

Assessing the need for repeatability in acquisition geometry of 4D (time-lapse) seismic data

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Outline

- 4D Seismic
- Problem Statement
- Methodology
- Experiment
- Results
- Conclusion
- Future work

Time-lapse (4D) Seismic

- seismic data acquired at different times over the same area
- to assess 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
- only 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

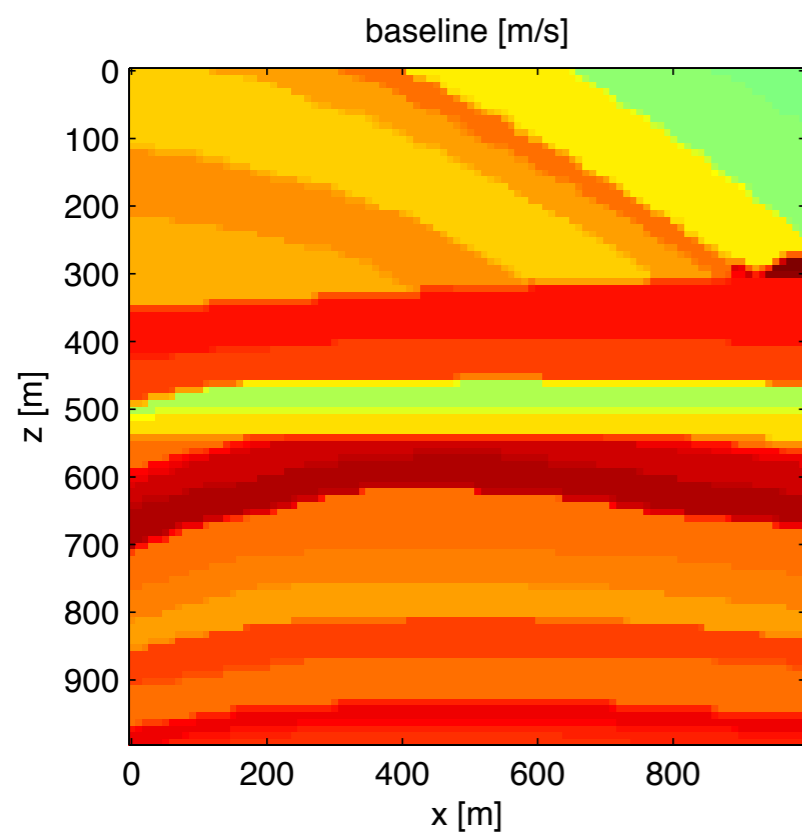
- *Investigate the effect of repeating the acquisition when there is an expected fluid change*
- *Study the effect of two different acquisitions when there is no expected fluid change*
- *Assess the effect of two different acquisitions when there is an expected fluid change*
- *In case of periodic and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

Modeling

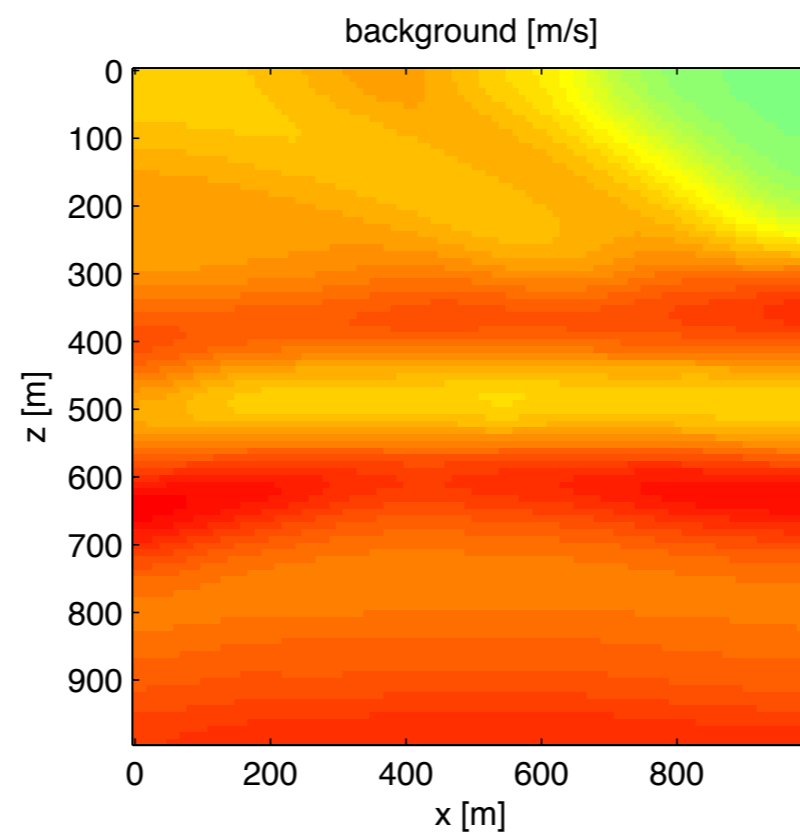
- We assume that the *smooth* background velocity doesn't change for both baseline survey and monitor survey
- different perturbation of background to get baseline and monitor velocity models

Baseline, smooth background and perturbation

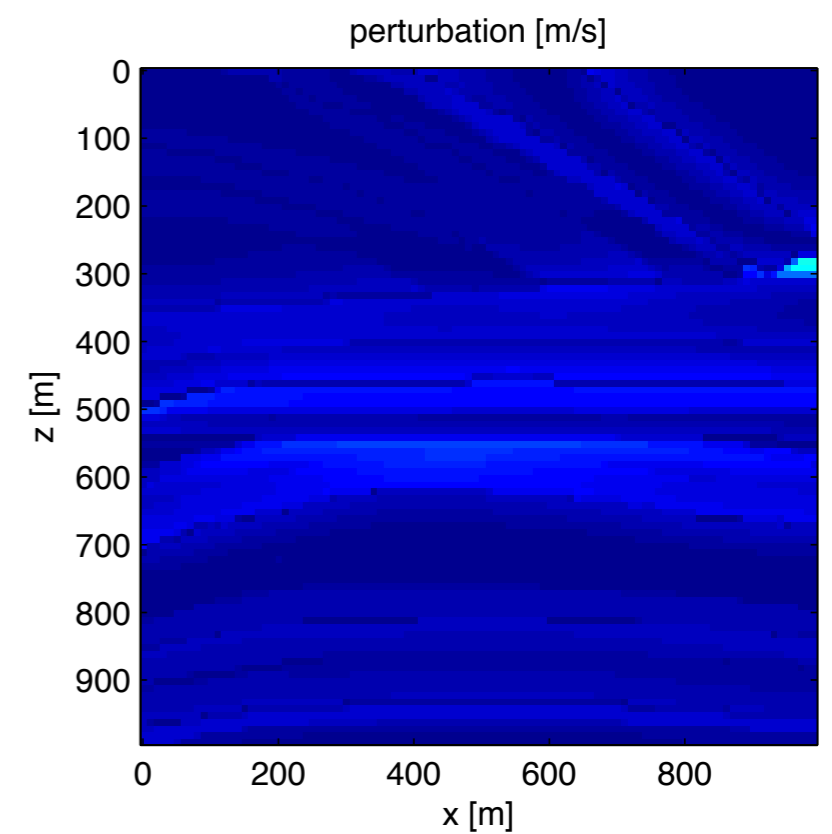
Baseline



background



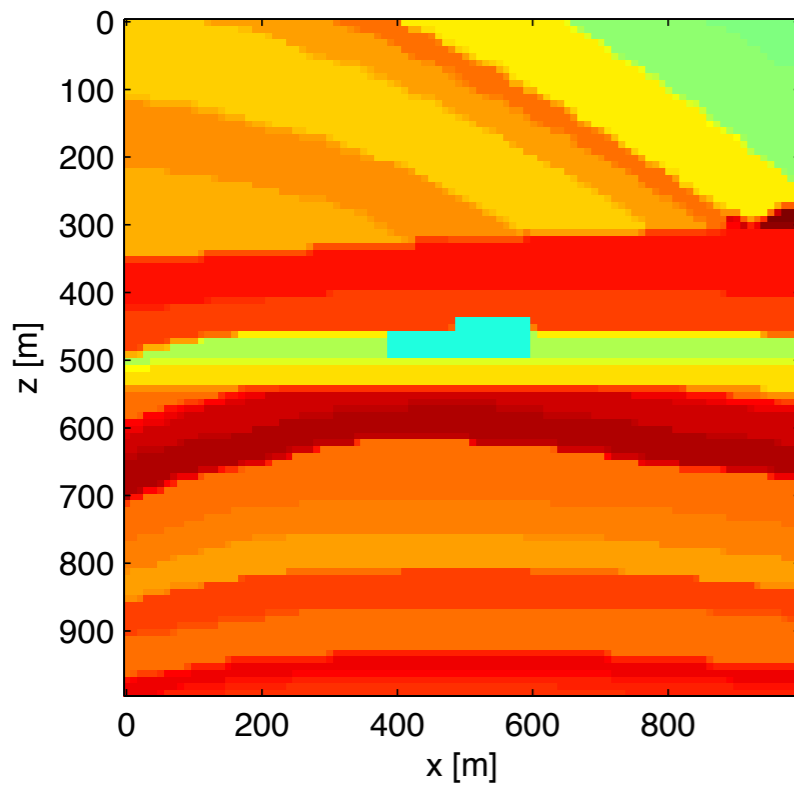
perturbation



Monitor, smooth background and perturbation

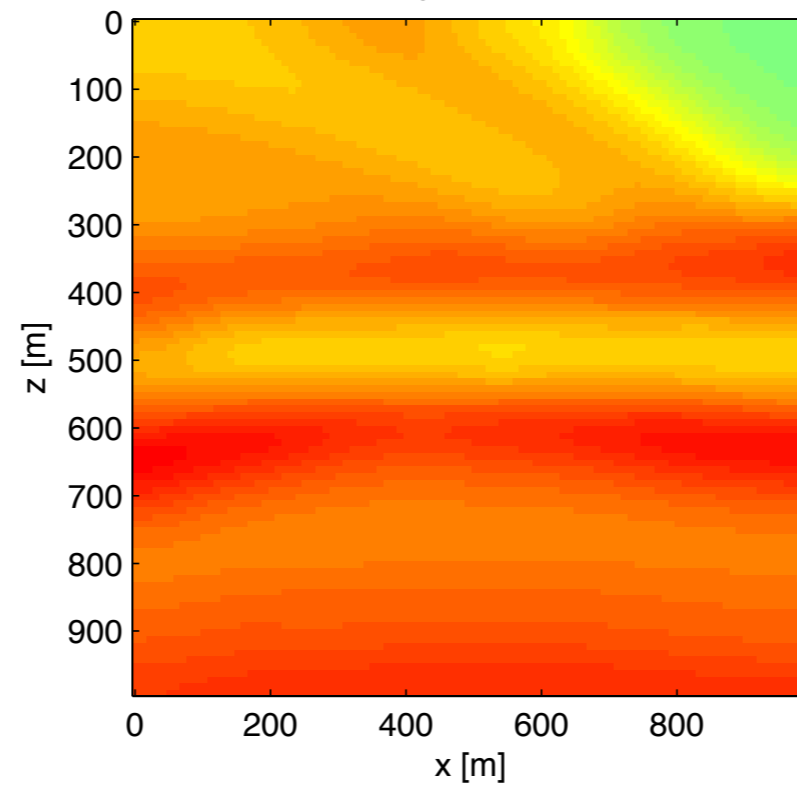
Monitor

monitor [m/s]



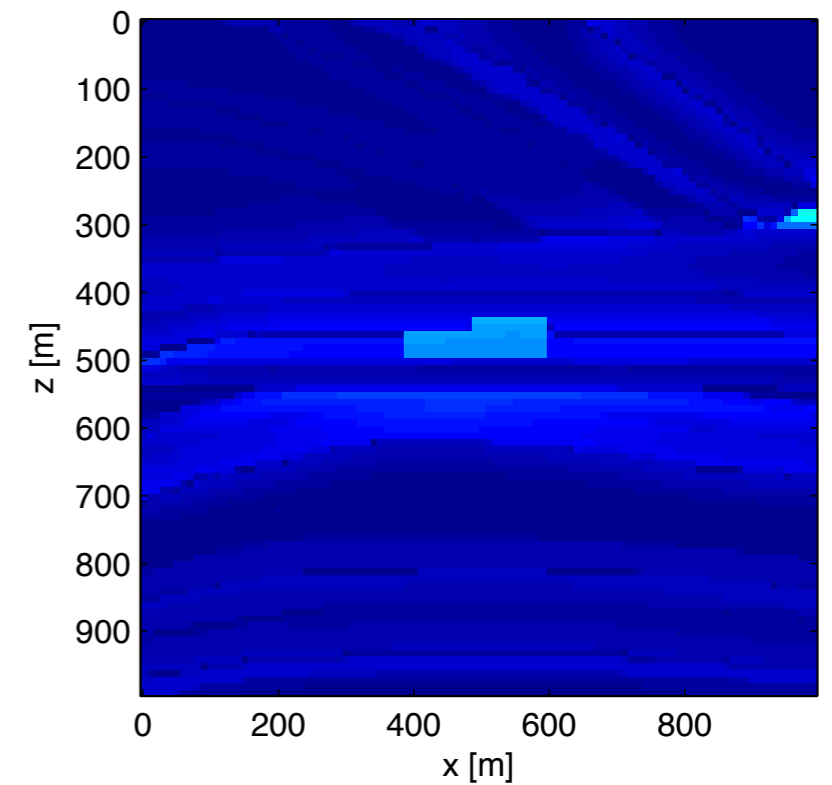
background

background [m/s]



perturbation

perturbation [m/s]



Some modeling parameters

- Number of shot points 50
- Number of receivers 100
- Frequencies 5,10, 15, and 20Hz
- 1km X 1 km grid for velocity model

Imaging

- Since the background velocity doesn't change
- Let m_0 , m_b , and m_m represent the *slowness* for the smooth background, baseline and monitor velocity models respectively

slowness (s^2/m^2) is defined as $\frac{1e6}{v^2}$ where v is the velocity.

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 all at the same scale

F is the forward modeling operator

Data acquisition

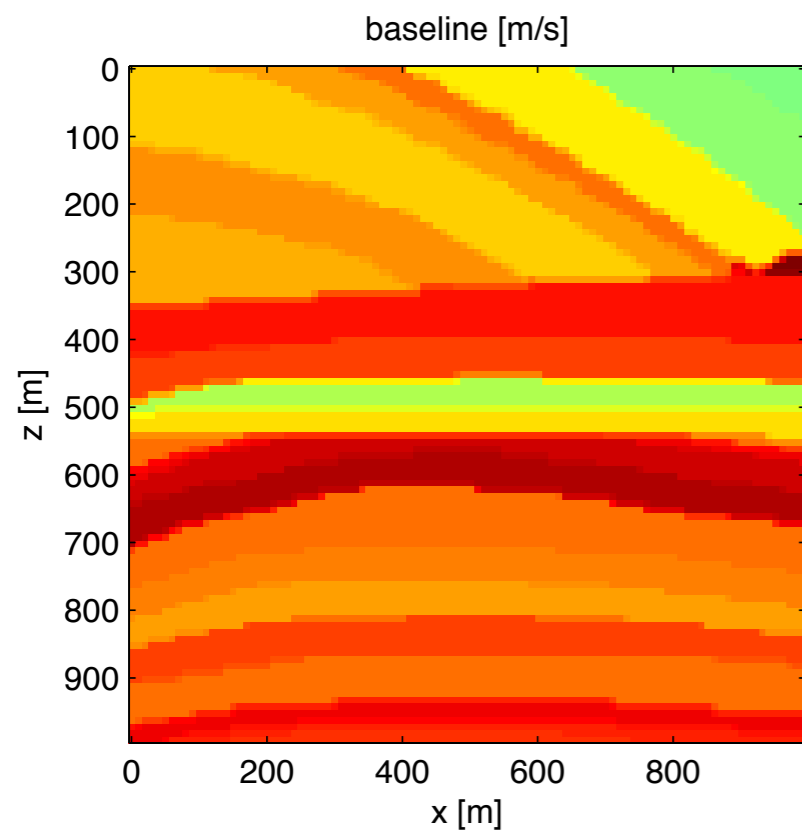
- Case 1 – data is *fully* sampled during *baseline* and *monitor* surveys
- Case 2 – data is *randomly* sampled as proposed by Compressed Sensing
- Consider three scenarios for each

Scenario 1

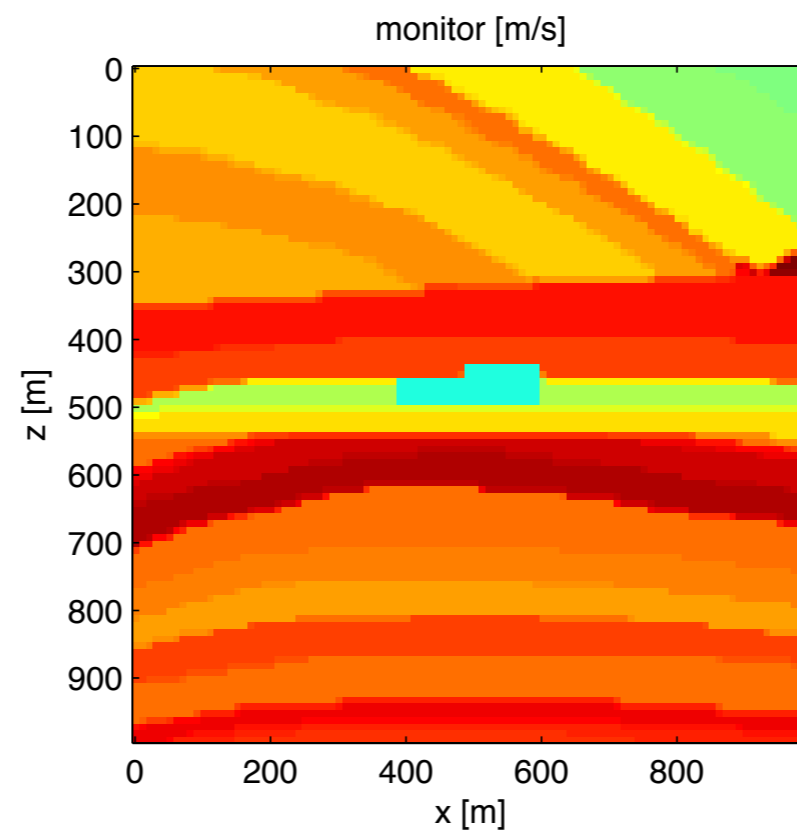
- When there is a 4D change, what happens when we *repeat* the sampling for both *baseline* and *monitor* surveys as a function of receiver spacing and position?

Velocity Model - with a 4D change

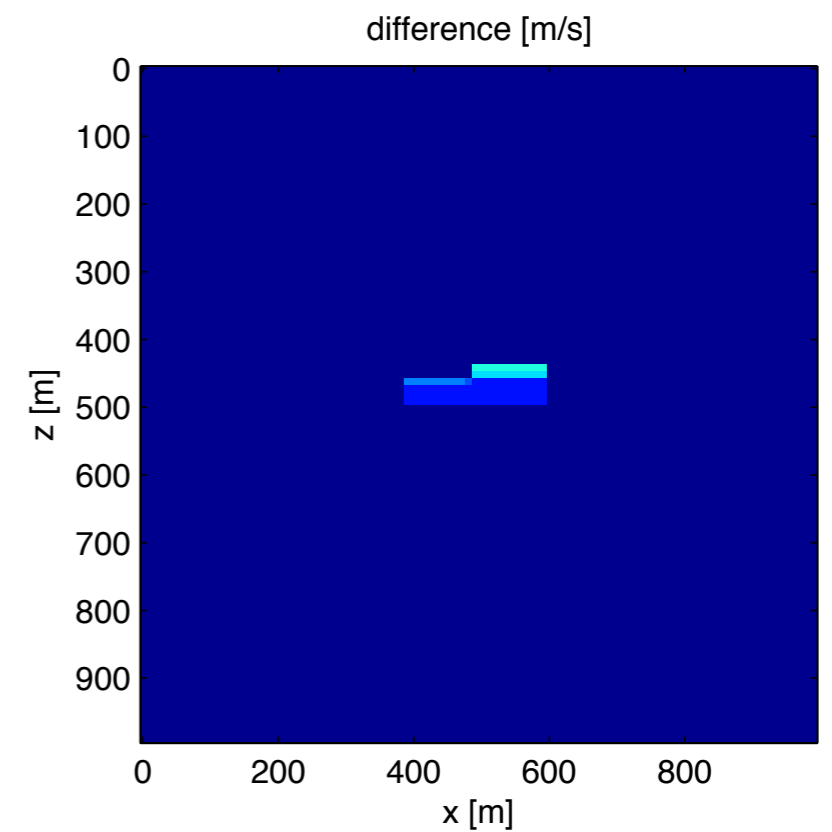
baseline



monitor



difference



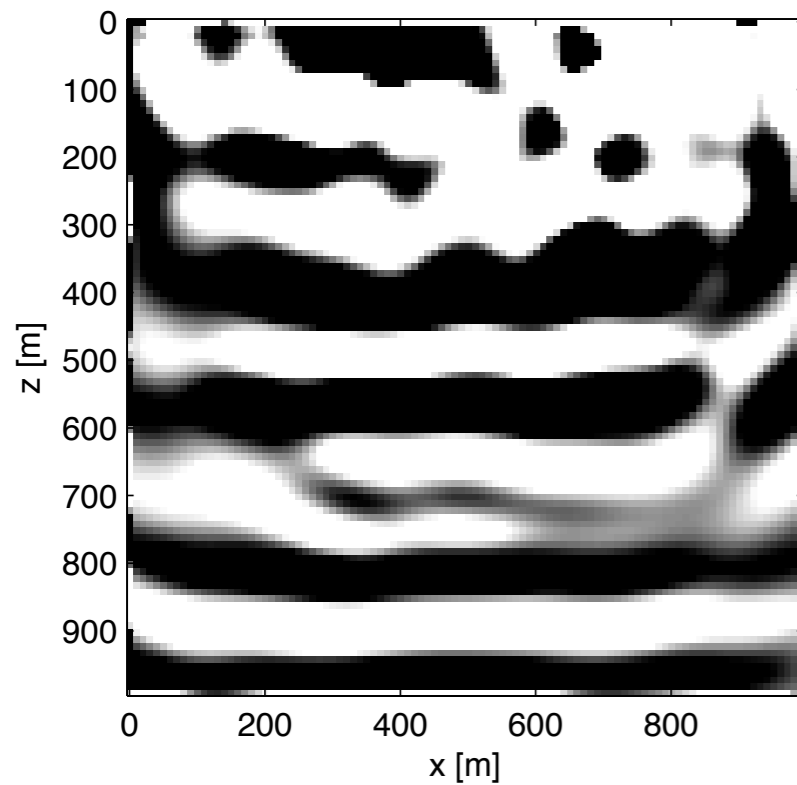
observe the 4D change, all plots at the same colour scale

Periodic sampling

baseline at 10m, monitor at 10m

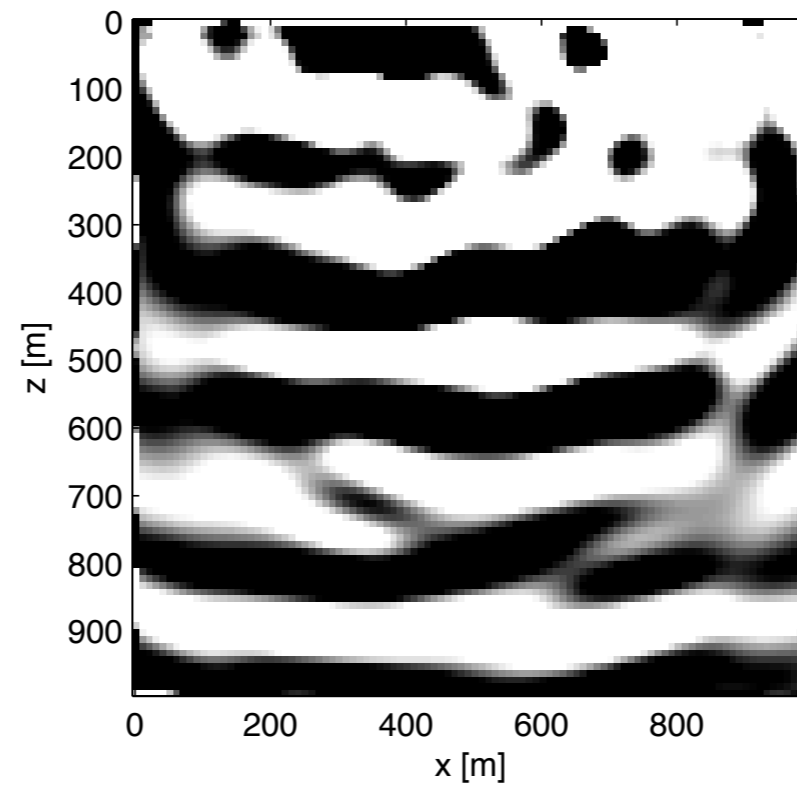
baseline

D0



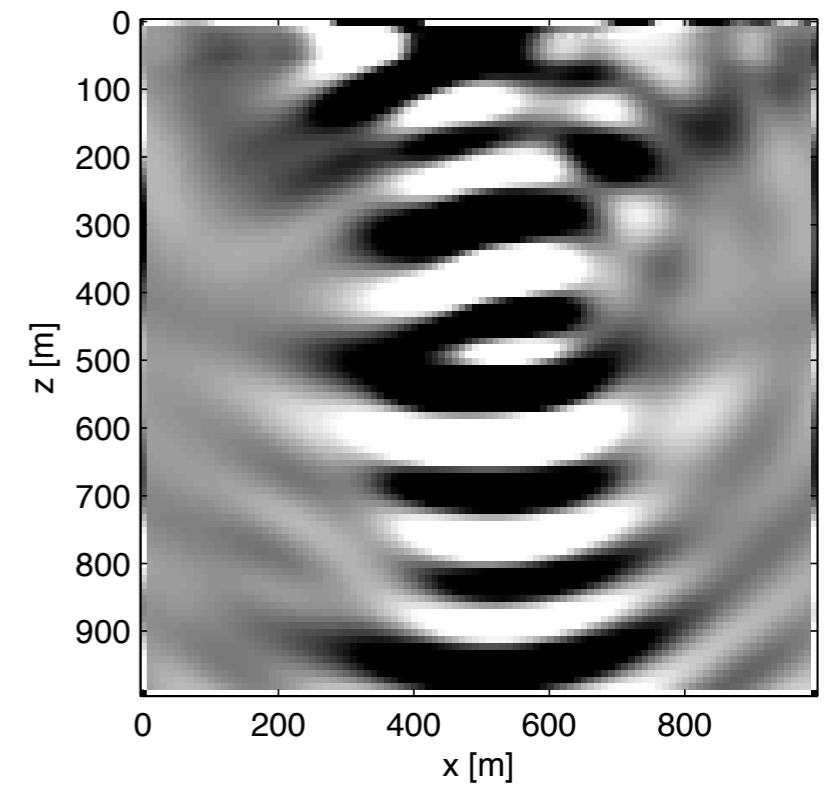
monitor

D1



difference

D0-D1



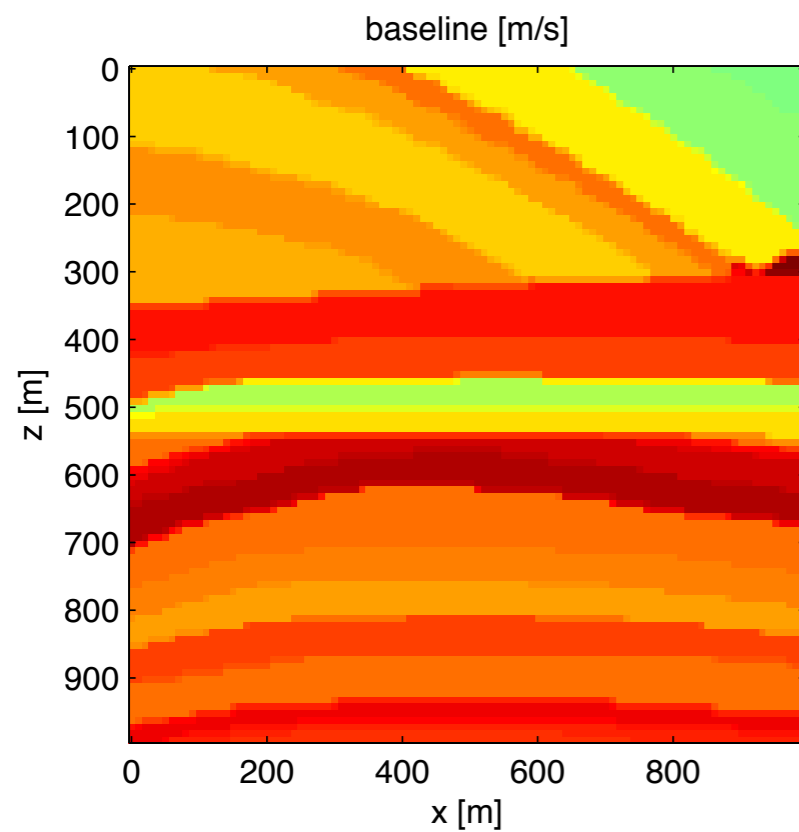
this emphasizes the importance of repetition

Scenario 2

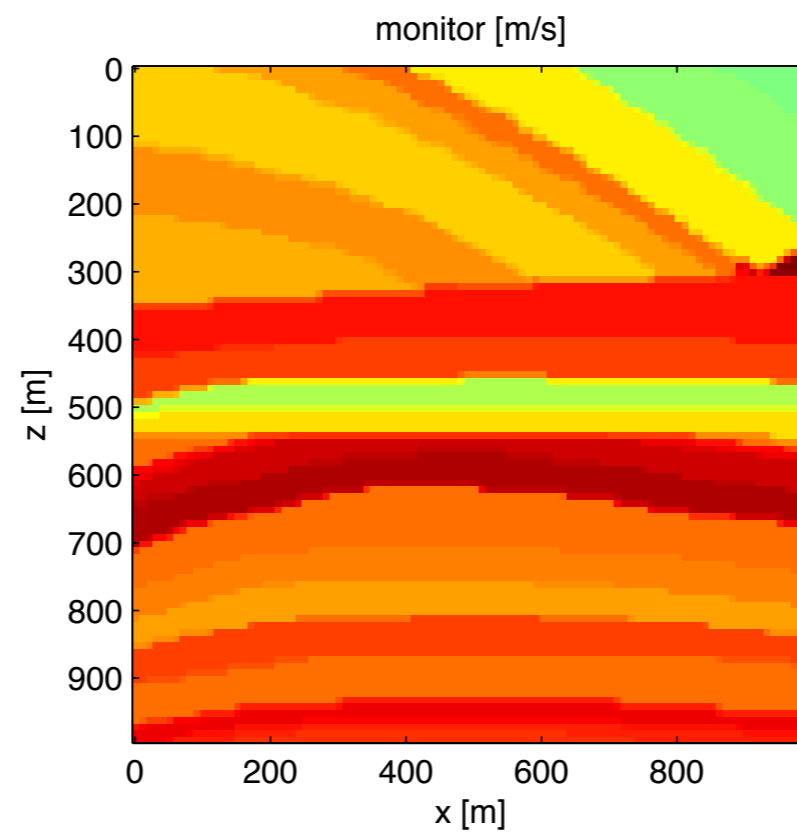
- When there is *no* 4D change, what happens, if we do *not* repeat the *sampling* for *both* *baseline* and *monitor* surveys?

Velocity Model - with no 4D change

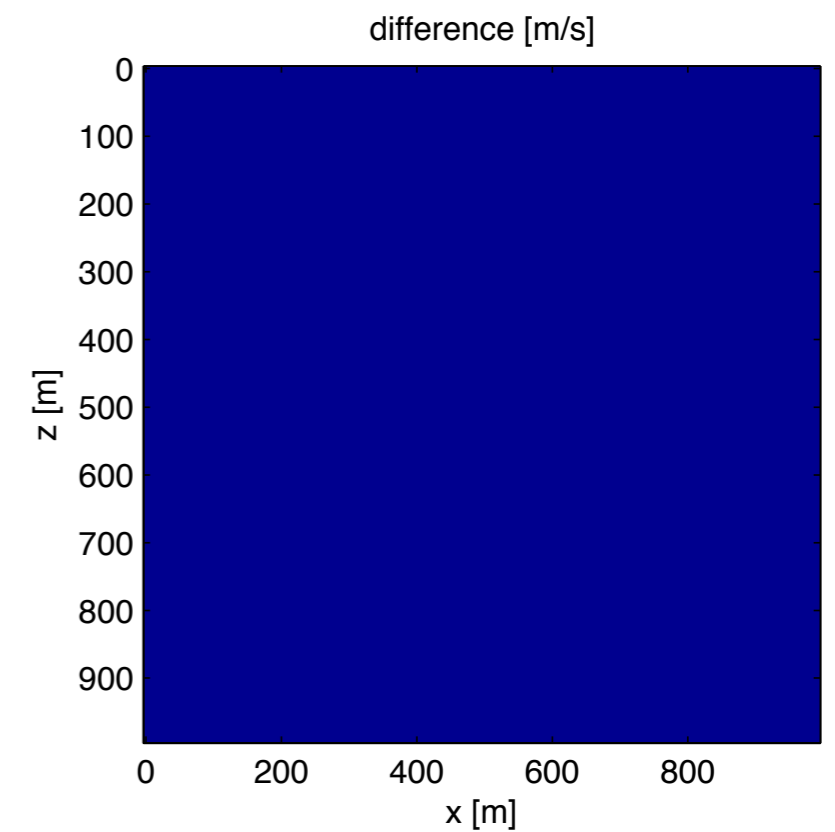
baseline



monitor



difference

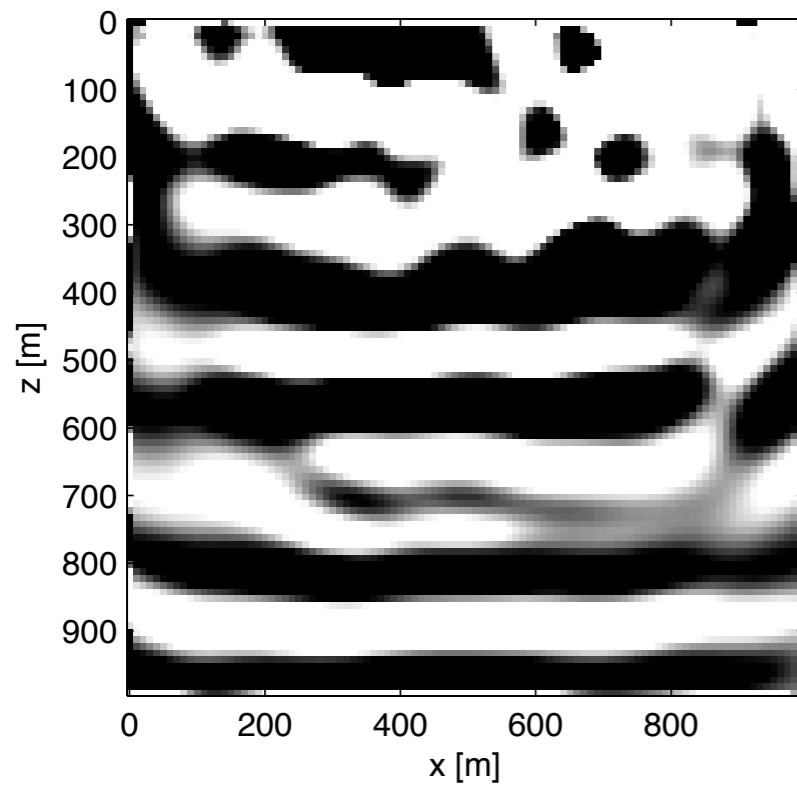


Periodic sampling

baseline at 10m , monitor at 5m

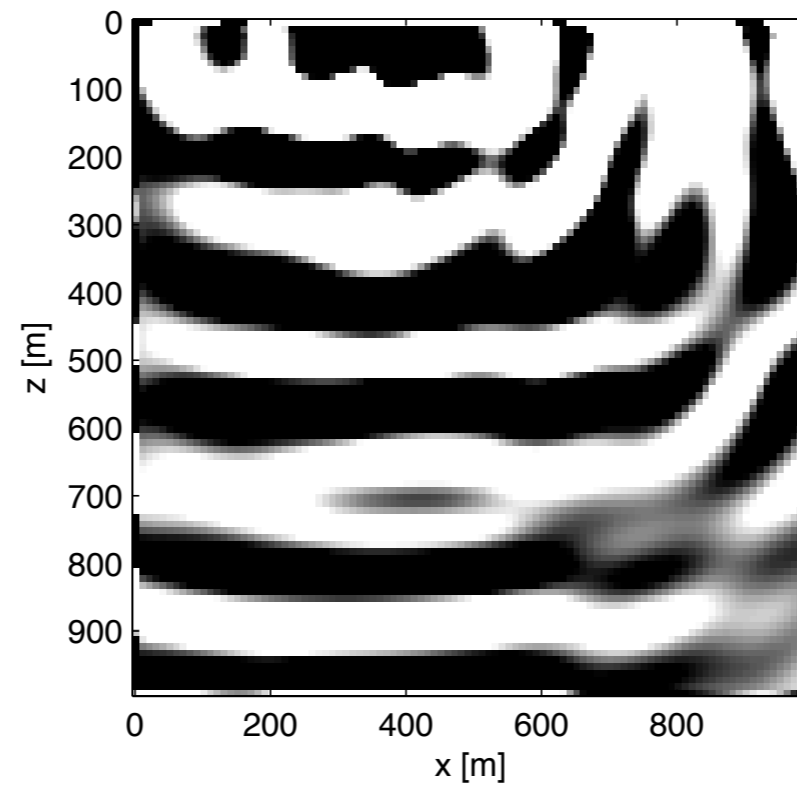
baseline

D0



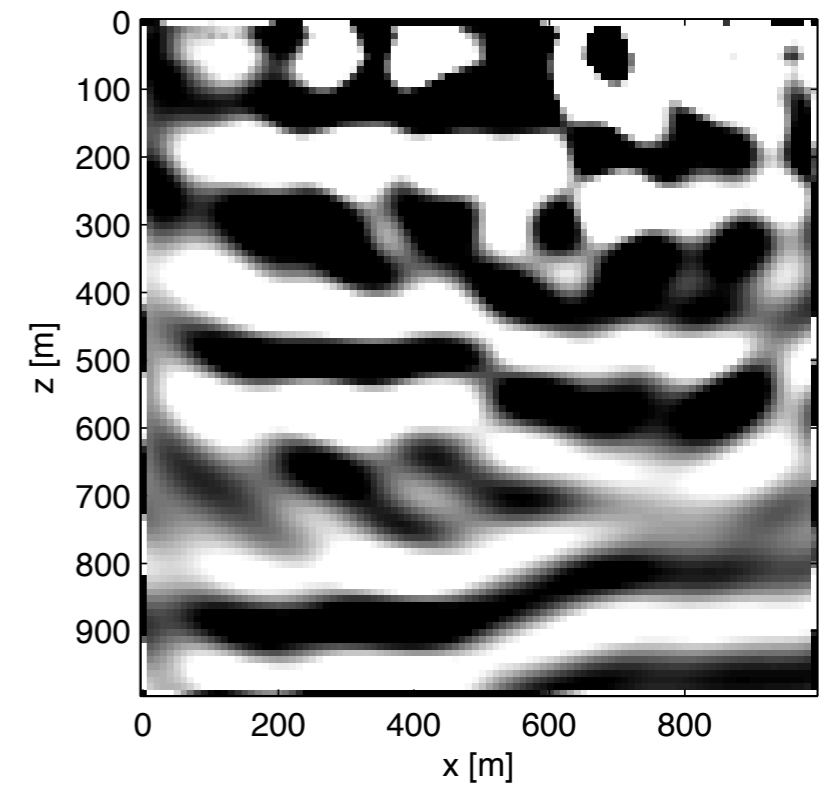
monitor

D1



difference

D0-D1

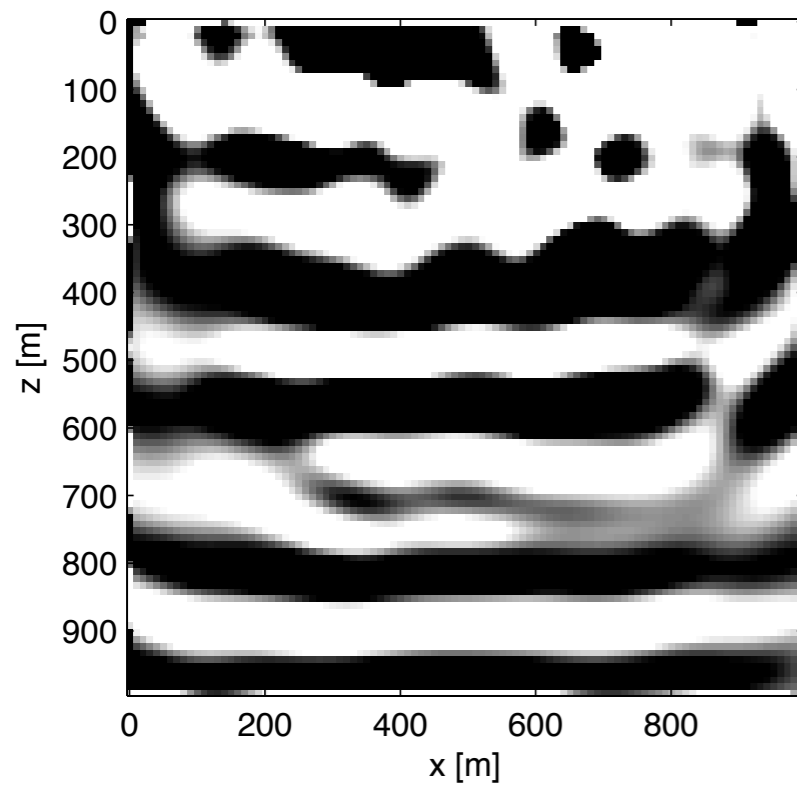


Periodic sampling

baseline at 10m, monitor at another 5m

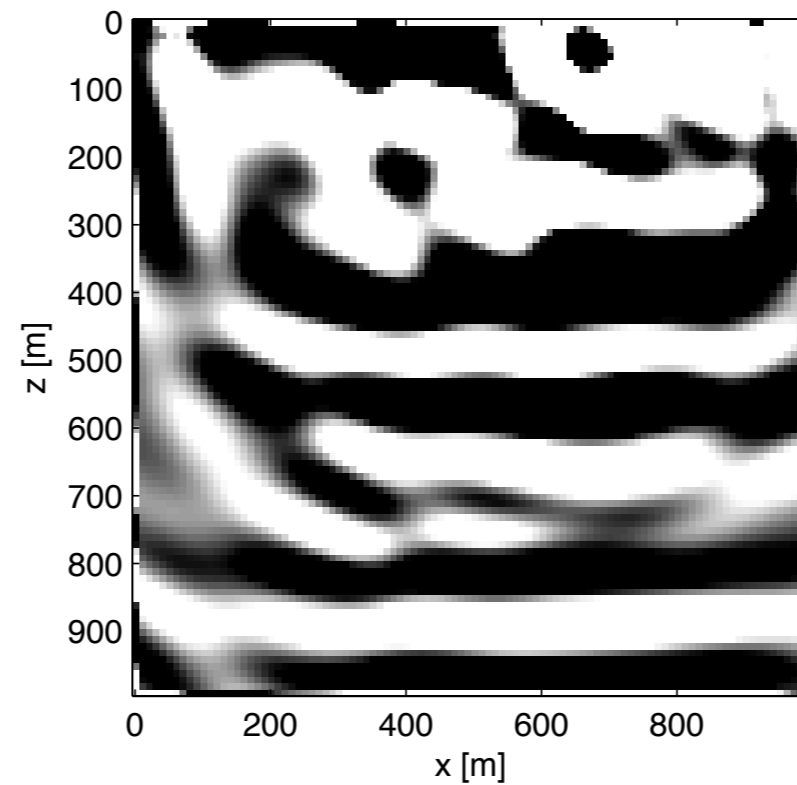
baseline

D0



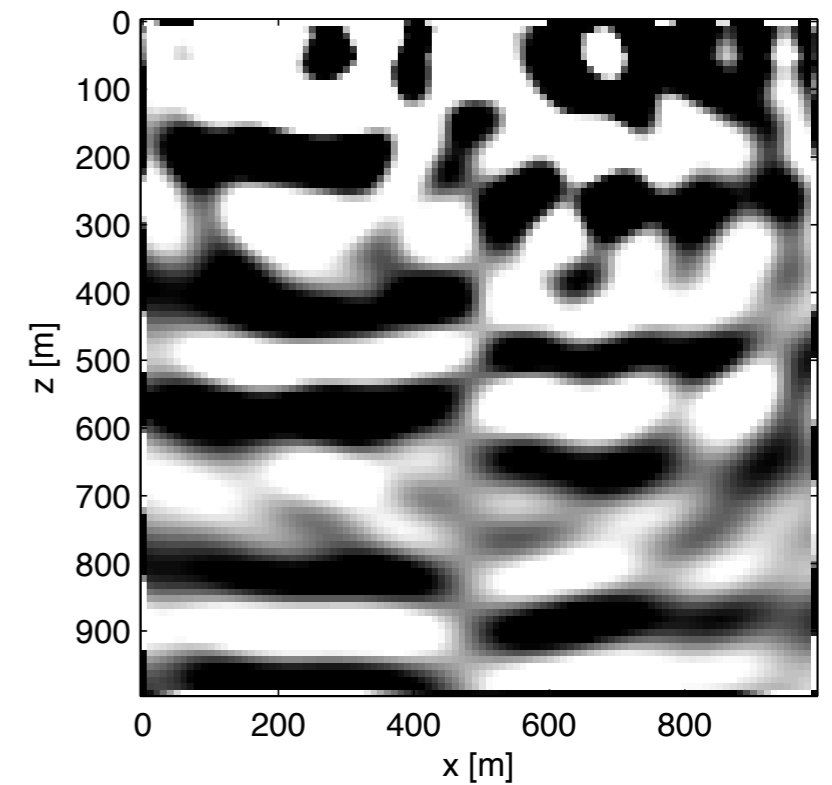
monitor

D1



difference

D0-D1



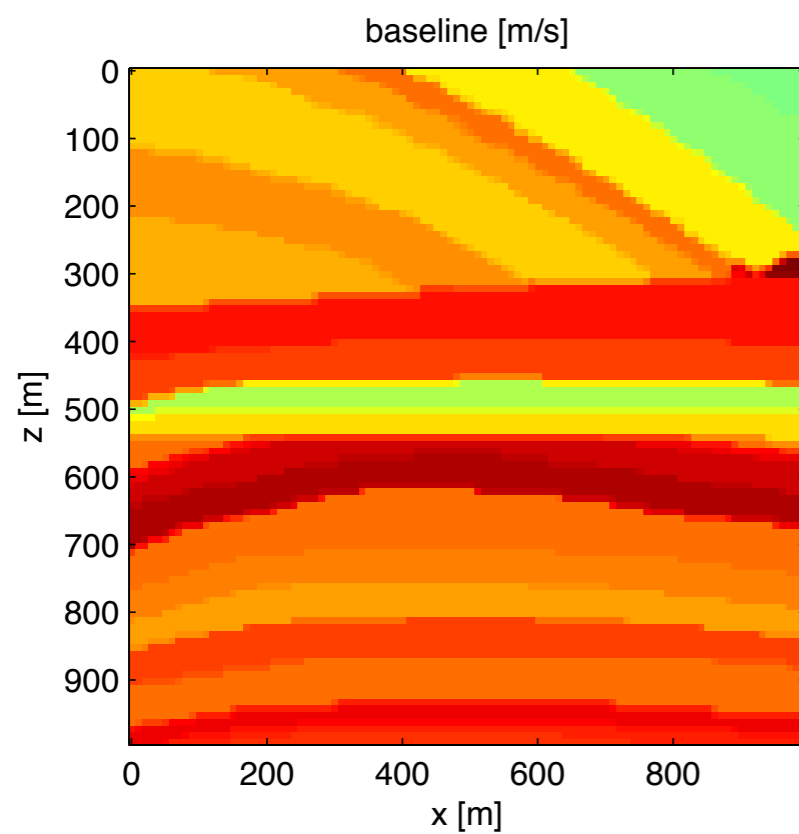
we see acquisition imprints, despite no fluid changes

Scenario 3

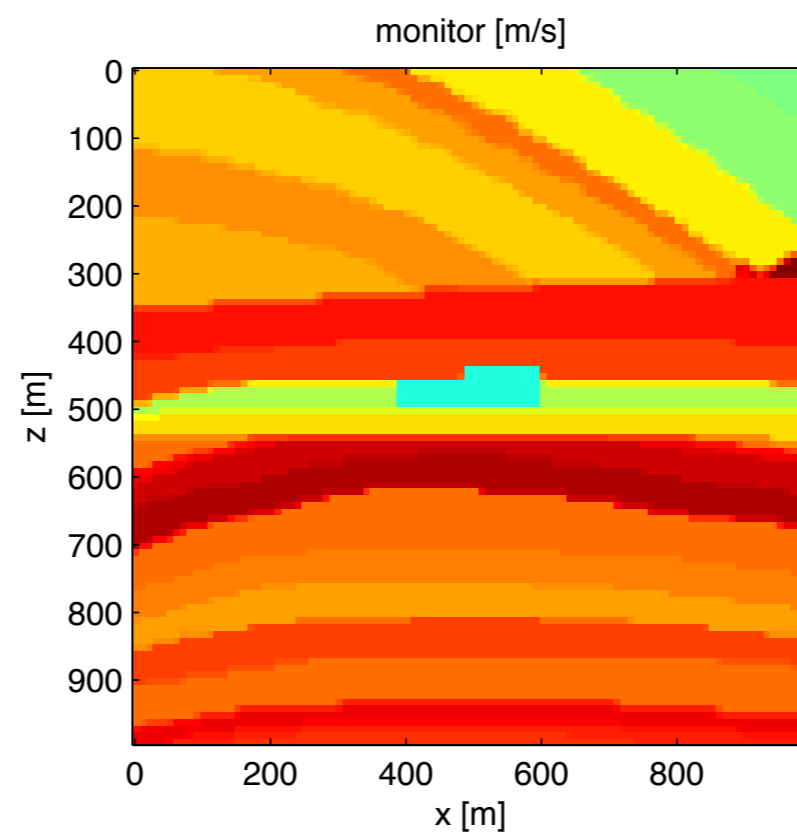
- When there is a 4D change, what happens when we do *not* repeat the sampling for both *baseline* and *monitor* surveys?

Velocity Model - with a 4D change

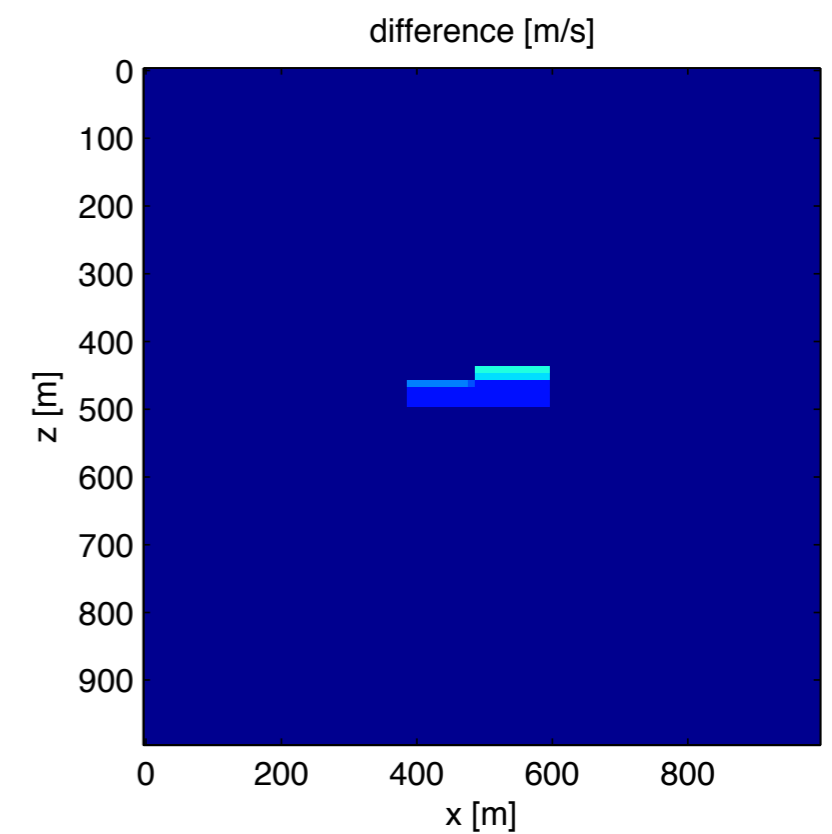
baseline



monitor



difference

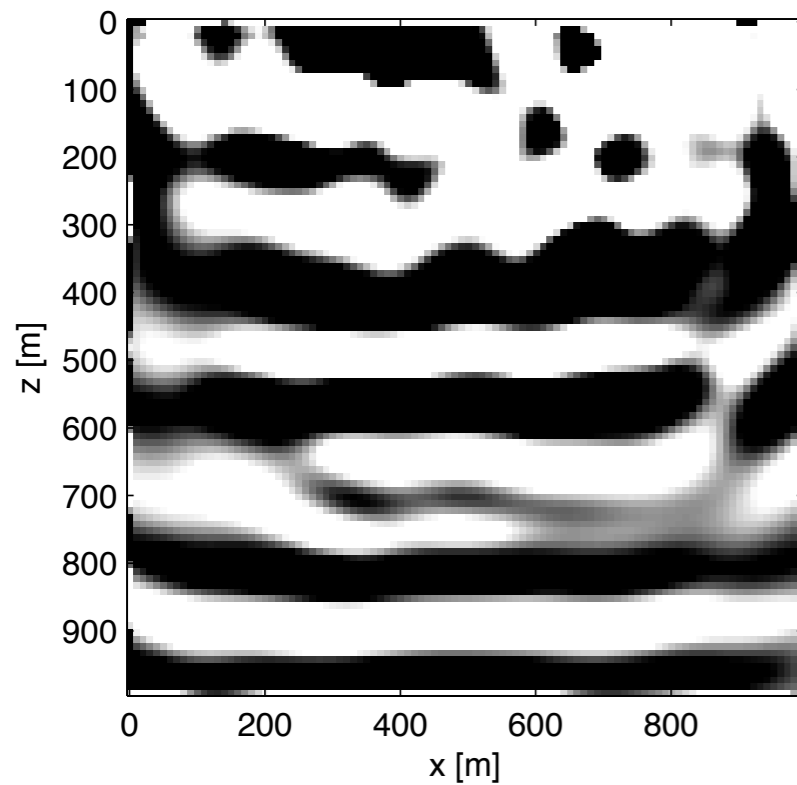


Periodic sampling

baseline at 10m, monitor at 5m

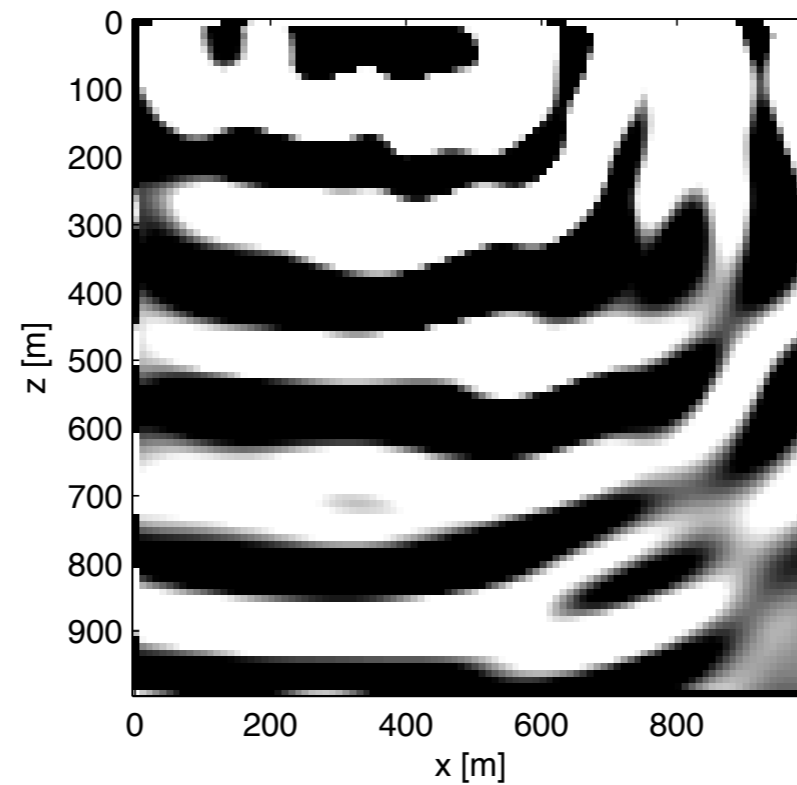
baseline

D0



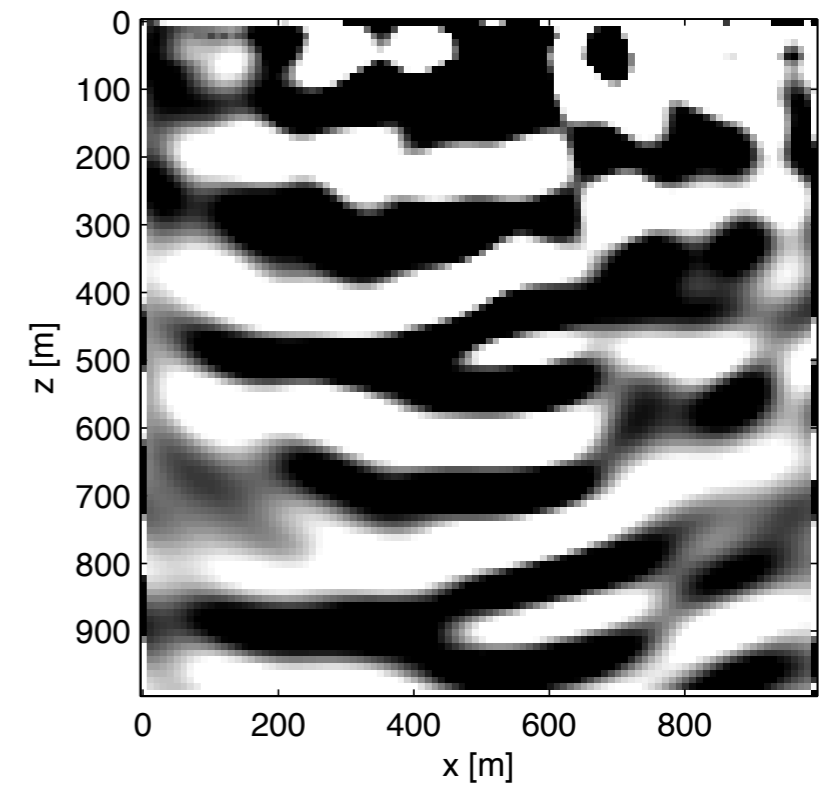
monitor

D1



difference

D0-D1



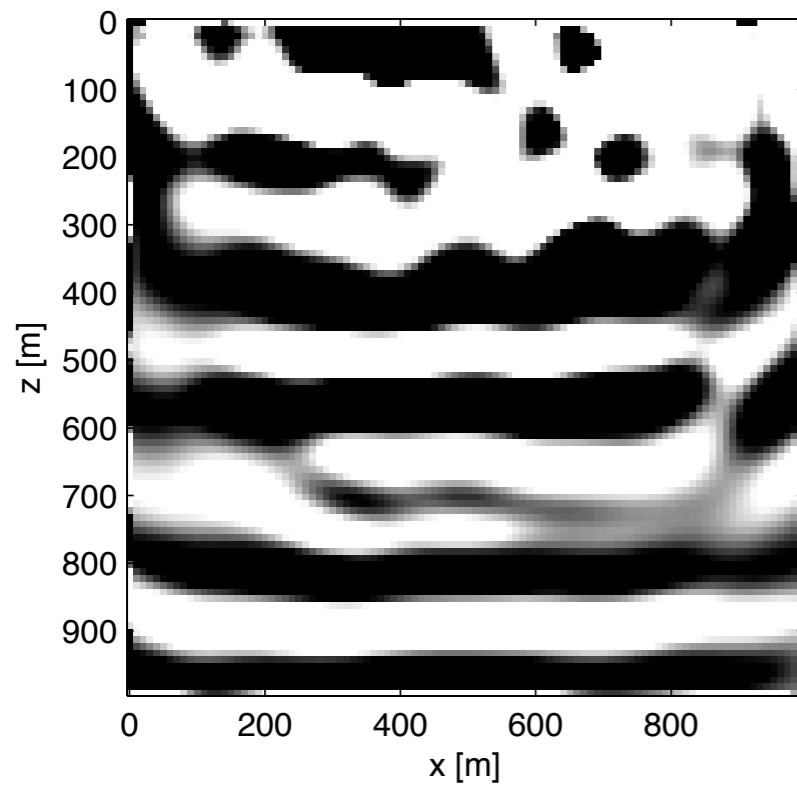
we see acquisition imprints, together with fluid changes

Periodic sampling

baseline at 10m, monitor at another 5m

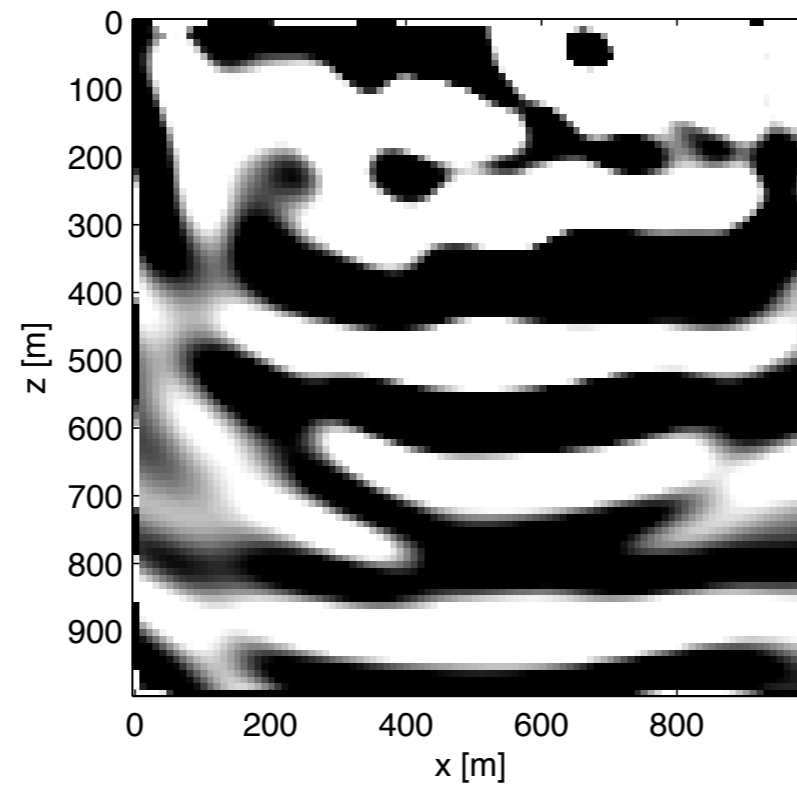
baseline

D0



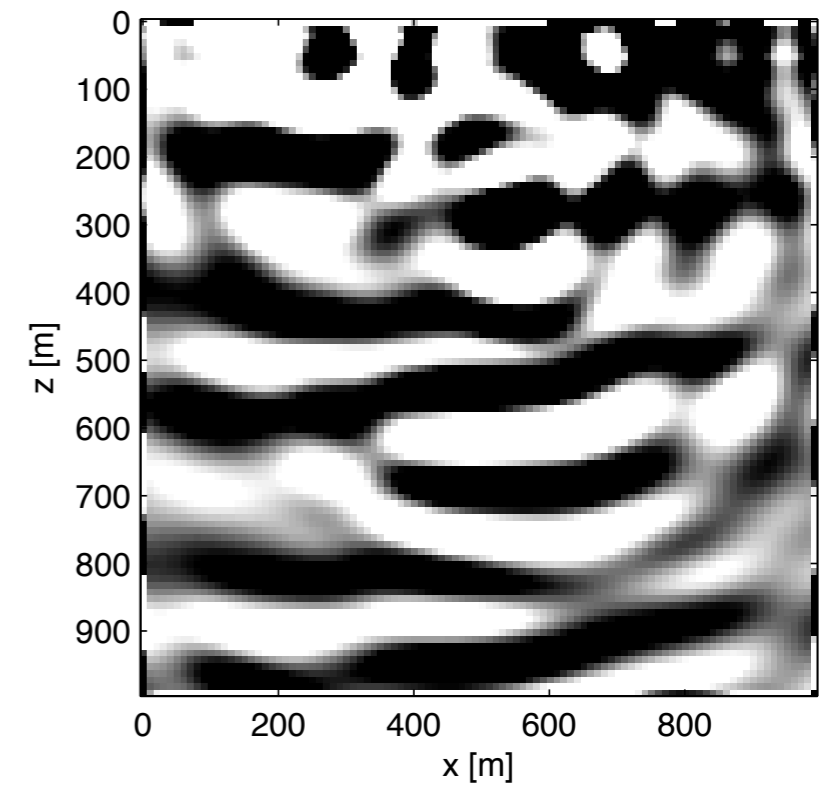
monitor

D1



difference

D0-D1



overlap of fluid change effect and acquisition effect

Randomized sampling

- Again, we shall look at the three scenarios shown for fully periodic sampling
- We shall show results as sampling ratio increases

Scenario 1

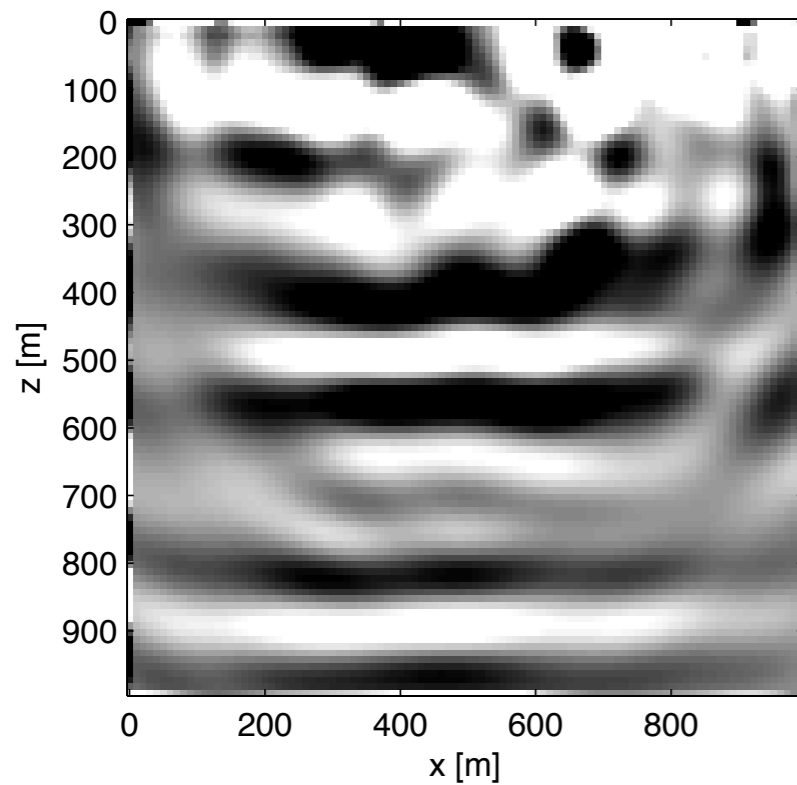
- When there is a 4D change, what happens if we repeat the *randomized* sampling for both *baseline* and *monitor* surveys?

Randomized sampling

25% sampling

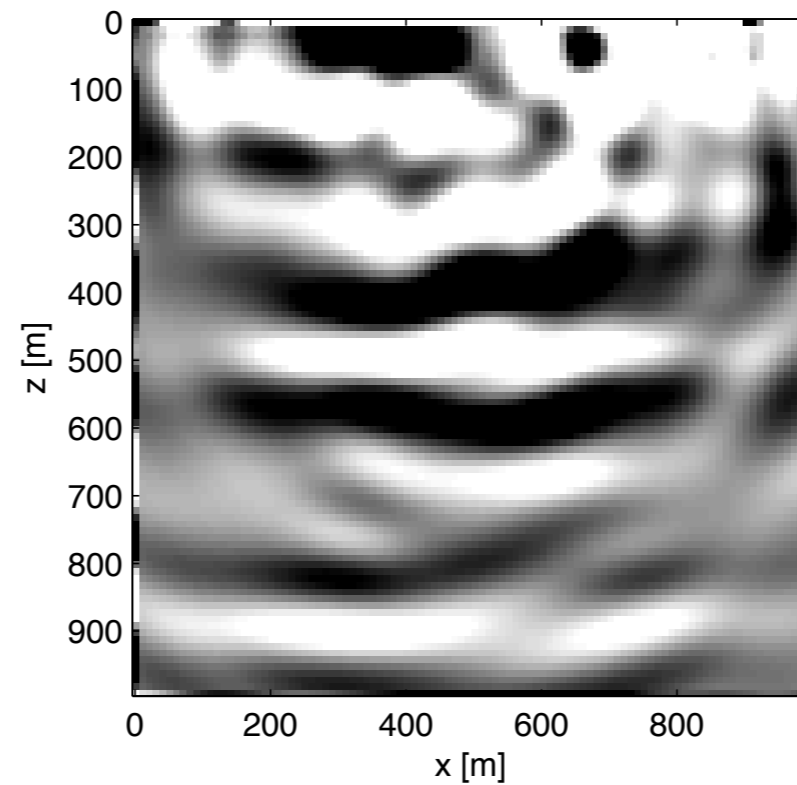
baseline

D0



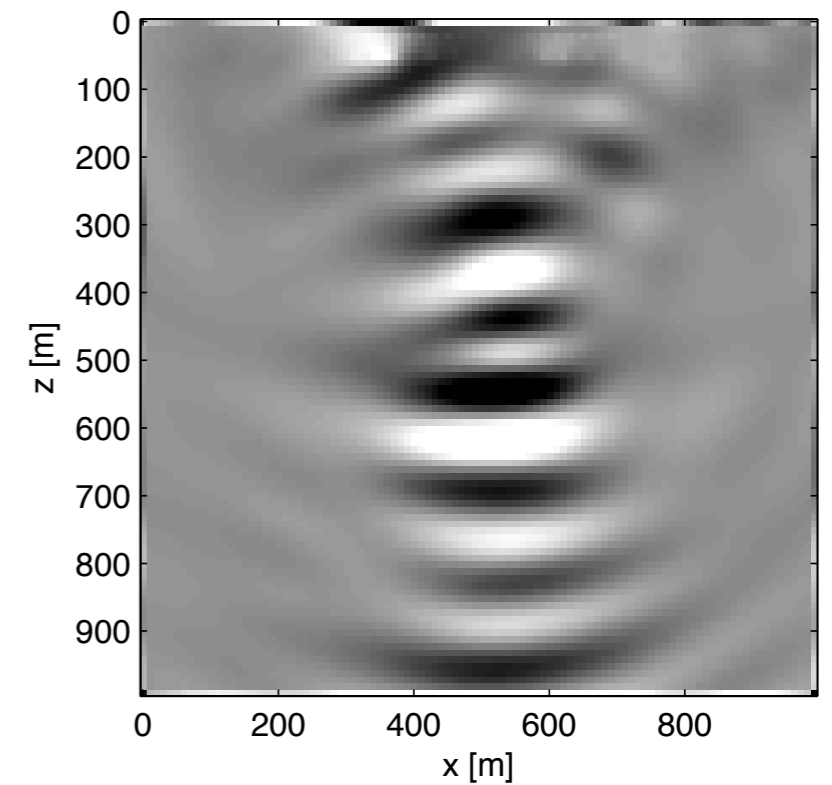
monitor

D1



difference

D0-D1

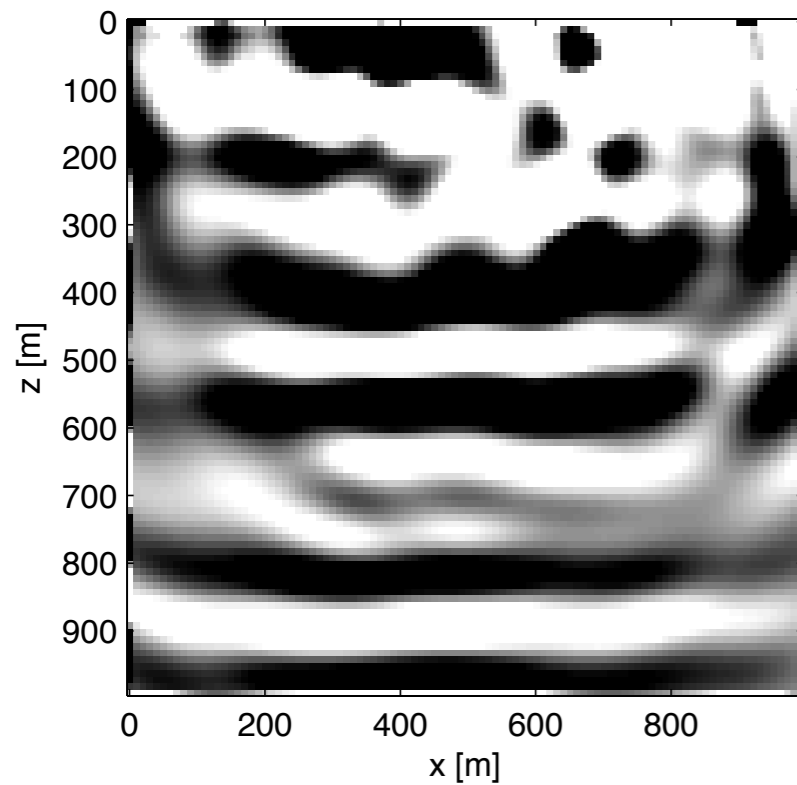


Randomized sampling

50% sampling

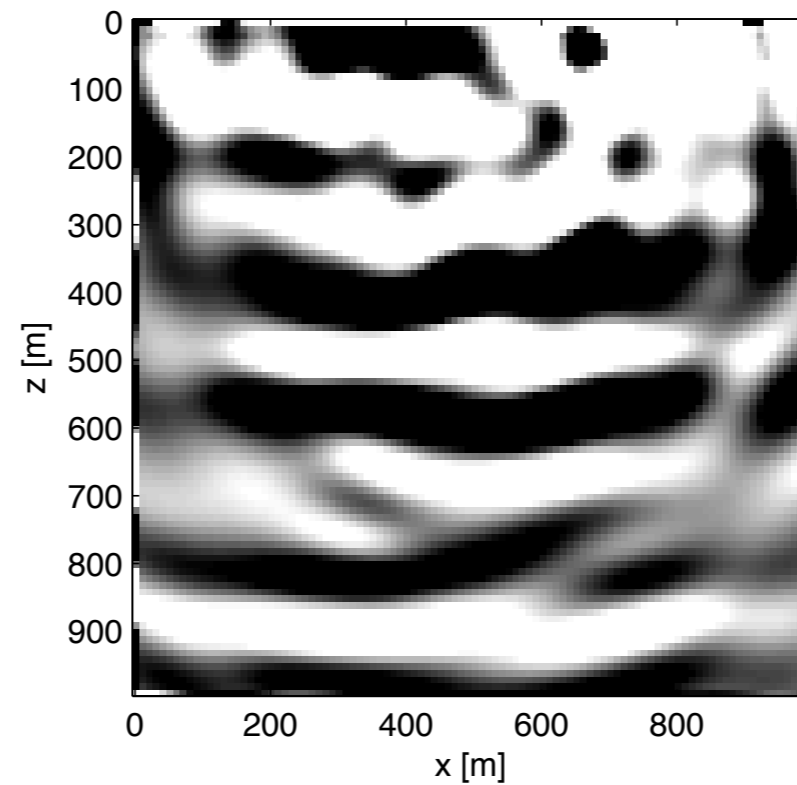
baseline

D0



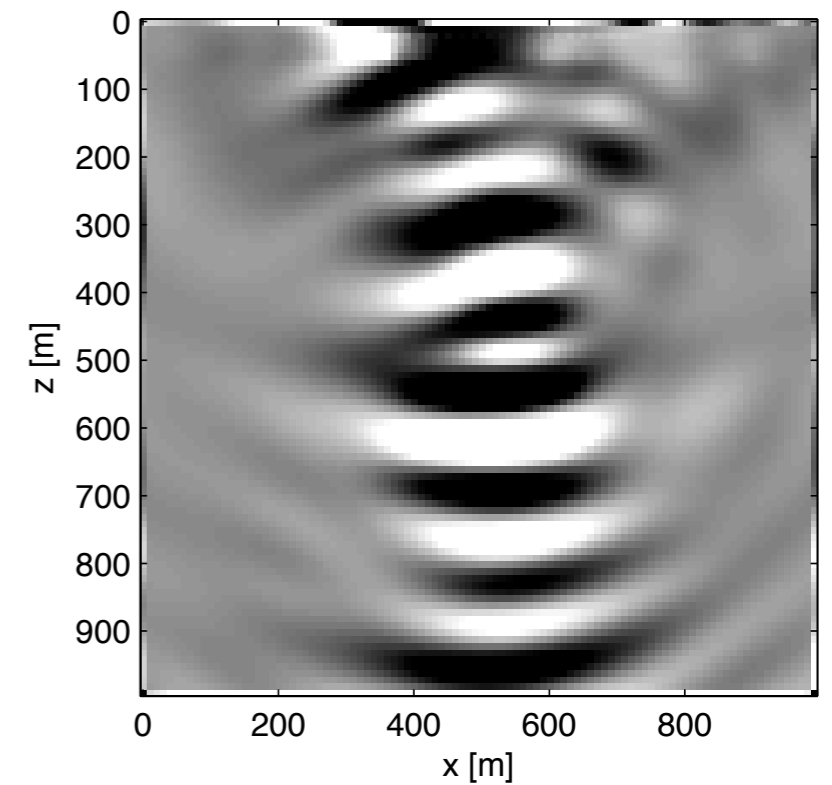
monitor

D1



difference

D0-D1

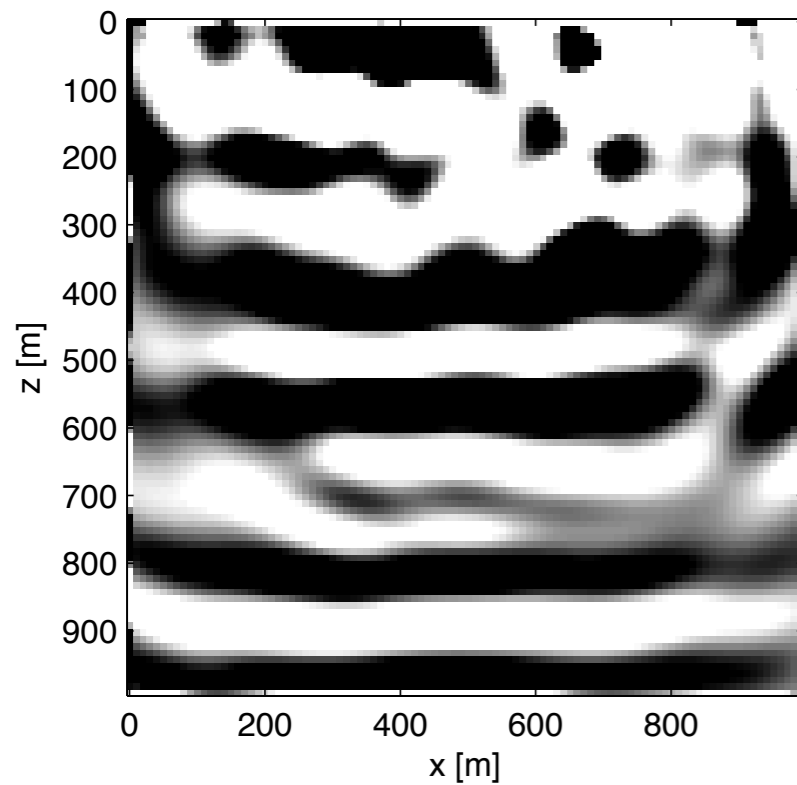


Randomized sampling

75% sampling

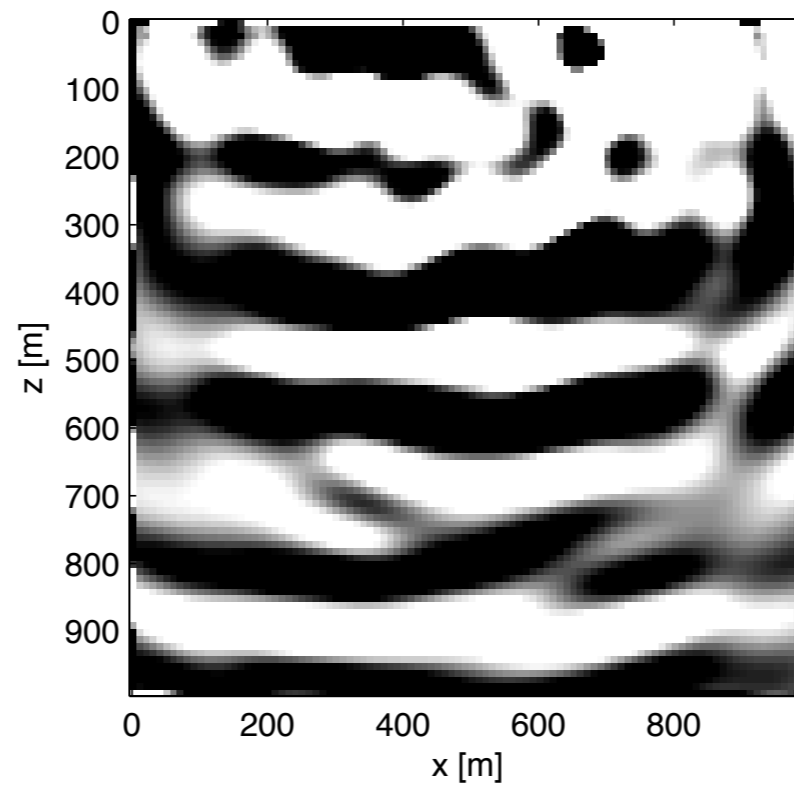
baseline

D0



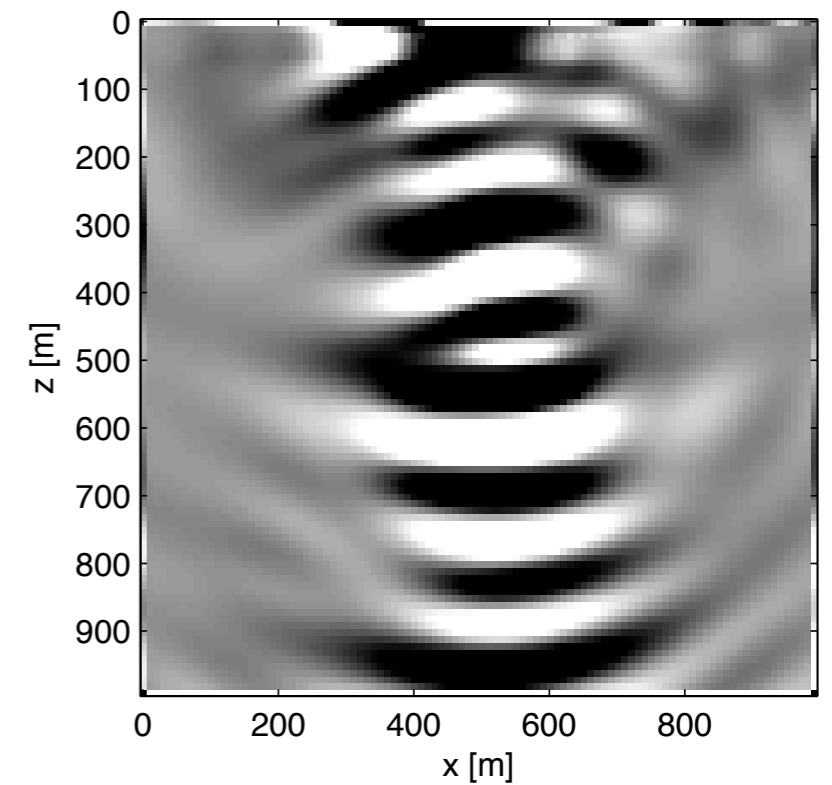
monitor

D1



difference

D0-D1



clearly we can resolve the 4D change

Scenario 2

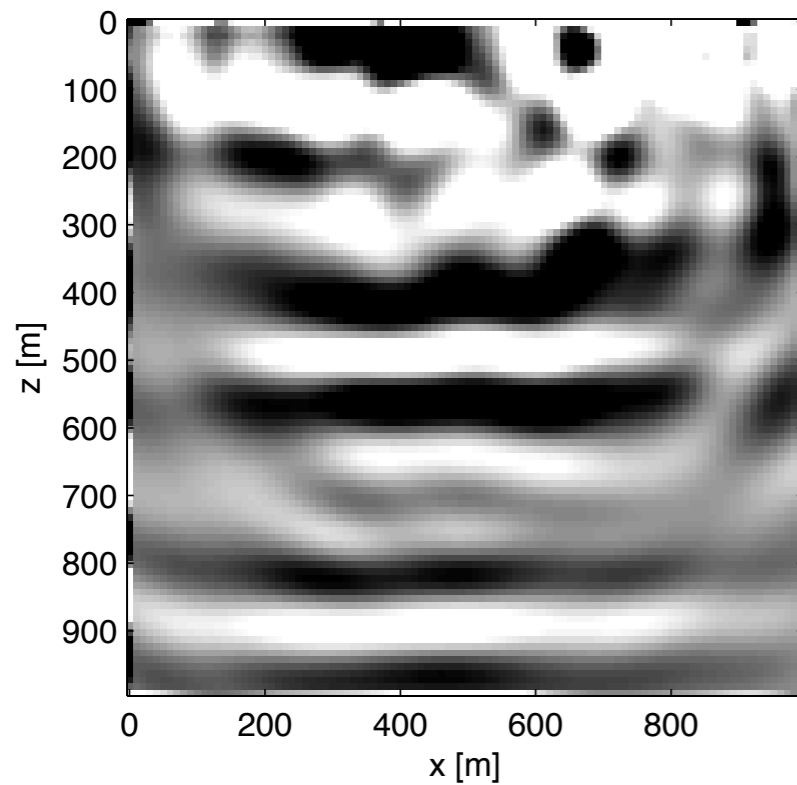
- When there is no 4D change, what happens if we do *not* repeat the *randomized* sampling for both *baseline* and *monitor* surveys?

Randomized sampling

25% sampling

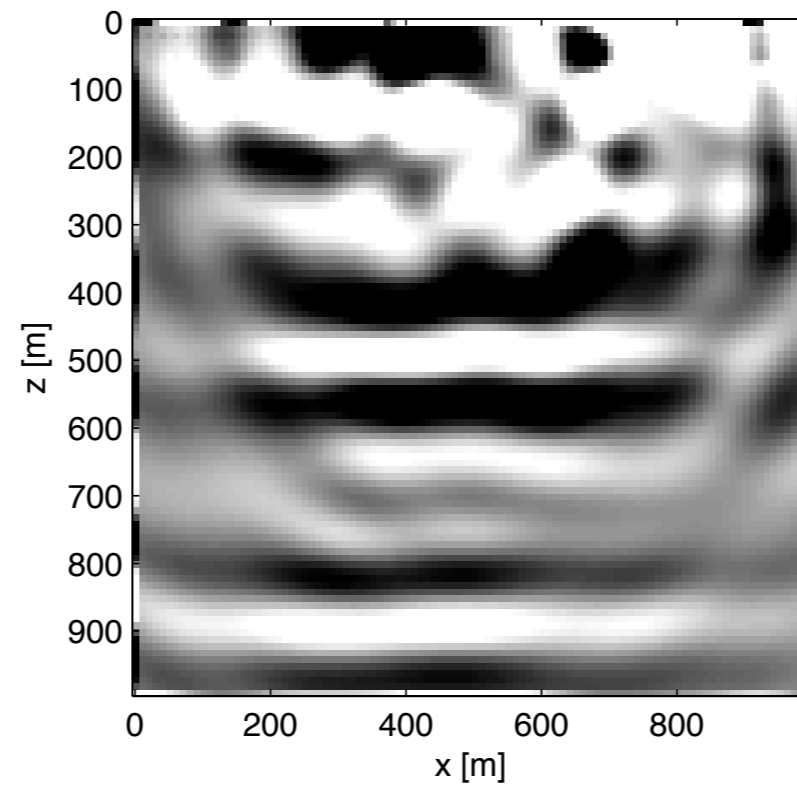
baseline

D0



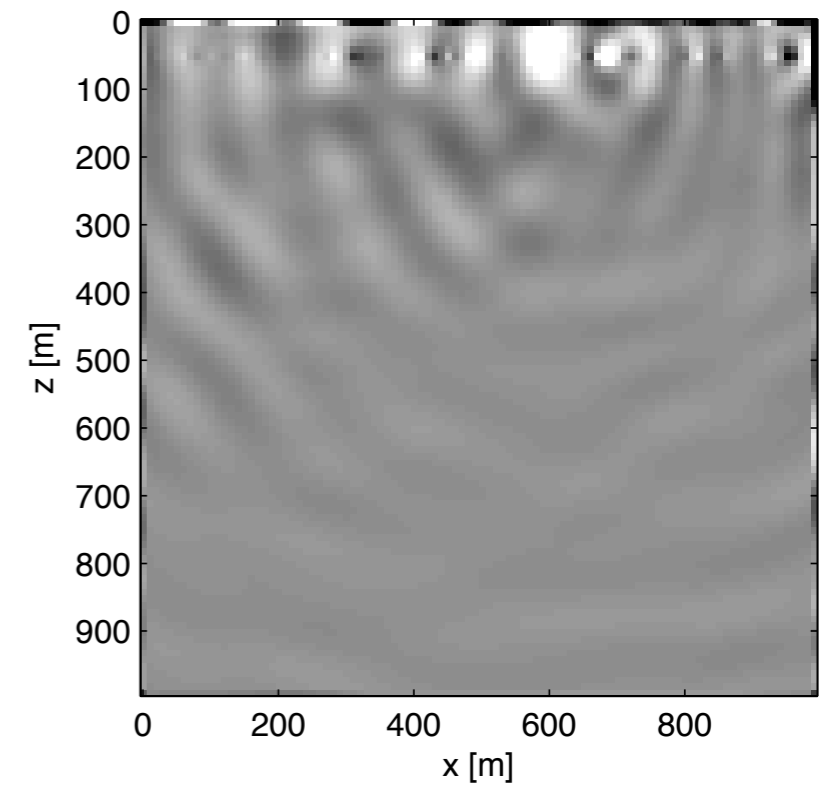
monitor

D1



difference

D0-D1

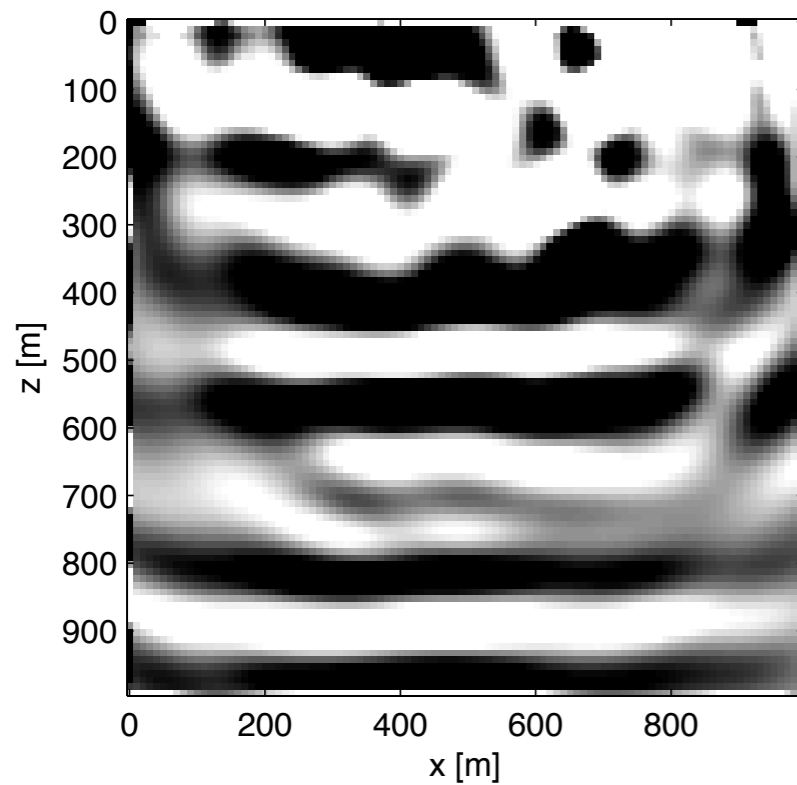


Randomized sampling

50% sampling

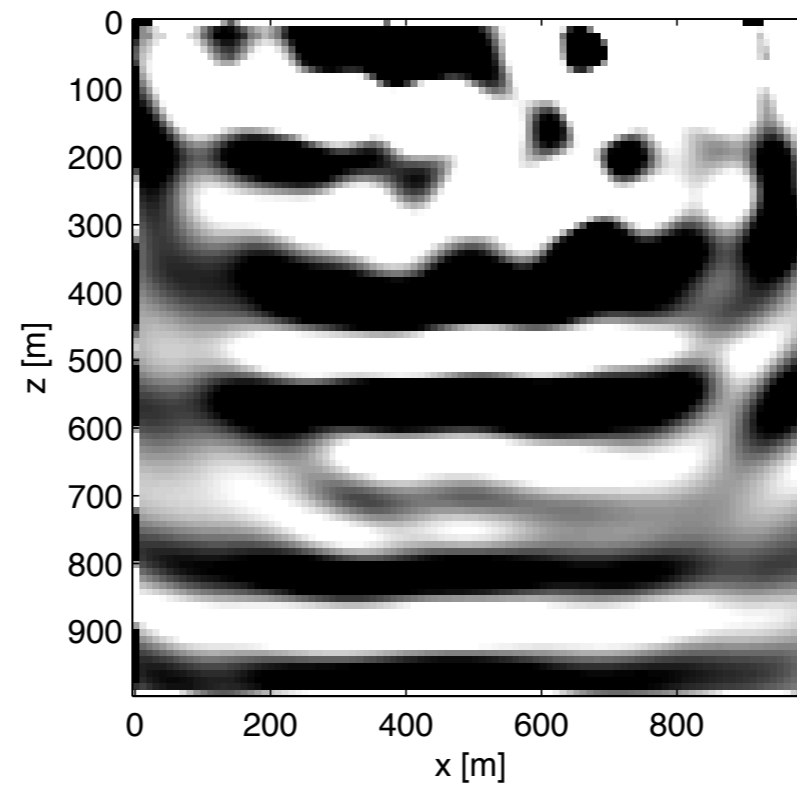
baseline

D0



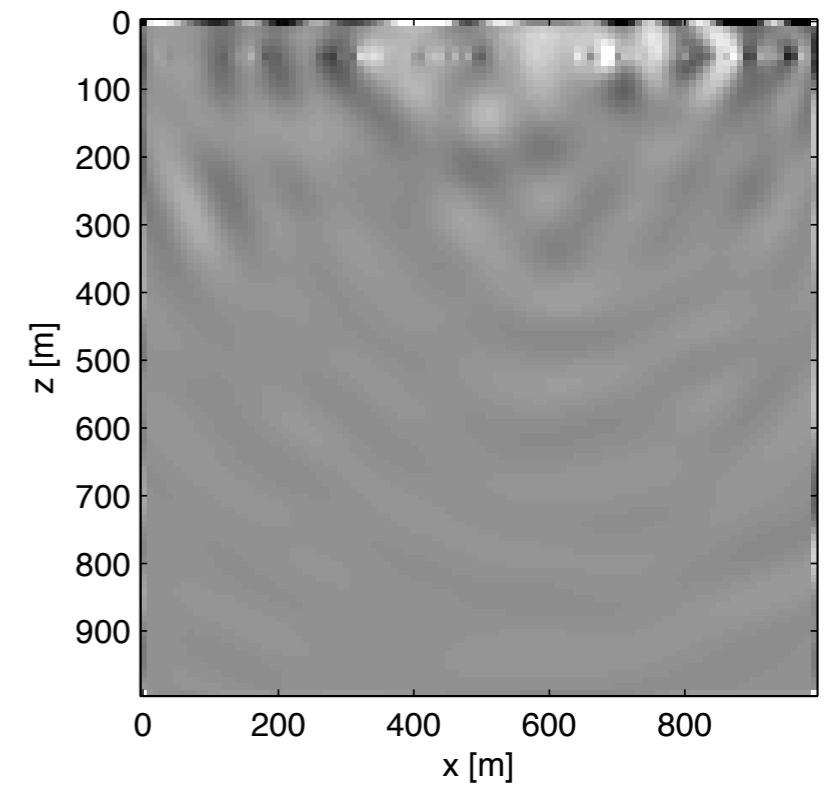
monitor

D1



difference

D0-D1

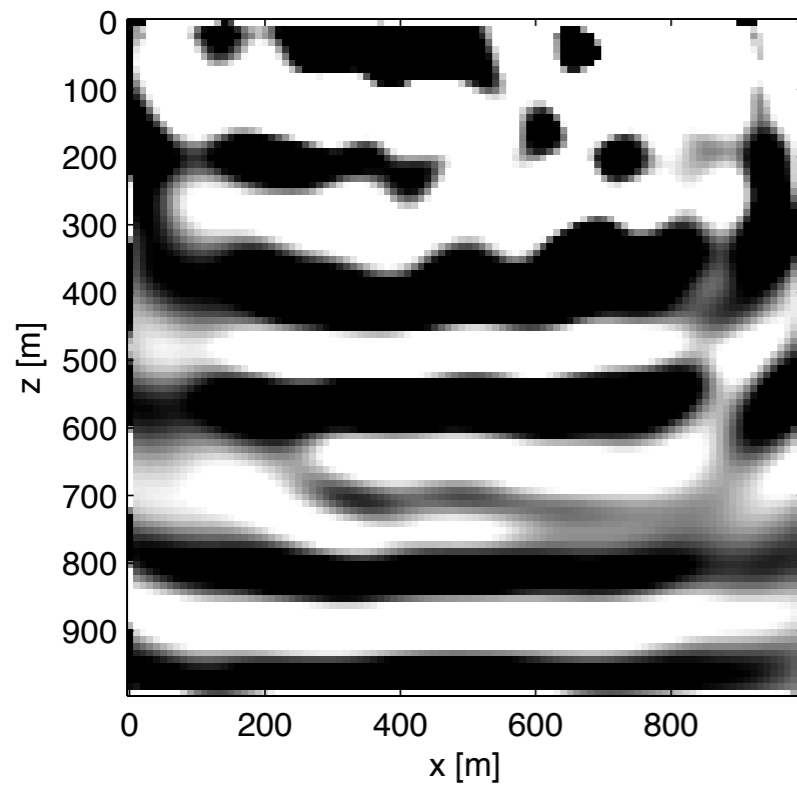


Randomized sampling

75% sampling

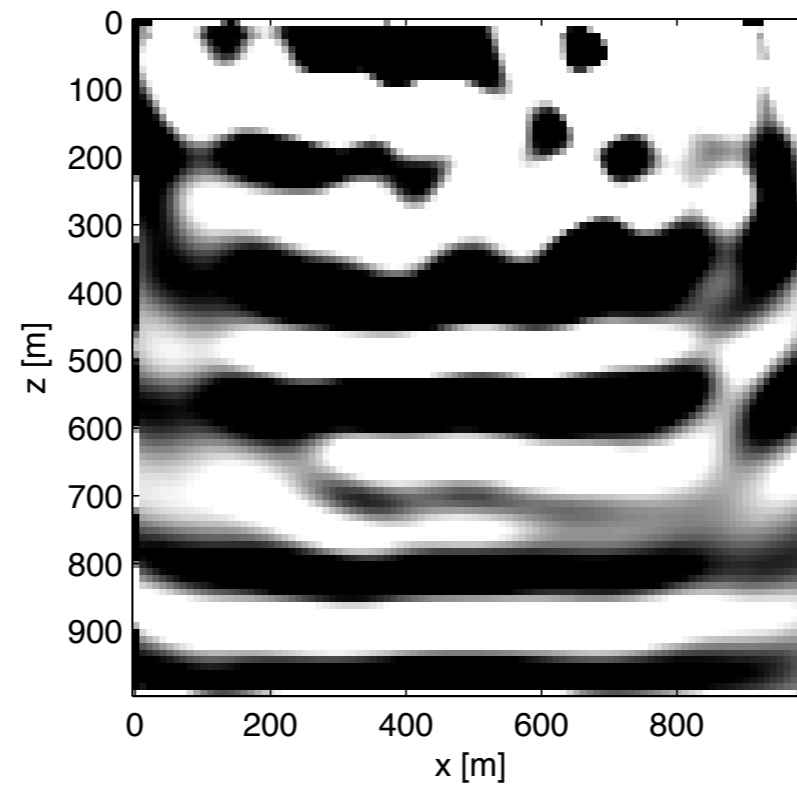
baseline

D0



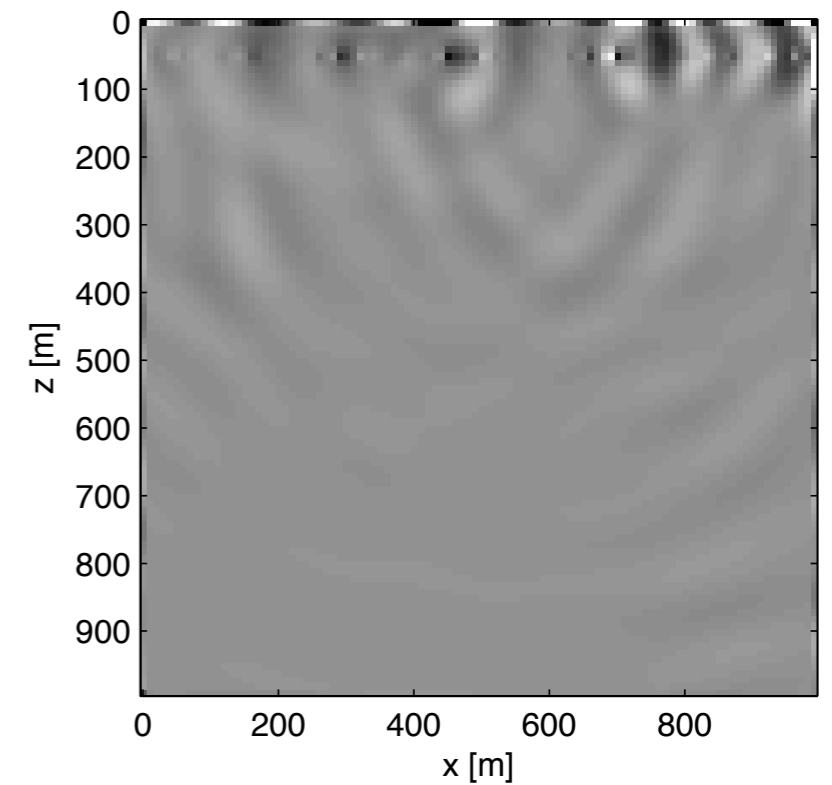
monitor

D1



difference

D0-D1



clearly we can resolve that there was no 4D change

Scenario 3

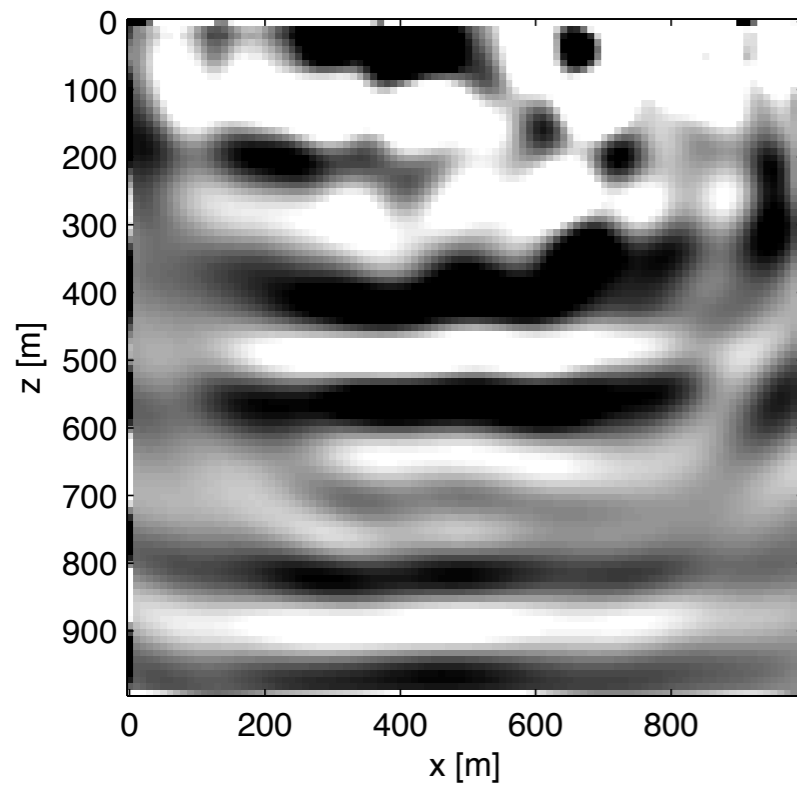
- When there is a 4D change, what happens if we do *not* repeat the random sampling for both *baseline* and *monitor* surveys?

Randomized sampling

independent 25% samplings

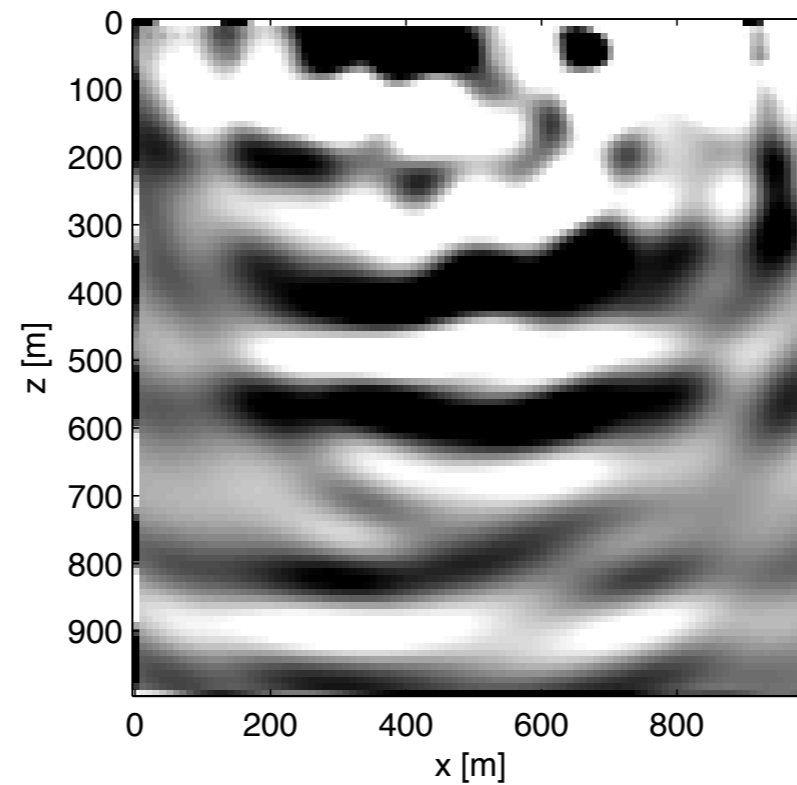
baseline

D0



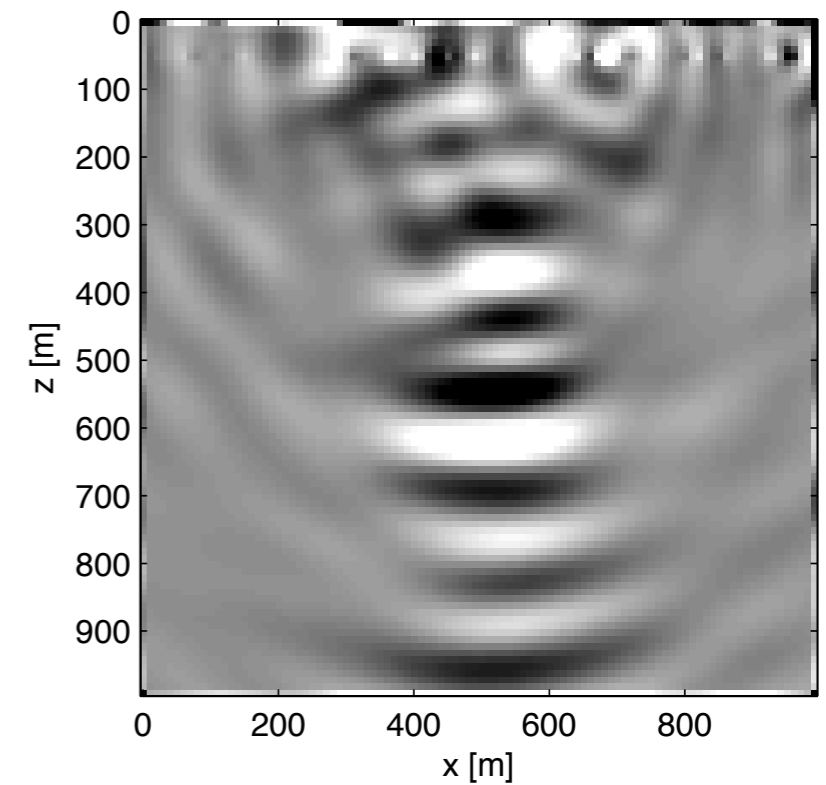
monitor

D1



difference

D0-D1

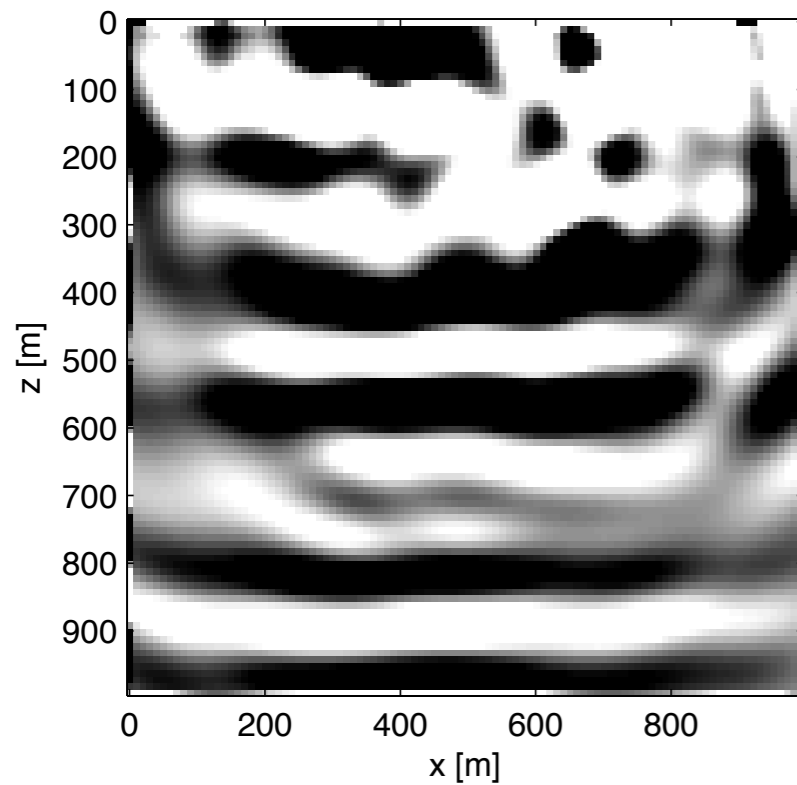


Randomized sampling

independent 50% samplings

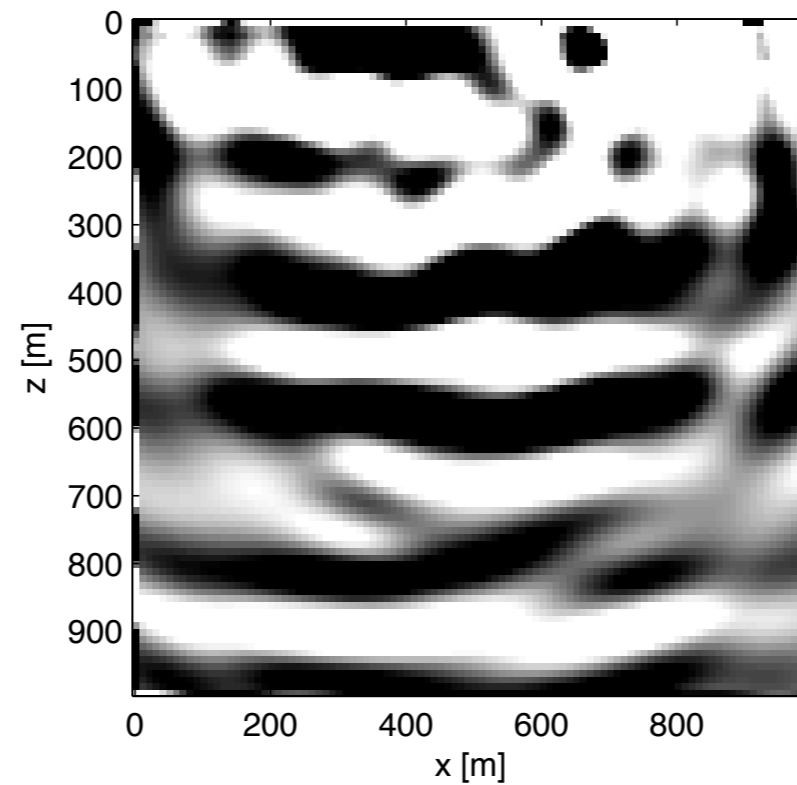
baseline

D0



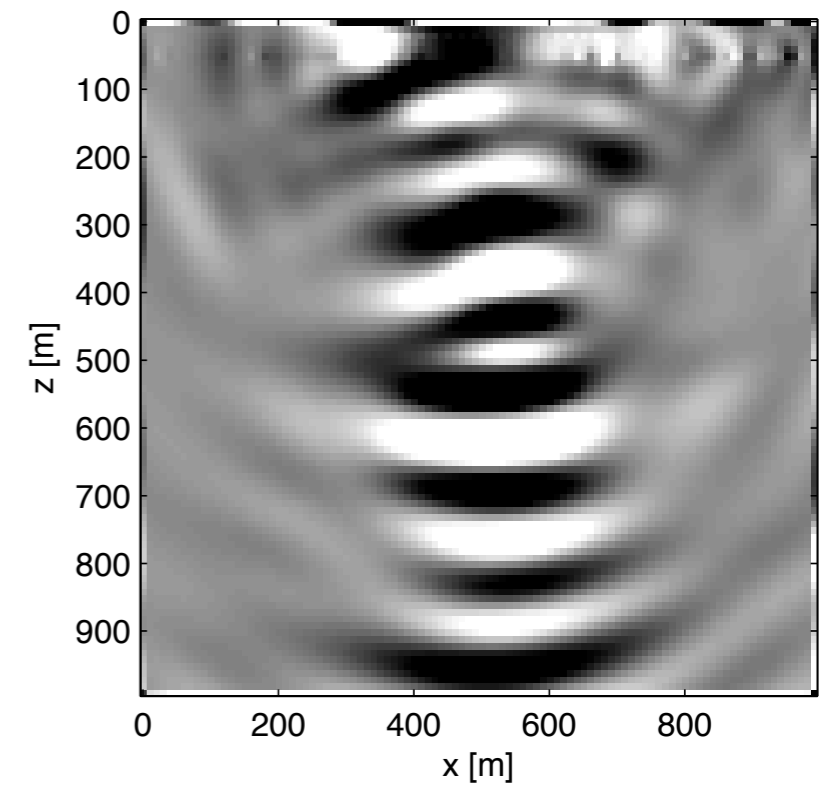
monitor

D1



difference

D0-D1

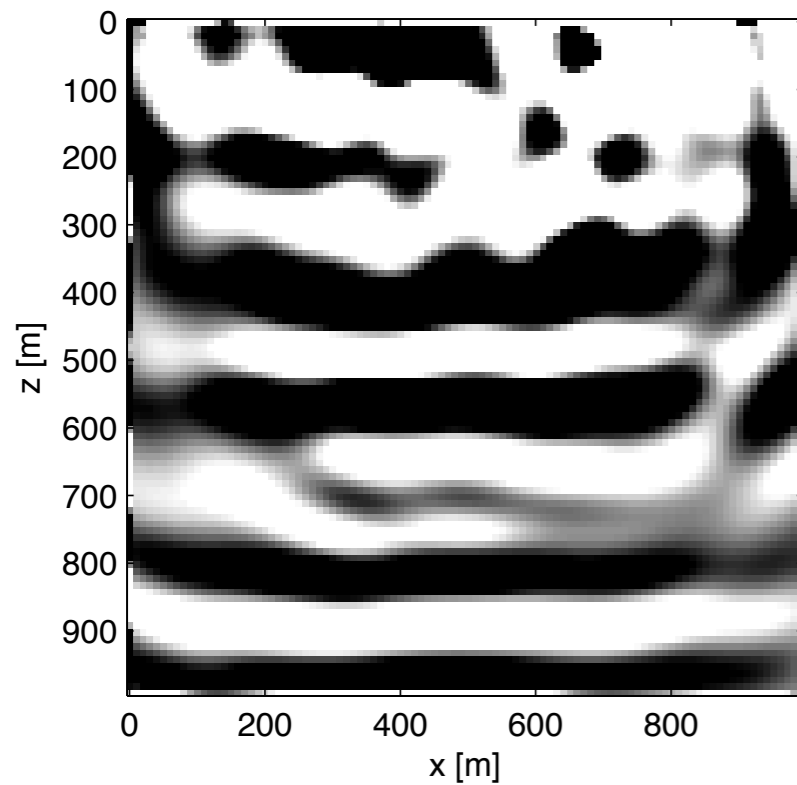


Randomized sampling

independent 75% samplings

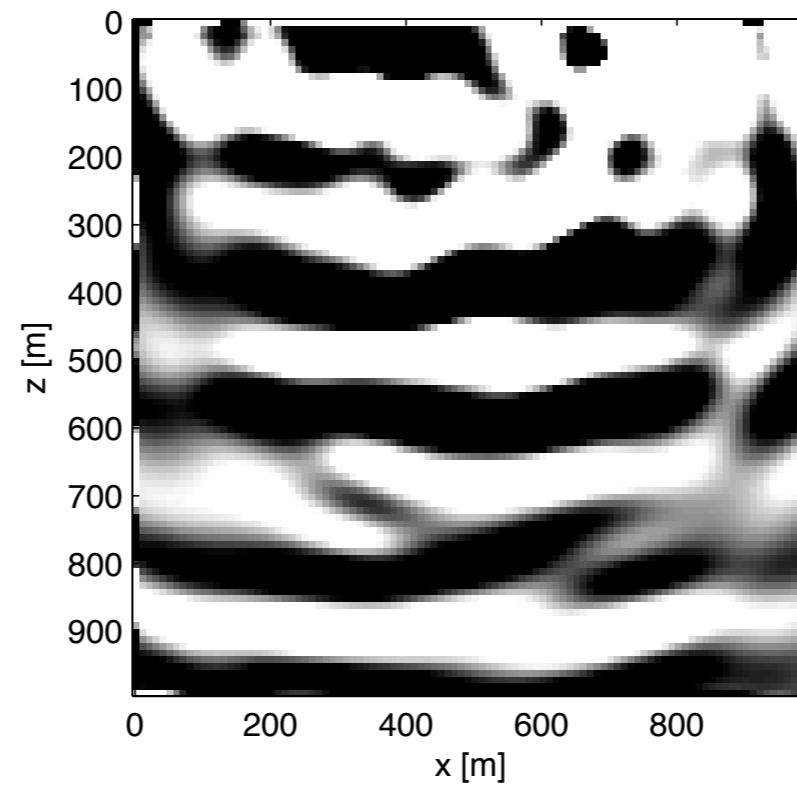
baseline

D0



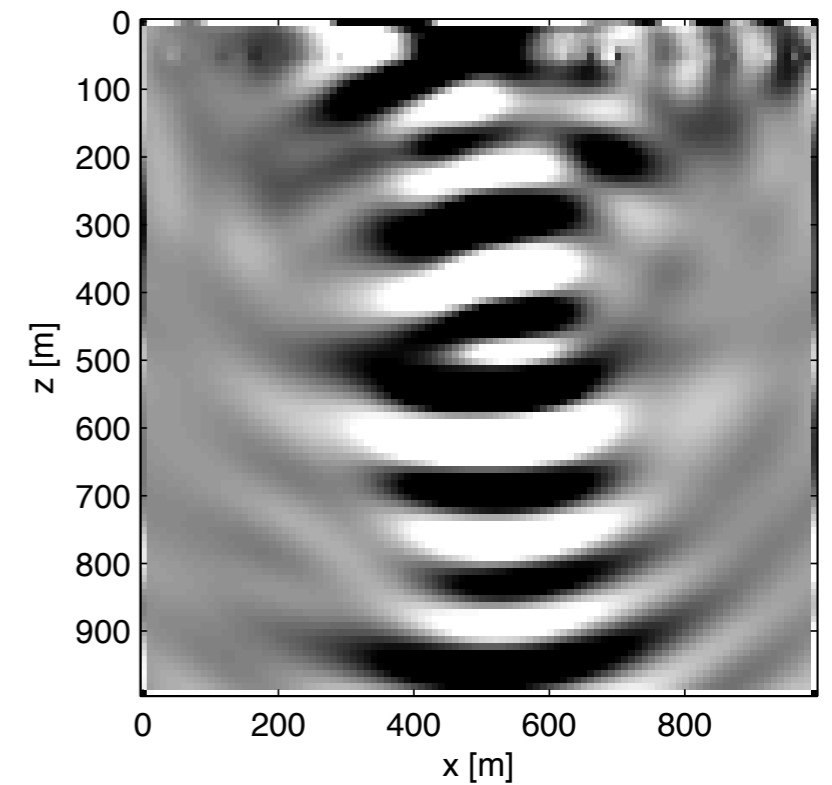
monitor

D1



difference

D0-D1



Conclusions

- Repeatability is *very important* if we are to fully sample *periodically*, in order to *delineate* true time-lapse changes in the medium

Conclusions

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

Future Work

- Detect 4D changes in *noisy* environments with *high* subsampling *ratios*
- Improve on resolution of 4D images
- Extend to randomized *simultaneous* marine *acquisition* with *randomized* OBN

Acknowledgements

Thanks for your attention

SINBAD



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