

CONVEYING LOCAL AND GLOBAL EFFECTS OF SEA LEVEL RISE WITHIN AN HDTV FEATURE FILM PRODUCTION

N. Gardiner^{a,b}, H.B. Allen^b, and A. Ducao^a

^aScience Bulletins, American Museum of Natural History, Central Park West at 79th, New York, NY 10024; correspondence may be sent to ned@amnh.org

^bCenter for Remote Sensing and Mapping Science, Department of Geography, University of Georgia, Athens, Georgia 30602

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ABSTRACT:

New York's American Museum of Natural History produces and distributes original geovisualizations to a potential audience exceeding 20 million in the United States, Canada, and Australia via its own current science program, Science Bulletins (sciencebulletins.amnh.org). Experience suggested that narrative guidance offers a more rich experience for viewers, so visualizations are now being produced and incorporated into feature documentaries. This technique allows scientists' own words, facial expressions, and other sources of evidence to contextualize visual elements offered through the visualizations themselves. A recently completed feature story explains to viewers the potential effects of 6 m sea level rise if substantial portions of the Greenland and/or West Antarctic Ice Sheets were to melt in coming centuries. We produced visualizations utilizing data with spatial resolutions spanning seven orders of magnitude, offering global and local glimpses of the outcome of such an event. The visualization utilized GIS, remote sensing, layout production, 2d and 3d rendering software for a 28-second segment. Blending data and image outputs from these various environments raises challenges for the geovisualization community, especially remote sensing data compilation; optical imagery color blending; camera and lighting setup in different rendering environments; and computational improvements. We present a novel method for presenting HDTV geovisualizations, which spans multiple software and hardware architectures, and offer specific suggestions for other geovisualization experts to consider in their own work.

1. INTRODUCTION

"Cryosphere" is not a household term. Perhaps it should be or will be to the current generations as they age. Earth's frozen water plays a crucial role in our longevity since most humans rely on water from snowmelt for their sustenance. Ice also regulates the heat balance of the planet. Summertime Arctic sea ice has decreased in area by over 9%/decade for the past three decades, and at least 38% of this is due to anthropogenic global warming (Stroeve et al., 2007). Less ice in the Arctic Ocean has decreased Earth's albedo, and, in an excellent example of positive feedback, the now-exposed ocean absorbs and re-radiates heat from the sun and therefore augments global warming.

If access to fresh water and positive feedbacks to global warming do not capture public interest, perhaps rising sea level is sufficiently compelling. If all the water locked within the cryosphere were to melt, the ocean would be 65 m higher than it is today. While that is not likely to happen in the near term, or even on a geologic time scale, recent observations show that sea level is rising at an accelerating pace and that ice locked in glaciers and ice caps is contributing to that accelerating pace of sea level rise (IPCC 2007).

Research published in the past 12 months has documented the phenomenon and mechanisms underlying accelerated retreat of outlet glaciers of ice caps (Velicogna and Wahr 2006; Howat et al. 2007; Figure 1) and increased calving of ice shelves such as the Larsen Ice Shelf, a millennia-old feature that collapsed during a 2.5-day period in 2002. During the 20th century, sea level rose by 17 cm, largely due to thermal expansion as ocean temperature rose on a global basis (IPCC 2007). The rate of sea level rise increased by over 70% from 1993-2003, relative to rate observed from 1961-2003. While Earth scientists decipher the physics underlying continued ice loss from the ice caps, the

public will need to understand the potential impact to society of the consequent sea level rise.



Figure 1. Science Bulletins captured a portion of the Russell Glacier calving from the Greenland Ice Sheet while filming the story in which we inserted 3d geovisualizations.

The American Museum of Natural History's current science program Science Bulletins produced a seven-minute documentary entitled "Melting Ice, Rising Seas" to elaborate efforts by Earth scientists to understand the consequences of sea level rise that would accompany substantial melting of the Greenland Ice Sheet.

Many of the scenarios for future warming detailed by the IPCC (2007) suggest the Greenland Ice Sheet will continue to melt and elevate sea levels. Future temperatures in Greenland could be comparable to those observed 125,000 years ago, when polar ice raised sea elevation between 4 and 6 m, relative to present-day levels (Overpeck et al. 2006).

Museum audiences are of all ages, backgrounds, and scientific understanding. Producing high definition video for diverse audiences requires content that is scientifically vetted and also that is made digestible through composition and editing. Earth science stories require that both global processes and local effects be accurately represented. Given the import and magnitude of sea level rise effects stemming from the melting of Earth's major ice sheets, this video production effort had real

urgency: to convey the hazards and vulnerability of coastal communities to the effects of sea level rise around the world.

We had two objectives in the work described here. First, we sought to show general audiences the local and global effects of sea level rise if it reaches 6 m; simultaneously, we sought to show the connection with the melting of Earth's ice masses. Meeting this objective required that realistic data be used at all scales. Simultaneously, projected sea level rise was to be presented in the form of scenarios rather than as projections. The former definition implies possibility while the second implies realism, or likely future conditions, and since the fate of the ice caps and sea level rise are in question, we chose to emphasize the hypothetical nature of ice cap melting and sea level rise in our visualizations. Our second objective was to embed a geovisualization built from geospatial data into the format of a feature film that also incorporated field footage, interviews, and tangible examples illustrated by expert scientists themselves. That combination of direct narration by scientists, *in situ* footage, and visualized data underlies efforts by Science Bulletins to target all audiences. These two objectives guided development of an authentic educational tool focused on a timely and important Earth science issue.

2. VISUALIZING RISING SEAS

2.1 Seven Orders of Magnitude

To build a continuous camera movement linking global information with local data for South Miami Beach, we compiled true color optical imagery for a nested set of regions: global images of land cover¹ and simulated sea level rise²; southern Florida, the Gulf of Mexico, and the southern Atlantic Ocean depicted by the moderate resolution imaging spectroradiometer (MODIS; Figure 2a); southern Florida alone depicted by a mosaic of Landsat images (Figure 2b) archived at the University of Maryland's Global Land Cover Facility (<http://glcf.umd.edu>); and a digital orthorectified aerial photograph from the United States Geologic Survey (USGS; Figure 2c). The data used in the visualizations described here span seven orders of magnitude (4×10^7 m circumference of Earth relative to ~1 m resolution DOQ data).



Figure 2a



Figure 2b.

Figure 2c.

Figure 2. Nested images used in these visualizations derived from (a) MODIS, (b) Landsat, and (c) digital orthophotos.

Data were color-corrected using Adobe Photoshop so that images would blend with one another. Mosaicking and geotiff attribution were performed using ITT Visualization's ENVI.

2.2 Rendering Global Data using Maya

To illustrate global consequences of possible sea level rise² using video production methods, we employed a three-dimensional rendering software package called Maya (Alias Systems 2005). Images of the globe, such as NASA's Blue Marble (blumarble.nasa.gov), can be represented on a spherical or other shape to represent the Earth as a sphere or in a flattened perspective, such as a Mollweide projection. This ability to transform global images between three-dimensional and two-dimensional representations makes Maya a powerful tool for relating geographical phenomena.

Transformation between shapes requires that a wire frame be constructed. For global images, that frame is typically constructed in a 2x1 aspect ratio to accommodate 360 degrees of longitude and 180 degrees of latitude. The global image, called a "texture" by animators, is then applied to the rectangular shape. Vertex points may be moved to create new shapes from the wire mesh. "Keyframes" record the positions of these repositioned vertices. Time codes are set for each keyframe so that the transformation may be animated. As the wire mesh is animated, Maya projects pixels coordinates of the applied texture to the appropriate positions on the animated shape, thus generating animated images of Earth.

All objects in Maya have nine attributes: x, y, and z values for translation, rotation, and scale. Keyframing these attributes and controlling the keyframes' motion curves are Maya's foundational animation techniques. These techniques are used to animate the movement of solid objects, for example to spin a globe or move a camera. By default, new objects are placed, unrotated, at the center of the Maya universe: x,y,z translation = 0,0,0; x,y,z rotation = 0,0,0; x,y,z scale is 1,1,1. Rotation is measured in degrees, so for an object to be rotated fully, successive keyframes range from 0 to 360 degrees.

Once an object's keyframes are set, the motion of the object is controlled by position and time values for the keyframes. These tuples form "animation curves." The shape of animation curves determines how smoothly or jarringly an object moves from one keyframe to the next. For instance, if all the keyframes are set with Bezier curves, the object transitions are smooth; if all animation curves are set with straight lines, the object will move more jerkily. Because Maya provides complete control over the movement of objects, it is a flexible animation tool for portraying global data sets.

Weiss and Overpeck have published a series of global images that depict ocean levels as they would appear with an added 1-6 m in elevation³. Those images were generated using 1-km resolution digital elevation models (DEMs; GTOPO30 was used) to model the flow of water from the oceans inland. These global data can be represented well using Maya and the methods described above.

¹ <http://blumarble.nasa.gov/>

²For a description of work by Weiss and Overpeck, see http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm

³<http://geongrid.geo.arizona.edu/arcims/website/slrworld/viewer.htm>

2.3 Rendering Local Data Using Visual Nature Studio

Global images of projected sea level rise are jarring to view, for entire coastlines would be transformed under those scenarios. To demonstrate the effect of sea level rise on local communities, we used Visual Nature Studio (VNS) by 3D Nature⁴ (2006); VNS allows the artist/analyst to incorporate spatially referenced data, including high resolution DEMs as well as hyperspatial optical data. We used lidar elevation data obtained by a consortium of Federal agencies and distributed by the National Oceanic and Atmospheric Administration⁵; elevation data had nominal postings of 0.75 m and thus provided apt representations of the heterogeneous elevation structure inherent to South Miami Beach, Florida.

Using VNS, we draped 0.75 m resolution orthorectified aerial photographs obtained from the seamless data server of the United States Geological Survey⁶ (Figure 3a) onto the lidar data. We used VNS' capacity to depict lakes in order to portray areas at risk to inundation given 0-6 m sea level rise scenarios. The color red was used to convey both urgency and that this is a scenario, not a projected impact (Figure 3b).



Figure 3. Two views of South Miami Beach. (a) On the left is an orthophotograph depicting the city as it appeared during an overflight. (b) On the right is the same area with a simulated increase of 6 m sea level rise. The red color is meant to contrast with the realistic ocean elevation since these are simulated data.

We utilized VNS to construct a series of keyframes for a camera moving over southern Florida and South Miami Beach (Figure 4).

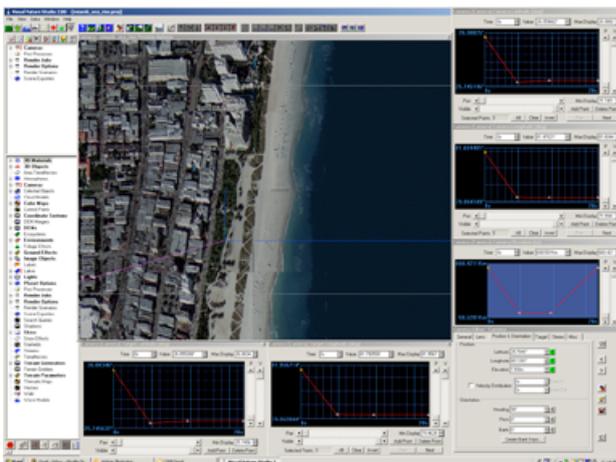


Figure 4. VNS keyframes are manipulated for both the camera and target.

While simulating a flight over South Miami Beach, we utilized VNS to simulate sea level rise effects. VNS has built-in capabilities to render changing elevations in water surfaces, and these proved effective for our purposes.

⁴ <http://3dnature.com/>

⁵ <http://maps.csc.noaa.gov/TCM/>

⁶ <http://seamless.usgs.gov/>

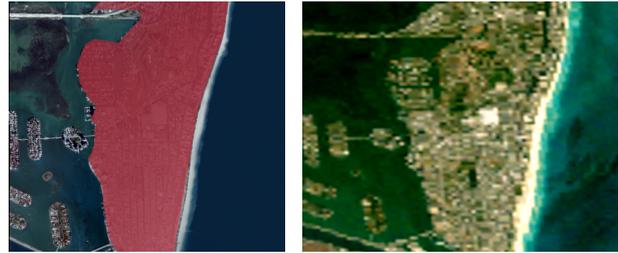


Figure 5. Matchframes: views of South Miami Beach rendered from (a) VNS, with a 6 m sea level rise mask overlain on an aerial photo; and (b) from Maya, viewing Landsat imagery.

As the camera pulled away from the scene depicting the effects of sea level rise, we established a frame of reference (Figure 5a) similar to one depicted using Maya (Figure 5b). This “match frame” established a point at which the sequence rendered from VNS could be joined with one rendered from Maya.

2.4 Compositing Visualized Data

Our strategy employed Maya to render global data and employed VNS to render regional to local-scale data. We used Adobe After Effects (Adobe Systems 2006) to blend animations from both packages. After Effects allowed these sequences to be combined into a single, 28 s animation that began with a wide view of southern Florida; continued as the camera flew into South Miami Beach and along its beach while a simulated sea level rise was animated; and completed with a pull away from south Florida until the Earth was visible with a global sea level rise product overlain. Editors blended the completed animation with audio tracks of Dr. J. Overpeck describing the Earth science concepts that underlie projected sea level rise in global as well as local contexts. The blended audio/video tracks were incorporated into the HDTV editing process⁷.

2.5 Global Cryosphere Visualization

We used the techniques described above to generate an additional sequence during which Dr. J. Overpeck discusses the distribution of glaciers around the world and the major ice caps in Greenland and Antarctica (Figure 6). The sequence opens with Earth represented in an Apianus projection using Blue Marble data as the global image texture. Draped onto the Blue Marble is a layer representing the mountain glaciers of the world (NSIDC 2005). Many among our audience might not be aware of this global distribution. While glaciers worldwide are melting and are contributing approximately 0.3 mm/yr to sea level rise, they are not going to contribute as great a proportion to future sea level if IPCC scenarios are representative of likely future conditions.

⁷ The video production methods used to combine video, audio, and animated frames are beyond the scope of this visualization effort.

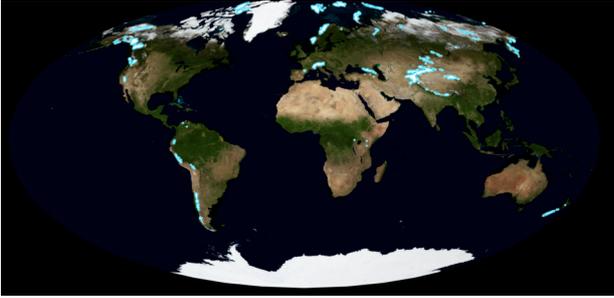


Figure 6. Distribution of mountain glaciers (NSIDC 2005).

Further in the video, Overpeck states that complete melting of the Greenland Ice Sheet would raise sea level by 7 meters. Coincident with those words, we generated an animation showing the Greenland Ice Sheet changing from white to green (Figure 7). This was accomplished by drawing a shape on the inner shore of Greenland. That shape was transformed from one approximately the size of Greenland (Figure 7a) to a vanishingly small one. As it disappears, that animated shape reveals a green color (Figure 7b) to enforce the concept of Greenland potentially melting. This sequence closes with a similar animation depicting potential loss of the West Antarctic Ice Sheet.

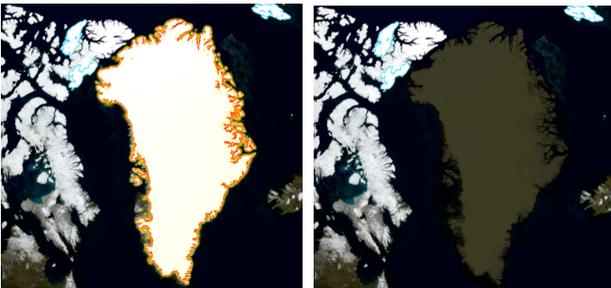


Figure 7. Start (a, left) and end (b, right) points of an animation depicting the potential loss of the Greenland Ice Sheet.

2.6 Future Work

The largest obstacle to effectively combining global representations from Maya with local representations from VNS is that the two software environments provide different methods for controlling camera movement and rendering options. This makes it difficult to generate high fidelity match frames (Figure 5) when using both packages for a single visualization project. The object model within Maya is very flexible, allowing artistic control over object movements in space and time. VNS provides similar capabilities but did not prove as flexible for simultaneously manipulating the camera and the ground object and/or target. However, VNS provides a clear set of strengths in its capacity to render detailed landscape representations using realistic elevation data and optical imagery.

We noted a variety of discrepancies between the ground footprint of true color, aerial photography and the elevation footprints captured by lidar. While beyond the scope of this effort, it is worth noting the discrepancies were not merely planimetric differences in ground coordinates. Rather, the central perspective of photographic imagery and its associated radial distortion made buildings unrealistic when draped onto lidar data. Object-oriented and other feature recognition methods for extruding 3d features using lidar would make the work described here more powerful, allowing realistic, close-up

views that are not possible by simply draping photos onto lidar data. The latter technique proved sloppy, as pixels captured through partially oblique, radially distorted views of the sides of buildings were smeared along sharp edges of buildings as projected upward by lidar data rendered as a landscape surface by VNS.

3. CONCLUSIONS

Science Bulletins produces geovisualizations routinely for its educational media that are distributed to audiences of over 20 million on an annual basis. We utilize stand-alone geovisualizations extensively but have found that visualized data are a powerful complement to traditional film production techniques. Unscripted, candid words of scientists (Figure 8) and a rich body of evidence, presented through captured and edited video provide context that help make visualized data meaningful for our audience.



Figure 8. Dr. J. Overpeck explains the ramifications of massive loss of the Greenland Ice Sheet on Global Sea Level and coastal communities.

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