Dall'Acqua, L., Çöltekin, A., & Noetzli, J. (2013). A comparative user evaluation of six alternative permafrost visualizations for reading and interpreting temperature information. In GeoViz Hamburg 2013 Interactive Maps that Help People Think.

A comparative user evaluation of six alternative permafrost visualizations for reading and interpreting temperature information

Luca Dall'Acqua Arzu Çöltekin and Jeannette Noetzli
Department of Geography, University of Zurich, Switzerland
{luca.dallacqua | arzu.coltekin | jeannette.noetzli} @geo.uzh.ch

Visualization of underground phenomena is a nontrivial task, because: a) they are usually volumetric, and volumetric visualizations inherently suffer from occlusion issues; b) they are located inside another volume (i.e. the terrain), and this presents a conflict with visualizing the potentially important "geographic context" on the surface along with the phenomenon itself under the ground. Surface cover (snow, vegetation) may interact with (e.g. impact or express) the distribution of the underground phenomena such as permafrost, especially in coarse regions like the Alps. In this study, we analyze, design and evaluate visualization solutions for underground phenomena using permafrost visualization(s) as a case study. Permafrost is defined as ground material with a temperature constantly at or below 0°C for at least two years. In mountainous areas, distribution patterns of permafrost are heterogeneous, patchy and complex. Mountain permafrost serves as an ideal example for this study, it is volumetric, underground and its extent is directly influenced by the ground surface temperature which is dependent on the solar radiation, the surface cover and the topography. Therefore, when visualizing permafrost and possible changes in its extent (size and shape), we are faced with the challenge to visualize multiple relevant phenomena at the same spatial location. Building upon these considerations, we can deduce that a visualization of mountain permafrost should have at least two main characteristics: 1) To avoid a mismatch between the three-dimensional (3D) nature of the phenomenon and its representation, and a consequent loss of information, we should display the data in 3D 2) Because the subsurface phenomenon is strictly related to the surface (i.e. topography or surface cover), adding "geographical context elements" to the visualization can provide useful information. However, do these characteristics (3D, context) really help users and if so, when do they help? Answering such a question requires multiple user studies with various tasks and user groups. In this paper we begin by one where we present our participants six alternative visualizations where we vary dimensionality (2D/3D), context (surface cover, no surface cover), and color (continuous/discrete) and a set of tasks that are common when working with permafrost visualizations, i.e., to read and interpret temperature information.

In the case study, we used a transient 3D temperature simulation of the Zugspitze originally produced to study the distribution of mountain permafrost in the highest peak of Germany and its possible response to climate change (Noetzli et al. 2010). To visualize the simulation data we surveyed software that can render volumetric datasets. Medical imaging is the main actor in this field: many approaches and tools have been developed to show the interior of the human body (Walter et al. 2010). After a software survey, we decided to use *3D Slicer* which it intended for the analysis and visualization of medical images (Pieper et al., 2006). Borkin et al. (2005) successfully used the software to visualize, explore and analyze astronomical data, i.e., the tool is used to visualize micro scale phenomena (human body) as well as macro scale phenomena (galaxy) and with this study we demonstrate a use case with meso scale phenomena (mountain). Along with *3D Slicer*, we used Google's *Sketchup* and *Earth* for producing the visualizations. Following the *software survey*, we conducted a preliminary *expert opinion survey* with a number of alternative permafrost visualizations. Based on an evaluation of these opinions; we produced three static visualizations which show the temperature field and the extent of the permafrost inside the mountain. The three visualizations represent the same section of the mountain but include three different levels of information load and complexity (Figure 1).

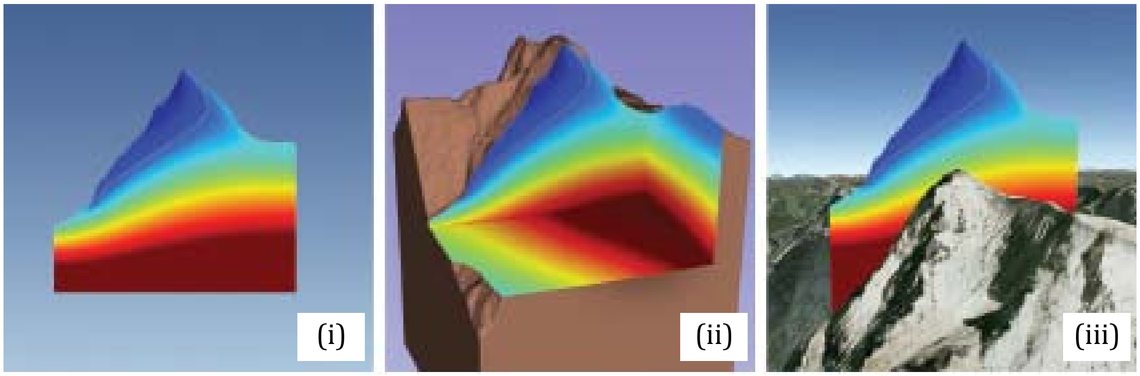

Figure 1: With increasing complexity: (i) a 2D slice, (ii) a 3D block diagram with a sliced slope, and (iii) a 2D slice inserted in a panorama containing elements of geographic context ("2D+context").

The three visualizations were produced with a continuous color scheme as this is closer to the reality of the phenomenon we study (permafrost is typically a continuous phenomenon) in "rainbow" color scheme (software default). However, many studies indicate that the rainbow color scheme is considered difficult to read. Thus, we reproduced the visualizations with a discrete color set to further study the color scheme. A ruler was added to the visualizations to enable reading the plot. The resulting six visualizations have been tested in an online survey with 184 participants for two tasks. The two tasks consisted reading a temperature value vertically below a point on the surface and describing the temperature trend vertically below another point on the surface. Tasks were repeated for discrete-color versions of each alternative; i.e. every participant solved four tasks. Stimuli were shown in randomized order to account for learning bias. The accuracy, response time and satisfaction scores were recorded during the survey.

Analysis revealed that for the given tasks, overall the 2D variants "win"; not only participants were fastest with 2D but also made the least mistakes. The 2D+context variants are second best and 3D variants are the last. The mean total response time differs statistically significantly between the visualizations. Similarly discrete color scheme variants consistently perform better compared to continuous colors schemes both in terms of error rates and response times. The satisfaction scores were less decisive: all visualizations were rated positively; with slight favor towards the 2D variants than 3D and 2D+context, while the latter two were rated very similar. The results of the online survey demonstrate that, if the aim of the visualization is to read data from a plot, 2D visualizations perform better than more complex variants. Further testing is underway to establish in which cases 2D+context and 3D visualizations may be more appropriate.

References

M.A. Borkin, N.A. Ridge, A.A. Goodman, and M.Halle. Demonstration of the applicability of 3D slicer to astronomical data using 13co and c18o observations of ic 348., 2005.

J. Noetzli, S. Gruber, and A. Poschinger. Modellierung und Messung von Permafrosttemperaturen im Gipfelgrat der Zugspitze, Deutschland. Geographica Helvetica, 2, 113–123, 2010.

S. Pieper, W. Lorensen, W. Schroeder, and R. Kikinis. The na-mic kit: Itk, vtk, pipelines, grids and 3D slicer as an open platform for the medical image computing community. pages 698–701., Proc IEEE Intl Symp on Biomedical Imaging ISBI, 04 2006.

T. Walter, D.W. Shattuck, R. Baldock, M.E. Bastin, A.E. Carpenter, S. Duce, J.Ellenberg, A. Fraser, N. Hamilton, S. Pieper, M.A. Ragan, J.E. Schneider, P. Tomancak, and J. Hériché. Visualization of image data from cells to organisms. *Nature Methods*, 7(3):526–541, 2010.