Challenges of mapping and monitoring anthropogenic surface deformation using terrestrial and satellite radar interferometry

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Passion for Geoscience

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TRI for slope stability

TRI and SlopeSCAN

- Technical capabilities:
  - High resolution: Range = ~0.75 m, azimuth = ~8 m @ 1 km
  - 360° field of view, acquisition speed: up to 10 degrees/second
  - Long range: 0.1 – 10 km optimal, maximum ~16 km
  - Deformation accuracy: < 1 mm, measurement sensitivity: 0.01 mm
  - Portable, rapid deployment, autonomous operation

- Defining the terminology:
  - **GPRI2**: The instrument
  - **TRI**: Terrestrial Radar Interferometry – the technique
  - **SlopeSCAN**: The commercial service

Challenges – atmosphere

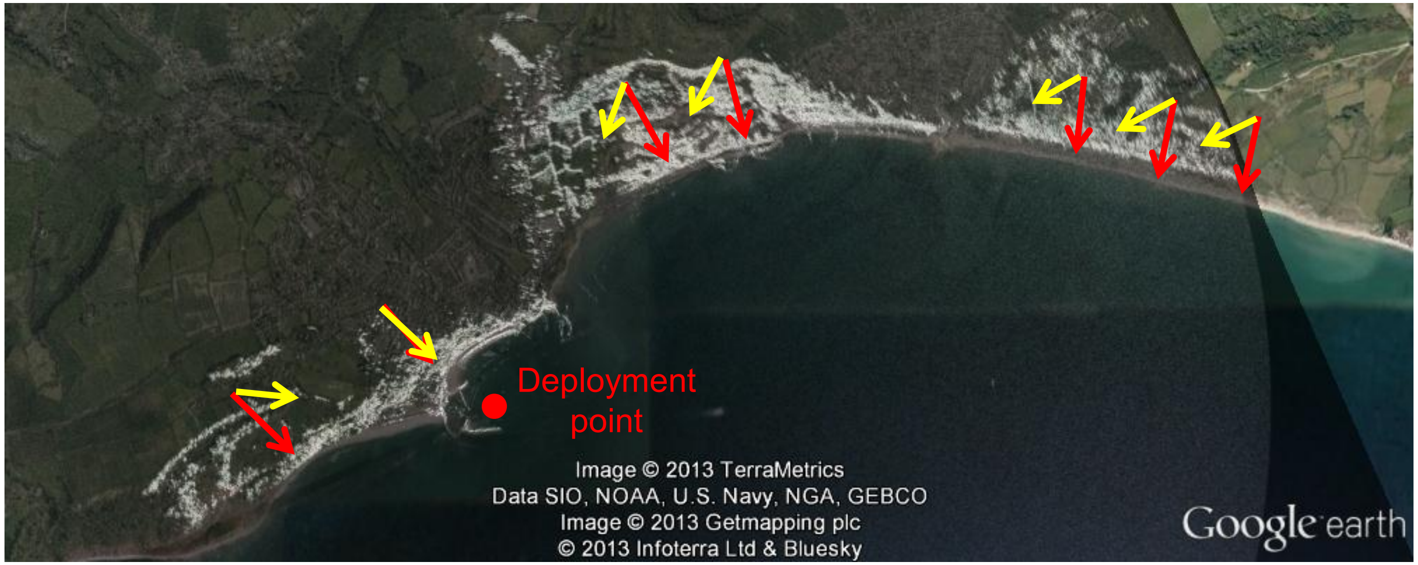
- Atmosphere – range-dependent phase trends, can mitigate empirically
- Height-dependent and localised components – large elevation differences, microclimate effects
- Effects seen over timescales of tens of minutes upwards
- Operational requirement for near-real-time results – processing must be automated and standardised, no *a posteriori* data or analysis

Challenges – viewing geometry

- Viewing geometry
  - Shadowing more of a problem because don't have a high vantage point (c.f. satellite InSAR)
  - Layover and foreshortening a consideration for steep slopes, structures etc
- Vantage points
  - Coastal cliff/landslide stability studies challenging
  - Relying on local topography to get suitable elevation at desired viewing distance
  - Trade-off between ideal imaging geometry and LOS vector of motion

Landslides, Lyme Regis, UK

Challenges – viewing geometry

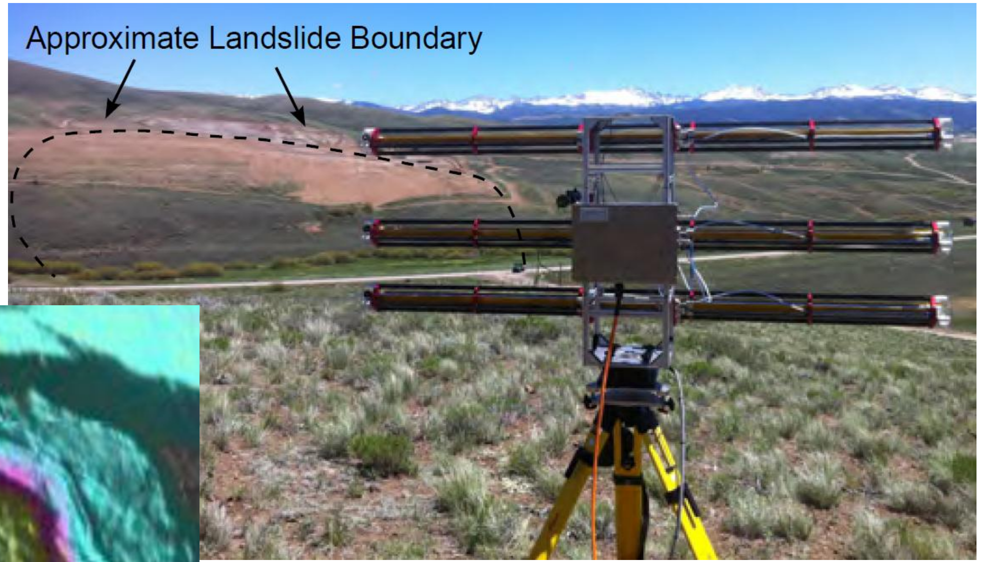


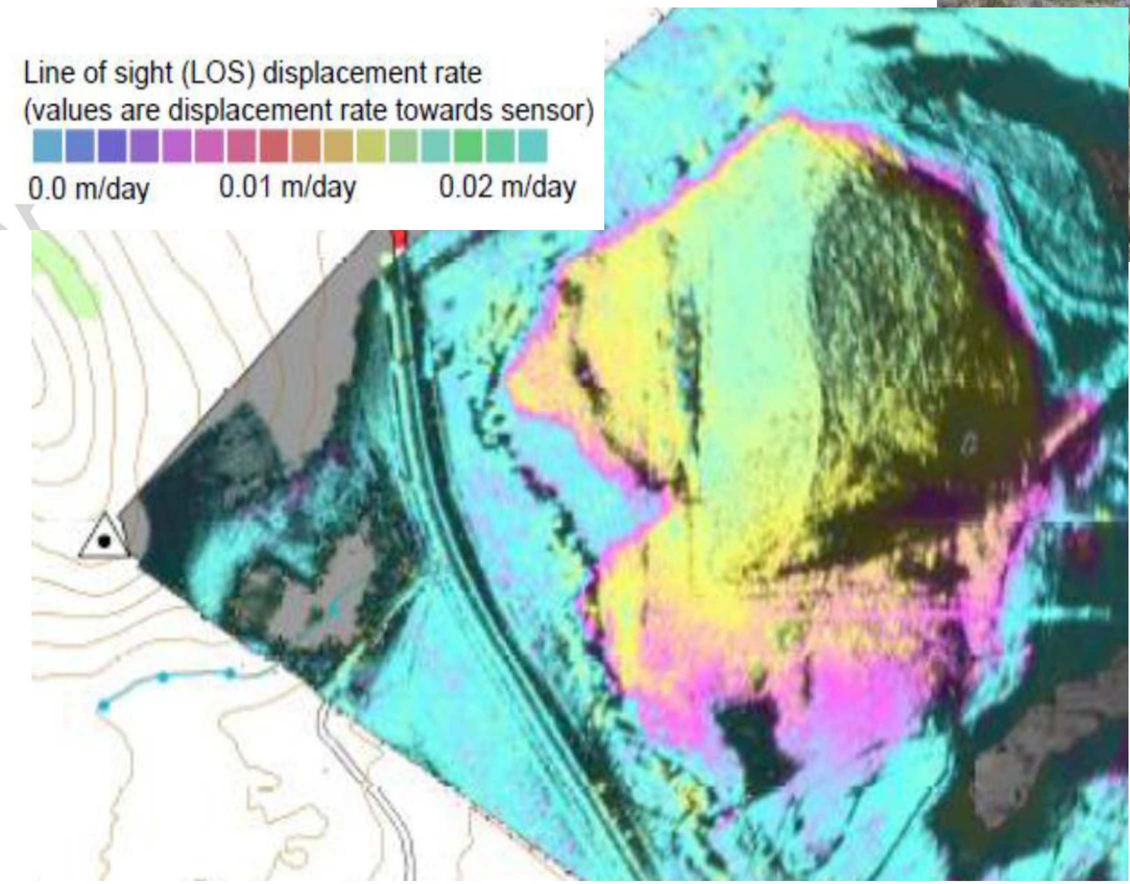
Challenges – vegetation

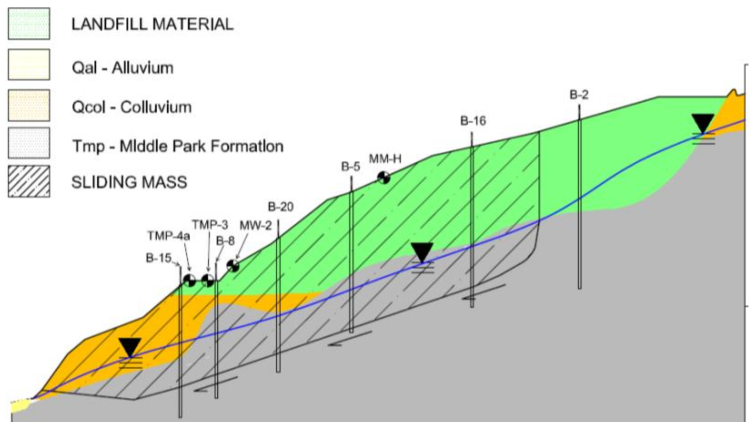
- Thin vegetation requires shorter revisit times to retain coherence
- Thick vegetation decorrelates quickly, measurements not possible

Granby Landslide, Colorado

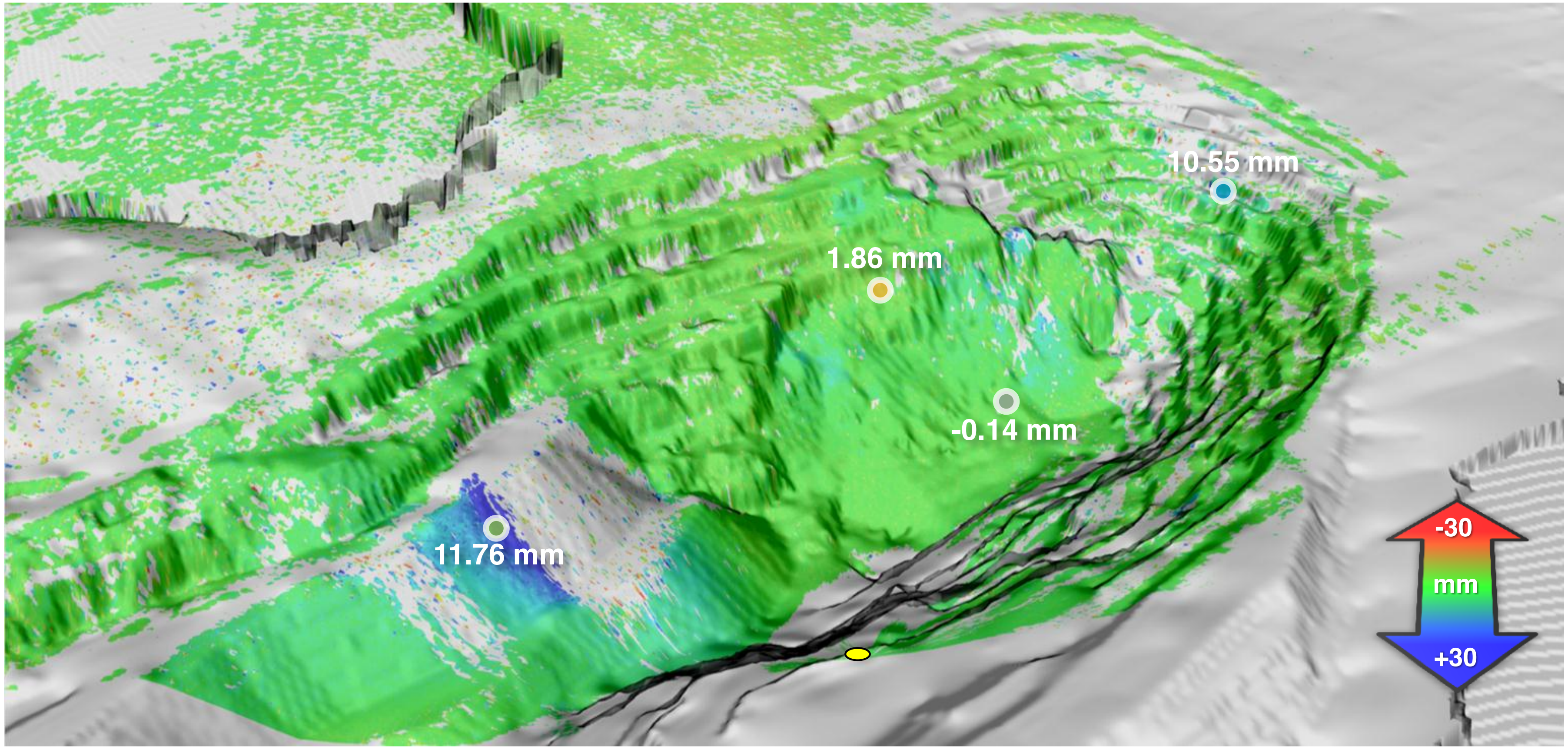
Ben Lowry, Colorado School of Mines
Paco Gomez , University of Missouri
Lowry *et al* 2013, doi: 10.1016/j.enggeo.2013.07.007







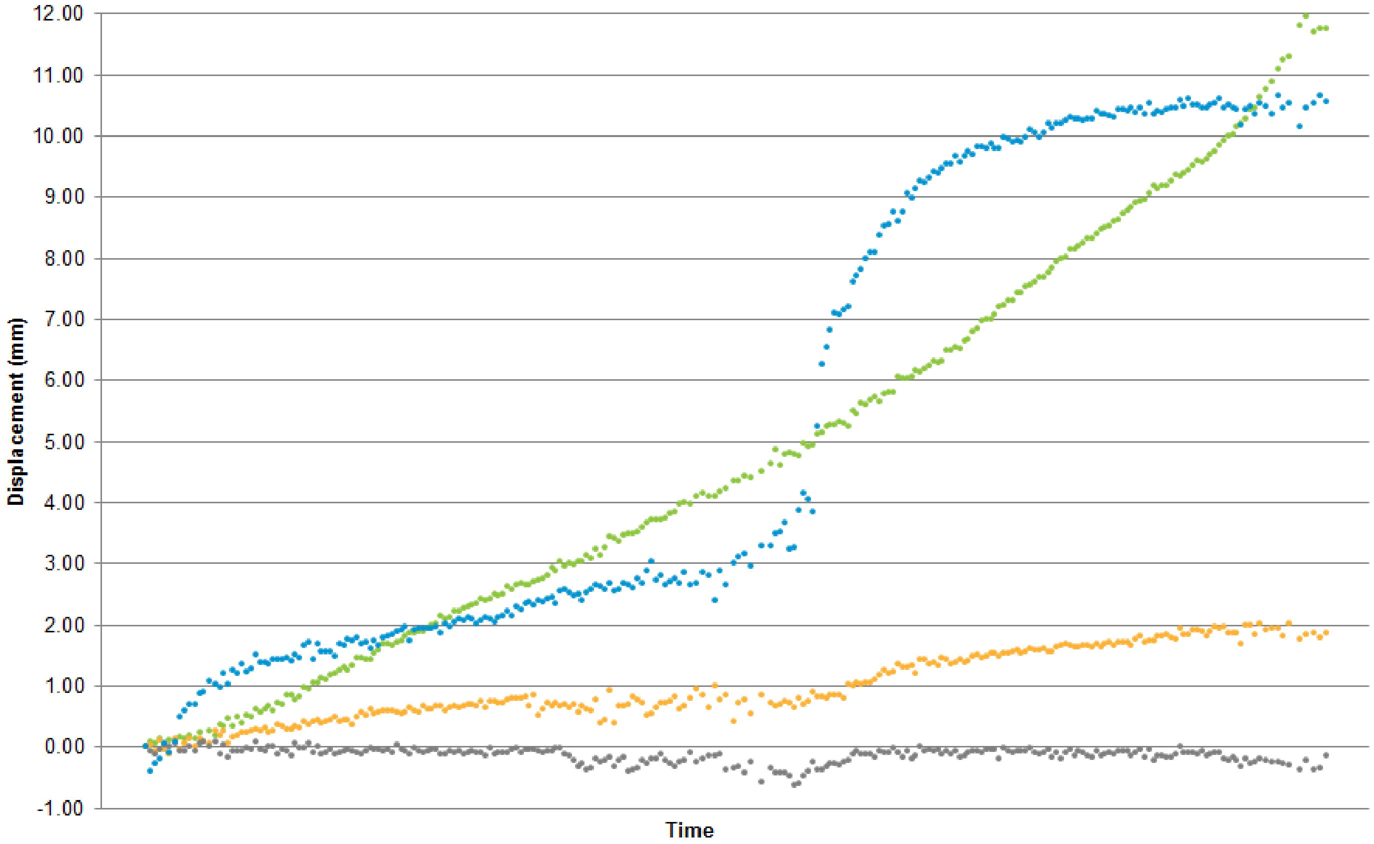
Active Quarry – Slope Stability Overview



Displacement map spanning the 2-day survey. Displacement data is draped over a DTM.

- Displacements detected in multiple locations (ranging from 2 mm to 28 mm) and predominantly towards the radar (yellow circle).

Active Quarry – Time series

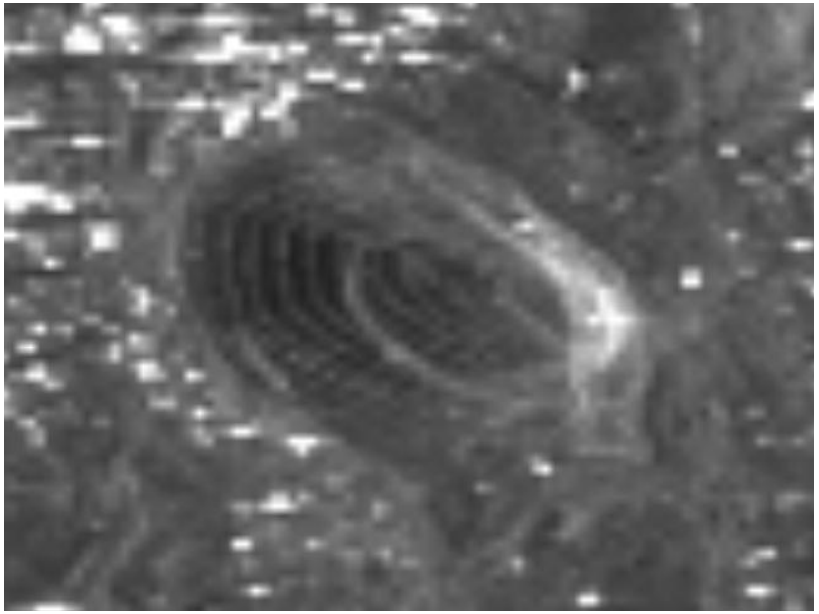


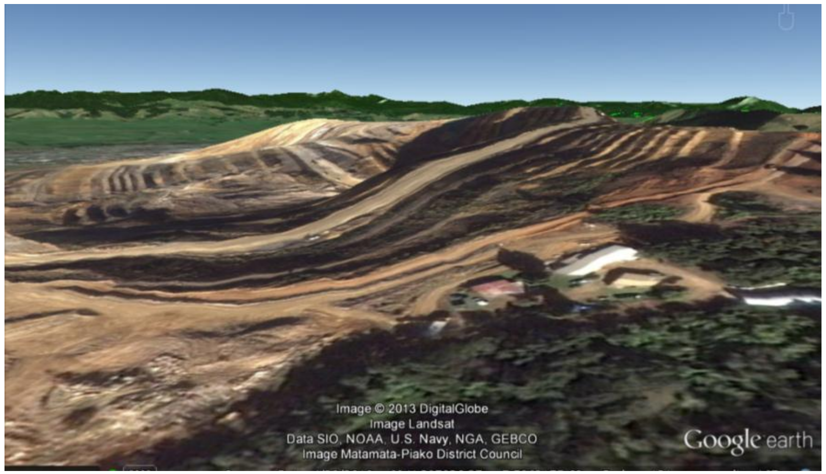
Time series of four selected points within the quarry

Satellite InSAR for mining applications

Challenges – topography and surface cover

- Surface mines
  - slope angles: foreshortening, layover and shadow
  - Surface change due to excavation and site use
  - DEM errors – tailings, spoil, excavation





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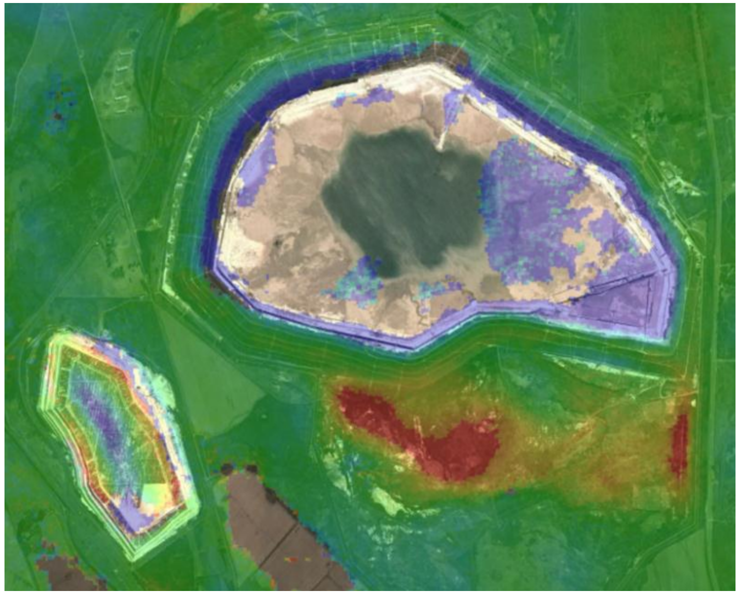
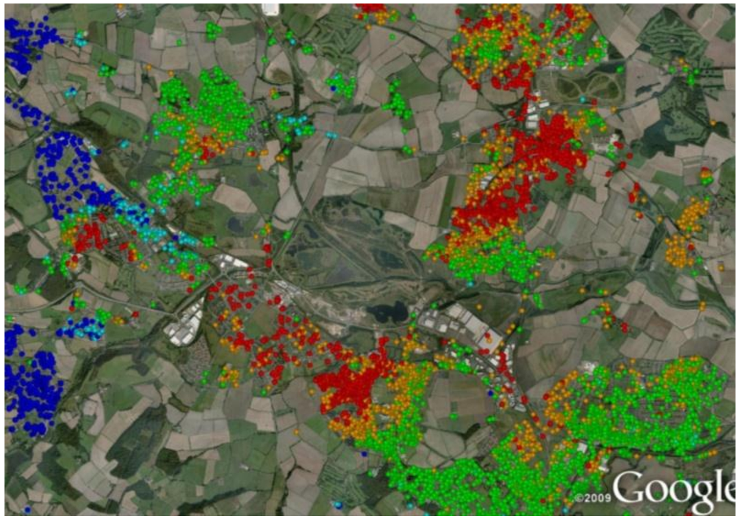


- Underground mines
  - Ground cover coherence (or PS density) limitations
  - DEM errors – tailings, spoil



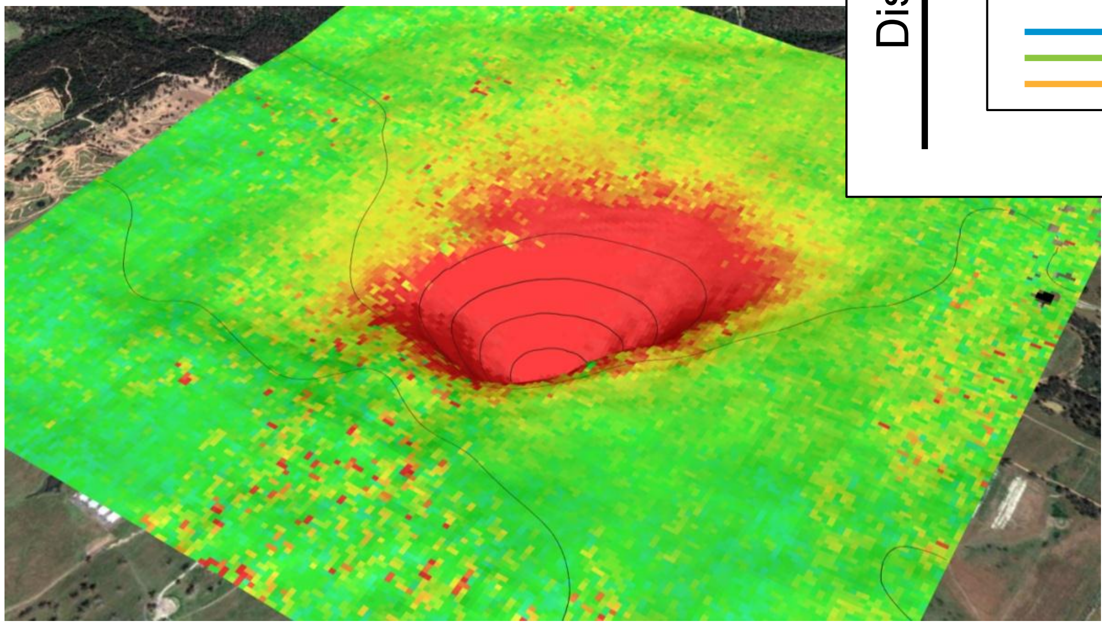
Challenges – motion characteristics

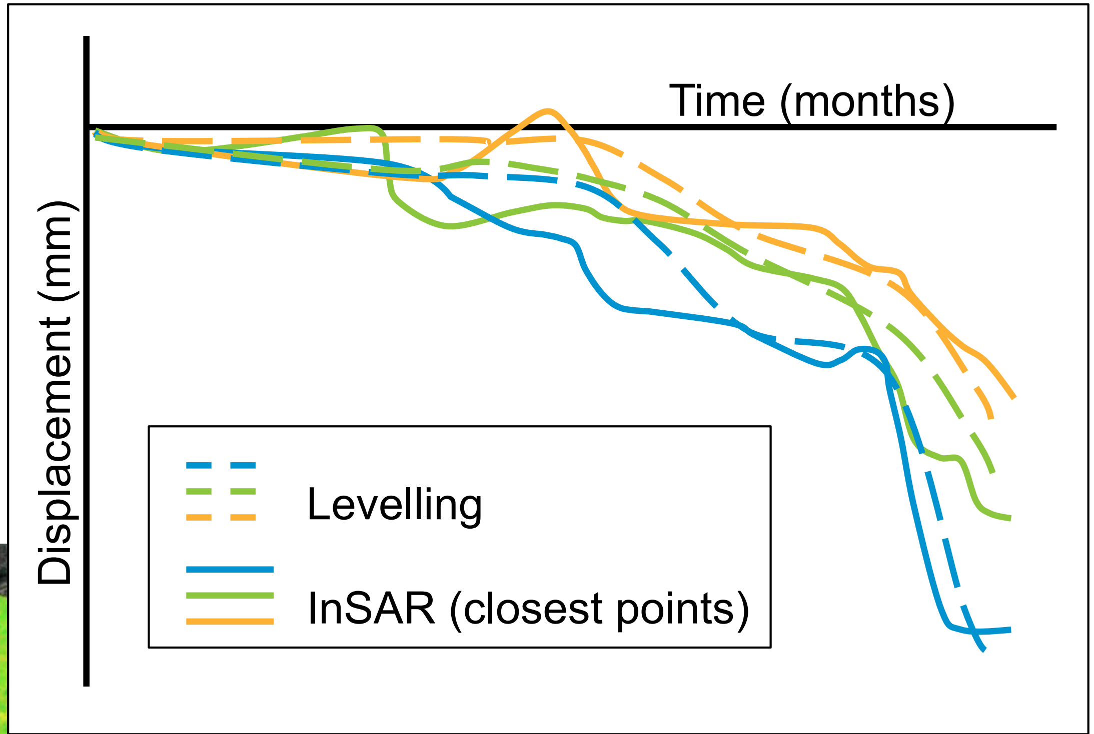
- Magnitude of motion
  - High magnitudes possible
  - Can partially mitigate using frequent temporal sampling (e.g. TSX)

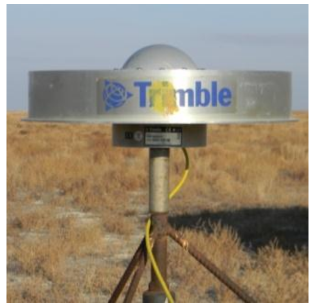
- Spatial scale
  - Features smaller than data resolution (e.g. sinkholes)

Integration

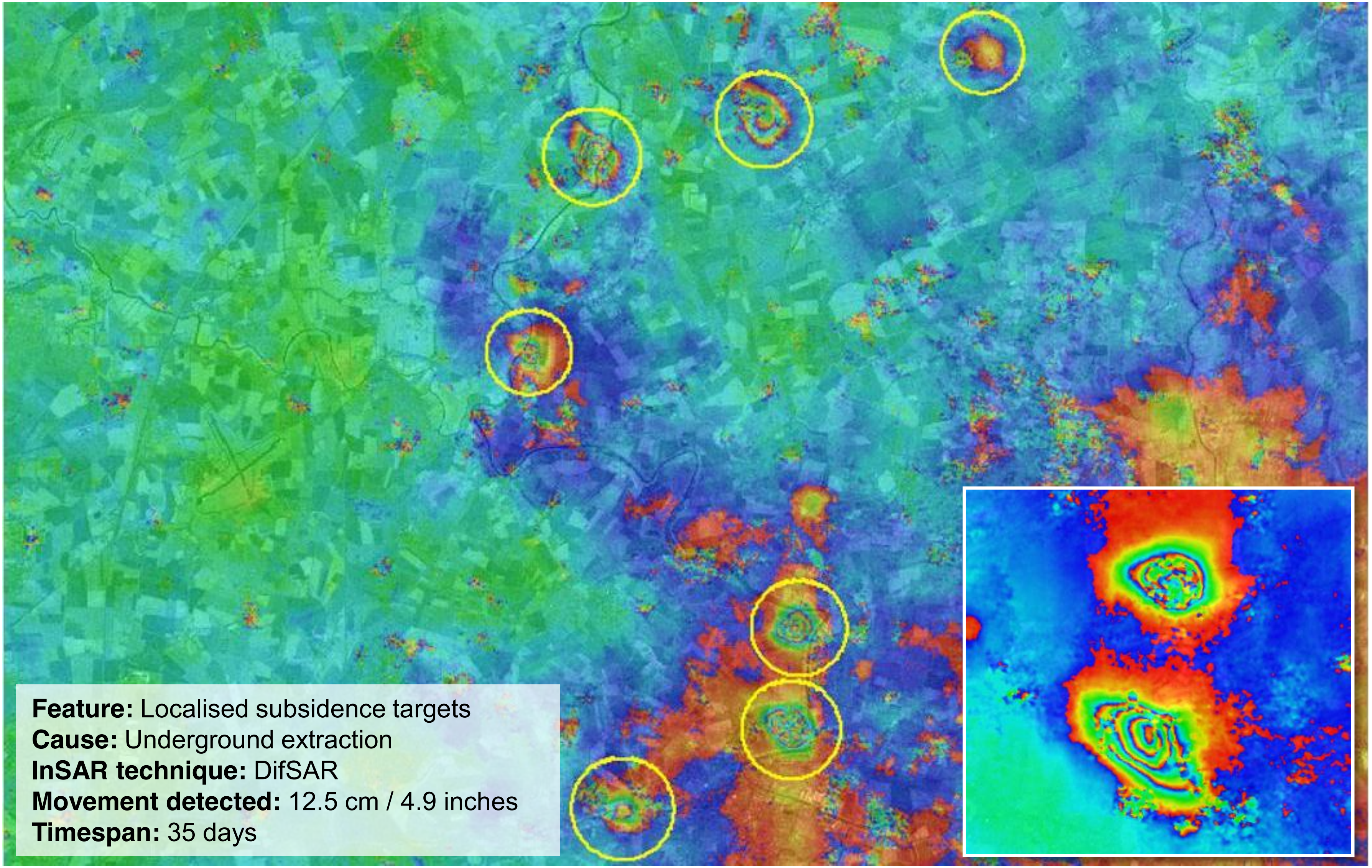
- Comparison, co-visualisation and integration with other geodetic and geophysical datasets key to meaningful interpretation





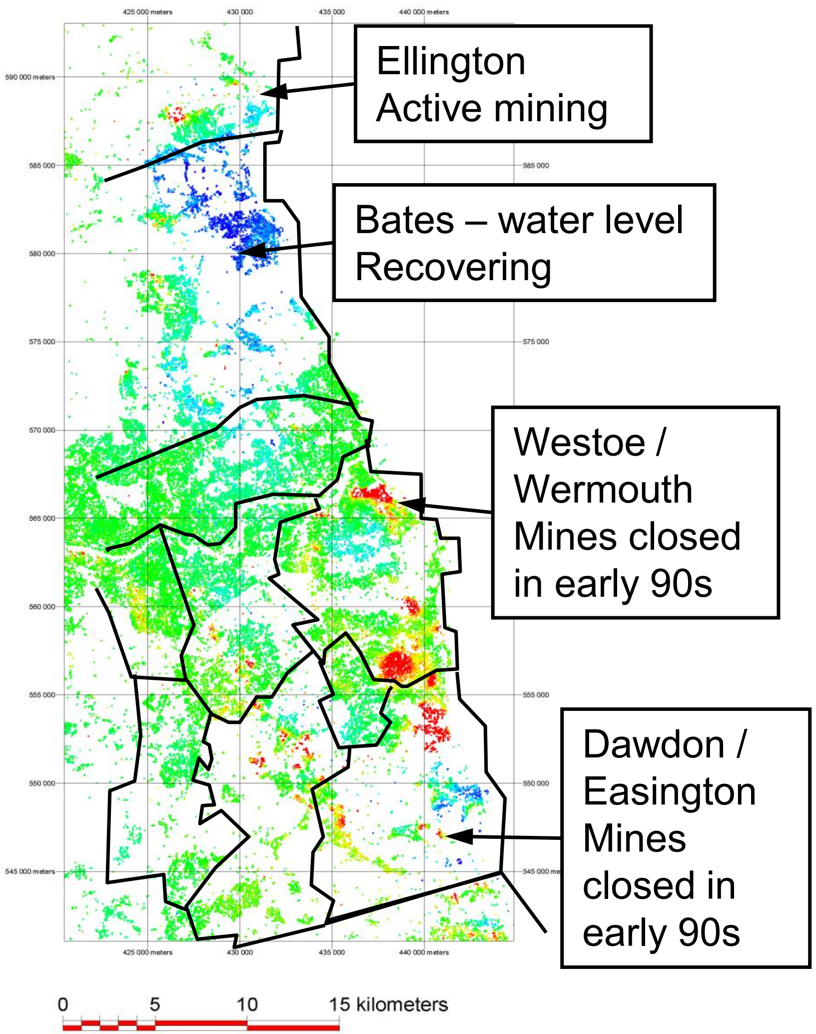


DifSAR: Mining subsidence, northern UK



Feature: Localised subsidence targets
Cause: Underground extraction
InSAR technique: DifSAR
Movement detected: 12.5 cm / 4.9 inches
Timespan: 35 days

Northumberland and Durham



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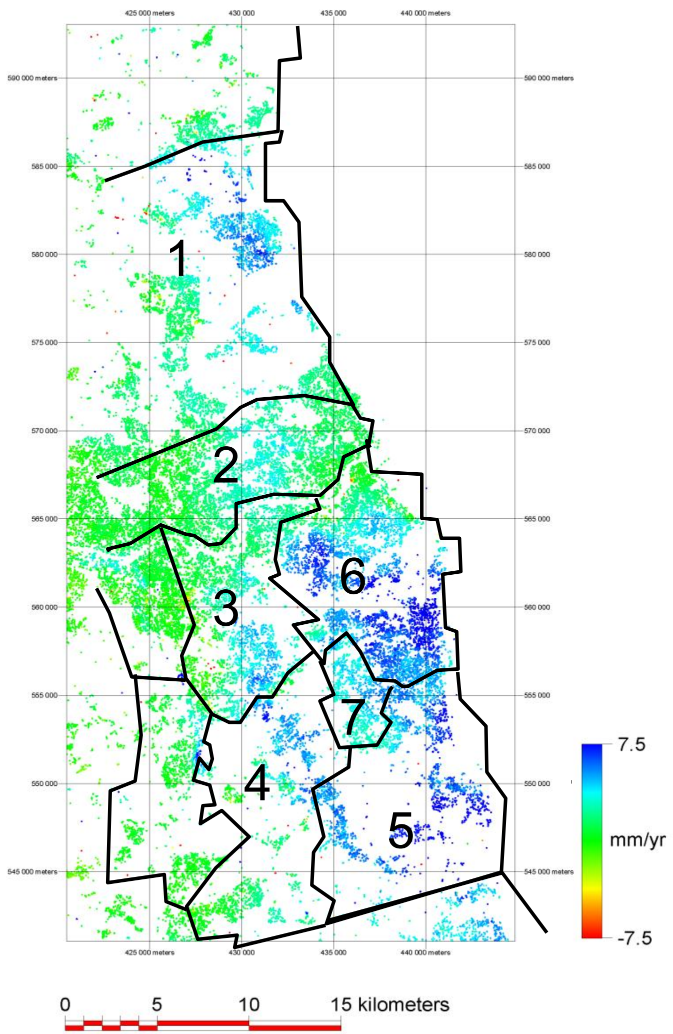
1995 - 2000



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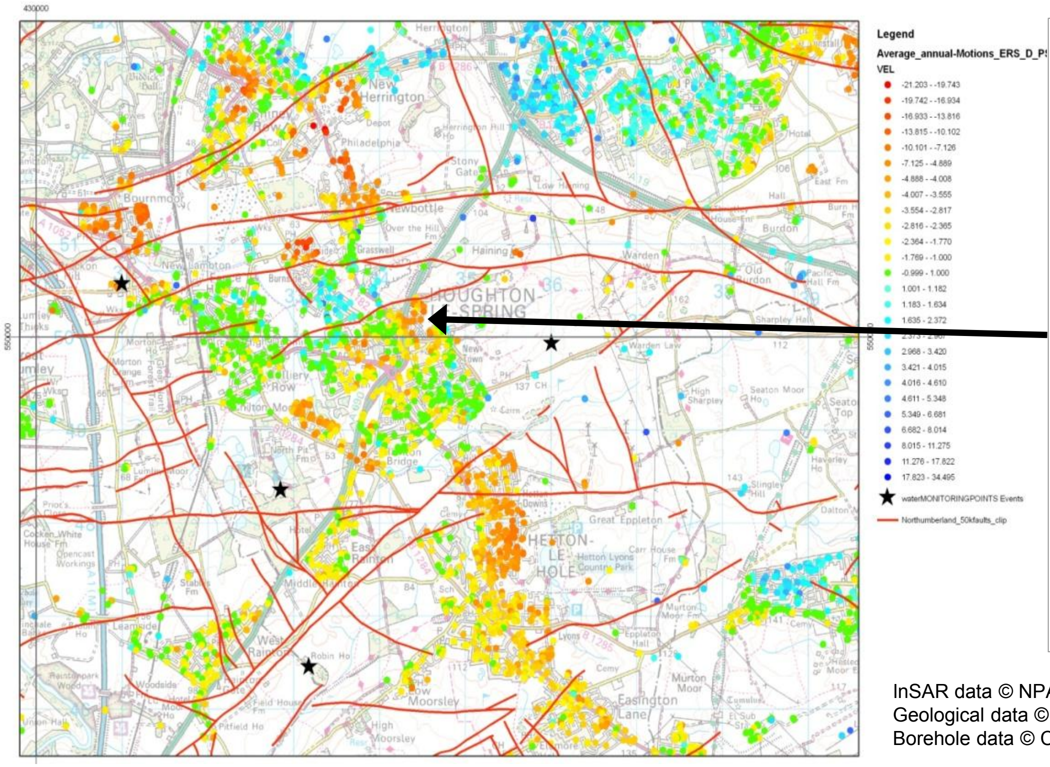
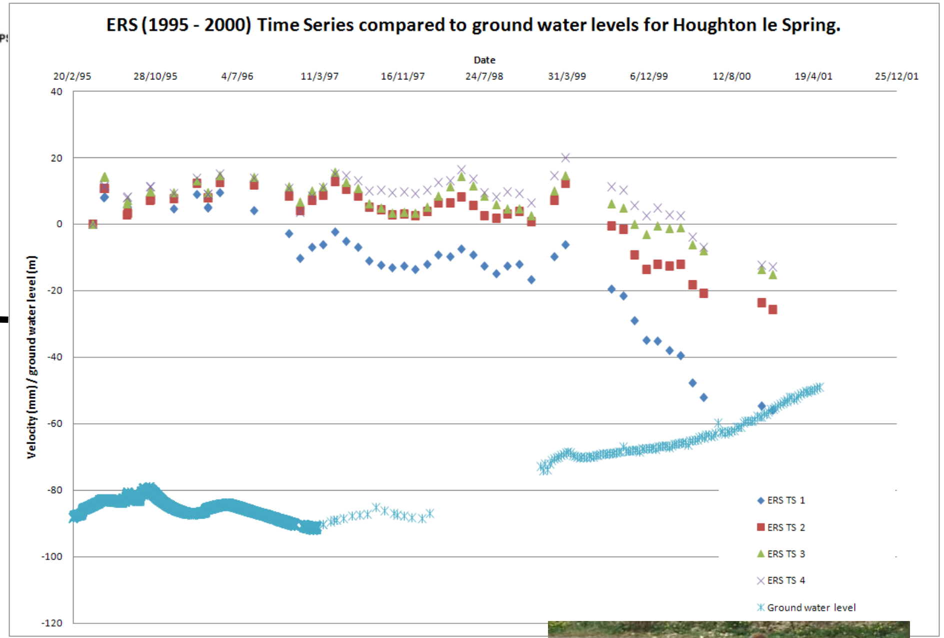
2002 - 2008

Houghton Le Spring





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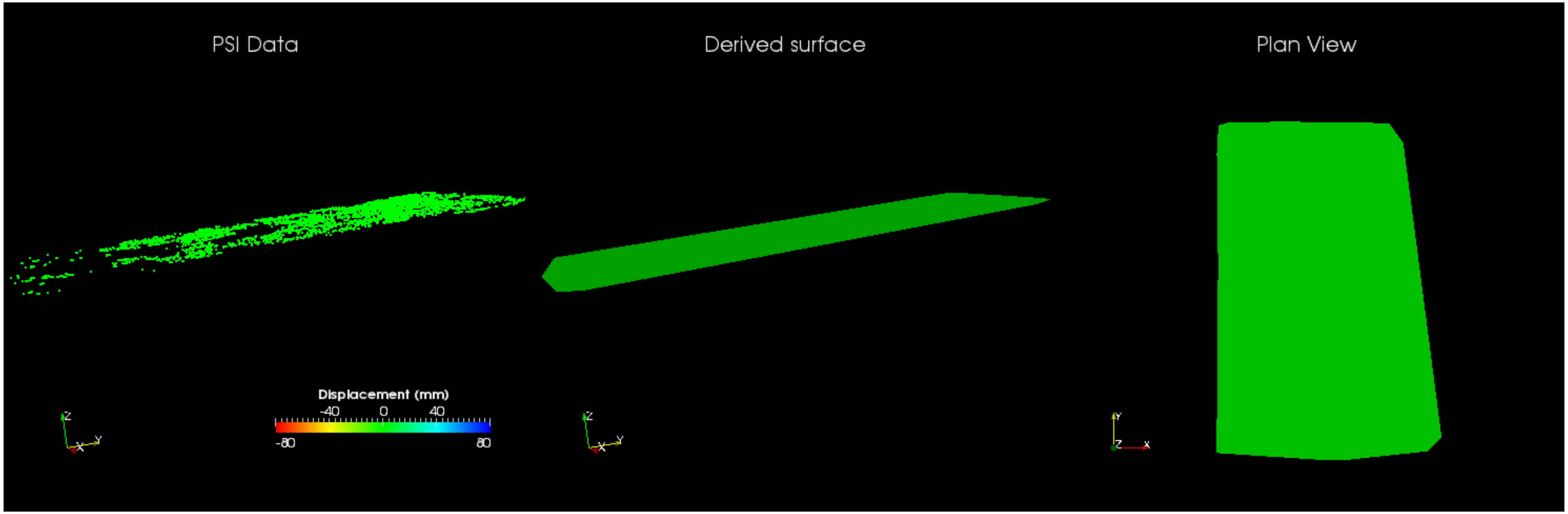
- Deformation correlated with faulting and ground water level.
  - Uplift north of fault & subsidence to south.
  - Ground water raised to levels that have impinged on the fault plane. Increase pore water pressure causing a reduction in the coefficient of friction across the fault therefore resulting in reactivation.
- Evidence of fissures and cavities opening due to fault reactivation

The COAL AUTHORITY

Ryhope Colliery - temporal evolution (1995 to 2000)



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- Temporal behaviour of subsidence signal partitioned by faults – motion initially limited to southern area, but expands northwards later

EGU2013-11551: McCormack *et al*, April 2013

Thank you