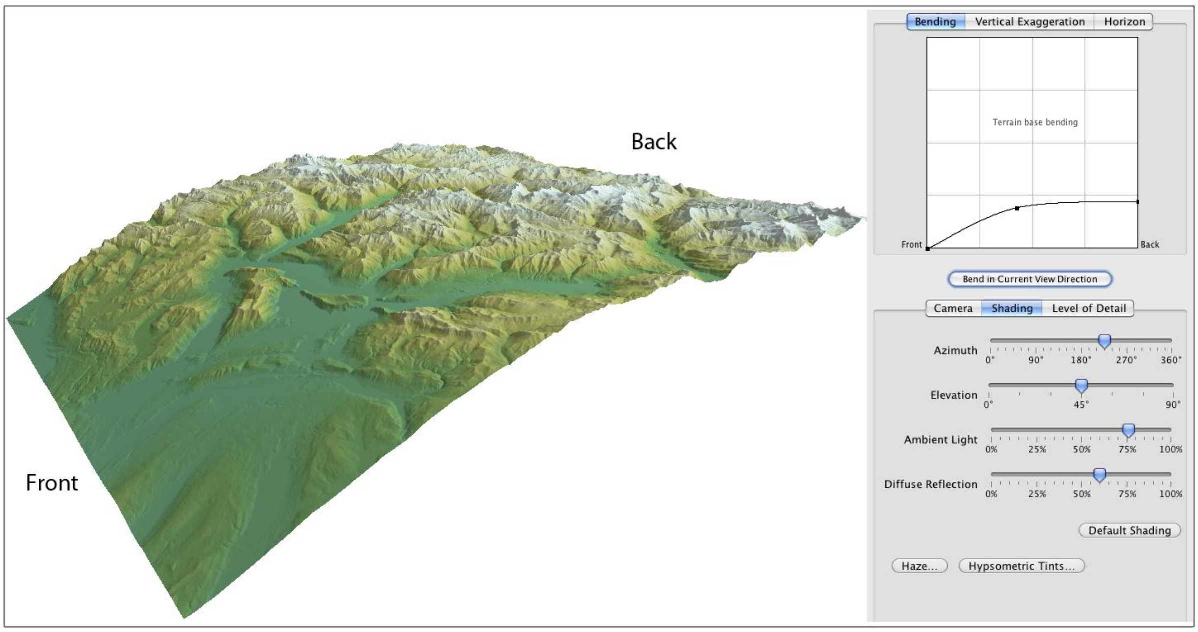

*Figure 2 User interface of the Terrain Bender Sofware: preview of the terrain with global progressive bending (left), interactive curve graph for selecting a deformation profile (right)*

By clicking on the curve to add points and dragging them, the user can create a deformation profile. The terrain base (Figure 3 middle) shares the same number of grid cells with the model. The deformation selected with the interactive deformation curve graph is translated to the terrain base by adapting its elevation values. The altitudes of the undeformed terrain model and of the deformed base are summed-up. Combined, they form the altitudes in the resulting deformed elevation model (Figure 3 right). The grid cell positions in the horizontal plane remain unchanged and the model's regular structure is unaffected. This principle was first suggested by Patterson (2001) who edits elevation models as grey scale images in a graphics editor. Please refer to Jenny et al. (2010) for a detailed mathematical description of the global progressive deformation method.


*Figure 3 Concept of the global progressive bending method: altitudes in the undeformed elevation model (left) are combined with a bent terrain base (middle) into a bent elevation model (right)*

To apply local deformation, the user can add control points (Figure 8 red spheres) in the area of interest by clicking directly on the model preview. The control points can then be dragged to new positions. At the control point positions, the deformed terrain assumes the location of the dragged points; the rest of the model is smoothly interpolated. Control points, which are not moved, act as counterweights to the deformation and keep the region in place. Local deformation can be applied in vertical (altitude) as well as in horizontal direction. To compute the displacement vectors for each grid cells from the control point movements, we use two distance-weighting methods. The closer a landscape region is to the summed influence of the control points, the stronger it is deformed. Far away landscape regions are barely influenced and transition zones between deformed and mostly undeformed areas look smooth. For deformation in the horizontal plane, we use a moving least squares approach based on an image deformation method by Schaeffer et al. (2006). For deformation in the vertical direction (altitudes) we use inverse distance interpolation (Shepard, 1968). Please refer to Jenny et al. (in print) for a detailed mathematical description of the local deformation method. After local deformation the geometry of the digital elevation model is not regular anymore.

The two deformation modes can be applied in combination. In the preview, the model is deformed at interactive speed. For large terrain models, the user can choose to work with a downsampled version for display while adjusting the deformation and switch back to the original resolution for final rendering or export.

In addition to global progressive and local deformation, vertical background and foreground scaling can also be added. It fades off progressively towards the opposite model end. Vertical scaling is also a technique often used by panorama painters, e.g. to let background mountain ranges appear more impressive or to make the relief better discernable on small scale maps. The user can also curve the background of the terrain to form a curved horizon. This can be imagined as gripping the background corners of the terrain and pulling them downwards while the middle of the background is held in place, so that left, middle and right form an arc perpendicular to the viewing direction. The bending also fades out towards the foreground.

## PROGRESSIVE CYLINDRICAL STRIP PANORAMA

Another option in Terrain Bender is an extension of the global progressive bending. Instead of applying bending in only one direction along the deformation profile, one can imagine the viewer to turn 360° around the vertical axis. The deformation profile is applied in all viewing directions, so that the viewer stands at the center of a deformation funnel. To represent this 360° view, we create a cylindrical projection of the progressively bent view and render it as a strip panorama (Figure 4).

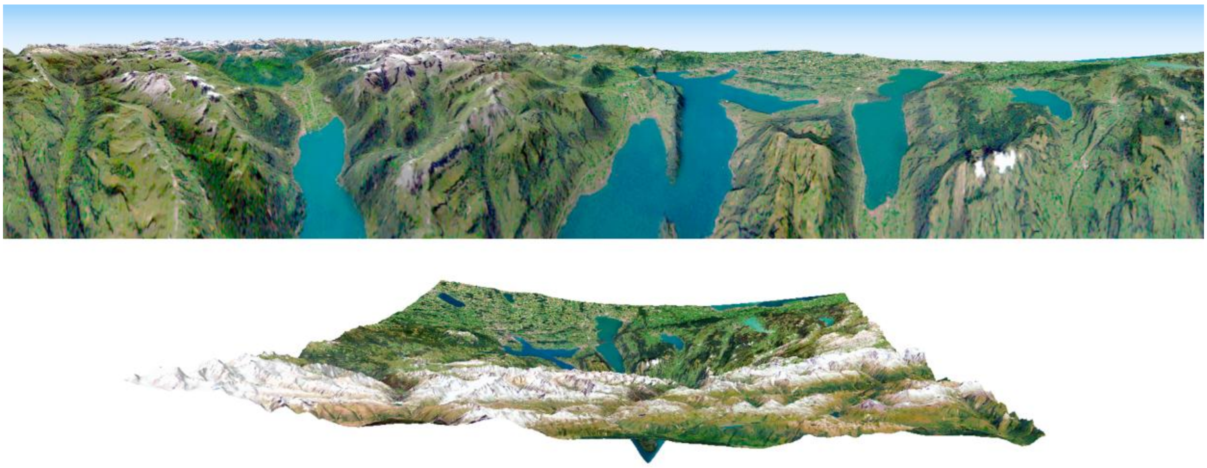

*Figure 4 Progressive-cylindrical projection (top) of the Vierwaldstätter See, Switzerland, derived from funnel deformation (bottom).*

**EXAMPLES OF DEFORMED DIGITAL 3D MAPS**

To demonstrate our deformation methods, we created a series of panoramas imitating an excerpt of the Greater Yellowstone panorama by H.C. Berann (Figure 5). The excerpt is marked with a yellow rectangle. In Figure 6, a digital panoramic view of the Yellowstone region is shown without deformation. Note that the Tetons appear only as a stub in the background. In Figure 7 we added strong vertical background and light vertical foreground scaling as well as global progressive bending. The Yellowstone Lake area in the foreground appears less foreshortened. It assumes more image space, thus providing more room to add for example additional information on touristic infrastructure and landmarks in the lake area. We also locally deformed the globally bent elevation model to imitate the Teton Range position on the hand-painted panorama. Figure 8 shows an orthogonal view of the Yellowstone region. On the left image, the positions of the control points (red spheres) in Terrain Bender are shown before local deformation and on the right image after local deformation. Note that only the topmost control point was dragged to rotate the Tetons in the horizontal plane. Figure 9 shows the panoramic view after deformation. The famous peaks of the Tetons, Grand Teton and Mount Moran, are now better recognizable after rotating the Teton Range. The image composition also appears more pleasing with a mountain background in Figure 9 compared to a flat area in the center of the image background in Figure 7.

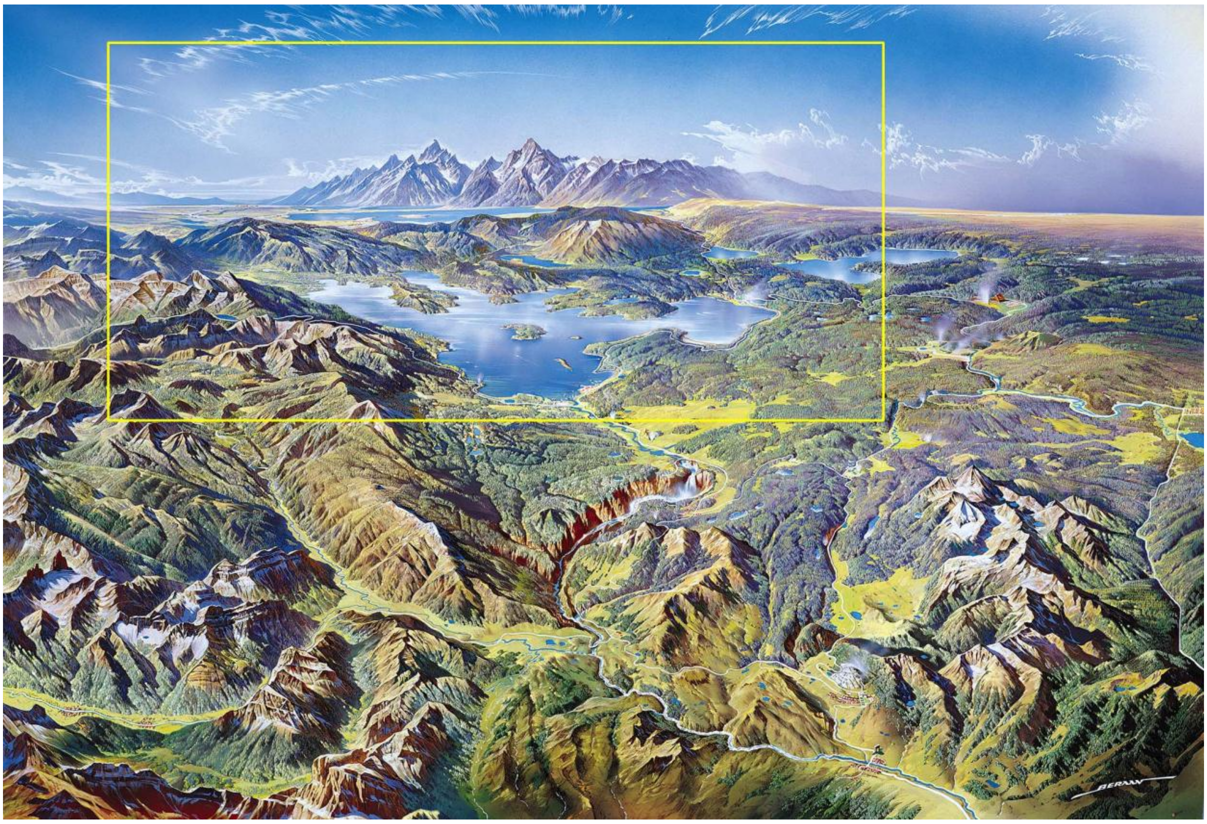

*Figure 5 Greater Yellowstone National Park, hand-painted panorama by H.C. Berann*

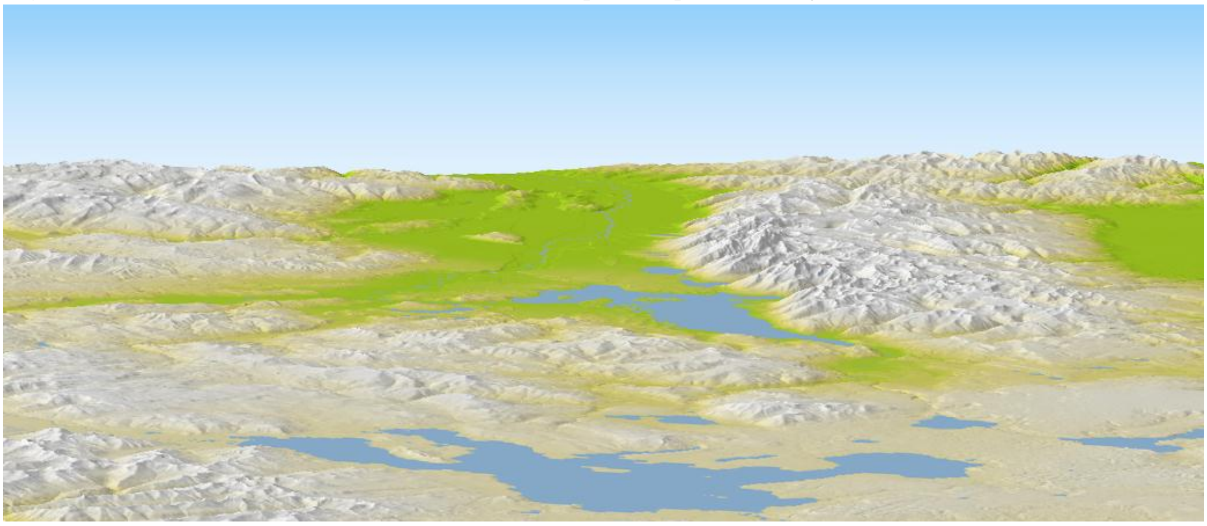
*Figure 6 Digital panoramic view of the Yellowstone region*

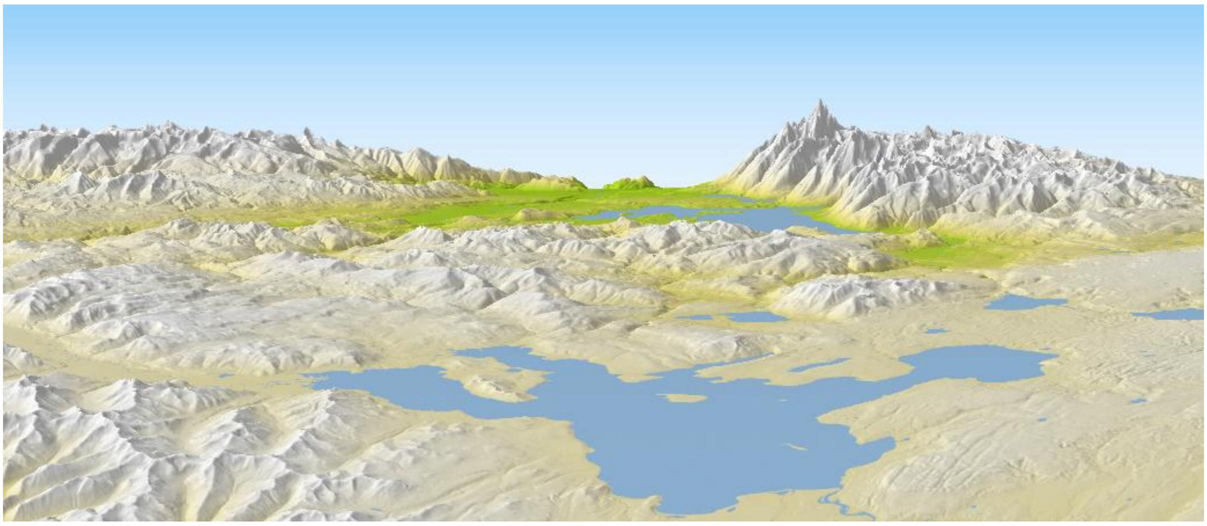

*Figure 7 Digital panorama of theYellowstone region with global progressive bending and vertical scaling*

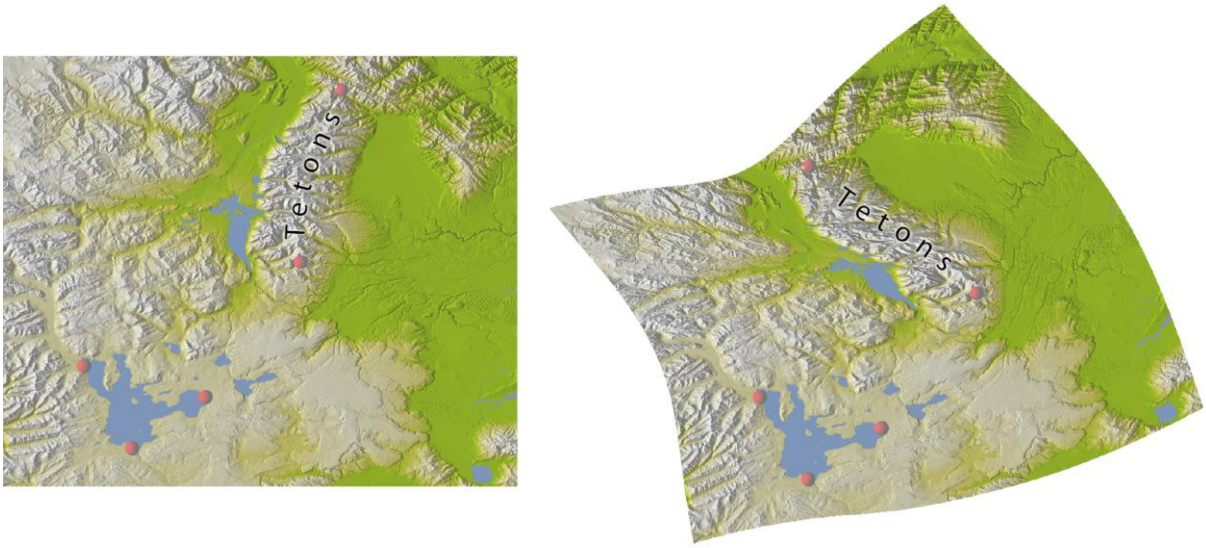


*Figure 8 Orthogonal view of the Yellowstone region: before local deformation (left), after deformation (right). The interactive control points are represented by red spheres.*

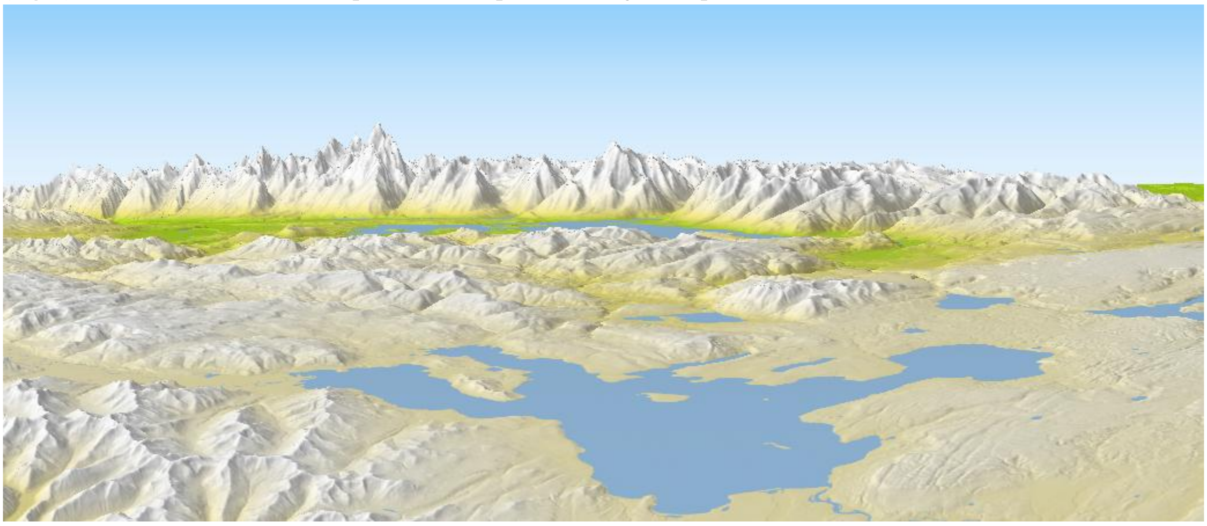

*Figure 9 Digital panoramic view of the Yellowstone region with local and global bending. The Teton Range in the background was rotated about 50°.*

**CONCLUSION**

Our methods for global progressive and local deformation allow the cartographer to solve typical challenges encountered when creating topographic 3D maps. Our algorithms were inspired by observing the manual techniques of panorama painters. With the Terrain Bender software, which implements these new methods, the cartographer can interactively deform a 2.5D digital elevation model. Special artistic talent and knowledge on rendering systems is not required. Creating a geometrically deformed panorama map with our software also is much faster compared to sketching or painting by hand. We also hope that by formalizing the panorama painters' approaches in algorithmic form, we contribute to preserving their knowledge developed over centuries and to make it available to modern cartographers.

**ACKNOWLEDGEMENTS**

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