Simulations of Seismic Acquisition Footprint

Joanna K. Cooper, Gary F. Margrave, and Don C. Lawton

November 30, 2007

CREWES

MITACS

UNIVERSITY OF CALGARY

Recap: Seismic Modelling in 3D

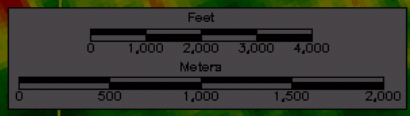
- Used Rayleigh-Sommerfeld modelling to create an exhaustive dataset
  - No significant spatial aliasing in either source or receiver gathers
- This study:
  - Used the exhaustive dataset, and various decimations of it, to study acquisition footprint

Outline

- Introduction to acquisition footprint
- Spatial aliasing
- Creation of decimated dataset
- Processing of exhaustive and decimated datasets
- Synthesis
- Conclusions and Future work

Acquisition Footprint

- Consists of amplitude modulations that mimic the survey geometry
- Causes confusion in extracting geological information from amplitudes
- Function of survey geometry and processing
- Contributors
  - Survey design: fold/offset variations
  - Noise
  - Residual NMO, NMO stretch, multiples
  - Spatial aliasing



Spatial Sampling and Aliasing

- 2D seismic - we sample in 3D: x_s, x_r, t

  After imaging we have 2D R(x,z)
- 3D seismic - we sample in 5D: x_s, y_s, x_r, y_r, t

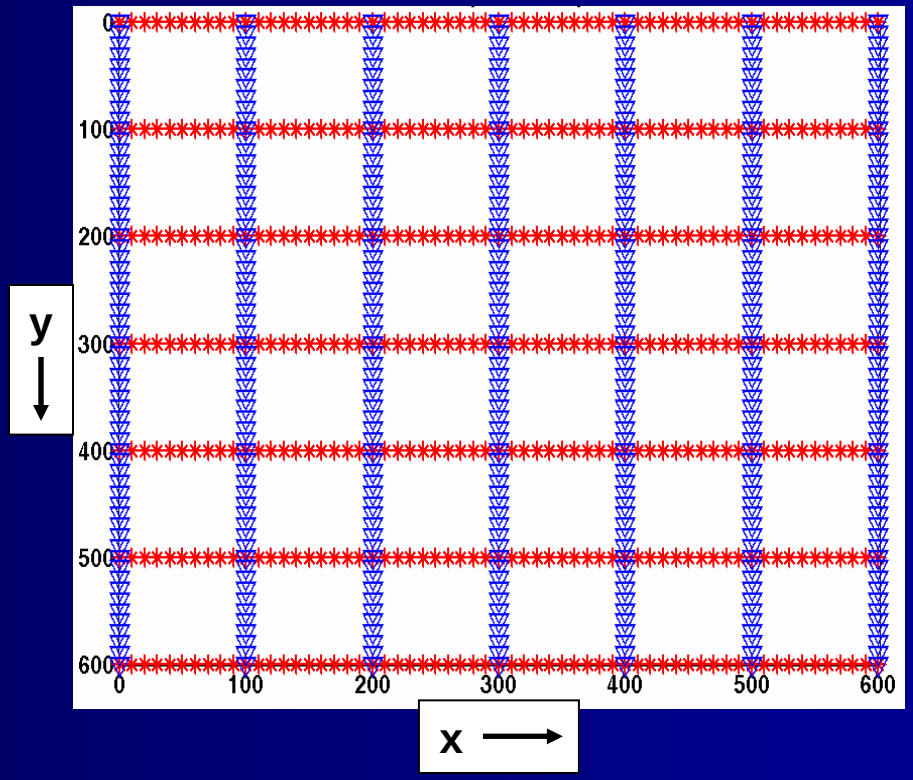
  After imaging we have 3D R(x,y,z)

- Image wavenumbers (k_x,k_y) come from source and receiver wavenumbers (k_{xs} , k_{ys}, k_{xr}, k_{yr})
- Spatial sampling theory:

  $\Delta x, \Delta y <= 1/(2*k_{MAX}) = v_{MIN}/(2*f_{MAX})$

Spatial Sampling and Aliasing

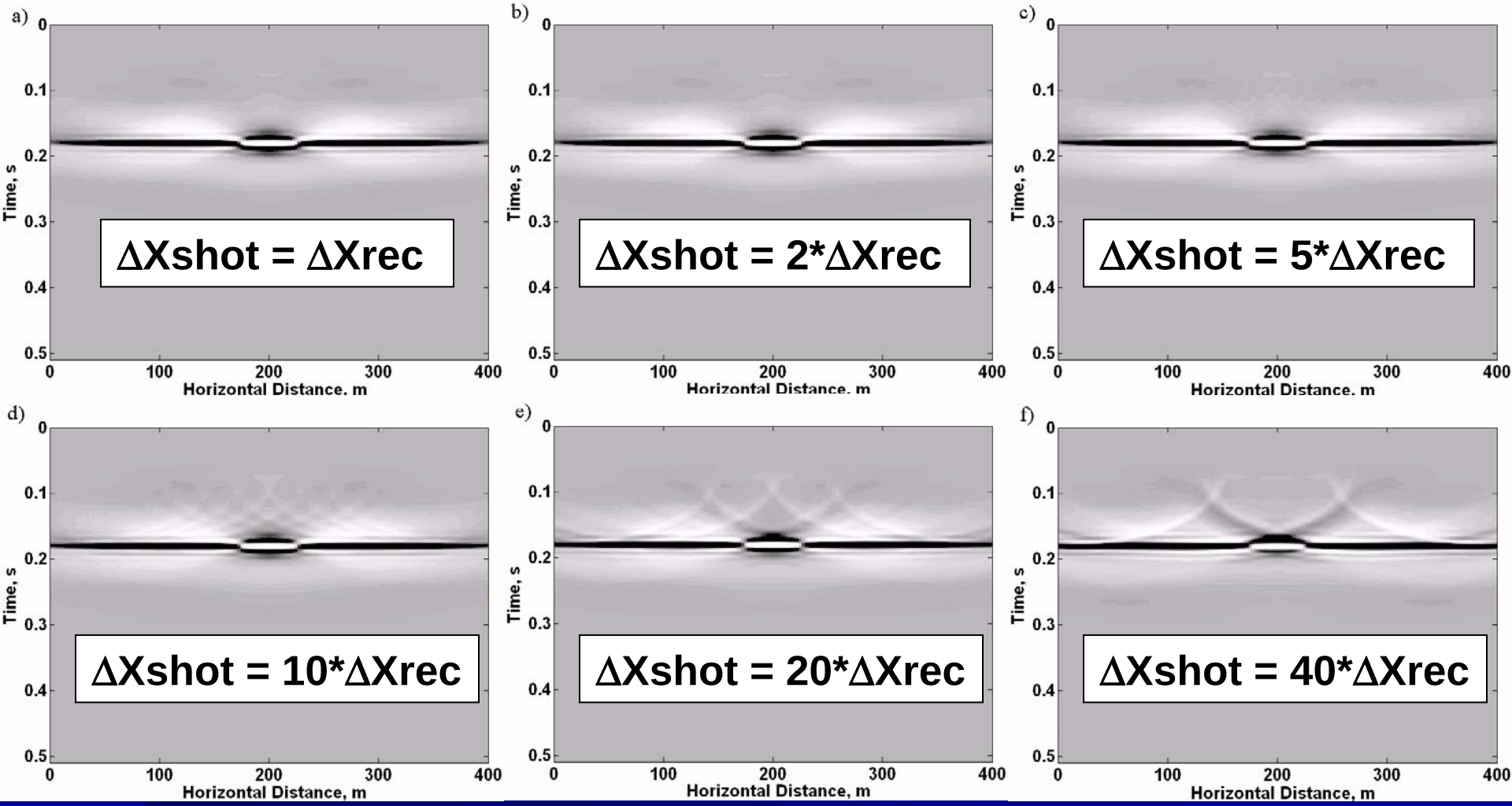
- In typical 3D surveys we violate the sampling theorem in 2 of 5 dimensions:
  - Δx_s, Δy_r are small (equal to station spacing), but Δy_s, Δx_r are large (equal to line spacing)



Spatial Sampling and Aliasing

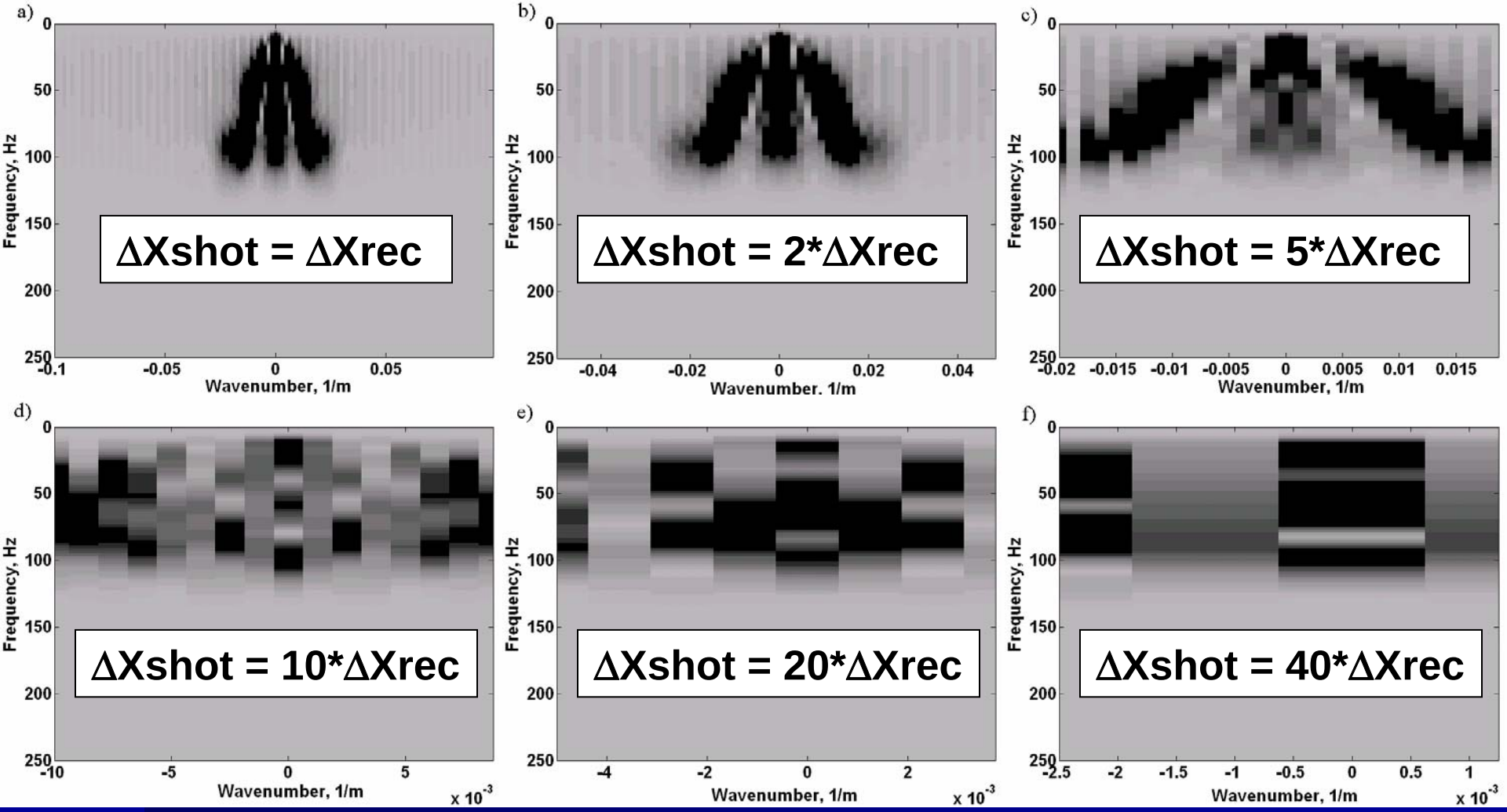
- In typical 3D surveys we violate the sampling theorem in 2 of 5 dimensions:
  - Δx_s, Δy_r are small (equal to station spacing), but Δy_s, Δx_r are large (equal to line spacing)
- Somehow processing helps us get away with this
  - Regularization, weighting
- Hypothesis: footprint artefacts can be caused by poor spatial sampling/inadequate processing algorithms

Spatial Aliasing and 2D Prestack Migration Footprint



Prestack migrated sections

Spatial Aliasing and 2D Prestack Migration Footprint



f-k spectra of common receiver gathers

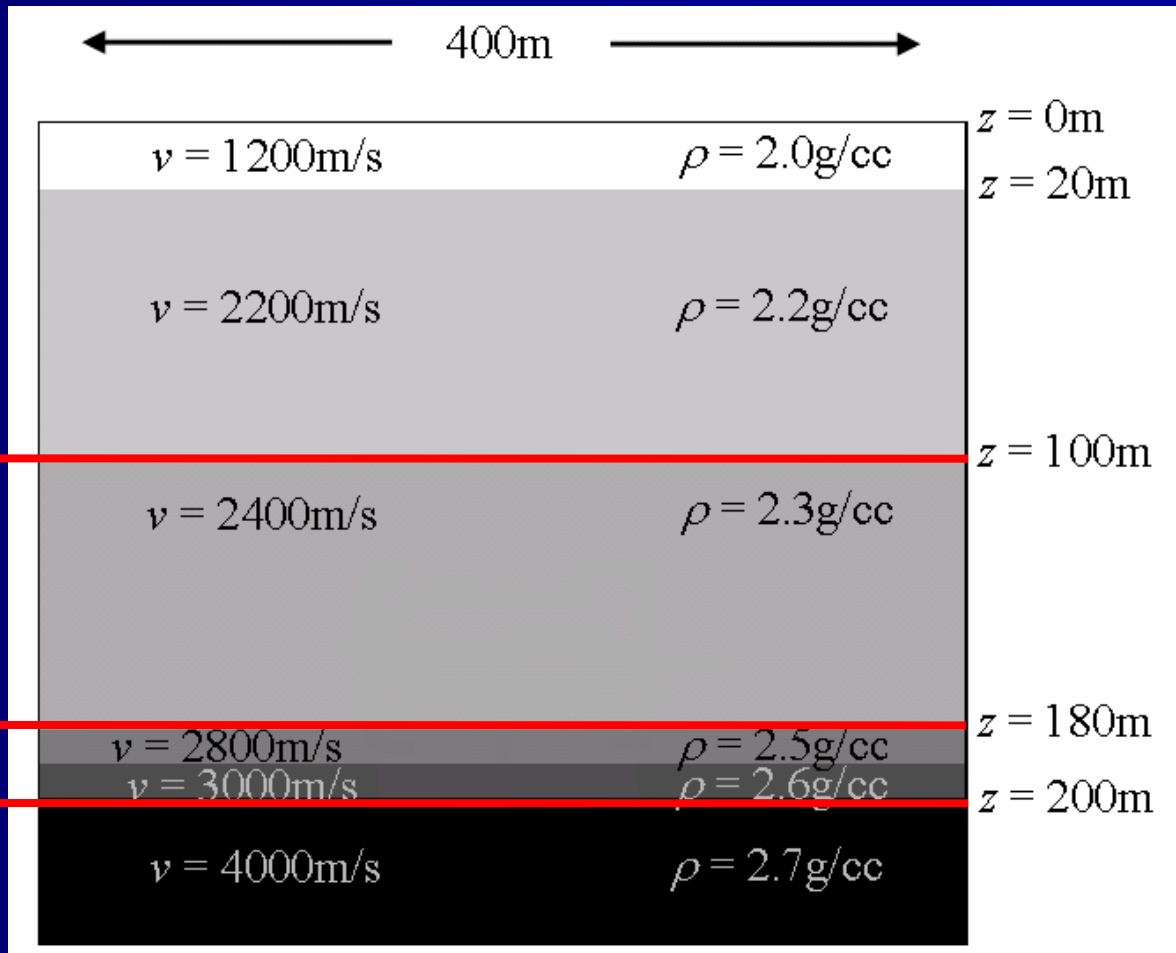
Recap: Geological Model

- 400m x 400m, V(z)
- 3 reflectors:

Featureless
100m
R=-0.05

Featureless
180m
R=+0.05

Channel
200m



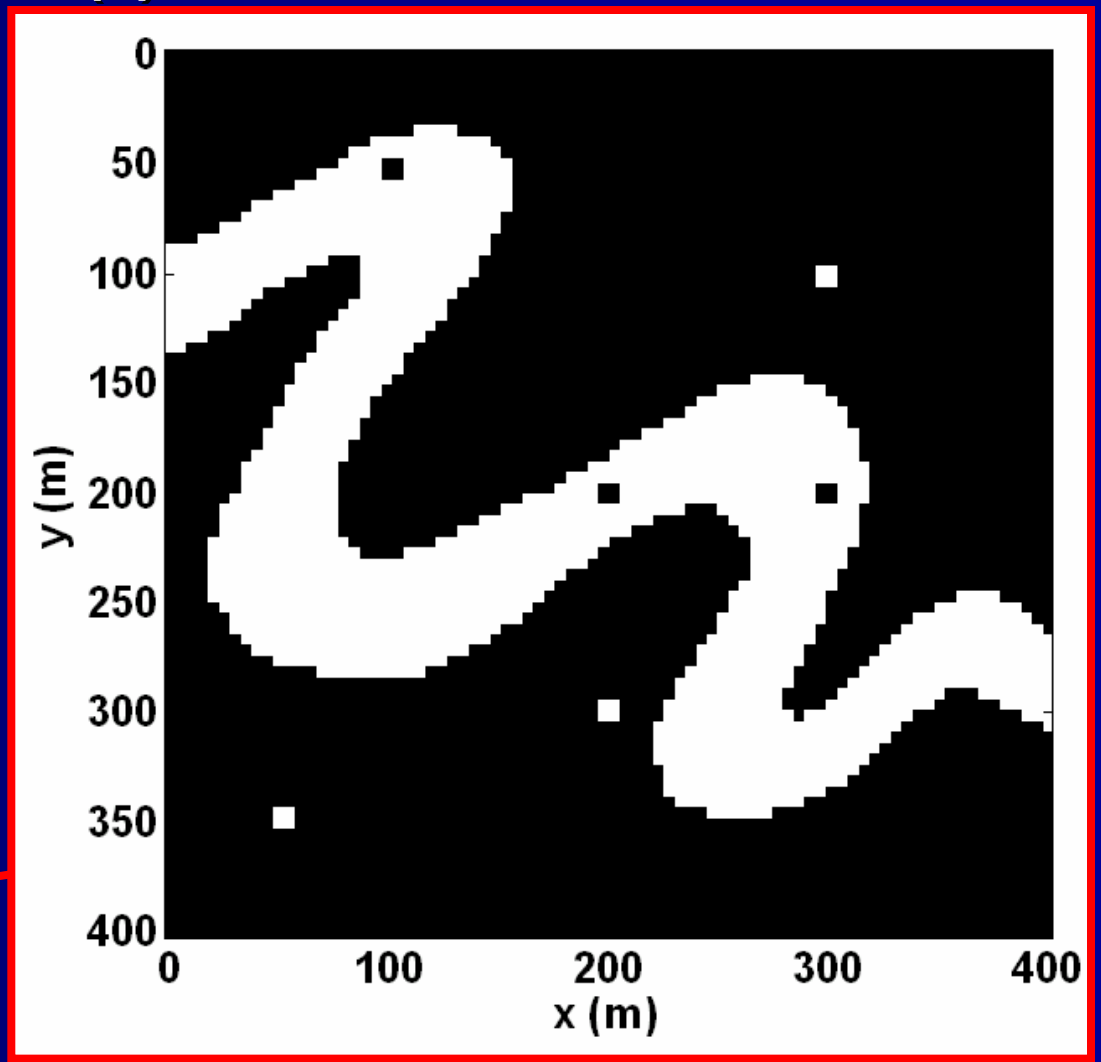
Recap: Geological Model

- 400m x 400m, V(z)
- 3 reflectors:

Featureless
100m
R=-0.05

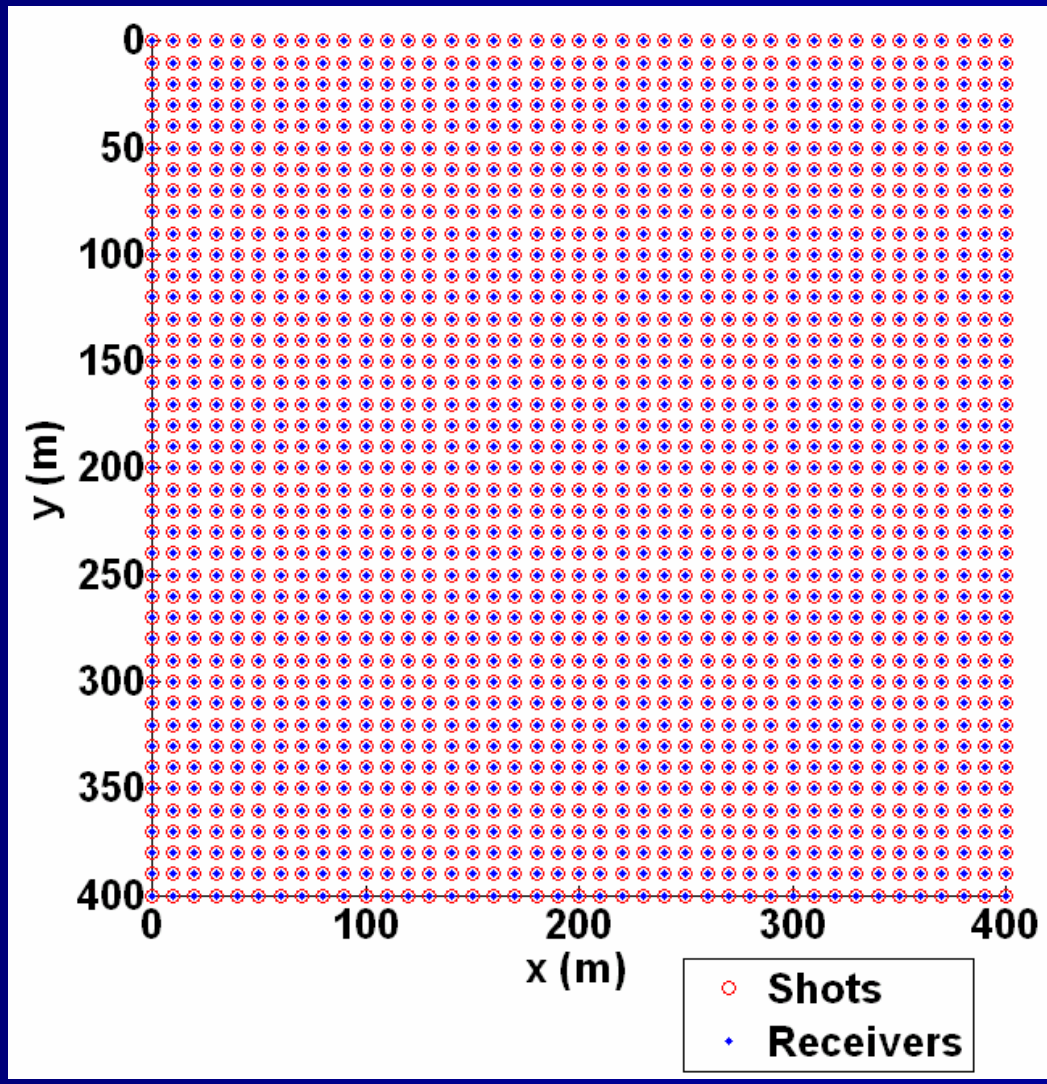
Featureless
180m
R=+0.05

Channel
200m



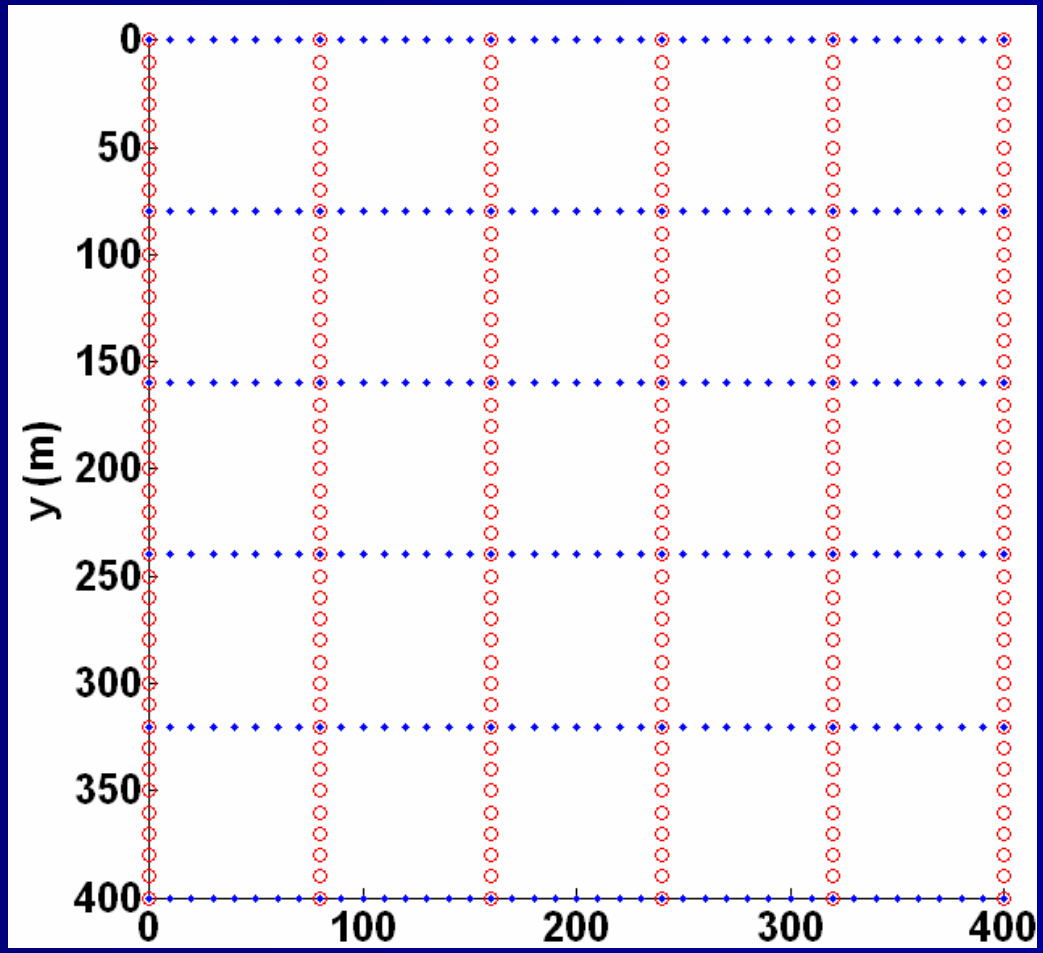
The Exhaustive Survey

- 1681 shots
- $\Delta x_s = 10m$
- $\Delta y_s = 10m$
- $\Delta x_r = 10m$
- $\Delta y_r = 10m$



The Decimated Survey

- 246 shots
- $\Delta x_s = 80m$
- $\Delta y_s = 10m$
- $\Delta x_r = 10m$
- $\Delta y_r = 80m$
- Orthogonal

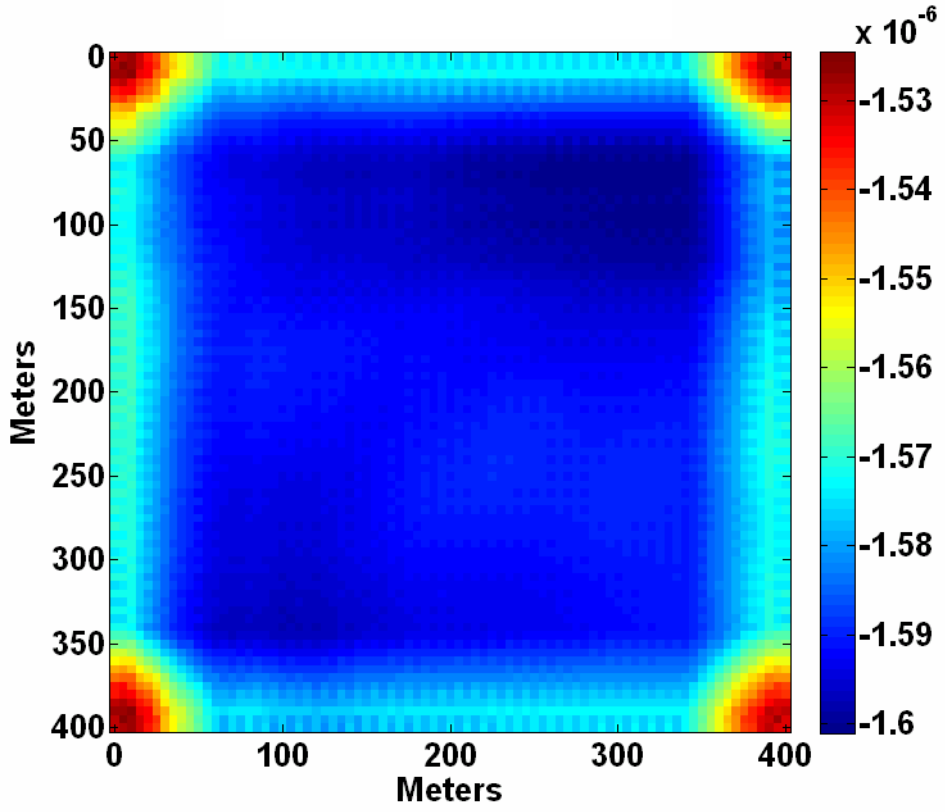


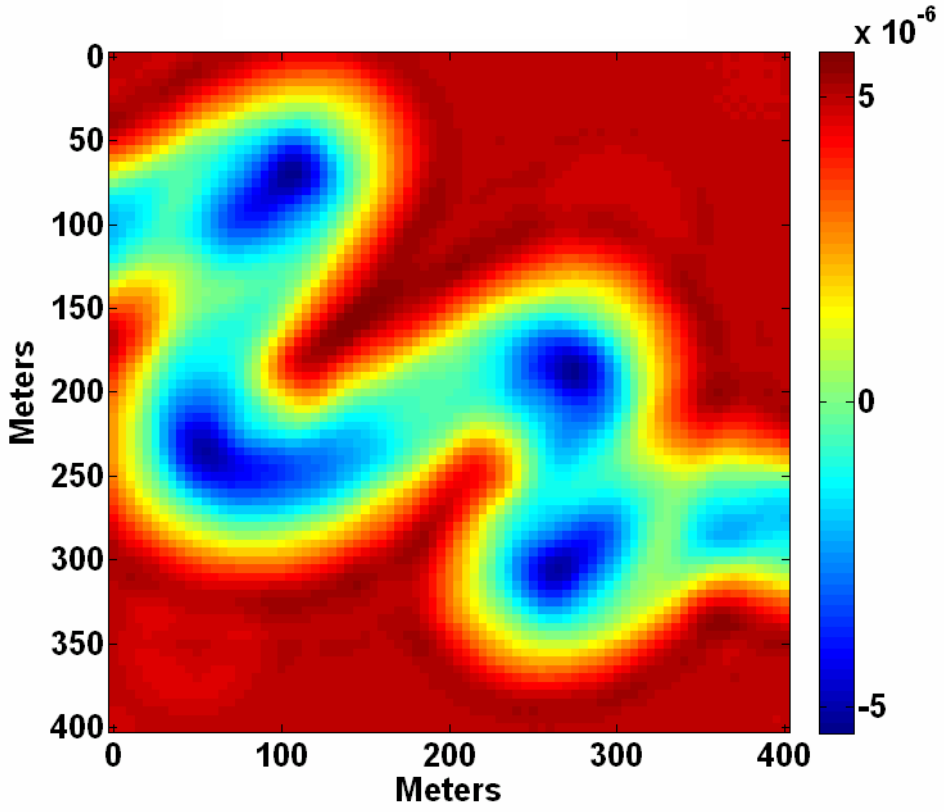
Data Processing

- Gain
- No deconvolution
- NMO with exact velocities
- Mute
- Stack
- Poststack migration
- Prestack migration – UofC Kirchhoff (shot-record), “Industrial” Kirchhoff (common-offset-vector, common-offset)

Results: Exhaustive survey

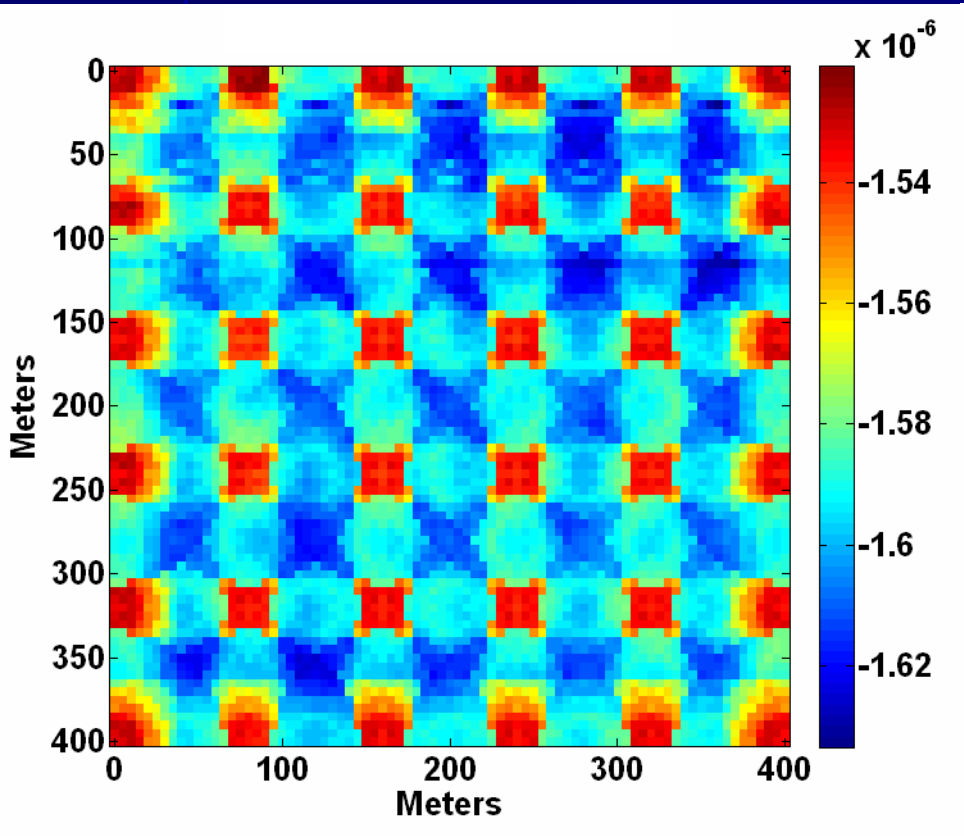
- UofC Stack:
  100m (Featureless) and Channel reflectors

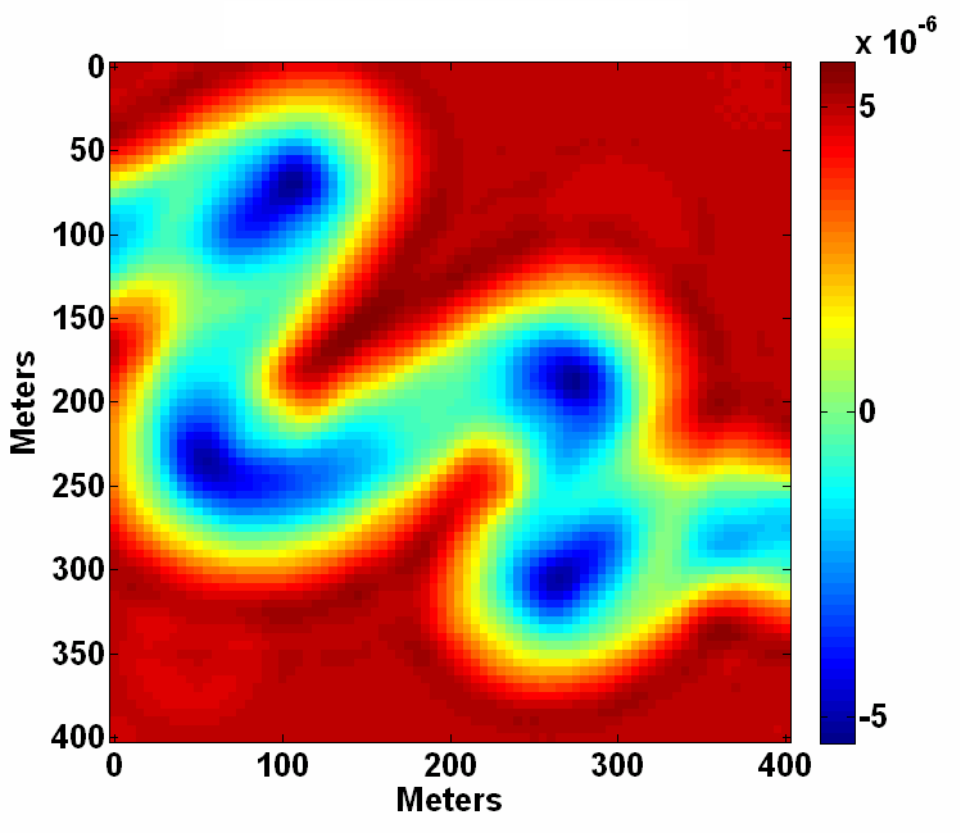




Results: Decimated survey

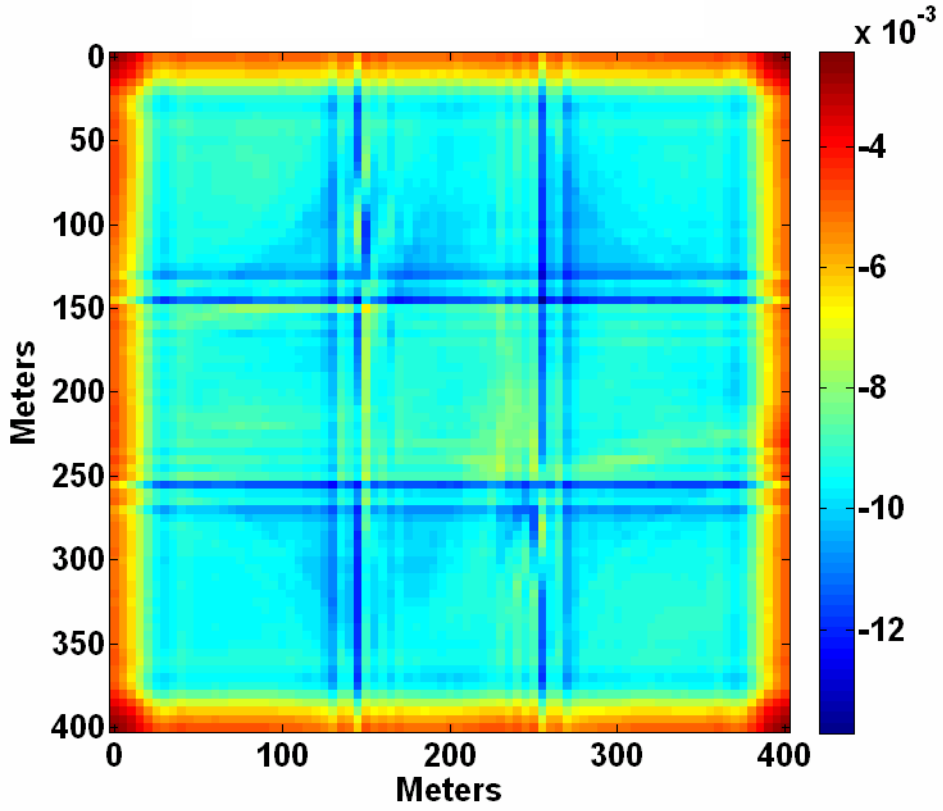
- UofC Stack:
  100m (Featureless) and Channel reflectors

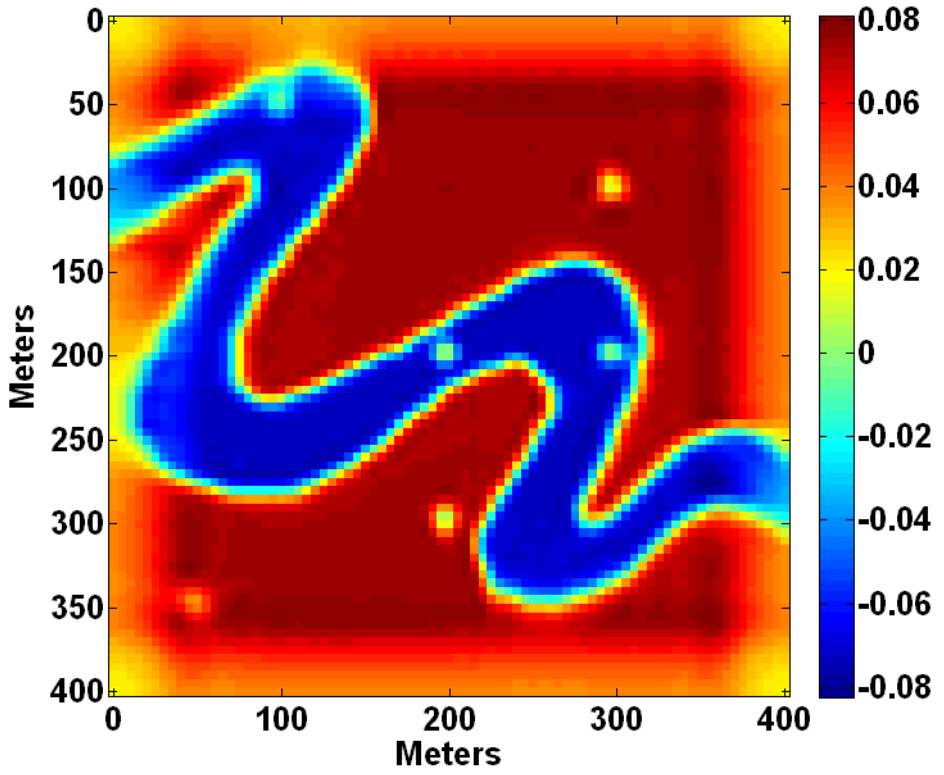




Results: Exhaustive survey

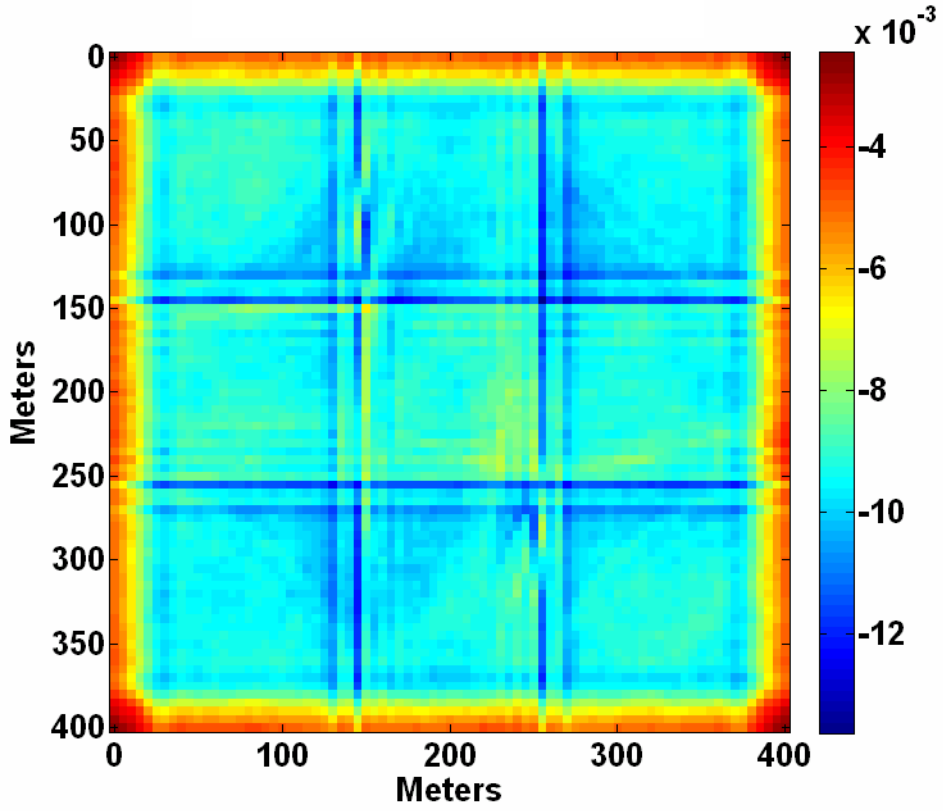
- UofC Poststack migration:
  100m (Featureless) and Channel reflectors

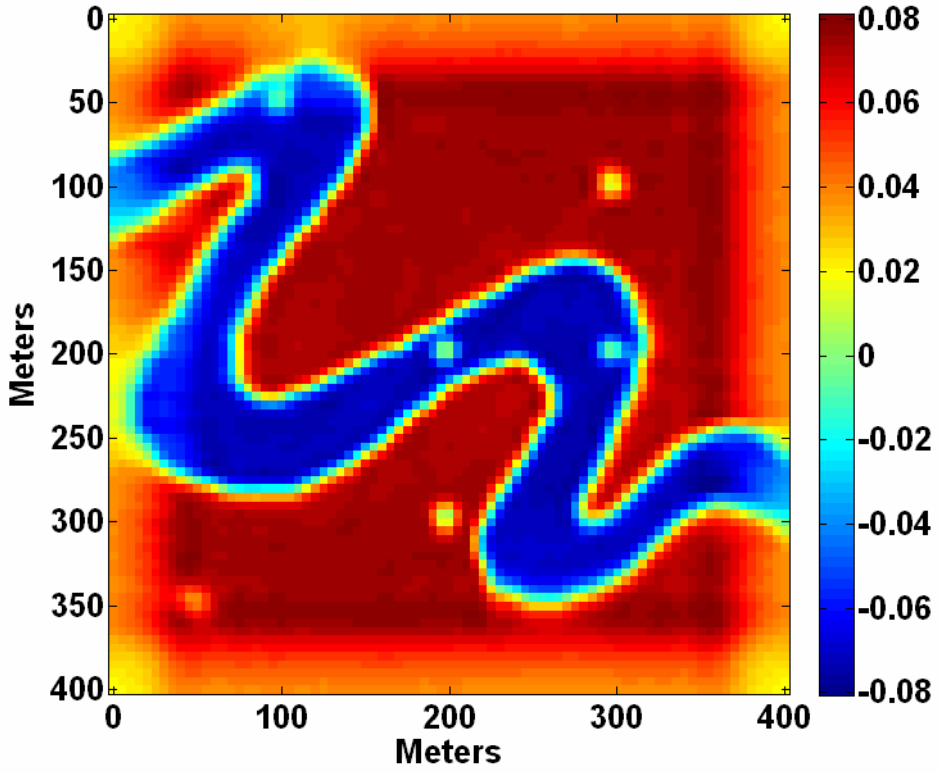




Results: Decimated survey

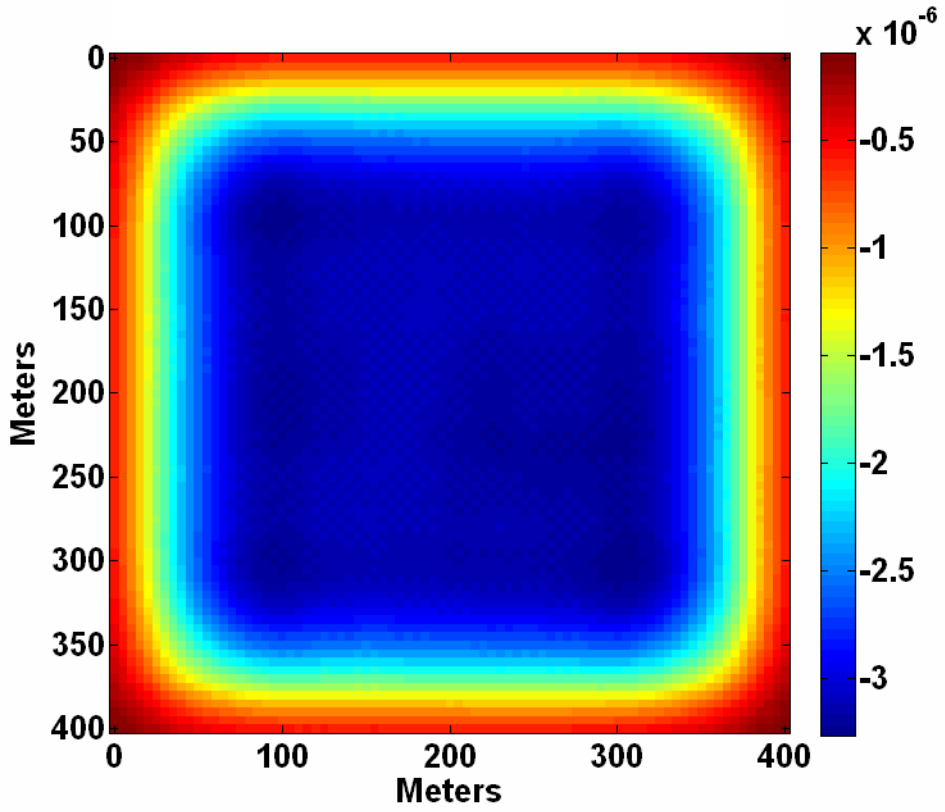
- UofC Poststack migration:
  100m (Featureless) and Channel reflectors

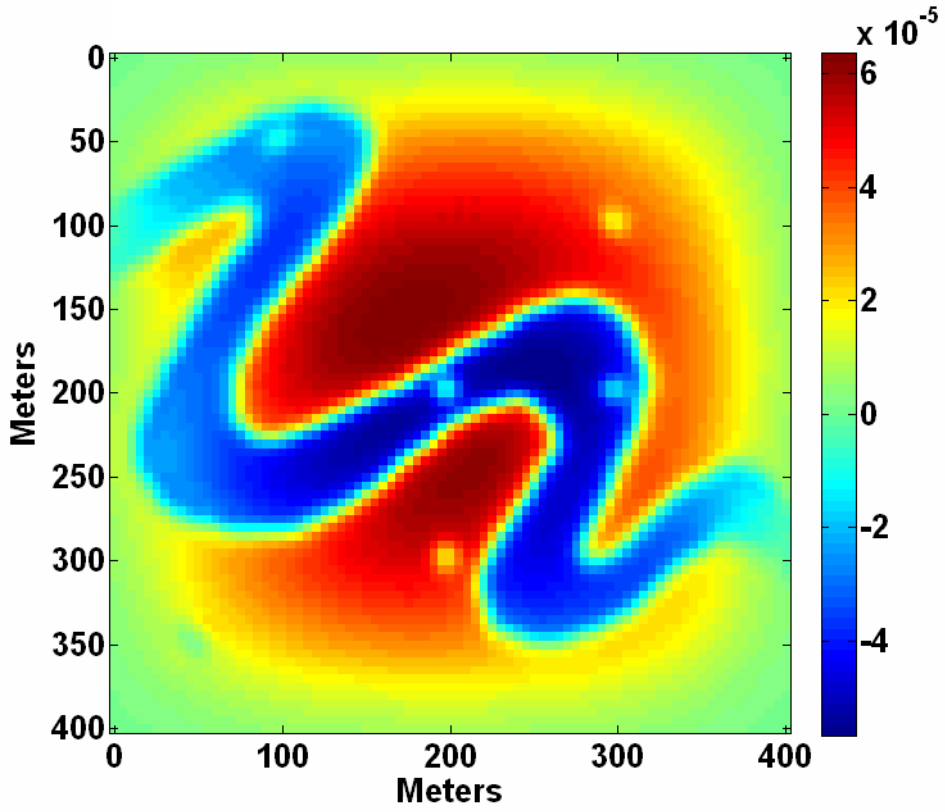




Results: Exhaustive survey

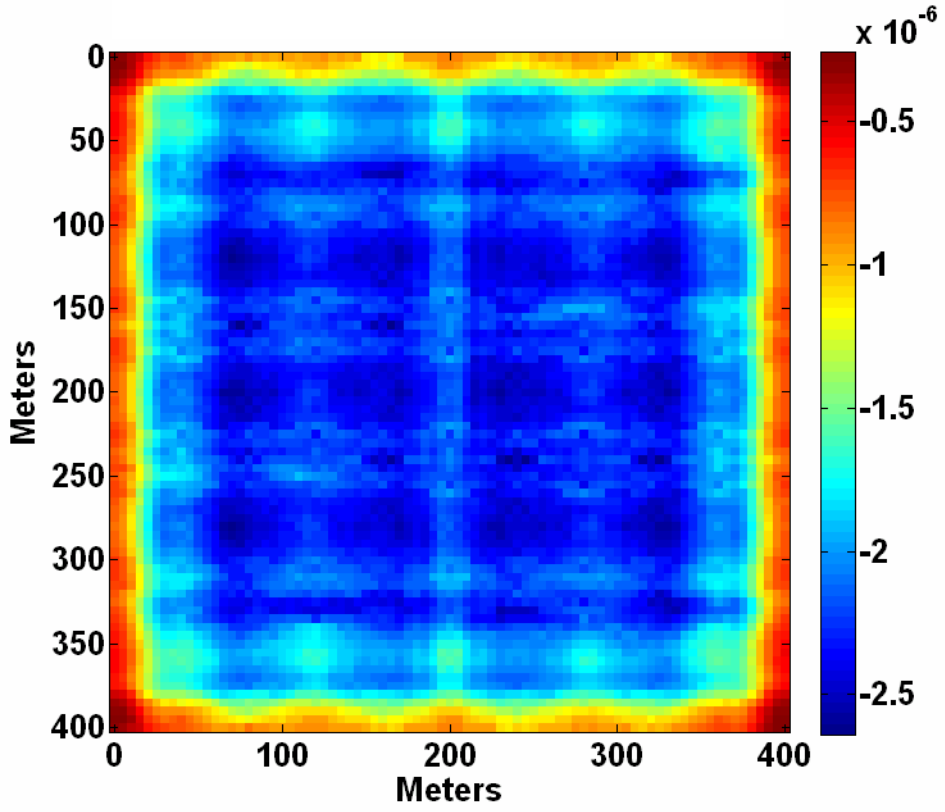
- UofC Prestack migration:
  100m (Featureless) and Channel reflectors

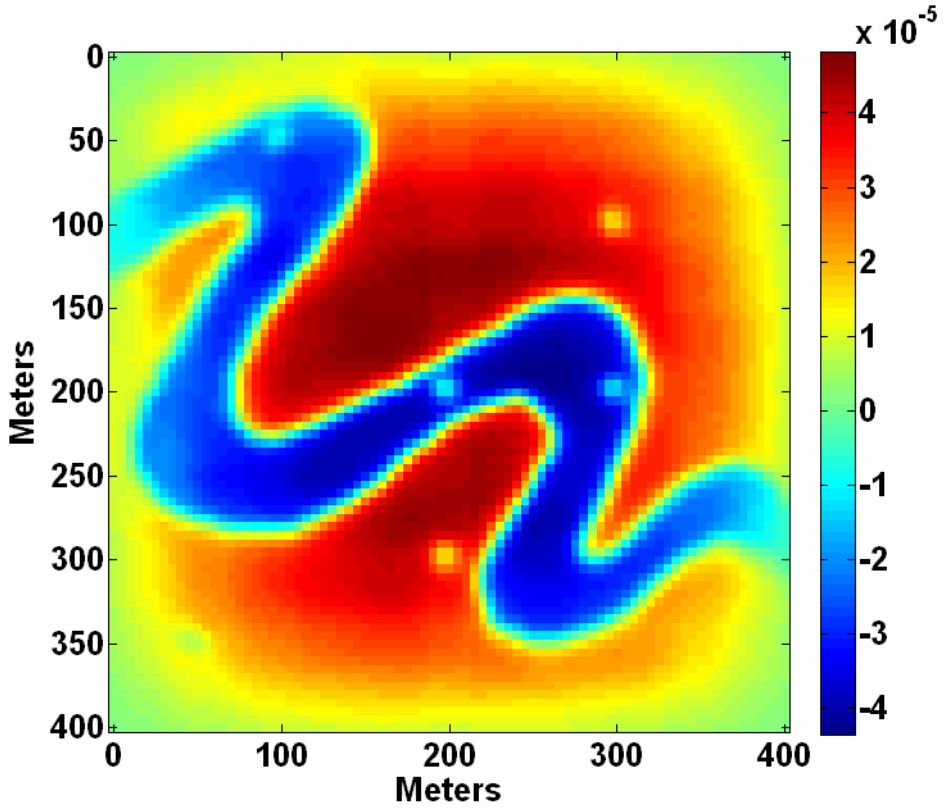




Results: Decimated survey

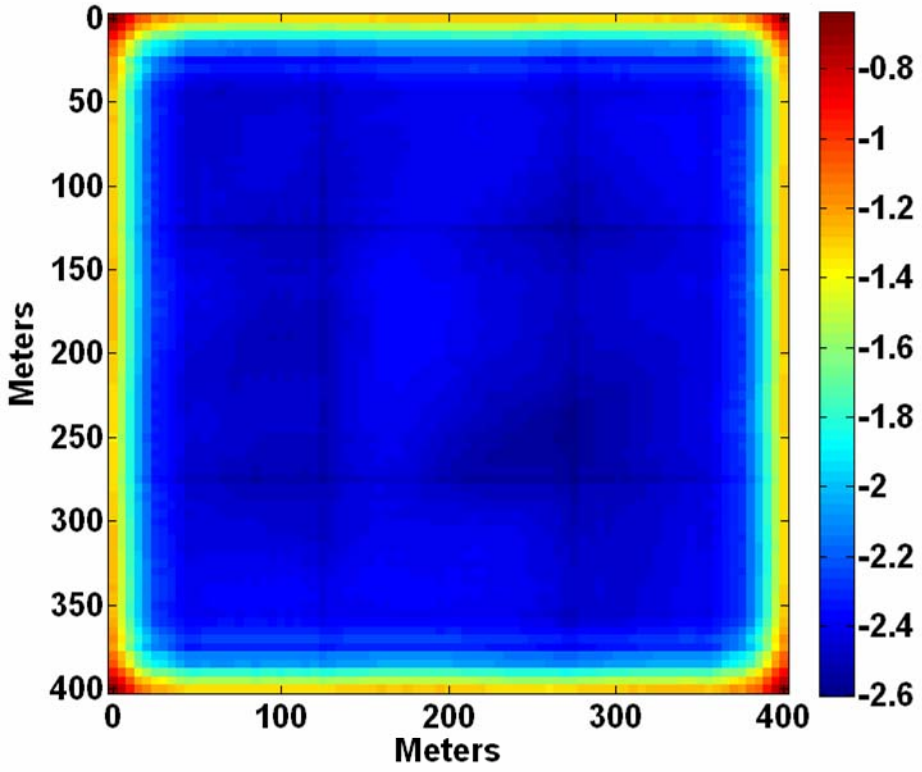
- UofC Prestack migration:
  100m (Featureless) and Channel reflectors

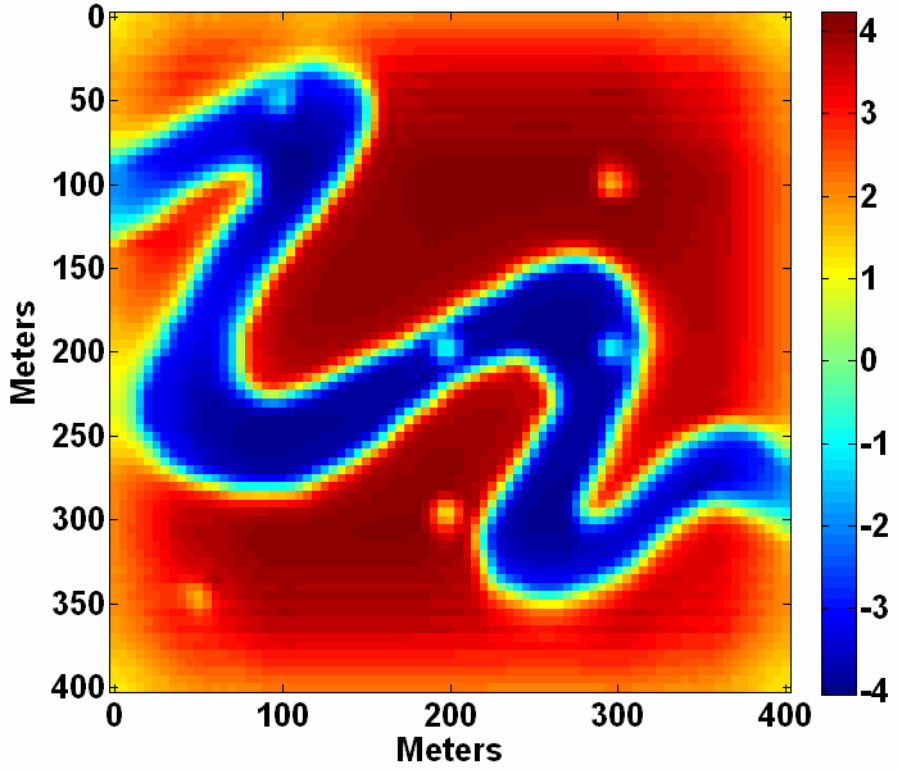




Results: Exhaustive survey

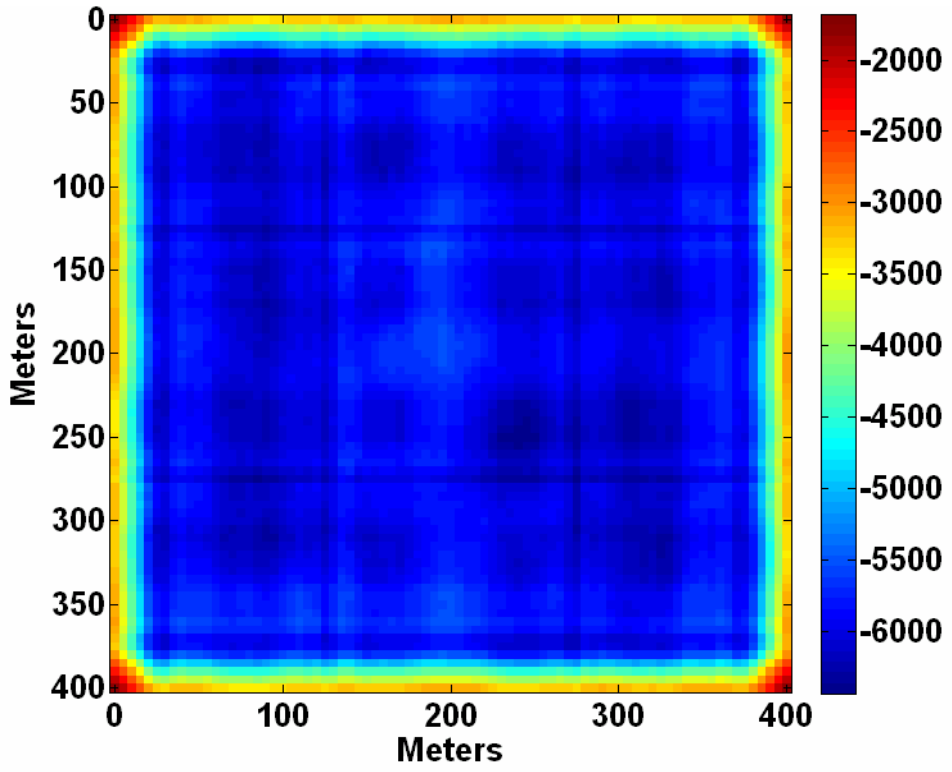
- Industrial Prestack migration A:
  100m (Featureless) and Channel reflectors

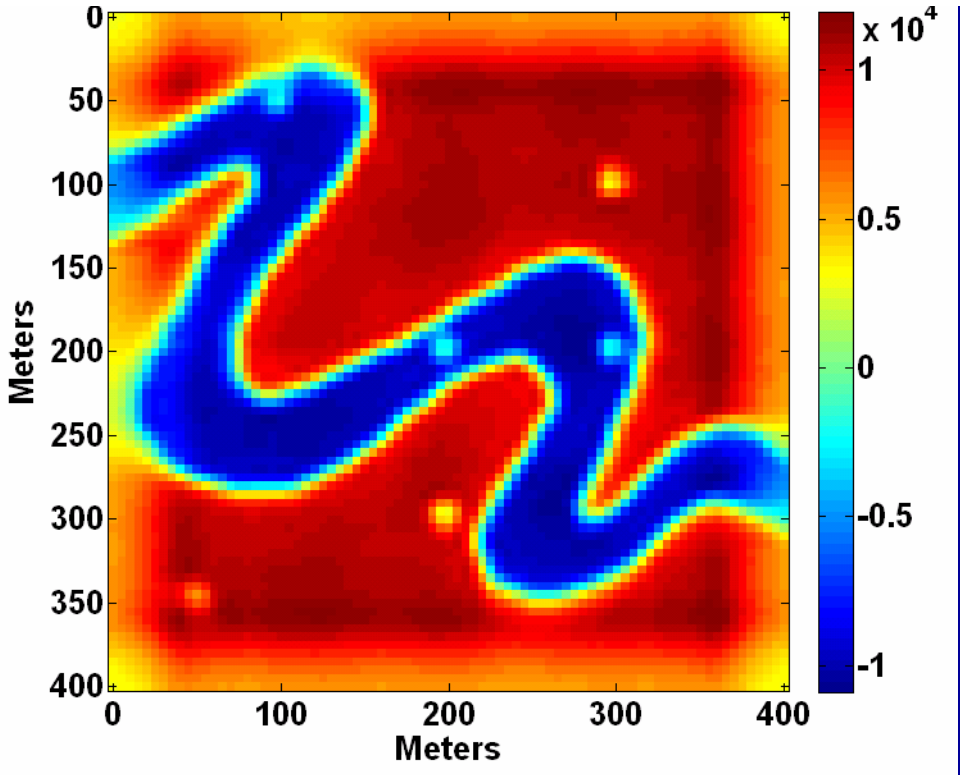




Results: Decimated survey

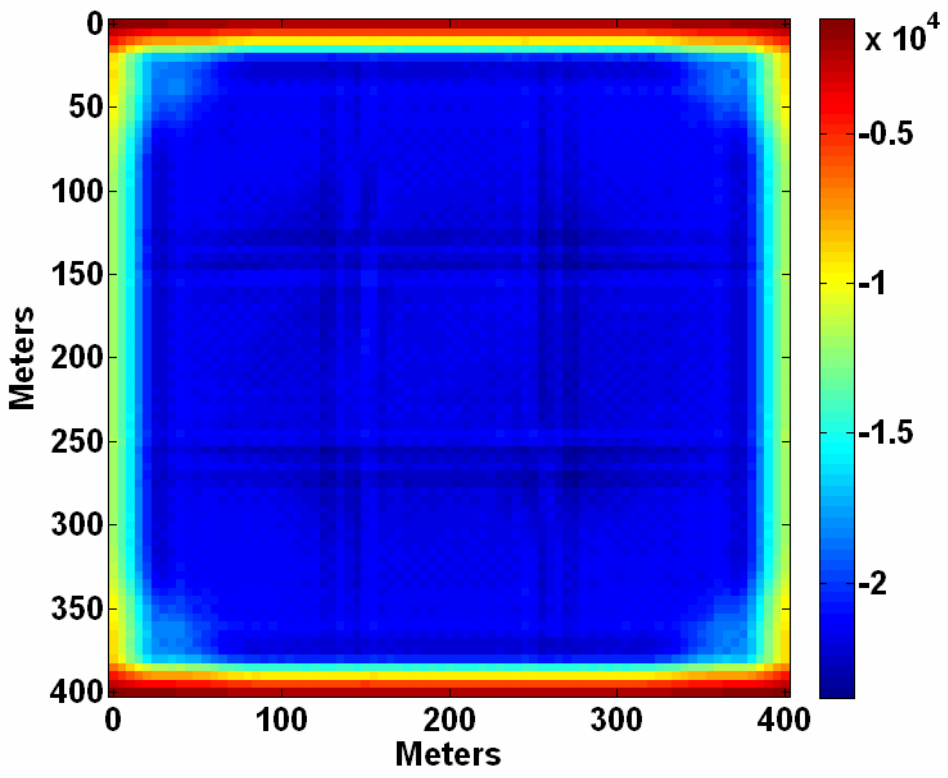
- Industrial Prestack migration A:
  100m (Featureless) and Channel reflectors

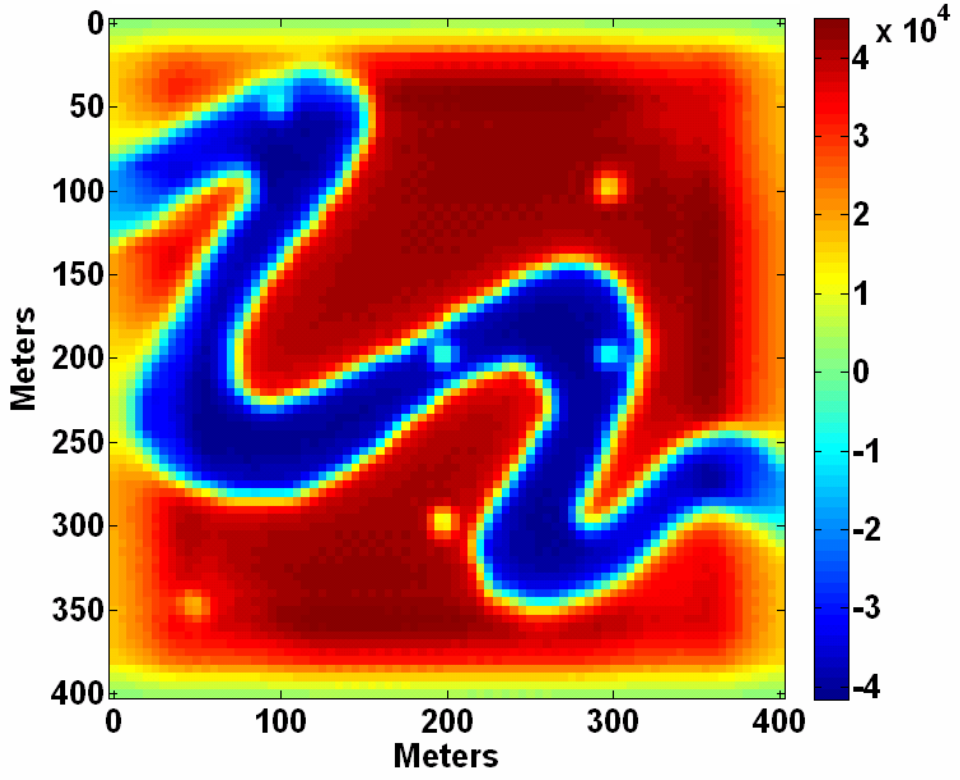




Results: Exhaustive survey

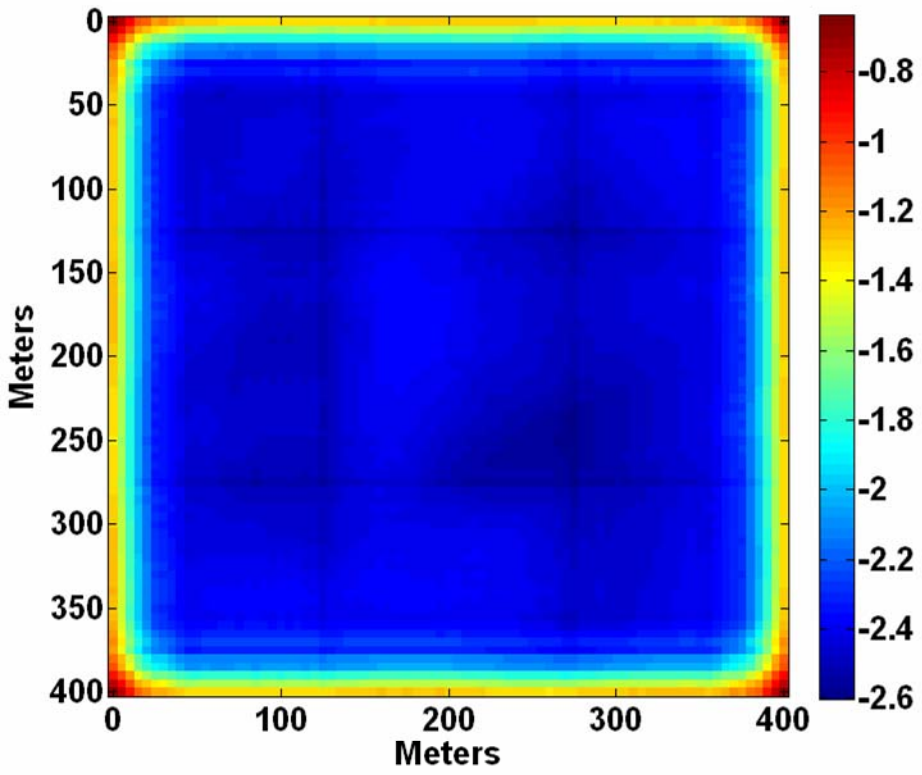
- Industrial Prestack migration B:
  100m (Featureless) and Channel reflectors

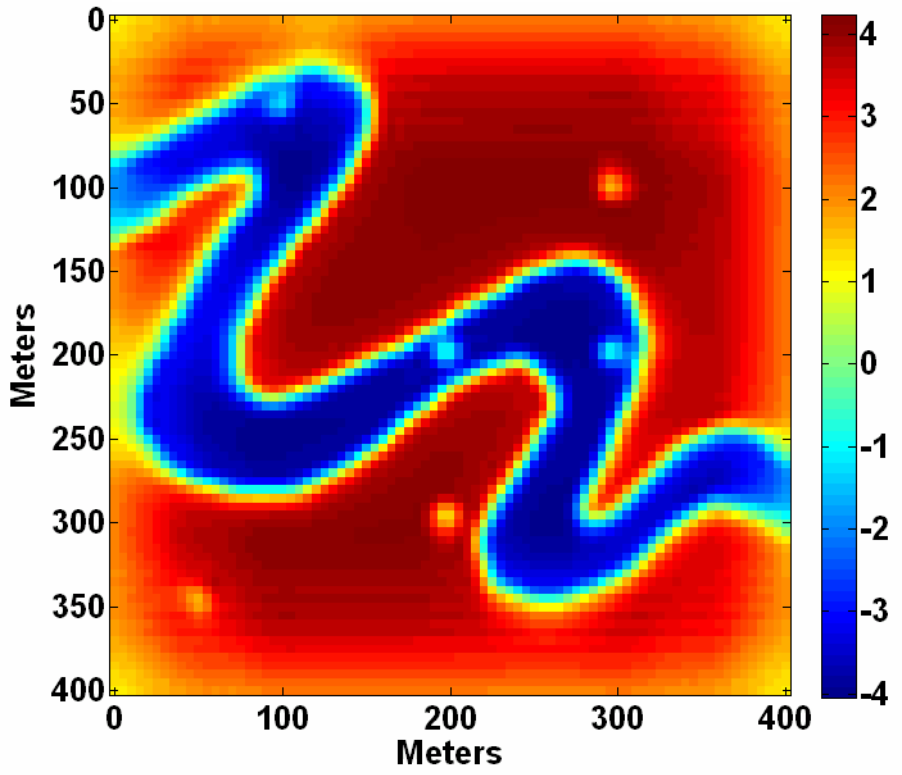




Results: Decimated survey

- Industrial Prestack migration B:
  100m (Featureless) and Channel reflectors





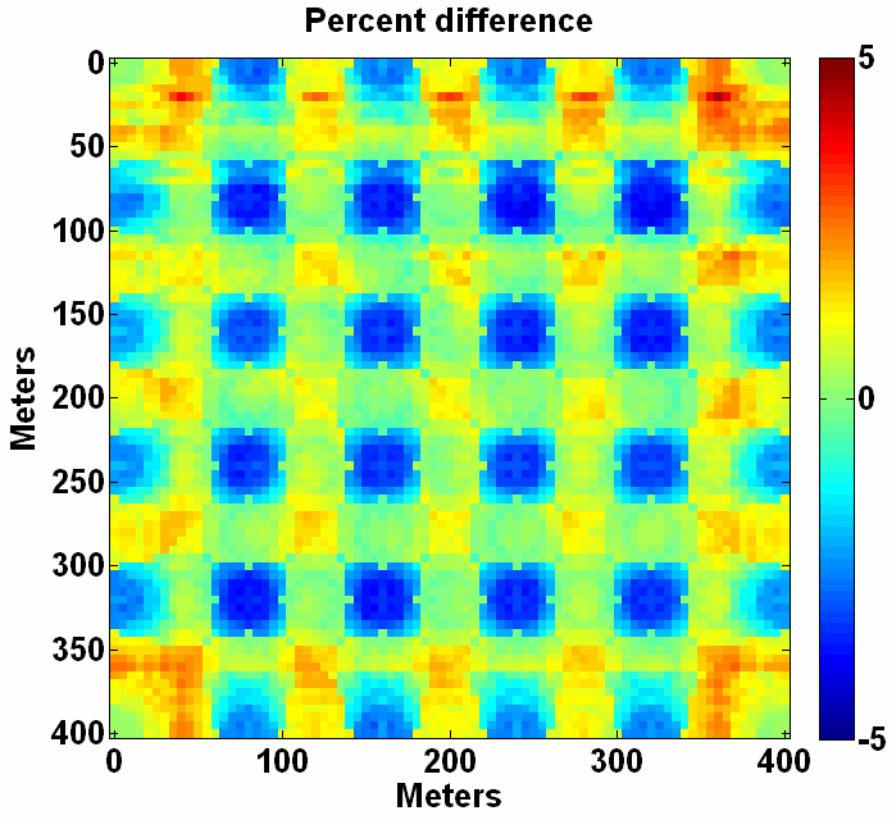
Synthesis

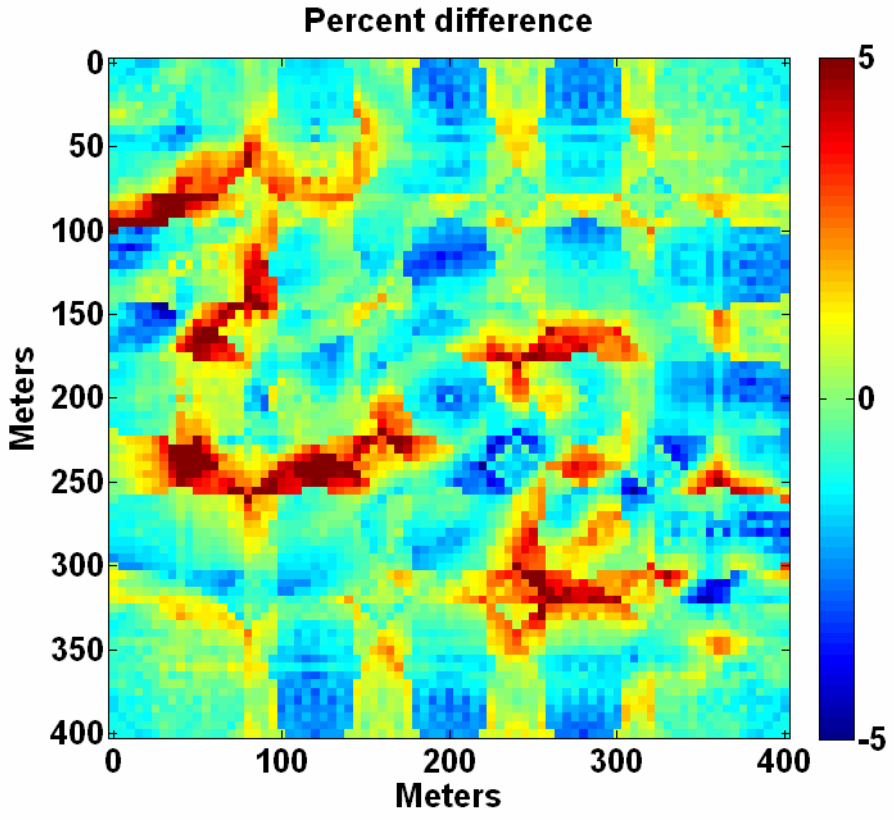
- Exhaustive survey shows some footprint
  - Aperture, Edge artefacts
- Decimated survey shows more footprint
- Processing algorithm makes a difference
- Independent scaling is misleading
- Require a quantification of footprint
  - Amplitude normalization - multiply decimated slice by least-squares scalar
  - % variation - divide by maximum absolute amplitude in exhaustive slice

Footprint as % difference

- Stack:

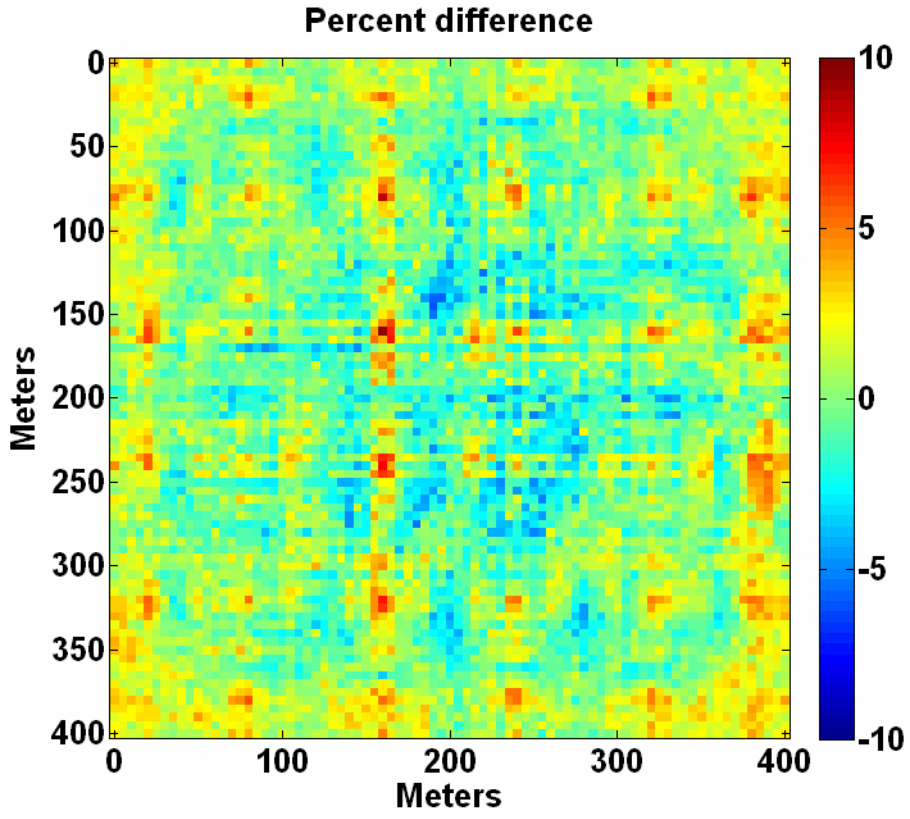
  Featureless: up to 4%, Channel: up to 9%

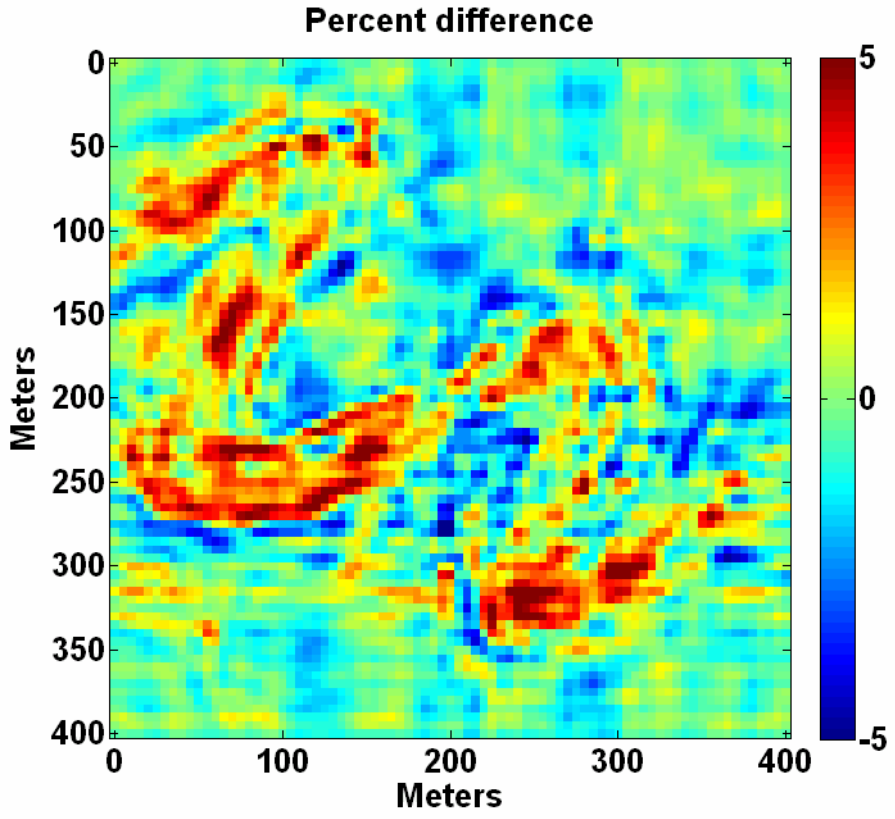




Footprint as % difference

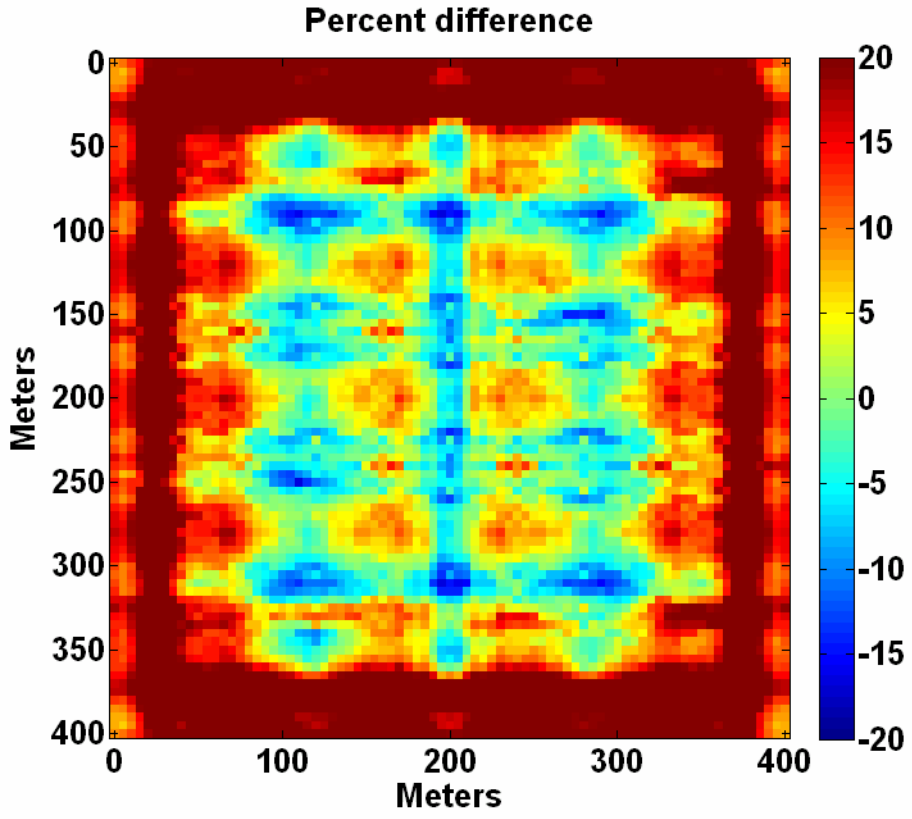
- Poststack migration:
  Featureless: up to 9%, Channel: up to 7%

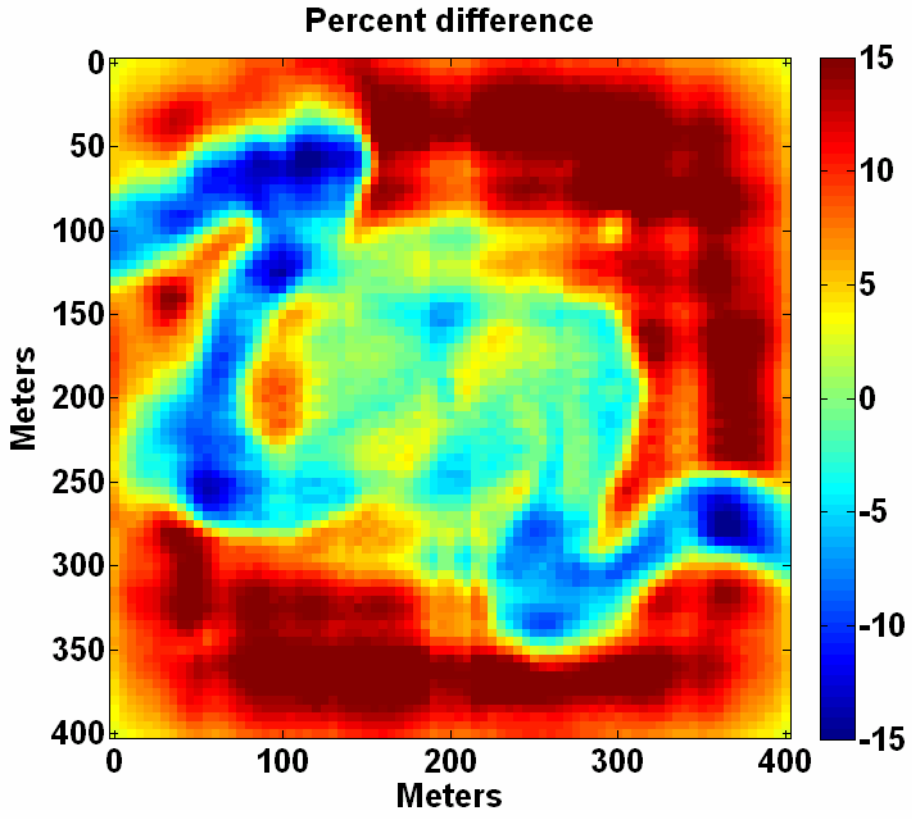




Footprint as % difference

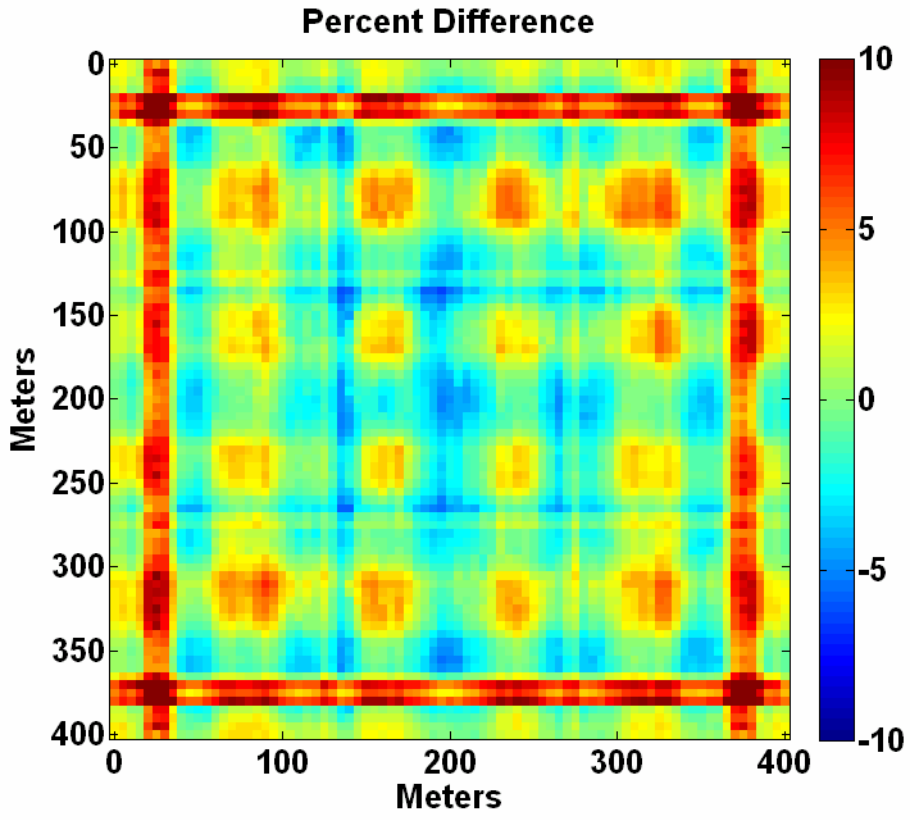
- UofC Prestack migration:
  Featureless: up to 17%, Channel: up to 14%

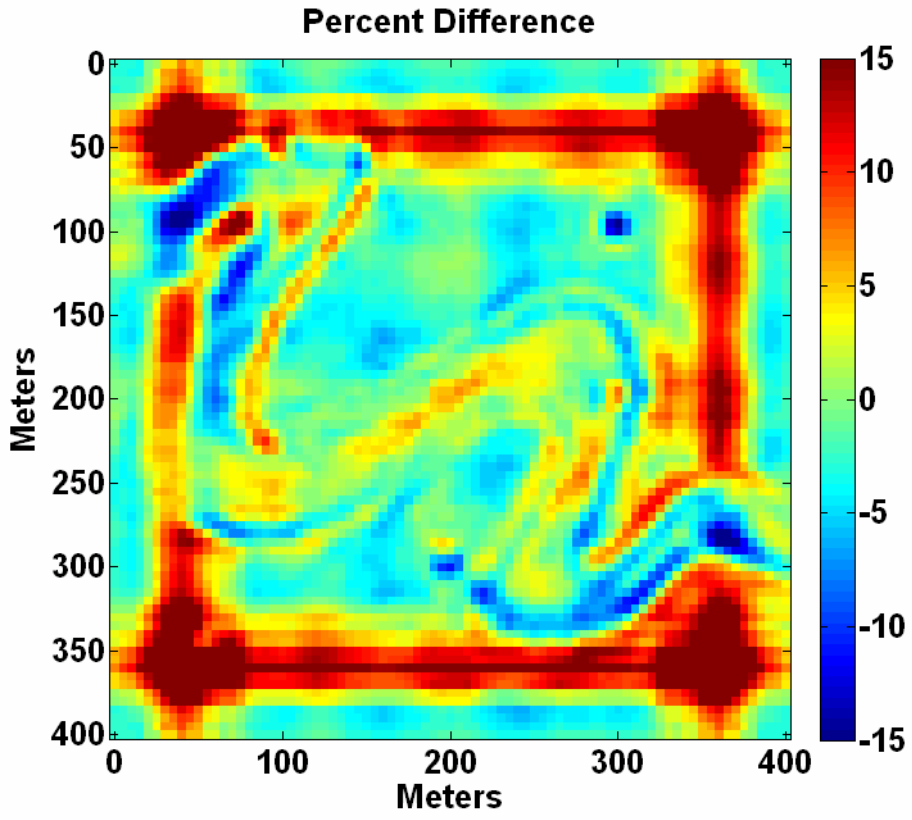




Footprint as % difference

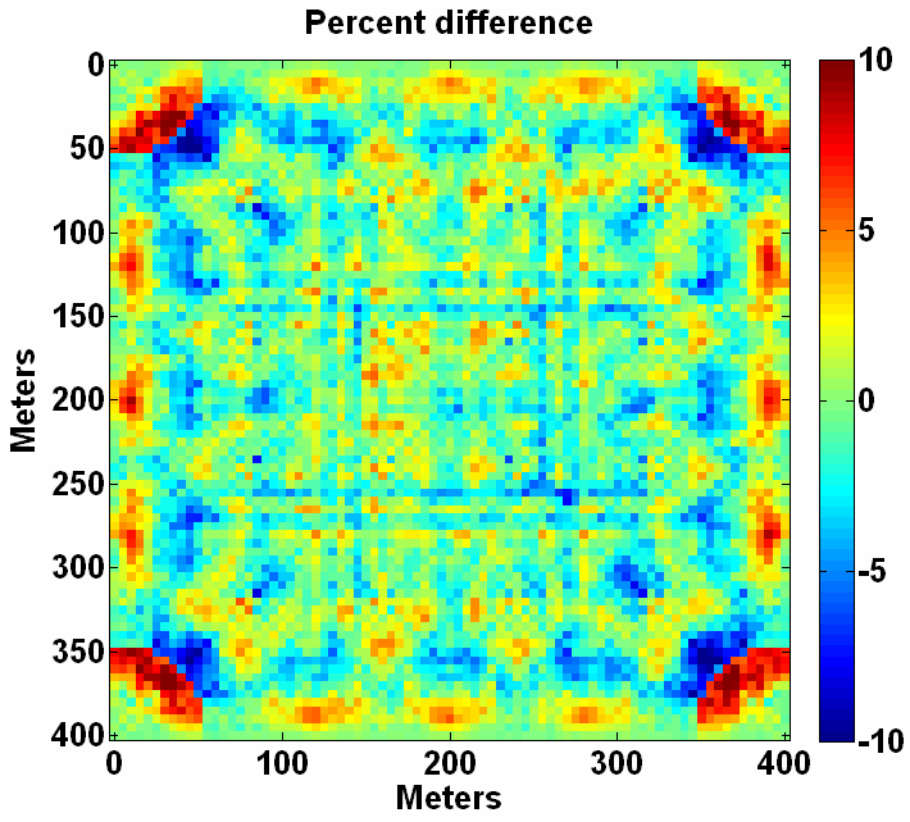
- Industrial Prestack migration A:
  Featureless: up to 7%, Channel: up to 13%

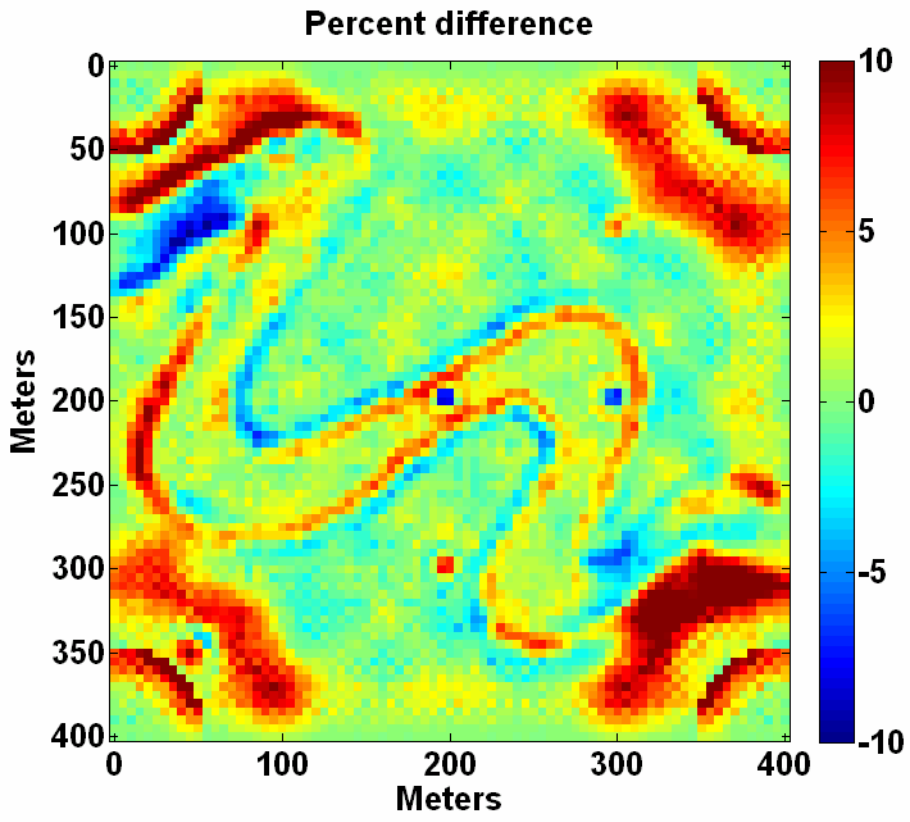




Footprint as % difference

- Industrial Prestack migration B:
  Featureless: up to 7%, Channel: up to 8%





Observations To Date

- Footprint most organized in stack on shallow reflector
- Footprint randomized somewhat after poststack migration
- Footprint most variable (and largest) in prestack migration, though weights make a difference
- Current method of comparing slices may not be ideal

Conclusions and Future Work

- Developed technique for investigation of footprint
  - Model exhaustive survey with “migration modelling” technique
  - Decimate to realistic survey geometries
  - Process with different methods and compare
- Preliminary results are interesting
- Plans for bigger, more realistic model
- Analyse other decimations
- Research on migration weights and interpolation

Acknowledgements

- Talisman Energy
  - Dave D'Amico, Mark Godlewski, Hugh Geiger, Gary Billings
- Sensor Geophysical
  - Peter Cary, Rod Couzens
- Divestco
  - Mike Perz, Ye Zheng, Wilf Reynish
- Husky Energy
  - Larry Mewhort, Ken Hedlin
- CREWES sponsors
- MITACS, NSERC, and AIF