# Reverse-time demigration using the extended imaging condition

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NTNU – Trondheim
Norwegian University of
Science and Technology

# Outline

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# Introduction

- The forward and inverse process of migration and demigration or remodeling has many interesting applications in seismic data processing
- Need for a method to transform seismic reflection data from the image-domain back to the prestack reflection data domain
- We developed a method to reconstruct seismic reflection data from common image point gathers contructed with RTM using an extended imaging condition
- The method is not directly dependent on the accuracy of velocity model

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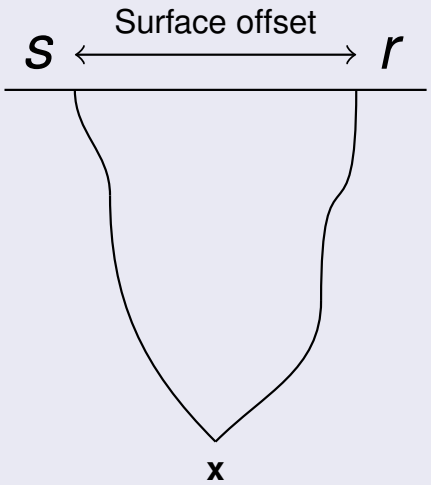
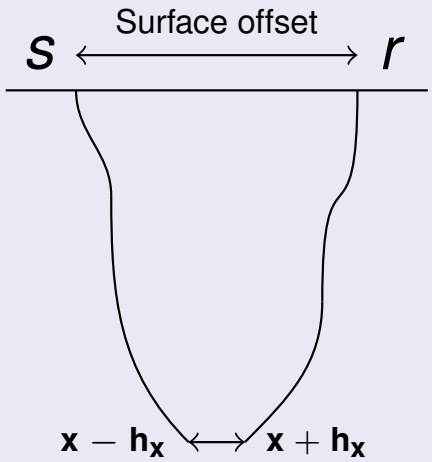
# Extended imaging condition

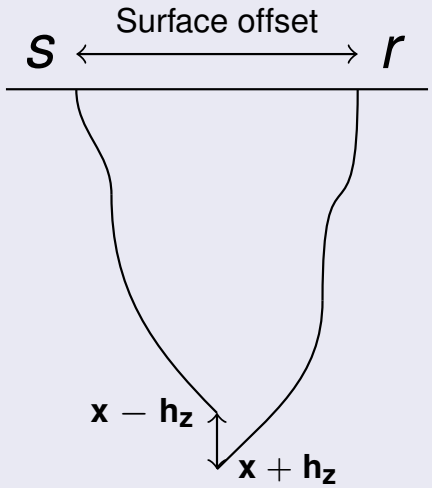
## Classical IC




[Claerbout, 1971]

## Extended IC




[Rickett and Sava, 2002]

# Reverse-time migration

## Migration

$$R(\mathbf{x},\mathbf{h}) = \int d\mathbf{s} \int dt\ W_s(\mathbf{x}-\mathbf{h},t,\mathbf{s}) \times \int d\mathbf{r} \int dt'\ G(\mathbf{x}+\mathbf{h},t;\mathbf{r},t')P(\mathbf{r},t',\mathbf{s}) \tag{1}$$

$$W_s(\mathbf{x},t,\mathbf{s}) = \int d\mathbf{s} \int dt'\ G(\mathbf{x},t;\mathbf{s},t')S(\mathbf{s},t') \tag{2}$$

# Reverse-time demigration

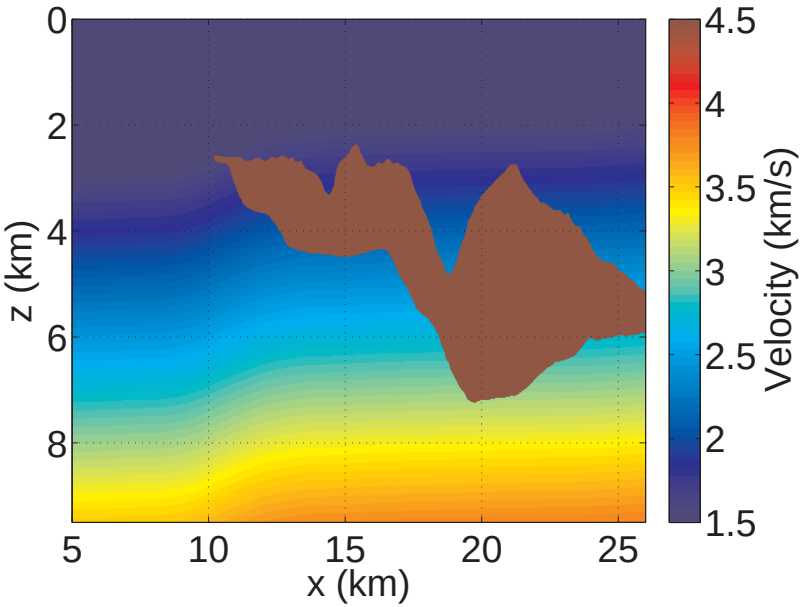
## Migration

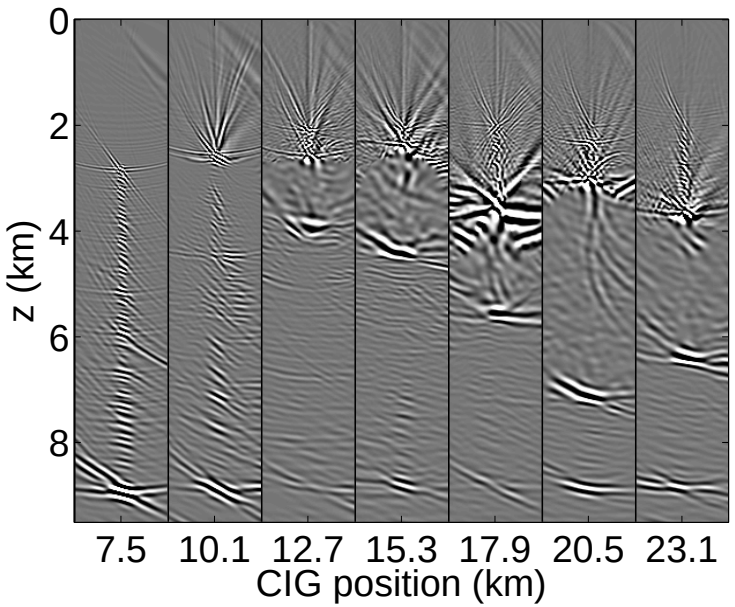
$$R(\mathbf{x},\mathbf{h}) = \int d\mathbf{s} \int dt\ W_s(\mathbf{x}-\mathbf{h},t,\mathbf{s}) \times \int d\mathbf{r} \int dt'\ G(\mathbf{x}+\mathbf{h},t;\mathbf{r},t')P(\mathbf{r},t',\mathbf{s}) \tag{3}$$

## Modeling (Born)

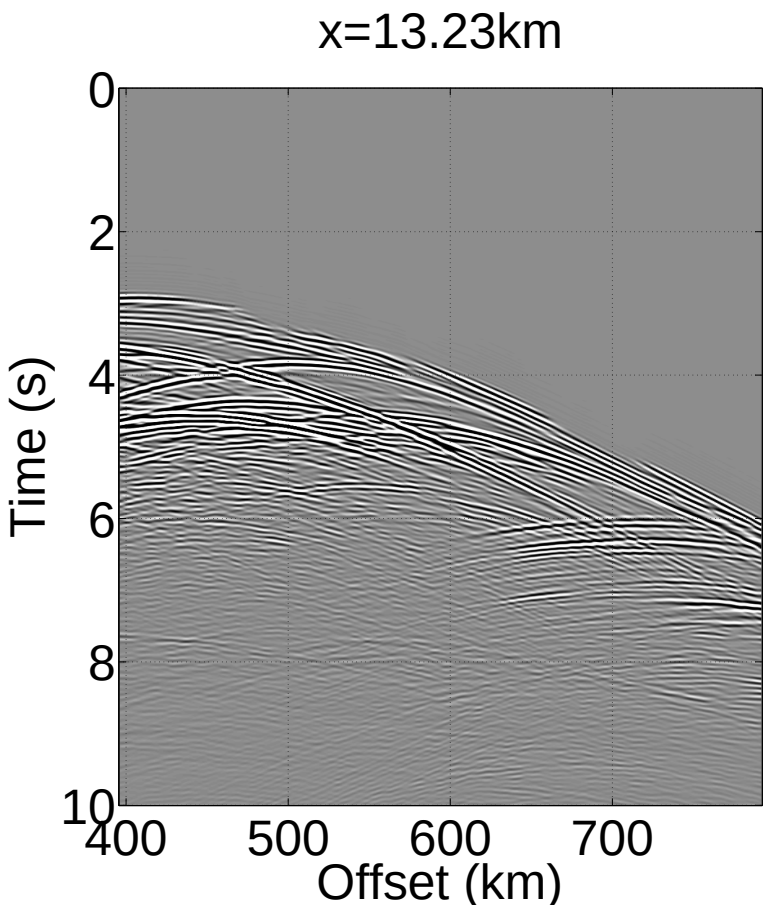
$$P(\mathbf{r},t,s) = \int d\mathbf{x} \int dt'\ G(\mathbf{r},t;\mathbf{x},t') \times \int d\mathbf{h} \frac{\partial^2 R}{\partial z^2}(\mathbf{x}-\mathbf{h},\mathbf{h}) W_s(\mathbf{x}-2\mathbf{h},t',s) \tag{4}$$

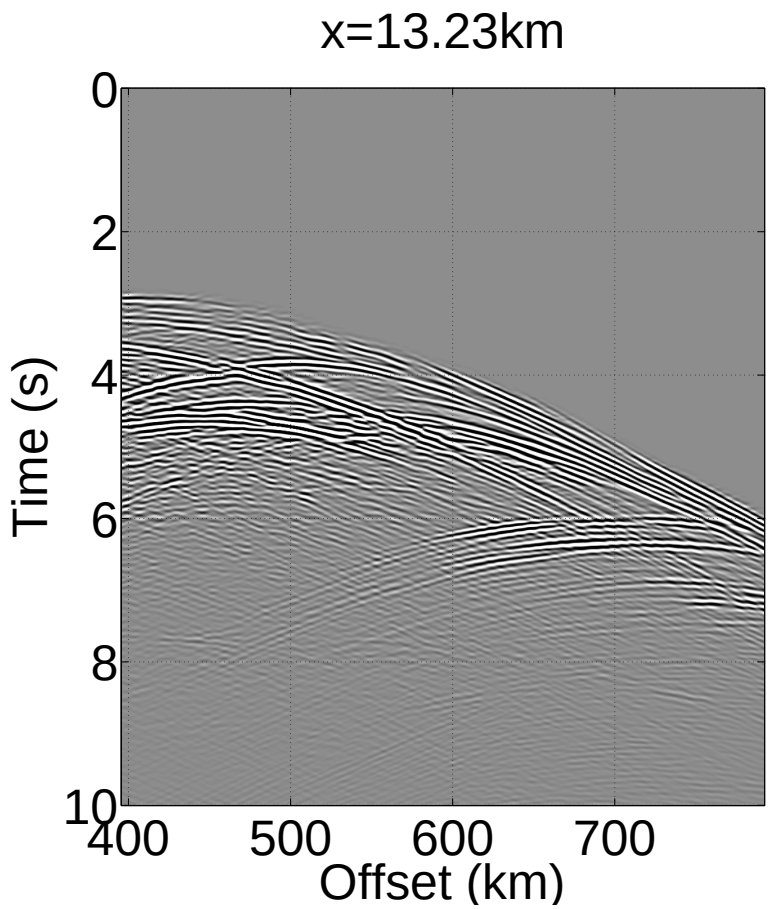
# Modeling (Born)



# Modeling (Born)



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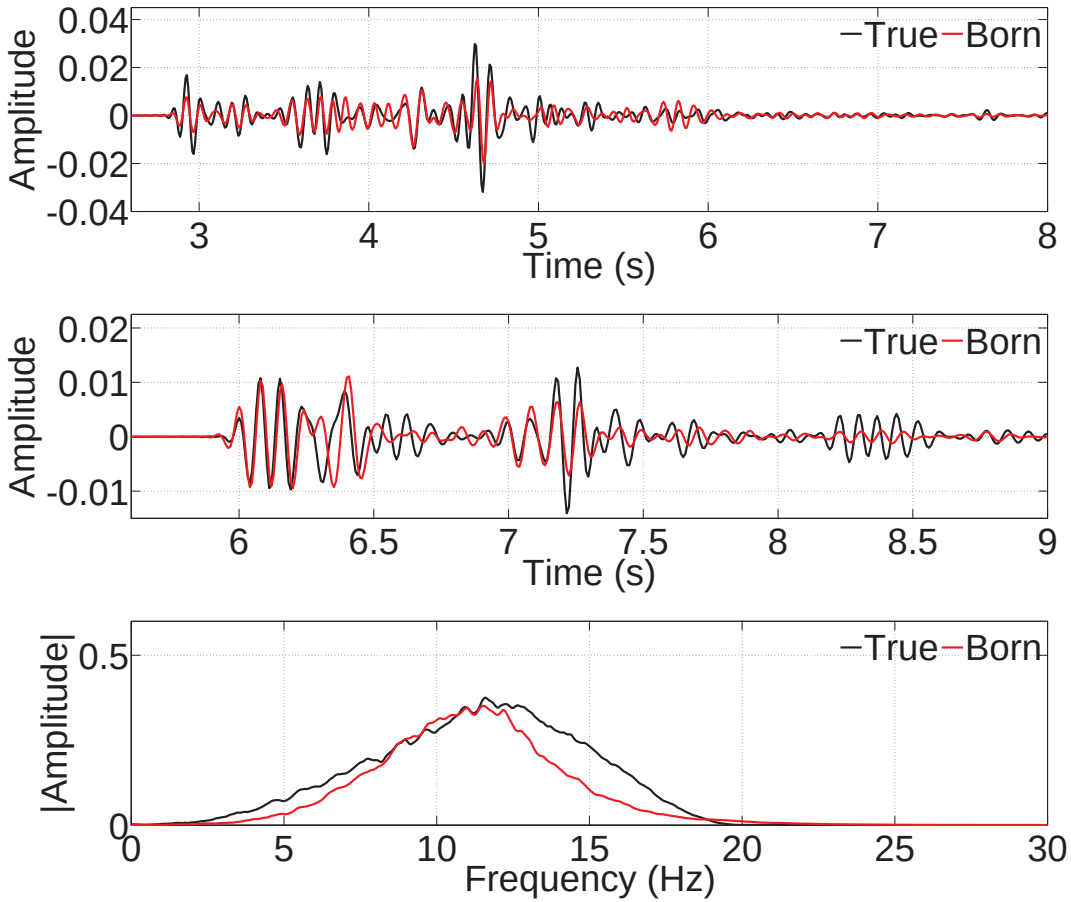


# Inversion

## Least squares error function

$$J = \frac{1}{2} \int d\mathbf{x} \int d\mathbf{h} \left[ \frac{\partial R^0}{\partial z}(\mathbf{x}, \mathbf{h}) - \frac{\partial R}{\partial z}(\mathbf{x}, \mathbf{h}) \right]^2 \tag{5}$$

# Inversion

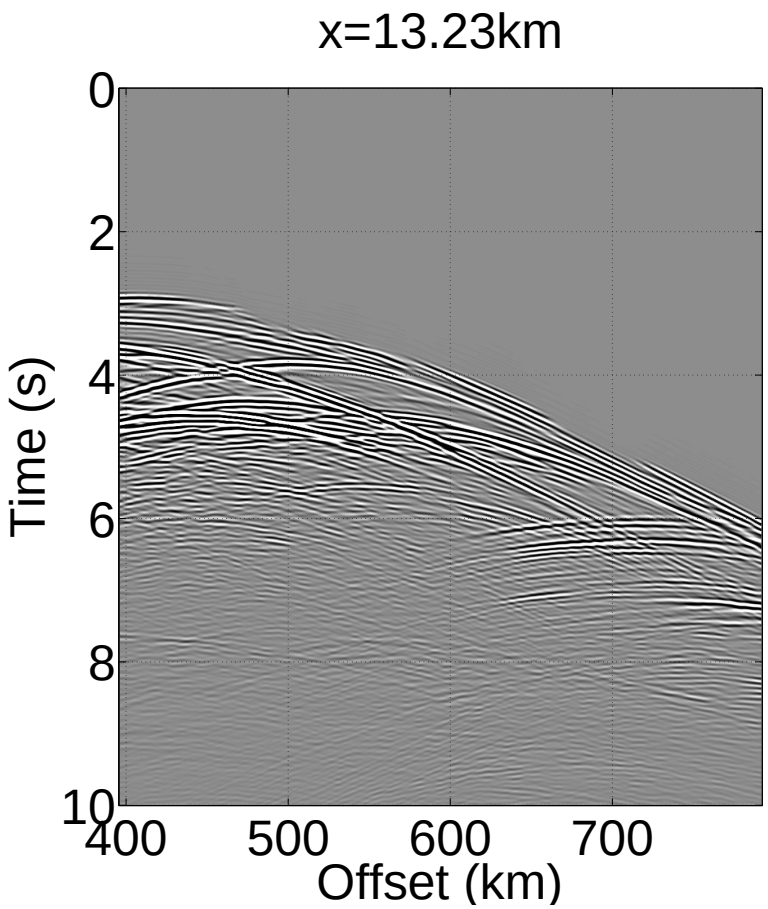
## Steepest descent

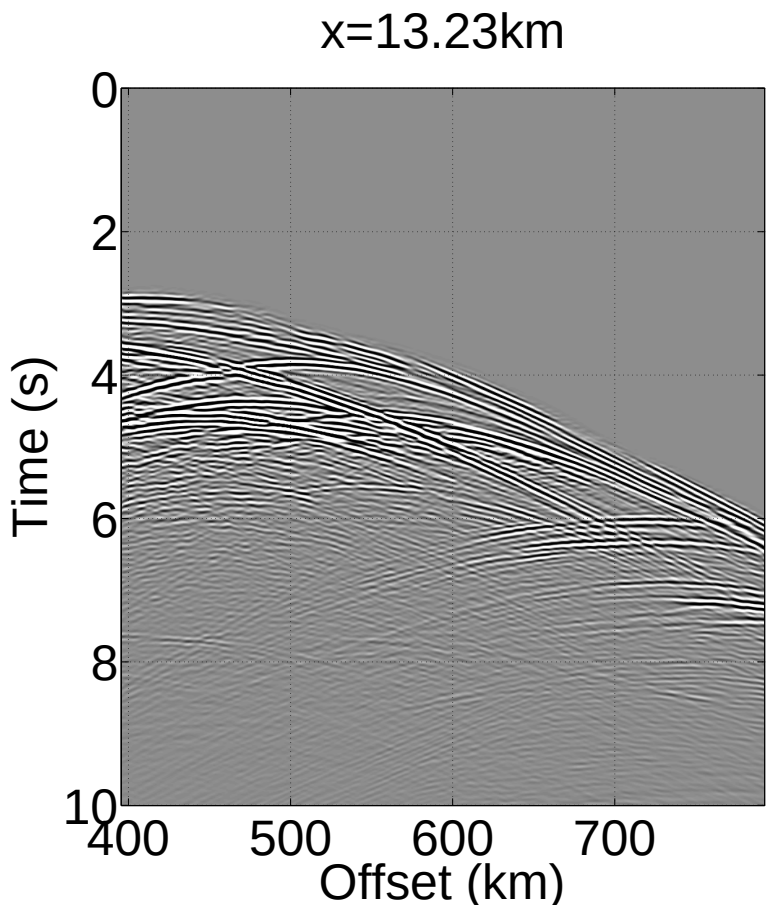
$$P_{i+1}(\mathbf{x}, t, s) = P_i(\mathbf{x}, t, s) - \alpha_i \frac{\partial J}{\partial P_i}(\mathbf{x}, t, s) \tag{6}$$

## Gradient

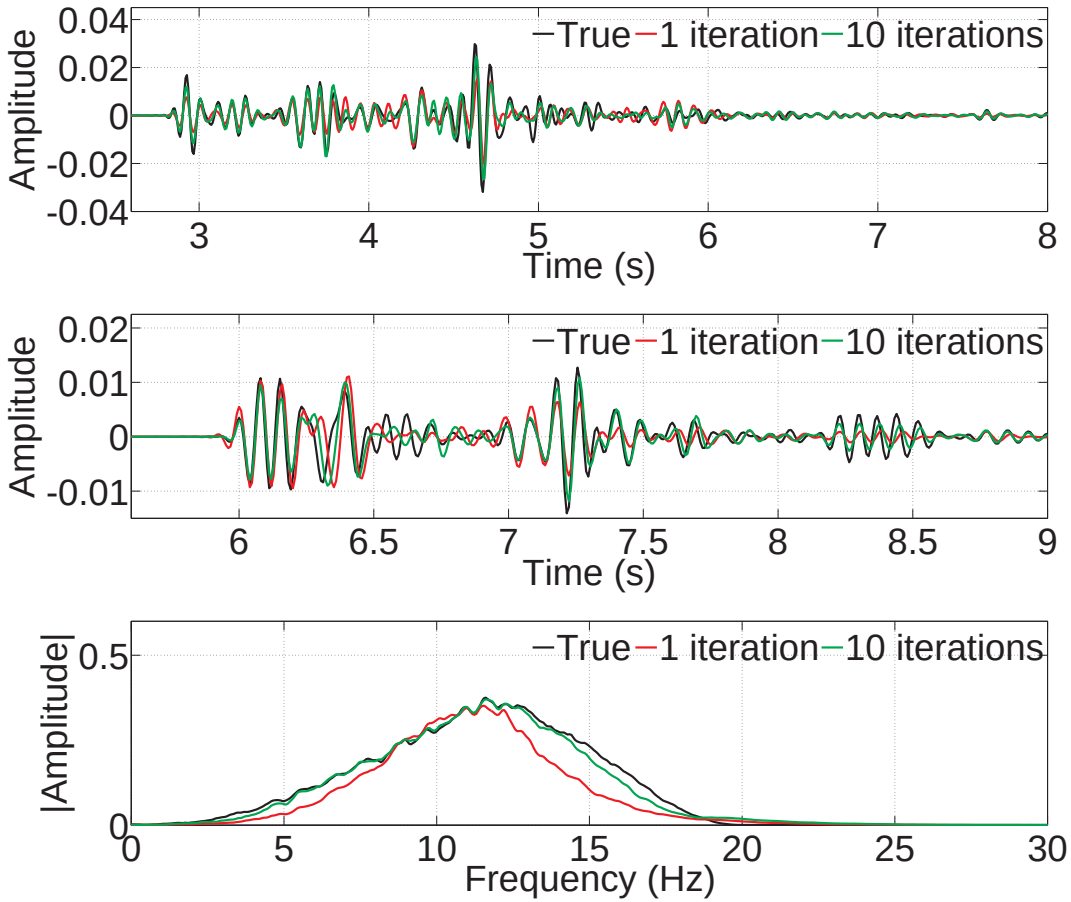
$$\frac{\partial J}{\partial P_i}(\mathbf{x}, t, s) = \int d\mathbf{x}' \int dt' \; G(\mathbf{x}, t; \mathbf{x}', t') \times \int d\mathbf{h} \frac{\partial^2 \Delta R_i}{\partial z^2}(\mathbf{x}' - \mathbf{h}, \mathbf{h}) W_s(\mathbf{x}' - 2\mathbf{h}, t', s) \tag{7}$$

# Inversion


x=13.23km
0
2
4
6
8
10
Time (s)
400
500
600
700
Offset (km)

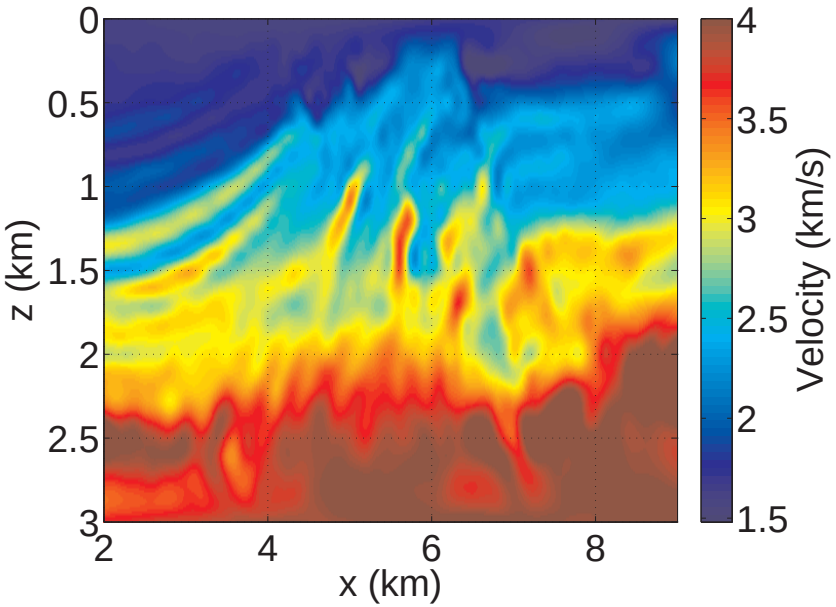

x=13.23km
0
2
4
6
8
10
Time (s)
400
500
600
700
Offset (km)

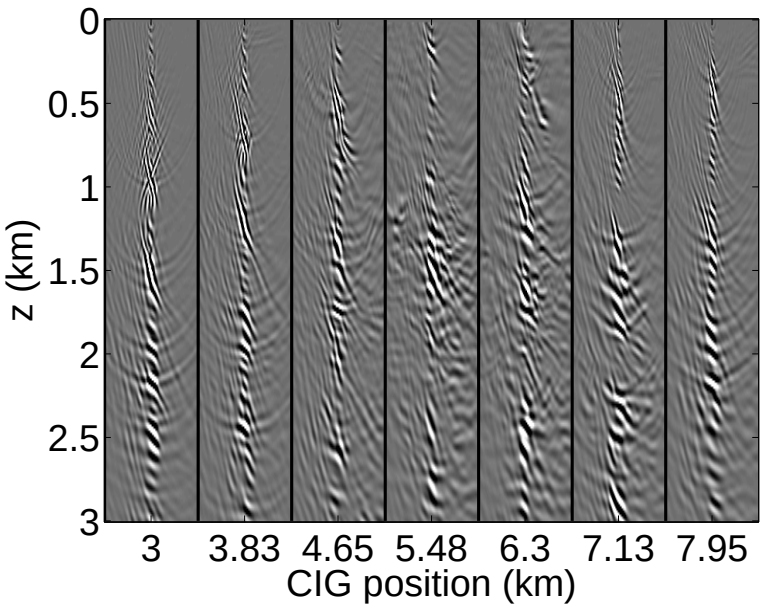
# Inversion


True
1 iteration
10 iterations
Amplitude
0.04
0.02
0
-0.02
-0.04
3
4
5
6
7
8
Time (s)
Amplitude
0.02
0.01
0
-0.01
6
6.5
7
7.5
8
8.5
9
Time (s)
|Amplitude|
0.5
0
0
5
10
15
20
25
30
Frequency (Hz)

# Outline

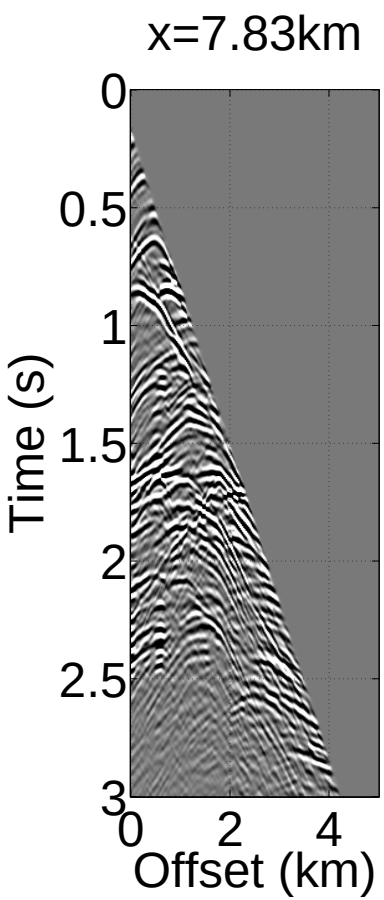
# Data reconstruction



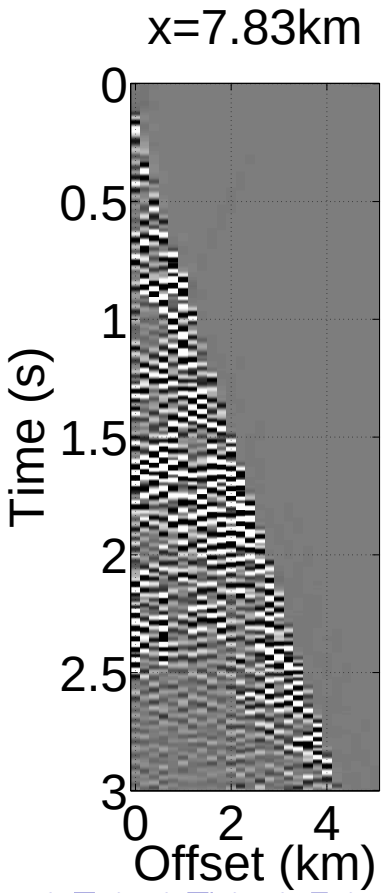



# Dip aliased shot gathers

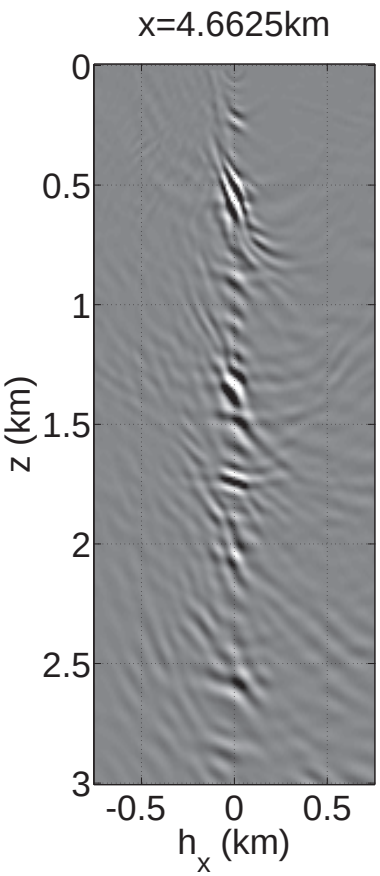
Original

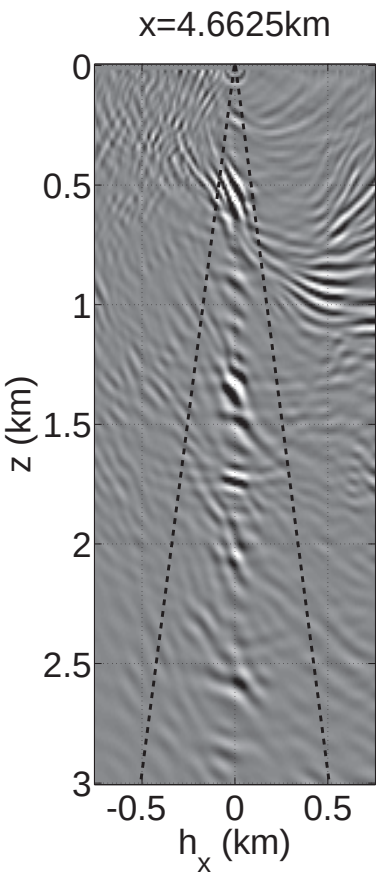


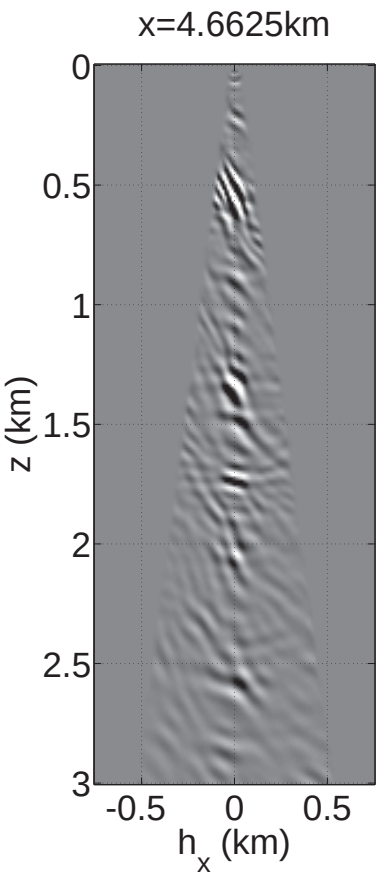

Decimated



# CIGs and dip aliasing

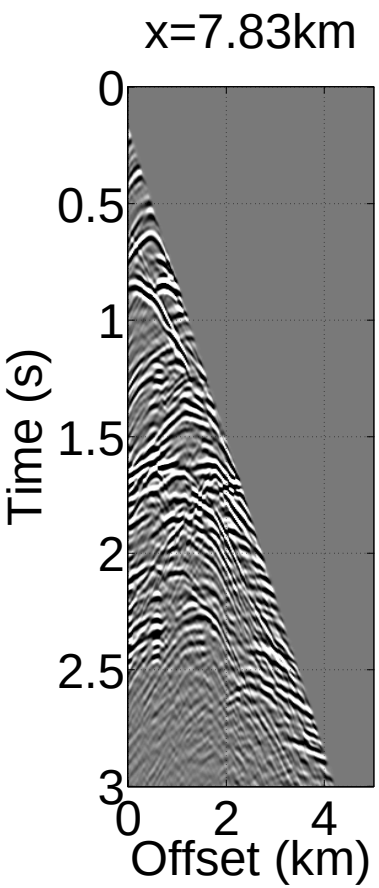


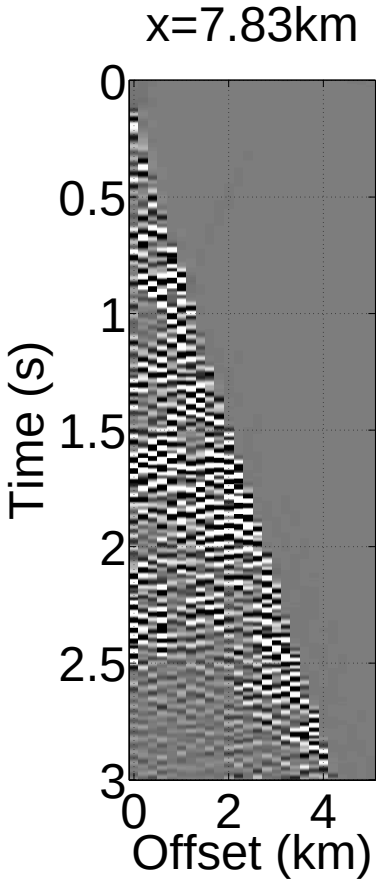



# Demigration

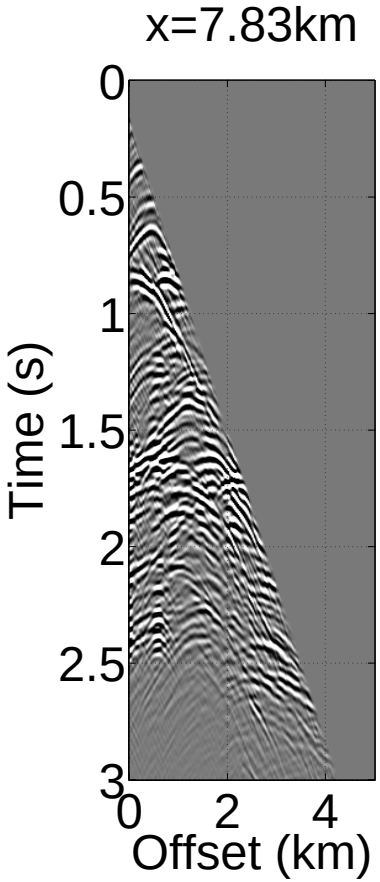
Original



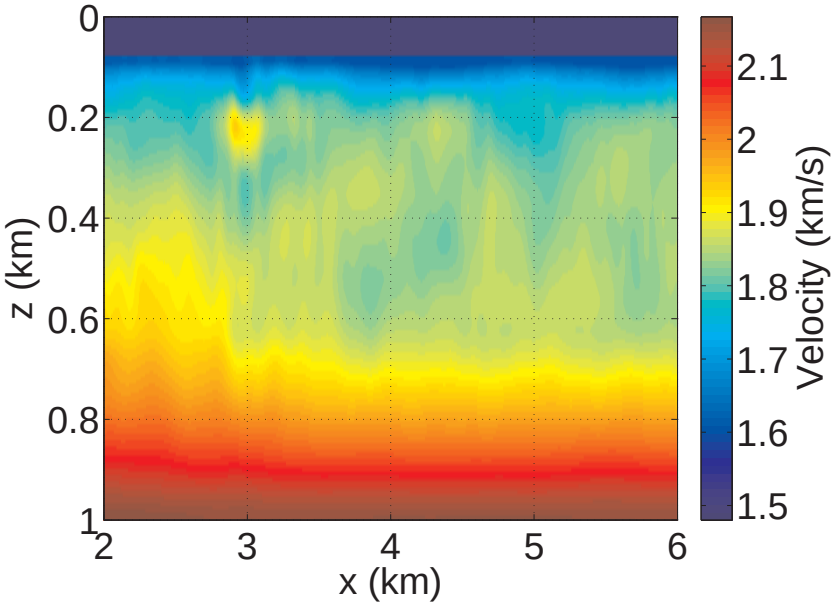

Decimated

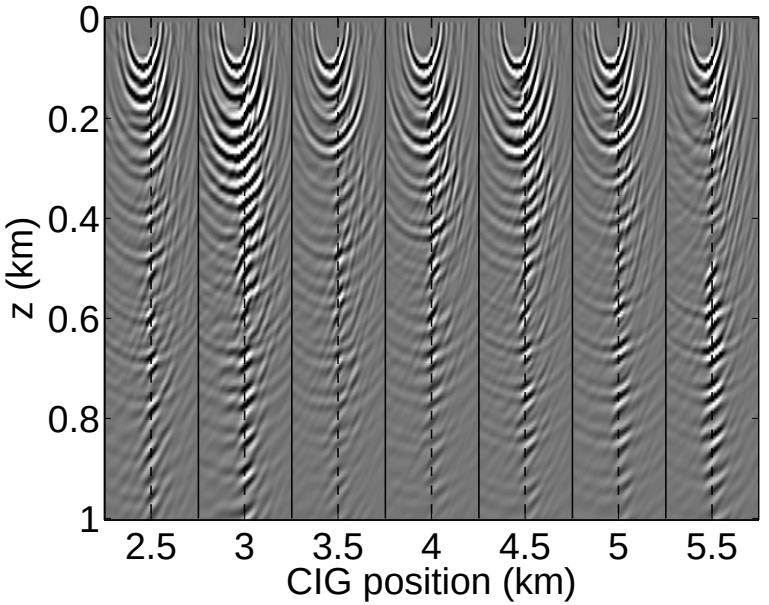



Reconstructed

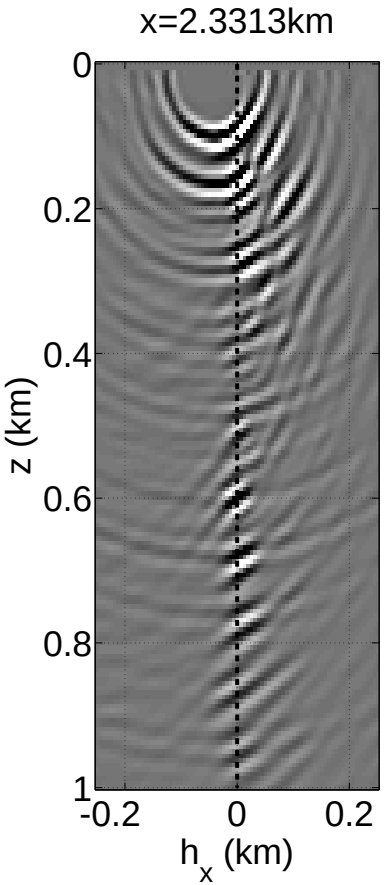


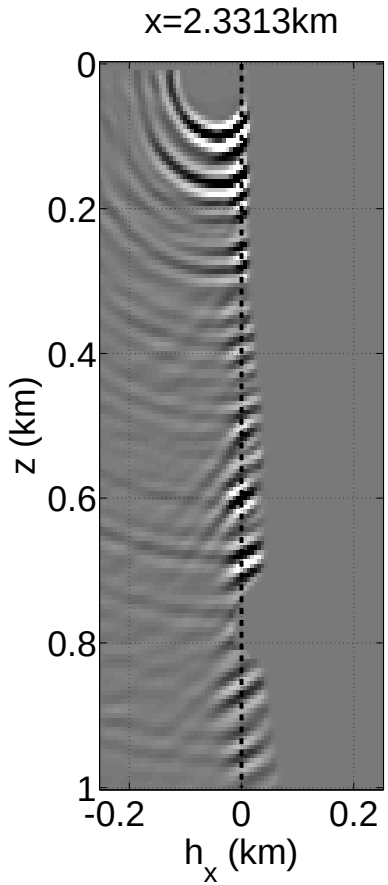
# Multiple attenuation



# CIGs and multiples



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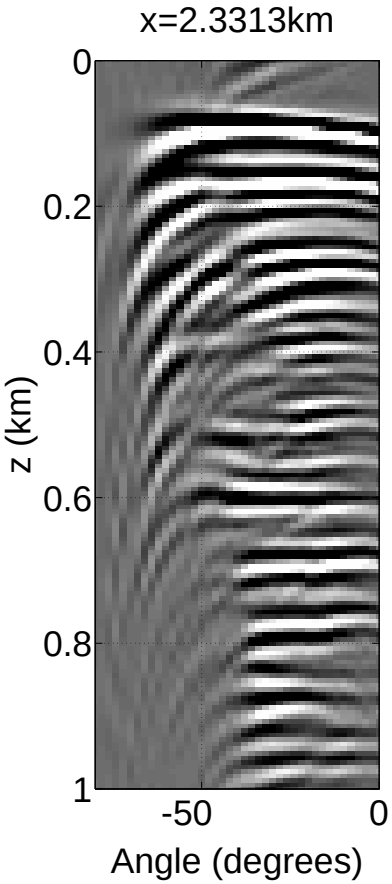
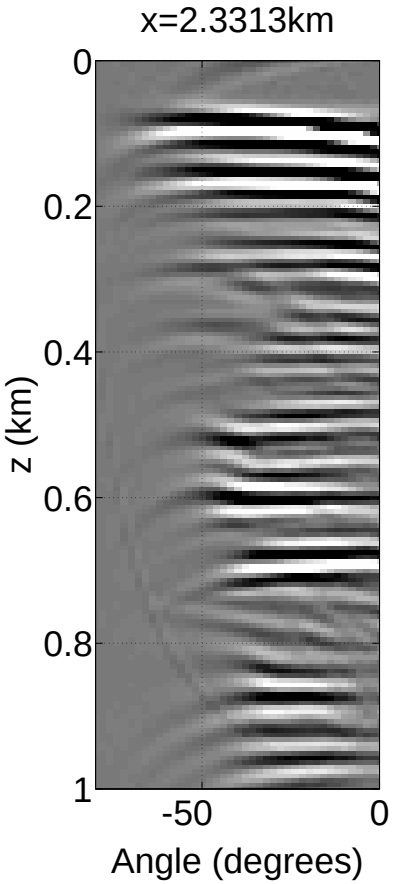
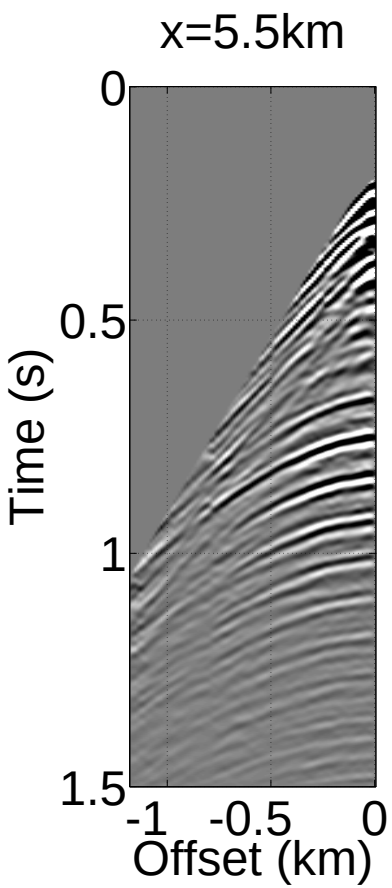


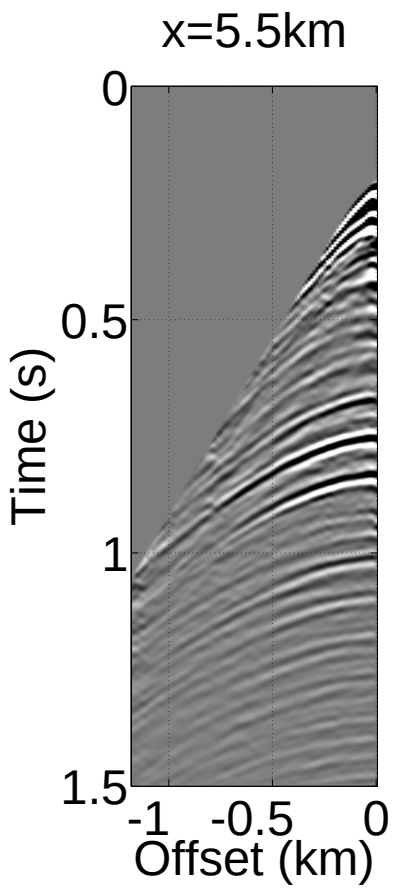



# Demigration

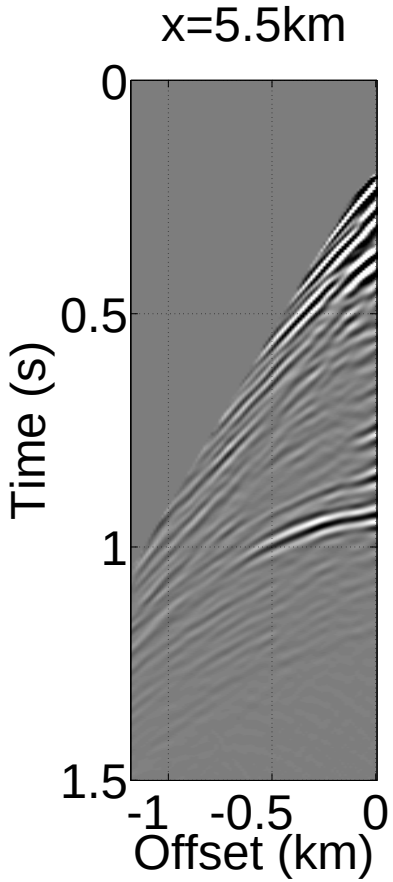
Original




Demigrated




Difference



# Outline

# Summary and remarks

- We developed a method to reconstruct seismic reflection data from CIGs constructed with RTM using an extended imaging condition
- The numerical experiments show that the method allows kinematic reconstruction of the data after 1 iteration
- On the other hand, amplitude reconstruction requires many iterations
- The method can be used to process data acquired over complex geological media

# Acknowledgments

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Statoil

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# Bibliography


- Claerbout, J. F., 1971, Toward a unified theory of reflector mapping: Geophysics, **36**, 467–481.
- Rickett, J. E., and P. C. Sava, 2002, Offset and angle-domain common image-point gathers for shot-profile migration: Geophysics, **67**, 883–889.