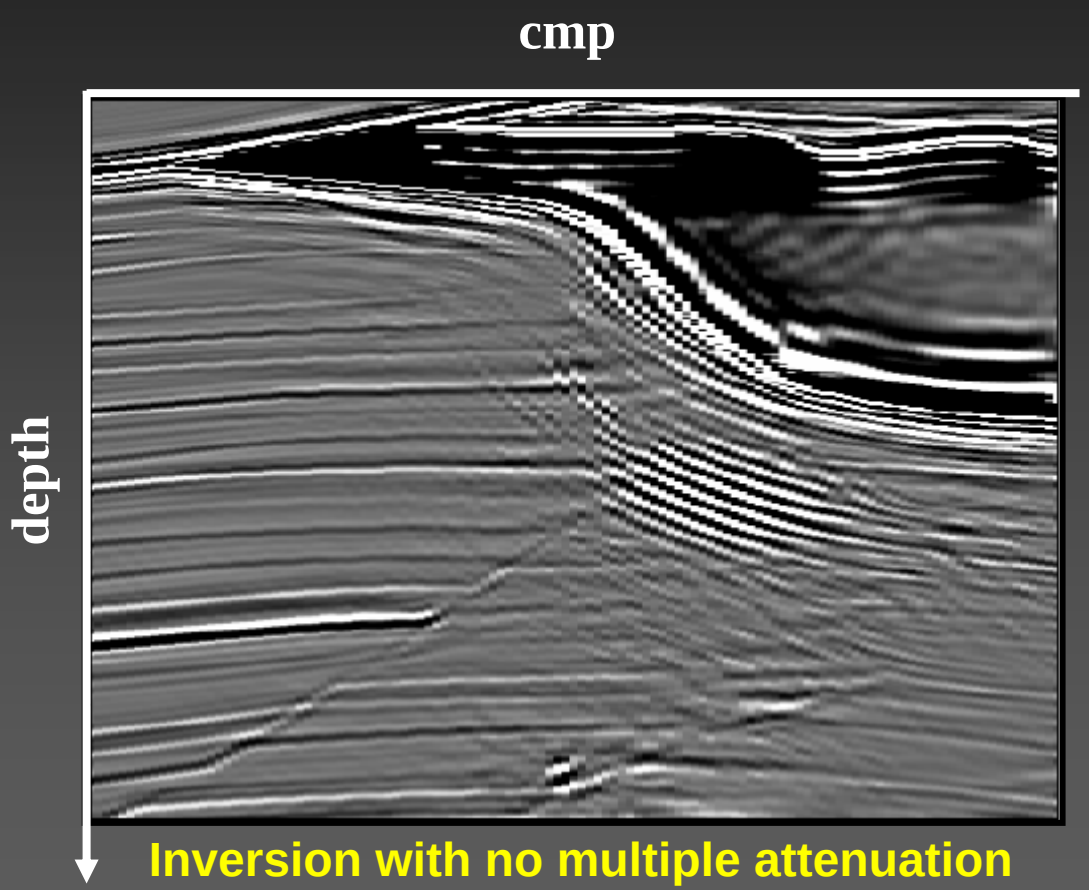
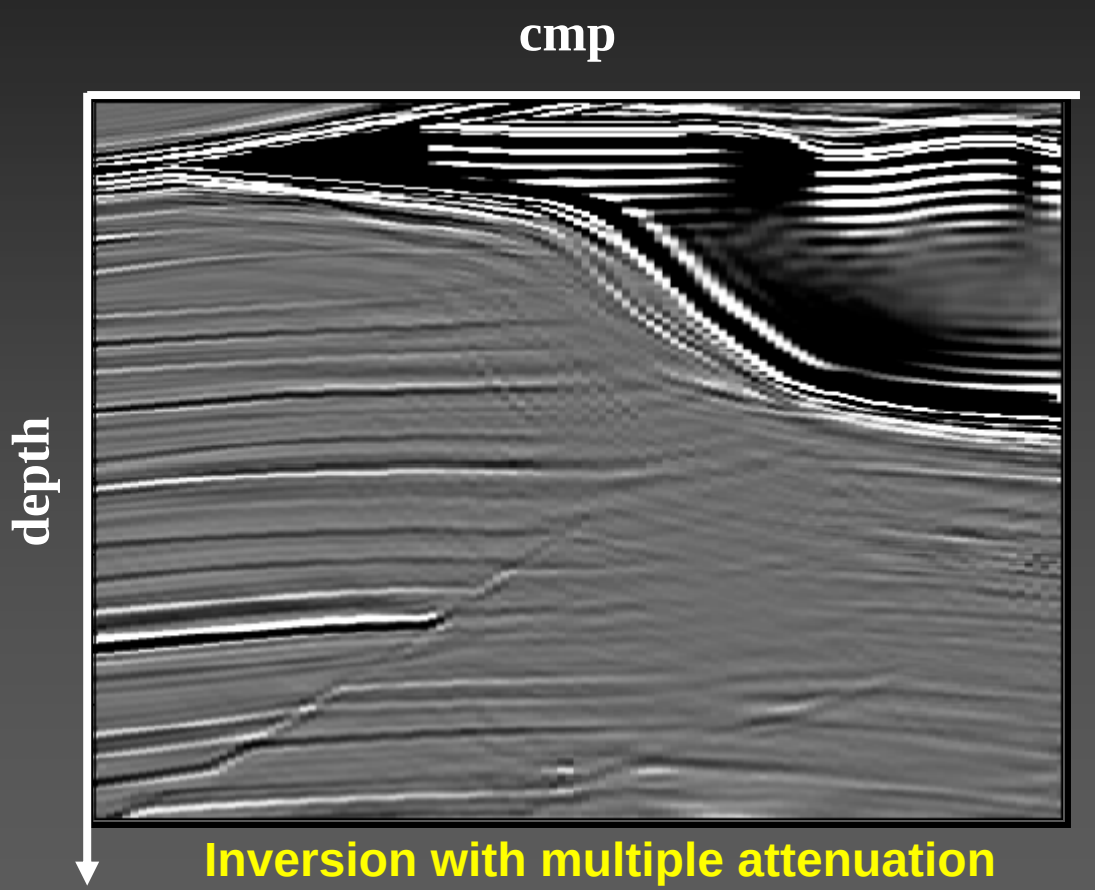
Multiple attenuation prior to wave-equation inversion





Claudio Guerra and Alejandro Valenciano

SEP-134, p.25

Initial considerations

- **Inversion is sensitive to noise**
  - noise does not fit forward modeling
  - slows down convergence
  - dominates the residuals
- **Incorporate the modeling of the noise**
  - physics explains the data
- **Pre-processing**
  - data fits the physics
- **Multiples**
  - not modeled by the one-way wave equation

Outline

- Linear least-squares wave-equation inversion
- Multiples in Sigsbee2b
- Results
- Conclusions

Linear least-squares wave-equation inversion

- **Valenciano (2008)**

$$\mathbf{S(m)} = \tfrac{1}{2}\|\mathbf{Lm} - \mathbf{d}_{obs}\|^2$$

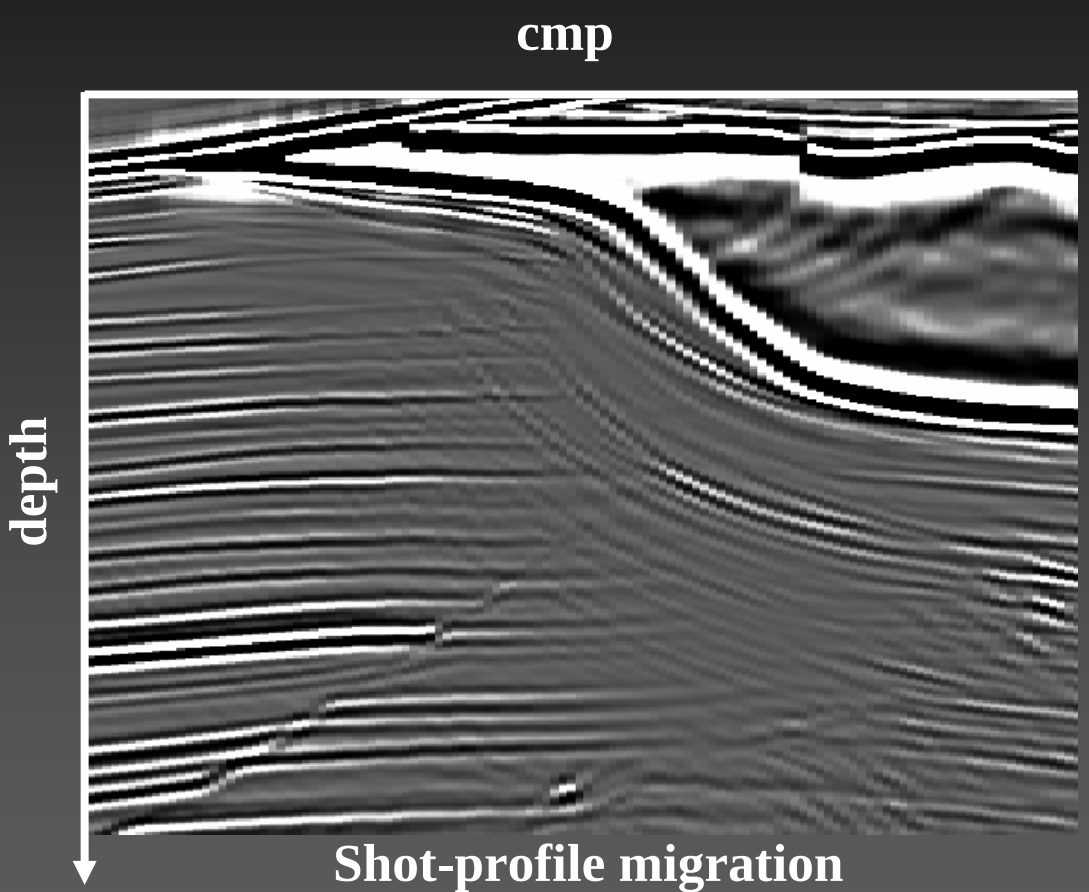
$$\hat{\mathbf{m}} = (\mathbf{L^*L})^{-1}\mathbf{L^*d}_{obs} = (\mathbf{L^*L})^{-1}\mathbf{m}_{mig} \qquad \partial^2\mathbf{S(m)}/\partial\mathbf{m}^2 = \mathbf{L^*L} = \mathbf{H}$$

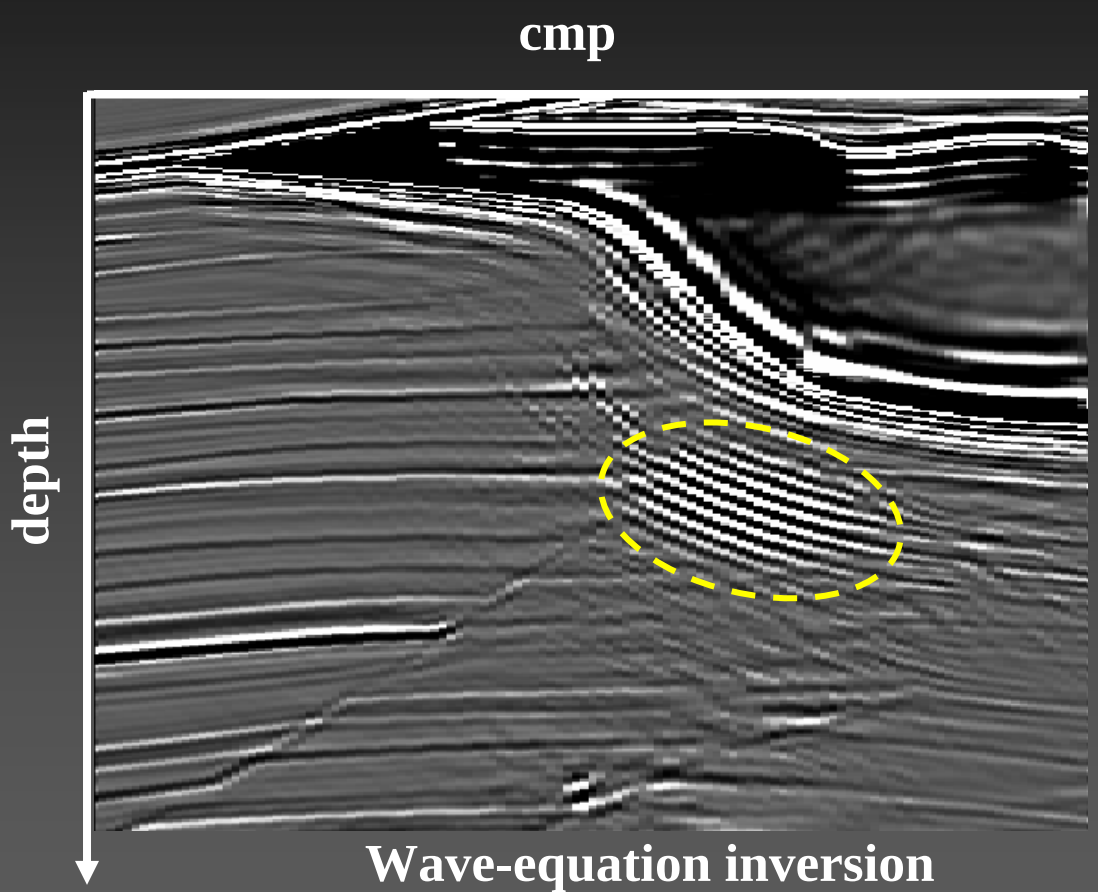
$$\boxed{\mathbf{H}\hat{\mathbf{m}} = \mathbf{m}_{mig}}$$

L – modeling operator
S(m) – cost function
$\mathbf{m}_{mig}$ – migrated image

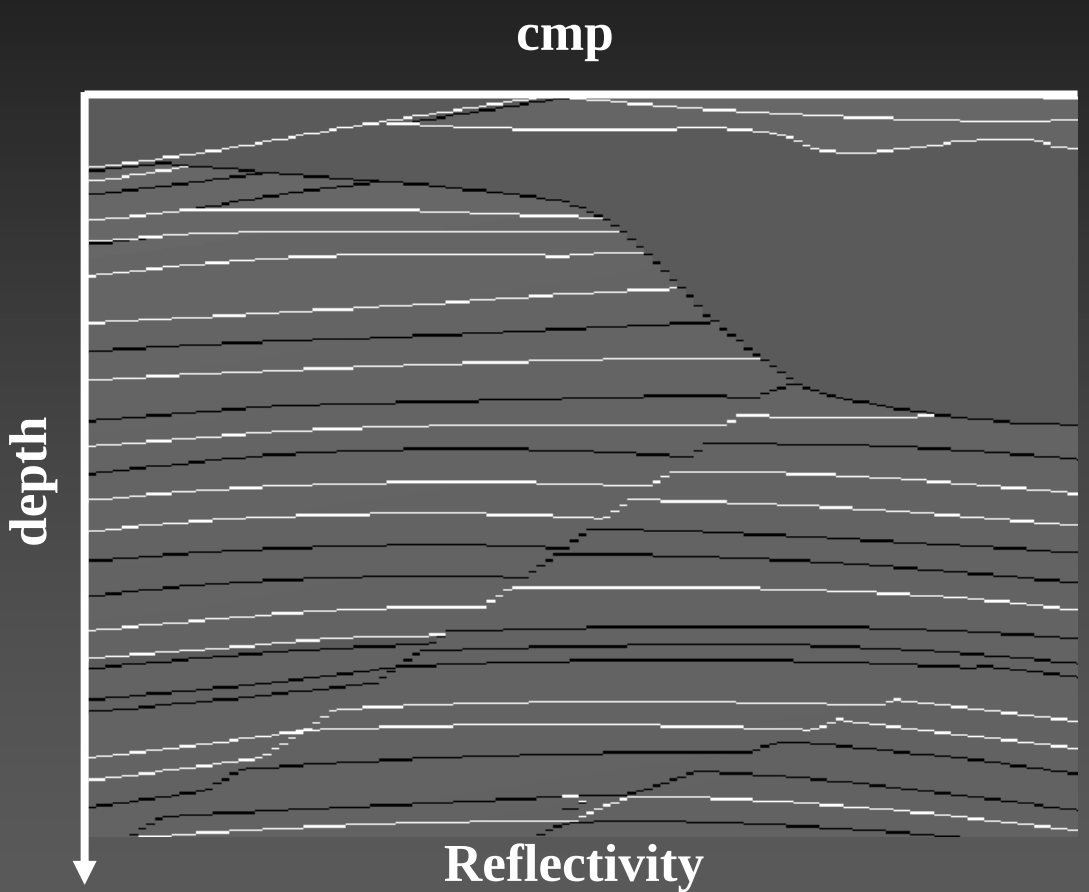
L* - migration
H – offset-domain Hessian
$\hat{\mathbf{m}}$ – inverse image

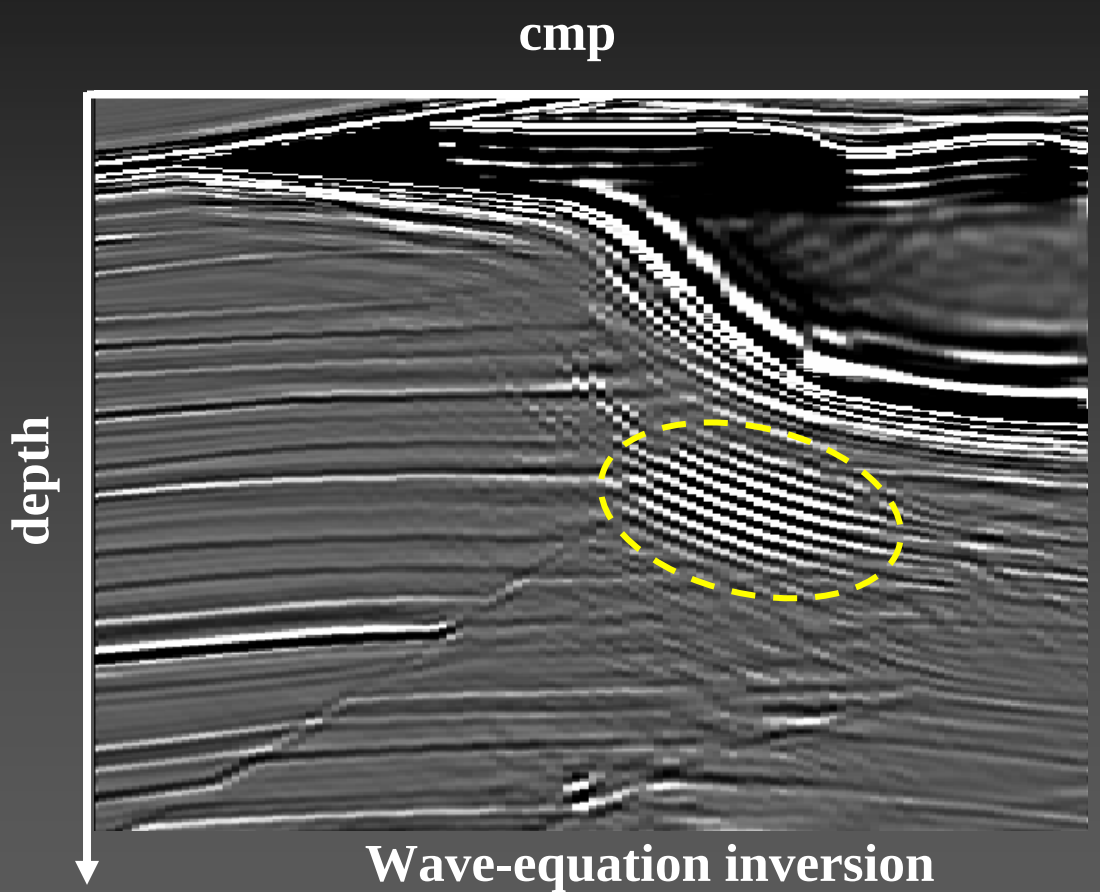
Linear least-squares wave-equation inversion



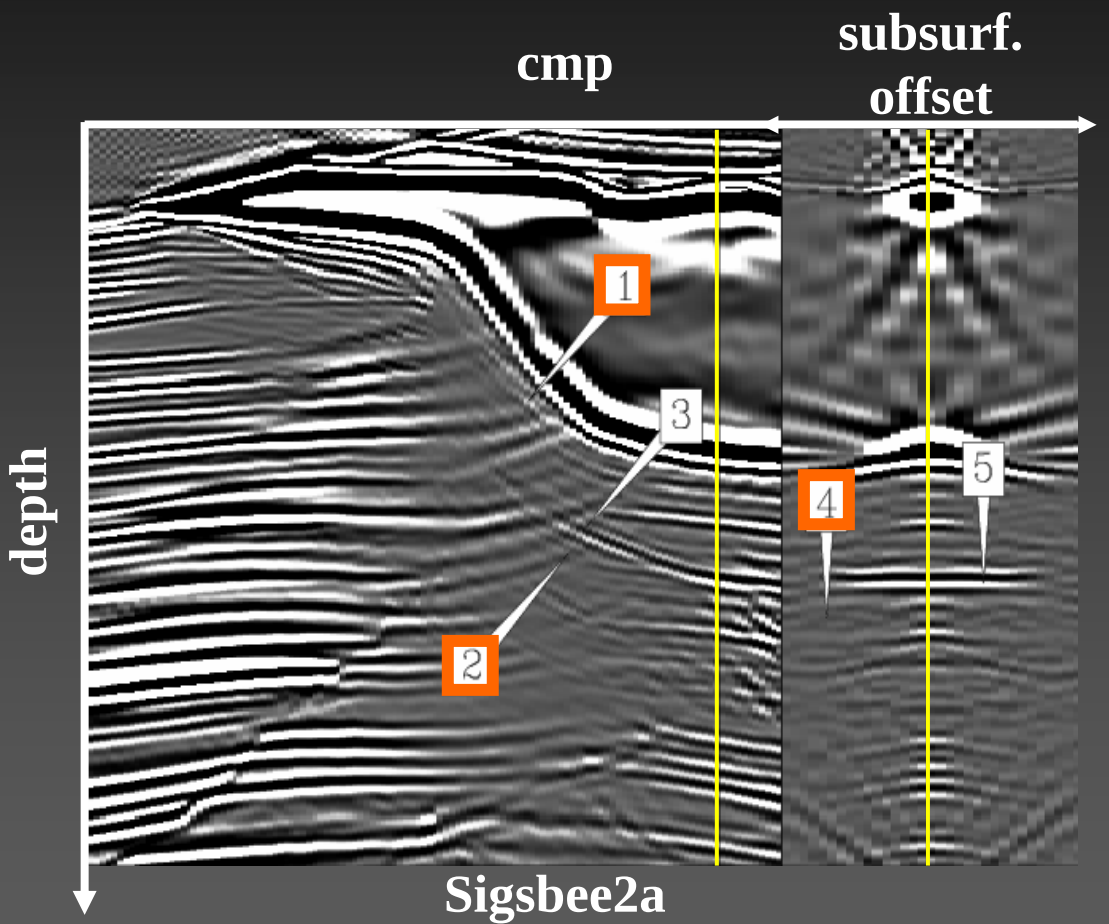


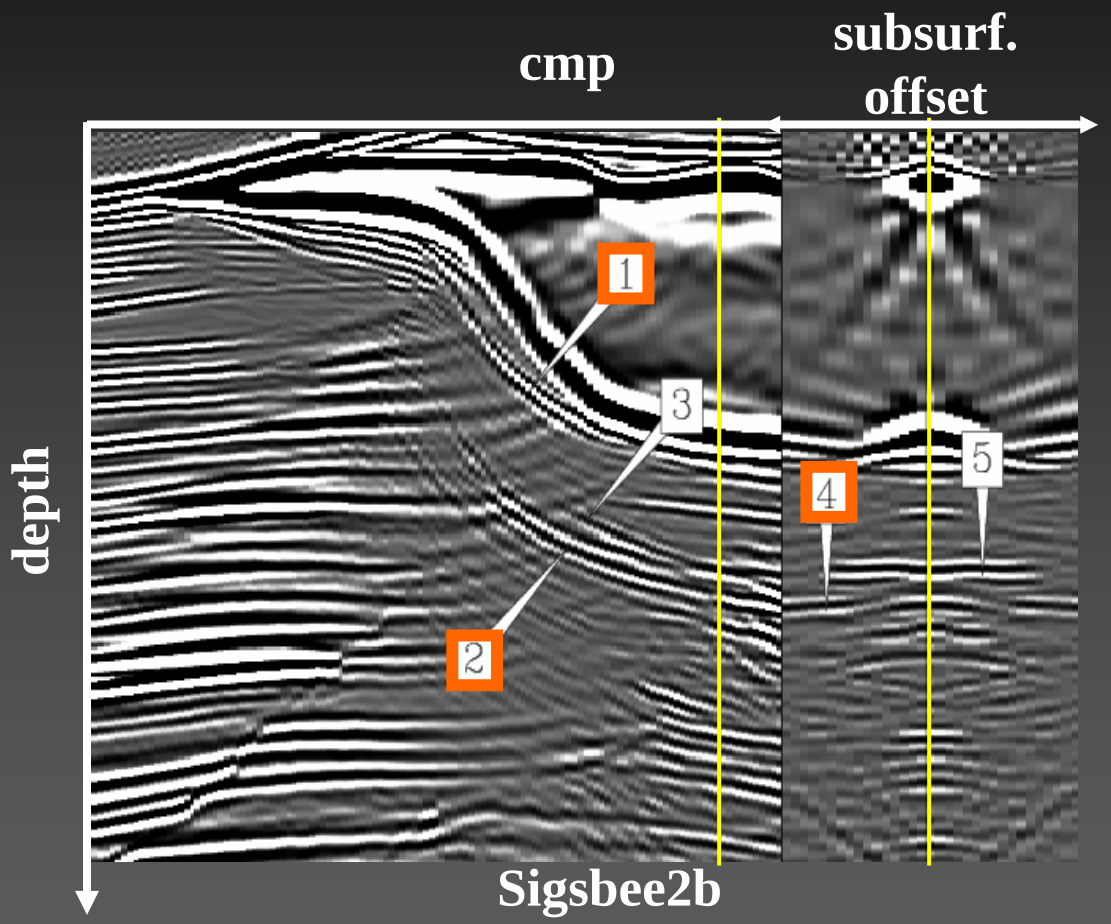
Linear least-squares wave-equation inversion





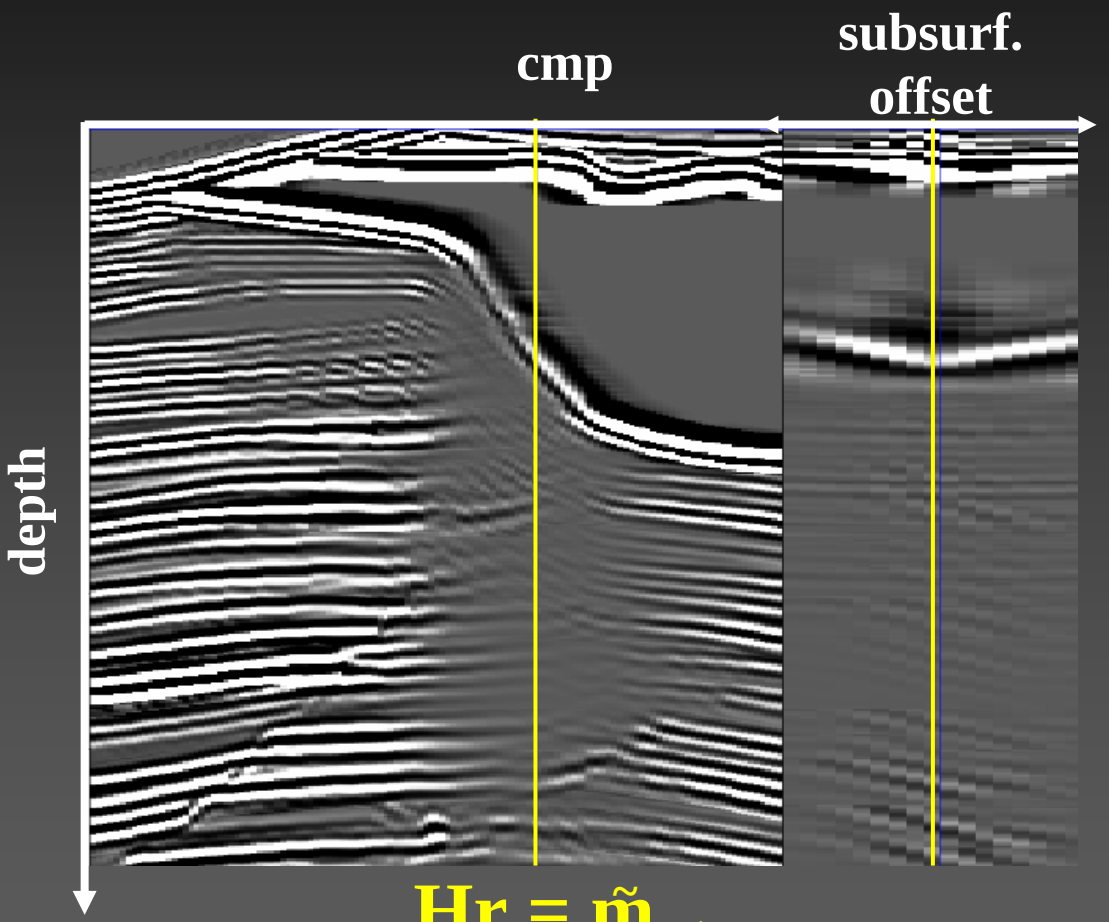
Multiples in Sigsbee2b



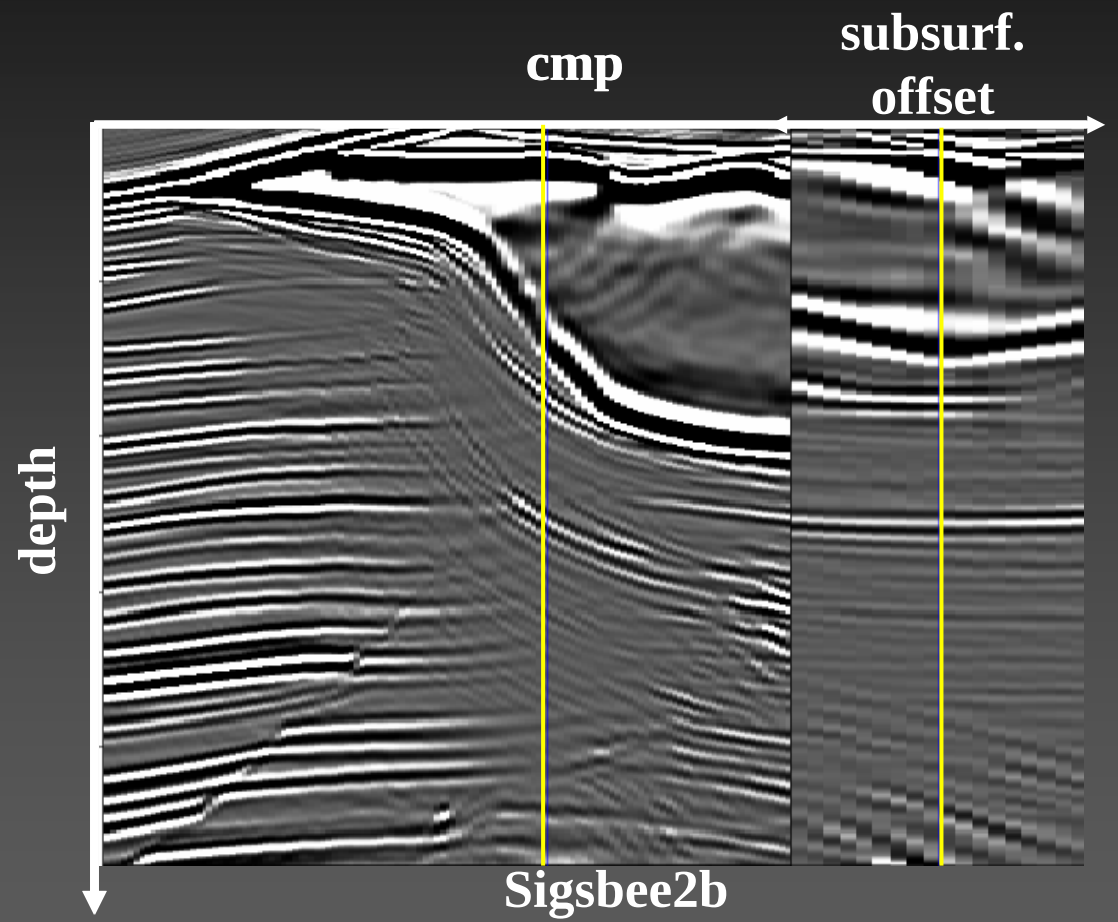


1, 2 and 4 – peg-leg multiples
3, 5 – internal multiples ....

Multiples in Sigsbee2b

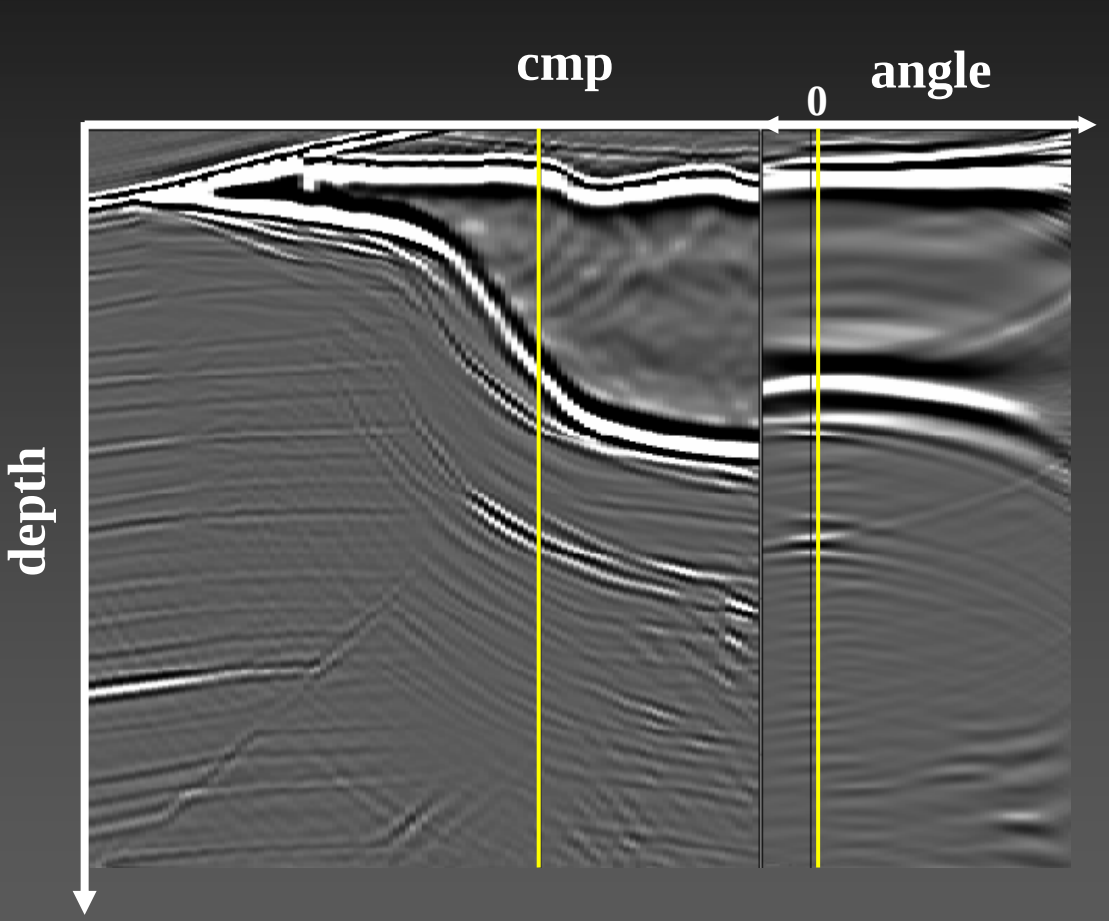


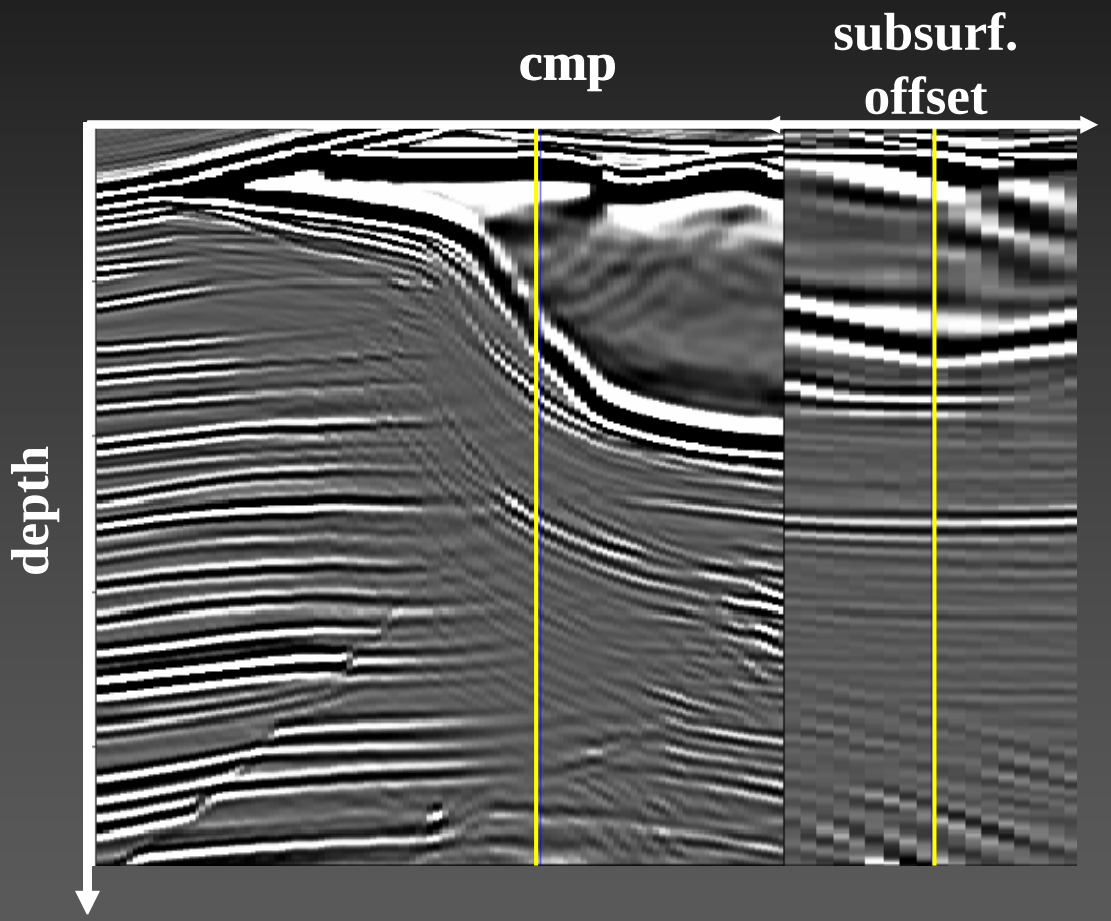
$$\mathbf{Hr} = \tilde{\mathbf{m}}_{\mathrm{mig}}$$



1, 2 and 4 – peg-leg multiples
3, 5 – internal multiples ....
or migration artifacts (?)

Multiples in Sigsbee2b





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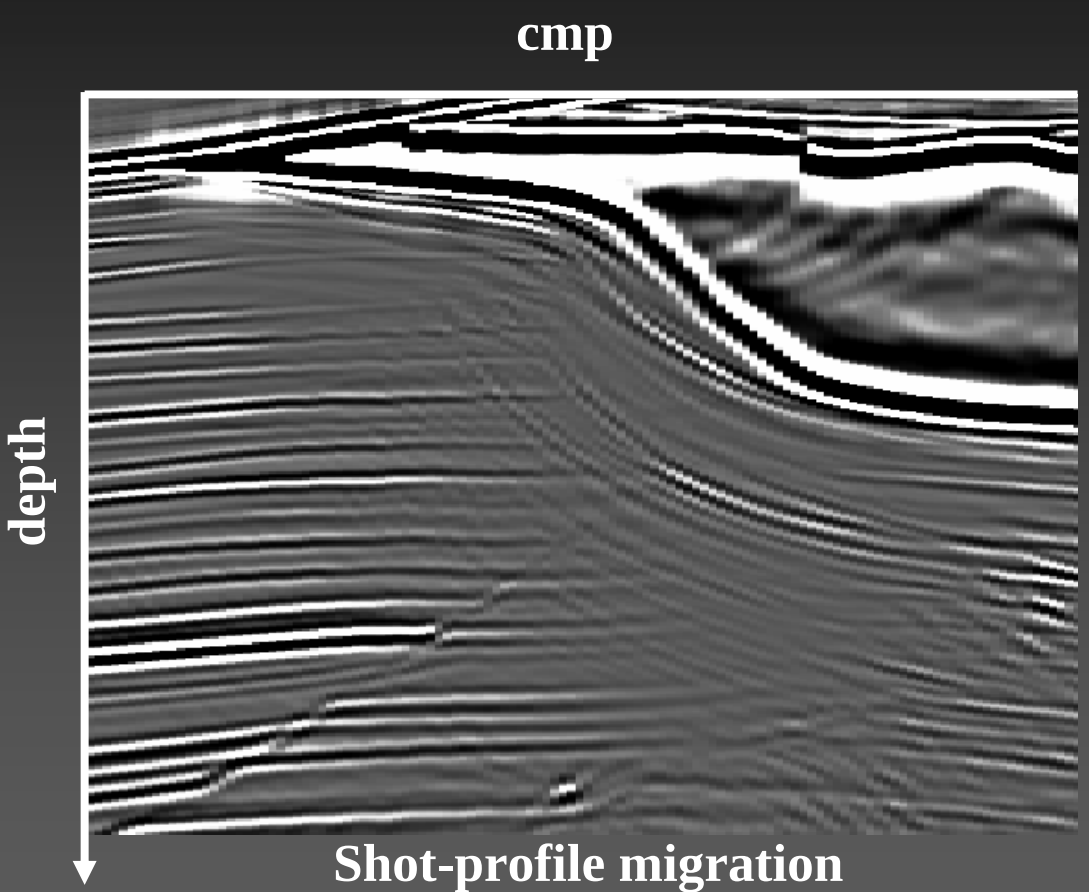
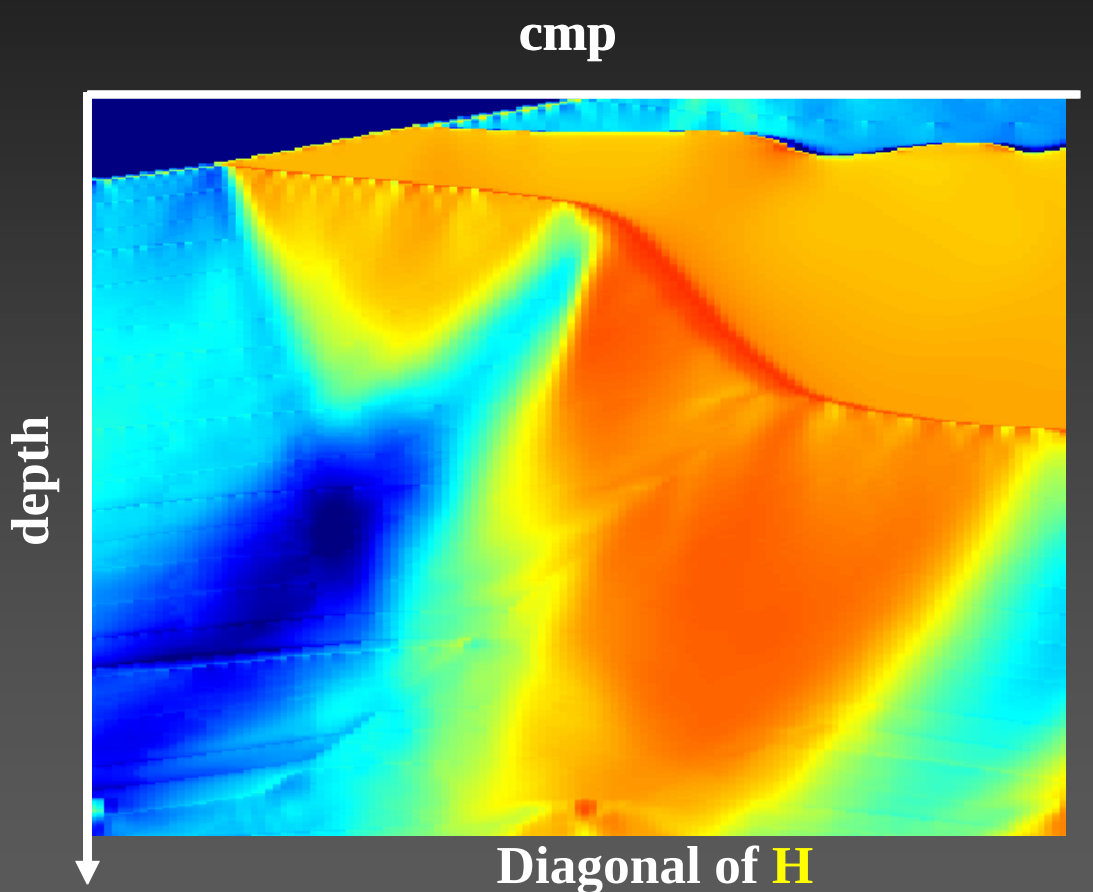
Multiples in Sigsbee2b



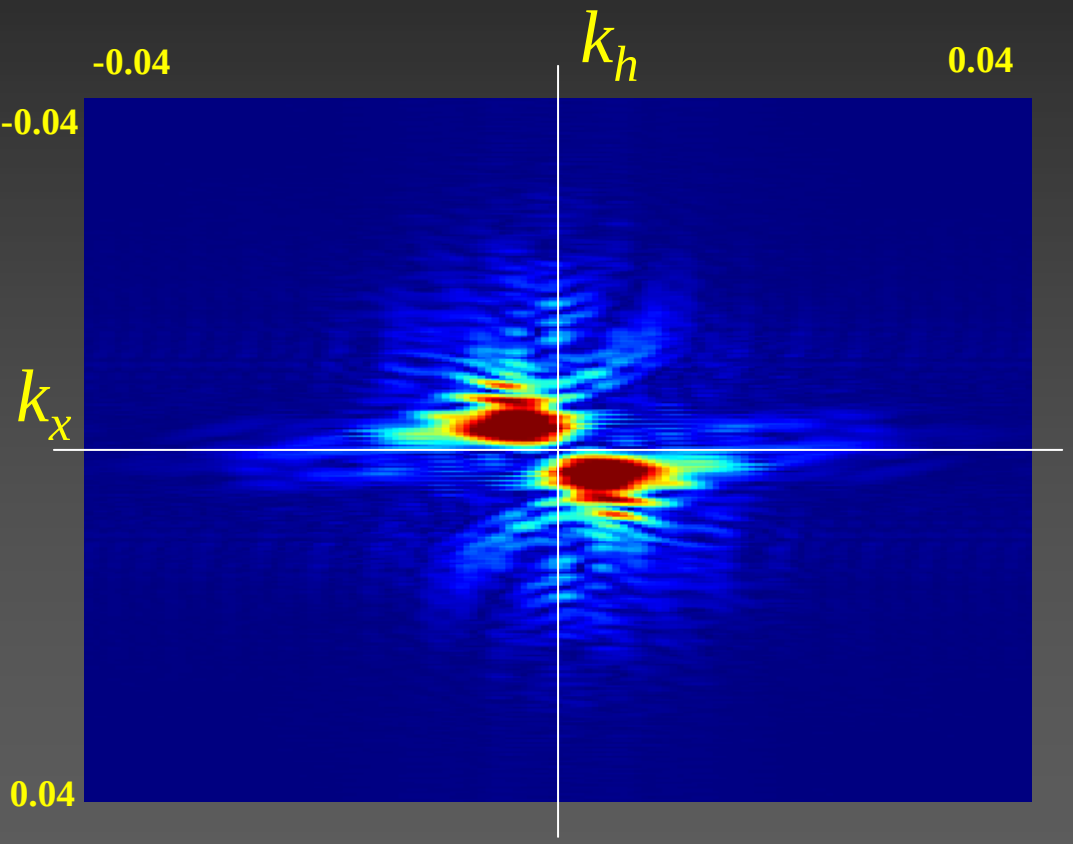


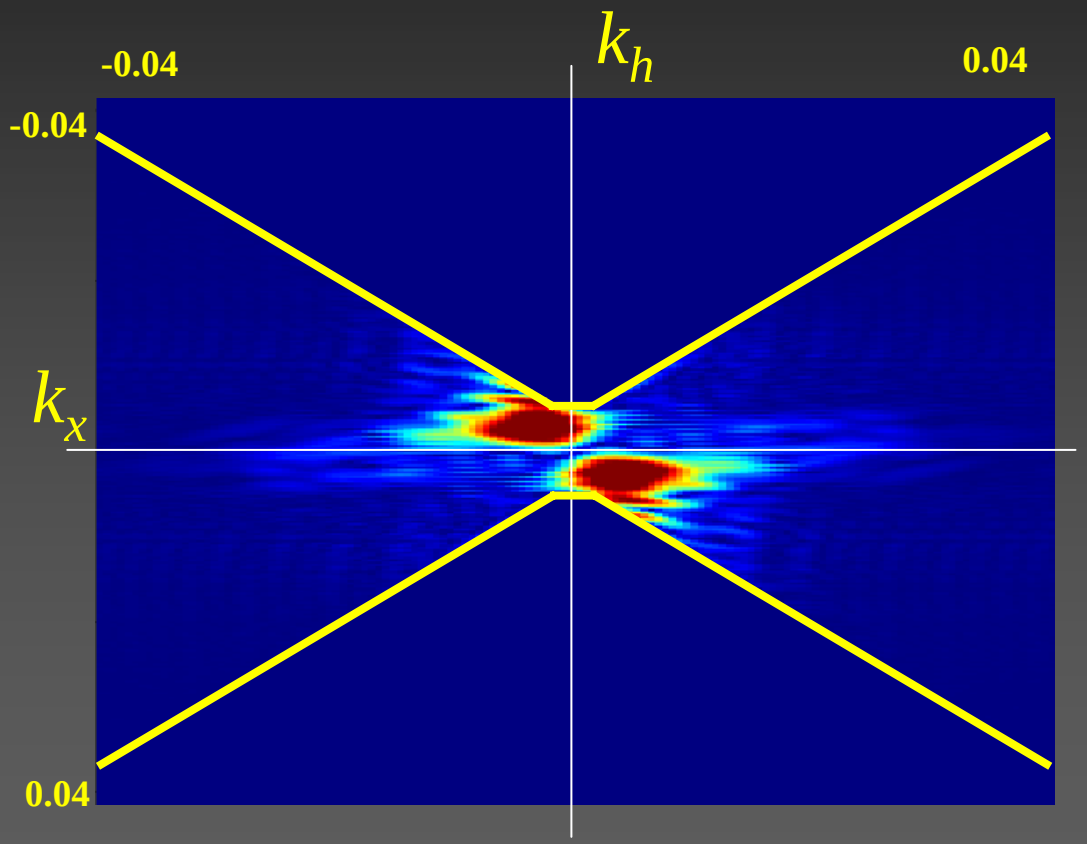
Multiples in Sigsbee2b

- Multiples are more pronounced in low illumination areas
  - so are the migration artifacts ...
- Multiples are flat in the subsurface-offset gathers (low k_h) and dipping in the common-subsurface-offset section (high k_x)
- Primaries are dipping in the subsurface-offset gathers (high k_h) and dip in different directions in a common-subsurface-offset section

Results

- Separate primaries and multiples in the k_x–k_h domain
  - generate an estimate for the multiples





Results

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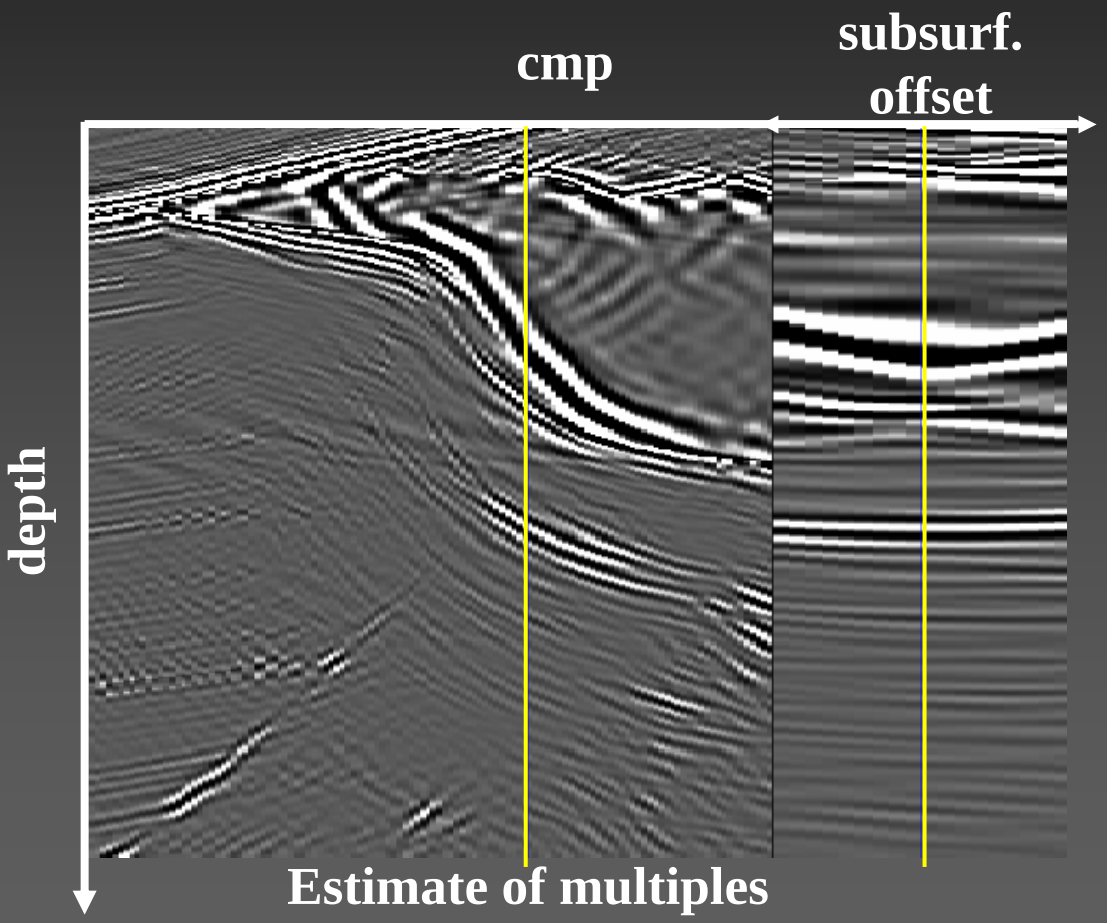
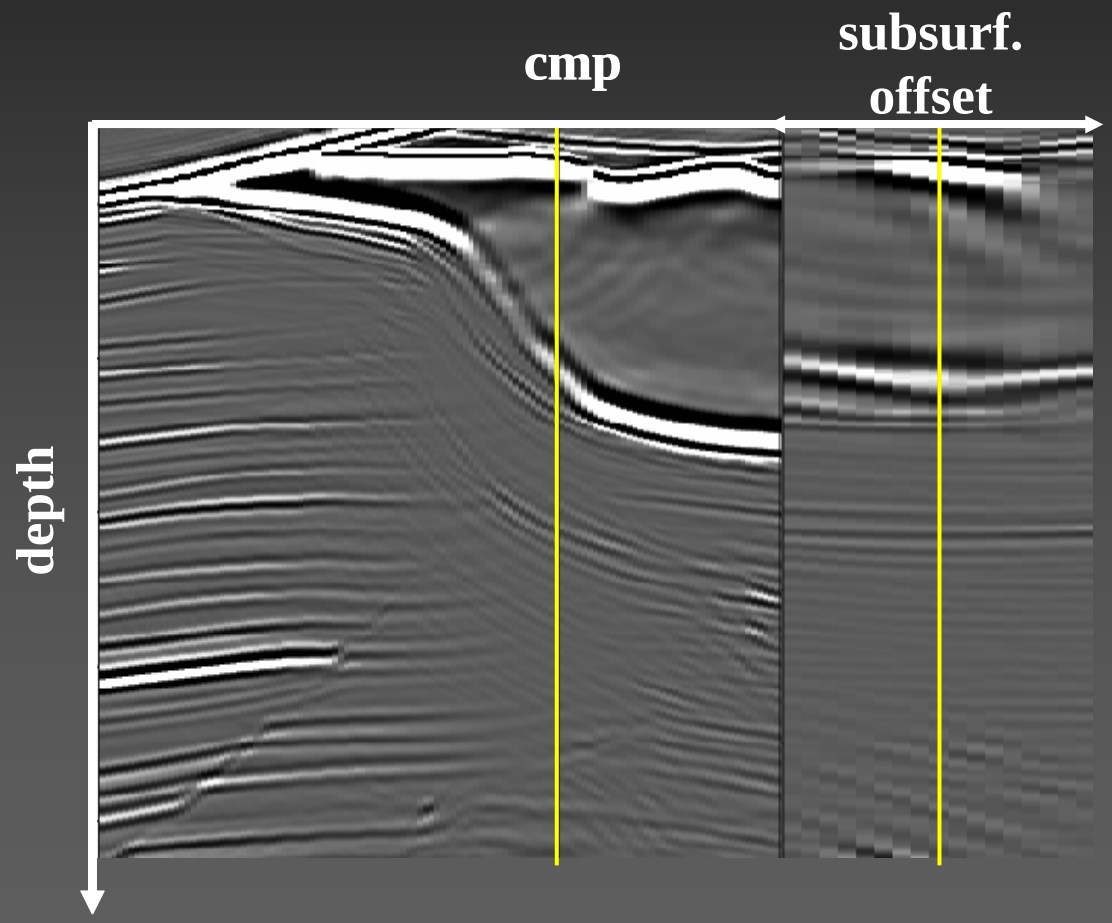




Results

- Adapt the amplitude and phase of the estimated multiple (Alvarez and Guitton, 2006)

$$\begin{bmatrix} \mathbf{M} & \mu\mathbf{P} \end{bmatrix} \begin{bmatrix} \mathbf{f_m} \\ \mathbf{f_p} \end{bmatrix} \approx \mathbf{0}$$

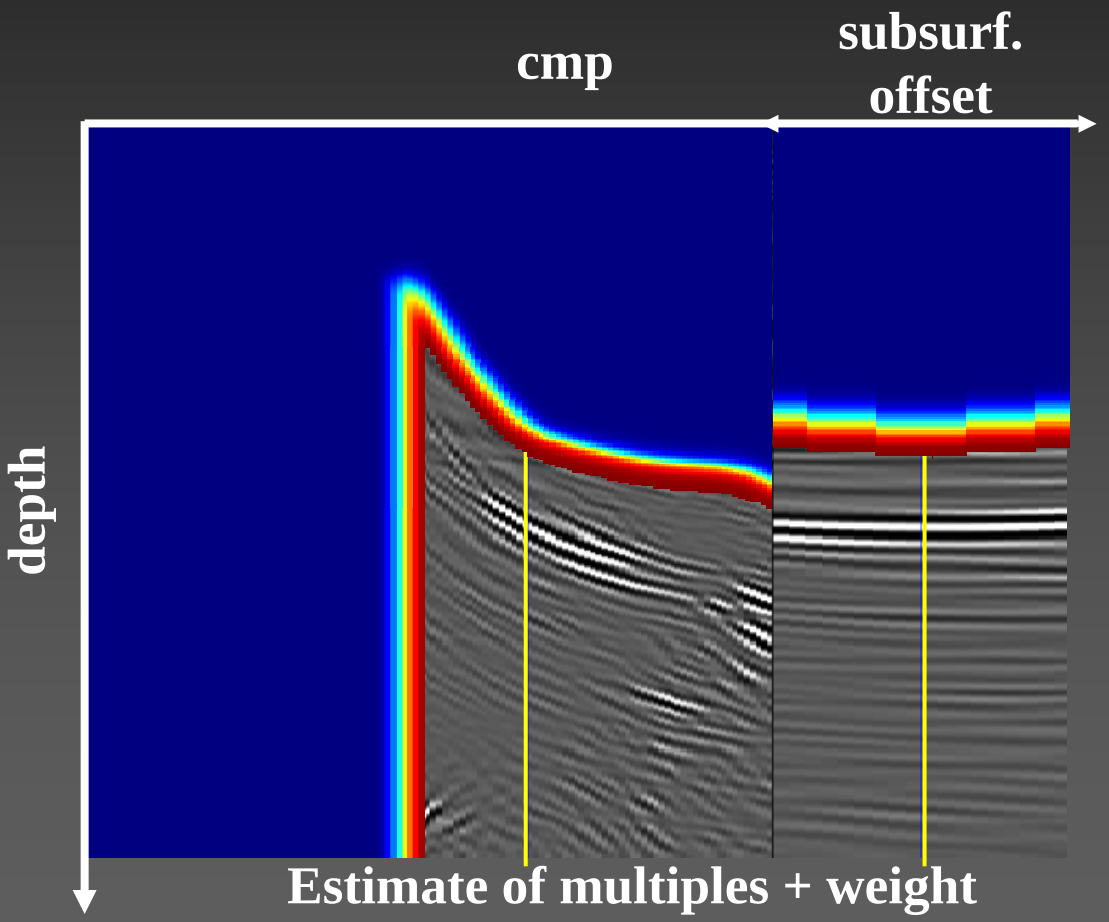
$$\varepsilon\mathbf{A} \begin{bmatrix} \mathbf{f_m} \\ \mathbf{f_p} \end{bmatrix} \approx \mathbf{0}$$

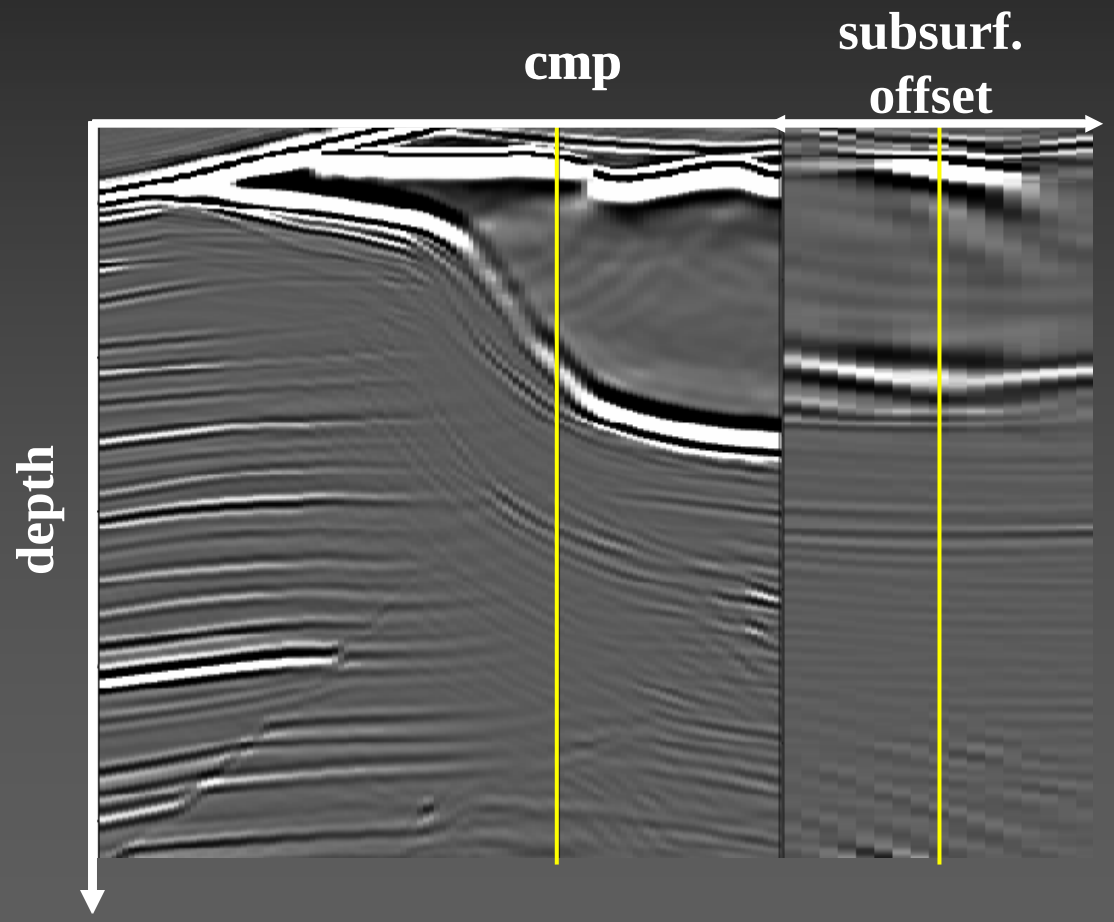
M – estimated multiples
P – estimated primaries
μ – parameter to balance **M** and **P**
ε – amount of regularization

$\mathbf{f_m}$ – matching filter for the multiple
$\mathbf{f_p}$ – matching filter for the primary
A – Laplacian operator

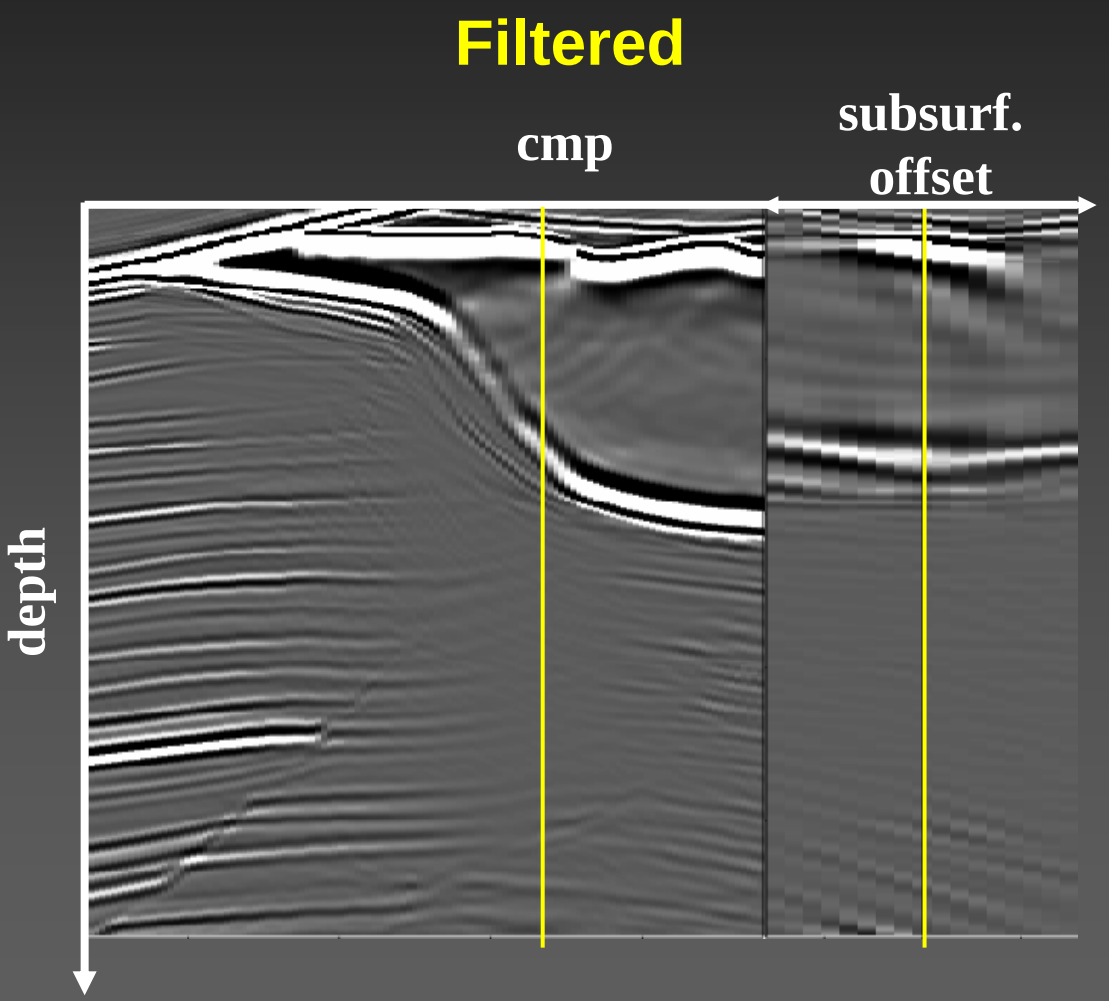
Results

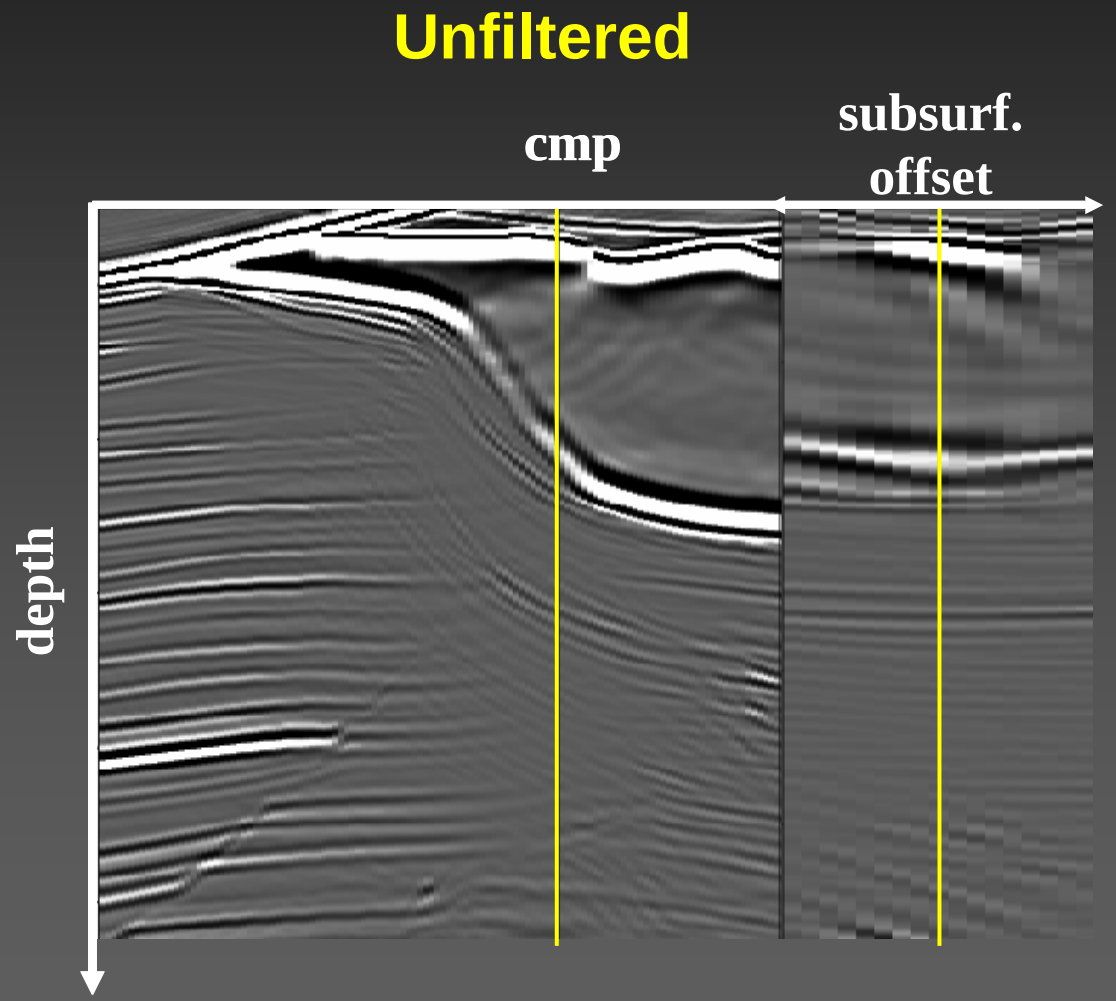
- Adapt the amplitude and phase of the estimated multiple
  - using weights





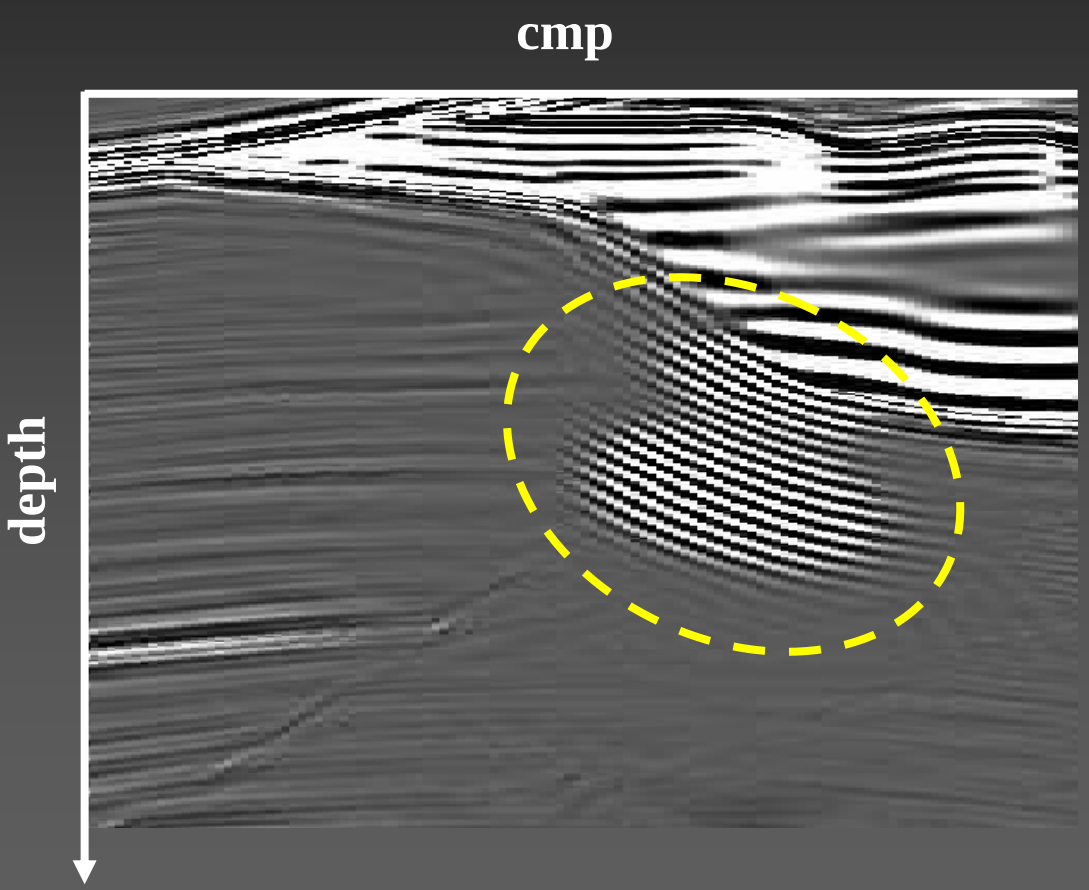
Results


Filtered
cmp
subsurf.
offset
depth

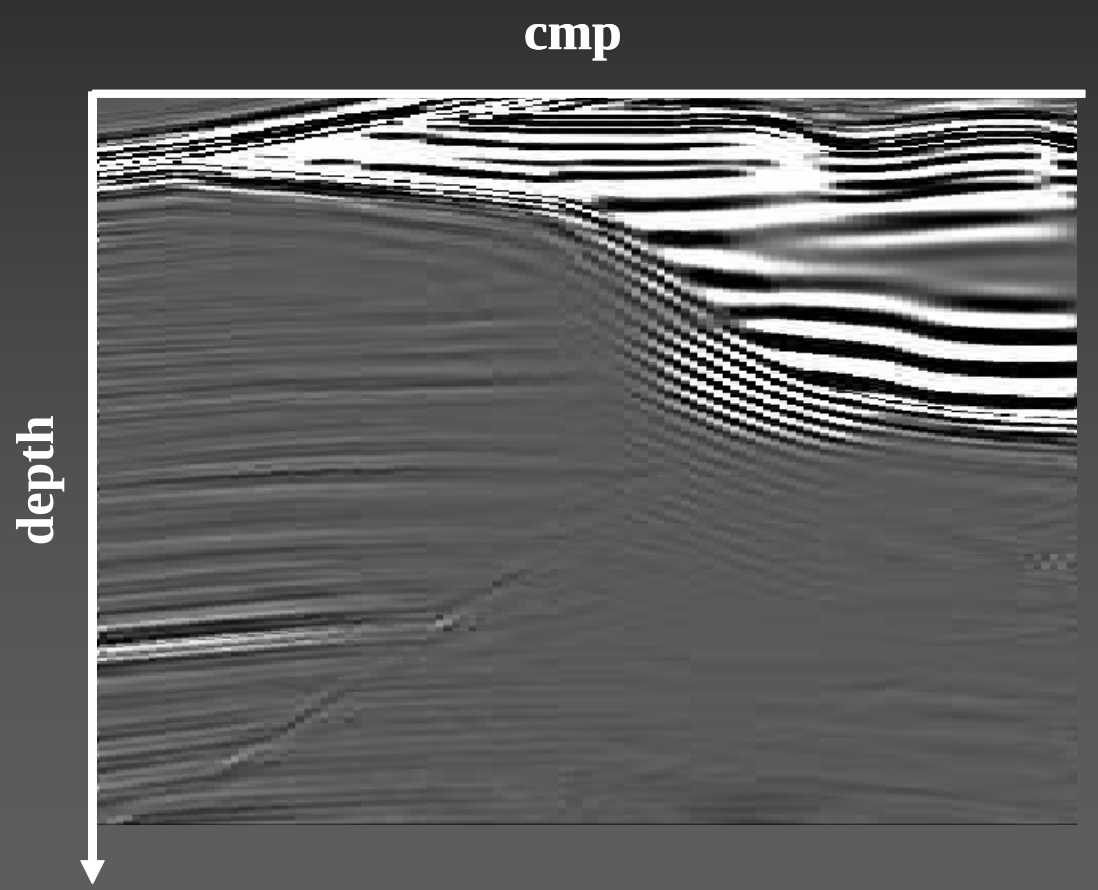

Unfiltered
cmp
subsurf.
offset
depth

Results

Residuals of the unfiltered inversion

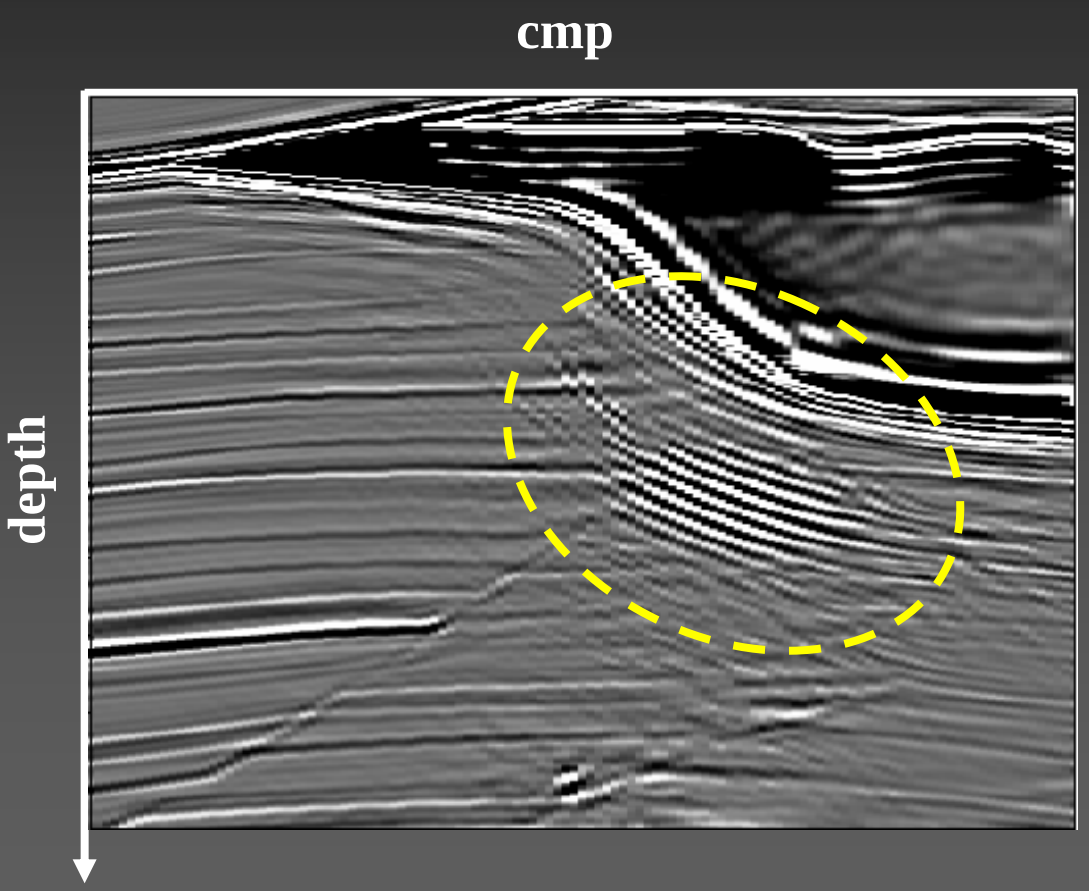


Residuals of the filtered inversion

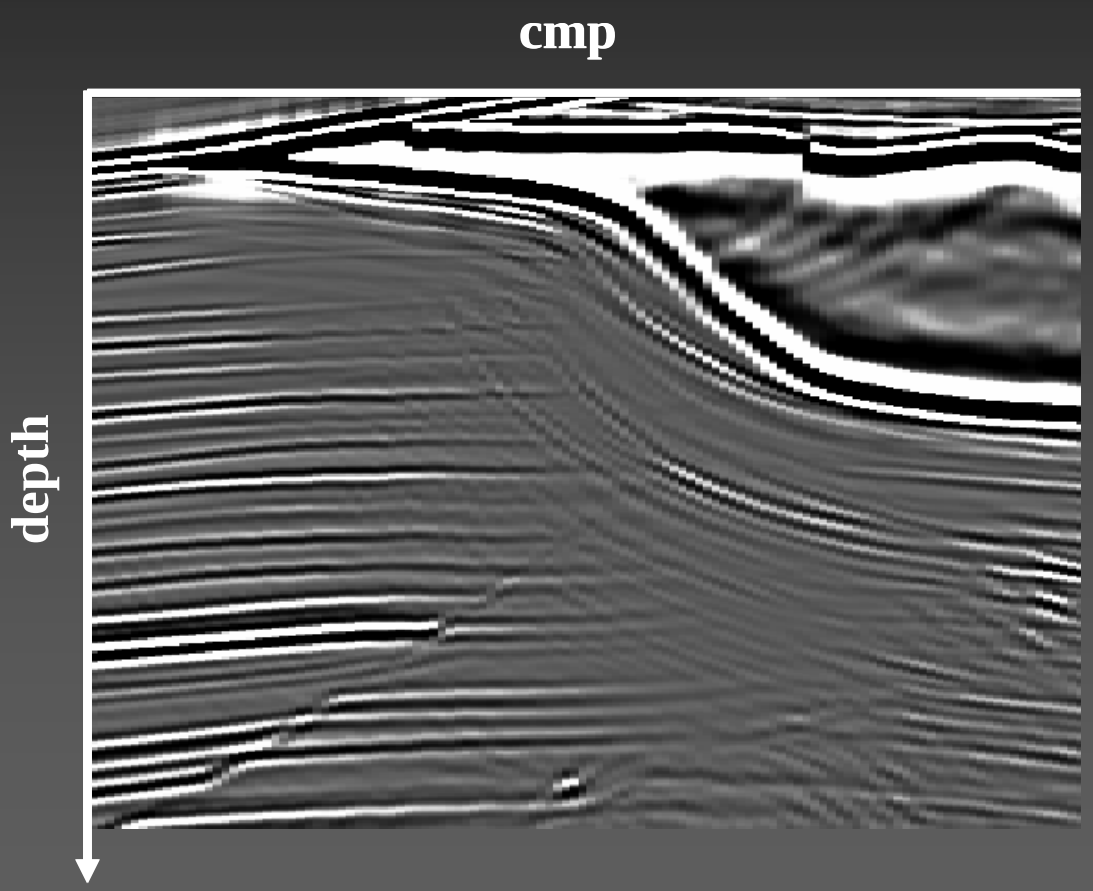


Results

Unfiltered inversion

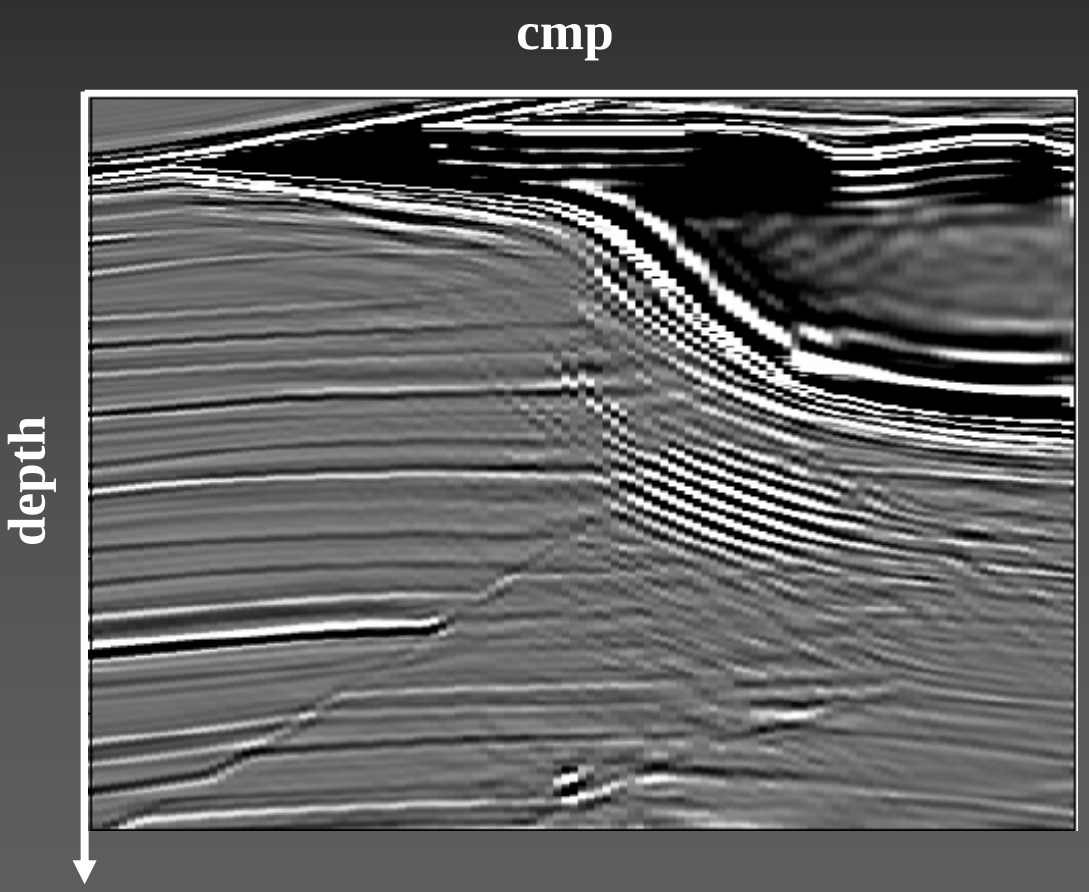


Unfiltered migration

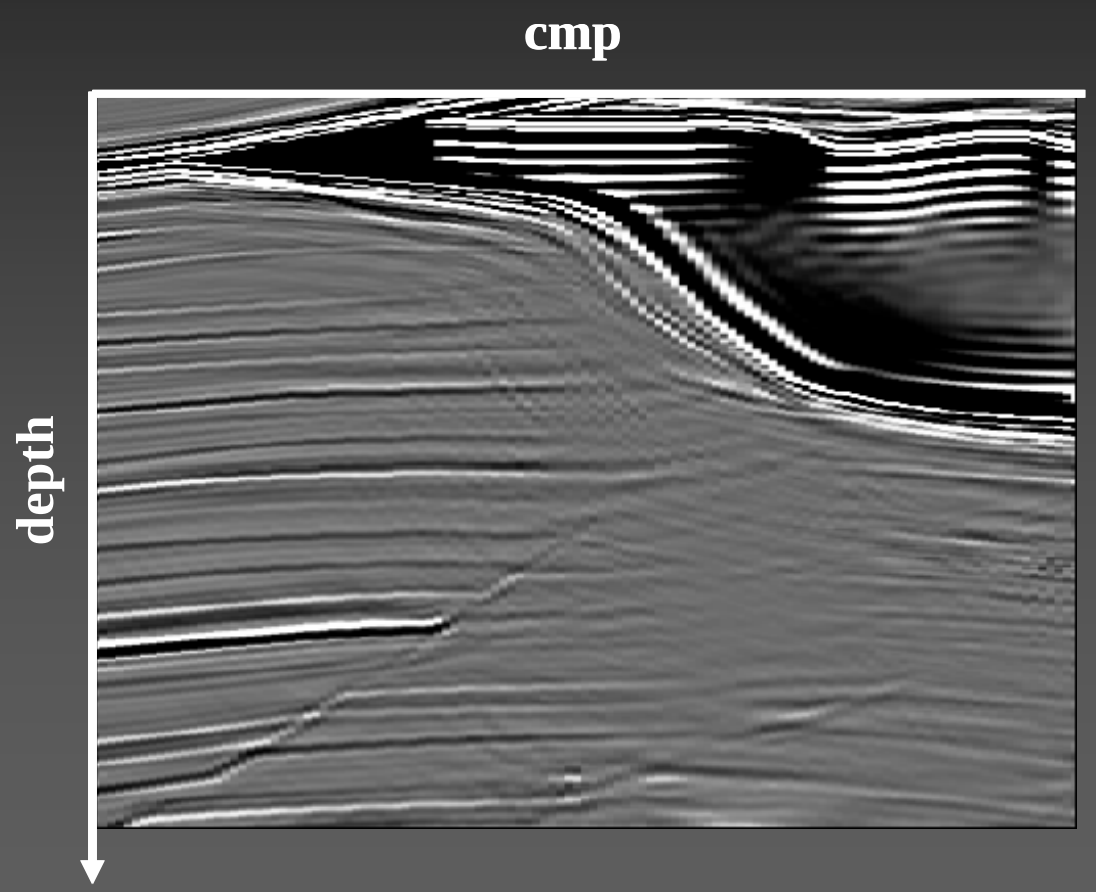


Results

Unfiltered inversion

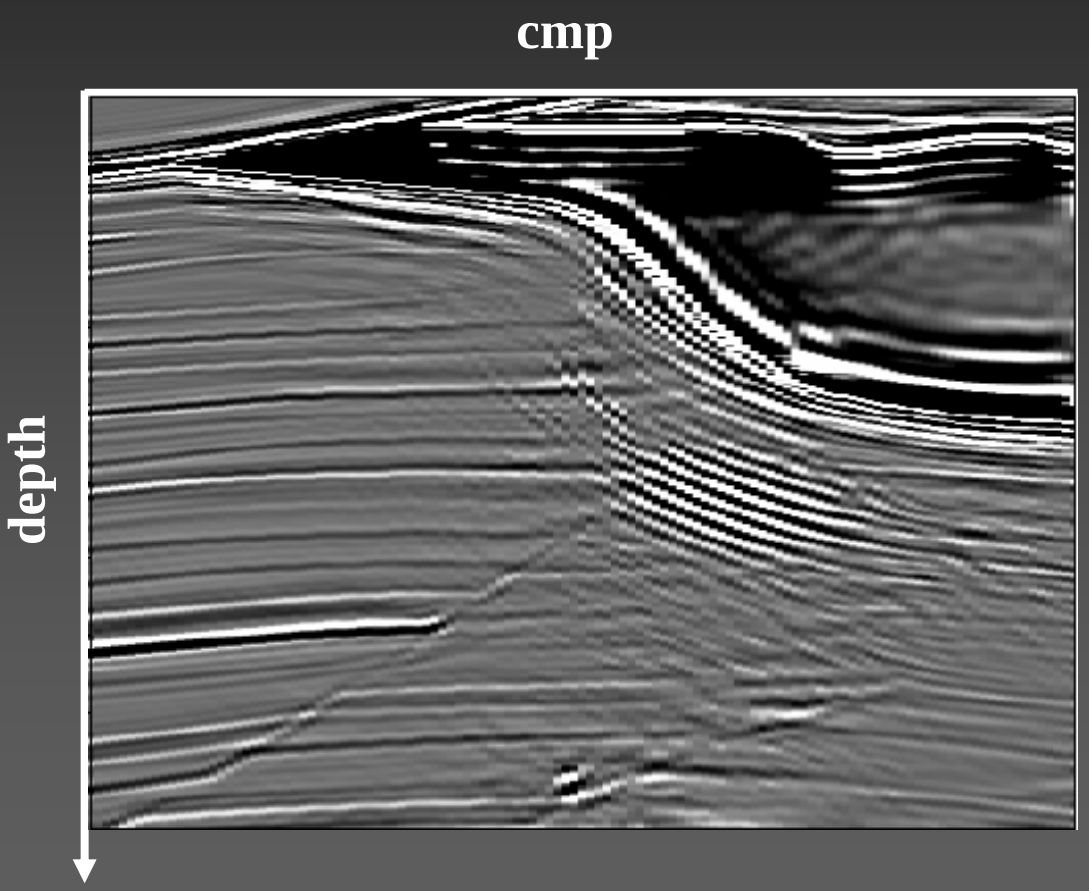


Filtered inversion

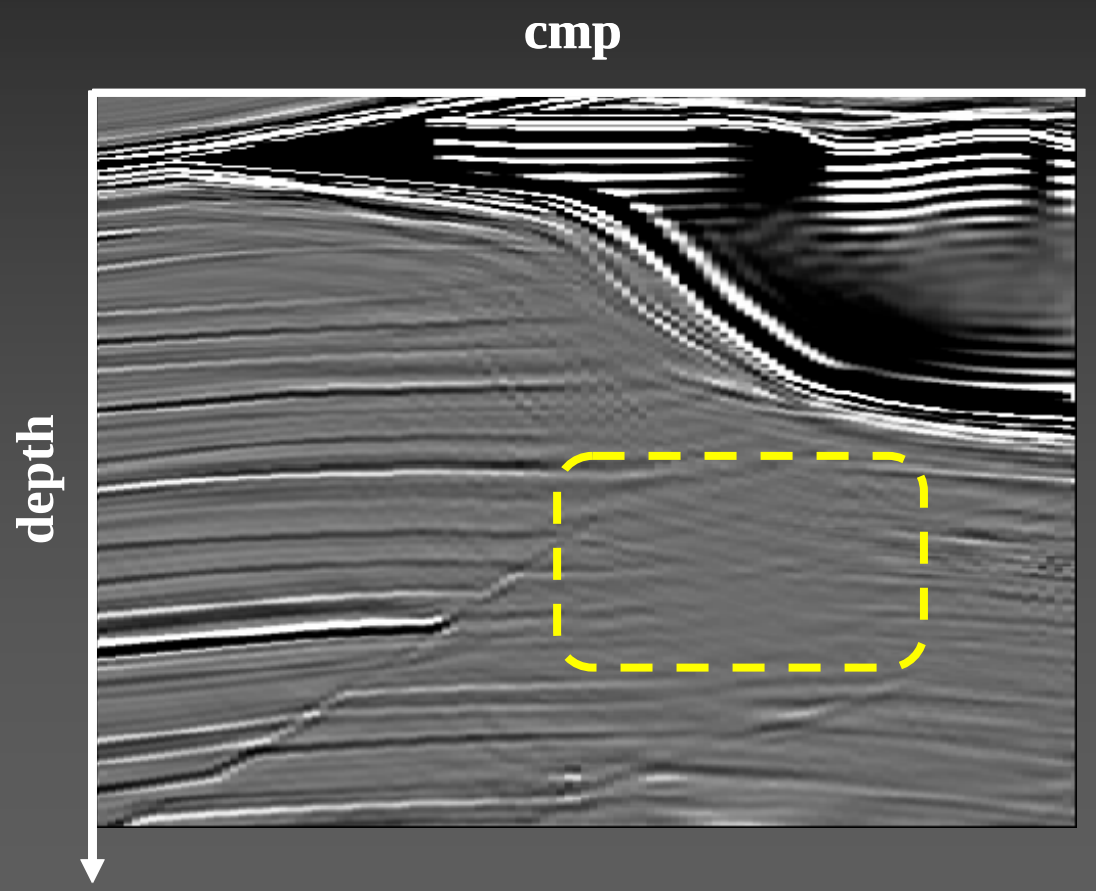


Results

Unfiltered inversion



Filtered inversion



Conclusions

- Multiples were characterized in the subsurface-offset domain;
  - distinguishable from primaries using dip information
  - ... but not from illumination artifacts
- Multiples are not predicted by the one-way modeling;
- Preprocessing largely improved the inversion results; and
  - ... but also filtered useful energy for inversion
- Need for a more robust formulation.

Multiples in Sigsbee2b

- Adapt the amplitude and phase of the estimated multiple
  - using weights