Radar Satellites: new technologies, applications, and a plethora of data

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Summary

The recent launches of synthetic aperture radar satellites into low earth orbit has started a new wave of data collection which will revolutionise observations of the earth. The satellites are equipped to image in the C, L and X bands which can see through clouds and image 24 hours a day. From their polar orbits it is also possible to repeat image on a weekly and even daily cycle. This huge about of data can now be downloaded to earth stations and processed quickly using enhanced computational power, so that results are quickly available at a reasonable cost. Examples of use include almost real time monitoring of ground movement, history matching of ground movement and the ability to monitor oil field production and CCUS activity. The radar imaging has become a routine deliverable without the need for specialist programing.

History/current state of SAR/InSAR applications

In 1995, a volcano was imaged and the ground movement calculated to show changes over time (Massonnet, D.; Briole, P.; and Arnaud, A. 1995). The ground movement was mapped and the resulting image published on the cover of Nature. The first mapping of a Canadian production InSitu oilfield was published by Stancliffe, R.P.W., and Van Der Kooij, M.W.A., in 2001, and the technology moved into becoming a more routine activity with the deployment of radar reflectors over fields of interest for the next 20 years. Often thermal producers in Western Canada present a yearly map to the regulator indicating compliance with their licences.

A Synthetic Aperture Radar satellite has a transmitter which sends out radiation commonly in the C, L and X bands and the reflected energy is received by a collector and then downloaded to a ground station. The travel time of the beam is dependent on the distance to the imaged object from the satellite. Synthetic Aperture Radar imaging can now resolve features less than 0.5m2 and the exact position in 3D space makes repeat imaging and the changes in elevation (down to the millimeter) simpler to resolve. This Interferometric Synthetic Aperture Radar (InSAR) dataset is large but now processable on high powered lap top computers using the latest generation software. A further issue has been the gap between repeat imaging making interpretation difficult and coverage over the earth was spotty. The recent launching of satellites has produced much more frequent imaging and new

computer processing techniques to handle the data load. Over 60 commercial and government satellites are now creating images (Rosen, 2021) which can be used for the observation of ground elevation change. An example is the Sentinel 1a and 1b satellites launched by the European Space Agency in 2014 and 2016 respectively (Figure 1) which are presently imaging the globe and creating InSAR map data (Figure 2).

Currently many shallow oilfields are imaged especially when the production process leads to ground elevation change. Examples include CSS production at Bakersfield, California; SAGD in the Athabasca, Alberta and gas production from the Groningen gas field in Holland. Commonly expensive purpose built reflectors were installed and only these points were analysed. However, more recently, any reflectance has been used as source data including buildings, pipelines, and powerlines. Even in remote areas it is now possible to create difference maps highlighting changes between satellite imaging passes.

Future applications

With the advent of many satellites imaging the earth so frequently there are now new potential applications of which are few are discussed below. These include the ability to image new SAGD/CSS wells during start up to determine where the steam is entering the reservoir. This is a critical time for the economics of the wells but is often poorly understood by the operations team. In fact, any well which injects fluids or gases into a reservoir can potentially change the surface elevation over time. A second area of future use is the ability to access historic data over an area of interest and find out what might have changed before there is a production issue. This could include a leak to surface, monitoring a change in production rates and even the successful abandonment of a well. The third application which is presently not being used to its fullest is the monitoring of surface structures over time.

Examples include processing plants above a producing reservoir, pipelines running through steep terrains, pit walls and mine road alterations, reclaimed tailings ponds and the areal interaction between two producing areas. The recent increase in CCUS activity can also be monitored for injected gas containment and necessary regulatory compliance assured.

Conclusions

The now routine imaging of the earth using SAR satellites has opened the possibility of resolving small ground movement and elevation change in almost real time. With the new processing power and programs developed it is possible to manipulate the large datasets created which in turn has opened new areas of application. In the near future, InSAR will image any point on the Earth at sub meter resolution and it will be possible to determine any elevation change in near real time at millimeter the scale.

Acknowledgements

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References

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Rosen, J., 2021. Fleets of radar satellites are measuring movement on earth like never before. Science, News Feature, 25th Feb 2021.

Stancliffe, R.P.W., and Van Der Kooij, M.W.A., 2001. The use of Satellite-Based Radar Interferometry to monitor production activity at the Cold Lake Heavy Oil Field, Alberta, Canada AAPG Bulletin (2001) 85 (5): 781–793.

Figure 1: ESA Sentinel 1 Radar Satellite. This first of the Copernicus constellation

After www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1/Facts_and_figures.

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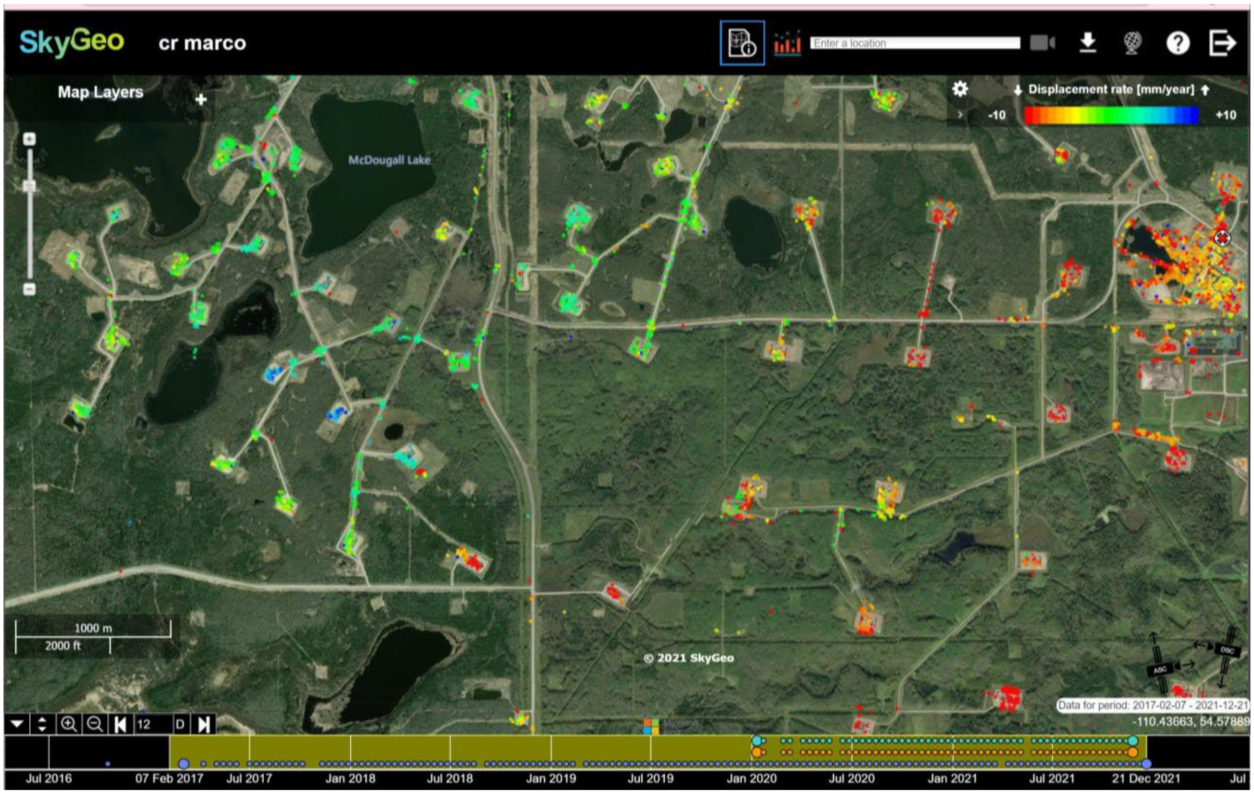

Figure 2: InSAR data from a CSS oilfield in East Central Alberta. Note the data collection every few weeks for 4 years and the changes in elevation across part of the filed including under production facilities