A Case Study on InSAR as a High Frequency Decision Making Tool for SAGD Operations

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Summary

A case study on the use of InSAR as a high frequency reservoir surveillance tool for SAGD operations. Focus of the study is to establish the scale at which InSAR can be a reliable, high frequency decision making tool on a SAGD pad.

Reservoir surveillance is a key component of SAGD operations. There are several widely used surveillance techniques which vary in spatial and temporal coverage, resolution and cost. The most common of which include pressure and temperature observation wells and 4D seismic. This study aims to demonstrate the value of InSAR over operating SAGD pads when used in a coordinated surveillance program alongside existing techniques.

Theory / Method / Workflow

In order to assess the value of InSAR as it pertains to SAGD surveillance, this case study includes 55 well pairs which were analysed using publicly available time delay data and high-resolution Cosmo-SkyMed (CSK) satellite data. The wells used in this study are located in a single SAGD field in Alberta, Canada, with an approximate operating depth between 150-250m TVD (true vertical depth). CSK satellite data is acquired from Agenzia Spaziale Italiana (i.e., the Italian Space Agency) which has a 16-day repeating cycle per image acquisition at a 3 m by 3 m pixel resolution. First, the quantitative relationship between the two data sets was examined. To do this InSAR displacement points and 4D time delay points which existed within 10 meters of each other (considered co-located) and the values from InSAR and 4D time delay were cross plotted to establish what relationship, if any, existed between the two surveillance techniques.

Data was analyzed where InSAR and 4D results were acquired during the same time period. However, since InSAR results were often only available in snow free months (May-October acquisition) while 4D seismic is generally acquired mid-winter (January-February acquisition) the first summer InSAR image was considered to be the most closely related to the 4D seismic.

To assess the qualitative value of InSAR, each well pair was divided into segments, at varying proportional divisions (Figure 1); half well division, third well division and a quarter well division. The relative results of the InSAR and 4D seismic time delay were then compared to determine if utilizing each data set would lead to the same conclusion and influence subsequent operational decisions in the same way.

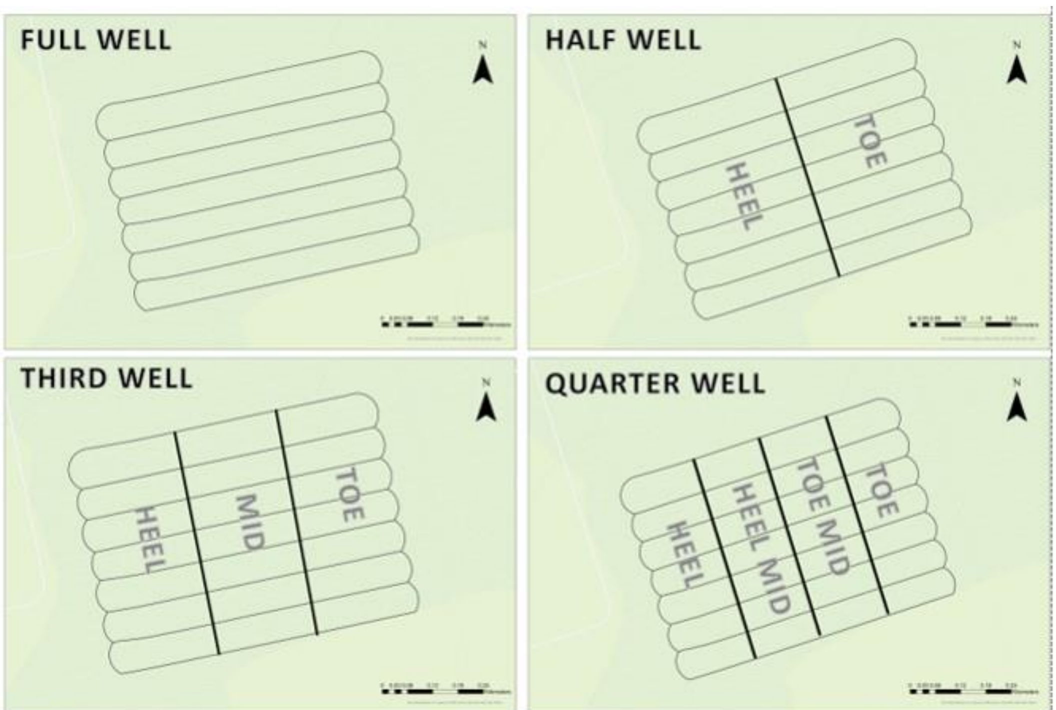
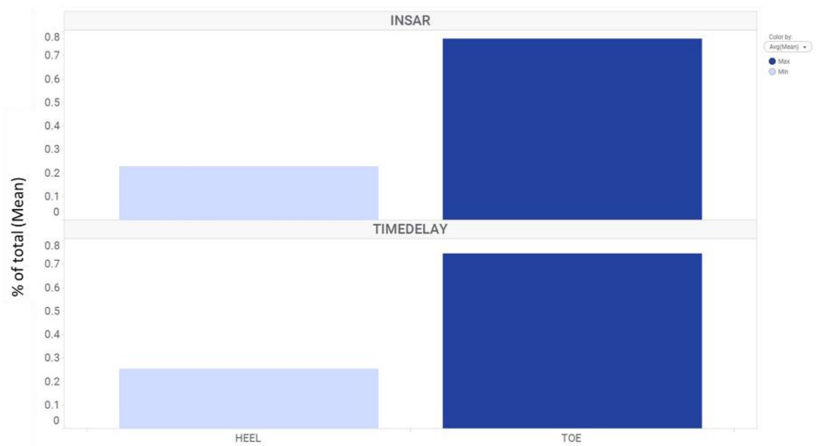


Figure 1: Schematic illustrating the divisions made within each wellbore to correlate InSAR to 4D seismic response.

Where both InSAR and 4D time delay data were collocated within a wellbore segment as defined above, minimum, maximum and mean values for each data type were calculated and summarized. From this data, relative responses were compared at each scale: half, third and quarter wellbore. Where the InSAR and the 4D time delay had the same relative response the results were classified as a match. For example, when looking at the half well division, if the time delay response was highest in the toe, and lowest in the heel; and likewise, the InSAR response was highest in the toe and lowest in the heel; it was concluded that the two data sets would lead to the same conclusion and subsequently could provide an operator with similar information upon which to make an operational decision.

This process was repeated for all 55 well pairs, for half well, third well and quarter well divisions. Examples of the InSAR vs 4D seismic time delay data are found in 2. Highlighted are cases where on a relative sense, InSAR results provide similar trends to those of the time delay.

The example below illustrates a half well analysis where, in both the InSAR and 4D seismic response, the toe of the well is showing significantly stronger response than the heel. Likewise, in the third well case, the toe is showing the strongest response from each technique, followed by the mid-well and lastly the heel. In the quarter well case, a partial match is observed wherein the toe-mid of the well is showing the strongest response from both techniques, the heel is showing the weakest, however the toe and heel-mid (ranking 2nd and 3rd) are inverted.



HALF WELL

THIRD WELL

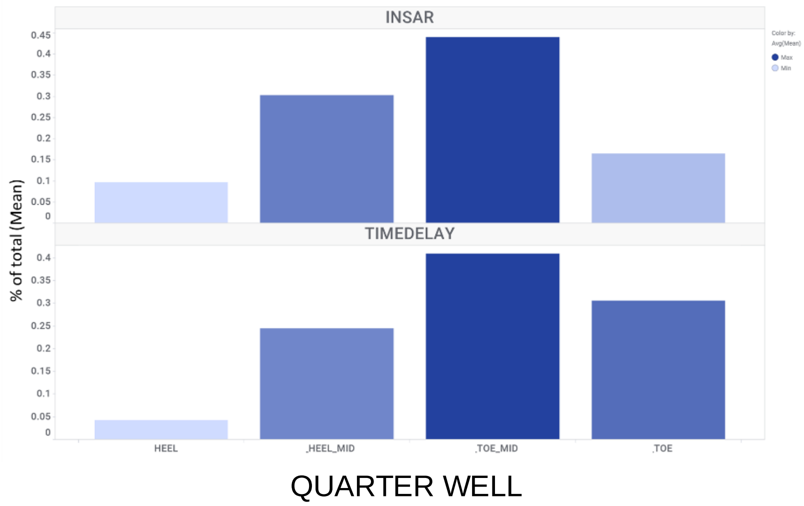


Figure 2: Example schematic of InSAR and 4D time delay comparisons. Similar plots were generated for all 55 well pairs and results were tabulated.

Results, Observations, Conclusions

To establish this qualitative relationship, each of the 55 well pairs were summarized at half, third and quarter well divisions. Where both the InSAR and 4D time delay data resulted in the same relative response the result was considered a qualitative match. For the third and quarter well divisions, if a partial but majority match (two of the three divisions or three of the four) was identified, this was also noted and considered a match. Table 1 summarizes the results of the qualitative analysis for the entire data set and for only the high-resolution data.

Table 1: Summary statistics for qualitative comparison between InSAR and 4D responses over SAGD well pairs

InSAR to 4D Time Delay Qualitative Match Statistics				
Division	% Match (inc. partial)	% Not Match	% Partial	% No data
Half	85	15	N/A	N/A
Third	81	19	35	N/A
Quarter	65	35	41	N/A

At the half well scale, the InSAR provides the same relative response as the 4D time delay 85% of the time for the high-resolution data. At the smaller, third well division InSAR provides the same or partial relative result in 81% of the high-resolution data. At the finest division considered, quarter well, InSAR provides the same or partial relative response in 65% of the high-resolution data.

The focus of these results is to highlight that in the majority of instances, InSAR can provide comparable relative information when considered against 4D seismic, and importantly can do so at a higher frequency in between or prior to shooting 4D surveys.
The key consideration thus becomes the scale at which operational decisions using InSAR can be made within each SAGD well pair. Examining the half and third well case, a strong match in the high-resolution data indicates that at the toe vs mid vs heel scale insights gained through InSAR may aid production optimization by providing similar relative information to that obtained by 4D seismic. Where subsurface teams have the ability to modify steam injection through outflow control devices, steam splitters or heel/toe tubing strings, decisions are often made at not more than the half or third well level.

Novel/Additive Information

Attempts to correlate InSAR to existing SAGD surveillance techniques have showed mixed, though often promising results. Difficulty in "proving" the application to SAGD surveillance has arisen from attempts to directly compare discrete InSAR values to those of other techniques, often resulting in poor regression coefficients and a lack of confidence. Qualitative comparisons of gridded surfaces provide little insight on how to utilize the InSAR data.

The gap has been what to do with the results of an InSAR study and how it can impact the decisions made on an operating pad. This study will demonstrate the scale at which InSAR can provide information to make operational SAGD decisions. This study demonstrates the qualitative decision-making value of InSAR technology and its application to SAGD pads.