Husky Energy CREWES

4D seismic monitoring with full-waveform tomography

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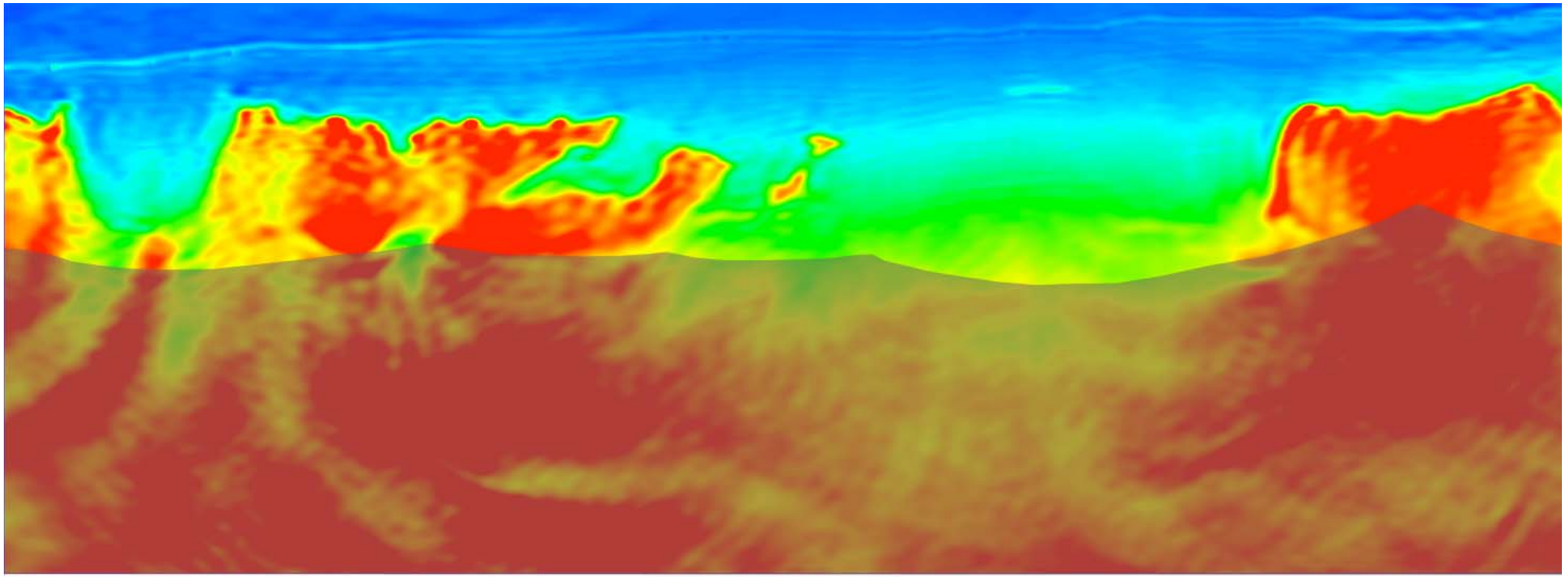


Waveform tomography in complex structure

from: Frequency Domain Waveform Tomography Using Refracted Arrivals. R.G. Pratt & A. Brenders. EAGE 2004

Waveform tomography

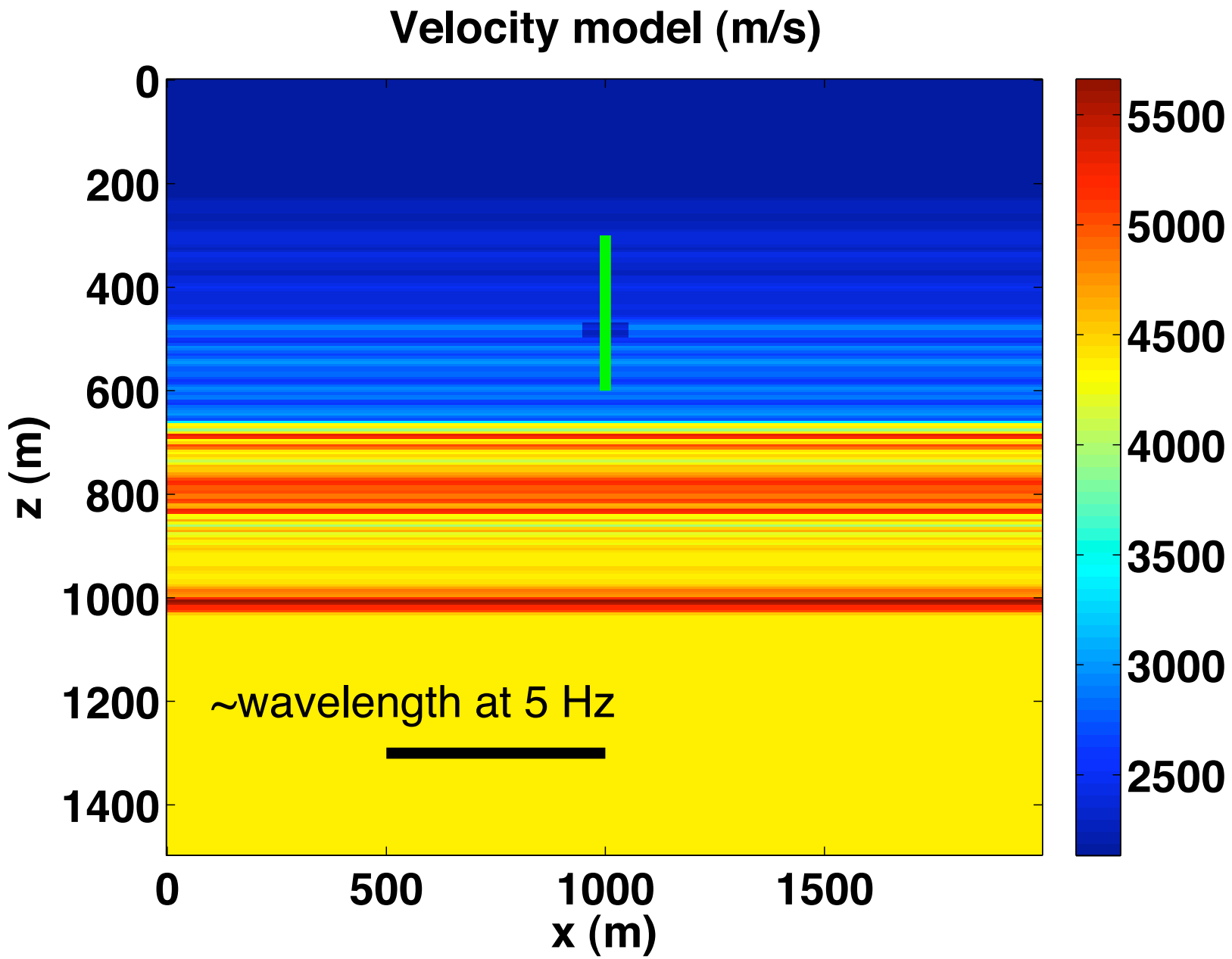
- Lailly, Tarantola, and Mora started things off in the early 80s, Marta Woodward and others later.

- Gerhard Pratt et al. have advanced the method, and produced reference code that we are learning to use.

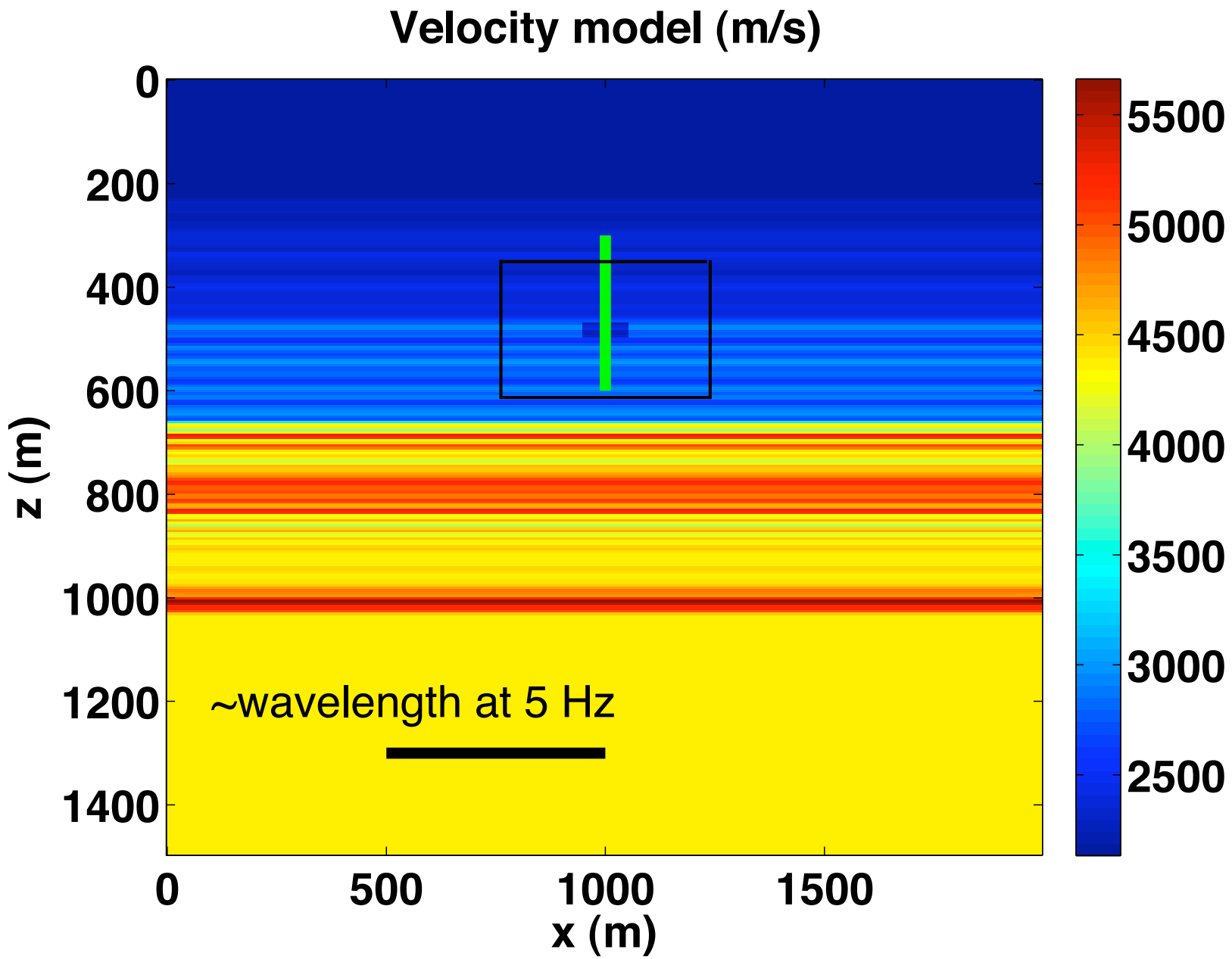
- Seiscope (Université Nice) is developing full-scale code.

Waveform tomography

- The method finds perturbations to a “high quality” initial starting model, and to a source waveform.
- Traditional velocity analysis and/or traveltime tomography may be used to find a starting model.
- We need “long” offsets, “low frequency” data, and “good” starting models.
- Apply it to 4D problems!



Green line marks the location of VSP receivers



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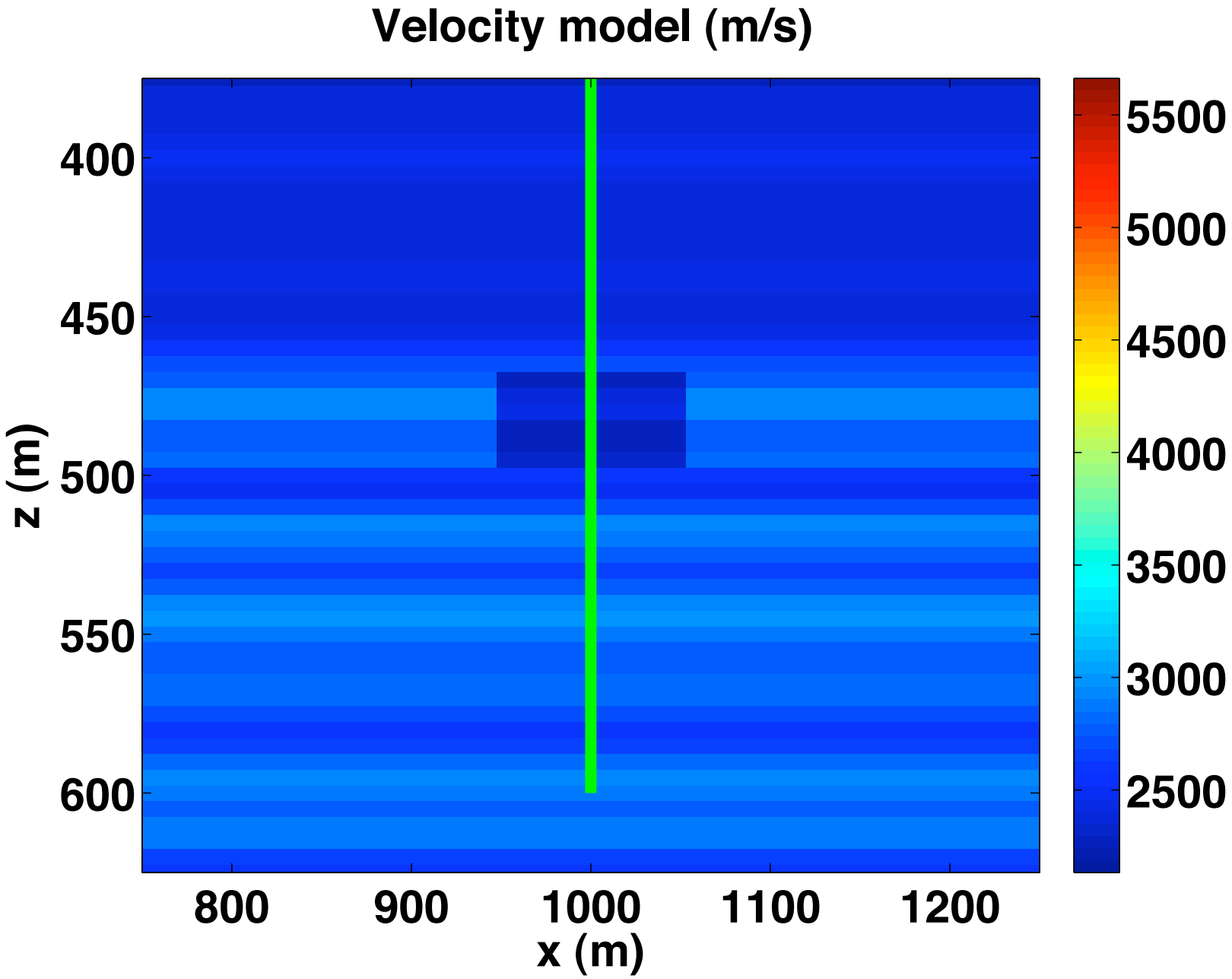

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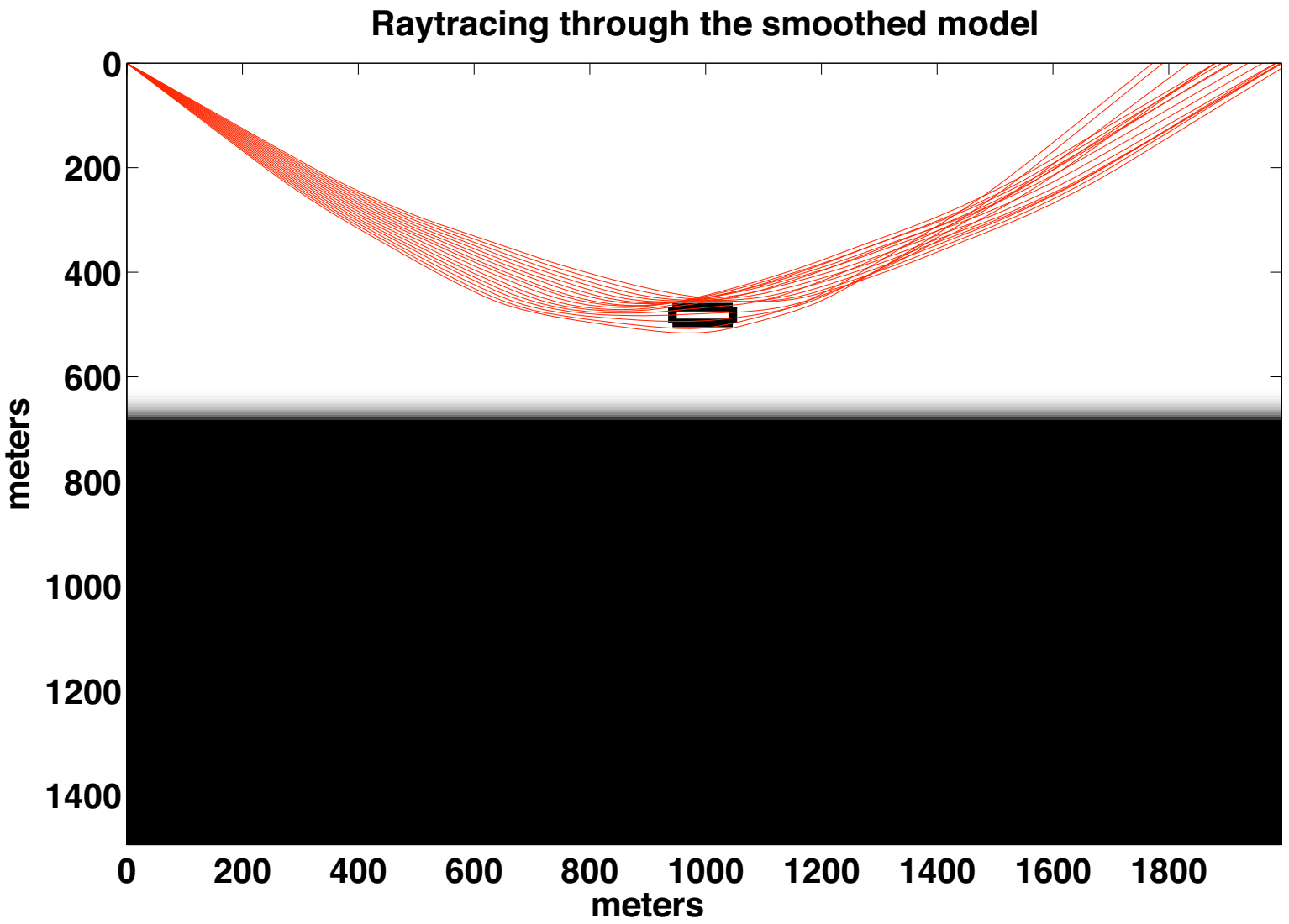
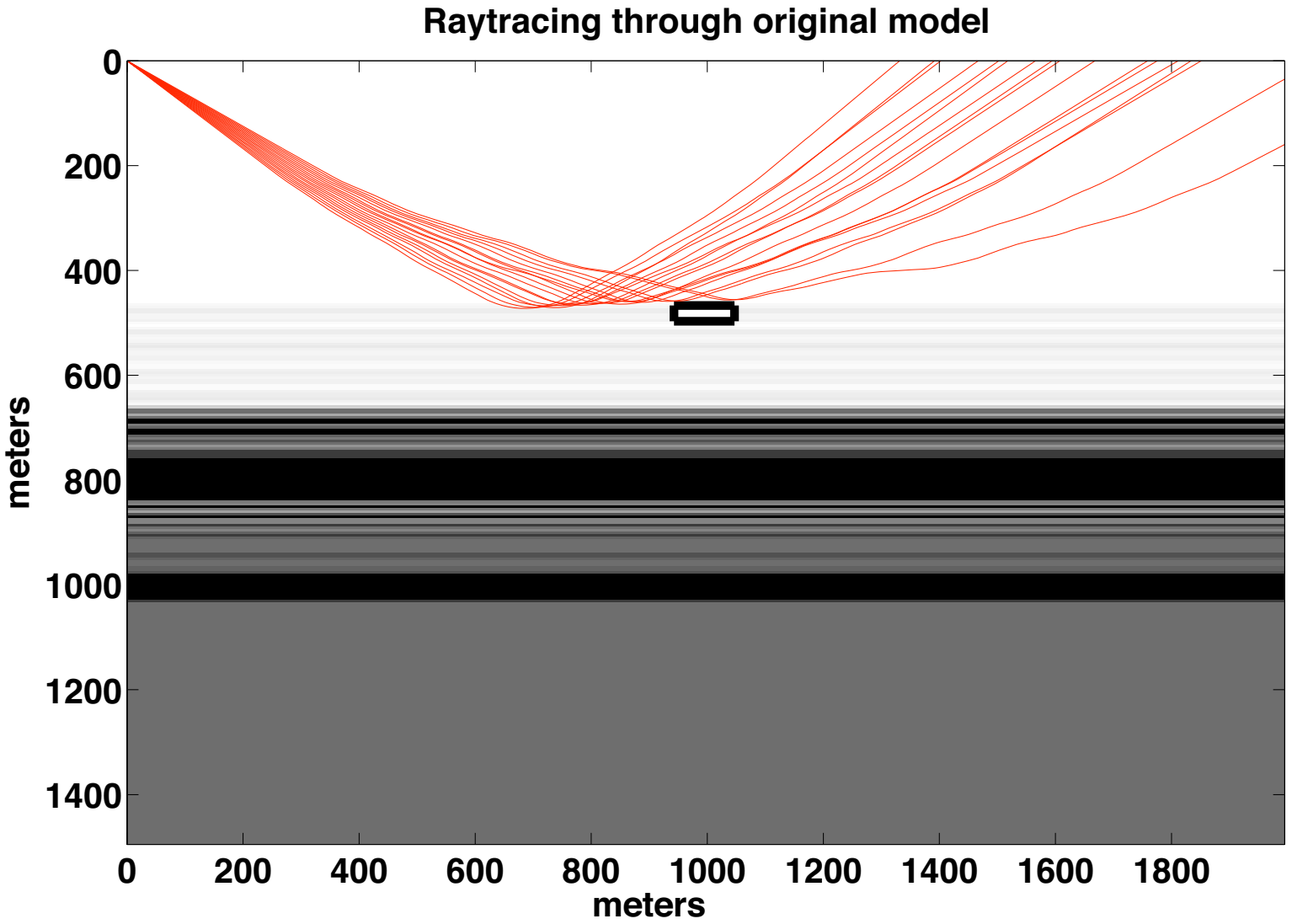


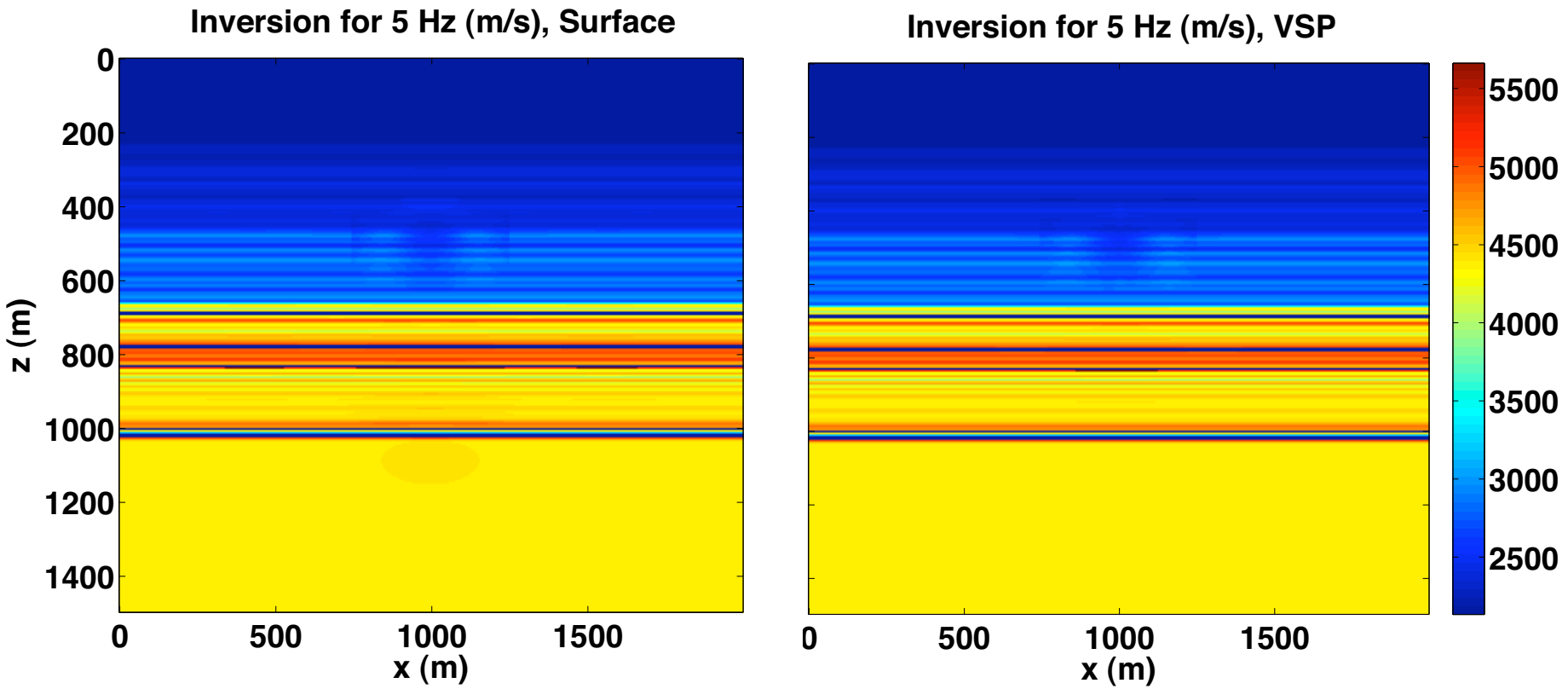
Long offsets give us tomographic data.

Smoothed with 20m Gaussian.



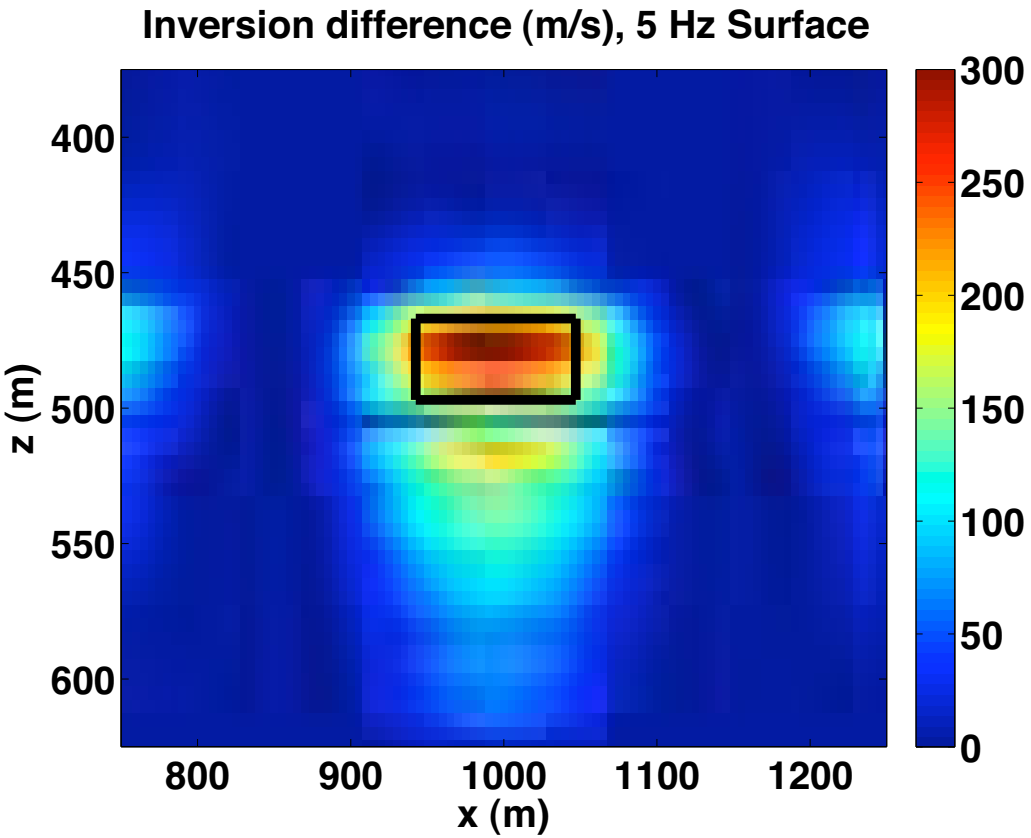
Long offsets give us tomographic data.

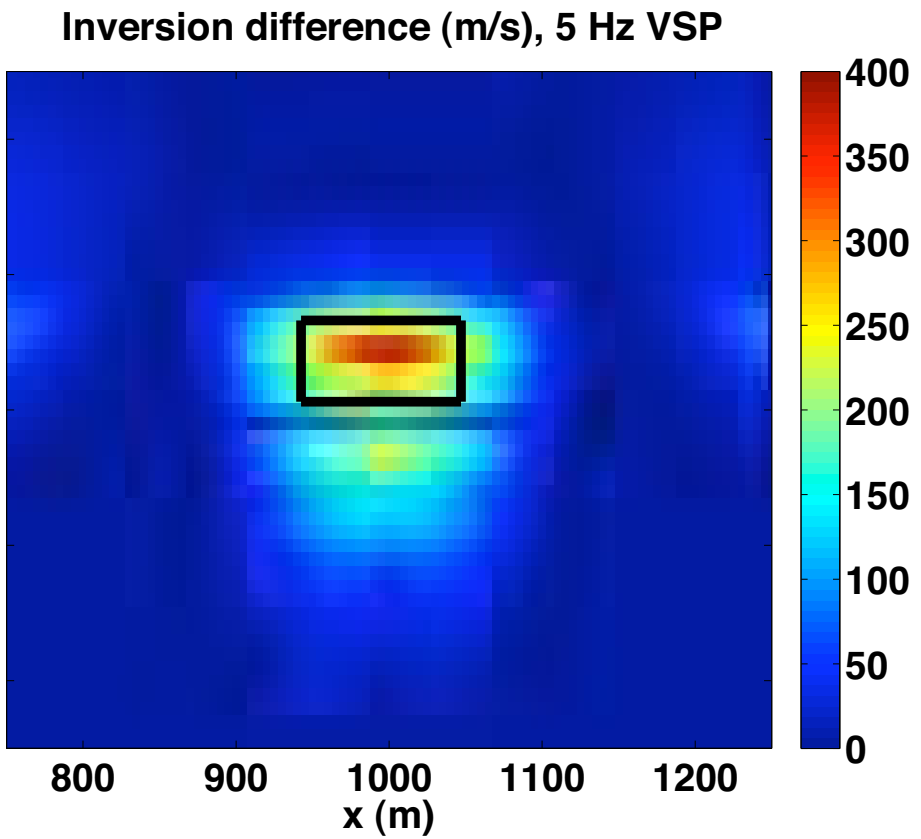
Smoothing implies low frequency?



Inversion for 5 Hz

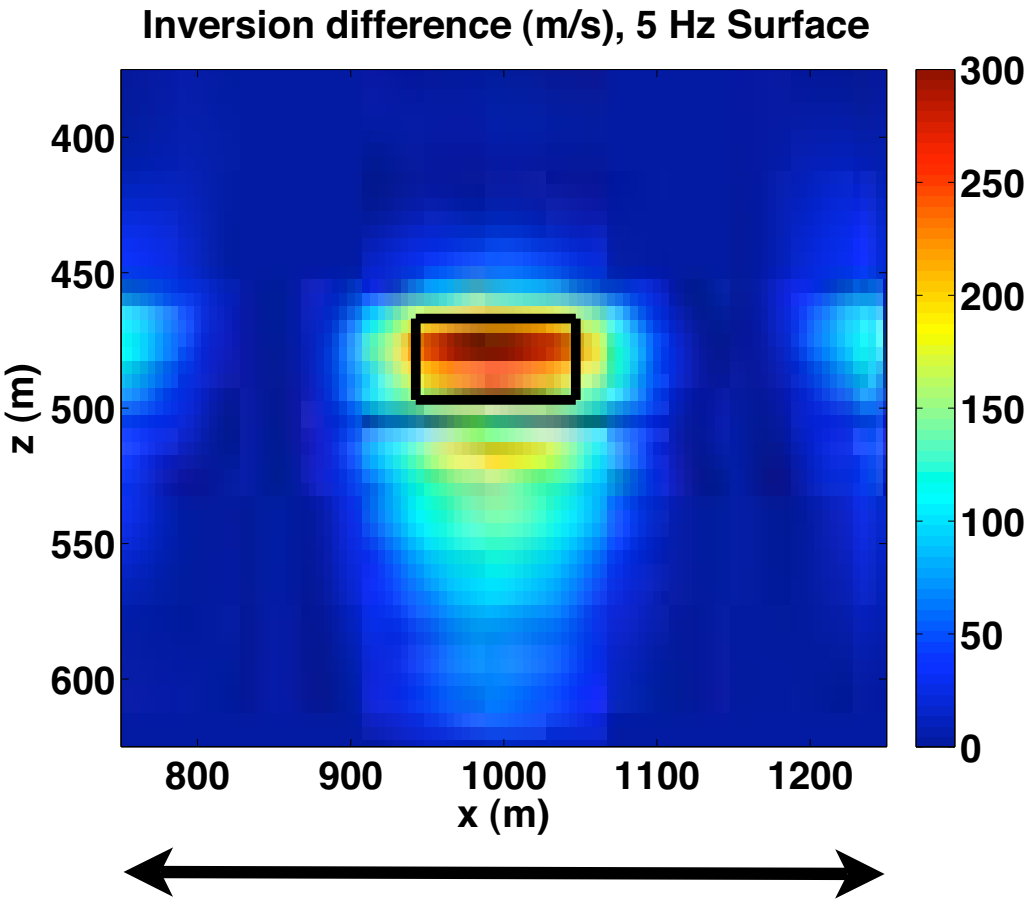
Constrained to target area

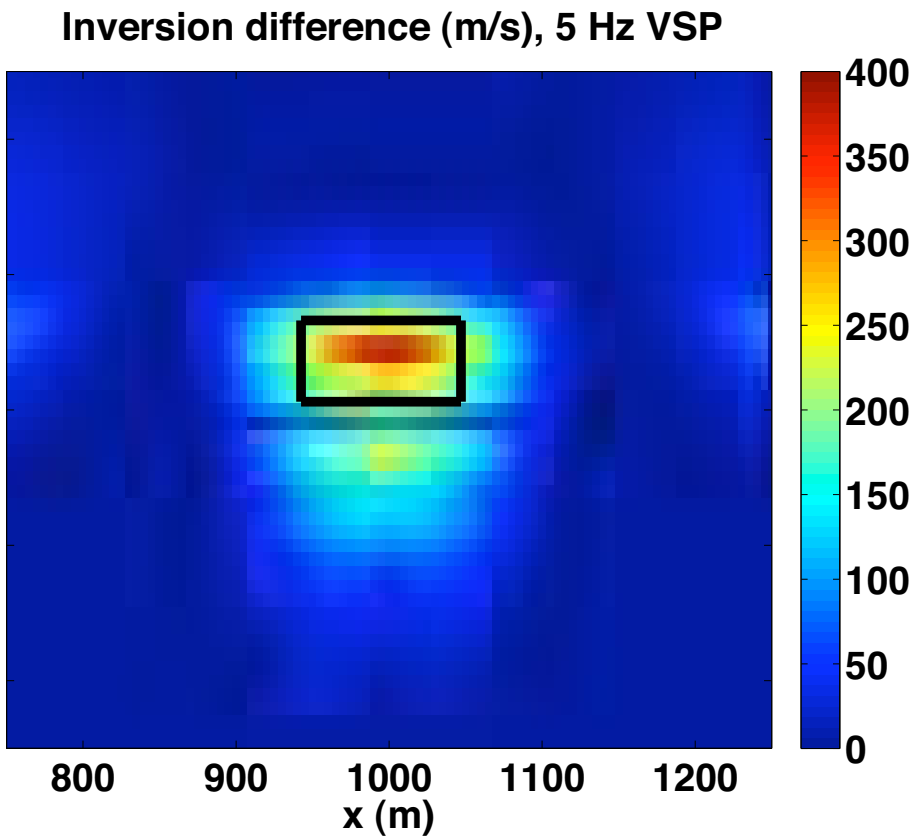




Inversion for 5 Hz

update constrained to target region



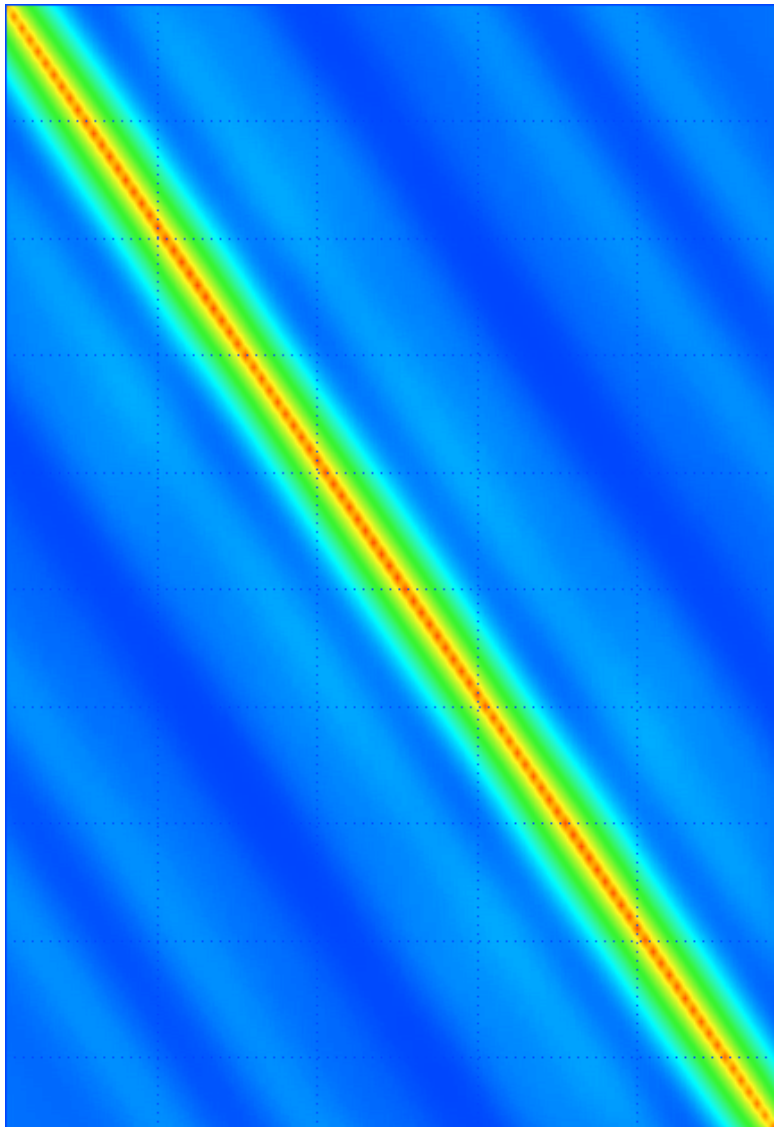


wavelength

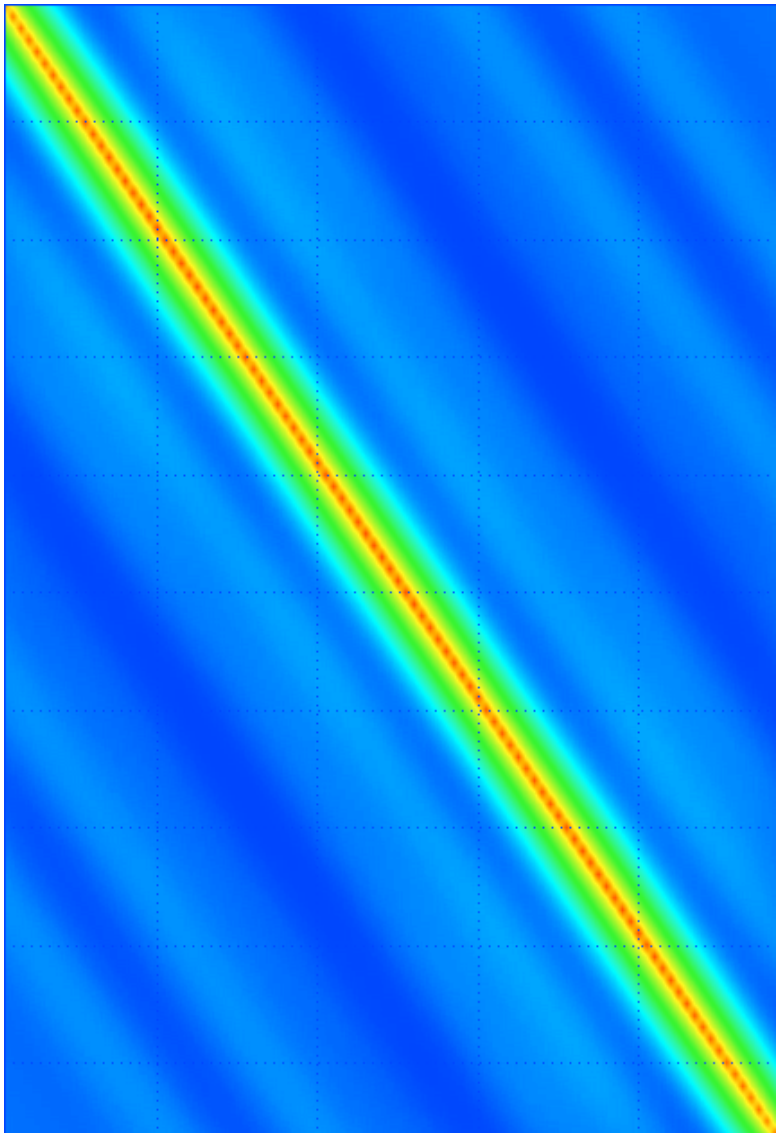
Inversion for 5 Hz

update constrained to target region

“real” data



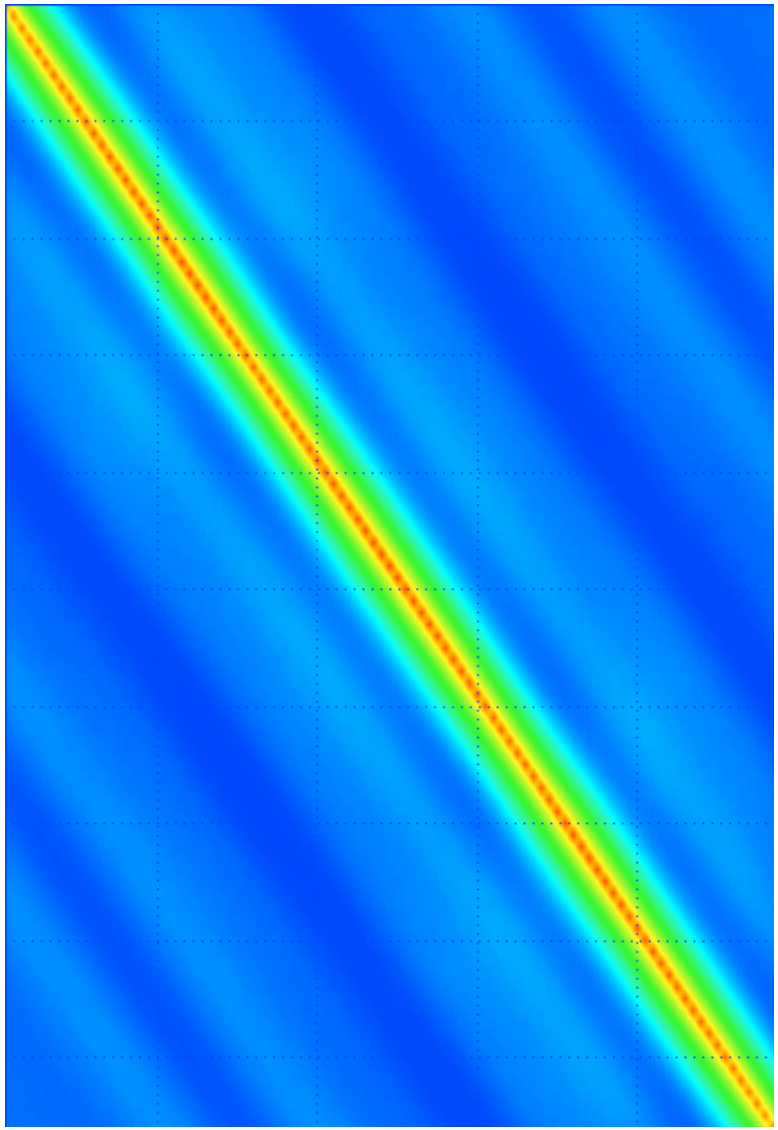
estimated data



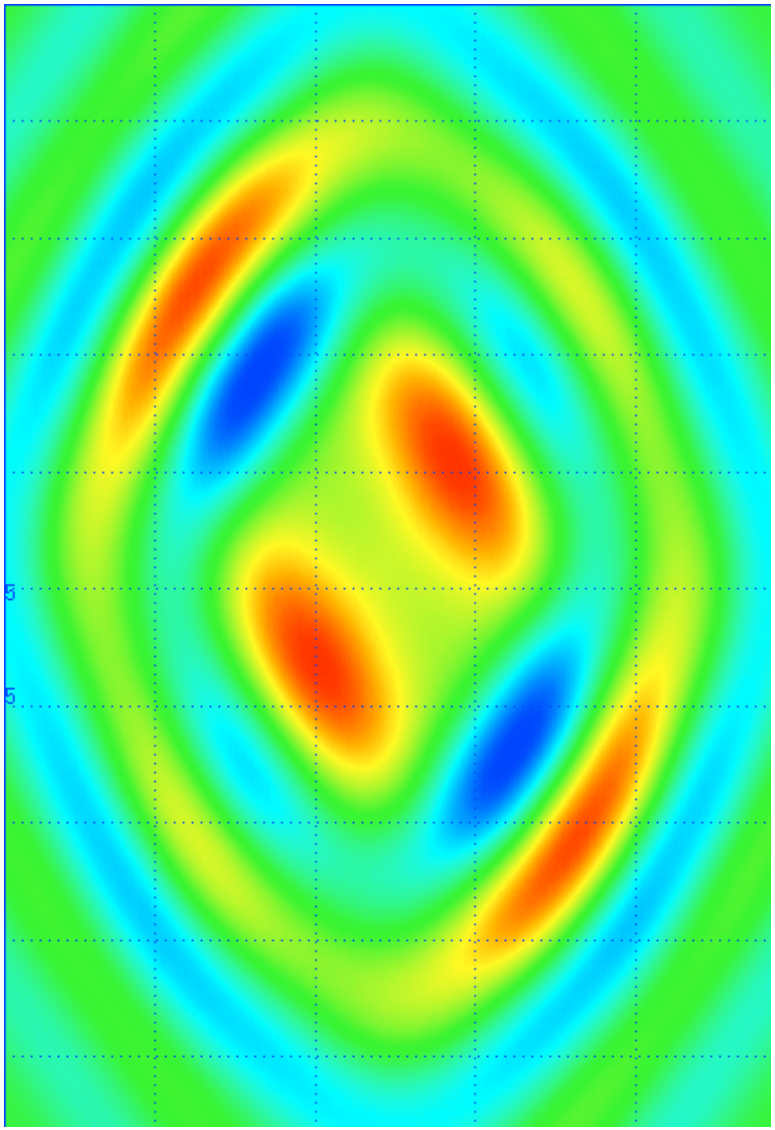
Inversion in FK

We want these to be the same

“real” data

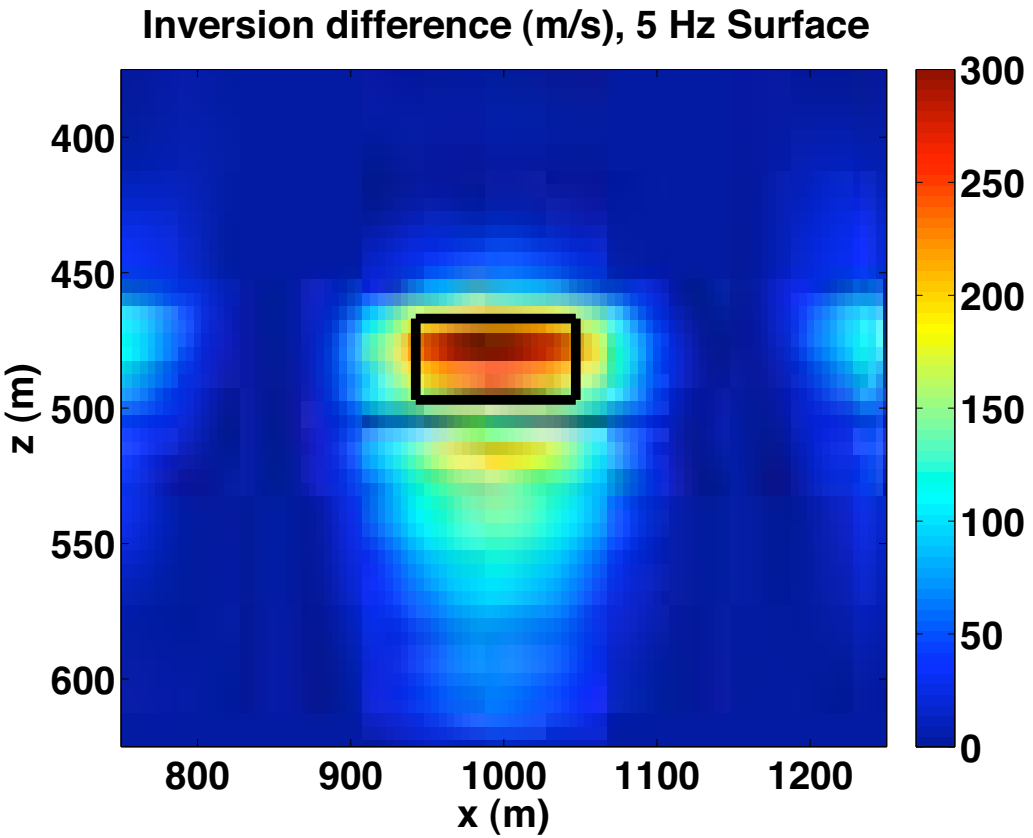


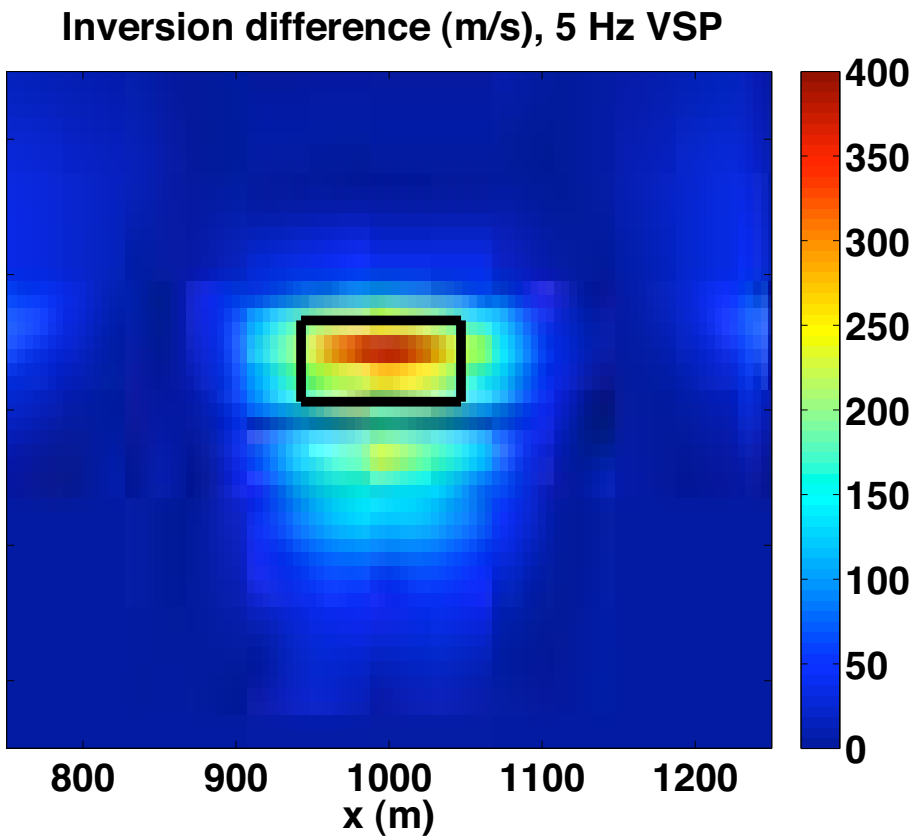
difference (x100)



Inversion in FK

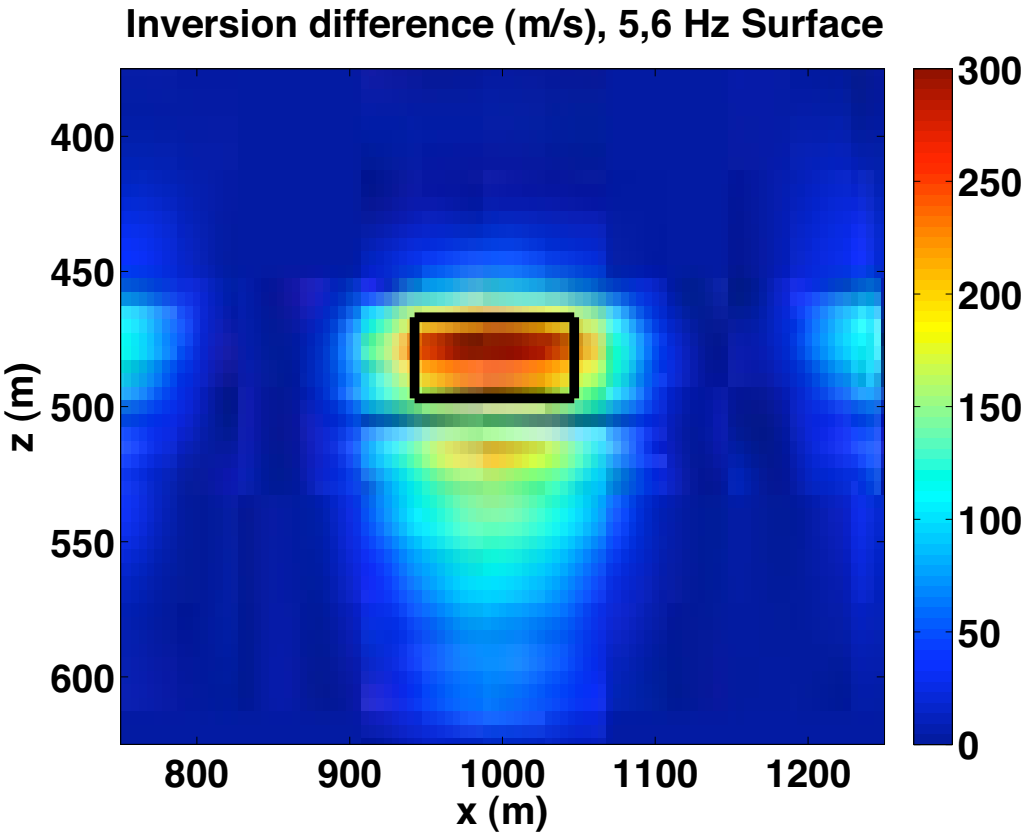
back-propagating the difference
gives hints about the perturbation

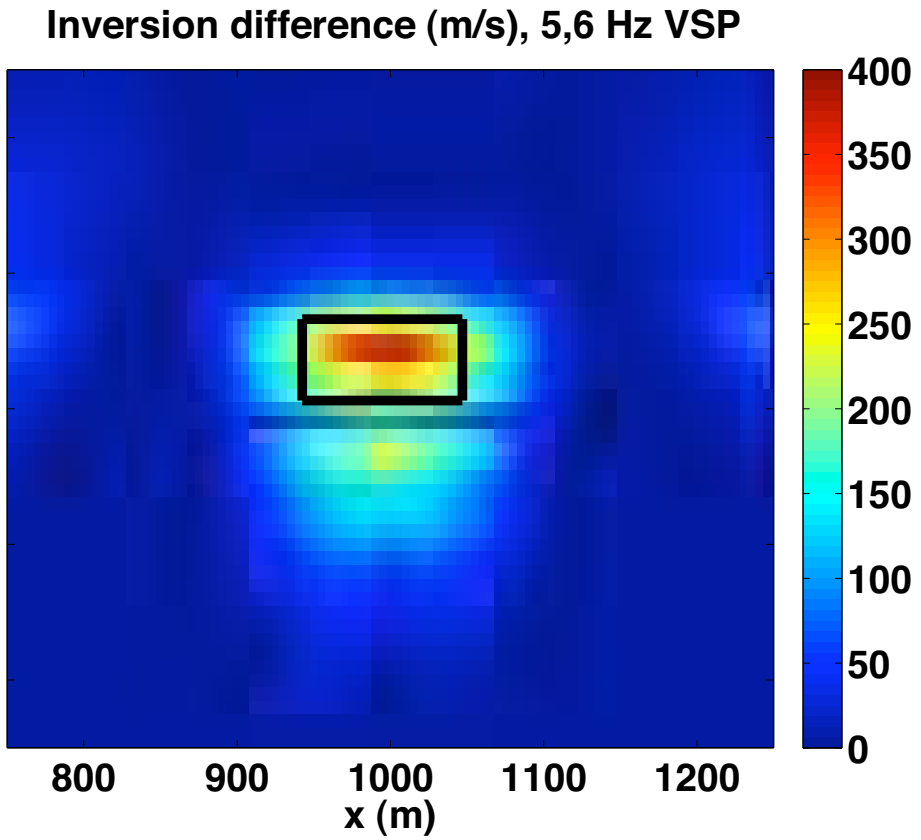




Inversion for 5 Hz

update constrained to target region





Inversion for 5 & 6 Hz

update constrained to target region

Inversion results

- Lower than 5 Hz? Not required, and probably not feasible anyhow. But we need a good model!
- Higher than 6 Hz? Very little update in the target region due to very low energy penetration, and therefore highly unstable.
- Modelling and geometry seems crucial to success.

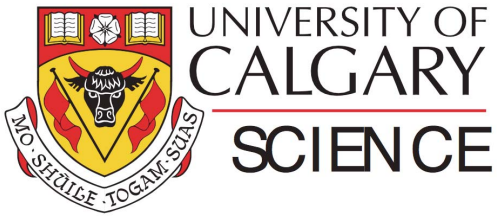
The good news

- 5 Hz could be “low frequency” with “good” starting models.
- 2:1 or 3:1 offset:depth ratios might be reasonable.
- Raytracing & modelling can help with survey design.
- Small perturbations (much below a typical wavelength) may be imaged, with some reasonable magnitude information.

The challenges

- What about random and coherent noise? Elastic effects?
- What about smoothed (or incorrect!) velocity models?
- What about unknown source waveforms?
- What about perturbation size and magnitude?
- ...and many more.

Acknowledgements



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