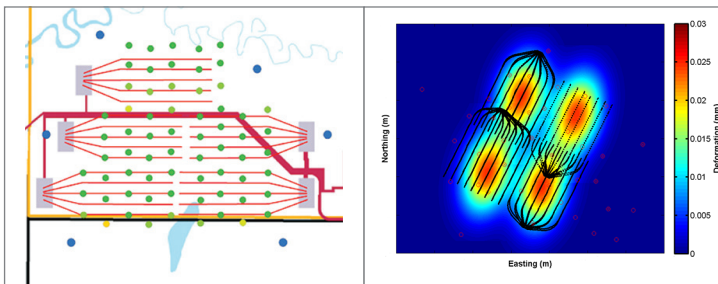


## MONITOR SURFACE IMPACT OF STEAM IN SAGD OR CSS OPERATIONS

**MDA's proven InSAR solutions monitor surface movement to help clients detect caprock integrity issues and monitor subsurface pressure impact. This allows better understanding of reservoir characteristics to help optimize production and reduce risk to operations.**

Steam-Assisted Gravity Drainage (SAGD) and Cyclic Steam Stimulation (CSS) oilfield operators inject steam at variable pressures which creates risk of caprock failure, out of zone fluid movement, and damage to facilities leading to the potential for production shutdown. Heavy oil producers manage their operational costs by using the best technology available to reduce production down-time and potential asset or environmental damage.

Interferometric Synthetic Aperture RADAR (InSAR) is a proven, accurate and cost effective method of monitoring surface movement, helping reduce equipment damage and production down time.



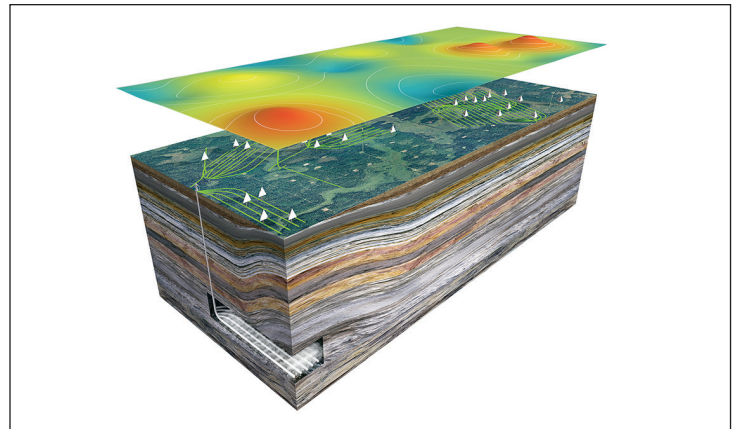
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*MDA provides Survey Designs that will accurately capture the expected ground motion while minimizing installation costs. The left image shows an example of a typical Survey Design with the right image showing a typical simulated deformation.*

MDA's geospatial products enable SAGD and CSS operators to understand how steam injection impacts the reservoir and caprock integrity to help mitigate environmental risks and increase revenue through optimized production strategies.

### Understanding Reservoir Behaviour through Surface Movement

Insight into the underground flow of steam and its impact on the



*The image above shows MDA's Surface Monitoring product capability of detecting millimetre changes in surface movement. Surface movement is a prime indicator of stress in the caprock.*

reservoir can be gained through monitoring the heave and subsidence of the surface above the reservoir. Problems related to unanticipated reservoir changes can be identified through surface movement expressions that may indicate migration of steam out of the intended zone, detection of excess heave, or heave gradients that may activate fracture planes.

MDA's accurate measurement of land subsidence and uplift using InSAR enables oil and gas operators to minimize subsidence by controlling injection volumes. Subsidence can cause slippage in surface layers along weak planes resulting in well casing dog legs and failures.

InSAR can detect and highlight areas of near surface horizontal and vertical shear zones. It shows the location and extent of unexpected fluid or gas mitigation to other zones, along faults, or to other wells, that can give early warning of caprock integrity failure, break-outs at surface, damage to infrastructure and eruptions.

Historic analysis of surface movement over time provides a knowledge baseline on which more effective steam injection strategies can be built. InSAR surface measurements can be used for the calibration

and validation of geomechanical models. Steam injector pressures are currently being modified by MDA clients to optimize distribution by well pads and patterns.

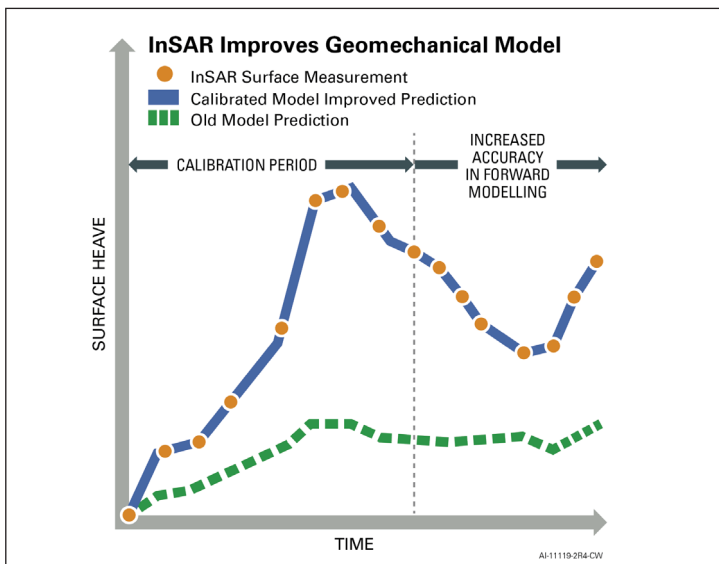
### Millimeter Accuracy From Space

SAGD and CSS operators rely on MDA oil and gas services to deliver accurate InSAR information products that can measure critical shifts in surface elevation to millimeter level accuracy. MDA InSAR solutions are commonly implemented as stand-alone monitoring programs, but are also used by clients to integrate with in-situ monitoring programs using microseismic, GPS or tiltmeter networks.

MDA's RADARSAT-2 satellite reliably provides very high resolution, weather independent coverage of oil and gas fields worldwide. Quarterly, monthly, and even weekly land surface information is delivered online to clients, enabling reservoir engineers, facility managers and geoscientists to optimize production or injection rates and take remedial actions (e.g., shut-in wells, or turn-off injectors) before problems escalate to cause damage or impact production. More than a decade of archived global data makes historical site monitoring possible, allowing us to further highlight specific known events at a field, as well as show long-term surface trends.

### MDA's Surface Monitoring Benefits

**Improved Geo-mechanical Models:** Surface uplift and subsidence measurements provide the ground truth boundary conditions that can be used to calibrate coupled geomechanical and reservoir models.



Surface uplift and subsidence measurements provide the boundary conditions used to calibrate geomechanical models or coupled geomechanical and reservoir models. Comparing the predicted surface movement from models with InSAR measurements enables calibration, and improves the model's forecasts.

**Increased Production Efficiency:** Injection and production can be adjusted in response to surface heave data to improve the efficiency of operations. By using information about where steam is going and where heave is not conforming to expectations, operators can adjust injection to increase the efficiency of operation.

**Regulatory Compliance:** In many regions, surface monitoring and reporting to regulatory authorities is required. InSAR is recognized as a best practice method of monitoring EOR fields and the results are well accepted in reports to regulators.

**Risk Mitigation:** Regular monitoring provides wide area detailed uplift and subsidence information which helps provide early warning of potential problems such as caprock failure, fault activation and damage to surface facilities. Early warning can reduce risk of costly equipment damage or production shutdown.

**Industry Best Practice:** Companies can show investors, government and the local community that they are responsible operators and are serious about health, safety and the environment by using best practices to operate their oil fields.

**Reliable Monitoring with RADARSAT-2:** MDA's track record of routine service provides operators with the confidence in monitoring accuracy.

**Integrated R&D and Production:** Customer needs are resolved quickly, and results are reproduced consistently and cost effectively in the production environment.

### CUSTOMER SATISFACTION

For over four decades, we have worked closely with our worldwide customer base to provide them with information solutions that leverage advanced technologies and allow them to conduct their business more efficiently.

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