Use of remote sensing for proactive management of geotechnical assets on the strategic road network in England

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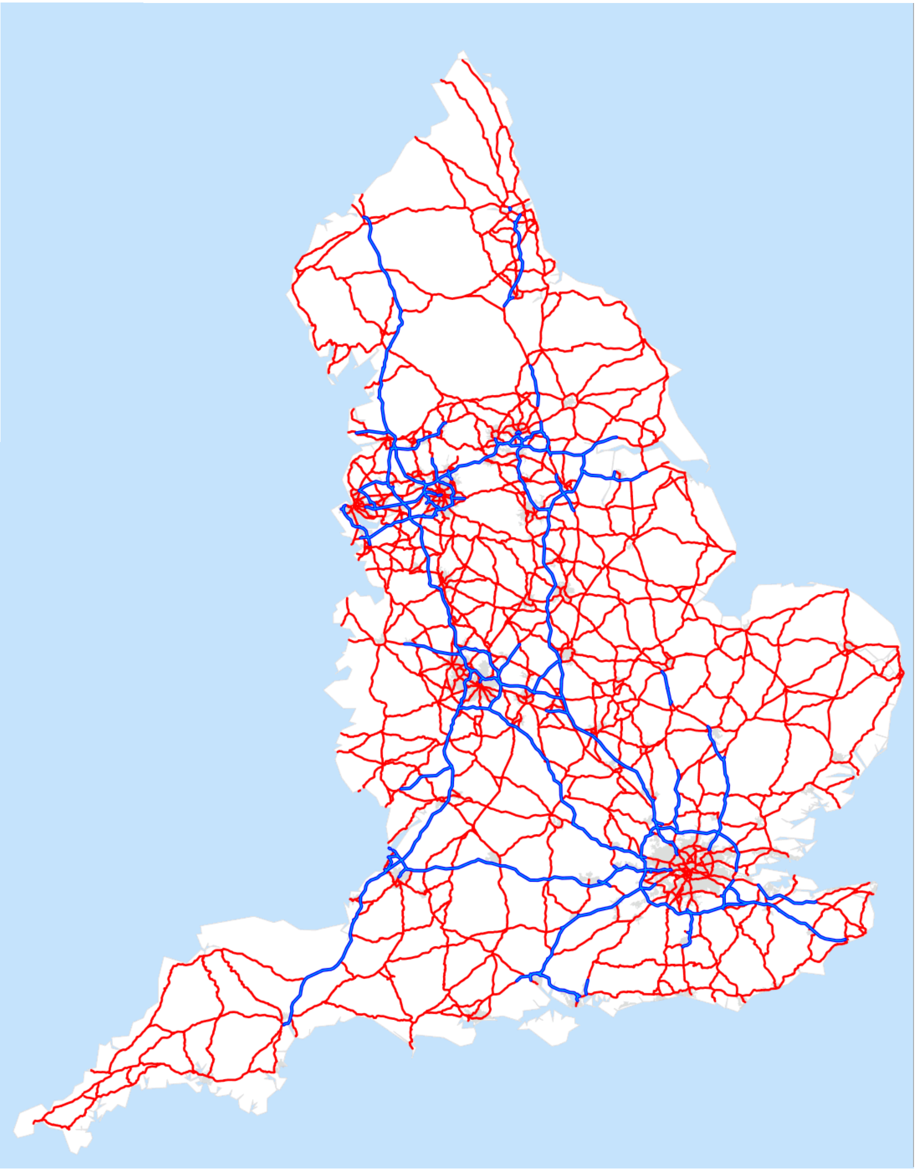
Ground Related Risk to Transportation Infrastructure
October 26th-27th 2017

Introduction

- Summary of findings of recent research study into remote sensing data owned by Highways England

- Highways England:
  - Manage 6,900 km of motorways and trunk roads
  - Carry 1/3 traffic (by mileage)
  - Carry 2/3 heavy goods
  - Represent 2% all roads (by length)
  - Delays cost £2bn/year



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Highways England faces many ground hazards

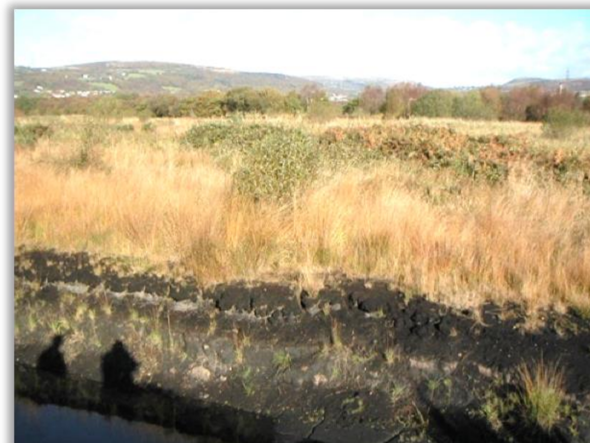
Settlement and collapse due to coal and other mining

Subsidence from brine extraction

Groundwater flooding

Subsidence and contamination from landfill

Aggressive/Corrosive ground and groundwater



Compressible soil

Highways England faces many ground hazards

Rock slope failure

Soluble ground

Engineered soil slope failure

Shrink/Swell

Natural slope instability

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How are these hazards being managed?

1. Identify hazards

2. Identify triggers

3. Assess likelihood

4. Assess consequences

5. Calculate risk

6. Mitigate risk

Risk Management Framework →

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Risk Management Framework

Remote sensing

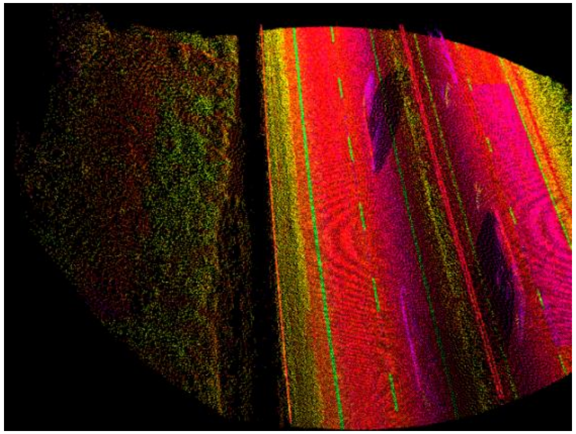
- Like traditional inspection regimes, remote sensing can be used to determine:
  - Earthwork geometry
  - Ground movement
  - Vegetation growth
  - Soil moisture
  - Chemical composition of the ground

But it also

- Reduces need for time consuming and costly physical surveys
- Improves safety
- Provides an auditable visual record of the earthwork condition
- Builds up an archive record that improves deterioration monitoring

Asset Visualisation Information System (AVIS)

- Nationwide repository for Highways England’s visual data including photographic imagery and LiDAR point clouds
- Collected via vehicle mounted sensors – provides a “drivers-eye” view
- Imagery collected approximately 1-3 year frequency
- Useful tool for geotechnical applications
  - Allows general observations about geotechnical assets
  - Could be used to support remote inspections of cuttings
- Version 2 has recently been released



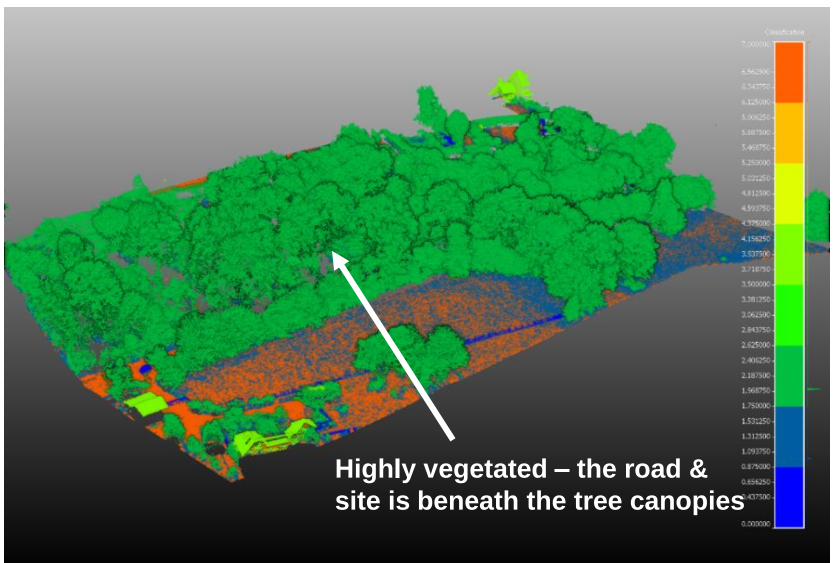
Remote sensing and proactive management

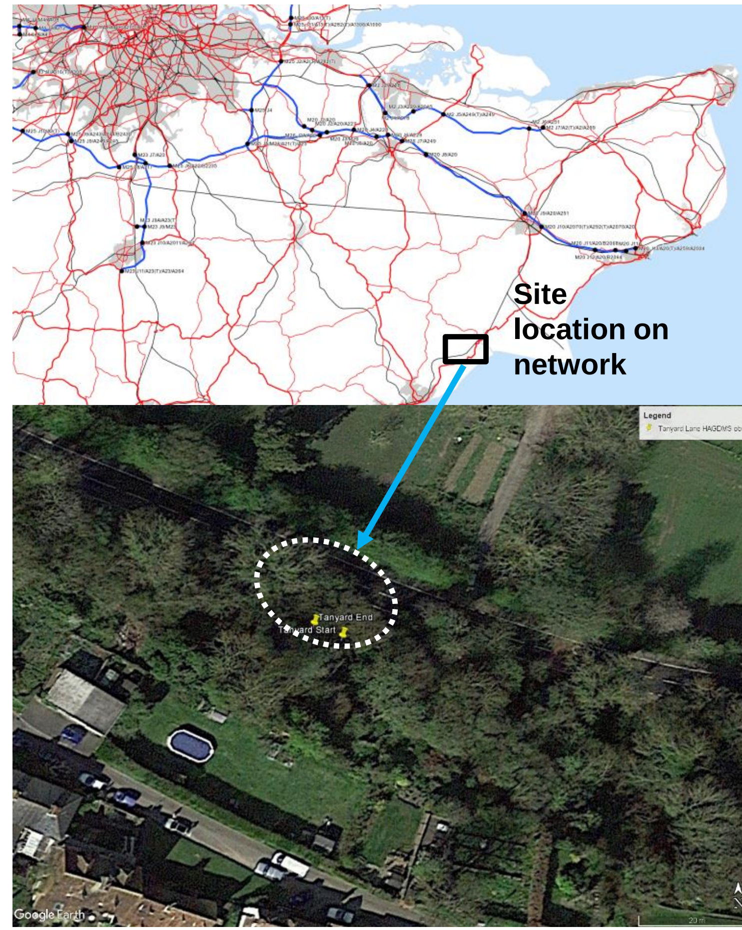
- Techniques discussed in this talk include:
  - LiDAR
  - Aerial photography
  - Hyperspectral imaging
  - Interferometric Synthetic Aperture Radar (InSAR)

- Remote sensing can be used to proactively manage geotechnical assets: this means identifying hazards/triggers and their likelihood before an event occurs e.g.
  - Understanding the extent of previous failures using LiDAR
  - Monitoring geotechnical interventions (known as special geotechnical measures at Highways England) using LiDAR
  - Visualising drainage using Hyperspectral Imaging
  - Measuring small scale subsidence over a large area (e.g. due to mining) using InSAR

LiDAR case study: natural slope failure

- Tanyard Lane on A259
- Dense vegetation (trees, shrubs, grass)
- Natural slope failure in 2014
- LiDAR captured by Rotary Wing in 2016





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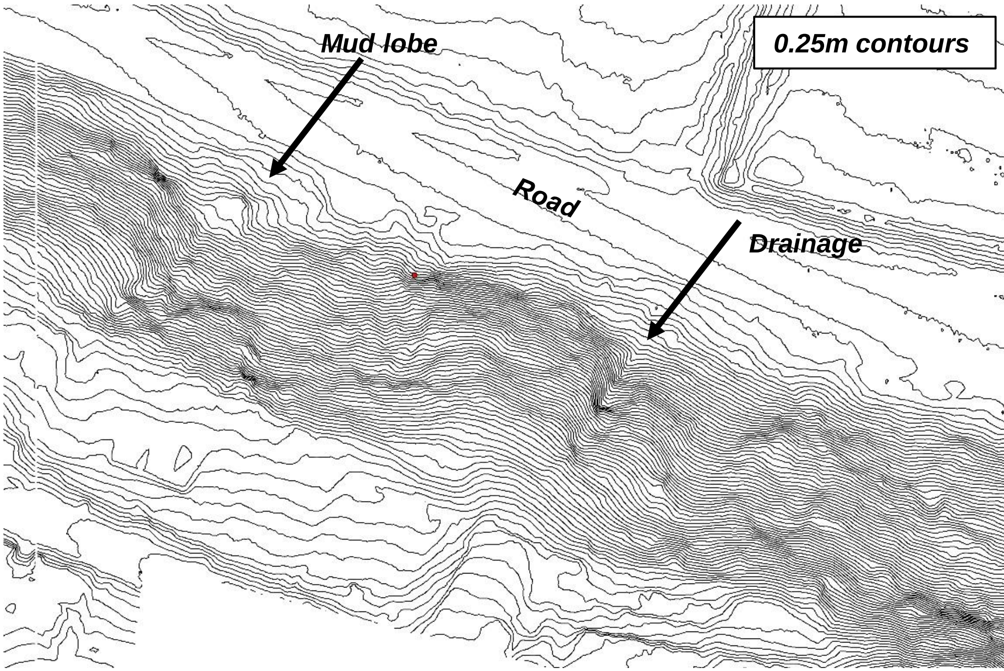
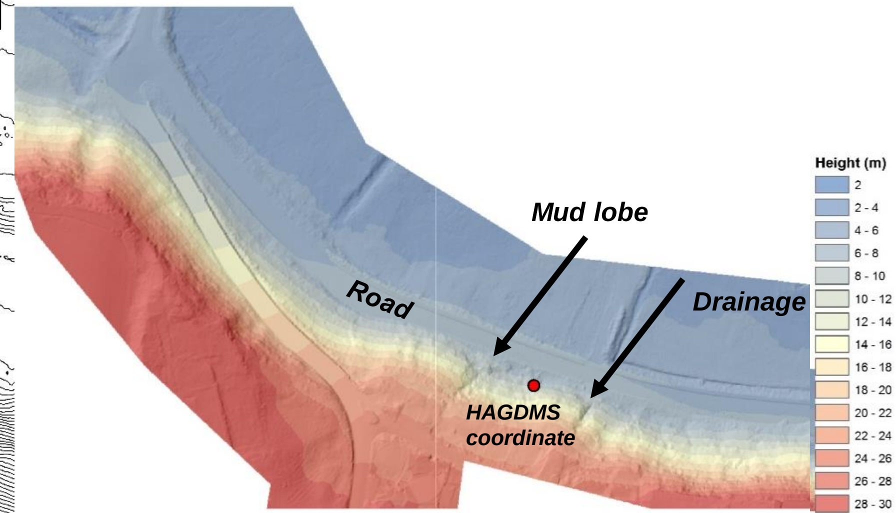
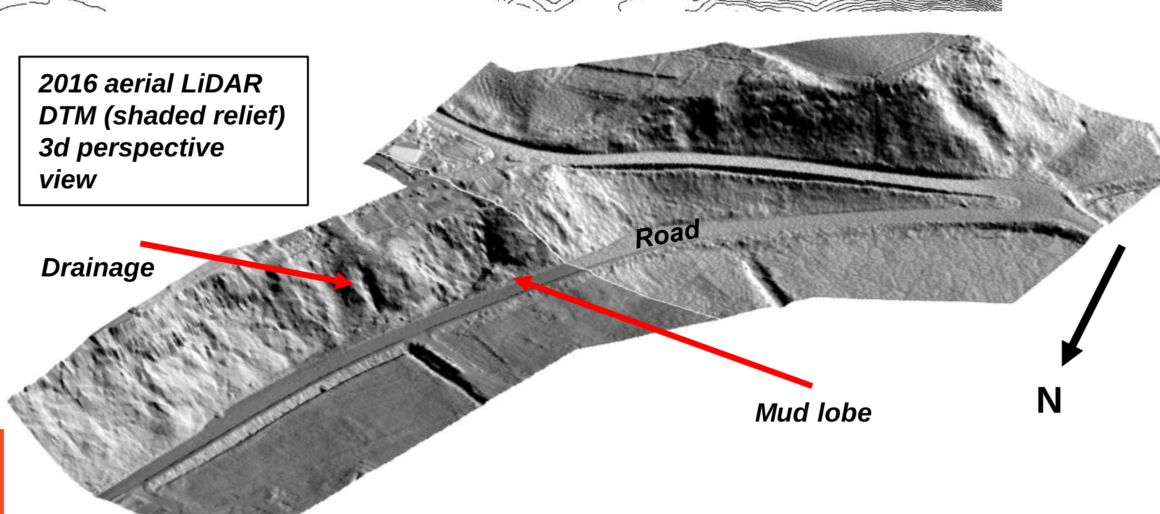
LiDAR case study: natural slope failure

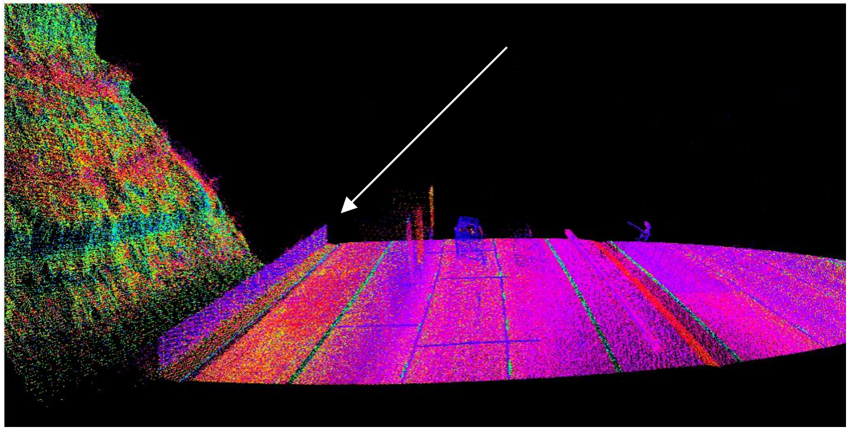


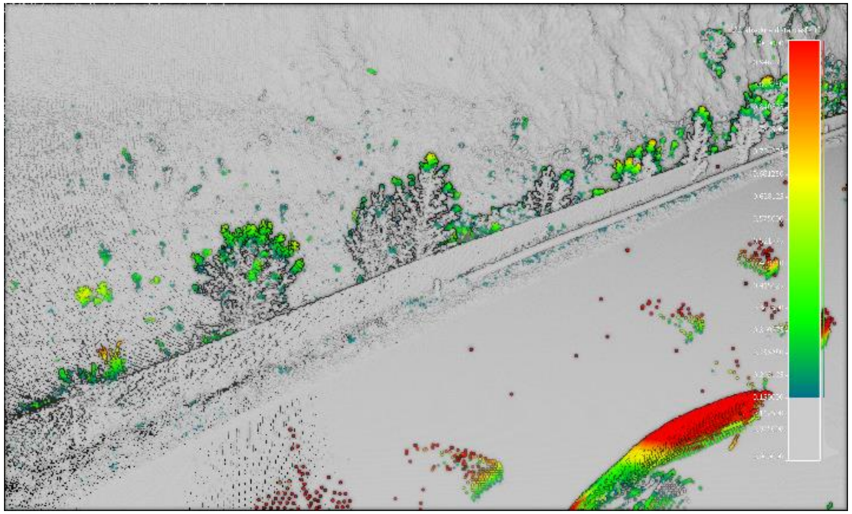




LiDAR case study: special geotechnical measures

- Site has rockfall mitigation fencing installed at the base of the cutting
- Carried out change detection between 2013 and 2014 LiDAR data captured by vehicle mounted sensors
- No changes found in catch fencing over 1 year
- The analysis highlighted vegetation growth





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Hyperspectral imaging case study: drainage and soil moisture

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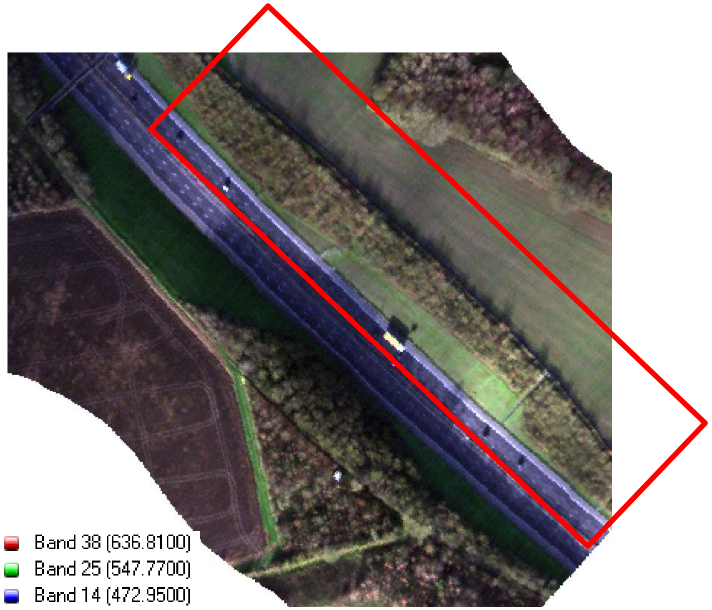
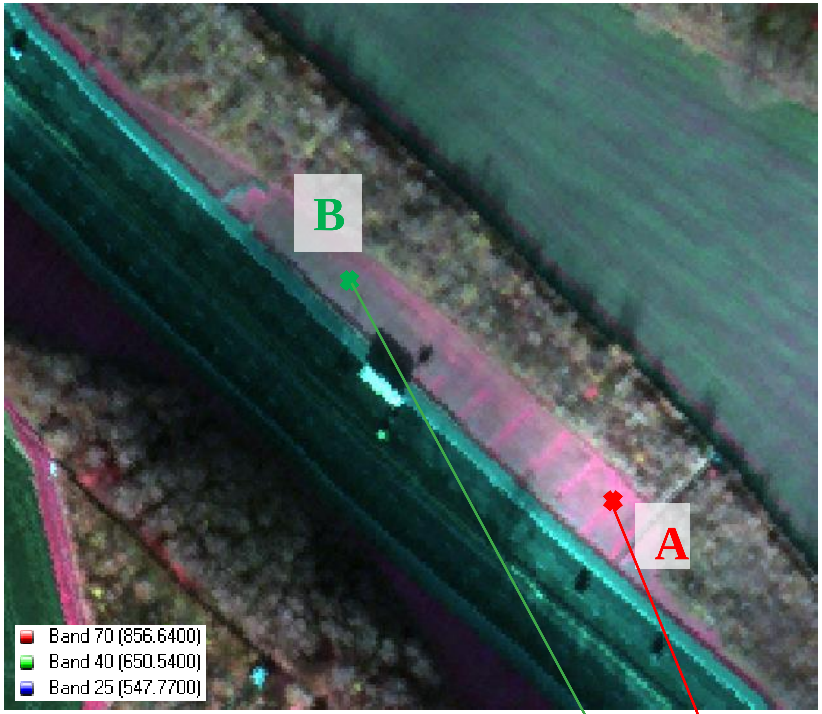
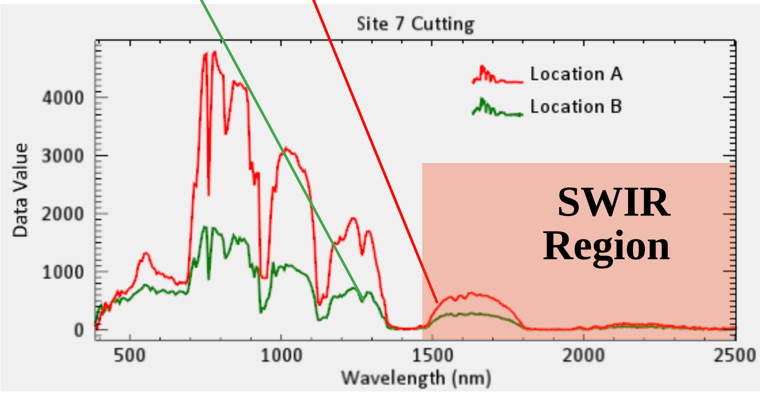
Hyperspectral imaging case study: drainage and soil moisture



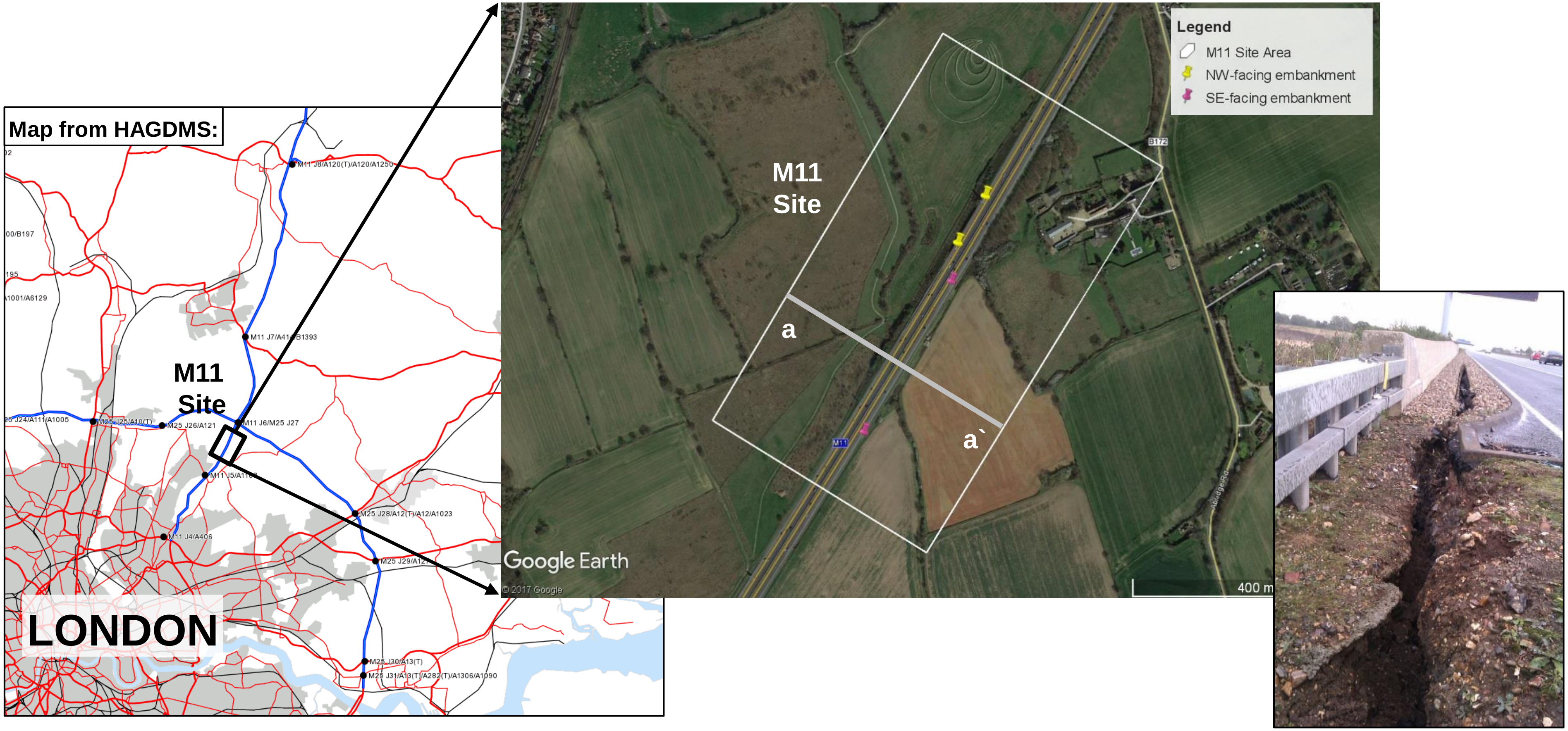


- Drains highlighted clearly in the Colour Infrared band combination
- Spectral profile in the SWIR section shows higher reflectance at point A than point B suggesting the slope is drier at point A (where the drainage is)



InSAR case study: slope failure

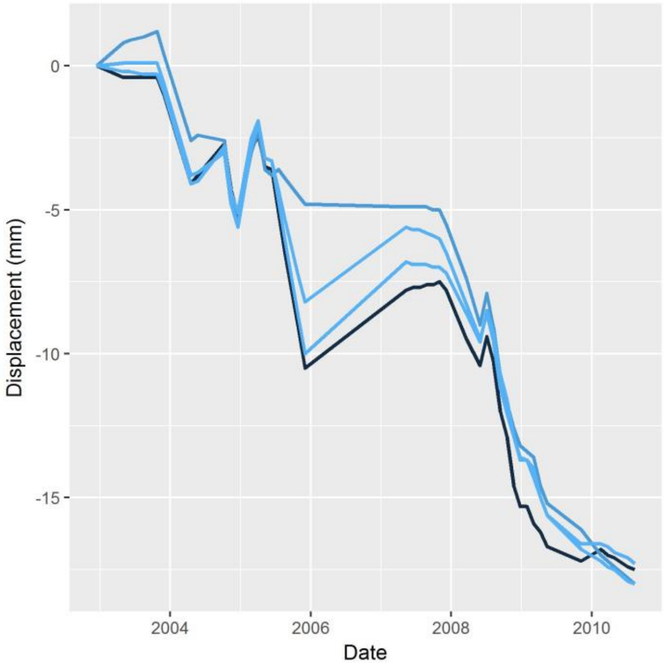
- Data and processing provided at no cost by National Physical Laboratory and CGG for a site within the PLIMM area (i.e. London area)



InSAR case study: slope failure

Persistent Scatterer (PS) results

- Only 19 points on the carriageway, most associated with the gantry
- Average of 1.5-3.5 mm/yr subsidence



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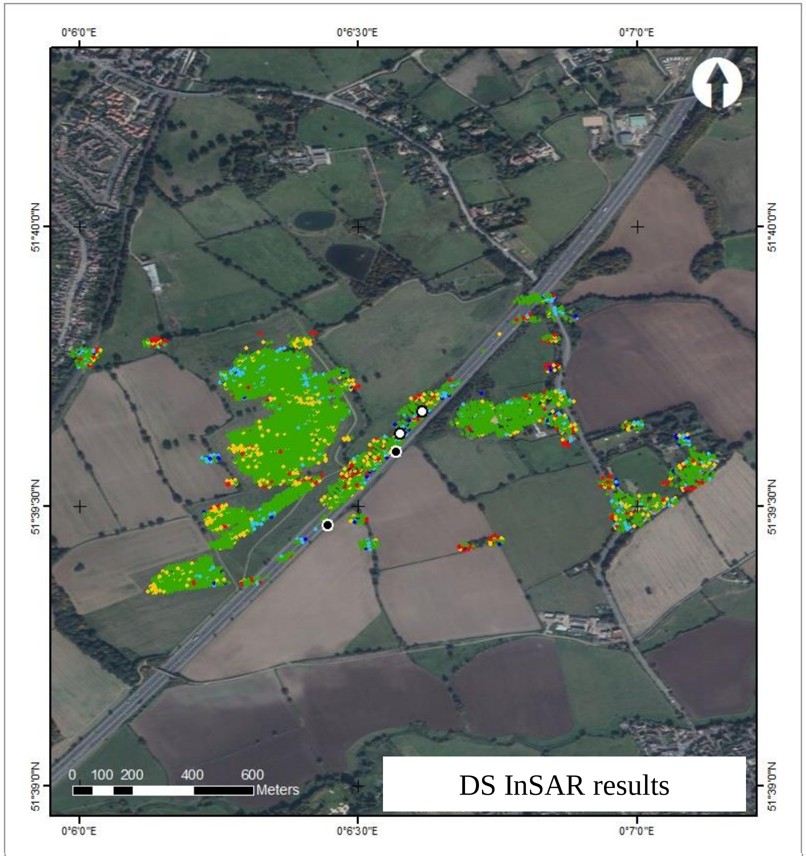
InSAR case study: slope failure



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VEL

- -10 mm/yr and more (subsiding)
- -10 to -5 mm/yr
- -5 to +5 mm/yr
- +5 to +10 mm/yr
- +10 mm/yr and more (uplifting)

Distributed Scatterer (DS) results

- Point density is much greater than PS results but low point density on the southeast facing slope.
- The lack of data related to:

1) The satellite look direction and relative to the orientation of the feature of interest.
2) Lack of good reflectors within the pixels.

- InSAR in this case not useful for earthworks
- However, in urban areas there are many more suitable reflectors
- Potential for assessing wide area subsidence e.g. coal mining/other mining/brine extraction
- This InSAR was from older radar scenes freely available for download
- Higher resolution outputs are possible with TerraSAR-X and others

Conclusions

- Multiscale approach is required, ranging from widespread low resolution data across the entire network to narrow corridor high resolution to account for all hazards
- LiDAR and high resolution imaging have more applications and there is more familiarity across the industry
- A combination of techniques is most effective
- To get best value specifications should be optimised for cross asset applications
- Remote sensing is only one of many monitoring methods and should be used alongside instrumented slope monitoring and on-foot inspections where necessary
- AVIS is a good platform for ease of viewing imagery and LiDAR point clouds of the network and has potential for earthworks assessments

Acknowledgements

- Funded by Highways England

- Hyperspectral data processing: Cyient Ltd
- InSAR data provision and processing: National Physical Laboratory and CGG
- M11 site suggested by Atkins

- Image sources: www.geograph.org.uk, Cheshire Brine Subsidence Compensation Board, BGS, HAGDMS, BBC (Tracey Jones), www.volcano.si.edu

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