STANFORD EXPLORATION PROJECT

SEP Annual Meeting

Toward PZ summation without Z

(SEP155-p.119; SEP158-p.323)

Ettore Biondi* and Stewart Levin

18-21 May 2015

Outline

- PZ summation with calibration filters based on critically refracted waves (SEP155-p.119)

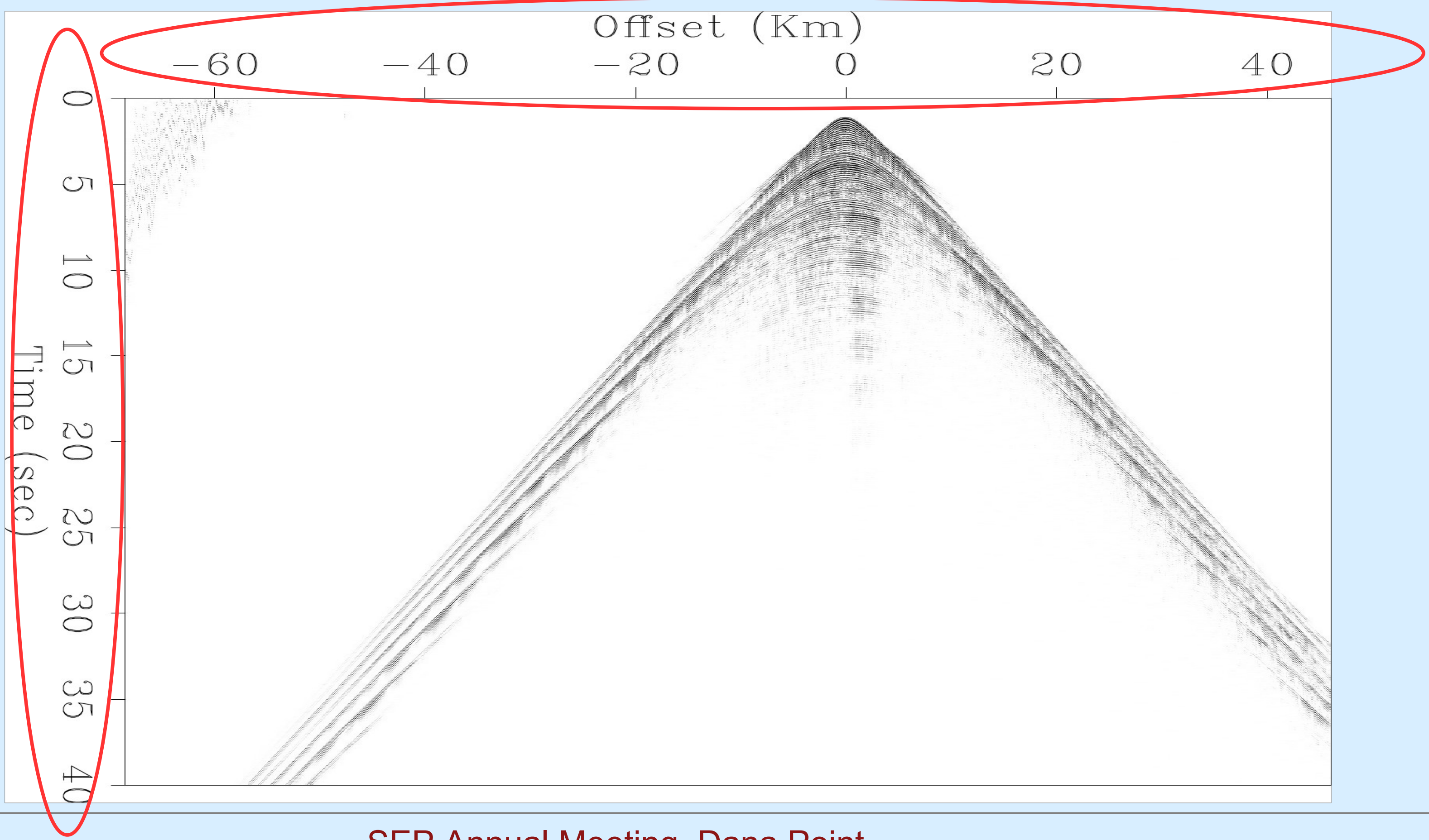
- Toward PZ summation without Z (SEP158-p.323)

Outline

- **PZ summation with calibration filters based on critically refracted waves (SEP155-p.119)**
  - Ocean bottom acquisition: an interesting long-offset dataset
  - PZ summation for wavefield separation
  - Intermediate and Final Results
  - Conclusions

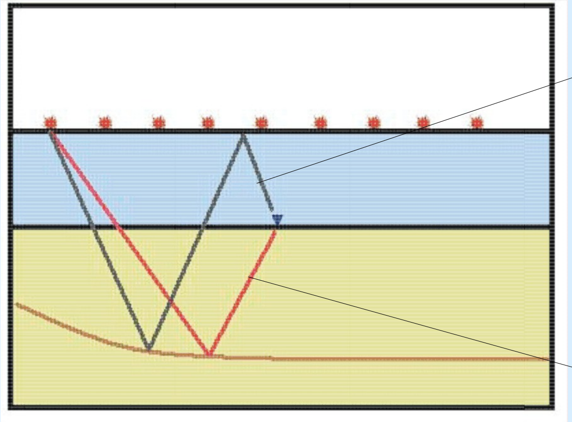
Long-offset OBN dataset

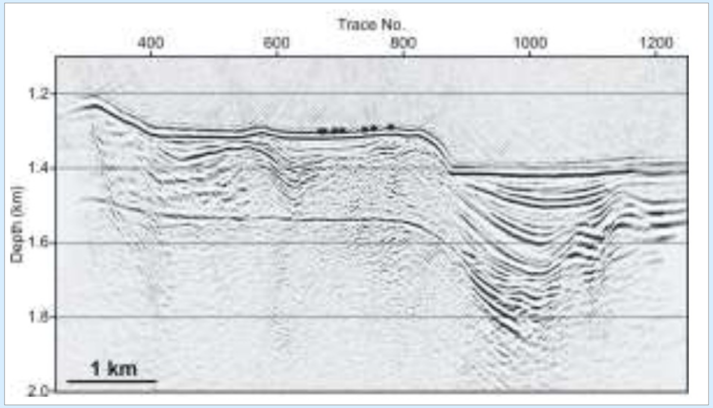
Seabed Geosolutions provides us with a very interesting dataset



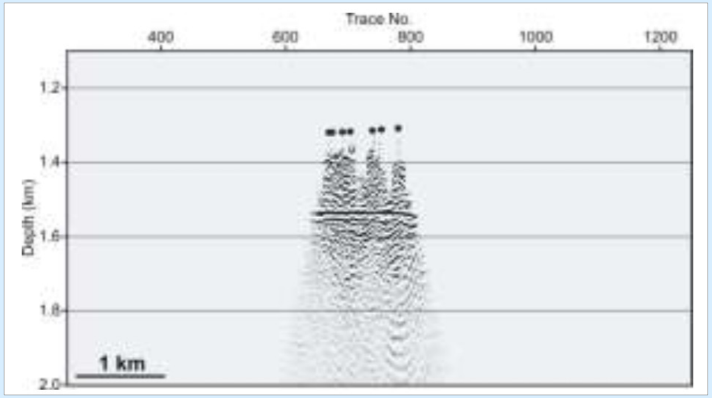
Mirror imaging

Illumination of primary and sea surface multiple





Down-going



Up-going

Dash et al., 2009

Up-down separation

Pressure component

Vertical component

Up-going pressure → $$P_{up}(f,k)=\boxed{\frac{1}{2}P(f,k)}+\frac{\rho}{2q(f,k)}\boxed{Z(f,k)}$$

Down-going pressure → $$P_{down}(f,k)=\boxed{\frac{1}{2}P(f,k)}-\frac{\rho}{2q(f,k)}\boxed{Z(f,k)}$$

Calibration term

$$P_{down}(f,k)=\frac{1}{2}P(f,k)-\boxed{A(f)\frac{\rho}{2q(f,k)}}Z(f,k)$$

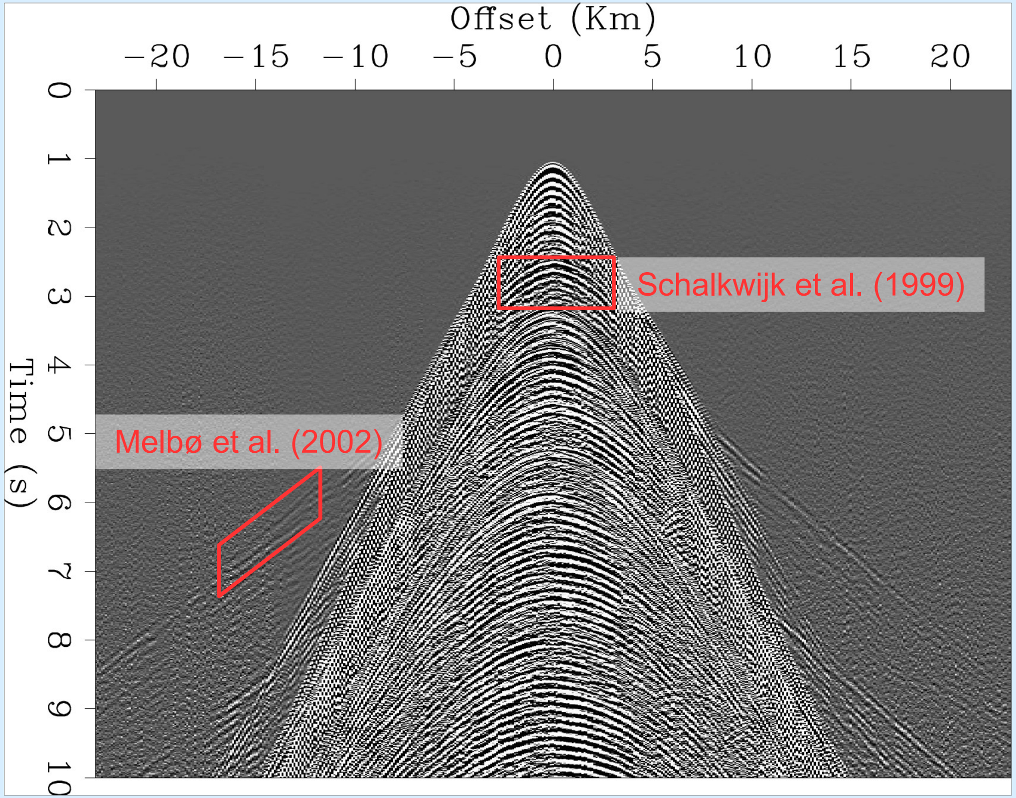
Up-down separation

How to find the calibration filter?

$$\|P_{down}\|_A^2 = \|\frac{1}{2}P + A\frac{\rho}{2q}Z\|_A^2 \rightarrow min$$

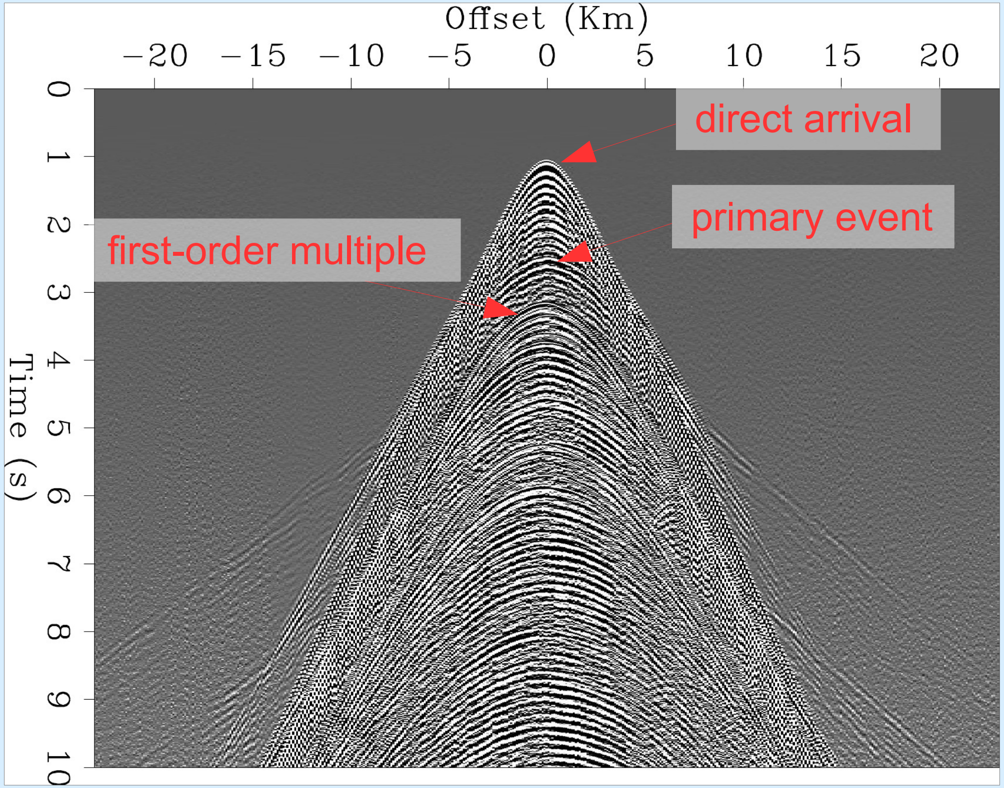
With a shaping filter within a certain window

$$P(f,k) = A(f)\frac{\rho}{q}Z(f,k) = C(f)Z(f,k)$$



Up-down separation: first step

Receiver **impulse response designature**



Original Hydrophone component

Up-down separation: first step

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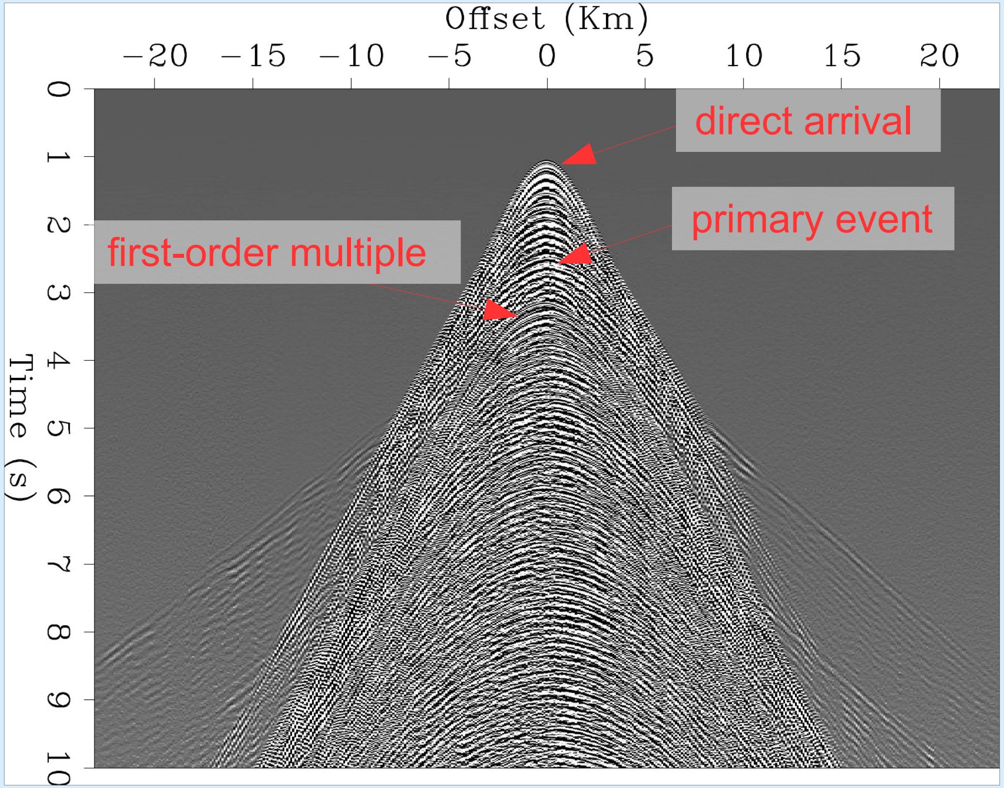
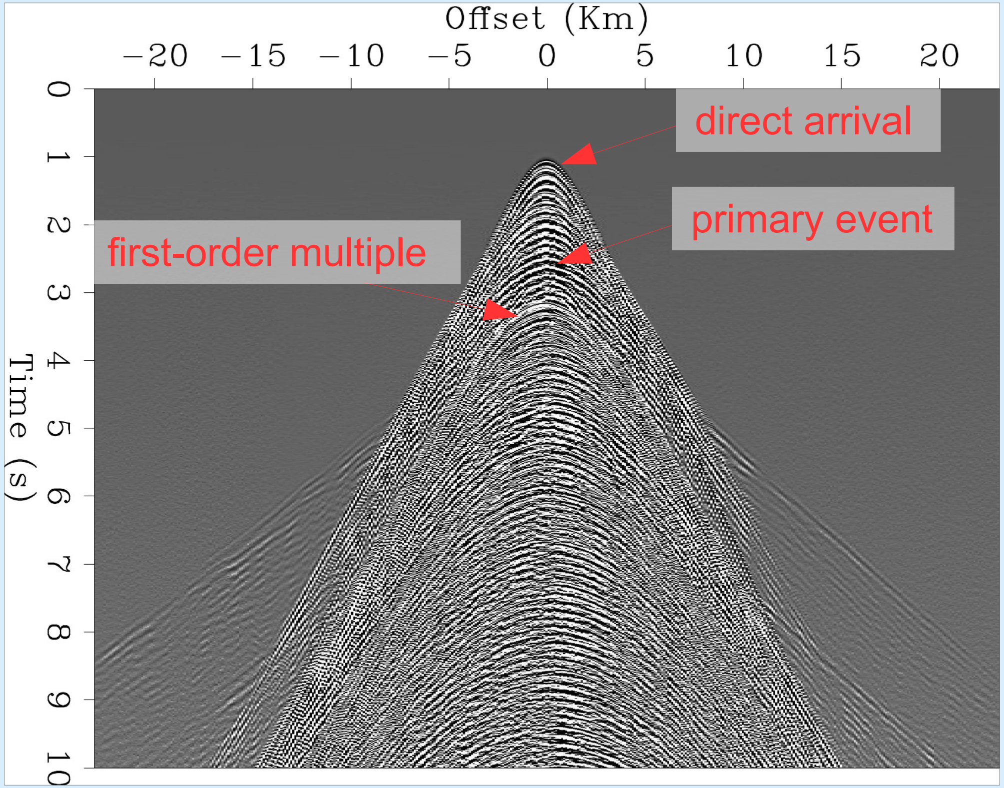


Original Vertical component

Up-down separation: first step

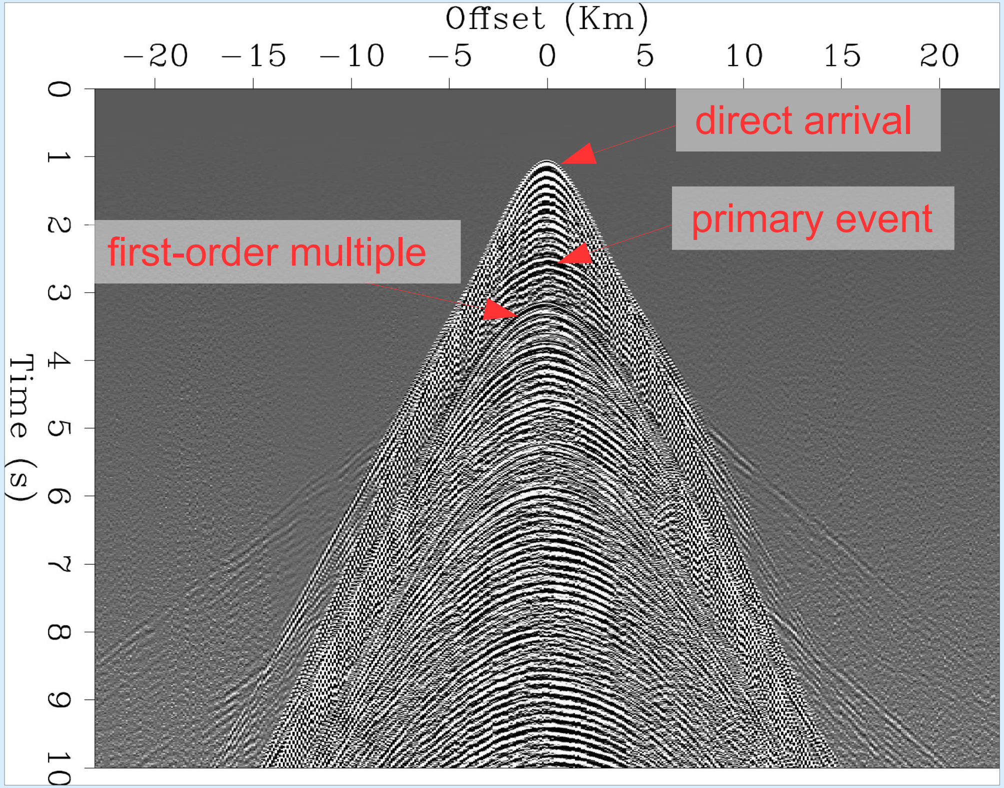
Receiver **impulse response designature**



Deconvolved Vertical component

Up-down separation: first step

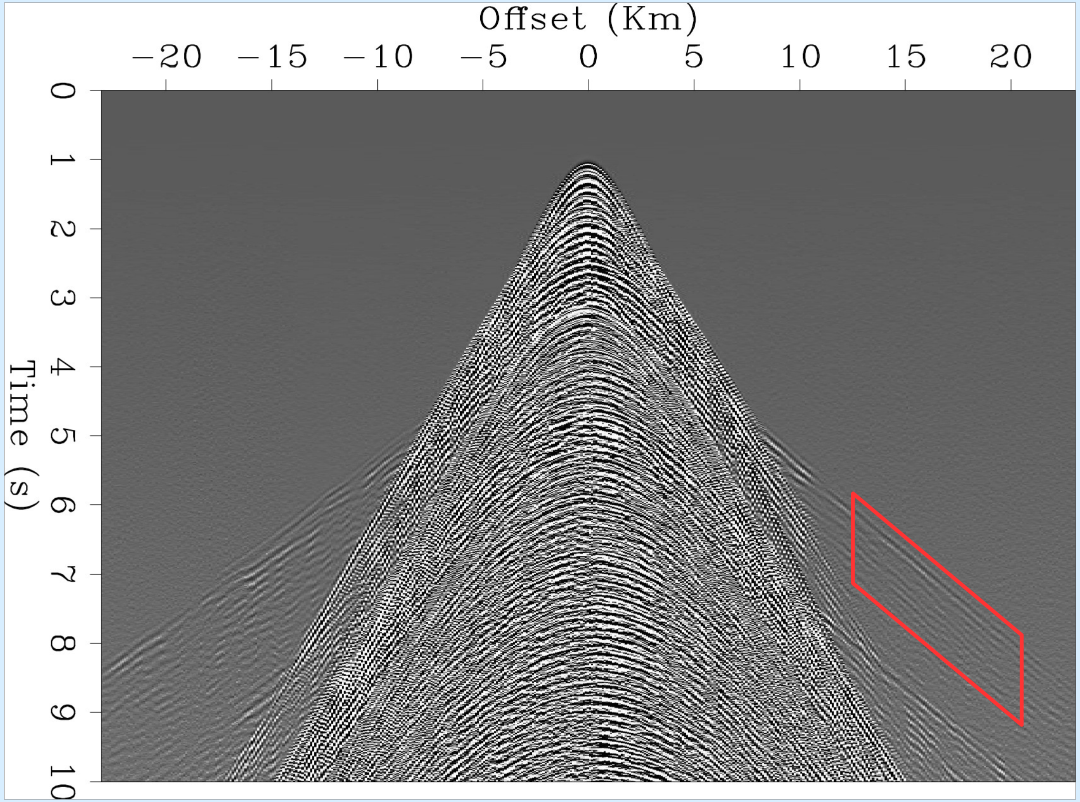
Receiver **impulse response designature**



Deconvolved Pressure component

Up-down separation: second step

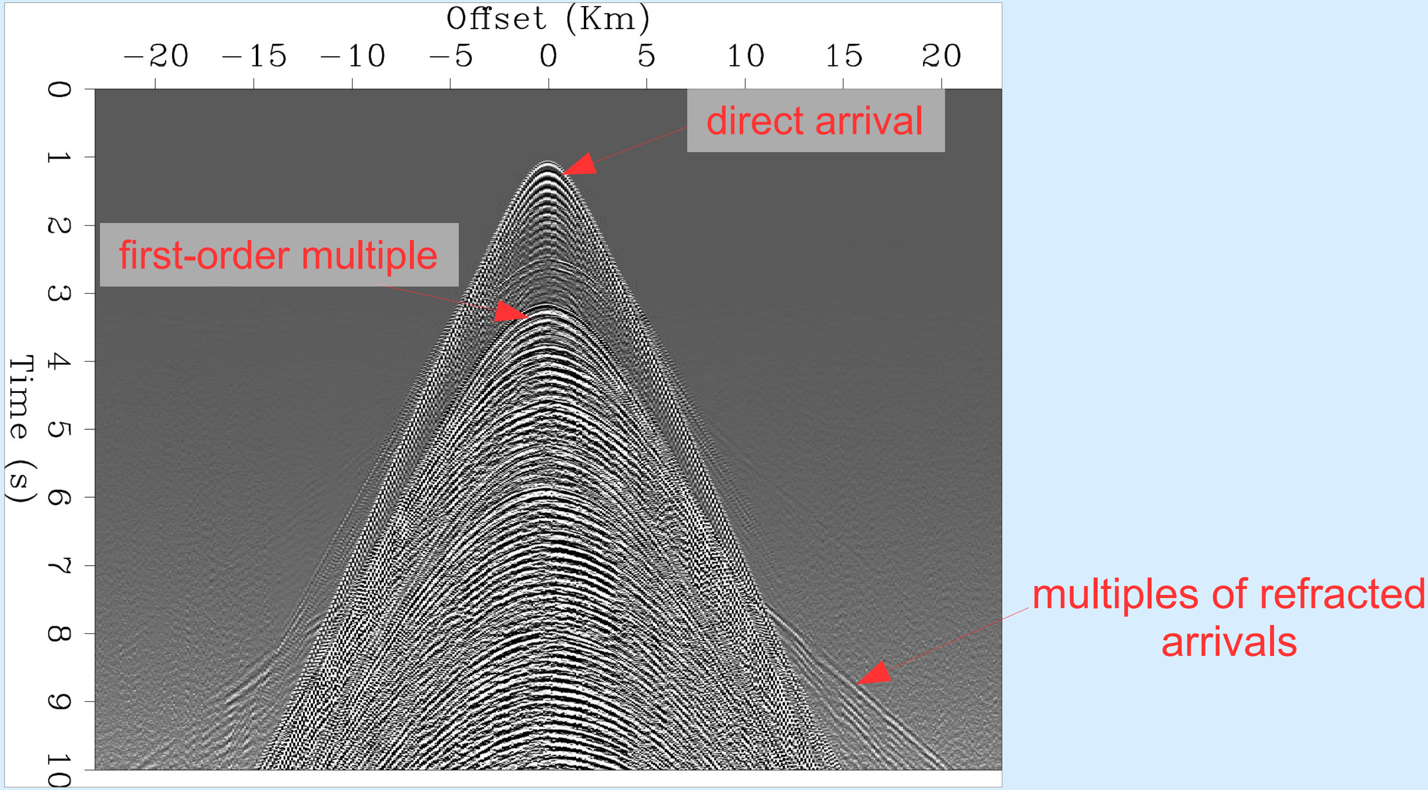
Windowing refracted arrivals and **computing calibration filters**



Up-down separation: third step

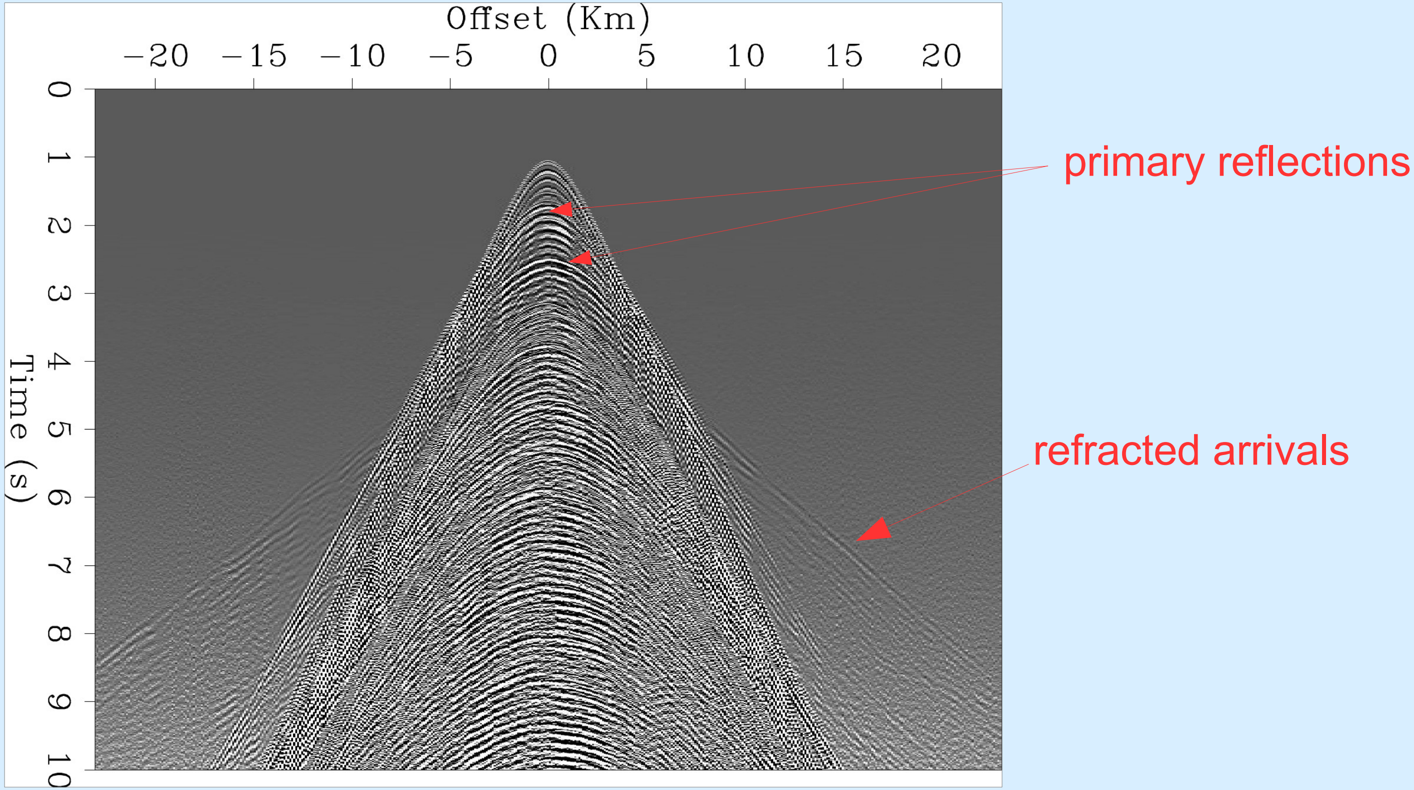
Wavefield decomposition

Down-going pressure component



Up-down separation: third step

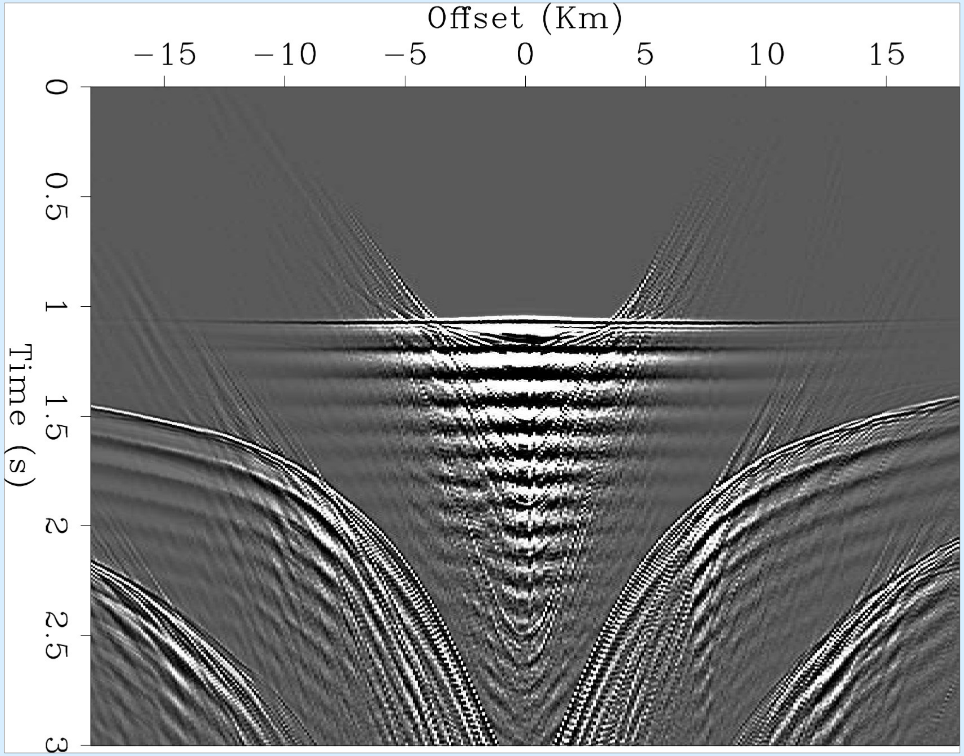
Wavefield decomposition
Up-going pressure component



Up-down separation: fourth step

Adaptive subtraction

Down-going pressure field after HMO



Up-down separation: fourth step

Adaptive subtraction

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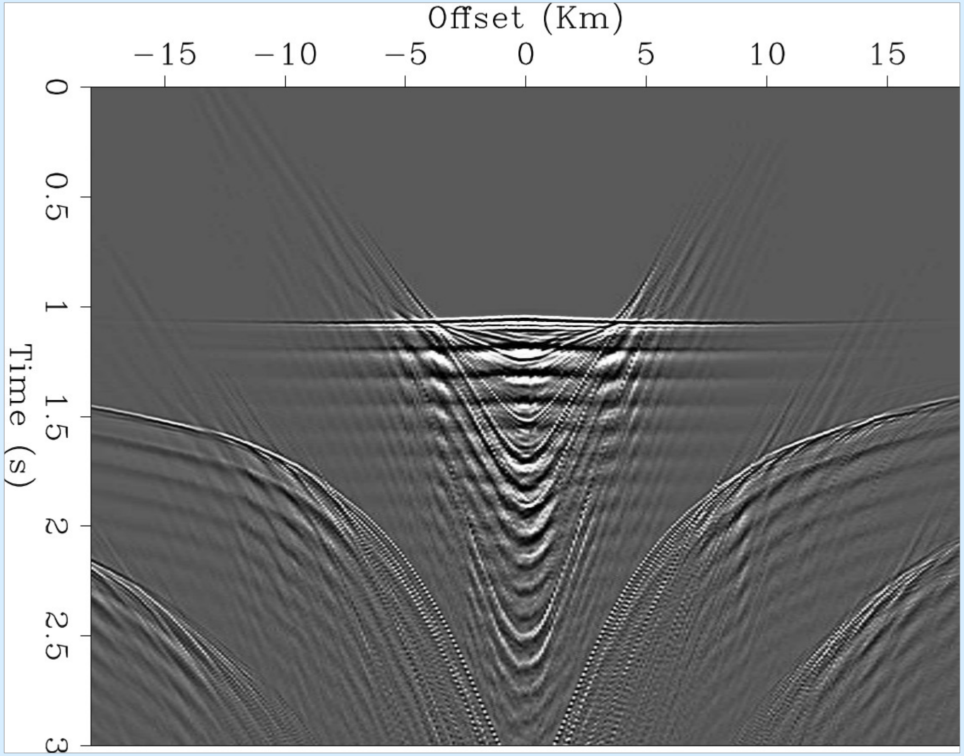
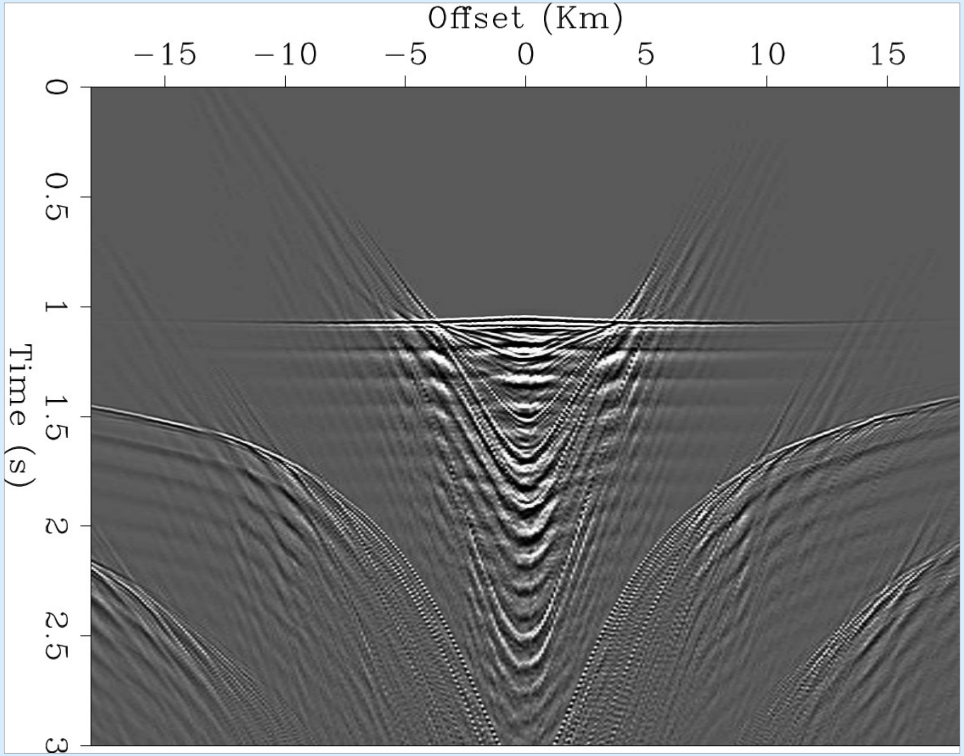


Up-down separation: fourth step

Adaptive subtraction

Up-going pressure field **after adaptive subtraction**



Conclusions

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  - Phase differences can be eliminated by receiver impulse response deconvolution
  - Calibration filters computed on refracted arrivals can separate up- from down-going energy at **long offsets**
  - Adaptive subtraction improves the separation at **near offsets**
  - This result enables us to carry out further processing (source wavelet estimation,multiple removal, etc...)

Outline

- PZ summation with calibration filters based on critically refracted waves (SEP155-p.119)

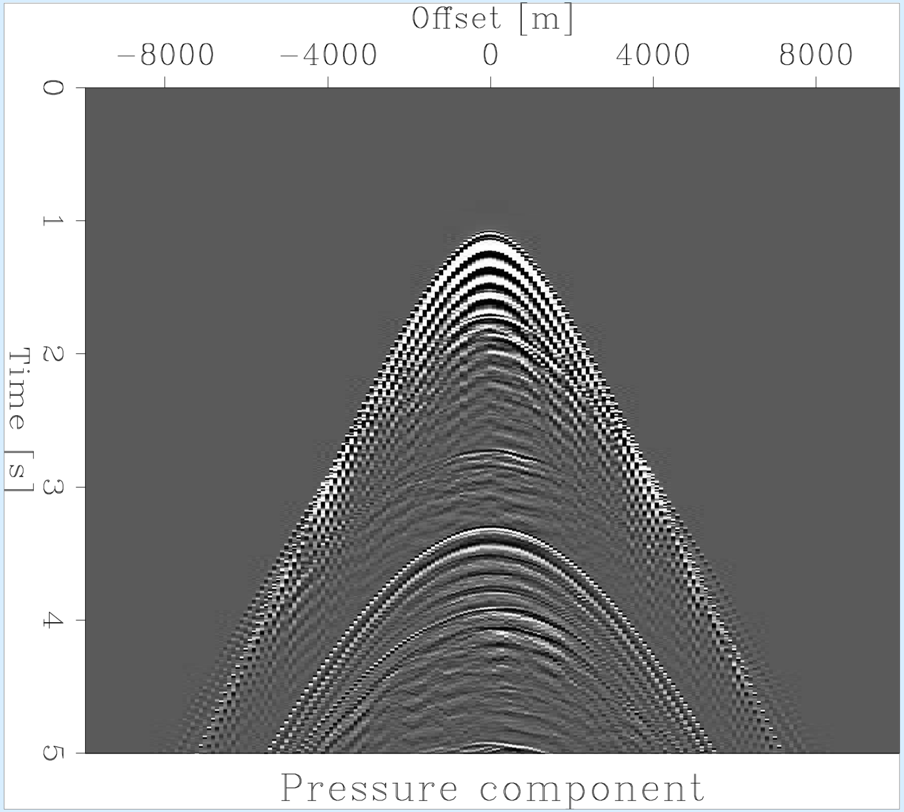
- **Toward PZ summation without Z (SEP158-p.323)**

Outline

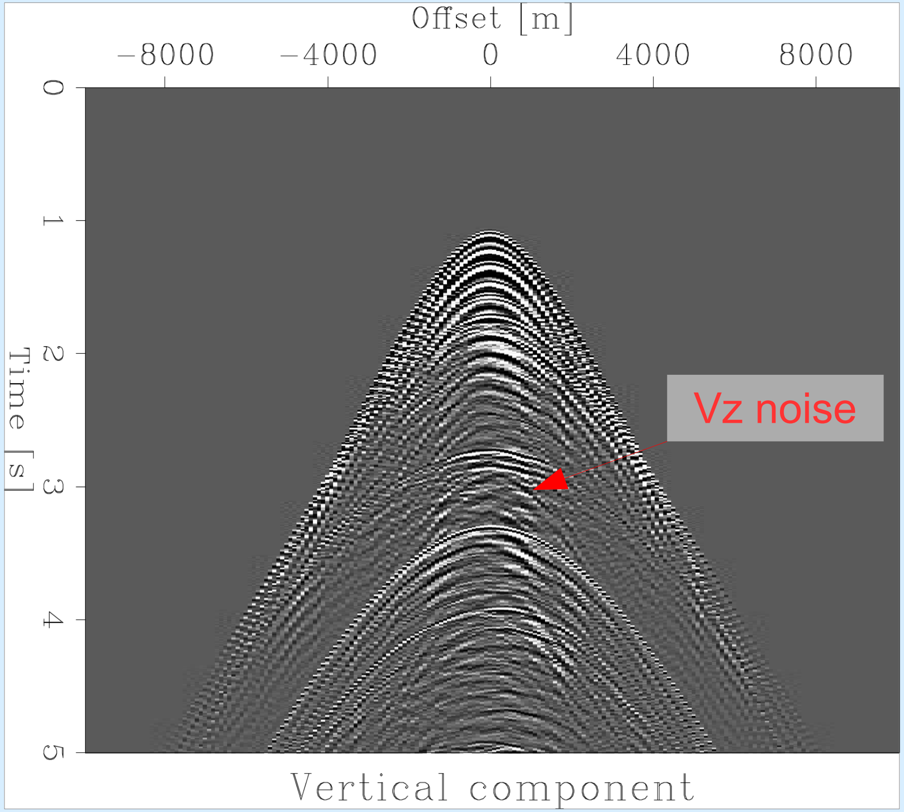
- **Toward PZ summation without Z (SEP158-p.323)**
  - Why a single-component based up-down separation
  - Main assumption
  - Curvelet domain and simple tests
  - Conclusions

Vz noise

Pressure component



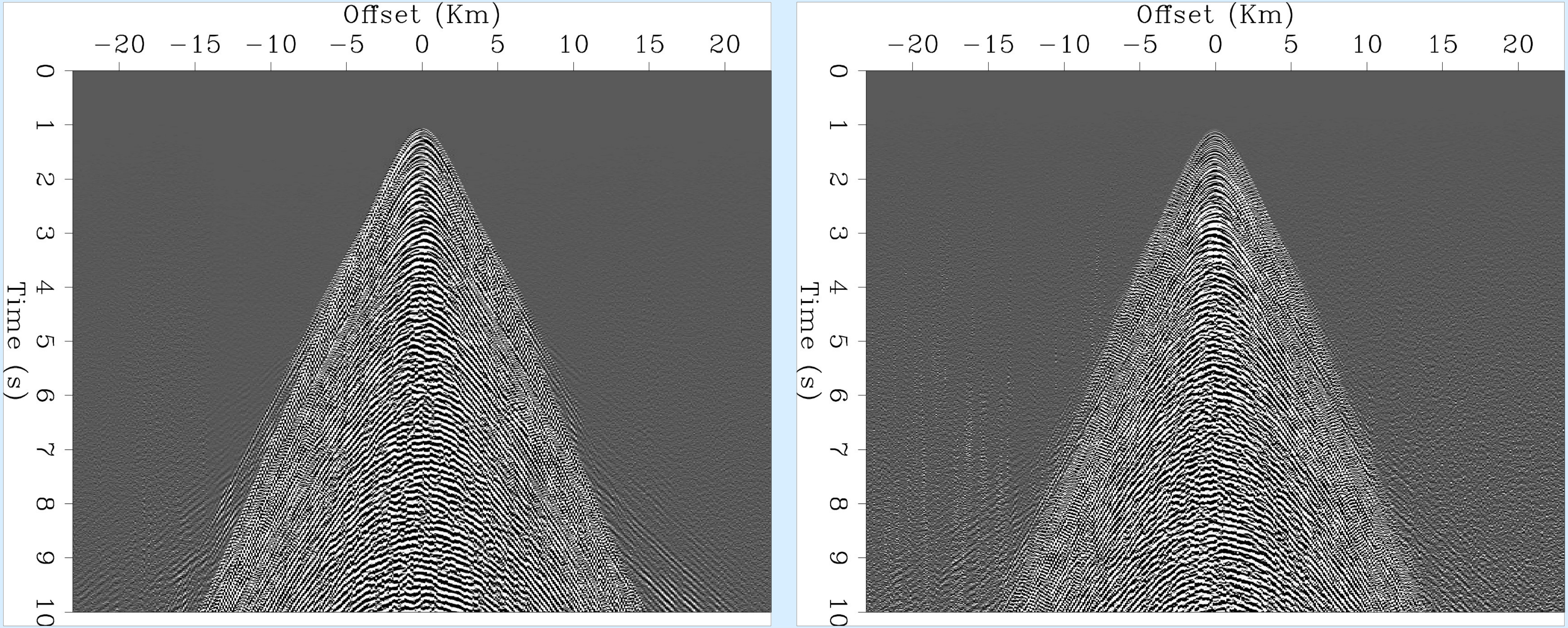
Vertical component



Horizontal-component separation

Radial component

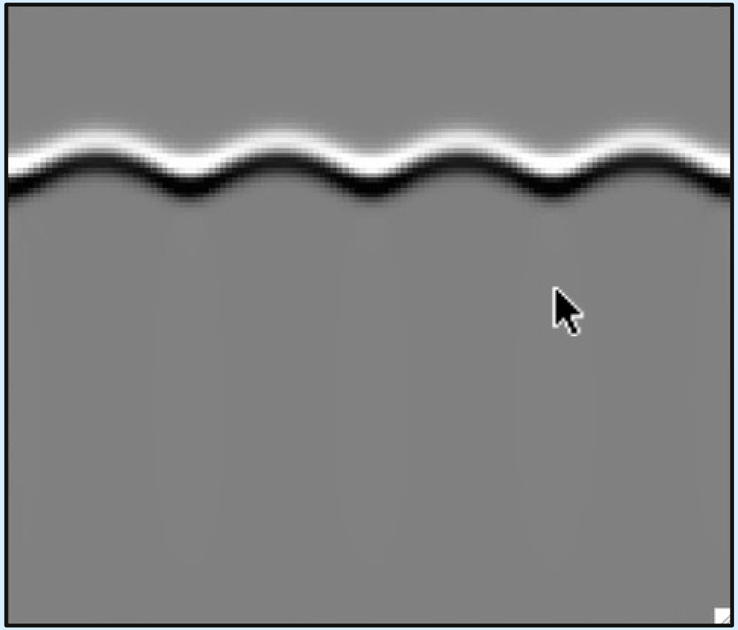
Transverse component



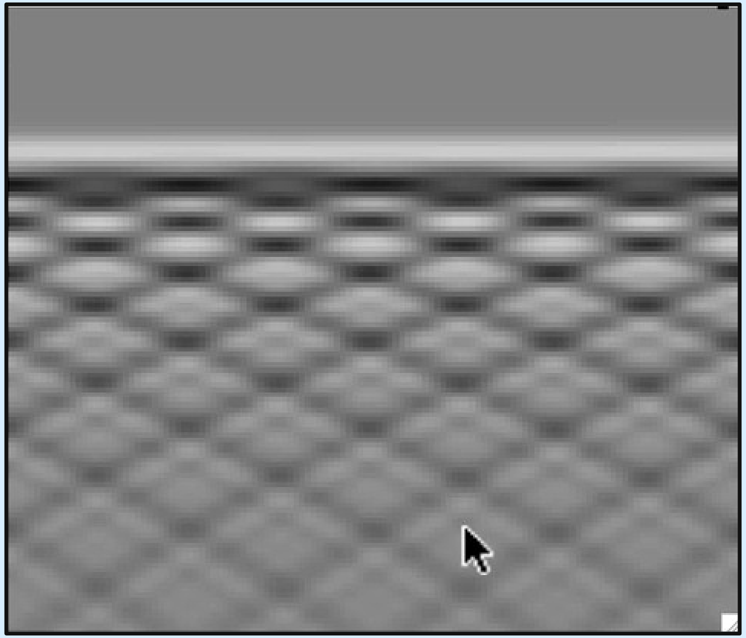
Wavefront healing

Figures from FGDP

Wavefield after passing through **inhomogeneity**

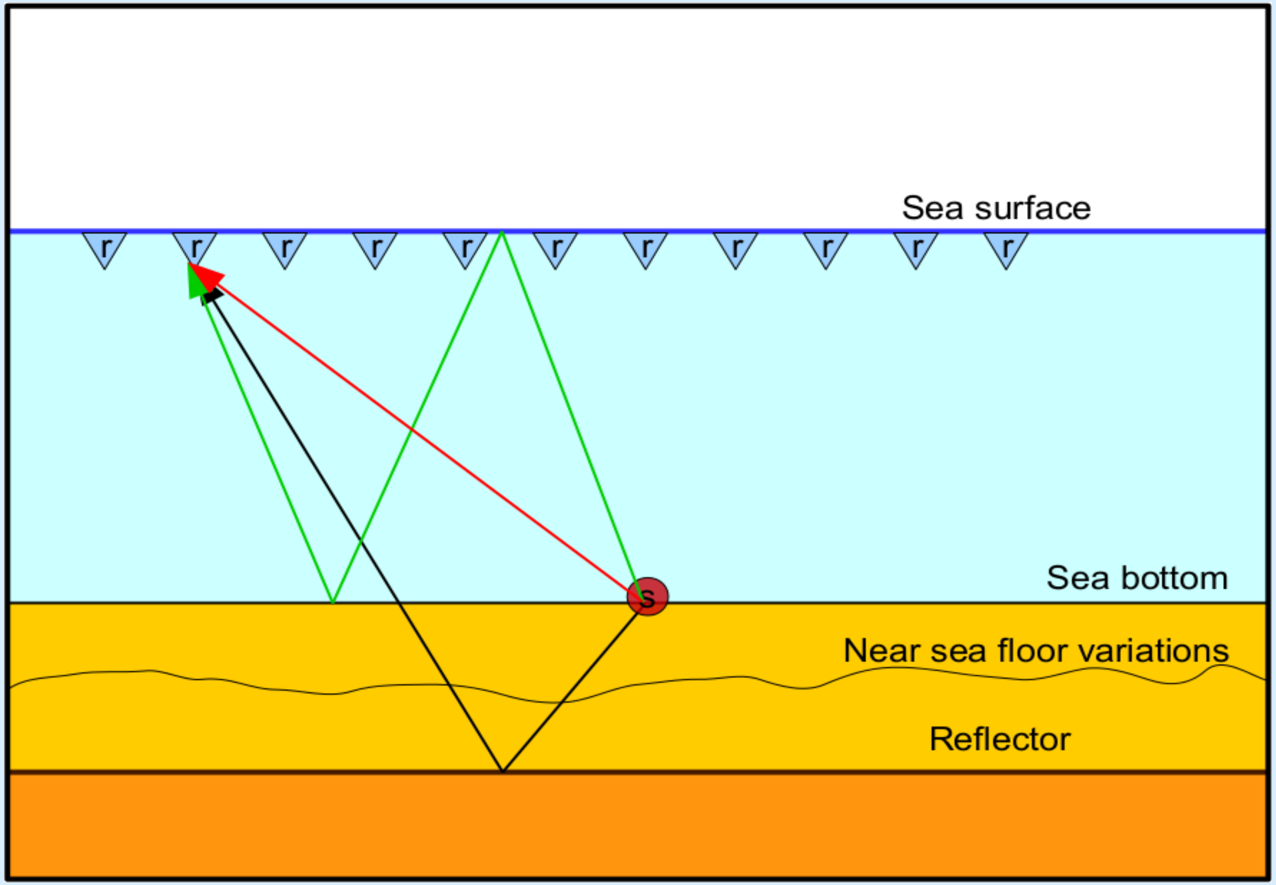


Wavefield after traveling in **homogeneous** medium



Wavefront healing

Using **reciprocity**, we exchange shots with receiver



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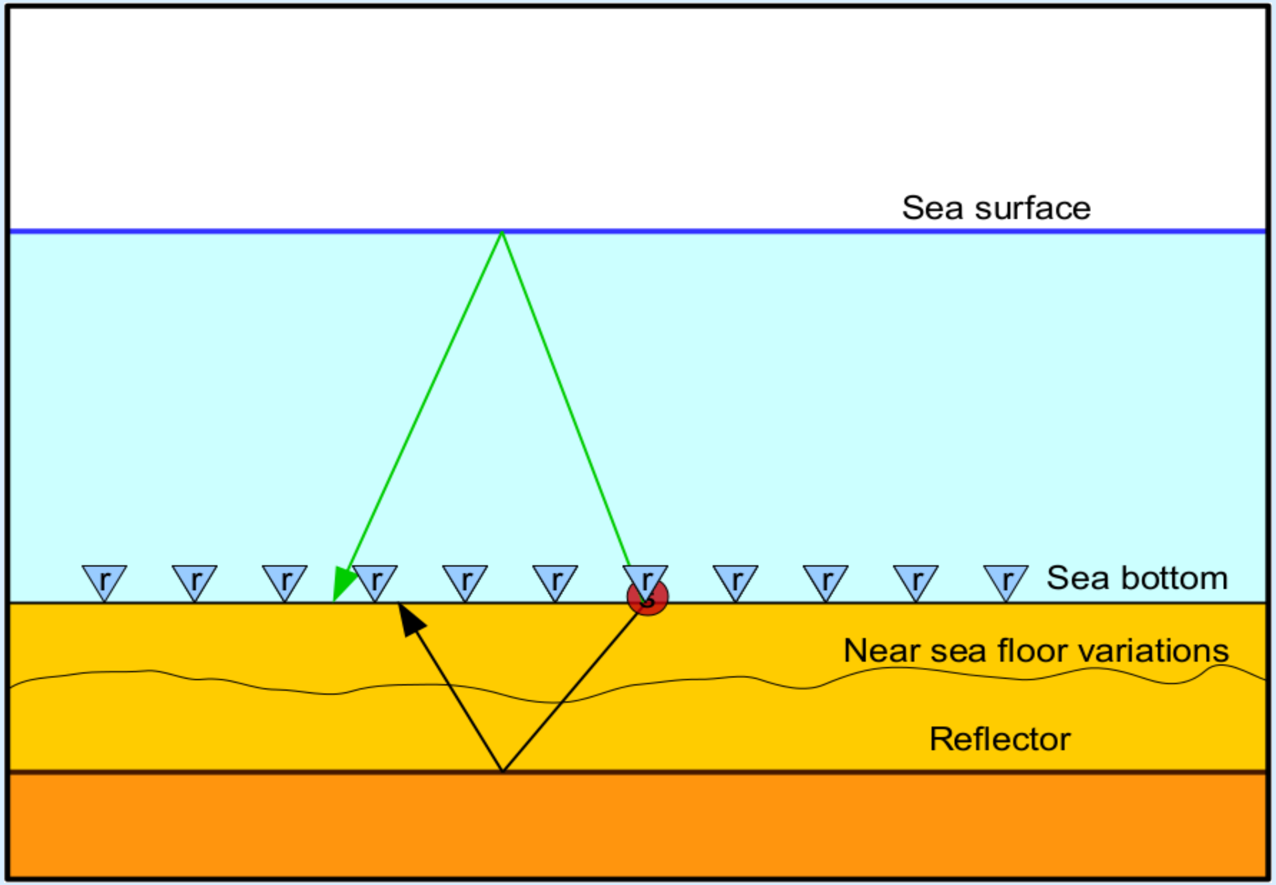
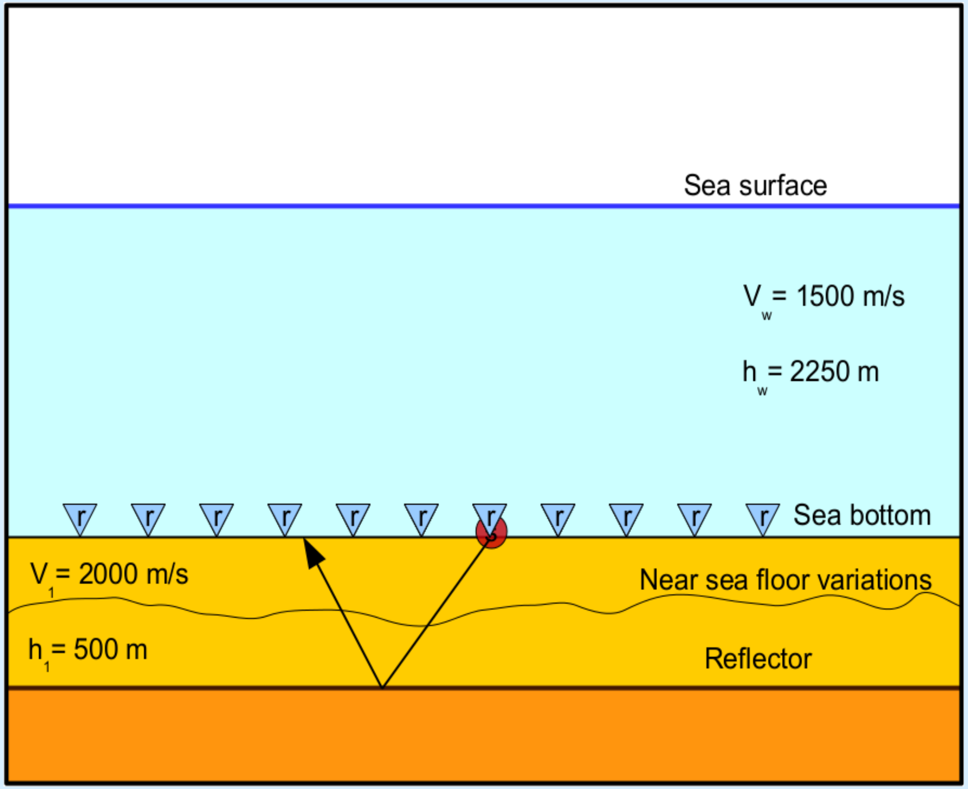
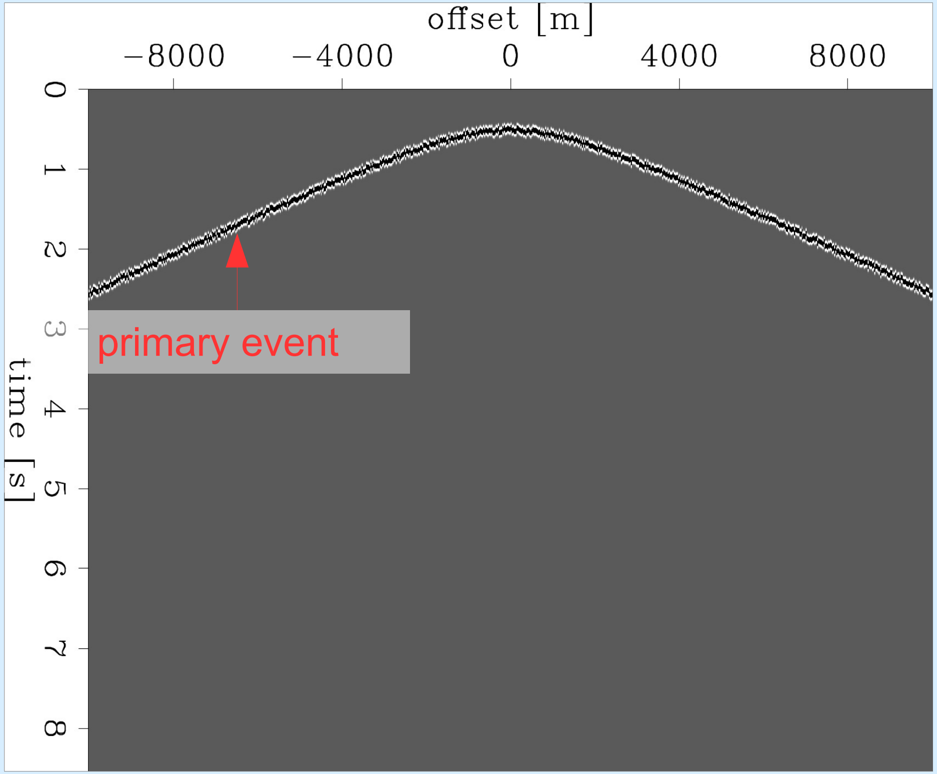


The effect of statics





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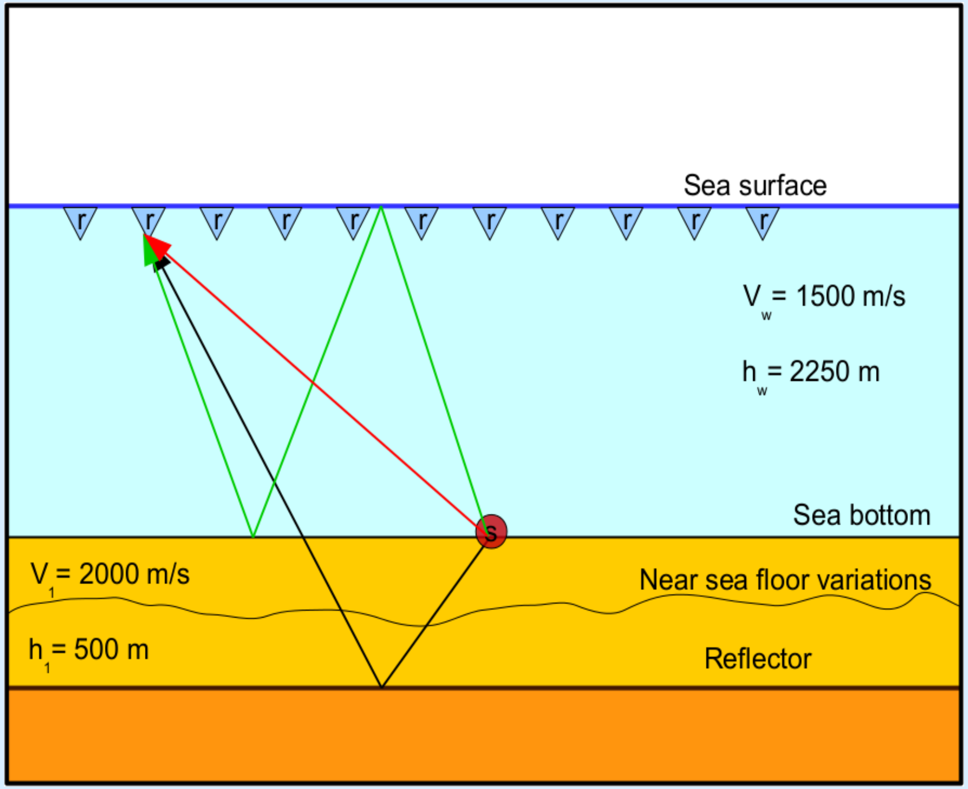

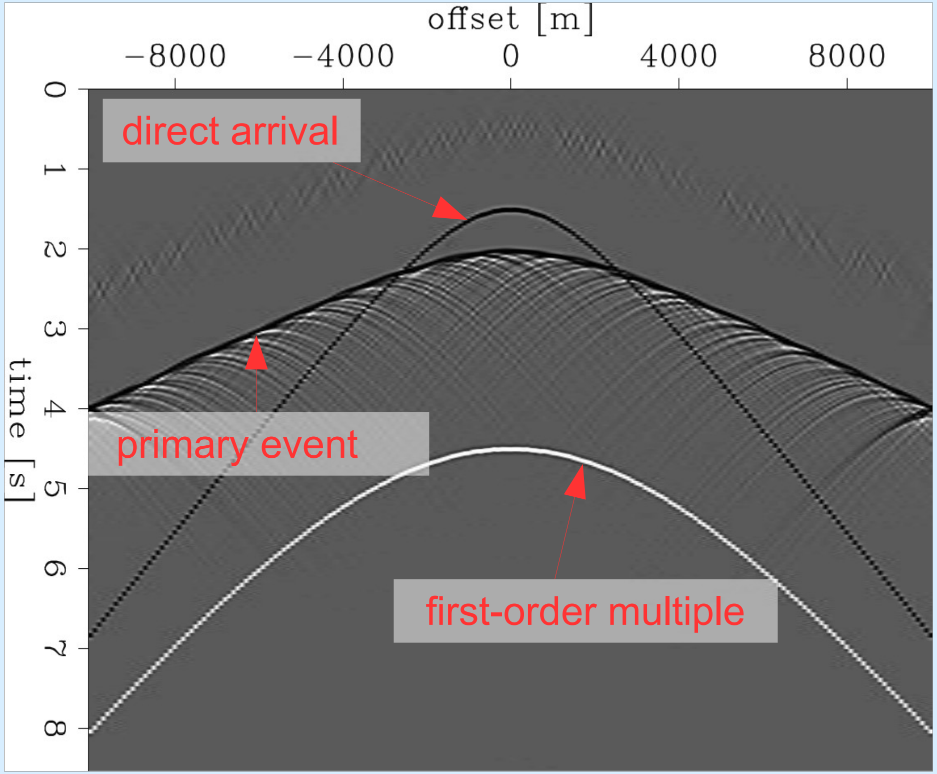

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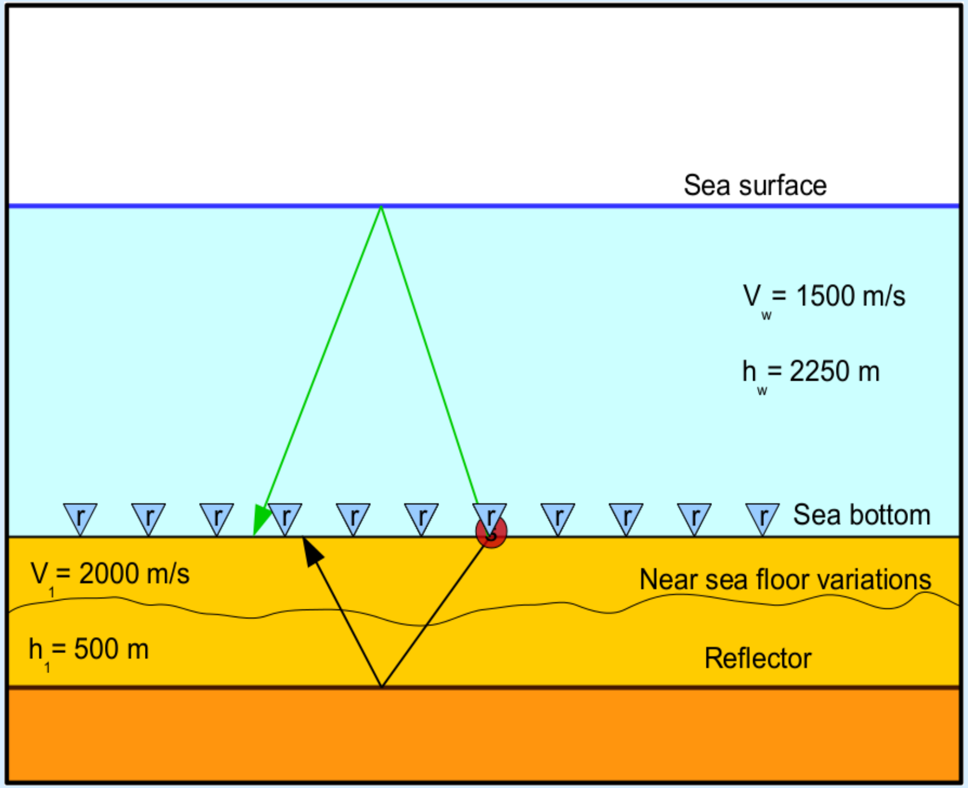
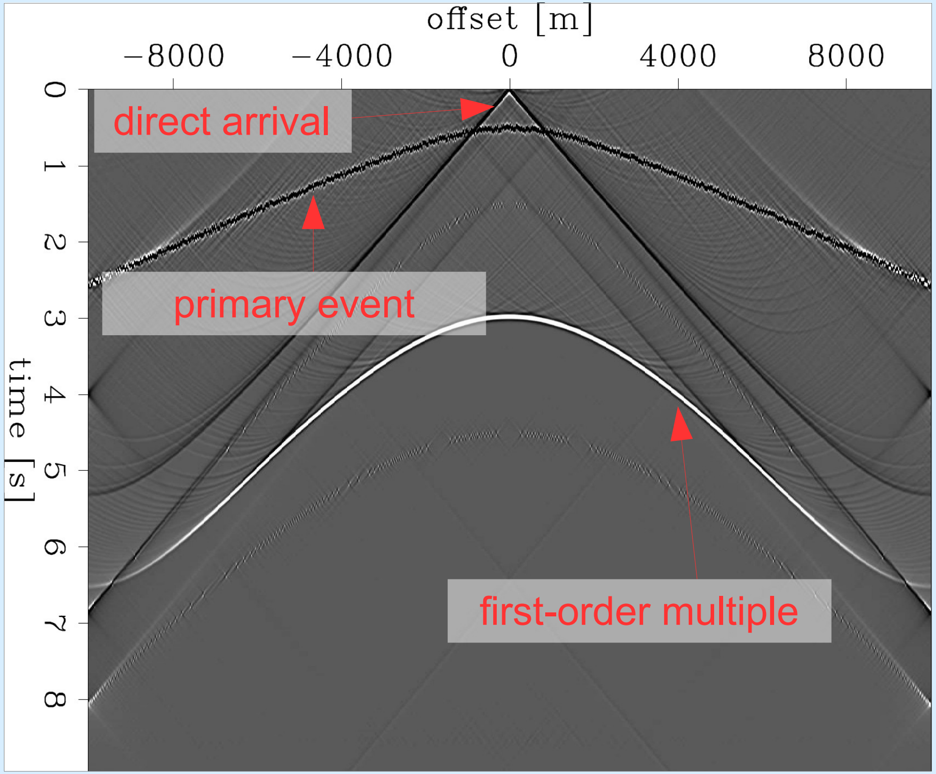




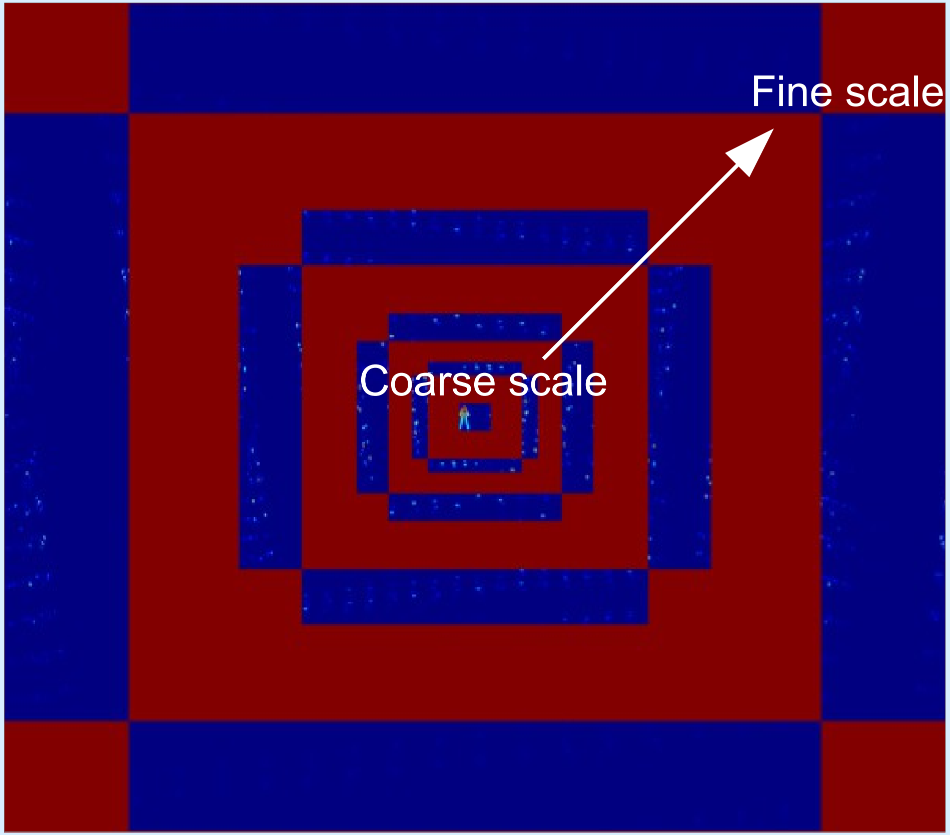
The curvelet domain

How does the curvelet transform work?

coefficient　　　　　　　Basis function

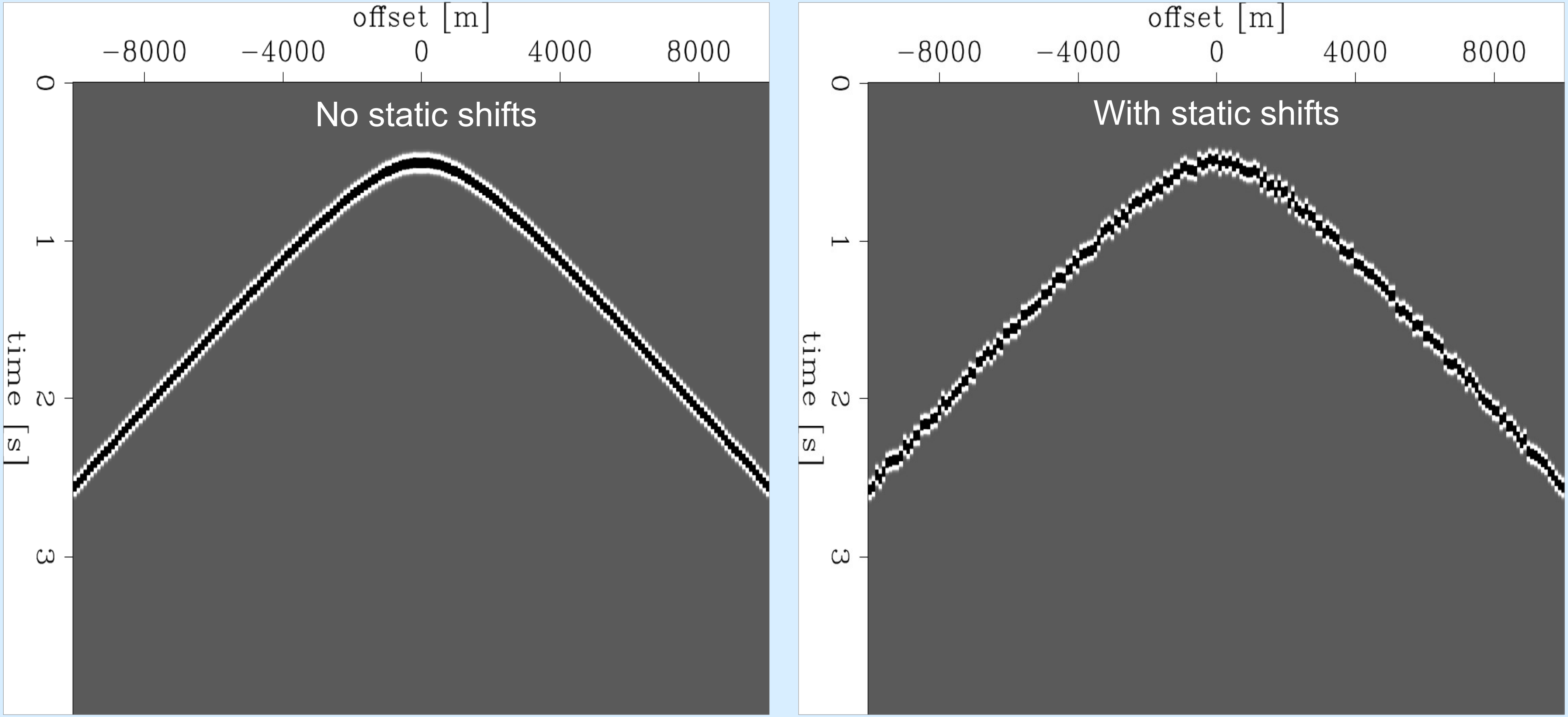
$$\boxed{c(j,l,k)} = \int f(\omega)\,\boxed{U_j\left(S_{\theta_l}^{-1}\omega\right)e^{i\langle S_{\theta_l}^{-T}b,\,\omega\rangle}}\,d\omega$$

$$j = scale$$
$$l = orientation\ of\ the\ wavelet$$
$$k = position\ of\ the\ wavelet$$

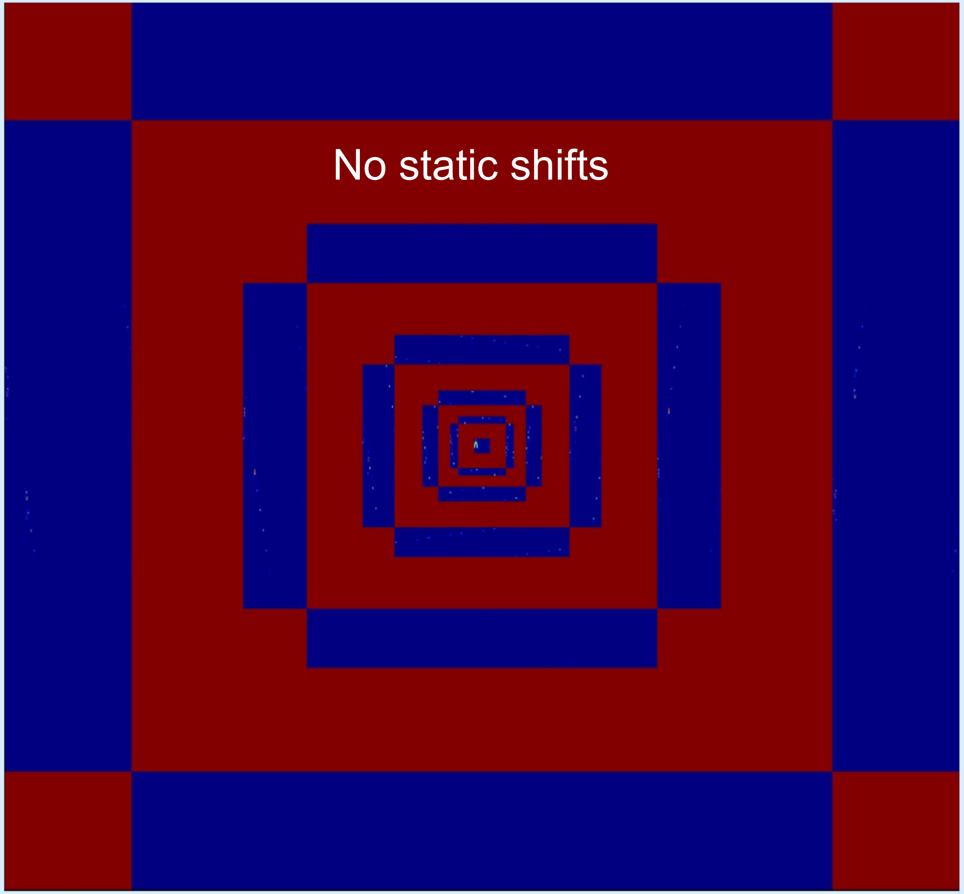


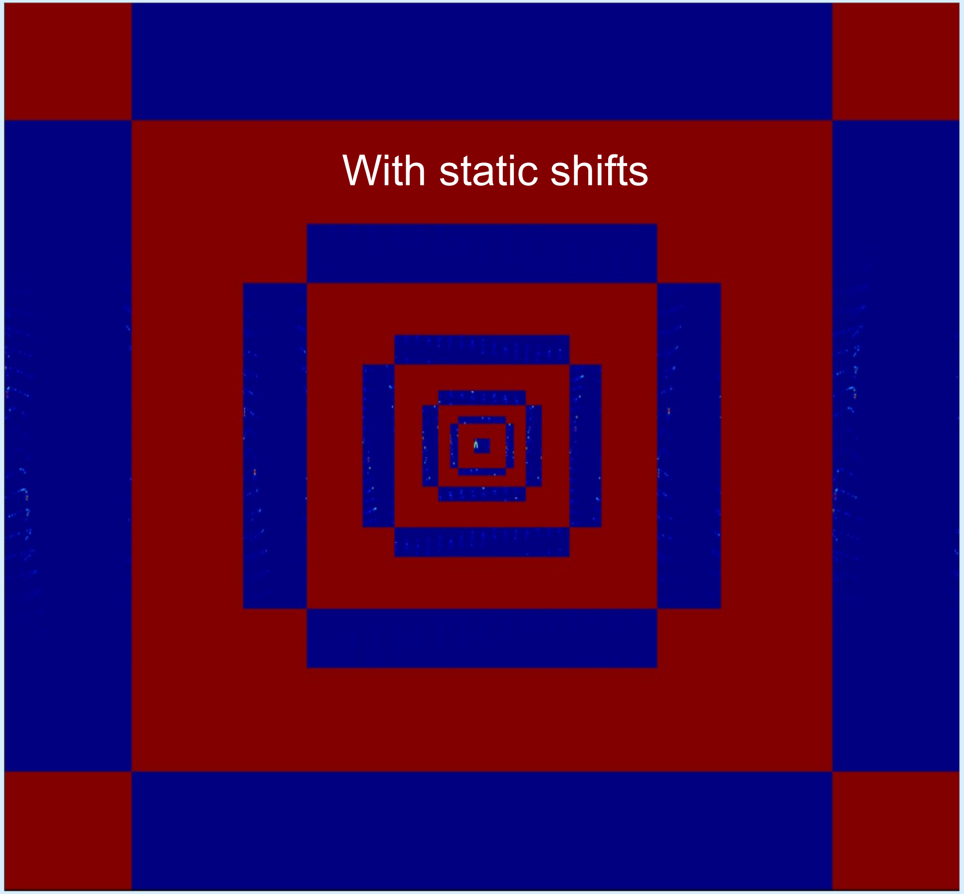
Starck et al., 2002

First test


offset [m]
−8000
−4000
0
4000
8000
time [s]
0
1
2
3
No static shifts
offset [m]
−8000
−4000
0
4000
8000
time [s]
0
1
2
3
With static shifts

First test





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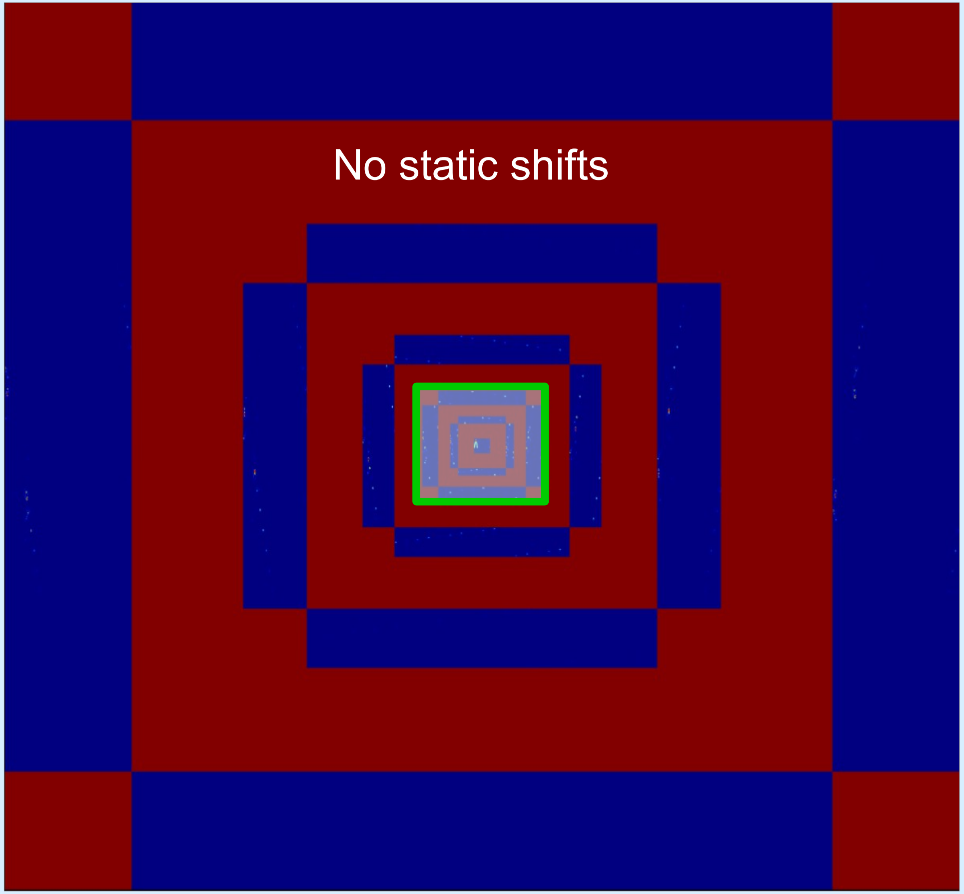

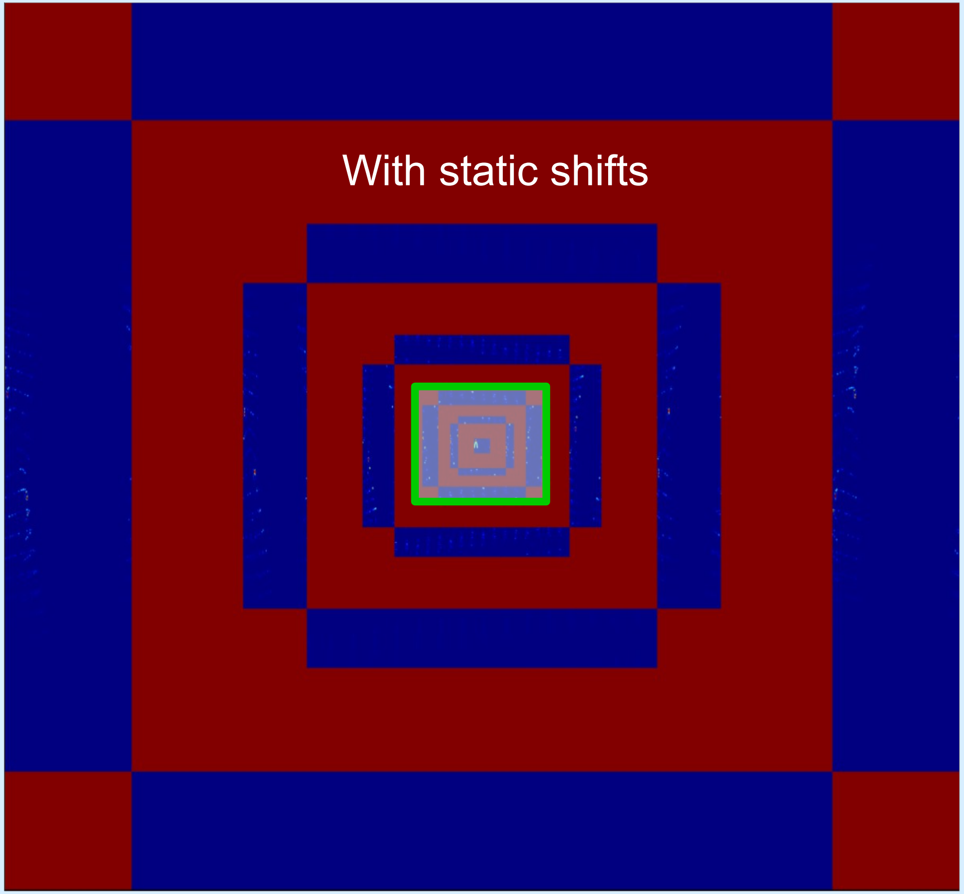

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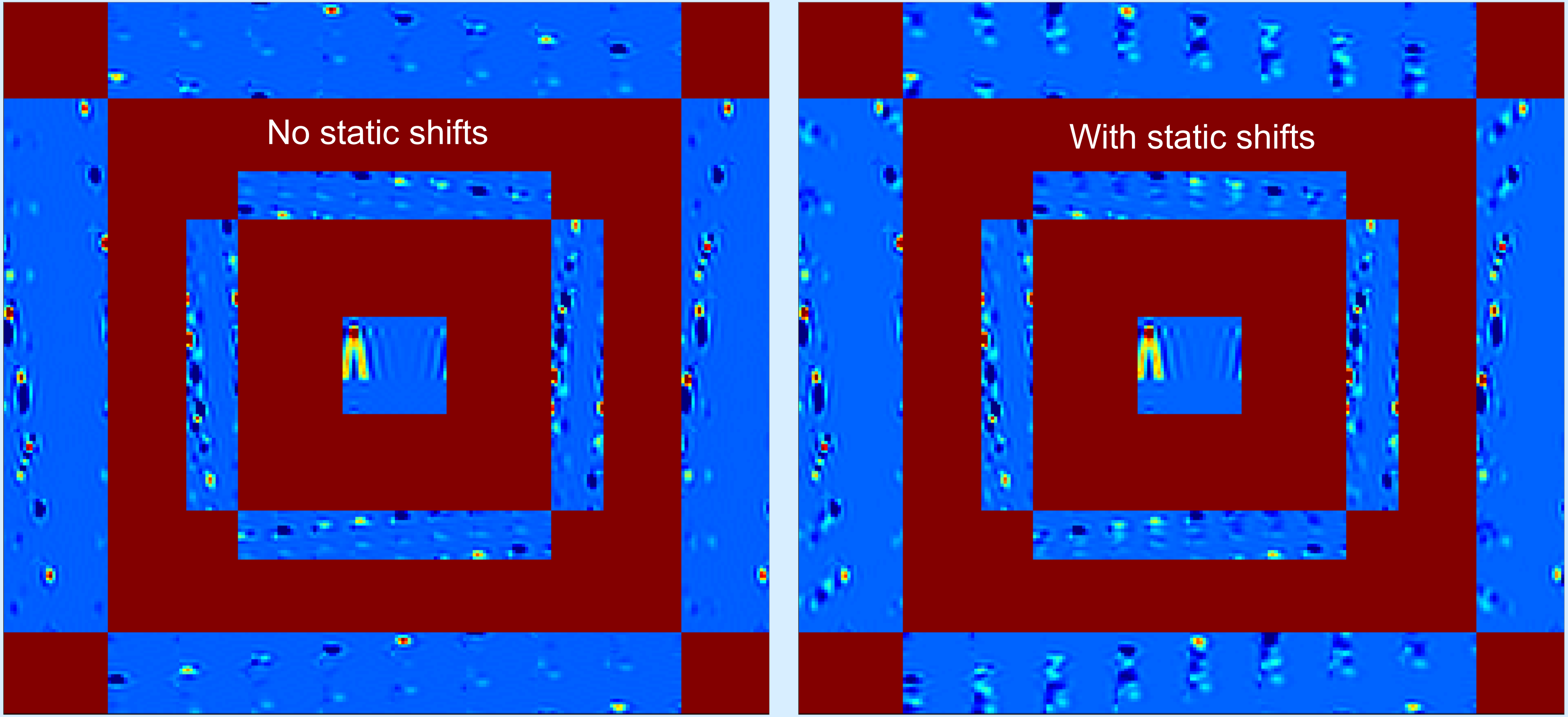
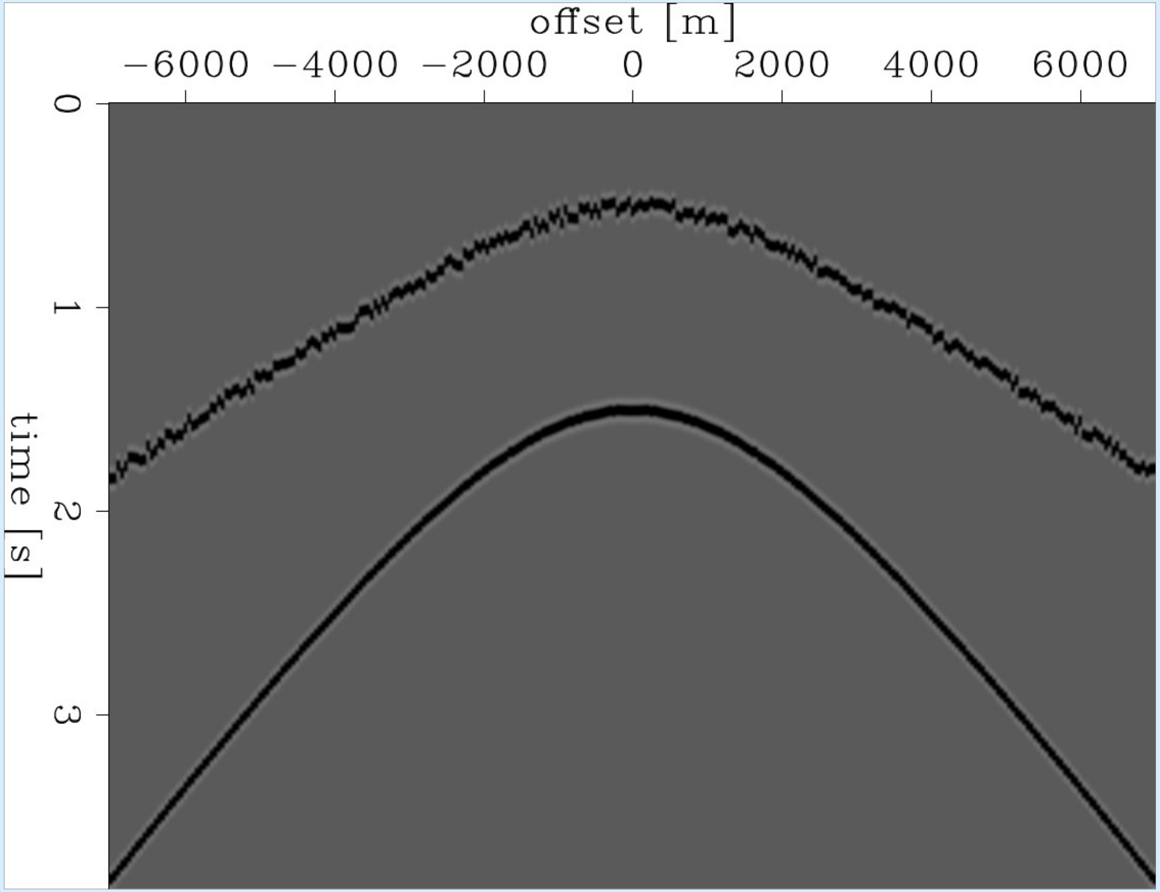


Second test



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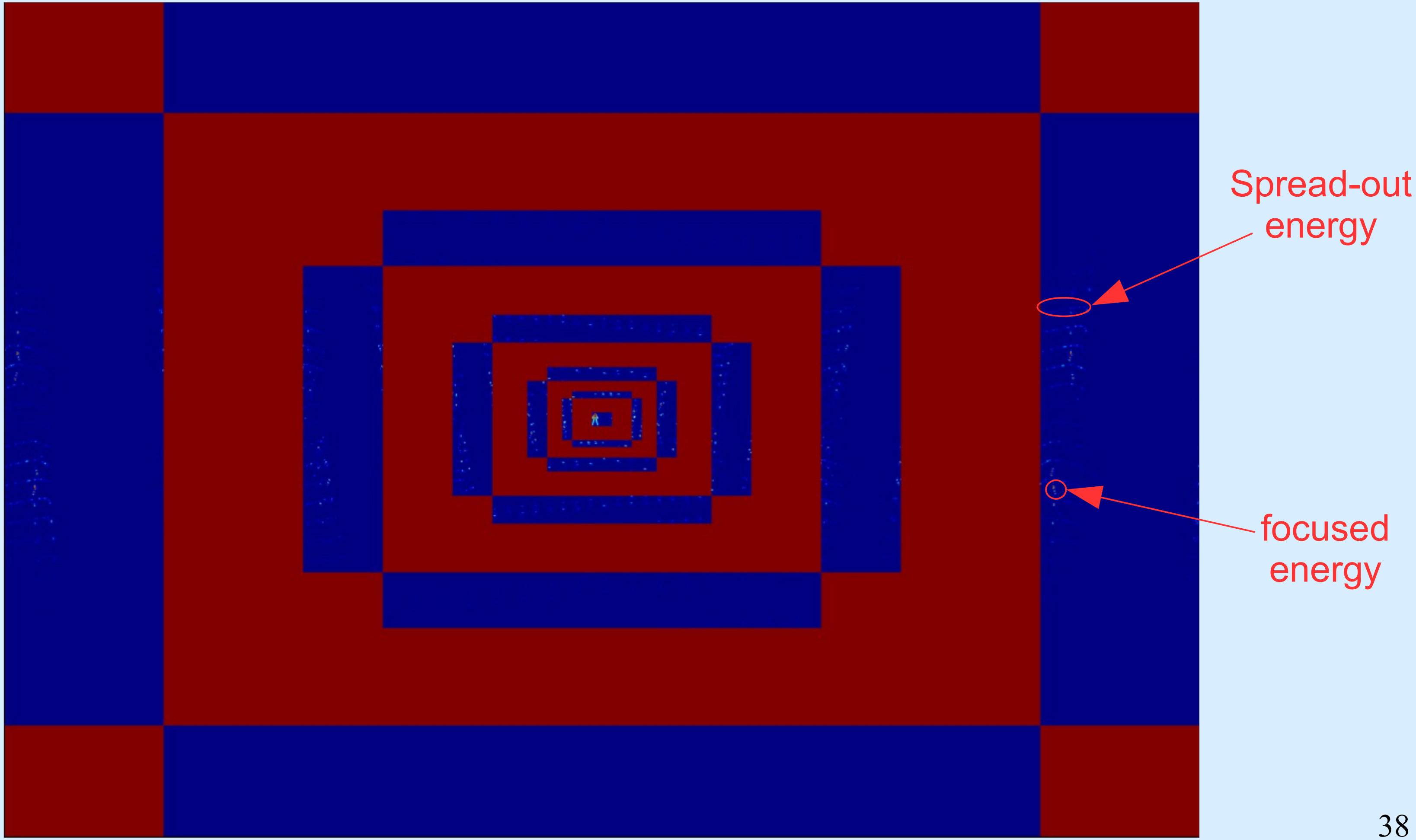
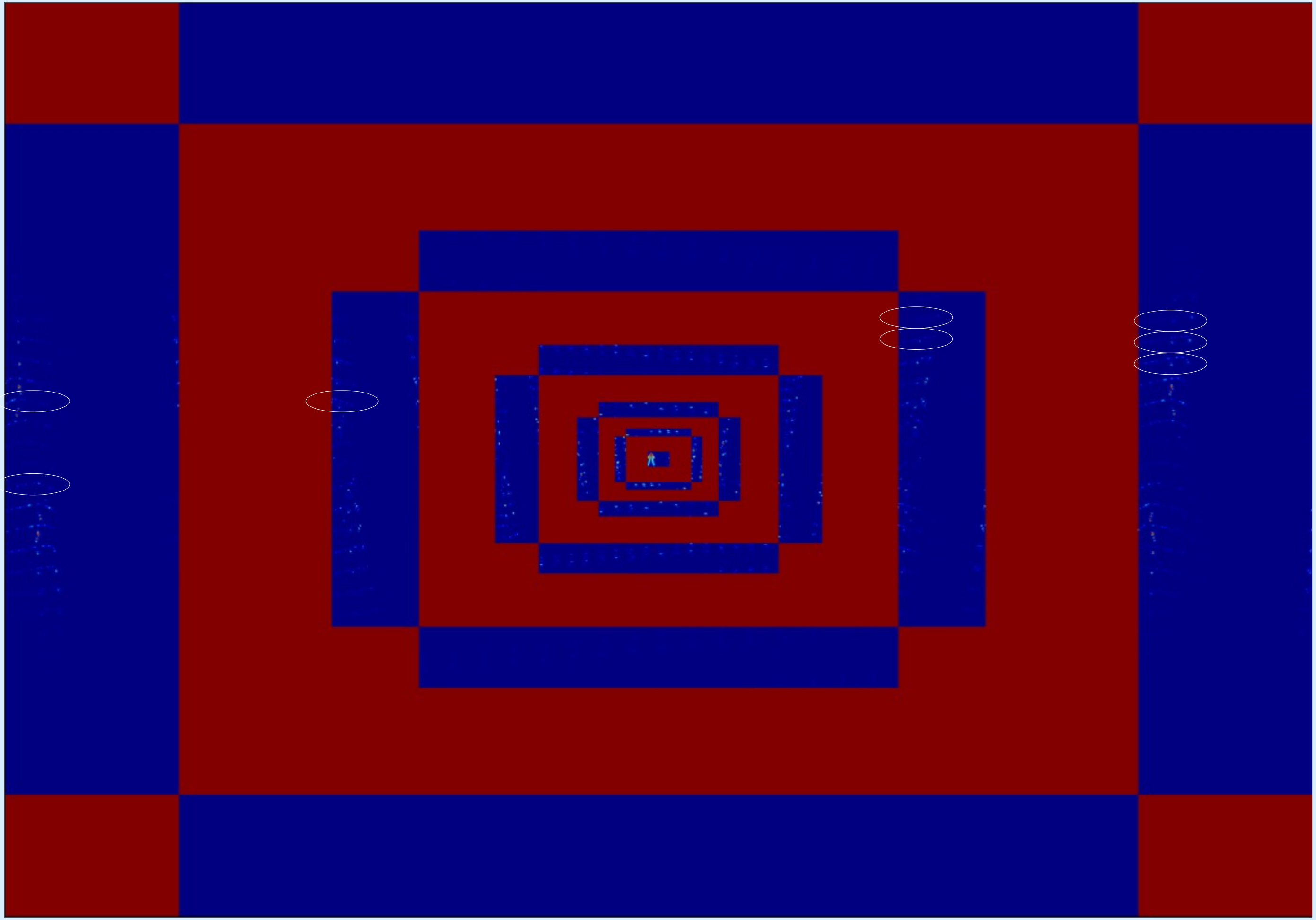


Second test



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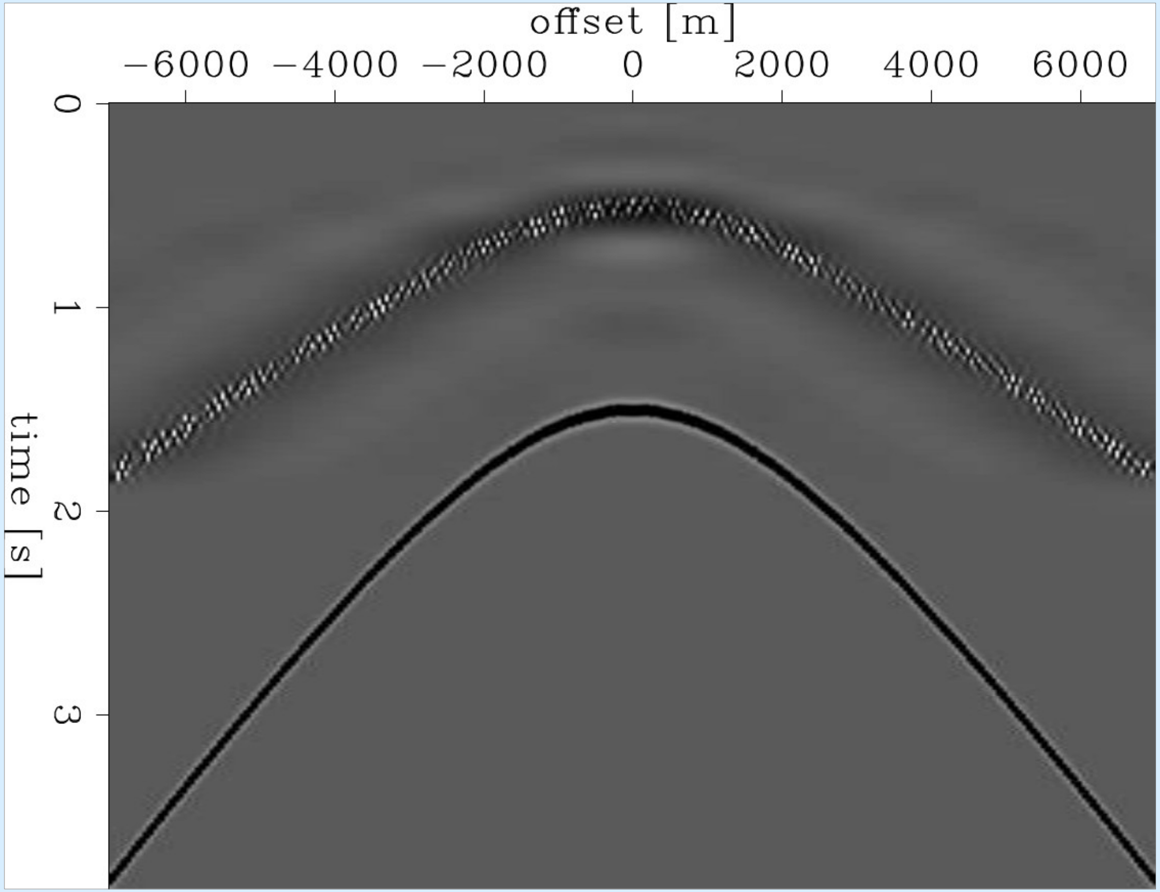

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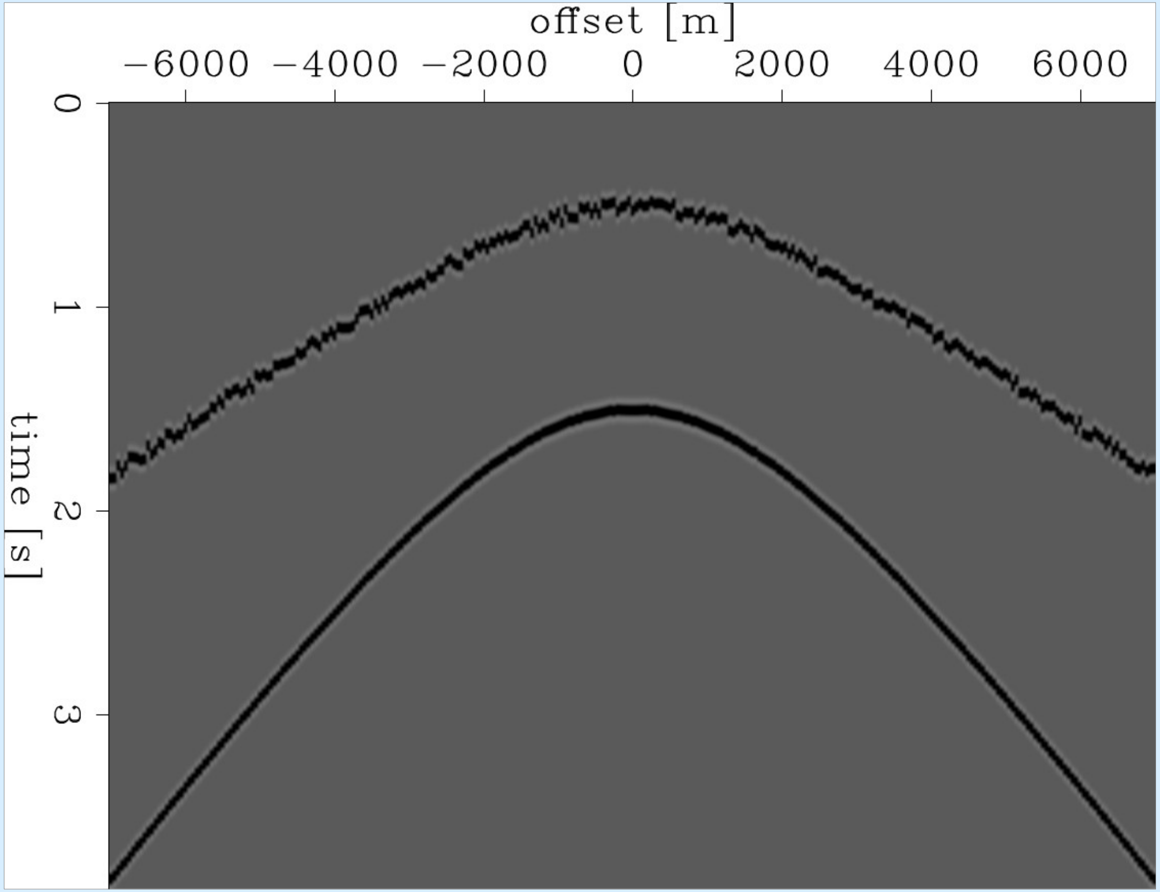

Conclusions

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  - Static effects, that should affect up-going energy, can be retrieved by downward continuation
  - These static effects seem to be captured at fine scale in curvelet domain
  - Continue to explore this single-component up-down separation

Acknowledgments

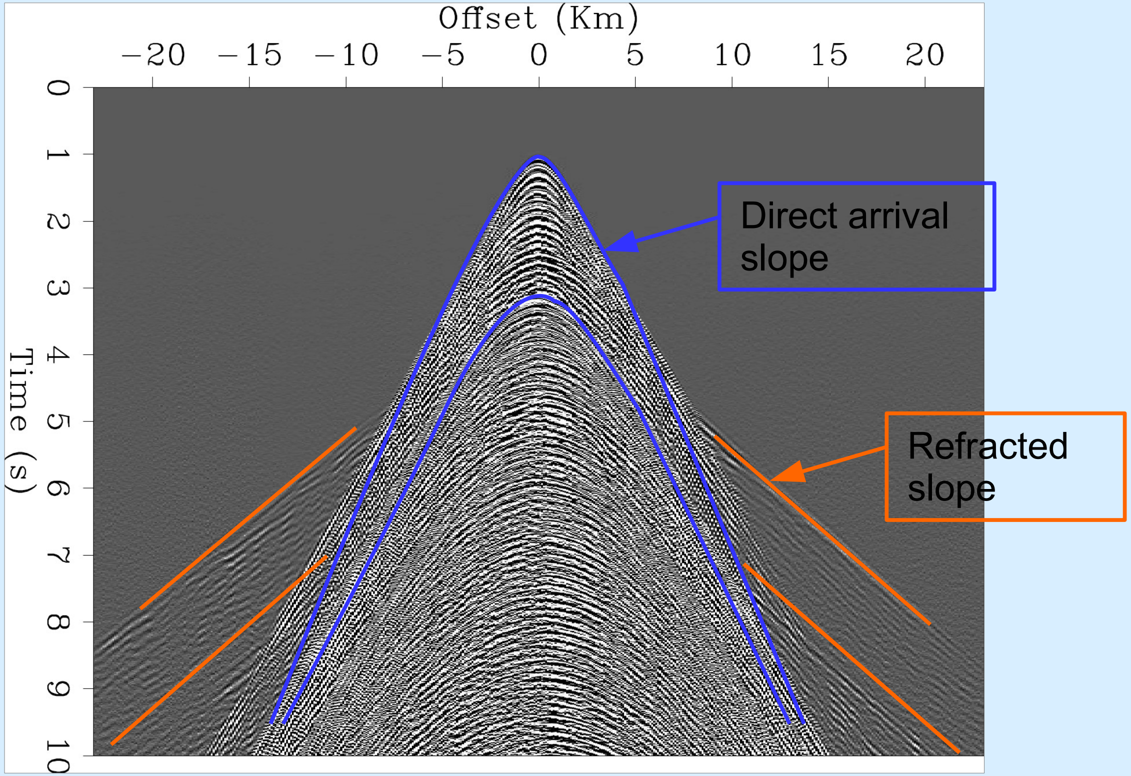
We thank **Seabed Geosolutions** for releasing the field data and for supporting the data handover by **Paul Milligan** and **Shuki Ronen**.

Thanks for your attention

Up-down separation

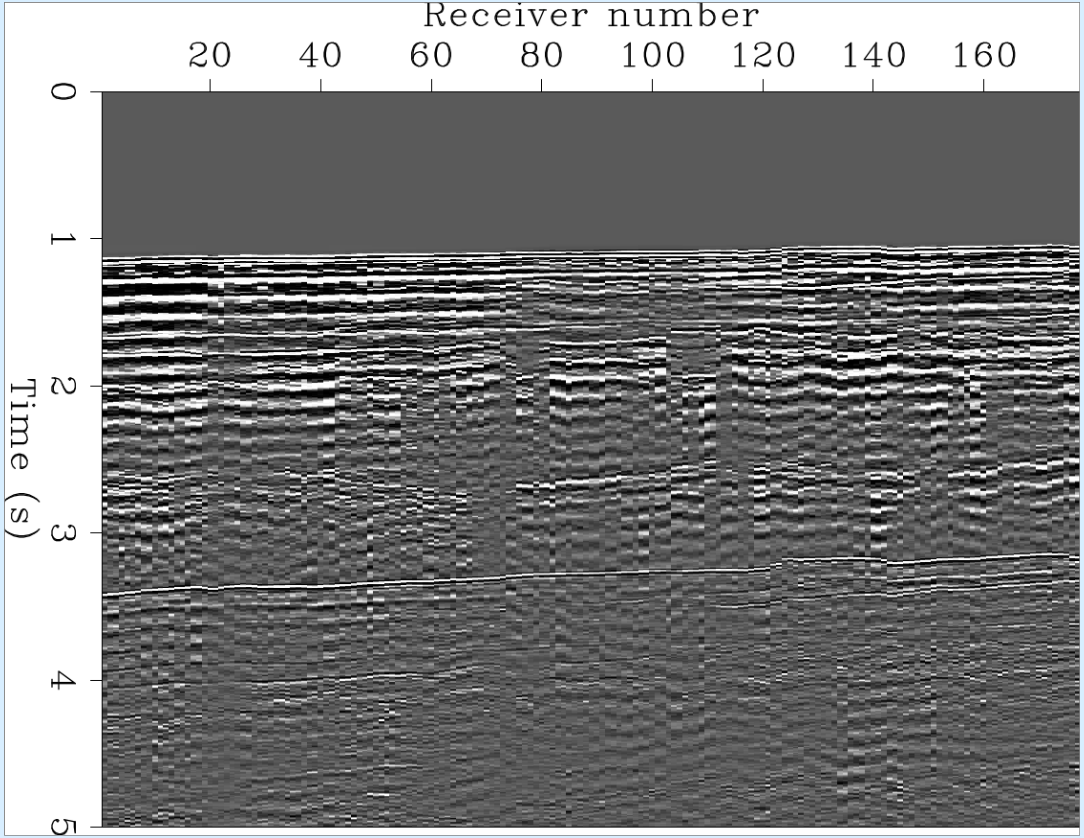
$$P_{up}(f,k)=\frac{1}{2}P(f,k)+\frac{q_0}{2q(f,k)}A(f)\frac{\rho}{q_0}Z(f,k)=\frac{1}{2}P(f,k)+\frac{q_0}{2q(f,k)}C(f)Z(f,k)$$

We have to **estimate** the **slowness** factor **for the other portions** of the gather.



Up-down separation

Near **constant-offset section** of the **up-going** pressure



Up-down separation

Near **constant-offset section** of the **down-going** pressure