

RMO-based wave-equation MVA

A field data example



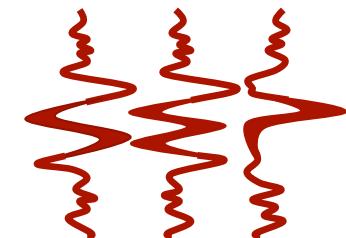
Y. Zhang and B. Biondi

SEP158, pp11-38

May, 2015

RMO: Residual moveout

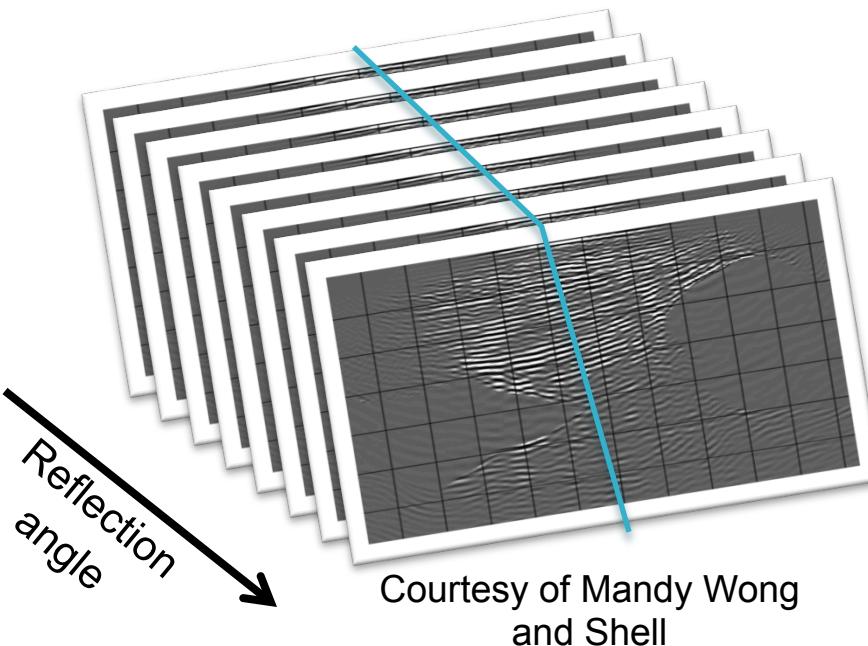
MVA: Migration velocity analysis



Outline

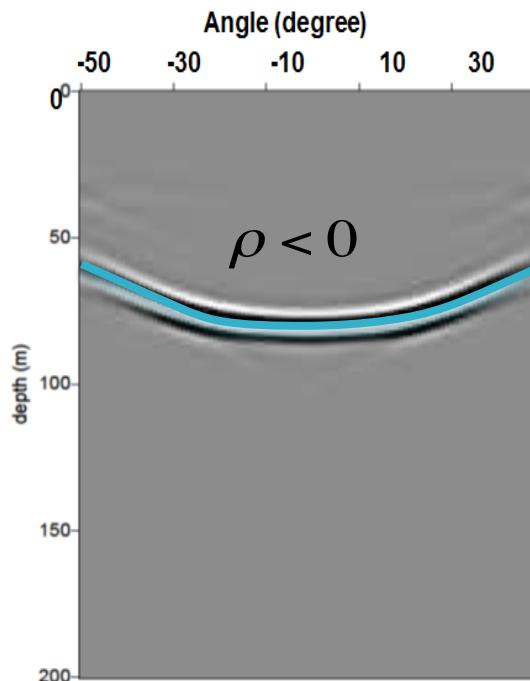
- Overview of RMO-based wave-equation migration velocity analysis (WEMVA)
- Application of RMO-based WEMVA to a 3-D Wide azimuth (WAZ) field data set
 - Target-oriented subsalt velocity estimation

Angle domain common image gathers

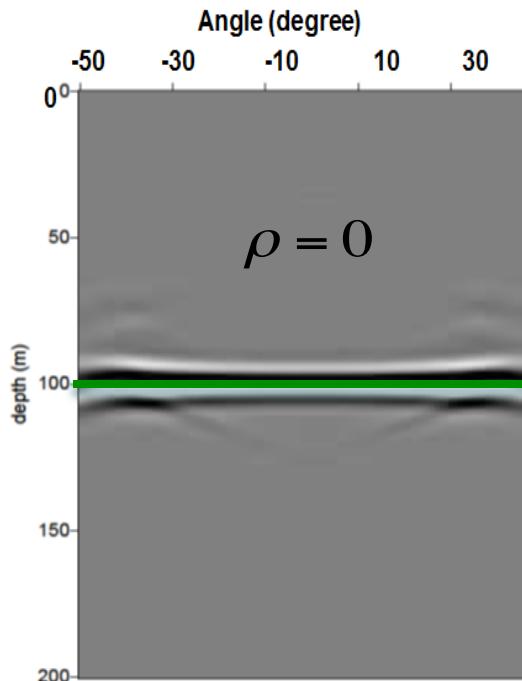


- If the earth model is correct, the images should resemble each other
- Coherence -> model correctness
(e.g., Sava and Biondi, 2004)

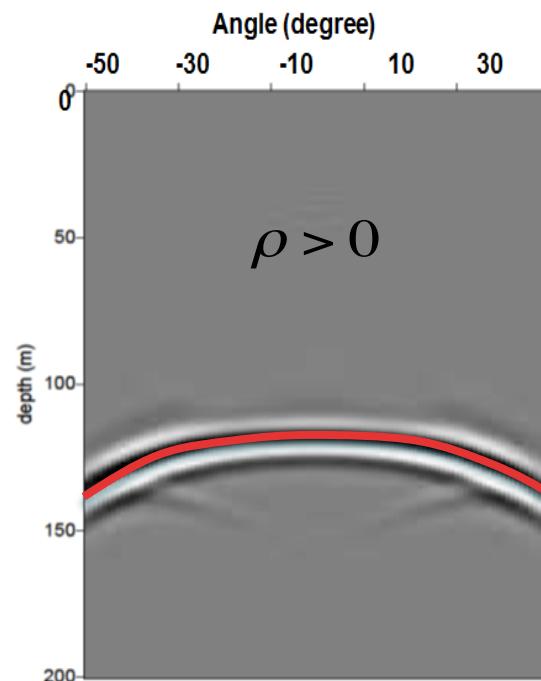
RMO on ADCIG (ρ is the curvature)



Negative v error



Correct v



Positive v error

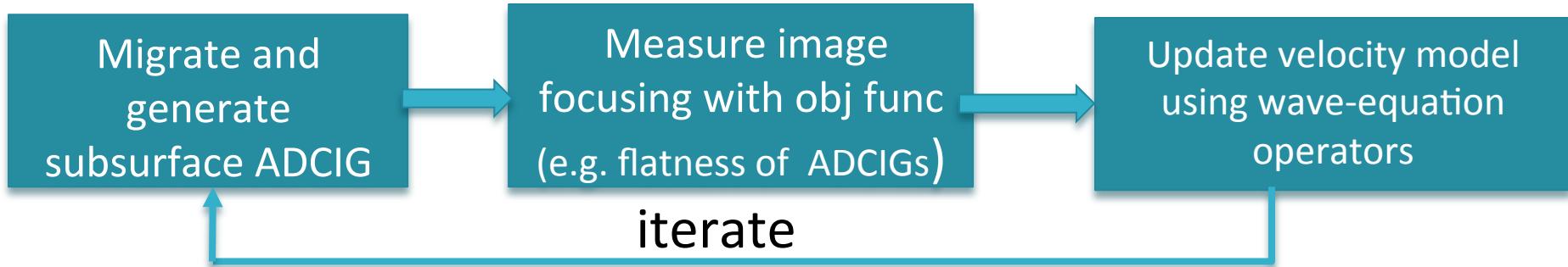
Courtesy of Yunyue Li

Common-image gather in subsurface offset domain (ODCIG)

- Subsurface offset is often known as space-lag in image domain
- Different from surface offset-gathers used frequently in Kirchhoff migration
- In ideal case, the more correct the velocity model, the gathers are **more focused on $h=0$** (rather than being flat)
- Computationally easy to implement

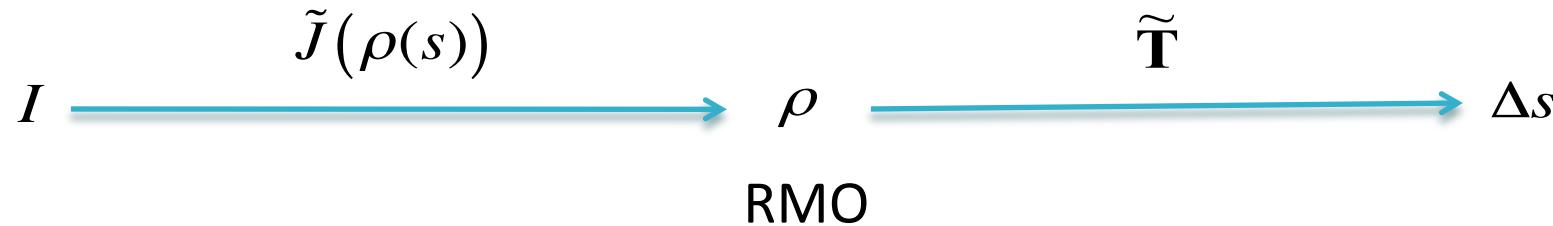
$$I(z, x, h) = \sum_t S(z, x + h, t) R(z, x - h, t)$$

WEMVA workflow



RMO-based WEMVA: concept

Combining ray-tomography workflow and
wave-equation operators



\tilde{J} : Cost function associating velocity model through moveout

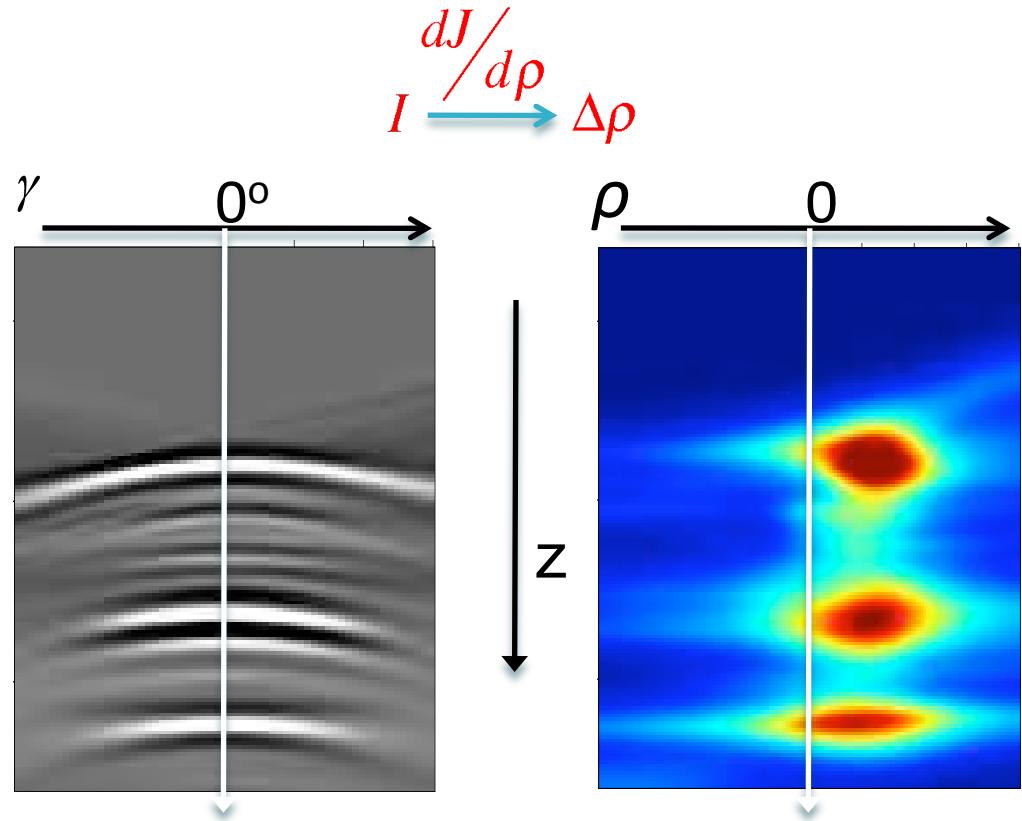
\tilde{T} : Modified image space wave-equation tomographic operator

RMO-based WEMVA: benefits

- More robust to the cycle-skipping issue, RMO parameters scales linearly with the velocity error
- Produces the wave-equation based sensitivity kernel
- Produces less artifacts by focusing on kinematics

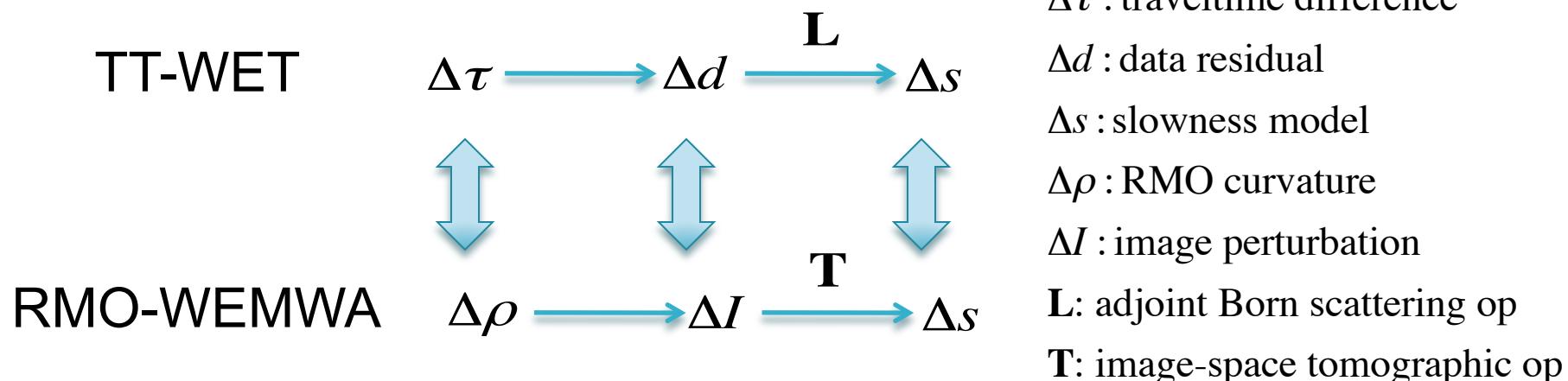
RMO Objective function (I)

- J is defined as a sum of semblance (normalized)
- $dJ/d\rho$ measures the polarity of the curvature (lateral smoothing along ρ)



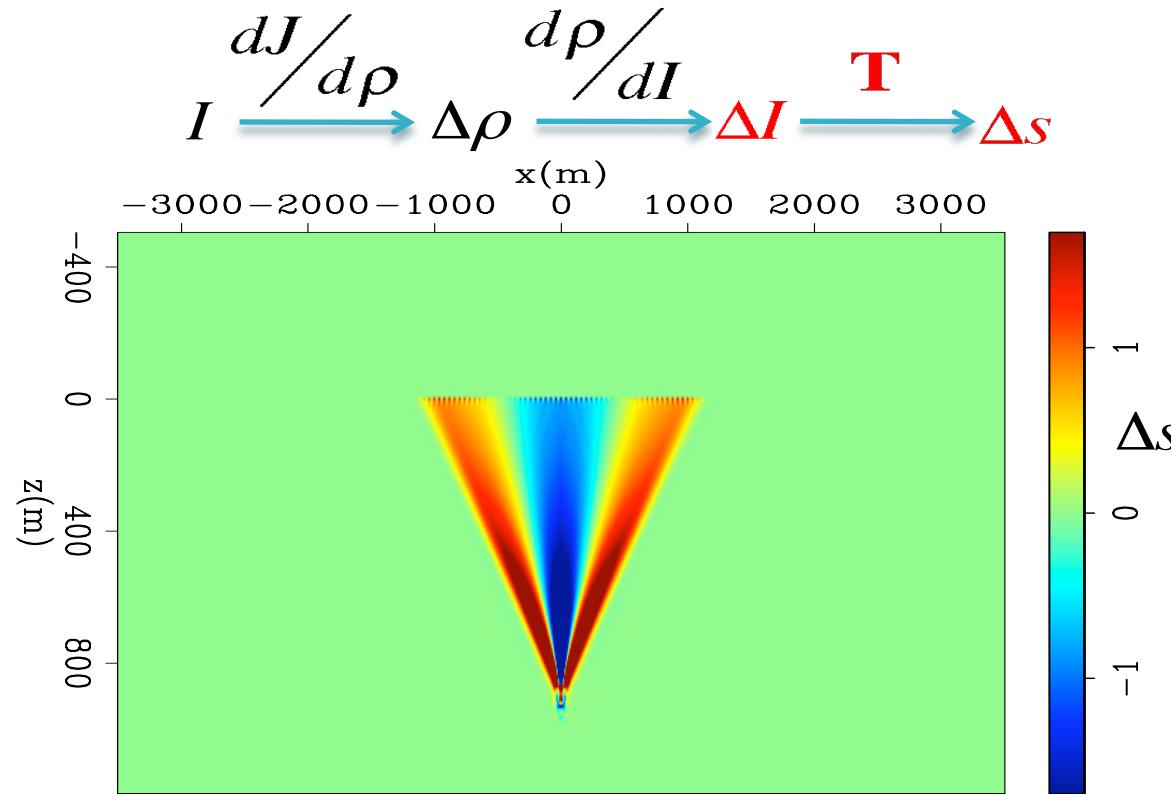
RMO Objective function (II)

- Analogy to travel-time wave-equation tomography (TT-WET) (Luo&Schuster, 1991).

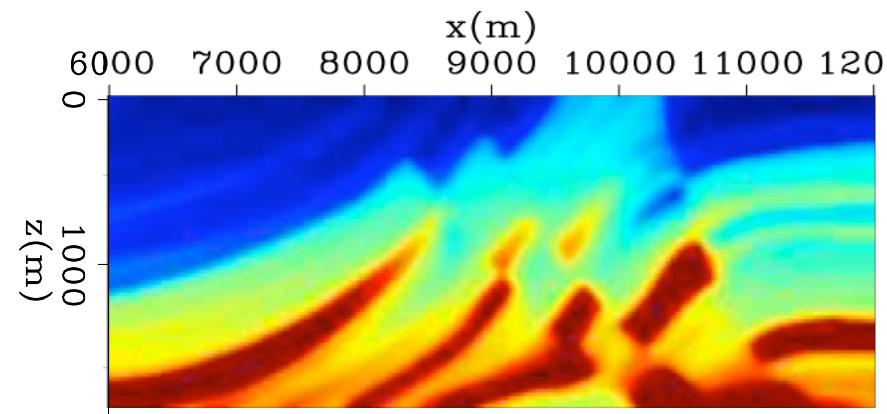


- Need to identify *anchor points* to handle multiple events

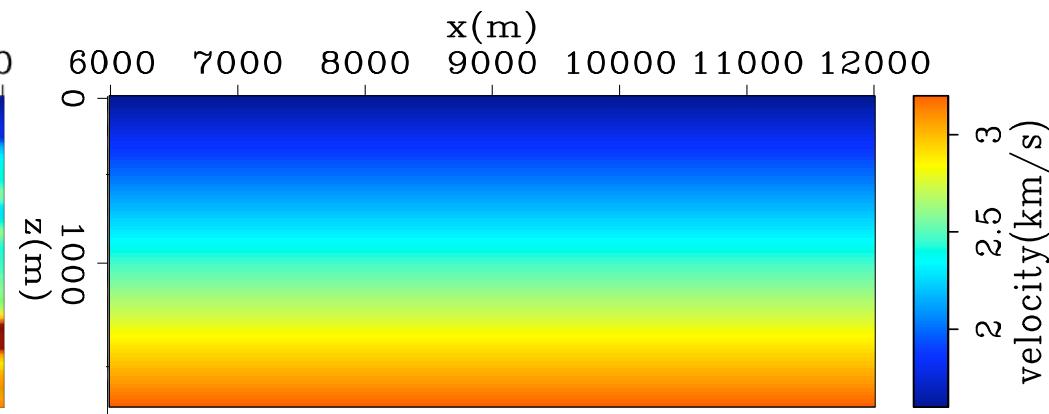
Gradient: 3) back project ΔI into model



2-D Marmousi example

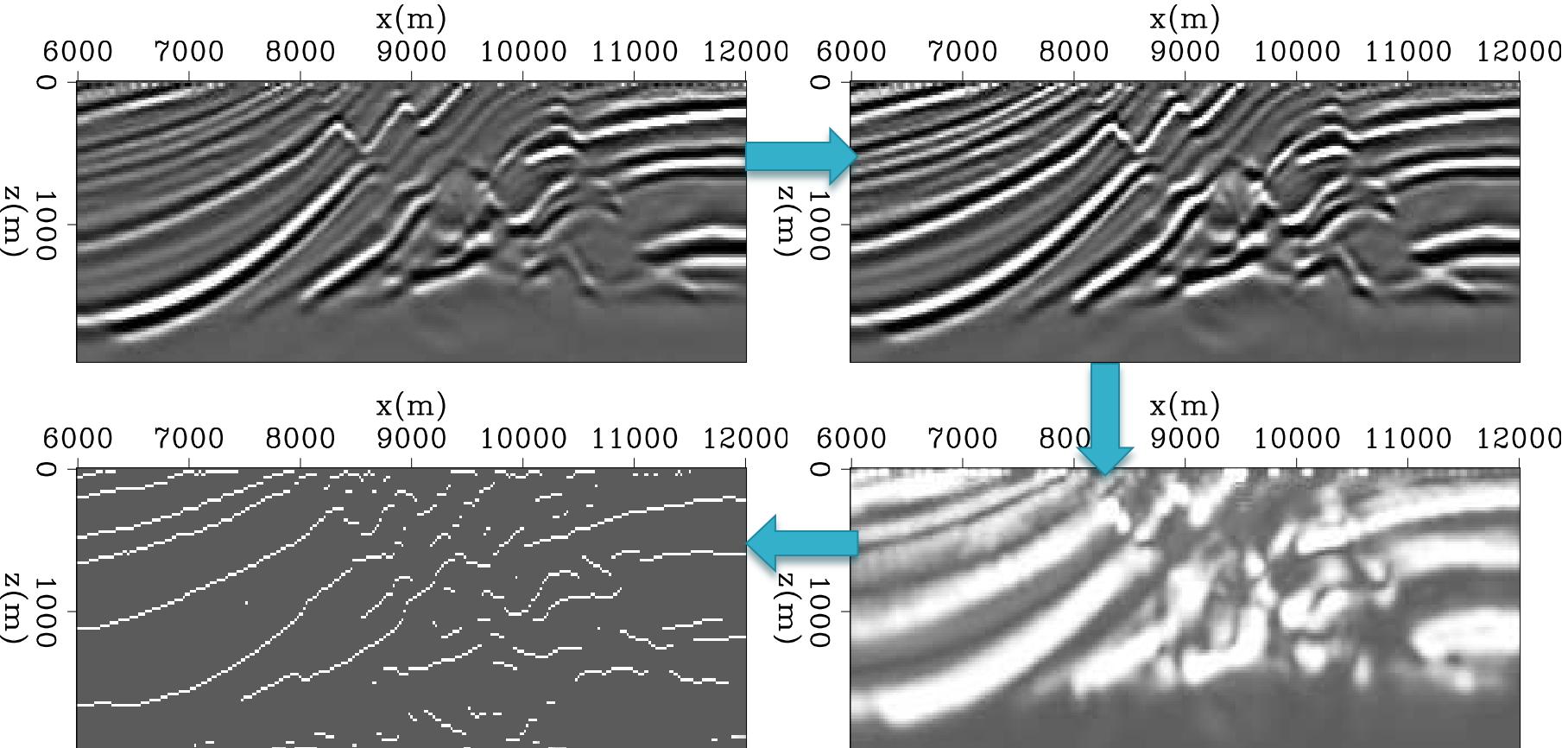


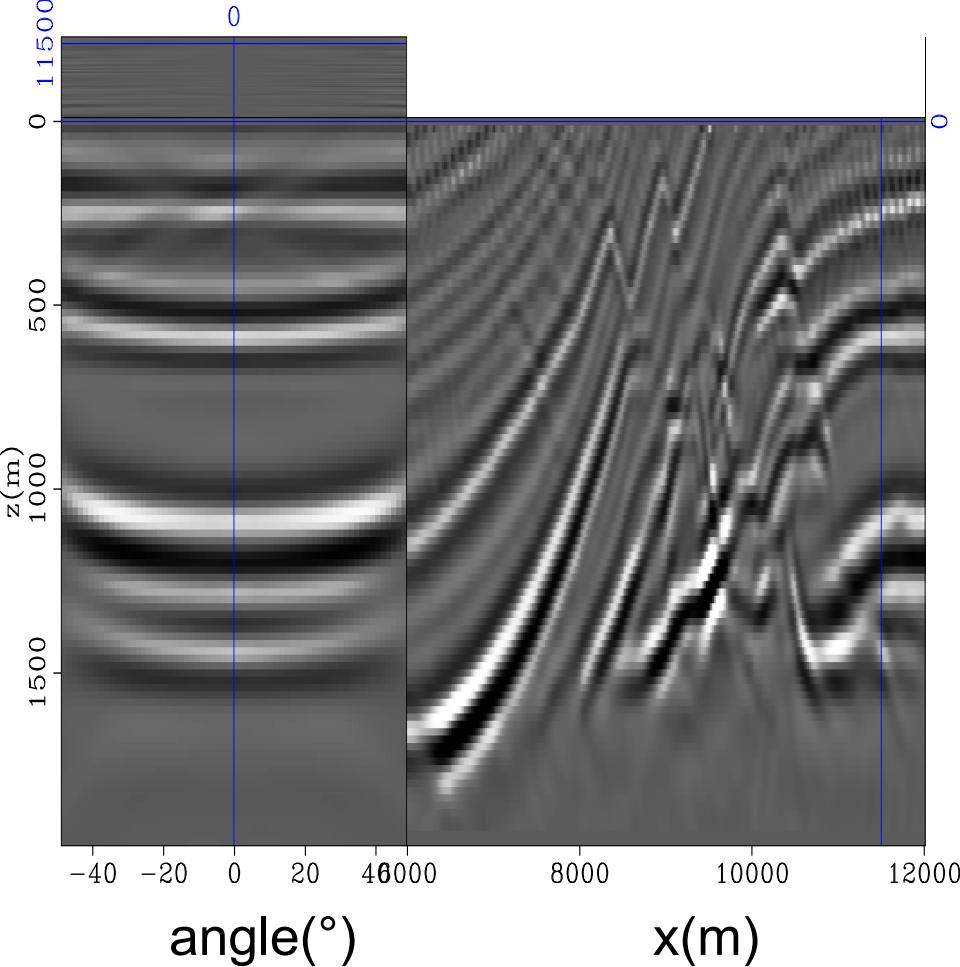
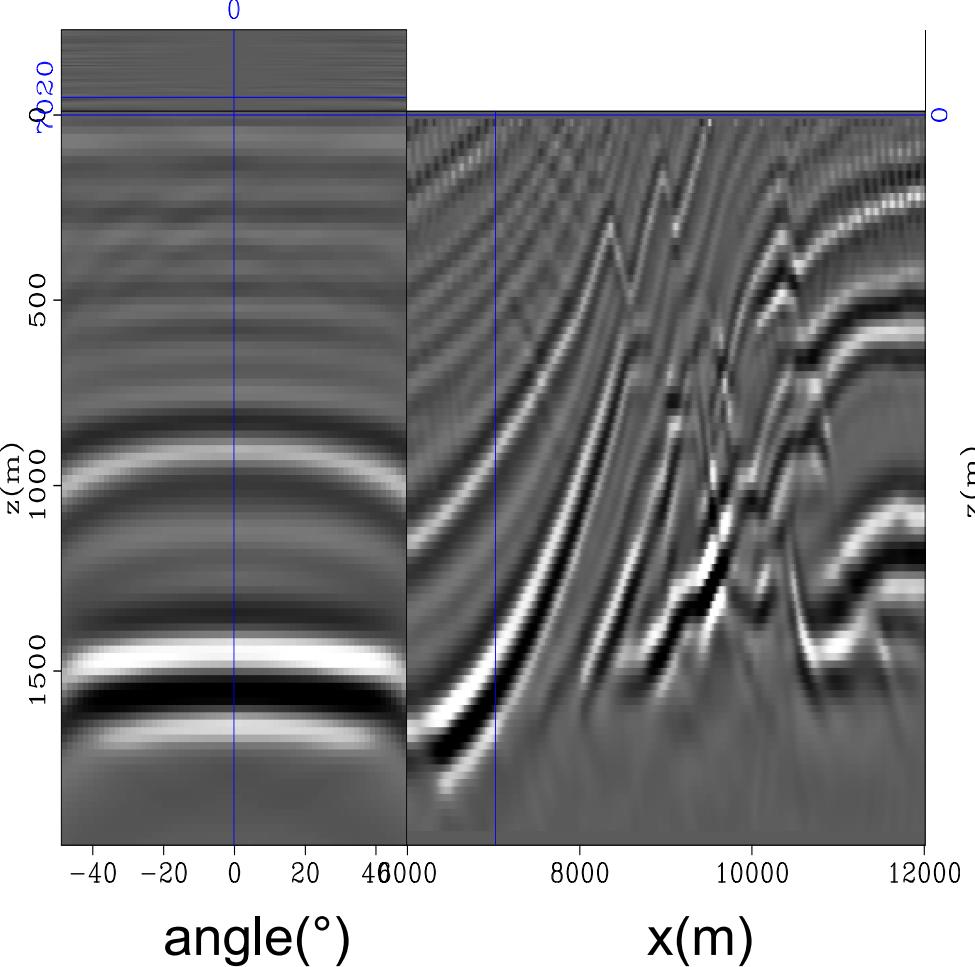
True model

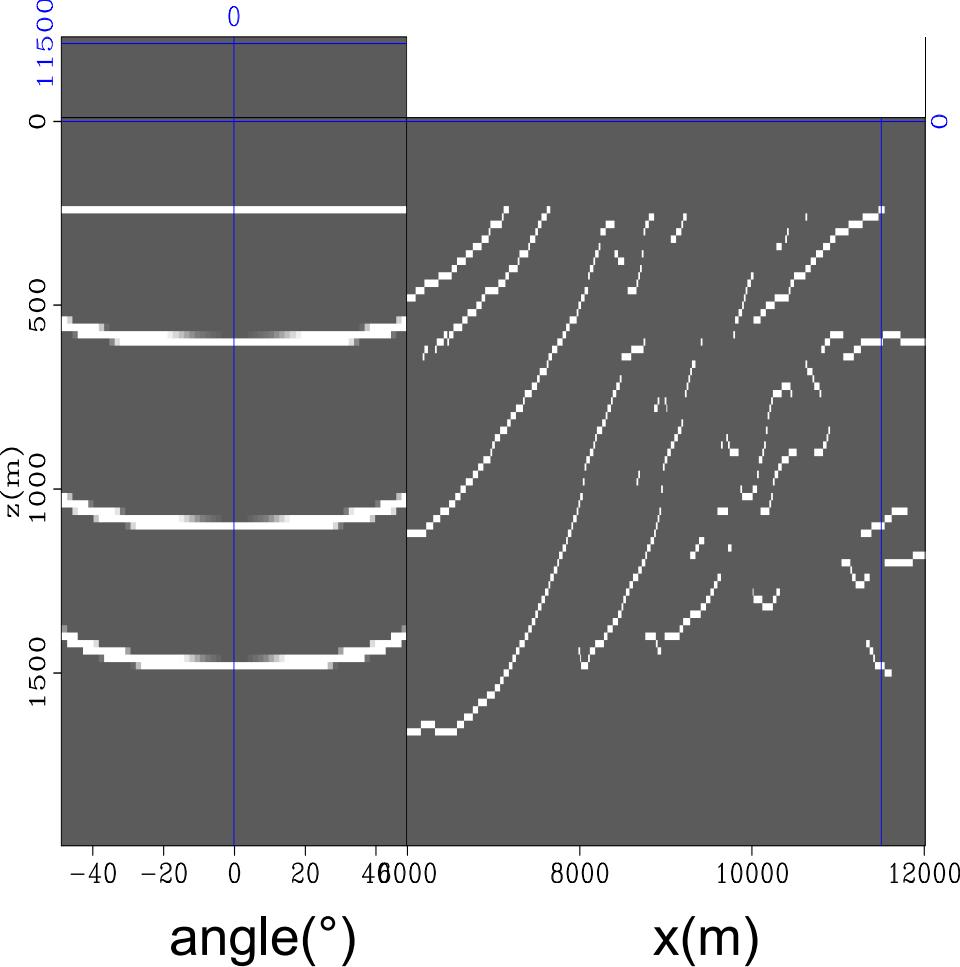
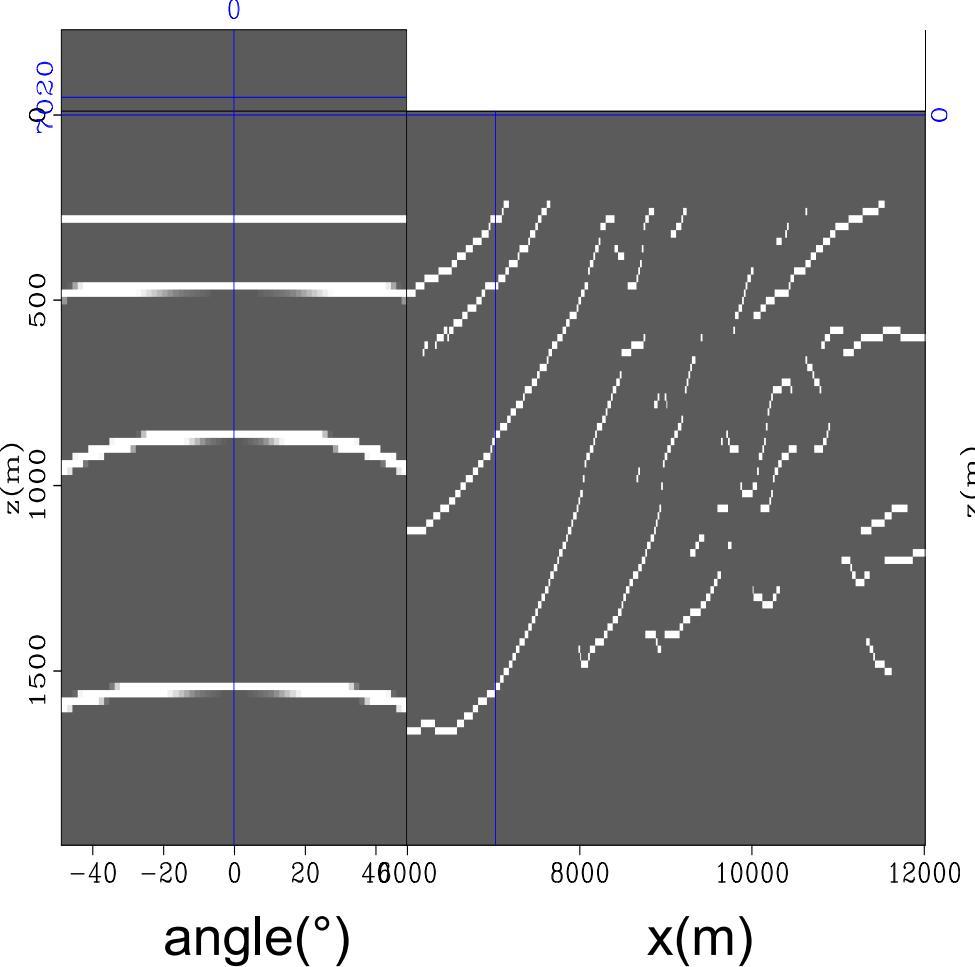


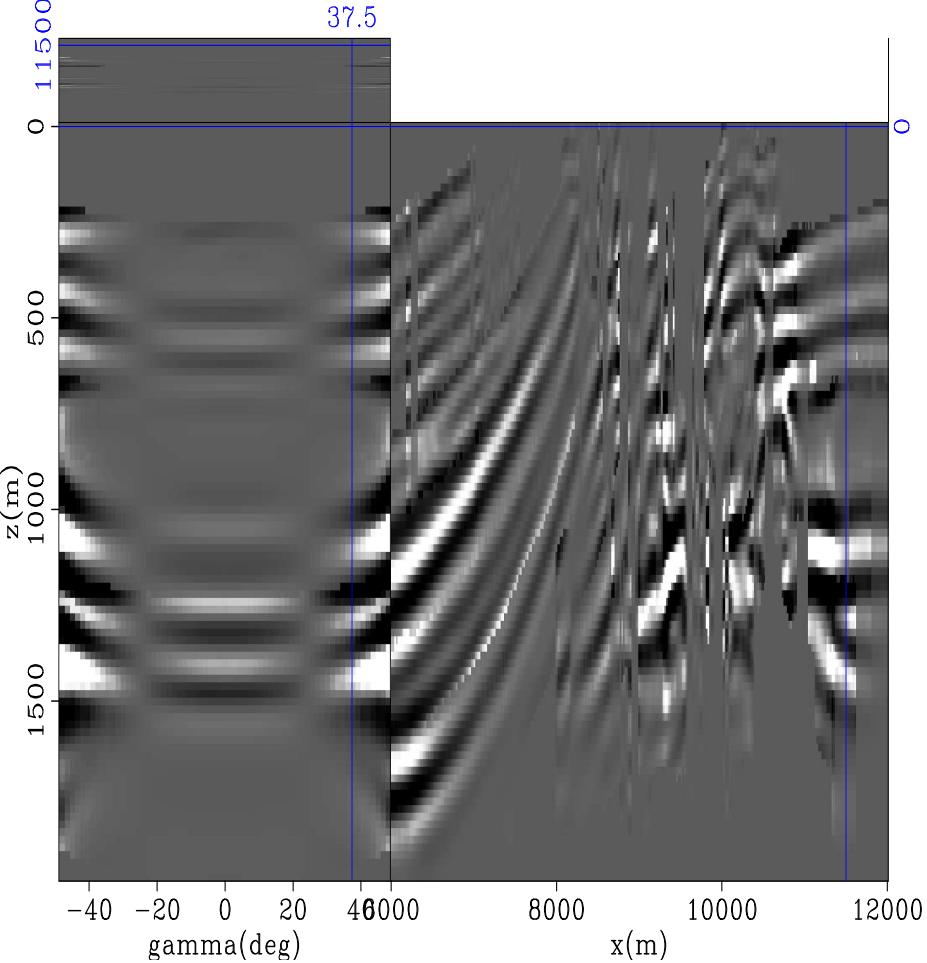
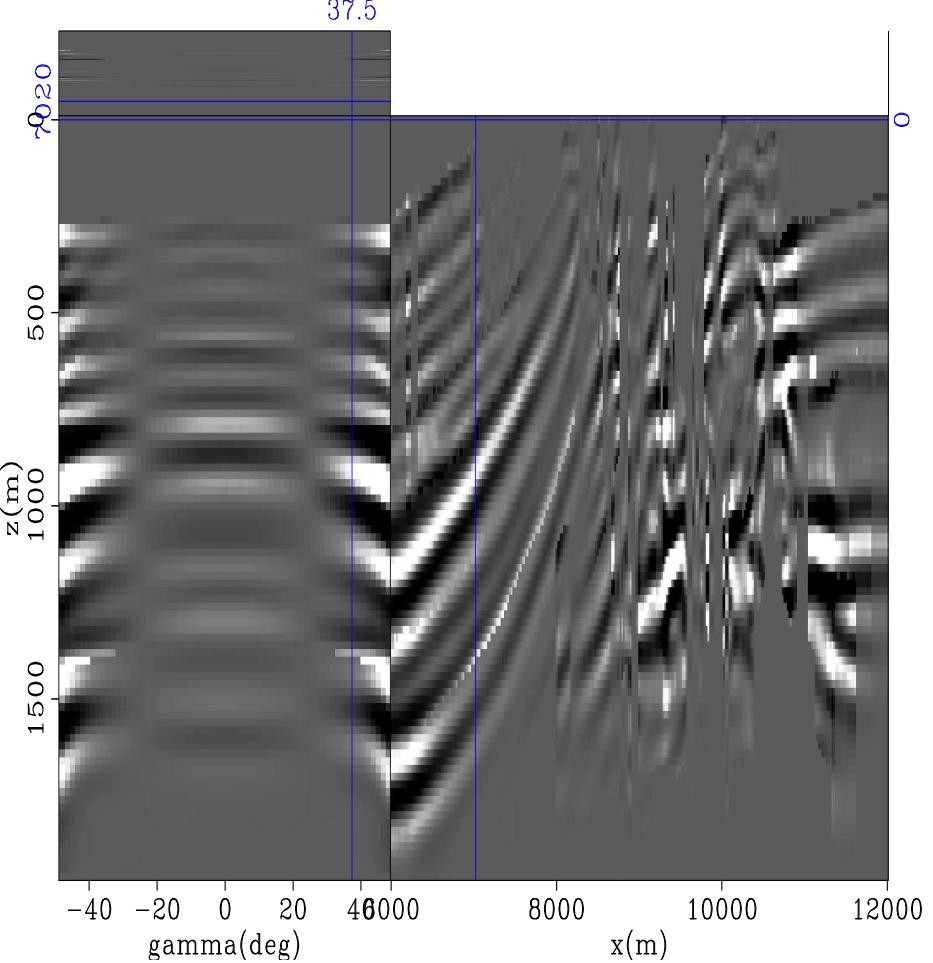
Starting model $v(z) = v_0 + az$

2-D Example: Anchor point extraction

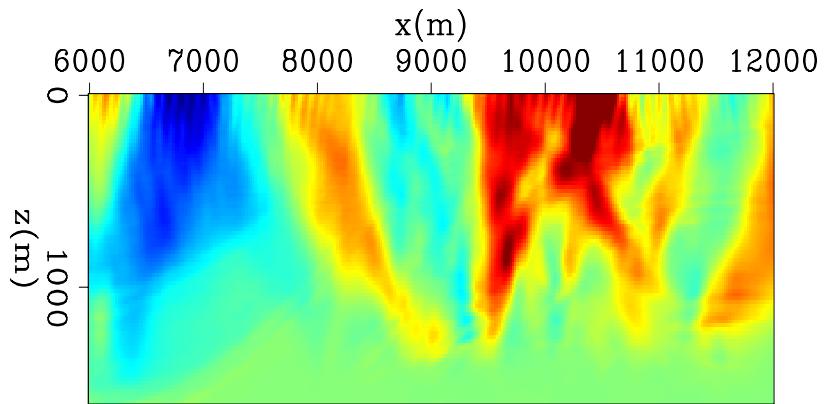




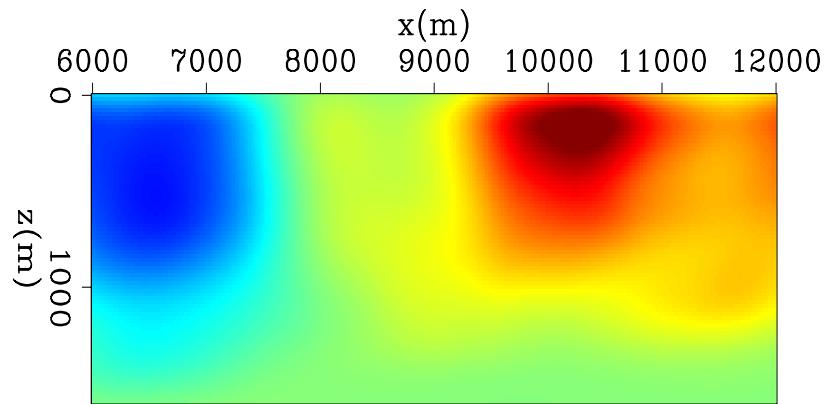


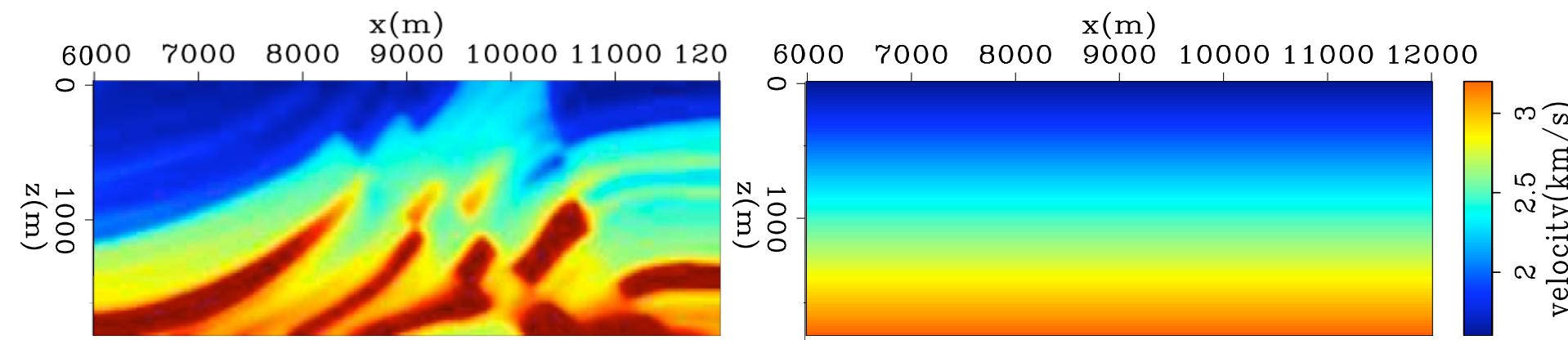


First search direction



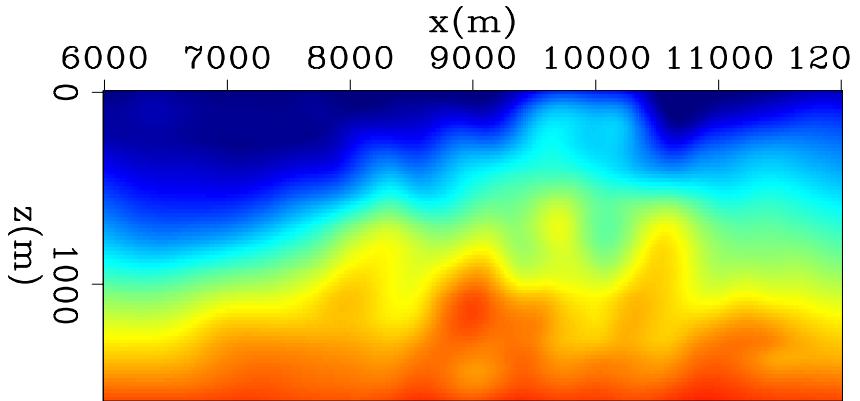
Smoothed





True model

Starting model $v(z) = v_0 + az$

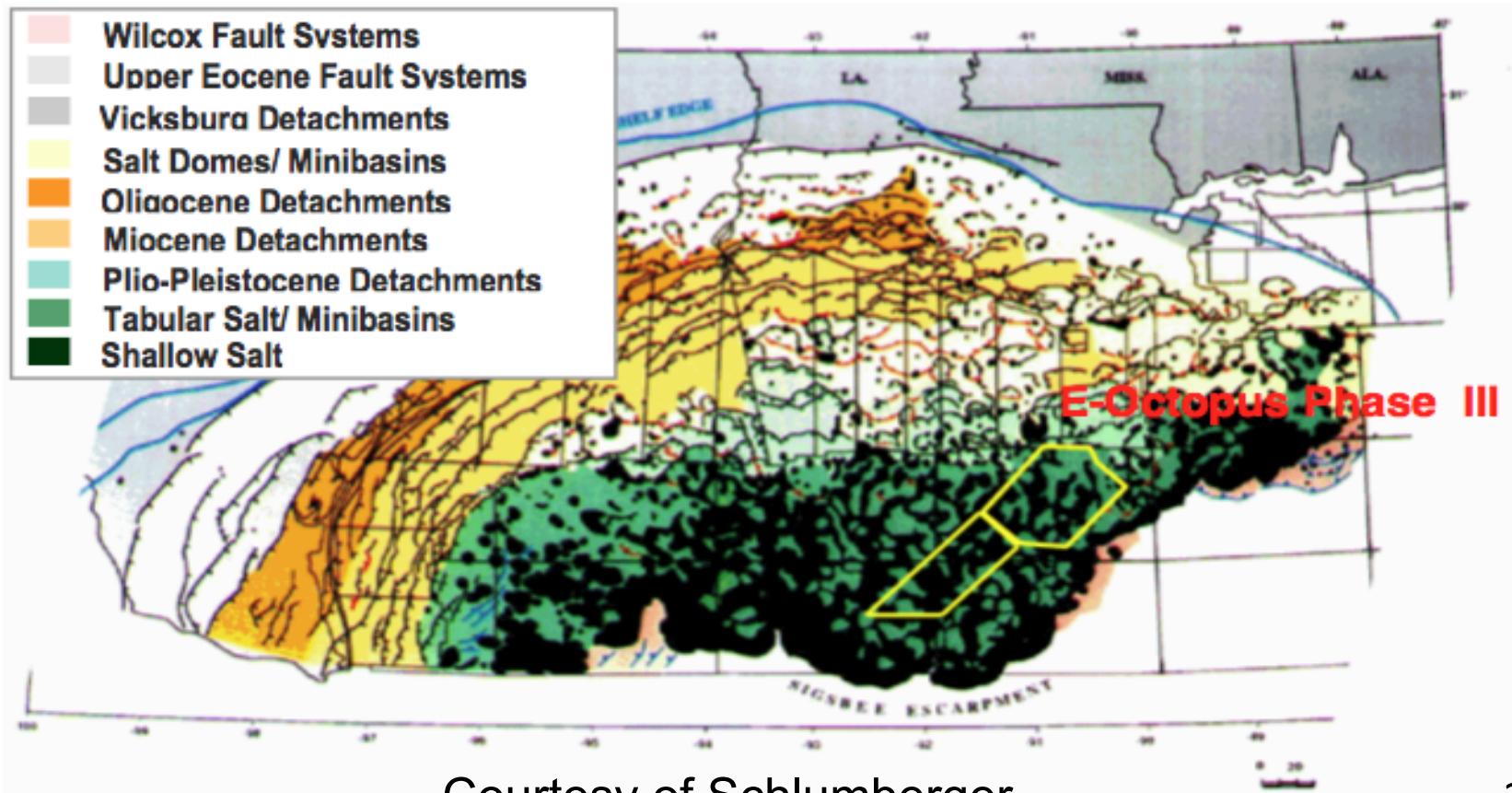


RMO-based WEMVA (20 iters)

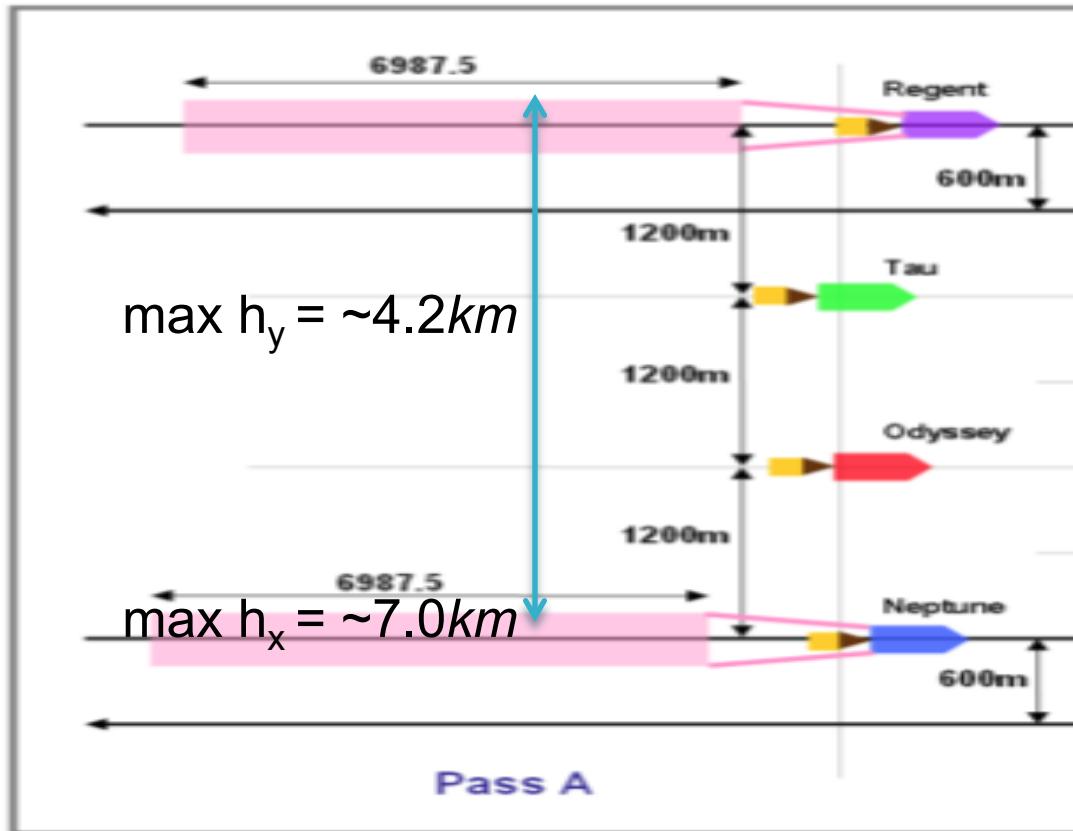
Outline

- Overview of RMO-based wave-equation migration velocity analysis (WEMVA)
- Application of RMO-based WEMVA to a 3-D WAZ field data set
 - Target-oriented subsalt velocity estimation

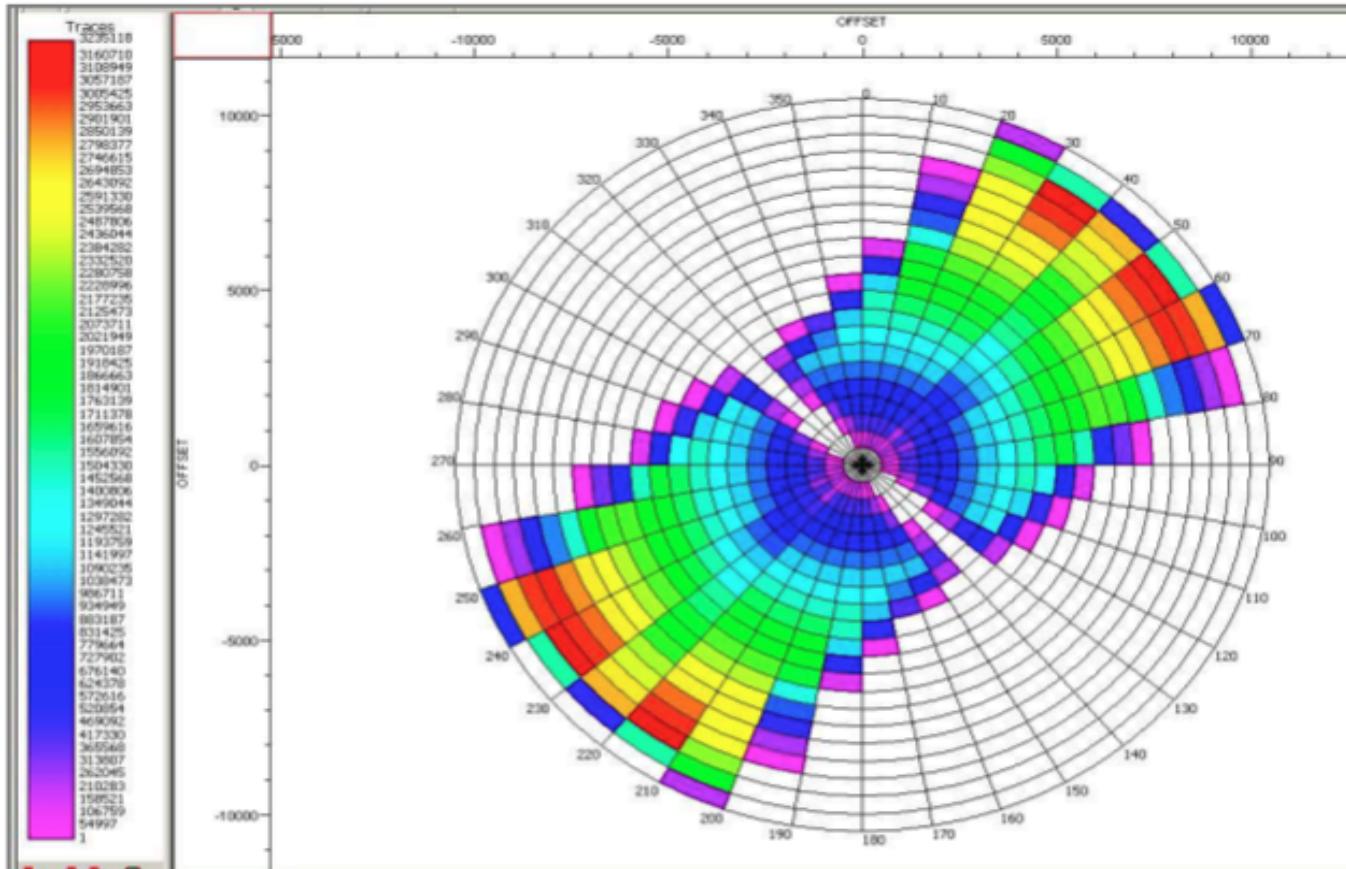
Regional geological structure



Nominal acquisition settings

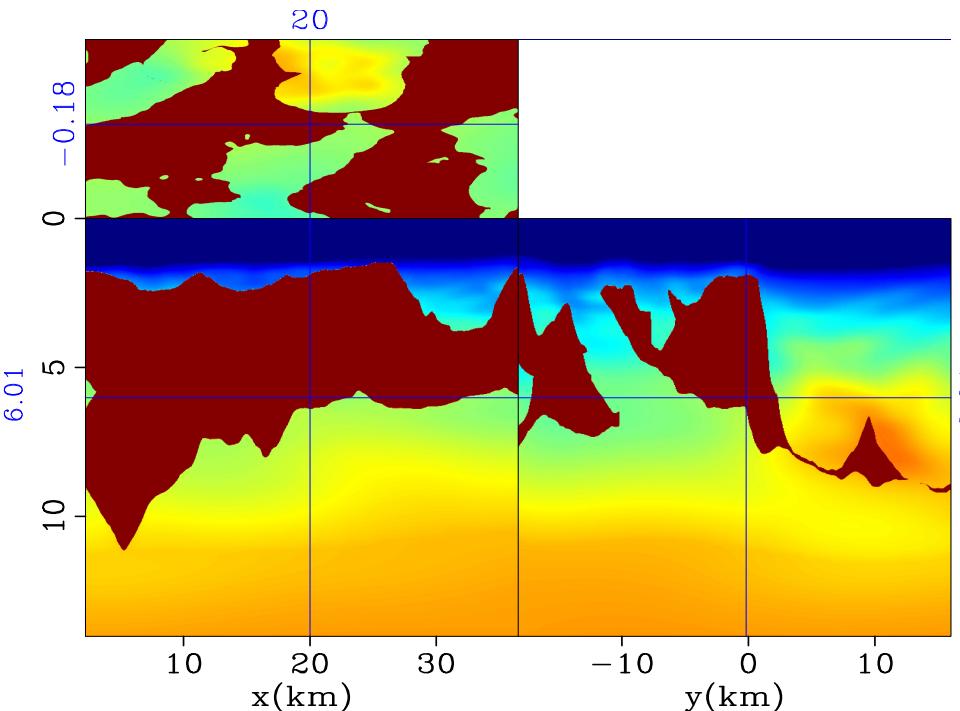
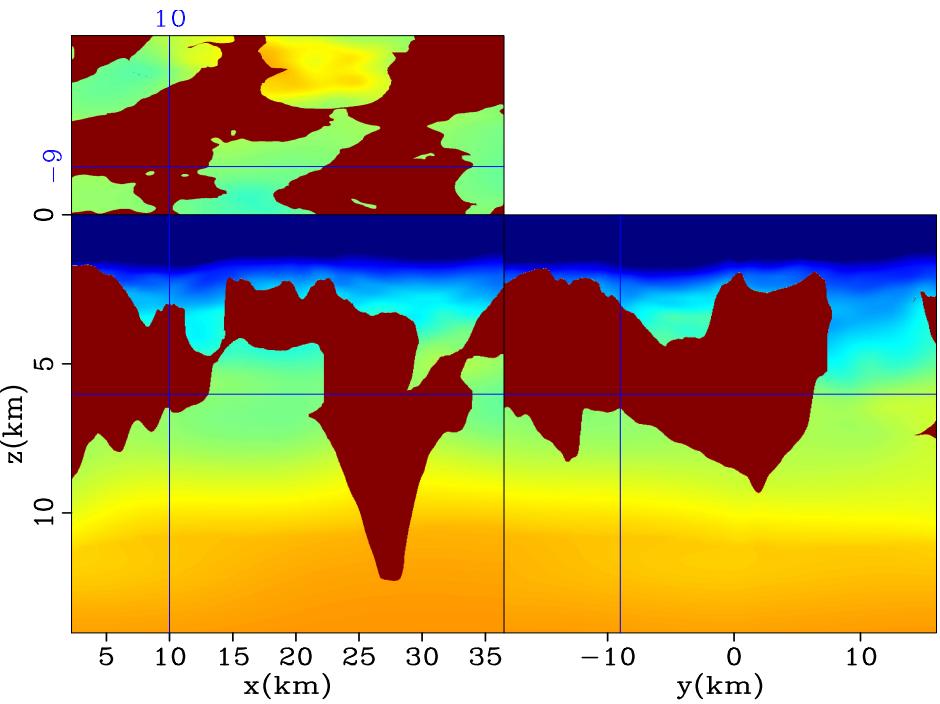


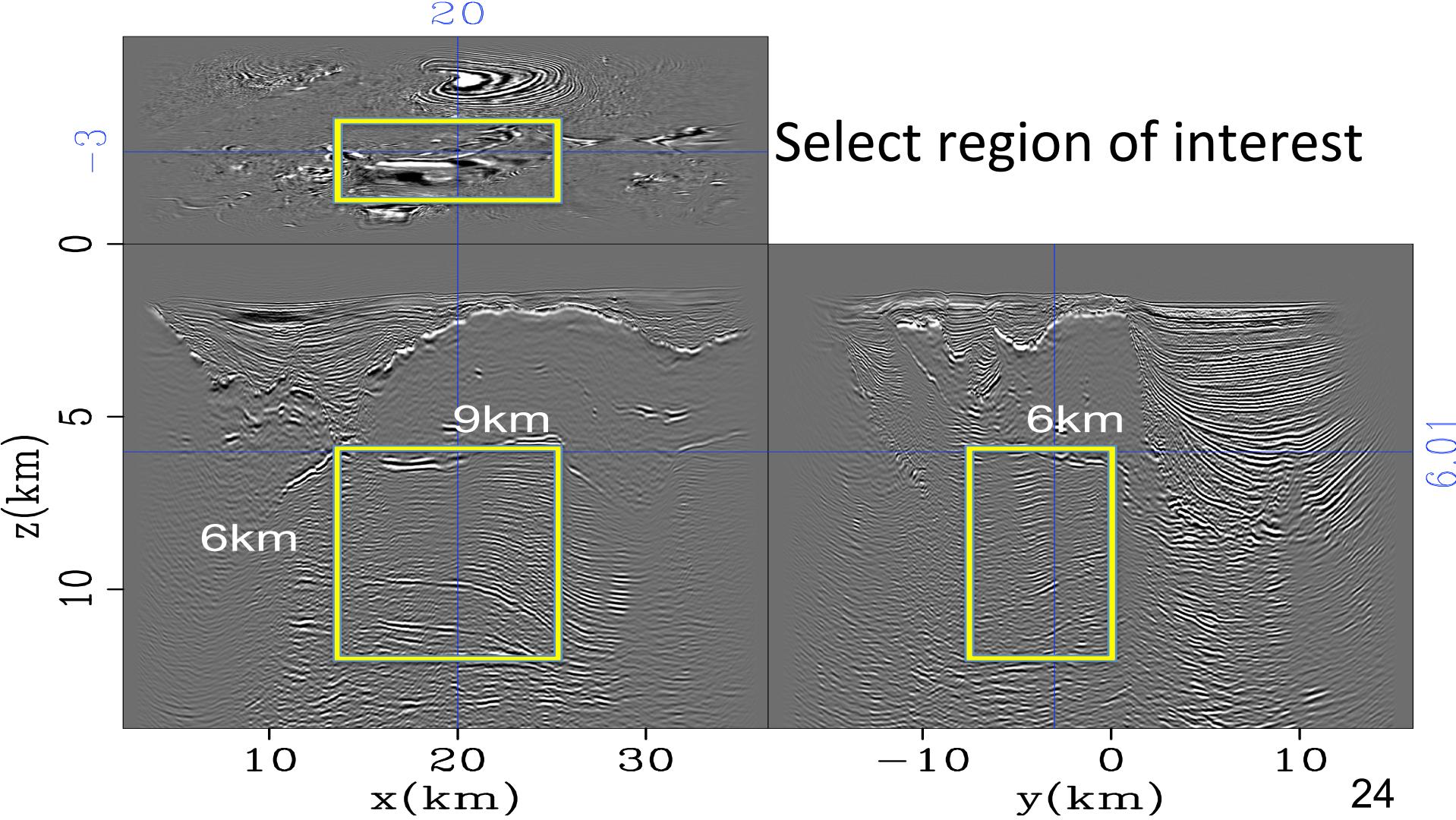
Rose diagram, azimuth coverage

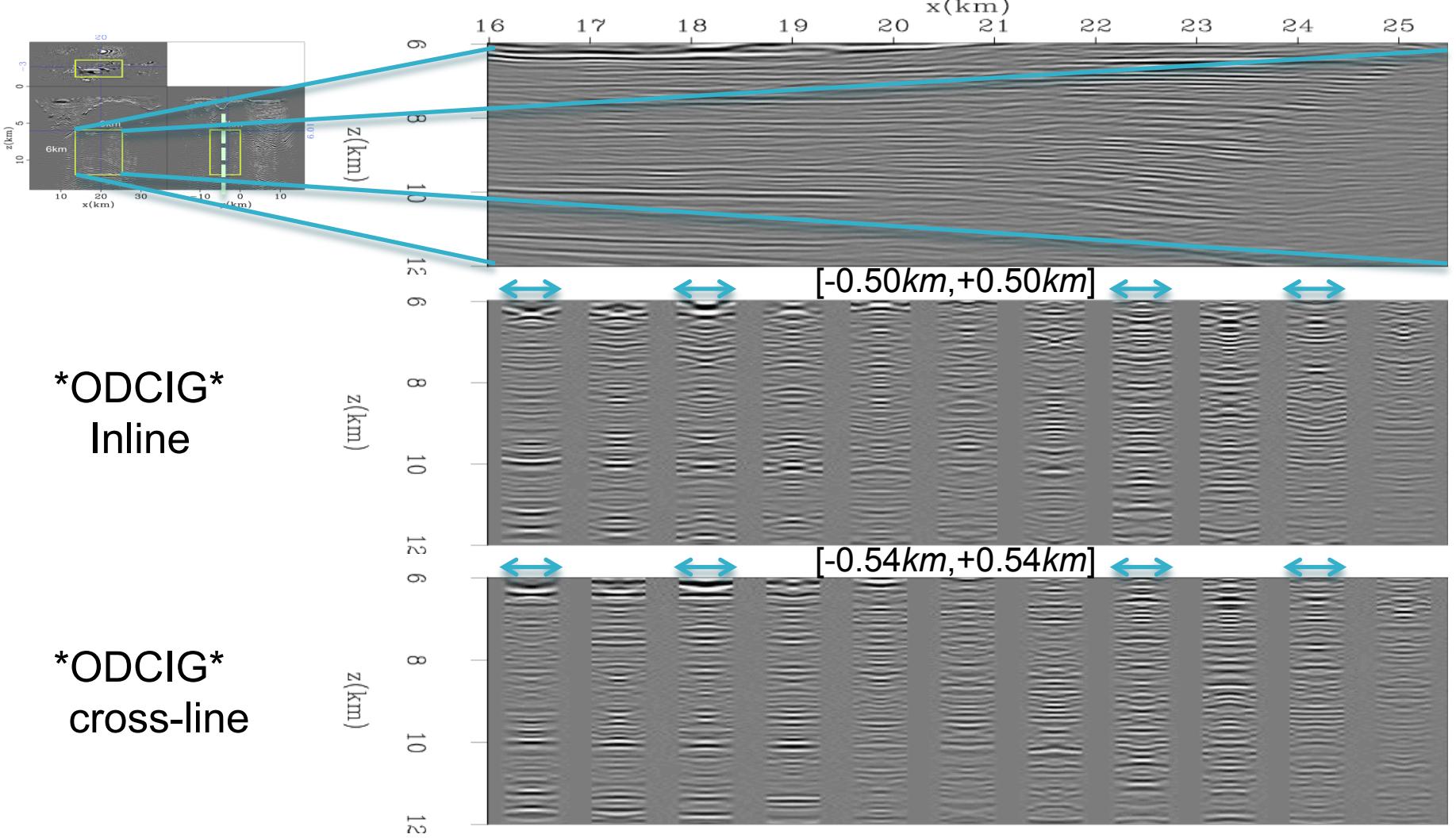


Courtesy of Schlumberger

Velocity model for migration



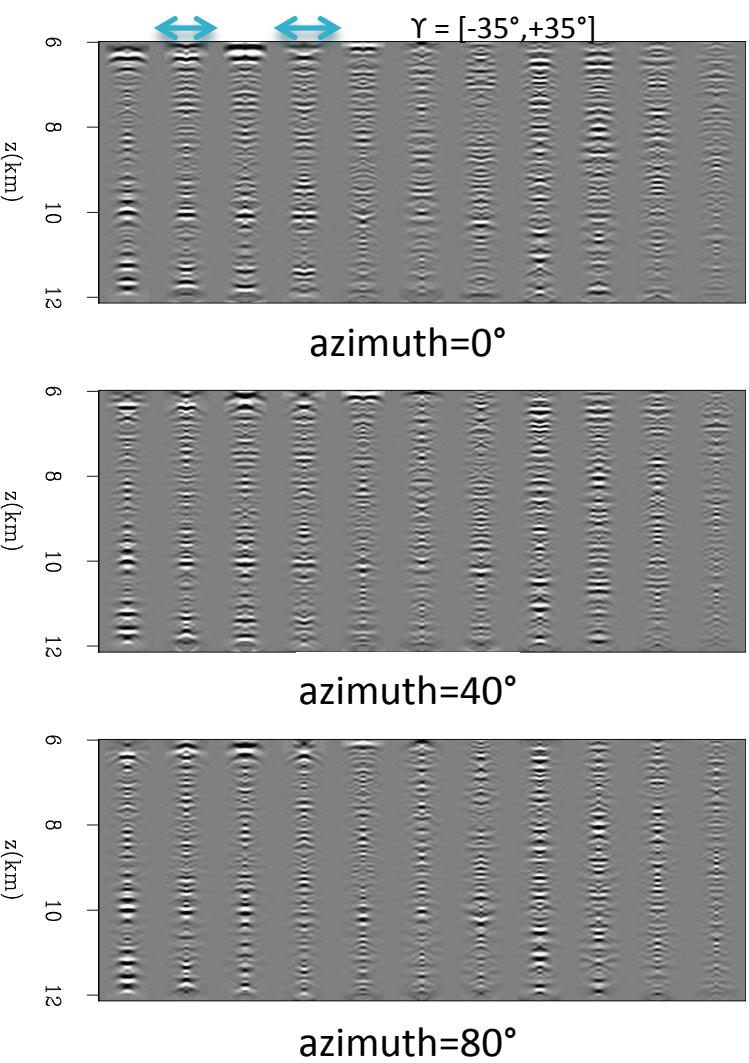
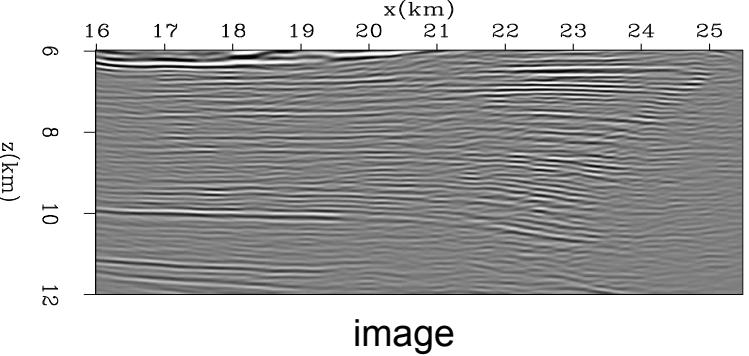
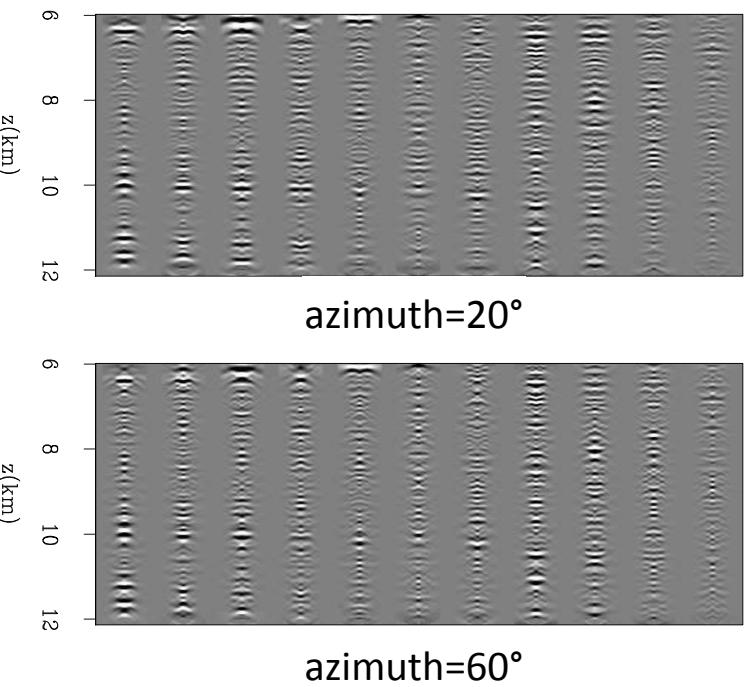




Observation from the gathers

- Need very long subsurface offset range
 - Partially because of velocity inaccuracy
 - Partially because of limited illumination
 - In subsurface offset domain it is hard to differentiate the two effects

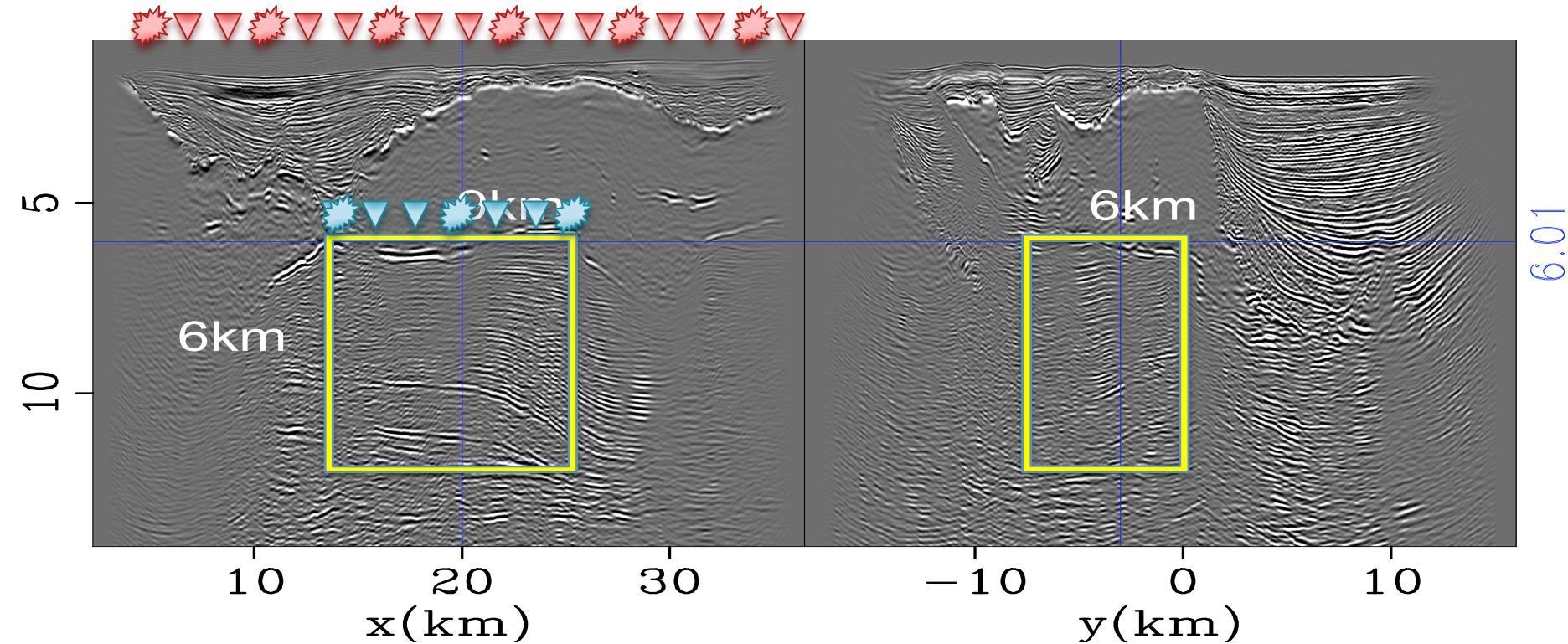
ADCIGs



Observation from the gathers

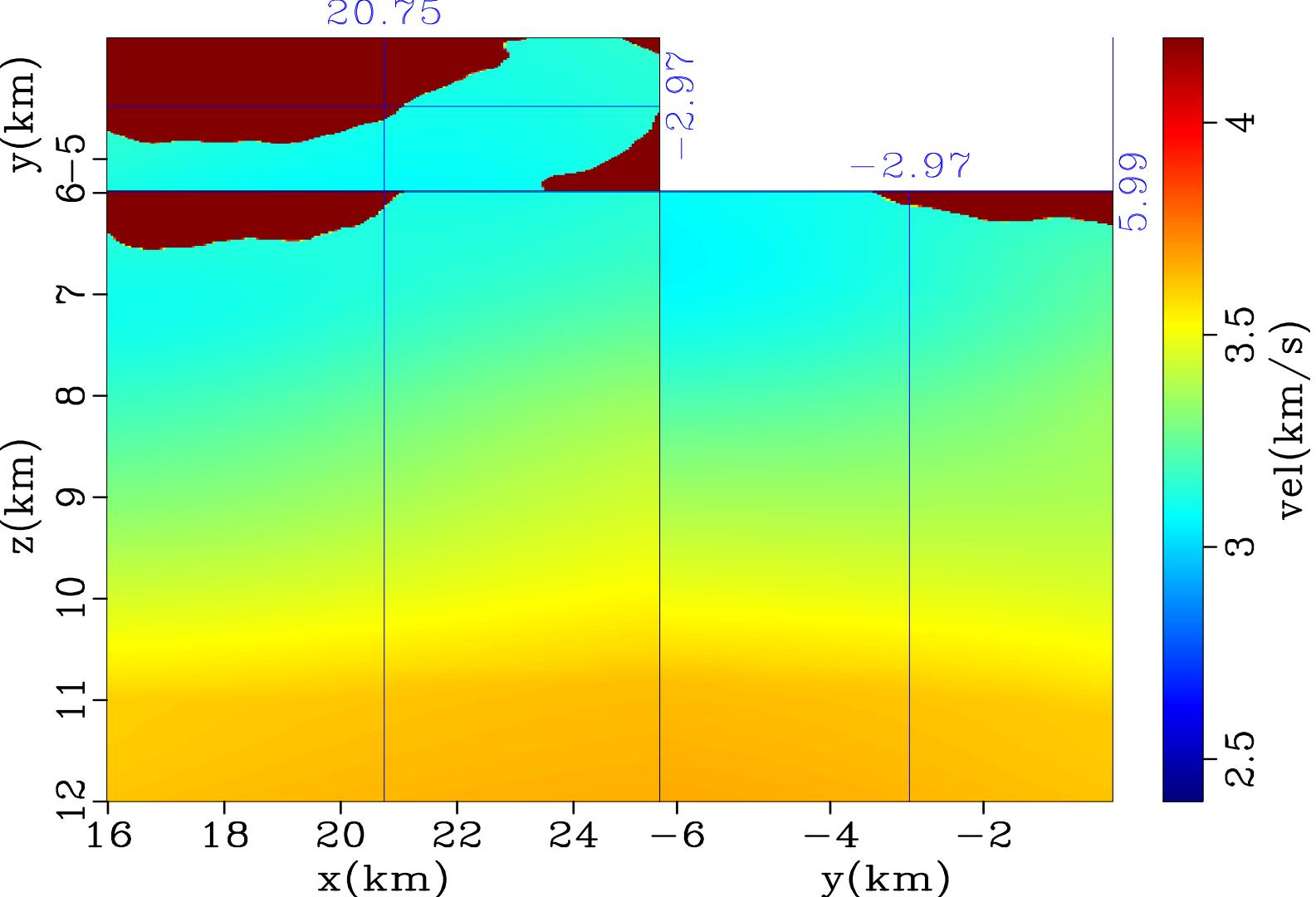
- Need very long subsurface offset range
- The valid angle range in the angle gathers are very limited, nonetheless there are non-zero curvatures

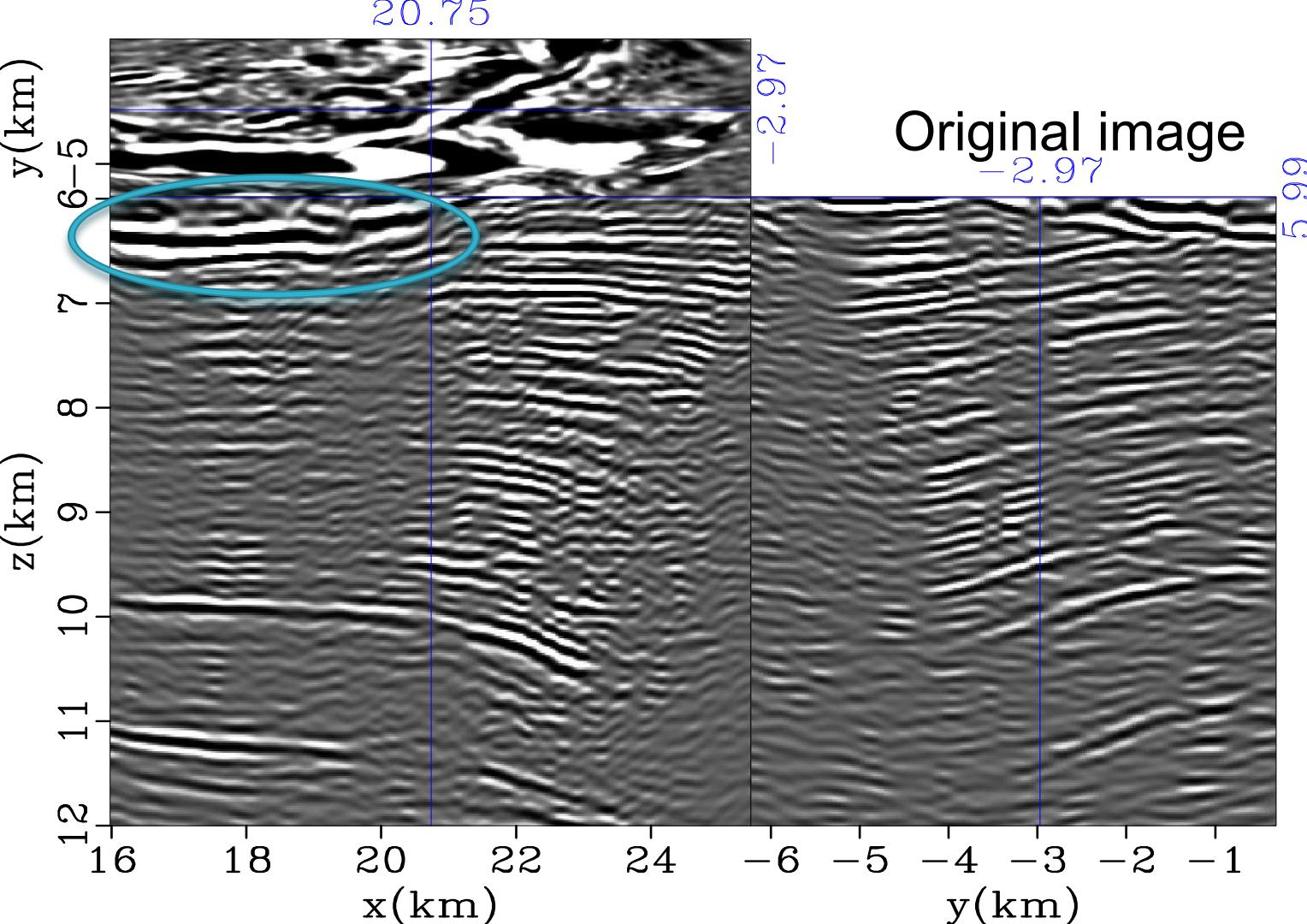
Target oriented scheme

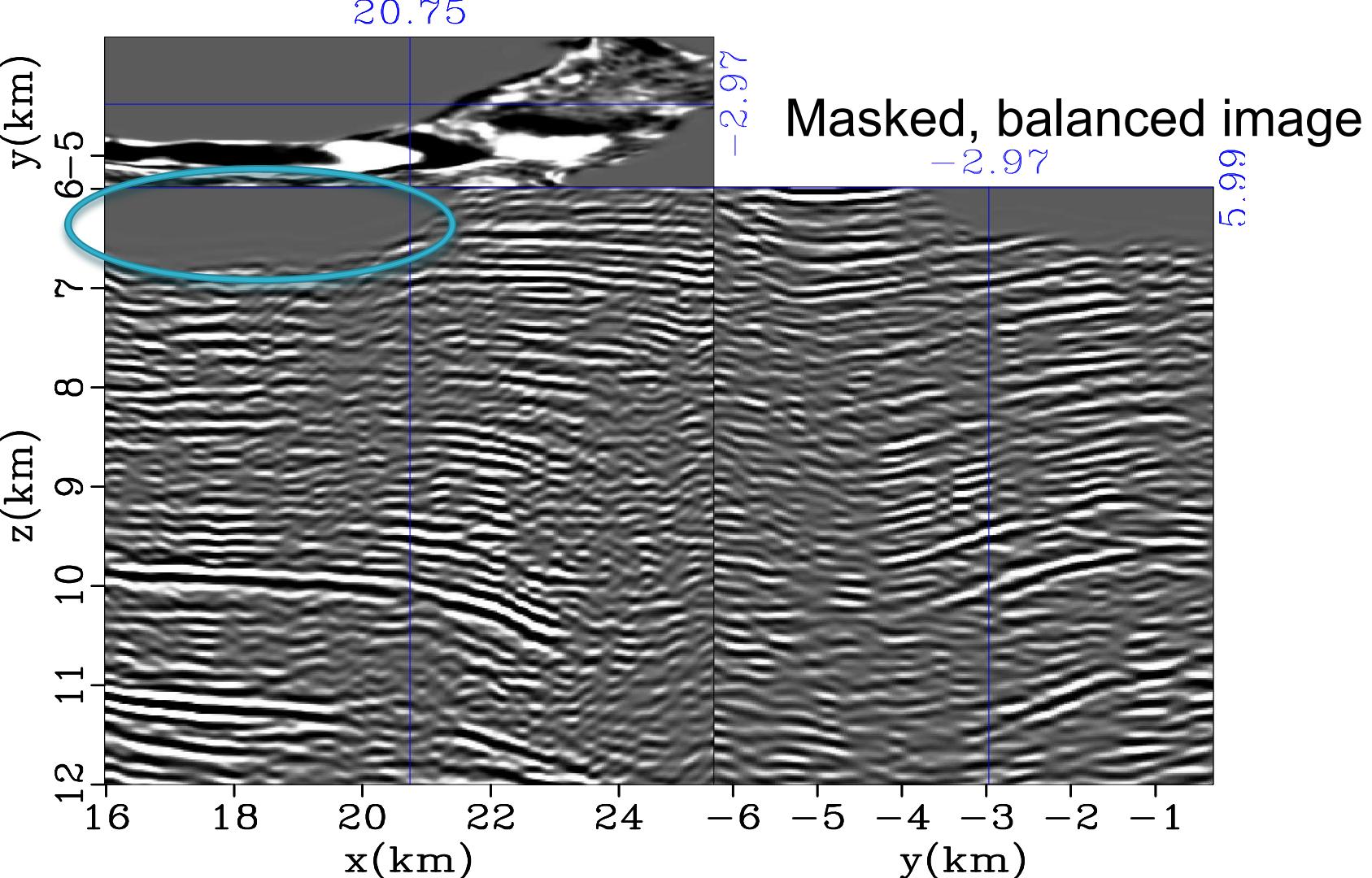


Target oriented tomography using demigrated Born data

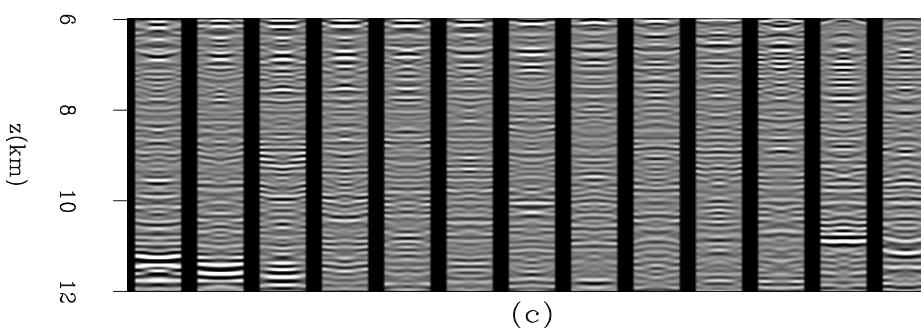
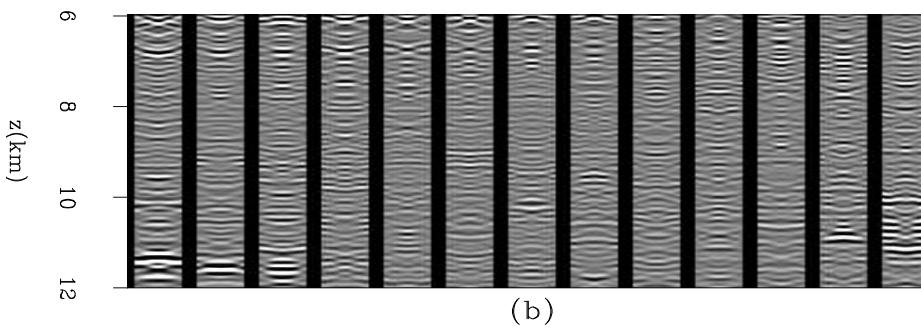
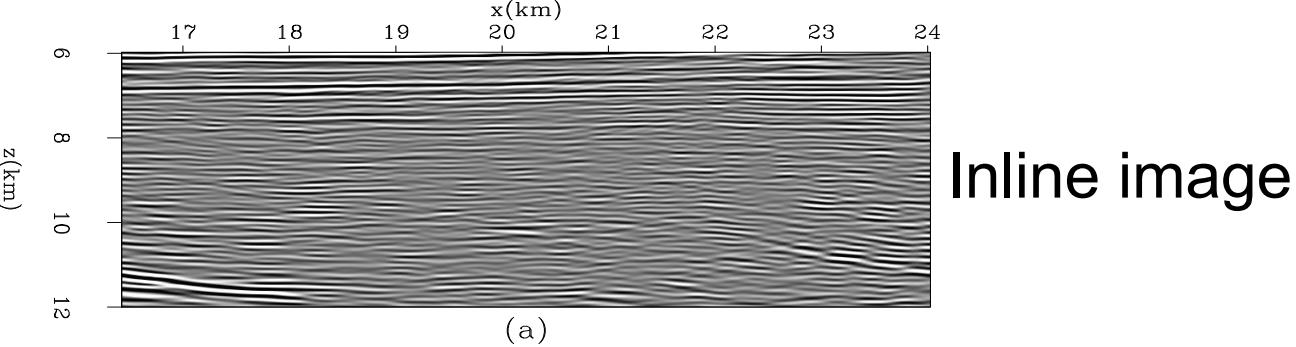
- Proposed by Yaxun Tang in 2010
- Three major steps:
 - Migrate the initial data into image of the target region (keeping all subsurface offsets)
 - Compensate the illumination on the migrated image
 - Perform a Born modeling with the new acquisition geometry on the balanced subsurface offset image



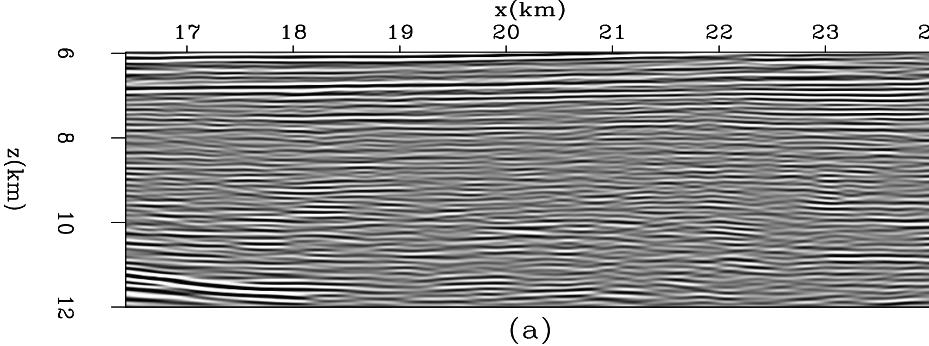




Input ODCIG
(y=-4.77km)

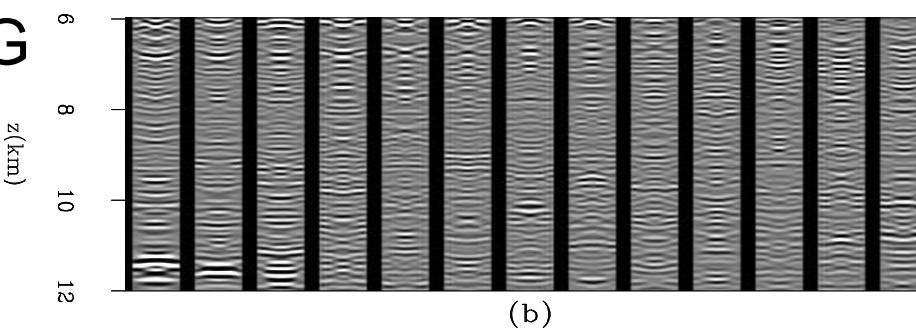


Re-migrated ODCIG (y=-4.77km)



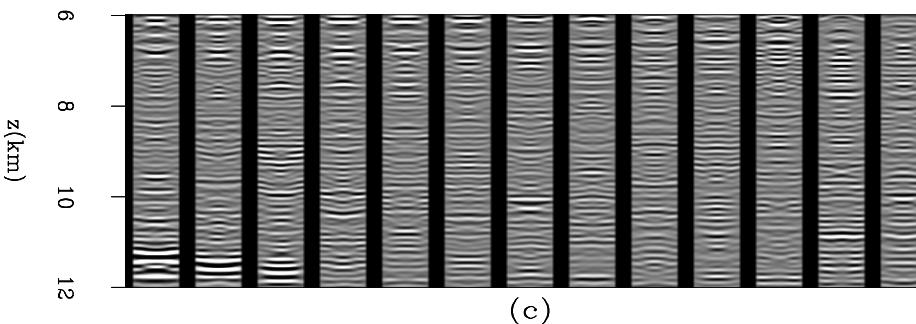
Inline image

(a)



(b)

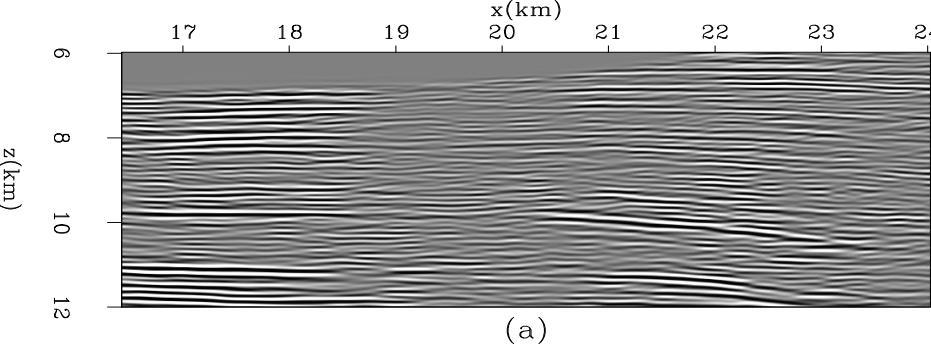
h_x



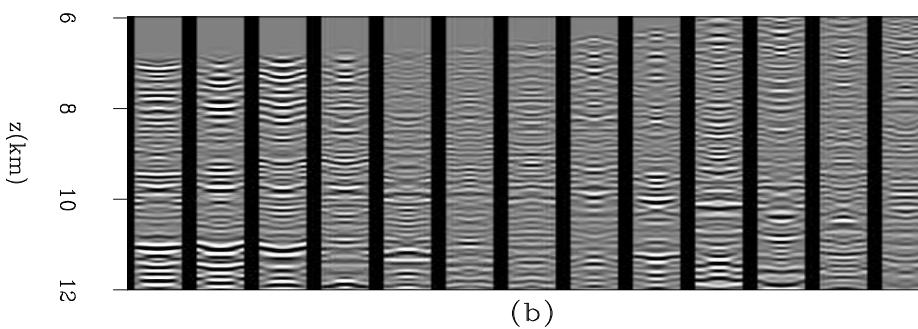
(c)

h_y

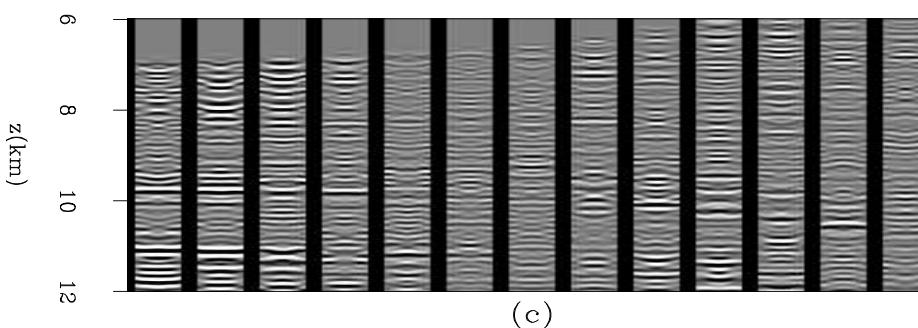
Input ODCIG
(y=-2.49km)



Inline image

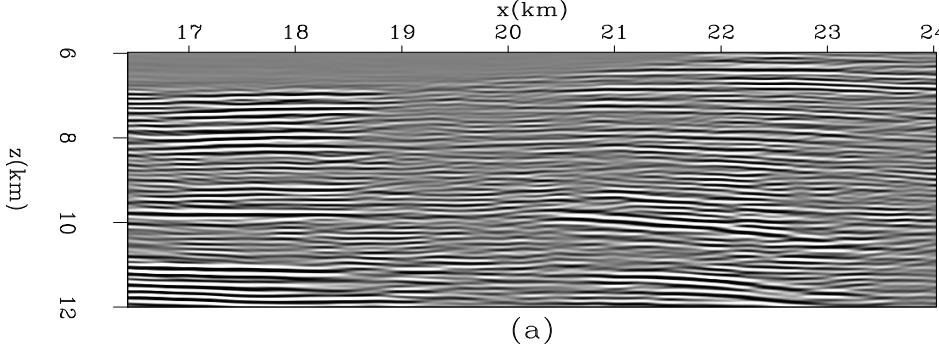


h_x



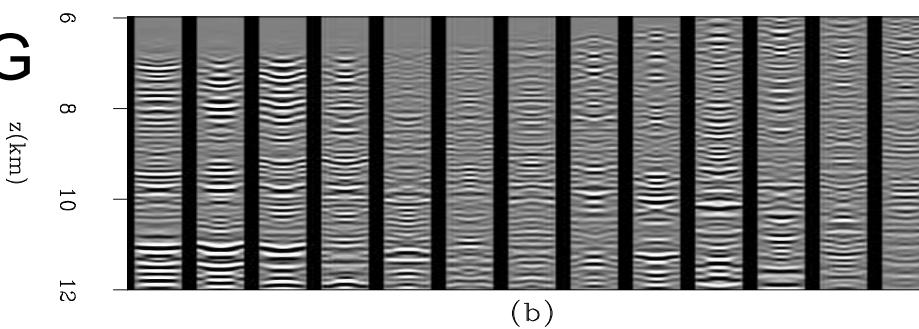
h_y

Re-migrated ODCIG (y=-2.49km)



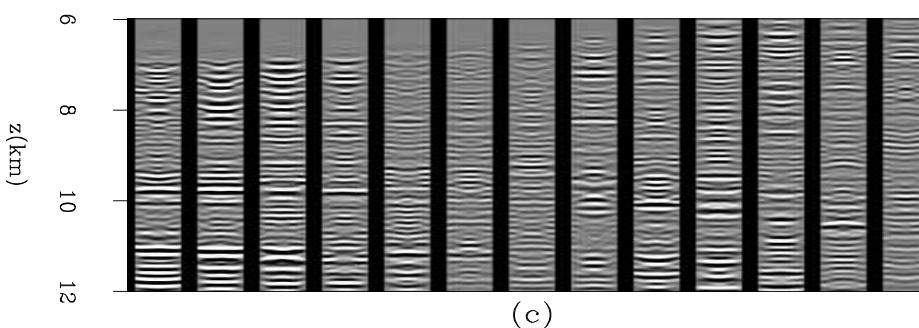
Inline image

(a)



h_x

(b)



h_y

(c)

Savings from target-oriented scheme

- Computation time (per migration) reduced by 97% (5000 node*hrs to 150 node*hrs)
 - Data set size reduced by 90%
 - Propagation domain reduced by 96%

RMO-based WEMVA inversion using the synthesized target-oriented data set

Permission on the field data results on the way~ Sorry
for the inconvenience.

But for sure, the slide with the field results will be
available on sep website afterwards.

Conclusion

- RMO-based WEMVA is a robust reflection tomography method
- The application of our method on a challenging area in a 3D GOM field data produces a geophysically more consistent model
 - however, with large model uncertainty

Acknowledgment

- Schlumberger for the donation of this field data set and the permission to publish
- Yaxun Tang, Bob Clapp, Dave Nichols, Guojian Shan, Ali Almomin, Elita Li, etc.
- SEP sponsors (fare-well)

$$S_m(\rho, z, x; s_0) = \frac{\sum_{z_w} \left[\sum_{\gamma} I(\gamma, z + z_w + \rho \tan^2 \gamma, x; s_0) \right]^2}{\sum_{z_w} \sum_{\gamma} I^2(\gamma, z + z_w + \rho \tan^2 \gamma, x; s_0)}$$

$$J_{S_m}(\rho(s)) = \sum_x \sum_z S_m(\rho(z, x), z, x; s_0)$$

$$\frac{\partial J_{S_m}}{\partial s} = \sum_x \sum_z \frac{\partial \rho(z, x)}{\partial s} \frac{\partial S_m(\rho(z, x), z, x; s_0)}{\partial \rho(z, x)}$$

$$\begin{aligned}
J_{S_m}^G(s) &= \sum_x \sum_z S_m(\rho = 0, z, x; s) \\
&= \sum_x \sum_z \frac{\sum_{z_w} \left[\sum_\gamma I(z + z_w, \gamma, x; s) \right]^2}{\sum_{z_w} \sum_\gamma I^2(z + z_w, \gamma, x; s)}
\end{aligned}$$