CASE STUDY

Location: Iceland
Solution by InSAR

THE LAND OF FIRE, ICE & LANDSLIDES

In July 2018 one of the largest recorded landslides occurred in a remote part of Iceland. Although its remoteness meant it had little notable impact, it serves to highlight the unpredictability of landslide hazards and the need for the identification of 'at risk' areas before they occur. Here we show how satellite InSAR is used to monitor precursor deformation associated with landslides.

CHALLENGE

Climate change and land-use have a direct relationship with the number of landslides that occur in any given year. With a growing global population they pose a significant hazard to communities and infrastructure, as well as posing a direct risk to life. Often, prior to a landslide, precursor deformation can be detected using ground-based techniques, however these can be expensive, poorly suited to monitoring remote regions, and pose a risk to the safety of field personnel. An alternative solution is needed that can identify potential landslide hazards before they occur.

SOLUTION

Satellite InSAR, utilizing freely available Sentinel-1 radar data, has been used to identify the extent and magnitude of deformation prior to a large landslide that occurred in July 2018 in western Iceland. The result shows that precursor deformation can be monitored in the years leading up to slope failure.

CONCLUSION

InSAR allows for the remote and cost-effective identification of potential landslides before the main failure occurs. Not only can the extent of the movement be identified, but a time series of the magnitude of displacement can be generated, which provides further insight into slope stability.

BACKGROUND

The Fagraskógarfjall landslide, located in western Iceland (Figure 1), is up to 2.5 km long, 1.5 km wide, 20 m thick and has a volume up to 10 – 20 million cubic meters[1]. This large landslide occurred at 05:17 on 07/07/2018 and may have been preceded by a smaller landslide at 23:30 the previous evening, which could have destabilized the rest of the hillside. Fortunately the landslide occurred in a remote area (Figure 2), but the substantial size and unexpected occurrence may mean that other, more populated areas, are at risk of a similar event.

Landslides are common in areas of steep natural or artificial topography such as mountain ranges, hillsides and open-pit mines. Landslides can be triggered by natural processes such as excess groundwater, extreme rainfall, melting of permafrost, as well as by earthquakes and volcanic eruptions. Human activity such as deforestation, construction and blasting can further trigger or enhance the likelihood of a landslide.

The Fagraskógarfjall landslide was likely triggered by the large volume of rainfall that Iceland received in the summer of 2018[2]. This may have exacerbated the slip detected from historical satellite data, which suggested the hillside was unstable and moving since 2015[1]. Detecting such movement before a critical failure is key to identifying at risk areas and adopting an appropriate mitigation strategy.

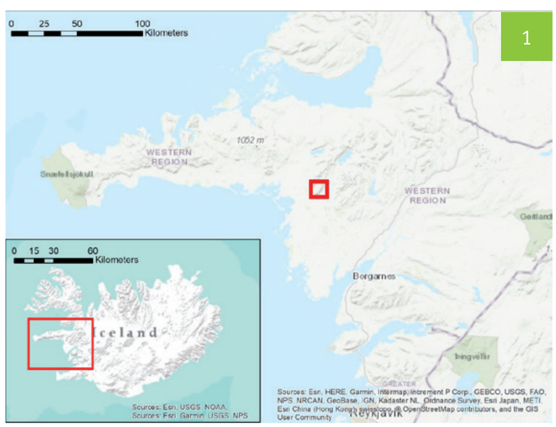

Figure 1. Location of the landslide in Iceland. The red box in the inset highlights the general region in western Iceland. The red box in the main map shows the location of the landslide.

Figure 2. Photograph of the Fagraskógarfjall landslide. Image taken by the Icelandic Coastguard.

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CHALLENGE

Landslides can be highly disruptive leading to damage of infrastructure (such as roads, railways and pipelines), blocking and diverting watercourses, disrupting mine operations, and in the worst cases resulting in loss of life. Where a potential landslide is detected prior to critical failure it is possible to mitigate the hazard, either through stabilizing the slope, evacuating those that could be impacted, or monitoring. However, such mitigation is predicated on knowledge that the slope is either moving in the first place, or at risk of doing so.

Movement of a landslide prior to a critical failure can be effectively detected and monitored using ground based techniques such as GPS, inclinometers, piezometers, levelling, terrestrial LiDAR, and photogrammetry. However, these techniques can be expensive, time consuming, cover a limited area, and are ill-suited to monitoring remote or dangerous regions. There are also safety implications associated with sending personnel to difficult to access and potentially unstable slopes. Furthermore, ground based surveys require an understanding that either a slope is at risk of moving or is already beginning to creep. The most dangerous and disruptive landslides occur where there is poor knowledge of the ground conditions, thus a low-cost and accurate method to monitor potential landslides is needed to provide further insight into landslide hazards.

SOLUTION

Differential InSAR (DifSAR) applied to freely available Sentinel-1 SAR data has been used to retrospectively analyse precursor movement associated with the Fagraskógarfjall landslide between July 2017 and July 2018. From this data it was possible to precisely determine the rate of deformation between July and November 2017 (Figure 3). Figure 4 shows an oblique view of a map of the deformation rate overlain on the pre-landslide topography, up to 2 m/yr of movement occurred on the hillside. The area of greatest movement is found approximately one third of the way down the landslide, coinciding with a steeper area. The central portion of the landslide was moving faster than both the top and base, which may have contributed to the over-steepening and eventual failure of the slope.

Unlike traditional surveying techniques, InSAR can cover large areas at low cost without putting field personnel at risk. It also allows us to look at historical data to see how the movement of a landslide may have changed with time. In the case of the Fagraskógarfjall landslide we observe that in the months prior to the slope failure the landslide accelerated, to the extent that it exceeded the rate detection limit of the InSAR processing. The results highlight the effectiveness of remote sensing techniques for the monitoring of potential landslides, with applications for hazard monitoring, protection of infrastructure, and open-pit mining.

REFERENCES

- 1. http://en.vedur.is/about-imo/news/a-large-landslide-falls-in-hitardalur-valley 10/7/2018
- 2. https://blogs.agu.org/landslideblog/2018/07/26/fagraskogarfjall-landslide 26/07/2018

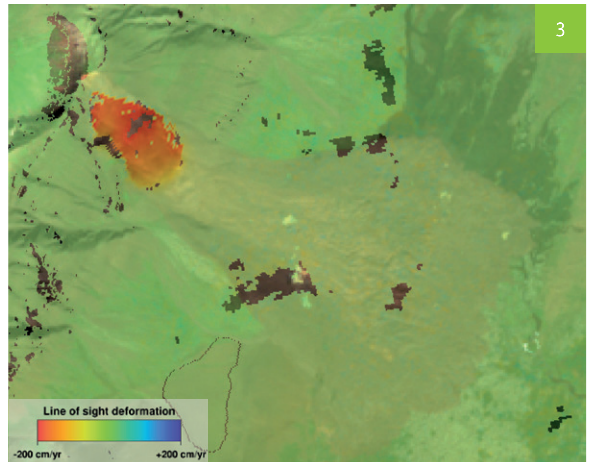

Figure 3. Yearly rate map of the Fagraskógarfjall landslide between July and November 2017. Green represents relatively stable areas while the red-yellow region highlights significant slip of the landslide. Up to 2 m per year of slip may have occurred in some parts of the landslide. © CGG 2018. Images contain modified Copernicus Sentinel data (2018).

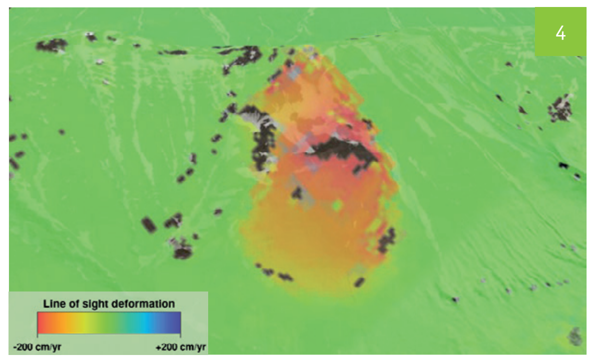

Figure 4. Oblique view of the cumulative displacement associated with the Fagraskógarfjall landslide, spanning July to November 2017. The upper and middle portions of the landslide were moving significantly faster than the lower portion. The area of greatest movement is associated with a steeper area of the hillside. Measurement gaps along the landslide primarily relate to rapid levels of deformation © CGG 2018. Images contain modified Copernicus Sentinel data (2018).

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