

# Using corner reflectors for enhancing landslide monitoring in the UK

K Kelevitz<sup>1</sup>, J E Chambers<sup>2</sup>, J Boyd<sup>2</sup>, A Novellino<sup>2</sup>, A Watlet<sup>2</sup>, C Jordan<sup>2</sup>, J Biggs<sup>3</sup>, S Selvakumaran<sup>4</sup>, T J Wright<sup>1</sup>, A Hooper<sup>1</sup>

1: COMET, University of Leeds 2: British Geological Survey 3: COMET, University of Bristol 4: CDBB, University of Cambridge



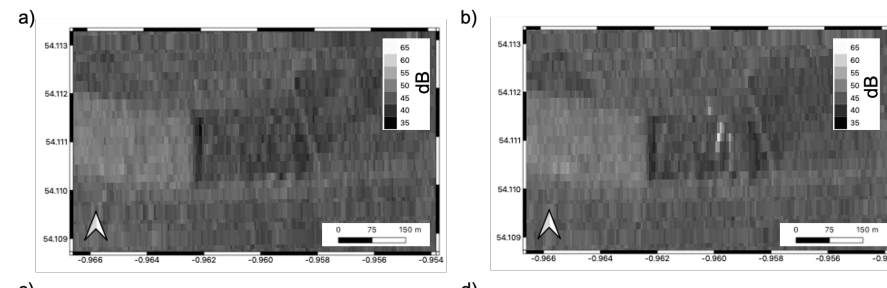
## Hollin Hill landslide - background



Installation of corner reflectors.  
(Photo: A. Novellino)

Hollin Hill is a well-studied landslide acting as a field laboratory managed by BGS to support UK landslide research.

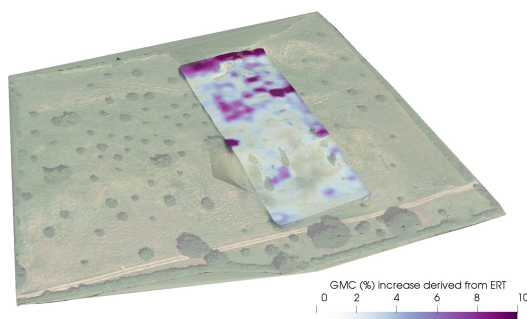
## InSAR measurements before and after the installation of Corner reflectors



Improvement in amplitude due to the installation of corner reflectors (distribution shown below with yellow triangles) on the 17 July 2019.

- a) Average amplitudes of ascending acquisitions between 1 Jul 2018 and 16 Jul 2019
- b) Average amplitudes of ascending acquisitions between 20 Jul 2019 and 20 Feb 2021

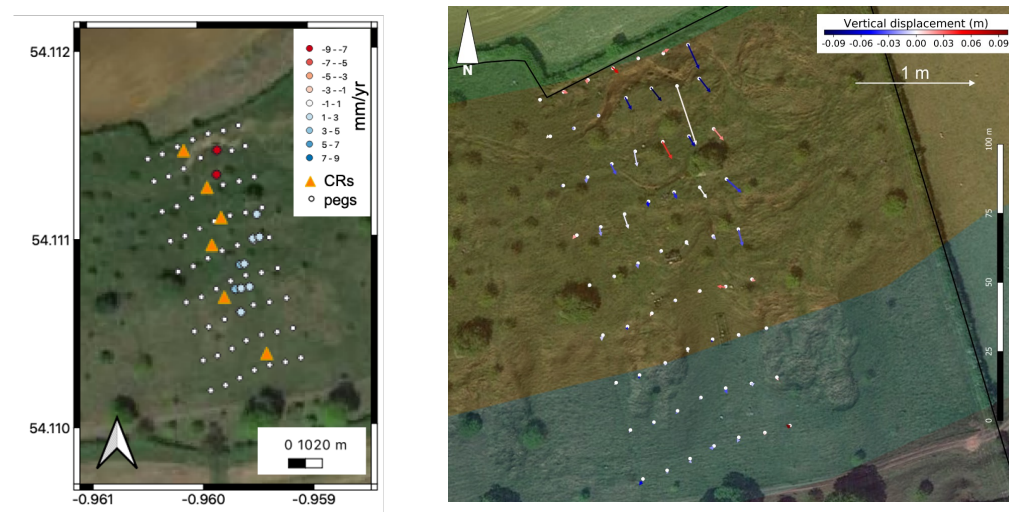
## Ground based measurements



2021-02-06

Ground-based geophysical methods are used to monitor the site, such as Electrical Resistivity Tomography (ERT), Self Potential (SP), and strain and tilt meters. The figure shows results of moisture content change between 21 Nov 2020 and 6 Feb 2021.

## Movement on the top part of the landslide in Jan 2021



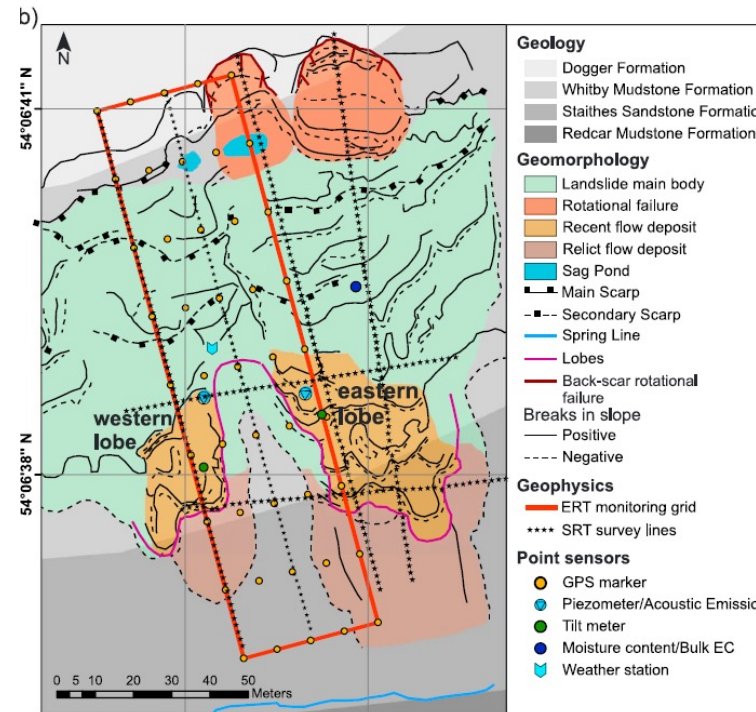
Both InSAR (left, red-blue circles) and ground-based GNSS measurements (right) confirm movement at the top of the slope in Jan 2021.

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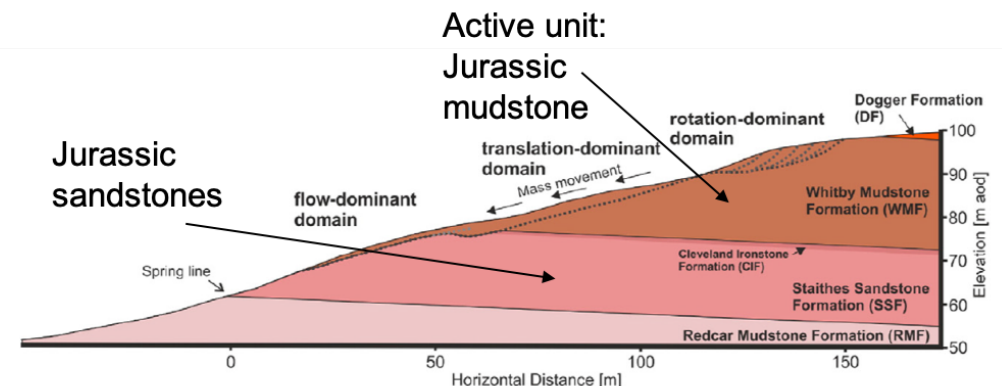
## Hollin Hill landslide - background



Uhlemann et al., 2017

The slope at Hollin Hill consists of Redcar Mudstone (Lower Lias) at the base, with an outcrop of the Staithes Sandstone Formation (Middle Lias) running across the middle section of the slope. The Whitby Mudstone Formation (Upper Lias) overlies this, with the upper part of the slope composed of the Dogger Formation. The Whitby Mudstone Formation is highly susceptible to landsliding, and movement across the entire slope is due to this Formation.

The landslide is largely caused by the movement of the Whitby Mudstone Formation, which is highly prone to landsliding. The landslide is characterised by shallow rotational failures at the top of the slope in the Whitby Mudstone, which move through an area of translational landslide movement and “cascade” over the *in situ* Staithes Sandstone Formation feeding into four larger-scale slow-moving (i.e. tens of centimetres per year) lobes of slumped material at the bottom of the slope. (Source: <https://www.bgs.ac.uk/landslides/hollinHill.html>)



Uhlemann et al., 2016

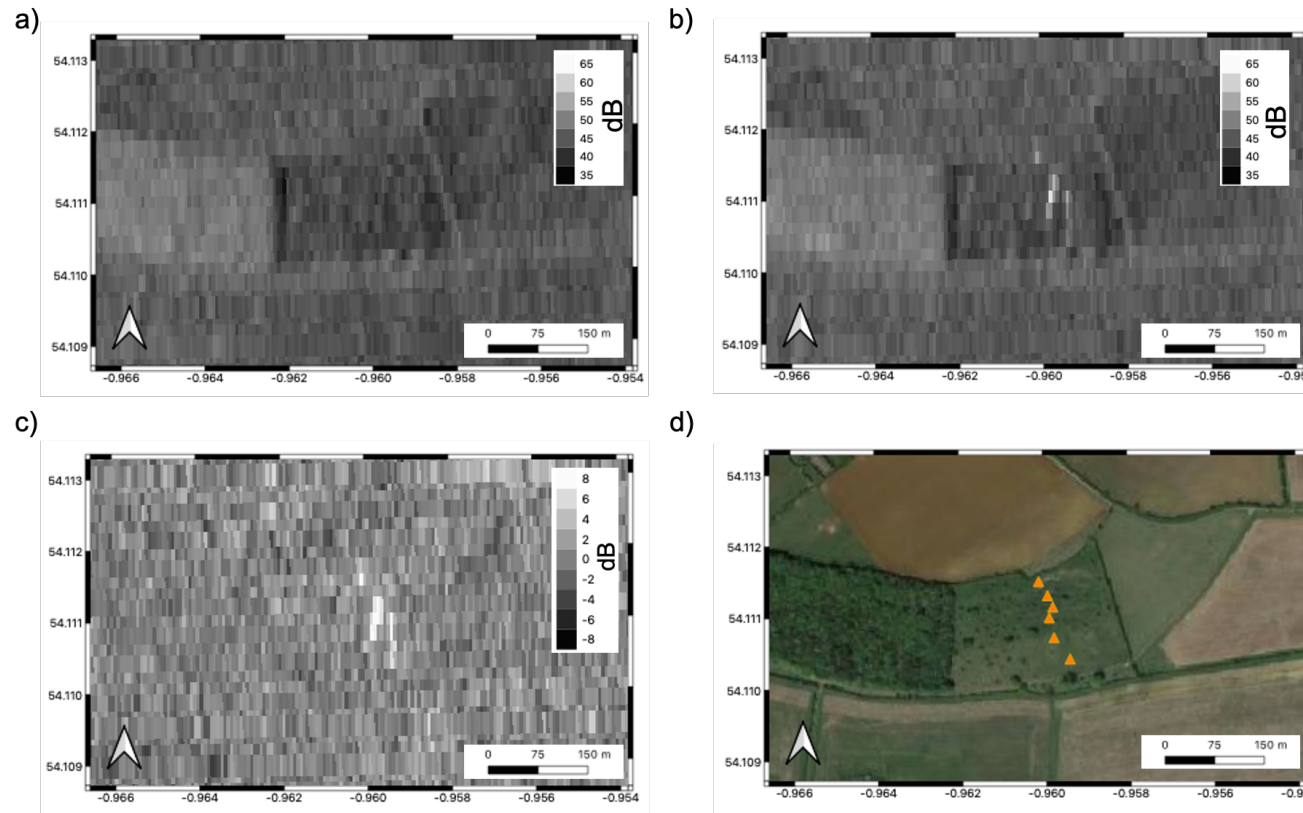
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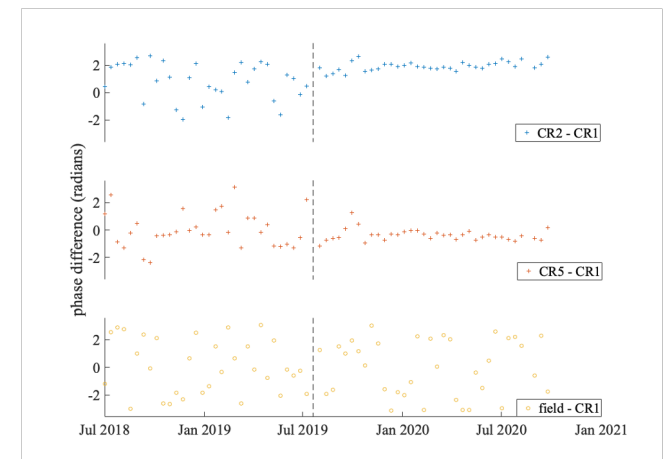
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## InSAR measurements and Corner Reflectors



Installation of corner reflectors. (Photo: A. Novellino)



Stabilisation of phase differences after the installation of corner reflectors in July 2019.

No change when compared to a random noisy pixel in the “field”

Improvement in amplitude due to the installation of corner reflectors (yellow triangles) on the 17 July 2019.

- a) Average amplitudes of ascending acquisitions between 1 Jul 2018 and 16 Jul 2019
- b) Average amplitudes of ascending acquisitions between 20 Jul 2019 and 20 Feb 2021
- c) Difference in amplitudes between a) and b)
- d) Satellite image of the area with the locations of the corner reflectors

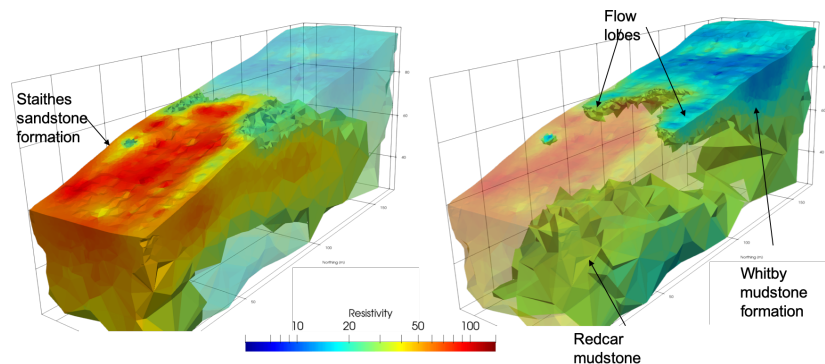
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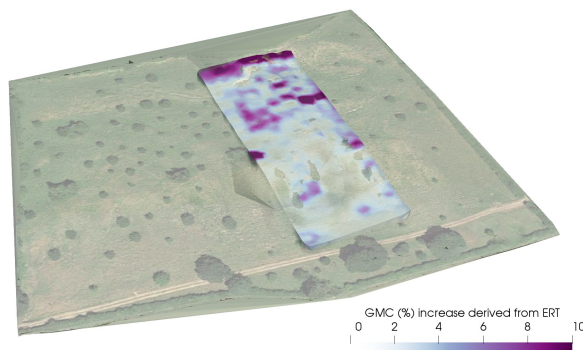
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## Ground based measurements

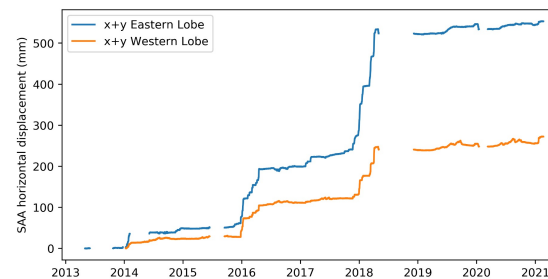


Results of the 3D Electrical Resistivity Tomography:  
Overview of resistivity domains, source: J. Boyd et al., 2019



2021-02-06

Moisture increase derived from Electrical Resistivity Tomography (ERT) during the recent 2021 Jan event



Results from tiltmeters located on the eastern and western lobes of the landslide.



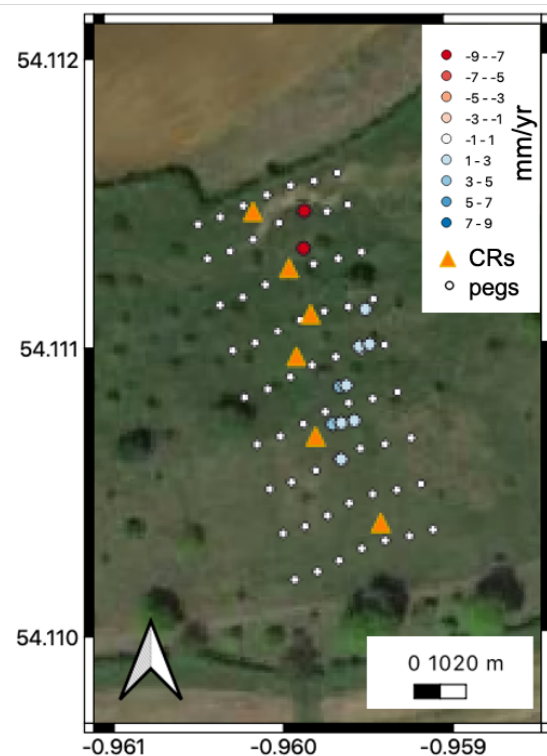
Motion of the pegs during the 2021 Jan event

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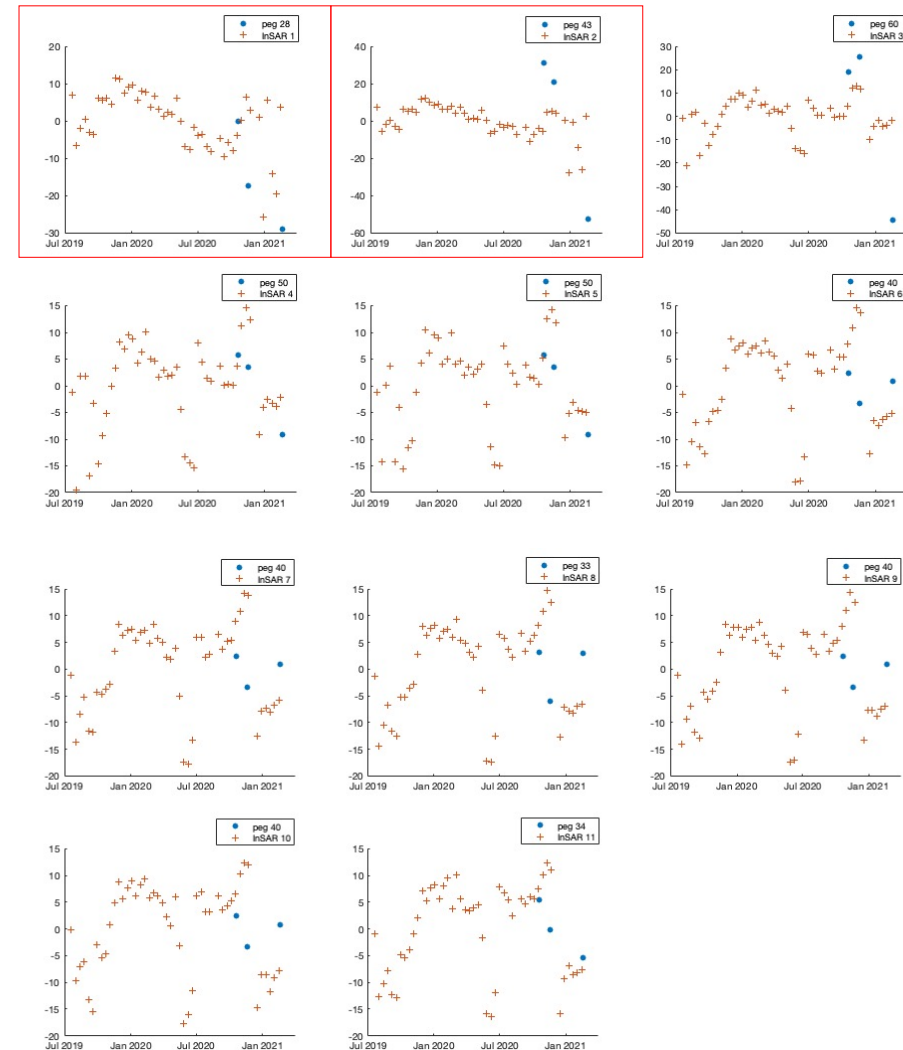
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## Movement on the top part of the landslide in Jan 2021



Insar velocities derived from ascending acquisitions since the installation of the 6 corner reflectors in July 2019. Orange triangles show the location of corner reflectors and white dots show the location of pegs placed on the ground.

- Combination of ground-based and InSAR measurements is challenging, because of the small number of coherent InSAR pixels and their sparse and irregular distribution.
- The installation of corner reflectors improves the quality of the InSAR data and the comparison between the movement of individual pegs and the corresponding InSAR pixels.



Individual InSAR time series (orange +) compared to movements of the closest peg (blue circles). Time series corresponding to the 2 northern points are shown in the red boxes, corresponding to the red dots on the left figure.