True amplitude cross-correlation imaging condition for Reverse Time Migration

B. Arntsen and E. B. Raknes

NTNU
Department of Geoscience and petroleum
borge.arntsen@ntnu.no

EGU General Assembly 2017

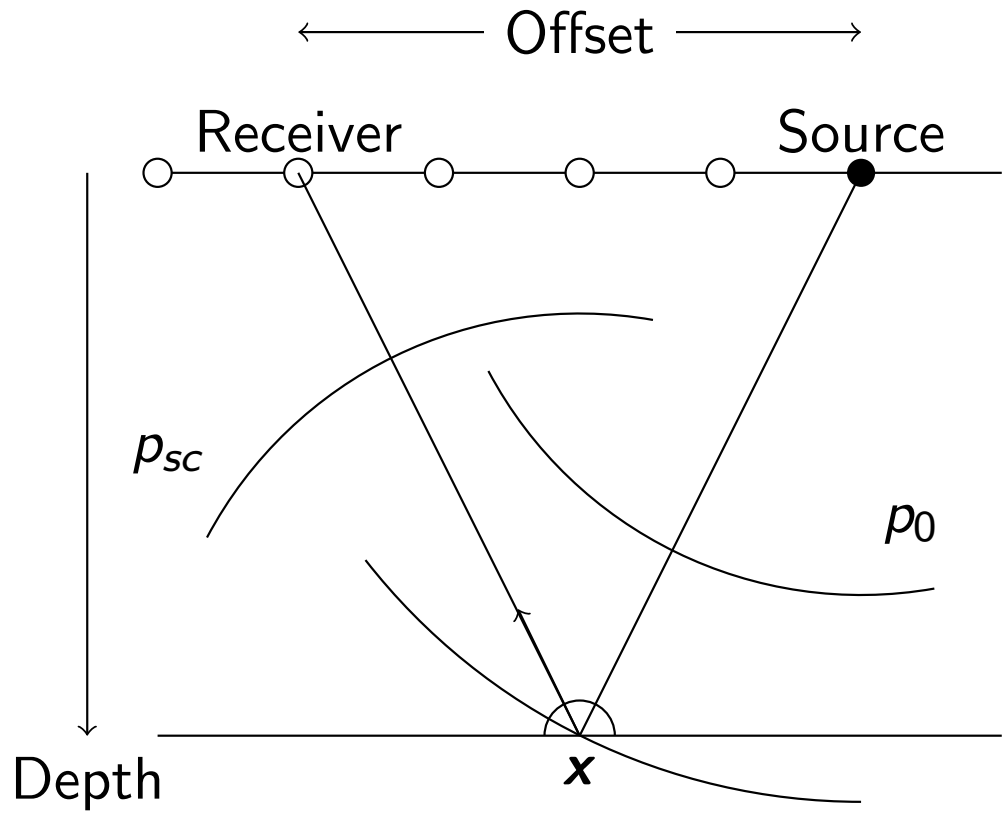
Overview

1. Introduction
2. True Amplitude Imaging condition
3. Numerical examples
4. Conclusions

Introduction

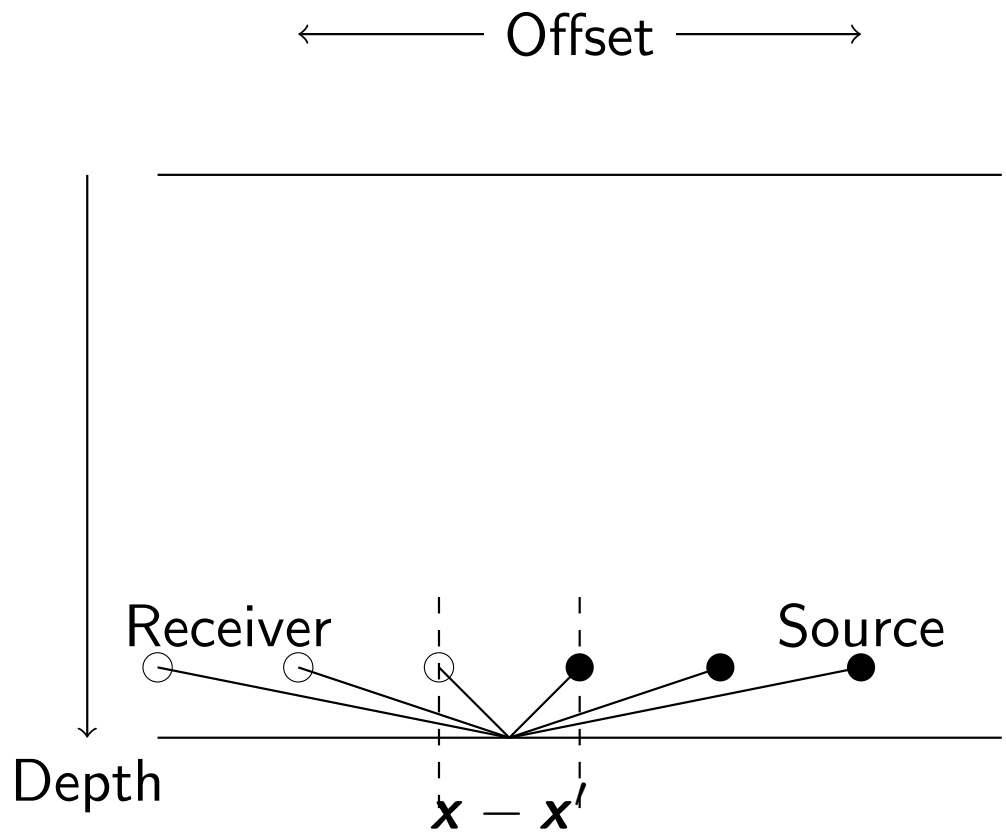
1. Reverse time migration is used both on exploration and global scale
2. The so called imaging condition is crucial for the resolution and accuracy of the image
3. The standard imaging condition in use today can be easily modified to give better accuracy and resolution
4. The modification also gives reflectivity with correct amplitudes

Imaging condition I



p_{sc}: Scattereded wavefield (data)
p_0: Modeled wavefield
$\boldsymbol{x}$: Spatial position

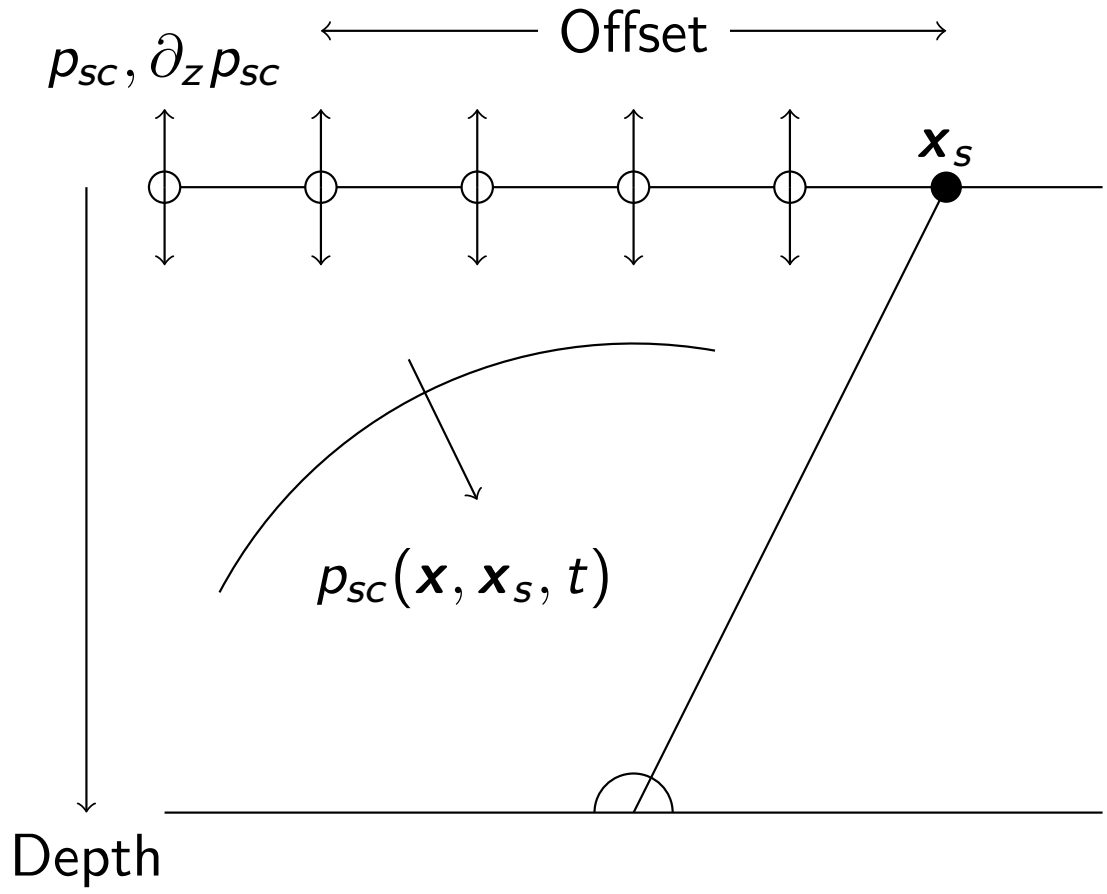
Imaging condition II



$\boldsymbol{x}$: Virtual receiver

$\boldsymbol{x}'$: Virtual source

Imaging condition III

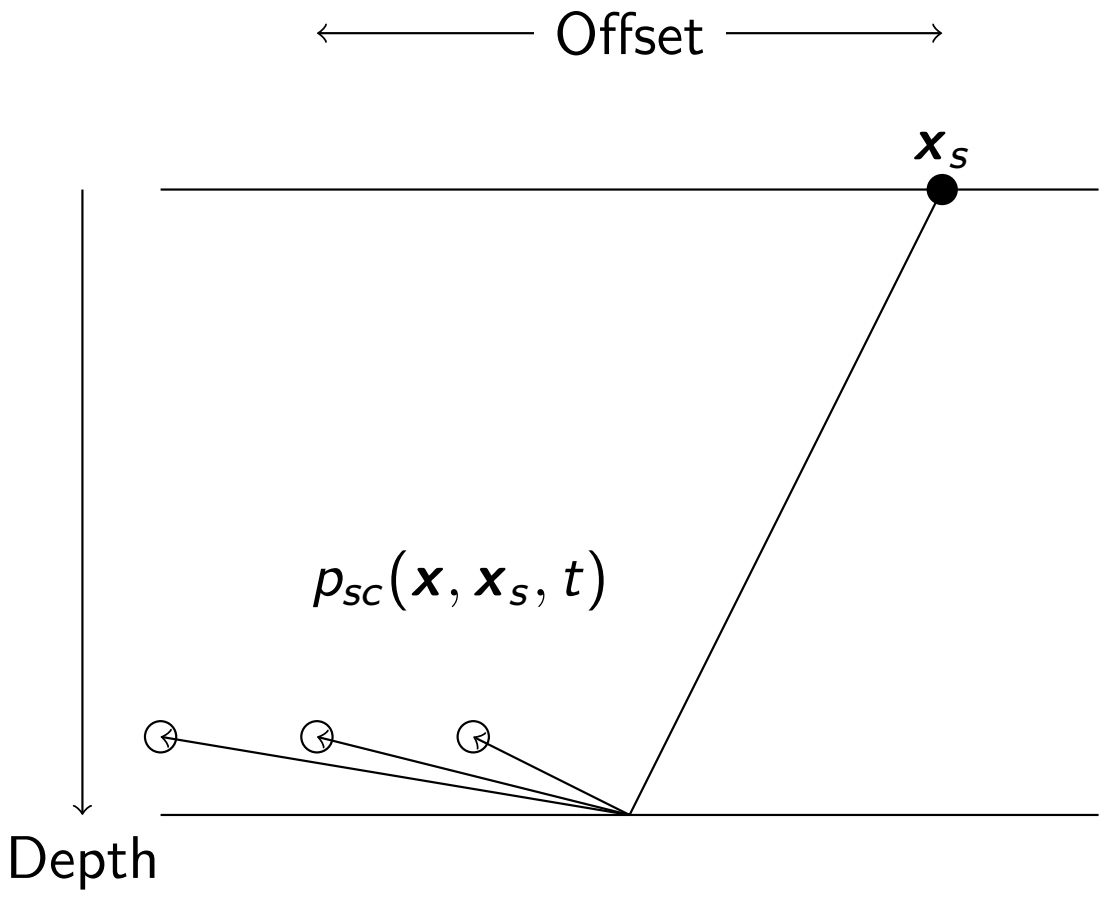


p_{sc}: Scattered wavefield

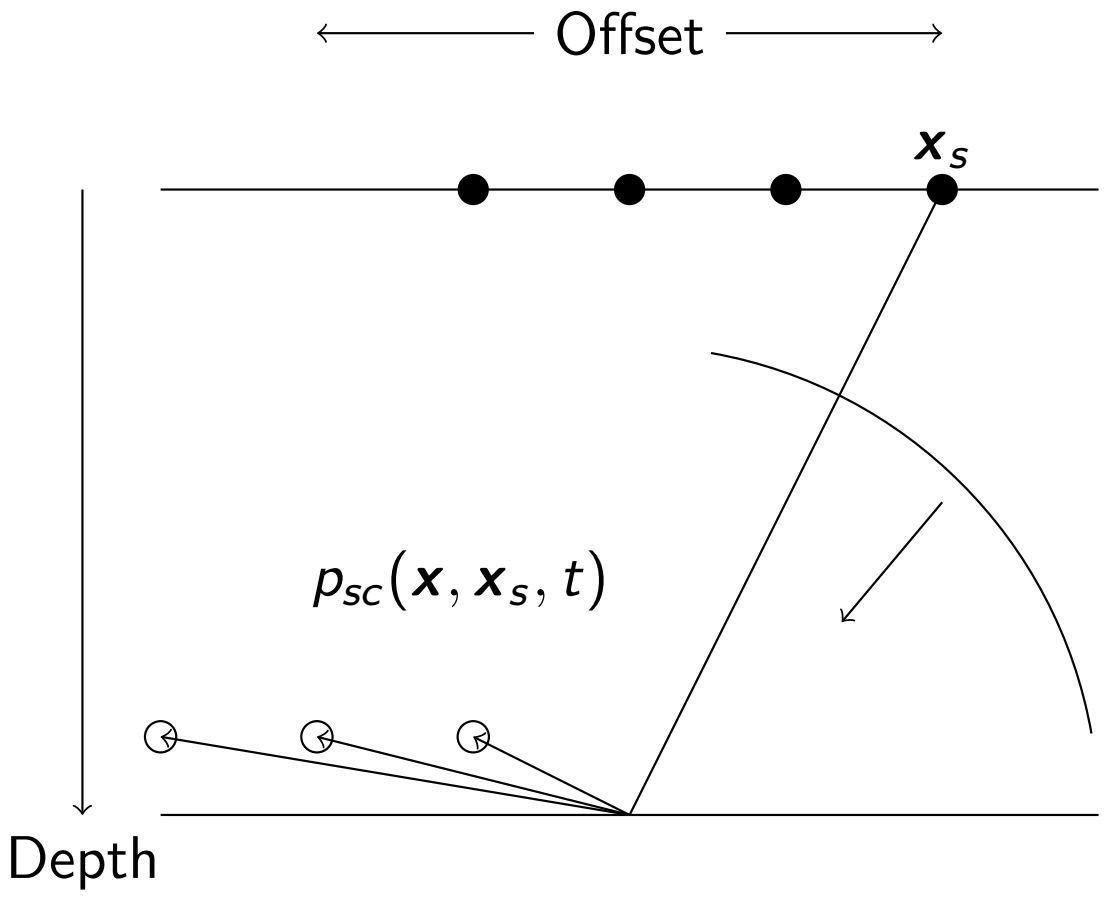
$\boldsymbol{x}_s$: Source position

$\boldsymbol{x}, t$: Position,time

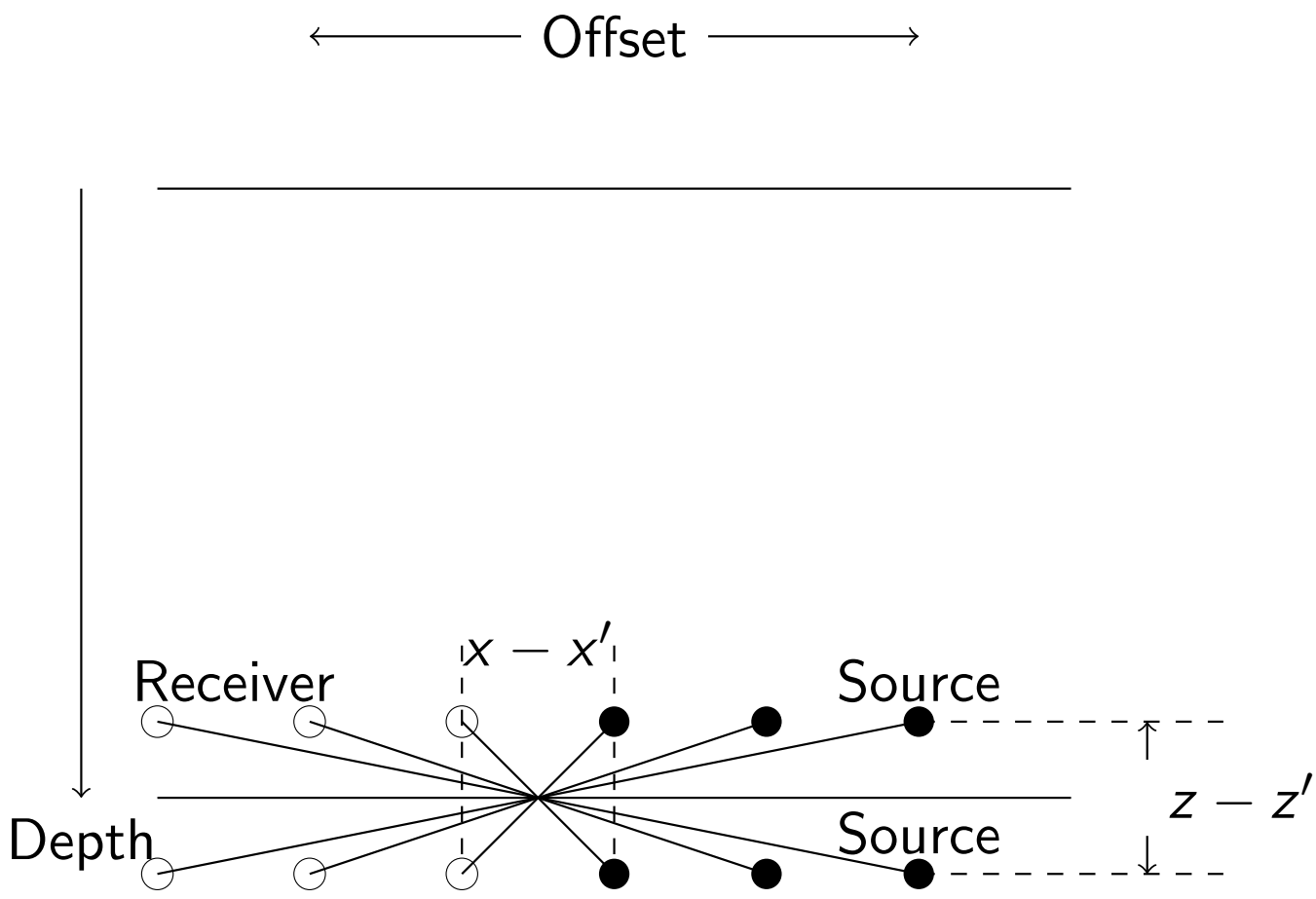
Imaging condition IV



Imaging condition V



Imaging condition VI



$x - x'$: Horizontal offset

$z - z'$: Vertical offset

New Imaging condition

Redatumed scattered wavefield:

$$p_{sc}(\boldsymbol{x}, \boldsymbol{x}', t) * s(-t) \approx 2 \sum_{\boldsymbol{x}_s} \sum_{\tau} \partial_{z_s} p_0(\boldsymbol{x}, \boldsymbol{x}_s, t+\tau) p_{sc}(\boldsymbol{x}', \boldsymbol{x}_s, \tau)$$

- $p_0(\boldsymbol{x}.\boldsymbol{x}_s, t)$: Forward simulated wavefield
- $p_s c(\boldsymbol{x}', \boldsymbol{x}_s)$: Back propagated scattered wavefield (data)
- $s(t)$: Source signature

(Oristaglio, 1989**?** and Wapenaar, 2007 **?**).

New imaging condition:

$$\begin{aligned} r(\boldsymbol{x}, \boldsymbol{x}') &= p_{sc}(\boldsymbol{x}, \boldsymbol{x}', t) * s(-t)|_{t=0} = \\ &\approx 2 \sum_{\boldsymbol{x}_s} \sum_{\tau} \partial_{z_s} p_0(\boldsymbol{x}, \boldsymbol{x}_s, \tau) p_{sc}(\boldsymbol{x}', \boldsymbol{x}_s, \tau) \end{aligned}$$

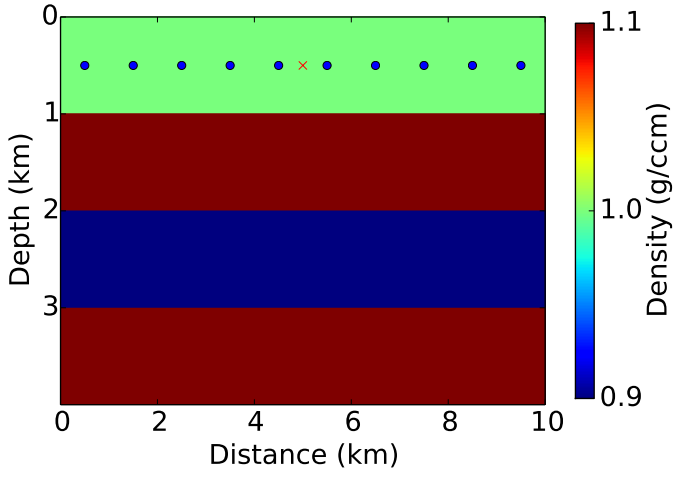
Classical Imaging condition

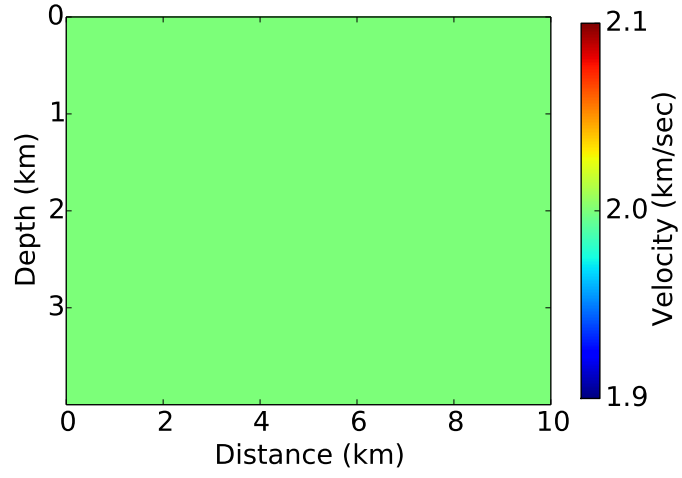
For $\boldsymbol{x}' = \boldsymbol{x}$ and by ignoring ∂_z this is the classical imaging condition (Claerbout, 1971) **?**

$$r_c(\boldsymbol{x}) = \sum_{\boldsymbol{x}_s} \sum_{\tau} p_0(\boldsymbol{x}, \boldsymbol{x}_s, \tau) p_{sc}(\boldsymbol{x}, \boldsymbol{x}_s, \tau)$$

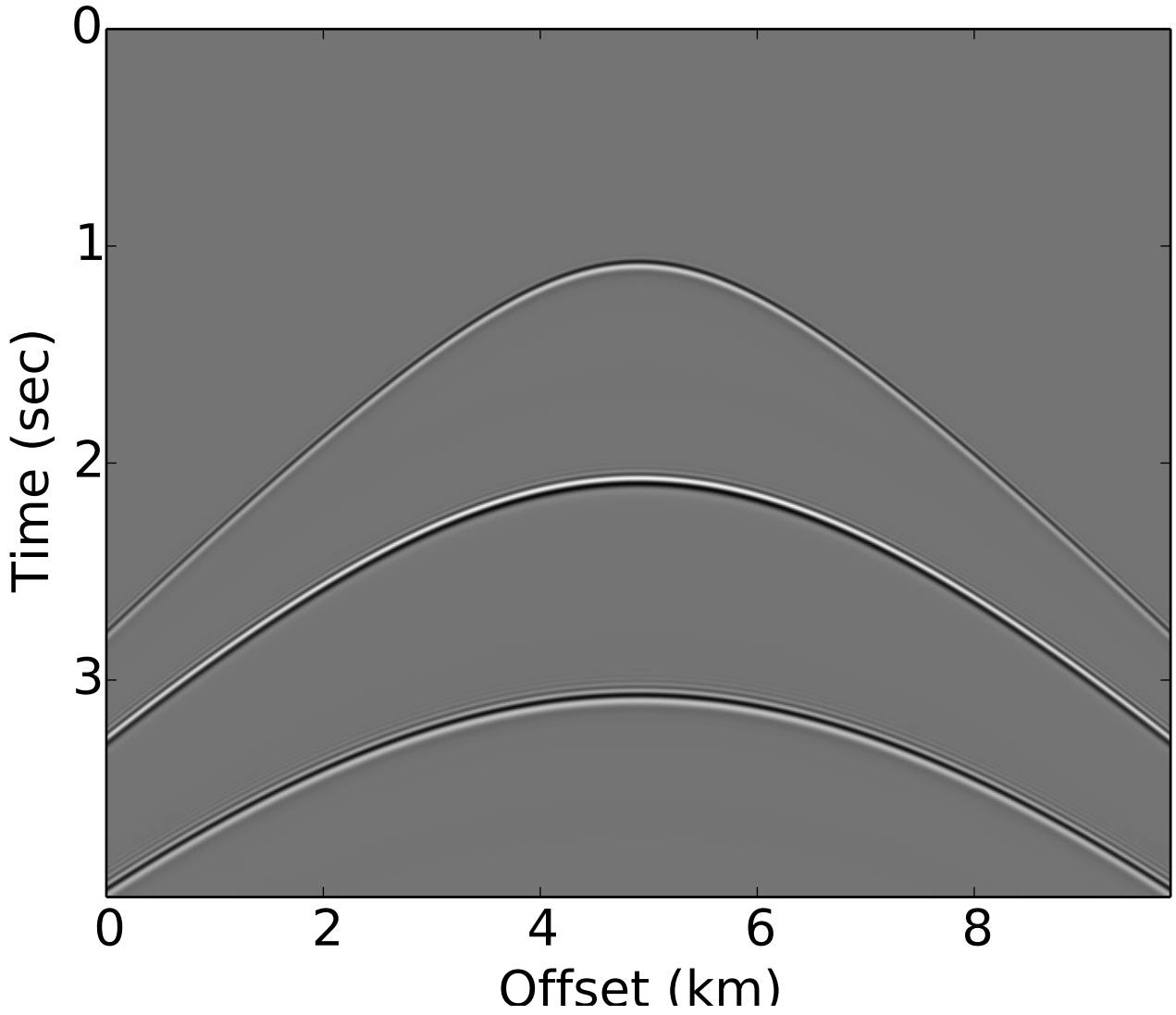
Ignoring ∂_z implies an unfocused image with less than optimal resolution and incorrect amplitudes.

Numerical examples



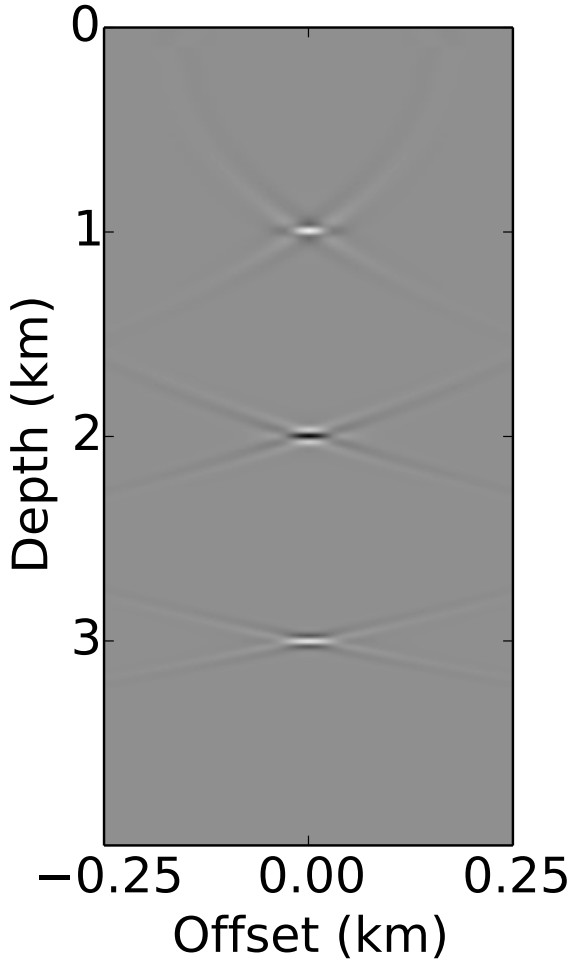


Numerical examples



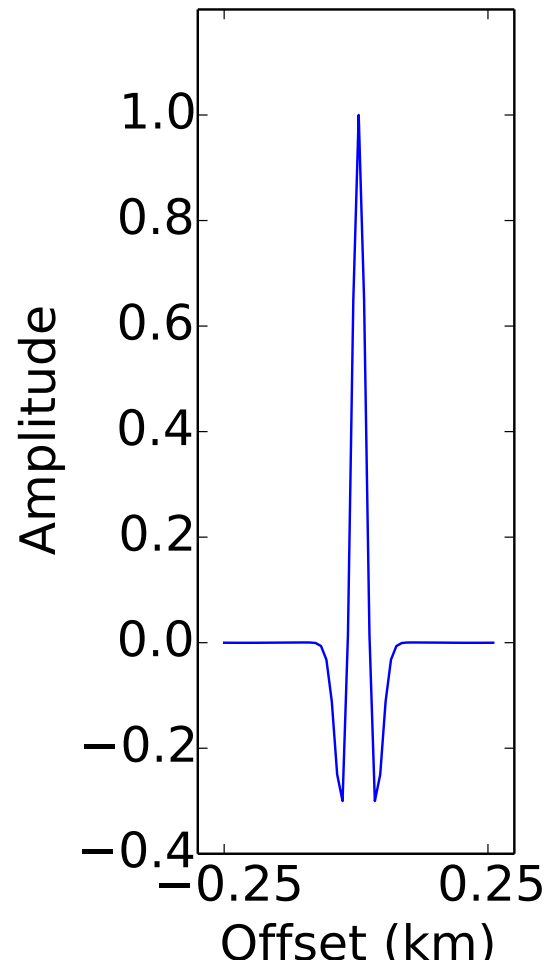
Numerical examples

Common image point gather (CIP) in the center of the model
Classical imaging condition:



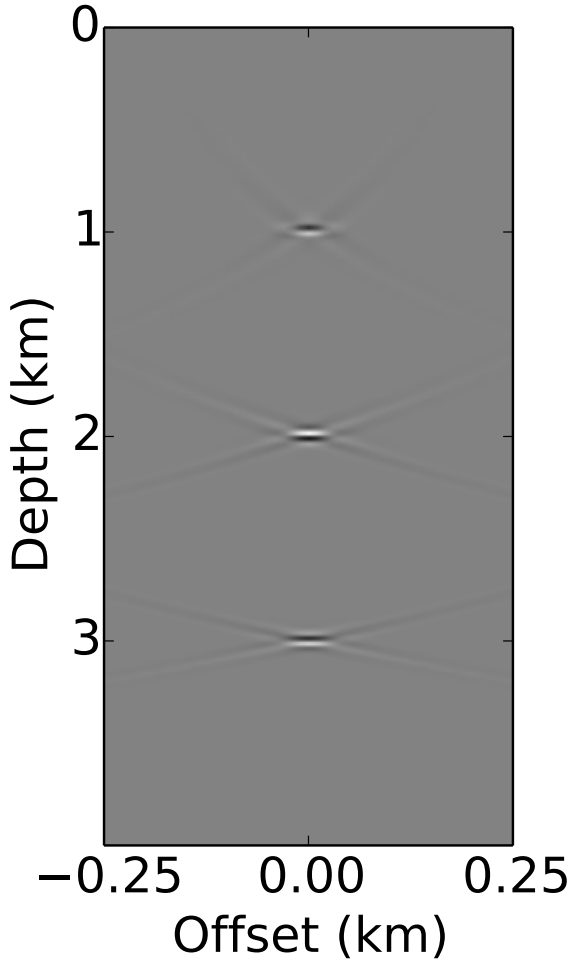
Numerical examples

Horizontal profile through reflector at 1000m depth



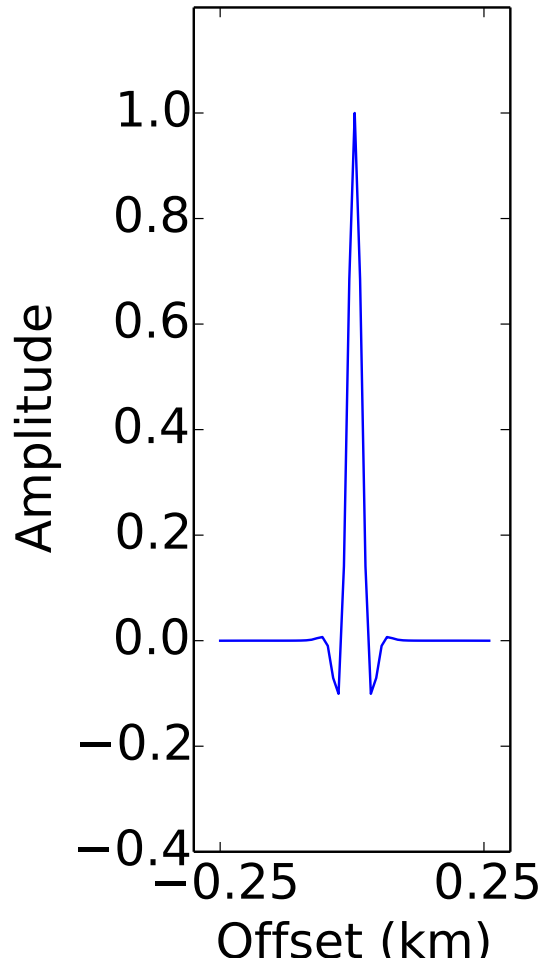
Numerical examples

Common image point gather (CIP) in the center of the model.
New imaging condition:



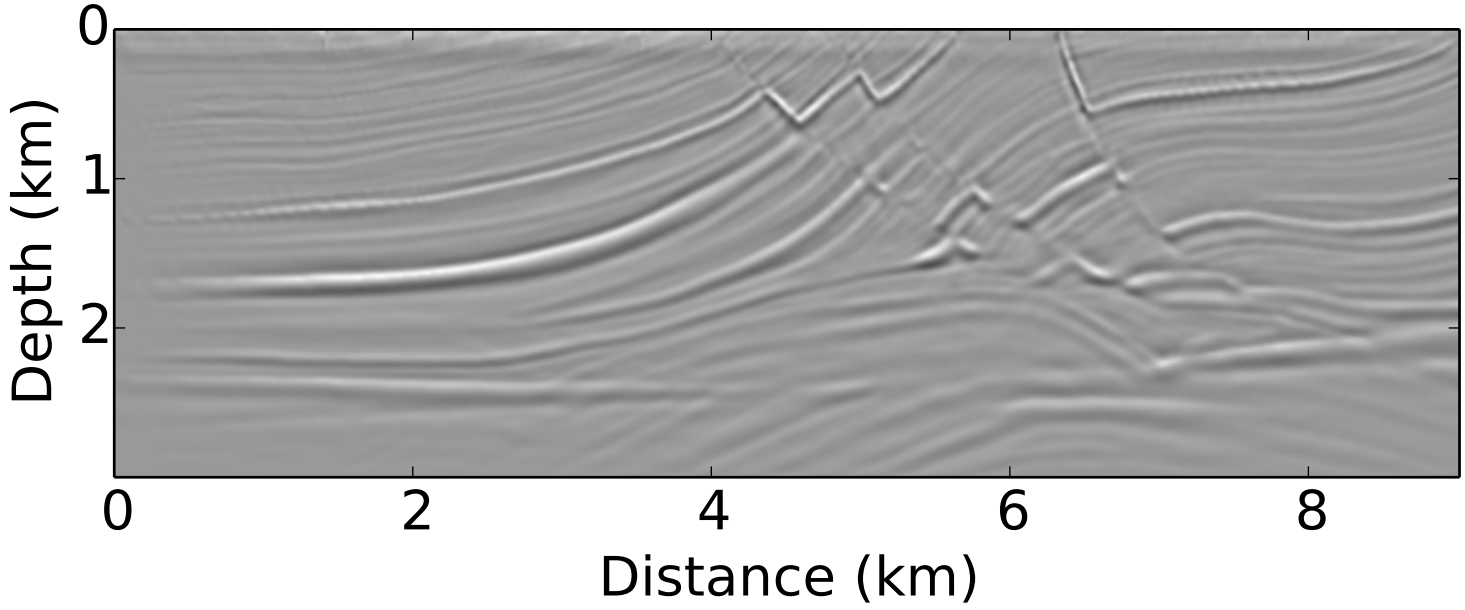
Numerical examples

Horizontal profile through reflector at 1000m depth



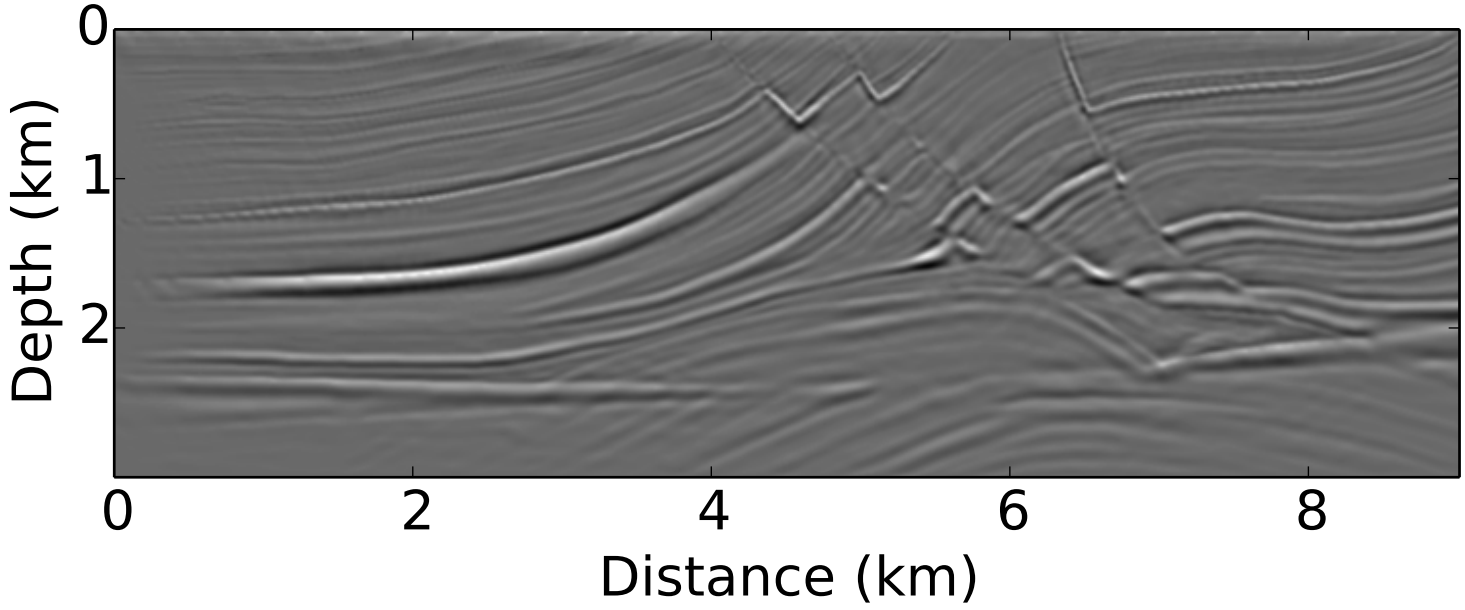
Numerical example

Conventional imaging condition:



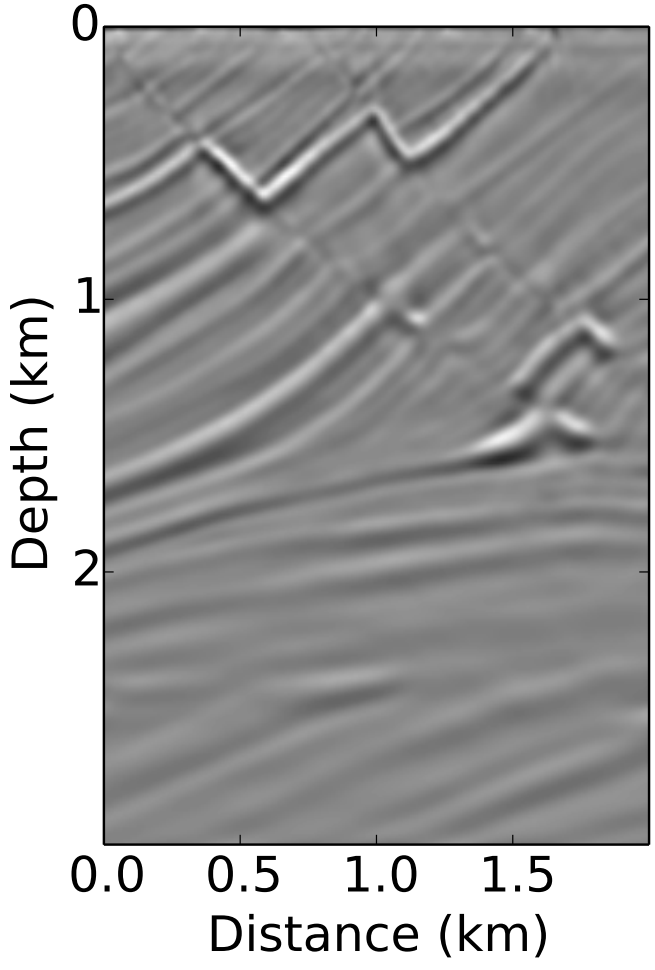
Numerical example

New imaging condition:



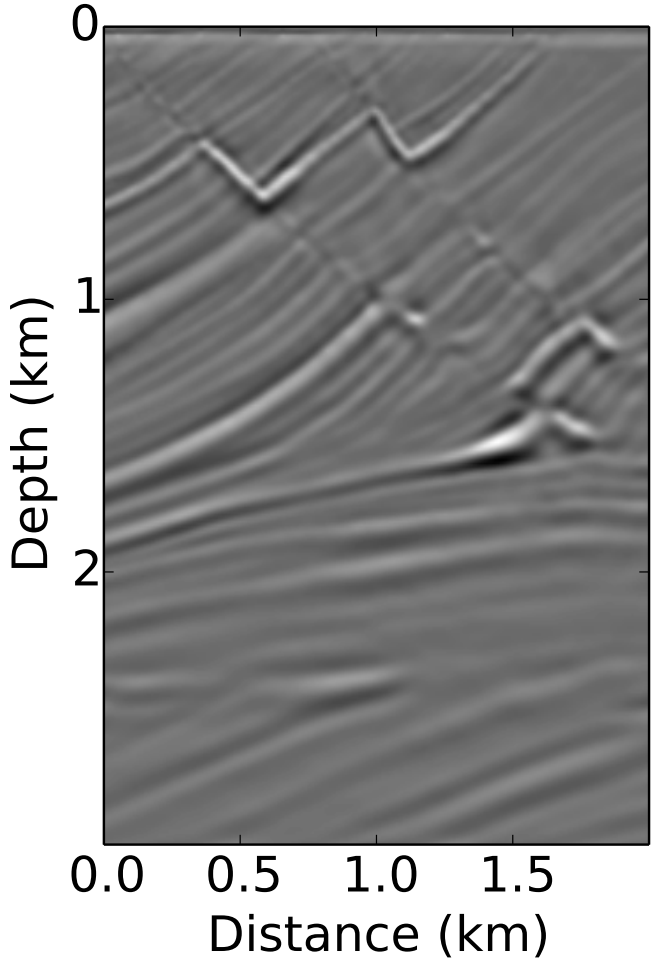
Numerical example

Conventional imaging condition:



Numerical example

New imaging condition:



Numerical example

From reflectivity to plane wave reflection coefficient

$$\partial_z r(\boldsymbol{x}, \boldsymbol{x}', t) \quad = \quad 2 \sum_{\boldsymbol{x}_s} \sum_{\tau} \partial_{z_s}^2 p_0(\boldsymbol{x}, \boldsymbol{x}_s, \tau + t) p_{sc}(\boldsymbol{x}', \boldsymbol{x}_s, \tau) \quad (1)$$

Plane wave reflection coefficient by mapping to $p - \tau$ (deBruin 1991**?**)

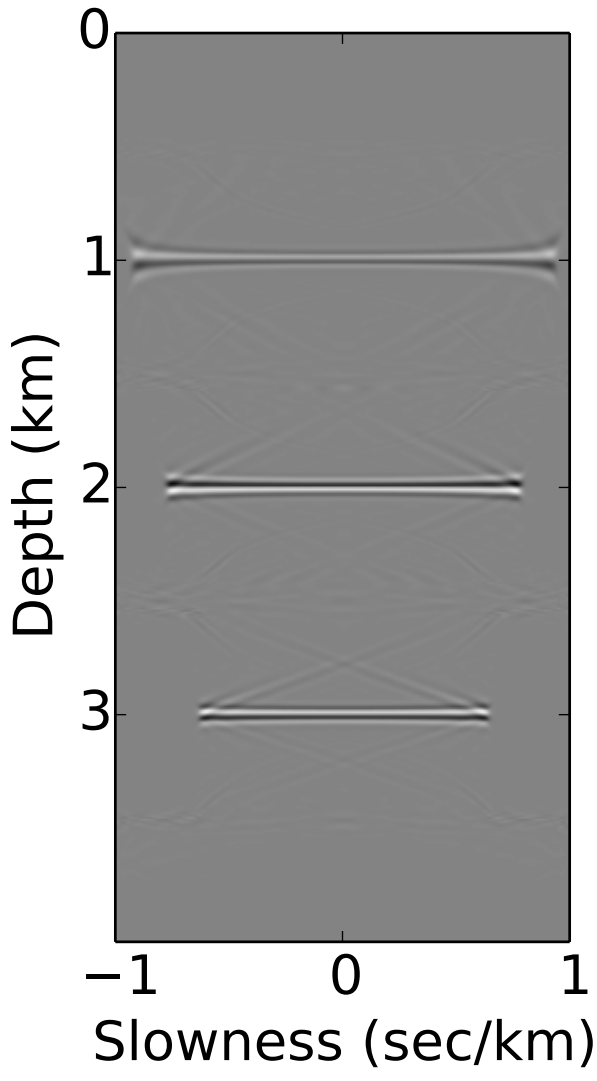
Conventional approach:

$$r(\boldsymbol{x}, \boldsymbol{x}', t) \quad = \quad 2 \sum_{\boldsymbol{x}_s} \sum_{\tau} p_0(\boldsymbol{x}, \boldsymbol{x}_s, \tau + t) p_{sc}(\boldsymbol{x}', \boldsymbol{x}_s, \tau) \quad (2)$$

Plane wave reflection coefficient by mapping to $p - \tau$ (deBruin 1991**?**)

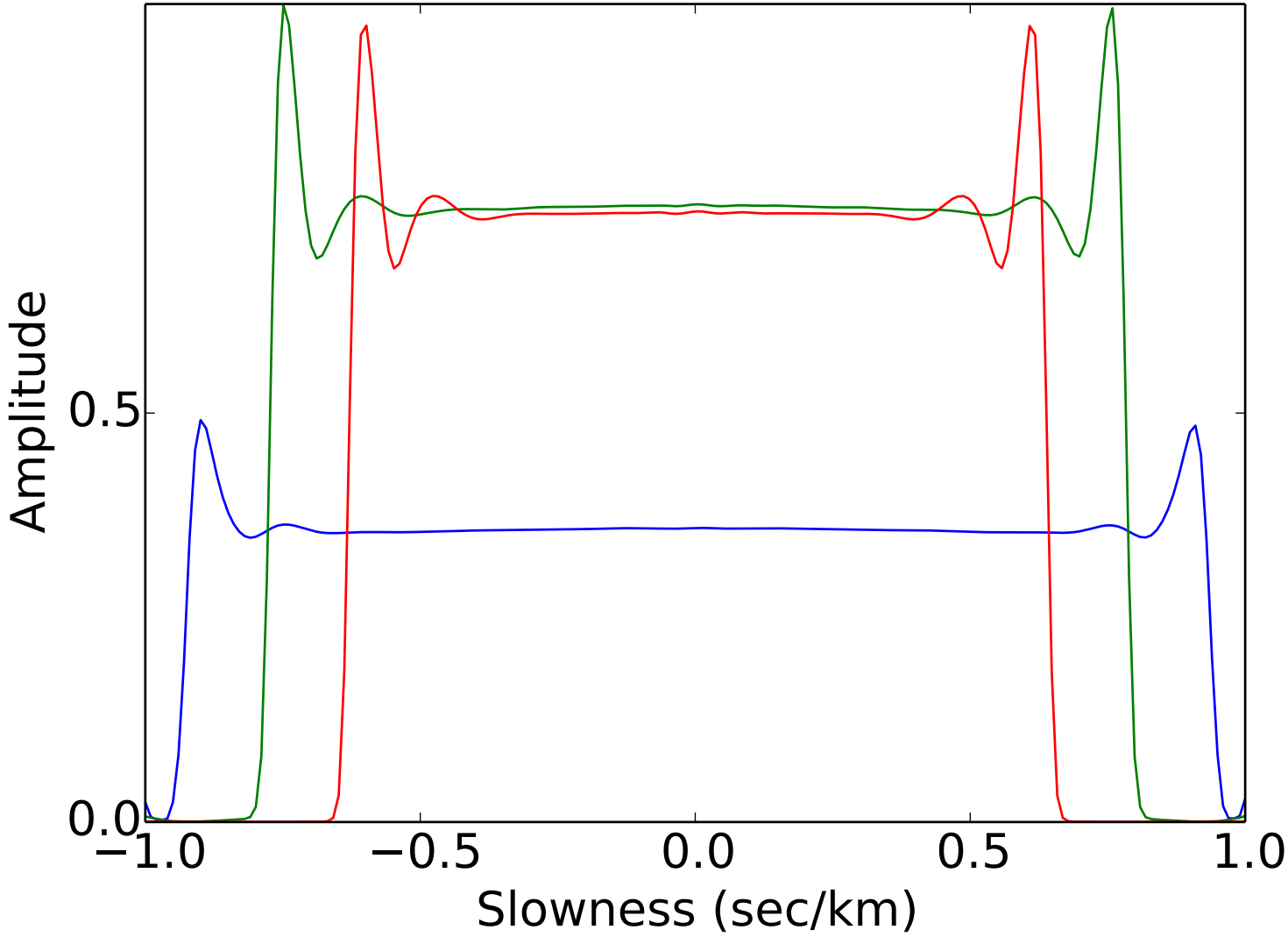
Numerical example

p-gather at the center of the model



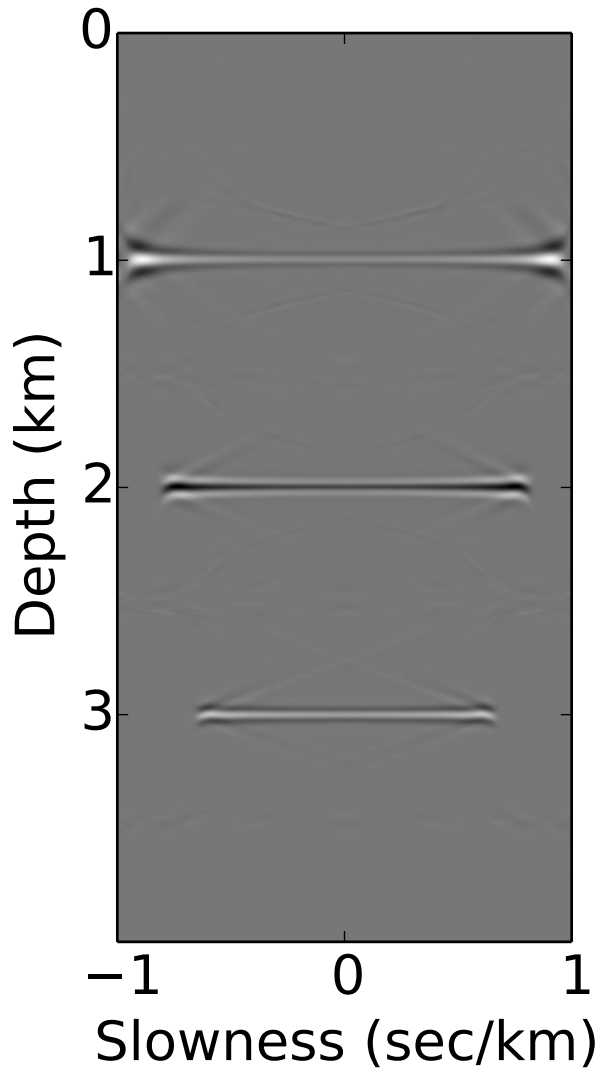
Numerical example

Amplitude picks along p-gather



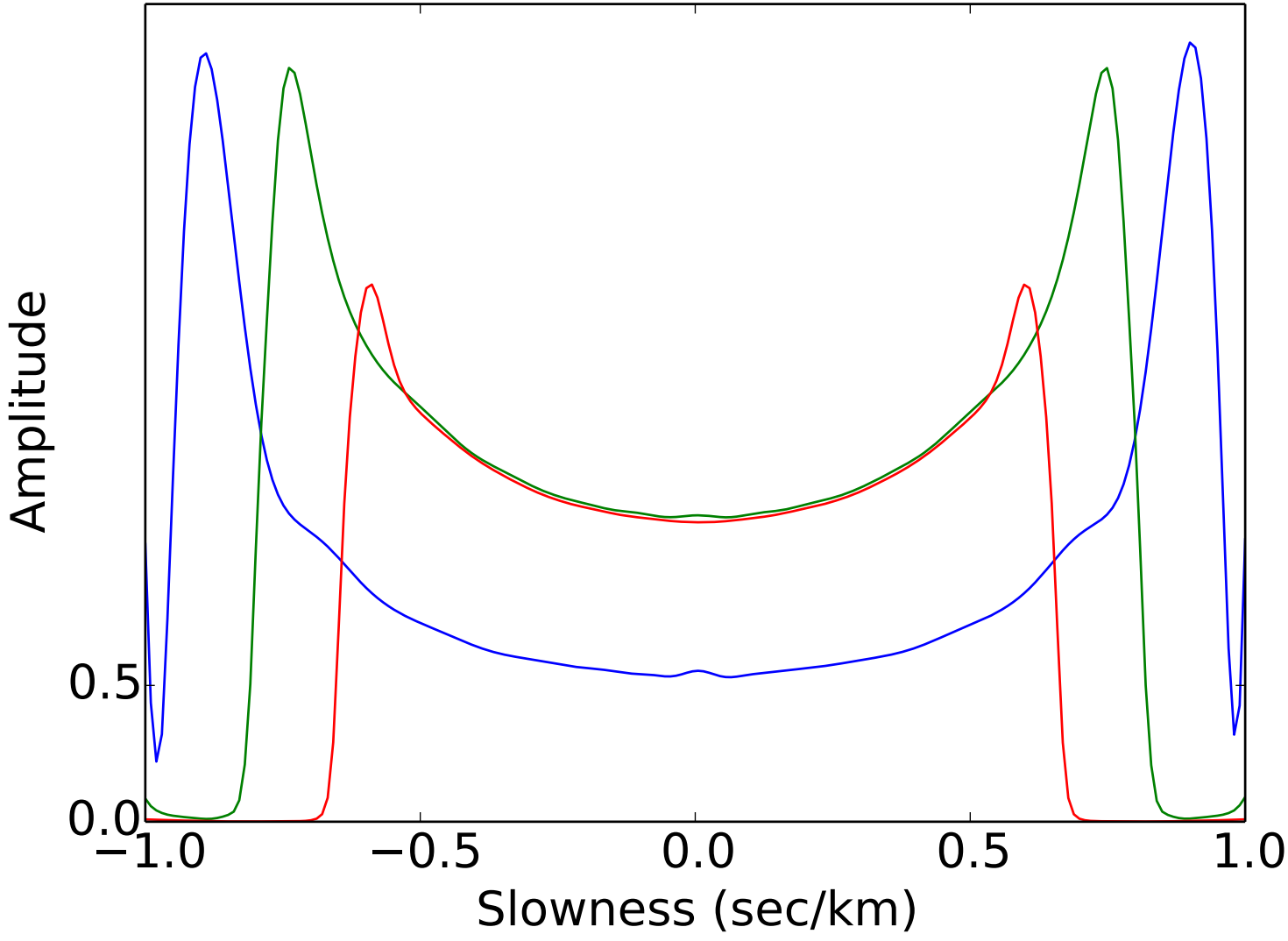
Numerical example

Conventional approach:



Numerical example

Amplitude picks along p-gather



Conclusions

Simple (trivial) modification of the classical imaging condition for Reverse-time migration gives

- Better resolution
- Reflectivity with correct angle behavior

Bibliography