# *Extended* images in *action*
## *(efficient AVA via probing)*

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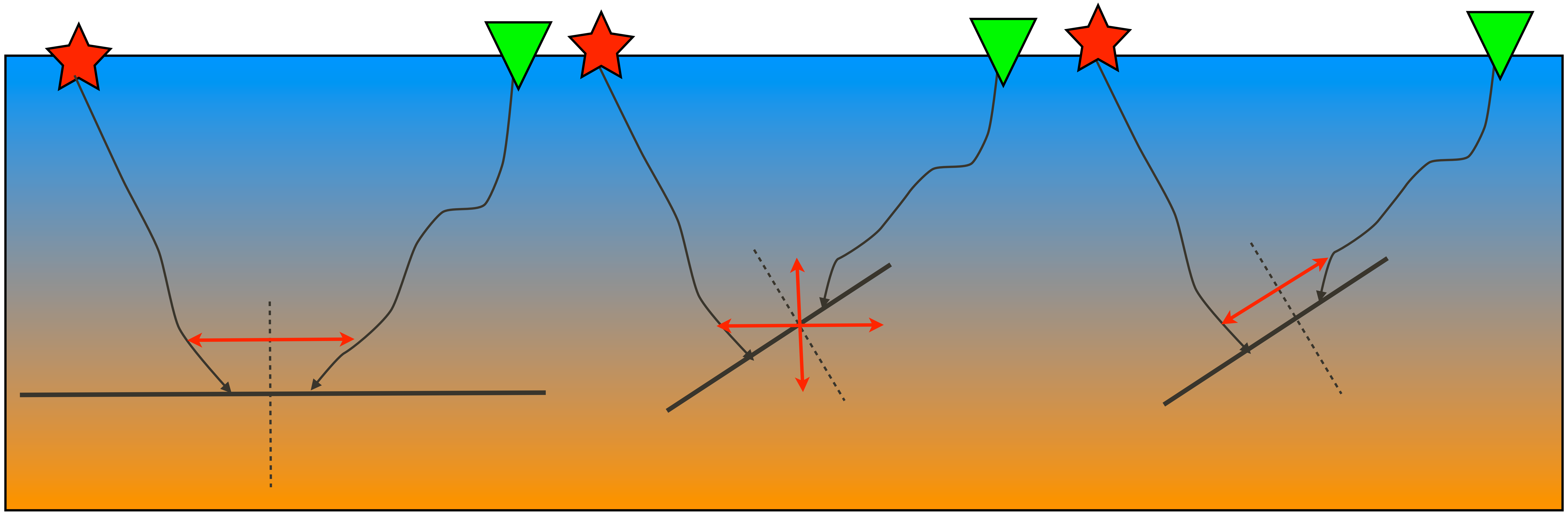
# Motivation

- Computation of *full*-subsurface offset volumes is computationally *prohibitively* expensive
  (storage & computation time)

- *Full*-subsurface *offset* volumes allow us to conduct
  - AVA w/ geologic *dip* corrections

  using information from *all* offset directions.

[Biondo & Symes, ’04 ;Sava & Vasconcelos, ’11]

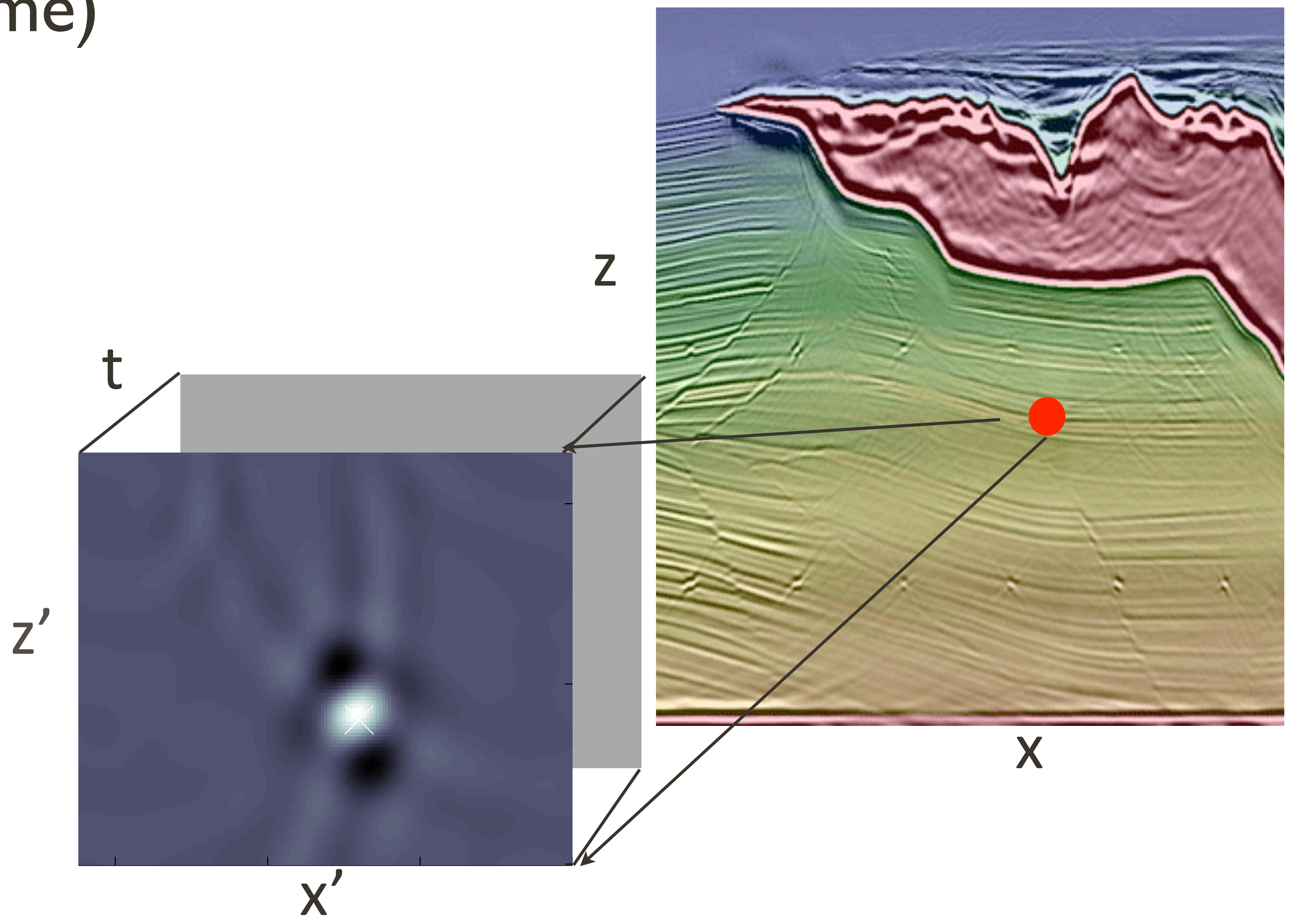


horizontal offset

horizontal +vertical offset

all offsets

- use *all* subsurface offsets (5D volume)
- 2-way wave-equation




but.... we can *never* hope to *compute* or *store* such an *extended* image volume!

Can we work with the *extended* volume *implicitly* ?

# Overview

- Anatomy
- Computation
- Dip angle gather
- Application
- Conclusion
- Future work

# Anatomy

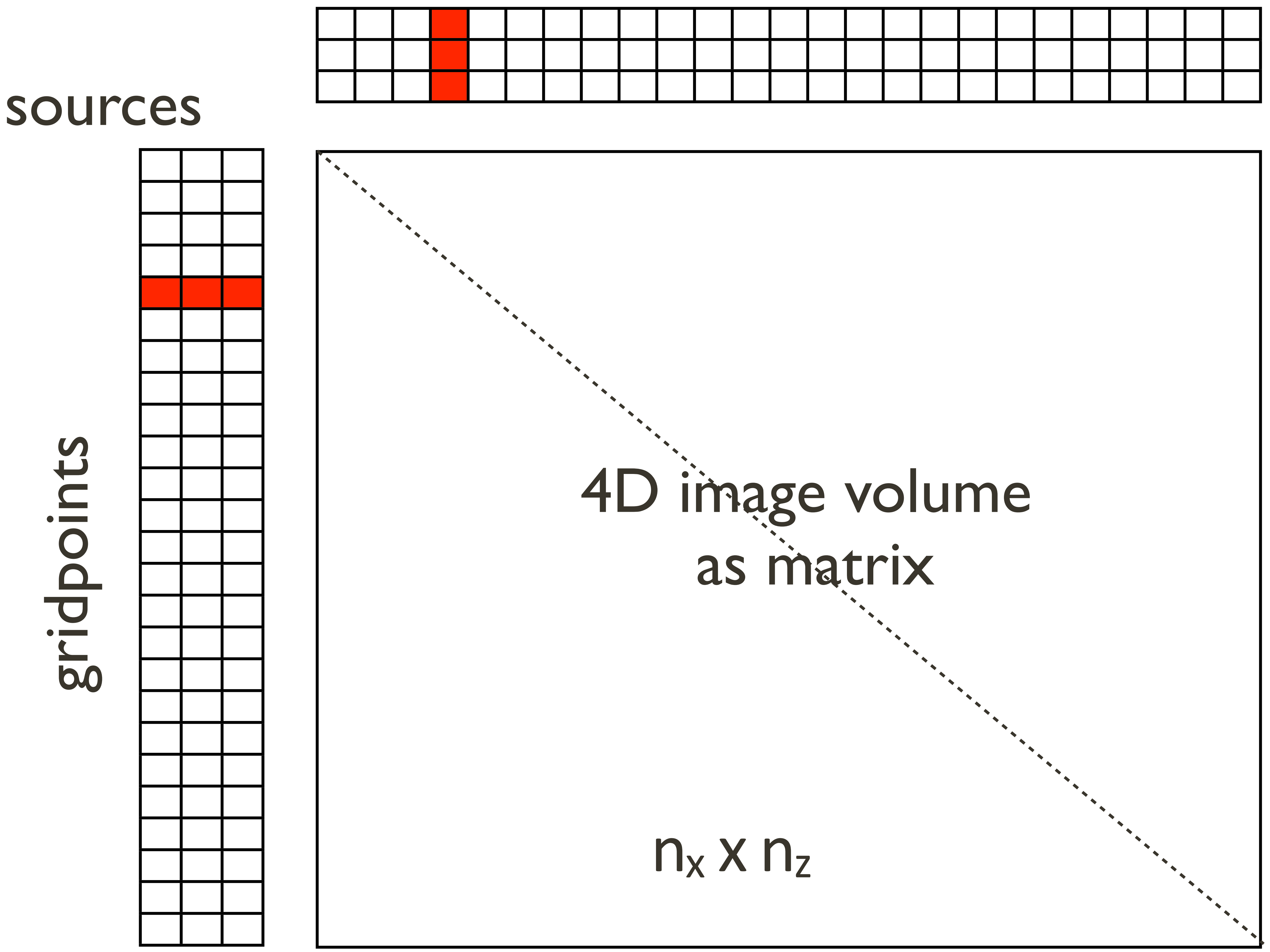
$$e(\omega, \mathbf{x}, \mathbf{x}') = \sum_i u_i(\omega, \mathbf{x}) v_i(\omega, \mathbf{x}')^*$$

- Organize wavefields in monochromatic data matrices

- Express *extended* image volume *tensor* as *matrix*

$$E = UV^*$$

# Extended images



# Computation

- *Complete* image volume too *large* to form: $(n_x \times n_z)^2$
- instead, *probe* volume for information via *mat-vecs* $E\mathbf{w}$ van Leeuwen 2012
- $\mathbf{w}$ can be interpreted as subsurface (sim.) *source* function

# Computation

- *mat-vec* with extended image :

$$\widetilde{E} = EW = H^{-1} P_s^T Q D^* P_r H^{-1} W$$

- $\widetilde{\mathbf{d}} = P_r H^{-1} \mathbf{y}$ *(one subsurface source)*
- $\widetilde{\mathbf{w}} = D^* \widetilde{\mathbf{d}}$ *( source weight)*
- $\widetilde{E} = H^{-1} P_s^T Q \widetilde{\mathbf{w}}$ *(one source)*

# Computation

Are able to compute full-subsurface offset extended images

- w/o *looping* over *all* source

- probe image space w/ arbitrary *test* function
  - *point* scatterers (one at location of subsurface point)
  - Gaussian weights (*simultaneous* source)

# Computation

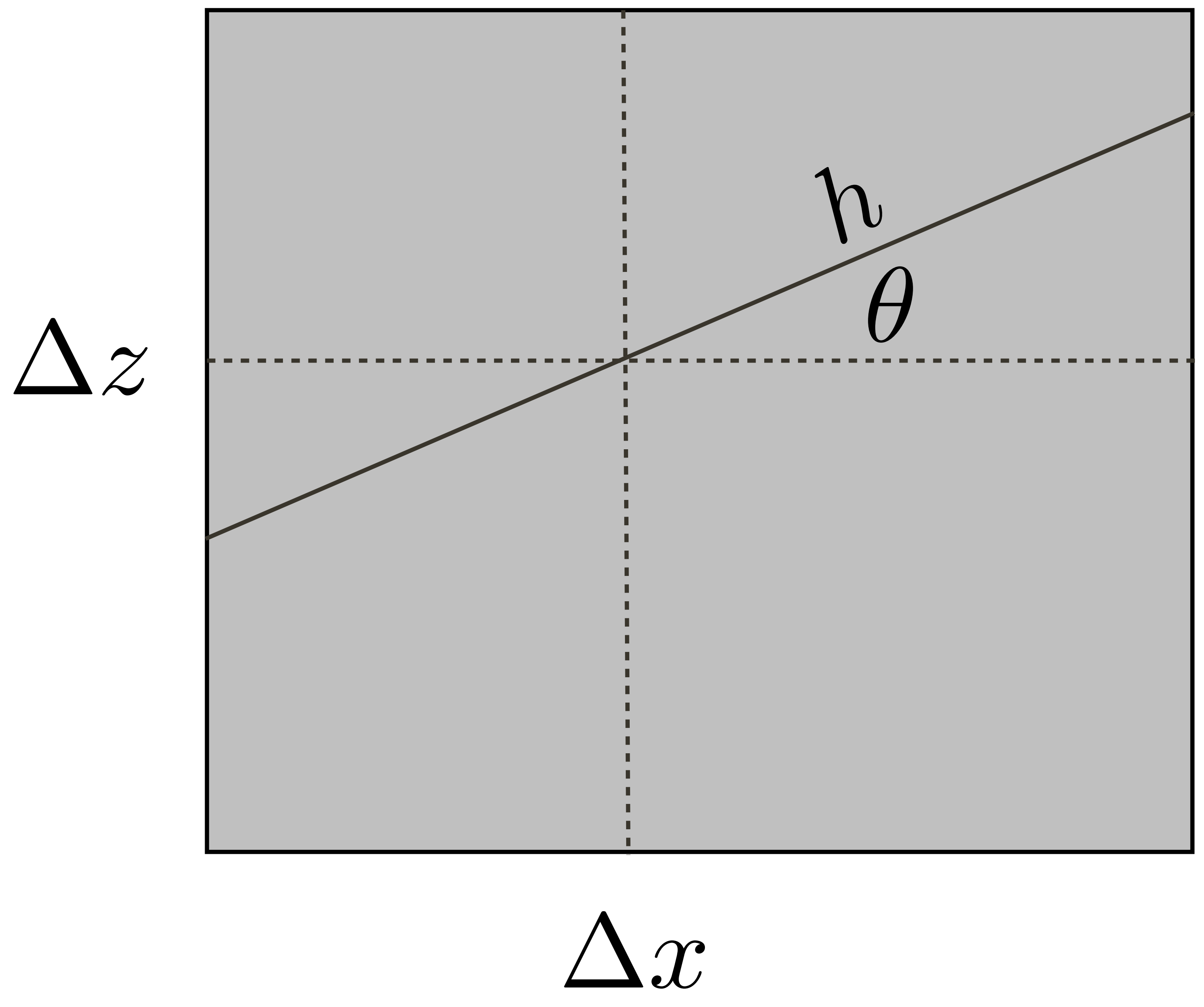
computation of an *image point gathe*

| | # of PDE solves | "flops for correlations" |
|---|---|---|
| conventional | $2N_s$ | $N_s \times N_h$ |
| mat-vecs | $2N_x$ | $N_s \times N_r$ |

$N_s$ - # of sources
$N_r$ - # of receivers
$N_h$ - # of subsurface offsets
$N_x$ - # of sample points

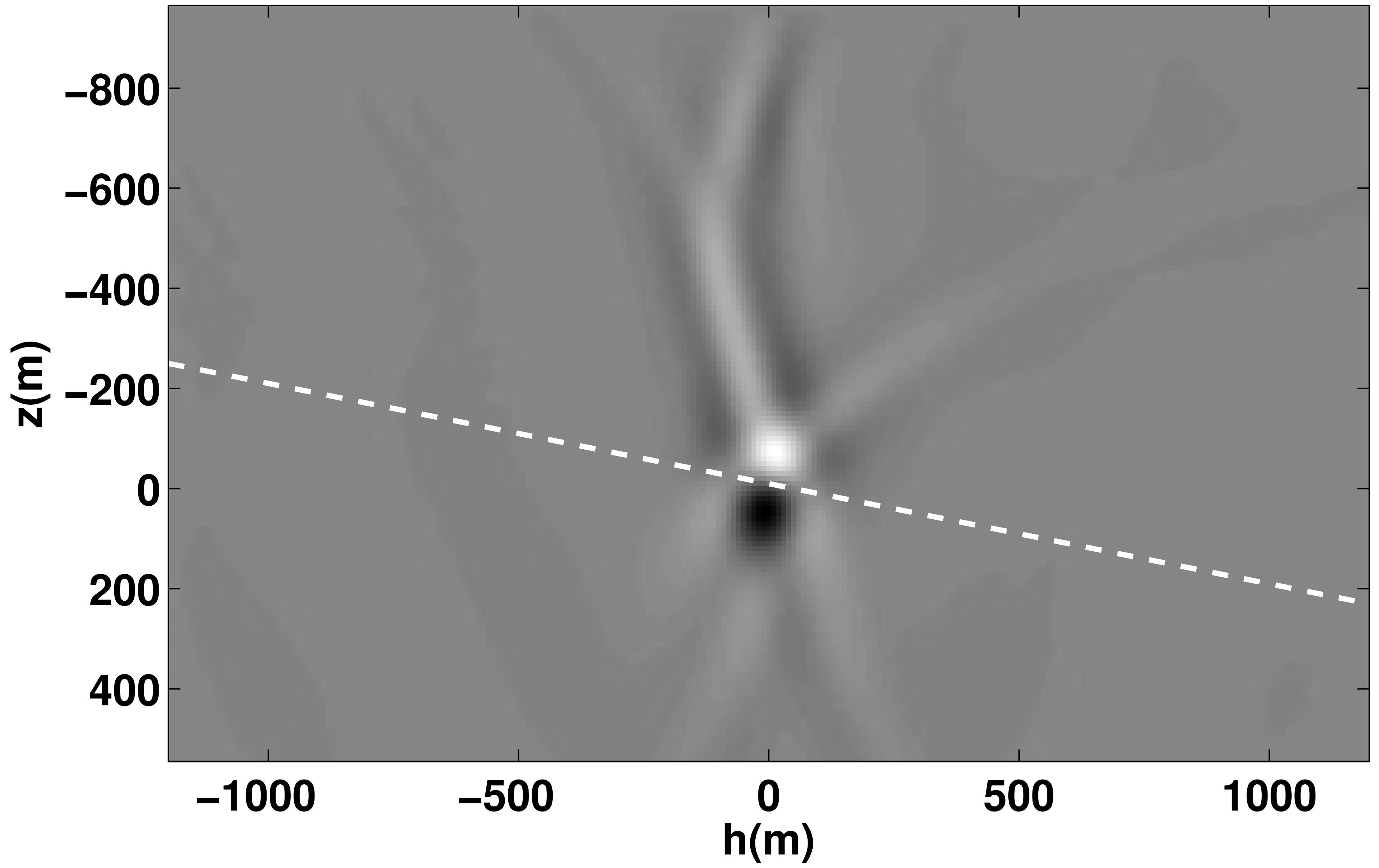
# Dip angle gathers

*align* subsurface *offset* with local dip



# Dip angle gathers

*dip* can be *detected* by measuring the *stack-power* normal to the *dip*



# Dip angle gathers

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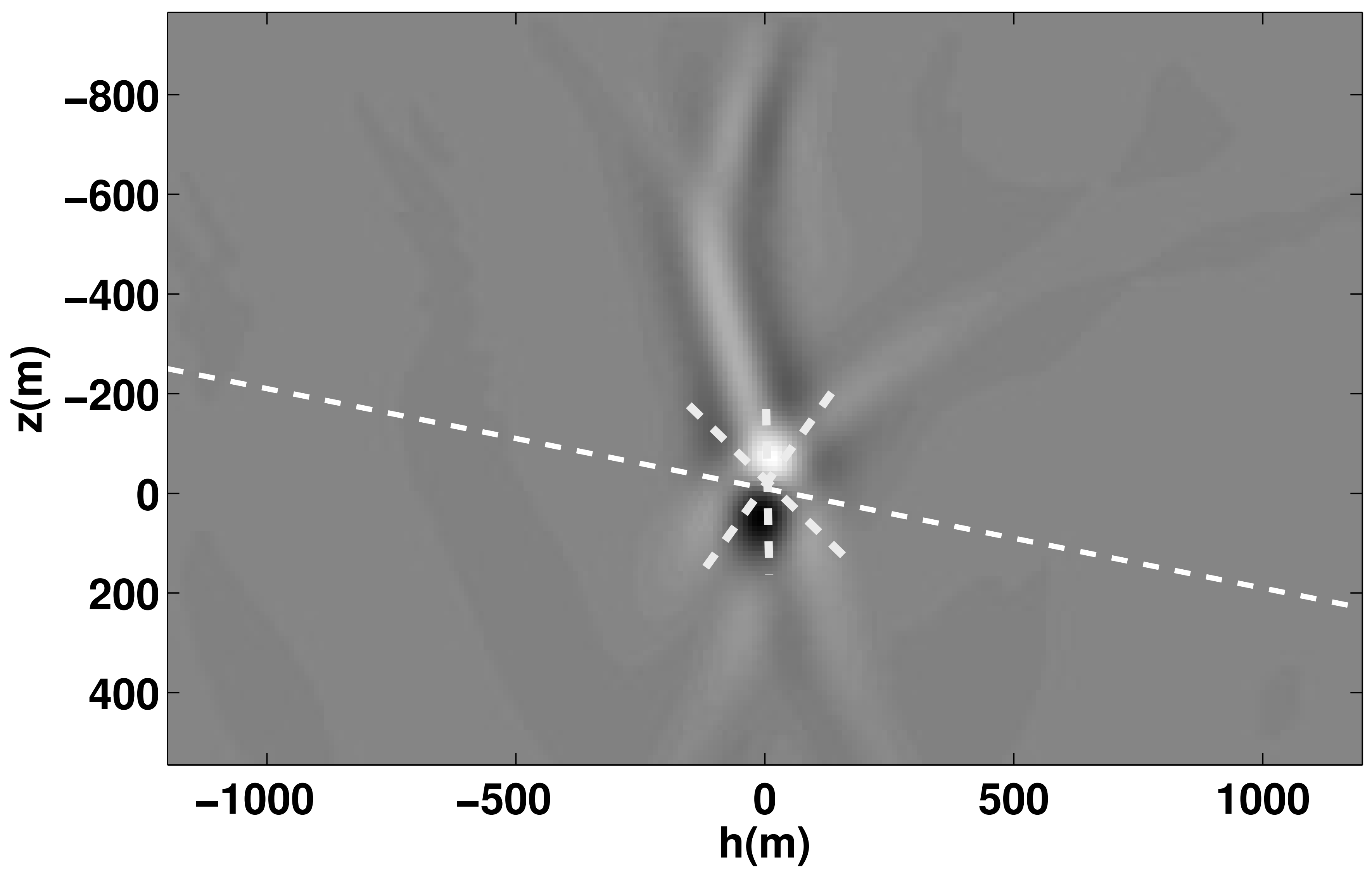


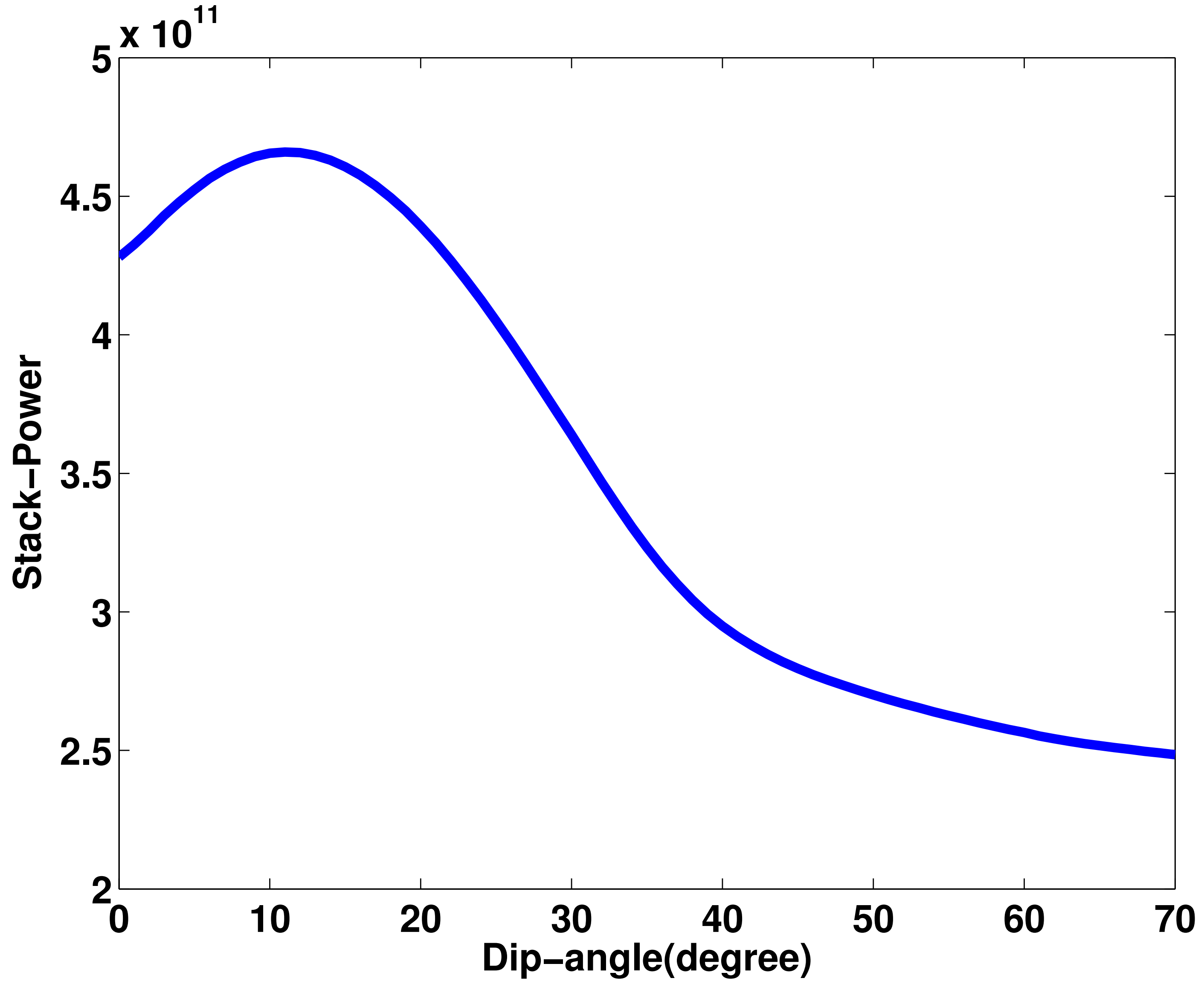

# Dip angle gathers

- *Compute* image point gather
- determine dip

$$\tilde{\theta} = \arg\max_{\theta} \sum_{h} \left| \sum_{\omega} e(\omega, \mathbf{x}_i, \mathbf{x}(h, \theta + \pi/2)) \right|$$

- extract *offset* along dip

[de Bruin et al. , 1990]

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# Dip angle gathers

*Radon* transform to compute *angle* gather

$$I(\mathbf{x}_i, p, \theta) = \sum_{\omega}\sum_{h} e(\omega, \mathbf{x}_i, \mathbf{x}(h, \theta))e^{\imath\omega ph}$$

where

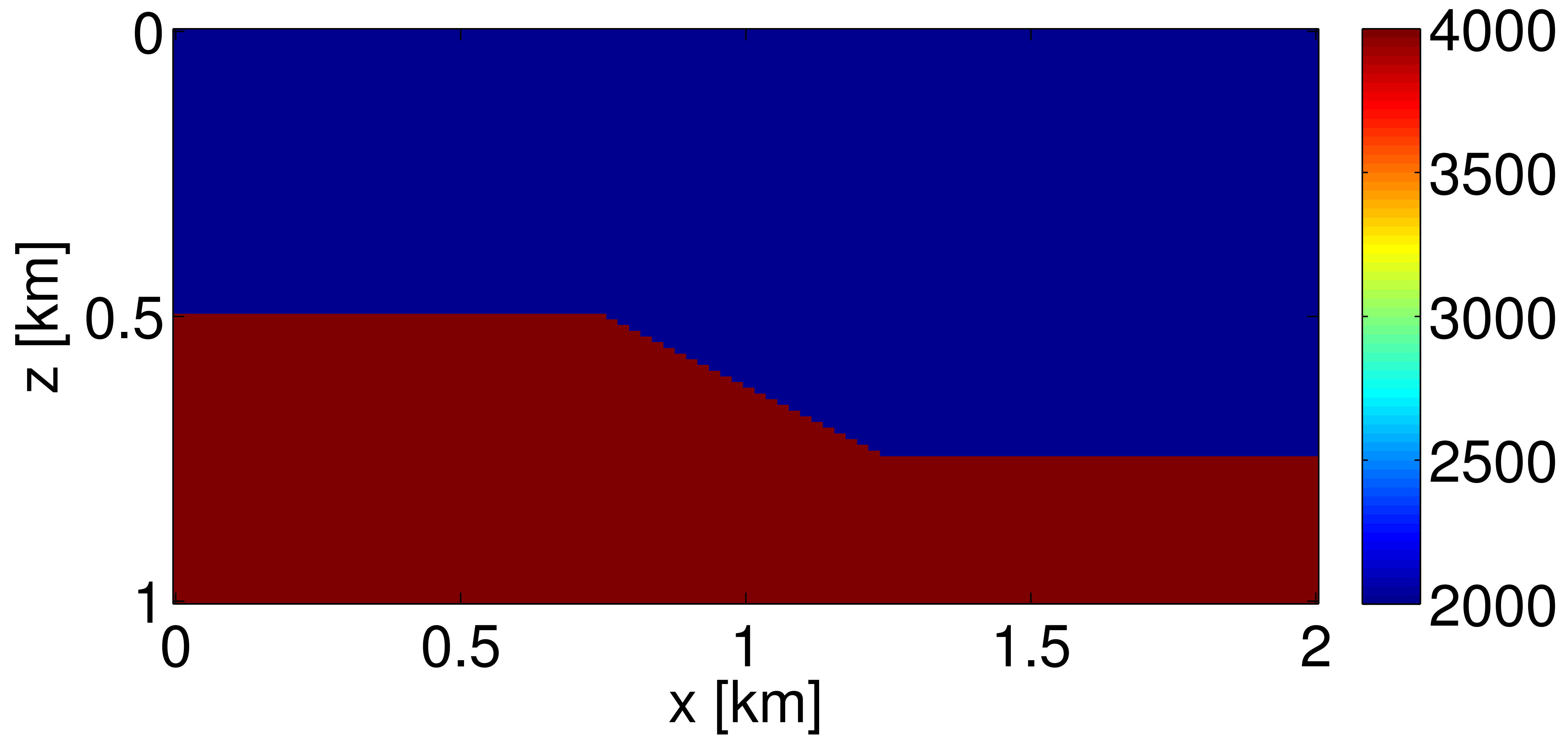
$$p = \frac{k_x}{\omega} = \frac{\sin(\alpha)}{v}$$

# Applications

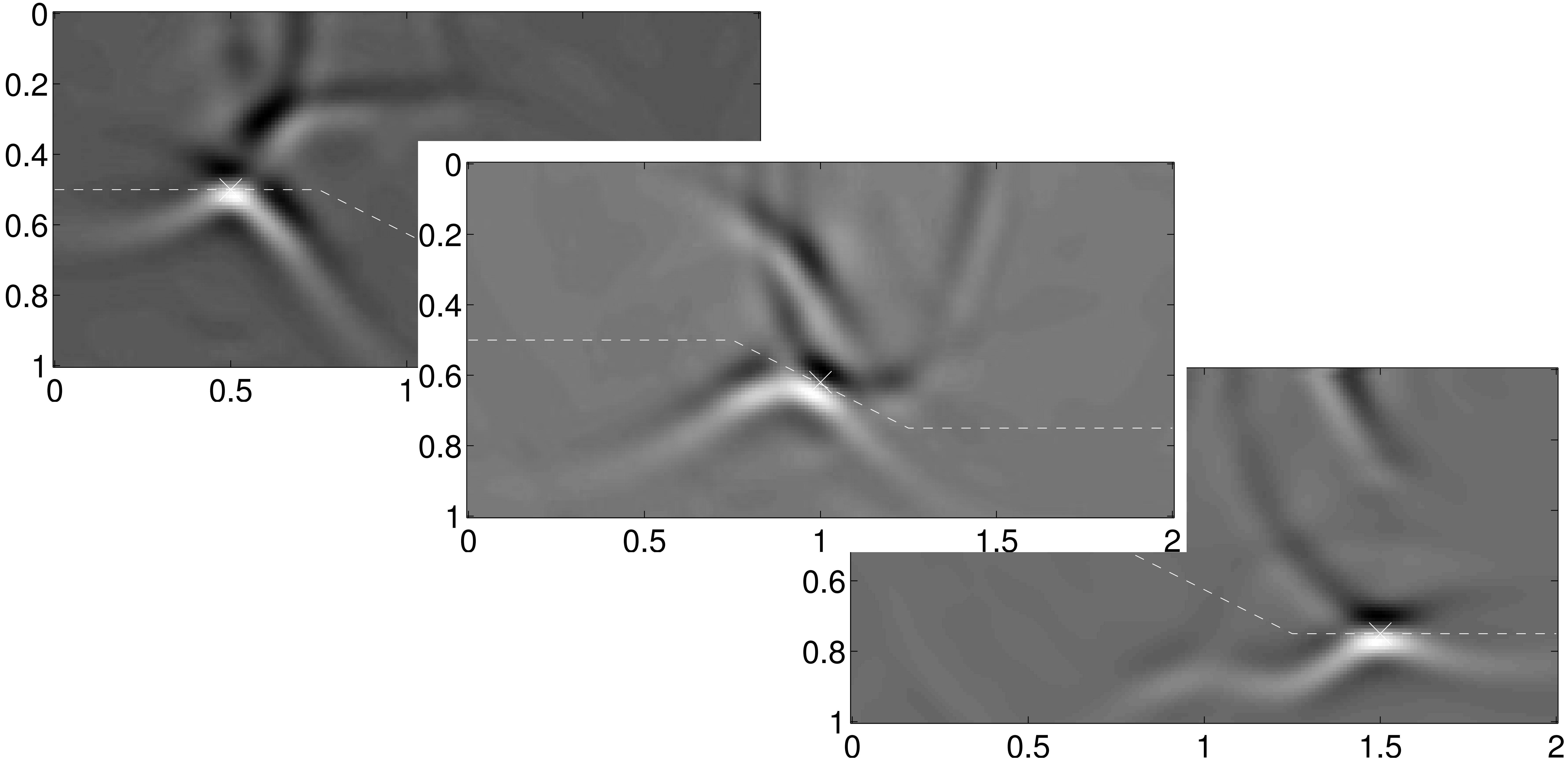
- *Dip estimation*
- AVA

# Dip-angle gathers

Example

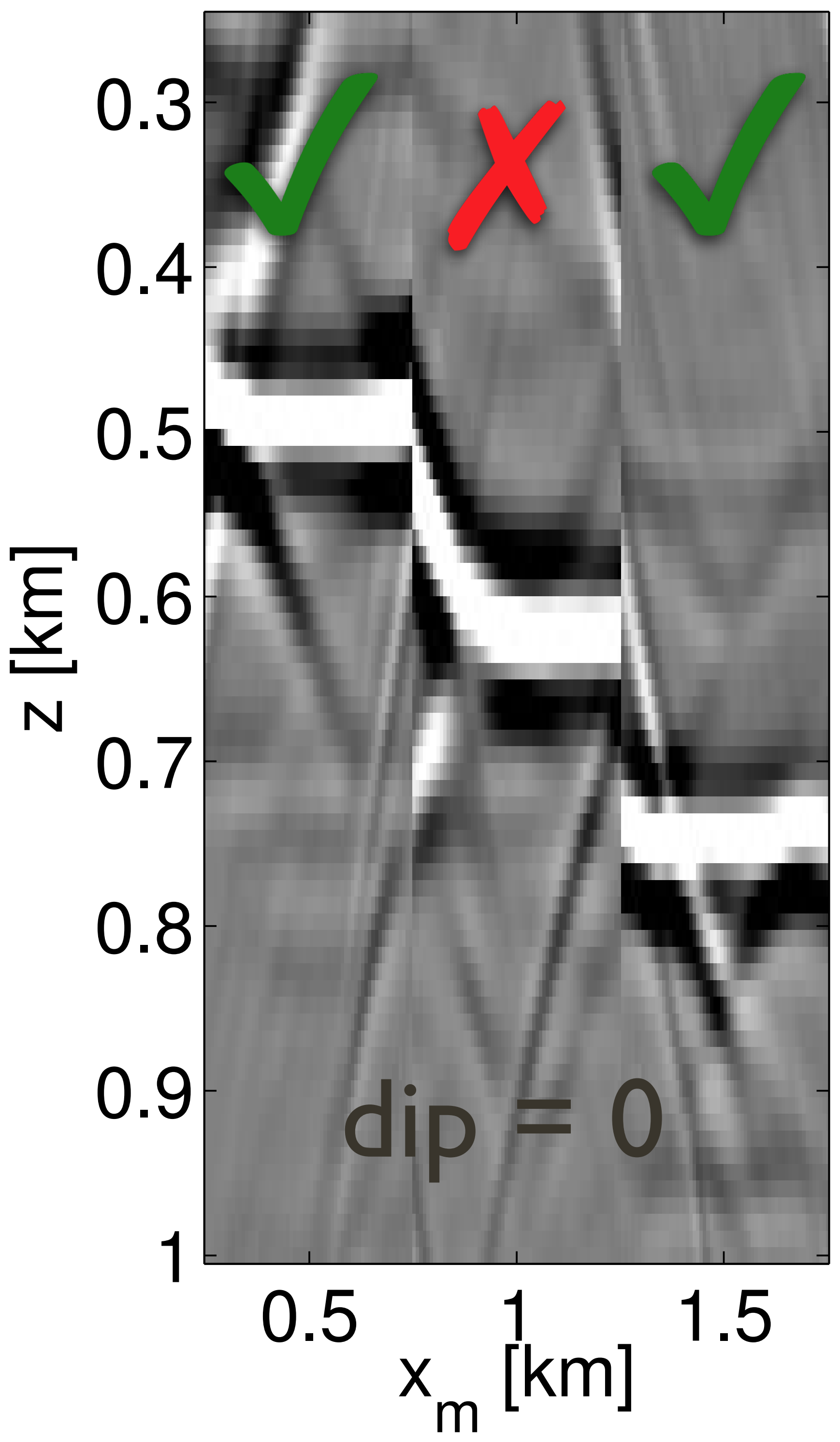


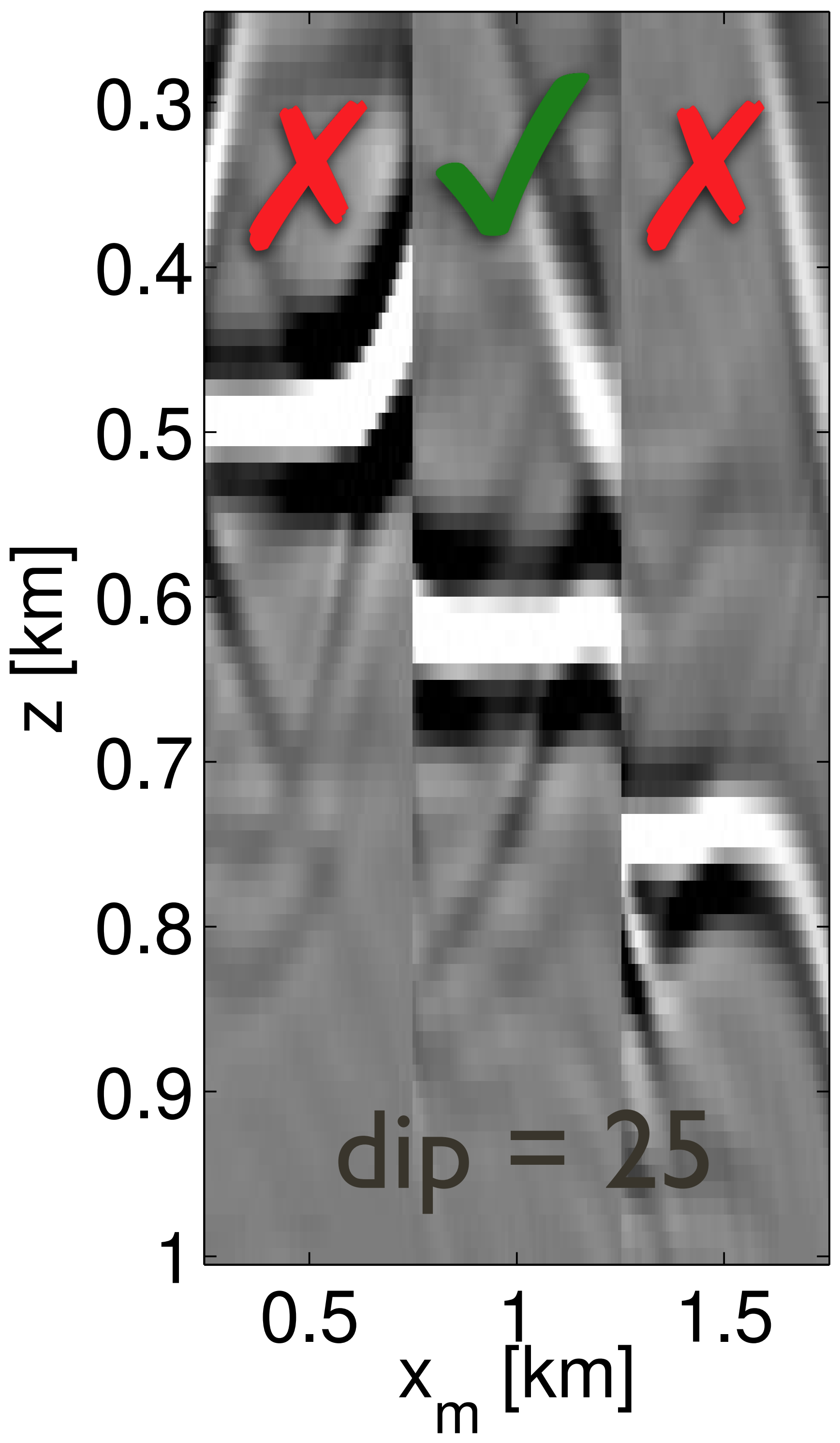
# Dip-angle gathers



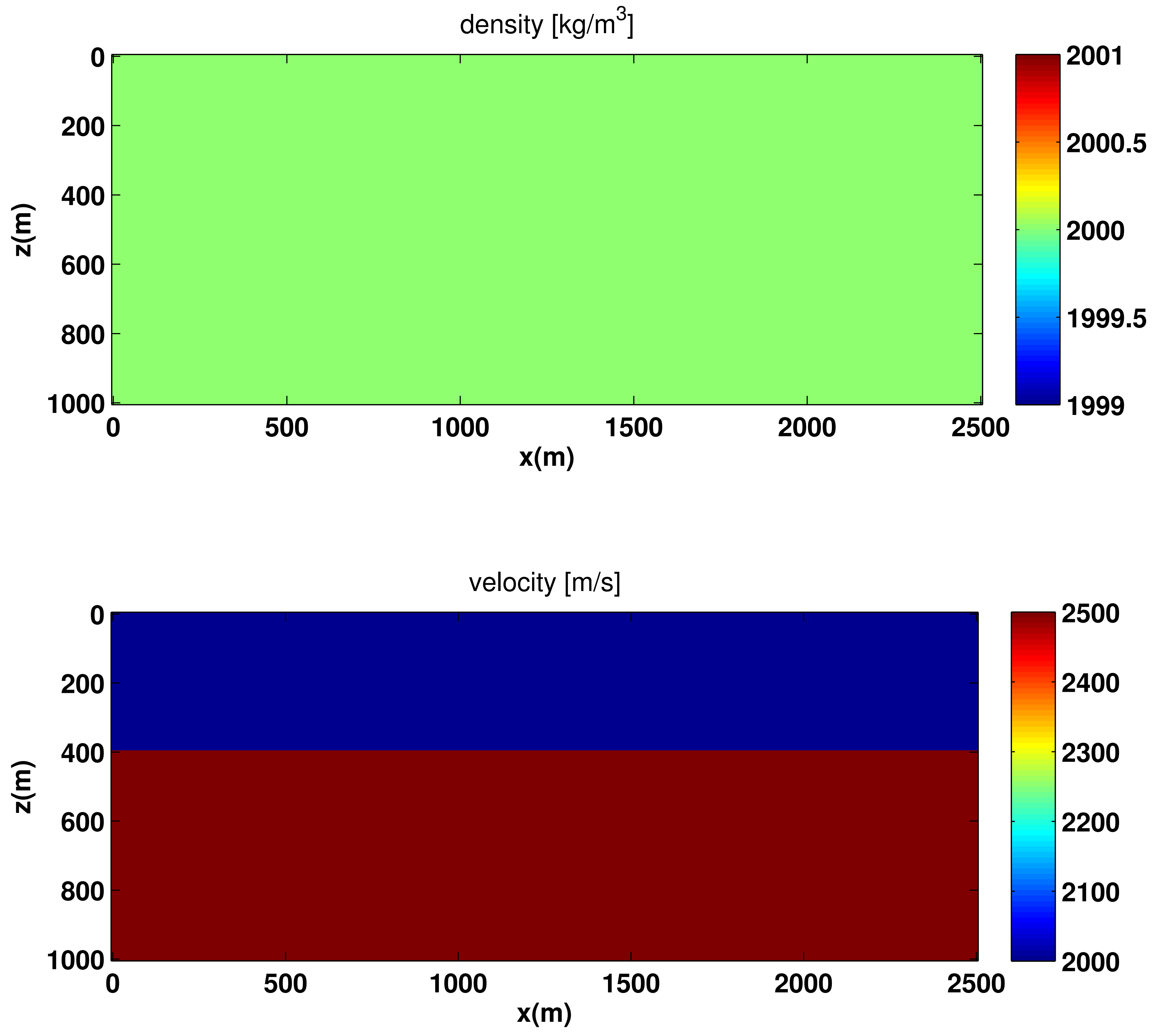
# Dip-angle gathers

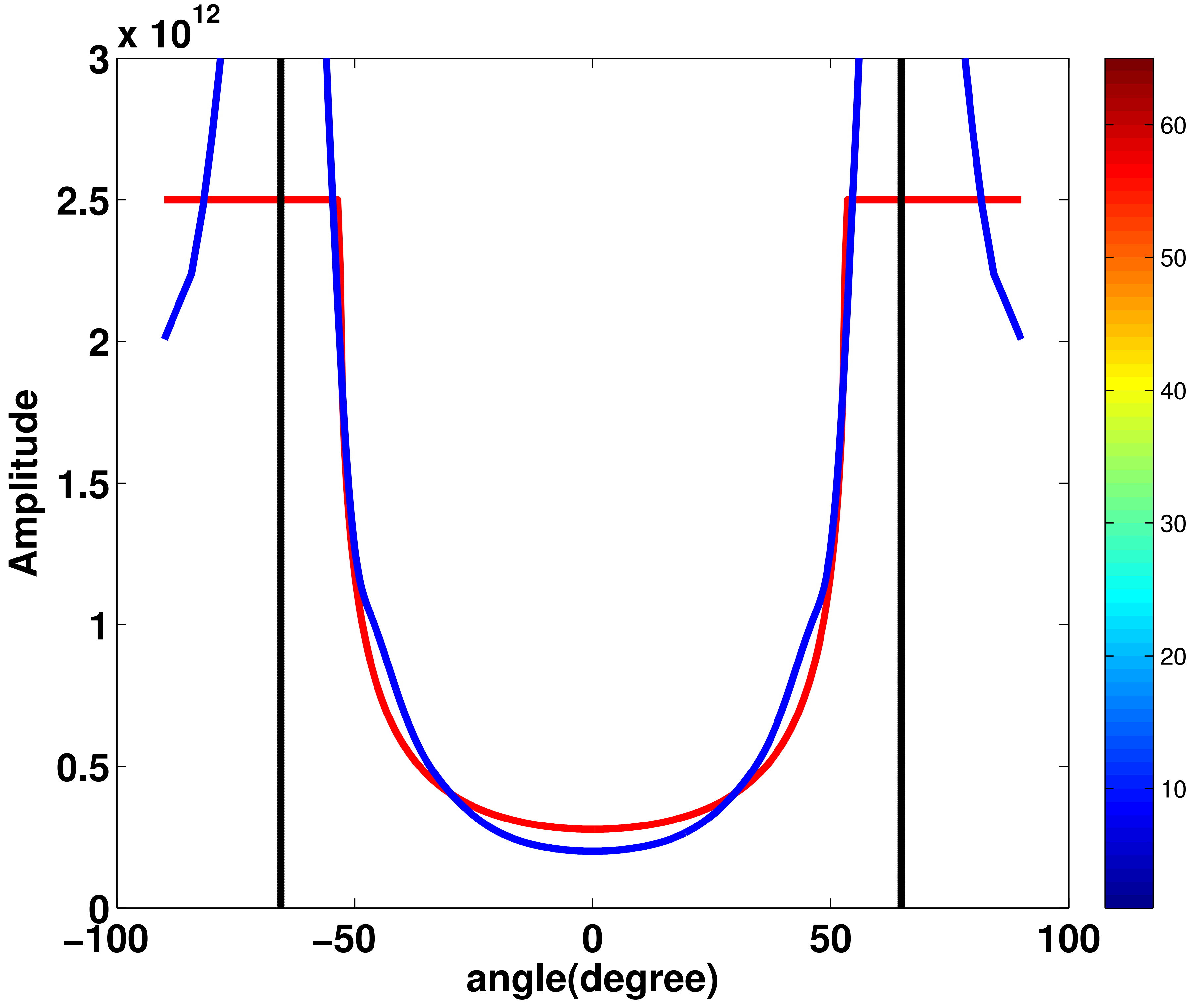
*angle gathers* for *correct* velocity, should all be *flat*



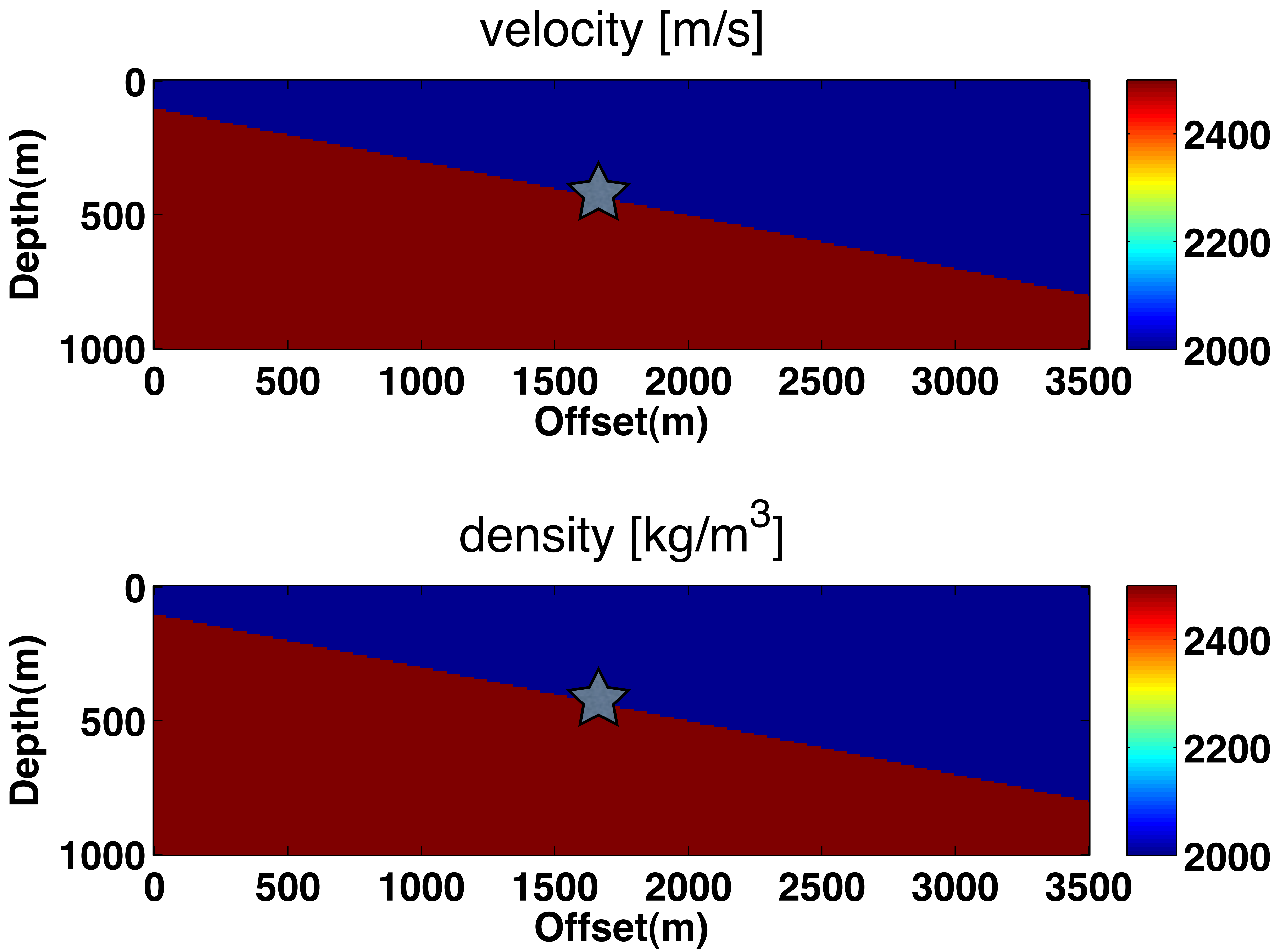
# AVA
## [1-layer model]



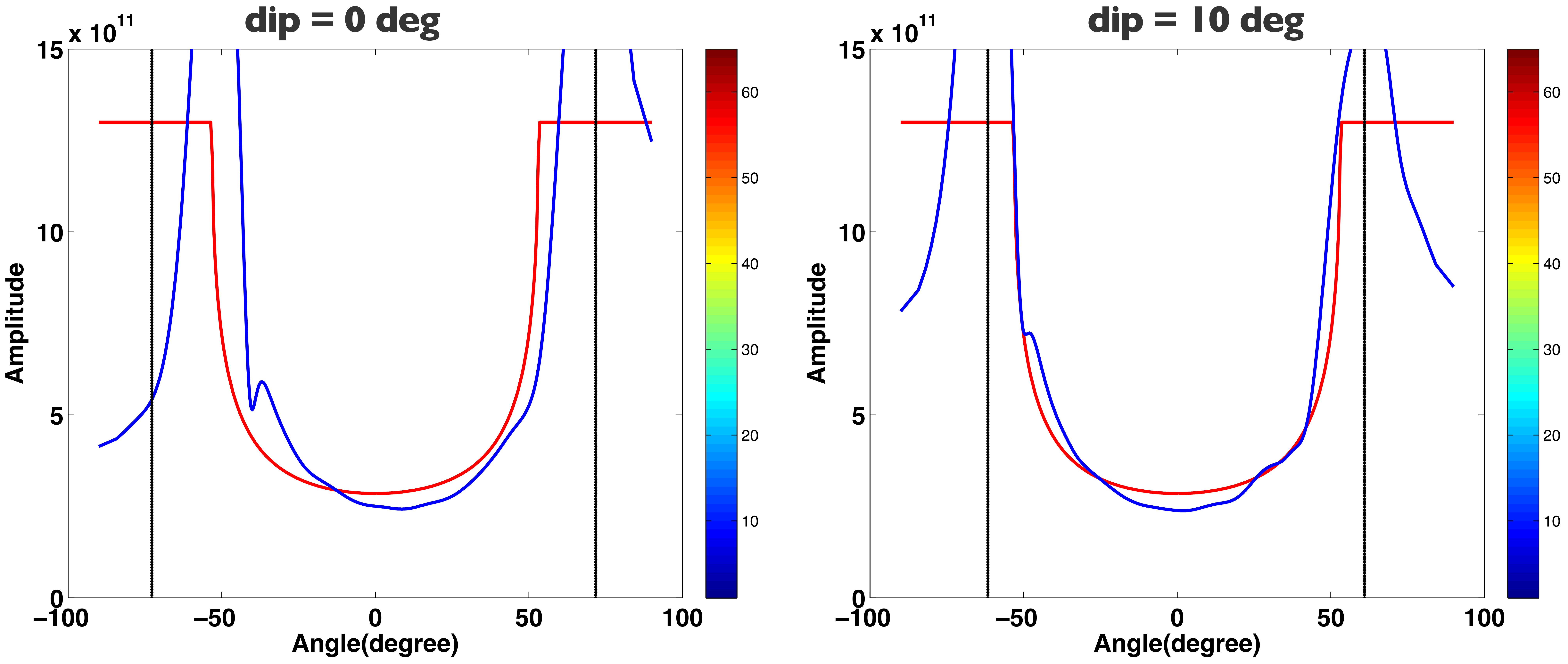




- Zoeppritz equation
- Predicted response

# AVA
## [dipping layer model]



# AVA
## [dipping layer model]




- Zoeppritz equation
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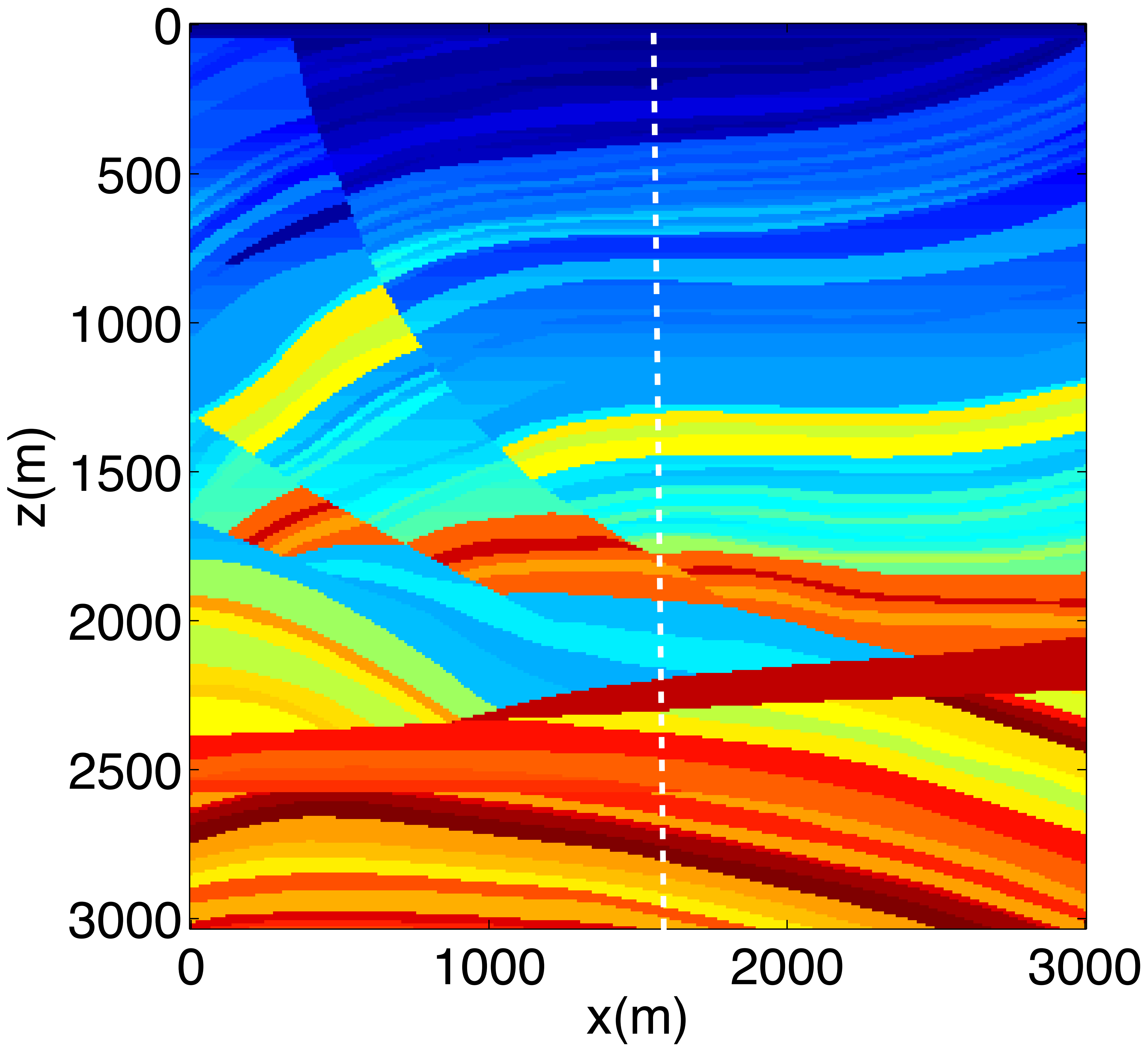
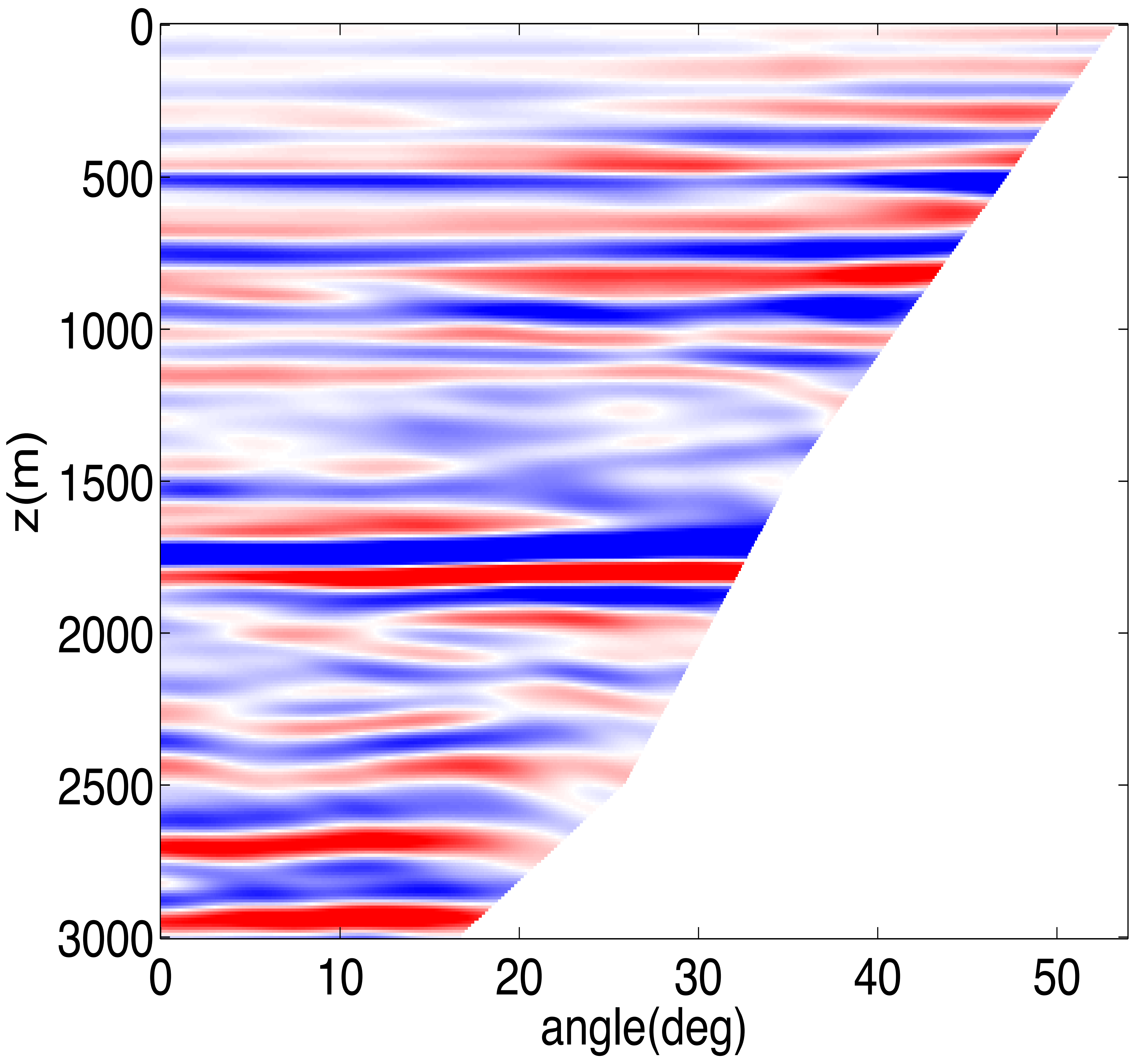
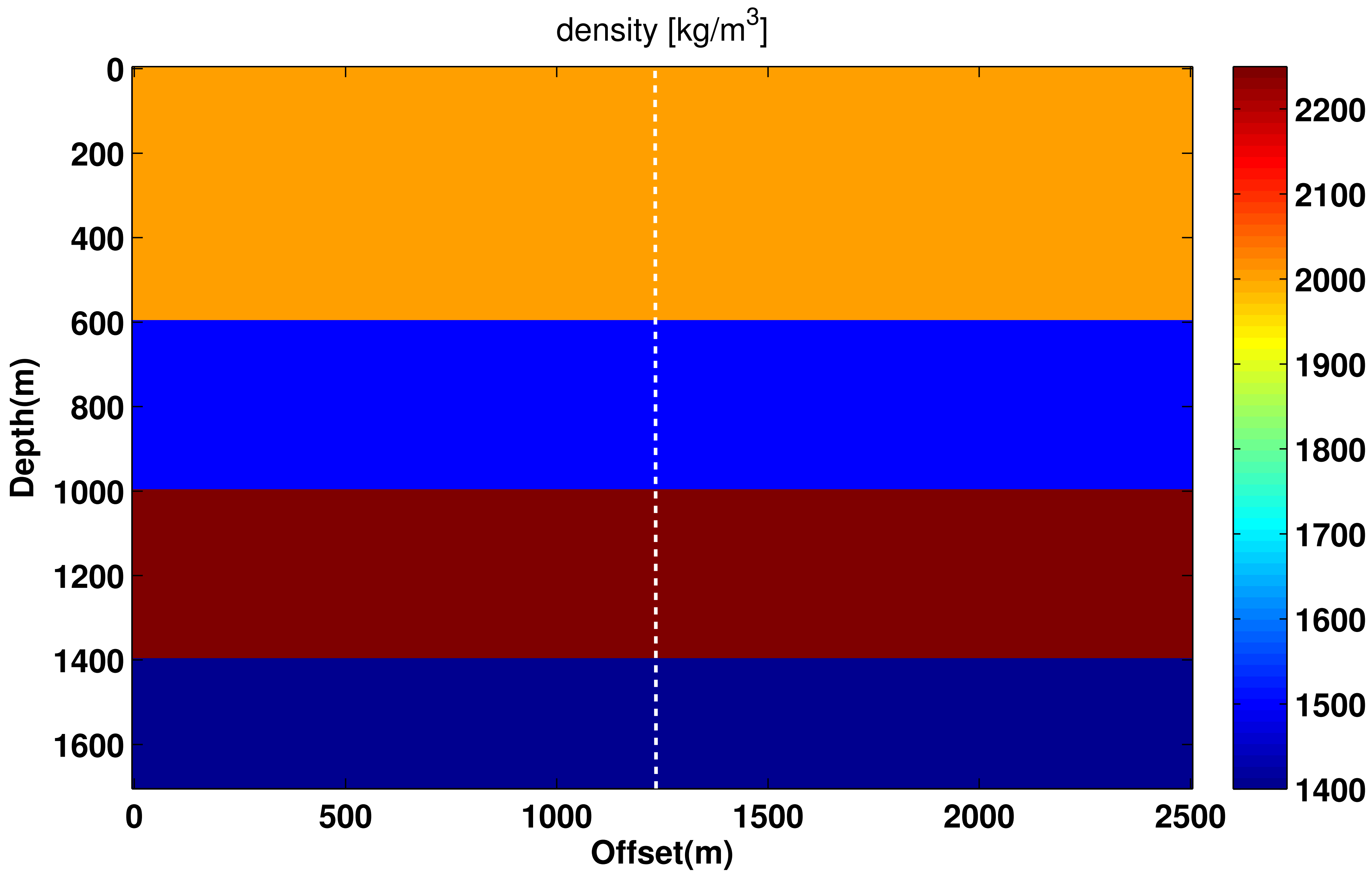
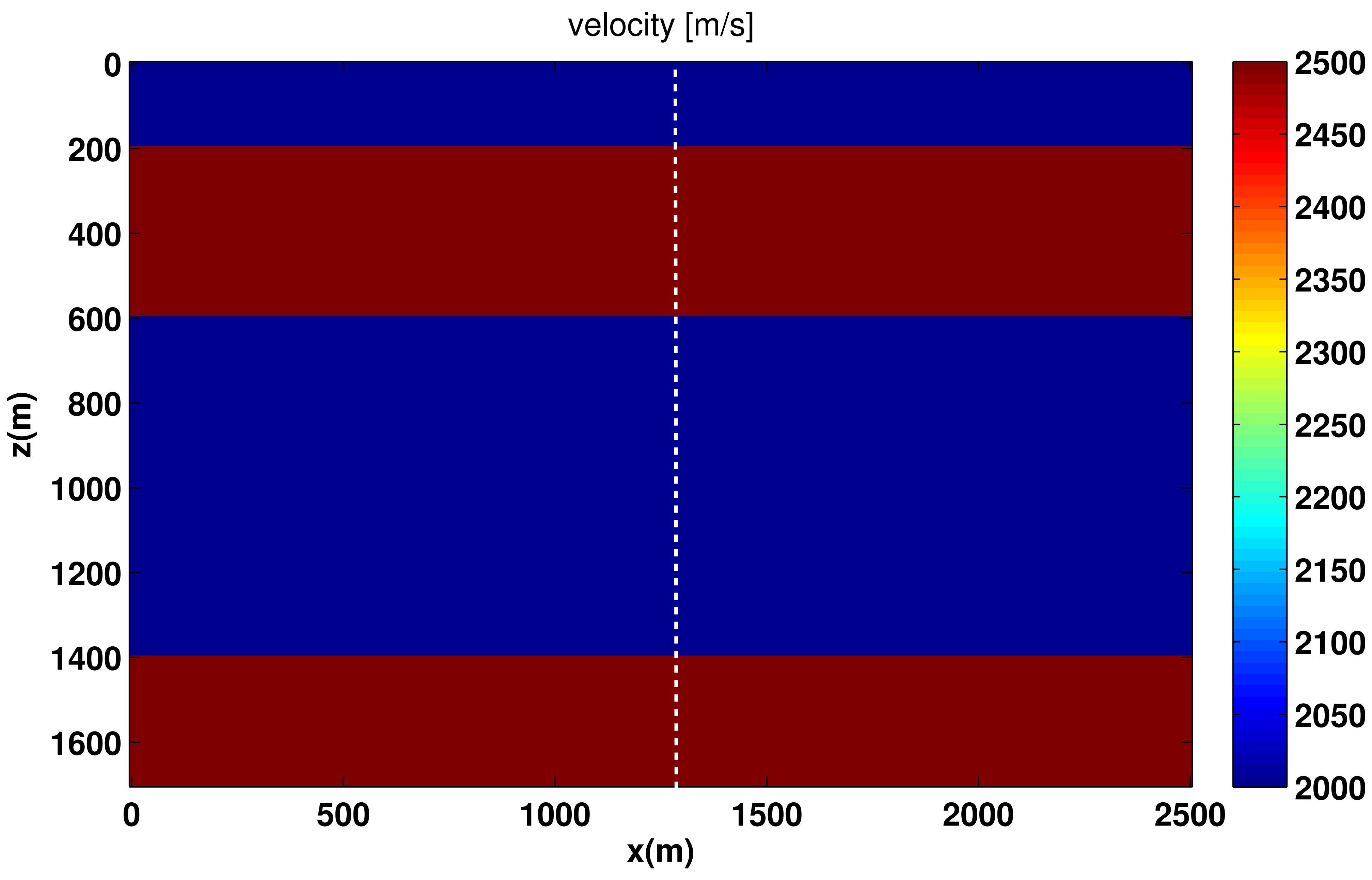
# AVA
## [marmousi model]



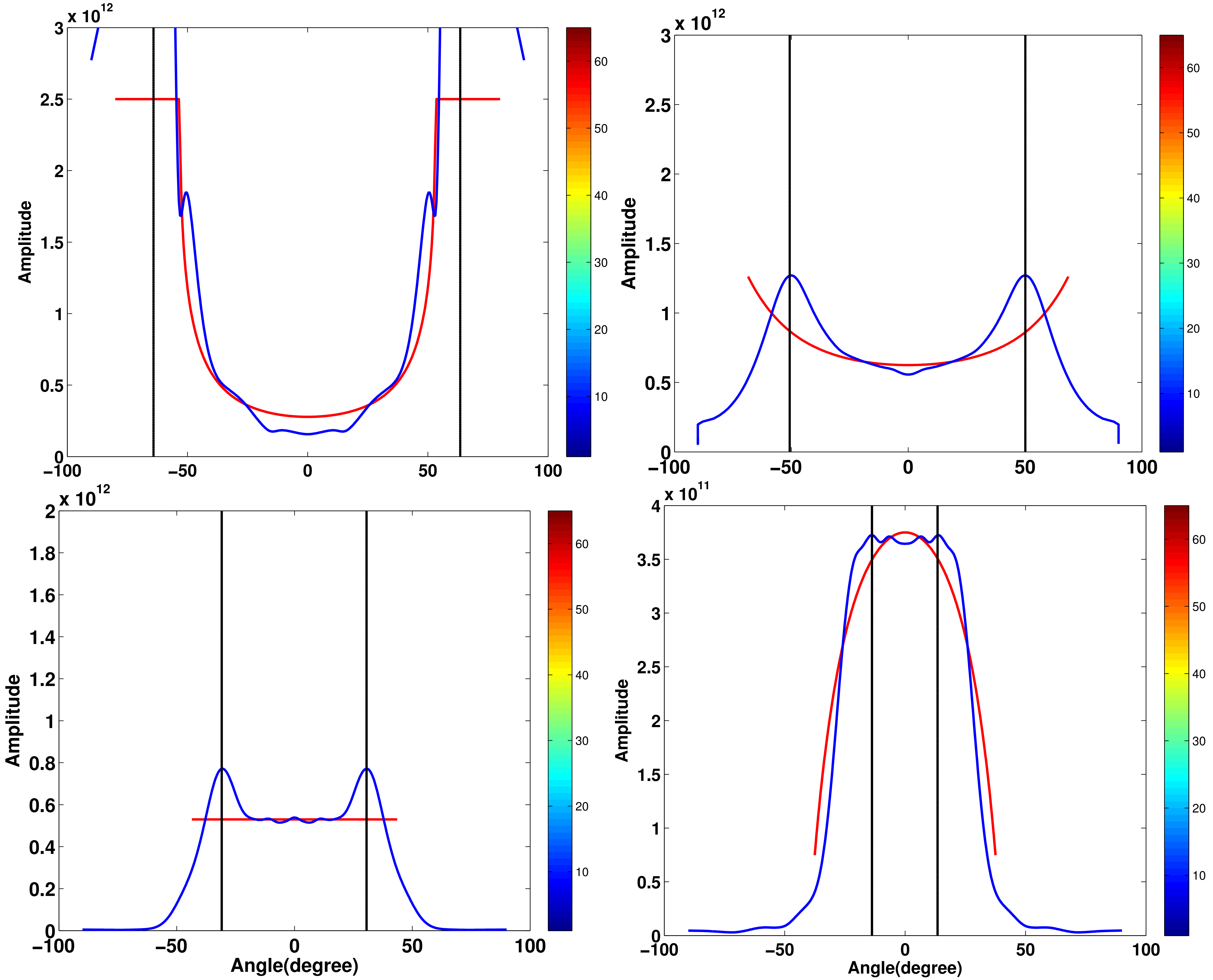



# AVA
## [4-layer model]



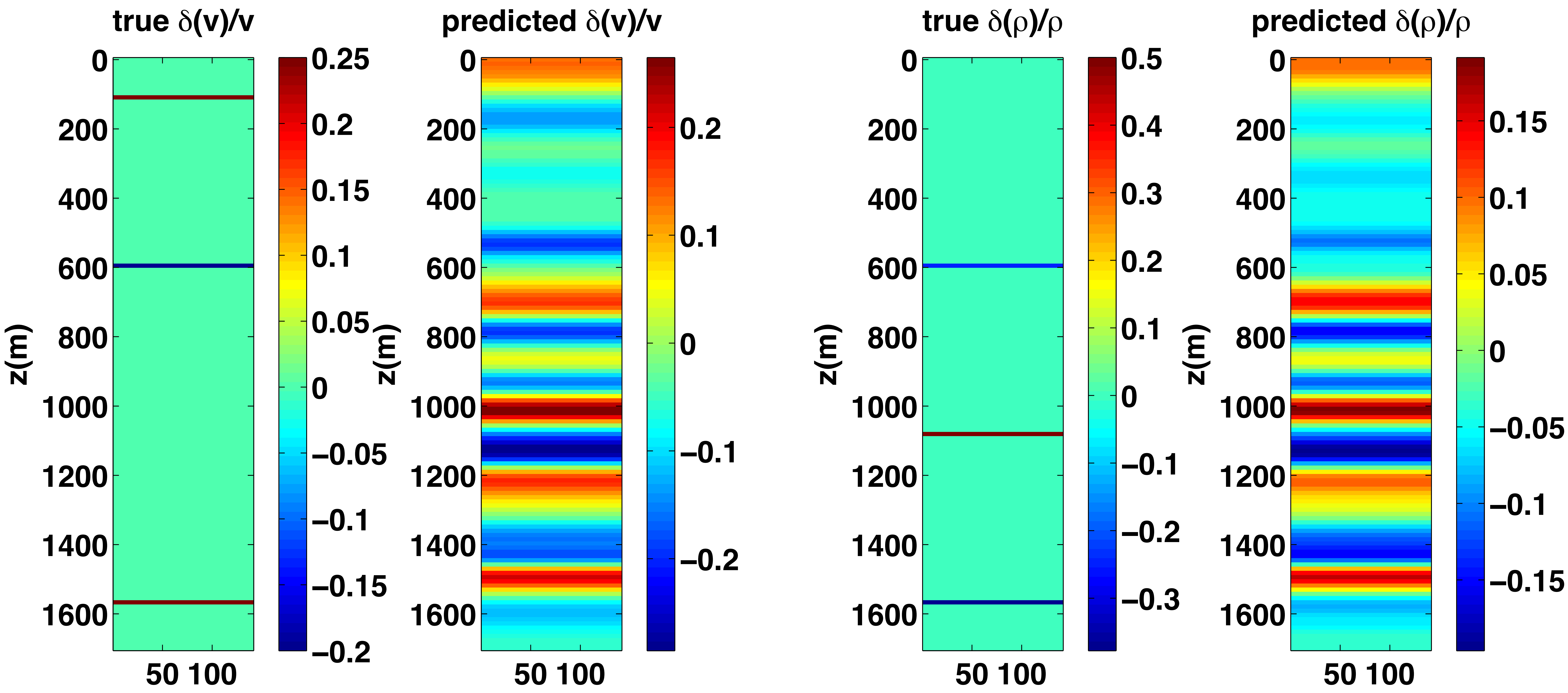
# AVA
## [4-layer model]




- Zoeppritz equation
- Predicted response

[Aki & Richards, 1980 ; Wijngaarden et al. , 1995]

# Acoustic impedance inversion
## [4 layer model]



# Conclusion

- *Probe* image volume with *mat-vecs*
- *Full subsurface offset* help to estimate dip *automatically*
- *Suitable* for AVA at targeted regions

# Future Work

- Explore the issues in acoustic impedance inversion
- Incorporate free-surface multiple to perform AVA analysis

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## Acknowledgements

# Thank you for your attention !

https://www.slim.eos.ubc.ca/

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