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Thermal monitoring of a granitic exfoliation sheet and cliff in Yosemite Valley, California (USA)

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In recent years, new remote sensing techniques such as Terrestrial Laser Scanner (TLS) and Infrared Thermography (IRT) have been used in parallel for rock weathering and weakness detection in slope stability analysis. Nevertheless, the effects of thermal stresses on rock face deformation are still poorly quantified, especially for steep and inaccessible cliffs. To better understand how daily temperature fluctuations influence the behavior of exfoliation joints (i.e. fractures separating exfoliation sheets), we monitored a granitic exfoliation sheet in detail using TLS and IRT over a several day period and also compiled a single TLS-IRT thermal panorama of a larger nearby granitic cliff composed of hundreds to thousands of similar exfoliation sheets. The exfoliation sheet had been previously instrumented for 3.5 years beginning in May 2010 using crackmeters and temperature sensors (Collins and Stock, 2010 and 2012), thereby providing an important baseline to compare our IRT measurements.

For several consecutive days, a series of infrared thermal images (collected every 20 min.) of the exfoliation flake (19 m by 4 m by 0.1 m) was taken with a long range IRISYS IRI 4040 thermal imager, as well as several ground-based LiDAR scans, collected at 4 mm point spacing. These pictures were draped on the TLS triangular meshes to quantify the lateral propagation of temperature during the warming and cooling periods. The evolution of vertical and horizontal temperature profiles was also investigated. Results show that the sheet edge undergoes the most significant temperature changes and that warming takes place from the inside part to the border of the flake; conversely cooling takes place from the outside-inwards. Furthermore, the comparison of point clouds indicates a maximum crack aperture of over 1 cm occurring in the afternoon (12:00 to 15:00), when temperatures are at their maximum.

The thermal panoramic image of the cliff (600 m wide by 300 m tall) was created using over 100 stitched pictures and also draped on a TLS mesh to generate a 3D color model. This model shows the apparent temperatures measured according to position and surface orientation of the cliff. This rock wall has many recent rockfall scars with lighter colored rock surface; these scars appear as spots of lower temperature surrounded by warmer areas and may undergo increased stress related to the thermal variations. However, these first results must be verified by further testing using calibrated models to distinguish the effects of emissivity and thermal radiation. Subsequently, we plan to fix the thermal camera on a GigaPan EPIC Pro device to take sequences of panoramas during rock cooling and heating and to perform additional investigation on air and water propagation in fractured zones.