RMO-based wave-equation MVA: A WAZ field data example. Part I

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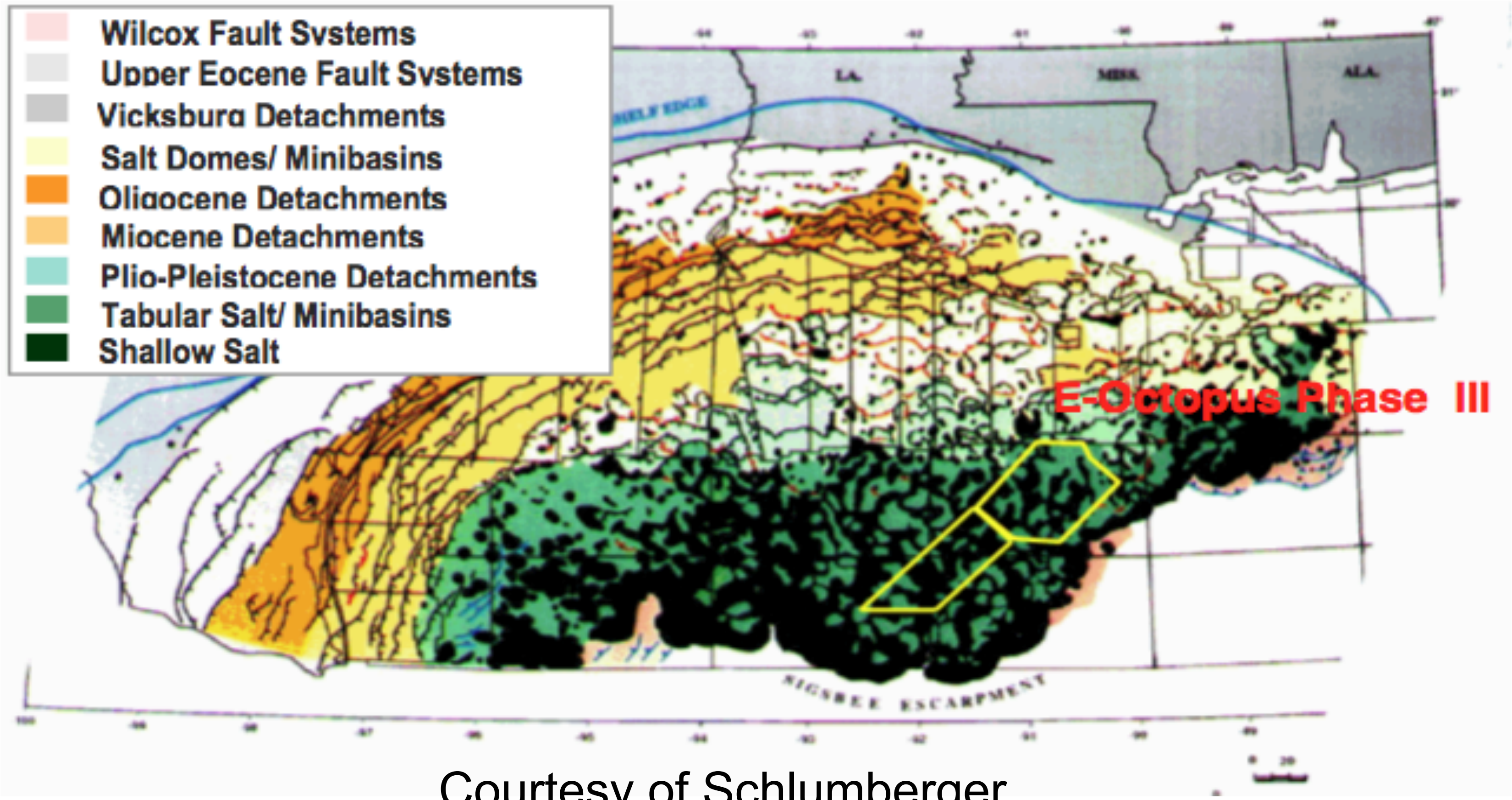
RMO: Residual moveout
MVA: Migration velocity analysis
WAZ: Wide azimuth

Outline (E-Octopus phase III, GOM)

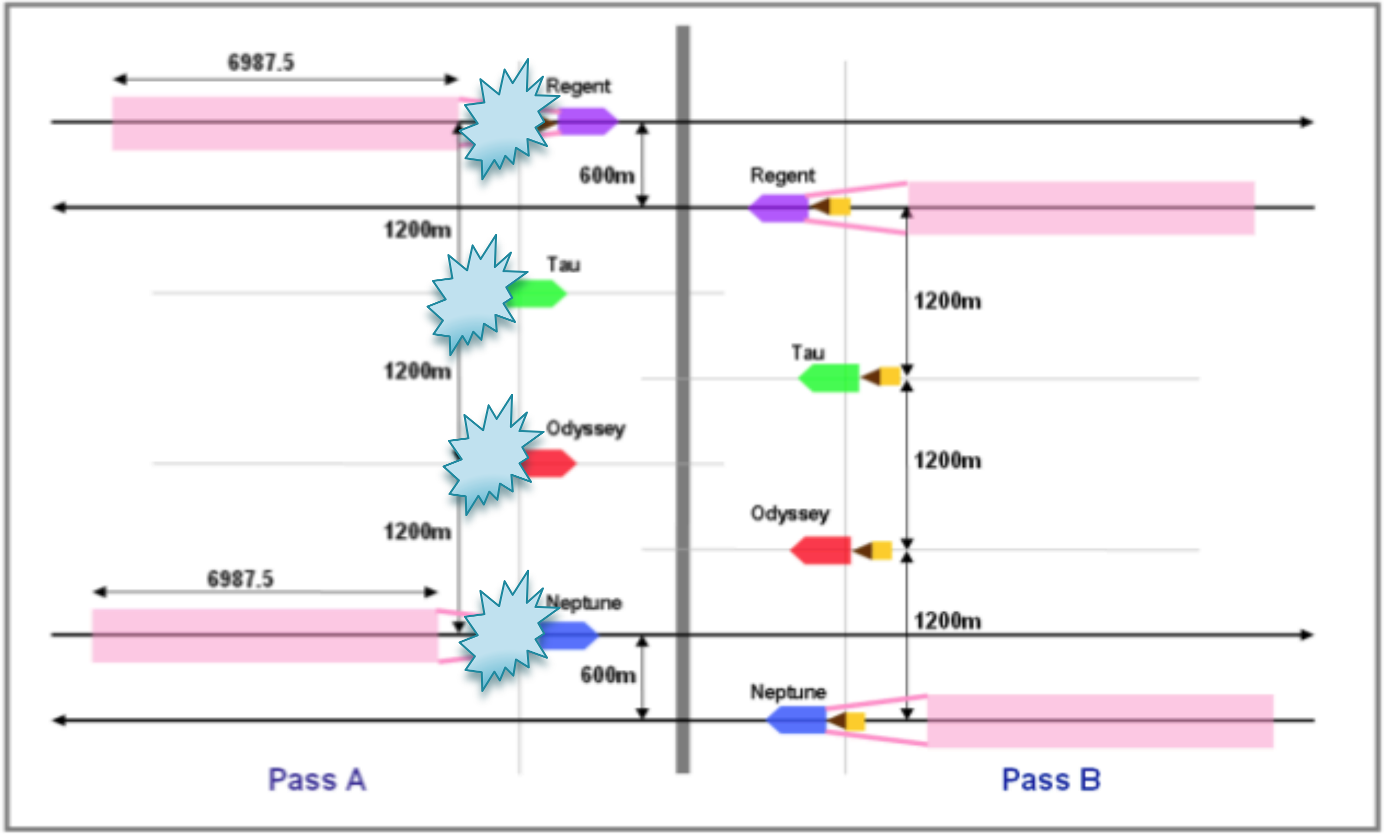
- Geological settings
- Acquisition geometry
- Data regularization
- Data pre-processing
- Initial migration and illumination study
- Target region identification
- 3-D ODCIGs and ADCIGs

Regional geological structure



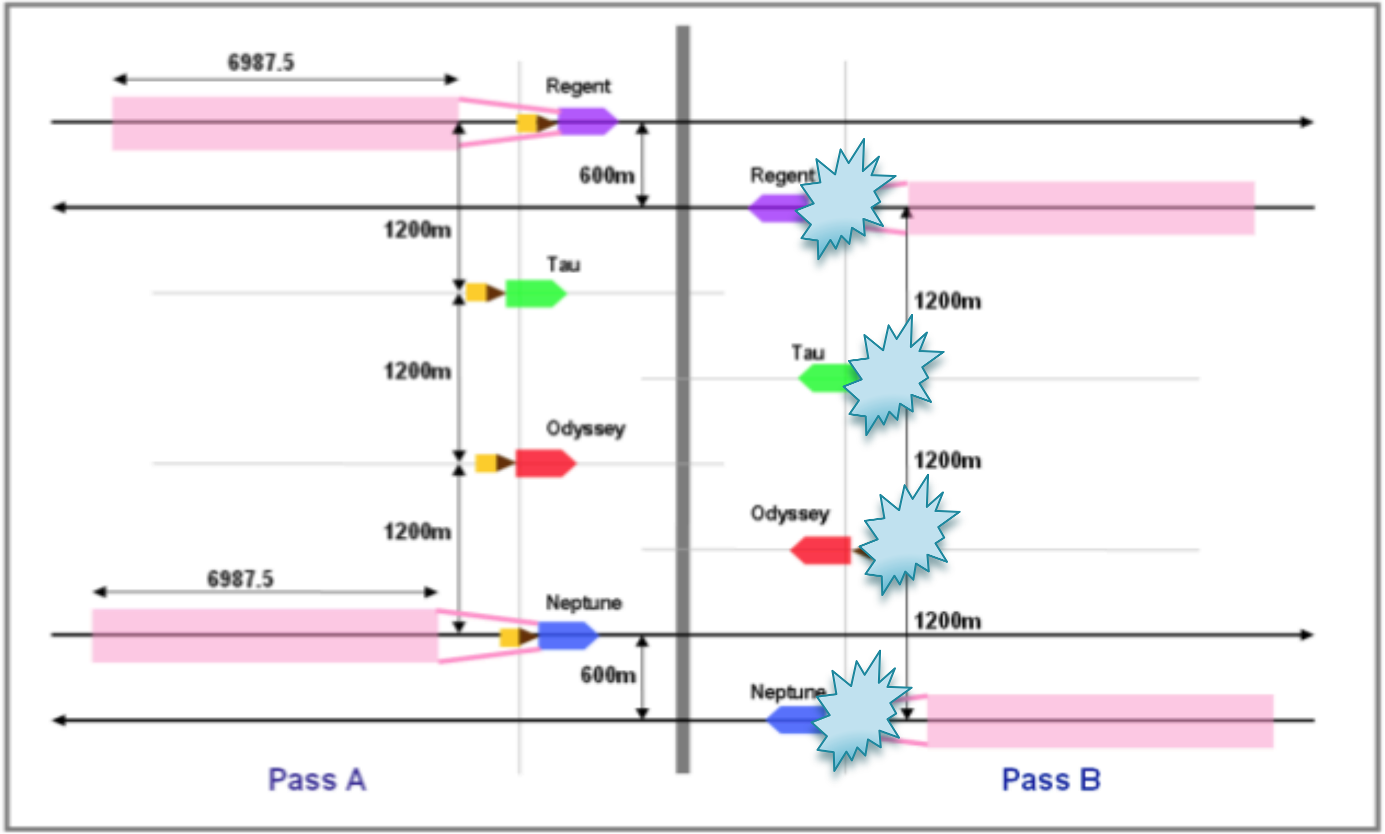
Courtesy of Schlumberger

Nominal acquisition settings

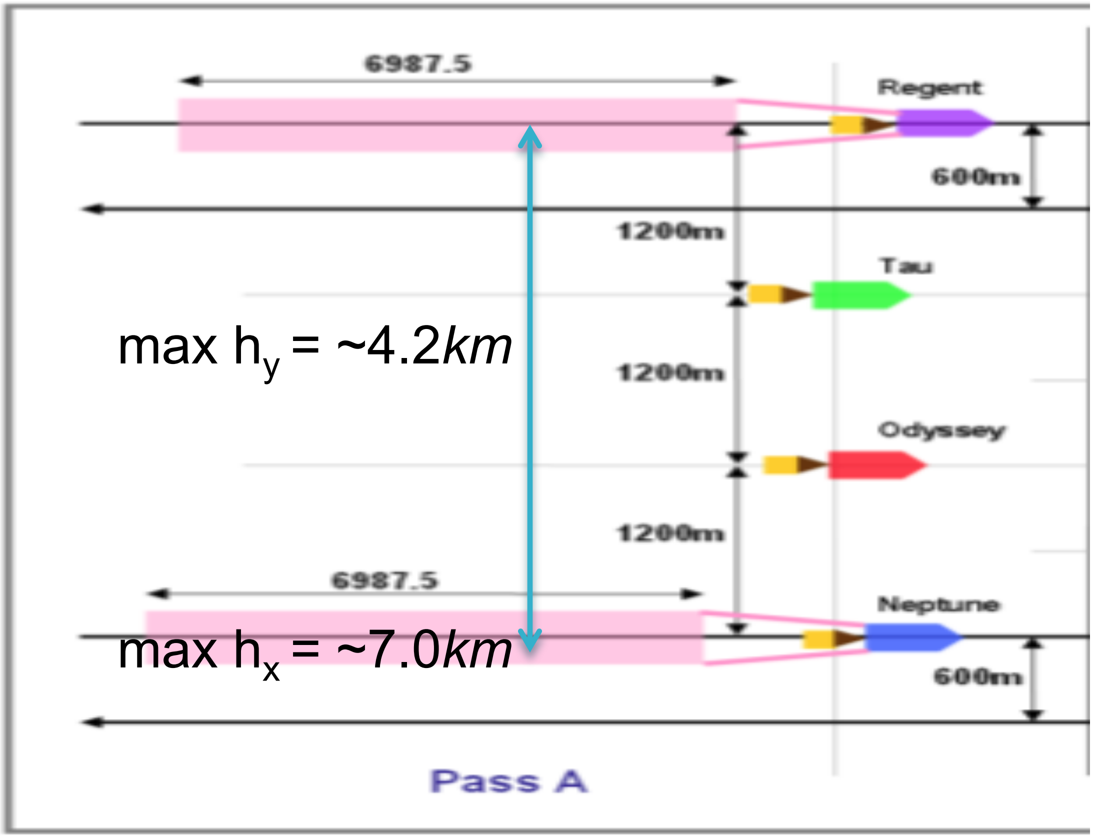


Courtesy of Schlumberger

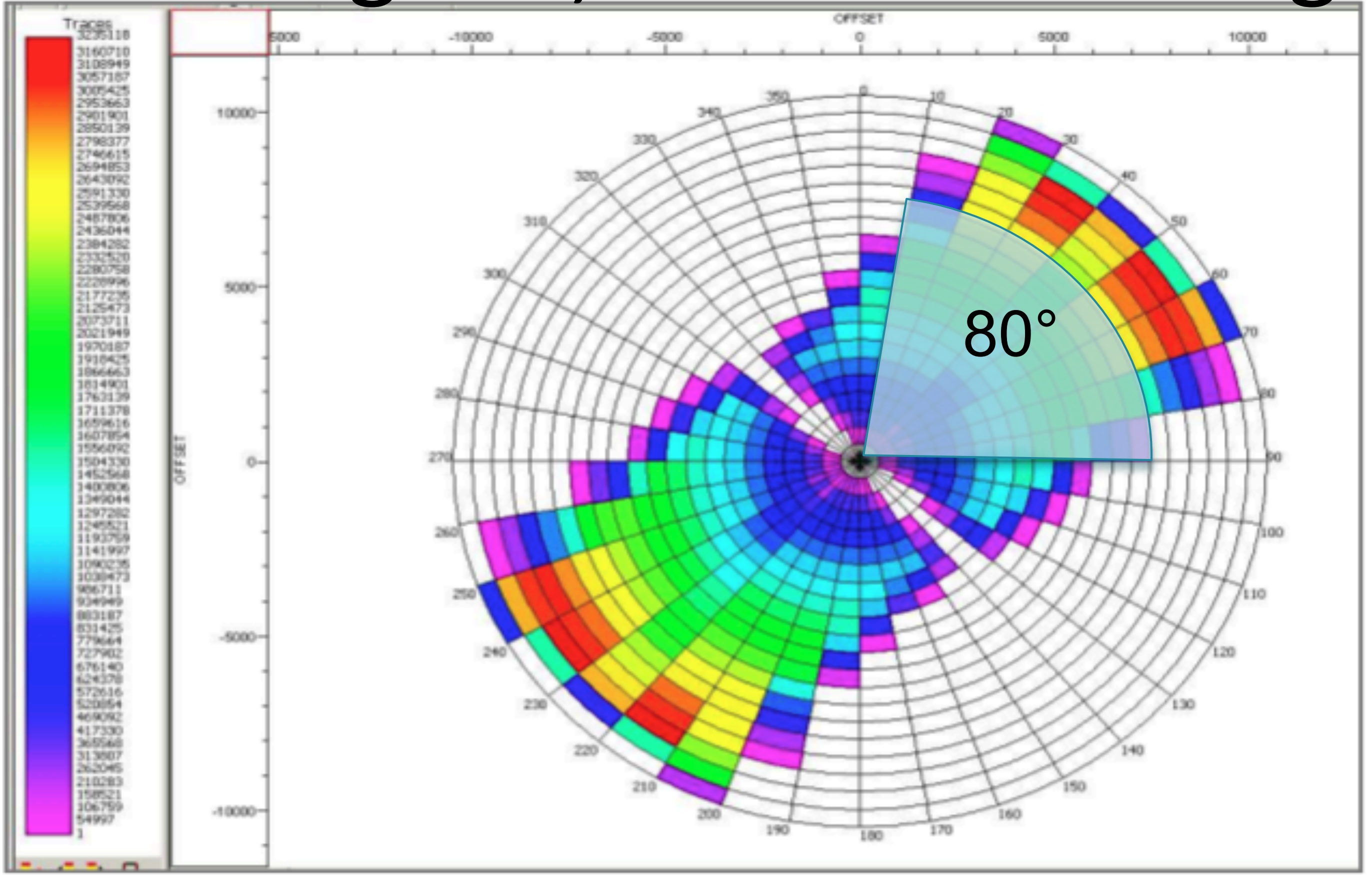
Nominal acquisition settings, cont.



Courtesy of Schlumberger


6987.5
Regent
600m
1200m
Tau
max h_y = ~4.2*km*
1200m
Odyssey
1200m
6987.5
Neptune
max h_x = ~7.0*km*
600m
Pass A

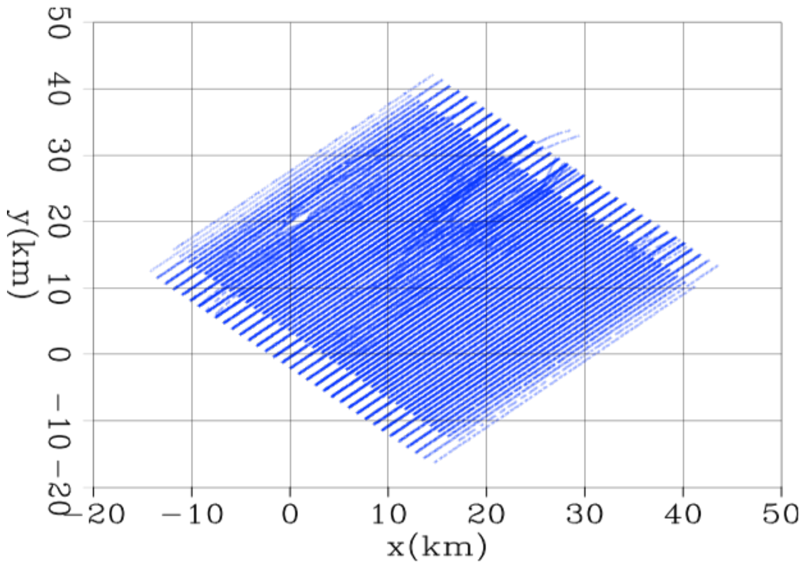
Rose diagram, azimuth coverage



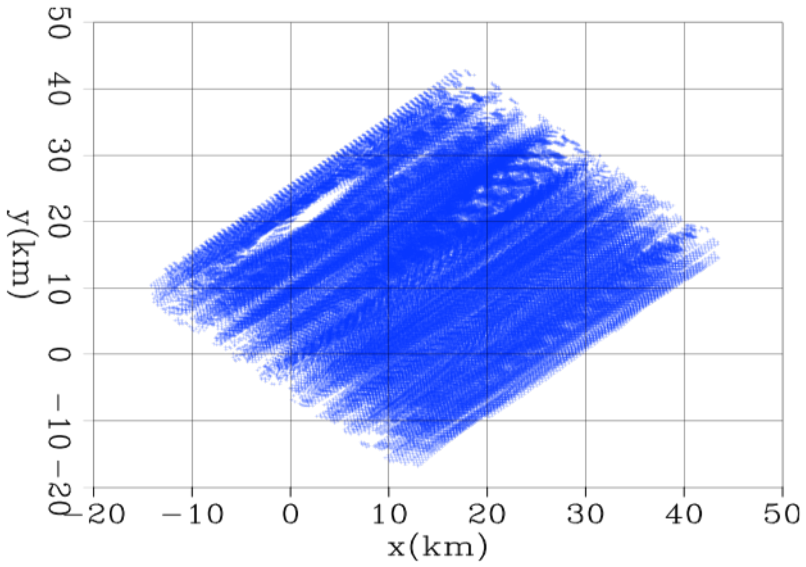
Courtesy of Schlumberger

Overall source/receiver coverage

sources

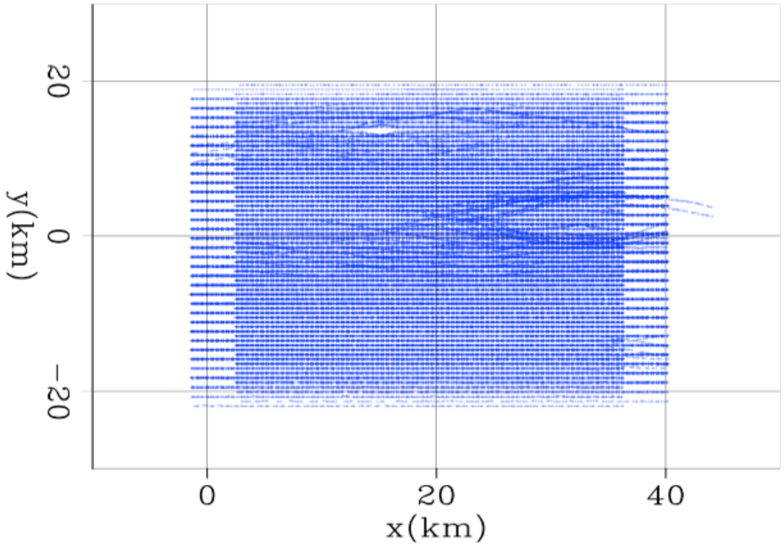


receivers

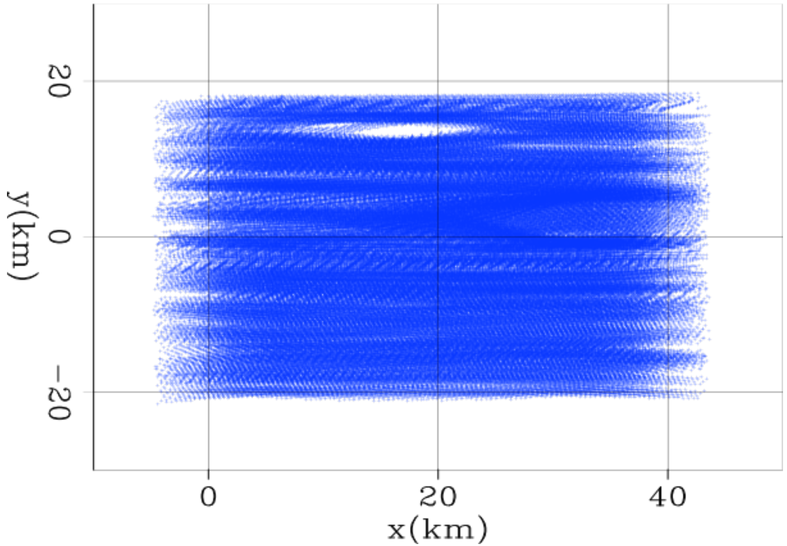


Overall source/receiver coverage

sources

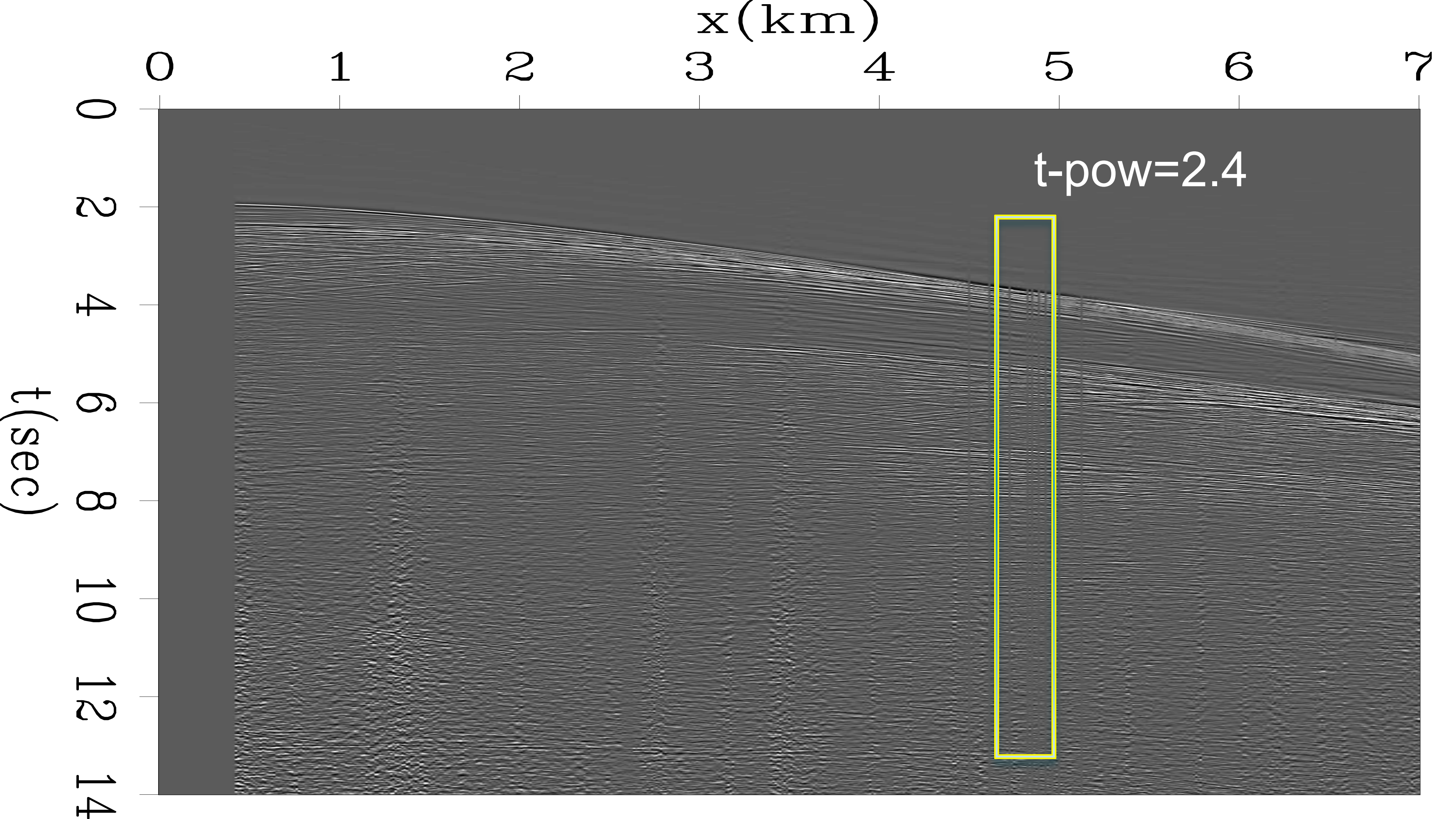


receivers

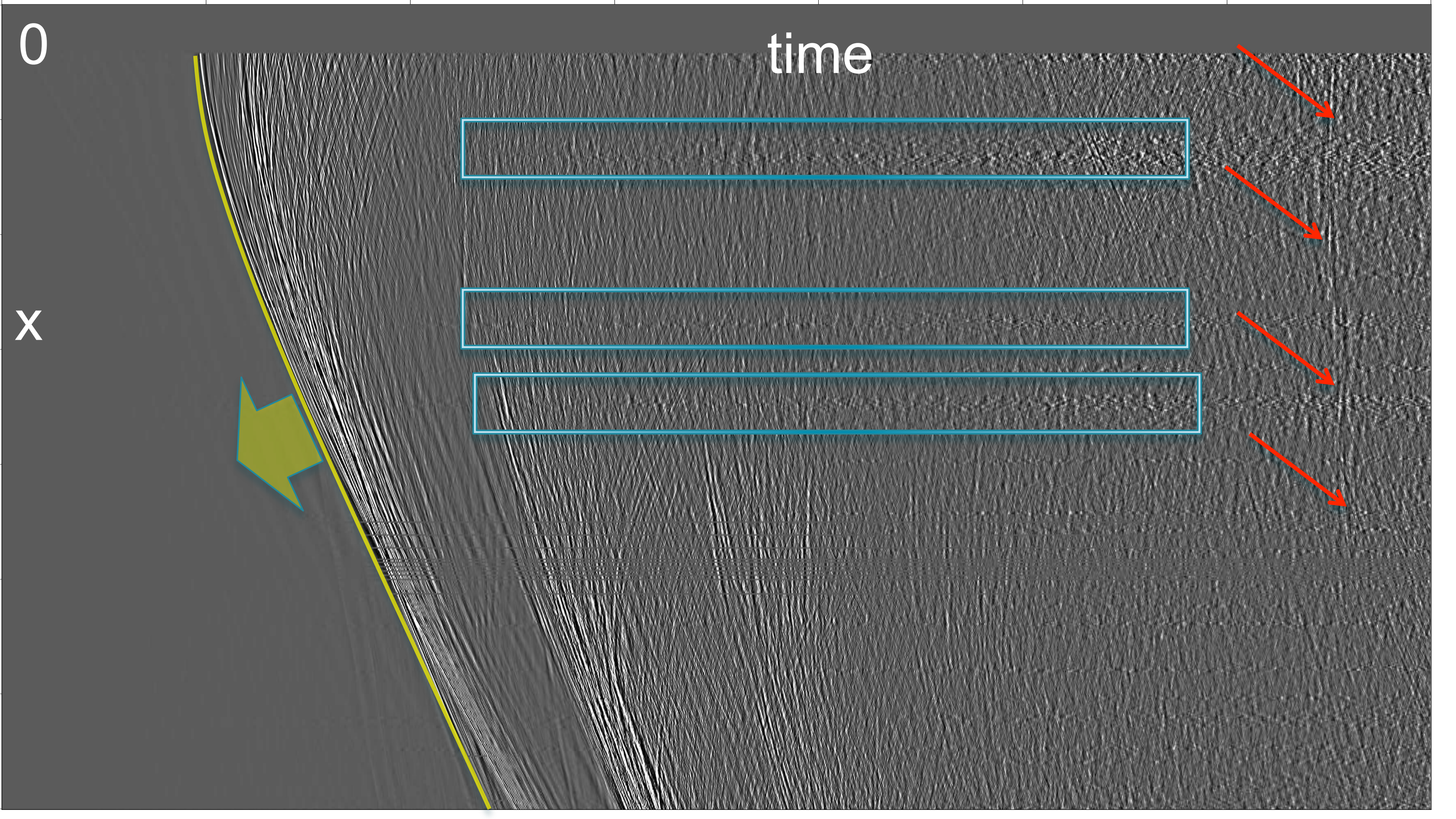


Data regularization, reduce 11TB to 1.9TB

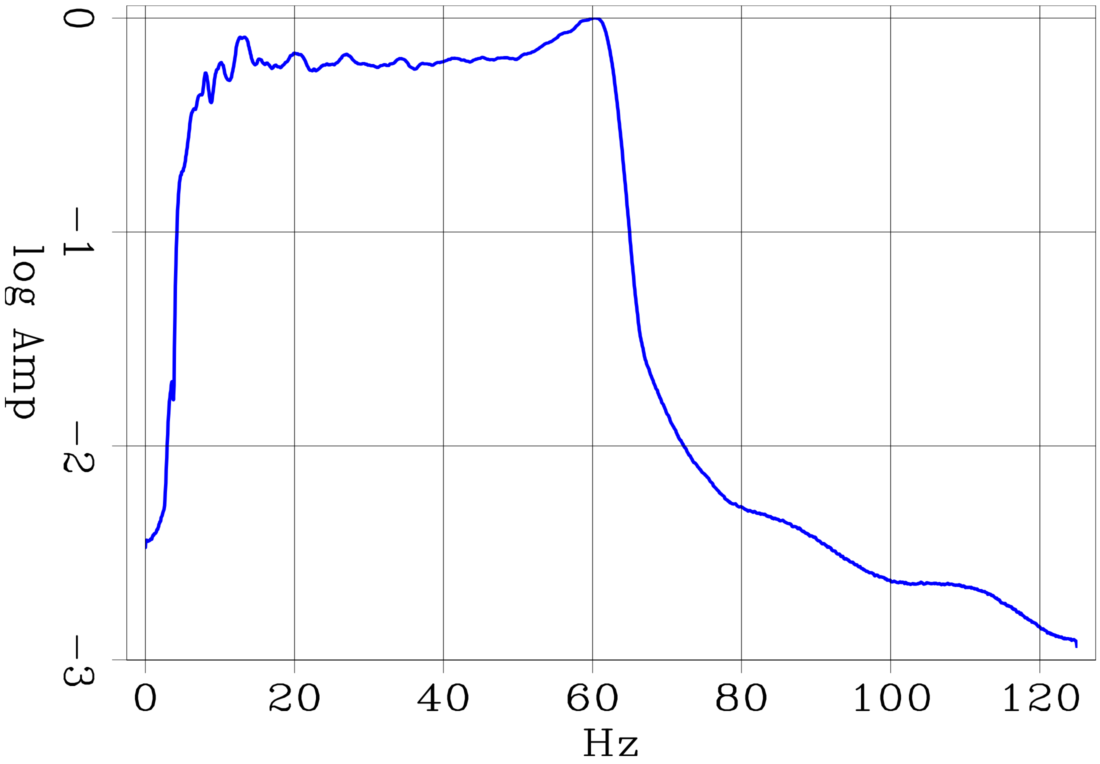
- Geometry rotation
- Sort by common-shot gathers. Pass A shot lines and Pass B shot lines separately.
- Increase inline receiver spacing to 25m
- Discard source-receiver pairs far away from the velocity model
- Group four neighboring shots (<75m inline) into one, reduce total No. of shots by 4x



x(km)
0
1
2
3
4
5
6
7
t(sec)
0
2
4
6
8
10
12
14
t-pow=2.4


0
time
x

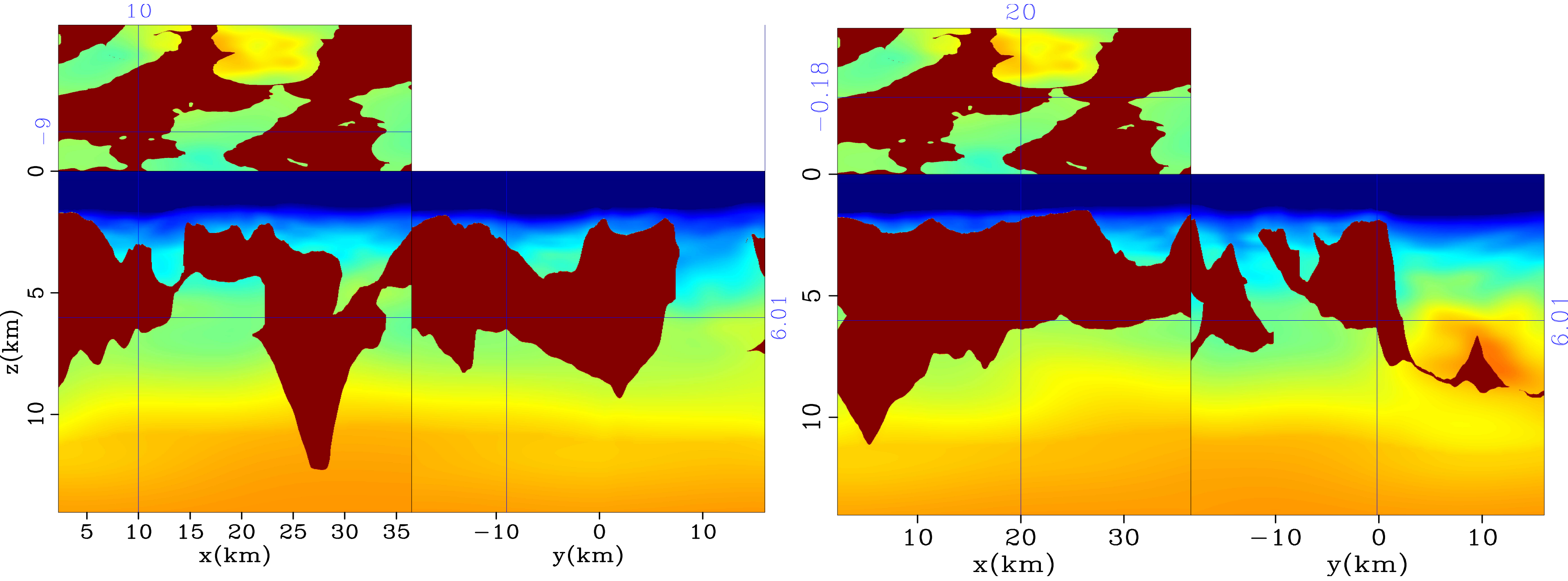
Data frequency spectrum

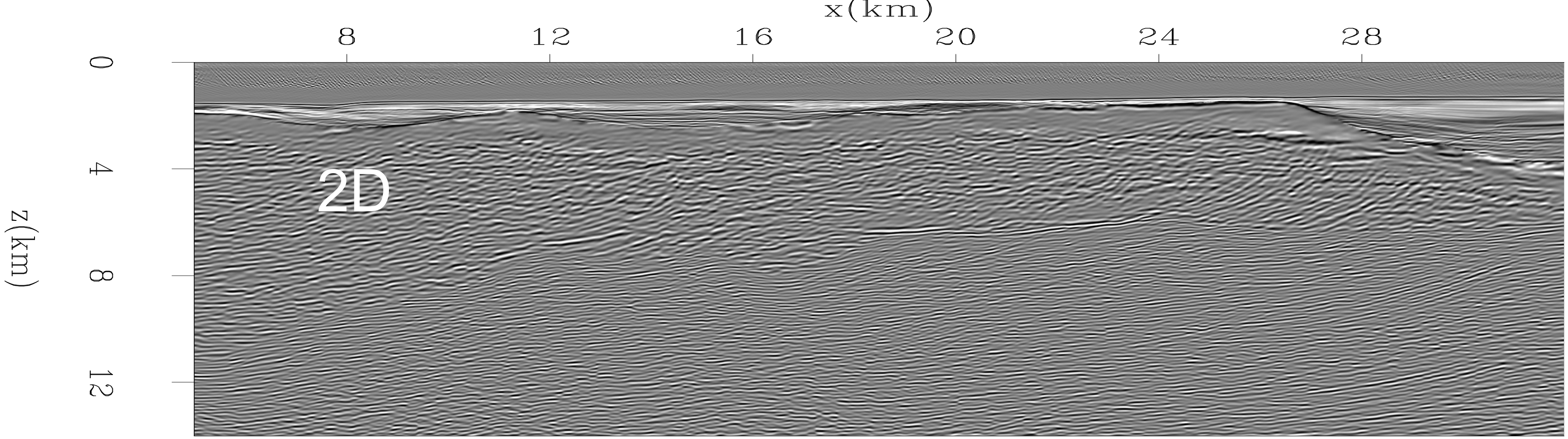


Data pre-processing before migration

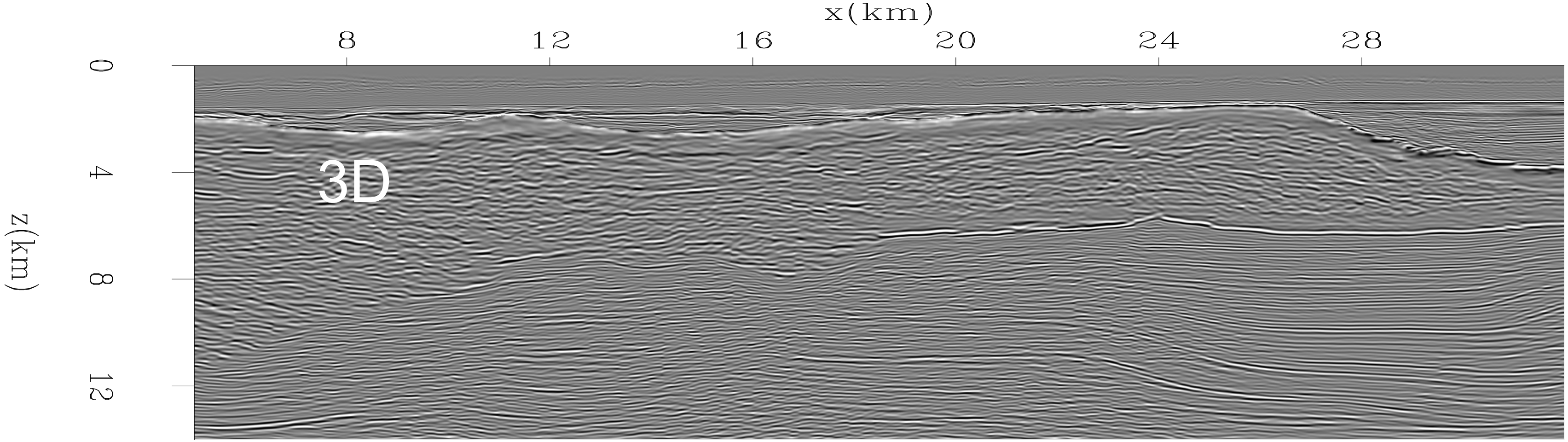
- Mute all events above water-bottom reflections
- Gain the data at later time value (Tpow)
- Using the frequency data in range [5*Hz*,20*Hz*], further reduce the data size and computation cost

Velocity model for migration

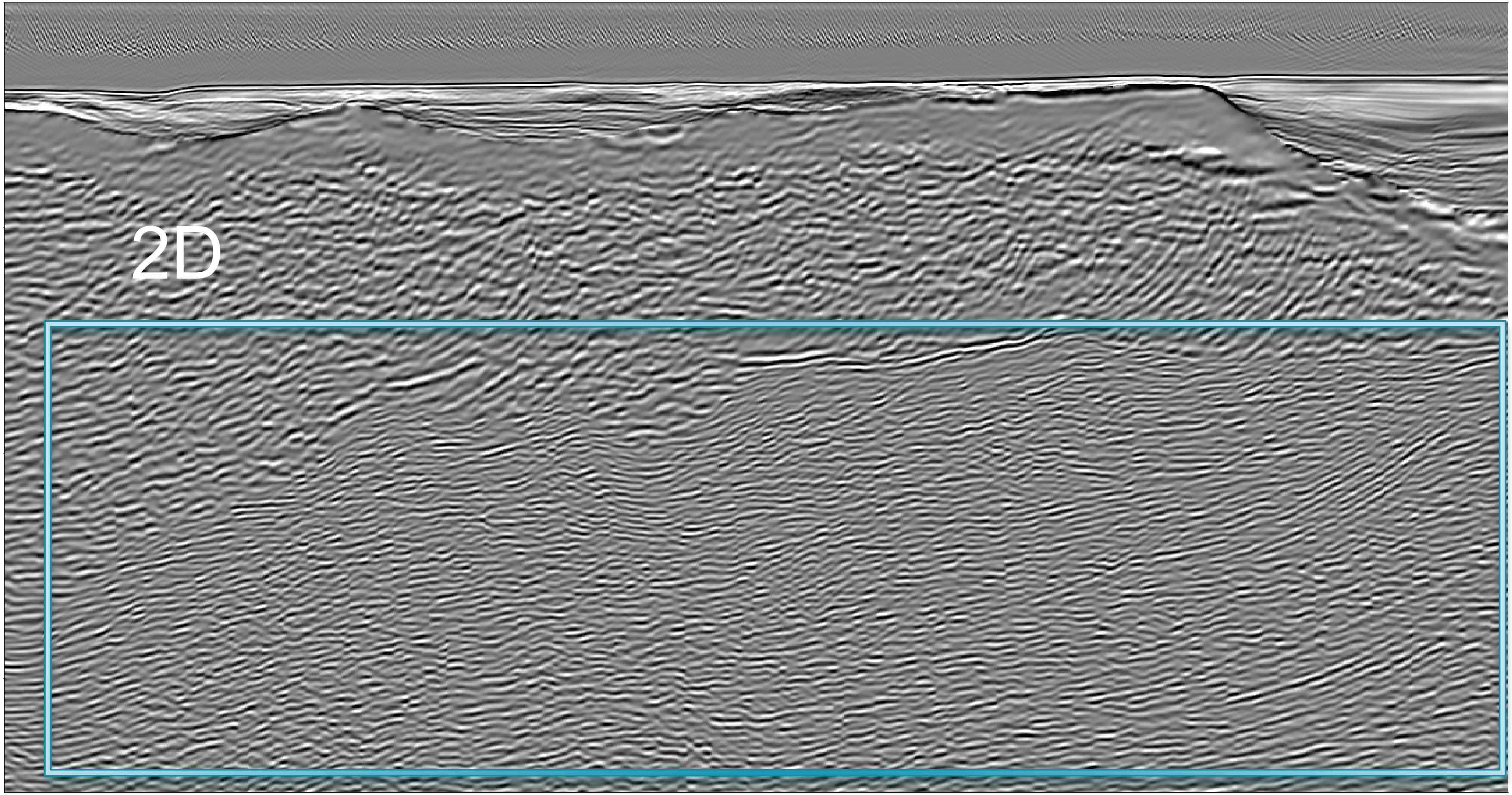


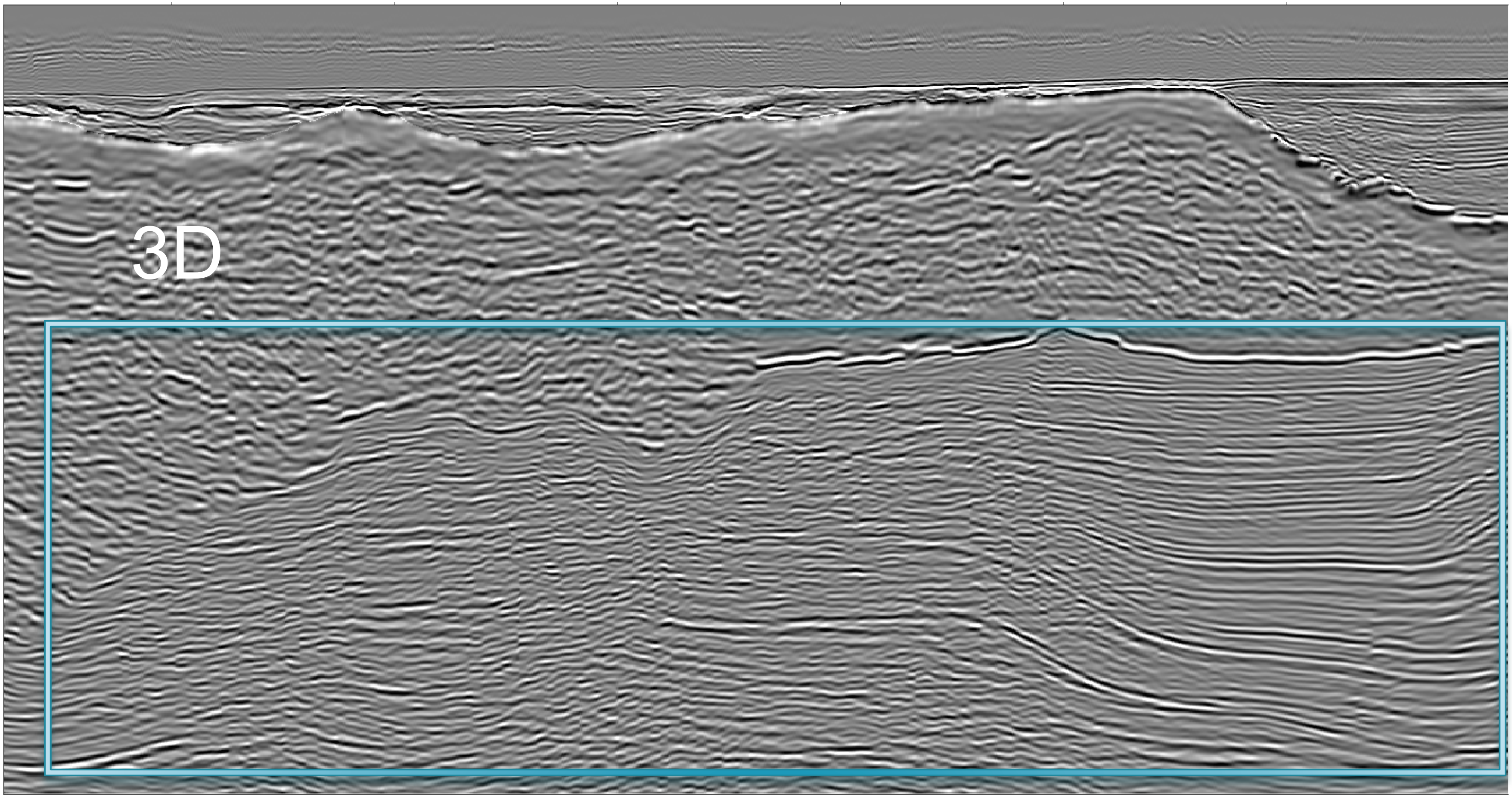


(a)

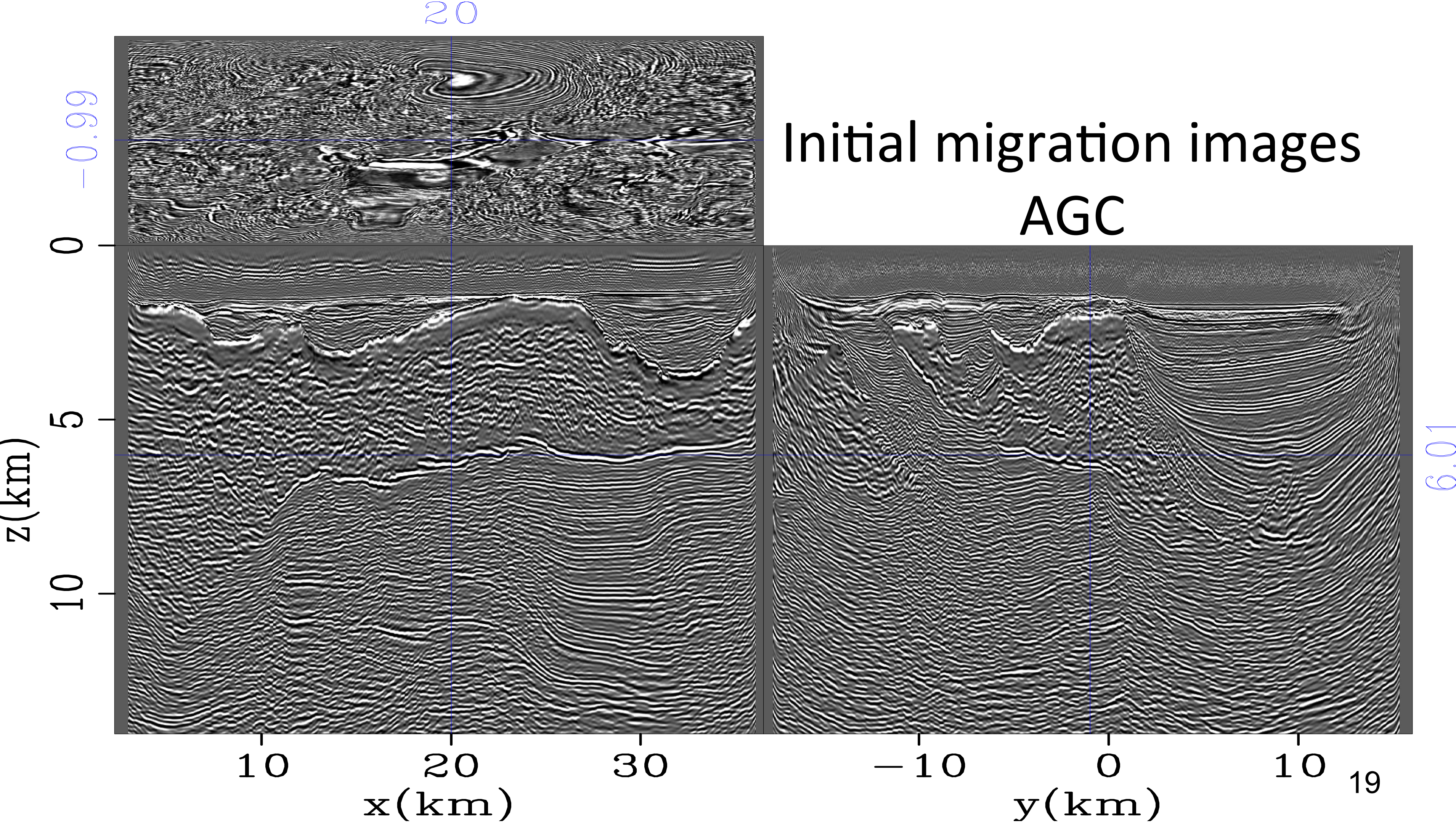


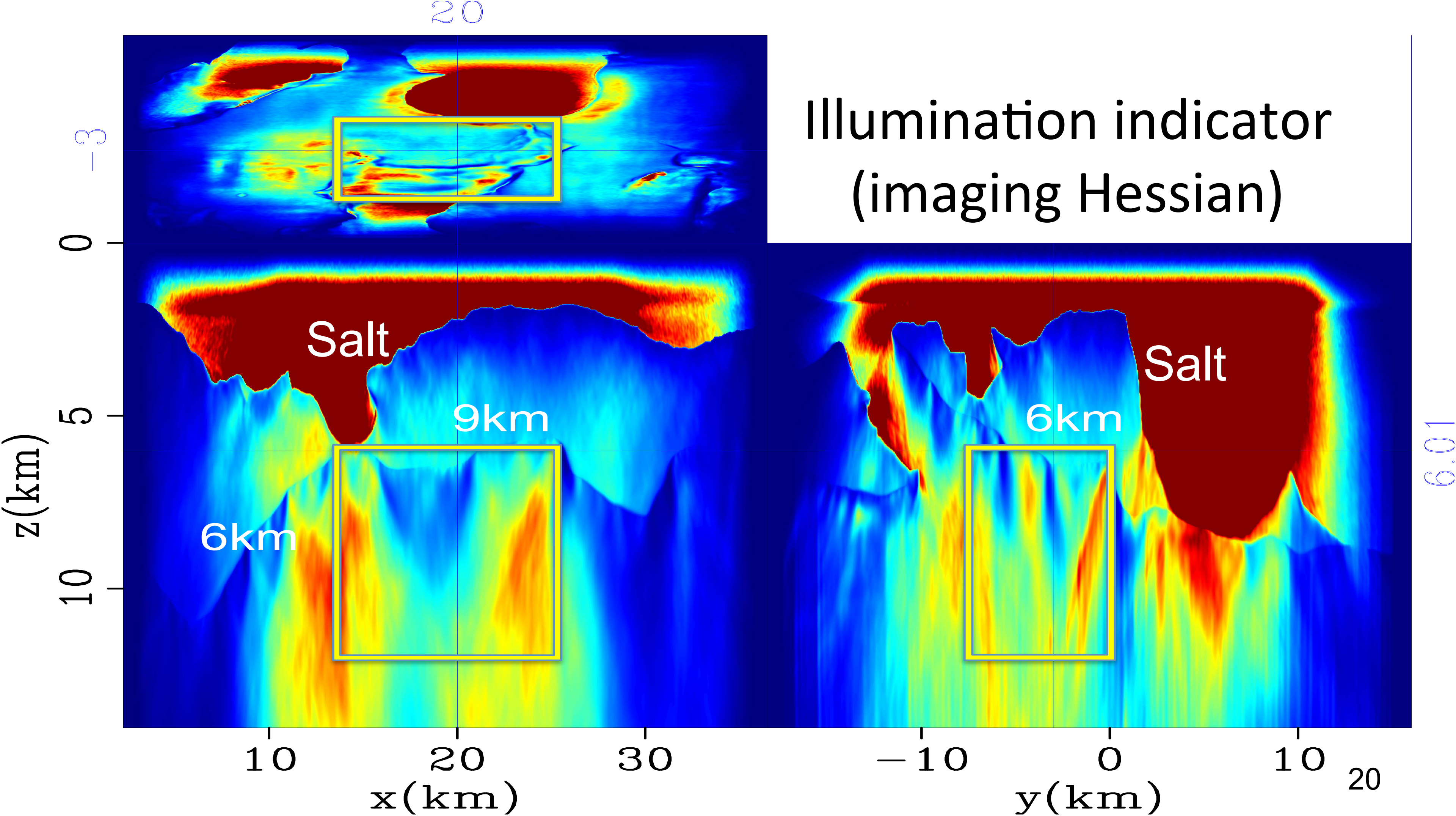
(b)


2D

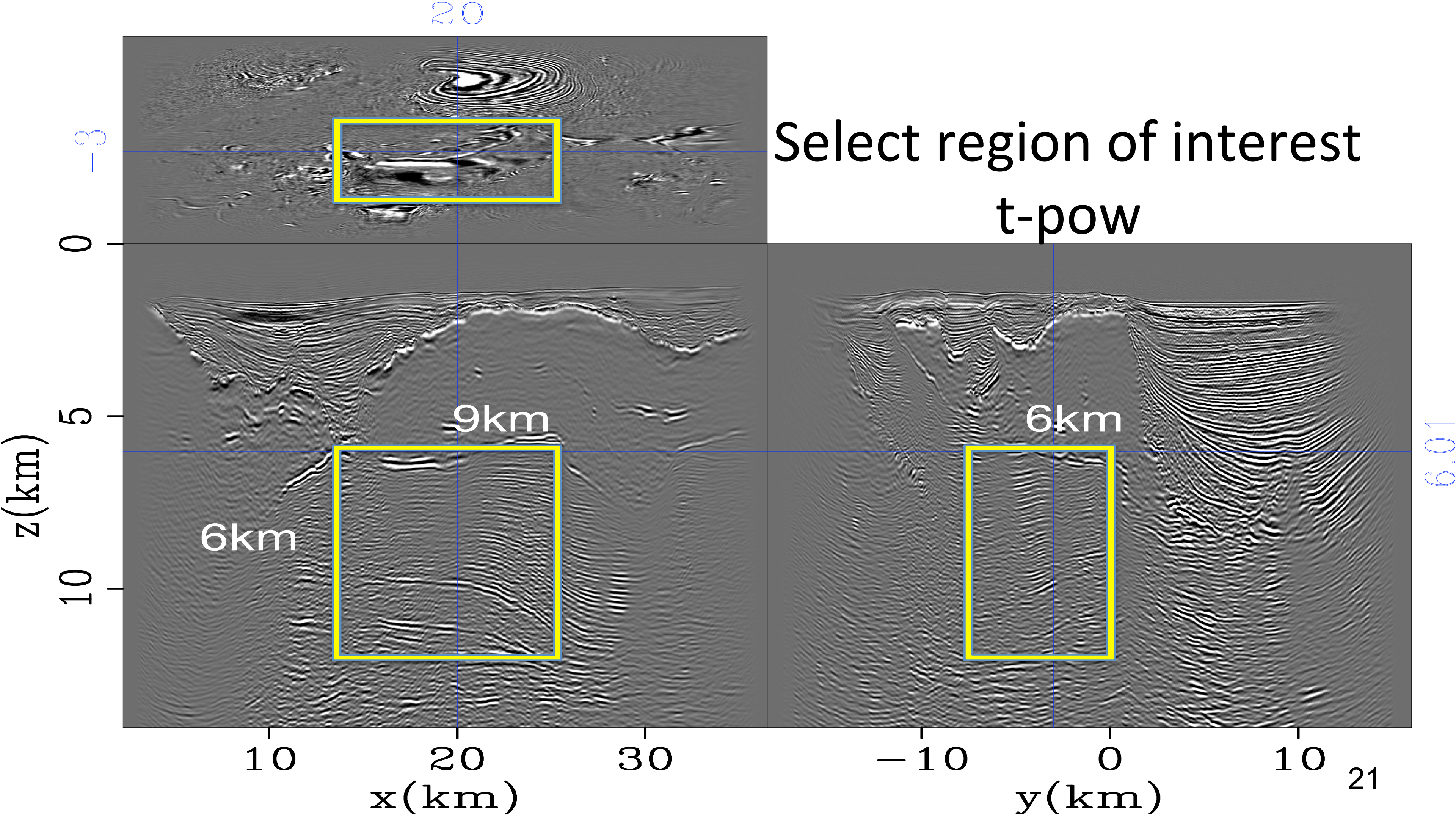

3D

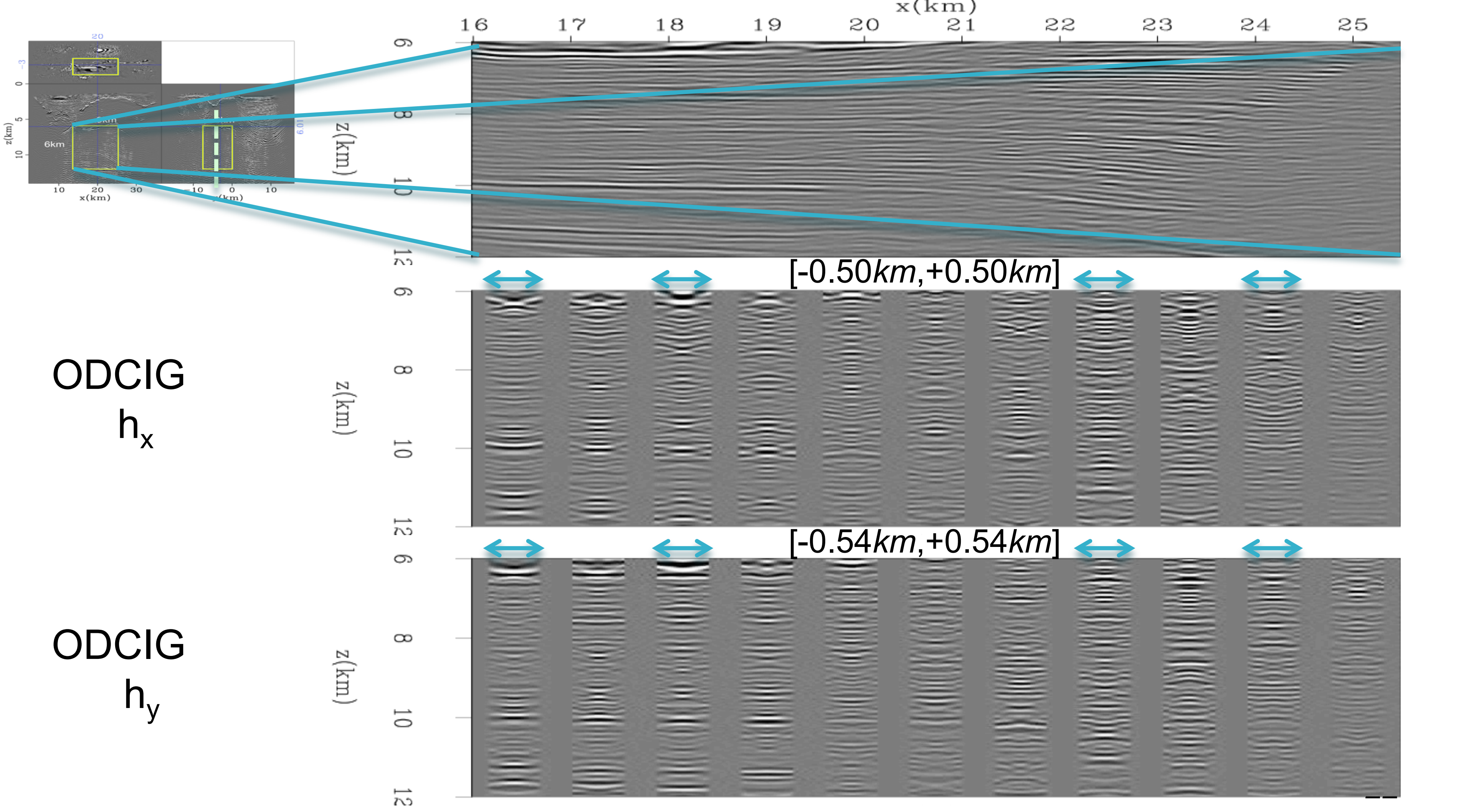
Initial migration images
AGC




Illumination indicator
(imaging Hessian)
Salt
Salt
9km
6km
6km
z(km)
x(km)
y(km)
0
5
10
10
20
30
−10
0
10
−3
20
6.01

Select region of interest
t-pow





x(km)
16
17
18
19
20
21
22
23
24
25
z(km)
6
8
10
12
[-0.50km,+0.50km]
ODCIG
h_x
[-0.54km,+0.54km]
ODCIG
h_y
x(km)
y(km)
6km

The transform of offset -> angle 3D CIGs

1. Perform Fourier transform $I(hx, hy, x, y, z) \rightarrow I(hx, hy, k_x, k_y, k_z)$.

2. For each (k_x, k_y, k_z),

   - apply Fourier transform $I(hx, hy) \rightarrow I(k_{hx}, k_{hy})$
   - map $I(k_{hx}, k_{hy}) \rightarrow I(\gamma, \phi)$ based on the following relations (Tisserant and Biondi, 2003):

$$
\begin{bmatrix} k'_x \\ k'_y \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} k_x \\ k_y \end{bmatrix}
$$

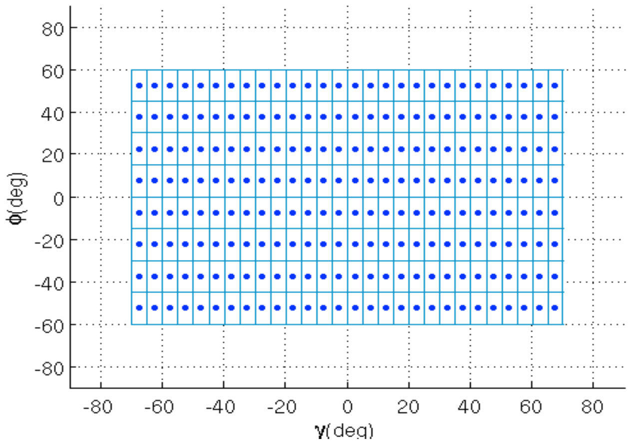
$$
k'_{hx} = k_z \sqrt{1 + (k'_y/k_z)^2} \tan\gamma
$$

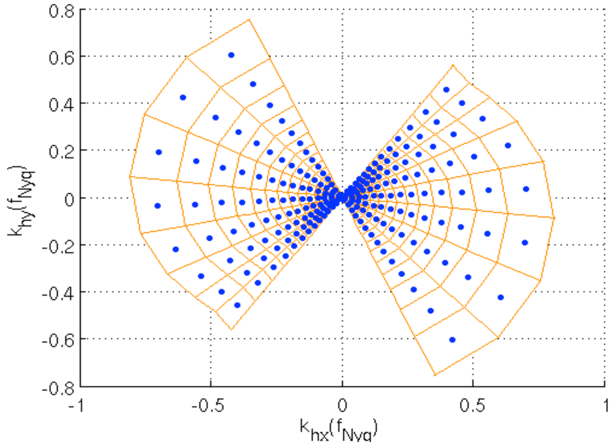
$$
k'_{hy} = \frac{k'_y k'_x k'_{hx}}{k'^2_y + k^2_z}
$$

$$
\begin{bmatrix} k_{hy} \\ k_{hy} \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} k'_{hx} \\ k'_{hy} \end{bmatrix}.
$$

3. Apply inverse Fourier transform $I(\gamma, \phi, k_x, k_y, k_z) \rightarrow I(\gamma, \phi, x, y, z)$.

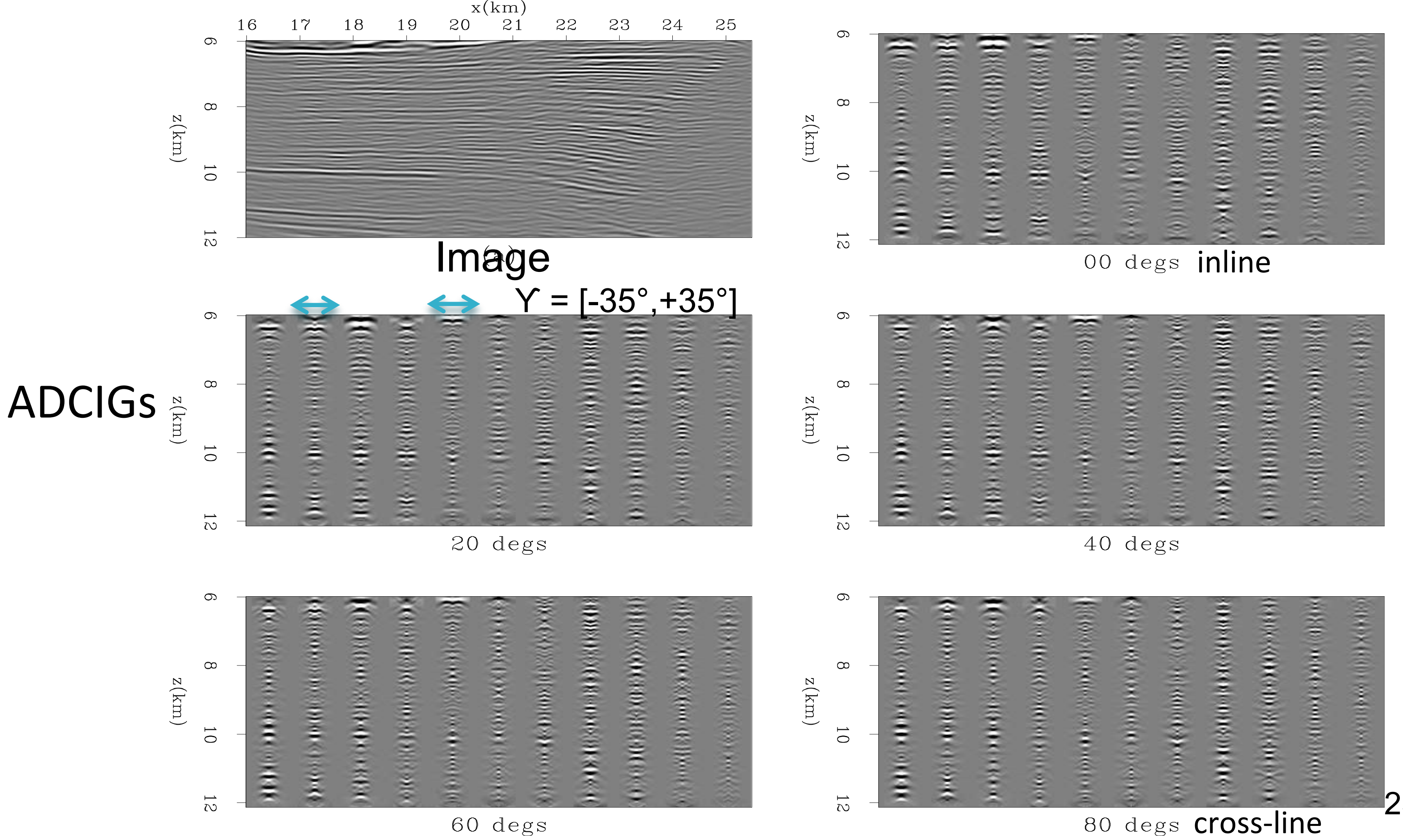
Angle to offset mapping, irregularity

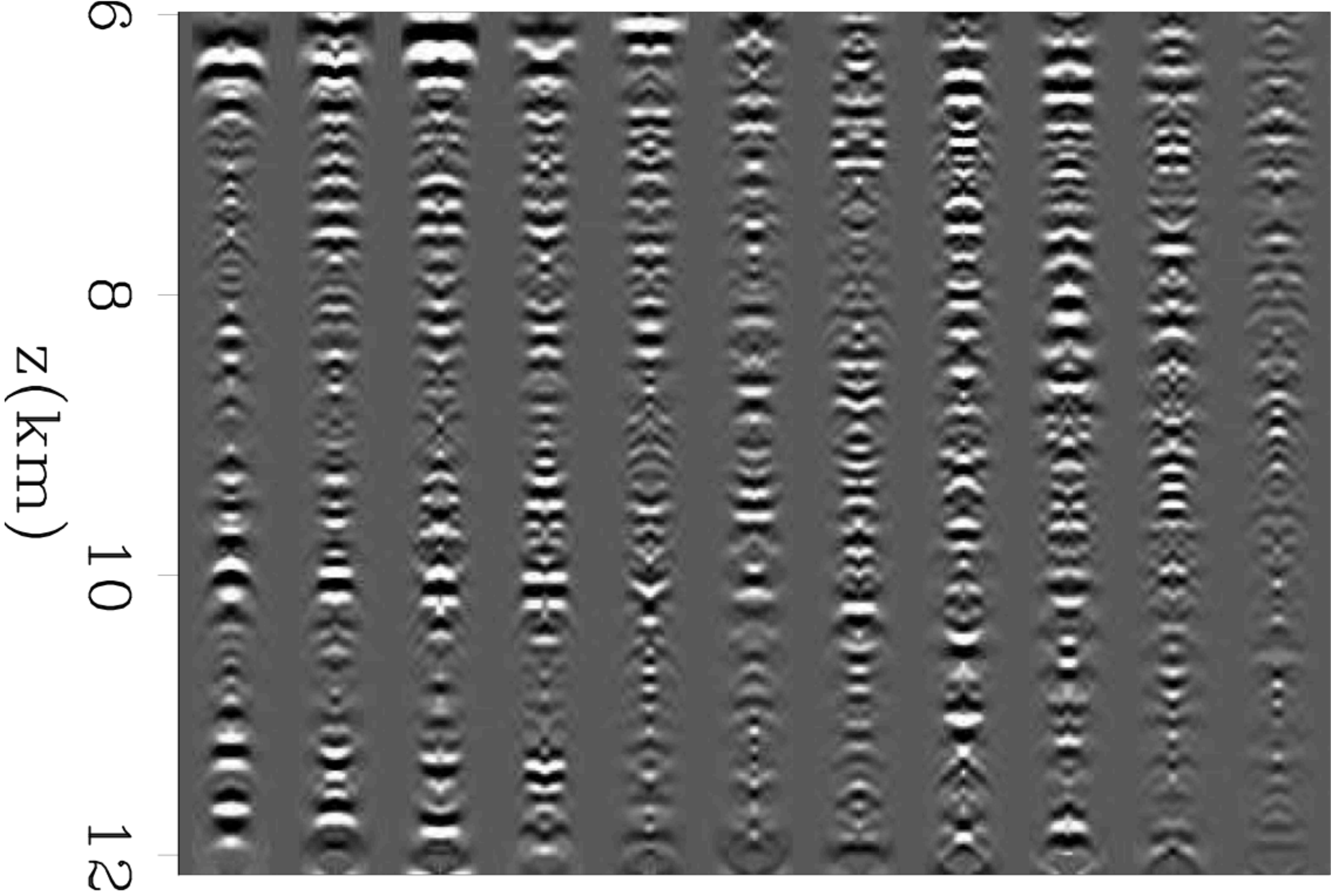




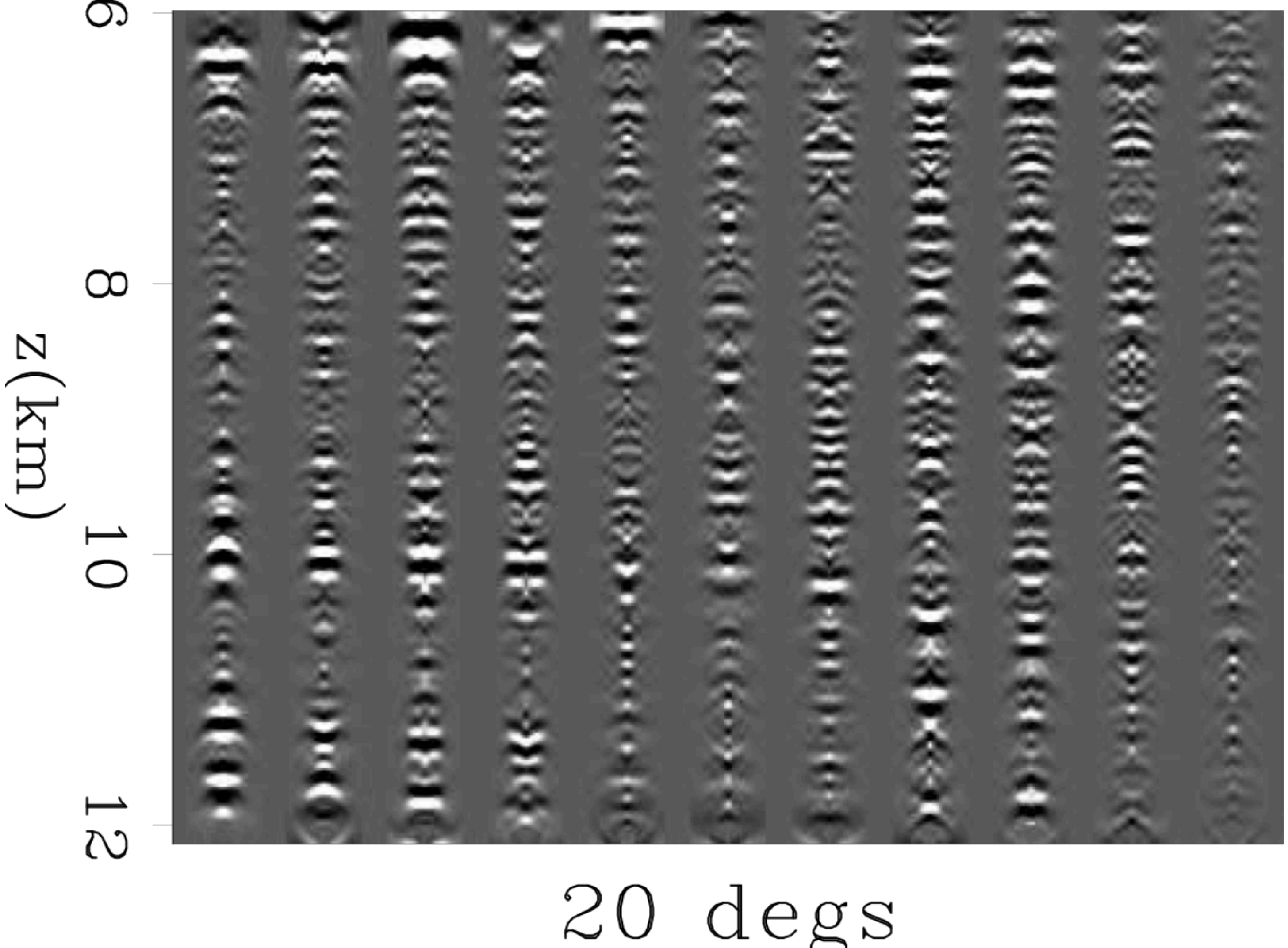
(γ, ϕ)

(k_{hx},k_{hy})

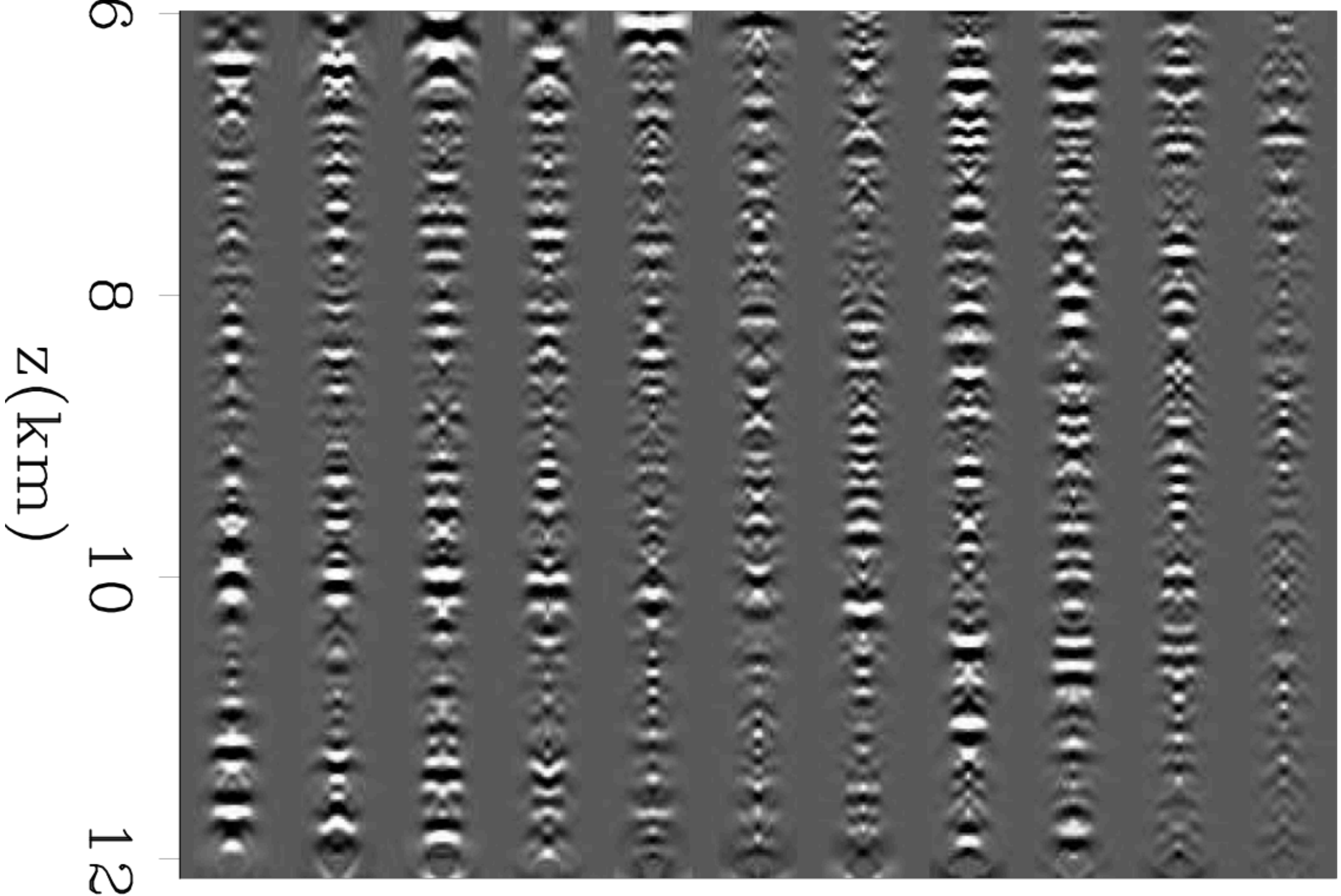

x(km)
16
17
18
19
20
21
22
23
24
25
z(km)
6
8
10
12
Image
Y = [-35°,+35°]
ADCIGs
00 degs
inline
20 degs
40 degs
60 degs
80 degs
cross-line



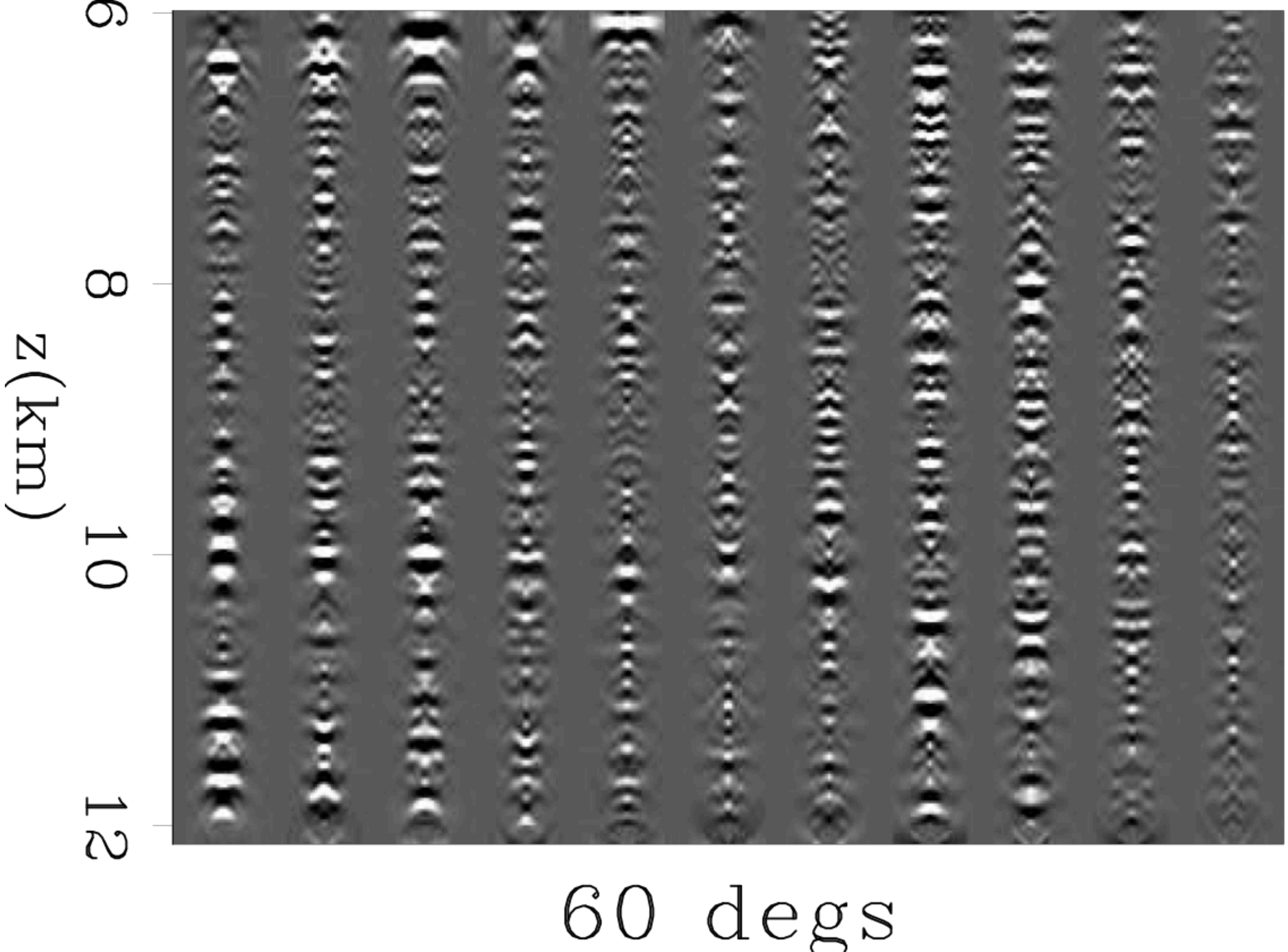
00 degs

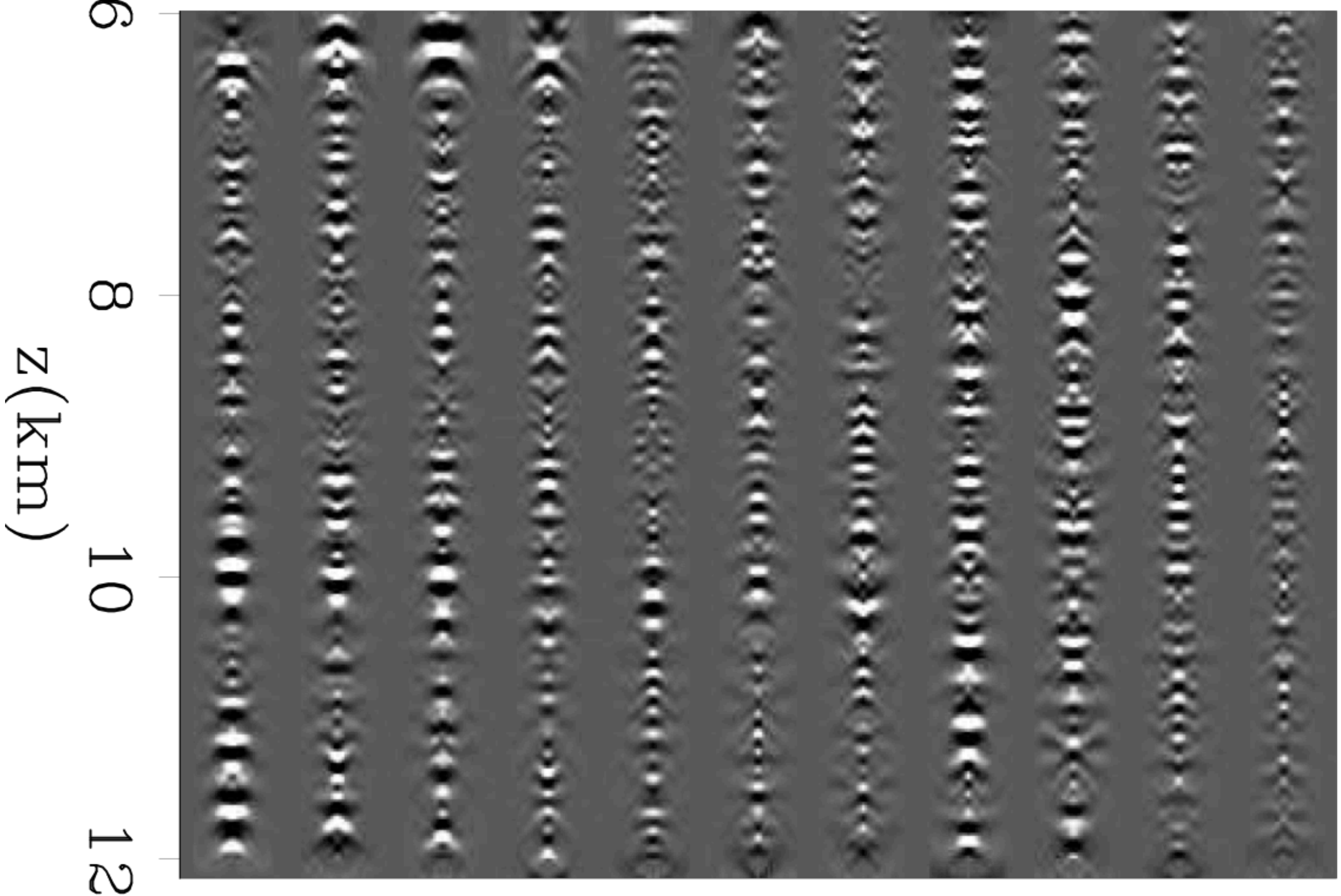


6
8
10
12
z(km)
20 degs



40 degs


6
8
10
12
z(km)
60 degs



80 degs

Conclusion

- We successfully applied our imaging algorithm on a large-scale 3-D field WAZ data set
- By careful data regularization and pre-processing, we are able to make the computational cost affordable on our academic computing cluster
- The computed 3-D ADCIGs demonstrated clearly indicates the room for velocity improvement in the target subsalt area

Future work

- Further tune our RMO-based WEMVA method on this data set to achieve more model improvement
- Test the compressive-sensing based ADCIGs reconstruction on this 3-D imaging example

Acknowledgement

- Schlumberger
- Bob Clapp, Dave Nichols, Elita Li, Yaxun Tang

Questions?

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