Ground motion in the Surat Basin: Extents, Magnitudes and Mechanisms

Phil Hayes and Sarah Brennand

UQ-CNG and School of Mechanical and Mining Engineering

UQ – Centre for Natural Gas Research Review

8 December 2022

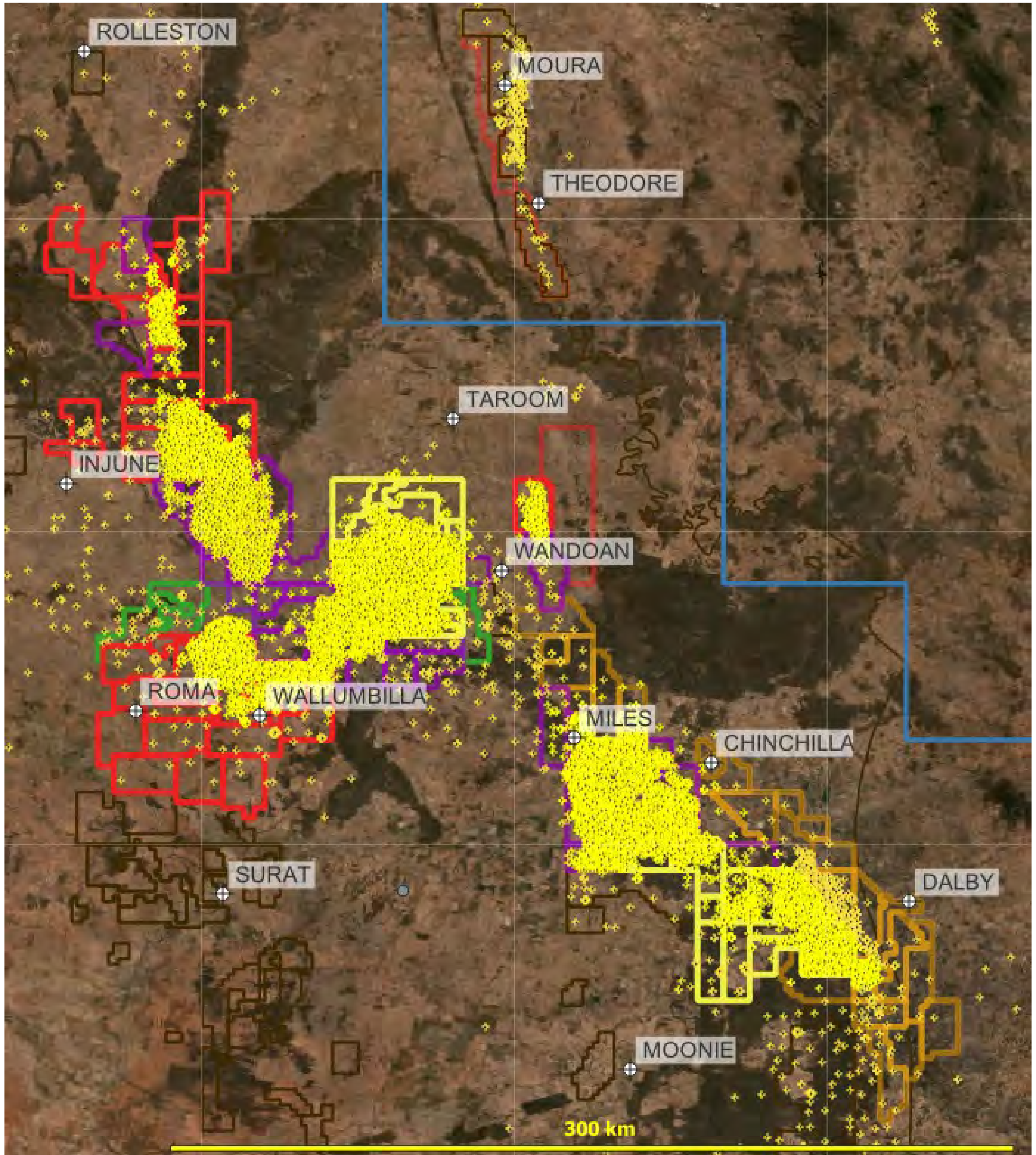
Notes

These slides have been modified from those presented on 8th December to remove some data and maps that are to be included in a number of journal publications currently under preparation at UQ and in Sarah Brennand's PhD thesis. Slides numbering provides an indication of where slides are omitted.

The University Of Queensland Australia

Workshop objectives

- Provide an overview
  - D-InSAR remote sensing research
  - Geomechanical studies
- Educate
  - Understanding of D-InSAR processing
  - Our learnings
- To promote discussion
  - Questions, thoughts
  - Ideas and feedback
  - So, not just presentation….



Format of workshop

1. Scene setting - PH
2. Basics of DInSAR - SB
3. D-InSAR data analysis - PH
   Techniques and observations
4. Sarah's PhD - Small baseline subsets – SB
5. Magnitudes and mechanisms – PH
6. Discussion

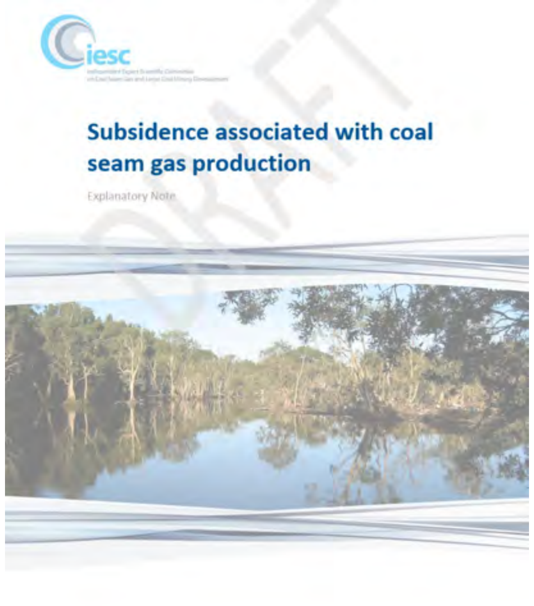
Please do not take photos.

We are *not* against sharing, but some of the work is currently unpublished, and some is Sarah's PhD.

Setting the scene

Use industry and stakeholder figures, possibly ABC stories on subsidence

UQ perspective - our research review, change to show what we've worked on



Predictions and measurements of subsidence (cm) above Groningen gas field, TNO, 2021

Subsidence is a live issue

- Others are completing studies too:
  - OGIA
  - GFCQ / OGIA study
  - Arrow
  - Other companies
- Drivers are slightly different, regulatory requirements and EA approvals drive OGIA's work and gas company reporting

UQ perspective - our research review, change to show what we've worked on

Predictions and monitoring: OGIA + gas companies

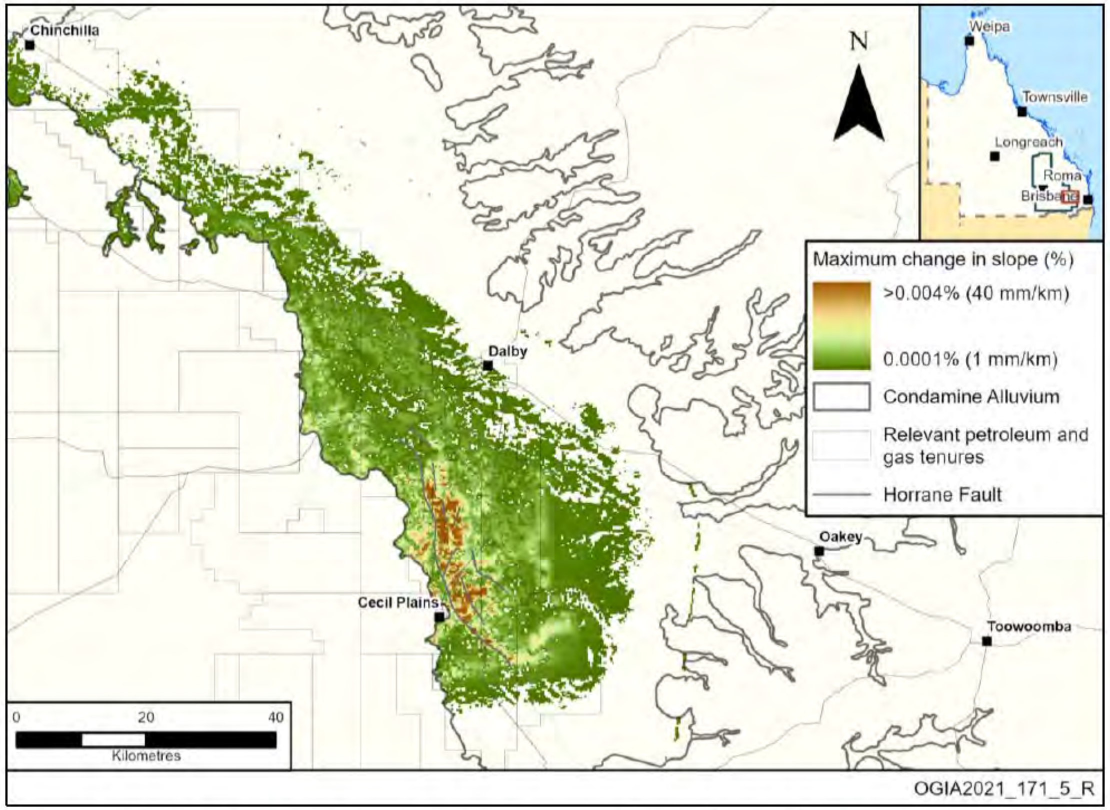
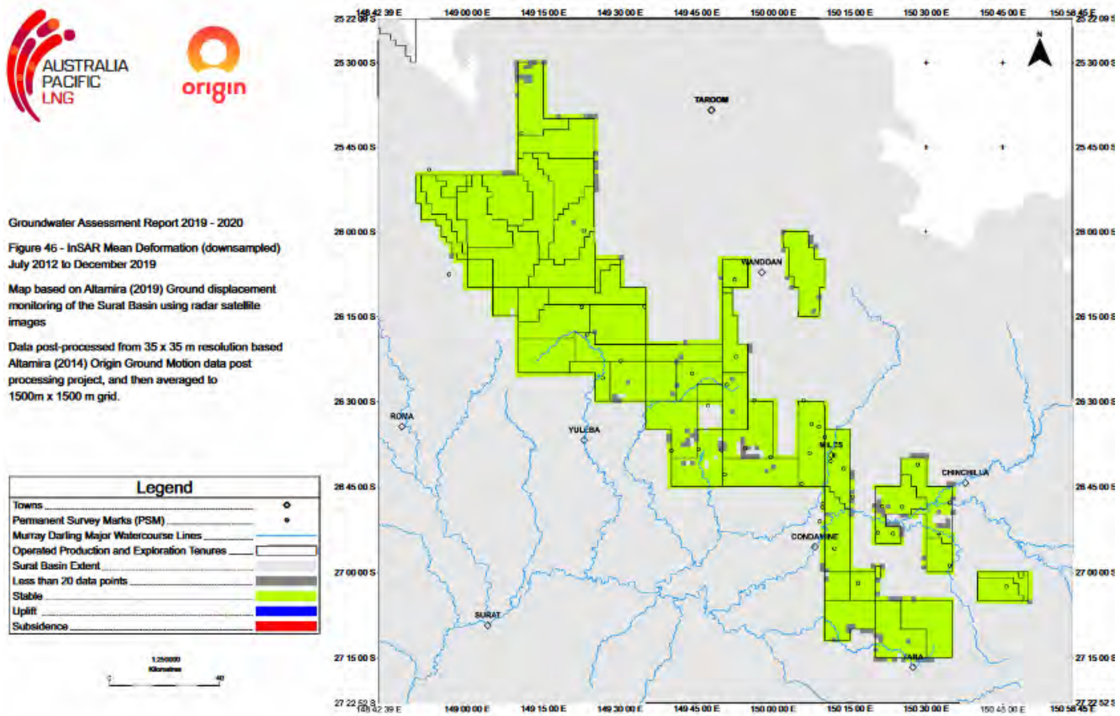


Figure 7-7: Predicted maximum change in ground slope from CSG-induced subsidence

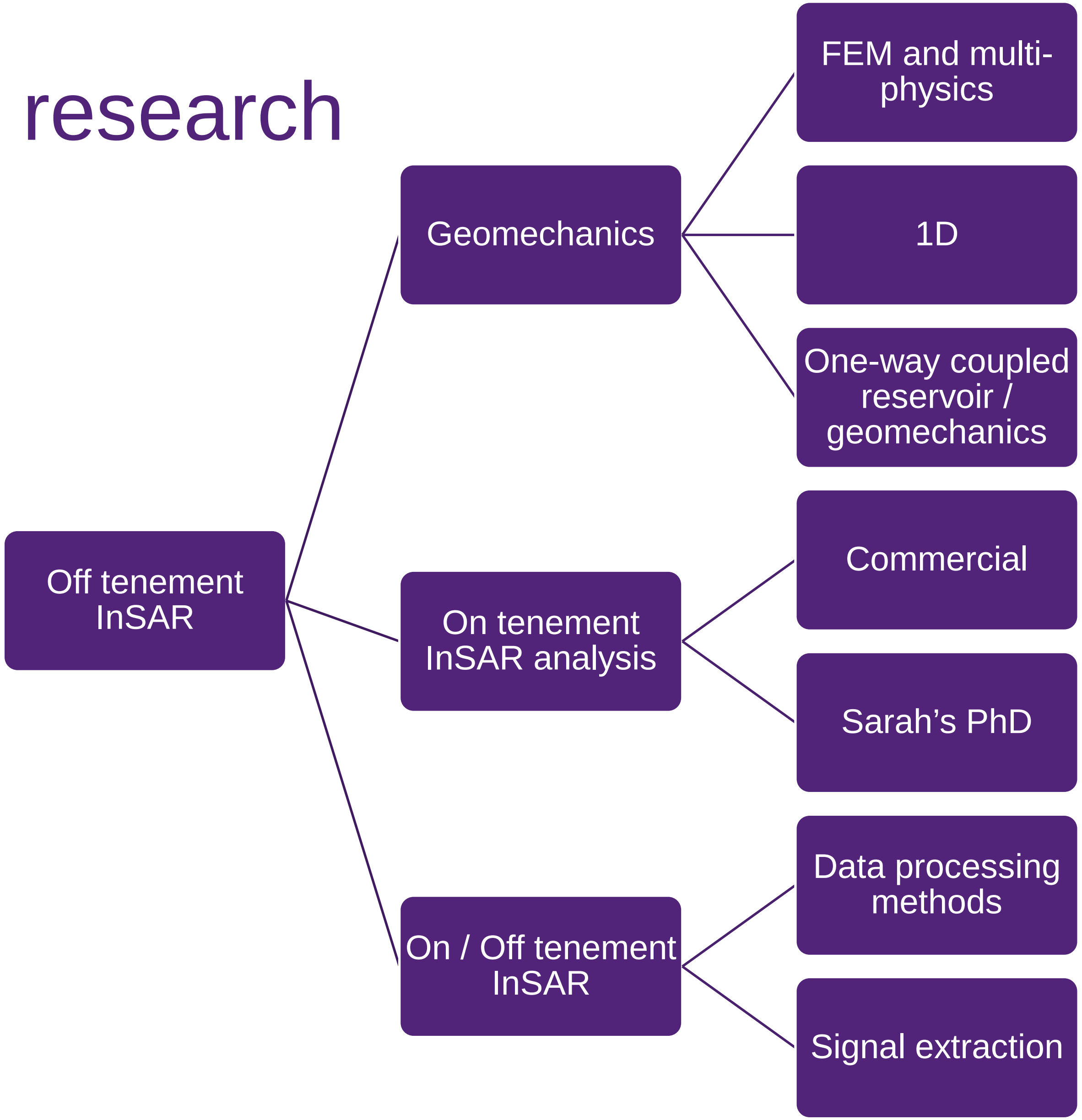


OGIA, UWIR 2021, Fig 7.1, and 7.2

Condamine Alluvium

modified from commons.wikimedia.org/wiki/File:StGeorgeCottonIrrig.jpg

Subsidence research



Questions / comments

1. Setting the scene

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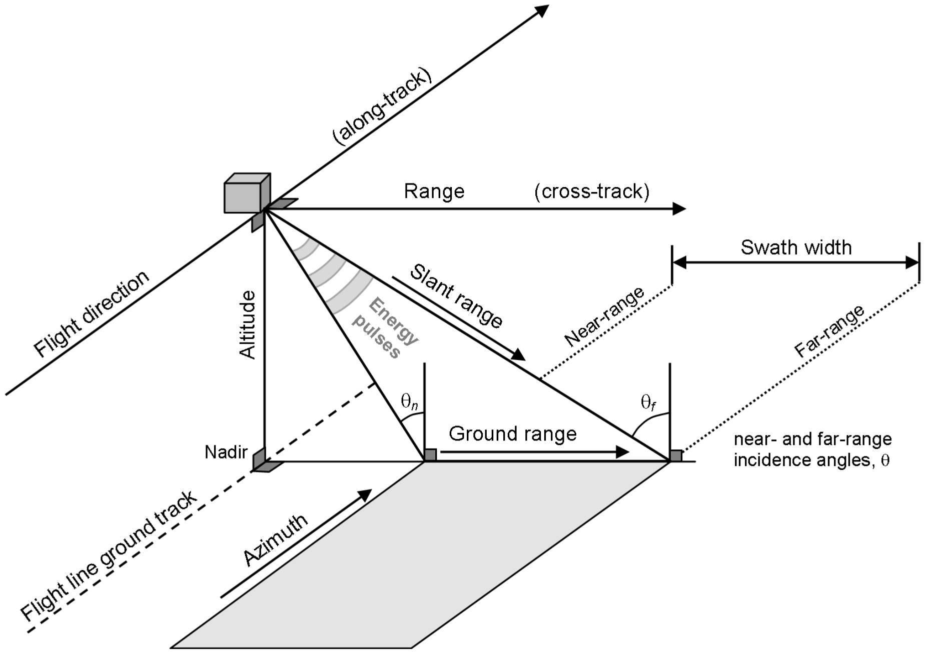
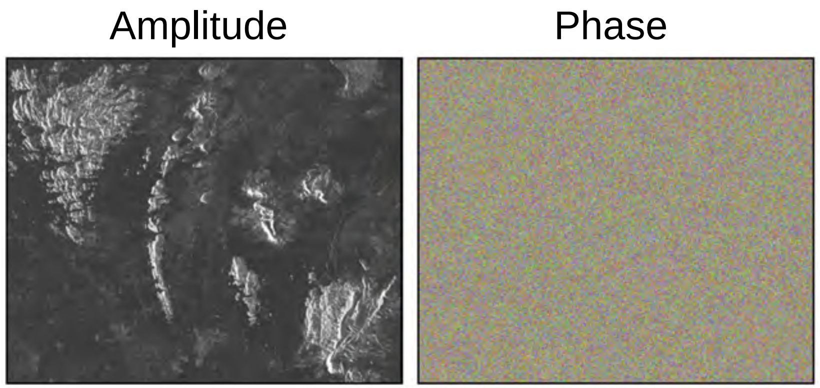
2. Introduction to InSAR

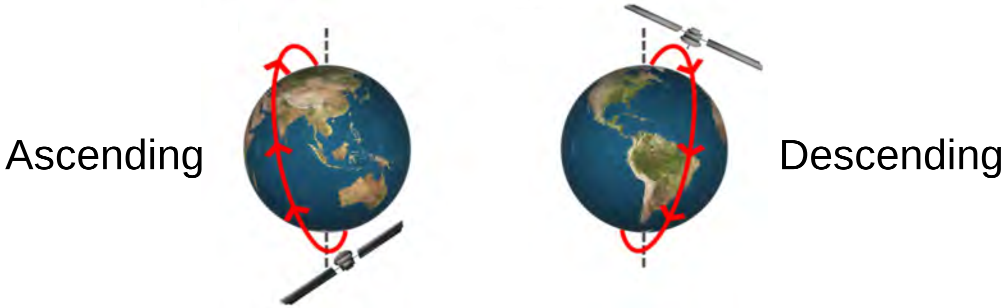
Sarah Brennand

Introduction to InSAR

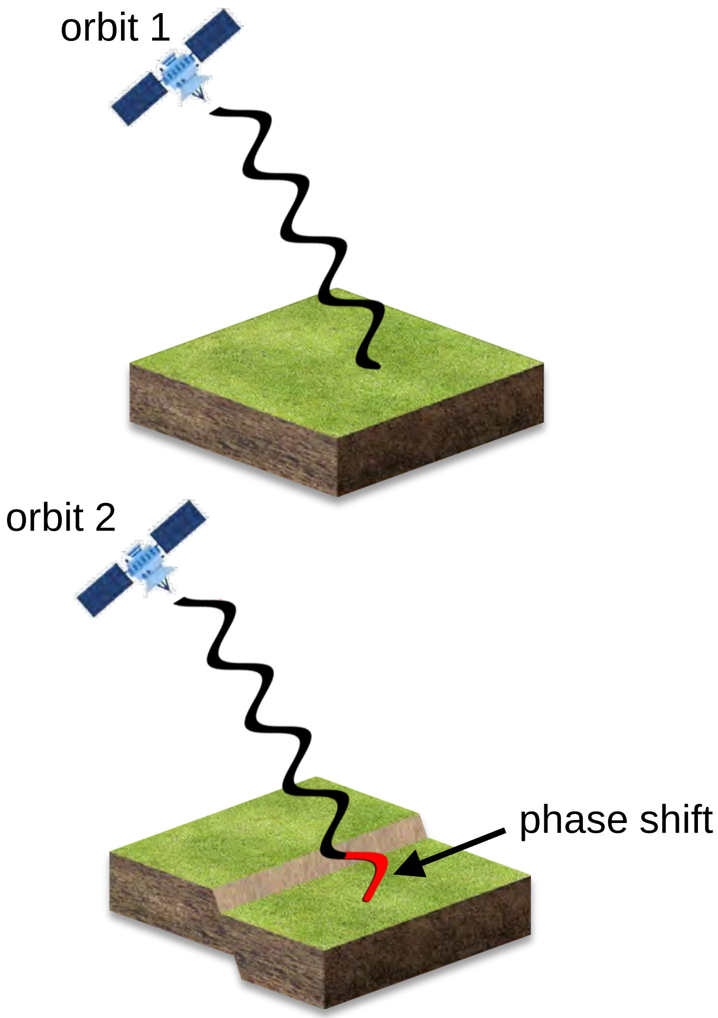
- Interferometric synthetic aperture radar (InSAR)
- Uses Synthetic Aperture Radar (SAR) imagery
  - Generally from satellites that fly in a near-polar orbit
  - Can work in all weather, day and night
- Microwave energy transmitted to the ground at an angle (line of sight - LOS)
- The energy received back from the ground is used to determine distance and physical characteristics





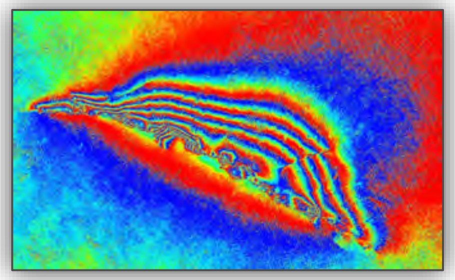


Introduction to InSAR



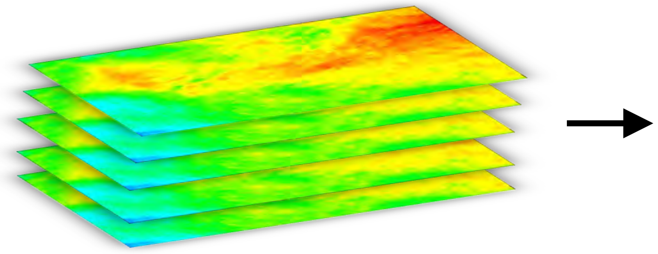
- By using two SAR images taken at different times, we can calculate changes ground height between them (interferogram)
- Large, sudden movements (e.g. earthquakes) easy to detect
- For small movements that develop over time, need to calculate a time-series from a stack of interferograms

interferogram



large sudden movement (earthquake)

interferogram stack



small movement over time (groundwater withdrawal)

time-series:

- average linear velocity (mm/year)
- cumulative movement
- incremental movement

Time-series generation

- Interferograms contain a number of signal components
- If the deformation signal is large (e.g. earthquake), it dominates the other signals
- For small movements, time-series processing involves isolating the deformation signal

$$\Delta\phi_{int} = \Delta\phi_{def} + \Delta\phi_{orb} + \Delta\phi_{topo} + \Delta\phi_{atm} + \Delta\phi_{scat} + \Delta\phi_{noise}$$

- $\Delta\phi_{def}$: deformation signal
- $\Delta\phi_{orb}$: orbital errors
- $\Delta\phi_{topo}$: topographic signal
- $\Delta\phi_{atm}$: atmospheric noise
- $\Delta\phi_{scat}$: scattering effects
- $\Delta\phi_{noise}$: residual noise

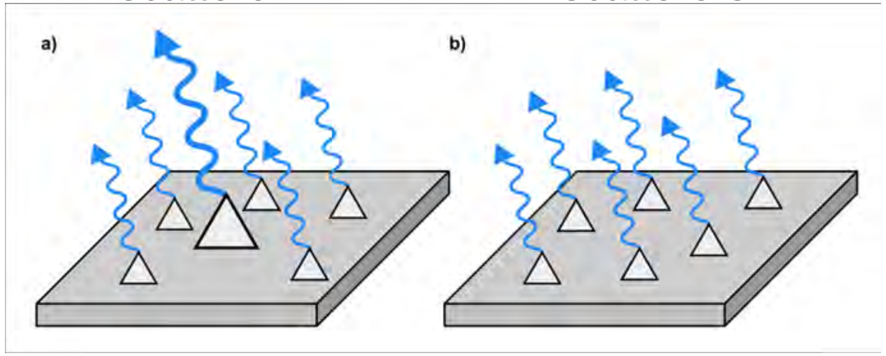
Time-series processing methodologies

Sarah's PhD method

1. Small baseline subset (SBAS)
   - Uses distributed scatterers
     - Points have 'coherent' response some of the time
     - More commonly found in rural regions
   - Dense network of connections between acquisition dates to maximise scatterer signals

persistent scatterer

distributed scatterers

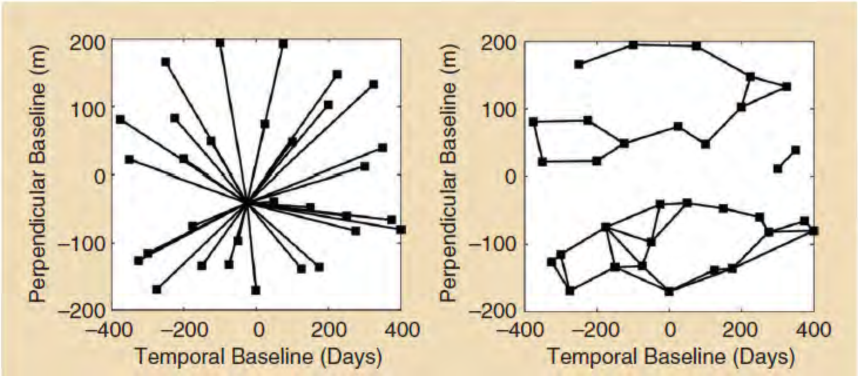


TRE Altamira

2. Persistent scatterer interferometry (PSI)
   - Uses persistent scatterers
     - Points have strong stable response through time
   - Commonly use single-reference networks
   - Excellent in urban environments
   - Modified version to include SBAS

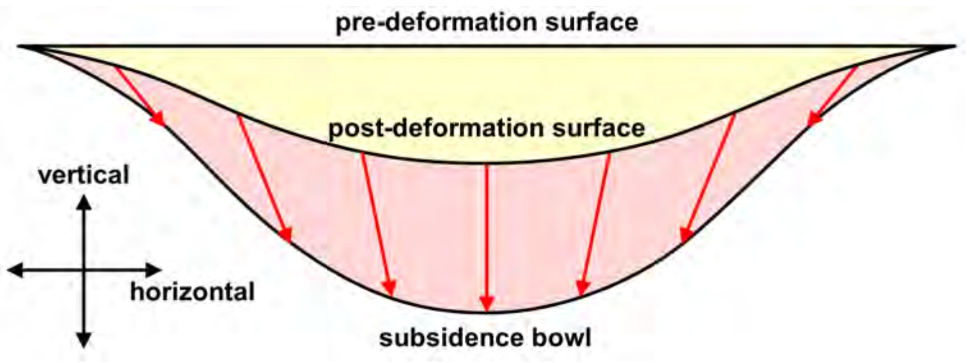
single-reference network

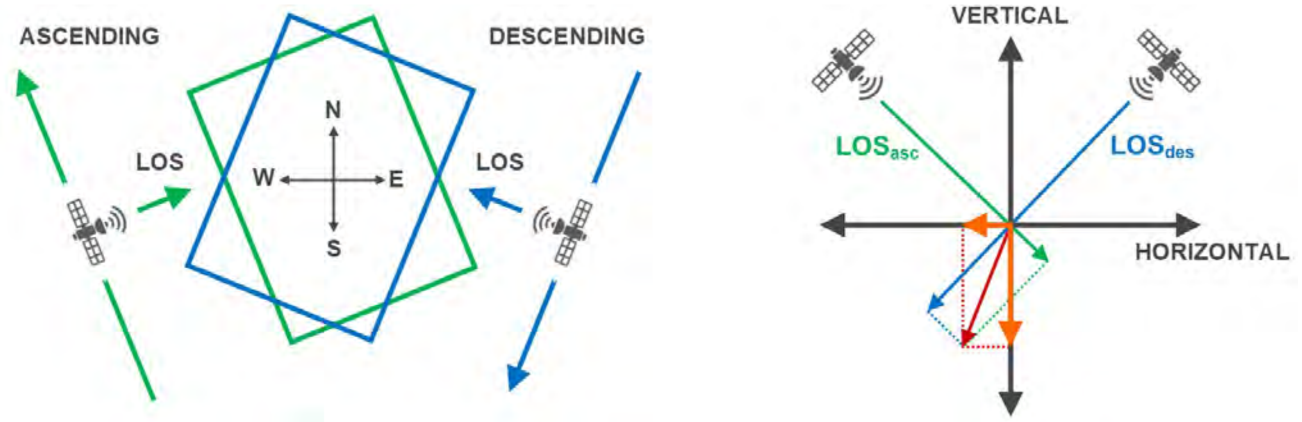
multi-reference network



Movement angle

- Ground movement tends to occur in 3D
  - up-down, east-west, north-south
- InSAR only provides movement in 1D (LOS)
- With ascending and descending data, can resolve up-down, east-west movement
  - Orbit orientation makes it insensitive to north-south movement





red arrow: actual movement
orange arrows: LOS resolved into up-down, east-west

Questions / comments

2. Introduction to InSAR

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3. D-InSAR data analysis Techniques and observations

Phil Hayes

The University of Queensland
Australia

The University of Queensland Australia | CREATE CHANGE

UQ Centre for Natural Gas
Annual Research Review
2019

Surface Movement and Shallow Processes

Dr Christopher Leonardi, A/Prof Phil Hayes, Dr Travis Mitchell, Mr Iain Rodger, Ms Sarah Brennand, Dr Zhongwei Chen, Prof Suzanne Hurter

The aim of this project is to (i) identify the processes which contribute to the baseline of net surface movement in the Surat CMA and (ii) develop an integrated, evidence-based workflow to quantify the magnitude of these processes.

The work program to date has focused on data analysis and modelling in a number of locations of interest:

- Basin-scale interrogation of InSAR maps of net surface movement, acquired from satellite;
- Geospatial correlation of movement with natural events and phenomena (e.g. rainfall, clay content and type);
- Computational modelling of poroelastic processes.

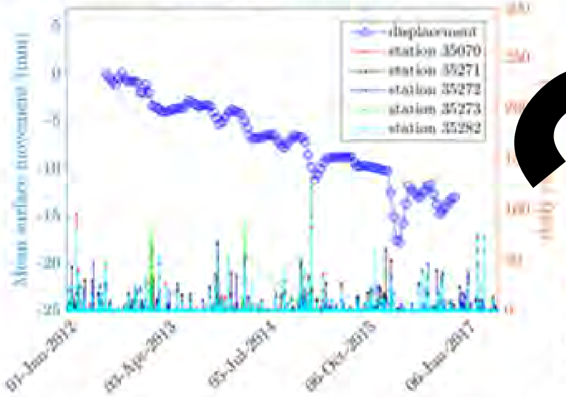


Fig 1 - Net surface movement and rainfall near Taroom, showing a background trend of downward movement and accelerated movement during the wet season.

Poroelastic finite element models have been developed to quantify the relative contributions of depressurisation and gas desorption (i.e. matrix shrinkage) on the compaction of coal seams, and r[illegible]ement.

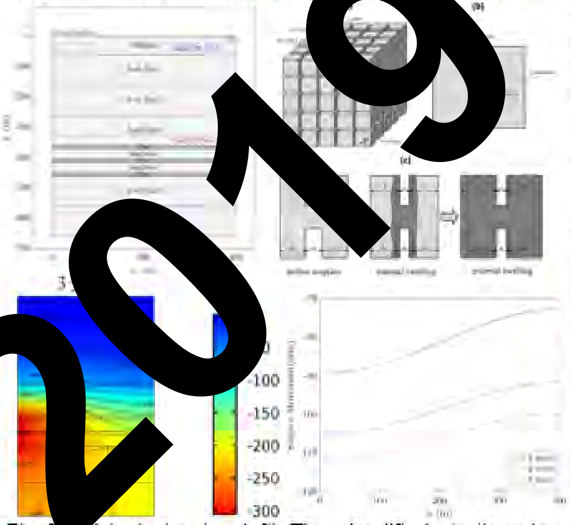


Fig 2 [illegible] (clockwise top left) The simplified stratigraphy used in modelling; mechanisms of internal and external coal swelling, depressurisation; and surface movement.

The ratio of internal to external swelling (a coal property) was found to significantly affect compaction. However, the resultant surface movement was of the same order as that observed in non-production areas. The methodology will now be expanded to three dimensional analysis.

The generation and interrogation of basin-scale surface movement maps from InSAR data will highlight any localised and regional movement trends in the Surat CMA. These trends can be compared against other in-situ- and remote sensing-derived datasets to identify, and ultimately predict, the impacts of long-term natural processes on surface movement within the Surat CMA and broader area.

Through an improved understanding of natural processes (e.g. long-term drying and shrinkage of clay-rich units) and their associated contribution to surface movement, it will be possible to quantify any impact of anthropogenic activities.

Fig 3 – Coverage of satellite data used for generating InSAR surface movement maps.

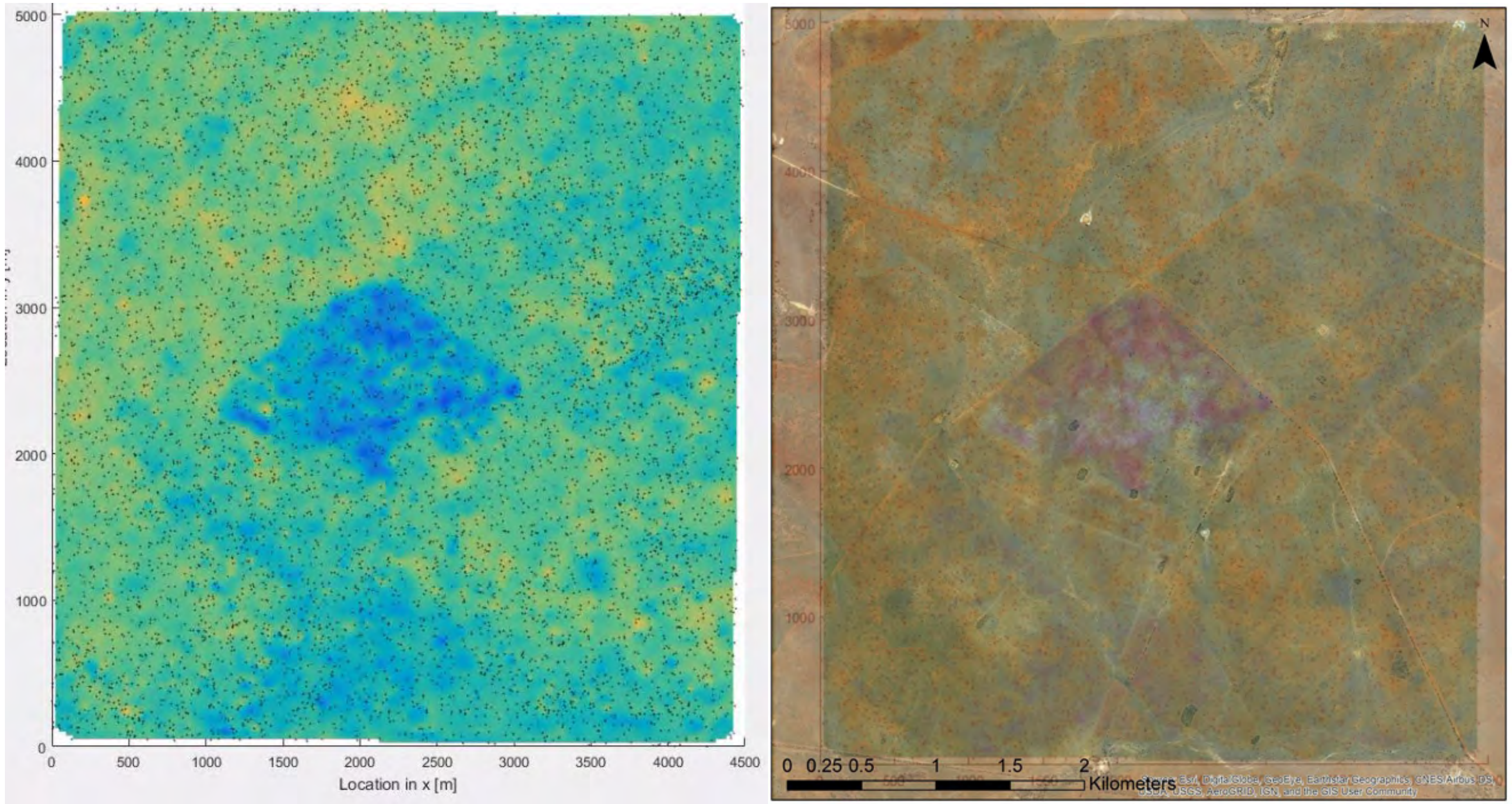
Research with real world impact

Acknowledgement

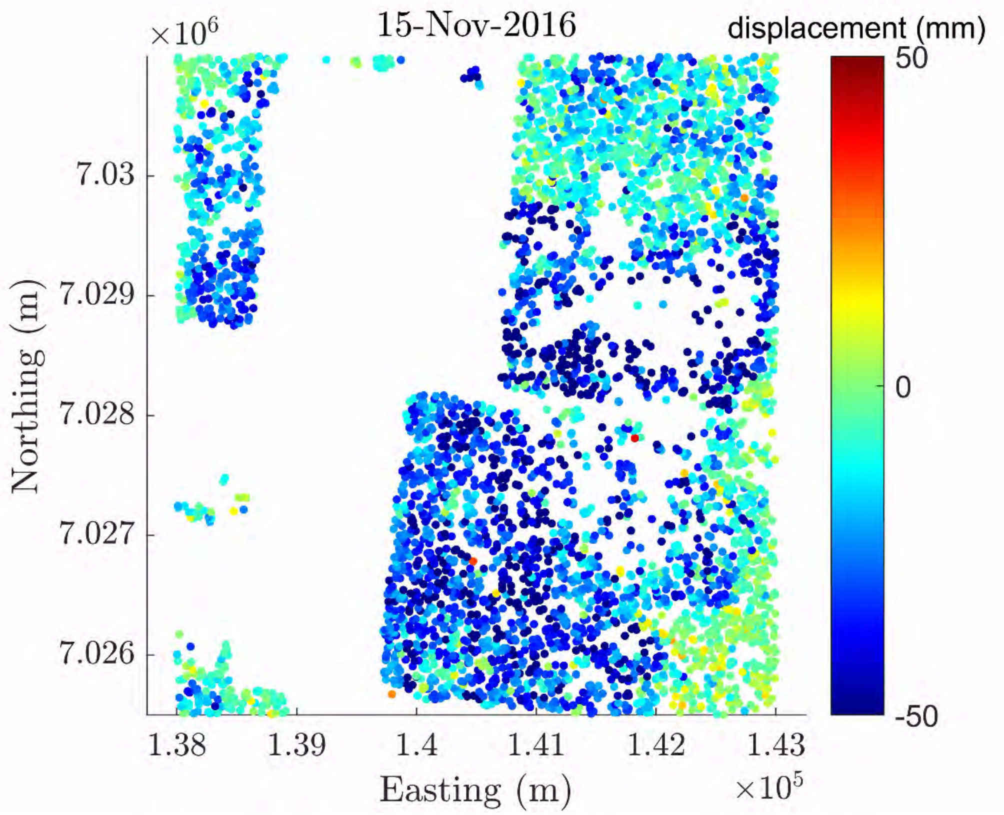
This research has been conducted with the support of the proponents of the UQ Centre for Natural Gas (Australia Pacific LNG, Santos, Arrow Energy) and Shell.

Initial work – off tenement (TRE data)

- A range of localised anomalies can be detected in the data, especially due to agricultural activity

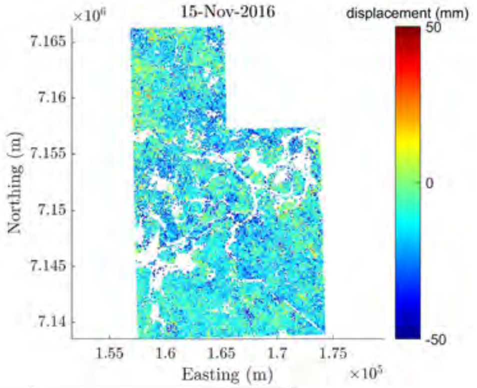


Registration of InSAR surface movement map and LANDSAT image of the same location

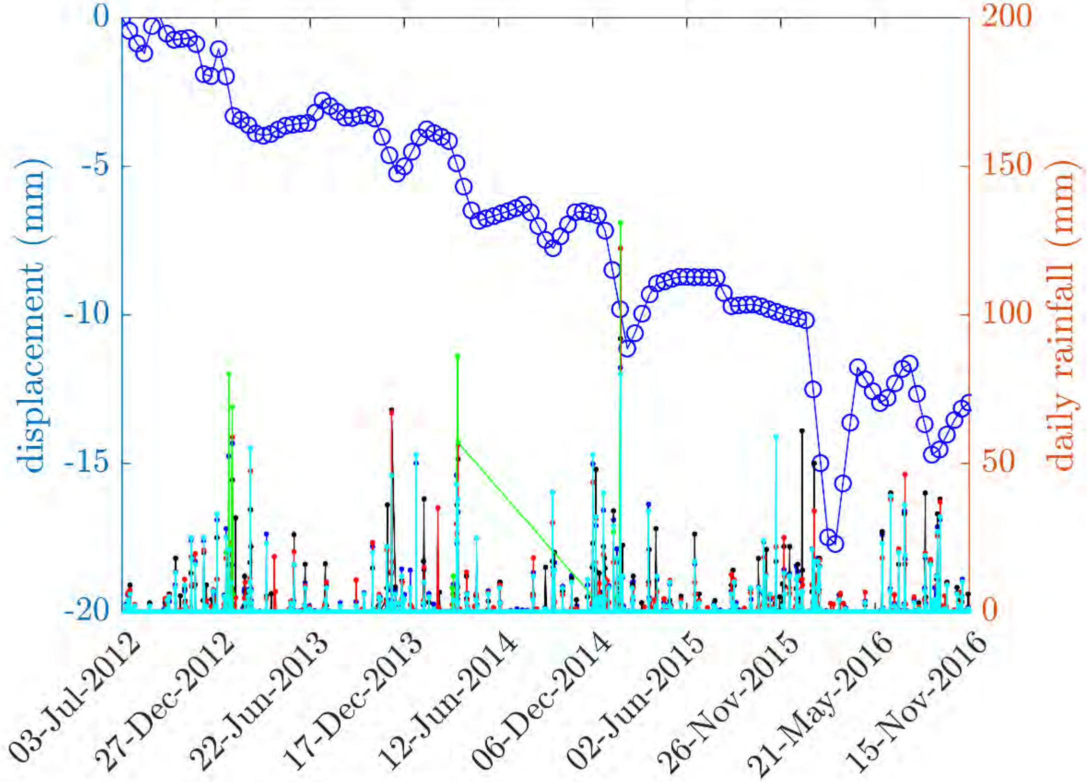


Differential subsidence and poor coherence due to cropping

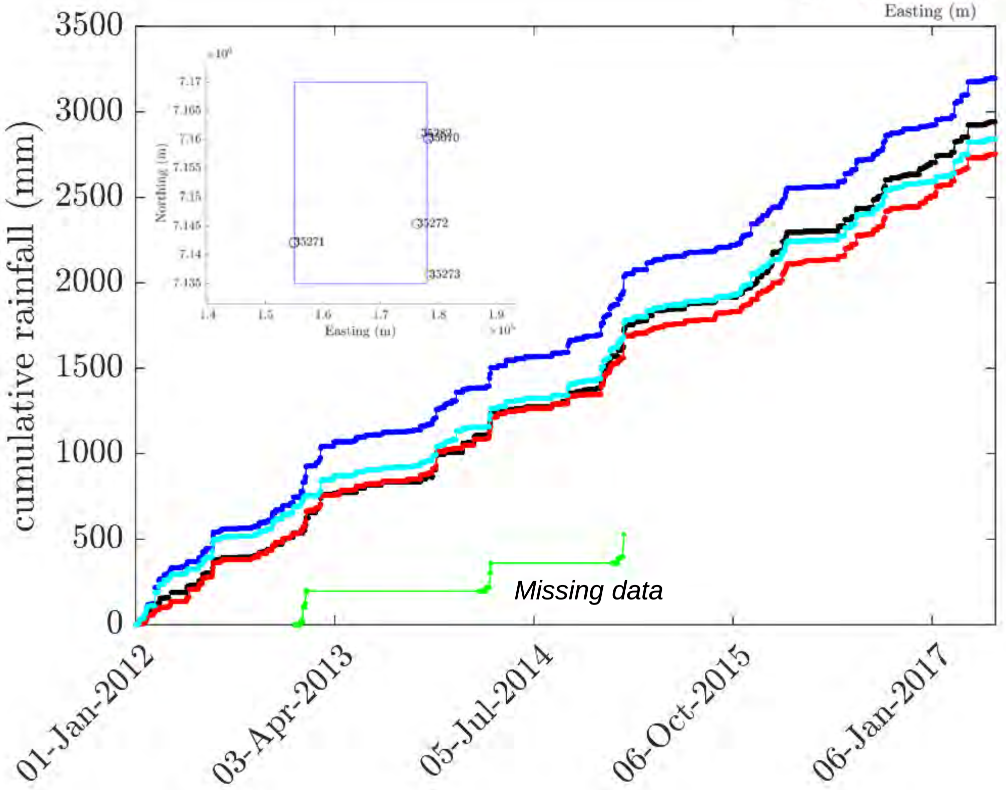
Surface Movement: Trends and Relationships



- Correlation with rainfall evident, as is a background trend of net downward movement
- Challenges with spatial rainfall datasets



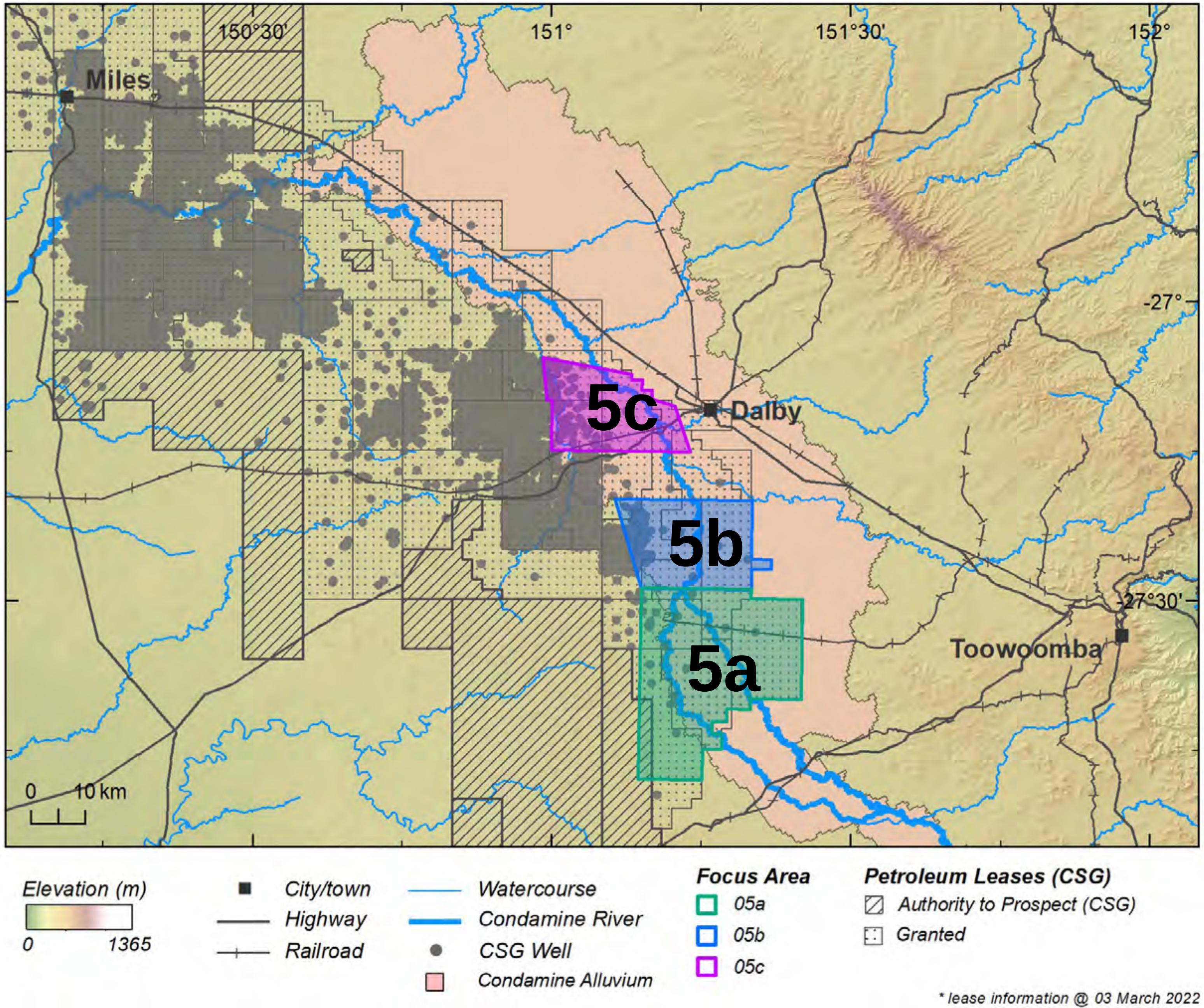
Average movement and instantaneous rainfall in the area



Scarcity and intermittency of rainfall data in the region

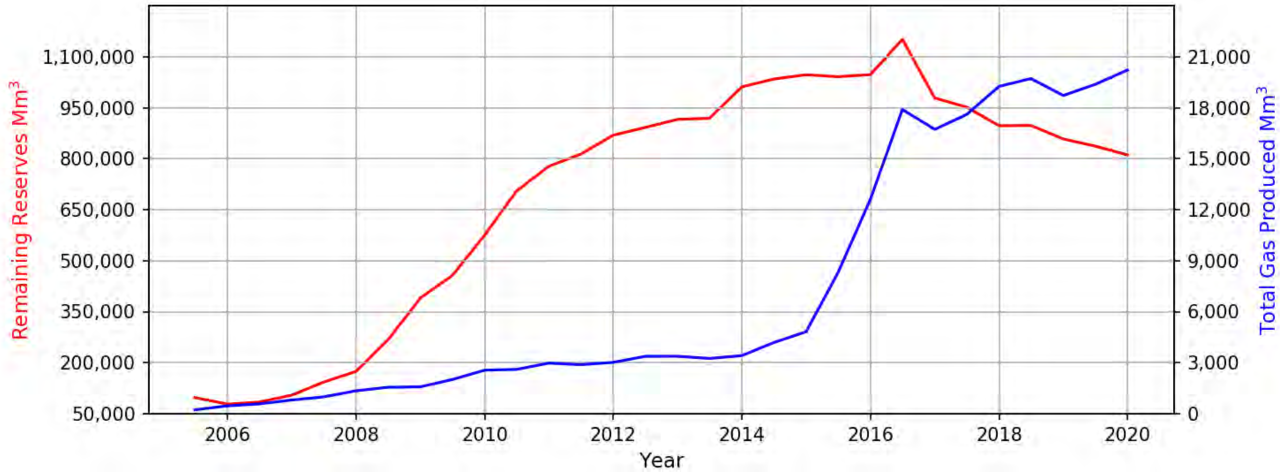
Condamine Focus Areas

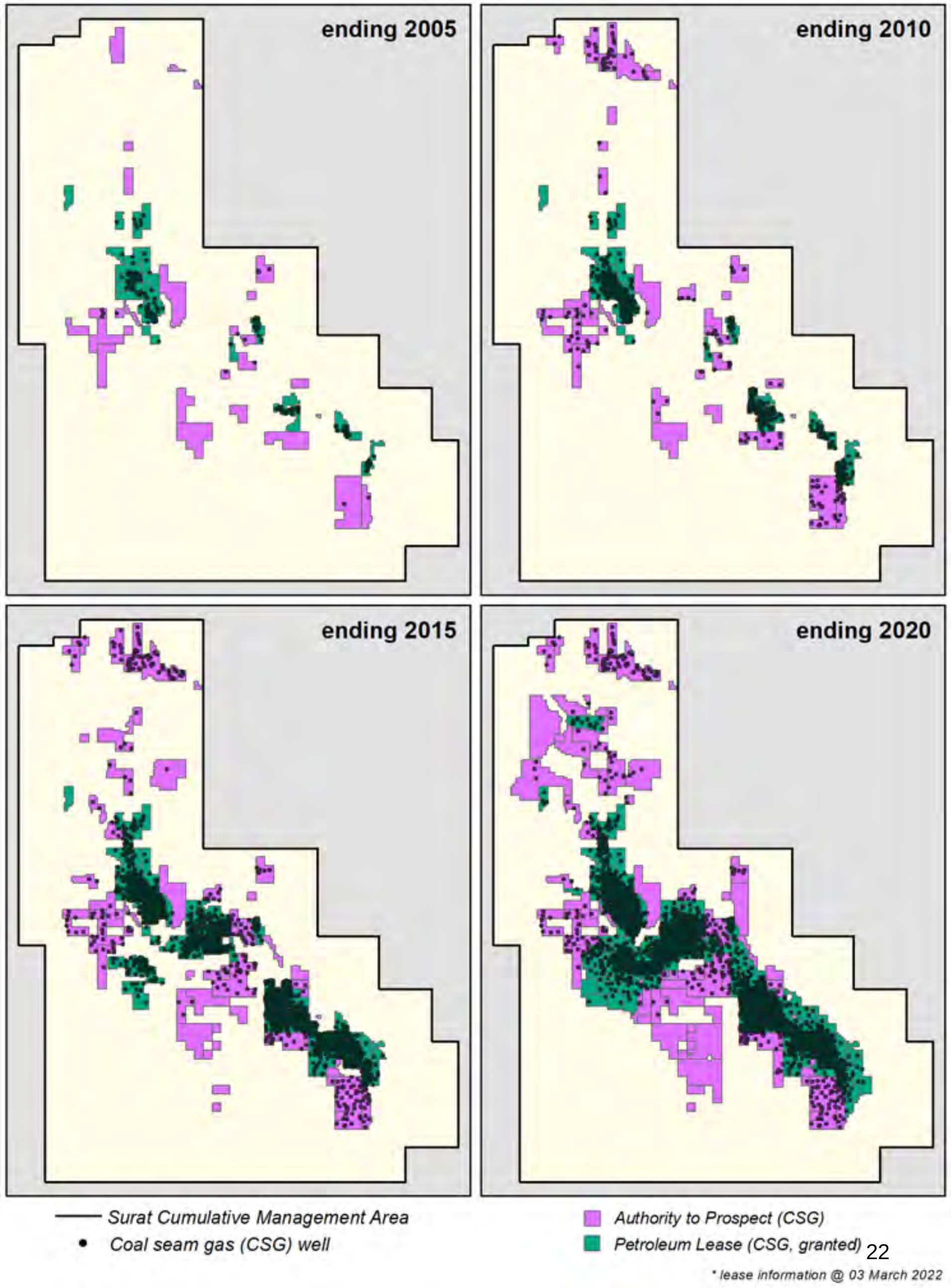
1. What does the progression of CSG activity in CMA look like?
2. What available data exists over the CMA, what is its resolution, frequency, how is it produced?
3. How does this look over the focus areas and what data is expected to be most useful?
4. Cleaning of data and search for patterns/options for data reduction → clearer pictures of change



What does the progression of CSG activity in CMA look like?

- Since 2005 can see rapid development in leasing tenements
- In 2020 → increase in wells to ~10,500
  - OGIA estimates ~680 wells per year completion rate with density of 1.5 wells/km^2
- Estimation of reserves appears to have peaked mid-2016
- Plateau of production also observed at this point



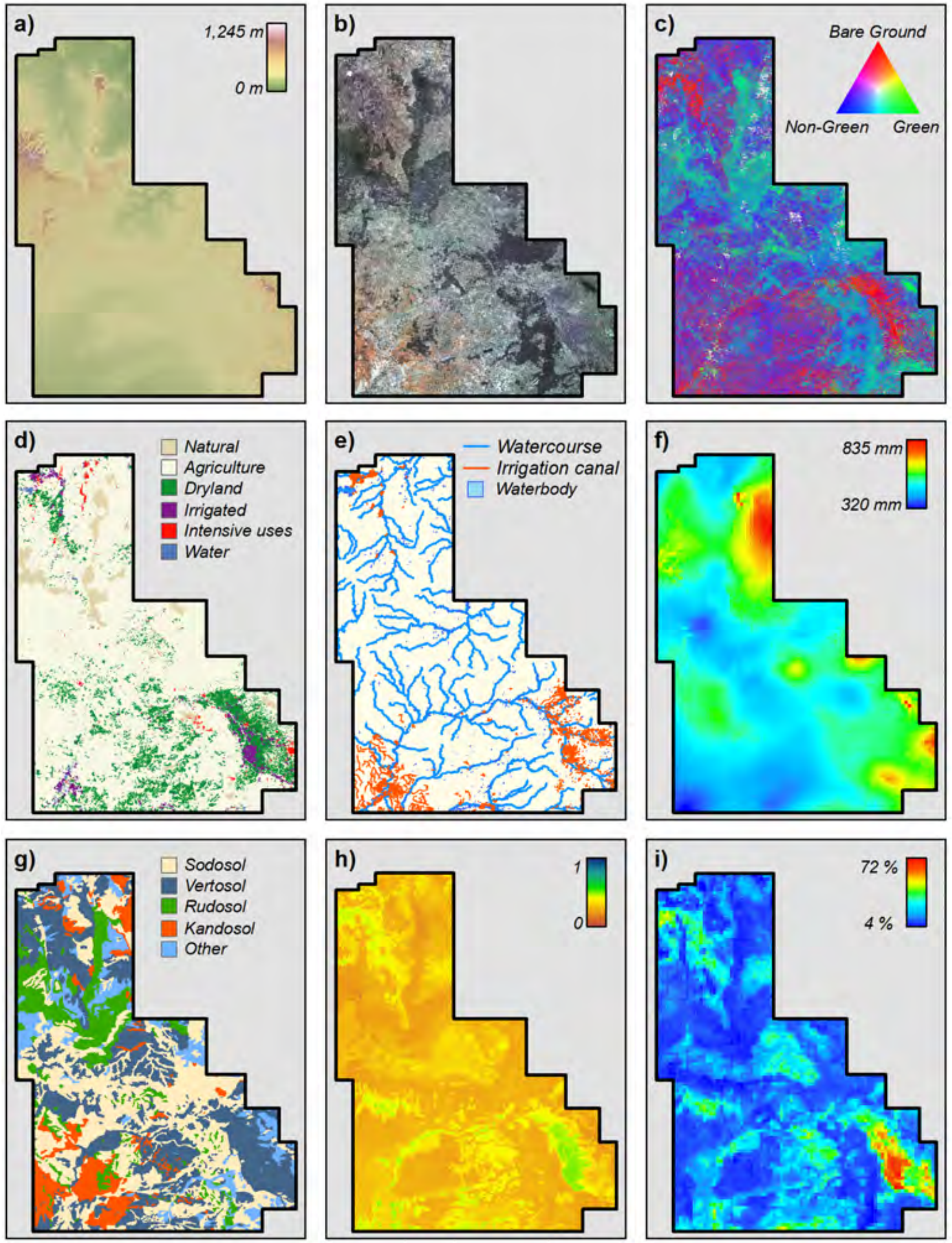


Available data

What is its resolution, frequency, how is it produced?

- Number of factors influence surface motion
- Need to understand availability to track these factors

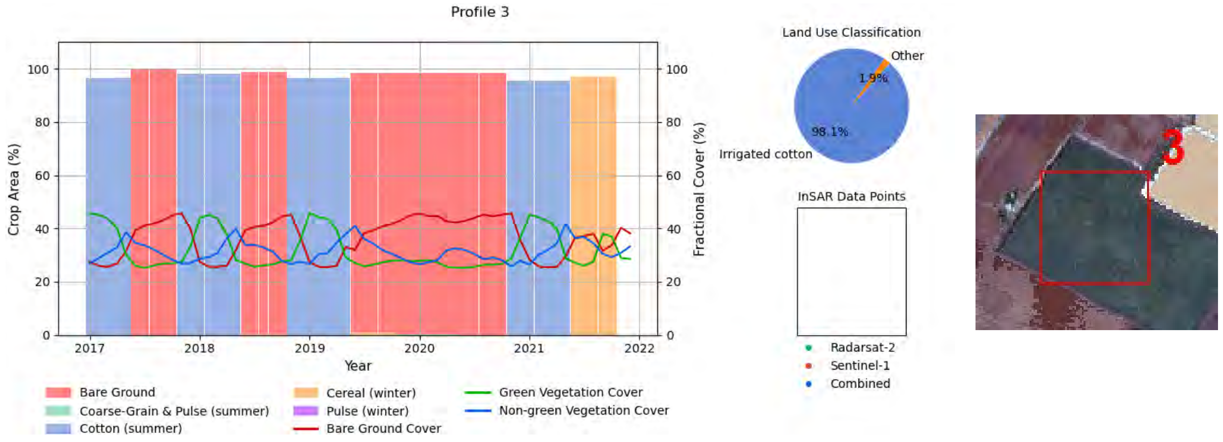
Dataset	Res / Freq	Type
DEM	30m / Static (2011)	Observations
Optical Sat	10/20/60m / 5-10 days	Observations
Fractional cover	30m / Monthly, seasonal	Observations, modelled
Land use	0.5km / Static (2019)	Observations, modelled
Hydrographic features	2.5km / Static (2021)	Observations, modelled
Precipitation	5km / Daily	Modelled
Soil types	20km / Static (1991)	Observations
Clay extents	90m / Static (2014)	Observations, modelled
Soil moisture	5km / Daily	Modelled

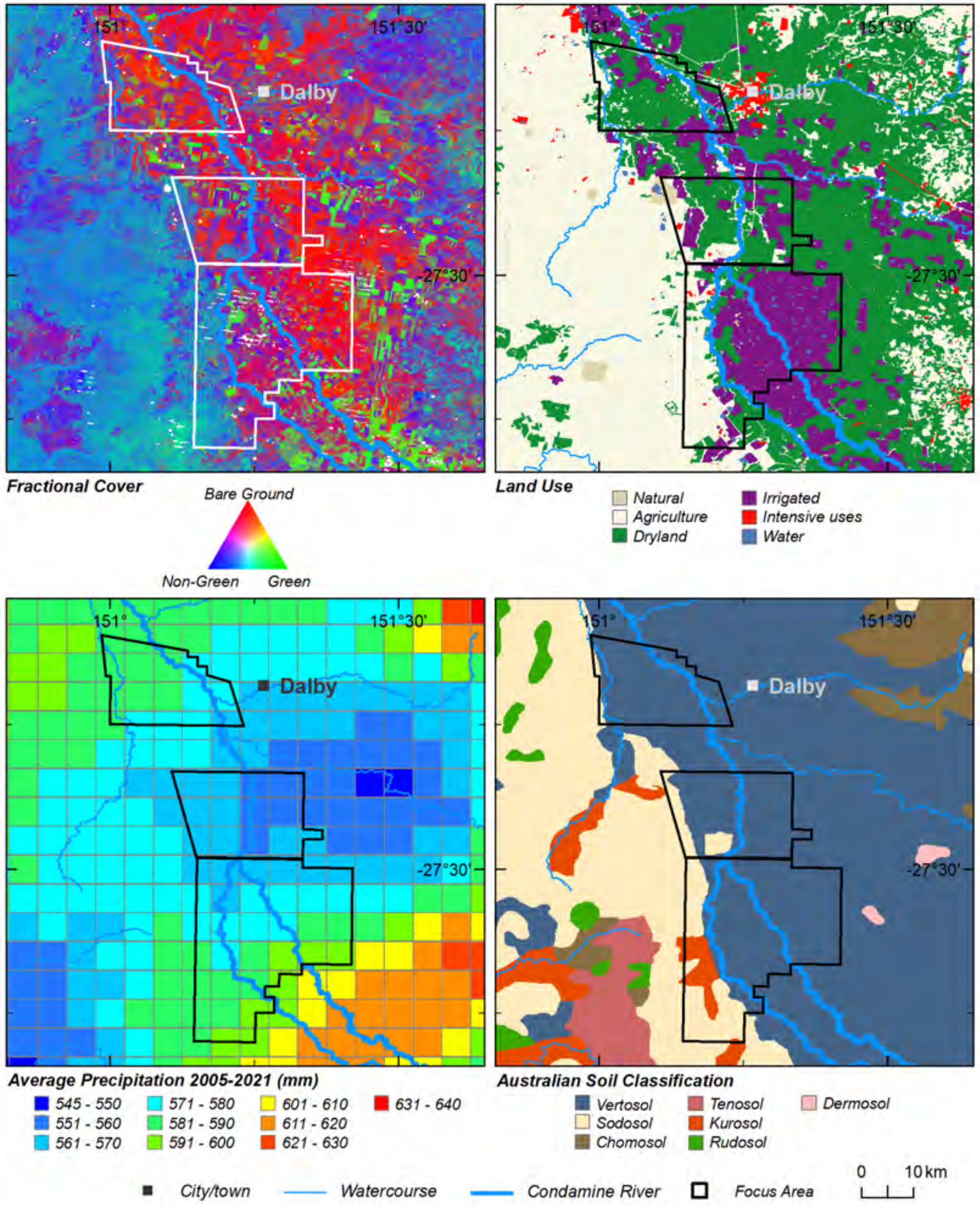


FA05

What data is expected to be most useful?

- The focus areas within the FA05 category are relatively small compared to resolution of available data
  - Especially considering quality of data in regions
- Can visually observe correlation between Fractional cover, Land use and Soil classification (*right*)
- Static maps don't show variability through time, so Sarah generated profile patches through to track fractional cover and crop area along with available InSAR (*below*)



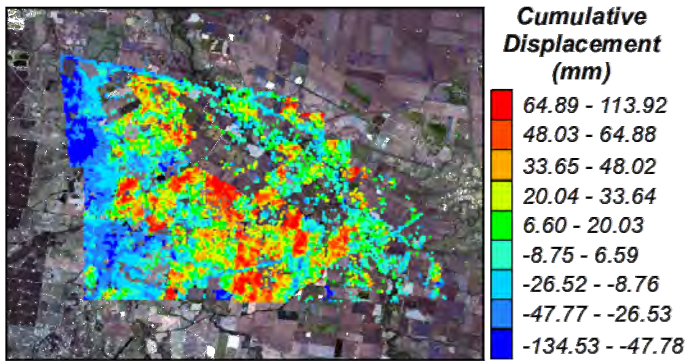


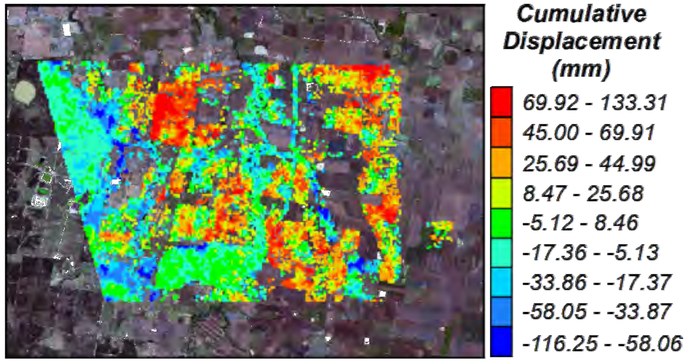
Patterns in the data

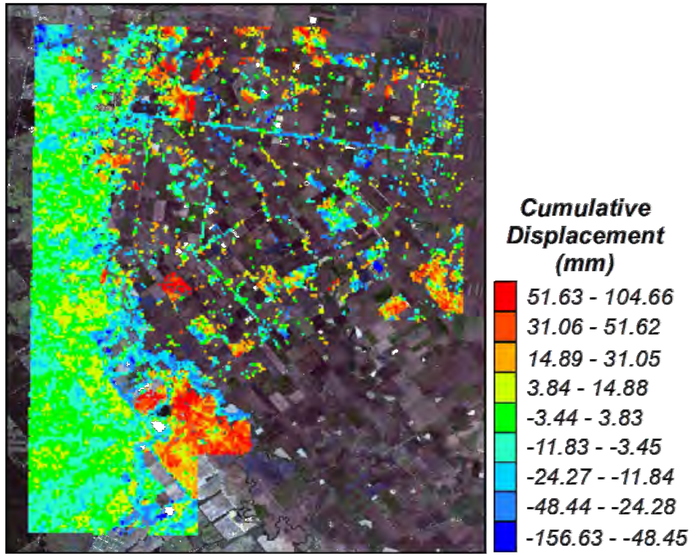
Can the influence of these other "data sources" be observed in the D-InSAR data?

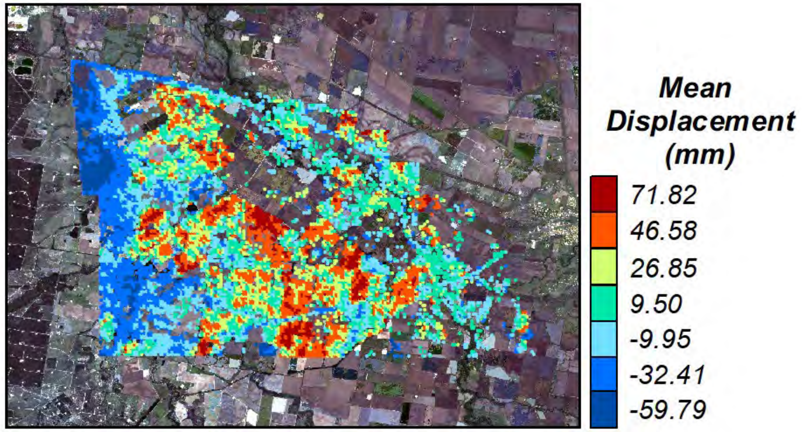
- First port of call was to reduce noise and (to some extent) the impact of bias in high point density areas (*images to right*)
  - Temporally interpolate to even spacing + exponentially smooth
  - Use radial basis function to interpolate to regular grid

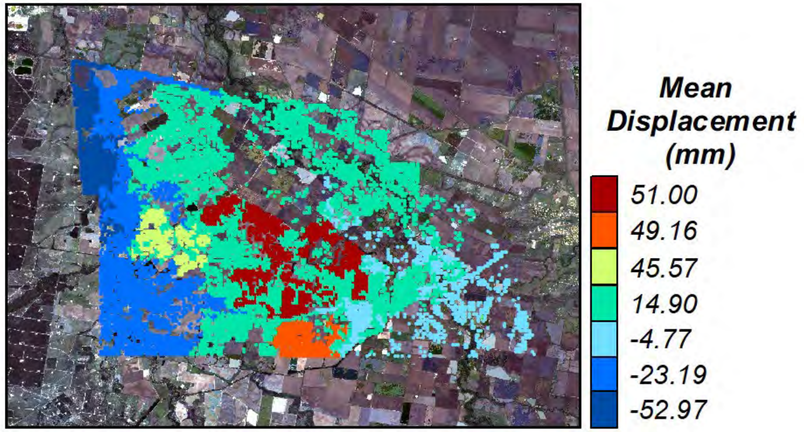
- Following this → apply hierarchical clustering with and without spatial constraints
  - i.e. automate identification of similar behaving areas
  - Example for FA05c without and with spatial constraint (*below*)







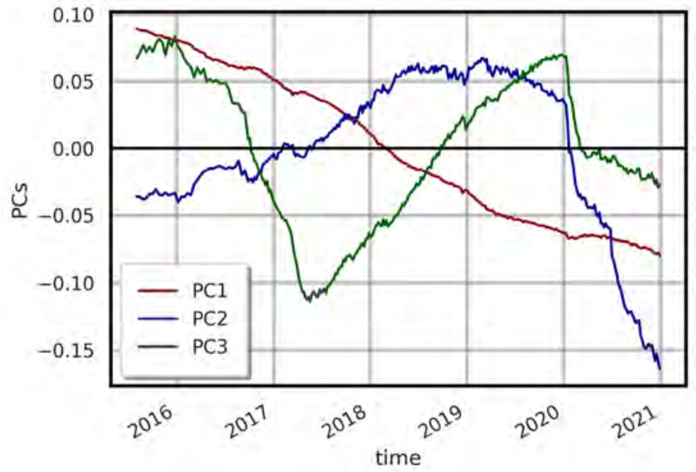


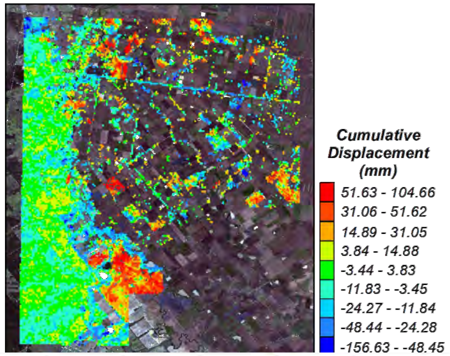


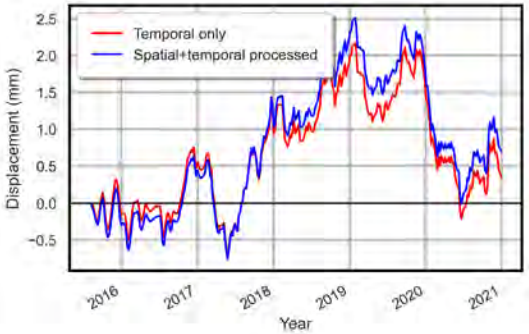
Patterns in the data – FA05a

Can the influence of these other "data sources" be observed in the D-InSAR data?

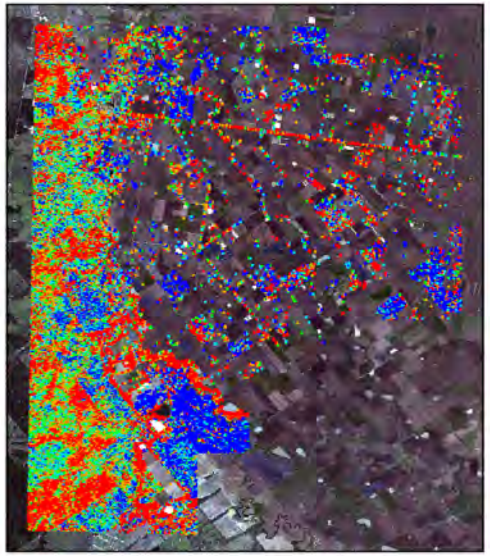
- Clustering doesn't account for temporal effects, try spatio-temporal principal component analysis (empirical orthogonal functions (EOF))



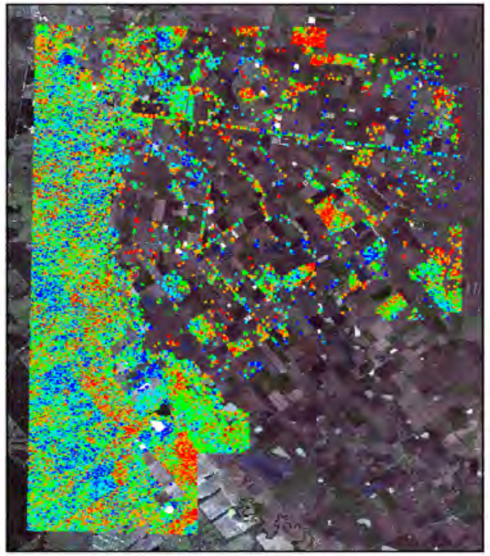




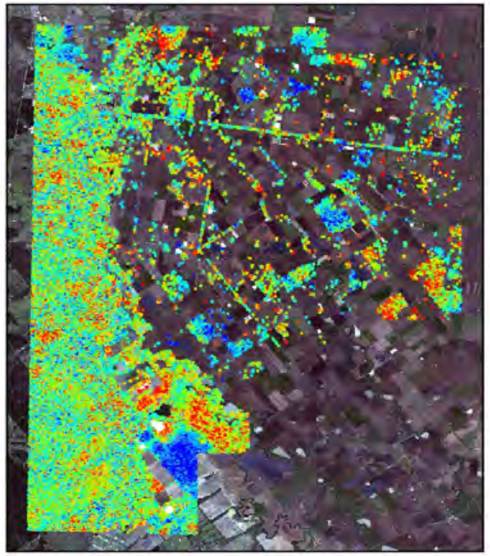
Smoothed data



First mode (39%)



Second mode (7%)



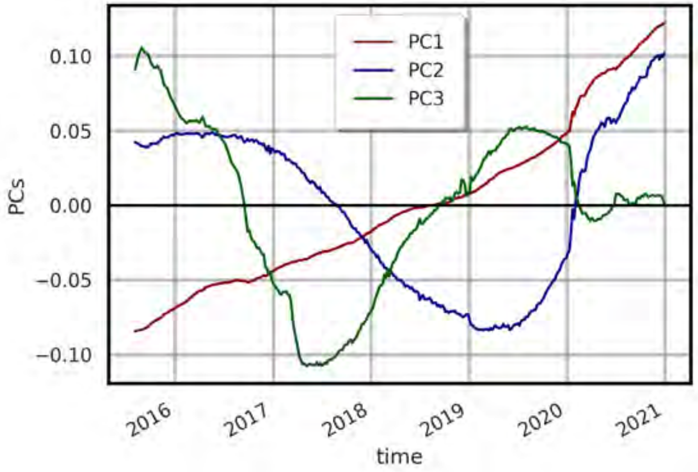
Third mode (3%)

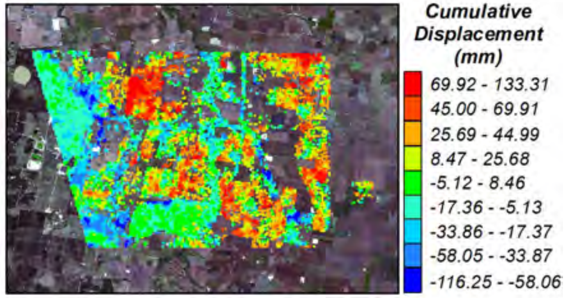
Colours in these plots are normalised as they need to be multiplied by the respective PC to reconstruct the overall trends

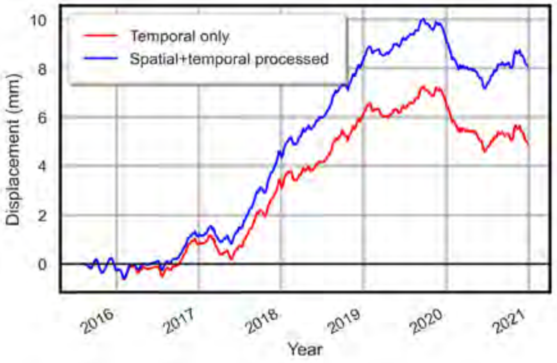
Patterns in the data – FA05b

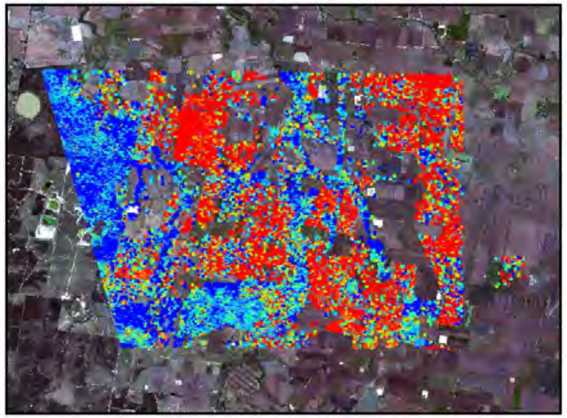
Can the influence of these other “data sources” be observed in the D-InSAR data?

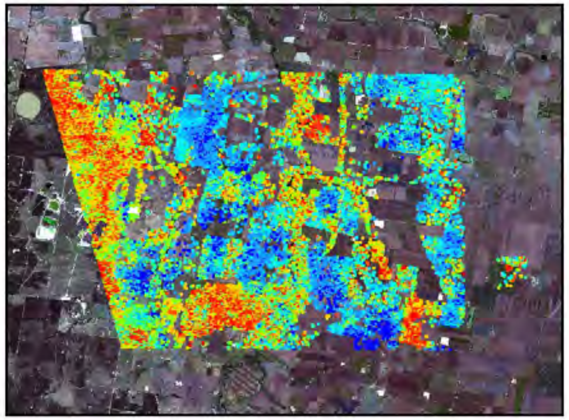
- Clustering doesn’t account for temporal effects, try spatio-temporal principal component analysis (empirical orthogonal functions (EOF))

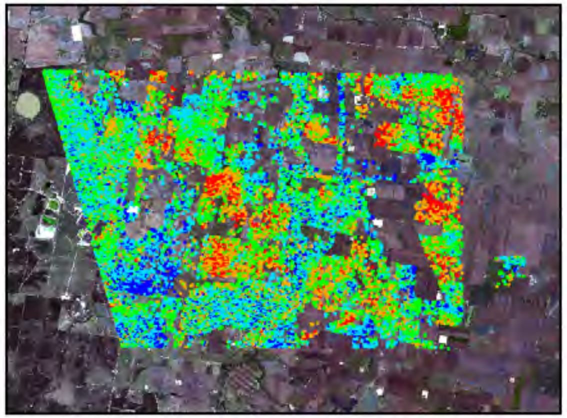












Smoothed data

First mode (55%)

Second mode (11%)

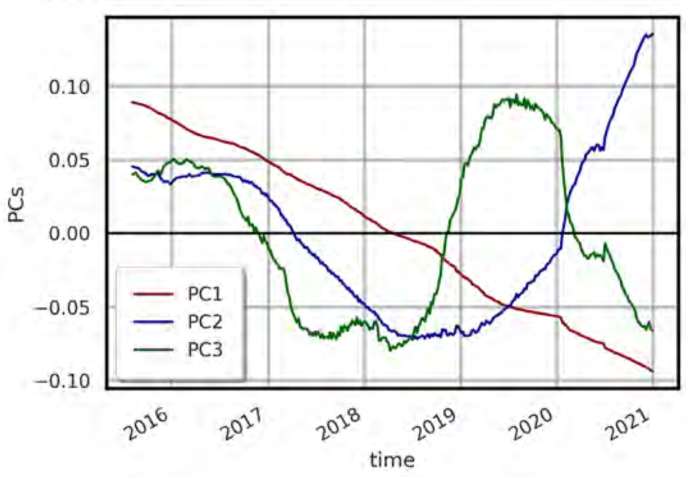
Third mode (3%)

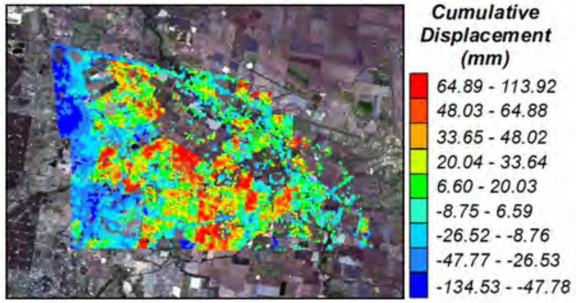
Colours in these plots are normalised as they need to be multiplied by the respective PC to reconstruct the overall trends

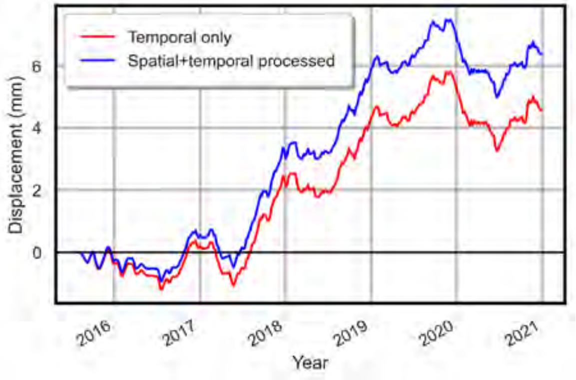
Patterns in the data – FA05c

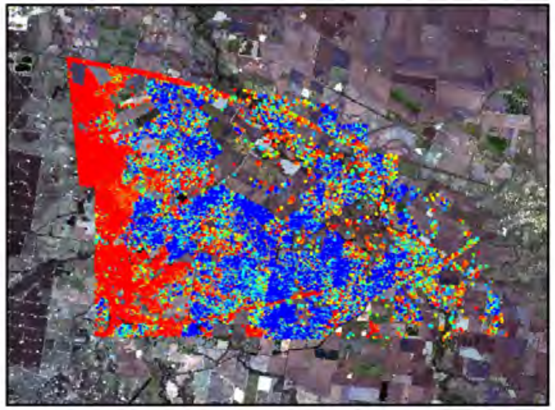
Can the influence of these other "data sources" be observed in the D-InSAR data?

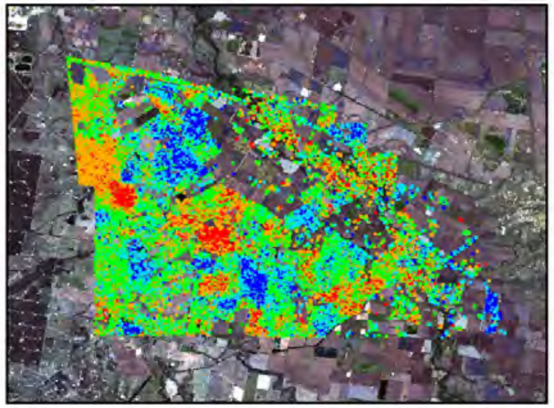
- Clustering doesn't account for temporal effects, try spatio-temporal principal component analysis (empirical orthogonal functions (EOF))

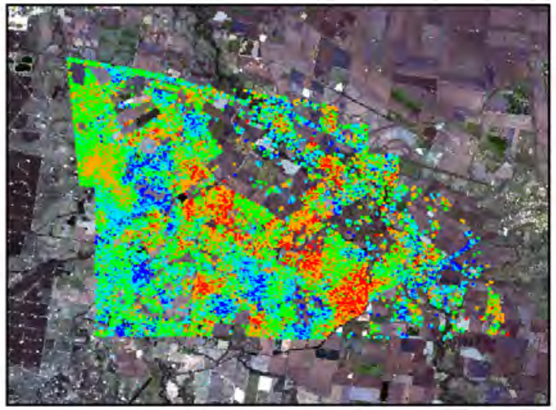












Smoothed data

First mode (66%)

Second mode (6%)

Third mode (3%)

Colours in these plots are normalised as they need to be multiplied by the respective PC to reconstruct the overall trends

TRE Altamira data

What do we take away from this type of analysis?

- Poor data quality over irrigated land → although good for some areas, D-InSAR is challenging in these regions
  - Data is sparse due to poor coherence
  - Data that is obtained has high variance (i.e., questionable accuracy)

- Poor coherence seems to align with variability in growth (e.g., tracking fractional cover through time) in these regions and possibly higher moisture/liquid content of the irrigated land

- Data storage requirements can be drastically reduced through either
  - Temporal + spatial smoothing
  - EOF analysis and retain only sufficient EOF modes to capture '*sufficient*' variance

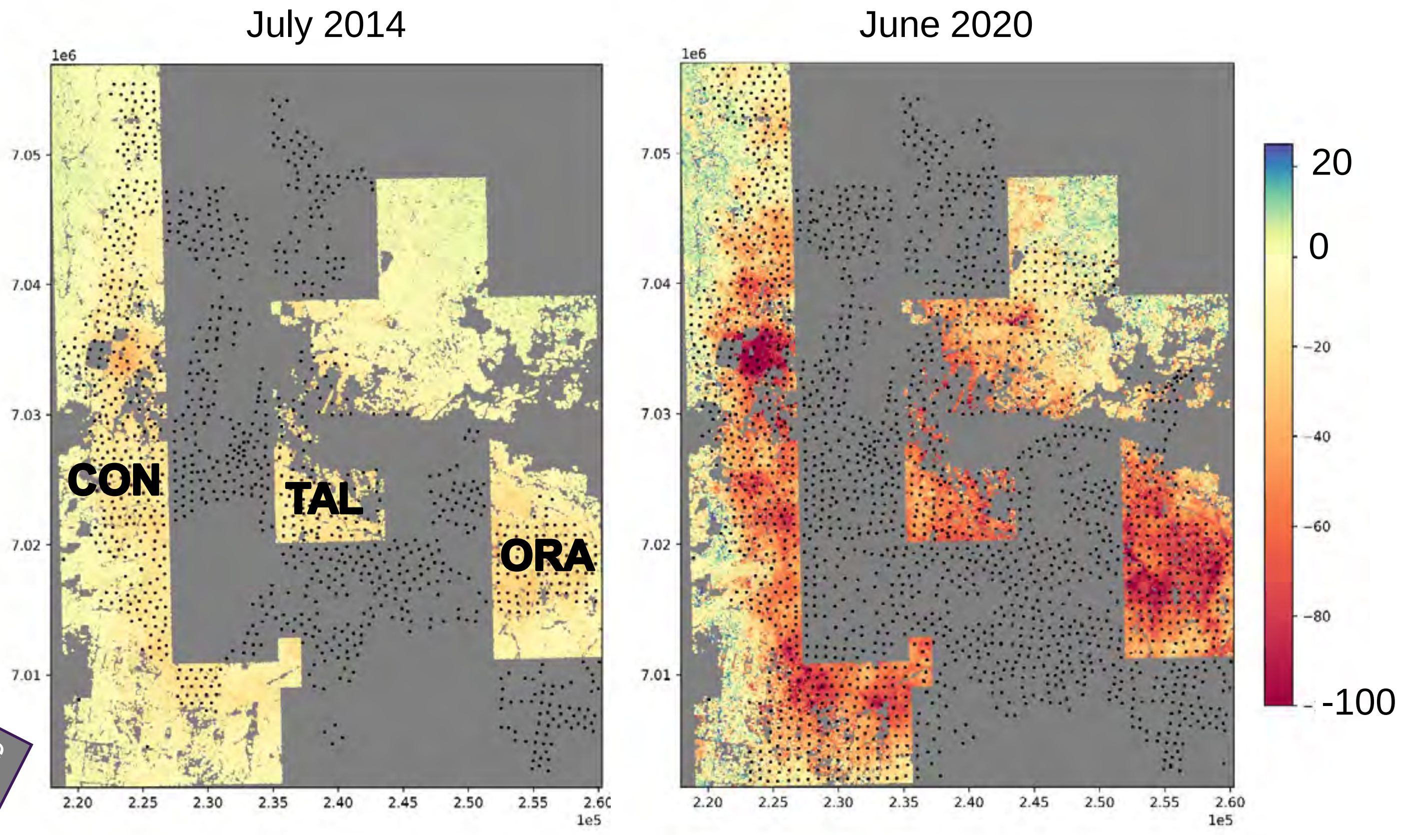
- PC's associated with EOF's reflect behavioural changes in time (e.g., mid-2017, 2020)

- Appears correlation between:
  - EOF signals and cluster groups to available measures of land use, fractional cover and soil type
  - To take precipitation into account, larger focus areas are required
  - Also appears dominant subsidence readings in regions closer to CSG activity

Detailed data analysis

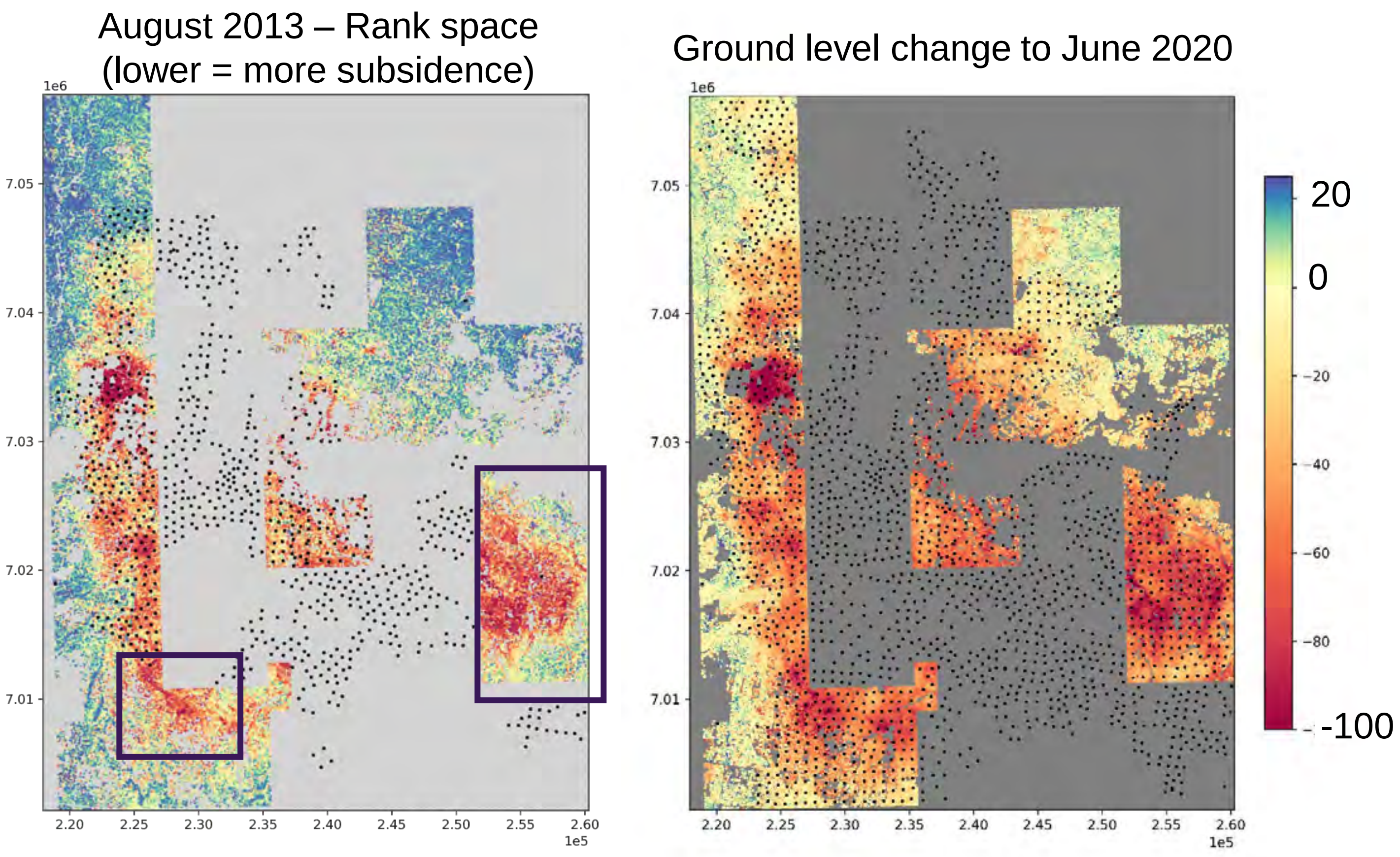
- Data starts in July 2012 and was used “as provided” (no other pre-processing)
- Maps show ground level change and wells drilled at the time.
- Plot below shows mean/p25/p75 GL change and well count (including QGC wells)

Ground Level (GL) change to:

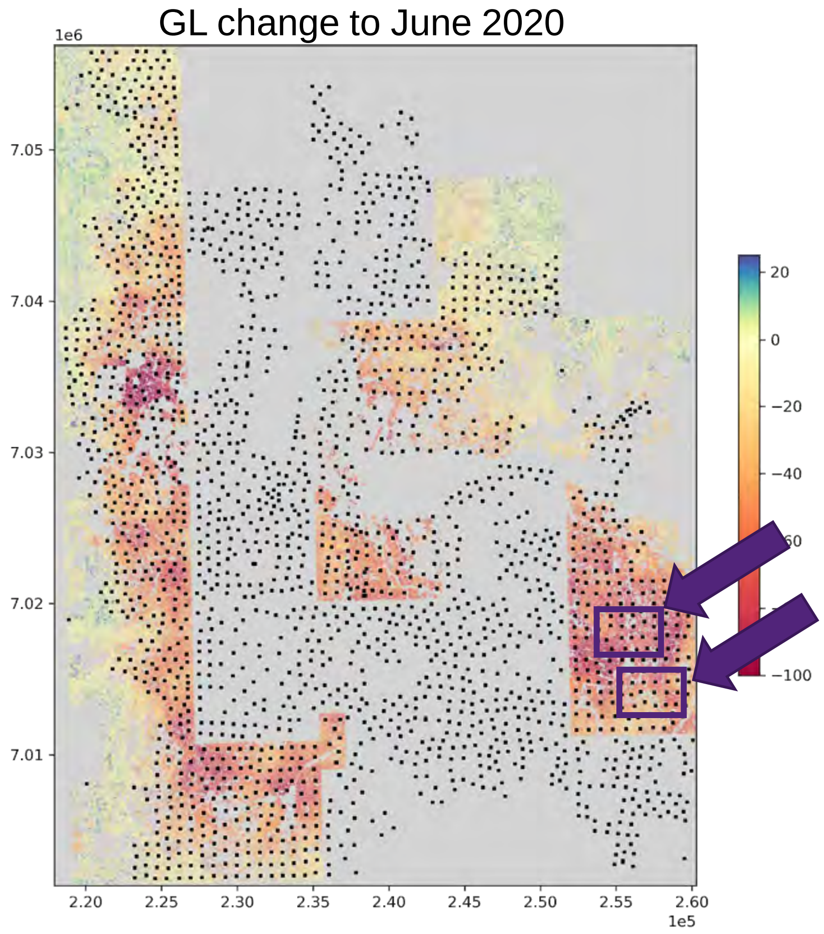


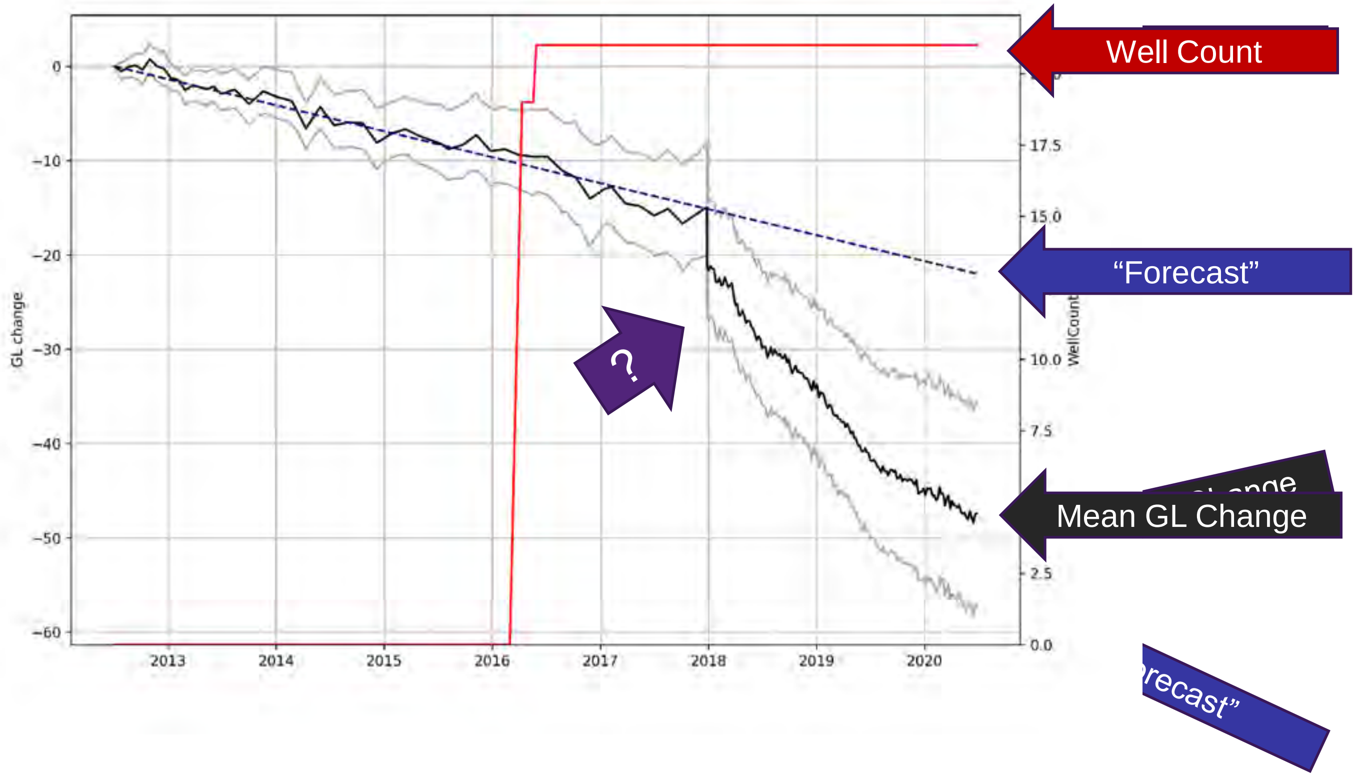
Early (pre-production?) Subsidence

- The right hand map (ground level change to June 2020) - perhaps suggests subsidence occurs in areas where wells are.
- The data from August 2013 is shown in rank space (so red areas are those with most subsidence)
- The spatial “pattern” of subsidence is already established.
- Including subsidence in areas where wells are yet to be drilled.



Ground Level Change vs Well Count

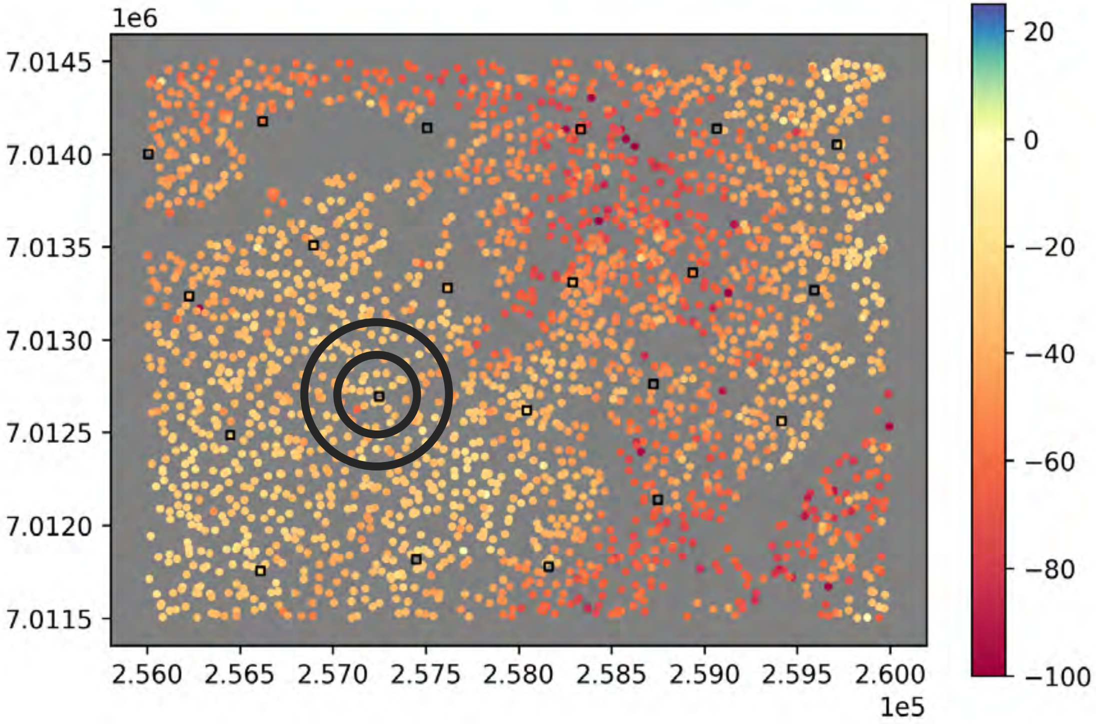




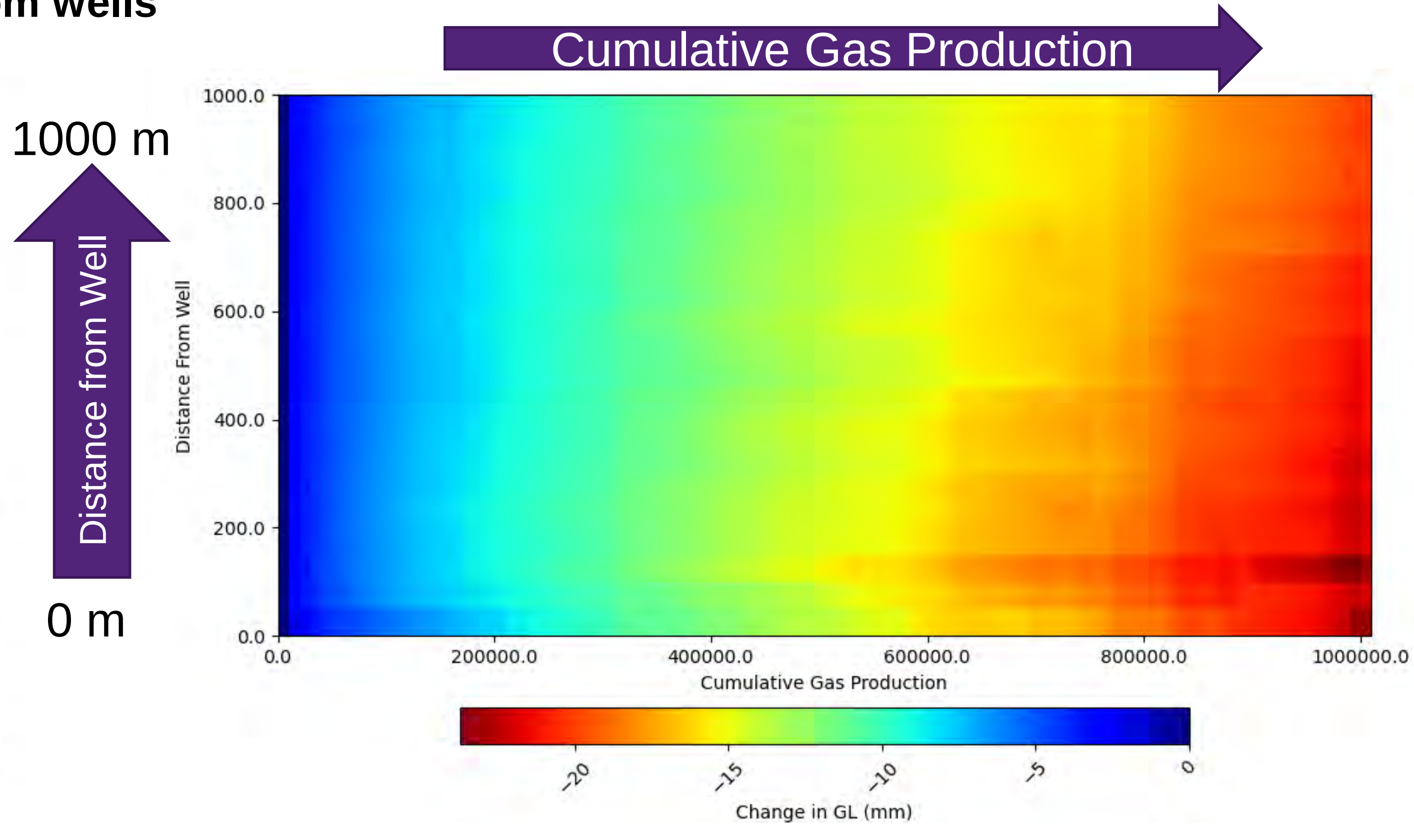
In this small area there is a change, but it seems to happen at the start of 2018, when the frequency of the data also changes

Interrogation of Data from Production Areas,

Subsidence as a function of time (i.e. gas production) and distance from wells



Schematic showing the grouping of subsidence observations around wells



Change in Ground Level (from start of Production

Summary and thoughts

TRE Altamira data

- Data shows subsidence occurring across the majority of the area, and in many areas this was happening before CSG wells were even drilled → longer term climate influences
- Analysis suggests the local impact of individual CSG wells is minimal.
- In some places, the observations are questionable.
Large changes in subsidence rates occur when the (satellite) data source was changed at the start of 2018. Can make comparisons harder.

Questions / comments

3. D-InSAR data analysis
Techniques and observations

4. Sarah's PhD - Small baseline subsets

Sarah Brennand

Study background

- CSG production extends over large regions
  - Challenge to monitor surface movement with in-situ instruments
- Legislation around managing potential environmental risks associated with CSG extraction
  - Some CSG companies in the Surat CMA commission regular surface movement reports
- InSAR identified as one of the most effective surface movement monitoring techniques for CSG projects in Australia

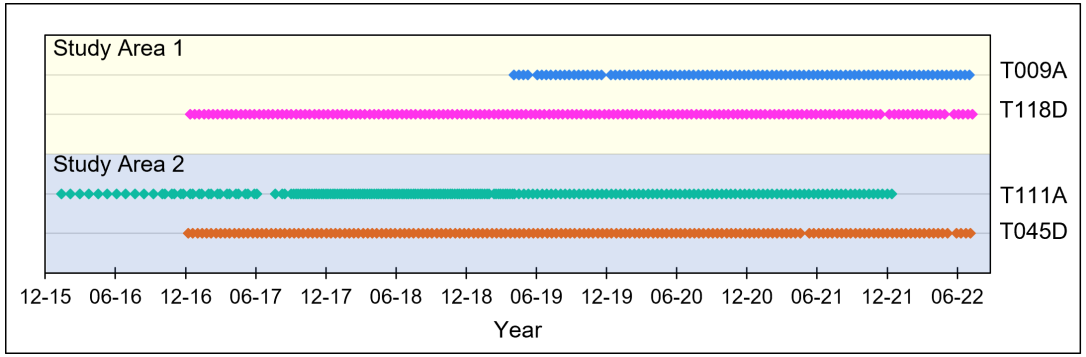
Research question

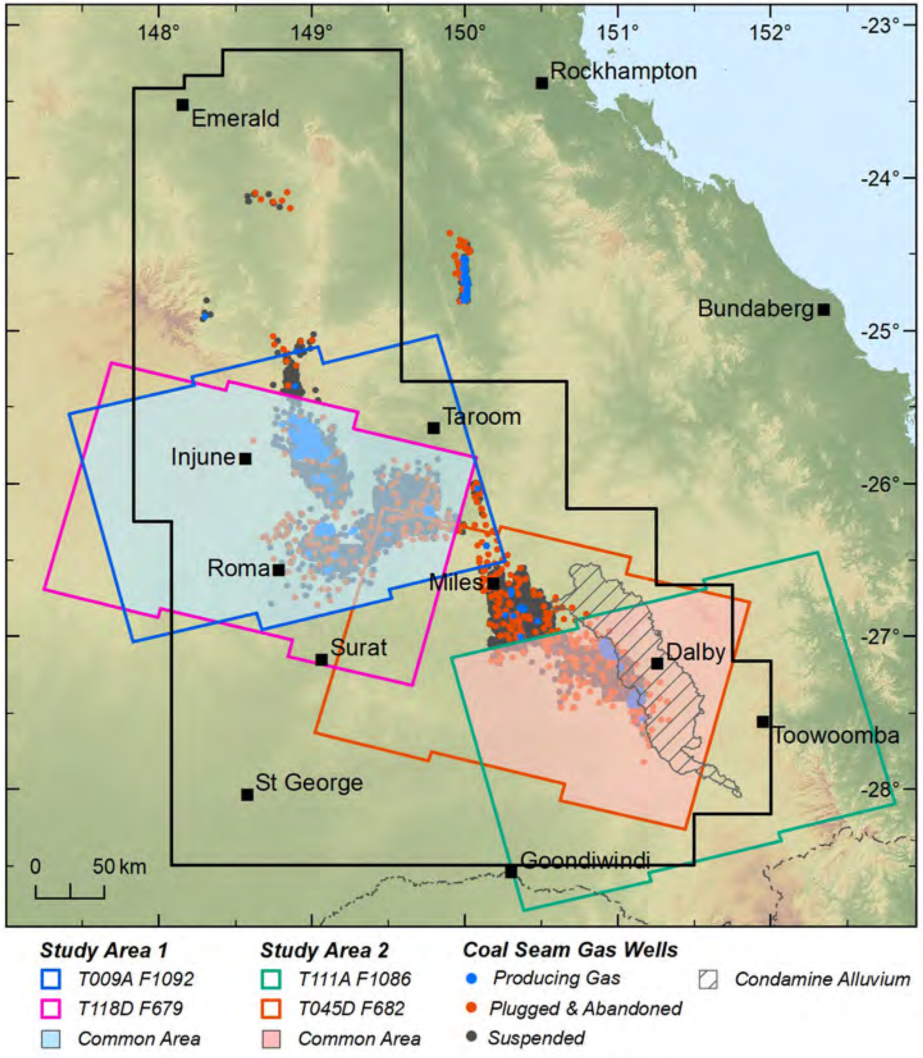
- To determine to what extent CSG extraction contributes to total observed surface movement, understanding the impact of natural processes on surface movement in these regions is required

Can the integration of InSAR time-series with other data be used to quantify and attribute the impact of natural processes on surface movement in the Surat CMA?

Study area

- Two study areas selected, based on:
  - Previous evidence of ground movement in non-CSG production region
  - SAR data availability (Sentinel-1)
  - Extent of CSG production
  - Extent of non-CSG production regions
  - Coverage over the Condamine Alluvium





Study Datasets

Ground Characteristics
- Topography, slope
- Hydrographic features
- Soils, clays
- Land use, vegetation
- Surface geology
- Cadastral
- Infrastructure

Sub-surface Characteristics
- Geological structures
- Aquifers
- Alluvium extent/depth
- Coal seam extent/depth

InSAR Time-series
- Average linear velocity (ascending)
- Average linear velocity (descending)
  - → Vertical & horizontal movement
- Cumulative time-series
- Incremental time-series

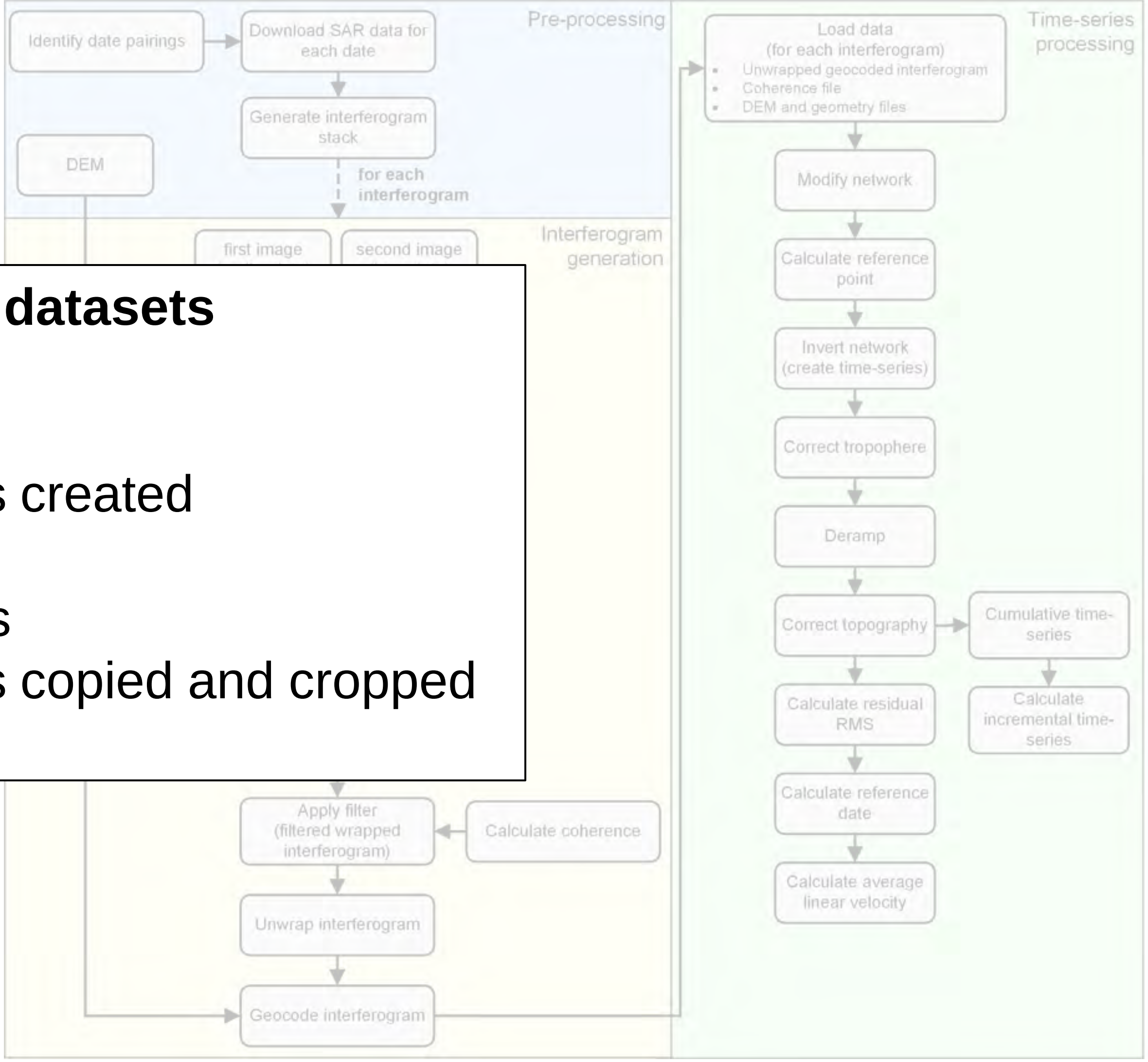
Dynamic Datasets
- Precipitation
- Soil moisture
- Fractional cover
- Groundwater extraction
- GNSS
- Land use, spectral reflectance

Time-series generation – SBAS approach

	Dataset	Date Range	# Dates	# interferograms
Study Area 1	T009A F1092	07 Apr 2019 – 08 Jul 2022	98	1,350
	T009A F1092 (common area)	07 Apr 20 08 Jul 202		
	T118D F679	13 Dec 20 15 Jul 202		
	T118D F679 (common area)	02 Apr 20 15 Jul 202		
Study Area 2	T111A F1086	12 Jan 20 17 Dec 20		
	T111A F1086 (common area)	13 Dec 20 17 Dec 20		
	T045D F682	08 Dec 2016 – 10 Jul 2022	169	2,415
	T045D F682 (common area)	08 Dec 2016 – 18 Dec 2021	153	2,175

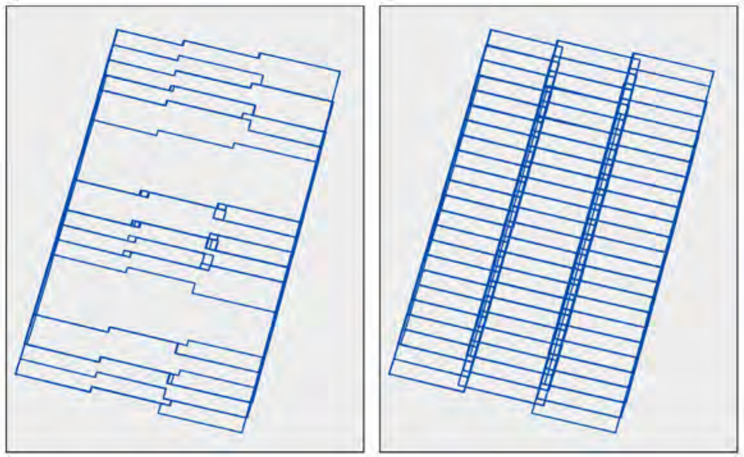
8 time-series datasets

- 4 full scene datasets
  - 9,285 interferograms created
- 4 common area datasets
  - 7,740 interferograms copied and cropped



Data processing challenges

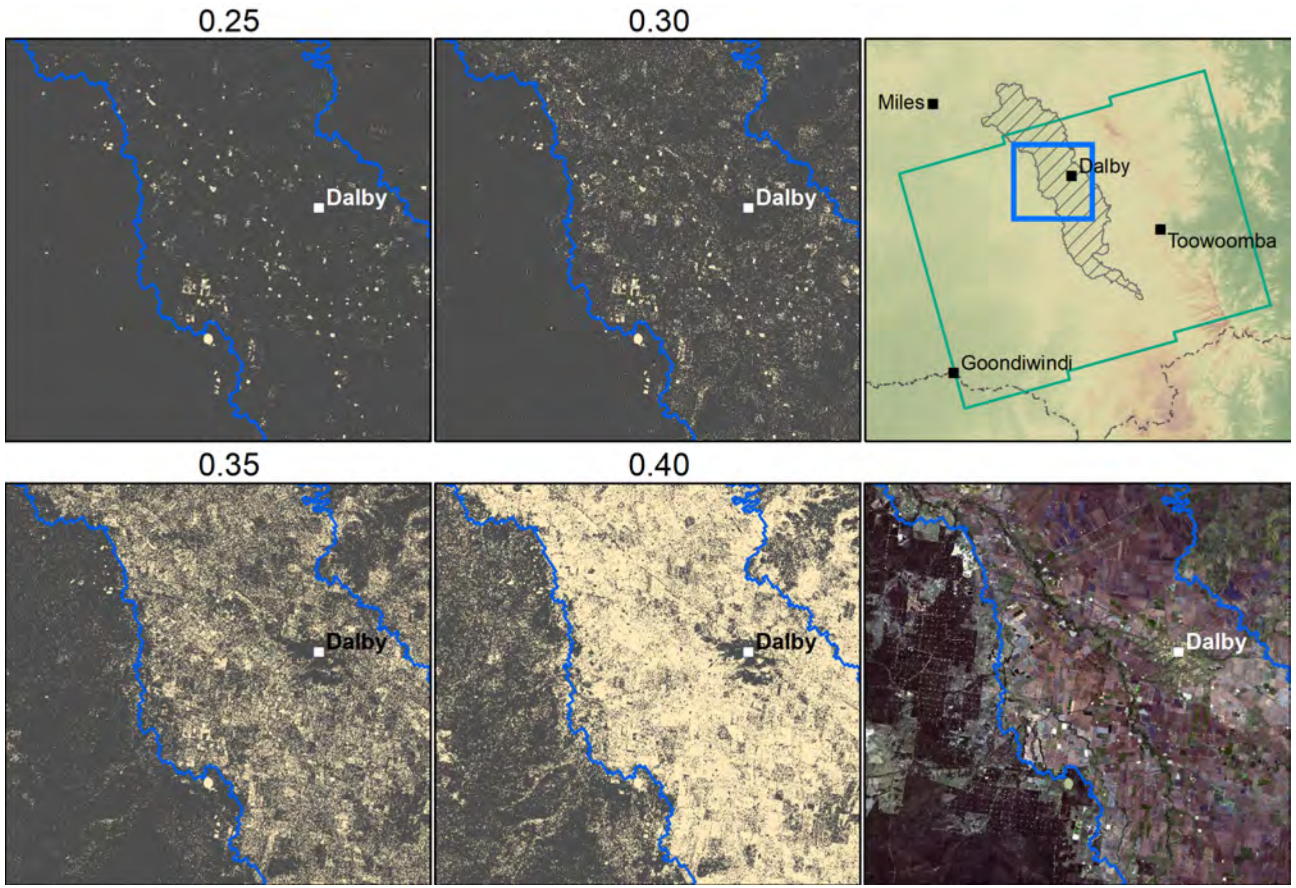
- SAR data slicing (Sentinel-1)
  - Early data was inconsistently sliced
  - Difficult to create a stack of data over the same area using all available acquisition dates
  - Can exploit underlying data structure (bursts) to create a custom stack, but limited by software compatibility



- Generating interferograms
  - Data structure (bursts, sub-swaths) increases processing complexity and potential errors
- Data storage requirements
  - 17,740 interferograms: ~34 TB
  - 8 time-series datasets: ~35 TB

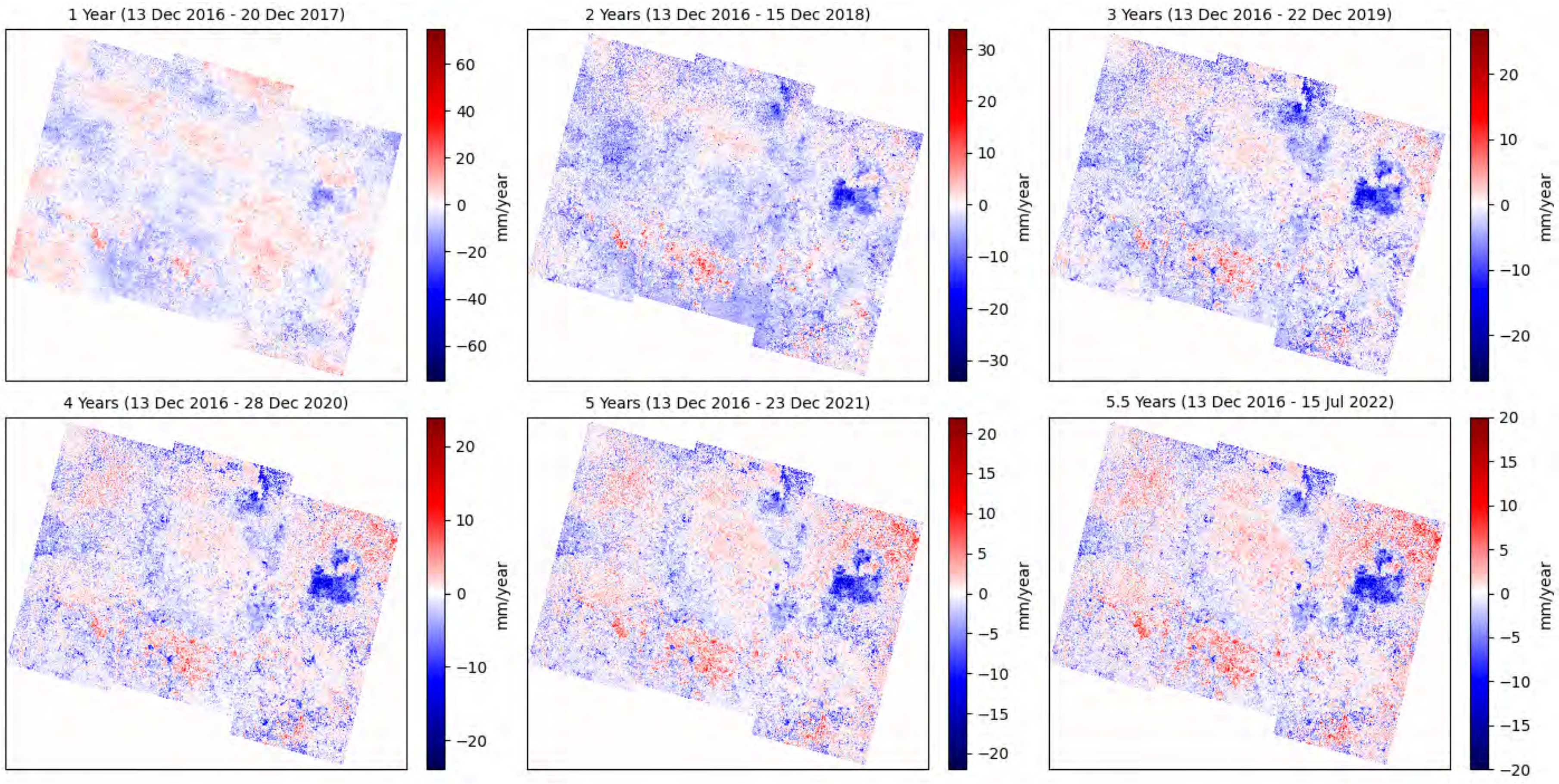
Data processing challenges

- Coherence
  - Microwave energy from both SAR images needs to be ‘coherent’
  - Coherence loss can be due to:
    - Satellite position for each SAR image varies to much
    - Steep topography
    - Ground movement too large to be detectable
    - Ground characteristics change too much between image dates
  - Mask low coherent regions to improve data quality



Data processing challenges

- Number of SAR acquisitions
  - Longer time period improves ground movement estimates

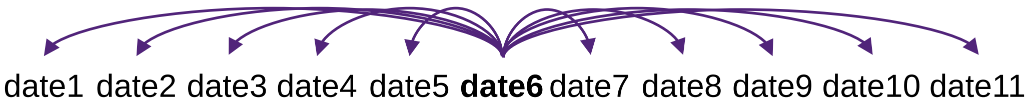


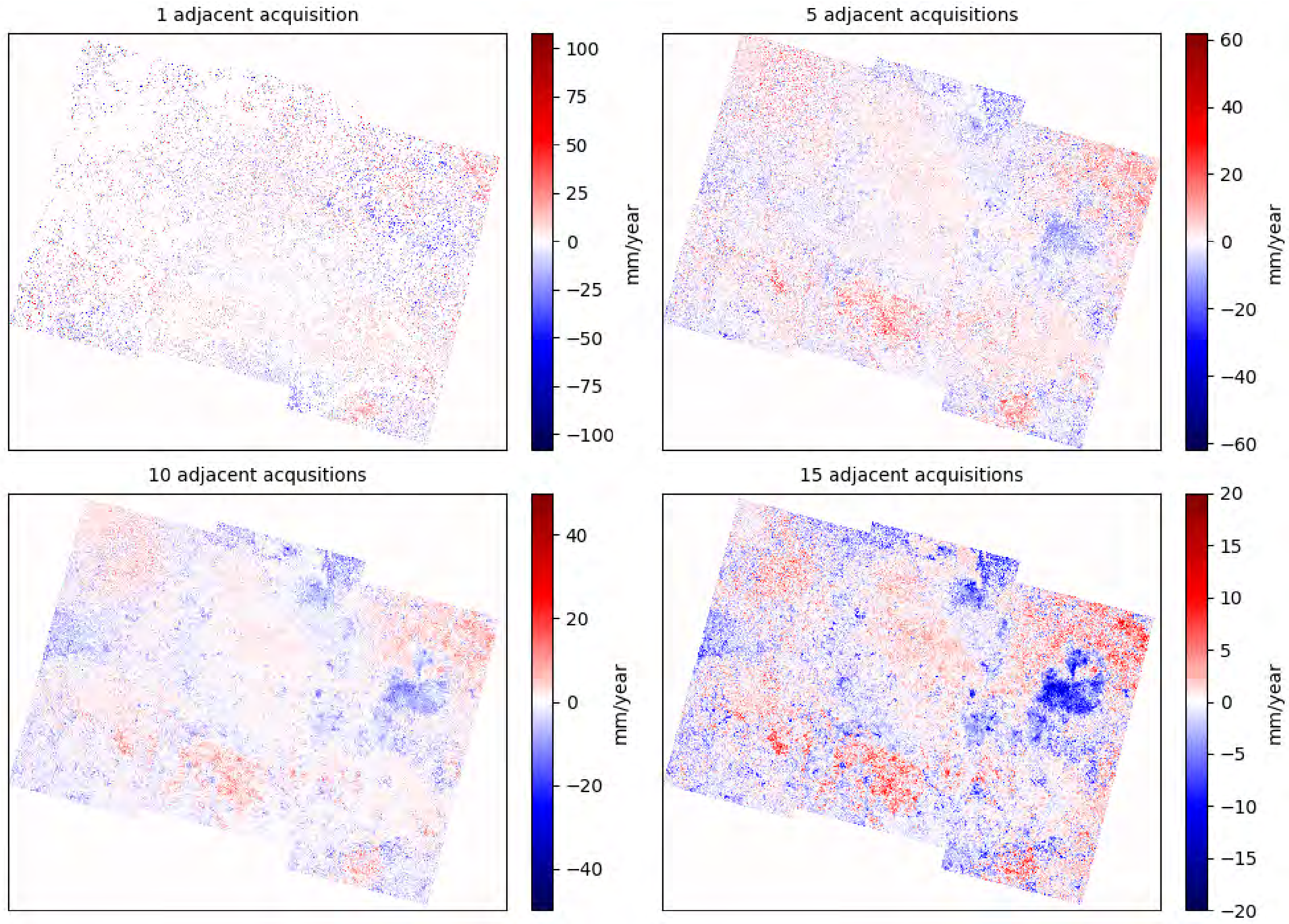
+ : uplift
- : subsidence

Data processing challenges

- Number of interferograms
  - Denser network of connections between acquisition dates (i.e. more interferograms) provides more data points for movement estimation

5 adjacent acquisition connections





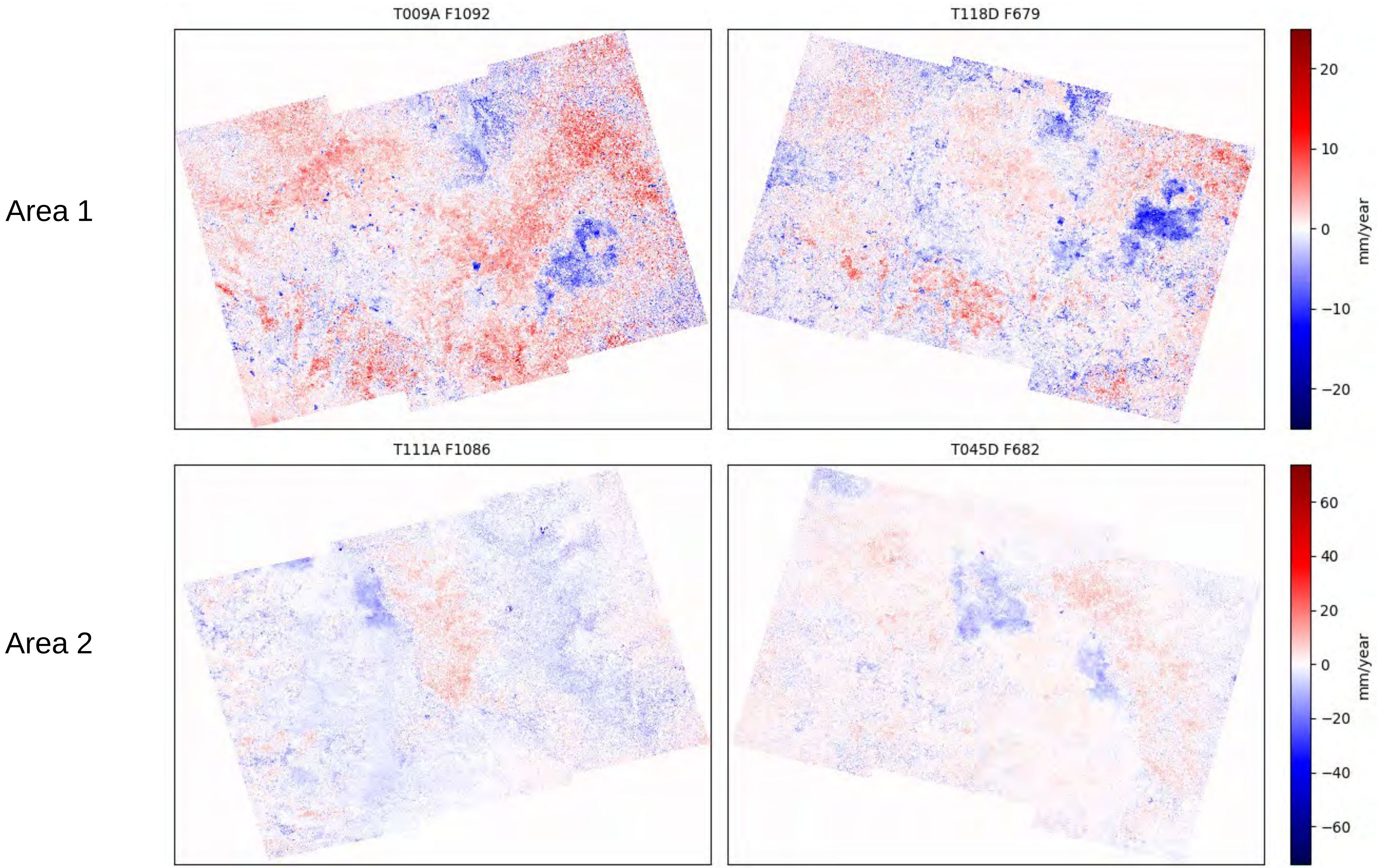
Data processing challenges

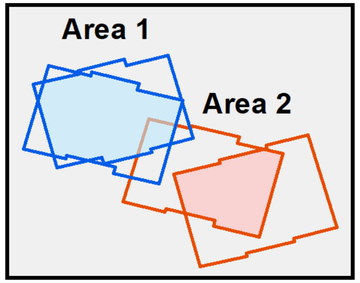
- Not ideal to use a ‘one size fits all’ for processing parameters
  - Surface characteristics can vary for each dataset, so important to test which parameters are appropriate a dataset
  - May lose valid data if parameters are not ideal
- Ground movement results in line of sight, not vertical
  - Need ascending and descending data to resolve vertical
  - Can calculate vertical for one dataset, but may over or under estimate the results

To aid in interpreting the results:

- Input data used (ascending/descending)
- Overall processing workflow
- Parameters used
- Any data issues
- Assumptions made

Average Linear Velocity

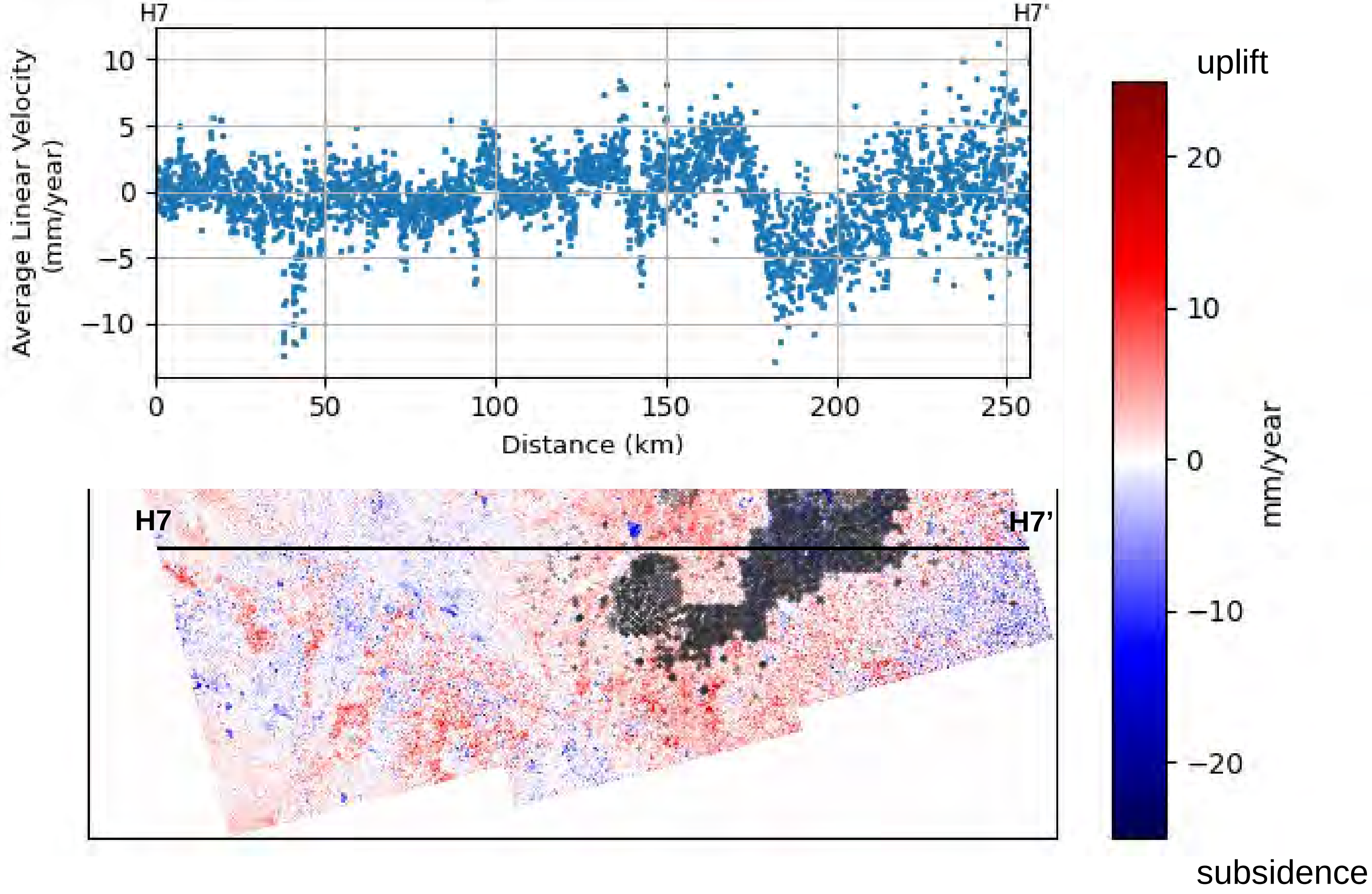




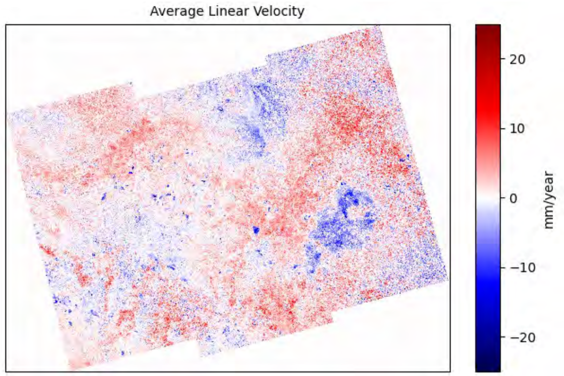
+ : uplift
- : subsidence

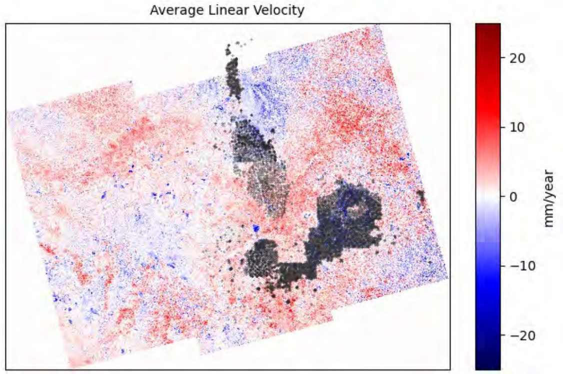
Average Linear Velocity

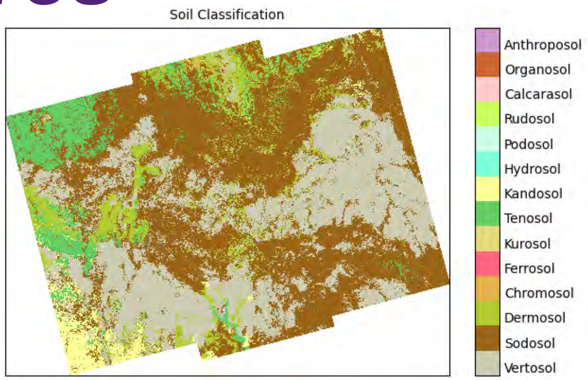
- Line of sight displacement per year

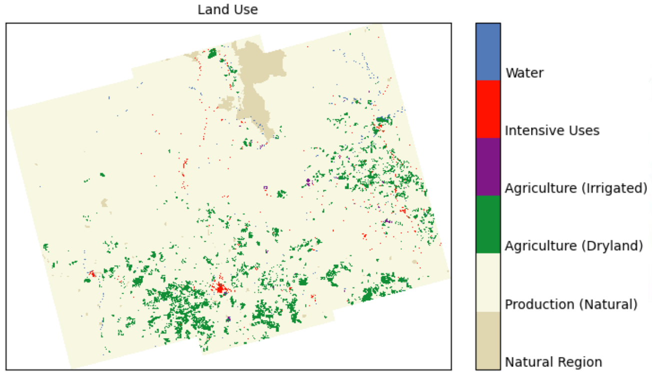


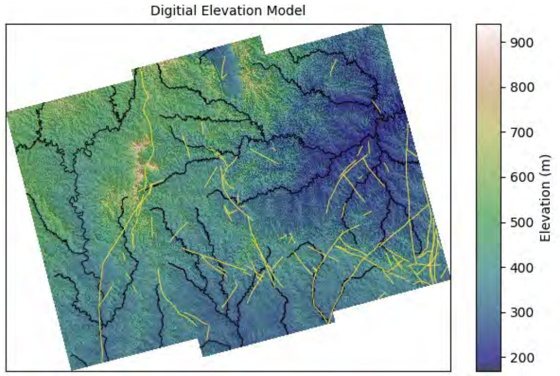
Surface features

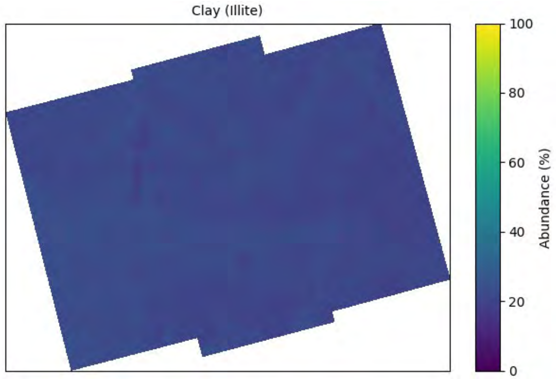


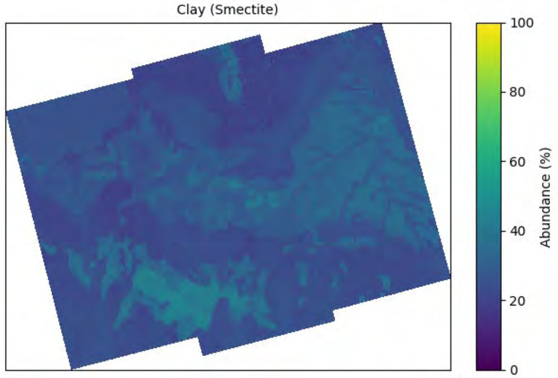


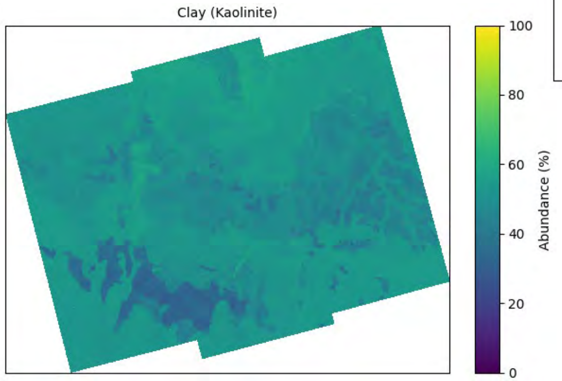












Dynamic processes:

- Seasonal crops
- Monthly fractional cover (green, non-green, bare earth)
- Daily precipitation models
- Daily soil moisture models

Questions / comments

4. Sarah’s PhD - Small baseline subsets

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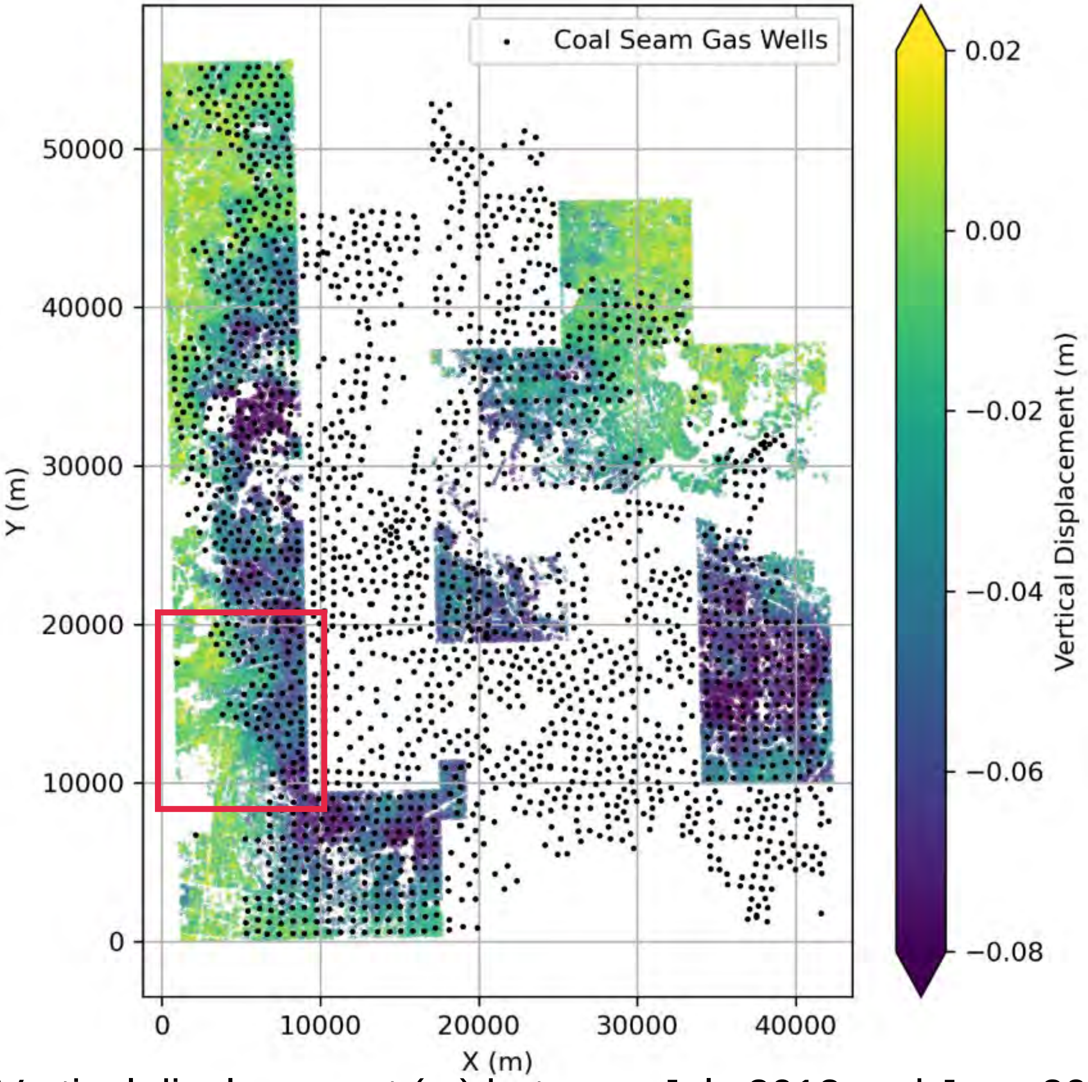
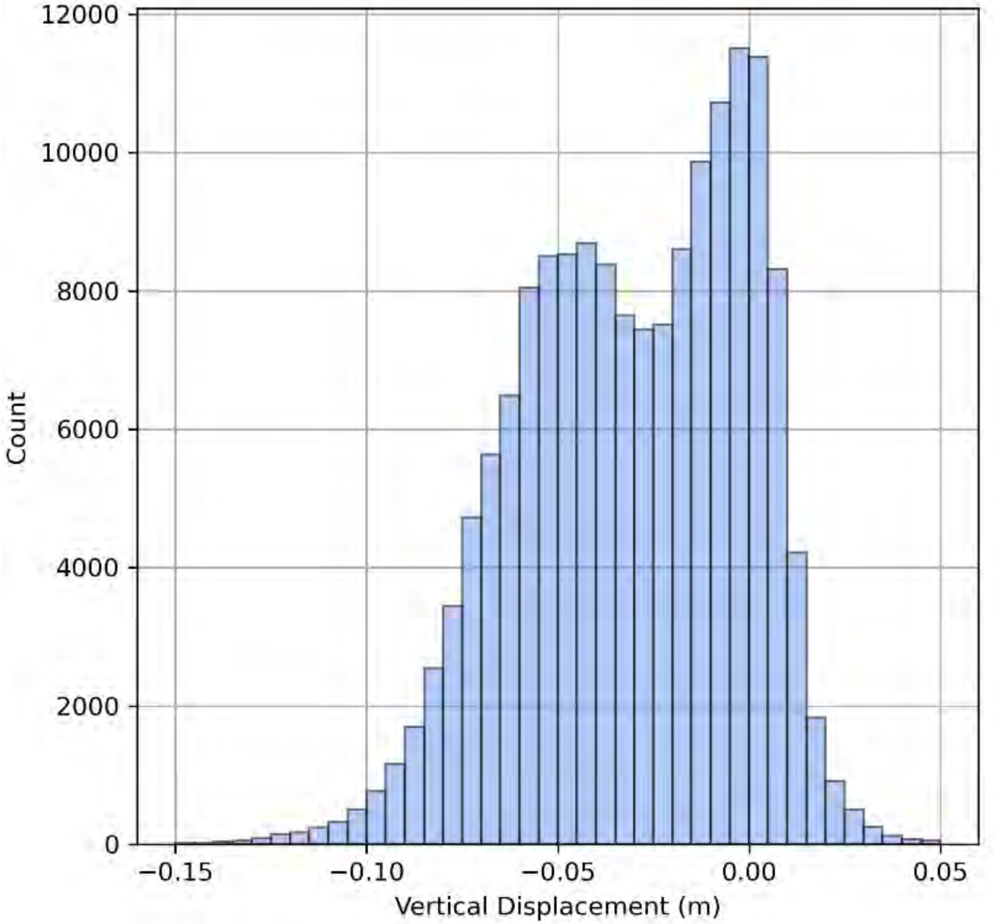
5. Magnitudes and mechanisms

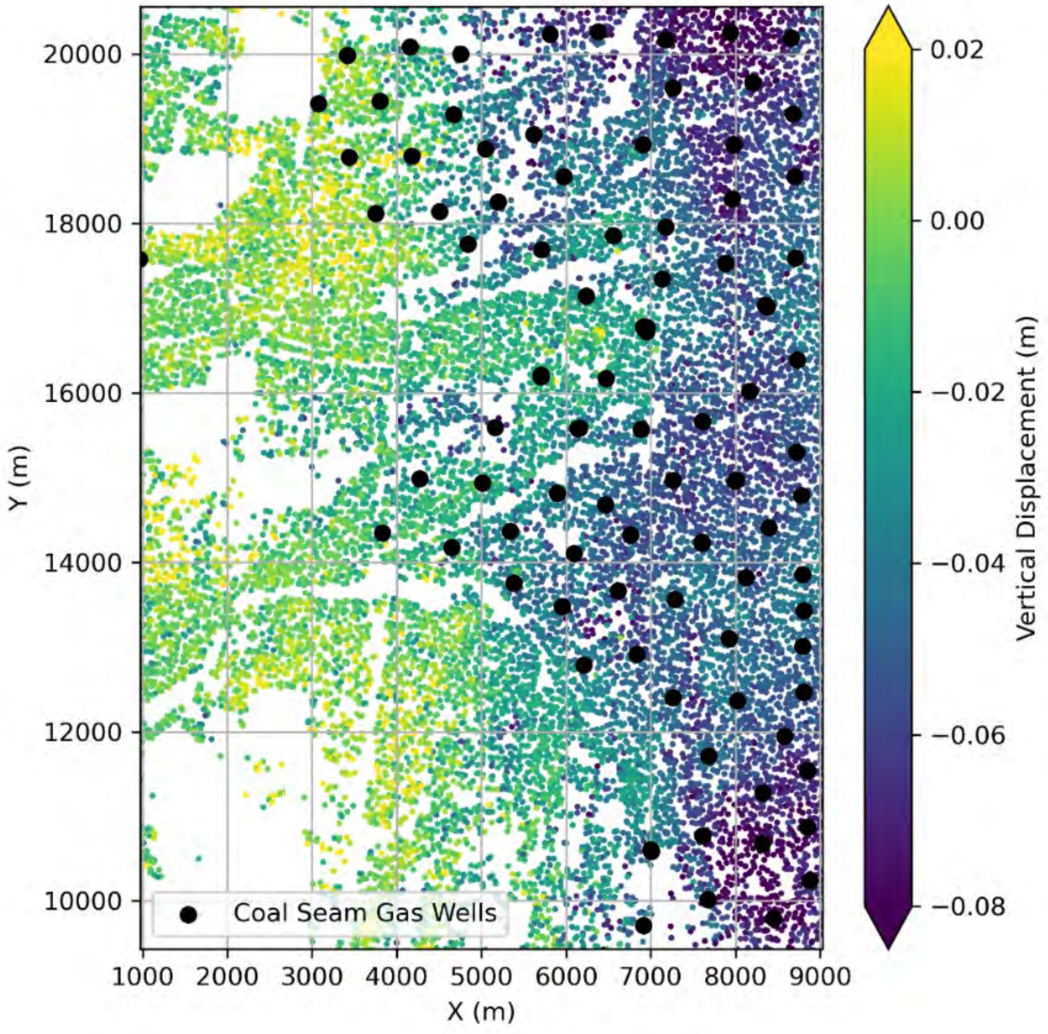
Phil Hayes



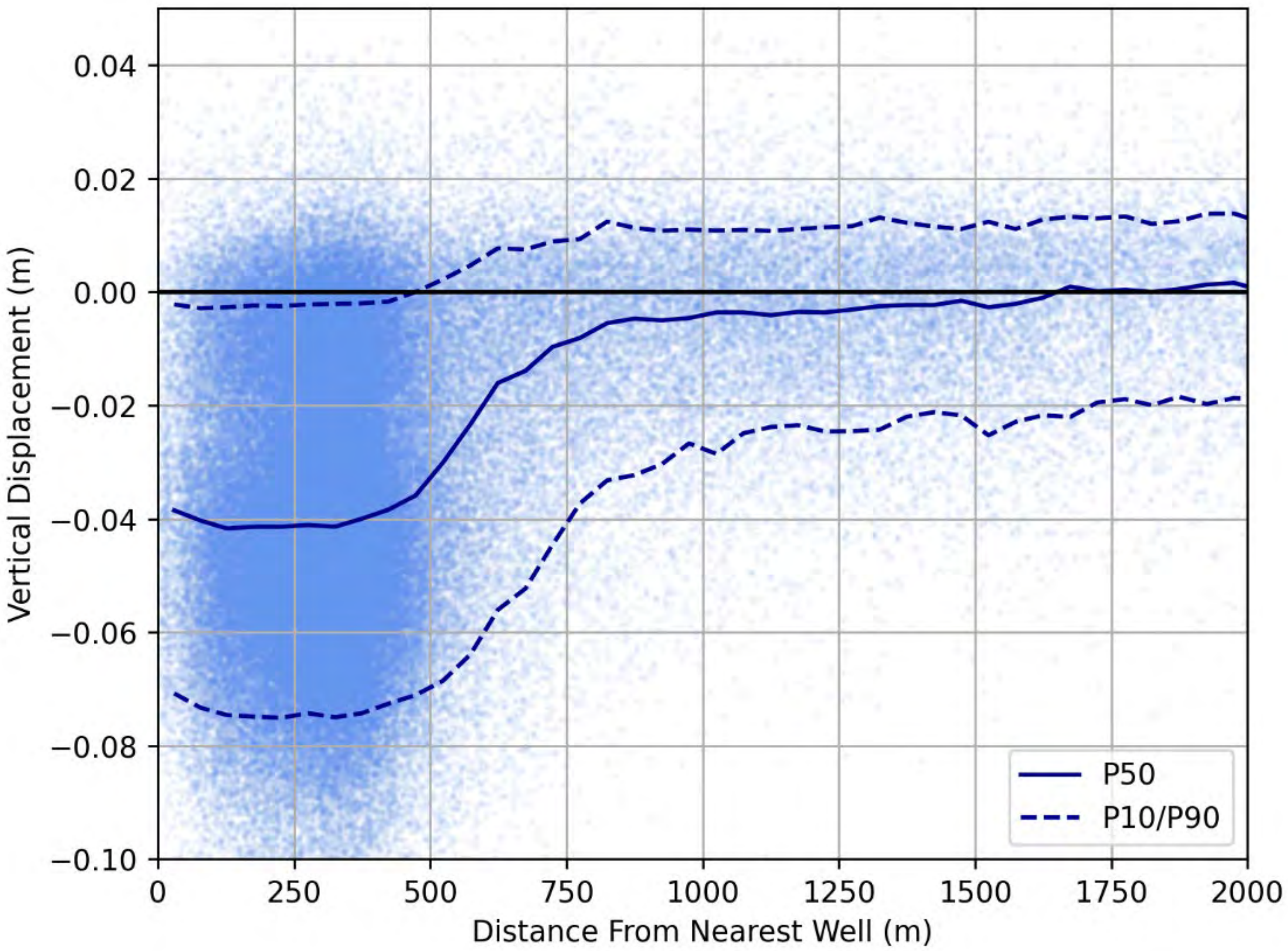
Vertical displacement (m) between July 2012 and June 2020. Negative displacement indicates downwards motion. CSG wells drilled prior to June 2020 are indicated by black points.



Histogram of vertical displacement.
Only 44 points (of 161,260 in total) do not fit within the range of the histogram shown.

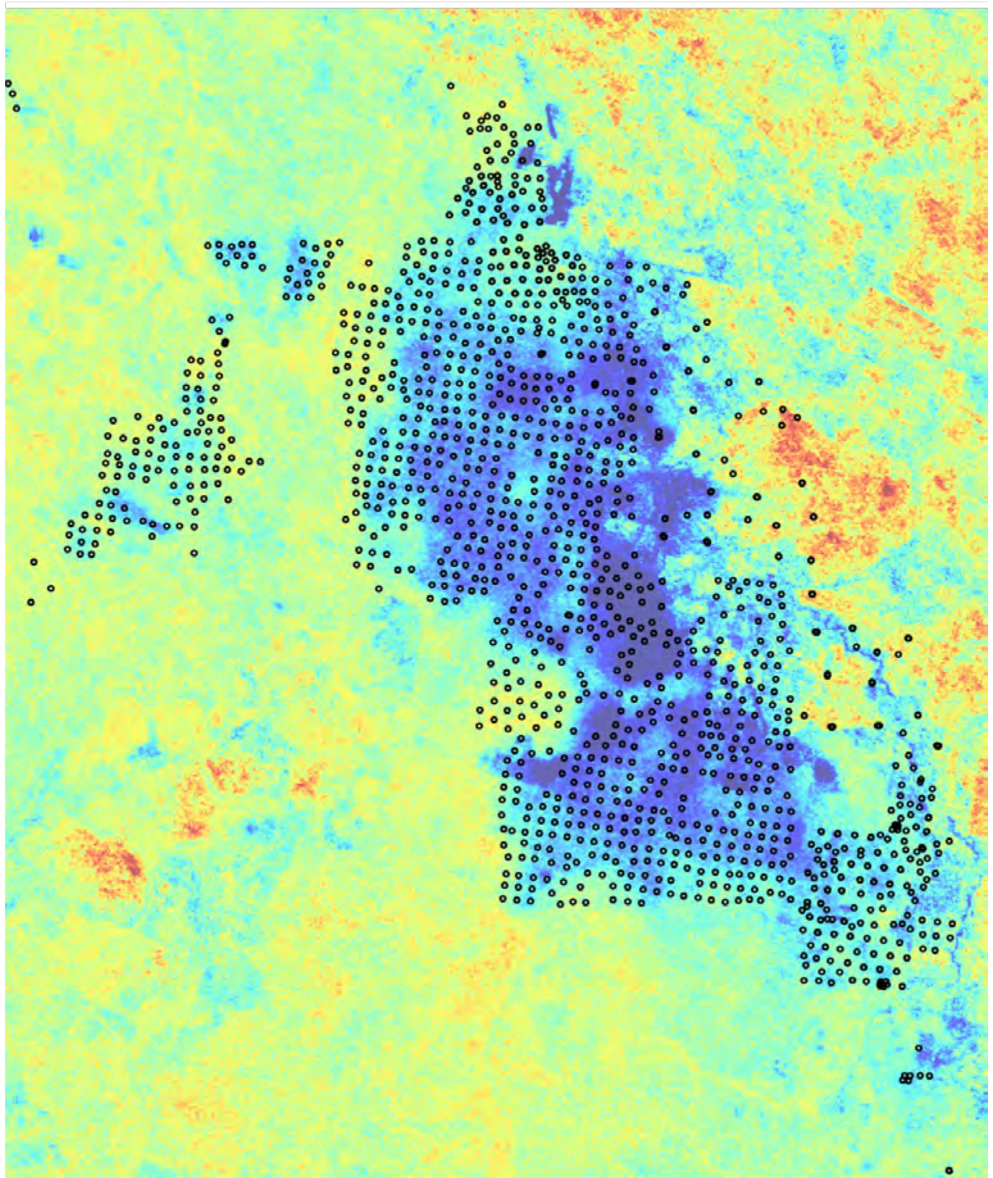


Zoomed in view of part of figure



Vertical displacement over 8 years v. against distance from the nearest CSG well.
Light blue points show individual data points, while P10/P50/P90 values based on 50m distance bins are shown as darker blue lines.

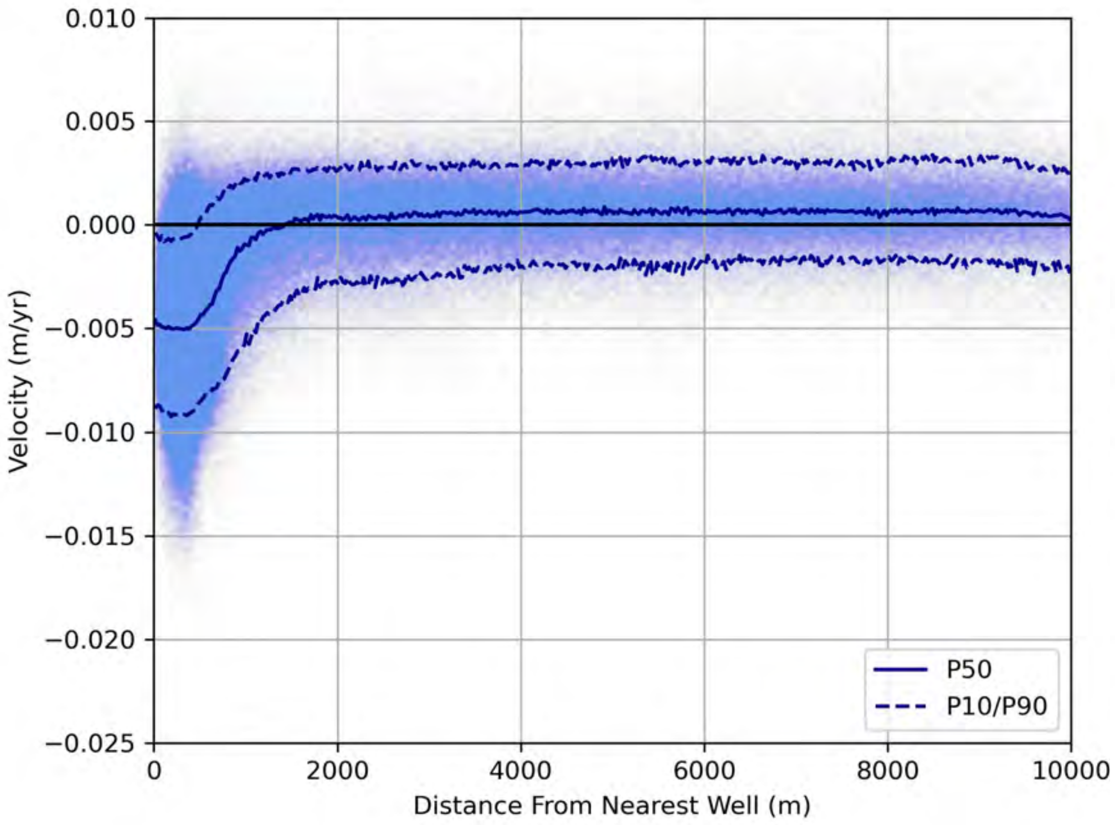
Sarah’s dataset – Condamine area

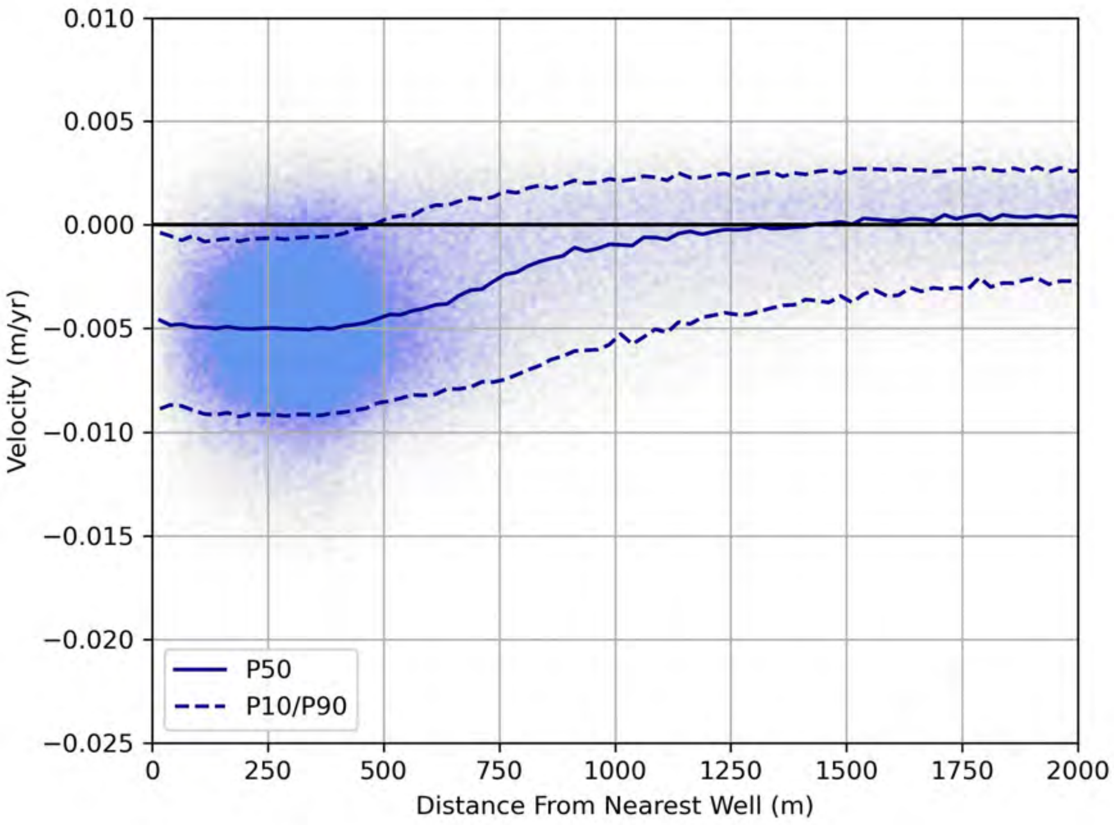


Sarah's dataset – Condamine area

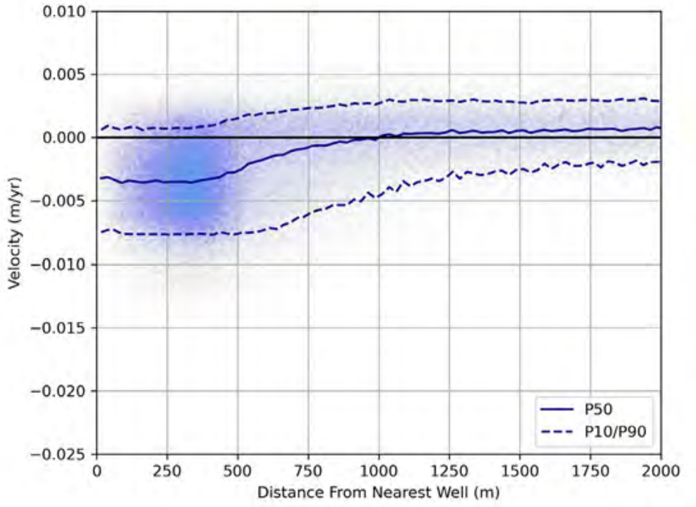
- The number of points is most dense around 350m because:
  - Area (and number of points) increases more at greater distance from a well, but…
  - Once you get ~350m away, you quite often move to being closer to a neighbouring well, so the distance is <350m again

Same patterns – so confirmation of results from commercial data





Observations raise a question



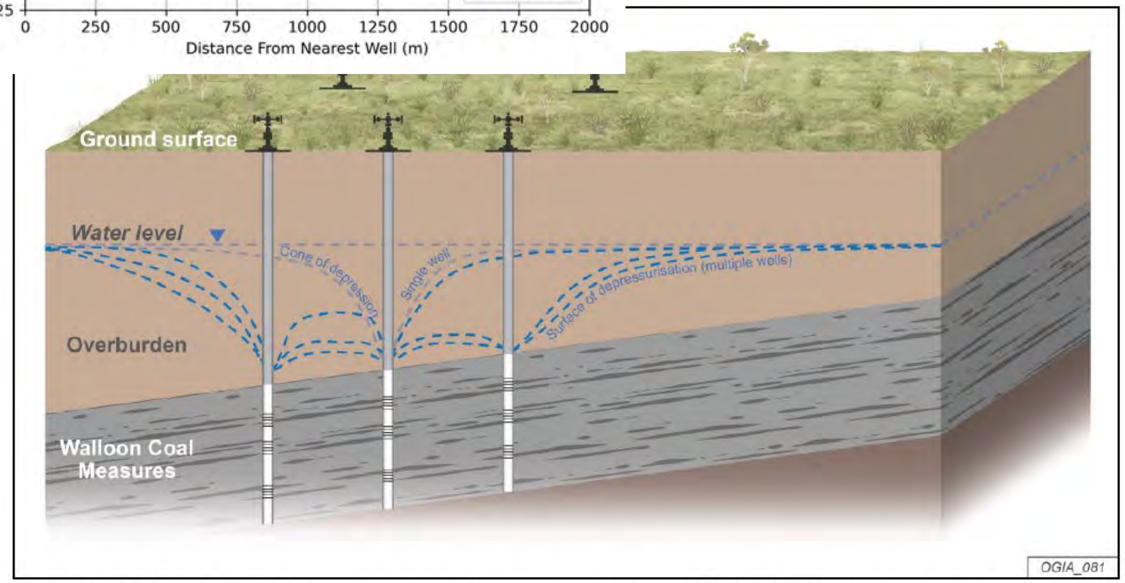


Figure 7-2: Schematic showing the interference and resulting depressurisation within and outside a CSG field

TRE Altamira and Sarah's datasets from both casual observation and detailed analysis both show:

- Little or no evidence of subsidence 'depressions' around producing wells
- That the influence of CSG wells on surface movement signals diminished to background at 1 to 2 km around producing fields.

So why don't we see surface 'depressions' around producing wells? Is it:

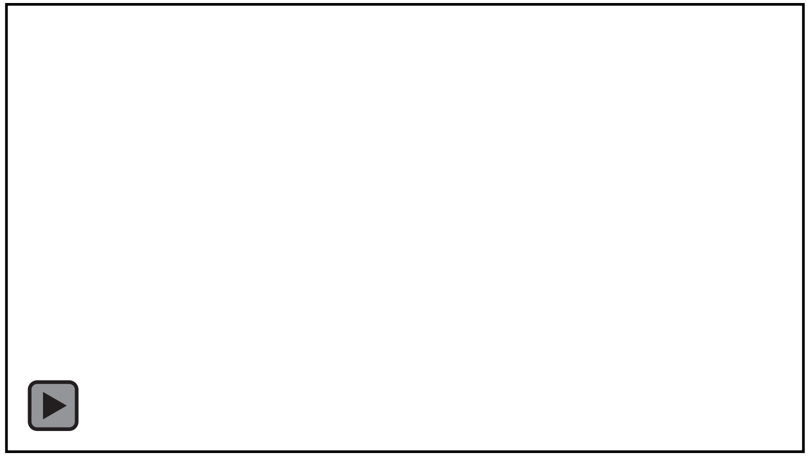
- Coal body size
- Coal body connections
- Mechanical bridging

OGIA, UWIR 2021, 7.2

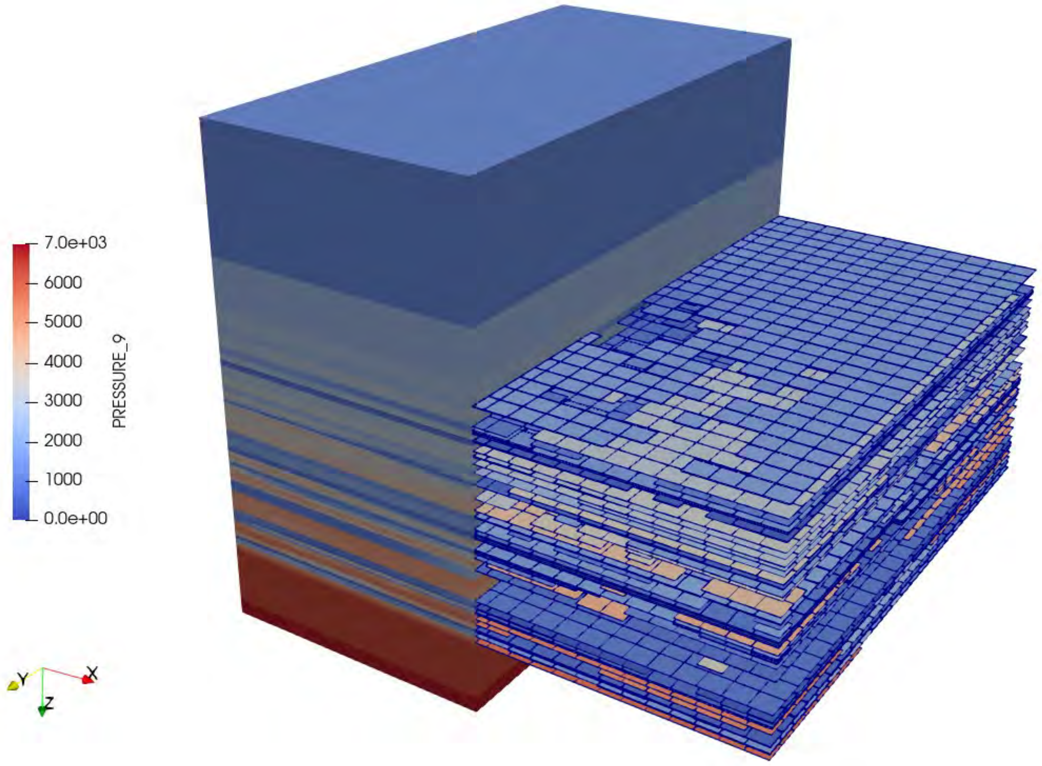
1D Calculation of Subsidence from Pressure Field

- Can we gain a useful estimate of subsidence from the pressure drop and material type alone?
  - Further, can we simplify the geometry on the right to understand the location and order of magnitude of subsidence?
- Take the reservoir compressibility and compaction as:

$$c_M = \frac{(1+\nu)(1-2\nu)}{(1-\nu)E}, \qquad \delta = c_M h \Delta p$$



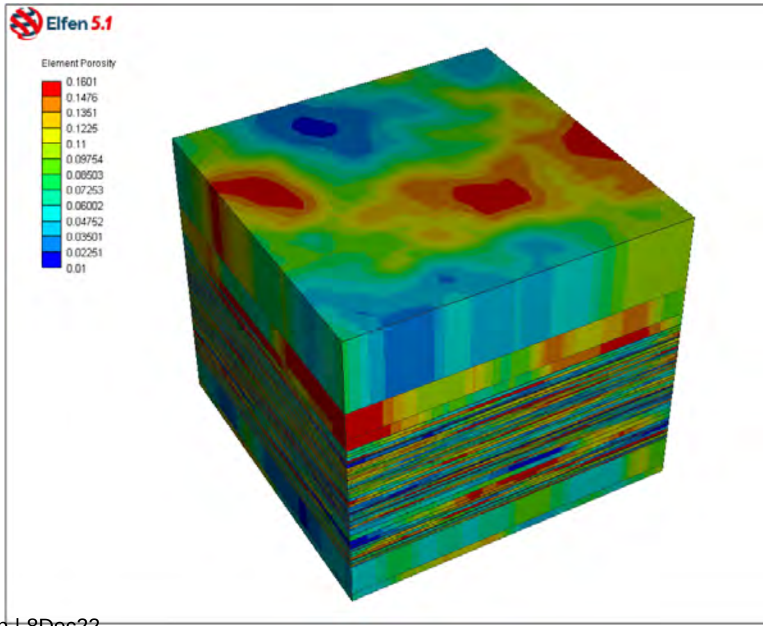
Collapsed data shown over time of depletion giving predicted locations impacted and order of cm's subsidence



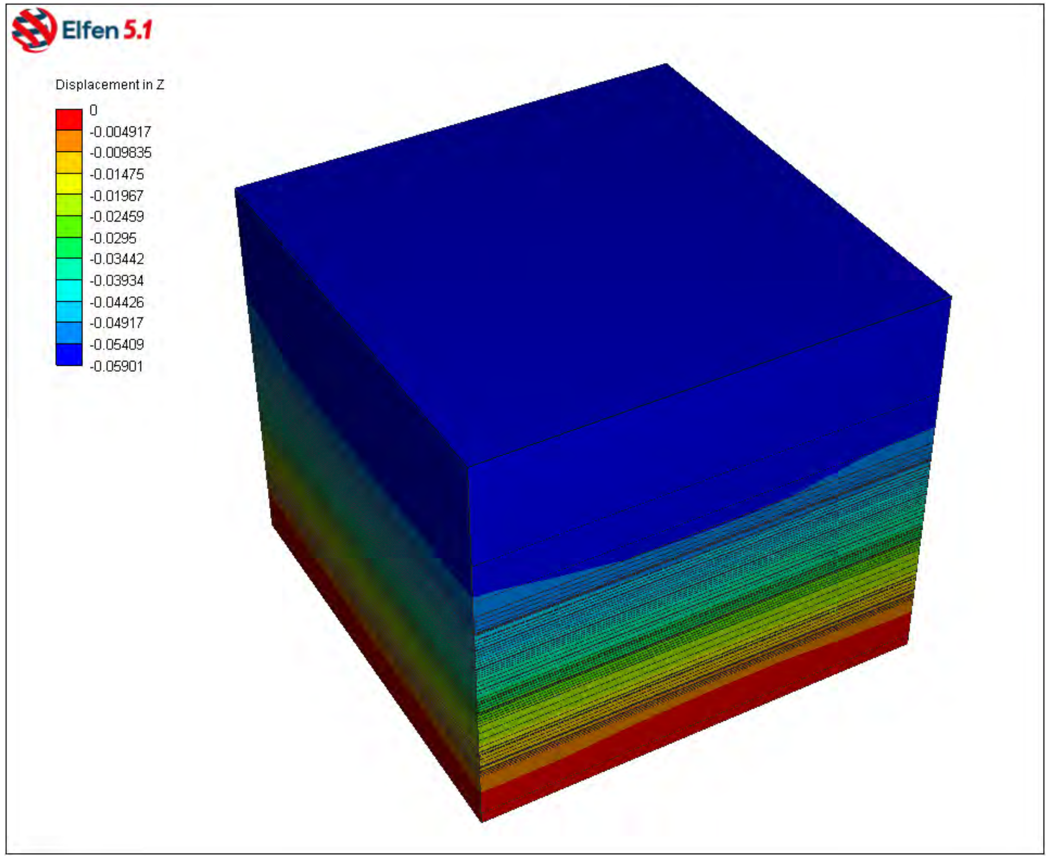
Collapsed data shown over time of depletion giving predicted locations impacted and order of cm's subsidence

3D Geomechanics: Increased Scenario Complexity

- Import spatial porosity, but simplify material types i.e. mono-material with variation induced by spatial state (i.e. neglecting specific behaviour of coals)
- Reservoir simulator to extract 10 year pressure history
- FEM simulation to predict subsidence behaviour through each geological layer and ultimately at the surface



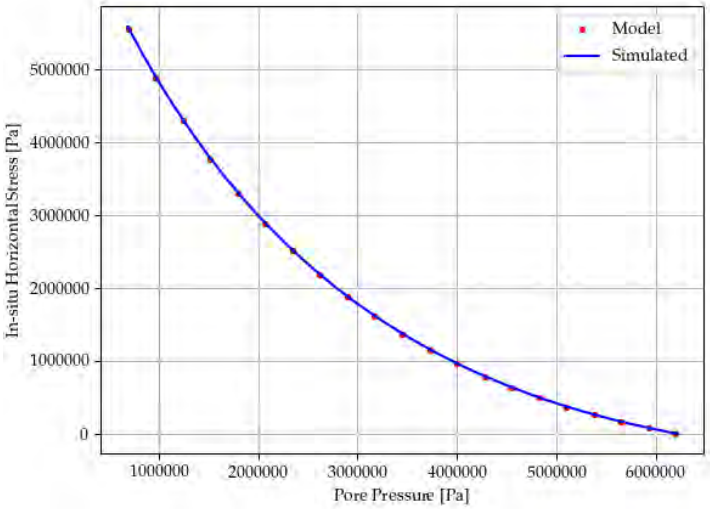
Imported porosity in the 3D model extracted from a reservoir simulator



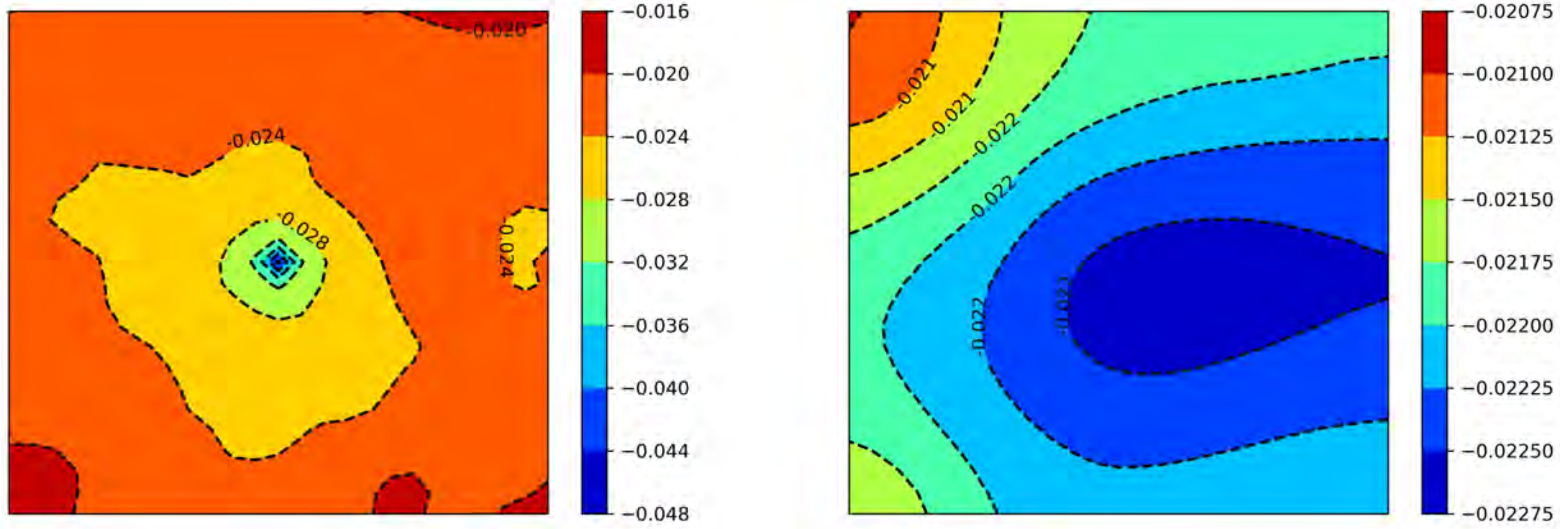
Subsidence on the order of cm predicted from the pressure history of a reservoir simulator

3D Compaction and Subsidence

- Shear resistance and bridging are important mechanisms
- Further coupling of the geomechanical and reservoir simulators?



The relationship between effective horizontal stress and pore pressure in a shrinking coal under uniaxial strain conditions

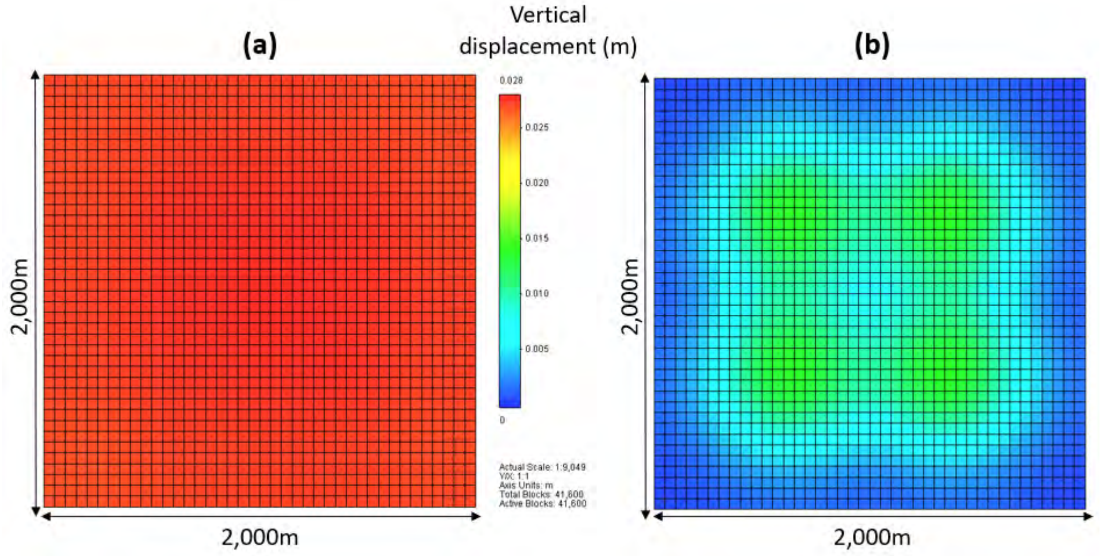


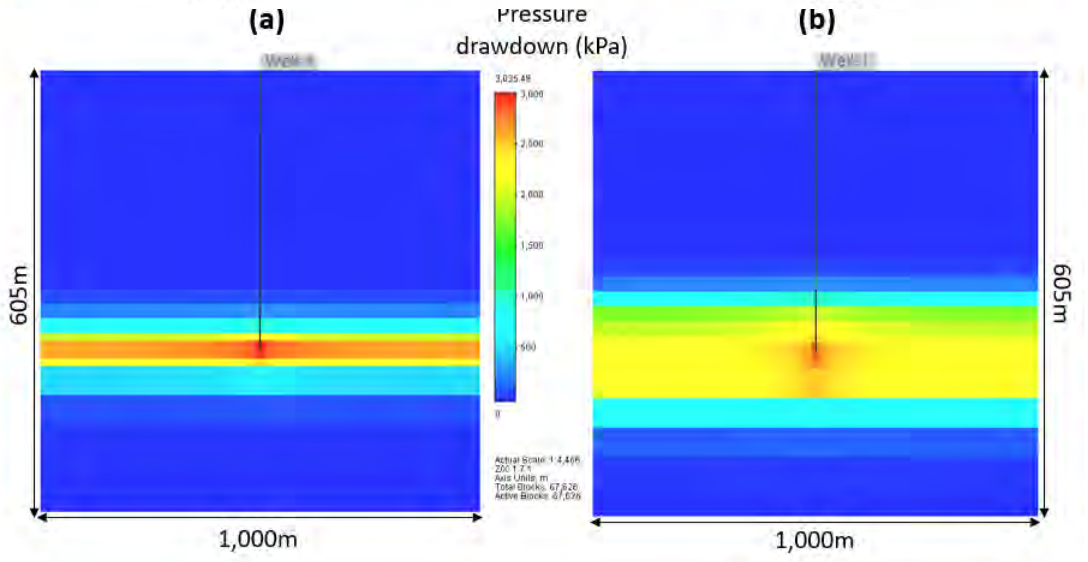
Preliminary predictions of subsidence for the same well using (left) the summation of 1D compressibility and (right) 3D geomechanical modelling

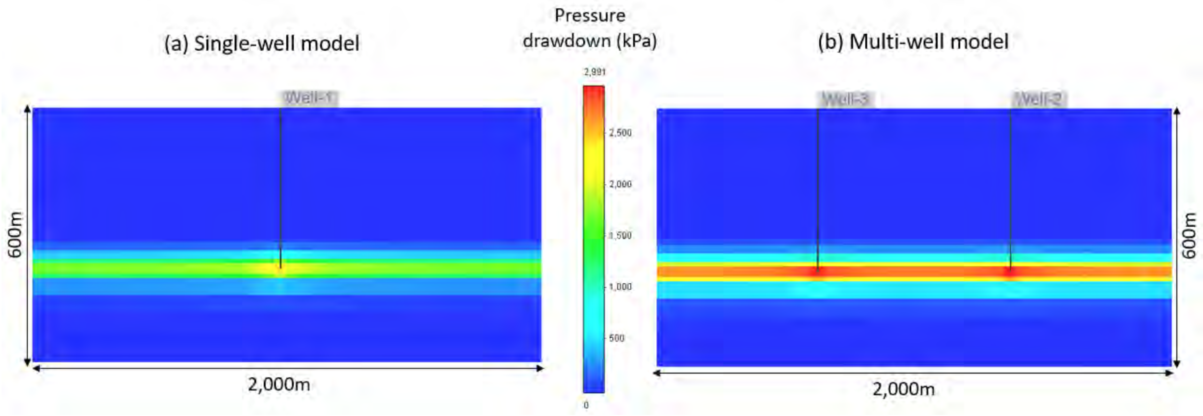
What are the main controls of our surface observations? Geology, reservoir, geomechanics or combinations

Using one-way coupled reservoir – geomechanical simulations we have explored:

- Effects of Coal Permeability
- Effects of Bounding Rock Permeability
- Effects of Overburden Stiffness
- Effects of Seam Depth
- Effects of Well Density
- Effects of Coal Connectivity







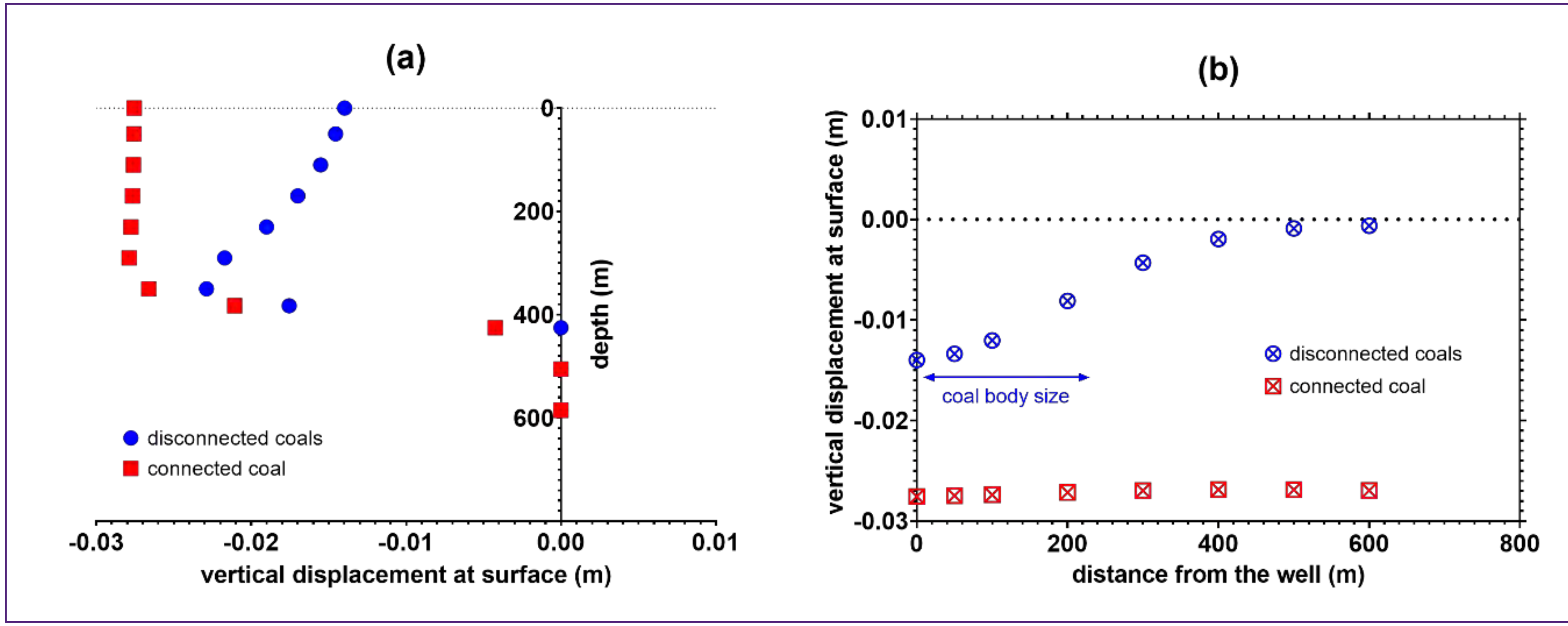
What are the main controls of our surface observations? Geology, reservoir, geomechanics or combinations

Using one-way coupled reservoir – geomechanical simulations we have explored:

- Effects of Coal Permeability
- Effects of Bounding Rock Perm
- Effects of Overburden Stiffness
- Effects of Seam Depth
- Effects of Well Density
- Effects of Coal Connectivity

And

- *Initial saturations*
- *Gas contents*
- *Etc…*



Effects of coal connectivity (or lateral heterogeneity) on (a) vertical displacement profile at the well block with depth and on (b) vertical displacement versus distance from the well

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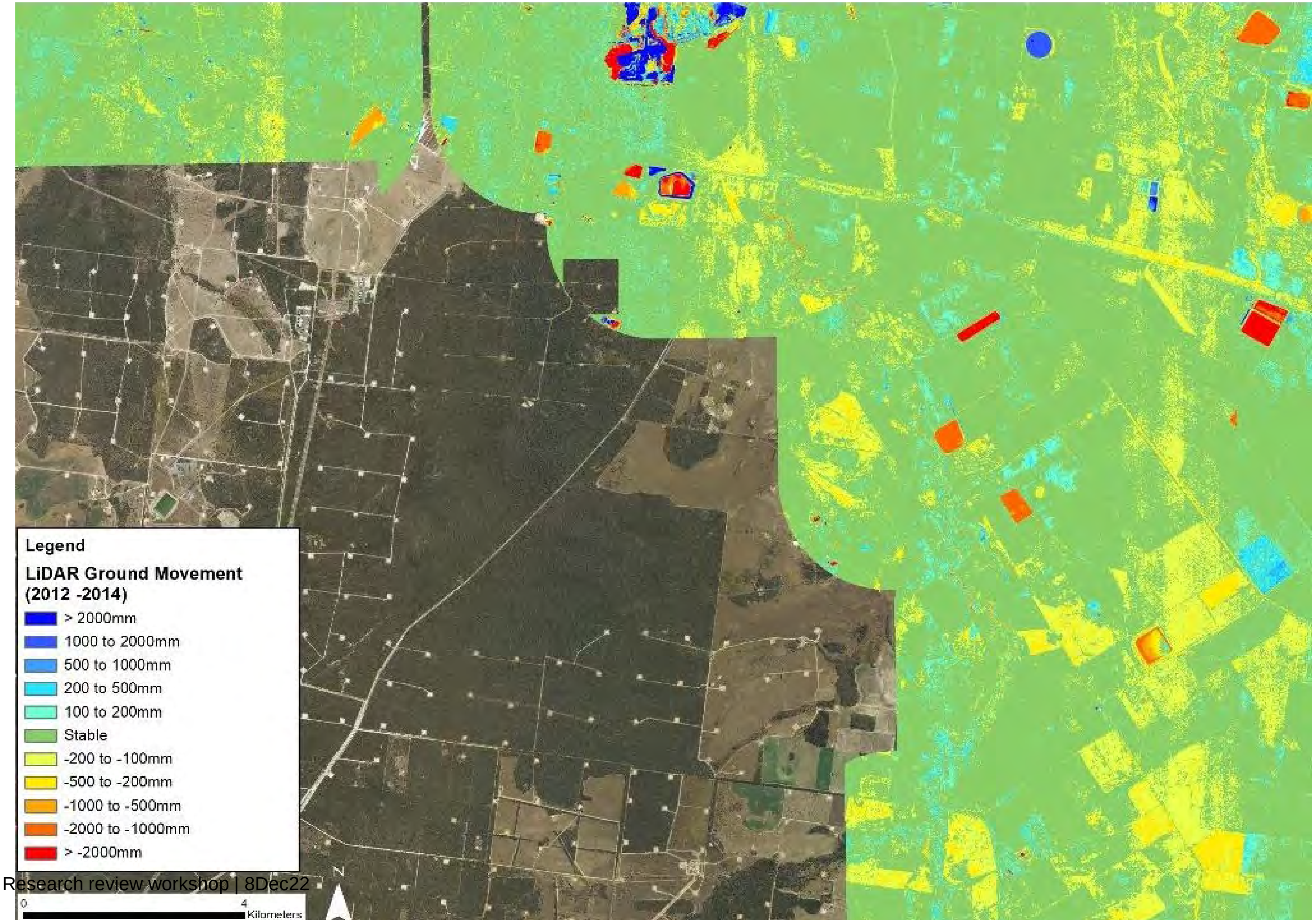
Questions / comments

5. Magnitudes and mechanisms

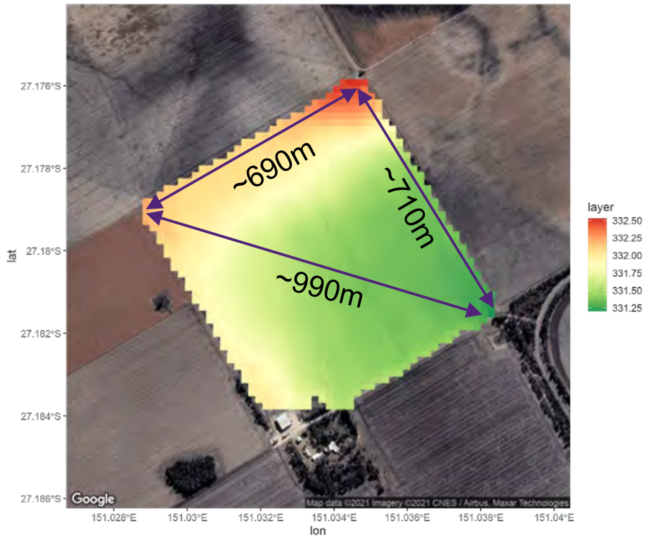
6. Discussion

Other monitoring methods: LiDAR

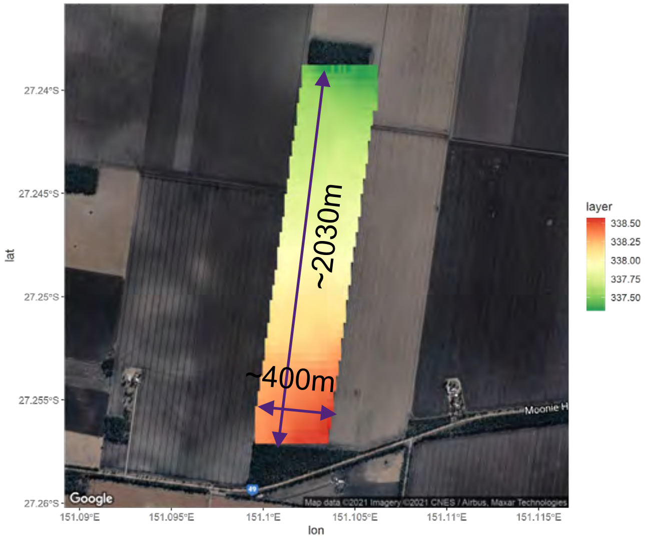


Other monitoring methods: RTK (Real-Time Kinematic)

Gradient, 0.75/990 ~ 0.0007

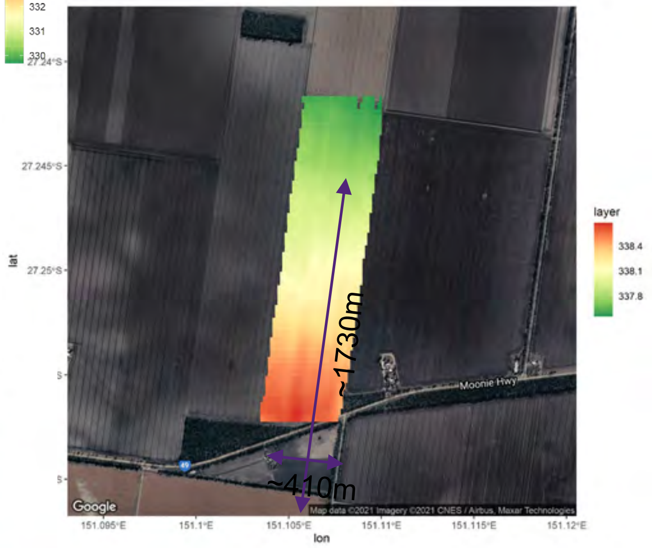


Gradient, 1.25/2030 ~ 0.0006

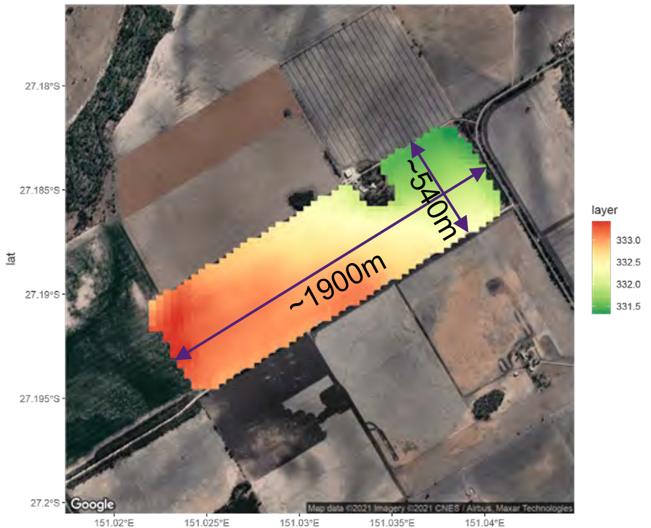


Gradient, 2.5/1030 ~ 0.002

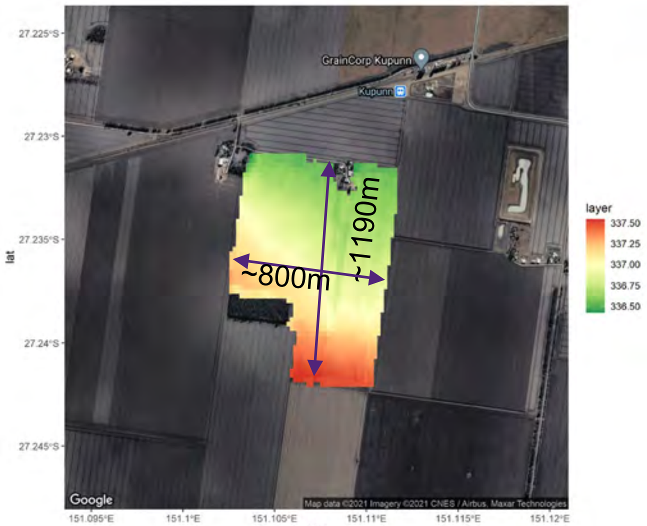
Max gradient, 1.2/1730 ~ 0.0007



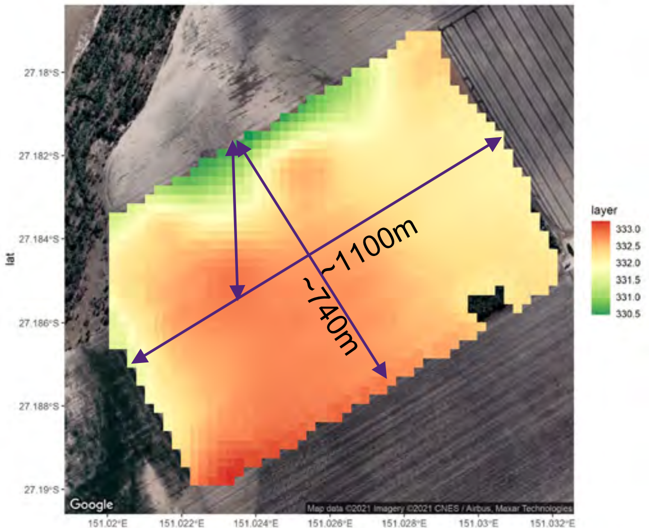
Gradient, 2.25/1900 ~ 0.0012



Gradient, 1.1/1190 ~ 0.0009



Gradient, 1.5/1100 ~ 0.0013



6. Discussion

Questions:

Are there learnings from what you've seen today that may assist in communicating surface movement monitoring techniques and results to stakeholders?

Questions:

Companies and OGIA/GFCQ have drivers such as monitoring/reporting, prediction and landholder engagement, that are different to UQ-CNG (beyond research).

How else can our research complement and help?

Questions:

Other methods monitoring methods are being deployed, such as LiDAR and ground base RTK monitoring, each with their own advantages and challenges.

What possibilities are there from further comparison and/or integration of results from different methods?

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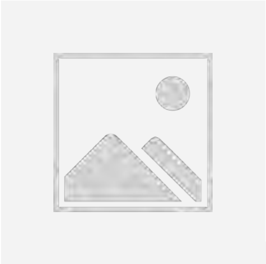
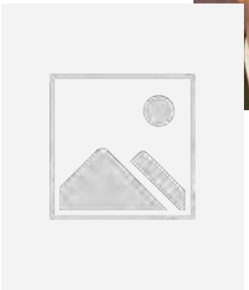
2. UQ Centre for Natural Gas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Thank you

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