Integration
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Assessing the need for repeatability in acquisition of time-lapse data

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Outline

- Time-lapse (4D) seismic
- Acquisition geometry
- Method
- Experiment
- Results
- Conclusion

Time-lapse (4D) Seismic

- seismic data acquired at different times over the same area
- to observe changes in the subsurface with time

Time-lapse (4D) Seismic

- fundamentally interested in fluid movement, pressure and temperature changes
- requires acquisition to be repeatable for baseline and monitor surveys

Why *repeatability*?

- repeatability is required to mitigate false events
- mainly interested in reservoir property changes or attributes related to fluid content

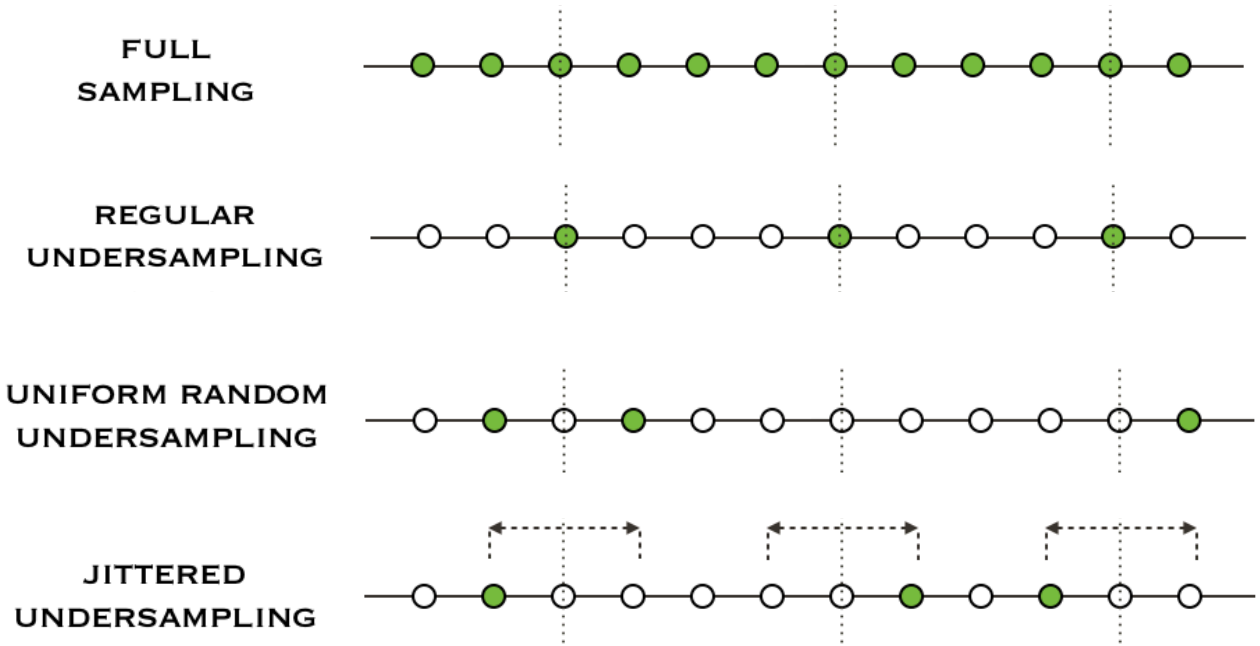
Problem statement

- Let's assume there is *no* observable 4D *change* in the *earth* model
- Since Compressed Sensing (CS) proposes *randomization* of the experiments
- Do we need to *repeat* our *randomized* sampling during monitor survey?
- If not, what is the *quality* of the *recovery* of the 4D effect as a function of the *subsampling* ratio?

Methodology

- *Investigate* the *effect* of *repeating* the acquisition when there is an *expected* fluid *change*
- *Study* the *effect* of two *different* acquisitions when there is *no* expected fluid *change*
- *Assess* the *effect* of two *different* acquisitions when there is an *expected* fluid *change*
- In case of *periodic* and *randomized* sampling

Acquisition geometries



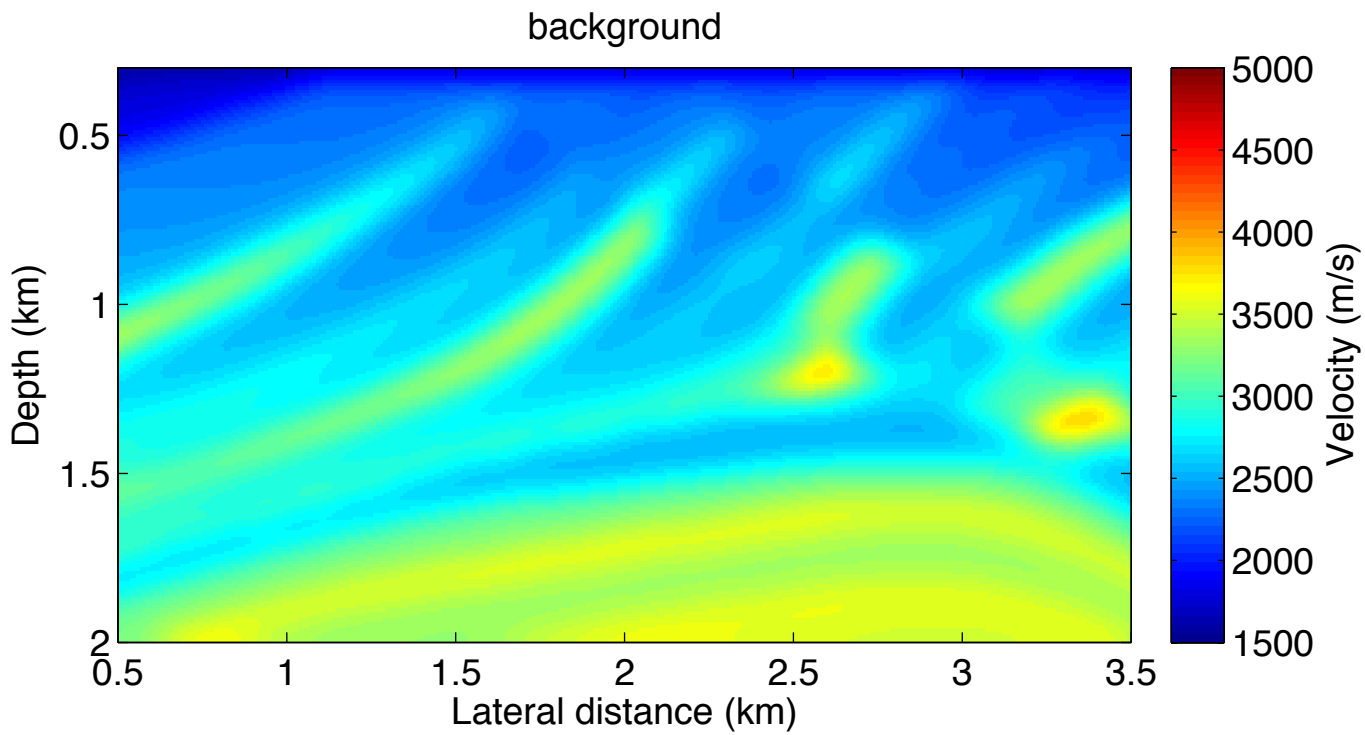
distribution of receivers, could also be shot locations

image credited to Wason H.

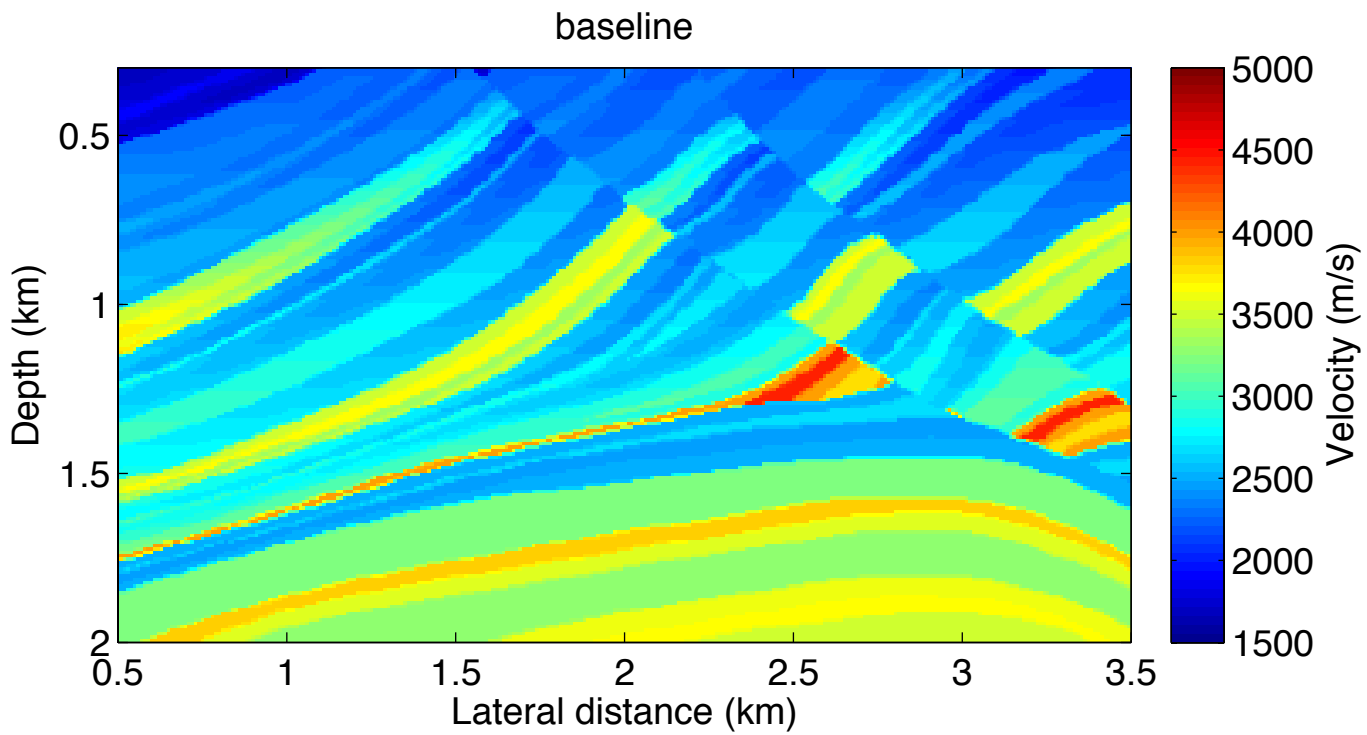
Modeling

- We assume that the *smooth* background velocity doesn't change for both baseline survey and monitor survey
- different perturbation of background to model baseline and monitor velocity models
- assume an acoustic model

Initial velocity model

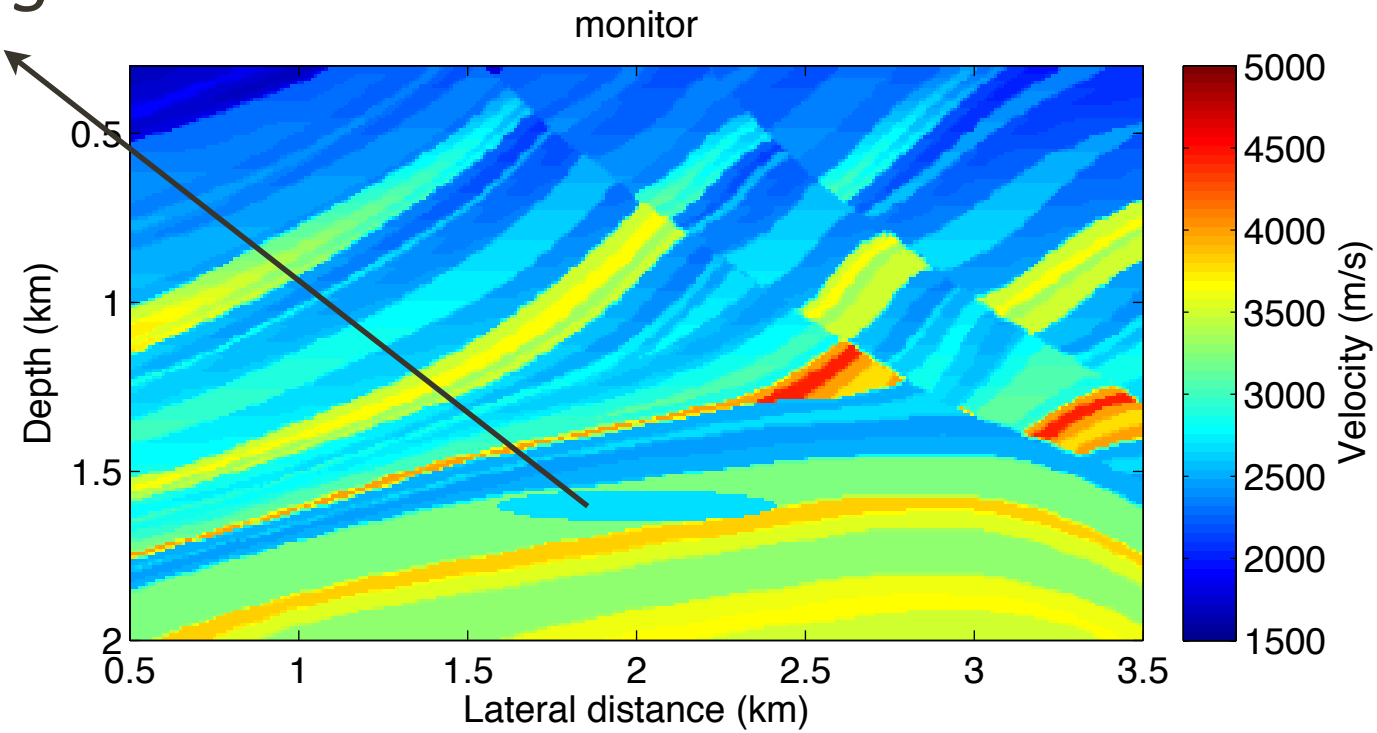


Velocity model (baseline)



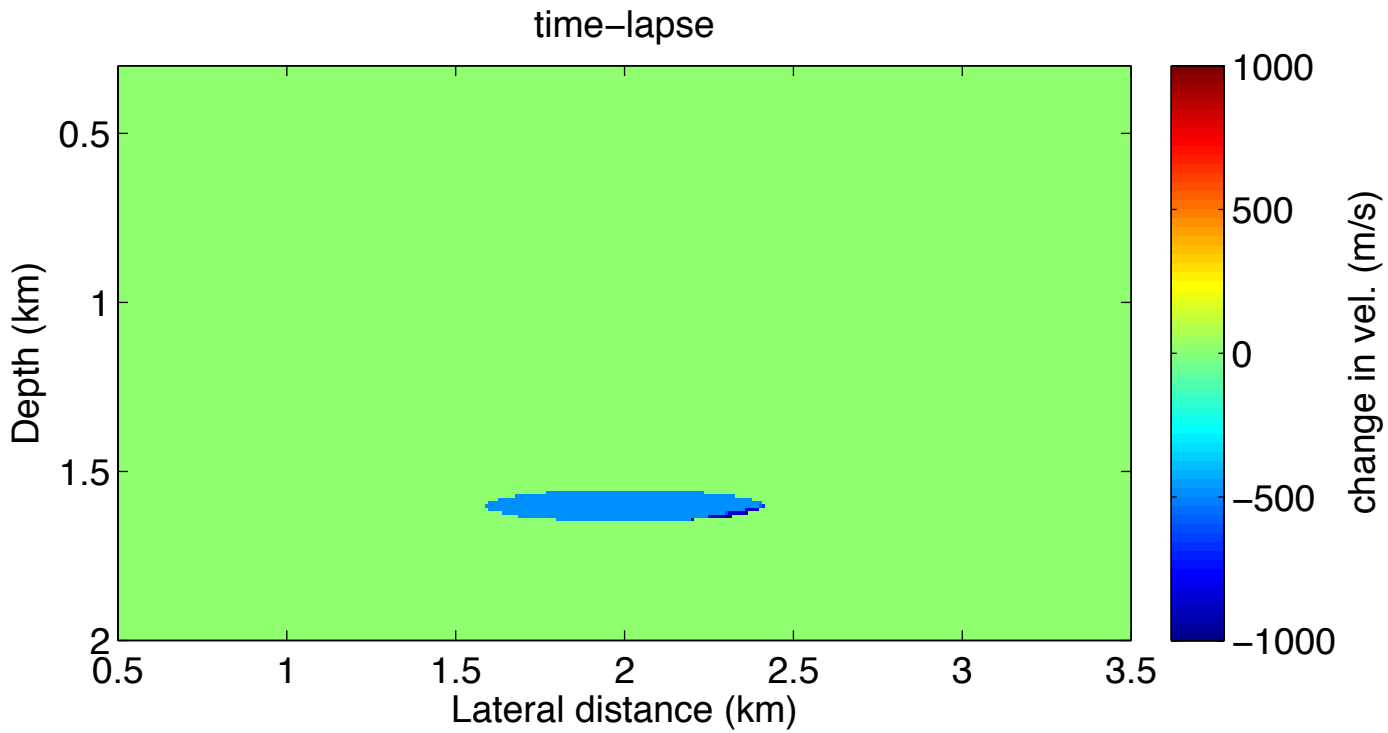
Velocity model (monitor)

change



Difference (change) in models

decrease in velocity from baseline to monitor



Some modeling parameters

- Number of shot points 100
- Number of receivers 200
- Frequencies 5 to 25Hz
- 2km X 3km grid for velocity model
- Ricker wavelet , with peak frequency 10Hz

Imaging

- We perform RTM on the *residual* data from the *baseline* $F[m_b] - F[m_0]$ and *monitor* $F[m_m] - F[m_0]$ velocity models
- results are shown as RTM Images

Sampling methods

- Case 1 – data is *regularly* sampled during *baseline* and *monitor* surveys
- Case 2 – data is *randomly* sampled according to a *uniform* distribution
- Case 3 - data is *randomly* sampled according to a *jittered* distribution

Format of results display

image from 1st acquisition

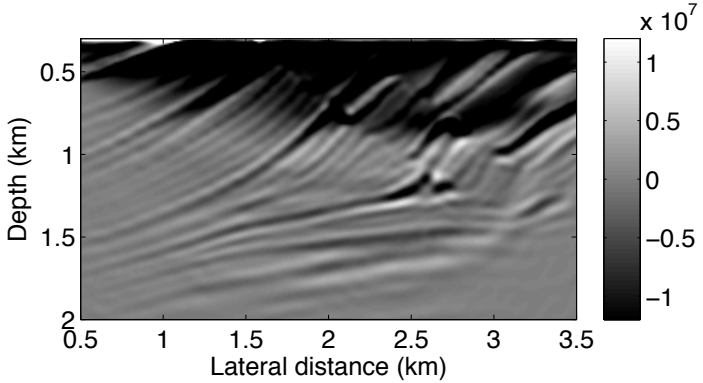
image from 2nd acquisition

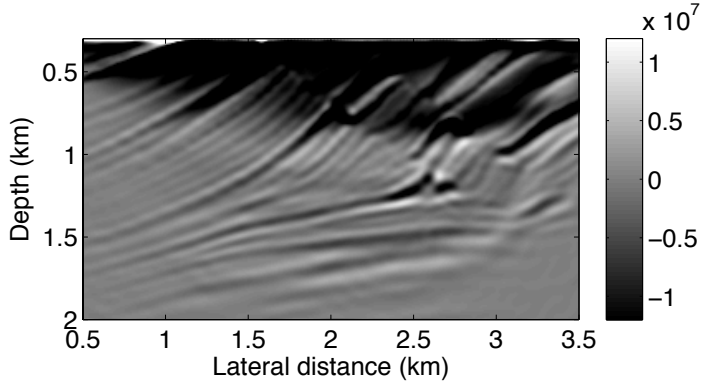
difference between the two images

Scenario 1

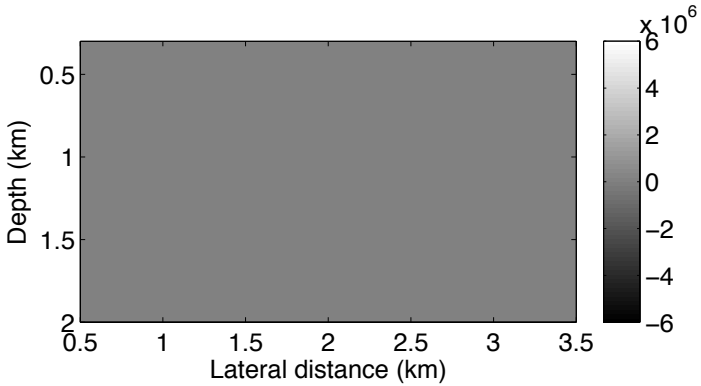
- There is no expected fluid change
- Acquisition is repeated
- Observe results for the different sampling schemes

Results : Regular sampling

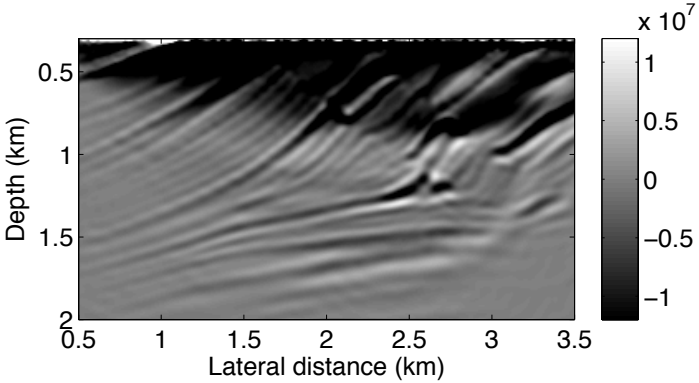


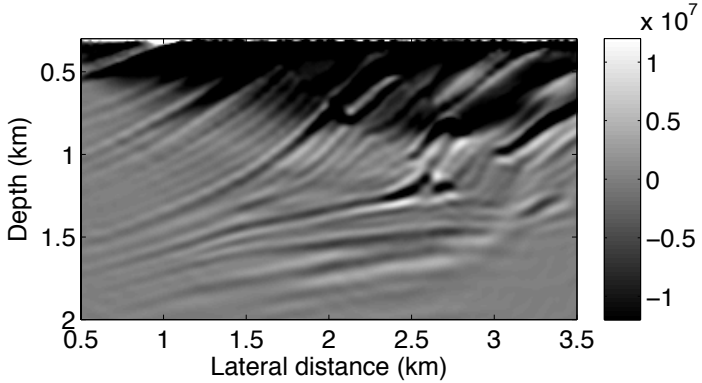


difference

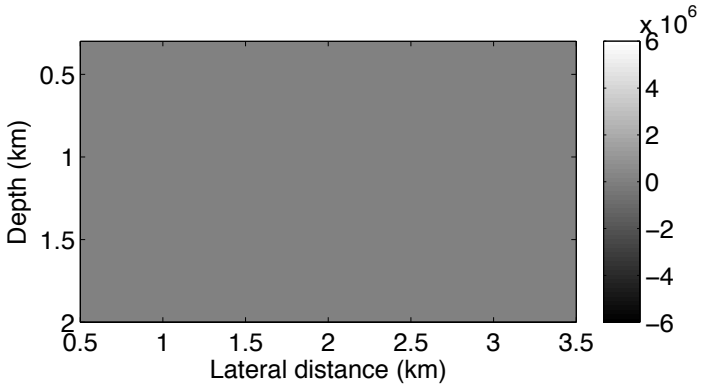


Results : Uniform random sampling

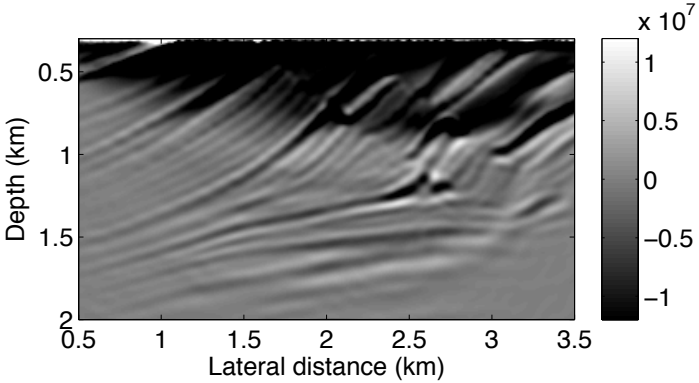


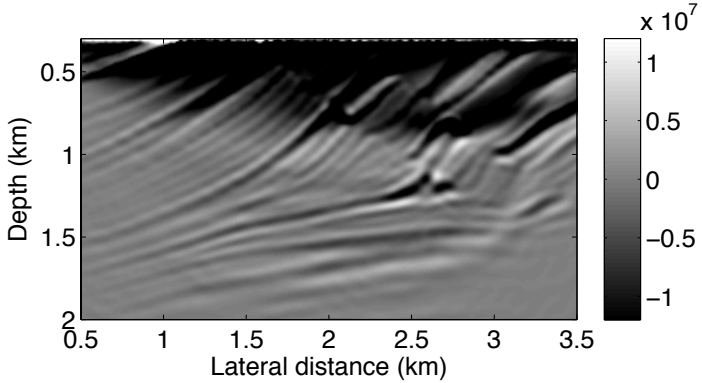


difference

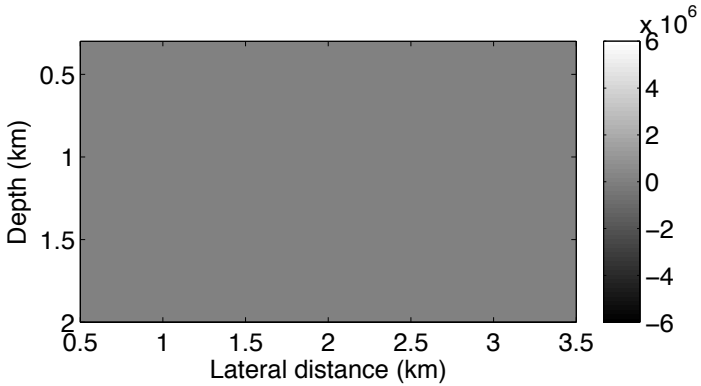


Results : Jittered random sampling





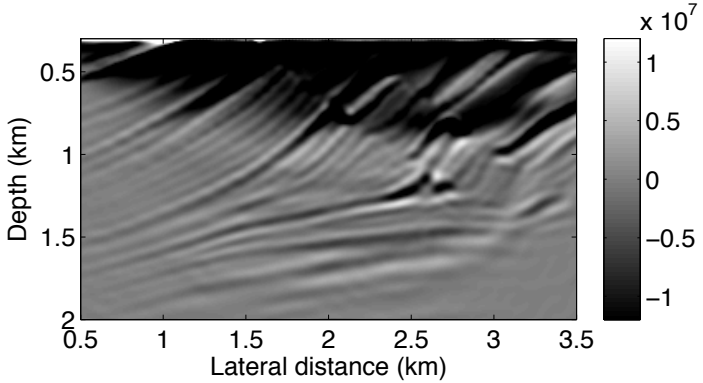
difference

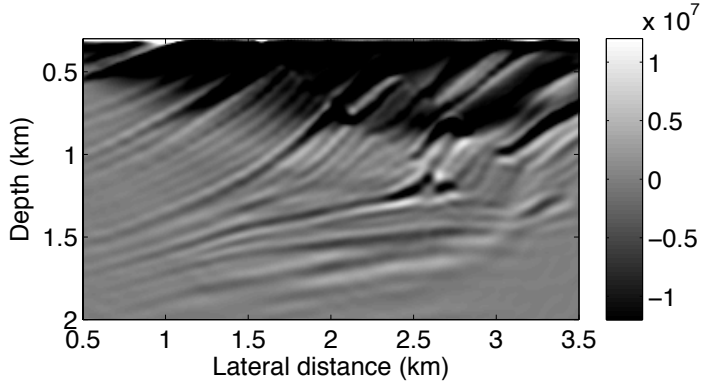


Scenario 2

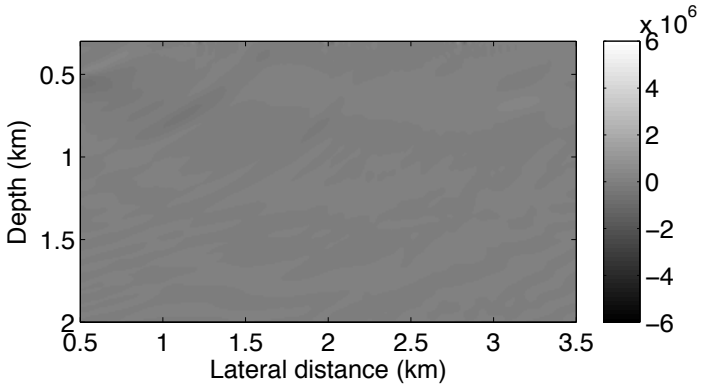
- There is no expected fluid change
- Acquisition is not repeated (maybe a shift in the periodic sampling)
- Observe results for the different sampling schemes

Results : Regular sampling



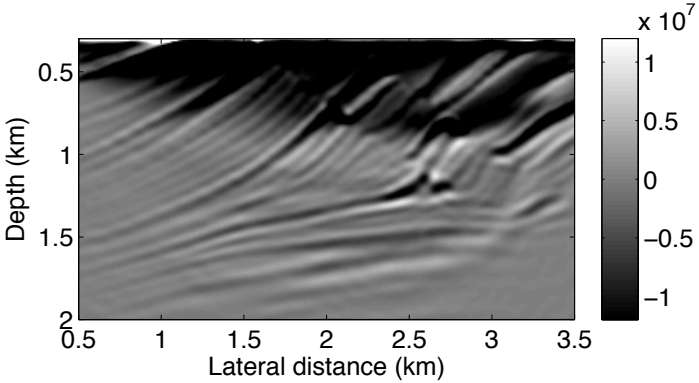


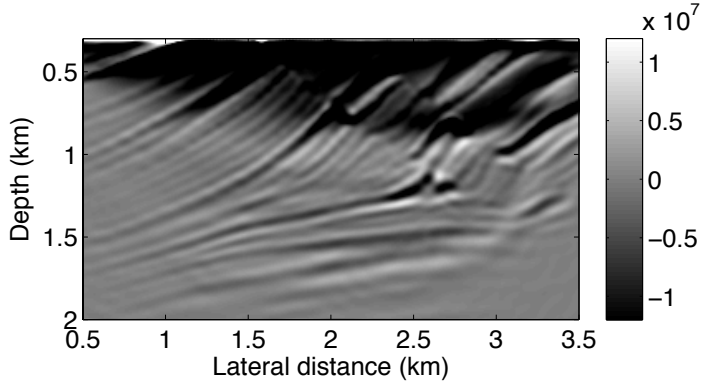
difference



shift of 20m

Results : Regular sampling





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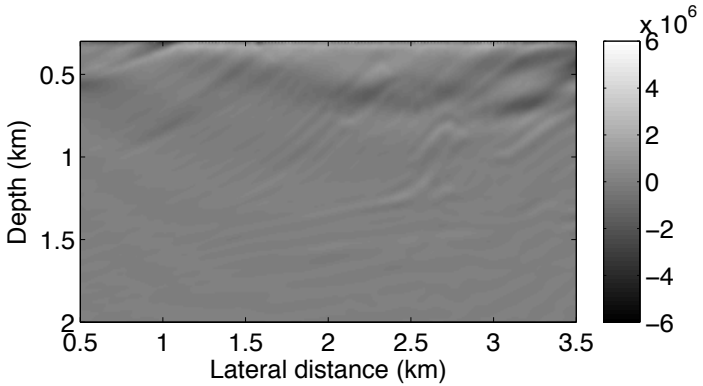
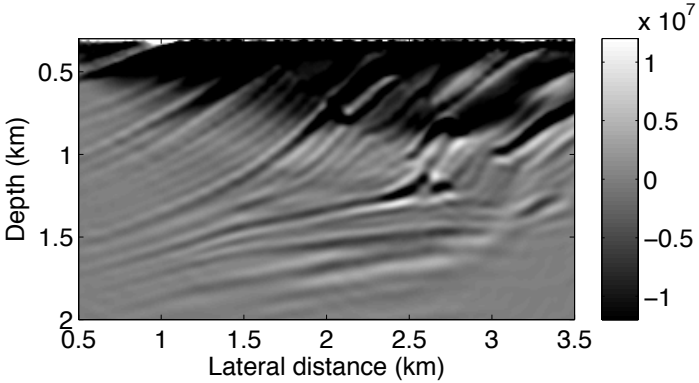
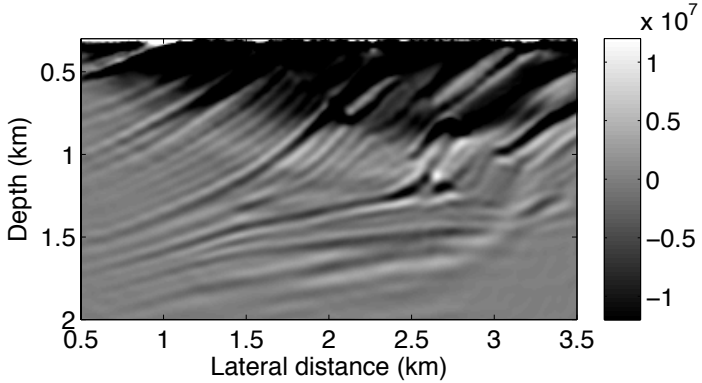


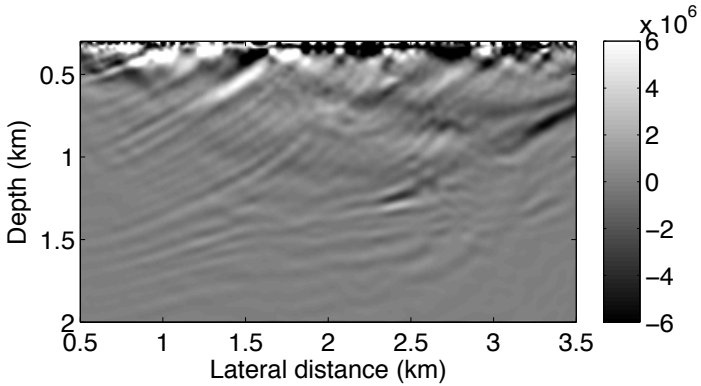
shift of 50m

Results : Uniform random sampling

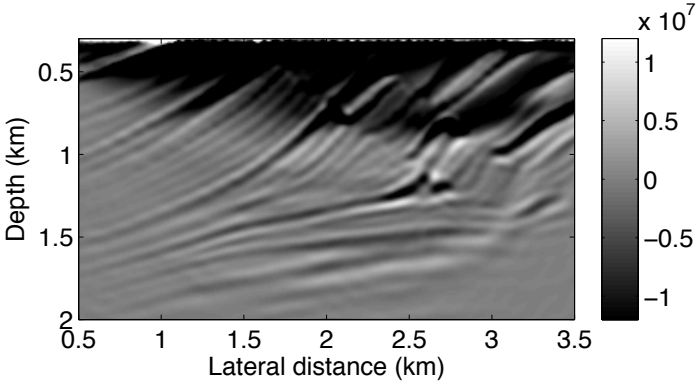


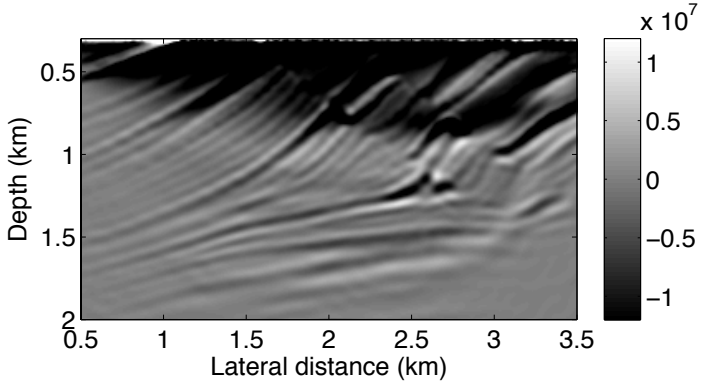


difference

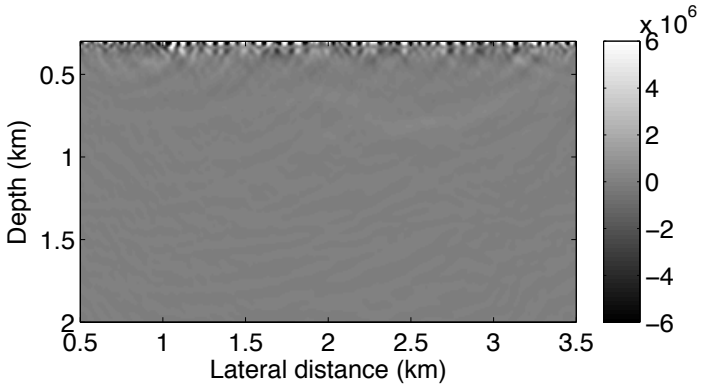


Results : Jittered random sampling





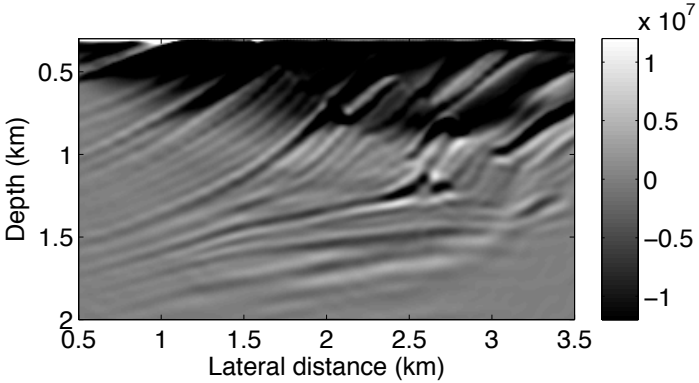
difference

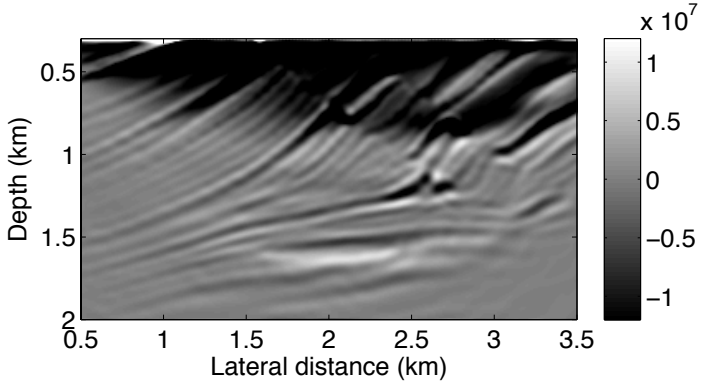


Scenario 3

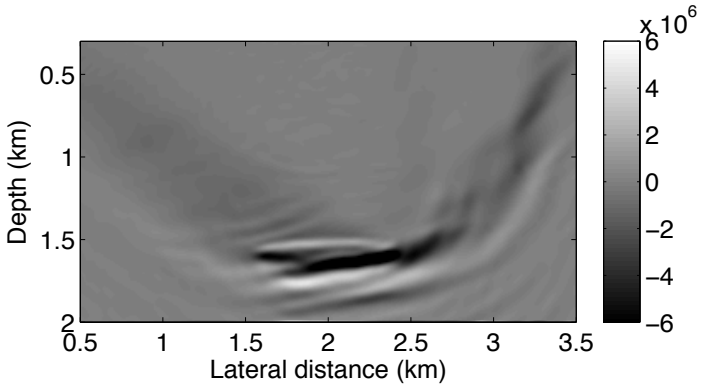
- There is an expected fluid change
- Acquisition is repeated as in Scenario 1
- Observe results for the different sampling schemes

Results : Regular sampling

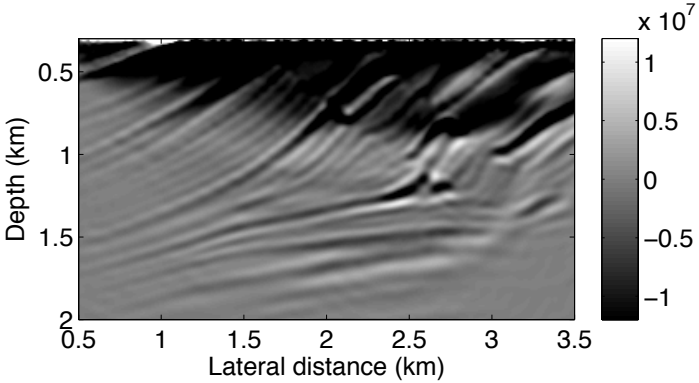


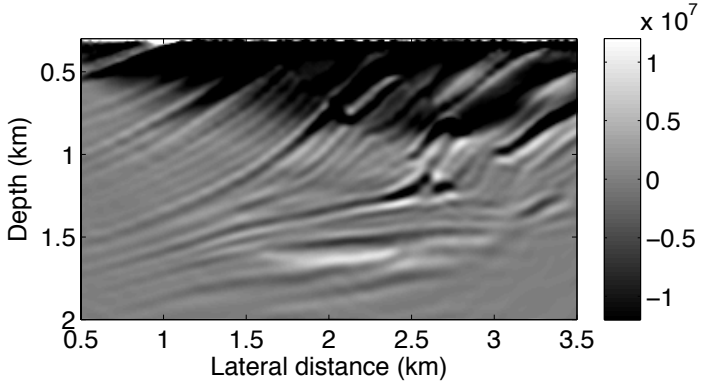


difference

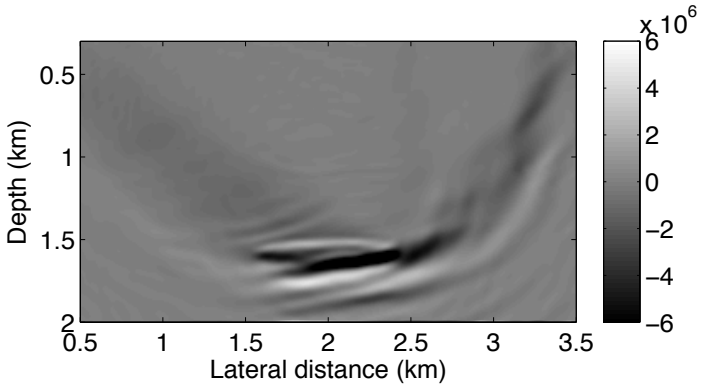


Results : Uniform random sampling

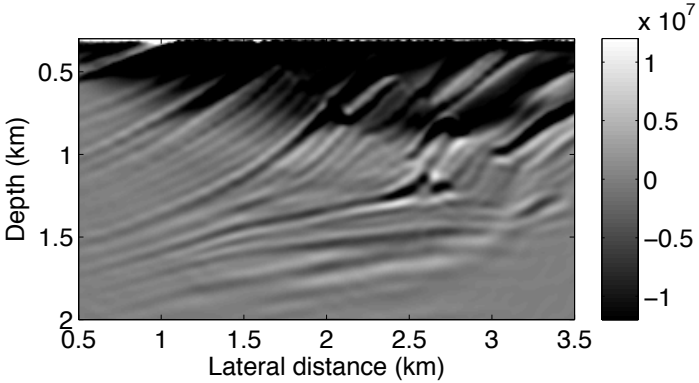


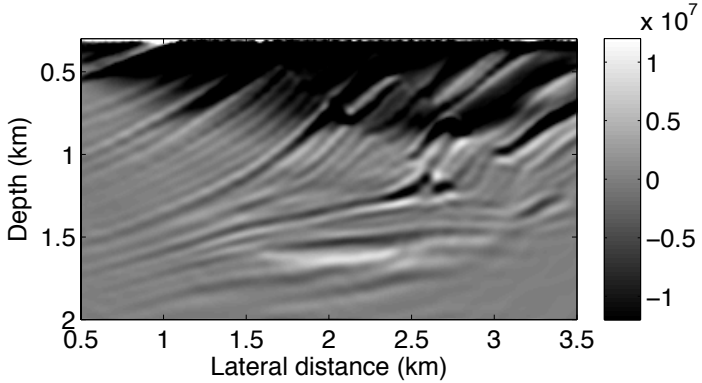


difference



Results : Jittered random sampling





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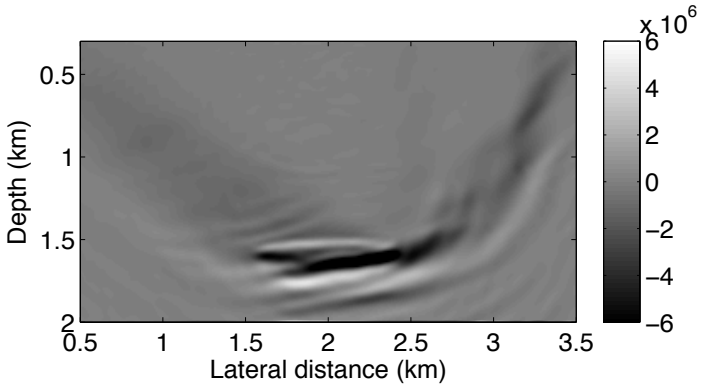
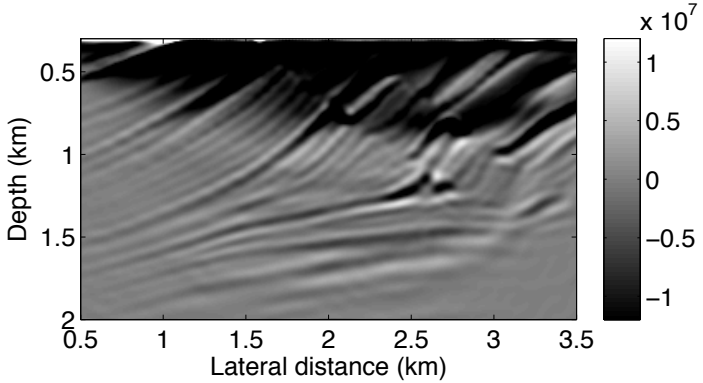
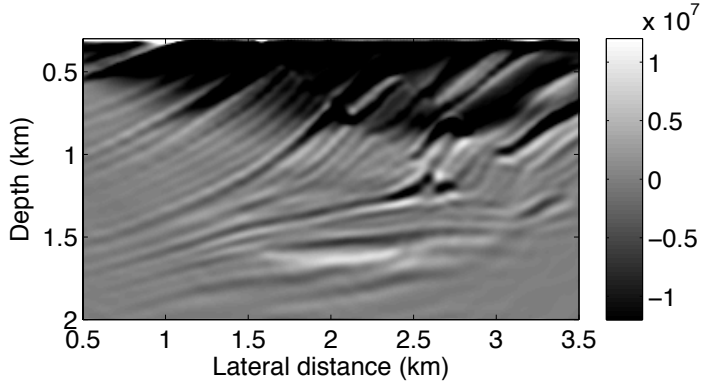


Scenario 4

- There is an expected fluid change
- Acquisition is not repeated as in Scenario 2
- Observe results for the different sampling schemes

Results : Regular sampling





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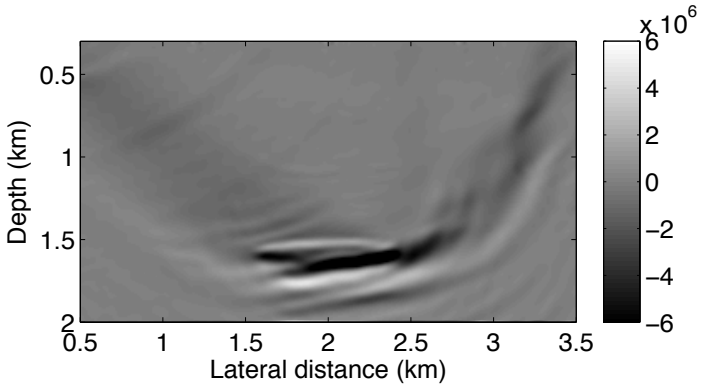
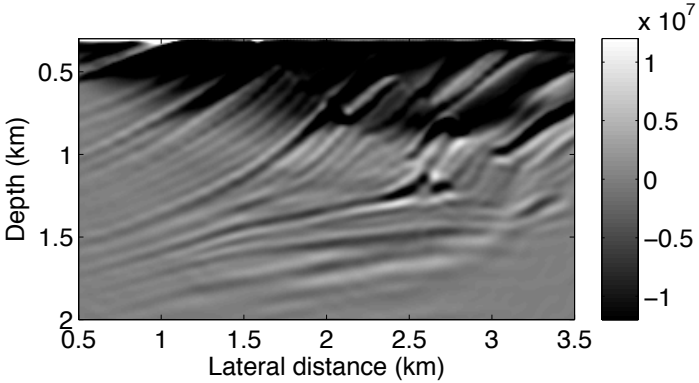
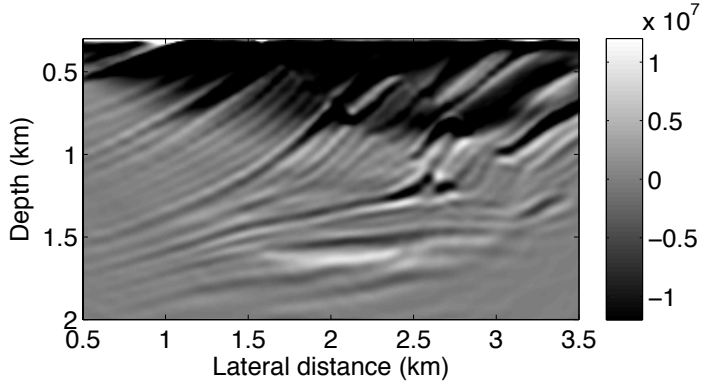


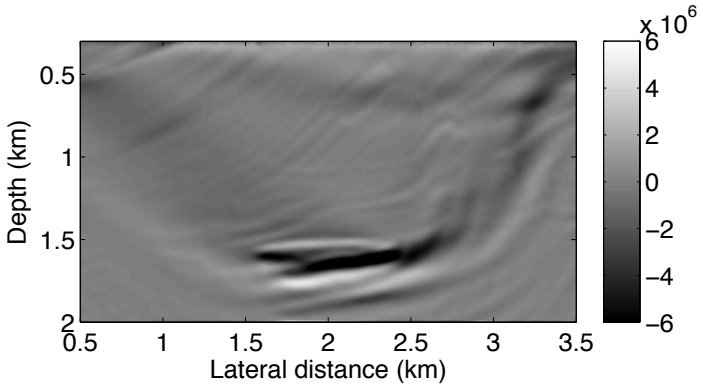
shift of 20m

Results : Regular sampling



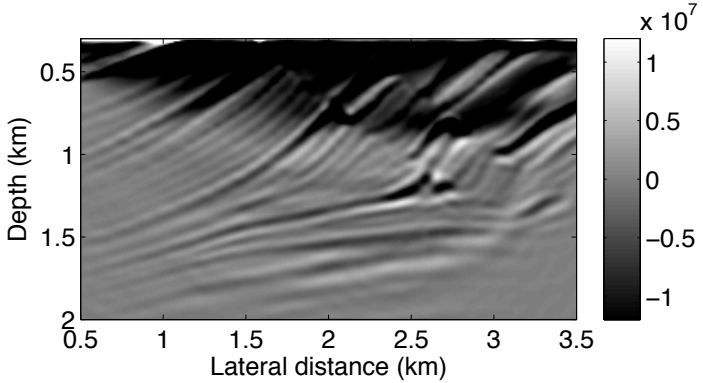


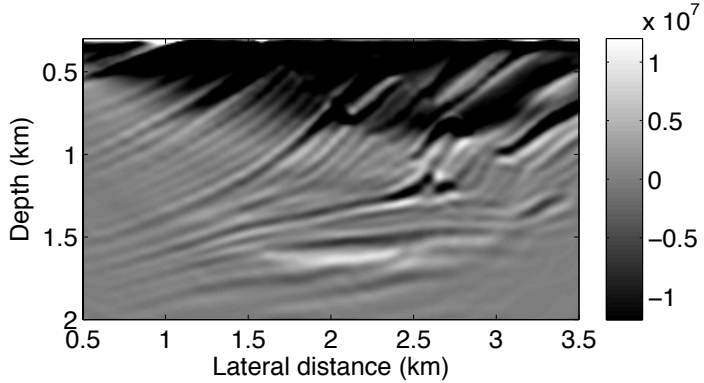
difference



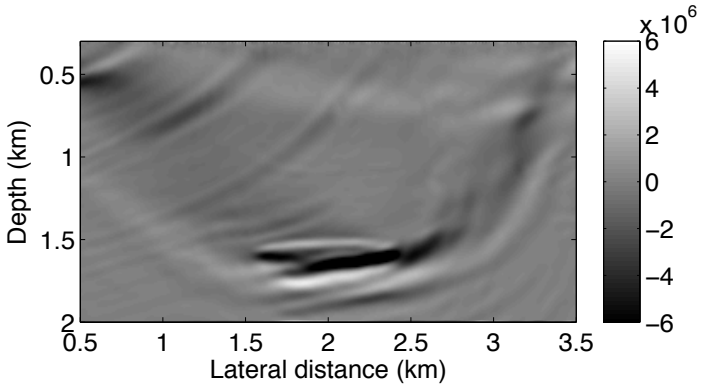
shift of 50m

Results : Regular sampling



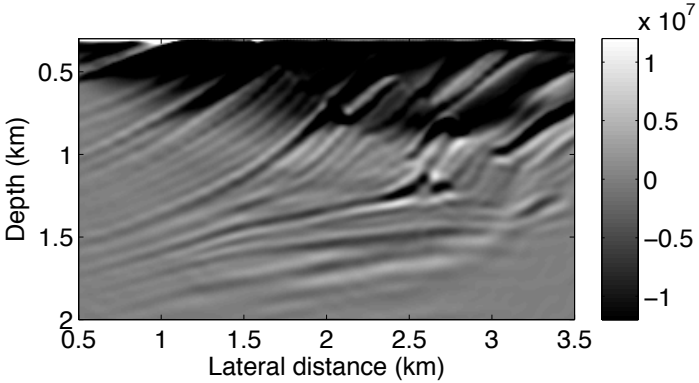


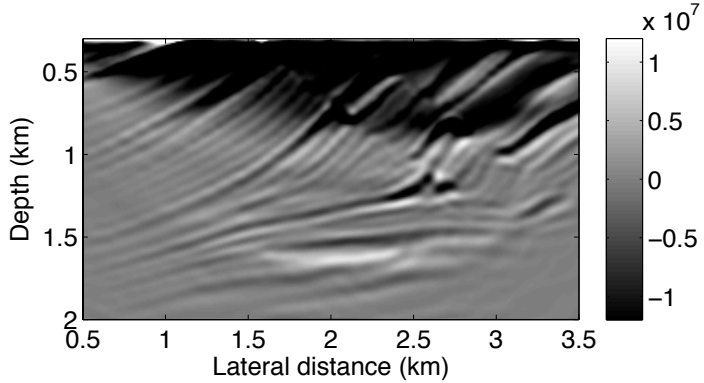
difference



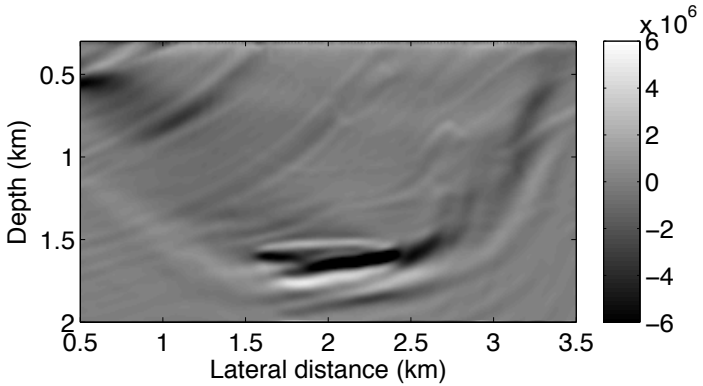
shift of 100m

Results : Regular sampling



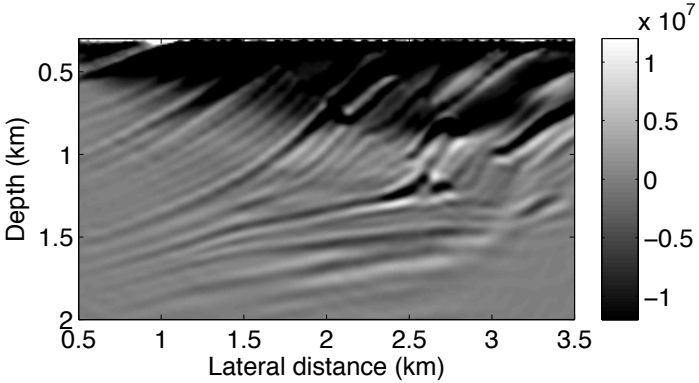


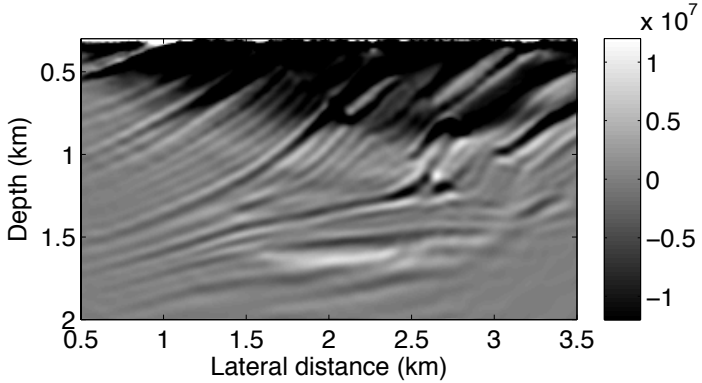
difference



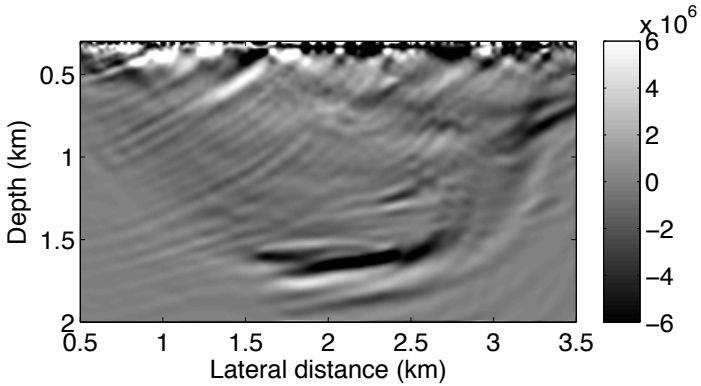
shift of 150m

Results : Uniform random sampling

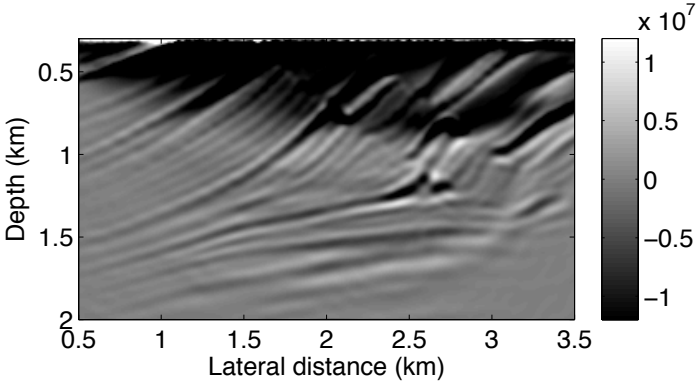


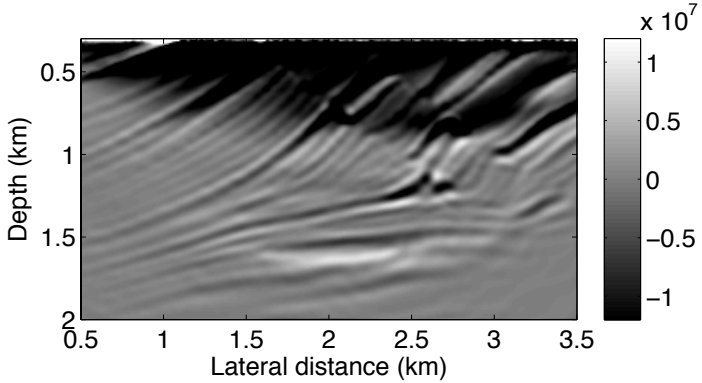


difference

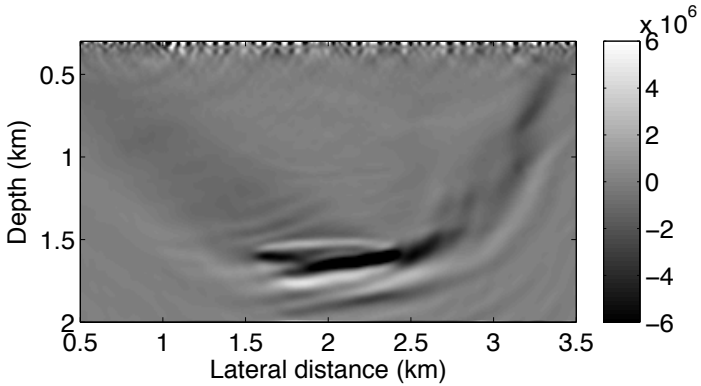


Results : Jittered random sampling





difference

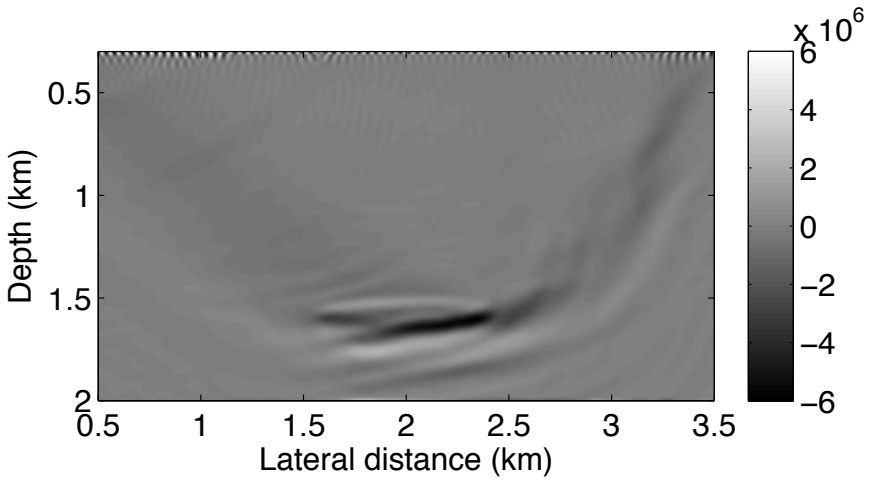


Subsampling

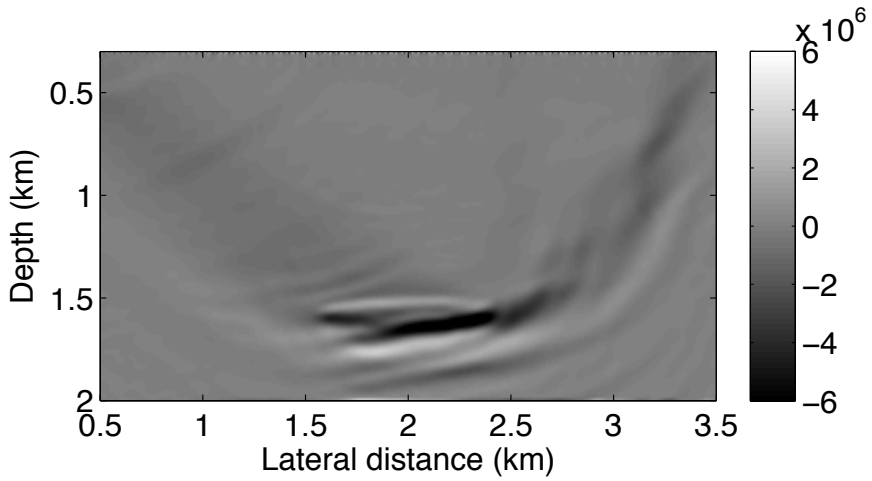
- Fluid change expected
- Acquisition is not repeated as in Scenario 2 and 4
- Observe results for the different sampling schemes, for 50% and 75% of receivers

Results : Regular subsampling

50%



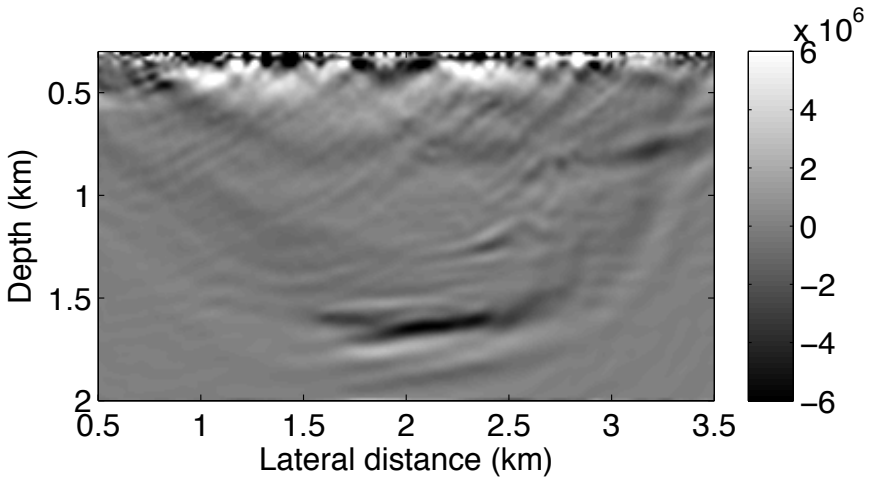
75%



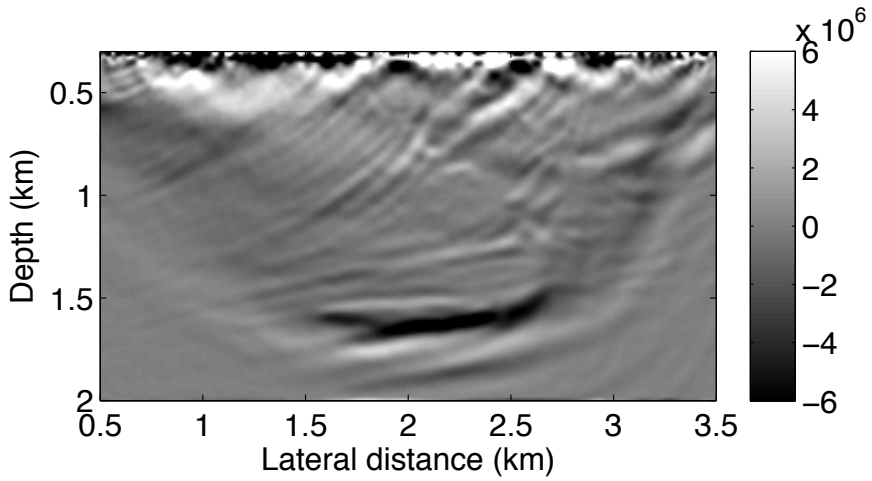
shift of 20m

Results : Uniform random subsampling

50%

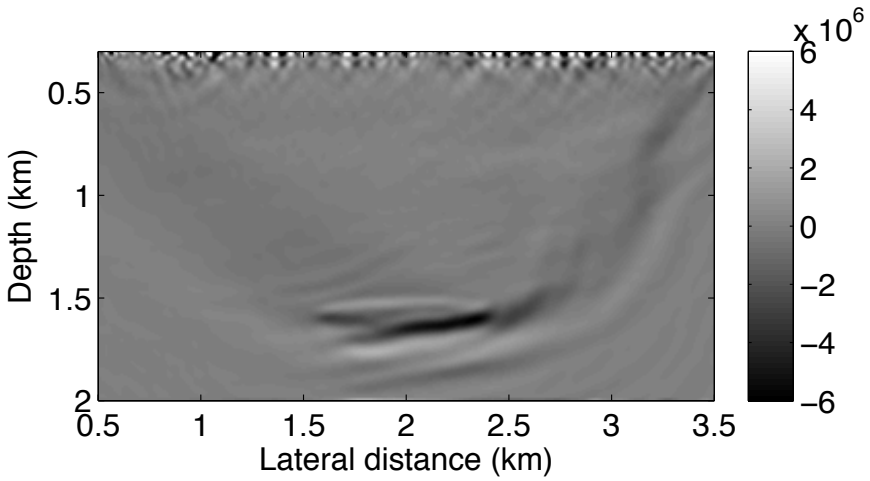


75%

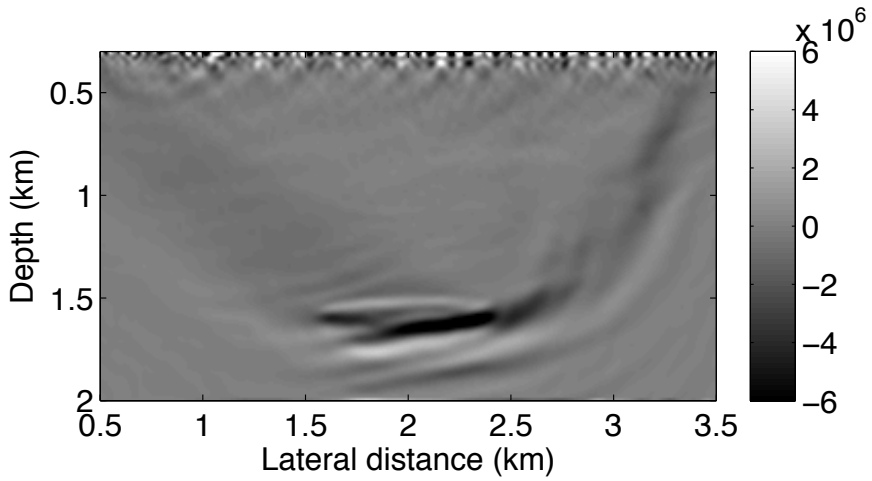


Results : Jittered random subsampling

50%



75%



Conclusions

- Repeatability is very *important* , in order to *delineate* true time-lapse changes in the medium
- Random jittered (under)sampling will at least reveal the zone of change, without repeating the survey
- Random jittered sampling will minimize acquisition imprints in the difference images

Conclusions

- As *subsampling* ratio *decreases*, *repeatability* of the *randomized samplings* may *no* longer be a *necessary criterium* to *resolve* any 4D *changes and the amplitude of the change*
- We have seen *satisfactory* results for 50% and 75%

Future Work

- Detect 4D changes in *noisy* environments with *high* subsampling *ratios*
- Extend to randomized *simultaneous* marine *acquisition* with *randomized* OBN
- Effect of increased spatio-temporal subsampling

Acknowledgements

Thank you for your attention

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