Multicomponent imaging with Distributed Acoustic Sensing

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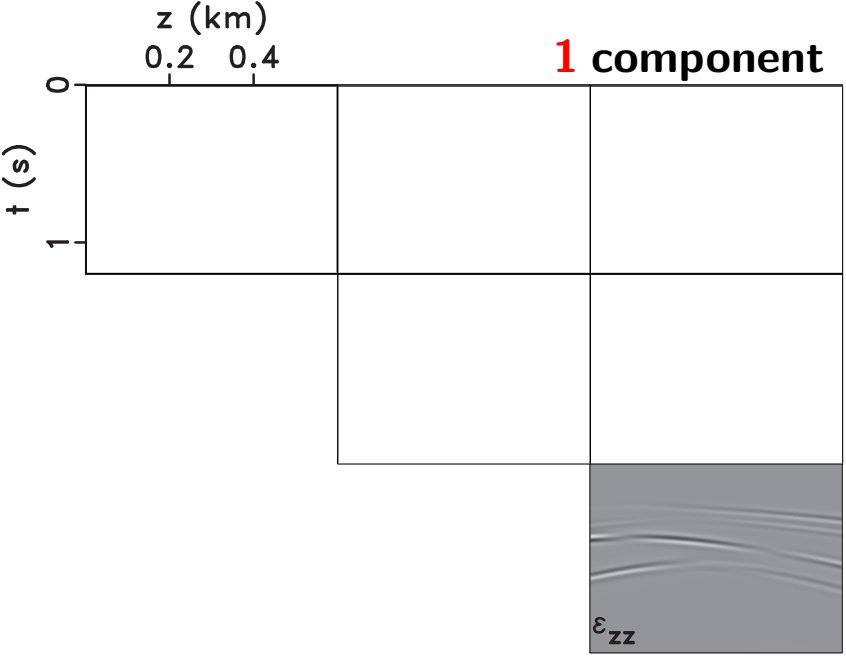
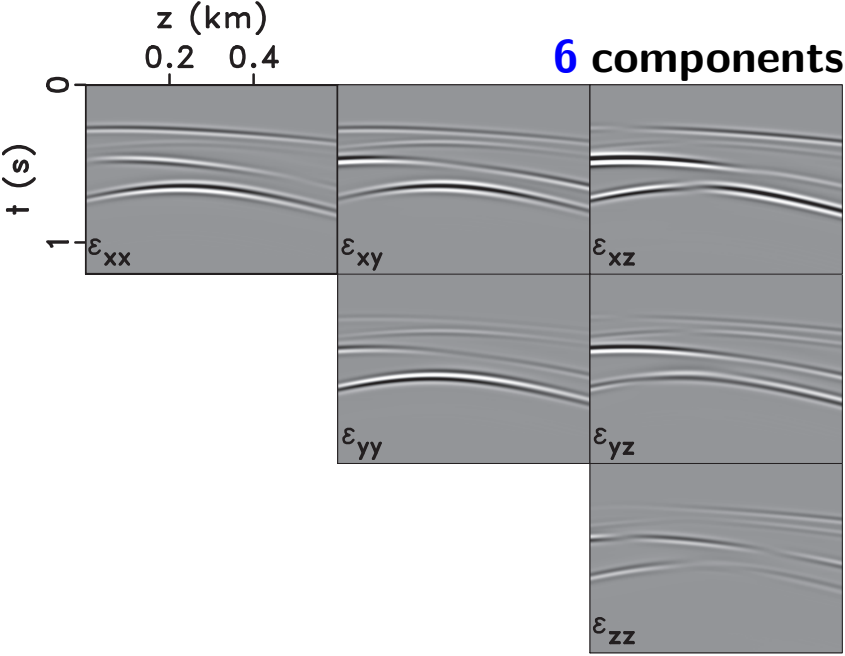
Multicomponent Imaging
with
Distributed Acoustic Sensing

The Golden Touch
Disney, 1935


z (km)
0.2
0.4
1 component
0
t (s)
1
ε_{zz}

6 components



equation of motion

$$\rho \ddot{\mathbf{u}} - \nabla \cdot \underline{\boldsymbol{\sigma}} = \mathbf{f}$$

stress-strain relation

$$-\underline{\boldsymbol{\sigma}} + \underline{\underline{\mathbf{c}}} : \underline{\varepsilon} = \underline{\mathbf{h}}$$

$\mathbf{u}$ = displacement

$\underline{\boldsymbol{\sigma}}$ = stress tensor

ρ = density

$\underline{\underline{\mathbf{c}}}$ = stiffness tensor

equation of motion

$$\rho \ddot{\mathbf{u}} - \nabla \cdot \underline{\boldsymbol{\sigma}} = \mathbf{f}$$

stress-strain relation

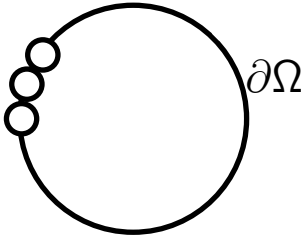
$$-\underline{\boldsymbol{\sigma}} + \underline{\underline{\mathbf{c}}} : \underline{\varepsilon} = \underline{\mathbf{h}}$$

$\mathbf{f}$ = volume force density

$\underline{\mathbf{h}}$ = deformation density

$$\mathbf{V} = -\oint_{\partial\Omega} ds \;\; \mathbf{u} * \mathbf{G}^{\mathbf{f}}$$

$\mathbf{G}^{\mathbf{f}}$ = propagator with $\mathbf{f}$ source

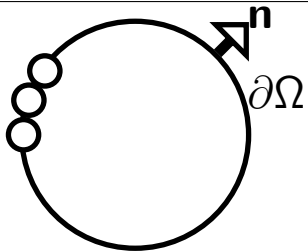


$$\mathbf{V} = -\oint_{\partial\Omega} ds \left[\boldsymbol{\sigma} * \mathbf{G}^{\mathbf{f}} + \mathbf{u} * \mathbf{G}^{\underline{\mathbf{h}}} \right] \cdot \mathbf{n}$$

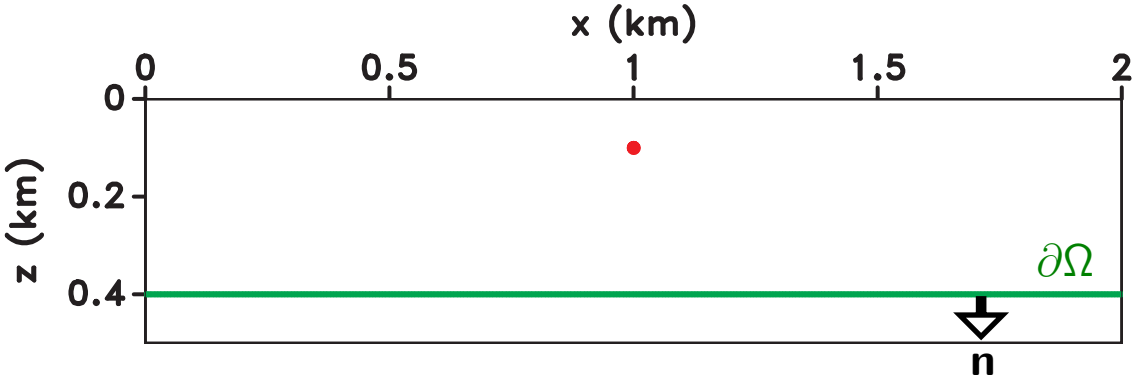
(Ravasi and Curtis, 2013)

$\mathbf{G}^{\mathbf{f}}$ = propagator with $\mathbf{f}$ source

$\mathbf{G}^{\underline{\mathbf{h}}}$ = propagator with $\underline{\mathbf{h}}$ source

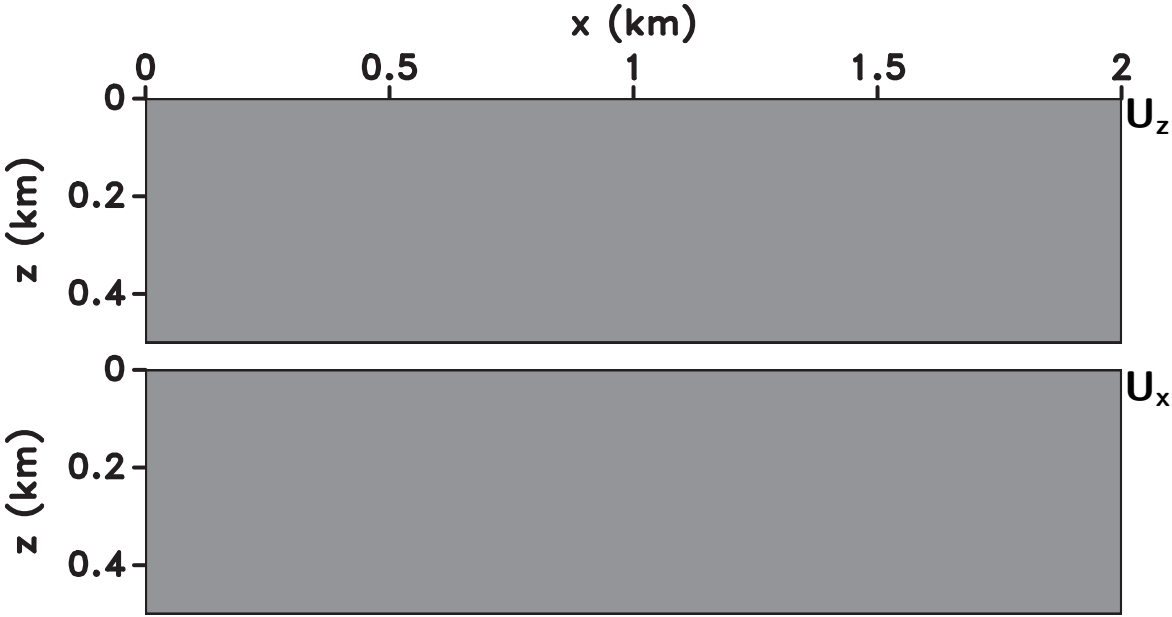


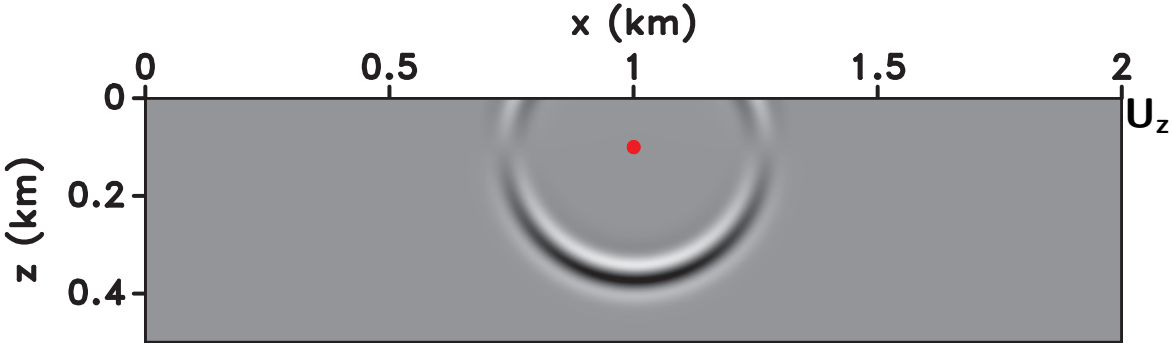
example

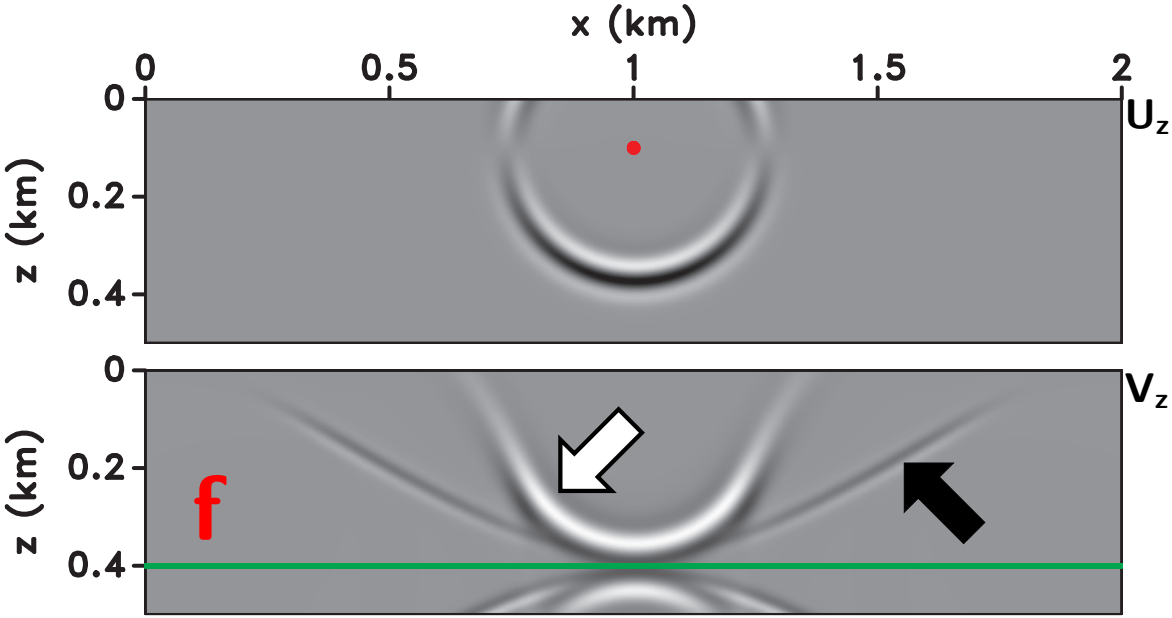


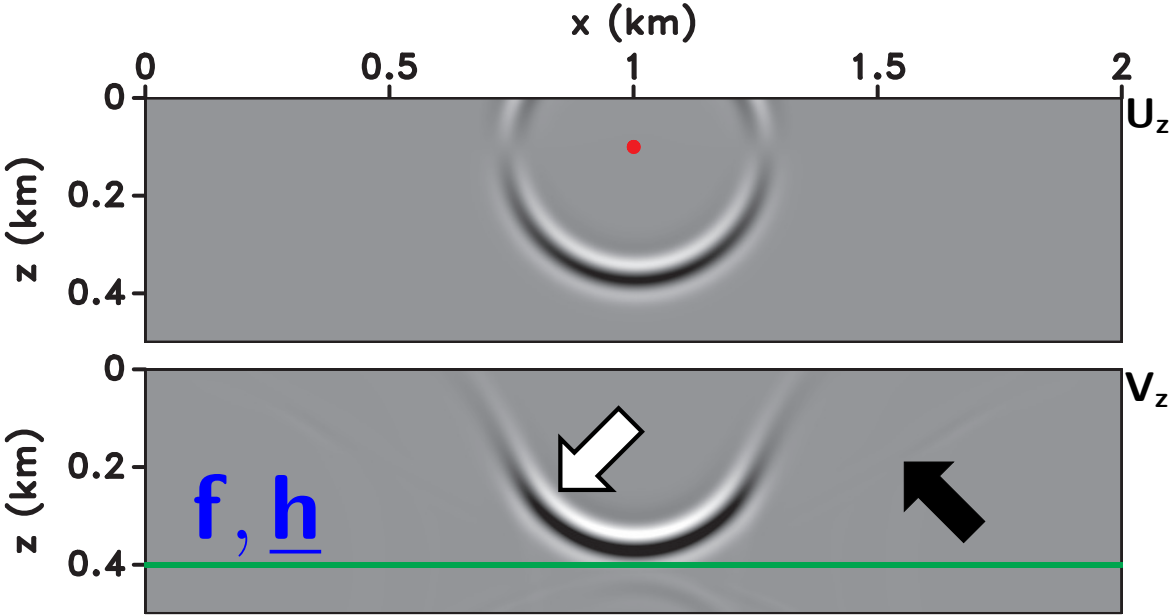
● explosive source

● multicomponent receivers

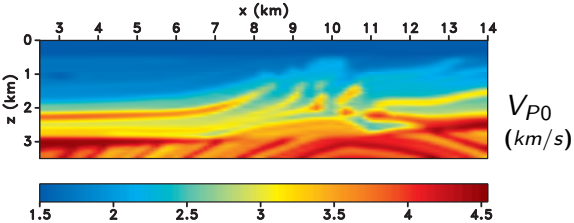

x (km)
0
0.5
1
1.5
2
0
0.2
0.4
z (km)
U_z
0
0.2
0.4
z (km)
U_x

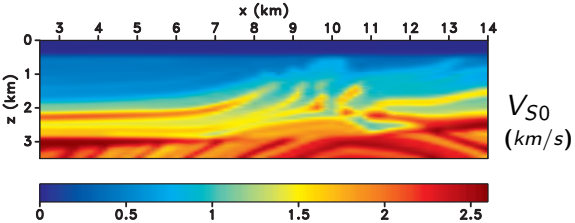

x (km)
0
0.5
1
1.5
2
0
0.2
0.4
z (km)
U_z

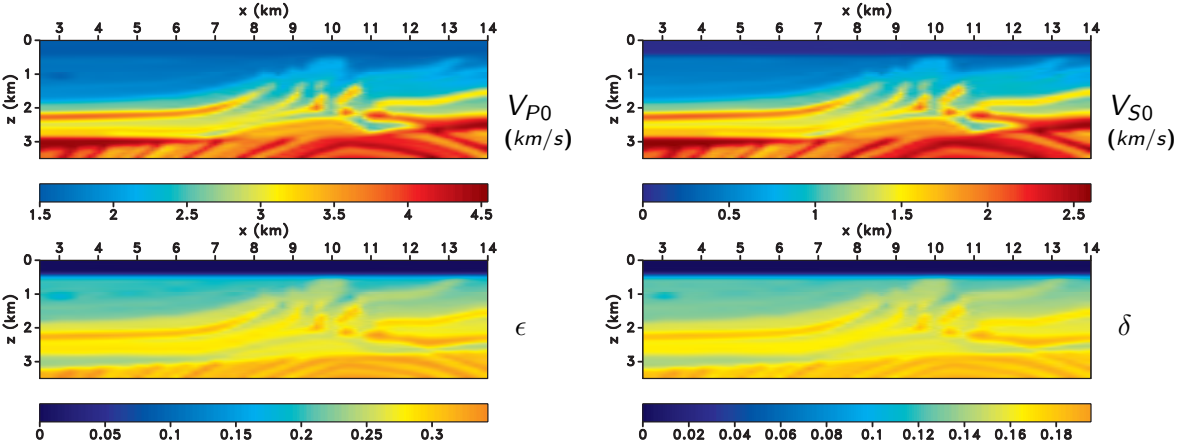

x (km)
0
0.5
1
1.5
2
0
0.2
0.4
z (km)
U_z
0
0.2
0.4
z (km)
V_z
f

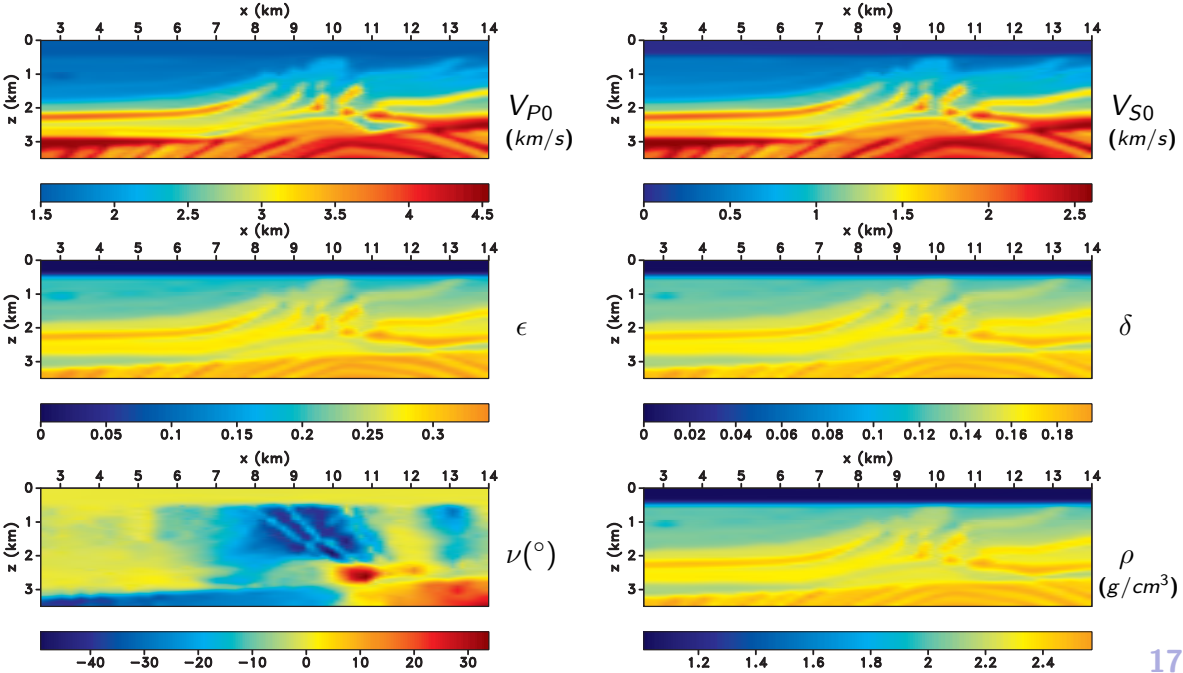

x (km)
0
0.5
1
1.5
2
z (km)
0
0.2
0.4
U_z
V_z
f, h

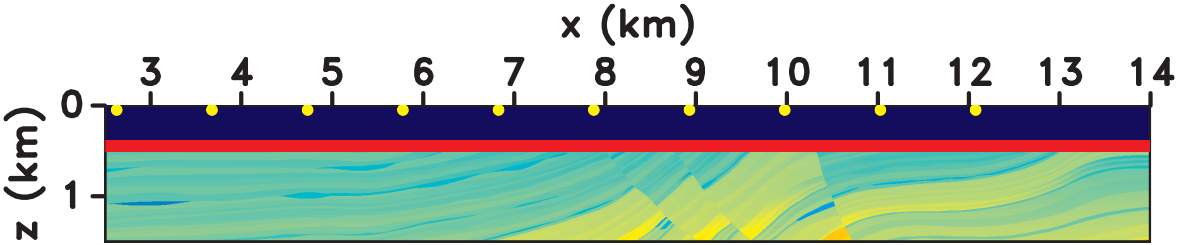
Marmousi II example


x (km)
3 4 5 6 7 8 9 10 11 12 13 14
z (km)
0 1 2 3
1.5 2 2.5 3 3.5 4 4.5
V_{P0}
(km/s)


x (km)
3 4 5 6 7 8 9 10 11 12 13 14
z (km)
0 1 2 3
0 0.5 1 1.5 2 2.5
V_{S0}
(km/s)


x (km)
z (km)
V_{P0} (km/s)
V_{S0} (km/s)
ϵ
δ


x (km)
z (km)
V_{P0} (km/s)
V_{S0} (km/s)
ϵ
δ
$\nu(^\circ)$
ρ (g/cm^3)



pressure sources

multicomponent receivers

$$I_E = \sum_{e,t} \left[\rho \dot{\mathbf{U}} \cdot \dot{\mathbf{V}} + \left(\underline{\underline{\mathbf{c}}} \nabla \mathbf{U} \right) : \nabla \mathbf{V} \right]$$

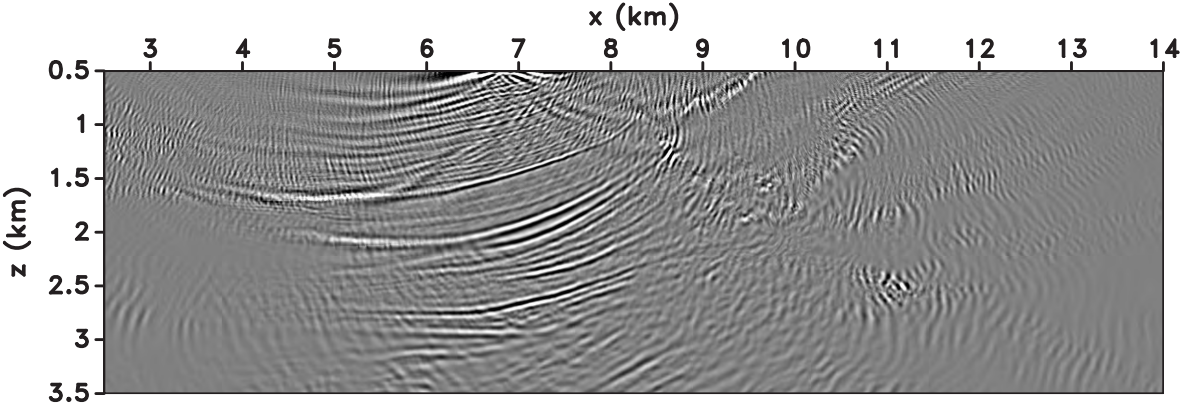
(Rocha et al., 2017)

$\mathbf{U}$ = source wavefield

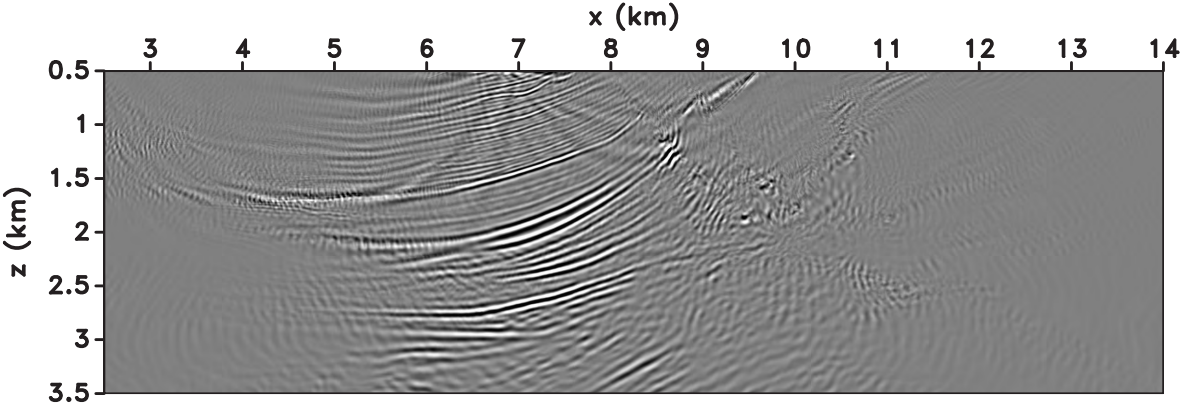
$\mathbf{V}$ = receiver wavefield

$\underline{\underline{\mathbf{c}}}$ = stiffness tensor

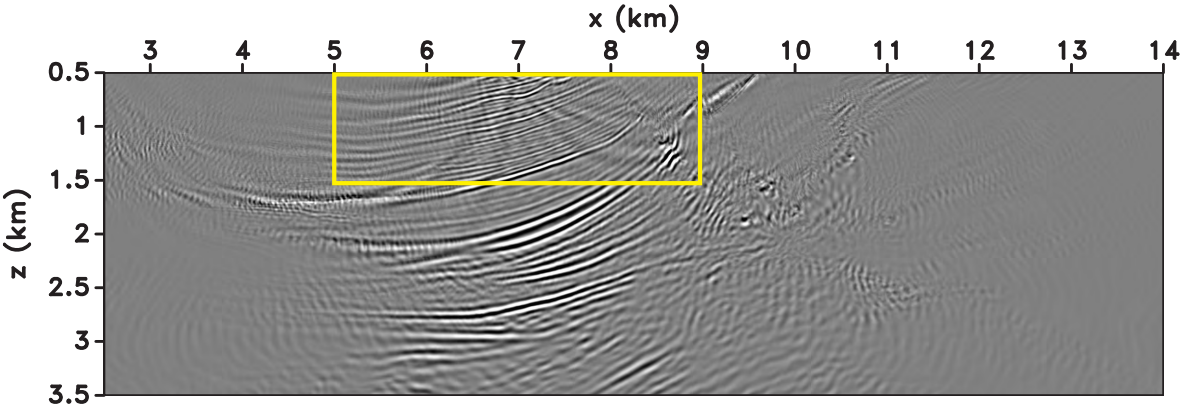
ρ = density



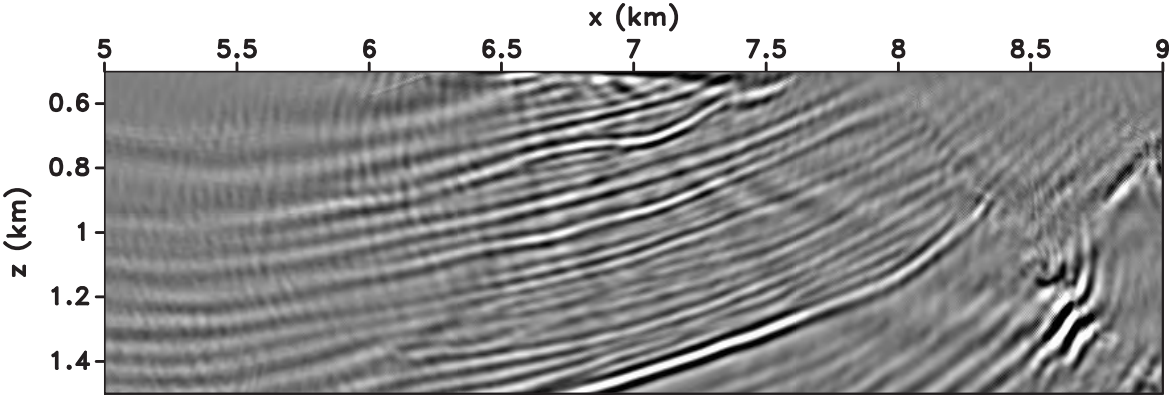
f



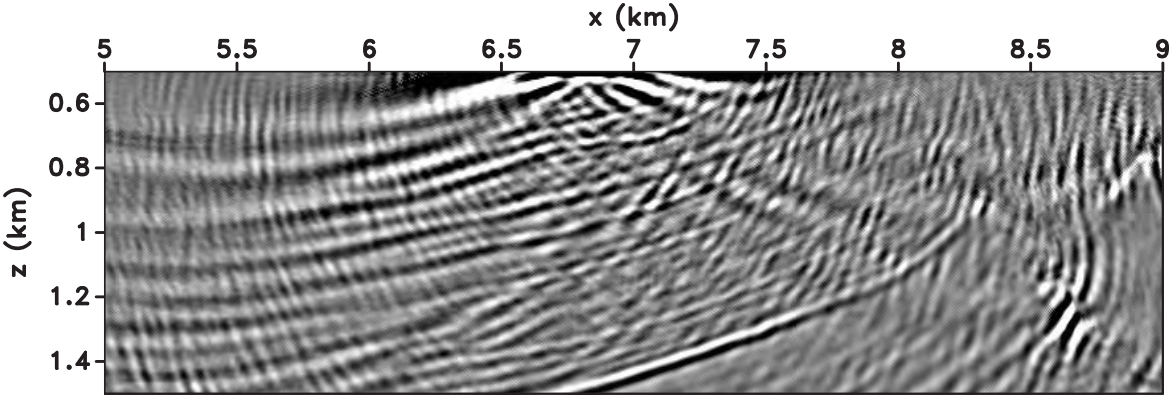
f, h



f, h



f, h



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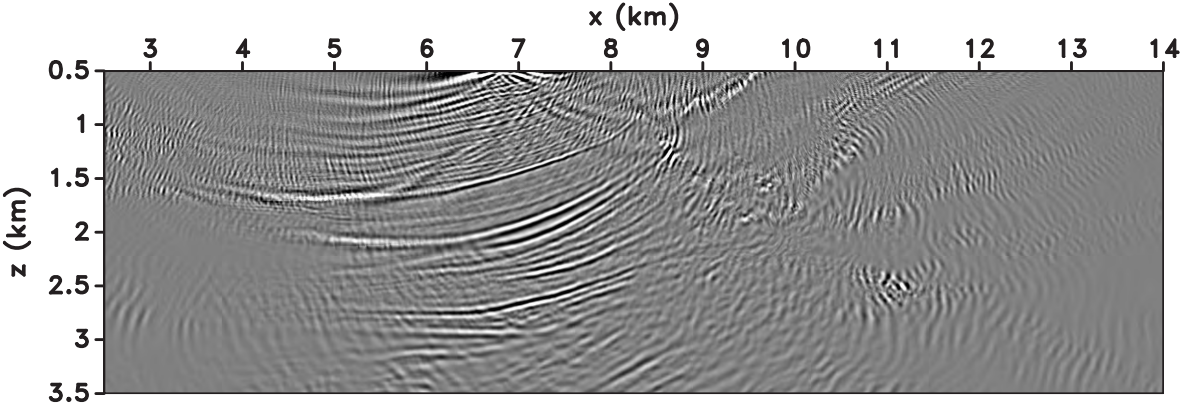

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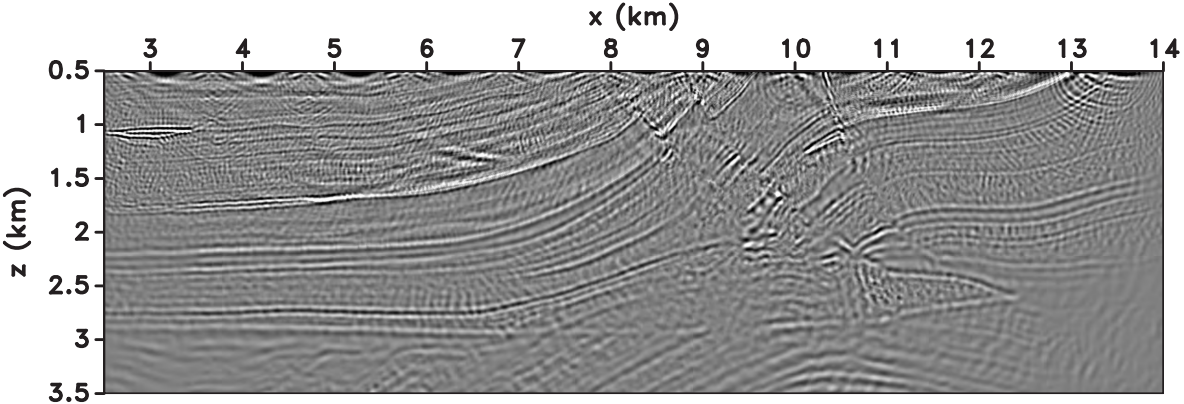

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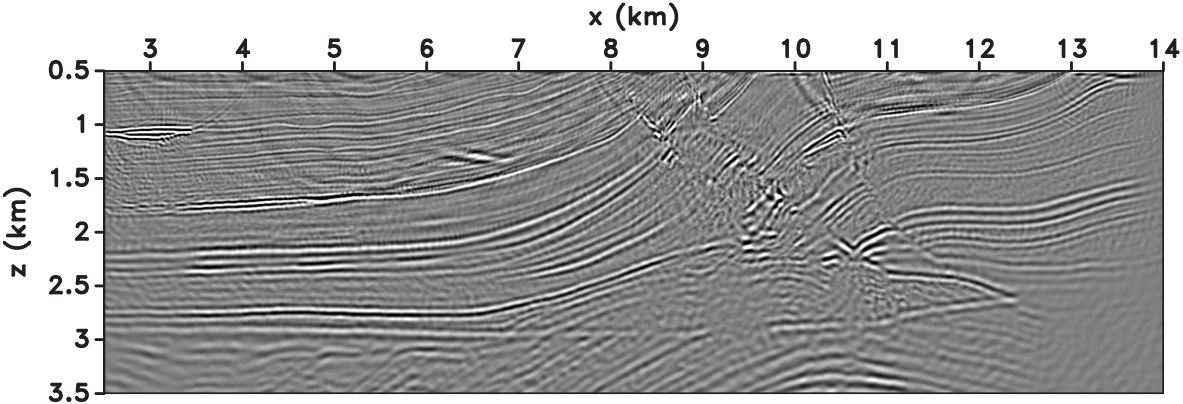
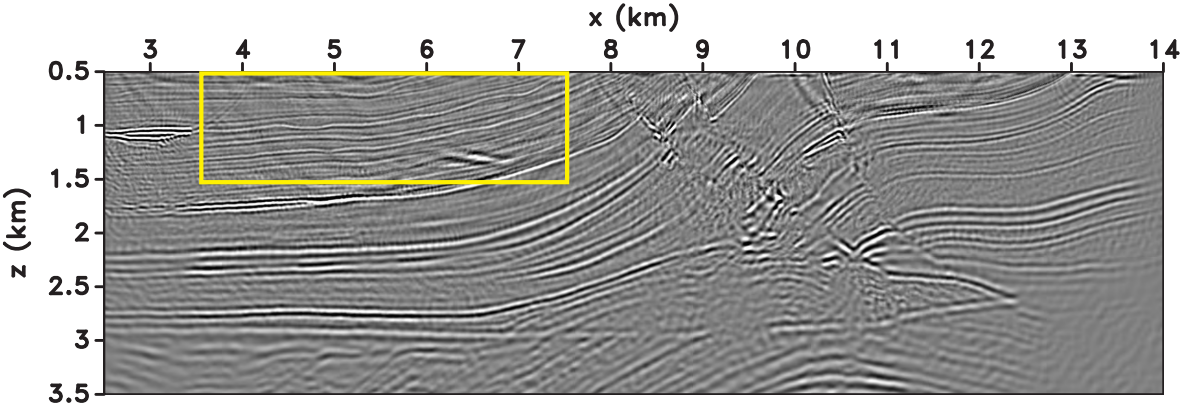
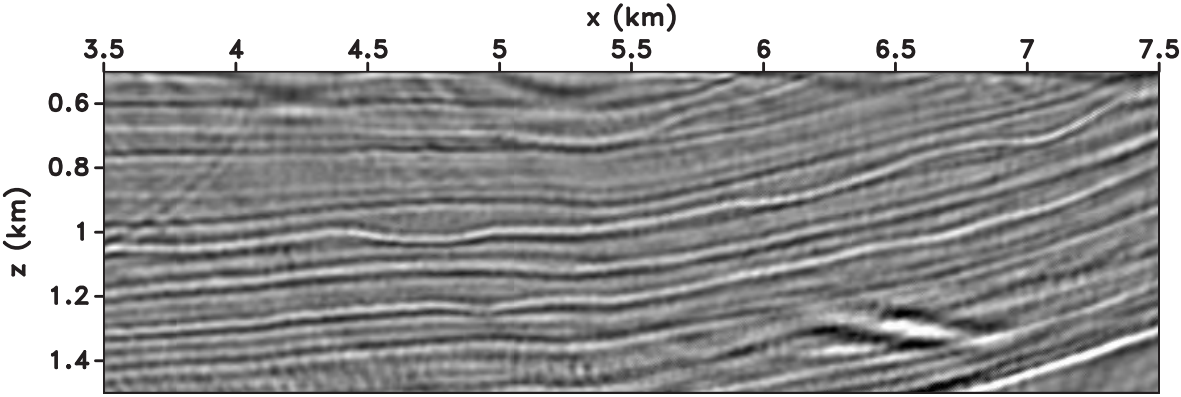


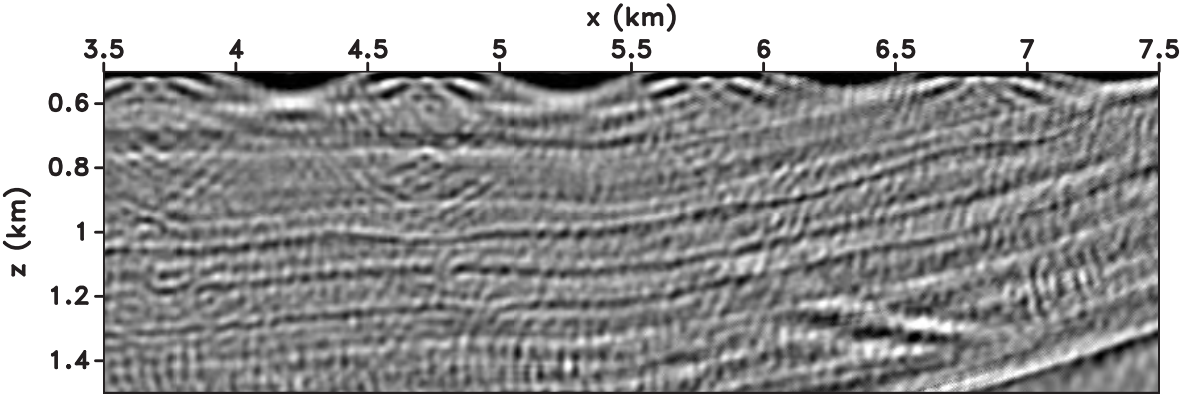
f, h



f, h

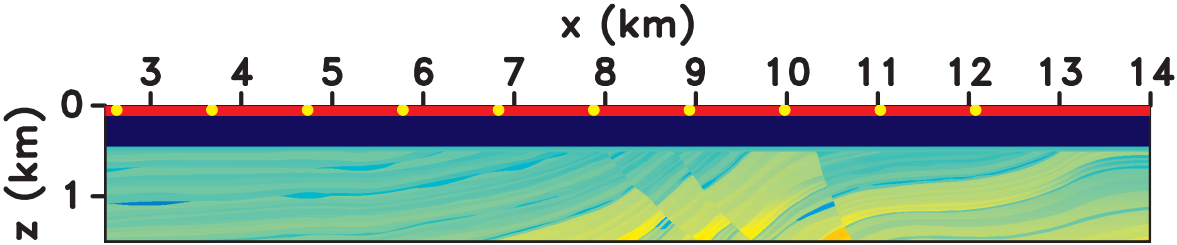


f, h



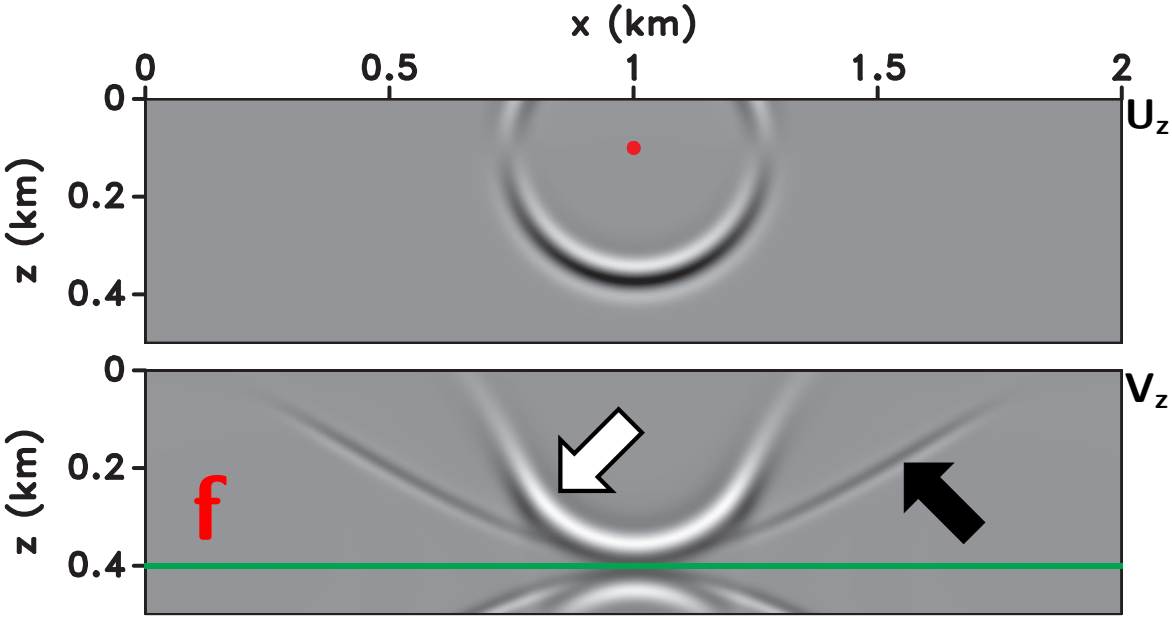
f

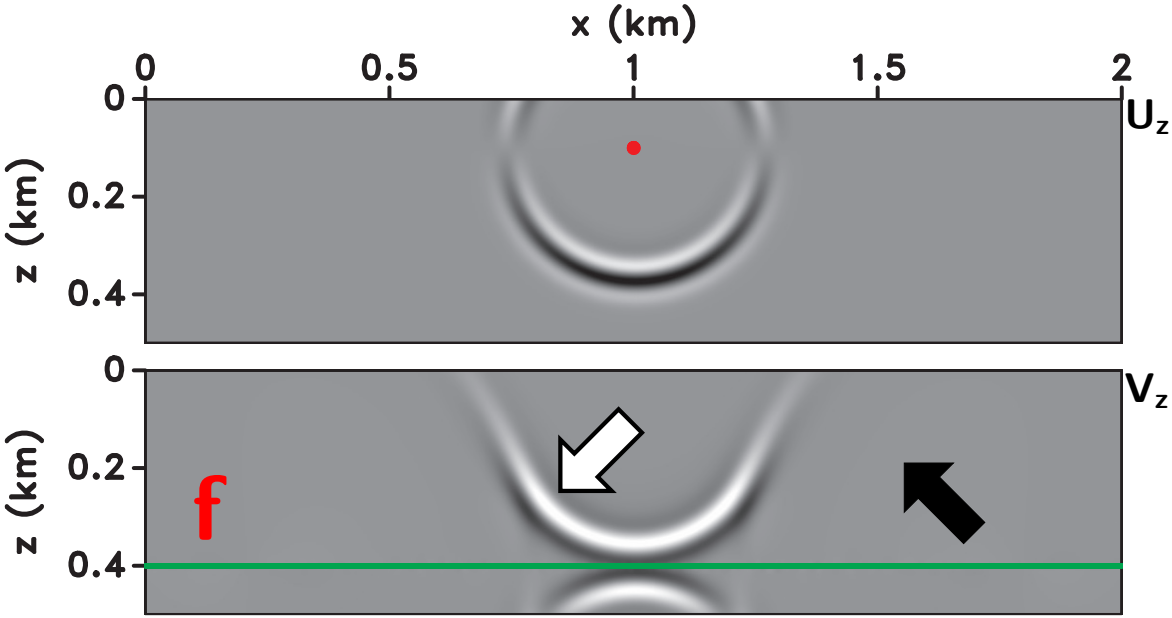
extrapolation from the water layer

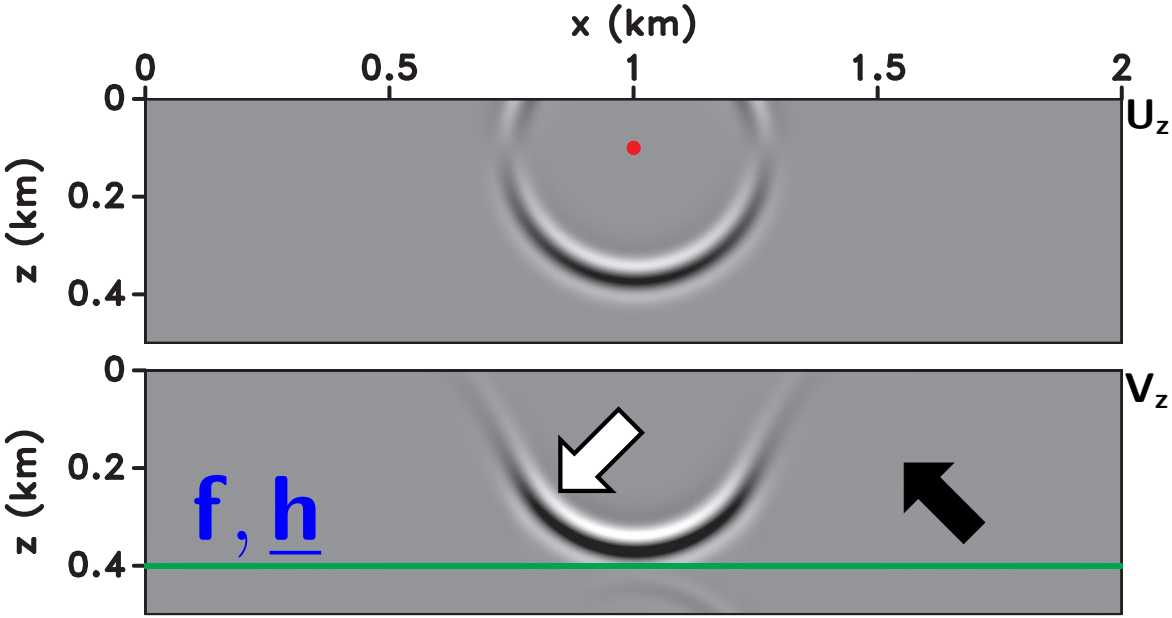


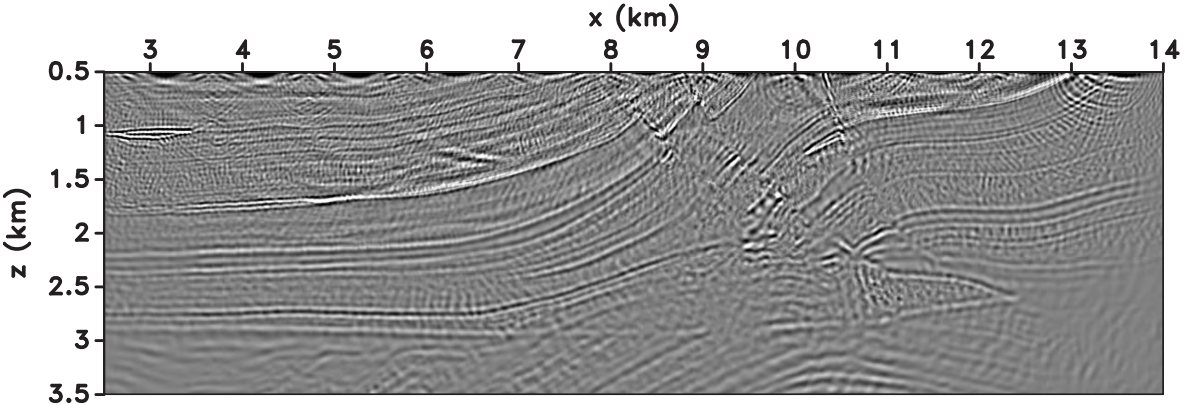
pressure sources

multicomponent receivers

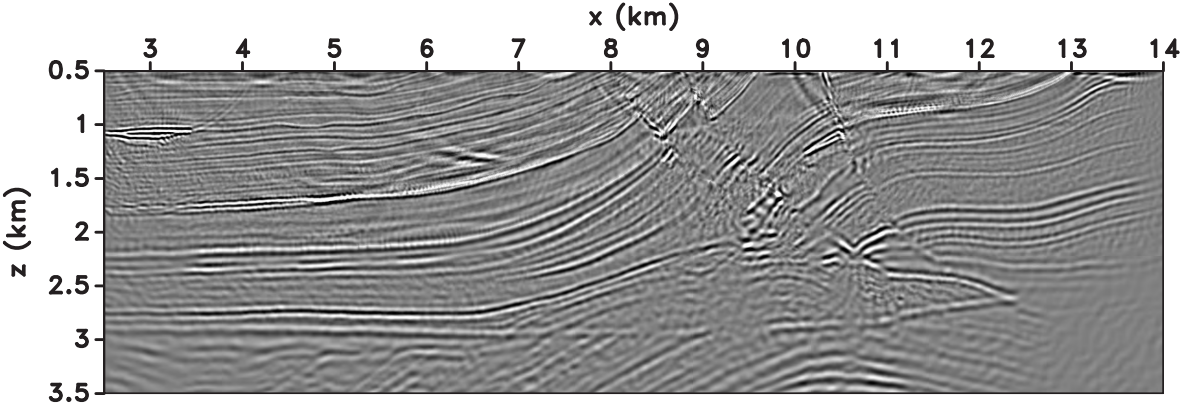

x (km)
0
0.5
1
1.5
2
z (km)
0
0.2
0.4
U_z
V_z
f


x (km)
0
0.5
1
1.5
2
z (km)
0
0.2
0.4
U_z
V_z
f

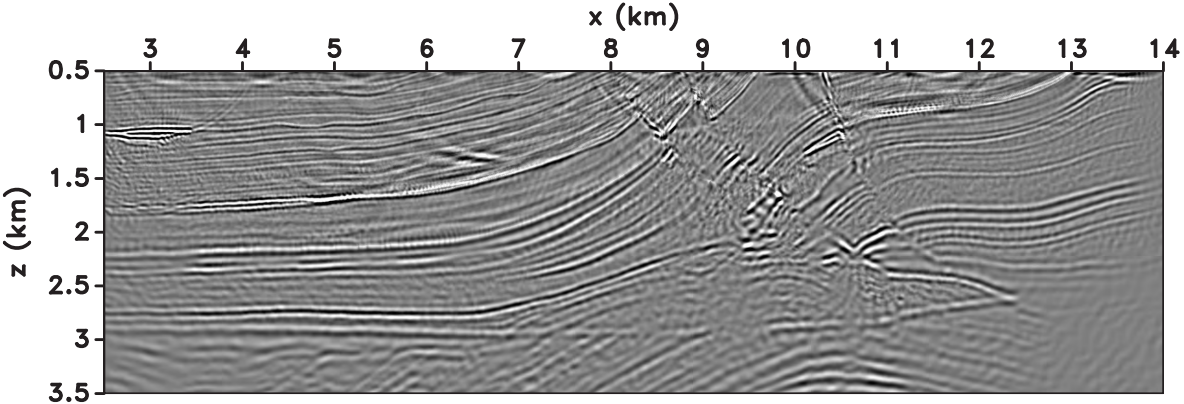

x (km)
0
0.5
1
1.5
2
z (km)
0
0.2
0.4
U_z
V_z
f, h



f: OBS



f: **streamer**



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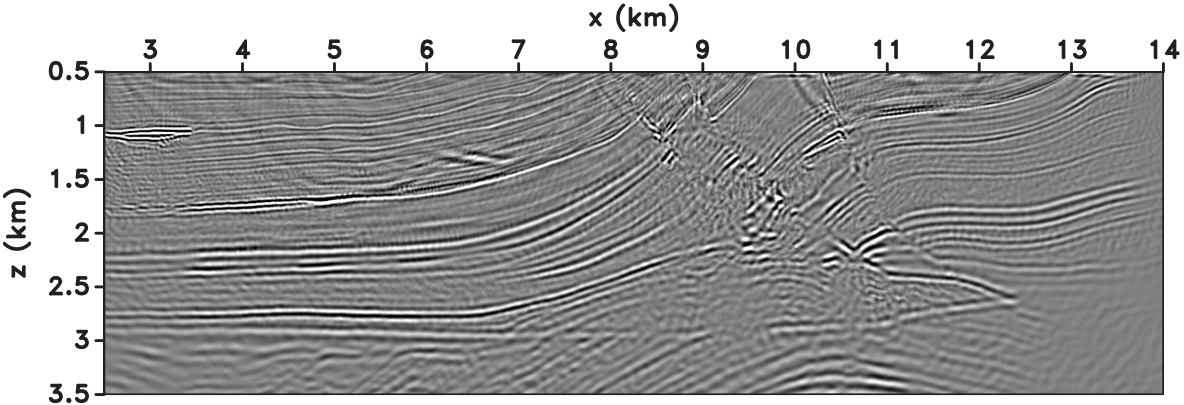
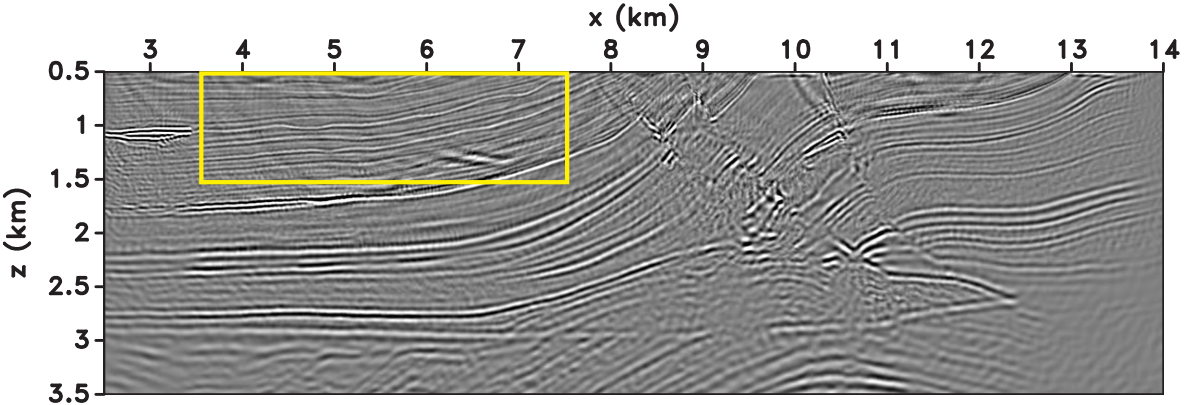
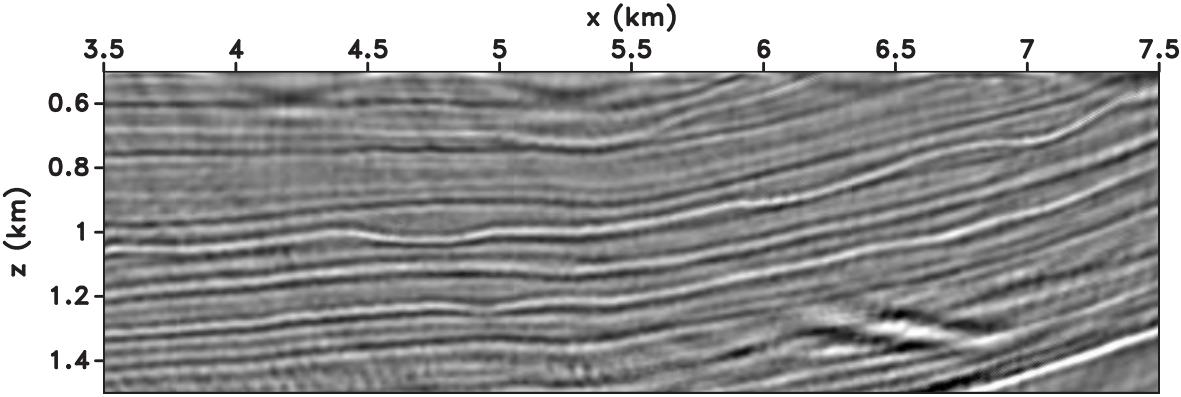


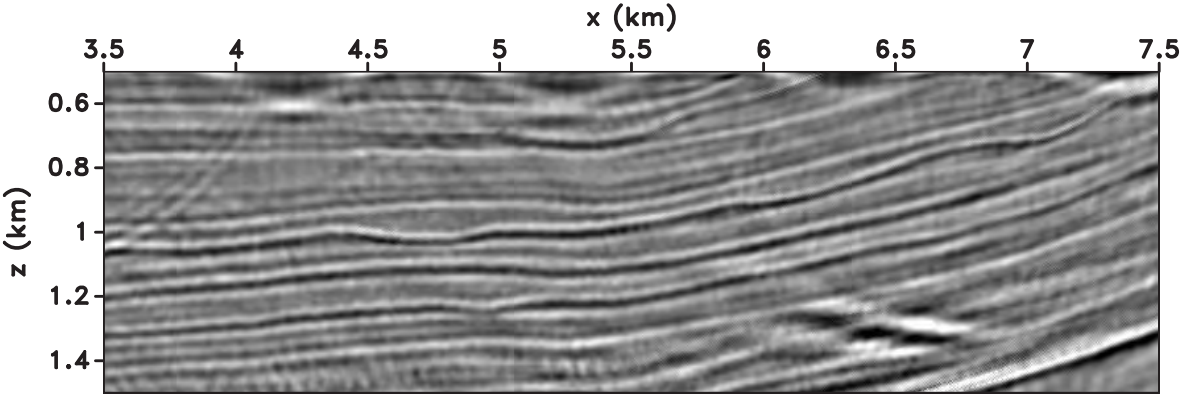
f, h



f, h



f, h



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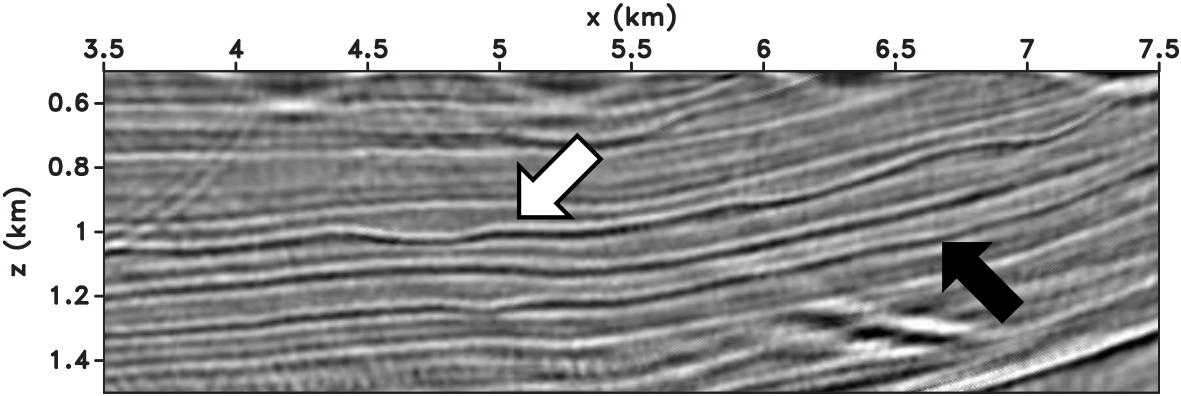

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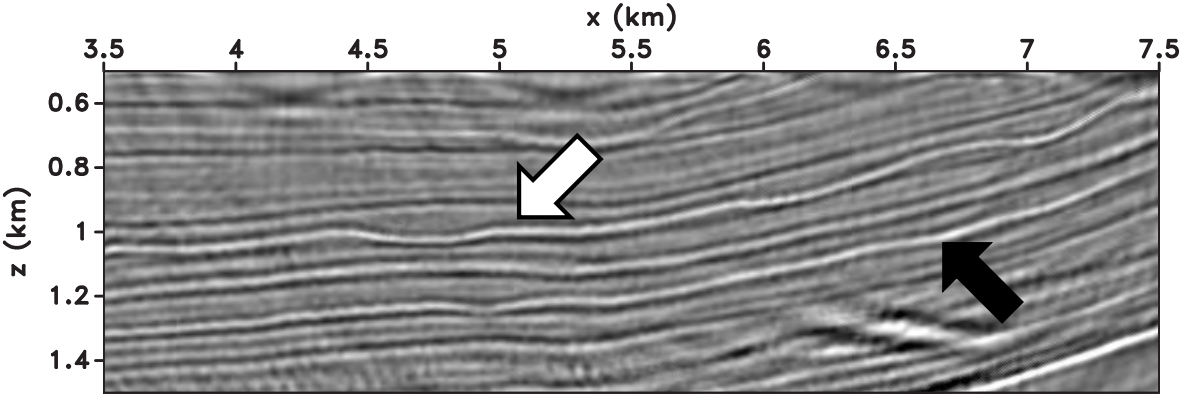

f, h

take home message

MIDAS improves elastic seismic imaging

acknowledgment

Matteo Ravasi, Statoil

Daniel Rocha

MIDAS