Mapping of Subsidence in Kuruman and Danielskuil East Areas for a Period of 44 Days

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Presentation Outline

- Introduction
- Description of Study Area, Data and Software Used
- Procedure of SAR Interferometry
- Data Processing & Analysis using InSAR (Methodology)
- Results obtained (Deformation & Displacement)
- Checking of results with Geology and Google Earth Pro
- Verification of some results in the field
- Conclusions

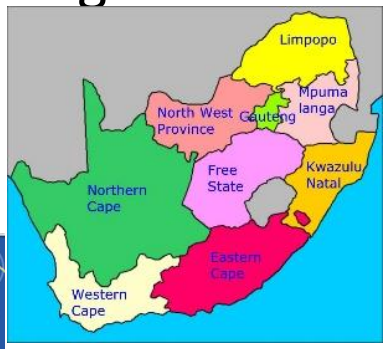
Introduction

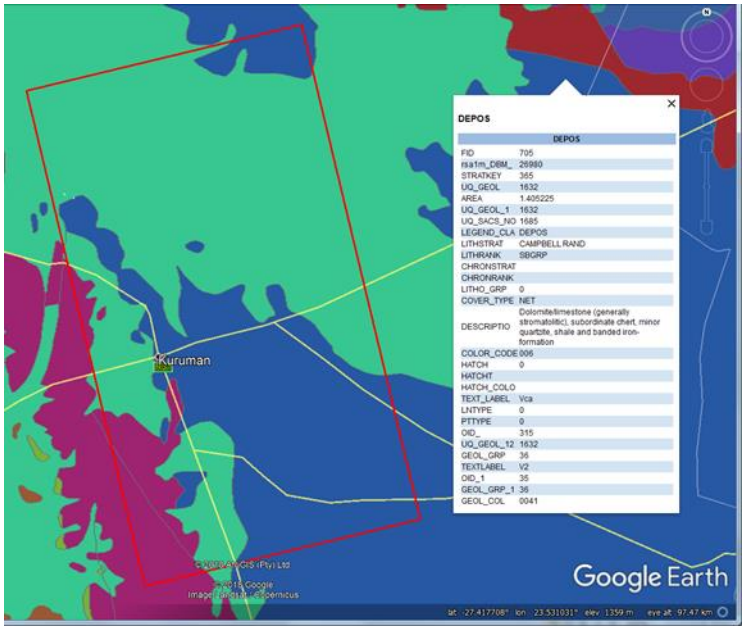
- **Radar Interferometry** involving use of Synthetic Aperture Radar (SAR) images acquired by satellites has widely been applied to study the surface deformation and displacements / subsidence.
- Presented here are the results obtained from radar interferometry using TerraSAR-X data for identifying surface deformation and vertical displacement in dolomitic areas of Kuruman and Danielskuil east areas using the **D**ifferential **In**terferometric **S**ynthetic **A**perture **R**adar (DInSAR).

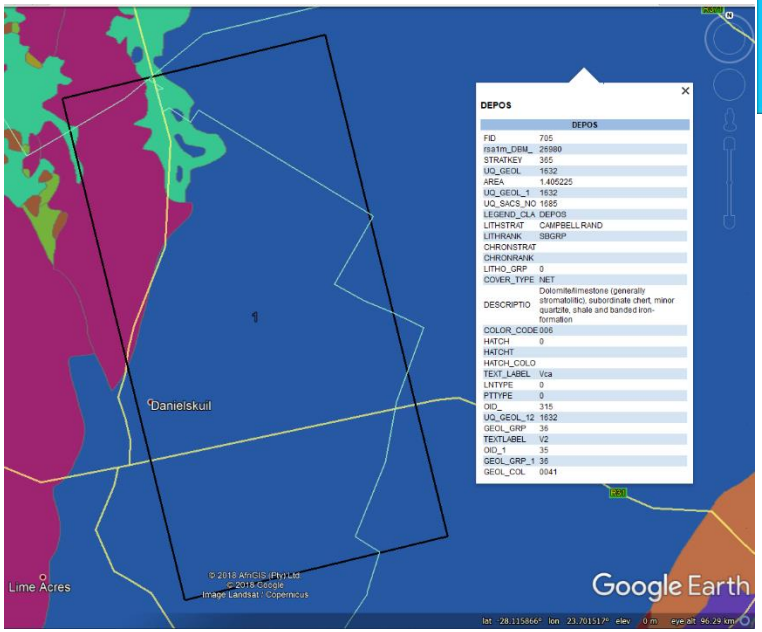
Study Area, Data and Software Used

The study area is covering Kuruman and Danielskuil east regions of Northern Cape Province underlain by dolomite.

The dolomites are notorious for the occurrence of sinkholes which can be triggered by changes in the ground water regime.







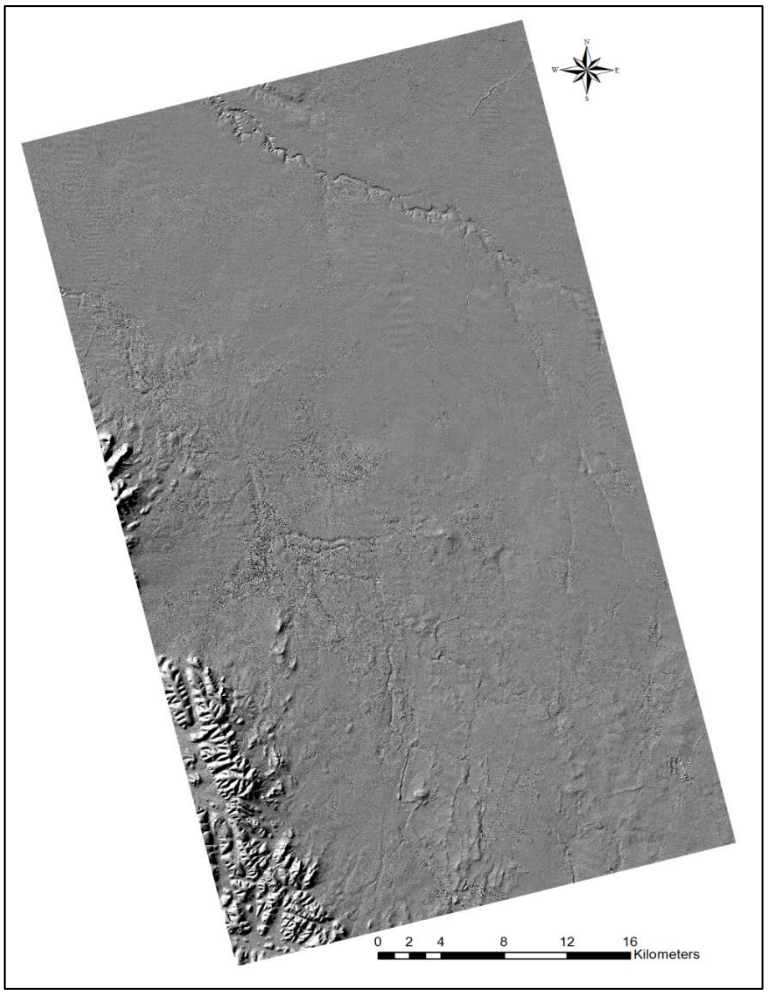
Characterised by dolomitic rock (Campbel Rand Group), banded iron-formation, superficial deposits etc.

Data Used: TerraSAR-X data (3m, Strip Map imaging mode) covering Kuruman and Danielskuil east acquired on 7 October and 20 November 2018, 2m DEM, 1 Million and Quarter Million Geology.

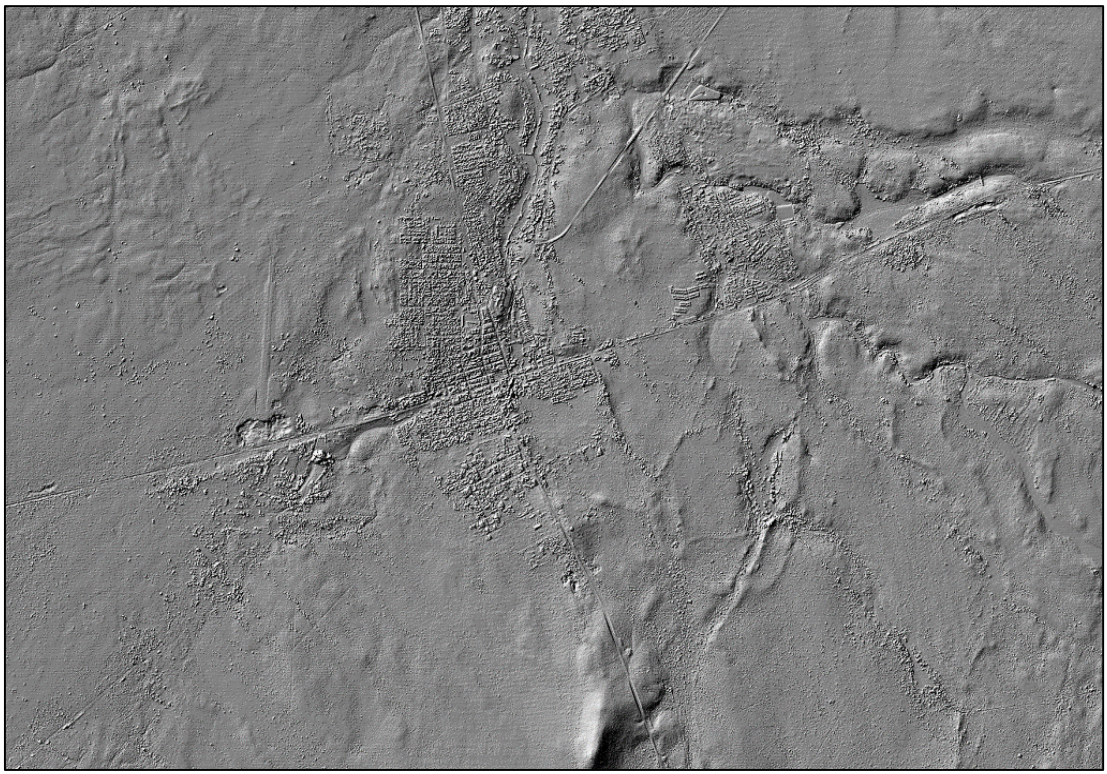
The software used are: Geomatica INSAR, Google Earth Pro and ArcGIS.

DEM Used

- The very high resolution (2m) DEM known as DEMSA2 provided by the Geosmart Space (Pty) Ltd was used.



2m DEM covering Kuruman TerraSAR-X scene



Zoomed DEM covering Kuruman urban area

Procedure of SAR Interferometry

A general InSAR/DINSAR procedure for surface deformation / displacement mapping includes the following steps:

1. the acquisition of an interferometric image pair;
2. the precise image registration;
3. the calculation of the interferogram;
4. Topographic phase removal, phase filtering,
5. Phase Unwrapping
6. Phase to Displacement Conversion and Geocoding (orthorectification)

The phase difference Δφ in an interferogram can have contributions from five different sources:

$$\Delta\varphi = \Delta\varphi_{flat} + \Delta\varphi_{elevation} + \Delta\varphi_{displacement} + \Delta\varphi_{atmosphere} + \Delta\varphi_{noise}$$

$$-\frac{4\pi}{\lambda}\frac{B_n s}{R\tan\theta}$$

$$-\frac{\Delta q}{\sin\theta}\cdot\frac{B_n}{R_0}\cdot\frac{4\pi}{\lambda}$$

$$+\frac{4\pi}{\lambda}d$$

The two pass DInSAR technique available in Geomatica InSAR modules was applied on SAR data in order to identify the location and amplitude of surface deformation or ground displacement.

Methodology: Interferometric Analysis Using PCI Geomatica InSAR Module

The Interferometric SAR (InSAR) package can be used to generate topographic products to characterize digital surface models (DSMs) or deformation products which identify subtle changes in surface elevation due to land subsidence.

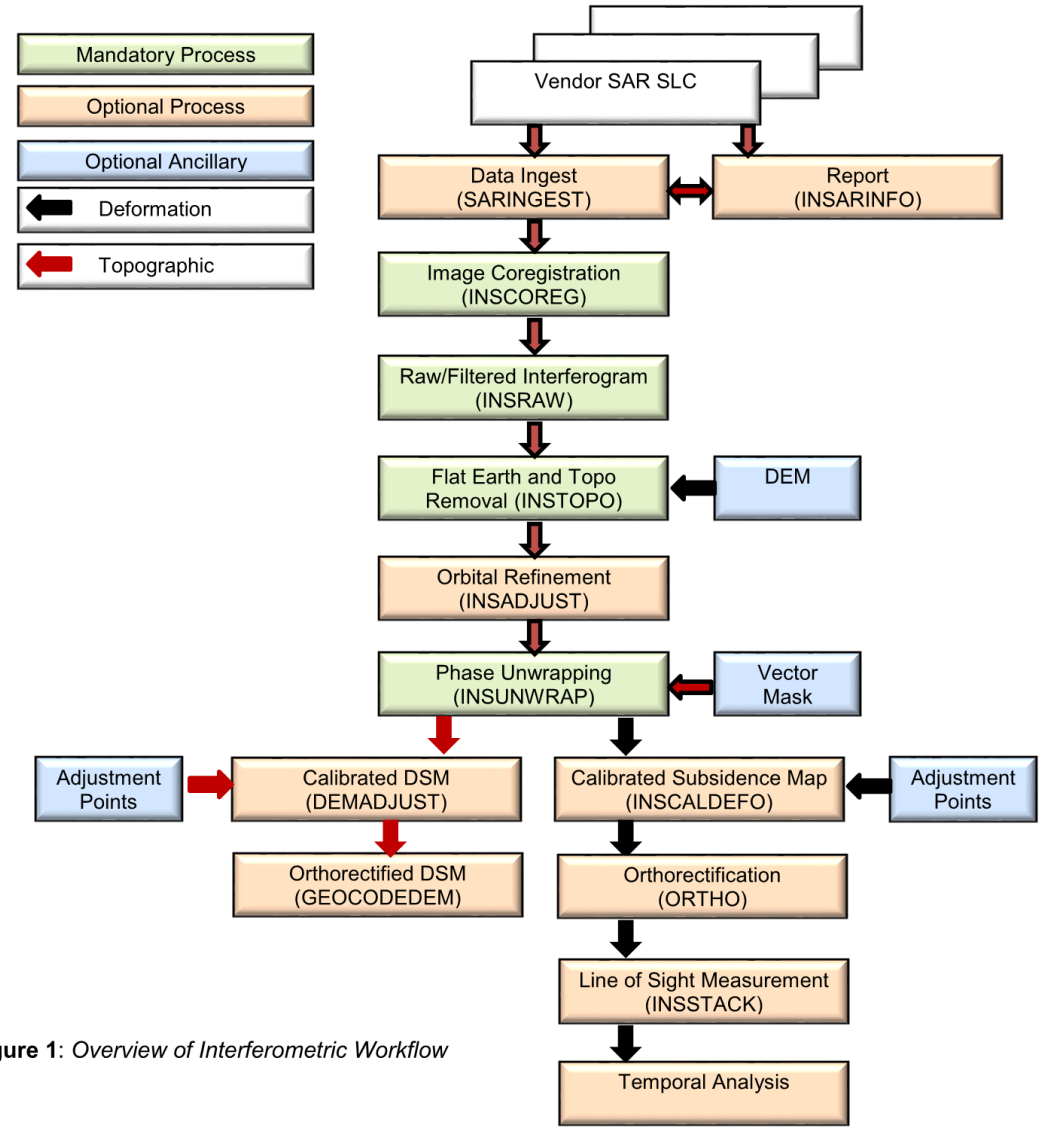
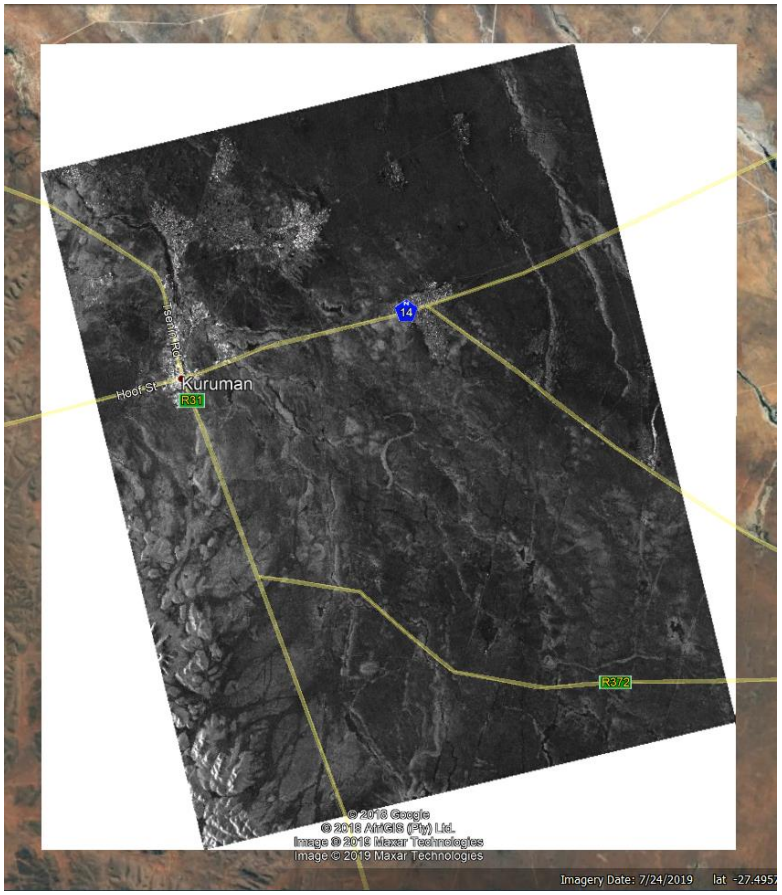


Figure 1: *Overview of Interferometric Workflow*

Automated Interferometric Analysis of TerraSAR-X Data Using InSAR Module

InSAR Deformation Mapping

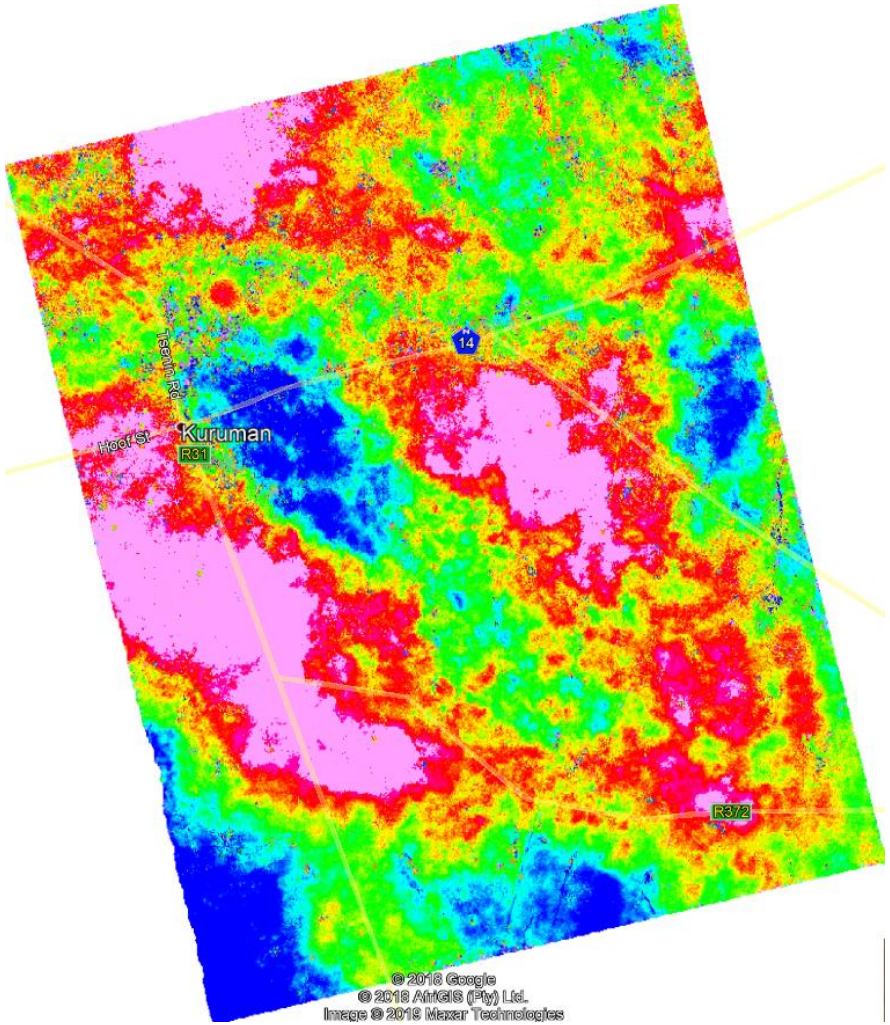
- A Python script was generated by PCI in 2017 for the InSAR Deformation Mapping workflow.
- It allows to specify coordinates for sub-setting ingested scenes.
- It was further modified in 2018 for filtering with a smaller window size and SNAPHU unwrapping using 2018 InSAR module.

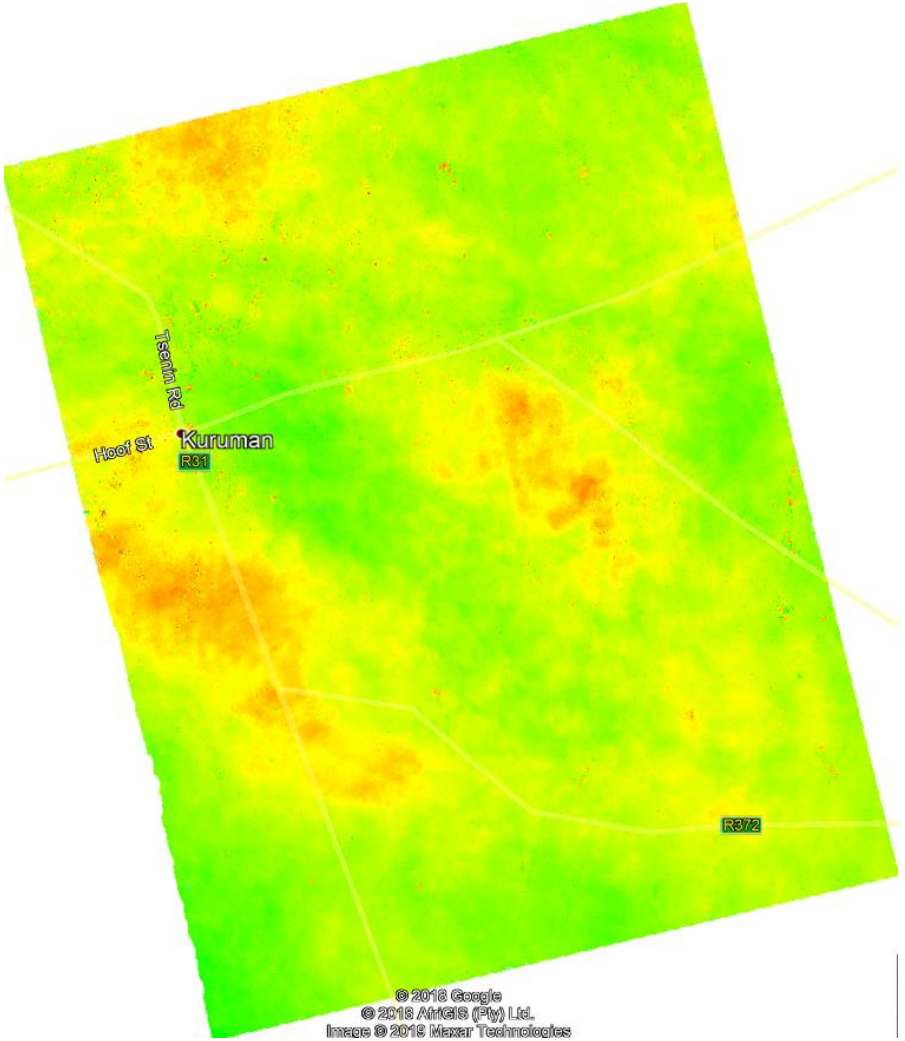


Extent of a subset of TerraSAR-X data (20 Nov 2018) of Kuruman covering the dolomitic region

Results of Displacement/Subsidence

Kuruman Vertical displacement for 44 days: 7 Oct – 20 Nov 2018

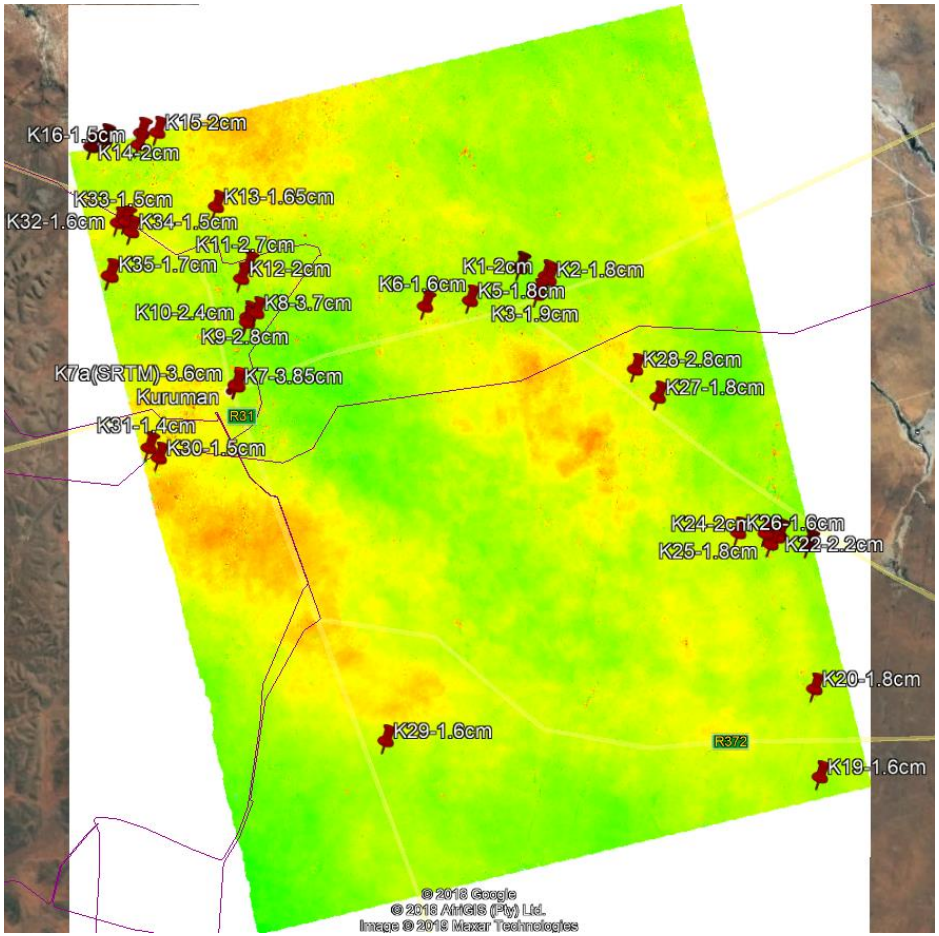


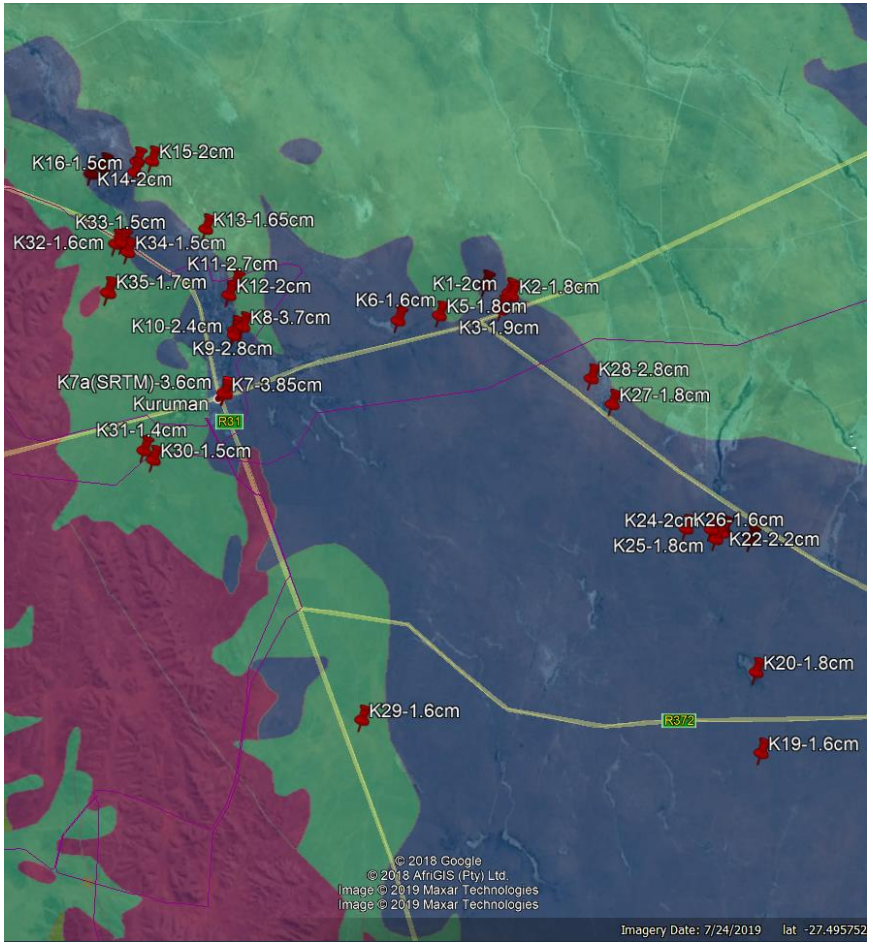


The surface deformation for the Kuruman region ranged from -3.85 to 3.2cm.

Results of Displacement/Subsidence

Vertical displacement of Kuruman for 44 days: 7 Oct – 20 Nov 2018

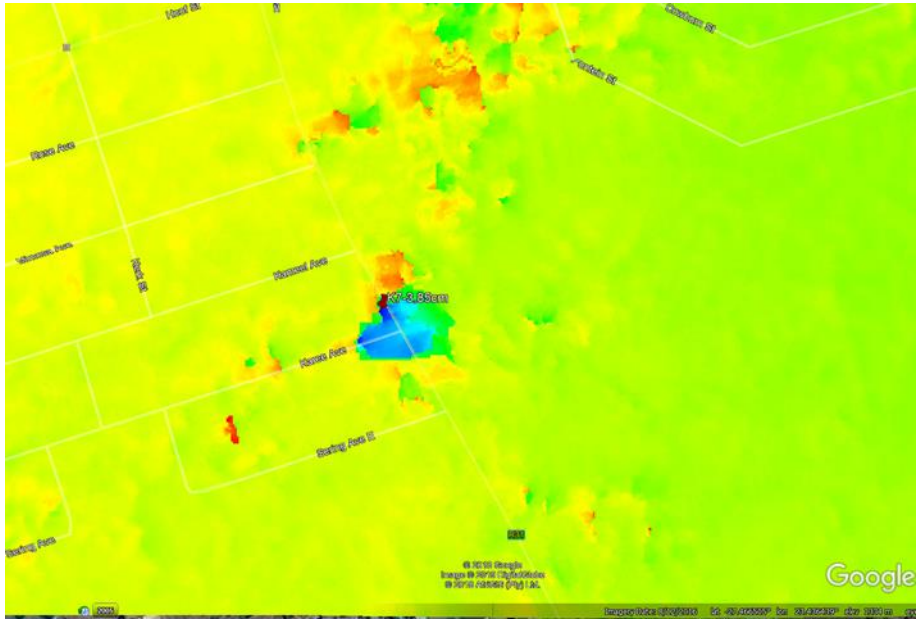




The surface deformation for the Kuruman region ranged from -3.85 to 3.2cm.

Thirty-five spots of major subsidence were identified from displacement layer for Kuruman. Eighteen spots of Kuruman subset were visited in February 2019.

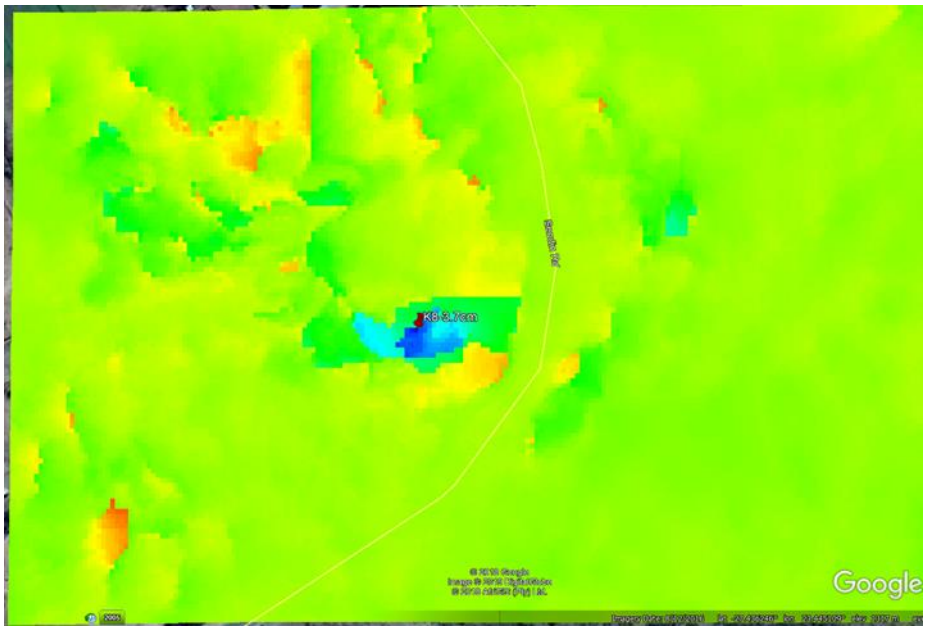
Areas of Subsidence Visited: Kuruman



3.85cm subsidence along the road of Kuruman area (Spot K7 at -27.466550°,-27.466550°)

Field photos of 3.85cm subsidence Spot K7 along the road of Kuruman area.

Areas of Subsidence Visited: Kuruman



3.7cm subsidence in a residential area of Kuruman (Spot K8 at -27.436319°, 23.444704°.)

Field photos of 3.7cm subsidence Spot K8 in a residential plot of Kuruman area.

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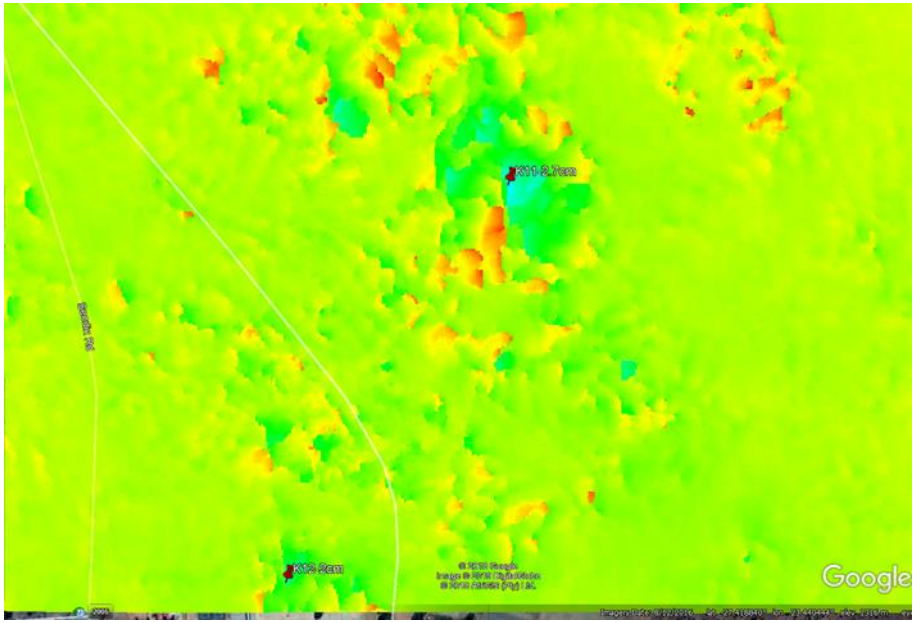
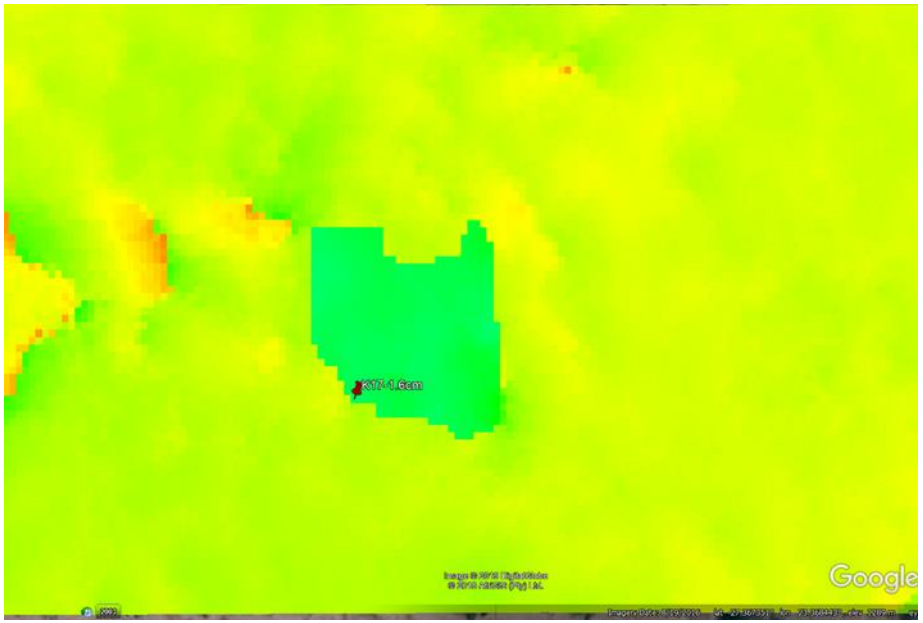
Areas of Subsidence Visited: Kuruman



2.7cm & 2cm subsidence - farm & playground of Kuruman (Spots K11 and K12)

Field photos of 2.7cm & 2cm subsidence (-27.417331°, 23.440715°; -27.422205°, 23.437646°).

Areas of Subsidence Visited: Kuruman

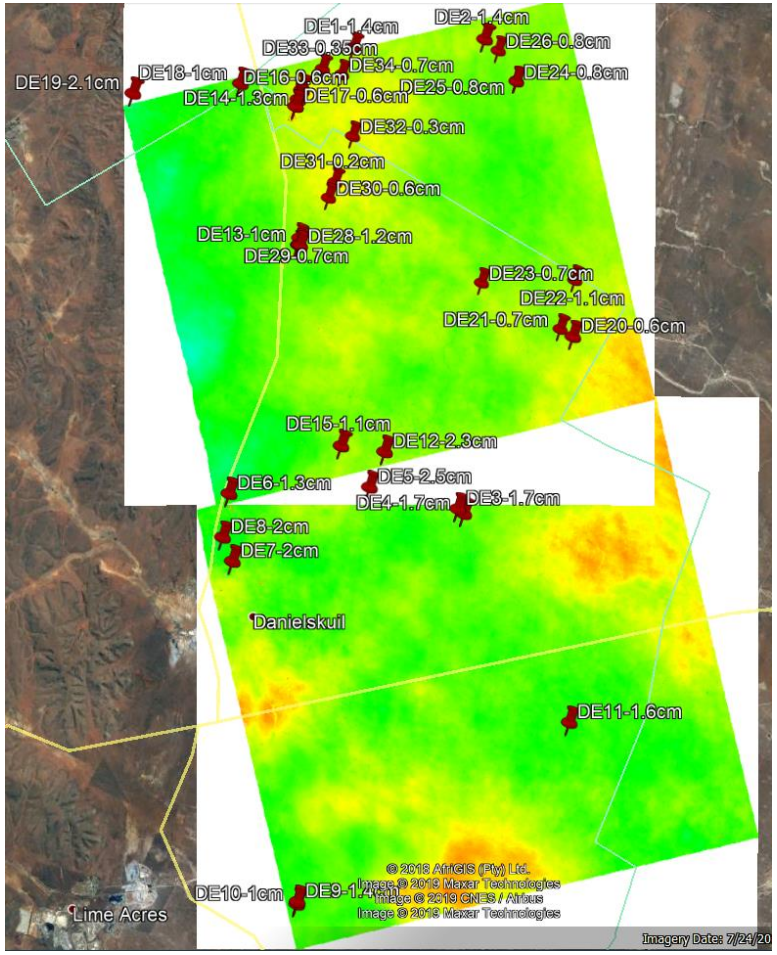


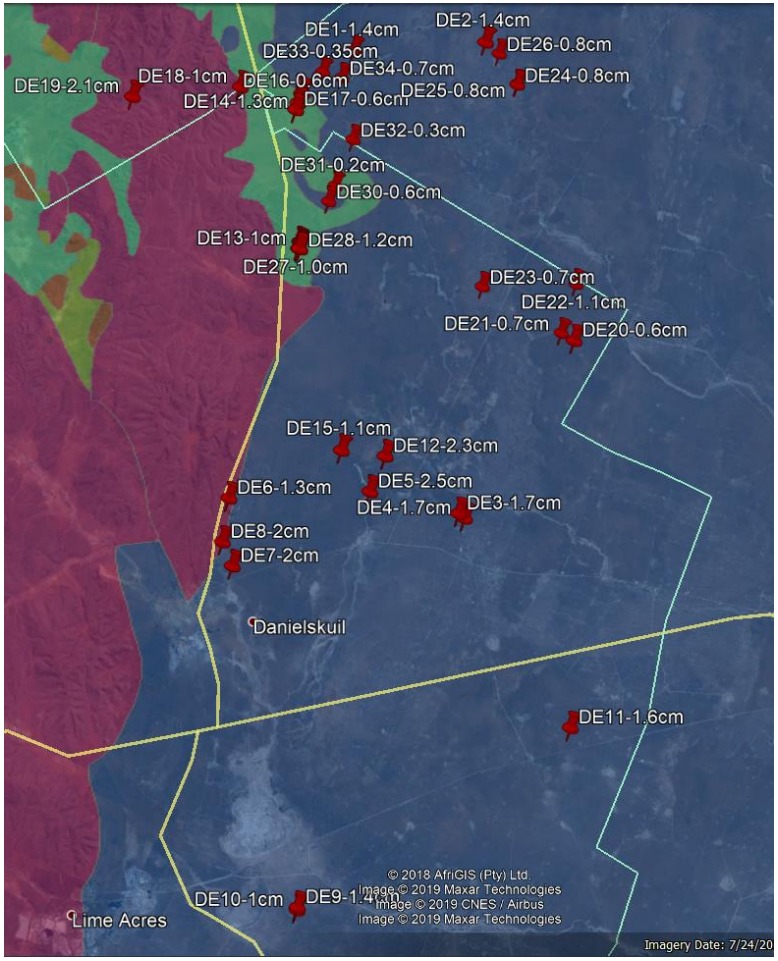
1.6cm subsidence in open area of Kuruman (Spot K17 at -27.367622°, 23.367970°)

Field photos of 1.6cm subsidence Spot K17 and its drone photo (far view).

Results of Displacement/Subsidence

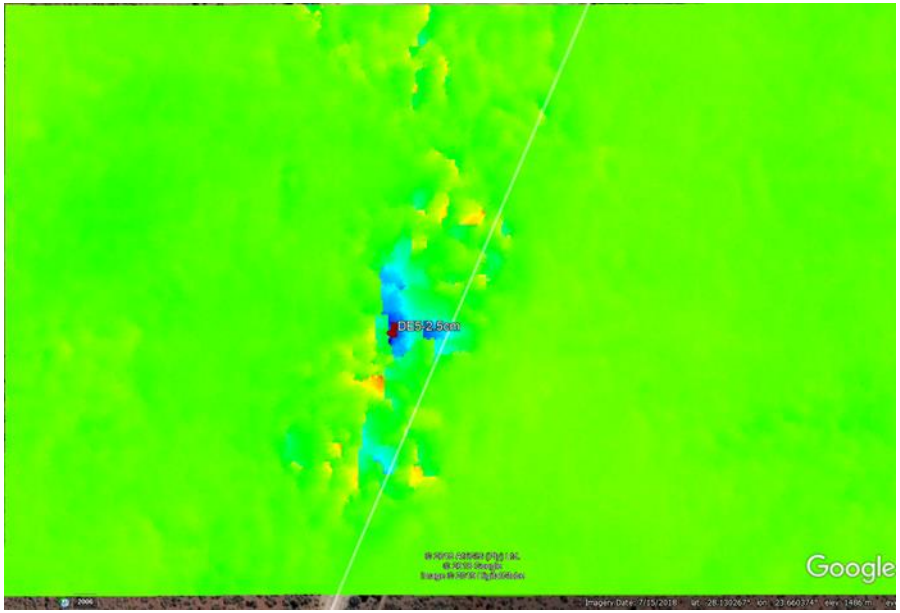
Danielskuil Vertical displacement for 44 days: 7 Oct – 20 Nov 2018





The surface deformation for the Danielskuil East subset 1 ranged from -2.29 to 3.99cm and in subset 2 it ranged from -2.47 to 2.93cm. 24 spots of major subsidence were identified for the subset 1 and similarly, 10 spots of major subsidence for the subset 2. Twenty nine spots of Danielskuil east subsets were visited in February 2019.

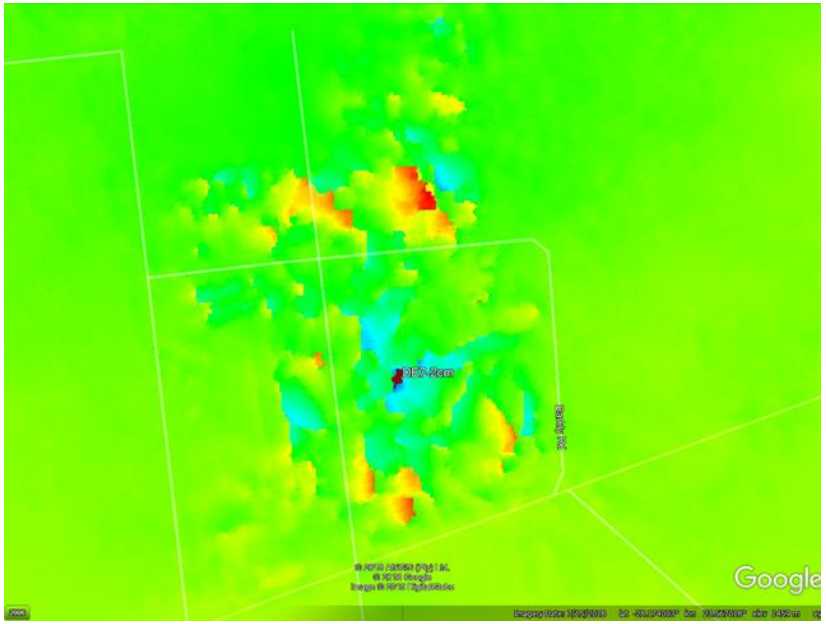
Areas of Subsidence Visited: Danielskuil



2.5cm subsidence in a farm of Danielskuil (Spot DE5-2.5cm at -28.130715°, 23.659400°)

Field photos of 2.5cm subsidence in a farm (Spot DE5-2.5cm).

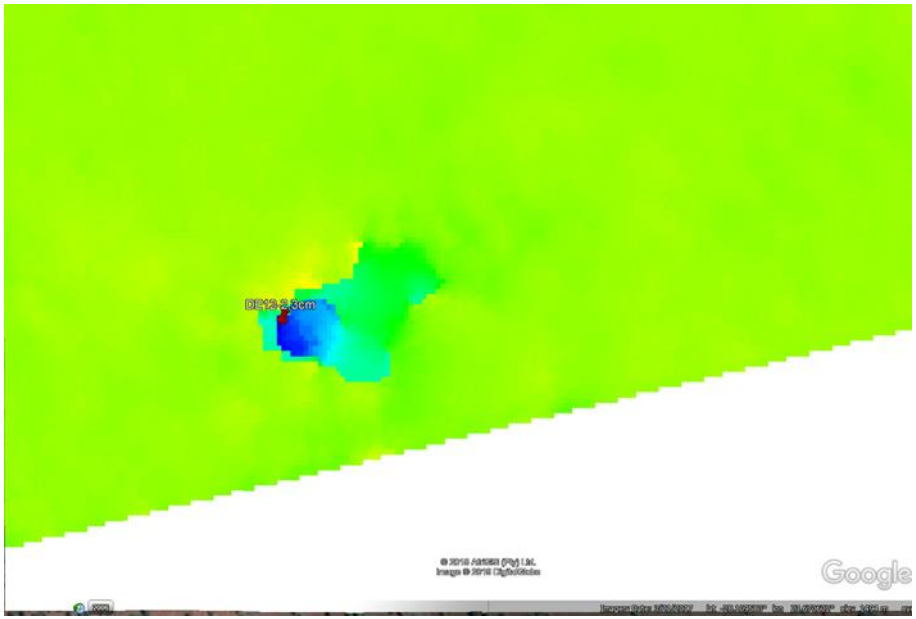
Areas of Subsidence Visited: Danielskuil



2cm subsidence in a farm of Danielskuil (Spot DE7-2cm at -28.130715°, 23.659400°)

Field photos of 2cm subsidence in a farm (Spot DE7-2cm).

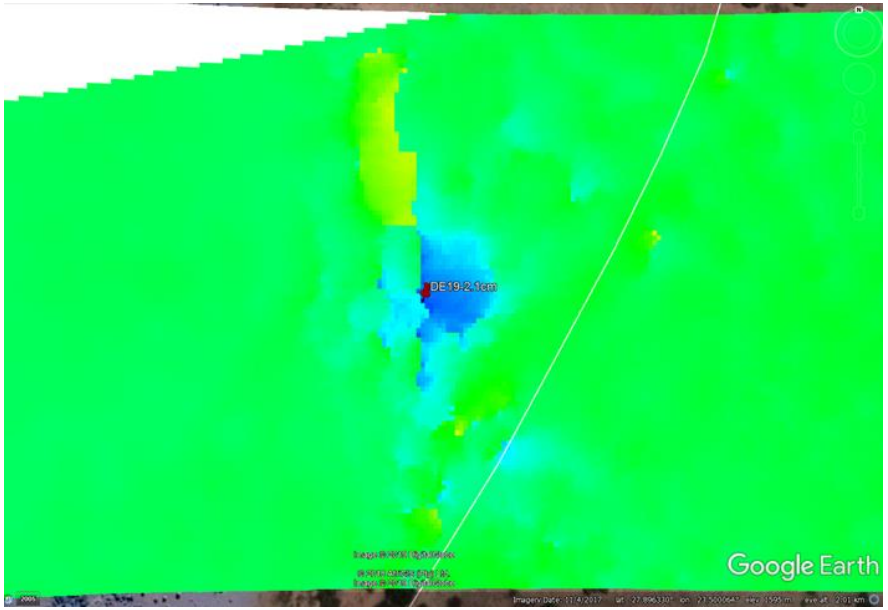
Areas of Subsidence Visited: Danielskuil



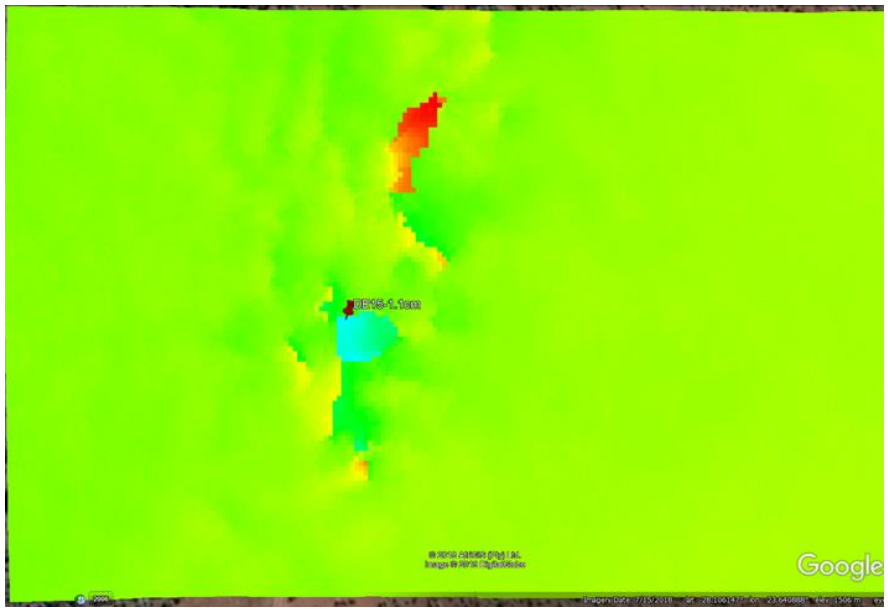
2.3cm subsidence in an open land of Danielskuil (Spot DE12-2.3cm at -28.130715°, 23.659400°)

Field photos of 2.3cm subsidence in an open land (Spot DE12-2.3cm).

Remote Subsidence Spots: Danielskuil



2.1cm subsidence in a open land of Danielskuil (Spot DE19-2.1cm at -27.896318°, 23.500157°)



1.1cm subsidence in a open land of Danielskuil (Spot DE15-1.1cm at -28.106207°, 23.640248°)

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Conclusions

- This study could illustrate the usefulness of DInSAR technique using TerraSAR-X data in mapping surface deformation and subsidence possibly associated with sinkhole development in dolomitic areas of Kuruman and Danielskuil east regions.
- All the sites visited indicated some low lying characteristics either possibly due to subsidence through sinkhole development underneath or existence of some doline features.
- Some locations of subsidence seen are in the low-lying pan areas. A significant number of visited subsidence spots were in the agricultural farming areas utilizing water for irrigation purposes.
- To detect sinkhole related subsidence, continuous monitoring using interferometric analysis using SAR data acquired at least on a 6 weeks interval is needed. As SAR data is costly, its cost is a constraint to monitor and predict any sinkhole development.
- The results of all these analysis should be used with some caution as change of vegetation over time and agricultural practices causes slight elevation differences. Ground verification is crucial to confirm results.

Thank you