Atlas of a Changing Earth Visualization of the ArcticDEM Survey and Vavilov Ice Cap Collapse

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***Abstract*—The Advanced Visualization Lab at the National Center for Supercomputing Applications created a cinematic scientific visualization of the ArcticDEM survey and Vavilov ice cap collapse for the documentary film *Atlas of a Changing Earth*, in both digital fulldome and flatscreen television formats. While the ArcticDEM dataset is the main one featured here, this visualization fills in gaps using other datasets, including a climate simulation by Bates et al and Landsat imagery. The visualization required a number of steps including: both manual and algorithmic data cleaning, processing, and alignment; data fusion; virtual scene design; morphing interpolation; lighting design; camera choreography; compositing; and rendering on the Blue Waters supercomputer.**

***Index Terms*—scientific visualization, cinematic visualization, explanatory visualization**

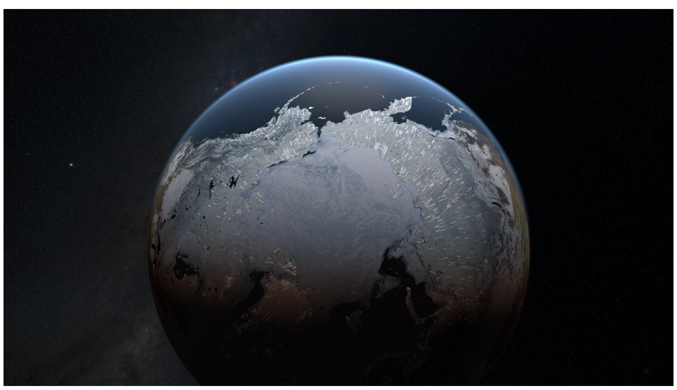

Fig. 1. The first frame of the visualization video, showing the ArcticDEM survey region.

I. Introduction

This visualization excerpt from the film *Atlas of a Changing Earth* is an explanatory visualization created for a general audience, ages 8-80. The camera starts by looking at the entire arctic as shown in Figure 1, and seamlessly traverses into a close-up view of the Vavilov ice cap, shown in Figure 2. A 3.5-minute video describing what went into creating this visualization is available online at https://www.youtube.com/watch?v=f_m20L2BbcM

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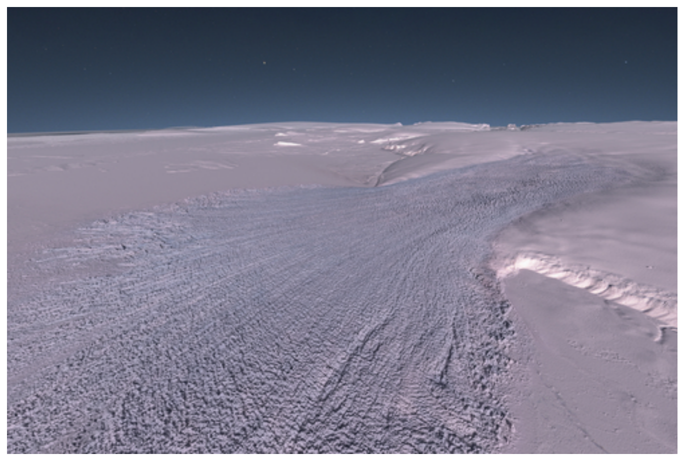

Fig. 2. A later image from the visualization video, showing the collapsing Vavilov ice cap.

II. The ArcticDEM Dataset

Digital elevation model (DEM) data is represented as imagery, where each pixel holds a value for the elevation at that location. The ArcticDEM dataset covers all land north of 60(see Figure 3), and it redefined the arctic from the worst to one of the best-mapped regions of the Earth [2]. The data is collected by the WorldView 1-3 satellites and GeoEye-1 satellite, and is processed to remove clouds and other errors, with an absolute error of <0.5 meters [3]. The ArcticDEM data is collected in "strips", with each strip being a snapshot of a particular area. This can be thought of as a puzzle piece. Over

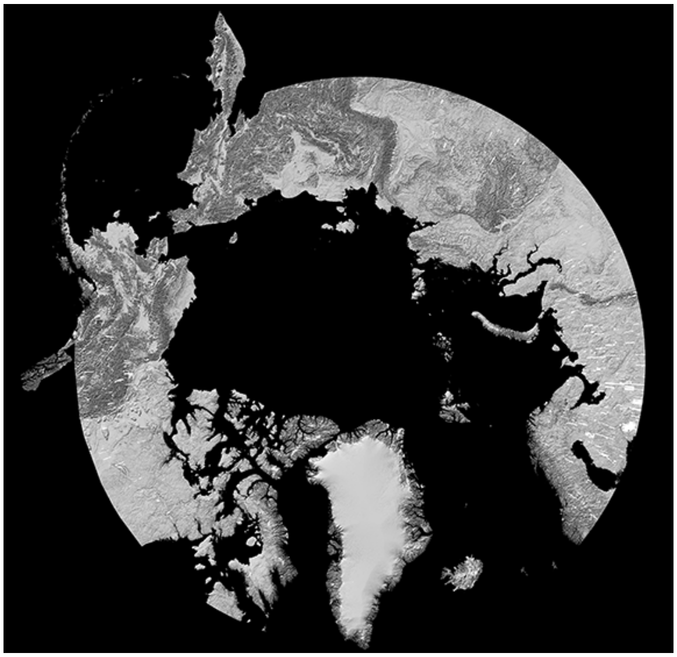

Fig. 3. Hillshaded image of the entire ArcticDEM dataset. Image from https://www.pgc.umn.edu/data/arcticdem/

time, the various puzzle pieces are gathered, and eventually there are enough to put together a complete puzzle. Because the strips are gathered at different points in time, putting them together does not create one single, seamless, final mosaic, but rather, puzzle pieces are periodically updated and replaced. This is where the puzzle analogy starts to break apart - a strip may cover some of the same area as a previous strip, but does not exactly "replace" a previous puzzle piece, as it may not have the same shape and coverage.

This DEM data was gathered by satellite, which means that clouds are an issue. The annual global mean cloud cover is approximately 66% [4], so Earth-facing satellites which aim to study the land collect noisy or incorrect data when clouds obstruct their view. Making this data more usable requires significant data cleaning. To build a cloud-free, complete mosaic for the *Atlas of a Changing Earth* documentary, cloud masks were manually created for each strip and multiplied against the data to remove the artifacts. The cloud-free strips were then accumulated to build up the mosaic, at which point the visualization video begins. The strips continue to update throughout the visualization. A multimedia specialist on the team used the software Nuke[1] to visually inspect the individual DEM strips, comparing them with strips gathered immediately before and after to identify and manually mask out areas that appeared to be artifact-ridden. Using a visual effects technique called rotoscoping, in which a vector mask is created in one image frame and filled in with imagery from another, the expert drew the masks for each new data strip by comparing the various images described above over time, interactively making adjustments to image intensity as needed for better visual acuity.

Cloud detection was a manual, time-consuming process during the documentary production, however, it produced a valuable output in addition to the visualization itself - a large collection of labelled data. This labelled data was used to train a machine learning model to identify cloud artifacts, and was released as CloudFindr [1], a byproduct of working on the documentary.

III. Data Visualization

This shot from *Atlas of a Changing Earth* animates the multi-year ArcticDEM survey in the context of a realistic-looking Earth. The visualization incorporates seasonal changes in Earth's appearance.

We created it in layers:

- a mask separating land from ocean,
- topography as measured by the ArcticDEM survey, with surveyed strips emphasized as the survey goes on,
- adding the atmosphere,
- the sky,
- a climate-model simulation of sea ice coverage

To design the unbroken animation path around the world and into Vavilov, we used AVL's interactive Virtual Director software. Virtual Director shows a simplified preview of the scene, in the correct 3D location. Final rendered elements fit right in.

Datasets, camera paths and so on are brought into the commercial software tool Houdini. Its node-based architecture supports a mix of programmable and interactive design.

The DEM survey data shows exquisite detail but contains many artifacts, thanks especially to clouds. Seen in a 3D landscape, every defect becomes even more prominent, as shown in Figure 4. Lots of manual work went into cleaning the raw survey data, masking out clouds and aligning strips with each other.

The DEM data was observed at discrete times, at irregular intervals, days or months apart. To give the sense of continuous motion, we used morphing interpolation in Nuke on the high-spatial-frequency ripples in the collapsing Vavilov ice to create 3-dimensional, evolving topography. Starting from a flat version of the landscape, we add the time-interpolated topographic relief, and use LANDSAT optical imagery to provide color. It too is interpolated over time.

Over wintertime darkness, we again alter the landscape color and lighting, and the sky, to suggest dim twilight. As springtime returns, so does LANDSAT imagery. The sun is very low as spring begins, so the early LANDSAT images are tinged pink with sunrise.

References

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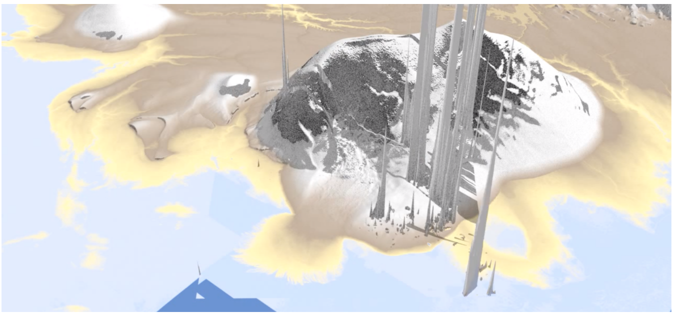

Fig. 4. An early visualization draft showing the data artifacts present in the raw data, which create spikes in the 3D visualization.

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