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Movement of Sandstone Arches as a Repose to Thermal Cycles

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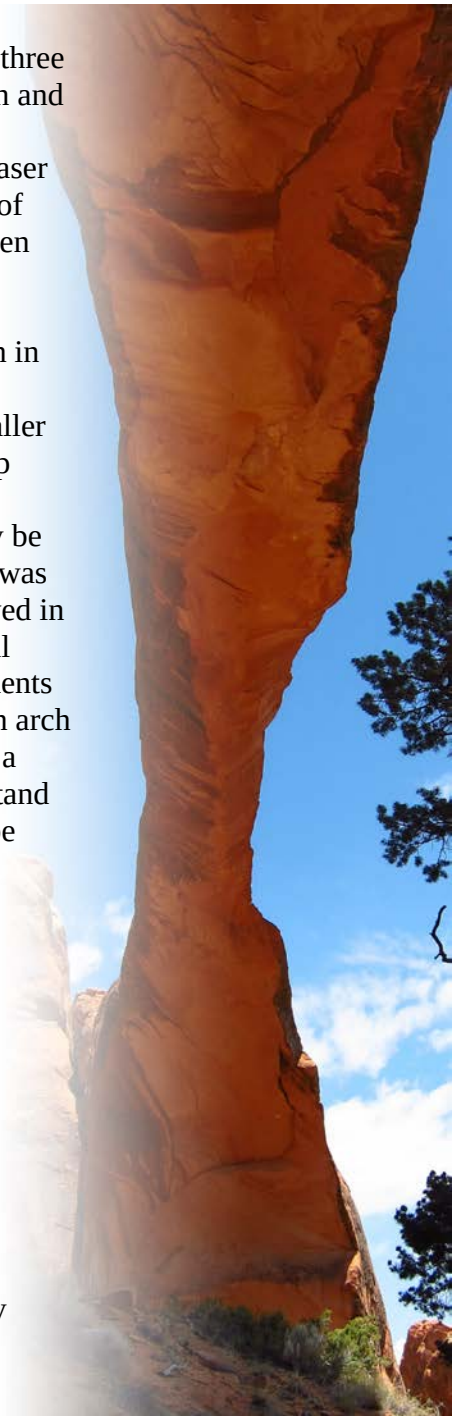
We combine laser distance measurements with rock temperature to study the physical responses to temperature of three prominent sandstone arches in southern Utah: Landscape Arch and Rainbow Arch in Arches National Park as well as Owachomo Bridge in Natural Bridges National Monument. We placed a laser distance meter under each arch and recorded up to three days of distance measurements. Paired with rock temperature data taken over the same time period from on or very near the arches themselves, we can see how each arch moves in response to changes in its temperature. Landscape Arch is the longest arch in North America (88 m span) and is remarkably slender, while Rainbow Arch (4 m span) is a lesser known arch of much smaller dimensions. While both these arches represent curved arch-top geometries, Owachomo Bridge (55 m span) has a flat-topped structure. Each arch has shown different responses which may be linked to arch structure and geometry. A repeat measurement was taken at Landscape Arch but did not confirm what was observed in the original measurement. This raises questions about seasonal variability in arch movement. More repeat distance measurements over time can be used to confirm and further assess changes in arch response to thermal cycles, which in turn provide evidence of a mechanism for progressive rock failure. Our goal is to understand how the arches respond to their environment, and ultimately be able to assess progressive damage of these iconic features.



Two three day measurements were taken at landscape arch. The first, in the spring of 2017, showed arch movement that corresponded directly to changes in rock temperature (Figure 1). Daily distance changes were between 1 and 1.5 cm while temperatures fluctuated approximately 30 degrees Celsius. As the rock heated during the day the arch moved up and away from the laser. At night movement back down towards the laser occurred in response to cooling. A second measurement was taken at Landscape Arch in the Fall of 2017. Unexpectedly we saw very different results. As the rock temperatures rose the arch sagged closer to the laser and then rebounded up and away during nightly cooling. The daily movement measured reached just over 0.5 cm and temperatures fluctuated about 15 degrees Celsius.

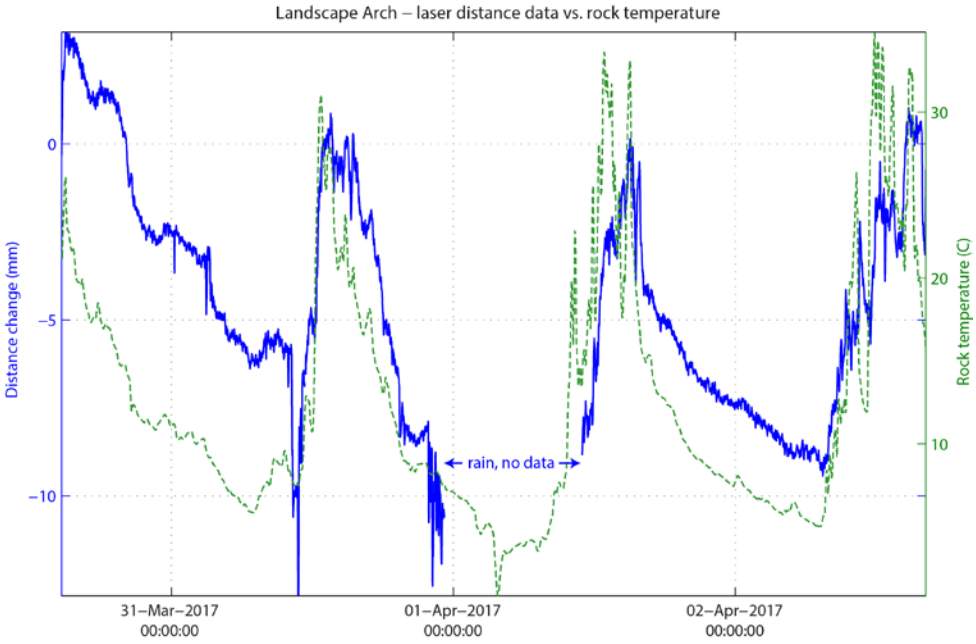


Figure 1 – Laser distance data (blue) paired with rock temperature data (green) measured between March 31st and April 2nd, 2017 at Landscape Arch.

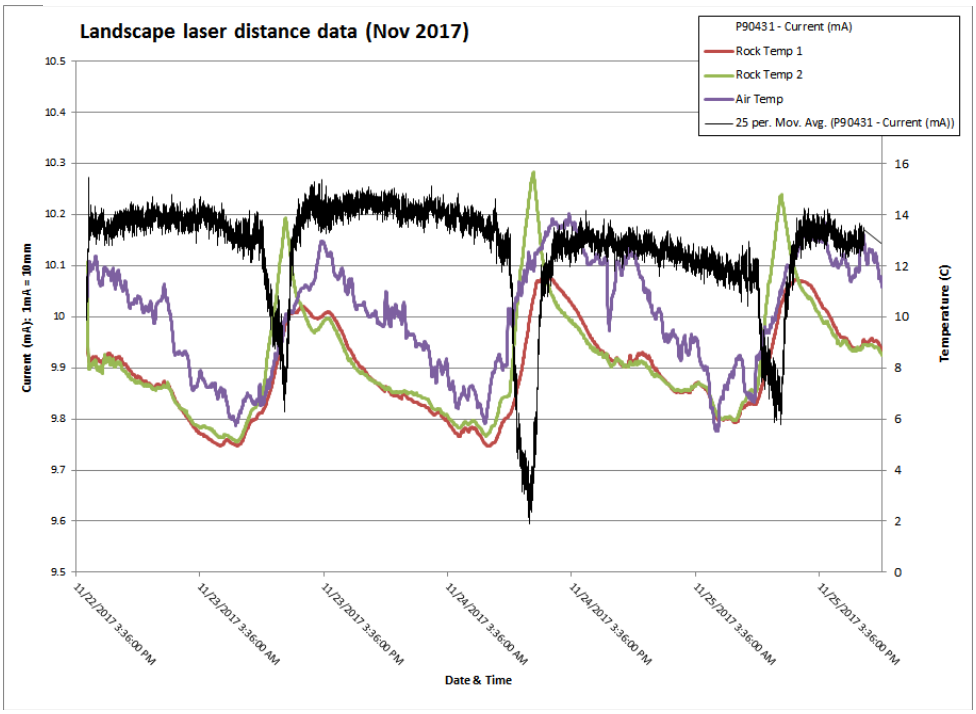


Figure 2 – Laser distance data (black) paired with air (purple) and rock (red and green) temperature data measured between November 22nd and 25th, 2017 at Landscape Arch.

Measurements were also taken at Owachomo Bridge in the Fall of 2016, and Rainbow Arch in the Spring of 2017. Owachomo exhibited similar motion as the second Landscape Arch measurement while Rainbow Arch looked similar to the first Landscape measurement. These variations seem to be seasonally distributed. This raises questions about the nature of thermally induced movements in these features on longer timescales. Future repeat measurements are needed to better establish these observations and further investigate differing responses to thermal forces.