Polar Panoramas: Images worth a thousand megabytes

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Recent developments in digital camera and photo editing software offer earth scientists new ways to document and explore the landscapes they work in through use of spherical and gigapixel panoramas. For polar scientists working in remote areas with landscapes that are affected on human time-scales by climate change, panoramic photography offers many new possibilities for long-term change assessment, après-field landscape analysis, and public outreach. This paper provides an overview of the basic concepts in photo acquisition, post-processing, and scientific uses.

Panoramic photography has existed since the early days of photography itself, but the advent of digital cameras and processing have made panoramic photography easier, better, and much higher resolution than previously possible. Panoramic photography takes three basic forms: 1) a single acquisition using a specialized camera that achieves a wide field of view by sweeping the lens or film, 2) cropping an elongated image (typically with aspect ratio of 3:1 or higher) from a single image, or 3) creating a single, seamless mosaic using a series of individual images taken with a standard camera. This paper describes the latter, called the 'stitching technique', and focuses on pure digital techniques. The digital mosaic can consist of any field of view, from a traditional 90° x 30°, to a single-row cylindrical stripe covering 360°, to a full spherical view of 360° x 180°. Gigapixel panoramas can cover any field of view, with the distinguishing feature being a total pixel count of at least 5×10^6. The final resolution of the digital mosaic is a function of the focal length of the lens used and the resolution of the digital sensor in the camera. For example, one can created a spherical panorama using a 10.5mm fisheye lens or a 50 mm prime lens – with a 12 megapixel (MP) camera, the fisheye lens will require 7 photos for a final resolution of about 11,000 x 5500 pixel (60 MP) and the 50 mm lens will require 486 photos for a final resolution of over 4 gigapixels (GP). Obviously there is a trade-off between time spent taking/stitching the photos and the final resolution desired.

Creating a digital mosaic has several basic steps:

1) acquiring the images
2) performing any pre-stitching photo adjustments (such as conversion from RAW format, pre-sharpening, exposure adjustments, etc)
3) stitching the images
4) blending the images to obscure the seams, exposure differences, or parallax errors
5) using a photo editing software such as Photoshop to make any final adjustments
6) converting to VR format to view at full resolution using pan, tilt and zoom features

There are a few principles to keep in mind when acquiring the photos to create high-quality panoramas. There are many websites, forums, and a few books that offer tutorials on digital stitching of panoramas (of note are http://wiki.panotools.org/ and the Panotools NG forum on Yahoo.com). Here I simply list a few of the principles to be aware of:

- Panoramic photography is at heart still photography – the better you understand your camera, its optical physics, the nature of light and its dynamic range, and the essentials of composition, focus, and exposure, the better your panoramas will be. The best books I have found on photography are the series by Ansel Adams: The Camera, The Negative, and The Print.
- Panoramic photography requires you to think and expose in 360 degrees, meaning that there will always be back-lighting and front-lighting on a sunny day. Your camera exposure (aperture, shutter speed and white balance) must remain constant (or nearly so) for all of your photos if you want them to blend to look like a single photo, and so you need to plan your exposure carefully and use a camera that has manual settings.
- The camera must be spun about its no parallax point (NPP) which varies with the lens used, otherwise the photos will not stitch together perfectly, especially if you have subjects in both near- and far-grounds. The NPP is almost always **not** located at the tripod mounting screw in the camera body, and so a special panoramic rig is required (I use the one from www.reallyrightstuff.com).
- The photos must have enough overlap between them to ensure enough points in common to stitch them together. Typically 30% is enough. The main difficulties are with pure blue skies, and here it helps to use a fixed rotational increment between photos and input this value into the stitching software directly.
- As with traditional photography, shooting in RAW format is best, as it allows for the most control of the exposure, white balance, sharpening, and saturation after the image is taken.

In terms of equipment, there is a lot to choose from, and here I will only describe the basics along with the equipment that I use and have found reliable. For spherical panoramas, the easiest method for field scientists is to use a fisheye lens and a monopod (or trekking pole with camera mount) with a tilting head. The Nikkor 10.5 mm fisheye is commonly considered the sharpest lens in the sub-$1000USD category, though ones from Sigma and Tokina are also used widely. Depending on the size of the camera sensor and the lens used, you will need between 3 and 7 photos to get full spherical coverage. The issue is that most lens/body combinations will not result in a true 180° coverage, so there will be a gap at either the top (zenith) or bottom (nadir) in the photo, and the camera must be tilted up or down (or both) to fill those holes. My preferred method is to shoot 6 shots around with camera tilted down to eliminate the nadir hole, then tilt the camera up to fill the zenith hole; the monopod must remain vertical during this process (use a bubble level), otherwise parallax errors will result. For gigapixel panoramas (or any panoramas using other than the fisheye lens) a tripod is required due to the larger number of shots. For scenes requiring hundreds of photos, a motordrive is helpful to help move the camera at a fixed increment and automatically release the shutter. I have used the motordrive from Seitz and can recommend it for its reliability and lightweight in remote field work. Nearly any modern D-SLR camera can be used for acquiring images; I use the Nikon D2xs and found it rugged, reliable in any temperature, and with long battery life and recommend its use.

Once the photos are acquired, they must be stitched and blended. There are numerous applications available for this. Arguably the best software is open-source code called PanoTools, developed by Dr. Helmut Dirsch, and many commercial packages use this engine. The most popular and among the cheapest commercial packages is PTgui, which I use exclusively, and it has an active and friendly on-line user community. Though the packages differ in implementation, the fundamentals remain the same: find points in common between photos ('control points'), use those control points to determine how to shift (or warp) the photos, and then blend the photos together to obscure any remaining errors. The best approach is to calibrate your lens (something you can do on your own with test photos) and enter those calibration coefficients into the stitching software, as this reduces the number of control points required and prevents the software from warping the photos in ways not intended by the user. Stitching and blending a spherical fisheye panorama at 16 bit and 11,000 x 5,500 resolution can take a fast modern computer between 5 minutes to 5 hours, depending on the software algorithms used. The blending algorithms have the most variations, and recently released algorithms appear to be 2 orders of magnitude faster than those of last year.

The final steps in production are preparing it for distribution and use, typically either print or on-line viewing. Tools like Photoshop are useful here, especially with cleaning up any visible seams or with overall contrast and exposure adjustments. Once the flat image is finalized, there are a number of tools that can be used to create the on-line display. I use "Pano2VR", as it is easy to use and inexpensive. Tools like these will take your flat image (typically a JPG) and convert them to QuickTime VR or Flash (or any number of other similar formats). The issue here is that only about 90° field of view can be shown without introducing substantial distortion, so that user's field of view must be restricted to this amount. The Quicktime and Flash applications allow the creator to limit the field of view as desired, and allow the user to pan, tilt and zoom to see the remaining image. For gigapixel panoramas, the best software currently available is Microsoft's HDview, but Zoomify is also a popular and useful tool. These applications take the enormous gigapixel panorama and split into thousands of smaller images with the 'pyramid resolution layers', such that the software can carefully manage the available bandwidth by only sending the user as much resolution as required given the zoom level and location of the user's browser. This is the same way that Google Earth and many other mapping software works.

To explore the scientific utility of spherical and panoramic photography, I took approximately 375 panoramas during an expedition to McCall Glacier Alaska in July/August of 2007. I have stitched approximately 60 of these at this time, and have found that it takes me about 2 hours for the complete workflow for each. I have uploaded all of these to http://arctic.360cities.net and they can also be viewed in Google Earth from http://arctic.360cities.net/ge.kml.

It remains to be seen what the long-term value of these panoramas will be, but I can offer several possibilities. I have found that my gigapixel panoramas allow me to explore the landscape from the office nearly as well as or better than standing in the field does, as the photo resolution is better than my eyes can see alone and there I can spend hours or days looking at the photo, but typically only a few minutes in the field. The spherical panoramas, which can be taken in a minute or so in the field, cover a broad spatial area and so provide nice documentation of the complete landscape of our primary glacier field site. I have used these photos on numerous occasions now to help collaborators who have not been to our study areas better understand the area, and all have commented on the power of the technique. In terms of being a long-term record, based on my own experiences using old photos, the panoramic technique is far superior, as it not only gives the would-be repeat photography a 360 degree view against which to assess change but also shows exactly the location of the photographer through the nadir image.

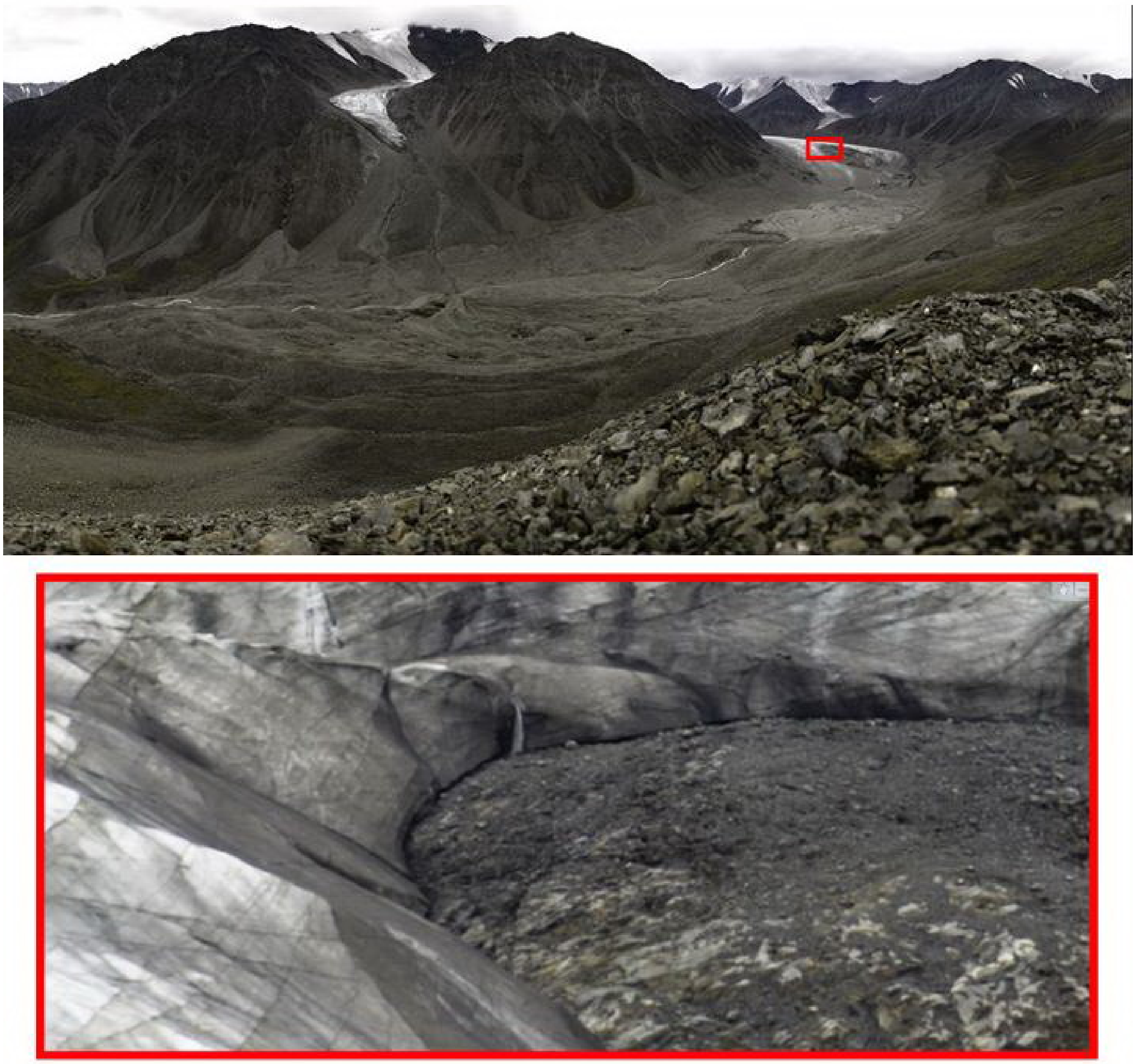

Figure 1. Gigapixel panorama of Okpilak Glacier, AK. The upper image is a mosaic composed of 504 images acquired with a 200 mm lens. The lower image is a cut-out of the mosaic demonstrating the detail captured by this technique. This photo-location was first used 100 years ago by Ernest Leffingwell, when the glacier almost completely filled the fresh moraine seen here. Gigapixel panoramas like this offer polar scientists new ways to document climate-sensitive landscapes, detect temporal change, and potentially develop better insights into the processes involved.