Candidate for FOSA Innovation Award

Project: Development of static strain and temperature sensing in a Rayleigh backscatter-based system

Timeline: Commenced mid 2018 as fundamental research, migrated to early product development in 2019/2020. 3rd validation undertaken late 2020 through 2021. Launched as a new fundamental capability in 2021 achieving first commercial sales the same year.

Contact: JJ Williams / Chris Minto. John.williams@optasense.com, chris.minto@optasense.com

People: Fundamental Research led by OptaSense New Product Development Team:

Roger Crickmore Initial Understanding and scoping capability

Paul Clarkson Development of deployable capability, extending performance understanding.

Alastair Godfrey Research Team lead

Chris Minto Key internal stakeholder / sponsor

JJ Williams Pioneering sales lead

Joe Ciorra Software team lead

Alex Hill Software architecture lead

Other Organisations / Key Locations:

British Geological Survey Supported initial performance verification at Hollin Hill: UK National Landslide Laboratory

Outline of Project:

The development of this fundamental underpinning capability started with a simple question and an attempt to go and actually test a flawed perception held by industry, users and ourselves. It goes something like this.

"Our Rayleigh based systems are affected by strain and temperature, is that right"

"Yes, that's fundamentally what we measure"

"But we can't measure static strain? "

"well we can, but really only for short periods of time"

"why is that then"

"not sure, I guess it's because our signals just aren't coherent over long durations"

"so, how long exactly?"

"um, dunno. Look Rayleigh based systems are dynamic not static – hence the DAS acronym"

"Shall we take a look?"

It's as simple as that. If you go take a look it's there, we looked and we found that with no modification to the interrogator we could comfortably measure strain and temperature with high resolution over long periods of time – microstrains and millikelvin levels.

Of course it's not quite as simple as that, otherwise it wouldn't really be a candidate for the award.

Firstly, you need a DC coupled interrogator – if your fundamental output is strain rate rather than strain then you are stuck with integrating the results and errors can just pile up. Secondly, the behaviour of the interrogator itself affects the results – changing temperatures or conditions in the IU will affect the results measured on all channels – but can be compensated for as a result.

If you are sensitive to milli Kelvin levels then a gust of wind in the lab might upset a sensitive strain measurement – or a patch of sunshine running across your test rig. How you acquire the data has an effect on the measurements and finally you have the subject of some fundamental uncertainty in your measurement as a result of the scattering centres not sitting there nicely while you take your measurement. At the molecular level, glass fibre is a dynamic medium and changes occurring during your speed of light measurement will add up to a drift of baseline.

Are these things important? Do they affect the measurement. Possibly yes and not necessarily – depends on what you want to measure.

The upshot though is a triumvirate of measurement possibly from a single box: Acoustics, Strain, Temperature in real time, with great precision, all the time.

After visiting these fundamentals we took our work to the field. Hollin Hill in North Yorkshire is a heavily instrumented landslide laboratory owned by the local farmer but operated by the British Geological Survey. It's a unique construction comprising a sandwich of mudstone (the jam) and the sandstone (the bread). In the winter when the mudstone gets wet it loses mechanical rigidity and is squeezed out the ends – very clearly. It's a hill that continuously rolls and translates following gravity. An ideal location for strain measurement.

We instrumented the hill with a dense network of cabling that was able to capture strain, temperature and separate the two (as well as keeping the acoustic for seismic measurements).

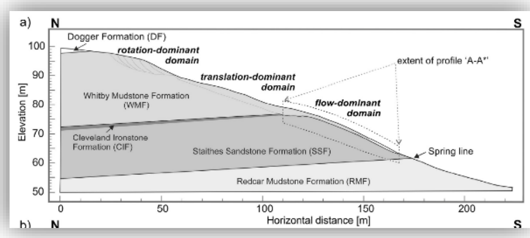
The results?

- A very clear 2D picture of evolving strain – the top of the hill predominantly in tension and the bottom in compression as the soil causes a slump and movement / strain on the cable.
- A very correlation of temperature with measured in soil – both diurnally, seasonally and as a result of weather.
- Fascinating behaviour of the hillside during storms – where a once static hill suddenly becomes a dynamic beast as tension starts to build.
- New and never before seen activity thanks to the ability to measure at all scales without averaging – as well as the significant evidence of movement events we see stiction events as friction builds up / is overcome and repeats and repeats – generally after an event as the hillside comes to a slow (well quick in geological terms, but you know what we mean) stop – but sometimes before as a build-up.
- Having thousands of such sensors provides a unique picture of the behaviour of the hillside.

As a result of these studies, the work has been co-presented at a range of major conferences throughout the summer 2021 season.

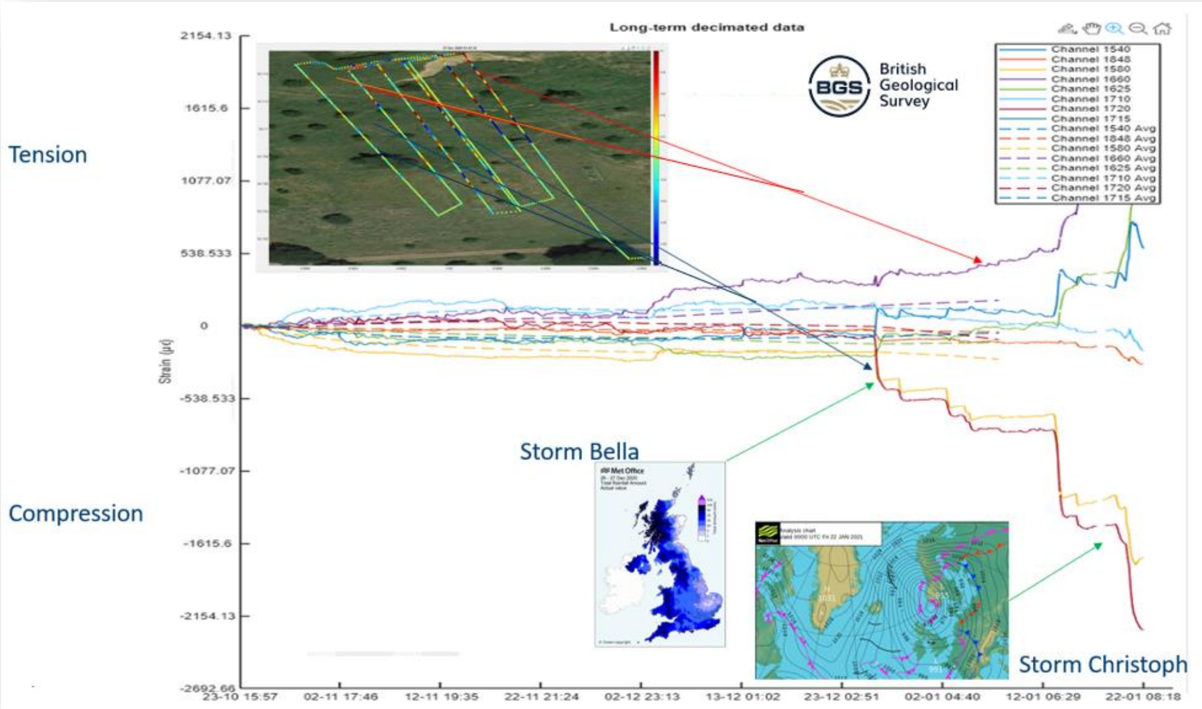
On the back of this success, the strong capability set present in “Distributed Rayleigh Sensing” (DAS becomes an application of DRS) has encouraged first commercial sales – from pipelines who want to conduct right of way monitoring at the same time as monitoring strain to tailing dams who want to be aware of dynamic failure as well as stress build up and in roads and railways where the stability of embankments and cuttings is key, but there is a desire not to have two sets of equipment doing a similar job.

So why should this development win the innovation award? This development opens up a brand-new field for all Rayleigh based sensing approaches so it’s good for members. It opens up the possibility for customers of getting strain, temperature and acoustic data in a single device which must be good for them. It means less power, space and cost require for a solution. The “live” nature of the data opens up new application areas which can dynamically look at strain and temperature with unprecedented resolution.



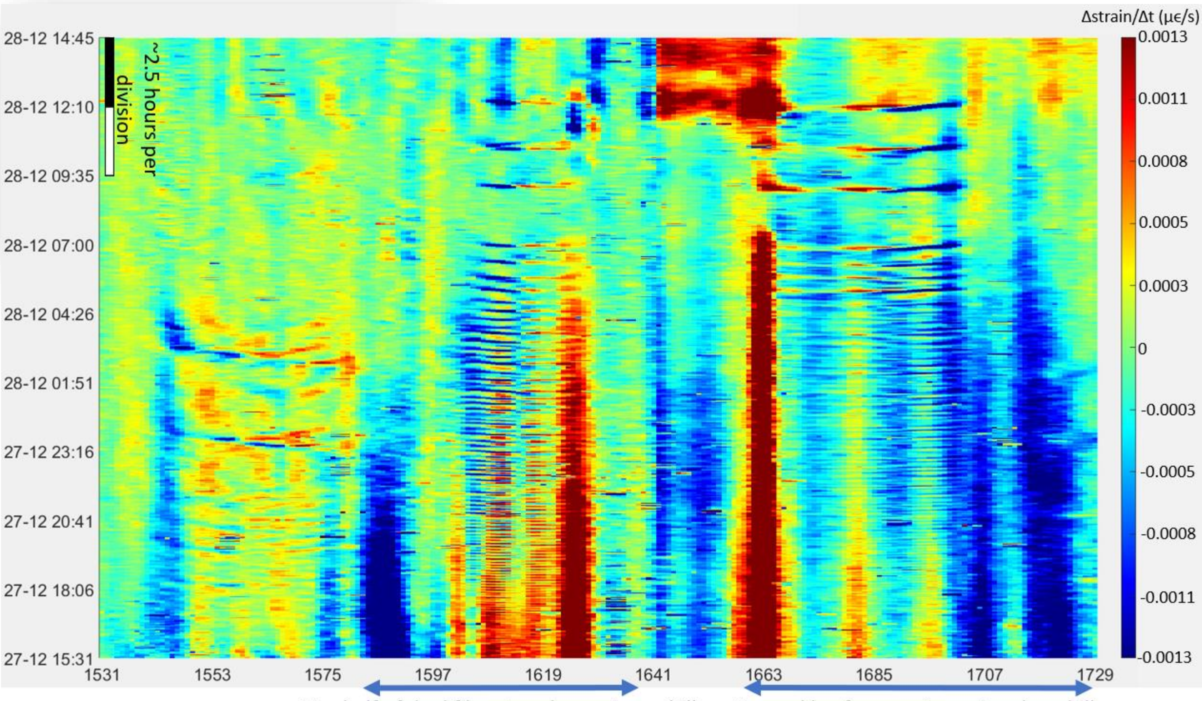
The situation at Hollin Hill near Terrington.

Whitby mudstone is squeezed out over the Staithes Sandstone with rotation at the top of the hill, leading to translation and a flow towards the bottom. Such features are very visible on site.



Monitoring the site over months allows you to look at both large scale features as we have here – large strains developing over months, punctuated by sharp transitions during bad weather.

At the same time, on very different scales we see the behavior of the soil in response to these writ large



Top half of dual fibre trench running uphill Second leg from east running downhill